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Supplementary Receiving Environment Assessment for Geraldine Stormwater Management Plan

Timaru District Council

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Supplementary Receiving Environment Assessment for Geraldine Stormwater Management Plan

∴ Prepared for

Timaru District Council

∴ November 2016

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Limitations:

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Executive Summary

Pattle Delamore Partners Ltd (PDP) undertook a field survey in October 2016 to collect water quality, sediment, and ecological data for Serpentine Creek and the Waihi River in the vicinity of Geraldine Township. As a result of this assessment there are now two data sets available to inform the Geraldine Stormwater Management Plan, one representing winter conditions (Opus, 2013) and one representing spring conditions (the current PDP sampling round).

The PDP survey was undertaken to build on, and fill information gaps in the Opus (2013) report *Waihi River & Serpentine Creek – Geraldine Urban Reaches, Ecological Assessment*. The additional sampling was considered necessary in order to establish a baseline to assess and monitor the performance of the SMP in the future, and to support future consent applications.

The results of this assessment indicate that there is no observable adverse effect caused by Serpentine Creek on the water quality and ecological condition of the Waihi River downstream of its confluence with Serpentine Creek.

Laboratory analysis showed elevated levels of dissolved zinc in surface water samples throughout Serpentine Creek, with possible additional nutrient and faecal coliform inputs being observed downstream of the urban areas in Serpentine Creek (compared with upstream). Elevated lead, mercury and PAH concentrations were reported in stream sediment samples within the Geraldine Township. However, only moderate levels of zinc were observed in the sediment of Serpentine Creek.

Ongoing monitoring of heavy metal concentrations in both surface water and sediments is desirable, particularly to define stream base flow characteristics in Serpentine Creek.

The monitoring indicates changes of water quality characteristics in Serpentine Creek downstream of the urban area that may affect Environment Canterbury's water way classification.

Both Serpentine Creek and the Waihi River (in the vicinity of Geraldine Township) have variability in flow and can remain dry and/ or drying for periods of the year. The fluctuations in flow need to be considered when interpreting data and determining each waterbody's classification.

The PDP survey aligns with the conclusions that were outlined by Opus in 2013. Serpentine Creek from the Geraldine Township downstream to the confluence with the Waihi River currently has little ecological value. The environment is likely to continue to be stressed due to the continual chronic long-term input of heavy metals, especially dissolved metals, and inputs from agricultural run-off from adjacent land. However currently, the discharge of Serpentine Creek into the Waihi River does not appear to be having an observable adverse effect on the downstream Waihi River environment.

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1.0 Introduction

Timaru District Council (TDC) has engaged Pattle Delamore Partners Ltd (PDP) to undertake additional surface water, sediment and ecological sampling to further characterise the receiving environment for the Geraldine Stormwater Management Plan (SMP). The additional sampling was undertaken to build on, and fill information gaps in the Opus (2013) report *Waihi River & Serpentine Creek – Geraldine Urban Reaches, Ecological Assessment*. The Opus (2013) report did not include an assessment of sediment quality of Serpentine Creek, nor make a comparison of water quality and macroinvertebrate community health in the Waihi River up and down stream of its confluence with Serpentine Creek. The additional sampling was considered necessary in order to establish a baseline to assess and monitor the performance of the SMP in the future, and to support future consent applications.

PDP undertook field sampling in both the Waihi River and the Serpentine Creek located in Geraldine. Sampling included collecting surface water samples and measurement of field parameters, collection of surface sediment samples from Serpentine Creek and collection of macroinvertebrate samples from the Waihi River.

2.0 Objectives

The objectives of the 2016 sampling were:

- To investigate if the discharge of Serpentine Creek in to the Waihi River is having an adverse effect on the water quality or ecology of the Waihi River.
- To investigate any changes in water chemistry occurring along Serpentine Creek in order to assist Environment Canterbury (ECan) in setting future water quality classification.
- To investigate the nature of stormwater related heavy metal contaminants in Serpentine Creek and the extent of their biological toxicity.
- To review and recommend appropriate long-term monitoring requirements to assess the impacts of stormwater discharges in Serpentine Creek and the Waihi River.

3.0 Methodology

All samples were collected on the 18/10/2016. Surface water and sediment samples were sent to Analytica Laboratories for analysis, while macroinvertebrate samples were processed by Stark Environmental Limited.

Sampling sites are shown in Figures 1 and 2, Appendix A. Sites 1 – 8 (upstream to downstream) are within Serpentine Creek. Sites 9 – 11 are within Waihi River.

Site 11 is the most upstream site within Waihi River, Site 9 is located before the confluence of Serpentine Creek and Site 10 is the most downstream point sampled.

3.1 Surface Water Sampling

Surface water samples and a range of field parameters were collected at five sites (three sites in Serpentine Creek and two sites on the Waihi River, see Figure 1). Water samples were analysed for total suspended solids (TSS), total nitrogen (TN), nitrate-nitrogen, nitrite-nitrogen, ammoniacal nitrogen (NH_4N), total phosphorus (TP), dissolved reactive phosphorus (DRP), *Escherichia coli (E.coli)*, total metals (B, As, Be, Cd, Cu, Cr, Hg, Ni, Pb, and Zn), dissolved metals (B, As, Be, Cd, Cu, Cr, Hg, Ni, Pb, and Zn), and total petroleum hydrocarbons (TPH).

Additionally, spot measurements of water quality field parameters (temperature, electrical conductivity, dissolved oxygen (DO), and pH) were undertaken at a number of sites in Serpentine Creek (Figure 2) to assess any changes in water quality occurring longitudinally downstream.

All field water quality measurements were collected using a calibrated water quality probe (YSI ProOdo).

PDP recommended that dissolved metals be included in the suite of parameters due to the high total concentrations recorded in the Opus (2013) report. Dissolved metals are biologically available in this form and so are considered to have a greater effect on the aquatic ecology. Assessment of total metal concentrations alone does not provide for this assessment.

3.2 Sediment and Substrate Composition Sampling

Sediment samples were collected and substrate composition was assessed in the field at three sites in Serpentine Creek, and substrate composition was assessed at three sites on the Waihi River (Figure 1).

Composite sediment samples were collected at four transects delineated across the sample reach. At each transect the top 20-50 mm of sediment was collected via hand trowel at a single sample point. Sampling of sediments was restricted to areas where adequate sediment was available.

Substrate composition was determined by visually assessing the substrate at five observation points at each of the four transects. The substrate composition at each site represents the average estimated percent coverage of each substrate type over a site reach.

Sediment samples were analysed for heavy metals (B, As, Be, Cd, Cu, Cr, Hg, Ni, Pb, and Zn), TPH, and polycyclic aromatic hydrocarbons (PAH.

3.3 Macroinvertebrate Sampling

Macroinvertebrate samples were taken at three sites on the Waihi River (up and down stream of the confluence of Serpentine Creek, and upstream of the township (Figure 1). Samples were collected and processed using the same method as Opus (2013) to enable comparison with their data.

A variety of commonly used metrics were used to assess the relative health of the macroinvertebrate communities:

- Taxa richness indicates the number of different taxonomic groups present in a sample. Streams supporting a high number of different taxa generally indicate healthy communities.
- The percent abundance and number of taxa of Ephemeroptera, Plecoptera, Trichoptera (%EPT taxa and %EPT abundance respectively). %EPT taxa measures the number of macroinvertebrate taxa, while %EPT abundance measures the proportion of EPT within the sample. Both metrics have been calculated with the pollution tolerant *Hydroptilidae sp* removed.
- Macroinvertebrate Community Index (MCI) allocates macroinvertebrate taxa a score between 1 (pollution tolerant) and 10 (pollution intolerant) depending on each taxon's tolerance to organic enrichment and is based on presence/absence data.
- Quantitative Macroinvertebrate Community Index (QMCI) utilizes the same macroinvertebrate taxa score's as MCI. The QMCI gives an average score per taxon and is more sensitive to changes in abundance or sample size.

4.0 Results and Discussion

4.1 Surface Water Quality Field Measurements

Field surface water quality results are tabulated in Table 1.

