Knights Stream and Prestons Stormwater Facility Monitoring 2020-2021 Annual Report

Prepared for

Christchurch City Council

June 2022

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TITLE	Knights Stream and Prestons Stormwater Facility Monitoring 2020-2021 Annual Report
CLIENT	Christchurch City Council
VERSION	Final
ISSUE DATE	17 June 2022
JOB REFERENCE	C03816300
SOURCE FILE(S)	C03816300R006_2020 Report_Final.docx

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Limitations:

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Executive Summary

Background

Pattle Delamore Partners Limited (PDP) has been undertaking water quality monitoring of the Knights Stream and Prestons stormwater facilities for Christchurch City Council (CCC) since 2018. The purpose of this monitoring has been to determine the treatment efficiency of the stormwater facilities and to assess the quality of stormwater that is discharging from these facilities into the receiving environment.

Methodology

Six targeted rainfall events have been sampled by PDP at these facilities since 2018, with four of those being within the 2020-2021 monitoring period. Five sampling sites were established at both the Knights Stream and Prestons subdivision stormwater facilities. Four of the sampling sites at Knights Stream utilised automatic samplers (autosamplers) for collection, with the remaining site using an in-sump first flush bottle. Three of the sites at Prestons used autosamplers, while the remaining two sites used in-sump first flush bottles. Following a successful round of sampling, composite samples were prepared for each autosampler site and were subsequentially delivered alongside the first flush samples to Hill Laboratories Limited for analysis.

In the 2021 monitoring period, the sampling methodology was updated based on the recommendations provided by Dr Jennifer Gadd from NIWA. The number of samples taken from each autosampler was increased from 24 to 72 for each rainfall event (i.e., three samples per bottle). Additionally, at each of the stormwater facilities, an autosampler upstream of the first flush basin was used to collect a first flush sample. This methodology was implemented for two of the four monitoring rounds in the 2020-2021 monitoring period.

The water quality results were analysed to determine the approximate reduction in contaminant concentration across each of the stormwater facilities. This reduction was compared to the expected ranges of treatment efficiencies by contaminant type from Chapter 6 of CCC's Waterways, Wetlands and Drainage Guide (WWDG). The water quality discharged into the receiving environment from the outlets of each wetland was compared to the in-stream water quality standards. The comparison with in-stream standards did not account for contaminant concentrations that exist within the receiving waterway upstream of the stormwater discharge.

Knights Stream Results Summary

A reduction in contaminant concentrations was generally seen between the first flush bottle within the sump and the first flush samples taken from the autosamplers upstream of the first flush basin. Removal efficiencies across the first flush basin were estimated using results from the autosamplers upstream of the basin and at the inlet to the wetland. These efficiencies were highly variable and are suspected to be influenced by the resuspension of sediment caused by the pump that discharges stormwater into the wetland. The study may therefore benefit from an additional sampling location at the outlet from the first flush basin if the removal efficiency through the first flush basin is of interest to CCC.

The removal of contaminants through the wetland was more consistent, with total suspended solids, lead, zinc, and dissolved inorganic nitrogen all being mostly within the WWDG treatment efficiency ranges. Copper removal was notably lower than the other heavy metals, and phosphorus had poor removal. Several chemical and environmental factors may be contributing to these low removals, including particle size distribution, pH, and soil phosphorus availability.

The quality of the observed discharge from the Knights Stream wetland met the receiving water quality standards for most contaminants, with the exception of turbidity, copper, and dissolved reactive phosphorus. The exceedances of the guidelines were mostly minor, particularly as the water quality standards are intended to be applied downstream of a discharge following reasonable mixing with the receiving waterbody.

Prestons Results Summary

Samples from the first flush bottles and the autosampler upstream of the first flush basin demonstrated a reduction in most contaminants, indicating some contaminant removal through the sumps and manholes in the stormwater network. The removal of total suspended solids through the first flush basin was highly variable; however, a high removal was seen for all heavy metals with the exception of arsenic. This is thought to be due to arsenic being naturally elevated in the soil and groundwater near Prestons, as discussed in previous reporting undertaken by PDP (PDP, 2018).

It is noted that a 450 m long planted swale conveys water from the first flush basin to the wetland inlet and is likely to contribute to the observed removal efficiencies estimated for the basin in this report. An additional monitoring location at the outlet from the first flush basin would be required if more representative estimates of first flush basin removal efficiencies are to be made.

The removal efficiency of total suspended solids was highly variable across the wetland. Wetland outlet samples were collected from the secondary sump and may be influenced by sediment resuspension from turbulence as water cascaded into the sump. It is recommended that the sampling location is moved outside of the sump to avoid this potential resuspension and confirm whether it is the cause of poor sediment removal. Zinc and copper removals met the WWDG treatment efficiencies in most events, whilst arsenic increased through the wetland due to the naturally elevated concentrations as discussed above.

Dissolved inorganic nitrogen had a high removal efficiency, whilst total nitrogen had a much lower removal efficiency. As with Knights Stream, Phosphorus removal was highly variable and may be influenced by particle size, pH, soil phosphorus availability, and bird droppings from waterfowl.

All contaminants except for turbidity met the receiving water standards in most events. Turbidity exceeded the standard by less than 1 NTU, and it is expected that turbidity would meet the standard following reasonable mixing with the Styx River assuming that the existing water quality in the river meets the standard.

Table of Contents

Table of Figures

Table of Tables

Appendices

1.0 Introduction

Pattle Delamore Partners Limited (PDP) has been engaged by Christchurch City Council (CCC) to provide ongoing stormwater quality monitoring at the Prestons and Knights Stream stormwater facilities. The most recent stormwater quality sampling, referred to as Stage 2 here-in, involved sampling five storm events over the 2020-2022 period and is subsequent to the Stage 1 monitoring which was carried out in 2018 by PDP. The aim of the stormwater monitoring is to determine the treatment efficiency and assess the discharge quality of these stormwater facilities.

This report includes the results from six rainfall events between September 2018 and May 2021. Four of these events have been captured during the Stage 2 monitoring programme. A second report will be prepared in 2022 including the 2021-2022 sampling results once they have been obtained.

This report details the methodology used to monitor the facilities, the rainfall events captured over the reporting period, and an analysis of the sampling results to date. The analysis includes an assessment of the treatment provided by the sumps, first flush basins, and wetlands at both facilities, as well as a comparison of the discharge quality to receiving water standards.

2.0 Methodology

The methodology used to collect stormwater samples is mostly consistent with the previous sampling carried out as part of Stage 1 and is described below. Updates to the methodology since Stage 1 are discussed in Section 2.5.

2.1 Sampling Equipment and Methodology

The sampling programme uses six ISCO 6712 automatic samplers and one Liquiport 2000 automatic sampler (referred to as autosamplers in this report) as well as three Thermo Scientific Nalgene Storm Water Samplers (referred to as first flush bottles in this report) in the locations described in Section 2.1.1. Samples from the ISCO 6712 autosamplers are collected in 1 L ISCO Propak single use plastic sample bags. The Liquiport 2000 autosampler is not compatible with the single use plastic sample bags, therefore 1 L reusable plastic bottles are used to collect samples in the Liquiport autosampler. The reusable plastic bottles from the Liquiport autosampler and the first flush bottles are rinsed with deionised water following each sampling event to remove the contaminants remaining in the bottles.

The ISCO autosamplers use ISCO 730 Bubbler Flow Modules to measure the water depth at each sampling location, whilst the Liquiport 2000 autosampler uses a PS98i pressure transducer to measure water depth. A trigger water level is set for each of the samplers, and when the Bubbler Flow Module or PS98i detects a level greater than the trigger level the sampling programme begins. In some cases, due to damaged Bubbler Flow Module tubing or issues with the

Liquiport programming, the samplers have been triggered manually or based on a programmed start time.

The National Institute of Water and Atmospheric Research's (NIWA) guidance for the development of stormwater monitoring programmes (NIWA, 2014) recommends that only rainfall events with a rainfall accumulation exceeding 2.5 mm per day should be considered as runoff-generating events. This is because the effects of evaporation and depression storage result in little (if any) runoff generation from such an event. As such, antecedent dry days are also defined as days having less than 2.5 mm of rainfall.

Due to the inability to measure flow at some of the sample locations time-weighted composite samples are the chosen sample type for this sampling programme. This method of sampling is not as accurate as flow-based sampling; however, as discussed in Section 2.1.1 below, collecting a large number of samples at each site per rainfall event can produce similar results to flow-based sampling.

Following a storm event which is sufficient to trigger the autosamplers, three 1 L composite samples are prepared from each autosampler. All three composite samples are sent to Hill Laboratories for testing. Two are analysed (duplicate samples), and the final sample is held cold until the results of the other samples are reported. If there are major discrepancies in the two samples, the third sample is analysed. Otherwise, the average concentration between the two duplicate samples is reported. As the first flush bottles only have a capacity of 1 L, no composite sample is made for these samples and the full 1 L of sample is transferred into a Hill Laboratories 1 L sample bottle for analysis.

2.1.1 2021 Updates to Methodology

Dr Jennifer Gadd from NIWA conducted a review of the methodologies for the various stormwater monitoring projects that are currently being carried out to inform CCC's Global Stormwater Consent monitoring (Gadd, 2020). This review acknowledged the limitations in measuring flow rates at the sampling sites and recommended that a suitable alternative solution was to increase the number of samples collected for each composite sample per site.

Dr Gadd's review recommends collecting at least 30 samples per storm event for each composite sample as this can provide an estimate of the event mean concentration (EMC) within 20% error, with greater sample numbers further reducing this error. EMC's are calculated from flow-based samples and are recommended for estimating treatment efficiencies in stormwater treatment facilities as they allow more accurate comparisons between inlet and outlet sites.

A meeting was held between PDP, CCC, and Dr Jennifer Gadd on 10 February 2021 to discuss the existing sampling methodology and suggested modifications to the methodology. The meeting concluded that the number of samples taken per sampling round should be increased by allowing multiple smaller-volume samples to be placed in each bottle, which would increase the number of "snapshots" of stormwater quality that the sampling covered and allow the composite samples to be more representative of the EMC. In addition, it was suggested that first flush samples should be taken from the autosamplers upstream of first flush basins to compare their water quality with samples from the first flush bottles.

The autosamplers were recalibrated prior to the May 2021 sampling round to ensure that the correct sample volumes were taken and to prevent the sample bottles from overflowing. The autosamplers were also reprogrammed to take samples at a third of their original timesteps (e.g., hourly sampling became one sample every 20 minutes) and to take three 330 mL samples per bottle. The maximum number of samples that an autosampler could now take was therefore increased from 24 to 72.

2.2 Site Selection

2.2.1 Knights Stream

The sampling layout at Knights Stream is shown in Figure 1 in Appendix A and Figure 1 below.

Below is a brief description of each sampling site:

- K_FFSwale: At this site an autosampler within a security housing collects samples from the inlet of a culvert that drains the swale and discharges into the first flush basin. The upstream catchment is currently undergoing development, and at times construction dewatering discharges enter the swale. The swale provides some treatment of stormwater, so the sampled stormwater is partially treated.
- K_FFB_Sump: At this site samples are collected from a double sump using a first flush bottle near the intersection of Kruger Road and Elba Crescent. The first flush bottle collects raw stormwater runoff from the road channel and provides a sample of the untreated stormwater that enters the Knights Stream stormwater treatment system.
- K_FFB: Sampling at this site occurs for storm events from 11 October 2018 onwards. It uses the Liquiport 2000 autosampler to collect samples from within a large bubble-up sump that serves as an inlet into the first flush basin. The stormwater retrieved at this location will have received some treatment from sumps and manholes, as well as undergoing some pollutant removal via settling in the bubble-up sump.
- K_Int: This site uses an autosampler to take samples from near the piped inlet to the wetland. Stormwater is pumped into the wetland from a pump chamber just prior to the inlet. Samples from this site serve as a baseline for pre-wetland treatment stormwater quality to allow the effectiveness of the wetland as a treatment device to be determined.

- K_Outlet: This site is the final sampling location in the Knights Stream treatment system and collects samples of treated stormwater using an autosampler within the wetland outlet structure. The sampler intake is secured to the grate in the intake of the outlet structure, upstream of the notched weir that controls the outflow from the outlet.

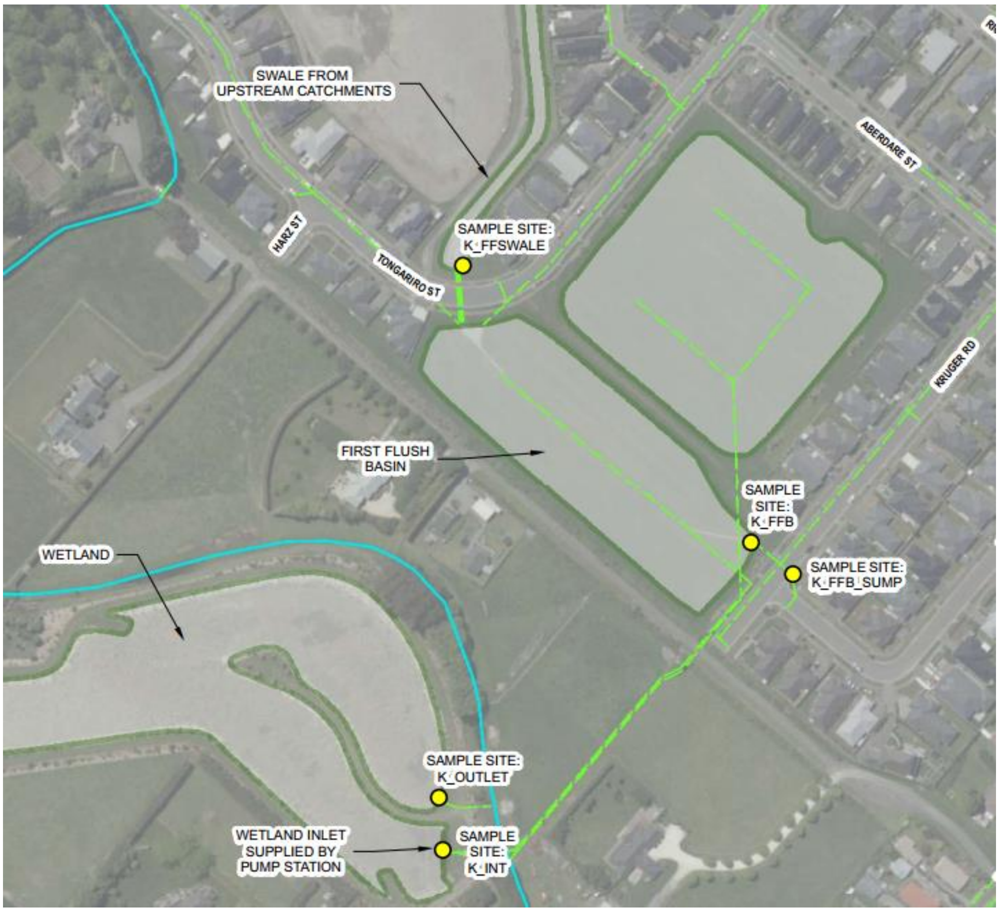

Figure 1. Knights Stream sampling locations. Refer to Appendix A for complete figure.

2.2.2 Prestons

Figure 2 in Appendix A and Figure 2 below shows the sampling layout at Prestons.

Descriptions of each sampled site are described below.

- P_FFBD_Sump: This site uses a first flush bottle to collect stormwater at the inlet to a double sump located on Makawe-Roa Street that contributes stormwater to First Flush Basin D. The stormwater is sampled directly from the road channel and is therefore untreated.

- P_FFBF_Sump: This site collects stormwater from a single sump on Te Whenu Crescent using a first flush bottle. The sump contributes stormwater to First Flush Basin F, and the collected stormwater is untreated.
- P_FFBF Inlet: An autosampler located in a security housing is used to collect stormwater samples directly from a manhole located just upstream of the discharge into First Flush Basin F. The stormwater that is collected has received some prior treatment from sumps and manholes but is representative of the stormwater that discharges to the first flush basin.
- P_Int: The stormwater samples for this site are collected from the wetland forebay cell. An autosampler situated in a security housing is used to collect stormwater from the wetland forebay, which is considered to be partially treated via the first flush basins and the sumps and manholes prior to them. Note that during the 24 September 2018 rainfall event the autosampler intake was located within the valve chamber upstream of the wetland forebay.
- P_Outlet: This site also consists of a valve chamber where the bubbler module is installed, which receives wetland-treated stormwater from Wetland Cell 3 and 4. An autosampler within a security housing collects stormwater from within the double sump in Wetland Cell 4 which is connected via a 225 mm diameter pipe to the valve chamber. The samples represent the final treated stormwater from the treatment system. Note that during the 24 September 2018 rainfall event the autosampler intake was located within the valve chamber.

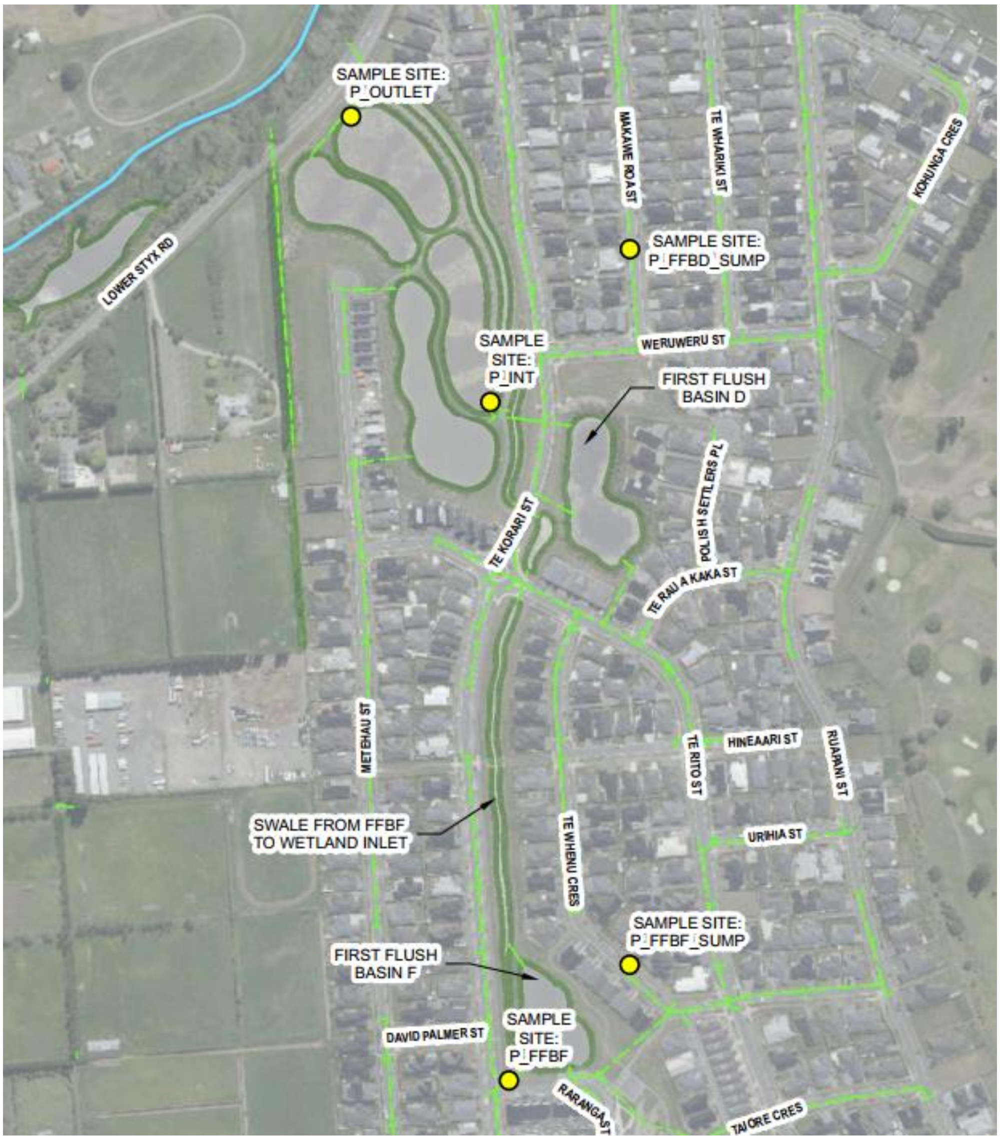

Figure 2. Prestons sampling locations. Refer to Appendix A for complete figure.

2.3 Laboratory Analysis

The sampling programme targets key pollutants of concern which are typically found in urban catchments. Stormwater samples are analysed for the following analytes:

- Turbidity;
- Total Suspended Solids (TSS);
- Suite of dissolved and total heavy metals (including arsenic (Prestons only), copper, lead, and zinc);
- Total nitrogen (TN);
- Dissolved inorganic nitrogen (DIN);
- Total phosphorus (TP); and
- Dissolved reactive phosphorus (DRP).

Due to the volatility of petroleum hydrocarbons and the extended periods of time that the samples will spend in the samplers without being sealed, it has been decided that these will not be included in the analysis. *E. coli* analysis is also not included due to the period between sample collection and analysis.

TSS is sourced from atmospheric deposition, vehicle traffic, and erosion during overland flow. TSS can decrease water clarity, smother the benthic layer of streambeds, and form a binding surface for heavy metals and other contaminants (Charters, Cochrane, & O'Sullivan, 2015). It is therefore an important pollutant for determining the effectiveness of a treatment facility.

