Water Quality Monitoring Results for Port Arthur Area by Environment Protection Authority (EPA) October 2021 to May 2022

July 2022

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Water Quality Monitoring Program

Introduction

The Water Section of the Environment Protection Authority (EPA) conducted water quality monitoring in the Port Arthur area from October 2021 to May 2022 to increase the understanding of water quality across the area and in particular within Long Bay.

Aims

- To provide water quality information to increase the understanding of water quality in the Port Arthur area and in particular Long Bay.
- To collect data on key indicators for comparison against Default Guideline Values (DGVs) for aquatic ecosystems developed for the Port Arthur area.
- To investigate if any departures from background conditions (DGVs) are attributable to anthropogenic or natural sources and if possible, show attribution.
- To provide seasonal snapshots for the extent of epiphytic growth on seagrass and reef habitat.

Description

The Port Arthur area is a large embayment on the Tasman Peninsula which opens directly to the Tasman Sea at its southern extent.

Default Guideline Values (DGVs)

Default Guideline Values (DGVs) for aquatic ecosystems have been developed for the Port Arthur area. The DGVs have been derived from site specific information in accordance with the National Water Quality Management Strategy (NWQMS).

The DGVs are based on data collected from August 2013 to July 2017 from four locations (PA1, PA2, PA3 and PA4). The available data has allowed for the derivation of Annual and seasonal DGVs of surface, 5 metre depth, integrated depth, and bottom waters for key indicators. For dissolved oxygen, temperature, and pH the 20th percentile represents the lower DGV and the 80th percentile the upper DGV, whilst for all other indicators the 80th percentile of the aforementioned data represents the DGV. When a value reported by the laboratory is below the Limit of Reporting (LoR), the reported value has been halved prior to inclusion in the dataset for DGV derivation. Information on all indicators (particularly nutrients) is not available at all depths due to being beyond the scope of the initial program requirements.

The Port Arthur area DGVs provide a level of refinement over the interim Default guideline values for Coastal and Marine waters based on the IMCRA bioregion.

Monitoring sites

Water quality data have been collected from nine (9) sites across the Port Arthur area, which include five (5) sites also monitored on a monthly basis by Tassal as required under the environmental licence conditions for lease MF55 (Long Bay Port Arthur). The proximity of site PA1 to the Long Bay lease should be considered when interpreting monitoring results. Due to the site being adjacent to the lease and within 60 metres of stocked cages the location is unlikely to represent ambient conditions. The site is however valuable in the interpretation of 'near field' effects. The Long Bay lease was stocked from September 2021 to the end of March 2022. Therefore, the April and May surveys were undertaken whilst the finfish lease was unstocked (fallow).

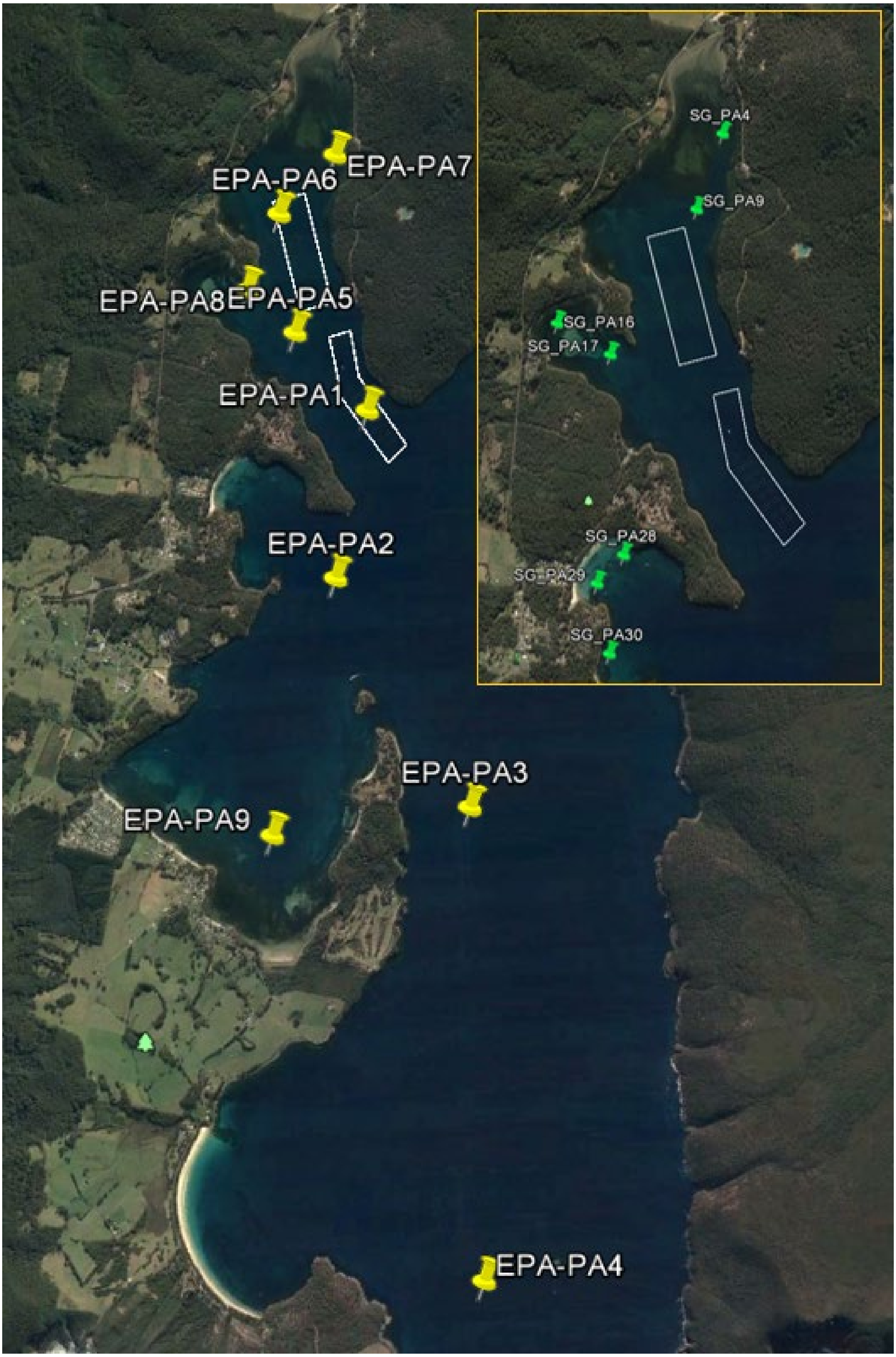
Epiphytic growth data have been collected on three (3) occasions from seven (7) sites across the Port Arthur area during the study period. The data represents a snapshot for November 2021, March 2022 and April 2022 at these locations, which was used to determine if there was a discernible seasonal pattern.

An overview of the monitoring locations is provided in Table 1 and distribution across the Port Arthur area in Map 1.

Table 1: Port Arthur monitoring locations

Site ID	Location	Easting	Northing	Monitoring	Distance from Lease boundary	Comment
EPA-PA1	North of Garden Point	570485	5224084	Nutrient, phytoplankton, physico-chem.	~ 20 m (near scale)	Co-located with BEMP-PA1
EPA-PA2	East of Fryingpan Point	570287	5222948	Nutrient, phytoplankton, physico-chem.	~ 1.0 km (intermediate)	Co-located with BEMP-PA2
EPA-PA3	South East of Suicide Point	571217	5221408	Nutrient, phytoplankton, physico-chem.	~ 2.5 km (intermediate)	Co-located with BEMP-PA3
EPA-PA4	East of Dog Bark	571352	5218242	Nutrient, phytoplankton, physico-chem.	~ 5.6 km (Far field)	Co-located with BEMP-PA4
EPA-PA5	Long Bay 300m off Garden Point Boat Ramp	569987	5224610	Nutrient, phytoplankton, physico-chem.	~ 300 m (near scale)	Co-located with BEMP-PA5
EPA-PA6	Long Bay west of shellfish lease	569865	5225420	Nutrient, phytoplankton, physico-chem.	~ 800 m (intermediate)	
EPA-PA7	Long Bay north east of shellfish lease	570240	5225825	Nutrient, phytoplankton, physico-chem.	~ 1.1 km (intermediate)	
EPA-PA8	Stingaree Bay	569655	5224900	Nutrient, phytoplankton, physico-chem.	~ 600 m (intermediate)	
EPA-PA9	Carnarvon Bay	569885	5221210	Nutrient, phytoplankton, physico-chem.	~ 2.8 km (intermediate)	
SG_PA17	Stingaree Bay	569640	5224888	Epiphyte cover		Co-located with IMAS_SG_PA17
SG_PA16	Stingaree Bay	569328	5225068	Epiphyte cover		Co-located with IMAS_SG_PA16
SG_PA9	Long Bay	570128	5225741	Epiphyte cover		Co-located with IMAS_SG_PA9
SG_PA4	Long Bay	570274	5226192	Epiphyte cover		Co-located with IMAS_SG_PA4
SG_PA28	Stewarts Bay	569739	5223742	Epiphyte cover		Co-located with IMAS_SG_PA28
SG_PA29	Stewarts Bay	569591	5223580	Epiphyte cover		Co-located with IMAS_SG_PA29
SG_PA30	Stewarts Bay	569669	5223188	Epiphyte cover		Co-located with IMAS_SG_PA30

Map 1: Port Arthur monitoring locations



Key Parameters/Indicators of Interest

The following table outlines the key water quality indicators of interest and the type of measurement from which the reported value is derived. The DGVs of surface and bottom waters are provided for the full year and summer period. For those indicators with a DGV range, the most relevant value from an environmental perspective is discussed. For temperature the upper value is reported against and for dissolved oxygen and pH the lower limit.

Table 2: Indicators of interest, measurement type and associated DGVs

Indicator	Measurement type	Summer surface	Annual surface	Summer Bottom	Annual Bottom
Nitrogen (Total) (mg/L)	Laboratory analysis	0.30	0.32	0.30	0.32
Nitrogen, Total Kjeldahl (mg/L)	Laboratory analysis	0.29	0.31	0.29	0.30
TAN (NH_3 and NH_4^+) (mg/L)	Laboratory analysis	0.008	0.007	0.013	0.010
Nitrate (mg/L)	Laboratory analysis	0.001	0.025	0.009	0.027
Nitrite (mg/L)	Laboratory analysis	Nil	Nil	Nil	Nil
Nitrate and Nitrite (mg/L)	Laboratory analysis	0.001	0.024	0.005	0.033
Phosphorus (Total) (mg/L)	Laboratory analysis)	0.03	0.03	0.04	0.04
Dissolved Reactive Phosphorus (mg/L)	Laboratory analysis	0.006	0.008	0.008	0.009
Silica, Molybdate Reactive (mg/L)	Laboratory analysis	0.1	0.2	0.1	0.2
NPOC (dissolved) (mg/L)	Laboratory analysis	Nil	Nil	Nil	Nil
Chlorophyll a (µg/L)	Laboratory analysis	1.0	1.5	Nil	Nil
Temperature (°C)	Field Instrument	14.8 - 17.6	12.3 - 16.9	14.0 - 16.4	12.0 -16.0
Salinity (PPT)	Field Instrument	35.4	35.6	35.4	35.6
Dissolved Oxygen (mg/L)	Field Instrument	8.0 – 8.8	7.9 – 8.8	8.0 – 8.7	7.7 – 8.7
Dissolved Oxygen (% saturation)	Field Instrument	103.4–108.0	98.6 – 106.5	97.6 – 105.9	96.1 – 101.4
pH	Field Instrument	8.1 – 8.3	8.1 – 8.2	8.2 - 8.3	8.1 - 8.2
SpCond (µS/cm)	Field Instrument	Nil	Nil	Nil	Nil
Turbidity (NTU)	Field Instrument	Nil	Nil	Nil	Nil
Epiphyte Score	Drop Camera	Nil	Nil	Nil	Nil

Integrated samples are also taken for the identification and enumeration of phytoplankton by AST.

Epiphytic growth

The EPA committed to undertake strategic monitoring of the volume and extent of epiphytic algae growth on shallow reef and seagrass habitats across the south east of Tasmania. The monitoring aims to improve the understanding of fluxes in epiphytic algal growth in response to natural coastal processes as well as anthropogenic interactions, in particular salmon farming activities. A key outcome of the monitoring is the provision of snapshots of broadscale epiphytic algal growth dynamics across the south east of Tasmania. The following table outlines the qualitative categories for assessing epiphytic growth on shallow reef and seagrass habitats.

Table 3: Description of scoring system used to assess epiphytic growth

Score	Description
0	No epiphytic growth present.
1	Very low epiphytic growth, virtually clean plant.
2	Low, minimal epiphytic growth.
3	Medium, obvious epiphytic growth.
4	High, most of plant covered.
5	Very high, plant completely covered.

For the Port Arthur area epiphytic algal growth surveys were undertaken on three (3) occasions at seven (7) locations as outlined in Table 1. The data was collected on 17 November 2021, 15 March 2022 and 20 April 2022 and as such the surveys represent snapshots for spring 2021, summer 2022 and autumn 2022 at these locations, respectively.

Images were captured using a GoPro camera mounted on a quadrat and frame (drop camera). The quadrat being 0.5mx0.5m in size and fully captured within the field of view of the camera. The quadrat is further divided into 0.1m^2 sections. At each location the camera was set at the surface to record images at 10 second intervals. Location information was recorded via the GoPro camera which is GPS enabled. Additional GPS information was recorded on the vessel via Garmin GPS.

For each location, 5 or 6 camera drops were conducted. For each camera drop a suitable image was selected for analysis. The selected images were scored against the qualitative categories outlined in Table 3. A total score for the location was derived based on the average value for the images assessed at the location.

Water Column Nutrients

Nutrients occur in many forms and an understanding of these forms is useful for interpreting the information within this report.

Nitrogen

Total Nitrogen is the sum of all nitrogen forms. Nitrogen exists as inorganic and organic species and also in dissolved and particulate forms. Inorganic nitrogen is typically found as the oxidized species of nitrate (NO_3) and nitrite (NO_2), which combined are referred to as NOx, and as the reduced species of Ammonium (NH_4^+) and Ammonia (NH_3), known collectively as Total Ammoniacal Nitrogen (TAN) and nitrogen gas (N_2). Total Kjeldahl Nitrogen (TKN) is the sum of TAN and Organic Nitrogen. Organic Nitrogen is principally found as proteins, amino acids, urea and humic acids. Particulate nitrogen consists of plants and animals, their remains as well as TAN adsorbed onto mineral particles.

The marine nitrogen cycle is driven by complex processes that make nitrogen biologically available. The cycle includes the processes of nitrogen fixation, nitrification, assimilation, ammonification and denitrification. Nitrogen fixation is the conversion of dissolved nitrogen gas (N_2) to TAN. TAN can then be assimilated by algae and plants into metabolic pathways (organic nitrogen). Nitrification is an oxidation process that converts TAN to NO_2 and NO_3. Denitrification is a reduction process that converts NO_2 and NO_3 into atmospheric nitrogen (N_2). Ammonification is the initial step in the process through which Organic Nitrogen is mineralized to TAN.

Phosphorus

Total Phosphorus is the sum of all Phosphorus forms (organic and inorganic). Dissolved Reactive Phosphorus (DRP) refers to the fraction of phosphorus which is in solution in the water as opposed to being attached to suspended particles (known as insoluble phosphorus).

Chlorophyll a

Chlorophyll a is the predominant form of chlorophyll found in green plants and algae. It allows the conversion of nutrients and sunlight through photosynthesis into organic compounds. Chlorophyll a is often incorporated as an indicator of phytoplankton biomass within water quality investigations. Elevated chlorophyll a levels and subsequently elevated phytoplankton biomass can reflect increased nutrient loads and if persistent, potential water quality issues.

Results

Water Quality

Graphical representation of data for key water quality indicators against surface and bottom water Annual and Summer DGVs.

