

# Port of Abbot Point Ambient Marine Water Quality Monitoring Program: Annual Report 2024-2025

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# Port of Abbot Point Ambient Marine Water Quality Monitoring Program: Annual Report 2024- 2025

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## EXECUTIVE SUMMARY

The 2024–2025 reporting year provides an updated assessment of ambient marine water quality across the Bowen–Abbot Point region. Through the integration of discrete water sampling, in situ profiling, passive samplers, high-frequency seafloor loggers, and multispectral benthic irradiance measurements, the monitoring program continues to strengthen a robust long-term evidence base for understanding water-quality variability in a dynamic, tidally energetic coastal environment.

Rainfall and hydrological conditions followed a typical dry-tropical seasonal pattern, with a late-November wet-season onset followed by two notable runoff events in early January and mid-February 2025. These events generated short-lived freshwater and sediment plumes from the Don River, Elliot River and Euri Creek, which dissipated rapidly under strong tidal mixing. Long-term rainfall and streamflow records indicate pronounced interannual variability but no sustained directional trend in freshwater delivery to the region.

Nutrient concentrations were generally variable across sites, with nitrogen persistently elevated relative to offshore background conditions and largely dominated by the dissolved fraction. Episodic wet season increases in particulate nutrients were associated with runoff and sediment resuspension. In contrast, chlorophyll-a concentrations remained low to moderate in absolute terms and well below levels associated with phytoplankton blooms or sustained biomass accumulation, indicating a persistent ambient nitrogen signal without a corresponding increase in phytoplankton biomass. Dissolved metal concentrations remained low throughout the reporting period.

Physicochemical parameters, including salinity, temperature, dissolved oxygen, turbidity and water clarity, displayed clear seasonal patterns reflecting alternating wet-season freshwater influence and dry-season marine dominance. Turbidity was generally low for much of the year, punctuated by short-lived increases during runoff events or wind- and tide-driven resuspension. Continuous logger data resolved these short-term dynamics and highlighted predictable seasonal mixing patterns. Multispectral irradiance measurements demonstrated strong blue–green light penetration during dry-season conditions and increased attenuation during periods of elevated turbidity, with McCanes Bay consistently exhibiting lower light quality than the more offshore island sites.

Long-term analyses indicate that variability in water quality across the Bowen–Abbot Point region is primarily driven by natural seasonal and interannual changes in rainfall, river discharge and mixing processes. Chlorophyll-a exhibited a gradual increase over the long-term monitoring period; however, concentrations remained low in absolute terms and well below levels associated with phytoplankton blooms or sustained biomass accumulation. No corresponding increases in turbidity or nutrient enrichment were observed. Overall, the 2024–2025 data describe a resilient, well-mixed coastal system in which water-quality conditions fluctuate episodically but remain stable over the long term, underscoring the importance of continued monitoring to detect emerging change and support effective environmental management of port activities within the Great Barrier Reef lagoon.

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# 1 INTRODUCTION

## 1.1. Background

The Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) at James Cook University (JCU) partners with North Queensland Bulk Ports (NQBP) to deliver long-term environmental monitoring and research surrounding the Port of Abbot Point. As part of this partnership, an ambient marine water-quality monitoring program has been established that incorporates discrete field measurements, continuous in situ dataloggers, and laboratory analysis of water samples for nutrients, pesticides, Per- and polyfluoroalkyl substances (PFAS), and dissolved metals. The program aims to characterise spatial and temporal variability in water quality to better understand potential impacts associated with port activities adjacent to sensitive marine habitats within the Great Barrier Reef (GBR) lagoon. Alongside routine water-quality sampling, the program also examines key meteorological and oceanographic processes that influence coastal conditions in the region, providing essential context for interpreting seasonal and interannual variability.

Declining water quality remains a major pressure on the GBR, with elevated fine sediments, nutrients, and pesticides from catchments reducing the resilience of ecosystems to extreme events such as cyclones and marine heatwaves (Brodie et al., 2019; Waterhouse et al., 2017, 2022; Lam et al., 2018). Despite sustained investment in land-based pollution reduction, recent assessments show that progress towards Reef 2050 water quality targets remains limited, with reductions in nutrients, fine sediments and pesticides still falling short of required trajectories (Waterhouse et al., 2022; Reef Water Quality Report Card, 2024). Maintaining high water quality is crucial for protecting the ecological health of the GBR and sustaining its substantial economic, cultural, and social value; recent assessments estimate the Reef contributes \$6.4 billion annually and supports ~64,000 jobs (GBRF, 2025).

## 1.2. Program objectives

As the Port of Abbot Point is situated within the Great Barrier Reef region, the primary objective of the monitoring program is to support NQBP in managing environmental risks associated with port operations. The program is designed to characterise ambient water quality in the vicinity of the port and adjacent habitats to ensure any potential impacts are detected early and effectively managed. Beyond core monitoring, the partnership incorporates broader scientific research initiatives across marine water quality, coastal habitats, seagrass and coral ecology, and natural resource management. The long-term datasets generated through this program provide an invaluable resource for understanding interannual variability, climatic influences and the processes that drive water-quality and ecological change along the central and northern Queensland coast.

## 2 METHODS

### 2.1. Regional description

The Bowen region occupies a distinctive position along the central Queensland coast, extending from Cape Gloucester in the south to Cape Upstart in the north. This coastal stretch includes a series of naturally sheltered embayments, offshore islands and fringing reef systems that create a highly diverse and dynamic marine environment. McCanes Bay (Port Denison), located immediately adjacent to the township of Bowen, forms one of the largest and most protected bays in the region, providing calmer conditions relative to the more exposed mid-shelf and offshore waters.

Water depth increases gradually from the Bowen shoreline across the inner shelf to approximately 60 m at the mid-shelf before dropping steeply at the continental shelf break around 200 km offshore. Nearshore tidal currents are generally weak and strongly influenced by local tidal phase and prevailing winds, whereas offshore currents tend to be stronger and more persistent. Along the wider Bowen–Abbot Point coastline, residual flow typically moves north-west, shaping the transport pathways of sediments, nutrients and freshwater signals during large rainfall events.

Freshwater input to the region is episodic and driven by several small, highly seasonal catchments, including the Don and Elliot Rivers and Euri Creek. These systems respond rapidly to intense wet-season rainfall, generating short-lived but often distinct freshwater plumes that disperse northwards along the coast. Although highly variable between years, these plume events play an important role in structuring local water-quality conditions, influencing turbidity, nutrient delivery, sediment resuspension, and ecological processes on adjacent inshore habitats.

### 2.2. Port description

The Port of Abbot Point is located approximately 25 km north of Bowen in naturally deep offshore waters, making it Australia's most northerly coal export facility. Operated by North Queensland Bulk Ports (NQB), the port currently has an export capacity of around 50 million tonnes per annum, with scope for future expansion. Its deep-water setting enables efficient vessel access with minimal dredging requirements, positioning Abbot Point as a regionally and nationally important strategic port.

Abbot Point forms a key component of NQB's broader marine environmental monitoring framework, delivered in partnership with TropWATER. Monitoring sites around Abbot Point complement those in McCanes Bay and elsewhere in the region, supporting a detailed understanding of ambient water quality, sediment dynamics, and ecological condition across the Bowen–Abbot Point coastal zone. This integrated, long-term dataset provides critical context for assessing natural variability, identifying emerging risks, and ensuring port operations continue to align with environmental values within the Great Barrier Reef lagoon.

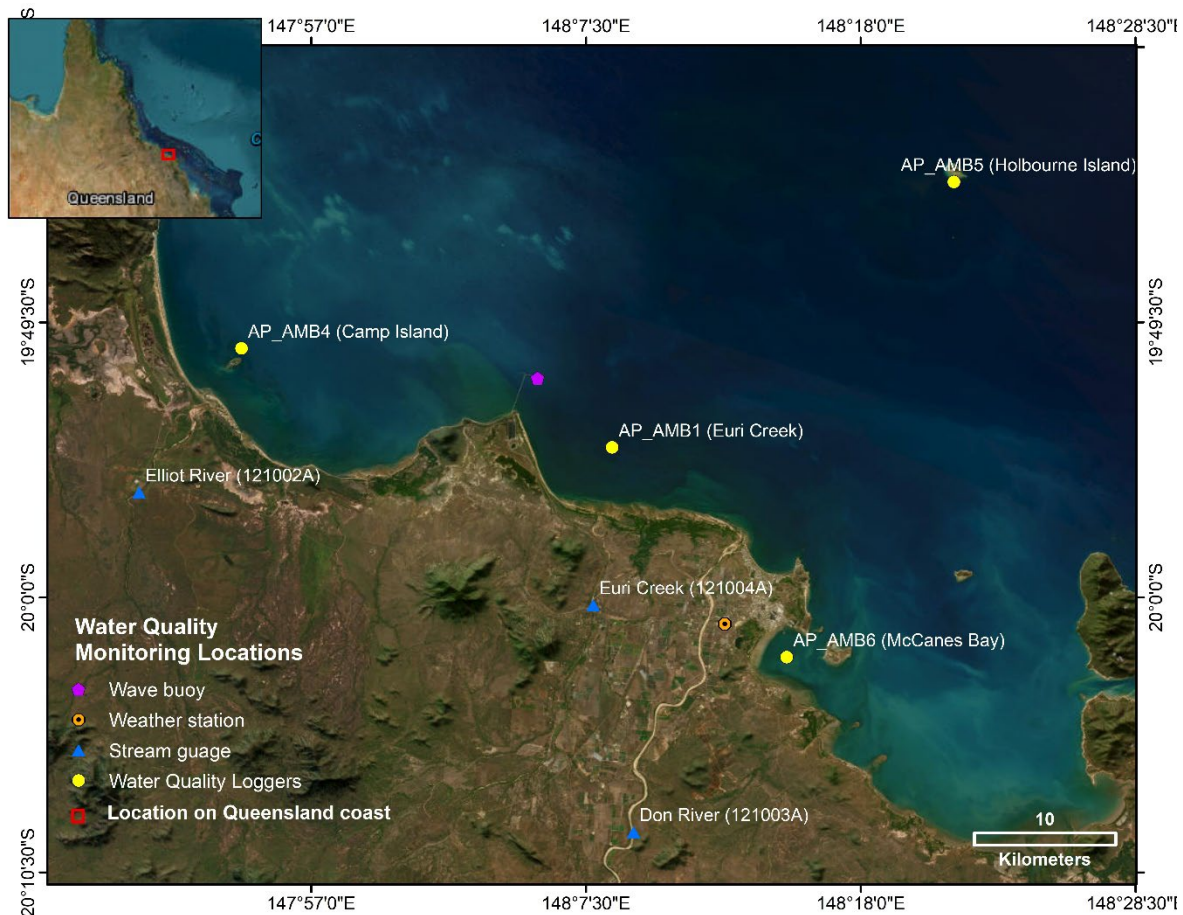


Figure 2-1 Map of Bowen/ Abbot Point showing the water quality monitoring locations (yellow circles), meteorological stations (orange squares), and stream gauges referred to in this report.

## 2.3. Characterisation of weather, hydrological status, and oceanographic conditions

### 2.3.1. Rainfall and hydrology

Climate data for the region was extracted from the Australian Bureau of Meteorology climate data online tool (<http://www.bom.gov.au/climate/data/>). Total rainfall, rainfall onset date, along with wet season rainfall totals were calculated. The nominal wet season is defined as 1<sup>st</sup> November to 30<sup>th</sup> April. The rainfall onset is calculated as the date when the rainfall total reaches 50 mm since 1<sup>st</sup> September. Stream discharge data for streams discharging into the coastal waters of the region was extracted from the Queensland Government water monitoring information portal (<https://water-monitoring.information.qld.gov.au/>). Total discharge and date of first significant discharge event were calculated. The water year reported throughout is defined as 1<sup>st</sup> July to 30<sup>th</sup> June.

### 2.3.2. Wave climate

Wave characteristics were derived from the AXYS TRIAXYS Directional Wave & Current Buoy located at Abbot Point. Significant wave height ( $H_s$ ) was used as the primary measure of wave energy and represents the average height of the highest one-third of waves recorded during each sampling interval. Peak wave direction describes the direction from which the most energetic waves are

propagating, based on the dominant component of the wave energy spectrum. These parameters together provide a fundamental description of the height and directional structure of the local wave field and are routinely used to assess coastal hydrodynamics, sediment transport potential, and the influence of regional weather systems.

Wave-period metrics were also examined to further characterise sea-state dynamics. Peak period ( $T_p$ ) represents the period associated with the strongest spectral energy, while zero-crossing period ( $T_z$ ) describes the mean interval between successive up-crossings of the average water level.  $T_p$  and  $T_z$  provide complementary information on the temporal structure of waves, enabling distinction between short-period, locally generated wind-sea and longer-period waves. Collectively,  $H_s$ , peak direction,  $T_p$  and  $T_z$  form a comprehensive description of wave climate conditions relevant to coastal processes and water quality variability within the monitoring region.

## 2.4. Monitoring and sampling design

### 2.4.1. Site overview

The Bowen region has four active ambient marine water quality monitoring sites, with the fourth site, McCanes Bay (AP\_AMB6) added to the program in June 2024 (Figure 2.1, Table 2.1). The McCanes Bay site was established late in the previous reporting year (June 2024) and also has a stand-alone report to complement the new seagrass monitoring area in the Bowen Wharf region.

The Euri Creek water quality monitoring site (AP\_AMB1) is located two nautical miles (nm) offshore of Euri Creek, four nm ESE of Abbot Point, and six nm NW of the Don River mouth. The site sits in approximately 10 m water depth, with a sandy-muddy bottom and extensive seagrass meadows, dominated by *Halophila*, *Halodule* and *Zostera* species.

The Camp Island water quality monitoring site (AP\_AMB4) is located in Abbot Bay ~ two nm offshore of Elliot River and 10 nm west of Abbot Point. The island contains a private resort and is surrounded by shallow waters and fringing coral reef, with the water monitoring site located on the northern side of the island in approximately 9 m of water. Extensive seagrass meadows are found further offshore from Camp Island.

Holbourne Island (AP\_AMB5) is a granitic continental high island located 18 nautical miles ENE offshore of Abbot Point in the offshore marine zone. The Island, a national park surrounded by fringing coral reef (Ryan et al., 2018), drops away rapidly to 45 m water depth, with the water quality monitoring site in ~ 15 m water close to the shore. Beyond Holbourne Island the shelf continues to drop away to 60 m (mid-shelf). More information about the condition of the seagrass meadows and coral reefs adjacent to these water quality sites are available in the companion reports on the TropWATER Technical Report page (e.g., [23/20 Port of Abbot Point long-term seagrass monitoring program 2022. Reason, C.L., McKenna, S., & Rasheed, M.A.](#); [21/45 Port of Abbot Point Ambient Coral Monitoring Surveys: 2020-2021. Chartrand, K.M., Hoffmann, L.R., Ayling, A., and Ayling, T.](#)).

Table 2-1. Site locations and main features

| Site name        | Site code | Latitude   | Longitude  | Depth (m) | Site features               |
|------------------|-----------|------------|------------|-----------|-----------------------------|
| Euri Creek       | AP_AMB1   | -19.908817 | 148.138047 | 10        | Seagrass                    |
| Camp Island      | AP_AMB4   | -19.842807 | 147.904126 | 9         | Coral/ macroalgae/ seagrass |
| Holbourne Island | AP_AMB5   | -19.724934 | 148.354198 | 15        | Coral                       |
| McCanes Bay      | AP_AMB6   | -20.038028 | 148.252881 | 5         | Seagrass                    |

Each site has a pair of dataloggers deployed on the seafloor to continuously record environmental data. The sites are revisited on an ~8 weekly schedule to conduct water sampling, record physiochemical measurements, and exchange dataloggers (Table 2.2).

#### 2.4.2. Field sampling schedule

Field sampling is undertaken at all sites approximately every eight weeks. Each visit includes retrieval and re-deployment of dataloggers, collection of discrete water samples for laboratory analysis, and collection of in situ water quality measurements. Table 2-2 lists sampling dates from July 2024 to June 2025.

Table 2-2 *Field dates for water sampling, logger maintenance, and metal detection sampling at the Abbot Point sites.*

| Date       | Water sampling | Logger maintenance | Metals sampling | Physico-chemical |
|------------|----------------|--------------------|-----------------|------------------|
| 2024-08-05 | Yes            | Yes                | No              | Hydrolab         |
| 2024-09-30 | Yes            | Yes                | No              | Hydrolab         |
| 2024-11-21 | Yes            | Yes                | Yes             | ProDSS           |
| 2025-02-19 | Yes            | Yes                | No              | ProDSS           |
| 2025-04-04 | Yes            | Yes                | Yes             | ProDSS           |
| 2025-06-02 | Yes            | Yes                | No              | ProDSS           |

## 2.5. Water quality sampling

### 2.5.1. Water sample collection

Surface water was collected manually from approximately 0.2 m below the water surface. Samples were obtained for laboratory analysis of nutrients (total nitrogen, total phosphorus, total dissolved nitrogen, total dissolved phosphorus), suspended solids, salinity, electrical conductivity, pH,

chlorophyll-a and phaeophytin-a (Table 2-3). Nutrient samples were filtered onsite using 0.45 µm PES syringe filters and stored on ice prior to transport to the laboratory. Total suspended solids (TSS) samples were collected in 1 L bottles, while chlorophyll samples were collected in dark 1 L bottles. Salinity and pH samples were collected in 60 mL vials. All samples were transported on ice and analysed promptly following standard laboratory procedures.

#### 2.5.2. Chlorophyll and pigment processing

Chlorophyll-a samples were filtered within 12 hours of collection using Whatman GF/F 0.45 µm glass fibre filters amended with approximately 0.2 mL of magnesium carbonate. The filters were wrapped in aluminium foil, frozen, and delivered to the TropWATER water quality laboratory for analysis. Chlorophyll-a and phaeophytin-a concentrations were determined spectrophotometrically following APHA Method 10200 H.

#### 2.5.3. Metals sampling

Water samples for ultra-trace filterable metals were collected on two occasions within the reporting period. Samples were filtered onsite using 0.45 µm PES syringe filters and stored on ice prior to laboratory analysis. Analytes included arsenic, cadmium, copper, zinc, lead, nickel, silver and mercury, with methods and reporting limits provided in Table 2-4.

#### 2.5.4. Laboratory analysis

Laboratory analysis of routine water quality parameters, nutrients, pigments and metals followed standard APHA methods. Reporting limits and analytical procedures are detailed in Tables 2-3 and 2-4.

#### 2.5.5. Water quality guidelines

Results from discrete water samples and continuous logger measurements were assessed against the water quality objectives (WQOs) specified in the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP, 2019), and against guideline values from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018), where applicable. Environmental values (EVs), management intents, and associated WQOs for surface waters in the Mackay–Whitsunday basins were revised in 2022 and are listed in Schedule 1 of the EPP (Water and Wetland Biodiversity).

For nutrients, chlorophyll-a, turbidity, and other physico-chemical parameters, results were compared directly to the site- and zone-specific WQOs defined for open coastal waters within the Mackay–Whitsunday region. These objectives are based on long-term regional monitoring datasets and can incorporate seasonal considerations (dry and wet season), or an annual mean/ median, reflecting expected background conditions for each management zone. The applicable WQOs differ among sites according to their designated environmental values and management intent and were applied accordingly when interpreting results.

The Euri Creek (AP\_AMB1), Camp Island (AP\_AMB4), and McCanes Bay (AP\_AMB6) sites are located within waters designated as open coastal waters landward of the plume line (WQ1222) and are managed as moderately disturbed (MD). The Holbourne Island site (AP\_AMB5) is in midshelf waters

and managed as high environmental value (HEV). As a result, the applicable nutrient and physico-chemical WQOs differ (are more stringent) at Holbourne Island.

For filterable metals, results were assessed using the default guideline values (DGVs) from the ANZG (2018), following the assessment framework outlined in the EPP (Water and Wetland Biodiversity) Policy 2019. In accordance with this framework, metal concentrations at sites classified as slightly to moderately disturbed (Euri Creek, Camp Island and McCanes Bay) were compared against guideline values corresponding to 95% species protection, while results from the high ecological value site at Holbourne Island was assessed against the more conservative criteria corresponding to 99% species protection.

This combined assessment approach ensures that nutrient and productivity-related parameters are evaluated against locally relevant, ecosystem-based objectives, while metals are assessed using nationally consistent, toxicity-based guideline values appropriate to each site's environmental value and management intent.

*Table 2-3 Water quality parameters that were analysed using water samples collected as part of the Port of Abbot Point water quality monitoring program, and the methods and reporting limits of the laboratory analysis.*

| Parameter                             | APHA method number                                                                              | Reporting limit           |
|---------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------|
| <b>Routine water quality analysis</b> |                                                                                                 |                           |
| pH                                    | 4500-H+ B                                                                                       | -                         |
| Salinity                              | 2520 B                                                                                          | 0.1 PSU                   |
| Electrical conductivity (EC)          | 2510 B                                                                                          | 5 $\mu\text{S cm}^{-1}$   |
| Total Suspended Solids (TSS)          | 2540 D @ 103 - 105°C                                                                            | 0.2 mg L <sup>-1</sup>    |
| <b>Nutrients</b>                      |                                                                                                 |                           |
| Total nitrogen (TN)                   | Simultaneous 4500-NO <sub>3</sub> -F and 4500-P F analyses after alkaline persulphate digestion | 10 $\mu\text{g N L}^{-1}$ |
| Total dissolved nitrogen (TDN)        |                                                                                                 |                           |
| Total phosphorus (TP)                 |                                                                                                 | 1 $\mu\text{g P L}^{-1}$  |
| Total Dissolved phosphorus (TDP)      |                                                                                                 |                           |
| Particulate nitrogen (PN)             | Calculated as PN = TN - TDN                                                                     | -                         |
| Particulate phosphorus (PP)           | Calculated as PP = TP - TDP                                                                     | -                         |
| <b>Chlorophyll</b>                    |                                                                                                 |                           |
| Chlorophyll-a                         | 10200-H                                                                                         | 0.2 $\mu\text{g L}^{-1}$  |

Phaeophytin-a

Table 2-4 Ultra trace filterable metals that were tested for from water samples collected at the four monitoring sites.

| Parameter                | APHA method number | Reporting limit               |
|--------------------------|--------------------|-------------------------------|
| <b>Filterable metals</b> |                    |                               |
| Arsenic (As)             | 3125B ORC/ICP/MS   | -                             |
| Cadmium (Cd)             |                    | 0.2 µg L <sup>-1</sup>        |
| Copper (Cu)              |                    | 1 µg L <sup>-1</sup>          |
| Zinc (Zn)                |                    | 5 µg L <sup>-1</sup>          |
| Lead (Pb)                |                    | 0.2 µg L <sup>-1</sup>        |
| Nickel (Ni)              |                    | 0.5 µg L <sup>-1</sup>        |
| Silver (Ag)              |                    | 0.1 µg L <sup>-1</sup>        |
| Mercury (Hg)             |                    | 0.1 / 0.04 µg L <sup>-1</sup> |

## 2.6. Pesticide monitoring

Passive samplers were deployed at Euri Creek (AP\_AMB1) to monitor pesticide concentrations (Table 2-5). Each deployment included an Empore™ SPE disk (ED), a microporous polyethylene tube (MPT), and a passive flow monitor (PFM). Concentrations of twenty-two pesticides and insecticides used in the calculation of pesticide risk metrics are reported in Table 2-6, with the full list of analytes and detections provided in Appendix 1. The second wet-season deployment (22/11/2024–19/02/2025) remained in the field longer than scheduled due to severe flooding, which prevented access to the site during two attempted retrievals.

Table 2-5 Pesticide and PFAS passive samplers deployed at Euri Creek (AP\_AMB1)) during the 2024-2025 wet season.

| Site name  | Site code | Start date | End date   | Duration (days) |
|------------|-----------|------------|------------|-----------------|
| Euri Creek | AP_AMB1   | 30/09/2024 | 22/11/2024 | 53              |
| Euri Creek | AP_AMB1   | 22/11/2024 | 19/02/2025 | 88              |

Table 2-6 Pesticide analytes used for ms-PAF calculations to determine the pesticide risk baseline. The type of pesticide photosystem two inhibiting herbicide (PSII), other herbicide (OH), and insecticide (I). Note: A full list of pesticides monitored via passive samplers is included in Appendix 1.

| Analyte                         | Type | Detection method | Limit of reporting (LOR)     |
|---------------------------------|------|------------------|------------------------------|
| 2,4-D                           | OH   | ED               | 5 ng sampler <sup>-1</sup>   |
| Ametryn                         | PSII | ED               | 5 ng sampler <sup>-1</sup>   |
| Atrazine                        | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Diuron                          | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Fipronil                        | I    | ED               | 5 ng sampler <sup>-1</sup>   |
| Fluroxypyr                      | OH   | ED               | 1 ng sampler <sup>-1</sup>   |
| Haloxypop                       | OH   | ED               | 1 ng sampler <sup>-1</sup>   |
| Hexazinone                      | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Imidacloprid                    | I    | ED               | 1 ng sampler <sup>-1</sup>   |
| Isoxaflutole (as diketonitrile) | OH   | ED               | 0.1 ng sampler <sup>-1</sup> |
| MCPA                            | OH   | ED               | 5 ng sampler <sup>-1</sup>   |
| Metolachlor                     | OH   | ED               | 1 ng sampler <sup>-1</sup>   |
| Metribuzin                      | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Metsulfuron-methyl              | OH   | ED               | 1 ng sampler <sup>-1</sup>   |
| Prometryn                       | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Simazine                        | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Tebuthiuron                     | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Terbuthylazine                  | PSII | ED               | 1 ng sampler <sup>-1</sup>   |
| Triclopyr                       | OH   | ED               | 5 ng sampler <sup>-1</sup>   |

## 2.7. In situ physicochemical measurements

In situ measurements of temperature, electrical conductivity, pH, dissolved oxygen (% saturation and concentration), and turbidity were collected using either a Hydrolab Quanta multiparameter water quality meter or a YSI ProDSS multiparameter sonde (see Table 2-2 for deployment information). Measurements were made at three depths: 0.25 m below the surface, mid-water, and 1 m above the seafloor. Photosynthetically active radiation (PAR) was measured concurrently at each depth, and above water, using a LI-192 underwater quantum sensor connected to a LI-250A light meter. Where possible, PAR measurements were collected without interference from clouds or vessel shading, although occasional variability was unavoidable. Water clarity was assessed at each visit using a Secchi disk.

Table 2-7      *Physiochemical measurements that were collected at four locations, Euri Creek, Camp Island, Holbourne Island and McCanes Bay.*

| Parameter                                 | Units                                |
|-------------------------------------------|--------------------------------------|
| <b>Multiparameter water quality meter</b> |                                      |
| Water temperature                         | Degrees Celsius (°C)                 |
| Electrical conductivity (SpC)             | mS cm <sup>-1</sup>                  |
| Salinity                                  | PSU                                  |
| pH                                        |                                      |
| Dissolved Oxygen                          | %sat                                 |
| Dissolved Oxygen                          | mg L <sup>-1</sup>                   |
| Turbidity                                 | FNU                                  |
| <b>Light meter</b>                        |                                      |
| Photosynthetically active radiation (PAR) | μmol m <sup>-2</sup> s <sup>-1</sup> |
| <b>Water clarity</b>                      |                                      |
| Secchi disk depth                         | Meters (m)                           |

## 2.8. Seafloor mounted continuous dataloggers

Continuous water quality measurements at the Abbot Point water quality monitoring sites were obtained using a pair of seafloor-mounted dataloggers attached to a stainless-steel instrument frame (Figure 2-2). The instrumentation included an NTU-LPT turbidity logger and an MS9-LPT multispectral light logger, both manufactured by In-situ Marine Optics (Perth, WA; <https://insitumarineoptics.com>). Each logger collected bursts of 50 measurements at 5 Hz every 10 minutes, providing high-frequency data on water temperature (°C), water depth (m), turbidity (NTU) and underwater light (photosynthetically active radiation; PAR, μmol m<sup>-2</sup> s<sup>-1</sup>).



Figure 2-2 Water quality loggers attached to instrument frames ready for seafloor deployment. The horizontally oriented logger is an NTU-LPT turbidity logger; the vertically oriented logger is an MS9-LPT multispectral light logger (In-situ Marine Optics).

The logger pair remained in situ on the seafloor between field visits and were retrieved and redeployed approximately every eight weeks during routine sampling. This deployment approach ensures continuous, comparable data while enabling regular calibration checks, servicing and data download. Specifications for the loggers, including sensor ranges and accuracy, are provided in Table 2-8.

Table 2-8 Specifications of NTU-LPT turbidity logger and MS9-LPT multispectral light loggers.

| Parameter         | Units                                 | Sensor range                                  | Accuracy / Resolution                                  |
|-------------------|---------------------------------------|-----------------------------------------------|--------------------------------------------------------|
| Water temperature | Degrees Celsius (°C)                  | -55 to 125 °C                                 | +/- 1.0 °C                                             |
| Water depth       | Meters (m)                            | 0 – 90 m                                      | +/- 1.0 %                                              |
| Turbidity         | Nephelometric turbidity units (NTU)   | 0 – 400/1000 NTU                              | 0.05 NTU                                               |
| Irradiance        | $\mu\text{W cm}^{-2} \text{ nm}^{-1}$ | 0 – 400 $\mu\text{W cm}^{-2} \text{ nm}^{-1}$ | $2.5 \times 10^{-3} \text{ W cm}^{-2} \text{ nm}^{-1}$ |

### 2.8.1. Logger data processing and quality control

Following each deployment, dataloggers were returned to the laboratory for pre-processing and quality control. Raw logfiles were initially processed to calculate median values for water temperature, water depth, turbidity and irradiance for each 10-minute burst interval (50

measurements at 5 Hz). These median values form the basis of the high-frequency time-series used in subsequent analysis.

Automated rule-based quality control (QC) was then applied using procedures described in Iles et al. (2023). This automated step detects and flags spurious readings resulting from instrument fouling, low battery voltage, sensor drift, surface interference, shading, or anomalous values outside expected environmental ranges. Following automated QC, each dataset was visually inspected and subjected to manual QC to ensure removal of artefacts not captured by rule-based processes. Final datasets were then ingested into the water quality database for analysis and reporting. A detailed description of QC rules is provided in the Appendix and further details in Iles et al. (2023).

### 2.8.2. Suspended sediment concentration

Suspended sediment concentration (SSC) was derived from turbidity measurements by applying site-specific conversion factors established previously for the Bowen region (Cartwright et al., 2022). The relationship between turbidity (NTU) and SSC ( $\text{mg L}^{-1}$ ) is typically site-dependent, reflecting differences in particle size distribution, composition and optical properties of suspended sediments. Although there is no formalised protocol for re-establishing turbidity–SSC relationships, recalibration is recommended periodically, particularly following major hydrodynamic or sediment disturbance events that could alter sediment characteristics at the seabed.

SSC was calculated from logger-derived turbidity values using the following equation:

$$SSC = Turb * Cf \pm e \quad \text{[Equation 1]}$$

Where:

SSC is the calculated suspended sediment concentration in  $\text{mg L}^{-1}$

Turb is the measured turbidity value in NTU

$C_f$  is the conversion factor (unique for each site)

$e$  is the root mean square error value

Note that error values are not presented in the converted data values.

..

### 2.8.3. RMS water depth

The MS9-LPT logger includes an integrated pressure sensor used to determine water depth and to derive a proxy measure of wave activity at the seafloor. Both the mean water depth and the root mean square (RMS) water depth are useful for examining the influence of tide and wave-driven pressure fluctuations on turbidity, sediment resuspension and benthic light availability.

RMS water depth represents short-term variability in pressure over the 10-second burst interval and is therefore related to wave energy at the seabed. It is important to note that RMS water depth does not measure wave height at the sea surface. Instead, it provides an index of near-bed orbital motion or wave shear stress, which varies with depth. For instance, identical surface wave conditions may produce markedly different RMS values at shallow versus deep sites. Consequently,

RMS water depth is a useful relative indicator of potential resuspension between sites of different depths.

For each burst, the pressure sensor records 50 readings over a 10-second period. Average depth (m) and RMS water depth are then calculated from these 50 readings.

RMS water height,  $D_{rms}$ , is calculated as follows:

$$RMS_{depth} = \sqrt{\frac{\sum_{n=1}^N (D_n - \bar{D})^2}{N}} \quad \text{[Equation 2]}$$

Where  $D_n$  is the  $n_{th}$  of the 50 readings and  $\bar{D}$  is the mean water depth of the  $n$  readings.

#### 2.8.4. Analysis of Turbidity Behaviour Relative to RMS Depth

Turbidity behaviour was assessed in relation to short-period variation in water depth (RMS depth), which provides an index of high-frequency water-column motion around the sensor. RMS depth was calculated from the 1-minute depth record using a rolling window (7-point centred mean), and the first derivative of the smoothed depth series was used to classify each observation into one of three tidal stages: rising, falling, or stable. Rising tide was defined as periods where the rate of depth increase exceeded 0.005 m per time-step, falling tide where the rate of decrease exceeded 0.005 m per time-step, and all remaining periods were classified as stable.

For each tidal stage, turbidity (NTU) was paired with the corresponding RMS depth value and analysed using Pearson correlation to quantify the strength of association. Scatterplots of RMS depth vs NTU were produced for each site, coloured by tidal stage, with fitted linear regression lines to illustrate differences in slope and data structure among tidal conditions. High-resolution figures were exported for reporting, and correlation coefficients were included directly in the plot legends for clarity. This approach allowed assessment of whether turbidity variability at each site was linked to short-period water motion and whether this relationship differed between rising, falling and stable tidal states.

#### 2.8.5. Benthic photosynthetically active radiation (bPAR)

Turbidity is often assumed to be the primary driver of light limitation at the seabed (Erftemeijer et al., 2012), but the relationship between turbidity and benthic photosynthetically active radiation (bPAR) is not always consistent (Sofonia & Unsworth, 2010). Because bPAR represents the amount of light actually reaching benthic photosynthetic habitats (e.g. seagrass, algae, corals), it is considered a more biologically relevant indicator of habitat condition and has been incorporated increasingly into management frameworks and threshold-based guidelines (e.g. Chartrand et al., 2012).

Light attenuation in water follows an exponential decay with depth due to absorption and scattering by dissolved and particulate matter (Kirk, 1994). As a result, absolute bPAR values are not directly comparable among sites with differing depths. To address this, bPAR was calculated from the nine irradiance channels of the MS9 logger, with wavelengths between 400–700 nm

interpolated and integrated internally. Median bPAR for each burst was derived from the 50 measurements collected over the 10-second interval.

The daily light integral (DLI), representing the total number of photosynthetically active photons delivered to the seabed over a 24-hour period, was calculated from the bPAR time series using Equation 2.

Daily light integral (DLI) was calculated as follows:

$$DLI = \sum_i PAR_i * \frac{600}{1000000} \quad \text{[Equation 3]}$$

Where:

DLI is the daily light integral in mol photons m<sup>-2</sup> d<sup>-1</sup>

*i* is each bPAR reading during the day

bPAR is the benthic photosynthetically active radiation in μmol photons m<sup>-2</sup> s<sup>-1</sup>

600 is the time interval between readings

1,000,000 is the unit conversion

## 2.9. Benthic multispectral irradiance

Spectral light is a key determinant of benthic primary production because different phototrophic organisms—such as corals, seagrasses and macroalgae—use specific wavelengths of the visible spectrum with differing efficiency (Jones et al., 2021). Bulk PAR alone does not fully characterise the underwater light environment because spectral composition can vary independently of total irradiance due to turbidity, sediment resuspension, phytoplankton biomass and coloured dissolved organic matter.

Benthic multispectral irradiance was measured at each ambient monitoring site using IMO-LPT MS9 loggers mounted on seafloor frames. Each logger contains nine discrete irradiance channels spanning 410–700 nm (Table 2.9), enabling wavelength-specific assessment of attenuation across the blue, green, yellow and red regions of the spectrum.

### 2.9.1. Data extraction and normalisation (spectral-shape analysis)

Raw spectral irradiance values were extracted from each MS9 logger and filtered to include daylight measurements only. To examine relative spectral shape, irradiance from all nine wavelength channels was normalised to the maximum channel value within each observation. This normalisation removes the influence of absolute light intensity and short-term variability associated with cloud cover, sun angle, and surface conditions, enabling direct comparison of wavelength-specific contributions across time, sites, and seasons. Normalised spectra were used to assess changes in relative spectral composition rather than absolute light availability.

Table 2-9 Wavelength specifications of the In-situ Marine Optics MS9 nine wavelength multispectral light sensor. Each channel has a 10 nm full-width-half-maximum spectral response.

| Irradiance channel | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------------|---|---|---|---|---|---|---|---|---|
|--------------------|---|---|---|---|---|---|---|---|---|

| Wavelength (nm) | 410    | 440  | 490  | 520   | 550   | 570    | 610    | 660 | 700 |
|-----------------|--------|------|------|-------|-------|--------|--------|-----|-----|
| Colour          | Violet | Blue | Cyan | Green | Green | Yellow | Orange | Red | Red |

### 2.9.2. Turbidity classification for spectral response analysis

To support interpretation of spectral-shape variability, each daylight spectral observation was paired with a two-hour mean turbidity value derived from co-located nephelometric sensors. Observations were categorised into three turbidity classes: low (<1 NTU), moderate (1–5 NTU), and high (>5 NTU).

These turbidity classes were applied specifically to interpret normalised multispectral irradiance profiles and to examine how wavelength-specific attenuation patterns varied under contrasting optical conditions associated with sediment resuspension and seasonal hydrodynamics.

### 2.9.3. Spectral Indices

To quantify changes in benthic light quality, spectral indices were calculated from raw, non-normalised irradiance values. These indices summarise the relative shape of the light field, providing sensitive indicators of turbidity, scattering, absorption, and overall benthic light quality. Because different wavelengths attenuate at different rates—blue light being most sensitive to suspended sediments, and red light strongly absorbed by water—spectral indices allow optical changes to be detected even when total PAR remains relatively unchanged.

These metrics are particularly relevant for assessing habitat condition because seagrass and many coral symbionts rely disproportionately on the blue–green portion of the spectrum for efficient photosynthesis. Changes in spectral quality can therefore influence ecological performance even when light quantity is sufficient.

The following subsections describe each spectral index used in this study and the specific optical processes they represent.

#### BLUE:GREEN RATIO (BG RATIO)

The BG ratio measures the relative contribution of short-wavelength (blue) light to mid-wavelength (green) light:

$$BG\ ratio = \frac{mean(410-490\ nm)}{mean(520-570\ nm)} \quad [Equation\ 4]$$

Higher values indicate clearer water and lower scattering, as blue wavelengths are preferentially attenuated by suspended sediments.

#### NORMALISED 490 NM IRRADIANCE (N490)

N490 is the normalised irradiance at 490 nm and serves as an indicator of blue-light penetration. It is particularly sensitive to suspended particulate matter and is widely used in both in situ and remote-sensing optical assessments.

## PAR QUALITY INDEX (PQI)

PQI quantifies the proportion of irradiance within the wavelength range most efficiently used by seagrass, macroalgae, and some coral symbionts:

$$PQI = \frac{chan440 + chan490 + chan520 + chan550}{\text{sum of all 9 channels}} \quad [\text{Equation 5}]$$

Higher PQI values correspond to a greater proportion of photosynthetically efficient blue-green light within the total PAR spectrum, and therefore higher-quality benthic light conditions.

