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Purpose

Hawke's Bay Regional Council's riparian monitoring programme was initiated in 1999 to investigate the water quality of some specific Hawke's Bay streams that had been targeted for catchment scale erosion control. The Environmental Monitoring Section of Council has focused on water quality monitoring of three streams (the Huatokitoki stream in Porangahau, the Puhokio Stream in Waimarama and the Waitahora Stream near Frasertown) since this time. Unfortunately, due to time and budgetary constraints, these three streams had not been monitored at an adequate sampling frequency to determine seasonal variations in water quality.

This report presents results for the first year of uninterrupted monthly monitoring of the Puhokio Stream in Waimarama. Monitoring commenced on 11/09/01 and finished on 10/09/02. The purpose of this report is to:

- Determine the likely impacts of land use within the catchment and its implications in regards to water quality for instream ecology
- Provide an environmental baseline that can be used for comparison with future years monitoring
- Identify any problems that require remedial actions or further study

For more detailed information on the bacteriological water quality of the Puhokio Stream and its suitability for swimming see Technical Report EMI 0301 entitled "The Bacteriological Water Quality of the Puhokio Stream" published in January 2003.

Background

The Puhokio Stream has been targeted as a priority catchment for riparian management since 1999. It is expected that the current and planned soil conservation improvements for the catchment will be reflected in improvement of the overall health of the Puhokio Stream in years to come.

Introduction

The Puhokio Stream is a fourth order stream that has its headwaters located up Te Apiti Valley. A major tributary of the Puhokio Stream (the Kaikopu Stream) has its headwaters located at the edge of the Maraetotara Plateau. The Puhokio Stream Catchment follows a course predominantly surrounded by pastoral farming and discharges to sea at Waimarama Beach. The lower reach of the stream forms a lagoon, which has historically been a popular bathing site for many people.

Like many small agricultural streams in New Zealand, the Puhokio Stream has suffered a history of neglect in terms of surrounding land use and wastewater disposal practices (see appendix 2 for details). Grazing has been to the waters edge for most of the stream length that has resulted in a moderate degree of stream bank erosion and a lack of any significant native riparian vegetation regeneration.

In recent years there has been a growing awareness that appropriate riparian management is vital to maintaining the quality and biodiversity of our water bodies. Healthy functional riparian zones provide three important benefits:

1. They reduce or buffer the impact of land-based processes (natural or human-induced) on waterways by:
 - Reducing erosion by slowing down the speed of overland water flow before it reaches the stream
 - Filtering inputs of nutrient, soil, microbes and pesticides in overland flow
 - Denitrifying groundwater
 - Utilising some nutrients for plant growth before they enter the stream
 2. They reduce or buffer the impact of water-borne processes (natural and human induced) on adjacent land by:
 - Protecting banks from erosion
 - Buffering channels from localised changes in morphology
 - Buffering the impacts of floods
 3. They promote and sustain instream plants and animals by:
 - Reducing fine sediment levels
 - Maintaining water clarity
 - Providing instream food supplies and habitat
 - Preventing nuisance plant growths through shading
 - Maintaining lower summer maximum water temperatures
 - Reducing light levels
 - Maintaining natural food webs
- (Adapted from Ministry for the Environment 1999)

The programme

Water quality and ecology

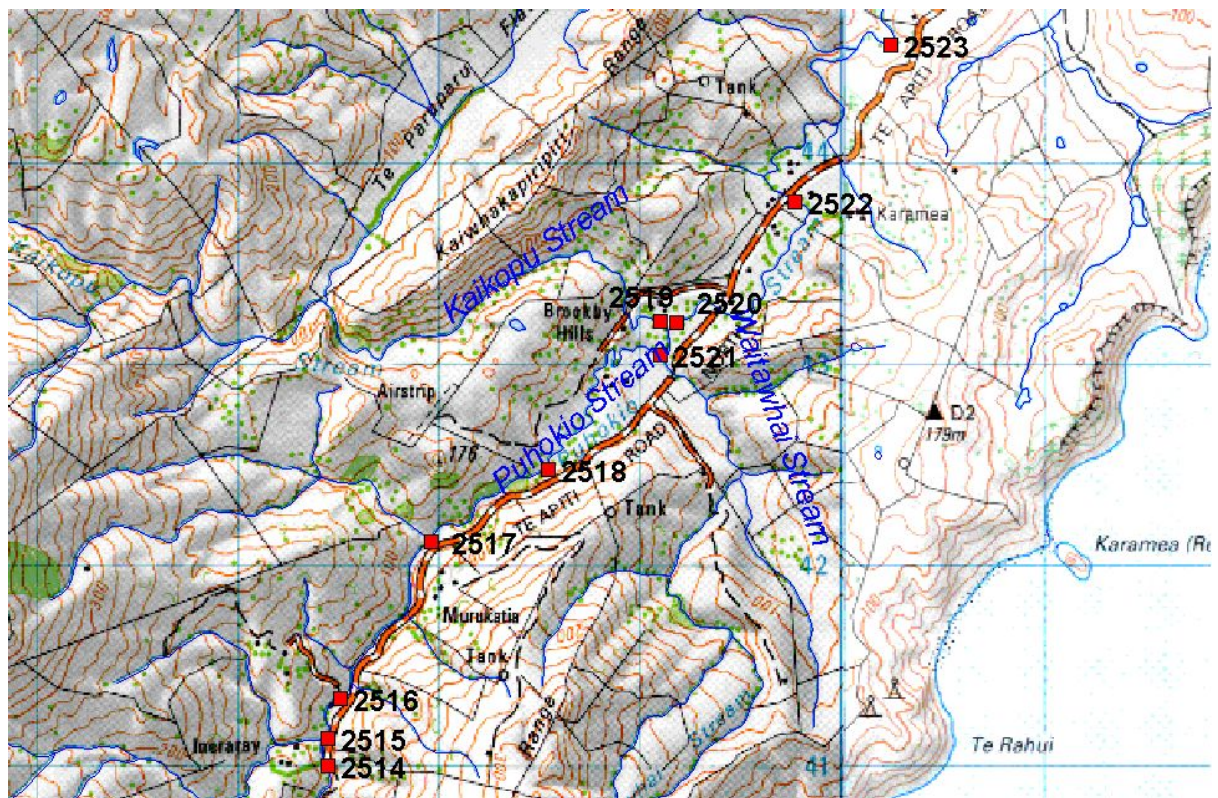
The Puhokio Stream has undergone intensive monthly water quality and flow monitoring for the period 11/09/01 to 10/09/01. Sampling site locations are shown in the following tables and map. Photographs of the sampling sites are given in Appendix 3.