Temperature

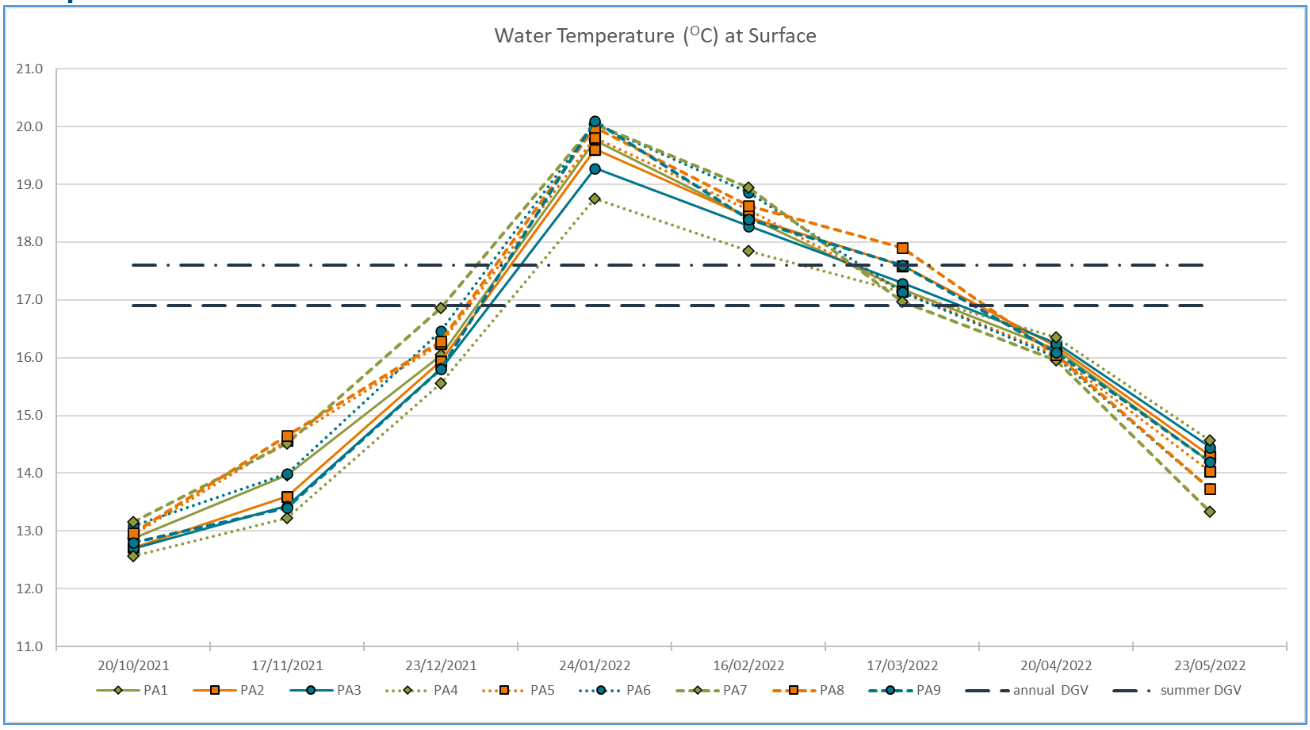


Figure 1: Water temperature at surface and associated DGVs

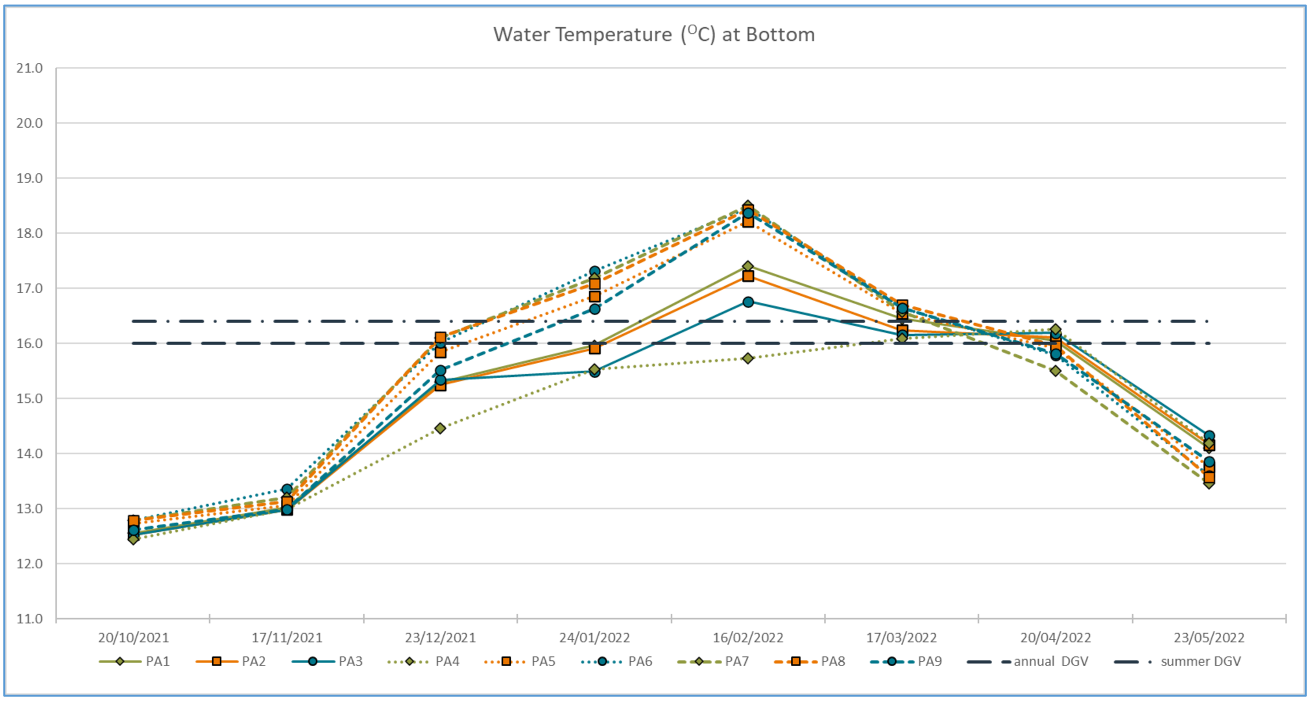


Figure 2: Water temperature at bottom and associated DGVs

Dissolved Oxygen

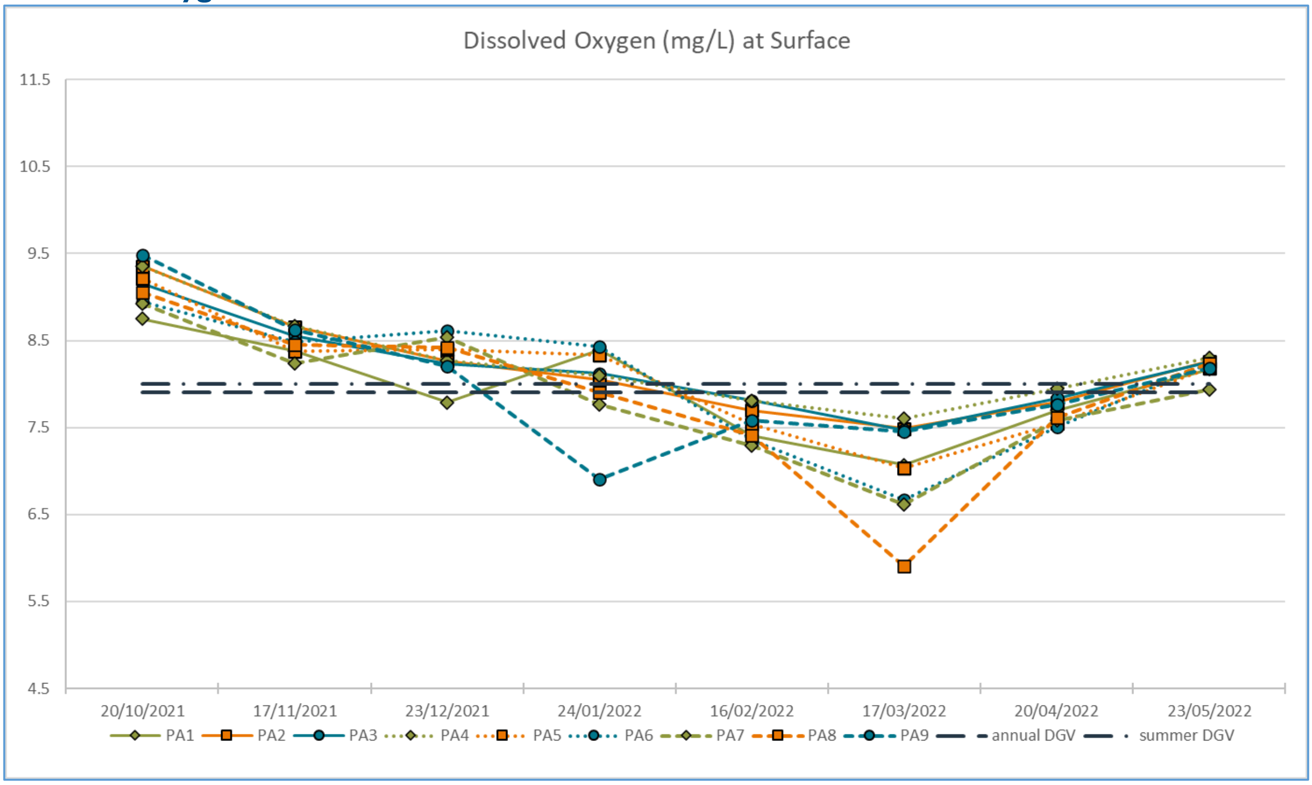


Figure 3: Dissolved oxygen (mg/L) levels at surface and associated DGVs

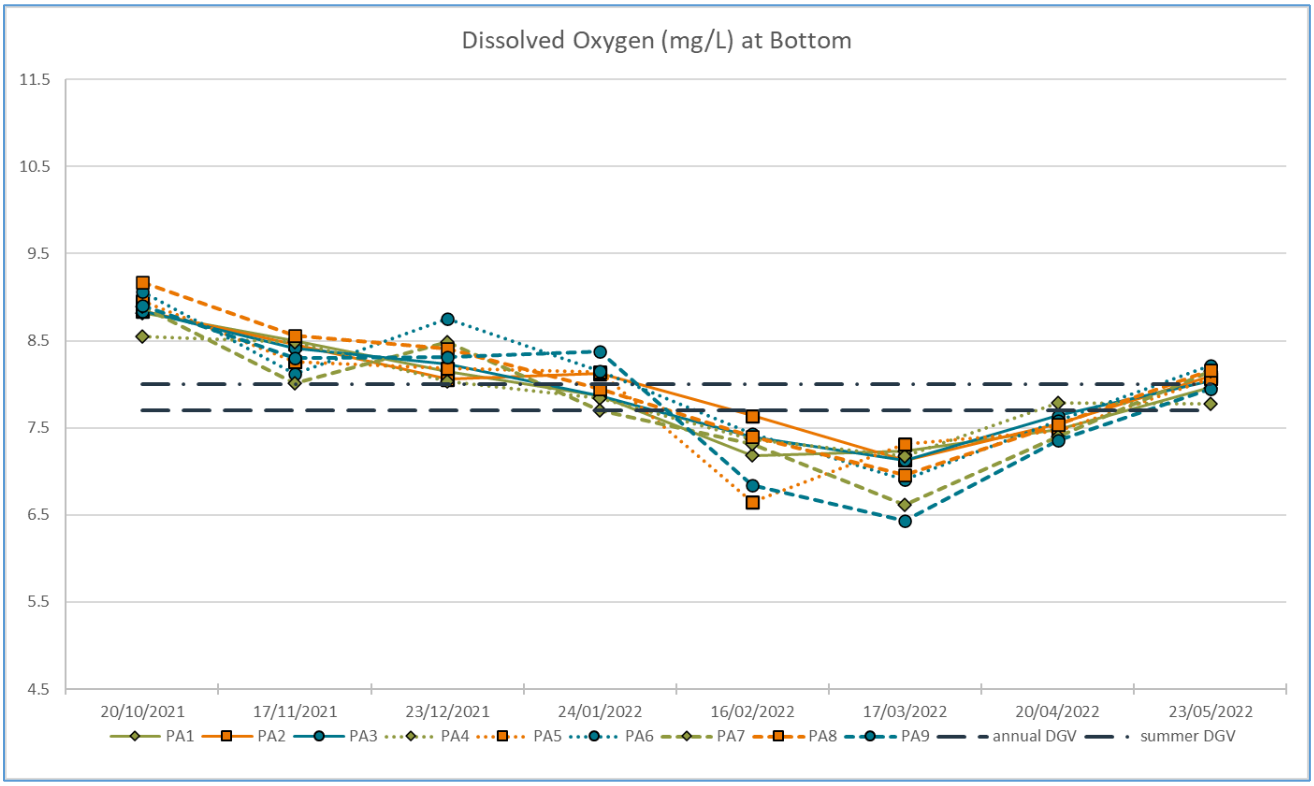


Figure 4: Dissolved oxygen (mg/L) levels at bottom and associated DGVs

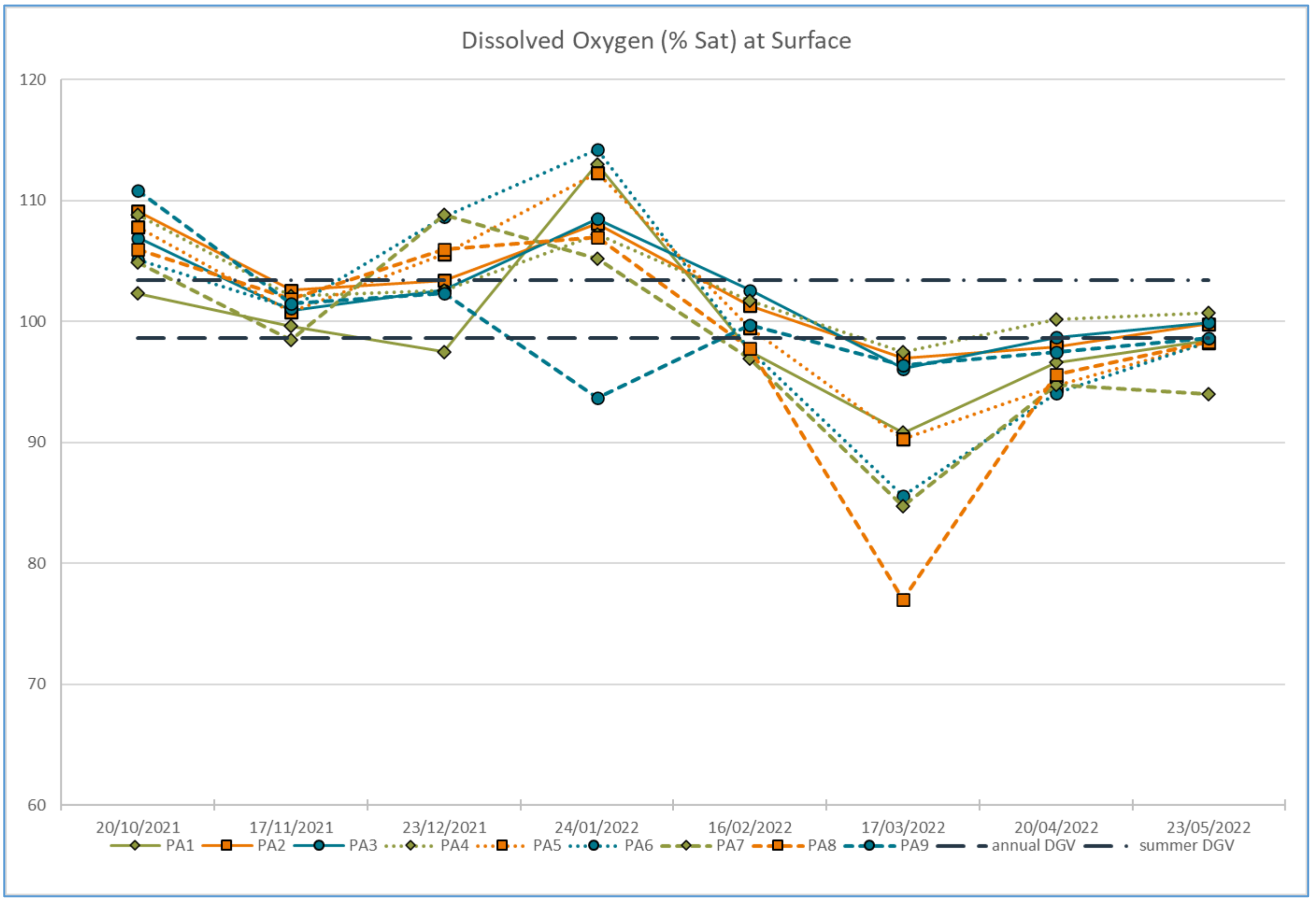


Figure 5: Dissolved oxygen (%Sat) levels at surface and associated DGVs

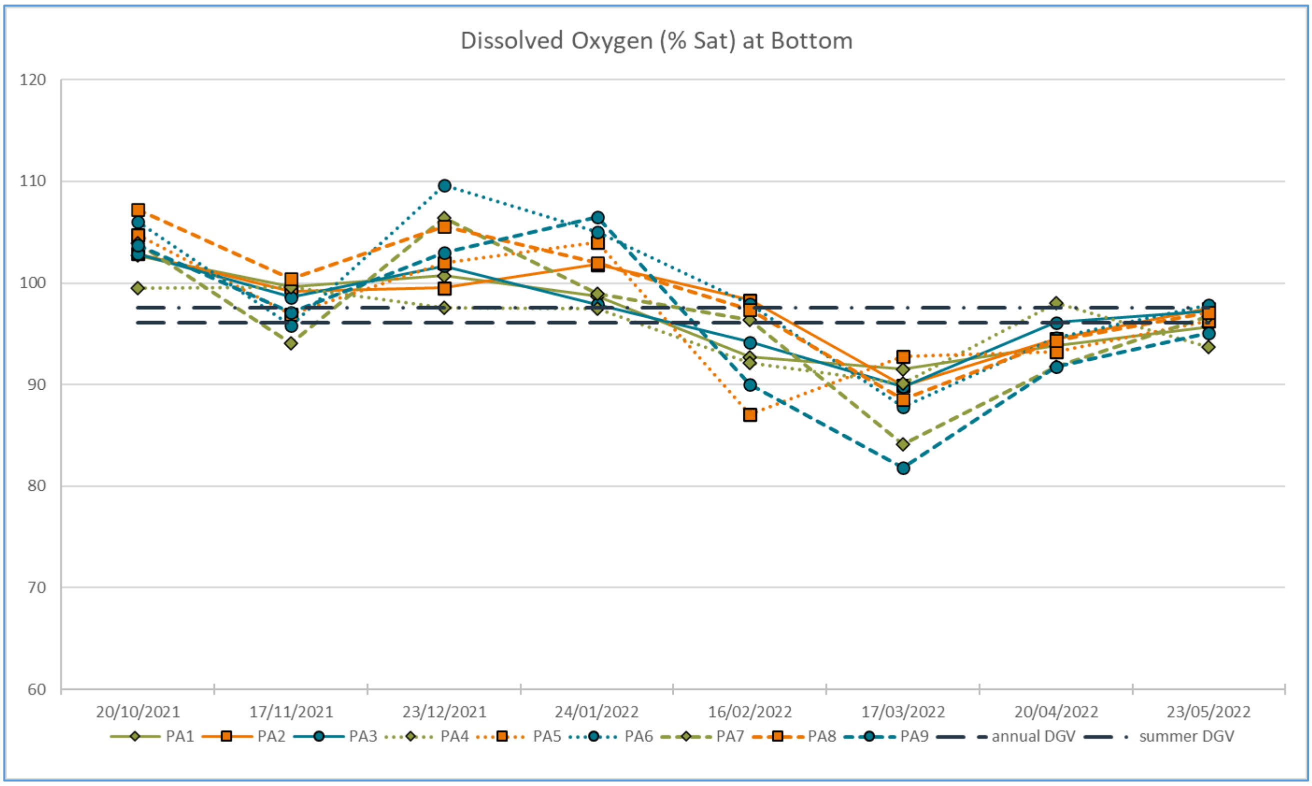


Figure 6: Dissolved oxygen (%Sat) levels at bottom and associated DGVs

Salinity

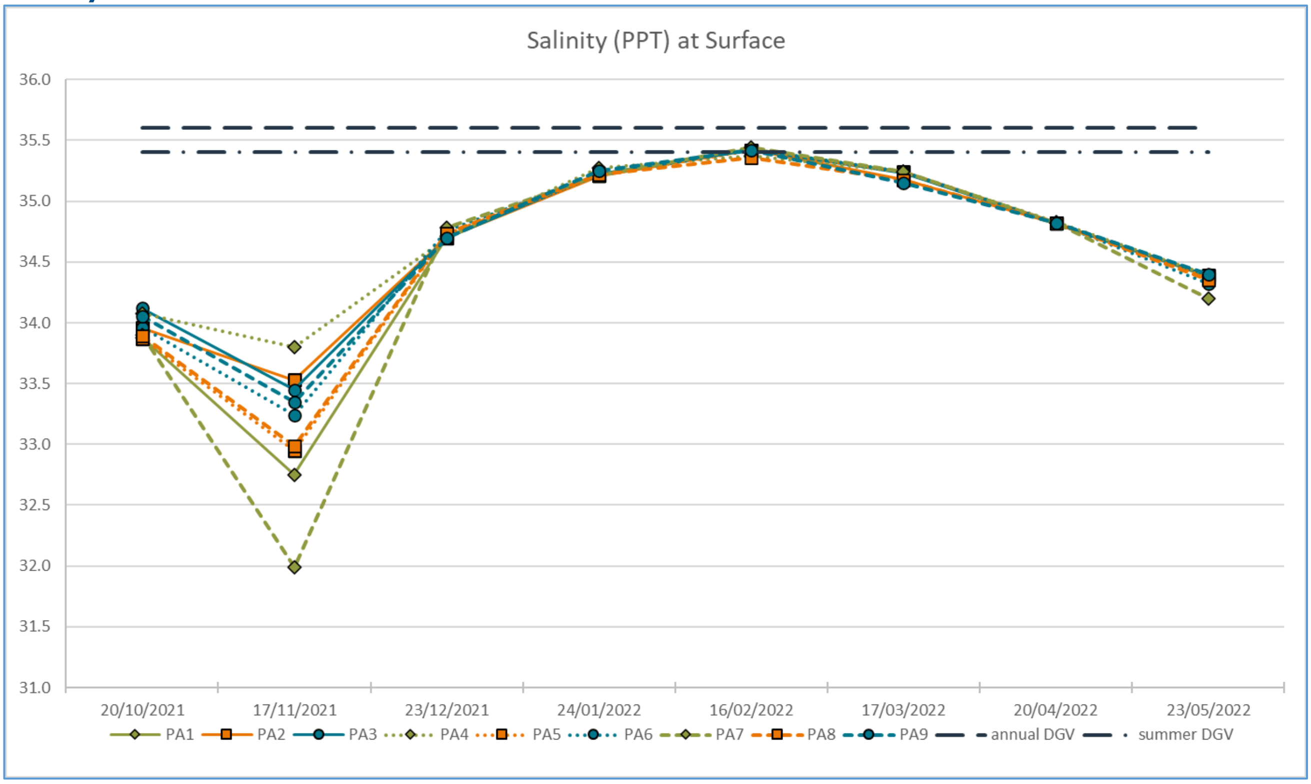


Figure 7: Salinity levels at surface and associated DGVs

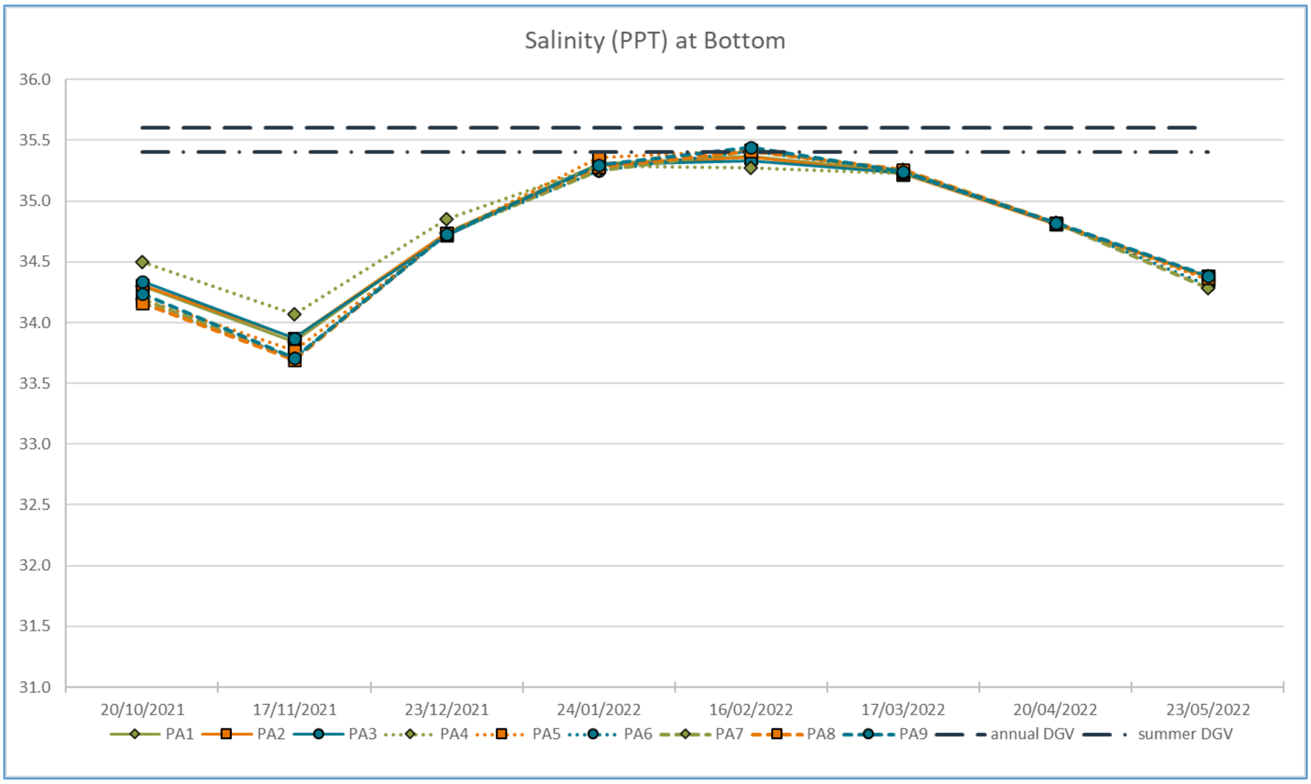


Figure 8: Salinity levels at bottom and associated DGVs

pH

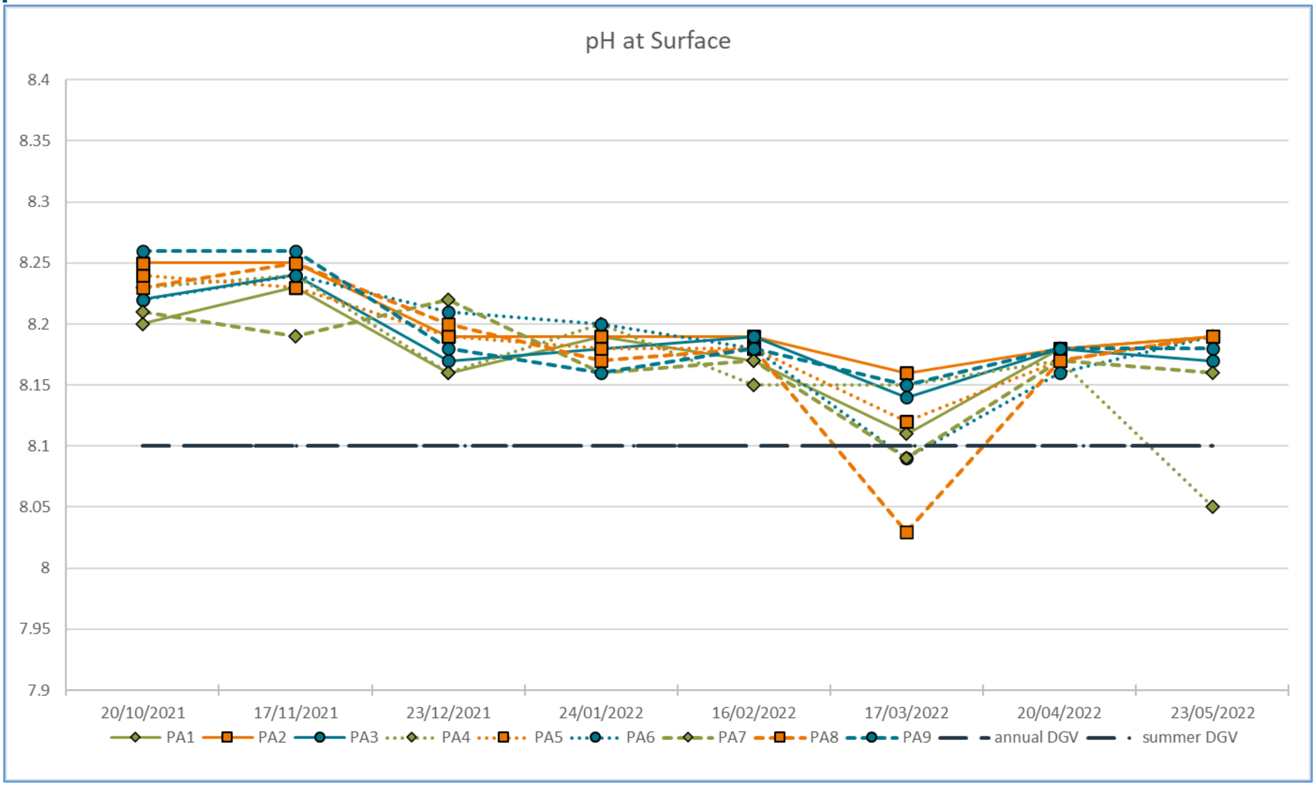


Figure 9: pH levels at surface and associated DGVs

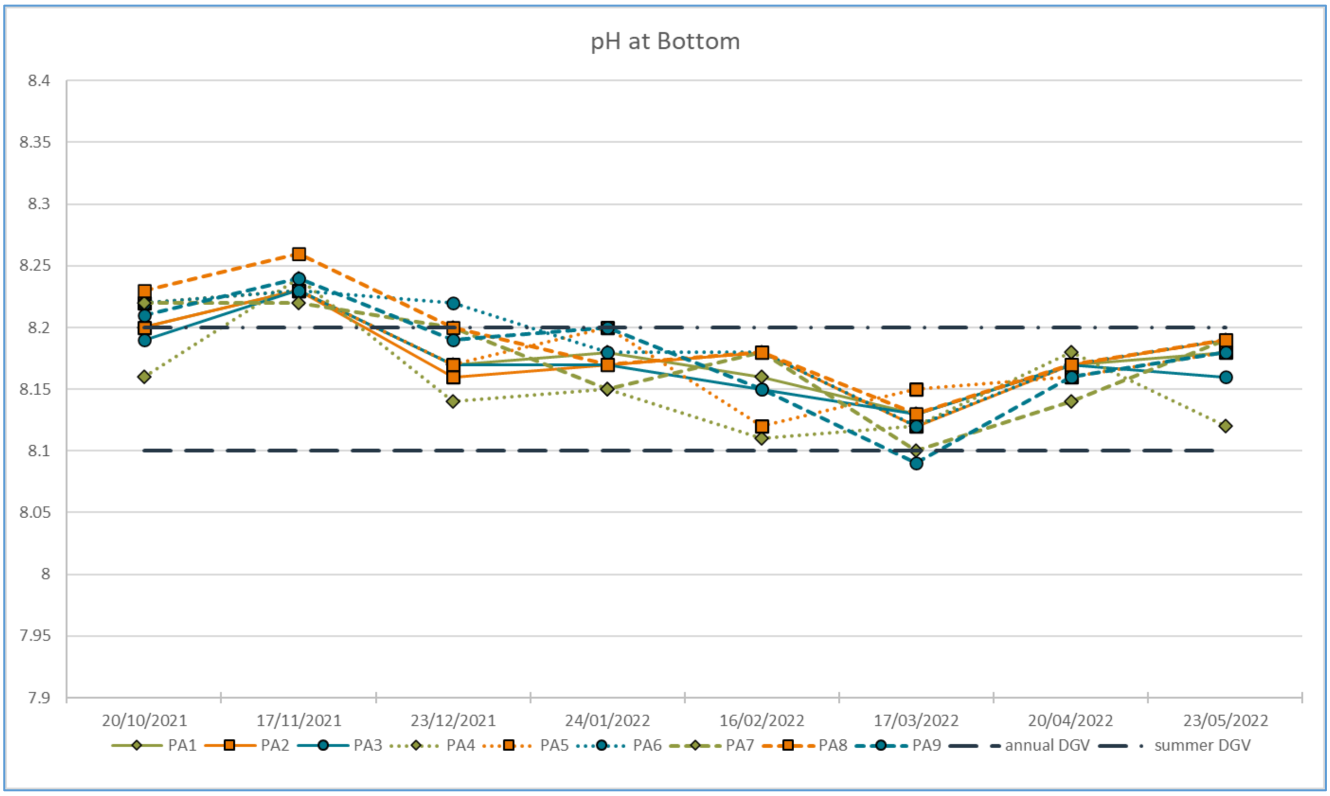


Figure 10: pH levels at bottom and associated DGVs

TAN (Total Ammoniacal Nitrogen)