## RED ATTENUATION RATIO (RAR)

RAR expresses the relative dominance of red wavelengths compared to shorter wavelengths:

$$RAR = \frac{\text{mean}(610-700 \text{ nm})}{\text{mean}(410-570 \text{ nm})} \quad [\text{Equation 6}]$$

Elevated RAR values generally indicate increased turbidity, higher scattering of short wavelengths, or the influence of coloured dissolved organic matter.

## BLUE→GREEN SPECTRAL SLOPE (SLOPE\_{BG})

The spectral slope between 438.8 nm and 568.3 nm quantifies the rate at which short wavelengths are attenuated relative to green light:

$$\text{Slope}_{BG} = \frac{I_{570} - I_{440}}{570 - 440} \quad [\text{Equation 7}]$$

Positive values indicate strong blue attenuation, while values approaching zero reflect optically clear conditions.

## 2.10. Long term trend analysis

The Bowen region ambient marine water quality program has been running since November 2017, providing more than seven years of continuous data suitable for exploring temporal patterns and long-term trends in key water quality parameters. To analyse these irregularly spaced time series, Generalized Additive Models (GAMs) were applied using the *mgcv* package in R (Wood, 2017). Data were pooled across sites to improve power for detecting seasonal and interannual patterns and to provide a regional summary of ambient conditions.

Multi-year data from discrete water sample collections were modelled using the general form:

$$\text{response} \sim \text{month} + \text{time}$$

where the response is the parameter of interest, *month* represents seasonal cyclicity, and *time* represents long-term change

Seasonality was modelled using a cyclic cubic regression spline applied to the month term, while long-term trends were modelled using a thin-plate regression spline applied to time. To limit overfitting, spline flexibility was constrained to  $k = 5$  for the seasonal component and  $k = 20$  for the long-term trend. Outliers were removed only where values failed standard QA/QC procedures or were identified as non-physical (e.g. sensor fouling, calibration artefacts). Environmentally plausible extreme values were retained to preserve the full range of natural variability.

A gamma error distribution with a log link was used, reflecting the non-negative, right-skewed nature of most water quality parameters and its robust performance for environmental time-series data.

Model outputs include two smooth components: a seasonal smooth describing the average wet-dry cycle, and a long-term smooth describing gradual temporal change. The fitted values shown in the plots represent the combined effect of these components, with seasonal oscillations superimposed on the broader multi-year trend. Examining both smooths together allows assessment of whether observed variability is dominated by seasonal processes, longer-term change, or short-term event-driven fluctuations

## 3 RESULTS AND DISCUSSION

### 3.1. Rainfall and river flows

Rainfall across the Bowen region during the 2024–2025 reporting period showed a broadly typical seasonal pattern for this part of the central Queensland coast, with very dry conditions from July to early spring, a clear transition into the wet season during October, and peak rainfall occurring from late December through February (Figure 3-1). Daily rainfall was minimal through winter and early spring, with only scattered light falls until the wet-season onset on 10 October 2024. The rainfall onset metric is based on the date when cumulative rainfall since 1 September first exceeds 50 mm, providing a more functional indicator of the beginning of catchment wetting and runoff potential.

Rainfall increased sharply in December, with the first significant storm events delivering 25–100 mm falls and activating the dry catchments. Conditions intensified in January and February 2025, during which several strong trough-driven systems produced multiple high-intensity rainfall days. A major event in early February exceeded 100 mm in a single day, marking the largest rainfall total of the season for Mount Dangar. This mid-wet-season rainfall pulse aligns with long-term patterns where the Bowen region often experiences episodic but intense rainfall associated with coastal troughs, monsoon incursions, or decaying tropical systems. Rainfall decreased through March and April, with only sparse, isolated events by May, marking the return to dry-season conditions.

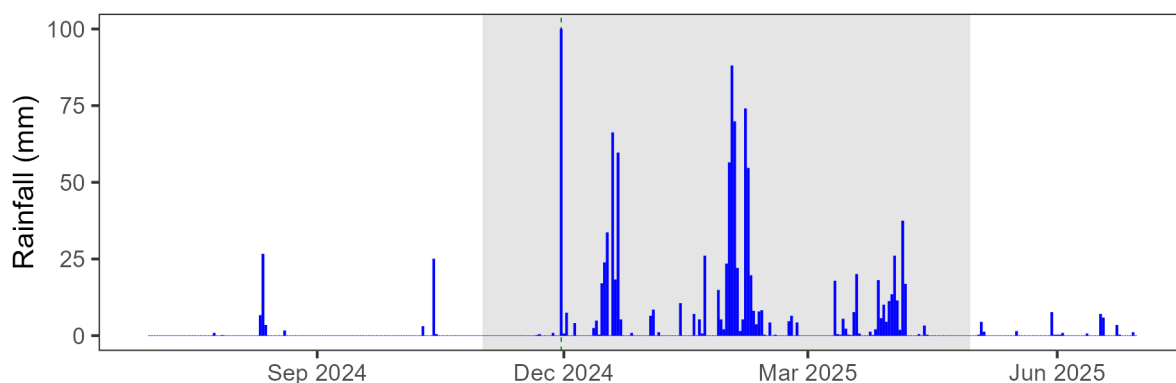


Figure 3-1 Rainfall recorded at Mount Dangar (station 033096) and Mount Dangar Alert (station 033267) for the 2024-2025 water year. The nominal wet season period is shaded grey. Green vertical dash indicates northern rainfall onset. Data source: <http://www.bom.gov.au/climate/data/>

Long-term rainfall analysis (Figure 3-2) shows that 2024–2025 sits within the normal interannual range for the Bowen area. Total annual rainfall was moderate relative to long-term averages—substantially lower than major wet years (e.g., 2010–2011, 2016–2017) but consistent with typical wet seasons characterised by several short, intense rainfall bursts rather than sustained monsoonal activity. The wet-season/dry-season bars demonstrates that the 2024–2025 wet season contributed the majority of annual rainfall, with a modest dry-season component, consistent with long-term climatology.

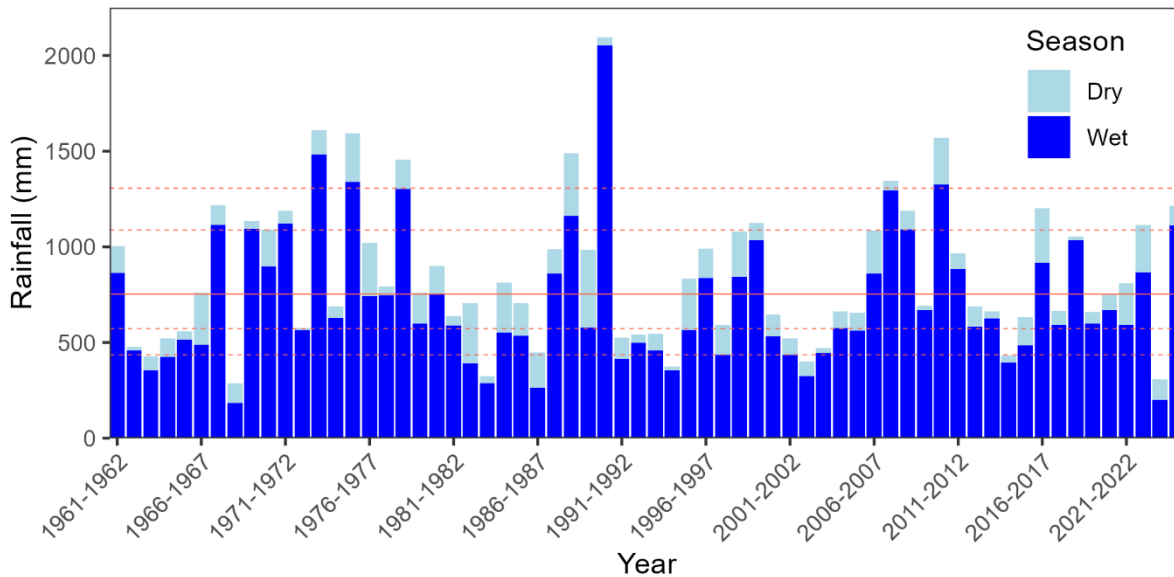


Figure 3-2 Annual rainfall by water year for the Bowen region during wet season (blue) and dry season (light blue). Totals were calculated for the wet season period 1st November to 30th April for each water year. Water year runs from 1<sup>st</sup> July to 30<sup>th</sup> June. Solid red line represents median annual rainfall by water year, dashed lines represent 10<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup>, and 90<sup>th</sup> percentiles. Daily rainfall data was obtained from the Mount Danger (station 033096) and Mount Danger Alert (station 033267) weather stations. Note that some data was missing from the source during the 2023-2024 wet season and therefore this graph may be an underrepresentation of actual rainfall in the 2023-2024 period. Data source: <http://www.bom.gov.au/climate/data/>

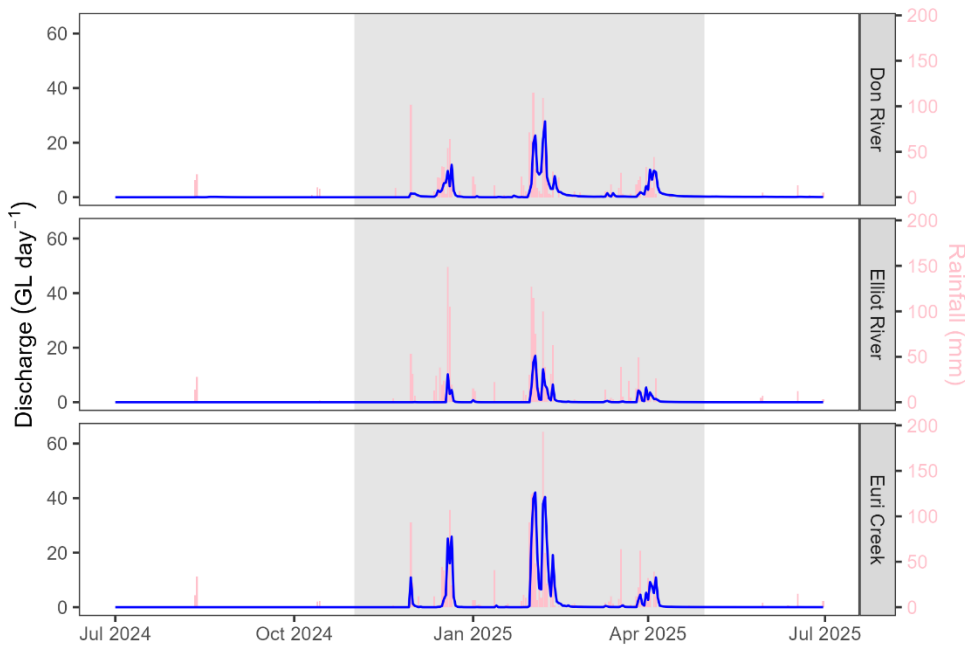


Figure 3-3 Stream discharge ( $\text{GL d}^{-1}$ ) from the Don River (station 121003A), Elliot River (station 121002A), and Euri Creek (station 121004A) during the 2024-2025 reporting period. Daily rainfall totals from each corresponding stream gauge shown in pink. The nominal wet season period is shaded grey. Data source: <https://water-monitoring.information.qld.gov.au/>

Streamflow patterns across the Bowen region during the 2024–2025 reporting period closely followed the timing and intensity of seasonal rainfall, with coordinated runoff responses evident in the Don River, Elliot River and Euri Creek (Figure 3-3). All three catchments exhibited prolonged low-flow to near-zero discharge conditions through much of the late dry season, with only minor and short-lived responses to isolated rainfall events prior to the establishment of the wet season.

A clear transition into the wet season is evident from December 2024, when the first meaningful rainfall events generated small but distinct runoff pulses across all three waterways. These early wet-season responses were short-lived and rapidly receded, reflecting modest rainfall totals and limited antecedent soil moisture typical of early wet-season conditions in the region.

Sustained catchment runoff developed from January 2025, with increasing discharge magnitude and frequency observed across all systems. During this period, the Don River displayed broader, more sustained flow responses consistent with its larger catchment, while Euri Creek showed sharper and more episodic peaks indicative of a smaller, more responsive system. The Elliot River exhibited intermediate behaviour, with moderate event-driven pulses superimposed on otherwise low background flows.

The largest hydrological event of the reporting year occurred in early February 2025, following several days of intense rainfall. This event produced pronounced flood peaks in all three waterways, with Euri Creek exhibiting the strongest and most rapid response, the Don River recording sustained high discharges, and the Elliot River reaching moderate peak flows relative to the other systems. Sentinel-2 imagery acquired on 18 February 2025 (Figure 3-4) captures the coastal expression of this event, showing sediment-rich flood plumes at the river mouths that transition offshore into lighter turquoise waters as suspended material settled and freshwater mixed with marine waters.

Although a large Burdekin River plume was present to the north at the time, Figure 3-4 highlights the distinct contribution of the Bowen catchments to local coastal plume development.

A secondary but notable runoff period occurred in late March to early April 2025. While smaller in magnitude than the February event, this system produced coordinated discharge responses across all three waterways, particularly evident as short-duration peaks in Euri Creek and renewed moderate flows in the Don and Elliot rivers. These late-season events extended the period of freshwater influence along the Bowen coastline beyond the peak wet-season months.

From April onwards, streamflows declined steadily as rainfall decreased. Only minor, short-duration flow responses were recorded following isolated rainfall events, and by May–June 2025 all three waterways had returned to near-zero discharge, marking the transition back to dry-season baseflow conditions.

Overall, the 2024–2025 hydrological year in the Bowen region was characterised by a gradual wet-season onset, followed by a dominant flood event in early February and a smaller late-season runoff pulse. These events governed the timing and magnitude of freshwater inflows, sediment delivery, and coastal plume dynamics observed during the reporting period, with direct implications for nearshore water quality patterns along the Bowen–Abbot Point coastline.

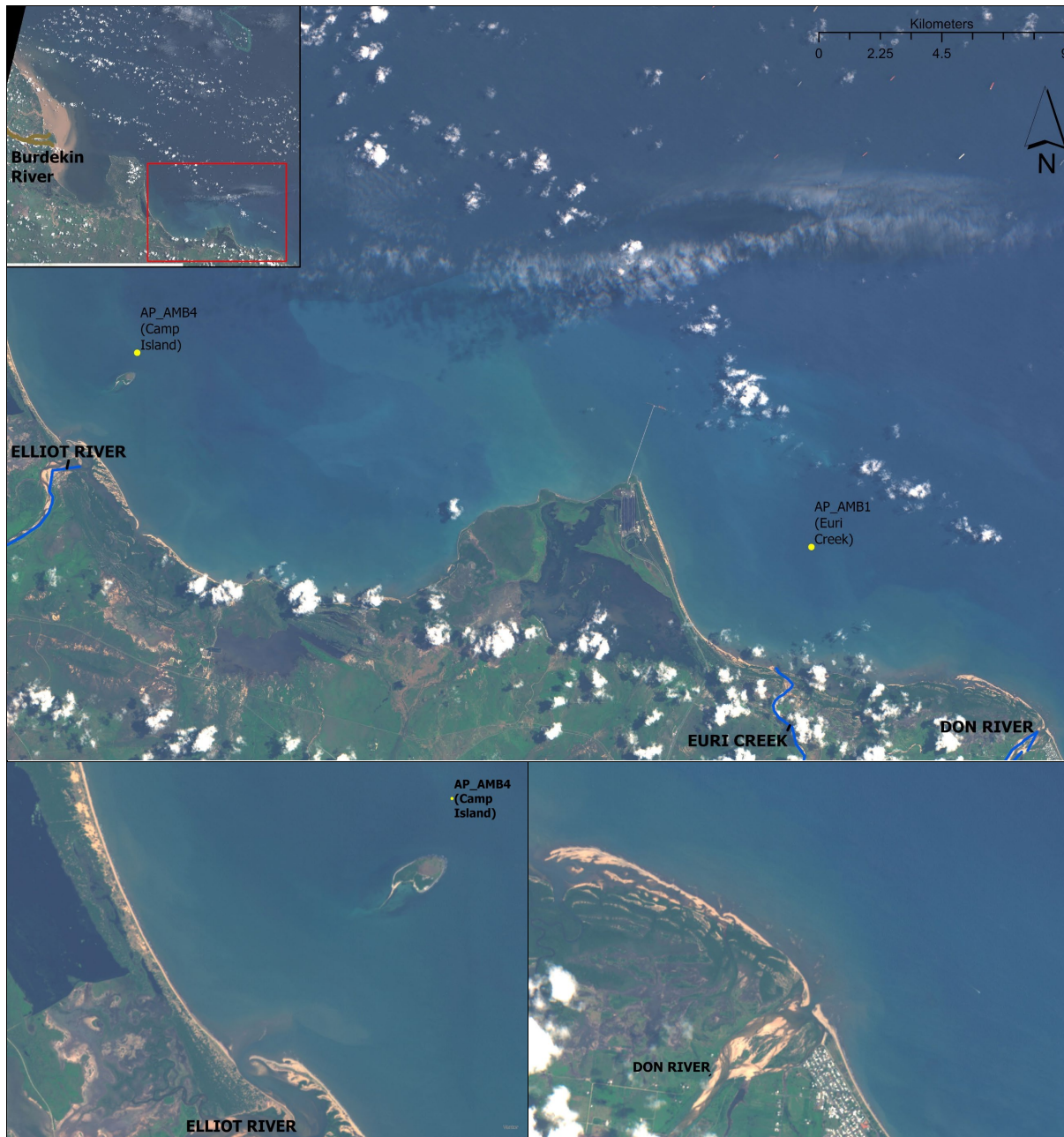


Figure 3-4 Sentinel-2 true-colour imagery acquired on 18 February 2025, captured shortly after the largest river flows of the 2024–2025 wet season, showing coastal flood-plume conditions in the Bowen–Abbot Point region. Brown, sediment-rich water is visible at the mouths of the Don River, Elliot River, and Euri Creek, transitioning offshore into lighter turquoise water representing more diluted freshwater and finer suspended material. A large Burdekin River flood plume to the north is visible in the inset map, included for regional context, but is not the focus of the figure. Monitoring sites AP\_AMB1 (Euri Creek) and AP\_AMB4 (Camp Island) are shown.

### 3.2. Wave Climate

Wave conditions at Abbot Point during the 2024–2025 reporting year were strongly directional and consistent with an inshore, wind-sea–dominated coastal environment. The annual and seasonal

wave roses (Figure 3-5; Figure 3-6) show a clear dominance of waves approaching from the east to east-northeast sector, with relatively little contribution from other directions. This pattern persisted throughout the year, with only modest seasonal broadening during the wet season when episodic weather systems increased directional variability. Overall, the wave-directional regime reflects persistent easterly forcing along the Bowen–Abbot Point coastline rather than long-period swell influence.

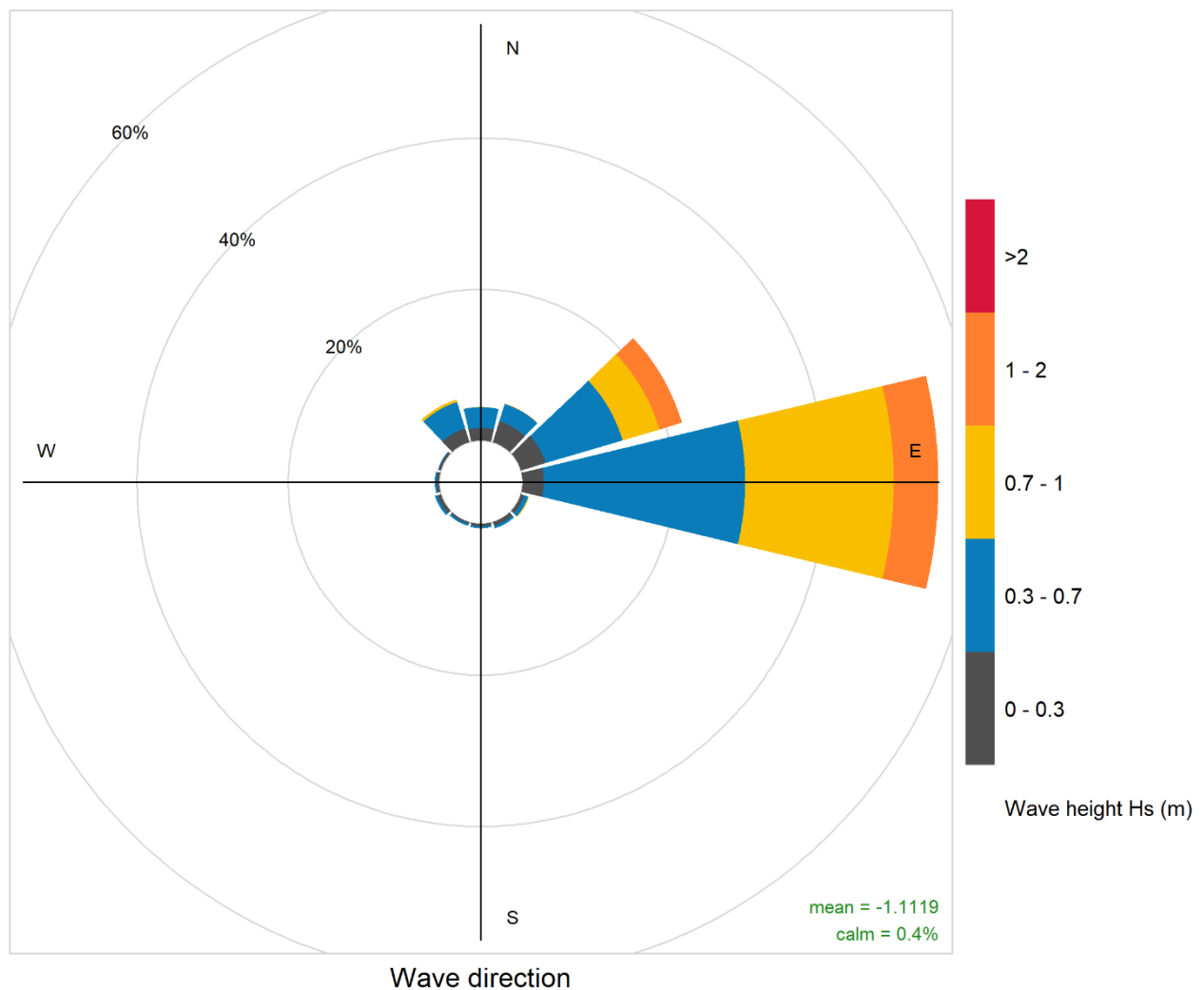
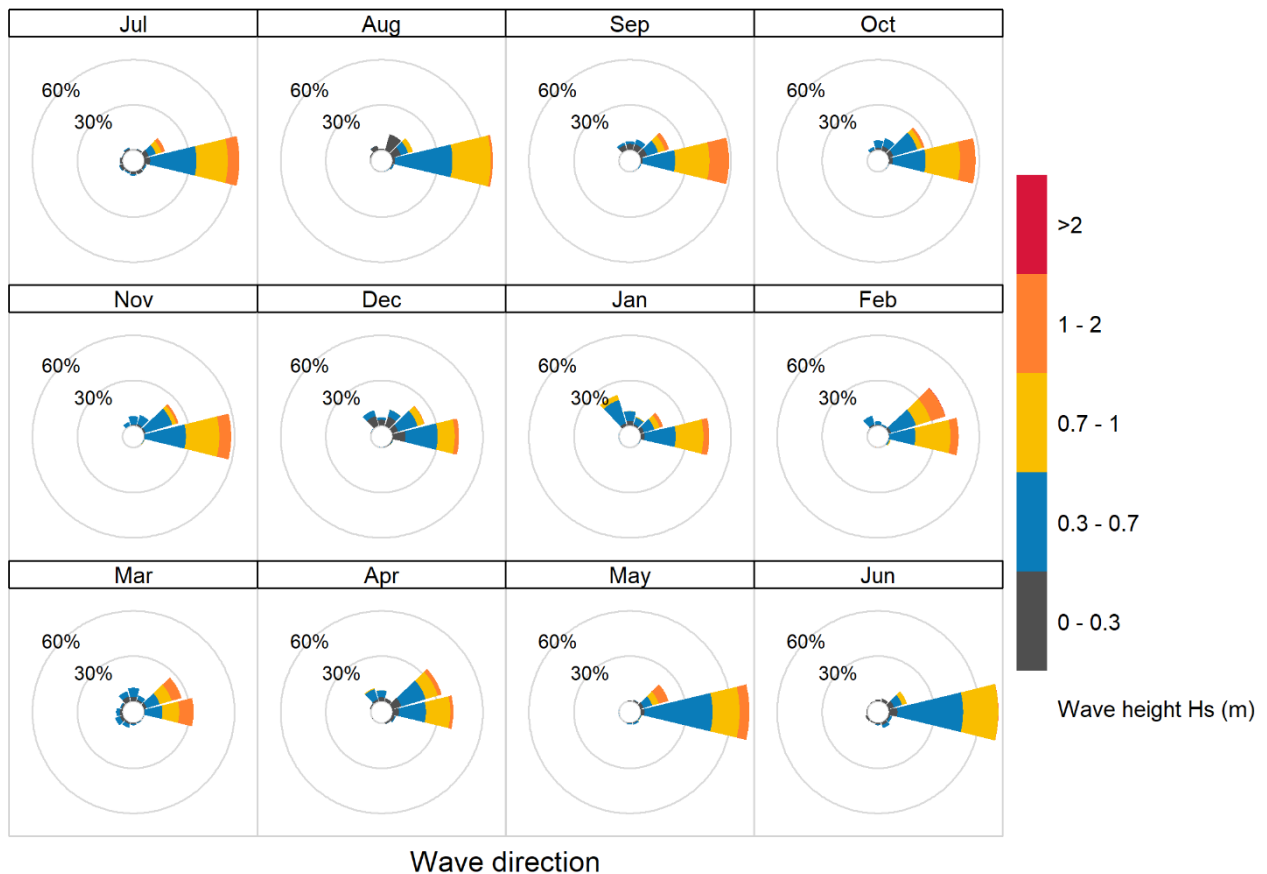


Figure 3-5 Frequency of counts by wave direction (%), and significant wave height (m) at the Abbot Point wave buoy station between July 1, 2024, and June 30, 2025.

Significant wave height (Hs) during the reporting year was generally low to moderate, ranging from near-calm conditions to a maximum of 2.12 m, with a median value of 0.57 m and most observations below 1 m (Figure 3-7). Maximum wave height (Hmax) typically remained around 1 m (median 0.96 m) but reached up to 4.10 m during short-lived higher-energy events, indicating episodic periods of increased wind forcing rather than sustained energetic conditions. These higher-energy events were infrequent and did not dominate the overall wave climate.

Wave period data further support the interpretation of Abbot Point as a sheltered, locally forced system (Figure 3-8). Peak wave period (Tp) was typically short, with a median of 4.2 s and most

values between 3.4 and 4.8 s, while zero-crossing period ( $T_z$ ) was tightly constrained around  $\sim 3$  s (median 3.0 s). Longer periods were rare and generally coincided with isolated energetic events. Together, the height and period characteristics indicate that the Abbot Point wave climate during FY 2024–2025 was dominated by short-period wind-sea conditions, with limited influence from longer-period swell.



*Figure 3-6 Frequency of counts by wave direction (%), and significant wave height (m) for each month at the Abbot Point wave buoy station between July 1, 2024, and June 30, 2025.*

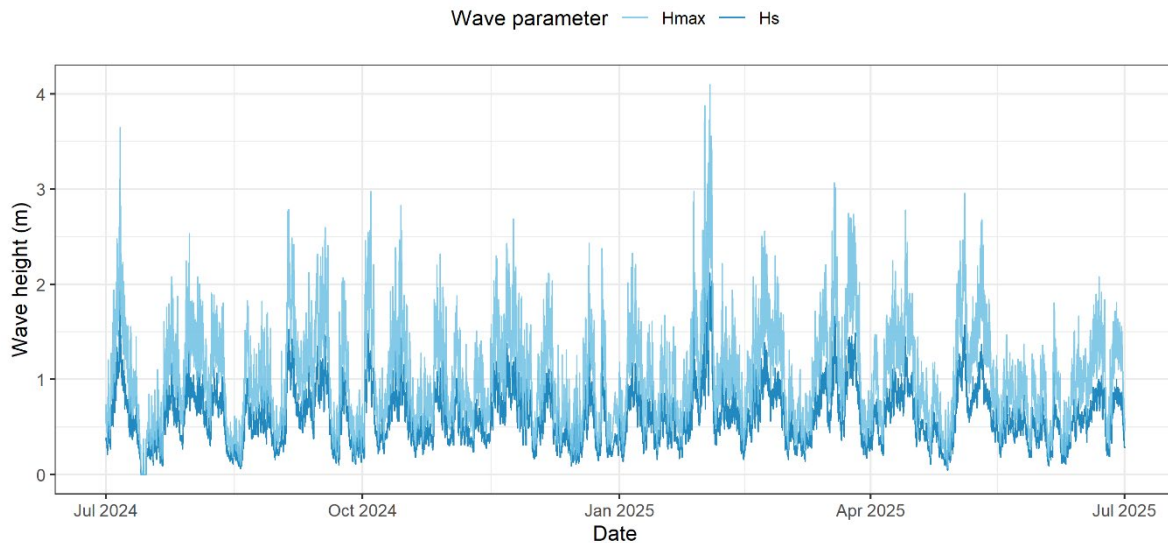


Figure 3-7 Time series of significant wave height ( $H_s$ ) and maximum wave height ( $H_{max}$ ) at the Hay Point wave buoy station between July 1, 2024, and June 30, 2025.

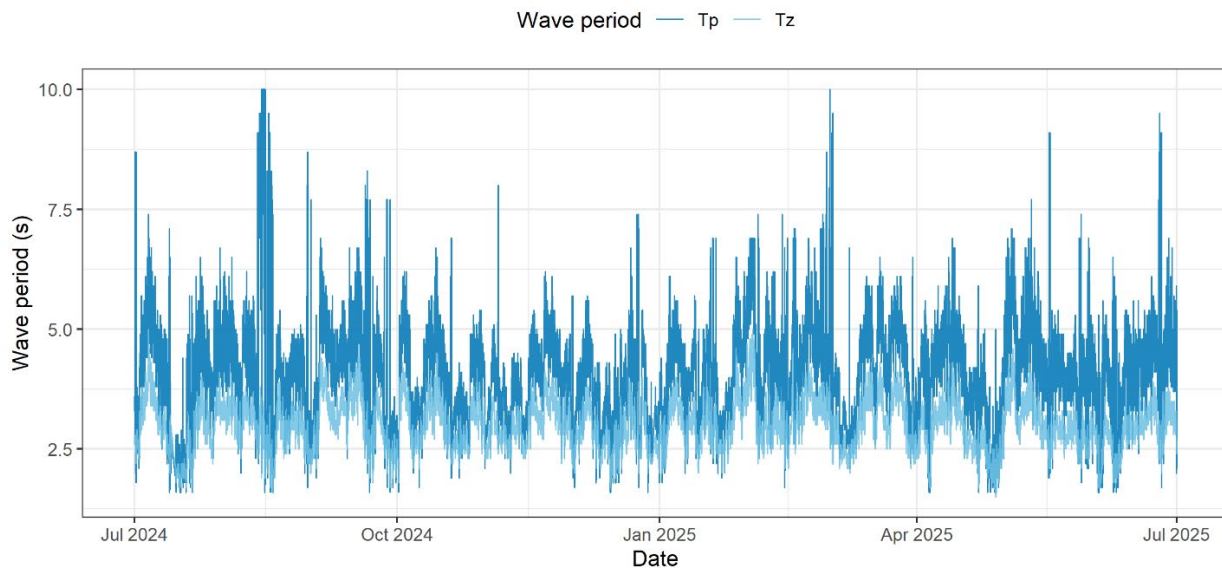


Figure 3-8 Time series of wave period at the Hay Point wave buoy station between July 1, 2024, and June 30, 2025. Peak energy wave ( $T_p$ : light blue) and zero upcrossing wave ( $T_z$ : dark blue).

Overall, the 2024–2025 wave climate at Abbot Point was stable and predictable, characterised by predominantly easterly wave approach, low to moderate wave heights, and short wave periods. These conditions provide important context for interpreting nearshore processes such as sediment resuspension, turbidity dynamics, and hydrodynamic variability in the Bowen–Abbot Point region.

### 3.3. Water quality

#### 3.3.1. Nutrients

Nutrient concentrations across the Bowen ambient monitoring sites were broadly characteristic of well-flushed inshore coastal waters, with low to moderate nitrogen concentrations and consistently low phosphorus levels throughout the 2024–2025 reporting period (August 2024 – June 2025).

Total nitrogen (TN) concentrations ranged from approximately 105 to 210  $\mu\text{g L}^{-1}$  across the four sites, with median values typically between  $\sim 115$  and 140  $\mu\text{g L}^{-1}$ . TN remained relatively stable for much of the year, with higher concentrations recorded during wet-season sampling, particularly at McCanes Bay and Camp Island in February and April 2025. These increases coincided with elevated particulate nitrogen concentrations, while dissolved nitrogen remained comparatively stable.

Total dissolved nitrogen (TDN) ranged from 92 to 145  $\mu\text{g L}^{-1}$  and generally comprised the majority of TN across all sites and sampling occasions. Dissolved nitrogen showed limited seasonal variability, consistent with coastal waters influenced by episodic runoff but subject to strong tidal mixing and flushing.

Particulate nitrogen (PN) exhibited the greatest variability, ranging from 3 to 102  $\mu\text{g L}^{-1}$ . The highest PN concentrations were recorded at Camp Island and McCanes Bay during February 2025, coinciding with wet-season conditions. Outside of these events, PN concentrations were generally low across all sites, consistent with predominantly dry-season or well-mixed coastal conditions.

Total phosphorus (TP) concentrations were consistently low across the region, typically ranging from 4 to 10  $\mu\text{g L}^{-1}$ . Slightly higher TP values were observed during wet-season sampling at some sites but remained within guideline values for coastal waters. Total dissolved phosphorus (TDP) generally ranged from 2 to 7  $\mu\text{g L}^{-1}$ , while particulate phosphorus (PP) was typically  $\leq 4 \mu\text{g L}^{-1}$ , with occasional higher values during periods of increased suspended sediment.

Overall, while nitrogen concentrations—particularly TN and TDN—were commonly at or above regional water-quality objectives when assessed on a statistical basis (Tables 3-3 – 3-5), concentrations were spatially consistent across Bowen sites and dominated by dissolved forms. This pattern suggests broad regional and catchment-scale influences, rather than localised enrichment associated with port or nearshore activities. Phosphorus concentrations generally remained low and largely within applicable water-quality objectives, with short-lived increases in particulate fractions occurring during isolated sampling events rather than reflecting persistently elevated conditions.

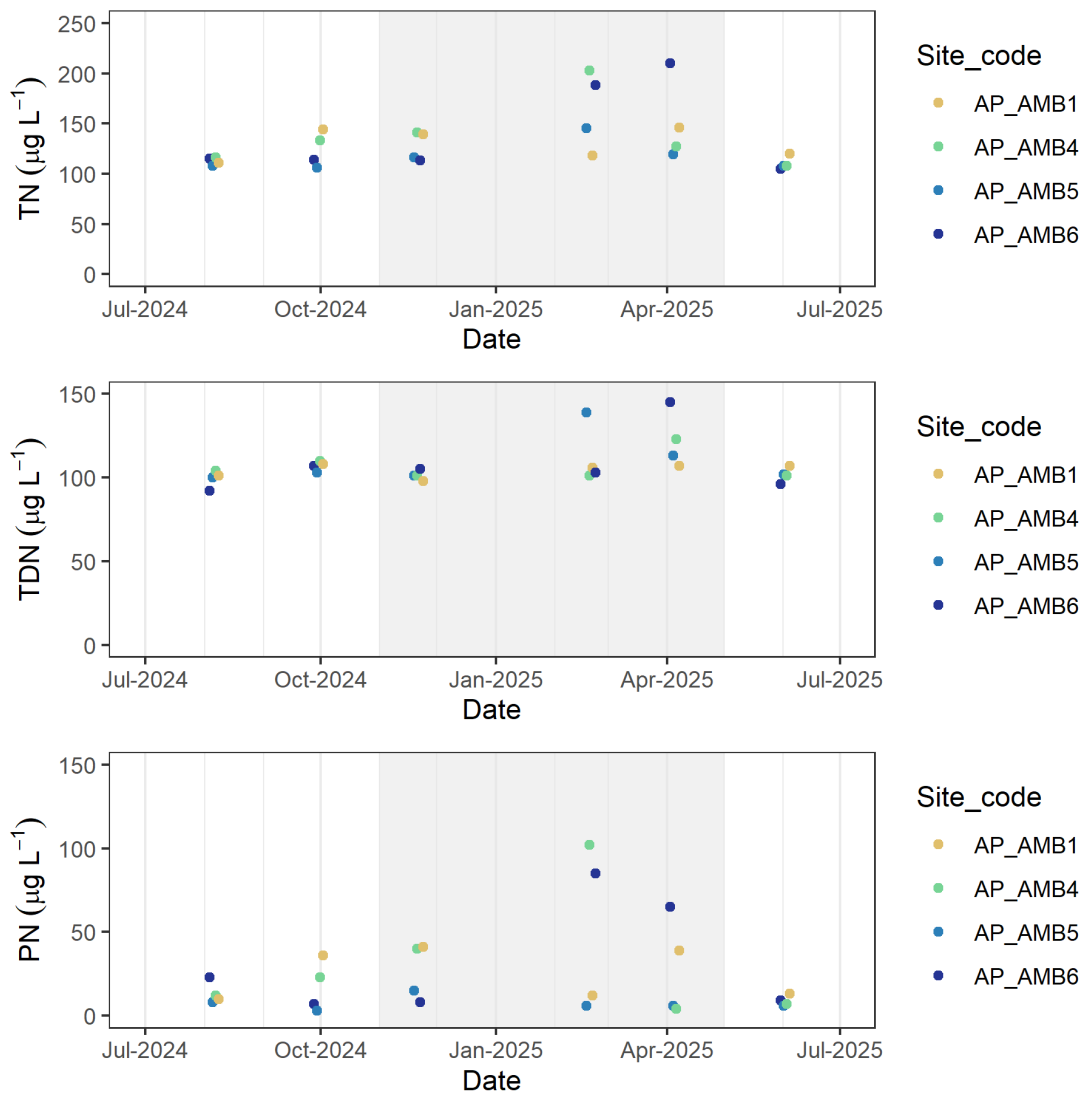


Figure 3-9 Total nitrogen (TN;  $\mu\text{g L}^{-1}$ ), total dissolved nitrogen (TDN;  $\mu\text{g L}^{-1}$ ), and particulate nitrogen (PN;  $\mu\text{g L}^{-1}$ ) concentrations measured in water samples collected from the four water-quality sites in the Bowen region—Euri Creek (AP\_AMB1), Camp Island (AP\_AMB4), Holbourne Island (AP\_AMB5), and McCanes Bay (AP\_AMB6)—during the 2024–2025 reporting period, with the shaded area representing the wet season.

