ENVIRONMENTAL MANAGEMENT GROUP

Technical report

INTERNAL

HAWKE'S BAY REGIONAL COUNCIL

SAFEGUARDING YOUR ENVIRONMENT + KAITIAKI TUKU IHO

Nearshore Coastal Water Quality in Hawke's Bay

June 2006
EMI 05/16
HBRC Plan No. 3792

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Environmental Management Group
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Internal

Environmental Monitoring Section

Nearshore Coastal Water Quality in Hawke's Bay

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Cover Photo: Common dolphin (*Delphinus delphis*) in Hawke Bay, Bryce Lawrence

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ANZECC – Australian and New Zealand Guidelines for fresh and marine water quality (2000)
CWQMP – Coastal Water Quality Monitoring Pilot study
DIN – Dissolved Inorganic Nitrogen (NOxN + NH4N)
DRP – Dissolved Reactive Phosphorus
HBRC – Hawke's Bay Regional Council
NH4N –Ammoniacal Nitrogen
NOxN – Nitrate + Nitrite Nitrogen (Total oxidisable nitrogen)
NO2N – Nitrite Nitrogen
NO3N – Nitrate Nitroge
RCP – Regional Coastal Plan
RMA – Resource Management Act (1991)
TKN – Total Kjeldahl Nitrogen
TN – Total Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Solids

1.0 INTRODUCTION

Coastal inshore waters of the Hawke's Bay region provide for a range of biological, social, economic and recreational activities. However these areas are also the receiving environments for the impacts of nearly all land-based activity, and are thus susceptible to a number of water quality issues. These issues are particularly pertinent for regions such as Hawke's Bay, where large river systems contribute to the direct transport of pollutants to the inshore waters of the marine environment.

Anthropogenic effects on water quality in the Hawke's Bay area include pollutants derived from urban and rural runoff, stormwater discharges, sewer discharges from municipal outfalls, and seepage from malfunctioning or poorly maintained septic tank systems. These discharges can contain nutrients, sediments, bacteria, viruses and pathogens, pesticides, and heavy metal compounds. The discharge constituents can have both chronic and acute effects on benthic and pelagic species, and can consequently cause degradation of these ecosystems.

The addition of nutrients to inshore waters can significantly alter nutrient dynamics within the marine system. The majority of nutrients entering coastal waters are terrestrial in origin (Scheltinga et al, 2004), and therefore increases in nutrient loading of coastal waters can ultimately reflect land-use practices and management. With national increases in dairy farming (up 47% between 1986 and 2002 (StatNZ, 2006)), and the significant increase in fertiliser requirements (113%), runoff and leaching to ground and surface waters is increasingly likely (StatNZ, 2006). Nutrient loaded waters contain elevated concentrations of nitrogen and phosphorous, and it is these elements which would normally limit primary production (plant growth) in marine waters. An increase in the concentration of the limiting nutrient can lead to algal blooms, and the subsequent anoxic or hypoxic conditions that accompany and follow large bloom events. Algal blooms caused by excess nutrients can cause changes to plankton composition through increased abundance of the dominant blooming species, and cause reductions in the biomass of large algal species (seaweeds) through reduced light availability (Scheltinga et al, 2004). In many cases nitrogen, specifically nitrate is most often the limiting nutrient (Scheltinga et al, 2004; Castro and Huber, 1997). It has also been suggested that nutrients, particularly nitrogen from river systems can accumulate within the coastal margin, making these areas more prone to nutrient enrichment than other marine environments (Park, 1998).

Turbidity in coastal waters can also be influenced by terrestrial inputs, which typically contain high levels of suspended solids, as well as being a consequence of algal blooms. Increased sediment loads enter the marine environment via stormwater, sewer outfalls, and runoff, and can have pronounced effects on the ecology of marine habitats. Increased rates of sedimentation can bury marine organisms, affecting access to light, food and oxygen, and result in the accumulation of waste products (Airoldi, 2003). Aside from acute episodic events such as storms, chronic increases in sediments can reduce light availability affecting plant growth; alter community structure (Watling and Norse, 1998); and cause reductions in reproductive condition (e.g. *Pecten noaezelandiae* - scallop), decreases in feeding rates (e.g. *Boccardia syrtis* – polychaete), increased mortality (e.g. *Macomona liliana* – wedge shell) (Nicholls et al, 2003), and can clog the siphons and branchial walls of organisms such as ascidians (e.g. sea squirts) (Naranjo et al, 1996).

A comprehensive study has not been conducted for the Hawke Bay area since Bradford et al's original 1976 study. Since this time catchment land-use has undoubtedly changed dramatically, laboratory techniques refined, and our own understanding of coastal water quality increased.

1.1 Statutory Context

Hawke's Bay Regional Council must establish, implement and review objectives, policies and methods to promote the sustainable management of the regions natural and physical resources. Council is required under section 35 of the RMA to monitor those aspects of the environment that will enable it to carry out its functions under the Act. This is reaffirmed in the operative Regional Coastal Plan (1993; RCP), which asserts the necessity for Council to monitor 'nearshore[1] coastal water quality' (section 13.2). Whilst this has in some way been meet through the microbiological monitoring of coastal waters, this does not adequately address the greatest pressures on Hawke's Bay coastal waters, nutrient enrichment and sediment inputs, and there remains a paucity of information concerning how well regional plans are addressing these issues. The following report proposes a Nearshore Coastal Water Quality monitoring programme to deliver on that requirement.

1.2 Objectives

The objectives of the Coastal Water Quality Monitoring Pilot study (CWQMP) were;

1) To determine the characteristics of Hawke's Bay's waters with regard to the parameters sampled at a singular point in time;
2) To assess variability of the surface waters within any given site;
3) To determine whether there a significant difference in water quality between sites; and
4) Overall, to assess the quality of Hawke's Bay coastal waters, specifically with regard to nutrient concentrations and how they compare to commonly used guideline values.

In addition to the aims of the pilot study, an ongoing State of the Environment Coastal Water Quality monitoring programme would aim to assess temporal (seasonal and annual) variation in coastal water quality characteristics in order to:

- o Provide an assessment of coastal water quality throughout the region and over time, thereby providing a context for one-off or short-term studies;
- o Provide a basis for the identification of water quality trends and issues;
- o Monitor Council's progress towards achieving the objectives described for coastal waters in the RCP; and
- o Assess the effectiveness of Council policy relating to the adverse effects of diffuse runoff on coastal water quality.

1.3 Definitions

For the purposes of this report 'coastal waters' are defined according to the RMA (1991) as seawater within the outer limits of the territorial sea and including;

a) seawater with a substantial freshwater component; and
b) seawater in estuaries, fiords, inlets or embayments.

Nearshore is defined as the zone extending from the swash zone[2] to the position marking the start of the offshore zone[3], typically at water depths around 20m (WSDE, 2005).

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[1] The zone that extends from the swash zone to the position marking the start of the offshore zone, typically at water depths of the order of 20m.

[2] The area of the shoreline characterised by wave uprush and retreat.

[3] The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the seabed on wave action is small in comparison with the effect of wind.

2.0 METHODOLOGY

2.1 Indicator selection

Indicators were selected to align with those issues identified as potentially being the greatest risk to the health and environmental integrity of Hawke's Bay coastal waters. Changes to the loading or bioavailability of nutrients particularly through river discharges, microbiological contamination of coastal and estuarine waters, and sedimentation were identified as key pressures on coastal water quality and therefore indicators that would elucidate trends associated with these pressures were chosen for measurement. All sites were sampled for the complete set of parameters, with the exception of microbiological sampling where the Ahuriri Estuary was sampled for *Escherichia* coli, and the marine sites for enterococci bacteria in line with current guidelines. The pressures, indicator descriptions, and measurement and reporting techniques are described in appendix one.

2.2 Site selection and description

For the initial pilot study, sites were selected which would not only typify Hawke's Bay coastal waters and best illustrate the effects of land use, but which were also likely to be representative of areas with the highest level of variability. With that in mind, sites were selected which aligned with major river mouths, and at locations along the coast that would enable representation of the coast within a limited number of sites. A description of each site and explanation for its choice is given in appendix two.

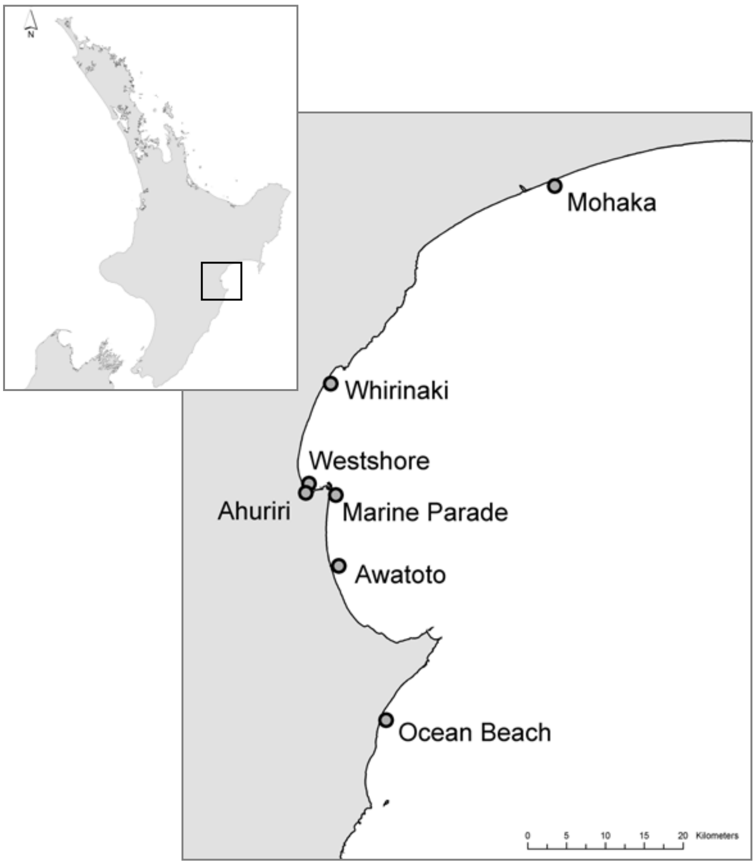


Figure 1: Location of coastal water quality pilot study sites, Hawke's Bay.

