Lyttelton Port Company
Channel Deepening Project
Environmental Monitoring

Water Quality Environmental Monitoring Services – Monthly Report

December 2018

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Summary

Since September 2016, Vision Environment (VE) has been undertaking water quality monitoring for the Environmental Monitoring and Management Plan (EMMP) associated with the Lyttelton Port Company (LPC) Channel Deepening Project (CDP) (Envisor, 2018). Baseline datasets were acquired from three spoil ground sites (SG1, SG2 and SG3), seven offshore sites (OS1 to OS7) and five inshore sites (UH1 to UH3, CH1 and CH2) to assess potential impacts of the dredging project.

Construction works as part of the 'Lyttelton Harbour wastewater scheme' which commenced in July 2018, were completed on 14 December 2018. Dredging operations for the CDP, which commenced on 29 August 2018 were also completed on 29 November 2018, taking the monitoring into a post dredge phase. Continuing with the dredge phase monitoring report format, the monthly report includes comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 (Fox, 2018). Monitoring results collected during December 2018 are presented within this report. This includes KZ filtered data, which although not applicable to the post dredge phase, was compared to compliance trigger values during dredging operations.

Climatic Conditions: Rainfall at Cashin Quay during December 2018 totalled 38.2 mm, lower than precipitation levels (58 mm) experienced the previous month. Climatic conditions in December were considered fairly mild compared to conditions in November, where stronger wind speeds and a large flow from the Waimakariri River resulted in significant changes in a number of physiochemical parameters at all sites. Mean inshore wind speeds ranged from 4.8 to 10.9 knots with highest wind speeds in the first week of December. Peak wave heights of 2.0 m also occurred on 1 December. Air temperatures continued the seasonal warming trend, with a monthly average of 16°C, approximately 3°C higher than in November.

Currents: ADCP units at sites SG1 and SG3 remained offline during December 2018 and are scheduled for maintenance in early 2019. Current data received from the Watchkeeper buoy at SG2a is included within this report.

Coinciding with highest monthly wave heights and wind speeds in the first week of December, maximum near-surface current velocity reached 342 mm/s at the near surface on 4 December and 286 mm/s near the seabed on 1 December. As typically observed the monthly mean current speed was higher at the near-seabed than at the surface with velocities overall lower than those observed during the more challenging sea states of November. Consistent with previous directional data acquired from SG1 and SG3, currents at SG2a displayed a strong dominance of flow along a west to east axis.

Turbidity: Consistent with previous results, turbidity was higher at the inshore monitoring sites of the central and upper harbour, than at nearshore and offshore monitoring locations. Mean turbidity values for December in addition to percentile statistics were lower than they were during the previous months and lower than those recorded during the baseline monitoring period, reflecting calmer sea states. Flocculation of fine sediments which occurred in mid-November at inshore sites after freshwater inundation from the Waimakariri River, is likely to have removed the fine sediments that were previously available for resuspension resulting in lower inshore turbidity.

Continuing previous monthly trends, turbidity at site CH2 located in the southern harbour tended to be overall lower than other inshore sites. Site UH2 which had previously also displayed overall lower values until mid-November, continued to trend with other inshore sites during December. Turbidity at offshore and spoil ground sites remained fairly stable after the first week in December, responding to increased wind and wave events as typically observed. Benthic turbidity units trended similarly to one another but were more volatile than their surface cohorts.

Other Physicochemical Parameters: Monthly mean surface water temperatures around Lyttelton Harbour continued the warming trend observed during the previous months. Reversing the spatial relationship between sites during austral winter, the warmest temperatures continued to be recorded in the shallow waters of the upper and central harbour. Brief periods of cooling were observed during the main rainfall period in mid December. Additionally, declines in water temperatures in both surface and benthic units were observed from 7 December in response to cooler overnight minimums, particularly at the more southern offshore sites. Benthic temperatures which were once again up to several degrees cooler than those of the surface, took longer to recover from the cooling period than did their surface counterparts.

Consistent with previous reports, pH during December did not display any particular spatial or temporal patterns across the monitoring network. Conductivity in December was much more stable compared to the volatility recorded in November as a result of freshwater inundation from the Waimakariri River. Declines in conductivity occurred on three occasions in December at the most northern offshore sites, which appeared not entirely related to the limited flow events from the Waimakariri River. Conductivity in December was overall lower than the previous month as a result of the lasting effect of the previous months freshwater intrusion. Benthic conductivity was overall higher and more stable than that at the surface as typically observed.

Dissolved oxygen (DO) concentrations were far more stable and slightly more elevated in December than in the previous month. DO trended with temperature also declining in response to the cooler overnight ambient temperatures on 7 December. Similar to temperature, DO at benthic sites took longer to recover from this event than DO at the surface. Increased cloud cover and lower air temperatures is likely to have resulted in reductions in photosynthesis and thus oxygen generation. Similarly, DO peaked particularly during periods of higher air temperatures during daylight hours later in the month.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 12 December. Similar to the profiles typically obtained during the monitoring program, the inner harbour monitoring sites indicated a well-mixed water column. This is in contrast from November where gradients occurred with depth for some parameters. Benthic waters at these sites were characterised by slight increases in turbidity near the seabed. Slightly fresher surface waters were observed at site CH2 that may represent a residual signal from Waimakariri outflow intrusions into the harbour reported during November.

Outside of Lyttelton Harbour, vertical profiling of the nearshore and offshore sites indicated warmer, fresher surface waters overlying the cooler, more saline benthic environment. Both regions displayed lower pH and DO conditions near the benthos, which may be a representation of respiration associated with microbial degradation of sinking organic matter. As commonly observed throughout the monitoring program, turbidity at most of these monitoring sites also increased towards the seabed. However, due to the greater water depth than within the harbour, such increases in benthic turbidity did not have a notable influence on the calculations of vertical light attenuation.

Turbidity and total suspended solids (TSS) measurements for surface waters were again elevated at inshore sites compared to the offshore areas, resulting in the shallowest estimations of the euphotic depth as typically recorded during the monitoring program. However, turbidity and TSS overall was at some of the lowest recorded for the project. As a result, euphotic depth at the spoil ground was high; estimated to be at 42.6 m at SG3. No exceedances of WQG were observed for sub-surface turbidity during the December sampling.

Total phosphorous and dissolved reactive phosphorous concentrations were higher inshore and decreased with increasing distance offshore as commonly found. Concentrations of total nitrogen and total kjeldahl nitrogen remained below detection limits at all sampling sites. Nitrogen oxides were also below LOR and total ammonia at low levels at all sites. Concentrations of chlorophyll *a*, an indicator of phytoplankton biomass, were low at all sites and below WQG across the harbour indicating a reduction from the previous month.

In contrast to previous months, total aluminium concentrations which typically exceed designated WQG at most sites, were only above the WQG at inshore sites in addition to the OS1 and OS2 at the harbour entrance. Dissolved aluminium followed a similar trend indicating that some of aluminium present was not associated with particulate matter and thus deemed biologically available. Regardless, none of the dissolved concentrations were above WQG, as were the remaining metals with designated WQG. This included dissolved copper which commonly exceeds WQG at a handful of sites.

While no WQG are available for iron, concentrations were low and similar to those in November which were a large decrease from the elevated concentrations recorded during September and October 2018. The reduction in both total aluminium and iron in November and December may be a result of the settling of suspended sediment particles due to the flocculation process associated with fresh water inundation in November. Similar to patterns observed during previous months and the baseline monitoring phase, manganese, vanadium and molybdenum concentrations were detected within the inshore and nearshore environments.

All organic compounds measured biannually in and around Lyttelton Harbour were once again below laboratory limits of reporting.

Benthic Photosynthetically Active Radiation (BPAR): Levels of ambient sunlight during December, in terms of the monthly mean and the range, were lower than that experienced in November, despite longer day lengths.

Elevated surface turbidity was observed at both sites during the first week of the month, and this particulate matter limited benthic light availability at the time. However, once surface turbidity declined, elevated BPAR intensities were recorded particularly between 11 and 17 December, before rainfall events increased cloud cover. Monthly mean BPAR was greater at OS2; despite the slightly deeper water depth. Spatial variations in benthic light intensity between sites was high, as was variability between BPAR and ambient solar radiation measured in Christchurch. These differences highlight the complexities of BPAR through the integrated effects of the overlying water column.

Sedimentation: During the first week of December, bed level at the harbour entrance was variable, most likely due to elevated offshore wave heights that were recorded during this time. Following a reduction in waves and offshore wind speeds, bed level stabilised to around 10 December and then indicated a period of steady rate sediment deposition for the remainder of the month. During December, there was a net deposition of 23 mm of sediment onto the seafloor at OS2.

Unfortunately, equipment malfunction prevented the acquisition of altimeter data during the first 10 days of December, when bed level at the harbour mouth exhibited notable variability. However, in a similar manner to OS2, bed level at UH3 displayed a steady increase from 10 to 23 December. As easterly inshore wind speeds increased during the final week of December, the upper harbour experienced a period of sediment erosion. This removal of sediment from the seafloor resulted in a reduced net bed level change of +12 mm.

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Acronyms

ADCP	Acoustic Doppler Current Profiler
BPAR	Benthic Photosynthetically Active Radiation
BSL	Benthic self-logging sonde
CDP	Channel Deepening Project
DO	Dissolved oxygen
ECan	Environment Canterbury
EMMP	Environmental Monitoring and Management Plan
K_d	Light attenuation coefficient
KZ filter	Kolmogorov-Zurbenko filter
LOR	Limits of Reporting
LPC	Lyttelton Port Company
LYT	Lyttelton Port of Christchurch
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
QA/QC	Quality Assurance/Quality Control
SL	Self-Logger
ST	Subsurface telemetry
ST/ADCP	Subsurface telemetry/Acoustic Doppler Current Profiler
TAG	Technical Advisory Group
TDP	Total daily PAR
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VBCC	Vision Base Christchurch
VE	Vision Environment
WK	WatchKeeper telemetered weather station
WQG	Water Quality Guidelines

1 INTRODUCTION

Lyttelton Port Company (LPC) is undertaking a Channel Deepening Project (CDP) to extend the existing navigational channel to allow larger vessels access to the Lyttelton Port of Christchurch (LYT), the South Island's largest port. Utilising background information provided by LPC and advice from the Technical Advisory Group (TAG) in relation to ambient conditions, locations of sensitive habitats and dredge impact hydrodynamic modelling scenarios, a water quality monitoring design was proposed for the initial 12 month baseline monitoring phase. Baseline water quality monitoring and data collection undertaken by Vision Environment (VE) commenced in September 2016, progressing into dredge operations monitoring from 29 August to completion of the works on 29 November 2018. Monitoring is now continuing into a post dredge phase. The interpreted environmental data provided by VE supports the process of the Environmental Monitoring and Management Plan (EMMP) for the LPC CDP (Envisor, 2018) and will assist to ascertain the potential impacts of the project.

2 METHODOLOGY

2.1 Approach

An overview of the methodology for baseline and operations phase of water quality monitoring is provided in this section. A more detailed description of the importance of the measured parameters and the specific methodology for the CDP data collection and processing protocols, can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

2.1.1 Monitoring Locations and Equipment

Guided by the results of preliminary hydrodynamic modelling (MetOcean, 2016a, b) in addition to advice from the TAG, baseline and dredge operations monitoring sites were located outside the area of predicted direct impact (i.e. dredge footprint and offshore disposal ground), but within the zone of dredging and dredge material placement influence, in addition to being in the vicinity of sensitive receptors (e.g. mussels farms and important mahinga kai sites). For ease of identification the harbour was divided into four areas: spoil ground (SG); offshore (OS); central harbour (CH); and upper harbour (UH), in which 15 locations were selected for monitoring (Figure 1). In each area, one to three monitoring sites were selected for the deployment of the various individual types of equipment, which are identified in Table 1. A total of 22 monitoring units were deployed across the 15 locations.

The offshore monitoring area (encompassing monitoring sites SG1 to SG3 and OS1 to OS7) is a deep water (generally >15 m) oceanic environment, where turbidity appears to be mostly driven by wind speeds and wave heights, resulting in resuspension of material from the benthos. A combination of both surface loggers and benthic loggers have been utilised at a number of offshore locations.

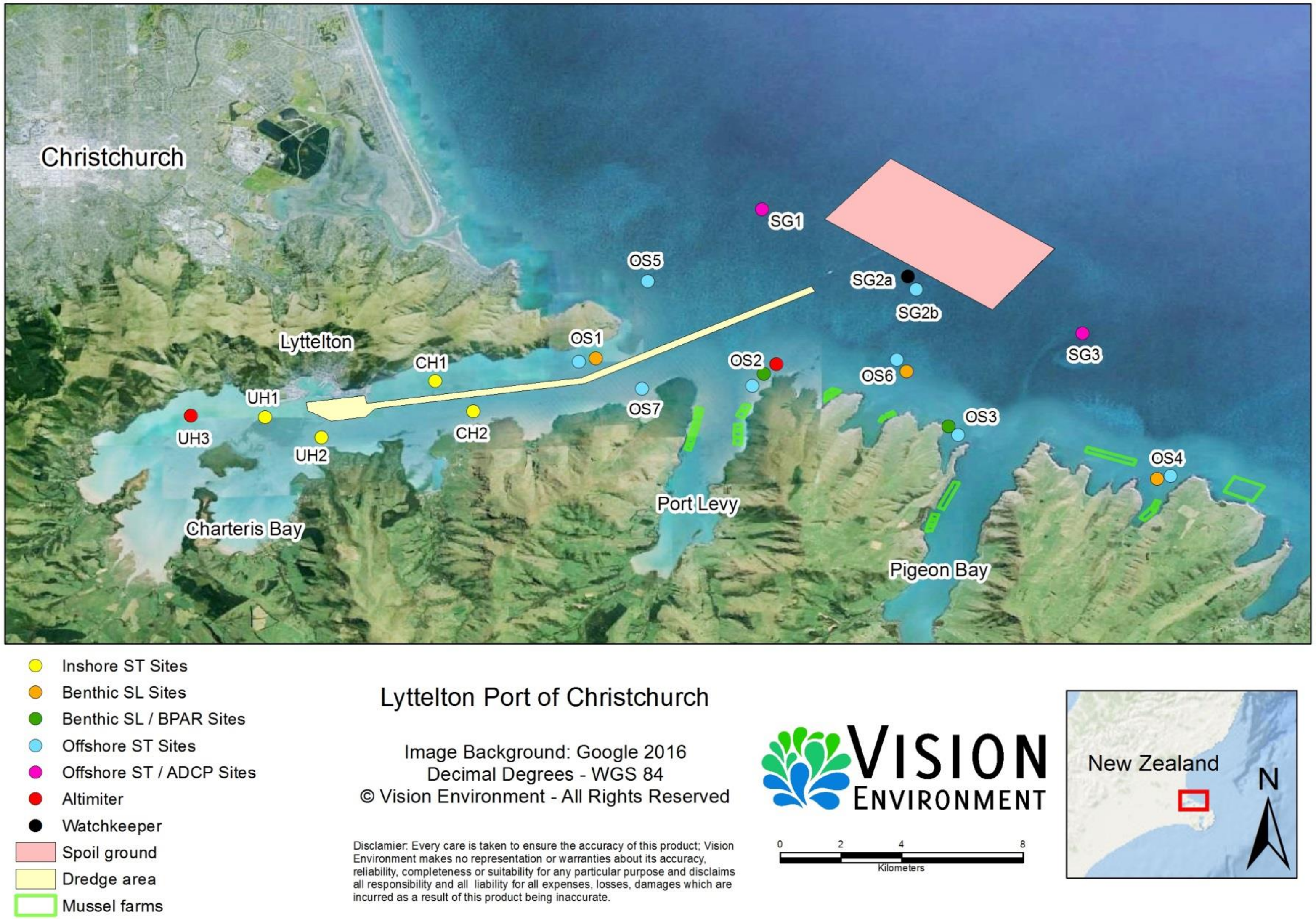


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

The inshore monitoring area (including monitoring sites CH1 and CH2, and UH1 to UH3) is a shallow (<10 m depth) marine environment that, in addition to wind speeds and wave heights, is also influenced by tides (~ 0.2 m/s). The water column is well mixed at these sites, with little to no stratification. Therefore, surface loggers only have predominantly been utilised at these sites.

Table 1 Summary of monitoring sites and deployment equipment for the LPC Channel Deepening Project.
ST = subsurface telemetry, SL = self-logger, BSL = benthic self-logger, BPAR = benthic photosynthetically active radiation, and ADCP = Acoustic Doppler Current Profiler, WK = WatchKeeper telemetered weather station.

Site	WK	ST/ADCP	ST	BSL sonde	BSL sonde/BPAR	Altimeter
	WatchKeeper telemetered weather station with currents and waves	Subsurface telemetered dual physico-chemistry and currents	Subsurface telemetered dual physico-chemistry	Benthic self-logging dual physico-chemistry	Benthic self-logging dual physico-chemistry and self-logging BPAR	Benthic self-logging dual altimeter
SG2a	√					
SG2b			√			
SG1		√				
SG3		√				
OS1			√	√		
OS2			√		√	√
OS3			√		√	
OS4			√	√		
OS5			√			
OS6			√	√		
OS7			√			
CH1			√			
CH2			√			
UH1			√			
UH2			√			
UH3						√
Total	1	2	12	3	2	2

The comprehensive water quality component of the program involves the monitoring of:

- Physicochemistry, including turbidity; temperature; pH; conductivity and dissolved oxygen (DO);
- Light attenuation (Photosynthetic Active Radiation or PAR);
- Benthic light (Benthic Photosynthetic Active Radiation or BPAR);
- Total Suspended Solids (TSS);
- Sedimentation rates;
- Nutrients and chlorophyll *a*;
- Metals (total and dissolved); and
- Organic compounds (biannually).

This monthly report presents data collected from the 22 monitoring locations from 1 to 31 December 2018 during post dredge operations. Monthly water sampling was conducted on 12 December and included biannual organics sampling. A summary of climatic conditions during this period is provided, in addition to the results of continuous and discrete water sampling with comparisons to the baseline monitoring period.

2.1.2 Water Quality Guidelines

Water quality monitoring data from LYT were compared to the Australian and New Zealand Water Quality Guidelines (WQG) (ANZECC/ARMCANZ, 2000) default interim trigger values. In the absence of specific default trigger values for estuarine or marine ecosystems, which are yet to be developed in New Zealand, the WQG suggest the use of interim trigger values for south-east Australian estuarine and marine ecosystems.

Total metals represent the concentration of metals determined in an unfiltered sample (those bound to sediments or colloidal particles in addition to dissolved metals), while dissolved metals are defined as those which pass through a 0.45 µm membrane filter (APHA, 2005). Specific trigger levels for varying levels of ecosystem protection (99%, 95%, 90% and 80% of species) have been derived for a number of metals. These guidelines refer to the dissolved fraction, as they are considered to be the potentially bioavailable fraction (ANZECC/ARMCANZ, 2000). The LYT coastal environment could be described as slightly-to-moderately disturbed, therefore the 95% WQG trigger value was considered appropriate for comparison.

3 RESULTS & DISCUSSION

3.1 Metocean Conditions

3.1.1 Wind and precipitation

The December 2018 total precipitation of 38.2 mm received at Cashin Quay over 16 days was relatively high in comparison to previous months but remained lower than the 52.0 mm of rainfall received in November (Figure 2). The majority of the precipitation (7.8 and 10.6 mm) occurred on 19 and 22 December, respectively, with smaller falls dispersed evenly across the month (Metconnect, 2018).

Freshwater flows (Figure 2) from the Waimakariri River, which can be transported south along the coastline and enter Lyttelton Harbour several days later, were less than 200 m^3/s (Figure 3) for the duration of the month (ECAN, 2018) with the exception of a short flow event on 6 December which peaked at 340 m^3/s. This is in contrast to the previous month where a single large flow event introduced noticeable volumes of freshwater into the upper harbour area.

Inshore wind speeds in December were relatively low with maximum daily mean inshore wind speeds measured at Cashin Quay ranging from 4.8 to 10.9 knots (Figure 2), mostly from an east-north-easterly direction, as they were in November (Metconnect, 2018). Daily mean air temperatures at Cashin Quay ranged from 11 to 27°C, resulting in a warmer monthly mean temperature of 16°C compared to 13°C during the previous month (Metconnect, 2018). Minimum overnight temperatures were also 4°C higher than the previous month.

Offshore significant wave heights peaked at 2.0 m on 1 December travelling in a south westerly direction (Figure 3) but remained at less than 1.3 m from 6 December to the end of the month. Wind speeds and gusts were also highest during the first week of December with average daily speeds peaking at 13.9 knots on 6 December and maximum gusts of 24.5 knots recorded on 4 December (Figure 3). Offshore wind speeds remained relatively low for the remainder of the month.

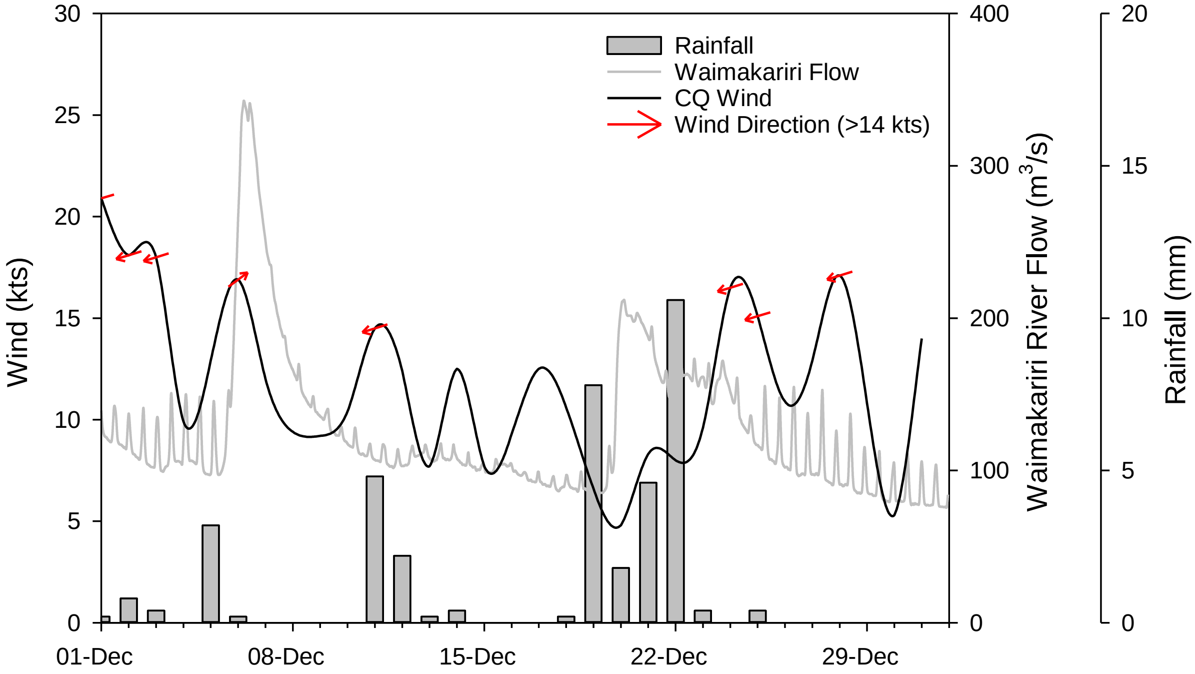


Figure 2 Inshore metocean conditions, including daily averaged wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during December 2018.
Note: Arrows indicate the direction of travel for inshore winds greater than 14 knots.

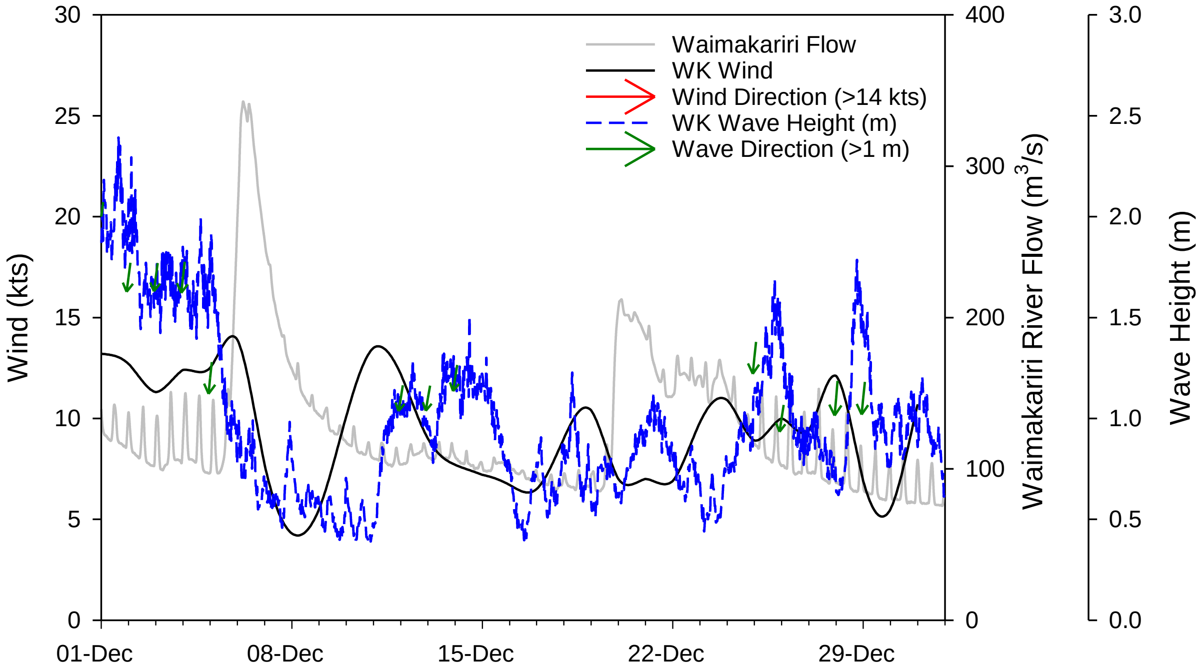


Figure 3 Offshore metocean conditions, including wind speed and direction, significant wave height and daily averaged wave direction as measured by the WatchKeeper Buoy at site SG2a, and Waimakariri River flow at the Old Harbour Bridge station, during December 2018.
Note: Arrows indicate the direction of travel for offshore winds greater than 14 knots and offshore waves above 1 m significant wave height. Directions from the WatchKeeper buoy have not been corrected for magnetic declination.