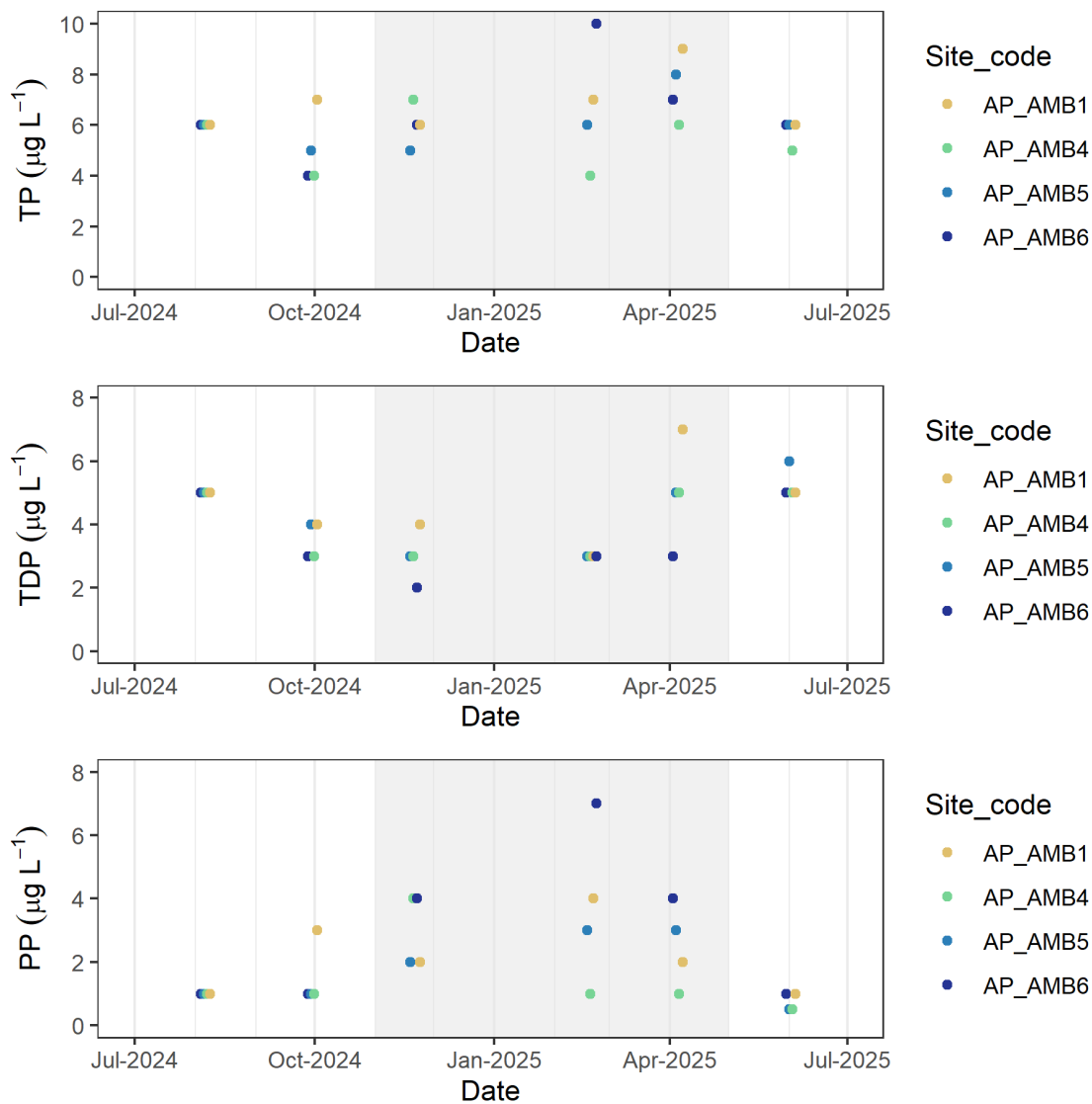


Figure 3-10 Total phosphorus (TP), total dissolved phosphorus (TDP), and particulate phosphorus (PP) concentrations measured in water samples collected from the four water-quality sites in the Bowen region—Euri Creek (AP\_AMB1), Camp Island (AP\_AMB4), Holbourne Island (AP\_AMB5), and McCanes Bay (AP\_AMB6)—during the 2024–2025 reporting period, with the shaded area representing the wet season.

### 3.3.2. Chlorophyll

Chlorophyll-a concentrations across the Bowen ambient monitoring sites were generally low to moderate throughout the 2024–2025 reporting period, characteristic of a well-flushed inshore coastal environment with limited phytoplankton accumulation. Concentrations ranged from  $<0.2$  to  $2.08 \mu\text{g L}^{-1}$ , with the majority of observations  $\leq 1 \mu\text{g L}^{-1}$  and a median concentration of approximately  $0.45 \mu\text{g L}^{-1}$ .

The highest chlorophyll-a concentration ( $2.08 \mu\text{g L}^{-1}$ ) was recorded at Euri Creek in September 2024, representing an isolated peak rather than a sustained increase. Elevated concentrations were

also observed at McCanes Bay in November 2024 ( $1.74 \mu\text{g L}^{-1}$ ). Outside these isolated observations, chlorophyll-*a* concentrations showed limited temporal persistence and no evidence of prolonged elevation at any site.

When assessed against the EPP (2019) water-quality objectives, mean chlorophyll-*a* concentrations exceeded the applicable guideline values at most Bowen ambient monitoring sites. These exceedances reflect the low numerical thresholds specified for open coastal waters rather than the occurrence of bloom conditions or sustained elevations in phytoplankton biomass. This interpretation is supported by the absence of persistent chlorophyll-*a* elevation and by consistently low phaeophytin-*a* concentrations ( $<0.2 \mu\text{g L}^{-1}$  in most samples), indicating limited pigment degradation and a lack of senescent phytoplankton accumulation.

Overall, chlorophyll-*a* concentrations indicate a system characterised by low median biomass with episodic increases likely driven by short-term local conditions rather than sustained phytoplankton growth. This pattern is consistent with the generally low nutrient concentrations and strong hydrodynamic flushing characteristic of the Bowen–Abbot Point coastal environment.

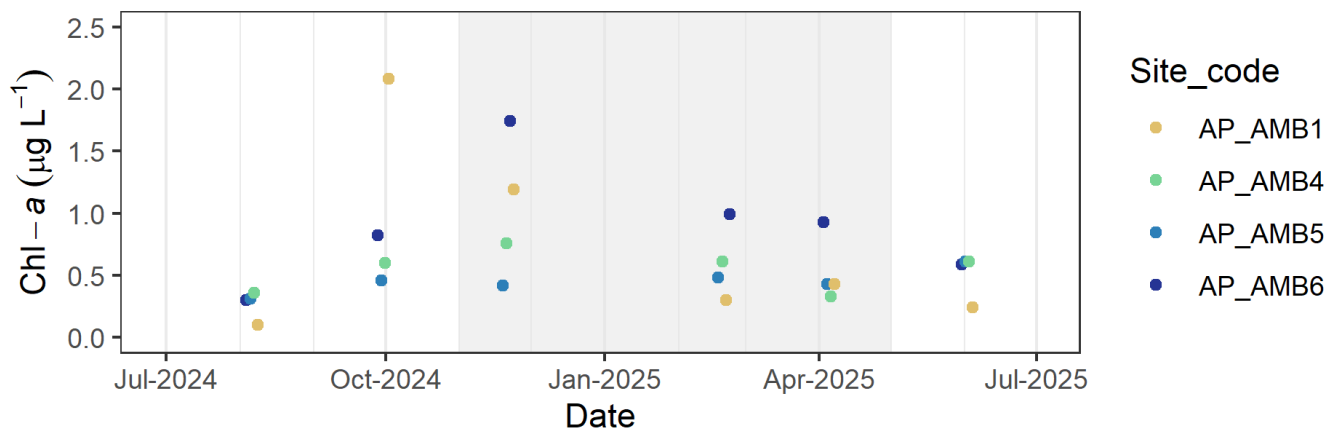


Figure 3-11 Chlorophyll-*a* concentrations ( $\mu\text{g L}^{-1}$ ) measured in water samples collected from the four water quality sites in the Bowen region; Euri Creek (AP\_AMB1), Camp Island (AP\_AMB4), Holbourne Island (AP\_AMB5) and McCanes Bay (AP\_AMB6), for the 2024-2025 reporting period, with the shaded area representative of the wet season.

### 3.3.3. Filterable metals

Filterable metal concentrations measured across the Bowen ambient monitoring sites were uniformly low during the 2024–2025 monitoring period, with most analytes recorded at or near analytical detection limits. This pattern is consistent with well-flushed inshore coastal waters and indicates minimal contamination pressure across the Bowen–Abbot Point region.

Arsenic concentrations showed little spatial or temporal variability, ranging from  $1.2$  to  $1.5 \mu\text{g L}^{-1}$  across all sites and sampling occasions. These values are consistent with natural background concentrations typically observed in marine waters and do not indicate local enrichment.

Copper concentrations were below detection limits ( $<1 \mu\text{g L}^{-1}$ ) in all samples, indicating very low dissolved copper availability throughout the region. Similarly, cadmium concentrations were consistently below the detection limit ( $<0.2 \mu\text{g L}^{-1}$ ) at all sites and times sampled.

Lead concentrations were also generally below detection ( $<0.2 \mu\text{g L}^{-1}$ ), with a single slightly elevated value of  $0.4 \mu\text{g L}^{-1}$  recorded at McCanes Bay in November 2024. This isolated result remains well below the ANZG 99% level of species protection guideline value and is not indicative of persistent or widespread metal enrichment.

Nickel, silver, and mercury were recorded at or near their respective detection limits in all samples. Nickel concentrations were consistently  $<0.5 \mu\text{g L}^{-1}$ , silver  $<0.1 \mu\text{g L}^{-1}$ , and mercury  $<0.0001 \mu\text{g L}^{-1}$ , reflecting very low dissolved metal concentrations across the monitoring period.

When assessed against the ANZG (2018) default guideline values at 95% species protection for slightly to moderately disturbed sites (Euri Creek, Camp Island, and McCanes Bay) and 99% species protection for the high ecological value site at Holbourne Island, no exceedances were recorded during either the dry or wet season sampling events. Overall, the consistently low and stable metal concentrations indicate no evidence of anthropogenic metal enrichment and reflect the naturally low-metal background typical of sandy, well-mixed coastal waters in the Bowen region.

Table 3-1 Filterable metal from the Bowen/ Abbot Point monitoring sites over the wet and dry seasons. Bold values indicate values above limit of detection.

| Site name                                   | Site code | Ag                   | As                   | Cd                   | Cu                   | Hg                   | Ni                   | Pb                   |
|---------------------------------------------|-----------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| <b>Dry season (04/09/2024)</b>              |           | $\mu\text{g L}^{-1}$ | $\mu\text{g L}^{-1}$ | $\mu\text{g L}^{-1}$ | $\mu\text{g L}^{-1}$ | $\mu\text{g L}^{-1}$ | $\mu\text{g L}^{-1}$ | $\mu\text{g L}^{-1}$ |
| Euri Creek                                  | AP_AMB1   | $<0.1$               | <b>1.3</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| Camp Island                                 | AP_AMB4   | $<0.1$               | <b>1.4</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| Holbourne Island                            | AP_AMB5   | $<0.1$               | <b>1.3</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| McCanes Bay                                 | AP_AMB6   | $<0.1$               | <b>1.2</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| <b>Wet season (27/02/2025)</b>              |           |                      |                      |                      |                      |                      |                      |                      |
| Euri Creek                                  | AP_AMB1   | $<0.1$               | <b>1.4</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| Camp Island                                 | AP_AMB4   | $<0.1$               | <b>1.3</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| Holbourne Island                            | AP_AMB5   | $<0.1$               | <b>1.4</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | $<0.2$               |
| McCanes Bay                                 | AP_AMB6   | $<0.1$               | <b>1.5</b>           | $<0.2$               | $<1$                 | $<0.1$               | $<0.5$               | <b>0.4</b>           |
| <b>Limit of detection (LOD)<sup>#</sup></b> |           | 0.1                  | 0.5                  | 0.2                  | 1                    | 0.1                  | 0.5                  | 0.2                  |
| <b>ANZG 99% level of species protection</b> |           | 0.8                  | -                    | 0.7                  | 0.3                  | 0.1                  | 7                    | 2.2                  |
| <b>ANZG 95% level of species protection</b> |           | 1.4                  | -                    | 5.5                  | 1.3                  | 0.4                  | 70                   | 4.4                  |

#### 3.3.4. Ambient Nutrient Variability in Relation to Regional Water Quality Objectives

Nutrient and chlorophyll-a concentrations measured at the Abbot Point ambient water-quality monitoring sites were compared with the relevant regional water-quality objectives (WQOs) defined under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP 2019) to provide context for interpreting ambient spatial and seasonal variability. These comparisons are intended to support understanding of background conditions in inshore coastal waters and do not represent compliance thresholds for port-related activities, which are assessed separately using site-specific criteria and predictive modelling frameworks defined under relevant Long-Term Dredge Management Plans (LTDMs).

EPP (2019) WQOs vary by parameter and location and are defined using different statistical forms, including annual medians, seasonal means and percentile-based targets. Accordingly, the comparisons presented here apply the form of statistic specified by each WQO—annual, seasonal or percentile-based—with seasonal statistics emphasised where appropriate to reflect the strong seasonal signal and episodic, event-driven behaviour characteristic of the Bowen region, rather than as pass/fail compliance assessments.

Table 3-2 Seasonal nutrient and chlorophyll-a statistics for Euri Creek (AP\_AMB1), summarised as dry- and wet-season mean, or annual median consistent with EPP (2019) open-coastal water-quality objectives, with interpretation focused on natural seasonal and event-driven variability.

| Parameter                        | ( $\mu\text{g L}^{-1}$ ) | WQO        | WQO Basis                      | Status - wet/dry | Interpretive context (ambient conditions)                                                                                                                                                                                                                                |
|----------------------------------|--------------------------|------------|--------------------------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chlorophyll-a                    | 0.88 / 0.64              | 0.32/ 0.63 | Dry season/<br>Wet season mean | Above/<br>above  | Mean concentrations exceeded both seasonal objectives, with elevated dry-season values and comparatively high phaeophytin indicating the presence of degraded or senescent phytoplankton biomass persisting outside peak runoff periods.                                 |
| Particulate Nitrogen (PN)        | 24/ 31                   | 16/ 24     | Dry season/<br>Wet season mean | Above/<br>above  | Dry season means exceeded the objective and increased further in the wet season, indicating enhanced particulate enrichment during runoff periods.                                                                                                                       |
| Particulate Phosphorus (PP)      | 2.0/ 2.7                 | 2.3/ 3.3   | Dry season/<br>Wet season mean | Below/<br>below  | Dry season means were below the objective, with wet-season values approaching the higher benchmark, consistent with episodic particulate phosphorus inputs.                                                                                                              |
| Total Dissolved Nitrogen (TDN)   | 106.5                    | 70         | Annual median                  | Above WQO        | Median TDN concentrations exceeded the annual WQO, indicating elevated dissolved nitrogen relative to guideline expectations. This elevation was persistent but stable and likely reflects regional marine nutrient background rather than episodic or localised inputs. |
| Total Dissolved Phosphorus (TDP) | 4.5                      | 6          | Annual median                  | Below WQO        | Median TDP concentrations were low and below the annual WQO. This indicates limited dissolved phosphorus availability at this site.                                                                                                                                      |

|                                                                                                                                                                                                                              |        |     |               |           |                                                                                                                                                                                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-----|---------------|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Total Nitrogen (TN)                                                                                                                                                                                                          | 129.50 | 100 | Annual median | Above WQO | Median TN concentrations exceeded the annual WQO, driven primarily by the dissolved nitrogen fraction. Concentrations were stable across seasons, suggesting a consistent ambient nitrogen signal rather than event-driven enrichment. |
| Total Phosphorus (TP)                                                                                                                                                                                                        | 6.5    | 12  | Annual median | Below WQO | TP concentrations remained below the annual median WQO. Variability was limited and consistent with low particulate and dissolved phosphorus inputs.                                                                                   |
| Values shown represent seasonal summary statistics used to contextualise ambient variability relative to regional WQOs. These comparisons are not intended to represent compliance criteria for dredging or port operations. |        |     |               |           |                                                                                                                                                                                                                                        |

Table 3-3 Seasonal nutrient and chlorophyll-a statistics for Camp Island (AP\_AMB4), summarised as dry- and wet-season mean, or annual median consistent with EPP (2019) open-coastal water-quality objectives, with interpretation focused on natural seasonal and event-driven variability.

| Parameter                   | Seasonal Mean / Annual Median ( $\mu\text{g L}^{-1}$ ) | WQO        | WQO Basis                      | Status - wet/dry | Interpretive context (ambient conditions)                                                                                                                  |
|-----------------------------|--------------------------------------------------------|------------|--------------------------------|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chlorophyll-a               | 0.52 / 0.57                                            | 0.32/ 0.63 | Dry season/<br>Wet season mean | Above/<br>below  | Mean concentrations exceeded the dry-season objective and approached the wet-season benchmark, indicating moderate but persistent phytoplankton biomass.   |
| Particulate Nitrogen (PN)   | 15.5/<br>36.5                                          | 16/ 24     | Dry season/<br>Wet season mean | Below/<br>above  | Dry-season means were near the objective, while wet-season means substantially exceeded the benchmark, indicating strong runoff-driven particulate inputs. |
| Particulate Phosphorus (PP) | 1.2/ 1.8                                               | 2.3/ 3.3   | Dry season/<br>Wet season mean | Below/<br>below  | Mean concentrations remained below both seasonal objectives, suggesting limited particulate phosphorus enrichment despite elevated wet-season flows.       |

|                                                                                                                                                                                                                              |       |     |               |           |                                                                                                                                                                                            |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----|---------------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Total Dissolved Nitrogen (TDN)                                                                                                                                                                                               | 102.5 | 70  | Annual median | Above WQO | Median concentrations exceeded the annual WQO, indicating consistently high dissolved nitrogen availability throughout the monitoring period.                                              |
| Total Dissolved Phosphorus (TDP)                                                                                                                                                                                             | 4.0   | 6   | Annual median | Below WQO | Median concentrations were low and below the annual WQO, indicating limited dissolved phosphorus availability despite elevated nitrogen levels.                                            |
| Total Nitrogen (TN)                                                                                                                                                                                                          | 130.0 | 100 | Annual median | Above WQO | Median concentrations exceeded the annual WQO and were dominated by the dissolved nitrogen fraction, suggesting sustained nitrogen availability rather than short-lived enrichment events. |
| Total Phosphorus (TP)                                                                                                                                                                                                        | 5.5   | 12  | Annual median | Below WQO | Median concentrations remained below the annual WQO, with limited variability consistent with low overall phosphorus inputs.                                                               |
| Values shown represent seasonal summary statistics used to contextualise ambient variability relative to regional WQOs. These comparisons are not intended to represent compliance criteria for dredging or port operations. |       |     |               |           |                                                                                                                                                                                            |

*Table 3-4 Seasonal nutrient and chlorophyll-a statistics for Holbourne Island (AP\_AMB5), presented as dry- and wet-season mean, median, or percentile-based values (20th, 50th and 80th percentiles), consistent with the form of the applicable EPP (2019) open-coastal water-quality objectives. Results are provided to contextualise ambient variability, with interpretive notes highlighting dominant seasonal and episodic influences. Percentiles should be interpreted with caution due to the limited number of observations; values are indicative of typical conditions over the monitoring period rather than long-term climatological distributions.*

| Parameter     | Annual percentiles ( $\mu\text{g L}^{-1}$ ) | WQO            | WQO Basis                                                     | Status    | Interpretive context (ambient conditions)                                                                                                                                                                           |
|---------------|---------------------------------------------|----------------|---------------------------------------------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chlorophyll-a | 0.31-0.45-0.61                              | 0.18-0.33-0.57 | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Above WQO | Median chlorophyll-a slightly exceeded the mid-point WQO, with the upper percentile marginally above the 80th percentile guideline, suggesting occasional phytoplankton enhancement rather than chronic enrichment. |

|                                                                                                                                                                                                                     |               |             |                                                               |           |                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------|---------------------------------------------------------------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Particulate Nitrogen (PN)                                                                                                                                                                                           | 3-6-15        | 9-14-20     | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Below WQO | Concentrations were generally low to moderate and mostly within guideline ranges, indicating limited particulate nutrient loading.                                              |
| Particulate Phosphorus (PP)                                                                                                                                                                                         | 1-2-3         | 1.5-2.0-2.8 | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Below WQO | Concentrations were typically low, with upper percentile values approaching guideline thresholds, consistent with occasional particulate inputs rather than chronic enrichment. |
| Total Dissolved Nitrogen (TDN)                                                                                                                                                                                      | 100-103-139   | 40-65-90    | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Above WQO | Dissolved nitrogen concentrations were consistently above guideline thresholds, suggesting persistent nitrogen enrichment in the dissolved phase.                               |
| Total Dissolved Phosphorus (TDP)                                                                                                                                                                                    | 3-4-6         | 2-6-10      | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Below WQO | Dissolved phosphorus concentrations were low and aligned with guideline values, indicating limited bioavailable phosphorus enrichment.                                          |
| Total Nitrogen (TN)                                                                                                                                                                                                 | 108-117.5-145 | 50-90-110   | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Above WQO | All percentile values exceeded guideline levels, indicating episodic enrichment and elevated nitrogen availability relative to water quality objectives.                        |
| Total Phosphorus (TP)                                                                                                                                                                                               | 5-5-8         | 5-10-15     | 20 <sup>th</sup> 50 <sup>th</sup> 80 <sup>th</sup> percentile | Below WQO | Values were low and remained within water quality objectives across the percentile range, suggesting phosphorus was not a primary driver of variability.                        |
| Values shown represent summary statistics used to contextualise ambient variability relative to regional WQOs. These comparisons are not intended to represent compliance criteria for dredging or port operations. |               |             |                                                               |           |                                                                                                                                                                                 |

Table 3-5 Seasonal nutrient and chlorophyll-a statistics for McCanes Bay (AP\_AMB6), summarised as dry- and wet-season mean, or annual median consistent with EPP (2019) open-coastal water-quality objectives, with interpretation focused on natural seasonal and event-driven variability.

| Parameter | Seasonal Mean / Annual | WQO | WQO Basis | Status - wet/dry | Interpretive context (ambient conditions) |
|-----------|------------------------|-----|-----------|------------------|-------------------------------------------|
|-----------|------------------------|-----|-----------|------------------|-------------------------------------------|

|                                     | Median<br>( $\mu\text{g L}^{-1}$ ) |            |                                   |                 |                                                                                                                                                                                   |
|-------------------------------------|------------------------------------|------------|-----------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chlorophyll-a                       | 0.54 /<br>1.22                     | 0.32/ 0.63 | Dry season/<br>Wet season<br>mean | Above/<br>below | Mean concentrations exceeded both seasonal objectives, with markedly higher wet-season values indicating strong phytoplankton responses to nutrient-rich runoff.                  |
| Particulate<br>Nitrogen (PN)        | 13.0/<br>45.3                      | 16/ 24     | Dry season/<br>Wet season<br>mean | Below/<br>above | Dry-season means were below the objective, while wet-season means greatly exceeded the benchmark, indicating strong episodic particulate loading during high-flow conditions.     |
| Particulate<br>Phosphorus (PP)      | 1.0/ 4.0                           | 2.3/ 3.3   | Dry season/<br>Wet season<br>mean | Below/<br>below | Dry-season means were low, with wet-season values exceeding the benchmark, consistent with substantial particulate phosphorus mobilisation.                                       |
| Total Dissolved<br>Nitrogen (TDN)   | 104.0                              | 70         | Annual<br>median                  | Above<br>WQO    | Median concentrations exceeded the annual WQO, indicating consistently high dissolved nitrogen availability throughout the monitoring period.                                     |
| Total Dissolved<br>Phosphorus (TDP) | 3.0                                | 6          | Annual<br>median                  | Below<br>WQO    | Median concentrations were below the annual WQO, indicating limited dissolved phosphorus availability relative to nitrogen.                                                       |
| Total Nitrogen (TN)                 | 114.5                              | 100        | Annual<br>median                  | Above<br>WQO    | Median concentrations exceeded the annual WQO, reflecting elevated nitrogen loads, with variability suggesting contributions from both background conditions and episodic inputs. |
| Total Phosphorus<br>(TP)            | 6.0                                | 12         | Annual<br>median                  | Below<br>WQO    | Median concentrations remained below the annual WQO, suggesting that phosphorus was not persistently elevated despite episodic particulate inputs during high-flow conditions.    |

Values shown represent seasonal summary statistics used to contextualise ambient variability relative to regional WQOs. These comparisons are not intended to represent compliance criteria for dredging or port operations.

### 3.4. Physicochemical

#### 3.4.1. Dissolved oxygen

Dissolved oxygen (DO) concentrations across the Bowen–Abbot Point ambient monitoring sites were consistently within healthy marine ranges throughout the 2024–2025 reporting period (Figure 3-13). Across all sites and depths, DO generally ranged from approximately 6.0–7.9 mg L<sup>-1</sup>, with corresponding oxygen saturation values typically between ~87 and 113% (Figure 3-14). These values indicate well-oxygenated conditions across the water column.

Slightly elevated oxygen saturation (>110%) was occasionally observed, particularly during late dry-season and early wet-season sampling events (e.g. Holbourne Island in November), likely reflecting enhanced daytime photosynthetic activity under warm, high-light conditions. Vertical differences in DO were minor, with concentrations typically highest at the surface and marginally lower near the seabed. No hypoxic or low-oxygen conditions were observed at any site or depth. DO is reported both as mg L<sup>-1</sup> (absolute concentration) and % saturation (relative to solubility at the measured temperature and salinity), allowing clearer interpretation under varying seasonal and physical conditions.

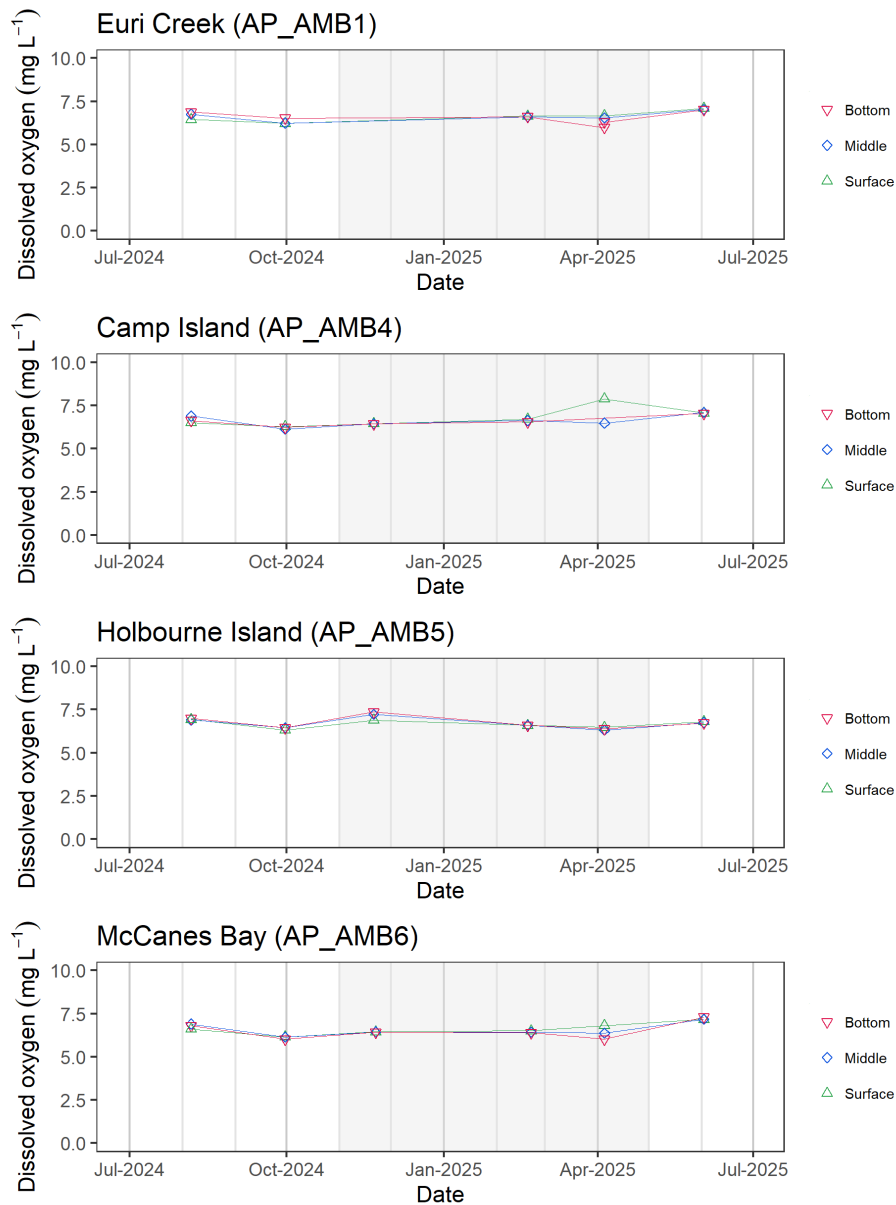


Figure 3-12 Dissolved oxygen concentration ( $\text{mg L}^{-1}$ ) at Bowen ambient sites, shown for surface, mid-water, and bottom depths. Grey area indicates wet season.

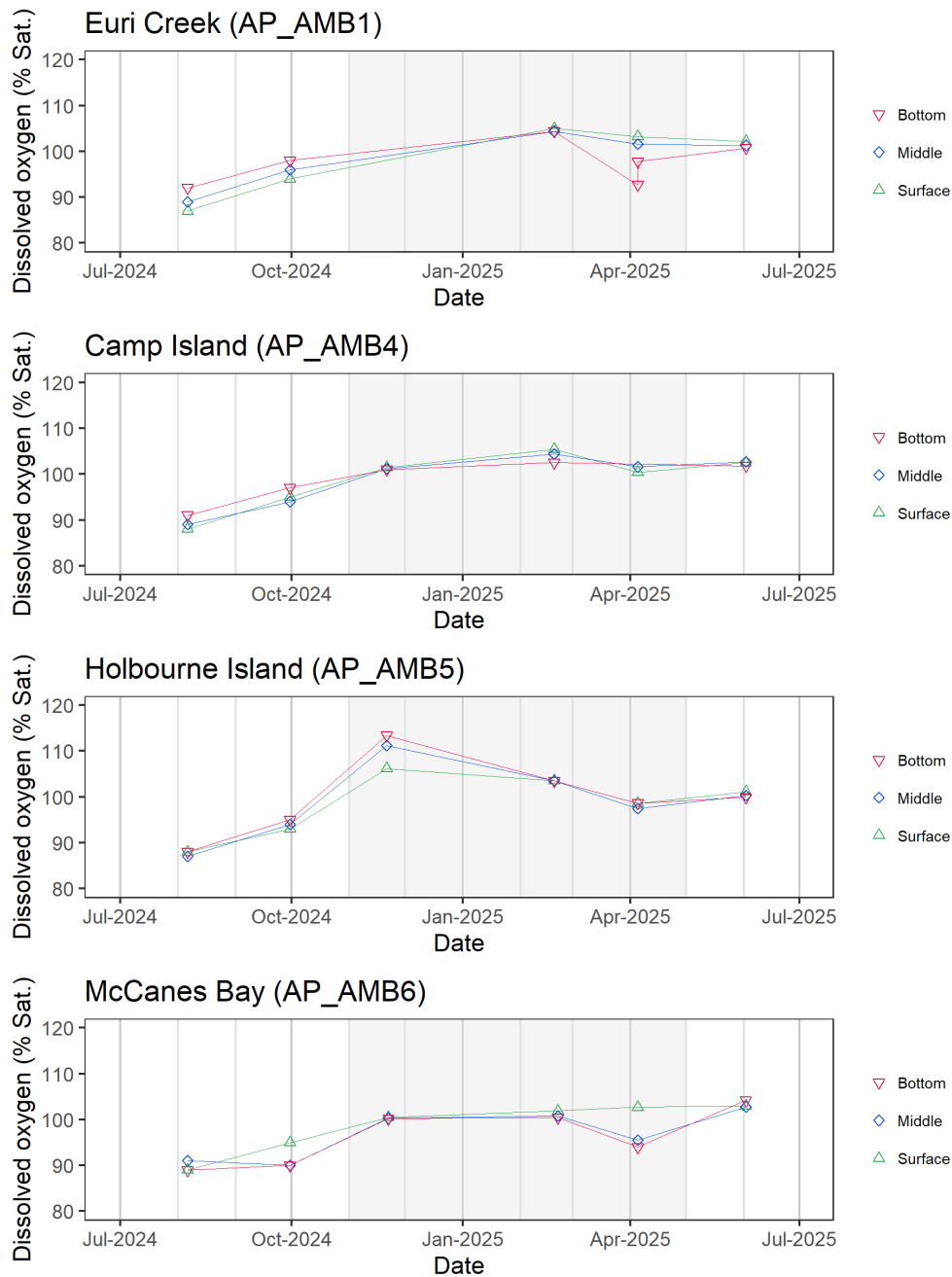


Figure 3-13 Dissolved oxygen (% saturation) at Bowen ambient sites. Grey area indicates wet season.

### 3.4.2. Conductivity

Electrical conductivity (EC) at the Bowen ambient monitoring sites showed the expected seasonal variability for tropical inshore to mid-shelf marine waters (Figure 3-15). Across the reporting period, EC values were generally highest during the dry season (August–October 2024), reflecting stable marine conditions and evaporative concentration, and lowest during the late wet season (February–April 2025), coinciding with periods of reduced salinity associated with freshwater inputs and rainfall.

At Euri Creek (AP\_AMB1), Camp Island (AP\_AMB4), and McCanes Bay (AP\_AMB6), EC typically ranged from approximately 45 to 55 mS cm<sup>-1</sup>, consistent with fully marine conditions for the Bowen region. Lower EC values were recorded during late wet-season sampling (February–April 2025), particularly at Euri Creek and McCanes Bay, corresponding with observed reductions in salinity and increased turbidity during periods of freshwater influence.

At Holbourne Island (AP\_AMB5), EC values were comparable to the other monitoring sites and indicative of predominantly marine conditions throughout the year. EC ranged from approximately 39 to 55 mS cm<sup>-1</sup>, with slightly lower values observed during August 2024 and higher values during subsequent dry-season sampling. These patterns are consistent with expected seasonal variability for a mid-shelf site influenced primarily by marine processes.

Vertical gradients in EC were generally small at all sites, indicating a well-mixed water column during most sampling events. Slight increases in EC with depth were occasionally observed during wet-season conditions, consistent with surface freshening rather than persistent stratification.

Overall, EC patterns across the Bowen monitoring sites indicate a predominantly marine system with modest seasonal dilution during the wet season and no evidence of prolonged or anomalous freshwater influence beyond short-lived events.

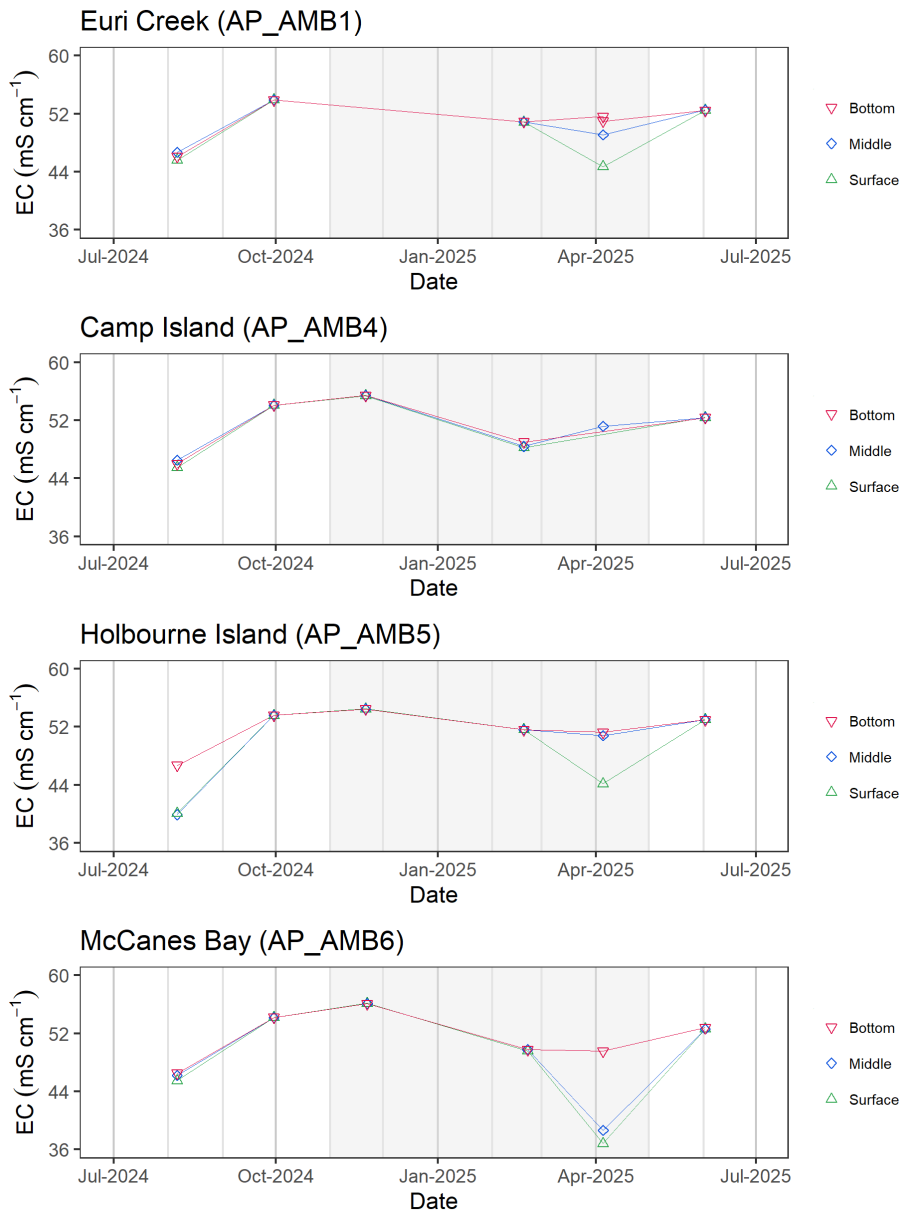


Figure 3-14 Electrical conductivity ( $\text{mS cm}^{-1}$ ) recorded at the Bowen ambient monitoring sites for surface, mid-water, and bottom depths. Grey area indicates wet season.

### 3.4.3. Salinity

Salinity varied through the reporting period in line with rainfall and runoff influence (Figure 3-16). Recorded values ranged from approximately ~23 to 37 PSU, with the lowest salinities occurring during late wet-season conditions at the inshore sites and the highest values occurring during dry-season / early wet-season sampling when evaporative concentration and reduced freshwater influence prevailed. Vertical salinity gradients were generally small during sampling, indicating a largely well-mixed water column, with only minor stratification evident during some wet-season events.