Sites selection criteria were designed to fulfil the above requirements whilst also enabling comparison with other published and unpublished information on coastal water quality. Therefore, sites were required to be within 5-10m to enable a determination of mixing and be comparable with external information, and approximately 500-1000m from shore.

Given the proximity of sampling sites to major river mouths, each site was initially sampled to ensure that the waters were fully mixed. Salinity and dissolved oxygen concentrations were taken in the surface waters (<0.5m) and at depth (5m), and waters were defined as fully mixed if salinity did not vary by more than 2 parts per thousand (ppt), and/or dissolved oxygen concentrations were within 5% (*sensu* ARC, 2004; R. Winterbourne pers. comm.).

2.3 Sampling

Sampling was conducted by boat for the marine sites and kayak for the estuary in July 2005. The estuarine sampling was undertaken on a receding tide, approximately 1 - 1.5 hours after high tide. At each sites surface and depth measurements were taken for salinity and dissolved oxygen to ensure waters were fully mixed. Five replicate samples were then collected and analysed for each of the parameters outlined in appendix one in accordance with standard water sampling protocols. All samples were stored in chilled containers, and couriered overnight to the laboratory on return.

2.4 Laboratory Methods

Analyses of saline and estuarine waters were conducted by Hills Laboratories in Hamilton. Methods and detection limits are described in appendix three. WTW MultiLine P4 and YSI 85 handheld instrumentation was used to assess physico-chemical parameters in the field.

2.5 Data Analyses

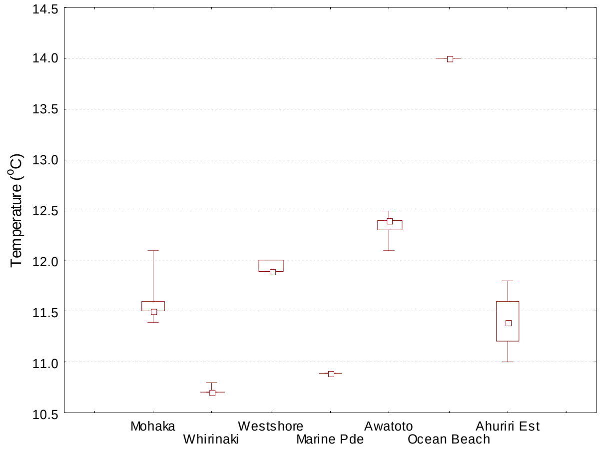
Results were analysed using the Kruskall-Wallis test (Statistica v7.1) to determine whether between-site differences in the parameters sampled were significant. This test is useful when dealing with data with outlier values that are not representative of the general variance heterogeneity. Individual results are detailed in appendix four.

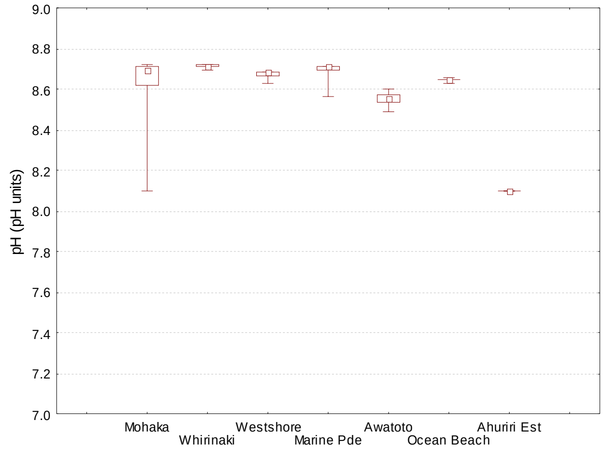
Where concentrations were below analytical limits of detection, the results were reported as 'less than' the detection limit. This value was converted to half of the detection limit for statistical analyses.

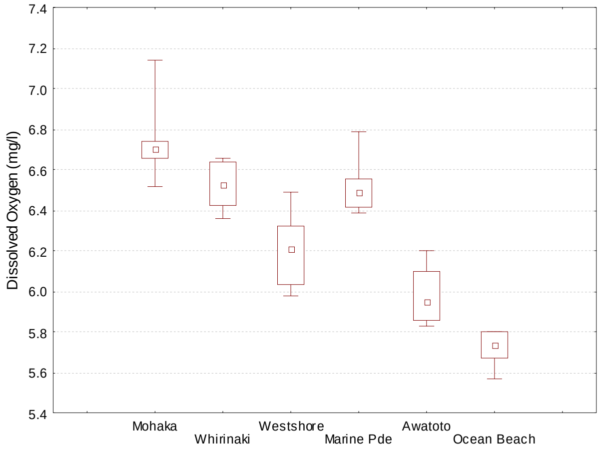
3.0 RESULTS

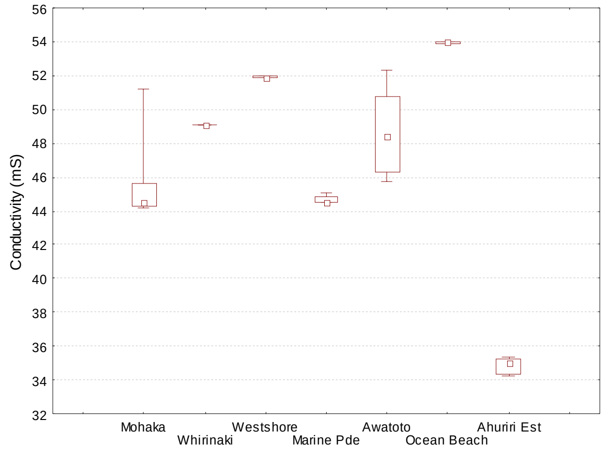
3.1 Physicochemical properties

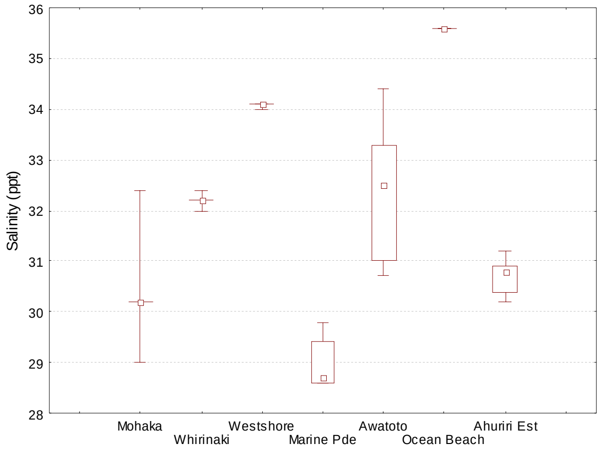
Note: Small box = median, large box = interquartile ranges, whisker ends = minimum and maximum observations.







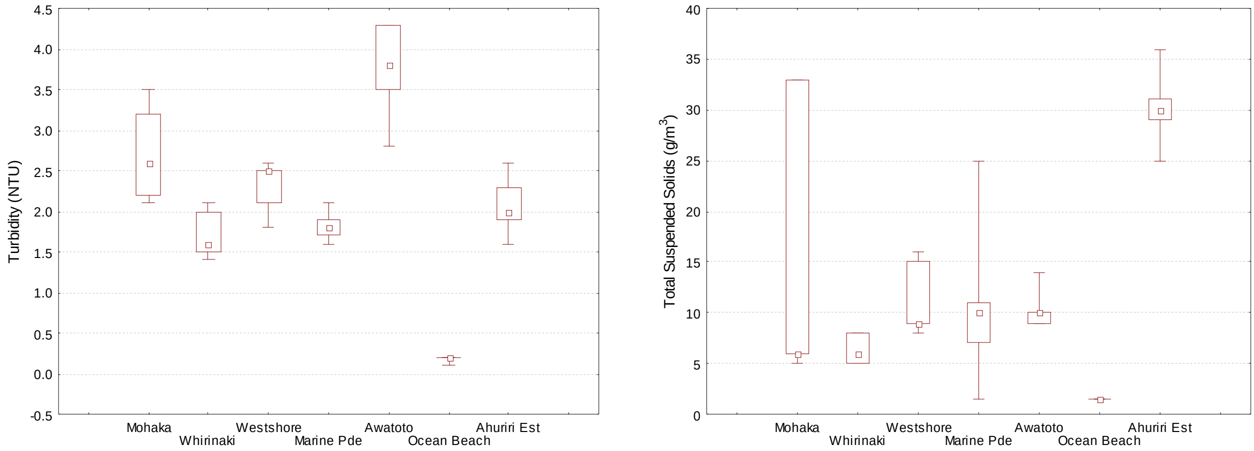




Figures 2-6: Physicochemical results for coastal water sampling.

The physicochemical properties largely reflected the type and source of water. Samples taken at Ocean Beach, outside of Hawke Bay, were characterised by generally higher temperatures and salinity, and corresponding lower levels of dissolved oxygen than sites within Hawke Bay. Dissolved oxygen levels at all sites were above the 5mg/L threshold, below which adverse biological affects are known to occur, indicating reasonably well oxygenated waters. Conductivity and pH was expectedly lower in the estuary site than in the adjacent marine sites. pH values for open coastal sites are high, and may have resulted from instrumentation error.

3.2 Water Clarity



Figures 7 & 8: Water clarity of coastal waters.

