Lyttelton Port Company Channel Deepening Project Environmental Monitoring

Water Quality Environmental Monitoring Services – Monthly Report

June 2019

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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, which commenced on 29 August 2018, were completed on 29 November 2018, taking the monitoring into a post dredge phase up until 11 March when a smaller dredging operation began for the reclamation works at Cashin Quay. Monitoring results collected during May 2019 are presented within this report. Continuing with the dredge phase monitoring report format, 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 are compared to compliance trigger values during reclamation dredging operations.

Climatic Conditions: During June, 69.0 mm of rainfall was recorded at Cashin Quay, approximately three times more than recorded in May. Heaviest falls occurred at the beginning of the month with lighter rainfall < 5 mm throughout June. Maximum daily inshore wind speeds (18.9 kts) and gusts (47 kts) were recorded on 8 June. Maximum flow from the Waimakariri River (551 m^3/s) was recorded on the 1 June and was the residual flow from the rainfall that occurred in late May and early June. Monthly average temperature (9°C) was lower than that recorded in May.

Offshore, both wind speeds and wave heights displayed similar temporal variations over the month. Similar to the inshore environment, the offshore wind speeds were also elevated on 8 June with gusts reaching over 20 kts, however no significant wave heights were recorded for this event. A second offshore wind speed event accompanied by elevated wave heights was experienced on 15 June.

Currents: ADCP data at sites SG1 and SG3 was not available for the period of 17 to 24 June and the 8 June for SG3, whereas SG2a had full data recovery. Near-surface and near-seabed currents at SG1 and SG3 were highest on 6 June and 1 June respectively. Whereas, SG2a near-surface and near-seabed highest currents both occurred on the 30 June. The dates of highest current flow follow the same previous patterns of SG1 and SG3 having higher velocities at the near-surface than SG2a which are consistently lower. These site differences are attributed to the varying topography across the spoil ground. Near-surface and near-seabed current direction for June for SG1 exhibited currents in a north-west/north direction and SG3 exhibited north-west and south-east flows. While SG2a had dominant near-surface flows from the north-west/west and contrasting near-seabed flows form the west and east.

Turbidity: Consistent with previous results, turbidity was more elvated at the inshore monitoring sites of the central and upper harbour than at the nearshore and offshore monitoring locations. Mean turbidity values for June were generally similar to May and also to those recorded during the baseline monitoring period.

Turbidity peaks were recorded at all sites at multiple times from 1 to 22 June in response to strong inshore wind speeds coming from a south-westerly direction. Surface turbidity peaks

at UH1 and OS1 reached 10 NTU, with the remainder of June displaying low turbidity concentrations. The turbidity peaks observed at the offshore and spoil ground sites were not as pronounced as the inner harbour peaks with turbidity peaks remaining below 10 NTU.

Benthic turbidity at all sites responded to both wind speed and wave height events in June with turbidity levels being higher than surface concentrations as typically observed.

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

Other Physicochemical Parameters: The trend for water cooling across all sites was consistent throughout June, with monthly means up to 2.5 ºC lower than May. Continuing the trend which commenced in April, cooler water temperatures were recorded in the upper and central harbour rather than the offshore sites. A brief period of warming occurred within the inner harbour from the 14 to 17 June, then water temperatures continued to decline for the remainder of June. Benthic temperatures were consistent with those at the surface indicating a well-mixed water column.

Consistent with previous reports, pH during June was consistent across all sites, both surface and benthic. Conductivity was reasonably consistent at each site for June, with a slight decrease on the 3 June within the inner harbour sites due to high rainfall occurring in early June.

Dissolved oxygen (DO) concentrations during June were similar to those in May and remained relatively stable throughout. Diurnal fluctuations in DO were observed at the majority of sites for the month of June. Lower DO at the start of June, which was likely due to late May metocean conditions, demonstrated recovery at all sites for the rest of June at all sites. Benthic DO trended similarly to the surface although OS1 benthic exhibited a decrease in DO after the 28 June.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 13 June 2019. Similar to profiles typically obtained during the monitoring program, inner harbour and nearshore monitoring sites indicated a well-mixed water column. Further offshore and at spoil ground sites, depth profiling indicated a continuation of vertically mixed conditions, with turbidity increasing near the benthos.

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 16.4 m at SG3. No exceedances of WQG were observed for sub-surface during the June 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 were recorded at all sites.

Concentrations of total nitrogen and total kjeldahl nitrogen once again remained below detection limits at all sampling sites. Ammonia and nitrogen oxides (NOx) were elevated in June as they were in May, with the majority of sites exceeding both the ammonia and NOx, WQG. These exceedances were observed the previous year and could be due to seasonal runoff or potentially the release of nitrogenous products from the breakdown of detritus such as algae. Cholorphyll *a* concentrations remained low and below the WQG (4 µg/L) at all sites, despite the high nutrient availability.

Several metals were reported as below the limit of reporting (LOR) at all sites as commonly found. As typically observed, total aluminium concentrations exceeded designated WQG at majority of the monitoring sites. Dissolved aluminium concentrations, however, remained well below the WQG at all sites. A similar spatial pattern was observed for total iron, although no WQG are available for iron. No other exceedances occurred for metals.

Detectable concentrations of manganese were once again recorded in the upper harbour, with a relatively even split between dissolved and particulate components and a decreasing gradient from inner to outer harbour. Chromium, vanadium and molybdenum were also reported above LOR during June at some sites with little spatial variability and a large component contained within the dissolved phase and therefore easily dispersed across the harbour.

All organic compounds measured biannually in and around Lyttelton harbour were once again below laboratory limits of reporting. One exception was that oxyfluorfen recorded a LOR value at OS6 but should not be considered a real value.

Benthic Photosynthetically Active Radiation (BPAR): Levels of ambient sunlight were fairly consistent during June but lower than that in May, and this was reflected in lower overall BPAR levels. Both sites displayed similar intermittent BPAR peaks in response to similarly low turbidity throughout June.

Sedimentation: During June, bed level at OS2 displayed an overall increase of +16 mm, which incrementally increased over June in response to the intermittent weather events. Sediment flux at UH3 was relatively stable for June with slight erosion in early June and then deposition occurred after the 18 June wind event. This resulted in an overall accretion of +2.5 mm for the month of June.

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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 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. 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 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.

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.

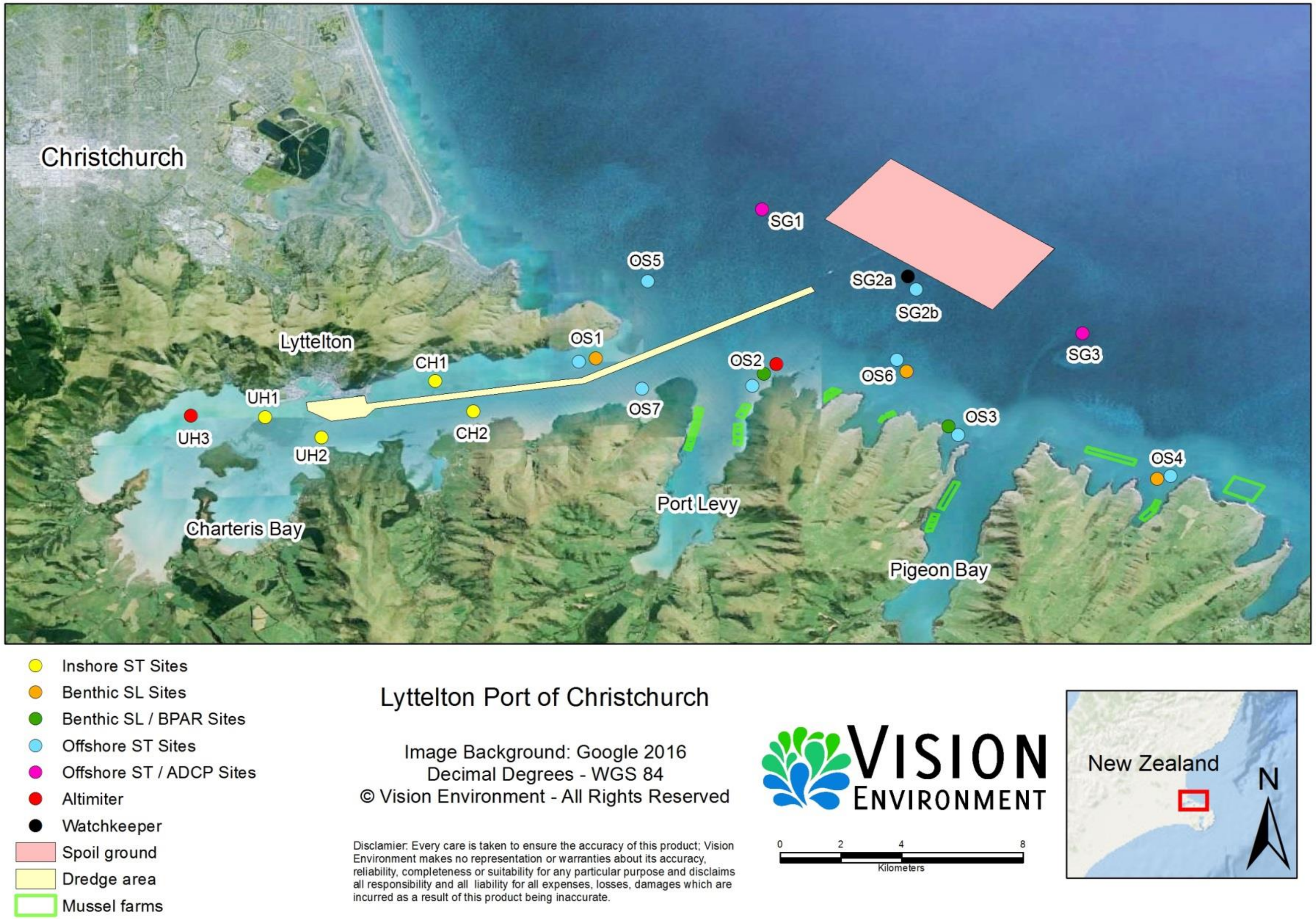


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

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 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 June 2019 during dredge operations. Monthly water sampling and depth profiling was conducted on 13 June 2019 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 several 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

A total of 69.0 mm of rainfall was recorded at Cashin Quay during June 2019, which was approximately more than three times the precipitation recorded in May (18.0 mm). Rainfall was predominantly at the beginning of the month with the largest fall (37.2 mm) recorded on 1 June followed by smaller falls occurring throughout the first half of June (Metconnect, 2019). Freshwater flows from the Waimakariri River, can be transported south along the coastline and enter Lyttelton Harbour several days post flow. Flows were highest at the beginning of June with a peak of 551 m^3/s on 1 June which followed on from 30 May peak of 1244 m^3/s. Flows then decreased reaching low flows of 60 m^3/s on the 30 June (Figure 2)(ECAN, 2019). Impacts to offshore monitoring sites from this late May early June flow event were observed in the first week of June.

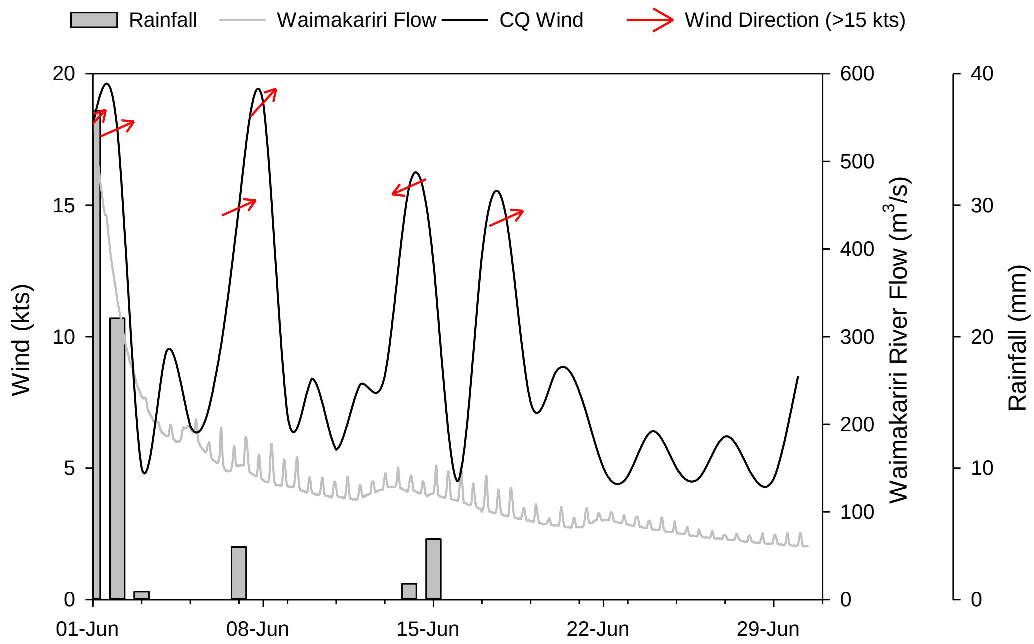


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during June 2019.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

Inshore wind direction varied greatly throughout June, with higher west-south-westerly to south-westerly winds predominating for eight days between 1 to 22 June, with maximum average gusts up to 18.9 kts (8 June). Late June was dominated with lighter (<10 kts) westerly winds (Metconnect, 2019). However, another wind peak on the 14 June occurred from an east-north-easterly direction, which was the prominent wind direction noted in May. Daily mean air temperatures at Cashin Quay ranged from 7 to 13°C, resulting in a monthly mean temperature of 9°C (Metconnect, 2019), which was lower than the May mean temperature of 13°C.

Offshore significant wave heights >1.3 m peaked on the 2 and 15 June travelling in a south westerly direction (Figure 3) but remained below 1 m for the rest of June. Offshore winds were predominantly from the south-west (Figure 32). Wind speeds and gusts > 20 kts were also highest on the 1, 8 and 17 June with the strong winds on the 8 June not resulting in significant wave heights >1m (Figure 3). Offshore wind speeds remained relatively low for the remainder of the month.

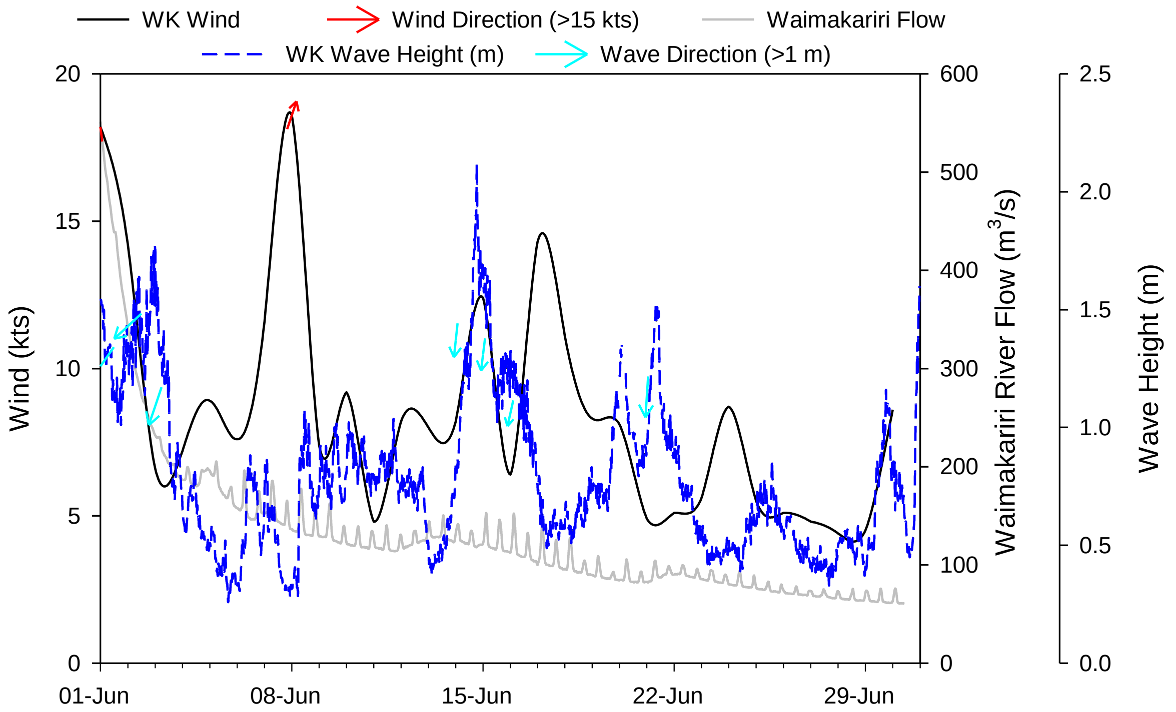


Figure 3 Offshore metocean conditions including wind speed and direction, significant wave height and daily averaged wave direction as measured by the WatchKeeper Buoy at site SG2a, and Waimakariri River flow at the Old Harbour Bridge station, during June 2019.
Note: Arrows indicate the direction of 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 and SG3, reporting the speed and direction of currents in a profile from the sea surface to seabed. Data availability reported periods of missing data form the 17 to 24 June for SG1 and SG3 and the 8 June for SG3 when issued occurred with connection to the mobile network. The Watchkeeper (SG2a) presented no missing data during this period. Summary ADCP statistics are presented within Figures 4 to 6 and Table 2. Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 33 and 38 in the Appendix. Note that the ADCP data are presented in this report using the UTC time format.

Maximum currents at SG1 coincided with currents at SG3 with near-surface currents (385 mm/s and 577 mm/s, respectively) peaking on 6 June and near-seabed (319 mm/s and 427 mm/s, respectively) currents peaking on 1 June (Table 2). Whereas at SG2a near-surface (153 mm/s) and near-seabed (213 mm/s) maximum currents both occurred on the 30 June. Differences in current flows were also noted within the strength of the current with the velocity at SG2 being consistently lower than the those recorded at SG1 and SG3 (Table 2). These differences have been attributed to varying topography across the spoil ground sites.

Table 2 Parameter statistics for spoil ground ADCPs during June 2019.

Parameter	Depth	Site		
		SG1	**SG2a**	**SG3**
Minimum current speed (mm/s)	*Near-surface*	2	0	1
	Near-seabed	2	1	5
Maximum current speed (mm/s)	*Near-surface*	385	153	577
	Near-seabed	319	213	427
Mean current speed (mm/s)	*Near-surface*	98	15	124
	Near-seabed	83	60	115
Standard deviation of current speed (mm/s)	*Near-surface*	61	14	89
	Near-seabed	48	28	69
Current speed, 95th percentile (mm/s)	*Near-surface*	221	42	292
	Near-seabed	176	111	256

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 (the opposite is true for wind direction, where the reference is the direction from which the wind is coming from). Near-surface current direction at SG1 during June tended to flow towards the north-west (25.1%) and north (21.3%). SG1 near-seabed current flow directions were similar to near-surface with predominant flows from the north-west of 19.5%, followed by strong flows from the south-east 13.2% and the north 13%. Flow directions at SG3 were similar to May with dominant flows at the near-surface (north-west: 33.8%; south-east 20.9%) and near-seabed (north-west: 20.8%; south-east 21.5%) and had less influence from the inshore northerly winds as seen at SG1. Current flow at SG2a at the near-surface tended to be in the same direction as SG1 and SG3 with dominant flows towards the north-west 23.4% and to the west 17.8%, whereas the near-seabed had dominant flows to the west 22.0% and to the east 20.0% at SG2a.

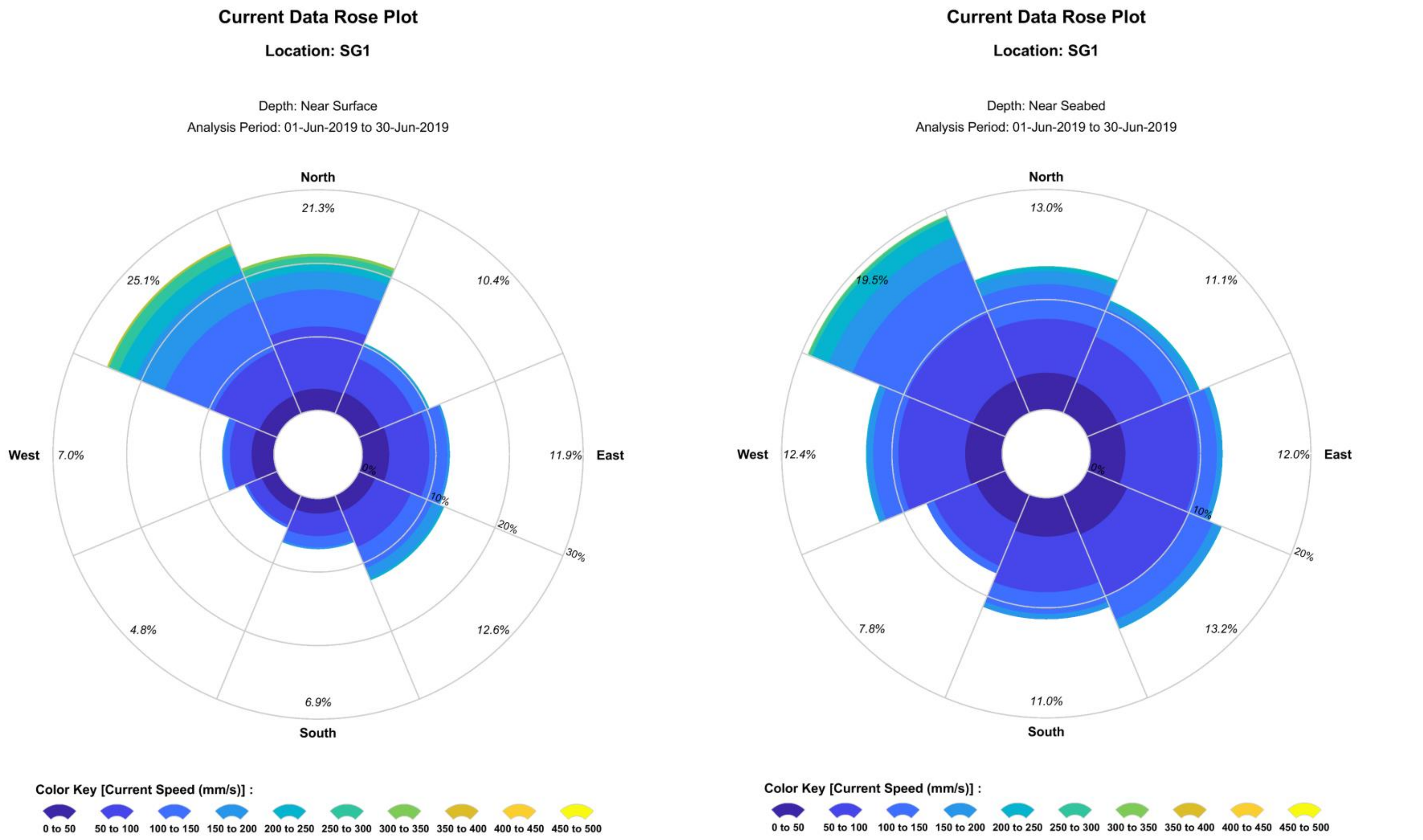
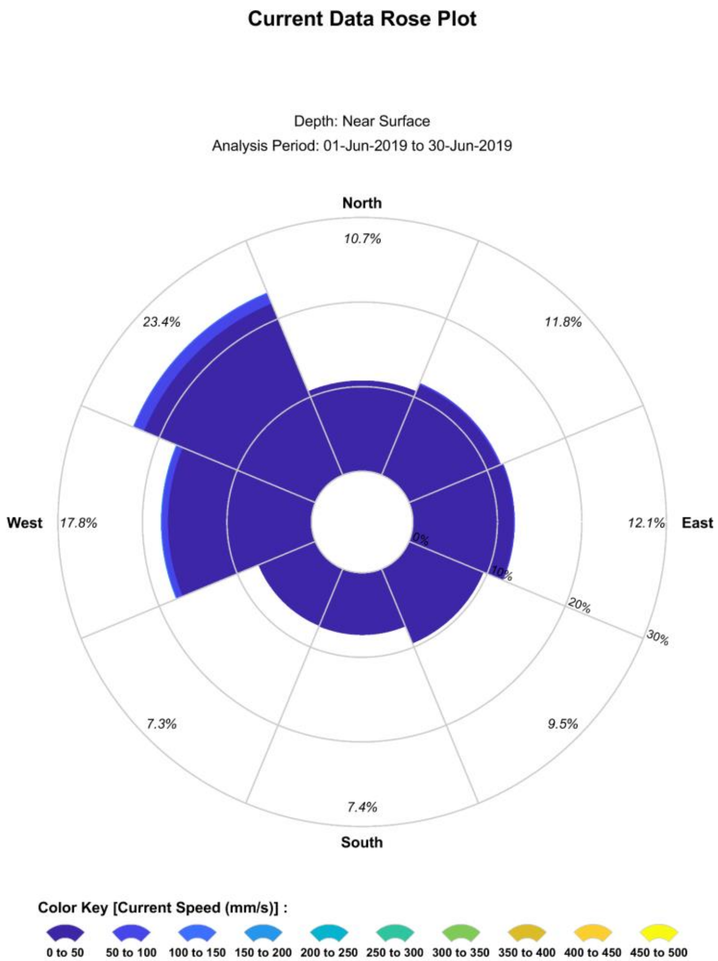


Figure 4 Near-surface and near-seabed current speed and direction at SG1 during June 2019.
Speed intervals of 50 mm/s are used.



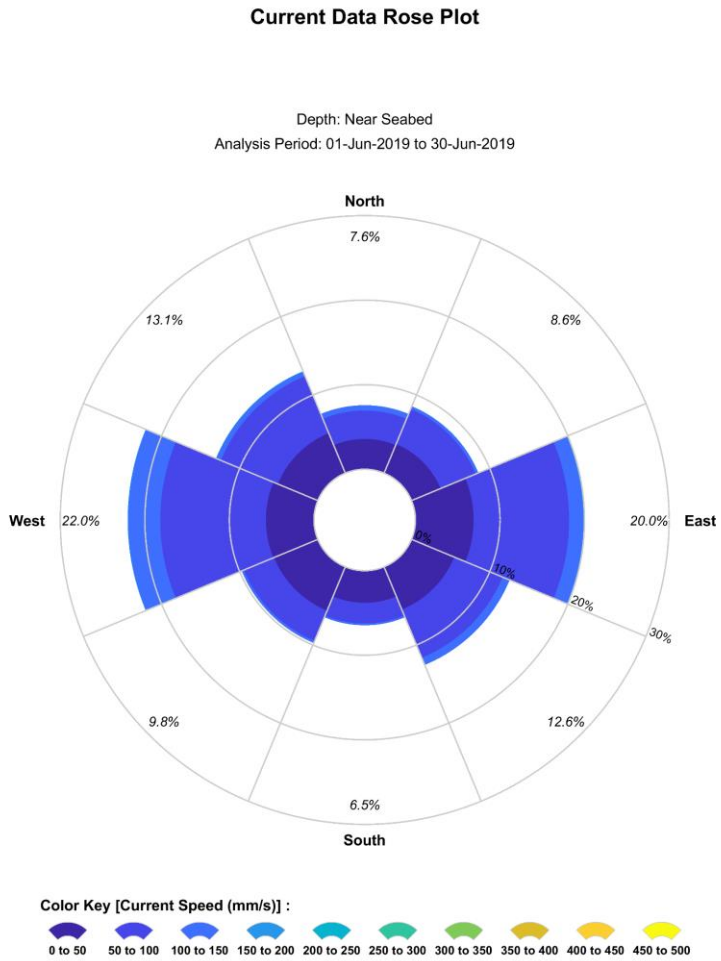
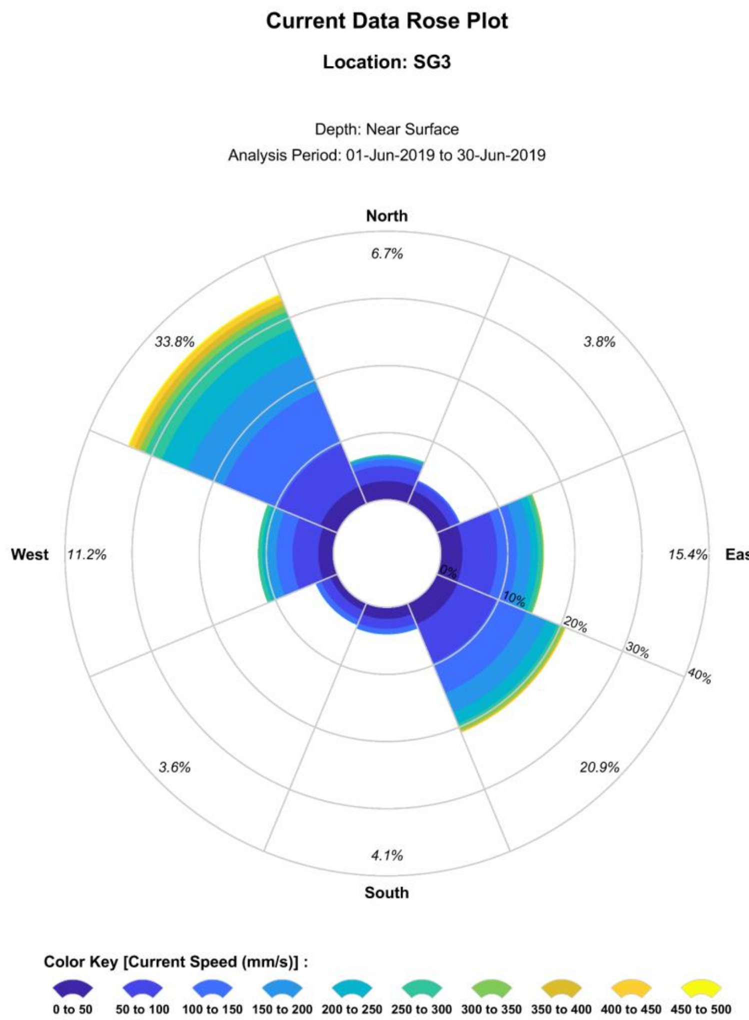


Figure 5 Near-surface and near-seabed current speed and direction at SG2a (Watchkeeper) during June 2019.
Speed intervals of 50 mm/s are used.



