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Municipal & Industrial Water Values in the Waikato River Catchment

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The Technical Leaders Group approves the release of this report to Project Partners and the Collaborative Stakeholder Group for the Healthy Rivers Wai Ora Project.

Signed by:

Date: 9 October 2015

A report on investments in wastewater and stormwater infrastructure and contaminant loadings prevented from entering the catchment

Municipal & industrial water values in the Waikato River catchment

OPUS

Municipal & industrial water values in the Waikato River catchment

Prepared By

Anna Robak
Senior Asset Manager

Reviewed By

John Crawford
Technical Principal-Wastewater

John Vessey
Technical Principal-Economic Assessment and Asset Valuations

Opus International Consultants Ltd
Auckland Environmental Office
The Westhaven, 100 Beaumont St
PO Box 5848, Auckland 1141
New Zealand

Telephone: +64 9 355 9500
Facsimile: +64 9 355 9584

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Executive Summary

This study aims to

1. Identify all entities with controlled discharge rights (municipal and industrial) within the Waikato River catchment and their current (actual) level of discharge

2. Assess the wastewater treatment costs accruing to these entities

3. Assess the costs and reduced contamination expected under five different treatment scenarios: none, primary, secondary, tertiary, and land disposal

The infrastructure value has been assessed using infrastructure replacement costs. To understand the marginal cost effectiveness of higher levels of wastewater treatment for potential comparison to other freshwater quality improvement options, this study estimated the total contaminant load removed as a result of these treatment investments. Estimates from this study are based on a combination of site-specific data and generalisations about wastewater removal capabilities; although overall confidence in the current situation is moderate to high, site-by-site estimates may not reflect each site's specific constraints and characteristics. Confidence in industrial sites is moderate to low due to a lack of site-specific data on costs and raw wastewater characteristics.

This study has found that municipal and industrial bodies within the catchment hold wastewater treatment infrastructure with a replacement value of approximately $306m (2013 NZD), and spend approximately $21m per year operating and maintaining the infrastructure[1] (refer Table 1). The wastewater treatment infrastructures and the associated operations prevent between 59 and 99.9% of BOD, Suspended Solids (SS), Total Nitrogen (TN), Ammonia-Nitrogen (NH3-N), Total Phosphorus (TP), faecal coliforms (FC), and *Escherichia Coli* (*E. coli*) from entering the Waikato River Catchment, as summarised in Table 1.

These estimates show that in order to ensure total contaminant removal, expenditures over the next ten years would need to be nearly four times the currently planned expenditures. This increased expenditure does not reflect the environmental impacts of the additional power, fuel, and materials that would be extracted, consumed and disposed of as a result of these additional infrastructures. If increased levels of treatment are proposed in the Waikato River catchment, a cradle-to-cradle Life Cycle Analysis of the treatment infrastructure and associated operational activities is recommended. This analysis will help ensure that alternative environmental impacts not directly related to freshwater quality are accounted for.

There is inadequate information available about stormwater treatment devices to estimate the amount of contaminant load that stormwater treatment devices prevent from entering the catchment, or to estimate the costs associated with a higher level of treatment. Confidence in the contaminant loads released into the catchment is relatively high, as these are based on water quality monitoring data from each local council.

[1] These costs do not include renewals or upgrades, which form part of assets' lifecycle costs

Table 1 Summary of stormwater and wastewater treatment infrastructure

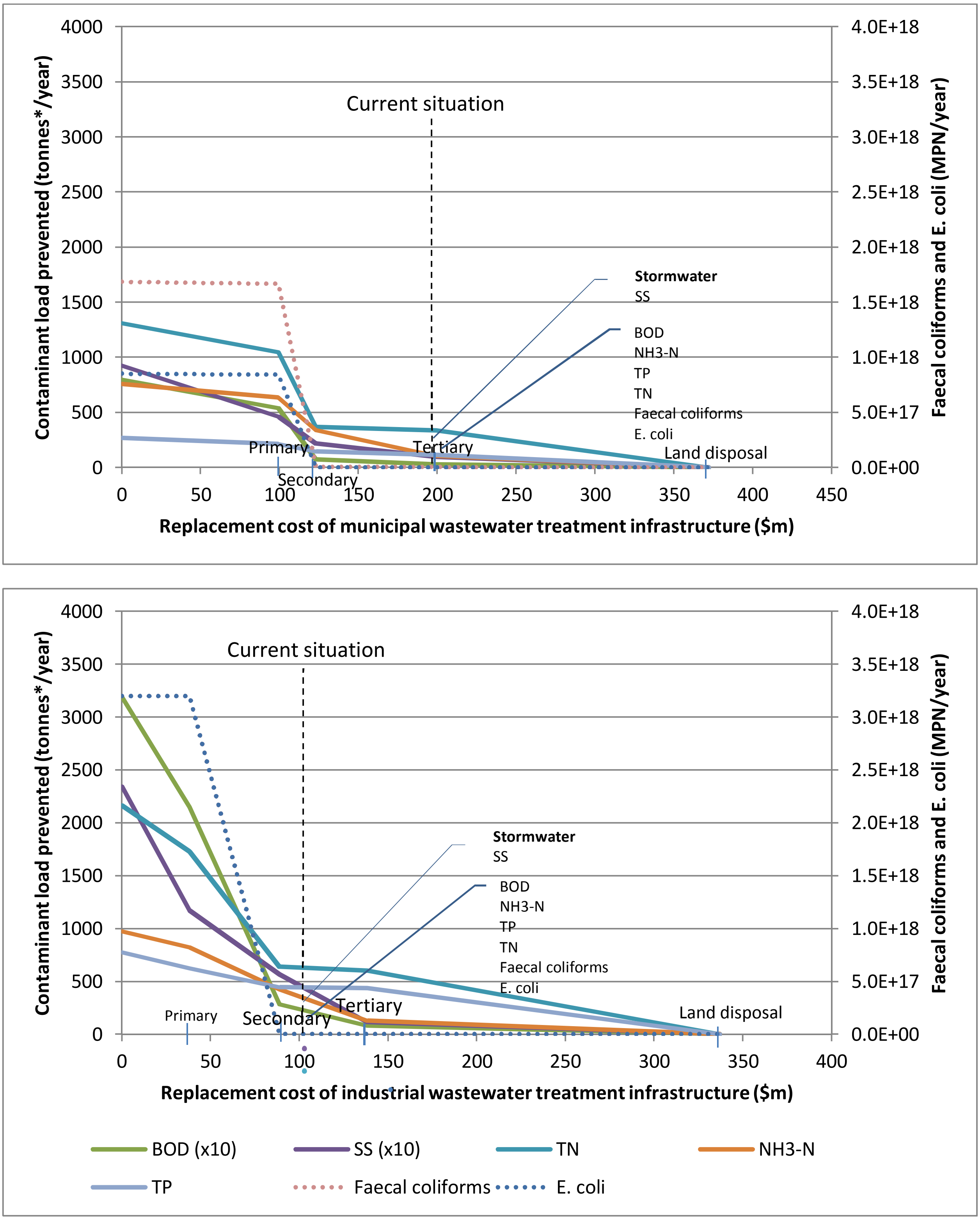
	Municipal wastewater	Municipal stormwater	Industrial wastewater	Total
Current situation: Treatment investments				
Replacement cost* (2013 $m)	194	6	106	306
Annual operating cost (2013 $m)	12		9	21
Current situation: Annual contaminant load prevented from catchment river (%)				
Biochemical Oxygen Demand (BOD)	97%	UNK	92%	93%
Suspended Solids (SS)	90%	UNK	94%	93%
Total Nitrogen (TN)	79%	UNK	66%	71%
Ammonia Nitrogen (NH3-N)	77%	UNK	73%	75%
Total Phosphorus (TP)	59%	UNK	91%	83%
Faecal coliforms	99.85%	UNK	99.93%	99.90%
E. coli	99.89%	UNK	99.93%	99.92%
	*Expenditures expected over next 10 years (2013 $m)***			
Current situation	156	UNK	91	247
100% containment***	559	UNK	373	836

Notes: UNK=Unknown
* The replacement cost includes all materials, labour and equipment required to replace existing assets.
** These expenditures are a summation of non-discounted cash flow for expected capital and operations and maintenance expenditures. For municipal wastewater treatment plants, these estimates were obtained from local councils' Long Term Plans and Assessments of Environmental Effects. This information was not available for industrial sites. For a reliable Net Present Value calculation of expected wastewater treatment expenditures, forward works programmes would be required for the industrial sites or an estimate of the remaining useful life of the equipment. This information was not readily available.
*** Assumes land disposal for all municipal and industrial wastewater treatment plants in study. These non-discounted cash flow estimates are based on estimates from Assessments of Environmental Effects and the NIWA (2010) cost curve for land disposal of wastewater, as well as wastewater treatment specialists' knowledge of the sites and soil conditions in the Waikato. In a properly designed land disposal system, nutrients will be taken up by the vegetation and will not make their way into the groundwater; however, there is some potential for this to occur.

Figure 1 shows the contaminant load that would be released into the catchment under five treatment scenarios (none, primary, secondary, tertiary, and land disposal). The '0' on the replacement cost axis represents the 'no treatment' scenario, which shows that in the absence of any wastewater treatment, municipal sites would discharge approximately 1335 tonnes of Total Nitrogen per year. Under the current scenario (dashed vertical line), approximately 275 tonnes are released each year.

The figure shows that for most – if not all – contaminants, industrial wastewater sites generate higher levels of contaminants compared to municipal wastewater sites and overall, have a lower level of treatment. However, existing industrial wastewater treatment prevents thousands of tonnes of contaminant per year from entering the Waikato River catchment.

If just one of these contaminants was to be targeted, intermediate levels of treatment may be possible that are less than the cost of land disposal (e.g., denitrification beds); however, these intermediate forms of treatment will reduce contaminants by a moderate percentage rather than remove them altogether.



* Faecal coliforms and *E. coli* measured in MPN (Most Probable Number) per year

Figure 1 Contaminant load released into the catchment and replacement cost of wastewater treatment infrastructure

1 Introduction

1.1 Purpose of this report

This report is part of a larger project investigating the economic impacts of setting quality limits on freshwater in the Waikato River catchment.

This study aims to

1. Identify all entities with controlled discharge rights (municipal and industrial) within the Waikato River catchment and their current (actual) level of discharge

2. Assess the wastewater and stormwater treatment costs accruing to these entities

3. Assess the costs and reduced contamination expected under five different treatment scenarios: none, primary, secondary, tertiary, and land disposal

This report assesses the costs and benefits of the treatment infrastructure installed at certain types of point source discharges (municipal wastewater, industrial wastewater, and municipal stormwater), where benefits are expressed in terms of contaminant loadings prevented from entering the Waikato River catchment[2]. In addition, this report estimates the marginal costs associated with new discharge consent limits.

1.2 Information sources

This investigation is based on information that Waikato Regional Council holds, or that is available from local councils' websites. Where site-specific information was not available, the literature and local wastewater and stormwater treatment engineering experience was used to estimate costs and benefits. In order of priority, data sources were as follows:

1. Waikato Regional Council's consent compliance spreadsheets for each discharge point
2. Assessments of Environmental Effects (AEEs) – documents prepared for regional councils that assess the effects of new or upgraded infrastructure on the environment. Typically AEEs in the wastewater treatment context focus on impacts on freshwater resources and aquatic life, and the likelihood of meeting existing or proposed resource consent conditions
3. Stormwater and catchment management plans
4. Asset Management Plans
5. Water and Sanitary Services Assessments
6. Wastewater and stormwater treatment engineers' site knowledge and knowledge of similar installations. Opus wastewater treatment engineers live in the Waikato and are familiar with the technologies and equipment used at all sites in the catchment.
7. NIWA's Waikato River Independent Scoping Study
8. Opus infrastructure cost curves – cost curves that were developed based on a number of wastewater treatment plants throughout New Zealand. Three regression curves were

[2] This research is not a full cost benefit analysis, as it does not estimate the economic value of benefits; nor is it a complete cost effectiveness analysis, as treatment processes are specifically designed to remove certain types of contaminants. Disentangling the costs attributable to each treatment process (and therefore the cost effectiveness of each process) is unnecessarily complex for this investigation, as the main purpose is to compare total investments in each type of treatment and total loading prevented from entering the catchment for each of six contaminant types.

developed: one based on population, one based on flow for low-population areas, and one based on flow for high-population areas

9. Waikato- and New Zealand-specific literature
10. International literature

Table 2 summarises the percentage of data that were obtained from site-specific (items 1-6 from the list above), estimated (items 7-8), and 'transferred' (from the literature) (items 9-10) data. Table 2 shows that a high degree of site-specific data were available for municipal wastewater treatment sites, with the greatest uncertainty around replacement and operating costs. For industrial wastewater treatment, there was site-specific treated water characteristics for most sites, but most of the raw water characteristics and costs were estimated. There is therefore a moderate to high degree of uncertainty around the results for the industrial sites. For stormwater sites, information about treatment assets was limited to a single local council. Although the discharged water characteristics are available for most local councils, the discharge points represent only 1.3% of the total number of stormwater discharge points. Furthermore, there are no data showing water quality characteristics before and after any stormwater treatment processes. This information would be required to estimate the value of any stormwater treatment infrastructure.