3.1.2 Currents

Acoustic Doppler Current Profilers (ADCPs) are deployed at the spoil ground monitoring sites SG1 and SG3, reporting the speed and direction of currents in close proximity to the sea surface and seabed. Unfortunately, both ADCP units stopped sending data in late August/early September 2018 and have not been removed from the spoil ground for maintenance due to the requirement for turbidity monitoring to continue at these sites during the dredge operations. Whilst no data are being transferred over the telemetry system, it is likely that the units are internally logging and the data may be available through manual download at a later date. The units are scheduled for maintenance in early 2019 during the post dredge phase.

In the interim, ADCP data collected from the WatchKeeper Buoy at SG2a are provided within this report. Summary ADCP statistics are presented within Figure 4 and Table 2. Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 30 and 31 in the Appendix.

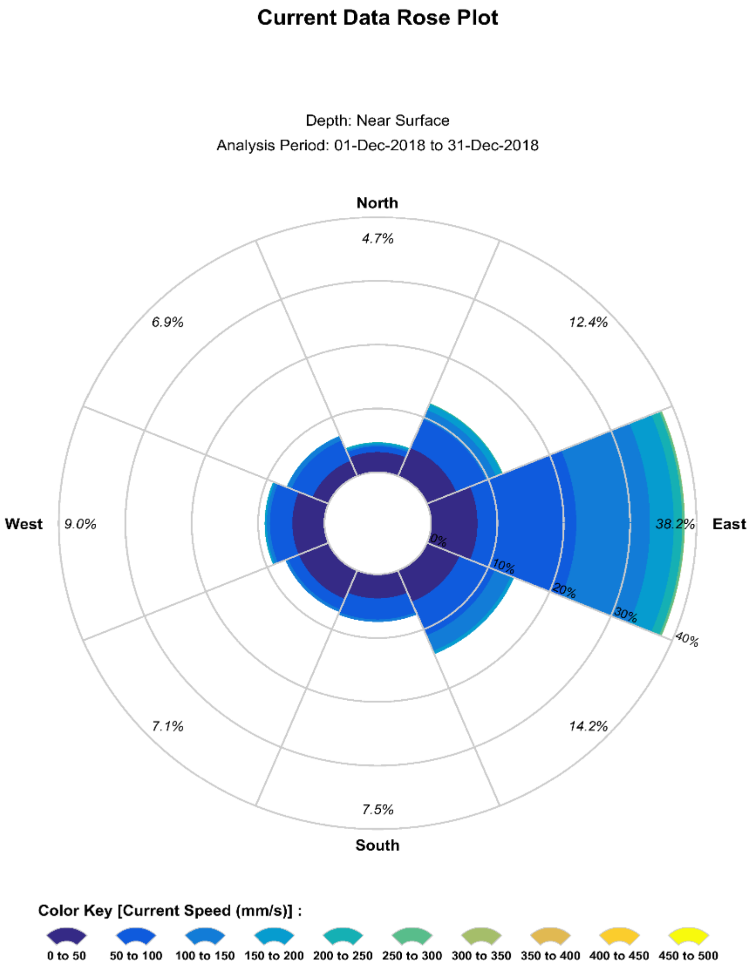
The maximum near-surface current velocity at SG2a was recorded on 4 December at 342 mm/s (Table 2), coinciding with increased offshore significant wave heights which peaked on 1 December and remained elevated until 5 December (Figure 3). Near the seabed, maximum current velocities of 286 mm/s were recorded on 1 December coinciding with peak wave heights. The monthly mean current speed for the near-seabed (95 mm/s) was greater than that recorded for the near surface (75 mm/s) as typically found. Current velocities tended to be overall lower than the previous month reflecting the calmer metocean conditions experienced in December 2018.

Table 2 Parameter statistics for ADCP at SG2a (WatchKeeper buoy) during December 2018.

Parameter	SG2a	
	Near-surface	*Near-seabed*
Minimum current speed (mm/s)	1	3
Maximum current speed (mm/s)	342	286
Mean current speed (mm/s)	75	95
Standard deviation of current speed (mm/s)	48	50
Current speed, 95^{th} percentile (mm/s)	171	194

The time-series plots (Figures 28 and 29 in Appendix) illustrate time-varying current direction, whilst the current rose diagram (Figure 4) depicts the distribution of current direction and velocity in the near-surface and near-seabed layers. When interpreting the current data, please note that the convention for defining current direction is the direction in which the current flows *towards*, which is the reference used throughout the figures presented (the opposite is true for wind direction, where the reference is the direction from which the wind is coming from).

Similar to the data recorded during October and November 2018, current direction data from SG2a during December displayed a strong dominance of flow along the west to east axis (38.2%) at the near-surface (Figure 4). The near-seabed current directions in December were also predominantly from west to east (24.2%) in addition to a southeast direction (17.2%).



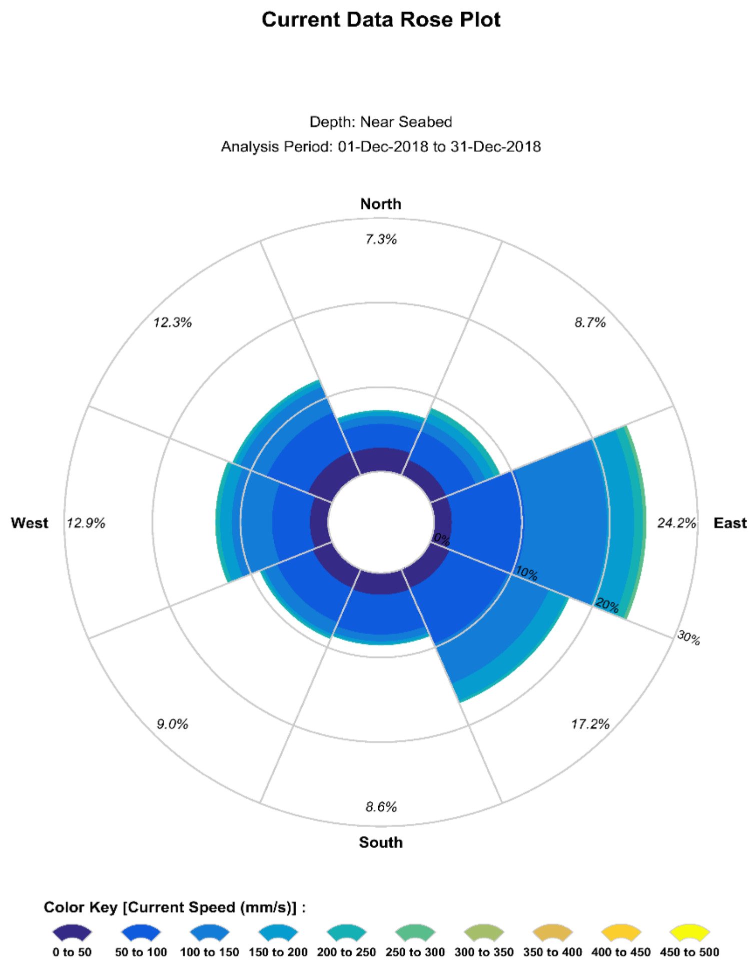


Figure 4 WatchKeeper near-surface and near-seabed current speed and direction during December 2018.
Speed intervals of 50 mm/s are used

3.2 Continuous Physicochemistry Loggers

Physical and chemical properties (turbidity, temperature, conductivity [normalised to a reference temperature of 25°C], pH and DO) of the water column are measured at monitoring sites every 15 minutes by dual telemetered surface loggers. Additional dual sets of benthic loggers have also been deployed at five offshore sites (OS1 to OS4 and OS6). In conjunction with the continuous loggers, discrete depth profiles of all physicochemical parameters were also conducted at all 15 monitoring sites on 12 December 2018. Further details regarding the methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Summary statistics for each physicochemical parameter recorded during December are presented in Tables 3 to 12. Validated datasets for surface and benthic measurements are also presented in Figures 5 to 20. Due to the inherent high level of variability in the turbidity datasets, a 24-hour rolling average has been calculated every 15 minutes to act as an interim smoothing technique and aid in data interpretation.

3.2.1 Turbidity

Of key importance within the real time parameters recorded are the surface turbidity measurements, due to their relevance to established trigger values for management of dredge operations. As such, summary turbidity statistics for the initial baseline period of monitoring from 1 November 2016 to 31 October 2017 (Fox, 2018) are also presented in Tables 3 to 5 to allow a comparison with the December 2018 post dredge data.

Summary statistics for KZ filtered turbidity data used for real time compliance monitoring during dredge operations but not applicable during the post dredge phase, are also presented in Tables 19 to 21 in the Appendix for comparison with previous months dredge compliance reports. Similarly, plots of KZ filtered turbidity data with site specific trigger values are also presented within Figures 30 to 33 in the Appendix.

Surface Turbidity:

Consistent with previous monitoring months, surface turbidity values were typically highest (monthly means of 4.2 to 10 NTU) at the inshore monitoring sites (Tables 3 to 5, Figure 5). Further offshore, the spoil ground sites exhibited lower (monthly means of 1.1 to 2.1 NTU) surface turbidity values (Table 4), which are likely due to the deeper water column limiting disturbance expressions at the sub-surface. As typically observed, nearshore sites experienced intermediate turbidity values (1.2 to 3.6 NTU) during December (Table 5). All turbidity monthly means were noticeably lower than the previous month most likely due to the calmer metocean conditions experienced in December. Flocculation of fine sediments which occurred mid-November at inshore sites after freshwater inundation from the Waimakariri River is likely to have removed the amount of fine sediments that were previously available for resuspension, resulting in lower inshore turbidity.

Continuing a trend observed in both October and November, surface turbidity at CH2 on the southern side of the harbour remained lower than the other three inshore sites. Site UH2 also in the southern harbour, which had displayed similarly lower turbidity values up until mid-November, continued to trend with the two other inshore sites throughout December. Patterns of turbidity for all four sites were reflective of inshore wind conditions experienced at the time (Figures 5 and 6) with elevated turbidity occurring during the first week of December. For the remainder of the month turbidity at all sites was fairly stable, with slight elevations on 29 December corresponding to increasing inshore wind speeds.

Similarly offshore sites trended together by displaying increases in turbidity in response to increased wind speed and wave height events, particularly in the first week of December. Site OS3 displayed some of the highest turbidity peaks as typically previously observed (Figure 5 and Figures 7 to 9). Spoil ground sites also responded to the early December wind event but to a lesser extent (Figures 5 and 10). All offshore and spoil ground sites remained fairly stable to the end of December in line with relatively low offshore wind speed and wave heights.

Table 3 Mean turbidity and statistics at inshore water quality logger sites during December 2018 and Baseline period (1 November 2016 to 31 October 2017).
Values for December are means ± se, range and percentiles (n = 2938 to 2957) Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface December	Surface Baseline
UH1	Mean ± se	10 ± 0	12
	Range	<1 – 46	-
	99th	31	39
	95th	19	22
	80th	13	15
UH2	Mean ± se	9.0 ± 0.1	10
	Range	<1 – 38	-
	99th	27	32
	95th	19	20
	80th	11	13
CH1	Mean ± se	7.3 ± 0.1	9
	Range	2 – 25	-
	99th	16	29
	95th	12	18
	80th	9.6	12
CH2	Mean ± se	4.2 ± 0.0	8
	Range	<1 – 16	-
	99th	10	24
	95th	7.8	16
	80th	5.5	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during December 2018 and Baseline period (1 November 2016 to 31 October 2017).
Values for December are means ± se, range and percentiles (n = 2974 to 2976). Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface December	Surface Baseline
SG1	Mean ± se	1.4 ± 0.0	4.2
	Range	<1 – 10	-
	99th	5.1	14
	95th	3.4	10
	80th	1.7	6.2
SG2	Mean ± se	2.1 ± 0.0	4.6
	Range	<1 – 6.4	-
	99th	4.7	20
	95th	3.8	11
	80th	3.0	7.0
SG3	Mean ± se	1.1 ± 0.0	3.6
	Range	<1 – 9.7	-
	99th	5.7	13
	95th	3.3	7.7
	80th	1.6	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during December 2018 and Baseline period (1 November 2016 to 31 October 2017).
Values for December are means ± se, range and percentiles (n = 212 to 2973). Baseline values modified from Fox 2018.*

Site	Statistic	Turbidity (NTU)		
		Surface December	Surface Baseline	Benthic December
OS1	Mean ± se	3.6 ± 0.0	7.5	30 ± 1
	Range	<1 – 14	-	<1 – 195
	99th	10	24	136
	95th	7.8	16	91
	80th	5.1	10	43
OS2	Mean ± se	2.6 ± 0.0	6.4	16 ± 0*
	Range	<1 – 13	-	9 – 37
	99th	9.1	18	34
	95th	5.7	13	29
	80th	3.6	9.0	19
OS3	Mean ± se	3.2 ± 0.0	6.6	33 ± 1
	Range	<1 – 18	-	1 – 217
	99th	13	27	136
	95th	7.7	15	100
	80th	3.8	8.9	52
OS4	Mean ± se	1.6 ± 0.0	5.9	19 ± 0
	Range	<1 – 11	-	2 – 128
	99th	8.3	20	88
	95th	5.8	13	54
	80th	2.2	8.3	28
OS5	Mean ± se	2.6 ± 0.0	4.6	–
	Range	<1 – 9.5	-	–
	99th	6.1	19	–
	95th	4.8	11	–
	80th	3.5	6.4	–
OS6	Mean ± se	1.2 ± 0.0	4.7	34 ± 1
	Range	<1 – 9.2	-	4 – 158
	99th	5.2	19	105
	95th	3.2	12	77
	80th	1.8	7.2	52
OS7	Mean ± se	2.4 ± 0.0	6.4	–
	Range	<1 – 15	-	–
	99th	8.6	23	–
	95th	6.2	14	–
	80th	3.8	9.2	–

Benthic:

Benthic data recovery from all sondes up until exchange on 10 December was limited. A new benthic unit was deployed at OS6 to replace the missing unit at this time. Although benthic units responded similarly to each other for the majority of the remainder of the month they did not necessarily respond similarly to their surface counterparts. Turbidity at benthic sites increased in response to small fluctuations in wind and wave events, whereas the surface sonde turbidity tended to remain more stable.

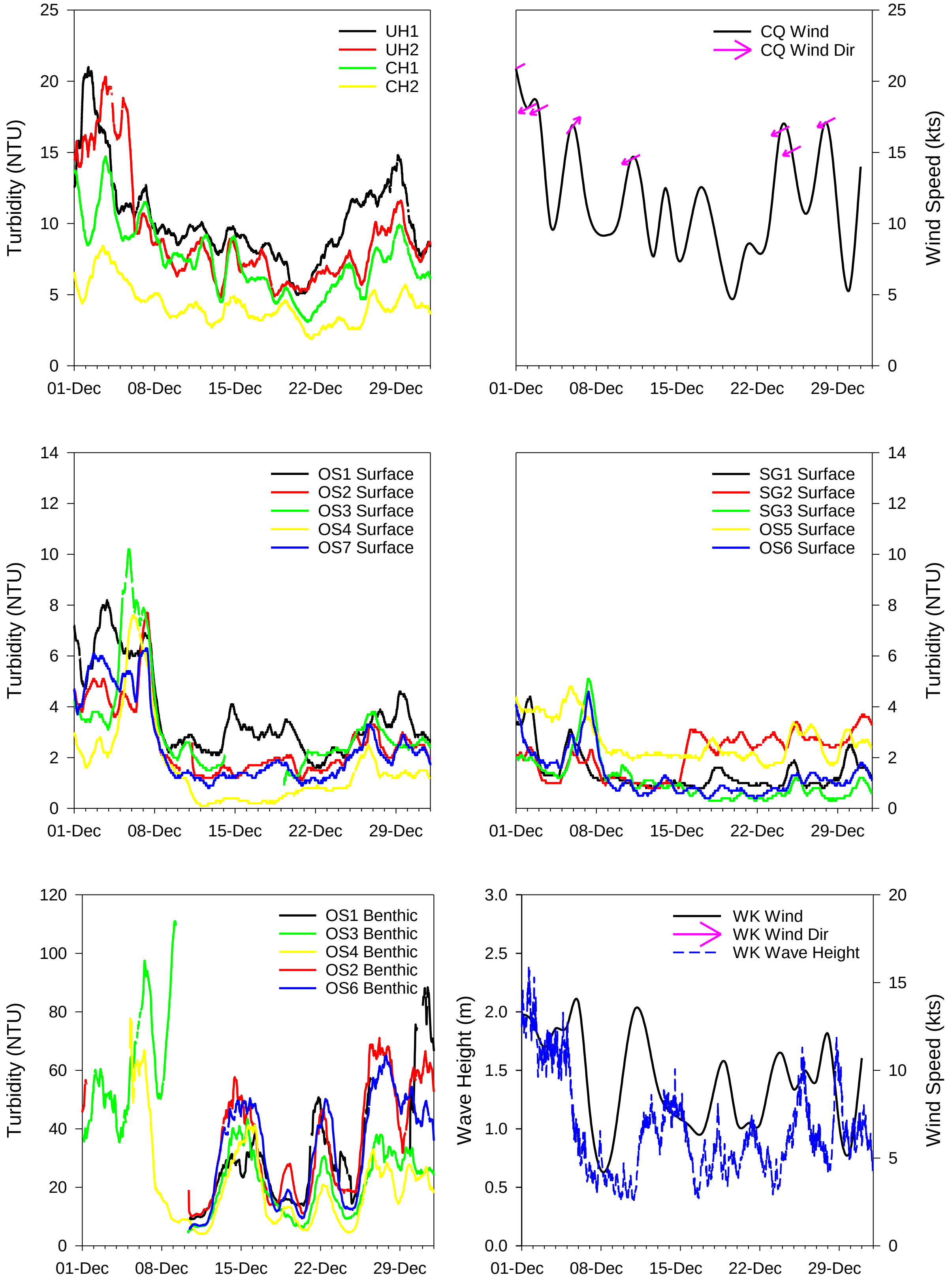


Figure 5 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore and benthic monitoring stations.
Note differing scales between plots. Arrows indicate the direction of travel for inshore/offshore winds greater than 14 knots.

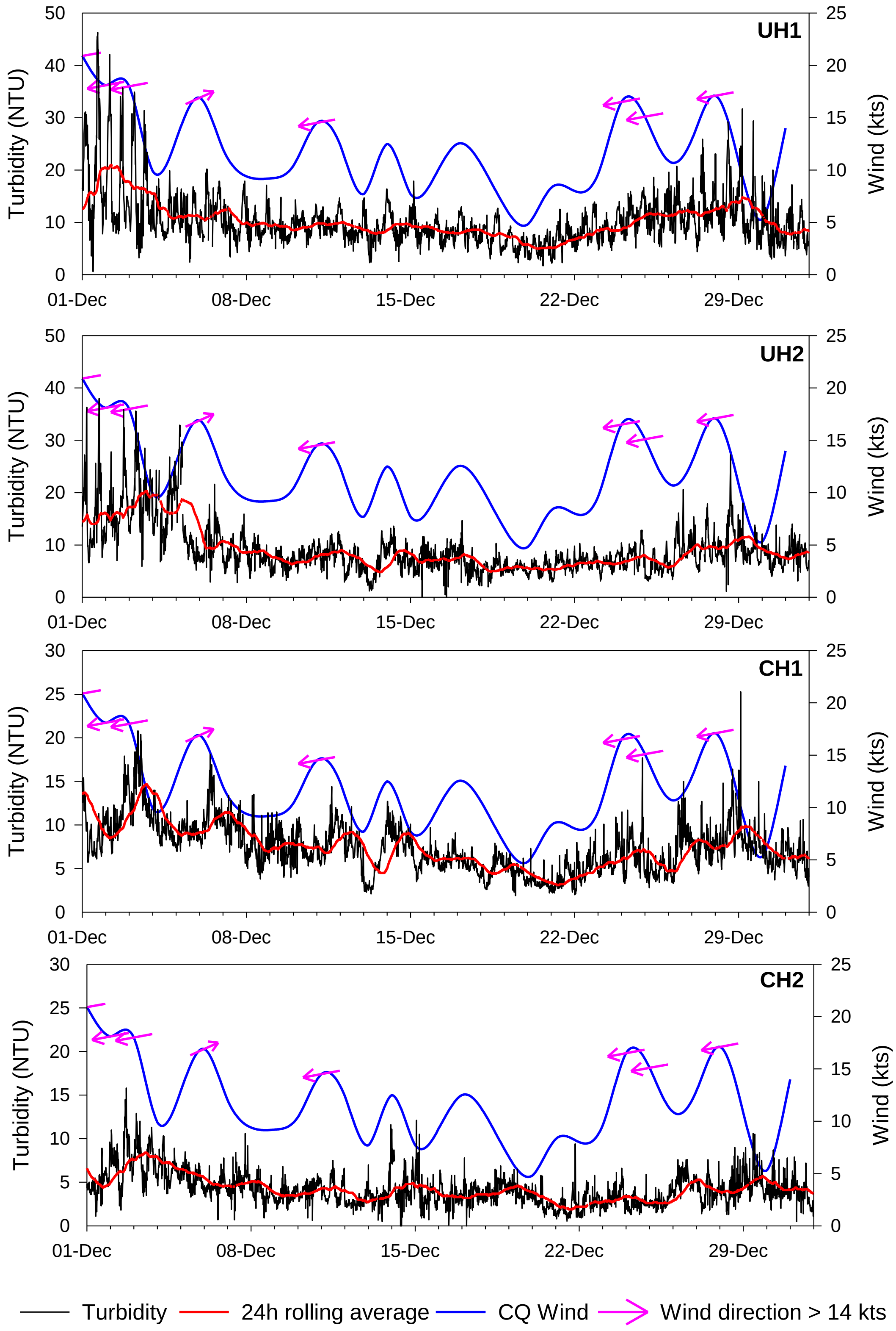


Figure 6 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during December 2018.
Note differing scales for each plot. Arrows indicate the direction of travel for inshore winds greater than 14 knots. Grey shading indicates the baseline mean turbidity.

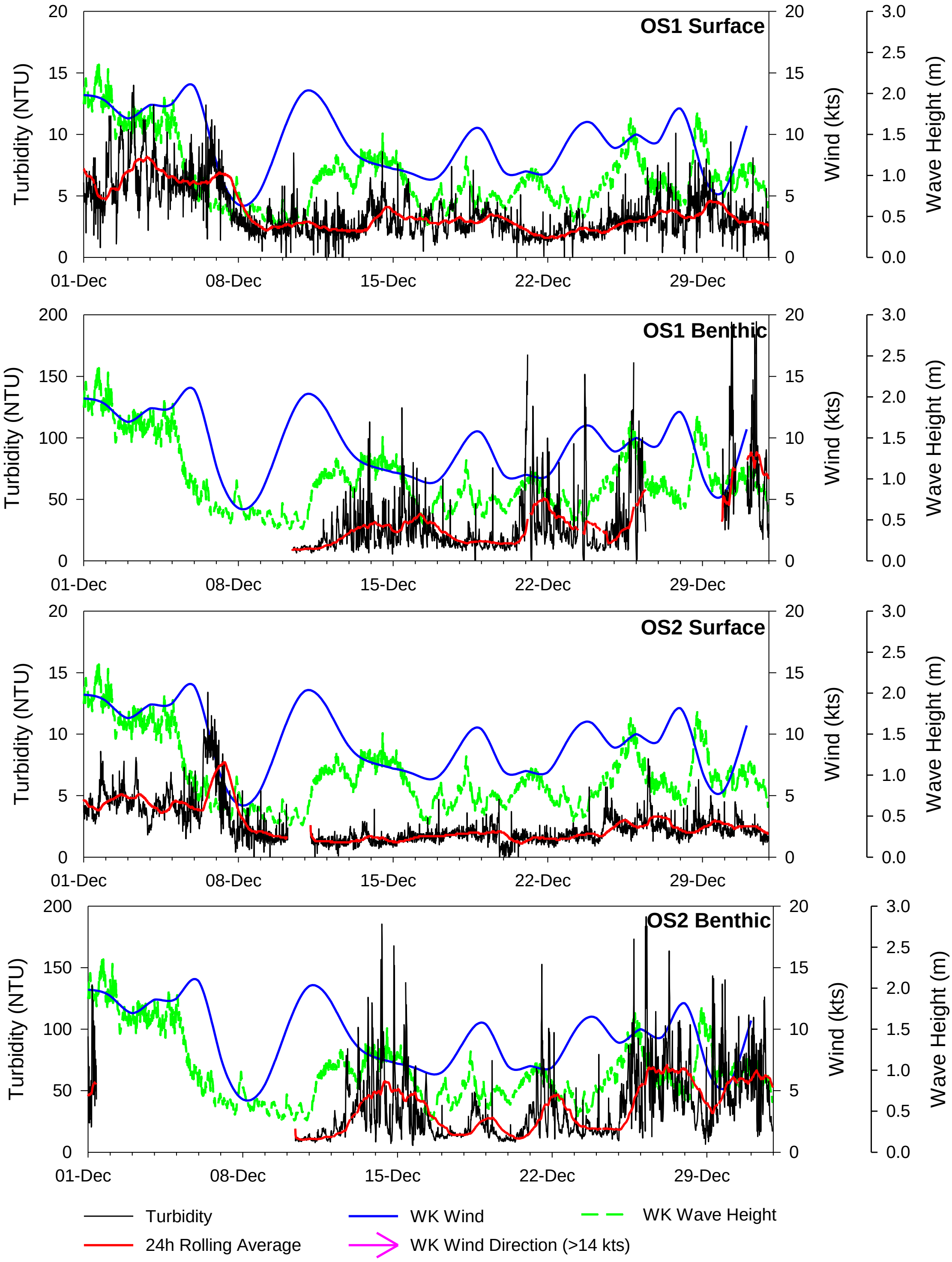


Figure 7 Surface and benthic turbidity and daily averaged winds at offshore sites (OS1 and OS2) during December 2018.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Grey shading indicates the baseline mean turbidity.

