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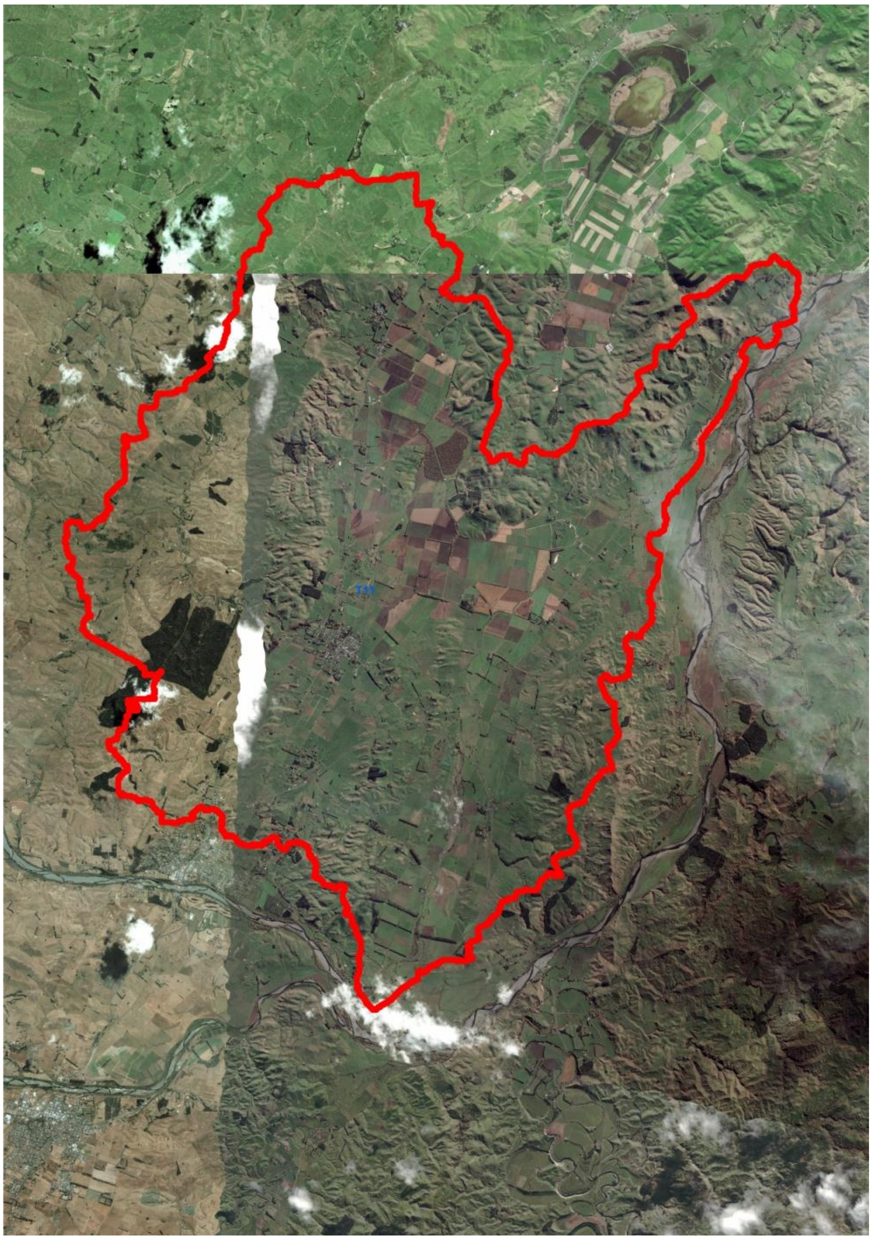

Papanui Catchment

An Environmental Characterisation

February 2013
ISSN Print 1179 8513
ISSN On Line 2230 4894
EMT 12/11
HBRC plan No. 4372

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Resource Management Group

Environmental Science Section

Papanui Catchment

An Environmental Characterisation

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EXECUTIVE SUMMARY

A major water quality issue in the Tukituki River catchment is proliferation of periphyton (including nuisance algal growths). This occurs during the summer in response to stable flows, stable substrates and adequate nutrient concentrations (nitrogen and phosphorus). A key objective of a Tukituki catchment plan change (TPC) is reduction of algal growths. Construction of a storage dam in the upper catchment is also proposed. Both the plan change and water storage project required a characterisation of the Papanui Stream catchment, because it provides a disproportionately large phosphorus contribution to the Tukituki River main stem. The potential for land use intensification is also high, which may increase the phosphorus load entering the lower Tukituki River. This report summarises our knowledge of the land, groundwater and surface water resources, describes the predicted impact of human activities on stream ecology and identifies the likely impact of climate change on land use. Gaps in our knowledge that may be targeted in future investigations are also identified.

The Papanui catchment covers an area of approximately 16,400 ha. The topography of the catchment is quite varied, with the flatter land occurring mainly in the central and eastern parts of the catchment. The soil resource is also quite varied, with 20 different soil series represented in the catchment. Seventy percent of the soil can be covered by five soil series i.e. Crownthorpe, Matapiro, Okawa, Otane and Vernon. The main land use in the catchment is sheep and beef farming. Land use change has lead to the drainage of wetlands and an increase in the proportion of cropping. The potential exists for farming enterprises to further intensify.

While it was known that the Papanui catchment is a significant source of phosphorus to the Tukituki River main stem, sources of phosphorus in the catchment were poorly understood. A targeted investigation was carried out in June 2012 to identify õhot spotsô or sources of phosphorus within the catchment. At least two source areas were found. Analysis of historic data showed that phosphorus concentrations in the streams draining the catchment were increasing over time. Further investigation of the sources of phosphorus is required. More accurate quantification of the phosphorus loads exported by sub catchment streams is also required.

Our knowledge of the ecological status of this catchment is also limited. Very little data regarding the ecology of this catchment exists, and a desktop study had to be carried out to provide an estimate of the ecological profile. The same applies to groundwater quality where sporadic measurements exist for the period from 1997 ï 2003. Hawkeõs Bay Regional Council is not currently measuring groundwater quality in this catchment and little is known regarding the movement and character of the groundwater in this area.

Provision of additional irrigation water from the water storage project increases the potential for land use intensification in the Papanui catchment. Unless adequate remedial measures are implemented, phosphorus and sediment export from the catchment is likely to increase ï this may compromise the objectives of the Tukituki Plan Change.

Further assessment of land use change, water quality (both surface water and ground water) and ecology is required to confirm and more accurately quantify the findings of this preliminary characterisation.

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1. INTRODUCTION

One of the major water quality issues in the Tukituki River catchment is proliferation of periphyton (including nuisance algal growths). This occurs during the summer in response to stable flows, stable substrates and adequate nutrient concentrations (nitrogen and phosphorus). A key objective of a Tukituki Catchment Plan change (TPC) is a reduction of algal growths. Construction of a storage dam in the upper catchment is also proposed. Both the plan change and water storage project required a characterisation of the Papanui Stream catchment, because it provides a disproportionately large phosphorus contribution to the Tukituki River main stem. The potential for land use intensification is also high, which may increase the phosphorus load entering the lower Tukituki River. This report summarises our knowledge of the land, groundwater and surface water resources, describes the predicted impact of human activities on stream ecology and identifies the likely impact of climate change on land use. Gaps in our knowledge that may be a target for future investigation are also identified.

2. CATCHMENT OVERVIEW

The Papanui catchment is one of 16 sub-catchments that make up the main Tukituki catchment. The town of Otane lies in the centre of the Papanui catchment, which covers an area of approximately 16,400 hectares (Figure 1).

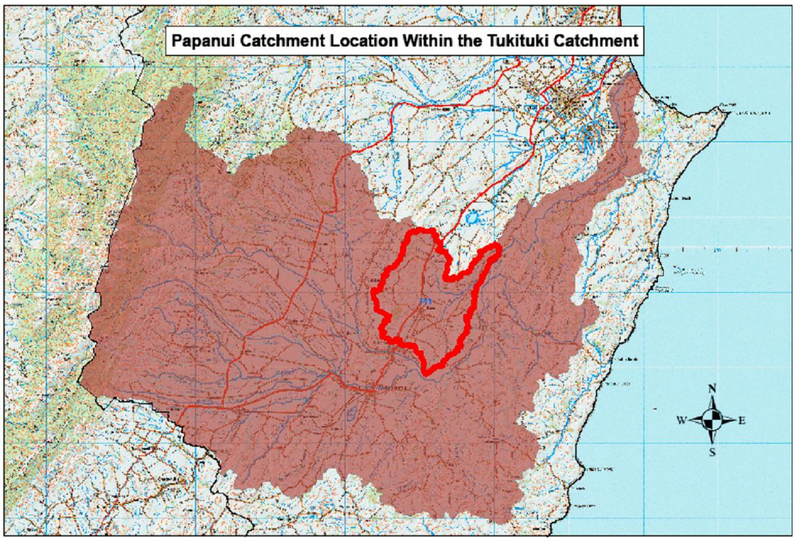

Figure 1: Papanui Catchment location

The main land use in the catchment is sheep and beef farming. The Papanui Stream drains this catchment and flows into the lower Tukituki River.

3. PAPANUI CLIMATE

Average annual rainfall in the Papanui sub-catchment is 916 mm and ranges from about 800 mm near Pukehou to almost 1200 mm in the Kaokaoroa Range (Figure 2).

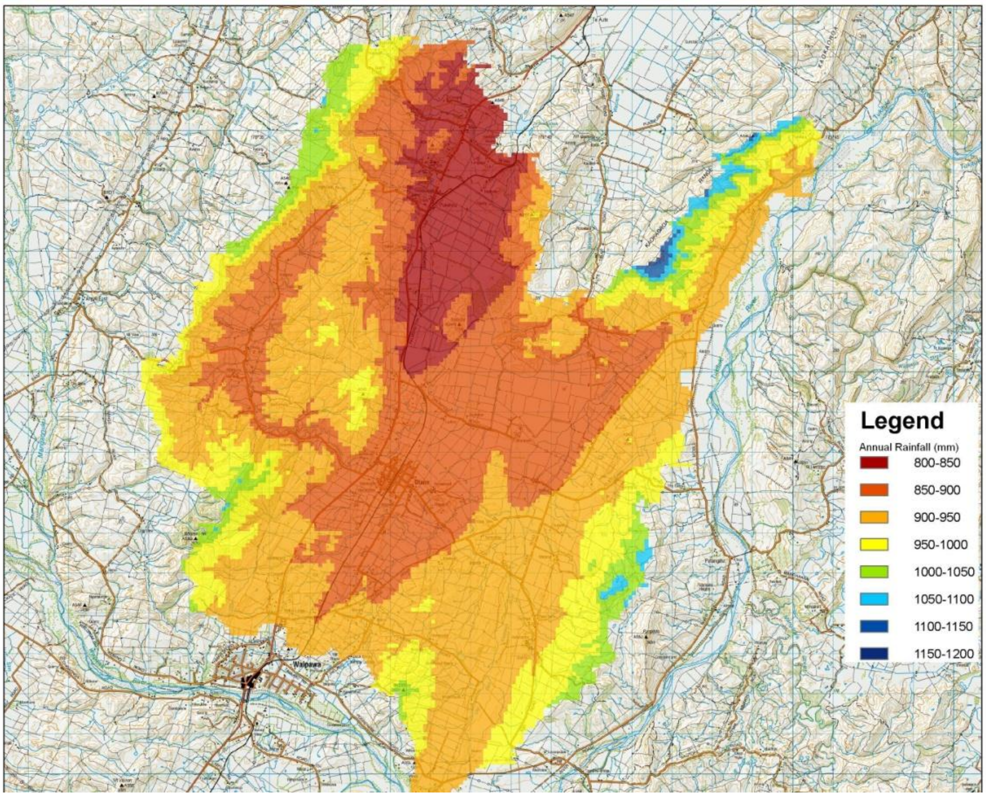

Figure 2: Average annual rainfall (in millimetres) across the Papanui sub-catchment (data from period 1965 – 1995).

Potential evapotranspiration exceeds rainfall in this area by approximately 280 mm on an annual basis and is closer to 450 mm over the ñgrowing seasonò- October to March inclusive (Figure 2). Average rainfall during the growing season is about 550 mm.

The average annual minimum temperature in the sub-catchment is 7°C which is similar to the regional average. The mean maximum temperature is 18°C (Figure 4) which is warmer than the 16°C experienced region-wide. While frosts do not typically extend into the growing season, once every five years (on average) there may be 1-3 frosts in October (Porteous and Tait, 2008). Growing Degree Days (GDDs) are a method of describing heat accumulation and crop heat requirements. It is an accumulation of the number of temperature degrees above a particular base temperature which a plant needs in order to grow. The base temperature varies according to the crop - a base of 4°C is useful for pasture and 10°C for subtropical crops. For example, 1000 GDDs (base 10°C) are typically sufficient for growing grapes (Tait, 2008). The annual average number of GDDs in the sub-catchment is 1200 for a base temperature of 10°C and almost 3116 for a base of 4°C. This implies that annual GDDs are not likely to be a limiting factor to pasture growth or grape growing in this area.

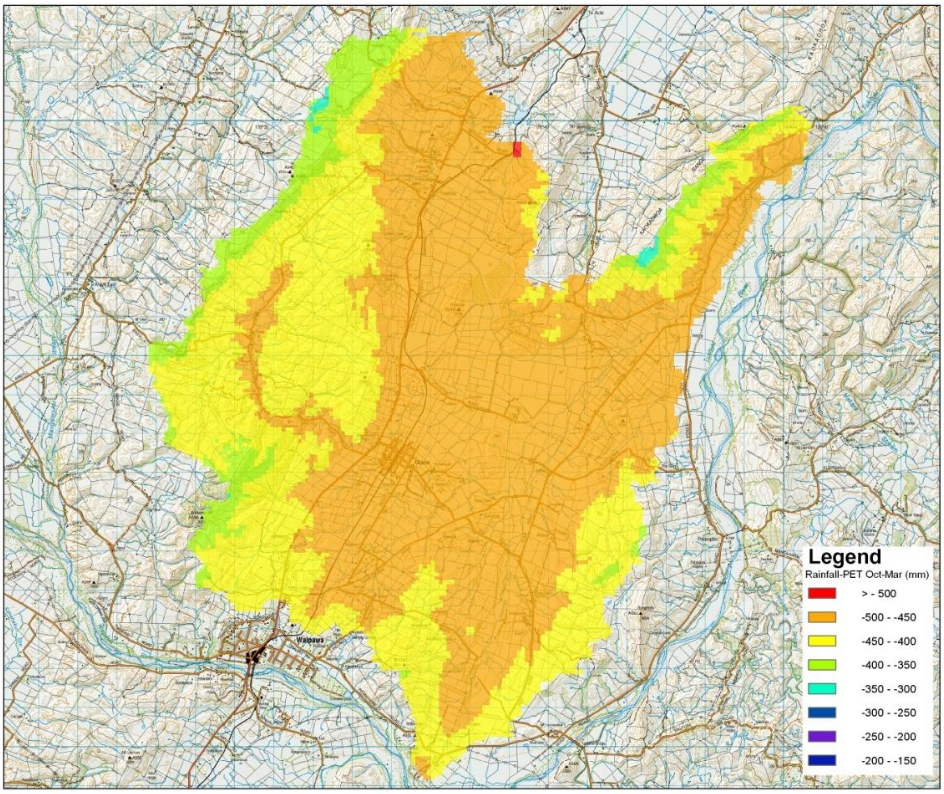

Figure 3: Difference between rainfall and potential evapotranspiration (PET), in millimetres, during October to March in the Papanui catchment.

Negative values indicate PET exceeds rainfall (based on data from 1965-1995, calculated using SimCLIM software developed by CLIMsystems Ltd).

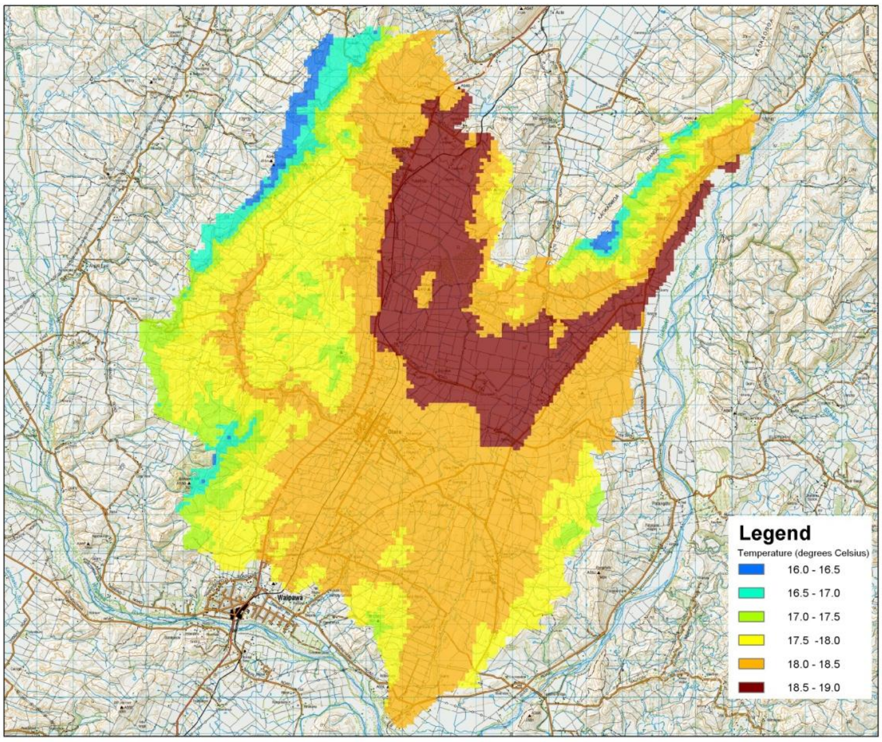

Figure 4: Annual Average Maximum Temperature (°C) in the Papanui sub-catchment
(Based on data from 1965-1995, calculated using SimCLIM software developed by CLIMsystems)

Under a ñmiddle of the roadò A1B climate change scenario, by 2050 annual rainfall in the sub-catchment is forecast to decrease 2-3% from 1990 baseline values (Figure 5). The predicted change is mainly due to a decrease in rainfall during winter months of around 5%, while rainfall over the growing season is expected to increase by 1-2%. Despite a predicted increase in rainfall during the October to March period, a 1°C rise in both maximum and minimum temperatures under this climate change scenario results in greater PET so that the deficit between rainfall and PET increases by a further 15 mm in the growing season. Annual GDDs are predicted to increase to approximately 1500 and 3500 for base temperatures of 10°C and 4°C respectively.

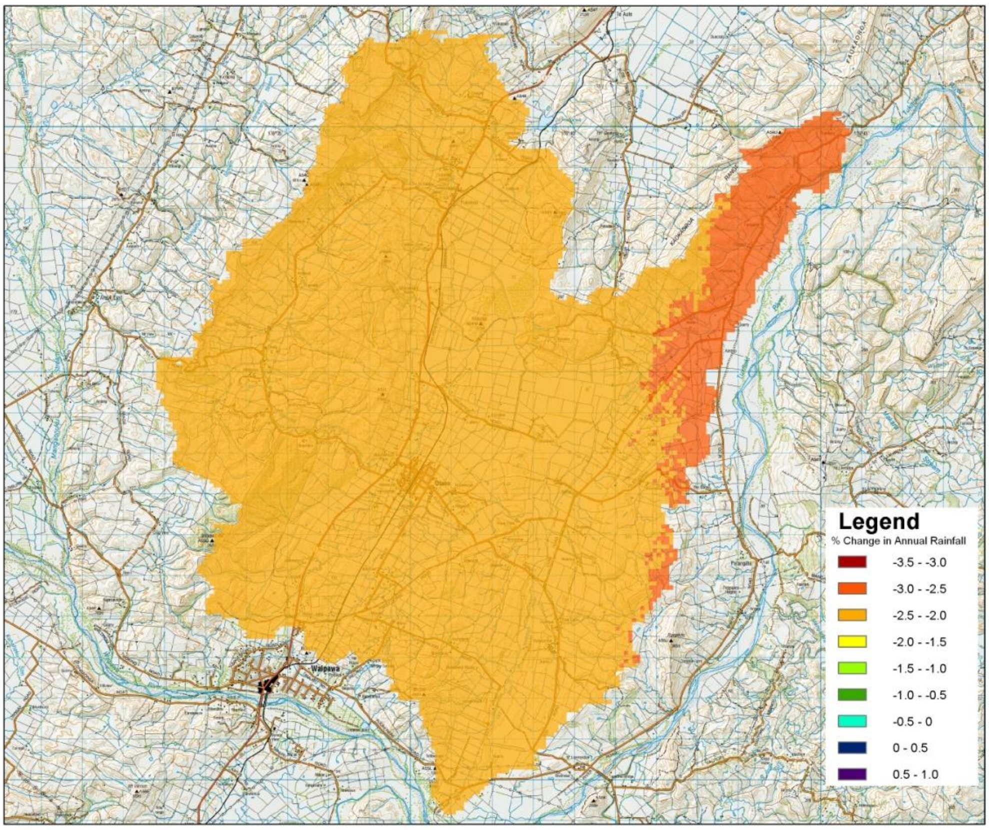

Figure 5: The predicted percentage change in annual rainfall from baseline values (1990) to 2050 using the A1B climate change scenario
(Modelled using SimCLIM software developed by CLIMsystems Ltd).

4. HYDROLOGY

4.1. Papanui Stream Flow Statistics (Definitions in Appendix III)

There are a number of sites within the Papanui Stream Catchment with limited gauged flow records and only one site with a short-term continuous rated flow record. It is preferable to use long-term continuous flow records as a base with which to calculate summary flow statistics. Synthetic flow records for two sites (Papanui Stream at Newmans Ford and the Papanui Stream at Middle Road) have therefore been derived and used to estimate long-term flow statistics. The location of these two sites is shown in Figure 6. The available rated flow record for the Papanui Stream at Newmans Ford (1978-1989) was extended with a synthetic record and a full synthetic record was derived from the Papanui Stream at Middle Road. The details of these records are provided in Table 1.

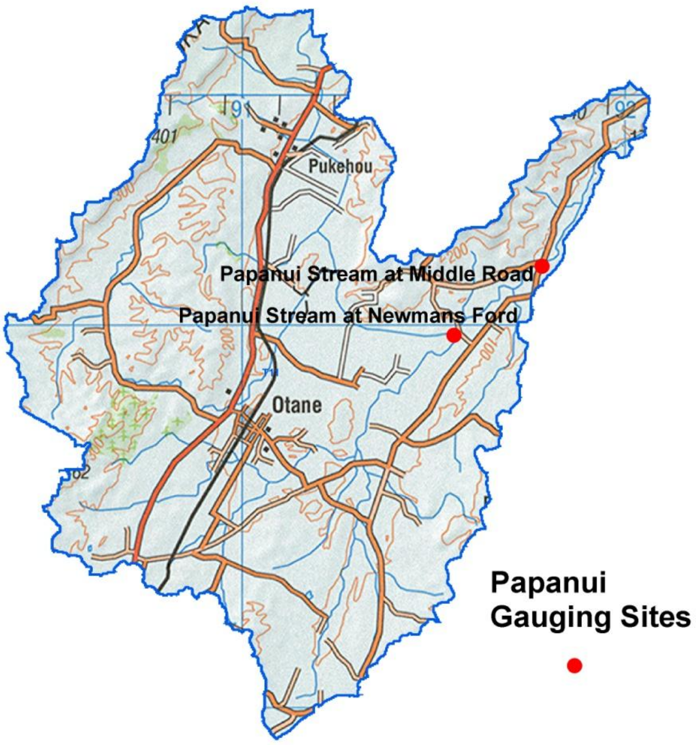

Figure 6: Hydrological gauging sites used in the Papanui Catchment.