Table 2 Percent of information from site-specific, estimated, and default information sources

	Percentage of information from sources, from most to least site-specific		
	Site-specific[1] (High confidence)	**Estimated[2] (Moderate confidence)**	**Transferred[3] (Low confidence)**
Municipal wastewater sites			
Raw water characteristics	58%	42%	
Treated water characteristics	97%	3%	
Treatment processes*	92%	8%	
Replacement costs	50%	50%	
Operating costs	58%	42%	
Industrial wastewater sites			
Raw water characteristics	11%		89%
Treated water characteristics	95%	5%	
Treatment processes	20%	80%	
Replacement costs	10%	90%	
Operating costs		100%	
Municipal stormwater sites			
Number of discharge points	30%	70%	
Discharged water characteristics**	80%	20%	
Treatment processes	14%		
Replacement costs	14%		

1. From local ouncil data and reports, including consent compliance spreadsheets submitted to Waikato Regional Council, Assessments of Environmental Effects, Asset Management Plans, Water and Sanitary Services Assessments, Valuations, and Waikato River Independent Scoping Study.

2. Based on an interpolation of data from other sites, Opus cost curves, and treatment engineers' knowledge of site-specific treatment processes.

3. From literature.

* Some AEE information was out of date. Local engineering knowledge was used to supplement this information

** Contaminant concentrations are based on between three and ten sites per local council, compared to the hundreds of discharge points

Table 2 shows that there is low confidence in the raw water characteristics of the industrial wastewater treatment sites. Because total tonnage of contaminant removed is derived by subtracting treated water contaminant loading from raw water contaminant loadings, confidence in removal rates at the industrial sites is low. Further details of information sources and assumptions are provided in Appendix A.

In addition to data relating to current investments and contaminant loadings, costs and contaminant loadings of alternative treatment scenarios were estimated based on the literature[3] and on other treatment plants in the catchment having the relevant level of treatment (e.g., secondary, tertiary). All costs were converted to 2013 New Zealand dollars.

1.3 Limitations

Overall, confidence in municipal wastewater contaminant loads and cost estimates is relatively high due to availability of site-specific data and estimates, and the comparative uniformity of municipal wastewater. Table 2 shows that there is moderate to high confidence in the municipal data.

Confidence in industrial estimates is much lower because more of the data were estimated or 'borrowed'.

1.3.1 Contaminant load estimates

Current situation

Overall: Raw and treated water contaminant loads fluctuate throughout the year and even throughout the week. Averages and median values have been reported and may not reflect raw and treated water quality data for the same point in time. These limitations mean there is a degree of uncertainty in the amount of contaminant the wastewater treatment processes remove.

Municipal sites: Most municipal sites had site-specific data for both raw (58%) and treated (97%) water characteristics. Seasonal and even weekly fluctuations, however, mean that despite monthly site-specific data for the municipal wastewater treatment sites, there is some residual uncertainty in these estimates.

Industrial sites: This uncertainty in the amount of contaminant removed is high for the industrial wastewater discharges, where site-specific raw water quality data were unavailable for 90% of the sites (refer Table 2). Nevertheless, confidence in the contaminant loads released into the catchment is reasonably high, as 95% of the data were site-specific data.

Alternative wastewater treatment scenarios (e.g., primary, secondary)

Municipal sites: The Waikato River catchment contains wastewater treatment plants that have primary, secondary, tertiary, and land disposal treatment. Contaminant removal rates were calculated for each of these plants (e.g., Otorohanga plant, a secondary wastewater treatment plant, removes 88% of suspended solids prior to discharge). The average removal rate was calculated for each wastewater treatment category. This average was used as the basis for estimating other plants' 'alternative' removal rates.

Although there is one treatment plant in the Waikato River catchment that is considered primary, Meremere, the treatment processes used have removal rates that are more like those of secondary wastewater treatment plants. This is because Meremere uses an oxidation pond rather than more

[3] As referenced in Appendix B (e.g., costs based on Berbeka, Czajkowski & Markowska (2012), Singhirunnusorn & Stenstrom (2010) and Butts & Evans (1970); effluent estimates based on Asano & Tchobanoglous (1987))

traditional primary treatment such as primary settlement. To reflect primary treatment, removal rates were estimated based on Asano & Tchobanoglous (1987). Despite its age, this literature is still relevant today. Few other studies report this level of detail.

It was assumed that land disposal would remove all contaminants from the wastewater.

Industrial sites: Due to high variability in treatment processes at industrial sites, ratios from the municipal sites were used to estimate removal rates for alternative treatment scenarios.

1.3.2 Cost estimates

Current situation

Replacement and operating costs were only available for half the municipal and 10% of the industrial sites. For the municipal sites, the remaining sites were estimated based on cost curves based on New Zealand wastewater treatment plants. For the industrial sites, a significant amount of information was missing about treatment processes; confidence in this assessment is moderate. In some cases, for example, the most recent AEEs for industrial sites were from the 1990's. In these cases, the treatment processes reported and their value are likely to be significantly different in 2013.

Even with site-specific data, the true replacement costs and cash flows of future renewals, replacements, operation and maintenance (O&M) and upgrades will vary from those reported due to the following:

- Changes in legislation and standards
- Growth in population and development infrastructure
- Changes in nature of influent wastewater (e.g., new industrial connections to municipal wastewater)
- Technology changes

An additional limiting factor for the O&M costs was a lack of detail provided on which costs were included in the main cost categories. Some costs, for example, may consider only consumables such as chemicals and power, while others may also include labour, transportation, and compliance and reporting costs. As the cost breakdowns were not provided, it was assumed that all reported costs include all the relevant labour and materials related to operating and maintaining the wastewater treatment plants.

Alternative wastewater treatment scenarios

Cost estimates for alternative treatment levels were estimated using ratios of current cost estimates, where ratios were derived from available international studies in Poland (Berbeka, Czajkowski & Markowska, 2012) and Thailand (Singhirunnusorn & Stenstrom, 2010). The same basic treatment processes are used internationally, but costs are likely to differ based on cost of labour and materials and foreign exchange, as well as components included in the costs (e.g., sludge dewatering and digesting are not typically included in wastewater treatment costs in New Zealand). Ratios between the treatment levels were therefore used to estimate costs of alternative treatment scenarios in New Zealand.

Cost estimates for land disposal were based on AEEs where available. The exception is Hamilton, for which an AEE cost estimate is available but was not used. Wastewater treatment specialists report that the Hamilton land disposal cost estimate was not based on 100% contaminant removal, as the identified site had highly erodible sands.

For other wastewater treatment plants, land disposal cost estimates were based on the replacement and O&M costs of Taupo's land disposal scheme, proportional to the flow at each site. It should be noted that the use of the cost curve does not account for the many site-specific factors such as the availability of suitable land, (longer and larger pipes and pump stations), the land's soil moisture deficit, and the ability of the soil and vegetation to assimilate nitrogen and phosphorus without leaching. These factors can increase capital and O&M costs by several times. While the overall cost estimate may be approximately correct, site-by-site estimates based on the cost curves may be significantly different to cost estimates derived from a site-specific estimate. These cost estimates are likely to be on the low side, as Taupo has particularly good pumice soils and can harvest year-round, while the rest of the Waikato is swampier and has more clayey soils; year-round land disposal may not be possible.

2 Point source discharges in the Waikato River catchment

There are approximately 4000 point source discharge points in the Waikato River catchment, of which the bulk (99.5%) are stormwater discharge points; there are just 11 municipal wastewater treatment plants discharging to the catchment and nine industrial wastewater treatment plants that are included in this investigation[4]. In addition to these point source discharges, municipal wastewater from Taupo is discharged to land. Approximate locations of these wastewater discharge points are shown in Figure 2, while stormwater discharges in each township are indicated by a single point.

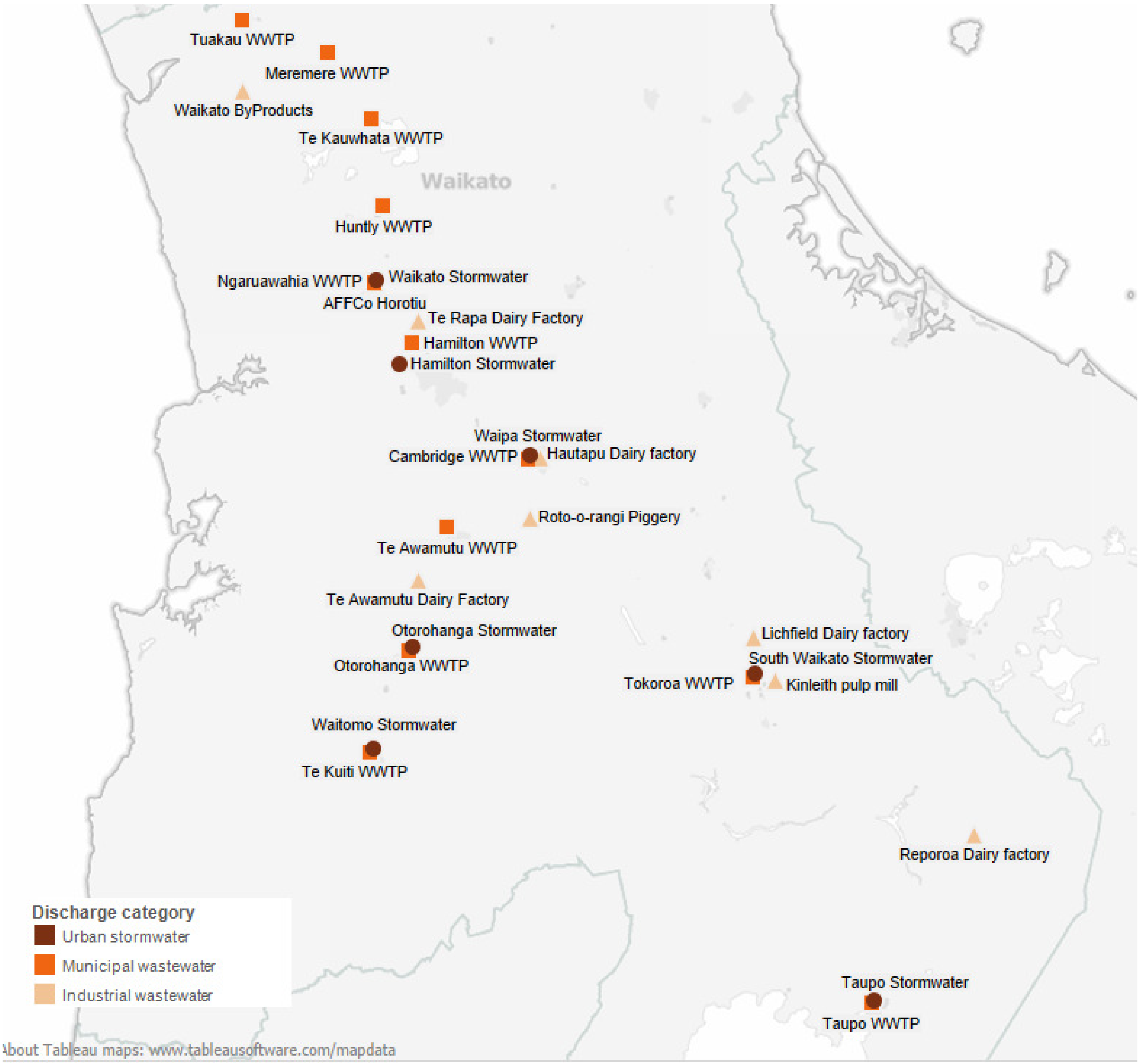


Figure 2 Wastewater and stormwater discharge points in the Waikato River catchment

4 There may be smaller industrial discharge points but these are considered to be negligible.

3 Estimating the value of treatment infrastructure

3.1 Current infrastructure

To determine the current value of wastewater treatment infrastructure in the Waikato River catchment, both the capital and operating costs of the infrastructure were considered. The capital cost was based on the replacement cost of the asset, while operating costs included materials, power consumption, and labour. Two main information sources were used for wastewater treatment plant replacement costs. In order of priority, these sources included:

1. Asset valuations published in local council plans and reports
2. Cost curves, with site-specific estimates verified by wastewater treatment specialist with local knowledge or knowledge of similar installations

The Assessments of Environmental Effects also provided cost estimates of proposed upgrades, and this information was incorporated into the estimates.