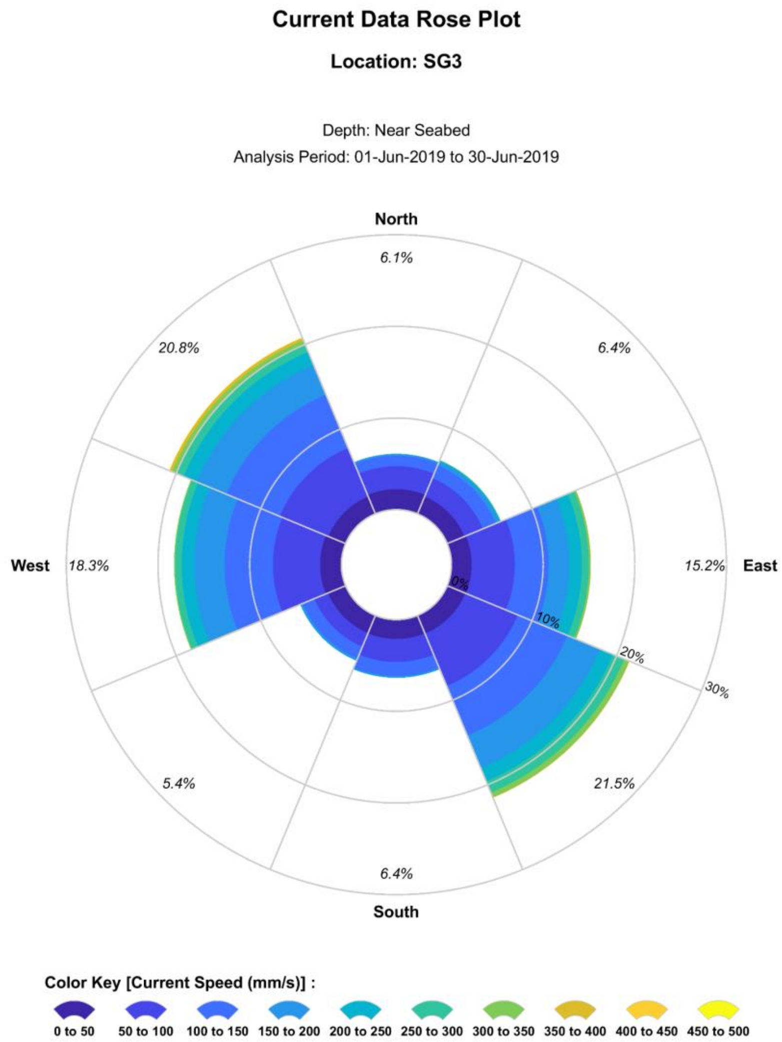


Figure 6 Near-surface and near-seabed current speed and direction at SG3 during June 2019.
Speed intervals of 50 mm/s are used.

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 13 June 2019. 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 June 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 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 June 2019 dredge data. Summary statistics for KZ filtered turbidity data, used for real time compliance monitoring during dredge operations, are also presented in Tables 23 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.

June Turbidity:

Consistent with the entire monitoring program, surface turbidity values were highest (monthly means of 3.7 to 6.7 NTU) at the inshore monitoring sites (Table 3, Figure 7). Further offshore, the spoil ground sites (Table 4) exhibited lower surface turbidity values of 2.7 NTU at SG2 and SG3 and slightly higher turbidity at SG1 (5.1 NTU). Nearshore sites experienced intermediate mean turbidity values (3.0 to 6.1 NTU) during June (Table 5), as typically observed. Turbidity across all monitoring sites was overall similar to May.

Turbidity across the inner harbour displayed a number of peaks that occurred in response to the inshore strong west-south-westerly winds, with UH1 displaying the highest overall response (Figure 7). Inshore sites CH1 and CH2 however, did not display a response to 7 - 8 June wind speed event that was observed at UH1 and to a lesser extent UH2.

Turbidity at nearshore sites of the monitoring program (OS1 to 4 and OS7) mimicked that of the inshore sites peaking on 2 June and 16 to 18 June and at levels similar to inner harbour, or slightly higher as observed at OS1 (rolling average peaks >12 NTU, Figure 7). Unlike the inner harbour sites, the later large turbidity peak was also likely recorded at these sites as a result of the elevated offshore wind speeds and wave heights recorded on 14 June. Similar to sites CH1 and CH2 the offshore sites did not response to the wind speed event of 8 June despite elevated wind speeds being recorded both inshore and offshore. Elevated wave heights which are often more influential, were not recorded at this time.

Table 3 Mean turbidity and statistics at inshore water quality logger sites during June 2019 and Baseline period (1 November 2016 to 31 October 2017).
Values for June are means ± se, range and percentiles (n = 2589 to 2879) Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface May	Surface Baseline
UH1	Mean ± se	6.7 ± 0.1	12
	Range	<1 – 32	-
	99th	18	39
	95th	13	22
	80th	9	15
UH2	Mean ± se	3.7 ± 0.0	10
	Range	<1 – 21	-
	99th	11.2	32
	95th	8	20
	80th	5.4	13
CH1	Mean ± se	6.0 ± 0.0	9
	Range	2.5 – 18	-
	99th	13.6	29
	95th	10.1	18
	80th	7.4	12
CH2	Mean ± se	5.2 ± 0.0	8
	Range	1 – 14	-
	99th	11.4	24
	95th	9.5	16
	80th	7.3	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during June 2019 and Baseline period (1 November 2016 to 31 October 2017).
Values for June are means ± se, range and percentiles (n = 2877). Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface May	Surface Baseline
SG1	Mean ± se	5.1 ± 0.0	4.2
	Range	1.5 – 13	-
	99th	10.5	14
	95th	9.1	10
	80th	6.2	6.2
SG2	Mean ± se	2.7 ± 0.0	4.6
	Range	<1 – 22	-
	99th	8.8	20
	95th	6.8	11
	80th	3.8	7.0
SG3	Mean ± se	2.7 ± 0.0	3.6
	Range	<1 – 13	-
	99th	7.7	13
	95th	5.5	7.7
	80th	3.7	4.8

Further offshore at OS5, OS6 and the spoil ground sites, turbidity peaks also followed the same trends as at the nearshore sites with the 16 to 18 June peaks not as marked as the other sites. Turbidity peaks occurred when increases in both wind speed and wave heights were recorded (Figure 7) coinciding during the month of June.

Comparison to Baseline:
Mean surface turbidity values during June were overall lower to values calculated from the baseline monitoring period (Tables 3 to 5, Figures 8 to 12).

Benthic:

Benthic data recovery was good with all sites reporting values for the majority of June (Figure 7). There was consistency between surface and benthic turbidity patterns, however departures occurred within the benthic turbidity data due to a high correspondence with benthic turbidity and wind speed (Figure 7).

Table 5 Mean turbidity and statistics at offshore water quality logger sites during June 2019 and Baseline period (1 November 2016 to 31 October 2017).
*Values for June are means ± se, range and percentiles (n = 1815 to 2975). Baseline values modified from Fox 2018**

Site	Statistic	Turbidity (NTU)		
		Surface June	Surface Baseline	Benthic June
OS1	Mean ± se	6.1 ± 0.1	7.5	17 ± 0
	Range	<1 – 24	-	2 – 143
	99th	16	24	99
	95th	12.4	16	58
	80th	9	10	25
OS2	Mean ± se	4.7 ± 0.0	6.4	20 ± 0
	Range	<1.5 – 19	-	<1 – 132
	99th	12	18	88
	95th	9	13	57
	80th	6	9.0	31
OS3	Mean ± se	4.6 ± 0.0	6.6	17 ± 0
	Range	<1 – 19	-	<1 – 126
	99th	12	27	76
	95th	8.8	15	50
	80th	6.1	8.9	25
OS4	Mean ± se	3.7 ± 0.0	5.9	23 ± 1
	Range	<1 – 17	-	<1 – 150
	99th	10.4	20	109
	95th	7.4	13	79
	80th	5.1	8.3	39
OS5	Mean ± se	3.0 ± 0.0	4.6	–
	Range	<1 – 19	-	–
	99th	12.2	19	–
	95th	9	11	–
	80th	4.8	6.4	–
OS6	Mean ± se	3.0 ± 0.0	4.7	23 ± 0
	Range	<1 – 12	-	<1 – 137
	99th	8.7	19	103
	95th	6.6	12	70
	80th	4.1	7.2	36
OS7	Mean ± se	4.9 ± 0.0	6.4	–
	Range	<1 – 15.5	-	–
	99th	12.5	23	–
	95th	10	14	–
	80th	6.5	9.2	–

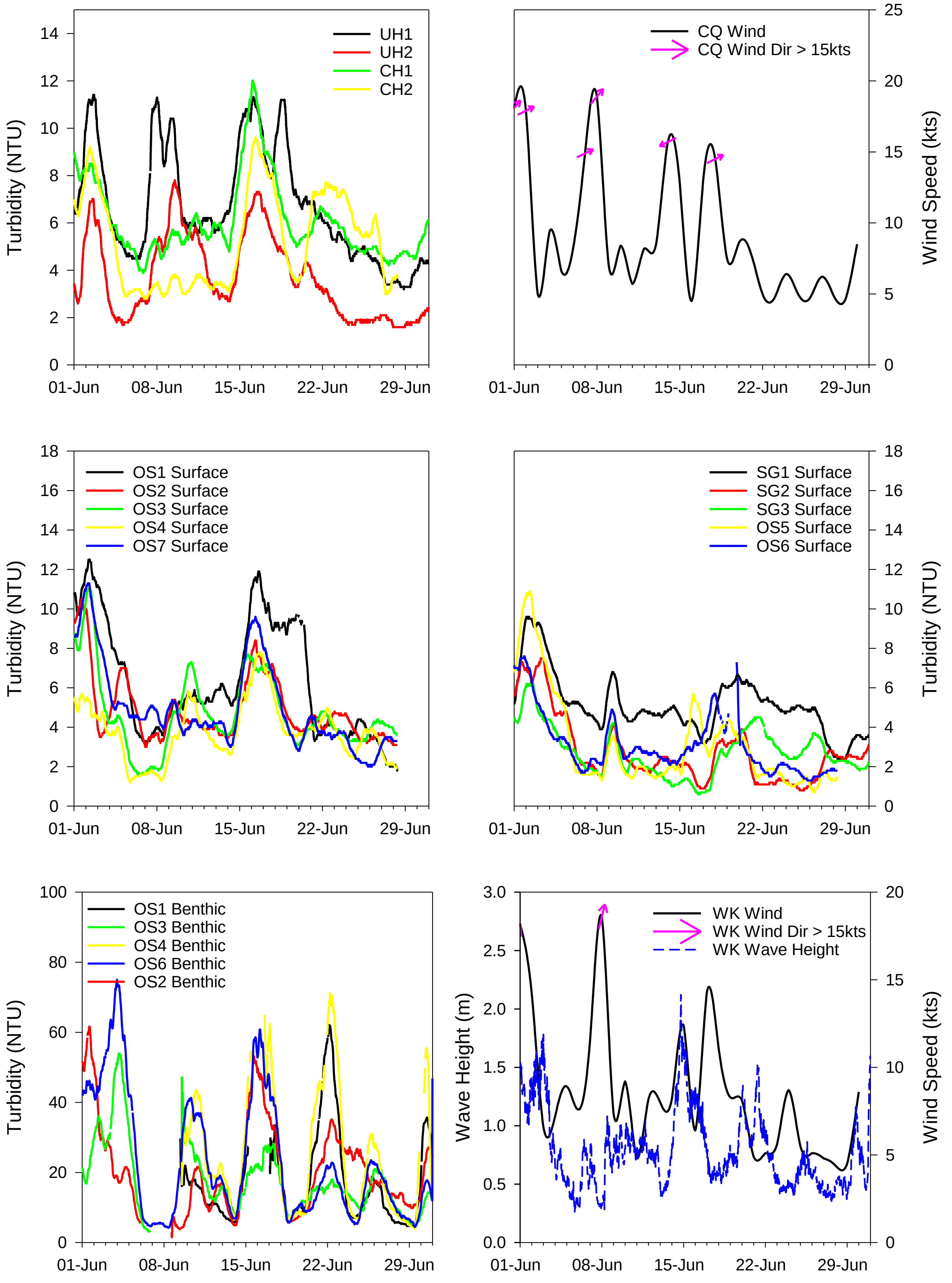


Figure 7 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore and benthic monitoring stations.
Note differing scales between plots. Arrows indicate the direction of travel for inshore/offshore winds greater than 15 knots.

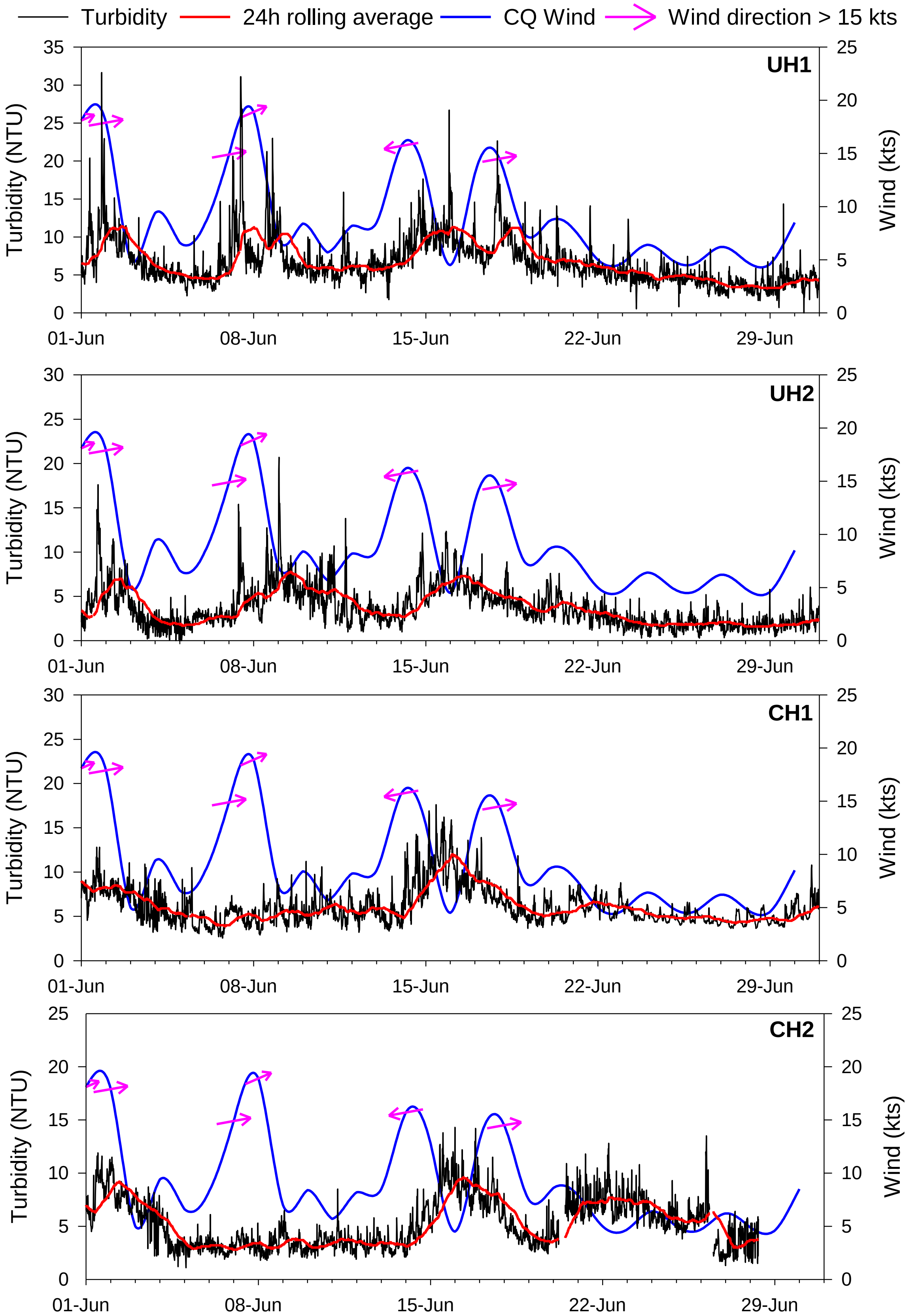


Figure 8 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during June 2019.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

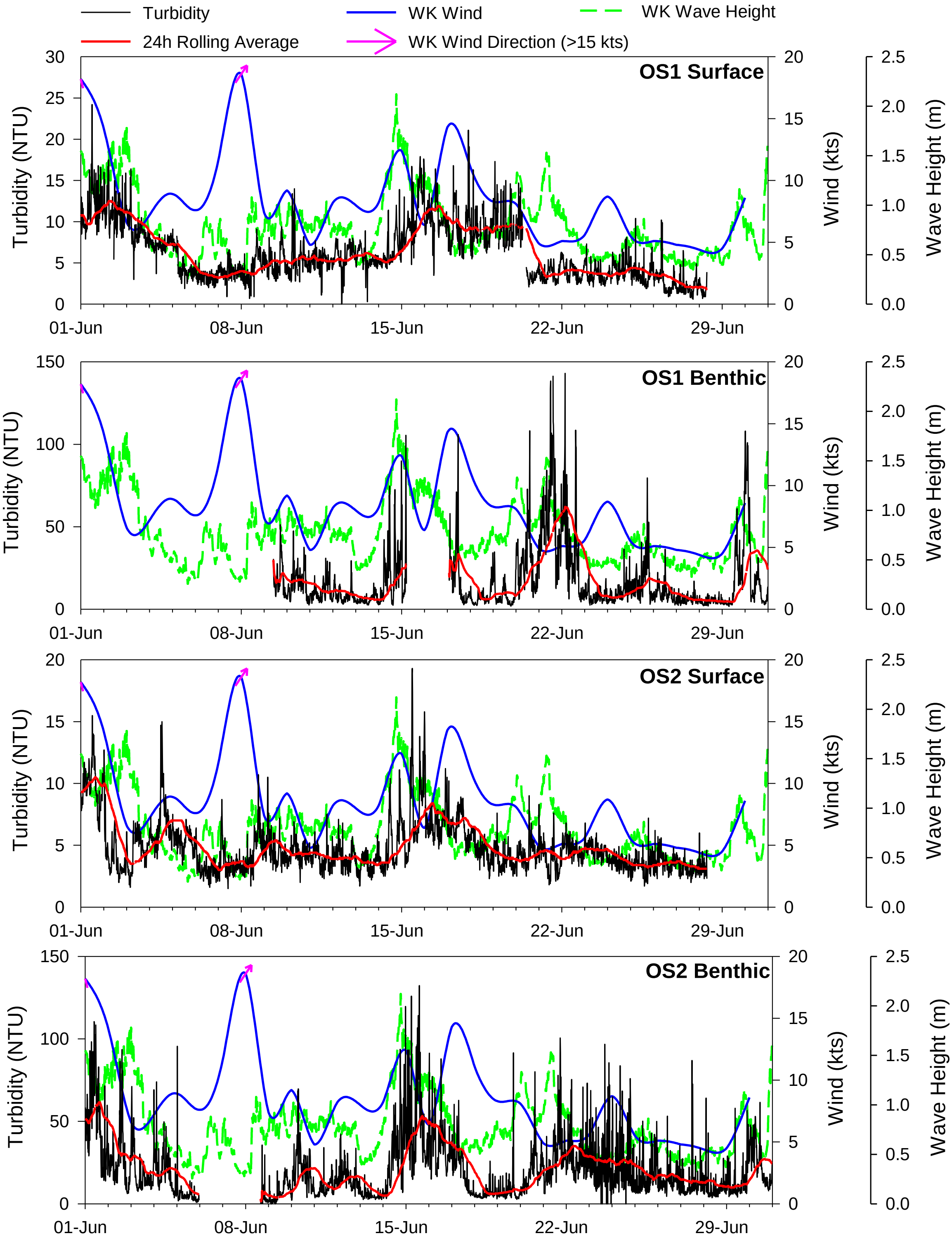


Figure 9 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS1 and OS2) during June 2019.

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.

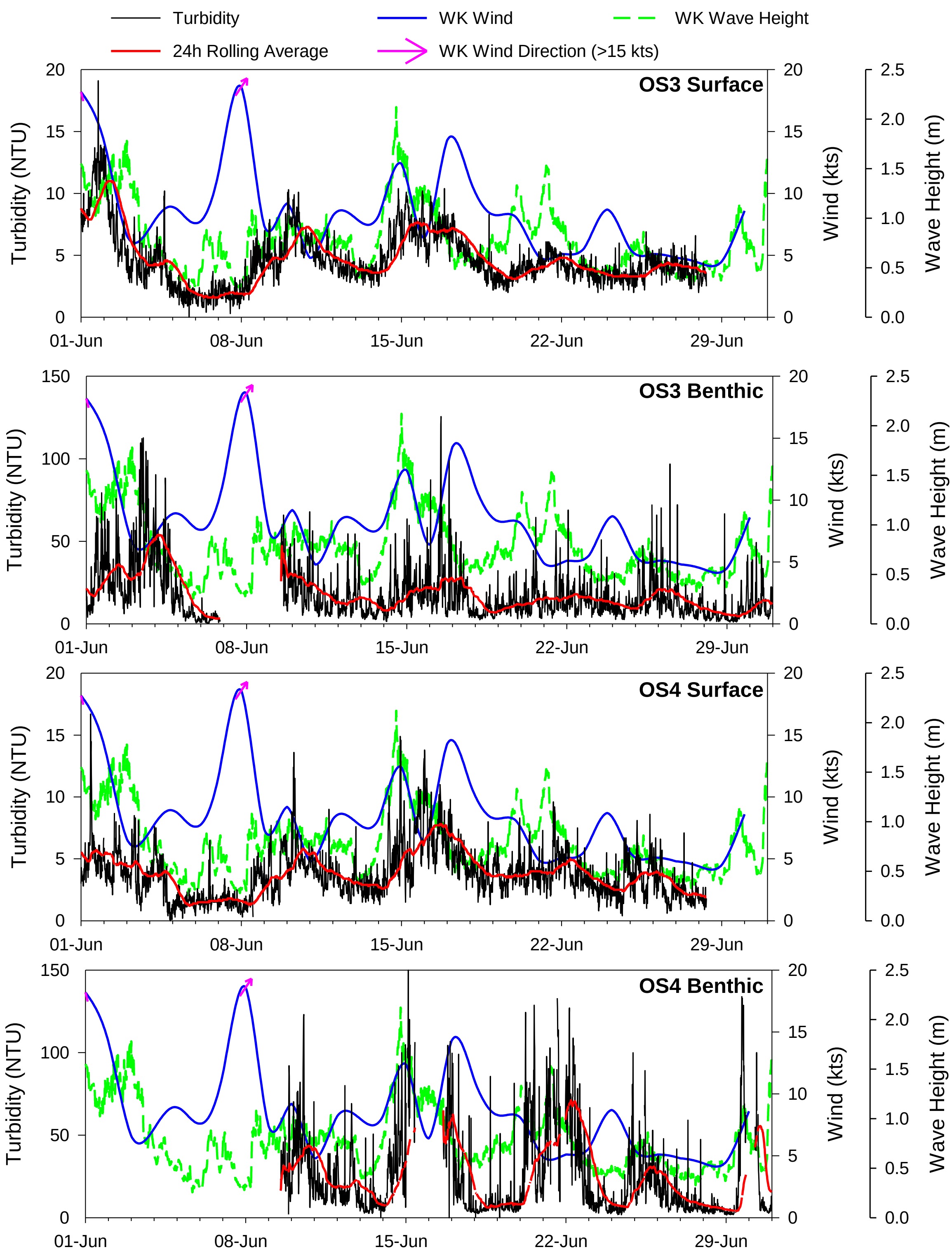


Figure 10 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS3 and OS4) during June 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

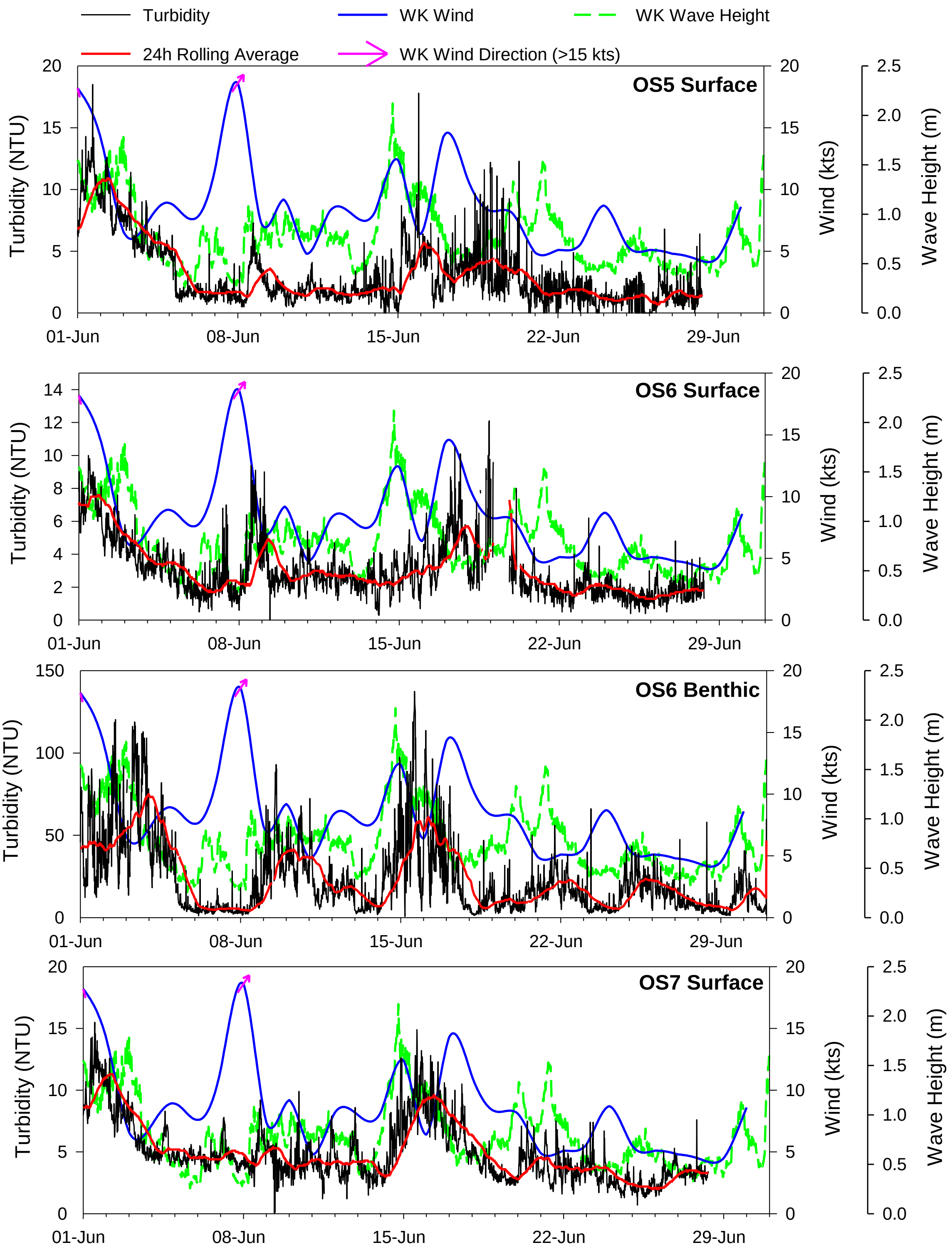


Figure 11 Surface and benthic turbidity and daily averaged winds at nearshore and offshore sites (OS5, OS6 and OS7) during June 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