Dissolved metals are more bioavailable and therefore more toxic to the aquatic environment (ANZECC, 2000). However, particulate metals are able to accumulate in streambeds and can dissolve or become re-suspended over time. Therefore, it is important to analyse the samples for both total and dissolved metals.

DIN and DRP are the dissolved inorganic forms of nitrogen and phosphorus which are available for immediate uptake by plants. TN and TP include bound forms of the nutrients that are less bioavailable. Environment Canterbury's (ECan) current guideline for receiving water bodies includes guideline values for DIN and DRP in rivers and artificial water courses, and TN and TP in lakes. Both DIN and DRP can influence the growth of periphyton in rivers which can lead to excessive algae growth. This growth can cause issues such as a reduction in habitat for aquatic life, altered water chemistry, and obstruct the flow in waterways (ANZECC, 2000). Therefore, it is important to establish the level of nutrient treatment provided by the stormwater facilities.

The raw laboratory results data for the Stage 2 sampling is presented in Appendix B.

2.4 Treatment Efficiency and Water Quality Standards

Observed treatment efficiencies for the stormwater facilities have been estimated from the sampled contaminant concentrations and have been compared to treatment efficiencies in Chapter 6 of CCC's Waterways, Wetlands and Drainage Guide (WWDG). WWDG efficiencies have been adopted from studies in Auckland and overseas, and are used as a design basis for estimating treatment efficiencies for new treatment devices in Christchurch.

Water quality standards for Knights Stream and Prestons have been obtained from the ECan's Land and Water Regional Plan (LWRP) Schedule 5 for the "Spring-fed – plains" water quality class, Rule 5.94A of the LWRP, and the Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) 2018.

These standards are for chronic (longer term) exposure and, with the exception of Rule 5.94A of the LWRP, are intended to be applied to a discharge following reasonable mixing with the receiving waterway. They are therefore intended to be used as a guide for comparing the sampling results to and to identify which contaminants may be of concern for the receiving waterway.

2.5 Assumptions and Limitations

The samples are taken at pre-programmed intervals and therefore do not account for the volume of water that has passed through the sampling point between each sample. However, as discussed in Section 2.1.1, having a high number of samples for each sampling location per rainfall event enables an approximation of the EMC to be made based on composite sampling. The ability to make this approximation is a key assumption for this study, as EMCs are required to calculate treatment efficiencies across the stormwater facilities.

3.0 Knights Stream

3.1 Event Summary

A total of six rainfall events have been sampled at the Knights Stream monitoring site. The sampled rainfall events have a range of rainfall characteristics as shown in Table 1. During Events 1 and 5 there were issues with the Liquiport autosampler at the K_FFB sampling location that caused it to not trigger correctly, so no sample was obtained from the site.

Table 1: Rainfall characteristics of sampled events at Knights Stream[1]

Event Number and Start Date	Total Rainfall (mm)	Duration (hrs)	Peak Intensity (mm/hr)	Antecedent Dry Days[2] (days)	Samples Obtained
Event 1: 24 September 2018	19.4	18	7	20	K_FFB_Sump K_FFSwale K_Int K_Outlet
Event 2: 11 October 2018	29.2	46	3.6	15	K_FFB_Sump K_FFB K_FFSwale K_Int K_Outlet
Event 3: 25 May 2020	14.8	22	2.2	19	K_FFB_Sump K_FFB K_FFSwale K_Int K_Outlet
Event 4: 7 November 2020	44.8	19	5.8	10	K_FFB_Sump K_FFB K_FFSwale K_Int K_Outlet
Event 5: 11 May 2021	24.2	33	5.8	16	K_FFB_Sump K_FFSwale_FF[3] K_FFSwale K_Int K_Outlet
Event 6: 29 May 2021	143.6	82	7	4	K_FFB_Sump K_FFB_FF[3] K_FFB K_FFSwale_FF[3] K_FFSwale K_Int K_Outlet

Notes:

1. *Measured at CCC's Sparks Road weather station (Station ID: 325618).*
2. *Days since last rainfall exceeding 2.5 mm in 24 hours.*
3. *First flush samples obtained upstream of first flush basins as per updated methodology.*

All of the ISCO autosamplers at both Knights Stream and Prestons had their internal batteries replaced following Event 3, where depleted internal batteries had resulted in the autosampler pump programming being incorrect. This caused two of the Prestons autosamplers to not collect any useable samples during this period, however no issues occurred at the Knights Stream site.

The laboratory diluted the samples from Event 6 prior to analysis, resulting in a high number of samples being beneath the laboratory detection limit and subsequently deemed non-detect samples. Triplicate samples were analysed for the sites that had samples diluted (K_FFSwale, K_FFB, K_Int, K_Outlet), however first flush samples were unable to be re-analysed. This additional analysis was carried out free of charge by the laboratory as they acknowledged the error in diluting the samples.

3.2 First Flush

The sampling methodology was updated in 2021 to include additional first flush samples taken from the first bottles in the autosamplers upstream of the first flush basins. Table 2 compares the sample results from the first flush bottle located within a sump (K_FFB_Sump) with the first flush samples taken from the autosamplers (K_FFB_FF and K_FFSwale_FF) during Events 5 and 6. Although K_FFB_Sump discharges into the FFB at the K_FFB_FF site and not the K_FFSwale_FF site, it is considered to be representative of typical runoff within the Knights Stream subdivision.

During Event 5 a reduction in concentration between the sump and the K_FFSwale_FF autosampler was observed for all contaminants except nitrogen and phosphorus.

In Event 6, the concentration between the sump and the K_FFSwale_FF autosampler decreased for all contaminants except DIN, DRP, and TP. In comparison, the concentration between the sump and K_FFB_FF decreased for all contaminants with the exception of DRP.

Table 2: Comparison of first flush samples at Knights Stream (mg/L)

Contaminant	Event 5		Event 6 [1]		
	K_FFB_Sump	K_FFSwale_FF	K_FFB_Sump	K_FFSwale_FF	K_FFB_FF
Turbidity	23	5.3	8.2	3.2	3.6
Total Suspended Solids	64	10	15	8	5
Dissolved Copper	0.0042	0.0028	0.0028	0.0012	0.0013
Total Copper	0.0102	0.0036	-	-	-
Dissolved Lead	0.0002	0.00005	-	-	-
Total Lead	0.0048	0.00053	-	-	-
Dissolved Zinc	0.073	0.028	0.028	0.018	0.026
Total Zinc	0.168	0.043	0.036	0.031	0.035
Dissolved Inorganic Nitrogen	1.070	1.920	0.450	0.450	0.390
Total Nitrogen	1.870	2.800	1.300	0.690	0.520
Dissolved Reactive Phosphorus	0.0360	0.2600	0.0140	0.0230	0.0150
Total Phosphorus	0.1730	0.3800	0.0530	0.0620	0.0390

Notes:

1. *Laboratory dilution resulted in non-detects for many contaminants during this event. First flush samples did not have triplicates available for re-analysis.*

3.3 Removal Efficiencies

3.3.1 First Flush Basin (FFB)

Removal efficiencies for the Knights Stream first flush basin have been estimated between the K_FFSwale and K_Int sites for each event. The removal efficiencies were estimated by subtracting the concentration at the downstream (K_Int) site from the upstream (K_FFSwale) site and dividing this by the concentration at the upstream site.

The K_FFB site was not chosen for this assessment as the site has only been sampled in four out of the six events. It is difficult to determine contaminant removals across the FFB due to potential contaminant resuspension and/or transformation between dissolved or particulate forms (in the case of metals and nutrients) between the FFB and the wetland inlet. To more accurately assess the removal efficiency of the FFB an additional sampling location could be established at the outlet from the FFB.

Figure 3 shows the calculated removal efficiencies of TSS for each event through the FFB. Only Event 3 had a removal efficiency within the WWDG range, with the remaining 5 events being below the range.

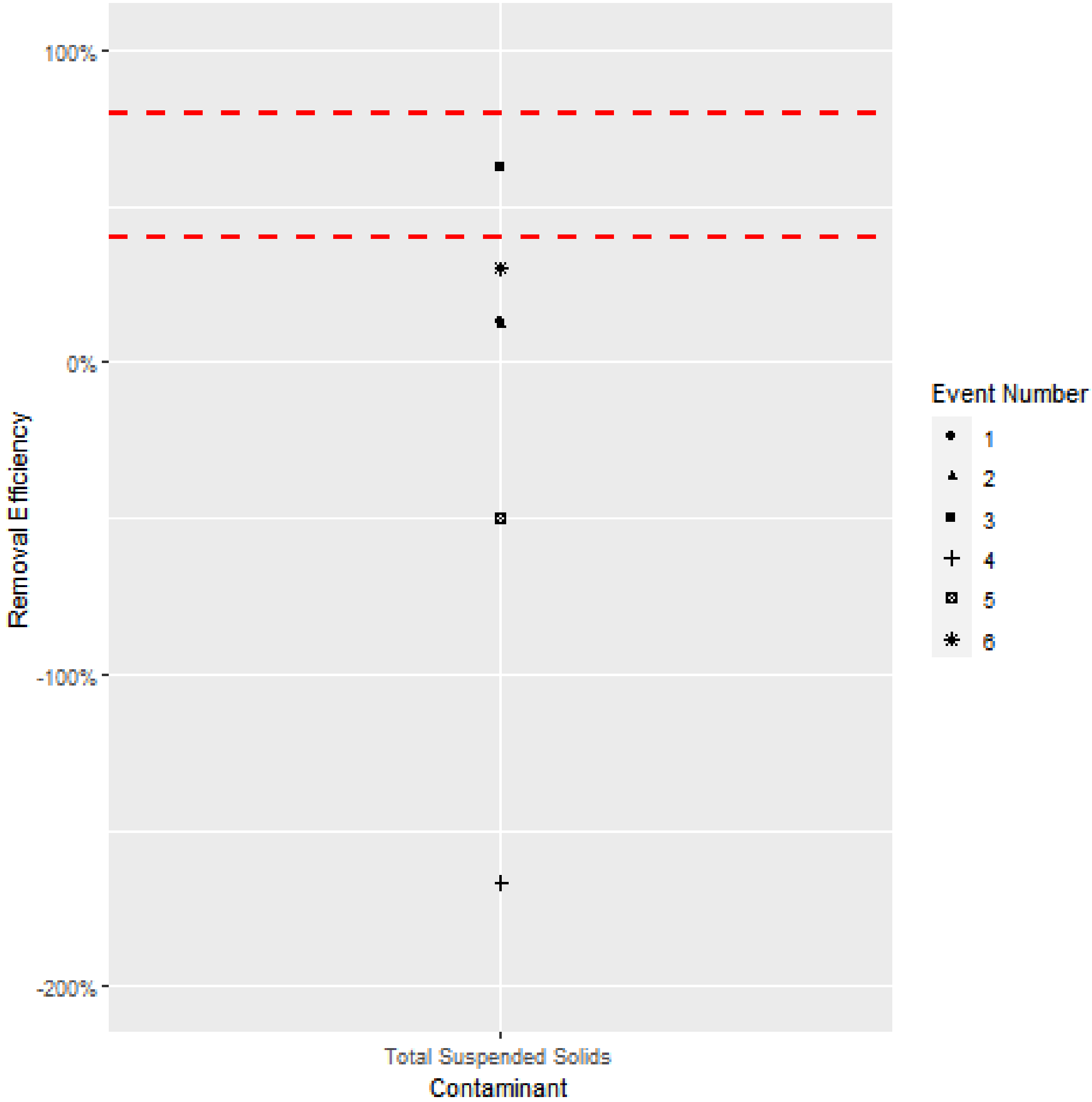

Figure 3. TSS removal efficiency for the Knights Stream first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

Figure 4 shows the removal efficiencies of total and dissolved metals (copper, lead, and zinc) for the FFB. With the exception of total copper, all other metals were at or above the WWDG lower removal efficiency in two out of the six events.

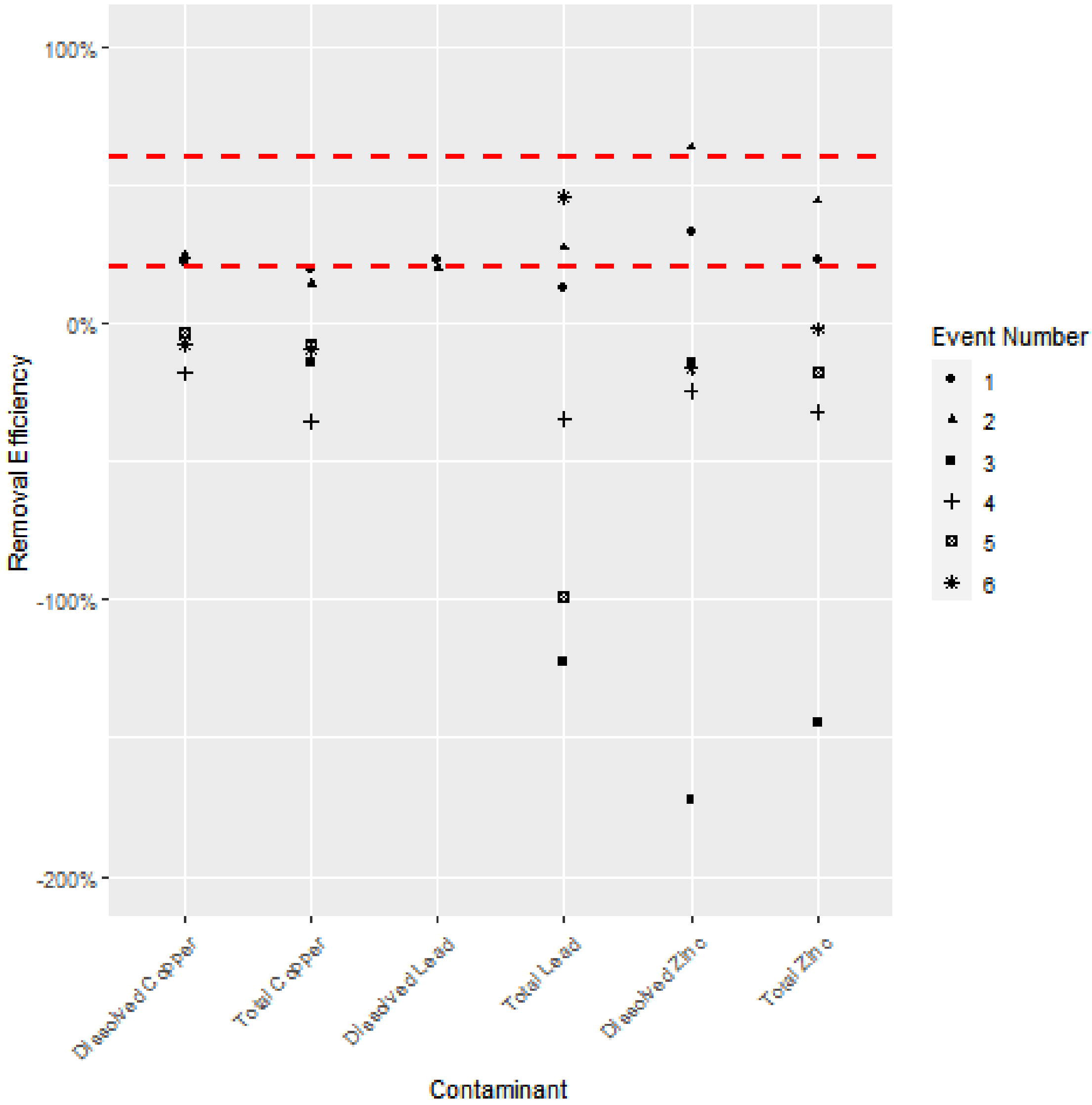

Figure 4. Heavy metals removal efficiencies for the Knights Stream first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

Figure 5 compares the DIN and TN removal efficiencies with the WWDG values. The removal efficiencies were above the lower bound of the WWDG efficiencies in only two events (events 3 and 5) for both contaminants. The remaining four events had negative removal efficiencies for DIN whilst two events had negative removal efficiencies for TN.

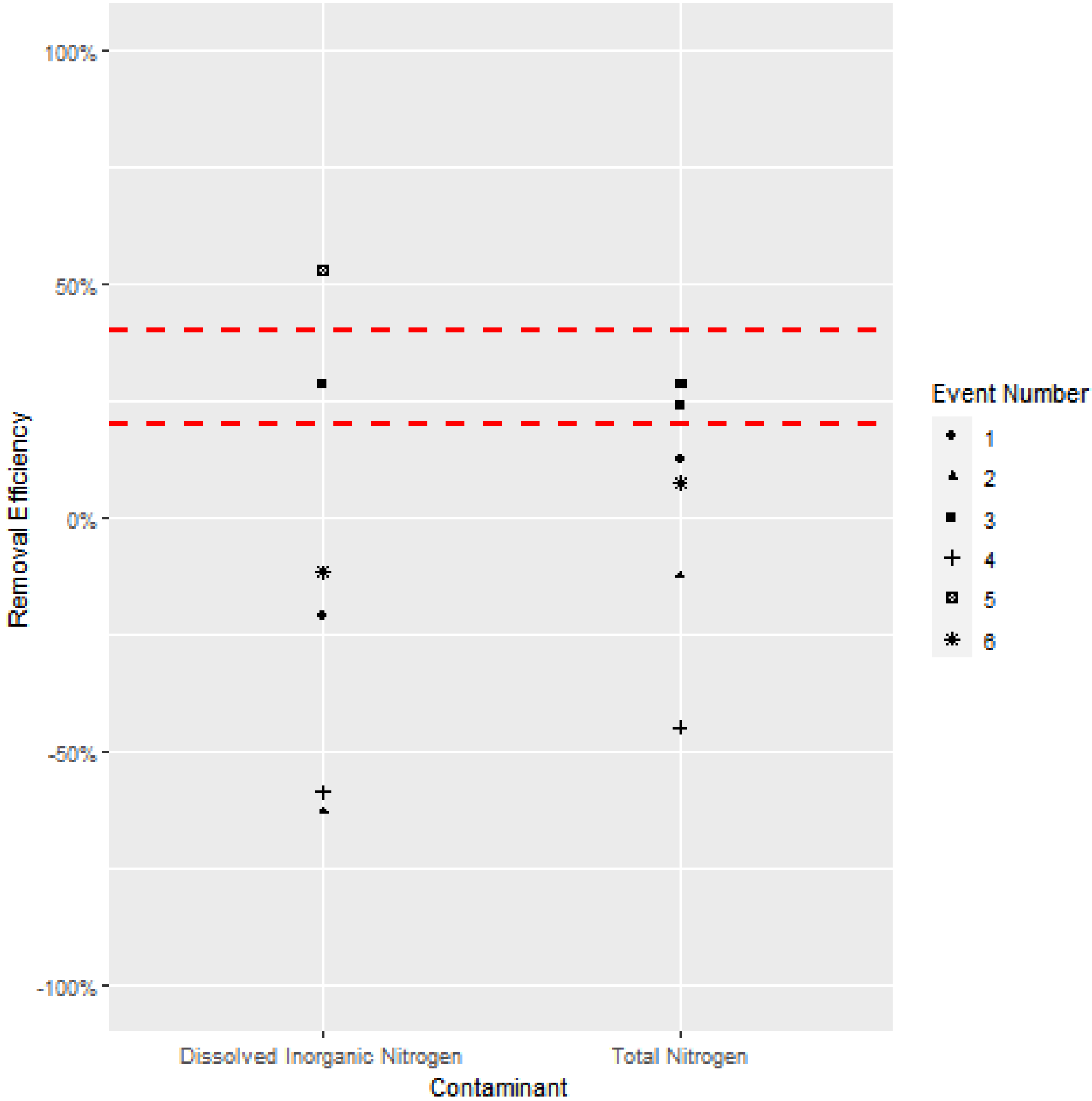

Figure 5. Nitrogen removal efficiencies for the Knights Stream first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

Figure 6 presents the DRP and TP removal efficiencies for the Knights Stream FFB. Events 1, 2, and 3 (in descending order of removal efficiency) had the highest removal efficiencies for both contaminants.