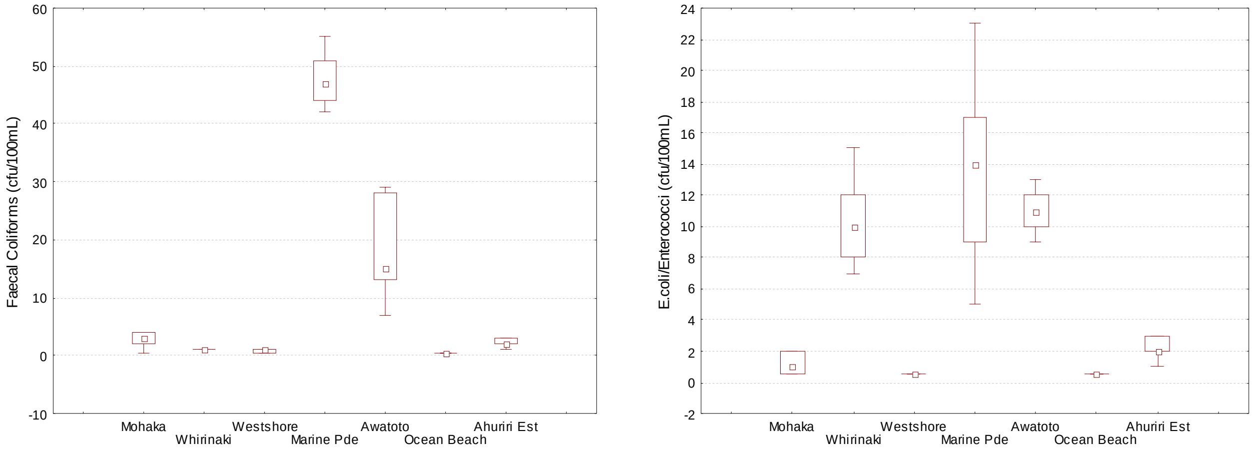
Water clarity was highest at Ocean Beach with lower suspended solids resulting in lower turbidity levels. Turbidity was generally low, with expectedly higher suspended solid levels within the Ahuriri Estuary.

3.3 Chorlophyll a and carbonaceous Biochemical Oxygen Demand

Chlorophyll a was below the detection level of 3µg/L at all sites sampled. This precluded assessment of the water quality in line with guideline values (ANZECC, 2000), which have a trigger level for slightly disturbed waters if 1µg/L. Future samples will be analysed using fluorometric methods to ensure a more accurate level of reporting that can be used to assess water quality.

Carbonaceous Biochemical Oxygen Demand was tested to account for the oxygen demand required by organic compounds excluding the oxygen demand required to convert nitrogenous compounds. Most samples were below detection limits, and of those above, cBOD was low between 1-2 gO_2m^{-3}, indicating low levels of oxidisable organic matter.

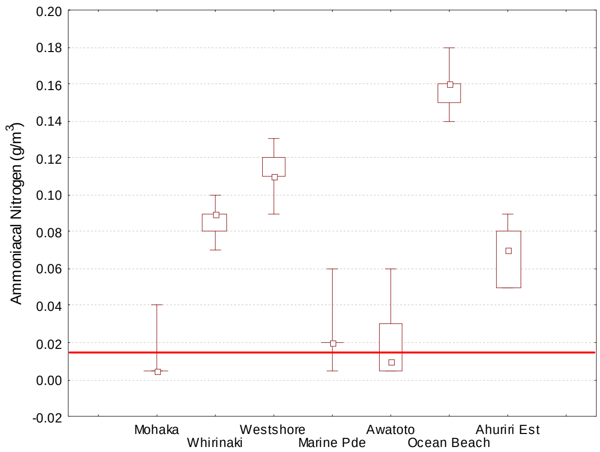
3.3 Bacteria

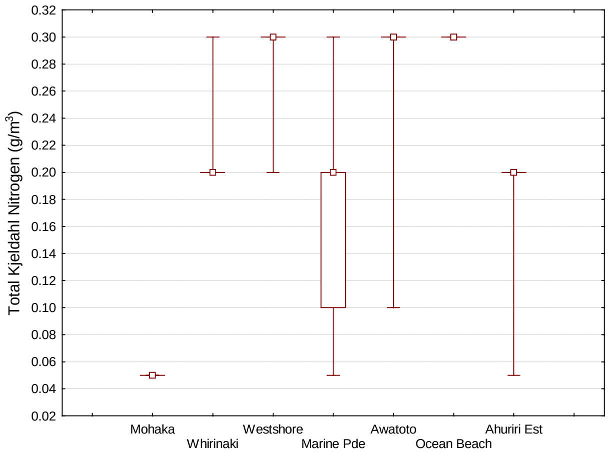


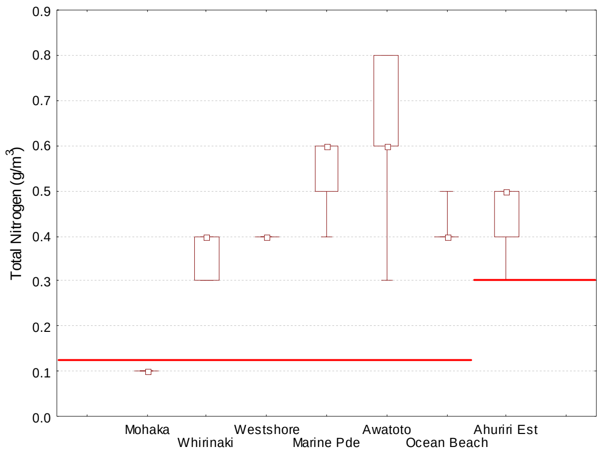
Figures 9 & 10: Bacteria levels in coastal waters.

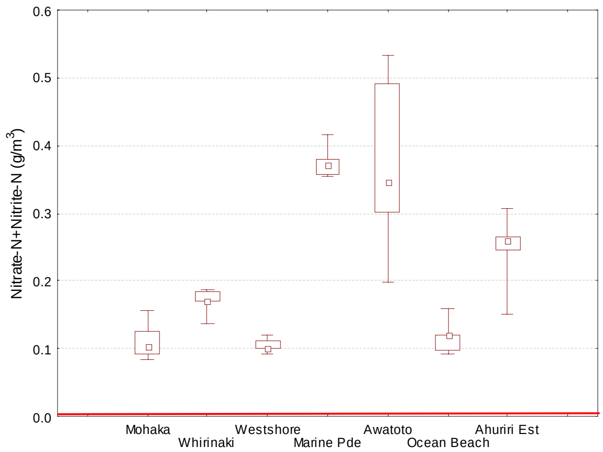
Coastal waters had relatively low microbiological concentrations with all results well within Ministry of Health and Ministry for the Environment Recreational Water Quality Guidelines. Slightly elevated concentrations were evident at Whirinaki Beach, Marine Parade and Awatoto, which may have been influenced by wastewater treatment systems (septic tanks – Whirinaki, municipal outfall Awatoto).

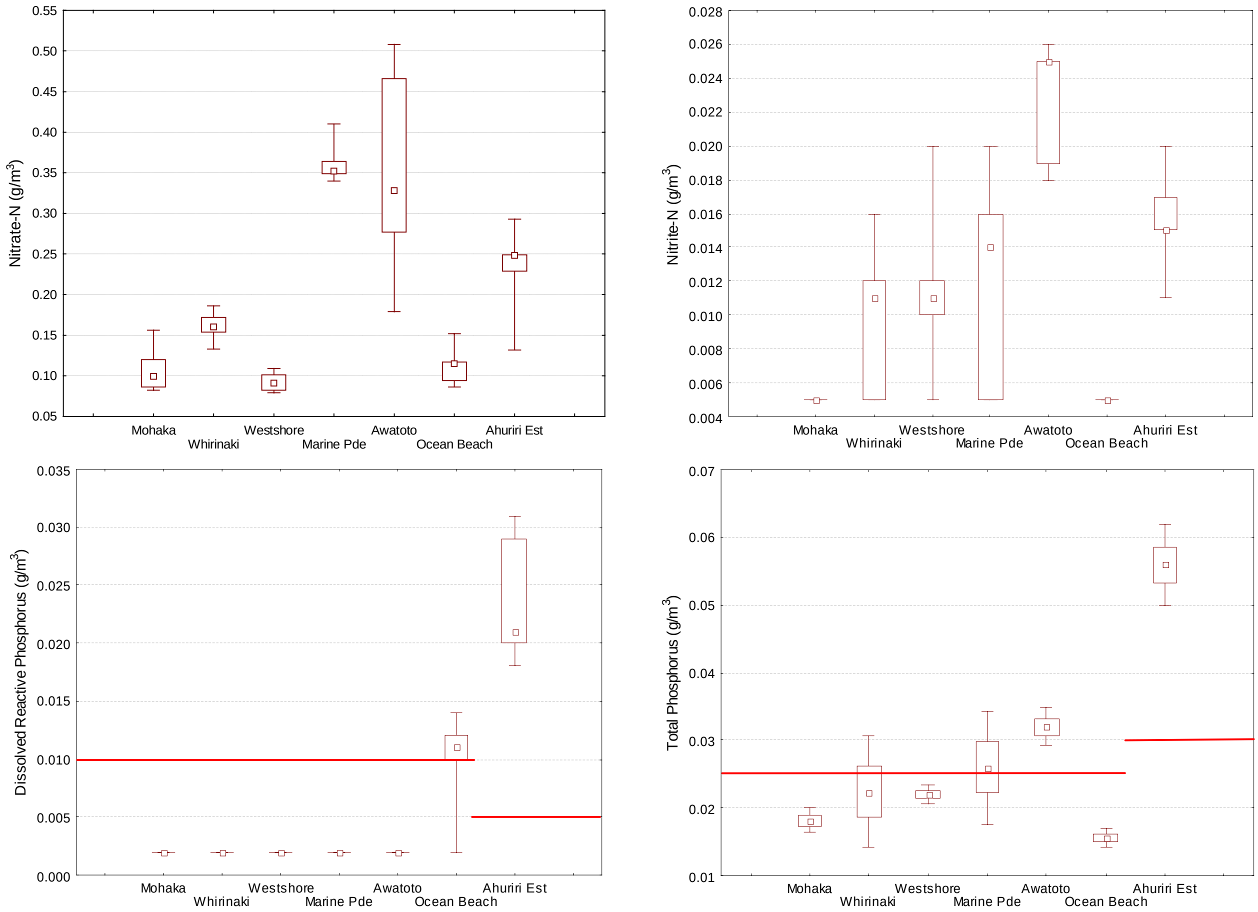
3.4 Nutrients











Figures 11-18: Nutrient concentrations of coastal waters.
Red line indicates ANZECC, 2000 default trigger values (guideline) for slightly disturbed ecosystems (Guidelines not yet available for NZ waters, currently use values listed for South-eastern Australian Marine waters as recommended in ANZECC). Guideline values may differ between marine and estuarine systems.