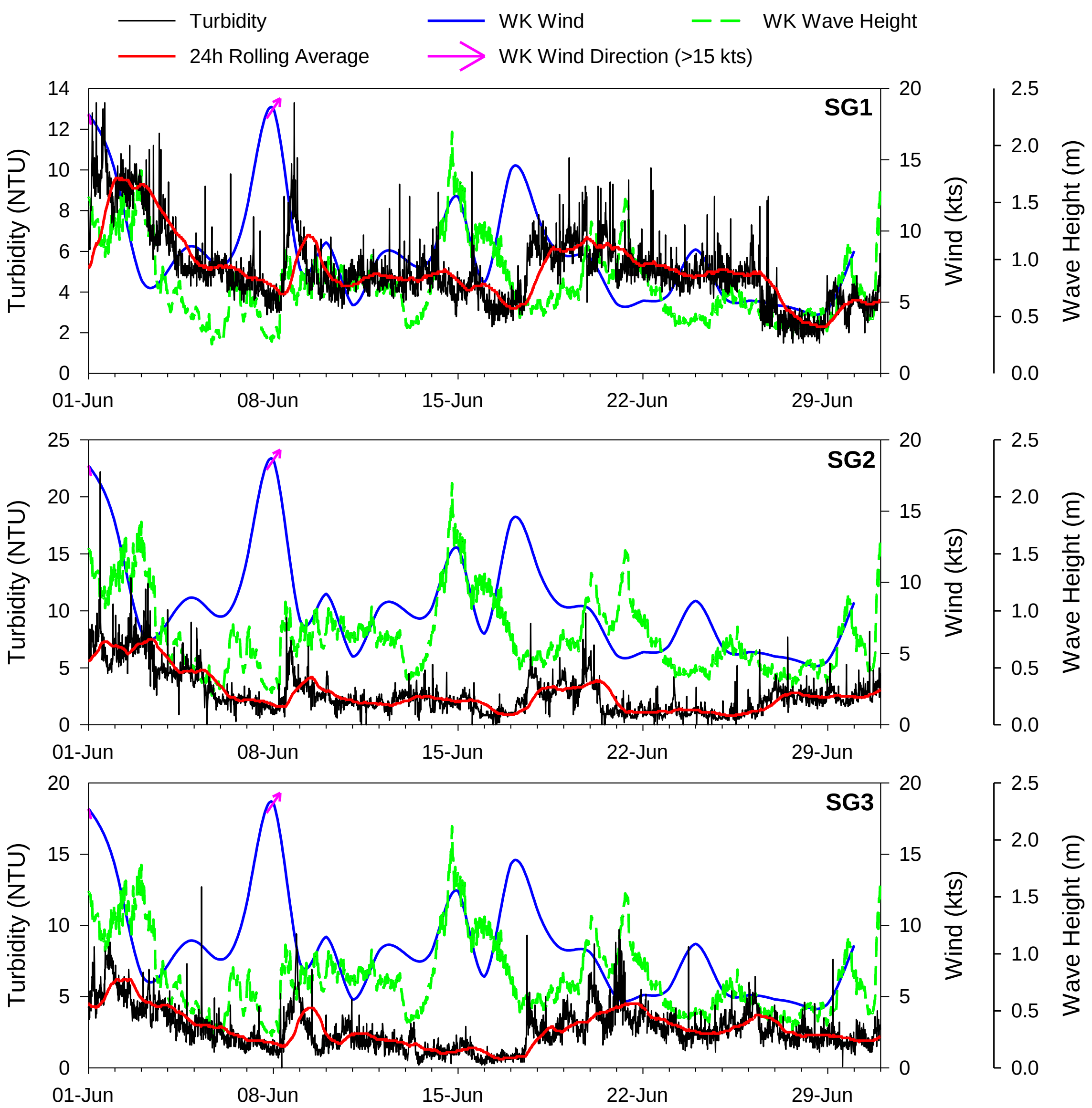


Figure 12 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during June 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

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 Turbidity intensity values for each site 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 June the Tier 3 intensity values were not exceeded at any site within the monitoring network (Table 7).

Table 7 Tier 3 intensity value exceedances and maximum hour counts during June 2019.

Site	P99 Count >7.2 Hours Start Time	P99 Count >7.2 Hours End Time	Maximum P99 Count (Hours)
UH1	-	-	6.25
UH2	–	–	1.50
CH1	–	–	2.25
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

Surface turbidity levels during June were largely similar to or below baseline conditions, and as such no validated P99 exceedance counts were accumulated (Table 7) nor removed (Table 8).

Table 8 Hour counts removed from monitoring statistics during June 2019.

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

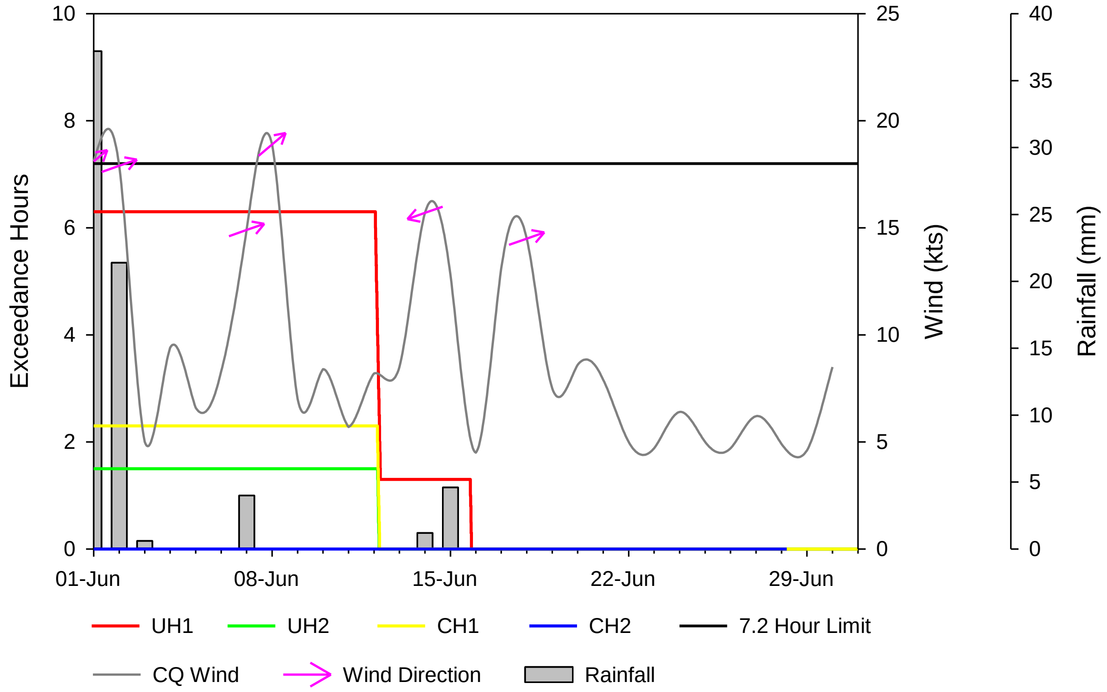


Figure 13 Tier 3 allowable hour counts at UH1, UH2, CH1 and CH2 after exceedance of the intensity values during June 2019.

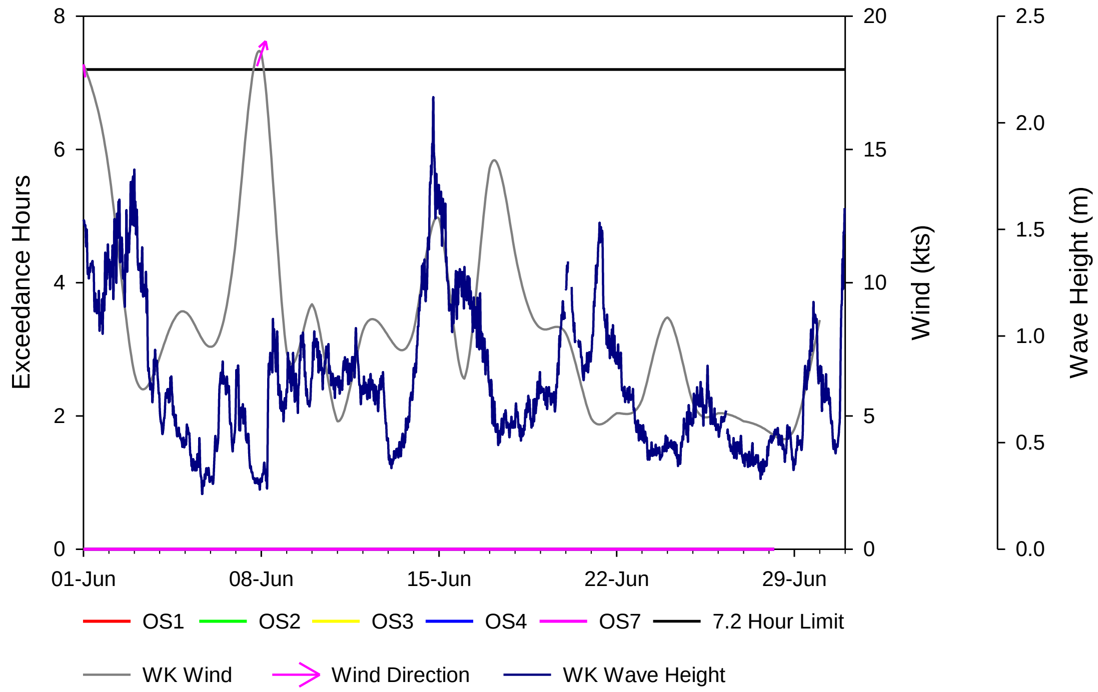


Figure 14 Tier 3 allowable hour counts at OS1-OS3, and OS7 after exceedance of the intensity values during June 2019.
Note there is no trigger value for the reference site OS4.

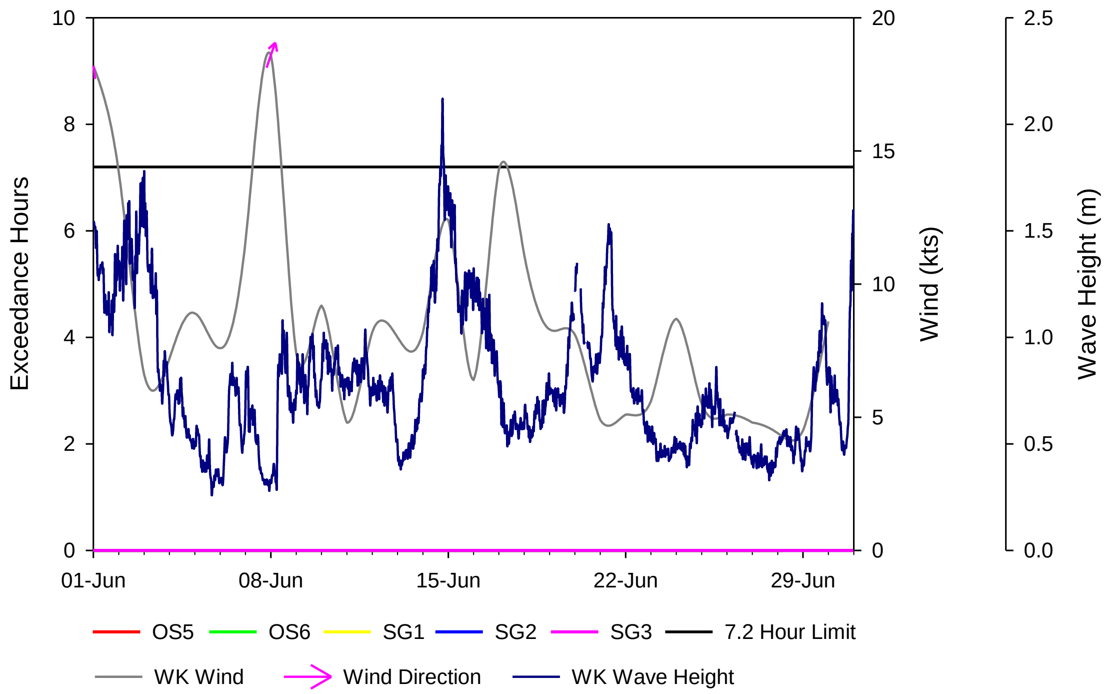


Figure 15 Tier 3 allowable hour counts at OS5, OS6, SG1, SG2b and SG3 after exceedance of the intensity values during June 2019.

3.2.3 Temperature

Mean monthly sea surface temperatures around Lyttelton Harbour were considerably cooler than those experienced during May, ranging from 9.5 to 11.8°C (Table 9) (c.f. 12.4 to 13.8°C in May) continuing the trend for seasonal cooling associated with the winter months. Continuing trends for the previous month, slightly cooler temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore sites.

All sites displayed a long-term cooling trend across the month, with a brief period of warming within the inner harbour from 14 to 17 June (Table 9, Figure 16).

Semidiurnal variability (associated with tidal water movements and solar radiation) was again observed within the surface temperature datasets, particularly at the inner harbour sites and at site OS1 at the harbour entrance. Benthic temperatures were similar to overlying surface waters (Table 9, Figure 17), again indicating a well-mixed water column.

Table 9 Mean temperature at inshore, spoil ground and offshore water quality sites during June 2019. *Values are means ± se (n = 2869 to 2976).*

Site	Temperature (°C)	
	Surface loggers	Benthic loggers
UH1	9.5 ± 0.0	–
UH2	9.6 ± 0.0	–
CH1	10.1 ± 0.0	–
CH2	10.4 ± 0.0	–
SG1	11.2 ± 0.0	–
SG2	11.3 ± 0.0	–
SG3	11.8 ± 0.0	–
OS1	10.5 ± 0.0	10.8 ± 0.0
OS2	10.9 ± 0.0	11.2 ± 0.0
OS3	11.1 ± 0.0	11.3 ± 0.0
OS4	11.2 ± 0.0	11.4 ± 0.0
OS5	10.9 ± 0.0	–
OS6	11.2 ± 0.0	11.4 ± 0.0
OS7	10.8 ± 0.0	–

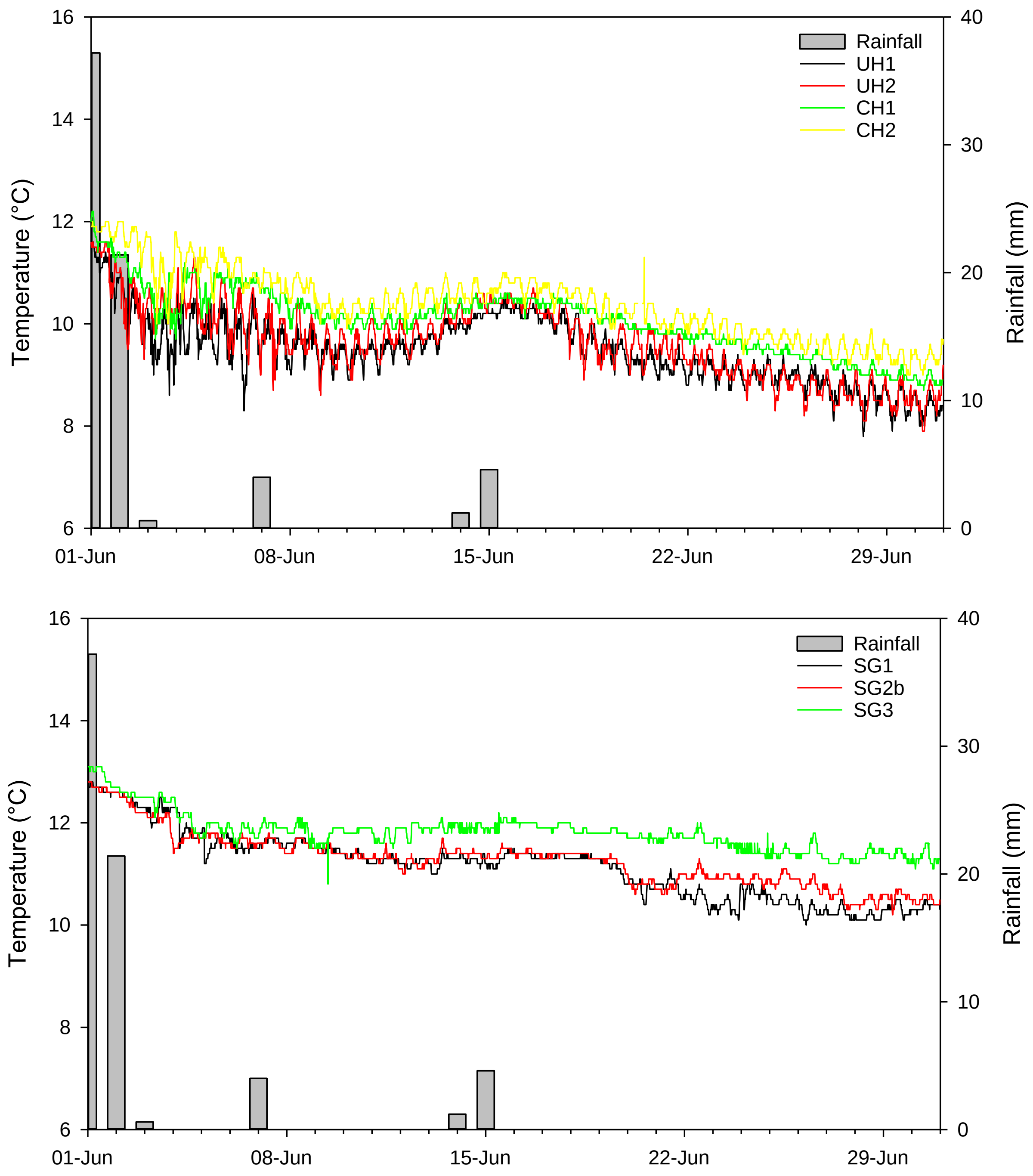
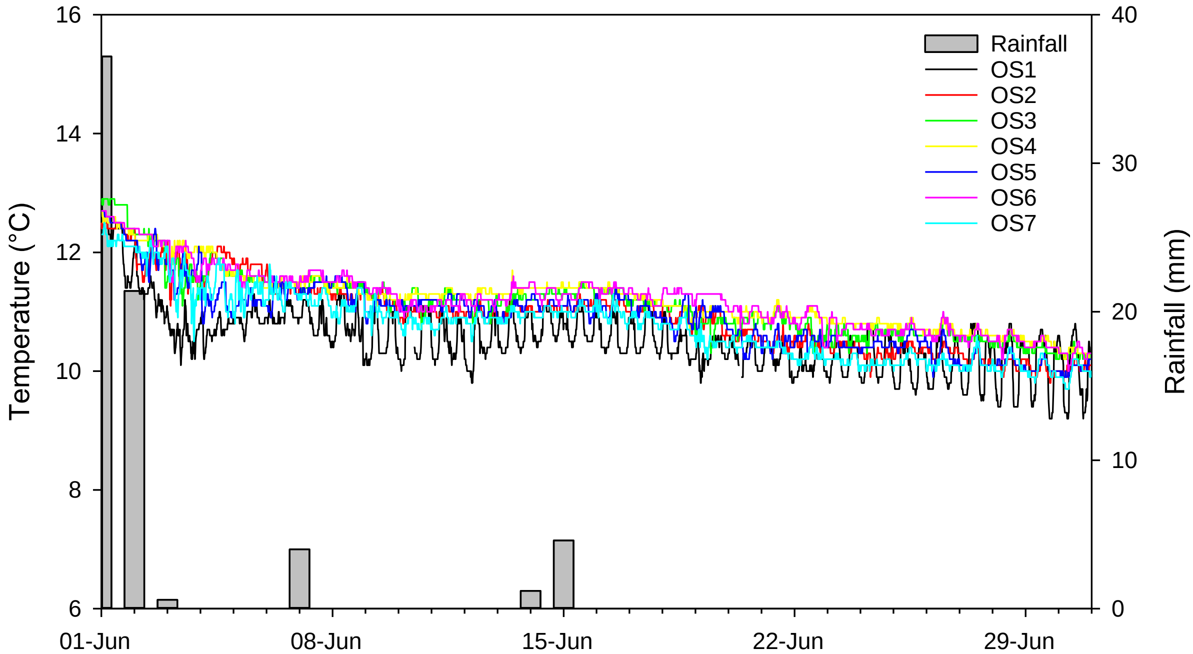


Figure 16 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during June 2019.



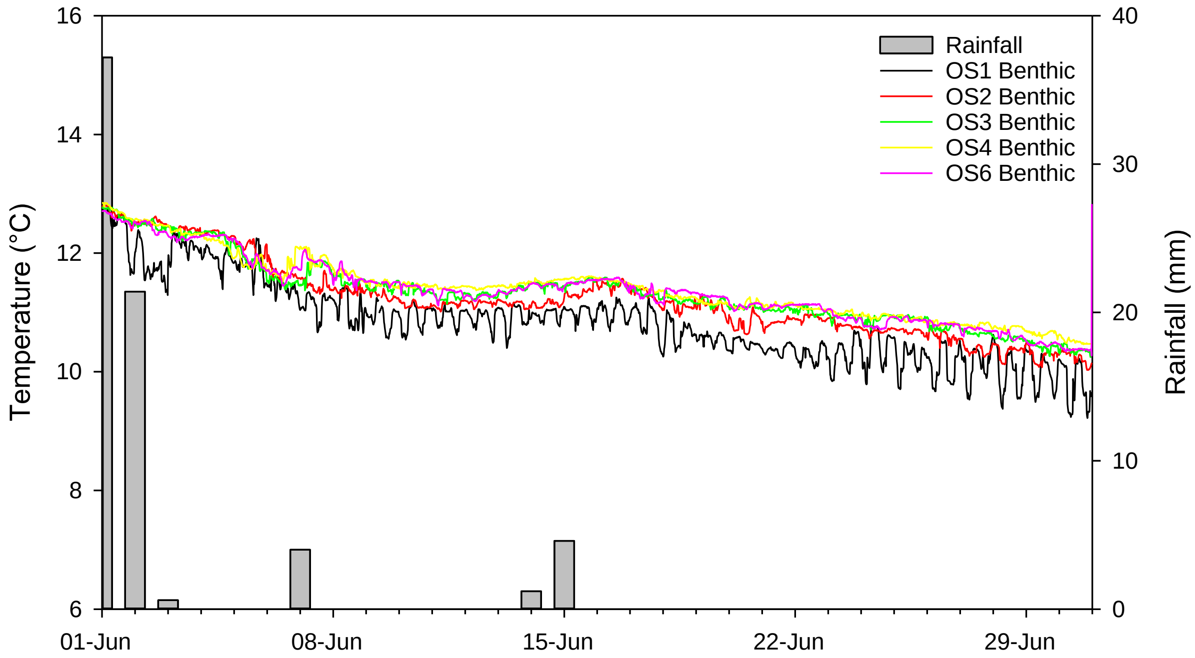


Figure 17 Surface temperature (OS1 to OS7) and benthic temperature (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during June 2019.

3.2.4 pH

The pH in June was consistent across all sites, both surface and benthic, with monthly means ranging between 7.9 and 8.3 (Table 10, Figures 18 and 19). Some post calibration issues have been encountered with pH probes during March to June which has resulted in some unacceptable data. Continued firmware updates and replacement probes are expected to resolve these issues in the near future. No notable temporal trends were observed across the month.

