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PROJECT TWIN STREAMS TRENDS 2016 REPORT

AUCKLAND COUNCIL

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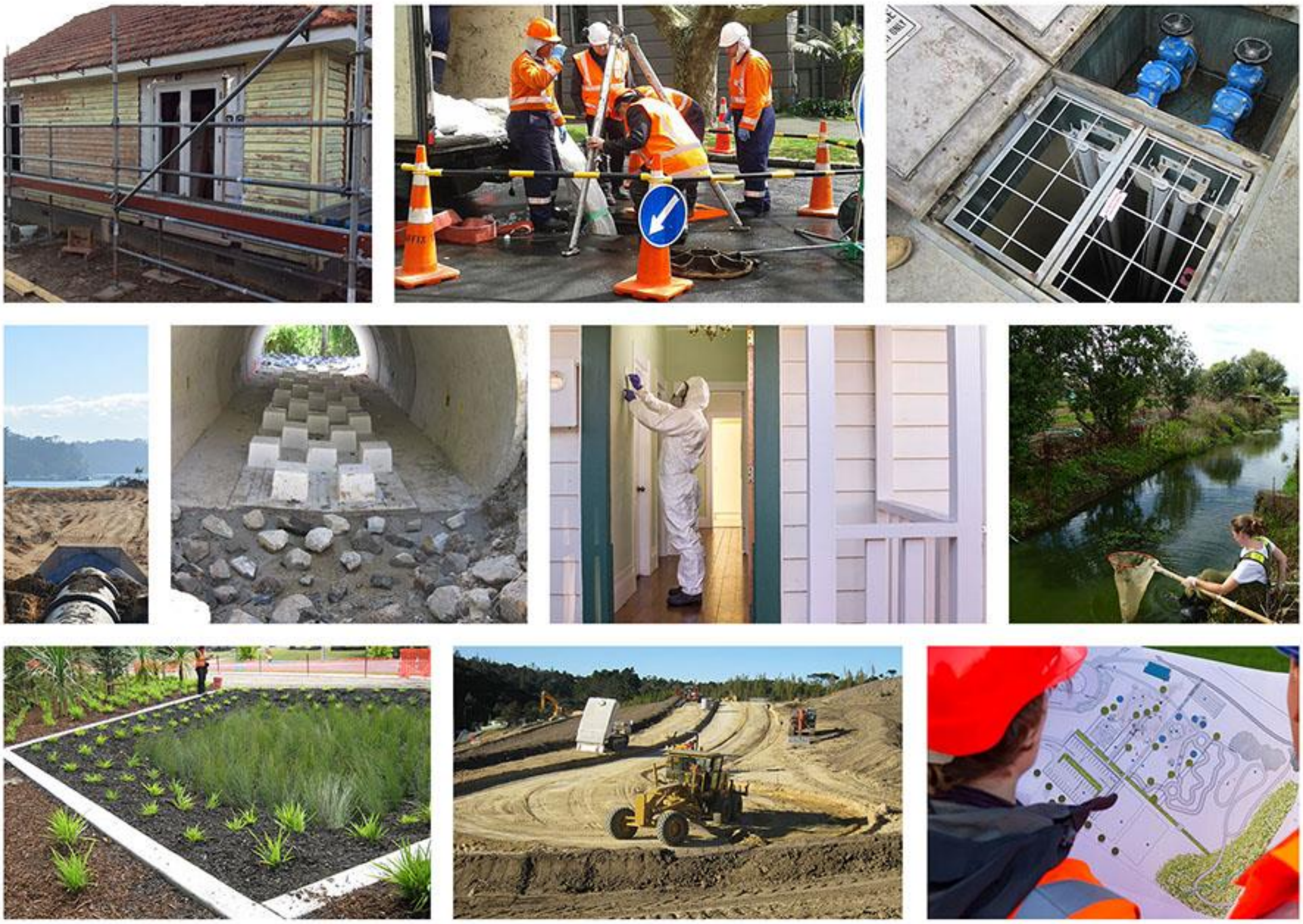

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Lead Author	Brett Stansfield Director Environmental Impact Assessments Limited 30/6/2016 Signature Date
Reviewed and Approved By:	Melanie Dixon Principle Ecologist Thomas Civil & Environmental Consultants Limited 30/6/2016 Signature Date

1 INTRODUCTION

1.1 PROJECT TWIN STREAMS

Project Twin Streams (PTS) is a large-scale environmental restoration project in West Auckland, initiated by Waitakere City Council in 2003, and continued by Auckland Council. It aims to provide integrated stormwater management and has involved (amongst other things) the purchase of properties in the flood plain, stormwater treatment (including developing treatment wetlands) and restoring native trees along stream banks. Project Twin Streams covers the stream catchments draining to Henderson Creek and Huruhuru Creek. This includes the Oratia, Opanuku, Waikumete and Swanson Streams (Appendix 1). The streams run through a mixture of native bush, rural and urban areas.

PTS recognises the importance of the local communities that these streams flow through by involving them in the project. Auckland Council has partnered with local community organisations in the delivery of this project. It has also looked at how households can become more sustainable, and more connected to the stream environments and has included building cycle and walkways.

This report summarises the comprehensive environmental and social monitoring conducted in May and June 2016, and compares it with previous monitoring (where possible) to illustrate any changes or trends, especially in water quality and stream habitat.

1.2 SCOPE OF REPORT

This report provides an update of temporal trends (time series trends) of the streams of Project Twin Streams. Temporal changes in state assessed from historical monitoring of 2003/04, 2005/06, 2010 and 2016 are provided in this report.

Whilst the focus and overwhelming content is on freshwater values, this report also contains a summary of social and terrestrial investigations completed in 2016.

2 FRESHWATER

2.1 INTRODUCTION

2.1.1 *BACKGROUND*

Freshwater environments such as streams, lakes and wetlands are often the final receiving environments of any land use activities. It is for this reason that the monitoring and reporting of freshwater environments enables us to better understand the impacts of our land uses, as well as test for improvements that may arise from catchment mitigation measures. In the previous report, three land cover types were identified as being relevant to Project Twin Streams monitoring – forested, pastoral and urban. The previous Pressure State Response reporting was based on the assumption that forested streams within the PTS catchment act as a reference condition as these streams are devoid of any significant pastoral or urban land uses.

Pastoral and urban streams are subject to different land use pressures. For example, pastoral streams are often subject to erosion caused by stock wandering in and out of the streams. Pastoral streams may also be fertilised regularly to maintain good pasture growth and may be subject to water abstraction for irrigation purposes. Conversely, urban streams are subject to a

high degree of imperviousness, giving rise to a more peaky hydrograph[1] during rainfall events. Urban streams may also have lower base flows owing to complete stream paths being concreted and these do not allow the necessary influx of cool groundwater to maintain water levels and temperatures. Urban streams also receive a much larger number of stormwater inputs from roading and car parks etc. This stormwater carries with it a large amount of traffic pollution, such as lead from wheel weights, copper from brake pad wear and zinc from tyre wear. Other inputs include copper from spouting and zinc from galvanised surfaces.

Urban streams are often more modified in their stream channel to accommodate urban development. The stream channels have often been straightened for flood mitigation purposes. This results in a stream with less hydrologic heterogeneity, meaning the stream is predominantly run habitat with few pools or riffles.

Both pastoral and urban streams tend to have narrower riparian margins to buffer them from surrounding land uses. Often the amount of shading provided by the riparian buffer may be insufficient to adequately shade the stream. This can result in prolific periphyton and aquatic macrophyte growth as well as warmer water temperatures. The photosynthesis and respiration of the periphyton and macrophytes can give rise to large diurnal (daily) swings in dissolved oxygen concentrations that can stress the aquatic biota. Furthermore, if macrophyte growths become dense, areas of anoxia (low oxygen) may occur within the macrophyte bed. This can stress the aquatic biota of the stream.

Research indicates that urban land use effects are of a greater magnitude than pastoral land use effects. This was confirmed by the previous water quality and ecology state PTS report (Stansfield 2016). In keeping with the previous report, water quality and ecology results have been grouped according to forested streams, pastoral streams and urban streams.

2.1.2 *FRESHWATER SCOPE*

Thomas Civil and Environmental Consultants Limited (TCEC) was requested to repeat the Pressure-State-Response investigative reporting previously carried out by other consultancies (Eco Water Solutions 2004, Kingett Mitchell 2006, and Golders 2010).

The freshwater monitoring program of PTS comprises:

- Pressure monitoring using urban infrastructural indicators, including percent land use, and community response measures such as riparian planting;
- Aquatic ecology and habitat quality assessments
- Stream water quality and flow monitoring
- Stream sediment quality monitoring

While the pressure state response reporting has been conducted for the previous state report, it has not been used for this time series report because some pressure indicators were not recorded in the first two time periods (total pipe length 2003/04 & 2005/06), while for other indicators (e.g. % imperviousness, % land cover) there is a possibility that different data sets or desk top procedures were used.

This report documents water quality, ecology, and stream sediment quality time series analysis for all PTS data (including the April and May 2016 data) and provides a summary of temporal trends of this data. As with the previous report, the river environment classification (REC) and

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[1] Hydrograph = a plot showing the rate of flow against time, at a specific point in the stream

land cover database (LCDB) information has been used as a reporting framework to ensure that non-human induced effects on water quality and ecology (e.g. climate, source of flow, geology etc.) are factored out, thereby comparing like stream types. This report includes comparisons of the PTS sites with other sites from Auckland Council's State of the Environment (SOE) monitoring programme. By making these comparisons, context is provided for how PTS catchments compare to catchments in other parts of the Auckland Region.

2.1.3 *CAUTION*

Several notes of caution are appropriate when reading this report. Most notable is in the comparisons of data and monitoring results between years. Where every attempt has been made to make sure that all field sampling and laboratory protocols have been consistent for each period of data collection, as different personnel have been involved over the thirteen year period of data collection some individual variation may have occurred. This will be most notable amongst the measures requiring human judgement or visual assessment (e.g. habitat assessments or water clarity) in contrast to empirical laboratory measurements.

For the most part, sampling for PTS has been over the spring and summer period (2003/04 and 2005/06 sampling). However, in 2010 sampling was undertaken during the autumn and winter months – a period when stream conditions can be very different from the summer conditions (typically lower water temperatures, greater runoff and higher flows) while the 2016 sampling occurred during the autumn months of April and May. Deseasonalising of data has been undertaken for time series analysis of most analytes to remove any bias of season in the entire data set, however deseasonalising has not been undertaken for some data (e.g. macroinvertebrate data, turbidity, water clarity, sediment quality data) owing to these latter data sets being of insufficient size to determine seasonality. Deseasonalising data requires at least three years of a season to determine whether a seasonal effect is occurring over the time series period.

Water quality data is also affected by flows, however most sites in the SOE monitoring programme are not monitored for flow, therefore flow adjustment has not been possible for this water quality data. To make the comparisons of PTS sites with SOE sites, flow adjustment has not been undertaken.

Detailed methods of previous PTS reports were not available for some variables. In these instances, TCEC had to make an assumption as to what was previously done. This is particularly so for the stream habitat assessments.

Data for the 2016 SOE monitoring sites was unavailable for this project. Therefore time series analysis of the PTS sites has an additional two data points from the water quality monitoring of 2016 and one additional data point for ecological sampling. There is likely to be an error in making this comparison, particularly in light of climate change. For example, March 2016 was the warmest March on historical record and this could have resulted in an increase of stress to aquatic ecosystems not previously experienced.