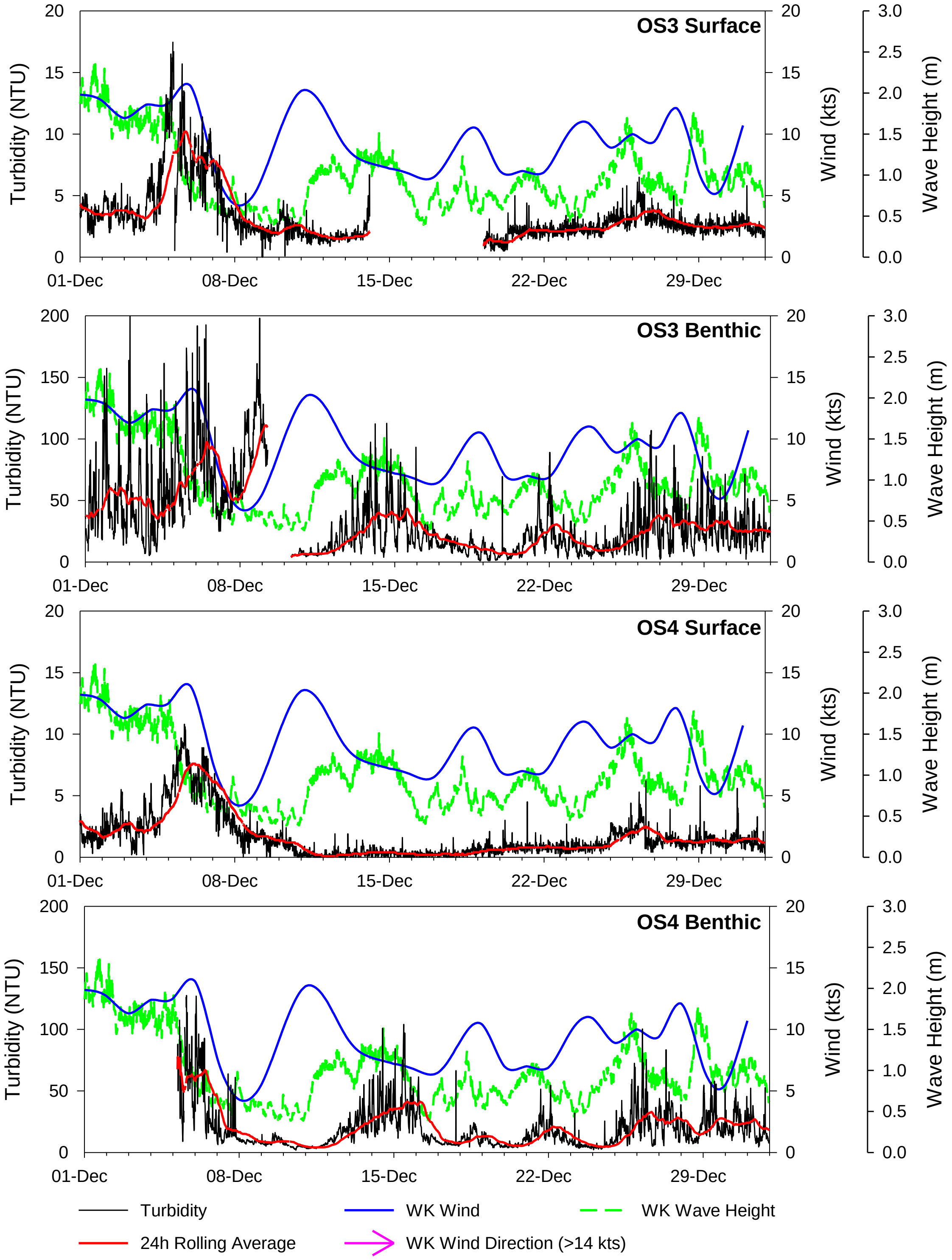


Figure 8 Surface and benthic turbidity and daily averaged winds at offshore sites (OS3 and OS4) during December 2018.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Grey shading indicates the baseline mean turbidity.

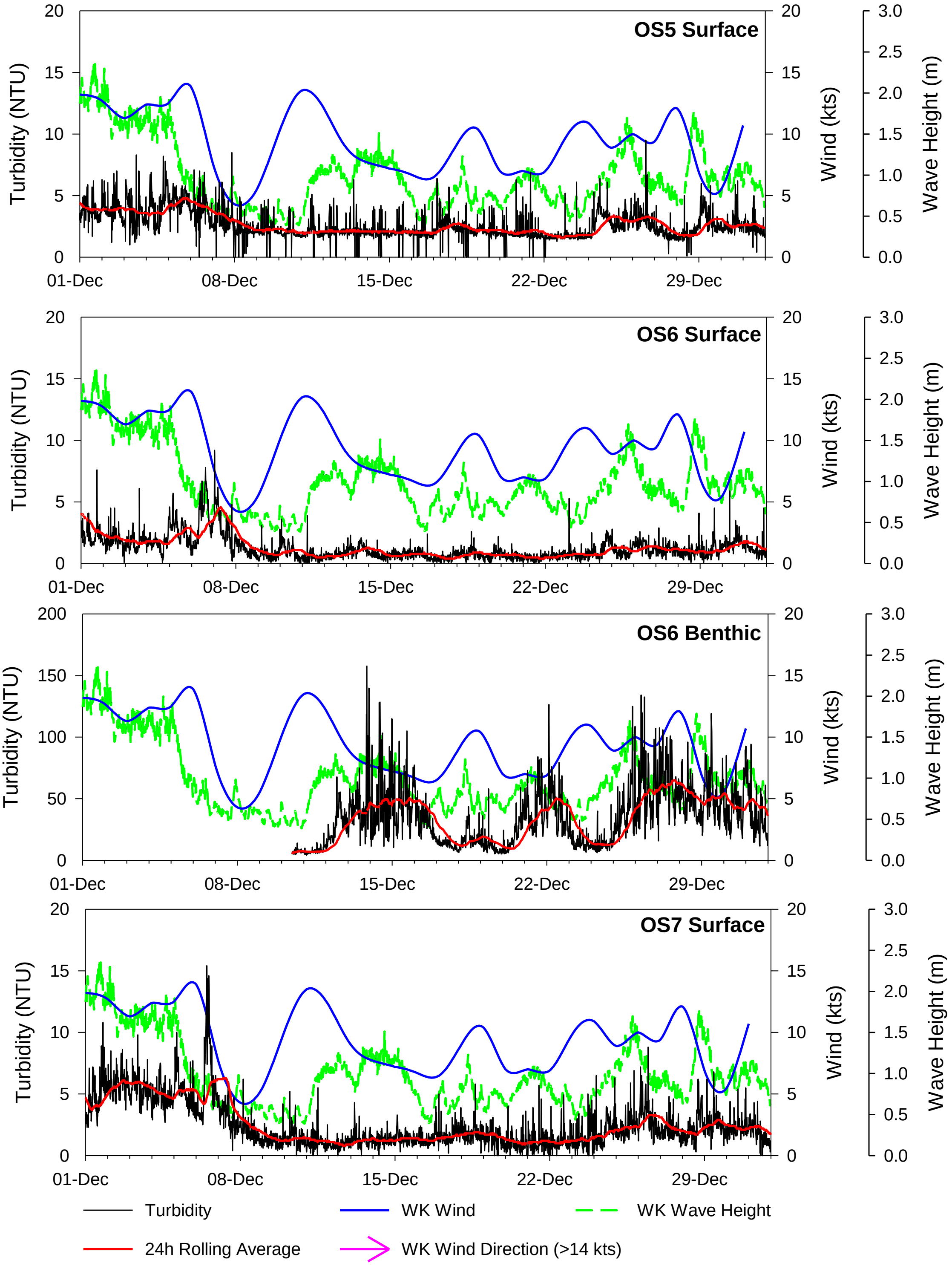


Figure 9 Surface turbidity and daily averaged winds at offshore sites (OS5, OS6 and OS7) during December 2018.

Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Grey shading indicates the baseline mean turbidity.

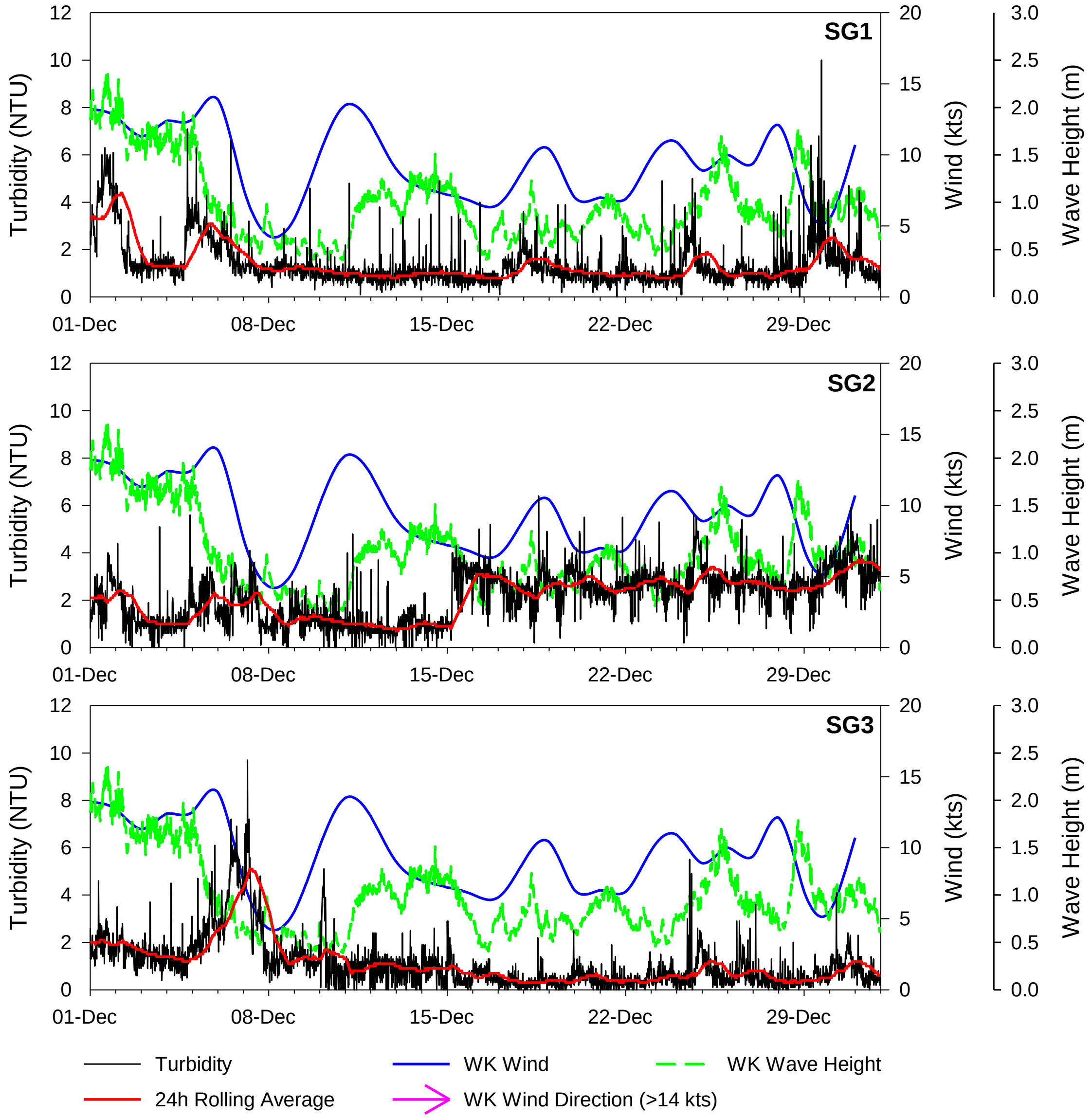


Figure 10 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during December 2018. *Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Grey shading indicates the baseline mean turbidity.*

Comparison to Baseline:

Mean surface turbidity and higher order percentile statistics from all monitoring sites in December were markedly lower than calculated baseline values (Tables 3 to 5, Figures 6 to 10). This is in contrast to previous months where at inshore sites UH1, UH2 and CH2, turbidity statistics tended to be only slightly lower, or similar to baseline. Site CH1 which had previously recorded a monthly mean 2 NTU greater than that of the baseline (Table 3), recorded a monthly mean 1.7 NTU lower in December. Percentile statistics for all sites were lower in December than those recorded for baseline monitoring. As previously mentioned, flocculation of fine sediments from freshwater inundation in November may have contributed to the lower overall values.

3.2.2 Temperature

Average surface water temperatures during December were warmer than those experienced during the previous months, ranging from 16.3 to 17.5°C (Table 6), compared to 14.7 to

16.1°C in November, as a result of warmer ambient air temperatures. Once again the shallow waters of the upper and central harbour displayed the warmest mean temperatures, which is in contrast to the winter months. All sites exhibited a warming trend across the month, with small decreases occurring during periods of heavier rainfall particularly from 19 to 22 December (Figures 11 and 12).

Semidiurnal variability (associated with tidal water movements and solar radiation) was again observed within the datasets. Sites OS1 and OS7 at the harbour entrance in addition to SG1, recorded more elevated temperatures on 18 December compared to surrounding sites in line with peak mean daily ambient temperatures for the month. Sudden declines in temperature were observed at the majority of offshore sites in particular OS3 and OS4 in addition to SG3, in response to the lower overnight minimum air temperatures on 7 December.

Similar to previous months, benthic temperatures were a few degrees cooler than those of the surface waters. Declines in temperature were also recorded at OS2, OS3 and OS4 benthic sites from the 7 December but benthic water temperatures did not recover as quickly as they did at the surface. Site OS1 benthic continued to demonstrate cyclical responses to tidal variation.

Table 6 Mean temperature at inshore, spoil ground and offshore water quality sites during December 2018.
Values are means ± se (n = 217 to 2976).*

Site	Temperature (°C)	
	Surface loggers	Benthic loggers
UH1	17.5 ± 0.0	–
UH2	17.3 ± 0.0	–
CH1	17.0 ± 0.0	–
CH2	17.0 ± 0.0	–
SG1	16.6 ± 0.0	–
SG2	16.5 ± 0.0	–
SG3	16.5 ± 0.0	–
OS1	16.9 ± 0.0	15.3 ± 0.0
OS2	16.9 ± 0.0	14.5 ± 0.0
OS3	16.4 ± 0.0	13.8 ± 0.0
OS4	16.3 ± 0.0	13.7 ± 0.0
OS5	16.8 ± 0.0	–
OS6	16.6 ± 0.0	13.7 ± 0.0
OS7	17.0 ± 0.0	–

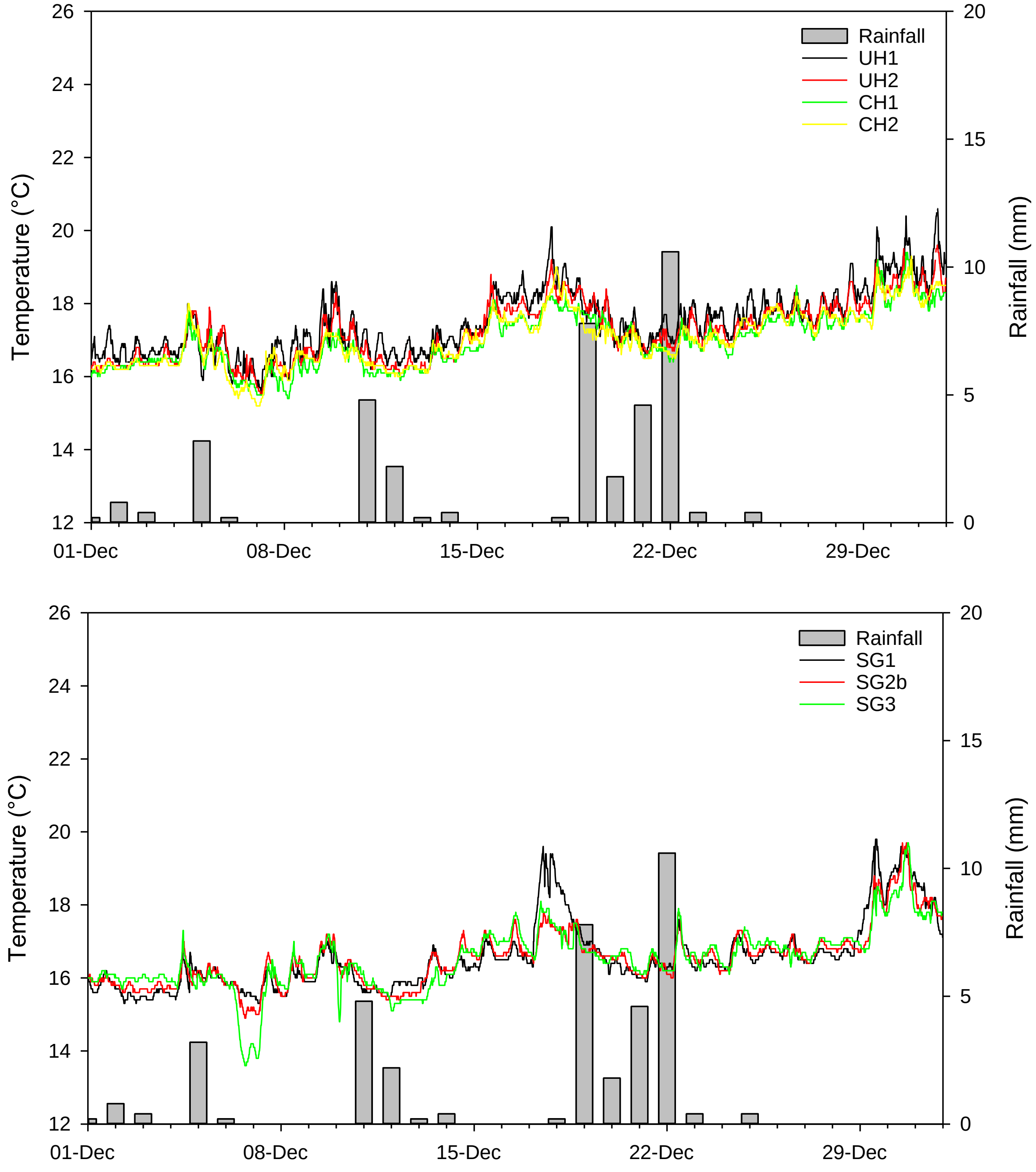
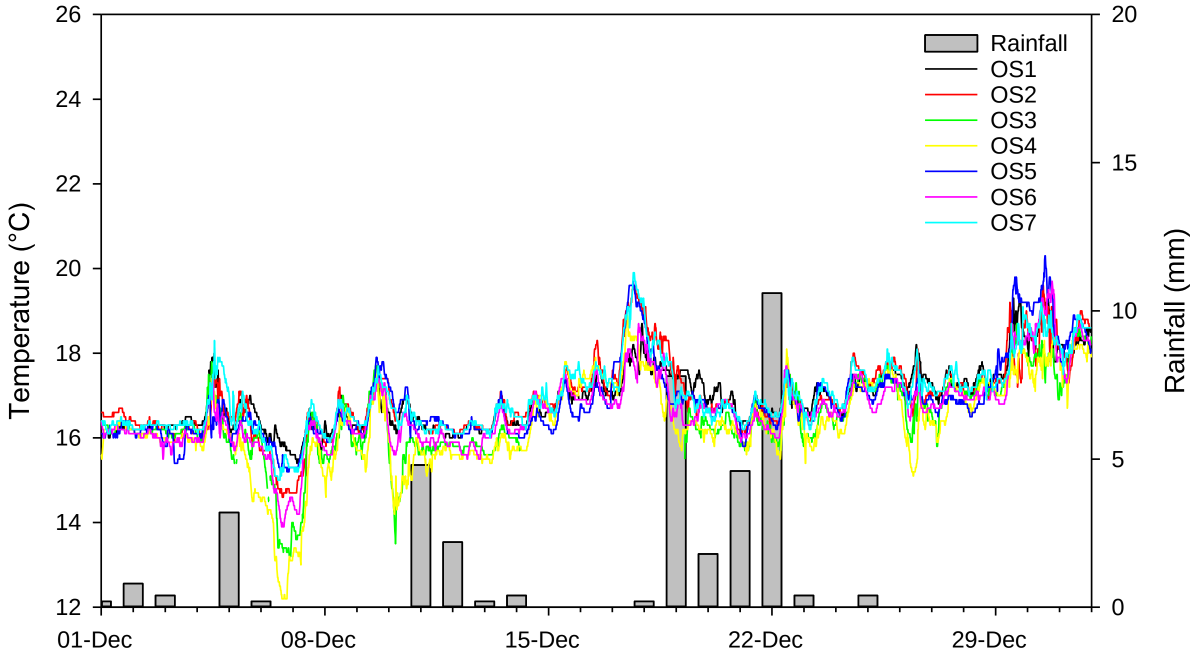


Figure 11 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during December 2018.



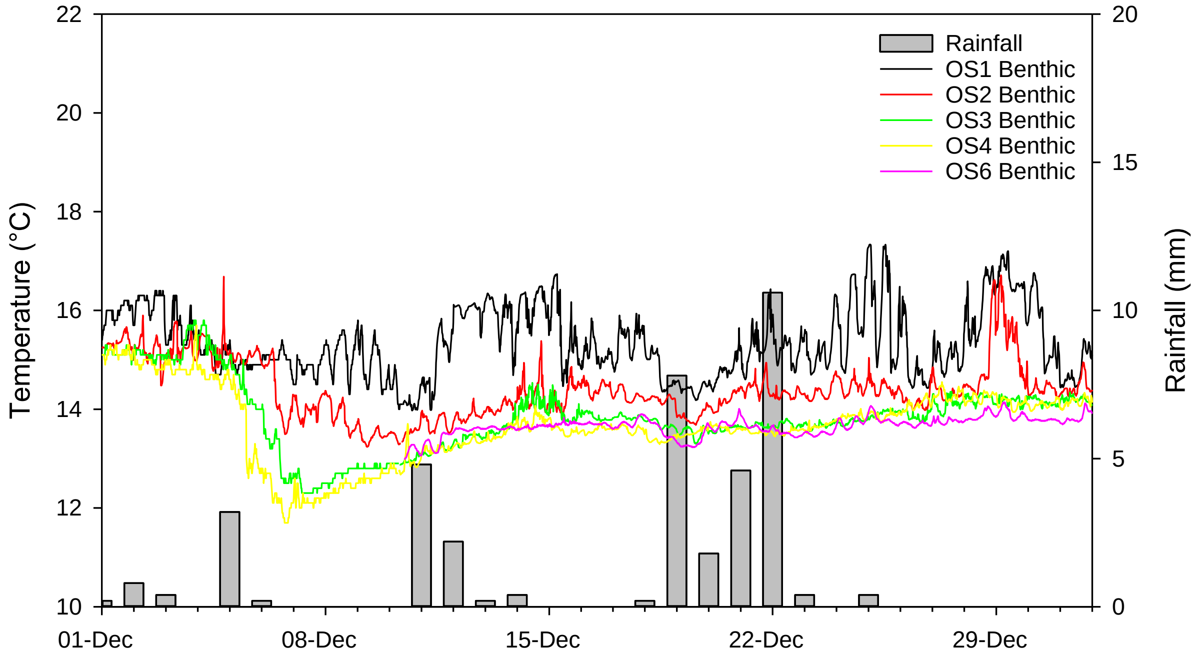


Figure 12 Surface temperature (OS1 to OS7) and benthic temperature (OS1 to OS4 and OS6) at offshore water quality sites during December 2018.

3.2.3 pH

Once again, the pH data collected from surface sondes did not demonstrate any strong spatial patterns, with mean monthly surface pH for November ranging from 8.1 to 8.2 (Table 7). Temporally, surface pH did not appear to display any trends associated with the month's rainfall events (Figures 13 and 14). There was a high level of variability inherently incorporated within the data as typically observed.

Benthic pH was lower than at the surface ranging from 7.9 to 8.0. As expected benthic pH displayed greater stability than that of the surface waters (Figure 14), due to the reduced influence of photosynthesis and respiration at depth.