Table 10 Mean pH at inshore, spoil ground and offshore water quality sites during June 2019. *Values are means ± se (n = 562 to 2976).*

Site	pH	
	Surface loggers	Benthic loggers
UH1	8.1 ± 0.0	–
UH2	8.1 ± 0.0	–
CH1	8.0 ± 0.0	–
CH2	8.0 ± 0.0	–
SG1	8.1 ± 0.0	–
SG2	8.1 ± 0.0	–
SG3	8.1 ± 0.0	–
OS1	8.0 ± 0.0	8.1 ± 0.0
OS2	8.1 ± 0.0	8.0 ± 0.0
OS3	8.0 ± 0.0	7.9 ± 0.0
OS4	8.1 ± 0.0	8.1 ± 0.0
OS5	8.2 ± 0.0	–
OS6	8.1 ± 0.0	8.3 ± 0.0
OS7	8.2 ± 0.0	–

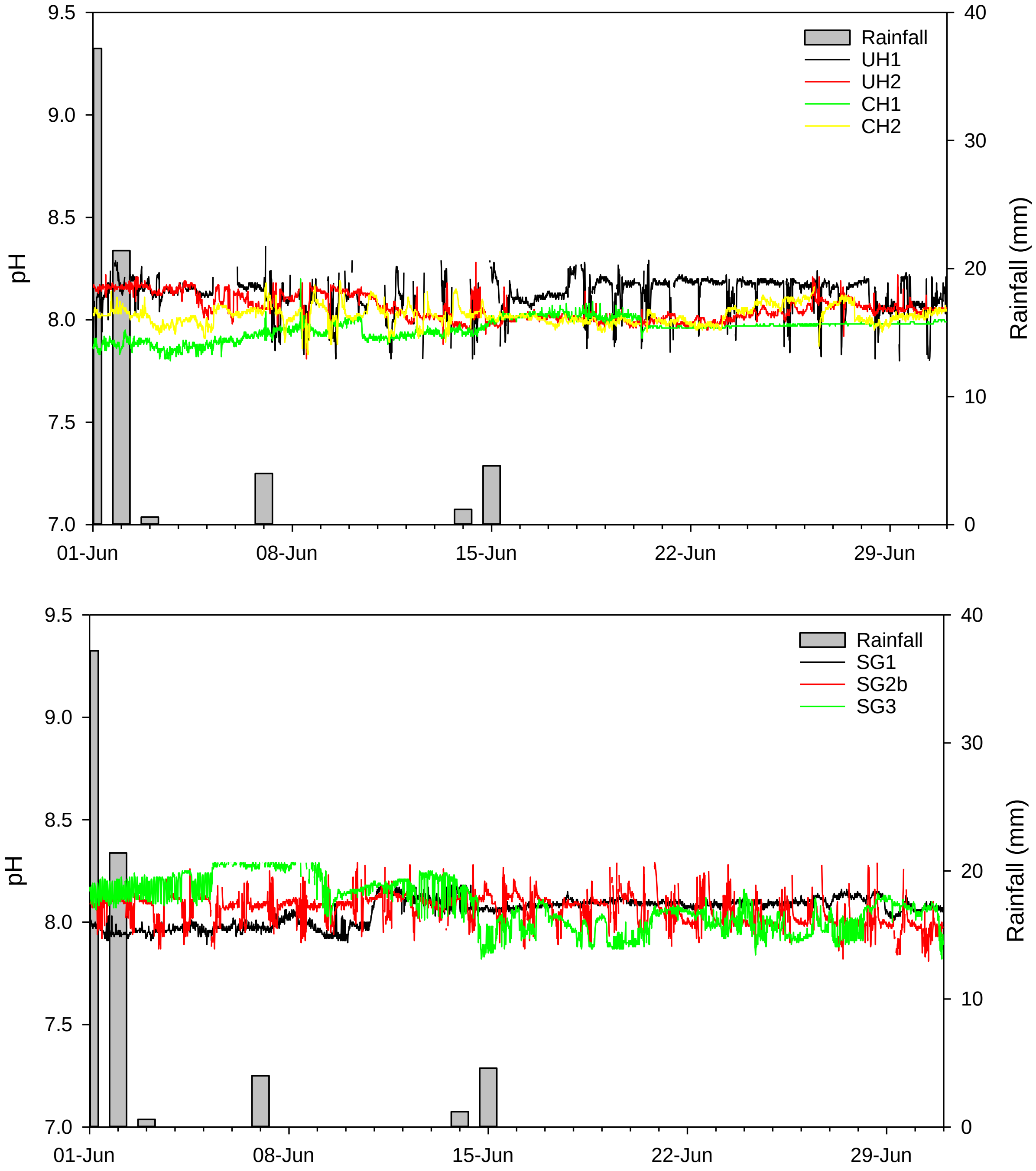
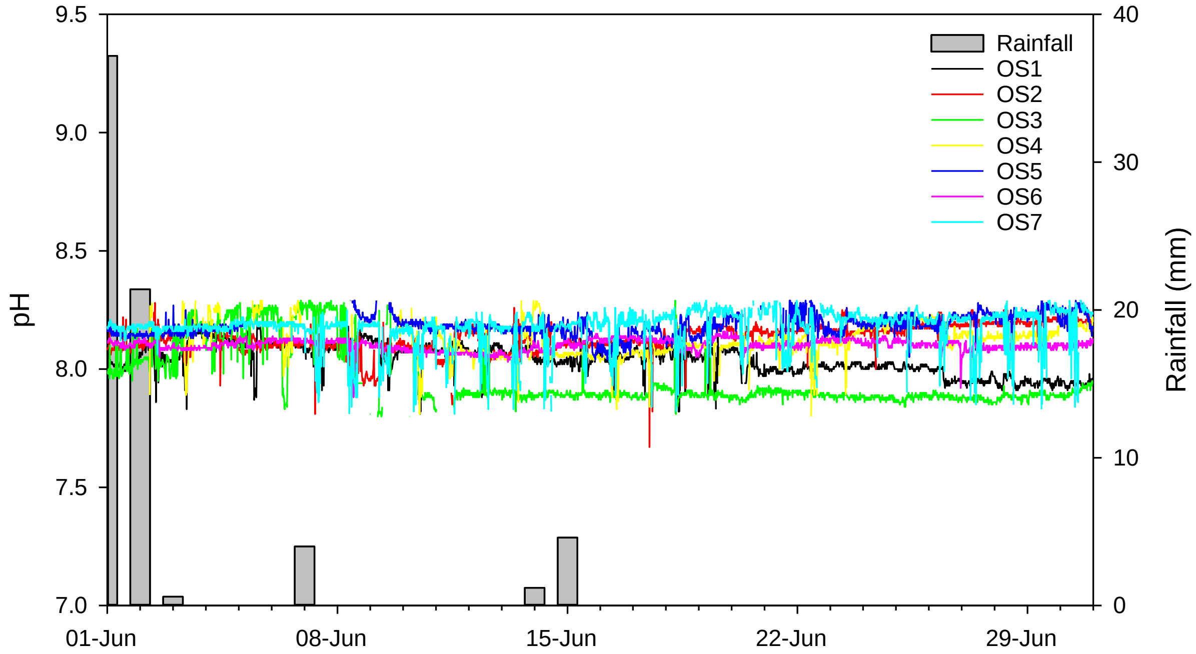


Figure 18 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during June 2019.



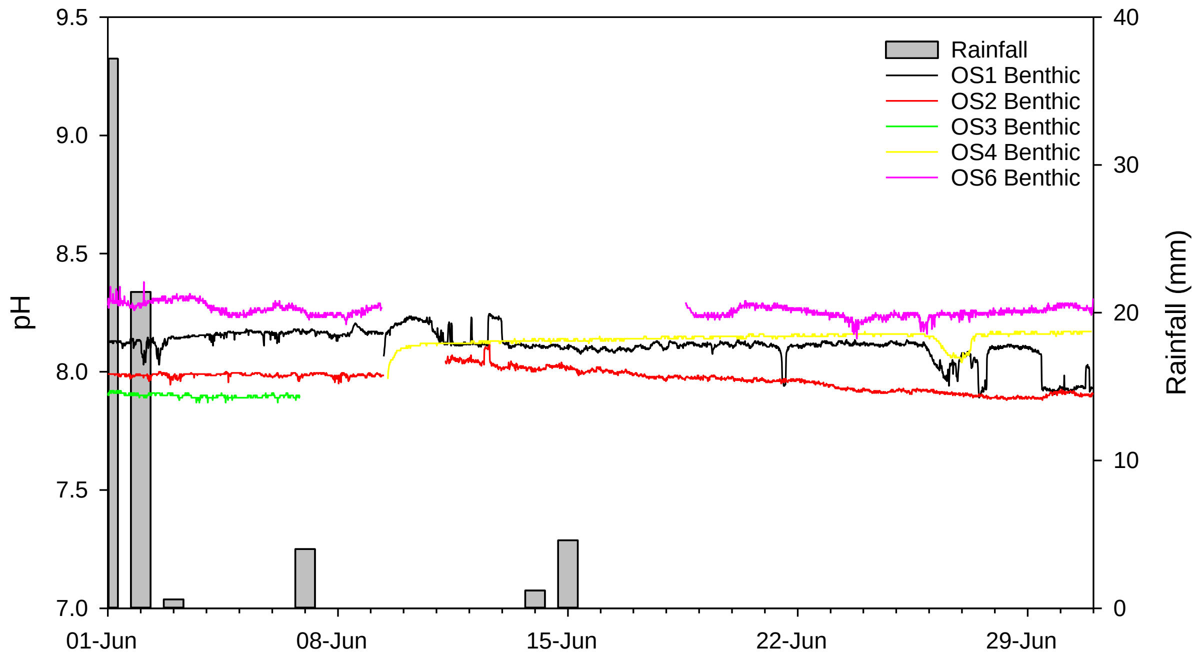


Figure 19 Surface pH (OS1 to OS7) and benthic pH (OS1 to OS4) at nearshore and offshore water quality sites during June 2019.

3.2.5 Conductivity

Surface conductivity in June ranged from 52.6 mS/cm to 54.7 mS/cm (Table 11, Figure 20 and 21), while benthic conductivity was slightly lower ranging from 50.2 mS/cm to 53.1 mS/cm, which were similar to monthly mean values calculated for May. Surface conductivity was noted to slightly decline on the 3 June within the inner harbour and offshore sites, due to the preceding rainfall and increased flow from the Waimakariri river. Conductivity then returned to stable values for the remainder of the month at all sites.

Table 11 Mean conductivity at inshore, spoil ground and offshore water quality sites during June 2019.
Values are means ± se (n = 2061 to 2976).

Site	Conductivity (mS/cm)	
	Surface loggers	Benthic loggers
UH1	52.6 ± 0.0	–
UH2	54.1 ± 0.0	–
CH1	52.1 ± 0.0	–
CH2	54.1 ± 0.0	–
SG1	54.7 ± 0.0	–
SG2	54.5 ± 0.0	–
SG3	54.6 ± 0.0	–
OS1	52.8 ± 0.0	53.1 ± 0.0
OS2	53.7 ± 0.0	51.5 ± 0.0
OS3	54.0 ± 0.0	52.4 ± 0.0
OS4	54.5 ± 0.0	50.2 ± 0.0
OS5	53.8 ± 0.0	–
OS6	53.8 ± 0.0	54.2 ± 0.0
OS7	54.0 ± 0.0	–

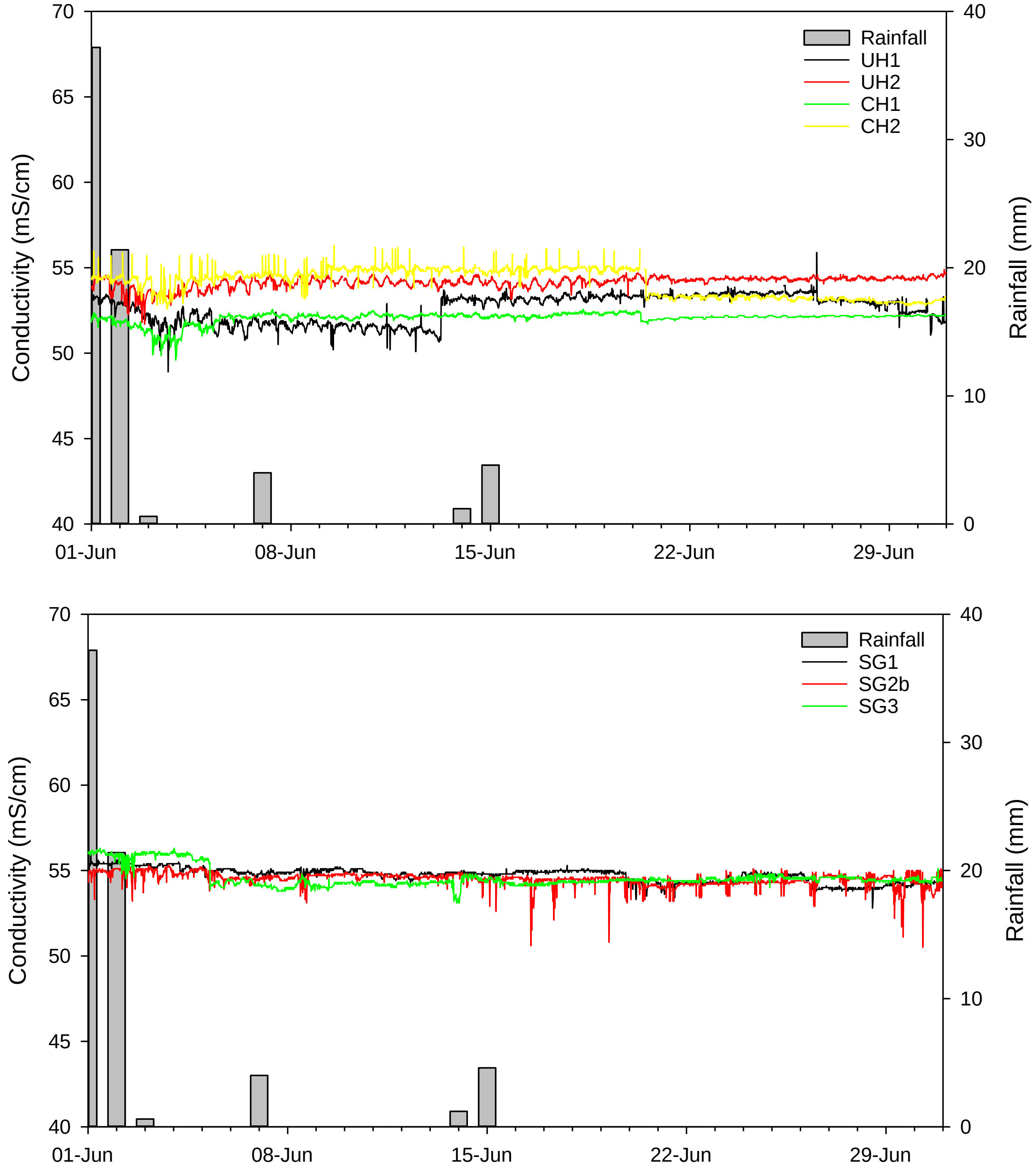


Figure 20 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during June 2019.

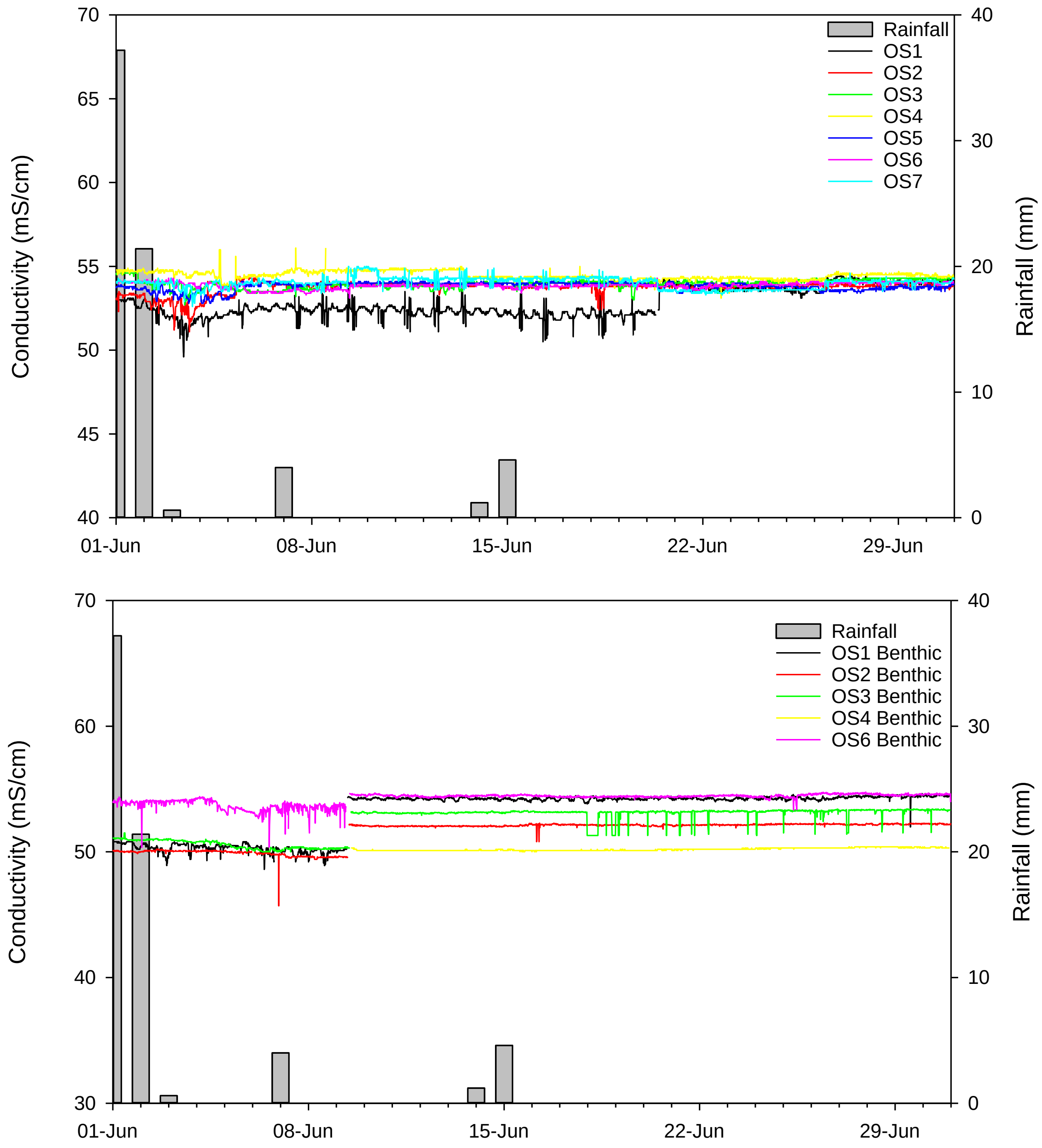


Figure 21 Surface conductivity (OS1 to OS7) and benthic conductivity (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during June 2019.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations in June ranged from 93 to 97% saturation, similar overall to May values (93 to 98% saturation). Stable DO concentrations steadily increased over June with notable increases at the end June for sites SG1, OS5 and OS7, which did not appear to coincide with any specific metocean condition (Figure 22 and 23). Increased photosynthesis due to localised phytoplankton or organic matter growth may be a contributing factor. Mean monthly benthic DO concentrations were similar to corresponding surface readings ranging from 93 to 98% saturation (Table 12, Figures 22 and 23), again indicating a well-mixed water column.

Large diurnal fluctuations in DO were recorded at all sites including the spoil ground for the entire month of June. DO was lower at the inner harbour sites at the start of the month most likely in response to the late May early June weather event but displayed a steady increase until the small weather event of 15 June. This event included precipitation and therefore cloud cover, thus potentially reducing photosynthesis. DO declined at the inner harbour sites during this second weather period, whereas the other sites remained stable.

Table 12 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during June 2019.
Values are means ± se (n = 2115 to 2976).

Site	Dissolved oxygen (% saturation)	
	Surface loggers	Benthic loggers
UH1	96 ± 0	–
UH2	96 ± 0	–
CH1	95 ± 0	–
CH2	93 ± 0	–
SG1	94 ± 0	–
SG2	95 ± 0	–
SG3	95 ± 0	–
OS1	94 ± 0	93 ± 0
OS2	93 ± 0	93 ± 0
OS3	93 ± 0	96 ± 0
OS4	94 ± 0	98 ± 0
OS5	95 ± 0	–
OS6	97 ± 0	96 ± 0
OS7	95 ± 0	–

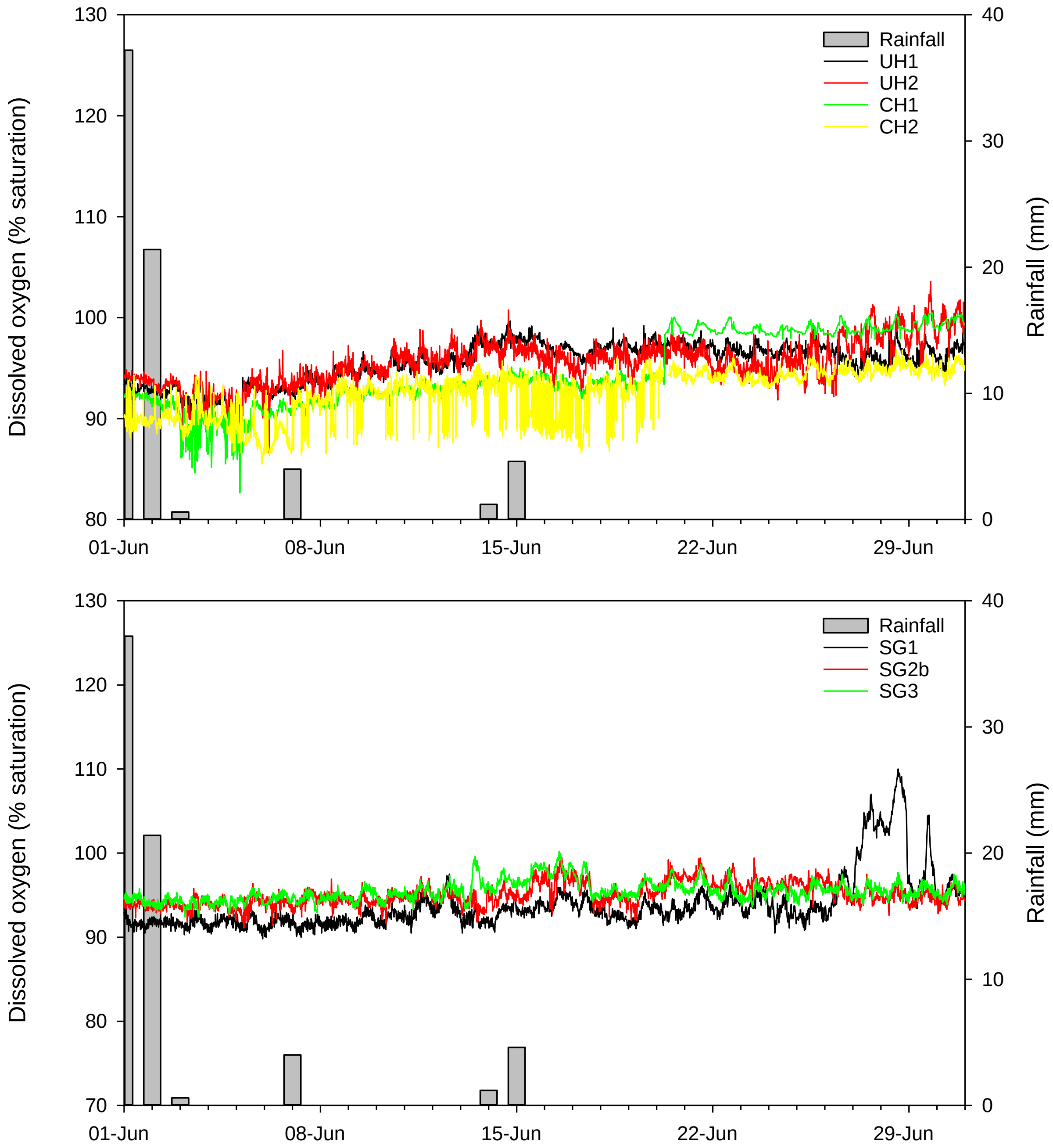


Figure 22 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during June 2019.

Benthic DO displayed a similar pattern to surface counterparts with a relatively stable increase over the month (Figure 23). OS1 benthic DO displayed a departure to the other sites with a decline in DO at the end of the month.

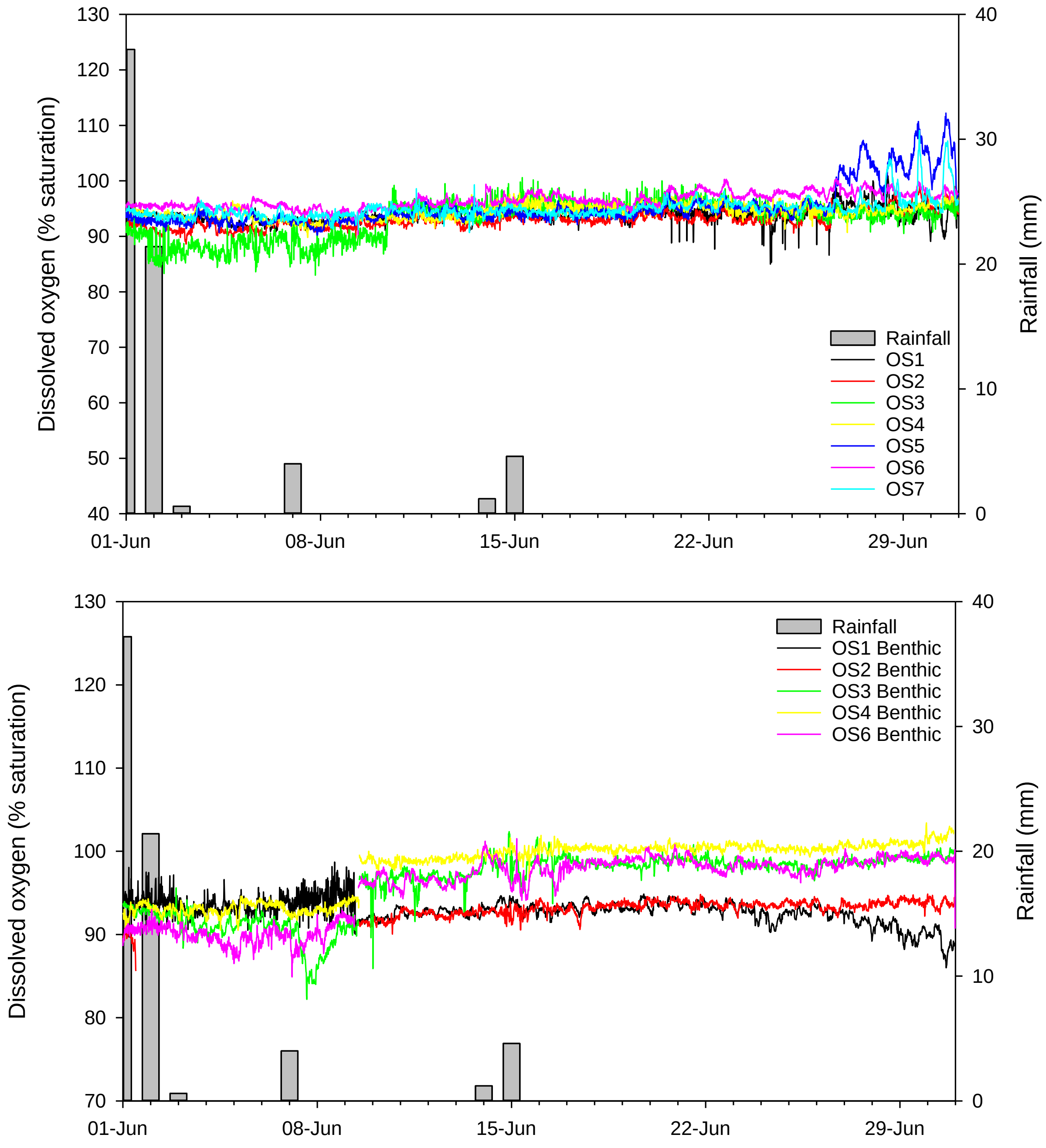


Figure 23 Surface DO (OS1 to OS7) and benthic DO (OS1 to OS 4 and OS6) at nearshore and offshore water quality sites during June 2019.

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 13 June 2019. 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 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 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, however slightly warmer temperatures were recorded near the benthos for CH2, UH2 and to less of a degree at UH1 (Figure 24). These increases in temperature were counteracted by similar increases in conductivity with depth that would have maintained a vertically stable water column at these harbour mouth locations. Similar to the continuous loggers, the uppermost harbour site UH3, displayed the lowest temperature and conductivity readings within the harbour, as was also observed in May. There appeared to be little benthic resuspension at inshore sites in June, with little change in turbidity at the benthos as is often observed.

Within the nearshore region, physicochemical data collected also indicated the persistence of strong vertical mixing, with little change for all recorded parameters through the water column (Figure 25).

Within the offshore region of the spoil ground, OS5 and OS6, the water column was once again recorded to be well mixed with slightly higher conductivity at the benthos than the surface for all sites (Figure 26). DO recorded a steady decreasing gradient at all sites with SG3 displaying a sharper decline. Benthic resuspension was observed at all sites.

The shallowest euphotic depths that ranged from 4.8 m to 13.8 m were calculated for upper and central harbour monitoring sites (Table 14), which reflects the typically higher levels of turbidity experienced (Figure 24) at these sites. The deepest euphotic depth was calculated to be 16.4 m at SG3 (Table 15) where turbidity in the surface and mid-column was low. No exceedances of WQG were recorded for the sub-surface during the June vertical profiling.