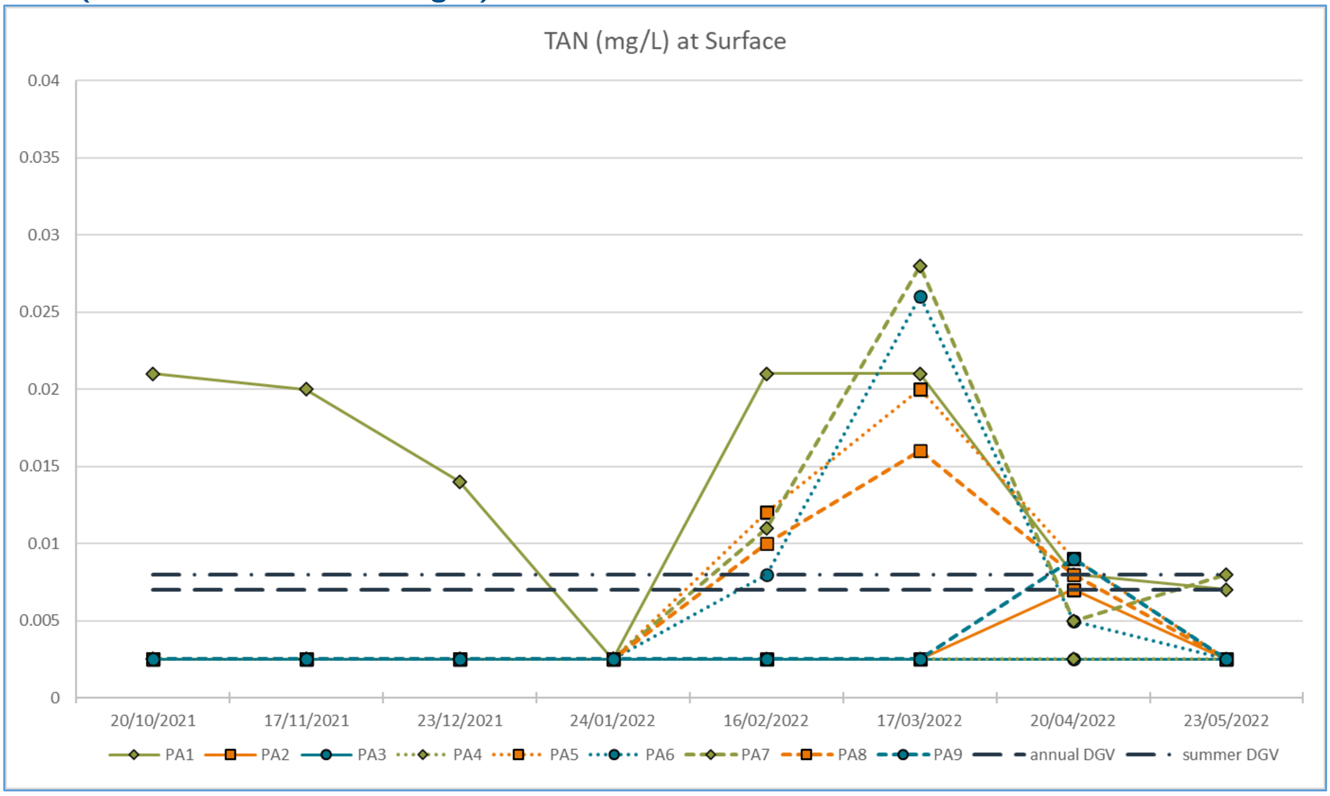


Figure 11: TAN concentrations at surface and associated DGVs

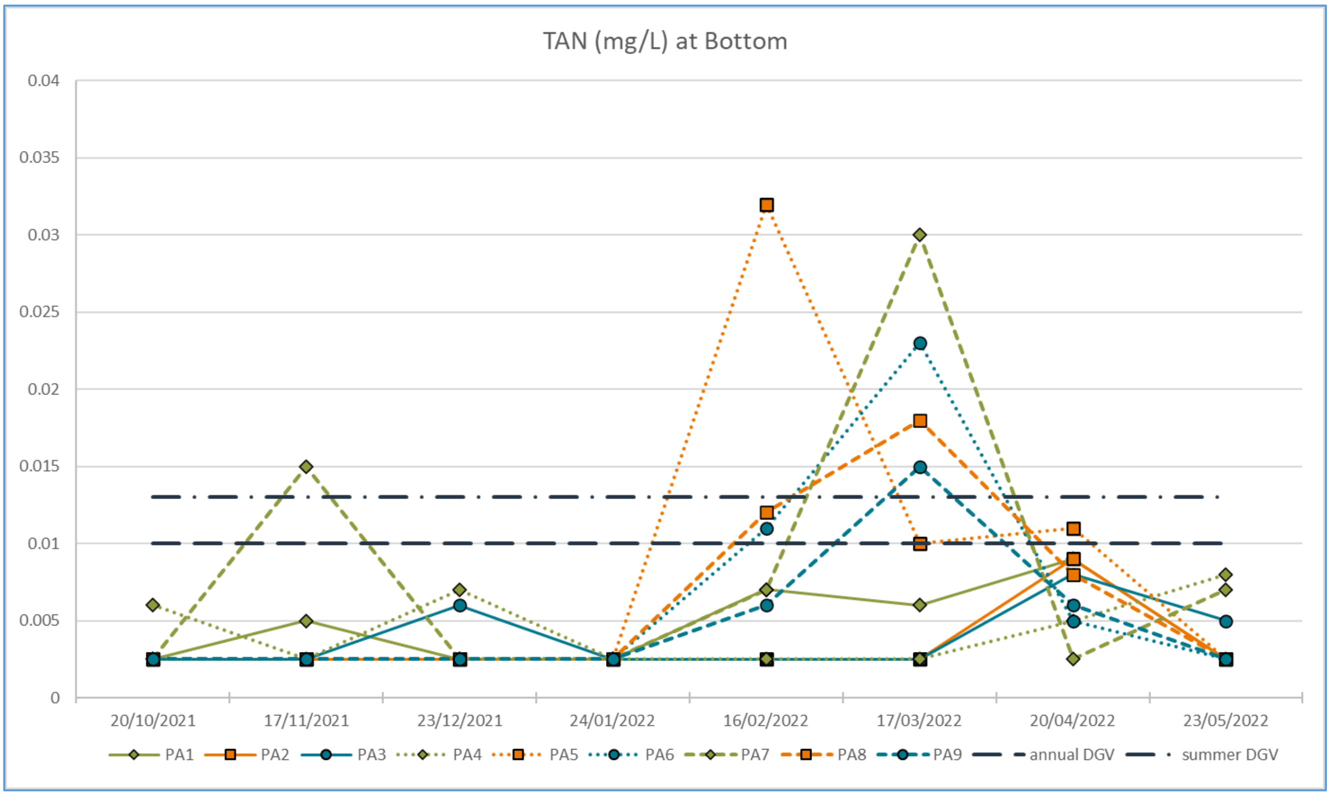


Figure 12: TAN concentrations at bottom and associated DGVs

NO_3 (Nitrate)

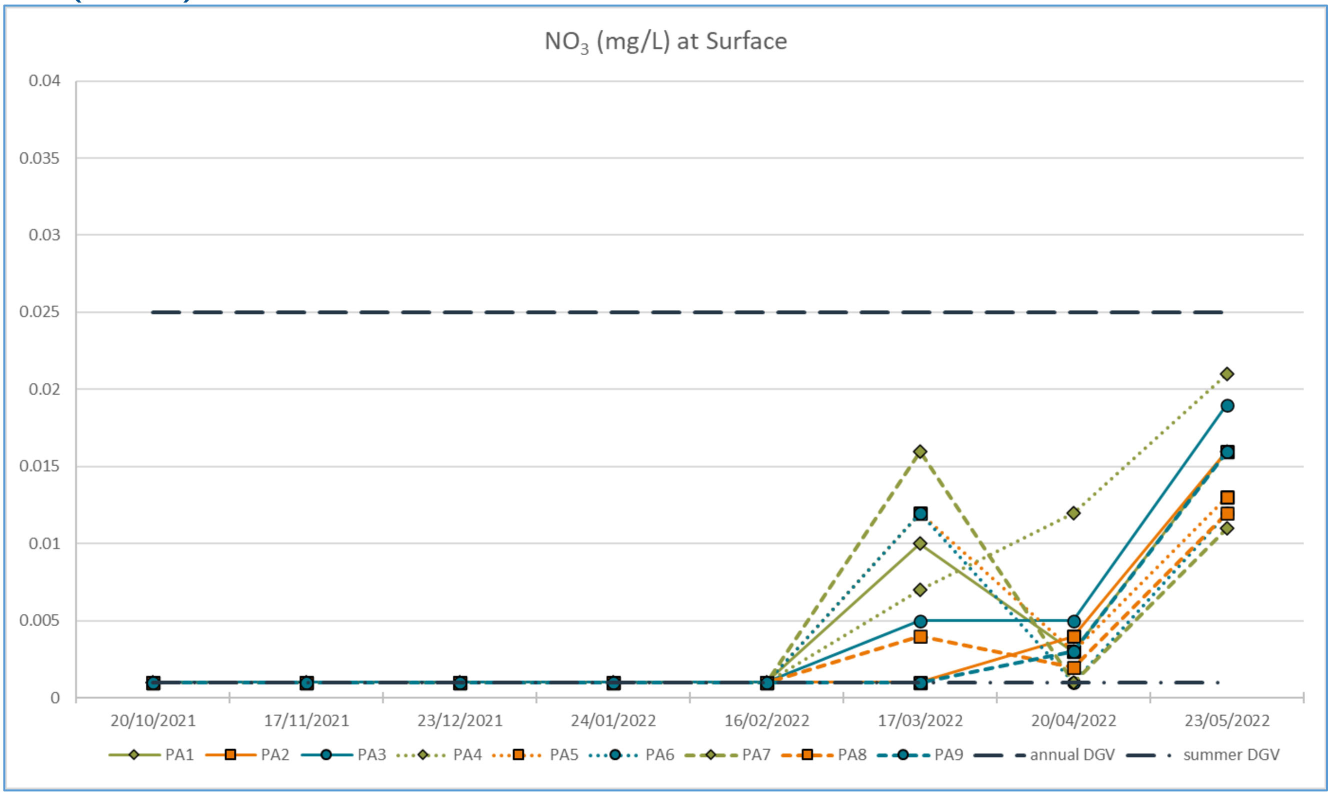


Figure 13: NO_3 concentrations at surface and associated DGVs

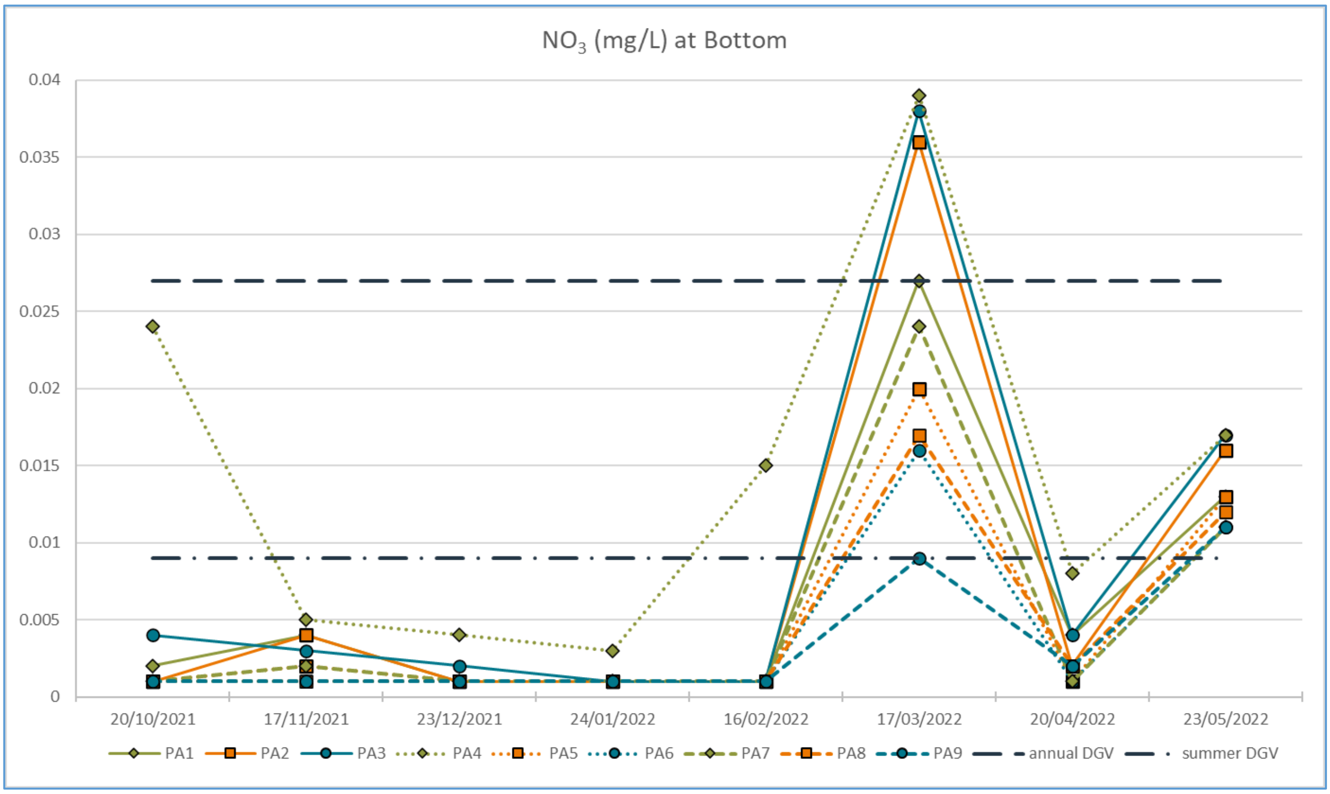


Figure 14: NO_3 concentrations at bottom and associated DGVs

NOx (Nitrate and Nitrite)

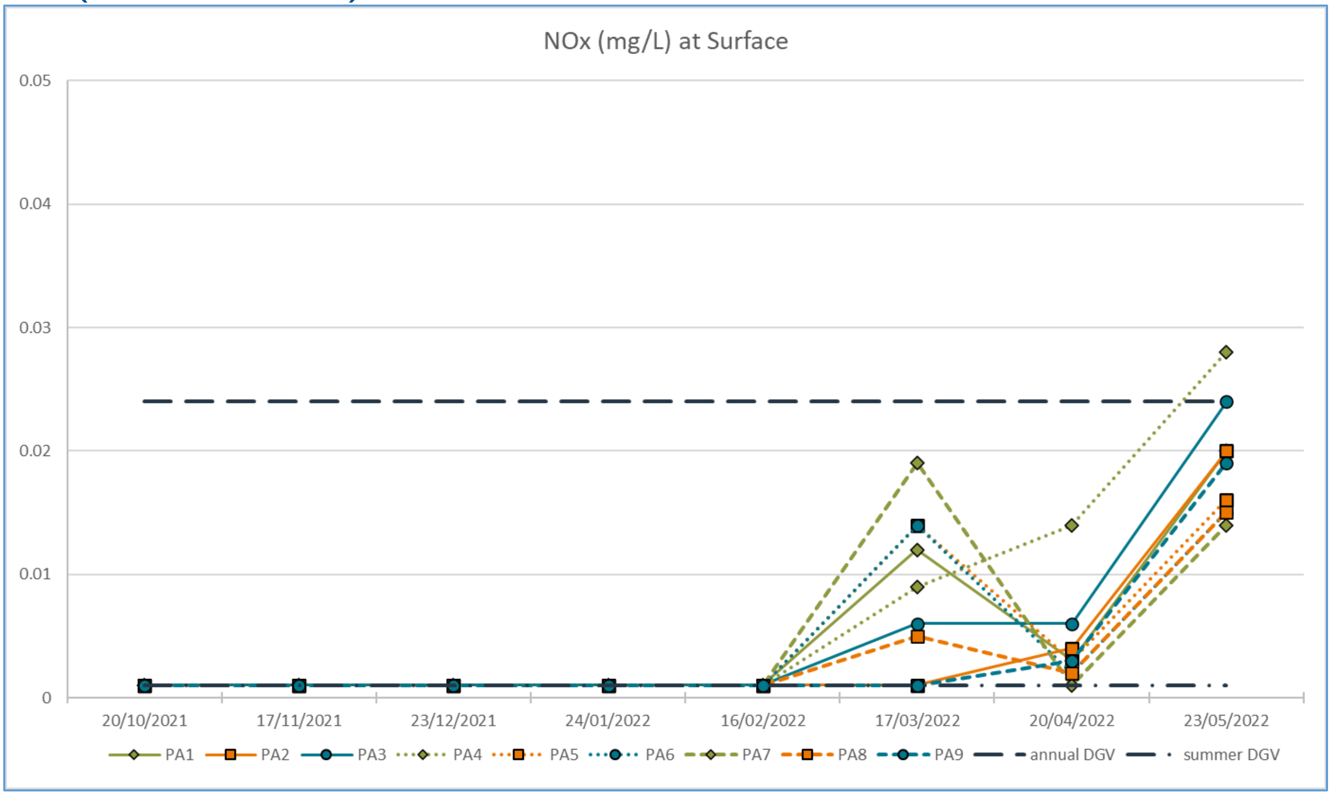


Figure 15: NOx concentrations at surface and associated DGVs

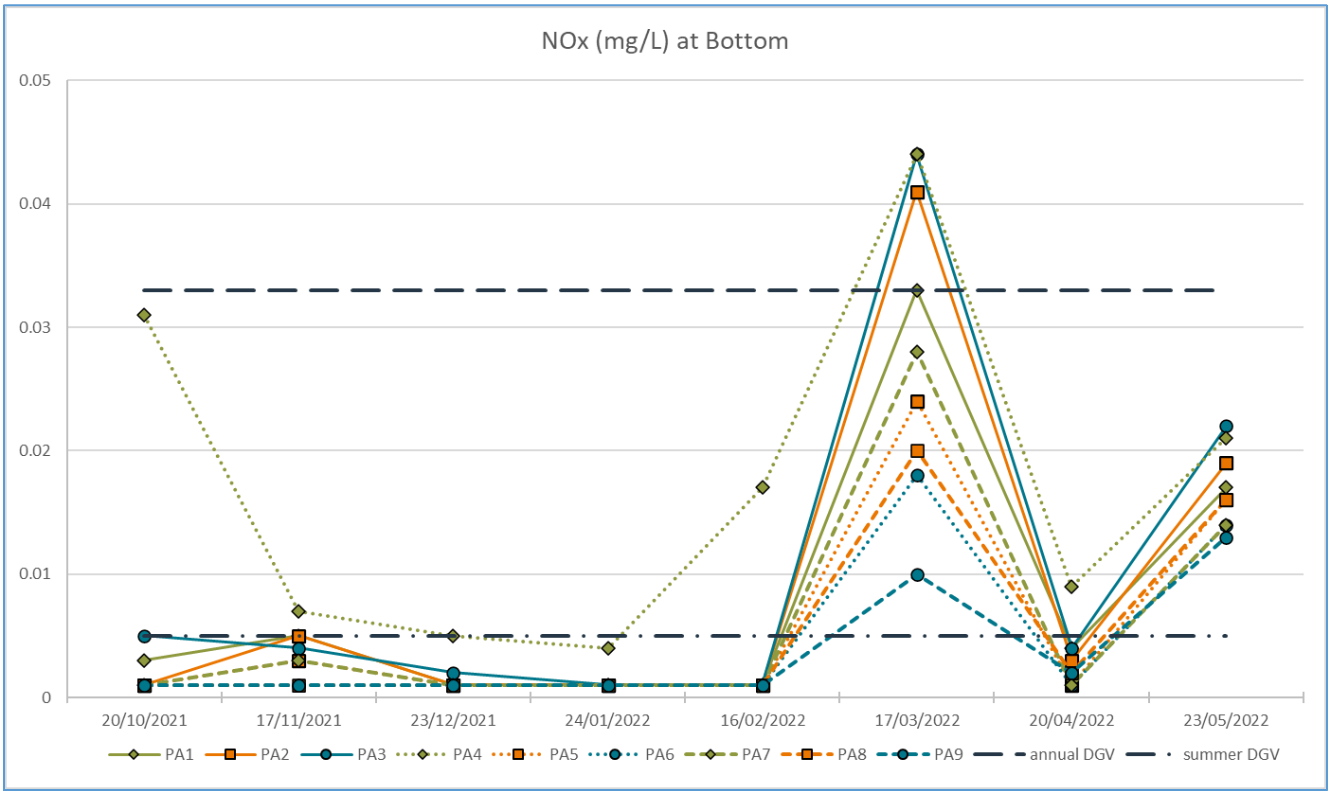


Figure 16: NOx concentrations at bottom and associated DGVs

Total Kjeldahl Nitrogen (TKN)