3.4.1 Ammoniacal Nitrogen

Ammoniacal nitrogen levels were significantly higher at Ocean Beach than Mohaka, Marine Parade and Awatoto, and at Westshore Beach than the Mohaka site. Median values at five of the seven sites; Whirinaki, Westshore, Marine Parade, Ocean Beach and Ahuriri Estuary, were all above ANZECC trigger values to assess the risk of adverse effects of nutrients in slightly disturbed ecosystems. Median NH4N levels were lowest at that Mohaka site, and highest at the Ocean Beach site with samples at this site returning values between nine and 12 times the trigger values.

3.4.2 Total Nitrogen

Similarly, median total nitrogen levels were again lowest at the Mohaka site, with two sites; Marine Parade and Awatoto having significantly higher levels. Median levels of total nitrogen were between two and seven time higher than guideline values, the Mohaka site was the only site with median total nitrogen levels within guideline values. With the exception of the Mohaka site, median concentrations of total Nitrogen were well above guideline values.

3.4.3 Total Kjeldahl Nitrogen (TKN)

Total kjeldahl nitrogen levels were variable, with the exception of the Mohaka site, which was consistently below detection levels. For all other sites TKN made up the majority of the total nitrogen concentration. TKN levels at Mohaka were significantly lower than Westshore, Awatoto and Ocean Beach, but similar between all other sites.

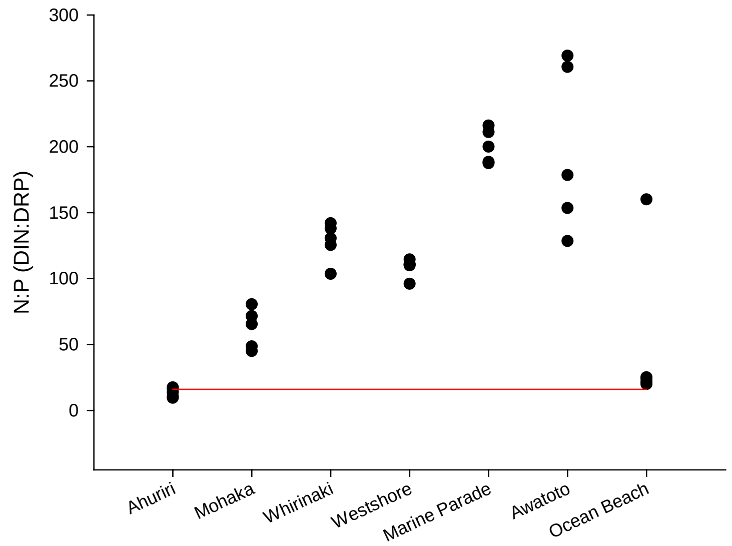
3.4.4 Nitrate + Nitrite Nitrogen (NOxN)
All sites exceeded ANZECC trigger values for total oxidised nitrogen, by between 10 (Ahuriri) and 106 (Awatoto) times. Nitrite levels were, as expected, very low.

3.4.5 Dissolved Reactive Phosphorus (DRP)
Dissolved Reactive Phosphorus levels were consistently below analytical detection limits for all marine sites within Hawke Bay. Unexpectedly, median levels at Ocean Beach exceeded guideline values. The highest DRP levels were recorded at the Ahuriri Estuary site, and although these represent values between 3.6 and 6.2 times higher than guideline values, the results are fairly consistent with samples taken monthly by HBRC between 1995 and 1997. There were significant differences between DRP levels at any of the sites sampled.

3.4.6 Total Phosphorus
Median total phosphorus levels were between 1 and 2 times above guideline values at Marine Parade, Awatoto and Ahuriri Estuary. Again, total phosphorus levels were found to be highest at the Ahuriri estuary. However these results were consistent with samples taken by HBRC between 1995 and 1997. Total phosphorus at Ocean Beach was low and within guideline values, indicating that little phosphorus was present in particulate form. Ahuriri estuary had significantly higher levels of TP than Mohaka or Ocean Beach; levels at Awatoto were also significantly higher than Ocean Beach. No differences in TP levels were found to be significant at any of the other sites sampled.

In general concentrations of nitrogen forms and total phosphorus exceeded guideline values at a number of sites. Nutrient concentrations were lowest at the Mohaka site, and generally highest at either the Awatoto or Ahuriri estuary site depending on the parameter.

To determine the limiting nutrient for each sample at each site, N:P ratios were calculated. The ratio of dissolved inorganic nitrogen (DIN = NNN + NH4N) and dissolved reactive phosphorus were used to reflect those nutrients available for uptake and therefore likely to affect primary production.



Figures 19: DIN:DRP ratios of coastal waters, red line indicates Redfield Ratio 16:1

The DIN:DRP ratios for 32 of the 35 samples taken were more than 16:1 indicating that production was limited by phosphorus availability. This is contrary to expected results as nitrogen is generally the limiting nutrient in marine systems.

3.5 Precision Estimates

To determine the number of sampling units (*n)* that would need to be collected in future monitoring to achieve a pre-selected level of precision, precision estimates were calculated. The replicated preliminary data collected from the pilot study was analysed to determine the number of samples needed to achieve a 0.1 level of precision (where *sd* = the standard deviation, *p* = 0.1 level of precision of the mean, *x*). This was undertaken to provide information on the number of samples that would be needed to ensure that results accurately reflected general water quality.

The results for each parameter at each site are detailed below:

$$n = [sd/(px)]^2$$

Site	NH4N	TN	TKN	NNN	NO3N	NO2N	DRP	TP
Ahuriri	6.9	4.1	15.6	5.5	6.7	4.4	5.9	1.2
Mohaka	170.1	0.0	0.0	6.6	7.8	0.0	0.0	1.0
Whiriniaki	1.8	2.3	4.1	1.3	1.5	23.6	0.0	13.6
Westshore	1.8	0.0	2.6	1.1	1.9	21.8	0.0	0.4
Marine Parade	68.0	2.7	32.9	0.4	0.6	31.6	0.0	10.4
Awatoto	115.2	10.9	11.8	13.6	14.9	2.8	0.0	0.7
Ocean Beach	0.9	1.1	0.0	5.2	5.2	0.0	22.1	0.7
Min	0.9	0.0	0.0	0.4	0.6	0.0	0.0	0.4
Max	170.1	10.9	32.9	13.6	14.9	31.6	22.1	13.6

Site	cBOD	FC	Enterococci	Turbidity	TSS
Ahuriri	0.0	14.5		3.4	1.7
Mohaka	13.9	30.2	39.9	5.1	81.4
Whiriniaki	13.9	0.0	9.5	3.3	5.6
Westshore	0.0	11.7	0.0	2.2	11.0
Marine Parade	15.3	1.2	26.4	1.1	63.8
Awatoto	6.2	27.7	2.1	2.8	4.0
Ocean Beach	6.2	0.0	0.0	6.2	0.0
Min	0.0	0.0	0.0	1.1	0.0
Max	15.3	30.2	39.9	6.2	81.4

The number of samples required to achieve a 0.1 level of precision varied depending on the parameter and site between 0 and 170 samples, and were affected greatly by non-detect results. Therefore, the use of replicate samples cannot be validated at this time and sampling will be restricted to one sample per parameter, per site. Long-term coastal water quality monitoring by the Auckland Regional Council has demonstrated that unreplicated sampling is effective in achieving trend detection (Shane Kelly, pers. comm.)

4.0 CONCLUSION

Water circulation within Hawke Bay is driven by shelf-water inflowing into the bay before separating out and moving north and south along the coast (Ross, 2002), although on smaller scales currents have been recorded travelling in many directions (Burgess, 1976). With the input of land-based contaminants from Hawke's Bays large river systems, contaminant loads have the potential to be spread extensively throughout the Bay. The residence time of the Bay is not known, however flushing times for activities occurring within the Bay indicate relatively high replacement driven by moderate to strong currents.

Nitrogen concentrations in Hawke's Bays coastal waters appear relatively high compared to other open coastal and harbour sites around New Zealand (ARC, 2002; Bolton-Ritchie, 2004; Park, 1998). Studies undertaken in 1999 on behalf of the Napier City Council recorded nitrate-nitrogen concentrations consistently less than 0.04mg/L (NCC, 1999). These were considered 'normal' nutrient concentrations for New Zealand coastal waters (Knox, 1988; NCC, 1999) and are consistent with nitrate-nitrogen levels in the Bay reported by Bradford et. al.(1976). The nitrate levels recorded in the current study were significantly higher, with an average value of 0.2 mg/L. Further investigations are clearly warranted to determine if there has been a significant increase in the nitrate-nitrogen concentration.

Dissolved reactive phosphorus levels in the Hawke Bay were low compared to open coastal and sheltered harbour sites out of the direct influence of discharge sources (ARC, 2002; Bolton-Ritchie, 2004), and lower than those recorded in both the Bradford and NCC studies (1976 and 1999, respectively).

Given the relatively high nutrient levels recorded, an assessment was made of nutrient concentrations in relation to current water quality guidelines (ANZECC, 2000). This indicated that the nutrient status of Hawke's Bays waters is above trigger values used to assess the risk of adverse effects of nutrients on the marine and estuarine ecosystem. However with such limited temporal information there is little scope to determine whether these elevated levels correspond to actual adverse effects. Chlorophyll a levels, which may have provided insight into the effect of nutrients, were not analysed at sufficient resolution to be able to determine whether primary production was considered high. Future analyses will be made using methods that will provide a higher level of detection.

Increases in primary production are driven by the relative availability of the major nutrients nitrogen and phosphorus. This is dependant on the input rate, fixation, and preferential storage, recycling and loss of each nutrient in the system. Marine systems are normally nitrogen limited as organic phosphorus is generally cycled faster than organic nitrogen (NRC, 2000). The results of the current study however indicate phosphorus limitation, although further sampling would be required to determine whether this is a characteristic of Hawke's Bay waters naturally or due to land-based activities, a seasonal characteristic, or an anomaly of the sampling.