Table 1: Rated flow record available for sites in the Papanui Stream catchment.

Site Name	Nature of Record	Record Length
Papanui Stream at Newmans Ford	Rated + Extended Synthetic Flow	1968-2012
Papanui Stream at Middle Road	Synthetic Flow	1968-2012

Summary flow statistics for each site in the Papanui Stream catchment are presented in Table 2. Synthetic flows derived for the Papanui Stream at Middle Road are considered unreliable above mean flow due to the limitations of available data. Accordingly, high range flow statistics are not presented in Table 2.

Table 2: Summary of flow statistics (L/s) for sites in the Papanui Stream catchment

Site Name	Min*	Max	Mean	Median	Q95	Q5	MALF	MAMF
Papanui Stream at Newmans Ford	0	74596	411	132	49	1352	46	23686
Papanui Stream at Middle Road	0	NA	1169	317	63	NA	57	NA

Note: NA = Flow statistic not available. *Definitions of terms shown in appendix III.

5. THE LAND RESOURCE

Many distinct factors must be considered when describing the land resource in the Papanui catchment. In this report both environmental and anthropogenic factors will be examined and the following areas will be discussed:

- topography and geology
- soil types
- land use change over the last decade
- current land use.

5.1. Papanui catchment topography and geology

5.1.1. Topography

The topography of the Papanui catchment is quite varied. Figure 7 shows the flatter land tracking across the catchment from the south west to the north east. This represents the area most suitable for land use intensification. .

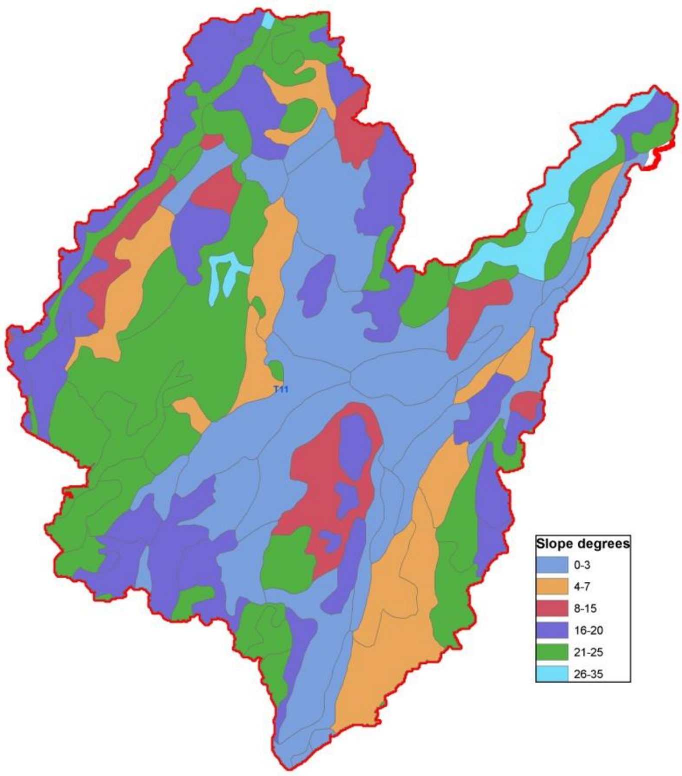

Figure 7: Slope classes in the Papanui Catchment

5.1.2. Geology

The geological map of the Papanui Catchment is part of the national QMAP (Quarter million map; Kingman 1962) series produced by GNS Science, which superseded the earlier 1:250,000 series geological maps covering the Hawke’s Bay area (Grindley,1960 and Moore, 1988). The Papanui catchment includes quaternary river and swamp deposits, flanked and underlain by Cretaceous mudstones and erosion resistant Pliocene limestones and Miocene turbite sandstones (Lee, 2011)

The oldest outcropping rocks in the Papanui Catchment are from the Cretaceous period and are composed of sandstone from the Tangaruhe formation and mudstones from the Whangai and Waipawa formations. The Cretaceous rocks are part of the western sub-belt, separated by the Omakere Fault and Elsthorpe anticline (Adams, 1985). These are structurally less

complex and generally finer-grained than the Cretaceous rocks found on the eastern sub-belt. The Tangaruhe Formation is up to 280 m thick in the Whangai Range and is present as a faulted sliver west of Otane (Crampton, 1989 and Moore et al, 1985). Basal pebbly sandstone and mudstone are typically overlain by mudstone, alternating glauconitic sandstone and mudstone, and minor red mudstone (Crampton, 1997). The formation also includes greensand dykes, and barite and other concretions (Crampton, 1989). The Whangai and Waipawa formations represent the predominant Cretaceous rocks and together are up to 500 metres thick. In areas around the Whangai Range and Otane the typical lithology is well-indurated, very poorly bedded, dark grey, siliceous mudstone, grading up into calcareous mudstone (Flemming, 1959).
The Waipawa formation (Moore, 1989 and Beu, 1995) conformably overlies the Whangai formation and its distribution in Hawke's Bay is poorly known (Lee, 2011). The Waipawa formation is a moderately hard to soft, micaceous, dark brown to black mudstone, with minor glauconitic sandstone and greensand.

The Tolaga, Mangatu and Mangaheia Groups represent Miocene and Pliocene rocks in the Papanui Catchment. The Wanstead formation represents a small part of the Mangatu Group which outcrops north of Waipawa and Otane near the southern boundary of the catchment. The Wanstead formation is typically a soft, green-grey or reddish mudstone, which shows some regional variations. To the north and east of the Whangai Range, the Wanstead formation contains smectitic clays that swell when wet, resulting in slope instability and rapid erosion of the mudstone. The Tolaga Group unconformably overlies either Mangatu or Tinui groups, or Kaweka basement rocks. There are local variations in lithofacies and thicknesses, but the Tolaga Group is generally represented by massive mudstones and alternating sandstone and mudstone. The rolling hills that separate the old bed of the Waipawa River and the current bed of the Tukituki River are composed mainly of Tolaga Group sandstones, mudstones and limestones.

The northern hills of the catchment are composed of Awapapa, Rotookiwa and Te Onepu limestone formations which are part of the Mangaheia Group. The Awapapa limestone formations consist of up to 120 m of yellow-grey, cross-bedded, barnacle-rich limestone, of early Late Pliocene age unconformably overlying Tolaga Group or conformably overlying Early Pliocene rocks. A stratigraphically younger, soft, barnacle-rich, creamy-yellow limestone, which forms the western side of the Kaokaoroa Range (Rotookiwa Limestone) (Kelsey, 1993) is poorly exposed; it is conformably overlain by lower Late Pliocene fossiliferous mudstone and sandstone that is hundreds of meters thick. The Te Onepu Limestone is a yellow-grey, coarse-grained limestone with well developed cross beds, with outcrops mainly in a northeast trending belt from the Turiri Range in the south, northward to the Raukawa Range. It unconformably overlies the Whangai formation and the Tolaga Group and is locally conformable on Late Pliocene Whetukura Limestone or Mangaheia group massive mudstone near Hastings.

The Kidnappers group, which overlie Pliocene Mangaheia Group, represent middle to late Quaternary sediments. The deposits crop out near Tod Road along the eastern bank of the old Waipawa River bed. These sediments are described as alluvial deposits, consisting of sandstone, mudstone, tephra, silt and lignite.

Alluvial fan, scree and colluvial deposits are found throughout the catchment. The most prominent fan deposit is located along College Road. It lies between limestone of the Mangahea Group and mudstone of the Tinui Group. The area of plains south of Drumpeel Road represents late quaternary deposits of moderately weathered, undifferentiated, poorly sorted, loess-covered alluvial gravels, and includes fluvial deposits of the old Waipawa River Bed. North of Drumpeel Road (beneath the plains), the geology represents poorly sorted alluvial gravel, sand and soft, dark brown to black organic swamp mud, muddy peat and woody peat with minor overbank sand, silt and mud (Lee, 2011)

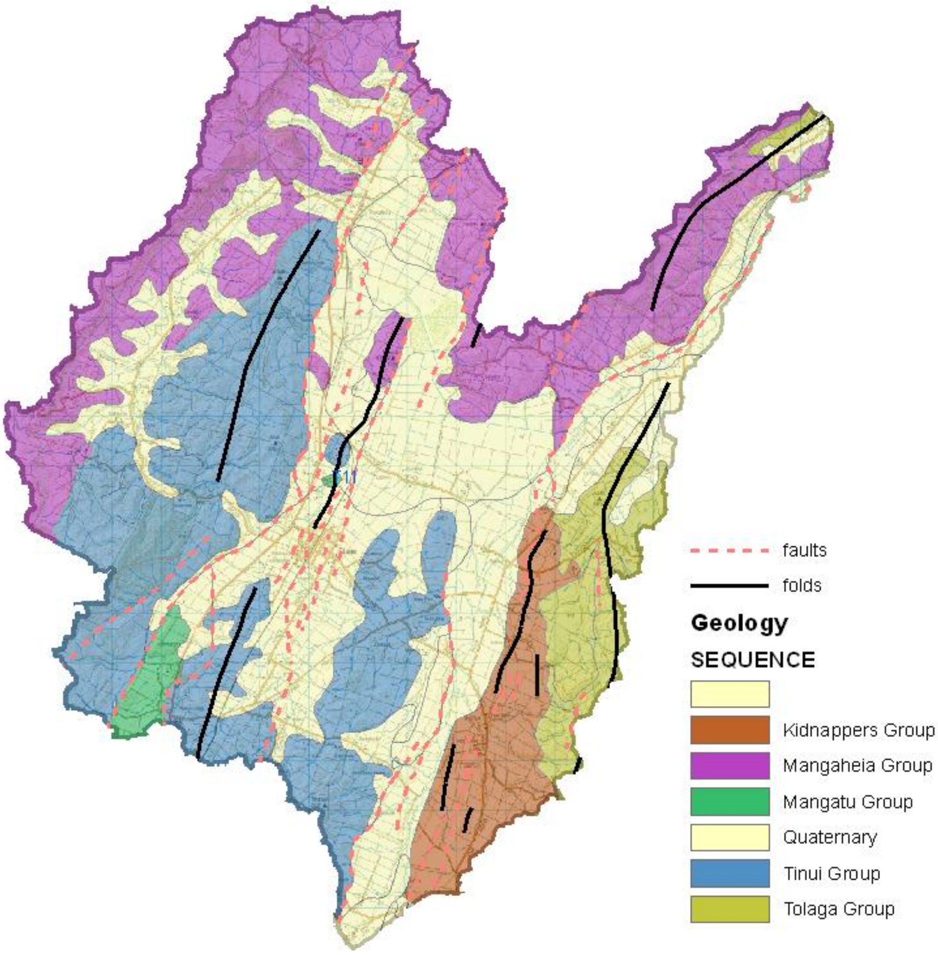

Figure 8: Geological map for the Papanui Catchment (Lee, 2011)

5.2. Soils of the Papanui catchment

As shown in Figure 9, the soils of the Papanui catchment are quite complex. While there are approximately 20 different soil series within this catchment, nearly 70% of the soils are covered by five soil series i.e. Crownthorpe, Matapiro, Okawa, Otane and Vernon. It should be noted that, as with any soil mapping, the areas covered by any soil type are only approximations and are not exact. Further soil sampling/mapping is planned for this area in the future to refine our understanding of soils.

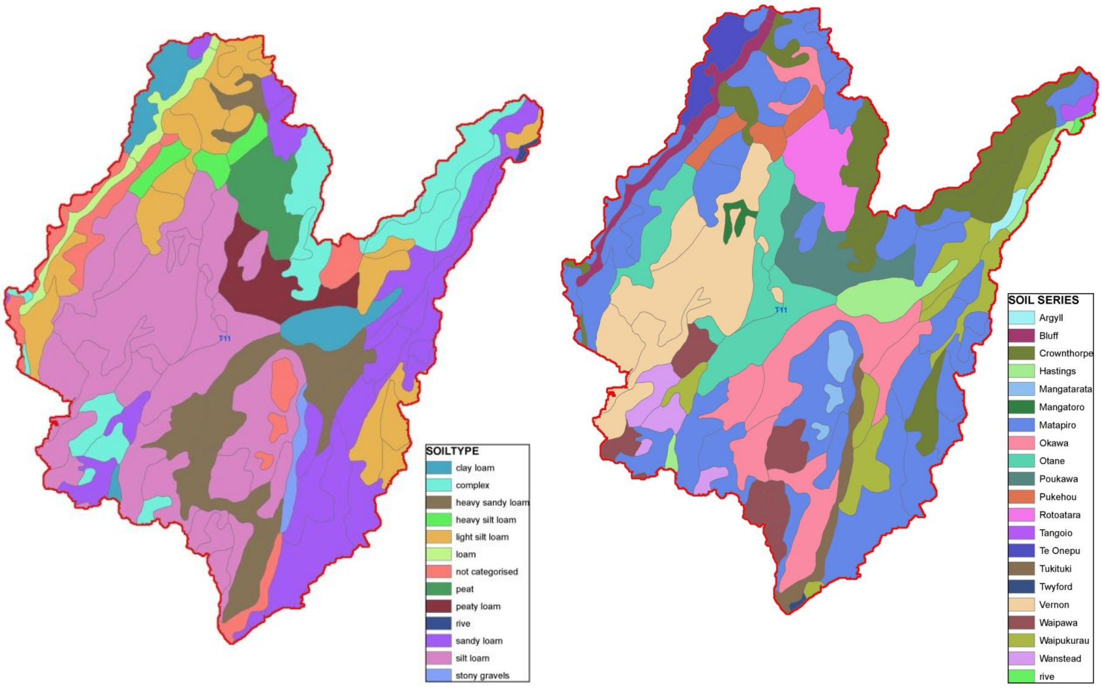

Figure 9: Soil types (left) and soil series (right) in the Papanui catchment

Table 3 summarises all of the soil series in the Papanui catchment, with the five main series in bold.

Table 3: Different soil series thought to be present in the Catchment

SERIES	Land area represented by each soil series (Ha)	Proportion of total land area (%)
Argyll	57.4	0.3
Bluff	303.8	1.9
Crownthorpe	1,573.1	9.6
Hastings	450.4	2.7
Mangatarata	160.4	1.0
Mangatoro	63.1	0.4
Matapiro	5,005.8	30.5
Okawa	1,685.1	10.3
Otane	1,253.8	7.6
Poukawa	564.2	3.4
Rotoatara	528.4	3.2
Tangoio	58.7	0.4
Te Onepu	285.4	1.7
Tukituki	261.3	1.6
Twyford	11.5	0.1
Vernon	1,928.4	11.7
Waipawa	626.4	3.8
Waipukurau	972.2	5.9
Wanstead	313.6	1.9
Pukehou	293.3	1.8
Grand Total	16,396.4	100

The characteristics of and differences between the five main soil series are described below.

5.2.1. Soil descriptions

The soil descriptions that follow were adapted from Pohlen et al, (1947).

Crownthorpe soils:

Soils of the Crownthorpe Series are fairly fertile and occur on moderately steep slopes. They have compact subsoils, cemented in places to form hardpan. They are formed on pumiceous muddy sandstones which in some localities contain beds of limestone, greywacke conglomerate or pumice sands.

Most of the Crownthorpe soils have fairly rapid drainage - drainage waters are able to percolate downhill along the sandy subsurface horizon above the compact subsoil. However, during periods of prolonged rainfall the drainage water can reappear at the surface on lower slopes as seepages. The subsurface materials exposed by erosion are infertile and re-grass slowly.

Matapiro soils:

The soils of the Matapiro Series have a sandy top soil and heavier subsoils which are cemented to form hardpan in most of the types. The natural fertility is good but varies according to the lime content of the underlying parent rock. The latter are typically pumiceous muddy sandstone, containing beds of limestone and greywacke conglomerate of variable thickness.

The Matapiro soils are moderately acid and have a medium to good supply of lime. The phosphate content is low.

Okawa soils:

The Okawa series contains heavy soils of good natural fertility lying on flat or gently sloping terraces generally 3 ï 10 m above mean stream level. The subsoils are claypans or hardpans. The pan resists root penetration strongly and many farm shelter trees are forced to adopt a shallow rooting system, with the result that they are easily uprooted by strong winds. Okawa soils are moderately acid and have a medium supply of lime in the topsoil. Potash varies from low to medium and the phosphate content is low.

Otane soils:

The Otane series soil is light with good natural fertility. It occurs on low elevation, gently sloping terraces. They are formed on river deposited sediments derived chiefly from argillites, muddy sandstones, mudstones and limestones. Near Otane some areas of the soil appear to be more fertile than the surrounding Otane soils. This could be due to this area having been submerged below lake level in the recent past.

The Otane soil is slightly acid, well supplied with lime and low in phosphate. The potash content is medium.

Vernon soils:

Vernon soil is a light, shallow, gravelly soil with fairly good natural fertility. It lies on steep slopes and is formed on hard, shattered, white argillite.

Vernon soil is slightly acid and is low in phosphate. Analyses of samples taken from the Papanui catchment indicate a plentiful supply of lime and a medium supply of potash.

5.3. Land use change over the last decade.

According to AgriBaseÊ, the biggest land use change over the past 10 years has been from sheep farming to sheep and beef farming (2,417 ha), with the next biggest change being conversions from beef operations to sheep and beef (1,299 ha). These two changes account for over 47% of all land use change in the catchment. A table showing all land use change in the catchment, as well as an accompanying map can be found in APPENDIX I.

5.4. Current land use

The extent of current land use in the Papanui catchment was estimated using a combination of AgriBaseÊ and the Land Cover Data Base 3 (LCDB3). AgriBaseÊ is a data base to which farmers voluntary add their farm details, such as farm address, key personnel, land area, stock numbers, land use etc. The LCDB3 has been developed by Landcare Research and shows land cover as opposed to land use. Using LCDB3 helps increase the resolution of the map because it reveals detail such as areas under fodder crops.

In the Papanui catchment the largest single land uses are currently sheep and/or beef farming, which together utilise 80% of the land area, followed by arable farming and then dairy farming as shown in Figure 10. Table 4 shows the current apportionment of land use in the Papanui catchment.

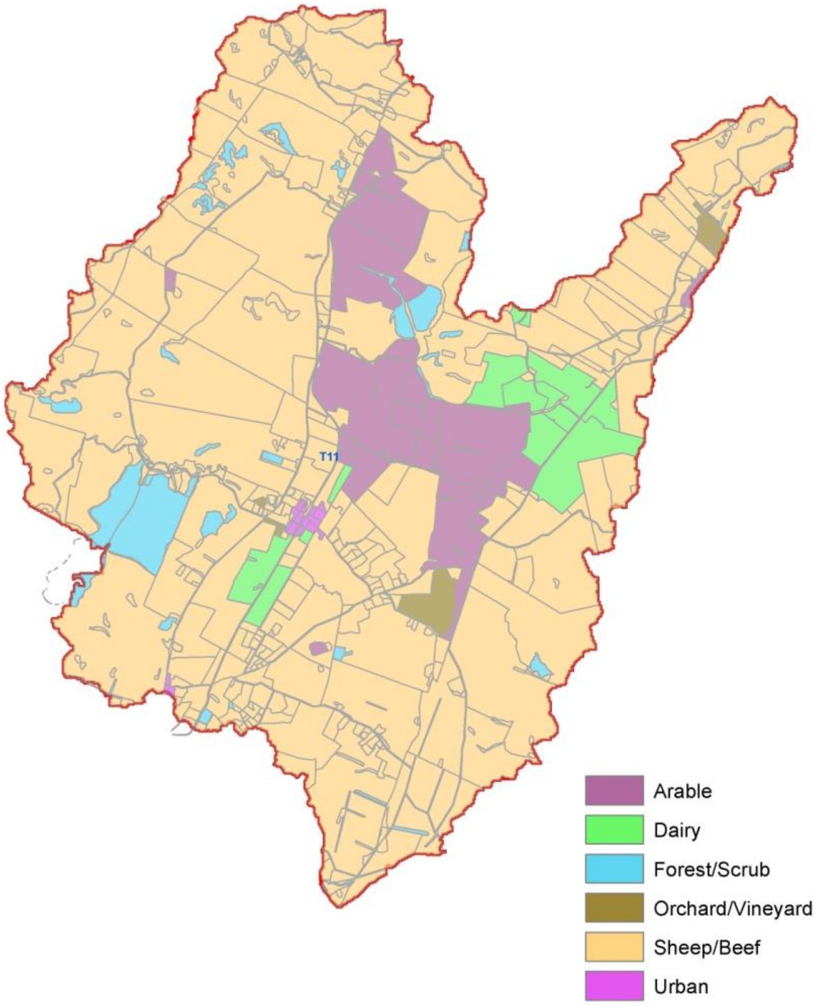

Figure 10: Current land use in the Papanui Catchment

Table 4: Land use in the Papanui Catchment

Land Use	Area Ha	Proportion of Land Area %
Arable	1,669	10.2
Dairy	744	4.5
Forest/Scrub	591	3.6
Orchard/Vineyard	152	0.9
Sheep/Beef	13,211	80.5
Urban	49	0.3
Grand Total	**16,416**	**100**

6. GROUNDWATER RESOURCES OF THE PAPANUI CATCHMENT

6.1. Previous reports

Ludecke (1998) described the chemistry of groundwater in the Papanui Catchment in the Tukituki River Catchment Water and Soils Resource Management Plan. The hydraulic properties of the main groundwater resources are characterised in various aquifer test reports; the most comprehensive aquifer test report for the catchment is provided by Luba (1999). A summary of groundwater information including all aquifer test results is provided by Larking (2004).

6.2. Water allocation

A total of 17 surface water and groundwater resource consents currently have been issued in the Papanui Catchment. The majority of allocated water is associated with 13 resource consents to take groundwater from 15 wells. The main groundwater use is for irrigation of crops and pastures, which account for approximately 70% of the total volume of water allocated from both surface water and groundwater. The bulk of surface water is allocated from the Kaikora Stream for irrigation, which accounts for 75% of the total volume of water allocated from surface water. The remaining surface water is allocated from the Papanui Stream.

Table 5: Volumes of groundwater and surface water allocated through resource consents

Groundwater use	Consent detail	Groundwater volume consented (m^3/week)	Surface water volume consented (m^3/week)	Totals (m^3/week)
Irrigation	Crops	98,005	35,000	133,005
	Pasture	39,305	7560	46,865
	Orchard	699	0	699
	Vineyard	4600	2016	6,616
Potable supply	Private and public facility	300	1500	1,800
Totals		**142,909**	**46,076**	**188,985**

There has been a marked increase in water allocation since the mid 1980s. In 1985 the total weekly allocated volume for both groundwater and surface water consents was approximately 20,000 m^3. By 2011, this volume had increased tenfold to approximately 190,000 m^3/week. In the early 1980's, the proportion of water allocated from groundwater and surface water was about equal. By 1995 however, the ratio was 2:1 respectively and by 2011 the ratio was over 3:1 (groundwater to surface water).