Table 7 Mean pH at inshore, spoil ground and offshore water quality sites during December 2018. *Values are means ± se (n = 1557 to 2971).*

Site	pH	
	Surface loggers	Benthic loggers
UH1	8.2 ± 0.0	–
UH2	8.1 ± 0.0	–
CH1	8.1 ± 0.0	–
CH2	8.2 ± 0.0	–
SG1	8.2 ± 0.0	–
SG2	8.2 ± 0.0	–
SG3	8.2 ± 0.0	–
OS1	8.1 ± 0.0	7.9 ± 0.0
OS2	8.1 ± 0.0	–*
OS3	8.2 ± 0.0	7.9 ± 0.0
OS4	8.1 ± 0.0	8.0 ± 0.0
OS5	8.1 ± 0.0	–
OS6	8.2 ± 0.0	8.0 ± 0.0
OS7	8.1 ± 0.0	–

**no benthic data available from OS2.*

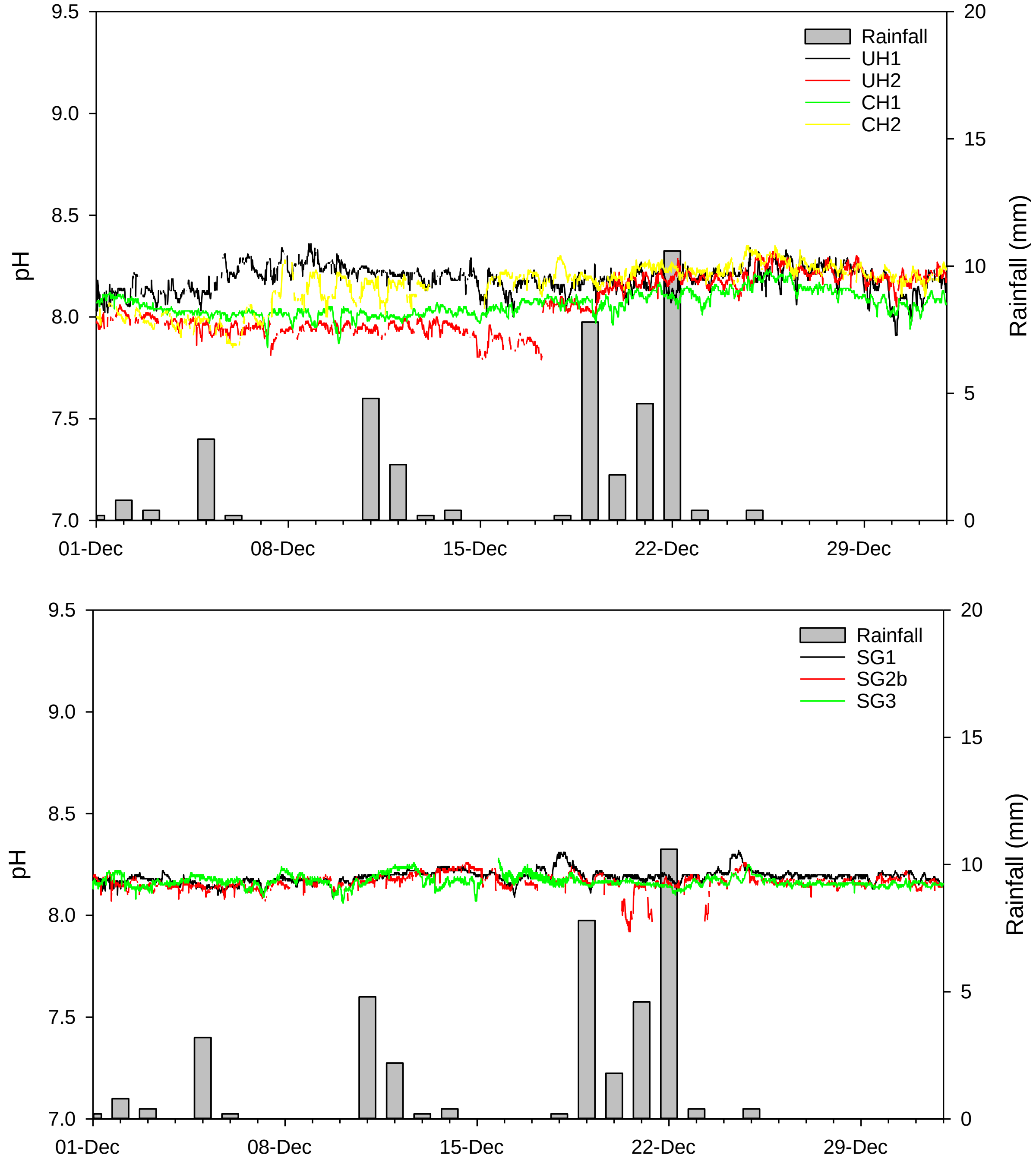


Figure 13 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during December 2018.

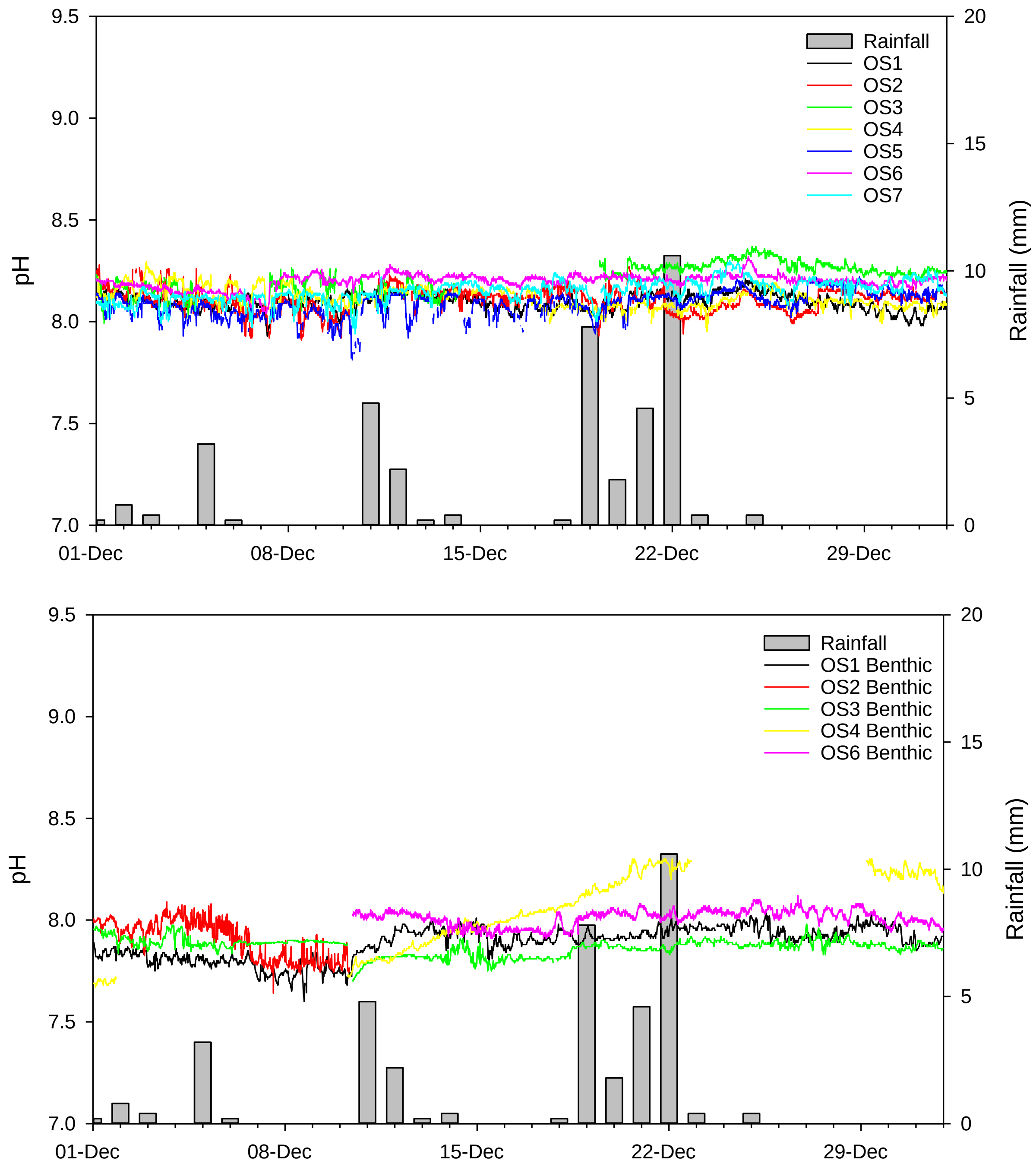


Figure 14 Surface pH (OS1 to OS7) and benthic pH (OS1 to OS4) at offshore water quality sites during December 2018.

3.2.4 Conductivity

Conductivity in December ranged from 51.2 to 54.4 mS/cm (Table 8) compared to 52.1 to 54.7 mS/cm in November and 53.5 to 55.8 mS/cm in October. The overall temporal decline was due to the combined influence of higher local rainfall and large freshwater inputs from the Waimakariri River into the harbour which have occurred since October.

Despite limited flow events from the Waimakariri River in December, there were noticeable declines in conductivity on three occasions at the spoil ground and the majority of the offshore sites on 17, 24 and 29 December particularly at SG1 and OS5 the most northern located sites (Figures 15 and 16). This does not coincide with any particular large flow events from the Waimakariri River (Figure 4).

Benthic conductivity, as typically observed, was overall more stable and higher than at the surface ranging from 52.9 to 53.9 mS/cm. This is due to the less dense fresh waters being more predominant at the surface (Figures 15 and 16).

Table 8 Mean conductivity at inshore, spoil ground and offshore water quality sites during December 2018.
Values are means ± se (n = 217 to 2976).

Site	Conductivity (mS/cm)	
	Surface loggers	Benthic loggers
UH1	51.7 ± 0.0	–
UH2	52.0 ± 0.0	–
CH1	51.7 ± 0.0	–
CH2	52.1 ± 0.0	–
SG1	53.2 ± 0.0	–
SG2	53.5 ± 0.0	–
SG3	54.4 ± 0.0	–
OS1	51.2 ± 0.0	53.0 ± 0.0
OS2	52.0 ± 0.0	52.9 ± 0.0
OS3	52.4 ± 0.0	53.9 ± 0.0
OS4	53.5 ± 0.0	53.6 ± 0.0
OS5	52.1 ± 0.0	–
OS6	52.6 ± 0.0	56.7 ± 0.0
OS7	52.0 ± 0.0	–

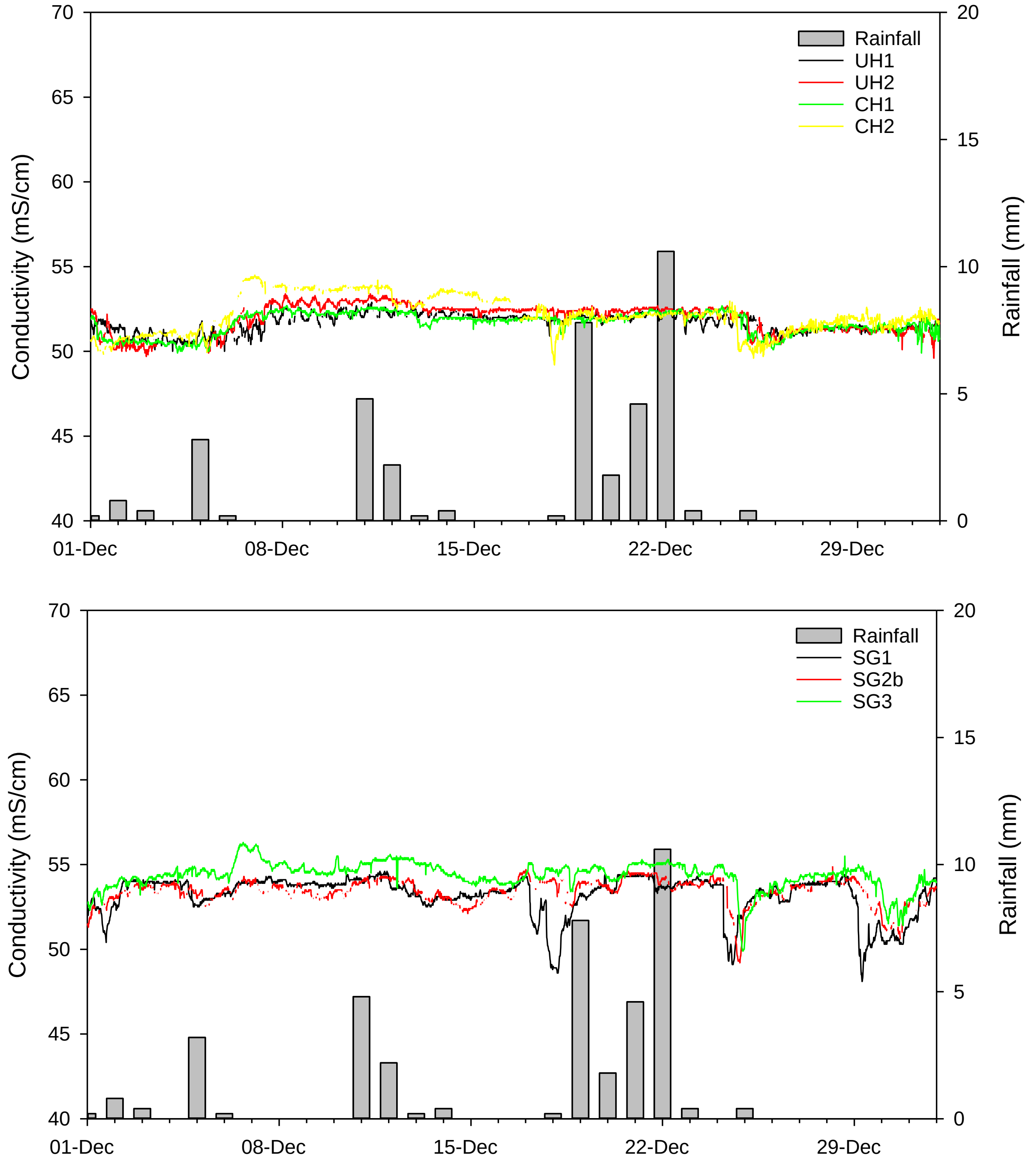


Figure 15 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during December 2018.

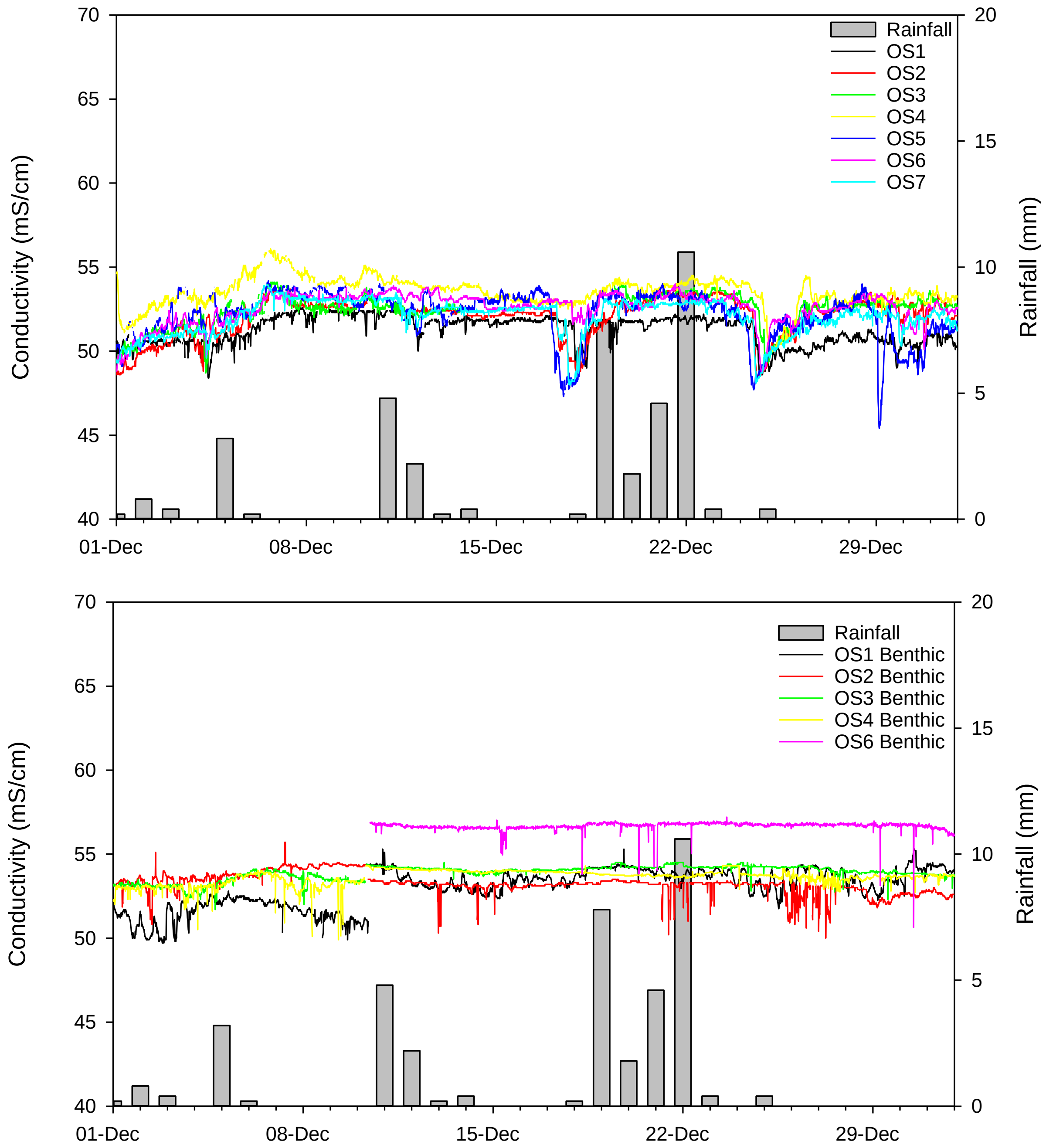


Figure 16 Surface conductivity (OS1 to OS7) and benthic conductivity (OS1 to OS4 and OS6) at offshore water quality sites during December 2018.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations in December (95 to 103% saturation) were slightly higher than in November (94 to 101% saturation) but similar to those recorded in October (Table 9). Diurnal fluctuations in DO were more pronounced at the inshore sites with additional peaks in DO during warmer days and declines following cooler cloudy days or rain events.

However overall DO in December was much more stable than in November as a result of calmer metocean conditions. At spoil ground and offshore sites DO was quite stable, although in a similar trend to surface temperature, large declines in DO were observed from the 7 December coinciding with cooler overnight minimum air temperatures (Figures 17 and 18). Similar to surface temperatures, declines were particularly noticeable at SG3 and OS2, OS3 and OS4. Increased cloud cover and lower air temperatures is likely to have resulted in reductions in photosynthesis and thus oxygen generation. Similarly, DO peaked particularly during periods of higher air temperatures during daylight hours.

Table 9 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during December 2018.
Values are means ± se (n = 2066 to 2976).

Site	Dissolved oxygen (% saturation)	
	Surface loggers	Benthic loggers
UH1	96 ± 0	–
UH2	96 ± 0	–
CH1	95 ± 0	–
CH2	101 ± 0	–
SG1	100 ± 0	–
SG2	100 ± 0	–
SG3	98 ± 0	–
OS1	98 ± 0	85 ± 0
OS2	100 ± 0	–*
OS3	101 ± 0	78 ± 0
OS4	102 ± 0	81 ± 0
OS5	100 ± 0	–
OS6	103 ± 0	78 ± 0
OS7	100 ± 0	–

**no benthic data available from OS2.*

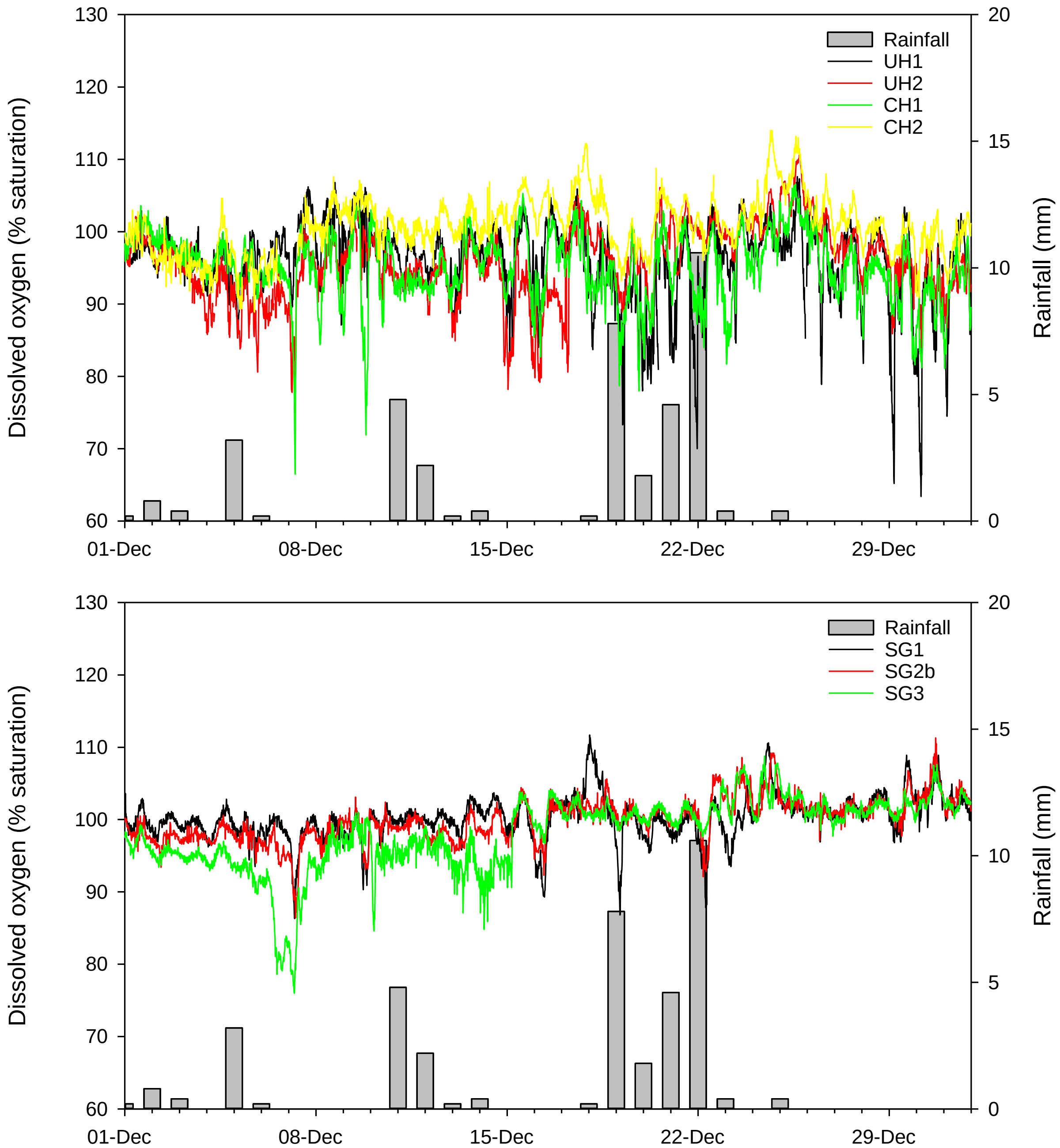


Figure 17 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during December 2018.

As typically observed, mean monthly benthic DO concentrations were slightly lower than the corresponding surface readings ranging from 78 to 85% saturation, due to reduced photosynthesis (producing less oxygen) occurring at depth (Table 9). From relatively elevated DO at the beginning of December, benthic DO declined in response to cooler air temperatures from 7 December, similar to surface DO and water temperatures but did not recover as quickly as DO at the surface. This is most likely due to intermittent cloud cover and rain events which followed up until 23 December. Benthic DO began to recover towards the end of the month with the cessation of precipitation events and warmer days (Figures 17 and 18).

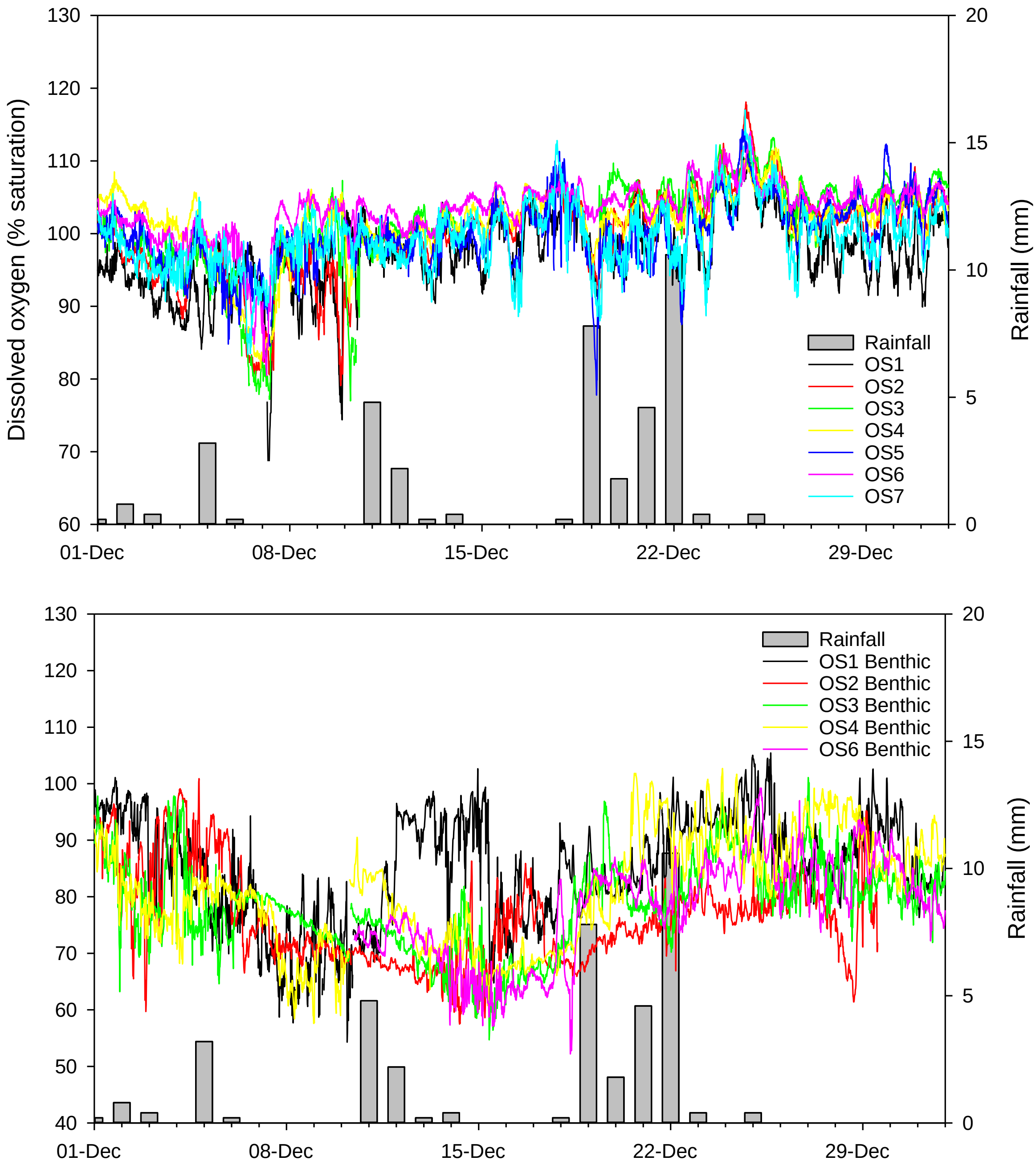


Figure 18 Surface DO (OS1 to OS7) and benthic DO (OS1 to OS 4 and OS6) at offshore water quality sites during December 2018.