In some instances, water quality analysis has not been conducted owing to sample sizes of data sets for particular sites being too small for comprehensive reporting. In each case a statement has been made where sites may not have been analysed.

Caution should be exercised in reading the water quality and aquatic ecology results as any trends determined have been based on very small data sets. As such any trends should be treated as preliminary findings.

Note also any trends determined for the SOE sites in this report should not be directly compared to other SOE reporting by Auckland Council. This is because the data set used in this report is smaller owing to it being matched to the same time periods of the PTS project.

2.1.4 *SAMPLING SITE LOCATIONS*

All sampling was undertaken by TCEC during the months of April and May 2016 following methods of previous reports.

Site locations and descriptions were the same as those monitored in 2010 with the exception of the SMU sites that were not part of this brief. Unlike previous reports, this report has compared PTS sites with sites of a similar River Environment Class from the Auckland Council's SOE programme. Note: Auckland Council's SOE programme does not include stream sediment monitoring, therefore no PTS and SOE comparisons can be made for the stream sediment quality data.

Site locations of the PTS monitoring project are provided in Table 1 below. These 19 sites were sampled for water quality on 6th and 7th April and 4th and 5th May 2016, providing two sets of water quality data per site. Aquatic macroinvertebrates were sampled on 6th and 7th April 2016, sediment sampling was undertaken on 4th and 5th May 2016 and habitat assessments were undertaken on 2nd, 3rd and 4th May 2016.

Appendix 2 shows the 19 sites. All of these streams have the same River Environment Classification for climate, source of flow and geology. They are all warm wet, low elevation, soft sedimentary streams. The next hierarchical driver of water quality that distinguishes the sites into groups is land cover. Appendix 2 shows that the sites can be grouped according to indigenous forest, pastoral, or urban. A description of these groupings follows.

2.1.4.1 URBAN STREAMS

Nine sites from PTS belong to this grouping (sites L, E, M, K, J, N, O, I, D) and for this report they have been compared to four sites from Auckland Council's SOE programme (Lucas Creek, Oteha Stream, Oakley Creek and Otaki Creek). The SOE programme only has one warm, wet, low elevation urban stream site (Oakley Creek) and it was felt that this was too few a number of sites for comparison. Therefore the additional three sites were brought in for comparison; however these sites (Lucas Creek, Oteha Stream and Otaki Creek) are of a warm dry climate. The urban stream sites have a stream order between 1 and 4 and have a catchment area of between 160 and 3036 Ha.

2.1.4.2 FORESTRY STREAMS

This grouping comprises three sites from PTS (A, F, P) and two sites from the SOE programme (Mahurangi LTB and Mahurangi River). The PTS sites are located in indigenous forest, while the SOE sites are located in exotic forest catchments. These sites have a stream order of either 2 or 3 and have a catchment area between 365ha and 693ha.

2.1.4.3 PASTORAL STREAMS

This group comprises seven PTS sites (B, Q, R, G, H, S, C) and four SOE sites (Okura Creek, Matakana LTB, Matakana River and Waiwera River). The land cover database shows that sites Q and G are surrounded by high-producing exotic grasslands, while Site H is surrounded by open park land. The remaining pastoral sites are surrounded by native vegetation. These stream sites are between 2nd to 4th order and have a catchment area varying between 671 and 3032 Ha.

Table 1: Project Twin Streams and State of the Environment Sampling Locations

Land Cover (REC)	Programme	Site ID	Site Name	Data Available	Easting (NZTM 2000)	Nothing (NZTM 2000)	Stream Order	REC Class	Distance to Sea (km)	Catchment Area (Ha)	Land Cover Database Category
Urban	SOE	8219	Otaki Creek	Water Quality	1764306	5907216	2	WD/L/M/U/LO/LG	0.8	159.4	Urban Parkland/Open Space
Urban	SOE	7830	Lucas Creek	Water Quality/ Ecology	1751468	5934510	3	WD/L/SS/U/MO/LG	2.3	628.3	Indigenous Forest
Urban	SOE	7811	Oteha Stream	Water Quality/ Ecology	1751325	5933519	3	WD/L/SS/U/MO/LG	3.0	1197.5	High Producing Exotic Grassland
Urban	SOE	8110	Oakley Creek	Water Quality/ Ecology	1751963	5917636	3	WW/L/M/U/MO/LG	0.4	1257.4	Indigenous Forest
Urban	PTS	L	Whakarino Stream	Water Quality/ Ecology	1746561	5912462	1	WW/L/M/U/LO/LG	9.2	60.2	Manuka and/or Kanuka
Urban	PTS	J	Hibernia Stream	Water Quality/ Ecology	1747239	5911113	1	WW/L/SS/U/LO/MG	10.2	79.3	Urban Parkland/Open Space
Urban	PTS	E	Potters Stream	Water Quality/ Ecology	1741754	5912319	1	WW/L/SS/U/LO/HG	11.3	88.1	Manuka and/or Kanuka
Urban	PTS	K	Hibernia Stream	Water Quality/ Ecology	1747172	5912545	2	WW/L/SS/U/LO/LG	8.8	213.3	Built-up Area (settlement)
Urban	PTS	M	Waikumete Stream	Water Quality/ Ecology	1746968	5912832	2	WW/L/SS/U/LO/LG	8.8	213.3	Built-up Area (settlement)
Urban	PTS	N	Waikumete Stream	Water Quality/ Ecology	1746415	5914001	3	WW/L/SS/U/MO/LG	7.2	601.7	Built-up Area (settlement)
Urban	PTS	O	Waikumete Stream	Water Quality /Ecology	1745545	5914964	3	WW/L/SS/U/MO/LG	5.8	899.9	Urban Parkland/Open Space
Urban	PTS	D	Opanuku Stream	Water Quality /Ecology	1745787	5917577	4	WW/L/SS/U/MO/LG	4.3	3036.6	Built-up Area (settlement)
Urban	PTS	I	Oratia Stream	Water Quality /Ecology	1745648	5917103	4	WW/L/SS/U/MO/LG	4.3	3036.7	Built-up Area (settlement)
Forest	PTS	P	Swanson Stream	Water Quality /Ecology	1739082	5917470	2	WW/L/SS/IF/LO/MG	8.0	349.0	Manuka and/or Kanuka
Forest	PTS	A	Opanuku Stream	Water Quality /Ecology	1739968	5914570	3	WW/L/SS/IF/MO/MG	12.0	429.6	Manuka and/or Kanuka
Forest	SOE	6850	Mahurangi LTB	Ecology	1747626	5964882	2	WW/L/SS/EF/LO/HG	13.4	495.9	Indigenous Forest
Forest	SOE	6811	Mahurangi River (HQ)	Water Quality	1747750	5965035	2	WW/L/SS/EF/LO/HG	13.4	495.9	High Producing Exotic Grassland
Forest	PTS	F	Oratia Stream	Water Quality /Ecology	1743245	5912933	3	WW/L/SS/IF/MO/LG	8.6	809.2	Exotic Forest
Pastoral	PTS	B	Opanuku Stream	Water Quality /Ecology	1742148	5915572	2	WW/L/SS/P/LO/LG	8.3	145.9	Manuka and/or Kanuka
Pastoral	PTS	Q	Swanson Stream	Water Quality /Ecology	1739942	5918975	3	WW/L/SS/P/MO/LG	6.1	722.5	High Producing Exotic Grassland
Pastoral	PTS	R	Swanson Stream	Water Quality /Ecology	1742116	5919464	4	WW/L/SS/P/MO/LG	3.2	1517.9	Manuka and/or Kanuka
Pastoral	PTS	G	Oratia Stream	Water Quality /Ecology	1744764	5914448	3	WW/L/SS/P/MO/LG	6.3	1700.5	High Producing Exotic Grassland
Pastoral	PTS	H	Oratia Stream	Water Quality /Ecology	1745197	5915230	3	WW/L/SS/P/MO/LG	6.0	1842.7	Urban Parkland/Open Space
Pastoral	SOE	6607	Matakana LTB	Ecology	1753615	5976422	4	WW/L/SS/P/MO/LG	2.0	1418.6	Indigenous Forest
Pastoral	SOE	6604	Matakana River	Water Quality	1753500	5976481	4	WW/L/SS/P/MO/LG	2.0	1418.6	Indigenous Forest
Pastoral	PTS	S	Swanson Stream	Water Quality /Ecology	1743823	5919975	4	WW/L/SS/P/MO/LG	1.8	2290.6	Indigenous Forest
Pastoral	PTS	C	Opanuku Stream	Water Quality /Ecology	1743911	5916067	4	WW/L/SS/P/MO/LG	6.2	2305.9	Broadleaved Indigenous Hardwoods
Pastoral	SOE	7173	Waiwera River	Water Quality	1748628	5953665	4	WW/L/SS/P/MO/LG	3.5	3032.4	Broadleaved Indigenous Hardwoods

2.2 METHODS

Actual sampling, processing and reporting methods of all variables are detailed in the PTS State Report (Stansfield 2016).

To ensure consistency of methods for the future, all statistical methods for temporal trend analysis are detailed in this section.

2.2.1 *STATISTICAL METHODS*

This report focuses on time series trends of the water and sediment quality analytes and macroinvertebrate biotic indices of water quality to determine whether any improvements in these variables have occurred since PTS catchment restoration efforts began. As with the previous report, any analyte for which the laboratory result was less than detection limit was halved or any laboratory result that was greater than the laboratory detection limit was entered as the detection limit. This is a standard data analysis protocol (Loftis & McBride 1990) that is recommended prior to conducting any spatial or temporal trend analysis of sites.

As with the previous water quality and ecology state report, comparisons of PTS sites with SOE sites have been made. Because the SOE sites are not monitored for flow no flow adjustment has been undertaken in determining the water quality temporal trends. This means that any trends detected in this report could be due to the influences of flow rather than any catchment restoration initiatives.

All water quality analytes were tested for seasonality prior to having temporal trend analysis conducted on them using the Kruskal-Wallis Statistic on Trend and Equivalence Analysis Version 5 using Windows 10. Seasonality testing requires that at least three years of a season are in the data set to determine whether a seasonal influence is occurring within the time series data set. Therefore any data sets that had less than three seasons (e.g. macroinvertebrate, turbidity, clarity or sediment data) were subject to trend analysis without seasonal adjustment using the Mann Kendall Trend Test using Trend and Equivalence Analysis Version 5.

2.3 RESULTS

2.3.1 *SEASONALITY OF DATA*

All water quality variables tested for seasonality, displayed seasonality, and results are provided in Appendix 3. An example of seasonality is displayed in the following chart.

Figure 1 shows that all land cover types show seasonality with respect to turbidity levels as the box plots for each quarterly period vary. This is particularly so for the pastoral land cover type which shows higher turbidity for the September to November period (Spring). Note the charts have been scaled to emphasise seasonal differences. The Kruskal-Wallis test indicates whether any seasons of the year are significantly different to one another. An example output is provided below.