In addition to nitrogen and phosphorus, silica and iron play a significant role in plankton production of coastal systems. The addition of these two elements does not in general promote plankton growth, but alters the community composition of the plankton. The concentration of these two elements was not assessed in the current study.

In all cases however, management of the limiting nutrient can not be looked at in isolation as reducing the inputs of one nutrient, but not managing inputs of another, can lead to situations where the other nutrient becomes the limiting factor in primary production.

The pilot programme has highlighted the need for a dataset spanning longer temporal scales to increase the confidence with which this information can be used to assist with environmental decision-making. Several issues have been raised with regard to the nutrient status of the nearshore coastal waters, which will only be rectified by gaining an understanding of the character and variability of the coastal waters through long-term monitoring. Long-term, repeated assessment of water quality will be necessary to determine the state and health of this resource, and to assess the effectiveness of Council policy in sustaining the life supporting capacity of our coastal waters.

5.0 RECOMMENDATIONS

Given the suggested propensity for accumulation of contaminants of concern (nutrients and sediments) within the coastal environment, and the effect of the constituent parts on the abundance and distribution of marine organisms, routine monitoring is required to ensure the long-term health of our coastal waters and ecosystems. Monitoring of water quality parameters will allow for the detection of change that may be beyond the resilience of the system, and therefore change which may have chronic effects leading to long-term environmental degradation. Monitoring will provide us with information that can assist in the management of our coastal areas, and assess the effectiveness of policies in maintaining environmental integrity.

Monitoring has been proposed through the Coastal Monitoring Strategy (Madarasz, 2006) as follows:

State of the Environment monitoring of seven coastal water sites (as per the pilot project), for all parameters tested within the pilot study excluding cBOD is recommended. Sampling frequency has been proposed at twice per season to assist with trend detection whilst still meeting resource limits. Once established, the sampling frequency can be reviewed by looking at temporal variations in water quality at each site.

Issue	What do we want to achieve?	How do we know if we are achieving this?
Coastal Water Quality (Eutrophication) including:		
- Discharge of contaminants	Enhancement of water quality where practicable	SOE Coastal Water Quality Monitoring Compliance Monitoring
	Minimise the effects of discharges of contaminants to the CMA. • DO 80% Saturation • No undesirable biological growths	SOE Coastal Water Quality Monitoring Targeted Investigations Compliance Monitoring
	Management of water to meet classification standards • DO 80% Saturation • No undesirable biological growths	SOE Coastal Water Quality Monitoring Compliance Monitoring
- Diffuse runoff	Enhancement of water quality where practicable	SOE Coastal Water Quality Monitoring Targeted Investigations

Benefits to Council
Hawke's Bay Regional Council does not currently possess the technical information concerning Hawke's Bays coastal water quality required to underpin environmental decision-making. This position may expose Council to challenge given that there remains no long-term monitoring information with which to support policy.

It is envisaged that a State of the Environment Coastal Water Quality Monitoring Programme will assist Council to:

- Monitor the effectiveness of rules and policies in achieving the desired objectives;
- Detect environmental trends and alert Council to environmental degradation;
- Determine which management practises are appropriate to sustain the life supporting capacity of coastal waters;
- Gauge the success or failure of management practises in achieving desired environmental results.

- Follow changes in the quality of water from specific discharges (e.g. improved treatment technologies);
- Determine the cost/benefit of management techniques and practises where appropriate;
- Understand the pressures exerted on coastal water quality, and the environments response to such pressures, to ensure effective policy development;
- Educate resource users on the background condition of coastal waters; and
- Will provide the technical information required to support Councils decision-making.

Duration of the programme
A State of the Environment monitoring programme is normally designed to continue in perpetuity, or until such time as a review is undertaken to assess the programmes outputs in relation to current information requirements.

A State of the Environment coastal water quality monitoring programme would be recommended as an ongoing programme, with reviews undertaken during the 5 yearly SOE reporting period.

Annual funding requirements for nearshore coastal water quality monitoring are detailed. Additional funding for targeted investigation and research may be required.

External Expenditure Requirements

Project	2006/07	2007/08	2008/09 LTCCP/ Review	2009/10	20010/11
SOE Coastal Water Quality Monitoring (based on 7 sites sampled twice per season, 1 replicate per site) (Includes Helicopter transport $9000 and sample analysis $11000)	$20,000	$20,000	$20,000	$20,000	$20,000

Internal Resources (weeks)

Section	2006/07	2007/08	2008/09 LTCCP/ Review	2009/10	20010/11
Data Collection	2.4	2.4	2.4	2.4	2.4
Data Management	0.6	0.6	0.6	0.6	0.6
Scientist	2.4	2.4	5	2.4	2.4
Corporate Support	0	0	0.1	0	0
Computer Services	0	0	0.1	0	0

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APPENDICIES

APPENDIX ONE: Selected Indicator Description

APPENDIX TWO: Site Description

APPENDIX THREE: Laboratory Methods

APPENDIX FOUR: ANOVA Results

APPENDIX FIVE: Catchment Land-use Characteristics

APPENDIX ONE: COASTAL WATER QUALITY INDICATORS

Changes to the loading, or bioavailability of nutrients in the water column.

Indicator	Type of indicator (P/S/R)	What does the indicator measure?	Collection	Analysis	Reporting
Chlorophyll *a*	State Indicator.	Chlorophyll *a*, the green photosynthetic pigment in plants, can be used as an indicator of the abundance and biomass of phytoplankton. It is also often used as an indirect measure of nutrients within the water body. The ability of a system to withstand nutrient loading can vary depending on the constituents of the system. For example a high abundance of bivalve filter feeders may mitigate the impacts of increased nutrients. Conversely, these effects may be exacerbated by declines in shellfish numbers, increased water temperatures or changes in flushing regimes. Used in combination, direct nutrient analysis and chlorophyll a analysis can measure both changes to the nutrient inputs, as well as the bioavailablity of the nutrients for plant growth.	Collection of 1L of water from the top 0.5m of water. Keep sample cool and dark. Spatial variations in phytoplankton and hence chlorophyll *a* concentrations can be reduced by sampling the same location at each sampling period. Similarly, temporal variations in phytoplankton communities caused by diurnal migration through the water column can be reduced by sampling at the same time of day. This can be achieved by setting up permanent sampling sites, and by undertaking sampling by visiting sites in a predetermined order.	Analysed from direct water samples by filtering through 0.45μ mesh filter paper. Chlorophyll *a* concentration determined via spectrophotometer and expressed as micrograms per litre (μg/l).	Reported as median chlorophyll *a* concentration.
Total and dissolved nutrients in the water column.	State Indicator.	Nutrient enrichment is pertinent to Hawke's Bay coastal water due to the surrounding land use activities, and associated inputs to waterways. Direct measures of total and dissolved nutrients can provide indication of changing land use practices, as well as provide insights into the cumulative effects of nutrient inputs. Nutrient analysis is required in order to determine the trophic status of the Hawke's Bay coastal waters. It will also be used to detect and seasonal variations.	Samples will be collected from the top 1m of water. Initially, samples will also be taken from 5m depth and salinity compared to ensure full mixing.	Sample will be analysed in line with APHA: Standard Methods for the Examination of Water and Wastewater (20th ed.).	Results will be reported as average concentration per site, per sampling period.

Changes to turbidity, sediment loads and clarity.

Indicator	Type of indicator (P/S/R)	What does the indicator measure?	Collection	Analysis	Reporting
Turbidity, Suspended Sediments and Clarity.	State Indicator.	Turbidity is a measure of the suspended material within water that gives it an 'unclear' or 'murky' appearance. Decreases in visual clarity can affect photosynthetic rate by limiting access to light. It can also affect community dynamics, such as an increase in predatory species that use non-visual cues, or increases in the preponderance of plankton species that can photosynthesise in low light or can control their position in the water, such as blue-green algae (Waterwatch, 2005). Reductions in primary productivity caused by light limitation can also act to increase dissolved nutrient concentrations (Scheltinga et al, 2004). Increased turbidity can alter temperature as suspended particles absorb heat within the water leading to increased temperatures, and subsequently decreased concentrations of dissolved oxygen (Waterwatch, 2005).	Turbidity and Suspended solid measurements will be collected by grab sample.	Sample will be analysed in line with APHA: Standard Methods for the Examination of Water and Wastewater (20th ed.).	Reported as average turbidity, SS per site, per sampling period.

Changes to the physio-chemical parameters of coastal waters.

Indicator	Type of indicator (P/S/R)	What does the indicator measure?	Collection	Analysis	Reporting
Temperature	State Indicator.	Temperature in water bodies fluctuates over many scales, both spatially and temporally. Most organisms can tolerate moderate changes in temperature. Changes beyond the tolerance range can result in sub-lethal and lethal effects, such as increases in normal metabolic functions. Photosynthesis and bacterial decomposition are both faster at higher temperatures, oxygen becomes less soluble and salts are more soluble in warmer waters (Waterwatch, 2005).	Temperature will be collected from the water by hand-held instrumentation.	N/A	Temperature will be reported as average temperature per site, per sampling period.