3.3 Physicochemistry Depth Profiling & TSS

Vertical depth profiling of the whole water column at each monitoring site was conducted in conjunction with monthly discrete water sampling on 12 December. In addition to the previously discussed physicochemical parameters, the light attenuation rate (K_d, the rate at which light or PAR diminishes with depth through the water column) and resultant euphotic depth (the optical depth to which photosynthesis can occur/where light levels are ~1% of those at the surface) were also calculated.

Water samples for the determination of TSS were also collected from three different depths (sub-surface, mid-column and approximately 1 m above the benthos) at the ten offshore and spoil ground sites. Due to the shallow water depths associated with the inshore monitoring sites, only surface TSS samples were collected from sites UH1, UH2, CH1 and CH2. Further information regarding the specific sampling methodology can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Statistical analyses of the resulting datasets are provided in Tables 10 to 12, with depth profile plots presented in Figures 19 to 21.

The relatively shallow sites of the upper and central harbour displayed well mixed conditions with little variation in measured parameters through the vertical water column. This was in contrast to the previous month where altering gradients for some parameters were observed due to the large freshwater inundation that had occurred one day prior to sampling, but a represents a return to more typical conditions.

Conductivity at the southern site of CH2, however, displayed a slight freshening in the surface 6 m that was not observed at the remaining inner harbour sites (Figure 19). Towards the benthos, conductivity increased to levels similar to those of nearby monitoring locations, suggesting that the surface characteristics may be a residual signal from Waimakariri outflow intrusions into the harbour that had occurred during November. Several sites once again indicated increased turbidity at the seabed, which would be typically observed due to the shear forces (friction between the overlying moving water and the seabed) providing energy for sediment resuspension.

Within the nearshore environment, vertical profiles collected during December did not display a similar level of vertical mixing as within the inner harbour. Surface waters extending down to approximately 8 m depth were warmer and fresher (i.e., lower density), overlying cooler, high conductivity (i.e., higher density) benthic waters. Both pH and DO displayed lower values near the benthos, which likely indicate an increased component of respiration compared to photosynthesis through microbial degradation of organic matter at depth (Figure 20).

Further offshore, at sites OS5, OS6 and the spoil ground, vertical patterns in physicochemical properties displayed a similar vertical pattern as those of the nearshore environment. Surface waters were well mixed to approximately 12 m depth, with higher temperature, conductivity, pH and DO than at the near-benthos. Surface conductivity at OS5 was notably lower than the remaining offshore sites (Figure 21), suggesting an influence of freshwater outflow from the Waimakariri River, which had occurred on the 7 December.

As previously observed throughout the baseline and dredge monitoring, the clearest waters were observed within the offshore environment and the spoil ground. Low levels of turbidity and TSS throughout the water column resulted in limited vertical light attenuation and thus the greatest calculations of euphotic depth at these sites (Tables 12 to 14). Across the spoil ground, euphotic depth ranged from 24.4 m to 42.6 m during the December sampling (Table 14), greater than that calculated from the November data and a reflection of increased water clarity. There were no exceedances of WQG for the sub-surface during the December sampling campaign.

Table 10 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the December 2018 sampling event. *Values are means ± se (n = 4 to 6 for sub-surface, n = 20 to 33 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
UH1	12/12/2018 06:45	Sub-surface	16.3 ± 0.0	7.9 ± 0.0	52.8 ± 0.0	95 ± 0	5.5 ± 0.1	10	1.0 ± 0.0	4.7
		Whole column	16.2 ± 0.0	7.9 ± 0.0	53.0 ± 0.0	95 ± 0	5.8 ± 0.1	–		
UH2	12/12/2018 06:58	Sub-surface	16.0 ± 0.0	8.0 ± 0.0	53.0 ± 0.0	99 ± 0	3.4 ± 0.2	10	0.7 ± 0.0	6.2
		Whole column	16.0 ± 0.0	8.0 ± 0.0	51.5 ± 1.6	98 ± 0	6.0 ± 1.7	–		
UH3	12/12/2018 06:09	Sub-surface	16.5 ± 0.0	7.7 ± 0.0	52.7 ± 0.0	95 ± 0	9.9 ± 0.1	20	1.7 ± 0.0	2.8
		Whole column	16.5 ± 0.0	7.8 ± 0.0	52.7 ± 0.0	94 ± 0	11 ± 1	–		
CH1	12/12/2018 07:28	Sub-surface	15.9 ± 0.0	8.0 ± 0.0	53.0 ± 0.0	96 ± 0	3.9 ± 0.2	6	0.8 ± 0.0	5.5
		Whole column	16.0 ± 0.0	8.0 ± 0.0	53.1 ± 0.0	95 ± 0	9.8 ± 3.1	–		
CH2	12/12/2018 07:17	Sub-surface	16.0 ± 0.0	8.0 ± 0.0	52.2 ± 0.0	100 ± 0	0.7 ± 0.0	<3	0.4 ± 0.0	11.3
		Whole column	16.0 ± 0.0	8.0 ± 0.0	52.5 ± 0.1	100 ± 0	2.1 ± 0.4	–		
WQG			–	**7.0 – 8.5**	–	**80-110**	**10**	–	–	–

Table 11 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the December 2018 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 32 to 38 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS1	12/12/2018 07:43	Sub-surface	16.0 ± 0.0	8.0 ± 0.0	52.3 ± 0.2	100 ± 0	1.1 ± 0.0	6	0.5 ± 0.1	9.0
		Mid	15.9 ± 0.0	8.0 ± 0.0	53.2 ± 0.0	97 ± 0	2.7 ± 0.1	3		
		Benthos	15.6 ± 0.0	8.0 ± 0.0	53.5 ± 0.0	95 ± 0	20 ± 9	4		
		Whole column	15.9 ± 0.0	8.0 ± 0.0	53.0 ± 0.1	98 ± 0	5.1 ± 2.1	–		
OS2	12/12/2018 11:30	Sub-surface	16.1 ± 0.0	8.0 ± 0.0	52.7 ± 0.0	100 ± 1	0.3 ± 0.0	<3	0.4 ± 0.0	12.2
		Mid	15.8 ± 0.2	8.0 ± 0.0	53.2 ± 0.2	99 ± 1	1.1 ± 0.5	<3		
		Benthos	13.8 ± 0.0	7.9 ± 0.0	54.5 ± 0.0	75 ± 1	9.3 ± 2.3	11		
		Whole column	15.4 ± 0.2	8.0 ± 0.0	53.3 ± 0.1	94 ± 2	2.4 ± 0.7	–		
OS3	12/12/2018 10:50	Sub-surface	15.6 ± 0.0	8.0 ± 0.0	53.3 ± 0.0	101 ± 0	0.2 ± 0.0	<3	0.3 ± 0.0	18.0
		Mid	15.6 ± 0.0	8.0 ± 0.0	53.4 ± 0.0	101 ± 0	0.2 ± 0.0	<3		
		Benthos	13.3 ± 0.0	7.9 ± 0.0	54.7 ± 0.0	77 ± 2	7.1 ± 0.6	9		
		Whole column	15.2 ± 0.1	8.0 ± 0.0	53.6 ± 0.1	97 ± 2	1.4 ± 0.4	–		
OS4	12/12/2018 10:20	Sub-surface	15.4 ± 0.0	8.0 ± 0.0	53.5 ± 0.0	100 ± 1	0.3 ± 0.0	<3	0.4 ± 0.0	10.8
		Mid	14.8 ± 0.2	8.0 ± 0.0	53.9 ± 0.1	97 ± 2	0.9 ± 0.3	<3		
		Benthos	13.1 ± 0.0	7.9 ± 0.0	54.7 ± 0.0	79 ± 0	13 ± 6	7		
		Whole column	14.5 ± 0.2	8.0 ± 0.0	54.0 ± 0.1	93 ± 2	3.2 ± 1.1	-		
OS7	12/12/2018 11:46	Sub-surface	16.1 ± 0.0	8.1 ± 0.0	52.0 ± 0.0	102 ± 0	0.1 ± 0.0	<3	0.3 ± 0.0	14.3
		Mid	16.1 ± 0.0	8.0 ± 0.0	52.6 ± 0.1	102 ± 0	0.3 ± 0.0	4		
		Benthos	15.6 ± 0.0	8.0 ± 0.0	53.5 ± 0.0	93 ± 1	5.5 ± 0.6	9		
		Whole column	16.0 ± 0.0	8.0 ± 0.0	52.6 ± 0.1	100 ± 1	1.5 ± 0.4	–		
WQG			–	**7.0 – 8.5**	–	**80-110**	**10**	–	–	

Table 12 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the December 2018 sampling event.
Values are means ± se (n =6 for sub-surface, mid and benthos, n = 39 to 48 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS5	12/12/2018 08:09	Sub-surface	16.0 ± 0.0	8.0 ± 0.0	51.5 ± 0.0	102 ± 0	0.2 ± 0.0	<3	0.2 ± 0.0	18.9
		Mid	15.9 ± 0.1	8.0 ± 0.0	53.1 ± 0.1	100 ± 0	0.5 ± 0.1	<3		
		Benthos	13.9 ± 0.1	7.9 ± 0.0	54.5 ± 0.1	85 ± 2	9.2 ± 6.1	<3		
		Whole column	15.5 ± 0.1	8.0 ± 0.0	52.9 ± 0.2	98 ± 1	1.7 ± 1.0	–		
OS6	12/12/2018 11:09	Sub-surface	15.5 ± 0.0	8.0 ± 0.0	53.6 ± 0.0	101 ± 0	0.1 ± 0.0	<3	0.2 ± 0.0	25.5
		Mid	15.4 ± 0.0	8.0 ± 0.0	53.9 ± 0.0	101 ± 0	0.0 ± 0.0	<3		
		Benthos	13.7 ± 0.1	7.9 ± 0.0	54.5 ± 0.0	77 ± 1	3.1 ± 0.5	4		
		Whole column	15.1 ± 0.1	8.0 ± 0.0	53.9 ± 0.1	97 ± 1	0.6 ± 0.2	–		
SG1	12/12/2018 09:38	Sub-surface	15.2 ± 0.0	8.0 ± 0.0	54.0 ± 0.0	103 ± 0	0.2 ± 0.1	<3	0.2 ± 0.0	26.1
		Mid	15.2 ± 0.0	8.0 ± 0.0	54.1 ± 0.0	104 ± 0	0.0 ± 0.0	3		
		Benthos	13.3 ± 0.0	7.9 ± 0.0	54.7 ± 0.0	83 ± 1	4.7 ± 0.4	18		
		Whole column	14.8 ± 0.1	8.0 ± 0.0	54.2 ± 0.0	100 ± 1	0.7 ± 0.2	–		
SG2b	12/12/2018 09:06	Sub-surface	15.3 ± 0.0	8.0 ± 0.0	54.0 ± 0.0	101 ± 0	0.0 ± 0.0	<3	0.2 ± 0.0	24.4
		Mid	15.1 ± 0.0	8.0 ± 0.0	54.1 ± 0.0	103 ± 0	0.0 ± 0.0	<3		
		Benthos	14.2 ± 0.1	8.0 ± 0.0	54.5 ± 0.0	98 ± 1	24 ± 18	7		
		Whole column	15.0 ± 0.1	8.0 ± 0.0	54.1 ± 0.0	102 ± 0	3.1 ± 2.5	–		
SG3	12/12/2018 08:35	Sub-surface	15.8 ± 0.0	8.0 ± 0.0	53.1 ± 0.0	102 ± 0	0.1 ± 0.1	<3	0.1 ± 0.0	42.6
		Mid	15.4 ± 0.0	8.0 ± 0.0	54.1 ± 0.0	103 ± 0	0.0 ± 0.0	<3		
		Benthos	13.9 ± 0.2	8.0 ± 0.0	54.6 ± 0.1	95 ± 2	7.3 ± 5.2	3		
		Whole column	15.3 ± 0.1	8.0 ± 0.0	53.9 ± 0.1	101 ± 0	1.0 ± 0.8	–		
WQG			**–**	**7.0 – 8.5**	**–**	**80-110**	**10**	**–**	**–**	

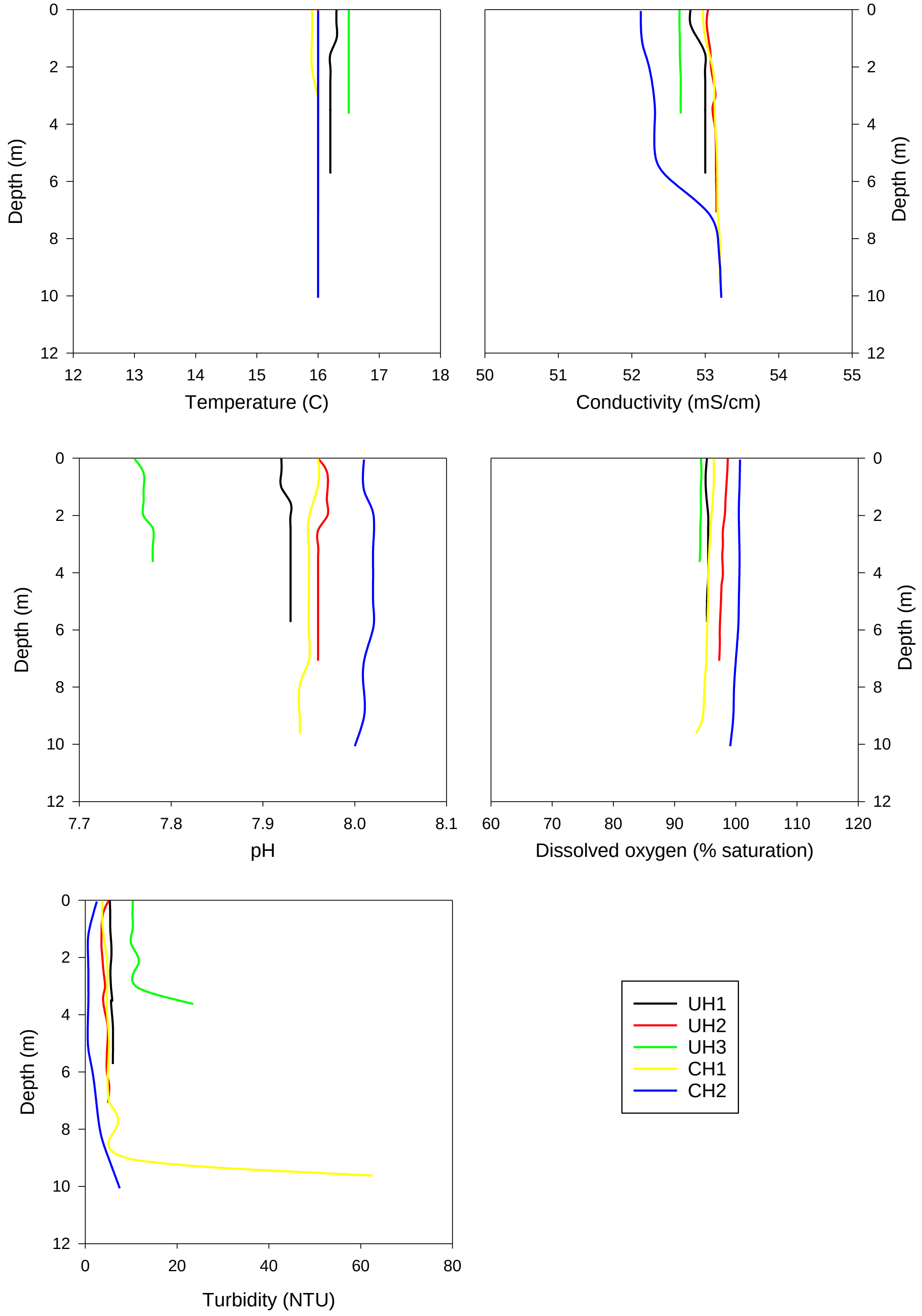


Figure 19 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 12 December 2018.

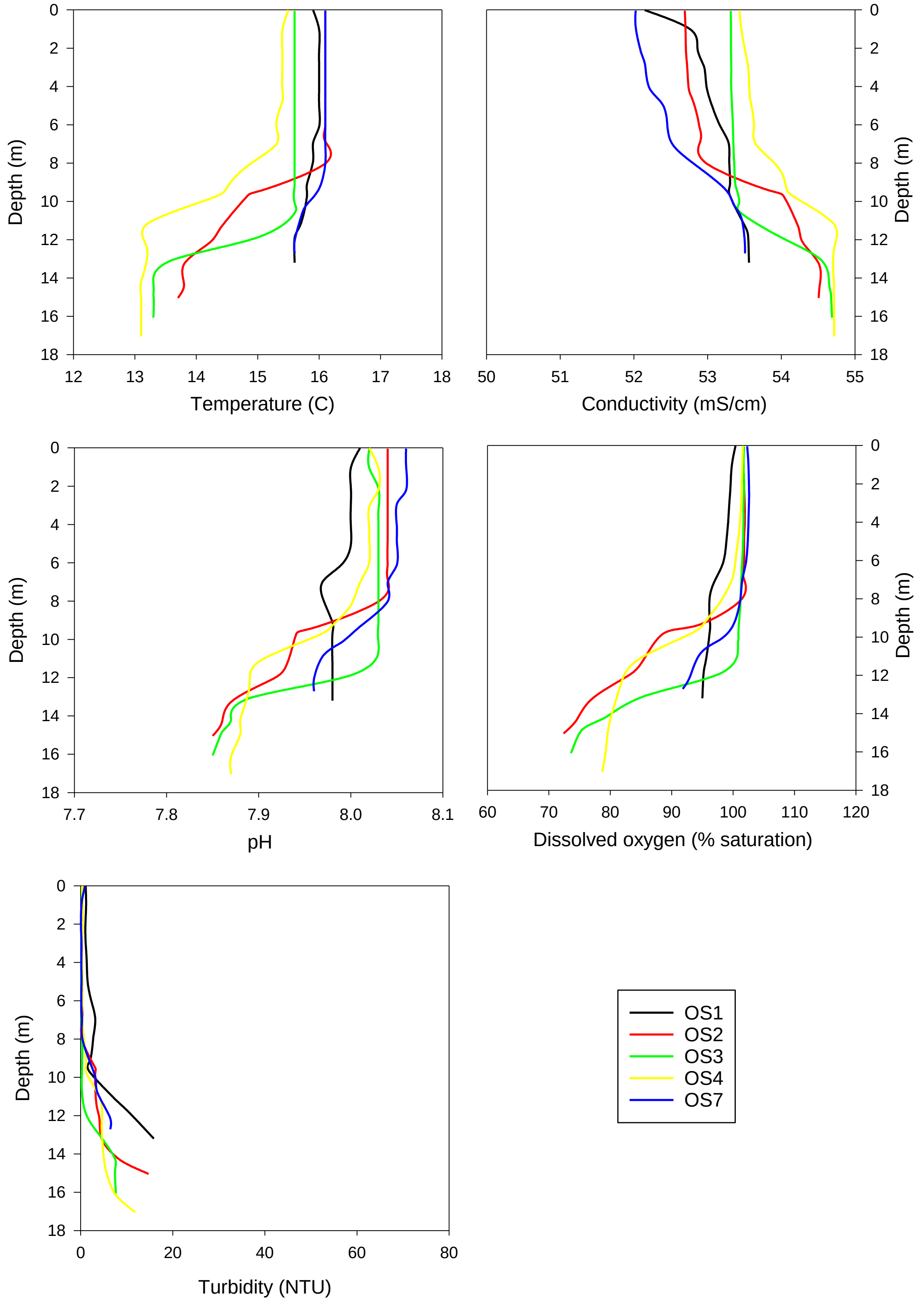


Figure 20 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 12 December 2018.

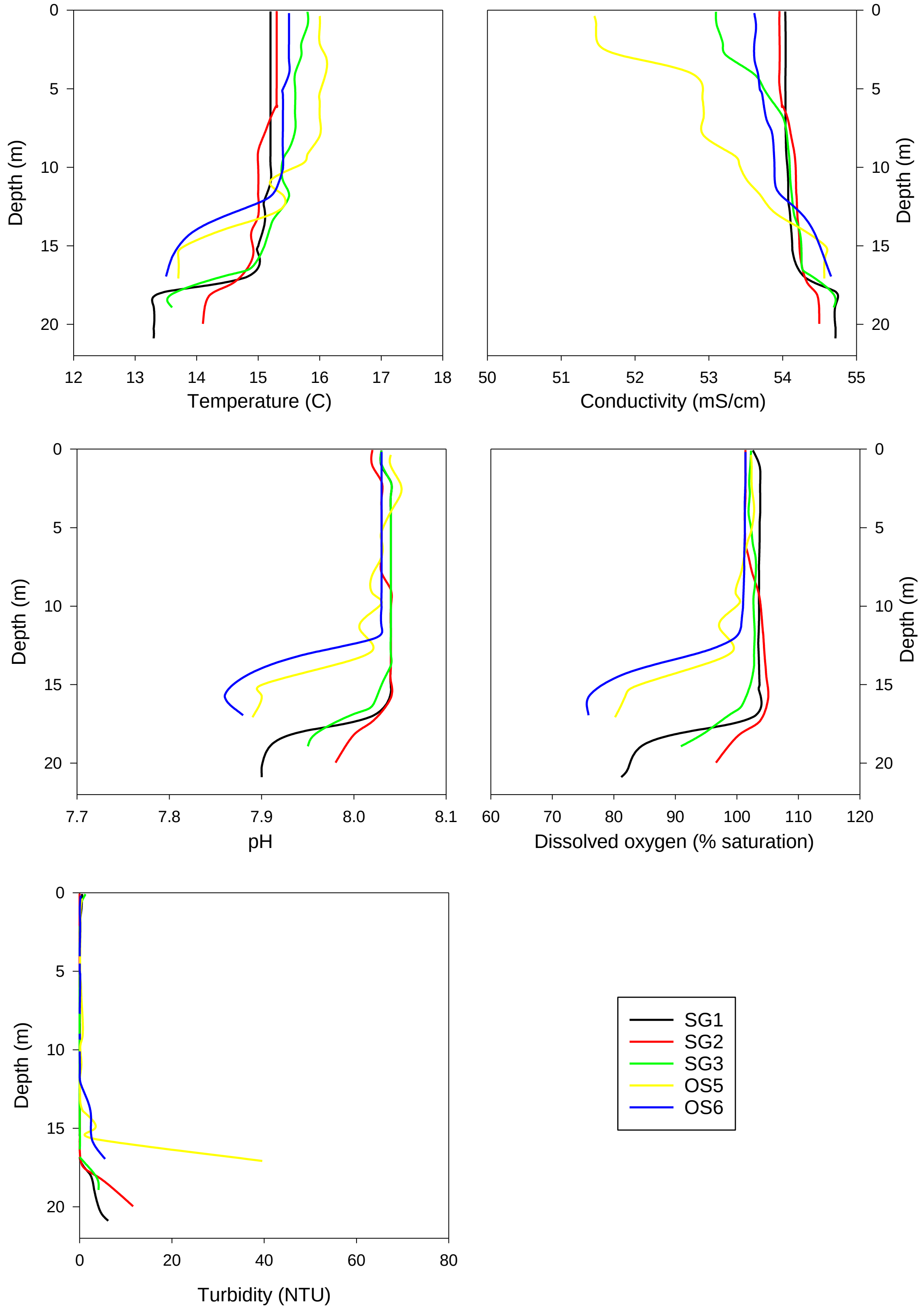


Figure 21 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 15 December 2018.

3.4 Continuous BPAR Loggers

Benthic PAR, or the amount of light reaching the benthos that can be utilised for photosynthesis, was measured at two offshore sites (OS2 and OS3) by autonomous dual PAR Odyssey loggers. Benthic PAR was compared to ambient PAR measured by telemetered PAR loggers located at the Vision Environment office in Christchurch (Vision Base Christchurch, VBCC) in order to account for variations in daily light intensity such as those induced by cloud cover. Further information on the specific methodology used in BPAR measurements can be obtained from the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

Statistical analyses on the monthly BPAR datasets are presented in Table 13, with the collected data from benthic and VBCC sensors presented in Figure 22. Data from the logger exchange date (10 December) were removed from the analyses.

Ambient PAR/total daily PAR (TDP) i.e., the amount of sunlight available to enter the water column), turbidity and the depth of the water column, all have a controlling factor on BPAR measurements. As typically observed in temperate regions with high levels of cloud cover, the amount of incoming solar radiation at VBCC displayed significant variation, with values ranging from 6,700 to 54,300 mmol/m^2/day (Table 13). Despite overall longer day lengths in December, mean TDP (31,010 mmol/m^2/day) was slightly lower than that observed during November (38,353 mmol/m^2/day).

Surface turbidity levels at both OS2 and OS3 were slightly elevated during the first week of December, with particulate matter limiting benthic light intensities during this period of time. However, as surface turbidity declined, BPAR concentrations increased to maximum levels between 11 and 17 December (Figure 22). As turbidity levels began to increase during the second half of the month, BPAR displayed a corresponding decline at both sampling locations.