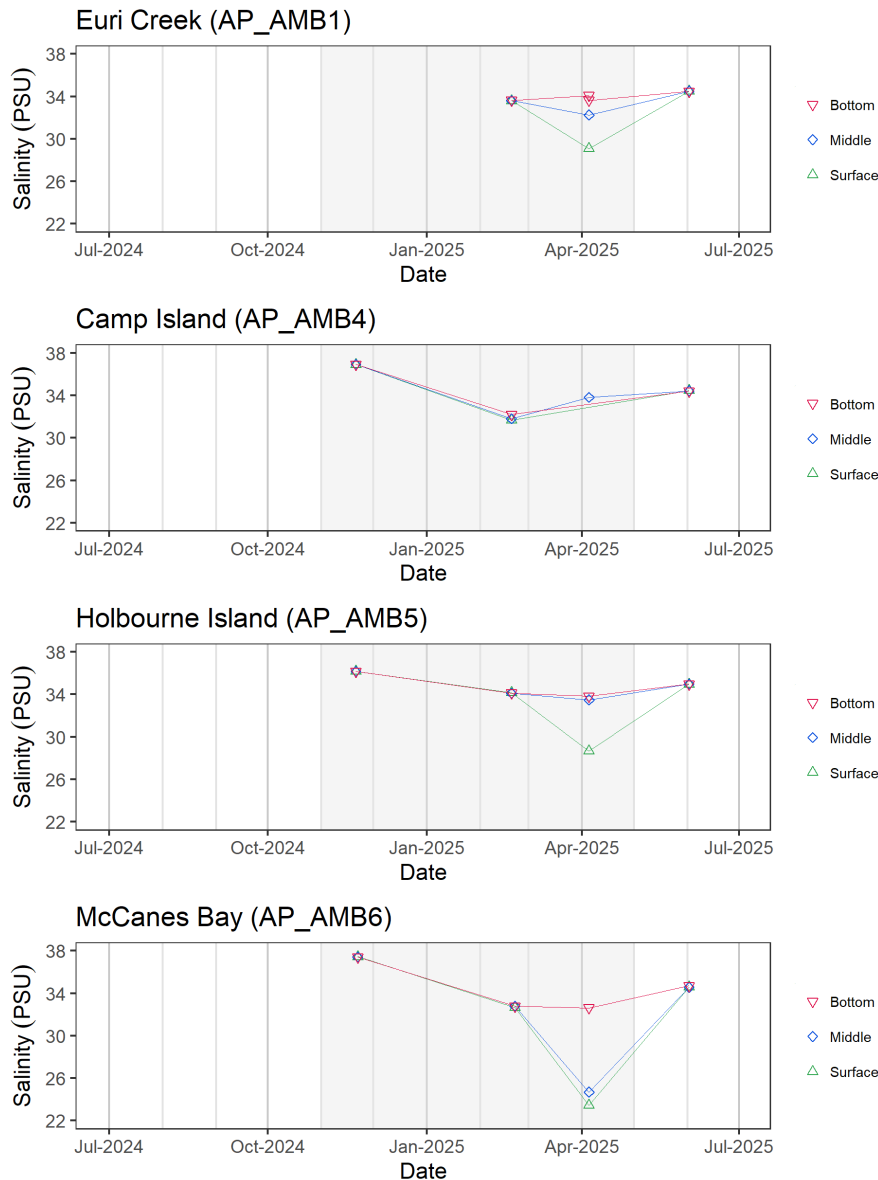


Figure 3-15 Salinity (PSU) recorded at the Bowen ambient monitoring sites for surface, mid-water, and bottom depths. Grey area indicates wet season. Note that salinity was only added to the in-situ measured parameters with the introduction of the YSI probe in November 2024.

#### 3.4.4. Water temperature

Water temperature showed clear seasonal variation characteristic of the Bowen region (Figure 3-17). The coolest temperatures were recorded during winter dry-season sampling in August (~21–22 °C), with temperatures increasing through spring and peaking during the wet season (February–April) at approximately ~29–30 °C. Temperature differences among depths were minimal across all sampling events, indicating a vertically well-mixed water column and an absence of persistent thermal stratification during discrete sampling.

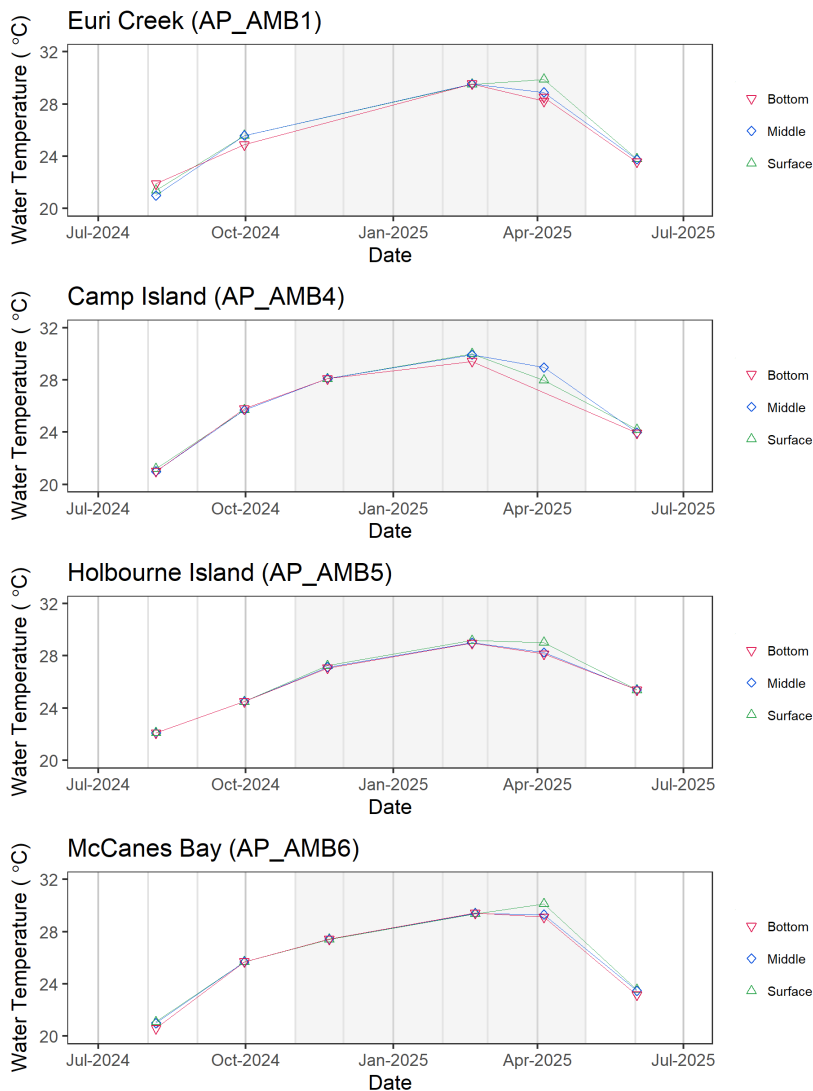


Figure 3-16 Water temperature recorded at the Bowen ambient sites for surface, mid-water, and bottom depths over the reporting period. Grey area indicates wet season.

### 3.4.5. pH

pH values remained stable across all Bowen sites and depths, typically ranging from ~7.9 to 8.4 (Figure 3-18). This narrow range is consistent with well-buffered coastal marine waters. Slightly elevated pH values were occasionally observed during dry-season sampling, likely reflecting increased photosynthetic uptake of CO<sub>2</sub> under high-light, low-turbidity conditions. No acidification events or departures from typical marine pH ranges were observed during the reporting period.

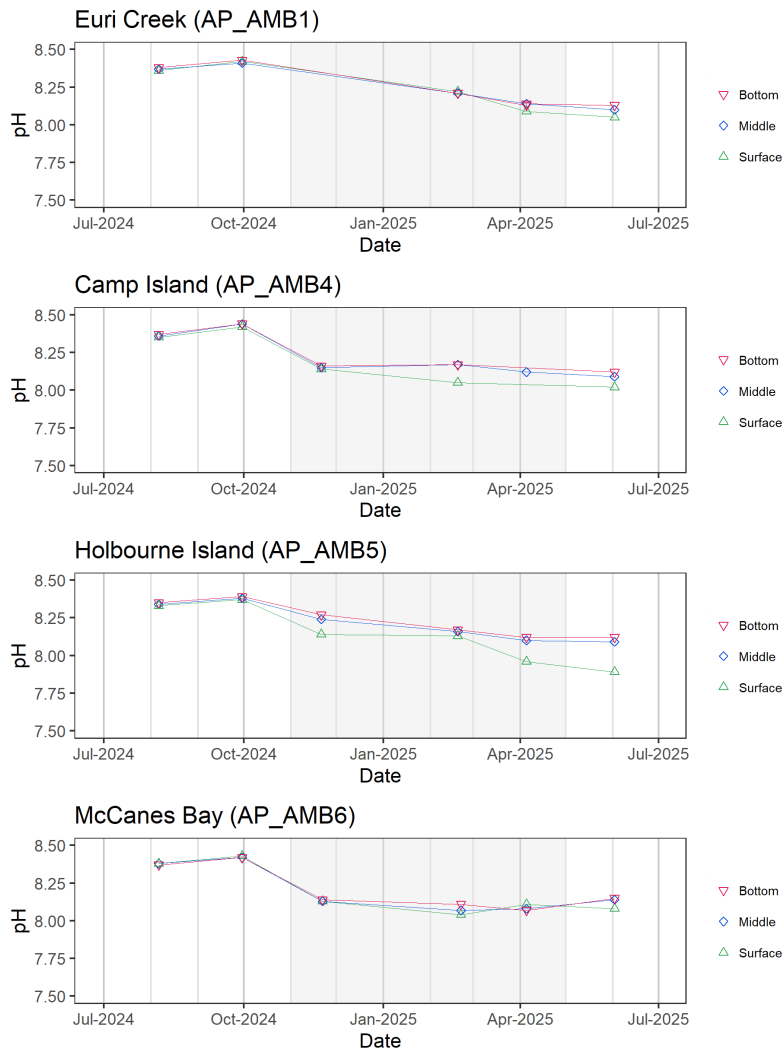


Figure 3-17 pH recorded at the Bowen ambient sites for surface, mid-water, and bottom depths over the reporting period. Grey area indicates wet season.

### 3.4.6. Water clarity

Secchi depth measurements revealed pronounced seasonal variation in water clarity across the Bowen–Abbot Point region (Figure 3-19). The clearest conditions generally occurred during the dry season, with Secchi depths commonly exceeding 5–8 m at the inshore sites and reaching >10 m at Holbourne Island.

Reduced water clarity was observed during wet-season and late wet-season sampling, particularly at the more inshore sites. Secchi depths as low as ~1–3 m were recorded at Euri Creek and McCanes Bay during November and February, consistent with increased suspended material associated with runoff, resuspension, and enhanced mixing. Holbourne Island consistently exhibited greater clarity than the inshore sites, reflecting its higher-energy, more offshore setting.

#### 3.4.7. Turbidity

In situ turbidity measurements (FNU) were collected from November 2024 onwards, following the introduction of the YSI multi-parameter instrument to the Bowen ambient monitoring program (Figure 3-20). As a result, turbidity observations primarily represent wet-season and late wet-season conditions rather than the full annual cycle.

Across the Bowen monitoring sites, turbidity was generally low to moderate, with values typically remaining below 2–3 FNU under calm, marine-dominated conditions. The lowest turbidity values were recorded at Holbourne Island, particularly during dry and transitional periods, reflecting its mid-shelf location and reduced exposure to nearshore sediment resuspension and catchment inputs.

Elevated turbidity values were recorded during wet-season sampling events in February and April 2025, most notably at Euri Creek, Camp Island, and McCanes Bay. Peak turbidity values at these sites coincided with periods of reduced salinity, increased river discharge, and visually observed discoloured waters, indicating the influence of freshwater runoff and suspended sediment inputs. The highest turbidity levels were observed at McCanes Bay during the February 2025 event, consistent with its proximity to the Don River and exposure to flood plume conditions.

Depth profiles showed clear vertical structure during higher-turbidity events. Bottom-water turbidity was often elevated relative to surface and mid-water values, particularly at Euri Creek and Camp Island, indicating sediment resuspension under energetic tidal and wind-driven conditions. In contrast, surface turbidity remained comparatively low at several sites during these events, suggesting that resuspension processes, rather than persistent surface plumes, were the dominant turbidity mechanism at those times.

Despite short-lived wet-season increases, turbidity returned to low levels by June 2025 across all sites, indicating rapid system recovery and generally well-flushed conditions. Overall, turbidity patterns across the Bowen region reflect a predominantly marine system punctuated by episodic wet-season sediment inputs and resuspension, rather than sustained turbidity or chronic water quality degradation.

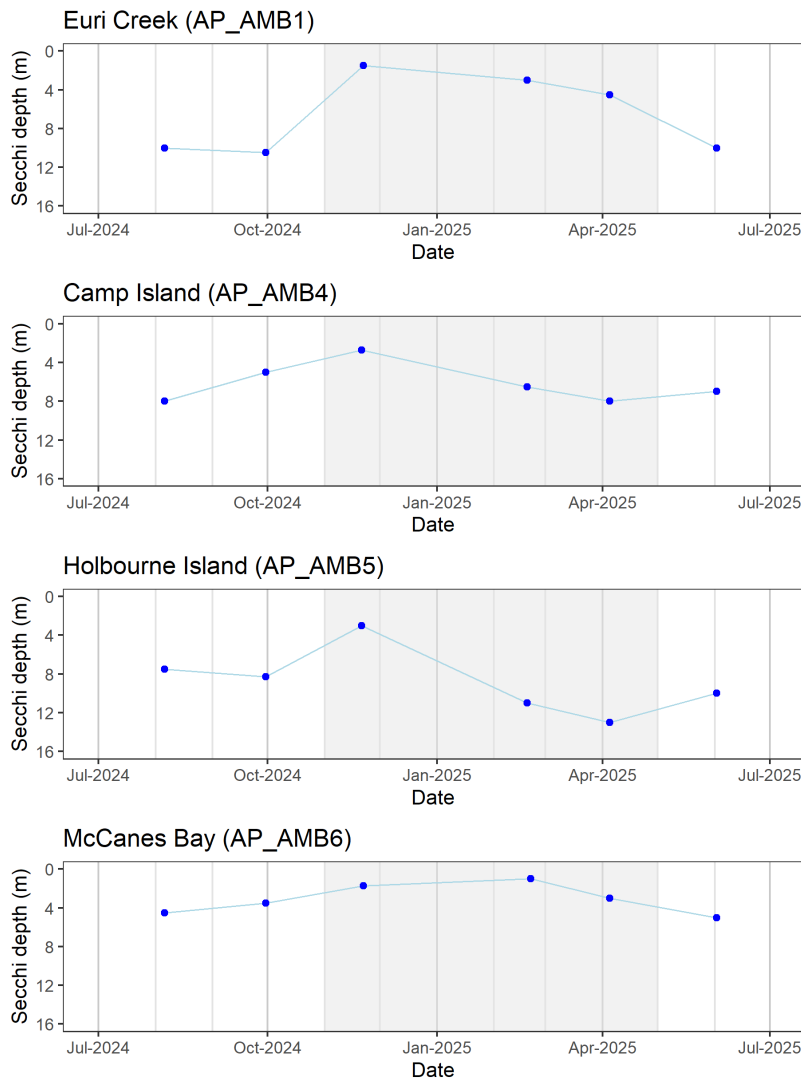


Figure 3-18 Secchi depth (m) recorded at the Bowen ambient monitoring sites over the reporting period. Grey area indicates wet season.

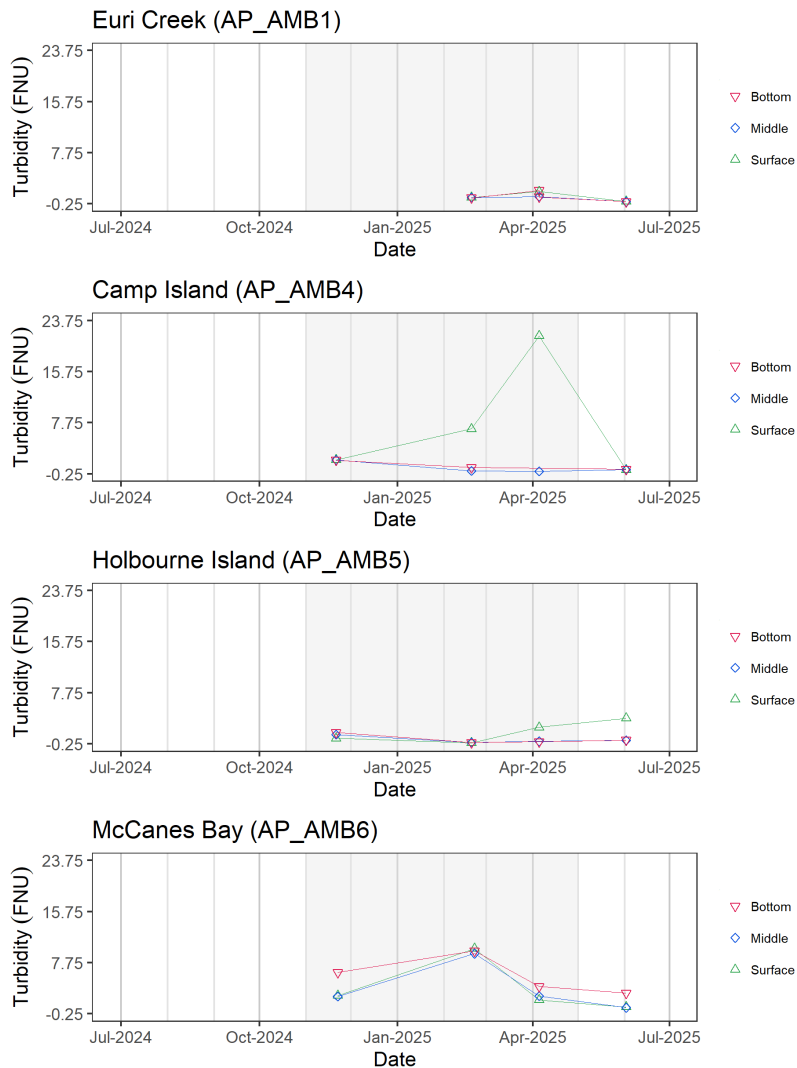


Figure 3-19 Turbidity (FNU) as detected by YSI multiparameter sonde during insitu measurements at each field sampling occasion (the YSI sonde was only introduced into the program in November 2024).

### 3.5. Seafloor mounted continuous dataloggers

#### 3.5.1. Water temperature

Seafloor water temperatures at the Bowen ambient sites exhibited a clear seasonal cycle, consistent across all locations and closely aligned with in situ water-column measurements. Temperatures were lowest during winter (July–August 2024), increased steadily through spring, and peaked during the late wet season (January–February 2025), before declining again into early winter 2025.

Across the monitoring period, daily mean temperatures ranged from approximately 19–31 °C. Euri Creek and Camp Island displayed similar seasonal trajectories, with summer maxima near 30 °C and winter minima around 20–21 °C. Holbourne Island showed slightly reduced seasonal amplitude and smoother temporal variability, consistent with its mid-shelf location and greater oceanic influence.

McCanes Bay exhibited the greatest short-term variability, reflecting its more enclosed setting and stronger response to episodic weather and mixing events.

Overall, the logger records confirm well-mixed conditions and strong seasonal control on thermal structure across the Bowen monitoring sites.

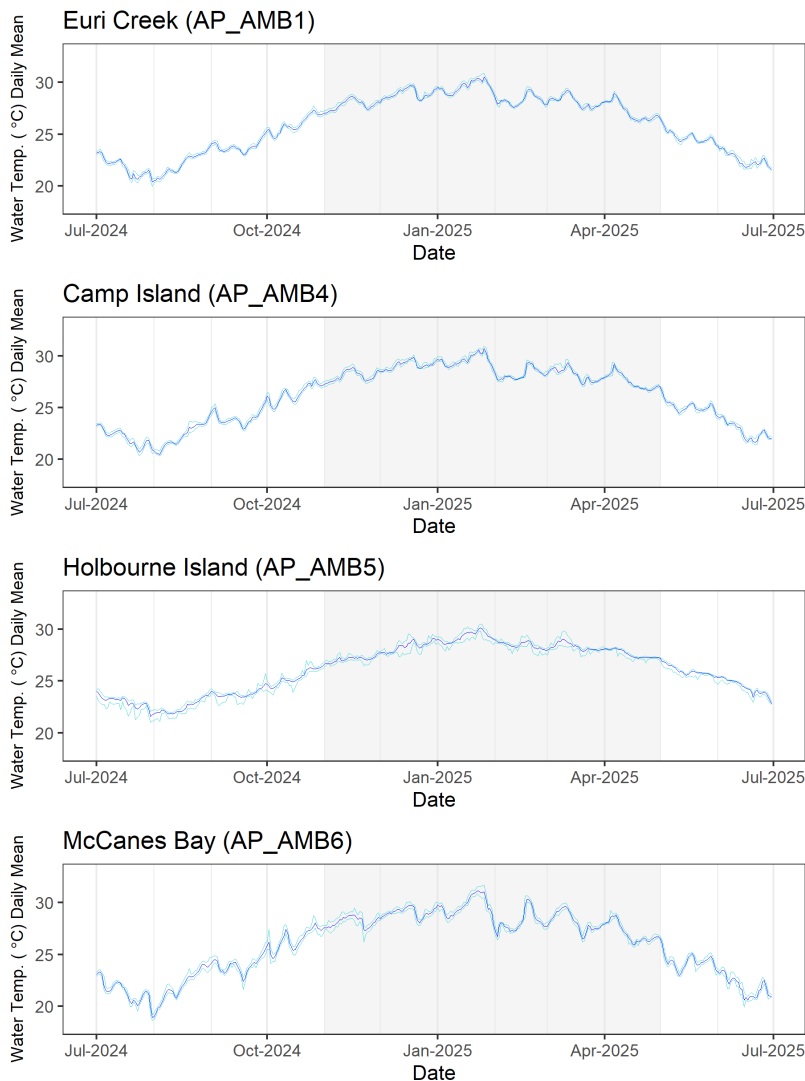


Figure 3-20 Daily mean water temperature (blue) and daily minimum and maximum (light blue) measured at Bowen ambient sites over the reporting period.

### 3.5.2. Water depth and tidal signal

Logger-derived records show a strong and persistent tidal signal across all Bowen ambient sites, consistent with a mixed semidiurnal, mesotidal regime. Daily tidal range followed a clear spring–neap cycle throughout the monitoring period, with typical daily ranges around ~2 m and larger spring-tide ranges approaching ~3 m.

Median logger depth differed among sites, reflecting local bathymetry and deployment position. Median depth was deepest at Euri Creek (10.93 m) and Camp Island (10.25 m), intermediate at Holbourne Island (9.86 m), and shallowest at McCanes Bay (6.39 m). Despite these differences in

absolute depth, the tidal-range signal was consistent across sites, indicating tide-driven water-level variability as a dominant physical driver in the Bowen monitoring region.

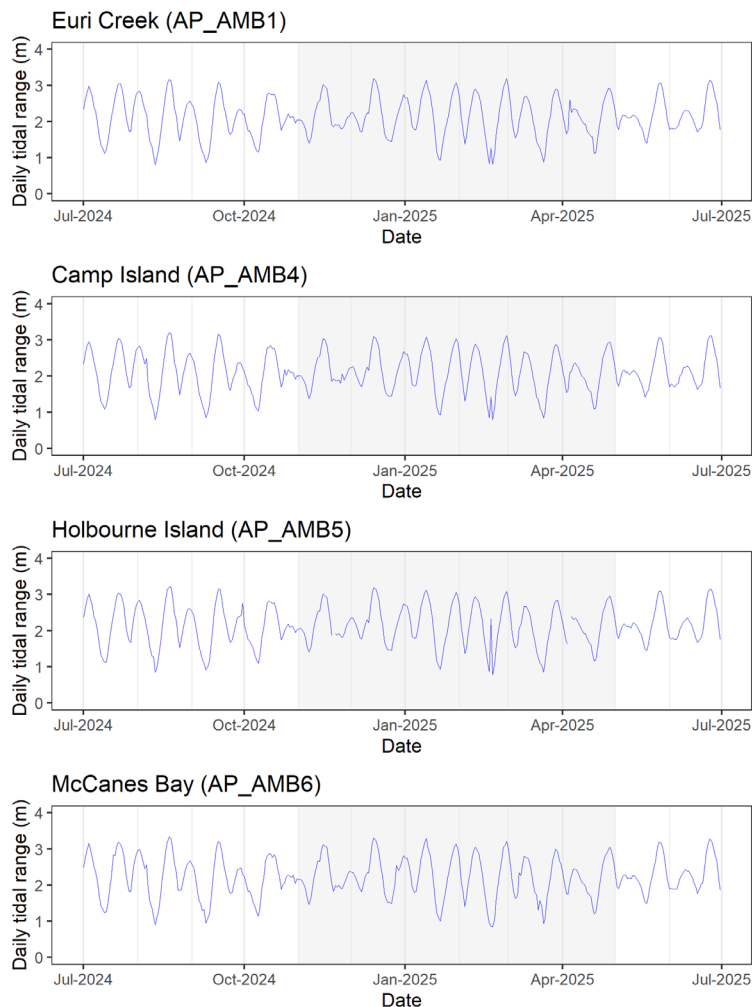


Figure 3-21 Daily tidal range measured at Bowen ambient sites over the reporting period.

### 3.5.3. Wave activity

Near-bed wave activity, assessed using the RMS depth metric, was generally low across all Bowen sites, indicating that hydrodynamic conditions at the seabed are dominated by tidal currents rather than wave-driven orbital motion.

Euri Creek and Camp Island exhibited low background RMS values with intermittent short-lived peaks, typically coinciding with periods of increased wind or energetic tidal conditions. Holbourne Island recorded consistently low RMS depths throughout the monitoring period, reflecting its more sheltered seabed conditions despite its offshore location. McCanes Bay showed the lowest overall RMS values, consistent with its semi-enclosed geometry and limited wave exposure.

These patterns indicate that wave-induced sediment mobilisation is generally minor across the Bowen sites and occurs primarily during brief, episodic events rather than persistently.

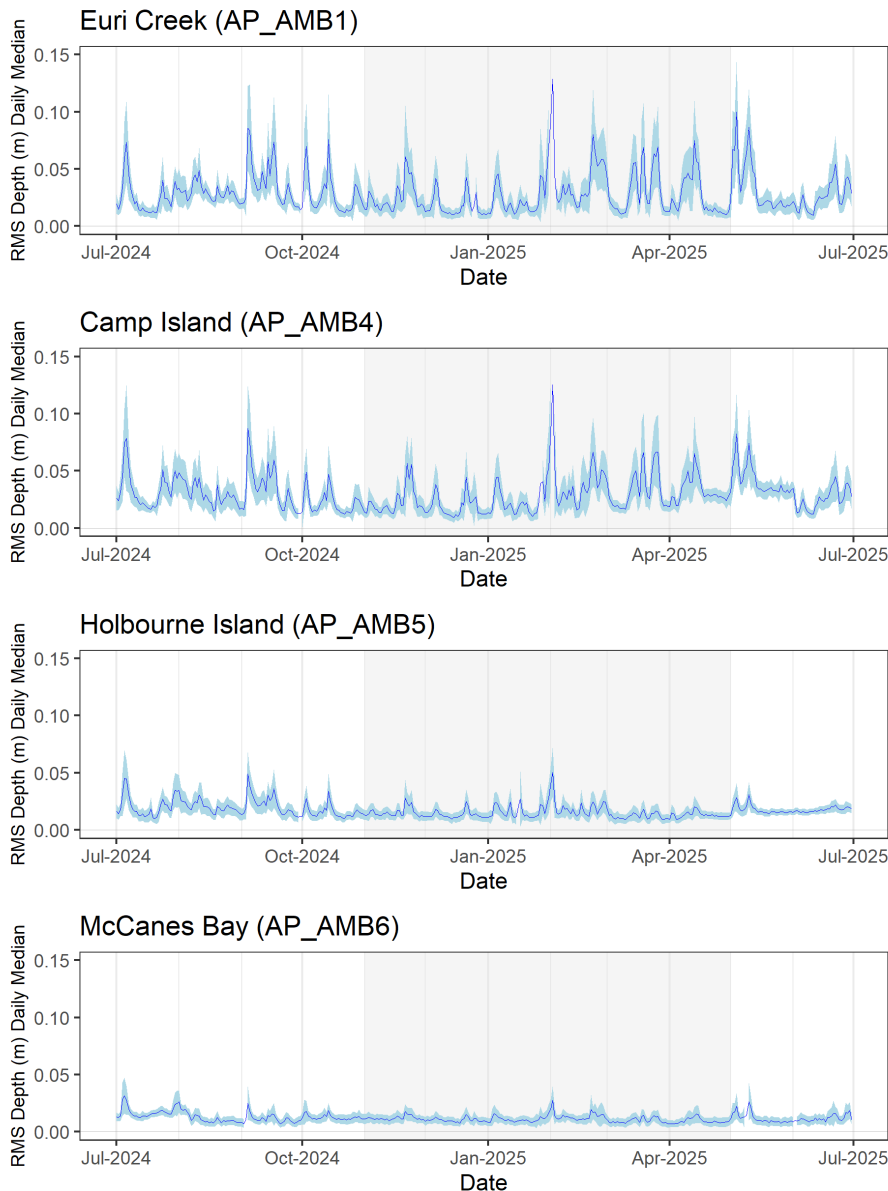


Figure 3-22 RMS depth (m) measured at Bowen ambient sites over the reporting period. Values presented are daily mean (blue line) +/- standard deviation (light blue ribbon).

### 3.5.4. Turbidity

Near-bed turbidity recorded by the seafloor-mounted continuous loggers showed generally low background conditions punctuated by short-lived spikes, consistent with episodic sediment resuspension under energetic tides and/or wind-driven mixing. Across the reporting period, typical turbidity conditions differed among sites. Holbourne Island recorded the lowest and most stable near-bed turbidity (daily median typically ~0.4–0.6 NTU; maximum daily mean ~26.6 NTU). Euri Creek and Camp Island were more dynamic, with low-to-moderate background turbidity (daily median ~0.9–1.3 NTU) and intermittent high-turbidity events (maximum daily mean ~377 NTU at Euri Creek and ~83.6 NTU at Camp Island). McCanes Bay exhibited consistently higher background turbidity than the other sites (daily median ~3.2 NTU; daily mean median ~3.8 NTU), with occasional increases up to ~21–23 NTU, indicating more persistent near-bed sediment influence at

this location. Overall, the continuous logger data indicate that ambient turbidity in the Bowen region is usually low at the seabed, with site-specific differences in baseline conditions and event-driven peaks that likely reflect local exposure, sediment availability, and short-term hydrodynamic forcing.

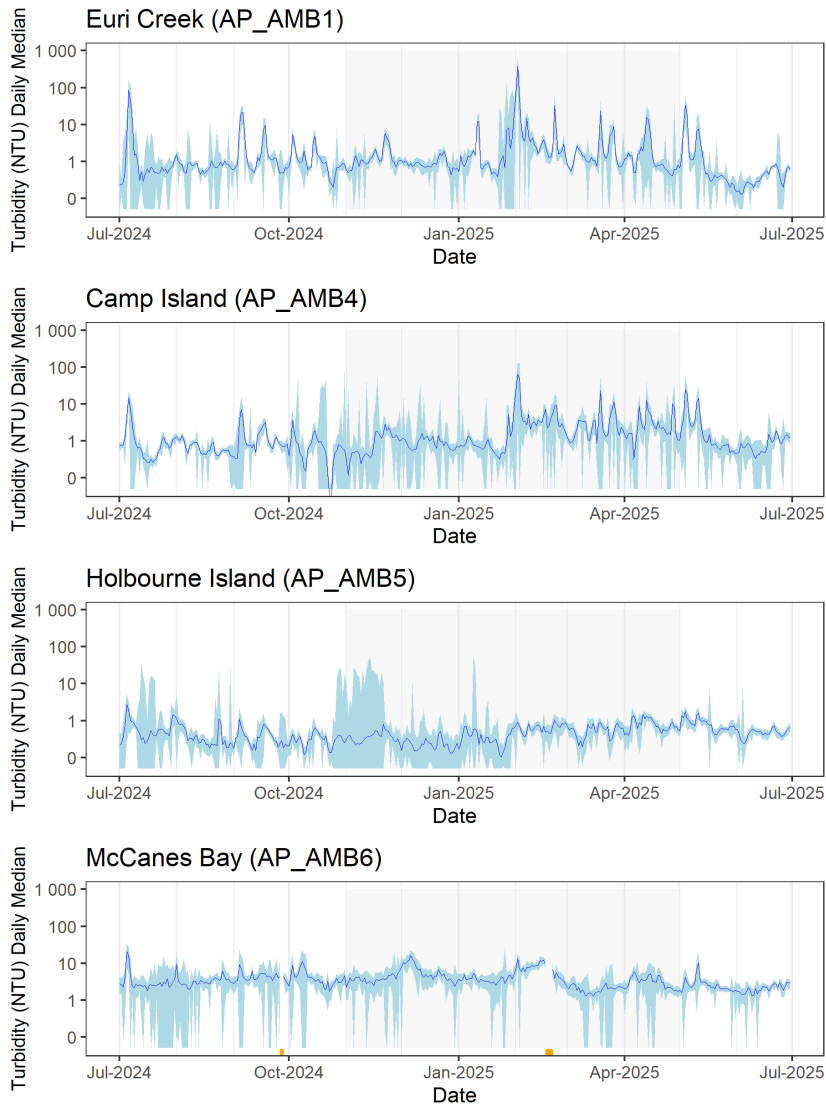


Figure 3-23 Near-bed turbidity (NTU) measured by seafloor-mounted loggers the Bowen ambient sites over the reporting period. Results presented are daily mean (blue line) and standard deviation (light blue). Y-axis is in log scale.

### 3.5.5. Relationship between turbidity and RMS depth

Analysis of turbidity behaviour relative to RMS depth showed weak to very weak associations across the Bowen ambient monitoring sites, with correlation coefficients generally below 0.30 for all tidal stages. At Euri Creek (AP\_AMB1), NTU and RMS depth exhibited low but consistent positive correlations ( $r = 0.20\text{--}0.28$ ), indicating that short-period water-column motion contributed modestly to turbidity variability in this shallow, estuarine-influenced setting. Camp Island (AP\_AMB4) displayed similarly weak relationships across rising, falling and stable tide conditions ( $r$

= 0.14–0.19), suggesting that turbidity at this site is influenced predominantly by broader hydrodynamic or catchment-driven processes rather than near-sensor motion.

At Holbourne Island (AP\_AMB5), correlations were extremely low ( $r \approx 0$  across all stages), indicating no meaningful relationship between RMS depth and NTU. This is consistent with conditions at this offshore island, where turbidity is usually very low, and likely governed by episodic wind-driven resuspension, coarse substrate, and large-scale hydrodynamics rather than short-period vertical movement around the logger. McCanes Bay (AP\_AMB6) also showed negligible association between RMS depth and turbidity ( $r = -0.03$  to  $-0.00$ ), reflecting the highly sheltered nature of the site where fine sediment dynamics, residence time and low-energy conditions dominate NTU behaviour. Across all Bowen locations, the analysis demonstrates that turbidity variability is driven more by environmental and catchment-scale processes than by short-period motion in the water column, with RMS depth contributing little explanatory power to NTU patterns.

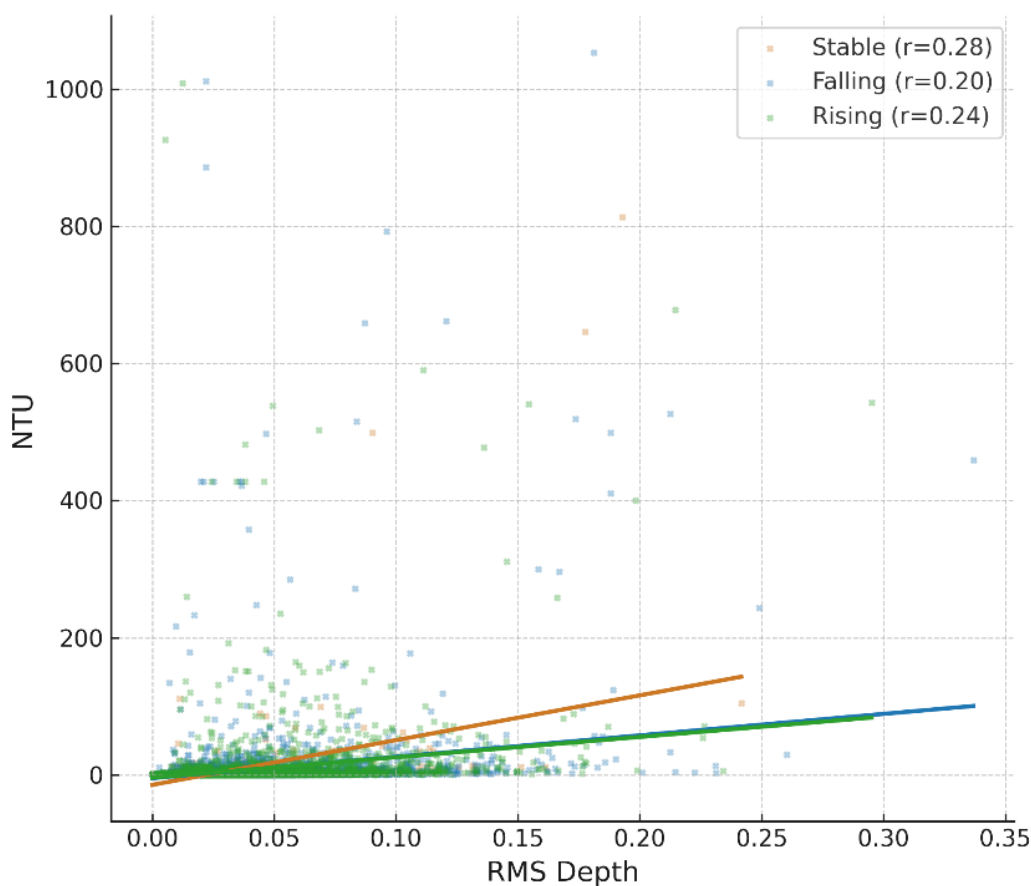


Figure 3-24 Relationship between turbidity (NTU) and RMS depth at Euri Creek (AP\_AMB1) coloured by tidal stage. Weak but consistent positive correlations were observed across rising, falling and stable tide conditions, indicating a modest influence of short-period water-column motion on turbidity.