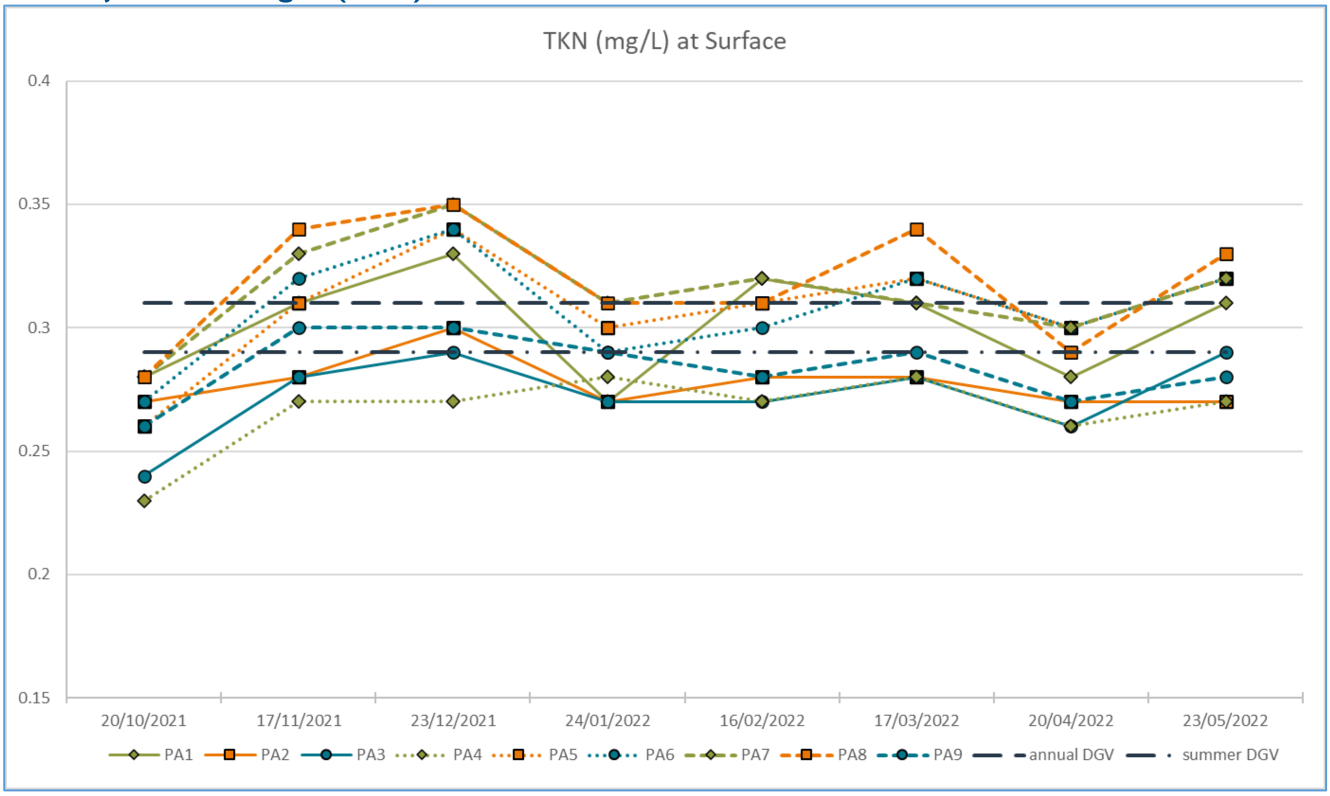


Figure 17: TKN concentrations at surface and associated DGVs

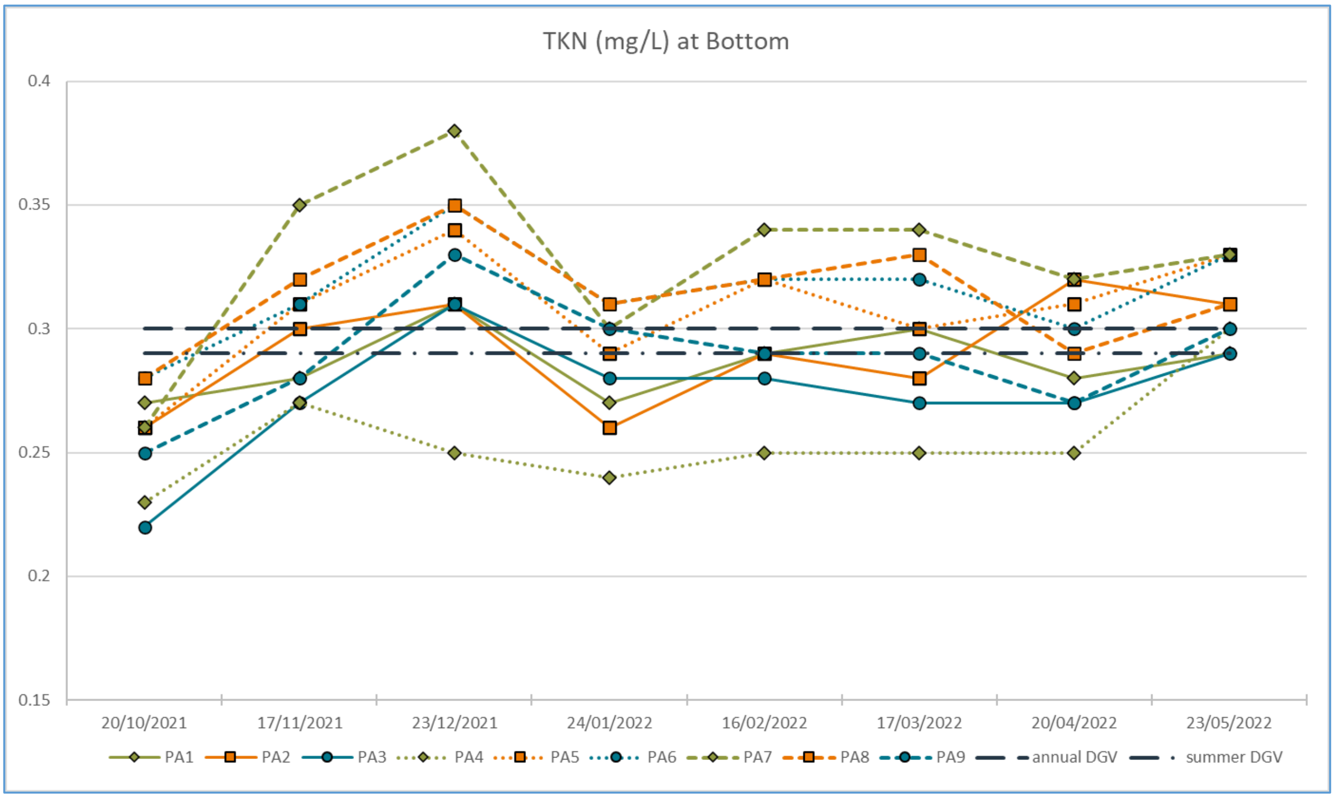


Figure 18: TKN concentrations at bottom and associated DGVs

Nitrogen (total)

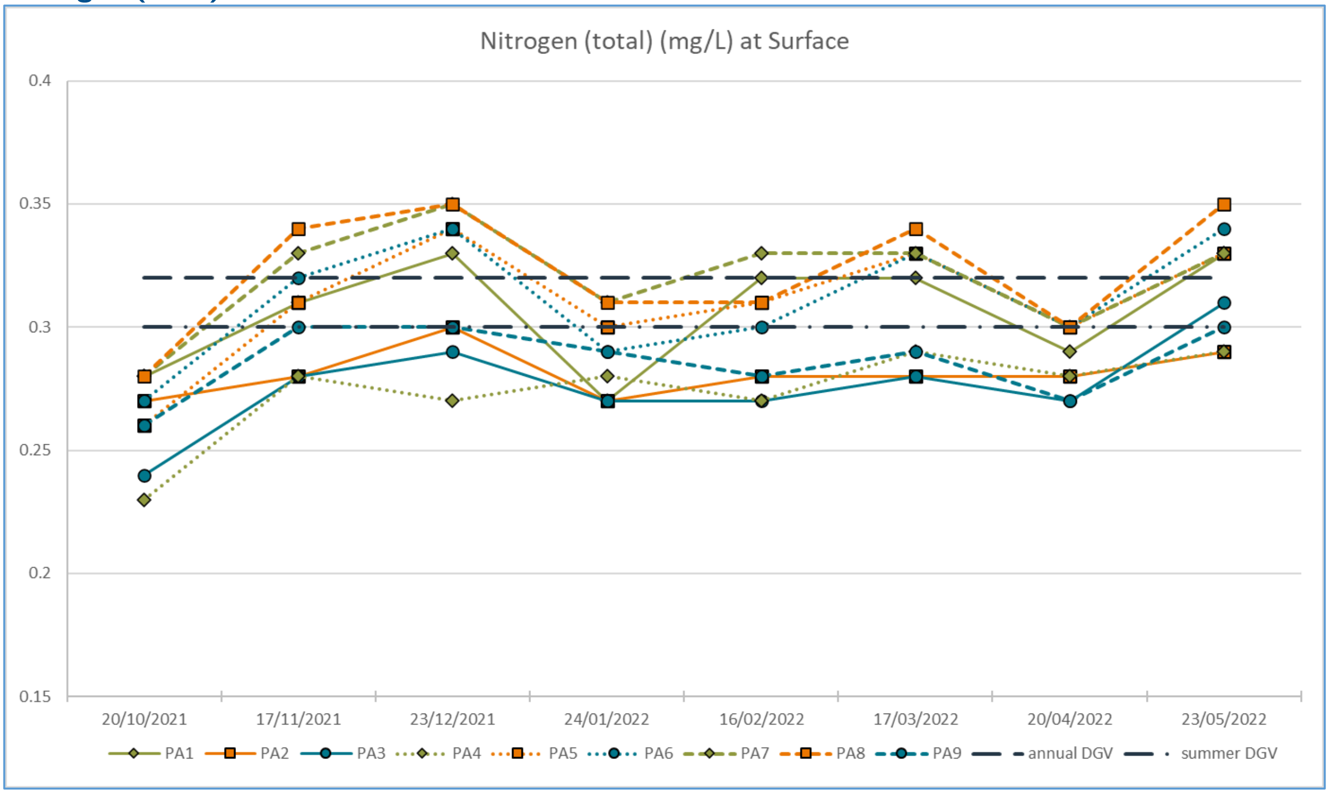


Figure 19: Nitrogen (total) concentrations at surface and associated DGVs

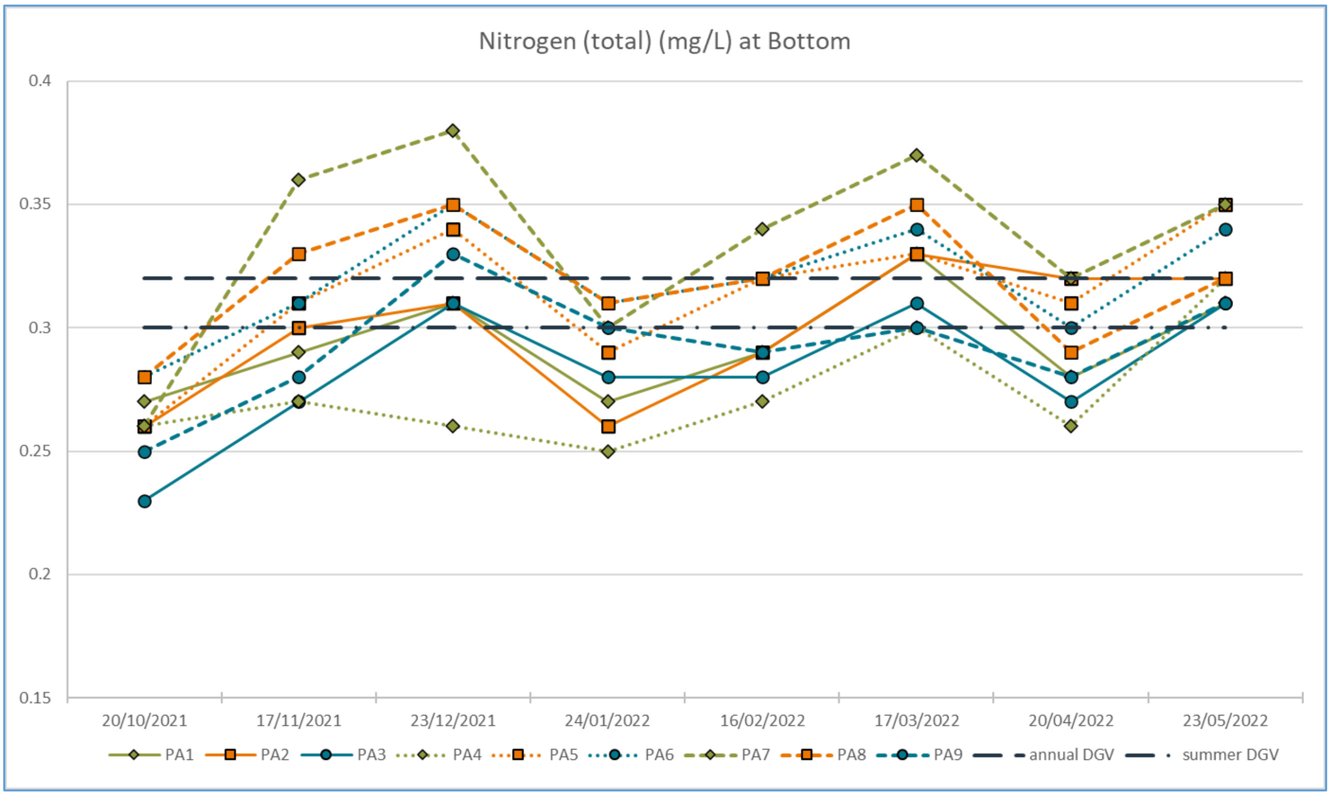


Figure 20: Nitrogen (total) concentrations at bottom and associated DGVs

Phosphorus (total)

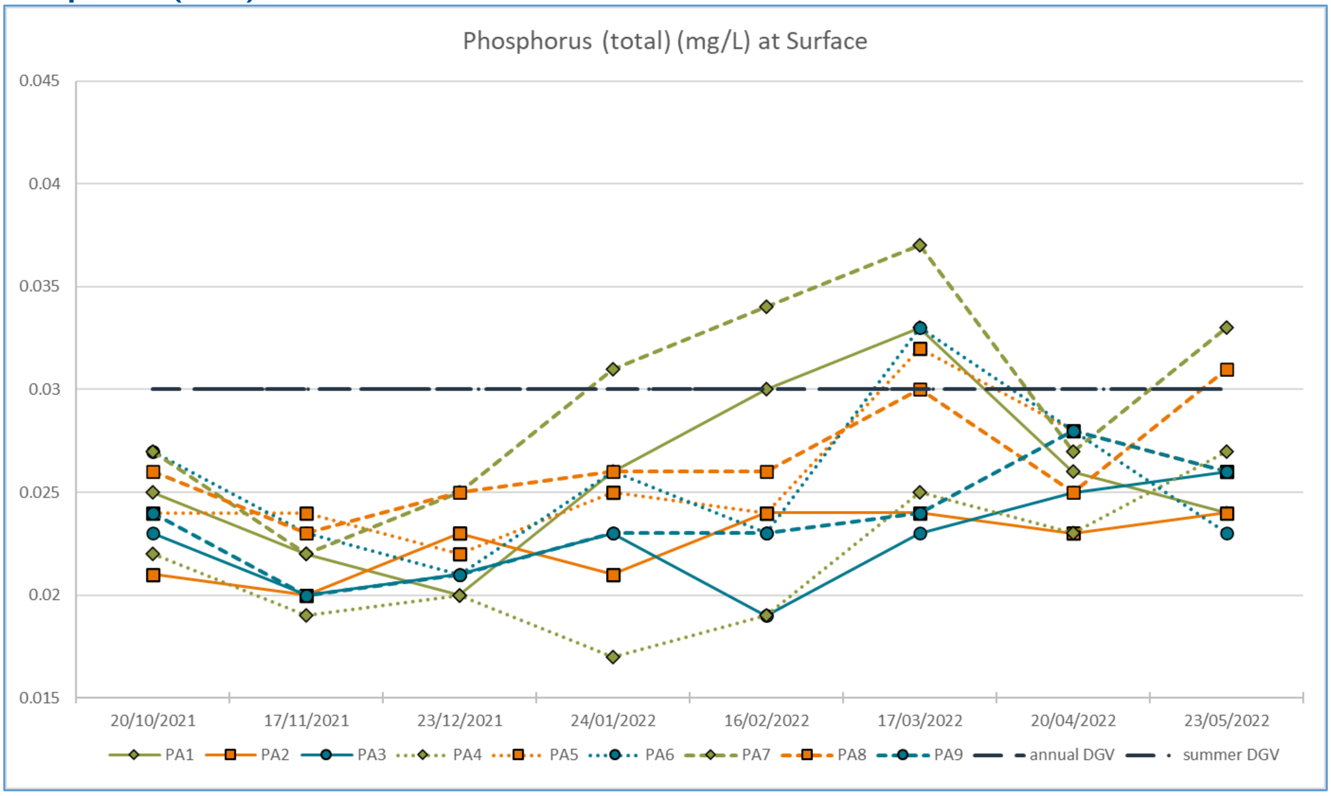


Figure 21: Phosphorus (total) concentrations at surface and associated DGVs

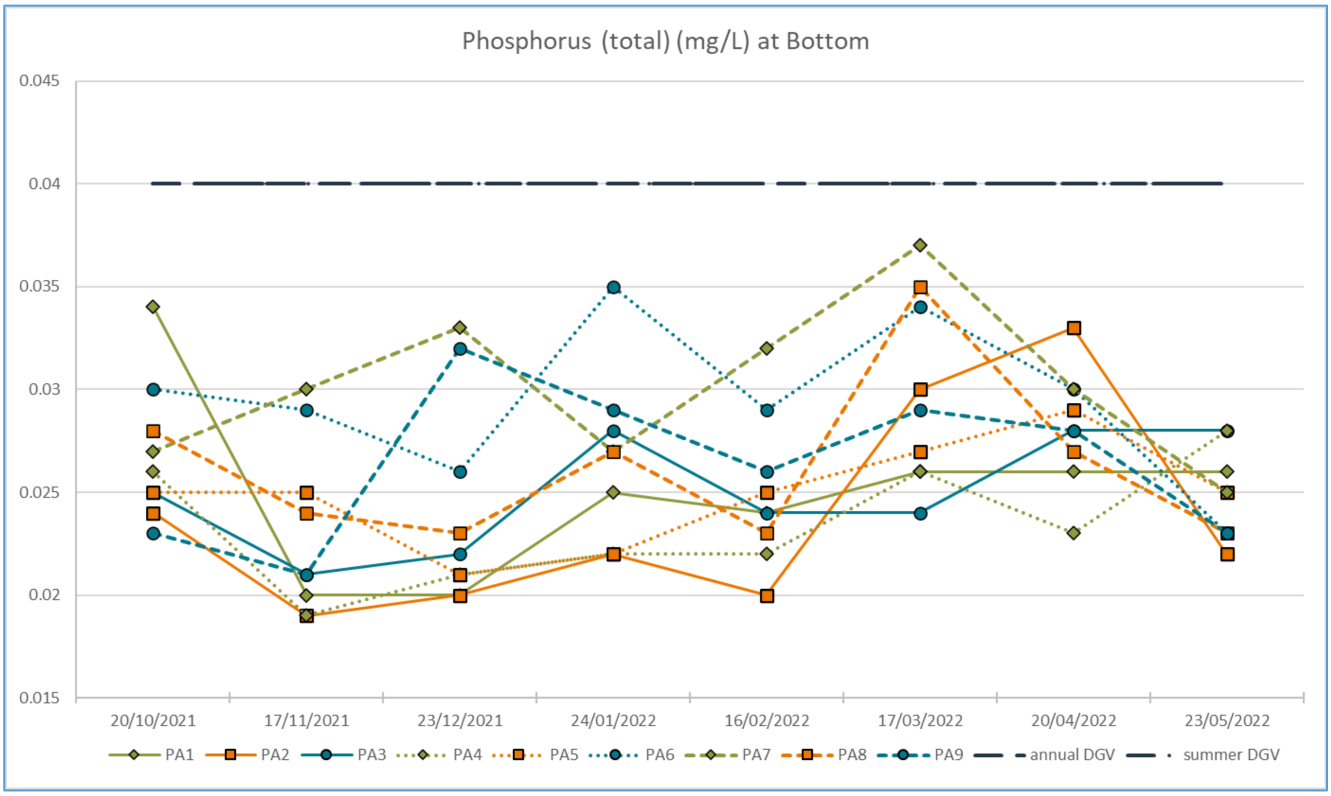


Figure 22: Phosphorus (total) concentrations at bottom and associated DGVs

DRP (Dissolved Reactive Phosphorus)