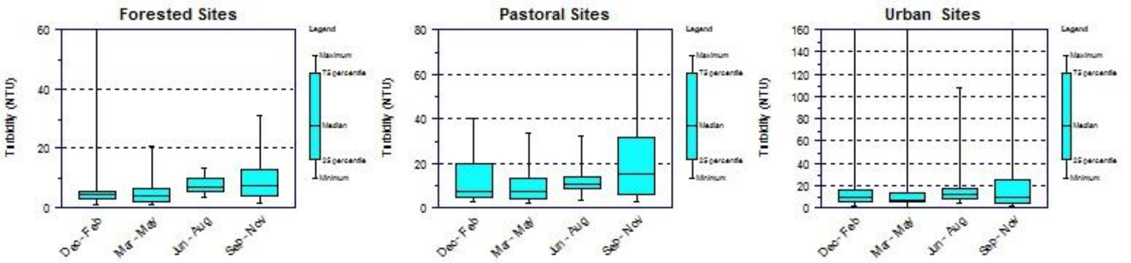

Figure 1: Seasonality of Turbidity levels by Land Cover

As a first step the Kruskal-Wallis test provides a comparison of summary statistics for each season (2). It then provides a comparison of each season by rank3). This is the equivalent to a non-parametric one-way analysis of variance. Finally, the statistical significance of the Kruskal-Wallis statistic is tested with a p value. The p value demonstrates the probability of having data at least as variable as the data set if the null hypothesis is true. In other words it tests the probability that the seasonal differences are due to chance. If the p value is < 0.05, then seasonality is confirmed. In the previous case seasonality is confirmed owing to the p value being less than 0.05. Note that some variables were not tested for seasonality (turbidity n=7, water clarity n=8, biotic indices n=4 and sediment quality n=4) owing to the data sets being of insufficient size to determine the presence of seasonality.

Table 2: summary Statistics by Season

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	18	18	0	0
N used	72	74	72	43
Non-detects	0	0	0	0
Mean	17.774	16.078	18.023	23.771
Median	9.755	7.150	11.600	9.400
25%	5.120	4.800	8.500	4.495
75%	15.450	12.500	16.700	24.500
Minimum	1.000	0.600	3.300	1.500
Maximum	232.000	164.000	108.000	193.000

Note: Kruskal-Wallis One-Way Analysis of Variance for Urban Sites for Stream Turbidity (NTU) grouped by season

Group Urban Turbidity (NTU): Group Urban Period analysed 13 years for water (years 2002 to 2015 beginning December)

Table 3: Kruskal-Wallis Analysis of Seasonal Values by Rank

261 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	72	128.688
Mar - May	74	112.473
Jun - Aug	72	153.514
Sep - Nov	43	129.058

Table 4: Value Output of the Kruskal-Wallis Statistic

Statistic	df	P (Chi2)
10.958	3	0.012

2.3.2 *TIME SERIES TRENDS*

Significant trends of the analytes must meet three requirements:

- The trend must have statistical significance ($p<0.05$) – this ensures that the trend is not simply due to chance.
- The magnitude of the trend must be greater than laboratory detection limits – this means the trend must be measurable. If the trend is less than the laboratory detection it is not considered a significant trend as it is likely a laboratory could not measure the difference between the beginning and the end of the time series.
- The trend must have environmental significance – as a general rule of thumb, water quality or sediment quality trends > 1% per annum are considered environmentally significant. For sediment analyses TCEC also adopted some descriptive criteria recommended by Auckland Council (Mills et al. 2012) that a trend of 1-2% is considered a small or emerging trend. A trend of changes of this magnitude could be largely associated with analytical and/or sampling variation, so trends in this range may not have any "real world" significance. Trends in this range have been assigned as "possibly increasing/decreasing" trends; and >±2% indicates a stronger trend, equivalent to > ±20 % per decade, which is probably worth investigating further to better understand possible causes. These changes have been termed "probably increasing/decreasing" trends.

TCEC also adopted the criteria recommended by Collier & Hamer (2012) for which an overall change of 15% or greater in MCI and the trend slope exceeding 1% per annum over the time period is considered ecologically significant.

2.3.2.1 SURFACE WATER QUALITY

All surface water quality variables showed no significant temporal trend for the PTS sites because they all failed to reach statistical significance ($p>0.05$). Some trends for ammoniacal nitrogen and total oxidised nitrogen were, however, detected for some SOE sites that are displayed below.

Figure 2 shows a decreasing trend of ammoniacal nitrogen concentrations over time at Oakley Creek. The trend has statistical significance ($p=0.002$) and the magnitude of change (0.045 g/m^3) is greater than laboratory detection (0.01 g/m^3). The slope equates to a change of -22% / yr which exceeds the environmental significance criteria of 1% / yr.

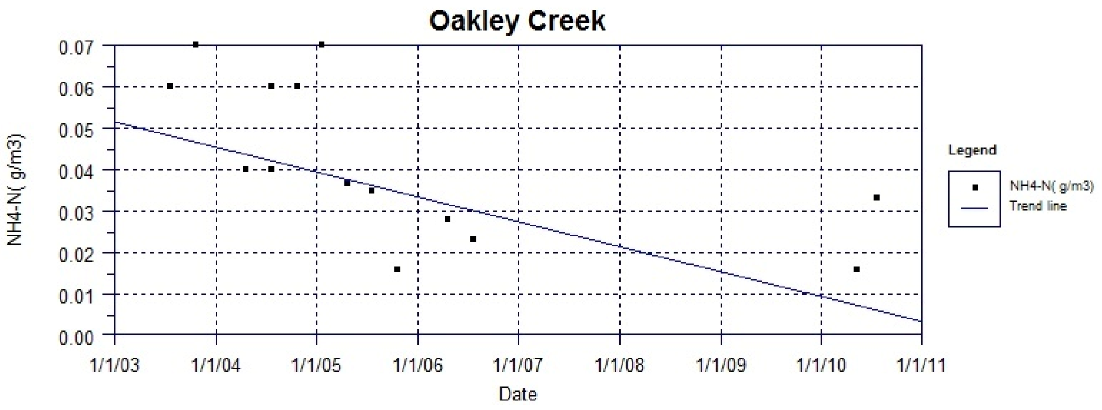

Figure 2: Ammoniacal Nitrogen Trend at Oakley Creek

Figure 3 shows a decreasing trend of ammoniacal nitrogen with time at Waiwera Stream. The trend has statistical significance ($p=0.02$) and the magnitude of change (0.04 g/m^3) is greater

than laboratory detection (0.01 g/ m^3). The slope equates to a percent annual change of -15% / yr which exceeds the environmental significance criteria of 1% / yr.

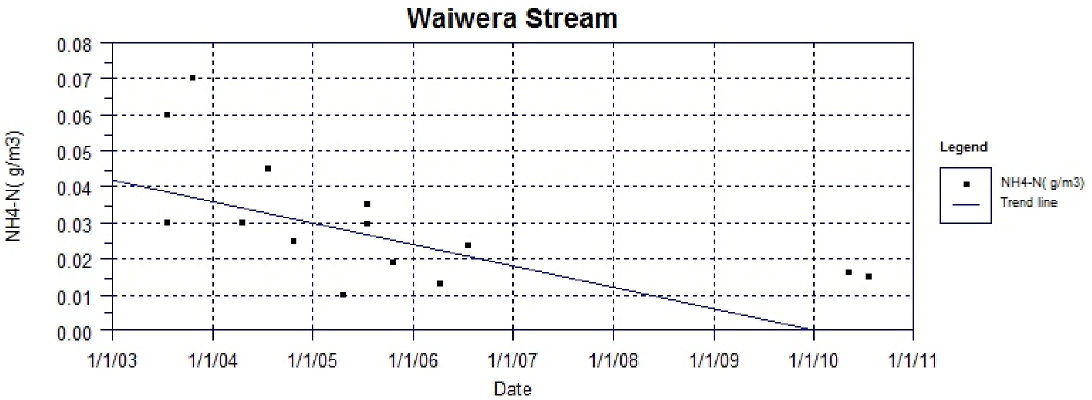

Figure 3: Ammoniacal Nitrogen Trend at Waiwera Stream

2.3.2.2 SEDIMENT QUALITY

Sediment quality was sampled on each of the PTS 2003, 2005, 2010 and 2016 surveys, giving the total sample size to n=4. This is a small data set so trends that have been identified should be treated with caution as preliminary findings. Note no sediment quality sampling is undertaken for the SOE monitoring programme, so reporting only focuses on PTS site results.

Figure 4 shows a decreasing trend of extractable copper at Site A (Opanuku Stream). The trend has statistical significance (p=0.04) and the magnitude of change (3 mg/kg) is greater than laboratory detection (1 g/ m^3). The slope equates to a percent annual change of -1.07% / yr which just exceeds the environmental significance criteria of 1% / yr. This 1.07% /yr change borders on non-significant to small emerging trend status according to Auckland Council marine benthic sediment contaminant trend criteria (Mills et al. 2012). All copper concentrations of the time period are below the ANZECC ISQG low guideline of 65 mg/kg extractable copper.

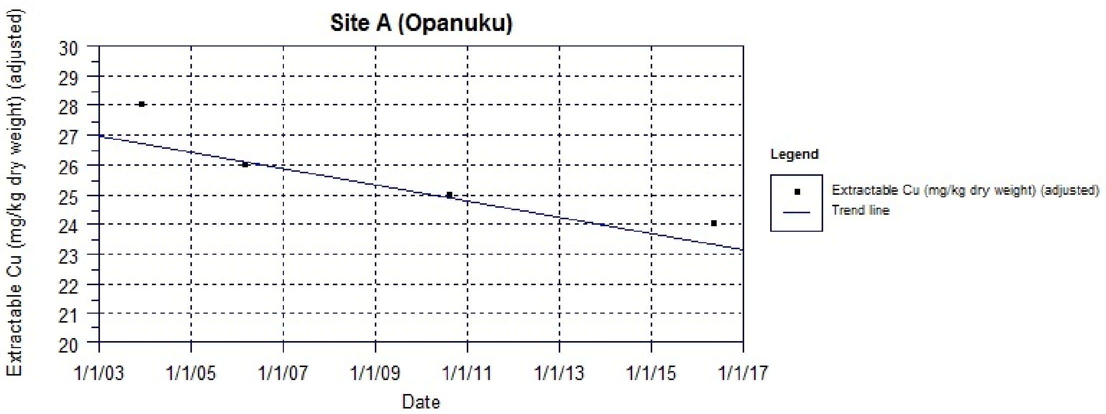

Figure 4: Extractable Copper Trend at Site A Opanuku Stream

Figure 5 shows an increasing trend of zinc concentrations at Site A (Opanuku Stream). The trend has statistical significance (p=0.04) and the magnitude of change (3 mg/kg) is greater than laboratory detection (2 mg/kg). The slope equates to a percent annual change of 2.79% / yr which exceeds the environmental significance criteria of 1% / yr. This 2.79% /yr change equates to a stronger trend that is worthy of follow up according to Auckland Council criteria (Mills et al. 2012).The zinc concentrations of the time period are all below the ANZECC ISQG Low guideline of 200 mg/kg extractable zinc.

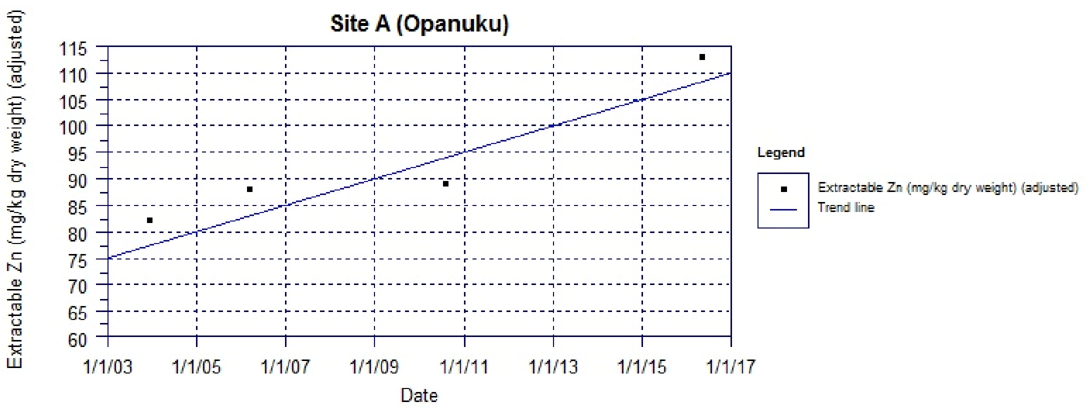

Figure 5: Extractable Zinc Trend at Site A Opanuku Stream

Figure 6 shows a decreasing trend of extractable lead over time at Site N (Waikumete Stream). The trend has statistical significance (p=0.04) and the magnitude of change (40 mg/kg) is greater than laboratory detection (0.2 mg/kg). The slope equates to a percent annual change of -4.2 % / yr which exceeds the environmental significance criteria of 1% / yr and fulfils the criteria

of a stronger trend worthy of follow up according to Auckland Council criteria (Mills et al. 2012). If this trend continues into the future it is likely to bring Site N (Waikumete Stream) into compliance with the ANZECC ISQG low guideline for extractable lead (50 mg/kg).