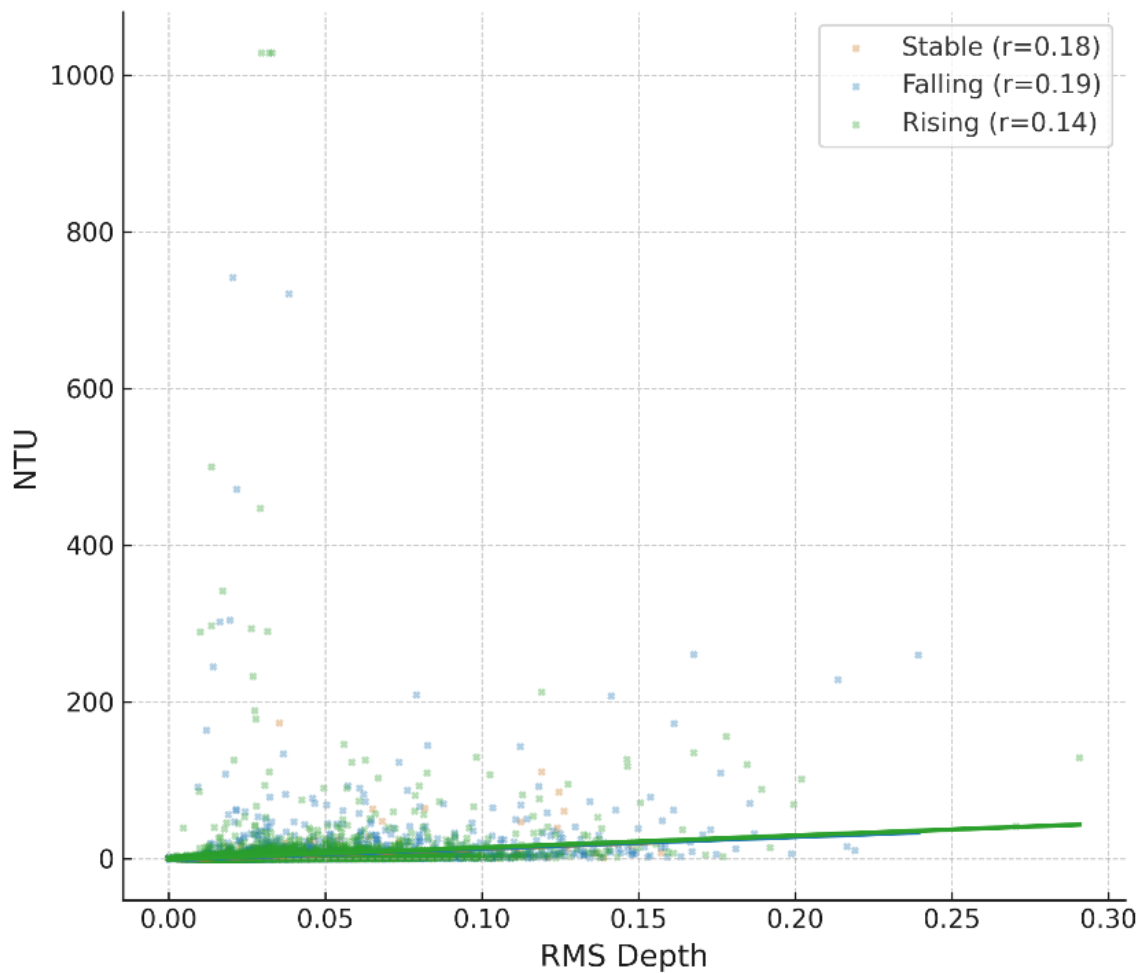


Figure 3-25 Relationship between turbidity (NTU) and RMS depth at Camp Island (AP\_AMB4). Correlations were low across all tidal stages, suggesting that turbidity at this site is primarily influenced by broader hydrodynamic and catchment drivers rather than short-period depth variability.

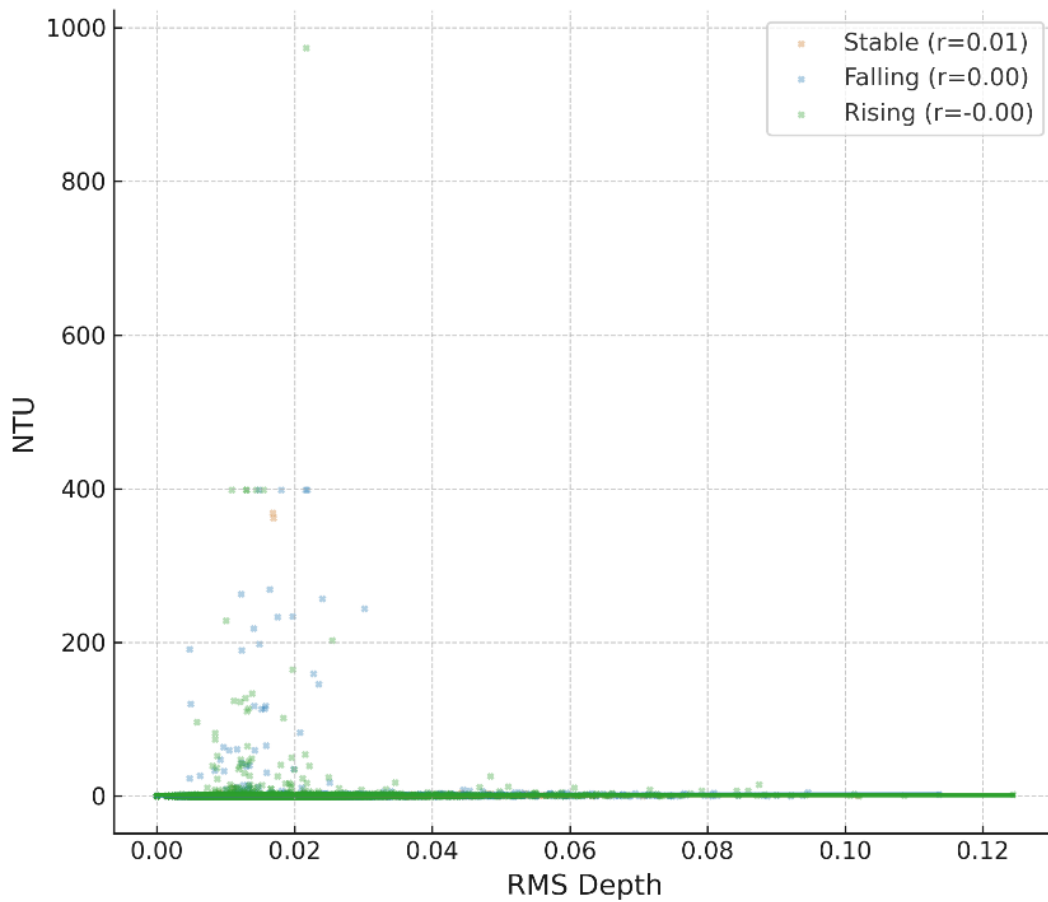


Figure 3-26 Turbidity (NTU) versus RMS depth at Holbourne Island (AP\_AMB5), showing no meaningful correlation under any tidal stage. This reflects the dominance of large-scale wave exposure and coarse substrate conditions over fine-scale water motion in controlling turbidity at this offshore island.

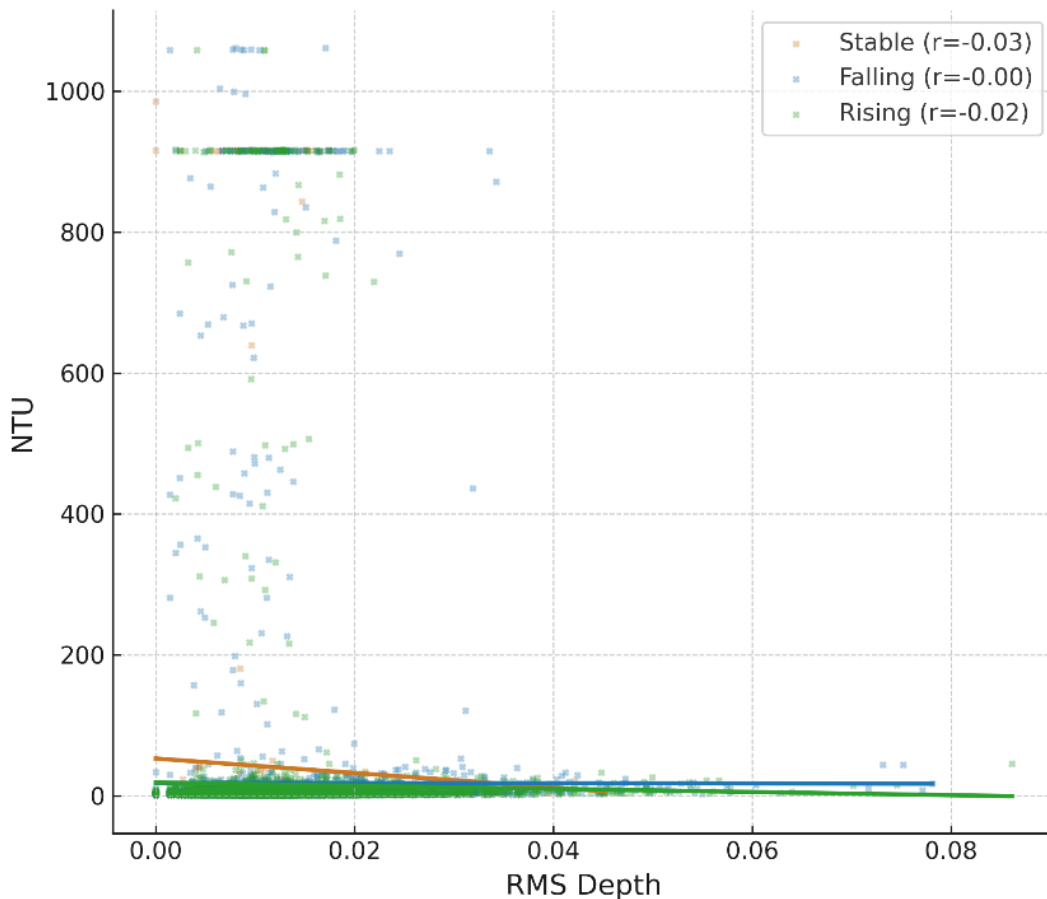


Figure 3-27 Relationship between turbidity (NTU) and RMS depth at McCanes Bay (AP\_AMB6). Correlations were negligible across rising, falling and stable tides, consistent with the sheltered, low-energy conditions that characterise this site.

### 3.5.6. Benthic photosynthetically active radiation (bPAR)

Benthic photosynthetically active radiation (bPAR) expressed as daily light integral (DLI; mol photons  $\text{m}^{-2} \text{d}^{-1}$ ) from the seabed-deployed loggers, reflected the combined effects of seasonal solar irradiance, cloud cover, and light attenuation in the water column. Across the Bowen sites, DLI ranged from  $<1$  on very low-light days to 21.4 under clear conditions, with Holbourne Island recording the highest benthic light availability overall (median 6.7, 95th percentile 20.0). The remaining sites showed lower typical bPAR, with medians of 3.1 at Euri Creek (95th percentile 7.2), 2.8 at Camp Island (95th percentile 7.8), and 2.1 at McCanes Bay (95th percentile 5.3).

McCanes Bay recorded the lowest bPAR despite being the shallowest site, indicating that light attenuation from turbidity and resuspension within the bay was a stronger control on benthic light than depth alone. A small number of days recorded extremely low DLI values (including an exact 0.0 at Euri Creek and Camp Island), consistent with periods of near-complete light limitation rather than missing data. Periods of missing DLI were present at multiple sites because records affected by logger tilt were removed during quality control (see QC in Appendix for details), resulting in

intermittent gaps in the bPAR time series (most notably at McCanes Bay from 16 Sep–16 Dec and at Holbourne Island from 22 Nov–10 Jan).

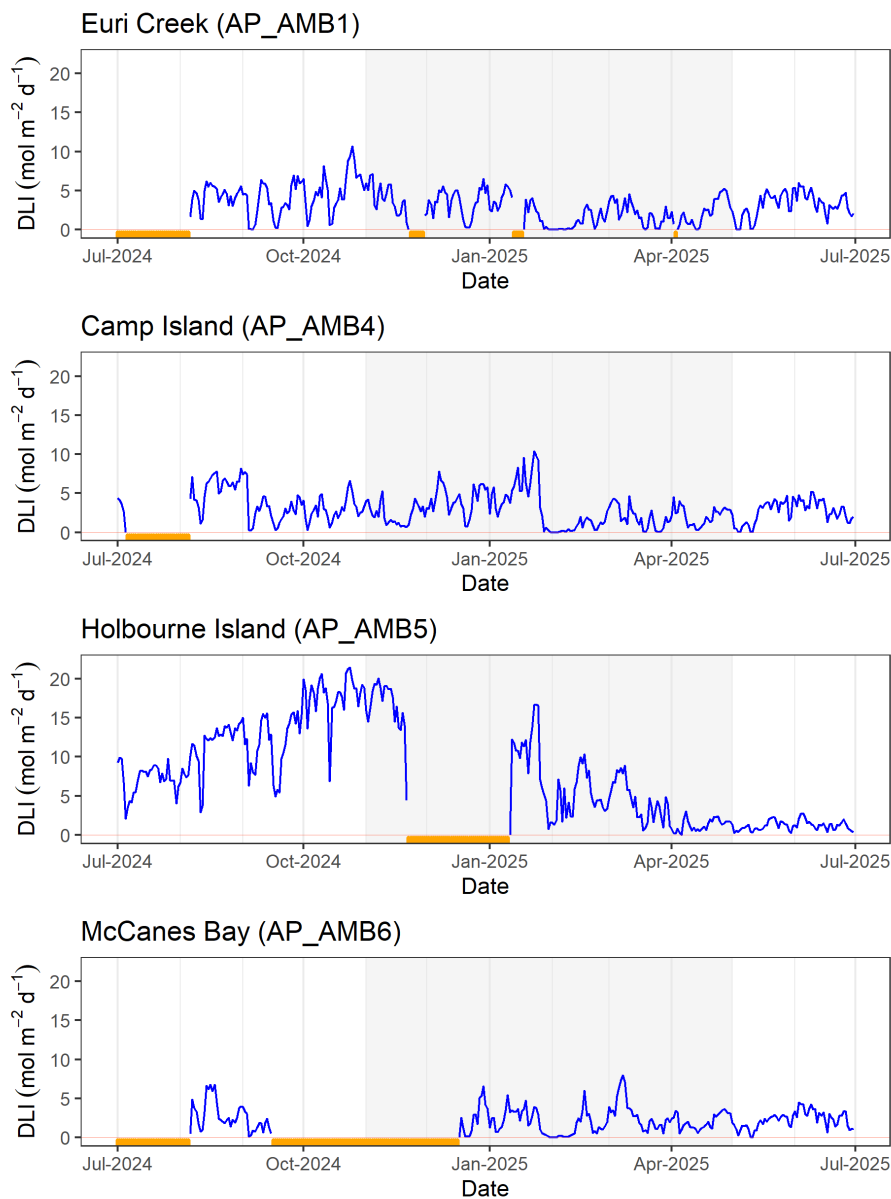


Figure 3-28 Daily light integral ( $\text{mol photons m}^{-2} \text{ d}^{-1}$ ) of benthic photosynthetically active radiation (PAR) measured at Bowen ambient sites over the reporting period. Periods of missing data are indicated by the orange bar.

### 3.6. Benthic multispectral irradiance and light-quality indices

Benthic multispectral irradiance measurements collected from MS9 loggers showed clear and consistent relationships between spectral light composition, turbidity, and seasonal hydrodynamics across the four Mackay and Hay Point monitoring sites. The fundamental driver of spectral shape was water clarity, with strong contrasts observed between dry-season low-turbidity conditions and wet-season sediment-affected periods. These patterns are illustrated in the normalised wavelength spectra for each site (Figure 3-29; Figure 3-30; Figure 3-31; Figure 3-32).

Across all sites, low-turbidity conditions (<1 NTU) were characterised by spectra dominated by high relative irradiance in the blue–green region (440–520 nm). Under these clear-water conditions, the spectral curve showed a broad peak centred around 490–550 nm, reflecting efficient transmission of short wavelengths. These periods coincided predominantly with the dry season (May–October), when calmer hydrodynamic conditions, reduced wind-driven resuspension and minimal freshwater inputs promoted higher optical clarity.

In contrast, wet-season (November–April) conditions and moderate to high turbidity events (>5 NTU) were associated with pronounced attenuation of shorter wavelengths (410–490 nm). This resulted in a shift of the spectral maximum toward 550–570 nm, coupled with increased dominance of yellow–green and red wavelengths. Wet-season spectra were substantially more variable, reflecting episodic sediment resuspension, riverine inputs, and changes in coloured dissolved organic matter. These shifts in spectral shape under different turbidity classes demonstrate the strong sensitivity of the blue portion of the spectrum to sediment-related light limitation.

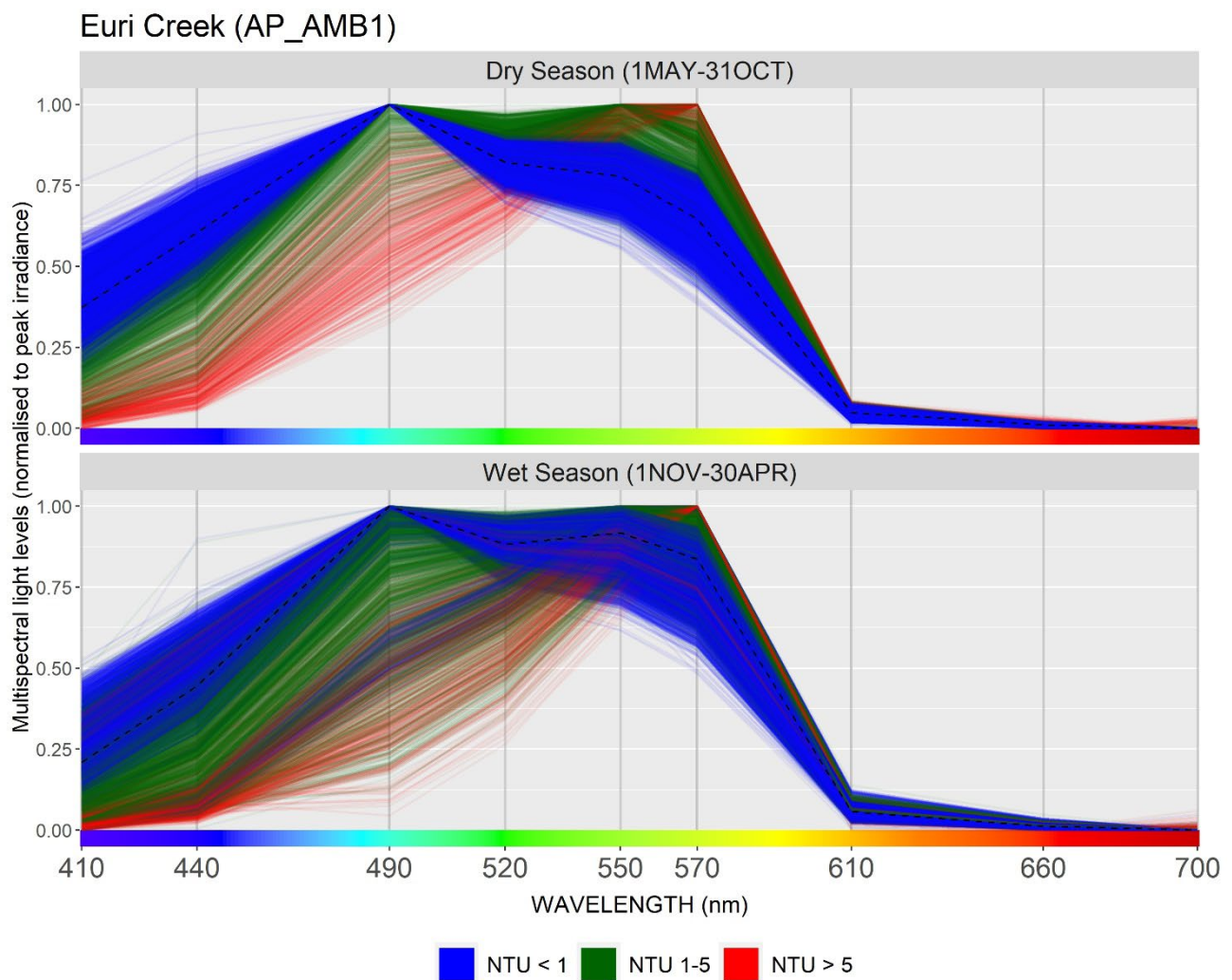


Figure 3-29 Multispectral irradiance profiles at Euri Creek (AP\_AMB1) in the dry (top) and wet (bottom) seasons. Spectral responses show clearer-water periods dominated by blue–green

irradiance, while higher-turbidity conditions are associated with reduced transmission at shorter wavelengths (410–490 nm) and a relative shift toward green–yellow wavelengths.

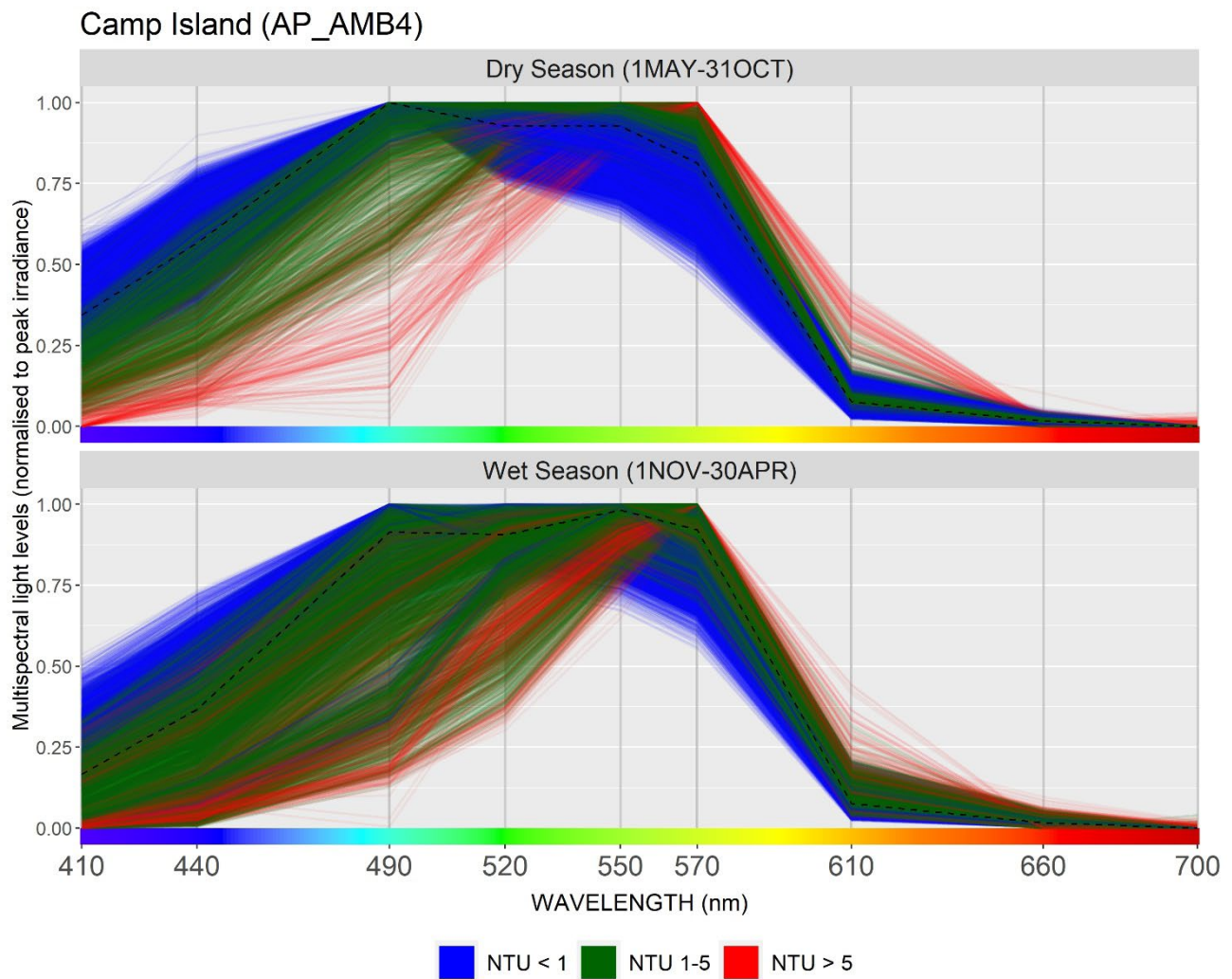


Figure 3-30 Multispectral irradiance profiles at Camp Island (AP\_AMB4) in the dry (top) and wet (bottom) seasons. Clear-water conditions show strong blue–green irradiance and a broad peak centred on the blue–green waveband, whereas turbid periods show greater attenuation of blue light and increased relative contribution from longer wavelengths.

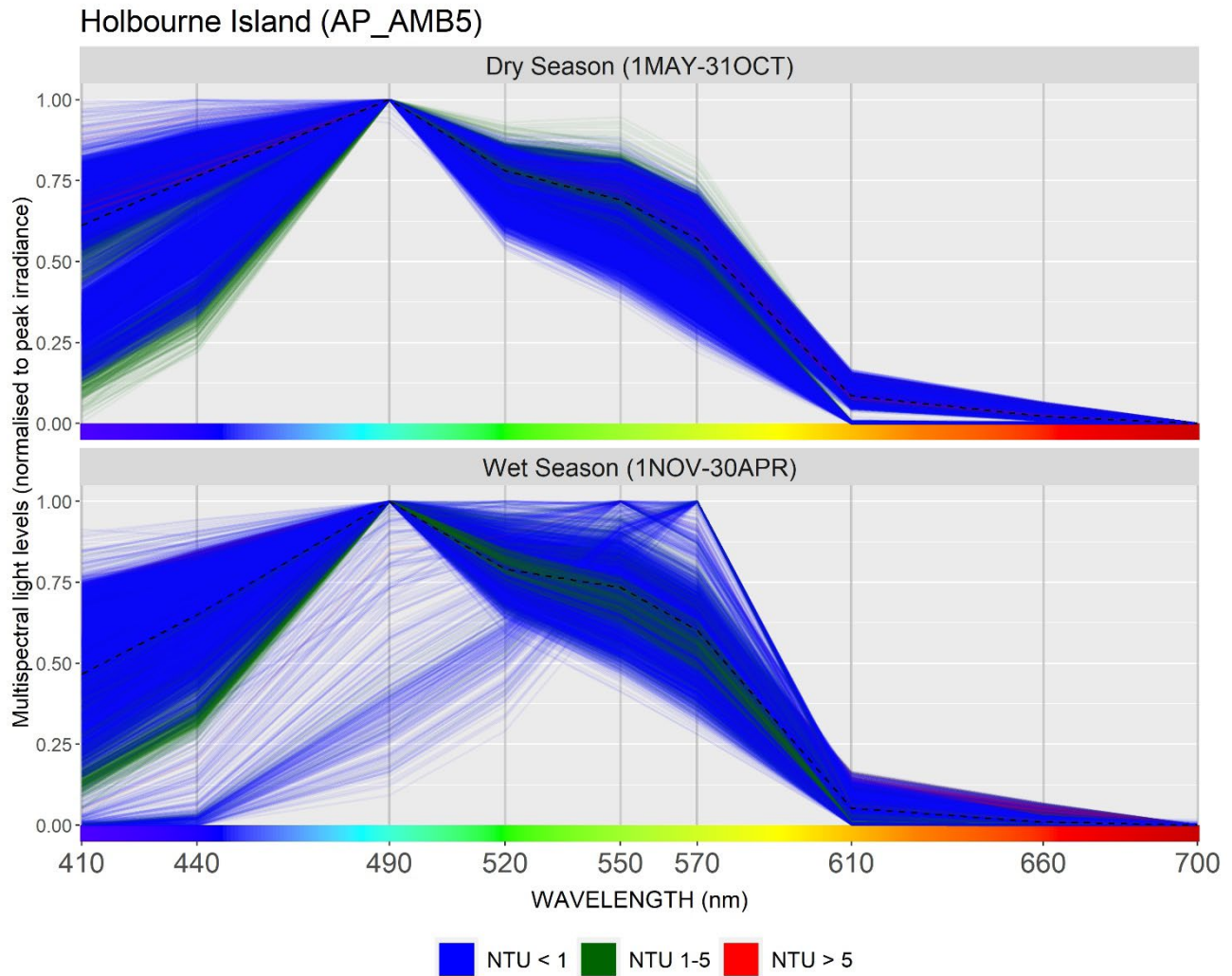


Figure 3-31 Multispectral irradiance profiles at Holbourne Island (AP\_AMB5) in the dry (top) and wet (bottom) seasons. Spectra are typically characterised by strong blue–green transmission under low-turbidity conditions, with episodic departures during reduced clarity reflected as increased suppression of the blue portion of the spectrum.

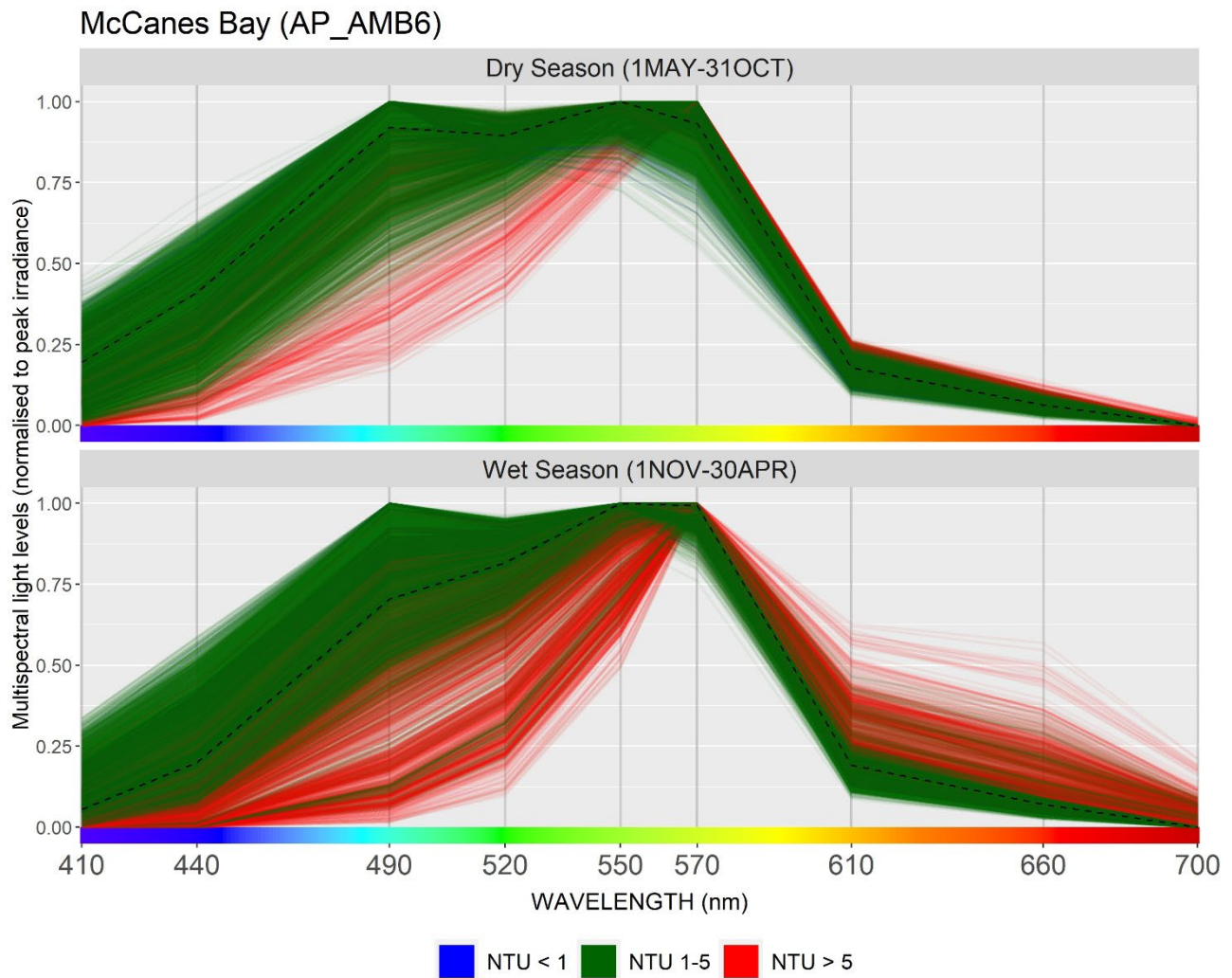


Figure 3-32 Multispectral irradiance profiles at McCanes Bay (AP\_AMB6) in the dry (top) and wet (bottom) seasons. Compared with the other Bowen sites, spectra show more frequent attenuation of short wavelengths and a stronger relative contribution from green–red wavelengths during degraded optical conditions.

To summarise these wavelength-specific behaviours, four spectral light-quality indices were calculated for the Bowen sites (N490, PQI, RAR and Slope\_BG). Spatial and seasonal patterns in these indices are shown in Figures 3-33 to 3-37. Consistent with the multispectral irradiance profiles, N490 and PQI were highest during clearer-water periods, indicating stronger transmission of short (blue) wavelengths and a greater proportion of benthic irradiance in the blue–green waveband. Conversely, RAR and Slope\_BG increased during degraded optical conditions, reflecting stronger attenuation of blue light relative to green and a greater relative contribution from longer wavelengths.

Across the Bowen region, the relationships between turbidity and spectral light quality were broadly consistent, reflecting strong regional control by seasonal wet–dry dynamics and episodic reductions in water clarity. However, differences among sites were evident in the frequency,

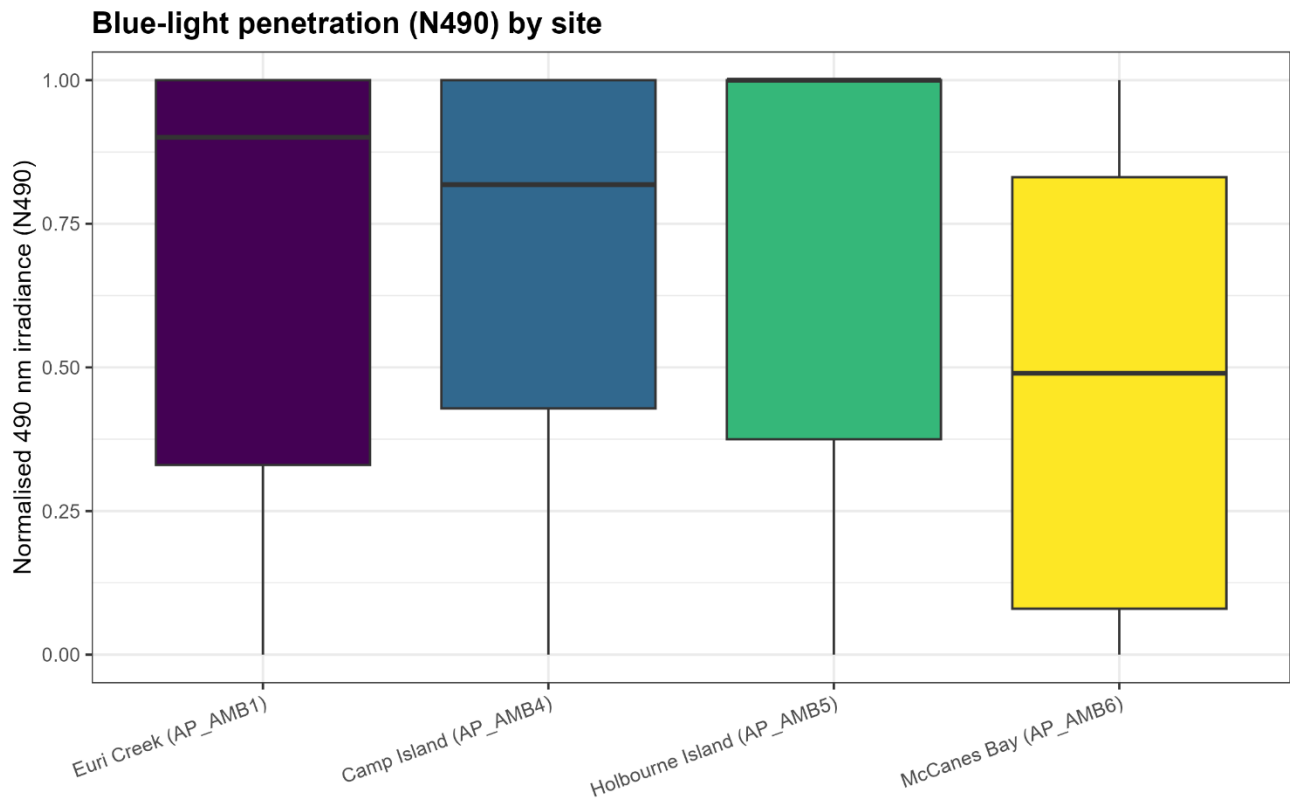
variability and persistence of higher- and lower-quality light conditions rather than as stark contrasts in absolute index values.

- Holbourne Island (AP\_AMB5) exhibited the most frequently favourable light environment, with generally high N490 and PQI values and comparatively low RAR during clear-water periods. However, these indices also showed a relatively broad spread, reflecting pronounced seasonal variability and episodic wet-season degradation superimposed on otherwise high-quality optical conditions.
- Camp Island (AP\_AMB4) also showed generally high PQI and N490, but with a broader distribution and more frequent short-lived declines in light quality, reflected in episodic increases in RAR and steeper Slope\_BG during periods of reduced clarity.
- Euri Creek (AP\_AMB1) displayed a similar overall range of PQI and N490 values to Camp Island, but with greater temporal variability and more frequent departures from clear-water spectral conditions, consistent with its proximity to episodic freshwater and sediment inputs.
- McCanes Bay (AP\_AMB6) had the least favourable spectral light environment overall, with lower median N490 and PQI, broader variability, and relatively elevated RAR and Slope\_BG. These patterns indicate more persistent suppression of blue wavelengths and a greater relative contribution from green–red light compared to the other sites.

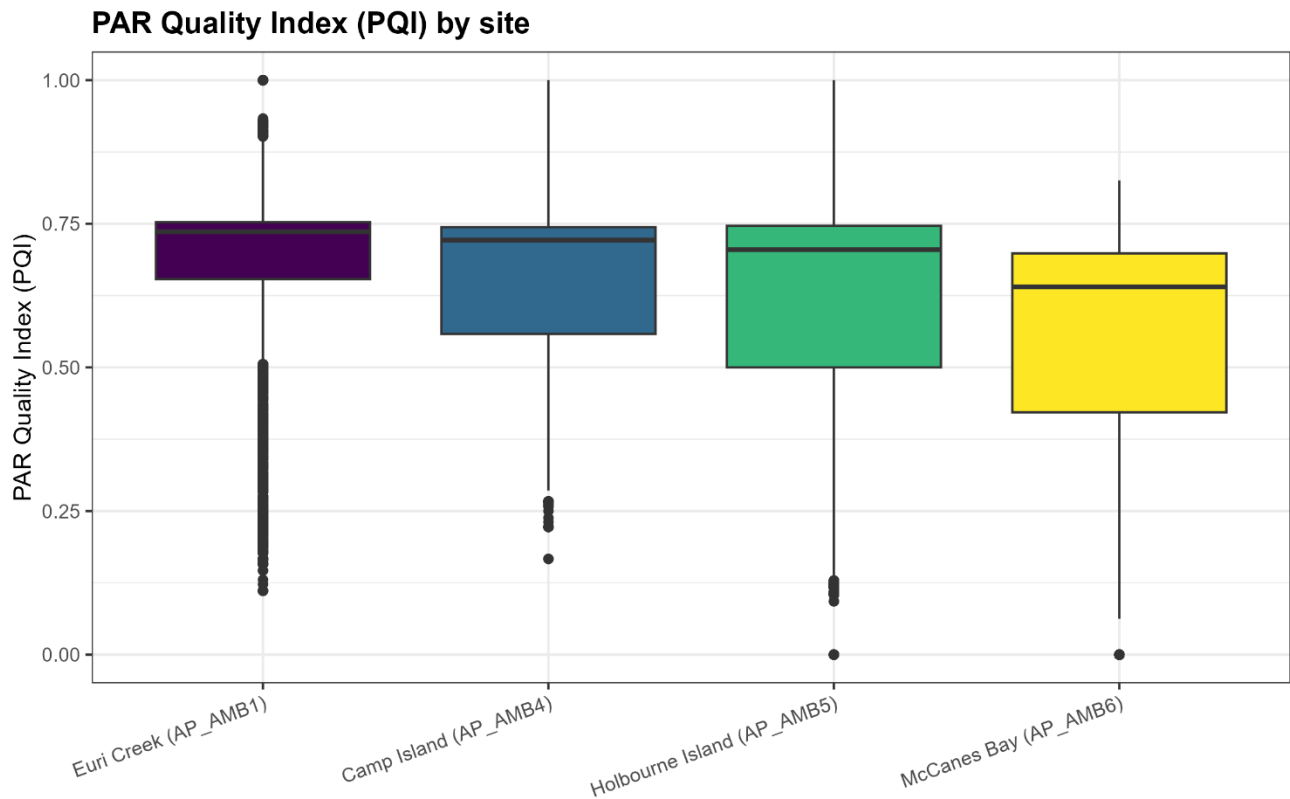
Together, these results show that benthic spectral irradiance in the Bowen region is governed by short-lived water-clarity changes superimposed on seasonal wet–dry dynamics, and that local hydrodynamic setting strongly influences the quality of photosynthetically usable radiation available to benthic phototrophic communities.