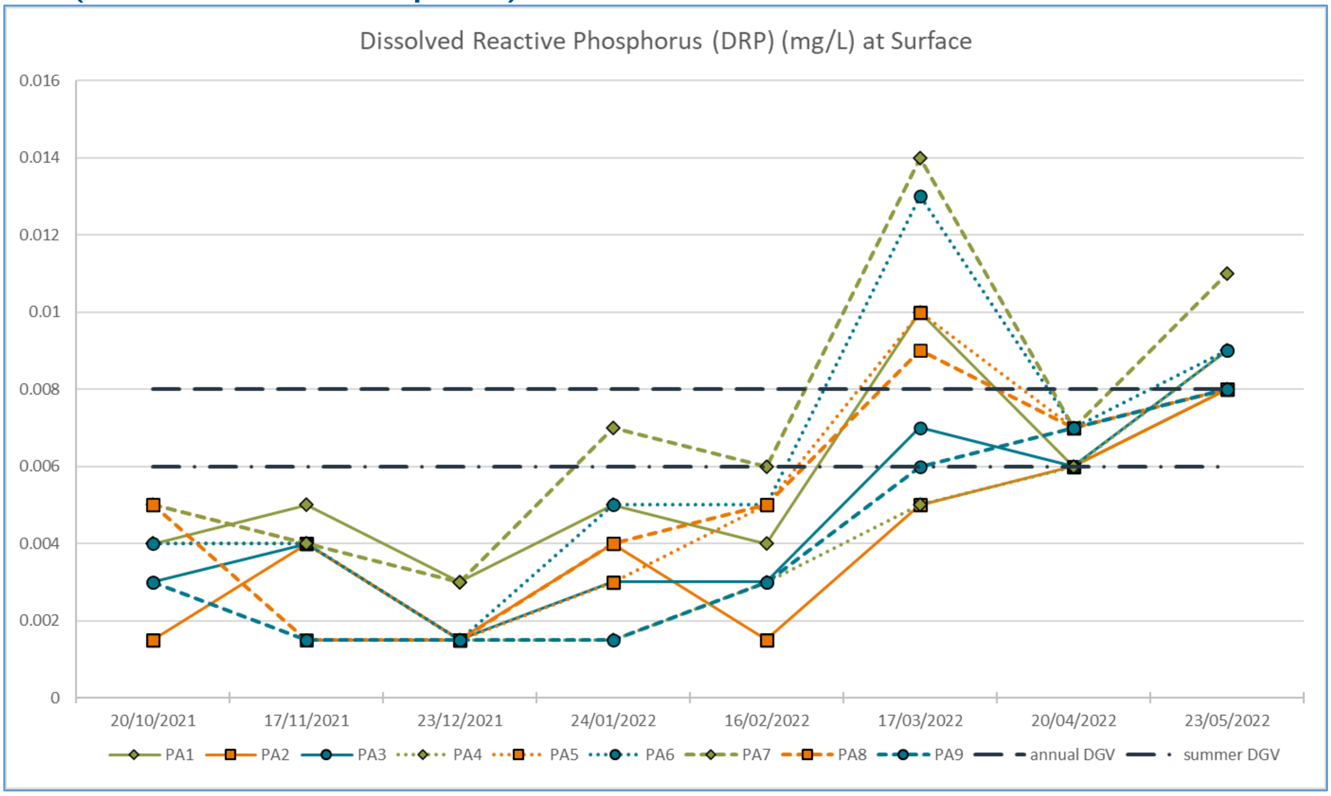


Figure 23: DRP concentrations at surface and associated DGVs

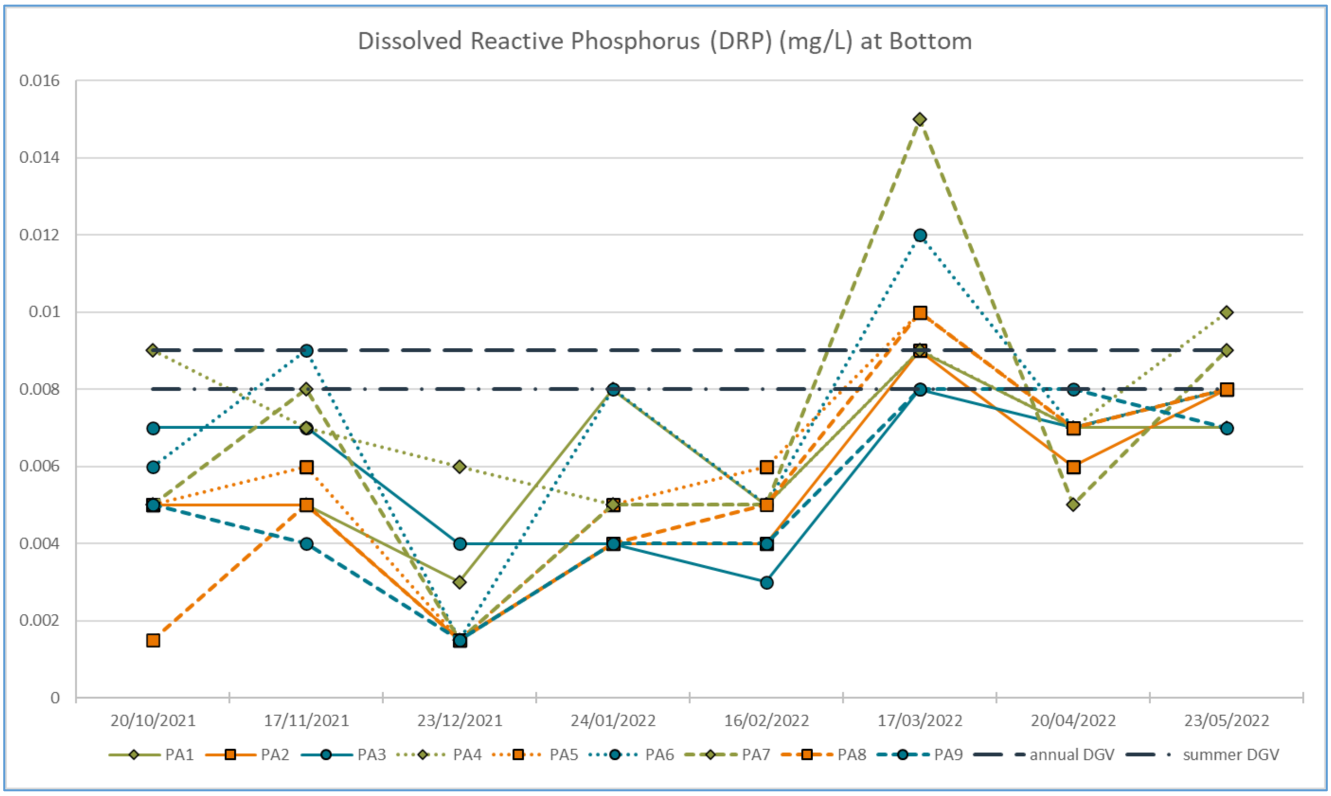


Figure 24: DRP concentrations at bottom and associated DGVs

Chlorophyll a

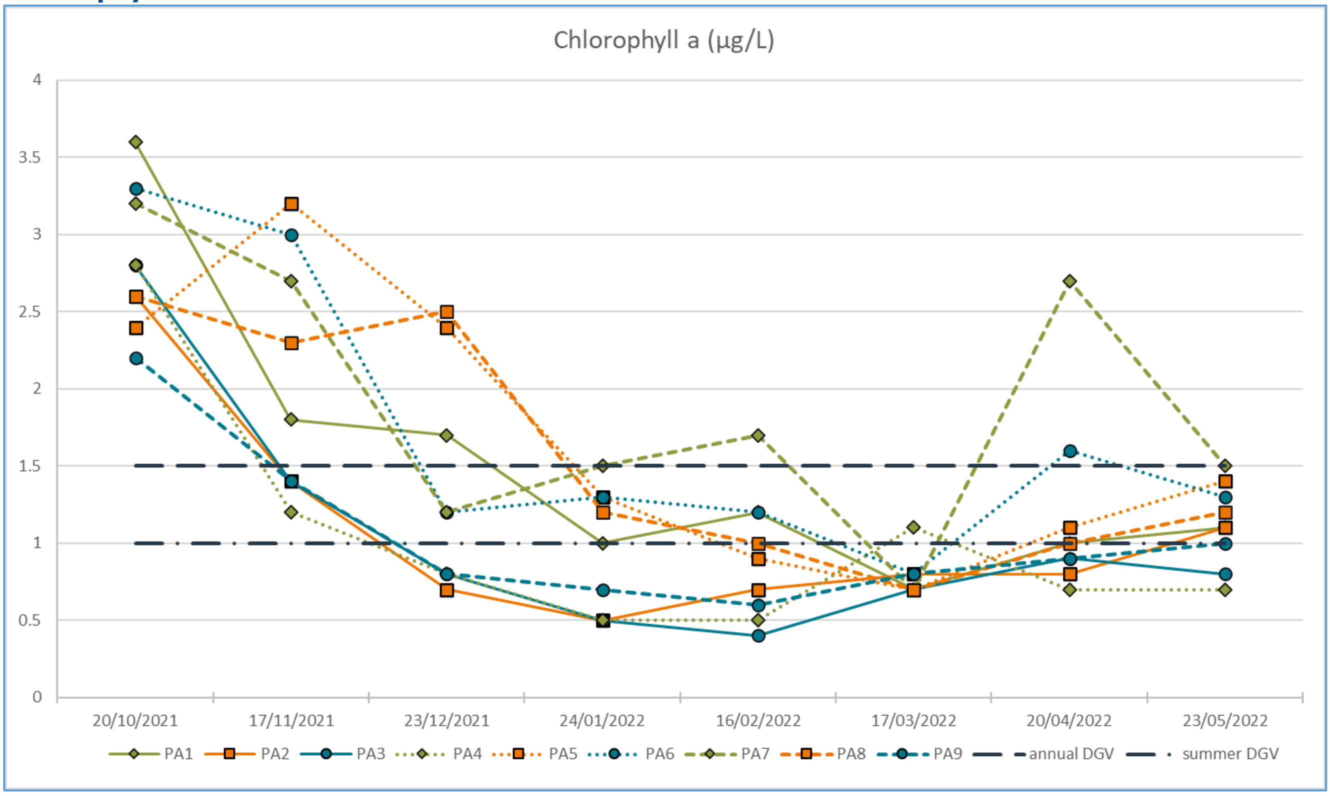


Figure 25: Chlorophyll levels from integrated sample and associated DGVs

Epiphytic Algal growth

Tabulated representation of survey location epiphytic algal growth scores.

Table 4: Average epiphytic algal growth score by survey location

Location	Spring 2021	Summer 2021-22	Autumn 2022
SG_PA17	5.0	2.8	3.7
SG_PA16	2.3	N/S	2.3
SG_PA9	4.0	Dust (3.0)	3.5
SG_PA4	3.0	N/S	3.3
SG_PA28	1.2	3.3	3.8
SG_PA29	3.0	3.5	2.8
SG_PA30	1.8	3.2	1.3

N/S – not sampled due to low tide

Discussion

In this section the results of the October 2021 to May 2022 water quality data will be discussed in relation to the Summer and the Annual Default Guideline Values (DGVs) for aquatic ecosystems for surface and bottom waters. It should be noted that the DGVs are based on data collected from August 2013 to July 2017 from four locations (PA1, PA2, PA3 and PA4). The resultant figures have been applied to the entire Port Arthur area. A degree of caution is required in interpreting the findings for sites in the upper reaches of Long Bay against the DGVs. However, in the absence of site specific data, the application of regional DGVs is the acceptable approach. It should also be noted that the Summer DGVs are based on the data from December to February (inclusive).

The results for epiphytic growth will be discussed in relation to the qualitative categories described in Table 3.

Water Quality

Temperature

The pattern observed for water temperature is as expected during summer where increased solar radiation increases surface water temperatures, particularly in shallow regions of waterways. The East Australian Current (EAC) transports warm water down the eastern seaboard during summer and this can also result in elevated water temperatures around Tasmania.

For October, November, December, May and April all surface water temperature readings bar the EPA-PA7 reading for December were below the Annual and Summer period DGVs. The EPA-PA7 surface water reading for December was equal to the Annual DGV (16.9 °C). For January and February, the surface water temperature readings for all sites were higher than that of the Annual and Summer DGVs. For March the surface water temperature readings for all sites were above the Annual DGV. The EPA-PA2 and EPA-PA9 surface water readings for March were equal to the Summer DGV (17.6 °C) and the EPA-PA8 surface water reading was higher than the Summer DGV. The surface water readings for the remaining sites during March were lower than the Summer DGV. The range observed for surface water readings is comparable to that of the baseline period, being 10.1 °C to 20.9 °C.

For October, November and April all bottom water temperature readings were lower than the Annual and Summer DGVs. For December all bottom water temperature readings were lower than the Summer DGV. The bottom water readings for EPA-PA7 and EPA-PA8 were higher than and that for EPA-PA6 equal to the Annual DGV. The temperature readings for the remaining sites during December were lower than the Annual DGV. For January, EPA-PA2, EPA-PA3 and EPA-PA4 were lower than the Summer DGV and Annual DGV values, whilst EPA-PA1 was equal to the Annual DGV (16.0 °C). The remaining sites (EPA-PA5 to EPA-PA8, and EPA-PA9) were higher than the Summer DGV (16.4 °C). This follows the trend observed last summer for bottom waters of the shallow sites within Long Bay and Carnarvon Bay. For February all sites except for EPA-PA4 were higher than the bottom water Summer DGV (16.4 °C). EPA-PA4 was below the Summer DGV and the Annual DGV. For March, bottom water temperatures for EPA-PA2, EPA-PA3 and EPA-PA4 were lower than the Summer DGV and higher than the Annual DGV whilst EPA-PA1 was equal to the Summer DGV (16.4 °C). The bottom water temperatures for the shallow water sites EPA-PA5 to EPA-PA8, and EPA-PA9 were all above the Summer DGV. For April, the bottom water temperatures for EPA-PA1, EPA-PA2, EPA-PA3 and EPA-PA4 were higher than the Annual DGV but lower than the Summer DGV. The bottom water temperatures for the shallow water sites EPA-PA5, EPA-PA6, EPA-PA7 and EPA-PA9 were all lower than the Annual DGV, whilst EPA-PA8 was equal to the Annual DGV (16.0 °C).

The temperature range observed for bottom waters is comparable to that of the baseline period, being 9.4 °C to 19.2 °C.

Dissolved Oxygen

Given that the Annual and Summer DGVs for surface waters of Port Arthur for dissolved oxygen are 7.9 mg/L and 8.0 mg/L, respectively, the results will be compared to the more conservative Summer DGV. For October and November all surface water dissolved oxygen readings were above the Summer DGV. For December all surface water dissolved oxygen readings except for EPA-PA1 were above the Summer DGV. EPA-PA1 was recorded as 7.8 mg/L. For January the surface water dissolved oxygen readings for EPA-PA1 to EPA-PA6 were above the Summer DGV, whilst EPA-PA7, EPA-PA8, and EPA-PA9 were below. Interestingly EPA-PA9 within Carnarvon Bay had the lowest reading (6.9 mg/L). For February and March, the surface water dissolved oxygen readings were below the Summer DGV for all sites. With the lowest values being within Long Bay. This is not unexpected given that as water temperature increases the carrying capacity for oxygen decreases. For April the surface water dissolved oxygen readings were below the Summer DGV for all sites except for EPA-PA4. EPA-PA4 was equal to the Summer DGV. For May the surface water dissolved oxygen readings were above the Summer DGV for all sites except for EPA-PA7. EPA-PA7 was recorded as 7.9 mg/L, which is equal to the Annual DGV. The range observed for surface water dissolved oxygen levels for EPA-PA1 to EPA-PA4 is comparable to that of the baseline period, being 7.2 mg/L to 9.6 mg/L.

As with the surface waters, bottom water dissolved oxygen levels were compared to the more conservative Summer DGV. For October all bottom water dissolved oxygen readings were above the Summer DGV. For November, EPA-PA7 was equal to the Summer DGV for bottom water and all other sites were above. For December, EPA-PA4 was equal to the Summer DGV for bottom water and all other sites above. For January, EPA-PA2, EPA-PA5, EPA-PA6 and EPA-PA9 were above, EPA-PA8 equal to and the remaining sites below the Summer DGV for bottom water. For February, March, and April all sites were below the Summer DGV for bottom waters. The levels for Carnarvon Bay tended to be lower than the shallow water Long Bay sites. This is a likely indicator of localised oxygen demand resulting from the combined influence of in-situ factors (such as senescence of algae) and external factors (such as runoff from the surrounding catchment). For May all sites except for EPA-PA4 were either equal to or above the Summer DGV for bottom water. EPA-PA4 was recorded as 7.8 mg/L, which was above the Annual DGV of 7.7 mg/L. The range observed for bottom water dissolved oxygen levels for EPA-PA1 to EPA-PA4 is comparable to that of the baseline period being 7.0 mg/L to 9.7 mg/L.

Dissolved oxygen loggers have been deployed in Long Bay and Boomer Bay since the beginning of 2022 and a graph of the results as rolling daily averages are provided in Appendix 2. The most notable difference between the bays is the presence of the finfish lease. Both loggers are in similar depths of water (around 4 metres) in seagrass dominated areas. Of note is that the dissolved oxygen saturation levels for Long Bay diverge from that of Boomer Bay during the middle of March through to early April. During this period dissolved oxygen saturation levels for Long Bay approach 160 %Sat. From mid April to the start of July both sites have dissolved oxygen saturation levels of around 100 %Sat.

Salinity

The salinity levels recorded indicate that the water column at all sites is dominated by water of marine origin. The values recorded were below that of the Annual DGV for surface and bottom waters on all occasions. The values recorded were below the Summer DGV for surface and bottom waters for all months except February. For February all sites were equal to the Summer DGV of 35.4 (PPT). Of interest is the variation in salinity levels noted for the surface waters during November. The lowest values are for sites EPA-PA7 and EPA-PA1, followed by EPA-PA5 and EPA-PA8, and then EPA-PA6. This pattern indicates that freshwater tends to flow down the eastern side of long Bay from Long Bay Creek and can be secondarily circulated back into Long Bay along the western side by entrainment in marine waters.

pH

The pattern observed for pH indicates that the water column at all sites is dominated by water of marine origin. Of note for surface waters is the lower value for EPA-PA8 in March compared to the other locations. The low value in the upper section of Long Bay may indicate catchment-based inputs. Of interest is the lower value for EPA-PA4 in May for both the surface waters and to a lesser degree the bottom waters. The range of values for the surface waters and bottom waters are comparable to that of the baseline period, being 7.3 to 8.4 and 7.5 to 8.4, respectively.

TAN (Total Ammoniacal Nitrogen)

For the monitoring period (October 2021 to May 2022) almost three-quarters (52 of 72 records) of surface water TAN (Total Ammoniacal Nitrogen) readings were either at or below the Limit of Reporting (LoR), being 0.005 mg/L. Site EPA-PA1 which is in close proximity to the finfish lease was the only site above the LoR for October to December. TAN for all sites was below the LoR in January. During February and March, the five sites within Long Bay (EAP-PA1, EPA-PA5, EPA-PA6, EPA-PA7, and EPA-PA8) had TAN records above the Summer and Annual DGVs, whilst the remaining sites were below the LoR. The elevated readings for Long Bay may indicate catchment-based inputs. In April, EAP-PA5 and EPA-PA9 were above the Annual and Summer DGVs, EPA-PA1 and EPA-PA8 above the Annual DGV but equal to the Summer DGV, EPA-PA2 equal to the Annual DGV and the remaining sites at or below the LoR. Of note is that TAN for EPA-PA3 and EPA-PA4 for the surface waters remained below the LoR for the entire period.

For the monitoring period (October 2021 to May 2022) almost two-thirds (46 of 72 readings) of bottom water TAN (Total Ammoniacal Nitrogen) readings were either at or below the Limit of Reporting (LoR), being 0.005 mg/L. Of the remaining readings, nine were equal to or above the Annual DGV, of 0.010 mg/L, and five of these were above the Summer DGV of 0.013 mg/L. For October and May all TAN readings were below the Annual DGV value of 0.010 mg/L with the majority of readings being equal to or below the LoR for TAN (0.0005 mg/L). During November, TAN for EPA-PA7 was 0.015 mg/L. This indicates catchment-based inputs to the head of Long Bay from Long Bay Creek. As with the surface waters, during February and March the bottom waters for the sites within Long Bay were elevated. In February only EPA-PA5 was above the Summer DGV. The value of 0.032 mg/L was the highest for all sites across the monitoring period however it is only marginally higher than the maximum of the baseline period (0.028 mg/L). In March EPA-PA6 (0.023 mg/L), EPA-PA7 (0.030), EPA-PA8 (0.018 mg/L) and EPA-PA9 (0.015 mg/L). Of these sites only EPA-PA7 was higher than the baseline period. The elevation of TAN for the shallow sites with Long Bay and Carnarvon Bay indicates catchment-based inputs. During April no sites were above the Summer DGV and only EPA-PA5 (0.011 mg/L) was above the Annual DGV for bottom waters.

NO_3 (Nitrate)

From October to February all surface water NO_3 (nitrate) readings were below the Limit of Reporting (LoR), being 0.002 mg/L. This is consistent with the summer period values used in deriving the DGVs where only a single value was above the LoR from August 2013 to July 2017. In March, the Carnarvon Bay sites EPA-PA2 and EPA-PA9 were below the LoR, whilst all other sites were above the LoR but below the Annual DGV of 0.025 mg/L. The highest values recorded were for the 3 sites within the upper section of Long Bay, EPA-PA5 (0.012 mg/L), EPA-PA6 (0.012 mg/L) and EPA-PA7 (0.016 mg/L). This pattern indicates catchment-based inputs to Long Bay from Long Bay Creek. For April EPA-PA3 and EPA-PA4 had the highest values, being 0.005 mg/L and 0.012 mg/L, respectively. In April EPA-PA9 (0.003 mg/L) was the only other site that showed an increase with the remainder of sites being stable or decreasing. In May all sites showed a marked increase which was more pronounced at the deep-water sites and those nearer to the seaward extent of Port Arthur than sites within Long Bay. The pattern observed indicates and input of marine water into the region with diminishing effect closer to the head of Long Bay.

From October to February EPA-PA4 had the highest bottom water NO_3 (nitrate) readings and was above the Summer DGV of 0.009 mg/L in October (0.024 mg/L) and February (0.015 mg/L). For all other sites the readings were below the Summer DGV with the majority of readings being below the LoR for NO_3 of 0.002 mg/L. For March all sites displayed elevated NO_3 (nitrate) readings with the highest observed for the deep-water sites. EPA-PA4 (0.039 mg/L), EPA-PA3 (0.038 mg/L) and EPA-PA2 (0.036 mg/L) were above the Annual DGV, whilst EPA-PA1 was equal to the Annual DGV (0.027 mg/L). The elevated levels for bottom waters in March suggest an influx of water associated with the Southern Ocean. The bottom waters of the Long Bay sites were also elevated and were above the Summer DGV of 0.009 mg/L but below the Annual DGV of 0.027 mg/L. The lowest reading was for EPA-PA9 (0.009 mg/L) which is equal to the Summer DGV. For April all sites were below the Summer DGV, with the highest value observed being for EPA-PA4 (0.008 mg/L). For May all sites were above the Summer DGV but lower than the Annual DGV. For May the pattern observed for NO_3 (nitrate) readings reflects that of the surface waters with the deep-water sites and those nearer to the seaward extent of Port Arthur having higher readings than sites within Long Bay.

The pattern observed in nitrate values for bottom waters at the deep-water sites reflects the intrusion of marine water masses from outside of Port Arthur. The nature of the marine water is strongly influenced by eddies of the EAC, intrusion of the Zeehan current from the west and currents within the Southern Ocean and Tasman Sea. The Zeehan current is a dominant current during winter and extends down the west coast of Tasmania and then past the south east in an easterly direction. Much like the EAC which is a dominant current over summer the Zeehan current is relatively warm and low in nitrate concentration. In contrast waters brought in by currents from the Southern Ocean are of sub-Antarctic origin and tend to be relatively cool with elevated nitrate concentrations.

NOx (Nitrate and Nitrite)

From October to February all surface water NOx (nitrate and nitrite) readings were below the Limit of Reporting (LoR), being 0.002 mg/L. This is consistent with the summer period values used in deriving the DGVs where only a single value was above the LoR from August 2013 to July 2017. In March, the Carnarvon Bay sites EPA-PA2 and EPA-PA9 were below the LoR, whilst all other sites were above the LoR but below the Annual DGV of 0.002 mg/L. The highest values recorded were for the 3 sites within the upper section of Long Bay, EPA-PA5 (0.014 mg/L), EPA-PA6 (0.014 mg/L) and EPA-PA7 (0.019 mg/L). This pattern indicates catchment-based inputs to Long Bay from Long Bay Creek. For April EPA-PA3 and EPA-PA4 had the highest values, being 0.006 mg/L and 0.014 mg/L, respectively. In April EPA-PA9 (0.003 mg/L) was the only other site that showed an increase with the remainder of sites being stable or decreasing. In May all sites showed a marked increase which was more pronounced at the deep-water sites and those nearer to the seaward extent of Port Arthur than sites within Long Bay. The pattern observed indicates an input of marine water into the region with diminishing effect closer to the head of Long Bay. Of note is that EPA-PA3 was equal to the Annual DGV of 0.024 mg/L and that EPA-PA4 which is the most seaward site was higher (0.028 mg/L).

From October to February EPA-PA4 had the highest bottom water NOx (nitrate and nitrite) readings and was above the Summer DGV of 0.005 mg/L in October (0.031 mg/L), November (0.007 mg/L) and February (0.017 mg/L). For all other sites the readings were below the Summer DGV with the majority of readings being below the LoR for NO_x of 0.002 mg/L. For March all sites displayed elevated NOx (nitrate and nitrite) readings with the highest observed for the deep-water sites. EPA-PA4 (0.044 mg/L), EPA-PA3 (0.044 mg/L) and EPA-PA2 (0.041 mg/L) were above the Annual DGV, whilst EPA-PA1 was equal to the Annual DGV (0.033 mg/L). The elevated levels for bottom waters in March suggest an influx of water associated with the Southern Ocean. The bottom waters of the Long Bay sites were also elevated and were above the Summer DGV of 0.005 mg/L but below the Annual DGV of 0.033 mg/L. Interestingly the lowest reading was for the shallow Carnarvon Bay sites (EPA-PA9) with a value of 0.010 mg/L. For April all sites except for EPA-PA4 with a reading of (0.009 mg/L) were below the Summer DGV. Of note is that the 3 sites within the upper section of Long Bay, EPA-PA5, EPA-PA6, and EPA-PA7 were below the LoR for NO_x of 0.002 mg/L. For May all sites were above the Summer DGV but lower than the Annual DGV. For May the pattern observed for NOx (nitrate and nitrite) readings reflects that of the surface waters with the deep-water sites and those nearer to the seaward extent of Port Arthur having higher readings than sites within Long Bay.

The pattern observed in NOx values for bottom waters at the deep-water sites reflects the intrusion of marine water masses from outside of Port Arthur, as described for Nitrate above.

Total Kjeldahl Nitrogen (TKN)

For October the Total Kjeldahl Nitrogen (TKN) readings for surface waters at all sites were below the Summer DGV of 0.29 mg/L. For November and December, the sites within Long Bay were equal to the Annual DGV of 0.31 mg/L or above. The remaining sites recorded values of 0.30 mg/L or lower. For January the readings for EPA-PA1, EPA-PA2, EPA-PA3 and EPA-PA4 were below the Summer DGV, with the remaining sites recording readings between 0.29 mg/L to 0.31 mg/L. For February to May the higher readings tended to be within Long Bay. The deep-water sites (EPA-PA2, EPA-PA3 and EPA-PA4) and the shallow site for Carnarvon Bay (EPA-PA9) were at or below the Summer DGV period for these months. The range observed for surface water TKN levels for EPA-PA1 to EPA-PA4 is encompassed by that of the baseline period, being 0.16 mg/L to 0.38 mg/L.