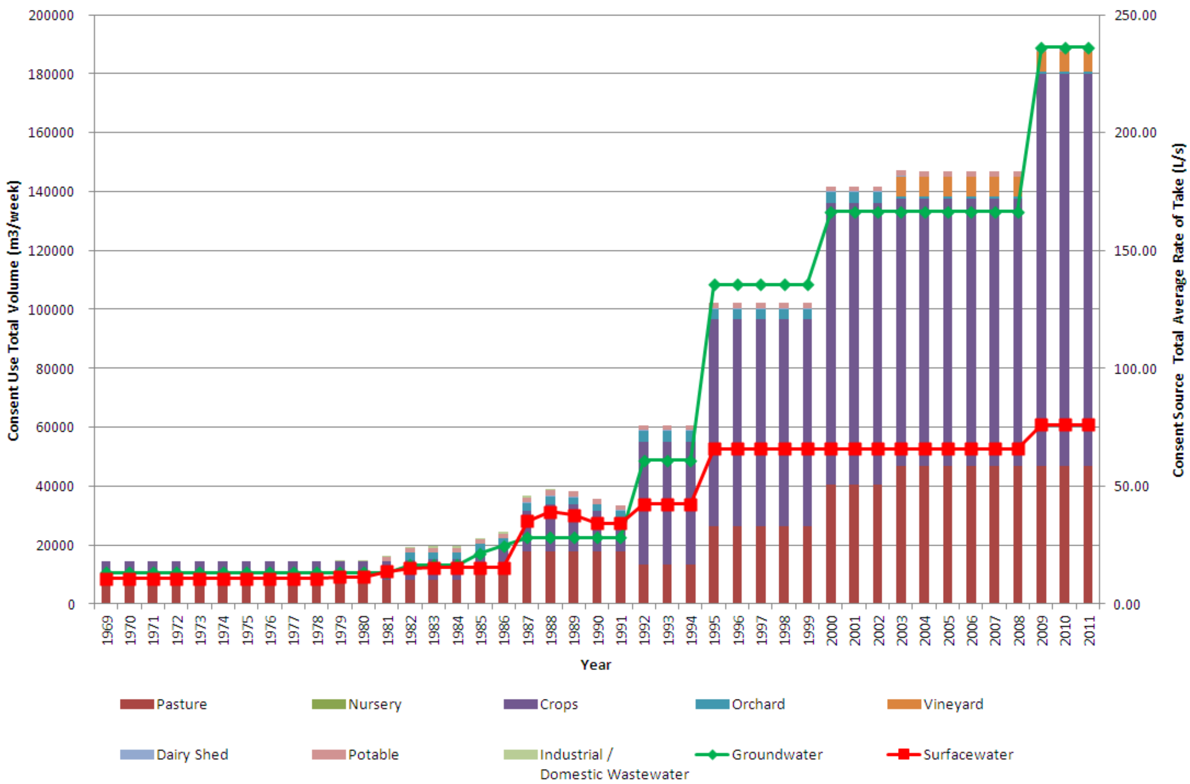

Figure 11: Trend in volume of consented surface water and groundwater allocated over time by use.

6.3. Catchment hydrogeology

Groundwater resources exist in most geological formations within the Papanui Catchment. The most productive aquifer system appears to be associated with the gravels from the Quaternary period, which underlie both the old Waipawa River bed and the Papanui Stream. Bore logs indicate that a relatively shallow strip of alluvium is wedged between Cretaceous and Pliocene mudstones and alluvium from the Cape Kidnappers Group. Well depths indicate that the aquifer system is deeper at the southern end of the catchment near the middle of the old Waipawa River bed; in this area, wells penetrate gravels up to 50 m deep. Further north, along the Papanui Stream, bore logs suggests alluvium is up to 30 m thick, with well screens open to both younger gravels and older sequences of mudstone or weathered limestone. Toward the west, along Drumpeel Road in the middle of the catchment, the aquifer system pinches out or grades into swampy deposits from the Quaternary period. The general flow of groundwater within the aquifer is unknown but is believed to move with the topographical gradient from southwest to northeast along the old Waipawa River bed. Secondary groundwater resources are found within limestones from the Mangaheia Group located in north of the catchment, swampy deposits from the Quaternary period (generally found beneath the plains), and Cretaceous mudstones from the Tinui Group near the township of Otane. Based on the lithology described in the well logs, the type of well construction used, and the absence of high volume consent allocation, these geological sequences are generally considered to be less productive than the gravel aquifers located beneath the Old Waipawa River bed and Papanui Stream.

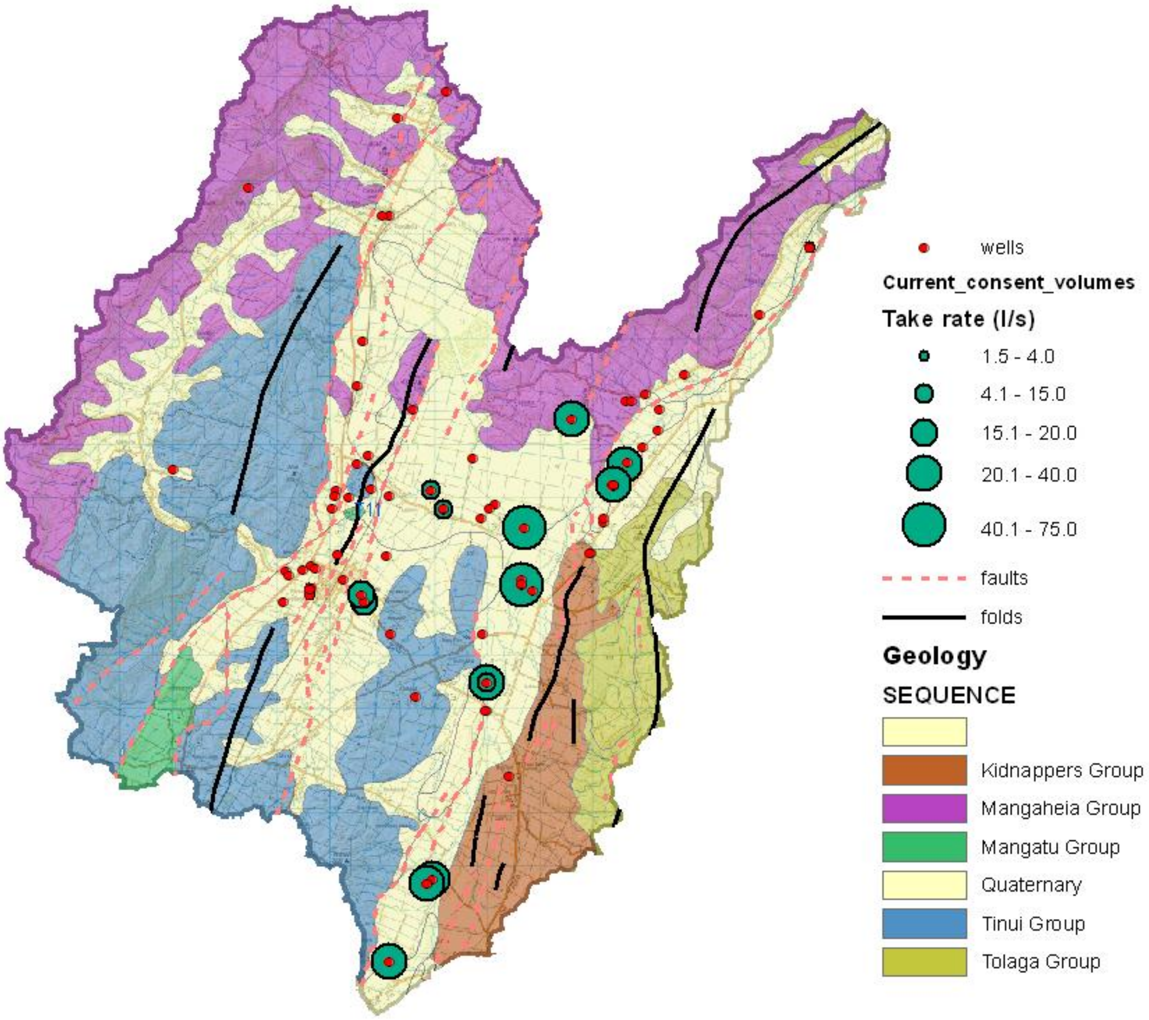

Figure 12: Location of wells and relative magnitude of groundwater abstraction consents.

6.4. Aquifer hydraulic properties

The hydraulic properties of the groundwater resources were characterised using drawdown data derived from pumping tests performed at eight different sites. Both step and constant rate tests were used to estimate aquifer parameters. The majority of results (five tests) characterise the hydraulic properties of the Quaternary aquifer system which lies beneath the old Waipawa River Bed and the Papanui Stream. Along this groundwater resource, transmissivity values range between 502 and 11,129 m^2/day and storativity indicates semi-confined conditions (based on the results from one test). Toward the west, along Drumpeel Road and near Otane, the results from three aquifer tests indicate that groundwater resources in this area are generally less transmissive and more confined. This is consistent with well lithology, which shows thick layers of silt, clay and mud, whereas the lithology beneath the Old Waipawa River bed and Papanui Stream show more gravelly deposits. Overall, the test results provide a summary of the likely hydraulic characteristics of the main groundwater resources; further review is required to confirm and qualify the results for other uses, such as well interference and stream depletion assessments.

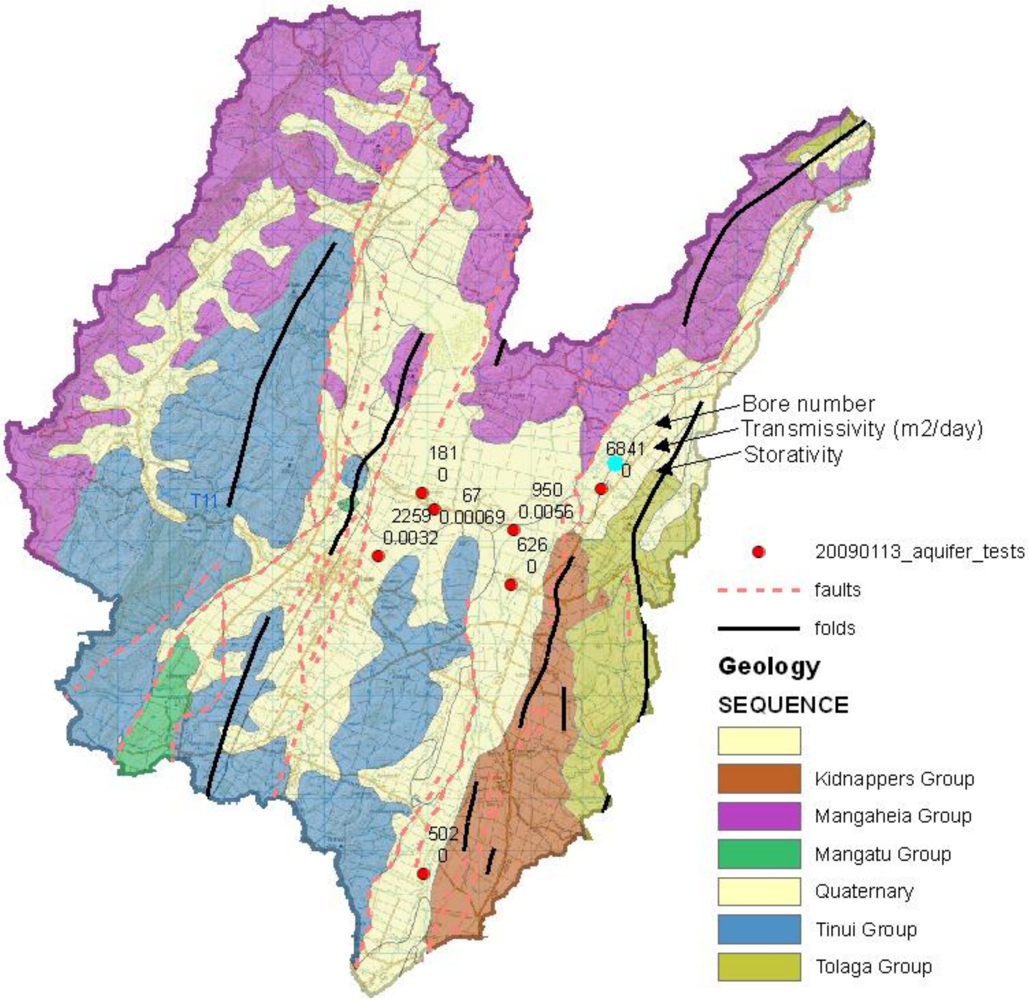

Figure 13: Location and summary of aquifer test results.

Table 6: Summary of aquifer test results

Well number	Screen (m)	Pump rate (L/s)	Aquifer test type	Test duration (minutes)	Analysis model	Transmissivity (m^2/day)	Storativity
3155	29.47 - 36	25.1	Step	2	Eden Hazel	626	
3159	9.14 ï 15.8	9	Step	62	Eden Hazel	181	
3495	25-37	27	Constant discharge	8.54	Theis	502	
3528	12-22	40	Step	2	Eden Hazel	6841	
3551	11.8 ï 30.4	48.67	Step	1.5	Eden Hazel	11129	
4167	30.75 ï 38.75	72.6	Constant discharge	24	Jacob	950	0.0056
4325	2.01 - 65	15.64	Constant discharge	24	Theis	2259	0.00318
15124	16.4 ï 19.69	3.8	Constant discharge	21	?	67	0.0006946

6.5. Groundwater quality

The quality of groundwater in the Papanui Basin is poorly understood. Knowledge of groundwater quality is based on relatively few historical monitoring results. Groundwater quality was measured sporadically between 1997 and 2003 at a limited number of wells for selected variables. These results are provided in Table 7. Table 8 summarises the New Zealand Drinking Water Standard (NZDWS) (Larking, 2004). Comparison of data in Table 7 with the values in Table 8 indicates that faecal coliform concentrations were exceeded in wells 3198 and 2860, and elevated levels of nitrate-nitrogen concentrations were observed in wells 2718 and 4617.

Ludecke (1988) made reference to shallow groundwater in the Papanui Stream valley, suggesting a similar water quality to the Waipawa River. Unfortunately the original water quality data cannot be located to verify this observation (Larking, 2004).

Table 7: Groundwater quality results

Determinants (mg/L unless otherwise stated)	Water quality by well number and date of sampling						
	3198	2718	4475	4475	2860	42671	3155
Sample date	16/6/2003	16/4/2003	20/7/2000	16/6/2003	16/6/2003	21/7/1999	24/3/1997
pH (units pH)			7.5			7.5	7.2
Iron						**2.4**	**0.2**
Manganese						0.1	<0.1
Zinc						0.4	0.15
Calcium			93			126	107
Magnesium			4.8			8.9	5.1
Sodium			19			56.5	21
Potassium			2.7			6.6	2.4
Chloride			28			32	31
Boron						0.1	0.1
Total alkalinity			230			335	278
Total hardness			**252**			**352**	**288**
Total dissolved solids			386			534	438
Bicarbonate			280.68			408.82	331.94
Conductivity			58			80	65
Copper						-0.05	<0.05
Ammoniacal nitrogen	0.01	<0.01		0.14	<0.01	0.6	<0.1
Nitrate nitrogen	0.469	**7.95**	1	0.002	1.56	**5.7**	2.9
Faecal coliform (cfu/100 mL)	**10**	<1		<1	10		
Nitrite + nitrate nitrogen	0.471	**7.98**		0.003	1.56		
Nitrite	<0.002	0.029		<0.022	<0.02		

Red text indicates exceedence of drinking water standard. **Underlined** text indicates concentrations greater than half the drinking water standard. < indicates less than

Table 8: Water quality standards

Variable (mg/L unless otherwise indicated)	Maximum acceptable value (MAV)	Guideline value (GV) (mg/L)	Comments
***Escherichia coli* (*E. coli*) (n/100 mL)**	**Less** than 1 in 100 mL of sample		Indicates faecal contamination. Where *E. coli* is not analysed for, faecal coli form may be used instead. A positive faecal coliform form result should be treated as though it were an *E. coli* result.
Ammoniacal nitrogen		1.5*[1]	Taste, odour.
Nitrate Nitrogen	11.3		
Nitrite	3		
Copper	2	1	Concentrations at or below the health-based guideline may affect the appearance, taste and odour of water. May also cause staining of laundry and sanitary ware.
Iron		0.2	Staining of laundry and sanitary ware.
Zinc		3	Appearance, taste.
Sodium		200	Taste.
Chloride		250	Taste, corrosion.
Boron	1.4		
Total hardness		200	Elevated hardness causes scum deposition. Low hardness possibly causes corrosion.
Total dissolved solids		1000	Taste.
Manganese	0.5	0.2	Concentrations at or below the health-based guideline may affect the appearance, taste or odour of water. Staining of laundry and sanitary ware.
pH (units)		7.0 ï 8.5	Should be between 7.0 ï 8.0. Low pH: aggressive water; high pH: taste, soapy feel. Preferably pH <8 for effective disinfection with chlorine.

*[1]Drinking water standard for Ammonia. To convert to ammonia: Ammoniacal nitrogen x (17/14).

6.6. Groundwater level trends

Groundwater levels have been measured at well 5006 along Drumpeel Road since 2003 at monthly intervals. Groundwater levels at well 5006 represent a confined gravel aquifer possibly linked to the Old Waipawa River bed. The groundwater levels display a distinct seasonal pattern, with higher groundwater levels measured over winter and lower groundwater levels measured over summer. The seasonal variation typically ranges about 2 m, between 0.5 and 2.5 m below land surface. Overall a downward trend is evident, with some recovery in groundwater level since 2008.

To test for statistically significant monotonic trend, the Seasonal Kendal test was applied to the data using NIWA’s Time Trends software[1]. The results indicate a statistically significant trend (P>0.05) within the data. The Kendall statistic indicates the trend is downward and the Sen’s slope estimator calculates a median annual rate of change of 80 mm per year.

[1] http://www.niwa.co.nz/our-science/freshwater/tools/time-trends

Table 9: Seasonal Kendal test results

Water level	Median value	Kendall statistic	Variance	Z	P	P(adjusted)	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	-1.46	-86.00	1109.33	-2.55	0.01	0.34	-0.08	-0.11	-0.04

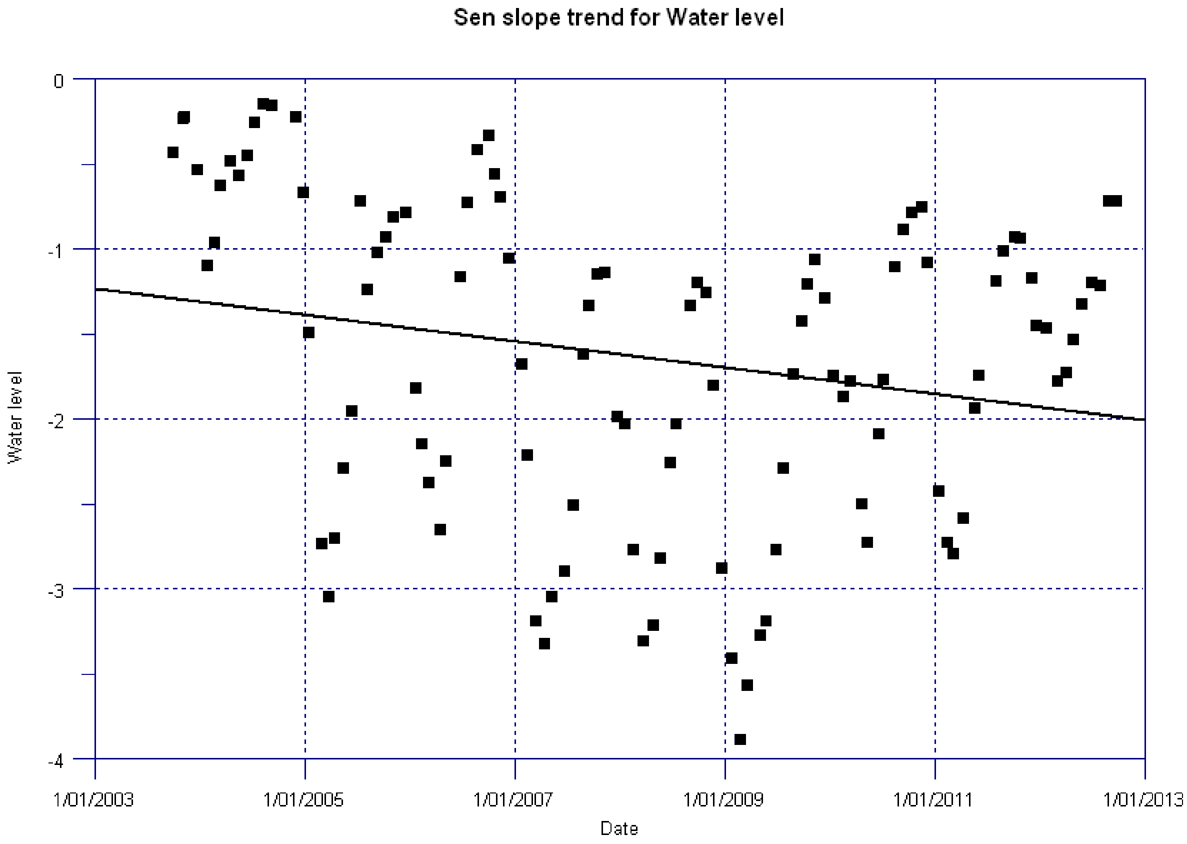

Figure 14: Plot of deseasonalised groundwater level data over plotted with Sen's slope estimate

7. PAPANUI TARGETED NUTRIENT INVESTIGATION

7.1. Introduction

A recent water quality study on Tukituki River subcatchments identified that the Papanui Stream contained high concentrations of soluble reactive phosphorus (SRP), total phosphorus (TP) and total nitrogen (TN). In response, a one-off sampling program was undertaken to identify possible sources of high phosphorus (in particular) and nitrogen within the Papanui catchment. On 22 June 2012, water quality samples were collected from 14 sites over the length of the catchment. These were submitted to a laboratory to determine concentrations of phosphorus and nitrogen species, as well as suspended solids. A range of other water quality variables (pH, turbidity, conductivity, dissolved oxygen, clarity and colour) were measured in situ. Flows were either visually estimated or measured using a Sontek Flowtracker. Flow values were used to calculate the daily instantaneous nutrient loads exported from tributary streams and at specific reaches within the catchment.

Additional water quality data for the Papanui Stream at Middle Road (bottom of the catchment) exist for the periods July 1994 ï September 1998 and December 2011 ï July 2012. Nutrient loads and yields were calculated for these periods using a synthetic flow record for the site[2]. Comparisons of nutrient loads were made between these two time periods, as well as with loads estimated for sites representing other Tukituki River subcatchments.

[2] provided by R. Waldron, HBRC Hydrology team

Artificial substrates are used as a technique to identify the limiting nutrient for periphyton growth in rivers and streams. In particular, nutrient diffusing substrates are used to measure biomass production rates where the precise effects of water quality are to be assessed but where the natural substrate cannot be sampled (Biggs and Kilroy, 2000). The nutrient diffusing steel tray is designed to hold jars of agar impregnated with nutrients (Nitrogen, Phosphorus, Nitrogen plus Phosphorus and untreated agar). A filter paper on the top of the jar acts as the colonisation surface for periphyton. The nutrients slowly diffuse out to the substrate providing a localised nutrient source for periphyton growth. One nutrient-diffusing substrate tray was deployed in the Papanui Stream at Middle Road on the 15th February 2011 and left to incubate in-situ for seven days. At the end of the incubation period the filter papers were analysed for Chlorophyll a concentration to identify the limiting nutrient for periphyton growth in the main stem of the Papanui Stream.