4.1.1 Serpentine Creek

Overall the Serpentine Creek results show that:

- pH and conductivity were stable at Sites 1 through to Site 6, while at Site 7 both parameters reduced significantly. The reduction in conductivity and pH suggests that there is an increase in groundwater and/ or surface water inputs to this reach of Serpentine Creek downstream of the urban area.
- DO values increased longitudinally downstream until Site 4, subsequently DO values generally decreased through to Site 8. Some of the measured values were at levels which are likely to stress aquatic organisms. DO levels were less than the Australian and New Zealand Guidelines for

Fresh and Marine Water Quality (ANZECC) for protection of aquatic ecosystems (80 % DO) at Sites 1, 2, 3 and 8. However, DO concentrations were within the National Policy Statement for Freshwater Management (NPS FM) 2014 attribute state B (i.e., between ≥ 5.0 and < 7.5 mg/L) at all sites except Site 8.

- Temperature values were consistent throughout Serpentine Creek and appeared to be influenced by the amount of riparian shading and water velocity/ flow. Sites 3, 7 and 8 all had areas of increased riparian shading and lower temperature values were observed at these locations. Overall, temperature values were lower than the maximum value of 20 °C set in the LWRP (2013).

4.1.2 Waihi River

The Waihi River results indicate that the river has excellent DO values even when temperatures were high, circumneutral pH values and low conductivity.

Table 1: Field Water Quality Measurements

Waterway	Site	Temperature	DO saturation	DO Concentration	pH	Conductivity
		°C	%	mg/L		µs/cm
Serpentine Creek	Site 1	13.5	**61**	6.03	7.63	217
	Site 2	17.3	**79.9**	7.65	7.59	194
	Site 3	11.3	**79.3**	8.05	7.61	206
	Site 4	16.7	109.9	10.67	7.64	206
	Site 5	15.5	97	9.68	7.65	209
	Site 6	16	102.7	10.13	7.98	219
	Site 7	13.7	**85.1**	8.83	**6.25**	163.8
	Site 8	12.2	**49.6**	**5.33**	7.02	158.2
Waihi River	Site 9	18.5	114	10.73	7.6	86.4
	Site 10	11.9	110.5	11.9	7.1	22.4
	Site 11	15.7	99.4	9.88	7.41	88.3
Trigger values/ outcomes						
ANZECC (2000)			80	6	6.5-8.5	
LWRP Hill fed - lower		20	90			
NPS FM (2014)				≥5.0 and <7.5		

Notes:

***Bold** values indicate that trigger values/ objectives were not met*

4.2 Surface Water Quality Samples

Laboratory results are presented in Tables 2 and Table 3. Results are compared against regional objectives (Table 1a, LWRP 2015) and, where applicable, national trigger values (ANZECC 2000, Hickey 2013, NPS FM 2014). Heavy metal results are assessed against the ANZECC (2000) 90% and 95% species protection level. The 95% protection level assumes that sites are located within a slightly disturbed system (via anthropological disturbance e.g., agriculture and minor urban development) and 90% protection levels assumes a highly disturbed system (e.g., urban streams receiving stormwater and road runoff).

4.2.1 Nutrients

DRP, NH_4-N and nitrate-N occur naturally in the environment, and in one form or another are essential for plant growth. NH_4-N is a by-product of the metabolism of organic material by bacteria. Whilst nitrate-N occurs naturally through the nitrogen cycle and via agricultural and urban runoff, industrial wastewaters and groundwater inputs (Hickey 2013).

Dissolved inorganic nitrogen (DIN) concentrations were indicative of an enriched nutrient condition in both Serpentine Creek and the Waihi River. Serpentine Creek DIN concentrations ranged from 0.483 – 1.611 mg/L and Waihi River DIN concentrations ranged from 0.568 – 1.182 mg/L. The dominant form of DIN in both Serpentine Creek and the Waihi River was in the form of nitrate-N.

Concentrations of NH_4-N and nitrate-N did not exceed any of the guideline values (ANZECC, 2000; Hickey, 2013; and NPS FM, 2014), at any of the sites in the Serpentine Creek and the Waihi River (refer to Table 2). NH_4-N measured at Serpentine Creek ranged from 0.095 – 0.12 mg/L. Nitrate-N concentrations ranged from 0.35 – 1.51 mg/L, were highest at Site 7 and reduced at Site 8 before the confluence with the Waihi River. Higher nitrate-N and NH_4-N concentrations are reported for those sites where agricultural impacts are considered to be greatest, and sites with little to no riparian vegetation.

At sites on the Waihi River, NH_4-N and nitrate-N concentrations were higher at the site downstream of the Serpentine Creek confluence (NH_4-N = 0.091 mg/L compared with 0.065 mg/L upstream, and nitrate-N = 0.5 mg/L compared to 1.09 mg/L upstream), while nitrite-N was higher upstream of the confluence.

DRP concentrations in Serpentine Creek ranged from 0.031 – 0.072 mg/L and were indicative of an enriched environment; while in the Waihi River lower concentrations were reported (0.012 and 0.016 mg/L) which are indicative of moderate enrichment (Stevenson *et al*., 2010).

Both NH_4-N and nitrate-N have the potential to be major environmental stressors to sensitive aquatic organisms (especially to some of the macroinvertebrates identified in the Waihi River). The low concentrations of these parameters recorded in the water quality sampling indicate that although TN is elevated, it is unlikely that nitrogen is significantly adversely affecting aquatic communities.

TN levels exceeded the ANZECC (2000) 95% species protection guideline value, and concentrations increased moving longitudinally downstream in both waterways. Total Kjedahl Nitrogen (TKN) concentrations reduced longitudinally downstream in both the Serpentine Creek and the Waihi River. TP concentrations were greater than the ANZECC (2000) 95% species protection guideline value at all sites within Serpentine Creek and at the most downstream site of the Waihi River. The elevated concentrations in both TP and TN in Serpentine Creek could be linked to the section of unfenced paddocks adjacent to the creek from Majors Road through to Site 7.

4.2.2 Total Suspended Solids

Total Suspended Solids (TSS) indicates the amount of sediment in a sample of water and measures the total mass of particles in the water column. High sediment loads (represented by suspended organic and inorganic matter in the water column) affects a range of ecological, amenity and recreational values of waterways. TSS can be naturally elevated during high flow conditions and through increased overland flow.

TSS concentrations were highest at the most upstream sites in Serpentine Creek and reduced significantly at downstream sites (Table 2). The Serpentine Creek TSS results suggest that suspended particles in the water column quickly drops out downstream of the township. TSS concentrations in Waihi River indicated clear water with minimal suspended matter in the water column (Table 2).

4.2.3 Escherichia Coli

E.coli are the bacteria commonly used as a freshwater indicator of the likely presence of pathogenic (disease causing) faecal contamination. The presence of faecal contamination primarily affects the suitability of water for human uses such as potable water supply, contact recreation and stock water supply. Faecal contamination rarely affects aquatic ecosystems. Applicable national microbiological guidelines include the contact recreation guidelines (< 260 and < 550 *E.coli* per 100 mL single sample Alert and Action level respectively; MfE/MoH 2003) and stock drinking water guidelines (100 faecal coliforms per 100 mL; ANZECC 2000).

E.coli values at the two sample sites on the Waihi River and at Site 2 in the Serpentine Creek were below all applicable guidelines.

E.coli values at Sites 7 (at Winchester-Geraldine Road) and 8 (above the Waihi River Confluence) in Serpentine Creek exceeded the alert (both sites) and action (Site 7) guideline values for the protection of contact recreation (MfE/MoH, 2003), the LWRP objective (Site 7), the NPS FM (2014) (Site 7) and the ANZECC (2000) guideline for stock drinking water (both sites). This is likely associated with adjacent agricultural land use/stock access to this waterway.