Conductivity and Salinity	State Indicator.	Salinity and conductivity measurements can provide an indication of the freshwater input, which can ultimately provide information on the pollutants expected to be associated with a given area. Most organisms have a tolerance range to changes in salinity. Alterations beyond this range begin to have lethal and sublethal effects. This parameter can be indicative of freshwater input and potential stratification of water bodies.	Conductivity/Salinity will be collected from the water by hand-held instrumentation.	N/A	Conductivity and salinity will be reported as average μScm^{-1} (microSiemens per cm) and as parts per thousand (ppt, $^{0}/_{00}$) respectively.
Dissolved Oxygen (DO)	State Indicator.	With the exception of marine mammals, all aquatic organisms rely on obtaining oxygen from the water in the form of DO. Currently there is a requirement within Regional Council plans that activities shall not result in reductions of DO beyond 20% of the saturation concentration. Consequently an understanding of the natural variability in the concentration of DO, particularly with regard to natural perturbations is essential for determining whether this standard is appropriate. Reductions in the concentration of DO leading to anoxic or hypoxic events can also indicate a response to stressors including eutrophication, increases in organic matter, and increased phytoplankton growth.	DO will be collected from the water using hand-held field instrumentation. Diurnal variation in DO can occur therefore sampling should be undertaken at the same time of day.	N/A	Reported as mg/l and % saturation.
pH – a measure of alkalinity or acidity of the water. pH should not vary much in highly buffered coastal waters.	State Indicator.	Alterations to pH levels beyond an organism's range of resilience can disrupt physiological processes, having lethal and sublethal effects on an individual scale (Scheltinga et al, 2004). Changes in pH can also affect the solubility, and toxicity of many compounds and heavy metals. Currently there is a requirement within Regional Council plans that activities must not result in any change in the pH of the receiving waters beyond the mixing zone.	pH will be collected from the surface waters using hand-held field instrumentation.	N/A	Average pH per site, per sampling period.

Changes in microbiological levels in estuarine and marine waters.

Indicator	Type of indicator (P/S/R)	What does the indicator measure?	Collection	Analysis	Reporting
Escherichia coli (E. coli) or Enterococci and Faecal Coliforms[NB:3]	State Indicator.	E. coli (brackish and freshwater) and enterococci (marine waters) are used to indicate faecal contamination of a waterway and relative risk to those using the area for contact recreation. This can be indicative of management issues resulting from on-site wastewater systems, coastal outfalls, and rural runoff.	Samples will be collected using protocols developed for the Recreational Water Quality Monitoring programme, in line with Ministry for the Environment and Ministry of Health Guidelines (2003).	Sample will be analysed in line with APHA: Standard Methods for the Examination of Water and Wastewater (20^{th} ed.).	Sample will be reported in terms of % compliance with guidelines.

Indicator	Analysis Cost[4]	Analysis
Chlorophyll a	$27.50	Laboratory
Total and Dissolved Nutrients[5]	$89.43	Laboratory
E. coli	$38.00	Laboratory
Faecal Coliforms		Laboratory
Enterococci		Laboratory
Suspended Solids	$16.15	Laboratory
Turbidity	$7.65	Laboratory
Clarity	N/A	Field–Black Disk
Temperature	N/A	Field
Conductivity	N/A	Field
Salinity	N/A	Field
Dissolved Oxygen (DO)	N/A	Field
pH	N/A	Field
TOTAL	**$ 178.73 Per Site**	

Nutrient Analyses:

TP	Total phosphorus	$16.15
NO3- - N	Nitrate Nitrogen	$47.60
NO2- - N	Nitrite Nitrogen	
TON	Total Organic Nitrogen	
DRP	Dissolved Reactive Phosphorus	
Ammoniacal N	Total Ammoniacal Nitrogen	
TKN	Total Kjeldahl Nitrogen	$21.68
TN (TKN + NoxN)	Total Nitrogen	$0.00
Filtration		$4.00
TOTAL		**$89.43**

**NB[3]: Although it is acknowledged that *E. coli* and Enterococci have been identified as more robust indicators of faecal contamination and subsequent risk of illness, faecal coliforms have been added to ensure consistency and interpretability between the results of this programme and guidelines (i.e. ANZECC), consent conditions, and plans (i.e. RCP and PRRMP).

[4] Based on quote provided by Hills Laboratories 13/6/2006.
[5] See break down of nutrient analyses.

APPENDIX TWO: SITE DESCRIPTIONS

Ahuriri Estuary (at Pandora Pond)
Reason for inclusion: The estuary has been identified as one of Napier's most significant areas of environmental value, despite extensive modification and stormwater discharges. In spite of the potential for contamination via numerous diffuse and point-source discharges, its proximity to a large urban centre, and an adjacent marine, this site has demonstrated an apparent resilience to reductions in water quality. Combined with its recreational and ecological value, it has been recommended for inclusion in the coastal SOE WQ monitoring project.

Other affiliations: This site is also part of the Recreational Water Quality Monitoring project (431-02), and is listed as a significant area within the RCP.

Coastal Mohaka River
Reason for inclusion: To assess the cumulative impacts of the Mohaka River catchment on the water quality of the coastal receiving environment.

Other affiliations: Site at Mohaka Beach (196), Corresponding Surface Water Quality Sites Mohaka River at Raupunga (3), Maungaturanga Stream at State Highway 2 bridge crossing (2115).

Whirinaki Beach
Whirinaki Beach, approximately 15km north of Napier, is a relatively shallow coastal area of sands and gravel subject to continual movement from waves (Barter and Keeley, 2003). The Esk River discharges to the south of Whirinaki Beach after draining areas of viticulture, horticulture, forestry and pasture. This site provides for consistent representation along the Hawke's Bay coastline, and can be used to assess catchment impacts on coastal water quality.

Other affiliations: The Esk River at Eskdale Park is part of the Recreational Water Quality Monitoring project (431-02).

Westshore Beach
Reason for inclusion: Westshore Beach is located adjacent to the Westshore community in central Napier. Its proximity to a large urban centre, marina, port area, and dredge disposal site, coupled with the stormwater discharges directly to the beach area make this area suitable as a site to assess the impacts of the urban catchment on water quality.

Other affiliations: This site is also part of the Recreational Water Quality Monitoring project (431-02). There are numerous adjacent water quality sites within the Ahuriri Estuary.

Marine Parade Beach
Reason for inclusion: Marine Parade Beach is located adjacent to the Napier central city and south of the Port of Napier. Its proximity to a large urban centre and port area, make this site suitable for assessing the impacts of the urban catchment on water quality.

Awatoto (Coastal Tutaekuri, Ngaruroro, Clive, Tukituki Rivers)
Reason for inclusion: To assess the cumulative impacts of the Tutaekuri, Ngaruroro, Clive and Tukituki River catchments on the water quality of the coastal receiving environment. This site may also indicate the influence of the Napier City and Hastings District sewer outfalls.

Other affiliations: There are numerous adjacent water quality sites within the individual river and estuarine areas

Ocean Beach
Reason for inclusion: Ocean Beach is located directly south of Cape Kidnappers, and its proximity to Napier and Hastings makes this beach a popular site for contact recreation. The southern end of Ocean Beach is included in the Waimarama Significant Conservation Area. The inclusion of this beach in the proposed SOE coastal water quality monitoring programme maintains consistent representation along the Hawke's Bay coastline.

Other affiliations: This site is also part of the Recreational Water Quality Monitoring project (431-02).

APPENDIX THREE: LABORATORY METHODS

Parameter	Method used	Detection Limit
pH	PH meter APHA 4500-H B 20th ed. 1998	0.1 pH unit
Turbidity	Hach 2100N Turbidity meter APHA 2130 B 20th ed. 1998	0.1 NTU
Total Suspended Solids	Filtration(GF/C 1.2μm) retained residue dried at 103-105°C, Gravimetric APHA 2540 D 30th ed. 1998	3 g.m3
Total Ammoniacal-N	Phenol/hypochlorite colorimetry. Discrete analyser. APHA 4500-NH_3F (modified from manual analysis) 20th ed. 1998	0.01 g.m3
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N	0.2 g.m3
Total Kjeldahl digestion	Sulphuric acid digestion with copper sulphate catalyst. APHA 4500-N_{org} D (modified) 20th ed. 1998.	N/A
Total Kjeldahl Nitrogen (TKN)	Kjeldahl digestion, phenol/hypochlorite colorimetry (Discrete analysis). APHA 4500-N_{org} C (modified) 4500- NH_3F (modified) 20th ed. 1998	0.1 g.m3
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction. Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m.3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) – Nitrite-N	0.002 g.m3
Nitrite-N	Automated Azo dye colorimetry, flow injection analyser. APHA 4500-NO_3^- I (Proposed) 20th ed. 1998	0.002 g.m3
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser, APHA 4500-P E (modified from manual analysis) 20th ed. 1998.	0.004 g.m3
Total Phosphorus	Acid persulphate digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 20th ed. 1998.	0.004 g.m3
Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. APHA 5210 B 20th ed. 1998	1 g.0_2.m3
Chlorophyll a*	Acetone extraction. Spectroscopy APHA 10200 H 20th ed. 1998	0.003 g.m3
Escherichia coli	Confirmation of colonies ex mFC by fluorescence of transferred membrane on NA-MUG after 4 hrs at 35°C. Analysed at BioTest Laboratories. APHA 9222 G, 20th ed. 1998	1 cfu/100 mL
Faecal Coliforms	Membrane filtration with resuscitation, count on mFC agar at 44.5°C after 24 hrs. Analysed at BioTest Laboratories. APHA 9222 D, 20th ed. 1998	1 cfu/100 mL
Enterococci	Membrane filtration, count on mE agar, confirmed by EIA agar at 41.5°C after 48 hrs. Analysed at BioTest Laboratories. APHA 9230 C, 20th ed. 1998	1 cfu/100 mL

APPENDIX FOUR: ANOVA RESULTS

TEMP

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Temp	11.6	28.59477	6	0.0001	32.45463	0

Multiple comparisons p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		0.530466	1.000000	1.000000	1.000000	0.352180	1.000000
Whiri	0.530466		0.070779	1.000000	**0.002561**	**0.000077**	1.000000
West	1.000000	0.070779		0.645825	1.000000	1.000000	1.000000
Mar Pde	1.000000	1.000000	0.645825		**0.044857**	**0.002405**	1.000000
Awatoto	1.000000	**0.002561**	1.000000	**0.044857**		1.000000	0.843084
Ocean	0.352180	**0.000077**	1.000000	**0.002405**	1.000000		0.094982
Ahuriri	1.000000	1.000000	1.000000	1.000000	0.843084	0.094982	

PH

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis p	
All	pH	8.65	20.58824	6	0.0022	23.98174	0.0005