Table 13 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the June 2019 sampling event.
Values are means ± se (n = 6 for sub-surface, n = 16 to 29 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	13/06/2019 08:31	Sub-surface	9.6 ± 0	7.9 ± 0	51.2 ± 0	96 ± 0	4.5 ± 0.3	6	0.7 ± 0	6.3
		Whole column	9.6 ± 0	7.9 ± 0	51.3 ± 0	96 ± 0	4.3 ± 0.1	–		
UH2	13/06/2019 09:02	Sub-surface	9.6 ± 0	7.9 ± 0	51.2 ± 0	97 ± 0	2.9 ± 0.1	8	0.5 ± 0	9.2
		Whole column	9.7 ± 0	7.9 ± 0	51.3 ± 0	97 ± 0	3.1 ± 0.1	–		
UH3	13/06/2019 08:44	Sub-surface	9.1 ± 0	7.9 ± 0	50.6 ± 0	97 ± 0	5.5 ± 0.1	11	1 ± 0.1	4.8
		Whole column	9.1 ± 0	7.9 ± 0	50.6 ± 0	97 ± 0	5.4 ± 0.1	–		
CH1	13/06/2019 09:44	Sub-surface	10 ± 0	7.9 ± 0	51.6 ± 0	97 ± 0	2.8 ± 0.1	3	0.5 ± 0	9.1
		Whole column	10 ± 0	7.9 ± 0	51.6 ± 0	97 ± 0	2.9 ± 0	–		
CH2	13/06/2019 09:25	Sub-surface	10.3 ± 0	7.9 ± 0	51.8 ± 0	97 ± 0	2 ± 0	< 3	0.3 ± 0	13.8
		Whole column	10.4 ± 0	7.9 ± 0	51.9 ± 0	97 ± 0	2 ± 0	–		
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 June 2019 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 30 to 42 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	13/06/2019 10:05	Sub-surface	10.8 ± 0	8 ± 0	52.1 ± 0	97 ± 0	2.6 ± 0.1	6	0.5 ± 0	10.0
		Mid	11 ± 0	8 ± 0	52.3 ± 0	96 ± 0	3.1 ± 0.1	6		
		Benthos	11 ± 0	8 ± 0	52.3 ± 0	95 ± 0	3.3 ± 0	5		
		Whole column	11 ± 0	8 ± 0	52.2 ± 0	96 ± 0	3 ± 0.1	–		
OS2	13/06/2019 10:46	Sub-surface	10.9 ± 0	8 ± 0	52.1 ± 0	97 ± 0	2.1 ± 0	3	0.5 ± 0	9.6
		Mid	10.9 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.9 ± 0.2	8		
		Benthos	10.9 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.6 ± 0.1	7		
		Whole column	10.9 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.5 ± 0.1	–		
OS3	13/06/2019 12:12	Sub-surface	11 ± 0	8 ± 0	52.1 ± 0	97 ± 0	1.7 ± 0.1	4	0.4 ± 0	12.8
		Mid	11.1 ± 0	8 ± 0	52.2 ± 0	96 ± 0	2 ± 0.1	4		
		Benthos	11.1 ± 0	8 ± 0	52.2 ± 0	95 ± 0	2.9 ± 0.1	3		
		Whole column	11 ± 0	8 ± 0	52.2 ± 0	96 ± 0	2.1 ± 0.1	–		
OS4	13/06/2019 12:42	Sub-surface	11.3 ± 0	8 ± 0	52.2 ± 0	97 ± 0	1.9 ± 0	< 3	0.5 ± 0	10.1
		Mid	11.2 ± 0	8 ± 0	52.3 ± 0	96 ± 0	2.5 ± 0.1	8		
		Benthos	11.2 ± 0	8 ± 0	52.3 ± 0	95 ± 0	2.7 ± 0.2	10		
		Whole column	11.2 ± 0	8 ± 0	52.2 ± 0	96 ± 0	2.3 ± 0.1	-		
OS7	13/06/2019 10:26	Sub-surface	10.8 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.3 ± 0	< 3	0.4 ± 0	11.9
		Mid	10.8 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.3 ± 0	7		
		Benthos	10.8 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.3 ± 0	6		
		Whole column	10.8 ± 0	8 ± 0	52.1 ± 0	96 ± 0	2.3 ± 0	–		
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 June 2019 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 40 to 50 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	13/06/2019 14:29	Sub-surface	10.9 ± 0	8 ± 0	52.1 ± 0	99 ± 0	2.1 ± 0	< 3	0.4 ± 0	11.5
		Mid	10.8 ± 0	8 ± 0	52.1 ± 0	97 ± 0	2 ± 0	24		
		Benthos	11.1 ± 0	8 ± 0	52.3 ± 0	96 ± 0	3.6 ± 0.3	7		
		Whole column	10.9 ± 0	8 ± 0	52.1 ± 0	98 ± 0	2.3 ± 0.1	–		
OS6	13/06/2019 11:08	Sub-surface	11.1 ± 0	8 ± 0	52.2 ± 0	97 ± 0	1.8 ± 0	< 3	0.4 ± 0	11.9
		Mid	11.2 ± 0	8 ± 0	52.3 ± 0	96 ± 0	2 ± 0.1	14		
		Benthos	11.2 ± 0	8 ± 0	52.3 ± 0	95 ± 0	3.8 ± 0.2	7		
		Whole column	11.2 ± 0	8 ± 0	52.3 ± 0	96 ± 0	2.2 ± 0.1	–		
SG1	13/06/2019 14:06	Sub-surface	11.2 ± 0	8 ± 0	52.2 ± 0	99 ± 0	1.7 ± 0	3	0.3 ± 0	13.3
		Mid	11 ± 0	8 ± 0	52.2 ± 0	97 ± 0	1.8 ± 0	9		
		Benthos	11.1 ± 0	8 ± 0	52.3 ± 0	94 ± 0	3.8 ± 0.2	6		
		Whole column	11.1 ± 0	8 ± 0	52.2 ± 0	97 ± 0	2.2 ± 0.1	–		
SG2	13/06/2019 13:38	Sub-surface	11.6 ± 0	8 ± 0	52.3 ± 0	98 ± 0	1.7 ± 0	< 3	0.3 ± 0	14.9
		Mid	11.3 ± 0	8 ± 0	52.4 ± 0	97 ± 0	1.3 ± 0	7		
		Benthos	11.3 ± 0	8 ± 0	52.5 ± 0	95 ± 0	4.2 ± 0.4	4		
		Whole column	11.3 ± 0	8 ± 0	52.4 ± 0	97 ± 0	2.2 ± 0.2	–		
SG3	13/06/2019 13:13	Sub-surface	11.5 ± 0	8 ± 0	52.3 ± 0	101 ± 0	0.5 ± 0	< 3	0.3 ± 0	16.4
		Mid	11.4 ± 0	8 ± 0	52.5 ± 0	98 ± 0	1.1 ± 0.1	11		
		Benthos	11.4 ± 0	8 ± 0	52.6 ± 0	95 ± 0	2.9 ± 0.2	5		
		Whole column	11.4 ± 0	8 ± 0	52.4 ± 0	99 ± 0	1.2 ± 0.1	–		
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

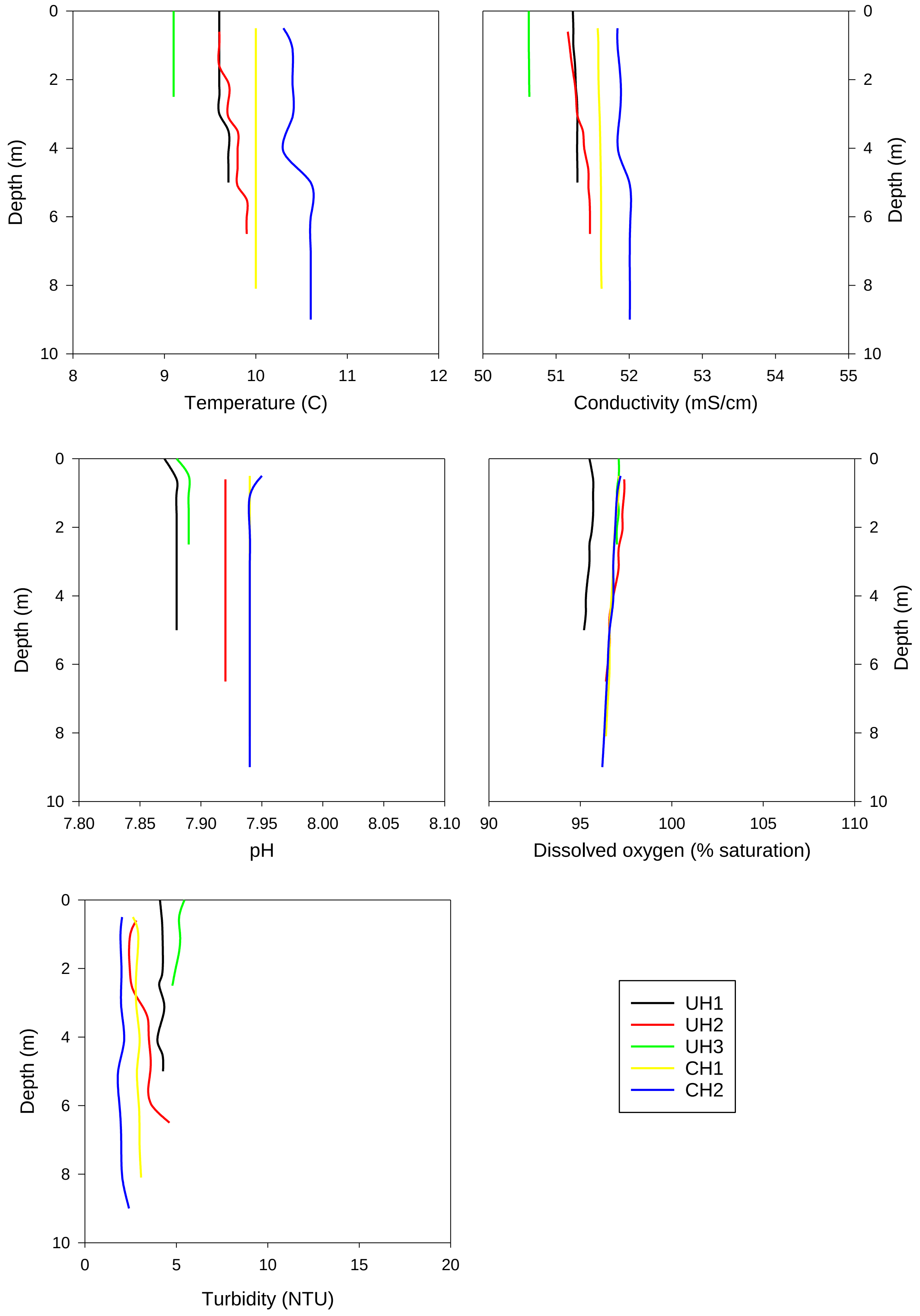


Figure 24 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 13 June 2019.

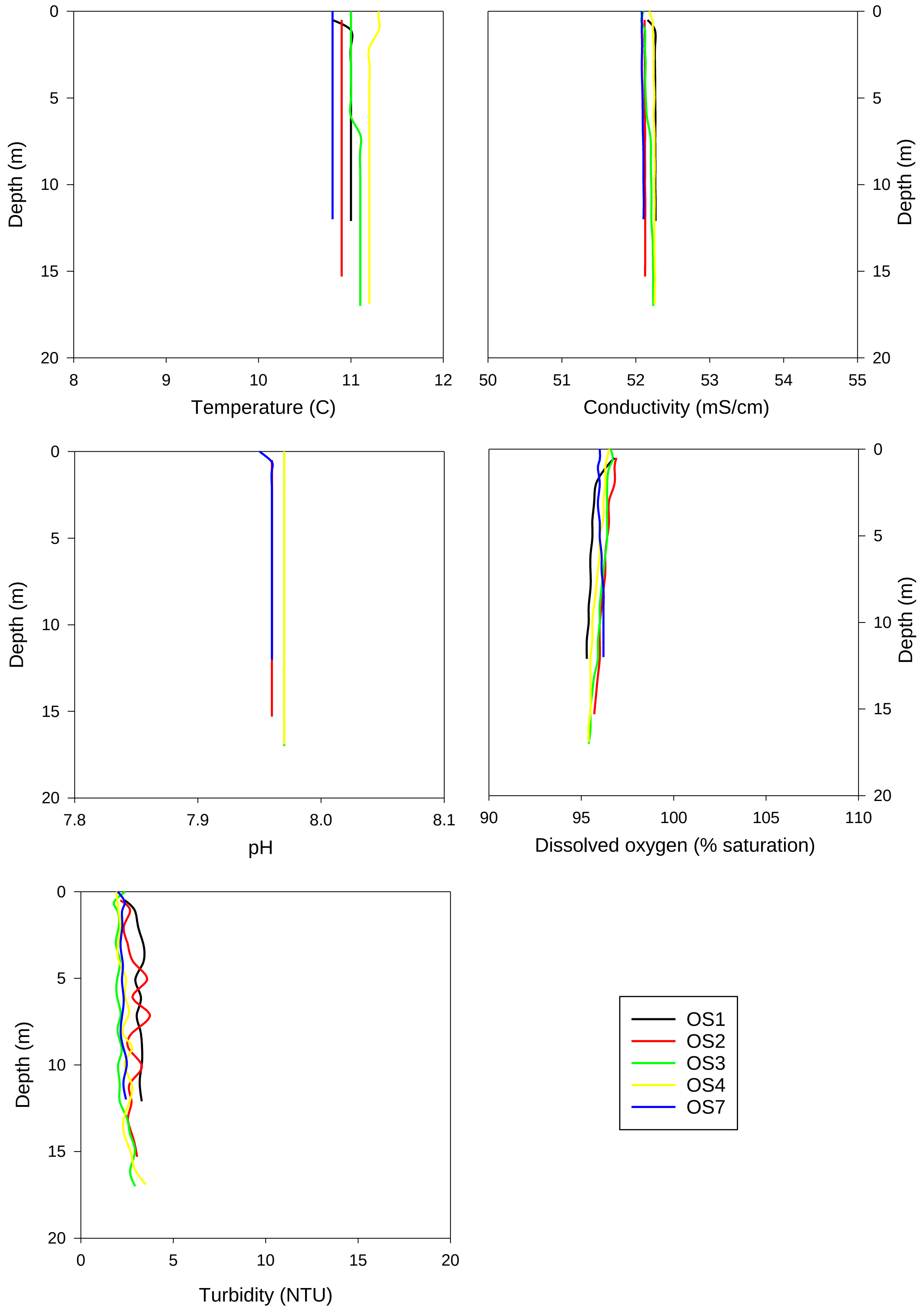


Figure 25 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 13 June 2019.

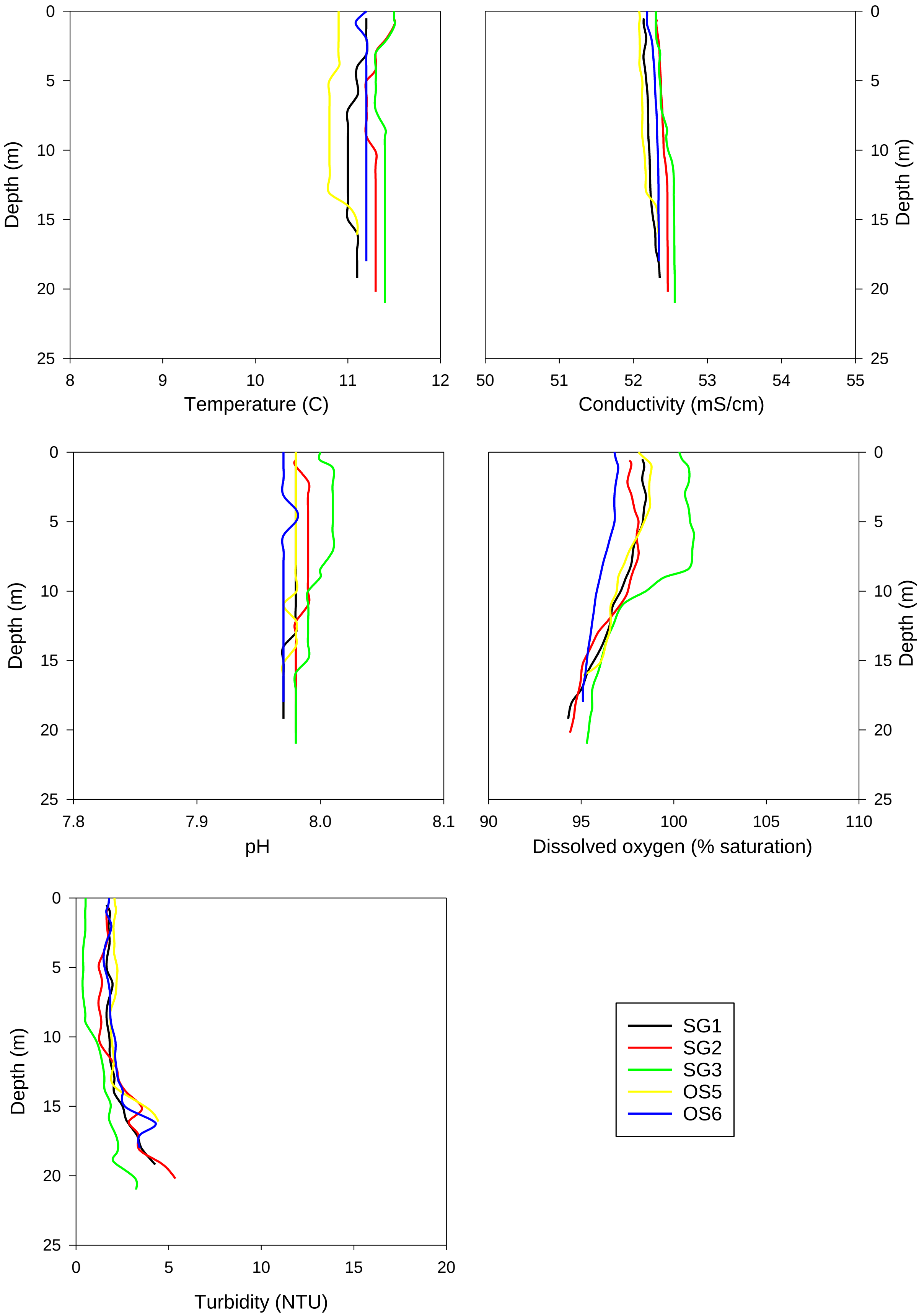


Figure 26 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 13 June 2019.

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 (9 June) were removed from the analyses.

Table 16 Total Daily PAR (TDP) statistics during June 2019.
Values are means ± se (n = 29 to 30). Note data from the BPAR exchange day on 9 June were not utilized in plots or statistics for sites OS2 and OS3.

Site	Depth (m)	TDP (mmol/m²/day)		
		Mean ± se	Median	Range
Base	-	9,060 ± 481	10,300	2,100 – 12,900
OS2	17	144 ± 29	102	<0.01 – 568
OS3	14	179 ± 38	104	<0.01 – 737

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 2,100 to 12,900 mmol/m^2/day (Table 16). This range was somewhat lower than that observed during May (3,300 to 18,400 mmol/m^2/day). The decline in available light is apparent within the monthly mean TDP of only 9,060 mmol/m^2/day (Table 16) c.f. 10,955 mmol/m^2/day recorded during May and continues the trend of shorter daylight hours with the continuing winter months.

The variability in TDP was fairly consistent across the month of June. The late May elevated turbidity continued into early June resulting in low BPAR at both sites. Turbidity decreased at OS3 and resulted in a peak of BPAR on 4 June but not at OS2 where turbidity remained elevated. Both sites displayed similar intermittent BPAR peaks in response to similarly intermittent low turbidity peaks throughout June (Figure 27). At OS2 mean BPAR intensity was recorded as 144 mmol/m^2/day, while mean BPAR at OS3 was slightly higher at 180 mmol/m^2/day.

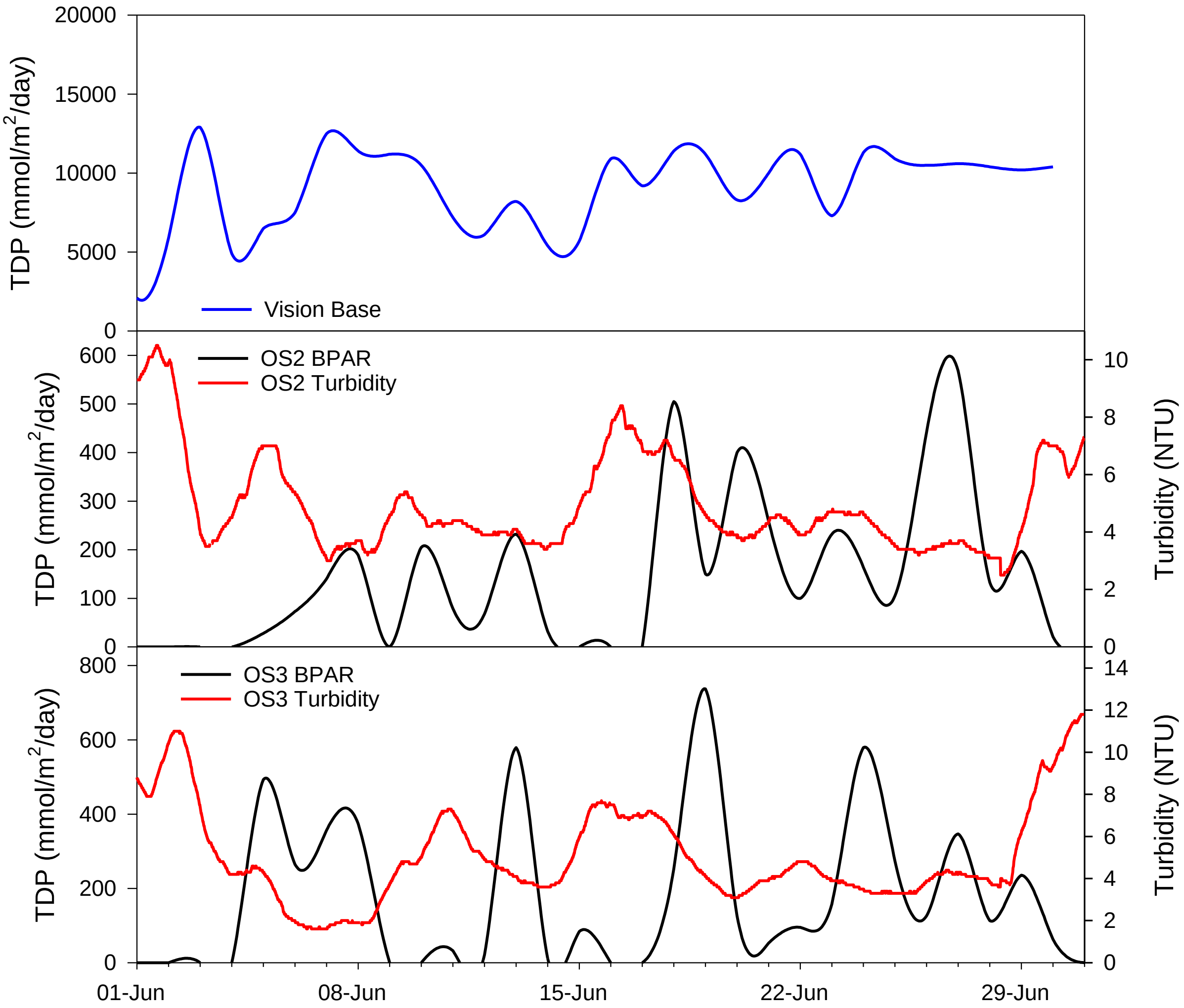


Figure 27 Total daily BPAR at OS2 and OS3 during June 2019 compared to ambient PAR and corresponding surface turbidity (24 hour rolling average).
Note data from the BPAR exchange day on 9 June were not utilized in plots or statistics.

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.

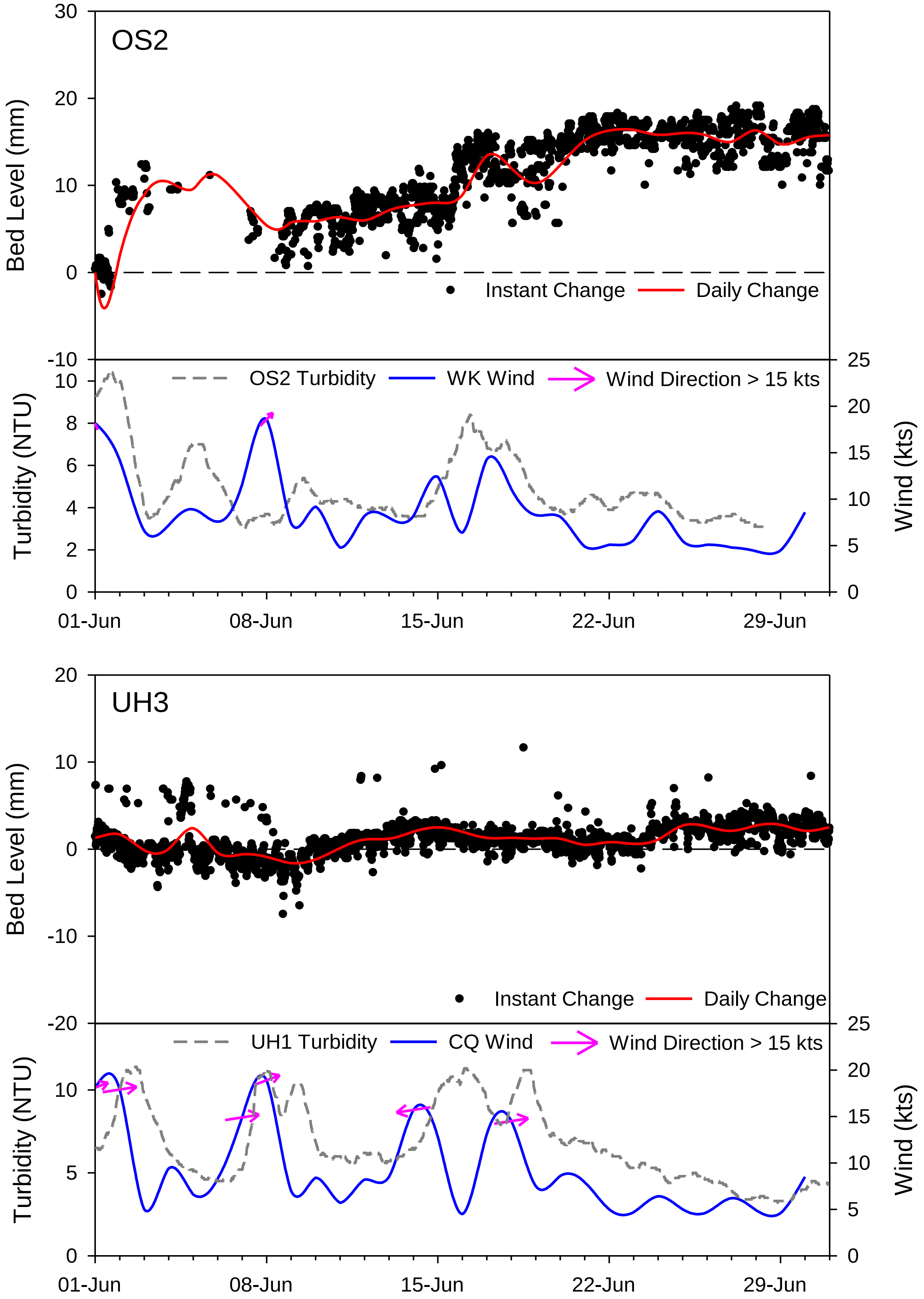


Figure 28 Mean instantaneous and daily averaged bed level change at OS2 and UH3 during June 2019 compared to ambient surface turbidity (24 hour rolling average), wind speed and direction.
Note: Arrows indicate the direction of travel for winds greater than 15 knots.

Limited data was returned from altimeters at OS2 from 2 to 7 June and so interpretation of data for this period should be treated with caution. Bed level at the offshore site OS2 displayed an initial increase in the first few days of June when already raised turbidity levels then declined and bed level then stabilised. Approximately 10 mm of sediment was deposited on the sea bed from 1 to 3 June 2019. Although the period from 2 to 7 June was not recorded, the new recorded bed level on 8 June suggests overall erosion of approximately 5 mm over this period (Figure 28). Bed level then displayed another period of continued deposition in response to the elevated wind speed and wave height event at 18 June. This resulted in an overall accretion of +16 mm for the month of June (Table 17).

As typically observed, bed level within the sheltered upper harbour at UH3 was more stable than that at OS2, with little apparent impact of inshore wind speed on sediment movement (Figure 28). Sediment erosion of 3 mm was noted from the 1 to 8 June which corresponded to the strong south westerly wind events. Following this period UH3 bed level gently increased in response to the inshore winds decreasing after 18 June to allow sediment deposition, as observed at OS2 (Figure 27). These variations over June resulted in a net bed level change of only 2.5 mm (Table 17).

Table 17 Net Bed Level Change statistics from data collected from altimeters deployed at OS2 and UH3 during June 2019.

Site	June 2019 Net bed level change (mm)
OS2	+16
UH3	+2.5

3.6 Water Samples

Discrete water sampling was conducted on 13 June 2019, 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 26 and Table 27 of the Appendix.

3.6.1 Nutrients

Total phosphorous concentrations reported during June 2019 remained below the WQG of 30 µg/L at all sites, with the highest concentrations once again reported in the upper and central harbour (Table 18, Figure 29), as commonly found. Similar to the May sampling, dissolved reactive phosphorous was elevated across the monitoring network, with concentrations ranging from 10.8 to 19.7 µg/L at SG3 and UH3 respectively, in a commonly observed spatial pattern and with values notably above the designated 5 µg/L WQG.