In addition to these replacement costs and annual operating and maintenance costs, an estimate was made for the non-discounted cash flow expected over the next ten years, for both the current scenario and the land disposal scenario. Expected cash flows under the current scenario were obtained from local councils' Long Term Plans, where available. This presentation of costs may assist in evaluating investments that would be required in the near to medium term, under more stringent policies. The site-by-site estimates are provided in Table 15, Appendix A.

3.2 Alternative infrastructure

In order of priority, the replacement and operating and maintenance costs of alternative infrastructure were estimated based on:

- The replacement cost of the infrastructure prior to upgrade from one level of treatment to the next. This cost was only available for the Taupo case.
- Site-specific estimates of upgrades. These costs were available for estimating land disposal costs of municipal wastewater treatment plants from the Waikato Regional Independent Scoping Study and Assessments of Environmental Effects. These costs estimates varied in terms of inclusion or exclusion of land purchase costs, length and size of pumping mains, any upgrades to existing equipment, and engineering and construction margins, and there is therefore a significant variation in the degree to which the cost estimates accurately reflect the total costs to upgrade from the current system to a land disposal system.
- Waikato wastewater treatment plant costs having the relevant treatment level. The cost of land disposal schemes was estimated proportional to the known costs of the Taupo land disposal scheme. Costs throughout the rest of the Waikato are likely to be higher due to less favourable soil conditions; however, Taupo was referenced as a 'proven' site.
- A factor of increase or decrease based on cost curves from the international literature.

For the factor of increase or decrease, cost curves from the literature were used (Butts & Evans 1970, Singhirunnusorn & Stenstrom 2010). The cost curves did not correspond directly to Waikato River catchment plant costs for the relevant treatment levels. To adjust for any differences in cost components considered, results from the cost curves were not applied directly. Instead, the ratio of costs from one treatment level to another (e.g., primary:tertiary = 1:2) was used.

For capital costs, Singhirunnusorn & Stenstrom (2010) estimated the construction costs of four types of secondary wastewater treatment plants[5]. Each of the four cost curves was applied to the Waikato wastewater treatment plants and the lowest of the four was used as the basis for the cost ratio.

Cost curves for primary treatment plants were only available from older literature; Butts & Evans (1970) provided cost curves for the capital costs of two types of primary[6] and three types of secondary treatment[7] as a function of population in the U.S.. The primary treatment cost curves were used in the estimates. The secondary treatment cost estimates derived from Butts & Evans were approximately 85% of the value derived from Singhirunnusorn & Stenstrom (2010), whose cost estimates were based on Thai wastewater treatment plants. The latter estimates were used as they are more likely to reflect contemporary technologies.

For operating and maintenance costs, Berbeka, Czajkowski & Markowska (2012) developed cost curves as a function of flow for primary, secondary and tertiary treatment in Poland. The tertiary O&M cost estimates were compared to the reported O&M costs. Berbeka's estimates were between equal and ten times greater than reported O&M costs. This discrepancy may be due to the inclusion of digestion and sludge dewatering in the Polish context. In New Zealand, tertiary treatment does not necessarily include these processes. To reflect the New Zealand context, the ratios of tertiary to primary and tertiary to secondary were therefore used to estimate O&M costs for primary and secondary wastewater treatment for municipal and industrial sites.

Further detail on the sources and figures derived for these estimates is provided in Appendix A.

4 Estimating influent and effluent contaminant loads under current and alternative treatment scenarios

4.1 Current infrastructure

Estimated annual contaminant loadings from each site are summarised in Table 3. This table also contains estimates for the "no treatment" option, which is based on influent water quality. Estimates for each site are provided in Table 28, Appendix B.

Influent water quality data and flows were available for approximately half of the municipal wastewater treatment plants. The literature on municipal and industrial wastewater treatment plants was used where these data were not available. See Appendix A for more detail on data sources and estimates.

Effluent water quality data were available from most sites. Recent monthly monitoring data were used where available. For stormwater, contaminant discharge data were available from several locations in the catchment. Although these discharge points reflect only a small percentage of stormwater discharge points, the concentrations were assumed to apply across the relevant local authority. Stormwater contaminant loading was based on the catchment area x concentration x

[5] Activated sludge, oxidation ditches, aerated lagoons and waste stabilisation ponds
[6] Digester and vacuum
[7] Trickling filter-digester, trickling filter-Imhoff, activated sludge (built on site) an activated sludge (factory built)

annual flows implied by Williamson (1993)[8]. In the absence of monitoring data, information from the Waikato Regional Independent Scoping Study was used.

4.2 Alternative infrastructure

Contaminant loadings for primary, secondary, tertiary[9], and land disposal are summarised in Table 3. For alternative treatment levels, secondary and tertiary removal rates were estimated based on average removal rates for secondary and tertiary wastewater treatment plants in the Waikato River catchment, while primary treatment removal rates were based on those published by Asano & Tchobanoglous (1987)[10] (refer Table 21, Appendix B).

4.3 Summary of current and alternative infrastructure scenarios

Table 3 shows that in the current situation, municipal and industrial wastewater treatment plants are preventing a large proportion of the contaminants generated from domestic and industrial wastewater from entering the Waikato River catchment. Site-by-site results are provided in Appendix B.

The stormwater data and literature are inadequate for estimating the costs and benefits of a higher level of treatment. To understand the level of contamination prevented from entering the catchment, water quality information would be required upstream and downstream of any treatment devices, and the catchment area would need to be defined. To understand the cost effectiveness of these stormwater treatment interventions, the capital and O&M costs of these structures would need to be reported. However, municipal stormwater contributes little relative to wastewater dischargers.

[8] Although this study is 20 years old, it is still widely referenced as a comprehensive study specific to the Waikato

[9] Some sites had secondary treatment, while others had tertiary or land disposal. In Table 3, each treatment scenario except for "current" shows the contaminant loadings and costs expected if *all* sites had the same level of treatment. For the secondary treatment scenario, for example, all of the municipal sites and some of the industrial would release greater contaminant loadings but would have lower replacement and operating costs.

[10] The results of this study are still widely used and form the basis for the widely referenced wastewater treatment textbook Metcalf & Eddy (2003)

Table 3 Contaminant loadings and costs expected from no treatment, primary, secondary, tertiary and land disposal treatment

Scenario	Source	Municipal wastewater	Industrial wastewater	Stormwater	Total
Current situation	Replacement cost ($m)	194	106	6	306
	Operating costs ($m/yr)	12	9	-	21
	BOD (tonnes/yr)	271	2,502	236	3,009
	SS (tonnes/yr)	956	1,438	2,445	4,839
	TN (tonnes/yr)	275	743	77	1,095
	NH3-N (tonnes/yr)	171	259	4	434
	TP (tonnes/yr)	108	74	29	211
	Faecal coliforms (MPN/yr)	2.6E+15	2.2E+15	1.8E+12	4.7E+15
	E. coli (MPN/yr)	9.2E+14	2.2E+15	1.7E+12	3.1E+15
No treatment	Replacement cost ($m)	-	-	-	-
	Operating costs ($m/yr)	-	-	-	-
	BOD (tonnes/yr)	8,022	31,883	236	40,141
	SS (tonnes/yr)	9,338	23,419	2,445	35,203
	TN (tonnes/yr)	1,334	2,165	77	3,576
	NH3-N (tonnes/yr)	758	973	4	1,735
	TP (tonnes/yr)	266	779	29	1,073
	Faecal coliforms (MPN/yr)	1.7E+18	3.2E+18	1.8E+12	4.9E+18
	E. coli (MPN/yr)	8.5E+17	3.2E+18	1.7E+12	4.0E+18
Primary	Replacement cost ($m)	99	66		
	Operating costs ($m/yr)	5	5		
	BOD (tonnes/yr)	5371	21521		
	SS (tonnes/yr)	4630	11710		
	TN (tonnes/yr)	1048	1732		
	NH3-N (tonnes/yr)	632	821		
	TP (tonnes/yr)	212	626		
	Faecal coliforms (MPN/yr)	1.7E+18	3.2E+18		
	E. coli (MPN/yr)	8.4E+17	3.2E+18		
Secondary	Replacement cost ($m)	123	83		
	Operating costs ($m/yr)	9	8		
	BOD (tonnes/yr)	724	2839		
	SS (tonnes/yr)	2161	5671		
	TN (tonnes/yr)	365	640		
	NH3-N (tonnes/yr)	340	429		
	TP (tonnes/yr)	147	448		
	Faecal coliforms (MPN/yr)	3.3E+15	7.4E+15		
	E. coli (MPN/yr)	1.4E+15	5.9E+15		
Tertiary	Replacement cost ($m)	199	138		
	Operating costs ($m/yr)	11	9		
	BOD (tonnes/yr)	257	824		
	SS (tonnes/yr)	935	1,145		
	TN (tonnes/yr)	334	602		
	NH3-N (tonnes/yr)	104	129		
	TP (tonnes/yr)	112	435		
	Faecal coliforms (MPN/yr)	2.5E+15	1.8E+15		
	E. coli (MPN/yr)	8.6E+14	4.3E+15		
Disposal to land	Replacement cost ($m)	372	337		709
	Operating costs ($m/yr)	40	23		64
	BOD (tonnes/yr)	-	-	-	-
	SS (tonnes/yr)	-	-	-	-
	TN (tonnes/yr)	-	-	-	-
	NH3-N (tonnes/yr)	-	-	-	-
	TP (tonnes/yr)	-	-	-	-
	Faecal coliforms (MPN/yr)	-	-	-	-
	E. coli (MPN/yr)	-	-	-	-

* MPN=Most Probable Number

5 Recommendations

5.1 Reducing contaminant loads in the Waikato River catchment

Any initiatives aimed at reducing contaminant loads in the Waikato River catchment should compare loads from wastewater and stormwater sites to loads from other sources to ensure the most cost effective alternative is pursued. If increased levels of treatment are proposed, a cradle-to-cradle Life Cycle Analysis is recommended to account for the associated environmental impacts, which will include power, fuel, and materials extracted, consumed and disposed of as a result of these additional infrastructures. This assessment will help ensure the benefits of the expenditure are not outweighed by environmental costs in other respects.

5.2 Waikato River catchment long-term data collection and reporting mechanisms

Waikato Regional Council's electronic municipal wastewater treatment flows and contaminant concentrations gave this study a high level of confidence. Similar information from industrial[11] and stormwater[12] sites would further increase confidence in these types of studies.

5.3 Similar studies throughout New Zealand

If similar studies to the current one are undertaken in the rest of New Zealand, costs and time could be reduced *and the study's validity could be increased from industry's viewpoint* if the researchers were permitted to contact industrial and municipal sites directly. A pro forma could be designed, indicating the required information. In many cases, industrial sites are unwilling to share information about the value of their equipment, but they are willing to share information about their treatment processes, including capacity and influent (where available) and effluent water quality. This information allows for reasonable cost estimates to be derived.

