Lyttelton Port Company
Channel Deepening Project
Environmental Monitoring

VISION ENVIRONMENT

Water Quality Environmental Monitoring Services – Monthly Report

January 2020

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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.

Dredging operations for the CDP were undertaken from 29 August to 29 November 2018. Post-dredge monitoring was undertaken until 11 March 2019, when a smaller dredging operation began for the reclamation works at Cashin Quay and is continuing. Channel maintenance dredging commenced at midday on 4 December 2019 and is likely to be completed in March 2020.

Monitoring results collected during January 2020 are presented within this report. This monthly report includes comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 (Fox, 2018). KZ filtered data are also included within the Appendix and are compared to compliance trigger values.

Climatic Conditions: During January lower rainfall was recorded at Cashin Quay (8.4 mm) than during December 2019 (25.8 mm), with highest daily rainfall recorded on 3 January (5.4 mm). Flows from the Waimakariri River were also low during the month with a peak flow of 287 m^3/s occurring on 13 January. The low volume of these freshwater flows had minimal influence on Lyttelton harbour.

Monthly average air temperature (17.5°C) was slightly higher than that recorded in December (16.7°C). Inshore winds were generally from an easterly to north-easterly direction, with mean daily wind speed of 20 kts recorded on 7 January. The highest offshore mean daily wind speeds (> 15 kts) were also recorded on 7 January, with greatest mean daily significant wave height recorded on 22 January (1.57 m).

Currents: Data availability for SG1, SG2a (WatchKeeper) and SG3 was good for January. Maximum near-surface and near-seabed currents at SG1, SG2a and SG3 occurred on different days to each other throughout January. Dominant metocean forces to explain maximum currents were due to corresponding significant wave events (> 1m) from an easterly direction in addition to moderate to high inshore and offshore winds from an easterly to southerly direction.

Near-surface predominant current movement for SG1 and SG3 tended to move in an east-southeast and northerly direction, while near-seabed currents moved in a westerly to north-easterly direction. In contrast, near-surface and near-seabed currents at SG2a moved in an east and west direction.

Turbidity: Consistent with previous results, turbidity was higher overall at the inshore monitoring sites of the central and upper harbour than at the offshore and spoil ground monitoring locations. Mean turbidity values for January in addition to percentile statistics were lower than those recorded during the baseline monitoring period.

Elevated turbidity was recorded at all sites on multiple days in January (10 to 25 NTU), due to moderate to high inshore and offshore winds and significant wave heights >1 m. The majority

of sites displayed increased turbidity from 7 to 8 January due to increased wind while increased turbidity from 11 to 12 and 22 to 23 January was due to increased significant wave heights and moderate wind.

Benthic turbidity responded to both wind speed and wave height events in January, with mean benthic turbidity being more elevated than their surface counterparts, as typically observed.

Dredge Compliance Turbidity Trigger Values: During January, there were no exceedances of the Tier 3 intensity values at any site within the monitoring network.

Other Physicochemical Parameters: Mean monthly water temperatures were warmer in January than December with all sites displaying a seasonal variation. Consistent with December, warmer temperatures were recorded in the upper and central harbour than the offshore sites. Benthic temperatures were consistent with those at the surface indicating a well-mixed water column with the exception of OS1 which recorded overall higher mean temperature than other benthic sites. This was mainly as a result of fluctuating elevated temperature recorded at this site from 20 January till the end of the month. This phenomenon has been observed previously during maintenance dredging campaigns and is thought to be attributed to warmer inshore sediments being deposited adjacent to the OS1 benthic location.

Consistent with previous reports, surface and benthic pH during January was similar across all sites. Higher flow rates from the Waimakariri River on the 13th January appear to have slightly reduced conductivity at most sites around the 17th January, the delay in reaching Lyttleton Harbour being attributed to distance and the current hugging the coast.

Dissolved oxygen (DO) concentrations fluctuated at all sites during January, with lower concentrations recorded on the 8 and 24 January following lower sea surface temperatures. Decreasing DO at two sites, OS3 and SG3, during 5 and 9 January could be attributed to degrading algal blooms. Diurnal fluctuations in DO were observed at most sites for the month of January as typically observed. Benthic DO trends were similar to surface DO throughout January.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 14 January 2020, and once again a well-mixed water column was indicated. DO showed a decreasing gradient through the water column at nearshore and offshore sites due to lower photosynthesis at depth.

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 euphotic depth as typically recorded during the monitoring program. Euphotic depths at the offshore monitoring locations were relatively high; estimated to be at 15.4 m at OS5. No exceedances of WQGs were observed for sub-surface during the January sampling.

As commonly observed, total and dissolved reactive phosphorous concentrations were highest at the inshore sites and decreased further offshore. Exceedances of the WQG for dissolved reactive phosphorous was recorded at all the inner harbour sites, as well as three offshore sites and one spoil ground site.

Concentrations of total nitrogen and total kjeldahl nitrogen remained below detection limits at all sampling sites. As recorded in previous months, ammonia concentrations were > WQG at a number of sites while nitrogen oxide concentrations were > WQG at two sites. Chlorophyll-

a concentrations were moderate across all sites and exceeded the WQG value (4 µg/L) at five sites. This suggests bioavailable forms of nutrients were being utilised by algal populations.

Several metals were reported as below the limit of reporting (LOR) at all sites as commonly found. Dissolved copper exceeded the designated WQG (1.3 µg/L) at SG3 (1.7 µg/L). No other dissolved metal fractions exceeded their designated WQG. Total aluminium concentrations exceeded designated WQG at the majority of the monitoring sites, but the dissolved and therefore readily bioavailable fraction, remained relatively undetectable. Total aluminium, iron and manganese displayed a strong spatial difference with elevated concentrations found in the inshore locations (associated with increased suspended sediments), whereas offshore and spoil ground sites reported the lowest concentrations. Total and dissolved chromium, vanadium and molybdenum were also detected during January, with little spatial variability and a large component contained within the dissolved phase.

Benthic Photosynthetically Active Radiation (BPAR): Levels of ambient sunlight were similar in January to December associated with the increased day lengths. However, mean BPAR at both OS2 and OS3 were higher than December due to increased benthic light as a result of decreased turbidity. Both sites recorded high BPAR peaks > 6000 mmol/m^2/day in the middle and late January, when ambient PAR was high and water turbidity was low.

Sedimentation: Overall accumulation of sediments at both OS2 and UH3 was evident in January. Sediment flux at OS2 experienced a period of stability at the beginning of January and then slowly accreted for the remainder of the month when winds and turbidity were low, leading to an overall accumulation of 9 mm of sediment over the month. Sediment flux at UH3 was unlike other months, where sediment flux was high in early January displaying multiple accretion and erosion periods. UH3 then displayed a period of slow accretion for the remainder of January. This resulted in an overall accumulation of 4.3 mm of sediments at this location.

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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 program was designed.

Baseline water quality monitoring and data collection undertaken by Vision Environment (VE) commenced in September 2016, progressing into dredge operations monitoring from 29 August 2018 with completion of works on 29 November 2018. Monitoring continued into a post-dredge phase up until 11 March 2019 when smaller scale dredging operations for the reclamation works commenced. Maintenance dredging of the channel commenced on 4 December 2019 and is expected to be completed in March 2020, with spoil being relocated to the maintenance dredge spoil ground located off Godley Head. 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 projects.

2 METHODOLOGY

2.1 Approach

An overview of the methodology for the baseline and operations phases 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 several offshore locations.

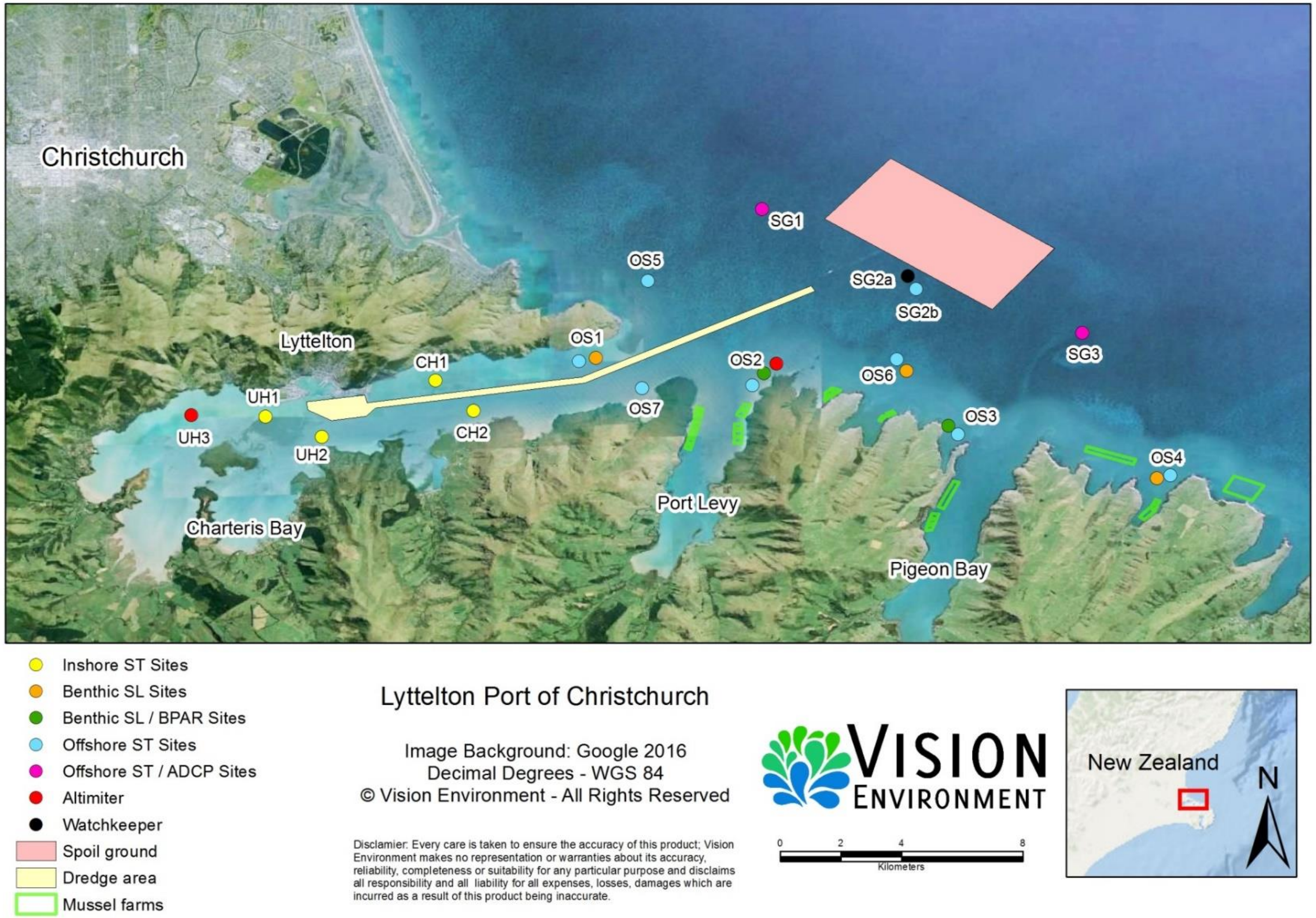


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

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 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.

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

- Physicochemistry, including turbidity; temperature; pH; conductivity and 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 for January 2020 during dredge operations. Monthly water sampling and depth profiling was conducted on 14 January 2020. 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) default trigger values (ANZG, 2018). In the absence of specific trigger values for New Zealand estuarine or marine ecosystems, the WQG suggest the use of 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 several metals. These guidelines refer to the dissolved fraction, as they are considered to be the potentially bioavailable fraction (ANZG, 2018). 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

A total of 8.4 mm of rainfall was recorded at Cashin Quay during January 2020, which was lower than the precipitation recorded in December (25.8 mm). Highest rainfall (5.4 mm) was recorded on 3 January (Metconnect, 2019) (Figure 2). Freshwater flows from the Waimakariri River, can be transported south along the coastline and enter Lyttelton Harbour several days post flow. Flows for January were low and ranged between 35 m^3/s and 287 m^3/s with the maximum flow occurring on the 13 January (ECAN, 2019). These lower flows recorded in addition to the low localised rainfall appear to have minimal impact on harbour parameters.

Inshore winds during January were generally from an easterly to north-easterly direction (Metconnect, 2019). Highest mean wind speed (20 kts) was recorded on 7 January from a west-south-westerly direction, with maximum wind gusts of 46 kts also occurring from the south-westerly direction. Daily mean wind speeds that were also elevated were recorded on the 17 and 31 January from an easterly and west-north-westerly direction (14.8 kts and 14.4 kts, respectively).

Daily mean air temperatures at Cashin Quay ranged from 13°C to 24°C, resulting in a monthly mean temperature of 17.5°C, slightly higher than the December mean temperature of 16.7°C (Metconnect, 2019).

Offshore significant wave height peaked at 1.87 m at 5:00 pm on 30 January, leading to a mean daily significant wave height of 1.0 m (Figure 3). However, the highest mean daily significant wave event was 1.57 m recorded on 22 January from an easterly direction and not associated with elevated offshore winds. Highest mean daily offshore wind speeds 15.9 kts was recorded on the 7 January with the daily mean offshore wind direction from a southerly direction, although offshore winds during January were recorded at 42% from a north-easterly direction (Figure 32).

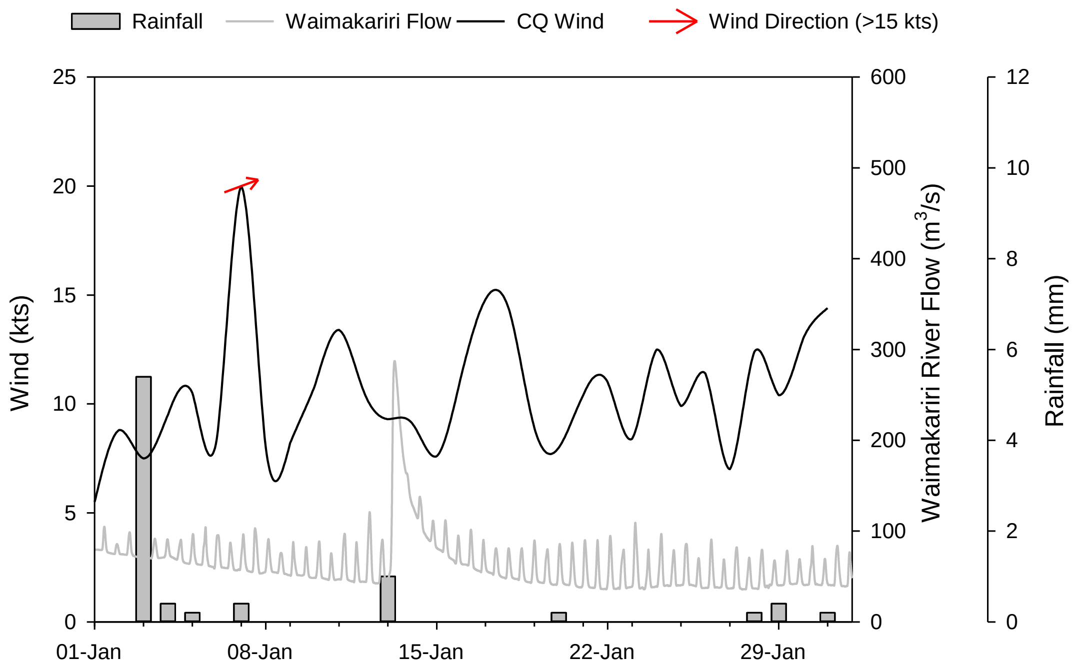


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during January 2020.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

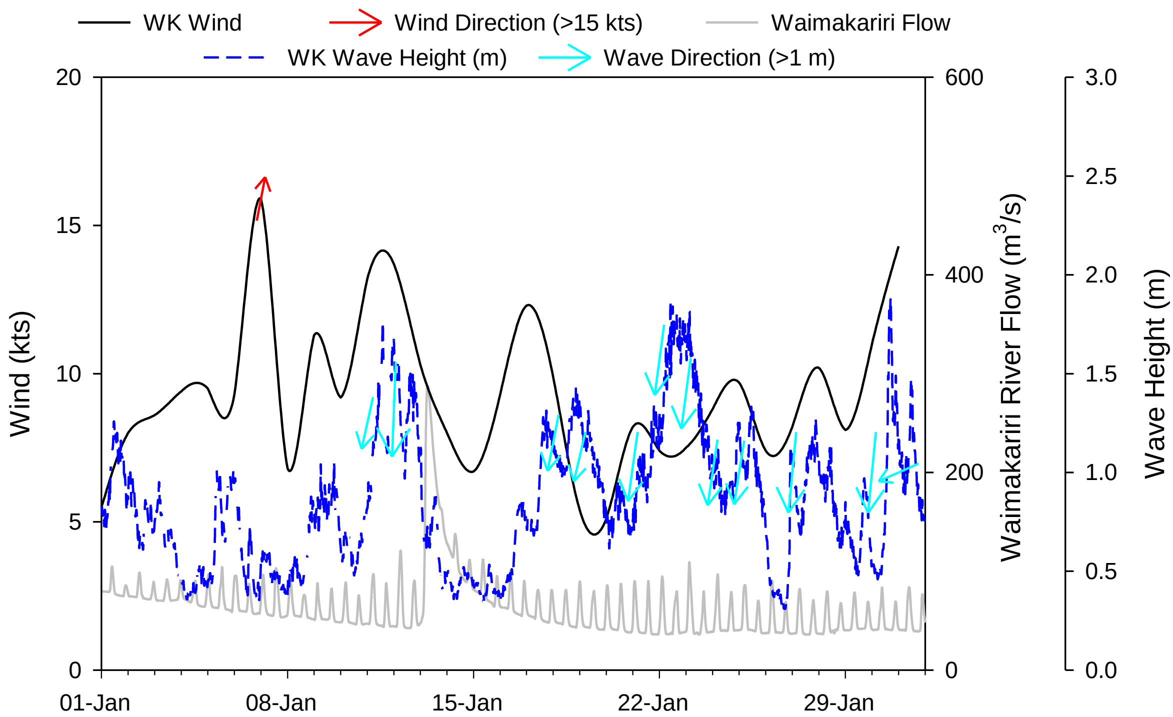


Figure 3 Offshore metocean conditions including wind speed and direction, significant wave height and daily averaged wave direction as measured by the WatchKeeper Buoy at site SG2a, and Waimakariri River flow at the Old Harbour Bridge station, during January 2020.
Note: Arrows indicate the direction of travel for offshore winds greater than 15 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, SG2a (Watchkeeper) and SG3, reporting the speed and direction of currents in a profile from the sea surface to seabed. Summary ADCP statistics of available data are presented within Table 2, and Figures 4 to 6. Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 33 to 38 in the Appendix. Note that the ADCP data are presented in this report using the UTC time format.

Table 2 Parameter statistics for spoil ground ADCPs during January 2020.

Parameter	Depth	Site		
		SG1	**SG2a**	**SG3**
Minimum current speed (mm/s)	*Near-surface*	1	2	1
	Near-seabed	<1	2	2
Maximum current speed (mm/s)	*Near-surface*	367	174	412
	Near-seabed	387	237	338
Mean current speed (mm/s)	*Near-surface*	104	49	119
	Near-seabed	87	85	119
Standard deviation of current speed (mm/s)	*Near-surface*	55	29	69
	Near-seabed	44	43	59
Current speed, 95th percentile (mm/s)	*Near-surface*	213	105	250
	Near-seabed	164	162	227

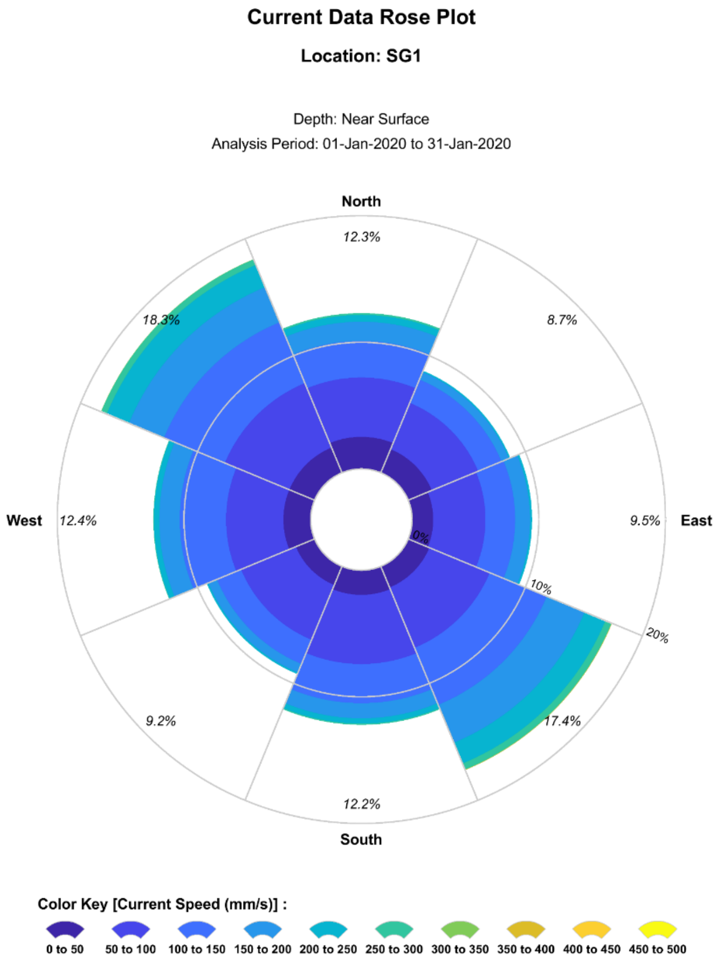
Maximum near-surface current speeds at SG1 (367 mm/s), SG2a (174 mm/s) and SG3 (412 mm/s) were recorded on the respective days 17, 7 and 5 January during periods of moderate to high offshore and onshore winds from a north-easterly to southerly direction and significant wave heights ≥1 m on 17 January from north-easterly direction.

Maximum near-seabed current speeds at SG1 (387 mm/s), SG2a (237 mm/s) and SG3 (338 mm/s) were recorded on the contrasting days to near-surface current speeds with maximums recorded 6, 15, and 18 January respectively. Daily offshore and onshore wind speeds were moderate from an easterly and southerly direction with maximum significant wave heights >1 m possibly explaining the increased near-seabed currents on 18 January.

The time-series plots (Figures 33 to 38 in Appendix) illustrate time-varying current direction, whilst the current rose diagrams (Figures 4 to 6) depict the distribution of current direction and velocity in the near-surface and near-seabed layers. When interpreting the current data, 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.

Similar to previous months, currents at SG1 near-surface during January tended to move in an west-northwest (43.0%) and south-southeast (29.6.8%) direction, while the near sea-bed currents moved in an east-southeasterly (34.7%) direction. SG3 was similar to previous months with near-surface current moving in an east-southeast (47.5%) and west-northwest (27.4%) direction, and near-seabed currents moving in a east-southeast (43.0%) and west-northwest (30.1%) direction.

Current movements at SG2a were found to be in a more east/west direction, similar to previous months. Near-surface currents moved in an east-northeast (40.7%) and west-northwest (30.7%) direction, while near-seabed currents moved in an easterly (55.1%) and west-northwesterly (26.7%) direction.



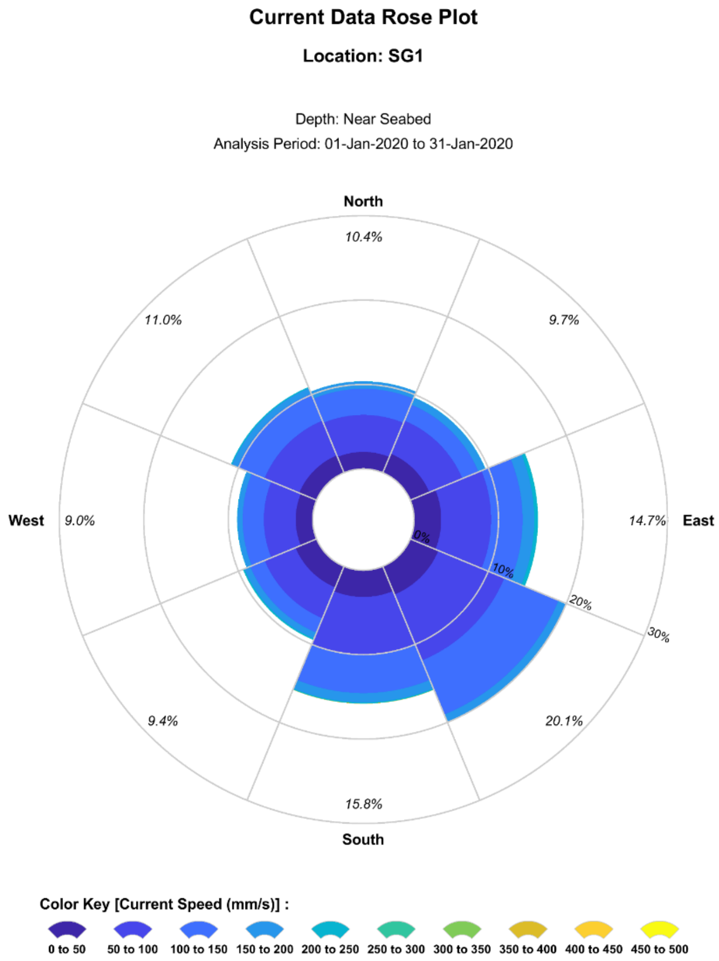
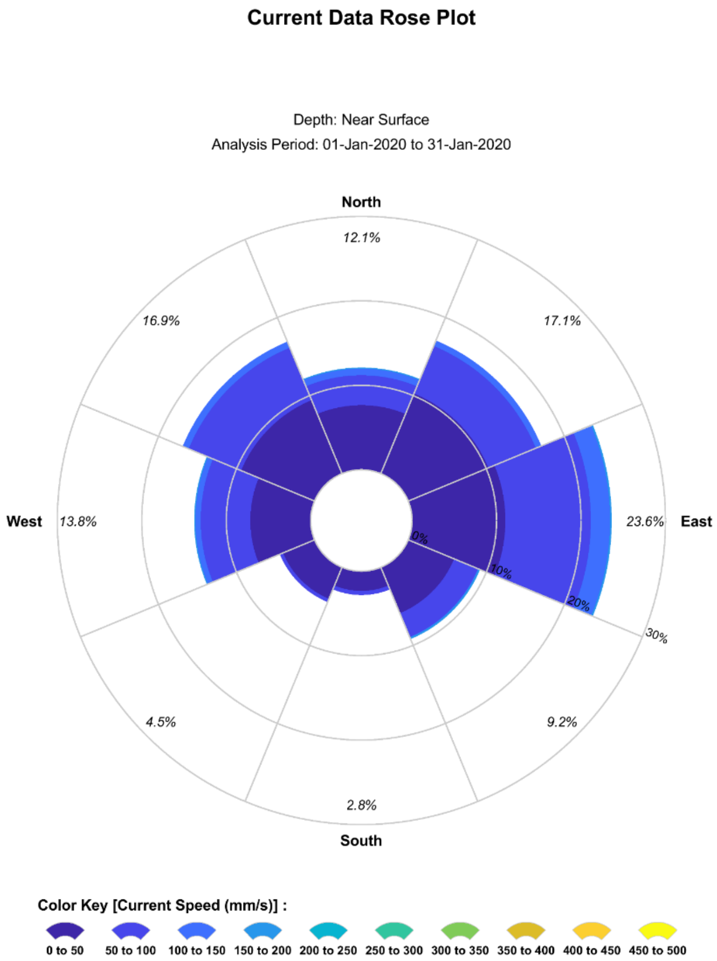


Figure 4 Near-surface and near-seabed current speed and direction at SG1 during January 2020.
Speed intervals of 50 mm/s are used.