Within the context of the current NQBP-TropWATER monitoring program, this indicates that benthic light availability is primarily driven by episodic disturbances rather than sustained deterioration, and that changes in photosynthetically usable radiation (PUR) are highly site-specific. The spectral indices applied here provide a sensitive and process-based means of detecting shifts in light quality and availability relevant to benthic phototrophic communities—including seagrass, macroalgae, and coral symbionts—beyond what can be inferred from turbidity or chlorophyll-a alone.

Importantly, these findings highlight opportunities for future integration of multispectral and in situ monitoring to improve port-related environmental management. Spectral metrics such as those presented here could support event-based assessments of light reduction during high-turbidity episodes, improve attribution of observed changes to natural versus operational drivers, and contribute to the development of site- and depth-specific light thresholds. Over time, the accumulation of comparable spectral datasets across locations and years has the potential to make a meaningful contribution to the evidence base required for refining or developing future guideline values for PUR, supporting more ecologically relevant and defensible light-based objectives in coastal and port environments.



**Figure 3-33** Distribution of normalised 490 nm irradiance (N490) recorded at the four Bowen ambient monitoring sites. Higher N490 values indicate stronger transmission of short (blue) wavelengths and generally clearer water conditions. Holbourne Island and Euri Creek showed the highest typical blue-light penetration, whereas McCanes Bay exhibited lower N490 values consistent with more persistent suppression of blue wavelengths.



**Figure 3-34** Boxplots showing the distribution of the PAR Quality Index (PQI) across the Bowen ambient monitoring sites. PQI represents the proportion of benthic irradiance contributed by blue–green wavelengths (440–570 nm). Higher PQI values correspond to clearer optical conditions and greater availability of photosynthetically usable radiation, with McCanes Bay showing lower PQI overall relative to the other sites.

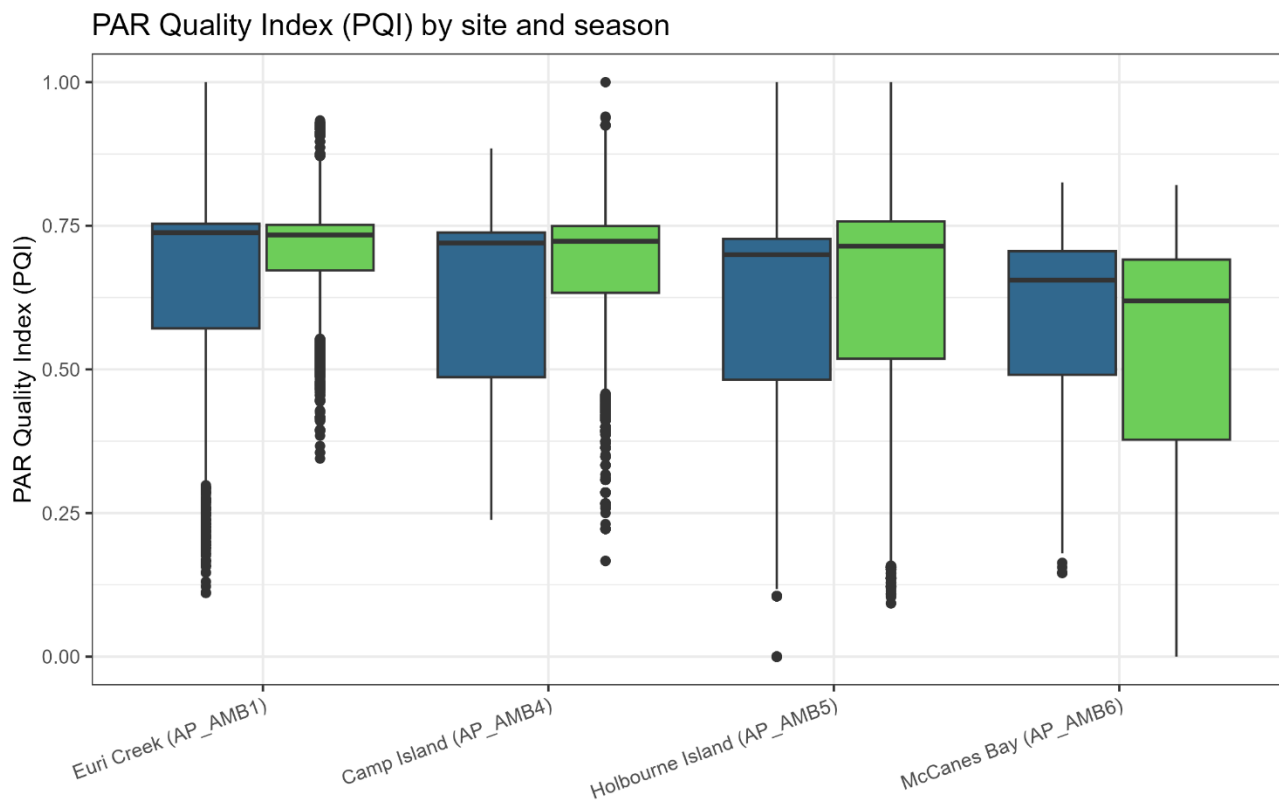
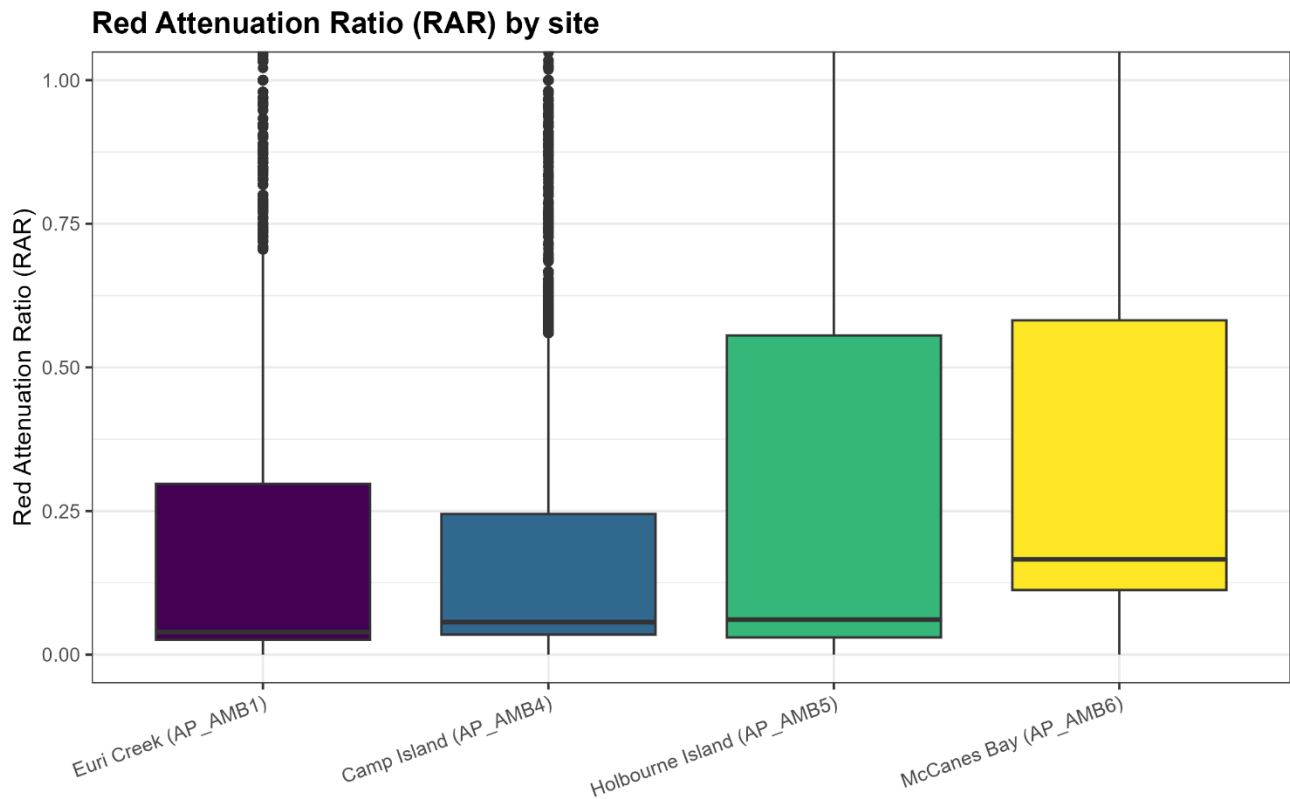
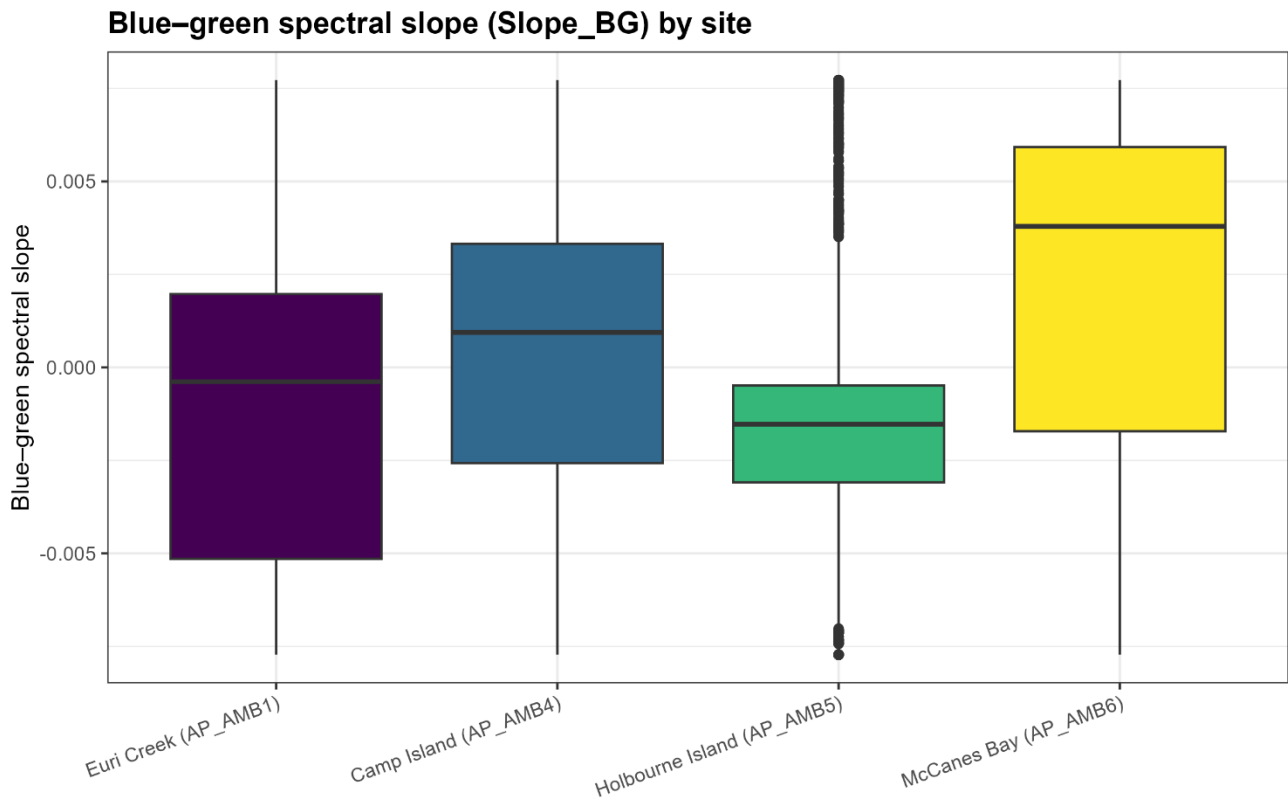


Figure 3-35 values separated into wet-season (Nov–Apr) and dry-season (May–Oct) conditions. Dry-season PQI values were generally higher and less variable, reflecting enhanced blue–green transmission during periods of reduced runoff and calmer conditions, while wet-season values showed greater spread and more frequent low-quality light conditions.



*Figure 3-36 Distribution of the Red Attenuation Ratio (RAR) across the Bowen ambient monitoring sites. RAR quantifies the relative dominance of red wavelengths (610–700 nm) compared with short and mid-visible wavelengths; elevated RAR values indicate stronger attenuation of blue–green light under poorer optical conditions. McCanes Bay showed higher typical RAR values than the other sites, consistent with increased suppression of blue light.*



*Figure 3-37 Distribution of the blue-green spectral slope (Slope\_BG) across the Bowen ambient monitoring sites. Slope\_BG describes the rate of attenuation between blue ( $\approx 440$  nm) and green ( $\approx 570$  nm) wavelengths; steeper (more positive) slopes indicate stronger suppression of blue light relative to green, typically associated with turbidity and/or coloured water. McCanes Bay displayed more positive slopes overall, indicating a greater tendency toward blue-light attenuation compared with the other sites.*

### 3.7. Long-term trend analysis

#### 3.7.1. Rainfall and river discharge

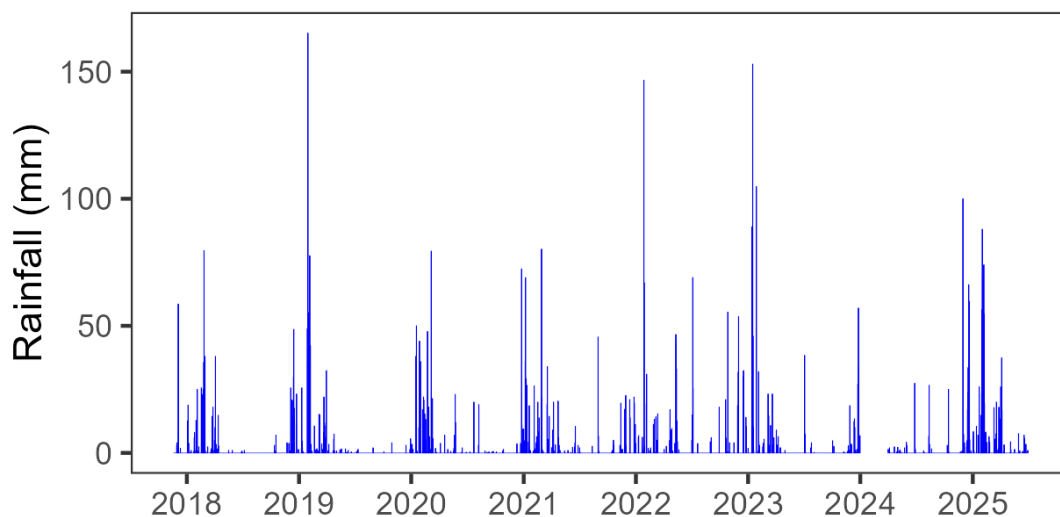
Long-term rainfall and streamflow records for the Bowen–Abbot Point region show a strongly episodic hydrological regime characteristic of dry-tropical eastern Queensland (Figure 3-39; Figure 3-40). Between 2017 and 2025, rainfall occurred predominantly as short-lived wet-season bursts, with long periods of negligible rainfall through the dry season. Several wet seasons produced high-magnitude rainfall pulses—most notably in early 2019, 2022–2023, and 2024–2025—during which daily totals frequently exceeded 50–150 mm. These events align closely with intense regional convective activity and monsoon-trough incursions, which drive the majority of annual rainfall in the area.

Stream discharge in the Don River, Elliot River and Euri Creek responded rapidly to these rainfall pulses, reflecting the flashy hydrology typical of small coastal catchments with steep headwaters and limited floodplain storage. High-flow events were brief but pronounced, with the Don River producing several large spikes exceeding  $30\text{--}60\text{ GL day}^{-1}$ , particularly in the 2019 and 2023 wet seasons. Elliot River and Euri Creek showed similar responsiveness but with smaller magnitude

peaks consistent with their smaller catchment areas; both systems generated multiple sharp pulses of 5–25 GL day<sup>-1</sup> during major rainfall episodes across the record.

Across the eight-year period, neither rainfall nor discharge exhibited a consistent long-term increasing or decreasing trend. Instead, variability was dominated by interannual climatic fluctuations associated with the El Niño–Southern Oscillation and variations in monsoonal activity. Years with multiple high-rainfall events (e.g. 2019, 2023 and 2025) corresponded with clusters of large discharge peaks, whereas years with subdued wet seasons produced little to no sustained flow in all three waterways.

These episodic high-flow events play a critical role in shaping coastal water quality and plume dynamics in the Bowen region. Large discharges deliver the majority of sediment, nutrients and freshwater to the nearshore environment, and years with strong wet-season rainfall exert a disproportionate influence on coastal turbidity and water-clarity conditions at Abbot Point. The long-term hydrological record therefore highlights the highly variable nature of freshwater delivery to the region and emphasises the need to interpret annual water-quality patterns within the context of broader climatic variability.



*Figure 3-38 Rainfall recorded at Mount Dangar (station 033096) for the duration of the ambient water quality monitoring program (Nov 2017– June 2025). Data source: <https://water-monitoring.information.qld.gov.au/>*

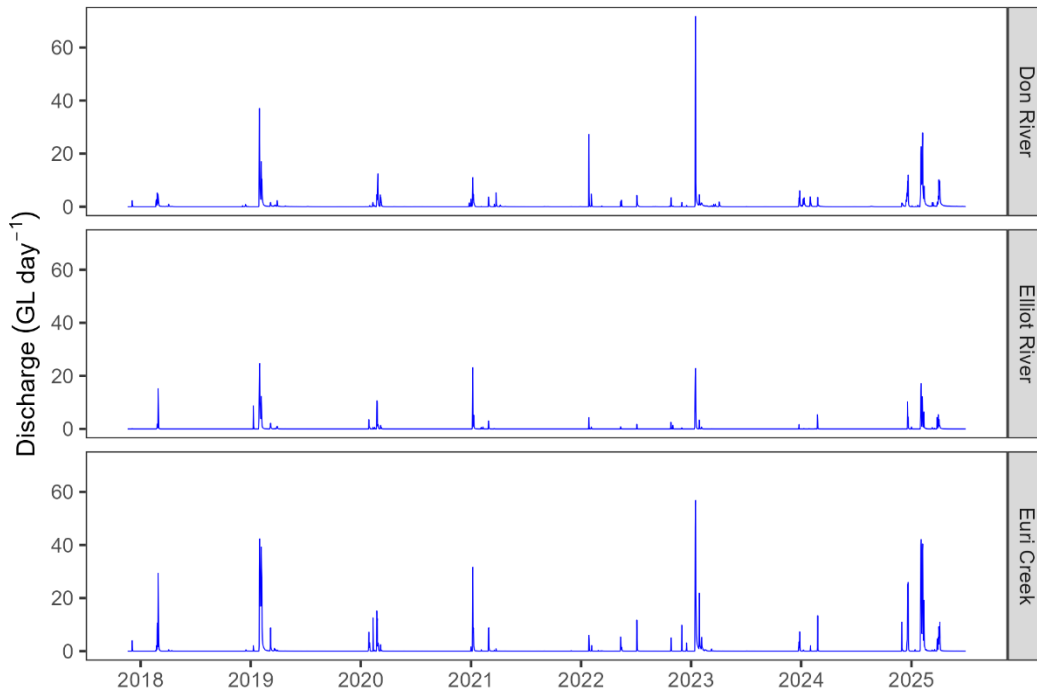


Figure 3-39. Stream discharge ( $\text{ML d}^{-1}$ ) from the Don River (station 121003A) for the duration of the ambient water quality monitoring program (Nov 2017– June 2025). Data source: <https://water-monitoring.information.qld.gov.au/>

Rainfall onset dates for the Bowen region indicate that the wet season generally begins between late October and mid-December, with several years clustering within this typical early-wet-season window (Table 3-6). Markedly late onsets have also occurred, most notably in January 2020 and mid-December 2018 and 2023, highlighting substantial interannual variability driven by shifts in early monsoonal activity and pre-monsoon trough development. The 2024–2025 wet season commenced on 30 November 2024, which falls within the usual seasonal range and is broadly consistent with the long-term pattern of late-spring to early-summer rainfall initiation in the Bowen catchments.

Table 3-6. Northern rainfall onset date as recorded at Mount Dangar (station 033096).

| Reporting year | Rainfall onset |
|----------------|----------------|
| 2017-2018      | 19/10/2017     |
| 2018-2019      | 8/12/2018      |
| 2019-2020      | 16/01/2020     |
| 2020-2021      | 25/12/2020     |
| 2021-2022      | 25/11/2021     |
| 2022-2023      | 22/10/2022     |
| 2023-2024      | 12/12/2023     |
| 2024-2025      | 30/11/2024     |

### 3.7.2. Generalized additive mixed effects models (GAMM)

GAMM outputs for nutrients, chlorophyll-a, total suspended solids and electrical conductivity are presented in Figures 3-40 to 3-42, with full model summaries provided in Appendix D. Relative to longer-term datasets such as Mackay, the Bowen time series (2017–2025) spans a shorter observational window and exhibits correspondingly simpler seasonal structure. Across most parameters, seasonal smooths were weak or non-significant, reflecting the episodic nature of runoff from the Don, Elliot and Euri Creek catchments and the strongly tidally mixed coastal setting around Abbot Point. Where seasonal effects were detected, they were consistent with short-lived wet-season pulses rather than persistent wet–dry separation.

In contrast, statistically significant long-term smooths were identified for several parameters. These smooths capture multi-year variability consistent with interannual climatic forcing rather than progressive directional change. As expected for dynamic coastal waters, GAMMs explained only a modest proportion of total variance for most parameters, with short-duration events and interannual variability accounting for much of the observed scatter.

#### NUTRIENTS

Total nitrogen (TN) and particulate nitrogen (PN) exhibited significant long-term variability characterised by broad, non-directional fluctuations over the 2018–2025 period. Both parameters increased from 2018 to around 2020–2021 before declining toward earlier levels by 2024, producing a “hump-shaped” pattern indicative of interannual variability rather than sustained enrichment. Seasonal structure was weak to moderate, and adjusted  $R^2$  values were low to moderate, consistent with strong event-driven control.

Total dissolved nitrogen (TDN) displayed both a significant seasonal component and a significant long-term smooth. Concentrations peaked around 2019–2020 and declined gradually thereafter, suggesting sensitivity to periods of stronger wet-season forcing rather than a persistent trend. Total

phosphorus (TP) showed no significant seasonal or long-term structure, with concentrations remaining stable throughout the record and dominated by short-term variability.

Total dissolved phosphorus (TDP) exhibited a strong seasonal signal associated with wet-season inputs, but only weak evidence of long-term change. Particulate phosphorus (PP) showed no coherent seasonal or long-term pattern, with concentrations fluctuating around a low background and occasional event-driven spikes. Together, nutrient GAMMs indicate stability in background concentrations with variability governed primarily by episodic hydrological and resuspension processes.

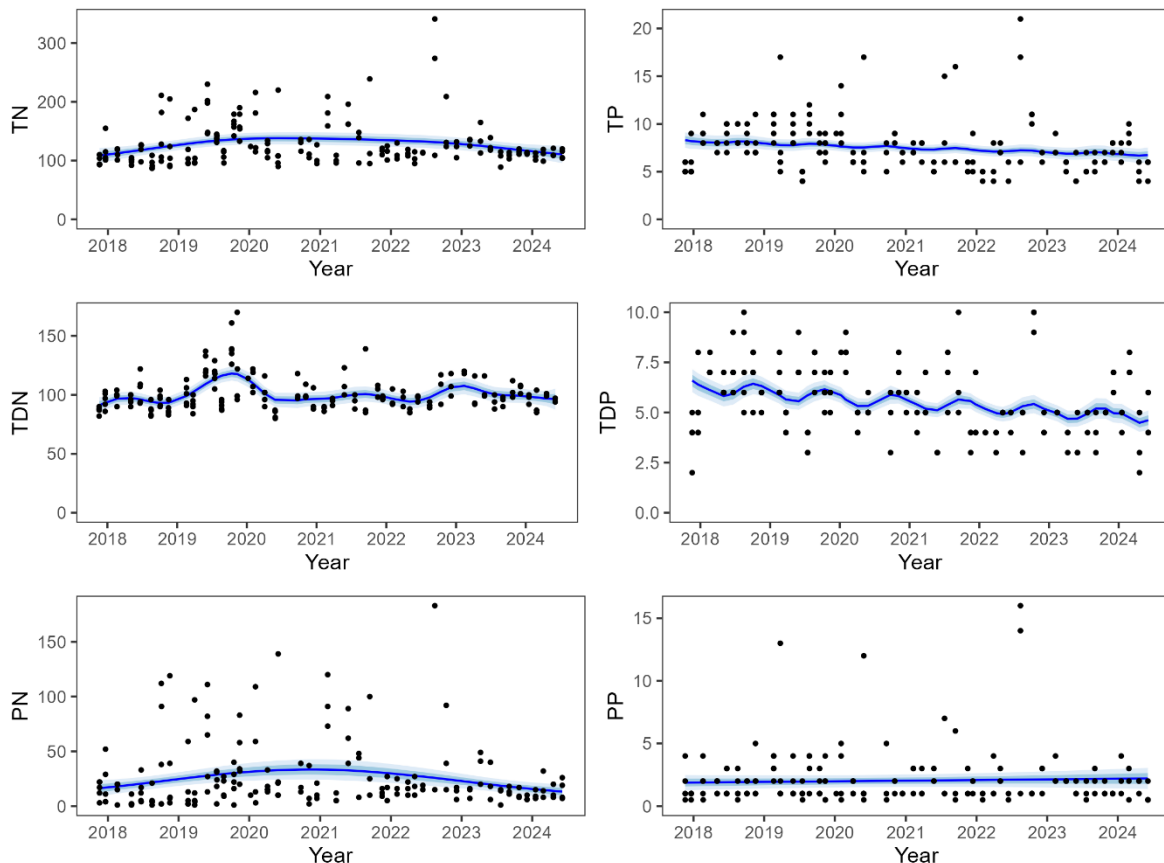


Figure 3-40 Nutrient data from water samples collected in the Bowen region between Nov 2017 and 2025. TN = total nitrogen, TP = total phosphorus, TDN = total dissolved nitrogen, TDP = total dissolved phosphorus, PN = particulate nitrogen, PP = particulate phosphorus. Units =  $\mu\text{g L}^{-1}$ . General additive mixed effects model (GAMM) showing standard error (blue ribbon) and 95% confidence intervals (light blue).

When assessed against the EPP (2019) water-quality objectives, median and percentile-based concentrations of total nitrogen (TN) and total dissolved nitrogen (TDN) exceeded guideline values at most Bowen ambient sites. These exceedances were spatially consistent and dominated by dissolved nitrogen fractions. While exceedances indicate elevated nitrogen availability relative to guideline thresholds, the GAMM results do not demonstrate a corresponding directional increase in nitrogen concentrations over time. The relationship between nitrogen availability and phytoplankton biomass is therefore considered further in the context of observed chlorophyll-a patterns below.

## CHLOROPHYLL-A

Chlorophyll-a showed no detectable seasonal cycle, indicating limited seasonal contrast in phytoplankton biomass despite pronounced wet–dry differences in rainfall, river discharge and turbidity (Figure 3-41). In contrast, the GAMM identified a statistically significant long-term increase in chlorophyll-a concentrations from 2018 to 2025. The temporal smooth (edf  $\approx 1$ ) indicates a simple, monotonic upward trend rather than cyclical behaviour.

Although concentrations remain low to moderate in absolute terms, chlorophyll-a frequently meets or exceeds the applicable water-quality objective for open coastal waters in later years of the record. These exceedances reflect the low numerical threshold of the guideline rather than bloom development, as concentrations remain well below levels typically associated with phytoplankton blooms or sustained biomass accumulation (eg.,  $>5\text{mg/L}$ ; Cloern et al., 2014). The modest model fit (adjusted  $R^2 \approx 0.11$ ) indicates that interannual change explains a measurable but limited proportion of overall variability, with short-term variability and episodic processes remaining important contributors to observed concentrations.

## ELECTRICAL CONDUCTIVITY

Electrical conductivity exhibited a clear and statistically significant seasonal signal, with predictable reductions during wet-season freshwater inputs (Figure 3-41). No significant long-term trend was detected, indicating stable salinity conditions over the monitoring period. Variability is dominated by short-term mixing and runoff events rather than gradual change, consistent with the tidally energetic nature of the Bowen coastal environment.

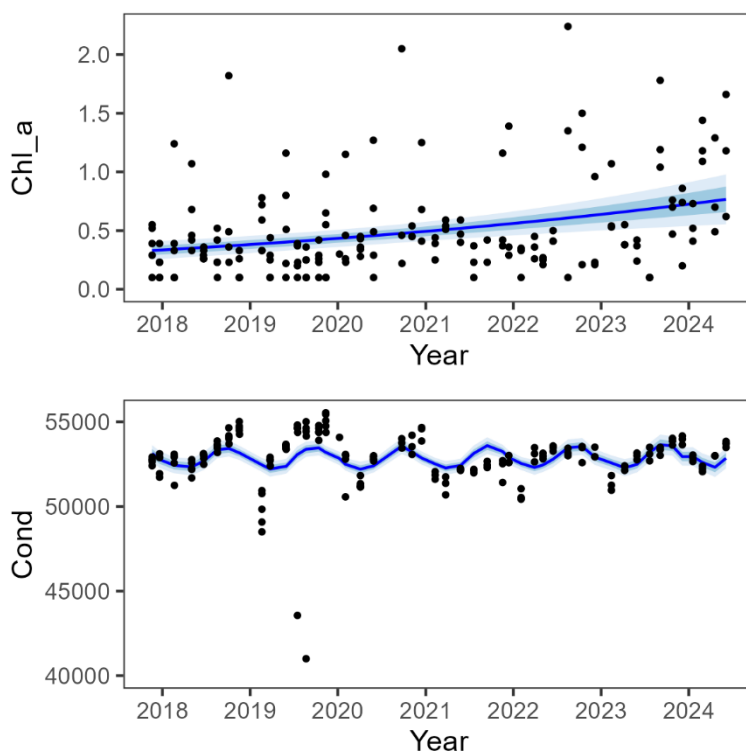


Figure 3-41 Long-term chlorophyll-a (top) and electrical conductivity (bottom) at the Bowen ambient monitoring sites from 2018–2025.

## TOTAL SUSPENDED SOLIDS (TSS)

Total suspended solids (TSS) showed no consistent seasonal structure but exhibited a highly significant long-term smooth (Figure 3-42). The fitted trend indicates a decline from elevated concentrations in the early part of the record (pre-2019), followed by stabilisation at lower levels from 2021 onwards. The relatively high adjusted  $R^2$  indicates that multi-year variability explains a substantial proportion of observed variation, consistent with TSS being strongly influenced by episodic hydrodynamic forcing rather than background biogeochemical processes.

Overall, the TSS GAMM suggests a reduction in suspended sediment levels over time, with no indication of increasing turbidity pressure in recent years.

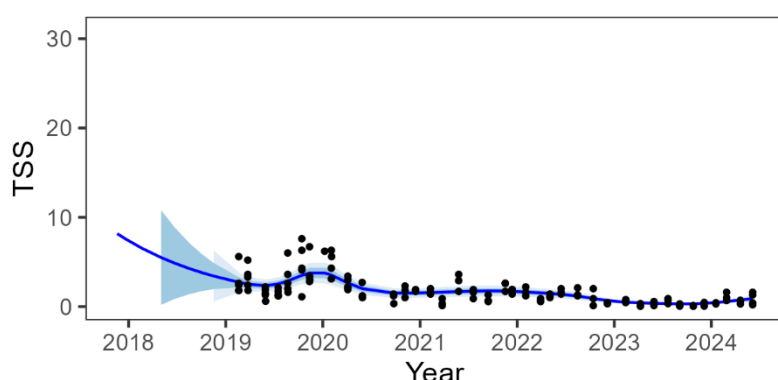


Figure 3-42 Long-term total suspended solids (TSS) showing a significant seasonal pattern and a declining trend after 2020.

### 3.7.3. Interpretation of Long-Term Trends

Taken together, the GAMM results indicate that long-term water quality in the Bowen–Abbot Point region is governed primarily by interannual climatic variability and episodic hydrodynamic forcing rather than progressive anthropogenic pressure. Nutrient concentrations, while frequently exceeding guideline values for nitrogen, show no evidence of sustained enrichment over time, chlorophyll-a remains well below bloom thresholds despite a modest upward trend, and suspended sediments have declined and stabilised over recent years. Seasonal structure is weak across most parameters, reflecting the episodic nature of catchment inputs and strong coastal mixing.

While continued long-term monitoring remains important—particularly under projected increases in climate variability and extreme rainfall—current evidence indicates that ambient water quality across the Bowen region remains stable, resilient and not subject to increasing nutrient or sediment stress.

## 4 CONCLUSION

The 2024–2025 ambient marine water-quality monitoring program provides a comprehensive assessment of seasonal dynamics and longer-term conditions across the Bowen–Abbot Point coastal region. Through the integration of discrete water sampling, in situ profiling, passive

samplers, continuous seafloor loggers, and multispectral benthic irradiance measurements, the program continues to build a robust evidence base for understanding water-quality variability in a dynamic, tidally energetic coastal environment adjacent to the Great Barrier Reef lagoon.

Hydrological conditions during the reporting year were characteristic of a dry-tropical system, with rainfall and river discharge dominated by short-duration wet-season events. Two principal runoff periods—an early wet-season pulse in January and a larger event in mid-February 2025—generated brief freshwater and sediment inputs to nearshore waters, clearly expressed in short-term in situ responses and satellite observations. These influences were transient, with rapid reversion to marine conditions following peak flows. Analysis of rainfall and streamflow records since 2017 indicates pronounced interannual variability but no evidence of a sustained directional change in freshwater delivery to the region.

Across all ambient monitoring sites, physicochemical conditions remained consistent with a well-mixed coastal system. Salinity, temperature, dissolved oxygen, pH and water clarity followed expected seasonal patterns and showed no evidence of persistent stratification or ecological stress. Trace metal concentrations remained low and well below applicable guideline values, indicating no evidence of metal enrichment.

Nutrient concentrations were generally low to moderate, with wet-season increases largely confined to particulate fractions associated with episodic runoff and sediment resuspension. When assessed against the EPP (2019) water-quality objectives, concentrations of total nitrogen (TN) and total dissolved nitrogen (TDN) frequently exceeded guideline values across the Bowen ambient sites. These exceedances were spatially consistent and dominated by dissolved nitrogen forms. In contrast, phosphorus fractions generally remained within guideline values, and particulate nutrient concentrations were typically low and episodic. Generalised additive mixed-effects model (GAMM) analysis showed no evidence of sustained long-term increases in nitrogen concentrations, indicating that exceedances reflect stable background conditions and interannual climatic variability rather than progressive nutrient enrichment.

Chlorophyll-a concentrations exhibited a statistically significant long-term increase over the monitoring period and frequently met or exceeded the applicable water-quality objective for open coastal waters in later years of the record. However, concentrations remained low to moderate in absolute terms and well below levels typically associated with phytoplankton blooms or sustained biomass accumulation. While nitrogen exceedances and increasing chlorophyll-a concentrations co-occur, the available data do not demonstrate bloom development or a transition toward eutrophic conditions. Interpretation of phytoplankton response therefore requires consideration of additional controlling factors, including light availability, hydrodynamic flushing and residence time, which were not explicitly resolved in this analysis.

Total suspended solids were dominated by event-driven variability rather than seasonal structure. GAMM results indicate a decline from higher concentrations early in the monitoring record (pre-2019), followed by stabilisation at consistently low levels in recent years. This pattern is consistent with interannual variability in hydrodynamic forcing and sediment resuspension, rather than increasing sediment pressure or catchment erosion. Benthic irradiance and spectral light-quality measurements further demonstrated strong seasonal modulation of light quantity and quality, with

reduced blue–green light availability during short-lived wet-season turbidity events and improved conditions during the dry season, reflecting natural sediment and mixing processes.

Overall, the GAMM analyses indicate that long-term water quality in the Bowen–Abbot Point region is governed primarily by interannual climatic variability and episodic hydrological and hydrodynamic processes, rather than progressive anthropogenic pressure. Although nitrogen concentrations frequently exceed guideline thresholds and chlorophyll-a has increased modestly over time, there is no evidence of sustained nutrient enrichment, bloom-level phytoplankton biomass, or increasing turbidity stress. The system remains well mixed and resilient, with water-quality variability largely driven by natural processes.

Continued long-term monitoring remains essential to maintain this context and to detect emerging changes under projected increases in climate variability and extreme rainfall. Based on current evidence, however, there is no indication of a sustained decline in ambient marine water quality across the Bowen region’s monitoring sites.