7.2. Description of surface water system

The Papanui Catchment comprises two tributary streams, the Papanui Stream and the Kaikora Stream. The main stem of the Papanui Stream flows in a north easterly direction, parallel with Te Kura and Evan Roads. Initially fed from groundwater, the Papanui Stream flows along the old bed of the Waipawa River. The flow is augmented by runoff from agricultural and horticultural lands, predominantly from ‘sheep and beef’, cropping and some dairy farming. Short-term rotational cropping occurs in the lowland northern and central part of the catchment (Figure 15). The stream is a clear, shallow gravel bed system with extensive macrophyte cover, particularly water celery (*Apium nodoflorum*). Occurrence of this species is often associated with high disturbance and elevated nutrient concentrations.

The Kaikora Stream drains the western hills into Otane and then flows north. In the upper catchment, upstream of Drumpeel Road, the stream is a small gravel bed system with some macrophyte growth and clear water. Stock were observed to have generally unimpeded access to the stream along these reaches. Further downstream the stream is channelised, flowing north and then east. In this reach it is generally referred to as the Te Aute drain or the Te Aute arm of the Papanui Stream. Waterways draining Lyons wetland and cropland south of Pukehou enter the lower reaches.

Long term flow data exists for Papanui Stream for the period 1968-1991. These records were used by R. Waldron (HBRC Hydrology section) to synthesise monthly and annual flow data from 1991 – present day. These data show that the calculated mean discharge for June 2012, when the targetted investigation took place, of 333 L/s was well below the long term average for that month which is 1683 L/s. Average discharge for the Dec 2011 – July 2012 period (in which routine monitoring of the Papanui Stream at Middle Road occured) of 1453.1 L/s was well above the long term mean discharge for those months, of 585.4 L/s.

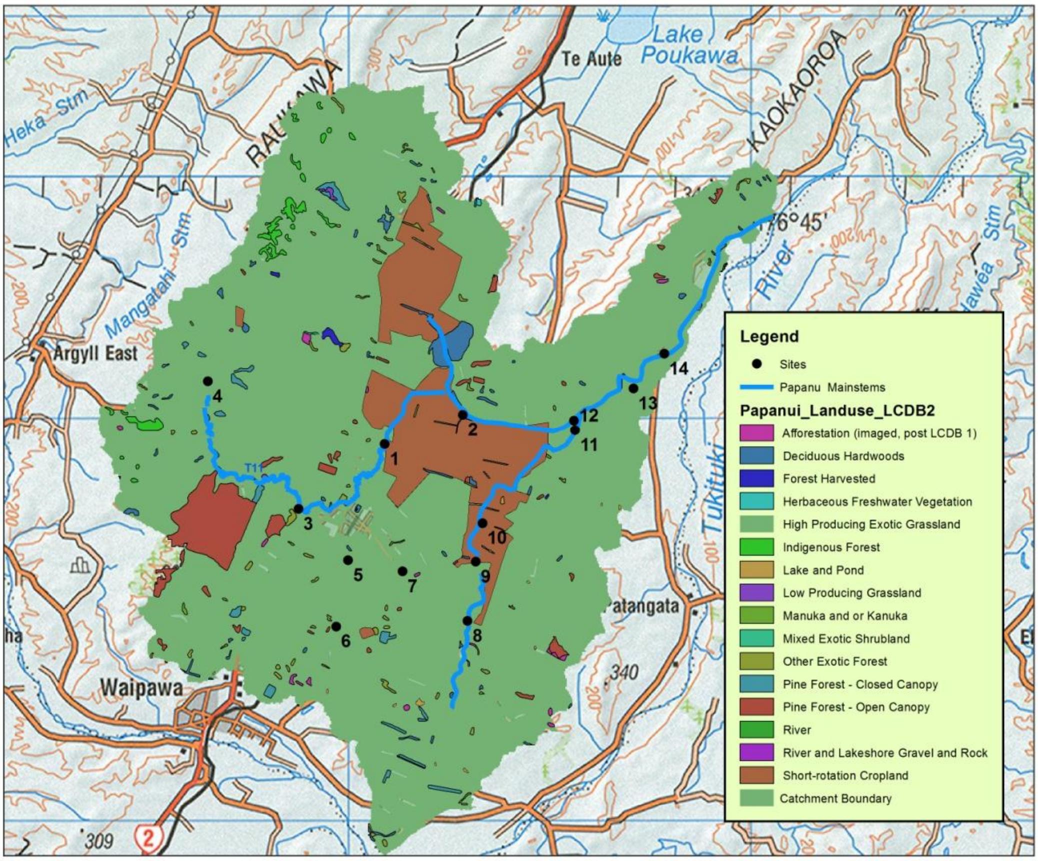

Figure 15: Land cover in the Papanui Catchment (LCDB2).

7.3. Sampling Sites

To provide a catchment-wide perspective of water quality, fourteen sites were selected for an intensive monitoring campaign (Figure 16). Sites along the Papanui Stream are numbered 8, 9, 10, 11, and 14. Site 14 (Papanui Stream at Middle Road) has been sampled historically (monthly between July 1994 and September 1996), as well as more recently (monthly from November 2011 to the present). The latter sampling formed part of the Tukituki Sub-catchment Monitoring Investigation, the results of which will be discussed later in this section. Stock had unimpeded access to the stream along the majority of observed stream length, with the exception of a reach near Site 10, where the stream banks were fenced.

Sampling sites on the Kaikora Stream are numbered 1, 2, 3, 4, and 12. Sites 1, 3 and 4 are located in the upper section, whereas Sites 2 and 12 are located in the lower, channelised section of the stream. Stock access to this waterway is limited by the steep banks and deeply incised channel. A small waterway fed by the Otane wastewater treatment ponds enters the stream downstream of Site 2.

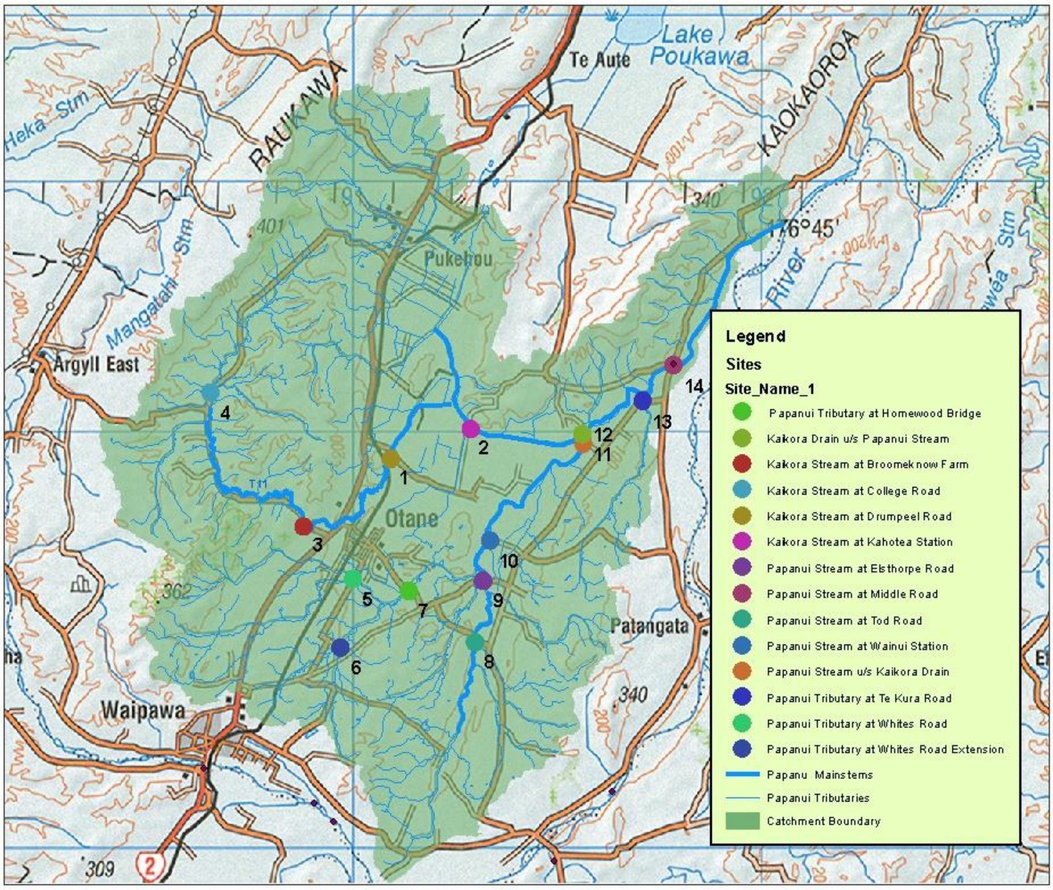

Figure 16: Sampling site locations in the Papanui Catchment. Papanui Stream and Kaikora Stream shown as 'Papanui Main stems' in bold blue.

7.4. Results

7.4.1. Targeted Nutrient Investigations

Several small first and second order streams were sampled to identify diffuse nutrient concentrations in the upper catchment - Sites 4, 5, 6, 7 and 13 (Figure 16). Flow in these streams were relatively low (Table 10), indicating that nutrient contributions (as loads and yields) are likely to be less significant. However, high nutrient concentrations in small streams still reflect high land-use pressure from the surrounding catchment. In addition, contributions from these small streams are cumulative and will influence water quality in receiving waters. Sites are presented in order of largest ï smallest flow. It should be noted that in Table 10, instantaneous loads for 11 of 14 sites are based on estimated stream flow (E) and measured nutrient concentration. Loads are therefore approximate estimates only.

Table 10: Estimated (E) and gauged (G) flows and calculated instantaneous daily nutrient loads for streams and stream sections in the Papanui Catchment on the 22 June 2012.

Site	Flow (m^3/s)	SRP Load (g/day)	TP Load (g/day)	Nitrate-N Load (g/day)	TN Load (g/day)
14. Papanui Stream at Middle Rd	0.4459 (G)	262	3544	24	77052
12. Kaikora Drain u/s Papanui Stream	0.1389 (G)	1008	1572	7441	31202
11. Papanui u/s Kaikora Drain	0.1187 (G)	379	451	2974	7589
10. Papanui Stream at Wainui Station	0.100 (E)	320	406	2160	5530
9. Old Waipawa River Bed at Elsthorpe Rd	0.090 (E)	420	568	2722	5365
8.Old Waipawa Bed at Tod Rd	0.085 (E)	125	140	3305	4186
2. Kaikora Stream at Kahotea Station	0.055 (E)	456	589	1948	12355
1.Kaikora Stream at Drumpeel Road	0.045 (E)	187	237	288	2022
3. Kaikora Stream at Broomeknow Farm	0.025 (E)	95	114	328	1793
7. Papanui Tributary at Homewood Bridge	0.012 (E)	36	89	206	1151
4. Kaikora Stream at College Rd	0.005 (E)	22	26	134	484
5. Papanui Tributary at White Rd	0.005 (E)	8	60	38	544
6. Papanui Tributary at White Rd Extension	0.002 (E)	12	21	7	213
13. Papanui Tributary at Te Kura Road	0.001 (E)	8	9	181	233

The results from this sampling campaign indicate that SRP and TP concentrations in most streams in the catchment are relatively high. The Hawkeӧs Bay Regional Council Regional Resource Management Plan (2006) guidelines for SRP in lowland streams (0.015 mg/L were exceeded at all sites (Figure 17). With the exception of one site, TP concentrations exceeded the Australian and New Zealand Environment and Conservation Council (ANZECC, 2000) trigger level for TP in lowland streams (0.033 mg/L), with results for many sites well above this trigger value (Figure 17).

While the smaller tributary streams (sites 5, 6, 7, 13) all had high concentrations of SRP and TP (Figure 17), because of their small flows their nutrient load contributions are minor.

There was a marked increase in SRP and TP concentrations in the Kaikora Stream between Drumpeel Road (Site 1) and Kahotea Station (Site 2). Over this reach, SRP increased by 0.048 mg/L (100%) and TP by 0.063 mg/L (103%). These are substantial increases relative to the trigger values of 0.015 mg/L and 0.033mg/L for SRP and TP respectively. Similar concentrations of SRP and TP persisted further downstream at Site 12.

These results also identified a large increase in SRP and TP concentrations in the reach between Tod Road (Site 8) and Elsthorpe Road (Site 9) - 0.037 mg/L (217%) and 0.054 mg/L (284%) respectively. These are significant increases in view of the relatively short distance between sites. A minor tributary not sampled as part of this investigation flows from the south east and may have contributed to this increase. SRP and TP concentrations decreased at the next two downstream Sites (10 and 11). It is likely that these decreases result from dilution, along with nutrient assimilation and uptake by plants.

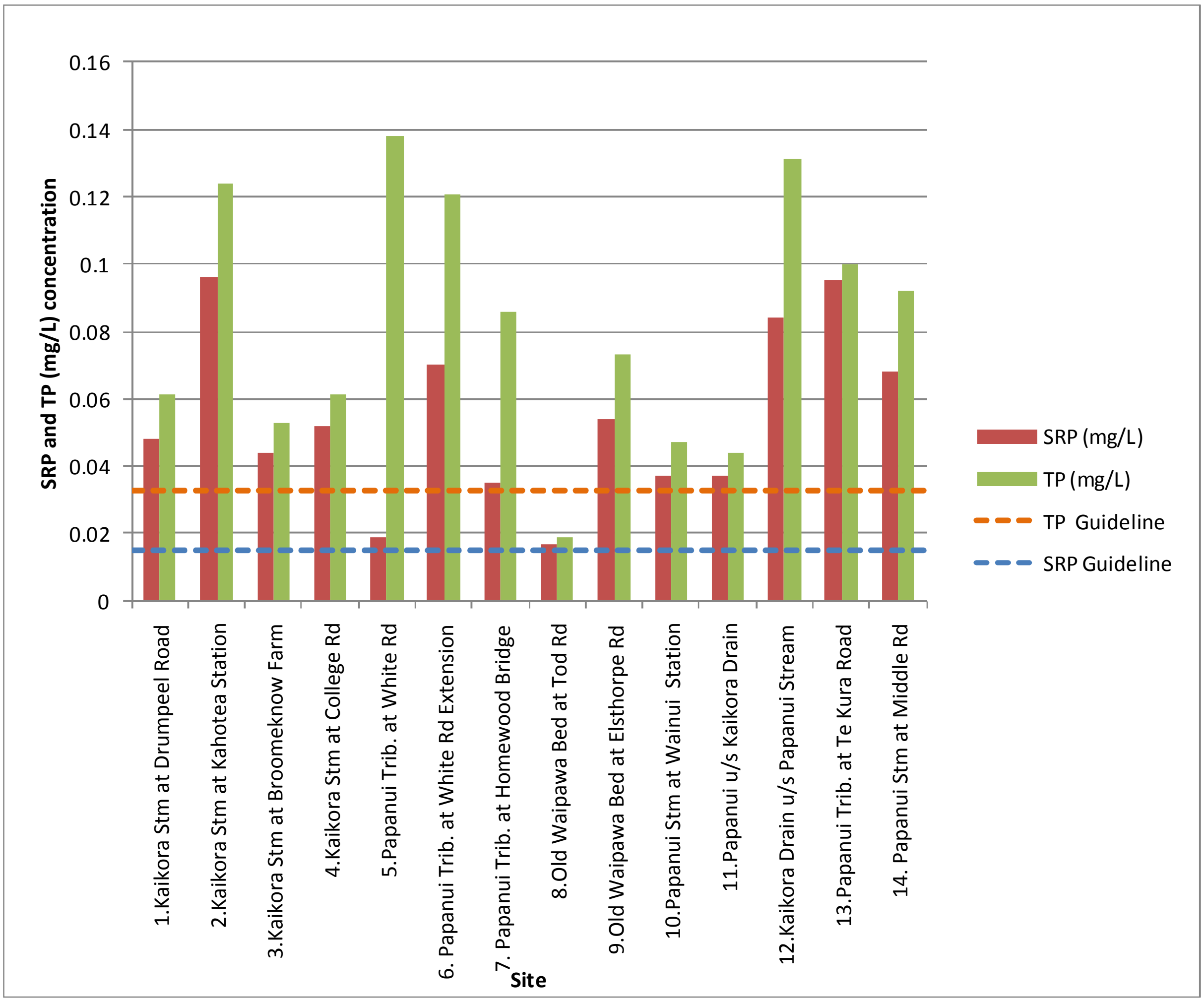

Figure 17: Soluble reactive phosphorus (SRP) and total phosphorus (TP) concentrations in the Papanui Catchment measured on the 22 June 2012.

Guideline value for TP based on ANZECC trigger value (2000) for lowland rivers of 0.033 mg/L. Guideline value for SRP of 0.015 mg/L based on limits set in the Hawke's Bay Regional Council Regional Resource Management Plan (2006).

All of the streams sampled were near or above the ANZECC trigger value of 0.614 mg/L for total nitrogen concentrations in lowland rivers (Figure 18). In main stem streams, exceedances were smaller than for phosphorus species. In the Kaikora Stream however, nitrate-N concentrations increased by 0.336 mg/L (454%) and TN concentrations increased by 2.08 mg/L (400%) over the reach between sites 1 and 2. These concentrations were reflected further downstream at site 12.

On the main stem of the Papanui Stream (Site 8), nitrateï N concentrations are high relative to TN. This relationship alters in a downstream direction, suggesting conversion of inorganic nitrogen to organic nitrogen as total nitrogen levels increase. This reflects an increase in the

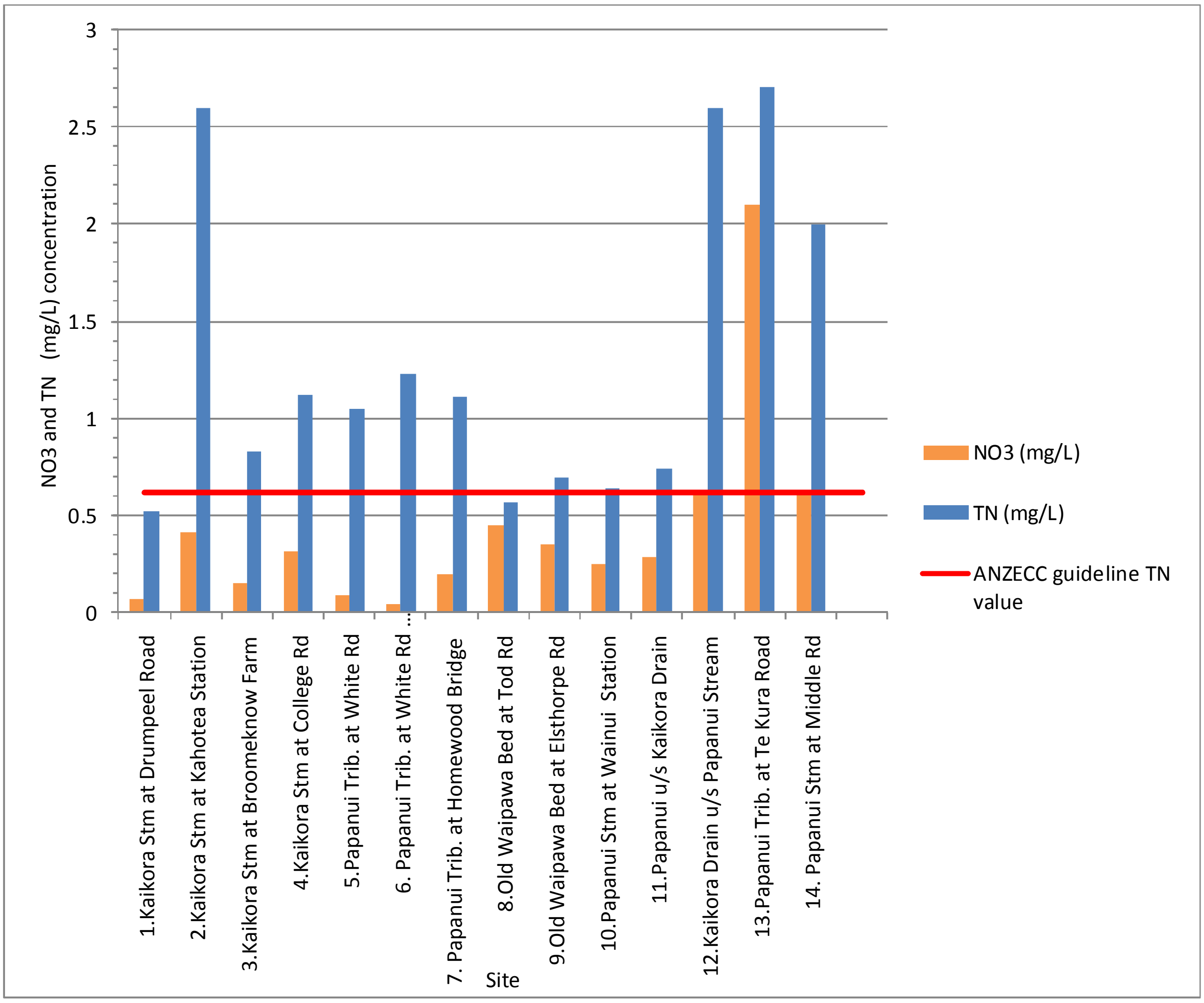

Figure 18: Total nitrogen (TN) and nitrate (NO3_N) concentrations in the Papanui Catchment measured on the 22 June 2012. Trigger TN value of 0.614 mg/L from ANZECC (2000).

in-stream organic nitrogen component. This is typical of the Papanui Stream at Middle Road as shown for a twelve-month period in Figure 19. Organic nitrogen dominates the total nitrogen component on all occasions and is extremely high in late summer, when TN concentrations are relatively low, showing a high level of assimilation and nutrient transformation by catchment and in-stream processes. The Papanui Stream catchment contains several drained wetlands with a high peat content. Breakdown of this peat material provides organic carbon which is expected to contribute to conversion of inorganic N to organic nitrogen and this peat may be a source of DON input to the stream. Additionally, the organic carbon is likely to increase denitrification of nitrate due to microbial breakdown of organic material under anoxic soil conditions. Abundant instream plant biomass in the streams is expected to result in organically enriched sediments (due to entrapment of organic solids in streambed sediments) and diurnal swings in dissolved oxygen, with low night-time levels due to plant respiration - a combination of conditions that enhances nitrate removal by denitrification to nitrogen gases that are lost to the atmosphere. These factors need to be considered when looking at levels of attenuation estimated from nitrogen loss from the catchment (root zone) and measured in-stream loads.