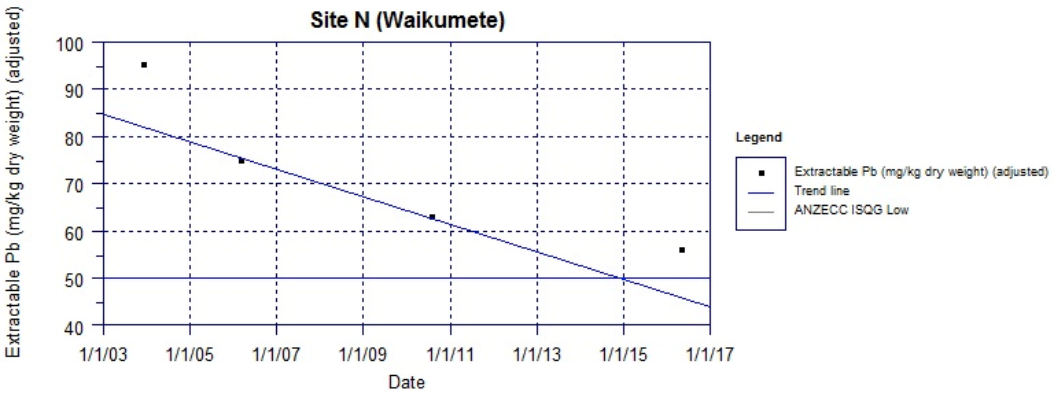

Figure 6: Extractable Lead Concentrations at Site N Waikumete Stream

Figure 7 shows a decreasing trend of extractable lead over time at Site I (Oratia Stream). The trend has statistical significance (p=0.04) and the magnitude of change (30 mg/kg) is greater than laboratory detection (0.2 mg/kg). The slope equates to a percent annual change of -3.5 % / yr which exceeds the environmental significance criteria of 1% / yr and fulfils the criteria of a stronger trend worthy of follow up according to Auckland Council criteria (Mills et al. 2012). If this trend continues into the future it is likely to bring Site I (Oratia Stream) into compliance with the ANZECC ISQG low guideline for extractable lead (50 mg/kg).

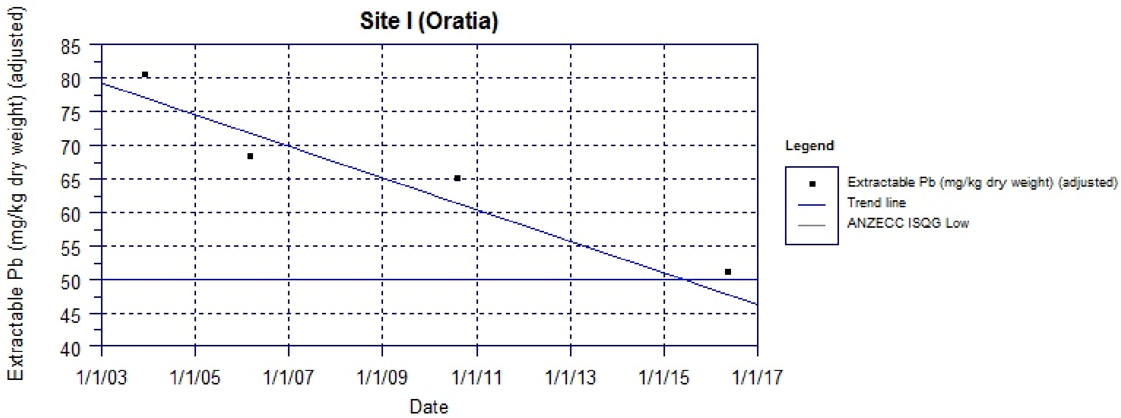

Figure 7: Extractable Lead Trend at Site I Oratia Stream

One characteristic of a stream that can influence time series trends of sediment quality is the sediment accrual period. Streams naturally transport sediment downstream and out to sea. The longer the time period since the last fresh in a stream the greater the period for sediment to accumulate at the streambed. During this period between freshes the sediment transported is likely to be devoid of significant amounts of metals as the sediment will be from natural erosion processes of the stream. Furthermore, urban stormwater contaminants will not be delivered to the stream if it is not raining. The following analysis looks at sediment accrual periods of the Opanuku and Oratia Streams. For this analysis a 3X median event is proposed as the flow event that mobilises the stream bed (Opanuku 3X median = 1.58 m^3/s, Oratia 3X median = 1.28 m^3/s). This has previously been proposed as an ecological flow threshold to reset benthic aquatic ecosystems as a result of streambed mobilisation (Clausen & Biggs 1997).

Figure 8 shows that sediment accrual periods have been highly variable since sampling commenced. This variability may have affected extractable metal concentrations during sampling.

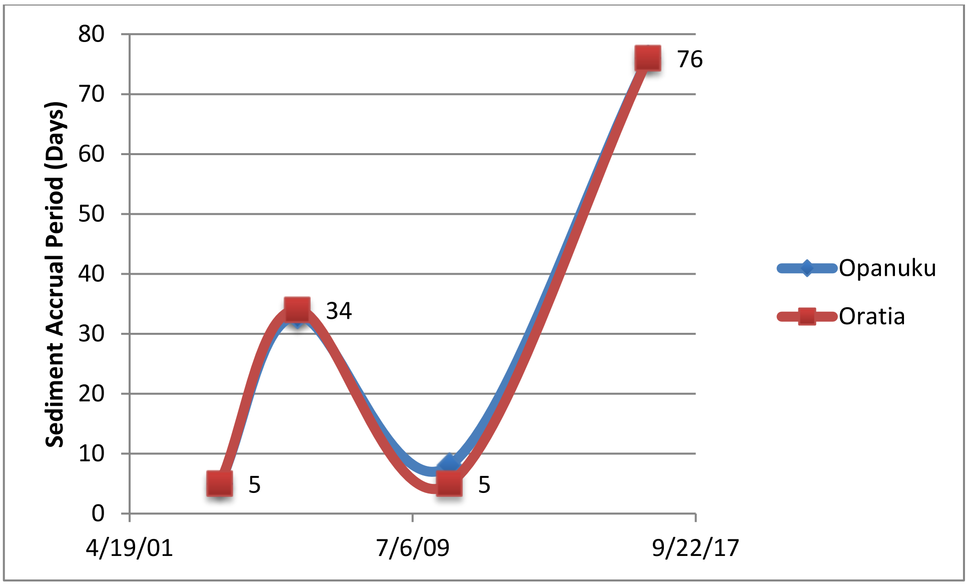

Figure 8: Sediment Accrual Period for the Opanuku and Oratia Steams

2.3.2.3 STREAM HABITAT QUALITY

For sites A to O four surveys of habitat quality data are available, while for sites P to S three surveys of habitat quality data are available. The results that follow focus mostly on sites for which a > 10% change in habitat quality has been observed. Any lesser change is considered within the margins of error in making the habitat assessment as it was undertaken making visual observations by different staff over the 13 year time period.

2.3.2.3.1 URBAN STREAMS

Urban streams have been a large focus of the PTS stream restoration project of which there are nine sites (Site L = Whakarino Stream, Site J = Hibernia Stream, Site E = Potters Stream, Site K = Hibernia Stream, Site M, N & O = Waikumete, Site D = Opanuku and Site I = Oratia). For habitat descriptions of these sites see the companion PTS State Report (Stansfield 2016).

Table 5 shows that sites J (Hibernia Stream), M and N (Waikumete Stream) have shown notable declines in habitat quality since 2004, while sites D (Opanuku Stream) and I (Oratia Stream) have shown notable improvements to habitat quality since 2004.

Table 5: Habitat Quality Temporal Changes of the Urban Stream Sites

Site	2004	2006	2010	2016	% Change (2004-2016)	Temporal Change
Site J (Hibernia/Waikumete)	74.0	64.0	76.0	66.5	-10.1	Decline
Site L (Whakarino/ Waikumete)	73.5	64.0	75.5	75.0	2.0	No Change
Site E (Potters/Oratia)	100.0	100.5	101.5	96.0	-4.2	No Change
Site K (Hibernia/Waikumete)	70.5	72.5	70.5	73.0	3.4	No Change
Site M (Waikumete)	80.0	69.5	37.0	53.5	-33.1	Decline
Site N (Waikumete)	77.5	69.0	41.5	63.5	-18.0	Decline
Site O (Waikumete)	78.5	64.5	61.5	78.5	0.0	No Change

Site I (Oratia)	54.5	77.5	73.5	83.5	34.7	Improvement
Site D (Opanuku)	53.0	58.5	52.5	79.0	32.9	Improvement

The following table shows the notable features that have given rise to the change in habitat assessment of these sites. Table 6 also shows that all sites that have shown a decline have been affected by aquatic habitat abundance and diversity. Site J (Hibernia Stream) has shown a decline in riparian vegetation on the right bank due to vegetation clearance, while the two Waikumete Stream sites have shown a decline in hydrological heterogeneity. Site N (Waikumete Stream) has also shown a notable decline in channel shading.

The two sites that have shown improved habitat quality have also been influenced by aquatic habitat abundance and diversity. Site I (Oratia Stream) has also shown a notable increase in stream channel shading. This latter contributing factor could be due to the maturation of PTS plantings over time as significant planting effort has gone into this catchment (see companion report).

Table 6: Driving Factors of Overall Habitat Quality Change

Key: Numbers in brackets indicate the change in state 2004-2016.

RB = Right Bank

Site	Temporal Change	Contributing Factors			
Site J (Hibernia)	Decline	Aquatic Habitat Abundance (12➔8)	Hydrologic Heterogeneity (17➔6)	Riparian Vegetation RB (6➔1)	
Site M (Waikumete)	Decline	Aquatic Habitat Abundance (12➔8)	Aquatic Habitat Diversity (17➔11)	Hydrologic Heterogeneity (12➔3)	
Site N (Waikumete)	Decline	Aquatic Habitat Abundance (19➔13)	Aquatic Habitat Diversity (18➔12)	Hydrologic Heterogeneity (18➔10)	Channel Shade (14➔9)
Site D (Opanuku)	Improvement	Aquatic Habitat Abundance (7➔15)	Aquatic Habitat Diversity (8➔15)		
Site I (Oratia)	Improvement	Aquatic Habitat Abundance (8➔18)	Aquatic Habitat Diversity (8➔15)	Channel Shade (8➔13)	

2.3.2.3.2 FORESTED STREAMS

There are three forested streams in the PTS catchment (Site P Swanson Stream, Site F Oratia Stream and Site A Opanuku Stream). Of these sites, the only one to show a notable change in habitat quality was Site F which showed a decline in total habitat score from 86 in 2004 to 64 in

2016. This equates to a 25% decline in habitat quality. Key habitat features that resulted in this decline included aquatic habitat abundance and diversity (19-12, 19-11), and hydrologic heterogeneity (18-4).