Table 1: Sampling Sites

Puhokio Stream Hawke's Bay Regional Council monitoring sites

Site location

	HBRC Site number	Easting	Northing	Map sheet
Puhokio Stream end of Te Apiti Rd	2514	2847437	6141003	W21
Puhokio Stream by gate downstream of Puhokio Stream and Puhokio Stream tributary junction	2515	2847437	6141137	W21
By red shearing shed	2516	2847499	6141339	W21
Opposite side road from green shed upstream Puhokio Stream and Puhokio Stream tributary junction	2517	2847948	6142121	W21
Puhokio Stream by silver pipe	2518	2848531	6142477	W21
Kaikopu Stream upstream of junction with Puhokio Stream	2519	2849092	6143218	W21
Downstream of confluence of Puhokio and Kaikopu Stream	2520	2849170	6143212	W21
Puhokio Stream upstream of confluence of Puhokio and Waitawhai Stream	2521	2849089	6143050	W21
Puhokio Stream at Allens bridge	2522	2849759	6143811	W21
Puhokio Stream by pine trees	2523	2850239	6144590	V22



Sampling Regime

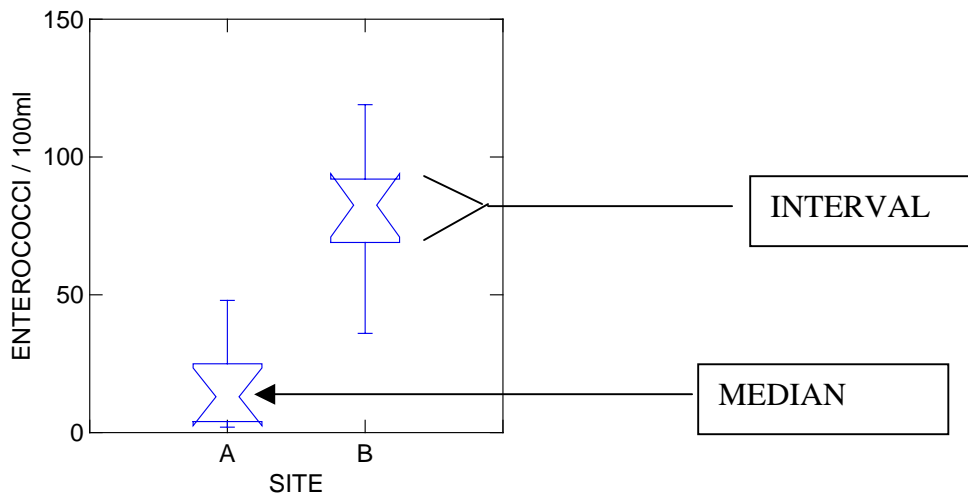
The Puhokio Stream sampling programme has involved monitoring the following variables

Water Quality Variable	Sampling Frequency
Ammoniacal Nitrogen	Monthly
Dissolved Oxygen	Monthly
% Saturation Dissolved Oxygen	Monthly
Water Clarity	Monthly
E.coli	Monthly
Faecal coliforms	Monthly
Nitrate Nitrogen	Monthly
PH	Monthly
Dissolved Reactive Phosphorus	Monthly
Suspended Solids	Monthly
Total Kedjal Nitrogen	Monthly
Total Phosphorus	Monthly
Temperature	Monthly
Flow	When flow permits Monthly
Macroinvertebrates	Annually – Summer
Algae	Annually – Summer
Stream Habitat Assessment	Annually - Winter

Box and Whisker Plots of Water Quality

The water quality results in this section are presented as box and whisker plots. A diagrammatical explanation of a box and whisker plot follows.

Figure 2: Box and Whisker Plot



A significant difference is detectable (with 95% confidence) if the confidence intervals around two medians do not overlap (McGill , Tukey, & Larsen 1978). Figure 2 shows that site B has significantly higher Enterococci concentrations compared to site A. This is depicted by the intervals around the two medians not overlapping.

If two intervals in a box and whisker plot do overlap but a trend is observed then the sites are referred to as being generally lower or higher to each other.

If the data has a wide range of values for a site, an asterisk will represent outliers while a small circle will represent extreme outliers.

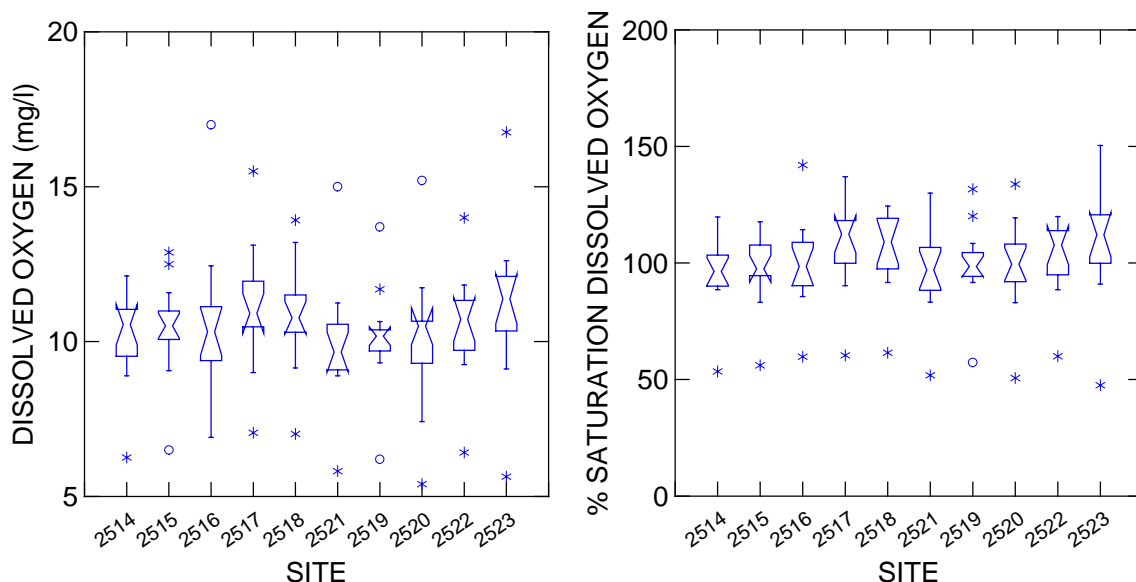


Figure 1: Dissolved Oxygen

The box and whisker plots in figure 1 indicate that dissolved oxygen concentrations are generally lower at sites 2521 (upstream of the Kaikopu Stream confluence) site 2519 (Kaikopu Stream) and site 2520 (downstream of the Kaikopu Stream confluence). Dissolved oxygen is measured as spot measurements when water sampling is undertaken and it is

possible that diurnal variations in dissolved oxygen may play some part in the observed trend which is not significant at the 5% level.