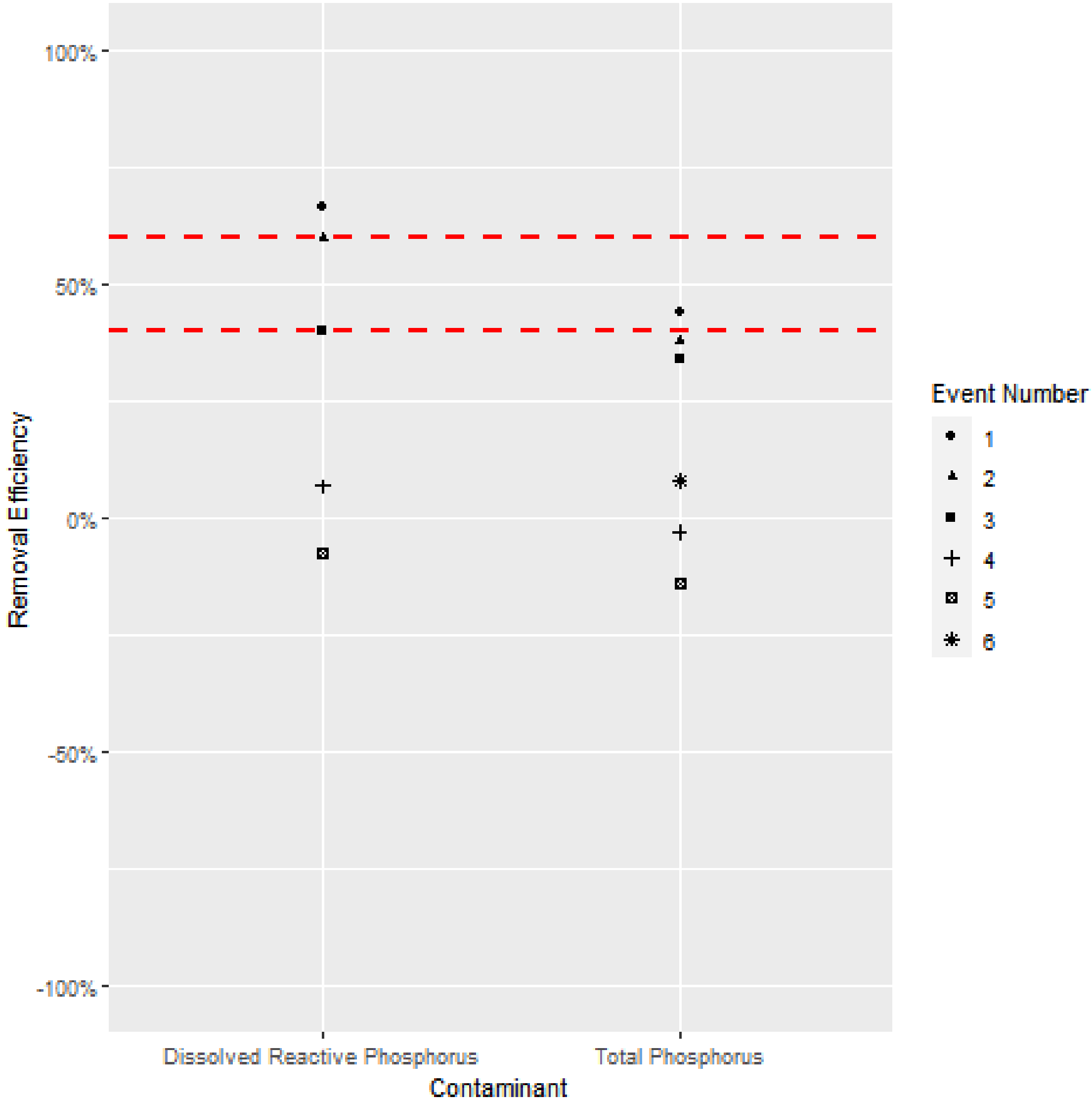

Figure 6. Phosphorus removal efficiencies for the Knights Stream first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

3.3.2 Wetland

Removal efficiencies have been calculated for each event between the K_Int and K_Outlet sampling locations.

Figure 7 shows the TSS removal efficiency for the Knights Stream Wetland. Three out of the six events had removal efficiencies above the WWDG lower bound. Event 3 shows a negative removal, however the TSS concentration at K_Int was below the laboratory detection limit so this result is not unexpected.

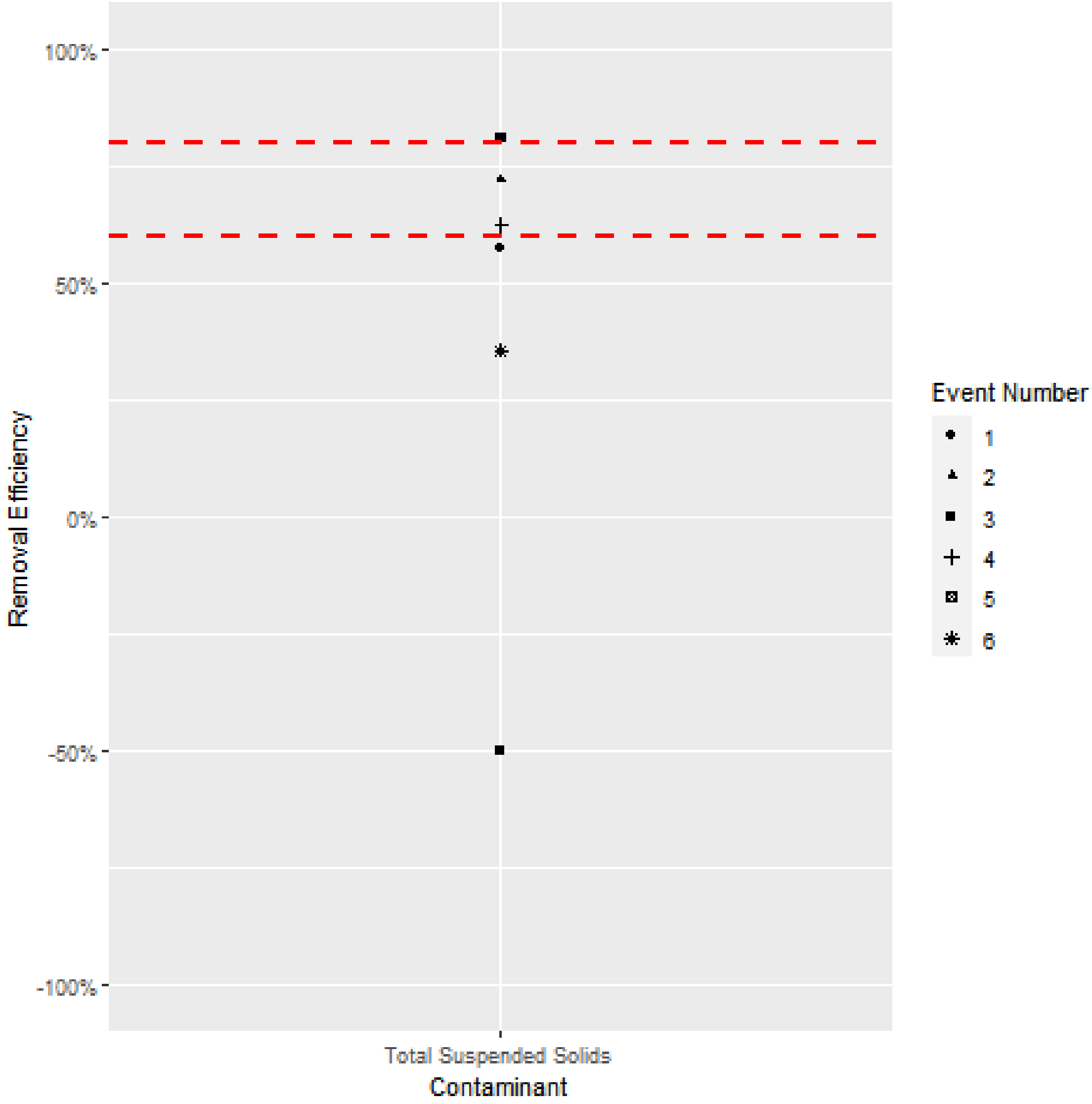

Figure 7. Total suspended solids removal efficiencies for the Knights Stream wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

Figure 8 shows the removal efficiencies for total and dissolved metals across the wetland. Both lead and zinc had removal efficiencies within the WWDG range for the majority of events; however, copper had generally lower removals. The discharge quality resulting from the wetland site is discussed further in Section 3.4.

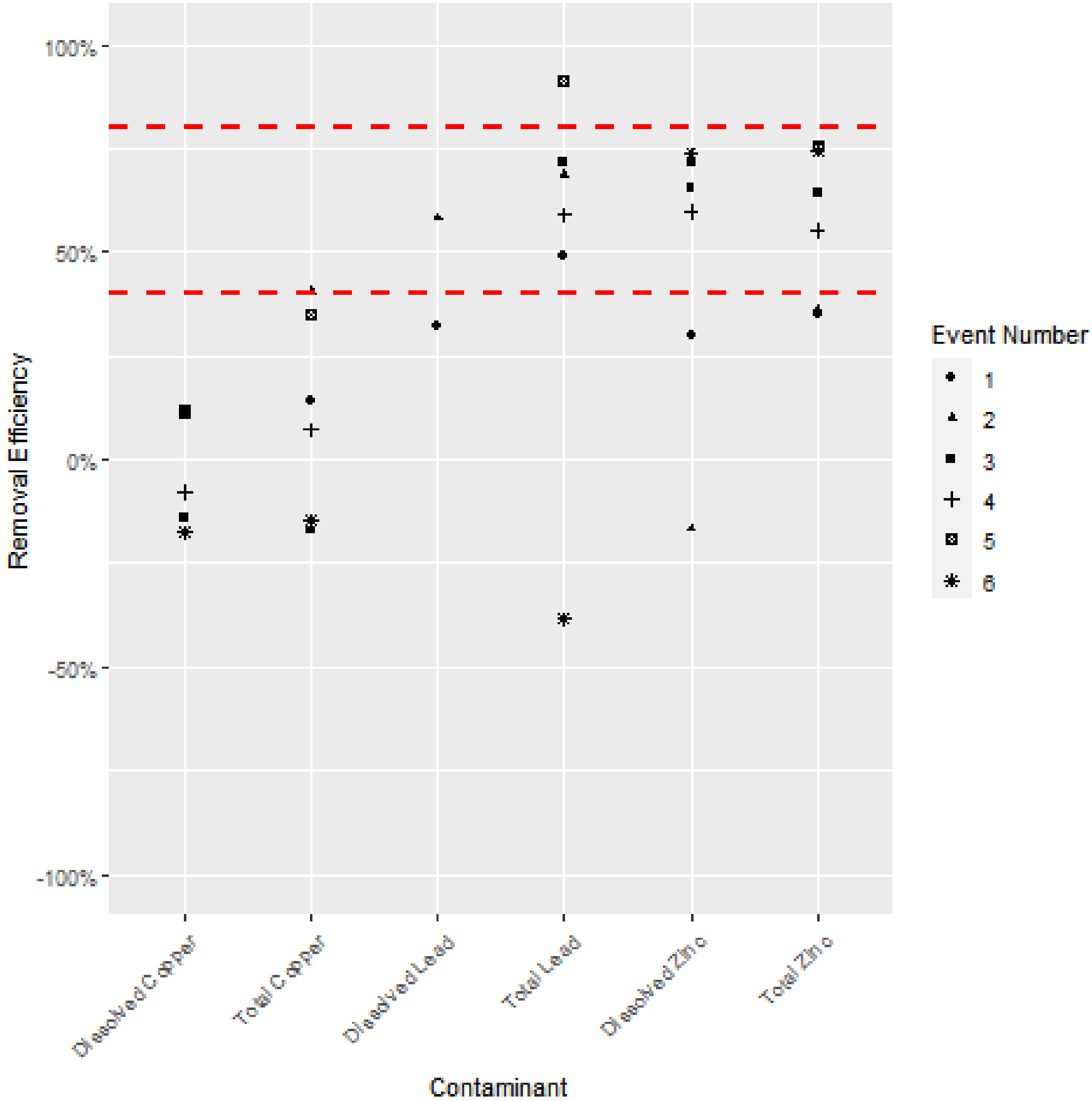

Figure 8. Heavy metals removal efficiencies for the Knights Stream wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

The removal efficiencies for DIN and TN shown in Figure 9 indicate differing performance of the wetland for inorganic forms of nitrogen (ammoniacal nitrogen and nitrate/nitrite) compared with organic. DIN is shown to be above the lower-bound of the WWDG removal efficiency for nitrogen, whilst TN had three events with reductions and three with increases across the wetland.

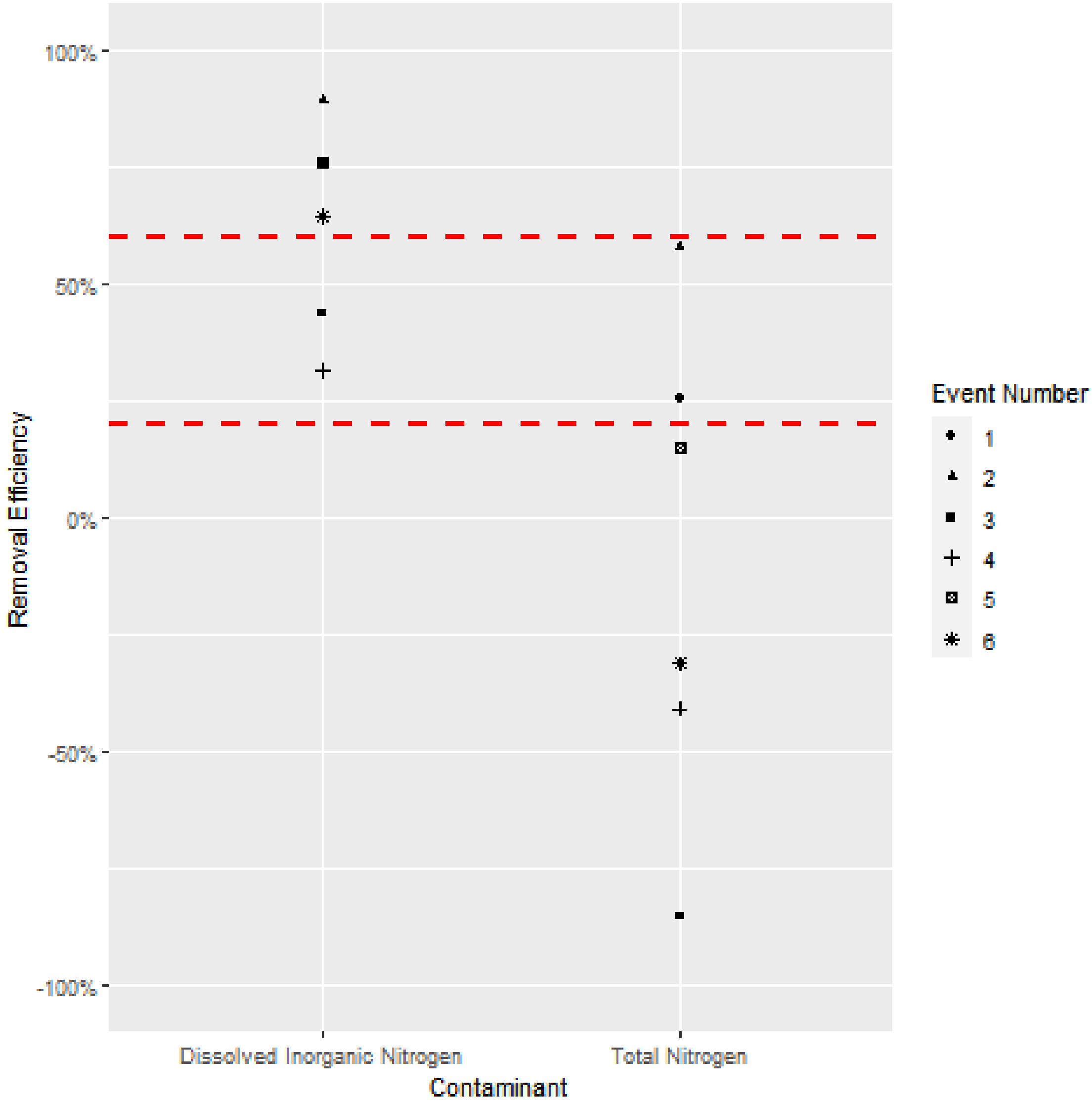

Figure 9. Nitrogen removal efficiencies for the Knights Stream wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

The removal efficiency of phosphorus in Figure 10 shows that the wetland underperforms for both DRP and TP compared with the WWDG removal efficiencies. The scaling of the graph excludes three highly negative removals of both DRP and TP.

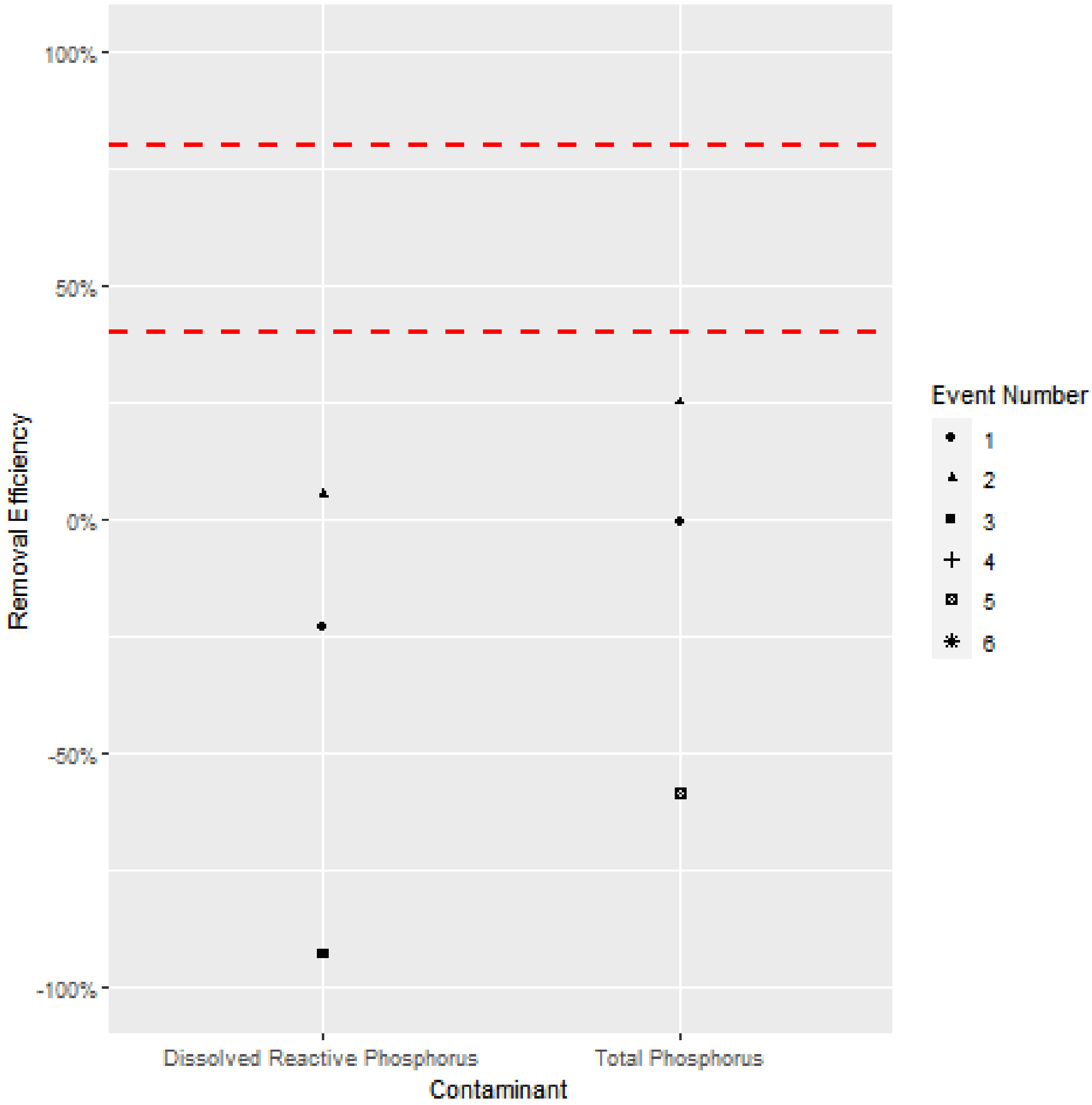

Figure 10. Phosphorus removal efficiencies for the Knights Stream wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

3.3.3 Treatment Train Summary

Removal efficiencies across the entire treatment train have been estimated for each contaminant. This was carried out by comparing the K_FFB_Sump results to the K_Outlet results for each event. With the exception of TP and DRP, positive removal efficiencies are seen for most contaminants in the majority of the rainfall events. TSS, metals, and nitrogen saw removals of greater than 50% in most events.

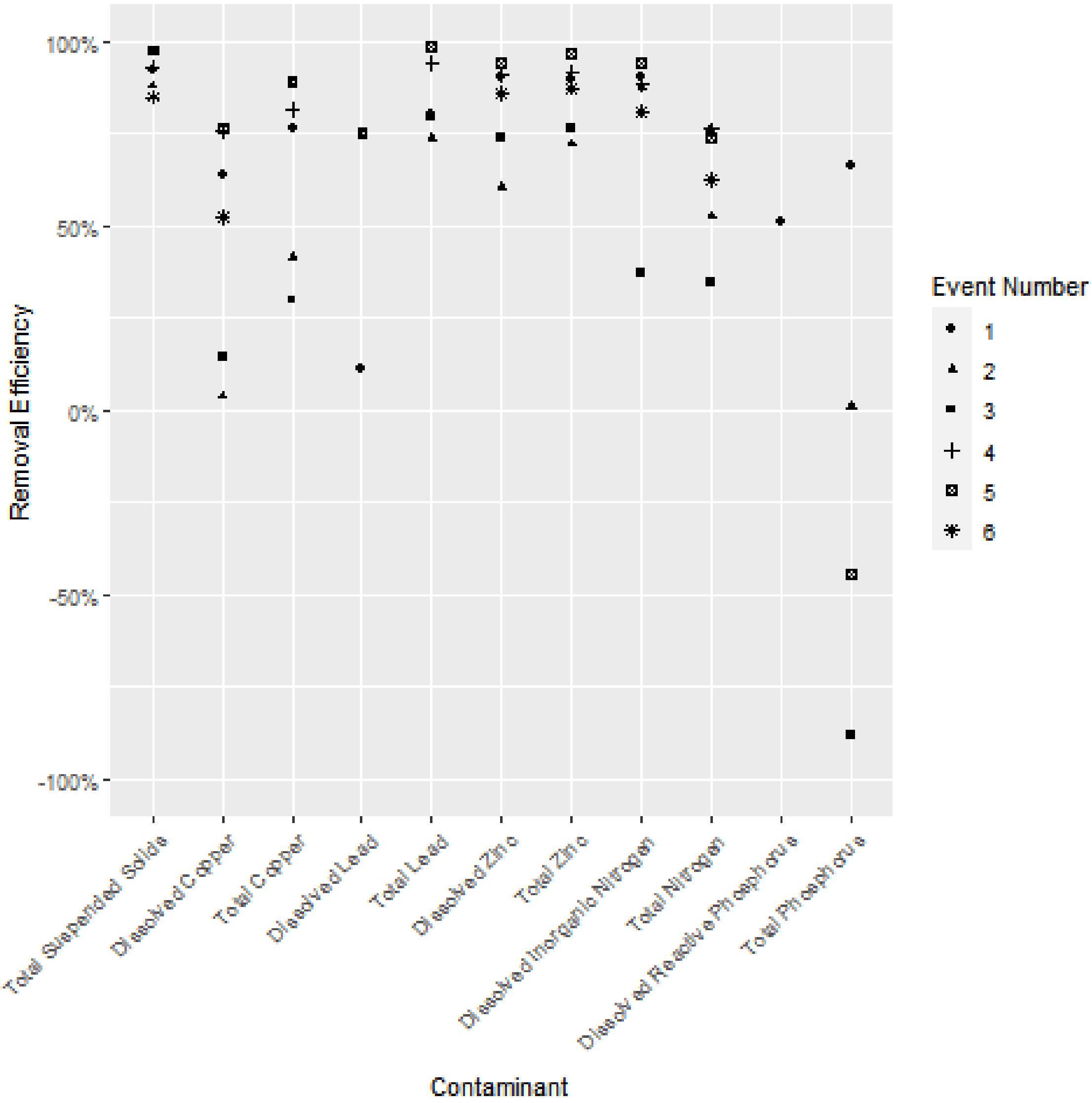

Figure 11. Contaminant removal efficiencies for the Knights Stream treatment train.