For October the Nitrogen total readings for bottom waters at all sites were below the Summer DGV value of 0.29 mg/L. For November to May the shallow water sites in Long Bay (EPA-PA5 to EPA-PA8) recorded readings equal to the Summer DGV or higher. The shallow water Carnarvon Bay site (EPA-PA9) as with the sites in Long Bay was equal to the Summer DGV or higher for this period. The exception being April where a value of 0.27 mg/L was observed. For December, EPA-PA1, EPA-PA2 and EPA-PA3 recorded values of 0.31 mg/L, whilst EPA-PA4 recorded a value of 0.25 mg/L. For February to May, EPA-PA1 and EPA-PA4 reached a maximum of 0.3 mg/L (equal to the Annual DGV), EPA-PA3 a maximum of 0.29 mg/L (equal to the Summer DGV) and EPA-PA2 a maximum of 0.32 mg/L. The range observed for bottom water TKN levels for EPA-PA1 to EPA-PA4 is encompassed by that of the baseline period, being 0.15 mg/L to 0.42 mg/L.

Nitrogen (total)

For October the Nitrogen total readings for surface waters at all sites were below the Summer DGV value of 0.30 mg/L. For November to May the shallow water sites in Long Bay (EPA-PA5 to EPA-PA8) recorded readings equal to the Summer DGV or higher. In December, March, and April the readings for these sites were above the Annual DGV of 0.32 mg/L. It should be noted that the maximum recorded for these sites was 0.35 mg/L which is within the range observed for the baseline period (0.16 mg/L to 0.46 mg/L) and lower than the summer maxima of 0.42 mg/L. EPA-PA9 in contrast was equal to the Summer DGV in November, December, and May but lower from January to April. The pattern observed for the deep-water sites EPA-PA2 to EPA-PA4 differed from the shallow water sites. EPA-PA4 was below the Summer DGV for all months, EPA-PA2 for all months except December when it was equal to and EPA-PA3 for all months except May when it was above (0.31 mg/L). EPA-PA1 was more similar to the shallow water sites within Long Bay than the deep-water sites. In January and April, the readings for EPA-PA1 were below the Summer DGV, in November between the Summer and Annual DGV (0.31 mg/L), in February and March equal to the Annual DGV and in December and April above the Annual DGV with values of 0.33 mg/L.

For October the Nitrogen total readings for bottom waters at all sites were below the Summer DGV value of 0.30 mg/L. For November to May the shallow water sites in Long Bay (EPA-PA5 to EPA-PA8) recorded readings equal to the Summer DGV or higher. The only exceptions being EPA-PA5 in January and EPA-PA8 in May where the observed values were 0.29 mg/L. Interestingly the bottom waters of EPA-PA9 tend to be higher than that of the surface waters. For November, February, and April the observed values were below the Summer DGV, in January and March equal to the Summer DGV, and for May above the Summer DGV but below the Annual DGV of 0.32 mg/L. In December the recorded value was 0.33 mg/L, which was above the Annual DGV of 0.32 mg/L. As for the surface waters the pattern observed for the deep-water sites differed to that of the shallow water sites. Of note is that EPA-PA2, EPA-PA3 and EPA-PA4 had readings above the Summer DGV on more occasions and EPA-PA1 on less occasions than did the surface waters. The highest readings for the deep-water sites were at EPA-PA1 and EPA-PA2 in March with the values being 0.33 mg/L. For the baseline period bottom water readings ranged from 0.16 mg/L to 0.45 mg/L, with a March maxima of 0.33 mg/L.

For all sites, organic nitrogen represents the majority of nitrogen within surface and bottom waters. Organic Nitrogen (ON) is calculated by removing the TAN component from Total Kjeldahl Nitrogen (TKN). The relative proportions of TAN, NOx, and organic nitrogen for each site on a monthly basis for surface and bottom waters are presented in Appendix 1.

Phosphorus (total)

For October, November, December all March all sites recorded Phosphorus total readings for surface waters tended below the Annual and Summer DGVs of 0.030 mg/L. For January all sites except for EPA-PA7 were below the DGVs. EPA-PA7 recorded a value of 0.031 during January. For February EPA-PA7 remained above the DGV recording a value of 0.034 mg/L. EPA-PA1 was equal to the DGVs whilst all other sites were below the DGVs. For March all sites within Long Bay were equal to or above the DGVs with the highest reading being recorded for EPA-PA7, being 0.037 mg/L. All other sites were below the DGVs. For April all sites were below the DGVs. The highest value recorded was 0.028 mg/L at EPA-PA5, EPA-PA6 and EPA-PA9. For May EPA-PA7 and EPA-PA8 were above the DGVs with values of 0.033 mg/L and 0.031 mg/L respectively. The remaining sites were below the DGVs of 0.030 mg/L. These values are well below the maximum recorded for the baseline period, being 0.07 mg/L for surface waters.

For all months the readings for bottom waters were below the Annual and Summer DGVs of 0.040 mg/L. EPA-PA7 had the highest readings of all sites in November (0.030 mg/L), December (0.033 mg/L), February (0.032 mg/L) and March (0.037 mg/L). EPA-PA6 also tended to be elevated during the above months but was highest for all sites in January (0.035 mg/L). The elevated readings for EPA-PA7 and EPA-PA6 may indicate catchment-based inputs. For the baseline period bottom water readings for Phosphorus total ranged from 0.020 mg/L to 0.070 mg/L.

DRP (Dissolved Reactive Phosphorus)

For October to February all surface water DRP (Dissolved Reactive Phosphorus) readings were or below the Summer DGV of 0.006 mg/L, except for EPA-PA7 during January and February. For January, EPA-PA7 had a reading of 0.007 mg/L, which is above the Summer DGV but below the Annual DGV (0.008 mg/L), and in February a reading of 0.006 mg/L which is equal to the Summer DGV. For March all sites showed a marked increase with the Long Bay sites being above the Annual DGV of 0.008 mg/L. EPA-PA6 and EPA-PA3 were equal to or above the Summer DGV with values of 0.006 mg/L and 0.007 mg/L respectively. EPA-PA2 and EPA-PA4 had the lowest readings for March with values of 0.005 mg/L. In April all deep-water sites recorded values of 0.006 mg/L (equal to the Summer DGV) and all shallow water sites recorded values of 0.007 mg/L. In May all sites showed an increase in DRP readings. EPA-PA1, EPA-PA2, EPA-PA5, EPA-PA8 and EPA-PA9 recorded values of 0.008 mg/L (equal to the Annual DGV). EPA-PA3, EPA-PA4 and EPA-PA6 recorded values of 0.009 mg/L, whilst EPA-PA7 recorded the highest value (0.011 mg/L).

For October to February bottom water DRP (Dissolved Reactive Phosphorus) readings were equal to or lower than the Summer DGV on all but 2 occasions. In October EPA-PA4 recorded a value of 0.009 mg/L and in November EPA-PA6 recorded a value of 0.009 mg/L. In March all sites showed a marked increase in DRP levels. EPA-PA3 and EPA-PA9 recorded values of 0.008 mg/L (equal to the Summer DGV), and EPA-PA1, EPA-PA2 and EPA-PA4 recorded values of 0.009 (equal to the Annual DGV). The shallow water sites in Long Bay (EPA-PA5, EPA-PA6, EPA-PA7 and EPA-PA8) recorded values above the Annual DGV. The highest values were at EPA-PA6 and EPA-PA7, with values of 0.012 mg/L and 0.015 mg/L, respectively. The elevated reading for EPA-PA6 and EPA-PA7 may indicate catchment-based inputs. In April all sites recorded values equal to or below the Summer DGV. EPA-PA7 recorded the lowest value of 0.005 mg/L. In May only two sites had values above the Summer DGV, being EPA-PA4 and EPA-PA7. Unlike the surface water readings, the highest reading was at EPA-PA4 (0.01 mg/L) rather than EPA-PA7 (0.009 mg/L).

Chlorophyll a

Chlorophyll a levels trended downwards for all sites except EPA-PA7 from October to February. EPA-PA7, which is the most upstream site in Long Bay showed an increase in chlorophyll a in January (1.5 µg/L) and February (1.7 µg/L) and was the only site that equaled or exceeded the Annual DGV of 1.5 µg/L for these months. In March all sites, except for EPA-PA4 were below the Summer DGV of 1.0 µg/L. EPA-PA4 recorded a reading of 1.1 µg/L. For April and May, EPA-PA7 was equal to or higher than the Annual DGV. EPA-PA6 was the only other site that exceeded the Annual DGV, and this only occurred during April.

It is not uncommon that chlorophyll a concentration is higher in shallow areas where light is not limited, and nutrients are available. The higher chlorophyll a levels for the shallow Long Bay sites (EPA-PA5, EPA-PA6, EPA-PA7, and EPA-PA8) indicate a higher level of nutrient availability compared to the shallow Carnarvon Bay site (EAP-PA9) which is of similar depth and water clarity.

Epiphytic Algal growth

The three snapshots of epiphytic growth show no clear trend in relation to location or season. For the sites within Long Bay, sites SG_PA17 and SG_PA9 exhibited their highest epiphyte growth in spring 2021, their lowest in summer 2022 and an increase in autumn 2022. Sites SG_PA16 and SG_PA4 displayed a similar level of epiphyte growth for spring 2021 and autumn 2022. Site SG_PA16 exhibited Low (minimal) epiphytic growth and SG_PA4 Medium (obvious) epiphytic growth. Due to tidal conditions sampling was not possible at SG_PA16 and SG_PA4 at the time the summer snapshot was conducted. For the sites within Stewarts Bay, sites SG_PA29 and SG_PA30 exhibited their highest levels in summer 2022 and dropped to below the spring 2021 levels in Autumn 2022. Site SGA_PA28 exhibited Low (minimal) epiphytic growth which steadily increased to Medium (obvious) in Summer 2022 and Autumn 2022.

Conclusion

The data reviewed in this document indicates that the water quality of the Port Arthur area is akin to that of the baseline period on which the DGVs were derived. For most parameters the levels have remained within the overall range of the baseline dataset even when lower or greater than the DGVs.

Water within the Port Arthur area is chiefly of marine origin and nature. The upper section of Long Bay is at times subject to catchment runoff following rainfall events. Some elevation in TAN and Nitrogen (total) is discernible within waters near the finfish lease. These elevations are not persistent over the period surveyed and seem to be limited to the surface water in the immediate vicinity of the lease as noted at EPA-PA1. Nutrient availability from marine inputs, catchment runoff and the finfish lease contribute to the elevated Chlorophyll a levels noted within Long Bay.

The pattern of epiphytic growth is not consistent for sites within Long Bay and or Stewarts Bay. The patterns observed are not clearly related to location or season.

Recommendations

- Repeat water quality monitoring for 2022/2023 Stocking season.
- Collection of water quality data from Long Bay Creek to determine water quality characteristics of the main catchment input to Long Bay.
- Continue deployment of in-situ water quality sensors in Long Bay and Boomer Bay.
- Review of existing ADCP information to determine if additional deployments may enhance the understanding of hydrodynamics in Long Bay.
- Investigate feasibility of region specific biogeochemical modelling.

Appendix I

Surface Water Nitrogen Compounds

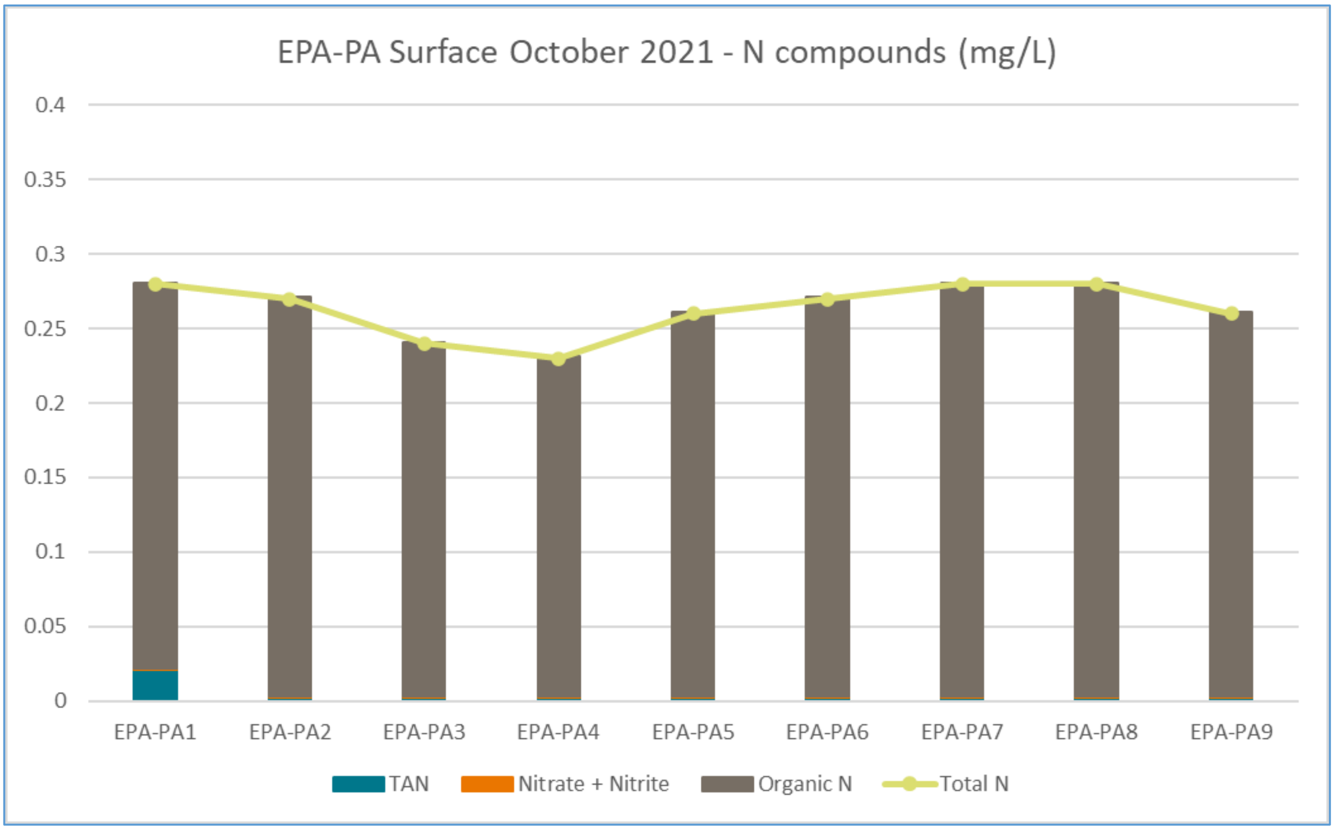


Figure 26: October 2021 surface water nitrogen compounds and budget for Port Arthur.

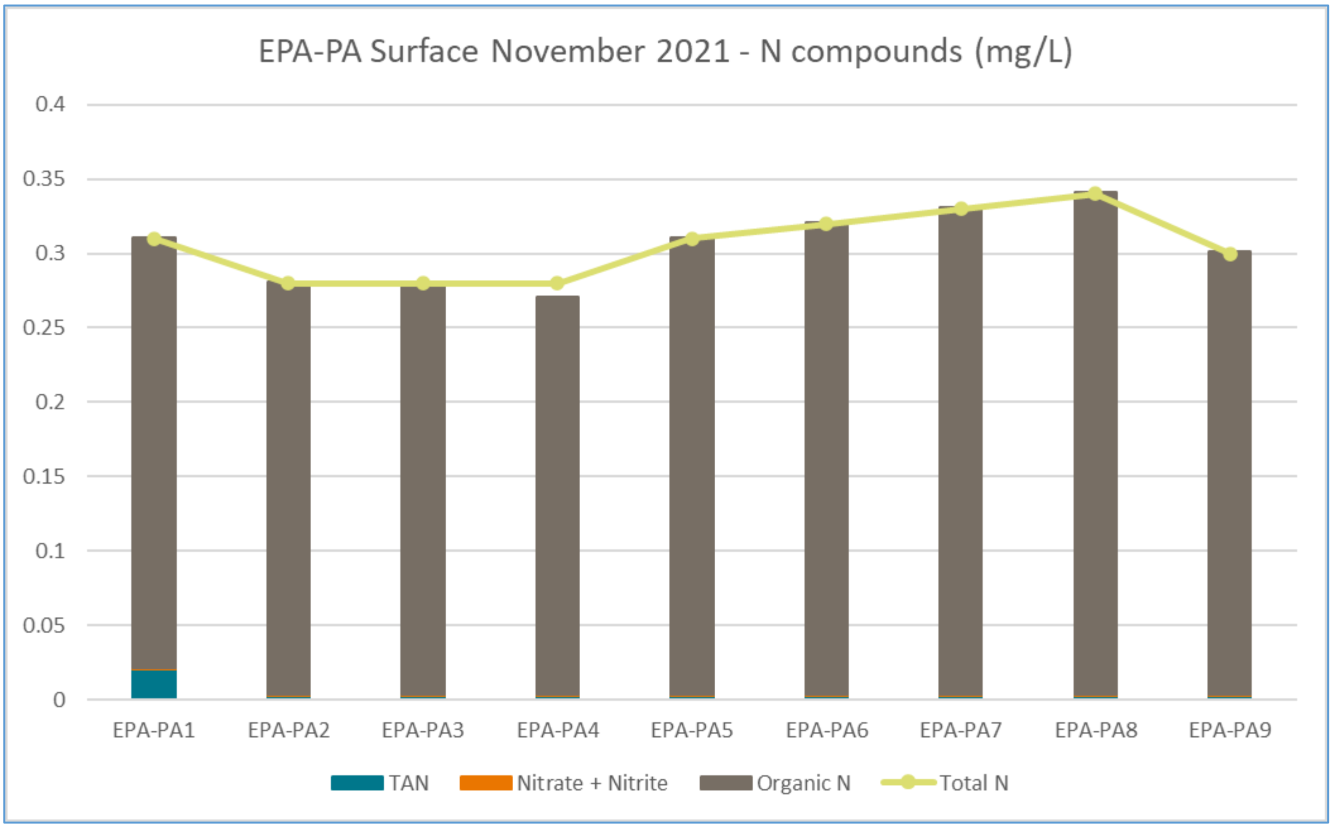


Figure 27: November 2021 surface water nitrogen compounds and budget for Port Arthur.

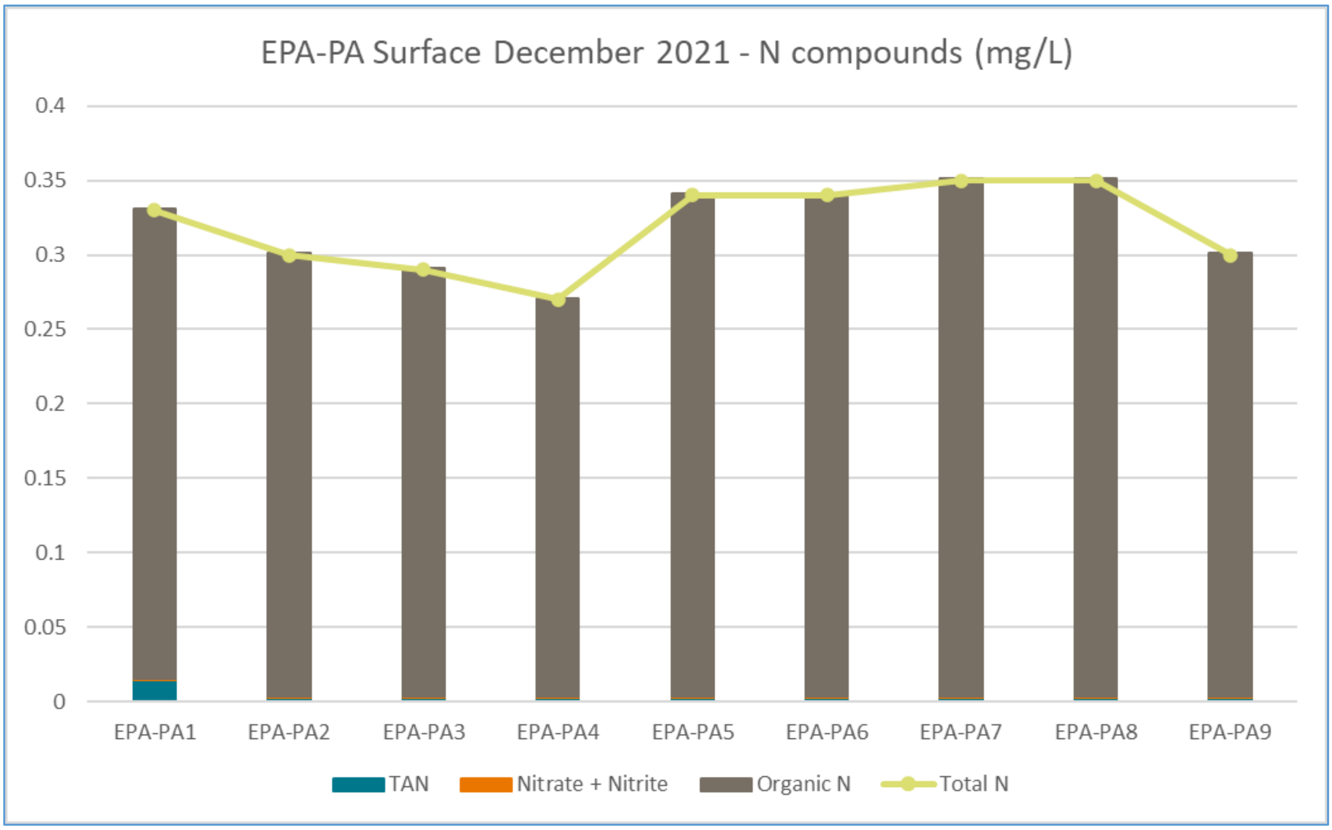


Figure 28: December 2021 surface water nitrogen compounds and budget for Port Arthur.