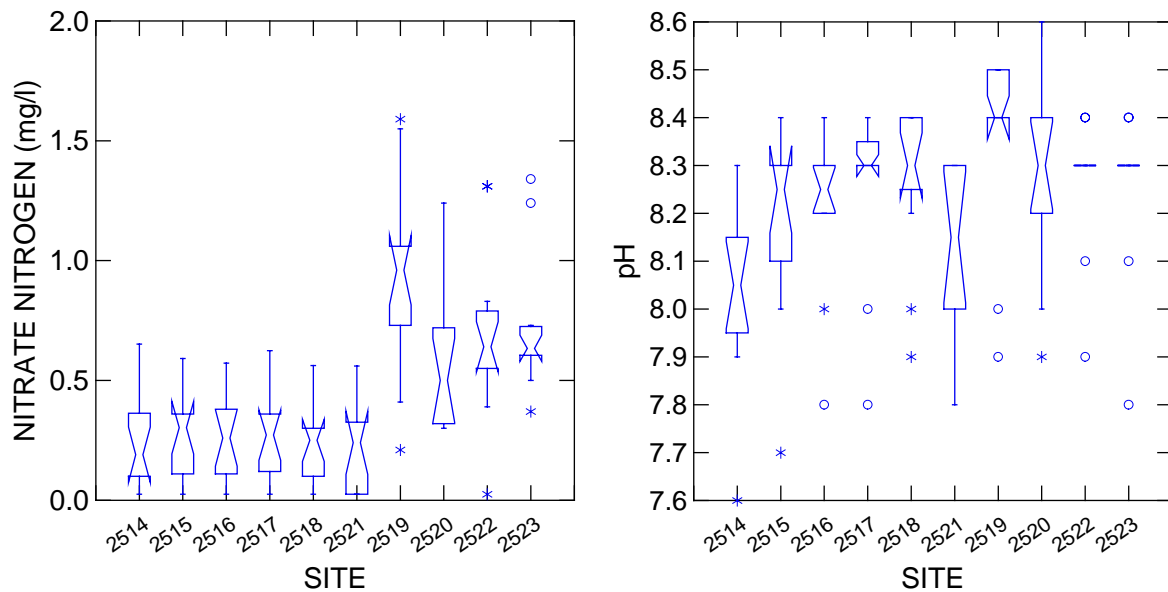


Figure 2: Nitrate Nitrogen and pH

Figure 2 shows that nitrate nitrogen concentrations are significantly higher at the Kaikopu Stream, which gives rise to significantly higher concentrations downstream of the confluence of the Kaikopu Stream with the Puhokio Stream. The reason for the elevated nitrate nitrogen concentrations in the Kaikopu Stream is unclear although intensive beef farming within the Kaikopu Stream Catchment could be contributing to this. pH levels in figure 2 show that the Puhokio Stream becomes increasingly alkaline as you head downstream until site 2521 is reached when pH levels drop again. The western tributaries (2515 and 2519) show high pH levels when compared to Puhokio Stream sites located upstream. It is likely that the geology of the western tributary catchments results in a more alkaline pH compared to the main stem of the Puhokio Stream, as it comprises more limestone.

No significant differences were found between the sites for ammoniacal nitrogen, water clarity, E. coli, Faecal coliforms, Dissolved Reactive Phosphorus, Suspended Solids, Total Kjeldahl Nitrogen, Total Phosphorus or Temperature. The box and whisker plots for these water quality variables are in Appendix 1.

Stream habitat and riparian assessment

In addition to the water quality monitoring, habitat assessments of the Puhokio Stream were undertaken during May and June 2002. The assessed variables comprised features of streamside vegetation, adjacent land use, stream bank stability, disturbances caused by stock, potential for contamination and sediment input as well as benthic habitat diversity of each stream site. The habitat assessment was conducted by walking the length of each stream during a low flow period (November 2000 and February 2001) and completing a questionnaire (see Appendix 3) wherever a visible change of the defined habitat variables occurred. The assessed section of the river / stream received a score for each habitat variable from which a total habitat score was calculated. A habitat class was also assigned to each site to indicate excellent (habitat score >470 = Class 1), good (313 – 469 = Class 2), poor (156 – 312 = Class 3) and very poor habitat (<155 = Class 4).

Habitat classes for stream reaches were plotted on GIS using ARC View to produce an aerial map of the Puhokio Stream catchment. The following map shows the habitat classes for the Puhokio Stream.

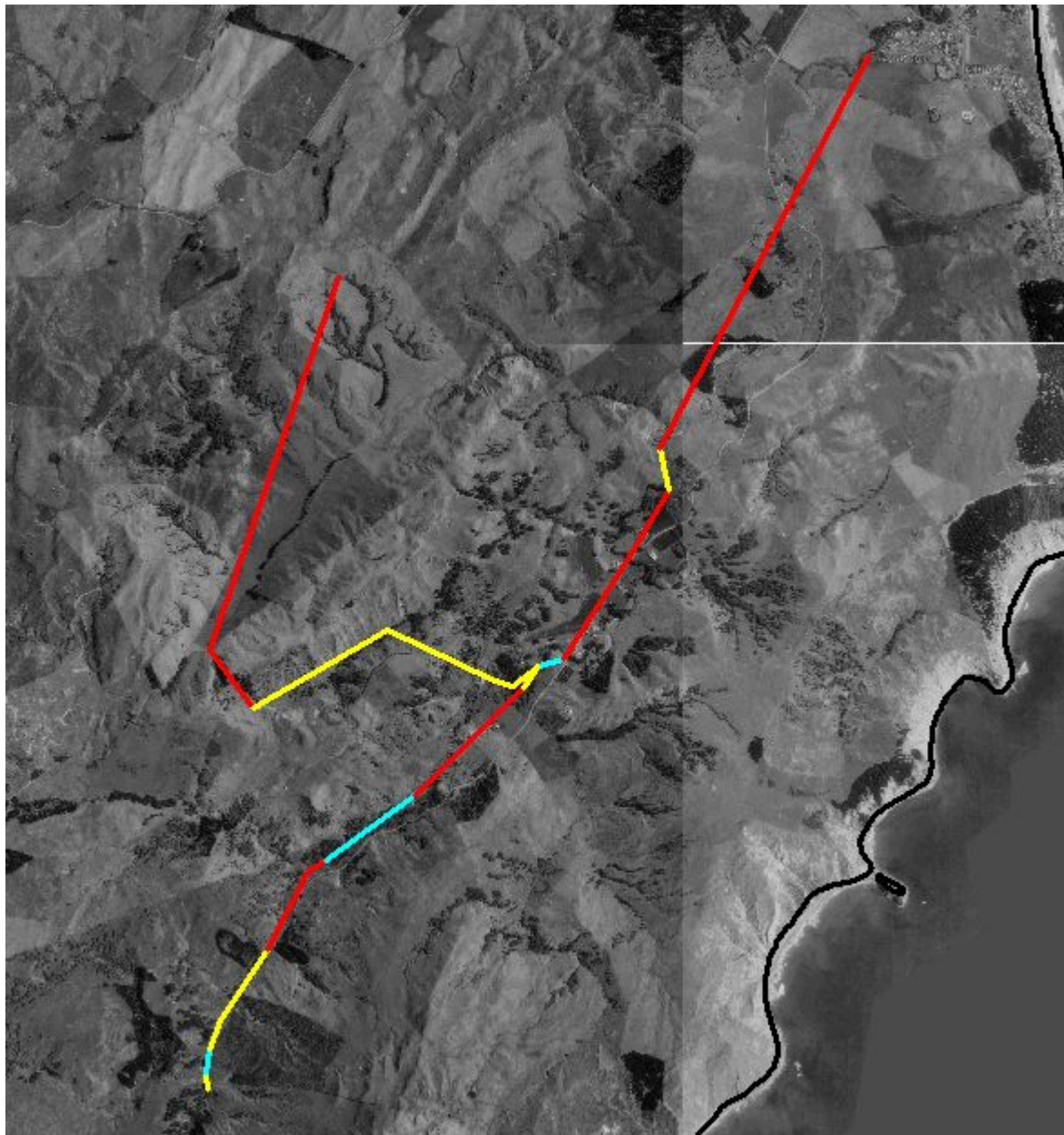


Figure 3: Habitat Classes of the Puhokio Stream and Kaikopu Stream

Key: excellent habitat	—————
good habitat	—————
poor habitat	—————
very poor habitat	—————

Figure 3 shows that both the Puhokio and Kaikopu Streams have a lot of very poor habitat. The following table displays the percentage of stream length in each habitat class. In all cases lower habitat values were attributable to stream bank damage caused by stock access and a lack of riparian shading.