2.3.2.3.3 PASTORAL STREAMS

There are seven pastoral streams in the PTS project (Sites B & C Opanuku Stream, Sites Q, R and S Swanson Stream, Sites G and H Oratia Stream). For habitat descriptions of these sites see the companion PTS State Report (Stansfield 2016).

Table 7 shows that Site H (Oratia) has shown notable decline in habitat quality since monitoring began, conversely Site S has shown a notable improvement in habitat quality since monitoring began. The following table shows the notable characteristics that have given rise to the change in habitat assessment of these sites.

Table 7: Total Habitat Scores for the Pastoral Streams

Site	2004	2006	2010	2016	% change (2004-2016)	Temporal Change
Site Q (Swanson)		75.0	68.0	78.5	4.6	No Change
Site R (Swanson)		67.5	79.5	67.5	0.0	No Change
Site G (Oratia)	60.5	65.5	83.0	60.0	-0.8	No Change
Site H (Oratia)	84.5	66.0	50.5	69.0	-18.3	Decline
Site B (Opanuku)	84.5	91.0	90.5	80.0	-5.6	No Change
Site S (Swanson)		72.0	61.5	81.5	11.6	Improvement
Site C (Opanuku)	70.0	79.5	73.5	67.5	-3.7	No Change

Table 8 shows that Site H Oratia has experienced a loss in value for channel alteration, channel shade and riparian vegetation integrity. The decline in habitat quality at Site H can be attributed to earthworks and vegetation clearance that was evident on the left bank side of the stream. Conversely Site S shows an improvement in all of these variables. Note although these improvements are quite small, they have significance for this site which originally had a fairly low total habitat score (see Table 7).

Table 8: Contributing Habitat Characteristics of Pastoral Stream Sites

Key: Numbers in brackets indicate the change in state 2004-2016.

LB = Left Bank RB = Right Bank

Site	Temporal Change	Contributing Factors			
Site H (Oratia)	Decline	Channel Alteration (19➔10)	Channel Shade (13➔6)	Riparian Vegetation LB (5➔2)	
Site S (Swanson)	Improvement	Aquatic Habitat Diversity (11➔13)	Hydrologic Heterogeneity (12➔15)	Channel Alteration (16➔18)	Stream Bank Stability RB (7➔10)

2.3.2.4 ECOLOGY

No statistically significant trends were determined with any of the biotic index data (Taxa Richness, EPT Richness, %EPT Taxa and MCI) for any sites. This was not surprising due to the data sets being very small (n=4 for most sites) and the data being highly variable owing to the winter sampling in 2010 raising biotic scores because of the season at most sites. Winter is a time when aqutic ecosystems are often less stressed owing to the cooler water temperatures, higher dissolved oxygen concentrations (which are dependent on water temperature), and lower periphyton and aquatic macrophyte growths having less influence on dissolved oxygen concentrations. Stark & Philips 2009 demonstrated statistically significant seasonal variability of the Taxa Richness, EPT Richness, % EPT Taxa Richness and MCI indices for both soft and hard bottom streams.

Although not statistically significant, five trends from the PTS project are worth noting which are shown below.

Figure 9 shows an increasing EPT score for Site L (Whakarino Stream). While not being statistically significant, the trend is deterministic in that a score of 0% was recorded for the 2003/04 and 2005/06 years, however this climbed to 2 taxa in 2010 (*Zephlebia* mayfly and *Acroperla* stonefly) followed by 3 taxa in 2016 (*Zephlebia* mayfly, *Polyplectropus* caddisfly and *Oxyethira* caddisfly). While the *Oxyethira* caddisfly and *Acroperla* stoneflies are not particularly sensitive invertebrate taxa, the remaining invertebrates are. For example, the maximum sensitive score for an invertebrate taxon is 10 and the *Zephlebia* mayfly (photo 1) has a biotic sensitivity score of 7, and the *Polyplectropus* caddisfly (photo 2) has a biotic sensitivity score of 8. Some photos of these taxa new to the Whakarino Stream are displayed below.

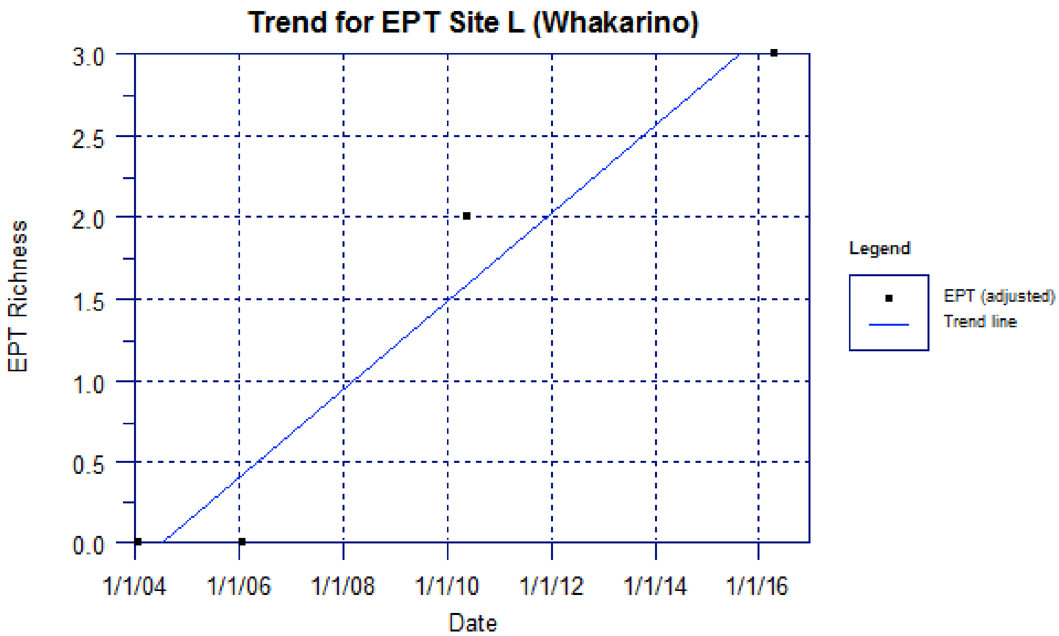

Figure 9: EPT Scores for Site L, Whakarino Stream/ Waikumete

Plate 1-1 The Zephlebia *mayfly, biotic sensitivity score 7. Source: Landcare Research*

Plate 1-2 The Polyplectropus caddisfly, found in the Whakarino Stream in April 2016. Source: Landcare Research

Figure 10 shows a significant decline in % EPT taxa and EPT richness during the 2016 sampling.

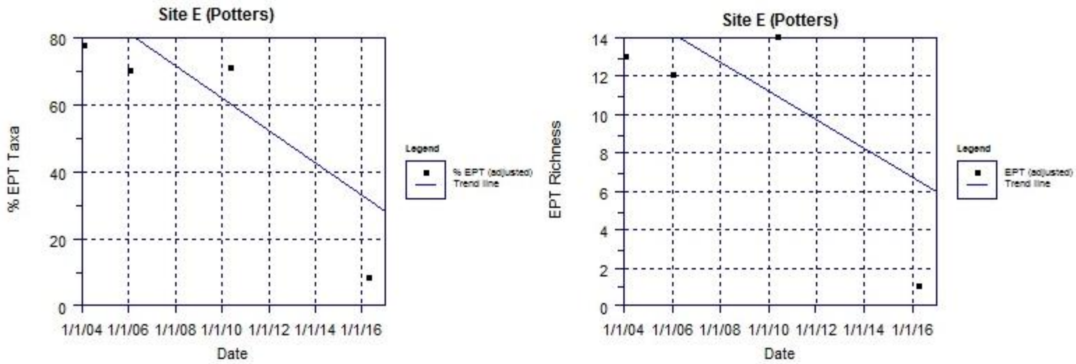

Figure 10: EPT Index Values at Potters Stream, Oratia

Figure 11 shows a significant decline in taxa richness and MCI value for the April 2016 sampling at Potters Stream/Oratia. The decline in MCI results indicates the invertebrate community changing from excellent water quality to a community representative of moderate pollution.

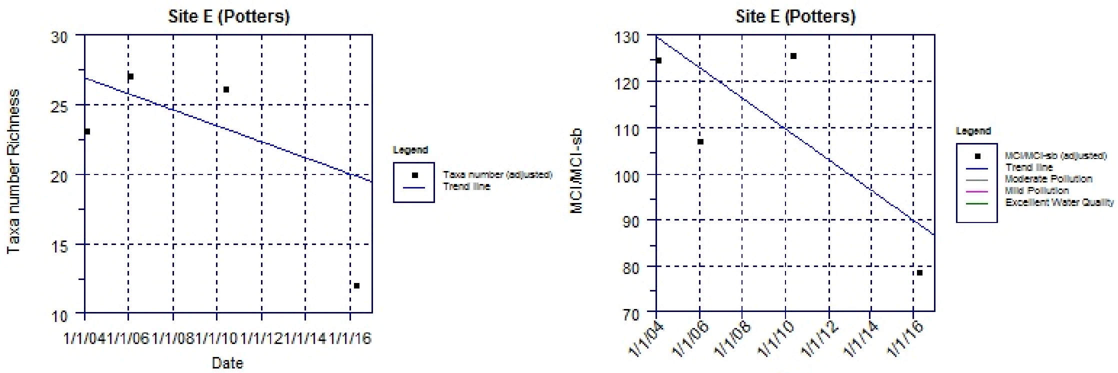

Figure 11: Taxa Richness and MCI Values of Potters Stream

2.4 DISCUSSION

The temporal trend analysis of surface water quality data for the PTS project has shown no statistically significant trends. This result is not surprising as the water quality data sets generated for the PTS project are very small. For sites A to O the number of samples for most variables = 17 while for sites P to S the number of samples = 11. Surface water quality is inherently variable and so to determine trends in surface water quality analytes requires monthly frequency data sets to have confidence that the underlying trend (if determined) is not simply due to chance.

Water quality monitoring of the PTS catchments has been rather ad hoc with differing sample sizes for each monitoring year. For example, the 2003/04 year sampling was conducted over a 6 month period from November to April, the 2005/06 year sampling was conducted over a 5 month period from December to May, the 2010 sampling was conducted over a 4 month period from May to August and the most recent monitoring was conducted over April and May 2016. A more accurate time series analysis could have been conducted if water samples had been collected every month of every year rather than the small snapshot of data collected.

Two trends in water quality were shown at some of the SOE sites, however these trends could simply be due to flow as flow will affect the concentration of any analyte of a stream water sample. Unfortunately the SOE sites are not monitored for flow so the trends cannot be adjusted for flow to determine the environmental significance of the trends.

Given that most catchment riparian planting efforts of the PTS project to date have occurred in the mid to lower reaches of the streams, it is highly likely that no improvement in water quality would be expected. This is because the cumulative contributions of contaminants from upstream are still entering the waterways.

There is a possibility that water temperatures may have become cooler in the PTS catchments, however to determine this would have required annual temperature sonde deployment at selected sites for the January to March period for 10 years. This has not been done, so the question remains unanswered as to whether PTS has been successful in lowering stream water temperatures.

The most successful way to improve water quality and ecology conditions of a stream is to start restoration efforts at the headwaters and progressively work your way downstream. This has not been the strategy of PTS as other goals (e.g. flooding abatement, community buy-in, improvements to community amenity value) were given priority over in-stream water quality and ecology values.