If direct contact is not possible, a study similar to NIWA's Waikato River Independent Scoping Study would be invaluable for other regions for the following items:

- Land disposal cost estimates (from AEE's)
- Contaminant loads and flows from industrial sites

[11] Influent wastewater quality and treatment devices at each site would also increase confidence in estimates of replacement and operating costs and contaminants prevented from entering the catchment.
[12] For stormwater sites, contaminant concentrations are available in stormwater and catchment management plans. This information would be useful in electronic format, along with relevant (specific to the discharge point) and total catchment area. In addition, only one local council reported on the value of stormwater treatment devices. No local council reported on treatment effectiveness.

6 Conclusion

Municipal and industrial wastewater managers in the Waikato River catchment have invested well over $300m[13] protecting freshwater resources from BOD, SS, TN, NH3-N, TP, faecal coliforms and *E. coli*. This infrastructure has prevented thousands of tonnes of contaminants from entering the Waikato River catchment. Based on a 40-year analysis period, the annual amortised investment is $23m per year. Over the next ten years, these wastewater managers expect to spend at least an additional $250m upgrading and operating new and existing equipment.

Wastewater managers have protected the catchment using largely tertiary treatment for municipal wastewater and a combination of secondary, tertiary and land disposal for industrial wastewater. A higher level of treatment (land disposal) would prevent the remaining 41-0.2% of contaminants from entering the catchment, but at nearly triple the current level of annual amortised costs. Table 4 shows the annual equivalent costs, in $m/year, and the cost to remove one tonne of each type of contaminant. The cost to remove an additional tonne of each type of contaminant is in the order of 5 to 26 times higher than current unit costs.

Table 4 Annual equivalent cost per tonne of contaminant removed – current situation and marginal costs for land disposal

	Annual equivalent cost per tonne of contaminant ($ per tonne per year)[14]	
Contaminant	**Current situation**	**Marginal costs of upgrading to land disposal**
Annual equivalent cost ($m/year)[15]	$ 23	$ 45
BOD	615	16,152
SS	753	18,709
TN	9,275	44,003
NH3-N	17,519	104,207
TP	26,442	245,230
Faecal coliforms (x10^12 MPN)	5	9,463
E. coli (x10^12 MPN)	6	14,464

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[13] The replacement cost of the existing infrastructure is approximately $306m; in addition, historic upgrades and annual operating and maintenance costs are part of a much larger investment

[14] The $ per tonne has been spread over total costs for each contaminant. In reality, different treatment processes 'target' different types of contaminants. For example, primary treatment removes little total nitrogen the bulk of the removal may occur in the secondary treatment processes. An accurate contaminant-by-contaminant analysis would consider only the costs incurred to remove each contaminant type. However, it is appropriate in this analysis, where the main consideration is the marginal step-change costs to land disposal, to consider the total cost spread over each contaminant type. If a single contaminant type is targeted, a specific cost analysis should be undertaken and treatment levels less than land disposal may be considered.

[15] Based on 6% Weighted Cost of Capital and 40-year analysis period as recommended in NZTA (2013). The NZTA reference is considered prescient of the next update of Treasury's (2008) Public Sector Discount Rates for Cost Benefit Analysis, as much of the rest of the world's governments are reducing their discount rates. To compare with any analyses using Treasury's current requirements of an 8% discount rate and 30-year analysis period, the 30-year annual equivalent marginal cost would be $53m and the marginal costs per tonne would be 18% higher than those shown in the table. Using a 7% discount rate, the 30-year annual equivalent marginal cost would be $51m and the marginal costs per tonne would be 14% higher than those shown in the table.

The costs and contaminant loads under alternative treatment scenarios must be compared against the costs and contaminant loads of alternative freshwater quality improvement options. Any options that can reduce current contaminant loads for lower costs than the marginal costs shown in Table 4, should be considered. If upgrading to land disposal across the Waikato appears to be a lower cost option than other alternatives for improving freshwater quality in the Waikato River catchment, then site-specific assessments should be undertaken where they have not previously been undertaken, to confirm upgrade and long-term operating and maintenance costs.

Table 5 shows the additional capital and operating costs that would be incurred, and the 40-year Net Present Value, of pursuing the land disposal option. The bottom section of the table shows the additional contaminant loading that would be prevented from entering the catchment if land disposal were pursued catchment-wide.

Table 5 Step change from current level of treatment to land disposal

	Municipal wastewater	Industrial wastewater	Total
Costs ($m)			
Capital upgrade cost	178	231	361
Additional annual operating costs	28	14	22
40-year Net Present Value[16]	592	430	1,017
Additional contaminant loading prevented from entering catchment (tonnes/year)			
BOD	271	2,502	2,773
SS	956	1,438	2,394
TN	275	743	1,018
NH3-N	171	259	430
TP	108	74	183
Faecal coliforms (MPN/yr)	2.6E+15	2.2E+15	4.7E+15
E. coli (MPN/yr)	9.2E+14	2.2E+15	3.1E+15

[16] Based on 6% Weighted Cost of Capital and 40-year analysis period as recommended in NZTA (2013). The NZTA reference is considered prescient of the next update of Treasury's (2008) Public Sector Discount Rates for Cost Benefit Analysis, as much of the rest of the world's governments are reducing their discount rates. To compare with any analyses using Treasury's current requirements of an 8% discount rate and 30-year analysis period, the 30-year NPV for land disposal at municipal sites would be $481m, and $372m for industrial sites for a total of $874m. Other studies in the Waikato have recently used discount rates of 7%. The 30-year NPV with a 7% discount rate would be $523m for municipal sites, $394 for industrial and $917m total.

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Appendix A

Data sources and estimates – current scenario

Stormwater

Stormwater quality monitoring data from AEEs were used to estimate the quality of stormwater discharges. Concentrations were multiplied by flows implied by typical loadings and concentrations, from Williamson (1993); average flows divided by average concentrations implied a flow of 3000m^3/ha/yr.

Although these stormwater quality monitoring data cover only a small number of discharge points, and may be selected specifically because they are areas of concern, recorded concentrations are generally lower than those found in the literature, as shown in Table 6.

Table 6 Average contaminant concentrations based on stormwater quality monitoring data from 2004-2013

Contaminant	Typical urban stormwater (mg/L) (Williamson 1993)	Waikato	Waitomo	Waipa	Taupo	South Waikato	Franklin	Otorohanga
Monitoring Dates		2002-04	2006-11	2009-12	2011-12	?	2011-13	2004-11
BOD	8.0	2.0	1.9	6.1	9.9	8.8		2.7
SS	170	22	15	69	52	64	86	154
TN	2.5		1.3	1.7	1.7		6.6	2.5
NH3-N	0.09	0.13	0.10	0.19	0.10			0.09
TP	0.42	0.26	0.07	0.38	0.20		4.75	0.55
FC			1892		3474	8144	1186	7797
EC			1574	7352	2160	7938		2080

The concentrations from Table 6 were multiplied by Williamson's typical flow and local councils' urban areas, which are summarised in Table 7. Where possible, urban drainage areas were obtained from stormwater or catchment management plans. For other areas, Google Earth was used to estimate areas.

Table 7 Data source for urban stormwater catchment area

Local council	Urban area	Area (ha)	Data source
Waikato	Huntly	1000	Google Earth
	Ngaruawahia	600	Google Earth
	Tamahere	1130	GHD (2011)
	Tuakau	361	Franklin District Council (2004)
	Pokeno	400	Franklin District Council (2004)
Waitomo	Te Kuiti	350	Google Earth
	Piopio	100	Google Earth
Waipa	Te Awamutu	900	Google Earth
	Cambridge	700	Google Earth
Otorohanga	Otorohanga	350	Google Earth
Hamilton City	Hamilton City	7504	WaterNZ (ref)
Taupo	Taupo (Taupo East, West, Central)	1500	Google Earth
	Turangi etc	565	Taupo Stormwater Management Plan (ref)
South Waikato	Tokoroa	922	SWDC (2013)
	Arapuni	34	SWDC (2013)

Few stormwater treatment devices were reported; it was therefore assumed that the contaminant load entering the Waikato River catchment was equal to the 'typical' urban stormwater load.

The number of stormwater discharge points was also reported. Where possible, local council data were used. For these data, the number of outlets was divided by pipe length and used the average of these values to estimate the number of stormwater outlets in other areas. This ratio ranged from 0.2 to 19, for an average of 7.0. There is therefore significant uncertainty around the total number of stormwater discharge points.

Table 8 Number of stormwater discharge points into the Waikato River catchment

Local council	Number of discharge points	Data source
Waikato	1,407	Based on percentage of pipe length, from South Waikato, Taupo and Waipa
Waitomo	27	Based on percentage of pipe length, from South Waikato, Taupo and Waipa
Hamilton	701	Direct communication with Hamilton City Council
South Waikato	1,470	South Waikato Council website (ref)
Taupo	300	Assumed two-thirds of "inlets & outlets" reported in WRC (2012)
Waipa	27	Waipa District Council (2013)
Otorohanga	3	Based on percentage of pipe length, from South Waikato, Taupo and Waipa

Estimates were not available for faecal coliforms or *E. coli*. These contaminant loadings are not included in this study.

Although many local councils have some form of stormwater treatment devices, , information about contaminant removal was not available, as local councils only report contaminant concentrations at particular discharge points, as opposed to a before and after. Evidence suggests that these treatment devices are few and small enough that they do not substantially affect contaminant loading estimates based on the literature. It was therefore assumed that no contaminant was removed due to stormwater investments; however, more detailed analysis is required to confirm the contaminant loading entering the river system.

Stormwater treatment costs were only available from Taupo District Council, which reported the stormwater treatment component[17] as 0.2% of its total stormwater infrastructure in 2009. In the absence of any other data, the same percentage was assumed to apply across all local councils, with the exception of Hamilton and Waipa – in these areas, local engineers are aware of some investments. Estimates of stormwater treatment infrastructure are as shown in Table 9. Replacement costs were not available for Waitomo District Council.

[17] Include CDS unit only. Other assets play a role in removing contaminants, but removal rates are typically minimal.

Table 9 Estimated replacement cost of stormwater treatment assets

Local council	Estimated replacement cost for stormwater treatment equipment ($m)	Stormwater asset replacement cost ($m)	Source for replacement cost of total stormwater asset
Waikato	0.08	33	WRC (2012)
Waitomo	0.02	9.5	Waitomo DC (2012)
Hamilton	5[18]	238	Local knowledge
South Waikato	0.06	22	SWDC (2006)
Taupo	0.12	51	WRC (2012)
Waipa	0.5[19]	44	Local knowledge
Otorohanga	0.01	2.7	WRC (2012)

Municipal wastewater

Table 10 shows the data used to estimate influent contaminant loadings at each municipal wastewater treatment plant. These data were available from Assessments of Environmental Effects (AEEs) for a number of wastewater treatment plants. For other plants, the average value from the AEEs was used. This average more fairly reflects wastewater influent quality in the Waikato than 'typical' effluent characteristics from textbooks. It is worth noting that the average values from these Waikato plants are at the upper end of those ranges suggested as 'typical', in texts such as Metcalf and Eddy (2003).