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	1.000000	1.000000	1.000000	0.145478
Whiri	1.000000		1.000000	1.000000	**0.025069**	0.782093	**0.000696**
West	1.000000	1.000000		1.000000	1.000000	1.000000	0.218905
Mar Pde	1.000000	1.000000	1.000000		0.382904	1.000000	**0.022487**
Awatoto	1.000000	**0.025069**	1.000000	0.382904		1.000000	1.000000
Ocean	1.000000	0.782093	1.000000	1.000000	1.000000		0.812102
Ahuriri	0.145478	**0.000696**	0.218905	**0.022487**	1.000000	0.812102	

DO

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	DO	6.375	23.6	5	0.0003	24.65258	0.0002

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	0.266252	1.000000	**0.025076**	**0.000428**	
Whiri	1.000000		1.000000	1.000000	0.446452	**0.019571**	
West	0.266252	1.000000		1.000000	1.000000	1.000000	
Mar Pde	1.000000	1.000000	1.000000		0.446452	**0.019571**	
Awatoto	**0.025076**	0.446452	1.000000	0.446452		1.000000	
Ocean	**0.000428**	**0.019571**	1.000000	**0.019571**	1.000000		
Ahuriri							

COND

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Conductivity	49.05	22.10526	6	0.0012	29.92076	0

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	0.399129	1.000000	1.000000	**0.022487**	1.000000
Whiri	1.000000		1.000000	1.000000	1.000000	0.942108	0.182950
West	0.399129	1.000000		0.284648	1.000000	1.000000	**0.004469**
Mar Pde	1.000000	1.000000	0.284648		1.000000	**0.014429**	1.000000
Awatoto	1.000000	1.000000	1.000000	1.000000		1.000000	0.167033
Ocean	**0.022487**	0.942108	1.000000	**0.014429**	1.000000		**0.000077**
Ahuriri	1.000000	0.182950	**0.004469**	1.000000	0.167033	**0.000077**	

SAL

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Salinity	32.2	23.56667	6	0.0006	29.6817	0

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	0.200209	1.000000	1.000000	**0.009127**	1.000000
Whiri	1.000000		1.000000	0.323641	1.000000	0.671318	1.000000
West	0.200209	1.000000		**0.005691**	1.000000	1.000000	0.530466
Mar Pde	1.000000	0.323641	**0.005691**		0.152368	**0.000104**	1.000000
Awatoto	1.000000	1.000000	1.000000	0.152368		1.000000	1.000000
Ocean	**0.009127**	0.671318	1.000000	**0.000104**	1.000000		**0.032767**
Ahuriri	1.000000	1.000000	0.530466	1.000000	1.000000	**0.032767**	

TURBDITY

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Turbidity	2.1	21.6667	6	0.0014	27.5244	0.001

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		0.551994	1.000000	1.000000	1.000000	**0.008121**	1.000000
Whiri	0.551994		1.000000	1.000000	**0.026460**	1.000000	1.000000
West	1.000000	1.000000		1.000000	1.000000	0.086188	1.000000
Mar Pde	1.000000	1.000000	1.000000		0.064056	1.000000	1.000000
Awatoto	1.000000	**0.026460**	1.000000	0.064056		**0.000112**	0.530466
Ocean	**0.008121**	1.000000	0.086188	1.000000	**0.000112**		0.433389
Ahuriri	1.000000	1.000000	1.000000	1.000000	0.530466	0.433389	

TSS

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	TSS	9	15.4	6	0.0174	21.71253	0.0014

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	1.000000	1.000000	0.297158	1.000000
Whiri	1.000000		1.000000	1.000000	1.000000	1.000000	**0.044857**
West	1.000000	1.000000		1.000000	1.000000	0.145478	1.000000
Mar Pde	1.000000	1.000000	1.000000		1.000000	0.489582	0.908063
Awatoto	1.000000	1.000000	1.000000	1.000000		0.132531	1.000000
Ocean	0.297158	1.000000	0.145478	0.489582	0.132531		**0.000376**
Ahuriri	1.000000	**0.044857**	1.000000	0.908063	1.000000	**0.000376**	

CHLORA

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Chlorphyll a	0.00154	0	6	1	0	1

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
Whiri	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
West	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
Mar Pde	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
Awatoto	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
Ocean	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
Ahuriri	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

CBOD

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	cBOD	0.5	21.9333	6	0.0012	22.27702	0.0011

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	0.261016	1.000000	1.000000	1.000000
Whiri	1.000000		1.000000	0.261016	1.000000	1.000000	1.000000
West	1.000000	1.000000		0.055058	0.875063	0.875063	1.000000
Mar Pde	0.261016	0.261016	0.055058		1.000000	1.000000	0.055058
Awatoto	1.000000	1.000000	0.875063	1.000000		1.000000	0.875063
Ocean	1.000000	1.000000	0.875063	1.000000	1.000000		0.875063
Ahuriri	1.000000	1.000000	1.000000	0.055058	0.875063	0.875063	

FC

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	FC	2	25.2	6	0.0003	29.67674	0

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	0.621167	1.000000	0.551994	1.000000
Whiri	1.000000		1.000000	**0.042593**	0.433389	1.000000	1.000000
West	1.000000	1.000000		**0.006413**	0.094982	1.000000	1.000000
Mar Pde	0.621167	**0.042593**	**0.006413**		1.000000	**0.000230**	0.645825
Awatoto	1.000000	0.433389	0.094982	1.000000		**0.006042**	1.000000
Ocean	0.551994	1.000000	1.000000	**0.000230**	**0.006042**		0.530466
Ahuriri	1.000000	1.000000	1.000000	0.645825	1.000000	0.530466	

ECOLENT

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskal Wallis	p
All	E.coli/Entn	2	30.19608	6	0	30.11031	0

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		0.451461	1.000000	0.152368	0.284648	1.000000	1.000000
Whiri	0.451461		**0.036416**	1.000000	1.000000	**0.036416**	1.000000
West	1.000000	**0.036416**		**0.009127**	**0.020153**	1.000000	1.000000
Mar Pde	0.152368	1.000000	**0.009127**		1.000000	**0.009127**	1.000000
Awatoto	0.284648	1.000000	**0.020153**	1.000000		**0.020153**	1.000000
Ocean	1.000000	**0.036416**	1.000000	**0.009127**	**0.020153**		1.000000
Ahuriri	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

NH4N

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskal Wallis	p
All	NH4N	0.07	26.94079	6	0.001	30.26308	0

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		0.218905	**0.017070**	1.000000	1.000000	**0.000568**	1.000000
Whiri	0.218905		1.000000	1.000000	0.782093	1.000000	1.000000
West	**0.017070**	1.000000		0.152368	0.086188	1.000000	1.000000
Mar Pde	1.000000	1.000000	0.152368		1.000000	**0.008610**	1.000000
Awatoto	1.000000	0.782093	0.086188	1.000000		**0.004205**	1.000000
Ocean	**0.000568**	1.000000	1.000000	**0.008610**	**0.004205**		0.489582
Ahuriri	1.000000	1.000000	1.000000	1.000000	1.000000	0.489582	

TKN

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskal Wallis	p
All	TKN	0.2	21.93333	6	0.0012	23.2158	0.0007

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		0.753034	**0.020153**	1.000000	**0.040434**	**0.004469**	1.000000
Whiri	0.753034		1.000000	1.000000	1.000000	1.000000	1.000000
West	**0.020153**	1.000000		1.000000	1.000000	1.000000	1.000000
Mar Pde	1.000000	1.000000	1.000000		1.000000	0.671318	1.000000
Awatoto	**0.040434**	1.000000	1.000000	1.000000		1.000000	1.000000
Ocean	**0.004469**	1.000000	1.000000	0.671318	1.000000		0.399129
Ahuriri	1.000000	1.000000	1.000000	1.000000	1.000000	0.399129	

TN

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskal Wallis	p
All	TN	0.4	19.02174	6	0.0041	22.41718	0.001

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	0.782093	**0.004205**	**0.002903**	0.367260	0.152368
Whiri	1.000000		1.000000	0.597324	0.470185	1.000000	1.000000
West	0.782093	1.000000		1.000000	1.000000	1.000000	1.000000
Mar Pde	**0.004205**	0.597324	1.000000		1.000000	1.000000	1.000000
Awatoto	**0.002903**	0.470185	1.000000	1.000000		1.000000	1.000000
Ocean	0.367260	1.000000	1.000000	1.000000	1.000000		1.000000
Ahuriri	0.152368	1.000000	1.000000	1.000000	1.000000	1.000000	

NOXN

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskal Wallis	p
All	NOxN	0.171	26.94079	6	0.0001	28.61849	0.0001

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	**0.010248**	**0.031072**	1.000000	0.551994
Whiri	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
West	1.000000	1.000000		**0.004205**	**0.013637**	1.000000	0.297158
Mar Pde	**0.010248**	1.000000	**0.004205**		1.000000	**0.019072**	1.000000
Awatoto	**0.031072**	1.000000	**0.013637**	1.000000		0.055058	1.000000
Ocean	1.000000	1.000000	1.000000	**0.019072**	0.055058		0.843084
Ahuriri	0.551994	1.000000	0.297158	1.000000	1.000000	0.843084	

NO3N

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Nitrate	0.156	26.99346	6	0.0001	28.49846	0.0001

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	**0.016143**	0.052326	1.000000	0.812102
Whiri	1.000000		0.977223	1.000000	1.000000	1.000000	1.000000
West	1.000000	0.977223		**0.001988**	**0.007658**	1.000000	0.191406
Mar Pde	**0.016143**	1.000000	**0.001988**		1.000000	**0.026460**	1.000000
Awatoto	0.052326	1.000000	**0.007658**	1.000000		0.082074	1.000000
Ocean	1.000000	1.000000	1.000000	**0.026460**	0.082074		1.000000
Ahuriri	0.812102	1.000000	0.191406	1.000000	1.000000	1.000000	

NO2N

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	Nitrite	0.011	17.26974	6	0.0083	22.74086	0.0009