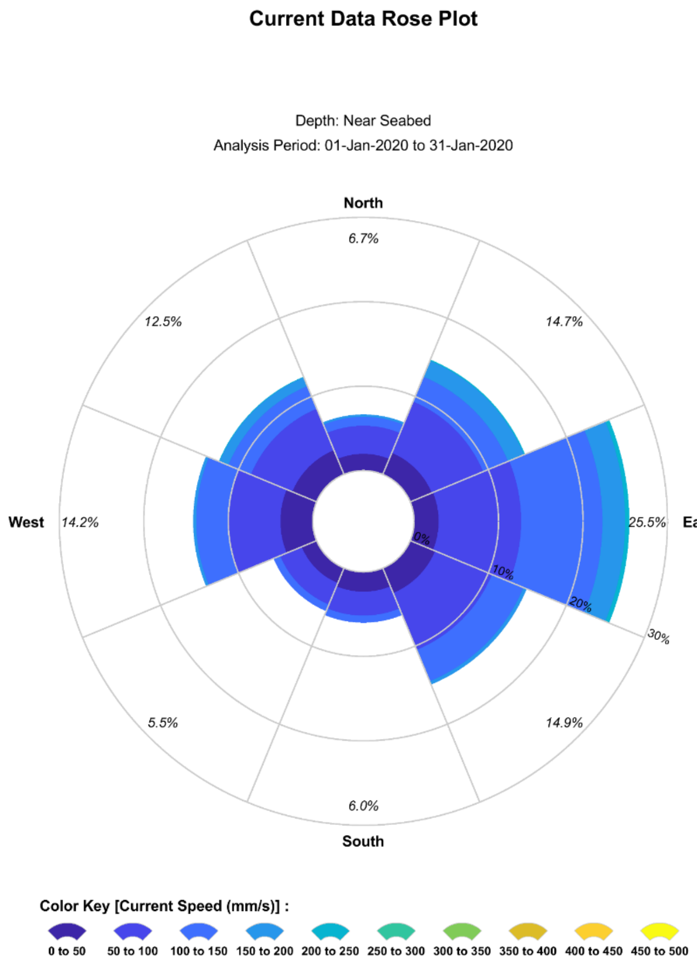
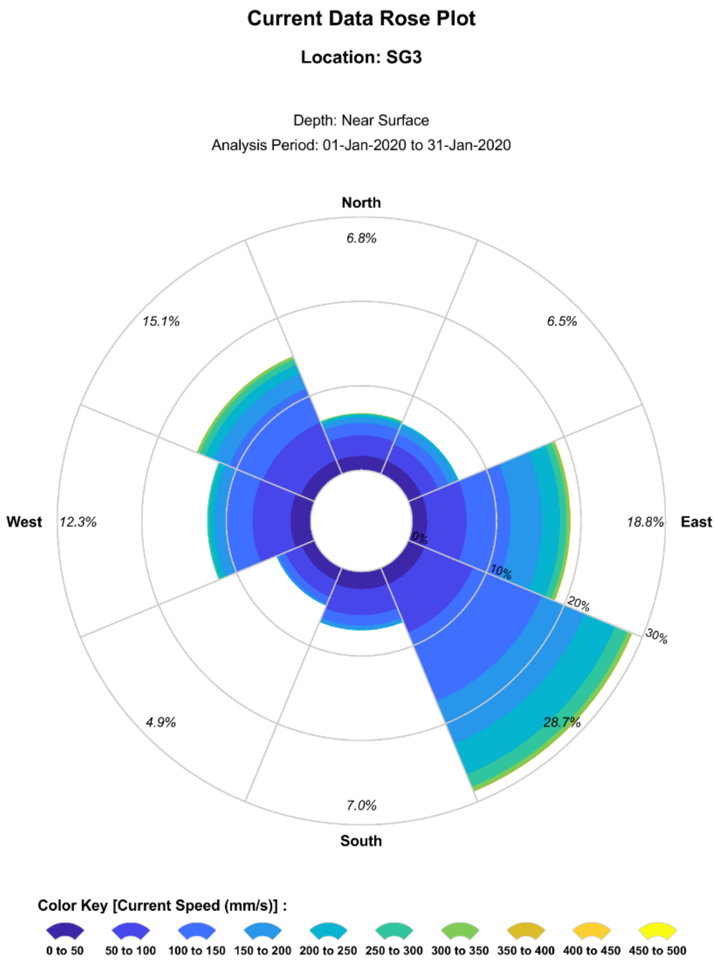


Figure 5 Near-surface and near-seabed current speed and direction at SG2a (Watchkeeper) during January 2020. *Speed intervals of 50 mm/s are used.*



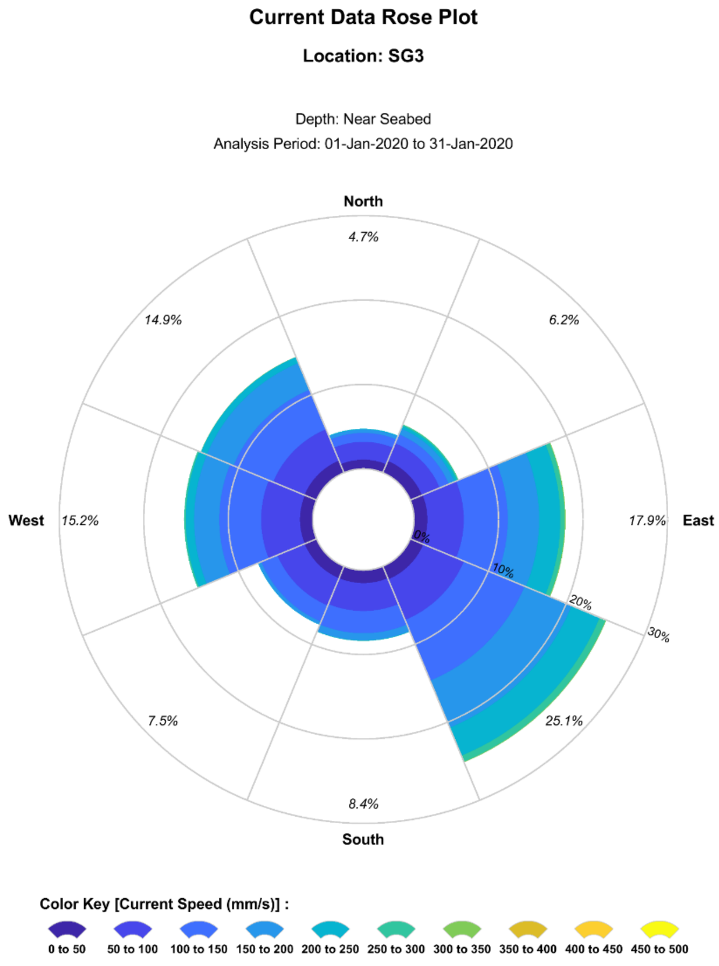


Figure 6 Near-surface and near-seabed current speed and direction at SG3 during January 2020.
Speed intervals of 50 mm/s are used.

3.2 Continuous Physicochemistry Loggers

Physical and chemical properties 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 14 January 2020. 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 January are presented in Tables 3 to 12. Validated datasets for surface and benthic measurements are also presented in Figures 7 to 23. 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 a 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 January 2020 dredge monitoring data. Summary statistics for KZ filtered turbidity data, used for real time compliance monitoring during dredge operations, are also presented in Tables 22 to 25 in the Appendix. Similarly, plots of KZ filtered turbidity data with site specific trigger values are also presented within Figures 39 to 42 in the Appendix.

January Turbidity:

Consistent with previous monitoring months, mean surface turbidity values were typically highest (monthly means of 3.4 to 6.5 NTU) at the inshore monitoring sites (Table 3 and Figure 6). Further offshore, the spoil ground sites (Table 4) exhibited lower surface turbidity values (0.5 to 1.5 NTU), which are likely due to the deeper water column limiting expressions of seafloor sediment resuspension at the sub-surface. As typically observed, offshore sites experienced intermediate mean turbidity values (1.2 to 3.1 NTU) during January (Table 5).

Turbidity across the inner harbour was relatively low (< 10 NTU) during January, with increased turbidity values occurring on 7 to 8 and 22 to 23 January coinciding with increased inshore winds and significant wave heights (>1m). Additional short-lived turbidity peaks (< 35 NTU) at sites UH1, UH2 and CH2 occurred on the 7, 18 and 22 January respectively, coinciding with increased inshore winds (>15kts). However, a short-lived validated turbidity peak of 22 NTU was recorded at CH1 on 15 January and did not correspond to metocean conditions (Figure 8).

Surface turbidity at the nearshore sites (OS1 to 4 and OS7) produced increased turbidity and peaks <20 NTU on 12 to 13 and 22 to 23 January in relation to high offshore winds from the south to westerly direction and significant waves > 1m.

Further offshore at OS5, OS6 and the spoil ground sites, turbidity peaks were evident on 12 to 13 and 22 to 24 January due to high offshore winds and significant wave heights. Turbidity at the spoil ground sites was less pronounced than at the inshore sites (Figures 11 and 12). This is likely due to greater depths at these sites, with less movement of benthic sediments during periods of higher wind speeds and wave heights.

Benthic:

Data return was gained for all benthic sites during January, except for OS1 and OS2 having limited data at the beginning of January. Benthic turbidity data corresponded with surface measurements, with increased turbidity evident during early and late January, during periods of high winds and waves (Figure 7).

Table 3 Mean turbidity and statistics at inshore water quality logger sites during January 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for January are means ± se, range and percentiles (n = 2741 to 2975) Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface January	Surface Baseline
UH1	Mean ± se	6.5 ± 0.0	12
	Range	2.3 – 34.8	-
	99th	14.5	39
	95th	10.7	22
	80th	8.1	15
UH2	Mean ± se	6.3 ± 0.0	10
	Range	<1 -26.9	-
	99th	14.9	32
	95th	10.8	20
	80th	7.6	13
CH1	Mean ± se	4.7 ± 0.0	9
	Range	2.1 – 21.6	-
	99th	8.9	29
	95th	7.1	18
	80th	5.9	12
CH2	Mean ± se	3.4 ± 0.0	8
	Range	1.3 – 13.0	-
	99th	7.9	24
	95th	6.9	16
	80th	4.2	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during January 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for January are means ± se, range and percentiles (n = 2900 to 2975). Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface January	Surface Baseline
SG1	Mean ± se	0.5 ± 0.0	4.2
	Range	<1 – 10.2	-
	99th	3.5	14
	95th	1.7	10
	80th	0.8	6.2
SG2	Mean ± se	1.5 ± 0.0	4.6
	Range	<1 – 4.1	-
	99th	3.6	20
	95th	2.6	11
	80th	1.7	7.0
SG3	Mean ± se	1.2 ± 0.0	3.6
	Range	<1 – 12.2	-
	99th	5.9	13
	95th	3.8	7.7
	80th	1.9	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during January 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for January are means ± se, range and percentiles (n = 2072 to 2976). Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU)		
		Surface January	Surface Baseline	Benthic January
OS1	Mean ± se	2.1± 0.0	7.5	36.6 ± 0.6
	Range	<1 – 7.2	-	2.1 – 216.5
	99th	5.2	24	160.9
	95th	4.0	16	102.1
	80th	2.8	10	56.9
OS2	Mean ± se	2.5 ± 0.0	6.4	30.3 ± 0.4
	Range	<1 – 30.2	-	0.4 – 150.1
	99th	10.9	18	119.5
	95th	5.9	13	81.3
	80th	3.3	9.0	46.4
OS3	Mean ± se	1.8 ± 0.0	6.6	22.6 ± 0.4
	Range	<1 – 16.2	-	0.0 – 169.2
	99th	9.1	27	92.3
	95th	5.8	15	61.2
	80th	2.9	8.9	35.2
OS4	Mean ± se	1.8 ± 0.0	5.9	32.5 ± 0.7
	Range	<1 -19.3	-	1.0 – 199.8
	99th	8.0	20	166.7
	95th	5.0	13	114.8
	80th	2.6	8.3	51.8
OS5	Mean ± se	1.2 ± 0.0	4.6	–
	Range	<1 – 14.7	-	–
	99th	5.0	19	–
	95th	2.8	11	–
	80th	1.7	6.4	–
OS6	Mean ± se	2.9 ± 0.0	4.7	87.9 ± 0.1
	Range	<1 – 14.9	-	69.7 – 100.3
	99th	11.9	19	99.7
	95th	6.7	12	97.4
	80th	4.1	7.2	93.3
OS7	Mean ± se	3.1 ± 0.0	6.4	–
	Range	<1 – 20.2	-	–
	99th	11.2	23	–
	95th	8.0	14	–
	80th	4.5	9.2	–

Comparison to Baseline:
Mean surface turbidity values during January were lower than the values calculated from the baseline monitoring period (Tables 3 to 5, Figures 7 to 12).

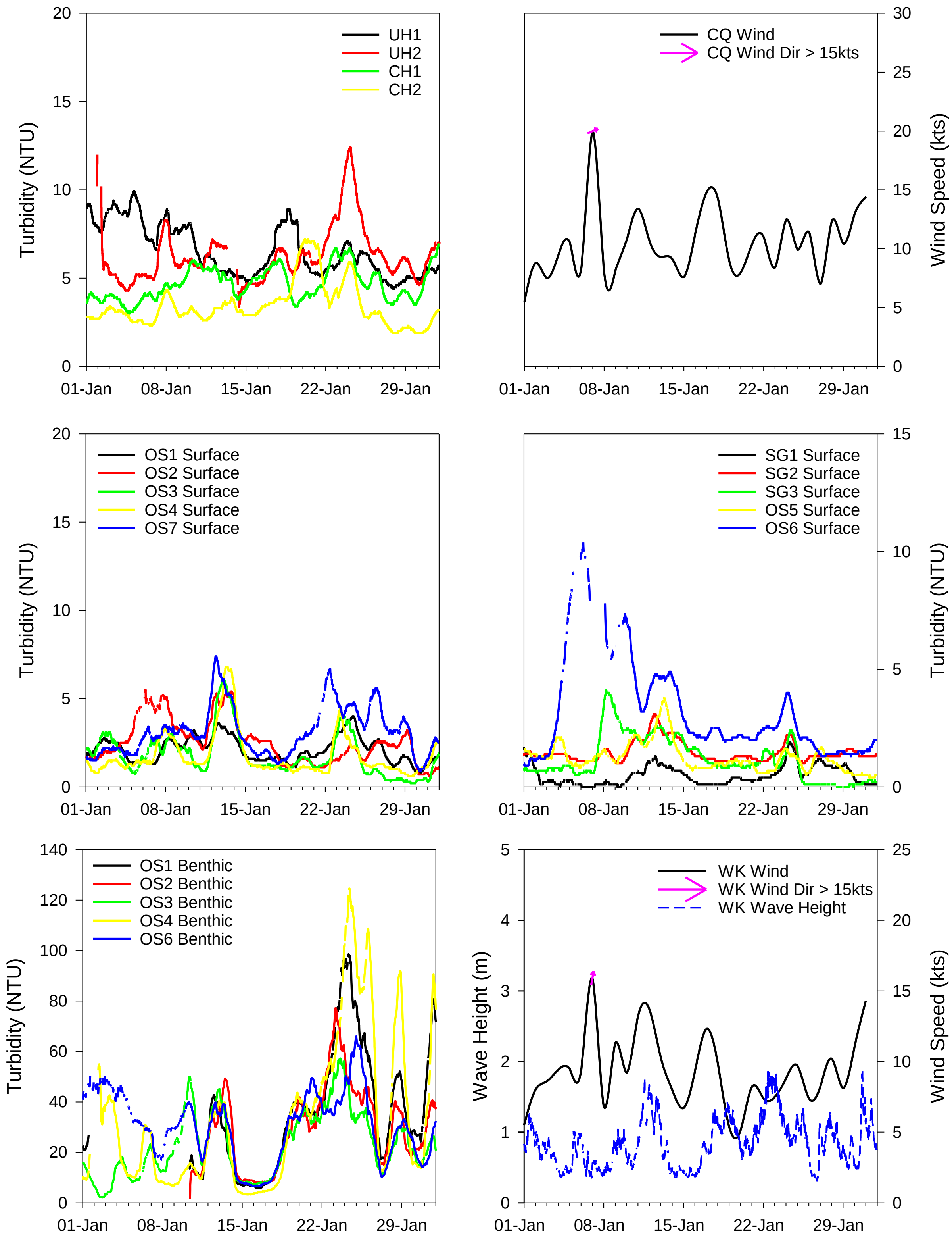


Figure 7 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore and benthic monitoring stations during January 2020.
Note differing scales between plots. Arrows indicate the direction of travel for inshore/offshore winds greater than 15 knots.

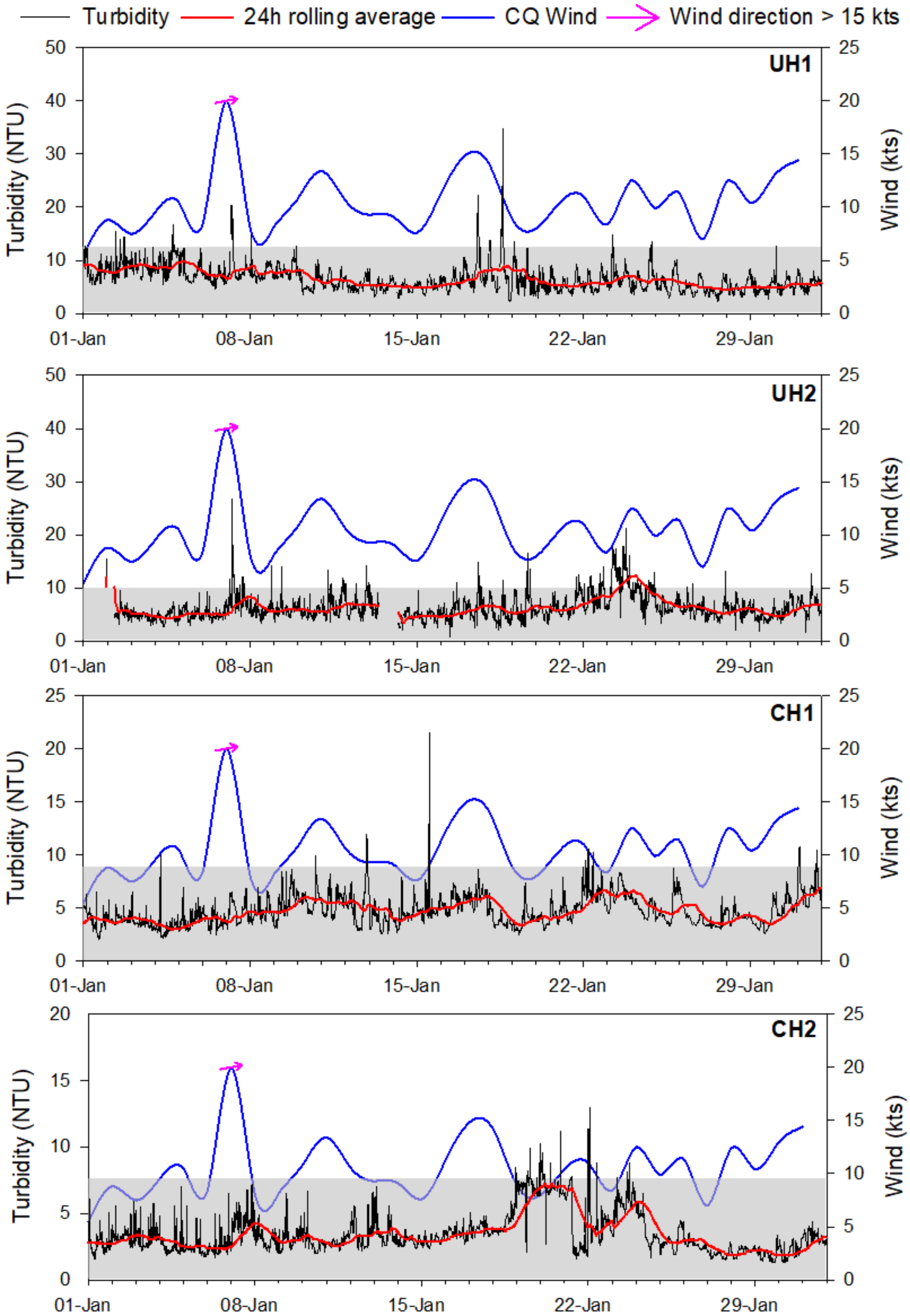


Figure 8 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during January 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

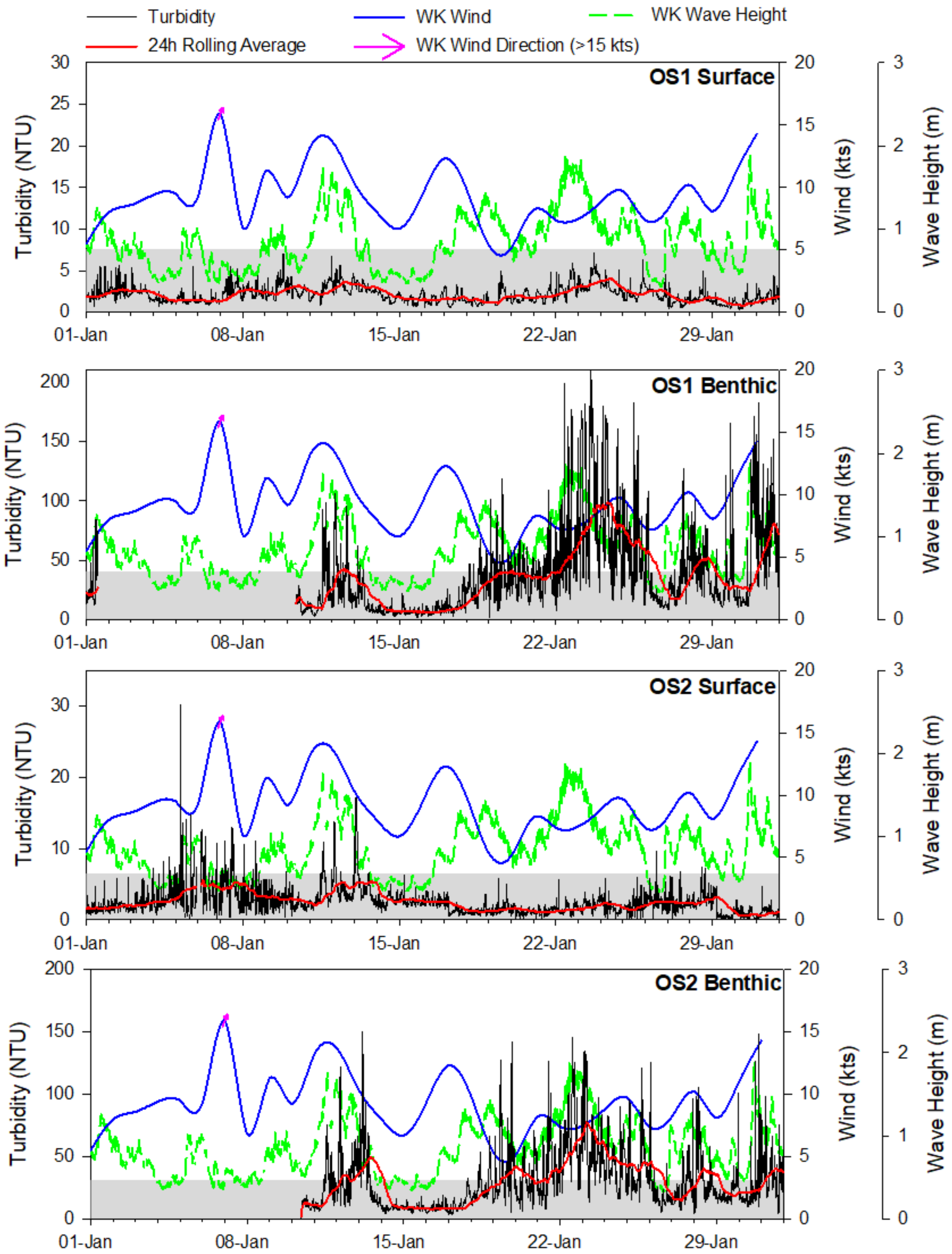


Figure 9 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS1 and OS2) during January 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity

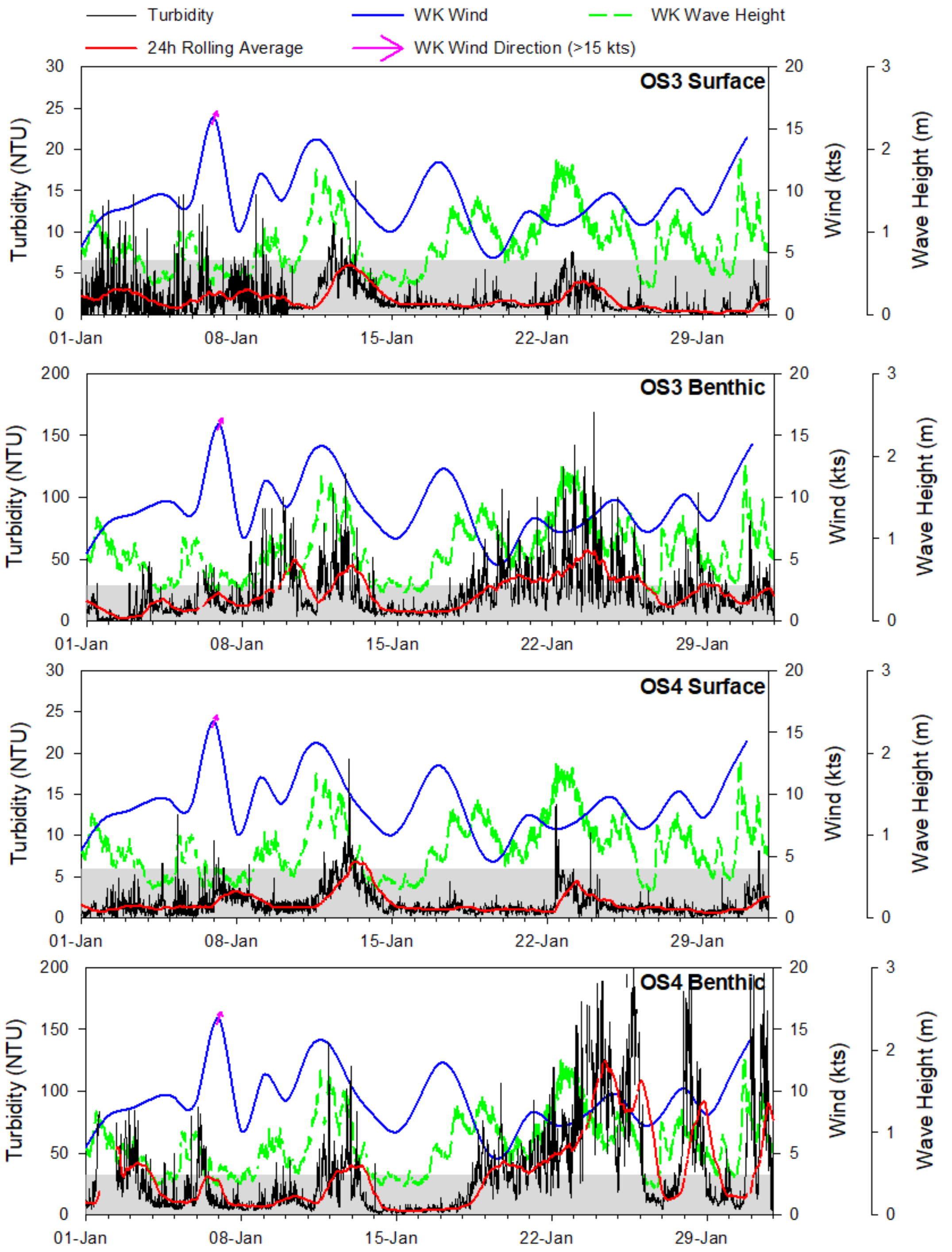


Figure 10 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS3 and OS4) during January 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

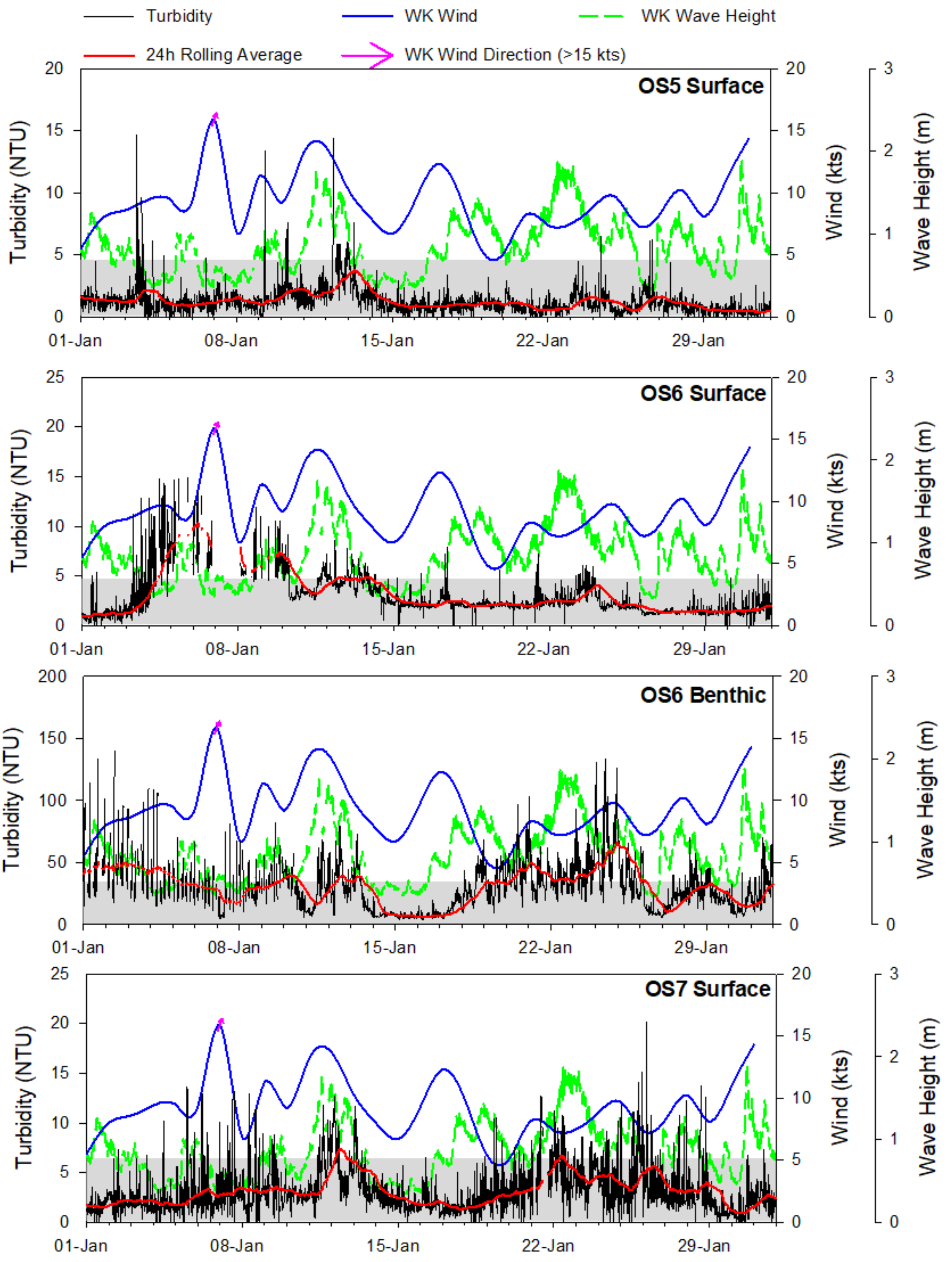


Figure 11 Surface and benthic turbidity and daily averaged winds at nearshore and offshore sites (OS5, OS6 and OS7) during January 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

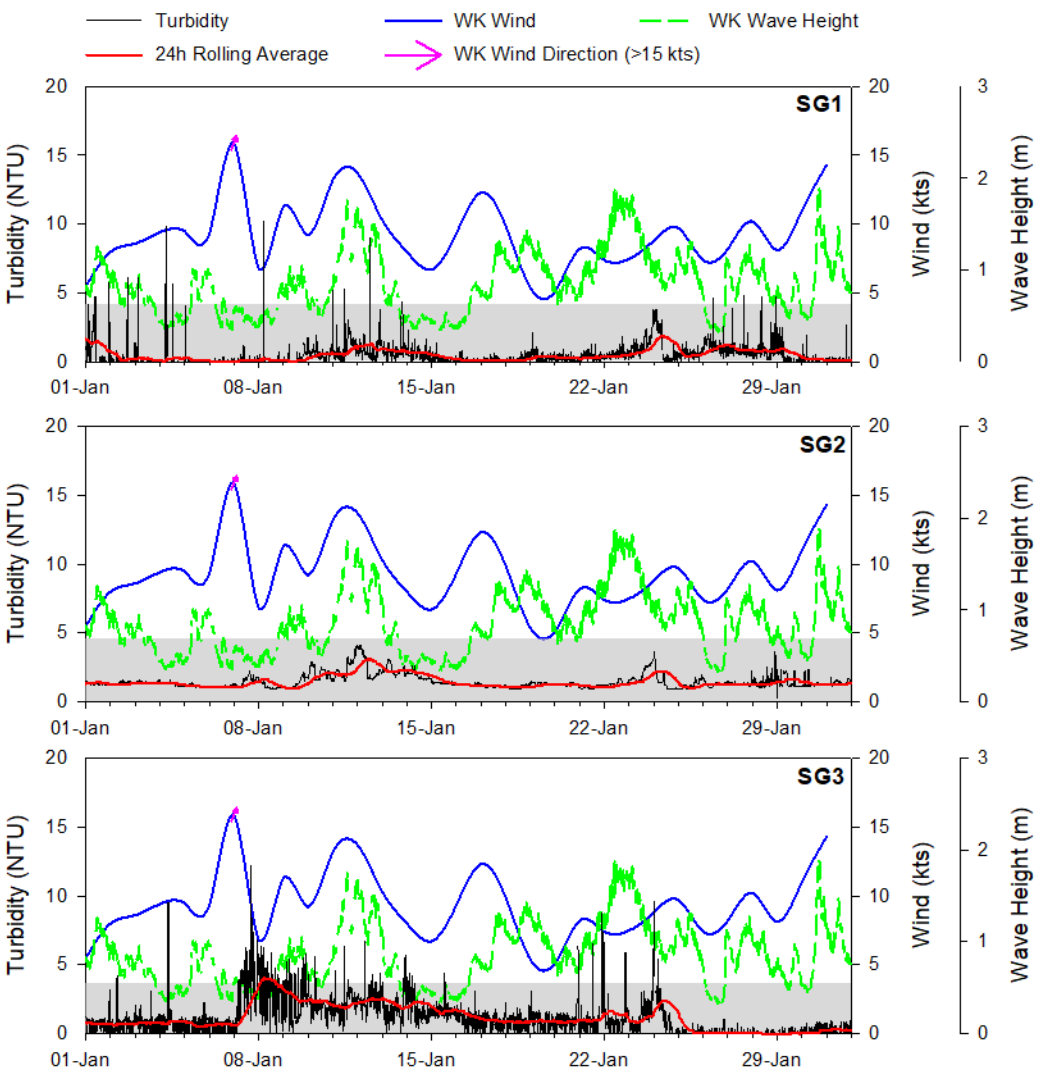


Figure 12 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during January 2020. *Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.*

3.2.2 Dredge Compliance Trigger Values

Management of dredge operations was guided using three tier levels of turbidity trigger values based on the higher order percentiles of baseline data (refer Section 2.1.2). Tier 1 (80^{th} percentile) and Tier 2 (95^{th} percentile) intensity values are designated for LPC internal use and provide early warning mechanisms for elevated turbidity conditions. A compliance alert is 'tripped' if:

1) The current KZ smoothed turbidity reading is above the relevant Tier 3 (99^{th} percentile) intensity level; **and**
2) The cumulative time of exceedances defined in 1) during the current 30-day rolling window exceeds the allowable hours given.

The Tier 1 to 3 intensity levels for KZ smoothed data and allowable hours calculated for the project (Fox, 2018), are outlined in Table 6.

Table 6 Site turbidity intensity values and allowable hours of exceedance in rolling 30-day period. *Allowable hours for Tiers 1 and 2 are indicative only and non-binding as these are for internal LPC use only.*

Site	Tier 1	Tier 2	Tier 3
UH1	15.1	21.7	42.9
UH2	13.0	19.6	30.2
CH1	11.6	17.6	28.1
CH2	10.4	15.2	22.7
OS1	9.9	15.1	23.4
OS2	8.9	12.4	17.3
OS3	8.9	14.2	30.6
OS4	Reference site		
OS5	6.2	11.2	18.3
OS6	7.3	11.5	18.8
OS7	9.2	14.2	22.7
SG1	6.3	9.6	13.9
SG2	6.9	10.6	20.1
SG3	4.7	7.4	13.1
Allowable hours	144	36	7.2

3.2.2.1 P99 Exceedance Counts

During January the Tier 3 intensity values were not exceeded at any site within the monitoring network (Table 7, Figures 13 to 15).

Table 7 Tier 3 intensity value exceedances and maximum hour counts during January 2020.

Site	P99 Count >7.2 Hours Start Time	P99 Count >7.2 Hours End Time	Maximum P99 Count (Hours)
UH1	-	-	0.00
UH2	–	–	0.00
CH1	–	–	0.00
CH2	–	–	0.00
OS1	–	–	0.00
OS2	–	–	0.00
OS3	–	–	0.00
OS4	Reference site		
OS5	–	–	0.00
OS6	–	–	0.00
OS7	–	–	0.00
SG1	–	–	0.00
SG2	–	–	0.00
SG3	–	–	0.00

3.2.2.2 P99 Exceedance Counts Consented Removal

No validated P99 exceedance counts were removed during January 2020 (Table 8).

Table 8 Hour counts removed from monitoring statistics during January 2020.

Site	Start Time (NZST)	End Time (NZST)
–	–	–

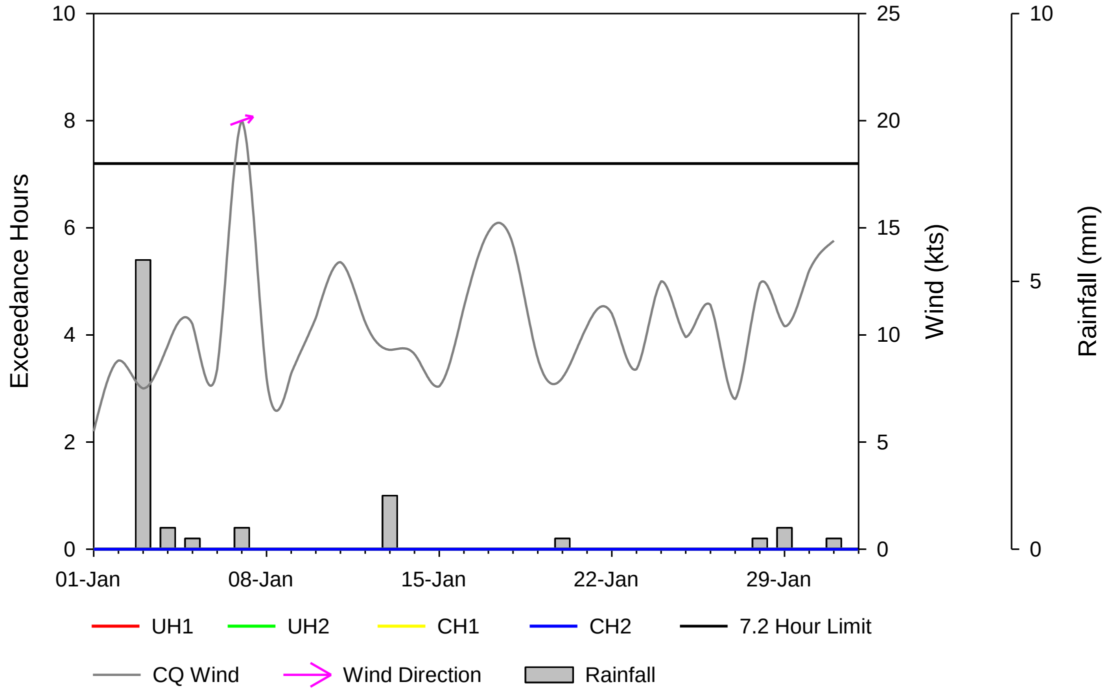


Figure 13 Tier 3 allowable hour counts at UH1, UH2, CH1 and CH2 after exceedance of the intensity values during January 2020.

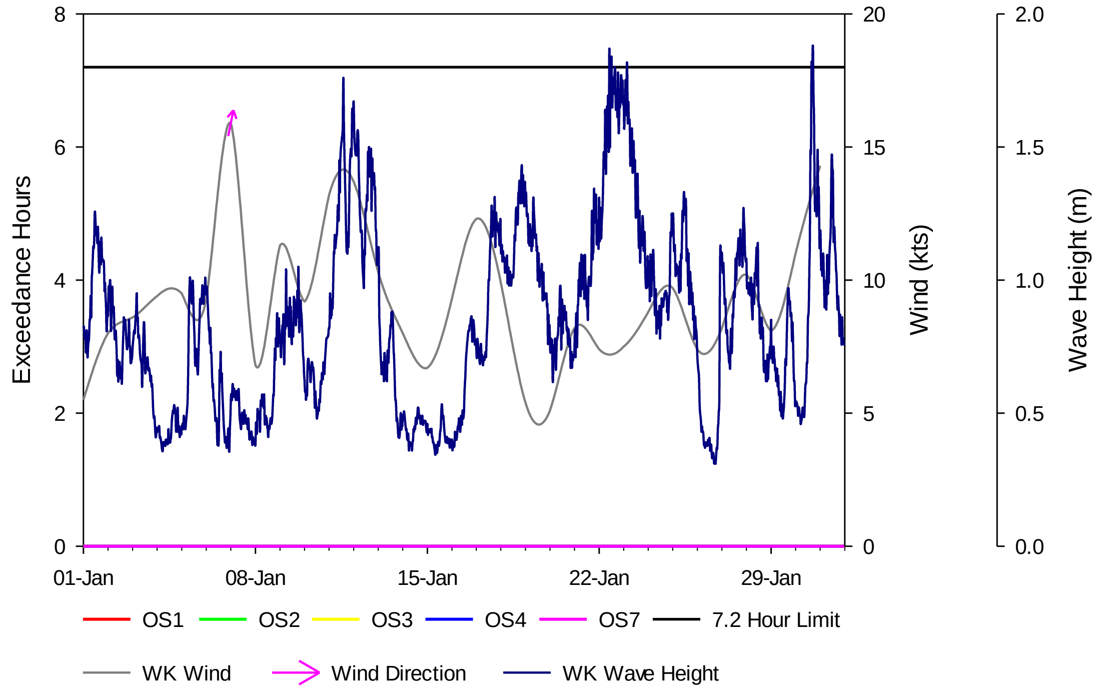


Figure 14 Tier 3 allowable hour counts at OS1-OS3, and OS7 after exceedance of the intensity values during January 2020.
Note there is no trigger value for the reference site OS4.

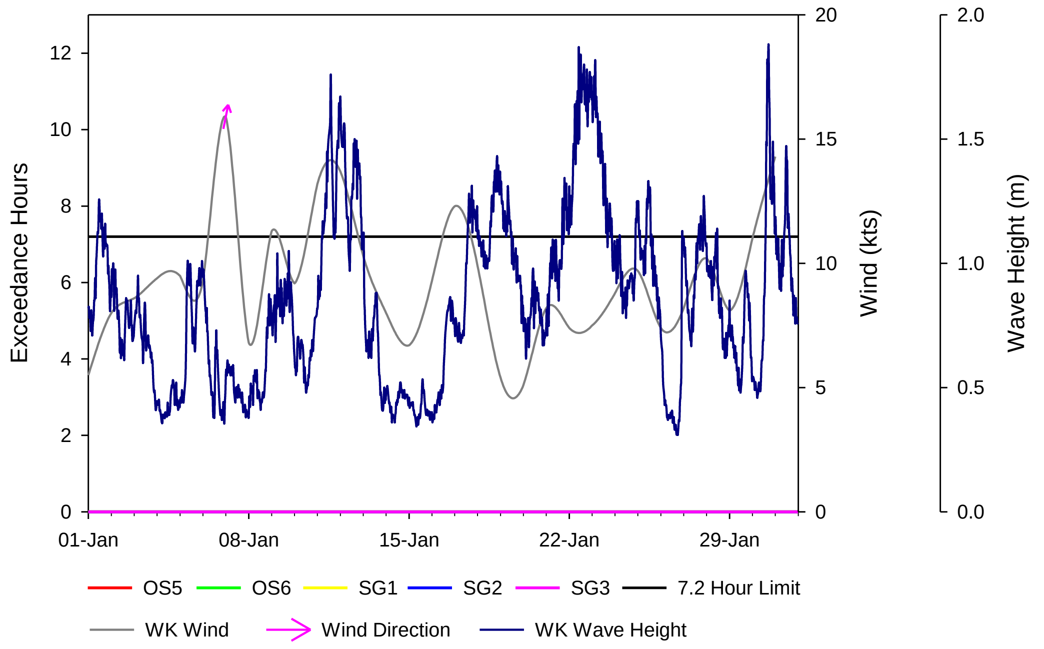


Figure 15 Tier 3 allowable hour counts at OS5, OS6, SG1, SG2b and SG3 after exceedance of the intensity values during January 2020.

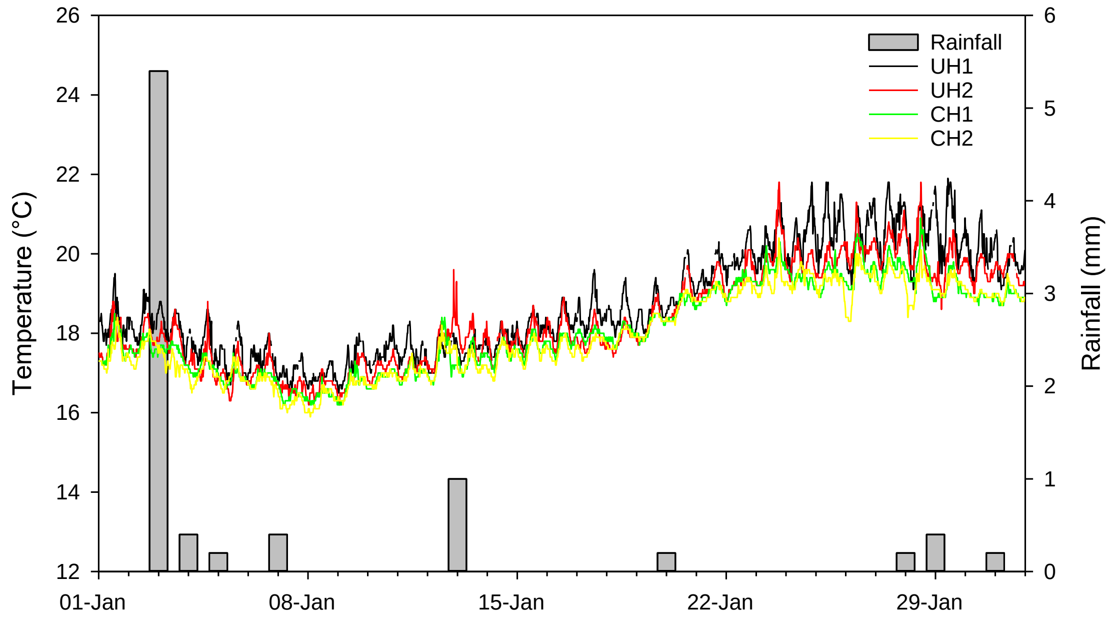
3.2.3 Temperature

Mean monthly sea surface temperatures during January (17.2 to 18.7 °C) (Table 9) were warmer than those experienced during December (15.1 to 17.1°C) indicating the continuation of seasonal warming noted in previous months. The overall temperature trend for January was an increase at all sites, with lower temperatures recorded at the beginning of the month in relation to lower air temperatures (Figures 16 and 17).

Table 9 Mean temperature at inshore, spoil ground and offshore water quality sites during January 2020.
Values are means ± se (n = 2888 to 2976).

Site	Temperature (°C)	
	Surface loggers	Benthic loggers
UH1	18.7 ± 0.0	–
UH2	18.4 ± 0.0	–
CH1	18.1 ± 0.0	–
CH2	18.0 ± 0.0	–
SG1	17.3 ± 0.0	–
SG2	17.4 ± 0.0	–
SG3	17.2 ± 0.0	–
OS1	17.7 ± 0.0	16.4 ± 0.0
OS2	17.5 ± 0.0	15.9 ± 0.0
OS3	17.3 ± 0.0	15.7 ± 0.0
OS4	17.2 ± 0.0	15.6 ± 0.0
OS5	17.5 ± 0.0	–
OS6	17.3 ± 0.0	15.6 ± 0.0
OS7	17.7 ± 0.0	–

Consistent with previous months, slightly warmer temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore sites during January. Semidiurnal variability (associated with tidal water movements and solar radiation) was again observed, particularly at the inner harbour and spoil ground sites. Benthic temperatures were lower than the overlying surface waters and generally displayed the same surface trends indicating a well-mixed water column. The exception was OS1 for which the mean temperature was higher than at other benthic sites (Table 9). Fluctuating elevations in benthic temperature at this site were observed from 20 January till the end of the month. This phenomenon was observed during the previous maintenance dredge campaign and may be due to warmer inshore sediments being deposited adjacent to OS1 benthic site (Figure 17).



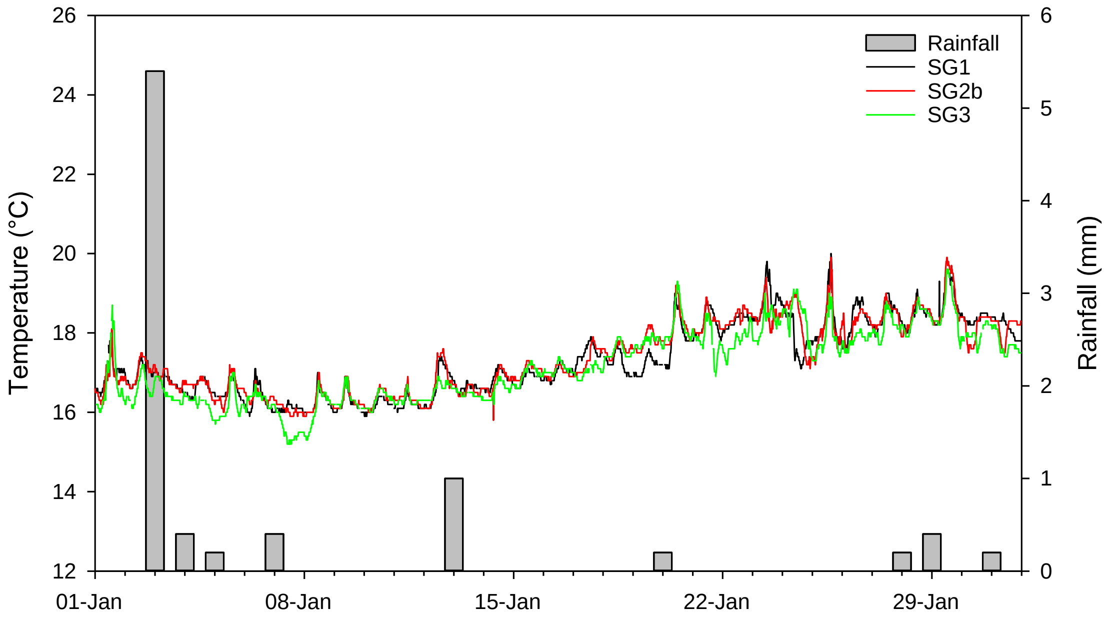
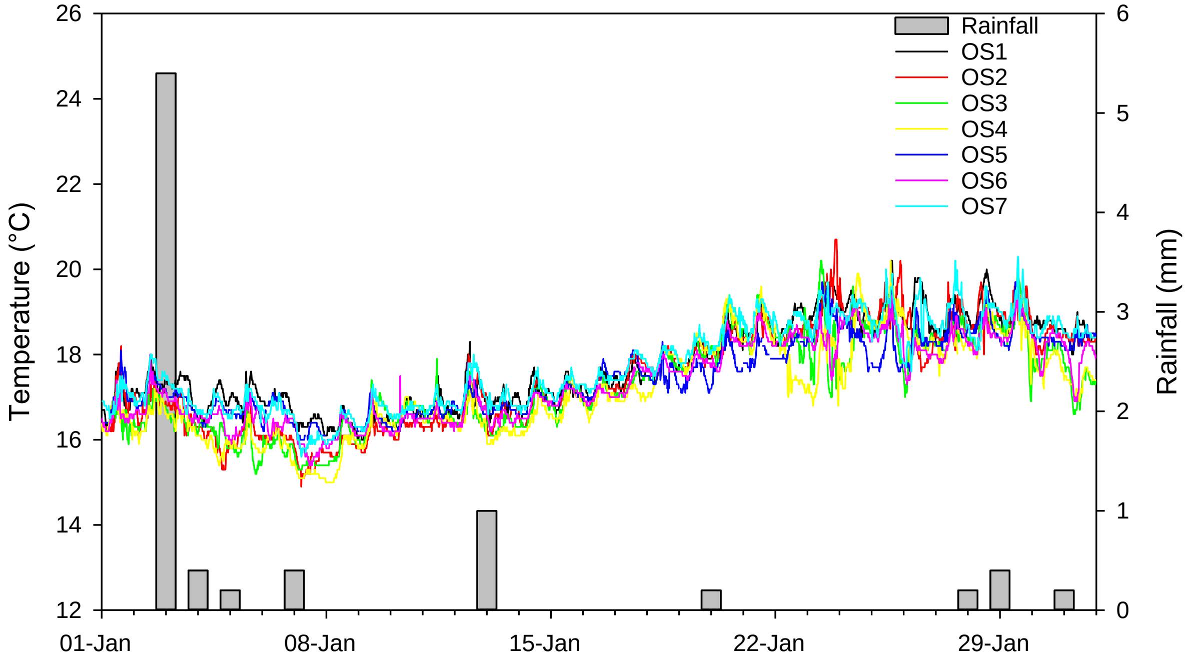


Figure 16 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during January 2020.