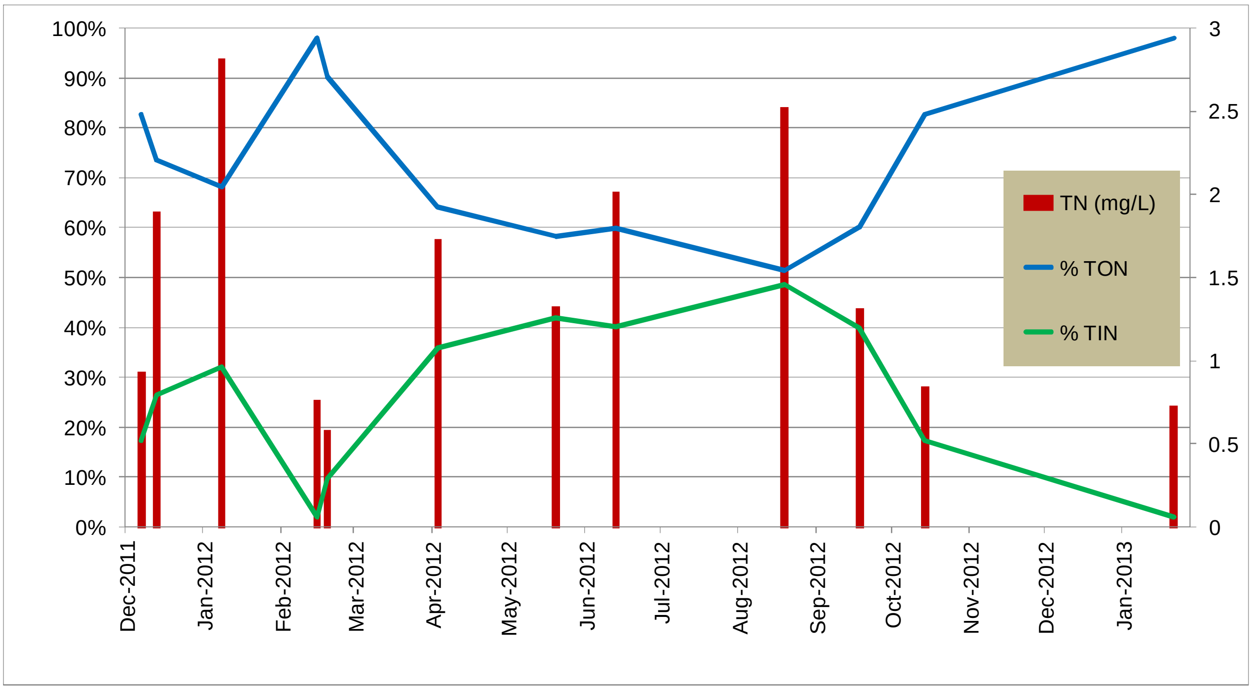

Figure 19: Relative contribution of total inorganic and organic nitrogen in the Papanui Stream at Middle Road from December 2011 to January 2013 .

On the date of the Papanui catchment targeted investigation (22 June 2012), SRP and TP concentrations at Site 14 were well below the average values for 2011 - 2012 (Table 11). This could be attributed to the lower flow conditions that existed at the time of sampling (as mentioned in section 7.2). Because phosphorus inputs to streams are associated primarily with overland flow, the potential for inputs from this transport pathway is reduced during drier periods. However, high phosphorus levels during summer conditions of low flows and high plant biomass likely result from phosphorus released from in-stream sediment due to night time sediment anoxia. This was unlikely to be occurring during the winter 2012 survey conditions of lower light, temperatures and lower macrophyte growth.

Nitrateï N and TN loads estimated using data collected on the 22nd June were however larger than the 2011 - 2012 average value (Table 11.). Under low flow conditions, the proportion of potentially nitrate ï rich groundwater in stream flow is higher, therefore increased concentrations could be experienced. Some evidence of this is evident from comparison of results collected on 22 June 2012 with results derived in previous months from the Papanui Stream at Middle Road site.

Average SRP and TP concentrations in the 2011-2012 period were much higher than average historical (1994-1998) levels. By contrast Nitrateï N concentrations were lower for the 2011-2012 period relative to historical results (Table 11). Historical TN data was not available.

Table 11: Comparison of SRP, TP, Nitrate-N and TN concentrations measured on 22 June 2012 with historic mean values

Papanui at Middle Road	SRP (mg/L)	TP (mg/L)	Nitrate-N (mg/L)	TN (mg/L)
22-June	0.07	0.09	0.62	2.00
2011- 2012 Mean	0.19	0.28	0.32	1.52
1994- 1998 Mean	0.04	0.14	0.90	**N/A**
Long Term Mean	0.08	0.16	0.78	**N/A**

Mean SRP and TP concentrations for the periods 1994 ï 1998 and 2011 -2012 were multiplied by estimates of mean annual flows (derived from ñsyntheticò flow data), to derive annual nutrient load estimates (tonnes of material/year) (Figure 20). Mean annual flow data for 2011 were used for the 2011- 2012 period because flow data for 2012 is incomplete. Load estimates for the 2011- 2012 period were much higher than estimates for previous years, with a 388% and 93% increase in SRP and TP respectively. Estimates of SRP loads for the Papanui Stream appear to be larger than the combined loads derived from the Waipukurau and Waipawa oxidation ponds. The recent finding (on 20/2/13) that under the current summer low flow conditions the flow increased from 2.4 L/s at Middle Rd to 403 L/s at the Camp David Bridge on the Tukituki flood plain (Peter Arnold NIWA Napier pers comm.) suggests the summer nutrient load may be substantially higher than that calculated from Middle Rd flow and nutrient data. This finding is highly significant when the importance of phosphorus inputs and periphyton growth in the lower Tukituki River is considered. It is possible that higher than average rainfall and stream flows (150% higher than the long term average) for the Dec 2011- Jun 2012 period may have contributed to these increased SRP and TP loads, so these comparisons must be treated with caution.

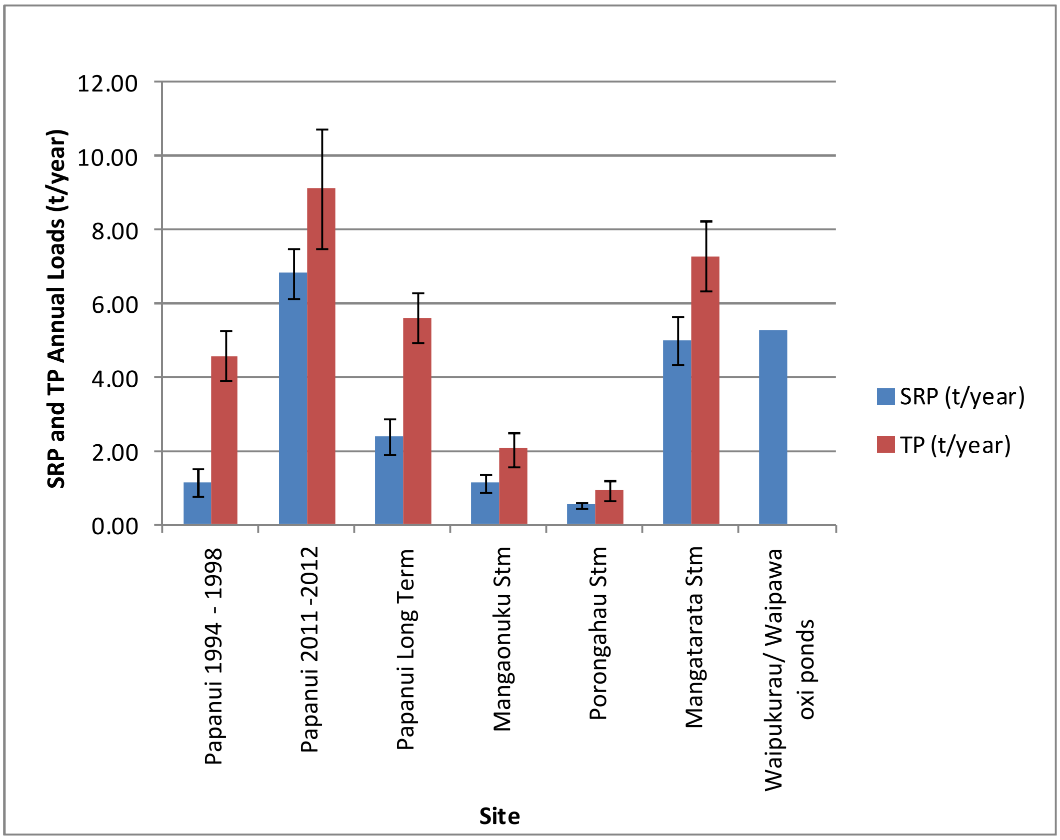

Figure 20: Comparison of recent and historical average annual SRP and TP loads for the Papanui Stream with selected Tukituki Subcatchment sites and Waipukarau and Waipawa oxidation ponds (2008 – 2012 data). Long term Papanui load is the average of all data available

Recent (2011- 2012) results identified a significant contribution of SRP and TP from the Papanui Stream into the Tukituki River during the summer. Figure 21 shows an increase of 198% (SRP) and 46% (TP) between sampling periods (1994-1998 and 2011-2012). Loads of SRP in the Papanui Stream during the 2011 -2012 period are only slightly smaller than those in the Tukituki River at Red Bridge, located downstream of the Papanui Stream confluence. This may be explained by considering the assimilation of SRP into plant biomass during the summer. The large supply of available phosphorus, warm water temperature and plentiful sunlight favours plant (algae and macrophyte) growth. This increasingly removes SRP from the Tukituki River water as it flows toward the mouth.

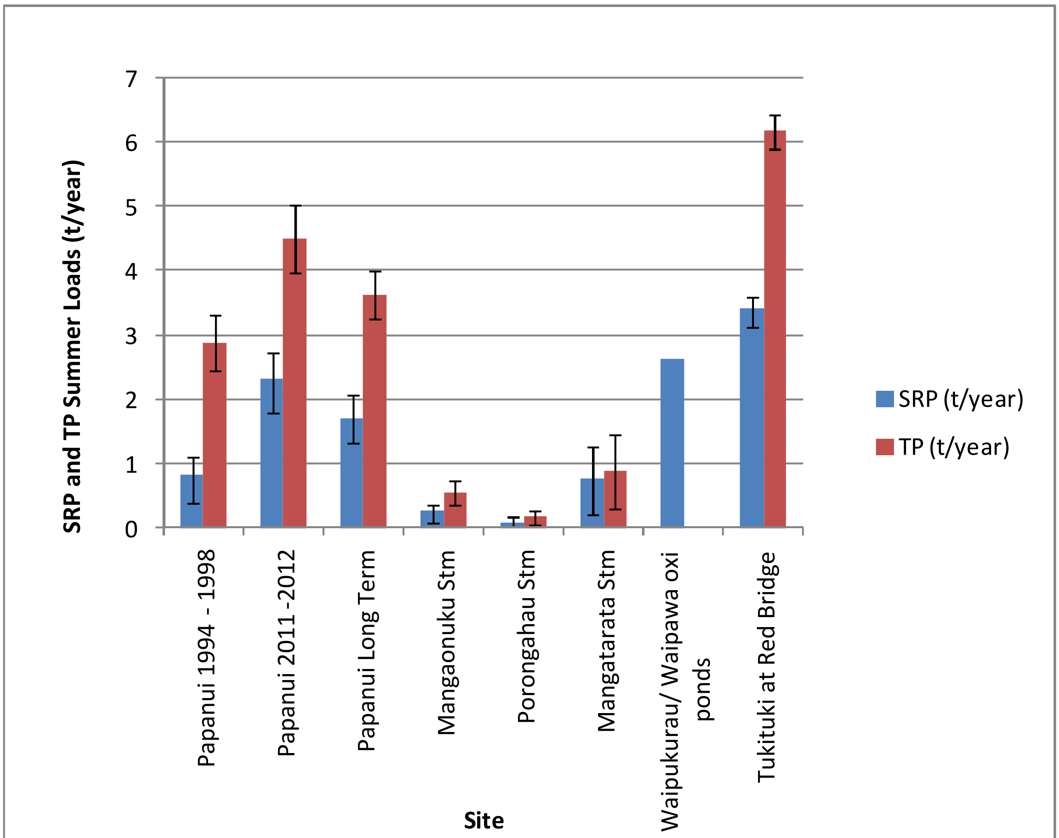

Figure 21: Average summer (November to April) SRP and TP loads for recent and historical Papanui Stream at Middle Road results, Waipukarau and Waipawa oxidation ponds and Tukituki River at Red Bridge. The 'Papanui Long Term' data is an average of all data available

As was done with the SRP and TP data, mean annual nitrateï N concentrate concentrations for the periods 1994 ï 1998 and 2011 -2012 were multiplied by estimated mean annual flows to provide an estimates of annual nitrate-N load (reported as tonnes/year) (Figure 22~~Figure 22~~). Average loads estimated for the 2011- 2012 period are significantly larger than historical mean loads (a 40% increase), however this may be due to the higher flows experienced during this period. The long term average remains high. The overall contribution of nitrate-N from the Papanui Stream to the Tukituki River is relatively low when compared with other sources, such as the Mangaonuku Stream.

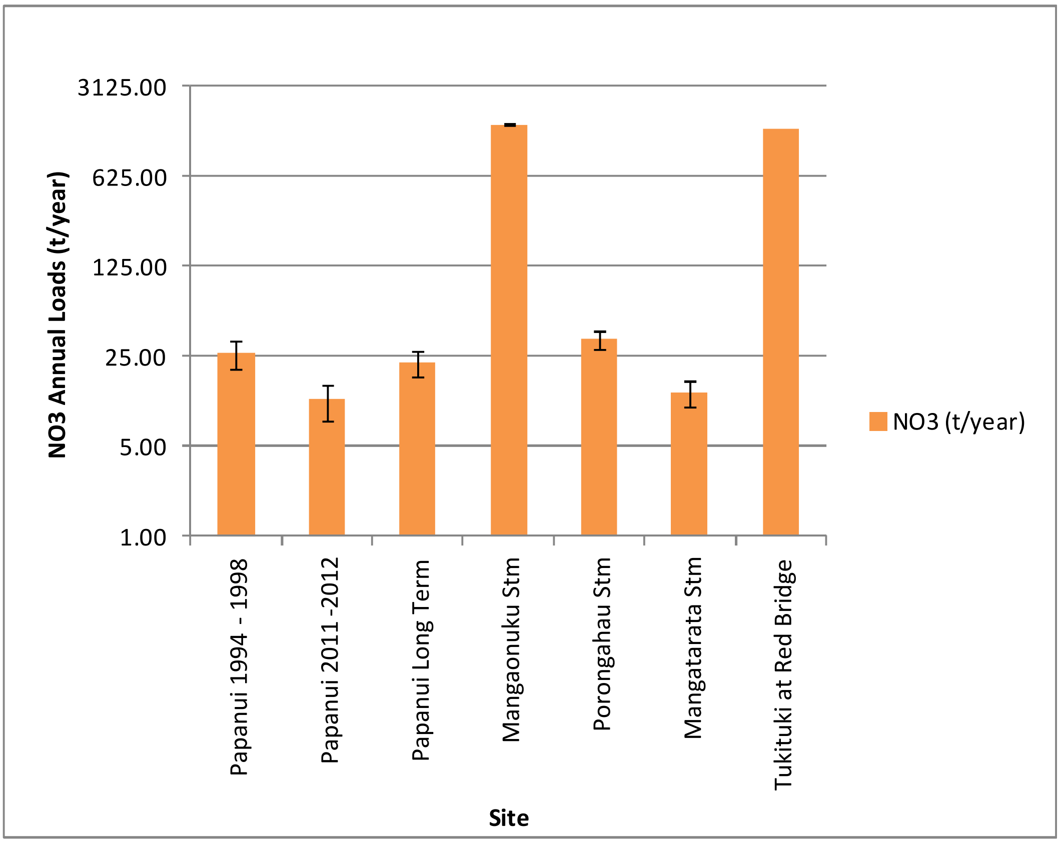

Figure 22: Comparison of average annual NO3_N loads for recent (2011-12) and historical (1994-98) Papanui Stream results, with selected Tukituki Subcatchment sites. Long term Papanui load is the average of all data to date. Data are log transformed.

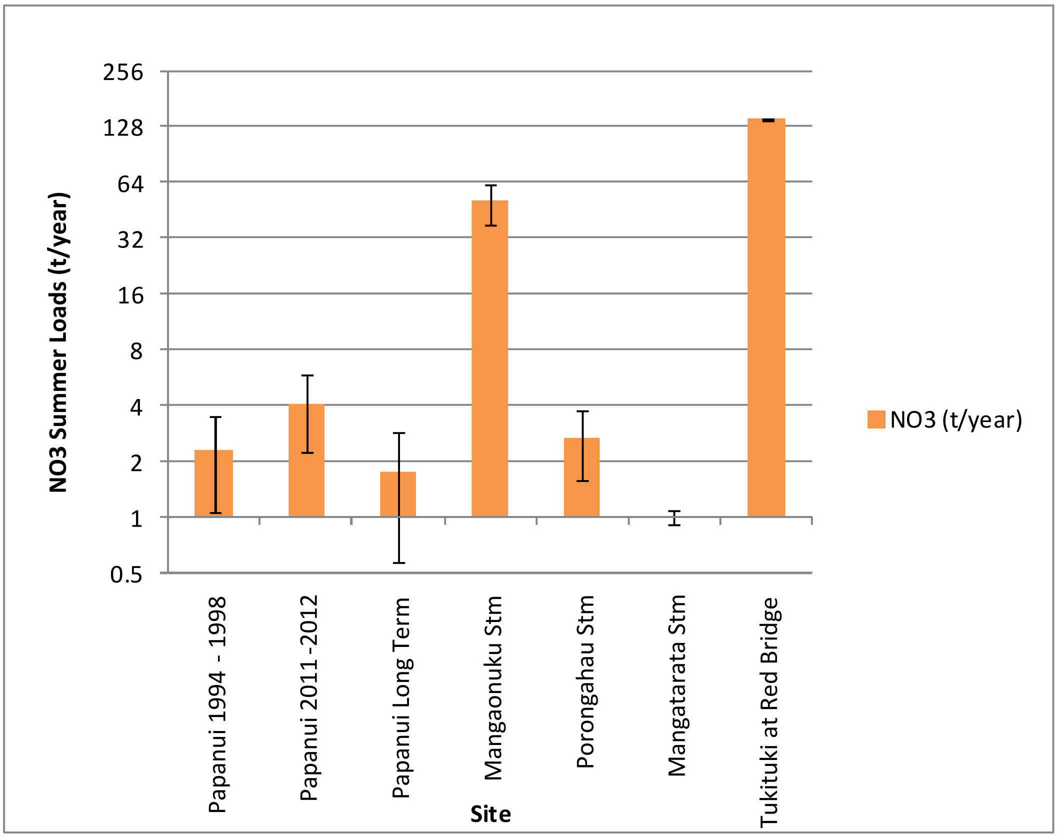

Figure 23: Comparison of average summer (November to April) NO3_N_N loads for recent (2011-12) and historical (1994-98) Papanui Stream results, with selected Tukituki Subcatchment sites. Long term Papanui load is the average of all data to date. Data are log transformed.

Figure 23 shows a 59.3% increase in summer NO3_N loading for 2011 ï 2012 compared with historical results. This possibly reflects higher than average summer rainfall and flow conditions and consequent run off over this period. As with annual loading results, the contribution of nitrate-N from the Papanui Stream to the Tukituki River is relatively low.

Figure 24 compares historical and recent estimates of mean annual yield for the Papanui Stream for SRP and TP with those from other streams. The mean annual yield measured in 2011-2012 in the Papanui catchment was the highest of the sub-catchments plotted in Figure 24. Catchments were chosen which represented similar catchment characteristics (size, land use, position in catchment) and annual nutrient loads. The Tukituki River at Red Bridge was included for reference.

Figure 25 compares historical and recent estimates of mean summer yield for the Papanui Stream for SRP and TP with those estimated for a number of other catchments. The summer TP yield from the Papanui Stream catchment appears generally larger than in other catchments, while in 2011/2012, the SRP yield was also much larger than in other rivers in the Tukituki catchment.

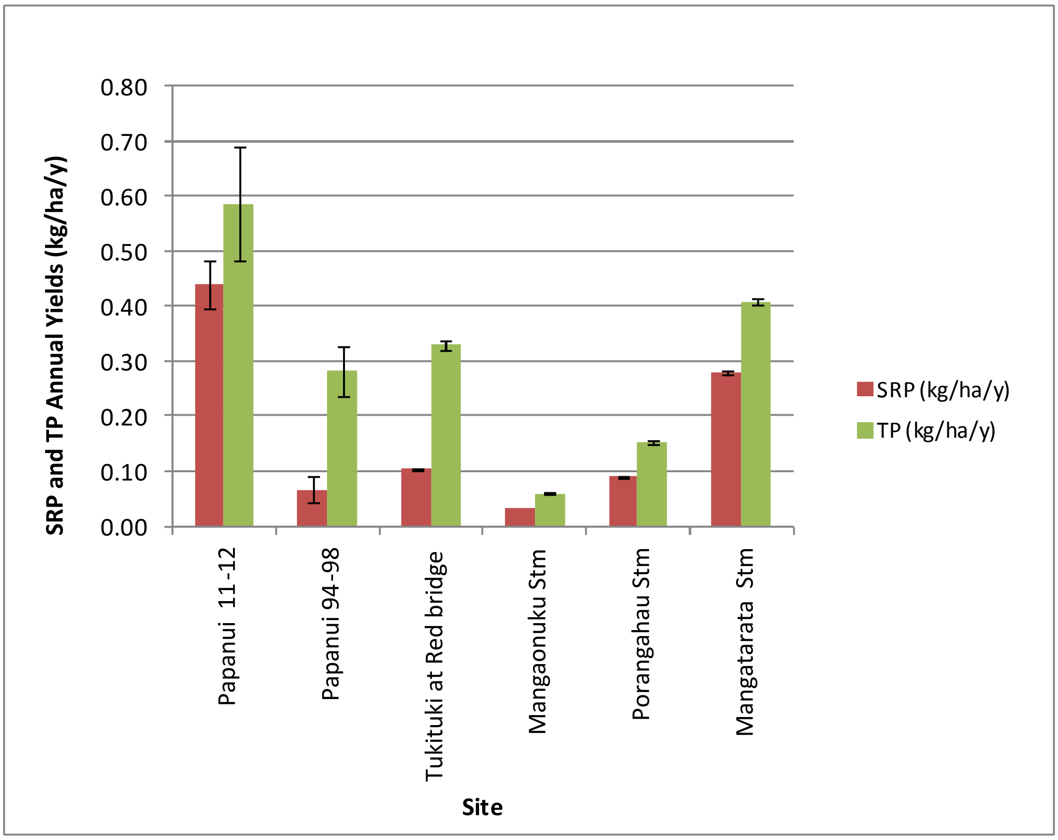

Figure 24: Annual SRP and TP yields in kg/ha/y for recent (2011-12) and historical (1994-98) Papanui at Middle Road results. Selected sites from the Tukituki are included (data collected monthly from 2004 to 2011) sites selected for similar position in catchment, surrounding land use and stream type.