Table 10 Influent water quality data and sources for municipal wastewater

	Contaminant (mg/L)							Data source		
Site	BOD	TSS	TN	NH3-N	TP	Faecal coliform*	*E. coli**	Mon. data	AEE	Avg
Ngaruawahia	226	208	53	41.3	11	7.34E+06	6.0E+06		√	
Tokoroa	301	360	57	30	10	6.5E+06	3.4E+06			√
Cambridge	166	210		36		7.8E+06			√	
			57		10		3.4E+06			√
Hamilton	300	340	47		10	6.5E+06			√	
				30			3.4E+04			√
Huntly	150	131	53	43	10.4	6.6E+06	4.1E+04		√	
Pukekohe	461	548	60	38	13				√	
						6.5E+06	3.4E+06			√
Te Kauwhata	301	360	57	30	10	6.5E+06	3.4E+06			√
Meremere	301	360	57	30	10	6.5E+06	3.4E+06			√
Te Kuiti	551	769		30	13				√	
			57			6.5E+06	3.4E+06			√
Te Awamutu	167	283	39	23	8	4.2E+06		√		
							2.1E+04		√	
Taupo	471	483	64	0.06	9.3				√	
						6.5E+06	3.4E+06			√
Otorohanga	221	268	83	29	7.4				√	
						6.5E+06	3.4E+06			√

* faecal coliforms and *E. coli* are measured in MPN/100mL

Table 11 shows the effluent water quality data used to estimate contaminant loadings flowing out of to each municipal wastewater treatment plant and the sources from which the data were obtained. In the first instance, the weighted average concentration for the most recent 12-month monitoring

[18] Every modern subdivision in north east Hamilton has stormwater detention systems and some have swale drains – possibly several millions of dollars' worth; however, cost estimates, quantities and dimensions are not available. There is an indicative estimate of $5m to show that investments are being made.
[19] Waipa operate a CDS interceptor in Cambridge. This is a rough order estimate.

period was used. If these data were unavailable, the Assessment of Environmental Effects (AEE) was used. Finally, in the absence of the AEE, information from the Waikato River Scoping Study was used.

Table 11 Effluent water quality data and sources for municipal wastewater

Site	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH3-N (mg/L)	TP (mg/L)	Faecal coliform (MPN/100mL)	*E. coli* (MPN/100mL)	Flow (m^3/d)	Source
Ngaruawahia	29		14	0.7	3			1750	Average of monthly monitoring data, Oct 2011-Sept 2012
		30				1500	1500		AEE (2009) for proposed water quality
Tokoroa	5.2	8.5	29	1.2	5.5	110		3242	AEE (average)
							88		Most recent monthly monitoring data, Jan-Oct 2005
Cambridge	18	26						5548*	Average of monthly monitoring data, Jun 2010-May 2011
			10	35	5.6	3000			AEE
							3000		Set equal to faecal coliforms
Hamilton	10	54	10	5	4	16,736	5,570		Average of monthly monitoring data, Jan 2011-Dec 2012
								40,000	Resource consent hearing, 2007
Huntly	23		10	1.7	3.6			2387	Average of monthly monitoring data, Jul 2011-Jun 2012
		30				1500	1500		AEE (2009) for proposed water quality
Pukekohe	8.7	9.2	9.0	1.5	4.5	823			Average of monthly monitoring data, Jan-Nov 2011
							823		Set equal to faecal coliforms
								4500**	AEE
Te Kauwhata	2.9	7.7	5.1	0.4	4.8	1183	684	554	Average of monthly monitoring data, Jul 2011-Jun 2012
Meremere	8	37	25	8	4	570	570	283	AEE (2011)
Te Kuiti	20	13	22	12	12	300	200	2895	AEE expected results
Te Awamutu	4	7.8			4.8	101		4100	Average of monthly monitoring data, Jan-Jun 2005
			5.2	0.4					Average of monthly monitoring data, Jul 2005-Dec 2006
							100		Set equal to faecal coliforms
Taupo	0	0	0	0	0	0	0	5400*	None; disposal to land
Otorohanga	15	33	28	17	4.9	1700	390	795	AEE (Median 2007-2011)

* Flow relevant for influent, not effluent

**Average Dry Weather Flow

Replacement costs of treatment infrastructure

To estimate the replacement costs of the wastewater treatment plants, the most recent valuations were used where available. For the Hamilton wastewater treatment plant, only the depreciated replacement cost was available. No assumptions were made about the asset's depreciation; the depreciated replacement cost was assumed to reflect the full replacement cost. In the absence of valuation data or AEE data, wastewater treatment specialists' knowledge of the sites was used where available, and in the absence of any other information, Opus's cost curves were used based on population served.

The AEE's also contained information about upgrade costs. Where replacement costs were unavailable, these upgrade costs were added directly to the costs derived from Opus's cost curves. This addition attempts to reflect that the upgrades may reflect improvements over the wastewater treatment plants on which the cost curves were developed.

The data sources for the values used are shown in Table 12. Replacement and operating costs were adjusted according to the Consumer Price Indices published on Statistics New Zealand's website. All prices were assumed to be June prices, which is common for valuations.

Table 12 Replacement costs of municipal wastewater infrastructure and data sources

Site	Replacement cost (2013 $m)	Valuation		AEE (upgrade)	Opus cost curve	Engineer's site or similar knowledge	Other
		RC	DRC				
Ngaruawahia	4.5			√	√		
Tokoroa	13.8			√	√		
Cambridge	7.2	√ (2009)					
Hamilton	81.0		√ (2009)	√			
Huntly	4.4			√	√		
Pukekohe	17.1	√					Estimated based on Auckland-wide valuation and percentage of population served
Te Kauwhata	12.0	√ (2008)					
Meremere	0.5					√	
Te Kuiti	11.1			√		√	
Te Awamutu	11.0	√ (2009)					
Taupo	28.7	√ (2010)					
Otorohanga	2.8				√		

The use of the Opus cost curves is an adequate approximation of the assets' values for this exercise. As a test, Opus's cost curves were run for plants for which valuation replacement costs were available. Table 13 shows that for most plants, the cost curve results are remarkably similar to most replacement costs – with the exception of Te Kauwhata. In addition, the wastewater treatment specialists are familiar with most sites around the Waikato and were able to verify reasonableness of the cost estimates.

Table 13 Comparison of valuation replacement costs and Opus's cost curve for municipal wastewater treatment plants, based on population served

Site	Effective treatment	Valuation replacement cost (2013 $m)	Opus cost curve
Cambridge	2	7.2	11.7
Hamilton	3	81.0*	57.6
Pukekohe	3	17.1	15.9
Te Kauwhata	3	12.0	2.4
Te Awamutu	3	11.0	11.2
Taupo**	4	28.7	16.6

* This was the depreciated replacement cost; the full replacement cost was not available. The replacement cost estimate for Hamilton WWTP includes recent upgrades to the plant.
** The Taupo wastewater treatment plant is a land disposal system, which was not a type included in the development of the cost curves.

Operating costs were reported in some AEEs. Where they were not reported, a similar type of plant within the Waikato River catchment was used where available, and pro-rated the costs based on average daily flow. Table 14 shows for which plants information was directly available from AEEs, and for which plants estimates were required.

Table 14 Operating costs of municipal wastewater infrastructure and data sources

Site	Annual operating cost (2013 $m)	AEE	Other	Source
Ngaruawahia	0.07	√		
Tokoroa	0.09	√		
Cambridge	0.6		√	Estimated based on Taupo case, pro rata according to replacement cost
Hamilton	4.0		√	Estimated as 5% of replacement cost. An operation and maintenance cost of $193k was provided in the AEE; however, this cost is not reasonable and may have referred to the marginal costs of the upgrade detailed in the AEE.
Huntly	0.07	√		
Pukekohe	1.8		√	Estimated based on Auckland-wide reported operating costs and percentage of population served
Te Kauwhata	0.13	√		
Meremere	0.07		√	Estimated based on Te Kauwhata case, pro rata according to replacement cost
Te Kuiti	0.9		√	Estimated based on Pukekohe case, pro rata according to replacement cost
Te Awamutu	1.5		√	The AEE provided an estimate of $1.98m; however, these costs are unlikely for this size of plant.
Taupo	2.23	√		
Otorohanga	0.03		√	Estimated based on Te Kauwhata case, pro rata according to replacement cost

The use of operating costs directly from AEEs can be problematic because of the different ways in which asset owners report costs. For example, some may only report the costs of power and materials, while others also report labour and monitoring and reporting costs. Annual operating costs as a percentage of asset replacement cost ranged from 0.4% for the Hamilton plant to 14% for Te Awamutu. No attempt was made to correct for any differences in reporting, as this would have required further assumptions.

To estimate the expected cash flows under the current treatment scenario, local councils' Long Term Plans were referenced. Upgrades were expected at six municipal wastewater treatment plants, although cost estimates were not available for two of the six. Where upgrade costs were not reported, it was assumed that only operating and maintenance costs would apply for the next ten years. These expected costs for each site are shown in Table 15.

Table 15 Expected cash flow over next ten years under current scenario, based on upgrades and operation and maintenance costs

Plant	**Works planned over next 10 years (Planned upgrade $m or type of expenditure expected)**	**O&M and capital works planned over next 10 years** (undiscounted cash flow, $m)
Municipal wastewater	*42.3*	*156+*
Ngaruawahia	O&M only	0.7
Tokoroa	15	15.9
Cambridge	13.5	19.1
Hamilton	O&M only	40.5
Huntly	O&M only	0.7
Pukekohe	Major process upgrades (capacity)	14.5+
Te Kauwhata	Major capacity upgrades also required (projected growth 143% over 20yrs)	1.3+
Meremere	O&M only	0.7
Te Kuiti	O&M only	11.6
Te Awamutu	O&M only	15.0
Taupo	3.2	25.5
Otorohanga	10.6	10.9
Industrial wastewater		*91*
Timber Mill		
Kinleith pulp mill		24.6
Prawn Farm Wairakei		
Te Awamutu Dairy Factory		10
Roto-o-rangi Piggery		4.0
Reporoa Dairy factory		6.0
Lichfield Dairy factory		6.0
Hautapu Dairy factory		6.0
Te Rapa Dairy Factory		20.0
AFFCo Horotiu		10.0
Waikato ByProducts		4.1
Total	**42.3**	**246.9**

Table 16 summarises the wastewater treatment equipment at each site. The numbers in the boxes indicate if the equipment is present on site or not; not the number of pieces of equipment.

Table 16 Wastewater treatment components at each municipal site

Plant	Treatment*	Primary						Secondary							Tertiary					
		Screens	Grit removal	Settlement	Clarifiers	Anaerobic pond	Oxidation pond	Aeration basins	Digestors	Clarifiers	Actiflo clarifier	Trickling filters	Activated sludge	SBR (batch reactor)	UV	Planted rock filters	Papatuanuku trench	Rapid infiltration basins	Aquamats	Discharge to land
Ngaruawahia	3						1								1	1				
Tokoroa	3			1					1				1		1					
Cambridge	2	1	1			1		1										1		
Hamilton	3	1	1	1	1				1	1			1		1					
Huntly	3	1						1			1				1	1				
Pukekohe	3	1	1											1						
Te Kauwhata	2						1												1	
Meremere	1						1									1				
Te Kuiti	3	1								1			1		1					
Te Awamutu	3	1	1							1			1		1		1			
Taupo	4	1			1				1	1		1								1
Otorohanga	3						1									1				

Industrial wastewater

Table 17 shows the data used to estimate influent contaminant loadings at each industrial wastewater treatment plant. These data were available from Assessments of Environmental Effects (AEEs) for the Reporoa Dairy Factory only. For all other plants, typical industrial wastewater characteristics were used where available from the literature.

Table 17 Influent water quality data and sources for industrial wastewater

Site	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH_3-N (mg/L)	TP (mg/L)	Faecal coliforms (MPN/100mL)	E coli (MPN/100mL)	Data source
Kinleith pulp mill	225	385						Bond & Straub (1974)
			13		4			Ammary (2004)
				4.1				Fiss & Stein (2008)
Te Awamutu, Reporoa and Te Rapa Dairy factories	2450		73.3		67			Reporoa AEE
		300						Bond & Straub (1974)
				35				Tanner, Clayton & Upsdell (1995)
Lichfield Dairy factory	2475							Set equal to discharge concentration (higher than 'typical')
			73.3		67			Reporoa AEE
		300						Bond & Straub (1974)
				35				Tanner, Clayton & Upsdell (1995)
Hautapu Dairy factory	2450		116		67			
				117				Set equal to discharge concentration (higher than 'typical')
		300						Bond & Straub (1974)
				35				Tanner, Clayton & Upsdell (1995)
Roto-o-rangi Piggery	33000	40200	4400	1400	1485			Gray, Uvukin & Biddlestone (1991)
							2.0×10^5	Chinivasagam et. al (2004)
						2.0×10^5		Set equal to *E. coli*
AFFCo Horotiu	2000	800						Bond & Straub (1974)
			165	75	34			Thayalakumaran (2002)
						1.8×10^8		Bazrafshan et al. (2012)
							1.8×10^8	Assumed equal to faecal coliforms
Waikato ByProducts	7000							Sindt (?)
					34			Used the same as for "meatworks"
			600	730				Irvine & Khan (2010)
		8400				5.0×10^6		USEPA (2008)
							5.0×10^6	Assumed equal to faecal coliforms

Table 18 shows the effluent water quality data used to estimate contaminant loadings flowing out of each industrial wastewater treatment plant and the sources from which the data were obtained. In the first instance, information from the Waikato River Scoping Study was used. AEEs were available for many of these sites, but they had been produced in the 1990s and are unlikely to reflect current conditions. They were used in the absence of any other information.