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	1.000000	**0.005046**	1.000000	0.218905
Whiri	1.000000		1.000000	1.000000	0.310150	1.000000	1.000000
West	1.000000	1.000000		1.000000	0.908063	1.000000	1.000000
Mar Pde	1.000000	1.000000	1.000000		0.977223	1.000000	1.000000
Awatoto	**0.005046**	0.310150	0.908063	0.977223		**0.005046**	1.000000
Ocean	1.000000	1.000000	1.000000	1.000000	**0.005046**		0.218905
Ahuriri	0.218905	1.000000	1.000000	1.000000	1.000000	0.218905	

DRP

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	DRP	30.81197	30.81197	6	0	30.85409	0

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	1.000000	1.000000	1.000000	0.055058
Whiri	1.000000		1.000000	1.000000	1.000000	1.000000	0.055058
West	1.000000	1.000000		1.000000	1.000000	1.000000	0.055058
Mar Pde	1.000000	1.000000	1.000000		1.000000	1.000000	0.055058
Awatoto	1.000000	1.000000	1.000000	1.000000		1.000000	0.055058
Ocean	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
Ahuriri	0.055058	0.055058	0.055058	0.055058	0.055058	1.000000	

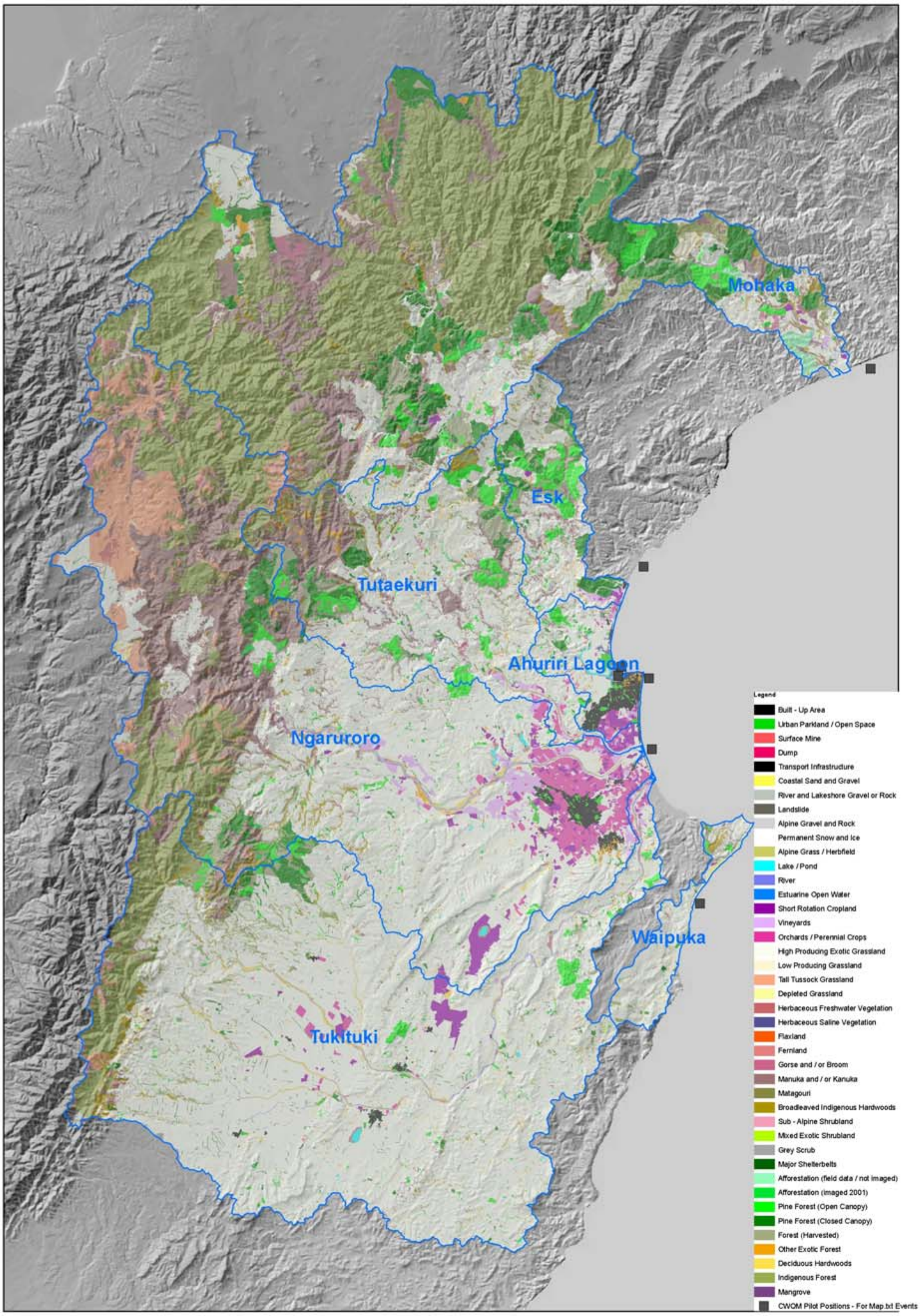
TP

Site	Parameter	Overall Med	Chi-Square	df	p	Kruskall Wallis	p
All	TP	0.022	22.10526	6	0.0012	28.26112	0.0001

Mulitple comparisions p values 2 tailed

	Moh	Whiri	West	Mar Pde	Awatoto	Ocean	Ahuriri
Moh		1.000000	1.000000	1.000000	0.200209	1.000000	**0.005046**
Whiri	1.000000		1.000000	1.000000	1.000000	1.000000	0.078139
West	1.000000	1.000000		1.000000	1.000000	0.489582	0.551994
Mar Pde	1.000000	1.000000	1.000000		1.000000	0.167033	1.000000
Awatoto	0.200209	1.000000	1.000000	1.000000		**0.013637**	1.000000
Ocean	1.000000	1.000000	0.489582	0.167033	**0.013637**		**0.000149**
Ahuriri	**0.005046**	0.078139	0.551994	1.000000	1.000000	**0.000149**	

APPENDIX FIVE: CATCHMENT LAND-USE CHARACTERISTICS



CATCHMENT LAND-USE CHARACTERISTICS – Sum of hectares

LCDB2 - Name	Ahuriri Lagoon	Esk River	Mohaka	Ngaruroro	Tukituki	Tutaekuri	Waipuka	GRAND TOTAL
Afforestation (imaged, post LCDB1)	49.02	129.58	771.02	1107.71	244.26	347.29	6.03	2654.91
Afforestation (not imaged)	1.47	55.78	1474.28	78.29	90.96	123.36		1824.14
Alpine Gravel and Rock			276.33	1301.87	287.74	208.7		2074.64
Broadleaved Ingidenous Hardwoods	41.45	243.98	4751.06	2957.14	3557.87	1668.92	339.2	13559.62
Built-up Area	2250.13	46.98	4.31	2156.82	582.8	67.93	9.54	5118.51
Coastal Sand and Gravel	17.23	5.77		26.27	7.32	12.98	235.24	304.81
Deciduous Hardwoods	36.39	78.1	156.49	1397.7	3192.67	478.31	123.09	5462.75
Depleted Tussock Grassland				253.15				253.15
Dump				16.65	3.73	5.43		25.81
Estuarine Open Water	73.37			0.08		3.22		76.67
Fernland			129.17	63.14	4.75	70.91	5.32	273.29
Forest Harvested	7.1	1497.41	4194.69	1207.85	1877.19	3333.38	2.34	12119.96
Gorse and Broom	71.23	113.76	1952.29	660.23	343.15	514.69	4.21	3659.56
Grey Scrub				23.61	34.71		70.11	128.43
Herbaceous Freshwater Vegetation	96.89		35.25	855.22	151.04	82.04	9.78	1230.22
Herbaceous Saline Vegetation	223.77			17	5.56			246.33
High Producing Exotic Grassland	8157.71	13448.87	31831.55	108635.61	192413.58	44537.12	9997.56	409022
Indigenous Forest	39.33	542.73	122893.71	40249.77	20879.1	4235.02	189.66	189029.32
Land and Pond	212.48	20.08	22.04	407.45	474.28	37.09	7.58	1181
Landslide			98.16	575.74	343.92	25.65	2.16	1045.63
Low Producing Grassland	11.25	736.77	4442.7	842.91	1793.34	394.67	74.54	8296.18
Major Shelterbelts	5.78	2.72	99.46	331.12	761.8	49.04	4.71	1254.63
Manuka or Kanuka	133.78	2384.1	32179.3	38847.98	2639.14	13004.37	215.71	89404.38
Mixed Exotic Shrubland			42.63	23.6	92.49		35.48	194.2
Orchard and Other Perennial Crops	467.88	77.21		8197.87	1151.42	560.54	4.78	10459.7
Other Exotic Shrubland	174.7	137.88	582.08	1017.88	1074.25	1272.6	56.91	4316.3
Pine Forest - Closed Canopy	388.99	3571.71	28201.66	4962.95	3845.25	4350	203.92	45524.48
Pine Forest - Open Canopy	592.39	3750.13	6496.61	2555.93	4015.88	5716.16	174.31	23301.41
River	0.73	45.43	779.76	712.35	949.47	268.47		2756.21
River and Lakeshore Gravel and Rock	4.72	2.49	202.52	1087.12	1835.85	199.65		3332.35
Short-rotation Cropland	647.35	206.46	286.66	4645.84	2128.01	672.62	24.21	8611.15
Sub Alpine Shrubland			71.24	1597.69	597.32	73.35		2339.6
Surface Mine			8.82	62.74	29.72		0.97	102.25
Tall Tussock Grassland			744.84	22189.79	1203.45	312.56		24450.64
Transport Infrastrusture		19.12	44.57	83.94	18.12	31.6		197.35
Urban Parkland/Open Space	557.39			547.49	213.19	40.27	1.09	1359.43
Vineyard	288.78	238.22	127.11	4400.53	346.55	587.16		5988.35
GRAND TOTAL	14551.31	27355.28	242900.31	254099.03	247189.88	83285.10	11798.45	**881179.36**