Spatial variability with the BPAR data was high, with dissimilar timings of peaks and troughs across the two sampling sites and with ambient solar radiation recorded at the Vision Base in Christchurch. Despite the deeper water depth, mean BPAR was greater at OS2 than OS3 (14 c.f. 9.3 mmol/m^2/day). This high level of variability emphasises the complex nature of benthic light intensity due to the integrated effects of the overlying water column.

Table 13 Total Daily PAR (TDP) statistics during December 2018.
Values are means ± se (n = 30 to 31). Note data from the BPAR exchange day on 10 December were not utilized in plots or statistics for sites OS2 and OS3.

Site	Depth (m)	TDP (mmol/m^2/day)		
		Mean ± se	**Median**	**Range**
Base	-	31,010 ± 2,562	32,600	6,700 – 54,300
OS2	17	14 ± 4	1.4	<0.01 – 65
OS3	14	9.3 ± 2.3	5.3	<0.01 – 57

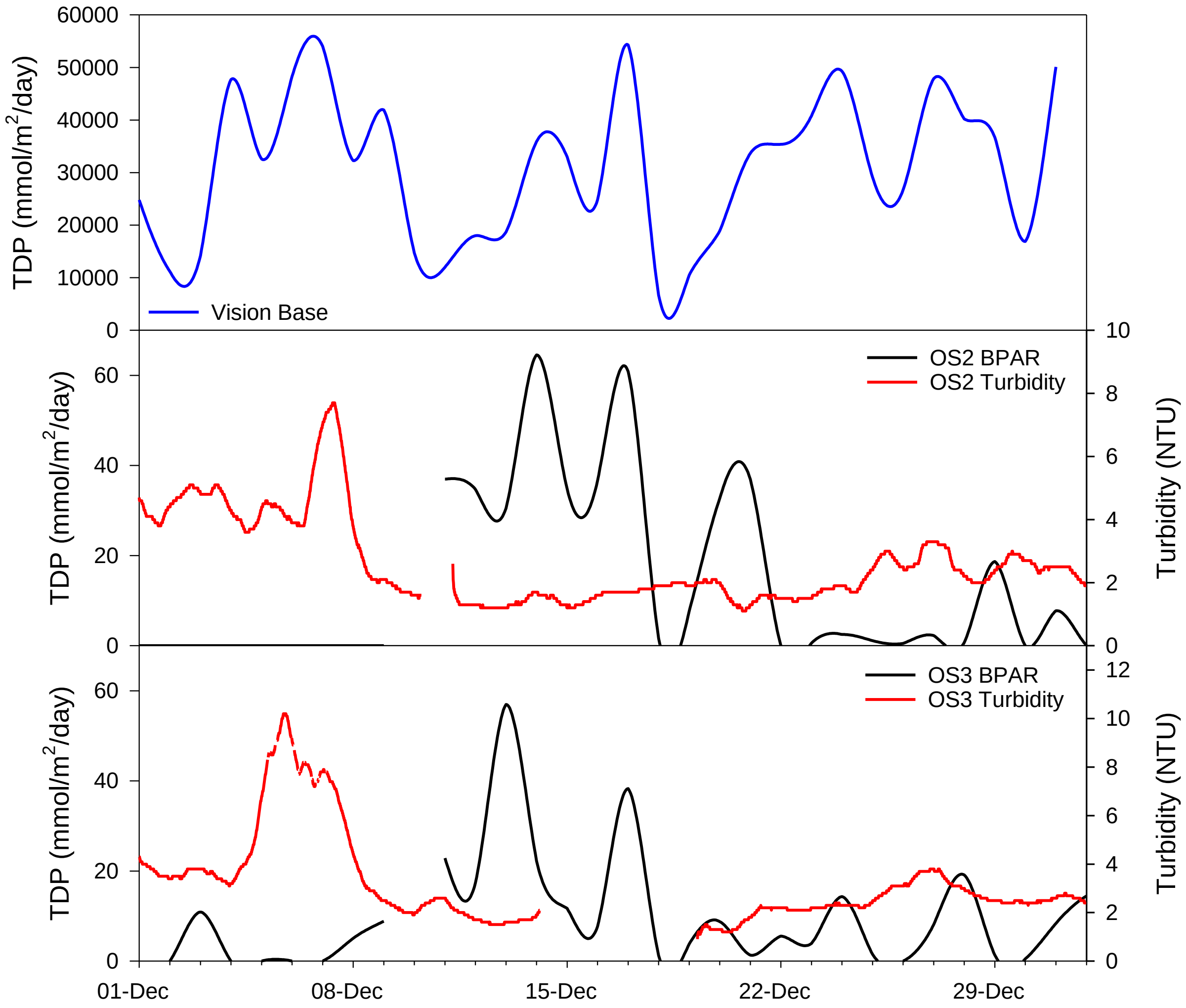


Figure 22 Total daily BPAR at OS2 and OS3 during December 2018 compared to ambient PAR and corresponding surface turbidity.
Note data from the BPAR exchange day on 10 December were not utilized in plots or statistics.

3.5 Continuous Sedimentation Loggers

Data on sediment deposition/erosion rates were collected at the inshore site UH3 and offshore site OS2, using ALTUS acoustic altimeters located approximately between 200 and 600 mm above the seabed in drop down frames. Further details on the specific methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Changes in energy from wind waves, currents and/or tidally induced flows can result in variations in sedimentation patterns, ranging from deposition of sediments originating from another location, resuspension of sediments with no net change in the seabed or the resuspension of sediments and transportation to another location. Altimeters provide two forms of information to help identify these processes:

- Instantaneous bed level change calculated every 15 minutes indicating the level of sediment flux occurring at a set point in time; and
- Net cumulative change in bed level over a given period.

Sustained, elevated offshore significant waves travelling in a southerly direction during the first week of December are likely to have been the driving factor of the variable seabed level measured at OS2, with alternating periods of 20 mm sediment erosion and deposition (Figure 23). As wind speeds and wave heights declined for the remainder of the month, surface turbidity and bed level remained relatively stable till 10 December 2018. Following this, altimeters deployed at OS2 indicate steady sediment deposition for the remainder of the month resulting in a net bed level change of +23 mm (Figure 23, Table 14).

Unfortunately, altimeter data from the typically more protected harbour head site at UH3 were not available during the first 10 days of December due to equipment malfunction during the November deployment. In a similar manner to sediment patterns at the harbour month, bed level data from UH3 indicate a period of sediment deposition from 10 to 23 December (Figure 23). However, during the final week of December, easterly inshore winds increased, and bed level data indicate a period of sediment erosion and increased surface turbidity. Given the secondary phase of sediment erosion that was not observed at OS2, the net bed level change at UH3 was slightly less at only +12 mm (Figure 23, Table 14).

Table 14 Net Bed Level Change statistics from data collected from altimeters deployed at OS2 and UH3 during December 2018.

Site	December 2018 Net bed level change (mm)
OS2	+23
UH3	+12*

**Note that UH3 data were only available from 10 to 31 December due to equipment malfunction prior to unit exchange on 10 December*

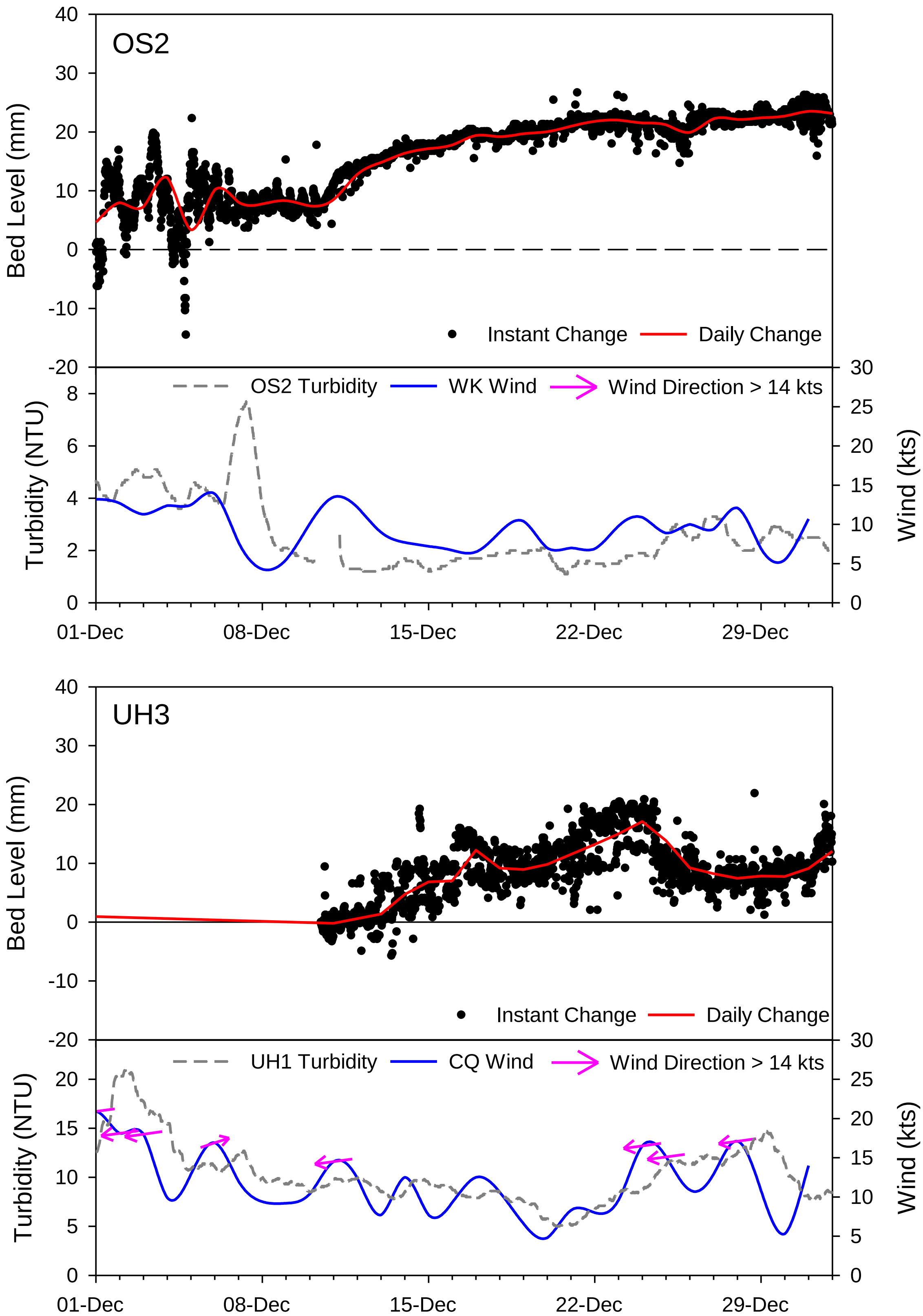


Figure 23 Mean instantaneous and daily averaged bed level change at OS2 and UH3 during December 2018 compared to ambient surface turbidity (24 hour rolling average) wind speed and direction.

*Note: Arrows indicate the direction of travel for winds greater than 14 knots. *Note that UH3 data from 10 to 31 December only due to equipment malfunction prior to exchange on 10 December*

3.6 Water Samples

Discrete water sampling was conducted on 12 December 2018, in conjunction with vertical physicochemical profiling through the water column. Quality assurance/quality control (QA/QC) procedures included a duplicate water sample collected at one site, in addition to a laboratory and field blank for each parameter. Further details on the specific sampling methodology can be found within the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Laboratory results associated with VE QA/QC procedures are presented in Table 25 of the appendix.

3.6.1 Nutrients

Total phosphorous concentrations reported during December 2018 displayed a similar spatial pattern to previous months, with higher concentrations reported in the shallower upper and central harbour sites decreasing further offshore (Table 15, Figure 24). The water quality guideline (WQG) for total phosphorous (30 µg/L) was not exceeded in December, with the highest concentrations of 29 µg/L recorded at UH3. There was no spatial trend in dissolved reactive phosphorous which was extremely low at all sites with no exceedances of the 5 µg/L WQG at any site (Table 15).

Of the remaining nutrients analysed, concentrations of total nitrogen and total kjeldahl nitrogen were below laboratory limits of reporting (LOR) at all sites, similar to previous months. Total ammonia ranged from 8 to 10 µg/L, which was lower than concentrations in November and the applicable WQG (15 µg/L). Nitrogen oxides at all sites was below LOR, which again was lower than concentrations recorded in November (Table 15).

Concentrations of chlorophyll *a*, an indicator of phytoplankton biomass remained low and below the WQG (4 µg/L) at all sites.

3.6.2 Total and Dissolved Metals

Concentrations of several metals were reported as below the limit of reporting (LOR) at all sites, including total and dissolved arsenic (<4 µg/L), cadmium (<0.2 µg/L), lead (<1 µg/L), nickel (<7 µg/L), selenium (<4 µg/L), silver (<0.4 µg/L) and tin (<5.3 µg/L). Total and dissolved copper which typically record concentrations above LOR and often exceed WQG at one or more sites were also below LOR in December (1.3 µg/L) at all sites. Total mercury which is generally reported below LOR recorded a value of 1.1 µg/L at site CH2, which was still below the WQG of 0.4 µg/L. Dissolved mercury was all below LOR as typically found (Tables 16 to 19).

Total aluminium concentrations are generally reported above the WQG of 24 µg/L (note that this WQG is designated for concentrations of the more readily available dissolved aluminium fraction) at all sites, with occasional exceptions at spoil ground sites. In December, however, exceedances were only recorded at inshore sites in addition to OS1 and OS2. A maximum of 520 µg/L was recorded at UH3. Concentrations of the more bioavailable dissolved fraction ranged between <LOR (12 µg/L) and 38 µg/L, exceeding WQG at all inshore sites with the exception of CH2. This indicates that some of the aluminium in the inshore sites was readily available for biological uptake. Dissolved aluminium was below LOR at all spoil ground sites (Figures 25 and 26).

Of the remaining metals analysed that have assigned WQGs, no exceedances were reported during the December 2018 water quality sampling campaign (Tables 16 to 19).

Table 15 Concentrations of nutrients and chlorophyll *a* at monitoring sites during December 2018.
Values outside recommended WQG are highlighted in blue.

Site	Parameter (µg/L)						
	Total Phosphorus	Dissolved Reactive Phosphorus	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)	Total Ammonia	Nitrogen Oxides (NOx)	Chlorophyll *a*
UH1	22	<1	<300	<200	9	<1	1.8
UH2	13	1.4	<300	<200	9	<1	1.5
UH3	29	<1	<300	<200	10	<1	1.8
CH1	11	<1	<300	<200	10	<1	1.6
CH2	10	1.1	<300	<200	9	<1	1.5
OS1	10	<1	<300	<200	8	<1	1.3
OS2	5	<1	<300	<200	8	<1	1.1
OS3	5	<1	<300	<200	8	<1	1.3
OS4	6	<1	<300	<200	8	<1	1.7
OS5	5	1.4	<300	<200	8	<1	1.1
OS6	10	<1	<300	<200	8	<1	0.9
OS7	4	<1	<300	<200	9	<1	1.0
SG1	10	1.1	<300	<200	8	<1	0.8
SG2	9	<1	<300	<200	8	<1	0.7
SG3	10	<1	<300	<200	8	<1	0.9
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

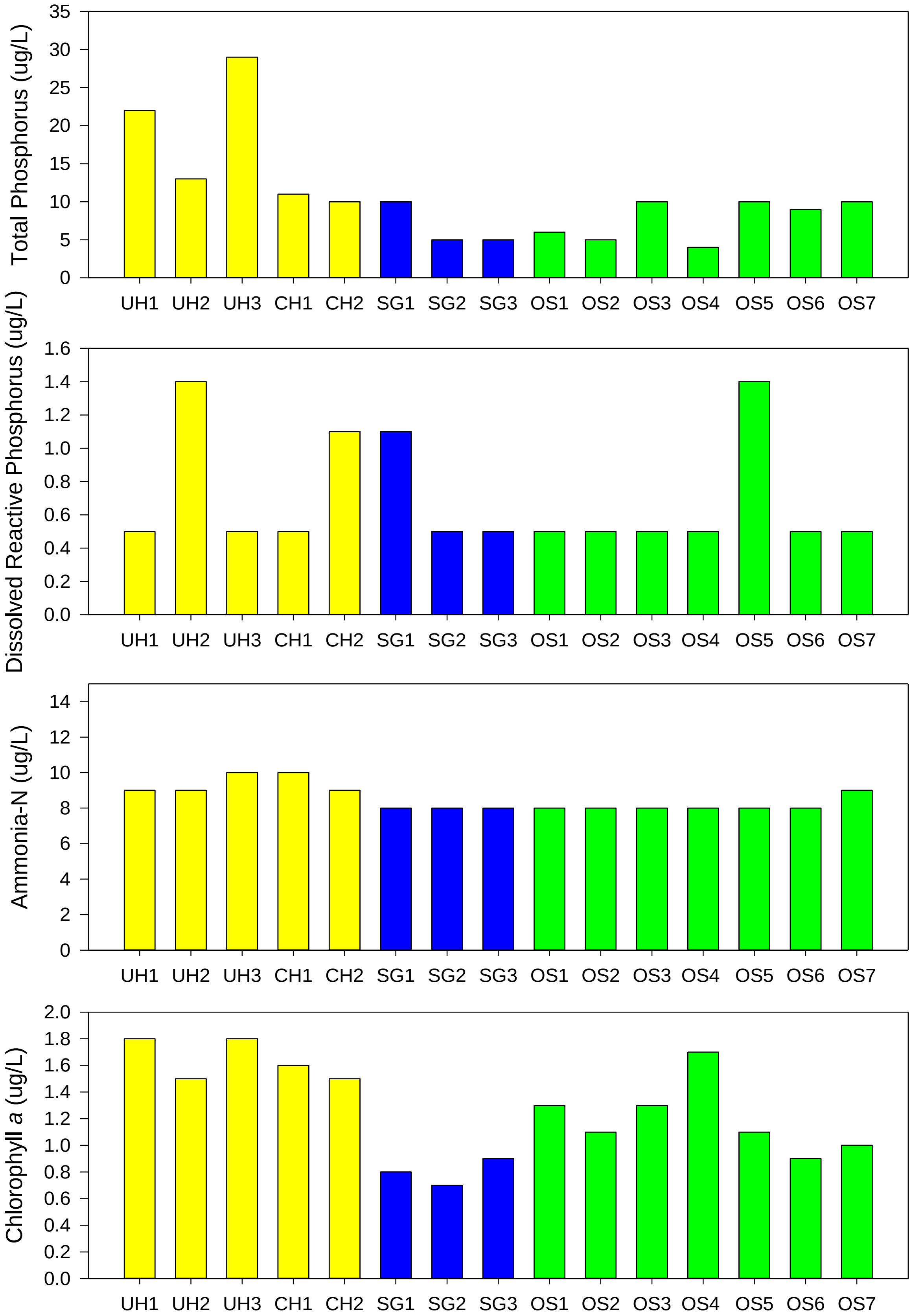


Figure 24 Nutrient and chlorophyll *a* concentrations at monitoring sites during December 2018. *Values which were <LOR, were plotted as half LOR. Total nitrogen, TKN and NOx concentrations were not plotted as all or most sites were < LOR.*

Table 16 Total and dissolved metal concentrations at inshore monitoring sites during December 2018. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	33	37	38	29	23	24
	Total	175	156	520	146	47	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4	<4	<4	<4	<4	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.2	<0.2	<0.2	<0.2	<0.2	
Chromium	Dissolved	1.8	1.8	2.1	1.2	1.8	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.6	2.4	2.2	2.9	1.8	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.6	<0.6	<0.6	<0.6	<0.6	
Copper	Dissolved	<1	<1	<1	<1	<1	1.3
	Total	<1	<1	<1	<1	<1	
Iron	Dissolved	21	17	13	15	8	-
	Total	153	147	520	136	43	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1	<1	<1	<1	<1	
Manganese	Dissolved	12.3	6.2	15.7	5.8	2.9	-
	Total	16.1	8.3	25	9.6	3.4	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	0.11	
Molybdenum	Dissolved	10.2	10.8	10.6	10.5	10.5	-
	Total	10.6	10.7	10.4	10.7	10.8	
Nickel	Dissolved	<6	<6	<6	<6	<6	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4	<4	<4	<4	<4	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.4	<0.4	<0.4	<0.4	<0.4	
Tin	Dissolved	<1.6	<1.6	<1.6	<1.6	<1.6	-
	Total	<1.7	<1.7	<1.7	<1.7	<1.7	
Vanadium	Dissolved	2.1	2.1	2	2	2	100
	Total	2.4	2.1	2.8	2.1	1.8	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	8.3	4.6	7.1	<4.2	<4.2	

Table 17 Total and dissolved metal concentrations at offshore monitoring sites during December 2018.
Values outside recommended WQG are highlighted in blue.

Metal (µg/L)		Sites							WQG
		OS1	OS2	OS3	OS4	OS5	OS6	OS7	
Aluminium	Dissolved	<12	<12	<12	13	19	<12	16	24
	Total	56	26	23	23	31	<21	<21	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4	<4	<4	<4	<4	<4	<4	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Chromium	Dissolved	2	1.7	1.5	<1	1.8	1.1	1.4	Cr(III) 27.4 Cr(VI) 4.4
	Total	2.2	2	1.7	1.4	2.4	1.6	1.3	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	
Copper	Dissolved	<1	<1	<1	<1	<1	<1	<1	1.3
	Total	<1	<1	<1	<1	<1	<1	<1	
Iron	Dissolved	11	27	<4	<4	<4	4	<4	-
	Total	48	34	13.6	23	22	8.5	4.5	
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1	<1	<1	<1	<1	<1	<1	
Manganese	Dissolved	2.8	2.4	1.5	1.5	1.7	1.1	1.9	-
	Total	3.8	2.6	1.8	2	2	1.4	2.6	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	10.9	11.2	10.8	11.3	10.6	10.9	10.5	-
	Total	10.5	11.5	11.1	11.2	11	10.9	10.9	
Nickel	Dissolved	<6	<6	<6	<6	<6	<6	<6	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4	<4	<4	<4	<4	<4	<4	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	
Tin	Dissolved	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	-
	Total	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	
Vanadium	Dissolved	1.7	2.6	2	2	1.8	2	1.7	100
	Total	2	1.9	1.7	1.7	1.6	1.8	1.6	
Zinc	Dissolved	<4	<4	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 18 Total and dissolved metal concentrations at spoil ground monitoring sites during December 2018.
Values outside recommended WQG are highlighted in blue.

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	<21	<21	<21	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4	<4	<4	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.2	<0.2	<0.2	
Chromium	Dissolved	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1	<1	<1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.6	<0.6	<0.6	
Copper	Dissolved	<1	<1	<1	1.3
	Total	<1	<1	<1	
Iron	Dissolved	<4	<4	<4	-
	Total	<4	<4	<4	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1	<1	<1	
Manganese	Dissolved	<1	<1	<1	-
	Total	<1	<1	<1	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	<1	<1	<1	-
	Total	<1	<1	<1	
Nickel	Dissolved	<6	<6	<6	70
	Total	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	-
	Total	<4	<4	<4	
Silver	Dissolved	<0.4	<0.4	<0.4	1.4
	Total	<0.4	<0.4	<0.4	
Tin	Dissolved	<1.6	<1.6	<1.6	-
	Total	<1.7	<1.7	<1.7	
Vanadium	Dissolved	<1	<1	<1	100
	Total	<1.1	<1.1	<1.1	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

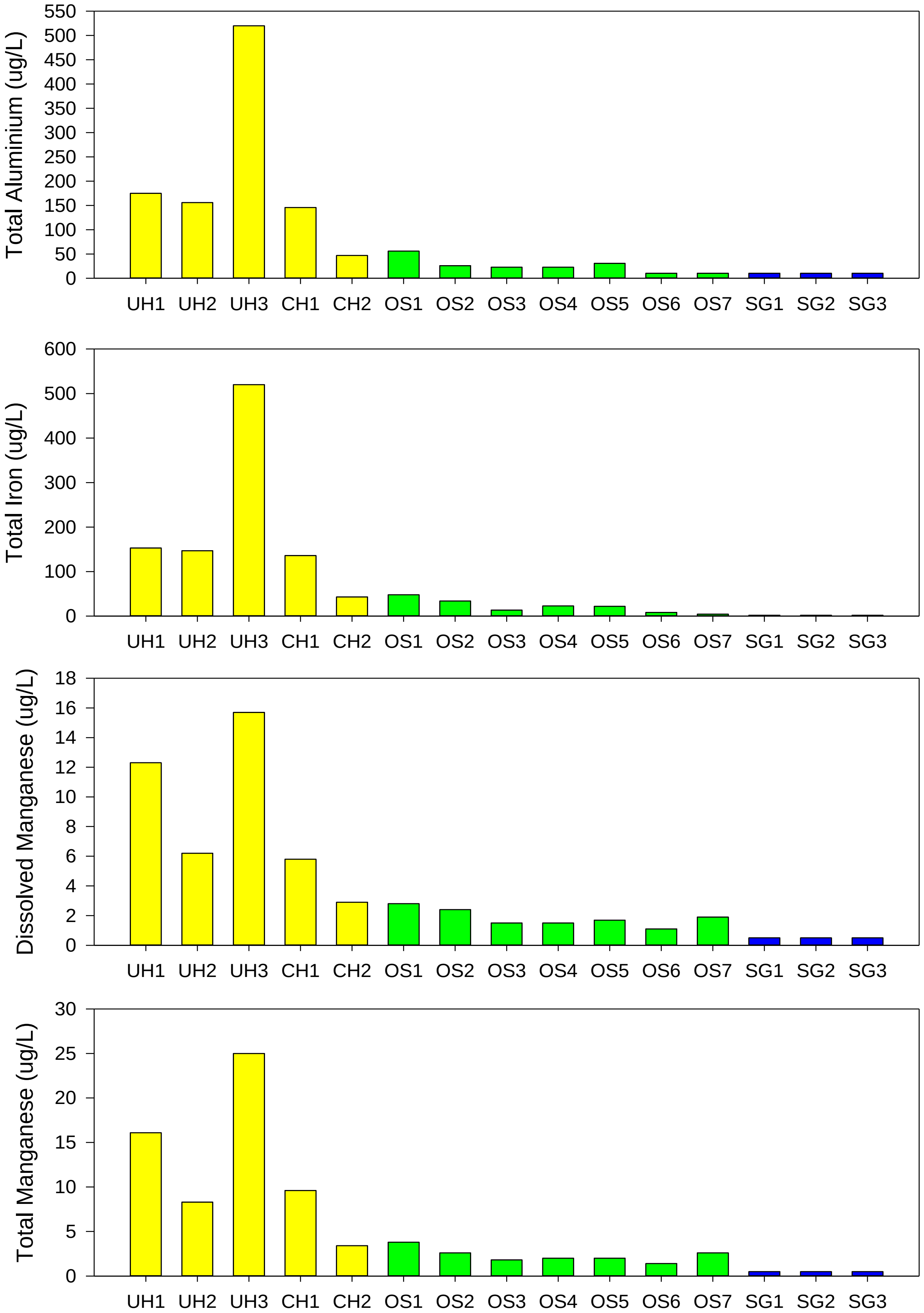


Figure 25 Total aluminium, total iron, and total and dissolved manganese concentrations at monitoring sites during December 2018.
Values which were <LOR, were plotted as half LOR. Metals which were below LOR at all sites were not plotted.