Table 2: Habitat Class By Percentage

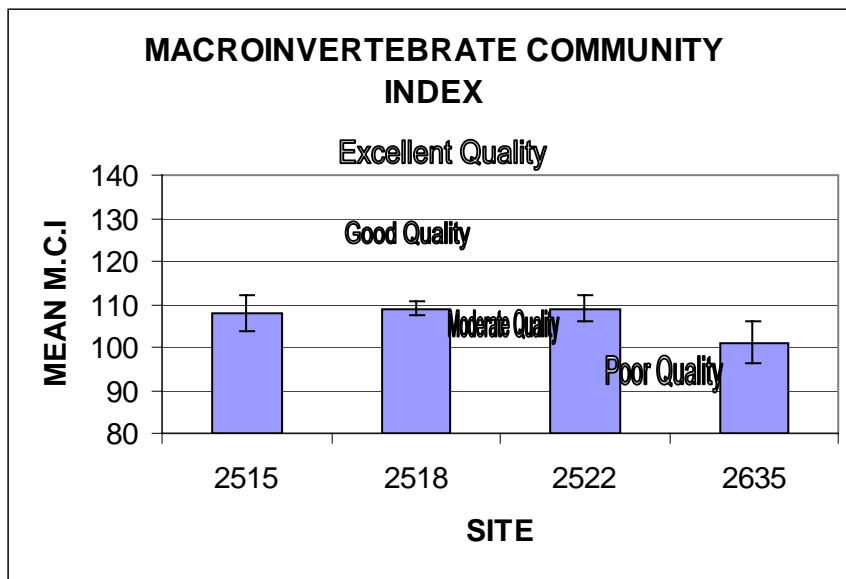
Stream	Class 1	Class 2	Class 3	Class 4
Kaikopu	0%	0%	41.1%	58.9%
Puhokio	0%	12.77%	15.92%	71.31%

A large proportion of the Puhokio and Kaikopu Streams have poor to very poor habitat. No reaches of these streams displayed excellent habitat (Class 1).

Macroinvertebrate Sampling

Macroinvertebrates were sampled from 4 sites of the Puhokio Stream. Four Surber samples were taken from representative riffle reaches of the stream sites. Samples were sent to Water Care Laboratory Services for taxonomic identifications. The data was condensed into a commonly used biological index of water quality namely the Macroinvertebrate Community Index (M.C.I). Analysis of variance of mean M.C.I values were undertaken to determine whether significant differences ($p < 0.05$) in mean MCI values were detectable between any sites.

Figure 4: Macroinvertebrate Community Index Values



The macroinvertebrate sampling indicates macroinvertebrate community structure that is characteristic of moderate nutrient enrichment. An analysis of variance of the mean MCI values indicated no significant differences between any of the four sites ($p > 0.05$).

Periphyton Monitoring

Five stones were scraped from the 4 macroinvertebrate sampling sites for periphyton taxonomic and biomass analysis. Samples were sent to Water Care Laboratory Services.

Table 3: Common Periphyton Taxa Found in Puhokio Stream

Site ID	Common Periphyton Taxa Found	Trophic Designation
2515	<i>Navicula radiosa</i> , <i>Suirella ovata</i> , <i>Synedra ulna</i>	Mesotrophic
2518	<i>Navicula radiosa</i> , <i>Opephora martyi</i> , <i>Synedra ulna</i>	Mesotrophic
2522	<i>Diatoma vulgare</i> , <i>Navicula radiosa</i>	Mesotrophic / Eutrophic
2563	<i>Diatoma vulgare</i> , <i>Navicula radiosa</i>	Mesotrophic / Eutrophic

The periphyton taxa found in the Puhokio Stream indicate that the communities found are characteristic of mesotrophic to eutrophic (moderate to high nutrient enrichment) waters.

Table 4: Periphyton Biomass

Site ID	Ash Free Dry Weight	Trout Habitat & Angling Guideline
2515	35.52	35
2518	21.67	35
2522	33.2	35
2563	41.91	35

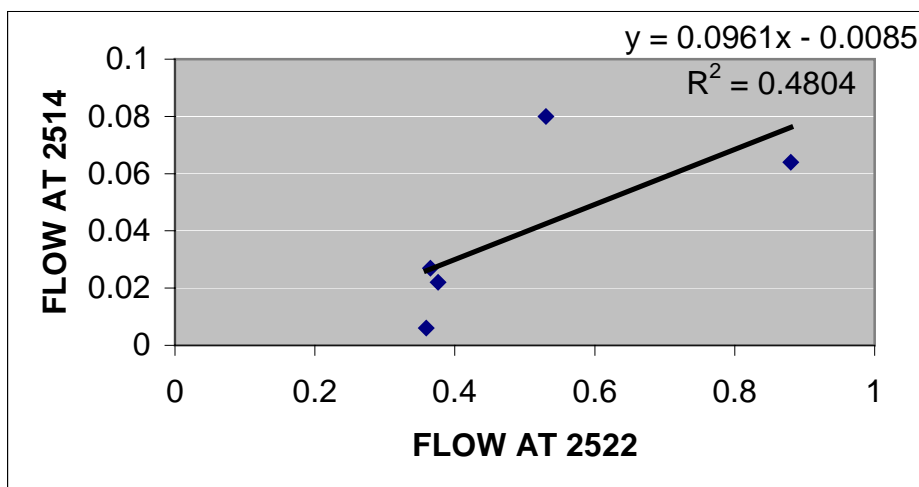
Table 4 Continued: Periphyton Biomass

Site ID	Chlorophyll a	Trout Habitat & Angling Guideline	Benthic Biodiversity Guideline
2515	16.87	200	50
2518	9.33	200	50
2522	31.61	200	50
2563	8.48	200	50