3.4 Discharge Quality

Table 3 compares the discharge water quality from the K_Outlet sampling location with the receiving water standards for each contaminant. Although the receiving water standards are intended to be used following reasonable mixing of the discharge with the receiving waterbody, they provide guidance on the quality of water discharging from the wetland. The contaminant concentrations within the receiving waterbody (Knights Stream) have not been considered in this comparison. Contaminants with no local guideline value have been excluded from the table.

Turbidity exceeded the ANZG guideline in all four events that it was analysed for, however the guideline is for the 80th percentile of natural streams and is intended for comparison after mixing. Although both total and dissolved copper exceeded the standards in at least one event, the exceedances are mostly minor with the exception of Event 1 where total copper was twice the standard.

Both total and dissolved zinc were higher than the standards in Events 1 and 2, with total zinc being twice the standard in Event 1. These contaminants were below the standards for the remaining four events. DRP exceeded the standard in all six sampled events and was significantly higher in the 2020-2021 events than the 2018 events.

Table 3: Comparison of discharge water quality with receiving water standards at Knights Stream (mg/L)

Contaminant	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Receiving Water Standard [1]
Turbidity	- [9]	- [9]	2.6	1.68	2.83	4	**1.3 [5]**
Total Suspended Solids	8.5	5	2.25	1.5 [6]	1.5 [6]	2.25	**50 [2]**
Dissolved Copper	0.0022	0.00125	0.0012	0.0014	0.001	0.0013	**0.0014 [3]**
Total Copper	0.0031	0.0015	0.0015	0.0015	0.0011	0.0015	
Dissolved Lead	0.00016	0.00005 [6]	0.00005 [6]	0.00005 [6]	0.00005 [6]	0.00005 [6]	**0.0034 [3]**
Total Lead	0.00073	0.000345	0.000055 [6]	0.000135	0.000055 [6]	0.00073	
Dissolved Zinc	0.0147	0.0115	0.0051	0.0053	0.0043	0.004	**0.008 [3]**
Total Zinc	0.023	0.0153	0.00595	0.00725	0.0052	0.0045	
Dissolved Inorganic Nitrogen	0.205	0.0785	0.163	0.1675	0.065	0.085	**1.5 [4]**
Total Ammoniacal Nitrogen	0.033	0.0305	0.094	0.1065	0.047	0.0395	**0.01 [5]**
Dissolved Reactive Phosphorus	0.043	0.034	0.2	0.31	0.182	0.295	**0.016 [4]**

Notes:

1. *The receiving water standard applies following reasonable mixing with the receiving waterbody and is therefore used as a guide only.*
2. *ECan LWRP Rule 5.97A(2)(a).*
3. *ECan LWRP Schedule 5 Table S5B.*
4. *ECan LWRP Schedule 5 Table S5A.*
5. *ANZG (2018) default guideline value for "Cool Dry Low-Elevation" 80th percentile of streams.*
6. *Sample is at or below the laboratory detection limit, so a value of half the detection limit has been used for analysis.*
7. *Reported concentrations are the average of the duplicate samples that have been analysed (where possible).*
8. *Samples that exceed the receiving water standard are highlighted orange.*
9. *Turbidity was added to the analysis list in Event 3.*

3.5 Discussion

3.5.1 First Flush

In general, there is a reduction in contaminant concentration between the raw first flush samples and the FFB inflow with the exception of nitrogen and phosphorus. Some contaminant removal via settling is likely to be occurring within the sump and downstream manholes, as well as within the swale; however, further first flush samples will be required from the autosamplers to determine whether this trend is consistent.

It is possible that the swale is receiving higher concentrations of nutrients from planted areas and fields within its catchment. The catchment area for the swale is also significantly larger than that of the K_FFB_FF site. Future sampling events should include first flush samples from both autosamplers upstream of the FFB to increase the size of the dataset so the level of treatment provided by the sump and swale can be better understood.

3.5.2 FFB Treatment

Removal efficiencies through the first flush basin were estimated for each contaminant and compared with the WWDG removal efficiencies. TSS removals were varied and are suspected to be influenced by resuspension at the K_Int site during the operation of the pump. Removal efficiencies for heavy metals vary and are also expected to be influenced by resuspension of particulates. Nitrogen removal was low or negative for the majority of sampled events, whilst phosphorus performed slightly better but was still highly variable.

The variability of the results highlights the limitations of comparing the FFB inflow concentration with the wetland inflow concentrations. More accurate removal efficiencies could be estimated if another sampling location was introduced at the outlet from the FFB, however this would require another autosampler to be installed. Additionally, as discussed in Section 2.1.1, having a greater number of samples at each site in future sampling is likely to provide a closer estimate to the EMC and will therefore provide a better estimate for the removal efficiency.

3.5.3 Wetland Treatment

The wetland removal efficiencies for TSS were mostly within the WWDG expected range, however the inflow concentrations may be influenced by resuspension. Heavy metals removal efficiencies were high for lead and zinc but were comparatively lower for total and dissolved copper. A number of factors may be influencing the lower removal of copper, including particle size distribution, pH, and redox conditions (The Water Research Foundation, 2020). Total copper concentrations at the outlet were also slightly elevated above the receiving water standards in most events.

DIN removal was high in most events, whilst TN had variable removal rates. The high DIN removal may be related to the ability of the plants and bacteria within the soil in wetland to uptake nitrate and nitrify ammonia, however further sampling is needed to confirm this.

In general, the removal efficiency of TP is higher than that of DRP, however low to negative removals are observed for both. A number of factors may be influencing the treatment performance of the wetland for phosphorus, including particle size distribution, partitioning between dissolved and particulate forms, bird droppings from waterfowl, and phosphorus availability in the wetland soils. Further sampling is required to determine whether this trend is consistent.

Further sampling using the updated 2021 methodology will allow more accurate conclusions to be drawn from the monitoring data. This would be achieved through both increasing the size of the data set as well as having composite samples which are more representative of the EMC and can therefore provide better estimates of the removal efficiencies.

3.5.4 Discharge Quality

The discharge quality from the wetland varied by contaminant but was mostly below the receiving water standards. Notable exceptions to this are turbidity, copper, and DRP, which had multiple exceedances of the standards. Turbidity exceeding the ANZG guidelines is to be expected in a stormwater discharge, particularly as the guidelines are aimed at undisturbed natural waterways rather than discharges from stormwater facilities.

Copper is mostly in dissolved form at the wetland outlet and is therefore more difficult to remove using the typical wetland processes of settling and filtration, which may be the cause of the elevated copper at the outlet. DRP exceeded the standards in all six events and was found to increase through the wetland in most events. As discussed in Section 3.5.3 above this could be a result of several factors, however in Events 3-6 the majority of phosphorus was in DRP form, which is more difficult to remove using settling and filtration.

The samples used in this analysis are composites over time periods of between 24 and 48 hours, and it is likely that contaminant concentrations will be higher than the receiving water standards during part of a given rainfall event. However, it is not expected that these short-term peaks in contaminant concentration will exceed the acute (short-term) toxicity limits within the receiving waterbodies, especially as the acute limits are typically much higher than the chronic toxicity limits and the composite sample concentrations are close to the chronic limits even without mixing.

4.0 Prestons

4.1 Event Summary

Table 4 presents a summary of the rainfall characteristics and samples obtained at the Prestons site since 2018. Samples were able to be collected from all sites in all events except for Event 3.

Only one autosampler at Prestons (at the wetland outlet) was able to collect samples during Event 3. Upon inspection of the autosamplers, it was discovered that the internal batteries (which maintain the programming memory and the internal clock) in several autosamplers were depleted. This reset the programmed intake tube lengths to the default length, so the autosamplers would stop pumping before water could reach the sample bottles. As a variation to the original scope of works, PDP disassembled the six ISCO autosamplers and replaced the internal batteries to ensure that no further loss of programming would occur.

Table 4: Rainfall characteristics of sampled events at Prestons[1]

Event Number and Start Date	Total Rainfall (mm)	Duration (hrs)	Peak Intensity (mm/hr)	Antecedent Dry Days[2] (days)	Samples Obtained
Event 1: 24 September 2018	5.8	15	1.4	20	P_FFBD_Sump P_FFBF_Sump P_FFBF P_Int P_Outlet
Event 2: 11 October 2018	13.2	57	1.4	15	P_FFBD_Sump P_FFBF_Sump P_FFBF P_Int P_Outlet
Event 3: 25 May 2020	15.4	18	2.2	19	P_FFBD_Sump P_FFBF_Sump P_Outlet
Event 4: 7 November 2020	31.2	20	4.4	8	P_FFBD_Sump P_FFBF_Sump P_FFBF P_Int P_Outlet
Event 5: 11 May 2021	13.6	27	2.4	8	P_FFBD_Sump P_FFBF_Sump P_FFBF_FF [3] P_FFBF

Table 4: Rainfall characteristics of sampled events at Prestons[1]

Event Number and Start Date	Total Rainfall (mm)	Duration (hrs)	Peak Intensity (mm/hr)	Antecedent Dry Days[2] (days)	Samples Obtained
					∴ P_Int ∴ P_Outlet
Event 6: 29 May 2021	92.6	77	7.4	3	∴ P_FFBD_Sump ∴ P_FFBF_Sump ∴ P_FFBF_FF [3] ∴ P_FFBF ∴ P_FFBF ∴ P_Int ∴ P_Outlet

Notes:

1. *Measured at CCC's Lower Styx weather station (Station ID: 66423).*
2. *Days since last rainfall exceeding 2.5 mm in 24 hours.*
3. *First flush samples obtained upstream of first flush basins as per updated methodology.*

4.2 First Flush

As with Knights Stream, first flush samples have been taken from the P_FFBF autosampler location in Events 5 and 6 and compared with the samples from the two first flush bottles installed in sumps (P_FFBF_Sump and P_FFBD_Sump) in Table 5. Although P_FFBF_Sump is in a different pipe network to P_FFBF_FF it is considered that activities near the sump are typical of those across the site and the discharge is into the same first flush basin, so the sites are comparable.

During Event 5, the turbidity in P_FFBD_Sump was significantly higher than in the other two first flush sampling sites. However, lead, zinc, and nutrients (nitrogen and phosphorus) were higher in P_FFBF_Sump than P_FFBD_Sump. The concentrations of arsenic, copper, DRP, and TP were higher in P_FFBF_FF than the sump within the same catchment (P_FFBF_Sump).

In Event 6, only a limited number of metals results were above the laboratory detection limit due to dilution of the samples by the laboratory. Similar turbidity and TSS concentrations were observed in the two sump locations, whilst the P_FFBF_FF site had notably lower concentrations of both. Similar dissolved copper concentrations were found between the P_FFBF_Sump and the P_FFBF_FF site, whilst zinc was much higher at P_FFBF_Sump compared with the other two first flush sites. TN and TP both decrease from the sumps to the P_FFBF_FF site, whilst DRP is highest at the P_FFBF_FF site and DIN is lower at the P_FFBD_Sump location than at the autosampler.

Table 5: Comparison of first flush samples at Prestons (mg/L)

Contaminant	Event 5			Event 6 [1]		
	P_FFBD_Sump	P_FFBF_Sump	P_FFBF_FF	P_FFBD_Sump	P_FFBF_Sump	P_FFBF_FF
Turbidity	87	11.7	4.9	11	15.3	3.1
Total Suspended Solids	- [2]	34	12	32	27	3
Dissolved Arsenic	0.0025	0.0005	0.0016	-	-	-
Total Arsenic	0.00265	0.0017	0.0022	-	-	-
Dissolved Copper	0.0011	0.0008	0.0030	-	0.0023	0.0022
Total Copper	0.0047	0.0043	0.0045	-	-	-
Dissolved Lead	0.00011	0.00018	0.00013	-	0.0004	-
Total Lead	0.0052	0.0102	0.00106	-	0.0016	-
Dissolved Zinc	0.010	0.059	0.026	0.0320	0.124	0.036
Total Zinc	0.0400	0.109	0.045	0.0380	0.136	0.040
Dissolved Inorganic Nitrogen	0.590	1.14	0.72	0.340	0.74	0.65
Total Nitrogen	0.910	2.70	1.39	1.280	1.44	0.9
Dissolved Reactive Phosphorus	0.0430	0.060	0.162	0.0240	0.036	0.047
Total Phosphorus	0.1690	0.177	0.33	0.1470	0.166	0.097

Notes:

1. *Laboratory dilution resulted in non-detects for many contaminants during this event. First flush samples did not have triplicates available for re-analysis.*
2. *Not enough sample available for TSS analysis.*

4.3 Removal Efficiencies

4.3.1 First Flush Basin (FFB)

Removal efficiencies for the FFB have been estimated between the P_FFBF and P_Int sampling locations. Between these sampling locations there is a conveyance swale approximately 450 m long, and two other FFB's discharge into the first cell of the wetland near the P_Int sampling location.

The removal of TSS through the Prestons FFB is shown in Figure 12. The removal rate varies between events, however only 2 out of six events had positive removal efficiencies. This low performance may be related to resuspension of TSS between the FFB and the wetland inlet, or TSS from the other FFB's affecting the sample at P_Int.

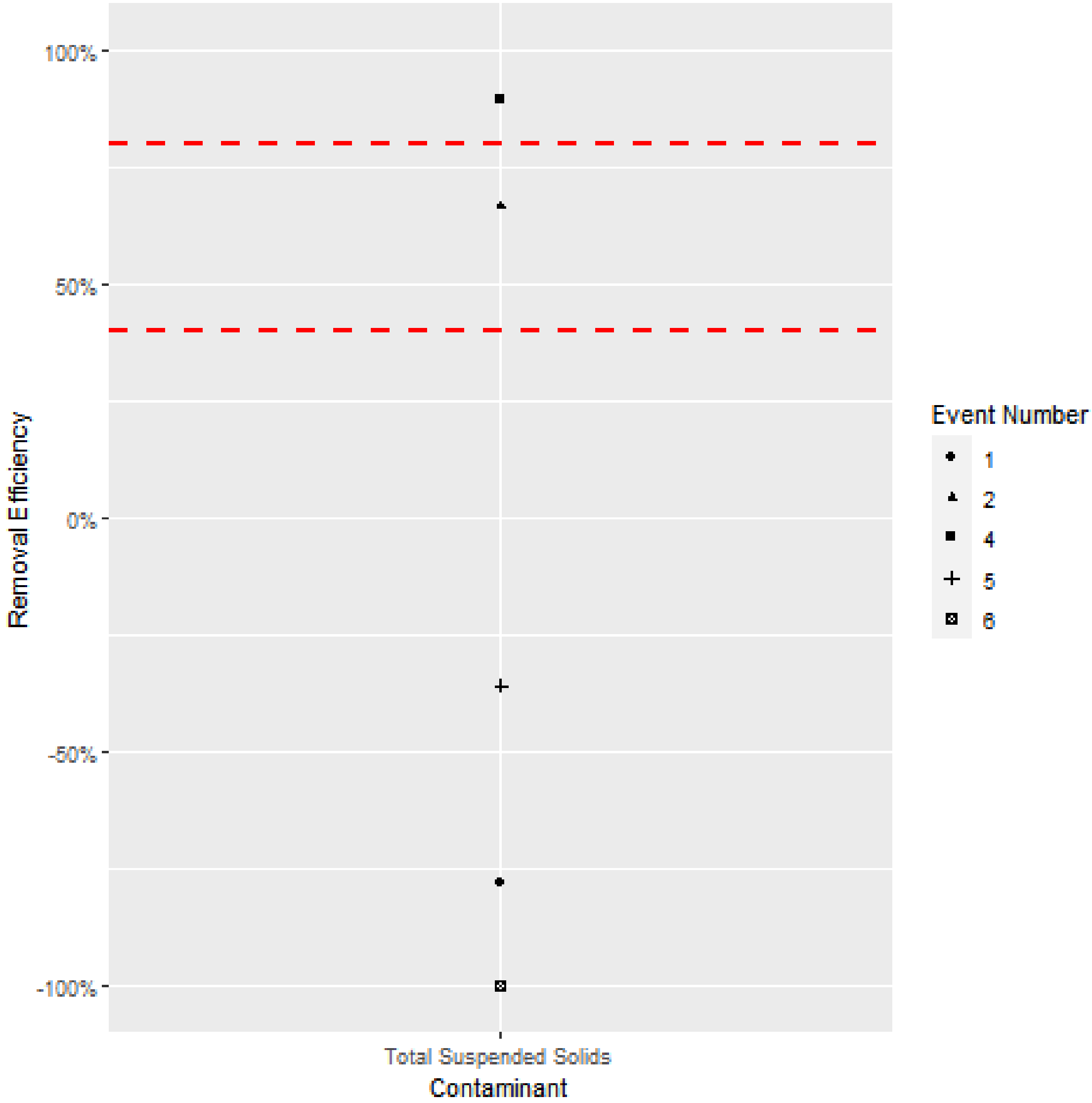

Figure 12. Total suspended solids removal efficiency for the Prestons first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

Figure 13 shows the removal efficiencies for the heavy metals suite through the Prestons FFB. With the exception of arsenic, all other heavy metals have removal efficiencies greater than the WWDG lower bound in the majority of rainfall events.

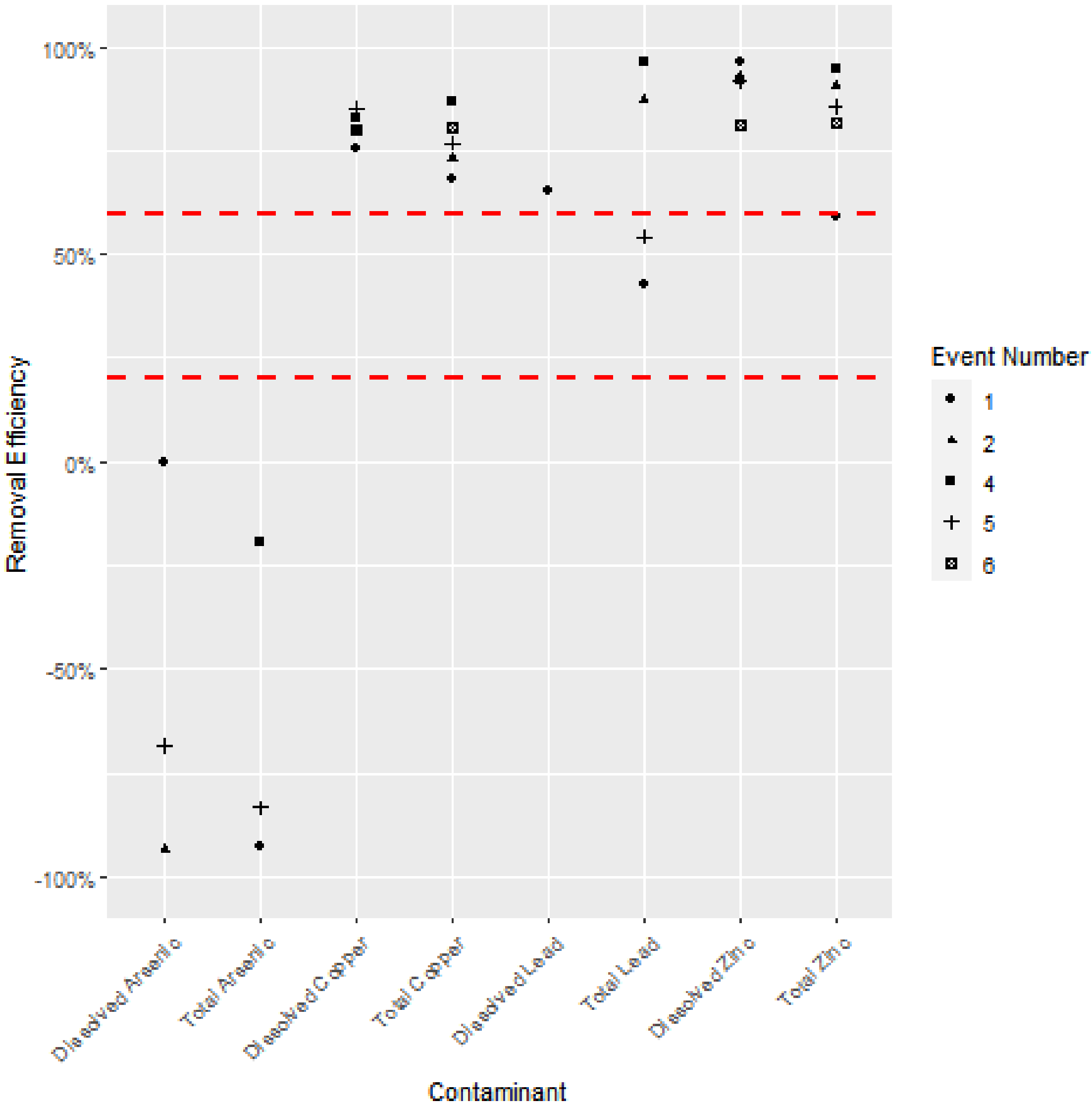

Figure 13. Heavy metals removal efficiencies for the Prestons first flush basin. CCC WWDG Table 6-6 removal efficiency range for a “Dry Detention Basin” shown with red dashed lines.