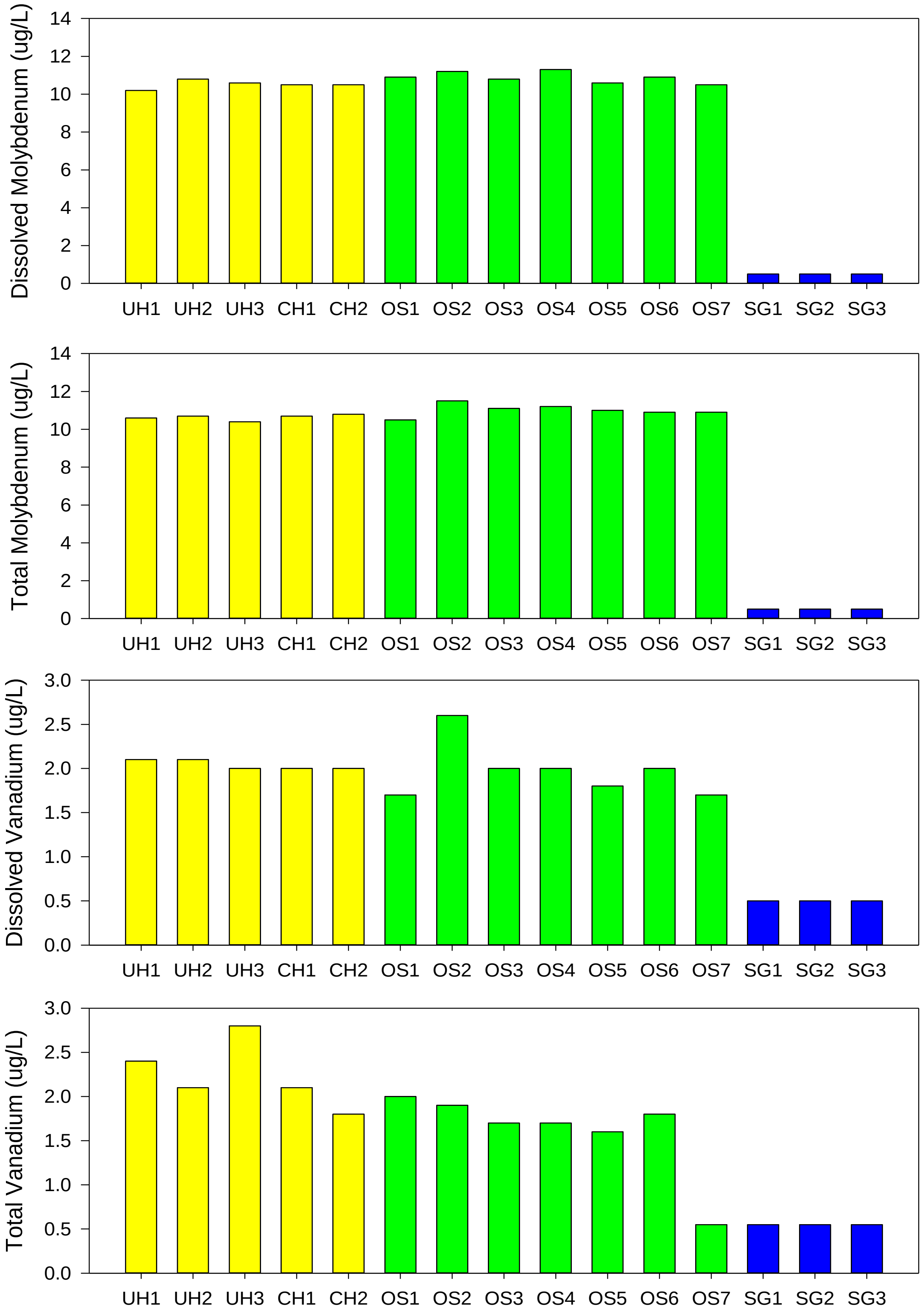


Figure 26 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during December 2018.
Values which were <LOR, were plotted as half LOR. Metals which were below LOR at all sites were not plotted.

Despite not having assigned WQGs, particulate iron has regularly been reported at elevated concentrations within Lyttelton Harbour during the baseline monitoring. During December concentrations of total iron were low with most sites < 100 µg/L; a similar to finding to that of November and in contrast to the elevated levels experienced in previous months. The exception was site UH3 with a maximum concentration of 520 µg/L. This site also recorded elevated total aluminium as both metals generally trend similarly. Similar to patterns in aluminum, dissolved concentrations of iron were again low but more elevated at the inshore sites than in November. However, in a continuing trend, iron within Lyttelton Harbour and the surrounds was predominantly present in the particulate phase, and thus not readily available for biological uptake.

Total and dissolved manganese were detected at all inshore and offshore sites but below LOR (<1 µg/L) at spoil ground sites in December. Highest concentrations were again recorded in the inner harbor. Relatively similar values for the dissolved and total components were reported, suggesting a high proportion of the total manganese present in the harbour was in the dissolved phase (Figure 25). Concentrations were overall lower than those in November.

Consistent with previous monitoring reports, molybdenum concentrations during December displayed little spatial variation across the inshore and offshore monitoring network (Figure 26). Given the similarity between the dissolved and total metal concentrations, the majority of appeared to be present in the dissolved phase (Tables 16 to 19 and Figure 26). Concentrations of total and dissolved vanadium displayed a similar pattern to that of molybdenum with concentrations at spoil ground sites below LOR and with a large proportion at inshore and offshore sites also present in the dissolved phase (Figure 26).

3.6.3 Organics

Organic compounds (herbicides, pesticides and hydrocarbons) are biannually measured as part of the monitoring project. Of the 209 compounds that were analysed: total petroleum hydrocarbons (C6 – C36) including PAH, multiresidue pesticides (179 individual), and acid herbicides (22 individual herbicides), all were below LOR (Table 19). This has been a consistent finding throughout the monitoring project.

Table 19 Organic compound concentrations at monitoring sites during December 2018.

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
C7 - C9	<60	<60	<60	<60	<60	<60	<60	<60	<60	<60	<60	<60	<60	<60	<60
C10 - C14	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
C15 - C36	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400
Total hydrocarbons (C7 - C36)	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,3,4,6-Tetrachlorophenol (TCP)	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
2,4,5-Trichlorophenoxyacetic acid (245T)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
2,4'-DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4'-DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4'-DDT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-Dichlorophenoxyacetic acid (24D)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
2,4-Dichlorophenoxybutyric acid (24DB)	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
2-methyl-4-chlorophenoxyacetic acid (MCPA)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
2-methyl-4-chlorophenoxybutanoic acid (MCPB)	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
4,4'-DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4,4'-DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4,4'-DDT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acetochlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Acifluorfen	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Alachlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Aldrin	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00	<0.00

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
alpha-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atrazine	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Atrazine-desethyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Atrazine-desisopropyl	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Azaconazole	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Azinphos-methyl	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Benalaxyl	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bendiocarb	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Benodanil	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Bentazone	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
beta-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bifenthrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bitertanol	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Bromacil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bromophos-ethyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bromopropylate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bromoxynil	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Bupirimate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Buprofezin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Butachlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Captafol	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Captan	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Carbaryl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carbofenothion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carbofuran	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carboxin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorfenvinphos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Chlorfluazuron	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorothalonil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorpropham	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chlorpyrifos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorpyrifos-methyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlortoluron	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chlozolinate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
cis-Chlordane	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Clopyralid	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11
Coumaphos	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Cyanazine	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyfluthrin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyhalothrin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cypermethrin	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Cyproconazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyprodinil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
delta-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deltamethrin (including Tralomethrin)	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Demeton-S-methyl	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Diazinon	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Dicamba	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Dichlobenil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichlofenthion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichlofluanid	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichloran	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorprop	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Dichlorvos	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Dicofol	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Dicrotophos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dieldrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Difenoconazole	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Dimethoate	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Dinocap	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Diphenylamine	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Disulfoton	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Diuron	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Endosulfan I	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan II	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan sulfate	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Endrin aldehyde	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Endrin ketone	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
EPN	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Esfenvalerate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ethion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Etrimfos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Famphur	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenamiphos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenarimol	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenitrothion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenpropathrin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenpropimorph	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Fensulfothion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenthion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenvalerate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluazifop	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluazifop-butyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluometuron	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluroxypyr	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Flusilazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluvalinate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Folpet	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Furalaxyl	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
gamma-BHC (Lindane)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Haloxyfop	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Haloxyfop-methyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Heptachlor	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Heptachlor epoxide	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hexachlorobenzene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Hexaconazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Hexazinone	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Hexythiazox	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Imazalil	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Indoxacarb	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Iodofenphos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
IPBC (3-Iodo-2-propynyl-n-butylcarbamate)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Isazophos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Isofenphos	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Kresoxim-methyl	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Leptophos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Linuron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
m&p-Xylene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Malathion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mecoprop	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Metalaxyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methacrifos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methidathion	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methiocarb	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methoxychlor	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Metolachlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Metribuzin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mevinphos	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Molinate	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Myclobutanil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Naled	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrofen	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Nitrothal-Isopropyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Norflurazon	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Oryzalin	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Oxadiazon	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Oxychlordane	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Oxyfluorfen	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
o-Xylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Paclobutrazol	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Parathion-ethyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Parathion-methyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Penconazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pendimethalin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pentachlorophenol (PCP)	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Permethrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phorate	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Phosmet	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Phosphamidon	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Picloram	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11
Pirimicarb	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pirimiphos-methyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Prochloraz	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Procymidone	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Prometryn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Propachlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Propanil	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Propazine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Propetamphos	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Propham	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Propiconazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Prothiofos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrazophos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrifenox	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrimethanil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyriproxyfen	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Quintozene	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Quizalofop	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Quizalofop-ethyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
Simazine	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Simetryn	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Sulfentrazone	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sulfotep	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
TCMTB [2-(thiocyanomethylthio) benzothiazole,Busan]	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Tebuconazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tebufenpyrad	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Terbacil	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbufos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbumeton	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbuthylazine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Terbuthylazine-desethyl	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbutryn	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tetrachlorvinphos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Thiabendazole	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Thiobencarb	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Thiometon	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Tolylfluanid	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Chlordane [(cis+trans)*100/42]	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total DDT Isomers	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
trans-Chlordane	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Triadimefon	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Triazophos	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Triclopyr	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Trifluralin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Vinclozolin	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

4 REFERENCES

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5 APPENDIX

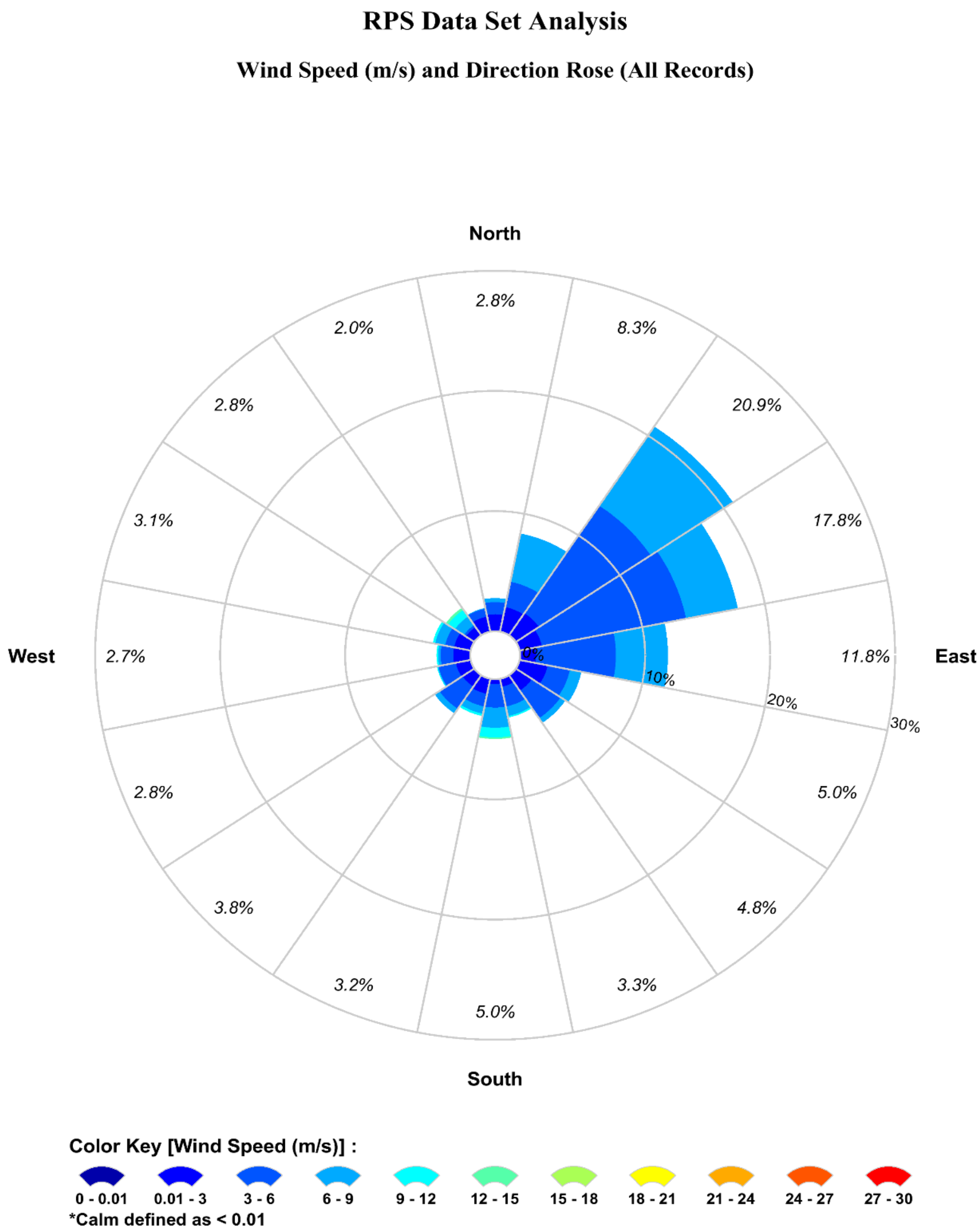
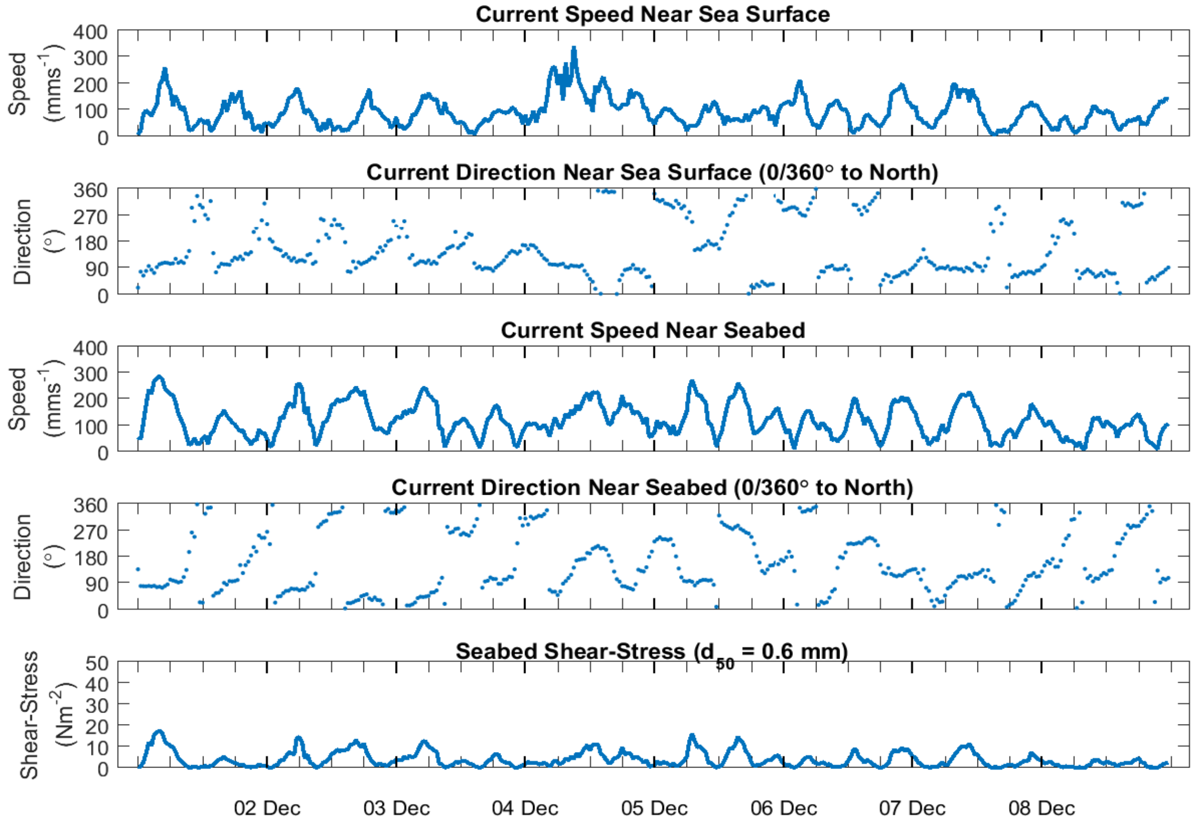


Figure 27 WatchKeeper wind speed (m/s) and direction rose (%) during December 2018.



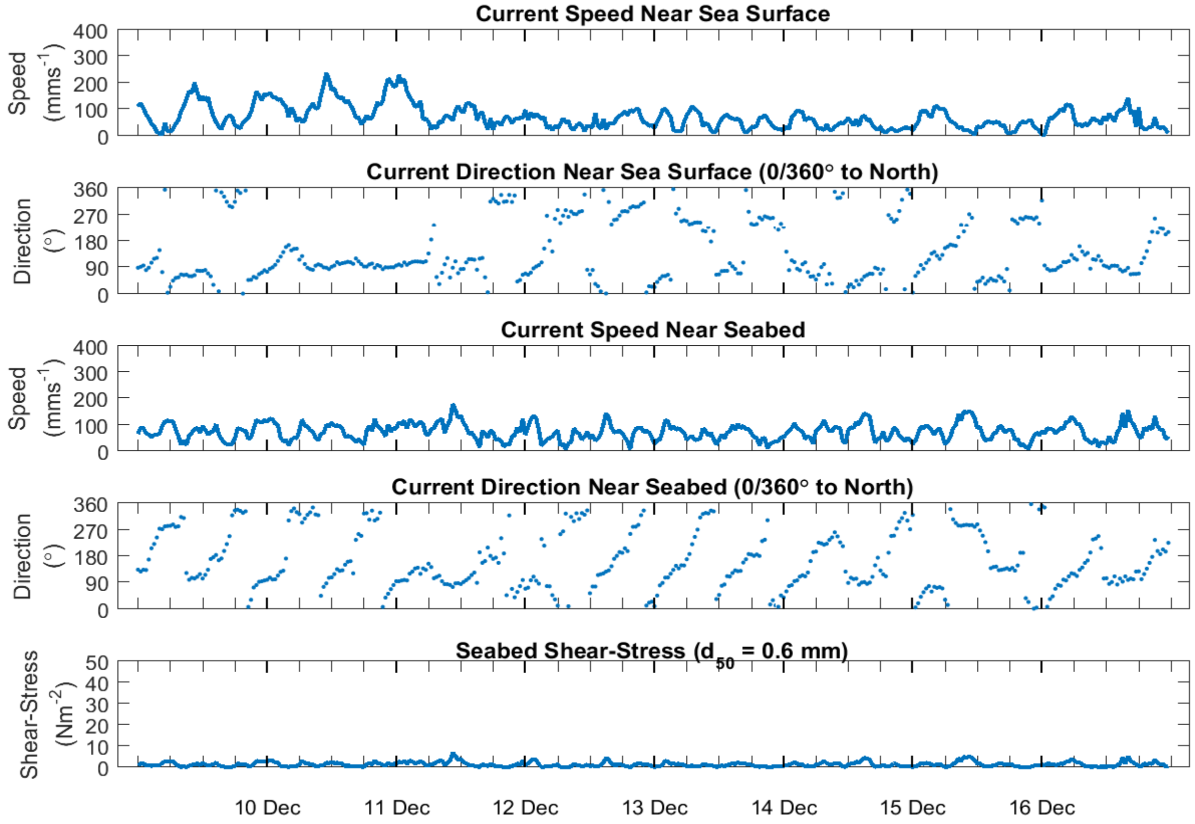
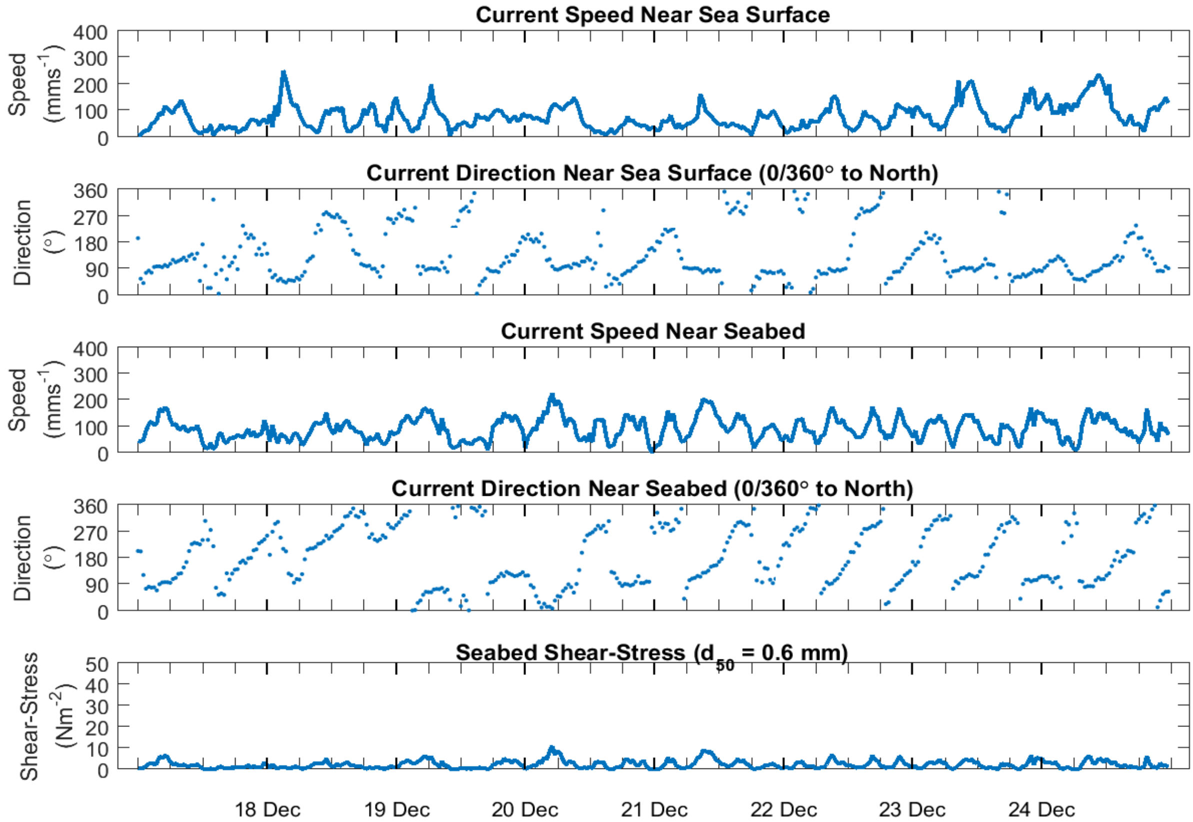


Figure 28 SG2a current speed, direction and shear bed stress 1 to 16 December 2018.