With the exception of the Zn sediment quality trend at Site A (Opanuku), the sediment quality trends are likely to have been affected by the preceding sediment accrual period of most sampling occasions. The exception to this is the sampling that occurred in August 2010 for which the sediment accrual period was five days. The reason for the increasing trend of zinc concentrations at Site A (Opanuku) is unclear. Increasing traffic volumes could be a possible contributor, however traffic volume data for this site is not available. The data set for sediment quality is very small (n=4) so any trends determined should be treated with caution. It is quite likely that these data sets are too small to provide a representative picture of the 13 year period for sediment quality.

Habitat quality monitoring of the sites has been undertaken by different staff over the 13 year time period so caution should be exercised in the interpretation of these results. It is for this reason that TCEC presents changes of > 10% at any site as possibly being significant. Of the urban streams, Site J (Hibernia Stream) has shown a 10.1% decline in habitat quality largely due to declines in aquatic habitat abundance, hydrologic heterogeneity and a decline in riparian vegetation integrity on the true right bank. This trend is possibly due to some land clearance to

accommodate a building on the true right bank. This is a concern as the Hibernia Stream shows particularly good ecosystem health and biodiversity value for an urban stream as measured by the biotic indices (see companion report). Fortunately these changes have not resulted in a decline in ecosystem health as measured by the biotic indices (EPT, % EPT Taxa, Taxa Richness and MCI).

The decline in habitat quality at sites M and N (Waikumete Stream) were not expected as the Waikumete Stream catchment has had a lot of riparian restoration work undertaken at these sites. The reason for this habitat quality decline is largely due to a loss of aquatic habitat diversity and abundance, a loss of hydrologic heterogeneity and for Site N a loss of stream channel shading. Fortunately the decline in habitat quality has not resulted in a decline in aquatic ecosystem health as measured by the biotic indices (EPT, % EPT Taxa, Taxa Richness and MCI).

Two sites of the urban stream group show improvements in habitat quality over time (Site D Opanuku and Site I Oratia). These improvements are due to improved aquatic habitat diversity and abundance and for Site I an improvement in stream channel shading. Unfortunately these habitat improvements have not resulted in any improvements to the macroinvertebrate community biotic indices. This may be because there have been no stormwater mitigation measures made upstream of these sites. Riparian plantings cannot intercept or treat any stormwater contaminants entering the streams as the stormwater contaminants are delivered directly to the stream environment via pipes.

For the forested stream group, the only site to show a notable change in habitat quality was Site F which showed a decline in total habitat score from 86 in 2004 to 64 in 2016. This equates to a 25% decline in habitat quality. Key habitat features that contributed to this decline included aquatic habitat abundance and diversity (19-12, 19-11), and a loss of hydrologic heterogeneity (18-4). This result was unexpected as the forested sites have not had any significant developments occurring within their catchments. Fortunately the decline in habitat quality has not resulted in a significant decline in macroinvertebrate community health as measured by the temporal trends of the biotic indices.

For the pastoral stream group Site H (Oratia) has shown notable decline in habitat quality since monitoring began. Key factors contributing to this decline include channel alteration, and channel shade and riparian vegetation integrity of the true left bank. These declines were expected as the technicians involved in this survey noted a large amount of vegetation clearance and earthworks on the true left bank. Fortunately there has been no significant decline in macroinvertebrate community health as measured by the biotic indices.

Site S has shown a notable improvement in habitat quality since monitoring began. This result is expected as significant riparian plantings have been undertaken near this site. Key attributes contributing to the improvement in habitat quality include aquatic habitat diversity, hydrologic heterogeneity, channel alteration and improved stream bank stability of the true right bank. Despite these improvements to habitat quality this has not resulted in any improvements to macroinvertebrate community health. This could be because untreated urban contaminants are still entering this stream directly via the stormwater reticulation network.

Although not statistically significant, the increase in EPT richness at Site L (Whakarino Stream) is encouraging while the decline in all biotic indices at Site E (Potters Stream) is a concern. Neither of these trends can be attributed to significant changes in habitat water or sediment quality. The appearance of the *Zephlebia* mayfly and *Polyplectropus* caddisfly could be the result of decreasing water temperatures however annual temperature sonde analysis has not been conducted at this site to help determine whether this has occurred.

The decline in macroinvertebrate community health at Site E (Potters Stream) during the April 2016 sampling is particularly concerning. The drop in MCI value at this site equates to a change in pollution class from mild pollution to moderate pollution. Also a significant decline in the EPT indices is evident meaning that many of the sensitive taxa are no longer in this stream. The abundance of animals of this site was the lowest of any site (34 individuals) which could mean that either the stream experienced a recent pollution event or sampling of the streambed was not sufficient to capture the contiguous distribution of the macroinvertebrates. Follow up macroinvertebrate sampling of Site E is recommended to determine whether the macroinvertebrate community has recovered.

3 TERRESTRIAL

Project Twin Streams undertook extensive weed control and replanting along stream banks with the purpose of creating an ecological linkage from the Waitakere Ranges to the Waitemata Harbour. The aim of the weed control and replanting of native plants was to return these areas to a state in which native plant species are dominant and self-sustaining.

Rapid assessments of vegetation transects were undertaken during May-June 2004 (Envirologic 2004 and Envirologic 2005). This methodology and the resulting data has been used to investigate changes in the vegetation present at these sites between 2004 and 2016, particularly looking at native dominance, weed abundance and seedling regeneration.

Overall, the results (TCEC 2016) indicate that the weeding and planting work undertaken by PTS has moved the sites towards a state where native species are dominant and self-sustaining (i.e. producing seedlings). However it is also clear that weed species are continuing to establish. Although the amount of weed control required to keep these sites relatively weed-free is now much less than in 2004, weed control is required on an on-going basis. Riparian corridors are by their nature long and thin and subject to strong edge effects. As such, they are more prone to weed invasion than large and compact forest remnants.

3.1 SOCIAL

Project Twin Streams contracted local community organisations to engage with residents and deliver the planting programme. The number of volunteers and volunteer hours on Project Twin Streams is large – in the 2014 calendar year alone there were almost 20,000 volunteer hours, provided by over 700 volunteers. In May 2016 TCEC conducted an online survey and phone survey of residents (Stevenson 2016). Note no benchmark studies were done prior to the start of PTS.

This study showed that 67% of the community had heard of PTS. Streamside planting is the main thing people associate with the project, and the most common activity that residents have been involved in. Those residents rate PTS as at least "valuable" if not "very valuable" to the local community. The residents score of 93% "valuable" compares well to the 2010 measure when it was 75%. According to residents, the walkways and cycleways have been a success. With over 90% of the people TCEC talked to saying they are a "great asset", this is even higher than in 2010 [2] when 73% said they were.

When asked what, if anything, had changed as a result of the activities or events that were part of Project Twin Streams, many said that it has increased the levels of community spirit and engagement.

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[2] Project Twin Streams Community and Volunteer survey, Key Research, 2010

4 RECOMMENDATIONS

Three stream types have been identified within the PTS stream catchments – urban, forested and pastoral streams. Each of these stream types have differing land use pressures, therefore the pressure and response components of future PSR reporting should be tailored according to the stream type. Unfortunately previous PSR reporting for the PTS project has largely focused on urban structural pressure indicators with less emphasis on pastoral land use pressure indicators. This has made the analysis for the pastoral streams less comprehensive than the urban streams.

Forested streams are good to include in any restoration project like PTS as it provides a baseline of stream condition in the absence of pastoral or urban stream pressures. It is therefore recommended that forested streams are included in any future restoration project similar to PTS to act as a control type stream.

PTS has focused most of its riparian restoration and stormwater mitigation work in the mid to lower reaches of the stream catchments as this is where best flooding mitigation, community buy-in, educational and amenity value could be achieved. The social research conducted shows that this buy-in has largely been achieved, and the terrestrial research shows that real improvements have been made to riparian vegetation.

Unfortunately, with respect to water quality, focusing these efforts in the mid to lower reaches of these stream catchments is unlikely to result in any significant improvements to water, sediment or in-stream ecology of these streams because they are still receiving cumulative contaminant inputs from sub catchments further upstream.

If the goal of a restoration project is to improve water, sediment and stream ecology of a catchment, then the best way to achieve this is to start the restoration measures from the headwaters and work your way downstream. Working in this manner also enables Council to make between catchment comparisons of different mitigation techniques to assess what measures deliver the best ecological gain.

Streams in the Project Twin Streams catchment generally have forested headwaters which then run through pastoral land cover, which is then followed by urban land cover. Therefore the future survey design adopted to measure the success of a restoration project will depend on how far down the catchment one might be..

In 2012 a restoration tool kit was developed by NIWA (Parkyn et al. 2012). The recommendations in the following paragraphs largely stem from this report. The reader is advised to read this report as it provides excellent guidance on what monitoring and survey design is best for various restoration scenarios.

Clear and measurable goals need to be established for a survey design to dictate appropriate monitoring and evaluate whether restoration has been successful. Ecological goals may include measurable improvements to stream habitat, water quality and biogeochemical functioning, or stream biota.

To judge whether a stream has been measurably enhanced towards a predetermined dynamic endpoint depends upon measurements from the stream prior to impairment and some measure of reference conditions at a comparable undisturbed or minimally disturbed site.

The expectation of most stream restoration is that habitat rehabilitation will be sufficient to restore stream biodiversity and functioning. This expectation has been referred to as the Field of Dreams Hypothesis: "if we build it, they will come" (Palmer et al. 1997, Lake et al. 2007 in Parkyn et al. 2012).

However, there is often insufficient (or no) testing of this hypothesis, in part because many restoration projects are not designed with scientific testing in mind (Lake et al. 2007). For

example, there is often no sampling before restoration works are begun and no suitable reference site to monitor in conjunction with the restored site as a control.

Unfortunately PTS did not include pre-restoration monitoring from which to make comparisons. This baseline monitoring is important for social and terrestrial components as well, and is strongly recommend for any future restoration project commenced.

There is opportunity for Council to undertake pilot studies of the effectiveness of any stormwater interception and treatment measures to gain an understanding of what mitigation tools may work best for a particular stream prior to embarking on a full scale catchment restoration project. For pastoral streams however more information is available on what measures to take to mitigate the effects of pastoral land use.

The monitoring frequency of PTS has resulted in a data set that is marginal for gauging success of any desired ecological endpoint of the restoration project.

The key steps in designing a monitoring programme begin with identifying project goals and catchment constraints, understanding the restoration site, and having a clear image or reference site to aim for.

Parkyn et al. (2012) identifies some key constraints of freshwater stream restoration outcomes for highly urbanised catchments connected to stormwater infrastructure. Some potentially unachievable goals could include providing improvements to water quality, aquatic biodiversity and natural habitat (Parkyn et al. 2012). Achievable goals for these systems could include improvements to some ecosystem functions, terrestrial plant biodiversity, aesthetics and habitat for tolerant biota (Parkyn et al. 2016. Certainly the urban stream sites of PTS fall into this category so it is perhaps not surprising that any water quality or aquatic biodiversity improvements have not been detected.

Similarly, improvements to water quality or aquatic biodiversity may be unachievable for pastoral streams without native forest in the headwaters and with an extensive length of unrestored stream upstream. However, goals of improved terrestrial plant biodiversity, aesthetics and ecosystem function could be achievable.

Future restoration projects should be tailored according to the recommendations of the restoration tool kit developed by NIWA.