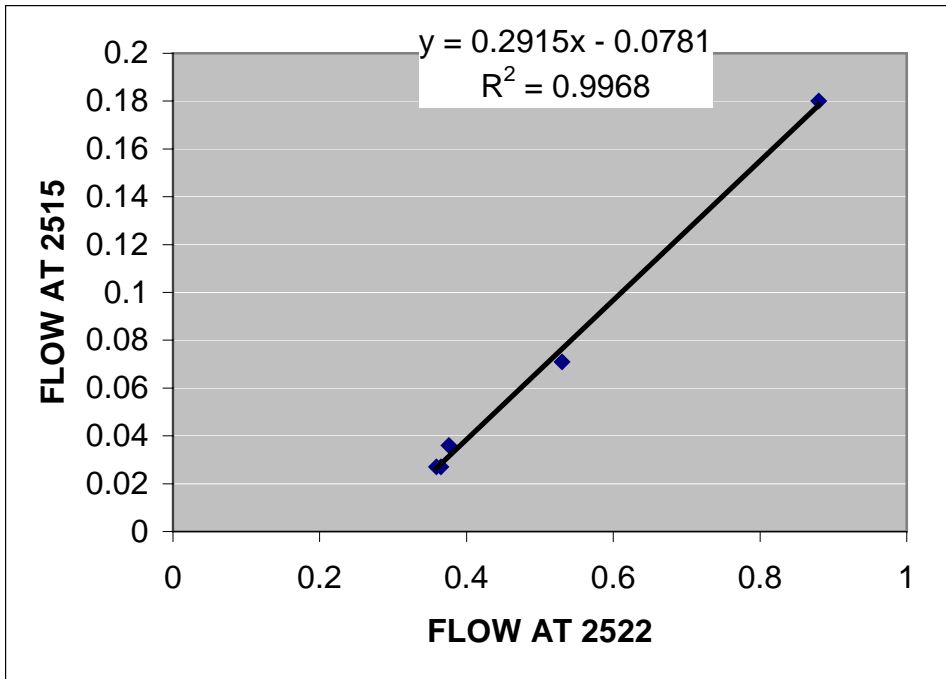
The biomass of periphyton in the Puhokio Stream sampled on 9 January 2001 was quite high. The Ministry for the Environment Periphyton Guidelines are breached (see red text) at the top and bottom sites indicating that the Puhokio Stream has periphyton biomass that is likely to be detrimental to trout habitat / angling but not benthic biodiversity.

Stream Flows and Sediment Loadings

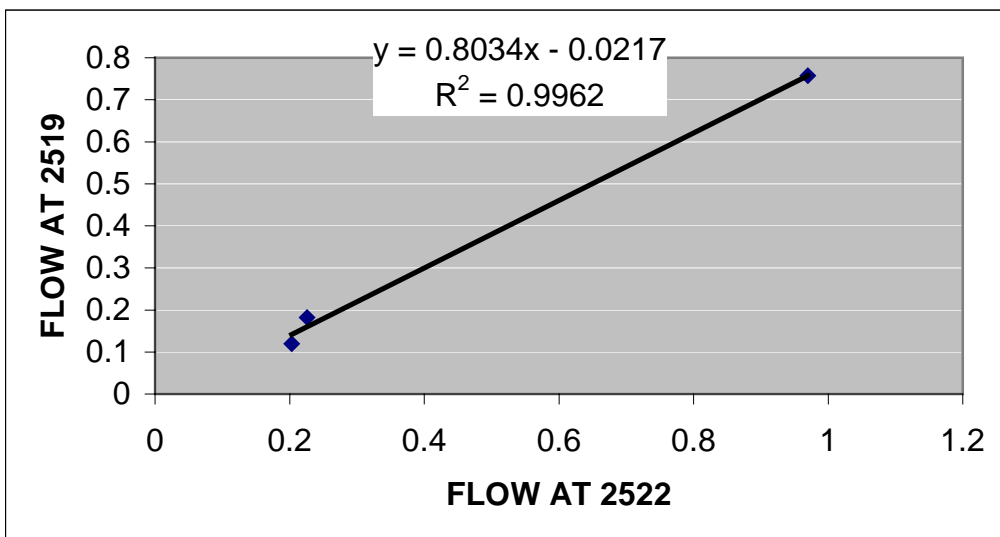
Flow gaugings were taken from 4 sites of the Puhokio Stream catchment to develop an understanding of where sediment loadings were most prevalent. In the initial stages of the study, flow gaugings concentrated on the two head water tributaries (sites 2514 & 2515) and a site further down the catchment (site 2522). Later in the programme flow gaugings concentrated on the Kaikopu Stream site (site 2519) and site 2522. Through having the greatest number of gaugings taken from site 2522, correlated flow values could be generated from sites 2514, 2515 and 2519 on dates at which they were not monitored.



Flows recorded at the top site (2514) were not well correlated to site 2522 ($R^2 = 0.48$). The reason for this may be due to the shallow nature of this site (often less than 10 cm maximum depth) and the unstable nature of the substrate. It is very difficult to gauge shallow streams that have an unstable substrate as this produces errors in flow velocities and cross sectional area calculations.



Flow gaugings at site 2515 showed a good correlation with flows measured from site 2522 ($R^2=0.99$). The uniform nature of the streambed and greater depth at site 2515 provided for more accurate estimates of flow.



The site at Kaikopu Stream (site 2519) also had a uniform channel with good depth. The flows generated from here showed a good correlation with site 2522.

Sediment Loads

From the flow gaugings undertaken, sediment loads could be calculated for site 2515, 2519 and 2522 by multiplying the suspended sediment concentrations by the flow on the day the water was sampled.

The following table shows the mean suspended solids loadings in mg/ second. From this annual loadings can be calculated.

Table 5: Mean Suspended Sediment Loadings within the Puhokio Stream Catchment

Site ID	Mean SS Loading mg/second	g/ minute	Kg/hr	Kg/day	Tonnes / yr
2515	9613.34	576.80	34.60	830.59	303.17
2519	49069.33	2944.16	176.65	4239.59	1547.45
2522	45852.93	2751.17	165.07	3961.69	1446.02

The suspended sediment loadings above show that a large proportion of sediment loading to the Puhokio Stream comes from the incoming Kaikopu Stream catchment (site 2519). Sediment loadings at site 2522 (further down the catchment) are less than that experienced in the Kaikopu Stream suggesting there may be some entrainment of sediments between the confluence of the Kaikopu Stream and further down the Puhokio Stream. This may mean that the streambed will slowly aggrade. Often after heavy rainfall it was noted how turbid the Kaikopu Stream looked in appearance compared to the main stem of the Puhokio Stream.

Discussion

The Puhokio Stream is characteristic of many small agricultural streams in New Zealand. It has little protection to its stream banks from stock damage and stock access to the water is widespread.

The land uses within the catchment are likely to be contributing to the high nutrient and sediment concentrations experienced in the stream but only in a minor way. The underlying geology of the Puhokio Stream catchment of mudstones and limestone is expected to be the prime reason for the poor water quality in the stream irrespective of the surrounding land uses. The mudstone geology provides nutrient rich water to the catchment while the limestone geology provides a highly erosive topography that gives rise to high concentrations of suspended sediments in the stream water.

The reason the Kaikopu Stream has significantly higher concentrations of nitrates compared to the main stem of the Puhokio Stream is unclear and determining the cause is beyond the scope of this study. The higher suspended sediments loading experienced in the Kaikopu Stream is likely to be due to the fact that it flows through an unconsolidated alluvial valley infill.