Table 2: Summary of water quality parameters from sites on Waihi River and Serpentine Creek

		Nitrate-N	Nitrite-N	NH_4N	NH_4N [a]	DIN	TKN	TN	TP	DRP	TSS	E.coli
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100 mL
Waihi River	Site 9 upstream of confluence	0.5	0.003	0.065	0.040	0.568	0.42	**0.93**	0.025	0.016	1.5	74
	Site 10 downstream of confluence	1.09	0.00125	0.091	0.039	1.182	0.05	**1.09**	**0.047**	0.012	3	25
Serpentine Creek	Site 2 at Domain	0.35	0.013	0.12	0.074	0.483	0.41	**0.78**	**0.15**	0.072	12	40
	Site 7 at Winchester Rd	1.51	0.006	0.095	0.034	1.611	0.44	**1.96**	**0.084**	0.031	13	**980**
	Site 8 above confluence	1.25	0.006	0.11	0.045	1.366	0.22	**1.47**	**0.075**	0.031	1.5	520
Trigger values and guidelines												
NPSFM Attribute state B	Annual Median	>1.0 and ≤ 2.4			>0.03 and ≤ 0.24							>260 and ≤540
	95th percentile	>1.5 and ≤ 3.5			>0.05 and ≤ 0.40							
NPSFM National Bottom Line	Annual Median	6.9			1.3							1000
	95th percentile	9.8			2.2							
LWRP (hill fed-lower)												<550
ANZECC (2000)		2.4[b]				0.44 and 2.00[c]		0.614	0.033	0.009 and 0.030[c]		

Notes:

a) *NH_4N has been* scaled to a pH value of 8 to allow comparison to the NPSFM attribute state concentrations.

b) *Hickey (2013) 95% nitrate N species protection level*

c) *Recreational/aesthetic guideline indicative of an enriched nutrient condition in Canterbury (40 day accrual) (MfE, 2000; Stevenson et al, 2010)*

Bold values indicate that trigger values/ objectives were not met.

4.2.4 Total Petroleum Hydrocarbons

Total petroleum hydrocarbon (TPH) is a broad term to describe a family of chemical compounds that originate from crude oil. Petroleum hydrocarbons and petroleum products are commonly used resources in modern society, and can include transportation fuels and oils, heating and power-generating fuels. Overall, petroleum hydrocarbons are a common environmental contaminant and the amount of TPH found in a sample is a useful indicator of petroleum contamination at a site. Due to the number of facilities, individuals, and processes and the various ways the products are stored and handled, environmental contamination is potentially widespread (ATSDR, 1999).

All sites had TPH concentrations below the laboratory analytical detection limit (results not included in Table 3).

Table 3: Metals Results

	Waihi River		Serpentine Creek			ANZECC trigger value	
	Site 9	Site 10	Site 2	Site 7	Site 8	90%	95%
	µg/L	µg/L	µg/L	µg/L	µg/L		
Recoverable Trace Elements							
Arsenic (As)	<0.5	<0.5	1.3	<0.5	<0.5	42[a]	13[a]
Boron (B)	7	7	11	15	15	680	370
Beryllium (Be)	<0.01	<0.01	0.02	0.02	<0.01		
Cadmium (Cd)	<0.01	<0.01	0.01	0.02	<0.01	0.4	0.2
Copper (Cu)	0.5	0.5	**2**	1	0.8	1.8	1.4
Chromium (Cr)	<0.2	<0.2	0.48	0.2	<0.2	6	1.0
Mercury (Hg)	<0.1	<0.1	<0.1	<0.1	<0.1	1.9	0.6
Nickel (Ni)	<0.1	<0.1	0.4	<0.1	<0.1	13	11
Lead (Pb)	<0.05	<0.05	1.14	0.52	0.12	5.6	3.4
Zinc (Zi)	<1	<1	**23**	7	12	15	8
Soluble Trace Elements							
Arsenic (As)	<0.5	<0.5	1.1	<0.5	<0.5	42[a]	13[a]
Boron (B)	10	10	10	10	10	680	370
Beryllium (Be)	<0.01	<0.01	<0.01	0.02	0.01		
Cadmium (Cd)	0.01	<0.01	<0.01	<0.01	0.01	0.4	0.2
Copper (Cu)	0.5	0.4	1.7	0.8	0.9	1.8	1.4
Chromium (Cr)	<0.2	<0.2	<0.2	<0.2	<0.2	6	1
Mercury (Hg)	<0.1	<0.1	<0.1	<0.1	<0.1	1.9	0.6
Nickel (Ni)	<0.2	<0.2	0.5	<0.2	<0.2	13	11
Lead (Pb)	<0.05	<0.05	0.41	<0.05	<0.05	5.6	3.4
Zinc (Zi)	<1	<1	**24**	5.1	14	15	8

Note:

a) Arsenic (V) trigger value has been used as it is more conservative

Underlined values indicate concentrations that do not meet the 95% species protection level
Bold values indicate concentrations that do not meet the 90% species protection level

4.2.5 Metals

There were no guideline exceedances in the Waihi River, with the majority of total and dissolved metals below detection limits.

In Serpentine Creek, total and soluble zinc (Zn) and total and soluble copper (Cu) were found to exceed the ANZECC 95 % and 90% protection level at Site 2 (Cu and Zn) and Site 8 (Zn only) (Table 2). Site 7 at Winchester-Geraldine Road reported elevated Zn and Cu concentrations but were less than the applicable ANZECC trigger values. All other metal concentrations were below the applicable guideline values. Generally, total and dissolved metal concentrations decreased moving downstream.

Table 4: Metals Results

	Waihi River		Serpentine Creek			ANZECC trigger value	
	Site 9	Site 10	Site 2	Site 7	Site 8	90%	95%
	µg/L	µg/L	µg/L	µg/L	µg/L		
Recoverable Trace Elements							
Arsenic (As)	<0.5	<0.5	1.3	<0.5	<0.5	42[a]	13[a]
Boron (B)	7	7	11	15	15	680	370
Beryllium (Be)	<0.01	<0.01	0.02	0.02	<0.01		
Cadmium (Cd)	<0.01	<0.01	0.01	0.02	<0.01	0.4	0.2
Copper (Cu)	0.5	0.5	**2**	1	0.8	1.8	1.4
Chromium (Cr)	<0.2	<0.2	0.48	0.2	<0.2	6	1.0
Mercury (Hg)	<0.1	<0.1	<0.1	<0.1	<0.1	1.9	0.6
Nickel (Ni)	<0.1	<0.1	0.4	<0.1	<0.1	13	11
Lead (Pb)	<0.05	<0.05	1.14	0.52	0.12	5.6	3.4
Zinc (Zi)	<1	<1	**23**	7	12	15	8
Soluble Trace Elements							
Arsenic (As)	<0.5	<0.5	1.1	<0.5	<0.5	42[a]	13[a]
Boron (B)	10	10	10	10	10	680	370
Beryllium (Be)	<0.01	<0.01	<0.01	0.02	0.01		
Cadmium (Cd)	0.01	<0.01	<0.01	<0.01	0.01	0.4	0.2
Copper (Cu)	0.5	0.4	1.7	0.8	0.9	1.8	1.4
Chromium (Cr)	<0.2	<0.2	<0.2	<0.2	<0.2	6	1
Mercury (Hg)	<0.1	<0.1	<0.1	<0.1	<0.1	1.9	0.6
Nickel (Ni)	<0.2	<0.2	0.5	<0.2	<0.2	13	11
Lead (Pb)	<0.05	<0.05	0.41	<0.05	<0.05	5.6	3.4
Zinc (Zi)	<1	<1	**24**	5.1	14	15	8

Note:

a) Arsenic (V) trigger value has been used as it is more conservative

Underlined values indicate concentrations that do not meet the 95% species protection level
Bold values indicate concentrations that do not meet the 90% species protection level

4.3 Surface Sediment

Results have been assessed against the Australia and New Zealand Guidelines for Freshwater and Marine Water Quality (ANZECC, 2000) interim sediment quality guidelines (ISQG) – low and high values, where the ISQG-low value is regarded as the species protection trigger value.

4.3.1 Metals

Overall, the sediment quality results show that lead (Pb) and mercury (Hg) exceeded the ANZECC ISQG-low trigger value at Site 2 (Pb and Hg) and Site 7 (Pb only) (refer to Table 3). There were no exceedances at Site 8 (upstream of the Waihi River confluence) (Table 3).

4.3.2 Polycyclic Aromatic Hydrocarbons

Polycyclic hydrocarbons (PAHs) are a group of chemicals that form during the incomplete burning of coal, oil, gas, wood, garbage, and/ or other organic substances. PAHs occur naturally and are found throughout the environment. PAHs commonly make their way into surface water bodies (and hence surface substrates) through discharges from industrial and wastewater plants. In sediments, PAHs are likely to stick tightly to soil particles, and generally take weeks to break down into longer-lasting products by the actions of microorganisms (ATSDR, 1995).