Table 18 Effluent water quality data and sources for industrial wastewater

Site	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	NH3-N (mg/L)	TP (mg/L)	Faecal coliforms (MPN/100mL)	Flow (m^3/d)	Data source
Kinleith pulp mill	21	40	5		0.6		87,600	Information from CHH
				0.09				AEE (1996)
Prawn Farm Wairakei		30	4.0		4.0		864	NIWA (2010)
Te Awamutu Dairy Factory	7			0.10			5128	Monitoring data (2001)
		30	30		2.7			NIWA (2010)
Roto-o-rangi Piggery	100			150			330	AEE
		30	19.7		3.9			NIWA (2010)
Reporoa Dairy factory	0	0	0	0	0		0	Land disposal
Lichfield Dairy factory				0.1			2200	NIWA (2010)
	20							Average of other dairy sites
		10	52		1.8			Land disposal
Hautapu Dairy factory	20	26	116	117			2200	AEE
					1.8			NIWA (2010)
Te Rapa Dairy Factory							5,000[20]	AEE
		10	40		2.5			NIWA (2010)
	20			0.1				Average of other dairy sites
AFFCo Horotiu	816					100,000	4838	AEE
		20	165	68	21			NIWA (2010)
Waikato ByProducts		62	100		10		1000	NIWA (2010)
	816			68		100,000		Set equal to AFFCo

[20] The full discharge is 10,000m^3/d, which includes 'cow water' – condensate straight off the evaporators. This receives no treatment at all as it is very low strength water. The actual flow to the WWTP is closer to 5000m^3/d at the strengths shown in this table.

Replacement costs were only available for the AFFCo plant through the AEE. All other industrial wastewater treatment plant replacement costs were based on the Opus cost curves for large flows.

Table 19 Replacement costs of industrial wastewater infrastructure and data sources

Site	Replacement cost (2013 $m)	AEE	Opus cost curve	Engineer's site knowledge
Kinleith pulp mill	40			√
Prawn Farm Wairakei				
Te Awamutu Dairy Factory	10		√	
Roto-o-rangi Piggery	4		√	
Reporoa Dairy factory	6			√
Lichfield Dairy factory	6			√
Hautapu Dairy factory**	6			√
Te Rapa Dairy Factory	20			√
AFFCo Horotiu	10			√
Waikato ByProducts	4		√	

The AFFCo wastewater treatment plant was the only one for which a true replacement cost was available; however, this AEE was from the mid 1990s. Wastewater treatment specialists estimated the replacement cost of the wastewater treatment infrastructure based on images from Google Earth. Table 20 summarises the treatment equipment at each industrial site and shows that only two treatment plants are assessed as having tertiary or greater treatment. However, this information was acquired from AEEs in the mid 1990s. Upgrades may have taken place since then. The numbers in the boxes indicate if the equipment is present on site or not; not the number of pieces of equipment.

Table 20 Wastewater treatment components at each industrial site

		Primary		Secondary								Tertiary			
Plant	Treatment*	Screens	Clarifiers	Aeration basins	Dissolved air flotation	Anaerobic reactor	Aerated lagoons	Oxidation pond	Clarifiers	Vermicomposting	Activated sludge	UV	Planted rock filters	Papatuanuku trench	Discharge to land
Timber Mill															
Kinleith pulp mill	2	1	1	1				1	1	1					
Prawn Farm Wairakei															
Te Awamutu Dairy Factory	2				1				1		1				
Roto-o-rangi Piggery															
Reporoa Dairy factory	4				1										1
Lichfield Dairy factory	4				1										1
Hautapu Dairy factory	4				1										1
Te Rapa Dairy Factory	3				1				1		1			1	
AFFCo Horotiu	3	1			1	1	1	1					1		
Waikato ByProducts	3					1					1	1	1		

Appendix B

Data sources and estimates – alternative scenarios

Effluent quality

To estimate the contaminant loadings under alternative treatment scenarios, for municipal and industrial sites, removal rates were based on Waikato River catchment secondary and tertiary wastewater treatment plants, as summarised in Table 21. Primary wastewater treatment plant removal rates were based on plants assessed by Asano & Tchobanoglous (1987), also summarised in Table 21. Although there is one primary municipal wastewater treatment plant in the Waikato River catchment, Meremere, its removal rates are similar to those of secondary wastewater treatment plants in the Waikato (refer Table 22 and Table 23). These higher removal rates are because Meremere uses oxidation ponds, which approximate secondary treatment. Due to high removal rates, it was assumed that Meremere did not represent primary municipal wastewater treatment plants. Asano & Tchobanoglous (1987) form the basis for the renowned wastewater treatment textbook Metcalf & Eddy (2003), and was therefore determined to be a reliable source.

The removal rates for primary treatment were averaged from the results of influent and effluent water characteristics from two primary wastewater treatment plants in California, as shown in Table 22. The average removal rate from the two plants was used. The removal rate for total phosphorus was estimated assuming an influent concentration equal to the average influent concentration for Waikato municipal wastewater treatment plants (11 mg/L). Some proportion of faecal coliforms and *E. coli* would likely be removed along with removal of suspended solids, but the literature did not provide information on which to base these estimates. It was assumed that these microorganisms would not be removed.

Table 21 Removal rates used for primary, secondary, tertiary and land disposal wastewater treatment

	Primary	Secondary	Tertiary	Land disposal
BOD	33%	91%	97%	100%
SS	50%	76%	95%	100%
TN	20%	70%	72%	100%
NH3-N	16%	56%	87%	100%
TP	20%	43%	44%	100%
Faecal coliforms	0%	99.77%	99.94%	100%
E. coli	0%	99.82%	99.86%	100%

Table 22 Source of primary wastewater treatment removal rates

Quality parameters	City of Davis			San Diego			Meremere
	Raw wastewater (mg/l)	Primary effluent (mg/l)	Removal rate[21]	Raw wastewater (mg/l)	Primary effluent (mg/l)	Removal rate	Removal rate[22]
Biochemical oxygen demand, BOD_5	112	73	35%	184	134	27%	97%
Suspended solids	185	72	61%	200	109	46%	90%
Total nitrogen	43.4	34.7	20%	-	-		56%
NH_3-N	35.6	26.2	26%	21	20	5%	74%
Total phosphorus	-	7.5	32%	-	10.2	7%	65%

Source: Adapted from Asano & Tchobanoglous (1987)

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21 Primary effluent concentration divided by raw wastewater concentration

22 Meremere's removal rates were not used but are shown here for comparison

Three municipal wastewater treatment plants in the Waikato are considered secondary treatment plants (Cambridge, Te Kauwhata, Otorohanga). In addition, AEEs for Huntly and Ngaruawahia contained treated water characteristics prior to tertiary treatment. The average of these data was used to estimate secondary wastewater treatment removal rates across the Waikato. In addition, these results were compared to results of influent and effluent water characteristics from four secondary wastewater treatment plants in California, as shown in Table 23.

Seven municipal wastewater treatment plants in the Waikato are now considered tertiary wastewater treatment plants. Removal rates are shown in Table 24. The average of the first five plants, for which post-upgrade data were available, was applied to secondary and primary wastewater treatment plants in the alternative scenarios.

The Taupo AEE contained effluent water quality prior to land disposal for all water quality characteristics except faecal coliforms. To estimate the Most Probable Number of faecal coliforms per 100mL of tertiary treated wastewater, the concentrations were averaged from all other municipal wastewater treatment plants. For all industrial wastewater treatment plants, the average removal rates were calculated for the municipal wastewater treatment plants.

Table 23 Source of secondary wastewater treatment removal rates

Quality parameter	Plant location: Trickling filters		Activated sludge		Estimated removal rate (based on Davis raw water)				Estimated removal rate (based on San Diego raw water)					Waikato values					
	Chino 1	Chino 2	Santa Rosa	Montecito	Chino 1	Chino 2	Santa Rosa	Montecito	Chino 1	Chino 2	Santa Rosa	Montecito	Average	Ngaruawahia	Huntly	Cambridge	Te Kauwhata	Otorohanga	Waikato average
	mg/L																		
Biochemical oxygen demand, BOD_5	21	8	-	11	81%	93%		90%	89%	96%		94%	90%	89%	85%	89%	99%	93%	91%
Suspended solids	18	26	-	13	90%	86%		93%	91%	87%		94%	90%	72%	34%	88%	98%	88%	76%
Total nitrogen	-	-	-	-										42%	71%	83%	91%	66%	70%
NH_3-N	25	11	10	1.4	30%	69%	72%	96%		48%	52%	93%	66%	49%	88%	3%	99%	41%	56%
Total phosphorus	-	-	12.5	-										37%	41%	46%	54%	34%	43%
Faecal coliforms														98.98%	99.95%	99.96%	99.98%	99.97%	99.77%
E. coli														99.27%	99.93%	99.98%	99.98%	99.99%	99.82%

Source: Adapted from Asano & Tchobanoglous (1987)

Table 24 Source of tertiary wastewater treatment removal rates

TERTIARY	WAIKATO PLANTS: Tokoroa	Hamilton	Pukekohe	Te Kuiti	Te Awamutu	Average	Ngaruawahia upgraded	Huntly upgraded
BIOCHEMICAL OXYGEN DEMAND, BOD_5	98%	97%	98%	96%	98%	97%	87%	85%
SUSPENDED SOLIDS	98%	84%	98%	98%	97%	95%	86%	77%
TOTAL NITROGEN	49%	79%	85%	61%	87%	72%	73%	82%
NH_3-N	96%	83%	96%	60%	98%	87%	98%	96%
TOTAL PHOSPHORUS	47%	62%	65%	8%	39%	44%	69%	66%
FAECAL COLIFORMS	100.00%	99.74%	99.99%	100.00%	100.00%	100%	99.98%	99.98%
E. COLI	100.00%	99.83%	99.98%	99.99%	99.52%	100%	99.98%	99.96%

Replacement costs and operating and maintenance costs

As described in section 3.2, replacement costs for primary and secondary wastewater treatment plants were based on cost curves by Singhirunnusorn & Stenstrom (2010) and Butt & Evans (1970). Estimates by treatment type and cost curve are provided for each site in Table 25.

Operating and maintenance costs were estimated using Berbeka's (2006) cost curves and inflating to 2013 dollars. In many cases the cost curves provided estimates several times higher than the reported O&M costs. Singhirunnusorn & Stenstrom (2010) also provided cost curves for estimating O&M costs for secondary treatment. Their costs were also higher than those reported and O&M costs were not available for other treatment levels. Rather than using Berbeka's estimates directly, the ratios of tertiary to primary and tertiary to secondary treatment were used. The cost estimates, ratios, and O&M costs used at each plant are shown in Table 26. The site-by-site costs show that in some cases, O&M costs for a higher level of treatment are lower than those for a lower level of treatment. Due to the small overlaps, no adjustment was made in these cases.

Most municipal wastewater treatment plants currently have tertiary treatment, and in these cases, reported costs were used. Industrial wastewater treatment plants are more complex, as they tend to have more than one treatment train. One of these trains may have secondary treatment only, while another may have tertiary treatment and / or land disposal. To estimate replacement costs of tertiary equipment, the ratios derived from reported municipal tertiary treatment replacement costs to secondary replacement costs (estimated from Singhirunnusorn & Stenstrom, 2010) were used. Similarly, for O&M costs, Berbeka's (2006) ratios were used to inflate reported secondary treatment costs to tertiary. These capital and O&M costs are shown in **Error! Reference source not found.**.