5 REFERENCES

ANZECC (Australia New Zealand Environment and Conservation Council) (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Councils of Australia and New Zealand, Canberra, Australia.

Clausen, B.; Biggs, B.J.F. (1997) Relationships between benthic biota and hydrological indices in New Zealand streams. *Freshwater Biology 38:*327- 342.

Collier, K. J. & Hamer, M (2012) The ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) Programme. Waikato Regional Council Technical Report 2012/27

EcoWater Solutions Ltd (2004) Project Twin Streams Catchment Monitoring Ecological Monitoring Report. Prepared for EcoWater Solutions By Diffuse Sources Ltd in Collaboration with Kingett Mitchell & Associates Ltd.

EcoWater Solutions Ltd (2006) Project Twin Streams Catchment Monitoring Water Quality Monitoring Report. Prepared for EcoWater Solutions By Diffuse Sources Ltd in Collaboration with Kingett Mitchell & Associates Ltd.

Golder Kingett Mitchell Ltd (2006) Project Twin Streams Catchment Monitoring Pressures and State of the Environment 2005-2006. Prepared for EcoWater Solutions By Diffuse Sources Ltd in Collaboration with Kingett Mitchell & Associates Ltd.

Golder Associates Ltd (2010) Pressure-State-Response Report Project Twin Streams Catchment Monitoring. Submitted to Waitakere City Council Private Bag 93109 Henderson, Waitakere 0650

Joy, M.K. & Death, R.G. (2004) Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. *Environmental Management*, 34, 415-428.

Lake, P.S.; Bond, N.; Reich, P. (2007) Linking ecological theory with stream restoration. *Freshwater Biology 52*: 597-615.

Mills, G.; Williamson, B.; Cameron, M and Vaughan, M. 2012 Marine sediment contaminants: Status and trends assessment 1998 to 2010. Prepared by Diffuse Sources Ltd for Auckland Council. Auckland Council technical report TR2012/041.

Palmer, M.A.; Ambrose, R.F.; Poff, N.L. (1997) Ecological theory and community restoration ecology. *Restoration Ecology 5*: 291-300.

Parkyn, S.; Collier, K.; Clapcott, J.; David, B.; Davies-Colley, R.; Matheson, F.; Quinn, J.; Shaw, W.; Storey, R. (2010) The restoration indicator toolkit: Indicators for monitoring the ecological success of stream restoration. National Institute of Water & Atmospheric Research Ltd, Hamilton, New Zealand. 134 pp.

Stansfield, B (2016) Project Twin Streams: Current State Report 2016: Volume 1: Freshwater. Unpublished Report prepared for Auckland Council by Thomas Civil and Environmental Consultants in association with Environmental Impact Assessment Limited.

Stark, J.D. & Phillips, N (2009) Seasonal variability in the Macroinvertebrate Community Index: Are seasonal correction factors required? *New Zealand Journal of Marine and Freshwater Research* 43:4, 867-882.

Stevenson, A (2016) Project Twin Streams: Current State Report 2016: Volume 2: Social Unpublished Report prepared for Auckland Council by Thomas Civil and Environmental Consultants in association with Tasman Research.

TCEC (2016) Project Twin Streams: Current State Report 2016: Volume 3: Terrestrial Unpublished Report prepared for Auckland Council by Thomas Civil and Environmental Consultants.

Ward, R.C., Loftis, J.C. & McBride, G.B (1990) Design of water quality monitoring systems. Published by John Wiley & Sons Inc. Hoboken, New Jersey.

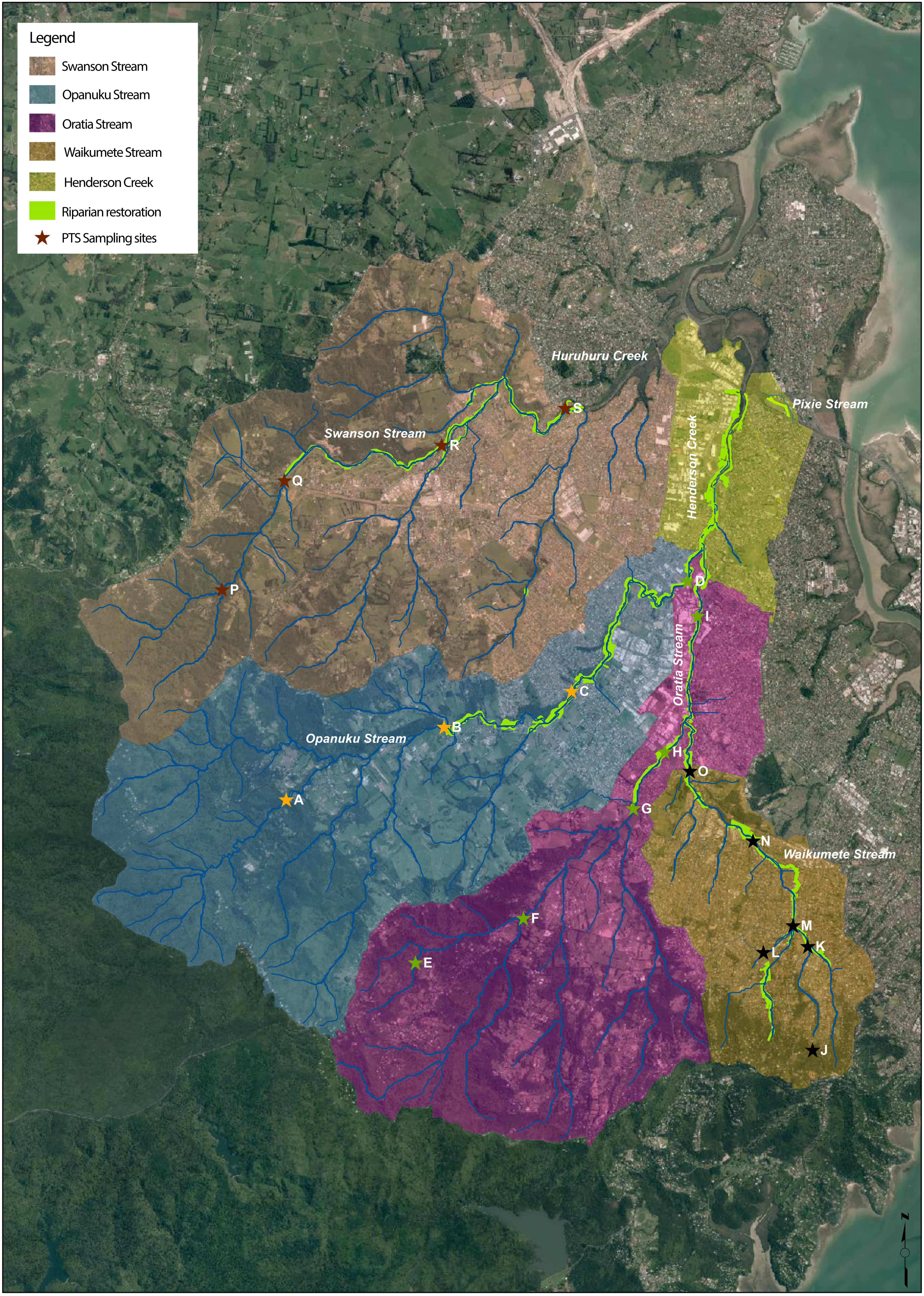
6 APPENDICES

1 - Project Twin Streams sampling locations

2 – Monitoring Sites of Project Twin Streams

3- Seasonality Testing Results

APPENDIX 1– PROJECT TWIN STREAMS SAMPLING LOCATIONS



PTS Catchments, monitoring sites and restoration areas

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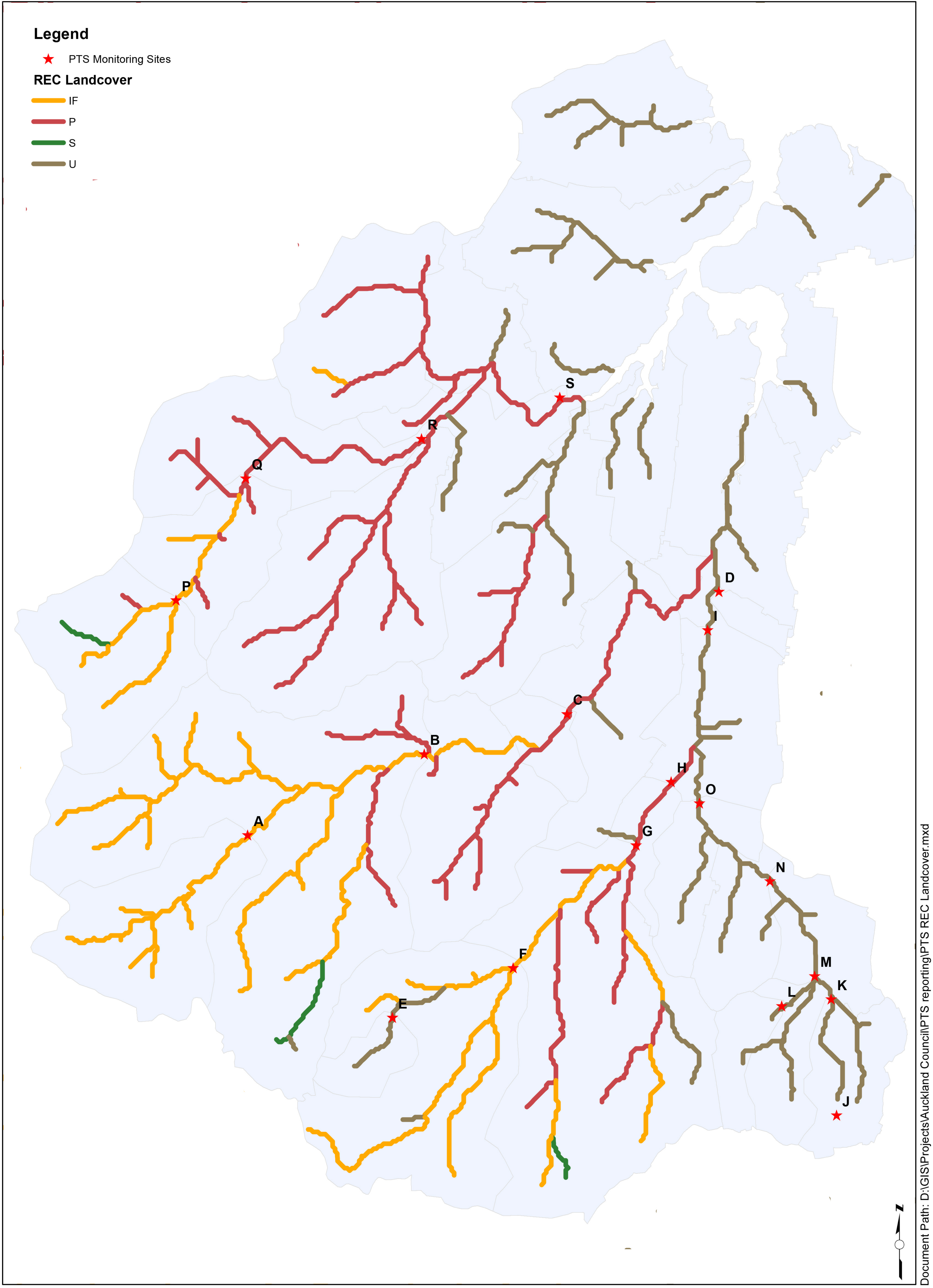
APPENDIX 2: MONITORING SITES OF PROJECT TWIN STREAMS