The most upstream site, Site 2, is more impacted by high levels of certain PAHs, with ten of the 18 standard PAHs assessed found to exceed the ANZECC ISQG-low trigger value (Table 3). The high levels of PAH's at Site 2 are likely to originate from the surrounding township. There were no exceedances of the ANZECC ISQC-low trigger values at the other two sites, and concentrations were typically similar at both sites or lower at Site 8.

4.3.3 Total Petroleum Hydrocarbons

Petroleum hydrocarbons were detectable within the surface sediments at all sites within Serpentine Creek. Site 2 and Site 8 had higher concentrations compared to Site 7 (Table 3). All of the hydrocarbons detected were within the C_{15}-C_{36} range (appearing to originate from heavy fuel oils, lubricating oils and waxes and related products.

Table 5: Sediment Quality

Sample Description	Serpentine Creek			ANZECC Guidelines	
	Site 2	Site 7	Site 8	ISQG-Low (Trigger value)	ISQG-High
Metals (mg/kg dry wt)					
Arsenic (As)	5.19	3.74	3.33	20	70
Beryllium (Be)	0.62	0.93	0.96		
Boron (B)	2.13	3.47	4.72		
Cadmium (Cd)	0.15	0.17	0.20	1.5	10
Chromium (Cr)	10.40	15.90	15.60	80	370
Copper (Cu)	13.40	19.10	14.40	65	270
Lead (Pb)	**64.80**	**56.90**	34.10	50	220
Mercury (Hg)	**0.16**	0.12	0.10	0.15	1
Nickel (Ni)	5.51	8.25	8.89	21	52
Zinc (Zn)	149.00	127.00	171.00	200	410
Total Polycyclic Hydrocarbons (PAH) (µg/kg)					
1-Methylnaphthalene	<10	<10	<10		
2-Methylnaphthalene	<10	<10	<10		
Acenaphthene	10	<10	<10	16	500
Acenaphthylene	**240**	30	20	44	640
Anthracene	**200**	30	20	85	1100
Benz[a]anthracene	**680**	70	50	261	1600
Benzo[a]pyrene	**650**	70	60	430	1600
Benzo[b]&[j] fluoranthene	880	100	90		
Benzo[g,h,i]perylene	430	50	60		
Benzo[k]fluoranthene	320	40	40		
Chrysene	**590**	70	70	384	2800
Dibenz(a,h)anthracene	**90**	<10	10	63	260
Fluoranthene	**1240**	130	110	600	5100
Fluorene	**30**	<10	<10	19	540
Indeno(1,2,3-cd)pyrene	540	60	60		
Naphthalene	<10	<10	<10	160	2100
Phenanthrene	**400**	40	30	240	1500
Pyrene	**1150**	130	100	665	2600
Benzo[a]pyrene TEQ	1000	90	100		
Total petroleum hydrocarbons (TPH) (mg/kg dry wt)					
C7-C9	<10	<10	<10		
C10-C14	<15	<15	<15		
C15-C36	251	192	260		
C7-C36 (Total)	251	192	260		

Note:

***Bold** values indicate concentrations that do not meet the ISQG-Low (trigger value)*

Underlined values indicate concentrations that do not meet the ISQG-high value

4.3.4 Substrate Composition

Serpentine Creek is dominated by soft muds and silts, especially at the uppermost site (Site 2). Moving downstream the muds and silts was observed to reduce, indicating that the substrate was becoming more heterogeneous. However, all sites still had a large proportion of the overall substrate dominated by loosely compacted fines, muds and/ or silts (Figure 3; Appendix A).

The substrate at all of the Waihi River sites was characteristic of a small – medium sized hill fed river. The substrate was well sorted with cobbles (both large and small) and gravels dominating the substrate composition. However, at the most downstream site muds and/ or silts had increased to a level where they will likely be impacting on the benthic community (Figure 3 and Figure 4; Appendix A).

4.4 Macroinvertebrates

4.4.1 Community Composition

Results are presented in Table 4. Taxonomic richness was similar at all three sites, ranging from 24 (Site 10) through to 26 (Site 11). Overall, 40 taxa were identified from all sites. The most abundant taxa overall were the common mayfly (*Deleatidium sp*), a cased caddis fly (*Pycnocentrodes sp*), a pollution tolerant purse cased caddis (*Oxyethira sp*), a species of fungas gnat (*Mycetophilidae*) and a non-biting midge (*Maoridiamesa*) (see Figure 5; Appendix A). The greatest abundance of macroinvertebrates was observed at Site 11. The lowest abundance in macroinvertebrates was observed at Site 9.

Macroinvertebrates from mayfly, stonefly and caddisfly orders (EPT) are generally the most sensitive macroinvertebrates within the water body. Low EPT usually coincides with low MCI and low habitat health, and vice versa. The percent abundance of EPT taxa with the removal of *Hydroptilidae sp* (%EPT abundance) and %EPT taxa were both lowest at Site 10, followed by Sites 9 and 11 (Table 4, Figure 6; Appendix A). Site 11 is the most upstream site and is characterised by a more diverse velocity/ depth regime and increased substrate complexity. This combination of habitats is likely to see greater abundance and diversity in EPT taxa.

4.4.2 Macroinvertebrate Community Index (MCI) and Quantitative Community Index (QMCI)

Site 10 scored the lowest MCI and QMCI values followed by Sites 9 and 11 (Table 5, Figures 7 and 8; Appendix A).

Sites 10 and 9 are located within the lower reaches that are known to periodically dry during spring and summer months, and samples were dominated by non-biting midges (e.g., Chironomids), snails, worms, and crustaceans. These sites had MCI values indicating “fair” quality and QMCI values indicating “poor” water/ habitat quality.

MCI and QMCI values were higher indicating “good” quality at the most upstream site (Site 11); this sample was dominated by mayflies and caddisflies, with fewer snails and non-biting midge species (e.g., Chironomids).

A shift in the macroinvertebrate community from one dominated by sensitive EPT taxa to one dominated by less sensitive taxa is resulting in lower QMCI and MCI values observed at the downstream Waihi River sites. MCI and QMCI values are likely to have been affected to some degree by the low flows that had occurred in the preceding weeks prior to sampling. Low flows can significantly affect the macroinvertebrate community by restricting the available habitat for sensitive species (especially EPT taxa), increasing the presence of nuisance periphyton growth and ultimately causing a shift in the macroinvertebrate community structure. However, habitat quality (e.g., substrate composition) at each site is also likely to be a factor affecting macroinvertebrate communities.

Table 6: Macroinvertebrate Results for Waihi River

	Site 11	Site 9	Site 10
Total number of taxa	26	25	24
Number of individuals	1789	390	584
MCI	102	84	83
QMCI	**5.70**	**3.80**	**2.95**
$\%EPT_{taxa}$	38.46	24.00	20.83
$\%EPT_{abundance}$	84.91	22.05	6.85

Notes:
***Bold** values indicate samples that have exceeded the LWRP Hill Fed lower QMCI outcome of 6*

4.5 Observed Flows

The current PDP flow observations were undertaken after 26.5 mm of precipitation in the preceding week (Woodbury Rain Gauge (NZTM: E1452456; N5122303) data range 10/10/2016 to 17/10/2016.

4.5.1 Serpentine Creek

Flows in Serpentine Creek were observed to be variable from Site 1 downstream to Site 6, in this section flows comprised of a narrow, approximately 20 – 80 cm wide channel with a water depth varying between < 10cm and 30 cm, deeper water occurred in sections of the creek were water flow was restricted and pooling had begun to occur. Flows in Serpentine Creek were observed to be consistent from Site 6 downstream to the creeks confluence with the Waihi River. This section of the Creek comprised of water flow largely dominated by a slow run with water depth varying between < 10 cm to 45 cm and wetted width increasing significantly downstream (from approximately 80 cm at Site 7 to approximately 2 m at Site 8). Direct run-off into Serpentine Creek was not observed.

During previous PDP site visits conducted in July and August 2016, the water levels of Serpentine Creek were lower throughout the upper catchment with the creek being completely dry at Site 6 (at Majors Rd). Downstream of Site 6, flow increased to a similar level observed during the October sampling at Site 7 (above the bridge on the Winchester – Geraldine Road). The increase in flow observed between Site 6 and 7 in earlier visits could be attributed to increased overland flow from adjacent paddocks and/ or from increased flows from groundwater.