The removal of DIN and TN in Figure 14 shows a similar pattern to the Knights Stream wetland, with higher removals of DIN than TN.

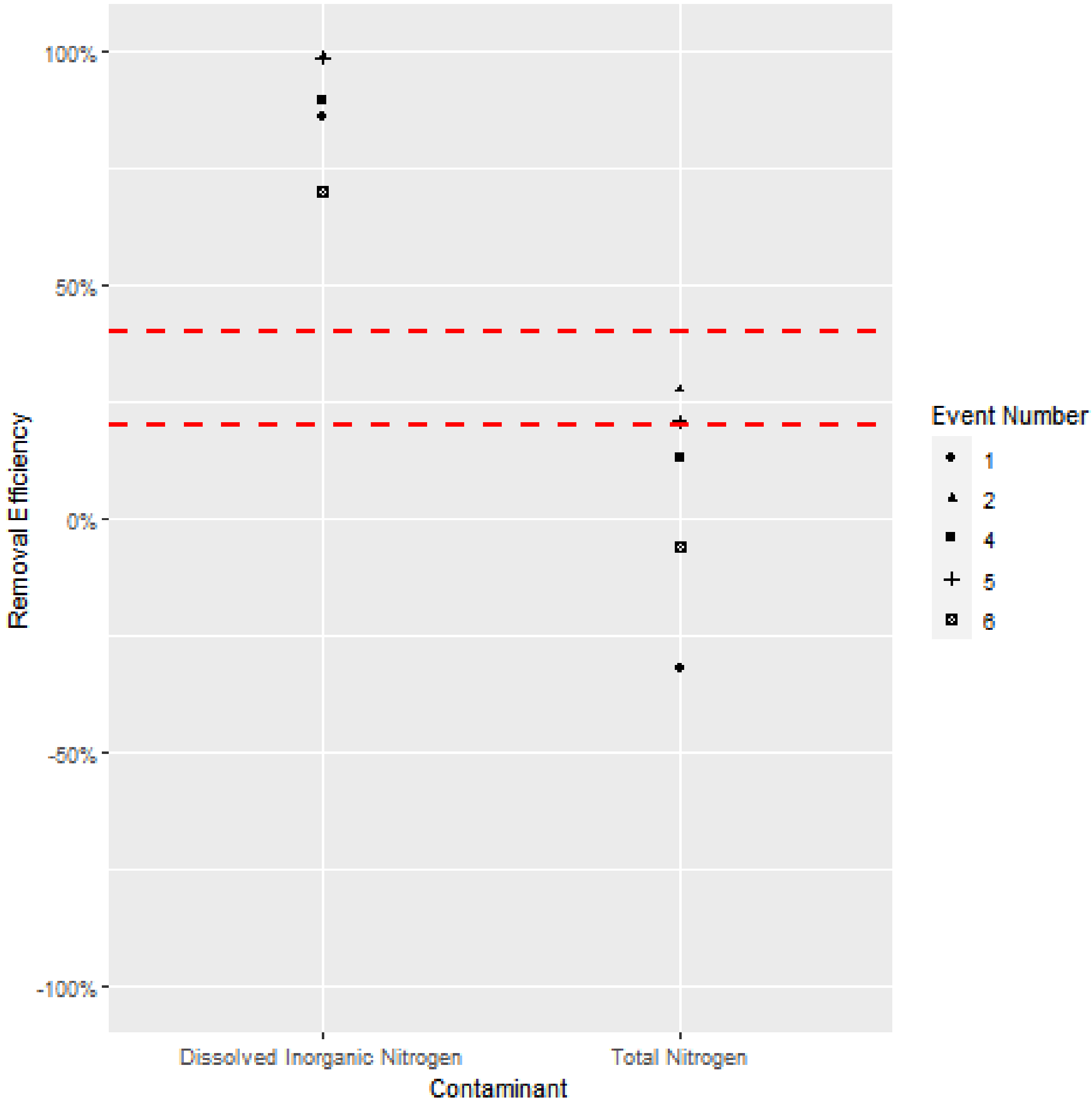

Figure 14. Nitrogen removal efficiencies for the Prestons first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

Figure 15 shows the removal efficiencies of DRP and TP between P_FFBF and P_Int. The removal efficiency of DRP is above the WWDG lower bound for all sampled events (no sample obtained at P_Int for Event 3), whilst TP is above the WWDG lower bound in three sampled events.

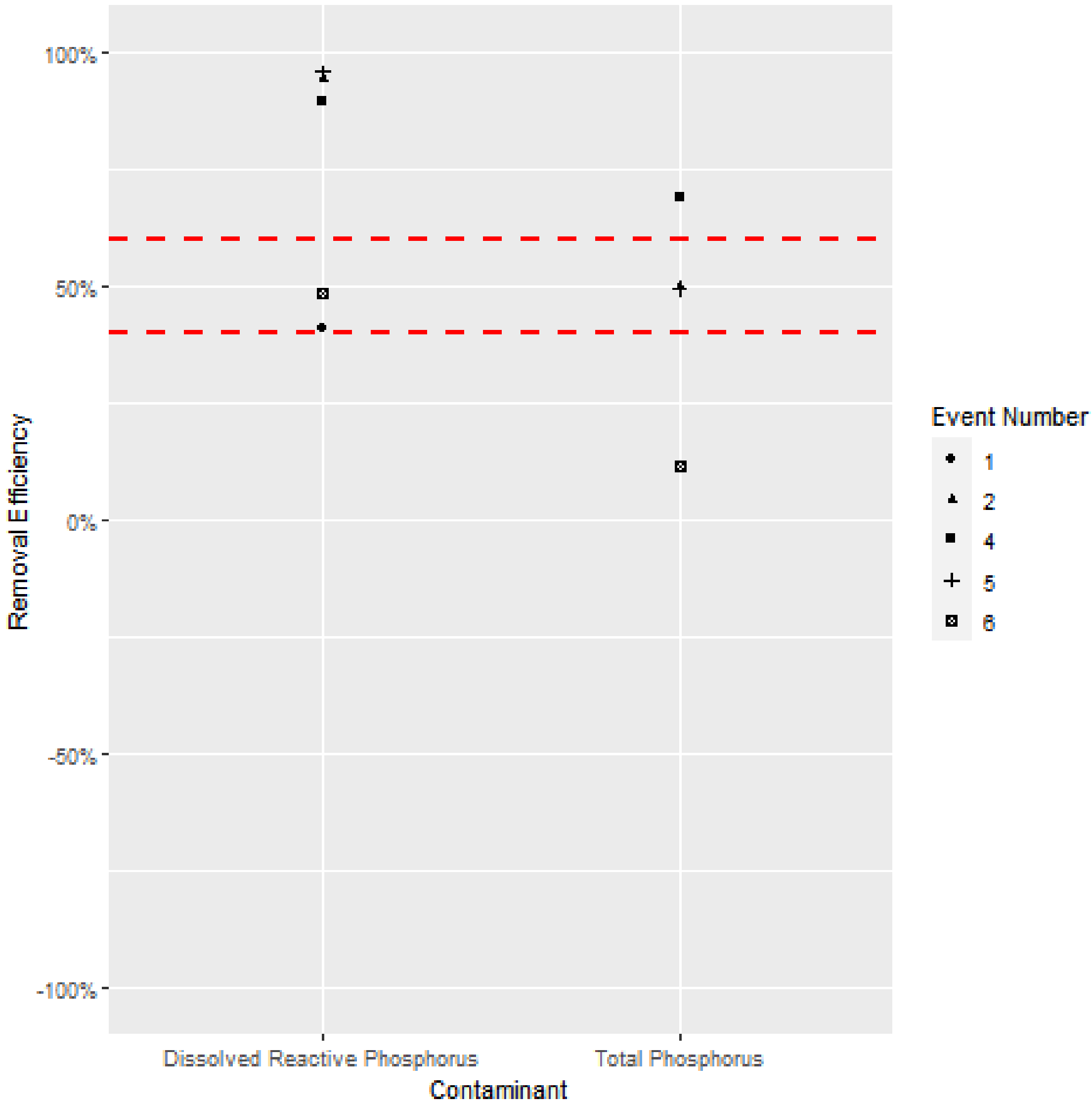

Figure 15. Phosphorus removal efficiencies for the Prestons first flush basin. CCC WWDG Table 6-6 removal efficiency range for a "Dry Detention Basin" shown with red dashed lines.

4.3.2 Wetland

Removal efficiencies across the Prestons wetland have been calculated between the P_Int and P_Outlet sampling locations.

The TSS removal through the wetland shown in Figure 16 is highly variable. This may be due to resuspension of solids through the wetland or within the outlet sump itself where the P_Outlet samples are taken as water from the wetland falls into the sump chamber where it may resuspend sediment.

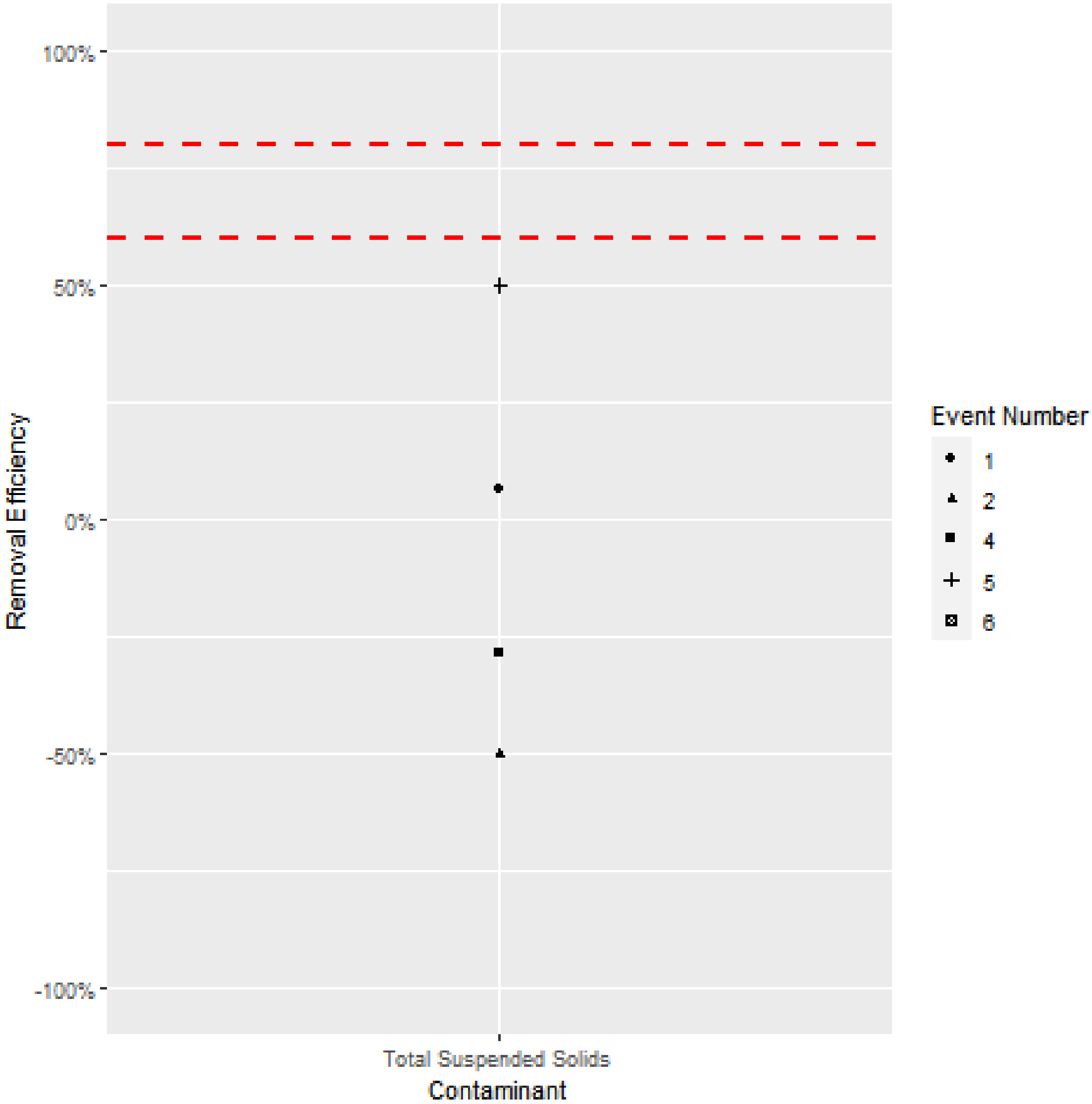

Figure 16. Total suspended solids removal efficiencies for the Prestons wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

Figure 17 shows the heavy metals suite removal efficiencies through the wetland. As with the FFB, arsenic increases through the wetland (see Section 4.3.1). Removal efficiencies above the WWDG lower bound are seen for all metals except lead in most sampled events. Only two dissolved copper efficiencies were calculated as the other events had concentrations below the laboratory detection limit at the inlet and outlet sampling sites.

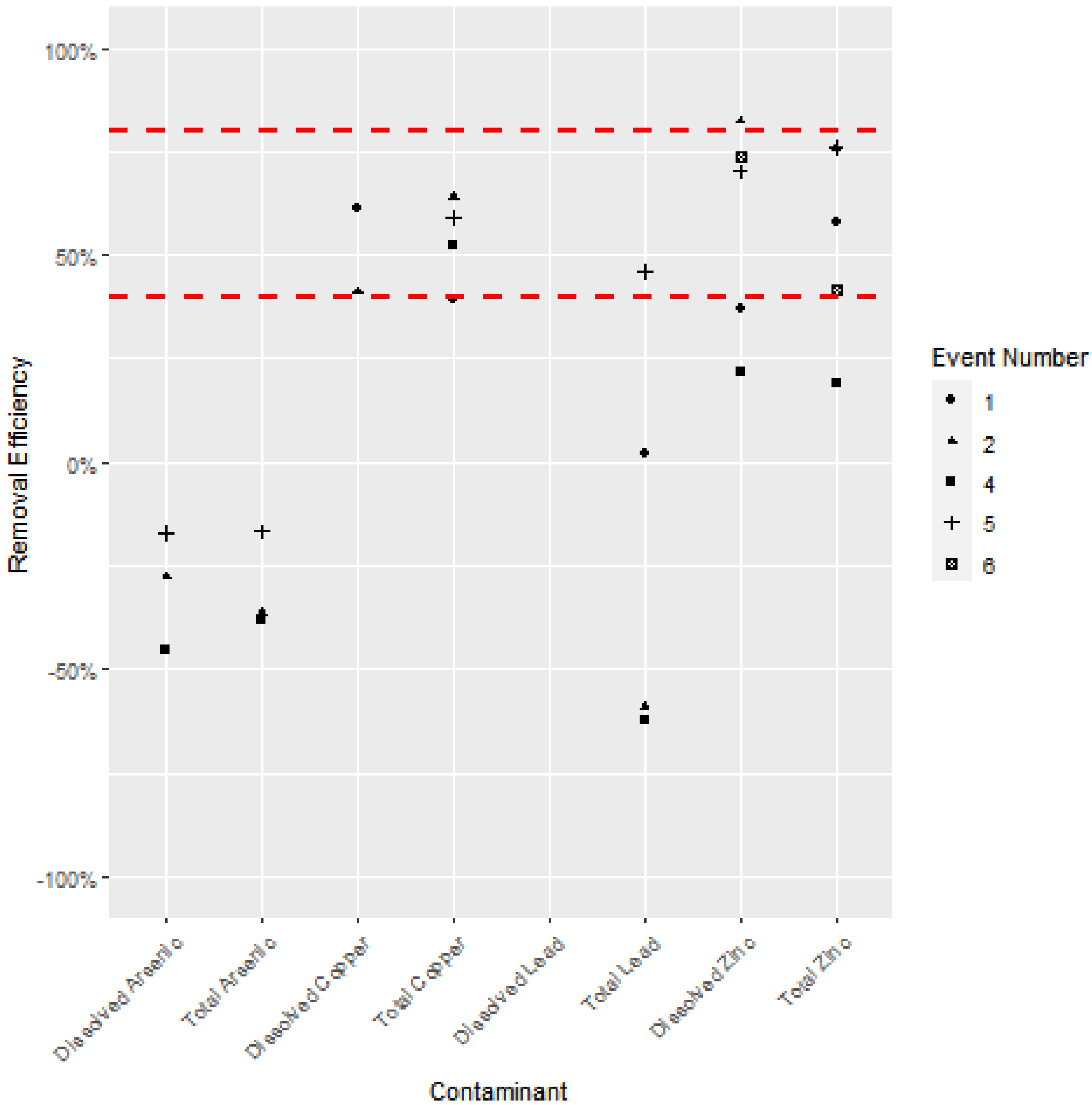

Figure 17. Heavy metals removal efficiencies for the Prestons wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

Similar to the Knights Stream wetland and the Prestons FFB, DIN removal efficiencies are high through the Prestons wetland whilst total nitrogen has low or negative removals. There is one outlier for DIN during Event 5 which is not shown on the graph below, which had a highly negative removal resulting from a non-detect concentration (0.0055 mg/L) at P_Int and a concentration of 0.0653 mg/L at P_Outlet.

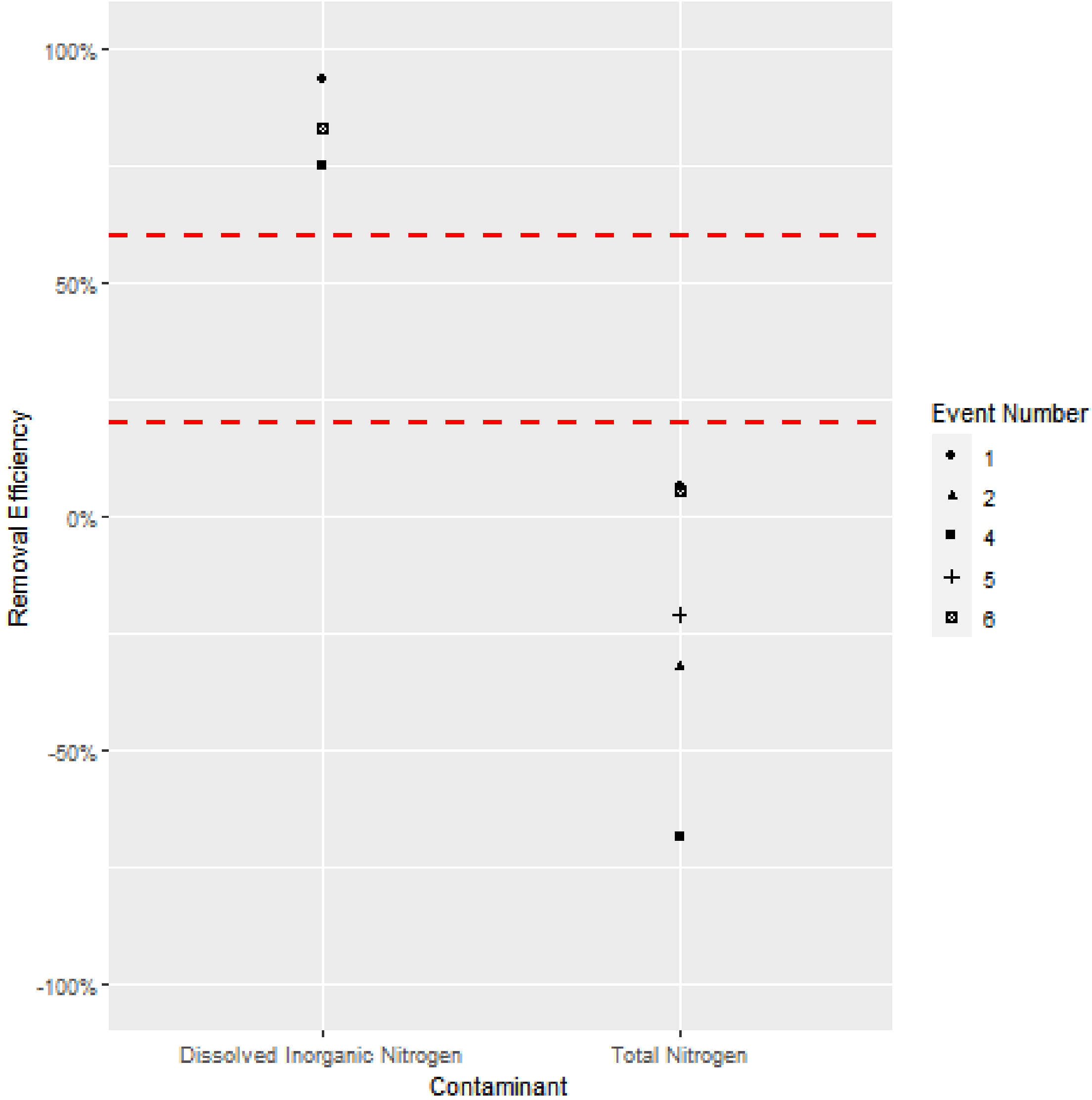

Figure 18. Nitrogen removal efficiencies for the Prestons wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

The removal efficiency of DRP and TN through the wetland is highly variable as shown in Figure 19.