16238 PTS Synthesis - REC - Landcover

APPENDIX 3: SEASONALITY TESTING RESULTS

- **Turbidity (NTU): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	38	38	0	0
N used	135	153	137	82
Non-detects	0	0	0	0
Mean	15.723	11.928	14.505	22.363
Median	7.800	6.840	10.700	9.850
25%	4.425	3.900	7.075	5.200
75%	15.200	11.650	14.750	25.600
Minimum	1.000	0.600	3.300	1.500
Maximum	232.000	164.000	108.000	193.000

Kruskal-Wallis One-Way Analysis of Variance for Turbidity (NTU) by season

507 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	135	241.770
Mar - May	153	214.065
Jun - Aug	137	296.066
Sep - Nov	82	278.366

Statistic	df	P (Chi2)
25.873	3	0.000

- **TSS (g/m^3): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	96	118	3	15
N used	115	111	134	67
Non-detects	0	0	0	0
Mean	9.406	8.310	7.874	19.186
Median	5.000	4.000	5.200	7.700
25%	2.375	1.500	3.000	3.250
75%	10.000	7.475	8.500	17.000
Minimum	0.400	0.820	0.700	0.800
Maximum	132.100	108.000	101.700	281.400

Kruskal-Wallis One-Way Analysis of Variance for TSS (g/m3) by season

427 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	115	216.230
Mar - May	111	183.140
Jun - Aug	134	212.978
Sep - Nov	67	263.343

Statistic	df	P (Chi2)
17.740	3	0.000

- **Dissolved Cu (g/m^3): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	142	158	43	54
N used	127	151	97	43
Non-detects	0	0	0	0
Mean	0.002	0.002	0.003	0.003
Median	0.002	0.002	0.002	0.002
25%	0.001	0.001	0.001	0.001
75%	0.003	0.003	0.004	0.005
Minimum	0.000	0.000	0.001	0.000
Maximum	0.014	0.014	0.005	0.011

Kruskal-Wallis One-Way Analysis of Variance for Dissolved Cu (g/m3) by season

418 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	127	192.835
Mar - May	151	192.394
Jun - Aug	97	246.170
Sep - Nov	43	236.070

Statistic	df	P (Chi2)
16.558	3	0.001

- **Total Cu (g/m³): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	285	281	150	108
N used	30	68	30	28
Non-detects	0	0	0	0
Mean	0.004	0.005	0.007	0.006
Median	0.006	0.002	0.006	0.006
25%	0.002	0.001	0.006	0.004
75%	0.006	0.006	0.006	0.006
Minimum	0.001	0.000	0.002	0.002
Maximum	0.009	0.093	0.028	0.019

Kruskal-Wallis One-Way Analysis of Variance for Total Cu (g/m3) by season

156 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	30	82.233
Mar - May	68	57.478
Jun - Aug	30	106.067
Sep - Nov	28	96.018

Statistic	df	P (Chi2)
31.556	3	0.000

- **Dissolved Zn (g/m³): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	331	321	190	147
N used	127	151	97	43
Non-detects	0	0	0	0
Mean	0.011	0.014	0.022	0.018
Median	0.007	0.007	0.015	0.012
25%	0.002	0.002	0.005	0.004
75%	0.016	0.017	0.039	0.029
Minimum	0.000	0.001	0.001	0.001
Maximum	0.061	0.240	0.070	0.084

Kruskal-Wallis One-Way Analysis of Variance for Dissolved Zn (g/m3) by season

418 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	127	187.476
Mar - May	151	188.685
Jun - Aug	97	261.237
Sep - Nov	43	230.930

Statistic	df	P (Chi2)
27.867	3	0.000

- **Total Zn (g/m^3): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	474	444	297	201
N used	30	68	30	28
Non-detects	0	0	0	0
Mean	0.024	0.020	0.047	0.046
Median	0.015	0.012	0.041	0.036
25%	0.011	0.003	0.027	0.020
75%	0.037	0.023	0.062	0.070
Minimum	0.003	0.001	0.006	0.009
Maximum	0.068	0.171	0.150	0.110

Kruskal-Wallis One-Way Analysis of Variance for Total Zn (g/m3) by season

156 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	30	71.867
Mar - May	68	56.912
Jun - Aug	30	107.667
Sep - Nov	28	106.786

Statistic	df	P (Chi2)
39.667	3	0.000

- ***E. coli* (MPN ⁄ 100 mL): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	542	506	357	259
N used	105	129	77	24
Non-detects	0	0	0	0
Mean	9667.524	2240.961	1788.857	1895.208
Median	1350.000	860.000	300.000	595.000
25%	585.000	287.500	157.500	395.000
75%	2510.000	2400.000	800.000	1245.000
Minimum	5.000	10.000	1.000	30.000
Maximum	700000.000	24200.000	53000.000	25000.000

Kruskal-Wallis One-Way Analysis of Variance for E. coli (MPN ⁄ 100mL) by season

335 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	105	200.943
Mar - May	129	175.934
Jun - Aug	77	114.474
Sep - Nov	24	152.958

Statistic	df	P (Chi2)
37.115	3	0.000

- **NH4-N(g⁄m^3): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	542	520	360	259
N used	173	177	134	82
Non-detects	0	0	0	0
Mean	0.044	0.040	0.047	0.047
Median	0.025	0.020	0.030	0.030
25%	0.009	0.005	0.014	0.020
75%	0.040	0.040	0.048	0.050
Minimum	0.005	0.005	0.005	0.005
Maximum	0.930	0.670	1.740	0.470

Kruskal-Wallis One-Way Analysis of Variance for NH4-N(g/m3) by season

566 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	173	274.393
Mar - May	177	250.734
Jun - Aug	134	307.821
Sep - Nov	82	333.695

Statistic	df	P (Chi2)
18.556	3	< 0.001

- **TOxN (g/m^3): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	542	520	360	259
N used	173	191	137	82
Non-detects	0	0	0	0
Mean	0.232	0.280	0.443	0.533
Median	0.150	0.178	0.270	0.223
25%	0.054	0.080	0.166	0.098
75%	0.292	0.348	0.443	0.494
Minimum	0.001	0.005	0.059	0.010
Maximum	1.570	2.260	2.470	3.840

Kruskal-Wallis One-Way Analysis of Variance for TOxN (g/m3) by season

583 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	173	245.913
Mar - May	191	274.914
Jun - Aug	137	358.609
Sep - Nov	82	317.744

Statistic	df	P (Chi2)
38.256	3	0.000

- **DRP (g/m^3): Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	**Dec - Feb**	**Mar - May**	**Jun - Aug**	**Sep - Nov**
Missing	542	520	360	259
N used	173	191	137	82
Non-detects	0	0	0	0
Mean	0.018	0.019	0.015	0.020
Median	0.016	0.012	0.010	0.020
25%	0.008	0.008	0.005	0.011
75%	0.020	0.022	0.020	0.020
Minimum	0.002	0.002	0.002	0.004
Maximum	0.100	0.090	0.096	0.080

Kruskal-Wallis One-Way Analysis of Variance for DRP (g/m3) by season

583 observations from 4 seasons

Season	**Count**	**Mean rank**
Dec - Feb	173	297.098
Mar - May	191	293.678
Jun - Aug	137	248.558
Sep - Nov	82	349.915

Statistic	**df**	**P (Chi2)**
19.102	3	0.000

- **Conductivity (mS/m): Period analysed 12 years and 7 months for water years 2002 to 2015 beginning December**

Season	**Dec - Feb**	**Mar - May**	**Jun - Aug**	**Sep - Nov**
Missing	598	569	383	284
N used	117	142	114	57
Non-detects	0	0	0	0
Mean	20.724	22.097	16.801	19.412
Median	20.560	20.650	15.000	18.900
25%	17.500	16.600	12.100	17.345
75%	23.213	24.500	18.720	22.870
Minimum	0.000	0.000	8.800	0.000
Maximum	61.400	222.700	37.810	34.490

Kruskal-Wallis One-Way Analysis of Variance for Conductivity (mS⁄m) by season

430 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	117	242.231
Mar - May	142	244.070
Jun - Aug	114	151.039
Sep - Nov	57	218.377

Statistic	df	P (Chi2)
43.620	3	0.000

- **pH: Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	637	607	384	285
N used	134	153	136	81
Non-detects	0	0	0	0
Mean	7.315	7.342	7.183	7.484
Median	7.315	7.400	7.200	7.500
25%	7.060	7.130	6.900	7.300
75%	7.560	7.600	7.500	7.700
Minimum	6.640	5.630	6.120	6.900
Maximum	8.110	8.200	7.830	8.150

Kruskal-Wallis One-Way Analysis of Variance for pH by season

504 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	134	249.351
Mar - May	153	266.954
Jun - Aug	136	197.360
Sep - Nov	81	322.988

Statistic	df	P (Chi2)
40.113	3	0.000

- **Temperature °C: Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	694	645	385	285
N used	116	153	136	82
Non-detects	0	0	0	0
Mean	18.017	14.904	11.644	13.874
Median	17.850	14.800	11.600	13.750
25%	16.600	13.675	10.800	12.600
75%	19.500	16.225	13.025	14.700
Minimum	14.200	1.800	6.100	7.100
Maximum	22.900	20.900	15.800	18.100

Kruskal-Wallis One-Way Analysis of Variance for Temperature C by season

487 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	116	401.280
Mar - May	153	270.216
Jun - Aug	136	98.103
Sep - Nov	82	214.567

Statistic	df	P (Chi2)
299.996	3	0.000

- **DO g/m^3: Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	751	701	386	285
N used	116	135	136	82
Non-detects	0	0	0	0
Mean	7.326	8.387	10.241	8.782
Median	7.450	8.210	10.400	8.875
25%	6.520	7.400	9.260	8.000
75%	8.200	9.645	11.285	9.500
Minimum	3.200	1.000	1.390	5.300
Maximum	11.000	14.820	13.930	11.800

Kruskal-Wallis One-Way Analysis of Variance for DO g/m3 by season

469 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	116	125.935
Mar - May	135	208.930
Jun - Aug	136	350.143
Sep - Nov	82	241.238

Statistic	df	P (Chi2)
178.465	3	0.000

- **DO Saturation : Period analysed 13 years for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	808	757	387	285
N used	116	135	136	82
Non-detects	0	0	0	0
Mean	78.327	82.826	94.074	85.104
Median	79.500	83.300	95.400	85.750
25%	70.500	73.600	87.000	79.100
75%	87.200	93.500	102.150	90.700
Minimum	32.700	8.500	13.300	54.000
Maximum	126.400	136.300	126.400	123.900

Kruskal-Wallis One-Way Analysis of Variance for DO Saturation by season

469 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	116	165.741
Mar - May	135	211.281
Jun - Aug	136	324.853
Sep - Nov	82	223.000

Statistic	df	P (Chi2)
94.844	3	0.000

- **Clarity: Period analysed 12 years and 7 months for water years 2002 to 2015 beginning December**

Season	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
Missing	916	848	507	332
N used	65	100	17	35
Non-detects	0	0	0	0
Mean	0.671	1.038	0.491	0.864
Median	0.610	0.765	0.480	0.650
25%	0.430	0.400	0.193	0.515
75%	0.795	1.480	0.662	0.960
Minimum	0.090	0.070	0.100	0.190
Maximum	2.850	7.000	1.470	3.090

Kruskal-Wallis One-Way Analysis of Variance for Clarity by season

217 observations from 4 seasons

Season	Count	Mean rank
Dec - Feb	65	98.092
Mar - May	100	120.750
Jun - Aug	17	71.235
Sep - Nov	35	114.029

Statistic	df	P (Chi2)
11.841	3	0.008