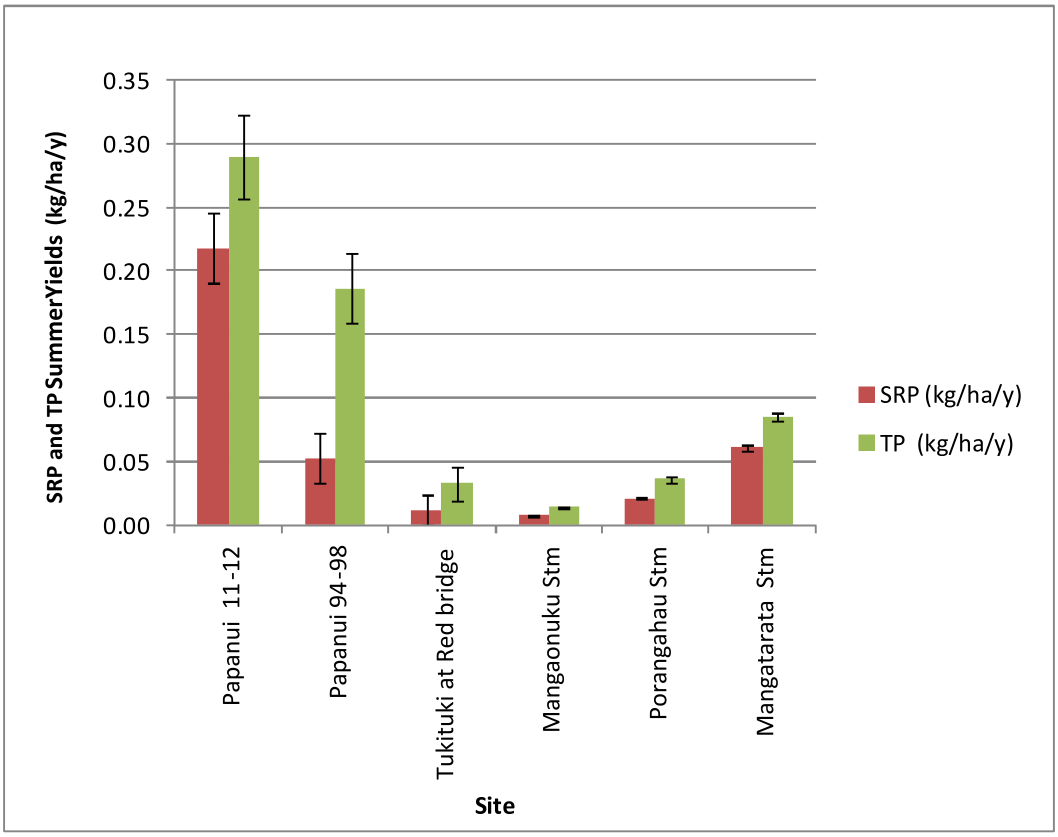

Figure 25: Average Summer SRP and TP yields in kg/ha/y for recent (2011-12) and historical (1994-98) Papanui at Middle Road results. Selected sites from the Tukituki are included (data collected monthly from 2004-2011). Sites selected for similar position in catchment, surrounding land use and stream type.

In Figure 26Figure 26 nitrate-N and TN yields for the Papanui Stream are compared between monitoring periods, as well as with yields estimated for other catchments in the Tukituki River catchment. Nitrate-N yields in the Papanui River catchment were lower in 2011/2012 than previously. Nitrate-N yields in 2011/12 were much smaller than in other catchments in the Tukituki River catchment. Both recent and historical figures appear low relative to other Tukituki sub-catchments shown in Figure 26Figure 26. TN data was not available for historical results.

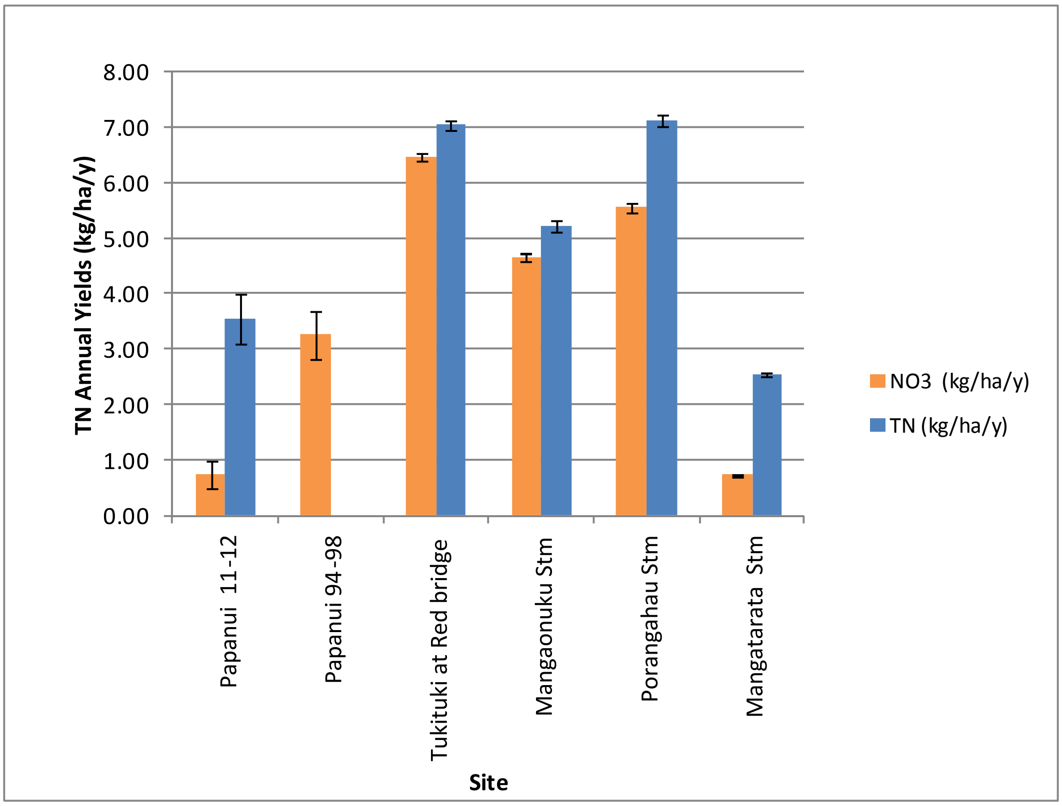

Figure 26: Average Summer (November to April) NO3_N and TN yields in kg/ha/y for recent (2011-12) and historical (1994-98) Papanui at Middle Road results. Selected sites from the Tukituki are included (data collected monthly from 2004-2011). Sites selected for similar position in catchment, surrounding land use and stream type.

7.4.2. Nutrient Limitation

Results from the nutrient limitation experiment in the Papanui Stream suggest that Nitrogen was the nutrient limiting algal growth at the time of the experiment. Five replicates of each treatment (Nitrogen, Phosphorus, Nitrogen plus Phosphorus and Control) were analysed for Chlorophyll a concentrations. The highest concentrations of Chlorophyll a were reported from the treatments impregnated with Nitrogen (N and N + P) indicating that Nitrogen is limiting algal growth in the Papanui stream during summer (Figure 27).

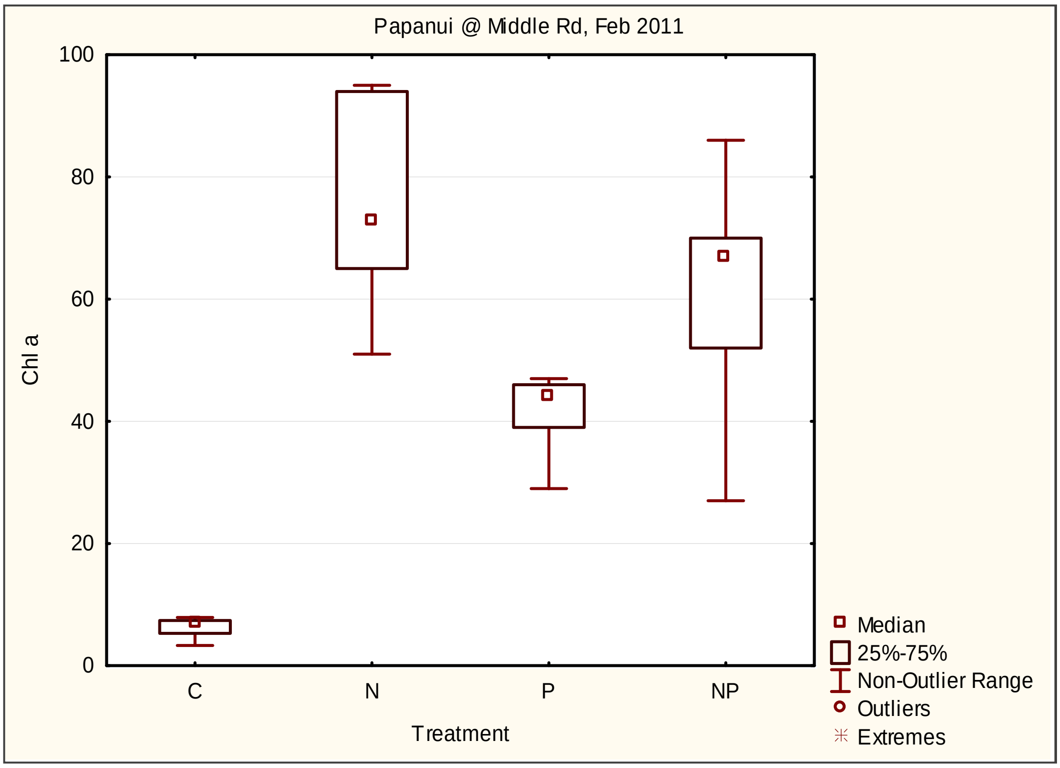

Figure 27: Chlorophyll a concentration per treatment for Papanui Stream at Middle Road

Table 12: Nutrient ratios for DIN and DRP and TN and TP for samples collected over the period 2011 to 2012 as part of the HBRC State of Environment monitoring program.

Sample Taken	SRP (mg/L)	TP (mg/L)	DIN (mg/L)	TN (mg/L)	DIN:DRP	TN:TP
8/12/2011	0.34	0.43	0.42	1.33	1.2	3.1
16/12/2011	0.27	0.36	0.16	0.92	0.6	2.6
22/12/2011	0.112	0.142	0.49	1.88	4.4	13.2
17/01/2012	0.154	0.22	0.89	2.8	5.8	12.7
24/02/2012	0.21	0.31	0.02	0.75	0.1	2.4
28/02/2012	0.21	0.25	0.051	0.57	0.2	2.3
12/04/2012	0.157	0.2	0.615	1.716	3.9	8.6
29/05/2012	0.071	0.083	0.558	1.31	7.9	15.8
22/06/2012	0.068	0.092	0.833	2	12.3	21.7
28/08/2012	0.2	0.28	1.219	2.509	6.1	9.0
27/09/2012	0.059	0.103	0.525	1.3	8.9	12.6
23/10/2012	0.063	0.087	0.144	0.827	2.3	9.5

Water quality samples collected during the State of Environment monitoring program between 2011 and 2012 are included in Appendix IV.

7.5. Discussion and Conclusion

Comparisons between recent sampling results for the Papanui Stream, Tukituki subcatchments and Waipawa and Waipukurau oxidation ponds reveal that the Papanui Stream is a major source of phosphorus to the lower Tukituki River. Average annual SRP and TP loads and yields appear to have increased between the two sampling periods for which data are available for the Papanui Stream, a result that may be influenced in part by wetter conditions during the recent surveys.

The results of the targeted sampling on 22 June 2012 show widespread phosphorus and moderate nitrogen loading in the Papanui catchment, with near catchment-wide exceedences of guideline trigger values of SRP and TP for healthy lowland streams. TN concentrations were also above guideline trigger values, with the Kaikora Stream having the greatest exceedances. Phosphorus and nitrogen concentrations appeared to be generally elevated relative to other Tukituki River subcatchments. It is likely that loss of riparian vegetation, inadequate fencing, the conversion of predominantly sheep farming to ósheep and beefô operations, generally unrestrained access of stock to the stream and the underlying mudstone and limestone which is present in the catchment favour input of nutrients to surface waters. Given the low flow conditions that existed when targeted sampling occurred, it is likely that measured concentrations and estimated loads are at the lower end of the range of possible values and probably do not reflect typical conditions at each site. Sampling across a range of flow conditions would allow variation in annual concentrations, loads and yields to be assessed. Despite the limitations in the data, large increases, longitudinal spatial, in nutrient concentrations and estimated loads were evident at Sites 2 and 9.

Satellite photographs and information from the Land Cover Database 3 (LCDB3) (MfE, 2012) reveal that short rotation cropping is the dominant land use in the catchment south of Pukehou which feeds the Kaikora Drain upstream of Site 2 (Figure 16). High SRP, TP and TN concentrations at Site 2 could possibly result from mobilisation of fertiliser and particulate materials in this subcatchment. Aerial photographs of the catchment from 1992 (photo 1) and recently (photo 2) is included in Appendix II. Photo 1 shows the plains (centre left) in flood. While it is difficult to infer land use change over time, it is clear from photo 2 that some drainage intensification has occurred. This could shorten nutrient transport pathways between land and waterways, reducing attenuation and generally increasing nutrient loads.

The catchment drained by the un-named tributary that joins the Papanui Stream between Sites 8 and 9 includes hill country sheep and beef and cropping land. Such land-use is typical of the entire Papanui catchment, making the considerable increase in SRP and TP (between Sites 8 and 9) more difficult to explain. The topography in this part of the catchment is rolling hill country. This suggests increased sediment transport associated with erosion processes, causing increases in in-stream phosphorus concentrations with phosphorus associated with particulate materials.

According to the AgriBaseÊ database, conversion from ósheepô farming to ósheep and beefô farming accounted for the most of the land use change that occurred within the Papanui catchment in the period from 2001-2011 (see Appendix I). While estimated nitrogen leaching rates assigned to ósheepô and ósheep and beefô land uses are similar, an increase in beef cattle numbers could potentially increase P loading trends as a consequence of river bank erosion and direct discharge of animal wastes into waterways (sheep normally spend less time in streams than cattle).

There has also been an increase in arable farming in the catchment - given the significantly higher rates of fertiliser application, leaching and potential for erosion of cultivated soils associated with cropping compared with sheep and beef (TN leaching of ~180kg/ha/y for cropland, compared with ~ 20kg/ha/y for sheep and beef), nutrient loads and concentrations measured in streams are likely to be very sensitive to this change in land use. The method employed to calculate nutrient loads and yields contains many assumptions and is subject to the quality and quantity of available data. Water quality is represented by relatively few data, which may poorly represent typical stream conditions. In addition, the accuracy of synthetic flow data may be low. Data for the 2011-2012 ‘recent’ calculations include relatively few results, which may inadequately represent annual conditions. Rainfall and flow conditions experienced during the summer of 2011/12 were also atypical – rainfall was much higher than average. In response, longer term mean flow data were used when calculating loads for the 2011-2012 period to reduce the influence of high flow events. This is especially evident in Figure 25, where average summer nutrient yields are far greater than similarly sized sub-catchments such as the Mangatarata Stream. Care should be taken when interpreting these results.

Despite these limitations, the results are considered informative. HBRC is committed to continued sampling of the Papanui Stream at Middle Road as part of the long-term SoE monitoring program. Monthly water quality testing over several years would provide a similar sample size to historic data, and enable more robust comparisons, particularly between historic and present conditions.

Phosphorus loads are of particular concern in the Tukituki River system - work to date suggests that it is the nutrient most likely to limit algal growth in the lower Tukituki River that the Papanui Stream discharges into (Uytendaal pers. com., 2012). This study has identified:

- the Papanui Stream is a major source of phosphorus to the Tukituki River, and
- the existence of two apparent ‘hotspots’ within the Papanui watershed
- an apparent increase in the loads exported from the Papanui catchment over time.

The Papanui Stream has also been identified as a major source of dissolved reactive phosphorus (DRP) to the lower Tukituki River by Rutherford (2012).

Further water quality sampling and investigation into land management practices and underlying geology in select areas will help identify the nutrient sources. This will support the development of policy and enable effective management decisions to be made to improve water quality in the Papanui and Tukituki catchments.

8. PAPANUI STREAM ECOLOGICAL VALUATION AND MACROINVERTEBRATE COMMUNITY INDEX

8.1. Introduction

The Hawke's Bay Regional Council has undertaken a Stream Ecological Valuation (SEV) (Storey et al., 2011) to assess the current ecological character of the Papanui Stream.

Table 13: Site locations of the reaches surveyed

Site	NZTM_Easting	NZTM_Northing
Papanui Stream @ Middle Road	1917809	5581644
Papanui Stream U/S Kaikora stream	1915607	5579940
Papanui Stream @ Wainui station	1913325	5577385
Papanui Stream @ Elsthorpe Road	1913167	5576414

8.1.1. Survey Reaches

The Papanui stream has been assessed at four sites along its length at sections most representative of the conditions of the stream (Figure 28).

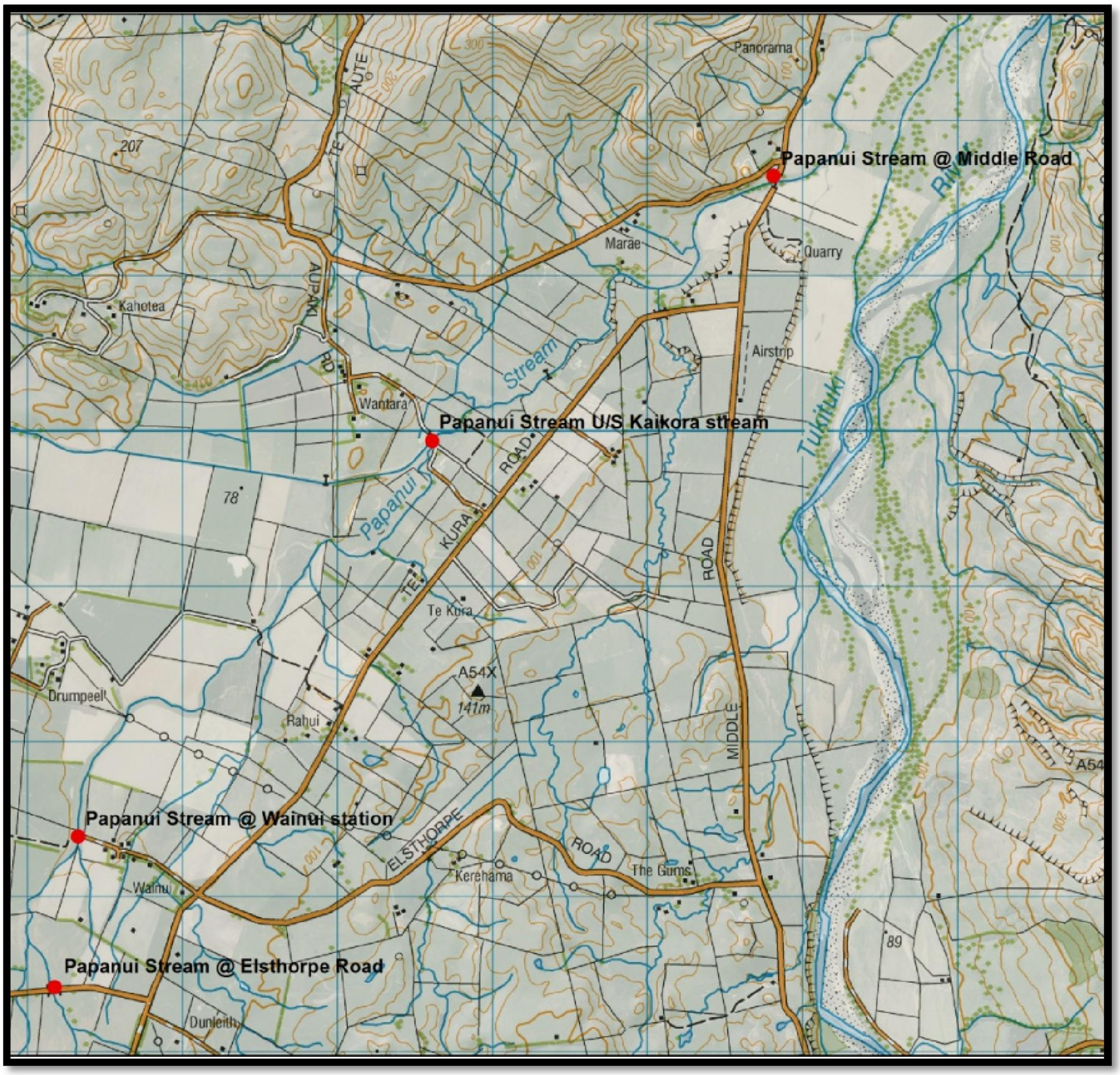

Figure 28: Locations of SEV survey reaches

Site 1- Papanui Stream @ Middle Road

Papanui @ Middle road site is situated upstream of the bridge. The immediate surrounding land-use is non-intensive pasture. The stream has good connection to the floodplain in this reach demonstrating a floodplain width greater than 50 meters. There is little riparian buffer to the stream in this reach and the site has minimal shading and extensive macrophyte growth. Stock has full access to the stream on the true left bank of this reach. Access is restricted on the true right bank due to fencing and a mature willow (*Salix spp.*) riparian edge.

Site 2 - Papanui Stream u/s Kaikora Stream

The Papanui stream U/S of Kaikora Stream is more channelised than site 1 and as such there is a low connection of the stream to a narrow floodplain. The surrounding land-use is intensive pasture and the stream runs through a dairy farm at this site. This reach has minimal shading and extensive macrophyte growth dominated by the introduced macrophyte Hornwort (*Ceratophylum demersum*). Stock does not have access to the stream at this reach due to the steep banks and fencing.

Site 3 - Papanui Stream @ Wainui Station

The Papanui @ Wainui station has a natural stream bed with cobble gravel substrate. The stream has no riparian buffer and has good connection to a wide floodplain. There is no protection from stock access and at the time of survey stock were seen in the stream. The site has extensive periphyton and macrophyte growth.

Site 4 - Papanui Stream @ Elsthorpe Rd bridge

Papanui @ Elsthorpe Rd site is situated downstream of the bridge. The stream has no riparian protective buffer and as a result has extensive macrophyte and periphyton growth. There is no protection from stock access on either bank.

8.2. Method

8.2.1. Stream Ecological Valuation (SEV)

The SEV is a technique used to score a stream reach based on 14 variables relating to the how the stream functions. These 14 variables are used to calculate four function scores; Hydraulic, biogeochemical, habitat provision and biodiversity (Figure 29). The SEV was originally developed to assess the condition of streams in the Auckland region, however it has been demonstrated as a robust technique for assessing streams in Hawke's Bay (refer Forbes 2008a, 2008b, and 2009) and elsewhere in New Zealand, and has been used to identify relationships between land-use and stream condition in agricultural systems (Macdonald, 2006).