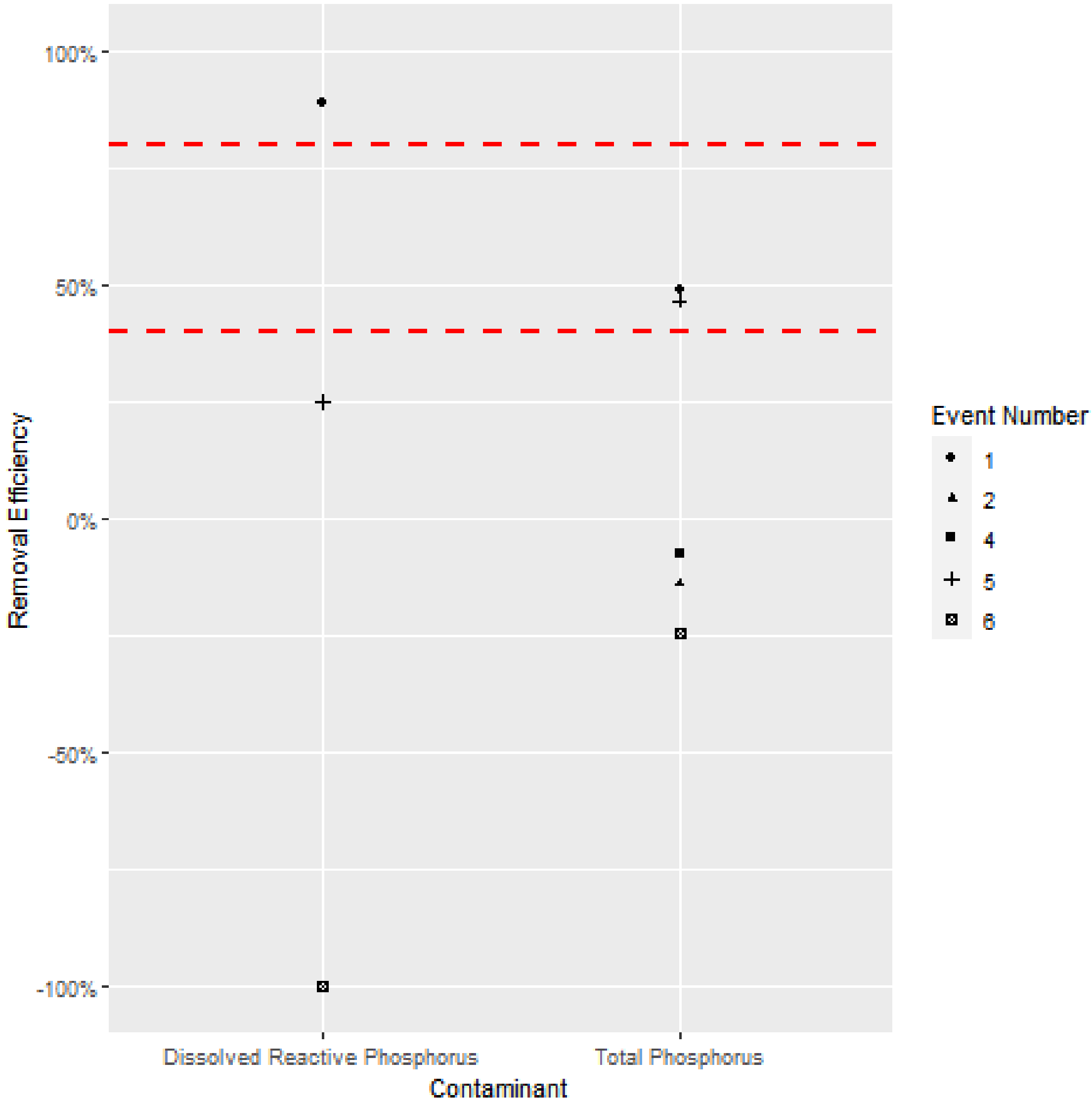

Figure 19. Phosphorus removal efficiencies for the Prestons wetland. CCC WWDG Table 6-6 removal efficiency range for "Wetlands" shown with red dashed lines.

4.3.3 Treatment Train Summary

The removal efficiency across the entire treatment train has been summarised in Figure 20. The removal efficiency has been calculated by comparing the results of P_FFBF_Sump to P_Outlet to calculate a total removal efficiency across the facility. With the exception of arsenic, the other contaminants show treatment train removal efficiencies of greater than 50% for most of the sampled events.

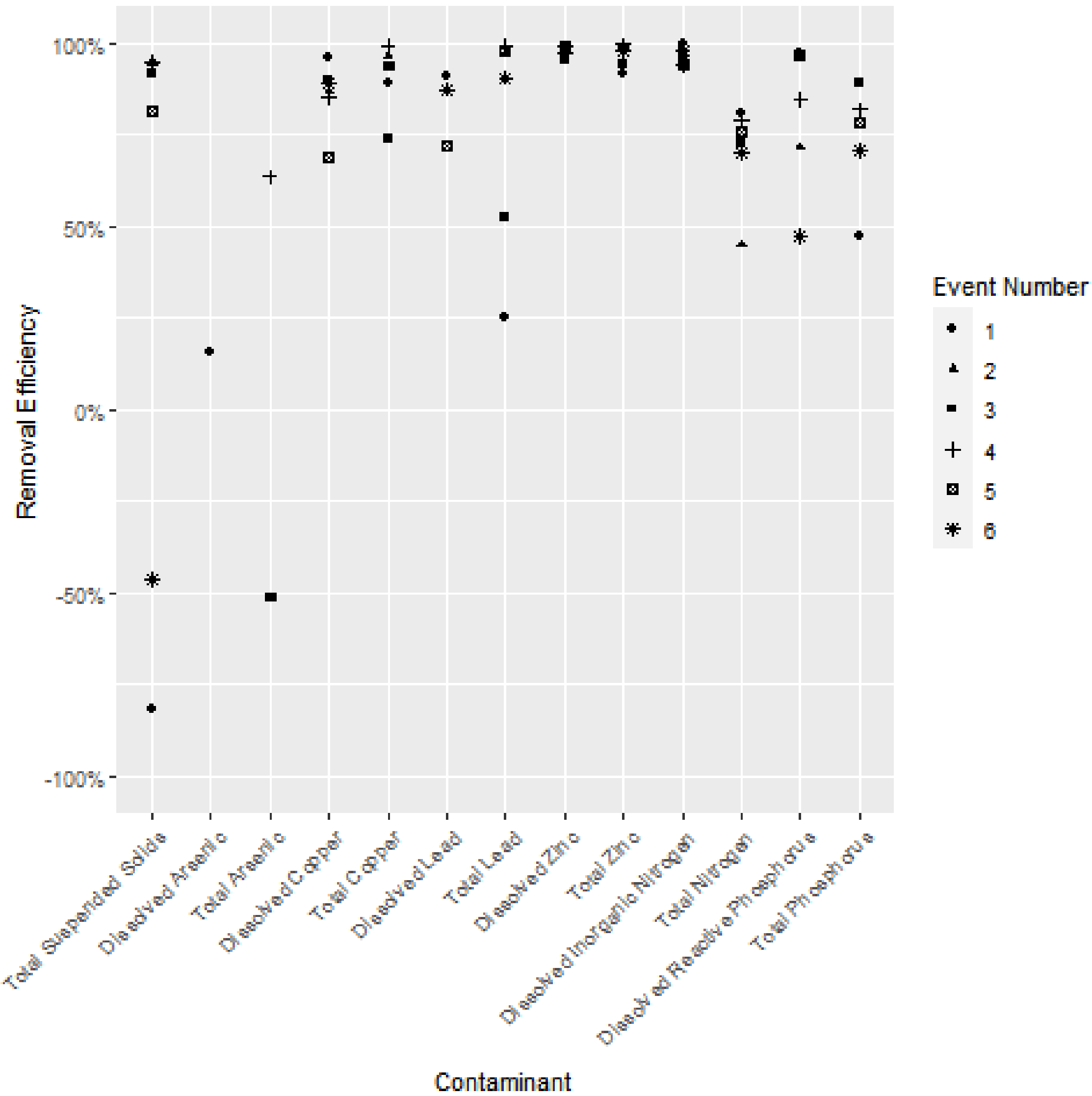

Figure 20. Contaminant removal efficiencies for the Prestons treatment train. CCC WWDG Table 6-6 removal efficiency range shown with red dashed lines.

4.4 Discharge Quality

Table 6 provides a comparison between the discharge quality for each of the six sampled events at the P_Outlet sampling location with the receiving water standards. The receiving water standards are intended for use on samples taken downstream of the mixing zone in the receiving waterbody, however they can be used as a guideline for assessing the quality of stormwater discharges. The contaminant concentrations within the receiving waterbody (Styx River) have not been considered in this comparison. Contaminants with no local guideline value have been excluded from the table.

Total zinc in Event 1 exceeded the receiving water standard by 0.003 mg/L but was below the standard for all other events. DRP also exceeded the standard by 0.003 mg/L in Event 6; however, DRP concentrations were below the standard in all other events. Turbidity exceeded the ANZG standard in all four events that it was analysed for.

Other than the contaminants discussed above, all samples were below the receiving water standards for all events.

Table 6: Comparison of discharge water quality with receiving water standards at Prestons (mg/L)

Contaminant	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Receiving Water Standard [1]
Turbidity	- [10]	- [10]	2.15	1.7	2.2	1.9	**1.3 [5]**
Total Suspended Solids	49	2.25	3.25	4.5	6.33	39.5	**50 [2]**
Dissolved Arsenic	0.0016	0.0019	0.0017	0.0024	0.0023	- [9]	**0.013 [3, 11]**
Total Arsenic	0.0061	0.0023	0.0018	0.0026	0.0026	- [9]	
Dissolved Copper	0.00025 [6]	0.00025 [6]	0.00025 [6]	0.00025 [6]	0.00025 [6]	0.00025 [6]	**0.0014 [3]**
Total Copper	0.0011	0.000265 [6]	0.00078	0.000265 [6]	0.000265 [6]	0.000265 [6]	
Dissolved Lead	0.00005 [6]	0.00005 [6]	0.00005 [6]	0.00005 [6]	0.00005 [6]	0.00005 [6]	**0.0034 [3]**
Total Lead	0.00172	0.00009	0.00019	0.00015	0.00019	0.00015	
Dissolved Zinc	0.00085	0.0005 [6]	0.00775	0.0009	0.00052	0.0012	**0.008 [3]**
Total Zinc	0.011	0.0011	0.0087	0.0019	0.0012	0.0028	
Dissolved Inorganic Nitrogen	0.0055 [6]	0.0055 [6]	0.0255	0.0055 [6]	0.0653	0.0135	**1.5 [4]**
Total Ammoniacal Nitrogen	0.005 [6]	0.005 [6]	0.005 [6]	0.005 [6]	0.019	0.005 [6]	**0.01 [5]**
Dissolved Reactive Phosphorus	0.002 [6]	0.002 [6]	0.002 [6]	0.002 [6]	0.002 [6]	0.019	**0.016 [4]**

Notes:

Table 6: Comparison of discharge water quality with receiving water standards at Prestons (mg/L)

1. *The receiving water standard applies following reasonable mixing with the receiving waterbody and is therefore used as a guide only.*
2. *ECan LWRP Rule 5.97A(2)(a).*
3. *ECan LWRP Schedule 5 Table S5B.*
4. *ECan LWRP Schedule 5 Table S5A.*
5. *ANZG (2018) default guideline value for "Cool Dry Low-Elevation" 80th percentile of streams.*
6. *Sample is at or below the laboratory detection limit, so a value of half the detection limit has been used for analysis.*
7. *Reported concentrations are the average of the duplicate samples that have been analysed (where possible).*
8. *Samples that exceed the receiving water standard are highlighted orange.*
9. *The laboratory did not analyse for arsenic on the triplicate samples following the over-dilution of the duplicate samples.*
10. *Turbidity was added to the analysis list in Event 3.*
11. *For conservatism the guideline value for Arsenic V (AsV) has been used.*

4.5 Discussion

4.5.1 First Flush

Concentration reductions are seen in both events between the sumps and the upstream autosampler, with the exception of arsenic, copper, and phosphorus. As with Knights Stream it is likely that the sumps and manholes in the network are removing some contaminants, however further first flush sampling at the autosampler is needed to develop trends further.

4.5.2 FFB Treatment

TSS removal through the FFB is highly variable and is expected to be influenced by sediment resuspension. With the exception of arsenic, high removal efficiencies are shown for all tested heavy metals. The increase in arsenic through the FFB is thought to be due to naturally elevated arsenic levels within the peaty soil of the area being released into the FFB or wetland inlet via either overland flow (erosion) and/or groundwater. This was discussed within the Stage 1 report (PDP, 2018).

As with the Knights Stream wetland, DIN removal efficiency through the FFB is much higher than that of TN. It is likely that DIN is being consumed by plants as the stormwater flows through the swale from the FFB to the wetland, resulting in high DIN removal. Some removal of DIN may be occurring within the FFB, however there is currently no sampling location at the FFB outlet to confirm this. Phosphorus removal efficiencies were high for DRP and TP, which may also be attributed to the long swale. To more accurately assess the removal efficiency of the FFB there would need to be an additional sampling location at the outlet from the FFB.

The removal efficiencies of the FFB are likely to be influenced by the 450 m long planted swale between the FFB and the P_Int sampling site as well as the two additional inflows into the wetland forebay. The additional inflows are sourced from first flush basins serving similar catchments; however, these inflows do not pass through a long swale prior to the wetland forebay. An additional sampling location at the outlet from the FFB as well as further sampling using the updated sampling methodology would be required to develop a more accurate estimate of the FFB's treatment efficiency.

4.5.3 Wetland Treatment

The wetland removal efficiencies were highly variable for TSS and it is suspected that resuspension of TSS in the wetland outlet due to turbulence within the sump may be contributing to elevated TSS. Moving the autosampler intake outside of the sump would eliminate this potential source of resuspension and is recommended for future sampling rounds.

As with the FFB, arsenic increases through the wetland and is suspected to be influenced by naturally elevated arsenic in the groundwater or soil, whilst copper and zinc meet the WWDG lower bound removal efficiency in most events.

DIN and TN showed similar patterns to the FFB and the Knights Stream wetland, with higher DIN removal than TN. Phosphorus removal was highly variable and, as with the Knights Stream wetland, may be influenced by particle size distribution, partitioning between dissolved and particulate forms, bird droppings from waterfowl, and phosphorus availability in the wetland soils (The Water Research Foundation, 2020).

4.5.4 Discharge Quality

With the exception of turbidity, zinc, and DRP, all contaminants were below the receiving water standards for all events. Turbidity exceeded the ANZG guidelines in all events, which is to be expected for a stormwater discharge as the ANZG guidelines are for natural streams rather than urban stormwater discharges. Total zinc and DRP both exceeded the guidelines once by 0.003 mg/L, which would likely be offset by mixing with the receiving waterbody (depending on the concentration within the receiving waterbody which has not been assessed).

As with Knights Stream, the contaminant concentrations discharging from the wetland will fluctuate throughout a rainfall event. However, it is not expected that short-term increases in contaminant concentrations within a rainfall event would exceed the acute toxicity limits in the receiving waterway as the composite sample concentrations are close to the receiving water standards prior to mixing.

5.0 Conclusion

The results of six rainfall events have been analysed for the Prestons and Knights Stream stormwater facilities to determine the treatment efficiencies of the sumps, FFBs, and wetlands. The discharge quality from these facilities have also been compared to the appropriate receiving water quality standards.

Overall, the treatment trains at both sites are treating most of the typical stormwater contaminants at both stormwater facilities, to the extent that many of these contaminants meet the receiving water standards in their outlets prior to mixing. Brief periods of contaminant concentrations that exceed the receiving water standards during a rainfall event are to be expected as the first flush of stormwater passes through the stormwater facility; however, these periods of elevated contaminant concentrations are not expected to result in exceedances of the acute toxicity limits following mixing with the receiving waterways.

Further sampling would allow the removal efficiencies and discharge qualities discussed in this report to be backed up by a larger evidence base, particularly for the first flush samples which have only been collected in two events. Additional sampling rounds using the updated sampling methodology would also increase the accuracy of the treatment efficiency estimates.

The study may also benefit from having additional sampling locations at the outlets from the first flush basins. This would allow the treatment efficiencies of these basins to be estimated with less interference from other parts of the stormwater network which may be either providing treatment or potential resuspension of contaminants.

6.0 References

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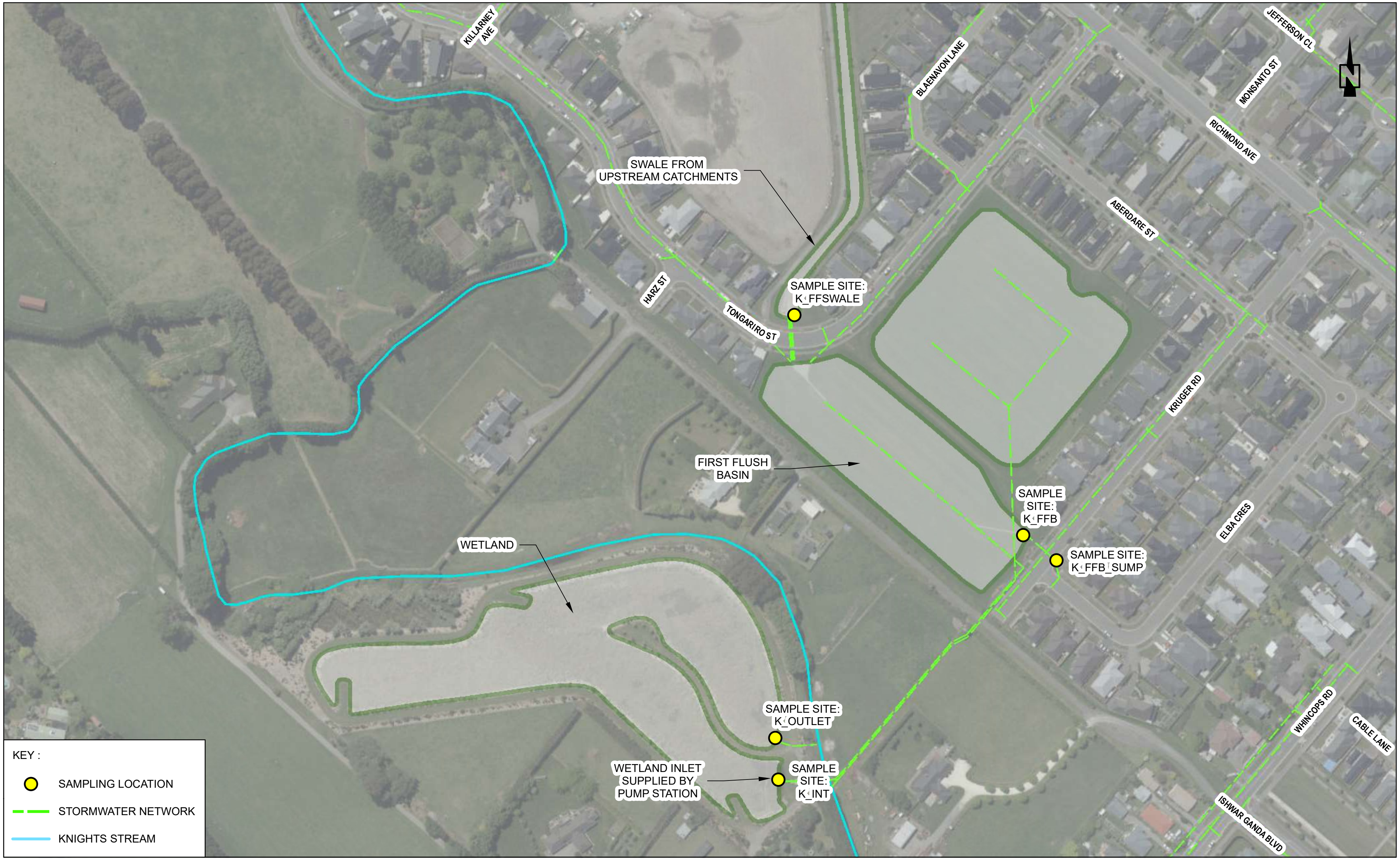
The Water Research Foundation. (2020). *International Stormwater BMP Database 2020 Summary Statistics.* Denver, Colorado, USA: The Water Research Foundation.

Appendix A: Sampler Layout



SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAPS PARTNERS LTD AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
2. STORMWATER ASSET DATA AND WATERWAY ALIGNMENT SOURCED FROM CHRISTCHURCH CITY COUNCIL'S GIS REST SERVICES AT https://gis.ccc.govt.nz/arcgis/rest/services/CorporateData/StormWater/MapServer AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE..