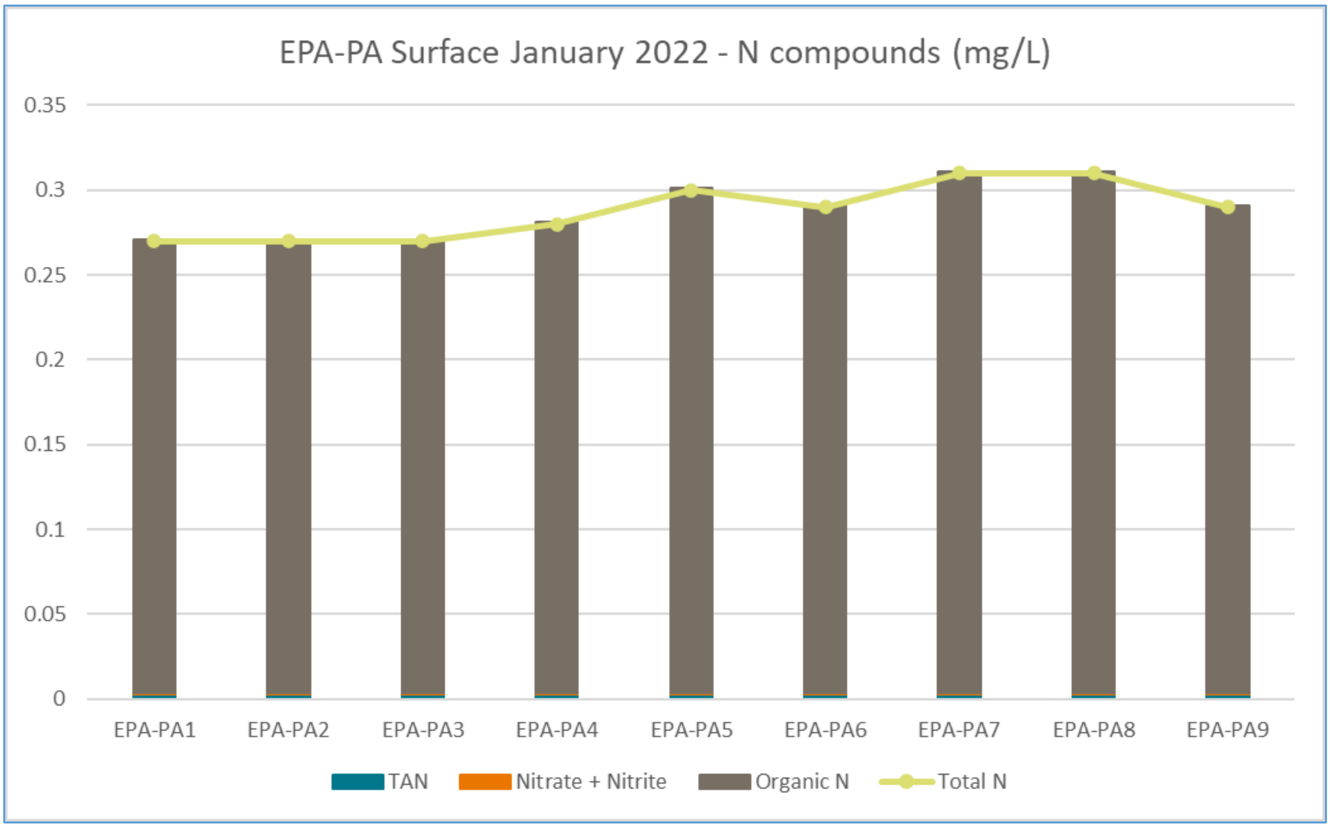


Figure 29: January 2022 surface water nitrogen compounds and budget for Port Arthur.

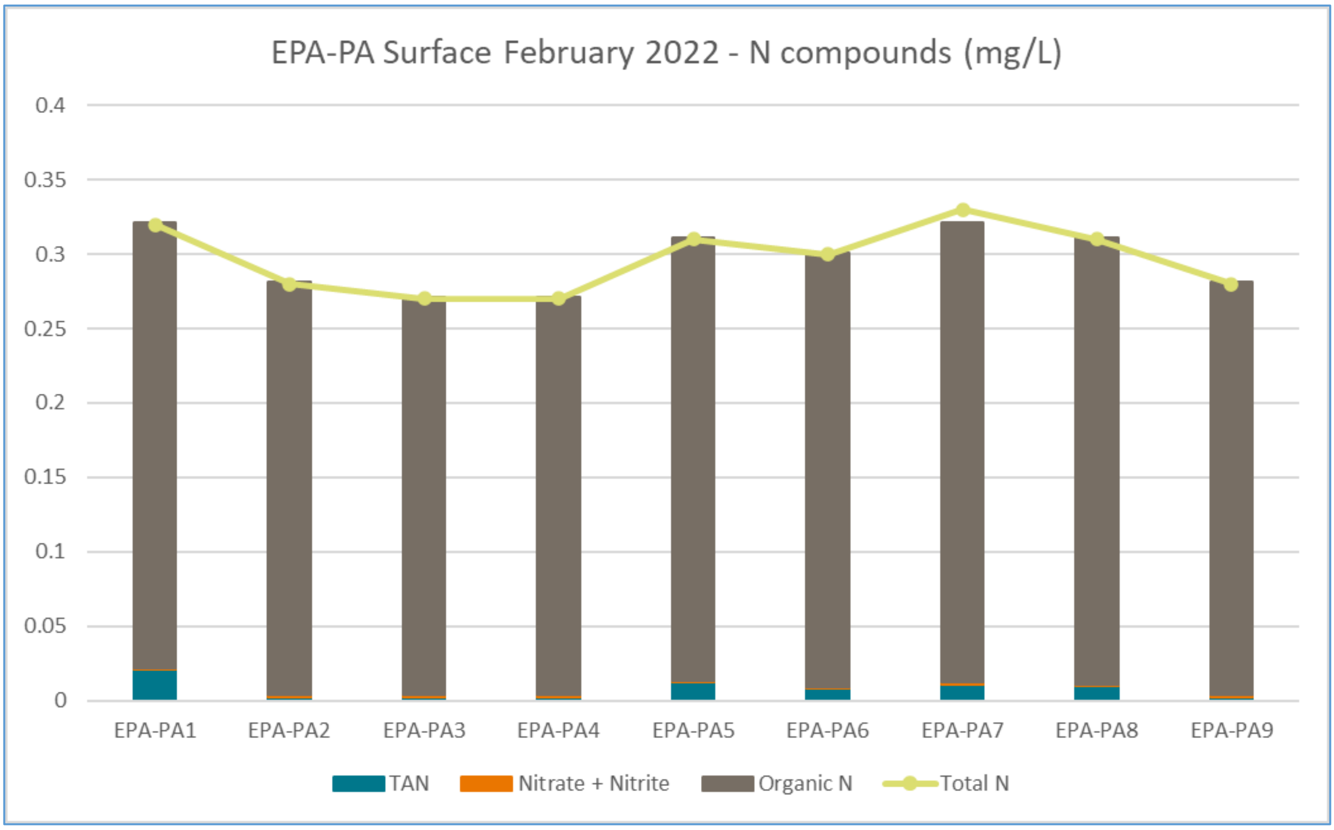


Figure 30: February 2022 surface water nitrogen compounds and budget for Port Arthur.

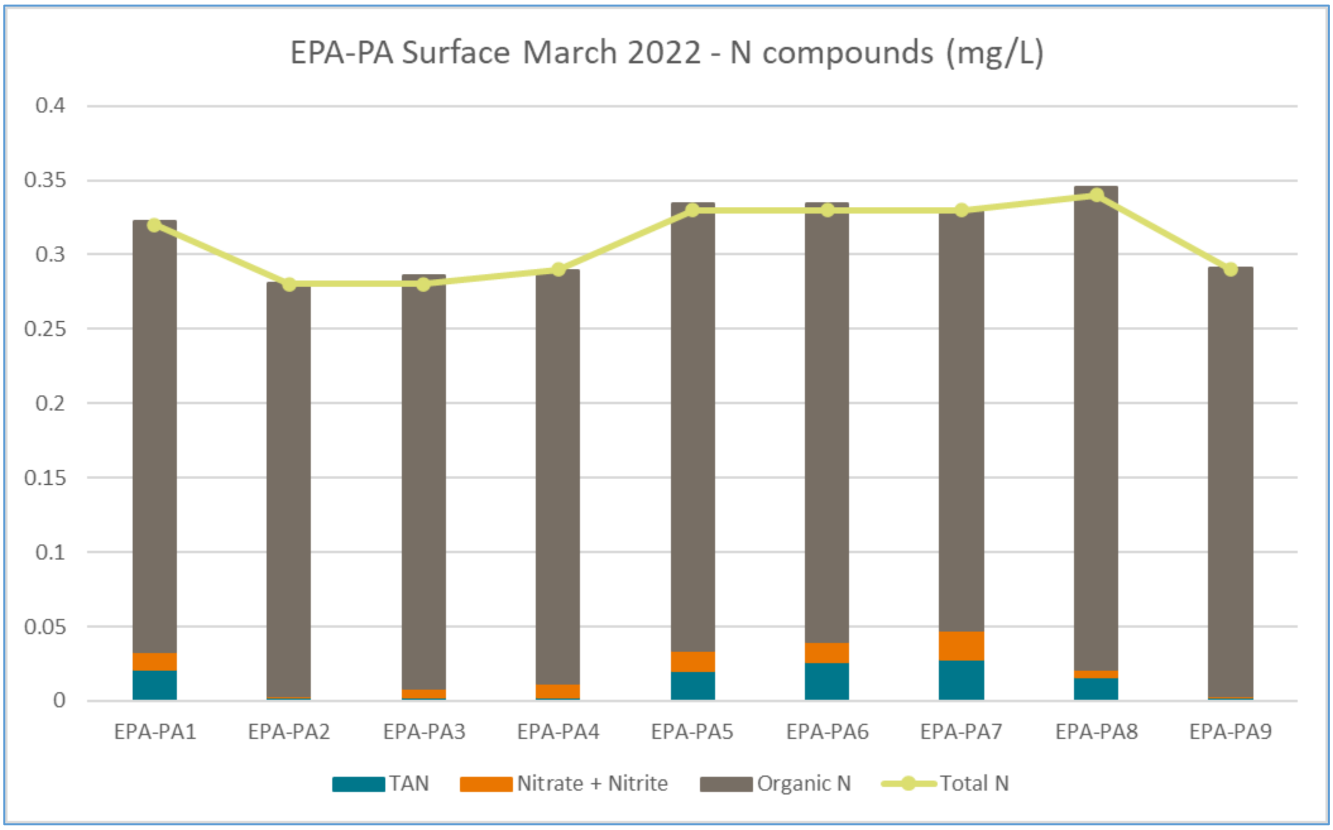


Figure 31: March 2022 surface water nitrogen compounds and budget for Port Arthur.

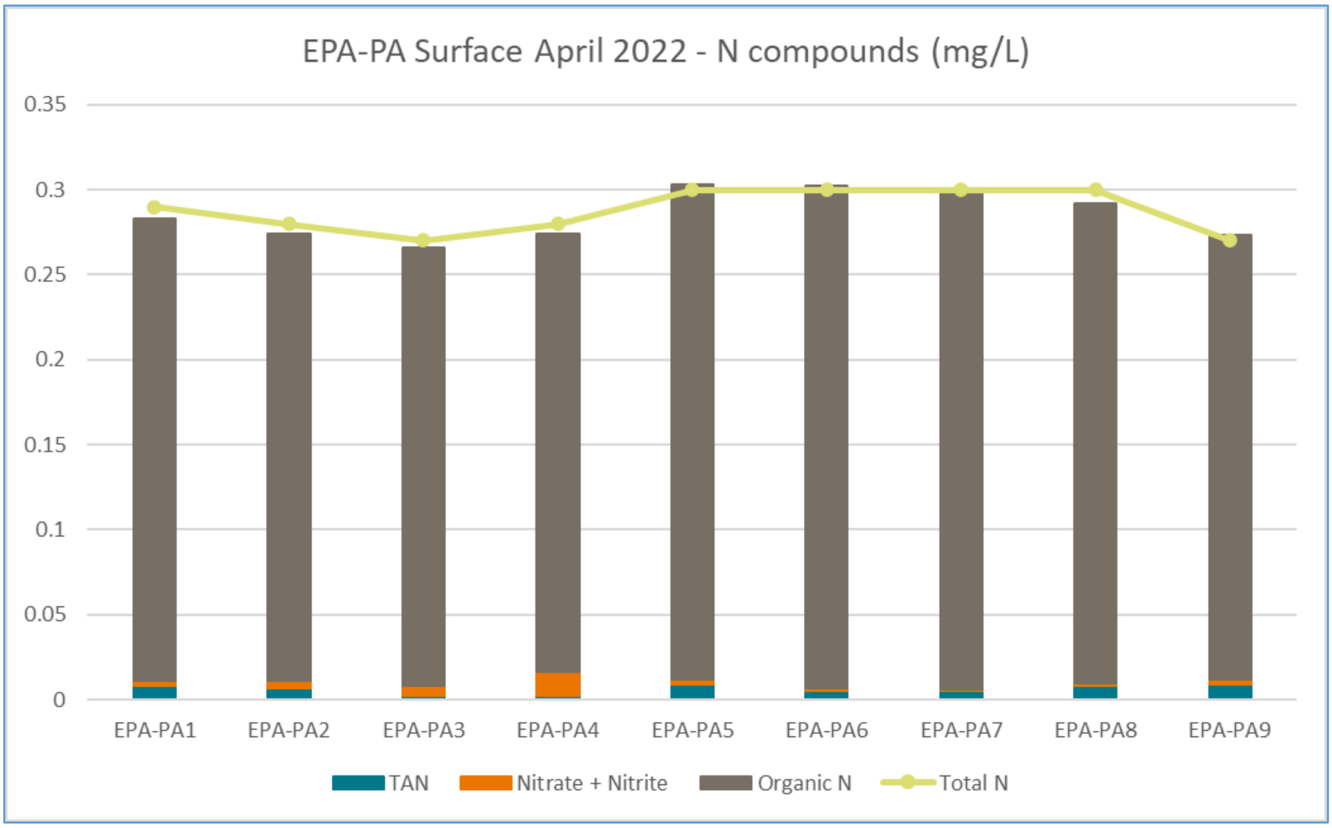


Figure 32: April 2022 surface water nitrogen compounds and budget for Port Arthur.

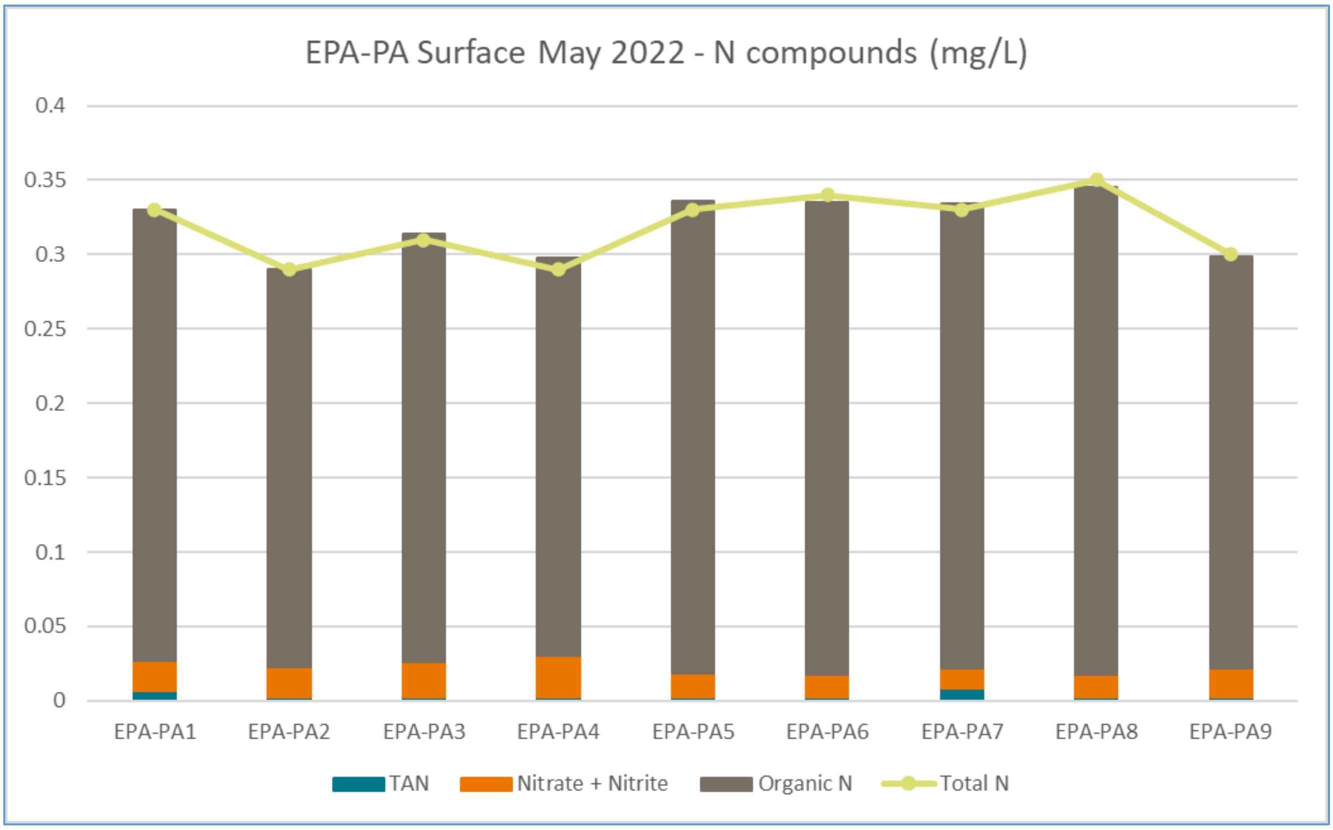


Figure 33: May 2022 surface water nitrogen compounds and budget for Port Arthur.

Bottom Water Nitrogen Compounds

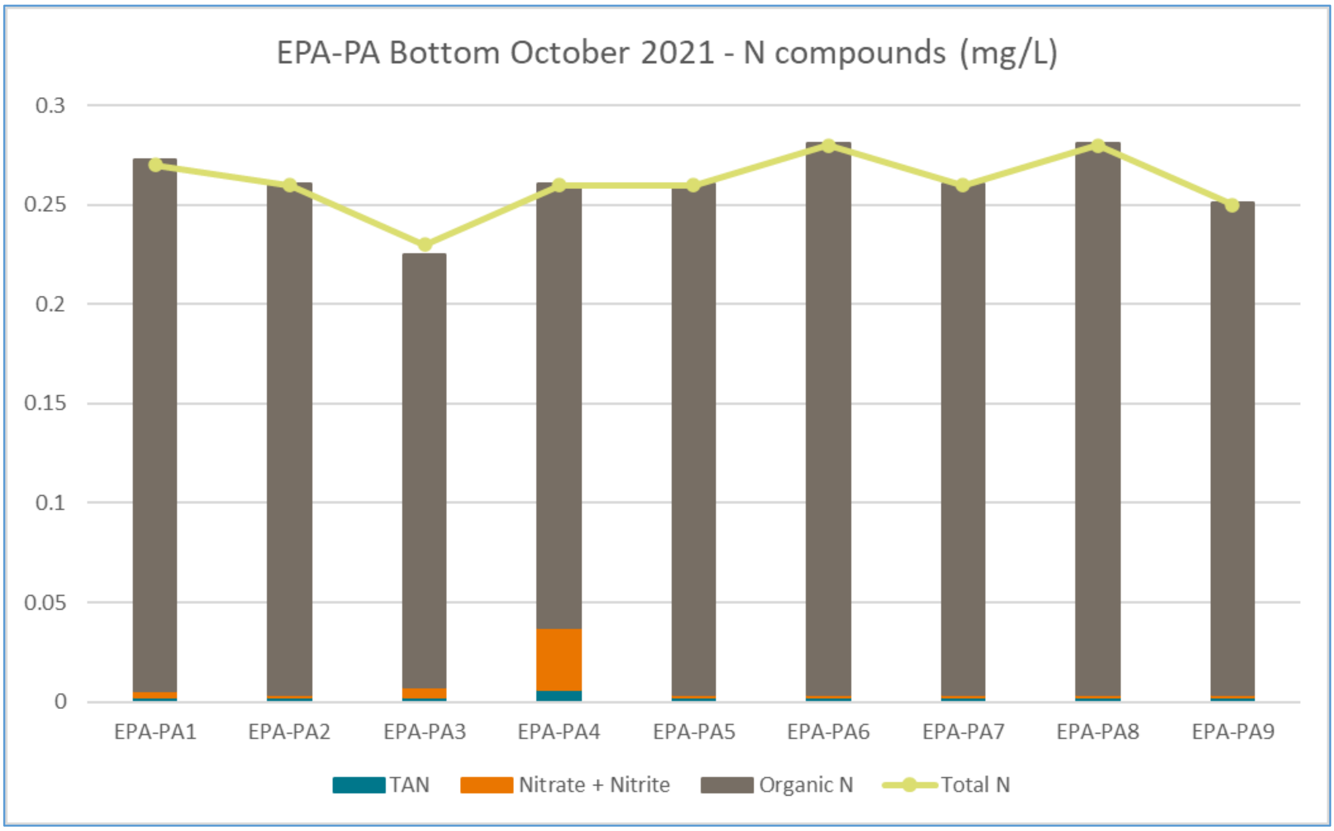


Figure 34: October 2021 bottom water nitrogen compounds and budget for Port Arthur.

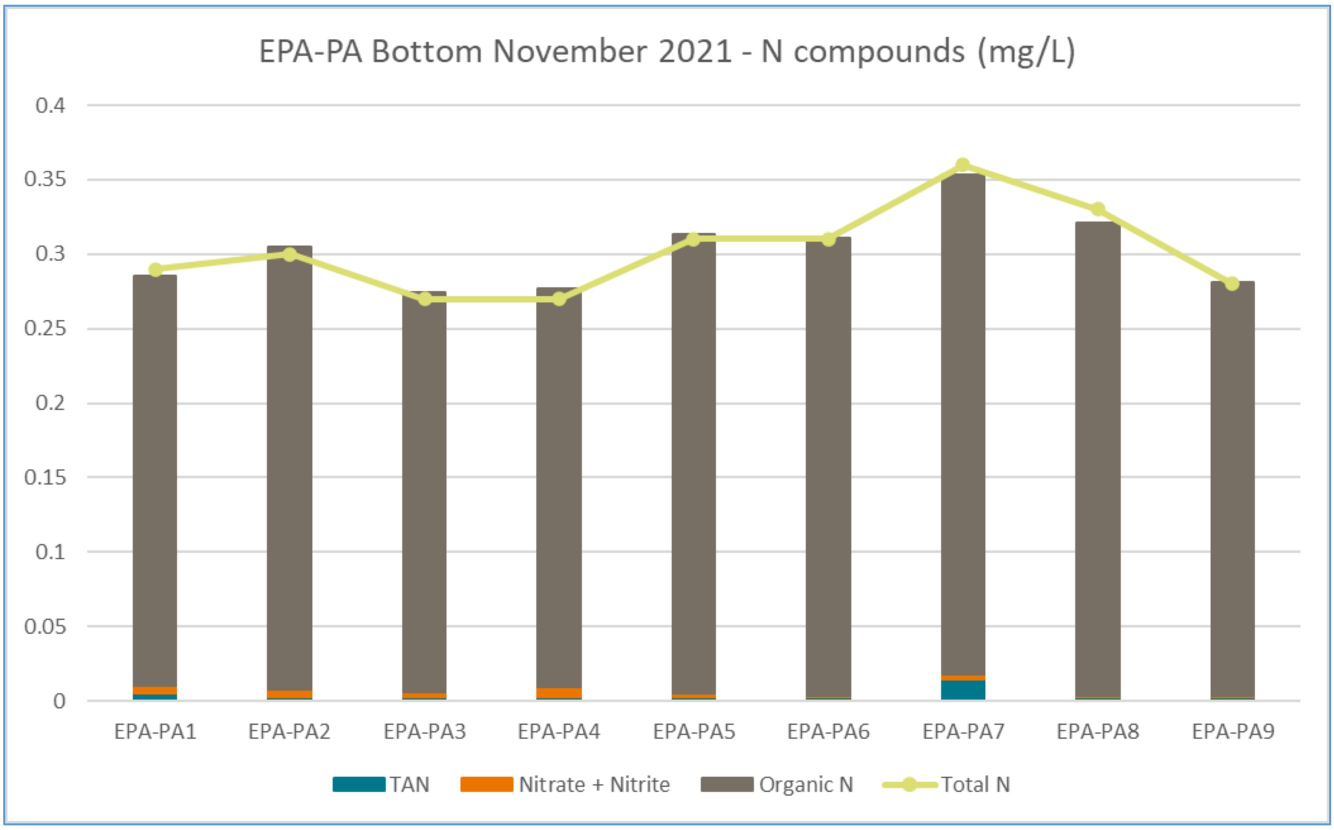


Figure 35: November 2021 bottom water nitrogen compounds and budget for Port Arthur.