NIWA (2010) provided land disposal cost estimates and cost curves. These were used to estimate the replacement cost of infrastructure in the land disposal scenario. O&M cost estimates were based on estimates from AEEs where available. All other O&M costs were based on a ratio of O&M to replacement cost where both replacement costs and O&M costs had been estimated for land disposal. Table 27 summarises the marginal replacement costs to install and operate and maintain land disposal treatment equipment at each site. The cost is absent where the treatment facilities are currently land disposal.

Table 25 Replacement cost estimates for primary and secondary wastewater treatment plants at each site ($m)

			Construction costs (Butt & Evans, 1970)							(Singhirunnusorn &Stenstrom, 2010)				Minimum cost from literature		Opus cost curve	Cost ratios from literature and Opus cost curves			Capital cost estimate		
			Primary		Secondary					Secondary												
Plant	Flow (m^3/d)	Reported capital	Digester	Vacuum	TF-digester	TF-imhoff	AS <10000 pop	AS > 10000 pop	AS factory built	AS	OD	AL	WSP	1ry	2ry	3ry	2ry/3ry	3ry/2ry	3ry/1ry	1ry	2ry	3ry
Municipal																						
Ngaruawahia	1750	4.5	2.4	1.2	2.3	1.9	2.3	1.9	1.8	3.0	2.1	3.1	1.5	1.2	1.8	6	1.4	1.39	2.0	3.1	4.5	6.2
Tokoroa	3242	13.8	3.5	2.1	3.9	3.3	3.5	4.0	2.9	5.2	3.6	4.8	2.9	2.1	2.9	11	1.4			7.0	8.6	13.8
Cambridge	5548	7.2	3.8	2.3	4.3	3.7	3.8	4.5	3.1	8.4	5.9	6.9	5.1	2.3	3.1	12	1.4	1.62	2.2	5.2	7.2	11.7
Hamilton	40000	81.0	12.3	10.3	20.2	18.1	12.6	39.5	13.1	47.8	35.6	26.5	41.1	10.3	12.6	58	1.2			41.1	50.6	81.0
Huntly	2387	4.4	2.6	1.4	2.6	2.1	2.5	2.2	2.0	4.0	2.7	3.9	2.1	1.4	2.0	7	1.4	1.58	2.3	3.0	4.4	6.9
Pukekohe	4500	17.1	4.7	3.0	5.8	5.0	4.7	6.8	4.1	7.0	4.9	6.0	4.1	3.0	4.1	16	1.4			8.7	10.7	17.1
Te Kauwhata	554	12.0	1.2	0.5	0.9	0.7	1.1	0.5	0.7	1.1	0.7	1.4	0.4	0.5	0.5	2	1.0		1.7	11.5	12.0	19.1
Meremere	283	0.5	0.7	0.2	0.4	0.4	0.6	0.2	0.4	0.6	0.4	0.9	0.2	0.2	0.2	1	0.8			0.5	0.7	1.2
Te Kuiti	2895	11.1	2.0	1.0	1.8	1.5	1.9	1.4	1.4	4.7	3.3	4.4	2.5	1.0	1.4	5	1.4			5.6	7.0	11.1
Te Awamutu	4102	11.0	3.7	2.2	4.1	3.5	3.6	4.2	3.0	6.4	4.5	5.6	3.7	2.2	3.0	11	1.4			5.6	6.9	11.0
Taupo	5400	28.7	4.9	3.2	6.0	5.2	4.9	7.3	4.3	8.2	5.8	6.8	4.9	3.2	4.3	17	1.4			5.7	7.8	16.6
Otorohanga	795	2.8	1.6	0.8	1.4	1.2	1.6	1.0	1.1	1.5	1.0	1.8	0.6	0.8	1.0	4	1.3		1.7	2.2	2.8	3.7
Industrial																	**1.38**	**1.60**	**1.97**			
Timber Mill																						
Kinleith pulp mill	87600	40								95.4	72.7	45.2	94.4							29.0	40.0	64
Prawn Farm Wairakei	864									1.6	1.1	1.9	0.7							-		0
Te Awamutu Dairy Factc	5128	10								7.8	5.5	6.5	4.7							7.3	10.0	16
Roto-o-rangi Piggery	330	4								0.7	0.5	1.0	0.3							3.0		6
Reporoa Dairy factory	1807	6								3.1	2.1	3.2	1.5							3.0	3.7	6
Lichfield Dairy factory	2200	6								3.7	2.5	3.7	1.9							3.0	3.7	6
Hautapu Dairy factory	2200	6								3.7	2.5	3.7	1.9							3.0	3.7	6
Te Rapa Dairy Factory	5000	20								7.7	5.4	6.4	4.5							10.1	12.5	20
AFFCo Horotiu	4838	10								7.4	5.2	6.3	4.4							5.1	6.2	10
Waikato ByProducts	1000	4								1.9	1.2	2.1	0.8							2.1	2.5	4

Notes: 1ry=primary; 2ry=secondary; 3ry=tertiary

TF=Trickling filter; AS=Activated sludge; OD=Oxidation ditches; AL=Aerated lagoons; WSP=Waste stabilisation ponds

Table 26 Operation and maintenance cost estimates for primary and secondary wastewater treatment plants at each site ($m /year)

			Berbeka (2006)						Singhirunnusorn & Stenstrom					O&M cost used		
Plant	Flow (m^3/d)	Reported O&M	Primary	Secondary	Tertiary	Ratio: Tertiary to primary	Ratio: Secondary to primary	Ratio: Tertiary to secondary	Activated sludge	Oxidation ditches	Aerated lagoons	Waste stabilisation ponds	Secondary treatment est	Primary treatment	Secondary treatment	Tertiary treatment
Municipal																
Ngaruawahia	1750	0.07	0.64	0.66	0.77	84%	98%	86%	0.084	0.121	0.069	0.028	0.1	0.065	0.066	0.08
Tokoroa	3242	0.09	0.97	1.10	1.31	74%	88%	84%	0.111	0.141	0.075	0.036	0.1	0.068	0.077	0.09
Cambridge	5548	0.56	1.30	1.73	2.07	63%	75%	83%	0.152	0.173	0.086	0.048	0.2	0.423	0.562	0.67
Hamilton	40000	4.05	1.41	8.88	10.63	13%	16%	84%	0.766	0.651	0.241	0.237	0.8	0.536	3.384	4.05
Huntly	2387	0.07	0.80	0.85	1.01	79%	93%	85%	0.095	0.129	0.071	0.031	0.1	0.062	0.066	0.08
Pukekohe	4500	1.80	1.17	1.45	1.73	68%	81%	84%	0.133	0.159	0.081	0.043	0.2	1.215	1.507	1.80
Te Kauwhata	554	0.13	0.26	0.25	0.28	92%	100%	89%	0.063	0.104	0.063	0.021	0.1	0.133	0.133	0.15
Meremere	283	0.07	0.15	0.14	0.16	93%	100%	91%	0.058	0.100	0.062	0.020	0.1	0.066	0.066	0.07
Te Kuiti	2895	1.16	0.90	1.00	1.19	76%	90%	84%	0.104	0.136	0.074	0.034	0.1	0.882	0.978	1.16
Te Awamutu	4102	1.50	1.11	1.34	1.60	69%	83%	84%	0.126	0.153	0.079	0.040	0.2	1.042	1.258	1.50
Taupo	5400	2.23	1.28	1.69	2.02	63%	76%	83%	0.149	0.171	0.085	0.048	0.2	0.634	0.835	1.00
Otorohanga	795	0.03	0.35	0.34	0.39	91%	100%	88%	0.067	0.107	0.064	0.022	0.1	0.031	0.031	0.04
Industrial																
Timber Mill																
Kinleith pulp mill	87600	2.5	0.61	16.96	19.88	3%	4%	85%	1.614	1.312	0.455	0.498	1.6	0.09	2.46	2.88
Prawn Farm Wairakei	864		0.38	0.37	0.42	90%	100%	87%	0.068	0.108	0.065	0.023	0.1			
Te Awamutu Dairy Factory	5128	1.0	1.25	1.62	1.93	65%	77%	84%	0.144	0.167	0.084	0.046	0.2	0.77	1.00	1.20
Roto-o-rangi Piggery	330	0.4	0.17	0.16	0.18	93%	100%	91%	0.059	0.101	0.062	0.020	0.1			
Reporoa Dairy factory	1807	0.6	0.66	0.68	0.79	83%	97%	85%	0.085	0.121	0.069	0.028	0.1	0.50	0.51	0.60
Lichfield Dairy factory	2200	0.6	0.76	0.80	0.94	81%	95%	85%	0.092	0.127	0.071	0.030	0.1	0.48	0.51	0.60
Hautapu Dairy factory	2200	0.6	0.76	0.80	0.94	81%	95%	85%	0.092	0.127	0.071	0.030	0.1	0.48	0.51	0.60
Te Rapa Dairy Factory	5000	2.0	1.23	1.58	1.89	65%	78%	84%	0.142	0.166	0.083	0.045	0.2	1.30	1.67	2.00
AFFCo Horotiu	4838	1.0	1.21	1.54	1.84	66%	79%	84%	0.139	0.163	0.082	0.045	0.2	0.66	0.84	1.00
Waikato ByProducts	1000	0.4	0.42	0.41	0.47	89%	100%	87%	0.071	0.110	0.065	0.023	0.1	0.36	0.35	0.41

Table 27 Estimate of marginal replacement costs and operating and maintenance costs for land disposal at each site[23]

Plant	Land disposal upgrade cost estimate (2013 $m)	Land disposal O&M (2013 $m)
Municipal wastewater	*178.3*	*28.5*
Ngaruawahia	3.9	0.6
Tokoroa	15.0	2.4
Cambridge	12.5	2.0
Hamilton	89.9	14.4
Huntly	5.4	0.9
Pukekohe	10.1	1.6
Te Kauwhata	13.8	2.2
Meremere	2.0	0.3
Te Kuiti	14.0	2.2
Te Awamutu	9.2	1.5
Taupo		
Otorohanga	2.5	0.4
Industrial wastewater	*231.1*	*14.2*
Kinleith pulp mill	157.7	9.7
Prawn Farm Wairakei	4.5	0.3
Te Awamutu Dairy Factory	17.8	1.1
Roto-o-rangi Piggery	2.2	0.1
Reporoa Dairy factory	8.0	0.5
Lichfield Dairy factory	9.3	0.6
Hautapu Dairy factory	9.3	0.6
Te Rapa Dairy Factory	17.4	1.1
AFFCo Horotiu		
Waikato ByProducts	5.1	0.3
Total	**409**	**43**

[23] These cost estimates contain differing levels of detail, including inclusion or exclusion of land purchase costs, and accurate accounting for length and size of pumping and piping equipment.

Appendix C

Site-by-site estimates of costs and contaminant loadings under current and alternative treatment scenarios

Current situation

Table 28 shows the estimated total tonnes of contaminant that are generated or managed at each site, and the total tonnes of contaminant that are released into the Waikato River catchment. Grey boxes represent attributes for which no data were available on which to make informed estimates. Table 29 shows the estimated rate of contaminant removal at each site.