Both total nitrogen and total kjeldahl nitrogen were < LOR at all sites. Total ammonia concentrations were elevated as they were the previous month, with exceedances of the 15 µg/L WQG recorded at all sites except the offshore site SG3. Concentrations of nitrogen oxides were double those previously recorded in May, ranging from 60 to 79 µg/L with all sites exceeding the 15 µg/L WQG. These concentrations are notably higher than recorded in previous months but were similar to June 2018 values, suggesting a seasonal influence.

Table 18 Concentrations of nutrients and chlorophyll *a* at monitoring sites during June 2019.
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	18.4	<300	<200	33	71	1.6
UH2	24	17.5	<300	<200	32	69	1.5
UH3	29	19.7	<300	<200	35	73	2.3
CH1	22	16.5	<300	<200	32	67	1.8
CH2	19	16.1	<300	<200	25	69	1.9
OS1	23	16.8	<300	<200	26	72	1.5
OS2	21	16.7	<300	<200	25	76	1.4
OS3	22	15.3	<300	<200	18	79	0.9
OS4	18	15.2	<300	<200	18	78	0.8
OS5	23	16	<300	<200	29	73	1.6
OS6	19	14.6	<300	<200	17	77	0.9
OS7	20	16.5	<300	<200	31	77	1.3
SG1	24	14.6	<300	<200	21	76	0.9
SG2	19	13.9	<300	<200	21	72	0.8
SG3	17	10.8	<300	<200	11	60	1.3
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

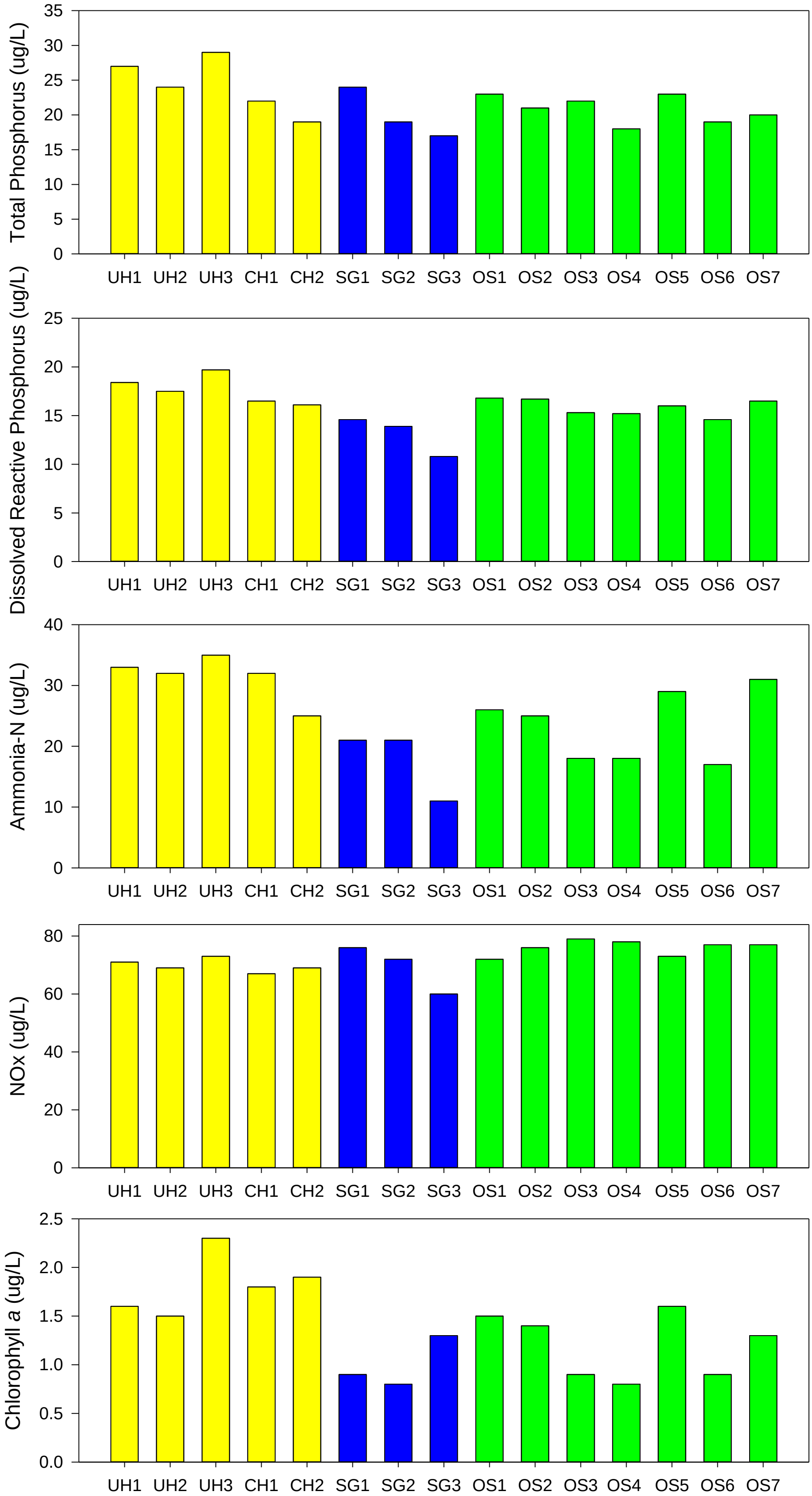


Figure 29 Nutrient and chlorophyll *a* concentrations at monitoring sites during June 2019.
Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were < LOR.

Concentrations of chlorophyll a, an indicator of phytoplankton biomass remained low and below the WQG (4 µg/L) at all sites (Table 18).

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), cobalt (<0.6 µg/L), lead (<1 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 µg/L). Contrasting previous months, concentrations of total copper which was above the WQG at UH3 in May was once again below the WQG (1.3 µg/L) (Tables 19 to 21).

As commonly observed, total aluminium concentrations were reported above the WQG of 24 µg/L at all sites across the monitoring network, except for SG3 (note that this WQG is designated for concentrations of the more readily available dissolved aluminium fraction). Concentrations of the more bioavailable dissolved aluminium fraction were all below LOR (<12 µg/L) (Tables 19 to 21, Figure 30). No other metal exceedances occurred during June 2019.

Despite not having assigned WQGs, particulate iron has regularly been reported at elevated concentrations within Lyttelton Harbour during the baseline monitoring. The greatest concentrations of total iron were recorded in the central harbour (220 µg/L) and declined with increasing distance offshore with the lower concentrations (<40 µg/L) at the spoil ground (Figure 30). Dissolved iron concentrations were once again low (<4 µg/L) indicating that iron was predominantly present in the particulate phase, and thus not readily available for biological uptake (Tables 19 to 21).

Total and dissolved chromium was above LOR at all sites, except OS1 where dissolved chromium was below LOR (<1 µg/L). Dissolved manganese concentrations were below LOR (<1 µg/L) at SG3 (Tables 19 to 21) in a similar spatial trend to May. Higher concentrations of total manganese were reported at all sites with a decreasing gradient from the inner harbor to offshore and spoil ground sites as commonly observed (Figure 31).

Consistent with previous monitoring reports, molybdenum concentrations which were recorded at all sites during June, displayed little spatial variation across the inshore and offshore monitoring network (Figure 31). Given the similarity between the dissolved and total metal concentrations, molybdenum present in the dissolved phase (Tables 19 to 21 and Figure 31) would be readily dispersed across the region. Concentrations of total and dissolved vanadium displayed a similar pattern to that of molybdenum, with equal or higher proportions of vanadium also present in the dissolved phase (Figure 31).

It should be noted that total chromium was detected in the field and laboratory blank at concentrations above the laboratory LOR, suggesting contamination of the laboratory supplied water (Table 26). Concentrations of dissolved vanadium were slightly higher than total vanadium at six sites suggesting sample water heterogeneity (Table 19 to 21).

Table 19 *Total and dissolved metal concentrations at inshore monitoring sites during June 2019.* 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	53	65	155	70	34	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.3	<4.3	<4.3	<4.3	<4.3	
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	1.6	1.8	1.3	1.5	1.9	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.3	2.2	2.3	1.9	2.1	
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	1.2	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	8	<4	<4	<4	-
	Total	176	78	220	99	39	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	4.7	4.1	4.3	3.5	2.7	-
	Total	6	6.3	8.5	5.4	2.9	
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	10.8	10.6	10.8	11	11.3	-
	Total	11	11	10.7	11.5	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	<0.4	<0.4	<0.4	<0.4	<0.4	
Tin	Dissolved	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.5	1.9	1.9	1.9	1.8	100
	Total	1.8	2	2.1	1.9	1.7	
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 June 2019. *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	62	49	44	39	38	38	49	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.3	<4.3	<4.3	<4.3	<4.3	<4.3	<4.3	
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	1.9	2.1	2.3	1.8	1.6	1.3	Cr(III) 27.4 Cr(VI) 4.4
	Total	2	2.2	2.1	1.6	1.3	2.6	1.6	
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	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	14	7	<4	<4	<4	<4	-
	Total	139	148	47	45	56	101	127	
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	1.4	1.7	1.7	1.3	1.3	1.2	2	-
	Total	3.5	3.6	2.6	2.1	2.7	2.2	3.5	
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	11.1	11	11.1	11.4	10.9	10.5	-
	Total	11.7	11.7	11.5	11.6	11.4	11.2	11.2	
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	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	
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	1.8	1.8	1.8	2.1	1.9	1.7	<1	100
	Total	2.1	1.5	2	1.7	1.9	1.2	1.7	
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 June 2019. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	31	24	<13	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4.3	<4.3	<4.3	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	
Chromium	Dissolved	1.7	1.6	1	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.9	2.1	1.5	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	
Iron	Dissolved	5	<4	<4	-
	Total	39	36	14.8	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.8	1.3	<1	-
	Total	2.7	2.3	1.2	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.4	10.6	11.3	-
	Total	11.5	11.8	11.6	
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	<0.4	<0.4	<0.4	
Tin	Dissolved	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.7	2.1	1.8	100
	Total	2.1	1.8	1.2	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

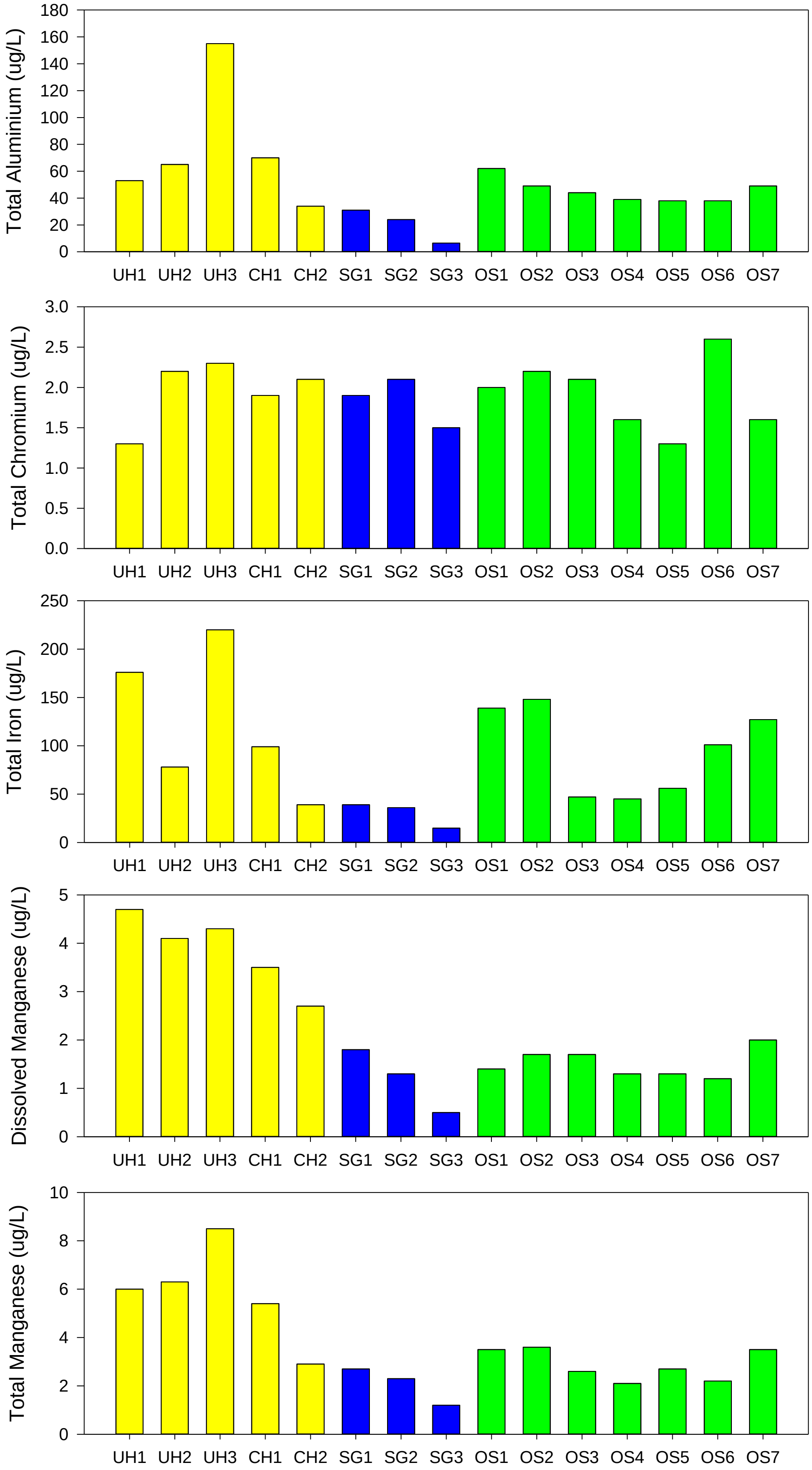


Figure 30 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during June 2019.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

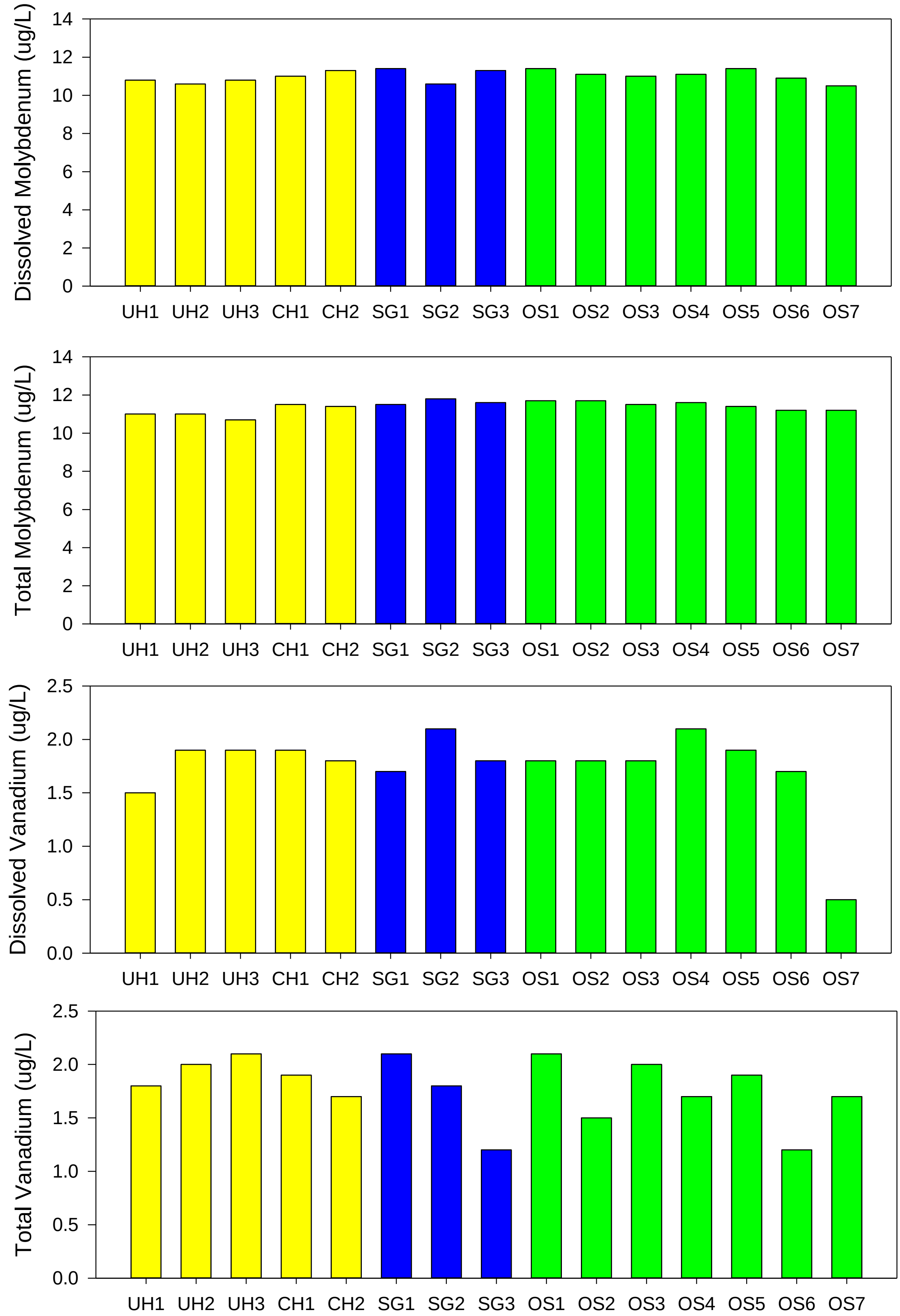


Figure 31 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during June 2019.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

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), except for one LOR value. The one exception is oxyfluorfen at OS6 which recorded an LOR value (0.02 µg/L). The below LOR values has been a consistent finding throughout the monitoring project.

It should be noted that toluene recorded values for the field and laboratory blanks (Table 27), but all site samples recorded values below LOR (Table 19).

Table 22 Organic compound concentrations at monitoring sites during June 2019.

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)	<0.04	<0.04	<0.04	<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-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)	<0.04	<0.04	<0.04	<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-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)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
4,4'-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

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
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	<0.005	<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
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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
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

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
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
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	<0.3	<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
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	<0.08	<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
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

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
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
Dicofol	<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
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

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
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
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	<0.08	<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
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

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
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
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

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
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
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)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
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	<0.3	<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
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

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
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
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

Parameter (µg/L)	**Site**														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
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

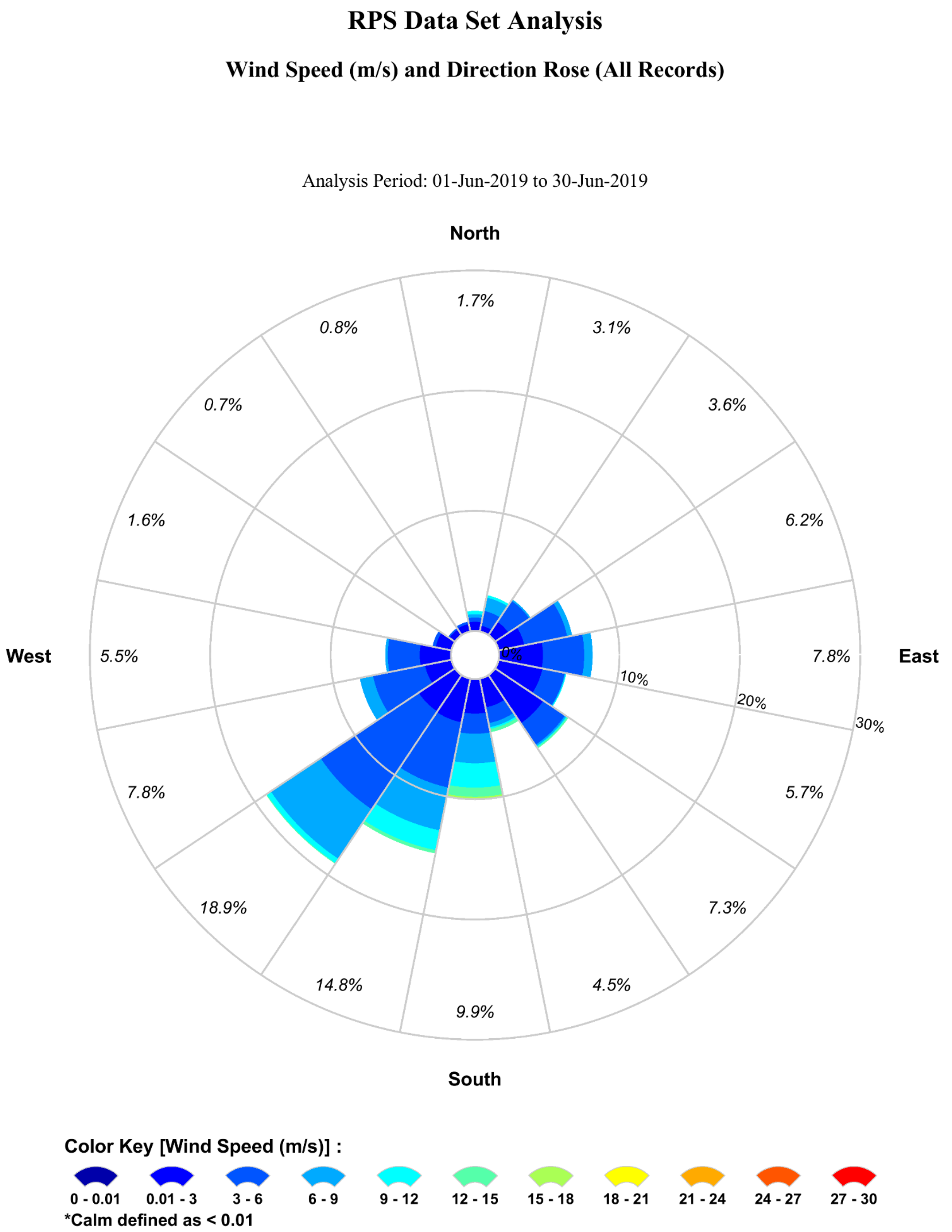

Figure 32 WatchKeeper wind speed (m/s) and direction rose (%) during June 2019.

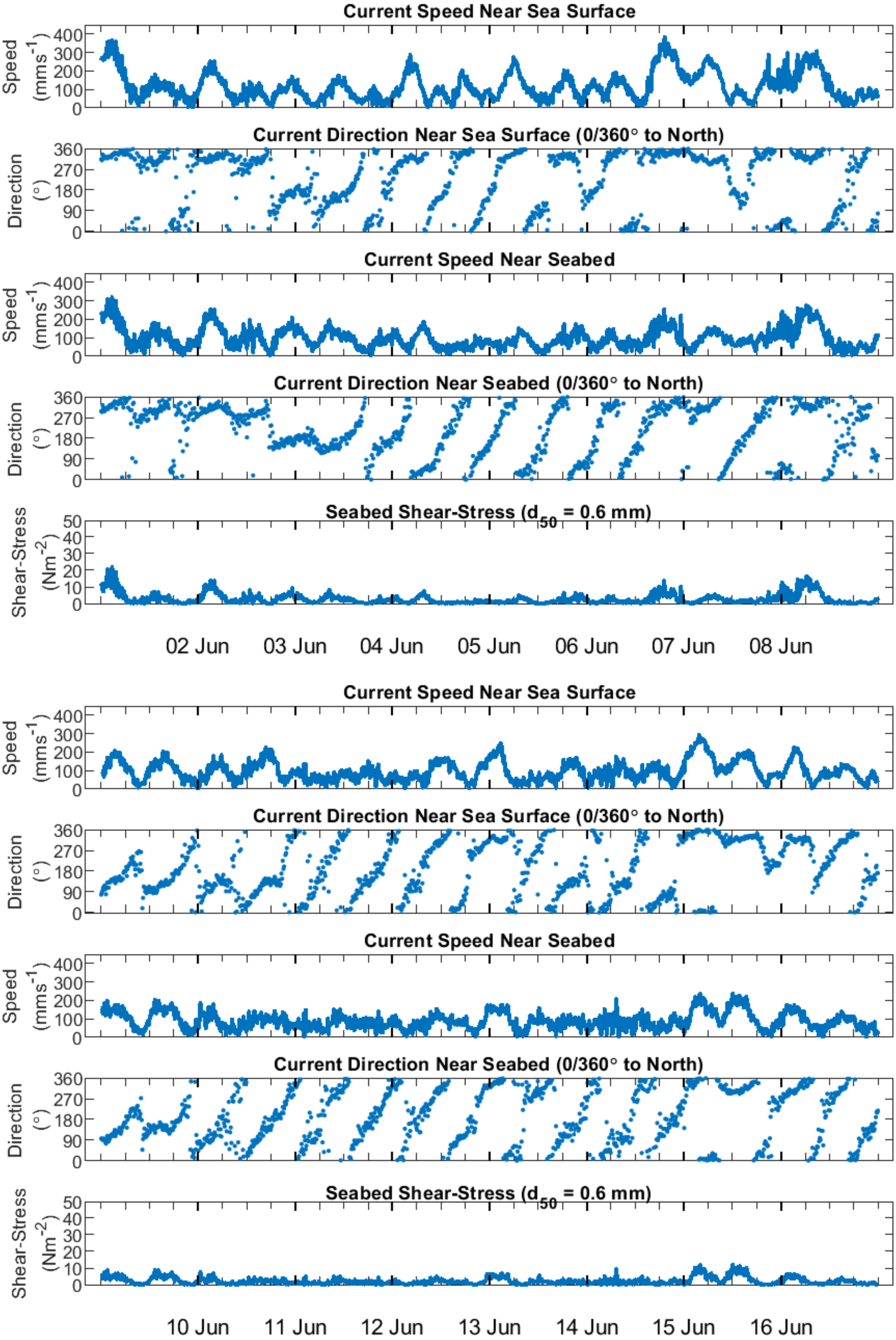

Figure 33 SG1 current speed, direction and shear bed stress 1 to 16 June 2019.

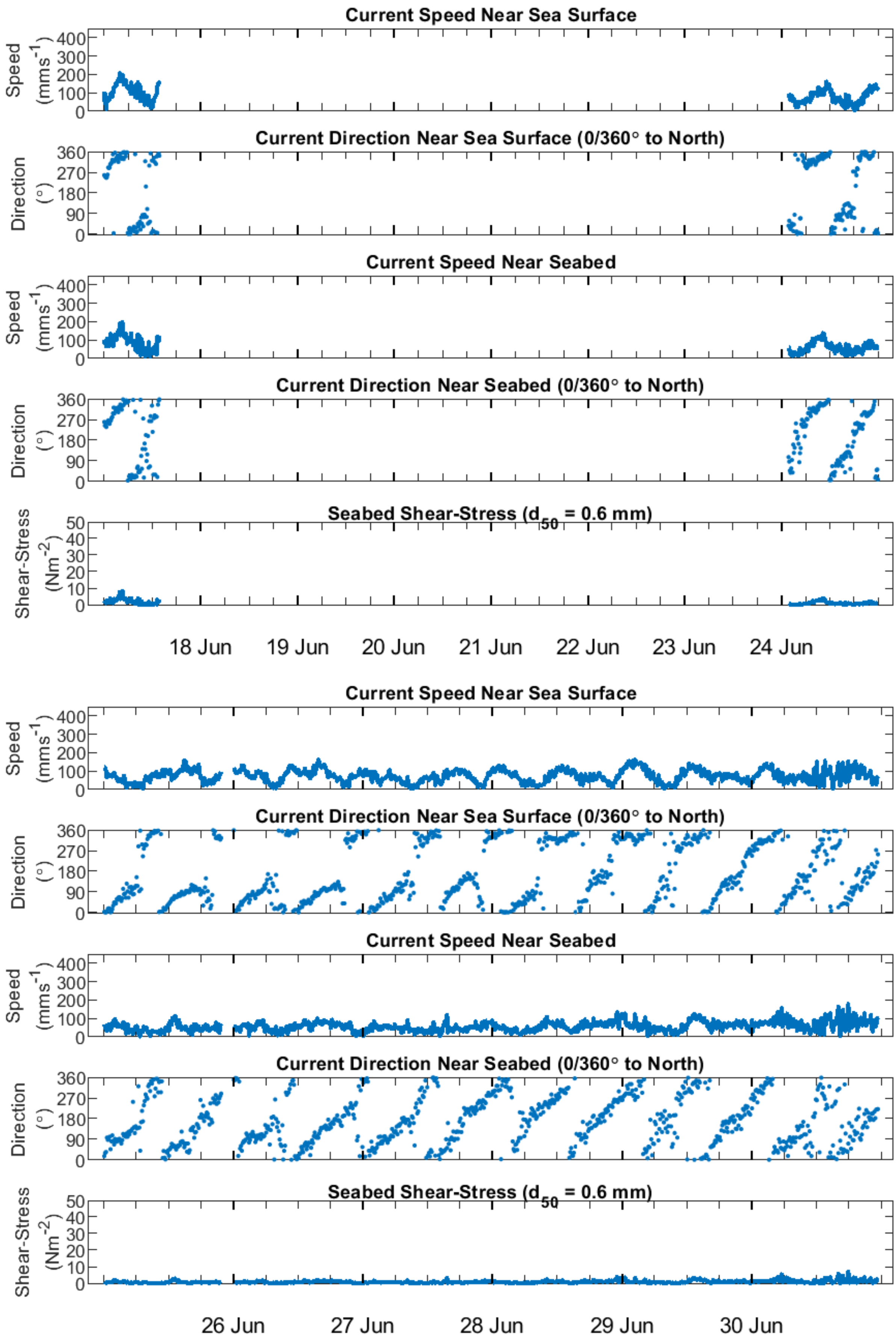

Figure 34 SG1 current speed, direction and shear bed stress 17 to 30 June 2019.