The biological sampling indicates that the periphyton and macroinvertebrate communities of the Puhokio Stream are characteristic of moderate to high nutrient water. The general ecological health of the Puhokio Stream could be improved if riparian planting and fencing of stock was initiated in the catchment. The planted riparian trees would provide adequate shading to reduce water temperatures, algal growths and localised land use disturbances to the stream.

This study has provided an important baseline from which future comparisons of stream ecology and water quality can be compared. In its present state the Puhokio Stream catchment has a large amount of riparian habitat that is in poor to very poor condition. Improvements to this riparian habitat are likely to result in improved ecology and biodiversity of the stream and its catchment but is unlikely to result in significant improvements in the water chemistry.

Unfortunately no in stream biological communities had been sampled from the Kaikopu Stream to determine whether the harsher physical environment of higher suspended solids loading and higher nitrate nitrogen concentrations resulted in poorer macroinvertebrate and algal communities compared to the Puhokio Stream.

Recommendations

It is recommended that the Puhokio Stream not be intensively monitored until any progress on riparian plantings has been made. Ideally the sites should be assessed again in 10 yrs time on the proviso that some riparian plantings and stock fencing has been done

Flow gaugings should be repeated at site 2522 and perhaps two other sites (perhaps 2518 and 2521) to develop a clearer picture of suspended sediment loadings within the catchment.

The Kaikopu Stream should be biologically monitored during the summer period of the next intensive sampling programme to determine the biological conditions in this stream.

Site 2514 could be taken out of the programme as the shallow nature of the site and the non-uniform nature of the streambed makes it difficult to gauge flows there.

Acknowledgements

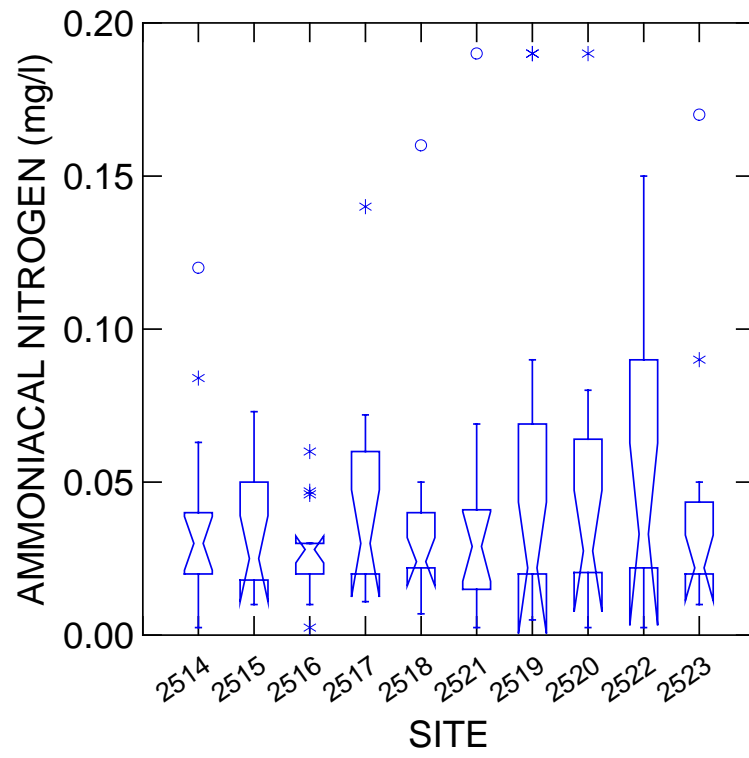
I'd like to thank Erna Zimmerman for her countless days in the field with me assisting with riparian habitat surveys and water quality monitoring. Many thanks also to Garth Eayles, Nigel Ironside and Jude Addenbrooke for providing useful comments towards the draft report. Water chemistry analyses were undertaken by Hills Laboratories of Hamilton and Kersons Laboratory of Hastings. Biological samples were analysed by Water Care Laboratory Services of Auckland.

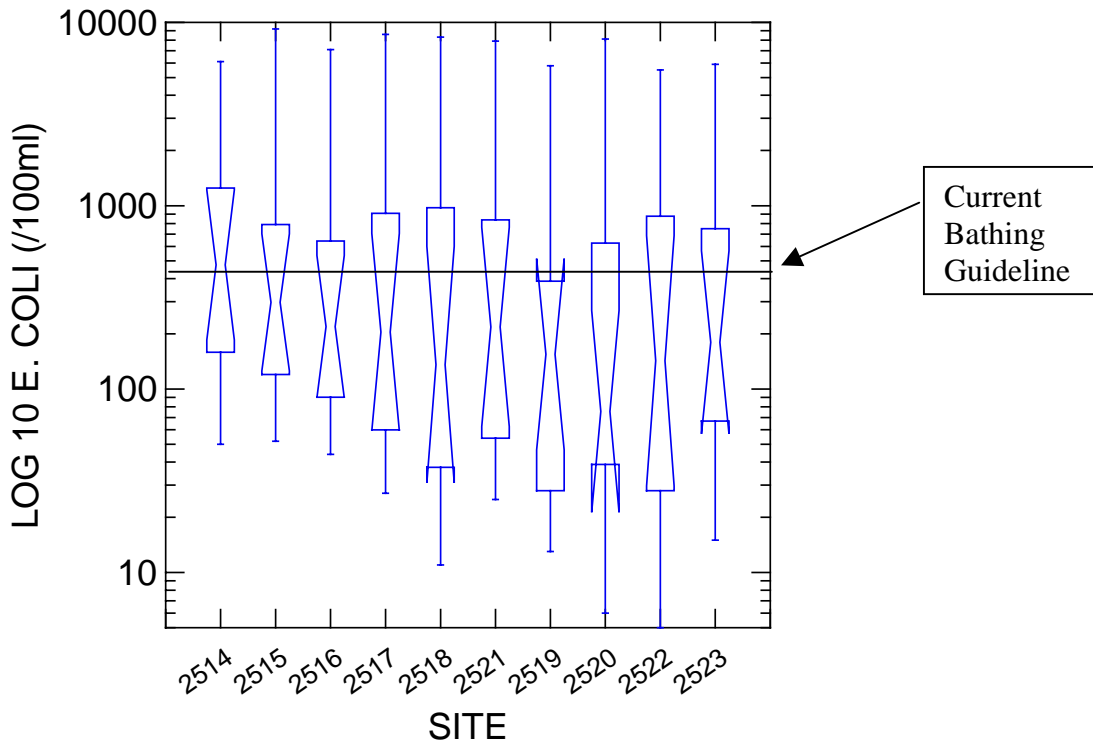
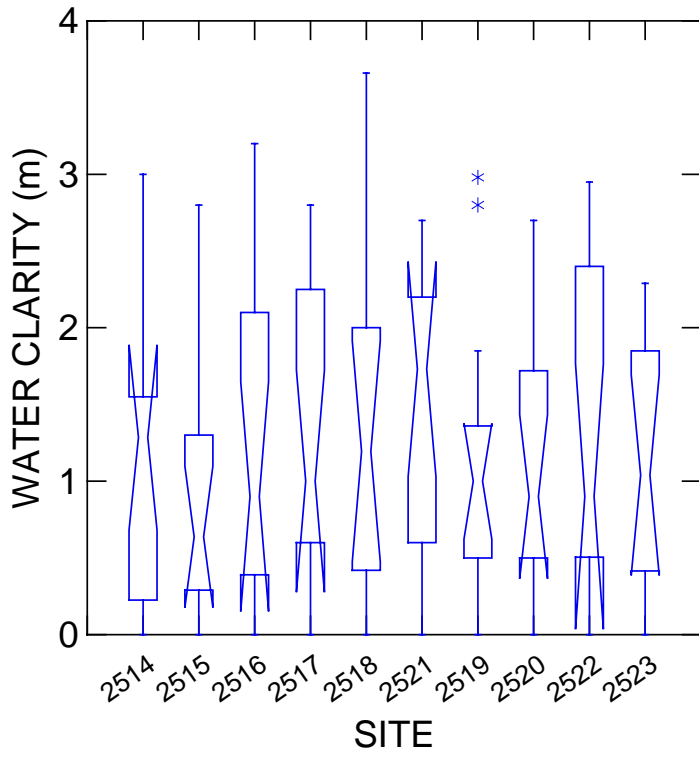
Literature Cited