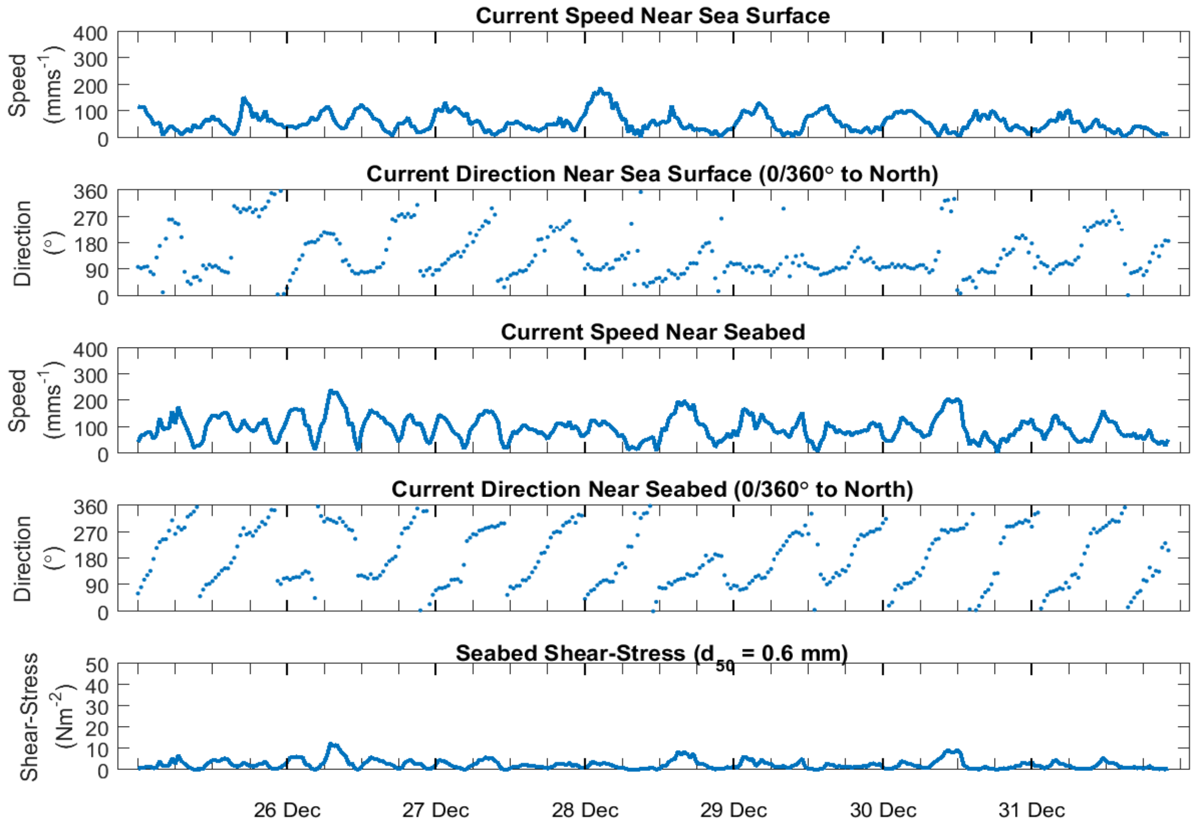


Figure 29 SG2a current speed, direction and shear bed stress 17 to 31 December 2018.

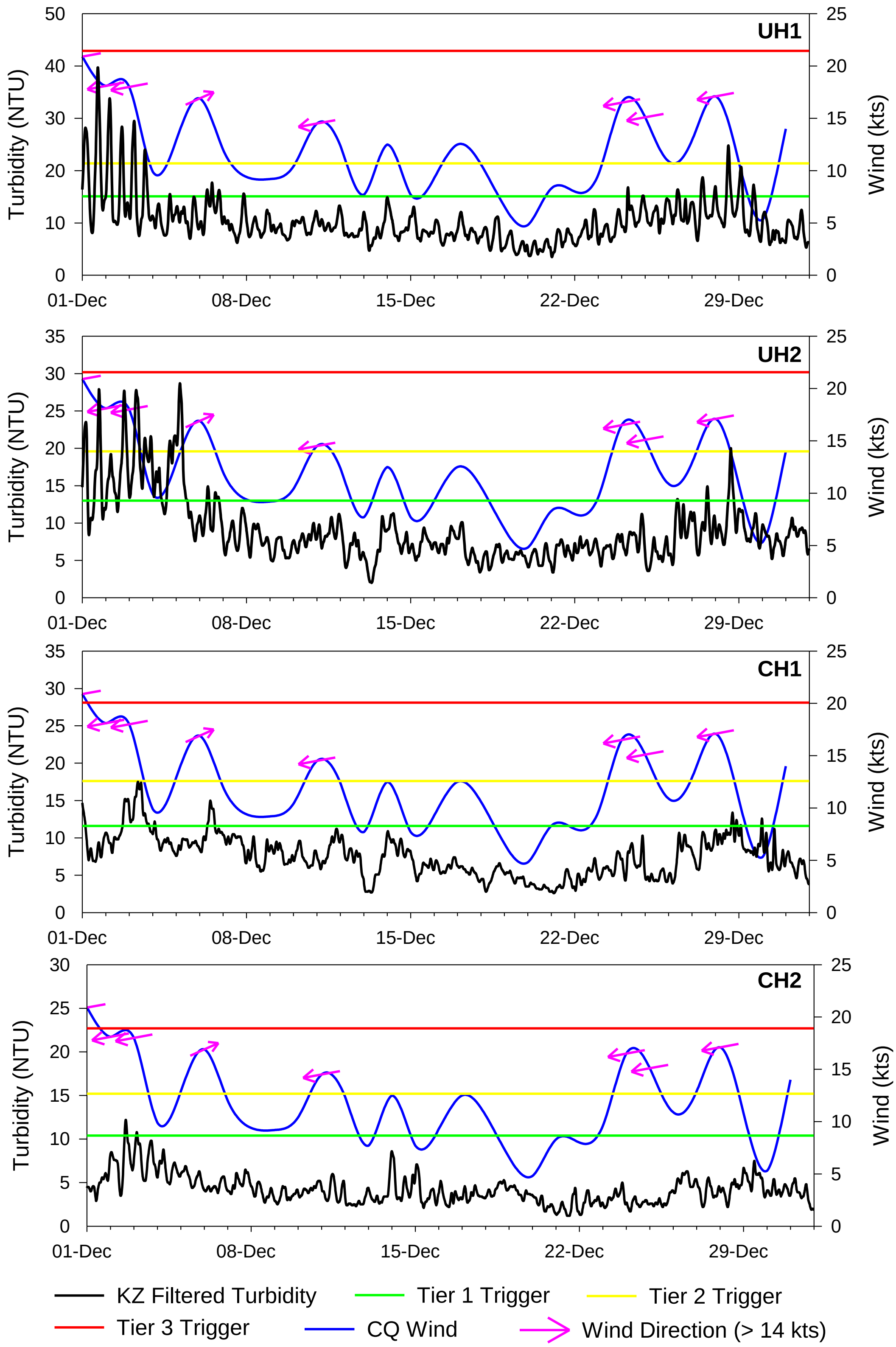


Figure 30 Surface KZ filtered turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during December 2018.
Note differing scales for each plot. Arrows indicate the direction of travel for inshore winds greater than 14 knots. Horizontal lines indicate turbidity intensity tier levels.

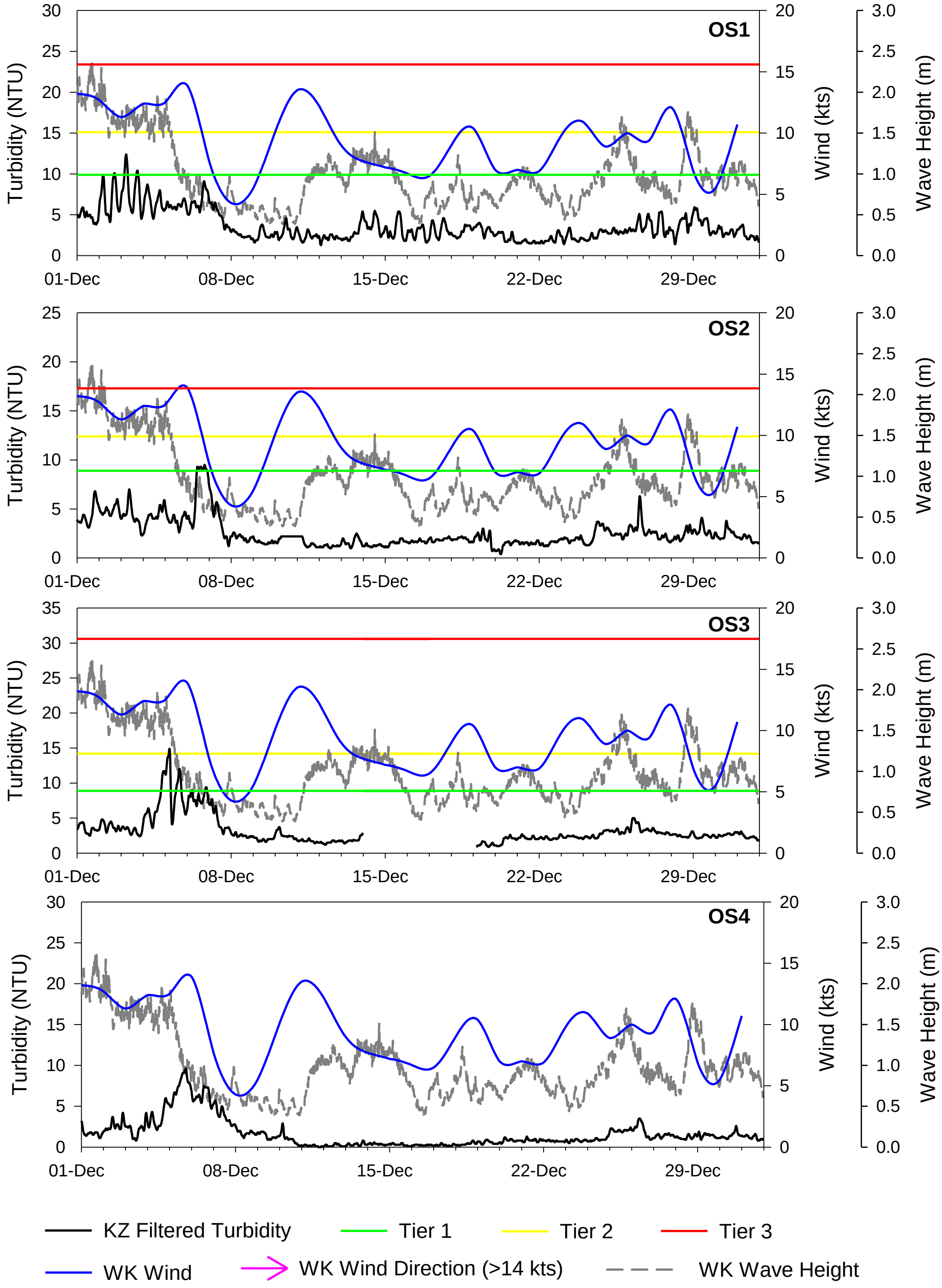


Figure 31 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS1 to OS4) during December 2018.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Horizontal lines indicate turbidity intensity tier levels.

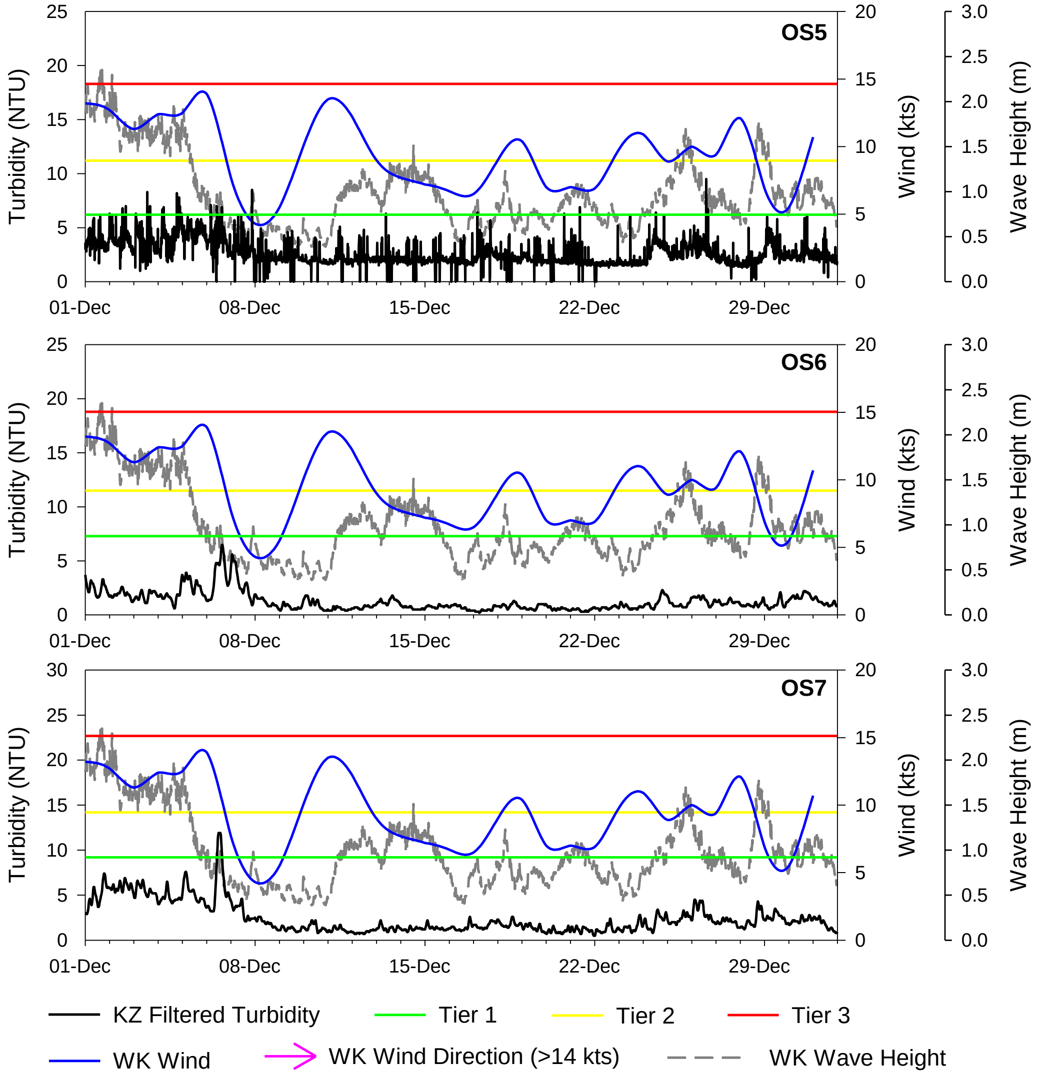


Figure 32 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS5 to OS7) during December 2018.

Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Horizontal lines indicate turbidity intensity tier levels.

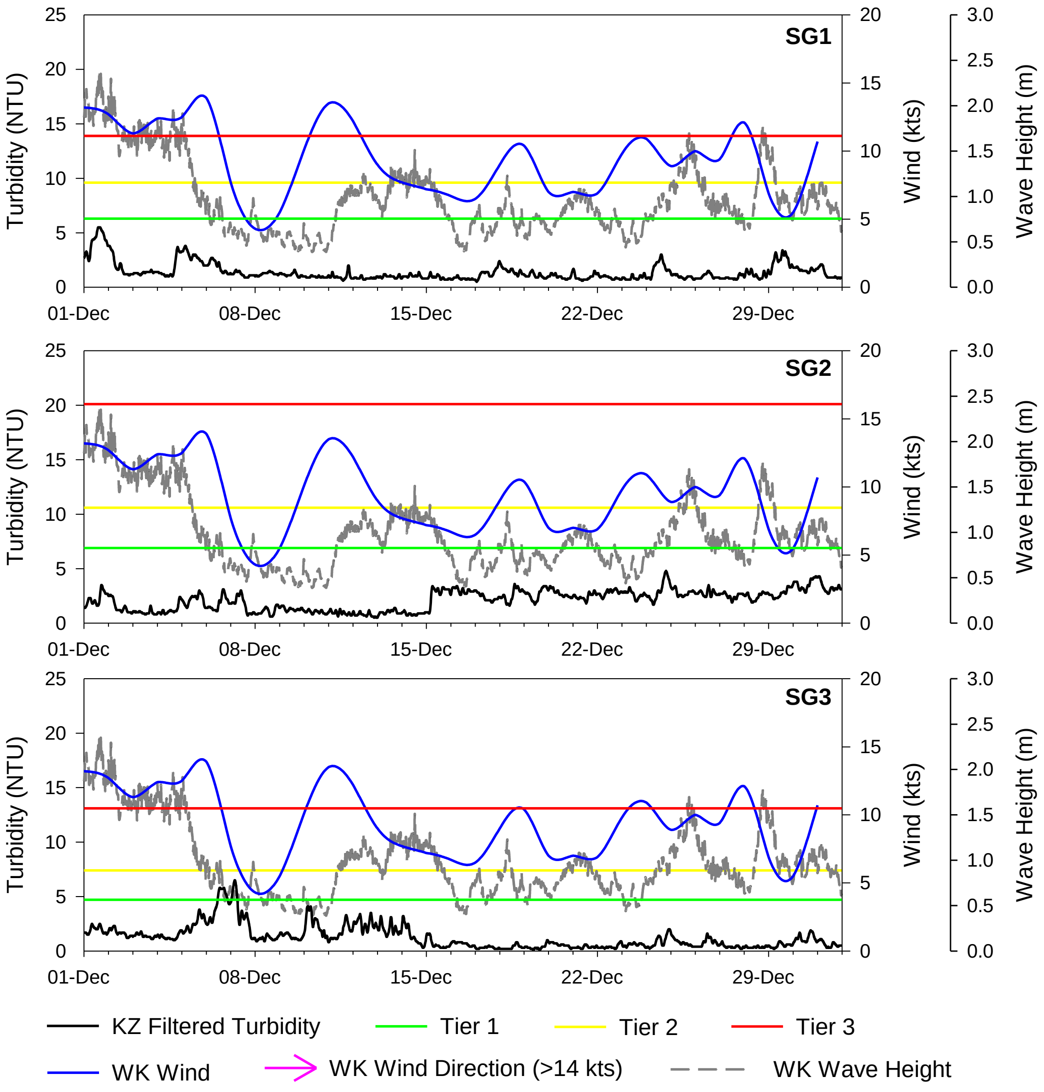


Figure 33 Surface KZ filtered turbidity and daily averaged winds at the spoil ground sites (SG1 to SG3) during December 2018.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 14 knots. Horizontal lines indicate turbidity intensity tier levels.

Table 20 Mean KZ filtered turbidity and statistics at inshore water quality logger sites during December 2018 and baseline period 1 November 2016 to 31 October 2017
Values for December are means ± se, range and percentiles (n = 2976). Baseline values modified from Fox 2018.

Site		KZ Filtered Turbidity (NTU)	
	Statistic	Surface December	Surface Baseline
UH1	Mean ± se	10 ± 0	12
	Range	4 – 40	2 – 155
	99th	28	37
	95th	18	21
	80th	12	15
UH2	Mean ± se	9.1 ± 0.1	9.9
	Range	2 – 29	2 – 59
	99th	26	29
	95th	19	19
	80th	11	13
CH1	Mean ± se	7.5 ± 0.0	8.8
	Range	3 – 18	<1 – 50
	99th	15	27
	95th	12	17
	80th	9.8	12
CH2	Mean ± se	4.2 ± 0.0	7.6
	Range	1 – 12	<1 – 39
	99th	9.7	22
	95th	7.4	15
	80th	5.3	10

Table 21 Mean KZ filtered turbidity and statistics at spoil ground water quality logger sites during December 2018 and baseline period 1 November 2016 to 31 October 2017.
Values for December are means ± se, range and percentiles (n = 2976). Baseline values modified from Fox 2018.

Site		KZ Filtered Turbidity (NTU)	
	Statistic	Surface December	Surface Baseline
SG1	Mean ± se	1.4 ± 0.0	4.2
	Range	<1 – 5.5	<1 – 31
	99th	4.7	14
	95th	3.2	9.5
	80th	1.6	6.1
SG2	Mean ± se	2.1 ± 0.0	4.6
	Range	<1 – 4.8	<1 – 33
	99th	4.2	20
	95th	3.4	10
	80th	2.9	6.9
SG3	Mean ± se	1.3 ± 0.0	3.6
	Range	<1 – 6.5	<1 – 22
	99th	5.7	13
	95th	3.3	7.3
	80th	1.9	4.7

Table 22 Mean KZ filtered turbidity and statistics at offshore water quality logger sites during December 2018 and baseline period 1 November 2016 to 31 October 2017.
Values for December are means ± se, range and percentiles (n = 2976). Baseline values modified from Fox 2018.

Site		KZ Filtered Turbidity (NTU)	
	Statistic	Surface December	Surface Baseline
OS1	Mean ± se	3.6 ± 0.0	7.5
	Range	1 – 12	<1 – 99
	99th	9.9	23
	95th	7.4	15
	80th	5.0	9.7
OS2	Mean ± se	2.6 ± 0.0	6.4
	Range	<1 – 9.5	<1 – 36
	99th	9.1	17
	95th	5.4	12
	80th	3.6	8.9
OS3	Mean ± se	3.2 ± 0.0	6.5
	Range	<1 – 15	<1 – 110
	99th	12	27
	95th	7.9	14
	80th	3.6	8.9
OS4	Mean ± se	1.6 ± 0.0	5.9
	Range	<1 – 9.6	<1 – 35
	99th	8.2	18
	95th	5.8	13
	80th	2.2	8.1
OS5	Mean ± se	2.6 ± 0.0	4.6
	Range	1.4 – 6.0	<1 – 35
	99th	5.1	18
	95th	4.4	11
	80th	3.3	6.1
OS6	Mean ± se	1.2 ± 0.0	4.7
	Range	<1 – 6.5	<1 – 37
	99th	5.0	18
	95th	3.0	11
	80th	1.7	7.1
OS7	Mean ± se	2.4 ± 0.0	6.3
	Range	<1 – 12	<1 – 48
	99th	7.5	22
	95th	5.9	14
	80th	3.8	9.1

Table 23 Summary of Vision Environment quality control data for December 2018 water sampling.
ND = not determined as one or more samples was below LOR. Variation between duplicate field samples ≥ 50% has been highlighted in blue. High variation indicates heterogeneity within the water column.

Parameter	VE Field Blank (µg/L)	VE Lab Blank (µg/L)	Duplicate		
			OS4 A (µg/L)	OS4 B (µg/L)	Variation (%)
Chlorophyll a	< 0.0002	< 0.0002	0.0017	0.0017	0%
TSS	< 3	< 3	< 3	< 3	ND
Total Phosphorus	< 0.004	< 0.004	0.006	0.01	40%
DR Phosphorus	< 0.004	< 0.004	< 0.0010	< 0.0010	ND
Total Nitrogen	< 0.11	< 0.11	< 0.3	< 0.3	ND
Total Kjeldahl Nitrogen	< 0.10	< 0.10	< 0.2	< 0.2	ND
Total Ammoniacal-N	< 0.010	< 0.010	0.008	0.008	0%
Nitrate-N + Nitrite-N	< 0.002	< 0.002	< 0.0010	< 0.0010	ND
Dissolved Aluminium	< 0.003	< 0.003	0.013	0.019	32%
Dissolved Arsenic	< 0.0010	< 0.0010	< 0.004	< 0.004	ND
Dissolved Cadmium	< 0.00005	< 0.00005	< 0.0002	< 0.0002	ND
Dissolved Chromium	< 0.0005	< 0.0005	< 0.0010	0.0015	ND
Dissolved Cobalt	< 0.0002	< 0.0002	< 0.0006	< 0.0006	ND
Dissolved Copper	< 0.0005	< 0.0005	< 0.0010	< 0.0010	ND
Dissolved Iron	< 0.02	< 0.02	< 0.004	< 0.004	ND
Dissolved Lead	< 0.00010	< 0.00010	< 0.0010	< 0.0010	ND
Dissolved Manganese	< 0.0005	< 0.0005	0.0015	0.0014	7%
Dissolved Mercury	< 0.00008	< 0.00008	< 0.00008	< 0.00008	ND
Dissolved Molybdenum	< 0.0002	< 0.0002	0.0113	0.0108	4%
Dissolved Nickel	< 0.0005	< 0.0005	< 0.007	< 0.007	ND
Dissolved Selenium	< 0.0010	< 0.0010	< 0.004	< 0.004	ND
Dissolved Silver	< 0.00010	< 0.00010	< 0.0004	< 0.0004	ND
Dissolved Tin	< 0.0005	< 0.0005	< 0.0050	< 0.0050	ND
Dissolved Vanadium	< 0.0010	< 0.0010	0.002	0.002	0%
Dissolved Zinc	< 0.0010	< 0.0010	< 0.004	< 0.004	ND
Total Aluminium	< 0.0032	< 0.0032	0.023	0.027	15%
Total Arsenic	< 0.0011	< 0.0011	< 0.0042	< 0.0042	ND
Total Cadmium	< 0.000053	< 0.000053	< 0.00021	< 0.00021	ND
Total Chromium	0.00088	< 0.00053	0.0014	0.0014	0%
Total Cobalt	< 0.00021	< 0.00021	< 0.00063	< 0.00063	ND
Total Copper	< 0.00053	< 0.00053	< 0.0011	< 0.0011	ND
Total Iron	< 0.021	< 0.021	0.023	0.022	4%
Total Lead	< 0.00011	< 0.00011	< 0.0011	< 0.0011	ND
Total Manganese	< 0.00053	< 0.00053	0.002	0.0021	5%
Total Mercury	< 0.00008	< 0.00008	< 0.00008	< 0.00008	ND
Total Molybdenum	< 0.00021	< 0.00021	0.0112	0.0111	1%
Total Nickel	< 0.00053	< 0.00053	< 0.0070	< 0.0070	ND
Total Selenium	< 0.0011	< 0.0011	< 0.0042	< 0.0042	ND
Total Silver	< 0.00011	< 0.00011	< 0.00043	< 0.00043	ND
Total Tin	< 0.00053	< 0.00053	< 0.0053	< 0.0053	ND
Total Vanadium	< 0.0011	< 0.0011	0.0017	0.0017	0%
Total Zinc	< 0.0011	< 0.0011	< 0.0042	< 0.0042	ND