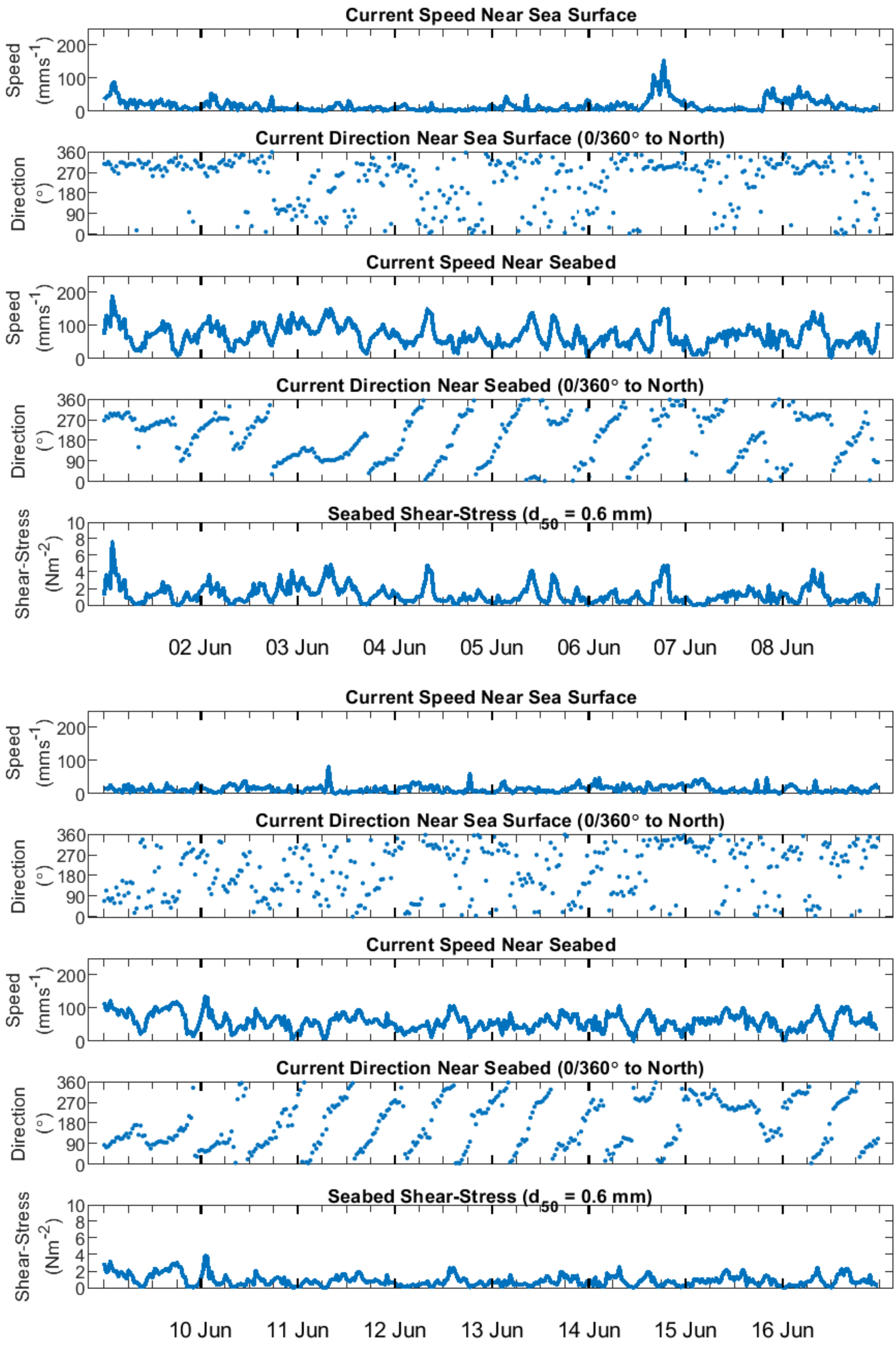

Figure 35 SG2a (WatchKeeper) current speed, direction and shear bed stress 1 to 16 June 2019.

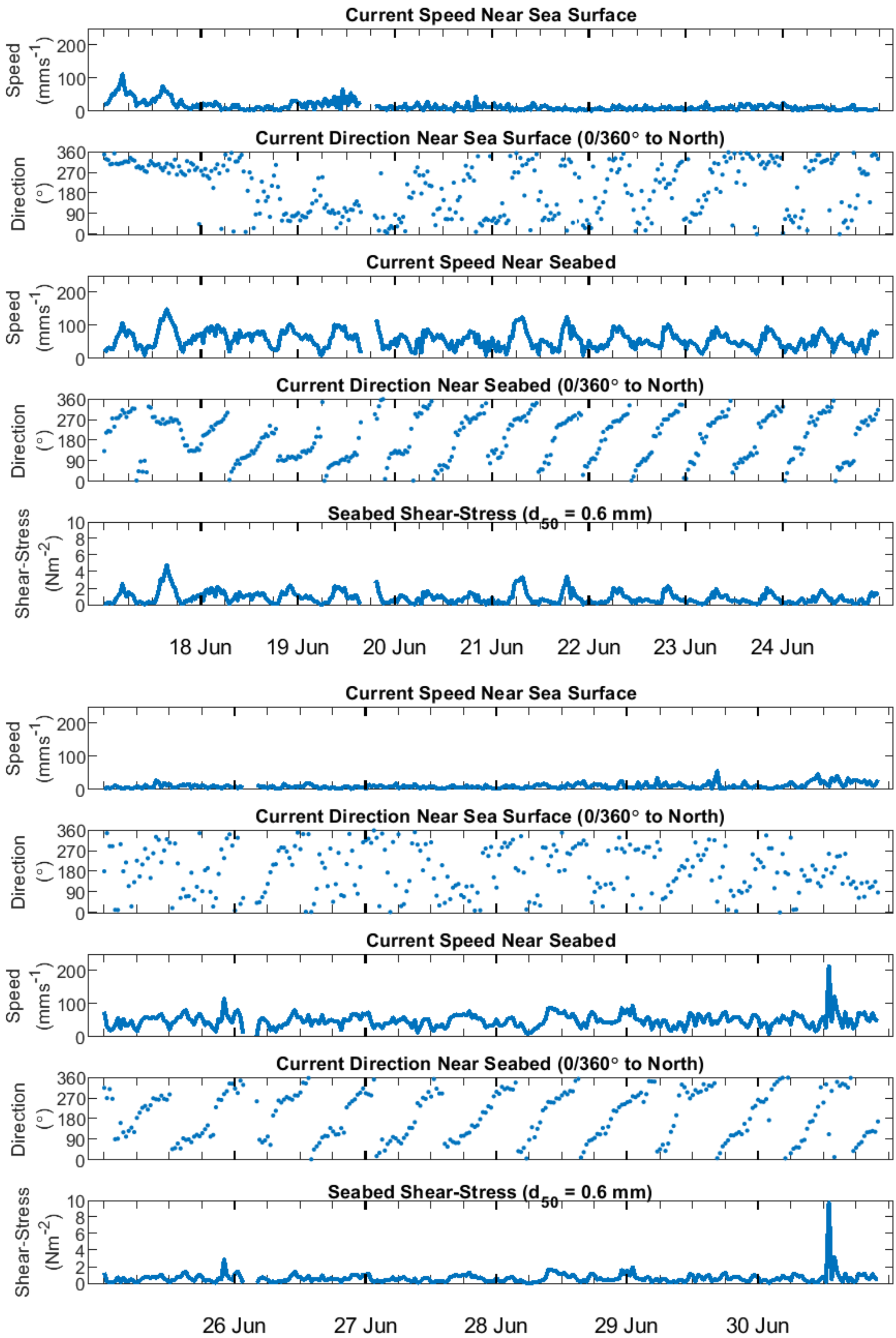

Figure 36 SG2a (WatchKeeper) current speed, direction and shear bed stress 17 to 30 June 2019.

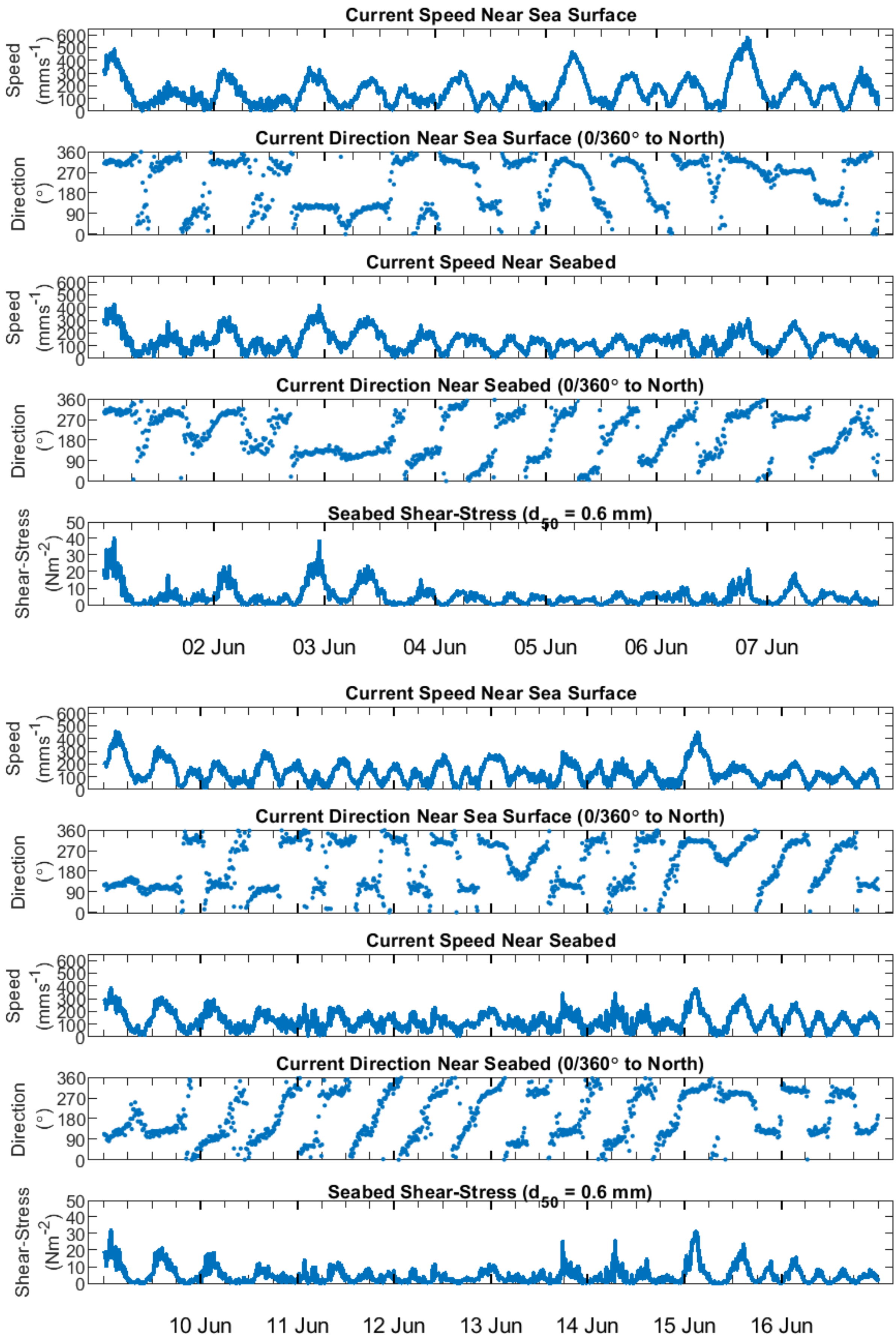

Figure 37 SG3 current speed, direction and shear bed stress 1 to 16 June 2019.

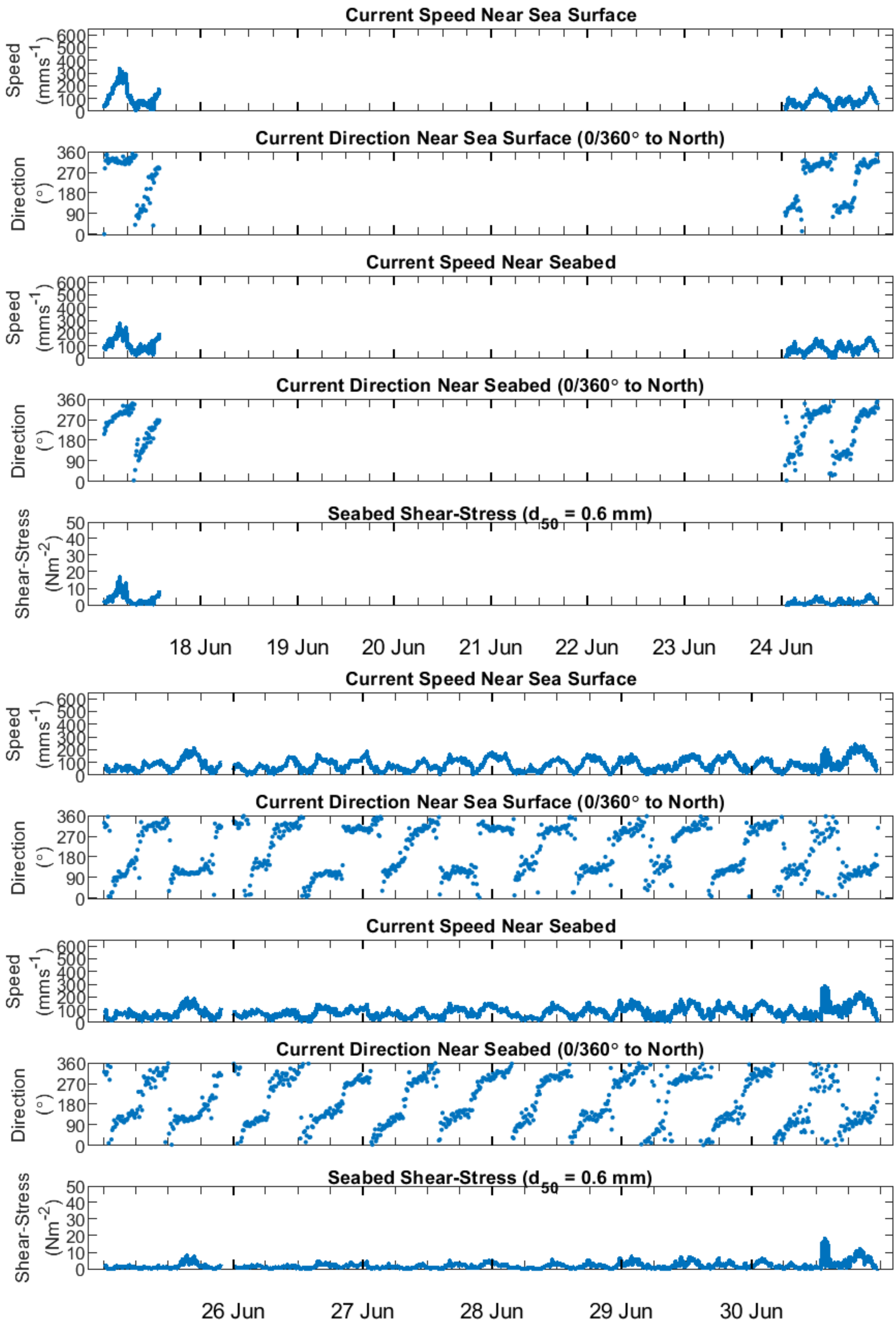

Figure 38 SG3 current speed, direction and shear bed stress 17 to 30 June 2019.

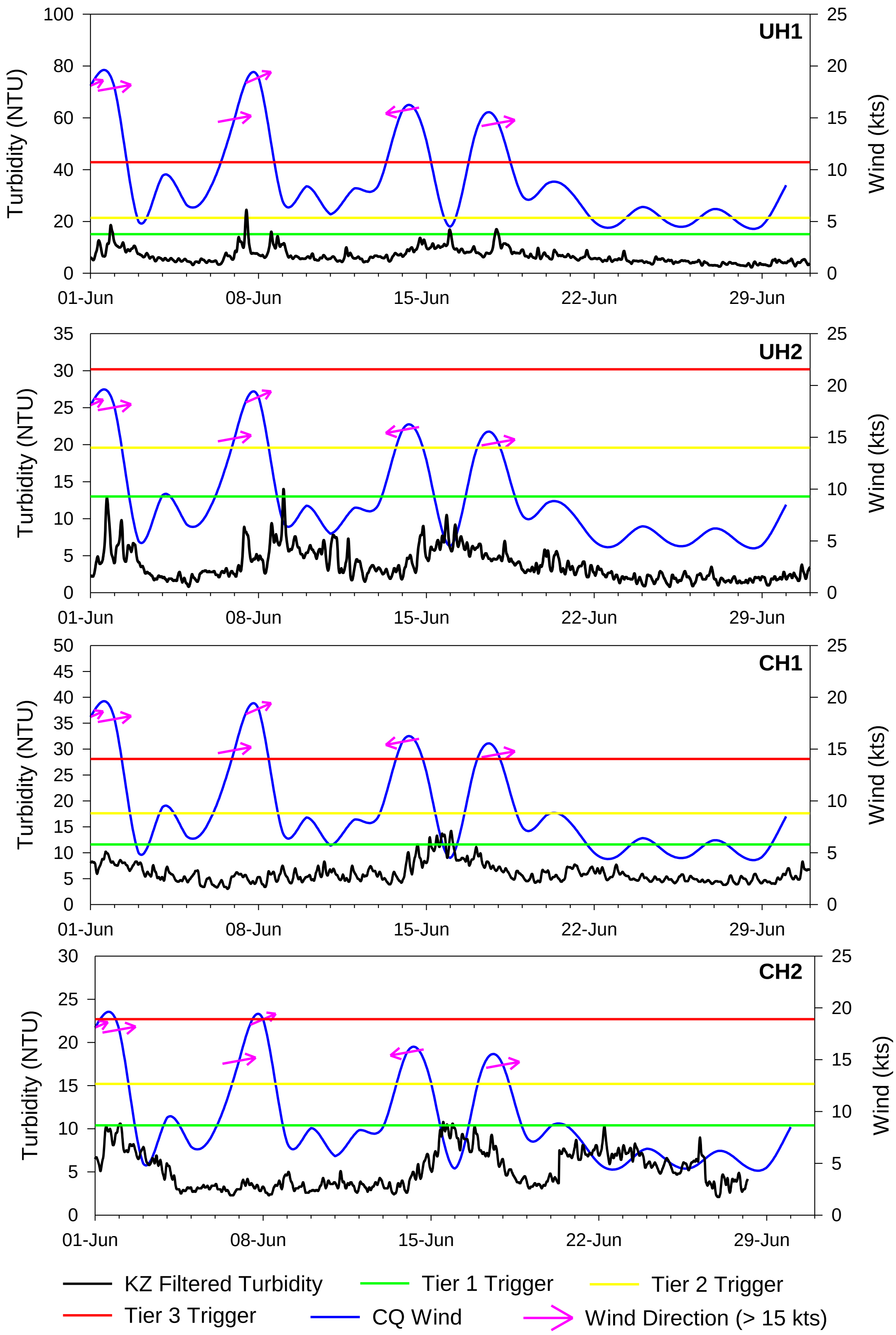

Figure 39 Surface KZ filtered turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during June 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for inshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

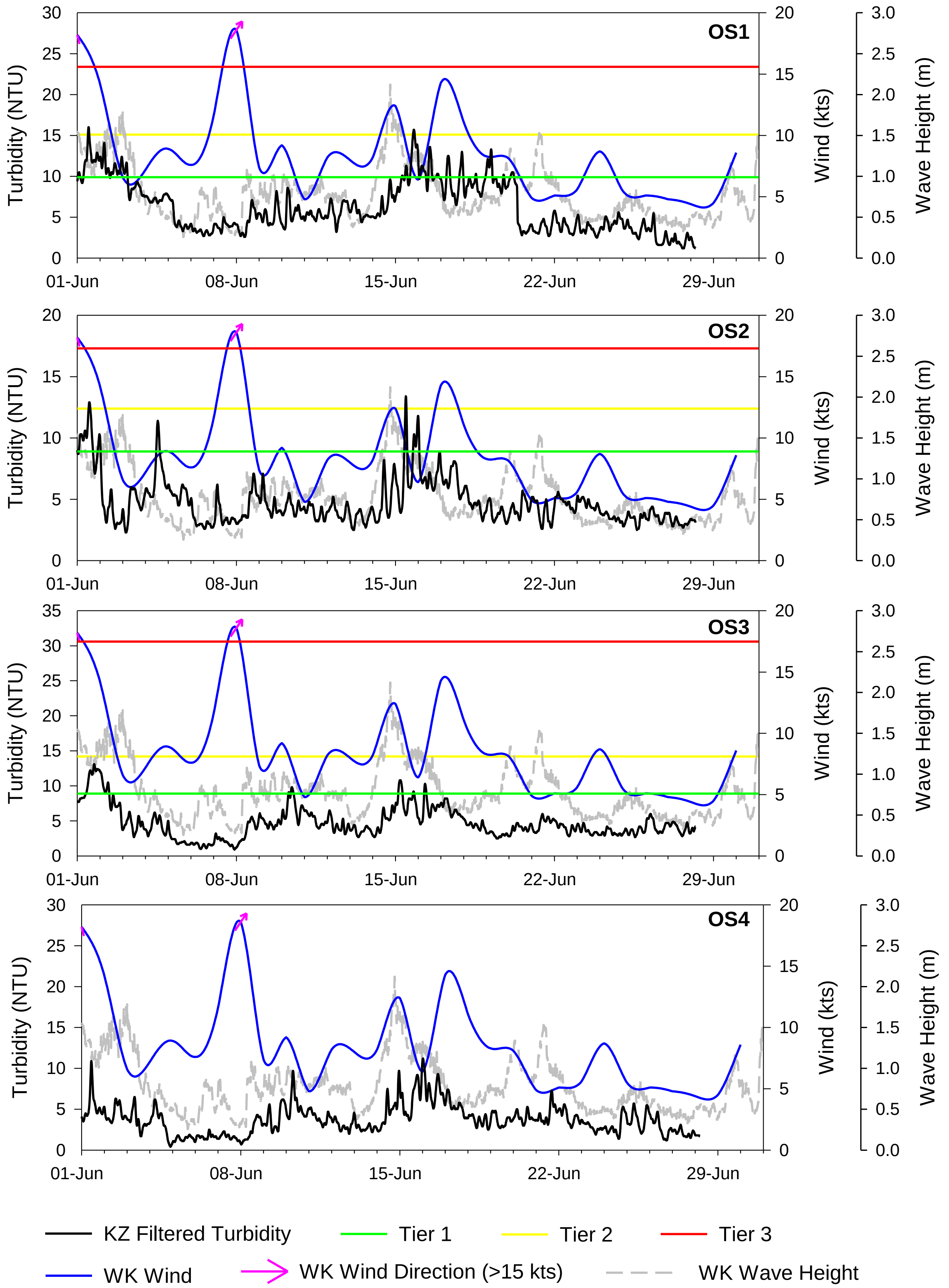

Figure 40 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS1 to OS4) during June 2019.

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.