Flows within Serpentine Creek for the current survey are evident of elevated base flows throughout the creek without any direct runoff observed. The previous PDP site visits and the Opus, 2013, surveys were undertaken during base flow conditions, i.e., no rainfall in the days preceding observations.

The flow observations and the field pH and conductivity results suggest that the flow in Serpentine Creek can be attributed to a combination of hill-fed base flows, stormwater and groundwater. It is likely that in the upper catchment (within the township) the majority of the creeks base flow is derived from a combination of hill-fed base flows and stormwater sourced flows. In the lower catchment (downstream of the township) additional groundwater and adjacent land runoff appear to impact flows.

4.5.2 Waihi River

The Waihi River is typical of many small to medium hill – fed rivers in Canterbury in that the river can be divided into two distinct areas: the steeper, permanently flowing headwaters and the lower gradient, intermittent reaches below the Geraldine Township. During the PDP site visit the Waihi River flow was beginning to recede in the sections downstream of the township, and the river had gone completely dry by the Coach Road Bridge (approximately 1.5 km downstream of the Serpentine Creek confluence). There was very little evidence of flows being effected by the previous weeks rain. Upstream of the Serpentine Creek confluence the mainstem of the Waihi River had been restricted to larger pools connected via wide and shallow riffle sections. At the uppermost site (Site 11) the Waihi River maintained a variety of flow and velocity regimes.

4.5.3 Water Quality Classification and Level of Protection

Future water quality requirements are dependent on the Environment Canterbury classification of the water body as set out in the Land and Water Plan (LWRP).

Spring-fed plains water bodies are assessed against the 95% species protection level, while hill-fed lower – urban water bodies are assessed against the 90% species protection level.

The Waihi River is considered to be consisted with a “Hill Feed- Lower” classification based on the classification of the adjacent Orari River

The nature of flows within the upper Serpentine Creek catchment (inclusive of the Geraldine Township) appear to be predominantly hill-fed seepages supplemented by stormwater flows after periods of rain. These conditions and the urban water quality characteristics are consistent with a "Hill-feed, Lower Urban" classification. While flows in the lower Serpentine Creek catchment appear to be are fed by additional groundwater interactions and adjacent land run off, which is considered more consistent with a "Spring-feed Lowland" classification.

5.0 Alignment with Opus (2013) Data

Opus undertook an assessment of the ecological values (surface water quality, macroinvertebrate and fish health) of both Serpentine Creek and the Waihi River over the 31st of July and 1st of August 2013. No significant rain had occurred in the week preceding sampling and therefore the sample results represent base flows.

5.1 Surface Water Quality

5.1.1 Nutrients

The PDP sampling indicates that Serpentine Creek is in an excessively enriched state in regards to phosphorus and in an enriched nitrogen condition (Stevenson *et al.,* 2010). The observed nutrient conditions are typical for a small waterbody running through agricultural land, small reductions in bioavailable nutrients that were observed between Site 7 and Site 8 are likely attributed to uptake by macrophytes within the stream.

The Waihi River nutrient conditions can be broadly described as being in an enriched nutrient condition (Stevenson *et al.*, 2010), with concentrations of most nutrient species increasing between the upstream and downstream sites. Once again the nutrient levels that occur within the Waihi River are fairly typical of a waterway that runs through a highly agricultural catchment.

The Opus, 2013, report closely aligns with the overall nutrient conditions that were observed by PDP.

5.1.2 E.coli

Serpentine Creek *E.coli* values were high at both downstream sites and indicate that the presence of faecal matter may be at a level which impacts recreational and stock drinking water users. The increase between upstream and downstream sites suggests that faecal matter is entering the stream via run off from the adjacent agricultural land.

The *E.coli* values recorded from the two Waihi Sites indicate that faecal matter is in the waterway and is at a level that is not safe for human consumption, however, it did not exceed the levels for safe recreational use or for safe stock drinking water.

The Opus, 2013, report indicated that faecal matter was present at the Serpentine Creek downstream site but was at a level that was safe for recreational activities. The PDP *E.coli* results indicate that the concentration of faecal matter at downstream sites exceeds the safety level for contact recreation. For the Waihi River the Opus, 2013, report and the PDP results are closely aligned with one another.

5.1.3 Total Petroleum Hydrocarbons

Total Petroleum Hydrocarbons were below the laboratory analytical detection limit within both the Opus, 2013, report and the current PDP sampling round.

5.1.4 Metals

The Opus, 2013, report and the current PDP sampling round show that both Zn and Cu concentrations in Serpentine Creek exceeded the ANZECC 95% species protection level at the upstream site. The source of these toxicants is not known but these are commonly associated with road run off, and industrial/ commercial discharges. A recent rain event could potentially have impacted the levels of Zn and Cu in Serpentine Creek. Opus undertook sampling at a time with little preceding rainfall and it is possible that elevated levels of these toxicants occur within the ponded water in between rain events.

Metal concentrations within the Waihi River were low and below the 95% ANZECC protection level.

The Opus, 2013, report closely aligns with the metal results that were obtained by PDP. The elevated Zn and Cu levels in Serpentine Creek do not appear to be adversely affecting the Waihi River downstream of the confluence.

5.2 Waihi Macroinvertebrate Community

The Opus, 2013, report outlined that all the sampled reaches within the Waihi River had high %EPT taxa, MCI and SQMCI (the semi quantitative variant of QMCI); indicating that the Waihi River upstream of and in the vicinity of Geraldine Township had 'good' to 'excellent' water quality. In contrast, the PDP macroinvertebrate sampling indicated that the macroinvertebrate community was only healthy at the upstream site (Site 11), and the two downstream sites were reduced in both the amount and abundance of sensitive taxa.

The observed differences between the Opus and PDP sampling results are most likely due to the time of year that the samples were collected rather than any effect due to toxicants/ contaminants. Macroinvertebrate assemblages can be spatially complex and temporally variable depending on a wide range of environmental and biological factors. Such factors as time of year, light, nutrients, physio-chemical conditions (i.e., temperature and dissolved oxygen), river velocity and flow, substrate, physical disturbance and competition can all influence diversity. It is likely that as the flow in the Waihi River is receding, and will continue to do so throughout the spring and summer, the 'health' of the macroinvertebrate community is changing to one that is dominated by generalist species associated with lower habitat and water quality.

6.0 Conclusions

There is relatively little water quality, sediment, or ecological data available for Serpentine Creek and the Waihi River in the vicinity of Geraldine township. At present there are two data sets, one representing winter conditions (Opus, 2013) and one representing spring conditions (current PDP sampling round).

Results from the PDP 2016 survey indicate that Cu and Zn within Serpentine Creek are elevated. The high dissolved metals fraction of Zn at Site 2 within Geraldine Township could present a significant toxicity risk to aquatic biota, especially if the elevated concentrations are not naturally sourced.

Sediment samples taken from three locations on Serpentine Creek showed elevated concentrations of Pb and Mg; and some PAHs. The highest readings were observed at the most upstream site (Site 2 in the Geraldine Township). Concentrations of both the heavy metals and PAHs reduced downstream; potentially due to sediments having settled out and PAHs not being biologically available and/ or their bioavailability declining.

Water levels and flow in Serpentine Creek are known to fluctuate during the year, with sections of the creek going dry or being restricted to pooled habitat. Field pH and conductivity results collected by PDP downstream of Site 6, at Majors Road, indicate additional effects on the quantity and quality of water discharging to the Waihi River from Serpentine Creek. These observations and field sampling results indicate additional groundwater interactions with the surface flows and potential effects of the changes in land use downstream of Majors Road.

Nutrients are elevated throughout Serpentine Creek, and were observed to increase downstream as potential agricultural inputs are present. The adjacent agricultural land downstream of Site 6 is almost entirely unfenced and there is further evidence of possible effects from localised run-off and stock access along this section of Serpentine Creek. Other water quality parameters analysed outline that Serpentine Creek has an excessively enriched (TP) and enriched (TN) nutrient condition, with biologically available nutrients reducing due to excessive macrophyte growth, and greater *E.coli* values indicating increased levels of faecal coliforms at downstream sites.

The Waihi River flow in the vicinity of the Geraldine Township consistently dries and/or recedes throughout spring and summer. During this time it is likely that the macroinvertebrate community within these habitats will be shifting to assemblages that are adapted to surviving these types of conditions. Species associated with receding/ drying reaches are generally less sensitive taxa with lower MCI scores. Therefore, it is not surprising to see low MCI and QMCI scores at the two downstream sites when compared to the upper site (Site 11).