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## APPENDIX A PESTICIDE ANALYSES

### A.1 ED-PPCP Water Concentration ng/L

| Site Name             | Euri Creek    | Euri Creek    |
|-----------------------|---------------|---------------|
| Deployed Date         | 30/09/2024    | 22/11/2024    |
| Retrieved Date        | 22/11/2024    | 19/02/2025    |
| Days Deployed         | 53            | 89            |
| Flow Rate (cm/s)      | 28.2          | 28.2          |
| Site Code             | AP-AMB1       | AP-AMB1       |
| Sample Name           | TRP124_ED_EUR | TRP225_ED_EUR |
| Analyte               |               |               |
| 2,4,5-T               | * $<0.128$    | * $<0.076$    |
| 2,4-D                 | $<0.536$      | $<0.319$      |
| 3,4 Dichloroaniline   | * $<0.128$    | * $<0.076$    |
| Ametryn               | $<0.966$      | $<0.575$      |
| Ametryn hydroxy       | * $<0.128$    | * $<0.076$    |
| Atrazine              | <b>0.186</b>  | <b>0.158</b>  |
| Atrazine desethyl     | $<0.153$      | $<0.091$      |
| Atrazine desisopropyl | * $<0.128$    | * $<0.076$    |
| Bendiocarb            | * $<0.064$    | * $<0.038$    |
| Bromacil              | $<0.087$      | $<0.052$      |
| Bromoxynil            | * $<0.128$    | * $<0.076$    |
| Carbaryl              | * $<0.064$    | * $<0.038$    |
| Carbendazim           | $<0.153$      | $<0.091$      |
| Carbofuran            | * $<0.128$    | * $<0.076$    |
| DCPMU                 | * $<0.013$    | * $<0.008$    |
| DCPU                  | * $<0.064$    | * $<0.038$    |
| Diazinon              | $<0.026$      | $<0.015$      |
| Difenoconazole        | * $<0.638$    | * $<0.380$    |
| Diketonitrile         | * $<0.013$    | <b>*0.020</b> |
| Diuron                | <b>0.132</b>  | <b>0.302</b>  |
| Fipronil              | $<0.056$      | $<0.033$      |

|                         |              |              |
|-------------------------|--------------|--------------|
| Fluazifop               | * $<0.013$   | * $<0.008$   |
| Fluometuron             | $<0.093$     | $<0.055$     |
| Fluroxypyr              | * $<0.128$   | * $<0.076$   |
| Haloxypop               | $<0.066$     | $<0.039$     |
| Hexazinone              | $<0.125$     | <b>0.467</b> |
| Imazapyr                | * $<0.191$   | * $<0.114$   |
| Imazethapyr             | * $<0.128$   | * $<0.076$   |
| Imidacloprid            | * $<0.128$   | * $<0.076$   |
| MCPA                    | $<0.388$     | $<0.231$     |
| Malathion               | * $<0.128$   | * $<0.076$   |
| Mecoprop                | $<0.070$     | $<0.042$     |
| Metalaxyl               | * $<0.013$   | * $<0.008$   |
| Methidathion            | * $<0.638$   | * $<0.380$   |
| Methiocarb              | * $<0.128$   | * $<0.076$   |
| Methomyl                | * $<0.128$   | * $<0.076$   |
| Metolachlor (S+R)       | <b>0.128</b> | <b>0.141</b> |
| Metribuzin              | * $<0.128$   | * $<0.076$   |
| Metsulfuron methyl      | * $<0.128$   | * $<0.076$   |
| Oryzalin                | * $<0.089$   | * $<0.053$   |
| Picloram                | * $<0.638$   | * $<0.380$   |
| Prometryn               | $<0.211$     | $<0.126$     |
| Propachlor              | * $<0.102$   | * $<0.061$   |
| Propazine               | * $<0.128$   | * $<0.076$   |
| Propiconazole           | * $<0.128$   | * $<0.076$   |
| Propoxur                | $<0.104$     | $<0.062$     |
| Simazine                | $<0.087$     | $<0.052$     |
| Simazine hydroxy        | * $<0.128$   | * $<0.076$   |
| Tebuconazole            | * $<0.128$   | * $<0.076$   |
| Tebuthiuron             | $<0.098$     | <b>3.27</b>  |
| Terbuthylazine          | $<0.118$     | $<0.070$     |
| Terbuthylazine desethyl | * $<0.128$   | * $<0.076$   |
| Thiamethoxam            | * $<0.089$   | * $<0.053$   |
| Triclopyr               | $<0.322$     | $<0.192$     |

## A.2 ED ng per sampler

| Site Name             |       | Euri Creek    | Euri Creek    |
|-----------------------|-------|---------------|---------------|
| Deployed Date         |       | 30/09/2024    | 22/11/2024    |
| Retrieved Date        |       | 22/11/2024    | 19/02/2025    |
| Days Deployed         |       | 53            | 89            |
| Flow Rate (cm/s)      |       | 28.2          | 28.2          |
| Site Code             |       | AP-AMB1       | AP-AMB1       |
| Sample Name           |       | TRP124_ED_EUR | TRP225_ED_EUR |
| Analyte               | LOQ   |               |               |
| 2,4,5-T               | 1.00  | <1.00         | <1.00         |
| 2,4-D                 | 5.00  | <5.00         | <5.00         |
| 3,4 Dichloroaniline   | 1.00  | <1.00         | <1.00         |
| Ametryn               | 5.00  | <5.00         | <5.00         |
| Ametryn hydroxy       | 1.00  | <1.00         | <1.00         |
| Atrazine              | 1.00  | 1.46          | 2.08          |
| Atrazine desethyl     | 1.00  | <1.00         | <1.00         |
| Atrazine desisopropyl | 1.00  | <1.00         | <1.00         |
| Bendiocarb            | 0.500 | <0.500        | <0.500        |
| Bromacil              | 1.00  | <1.00         | <1.00         |
| Bromoxynil            | 1.00  | <1.00         | <1.00         |
| Carbaryl              | 0.500 | <0.500        | <0.500        |
| Carbendazim           | 1.00  | <1.00         | <1.00         |
| Carbofuran            | 1.00  | <1.00         | <1.00         |
| DCPMU                 | 0.100 | <0.100        | <0.100        |
| DCPU                  | 0.500 | <0.500        | <0.500        |
| Diazinon              | 0.100 | <0.100        | <0.100        |
| Difenoconazole        | 5.00  | <5.00         | <5.00         |
| Diketonitrile         | 0.100 | <0.100        | 0.260         |
| Diuron                | 0.500 | 0.860         | 3.30          |
| Fipronil              | 0.500 | <0.500        | <0.500        |
| Fluazifop             | 0.100 | <0.100        | <0.100        |
| Fluometuron           | 1.00  | <1.00         | <1.00         |

|                         |       |             |             |
|-------------------------|-------|-------------|-------------|
| Fluroxypyr              | 1.00  | <1.00       | <1.00       |
| Haloxypop               | 1.00  | <1.00       | <1.00       |
| Hexazinone              | 1.00  | <1.00       | <b>6.27</b> |
| Imazapyr                | 1.50  | <1.50       | <1.50       |
| Imazethapyr             | 1.00  | <1.00       | <1.00       |
| Imidacloprid            | 1.00  | <1.00       | <1.00       |
| MCPA                    | 5.00  | <5.00       | <5.00       |
| Malathion               | 1.00  | <1.00       | <1.00       |
| Mecoprop                | 1.00  | <1.00       | <1.00       |
| Metalaxyl               | 0.100 | <0.100      | <0.100      |
| Methidathion            | 5.00  | <5.00       | <5.00       |
| Methiocarb              | 1.00  | <1.00       | <1.00       |
| Methomyl                | 1.00  | <1.00       | <1.00       |
| Metolachlor (S+R)       | 1.00  | <b>1.02</b> | <b>1.89</b> |
| Metribuzin              | 1.00  | <1.00       | <1.00       |
| Metsulfuron methyl      | 1.00  | <1.00       | <1.00       |
| Oryzalin                | 0.700 | <0.700      | <0.700      |
| Picloram                | 5.00  | <5.00       | <5.00       |
| Prometryn               | 1.00  | <1.00       | <1.00       |
| Propachlor              | 0.800 | <0.800      | <0.800      |
| Propazine               | 1.00  | <1.00       | <1.00       |
| Propiconazole           | 1.00  | <1.00       | <1.00       |
| Propoxur                | 1.00  | <1.00       | <1.00       |
| Simazine                | 1.00  | <1.00       | <1.00       |
| Simazine hydroxy        | 1.00  | <1.00       | <1.00       |
| Tebuconazole            | 1.00  | <1.00       | <1.00       |
| Tebuthiuron             | 1.00  | <1.00       | <b>56.0</b> |
| Terbuthylazine          | 1.00  | <1.00       | <1.00       |
| Terbuthylazine desethyl | 1.00  | <1.00       | <1.00       |
| Thiamethoxam            | 0.700 | <0.700      | <0.700      |
| Triclopyr               | 5.00  | <5.00       | <5.00       |

### A.3 PE ng per sampler

| Site Name        |       | Euri Creek |        | Euri Creek | Lab Blank       |
|------------------|-------|------------|--------|------------|-----------------|
| Deployed Date    |       | 30/09/2024 |        | 22/11/2024 |                 |
| Retrieved Date   |       | 22/11/2024 |        | 19/02/2025 |                 |
| Days Deployed    |       | 53         |        | 89         |                 |
| Site Code        |       | AP-AMB1    |        | AP-AMB1    |                 |
| QAEHS<br>Acronym | LOQ   |            |        |            |                 |
| PFBA             | 1.10  | <1.10      | <1.10  | <1.10      | 0.061           |
| PFPeA            | 1.10  | <1.10      | <1.10  | <1.10      | not<br>detected |
| PFHxA            | 0.900 | <0.900     | <0.900 | <0.900     | not<br>detected |
| PFHpA            | 0.900 | <0.900     | <0.900 | <0.900     | not<br>detected |
| PFOA             | 1.00  | <1.00      | <1.00  | <1.00      | not<br>detected |
| PFOA Total       | 1.00  | <1.00      | <1.00  | <1.00      | not<br>detected |
| PFNA             | 0.900 | <0.900     | <0.900 | <0.900     | not<br>detected |
| PFDA             | 0.800 | <0.800     | <0.800 | <0.800     | not<br>detected |
| PFUnDA           | 0.700 | <0.700     | <0.700 | <0.700     | not<br>detected |
| PFDoDA           | 1.70  | <1.70      | <1.70  | <1.70      | not<br>detected |
| PFPrS            | 1.10  | <1.10      | <1.10  | <1.10      | not<br>detected |
| PFBS             | 1.10  | <1.10      | <1.10  | <1.10      | not<br>detected |
| PFPeS            | 0.900 | <0.900     | <0.900 | <0.900     | not<br>detected |
| PFHxS            | 1.00  | <1.00      | <1.00  | <1.00      | not<br>detected |
| PFHxS Total      | 1.00  | <1.00      | <1.00  | <1.00      | not<br>detected |

|              |       |                    |                    |                    |              |
|--------------|-------|--------------------|--------------------|--------------------|--------------|
| PFHpS        | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| PFOS         | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| PFOS Total   | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| 8Cl-PFOS     | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| 9Cl-F53B     | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| PFECHS       | 1.60  | <1.60              | <1.60              | <1.60              | not detected |
| FBSA         | 0.900 | <0.900             | <0.900             | <0.900             | not detected |
| FHxSA        | 0.700 | <0.700             | <0.700             | <0.700             | not detected |
| FOSA         | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| N-EtFOSAA    | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| N-MeFOSAA    | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| 4:2 FTS      | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| 6:2 FTS      | 1.25  | <2.08 <sup>^</sup> | <2.08 <sup>^</sup> | <2.08 <sup>^</sup> | <b>1.05</b>  |
| 8:2 FTS      | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| 6:2 FTCA     | 0.900 | N/R (IS rec 0.0%)  | N/R (IS rec 0.0%)  | <0.900             | not detected |
| 8:2 FTCA     | 0.800 | N/R (IS rec 0.0%)  | N/R (IS rec 0.0%)  | <0.800             | not detected |
| 5:3 FTCA     | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| 6:2 FTAB_pos | 1.00  | <1.00              | <1.00              | <1.00              | not detected |
| ADONA        | 1.00  | <1.00              | <1.00              | <1.00              | <b>0.081</b> |
| GenX         | 1.20  | <1.20              | <1.20              | <1.20              | not detected |

## A.4 PE Water concentration ng/L

|                                                     | Site Name      | Euri Creek | Euri Creek | Euri Creek |
|-----------------------------------------------------|----------------|------------|------------|------------|
|                                                     | Deployed Date  | 30/09/2024 | 30/09/2024 | 22/11/2024 |
|                                                     | Retrieved Date | 22/11/2024 | 22/11/2024 | 19/02/2025 |
|                                                     | Days Deployed  | 53         | 53         | 89         |
|                                                     | Site Code      | AP-AMB1    | AP-AMB1    | AP-AMB1    |
| Analyte                                             | QAEHS Acronym  |            |            |            |
| Perfluorobutanoic acid                              | PFBA           | <1.86      | <1.86      | <1.11      |
| Perfluoropentanoic acid                             | PFPeA          | <2.11      | <2.11      | <1.26      |
| Perfluorohexanoic acid                              | PFHxA          | <1.54      | <1.54      | <0.919     |
| Perfluoroheptanoic acid                             | PFHpA          | <1.20      | <1.20      | <0.716     |
| Perfluorooctanoic acid                              | PFOA           | <1.73      | <1.73      | <1.03      |
| Total (linear + branched) Perfluorooctanoic acid    | PFOA Total     | <1.73      | <1.73      | <1.03      |
| Perfluorononanoic acid                              | PFNA           | <0.597     | <0.597     | <0.355     |
| Perfluorodecanoic acid                              | PFDA           | <0.877     | <0.877     | <0.522     |
| Perfluoroundecanoic acid                            | PFUnDA         | NA         | NA         | NA         |
| Perfluorododecanoic acid                            | PFDoDA         | NA         | NA         | NA         |
| Perfluoropropane sulfonate                          | PFPrS          | <1.43      | <1.43      | <0.850     |
| Perfluorobutane sulfonate                           | PFBS           | <1.50      | <1.50      | <0.894     |
| Perfluoropentane sulfonate                          | PFPeS          | <1.58      | <1.58      | <0.943     |
| Perfluorohexane sulfonate                           | PFHxS          | <1.58      | <1.58      | <0.939     |
| Total (linear + branched) Perfluorohexane sulfonate | PFHxS Total    | <1.58      | <1.58      | <0.939     |
| Perfluoroheptane sulfonate                          | PFHpS          | NA         | NA         | NA         |
| Perfluorooctane sulfonate                           | PFOS           | <1.53      | <1.53      | <0.913     |
| Total (linear + branched) Perfluorooctane sulfonate | PFOS Total     | <1.53      | <1.53      | <0.913     |
| 8-Chloroperfluoro-1-octanesulfonate                 | 8Cl-PFOS       | NA         | NA         | NA         |
| 9-Chlorohexadecafluoro-3-oxanonane-1-sulfonate      | 9Cl-F53B       | NA         | NA         | NA         |
| Perfluoroethylcyclohexane sulfonate                 | PFECHS         | NA         | NA         | NA         |
| Perfluorobutane sulfonamide                         | FBSA           | <0.923     | <0.923     | <0.550     |
| Perfluorohexane sulfonamide                         | FHxSA          | NA         | NA         | NA         |
| Perfluorooctane sulfonamide                         | FOSA           | NA         | NA         | NA         |

|                                                     |                     |    |    |    |
|-----------------------------------------------------|---------------------|----|----|----|
| <b>N-ethyl-fluorooctane sulfonamidoacetic acid</b>  | <b>N-EtFOSAA</b>    | NA | NA | NA |
| <b>N-methyl-fluorooctane sulfonamidoacetic acid</b> | <b>N-MeFOSAA</b>    | NA | NA | NA |
| <b>4:2-Fluorotelomer sulfonate</b>                  | <b>4:2 FTS</b>      | NA | NA | NA |
| <b>6:2-Fluorotelomer sulfonate</b>                  | <b>6:2 FTS</b>      | NA | NA | NA |
| <b>8:2-Fluorotelomer sulfonate</b>                  | <b>8:2 FTS</b>      | NA | NA | NA |
| <b>6:2 Fluorotelomer carboxylic acid</b>            | <b>6:2 FTCA</b>     | NA | NA | NA |
| <b>8:2 Fluorotelomer carboxylic acid</b>            | <b>8:2 FTCA</b>     | NA | NA | NA |
| <b>5:3 Fluorotelomer carboxylic acid</b>            | <b>5:3 FTCA</b>     | NA | NA | NA |
| <b>6:2 Fluorotelomer sulfonamido propyl betaine</b> | <b>6:2 FTAB_pos</b> | NA | NA | NA |
| <b>Trifluoromethoxy propoxy propanoate</b>          | <b>ADONA</b>        | NA | NA | NA |
| <b>Hexafluoropropylene oxide dimer acid</b>         | <b>GenX</b>         | NA | NA | NA |

^ - Limit of Reporting (LOR) raised by blank level: Where an analyte is detected in field or lab blanks above the Limit of Quantification (LOQ), the effective LOR is raised to the average blank value plus three times the standard deviation

Data reported as <LOR where applicable, and expressed as a water concentration estimate

N/R - Not Reportable: Where a data point is not able to be reliably reported due to unavoidable analytical issues such as matrix interference or unacceptable analyte performance/recovery

Water concentration estimates provided here are derived by applying sampling rates from calibration studies to the amount of analyte accumulated by the sampler

## APPENDIX B      LOGGER DATA SUMMARIES

| Site_code | param | Mean  | Median | sd   | min  | max   | Q1    | Q3    | n    | Month | Year |
|-----------|-------|-------|--------|------|------|-------|-------|-------|------|-------|------|
| AP_AMB1   | Depth | 11.01 | 10.97  | 0.68 | 9.55 | 12.73 | 10.51 | 11.46 | 4464 | Jul   | 2024 |
| AP_AMB1   | Depth | 10.89 | 10.86  | 0.67 | 9.29 | 12.74 | 10.41 | 11.32 | 4461 | Aug   | 2024 |
| AP_AMB1   | Depth | 11.01 | 10.98  | 0.64 | 9.68 | 12.77 | 10.52 | 11.45 | 4319 | Sep   | 2024 |
| AP_AMB1   | Depth | 11.09 | 11.01  | 0.65 | 9.61 | 12.72 | 10.57 | 11.62 | 4464 | Oct   | 2024 |
| AP_AMB1   | Depth | 11.10 | 11.04  | 0.64 | 9.52 | 12.64 | 10.62 | 11.60 | 4316 | Nov   | 2024 |
| AP_AMB1   | Depth | 11.04 | 11.00  | 0.66 | 9.46 | 12.70 | 10.57 | 11.52 | 4464 | Dec   | 2024 |
| AP_AMB1   | Depth | 11.27 | 11.24  | 0.68 | 9.63 | 12.98 | 10.79 | 11.68 | 4464 | Jan   | 2025 |
| AP_AMB1   | Depth | 11.25 | 11.23  | 0.67 | 9.57 | 12.92 | 10.75 | 11.68 | 4028 | Feb   | 2025 |
| AP_AMB1   | Depth | 10.90 | 10.88  | 0.68 | 9.45 | 12.61 | 10.36 | 11.40 | 4464 | Mar   | 2025 |
| AP_AMB1   | Depth | 10.75 | 10.71  | 0.66 | 9.04 | 12.09 | 10.23 | 11.27 | 4319 | Apr   | 2025 |
| AP_AMB1   | Depth | 10.77 | 10.69  | 0.66 | 9.11 | 12.20 | 10.26 | 11.30 | 4464 | May   | 2025 |
| AP_AMB1   | Depth | 10.54 | 10.49  | 0.66 | 9.03 | 12.18 | 10.05 | 11.04 | 4317 | Jun   | 2025 |
| AP_AMB4   | Depth | 10.50 | 10.49  | 0.67 | 8.93 | 12.24 | 10.02 | 10.92 | 4464 | Jul   | 2024 |
| AP_AMB4   | Depth | 10.11 | 10.05  | 0.71 | 8.44 | 12.23 | 9.61  | 10.57 | 4462 | Aug   | 2024 |
| AP_AMB4   | Depth | 10.08 | 10.04  | 0.65 | 8.72 | 11.91 | 9.59  | 10.55 | 4318 | Sep   | 2024 |
| AP_AMB4   | Depth | 10.02 | 9.95   | 0.63 | 8.56 | 11.66 | 9.52  | 10.50 | 4464 | Oct   | 2024 |
| AP_AMB4   | Depth | 10.21 | 10.15  | 0.66 | 8.50 | 11.60 | 9.72  | 10.73 | 4318 | Nov   | 2024 |
| AP_AMB4   | Depth | 10.47 | 10.42  | 0.65 | 8.90 | 12.07 | 9.99  | 10.97 | 4464 | Dec   | 2024 |
| AP_AMB4   | Depth | 10.60 | 10.56  | 0.67 | 9.02 | 12.27 | 10.13 | 11.03 | 4464 | Jan   | 2025 |
| AP_AMB4   | Depth | 10.47 | 10.43  | 0.65 | 8.93 | 12.14 | 9.97  | 10.91 | 4030 | Feb   | 2025 |
| AP_AMB4   | Depth | 10.27 | 10.23  | 0.66 | 8.87 | 11.88 | 9.76  | 10.76 | 4464 | Mar   | 2025 |
| AP_AMB4   | Depth | 10.26 | 10.19  | 0.65 | 8.62 | 11.61 | 9.75  | 10.78 | 4318 | Apr   | 2025 |
| AP_AMB4   | Depth | 10.30 | 10.22  | 0.65 | 8.65 | 11.73 | 9.83  | 10.82 | 4464 | May   | 2025 |
| AP_AMB4   | Depth | 10.17 | 10.12  | 0.64 | 8.67 | 11.83 | 9.71  | 10.64 | 4318 | Jun   | 2025 |

|         |           |       |       |      |       |       |       |       |      |     |      |
|---------|-----------|-------|-------|------|-------|-------|-------|-------|------|-----|------|
| AP_AMB5 | Depth     | 7.86  | 7.82  | 0.66 | 6.38  | 9.57  | 7.37  | 8.28  | 4464 | Jul | 2024 |
| AP_AMB5 | Depth     | 7.93  | 7.93  | 0.67 | 6.38  | 9.59  | 7.44  | 8.35  | 4462 | Aug | 2024 |
| AP_AMB5 | Depth     | 7.93  | 7.90  | 0.67 | 5.94  | 9.73  | 7.42  | 8.40  | 4319 | Sep | 2024 |
| AP_AMB5 | Depth     | 7.00  | 6.94  | 0.65 | 5.52  | 8.61  | 6.48  | 7.52  | 4464 | Oct | 2024 |
| AP_AMB5 | Depth     | 8.00  | 7.53  | 1.54 | 5.48  | 11.16 | 6.76  | 9.55  | 4319 | Nov | 2024 |
| AP_AMB5 | Depth     | 10.07 | 10.02 | 0.67 | 8.49  | 11.72 | 9.58  | 10.55 | 4464 | Dec | 2024 |
| AP_AMB5 | Depth     | 9.99  | 9.95  | 0.70 | 8.33  | 11.68 | 9.49  | 10.45 | 4464 | Jan | 2025 |
| AP_AMB5 | Depth     | 10.79 | 10.34 | 1.37 | 8.57  | 14.17 | 9.70  | 12.00 | 4030 | Feb | 2025 |
| AP_AMB5 | Depth     | 12.38 | 12.35 | 0.67 | 10.93 | 14.06 | 11.86 | 12.87 | 4464 | Mar | 2025 |
| AP_AMB5 | Depth     | 18.63 | 19.53 | 2.70 | 11.19 | 21.18 | 18.88 | 20.18 | 4318 | Apr | 2025 |
| AP_AMB5 | Depth     | 19.86 | 19.76 | 0.67 | 18.25 | 21.34 | 19.34 | 20.41 | 4464 | May | 2025 |
| AP_AMB5 | Depth     | 20.43 | 20.38 | 0.66 | 19.01 | 22.17 | 19.95 | 20.91 | 4317 | Jun | 2025 |
| AP_AMB6 | Depth     | 6.45  | 6.37  | 0.71 | 4.81  | 8.28  | 5.93  | 6.93  | 4464 | Jul | 2024 |
| AP_AMB6 | Depth     | 6.14  | 6.10  | 0.72 | 4.41  | 8.28  | 5.61  | 6.60  | 4462 | Aug | 2024 |
| AP_AMB6 | Depth     | 6.33  | 6.26  | 0.69 | 4.88  | 8.29  | 5.79  | 6.79  | 4319 | Sep | 2024 |
| AP_AMB6 | Depth     | 6.35  | 6.27  | 0.67 | 4.81  | 7.97  | 5.81  | 6.89  | 4464 | Oct | 2024 |
| AP_AMB6 | Depth     | 6.33  | 6.25  | 0.68 | 4.71  | 7.98  | 5.83  | 6.85  | 4319 | Nov | 2024 |
| AP_AMB6 | Depth     | 6.09  | 6.04  | 0.68 | 4.54  | 7.88  | 5.58  | 6.56  | 4464 | Dec | 2024 |
| AP_AMB6 | Depth     | 6.19  | 6.16  | 0.70 | 4.55  | 8.02  | 5.67  | 6.62  | 4464 | Jan | 2025 |
| AP_AMB6 | Depth     | 6.53  | 6.48  | 0.72 | 4.92  | 8.67  | 6.02  | 6.93  | 4029 | Feb | 2025 |
| AP_AMB6 | Depth     | 6.79  | 6.75  | 0.70 | 5.28  | 8.52  | 6.24  | 7.33  | 4464 | Mar | 2025 |
| AP_AMB6 | Depth     | 6.78  | 6.71  | 0.69 | 5.07  | 8.20  | 6.25  | 7.35  | 4318 | Apr | 2025 |
| AP_AMB6 | Depth     | 6.79  | 6.71  | 0.69 | 5.08  | 8.27  | 6.27  | 7.35  | 4464 | May | 2025 |
| AP_AMB6 | Depth     | 6.59  | 6.53  | 0.69 | 4.99  | 8.28  | 6.06  | 7.08  | 4317 | Jun | 2025 |
| AP_AMB1 | Depth_RMS | 0.03  | 0.02  | 0.02 | 0.00  | 0.20  | 0.01  | 0.03  | 4464 | Jul | 2024 |
| AP_AMB1 | Depth_RMS | 0.03  | 0.03  | 0.01 | 0.00  | 0.16  | 0.02  | 0.04  | 4461 | Aug | 2024 |
| AP_AMB1 | Depth_RMS | 0.04  | 0.03  | 0.03 | 0.00  | 0.25  | 0.02  | 0.05  | 4319 | Sep | 2024 |
| AP_AMB1 | Depth_RMS | 0.03  | 0.02  | 0.02 | 0.00  | 0.24  | 0.01  | 0.04  | 4464 | Oct | 2024 |
| AP_AMB1 | Depth_RMS | 0.03  | 0.02  | 0.02 | 0.00  | 0.21  | 0.01  | 0.03  | 4316 | Nov | 2024 |
| AP_AMB1 | Depth_RMS | 0.02  | 0.01  | 0.01 | 0.00  | 0.15  | 0.01  | 0.02  | 4464 | Dec | 2024 |

|         |           |      |      |      |      |      |      |      |      |     |      |
|---------|-----------|------|------|------|------|------|------|------|------|-----|------|
| AP_AMB1 | Depth_RMS | 0.03 | 0.02 | 0.02 | 0.00 | 0.23 | 0.01 | 0.03 | 4464 | Jan | 2025 |
| AP_AMB1 | Depth_RMS | 0.05 | 0.03 | 0.04 | 0.01 | 0.34 | 0.02 | 0.06 | 4028 | Feb | 2025 |
| AP_AMB1 | Depth_RMS | 0.03 | 0.02 | 0.03 | 0.00 | 0.21 | 0.01 | 0.04 | 4464 | Mar | 2025 |
| AP_AMB1 | Depth_RMS | 0.03 | 0.02 | 0.02 | 0.00 | 0.20 | 0.01 | 0.04 | 4319 | Apr | 2025 |
| AP_AMB1 | Depth_RMS | 0.04 | 0.03 | 0.03 | 0.00 | 0.25 | 0.02 | 0.05 | 4464 | May | 2025 |
| AP_AMB1 | Depth_RMS | 0.03 | 0.02 | 0.02 | 0.00 | 0.13 | 0.01 | 0.04 | 4317 | Jun | 2025 |
| AP_AMB4 | Depth_RMS | 0.04 | 0.03 | 0.02 | 0.01 | 0.31 | 0.02 | 0.04 | 4464 | Jul | 2024 |
| AP_AMB4 | Depth_RMS | 0.03 | 0.03 | 0.02 | 0.00 | 0.14 | 0.02 | 0.04 | 4462 | Aug | 2024 |
| AP_AMB4 | Depth_RMS | 0.04 | 0.03 | 0.03 | 0.00 | 0.23 | 0.02 | 0.05 | 4318 | Sep | 2024 |
| AP_AMB4 | Depth_RMS | 0.02 | 0.02 | 0.02 | 0.00 | 0.15 | 0.01 | 0.03 | 4464 | Oct | 2024 |
| AP_AMB4 | Depth_RMS | 0.02 | 0.02 | 0.02 | 0.00 | 0.15 | 0.01 | 0.03 | 4318 | Nov | 2024 |
| AP_AMB4 | Depth_RMS | 0.02 | 0.02 | 0.01 | 0.00 | 0.14 | 0.01 | 0.02 | 4464 | Dec | 2024 |
| AP_AMB4 | Depth_RMS | 0.03 | 0.02 | 0.02 | 0.00 | 0.22 | 0.01 | 0.03 | 4464 | Jan | 2025 |
| AP_AMB4 | Depth_RMS | 0.05 | 0.04 | 0.03 | 0.00 | 0.32 | 0.02 | 0.06 | 4030 | Feb | 2025 |
| AP_AMB4 | Depth_RMS | 0.04 | 0.03 | 0.02 | 0.01 | 0.18 | 0.02 | 0.04 | 4464 | Mar | 2025 |
| AP_AMB4 | Depth_RMS | 0.03 | 0.03 | 0.02 | 0.01 | 0.19 | 0.02 | 0.04 | 4318 | Apr | 2025 |
| AP_AMB4 | Depth_RMS | 0.04 | 0.04 | 0.02 | 0.01 | 0.21 | 0.03 | 0.05 | 4464 | May | 2025 |
| AP_AMB4 | Depth_RMS | 0.03 | 0.02 | 0.01 | 0.00 | 0.13 | 0.02 | 0.04 | 4318 | Jun | 2025 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.02 | 0.01 | 0.00 | 0.15 | 0.01 | 0.03 | 4464 | Jul | 2024 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.02 | 0.01 | 0.00 | 0.09 | 0.01 | 0.03 | 4462 | Aug | 2024 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.02 | 0.01 | 0.00 | 0.12 | 0.01 | 0.03 | 4319 | Sep | 2024 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.01 | 0.01 | 0.00 | 0.09 | 0.01 | 0.02 | 4464 | Oct | 2024 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.01 | 0.01 | 0.00 | 0.09 | 0.01 | 0.02 | 4319 | Nov | 2024 |
| AP_AMB5 | Depth_RMS | 0.01 | 0.01 | 0.01 | 0.00 | 0.08 | 0.01 | 0.02 | 4464 | Dec | 2024 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.01 | 0.01 | 0.00 | 0.17 | 0.01 | 0.02 | 4464 | Jan | 2025 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.02 | 0.01 | 0.00 | 0.11 | 0.01 | 0.02 | 4030 | Feb | 2025 |
| AP_AMB5 | Depth_RMS | 0.01 | 0.01 | 0.01 | 0.00 | 0.06 | 0.01 | 0.02 | 4464 | Mar | 2025 |
| AP_AMB5 | Depth_RMS | 0.01 | 0.01 | 0.01 | 0.00 | 0.07 | 0.01 | 0.02 | 4318 | Apr | 2025 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.02 | 0.01 | 0.01 | 0.07 | 0.01 | 0.02 | 4464 | May | 2025 |
| AP_AMB5 | Depth_RMS | 0.02 | 0.02 | 0.00 | 0.01 | 0.05 | 0.02 | 0.02 | 4317 | Jun | 2025 |

|         |           |       |      |       |       |         |      |      |      |     |      |
|---------|-----------|-------|------|-------|-------|---------|------|------|------|-----|------|
| AP_AMB6 | Depth_RMS | 0.02  | 0.02 | 0.01  | 0.00  | 0.11    | 0.01 | 0.02 | 4464 | Jul | 2024 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.07    | 0.01 | 0.02 | 4462 | Aug | 2024 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.09    | 0.01 | 0.01 | 4319 | Sep | 2024 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.06    | 0.01 | 0.02 | 4464 | Oct | 2024 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.00  | 0.00  | 0.04    | 0.01 | 0.01 | 4319 | Nov | 2024 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.00  | 0.00  | 0.04    | 0.01 | 0.01 | 4464 | Dec | 2024 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.06    | 0.01 | 0.01 | 4464 | Jan | 2025 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.08    | 0.01 | 0.02 | 4029 | Feb | 2025 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.00  | 0.00  | 0.04    | 0.01 | 0.01 | 4464 | Mar | 2025 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.05    | 0.01 | 0.01 | 4318 | Apr | 2025 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.09    | 0.01 | 0.01 | 4464 | May | 2025 |
| AP_AMB6 | Depth_RMS | 0.01  | 0.01 | 0.01  | 0.00  | 0.06    | 0.01 | 0.01 | 4317 | Jun | 2025 |
| AP_AMB1 | NTU       | 7.36  | 0.64 | 28.12 | 0.07  | 440.77  | 0.42 | 1.25 | 4462 | Jul | 2024 |
| AP_AMB1 | NTU       | 1.09  | 0.75 | 3.07  | 0.22  | 129.98  | 0.59 | 0.98 | 4461 | Aug | 2024 |
| AP_AMB1 | NTU       | 3.52  | 1.06 | 6.81  | 0.27  | 62.15   | 0.66 | 1.93 | 4319 | Sep | 2024 |
| AP_AMB1 | NTU       | 1.49  | 0.94 | 2.09  | 0.11  | 85.53   | 0.63 | 1.56 | 4424 | Oct | 2024 |
| AP_AMB1 | NTU       | 1.57  | 1.08 | 1.73  | 0.24  | 54.97   | 0.76 | 1.62 | 4316 | Nov | 2024 |
| AP_AMB1 | NTU       | 1.00  | 0.89 | 0.58  | 0.22  | 12.35   | 0.68 | 1.17 | 4458 | Dec | 2024 |
| AP_AMB1 | NTU       | 5.62  | 1.11 | 30.54 | 0.18  | 642.48  | 0.67 | 1.87 | 3934 | Jan | 2025 |
| AP_AMB1 | NTU       | 21.06 | 2.89 | 77.01 | 0.79  | 1054.52 | 1.81 | 6.97 | 2981 | Feb | 2025 |
| AP_AMB1 | NTU       | 3.04  | 1.32 | 6.57  | 0.39  | 77.77   | 0.87 | 2.30 | 4464 | Mar | 2025 |
| AP_AMB1 | NTU       | 2.97  | 0.98 | 8.73  | 0.22  | 199.32  | 0.65 | 1.78 | 4311 | Apr | 2025 |
| AP_AMB1 | NTU       | 3.65  | 0.53 | 9.80  | 0.07  | 127.72  | 0.33 | 1.78 | 4463 | May | 2025 |
| AP_AMB1 | NTU       | 0.46  | 0.36 | 1.31  | 0.07  | 68.72   | 0.23 | 0.60 | 4317 | Jun | 2025 |
| AP_AMB4 | NTU       | 1.88  | 0.74 | 4.05  | 0.13  | 44.99   | 0.45 | 1.16 | 4464 | Jul | 2024 |
| AP_AMB4 | NTU       | 0.73  | 0.62 | 0.43  | 0.17  | 14.03   | 0.46 | 0.92 | 4462 | Aug | 2024 |
| AP_AMB4 | NTU       | 1.76  | 0.88 | 3.11  | 0.10  | 61.98   | 0.66 | 1.64 | 4317 | Sep | 2024 |
| AP_AMB4 | NTU       | 2.34  | 0.69 | 20.17 | -0.15 | 472.03  | 0.36 | 1.17 | 4464 | Oct | 2024 |
| AP_AMB4 | NTU       | 1.74  | 0.89 | 13.28 | -0.08 | 471.69  | 0.41 | 1.54 | 4318 | Nov | 2024 |
| AP_AMB4 | NTU       | 1.40  | 0.89 | 7.74  | 0.25  | 388.63  | 0.62 | 1.20 | 4463 | Dec | 2024 |

|         |     |       |      |       |      |        |      |      |      |     |      |
|---------|-----|-------|------|-------|------|--------|------|------|------|-----|------|
| AP_AMB4 | NTU | 1.73  | 0.76 | 8.81  | 0.12 | 500.72 | 0.52 | 1.15 | 4461 | Jan | 2025 |
| AP_AMB4 | NTU | 11.26 | 3.65 | 28.17 | 1.01 | 364.69 | 2.39 | 7.16 | 4030 | Feb | 2025 |
| AP_AMB4 | NTU | 4.35  | 2.14 | 8.52  | 0.46 | 133.99 | 1.28 | 4.23 | 4463 | Mar | 2025 |
| AP_AMB4 | NTU | 4.66  | 2.12 | 9.76  | 0.08 | 195.03 | 1.40 | 4.08 | 4271 | Apr | 2025 |
| AP_AMB4 | NTU | 4.45  | 1.23 | 11.04 | 0.31 | 194.79 | 0.69 | 3.30 | 4464 | May | 2025 |
| AP_AMB4 | NTU | 1.16  | 0.87 | 1.38  | 0.12 | 20.35  | 0.55 | 1.34 | 4318 | Jun | 2025 |
| AP_AMB5 | NTU | 1.28  | 0.54 | 8.36  | 0.06 | 282.11 | 0.36 | 0.93 | 4464 | Jul | 2024 |
| AP_AMB5 | NTU | 0.86  | 0.31 | 6.50  | 0.06 | 226.98 | 0.21 | 0.61 | 4428 | Aug | 2024 |
| AP_AMB5 | NTU | 0.49  | 0.35 | 0.61  | 0.06 | 12.51  | 0.22 | 0.54 | 4288 | Sep | 2024 |
| AP_AMB5 | NTU | 0.74  | 0.31 | 7.41  | 0.06 | 259.20 | 0.22 | 0.42 | 4464 | Oct | 2024 |
| AP_AMB5 | NTU | 3.09  | 0.36 | 18.10 | 0.07 | 345.97 | 0.26 | 0.49 | 4319 | Nov | 2024 |
| AP_AMB5 | NTU | 0.37  | 0.23 | 1.92  | 0.02 | 108.17 | 0.15 | 0.33 | 4464 | Dec | 2024 |
| AP_AMB5 | NTU | 1.66  | 0.34 | 12.78 | 0.05 | 319.37 | 0.20 | 0.55 | 4458 | Jan | 2025 |
| AP_AMB5 | NTU | 0.72  | 0.65 | 0.43  | 0.13 | 9.75   | 0.49 | 0.84 | 4028 | Feb | 2025 |
| AP_AMB5 | NTU | 0.61  | 0.55 | 0.35  | 0.07 | 3.33   | 0.36 | 0.80 | 4463 | Mar | 2025 |
| AP_AMB5 | NTU | 0.87  | 0.76 | 0.48  | 0.14 | 8.43   | 0.55 | 1.12 | 4317 | Apr | 2025 |
| AP_AMB5 | NTU | 0.93  | 0.78 | 1.24  | 0.20 | 75.75  | 0.58 | 1.04 | 4455 | May | 2025 |
| AP_AMB5 | NTU | 0.53  | 0.48 | 1.41  | 0.12 | 90.87  | 0.39 | 0.59 | 4317 | Jun | 2025 |
| AP_AMB6 | NTU | 4.67  | 2.78 | 6.92  | 0.88 | 138.09 | 2.17 | 4.28 | 4458 | Jul | 2024 |
| AP_AMB6 | NTU | 4.21  | 3.28 | 4.18  | 1.29 | 77.80  | 2.60 | 4.24 | 4438 | Aug | 2024 |
| AP_AMB6 | NTU | 5.69  | 4.12 | 5.57  | 1.76 | 70.86  | 3.30 | 5.59 | 4035 | Sep | 2024 |
| AP_AMB6 | NTU | 5.09  | 3.70 | 5.34  | 0.33 | 50.30  | 2.63 | 5.17 | 4463 | Oct | 2024 |
| AP_AMB6 | NTU | 4.62  | 3.79 | 4.42  | 0.99 | 144.13 | 2.82 | 5.57 | 4319 | Nov | 2024 |
| AP_AMB6 | NTU | 7.06  | 5.63 | 5.32  | 0.71 | 91.50  | 3.74 | 8.99 | 4460 | Dec | 2024 |
| AP_AMB6 | NTU | 4.19  | 3.68 | 3.95  | 0.80 | 226.26 | 2.78 | 5.15 | 4350 | Jan | 2025 |
| AP_AMB6 | NTU | 7.70  | 7.11 | 4.11  | 1.84 | 54.98  | 4.59 | 9.86 | 3486 | Feb | 2025 |
| AP_AMB6 | NTU | 2.52  | 1.97 | 2.67  | 0.61 | 43.67  | 1.54 | 2.62 | 4460 | Mar | 2025 |
| AP_AMB6 | NTU | 3.85  | 2.98 | 3.11  | 0.44 | 40.50  | 2.12 | 4.53 | 4318 | Apr | 2025 |
| AP_AMB6 | NTU | 3.16  | 2.31 | 3.21  | 1.05 | 41.74  | 1.92 | 3.17 | 4464 | May | 2025 |
| AP_AMB6 | NTU | 2.29  | 2.13 | 1.01  | 0.69 | 29.32  | 1.62 | 2.78 | 4317 | Jun | 2025 |