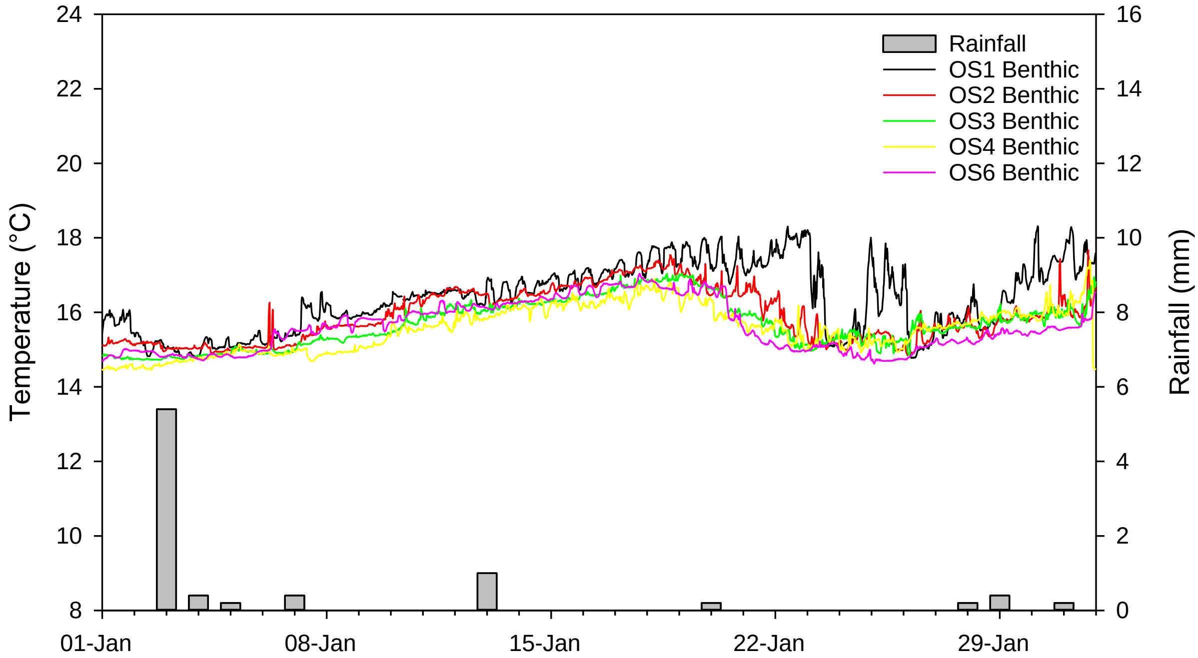


Figure 17 Surface temperature (OS1 to OS7) and benthic temperature (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during January 2020.

3.2.4 pH

The pH remained highly consistent across surface and benthic sites, with monthly means ranging between 8.0 and 8.2 (Table 10, Figures 18 and 19).

Table 10 Mean pH at inshore, spoil ground and offshore water quality sites January 2020. *Values are means ± se (n = 2068 to 2976).*

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

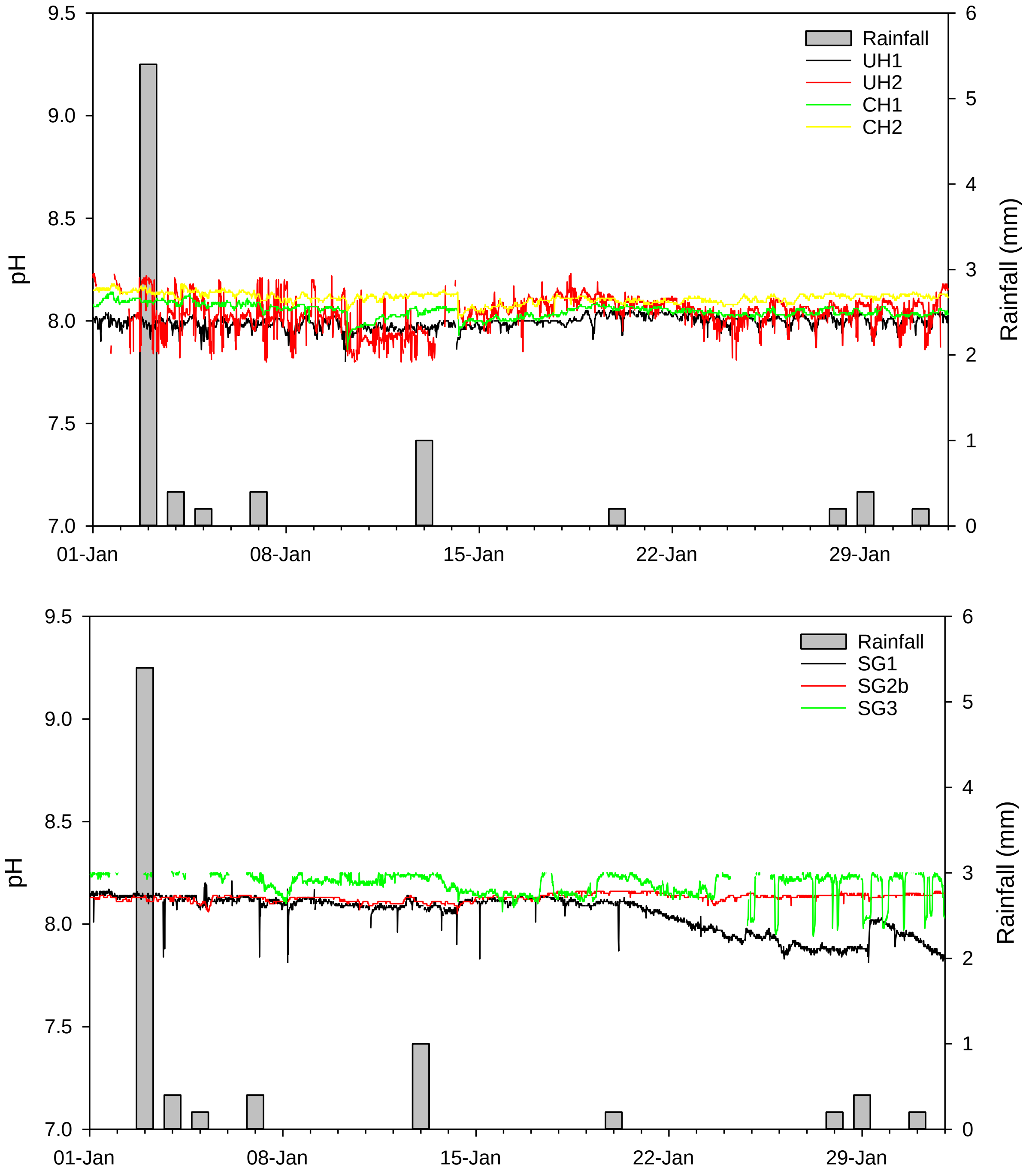


Figure 18 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during January 2020.

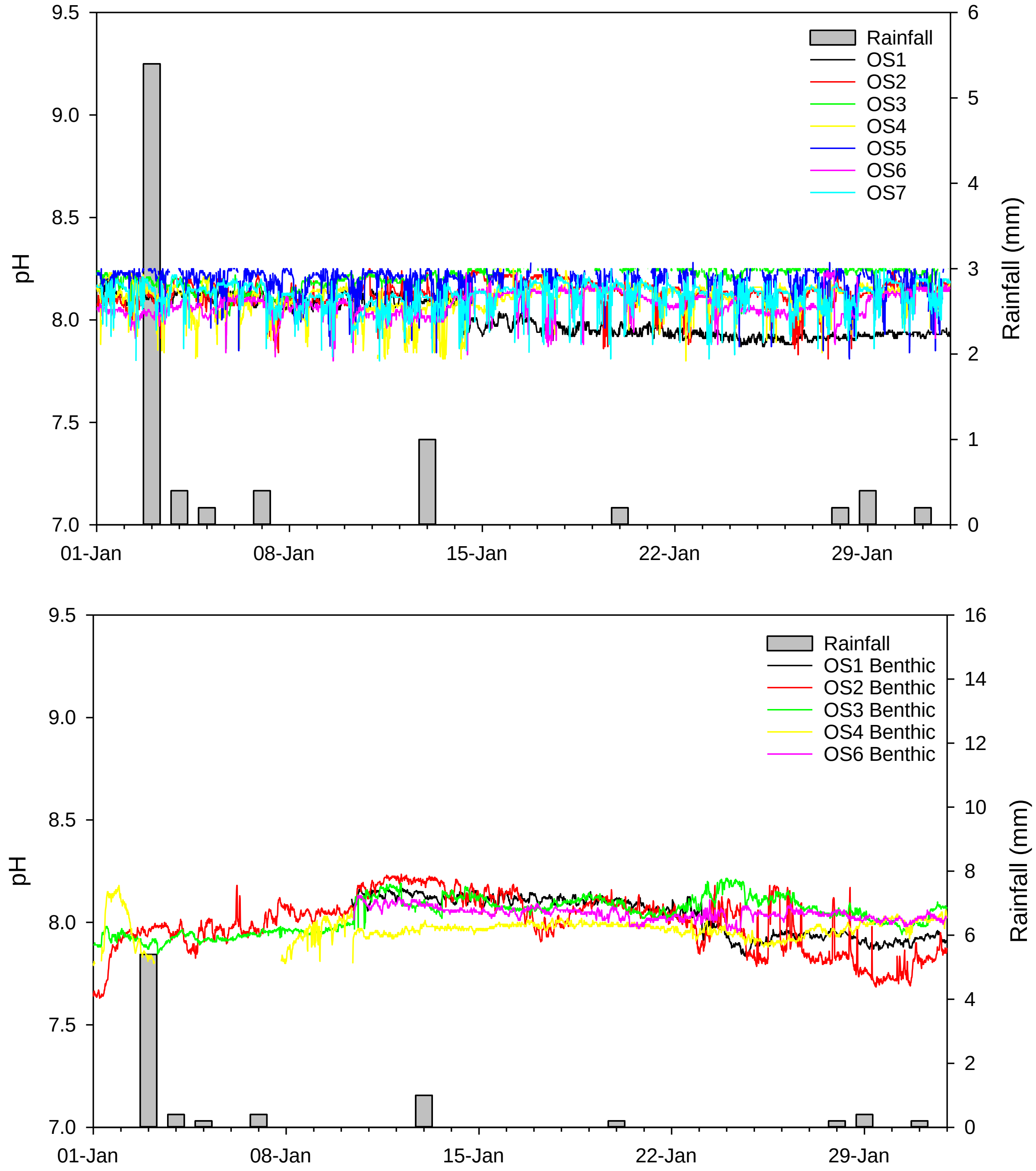


Figure 19 Surface pH (OS1 to OS7) and benthic pH (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during January 2020.

3.2.5 Conductivity

Surface conductivity in January ranged from 50.1 mS/cm to 53.9 mS/cm (Table 11, Figure 20 and 21), with benthic conductivity recorded at similar levels, ranging from 52.9 mS/cm to 54.1 mS/cm.

As previously observed inner harbour sites recorded slightly lower mean conductivity values than offshore and spoil ground sites due to previous localised freshwater influences compared to oceanic mixing. The increased flow (287 m^3/s) from the Waimakariri River on 13 January appears to have slightly decreased conductivity at majority of sites on the 17 January to ~49.0 mS/cm. The delay in reduced conductivity from the effect of the flow in reaching Lyttelton Harbour was probably due to the distance the freshwater needs to travel and the current hugging the coast.

Seawater at the benthos was not as impacted by the flow events, with the lower density freshwater remaining mostly in the surface layers during these events.

Table 11 Mean conductivity at inshore, spoil ground and offshore water quality sites during January 2020.
Values are means ± se (n = 2068 to 2976).

Site	Conductivity (mS/cm)	
	Surface loggers	Benthic loggers
UH1	51.5 ± 0.0	–
UH2	52.5 ± 0.0	–
CH1	51.1 ± 0.0	–
CH2	51.0 ± 0.0	–
SG1	52.6 ± 0.0	–
SG2	51.4 ± 0.0	–
SG3	53.9 ± 0.0	–
OS1	51.4 ± 0.0	54.0 ± 0.0
OS2	53.0 ± 0.0	53.2 ± 0.0
OS3	53.1 ± 0.0	54.1 ± 0.0
OS4	53.3 ± 0.0	53.9 ± 0.0
OS5	53.6 ± 0.0	–
OS6	53.5 ± 0.0	52.9 ± 0.0
OS7	52.1 ± 0.0	–

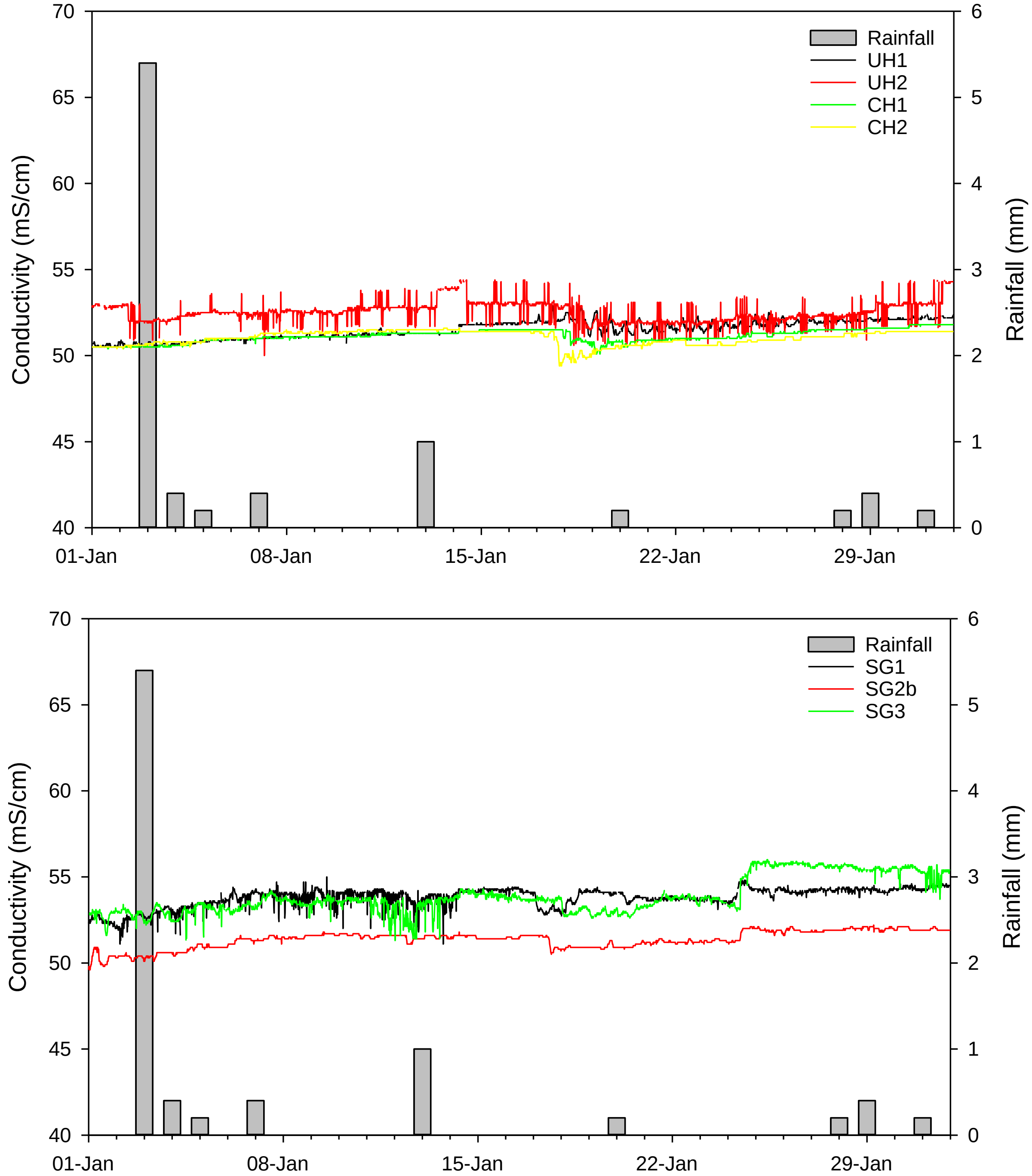


Figure 20 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during January 2020.

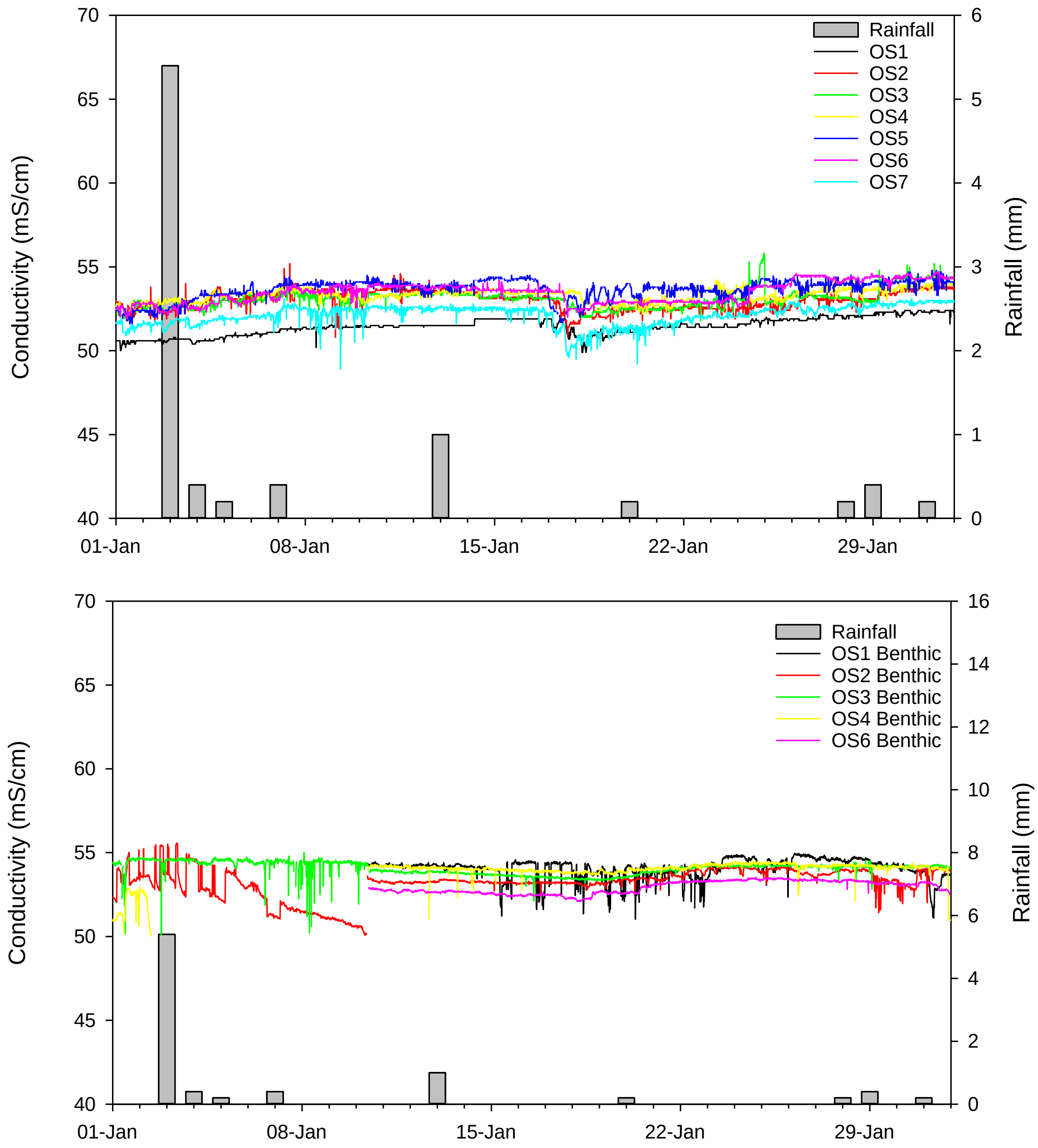


Figure 21 Surface conductivity (OS1 to OS7) and benthic conductivity (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during January 2020.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations in January ranged from 96 to 104% saturation. DO concentrations were observed to be lower around the 8 and 24 January following periods lower water temperatures. Noticeably declining DO (<90% saturation) at OS3 and SG3 on 5 and 9 January, respectively, may have been associated with degrading algal blooms in which bacterial degradation results in respiration and oxygen consumption. In a cyclical pattern, warmer temperatures associated with increased sunlight following this period likely stimulated microalgal growth, leading to recovery of algal populations, increased photosynthesis, and therefore increased DO concentrations. Flows from the Waimakariri River may have also introduced nutrients contributing to algal growth.

Mean monthly benthic DO concentrations were lower than corresponding surface readings ranging from 83 to 96% saturation (Table 12, Figures 22 and 23), indicative of lower photosynthesis at the benthos. Benthic DO however displayed a similar trend to surface cohorts.

Table 12 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during January 2020.
Values are means ± se (n = 2031 to 2976).

Site	Dissolved oxygen (% saturation)	
	Surface loggers	Benthic loggers
UH1	98 ± 0	–
UH2	96 ± 0	–
CH1	99 ± 0	–
CH2	101 ± 0	–
SG1	101 ± 0	–
SG2	104 ± 0	–
SG3	103 ± 0	–
OS1	102 ± 0	93 ± 0
OS2	99 ± 0	89 ± 0
OS3	99 ± 0	82 ± 0
OS4	101 ± 0	96 ± 0
OS5	102 ± 0	–
OS6	100 ± 0	88 ± 0
OS7	102 ± 0	–

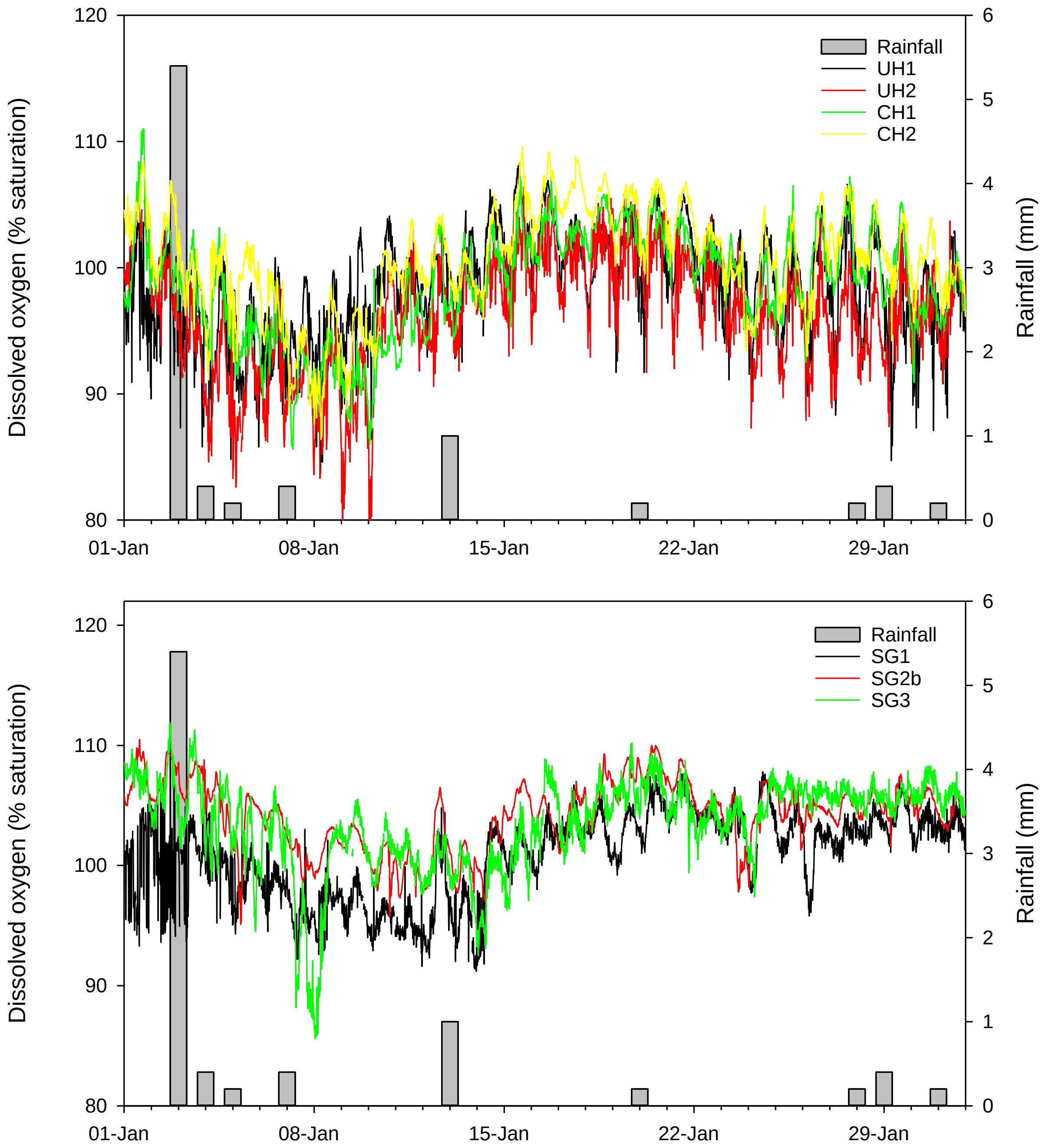


Figure 22 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during January 2020.