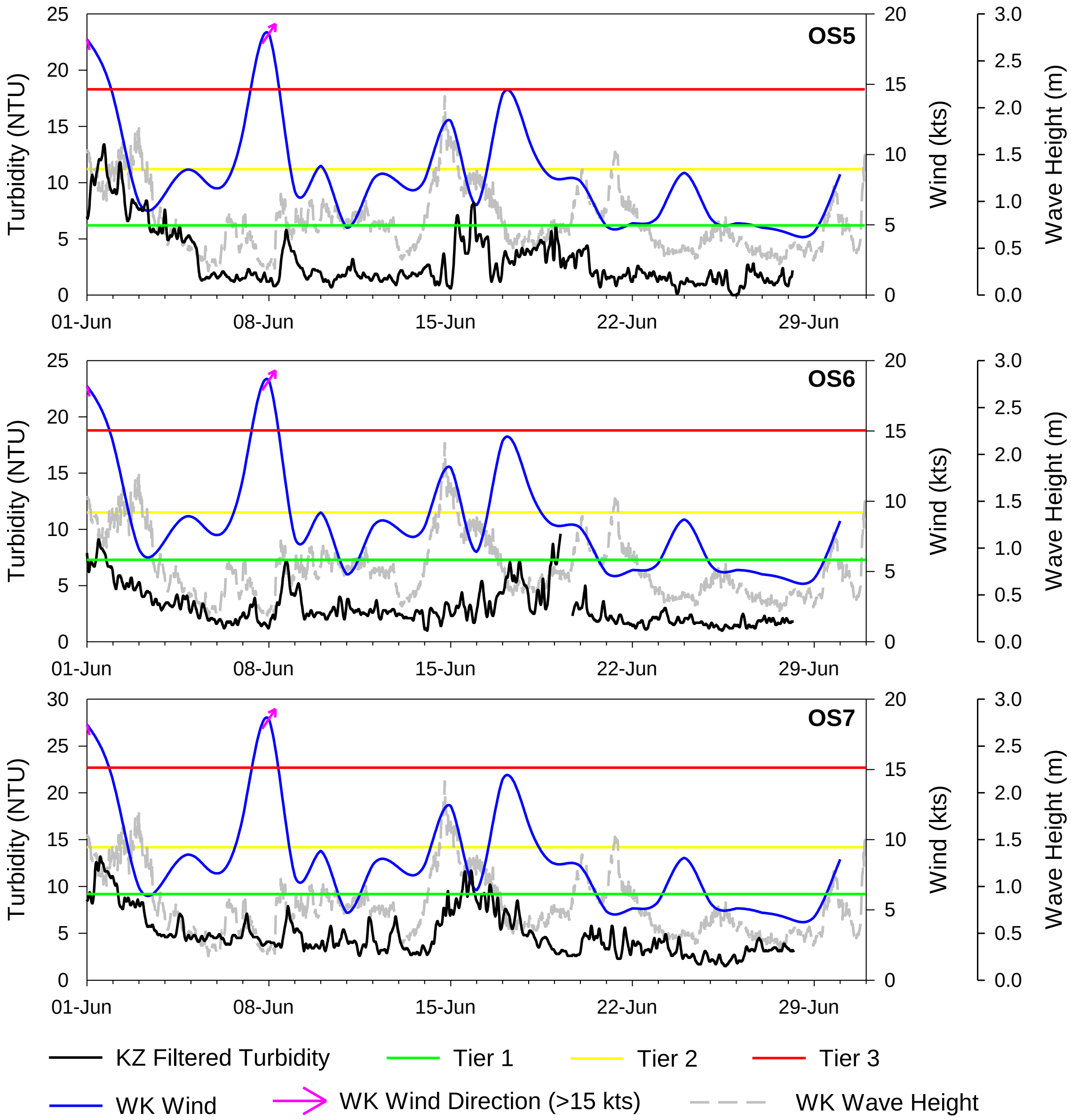

Figure 41 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS5 to OS7) during June 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

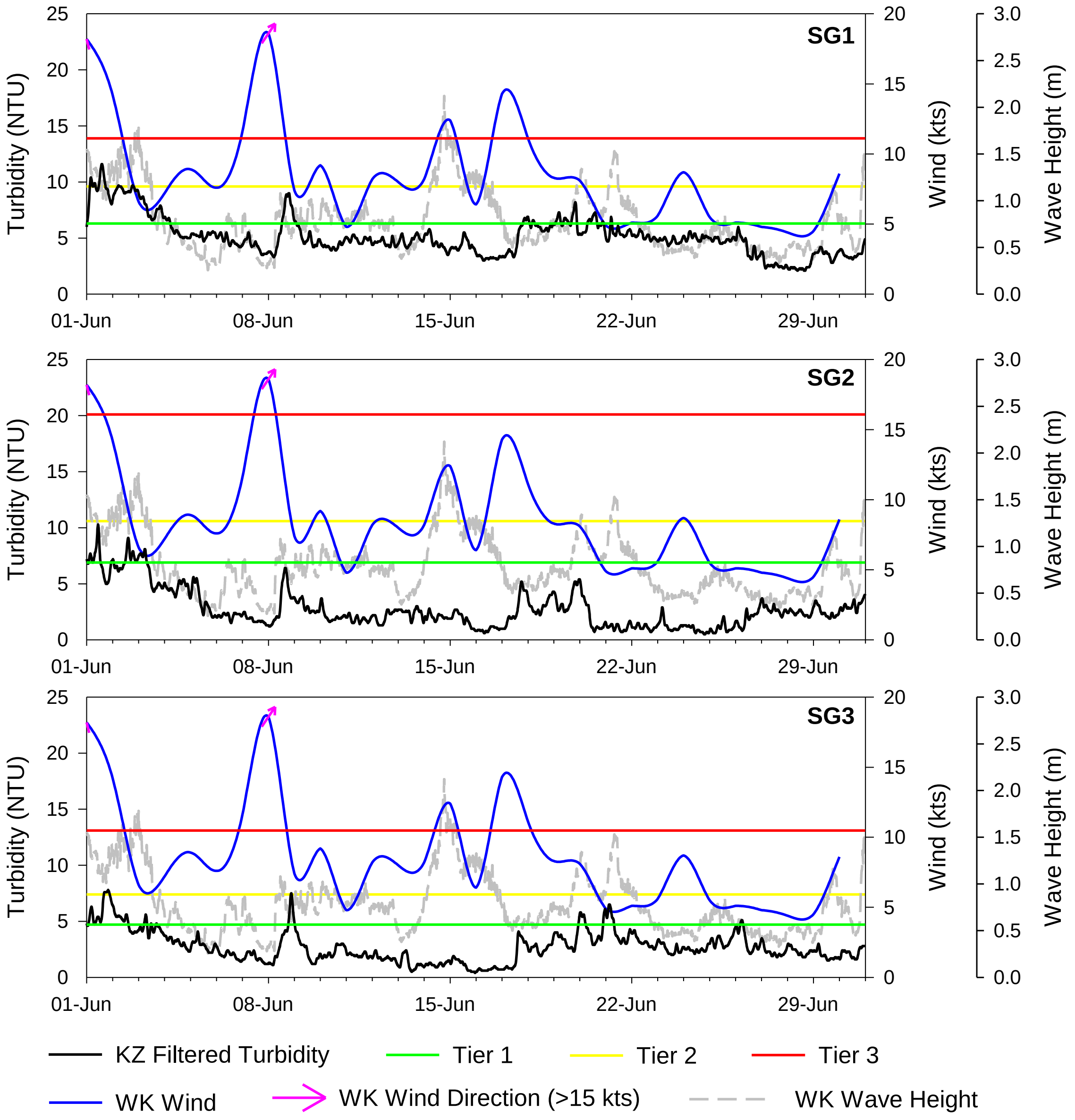

Figure 42 Surface KZ filtered turbidity and daily averaged winds at the spoil ground sites (SG1 to SG3) during June 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

Table 23 Mean KZ filtered turbidity and statistics at inshore water quality logger sites during June 2019 and baseline period 1 November 2016 to 31 October 2017
Values for June are means ± se, range and percentiles (n = 2613 to 2880). Baseline values modified from Fox 2018.

Site		KZ Filtered Turbidity (NTU)	
	Statistic	Surface June	Surface Baseline
UH1	Mean ± se	6.7 ± 0.1	12
	Range	2 – 25	2 – 155
	99th	17	37
	95th	12	21
	80th	9	15
UH2	Mean ± se	3.7 ± 0.0	9.9
	Range	<1 – 14	2 – 59
	99th	10	29
	95th	7.6	19
	80th	5.5	13
CH1	Mean ± se	6.0 ± 0.0	8.8
	Range	3 – 14	<1 – 50
	99th	13	27
	95th	10	17
	80th	7.2	12
CH2	Mean ± se	5.2 ± 0.0	7.6
	Range	2 – 11	<1 – 39
	99th	10.3	22
	95th	9.4	15
	80th	7.2	10

Table 24 Mean KZ filtered turbidity and statistics at spoil ground water quality logger sites during June 2019 and baseline period 1 November 2016 to 31 October 2017.
Values for June are means ± se, range and percentiles (n = 2880). Baseline values modified from Fox 2018.

Site		KZ Filtered Turbidity (NTU)	
	Statistic	Surface June	Surface Baseline
SG1	Mean ± se	5.1 ± 0.0	4.2
	Range	2 – 12	<1 – 31
	99th	10	14
	95th	9.1	9.5
	80th	6.1	6.1
SG2	Mean ± se	2.7 ± 0.0	4.6
	Range	<1 – 10	<1 – 33
	99th	8	20
	95th	6.8	10
	80th	3.7	6.9
SG3	Mean ± se	2.7 ± 0.0	3.6
	Range	<1 – 8	<1 – 22
	99th	7.2	13
	95th	5.4	7.3
	80th	3.7	4.7

Table 25 Mean KZ filtered turbidity and statistics at offshore water quality logger sites during June 2019 and baseline period 1 November 2016 to 31 October 2017.
Values for June are means ± se, range and percentiles (n = 2570 to 2613). Baseline values modified from Fox 2018.

Site	Statistic	KZ Filtered Turbidity (NTU) Surface June	Surface Baseline
OS1	Mean ± se	6.2 ± 0.1	7.5
	Range	1 – 16	<1 – 99
	99th	14	23
	95th	12	15
	80th	9.3	9.7
OS2	Mean ± se	4.7 ± 0.0	6.4
	Range	<2 – 13	<1 – 36
	99th	11	17
	95th	9.0	12
	80th	5.8	8.9
OS3	Mean ± se	4.7 ± 0.0	6.5
	Range	1 – 13	<1 – 110
	99th	12	27
	95th	9.1	14
	80th	6.1	8.9
OS4	Mean ± se	3.7 ± 0.0	5.9
	Range	<1 – 11	<1 – 35
	99th	9.4	18
	95th	7.0	13
	80th	5.0	8.1
OS5	Mean ± se	3.0 ± 0.0	4.6
	Range	<1 – 13	<1 – 35
	99th	12	18
	95th	8.5	11
	80th	4.7	6.1
OS6	Mean ± se	3.0 ± 0.0	4.7
	Range	<1 – 10	<1 – 37
	99th	8.3	18
	95th	6.8	11
	80th	4.1	7.1
OS7	Mean ± se	4.9 ± 0.0	6.3
	Range	2 – 13	<1 – 48
	99th	12	22
	95th	9.6	14
	80th	6.5	9.1

Table 26 Summary of Vision Environment quality control data for June 2019 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		
			UH2 (A) (µg/L)	UH2 (B) (µg/L)	Variation (%)
TSS	<3	<3	8	5	46
Dissolved Aluminium (ug/l)	<3	<3	<12	<12	ND
Total Aluminium (ug/l)	<3.2	<3.2	65	66	2
Dissolved Arsenic (ug/l)	<1	<1	<4	<4	ND
Total Arsenic (ug/l)	<1.1	<1.1	<4.2	<4.2	ND
Dissolved Cadmium (ug/l)	<0.05	<0.05	<0.2	<0.2	ND
Total Cadmium (ug/l)	<0.053	<0.053	<0.21	<0.21	ND
Dissolved Chromium (ug/l)	<0.5	<0.5	1.8	1.8	0
Total Chromium (ug/l)*	0.77	0.65	2.2	2.7	20
Dissolved Cobalt (ug/l)	<0.2	<0.2	<0.6	<0.6	ND
Total Cobalt (ug/l)	<0.21	<0.21	<0.63	<0.63	ND
Dissolved Copper (ug/l)	<0.5	<0.5	<1	<1	ND
Total Copper (ug/l)	<0.53	<0.53	<1.1	<1.1	ND
Dissolved Iron (ug/l)	<20	<20	8	<4	ND
Total Iron (ug/l)	<21	<21	78	82	5
Dissolved Lead (ug/l)	<0.1	<0.1	<1	<1	ND
Total Lead (ug/l)	<0.11	<0.11	<1.1	<1.1	ND
Dissolved Manganese (ug/l)	<0.5	<0.5	4.1	4	2
Total Manganese (ug/l)	<0.53	<0.53	6.3	4.9	25
Dissolved Mercury (ug/l)	<0.08	<0.08	<0.08	<0.08	ND
Total Mercury (ug/l)	<0.08	<0.08	<0.08	<0.08	ND
Dissolved Molybdenum (ug/l)	<0.2	<0.2	10.6	10.7	1
Total Molybdenum (ug/l)	<0.21	<0.21	11	11.4	4
Dissolved Nickel (ug/l)	<0.5	<0.5	<7	<7	ND
Total Nickel (ug/l)	<0.53	<0.53	<7	<7	ND
Dissolved Selenium (ug/l)	<1	<1	<4	<4	ND
Total Selenium (ug/l)	<1.1	<1.1	<4.2	<4.2	ND
Dissolved Silver (ug/l)	<0.1	<0.1	<0.4	<0.4	ND
Total Silver (ug/l)	<0.11	<0.11	<0.43	<0.43	ND
Dissolved Tin (ug/l)	<0.5	<0.5	<5	<5	ND
Total Tin (ug/l)	<0.53	<0.53	<5.3	<5.3	ND
Dissolved Vanadium (ug/l)	<1	<1	1.9	1.8	5
Total Vanadium (ug/l)	<1.1	<1.1	2	1.7	16
Dissolved Zinc (ug/l)	<1	<1	<4	<4	ND
Total Zinc (ug/l)	<1.1	<1.1	<4.2	<4.2	ND
Total Phosphorus (ug/l)	<4	<4	24	27	12
Dissolved Reactive Phosphorus (ug/l)	<4	<4	17.5	17.7	1
Total Nitrogen (ug/l)	<110	<110	<300	<300	ND
Total Kjeldahl Nitrogen (TKN) (ug/l)	<100	<100	<200	<200	ND
Total Ammonia (ug/l)	<10	<10	32	33	3
Nitrate-N + Nitrite-N (ug/l)	<2	<2	69	73	6
Chlorophyll a (ug/L)	<0.2	<0.2	1.5	1.6	6

Table 27 Summary of Vision Environment quality control data for June 2019 water organic sampling.
*ND = not determined as one or more samples was below LOR. * 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		
			UH 2 (A) (µg/l)	UH 2 (B) (µg/l)	Variation (%)
C7 - C9	<60	<60	<60	<60	ND
C10 - C14	<200	<200	<200	<200	ND
C15 - C36	<400	<400	<400	<400	ND
Total hydrocarbons (C7 - C36)	<700	<700	<700	<700	ND
Benzene	<1	<1	<1	<1	ND
Toluene*	2.2	2	<1	<1	ND
Ethylbenzene	<1	<1	<1	<1	ND
2,3,4,6-Tetrachlorophenol (TCP)	<0.04	<0.04	<0.04	<0.04	ND
2,4,5-Trichlorophenoxyacetic acid (245T)	<0.04	<0.04	<0.04	<0.04	ND
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	<0.04	<0.04	<0.04	<0.04	ND
2,4'-DDD	<0.01	<0.01	<0.01	<0.01	ND
2,4'-DDE	<0.01	<0.01	<0.01	<0.01	ND
2,4'-DDT	<0.01	<0.01	<0.01	<0.01	ND
2,4-Dichlorophenoxyacetic acid (24D)	<0.04	<0.04	<0.04	<0.04	ND
2,4-Dichlorophenoxybutyric acid (24DB)	<0.04	<0.04	<0.04	<0.04	ND
2-methyl-4-chlorophenoxyacetic acid (MCPA)	<0.04	<0.04	<0.04	<0.04	ND
2-methyl-4-chlorophenoxybutanoic acid (MCPB)	<0.04	<0.04	<0.04	<0.04	ND
4,4'-DDD	<0.01	<0.01	<0.01	<0.01	ND
4,4'-DDE	<0.01	<0.01	<0.01	<0.01	ND
4,4'-DDT	<0.01	<0.01	<0.01	<0.01	ND
Acetochlor	<0.04	<0.04	<0.04	<0.04	ND
Acifluorfen	<0.04	<0.04	<0.04	<0.04	ND
Alachlor	<0.04	<0.04	<0.04	<0.04	ND
Aldrin	<0.005	<0.005	<0.005	<0.005	ND
alpha-BHC	<0.01	<0.01	<0.01	<0.01	ND
Atrazine	<0.04	<0.04	<0.04	<0.04	ND
Atrazine-desethyl	<0.04	<0.04	<0.04	<0.04	ND
Atrazine-desisopropyl	<0.08	<0.08	<0.08	<0.08	ND
Azaconazole	<0.02	<0.02	<0.02	<0.02	ND
Azinphos-methyl	<0.08	<0.08	<0.08	<0.08	ND
Benalaxyl	<0.02	<0.02	<0.02	<0.02	ND
Bendiocarb	<0.04	<0.04	<0.04	<0.04	ND
Benodanil	<0.08	<0.08	<0.08	<0.08	ND
Bentazone	<0.04	<0.04	<0.04	<0.04	ND
beta-BHC	<0.01	<0.01	<0.01	<0.01	ND
Bifenthrin	<0.02	<0.02	<0.02	<0.02	ND
Bitertanol					
Bromacil	<0.04	<0.04	<0.04	<0.04	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 2 (A) (µg/l)	UH 2 (B) (µg/l)	Variation (%)
Bromophos-ethyl	<0.04	<0.04	<0.04	<0.04	ND
Bromopropylate	<0.04	<0.04	<0.04	<0.04	ND
Bromoxynil	<0.04	<0.04	<0.04	<0.04	ND
Bupirimate	<0.04	<0.04	<0.04	<0.04	ND
Buprofezin	<0.04	<0.04	<0.04	<0.04	ND
Butachlor	<0.04	<0.04	<0.04	<0.04	ND
Captafol	<0.2	<0.2	<0.2	<0.2	ND
Captan	<0.08	<0.08	<0.08	<0.08	ND
Carbaryl	<0.04	<0.04	<0.04	<0.04	ND
Carbofenothion	<0.04	<0.04	<0.04	<0.04	ND
Carbofuran	<0.04	<0.04	<0.04	<0.04	ND
Carboxin	<0.04	<0.04	<0.04	<0.04	ND
Chlorfenvinphos	<0.04	<0.04	<0.04	<0.04	ND
Chlorfluazuron	<0.04	<0.04	<0.04	<0.04	ND
Chlorothalonil	<0.04	<0.04	<0.04	<0.04	ND
Chlorpropham	<0.08	<0.08	<0.08	<0.08	ND
Chlorpyrifos	<0.04	<0.04	<0.04	<0.04	ND
Chlorpyrifos-methyl	<0.04	<0.04	<0.04	<0.04	ND
Chlortoluron	<0.08	<0.08	<0.08	<0.08	ND
Chlozolinate	<0.04	<0.04	<0.04	<0.04	ND
cis-Chlordane	<0.005	<0.005	<0.005	<0.005	ND
Clopyralid	<0.06	<0.06	<0.3	<0.3	ND
Coumaphos	<0.08	<0.08	<0.08	<0.08	ND
Cyanazine	<0.04	<0.04	<0.04	<0.04	ND
Cyfluthrin	<0.04	<0.04	<0.04	<0.04	ND
Cyhalothrin	<0.04	<0.04	<0.04	<0.04	ND
Cypermethrin	<0.08	<0.08	<0.08	<0.08	ND
Cyproconazole	<0.04	<0.04	<0.04	<0.04	ND
Cyprodinil	<0.04	<0.04	<0.04	<0.04	ND
delta-BHC	<0.01	<0.01	<0.01	<0.01	ND
Deltamethrin (including Tralomethrin)	<0.06	<0.06	<0.06	<0.06	ND
Demeton-S-methyl	<0.08	<0.08	<0.08	<0.08	ND
Diazinon	<0.02	<0.02	<0.02	<0.02	ND
Dicamba	<0.04	<0.04	<0.08	<0.08	ND
Dichlobenil	<0.04	<0.04	<0.04	<0.04	ND
Dichlofenthion	<0.04	<0.04	<0.04	<0.04	ND
Dichlofluanid	<0.04	<0.04	<0.04	<0.04	ND
Dichloran	<0.2	<0.2	<0.2	<0.2	ND
Dichlorprop	<0.04	<0.04	<0.04	<0.04	ND
Dichlorvos	<0.08	<0.08	<0.08	<0.08	ND
Dicofol	<0.2	<0.2	<0.2	<0.2	ND
Dicrotophos	<0.04	<0.04	<0.04	<0.04	ND
Dieldrin	<0.005	<0.005	<0.005	<0.005	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 2 (A) (µg/l)	UH 2 (B) (µg/l)	Variation (%)
Difenoconazole	<0.08	<0.08	<0.08	<0.08	ND
Dimethoate	<0.08	<0.08	<0.08	<0.08	ND
Dinocap	<0.3	<0.3	<0.3	<0.3	ND
Diphenylamine	<0.08	<0.08	<0.08	<0.08	ND
Disulfoton	<0.04	<0.04	<0.04	<0.04	ND
Diuron	<0.04	<0.04	<0.04	<0.04	ND
Endosulfan I	<0.01	<0.01	<0.01	<0.01	ND
Endosulfan II	<0.01	<0.01	<0.01	<0.01	ND
Endosulfan sulfate	<0.01	<0.01	<0.01	<0.01	ND
Endrin	<0.005	<0.005	<0.005	<0.005	ND
Endrin aldehyde	<0.005	<0.005	<0.005	<0.005	ND
Endrin ketone	<0.01	<0.01	<0.01	<0.01	ND
EPN	<0.04	<0.04	<0.04	<0.04	ND
Esfenvalerate	<0.04	<0.04	<0.04	<0.04	ND
Ethion	<0.04	<0.04	<0.04	<0.04	ND
Etrimfos	<0.04	<0.04	<0.04	<0.04	ND
Famphur	<0.04	<0.04	<0.04	<0.04	ND
Fenamiphos	<0.04	<0.04	<0.04	<0.04	ND
Fenarimol	<0.04	<0.04	<0.04	<0.04	ND
Fenitrothion	<0.04	<0.04	<0.04	<0.04	ND
Fenpropathrin	<0.04	<0.04	<0.04	<0.04	ND
Fenpropimorph	<0.04	<0.04	<0.04	<0.04	ND
Fensulfothion	<0.04	<0.04	<0.04	<0.04	ND
Fenthion	<0.04	<0.04	<0.04	<0.04	ND
Fenvalerate	<0.04	<0.04	<0.04	<0.04	ND
Fluazifop	<0.04	<0.04	<0.04	<0.04	ND
Fluazifop-butyl	<0.04	<0.04	<0.04	<0.04	ND
Fluometuron	<0.04	<0.04	<0.04	<0.04	ND
Fluroxypyr	<0.04	<0.04	<0.08	<0.08	ND
Flusilazole	<0.04	<0.04	<0.04	<0.04	ND
Fluvalinate	<0.04	<0.04	<0.04	<0.04	ND
Folpet	<0.08	<0.08	<0.08	<0.08	ND
Furalaxyl	<0.02	<0.02	<0.02	<0.02	ND
gamma-BHC (Lindane)	<0.01	<0.01	<0.01	<0.01	ND
Haloxyfop	<0.04	<0.04	<0.04	<0.04	ND
Haloxyfop-methyl	<0.04	<0.04	<0.04	<0.04	ND
Heptachlor	<0.005	<0.005	<0.005	<0.005	ND
Heptachlor epoxide	<0.005	<0.005	<0.005	<0.005	ND
Hexachlorobenzene	<0.04	<0.04	<0.04	<0.04	ND
Hexaconazole	<0.04	<0.04	<0.04	<0.04	ND
Hexazinone	<0.02	<0.02	<0.02	<0.02	ND
Hexythiazox	<0.2	<0.2	<0.2	<0.2	ND
Imazalil	<0.2	<0.2	<0.2	<0.2	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 2 (A) (µg/l)	UH 2 (B) (µg/l)	Variation (%)
Indoxacarb	<0.04	<0.04	<0.04	<0.04	ND
Iodofenphos	<0.04	<0.04	<0.04	<0.04	ND
IPBC (3-Iodo-2-propynyl-n-butylcarbamate)	<0.2	<0.2	<0.2	<0.2	ND
Isazophos	<0.04	<0.04	<0.04	<0.04	ND
Isofenphos	<0.02	<0.02	<0.02	<0.02	ND
Kresoxim-methyl	<0.02	<0.02	<0.02	<0.02	ND
Leptophos	<0.04	<0.04	<0.04	<0.04	ND
Linuron	<0.05	<0.05	<0.05	<0.05	ND
m&p-Xylene	<2	<2	<2	<2	ND
Malathion	<0.04	<0.04	<0.04	<0.04	ND
Mecoprop	<0.04	<0.04	<0.04	<0.04	ND
Metalaxyl	<0.04	<0.04	<0.04	<0.04	ND
Methacrifos	<0.04	<0.04	<0.04	<0.04	ND
Methidathion	<0.04	<0.04	<0.04	<0.04	ND
Methiocarb	<0.04	<0.04	<0.04	<0.04	ND
Methoxychlor	<0.005	<0.005	<0.005	<0.005	ND
Metolachlor	<0.04	<0.04	<0.04	<0.04	ND
Metribuzin	<0.04	<0.04	<0.04	<0.04	ND
Mevinphos	<0.08	<0.08	<0.08	<0.08	ND
Molinate	<0.08	<0.08	<0.08	<0.08	ND
Myclobutanil	<0.04	<0.04	<0.04	<0.04	ND
Naled	<0.2	<0.2	<0.2	<0.2	ND
Nitrofen	<0.08	<0.08	<0.08	<0.08	ND
Nitrothal-Isopropyl	<0.04	<0.04	<0.04	<0.04	ND
Norflurazon	<0.08	<0.08	<0.08	<0.08	ND
Oryzalin	<0.06	<0.06	<0.06	<0.06	ND
Oxadiazon	<0.04	<0.04	<0.04	<0.04	ND
Oxychlordane	<0.02	<0.02	<0.02	<0.02	ND
Oxyfluorfen	<0.02	<0.02	<0.02	<0.02	ND
o-Xylene	<1	<1	<1	<1	ND
Paclobutrazol	<0.04	<0.04	<0.04	<0.04	ND
Parathion-ethyl	<0.04	<0.04	<0.04	<0.04	ND
Parathion-methyl	<0.04	<0.04	<0.04	<0.04	ND
Penconazole	<0.04	<0.04	<0.04	<0.04	ND
Pendimethalin	<0.04	<0.04	<0.04	<0.04	ND
Pentachlorophenol (PCP)	<0.04	<0.04	<0.04	<0.04	ND
Permethrin	<0.02	<0.02	<0.02	<0.02	ND
Phorate	<0.08	<0.08	<0.08	<0.08	ND
Phosmet	<0.04	<0.04	<0.04	<0.04	ND
Phosphamidon	<0.04	<0.04	<0.04	<0.04	ND
Picloram	<0.06	<0.06	<0.3	<0.3	ND
Pirimicarb	<0.04	<0.04	<0.04	<0.04	ND
Pirimiphos-methyl	<0.04	<0.04	<0.04	<0.04	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 2 (A) (µg/l)	UH 2 (B) (µg/l)	Variation (%)
Prochloraz	<0.2	<0.2	<0.2	<0.2	ND
Procymidone	<0.04	<0.04	<0.04	<0.04	ND
Prometryn	<0.02	<0.02	<0.02	<0.02	ND
Propachlor	<0.04	<0.04	<0.04	<0.04	ND
Propanil	<0.2	<0.2	<0.2	<0.2	ND
Propazine	<0.02	<0.02	<0.02	<0.02	ND
Propetamphos	<0.06	<0.06	<0.06	<0.06	ND
Propham	<0.04	<0.04	<0.04	<0.04	ND
Propiconazole	<0.04	<0.04	<0.04	<0.04	ND
Prothiofos	<0.04	<0.04	<0.04	<0.04	ND
Pyrazophos	<0.04	<0.04	<0.04	<0.04	ND
Pyrifenox	<0.04	<0.04	<0.04	<0.04	ND
Pyrimethanil	<0.04	<0.04	<0.04	<0.04	ND
Pyriproxyfen	<0.04	<0.04	<0.04	<0.04	ND
Quintozene	<0.08	<0.08	<0.08	<0.08	ND
Quizalofop	<0.04	<0.04	<0.04	<0.04	ND
Quizalofop-ethyl	<0.04	<0.04	<0.04	<0.04	ND
Simazine	<0.04	<0.04	<0.04	<0.04	ND
Simetryn	<0.04	<0.04	<0.04	<0.04	ND
Sulfentrazone	<0.2	<0.2	<0.2	<0.2	ND
Sulfotep	<0.04	<0.04	<0.04	<0.04	ND
TCMTB [2-(thiocyanomethylthio) benzothiazole,Busan]	<0.08	<0.08	<0.08	<0.08	ND
Tebuconazole	<0.04	<0.04	<0.04	<0.04	ND
Tebufenpyrad	<0.02	<0.02	<0.02	<0.02	ND
Terbacil	<0.04	<0.04	<0.04	<0.04	ND
Terbufos	<0.04	<0.04	<0.04	<0.04	ND
Terbumeton	<0.04	<0.04	<0.04	<0.04	ND
Terbuthylazine	<0.02	<0.02	<0.02	<0.02	ND
Terbuthylazine-desethyl	<0.04	<0.04	<0.04	<0.04	ND
Terbutryn	<0.04	<0.04	<0.04	<0.04	ND
Tetrachlorvinphos	<0.04	<0.04	<0.04	<0.04	ND
Thiabendazole	<0.2	<0.2	<0.2	<0.2	ND
Thiobencarb	<0.04	<0.04	<0.04	<0.04	ND
Thiometon	<0.08	<0.08	<0.08	<0.08	ND
Tolylfluanid	<0.02	<0.02	<0.02	<0.02	ND
Total Chlordane [(cis+trans)*100/42]	<0.02	<0.02	<0.02	<0.02	ND
Total DDT Isomers	<0.06	<0.06	<0.06	<0.06	ND
trans-Chlordane	<0.005	<0.005	<0.005	<0.005	ND
Triadimefon	<0.04	<0.04	<0.04	<0.04	ND
Triazophos	<0.04	<0.04	<0.04	<0.04	ND
Triclopyr	<0.04	<0.04	<0.04	<0.04	ND
Trifluralin	<0.04	<0.04	<0.04	<0.04	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 2 (A) (µg/l)	UH 2 (B) (µg/l)	Variation (%)
Vinclozolin	<0.04	<0.04	<0.04	<0.04	ND