FIGURE 1 : KNIGHTS STREAM STORMWATER FACILITY
SAMPLING LOCATIONS

SCALE : 1:3,000 (A4)

0 10 20 40 60
METRES

C03816300Z001_Figure 1 Knights.mxd 20/09/2021 ISSUE 1

SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAPS PARTNERS LTD AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
2. STORMWATER ASSET DATA AND WATERWAY ALIGNMENT SOURCED FROM CHRISTCHURCH CITY COUNCIL'S GIS REST SERVICES AT https://gis.ccc.govt.nz/arcgis/rest/services/CorporateData/StormWater/MapServer AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE..

FIGURE 2 : PRESTONS STORMWATER FACILITY SAMPLING LOCATIONS

SCALE : 1:6,000 (A4)

0 25 50 100 150

METRES

PATTLE DELAMORE PARTNERS LTD

C03816300Z002_Figure 2 Prestons.mxd 04/08/2021 ISSUE 1

Appendix B: Stage 2 Raw Laboratory Data

Hill Laboratories
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Certificate of Analysis

Client:	Pattle Delamore Partners Limited	**Lab No:**	2373849	SPv1
Contact:	I Cooper	**Date Received:**	27-May-2020	
	C/- Pattle Delamore Partners Limited	**Date Reported:**	04-Jun-2020	
	PO Box 389	**Quote No:**	103440	
	Christchurch 8140	**Order No:**		
		Client Reference:		
		Submitted By:	Liam Allan	

Sample Type: Aqueous

Sample Name:		P_FFBF_Sump_1 25-May-2020 11:15 am	P_FFBD_Sump_1 25-May-2020 11:30 am	P_Outlet_1 27-May-2020 10:45 am	P_Outlet_2 27-May-2020 10:45 am	K_FFSW_Sump_1 25-May-2020 12:30 pm
Lab Number:		2373849.1	2373849.2	2373849.3	2373849.4	2373849.6
Turbidity	NTU	22	16.1	2.1	2.2	19.6
Total Suspended Solids	g/m³	38	82	5	< 3	96
Dissolved Arsenic	g/m³	< 0.0010	0.0012	0.0016	0.0017	-
Total Arsenic	g/m³	< 0.0011	0.0015	0.0018	0.0018	-
Dissolved Copper	g/m³	0.0025	0.0022	< 0.0005	< 0.0005	0.0040
Total Copper	g/m³	0.0030	0.0051	0.00101	0.00055	0.0070
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	0.00040	0.0022	0.00019	0.00019	0.0020
Dissolved Zinc	g/m³	0.160 #1	0.056	0.0075	0.0080	0.044
Total Zinc	g/m³	0.157	0.103	0.0085	0.0089	0.071
Dissolved Inorganic Nitrogen*	g/m³	0.80	0.59	0.026	0.025	1.18
Total Nitrogen	g/m³	1.45	1.28	0.49	0.31	2.6
Total Ammoniacal-N	g/m³	0.31	0.38	< 0.010	< 0.010	0.78
Nitrate-N + Nitrite-N	g/m³	0.49	0.21	0.026	0.025	0.40
Total Kjeldahl Nitrogen (TKN)	g/m³	0.96	1.07	0.47	0.28	2.2
Dissolved Reactive Phosphorus	g/m³	0.060	0.070	< 0.004	< 0.004	< 0.004
Total Phosphorus	g/m³	0.22	0.176	0.022	0.026	0.25

Sample Name:		K_FFB_Sump_1 25-May-2020 12:40 pm	K_FFSwale_1 26-May-2020 1:50 pm	K_FFSwale_2 26-May-2020 1:55 pm	K_FFB_1 26-May-2020 2:50 pm	K_FFB_2 26-May-2020 2:50 pm
Lab Number:		2373849.7	2373849.8	2373849.9	2373849.10	2373849.11
Turbidity	NTU	13.4	3.0	2.8	1.37	0.16
Total Suspended Solids	g/m³	79	4	4	< 3	< 15 #2
Dissolved Copper	g/m³	0.0014	0.0011	0.0010	0.0006	0.0005
Total Copper	g/m³	0.0022	0.00120	0.00110	0.00100	0.00098
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	0.00027	< 0.00011	0.00012	0.00013	0.00022
Dissolved Zinc	g/m³	0.0197	0.0055	0.0054	0.0175	0.0163
Total Zinc	g/m³	0.025	0.0068	0.0069	0.0193	0.0192
Dissolved Inorganic Nitrogen*	g/m³	0.26	0.41	0.40	0.20	0.191
Total Nitrogen	g/m³	1.33	0.56	0.68	0.31	0.32
Total Ammoniacal-N	g/m³	0.196	0.20	0.20	0.130	0.121
Nitrate-N + Nitrite-N	g/m³	0.060	0.20	0.195	0.074	0.070
Total Kjeldahl Nitrogen (TKN)	g/m³	1.27	0.35	0.49	0.24	0.25
Dissolved Reactive Phosphorus	g/m³	0.018	0.075	0.078	0.011	0.010
Total Phosphorus	g/m³	0.157	0.126	0.122	0.028	0.026

Sample Type: Aqueous						
	Sample Name:	K_Int_1 26-May-2020 3:45 pm	K_Int_2 26-May-2020 3:45 pm	K_Out_1 26-May-2020 2:30 pm	K_Out_2 26-May-2020 2:30 pm	
	Lab Number:	2373849.12	2373849.13	2373849.14	2373849.15	
Turbidity	NTU	3.4	3.3	2.6	2.6	-
Total Suspended Solids	g/m³	< 3	< 3	3	< 3	-
Dissolved Copper	g/m³	0.0010	0.0011	0.0012	0.0012	-
Total Copper	g/m³	0.00126	0.00137	0.00153	0.00155	-
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	-
Total Lead	g/m³	0.00015	0.00024	< 0.00011	< 0.00011	-
Dissolved Zinc	g/m³	0.0149	0.0148	0.0050	0.0052	-
Total Zinc	g/m³	0.0162	0.0173	0.0060	0.0059	-
Dissolved Inorganic Nitrogen*	g/m³	0.29	0.29	0.161	0.165	-
Total Nitrogen	g/m³	0.46	0.48	0.87	0.87	-
Total Ammoniacal-N	g/m³	0.138	0.137	0.092	0.096	-
Nitrate-N + Nitrite-N	g/m³	0.152	0.152	0.069	0.069	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.31	0.33	0.80	0.80	-
Dissolved Reactive Phosphorus	g/m³	0.046	0.046	0.20	0.20	-
Total Phosphorus	g/m³	0.082	0.081	0.29	0.30	-

Analyst's Comments

#1 It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

#2 There was insufficient sample left to filter the usual amount for the Total Suspended Solids test, so the detection limit is higher than normal.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-4, 6-15
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-4, 6-15
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-4, 6-15
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m³	1-4, 7-10, 12-15
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m³	6, 11
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-4, 6-15
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1-4
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m³	1-4
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m³	1-4, 6-15
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m³	1-4, 6-15
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.00010 g/m³	1-4, 6-15
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m³	1-4, 6-15
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1-4, 6-15

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-4, 6-15
Dissolved Inorganic Nitrogen*		0.002 - 0.010 g/m^3	1-4, 6-15
Dissolved Inorganic Nitrogen*	Calculation: NH_4-N + NO_3-N + NO_2-N. In-House.	0.010 g/m^3	1-4, 6-15
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-4, 6-15
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-4, 6-15
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-4, 6-15
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-4, 6-15
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-4, 6-15
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-4, 6-15

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Dates of testing are available on request. Please contact the laboratory for more information.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

Kim Harrison MSc
Client Services Manager - Environmental

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Certificate of Analysis

SPv1

Client:	Pattle Delamore Partners Limited	**Lab No:**	2472438
Contact:	Liam Allan	**Date Received:**	12-Nov-2020
	C/- Pattle Delamore Partners Limited	**Date Reported:**	19-Nov-2020
	PO Box 389	**Quote No:**	103440
	Christchurch 8140	**Order No:**	
		Client Reference:	
		Submitted By:	Liam Allan

Sample Type: Aqueous

Sample Name:		P_FFBF_Sump 09-Nov-2020 4:45 pm	P_FFBD_Sump 09-Nov-2020 5:00 pm	P_FFBF_1 10-Nov-2020 10:00 am	P_FFBF_2 10-Nov-2020 10:00 am	P_Int_1 10-Nov-2020 11:30 am
Lab Number:		2472438.1	2472438.2	2472438.3	2472438.4	2472438.5
Turbidity	NTU	42	4.6	8.4	24	1.75
Total Suspended Solids	g/m³	90	23	33	34	3
Dissolved Arsenic	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0016
Total Arsenic	g/m³	0.0070	< 0.0011	0.0015	0.0016	0.0019
Dissolved Copper	g/m³	0.0017	< 0.0005	0.0014	0.0015	< 0.0005
Total Copper	g/m³	0.047	0.0037	0.0041	0.0042	0.00057
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	0.029	0.0028	0.0025	0.0025	0.00013
Dissolved Zinc	g/m³	0.035	0.025	0.0151	0.0132	0.0013
Total Zinc	g/m³	0.43	0.066	0.045	0.045	0.0027
Dissolved Inorganic Nitrogen*	g/m³	0.092	0.110	0.22	0.195	0.024
Total Nitrogen	g/m³	3.4	0.47	0.50	0.48	0.44
Total Ammoniacal-N	g/m³	0.045	0.075	0.066	0.054	0.021
Nitrate-N + Nitrite-N	g/m³	0.047	0.035	0.150	0.141	0.002
Total Kjeldahl Nitrogen (TKN)	g/m³	3.4	0.44	0.35	0.34	0.43
Dissolved Reactive Phosphorus	g/m³	0.013	0.011	0.018	0.020	< 0.004
Total Phosphorus	g/m³	0.199	0.073	0.093	0.123	0.026

Sample Name:		P_Int_2 10-Nov-2020 11:30 am	P_Outlet_1 11-Nov-2020 4:30 pm	P_Outlet_2 11-Nov-2020 4:30 pm	K_FFB_Sump 09-Nov-2020 2:15 pm	K_FFSwale_1 10-Nov-2020 2:30 pm
Lab Number:		2472438.6	2472438.7	2472438.8	2472438.9	2472438.10
Turbidity	NTU	2.7	1.65	1.70	12.3	2.8
Total Suspended Solids	g/m³	4	5	4	22	< 3
Dissolved Arsenic	g/m³	0.0017	0.0024	0.0024	-	-
Total Arsenic	g/m³	0.0018	0.0026	0.0025	-	-
Dissolved Copper	g/m³	< 0.0005	< 0.0005	< 0.0005	0.0058	0.0011
Total Copper	g/m³	0.00054	< 0.00053	< 0.00053	0.0080	0.00116
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	< 0.00011	0.00016	0.00014	0.0023	0.00020
Dissolved Zinc	g/m³	0.0010	0.0013	< 0.0010	0.060	0.0110
Total Zinc	g/m³	0.0020	0.0021	0.0017	0.086	0.0119
Dissolved Inorganic Nitrogen*	g/m³	0.020	< 0.011	< 0.011	1.47	0.157
Total Nitrogen	g/m³	0.41	0.71	0.72	2.4	0.32
Total Ammoniacal-N	g/m³	0.020	< 0.010	< 0.010	1.00	0.092
Nitrate-N + Nitrite-N	g/m³	< 0.002	< 0.002	< 0.002	0.46	0.065
Total Kjeldahl Nitrogen (TKN)	g/m³	0.40	0.71	0.72	1.95	0.25
Dissolved Reactive Phosphorus	g/m³	< 0.004	< 0.004	< 0.004	0.039	0.064
Total Phosphorus	g/m³	0.041	0.034	0.038	0.136	0.103

Sample Type: Aqueous						
Sample Name:		K_FFSwale_2 10-Nov-2020 2:30 pm	K_FFB_1 10-Nov-2020 3:30 pm	K_FFB_2 10-Nov-2020 3:30 pm	K_Int_1 09-Nov-2020 3:00 pm	K_Int_2 09-Nov-2020 3:00 pm
Lab Number:		2472438.11	2472438.12	2472438.13	2472438.14	2472438.15
Turbidity	NTU	2.8	1.89	2.1	3.8	2.6
Total Suspended Solids	g/m³	< 3	4	4	4	4
Dissolved Copper	g/m³	0.0011	0.0011	0.0012	0.0012	0.0014
Total Copper	g/m³	0.00120	0.00193	0.00149	0.00156	0.00164
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	0.00029	0.00031	0.00025	0.00030	0.00036
Dissolved Zinc	g/m³	0.0102	0.023	0.022	0.0134	0.0130
Total Zinc	g/m³	0.0126	0.026	0.025	0.0164	0.0160
Dissolved Inorganic Nitrogen*	g/m³	0.152	0.178	0.188	0.25	0.24
Total Nitrogen	g/m³	0.24	1.7	0.44	0.41	0.40
Total Ammoniacal-N	g/m³	0.088	< 0.010	0.017	0.107	0.105
Nitrate-N + Nitrite-N	g/m³	0.064	0.172	0.171	0.140	0.137
Total Kjeldahl Nitrogen (TKN)	g/m³	0.18	1.5	0.27	0.27	0.26
Dissolved Reactive Phosphorus	g/m³	0.067	< 0.004	< 0.004	0.062	0.060
Total Phosphorus	g/m³	0.104	0.052	0.050	0.104	0.109

Sample Name:		K_Out_1 10-Nov-2020 4:30 pm	K_Out_2 10-Nov-2020 4:30 pm			
Lab Number:		2472438.16	2472438.17			
Turbidity	NTU	1.83	1.53	-	-	-
Total Suspended Solids	g/m³	< 3	< 3	-	-	-
Dissolved Copper	g/m³	0.0014	0.0014	-	-	-
Total Copper	g/m³	0.00148	0.00149	-	-	-
Dissolved Lead	g/m³	< 0.00010	< 0.00010	-	-	-
Total Lead	g/m³	0.00015	0.00012	-	-	-
Dissolved Zinc	g/m³	0.0054	0.0052	-	-	-
Total Zinc	g/m³	0.0075	0.0070	-	-	-
Dissolved Inorganic Nitrogen*	g/m³	0.164	0.171	-	-	-
Total Nitrogen	g/m³	0.62	0.52	-	-	-
Total Ammoniacal-N	g/m³	0.104	0.109	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.060	0.062	-	-	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.56	0.46	-	-	-
Dissolved Reactive Phosphorus	g/m³	0.30	0.32	-	-	-
Total Phosphorus	g/m³	0.39	0.38	-	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-17
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-17
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-17
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m³	1-17
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-17
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1-8
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m³	1-8

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m^3	1-17
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1-17
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.00010 g/m^3	1-17
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1-17
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-17
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-17
Dissolved Inorganic Nitrogen*		0.002 - 0.010 g/m^3	1-17
Dissolved Inorganic Nitrogen*	Calculation: NH_4-N + NO_3-N + NO_2-N. In-House.	0.010 g/m^3	1-17
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-17
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-17
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-17
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-17
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-17
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis and also modified to include a reductant to reduce interference from any arsenic present in the sample) 23rd ed. 2017. NWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-17

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 16-Nov-2020 and 19-Nov-2020. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Client Services Manager - Environmental

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Certificate of Analysis

SPv2

Client:	Pattle Delamore Partners Limited	**Lab No:**	2612393
Contact:	Liam Allan	**Date Received:**	14-May-2021
	C/- Pattle Delamore Partners Limited	**Date Reported:**	24-May-2021
	PO Box 389	**Quote No:**	103440
	Christchurch 8140	**Order No:**	
		Client Reference:	C03816300
		Submitted By:	Liam Allan

Sample Type: Aqueous

Sample Name:		P_FFBF_Sump 14-May-2021 2:00 pm	P_FFBF_Sump 14-May-2021 1:45 pm	P_FFBF_1 14-May-2021 9:00 am	P_FFBF_2 14-May-2021 9:00 am	P_Int_1 14-May-2021 11:30 am
Lab Number:		2612393.1	2612393.2	2612393.3	2612393.4	2612393.5
Turbidity	NTU	11.7	87	5.1	6.1	6.8
Total Suspended Solids	g/m^3	34	-	8	10	12
Dissolved Arsenic	g/m^3	< 0.0010	< 0.005	0.0012	0.0011	0.0019
Total Arsenic	g/m^3	0.0017	< 0.0053	0.0012	0.0011	0.0023
Dissolved Copper	g/m^3	0.0008	0.0011	0.0017	0.0016	< 0.0005
Total Copper	g/m^3	0.0043	0.0047	0.0027	0.0029	0.00060
Dissolved Lead	g/m^3	0.00018	0.00011	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m^3	0.0102	0.0052	0.00073	0.00087	0.00036
Dissolved Zinc	g/m^3	0.059	0.010	0.022	0.022	0.0015
Total Zinc	g/m^3	0.109	0.040	0.034	0.036	0.0049
Dissolved Inorganic Nitrogen*	g/m^3	1.14	0.59	0.40	0.41	< 0.011
Total Nitrogen	g/m^3	2.7	0.91	0.66	0.71	0.56
Total Ammoniacal-N	g/m^3	0.82	0.064	0.193	0.20	< 0.010
Nitrate-N + Nitrite-N	g/m^3	0.31	0.52	0.20	0.20	< 0.002
Total Kjeldahl Nitrogen (TKN)	g/m^3	2.4	0.38	0.46	0.51	0.56
Dissolved Reactive Phosphorus	g/m^3	0.060	0.043	0.064	0.062	< 0.004
Total Phosphorus	g/m^3	0.177	0.169	0.132	0.148	0.072

Sample Name:		P_Int_2 14-May-2021 11:30 am	P_Outlet_1 14-May-2021 1:00 pm	P_Outlet_2 14-May-2021 1:00 pm	P_FFBF_FF 14-May-2021 9:00 am	K_FFB_Sump 13-May-2021 11:20 am
Lab Number:		2612393.6	2612393.7	2612393.8	2612393.9	2612393.10
Turbidity	NTU	6.9	2.3	2.3	4.9	23
Total Suspended Solids	g/m^3	13	5	5	12	64
Dissolved Arsenic	g/m^3	0.0020	0.0023	0.0022	0.0016	0.0013
Total Arsenic	g/m^3	0.0022	0.0026	0.0027	0.0022	0.0022
Dissolved Copper	g/m^3	< 0.0005	< 0.0005	< 0.0005	0.0030	0.0042
Total Copper	g/m^3	0.00069	< 0.00053	< 0.00053	0.0045	0.0102
Dissolved Lead	g/m^3	< 0.00010	< 0.00010	< 0.00010	0.00013	0.00020
Total Lead	g/m^3	0.00034	0.00018	0.00020	0.00106	0.0048
Dissolved Zinc	g/m^3	0.0017	< 0.0010	< 0.0010	0.026	0.073
Total Zinc	g/m^3	0.0048	< 0.0011	0.0012	0.045	0.168
Dissolved Inorganic Nitrogen*	g/m^3	< 0.011	0.061	0.064	0.72	1.07
Total Nitrogen	g/m^3	0.52	0.59	0.60	1.39	1.87
Total Ammoniacal-N	g/m^3	< 0.010	0.015	0.015	0.20	0.62
Nitrate-N + Nitrite-N	g/m^3	< 0.002	0.046	0.049	0.52	0.45
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.52	0.54	0.55	0.87	1.42
Dissolved Reactive Phosphorus	g/m^3	< 0.004	< 0.004	< 0.004	0.162	0.036
Total Phosphorus	g/m^3	0.074	0.033	0.036	0.33	0.173

Sample Type: Aqueous

Sample Name:		K_FFSwale_1 13-May-2021 11:00 am	K_FFSwale_2 13-May-2021 11:00 am	K-Int_1 13-May-2021 12:00 pm	K-Int_2 13-May-2021 12:00 pm	K_Out_1 13-May-2021 1:00 pm
Lab Number:		2612393.11	2612393.12	2612393.13	2612393.14	2612393.15
Turbidity	NTU	3.8	3.8	9.7	10.2	3.3
Total Suspended Solids	g/m³	5	5	8	8	< 3
Dissolved Arsenic	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Arsenic	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Copper	g/m³	0.0011	0.0011	0.0012	0.0011	0.0010
Total Copper	g/m³	0.00151	0.00153	0.00166	0.00170	0.00108
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	0.00031	0.00033	0.00065	0.00065	< 0.00011
Dissolved Zinc	g/m³	0.0138	0.0131	0.0157	0.0152	0.0044
Total Zinc	g/m³	0.0184	0.0181	0.022	0.022	0.0053
Dissolved Inorganic Nitrogen*	g/m³	0.58	0.57	0.27	0.27	0.066
Total Nitrogen	g/m³	0.76	0.81	0.59	0.52	0.46
Total Ammoniacal-N	g/m³	0.35	0.34	0.168	0.176	0.047
Nitrate-N + Nitrite-N	g/m³	0.23	0.23	0.097	0.097	0.018
Total Kjeldahl Nitrogen (TKN)	g/m³	0.54	0.58	0.50	0.42	0.44
Dissolved Reactive Phosphorus	g/m³	0.088	0.089	0.093	0.097	0.183
Total Phosphorus	g/m³	0.146	0.136	0.161	0.156	0.25