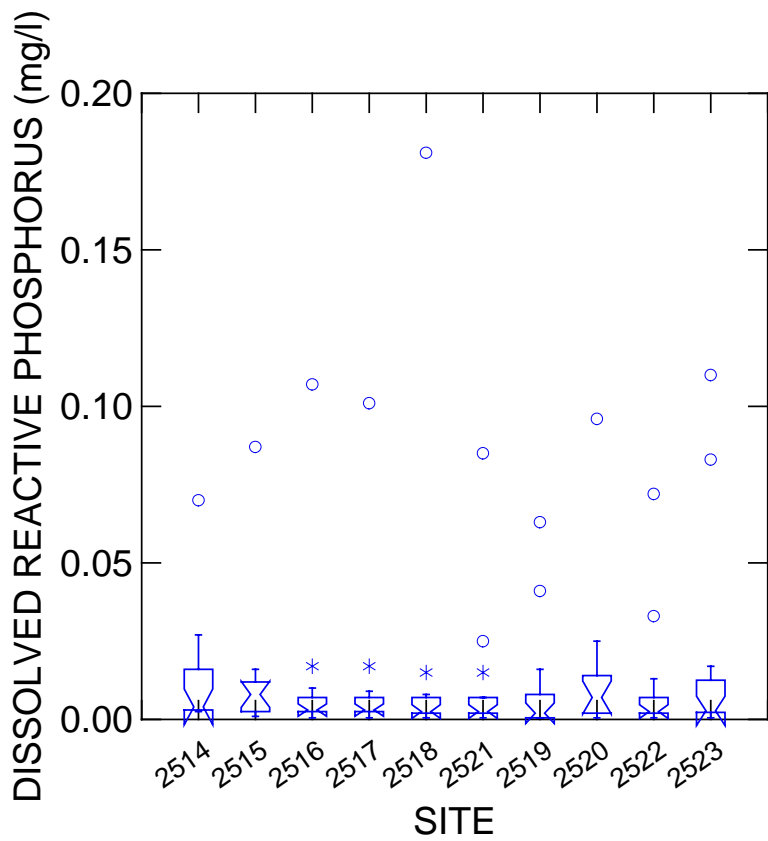
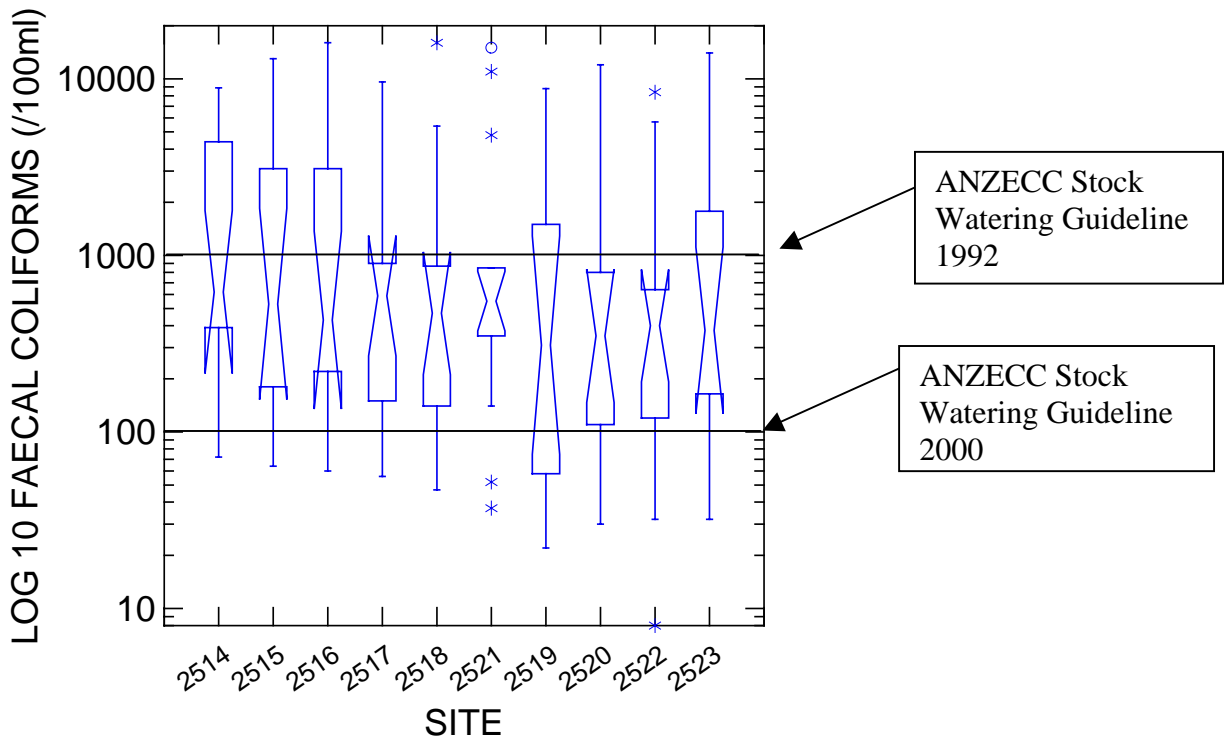
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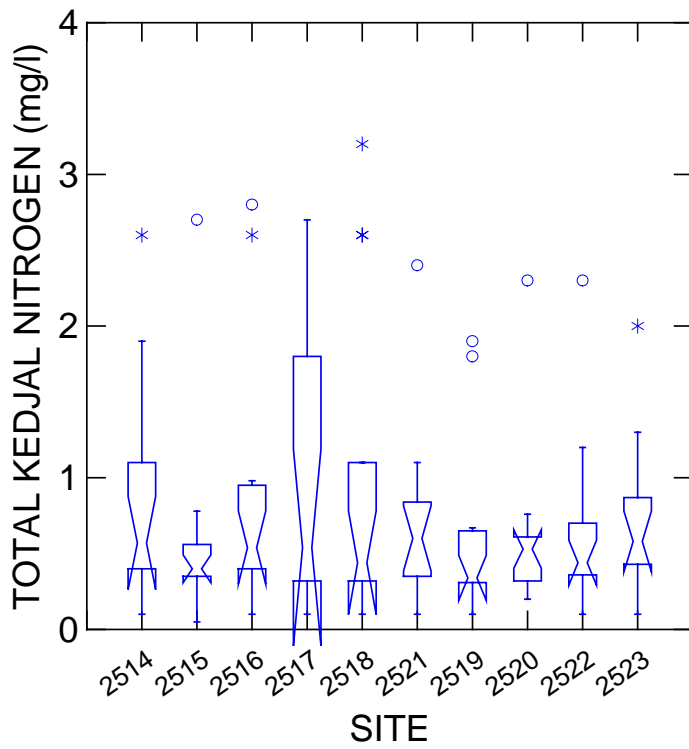
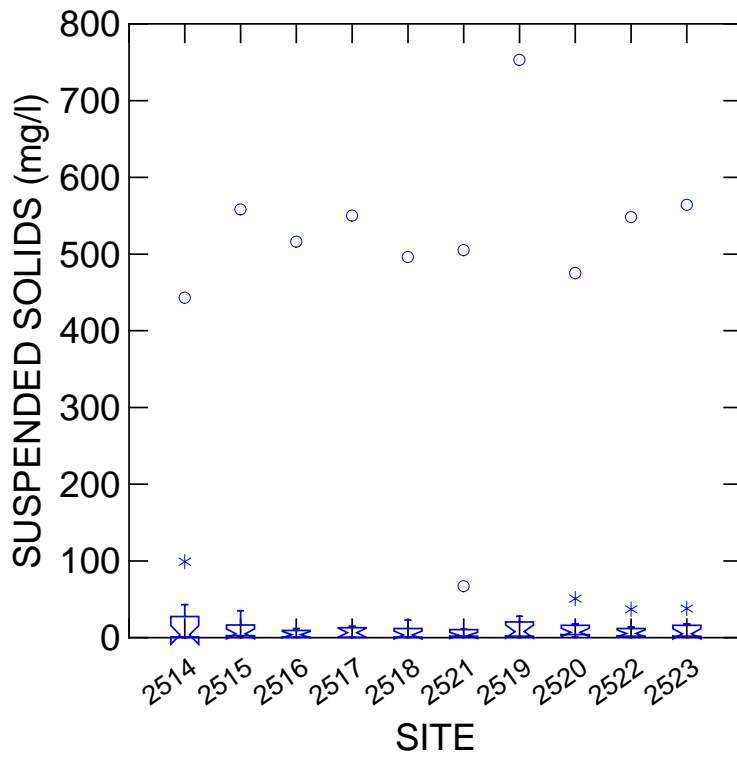
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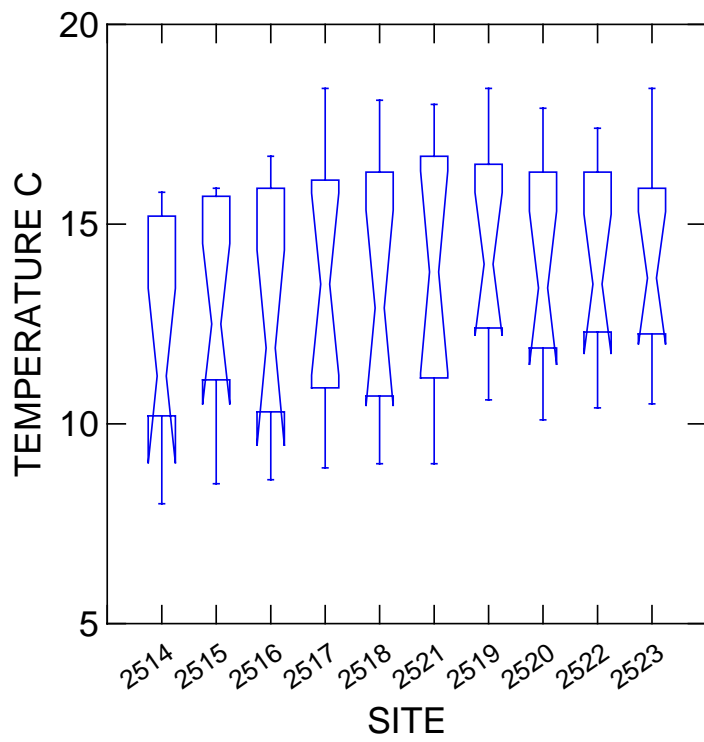
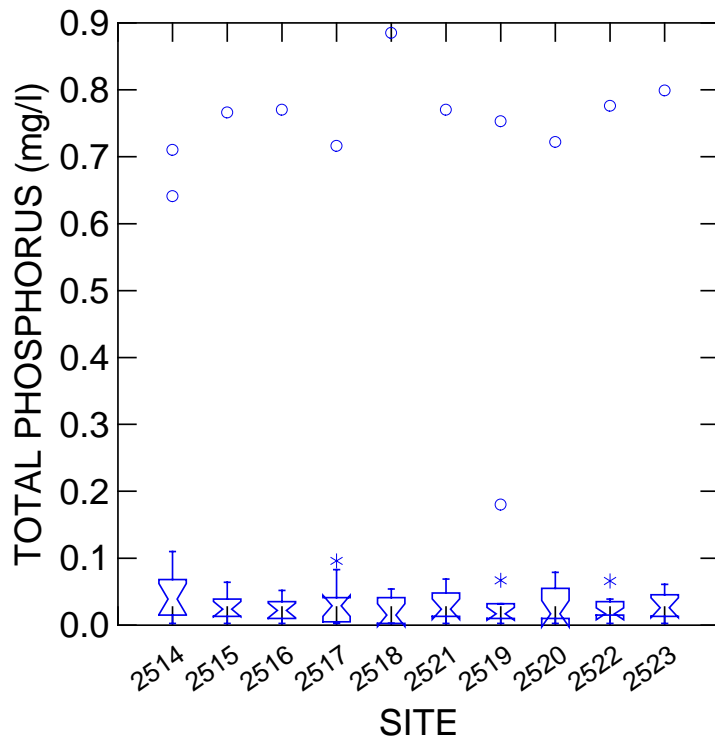
Appendix 1











Appendix 2: Photographs of Puhokio Stream











Appendix 3: Water Quality Sampling Sites

Below is a pictorial list of the sites on the Puhokio Stream and grid references.



Site 2514 Easting 28474373, Northing 6141003, Map W21



Site 2515 Easting 2847437, Northing 6141137, Map W21



Site 2516 Easting 2847499, Northing 6141339, Map W21



Site 2517 Easting 2847948, Northing 6142121, Map W21



Site 2518 Easting 2848531, Northing 6142477, Map W21



Site 2519 Easting 2849092, Northing 6143218, Map W21



Site 2520 Easting 2849170, Northing 6143212, Map W21



Site 2521 Easting 2849089, Northing 6143050, Map W21



Site 2522 Easting 2849759, Northing 6143811 Map W21



Site 2523 Easting 2850239, Northing 6144590 Map V21