|         |     |        |       |        |       |         |       |        |      |     |      |
|---------|-----|--------|-------|--------|-------|---------|-------|--------|------|-----|------|
| AP_AMB1 | PAR | NA     | NA    | NA     | NA    | NA      | NA    | NA     | NA   | Jul | 2024 |
| AP_AMB1 | PAR | 51.29  | 0.08  | 78.17  | 0.00  | 308.09  | 0.04  | 86.26  | 3661 | Aug | 2024 |
| AP_AMB1 | PAR | 41.10  | 0.10  | 72.71  | -0.05 | 346.55  | 0.05  | 52.97  | 4319 | Sep | 2024 |
| AP_AMB1 | PAR | 58.87  | 2.04  | 94.79  | -0.06 | 482.23  | -0.03 | 93.40  | 4464 | Oct | 2024 |
| AP_AMB1 | PAR | 46.04  | 4.15  | 70.00  | -0.05 | 325.51  | -0.01 | 71.98  | 3175 | Nov | 2024 |
| AP_AMB1 | PAR | 40.99  | 3.73  | 64.47  | 0.20  | 315.63  | 0.44  | 58.11  | 4464 | Dec | 2024 |
| AP_AMB1 | PAR | 33.26  | 1.08  | 56.25  | 0.17  | 309.72  | 0.21  | 45.79  | 3570 | Jan | 2025 |
| AP_AMB1 | PAR | 11.62  | 0.19  | 26.14  | -0.06 | 150.05  | 0.17  | 7.18   | 3969 | Feb | 2025 |
| AP_AMB1 | PAR | 24.35  | 0.10  | 45.39  | -0.08 | 278.82  | -0.04 | 32.07  | 4464 | Mar | 2025 |
| AP_AMB1 | PAR | 27.77  | 0.07  | 51.54  | -0.06 | 276.93  | 0.05  | 31.36  | 3860 | Apr | 2025 |
| AP_AMB1 | PAR | 32.90  | 0.08  | 59.96  | 0.03  | 309.63  | 0.05  | 38.79  | 4464 | May | 2025 |
| AP_AMB1 | PAR | 41.58  | 0.07  | 67.68  | 0.02  | 360.15  | 0.05  | 66.22  | 4317 | Jun | 2025 |
| AP_AMB4 | PAR | 42.09  | -0.01 | 66.11  | -0.04 | 244.86  | -0.03 | 68.58  | 585  | Jul | 2024 |
| AP_AMB4 | PAR | 66.98  | 0.01  | 101.67 | -0.10 | 401.40  | -0.06 | 112.66 | 3675 | Aug | 2024 |
| AP_AMB4 | PAR | 34.86  | 0.21  | 67.77  | -0.10 | 387.23  | -0.07 | 35.04  | 4318 | Sep | 2024 |
| AP_AMB4 | PAR | 34.09  | 1.39  | 57.41  | 0.00  | 393.63  | 0.04  | 50.06  | 4464 | Oct | 2024 |
| AP_AMB4 | PAR | 26.61  | 2.17  | 46.10  | 0.00  | 274.56  | 0.06  | 30.95  | 4314 | Nov | 2024 |
| AP_AMB4 | PAR | 50.07  | 4.62  | 76.88  | 0.01  | 431.28  | 0.05  | 77.28  | 4464 | Dec | 2024 |
| AP_AMB4 | PAR | 55.96  | 1.82  | 94.26  | 0.02  | 510.90  | 0.06  | 77.90  | 4462 | Jan | 2025 |
| AP_AMB4 | PAR | 9.08   | 0.06  | 20.61  | -0.02 | 143.46  | 0.04  | 6.46   | 4030 | Feb | 2025 |
| AP_AMB4 | PAR | 21.84  | 0.07  | 42.25  | -0.03 | 373.62  | 0.01  | 23.98  | 4464 | Mar | 2025 |
| AP_AMB4 | PAR | 24.39  | 0.17  | 43.63  | -0.02 | 313.90  | 0.11  | 30.60  | 4318 | Apr | 2025 |
| AP_AMB4 | PAR | 27.09  | 0.10  | 50.64  | 0.03  | 308.87  | 0.07  | 30.03  | 4464 | May | 2025 |
| AP_AMB4 | PAR | 36.15  | 1.91  | 57.49  | 0.03  | 338.56  | 1.90  | 52.84  | 4318 | Jun | 2025 |
| AP_AMB5 | PAR | 82.34  | 0.03  | 126.62 | -0.03 | 575.32  | 0.01  | 134.48 | 4464 | Jul | 2024 |
| AP_AMB5 | PAR | 129.45 | 0.17  | 192.28 | -0.02 | 722.03  | 0.08  | 236.12 | 4461 | Aug | 2024 |
| AP_AMB5 | PAR | 135.14 | 2.16  | 199.09 | 0.06  | 910.53  | 0.10  | 227.70 | 4318 | Sep | 2024 |
| AP_AMB5 | PAR | 207.68 | 13.89 | 279.24 | 0.11  | 1020.11 | 0.17  | 415.59 | 4464 | Oct | 2024 |
| AP_AMB5 | PAR | 194.06 | 26.83 | 258.41 | 0.17  | 985.49  | 0.20  | 361.53 | 2964 | Nov | 2024 |
| AP_AMB5 | PAR | NA     | NA    | NA     | NA    | NA      | NA    | NA     | NA   | Dec | 2024 |

|         |      |        |       |        |       |        |       |        |      |     |      |
|---------|------|--------|-------|--------|-------|--------|-------|--------|------|-----|------|
| AP_AMB5 | PAR  | 114.04 | 7.45  | 176.31 | 0.05  | 769.37 | 0.08  | 172.48 | 2915 | Jan | 2025 |
| AP_AMB5 | PAR  | 57.77  | 3.77  | 97.35  | 0.05  | 539.05 | 0.09  | 78.41  | 4030 | Feb | 2025 |
| AP_AMB5 | PAR  | 50.35  | 0.91  | 88.69  | 0.09  | 462.00 | 0.16  | 60.08  | 4464 | Mar | 2025 |
| AP_AMB5 | PAR  | 15.47  | 0.12  | 27.56  | -0.03 | 171.80 | 0.01  | 19.57  | 4102 | Apr | 2025 |
| AP_AMB5 | PAR  | 12.57  | 0.00  | 22.25  | -0.08 | 140.13 | -0.03 | 16.59  | 4464 | May | 2025 |
| AP_AMB5 | PAR  | 15.22  | -0.01 | 26.44  | -0.06 | 148.15 | -0.03 | 21.29  | 4314 | Jun | 2025 |
| AP_AMB6 | PAR  | 37.74  | 37.74 | NA     | 37.74 | 37.74  | 37.74 | 37.74  | 1    | Jul | 2024 |
| AP_AMB6 | PAR  | 38.96  | 0.35  | 68.78  | 0.27  | 423.91 | 0.31  | 54.87  | 3653 | Aug | 2024 |
| AP_AMB6 | PAR  | 19.34  | 0.35  | 35.85  | 0.11  | 200.66 | 0.14  | 22.55  | 2093 | Sep | 2024 |
| AP_AMB6 | PAR  | NA     | NA    | NA     | NA    | NA     | NA    | NA     | NA   | Oct | 2024 |
| AP_AMB6 | PAR  | NA     | NA    | NA     | NA    | NA     | NA    | NA     | NA   | Nov | 2024 |
| AP_AMB6 | PAR  | 30.63  | 0.91  | 59.00  | -0.03 | 356.55 | 0.00  | 32.59  | 2058 | Dec | 2024 |
| AP_AMB6 | PAR  | 26.86  | 1.64  | 46.51  | -0.04 | 314.43 | 0.00  | 35.52  | 4464 | Jan | 2025 |
| AP_AMB6 | PAR  | 14.47  | 0.08  | 34.53  | -0.03 | 318.43 | 0.01  | 8.25   | 4029 | Feb | 2025 |
| AP_AMB6 | PAR  | 34.46  | 0.67  | 64.79  | 0.01  | 422.76 | 0.05  | 43.20  | 4464 | Mar | 2025 |
| AP_AMB6 | PAR  | 24.21  | 0.12  | 41.31  | 0.03  | 246.58 | 0.07  | 33.32  | 4318 | Apr | 2025 |
| AP_AMB6 | PAR  | 20.90  | 0.11  | 36.29  | 0.05  | 207.93 | 0.09  | 27.43  | 4464 | May | 2025 |
| AP_AMB6 | PAR  | 31.67  | 0.09  | 52.31  | 0.02  | 286.03 | 0.06  | 46.22  | 4317 | Jun | 2025 |
| AP_AMB1 | Temp | 21.81  | 21.98 | 0.86   | 19.97 | 23.55  | 21.01 | 22.41  | 4464 | Jul | 2024 |
| AP_AMB1 | Temp | 22.07  | 22.07 | 0.99   | 20.32 | 24.04  | 21.27 | 22.95  | 4461 | Aug | 2024 |
| AP_AMB1 | Temp | 23.79  | 23.70 | 0.51   | 22.89 | 25.50  | 23.44 | 24.05  | 4319 | Sep | 2024 |
| AP_AMB1 | Temp | 25.96  | 25.80 | 0.81   | 24.39 | 27.71  | 25.38 | 26.80  | 4464 | Oct | 2024 |
| AP_AMB1 | Temp | 27.84  | 27.88 | 0.48   | 26.88 | 28.87  | 27.43 | 28.19  | 4316 | Nov | 2024 |
| AP_AMB1 | Temp | 28.90  | 28.84 | 0.48   | 27.92 | 29.88  | 28.52 | 29.30  | 4464 | Dec | 2024 |
| AP_AMB1 | Temp | 29.59  | 29.58 | 0.56   | 28.55 | 30.88  | 29.13 | 30.09  | 4464 | Jan | 2025 |
| AP_AMB1 | Temp | 28.29  | 28.23 | 0.49   | 27.44 | 29.57  | 27.89 | 28.57  | 4028 | Feb | 2025 |
| AP_AMB1 | Temp | 28.15  | 28.14 | 0.54   | 27.25 | 29.45  | 27.69 | 28.46  | 4464 | Mar | 2025 |
| AP_AMB1 | Temp | 27.20  | 26.80 | 0.86   | 26.04 | 29.16  | 26.45 | 28.09  | 4319 | Apr | 2025 |
| AP_AMB1 | Temp | 24.78  | 24.64 | 0.59   | 23.85 | 26.64  | 24.34 | 25.11  | 4464 | May | 2025 |
| AP_AMB1 | Temp | 22.54  | 22.39 | 0.67   | 21.45 | 24.01  | 21.99 | 23.09  | 4317 | Jun | 2025 |

|         |      |       |       |      |       |       |       |       |      |     |      |
|---------|------|-------|-------|------|-------|-------|-------|-------|------|-----|------|
| AP_AMB4 | Temp | 22.09 | 22.23 | 0.79 | 20.35 | 23.55 | 21.42 | 22.68 | 4464 | Jul | 2024 |
| AP_AMB4 | Temp | 22.25 | 22.15 | 1.08 | 20.29 | 24.43 | 21.46 | 23.31 | 4462 | Aug | 2024 |
| AP_AMB4 | Temp | 24.00 | 23.88 | 0.65 | 22.75 | 25.88 | 23.59 | 24.29 | 4318 | Sep | 2024 |
| AP_AMB4 | Temp | 26.36 | 26.40 | 0.82 | 24.63 | 27.93 | 25.76 | 27.09 | 4464 | Oct | 2024 |
| AP_AMB4 | Temp | 28.03 | 27.94 | 0.52 | 27.05 | 29.25 | 27.60 | 28.52 | 4318 | Nov | 2024 |
| AP_AMB4 | Temp | 29.10 | 29.09 | 0.41 | 28.36 | 30.12 | 28.80 | 29.44 | 4464 | Dec | 2024 |
| AP_AMB4 | Temp | 29.59 | 29.51 | 0.55 | 28.32 | 30.95 | 29.20 | 30.07 | 4464 | Jan | 2025 |
| AP_AMB4 | Temp | 28.23 | 28.04 | 0.53 | 27.49 | 29.61 | 27.84 | 28.53 | 4030 | Feb | 2025 |
| AP_AMB4 | Temp | 28.17 | 28.23 | 0.60 | 27.05 | 29.66 | 27.64 | 28.66 | 4464 | Mar | 2025 |
| AP_AMB4 | Temp | 27.53 | 27.24 | 0.73 | 26.47 | 29.37 | 26.89 | 28.11 | 4318 | Apr | 2025 |
| AP_AMB4 | Temp | 25.14 | 25.04 | 0.57 | 24.00 | 27.05 | 24.76 | 25.39 | 4464 | May | 2025 |
| AP_AMB4 | Temp | 22.76 | 22.69 | 0.82 | 21.42 | 24.36 | 22.03 | 23.41 | 4318 | Jun | 2025 |
| AP_AMB5 | Temp | 22.95 | 23.04 | 0.58 | 21.02 | 24.22 | 22.67 | 23.32 | 4464 | Jul | 2024 |
| AP_AMB5 | Temp | 22.50 | 22.21 | 0.64 | 21.09 | 24.16 | 21.98 | 22.97 | 4462 | Aug | 2024 |
| AP_AMB5 | Temp | 23.79 | 23.73 | 0.37 | 22.59 | 25.76 | 23.59 | 23.91 | 4319 | Sep | 2024 |
| AP_AMB5 | Temp | 25.36 | 25.19 | 0.71 | 23.62 | 27.00 | 24.86 | 26.06 | 4464 | Oct | 2024 |
| AP_AMB5 | Temp | 27.10 | 27.13 | 0.28 | 26.39 | 27.92 | 26.91 | 27.28 | 4319 | Nov | 2024 |
| AP_AMB5 | Temp | 28.34 | 28.44 | 0.52 | 27.35 | 29.57 | 27.78 | 28.70 | 4464 | Dec | 2024 |
| AP_AMB5 | Temp | 29.27 | 29.20 | 0.51 | 27.89 | 30.50 | 28.83 | 29.73 | 4464 | Jan | 2025 |
| AP_AMB5 | Temp | 28.49 | 28.48 | 0.32 | 27.42 | 29.43 | 28.29 | 28.73 | 4030 | Feb | 2025 |
| AP_AMB5 | Temp | 28.32 | 28.18 | 0.40 | 27.34 | 29.84 | 28.02 | 28.46 | 4464 | Mar | 2025 |
| AP_AMB5 | Temp | 27.60 | 27.37 | 0.38 | 26.74 | 28.29 | 27.26 | 28.04 | 4318 | Apr | 2025 |
| AP_AMB5 | Temp | 26.00 | 25.82 | 0.48 | 24.83 | 27.31 | 25.68 | 26.33 | 4464 | May | 2025 |
| AP_AMB5 | Temp | 24.40 | 24.38 | 0.72 | 22.68 | 25.48 | 23.87 | 25.03 | 4317 | Jun | 2025 |
| AP_AMB6 | Temp | 21.42 | 21.45 | 1.05 | 18.61 | 23.51 | 20.61 | 22.16 | 4464 | Jul | 2024 |
| AP_AMB6 | Temp | 21.98 | 22.00 | 1.46 | 18.70 | 24.70 | 20.93 | 23.22 | 4462 | Aug | 2024 |
| AP_AMB6 | Temp | 23.94 | 24.04 | 0.72 | 21.65 | 26.13 | 23.47 | 24.35 | 4319 | Sep | 2024 |
| AP_AMB6 | Temp | 26.45 | 26.47 | 0.98 | 24.14 | 28.76 | 25.69 | 27.33 | 4464 | Oct | 2024 |
| AP_AMB6 | Temp | 28.14 | 28.20 | 0.53 | 26.17 | 29.47 | 27.70 | 28.57 | 4319 | Nov | 2024 |
| AP_AMB6 | Temp | 29.06 | 29.08 | 0.47 | 27.78 | 30.10 | 28.77 | 29.40 | 4464 | Dec | 2024 |

|         |      |       |       |      |       |       |       |       |      |     |      |
|---------|------|-------|-------|------|-------|-------|-------|-------|------|-----|------|
| AP_AMB6 | Temp | 29.73 | 29.59 | 0.92 | 27.56 | 31.70 | 29.11 | 30.59 | 4464 | Jan | 2025 |
| AP_AMB6 | Temp | 28.16 | 27.96 | 0.97 | 26.38 | 30.70 | 27.48 | 28.40 | 4029 | Feb | 2025 |
| AP_AMB6 | Temp | 28.17 | 27.99 | 0.89 | 26.17 | 29.95 | 27.51 | 28.98 | 4464 | Mar | 2025 |
| AP_AMB6 | Temp | 27.09 | 26.71 | 0.93 | 25.72 | 29.26 | 26.37 | 27.97 | 4318 | Apr | 2025 |
| AP_AMB6 | Temp | 24.34 | 24.30 | 0.75 | 22.81 | 26.70 | 23.92 | 24.73 | 4464 | May | 2025 |
| AP_AMB6 | Temp | 21.88 | 21.87 | 0.95 | 19.90 | 23.78 | 20.98 | 22.59 | 4317 | Jun | 2025 |

## APPENDIX C      QUALITY CONTROL

To support the ongoing use of high-resolution in-situ loggers within the NQBP ambient monitoring program, a standardised and science-based quality control (QC) framework has been applied consistently across recent reporting years. This QC process is derived from internationally recognised Real-Time Oceanographic Data Quality Control (QARTOD) procedures (NOAA, 2020), which are widely adopted by CSIRO, IMOS and AIMS. The same framework has now been embedded in the program for several years, providing a robust and repeatable approach to ensuring confidence in long-term logger datasets.

Logger data undergo both automated and manual QC steps. The automated workflow applies 12 objective tests (Table A6), which evaluate sensor performance, environmental plausibility, stability, and instrument integrity. Each result is assigned a QC flag: ‘good data’ (green), ‘probably good data’ (blue), ‘probably bad data’ (yellow), or ‘bad data’ (red). These flags allow users to make transparent, reproducible decisions about data suitability for different applications.

Table A- 1      QC tests applied to logger data

|                                  |                                     |
|----------------------------------|-------------------------------------|
| QC rule 1: Syntax test           | QC rule 7: Spike test               |
| QC rule 2: Impossible date test  | QC rule 8: Rate of change test      |
| QC rule 3: In/out-water test     | QC rule 9: Stationary test          |
| QC rule 4: Global range test     | QC rule 10: Standard deviation test |
| QC rule 5: Regional range tests  | QC rule 11: Burst count test        |
| QC rule 6: Impossible depth test | QC rule 12: Orientation test        |

Each logger includes four core sensors—temperature, depth, tilt, and either turbidity (NTU) or photosynthetically active radiation (PAR). For every 10-minute interval, the ‘worst’ QC flag from tests 1–12 is retained for that sensor, providing a conservative assessment of data reliability.

Figures A 1 – A 4 presents the QC-flagged datasets for the current reporting period, while Figure A-5 summarises the proportion of records in each QC category for every parameter.

For most analyses, ‘good’ and ‘probably good’ data are considered fit-for-purpose, while ‘probably bad’ data may be usable with caution depending on context. ‘Bad’ data should be excluded. Data with specific QC categories can be easily filtered or masked in Excel, R, Python, or other data management platforms. Figure A-3 shows the

A full technical description of the QC methodology, test definitions and implementation is provided in the TropWATER technical report (Iles et al., 2023), available on the TropWATER website.

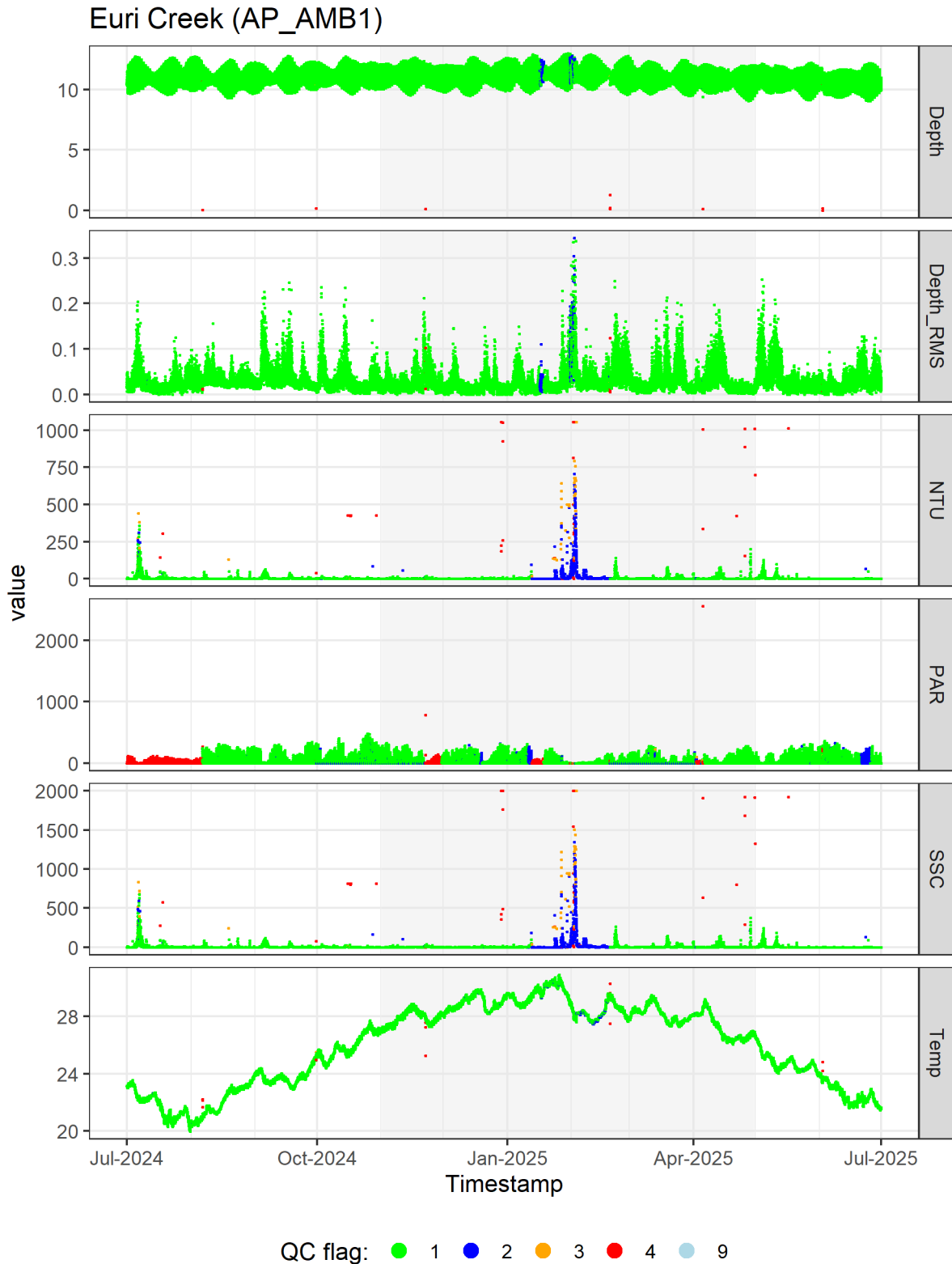


Figure A- 1 Raw data collected at Euri Creek with IMO loggers. Passed through automated and manual quality control (QC) steps. Symbol colour indicates QC flag designation where: 1 (green) = Good data, 2 (blue) = Probably good data, 3 (orange) = Suspect data, 4 (red) = Bad data, 9 (light blue) = Missing data.

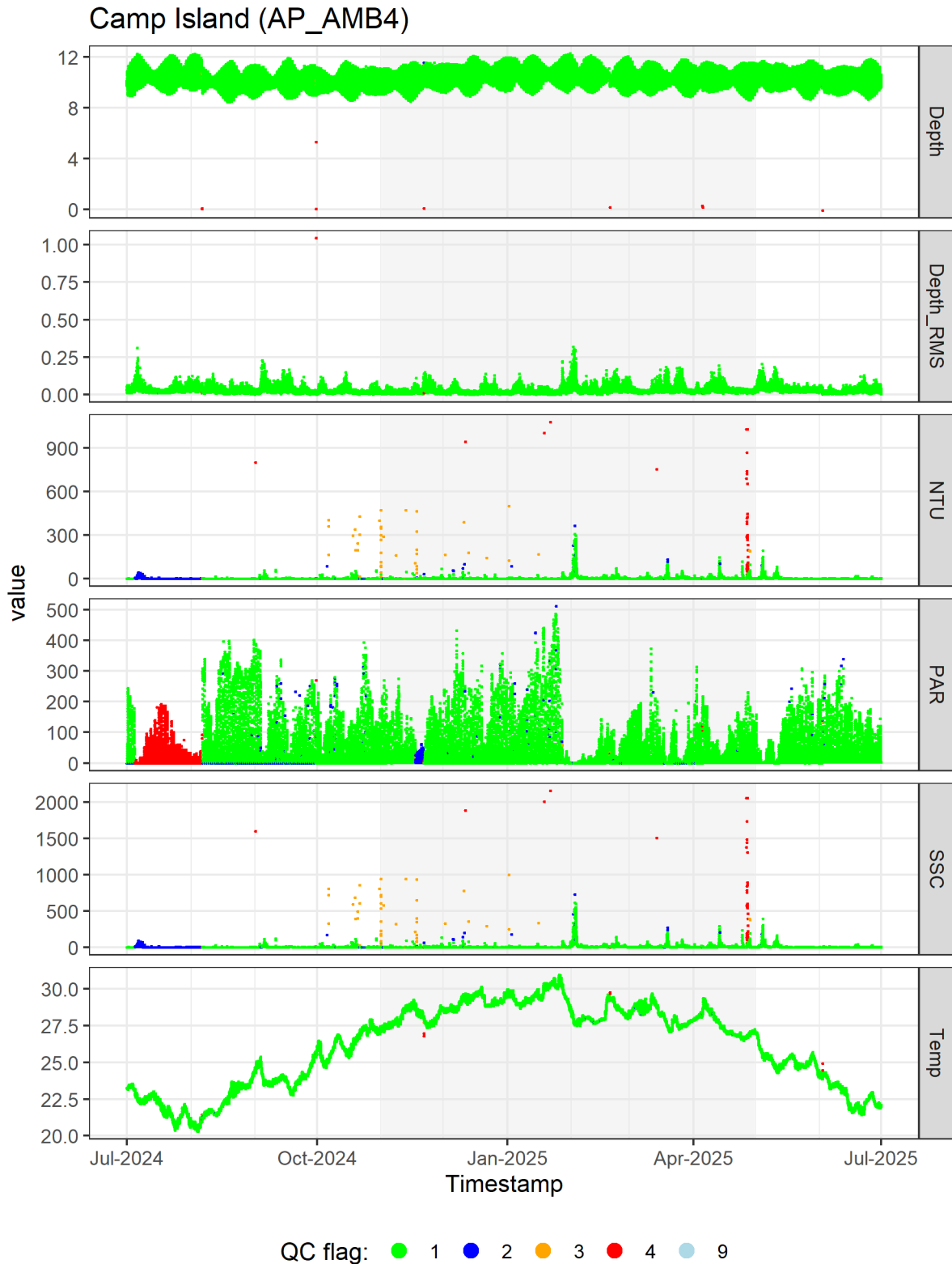


Figure A- 2 Raw data collected at Camp Island with IMO loggers. Passed through automated and manual quality control (QC) steps. Symbol colour indicates QC flag designation where: 1 (green) = Good data, 2 (blue) = Probably good data, 3 (orange) = Suspect data, 4 (red) = Bad data, 9 (light blue) = Missing data.

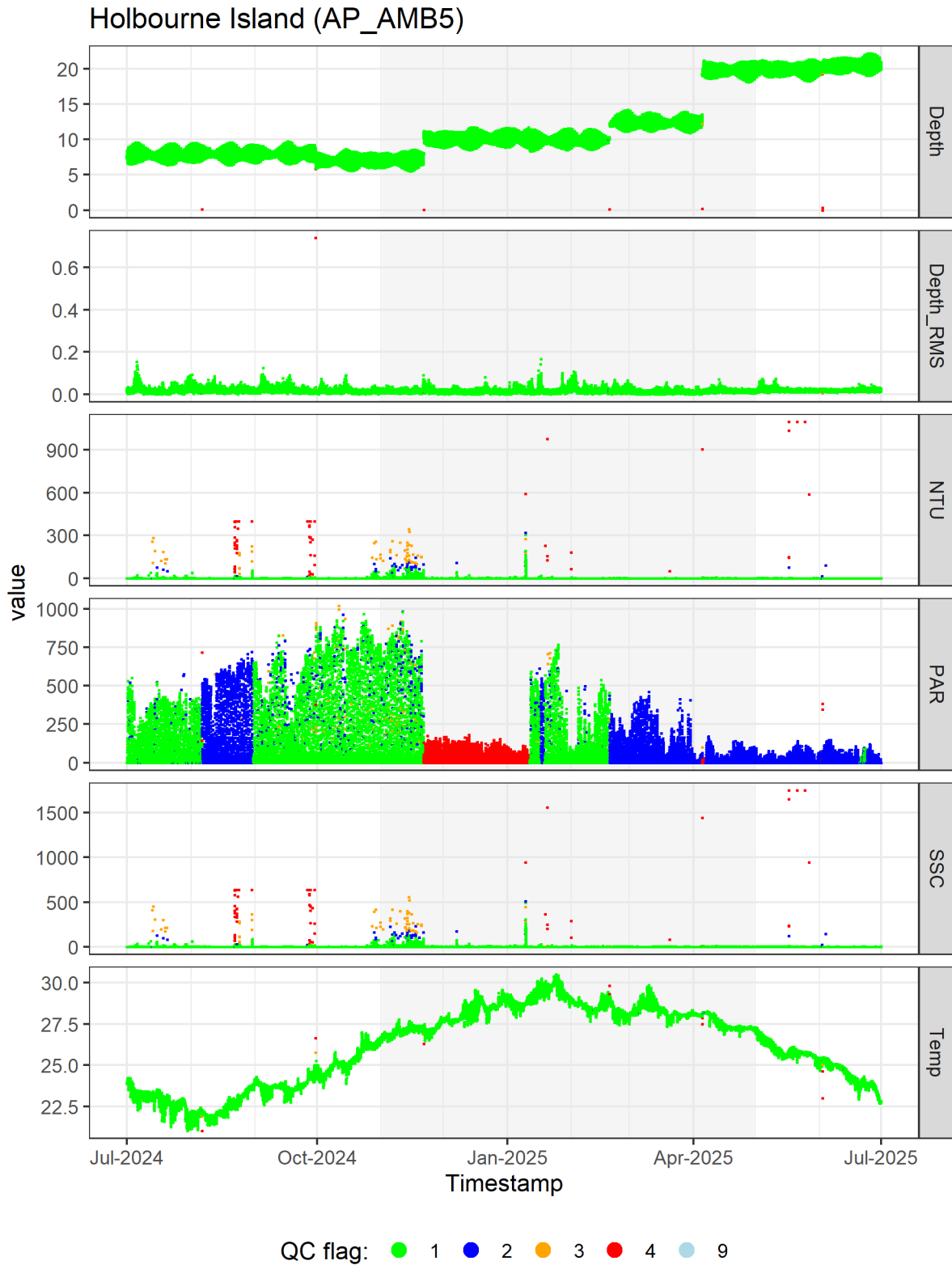


Figure A- 3 Raw data collected at Holbourne Island with IMO loggers. Passed through automated and manual quality control (QC) steps. Symbol colour indicates QC flag designation where: 1 (green) = Good data, 2 (blue) = Probably good data, 3 (orange) = Suspect data, 4 (red) = Bad data, 9 (light blue) = Missing data.

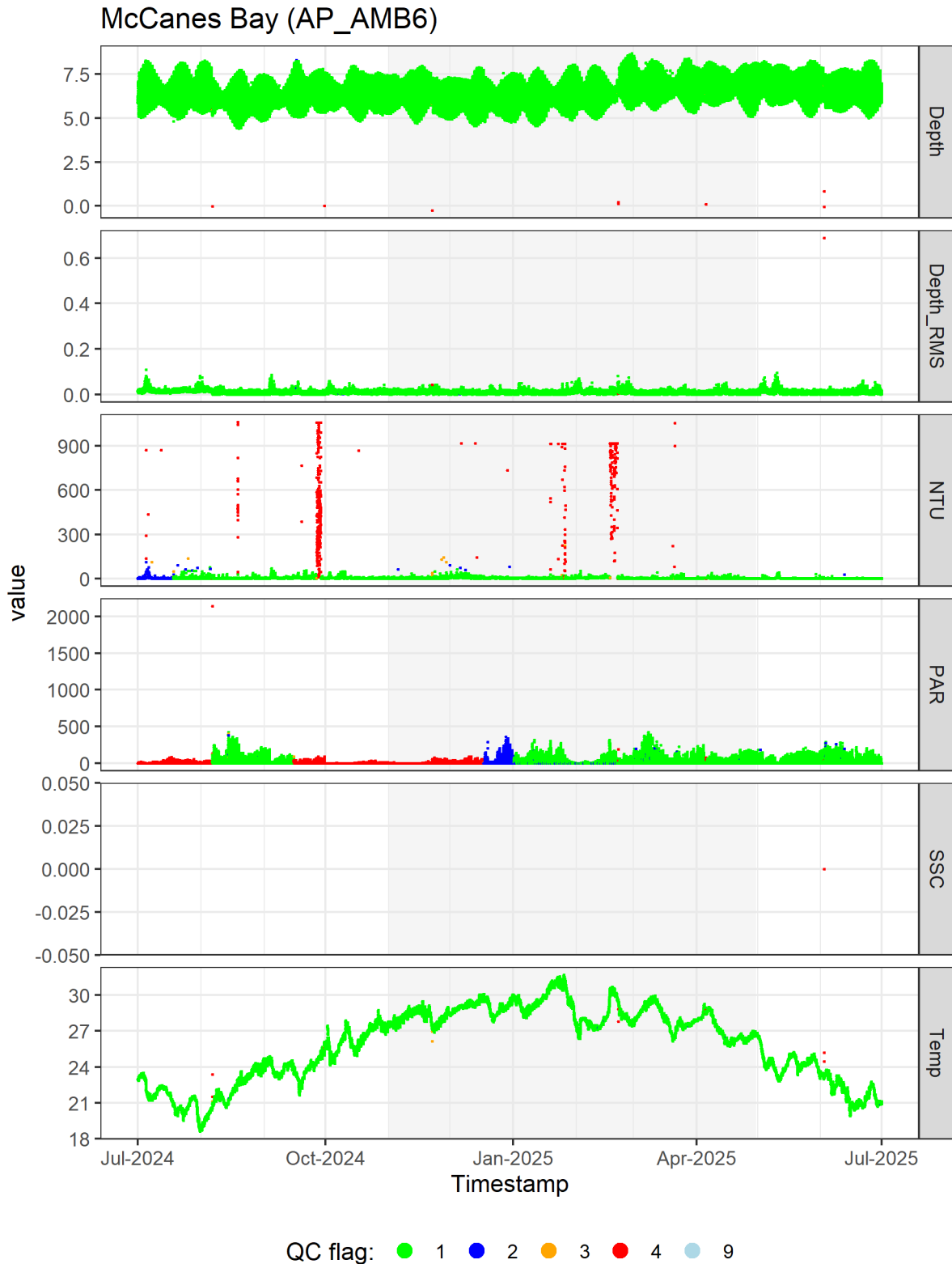


Figure A- 4 Raw data collected at McCanes Bay with IMO loggers. Passed through automated and manual quality control (QC) steps. Symbol colour indicates QC flag designation where: 1 (green) = Good data, 2 (blue) = Probably good data, 3 (orange) = Suspect data, 4 (red) = Bad data, 9 (light blue) = Missing data.

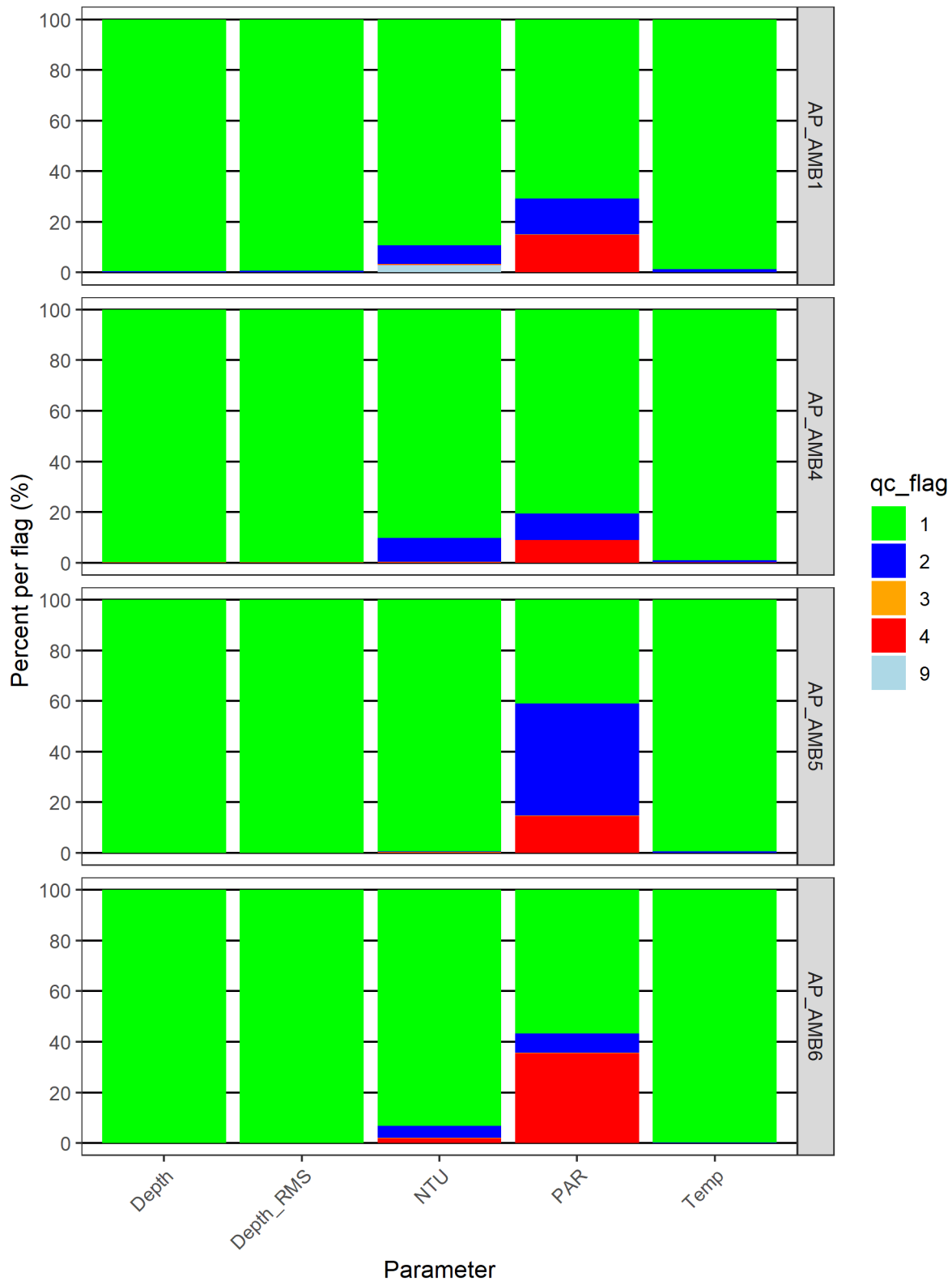


Figure A- 5 Logger data recovery stats for the Abbot Point monitoring sites

## APPENDIX D      GAMM MODEL OUTPUTS

(to be added to final pdf version)