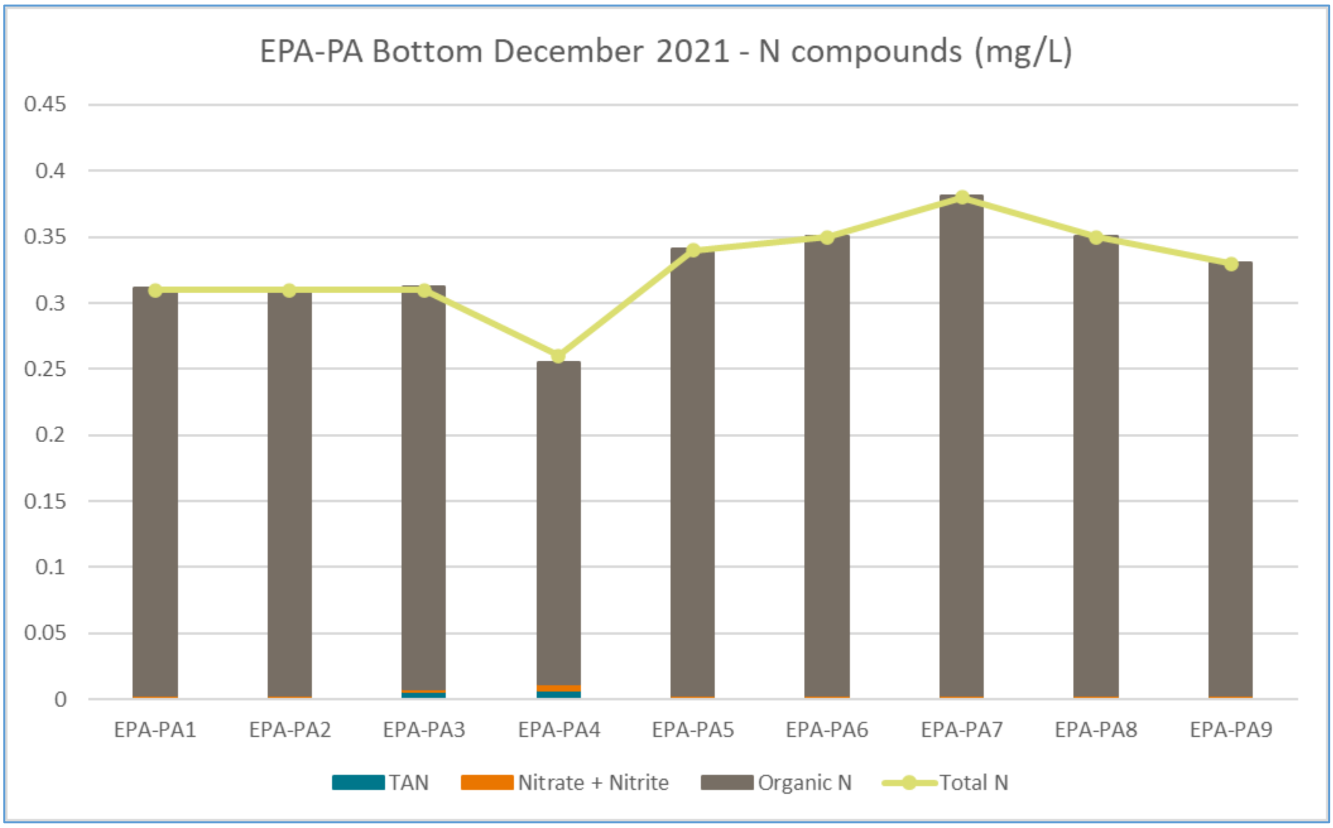


Figure 36: December 2021 bottom water nitrogen compounds and budget for Port Arthur.

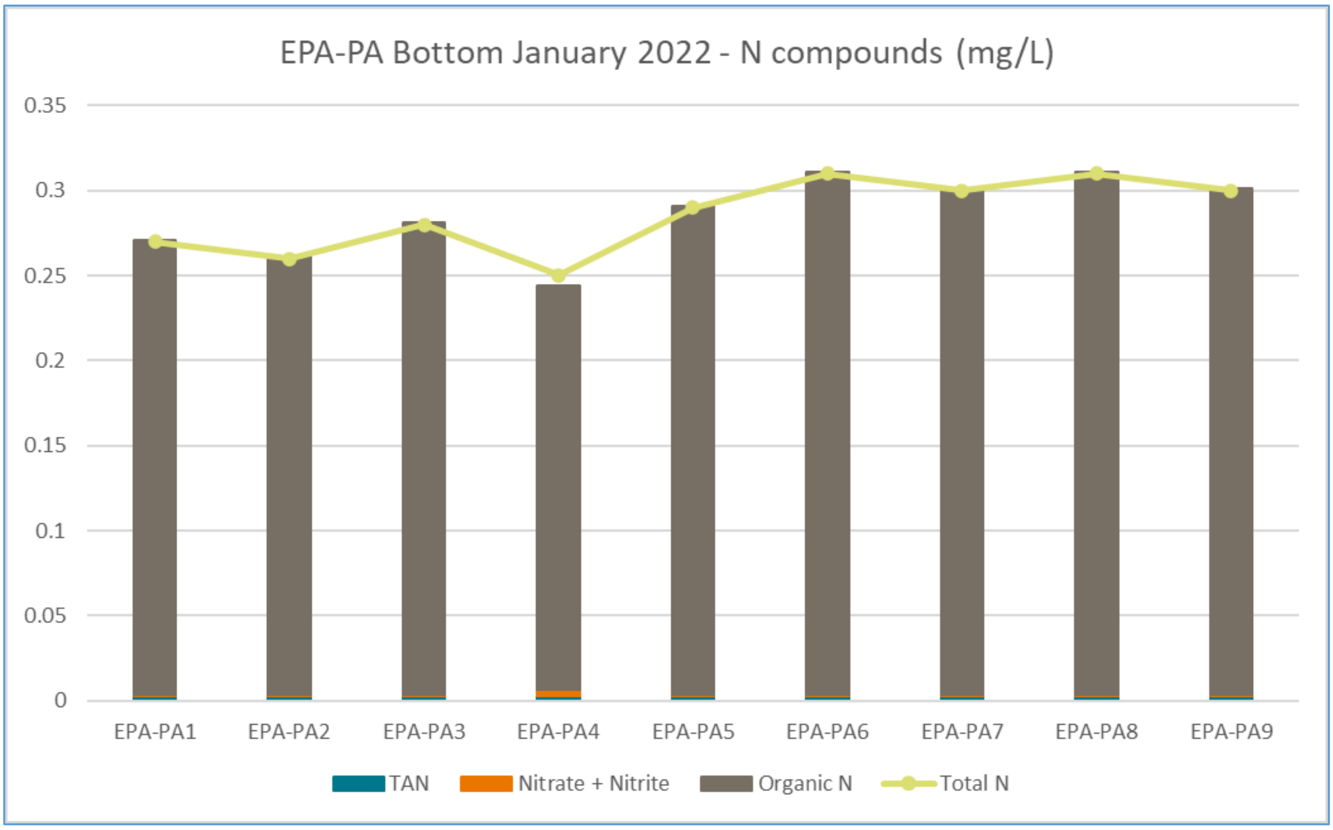


Figure 37: January 2022 bottom water nitrogen compounds and budget for Port Arthur.

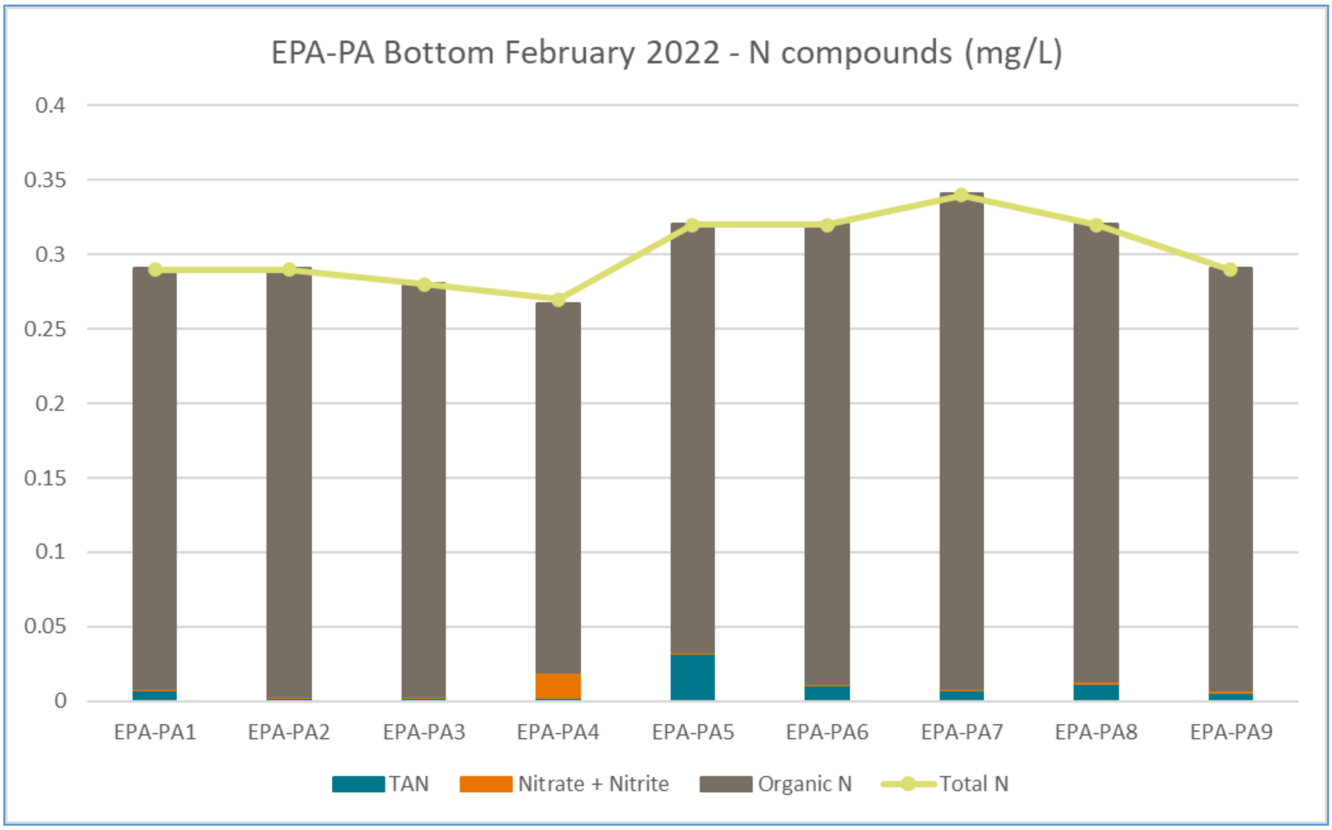


Figure 38: February 2022 bottom water nitrogen compounds and budget for Port Arthur.

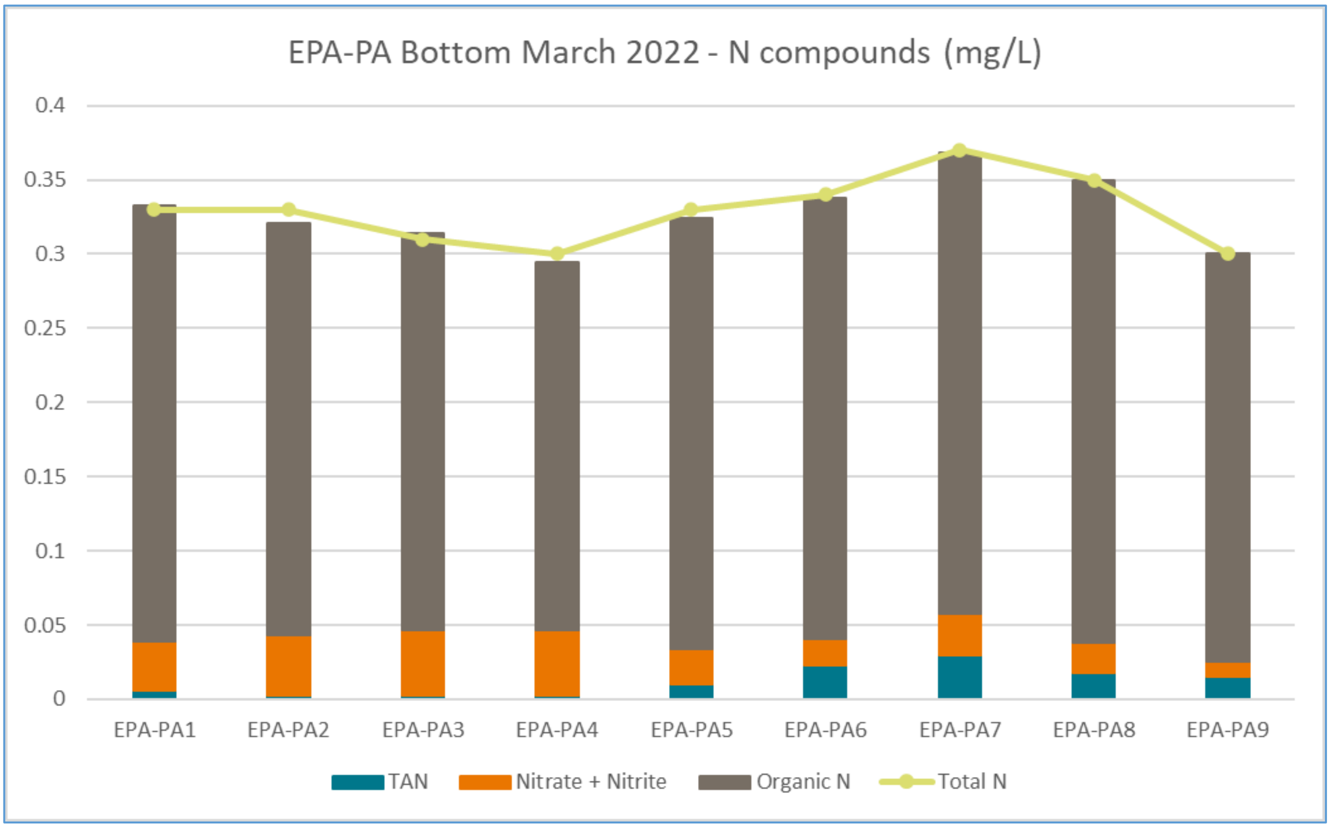


Figure 39: March 2022 bottom water nitrogen compounds and budget for Port Arthur.

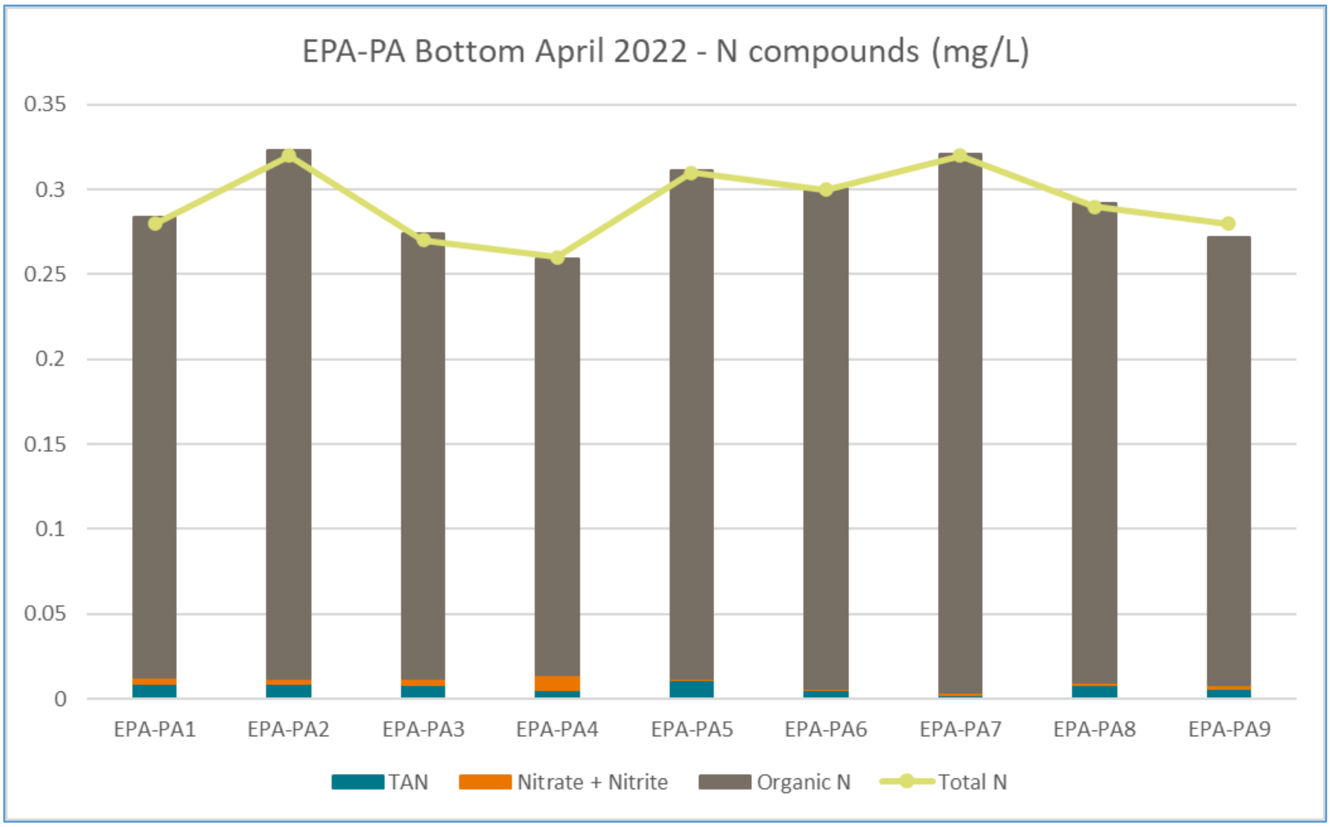


Figure 40: April 2022 bottom water nitrogen compounds and budget for Port Arthur.

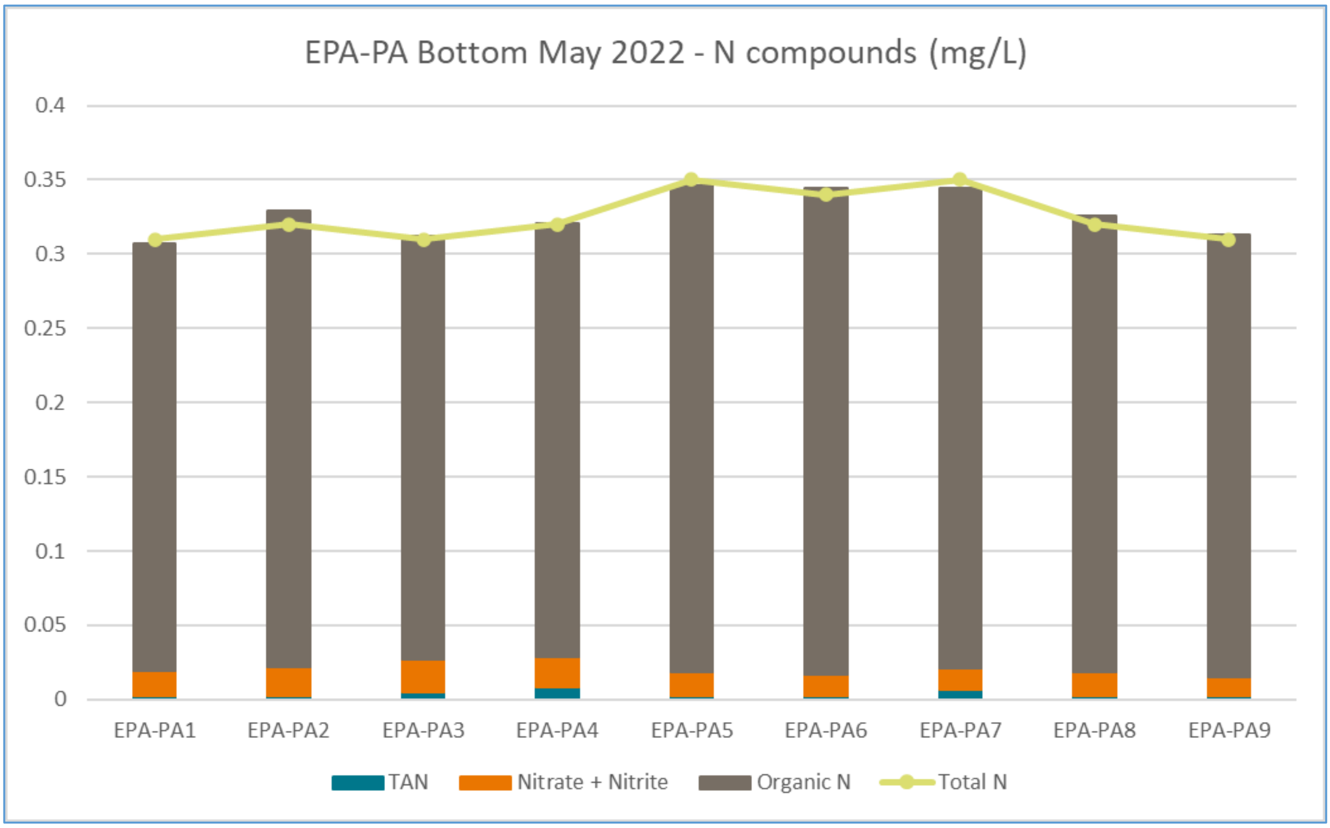


Figure 41: May 2022 bottom water nitrogen compounds and budget for Port Arthur.

Appendix 2

Dissolved oxygen logger results for Long Bay and Boomer Bay

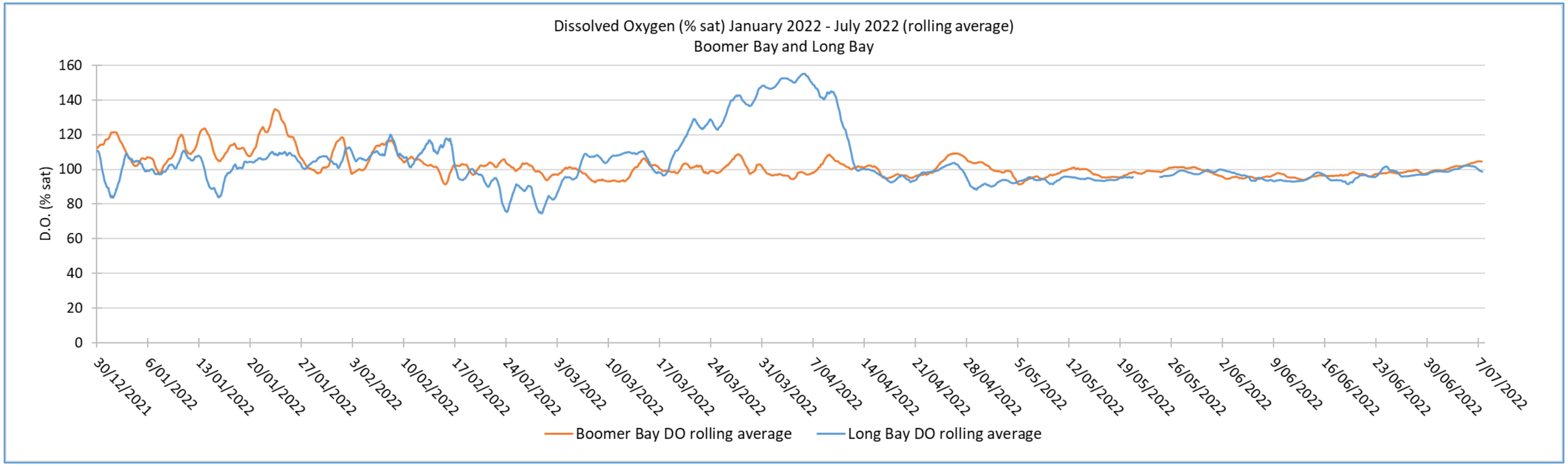


Figure 42: Dissolved Oxygen logger values for Long Bay and Boomer Bay for January 2022 to July 2022.

epa TASMANIA

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