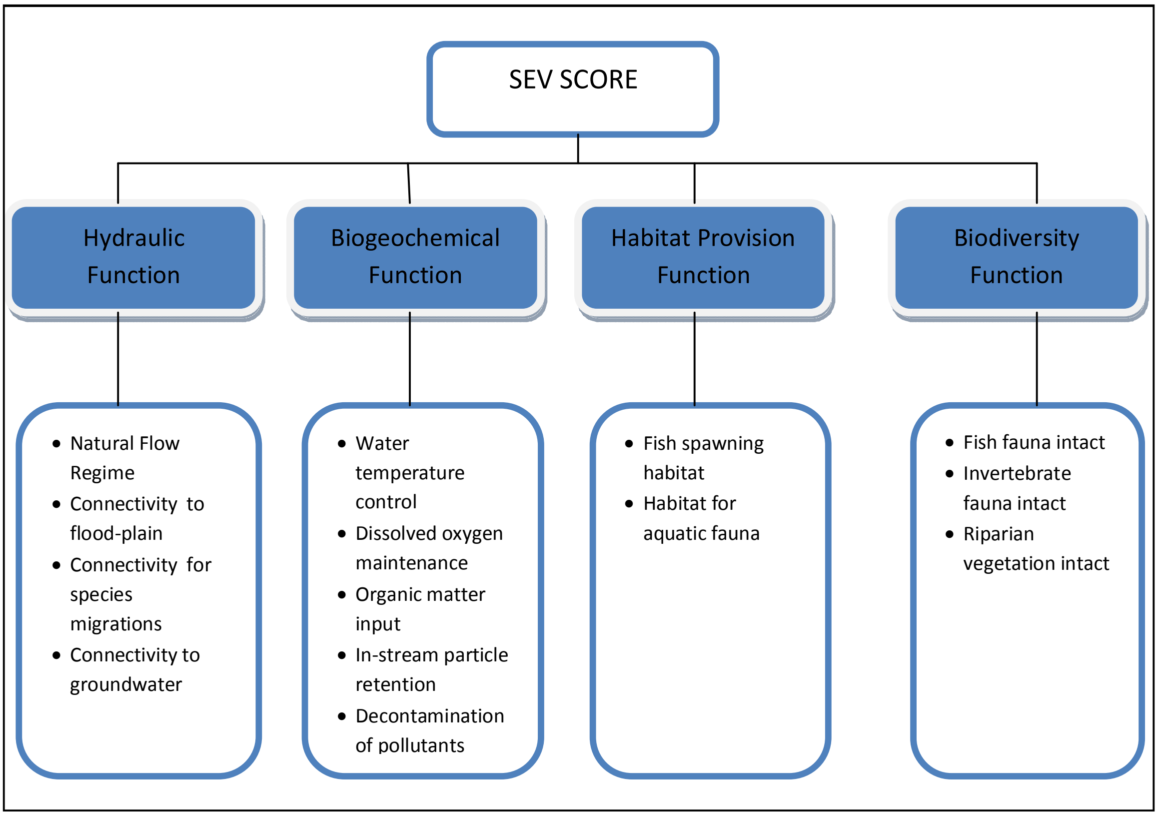

Figure 29: The four Functions and 14 variables used to assess the SEV score

The 4 sites were assessed on the 30th and 31st January 2013. The field assessment process included observations and the collection of macro-invertebrate samples in each reach according to the protocols for sampling macroinvertebrates in wadeable streams (Stark et al, 2001) and the taxonomy identified by Landcare Research. Survey reaches were standardised to 100m.

Desktop Analysis

The SEV requires that a fish and macro-invertebrate survey is carried out. In this case, an individual fishing assessment was not carried out and instead a GIS based analysis of the Point click fish database (Joy, 2005) was used to identify the fish communities likely to be present. It is recommended that a fishing assessment is carried out as part of future studies to confirm and refine these findings.
Catchment riparian shading and the proportion of impermeable land upstream of the reach were estimated upstream of the survey reaches using GIS and aerial imagery (Kiwiimage, NZ Defence Force).

Reference sites

The SEV methodology requires that the scores are standardised against streams of high ecological character. Reference sites should be un-impacted by human development or other human disturbance and should ideally demonstrate the same catchment and reach characteristics as the reaches being assessed.

Given the highly modified nature of the catchment, there are no suitable reference sites within the Ruataniwha Plains. In this instance, it was deemed acceptable to use the reference criteria applied to the Upper Karamu SEV (Cameron, 2010). The Papanui catchment shares very similar characteristics to the Poukawa catchment, of which the Upper Karamu is part.

8.2.2. Macroinvertebrate community index

The macroinvertebrate community of a stream adjusts to conditions in the aquatic environment, including changes and stressors affecting the ecosystem health. The macroinvertebrate community index (MCI) quantifies the stream condition with a single number that summarises the complexity of stream health and provides a measure that can be related to a wide range of factors. Assessing the composition of macroinvertebrate communities provides a long-term view of water quality - the animals are exposed to changes in conditions at the site generally for a year or even several years, depending on their life cycle. The community composition changes as sensitive species experiencing stress are lost, which leads to a community dominated by more tolerant species. While differences in communities can be induced by human activities, different communities also exist due to natural conditions such as drought and floods, or natural variation in stream bed substrate type.

The macroinvertebrate community index was developed to indicate water pollution by biodegradable organic contaminants; the index score also decreases when other factors (e.g. stream habitat functions) are impaired.
The quality classes indicated by the MCI score are (Stark & Maxted 2007):

≥120	Excellent quality, clean water
100-119	Good quality, possible mild pollution
80 ï 99	Fair quality, probable moderate pollution
< 80	Poor quality, probable severe pollution

The macroinvertebrate samples collected at the four sites on the Papanui stream were standardised to presence/absence and a Macroinvertebrate Community Index (MCI) score was calculated, using the formula: **MCI = 20 x [$\sum a_i$/ S]**

where a_i = Tolerance Values (TV) for the i^{th} taxon, S = total number of taxa

8.2.3. Water Samples

Water samples were collected from the four survey reaches at the time of the SEV survey and the results presented in appendix. IV

8.2.4. Periphyton Assessment

A visual assessment for periphyton and macrophytes was carried out at the four survey reaches and the results included in appendix V

8.3. Results

8.3.1. Stream Ecological Valuation

Ecological function scores and overall SEV scores for the four survey reaches and the Karamu reference streams are presented in Table 14. The four stream reaches did not have any barriers to species migrations and scored the highest score possible for this variable. Additionally the surveyed reaches scored well for the connection to groundwater and the natural flow regime variables due to the natural channel morphology and gravel cobble substrate. The lack of riparian vegetation at all of the reaches sampled contributed to low scores for water temperature control and organic matter input. Extensive macrophyte growth in the stream and the presence of the floating macrophytes (*Lemna minor and Azolla filiculoides)* at sites 1 and 2 led to low scores for in-stream particle retention. Site 1 had the highest score for fish spawning habitat due to the length of the stream reach that was suitable for *Galaxiid spp*. spawning as well as the presence of wood and other hard substrates suitable for spawning by *Gobiomorphus spp.* Invertebrate fauna was very poor at all four sites surveyed which is due to the lack of riparian vegetation and adequate temperature control at the sites.

Table 14: Function & SEV scores for the Papanui survey reaches and Karamu reference sites. Low function scores are highlighted in red.

Variable name	1-Papanui @ Middle Rd	2-Papanui u/s Kaikora stream	3-Papanui @ Wainui	4-Papanui @ Elsthorpe	Karamu 1	Karamu 2	Karamu 3
Natural flow regime	0.55	0.57	0.72	0.68	1.00	1.00	1.00
Connection to flood-plain	0.33	0.33	0.20	0.20	0.80	0.80	0.80
Connection for species migrations	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Connection to groundwater	0.87	0.84	0.98	0.97	1.00	1.00	1.00
Hydraulic function mean score	**0.69**	**0.69**	**0.72**	**0.71**	**0.95**	**0.95**	**0.95**
Water temperature control	0.04	0.16	0.00	0.00	0.80	0.80	0.80
Dissolved oxygen maintenance	0.40	0.34	0.68	0.68	1.00	1.00	1.00
Organic matter input	0.20	0.05	0.00	0.00	1.00	1.00	1.00
Instream particle retention	0.20	0.00	0.44	0.34	0.88	0.88	0.88
Decontamination of pollutants	0.65	0.62	0.60	0.60	0.73	0.73	0.73
Biogeochemical function mean score	**0.30**	**0.23**	**0.34**	**0.32**	**0.88**	**0.88**	**0.88**
Fish spawning habitat	0.53	0.17	0.05	0.05	1.00	1.00	1.00
Habitat for aquatic fauna	0.45	0.43	0.40	0.37	0.98	0.98	0.98
Habitat provision function mean score	**0.49**	**0.30**	**0.22**	**0.21**	**0.99**	**0.99**	**0.99**
Fish fauna intact	0.73	0.73	0.60	0.50	0.95	0.97	1.00
Invertebrate fauna intact	0.15	0.21	0.17	0.19	0.40	0.47	0.58
Riparian vegetation intact	0.23	0.16	0.10	0.10	0.32	0.32	0.32
Biodiversity function mean score	**0.37**	**0.37**	**0.29**	**0.26**	**0.56**	**0.59**	**0.63**
SEV SCORE	**0.453**	**0.400**	**0.424**	**0.406**	**0.846**	**0.853**	**0.862**

8.3.2. Macroinvertebrate Community Index

The sites surveyed demonstrate an impaired macroinvertebrate community with MCI scores below 80, indicating poor habitat quality (Figure 30). These results further corroborate the low function scores identified in the SEV.

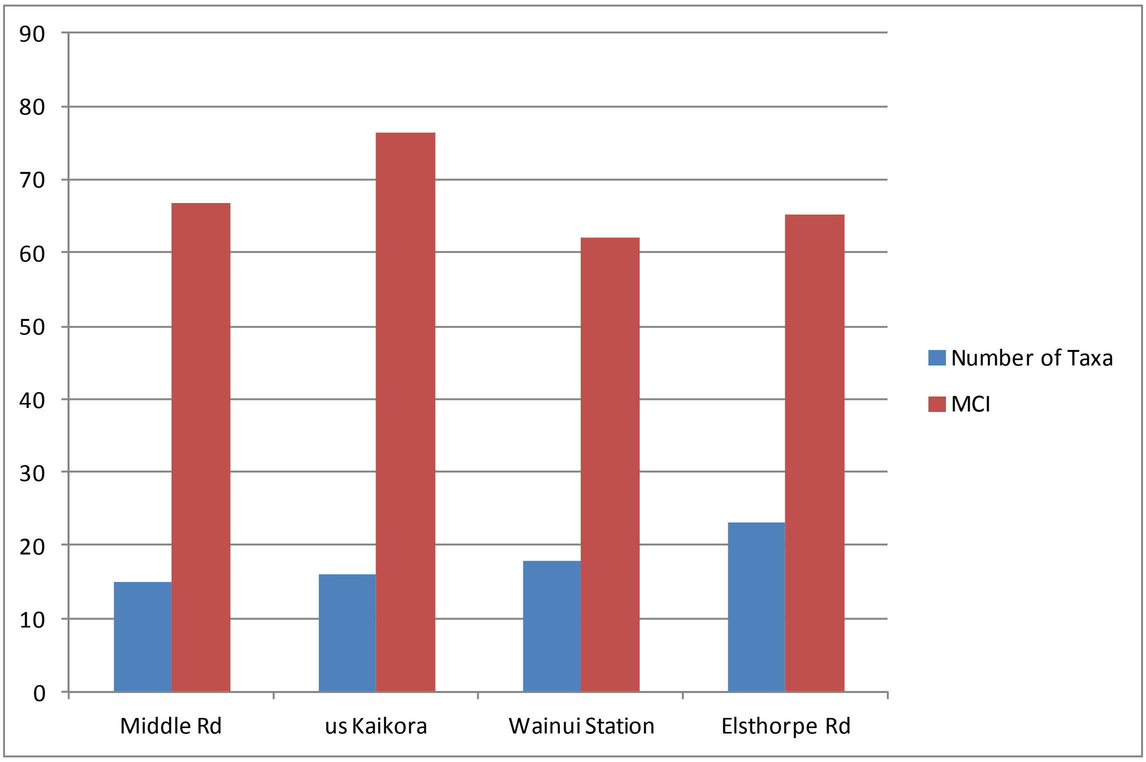

Figure 30: Number of taxa and Macroinvertebrate Community Index scores for the four SEV survey reaches

8.4. Fish values

The New Zealand Freshwater Fish Data Base (NZFFDB) contains four records derived from the Papanui water management zone, covering the period 1984 to 2006. These surveys indicate that eight species were present in the catchment. Two species are resident (upland bully and Crans bully) and the remaining species are migratory. The latter require direct access between the sea and freshwater to carry out their life cycles. Of the eight species found, three are classified as chronically threatened and "declining" (inanga, torrentfish and longfin eel) (Table 15).

Table 15: Indigenous fish species present in Papanui Catchment

Species	Status	Migration
Longfin eel	Declining	Catadromous[1]
Short fin eel	Not threatened	Catadromous
Torrent fish	Declining	Diadromous
Common bully	Not threatened	Diadromous
Inanga	Declining	Diadromous
Common smelt	Not threatened	Anadromous[2]
Upland bully	Not threatened	Non-migratory
Crans bully	Not threatened	Non-migratory

[1] Catadromous - Adults live in freshwater and migrate to the ocean to spawn
[2] Anadromous - Adults spend most of their life in the ocean and enter freshwater to spawn

8.5. Dissolved oxygen and in-stream metabolism

A dissolved oxygen logger was deployed in the Papanui Stream at Middle Road from 30th January 2013 to 2nd February 2013 (Figure 31). The objective of this was to assess diurnal dissolved oxygen levels in the stream as well as measuring respiration and gross primary production rates to assess in-stream metabolism.

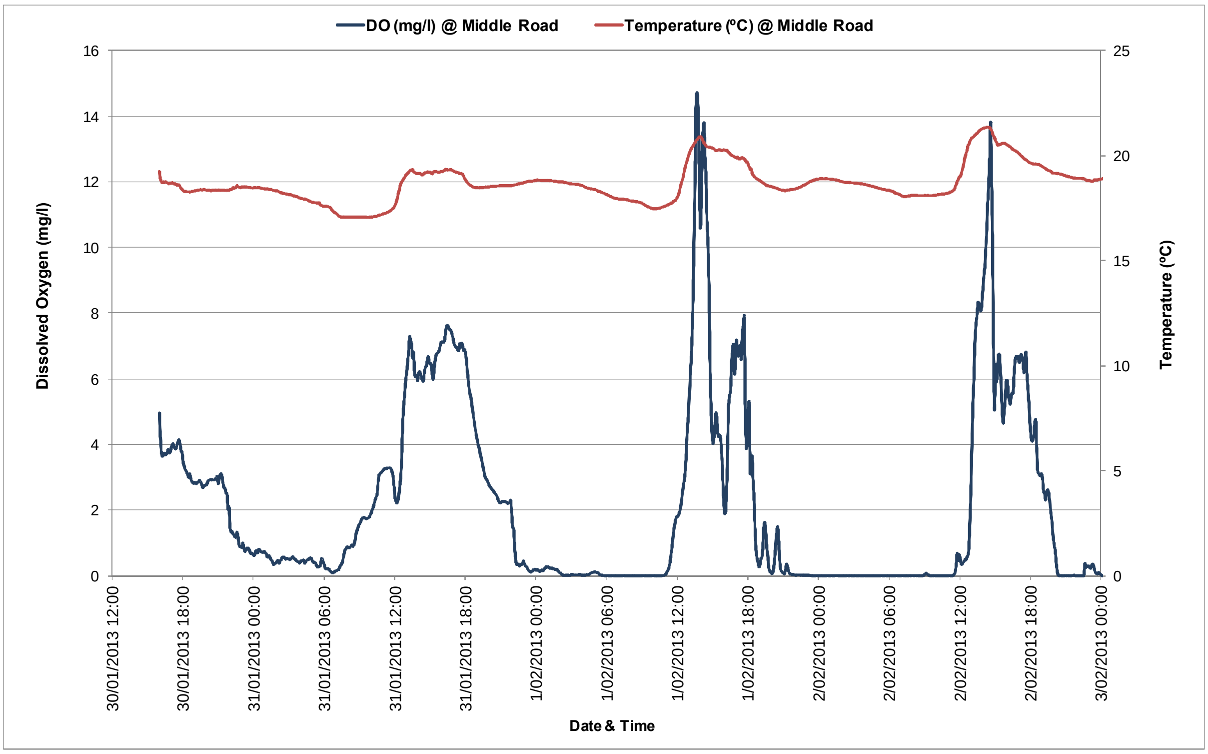

Figure 31: Dissolved oxygen (mg/L) and temperature measured in the Papanui Stream at Middle Road between 30th January and 3rd February 2013

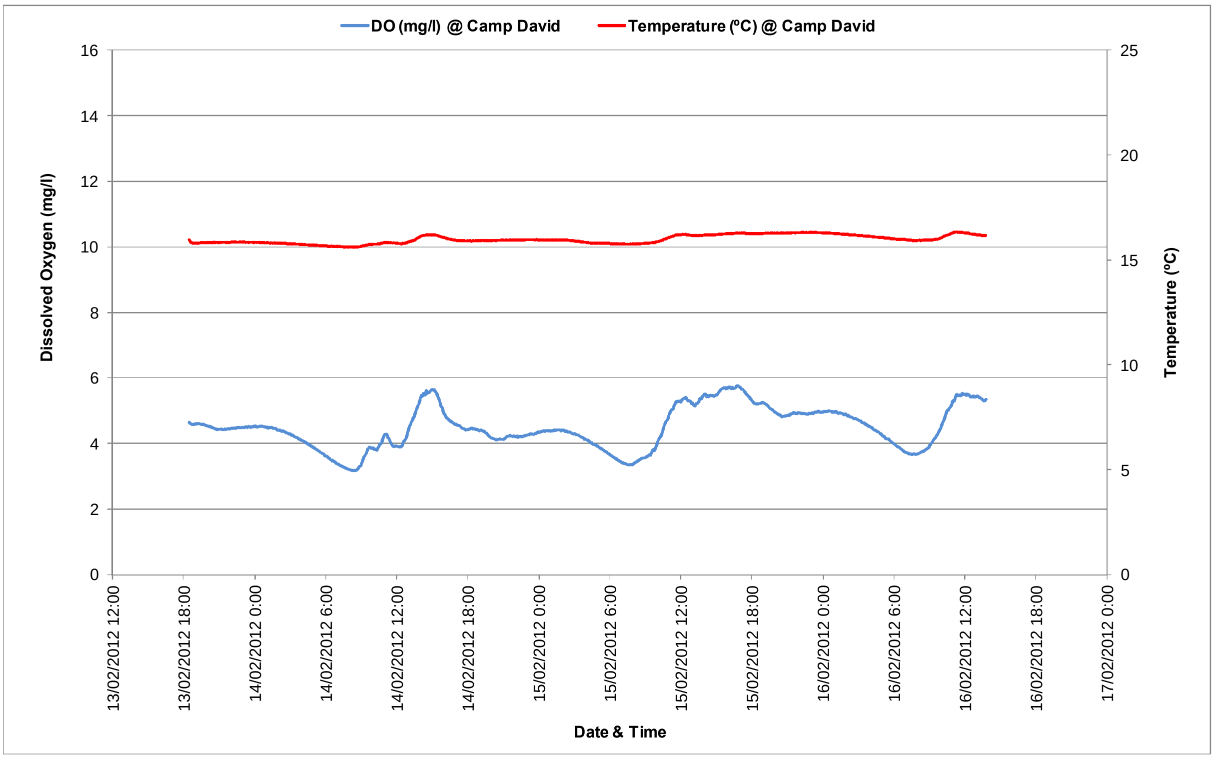

Figure 32: Dissolved oxygen (mg/L) and temperature measured in the Papanui Stream at Camp David between 13th February and 16th February 2012

The logger deployed at the Papanui stream at Middle Road recorded significant periods of anoxia with anoxic conditions (<0.2 mg/l) (Hagy et al, 2004) being present in the stream for up to 12 hours for the nights that the logger was deployed. Daytime dissolved oxygen levels increased to around 15 mg/L due to increased primary productivity (photosynthesis).

In-stream metabolism estimates were carried out courtesy of R. Young (Cawthron Institute) on the dissolved oxygen data presented in Figure 32. Young found that respiration far exceeded gross primary production with results indicating very high respiration rates (30-50 gO_2/m^2/day) and more normal photosynthesis rates (7-11 gO_2/m^2/day). However confidence in the results was low due to long periods of anoxia compromising some of the assumptions of the metabolism calculator used to estimate metabolism rates (R. Young, Cawthron Institute, pers. com.). The imbalance between respiration and photosynthesis rates combined with low rates of re-aeration and potentially inputs of low DO groundwater would be leading to the anoxic conditions in-stream.

The results from the oxygen logger deployed in the Papanui Stream at Middle Road site can be compared to a similar deployment in the Papanui stream at Camp David carried out by R Young (Cawthron Institute) during the period 13th February 2012 to 16th February 2012 (Figure 32). The Camp David site is located lower down on the Papanui Stream and shows a different daily pattern for dissolved oxygen concentrations, it doesn't follow the classic daily sine-curve pattern of DO change and the highs and lows appear to be offset by a few hours from what would be expected. The results are not unexpected for a macrophyte-filled, groundwater-fed system (Young, pers comm.) and could be due to increased influence of groundwater flows between the Middle Road site above the Tukituki Valley and the Camp David Bridge site 5m elevation below on the river flats (Uytendaal, pers comm.).

9. REPORT SUMMARY AND CONCLUSION

The Papanui catchment covers an area of approximately 16,400 ha. The topography of the catchment is quite varied with the flatter land mainly being found in the central and eastern parts of the catchment. The soil resource is also quite varied with 20 different soil series being represented in the catchment although 70% of the soil can be covered by 5 soil series i.e. Crownthorpe, Matapiro, Okawa, Otane and Vernon. The main land use in the catchment is sheep and beef farming followed by arable and dairying farming. Land use change has lead to the drainage of wetlands and an increase in the proportion of cropping especially in the north eastern section of the catchment. This land use intensification may be the reason why this catchment contributes a relatively (when compared to other sub catchments in the Tukituki catchment) high phosphorus load to the lower Tukituki river. The summer growth of abundant macrophytes, and their metabolic activity causing periods of night-time anoxia, likely drives high DRP release rates from streambed sediments during summer that contributes to the high calculated summer DRP load to the lower Tukituki.

The results of the ecological surveys show that that the surveyed reaches in the Papanui stream are in poor ecological condition; with SEV scores ranging from 0.4 to 0.453 and MCI scores below 80. The SEV scores are much reduced from the Karamu reference streams (Cameron, 2010).

All the reaches sampled would benefit greatly from protection of the margins through fencing and planting. This would result in an increased score for the water temperature control, organic matter input and riparian vegetation intactness variables and would result in improved overall ecological condition reflected by a higher SEV score and a more intact macroinvertebrate community.

The ecological condition confirms the findings of the water quality survey i.e. natural attenuation of phosphorus and sediment within the catchment has been impaired by land use practices and intensification.

Within the Papanui catchment the potential exists for intensification of land use. This is most likely in the central and western parts of the catchment, where the land is flat to gently rolling and the soil is comprised of sandy loam. If intensification does occur then good agricultural practise (GAP) will need to be employed to ensure water quality targets are met within the catchment.

Anoxic (low dissolved oxygen) conditions were measured in the Papanui Stream, particularly overnight, which seriously compromises the life supporting capacity of the stream. The overnight anoxic conditions are likely to be driven by high respiration rates of the macrophyte growths, although they may be further compounded by inflows of anoxic groundwater. Unimpeded livestock access and lack of riparian vegetation also mean generally poor in-stream physical habitat.

Under anoxic conditions:

- Phosphorus can be released from stream sediment which may explain the elevated DRP levels leaving the catchment and entering the Lower Tukituki River.
- Nitrate-nitrogen can be denitrified and released to the atmosphere as gaseous nitrogen, leading to low in-stream DIN concentration.

Therefore, although the Papanui Stream is N limited during periods of low stream flow, this is likely to be a consequence of the anoxic conditions, in turn likely to be caused by extensive growth of aquatic plants. Anoxic conditions increase both the likelihood and rates of denitrification. However, little information exists regarding the quantity or quality of groundwater that inflows into the stream, or of the influence of groundwater inflows on dissolved oxygen, phosphorus or nitrogen concentrations. Improving our understanding of surface water/groundwater interactions in the Papanui Stream will be a prerequisite for identifying the factors that compromise the life supporting capacity of the stream.