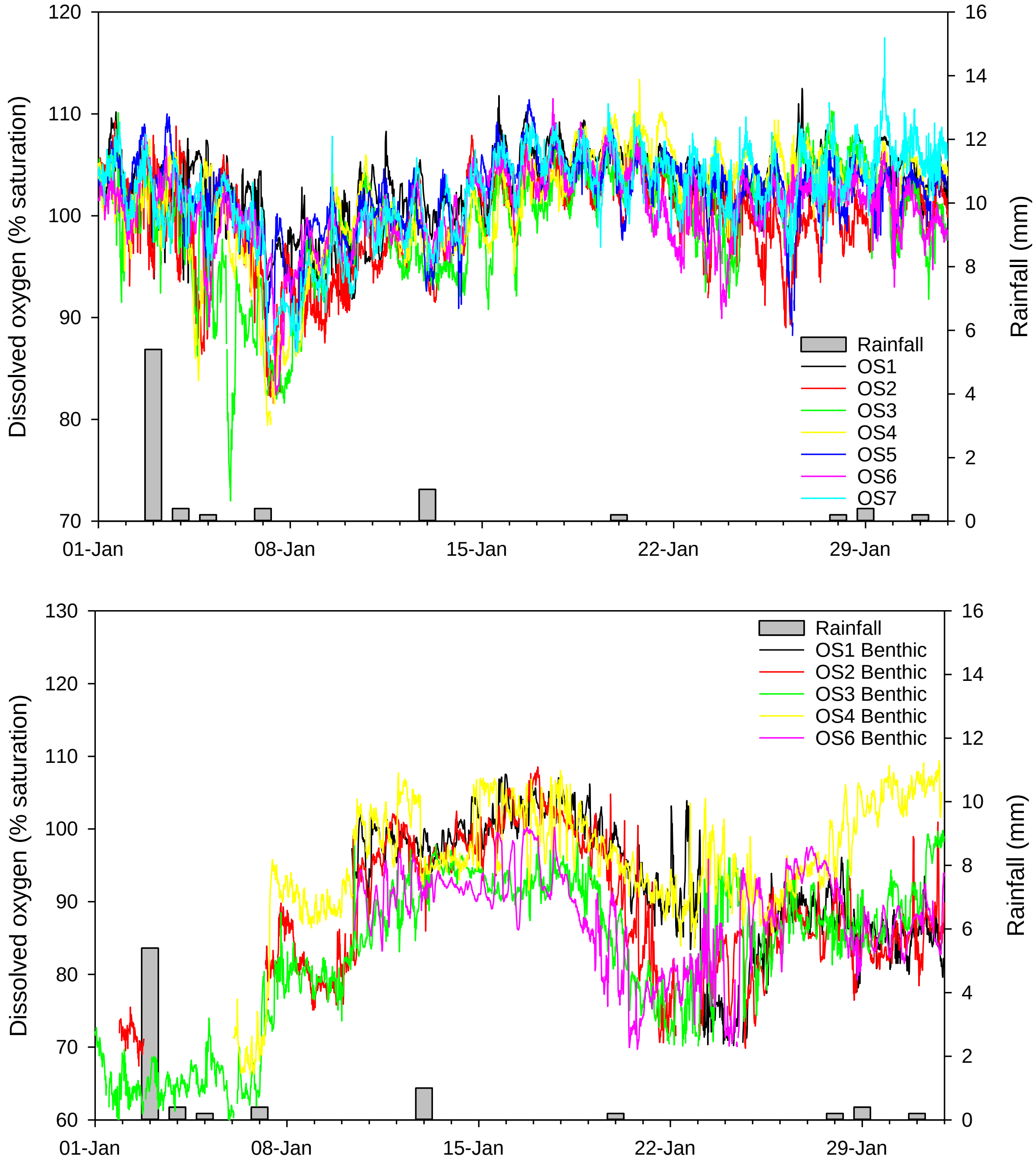


Figure 23 Surface DO (OS1 to OS7) and benthic DO (OS1 to OS 4 and OS6) at nearshore and offshore water quality sites during January 2020.

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 14 January 2020. 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 depth to which net photosynthesis can occur/where light levels are ~1% of those at the surface) were also calculated.

Water samples for the determination of TSS were 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 at the inshore monitoring sites, only surface TSS samples were collected from sites UH1, UH2, UH3, 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 13 to 15, with depth profile plots presented in Figures 24 to 26.

The relatively shallow sites of the upper and central harbour once again displayed well mixed conditions with little variability recorded in parameters through the water column (Figure 24). The uppermost harbour sites UH1 and UH3 provided higher temperature and turbidity records, and turbidity was also more variable in sub-surface waters at these two sites. CH1 exhibited a slight increase in turbidity at the benthos.

Within the nearshore region, physicochemical profiles for temperature, pH and conductivity were relatively consistent throughout the water column at all sites (Figure 25). DO concentrations at sites OS1, OS3 and OS4 were also consistent along the depth profile. However, DO concentrations at OS7 showed a decline at a depth of ~ 4 – 6 m and this was mirrored by the temperature profile of the site. Turbidity remained stable throughout the water column at all nearshore sites except for OS4 where up to 60 NTU was recorded at ~15 m, possibly due to resuspension of benthic sediments.

Within the offshore region of the spoil ground, OS5 and OS6, the water column displayed relative consistent temperature, pH and conductivity profiles (Figure 26). DO concentrations, decreased among all spoil ground sites closer to the benthos, due to reduced photosynthetic activity at depth. Turbidity remained stable until >15 m where it increased due to benthic resuspension at all sites.

The shallowest euphotic depth of 4.4 m occurred within upper harbour monitoring sites UH3 (Table 13), which reflects the typically higher levels of turbidity experienced in this area (Figure 24). The deepest euphotic depth was calculated to be 15.4 m at OS5 (Table 15) where turbidity throughout the column was low. During January no exceedances of WQG were recorded at the sub-surface during depth profiling.

Table 13 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the January 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, n = 22 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)
UH1	14/01/2020 04:07	Sub-surface	17.3 ± 0	7.9 ± 0	50.8 ± 0	99 ± 0	4.3 ± 0	9	1 ± 0	4.7
		Whole column	17.3 ± 0.9	7.9 ± 0	50.8 ± 0	98 ± 0	4.5 ± 0.1	–		
UH2	14/01/2020 04:55	Sub-surface	17.1 ± 0	8 ± 0	50.8 ± 0	99 ± 0	3 ± 0.1	8	0.7 ± 0	6.8
		Whole column	17.1 ± 0.8	8 ± 0	50.8 ± 0	99 ± 0	3.1 ± 0	–		
UH3	14/01/2020 04:27	Sub-surface	17.6 ± 0	8 ± 0	50.8 ± 0	101 ± 0	4.4 ± 0.1	11	1 ± 0.1	4.4
		Whole column	17.5 ± 1	8 ± 0	50.8 ± 0	101 ± 0	4.5 ± 0.1	–		
CH1	14/01/2020 05:49	Sub-surface	17.1 ± 0	8 ± 0	50.8 ± 0	99 ± 0	2.9 ± 0	5	0.6 ± 0	7.1
		Whole column	17.1 ± 0.9	8 ± 0	50.8 ± 0	98 ± 0	3.6 ± 0.2	–		
CH2	14/01/2020 05:25	Sub-surface	16.8 ± 0	8 ± 0	50.8 ± 0	99 ± 0	2.1 ± 0	4	0.5 ± 0	9.1
		Whole column	16.8 ± 0.8	8 ± 0	50.8 ± 0	99 ± 0	2.4 ± 0.1	–		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	–

Table 14 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the January 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 33 to 44 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	14/01/2020 06:16	Sub-surface	16.9 ± 0	8 ± 0	50.8 ± 0	100 ± 0	2.6 ± 0	3	0.5 ± 0	9.4
		Mid	16.6 ± 0	8 ± 0	50.8 ± 0	100 ± 0	2.5 ± 0	5		
		Benthos	16.5 ± 0	8 ± 0	50.8 ± 0	101 ± 0	3.7 ± 0.2	4		
		Whole column	16.7 ± 0.7	8 ± 0	50.8 ± 0	100 ± 0	2.8 ± 0.1	–		
OS2	14/01/2020 10:30	Sub-surface	17 ± 0	8 ± 0	50.8 ± 0	105 ± 0	1.8 ± 0	5	0.4 ± 0	11.1
		Mid	16.6 ± 0	8 ± 0	50.8 ± 0	103 ± 0	2.1 ± 0	3		
		Benthos	16.6 ± 0	8 ± 0	50.9 ± 0	98 ± 1	4.8 ± 0.7	4		
		Whole column	16.7 ± 0.6	8 ± 0	50.8 ± 0	103 ± 0	2.4 ± 0.2	–		
OS3	14/01/2020 09:24	Sub-surface	16.7 ± 0	8 ± 0	51 ± 0	97 ± 0	2.1 ± 0	6	0.4 ± 0	11.7
		Mid	16.4 ± 0	8 ± 0	51 ± 0	96 ± 0	2.6 ± 0.1	3		
		Benthos	16.2 ± 0	8 ± 0	51.1 ± 0	96 ± 0	3.3 ± 0.1	6		
		Whole column	16.5 ± 0.7	8 ± 0	51 ± 0	96 ± 0	2.6 ± 0.1	–		
OS4	14/01/2020 08:55	Sub-surface	16.5 ± 0.7	8 ± 0	51.1 ± 0	99 ± 0	1.9 ± 0	3	0.4 ± 0	12.6
		Mid	16.5 ± 0	8 ± 0	51.1 ± 0	98 ± 0	2.3 ± 0	5		
		Benthos	16.1 ± 0	8 ± 0	51.1 ± 0	97± 0	12.9 ± 9.6	4		
		Whole column	16.3 ± 0.6	8 ± 0	51.1 ± 0	98 ± 0	3.7 ± 1.4	-		
OS7	14/01/2020 10:55	Sub-surface	17.3 ± 0	8 ± 0	50.8 ± 0	105 ± 0	2 ± 0	4	0.4 ± 0	10.8
		Mid	16.8 ± 0.1	8 ± 0	50.8 ± 0	102 ± 1	2.3 ± 0.1	4		
		Benthos	16.7 ± 0	8 ± 0	50.8 ± 0	101 ± 0	3.3 ± 0.2	4		
		Whole column	17 ± 0.7	8 ± 0	50.8 ± 0	103 ± 0	2.5 ± 0.1	–		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	

Table 15 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the January 2020 sampling event.
Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 43 to 56 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	14/01/2020 06:50	Sub-surface	16.7 ± 0	8 ± 0	50.8 ± 0	103 ± 0	1.6 ± 0	<3	0.3 ± 0	15.4
		Mid	16.6 ± 0	8 ± 0	50.8 ± 0	102 ± 0	1.7 ± 0.1	<3		
		Benthos	16.4 ± 0	8 ± 0	50.9 ± 0	97 ± 1	7.9 ± 3	8		
		Whole column	16.6 ± 0.7	8 ± 0	50.8 ± 0	102 ± 0	2.5 ± 0.5	–		
OS6	14/01/2020 09:58	Sub-surface	17 ± 0	8 ± 0	50.9 ± 0	103 ± 0	1.8 ± 0	4	0.4 ± 0	11.2
		Mid	16.7 ± 0	8 ± 0	50.9 ± 0	101 ± 0	2.3 ± 0.1	4		
		Benthos	16.3 ± 0	8 ± 0	51 ± 0	94 ± 0	5 ± 0.3	6		
		Whole column	16.7 ± 0.6	8 ± 0	50.5 ± 0.4	100 ± 1	2.6 ± 0.2	–		
SG1	14/01/2020 07:19	Sub-surface	16.8 ± 0	8 ± 0	50.8 ± 0	103 ± 0	1.5 ± 0	<3	0.3 ± 0	14.9
		Mid	16.6 ± 0	8 ± 0	50.8 ± 0	102 ± 0	1.5 ± 0	<3		
		Benthos	16.4 ± 0	8 ± 0	50.9 ± 0	96 ± 1	4.9 ± 1.4	4		
		Whole column	16.6 ± 0.6	8 ± 0	50.8 ± 0	102 ± 0	1.9 ± 0.2	–		
SG2	14/01/2020 07:46	Sub-surface	16.6 ± 0	8 ± 0	51 ± 0	99 ± 0	1.8 ± 0	<3	0.4 ± 0	12.9
		Mid	16.4 ± 0	8 ± 0	51 ± 0	98 ± 0	2 ± 0	<3		
		Benthos	16.3 ± 0	8 ± 0	51 ± 0	97 ± 0	3.8 ± 0.6	4		
		Whole column	16.4 ± 0.6	8 ± 0	51 ± 0	98 ± 0	2.2 ± 0.1	–		
SG3	14/01/2020 08:20	Sub-surface	16.6 ± 0	8 ± 0	51.1 ± 0	102 ± 0	1.1 ± 0	4	0.3 ± 0	14.8
		Mid	16.3 ± 0	8 ± 0	51.1 ± 0	101 ± 0	1.1 ± 0	<3		
		Benthos	15.8 ± 0	8 ± 0	51.2 ± 0	94 ± 0	3.9 ± 0.2	8		
		Whole column	16.2 ± 0.6	8 ± 0	51.1 ± 0	100 ± 0	1.7 ± 0.1	–		
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

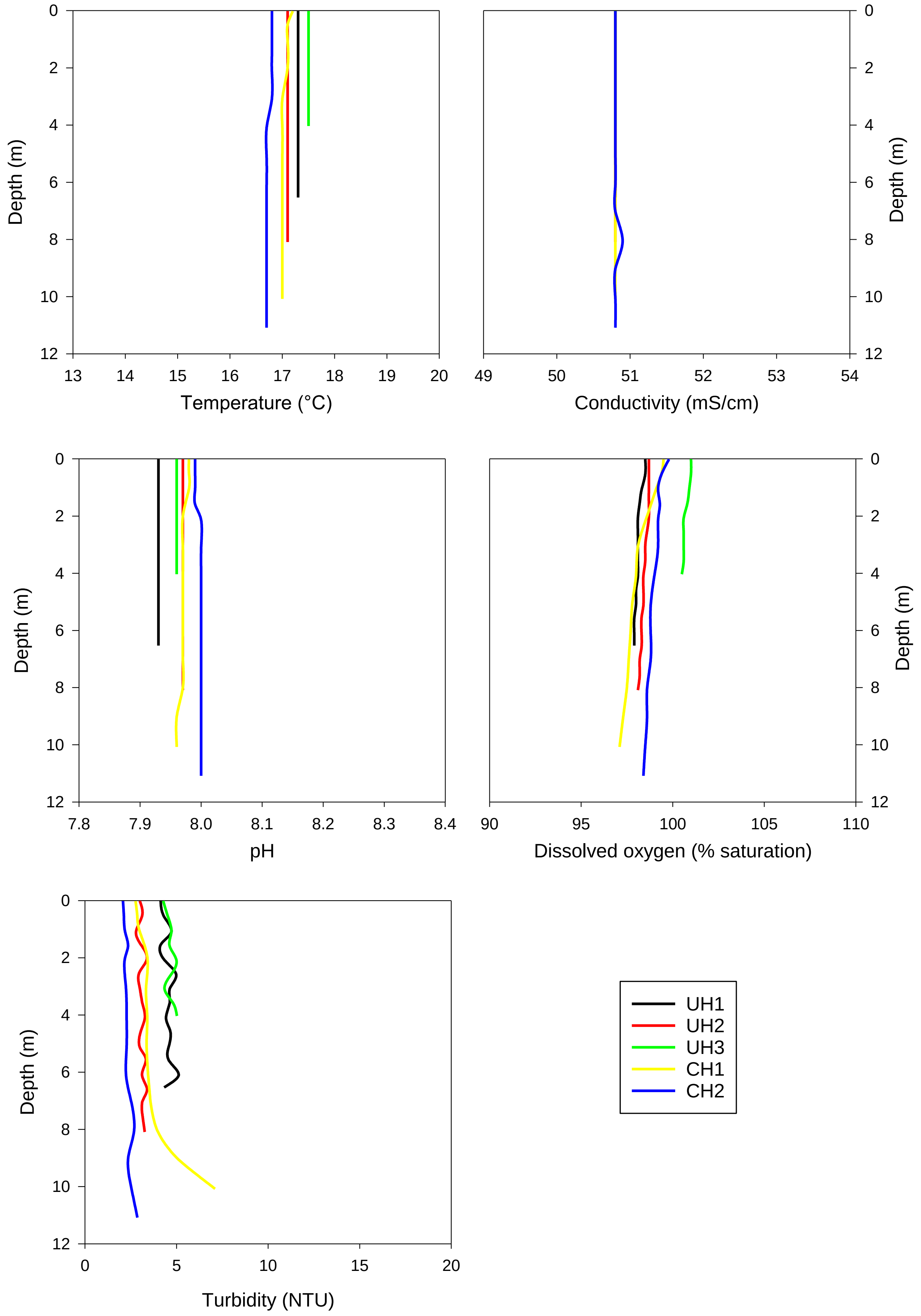


Figure 24 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 14 January 2020.

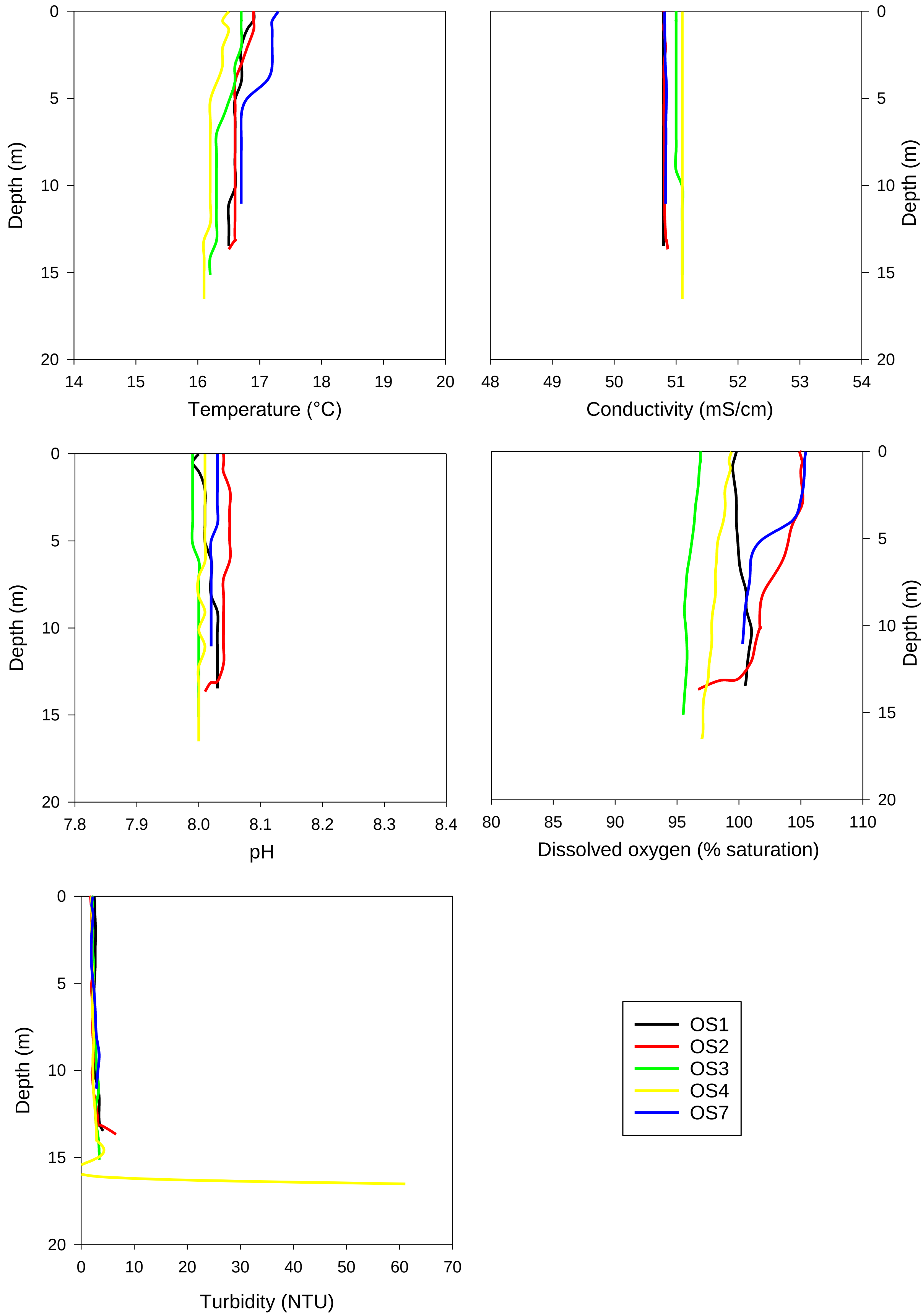


Figure 25 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 14 January 2020.

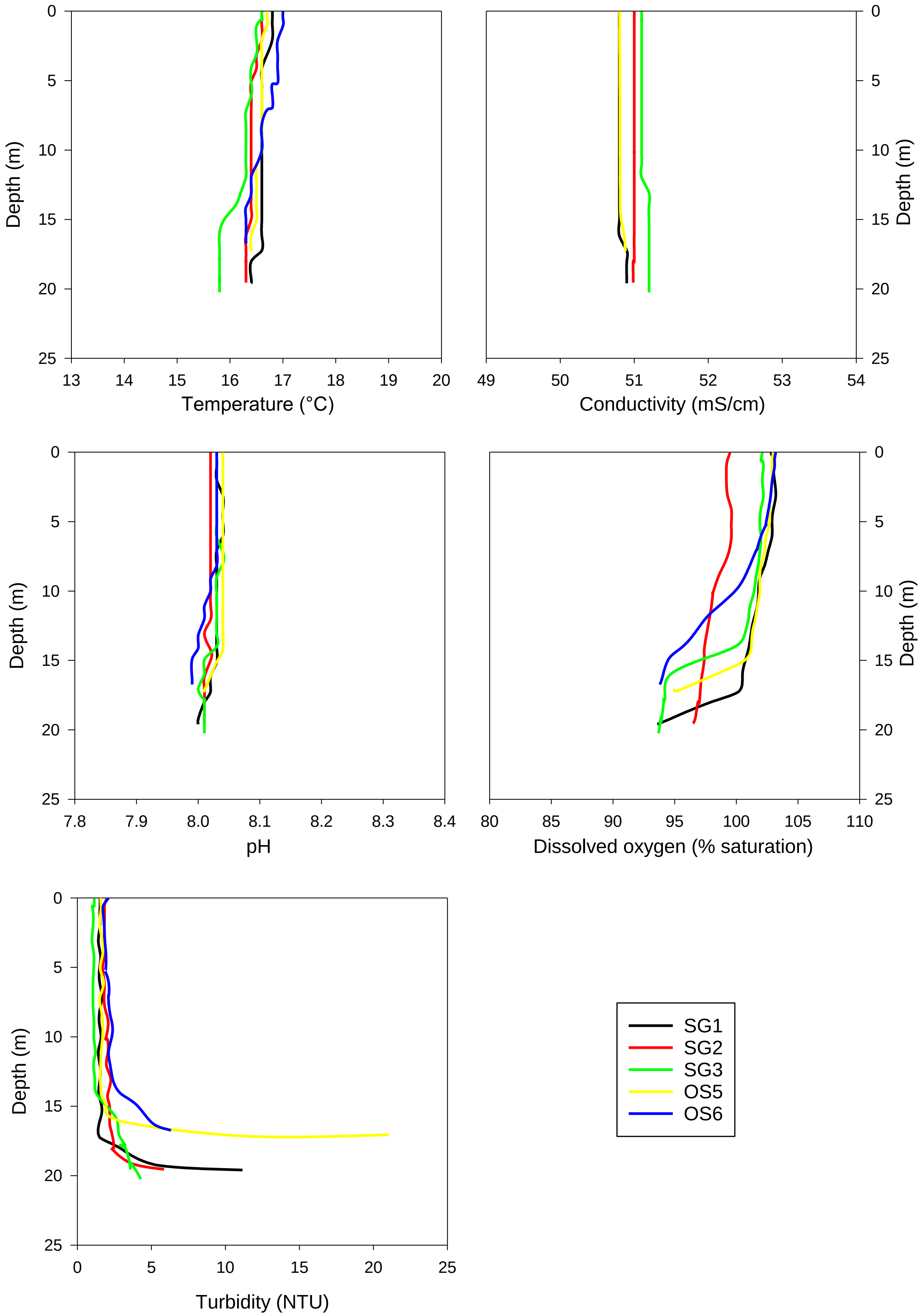


Figure 26 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 14 January 2020.

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 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 16, with the collected data from benthic and VBCC sensors presented in Figure 27. Data from the logger exchange date (10 January) were removed from the analyses.

Table 16 Total Daily PAR (TDP) statistics during January 2020.
Values are means ± se (n = 30). Note data from the BPAR exchange day on 10 January were not utilised in plots or statistics for sites OS2 and OS3.

Site	Depth (m)	TDP (mmol/m^2/day)		
		Mean ± se	Median	Range
Base	-	41,433 ± 1,928	42,450	13,800 – 58,900
OS2	17	4,156 ± 880	2,632	<0.1 – 18,895
OS3	14	3,005 ± 937	213	<0.1 – 20,879

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 was variable, ranging from 13,800 to 58,900 mmol/m^2/day (Table 16), which was similar to the range recorded during December (13,800 to 59,100 mmol/m^2/day). With the increase in longer day lengths in January, mean TDP (41,433 mmol/m^2/day) was similar than that observed during December (43,300 mmol/m^2/day).