Overall, the PDP survey aligns with the conclusions that were outlined by Opus in 2013. Serpentine Creek from the Geraldine Township downstream to the confluence with the Waihi River currently has low ecological value. The environment is likely to continue to be affected due to the continual chronic long-term input of heavy metals, especially dissolved metals, and inputs from agricultural run-off from adjacent land as well as the ephemeral flow regime. Currently, the discharge of Serpentine Creek into the Waihi River does not appear to be having a negative impact on the downstream environment.

The flow characteristics observed in Serpentine Creek appear to be consistent with a "hill-fed lower – urban" water body classification in the LWRP and the flow characteristics observed in Waihi River appear to be consistent with a "hill-fed lower" water body classification in the LWRP.

7.0 Recommendations

In order to assess the effectiveness and performance of the SMP in the future it is recommended that a baseline data set is collected over a longer timeframe, this will enable characterisation of the effects and performance of the SMP against a range of climatic variations and seasonal variability in water quality. This will allow more cost effective treatment solutions to be provided to mitigate any effects of stormwater discharges.

7.1 Baseline Monitoring

PDP recommend a combination of regular surface water quality monitoring at six sites (including sites on Waihi River and Serpentine Creek) and sediment quality monitoring at three sites (on Serpentine Creek). The assessment of both dissolved and total metals is to be included in the monitoring as dissolved metals are considered to have a greater effect on the aquatic ecology of a site due to their biological availability.

Incorporating macroinvertebrate sampling into the regular monitoring program may not provide the most reliable indicator of health in the Waihi River. As any reduction in macroinvertebrate 'health' at downstream sites may be a reflection on the reducing and degrading habitat due to low flows rather than any effect from Serpentine Creek. However, it is important that monitoring of macroinvertebrates, when conditions are adequate, will enable a thorough baseline monitoring program to be implemented.

7.1.1 Serpentine Creek

Serpentine Creek sites should include both surface water and surface sediment sampling at the following sites:

- Upstream of Jollies Street culvert to assess the upstream catchment inputs (when flows are present)
- the Geraldine Domain (PDP Site 2), and

- upstream of Kennedys Road bridge (when flows are present).

The upstream of Jollies Street site is included so that an upstream baseline is established. This will allow any natural levels of metals that may occur before the Geraldine Township to be separated out.

7.1.2 Waihi River

Waihi River sites should include surface water sampling at the following sites to help characterise and outline the water quality of the ultimate receiving environment of the stormwater discharges of Serpentine Creek:

- upstream of Geraldine Township (PDP Site 11),
- upstream of Serpentine Creek confluence (PDP Site 9), and
- downstream of Serpentine Creek confluence (PDP Site 10).
- PDP recommend that when appropriate conditions persist, a quarterly (e.g., summer, autumn, winter, spring) macroinvertebrate sample is to be collected at two sites; one site downstream of the Serpentine Creek confluence (PDP Site 10) and one upstream of the Geraldine Township (PDP Site 11). Sampling is to be undertaken following the methods outlined in Opus, 2013, report. Sampling is only to be conducted when both an upstream and downstream sample can be collected; if either can't be collected macroinvertebrate sampling should not be undertaken.
- Additionally, the inclusion of water quality grab samples of stormwater discharge points into the monitoring schedule. This will enable the characterisation of stormwater as it enters Serpentine Creek, and allow potential point source effects to be localised and remedied if it is appropriate to do so.

7.1.3 Sampling Frequency

It is recommended that the frequency of sampling and parameters for each component for the first year is:

- Monthly sampling of surface water quality for the following parameters;
  - TSS, full nutrient suite, *E.coli*, total and dissolved metals; TPH and spot field parameters (e.g., dissolved oxygen, temperature, conductivity and pH),
  - Visual flow observations at each site (photographic record).
- If conditions are adequate and both an upstream and downstream sample can be obtained, then quarterly macroinvertebrate sampling on the Waihi River should be undertaken.
- Annual sampling of sediment quality for the following parameters;
  - Heavy metals, TPH and PAH

After the first year of sampling PDP recommend that the results of the monthly and annual sampling are reviewed, with consideration given to reducing the range of parameters and the frequency of sampling to assist any consent monitoring that may be required.

8.0 References

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Stevenson M., Wilks T. & Hayward S. 2010. 'An overview of the state and trends in water quality of Canterbury's rivers and streams'. Environment Canterbury Report number R10/117.

Appendix A

Site Locations and Field Data

SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 1 : MONITORING LOCATIONS

SOURCE:
1. AERIAL IMAGERY SOURCED FROM CANTERBURY MAP PARTNERS ADMINISTERED BY ENVIRONMENT CANTERBURY (MAY NOT BE SPATIALLY ACCURATE).