Reducing anoxic conditions by reducing macrophyte growth is likely to lead to a reduction in in-stream DRP concentration and loads entering the lower Tukituki River, particularly during the critical summer period, but may also lead to an increase in in-stream DIN concentration. The current apparent N-limited status of the Papanui Stream may therefore change as a result of management actions aiming at reducing macrophyte growths.

Our limited knowledge of groundwater movement and hydrological processes in this catchment, limited long term surface water quality monitoring and absence of information regarding the ecology of the catchment are gaps that will need to be addressed. Further assessment of all of these aspects is required in order to confirm and more accurately quantify the findings of this preliminary and generally qualitative characterisation.

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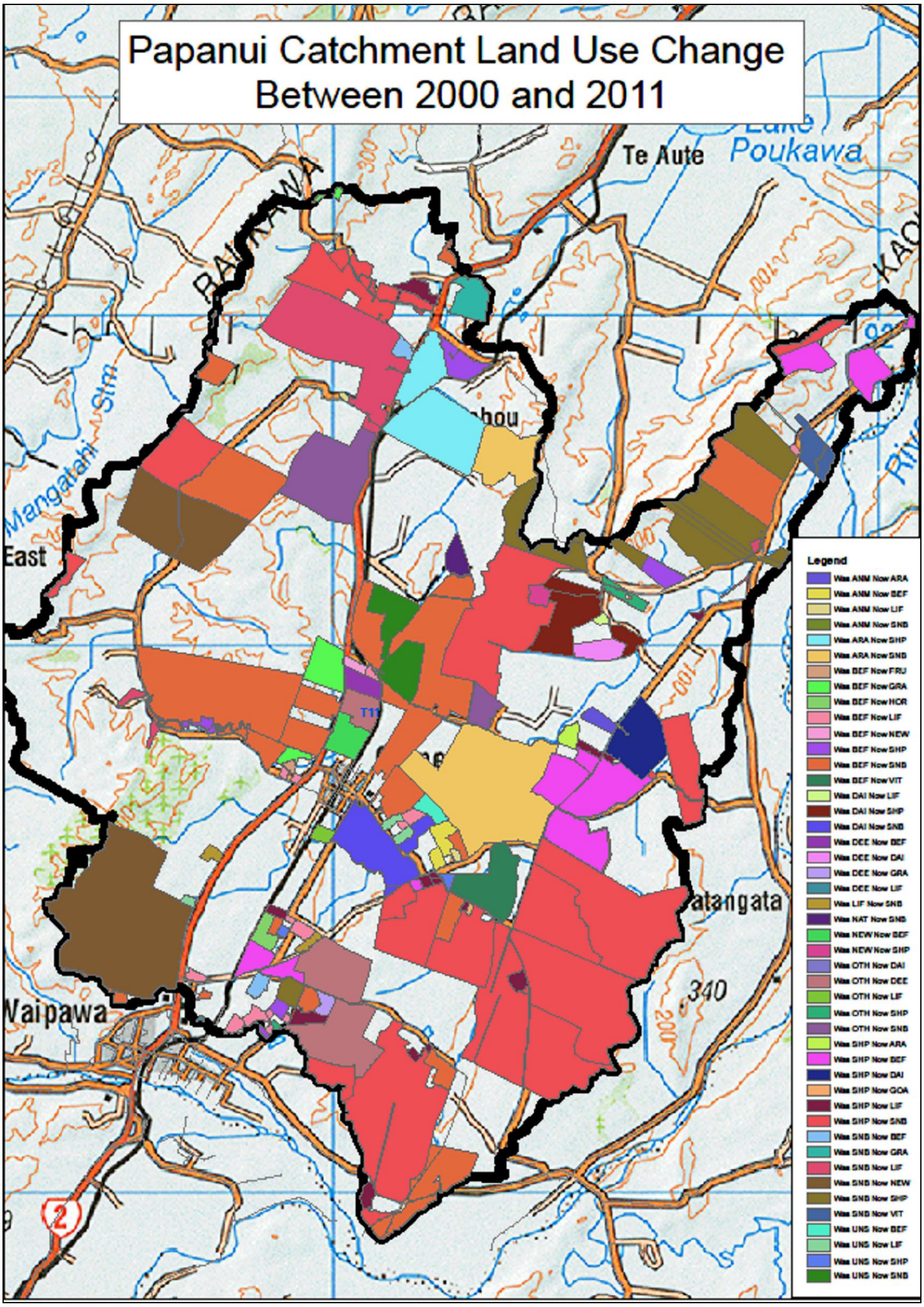
APPENDIX I: LAND USE CHANGE IN THE PAPANUI CATCHMENT FROM 2000 – 2011.

LU_Change	Area (ha)
Was ANM Now ARA	13.9
Was ANM Now BEF	26.2
Was ARA Now SHP	230.3
Was ARA Now SNB	494.6
Was BEF Now GRA	65.8
Was BEF Now HOR	19.3
Was BEF Now LIF	60.3
Was BEF Now SHP	72.3
Was BEF Now SNB	1,299.4
Was BEF Now VIT	97.7
Was DAI Now SHP	122.2
Was DAI Now SNB	135.6
Was DEE Now BEF	22.8
Was DEE Now DAI	29.9
Was DEE Now GRA	10.0
Was LIF Now SNB	13.7
Was NAT Now SNB	21.7
Was NEW Now BEF	39.3
Was NEW Now SHP	12.7
Was OTH Now DEE	274.9
Was OTH Now LIF	9.1
Was OTH Now SHP	16.3
Was OTH Now SNB	217.4
Was SHP Now ARA	12.7
Was SHP Now BEF	366.4
Was SHP Now DAI	96.7
Was SHP Now LIF	82.3
Was SHP Now SNB	2,416.6
Was SNB Now BEF	22.6
Was SNB Now GRA	41.6
Was SNB Now LIF	323.4
Was SNB Now NEW	746.0
Was SNB Now SHP	379.3
Was SNB Now VIT	37.8
Was UNS Now BEF	14.9
Was UNS Now LIF	16.2
Was UNS Now SHP	8.3
Grand Total	7,870.3


Papanui Catchment Land Use Change
Between 2000 and 2011
Te Aute
Poukawa
Mangatahi Stm
East
Waipawa
340
Legend
Was ANM Now ARA
Was ANM Now BEF
Was ANM Now LIF
Was ANM Now SNB
Was ARA Now SHP
Was ARA Now SNB
Was BEF Now FRU
Was BEF Now GRA
Was BEF Now HOR
Was BEF Now LIF
Was BEF Now NEW
Was BEF Now SHP
Was BEF Now SNB
Was BEF Now VIT
Was DAI Now LIF
Was DAI Now SHP
Was DAI Now SNB
Was DEE Now BEF
Was DEE Now DAI
Was DEE Now GRA
Was DEE Now LIF
Was LIF Now SNB
Was NAT Now SNB
Was NEW Now BEF
Was NEW Now SHP
Was OTH Now DAI
Was OTH Now DEE
Was OTH Now LIF
Was OTH Now SHP
Was OTH Now SNB
Was SHP Now ARA
Was SHP Now BEF
Was SHP Now DAI
Was SHP Now GOA
Was SHP Now LIF
Was SHP Now SNB
Was SNB Now BEF
Was SNB Now GRA
Was SNB Now LIF
Was SNB Now NEW
Was SNB Now SHP
Was SNB Now VIT
Was UNS Now BEF
Was UNS Now LIF
Was UNS Now SHP
Was UNS Now SNB

APPENDIX II: AERIAL PHOTOGRAPHS OF THE PLAINS SOUTH OF PUKEHOU.

Photo 1: 1992

Photo 2: 2010

APPENDIX III: FLOW STATISTIC DEFINITIONS

- ***Minimum (Min)*** *- the lowest recorded/measured flow from a single point in time in the period of record.*
- ***Maximum (Max)*** *- the highest recorded/measured flow from a single point in time in the period of record.*
- ***Mean*** *- a fundamental statistic of a flow record. This is the average recorded/measured flow over the period of record.*
- ***Median*** *- the flow that is equalled or exceeded for 50% of the time over the period of record.*
- Q_{95} *- the flow that is equalled or exceeded for 95% of the time over the period of record. The* Q_{95} *is used as a descriptor of the low flow of a river.*
- Q_5 *- the flow that is equalled or exceeded for 5% of the time over the period of record. The Q5 is used as a descriptor of the high flow of a river.*
- ***Mean Annual Low Flow (MALF)*** *- this is the average of the lowest flow recorded/measured in each year of the record. In this report MALF is calculated as 7-day moving average based on a hydrological year (Jul-Jun) excluding years with gaps in record during which the annual minimum may have occurred. Hawke's Bay Rivers regularly experience prolonged periods of low flow conditions over the summer months during which the lowest flow typically occurs. A hydrological year is used to calculate the MALF rather than a calendar year (Jan-Dec) so that the lowest flow from each annual summer low flow event is used in the MALF calculation. If the calendar year was used, low flows from the same event could be selected as the lowest value in two different years which would bias the sample of annual low flows. A seven day averaging interval is considered the most relevant when taking into account ecological processes, as it smoothes out short term flow fluctuations which are less important to in-stream biota, focussing on longer low flow events that dry out parts of the river bed (Henderson & Diettrich 2007).*
- ***Mean Annual Maximum Flow (MAMF)*** *- this is the average of the highest flow recorded/measured in each year of the record. In this report MAMF is calculated based on a calendar year (Jan-Dec) while excluding any years with gaps in record during which the annual maximum may have occurred.*

APPENDIX IV : WATER SAMPLE RESULTS AT MIDDLE ROAD FROM STATE OF ENVIRONMENT MONITORING PROGRAM. SAMPLES COLLECTED BETWEEN 8/12/2011 AND 23/10/2012

Date Sampled	8/12/2011	16/12/2011	22/12/2011	17/01/2012	24/02/2012
PH	8.01	8.23	8.03	8.72	N/A
DO (mg/l)	4.47	7.88	11.08	11.55	7.90
SDO (%)	23.80	51.60	89.00	121.20	128.00
EC (uS/cm)	500	623	715	628	414
SS (mg/L)	4.0	1.5	3.0	1.5	4.0
TURB (NTU)	N/A	N/A	1.57	3.30	4.14
TEMP (celcius)	21.35	21.80	19.60	20.28	21.68
SRP (mg/L)	0.34	0.27	0.11	0.15	0.21
TP (mg/L)	0.43	0.36	0.14	0.22	0.31
DIN (mg/L)	0.42	0.16	0.49	0.89	0.02
NH3_N (mg/L)	0.35	0.03	0.01	0.01	0.01
NNN (mg/L)	0.07	0.13	0.49	0.88	0.02
NO2_N (mg/L)	N/A	N/A	0.07	N/A	0.00
NO3_N (mg/L)	N/A	N/A	0.42	N/A	0.01
TKN (mg/L)	1.26	0.79	1.39	1.91	0.74
TON (mg/L)	0.91	0.76	1.39	1.91	0.74
TN (mg/L)	1.33	0.92	1.88	2.80	0.75

Date Sampled	28/02/2012	12/04/2012	29/05/2012	22/06/2012	28/08/2012
PH	8.48	7.88	7.50	N/A	7.23
DO (mg/l)	5.93	6.15	8.42	8.43	6.78
SDO (%)	91.20	61.70	62.80	76.90	62.60
EC (uS/cm)	371	595	542	706	837
SS (mg/L)	42.0	1.5	7.0	1.5	3.0
TURB (NTU)	0.96	8.87	4.14	4.18	9.17
TEMP (celcius)	17.10	16.60	11.11	9.40	11.80
SRP (mg/L)	0.21	0.16	0.07	0.07	0.20
TP (mg/L)	0.25	0.20	0.08	0.09	0.28
DIN (mg/L)	0.05	0.62	0.56	0.83	1.22
NH3_N (mg/L)	0.01	0.02	0.02	0.18	0.16
NNN (mg/L)	0.05	0.59	0.54	0.65	1.06
NO2_N (mg/L)	0.00	0.02	0.01	0.03	0.03
NO3_N (mg/L)	0.04	0.58	0.53	0.62	1.03
TKN (mg/L)	0.52	1.12	0.78	1.38	1.45
TON (mg/L)	0.52	1.10	0.76	1.20	1.29
TN (mg/L)	0.57	1.72	1.31	2.00	2.51

Date Sampled	27/09/2012	23/10/2012
PH	7.42	7.62
DO (mg/l)	13.80	8.90
SDO (%)	133.70	133.70
EC (uS/cm)	591	502
SS (mg/L)	10.0	5.0
TURB (NTU)	3.66	N/A
TEMP (celcius)	14.10	14.50
SRP (mg/L)	0.06	0.06
TP (mg/L)	0.10	0.09
DIN (mg/L)	0.53	0.14
NH3_N (mg/L)	0.01	0.02
NNN (mg/L)	0.52	0.13
NO2_N (mg/L)	0.02	0.01
NO3_N (mg/L)	0.49	0.12
TKN (mg/L)	0.79	0.70
TON (mg/L)	0.78	0.68
TN (mg/L)	1.30	0.83

APPENDIX V - WATER SAMPLE RESULTS FROM SEV SURVEY

SiteDesc	Sample Taken	BICARB (mg/L)	CA (mg/L)	CARB (mg/L)	CL (mg/L)	CO2 (g/m3 at 25 C)	DIN (mg/L)
Papanui Stream at Middle Rd	30/01/2013	270	73	< 1	27	23	0.014
Papanui stream @ Elsthorpe Road Bridge	31/01/2013	99	24	< 1	15	8.4	0.014
Papanui Stream at Wainui Station	31/01/2013	105	24	< 1	16.6	3.9	0.014
Papanui u/s Kaikora Drain	31/01/2013	109	24	< 1	19.1	3.9	0.014

SiteDesc	Sample Taken	DO (mg/L)	ECFLD (uS/cm)	K (mg/L)	MG (mg/L)	NA (mg/L)	NH3_N (mg/L)
Papanui Stream at Middle Rd	30/01/2013	7.6		2	6.3	22	< 0.01
Papanui stream @ Elsthorpe Road Bridge	31/01/2013	6.53	225.9	1.75	4.3	16	< 0.01
Papanui Stream at Wainui Station	31/01/2013	11.28	233.3	2.1	4.5	17.3	< 0.01
Papanui u/s Kaikora Drain	31/01/2013	2.32	245.3	2.2	4.7	18.4	< 0.01

SiteDesc	Sample Taken	NNN (mg/L)	NO2_N (mg/L)	NO3_N (mg/L)	PHFLD ()	PHLAB ()	SDO (%)
Papanui Stream at Middle Rd	30/01/2013	< 0.002	< 0.002	< 0.002		7.3	82.3
Papanui stream @ Elsthorpe Road Bridge	31/01/2013	< 0.002	< 0.002	< 0.002	7.27	7.3	63.9
Papanui Stream at Wainui Station	31/01/2013	< 0.002	< 0.002	< 0.002	8.04	7.6	133.2
Papanui u/s Kaikora Drain	31/01/2013	< 0.002	< 0.002	< 0.002	7.41	7.7	24.6

SiteDesc	Sample Taken	SILICA (mg/L)	SO4 (mg/L)	SRP (mg/L)	SS (mg/L)	TKN (mg/L)	TN (mg/L)
Papanui Stream at Middle Rd	30/01/2013	29	5.2	0.21	53	0.71	0.714
Papanui stream @ Elsthorpe Road Bridge	31/01/2013	22	10	0.012	< 3	0.24	0.24
Papanui Stream at Wainui Station	31/01/2013	24	8.4	0.026	4	0.33	0.334
Papanui u/s Kaikora Drain	31/01/2013	15.6	9.1	0.013	15	0.4	0.404

APPENDIX VI : PERIPHYTON VISUAL ASSESSMENT RESULTS

№ 45765

Visual assessment of periphyton and Substrate

Site: Papanui @ Middle Rd **Site ID** .... **Team** F.C + S.F

Date: 30/01/13 **Time:** 14:00 **% Shading** ....

Photos taken? yes / no ref. (if yes) .... **Water temp.** ...... **Conductivity** ....

Site/weather observations ....

Max. depth viewed .... Chl a samp. ID ....

A. Bank-side estimate of periphyton cover

Filaments (> 2 cm long)	Mats (> 2 mm thick)	Total cover (all algae)	Macrophytes (submerged)	Macrophytes (emergent)

B. Choose a run section. At each 30–40 m site view the bed at **5 equally spaced points** along **4 transects** to a max. depth of ~0.6 m; transects approx. transect width apart. Start downstream. Estimate % coverage by periphyton/plants in each view in 9 categories. For narrow margins, increase the number of part-transects; for wide, shallow rivers (> ~ 25 m) use two transects with 10 points each

View	No algae	Film< 3mm	Sludge	Mats	Phormid-ium	Fils_ green <2cm	Fils_ green >2cm	Fils_ Other <2cm	Fils_ other >2cm	Macro-phytes	Moss	Duckweed
1							60	[illegible]	[illegible]	40		
2							100		[illegible]			
3							40			60		
4							20			80		
5							20			80		
6						20				80		
7		5		30				65				
8		10				10		70			10	
9							70	30				
10							70	10			20	
11										100% under		100% surface
12										100 under		100 surface
13										100 under		100 surface
14										100 under		100 surface
15										100 under		100 surface
16										100 under		100 surface
17										100 under		100
18										100 under		100 surface
19										100 under		100 surface
20										100 under		100 surface

№ 45763

Visual assessment of periphyton and Substrate

Site: Pepenui @ Wainui...... **Site ID**........................**Team**......FC / NVW......

Date: 31/1/13... **Time:** ...12:00..... **% Shading**..

Photos taken? yes / no ref. (if yes) .... **Water temp.** ...... **Conductivity** ....

Site/weather observations ....

Max. depth viewed .... Chl a samp. ID ....

A. Bank-side estimate of periphyton cover

Filaments (> 2 cm long)	Mats (> 2 mm thick)	Total cover (all algae)	Macrophytes (submerged)	Macrophytes (emergent)

B. Choose a run section. At each 30–40 m site view the bed at **5 equally spaced points** along **4 transects** to a max. depth of ~0.6 m; transects approx. transect width apart. Start downstream. Estimate % coverage by periphyton/plants in each view in 9 categories. For narrow margins, increase the number of part-transects; for wide, shallow rivers (> ~ 25 m) use two transects with 10 points each

View	No algae	Film< 3mm	Sludge	Mats	Phormid-ium	Fils_ green <2cm	Fils_ green >2cm	Fils_ Other <2cm	Fils_ other >2cm	Macro-phytes	Moss	Surface
1		10	20				70					/
2		95					5					/
3		70					30					/
4		60					40					/
5		40					60					/
6		20					~~80~~			80		/
7		100										/
8		95					5					/
9		60								40		100 Lamna
10		100										100 Lamna
11										100		10 Lamna
12		15					80			5		/
13										100		75 Lamna 10 Macro 15 LGF
14							80			20		/
15		95								5		75 Lamna 10 Macro 15 nothing
16										100		80 Lamna 10 Macro 10 nothing
17										100		/
18							80			20		/
19							95			5		/
20							70			30		70 Lamna 30 Azola

[illegible initials/date]

Papanui @ Kaikura Drain

Nº 45767

Visual assessment of periphyton and Substrate

Site: 24/31/1/2013 .... **Site ID**........................ **Team** N/W / FC

Date: .... **Time:** .... **% Shading**......................................

Photos taken? yes / no ref. (if yes) .... **Water temp.** ...... **Conductivity** ....

Site/weather observations ....

Max. depth viewed .... Chl a samp. ID ....

A. Bank-side estimate of periphyton cover top 10% Duck weed

Filaments (> 2 cm long)	Mats (> 2 mm thick)	Total cover (all algae)	Macrophytes (submerged)	Macrophytes (emergent)

B. Choose a run section. At each 30–40 m site view the bed at **5 equally spaced points** along **4 transects** to a max. depth of ~0.6 m; transects approx. transect width apart. Start downstream. Estimate % coverage by periphyton/plants in each view in 9 categories. For narrow margins, increase the number of part-transects; for wide, shallow rivers (> ~ 25 m) use two transects with 10 points each

Transect	View	No algae	Film< 3mm	Sludge	Mats	Phormidium	Fils_ green <2cm	Fils_ green >2cm	Fils_ Other <2cm	Fils_ other >2cm	Macro-phytes	Moss	Surface
#1	1										100		100% Duck weed
	2							10			90		100% Azola
	3							5			95		100% Azola
	4							5			95		100% Azola
	5										100		/
#2	6							50			50		80% Azola 20 LGFil
	7										100		40 Azola 60 SGFil
	8							30			70		40 Azola 40 SGFil
	9							30			70		40 AZ 60 SGF
	10										100		20 AZ 80 SGF
#3	11										100		
	12	70 AZ 2 Lemna 14 Macroph		14 SGF			20				80		50 AZ 5 Lemna 5 Macro 40 SGF
	13										100		40 Lemna 40 AZ 10 SGF 10 Macro
	14	50 AZ 50 Lemna					40				60		
	15										100		100 Mac.
#4	16						5				95		45 Azola 45 Lemn 5 SGF 5 Macro
	17						5				95		as above
	18										100		30 AZ 30 Lemna 40 Macro
	19	20 Azola 60 Makro 20 Lemna					5				95		
	20										100		[illegible] Azola 80 Lemna 5 Marco 5 SGF

SGF growing on Hornwort (?) is that a usable substrate?
→ check lit

Visual assessment of periphyton and Substrate

№ 45764

Site: Papanui @ Elsthorpe Bridge **Site ID** .... **Team** NW / TC

Date: 31/1/13 .... **Time:** 2pm .... **% Shading** ....

Photos taken? (yes) / no ref. (if yes) .... **Water temp.** ...... **Conductivity** ....

Site/weather observations ....

Max. depth viewed .... Chl a samp. ID ....

A. Bank-side estimate of periphyton cover

Filaments (> 2 cm long)	Mats (> 2 mm thick)	Total cover (all algae)	Macrophytes (submerged)	Macrophytes (emergent)

B. Choose a run section. At each 30–40 m site view the bed at **5 equally spaced points** along **4 transects** to a max. depth of ~0.6 m; transects approx. transect width apart. Start downstream. Estimate % coverage by periphyton/plants in each view in 9 categories. For narrow margins, increase the number of part-transects; for wide, shallow rivers (> ~ 25 m) use two transects with 10 points each

Transect	View	No algae	Film< 3mm	Sludge	Mats	Phormid-ium	Fils_ green <2cm	Fils_ green >2cm	Fils_ Other <2cm	Fils_ other >2cm	Macro-phytes	Moss	Notes
	1							70			30		30 Azola 30 Lamna 40 LGF
	2	70									100		70 Azola 10 Lamna 20 Macro
#1	3										30		/
	4							100					/
	5										100		40 Azol 5 Lama 40 LGF 15 noth
	6										100		45Az 45La 10 Macro
	7										100		45Az 50La 5 Macro
#2	8							70			30		80 Az 10 Lamn 10LL
	9										100		/
	10							50			50		/
	11												45AZ 50 Lamn 5 Macro
	12		10		40			50					/
#3	13		5		10			80			5		15 AZ 15 Lam 10 Macro 5 LGF 55 nothing
nothing on surf	14		33				5	60			2		
nothing surf	15		[illegible]					40			60		
	16										100		85 Lamna 10 Macro 5 noth.
#4	17							70			30		70 AZ 30 Lamna
	18		30					60			10		/
	19		20					70			10		/
	20										100		100 Macro