As a result of high ambient PAR and lower turbidity, mean BPAR at both OS2 and OS3 was higher in January (4,156 and 3,005 mmol/m^2/day respectively) than December (859 and 619 mmol/m^2/day, respectively). Both sites displayed similar intermittent BPAR peaks in response to similarly intermittent low turbidity at the middle and end of January. Higher turbidity at both sites at the beginning of January (Figure 27) resulted in lower BPAR despite fluctuating ambient PAR. OS2 as usual, displayed additional BPAR peaks at the beginning of January and 19 January and higher median TDP values than OS3.

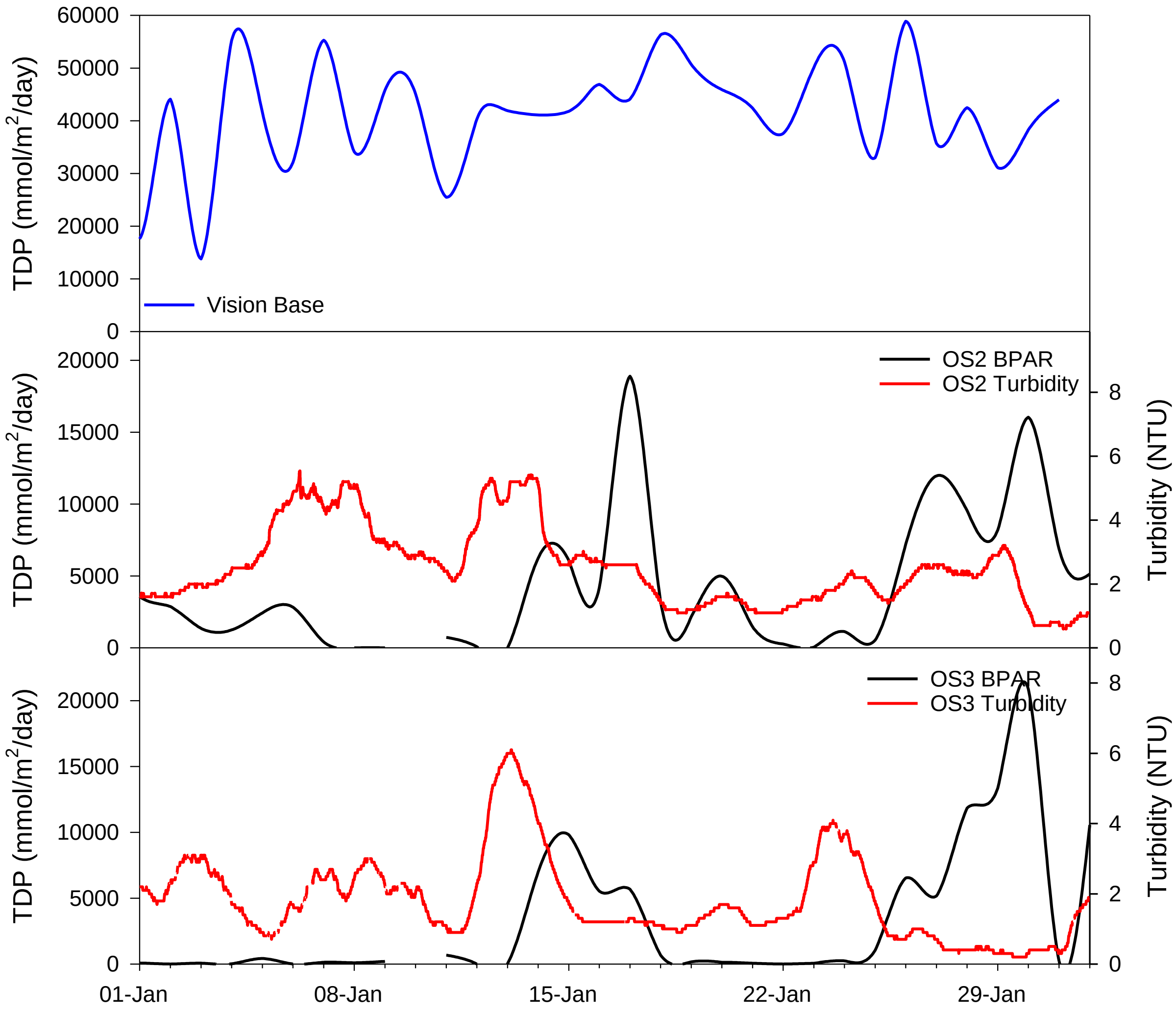


Figure 27 Total daily BPAR at OS2 and OS3 during January 2020 compared to ambient PAR and corresponding surface turbidity (24 hour rolling average).
Note data from the BPAR exchange day on 10 January were not utilized in plots or statistics.

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.

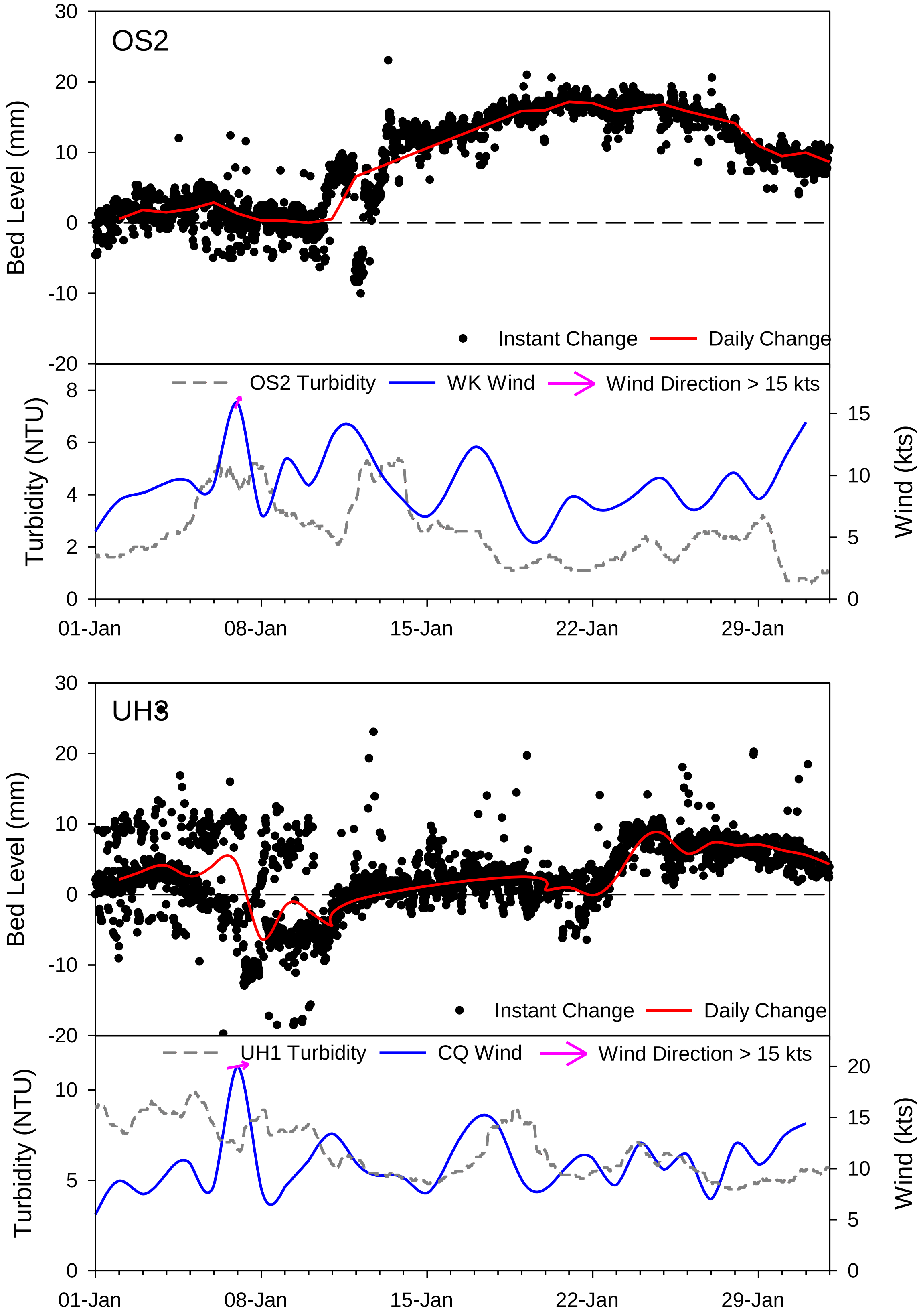


Figure 28 Mean instantaneous and daily averaged bed level change at OS2 and UH3 during January 2020 compared to ambient surface turbidity (24 hour rolling average), wind speed and direction.
Note: Arrows indicate the direction of travel for winds greater than 15 knots.

Bed level at the offshore site OS2 observed a period of stability the start of January most likely in response to the low significant wave events disturbing the sediment bed. Bed level then increased sharply on 9 January after the higher offshore wind event and a rise in turbidity. Bed level continued to slowly accrete up to 20 mm until 24 January where the bed level then experienced ~10 mm of erosion. The period of accretion corresponded to declining elevated offshore winds and turbidty. An overall accumulation of 9 mm was recorded in January 2020 (Table 17).

Unlike previous months, bed level within the sheltered upper harbour at UH3 was more dynamic and observed greater sediment flux than that at OS2. The beginning of January demonstrated high sediment flux with a number of periods of accretion and erosion occurring most likely in relation to the high inshore winds and turbidity, particularly on 7 January. Bed level then slowly accreted after 10 January until a period of slow erosion at the end of January in a similar trend to OS2. An overall accumulation of 4.3 mm was recorded in January 2020 (Table 17).

Table 17 Net Bed Level Change statistics from data collected from altimeters deployed at OS2 and UH3 during January 2020.

Site	January 2020 Net bed level change (mm)
OS2	+9
UH3	+4.3

3.6 Water Samples

Discrete water sampling was conducted on 14 January 2020, 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 exhibited a typical spatial pattern with higher concentrations within the inner harbour and lowest concentrations at the offshore and spoil ground sites. Total phosphorous remained below the WQG of 30 µg/L at all sites. Dissolved reactive phosphorous concentrations were above the WQG of 5 µg/L at 10 sites, notably all of the inshore sites reported values > WQG (5 µg/L). Sites OS1, OS3, OS5 and OS6 as well as the spoil ground site SG2 also exhibited dissolved reactive phosphorous concentrations > WQG (5 µg/L). Both total nitrogen and total kjeldahl nitrogen (TKN) were < LOR and < WQG at all sites.

Total ammonia ranged from 10 to 21 µg/L with six of the sites exceeding the WQG (15 µg/L), again more notably at inshore sites. Nitrogen oxide values, were relative low at all sites reporting values below the WQG (15 µg/L), except UH2 and OS2. OS2 recorded NOx values just above the WQG at 16.5 µg/L while UH2 exhibited a higher value of 96 µg/L, which may be an anomalie.

Table 18 Concentrations of nutrients and chlorophyll *a* at monitoring sites during January 2020.
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	27	12.7	<300	<200	18	6.9	5.9
UH2	22	9.1	200	<200	14	96	4.2
UH3	24	12.7	<300	<200	17	5.7	6.7
CH1	19	10.2	<300	<200	16	2.3	4.3
CH2	14	8.1	<300	<200	17	1.9	3.4
OS1	16	7.1	<300	<200	15	2.8	4.8
OS2	12	3.8	<300	<200	11	16.5	2.9
OS3	15	9.9	<300	<200	21	7.5	1.9
OS4	15	6.9	<300	<200	20	4.1	1.3
OS5	12	2.7	<300	<200	11	<1	2.9
OS6	13	5.4	<300	<200	13	<1	2.4
OS7	15	3.9	<300	<200	10	8.8	3.2
SG1	12	4.2	<300	<200	10	3.2	2.8
SG2	13	6.9	<300	<200	12	3.7	1.8
SG3	7	3.4	<300	<200	14	1.9	1.8
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

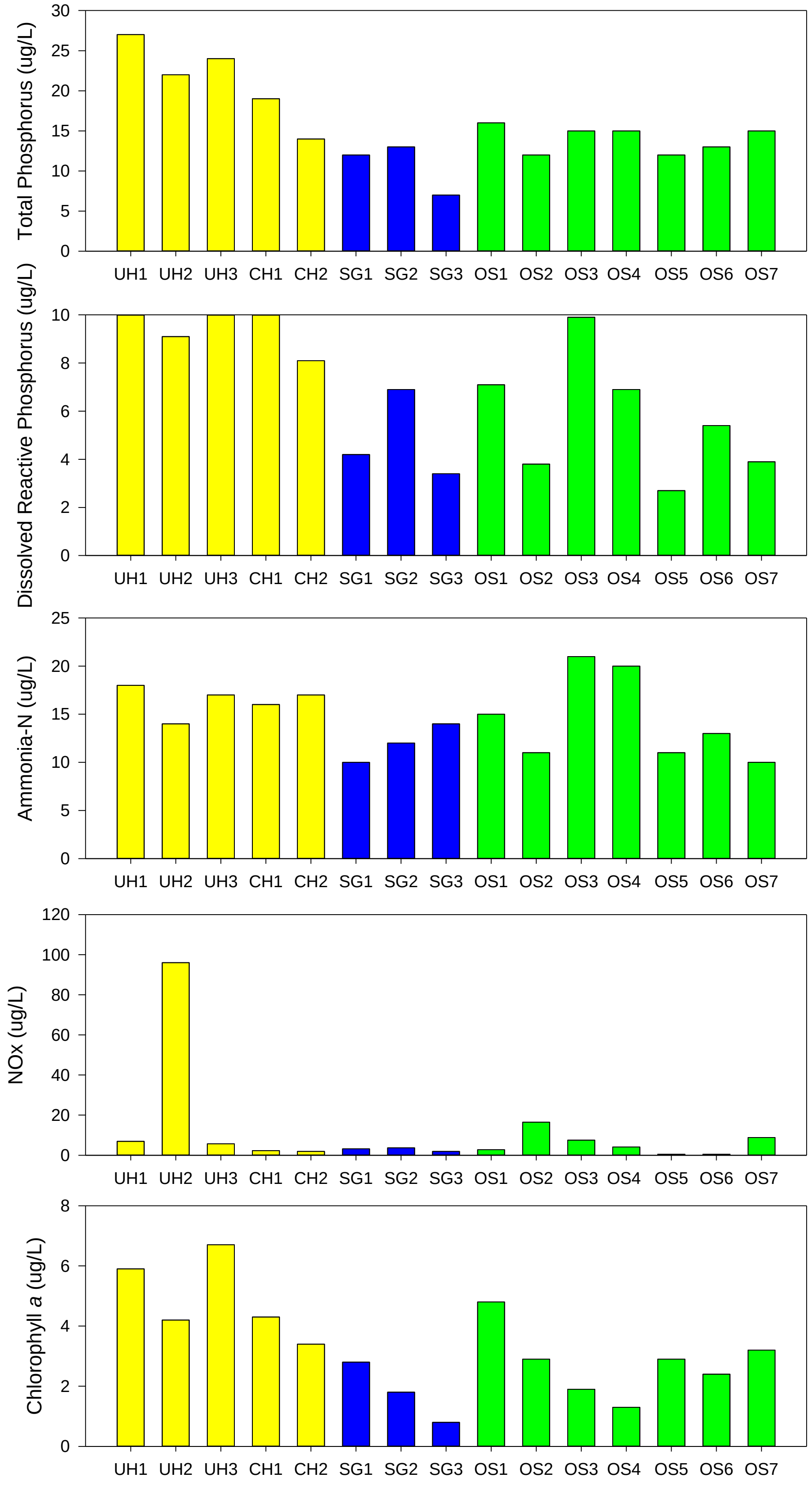


Figure 29 Nutrient and chlorophyll *a* concentrations at monitoring sites during January 2020. *Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were <LOR.*

Chlorophyll *a*, an indicator of phytoplankton biomass, recorded concentrations above the WQG value (4 µg/L) at five sites (Table 18), notably inshore. All sites in the upper harbour recorded concentration of chlorophyll *a* above the WQG along with CH1 and the offshore site OS1.

3.6.2 Total and Dissolved Metals

Concentrations of all recorded metals were relatively low in January. Concentrations of several metals (Tables 19 to 21) 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), cobalt (<0.6 µg/L), mercury (<0.08 µg/L), nickel (<7 µg/L), selenium (<4 µg/L), silver (<0.4 µg/L), tin (<5 µg/L) and zinc (4.2 µg/L). Dissolved and total lead concentrations were below LOR at all sites apart from UH3 where total lead was recorded at 1.8 µg/L, this value however was below WQG concentrations. Total copper was recorded at three sites (UH3 1.8 µg/L, OS4 3.7 µg/L and SG3 2.1 µg/L) with values above the WQG (1.3 µg/L). Dissolved copper was also recorded at these sites (UH3 1 µg/L, OS4 1 µg/L and SG3 1.7 µg/L) with SG3 exceeding the WQG (1.3 µg/L).

As reported in previous months dissolved concentrations of aluminium were < LOR at all sites, indicating limited bioavailability. Concentrations of total aluminium exceeded the designated 95% species protection figure value of 24 µg/L at all sites except one within the inner harbor (UH2) and one within the spoil ground site (SG3). However, the WQG is applicable to the dissolved fraction only (ANZG, 2018), therefore no exceedances were recorded in January. Concentrations of dissolved iron across all sites were reported between < 4 µg/L to 7 µg/L.

As usually reported, both total aluminium and iron appeared to be generally higher at the inshore sites (10.5 to 197 µg/L and 2 to 260 µg/L, respectively) compared to that of the offshore and spoil ground sites (10.5 to 70 µg/L and 32 µg/L to 105 µg/L, respectively). Two unusually low total aluminium and total iron values at site UH2 (10.5 and 2 µg/L respectively) may indicate an error in sample analysis.

Chromium, manganese, molybdenum and vanadium were recorded at all sites in both total and dissolved forms. Chromium concentrations across most sites (<1 to 1.3 µg/L) were well below the 95% species protection trigger value of 4.4 µg/L from CrVI and 27.4 µg/L for CrIII. The exception being SG3 where total chromium concentration was recorded at 5 µg/L. however, the dissolved fraction remained below the LOR < 1 µg/L. Vanadium concentrations (0.2 to 2 µg/L) were well below the 95% species protection trigger value of 100 µg/L.

No trigger values are available for either manganese or molybdenum. Total and dissolved manganese concentrations ranged from 1.4 to 15.9 µg/L at inshore and offshore sites and were lower at spoil ground sites (1.3 to 4.1 µg/L). Total and dissolved molybdenum concentrations exhibited little spatial variation, ranging from 10.8 to 12 µg/L, which is similar to previous monitoring results.

Table 19 Total and dissolved metal concentrations at inshore monitoring sites during January 2020. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	<12	<12	<12	<12	<12	24
	Total	184	10.5	197	99	91	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	0.55	0.55	1.3	1.4	1.6	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	1	<1	<1	1.3
	Total	<1.1	<1.1	1.8	<1.1	<1.1	
Iron	Dissolved	<4	<4	<4	<4	<4	-
	Total	240	2	260	135	118	
Lead	Dissolved	<1	<1	1	<1	<1	4.4
	Total	<1.1	<1.1	1.8	<1.1	<1.1	
Manganese	Dissolved	9.6	4.9	10	6.9	3.5	-
	Total	15.4	5	15.9	10.2	7.7	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.1	10.9	11.1	10.7	10.5	-
	Total	11.1	11	11.4	11.7	11.4	
Nickel	Dissolved	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.9	1.6	2	1.9	1.7	100
	Total	2	1.5	2.2	1.9	1.9	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 20 Total and dissolved metal concentrations at offshore monitoring sites during January 2020. *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	<12	<12	<12	<12	24
	Total	70	56	59	57	31	53	51	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	1.3	<1	<1	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.2	0.55	0.55	0.55	0.55	1.4	1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	3.7	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	<4	<4	<4	4	<4	7	-
	Total	105	71	65	64	32	64	73	
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	3.9	2.1	2.1	1.7	1.4	1.6	2.2	-
	Total	7.1	3.6	3.6	3.3	2.3	3.2	4.1	
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	11.4	10.8	11.5	11.3	10.9	10.8	11.5	-
	Total	11.4	11.3	10.9	11.2	11.1	11.7	11.1	
Nickel	Dissolved	<7	<7	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.4	1.1	1.7	1.7	0.2	1.4	1.2	100
	Total	1.7	1.5	2	1.7	1.5	1.8	1.4	
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 21 Total and dissolved metal concentrations at spoil ground monitoring sites during January 2020.
Values outside recommended WQG are highlighted in blue.

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	38	48	10.5	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	0.55	0.55	5	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	1.7	1.3
	Total	<1.1	<1.1	2.1	
Iron	Dissolved	<4	5	<4	-
	Total	33	84	33	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.5	2.1	1.3	-
	Total	3.1	4.1	2.4	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.2	11.1	11.3	-
	Total	11.4	12	12	
Nickel	Dissolved	<7	<7	<7	70
	Total	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.4	1.7	1.6	100
	Total	1.6	1.7	1.5	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

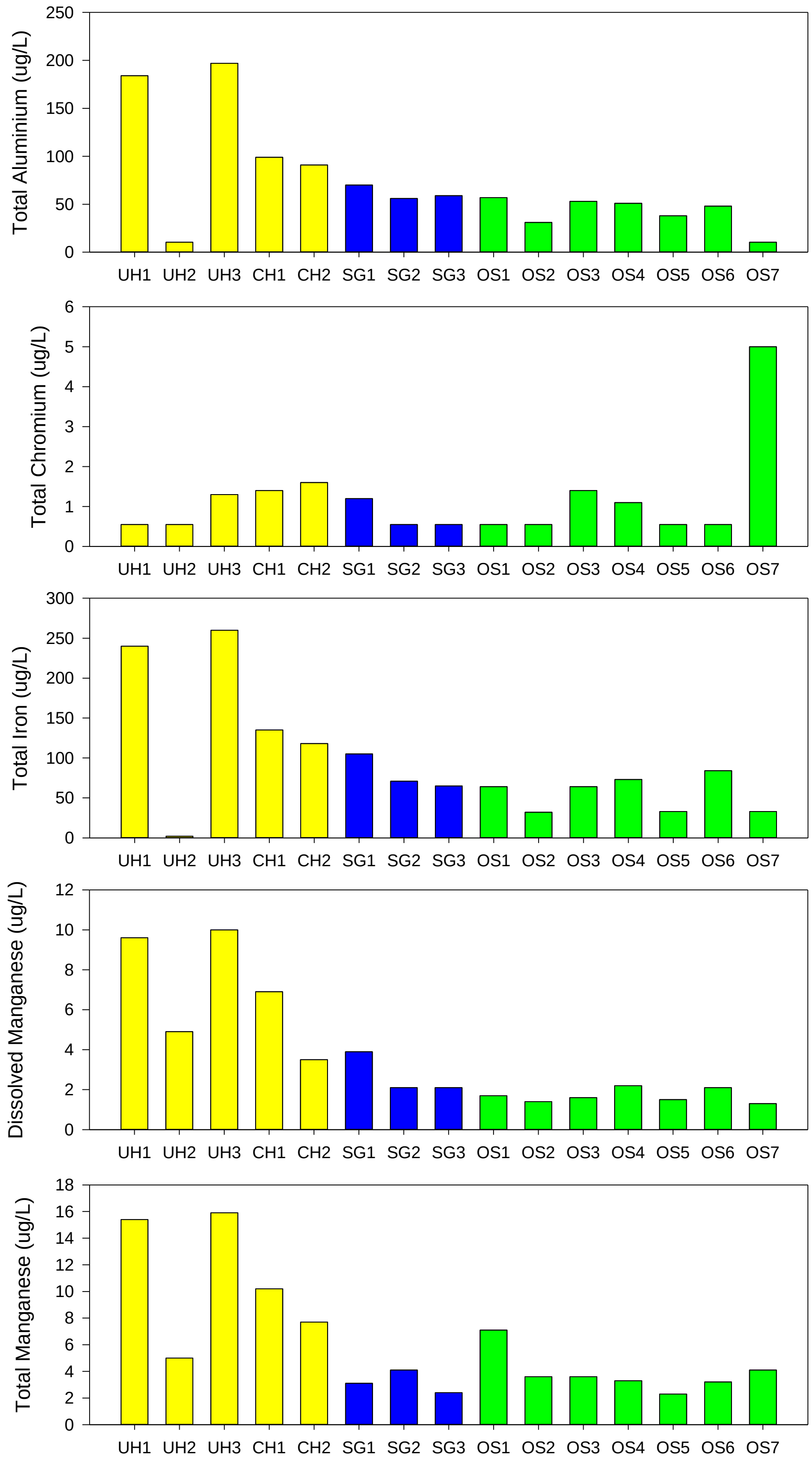


Figure 30 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during January 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

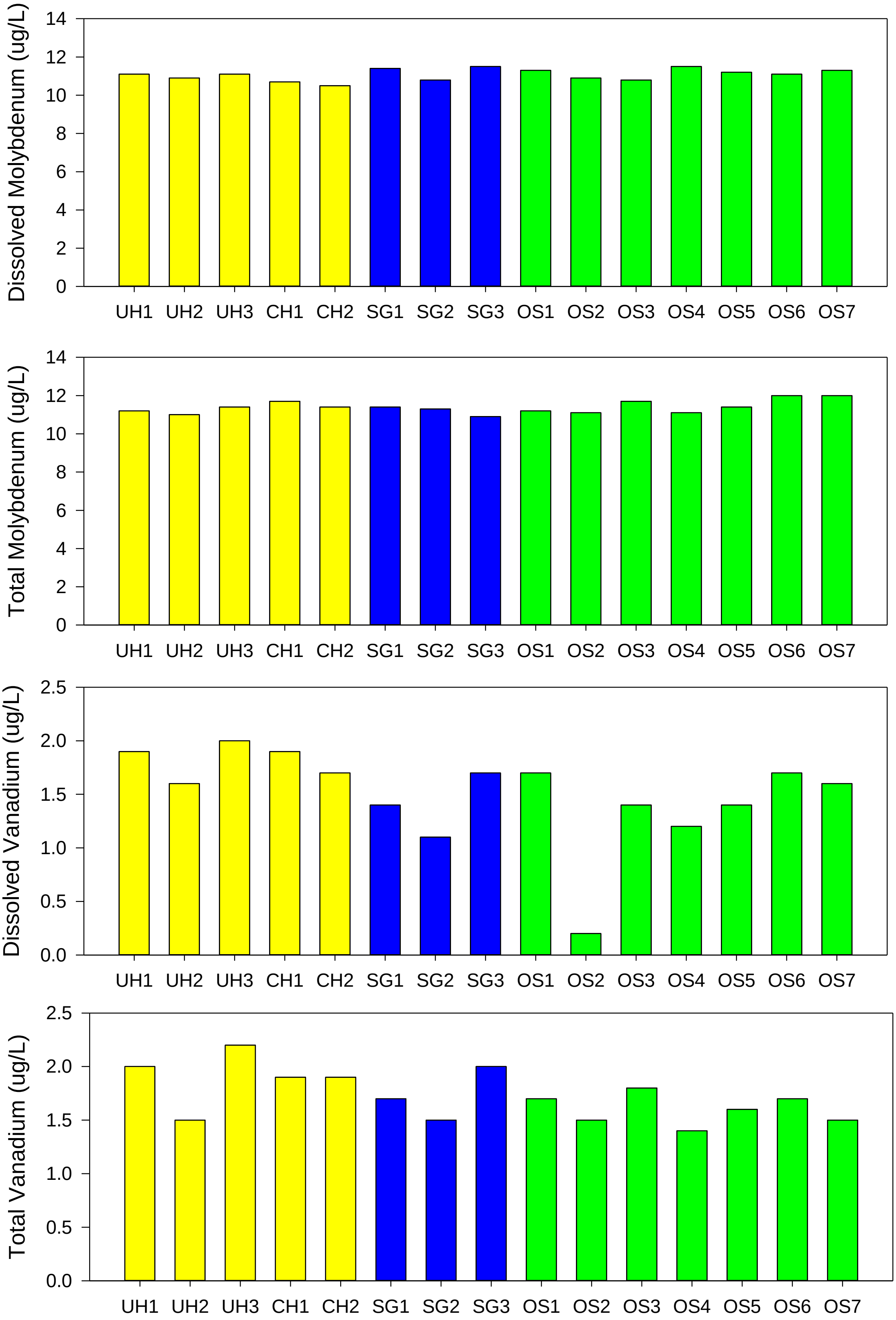


Figure 31 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during January 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