FIGURE 2 : FIELD WATER QUALITY MEASURING SITES

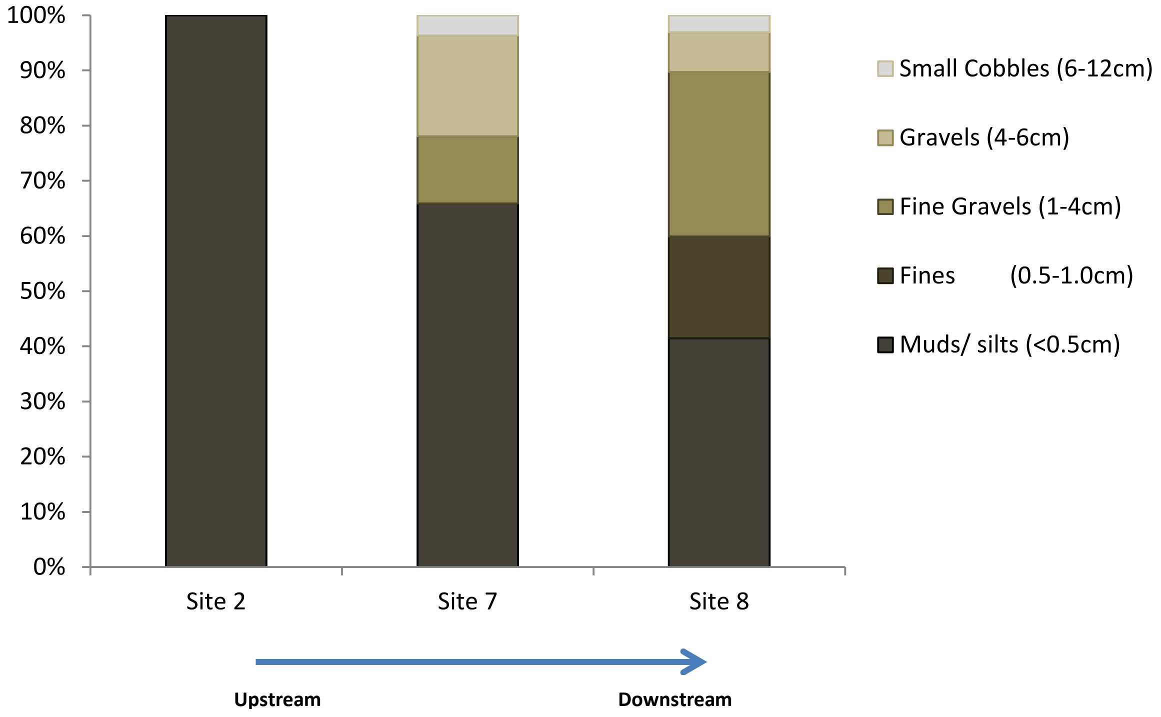

Figure 3. Substrate composition at sites on Serpentine Creek

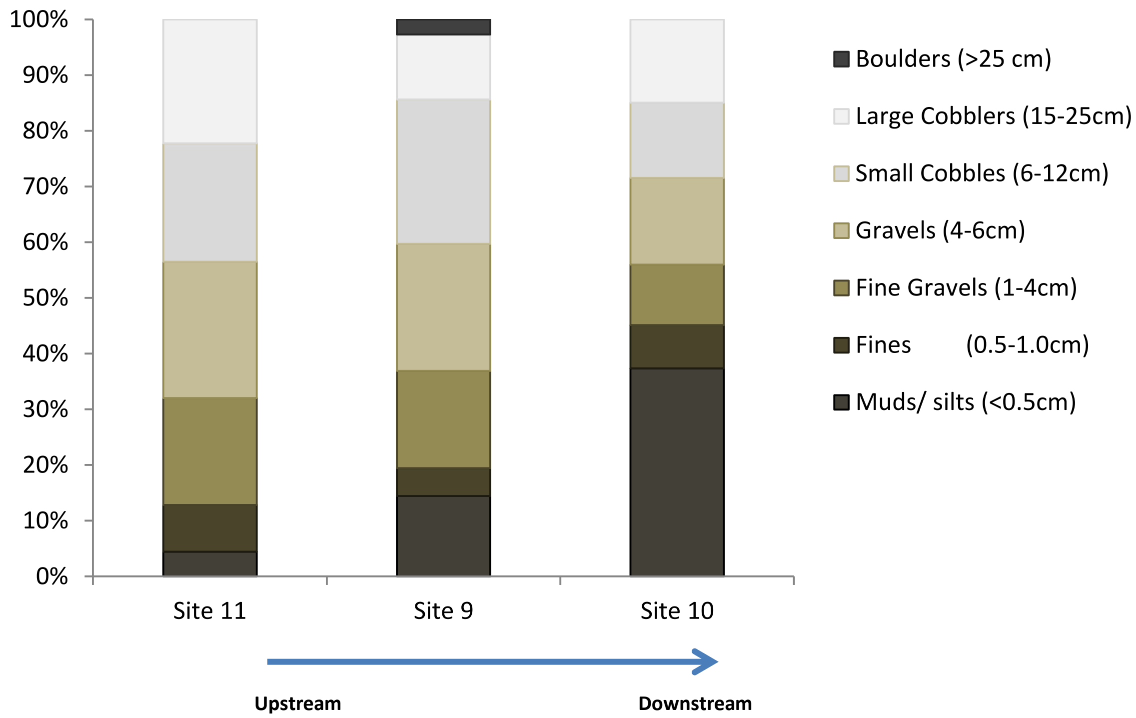

Figure 4. Substrate composition at sites on the Waihi River

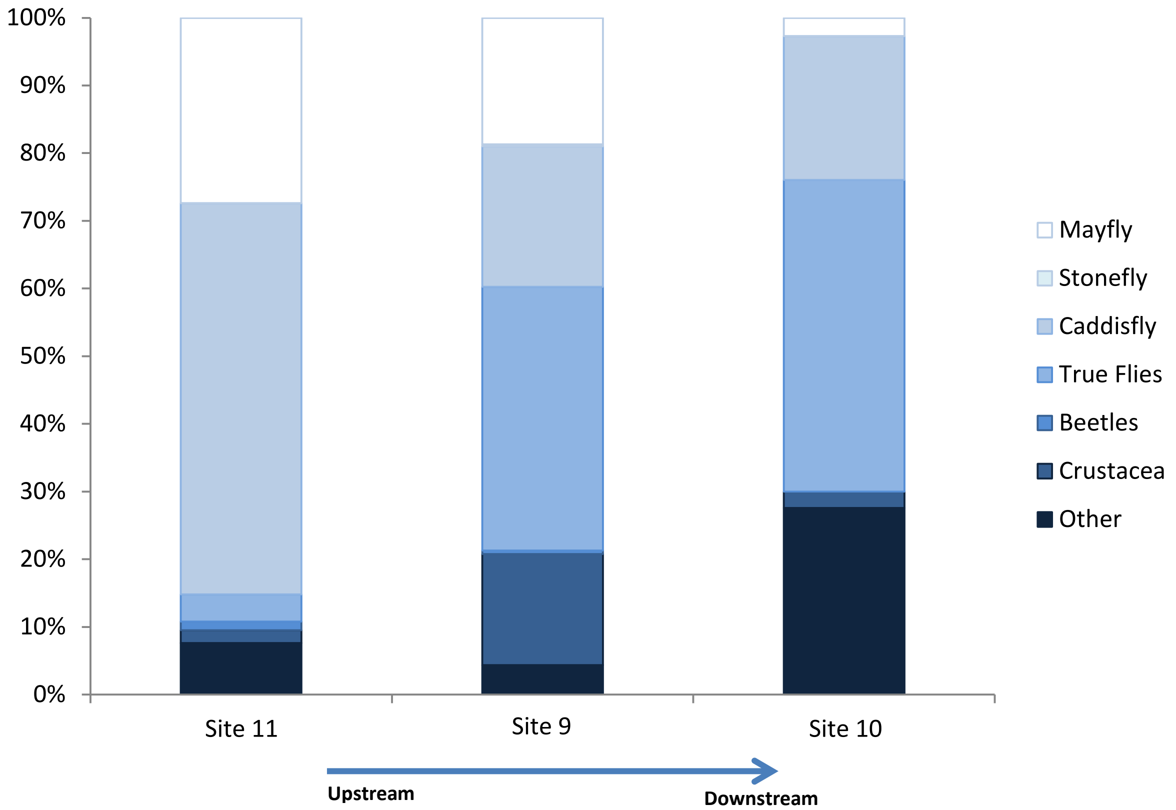

Figure 5. Macroinvertebrate community composition at three sites on the Waihi River

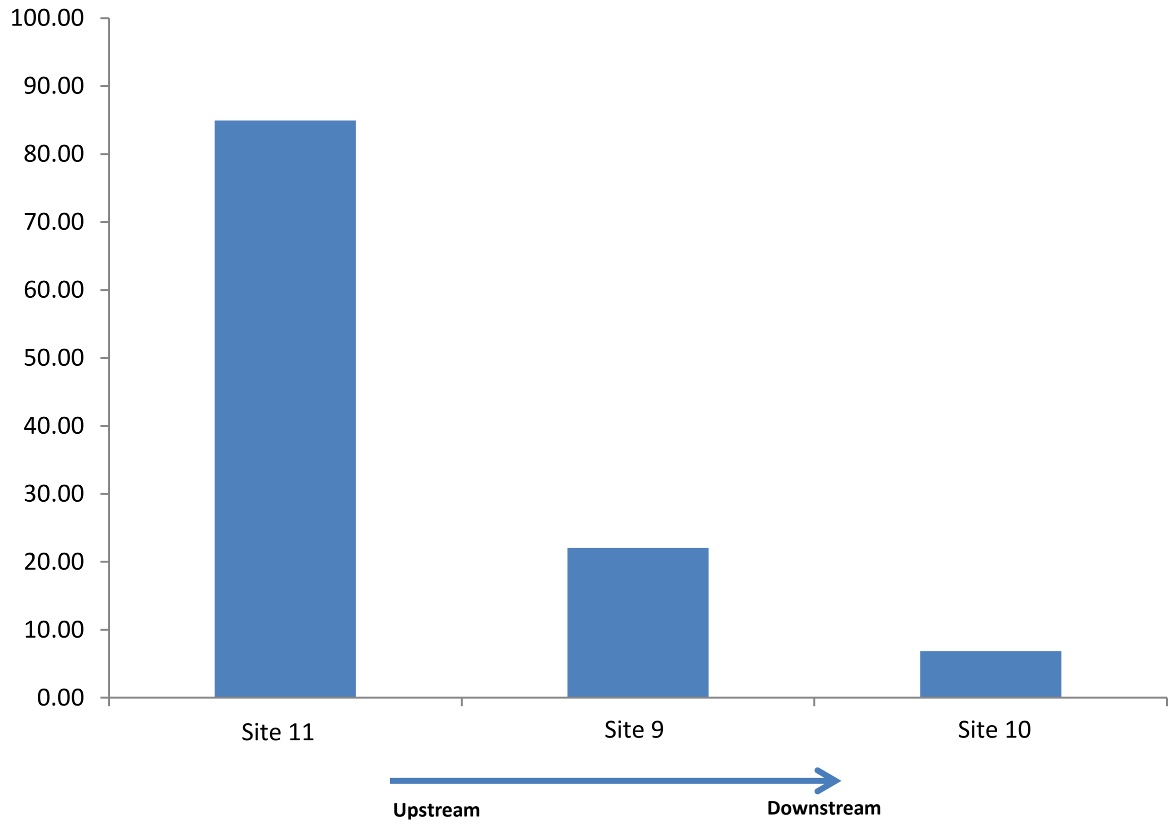

Figure 6. The percent abundance of Ephemeroptera, Plecoptera, Trichoptera (%EPT abundance) minus the pollution tolerant *Hydroptilidae sp* removed.