Table 28 Estimated annual tonnes of contaminant produced and released at each site

	Annual tonnes of contaminant													
	Produced							Released into catchment						
Plant	BOD	SS	TN	NH3-N	TP	FC*	Ecoli*	BOD	SS	TN	NH3-N	TP	FC*	Ecoli*
Municipal wastewater	*7,958*	*9,261*	*1,310*	*758*	*266*	*1.7E+18*	*8.5E+17*	*271*	*956*	*275*	*171*	*108*	*2.6E+15*	*9.2E+14*
Ngaruawahia	144.32	133	34	26	7	4.7E+16	3.8E+16	18.8	19	9	0.4	2.2	9.58E+12	9.58E+12
Tokoroa	357	426	67	36	12	7.7E+16	4.0E+16	6.2	10	34	1.4	6.5	1.3E+12	1.05E+12
Cambridge	336	425	115	73	21	1.6E+17	6.8E+16	36	52	20	71	11.3	6.08E+13	6.08E+13
Hamilton	4,380	4,964	686	439	146	9.4E+17	4.9E+17	143	793	146	75	55.0	2.44E+15	8.13E+14
Huntly	131	114	46	37	9	5.7E+16	3.6E+16	20.0	26	8	1.52	3.1	1.31E+13	1.31E+13
Pukekohe	757	900	99	62	21	1.1E+17	5.5E+16	14	15	15	2.4	7.4	1.35E+13	1.35E+13
Te Kauwhata	61	73	12	6	2	1.3E+16	6.8E+15	0.6	1.6	1.0	0.07	1.0	2.39E+12	1.38E+12
Meremere	31	37	6	3	1	6.7E+15	3.5E+15	0.9	3.8	2.6	0.8	0.4	5.88E+11	5.88E+11
Te Kuiti	582	813	60	32	14	6.8E+16	3.6E+16	21	14	23	13	12.7	3.17E+12	2.11E+12
Te Awamutu	249.90	424	59	35	12	6.3E+16	3.1E+14	6.1	12	8	0.53	7.2	1.5E+12	1.51E+12
Taupo	928	952	126	0.1	18	1.3E+17	6.6E+16	0	0	0	0	0.0	0	0
Otorohanga	64	78	24	8.4	2	1.9E+16	9.8E+15	4.4	9.6	8.1	4.9	1.4	4.93E+12	1.13E+12
Industrial wastewater	*31,883*	*23,419*	*2,165*	*973*	*779*	*3.2E+18*	*3.2E+18*	*2,502*	*1,438*	*743*	*259*	*74*	*2.2E+15*	*2.2E+15*
Kinleith pulp mill	7,194	12,310	416	131	128	4.8E+13	4.8E+13	669	1264	146	2.9	20	4.8E+13	4.8E+13
Prawn Farm Wairakei								0	9	1.3		1.3		
Te Awamutu Dairy Factory	4,586	562	374	66	125	3.7E+15	0.0E+00	13	56	56	0.2	5	0.0E+00	0.0E+00
Roto-o-rangi Piggery	3,975	4,842	530	169	179			12	4	2	18.1	0.5	0.0E+00	0.0E+00
Reporoa Dairy factory	1,616	198	48	23	44	0.0E+00	0.0E+00	0	0	0	0	0	0.0E+00	0.0E+00
Lichfield Dairy factory	1987	241	59	28	54	0.0E+00	0.0E+00	16	8	42	0	1.4	0.0E+00	0.0E+00
Hautapu Dairy factory	1967	241	93	94	54	0.0E+00	0.0E+00	16	21	93	94	1.4	0.0E+00	0.0E+00
Te Rapa Dairy Factory	4471	548	134	64	122	0.0E+00	0.0E+00	37	18	73	0	4.6	0.0E+00	0.0E+00
AFFCo Horotiu	3532	1413	292	132	60	3.2E+18	3.2E+18	1441	35	292	119	37	1.8E+15	1.8E+15
Waikato ByProducts	2555	3066	219	266	12	1.8E+16	1.8E+16	298	23	37	25	3.7	3.7E+14	3.7E+14
Total	**40,077**	**35,126**	**3,475**	**1,735**	**1,073**	**4.9E+18**	**4.0E+18**	**3,009**	**4,839**	**1,095**	**434**	**211**	**4.7E+15**	**3.1E+15**

* FC and E coli measured in MPN

Table 29 Estimated contaminant removal as a percentage of wastewater generated at each site

Plant	Annual contaminant load prevented from river catchment (%)						
	BOD	SS	TN	NH3-N	TP	FC*	Ecoli*
Municipal wastewater	*97%*	*91%*	*81%*	*77%*	*59%*	*99.85%*	*99.89%*
Ngaruawahia	87%	86%	73%	98%	69%	99.979%	99.975%
Tokoroa	98%	98%	49%	96%	47%	99.998%	99.997%
Cambridge	89%	88%	83%	3%	46%	99.962%	99.911%
Hamilton	97%	84%	79%	83%	62%	99.741%	99.835%
Huntly	85%	77%	82%	96%	66%	99.977%	99.963%
Pukekohe	98%	98%	85%	96%	65%	99.987%	99.976%
Te Kauwhata	99%	98%	91%	99%	54%	99.982%	99.980%
Meremere	97%	90%	56%	74%	65%	99.991%	99.983%
Te Kuiti	96%	98%	61%	60%	8%	99.995%	99.994%
Te Awamutu	98%	97%	87%	98%	39%	99.998%	99.519%
Taupo	100%	100%	100%	100%	100%	100.000%	100.000%
Otorohanga	93%	88%	66%	41%	34%	99.974%	99.988%
Industrial wastewater	*92%*	*94%*	*66%*	*73%*	*91%*	*99.93%*	*99.93%*
Kinleith pulp mill	91%	90%	65%	98%	84%	0.000%	0.000%
Prawn Farm Wairakei							
Te Awamutu Dairy Factory	100%	90%	85%	100%	96%		
Roto-o-rangi Piggery	100%	100%	100%	89%	100%		
Reporoa Dairy factory	100%	100%	100%	100%	100%		
Lichfield Dairy factory	99%	97%	29%	100%	97%		
Hautapu Dairy factory	99%	91%			97%		
Te Rapa Dairy Factory	99%	97%	45%	100%	96%		
AFFCo Horotiu	59%	98%	0%	10%	39%	99.944%	99.944%
Waikato ByProducts	88%	99%	83%	91%	71%	98.000%	98.000%
Total	**93%**	**86%**	**71%**	**75%**	**80%**	**99.90%**	**99.92%**

* FC and E coli measured in MPN

Alternative situation

The estimated contaminant load that would be released into the Waikato River catchment under primary and secondary treatment scenarios is shown in Table 30. Table 31 shows the expected contaminant load that would be released if all treatment plants had tertiary treatment.

Table 30 Estimated contaminant load released into catchment under primary and secondary treatment scenarios

	Annual contaminant load released into catchment (tonnes per year)													
	Hypothetical primary released							Hypothetical secondary released						
Plant	BOD	SS	TN	NH3-N	TP	FC*	Ecoli*	BOD	SS	TN	NH3-N	TP	FC*	Ecoli*
Municipal wastewater	*5,371*	*4,630*	*1,048*	*632*	*212*	*1.7E+18*	*8.4E+17*	*724*	*2,161*	*365*	*340*	*147*	*3.3E+15*	*1.4E+15*
Ngaruawahia	97	66	27	22	6	4.7E+16	3.8E+16	19	19	9	0	2	9.6E+12	9.6E+12
Tokoroa	241	213	54	30	10	7.7E+16	4.0E+16	32	103	20	16	7	1.8E+14	7.4E+13
Cambridge	227	213	92	62	17	1.6E+17	6.8E+16	36	52	20	71	11	6.1E+13	6.1E+13
Hamilton	2,957	2,482	549	370	117	9.4E+17	4.9E+17	390	1,202	203	193	84	2.2E+15	9.1E+14
Huntly	88	57	37	32	7	5.7E+16	3.6E+16	20	26	8	2	3	1.3E+13	1.3E+13
Pukekohe	511	450	79	53	17	1.1E+17	5.5E+16	67	218	29	27	12	2.5E+14	1.0E+14
Te Kauwhata	41	36	9	5	2	1.3E+16	6.8E+15	1	2	1	0	1	2.4E+12	1.4E+12
Meremere	21	19	5	3	1	6.7E+15	3.5E+15	3	9	2	1	1	1.5E+13	6.4E+12
Te Kuiti	393	406	48	27	11	6.8E+16	3.6E+16	52	197	18	14	8	1.6E+14	6.6E+13
Te Awamutu	169	212	47	29	9	6.3E+16	3.1E+14	22	103	17	15	7	1.4E+14	5.8E+11
Taupo	627	476	101	0	15	1.3E+17	6.6E+16	83	231	37	0	11	2.9E+14	1.2E+14
Otorohanga	43	39	19	7	2	1.9E+16	9.8E+15	4	10	8	5	1	4.9E+12	1.1E+12
Industrial wastewater	21,521	11,710	1,732	821	626	3.2E+18	3.2E+18	*2,839*	*5,671*	*640*	*429*	*448*	*7.4E+15*	*5.9E+15*
Kinleith pulp mill	4,856	6,155	333	111	103	4.8E+13	4.8E+13	641	2,981	123	58	74	1.1E+11	8.9E+10
Prawn Farm Wairakei														
Te Awamutu Dairy Factory	3,095	281	299	55	101	3.7E+15	0.0E+00	408	136	111	29	72	8.6E+12	0.0E+00
Roto-o-rangi Piggery	2,683	2,421	424	142	144	0.0E+00	0.0E+00	354	1,172	157	74	103	0.0E+00	0.0E+00
Reporoa Dairy factory	1,091	99	39	19	36	0.0E+00	0.0E+00	144	48	14	10	25	0.0E+00	0.0E+00
Lichfield Dairy factory	1,341	120	47	24	43	0.0E+00	0.0E+00	177	58	17	12	31	0.0E+00	0.0E+00
Hautapu Dairy factory	1,328	120	75	79	43	0.0E+00	0.0E+00	175	58	28	41	31	0.0E+00	0.0E+00
Te Rapa Dairy Factory	3,018	274	107	54	98	0.0E+00	0.0E+00	398	133	40	28	70	0.0E+00	0.0E+00
AFFCo Horotiu	2,384	706	234	112	48	3.2E+18	3.2E+18	314	342	86	58	35	7.3E+15	5.9E+15
Waikato ByProducts	1,725	1,533	175	225	10	1.8E+16	1.8E+16	227	742	65	117	7	4.2E+13	3.4E+13
Total	**26,892**	**16,340**	**2,780**	**1,454**	**839**	**4.9E+18**	**4.0E+18**	**3,563**	**7,832**	**1,005**	**769**	**594**	**1.1E+16**	**7.3E+15**

* FC and E coli measured in MPN

Table 31 Estimated contaminant load released into catchment under tertiary treatment sc

Plant	Annual contaminant load released into catchment (to					
	Hypothetical entering river-tertiary treatme					
	BOD	SS	TN	NH3-N	TP	FC
Municipal wastewater	*257*	*935*	*334*	*104*	*112*	*2.5E*
Ngaruawahia	0.5	0.9	3	0.1	1.2	5.4E
Tokoroa	6.2	10.1	34.3	1.4	6.5	1.3E
Cambridge	0.9	3	6	9.4	6.3	3.4E
Hamilton	143	793	146	75	55	2.4E
Huntly	0.5	1.3	2	0.2	1.7	7.3E
Pukekohe	14.3	15.1	14.7	2.4	7.4	1.4E
Te Kauwhata	0.02	0.1	0.3	0.01	0.5	1.3E
Meremere	0.02	0.2	0.7	0.1	0.2	3.3E
Te Kuiti	21.1	13.7	23.2	12.7	12.7	3.2E
Te Awamutu	6.1	11.7	7.8	0.5	7.2	1.5E
Taupo	65.0	87.3	96.0	2.2	13.6	4.9E
Otorohanga	0.1	0.5	2	0.7	0.8	2.8E
Industrial wastewater	*824*	*1,145*	*602*	*129*	*435*	*1.8E*
Kinleith pulp mill	186	602	116	17.43	71.38	2.7E
Prawn Farm Wairakei						
Te Awamutu Dairy Factory	119	27	104	8.71	69.99	2.1E
Roto-o-rangi Piggery	103	237	147	22.42	99.82	
Reporoa Dairy factory	42	10	13	3.07	24.66	
Lichfield Dairy factory	51	12	16	3.74	30.03	
Hautapu Dairy factory	51	12	26	12.49	30.03	
Te Rapa Dairy Factory	116	27	37	8.49	68.24	
AFFCo Horotiu	91	69	81	17.61	33.51	1.8E
Waikato ByProducts	66	150	61	35.43	6.93	1.0E
Total	**1,082**	**2,080**	**935**	**233**	**547**	**4.3E**

* FC and E coli measured in MPN

Opus International Consultants Ltd
The Westhaven, 100 Beaumont St
PO Box 5848, Auckland 1141
New Zealand

t: +64 9 355 9500
f: +64 9 355 9584
w: www.opus.co.nz