4 REFERENCES

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5 APPENDIX

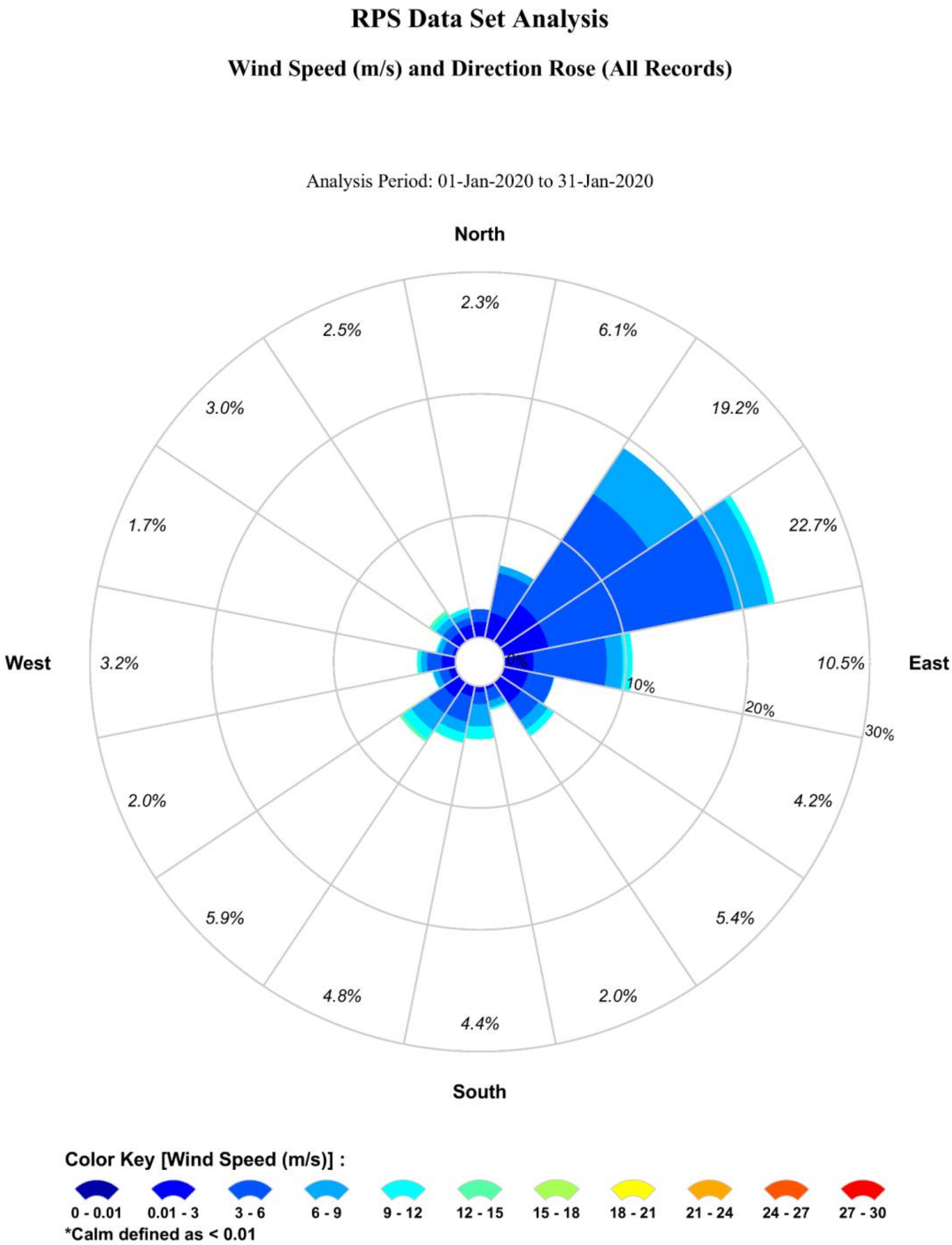


Figure 32 WatchKeeper wind speed (m/s) and direction rose (%) during January 2020.

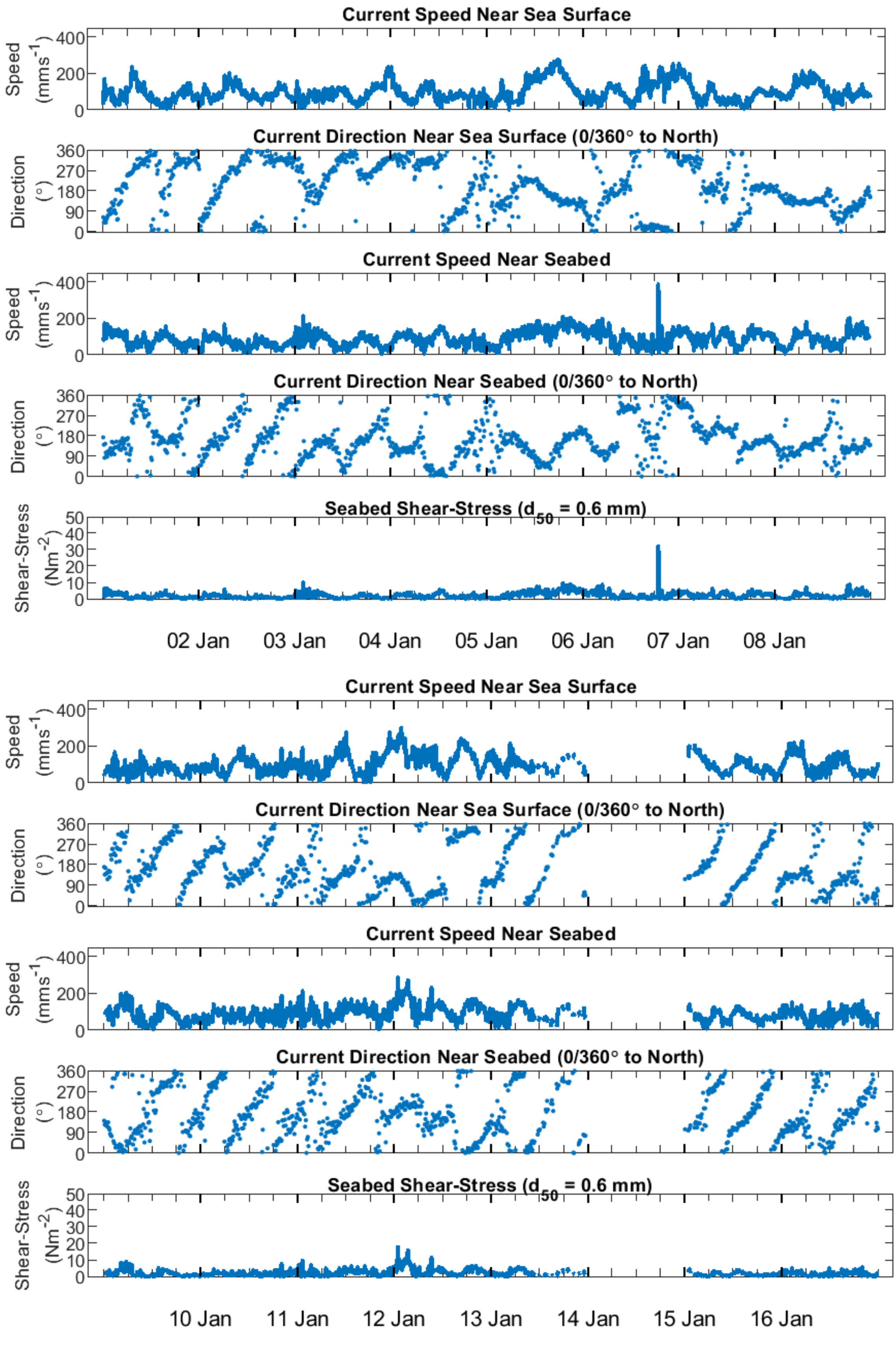
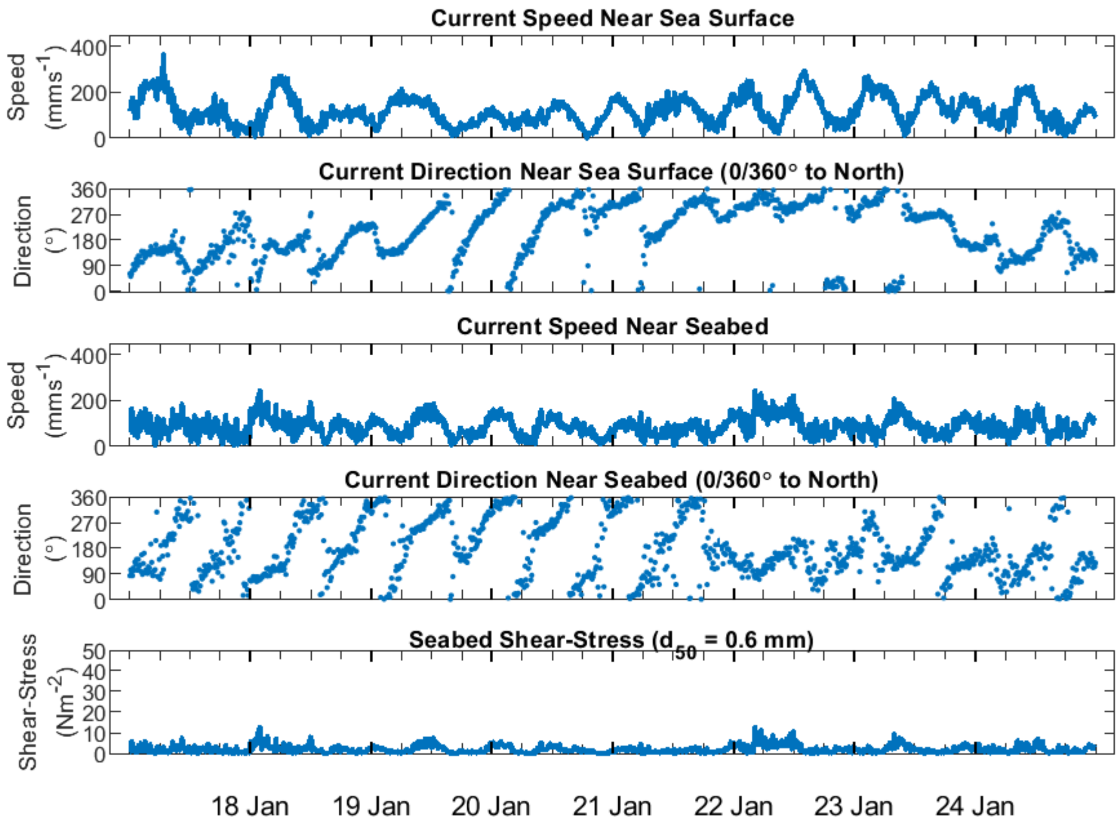


Figure 33 SG1 current speed, direction and shear bed stress 1 to 16 January 2020.



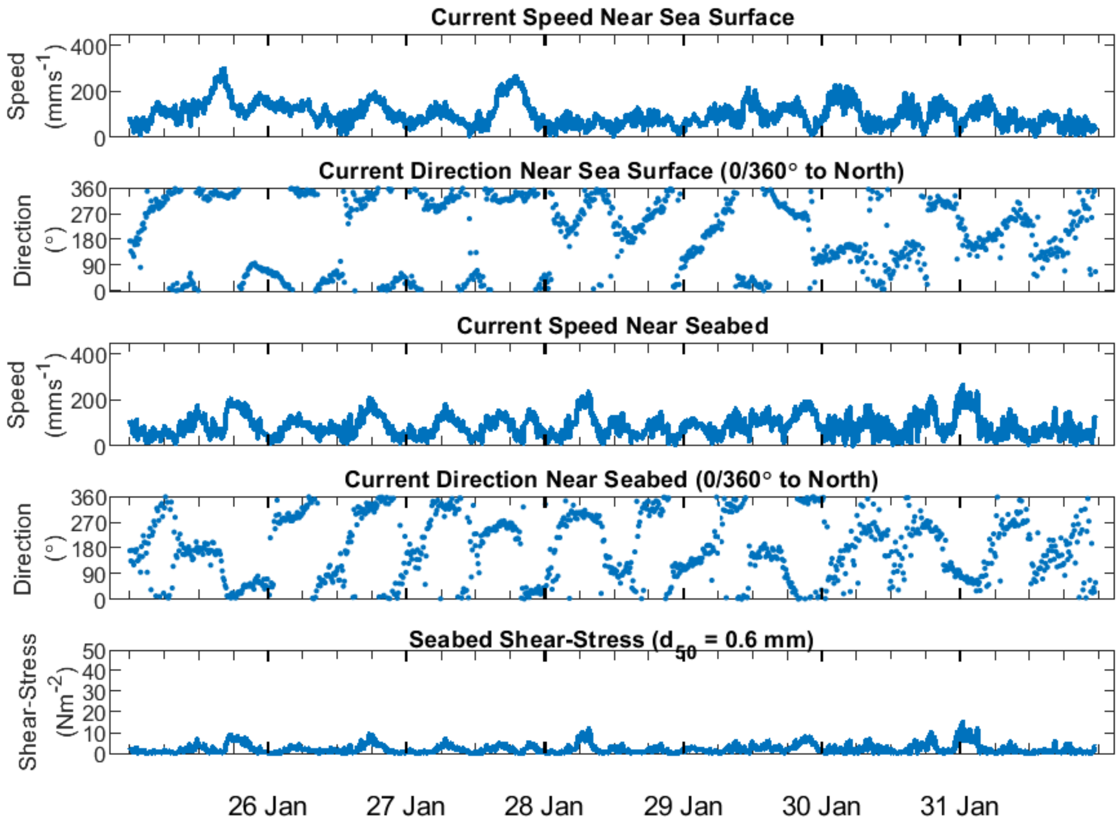


Figure 34 SG1 current speed, direction and shear bed stress 17 to 31 January 2020.

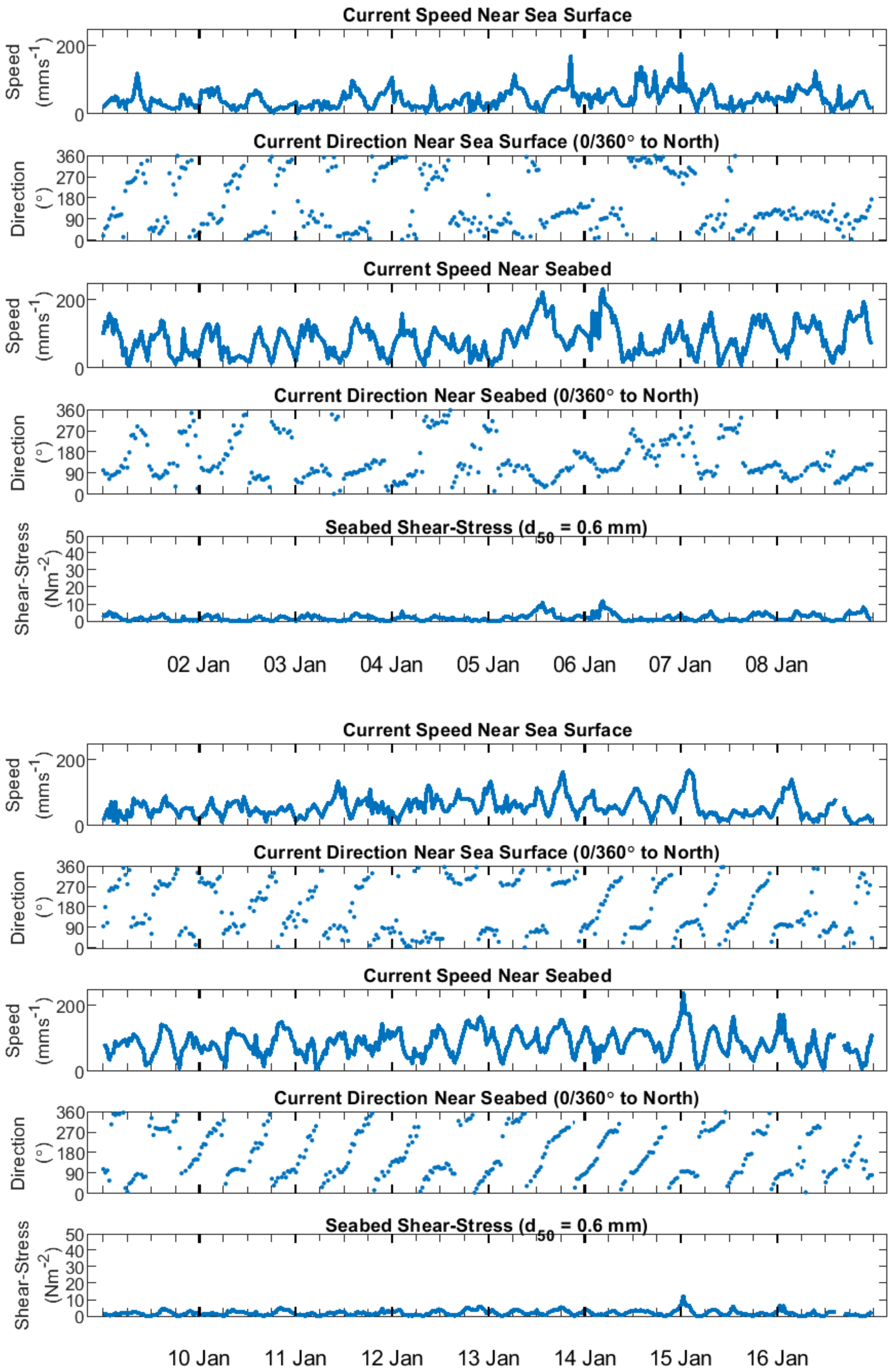


Figure 35 SG2a (WatchKeeper) current speed, direction and shear bed stress 1 to 16 January 2020.

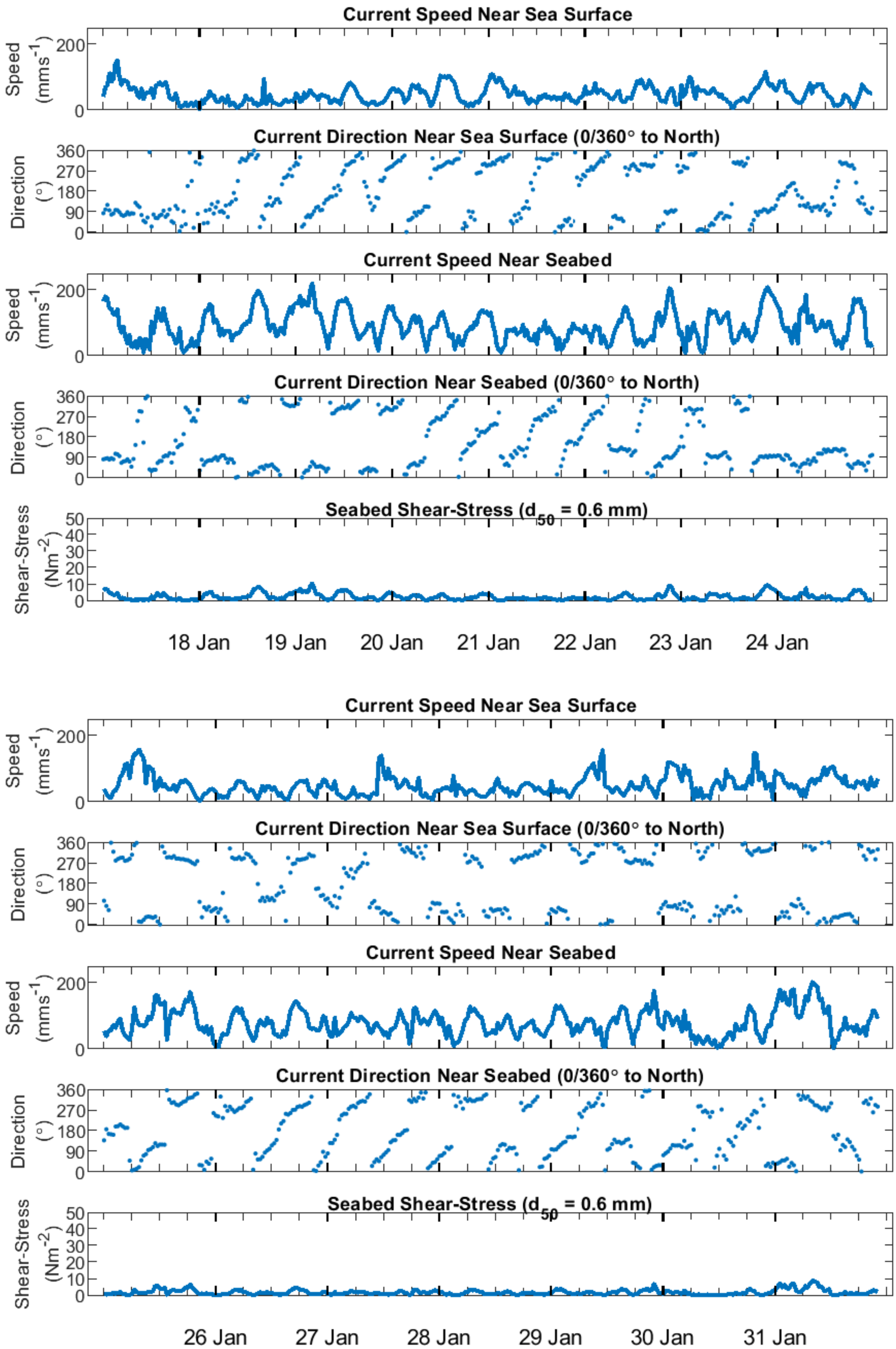


Figure 36 SG2a (WatchKeeper) current speed, direction and shear bed stress 17 to 31 January 2020.

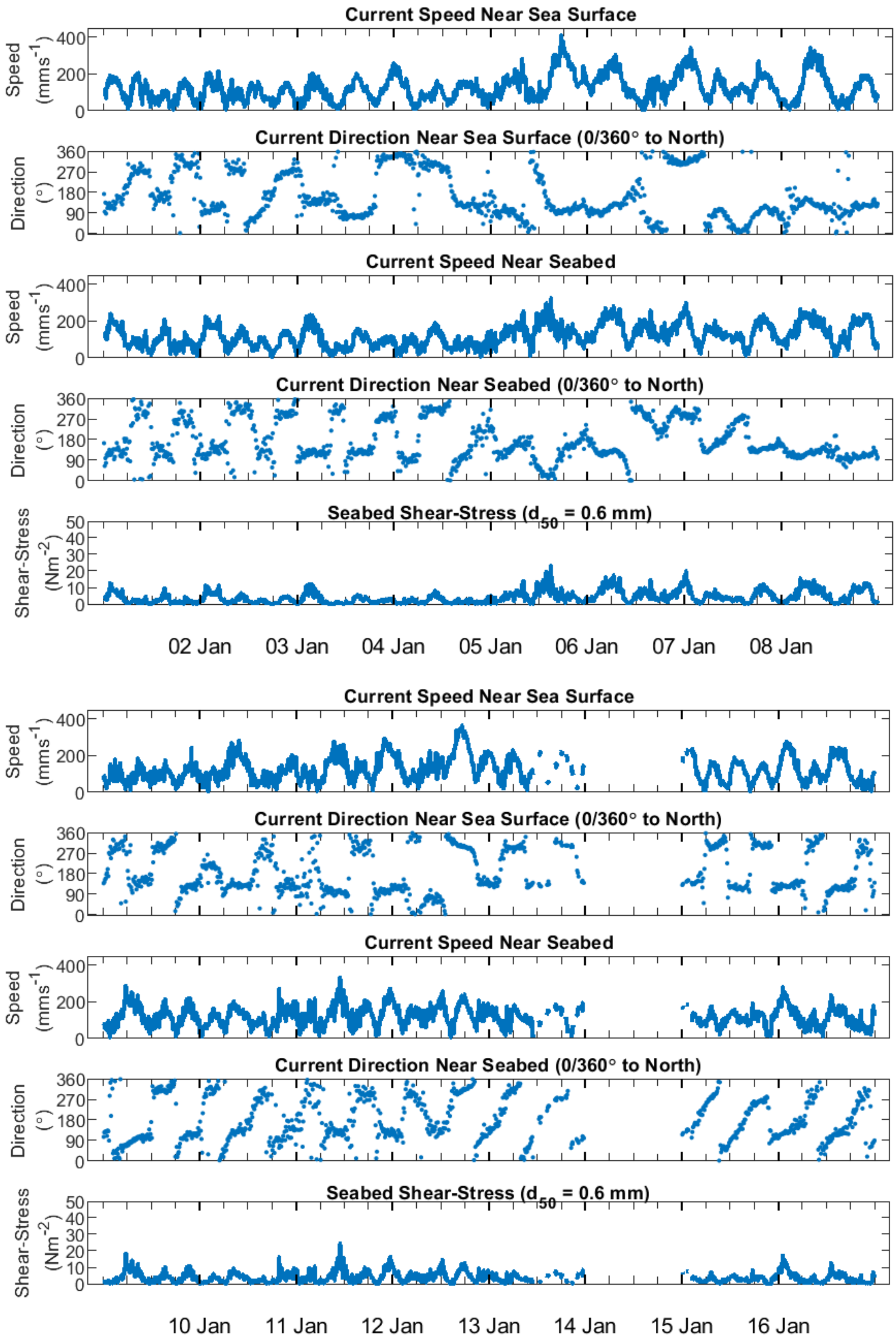


Figure 37 SG3 current speed, direction and shear bed stress 1 to 16 January 2020.

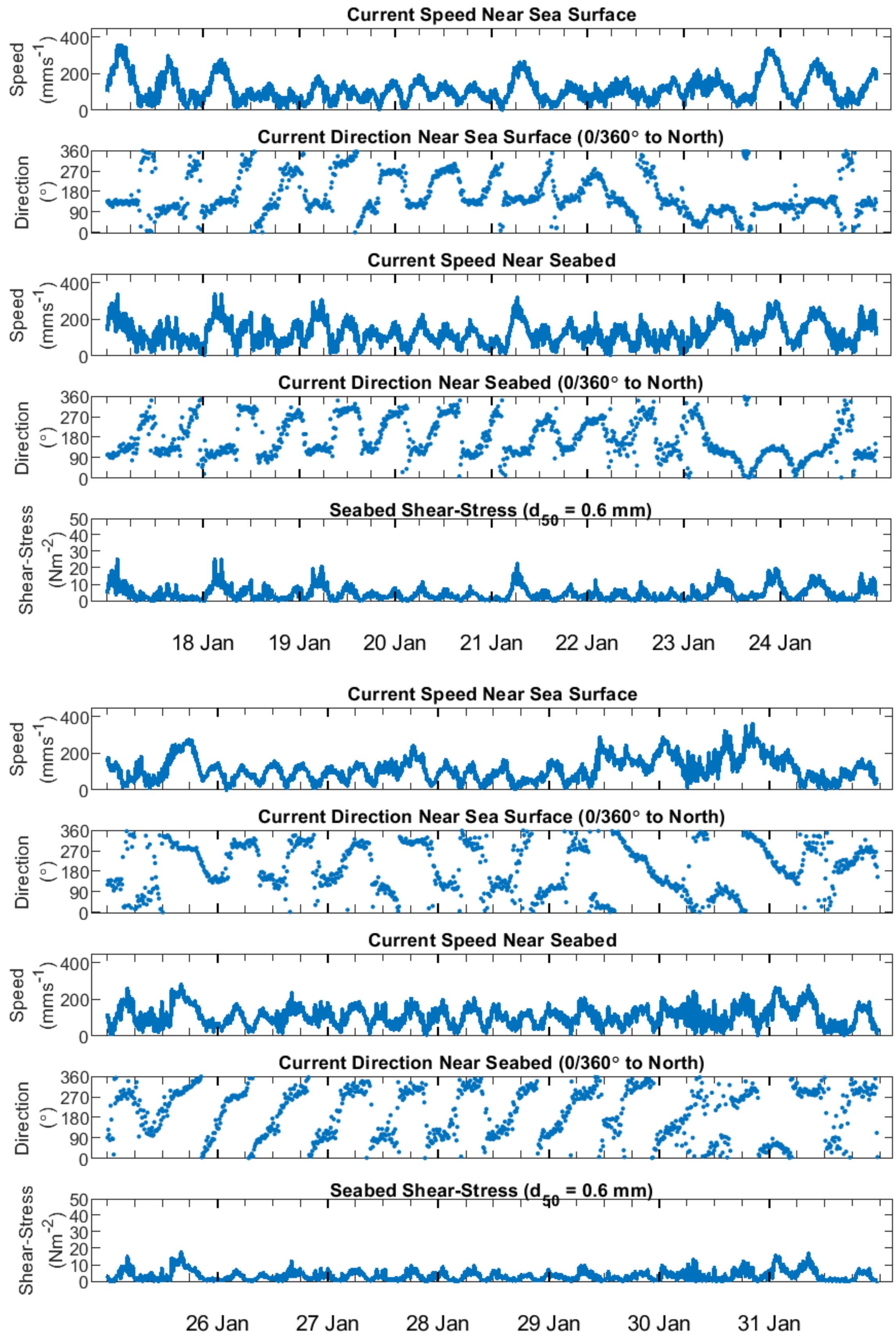


Figure 38 SG3 current speed, direction and shear bed stress 17 to 31 January 2020.

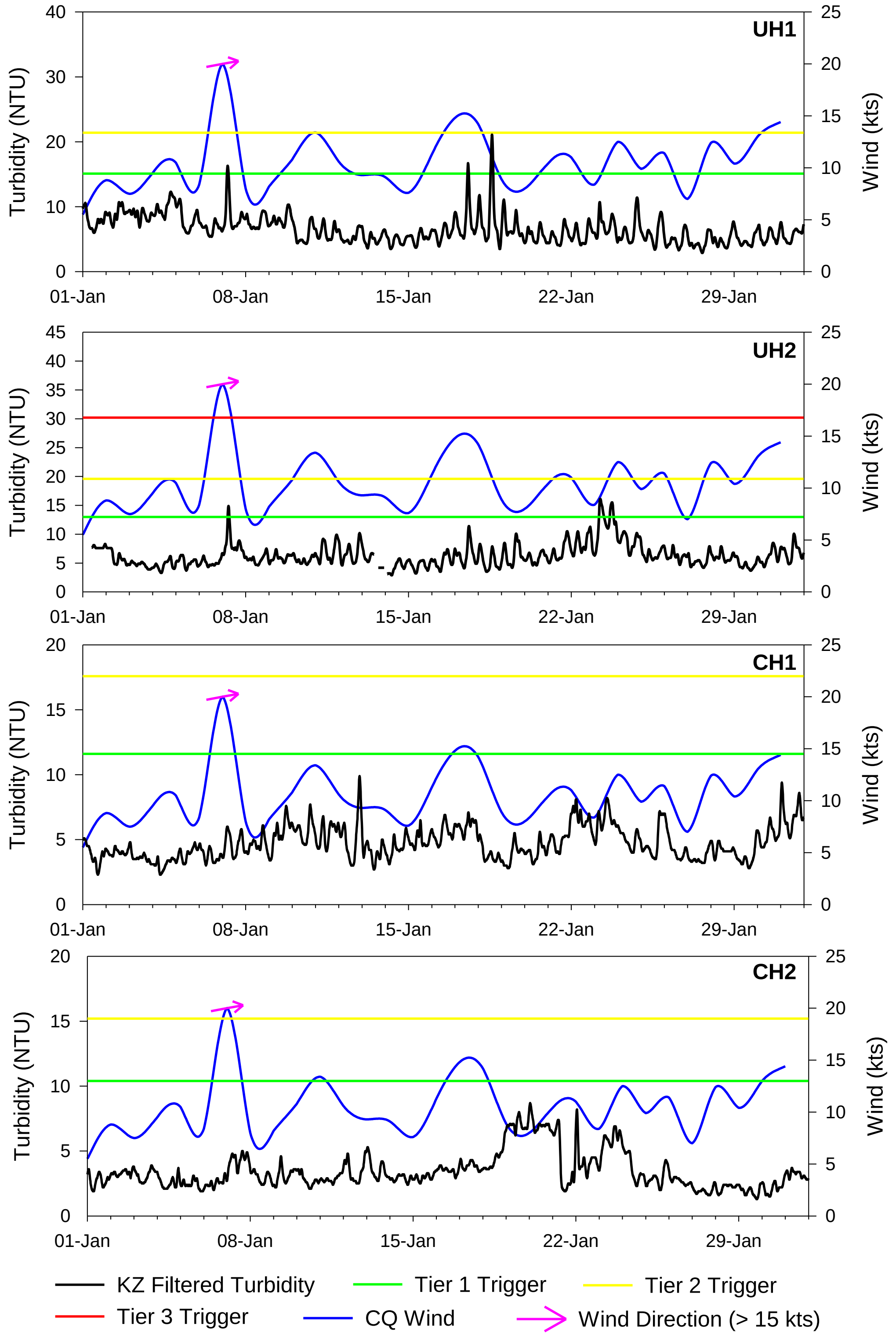


Figure 39 Surface KZ filtered turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during January 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for inshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

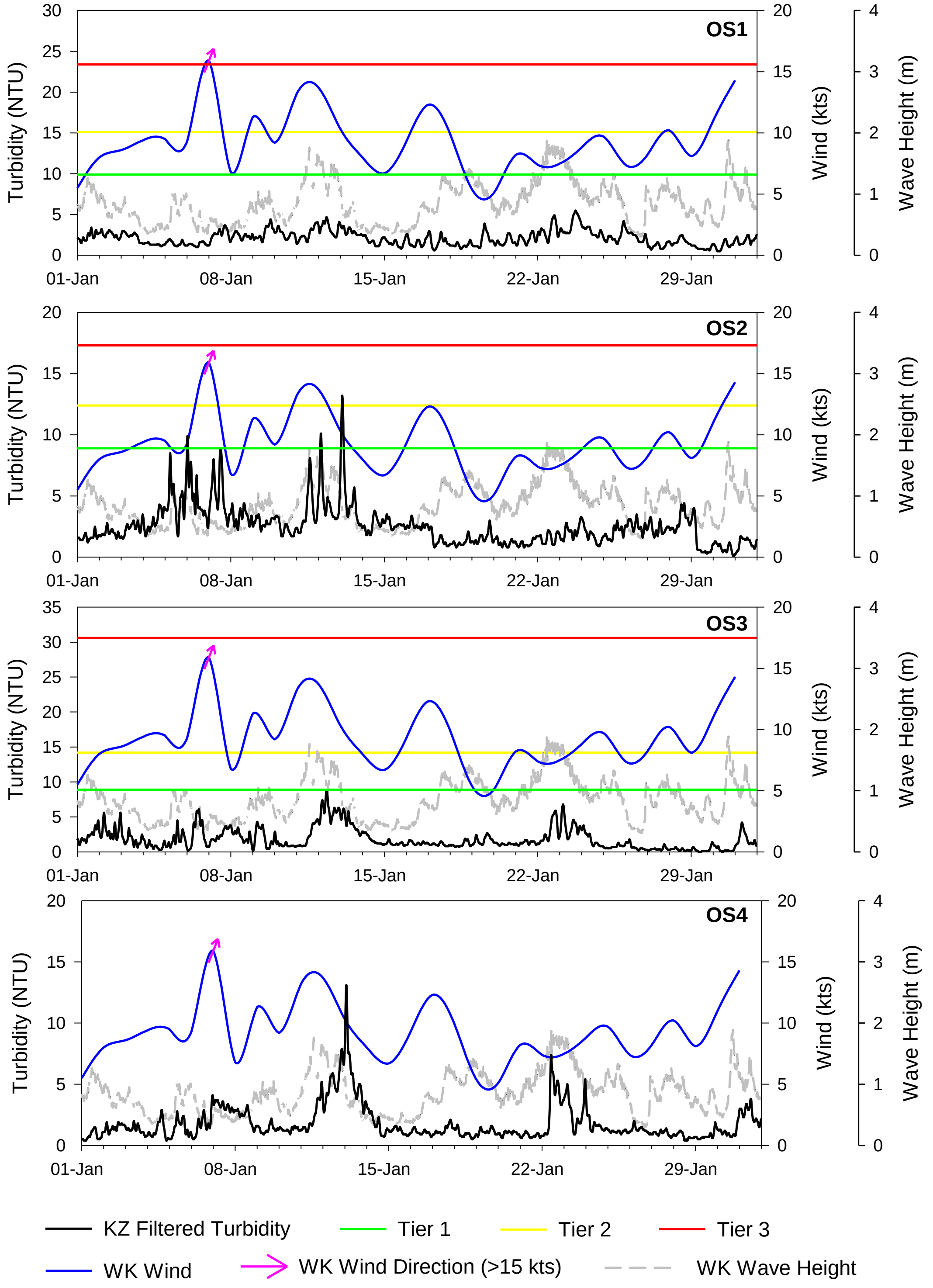


Figure 40 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS1 to OS4) during January 2020.

Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

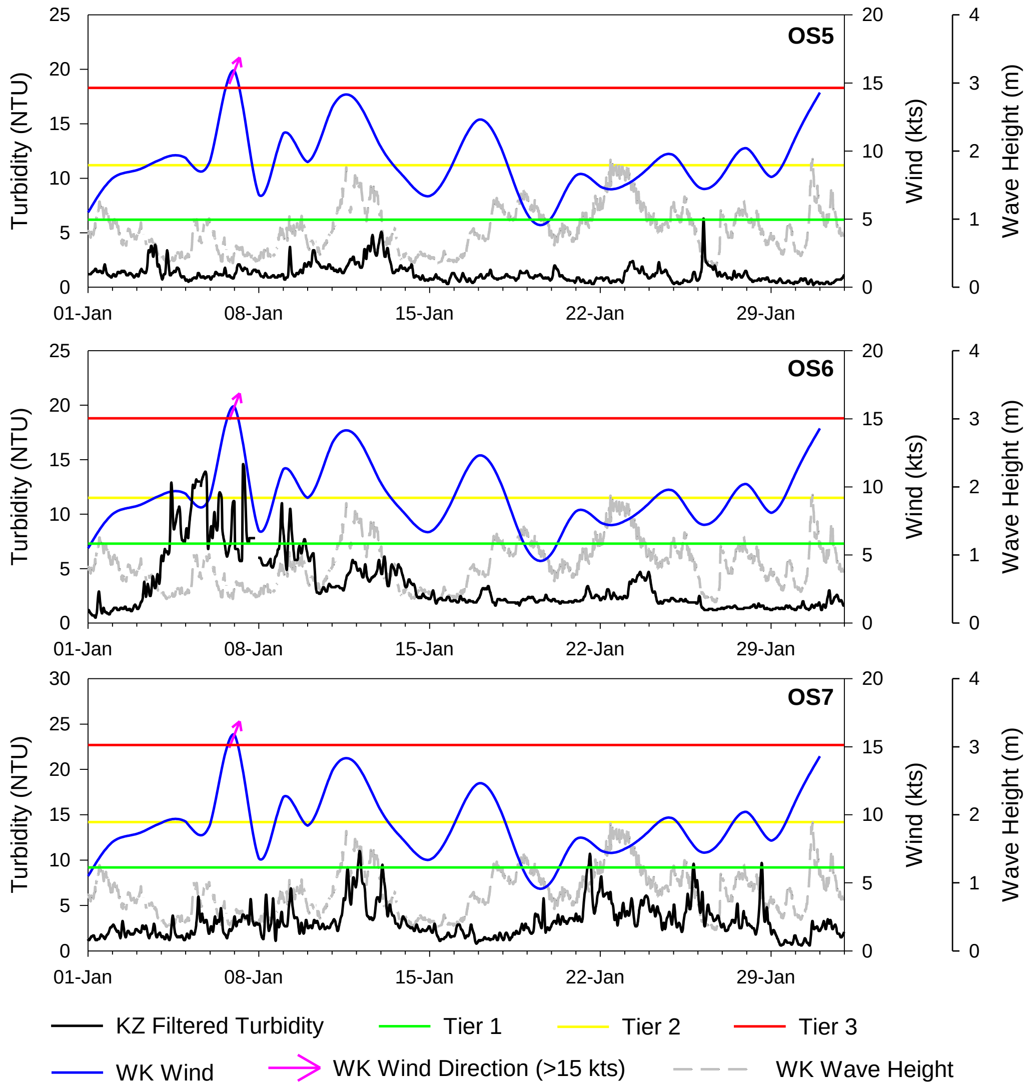


Figure 41 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS5 to OS7) during January 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

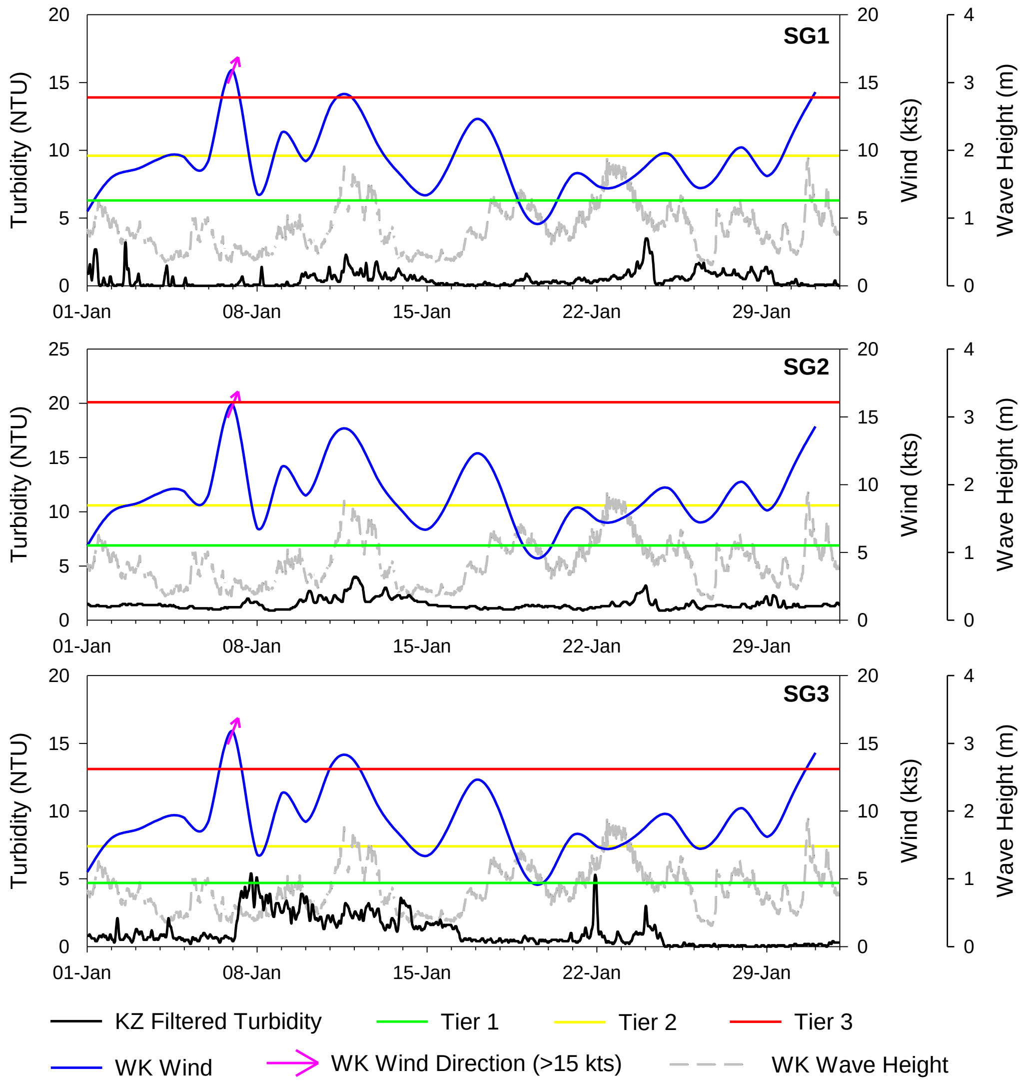


Figure 42 Surface KZ filtered turbidity and daily averaged winds at the spoil ground sites (SG1 to SG3) during January 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

Table 22 Mean KZ filtered turbidity and statistics at inshore water quality logger sites during January 2020 and baseline period 1 November 2016 to 31 October 2017
Values for January are means ± se, range and percentiles (n = 2912 - 2976). Baseline values modified from Fox 2018.

Site	KZ Filtered Turbidity (NTU)		
	Statistic	Surface January	Surface Baseline
UH1	Mean ± se	6.6 ± 0.0	12
	Range	2.9 – 21.1	2 – 155
	99th	13.7	37
	95th	10.3	21
	80th	8.1	15
UH2	Mean ± se	6.3 ± 0.0	9.9
	Range	2.9 – 16.1	2 – 59
	99th	14.2	29
	95th	10.1	19
	80th	7.6	13
CH1	Mean ± se	4.7 ± 0.0	8.8
	Range	2.3 – 9.9	<1 – 50
	99th	8.2	27
	95th	7.0	17
	80th	5.8	12
CH2	Mean ± se	3.4 ± 0.0	7.6
	Range	1.3 – 8.7	<1 – 39
	99th	7.7	22
	95th	6.9	15
	80th	4.1	10

Table 23 Mean KZ filtered turbidity and statistics at spoil ground water quality logger sites during January 2020 and baseline period 1 November 2016 to 31 October 2017.
Values for January are means ± se, range and percentiles (n = 2976). Baseline values modified from Fox 2018.

Site	KZ Filtered Turbidity (NTU)		
	Statistic	Surface January	Surface Baseline
SG1	Mean ± se	0.5 ± 0.0	4.2
	Range	<1 – 3.5	<1 – 31
	99th	2.7	14
	95th	1.5	9.5
	80th	0.8	6.1
SG2	Mean ± se	1.5 ± 0.0	4.6
	Range	<1 – 4	<1 – 33
	99th	3.5	20
	95th	2.5	10
	80th	1.7	6.9
SG3	Mean ± se	1.1 ± 0.0	3.6
	Range	<1 – 5.4	<1 – 22
	99th	4.5	13
	95th	3.4	7.3
	80th	2	4.7

Table 24 Mean KZ filtered turbidity and statistics at offshore water quality logger sites during January 2020 and baseline period 1 November 2016 to 31 October 2017.
Values for January are means ± se, range and percentiles (n = 2963 to 2976). Baseline values modified from Fox 2018.

Site	Statistic	KZ Filtered Turbidity (NTU)	
		Surface January	Surface Baseline
OS1	Mean ± se	2.1 ± 0.0	7.5
	Range	<1 – 5.5	<1 – 99
	99th	4.8	23
	95th	3.7	15
	80th	2.8	9.7
OS2	Mean ± se	2.5 ± 0.0	6.4
	Range	<1 – 13.2	<1 – 36
	99th	8.6	17
	95th	5.5	12
	80th	3.3	8.9
OS3	Mean ± se	1.8 ± 0.0	6.5
	Range	<1 – 8.9	<1 – 110
	99th	6.5	27
	95th	5.2	14
	80th	2.8	8.9
OS4	Mean ± se	1.8 ± 0.0	5.9
	Range	<1 – 13.1	<1 – 35
	99th	7.4	18
	95th	4.8	13
	80th	2.5	8.1
OS5	Mean ± se	1.2 ± 0.0	4.6
	Range	<1 – 6.3	<1 – 35
	99th	4.2	18
	95th	2.9	11
	80th	1.7	6.1
OS6	Mean ± se	3.6 ± 0.1	4.7
	Range	<1 – 14.6	<1 – 37
	99th	13.1	18
	95th	9.7	11
	80th	5.4	7.1
OS7	Mean ± se	3.2 ± 0.0	6.3
	Range	<1 – 11	<1 – 48
	99th	9.4	22
	95th	6.9	14
	80th	4.1	9.1

Table 25 Summary of Vision Environment quality control data for January 2020 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.
** Slightly higher concentrations in the field and lab blank, indicating potential sample contamination.*

Parameter	VE Field Blank (µg/L)	VE Lab Blank (µg/L)	Duplicate		
			UH1 (A) (µg/L)	UH1 (B) (µg/L)	Variation (%)
TSS	<3	<3	9	10	11
Dissolved Aluminium (µg/l)	<3	<3	<12	<12	ND
Total Aluminium (µg/l)	<3.2	<3.2	184	168	9
Dissolved Arsenic (µg/l)	<1	<1	<4	<4	ND
Total Arsenic (µg/l)	<1.1	<1.1	<4.2	<4.2	ND
Dissolved Cadmium (µg/l)	<0.05	<0.05	<0.2	<0.2	ND
Total Cadmium (µg/l)	<0.053	<0.053	<0.21	<0.21	ND
Dissolved Chromium (µg/l)	<0.5	<0.5	<1	<1	ND
Total Chromium (µg/l)	<0.53	<0.53	<1.1	1.4	ND
Dissolved Cobalt (µg/l)	<0.2	<0.2	<0.6	<0.6	ND
Total Cobalt (µg/l)	<0.21	<0.21	<0.63	<0.63	ND
Dissolved Copper (µg/l)	<0.5	<0.5	<1	<1	ND
Total Copper (µg/l)	<0.53	<0.53	<1.1	<1.1	ND
Dissolved Iron (µg/l)	<20	<20	< 4	< 4	ND
Total Iron (µg/l)	<21	<21	240	220	9
Dissolved Lead µg/l)	< 1	< 1	<1.1	<1.1	ND
Total Lead (µg/l)	<0.11	<0.11	<1.1	<1.1	ND
Dissolved Manganese (µg/l)	<0.5	<0.5	9.6	9.5	1
Total Manganese (µg/l)	<0.5	<0.5	15.4	14.6	5
Dissolved Mercury (µg/l)	<0.08	<0.08	<0.08	<0.08	ND
Total Mercury (µg/l)	<0.08	<0.08	<0.08	<0.08	ND
Dissolved Molybdenum (µg/l)	<0.2	<0.2	11.1	10.8	3
Total Molybdenum (µg/l)	<0.21	<0.21	11.2	10.9	3
Dissolved Nickel (µg/l)	<0.5	<0.5	<7	<7	ND
Total Nickel (µg/l)	<0.53	<0.53	<7	<7	ND
Dissolved Selenium (µg/l)	<1	<1	<4	<4	ND
Total Selenium (µg/l)	<4.2	<1.1	<4.2	<4.2	ND
Dissolved Silver (µg/l)	<0.11	<0.11	<0.43	<0.43	ND
Total Silver (µg/l)	<0.11	<0.11	<0.43	<0.43	ND
Dissolved Tin (µg/l)	<0.5	<0.5	<5	<5	ND
Total Tin (µg/l)	<0.53	<0.53	<5.3	<5.3	ND
Dissolved Vanadium (µg/l)	<1	<1	1.9	1.9	0
Total Vanadium (µg/l)	<1.1	<1.1	2	2.1	ND
Dissolved Zinc (µg/l)	<1	<1	<4	<4	ND
Total Zinc (µg/l)	1.2	<1.1	<4.2	<4.2	ND
Total Phosphorus (µg/l)	<4	-	27	25	8
Dissolved Reactive Phosphorus (µg/l)	<4	<4	12.7	12.8	1
Total Nitrogen (µg/l)	<110	<110	<300	<300	ND
Total Kjeldahl Nitrogen (TKN) (µg/l)	<100	<100	<200	<200	ND
Total Ammonia (µg/l)	<10	<10	18	18	0
Nitrate-N + Nitrite-N (µg/l)	<2	<2	6.9	4.2	49
Chlorophyll *a* (µg/L)	<0.2	<0.2	5.9	5.4	9