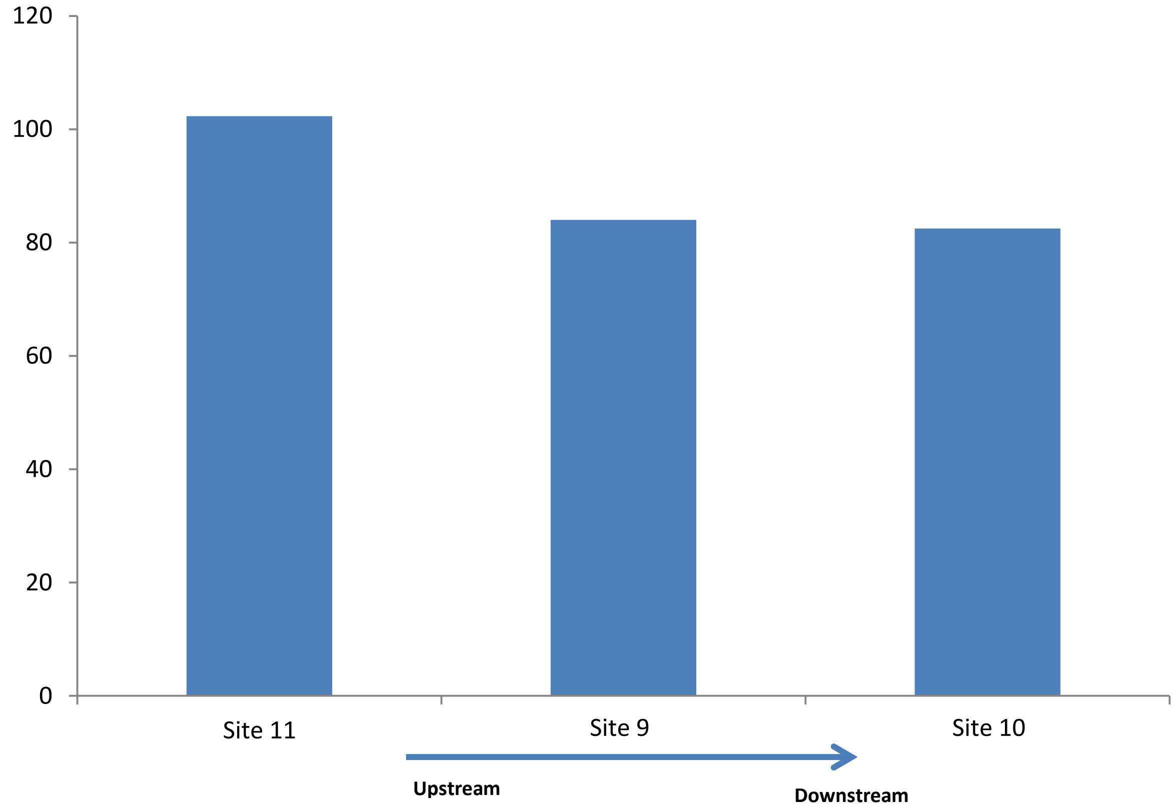

Figure 7. Macroinvertebrate Community Index (MCI) at three sites on the Waihi River

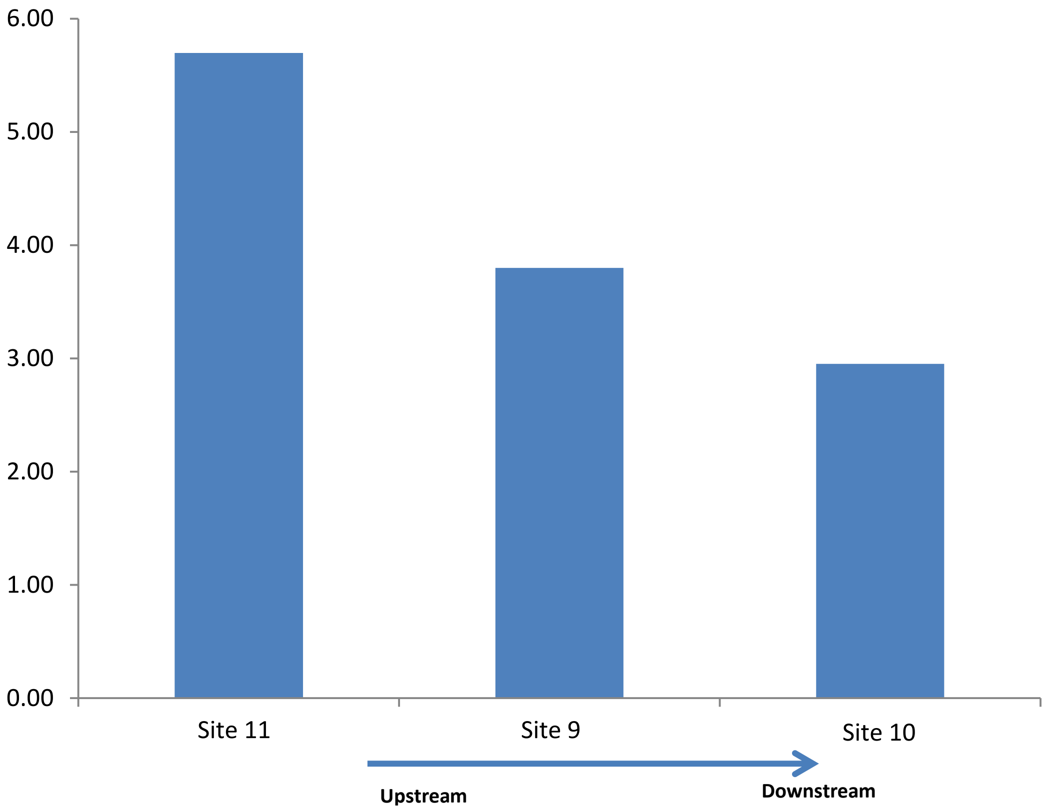

Figure 8. Quantitative Macroinvertebrate Community Index (QMCI) at three sites on the Waihi River

Table 1: Macroinvertebrate species identified in the Waihi River

	MCI	Waihi upstream	Waihi midpoint	Waihi downstream
		Site 11	Site 9	Site 10
	score	18-Oct-16	18-Oct-16	18-Oct-16
		Site 11	Site 9	Site 10
Mayflies				
Deleatidium	8	490	73	16
Stoneflies				
Zelandobius	5	-	1	-
Caddisflies				
Helicopsyche	10	1	-	-
Hudsonema amabile	6	47	-	-
Hydrobiosis	5	4	7	9
Olinga	9	19	-	1
Plectrocnemia	8	2	-	-
Polyplectropus	8	3	-	-
Psilochorema	8	32	2	13
Pycnocentria	7	1	1	-
Pycnocentrodes	5	920	2	1
Oxyethira	2	5	69	100
Beetles				
Antiporus	5	-	1	-
Berosus sp.	5	2	-	-
Elmidae	6	21	1	-
True Flies				
Anthomyiidae	3	-	1	1
Austrosimulium	3	2	8	2
Ceratopogonidae	3	3	-	-
Corynoneura	2	-	6	4
Empididae	3	16	3	-
Ephydrella	4	-	1	-
Maoridiamesa	3	5	6	100
Mycetophilidae	3	-	2	-
Orthocladiinae	2	23	120	160
Polypedilum	3	-	-	1
Tanypodinae	5	8	1	1
Tanytarsus	3	15	4	-
Crustacea				
Amphipoda	5	1	-	2
Cladocera	5	-	48	5
Copepoda	5	-	11	5
Ostracoda	3	33	5	2
Collembola	6	4	2	12
Mites	5	5	-	-
Worms	1	44	12	31
Round worms	3	-	-	1
Snails				
Gyraulus	3	-	3	16
Lymnaeidae	3	-	-	27
Physa	3	-	-	9
Potamopyrgus	4	83	-	65
Total number of taxa		26	25	24
Number of individuals		1789	390	584
MCI		102.31	84.00	82.50
QMCI		5.70	3.80	2.95
%EPT$_{\text{taxa (excl. hydroptilidae)}}$		38.5	24.0	20.8
%EPT$_{\text{abundance (excl. hydroptilidae)}}$		84.9	22.1	6.8