Sample Name:		K_Out_2 13-May-2021 1:00 pm	K_FFSwale_FF 13-May-2021 11:00 am	K_FFSwale_3 13-May-2021 11:00 am	K_Int_3 13-May-2021 12:00 pm	K_Out_3 13-May-2021 1:00 pm
Lab Number:		2612393.16	2612393.17	2612393.18	2612393.19	2612393.20
Turbidity	NTU	2.8	5.3	3.9	10.1	2.4
Total Suspended Solids	g/m³	< 3	10	6	8	< 3
Dissolved Arsenic	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Arsenic	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Copper	g/m³	0.0010	0.0028	0.0011	0.0011	0.0010
Total Copper	g/m³	0.00109	0.0036	0.00167	0.00170	0.00113
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	< 0.00011	0.00053	0.00033	0.00063	< 0.00011
Dissolved Zinc	g/m³	0.0041	0.028	0.0132	0.0151	0.0044
Total Zinc	g/m³	0.0053	0.043	0.0178	0.020	0.0050
Dissolved Inorganic Nitrogen*	g/m³	0.063	1.92	0.57	0.27	0.066
Total Nitrogen	g/m³	0.52	2.8	0.86	0.62	0.49
Total Ammoniacal-N	g/m³	0.045	1.02	0.34	0.171	0.048
Nitrate-N + Nitrite-N	g/m³	0.018	0.89	0.23	0.097	0.018
Total Kjeldahl Nitrogen (TKN)	g/m³	0.51	1.89	0.63	0.52	0.47
Dissolved Reactive Phosphorus	g/m³	0.179	0.26	0.087	0.093	0.183
Total Phosphorus	g/m³	0.25	0.38	0.134	0.156	0.25

Sample Name:		P_FFBF_3 14-May-2021 9:00 am	P_Int_3 14-May-2021 11:30 am	P_Outlet_3 14-May-2021 1:00 pm		
Lab Number:		2612393.21	2612393.22	2612393.23		
Turbidity	NTU	5.9	6.9	2.1	-	-
Total Suspended Solids	g/m³	10	13	9	-	-
Dissolved Arsenic	g/m³	0.0012	0.0020	0.0024	-	-
Total Arsenic	g/m³	0.0013	0.0021	0.0024	-	-
Dissolved Copper	g/m³	0.0017	< 0.0005	< 0.0005	-	-
Total Copper	g/m³	0.0028	0.00065	< 0.00053	-	-
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	-	-
Total Lead	g/m³	0.00076	0.00038	0.00020	-	-
Dissolved Zinc	g/m³	0.021	0.0020	< 0.0010	-	-
Total Zinc	g/m³	0.034	0.0052	0.0018	-	-
Dissolved Inorganic Nitrogen*	g/m³	0.40	< 0.011	0.071	-	-
Total Nitrogen	g/m³	0.69	0.55	0.78	-	-
Total Ammoniacal-N	g/m³	0.20	< 0.010	0.027	-	-
Nitrate-N + Nitrite-N	g/m³	0.20	< 0.002	0.045	-	-

Sample Type: Aqueous						
	Sample Name:	P_FFBF_3 14-May-2021 9:00 am	P_Int_3 14-May-2021 11:30 am	P_Outlet_3 14-May-2021 1:00 pm		
	Lab Number:	2612393.21	2612393.22	2612393.23		
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.49	0.55	0.74	-	-
Dissolved Reactive Phosphorus	g/m^3	0.064	0.004	< 0.004	-	-
Total Phosphorus	g/m^3	0.151	0.072	0.047	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-23
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-23
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-23
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1, 3-23
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-23
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-23
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-23
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m^3	1-23
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1-23
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.00010 g/m^3	1-23
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1-23
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-23
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-23
Dissolved Inorganic Nitrogen*		0.002 - 0.010 g/m^3	1-23
Dissolved Inorganic Nitrogen*	Calculation: NH_4-N + NO_3-N + NO_2-N. In-house calculation.	0.010 g/m^3	1-23
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3. In-house calculation.	0.05 g/m^3	1-23
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-23
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-23
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-23
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-23
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H 23rd ed. 2017.	0.002 g/m^3	1-23

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 15-May-2021 and 24-May-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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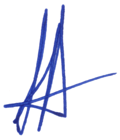

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Certificate of Analysis

Client:	Pattle Delamore Partners Limited	**Lab No:**	2629798	SPv1
Contact:	Liam Allan	**Date Received:**	04-Jun-2021	
	C/- Pattle Delamore Partners Limited	**Date Reported:**	17-Jun-2021	
	PO Box 389	**Quote No:**	103440	
	Christchurch 8140	**Order No:**		
		Client Reference:		
		Submitted By:	Liam Allan	

Sample Type: Aqueous

Sample Name:		P_FFBF_Sump 02-Jun-2021 3:00 pm	P_FFBD_Sump 02-Jun-2021 2:50 pm	P_FFBF_1 02-Jun-2021 3:00 pm	P_FFBF_2 02-Jun-2021 3:00 pm	P_Int_1 02-Jun-2021 3:30 pm
Lab Number:		2629798.1	2629798.2	2629798.3	2629798.4	2629798.5
Turbidity	NTU	15.3	11.0	2.8	2.1	2.8
Total Suspended Solids	g/m^3	27	32	< 3	3	3
Dissolved Arsenic	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Total Arsenic	g/m^3	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
Dissolved Copper	g/m^3	0.0023	< 0.0010	0.0014	0.0012	< 0.0010
Total Copper	g/m^3	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
Dissolved Lead	g/m^3	0.0004	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m^3	0.0016	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Zinc	g/m^3	0.124	0.032	0.024	0.023	0.005
Total Zinc	g/m^3	0.136	0.038	0.030	0.024	< 0.011
Dissolved Inorganic Nitrogen*	g/m^3	0.74	0.34	0.27	0.27	0.080
Total Nitrogen	g/m^3	1.44	1.28	0.45	0.41	0.44
Total Ammoniacal-N	g/m^3	0.137	0.30	0.127	0.128	< 0.010
Nitrate-N + Nitrite-N	g/m^3	0.60	0.041	0.143	0.141	0.071
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.84	1.23	0.30	0.27	0.37
Dissolved Reactive Phosphorus	g/m^3	0.036	0.024	0.018	0.019	0.010
Total Phosphorus	g/m^3	0.166	0.147	0.044	0.044	0.039

Sample Name:		P_Int_2 02-Jun-2021 3:30 pm	P_Outlet_1 02-Jun-2021 4:00 pm	P_Outlet_2 02-Jun-2021 4:00 pm	P_FFBF_FF 02-Jun-2021 3:00 pm	K_FFBF_Sump 02-Jun-2021 11:00 am
Lab Number:		2629798.6	2629798.7	2629798.8	2629798.9	2629798.10
Turbidity	NTU	2.6	2.0	1.86	3.1	8.2
Total Suspended Solids	g/m^3	6	76	3	3	15
Dissolved Arsenic	g/m^3	< 0.002	< 0.002	< 0.002	< 0.002	-
Total Arsenic	g/m^3	< 0.011	< 0.011	< 0.011	< 0.011	-
Dissolved Copper	g/m^3	< 0.0010	< 0.0010	< 0.0010	0.0022	0.0028
Total Copper	g/m^3	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
Dissolved Lead	g/m^3	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m^3	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Zinc	g/m^3	0.004	< 0.002	< 0.002	0.036	0.028
Total Zinc	g/m^3	< 0.011	< 0.011	< 0.011	0.040	0.036
Dissolved Inorganic Nitrogen*	g/m^3	0.081	0.014	0.013	0.65	0.45
Total Nitrogen	g/m^3	0.47	0.47	0.39	0.90	1.30
Total Ammoniacal-N	g/m^3	< 0.010	< 0.010	< 0.010	0.35	0.26
Nitrate-N + Nitrite-N	g/m^3	0.071	0.014	0.013	0.30	0.185
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.40	0.46	0.38	0.60	1.12
Dissolved Reactive Phosphorus	g/m^3	0.009	0.019	0.019	0.047	0.014
Total Phosphorus	g/m^3	0.039	0.041	0.056	0.097	0.053

Sample Type: Aqueous						
Sample Name:		K_FFSwale_1 02-Jun-2021 10:00 am	K_FFSwale_2 02-Jun-2021 10:00 am	K_FFB_1 02-Jun-2021 11:00 am	K_FFB_2 02-Jun-2021 11:00 am	K_Int_1 02-Jun-2021 12:00 pm
Lab Number:		2629798.11	2629798.12	2629798.13	2629798.14	2629798.15
Turbidity	NTU	7.9	8.6	3.2	2.8	5.4
Total Suspended Solids	g/m³	5	5	4	< 3	3
Dissolved Copper	g/m³	< 0.0010	0.0013	< 0.0010	< 0.0010	0.0012
Total Copper	g/m³	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
Dissolved Lead	g/m³	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Zinc	g/m³	0.013	0.012	0.017	0.018	0.014
Total Zinc	g/m³	0.019	0.017	0.023	0.019	0.018
Dissolved Inorganic Nitrogen*	g/m³	0.21	0.22	0.142	0.144	0.24
Total Nitrogen	g/m³	0.42	0.38	0.19	0.22	0.38
Total Ammoniacal-N	g/m³	0.107	0.116	0.073	0.074	0.099
Nitrate-N + Nitrite-N	g/m³	0.099	0.100	0.069	0.070	0.140
Total Kjeldahl Nitrogen (TKN)	g/m³	0.32	0.28	0.12	0.15	0.24
Dissolved Reactive Phosphorus	g/m³	0.034	0.036	0.017	0.020	0.035
Total Phosphorus	g/m³	0.066	0.070	0.033	0.033	0.062
Sample Name:		K_Int_2 02-Jun-2021 12:00 pm	K_Out_1 02-Jun-2021 12:45 pm	K_Out_2 02-Jun-2021 12:45 pm	K_FFSwale_FF 02-Jun-2021 10:00 am	K_FFB_FF 02-Jun-2021 11:00 am
Lab Number:		2629798.16	2629798.17	2629798.18	2629798.19	2629798.20
Turbidity	NTU	5.6	4.0	4.0	3.2	3.6
Total Suspended Solids	g/m³	4	3	< 3	8	5
Dissolved Copper	g/m³	0.0012	0.0013	0.0015	0.0012	0.0013
Total Copper	g/m³	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.011
Dissolved Lead	g/m³	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0021
Dissolved Zinc	g/m³	0.015	0.004	0.004	0.018	0.026
Total Zinc	g/m³	0.018	< 0.011	< 0.011	0.031	0.035
Dissolved Inorganic Nitrogen*	g/m³	0.24	0.077	0.093	0.45	0.39
Total Nitrogen	g/m³	0.36	0.52	0.45	0.69	0.52
Total Ammoniacal-N	g/m³	0.100	0.031	0.048	0.123	0.20
Nitrate-N + Nitrite-N	g/m³	0.140	0.046	0.046	0.33	0.187
Total Kjeldahl Nitrogen (TKN)	g/m³	0.22	0.48	0.40	0.36	0.33
Dissolved Reactive Phosphorus	g/m³	0.035	0.29	0.30	0.023	0.015
Total Phosphorus	g/m³	0.063	0.39	0.39	0.062	0.039

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-20
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-20
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-20
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m³	1-20
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-20
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m³	1-9
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m³	1-9

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m^3	1-20
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1-20
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.00010 g/m^3	1-20
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1-20
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-20
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-20
Dissolved Inorganic Nitrogen*		0.002 - 0.010 g/m^3	1-20
Dissolved Inorganic Nitrogen*	Calculation: NH_4-N + NO_3-N + NO_2-N. In-house calculation.	0.010 g/m^3	1-20
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3. In-house calculation.	0.05 g/m^3	1-20
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-20
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-20
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-20
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-20
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H 23rd ed. 2017.	0.002 g/m^3	1-20

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 04-Jun-2021 and 14-Jun-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Kim Harrison MSc
Client Services Manager - Environmental

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TRIED, TESTED AND TRUSTED

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Certificate of Analysis

Client:	Pattle Delamore Partners Limited	**Lab No:**	2629798	SPv2
Contact:	Liam Allan	**Date Received:**	04-Jun-2021	
	C/- Pattle Delamore Partners Limited	**Date Reported:**	02-Jul-2021	**(Amended)**
	PO Box 389	**Quote No:**	103440	
	Christchurch 8140	**Order No:**		
		Client Reference:		
		Submitted By:	Liam Allan	

Sample Type: Aqueous

Sample Name:		P_FFBF_Sump 02-Jun-2021 3:00 pm	P_FFBD_Sump 02-Jun-2021 2:50 pm	P_FFBF_1 02-Jun-2021 3:00 pm	P_FFBF_2 02-Jun-2021 3:00 pm	P_Int_1 02-Jun-2021 3:30 pm
Lab Number:		2629798.1	2629798.2	2629798.3	2629798.4	2629798.5
Turbidity	NTU	15.3	11.0	2.8	2.1	2.8
Total Suspended Solids	g/m³	27	32	< 3	3	3
Dissolved Arsenic	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Total Arsenic	g/m³	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
Dissolved Copper	g/m³	0.0023	< 0.0010	0.0014	0.0012	< 0.0010
Total Copper	g/m³	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
Dissolved Lead	g/m³	0.0004	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m³	0.0016	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Zinc	g/m³	0.124	0.032	0.024	0.023	0.005
Total Zinc	g/m³	0.136	0.038	0.030	0.024	< 0.011
Dissolved Inorganic Nitrogen*	g/m³	0.74	0.34	0.27	0.27	0.080
Total Nitrogen	g/m³	1.44	1.28	0.45	0.41	0.44
Total Ammoniacal-N	g/m³	0.137	0.30	0.127	0.128	< 0.010
Nitrate-N + Nitrite-N	g/m³	0.60	0.041	0.143	0.141	0.071
Total Kjeldahl Nitrogen (TKN)	g/m³	0.84	1.23	0.30	0.27	0.37
Dissolved Reactive Phosphorus	g/m³	0.036	0.024	0.018	0.019	0.010
Total Phosphorus	g/m³	0.166	0.147	0.044	0.044	0.039

Sample Name:		P_Int_2 02-Jun-2021 3:30 pm	P_Outlet_1 02-Jun-2021 4:00 pm	P_Outlet_2 02-Jun-2021 4:00 pm	P_FFBF_FF 02-Jun-2021 3:00 pm	K_FFBF_Sump 02-Jun-2021 11:00 am
Lab Number:		2629798.6	2629798.7	2629798.8	2629798.9	2629798.10
Turbidity	NTU	2.6	2.0	1.86	3.1	8.2
Total Suspended Solids	g/m³	6	76	3	3	15
Dissolved Arsenic	g/m³	< 0.002	< 0.002	< 0.002	< 0.002	-
Total Arsenic	g/m³	< 0.011	< 0.011	< 0.011	< 0.011	-
Dissolved Copper	g/m³	< 0.0010	< 0.0010	< 0.0010	0.0022	0.0028
Total Copper	g/m³	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
Dissolved Lead	g/m³	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Zinc	g/m³	0.004	< 0.002	< 0.002	0.036	0.028
Total Zinc	g/m³	< 0.011	< 0.011	< 0.011	0.040	0.036
Dissolved Inorganic Nitrogen*	g/m³	0.081	0.014	0.013	0.65	0.45
Total Nitrogen	g/m³	0.47	0.47	0.39	0.90	1.30
Total Ammoniacal-N	g/m³	< 0.010	< 0.010	< 0.010	0.35	0.26
Nitrate-N + Nitrite-N	g/m³	0.071	0.014	0.013	0.30	0.185
Total Kjeldahl Nitrogen (TKN)	g/m³	0.40	0.46	0.38	0.60	1.12
Dissolved Reactive Phosphorus	g/m³	0.009	0.019	0.019	0.047	0.014
Total Phosphorus	g/m³	0.039	0.041	0.056	0.097	0.053

Sample Type: Aqueous						
Sample Name:		K_FFSwale_1 02-Jun-2021 10:00 am	K_FFSwale_2 02-Jun-2021 10:00 am	K_FFB_1 02-Jun-2021 11:00 am	K_FFB_2 02-Jun-2021 11:00 am	K_Int_1 02-Jun-2021 12:00 pm
Lab Number:		2629798.11	2629798.12	2629798.13	2629798.14	2629798.15
Turbidity	NTU	7.9	8.6	3.2	2.8	5.4
Total Suspended Solids	g/m³	5	5	4	< 3	3
Dissolved Copper	g/m³	< 0.0010	0.0013	< 0.0010	< 0.0010	0.0012
Total Copper	g/m³	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.0053
Dissolved Lead	g/m³	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0011
Dissolved Zinc	g/m³	0.013	0.012	0.017	0.018	0.014
Total Zinc	g/m³	0.019	0.017	0.023	0.019	0.018
Dissolved Inorganic Nitrogen*	g/m³	0.21	0.22	0.142	0.144	0.24
Total Nitrogen	g/m³	0.42	0.38	0.19	0.22	0.38
Total Ammoniacal-N	g/m³	0.107	0.116	0.073	0.074	0.099
Nitrate-N + Nitrite-N	g/m³	0.099	0.100	0.069	0.070	0.140
Total Kjeldahl Nitrogen (TKN)	g/m³	0.32	0.28	0.12	0.15	0.24
Dissolved Reactive Phosphorus	g/m³	0.034	0.036	0.017	0.020	0.035
Total Phosphorus	g/m³	0.066	0.070	0.033	0.033	0.062

Sample Name:		K_Int_2 02-Jun-2021 12:00 pm	K_Out_1 02-Jun-2021 12:45 pm	K_Out_2 02-Jun-2021 12:45 pm	K_FFSwale_FF 02-Jun-2021 10:00 am	K_FFB_FF 02-Jun-2021 11:00 am
Lab Number:		2629798.16	2629798.17	2629798.18	2629798.19	2629798.20
Turbidity	NTU	5.6	4.0	4.0	3.2	3.6
Total Suspended Solids	g/m³	4	3	< 3	8	5
Dissolved Copper	g/m³	0.0012	0.0013	0.0015	0.0012	0.0013
Total Copper	g/m³	< 0.0053	< 0.0053	< 0.0053	< 0.0053	< 0.011
Dissolved Lead	g/m³	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Lead	g/m³	< 0.0011	< 0.0011	< 0.0011	< 0.0011	< 0.0021
Dissolved Zinc	g/m³	0.015	0.004	0.004	0.018	0.026
Total Zinc	g/m³	0.018	< 0.011	< 0.011	0.031	0.035
Dissolved Inorganic Nitrogen*	g/m³	0.24	0.077	0.093	0.45	0.39
Total Nitrogen	g/m³	0.36	0.52	0.45	0.69	0.52
Total Ammoniacal-N	g/m³	0.100	0.031	0.048	0.123	0.20
Nitrate-N + Nitrite-N	g/m³	0.140	0.046	0.046	0.33	0.187
Total Kjeldahl Nitrogen (TKN)	g/m³	0.22	0.48	0.40	0.36	0.33
Dissolved Reactive Phosphorus	g/m³	0.035	0.29	0.30	0.023	0.015
Total Phosphorus	g/m³	0.063	0.39	0.39	0.062	0.039

Sample Name:		K_FFSwale_3 02-Jun-2021 10:00 am	K_FFB_3 02-Jun-2021 11:00 am	K_Int_3 02-Jun-2021 12:00 pm	K_Out_3 02-Jun-2021 12:45 pm	P_FFBF_3 02-Jun-2021 3:00 pm
Lab Number:		2629798.21	2629798.22	2629798.23	2629798.24	2629798.25
Dissolved Copper	g/m³	0.0008	0.0006	0.0010	0.0012	0.0012
Total Copper	g/m³	0.00117	0.00089	0.00128	0.00147	0.00135
Dissolved Lead	g/m³	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010
Total Lead	g/m³	0.00024	< 0.00011	0.00013	0.00018	< 0.00011
Dissolved Zinc	g/m³	0.0138	0.0185 #1	0.0162	0.0039	0.026
Total Zinc	g/m³	0.0161	0.0182 #1	0.0172	0.0045	0.026

Sample Name:		P_Int_3 02-Jun-2021 3:30 pm	P_Outlet_3 02-Jun-2021 4:00 pm			
Lab Number:		2629798.26	2629798.27			
Dissolved Copper	g/m³	< 0.0005	< 0.0005	-	-	-
Total Copper	g/m³	< 0.00053	< 0.00053	-	-	-
Dissolved Lead	g/m³	< 0.00010	< 0.00010	-	-	-
Total Lead	g/m³	< 0.00011	0.00015	-	-	-
Dissolved Zinc	g/m³	0.0048	0.0012	-	-	-
Total Zinc	g/m³	0.0048	0.0028	-	-	-

Analyst's Comments

#1 It has been noted that the result for the dissolved fraction was greater than that for the total fraction, but within analytical variation of the methods.

Amended Report: This certificate of analysis replaces report '2629798-SPv1' issued on 17-Jun-2021 at 10:37 am. Reason for amendment: Additional metals testing added.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1-20
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-27
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-20
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-20
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 23rd ed. 2017.	-	1-27
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-9
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-9
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0005 g/m^3	1-27
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1-27
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.00010 g/m^3	1-27
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1-27
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0010 g/m^3	1-27
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1-27
Dissolved Inorganic Nitrogen*		0.002 - 0.010 g/m^3	1-20
Dissolved Inorganic Nitrogen*	Calculation: NH_4-N + NO_3-N + NO_2-N. In-house calculation.	0.010 g/m^3	1-20
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3. In-house calculation.	0.05 g/m^3	1-20
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-20
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-20
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-20
Dissolved Reactive Phosphorus	Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-20
Total Phosphorus	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H 23rd ed. 2017.	0.002 g/m^3	1-20

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 04-Jun-2021 and 02-Jul-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental