# MASTERTON WASTEWATER TREATMENT PLANT HEALTH IMPACT ASSESSMENT

**March 2007**

by

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Client Report
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## EXECUTIVE SUMMARY

This risk assessment has examined the pre and post upgrade microbial and chemical health risks associated with the discharge of effluent from the Masterton WWTP. Effluent currently enters the Ruamahanga River via a 365 day per year discharge to the Makoura Stream. After the upgrade, effluent will only be discharged to the river when river flows exceed median (in the summer) or half median (in the winter). Effluent will also enter the Ruamahanga River indirectly via recharge following land application of effluent adjacent to the river or oxidation pond leakage.

Risk requires both the presence of hazard (pathogenic micro-organisms or harmful substances) and exposure to the hazard.

The microbial hazards have been estimated in two ways: (1) assessment of what is expected (as inferred from a catchment assessment) and; (2) what is known to be present (as observed from monitoring data).

Three potential exposure routes have been identified (*i.e.* drinking-water consumption, ingestion during aquatic recreational water activity and consumption of mahinga kai).

Of these exposure routes, drinking water has been ruled out because no private or community drinking-water supplies are present in the impact area. Chemical hazards pose no threat to recreational water users due to the combination of very low concentrations in the river and the intermittent exposure posed by recreational activities in the river. Similarly, the threat of infectious disease following consumption of mahinga kai is remote because of the low concentration of pathogens in the river and because the main mahinga kai collected from the river is fish, which does not concentrate the pathogens.

However, two exposures have the potential to impact on public health: ingestion/inhalation of waterborne pathogens during aquatic recreational activity in the river and consumption of mahinga kai that may bioaccumulate certain chemicals present in low concentrations in the river.

It is not possible to conduct a robust risk assessment regarding bioaccumulated chemicals in fish without sufficient data on the chemical constitution of the wastewater and/or fish. However, examination of the types of discharge that enter the Masterton WWTP and the low concentrations of chemicals present in the small number of wastewater samples tested suggests that this is unlikely to constitute a significant health risk.

The highest risk posed by the Masterton WWTP is of infectious disease to recreational users of the river and estimation of this risk is the main focus of this report.

The outcome of the pathogen-based risk assessment should be viewed in the context of the existing state of the Ruamahanga River. The microbiological quality of the river is assessed by regular monitoring of *E. coli* at recreational sites throughout each bathing season. Monitoring at Te Ore Ore, the closest site upstream of Masterton, shows that the water quality is frequently poor. In the period between November 2001 and March 2005, the *E. coli* concentration has exceeded the alert level of 260/100mL on 19/83 (23%) occasions the alert level of 550/100mL on 9/83 (11%) occasions. The 95$^{th}$ percentile *E. coli* value of these data is 909/100mL, which makes

this a Microbiological Assessment Category D site under the Recreational Water Quality Guidelines. The risk of waterborne infection from swimming at a D category site is >5% (*i.e.* >50/1,000 swimmers), well in excess of the predicted risk of adenovirus infection emanating from the Masterton WWTP.

In all scenarios modelled, the pathogen associated with the greatest risk was adenovirus. Consequently, it is appropriate to assess the risk to recreational water users in terms of adenovirus infection. The present and future health risks to river users have been compared using the risk estimates based on all river flows for the present (direct river discharge and pond leakage) and future (direct river discharge, land disposal and pond leakage). The models predict that the overall risk of adenovirus infection at Wardells Bridge will fall from 7.3 per 1,000 the present to 1.0 per 1,000 under the proposed discharge regime for summer below-median flows when most recreational activity occurs in the river. At The Cliffs, the closest recognised swimming site downstream of the WWTP, the risk of infection falls to below 1/1,000. The risks are likely to be less than the values predicted by the models because of the precautionary approach that was taken with respect to increased dilution by the Waingawa River and removal of pathogens during pond leakage.

In conclusion, the microbiological water quality of the Ruamahanga River is sufficiently poor upstream and immediately downstream of Masterton that swimming in it should be discouraged whenever the river is above median flow. At present, the effluent adds significantly to the *E. coli* concentration in the river below the WWTP at lower flows, which is when most of the recreational activity occurs. The contribution of effluent will greatly diminish in this respect following the upgrade because direct discharge will not occur at low river flows. The estimated risk to swimmers emanating from pathogens in the WWTP effluent will reduce significantly following the upgrade to levels that are not excessive as gauged by the Recreational Water Quality Guidelines.

# 1 INTRODUCTION

This report was commissioned by BCHF as part of the assessment of environmental effects required for the proposed upgrade of the Masterton Wastewater Treatment Plant (WWTP). At present the wastewater passes through a screen followed by passage through an oxidation pond system comprising two primary ponds, a maturation pond and a polishing pond, after which it is discharged into Makoura Stream. Makoura Stream enters the Ruamahanga River about 800 m downstream of the point of effluent discharge. The Ruamahanga River is used for swimming and other aquatic recreational pursuits. The closest recognised swimming spot is at The Cliffs, some 7.8 km downstream of the confluence of Makoura Stream and the Ruamahanga River, at which point the two water bodies are fully mixed. However, swimming has been observed occasionally at Wardells Bridge, at which point full mixing has not occurred and is *ca.* 200 m downstream of the Makoura Stream, or 1.3 km downstream of the proposed outfall location, despite signage advising against swimming there.

The proposed WWTP upgrade includes:

- further partitioning of the secondary oxidation pond to create additional maturation cells to improve effluent quality
- discharging effluent to land adjacent to the river when the land is suitable for irrigation
- no direct discharge to the river in the summer when the river flow is less than median and in the winter when it is less than half median
- direct river discharge to be shifted from a pipe into Makoura Stream to a rock embankment diffuser in the Ruamahanga River, thereby achieving complete mixing by Wardells Bridge.

This report comprises three sections. The first section is a description of the state of the environment of the Ruamahanga River as it exists at the present time. This includes a description of the potential sources of contamination within the Ruamahanga River catchment and also draws together the available information about the water quality at surface water monitoring sites within the catchment.

The second section describes the aspects of the present health of the community relevant to the wastewater discharge. This includes a comparison of potentially waterborne diseases that have been notified nationally and in the Wairarapa district. Also an assessment of the potential exposures relevant to this situation (*i.e.* aquatic recreational contact, drinking-water and mahinga kai) is made.

The third section is the risk assessment based on the microbial and chemical hazards present in the wastewater and the waterborne exposures that may result as a consequence of the entry of wastewater into the receiving environment.

# 2 STATE OF THE RUAMAHANGA RIVER ENVIRONMENT

The following section is a compilation of microbiological water quality data in the Ruamahanga River that may be impacted by the Masterton wastewater treatment plant (WWTP) and other point sources to the river for which data are available. The purpose of this section is to describe the existing conditions of the river and its catchment as the basis of an impact assessment for the WWTP outfall.

## 2.1 SOURCES OF INFORMATION

Information pertaining to land use and point sources of pollution within the catchment was obtained from the Greater Wellington Regional Council.

Microbiological water quality data were obtained from:

- Masterton District Council (MDC)
- The Freshwater Microbiology Research Programme (FMRP) report conducted by the Ministries of Health and Environment.
- Greater Wellington Regional Council (GWRC).

## 2.2 CATCHMENT ASSESSMENT

Land use and point sources of pollution were assessed for the Ruamahanga River at its juncture with Makoura Stream. The effluent from the Masterton WWTP enters the Ruamahanga River at this juncture. At this point Ruamahanga River catchment drains 63,346 Ha.

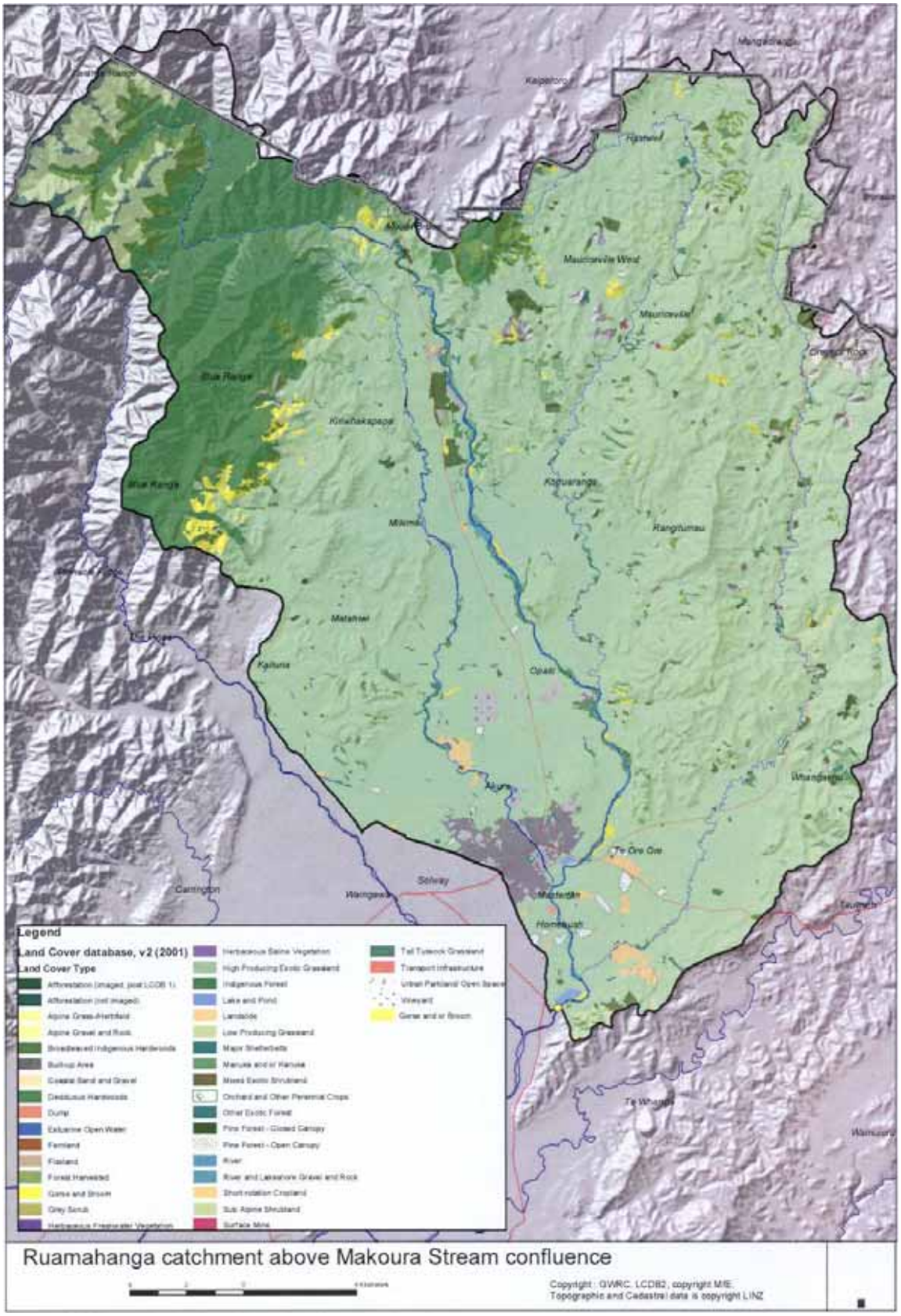
The land uses within this catchment are shown on Map 1. The various land use groups and estimates of the areas under them are given in the following table.

**Table 1 Land use in the Ruamahanga catchment**

| Land use | AREA (HA) | Percent of catchment |
|---|---|---|
| Bush/scrub/sparsely vegetated | 13,144 | 20.7% |
| Forestry | 1,668 | 2.6% |
| Pasture – high production | 46,259 | 73.0% |
| Grassland – low production | 573 | 0.9% |
| Cropping | 329 | 0.5% |
| Horticulture | 236 | 0.4% |
| Urban/dump/mine | 975 | 1.5% |
| River/lake | 163 | 0.3% |

Land-use information is based on the Land Cover database 2 (2001) and was kindly provided by John Gibson, GWRC.

**Map 1. Land use in Ruamahanga catchment above Makoura Stream**




Map kindly provided by J. Gibson, GWRC.

Contamination of rivers is classified into two types: diffuse and point sources.

### 2.2.1 Diffuse sources of microbial contamination

Diffuse sources of contamination often form the greater component of contaminants entering rivers in rural catchments. For faecal contamination, the source is farmed and wild animals and birds living in the catchment.

The numbers of livestock estimated by GWRC to be farmed in the catchment are:

- 35,000 beef cattle
- 12,000 dairy cattle
- 400,000 sheep.

### 2.2.2 Point sources of microbial contamination

Information on point pollution sources within the catchment is limited. Two sources of such information have been found.

A number of major authorised discharges to surface waters are shown in Figure 3.2 of the Greater Wellington Regional Council's Freshwater quality monitoring technical report (February 2006). Discharges of industrial stormwater, landfill leachate/stormwater, urban stormwater and two miscellaneous point sources are located on the Ruamahanga River at or about Masterton. Noted upstream of this are wastewater from Rathkaele College, landfill leachate/stormwater and two miscellaneous point sources. There are a number of point sources that enter the Ruamahanga River downstream of the Masterton WWTP outfall. These include overflow/backwash from two drinking-water treatment plants, three municipal wastewater plants (Carterton, Greytown and Martinborough), urban stormwater, industrial wastewater and two miscellaneous point sources.

The only detailed information available relating to the types of contaminants that may be present in the Masterton sewerage system was a list of businesses in the Masterton district that was provided by the Masterton District Council. A summary of the types of businesses is provided in Appendix 1. From this it is apparent that domestic sewage comprises by far the greatest load of pathogens and other micro-organisms in the sewerage system. Sewage from the hospital might be expected to contain a higher pathogen concentration than from household waste but probably not greatly so. The amount of animal wastes from businesses such as the two veterinary clinics and three butcheries will be minimal and constitute a minor source only of zoonotic pathogens.

## 2.3 EXISTING MICROBIAL WATER QUALITY OF THE RUAMAHANGA RIVER

Microbial water quality data have been obtained for a number of surface water sites within the Ruamahanga catchment. Most of these data are indicator bacteria that were tested as part of regular river quality monitoring programmes. The only information on pathogens in this catchment is from the FMRP survey that was carried out between 1998 and 2000 (McBride *et al.*, 2002) and a small baseline survey carried out by BCHF for this project.

### 2.3.1 GWRC river monitoring

The GWRC has carried out bacteriological monitoring at a number of sites in the catchment in recent years. Monitoring has been conducted during summer at six recreational sites in the Ruamahanga River and tributary sites on the Waiohine and Waingawa Rivers. Bacteriological water quality is also monitored as part of the State of the Environment monitoring programme at seven Ruamahanga River sites and three tributary sites on the Waiohine and Waingawa Rivers. Details of the sampling sites are shown in Appendix 2 and summary statistics for *E. coli* are presented in the following table.

**Table 2 GWRC *E. coli* monitoring – summary statistics (2001-2005)**

| Site | n | Min | Max | Median | 95%ile | MAC |
|---|---|---|---|---|---|---|
| *Recreational Monitoring (November – March)* | | | | | | |
| Ruamahanga @ Double Bridges | 86 | 9 | 6,200 | 124 | 647 | D |
| Ruamahanga @ Te Ore Ore | 83 | 24 | 11,400 | 140 | 1,364 | D |
| Ruamahanga @ The Cliffs | 83 | <1 | 10,400 | 45 | 909 | D |
| Ruamahanga @ Kokotau | 84 | <1 | 16,000 | 55 | 1,852 | D |
| Ruamahanga @ Morrisons Bush | 86 | 1 | 7,455 | 46 | 1,476 | D |
| Ruamahanga @ Waihenga | 85 | <3 | 20,000 | 53 | 1,833 | D |
| Waingawa @ Kaituna | 82 | <1 | 760 | 9 | 348 | C |
| Waingawa @ South Road | 82 | 2 | 3,400 | 22 | 356 | C |
| Waiohine @ SH2 | 82 | <1 | 2,700 | 4 | 104 | A |
| *State of the Environment Monitoring* | | | | | | |
| Ruamahanga @ McLays | 24 | <1 | 220 | 4 | 164 | |
| Ruamahanga @ Te Ore Ore | 68 | 2.5 | 4,500 | 60 | 1,969 | D |
| Ruamahanga @ Gladstone Bridge | 68 | <1 | 3,600 | 20 | 555 | D |
| Ruamahanga @ Pukio | 24 | 16 | 3,800 | 130 | 2,400 | D |
| Ruamahanga @ SH2 Mt Bruce | 43 | <1 | 80 | 5 | 63 | A |
| Ruamahanga @ Double Bridges | 43 | <1 | 390 | 20 | 166 | B |
| Ruamahanga @ Waihenga Bridge | 43 | <1 | 11,000 | 30 | 591 | D |
| Waingawa @ South Rd | 68 | <1 | 260 | 12 | 106 | A |
| Waingawa @ Gorge | 133 | <1 | 320 | 1 | 10 | A |
| Waiohine @ Bicknells | 68 | 1 | 820 | 33 | 450 | C |

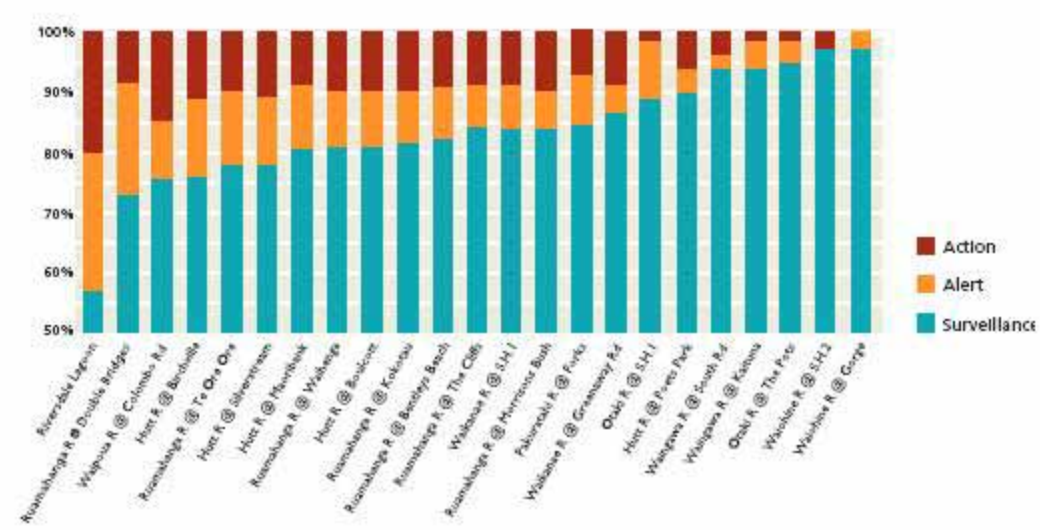
*E. coli* concentrations reported as cfu/100 mL.
MAC = Microbiological Assessment Category

The risk of *Campylobacter* infection associated with the Microbiological Assessment Categories stated in the Recreational Water Quality Guidelines (MfE/MoH, 2003) are: A (<0.1%), B (0.1 – 1%), C (1 – 5%), D(>5%).

Compliance with the Recreational Water Quality Guidelines is reported by Milne (2005). Figure 1 was extracted from the 2005 State of the Environment Report shows compliance of the recreational sites in the Greater Wellington area. This shows that all of the Ruamahanga River sites exceeded the *E. coli* alert level on more than 15% of sampling occasions and the action level more than 5% of sampling occasions.

It is interesting to note that the site that recorded the least compliance (as depicted by the blue bars on the following figure) was Double Bridges, which is well upstream of Masterton and all known point sources of human faecal contamination. Given that *E. coli* is a bacterium of faecal origin, this result points to animal wastes as the main source of faecal contamination in the upper Ruamahanga River.

**Figure 1 Compliance with the surveillance, alert and action levels of the New Zealand Recreational Water Quality Guidelines.**




Figures expressed as a percentage of total samples over the last four summer seasons.

### 2.3.2 FMRP survey of pathogens and indicator organisms

Water quality monitoring data were also made available for sampling carried out at the recreational sites on the Ruamahanga River as part of the MfE Freshwater Microbiology Programme[1]. Sampling was initially carried out as part of a scoping study in the period between May and August 1998 at Double Bridges, which is situated at the headwaters of the Ruamahanga River. Water from this site and another at Morrison's Bush was sampled at fortnightly intervals between December 1998 and February 2000 for the main survey. Samples were tested for a range of pathogens (*Salmonella*, *Campylobacter*, *Giardia*, *Cryptosporidium* and human-specific enteroviruses and adenoviruses) as well as indicators (*E. coli*, *Clostridium perfringens* spores, somatic coliphage, F-RNA phage and total coliforms). These comprise the only pathogen data available in the environment of the Ruamahanga River other than those obtained during the survey conducted by BCHF during October 2005. Summary statistics from the preliminary and main FMRP surveys are presented in Tables 3 and 4. The raw data obtained for this site are presented in Appendix 3.

[1] The FMRP final report is available at: http://www.mfe.govt.nz/publications/water/freshwater-microbiology-nov02/

**Table 3 Preliminary FMRP survey data – Double Bridges (1998)**

| Micro-organism | Units | n | Max | Min | Median | Mean | %(+)ve |
|---|---|---|---|---|---|---|---|
| *E. coli* | MPN/100mL | 20 | 238 | 8.6 | 48 | 65 | N/A |
| *C. perfringens* spores | cfu/100mL | 20 | 15 | <1 | 1 | 2.8 | N/A |
| Somatic coliphage | pfu/100mL | 20 | 21 | <1 | 2 | 4 | N/A |
| FRNA phage | pfu/100mL | 20 | 14 | <1 | <1 | 1.8 | N/A |
| *Salmonella* | MPN/L | 20 | 170 | <1 | <1 | 11.9 | 30% |
| *Campylobacter* | MPN/100mL | 20 | >110 | <1.2 | 4.6 | 31.7 | 75% |
| *Giardia* | cysts/100L | 20 | 12.3 | <1 | 0.6 | 2.6 | 50% |
| *Cryptosporidium* | oocysts/100L | 20 | 14.2 | <1 | 0 | 1.0 | 15% |
| Enterovirus * | | 20 | | | | | 15% |
| Adenovirus * | | 20 | | | | | 0% |

* tested by presence/absence method

**Table 4 FMRP main survey data – Double Bridges (1998-2000)**

| Microorganism | Units | n | Max | Min | Median | Mean | %(+)ve |
|---|---|---|---|---|---|---|---|
| *E. coli* | MPN/100mL | 29 | 2,419 | 17.1 | 119 | 283 | N/A |
| *C. perfringens* spores | cfu/100mL | 29 | 4 | <1 | 1 | 0.8 | N/A |
| Somatic coliphage | pfu/100mL | 29 | 308 | 1 | 8 | 34 | N/A |
| FRNA phage | pfu/100mL | 29 | 23 | <1 | <1 | 2.3 | N/A |
| *Salmonella* | MPN/L | 29 | <1.2 | <1.2 | <1.2 | <1.2 | 0% |
| *Campylobacter* | MPN/100mL | 29 | >110 | <0.3 | 0.3 | 17.2 | 55% |
| *Giardia* | cysts/100L | 29 | 2 | 0 | 0 | 0.1 | 3% |
| *Cryptosporidium* | oocysts/100L | 29 | 0 | 0 | 0 | 0 | 0% |
| Enterovirus * | /L | 29 | | | | | 24% |
| Adenovirus * | /L | 29 | | | | | 34% |

* tested by presence/absence method

The sampling site at Double Bridges was also used for both the preliminary and main FMRP surveys between December 1998 and February 2000 in which a wide range of pathogens were monitored in parallel with indicator organisms, including *E. coli*. During these surveys, *E. coli* concentrations varied between 8.6 and 2,419 MPN/100 mL with a median of 74 MPN/100 mL, which is higher than that shown by the Greater Wellington Regional Council's monitoring programme. Pathogens were also detected quite frequently at this site. *Campylobacter* were detected in 63% of samples with the maximum measurable concentration of 110 MPN/100mL being exceeded on four occasions. Human adenoviruses and enteroviruses were each detected in 20% of samples. Virus concentrations are not available because a presence/absence method was used. Salmonellae were detected in 12% of samples but the mean concentration of 5.2 was largely due to a single high count of 170 MPN/L. The presence of the protozoan parasites *Cryptosporidium* and *Giardia* were detected in 22% and 6% of samples respectively.

The results of the preliminary and main surveys at this site are not consistent. For example, the median *E. coli* concentration was lower in the preliminary survey than the main survey (48 *cf*. 119 MPN/100 mL. This effect was even more pronounced for some of the pathogens. *Salmonella* occurred in 30% of samples in the preliminary survey but remained undetected in the main survey. Similarly, *Giardia* and *Cryptosporidium* were detected far more often in the preliminary survey than the main survey. It is not possible to determine the cause of this discrepancy, which may be a genuine phenomenon or sporadic result, perhaps as a consequence of the

relatively short sampling period for the preliminary survey. Nevertheless, the pathogen results at Double Bridges show that bacterial, viral and protozoal pathogens occur in the Ruamahanga River upstream of the Masterton oxidation ponds.

### 2.3.3 Compliance monitoring

Microbiological monitoring was also obtained from the MDC for the nine surface water sites, ten bores and the oxidation pond effluent. Monitoring was carried out at surface water sites initially for faecal coliforms only until December 1999, when *E. coli* was also monitored. The microbial quality of the oxidation pond effluent was monitored using faecal coliforms and enterococci until October 2000, when *E. coli* was introduced as the main microbiological monitoring tool. Some samples were also tested for enterococci. Groundwater samples are primarily monitored for *E. coli*, with only sporadic faecal coliform analyses. Summary statistics from the MDC *E. coli* monitoring data are presented in the following table.

**Table 5 MDC *E. coli* monitoring – summary statistics**

| Site | Site Code | n | Min. | Max. | Median | 95%ile * |
|---|---|---|---|---|---|---|
| | | | *E. coli* / 100 mL | | | |
| Oxidation pond effluent | | 115 | 10 | 35,000 | 675 | 3,300 |
| Groundwater (combined test bores) | | 127 | <1 | 580 | <1 | 7 |
| Ruamahanga R. u/s of ponds | Rua1 | 117 | 1 | 21,400 | 45 | 501 |
| Ruamahanga R. at Wardells Bridge | Rua2 | 100 | 3 | 15,760 | 120 | 1,670 |
| Ruamahanga R. d/s of ponds | Rua3 | 90 | <5 | 25,920 | 50 | 700 |
| Ruamahanga R. at Waingawa R. | Rua4 | 62 | <5 | 32,400 | 60 | 1,688 |
| Ruamahunga R adjacent junction of ponds 1 & 2 | Rua5 | 24 | 11 | 580 | 38 | 348 |
| Ruamahunga R adjacent junction of ponds 2 & 3 | Rua6 | 24 | 11 | 560 | 35 | 553 |
| Ruamahunga R adjacent end of pond 3/4 | Rua7 | 24 | 10 | 360 | 33 | 296 |
| Makoura Stream u/s of discharge | Mak1 | 99 | <5 | 18,720 | 340 | 2,302 |
| Makoura Stream d/s of discharge | Mak2 | 99 | 60 | 26,000 | 590 | 3,388 |

* 95$^{th}$ percentiles calculated using the Hazen method.

The *E. coli* monitoring data display a pattern that is fairly typical of a point source discharge of treated wastewater into a river. Table 5 shows the *E. coli* concentration is typically higher in the treated effluent than in the receiving environment, as is expected for most river conditions. However, it is noted that *E. coli* concentrations in the river upstream sometimes exceed that of the effluent, particularly at high river flows. The high *E. coli* concentrations observed in Makoura Stream, which presently receive the effluent discharge, are diluted by the main flow of the Ruamahanga River. The *E. coli* concentration in the Ruamahanga River peaks at Wardells Bridge and then declines (see Table 2). By the time the Ruamahanga and Waingawa rivers converge the median *E. coli* concentration has halved.

The concentrations of *E. coli* in the river at Rua1 (upstream of the WWTP) and Rua2 (downstream of the WWTP) are plotted over time in Figure 2.

**Map 2. Key impact points in the Ruamahanga catchment**

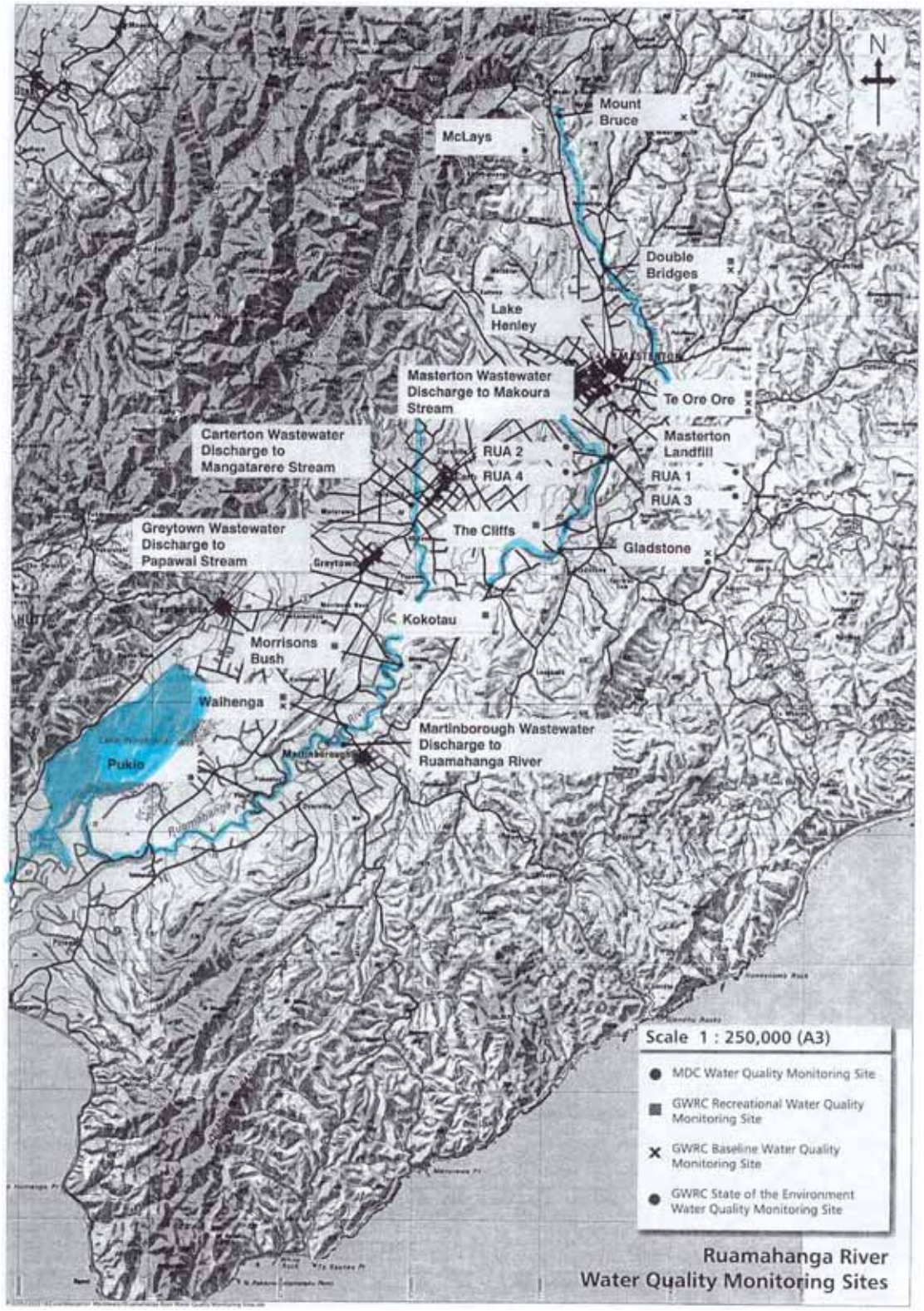
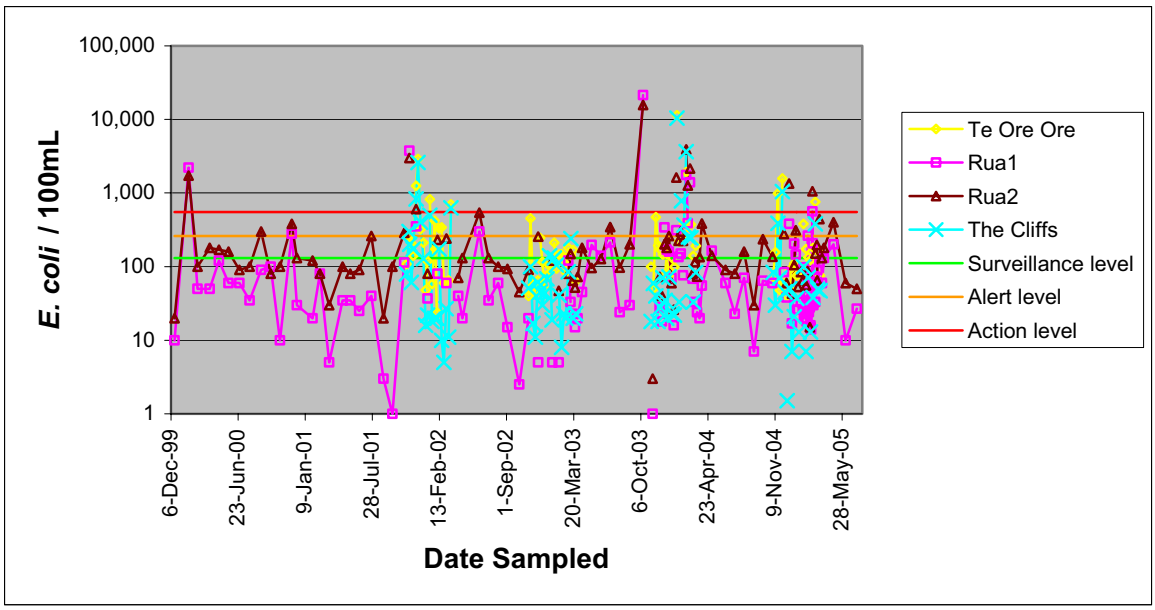



**Figure 2 Concentrations of *E. coli* in the Ruamahanga River above and below the Masterton WWTP outfall**




From this plot it can be seen that *E. coli* concentrations exceed the surveillance, alert and action levels of the Recreational Water Quality Guidelines more often downstream of the Masterton oxidation ponds than upstream of it, as expected. The Action level of 550/100 mL has been exceeded on 32 occasions over this period. On 15 of these occasions the action level was exceeded upstream of the oxidation ponds, indicating that much of the *E. coli* contamination is occurring further upstream in the catchment and is likely to be associated with heavy rain events in the Ruamahanga catchment.

### 2.3.4 Pathogen sampling

A limited microbiological monitoring programme was also commissioned by BCHF as part of the assessment of environmental effects. Indicator organisms (*E. coli*, somatic coliphage) and pathogens (*Campylobacter*, *Salmonella*, *Giardia*, *Cryptosporidium*, human enteroviruses and human adenoviruses) were collected at selected sites in the Ruamahanga River and Makoura Stream, oxidation pond effluent and several bores adjacent to the WWTP during October 2005. In addition, two pond sediment samples were collected and tested for the same organisms. The results of these analyses are presented in Appendix 4 and ranges shown in the following table.

**Table 6 Pathogen sampling – ranges of indicator and pathogen concentrations**

| Sampling sites | n | *E. coli* /100mL | Somatic coliphage pfu/100mL | *Campylobacter* MPN/100mL | *Salmonella* MPN/100mL | Human enterovirus pfu/L | Human adenovirus $TCID_{50}$/L | *Giardia* cysts/10L | *Cryptosporidium* oocysts/10L |
|---|---|---|---|---|---|---|---|---|---|
| **Surface water sites** | | | | | | | | | |
| Rua 1 | 3 | 130 - 1,300 | 60 - 650 | <0.3 - 2.3 | <0.3 | <1 | <1 | <1 | <1 - 1 |
| Rua 2 | 3 | 290 – 2,600 | 120 – 1,110 | 1.5 – 24 | <0.3 | <1 | <1 | <1 | <1 - 3 |
| Rua 7 | 1 | 800 | 91 | 110 | <0.3 | <1 | <1 | <1 | <1 |
| Mak 1 | 1 | 52 | 3,880 | <0.3 | <0.3 | <1 | <1 | <1 | 1 |
| Mak 2 | 1 | 720 | 1,130 | 24 | <0.3 | <1 | <1 | <1 | <1 |
| **Groundwater sites** | | | | | | | | | |
| HB 1 | 1 | <10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| HB 3 | 1 | 10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| HB 4 | 1 | <10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| HB 6 | 1 | <10 | 20 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| HB 11 | 1 | <10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| **Oxidation pond** | | | | | | | | | |
| | | /100mL | pfu/100mL | MPN/100mL | MPN/100mL | pfu/L | $TCID_{50}$/L | cysts/L | oocysts/L |
| Effluent | 3 | 410 - 840 | 80 – 630 | <3 | <0.3 – 0.4 | <5 | <5 | <1 | <1 |
| | | /100mL | pfu/100mL | MPN/100mL | MPN/100mL | pfu/g | $TCID_{50}$/5g | cysts/100g | oocysts/100g |
| Pond 1 Sediment | 1 | 82,000 | 11,100 | 2,300 | <18 | 0.5 | <1 | <1 | <1 |
| Pond 2 Sediment | 1 | 7,800 | 2,500 | <18 | <18 | 0.5 | <1 | <1 | <1 |

The survey, the results of which are shown in the preceding table, was carried out to obtain some pathogen data upon which to base a risk assessment. In addition, indicator organisms were tested so that a comparison could be made with existing data from other environmental monitoring programmes. The *E. coli* measurements in the effluent and at all the river sites except Rua 7 were similar to those found at similar sites in other monitoring programmes. The single sample taken at Rua 7 had an *E. coli* concentration of 800/100 mL, which exceeded the maximum observed in the 24 samples monitored by MDC (see Table 5). However, this difference was not great. Upon this basis, the pathogen analyses are assumed to be representative of the usual situation.

With the exception of *Salmonella*, none of pathogens tested exceeded the limit of detection in any of the three samples of treated effluent. *Salmonella* was detected in one effluent sample at a concentration of 0.4 MPN/100 mL. While one may interpret such results as being lower than expected, it is important to realise that the distribution of pathogens in environmental samples is very inconsistent. Consequently, such an interpretation cannot be made from such a small survey. However, these results suggest that pathogen concentrations are unlikely to be consistently higher in the Masterton WWTP effluent than in other oxidation ponds in New Zealand WWTPs, which have been studied in more detail.

The microbiological analyses of groundwater taken from five sites close to the oxidation pond were pathogen free and *E. coli* was detected in only one sample at the limit of detection (10/100 mL). This represents a reduction of more than 100-fold compared with the overlying oxidation pond effluent.

The two pond sediment samples were also devoid of the pathogens tested but contained indicator organisms at concentrations up to two orders of magnitude higher than in the overlying effluent. The indicator result is consistent with particulates settling in the oxidation pond, which the ponds are designed to facilitate. The absence of pathogens in the pond sediment further indicates that the effluent is unlikely to contain more than the expected number of pathogens.

## 2.4 SUMMARY

The Ruamahanga catchment above Makoura Stream is primarily a rural catchment with intensive livestock production being the main land use. In addition, several point source discharges have been identified in the catchment including industrial stormwater, landfill leachate/stormwater, urban stormwater (all associated with wet weather) and municipal wastewater.

The microbiological water quality of all monitored recreational sites exceeds the Recreational Water Quality Guidelines single point limit for *E. coli* quite frequently, particularly during wet weather. This includes the Ruamahanga River at sites both upstream and downstream of Masterton. All of the Ruamahanga River recreation sites monitored by GWRC score a D-grade Microbiological Assessment Category according to the 95$^{th}$ percentile *E. coli* concentrations. However, the discharge of treated effluent from the Masterton oxidation ponds does contribute to the degraded water quality of the Ruamahanga River in the vicinity of the discharge. At present, the effect of effluent discharge is greatest when the river is at low flows. The impact is reduced by the time it reaches the confluence of the Ruamahanga and Waingawa Rivers. By the time it reaches the closest designated swimming site at The Cliffs, the effluent is diluted by water from the Waingawa River, thus further reducing the impact.

From the small amount of information available about pathogens in the Ruamahanga River, and the large numbers of livestock farmed in the catchment, zoonotic pathogens are likely to be present upstream of Masterton. However, given that there is relatively little human effluent discharged in the catchment upstream of Masterton it is likely that the Masterton WWTP effluent would account for nearly all the human virus load immediately downstream of Makoura Stream.

The *E. coli* monitoring data from the recreational sites allows an assessment to be made of the influence of the WWTP effluent on the microbiological quality of the Ruamahanga River at the present time. It also enables the present and predicted future *E. coli* concentrations to be compared in Section 3. However, there are inadequate data on the concentrations of pathogens upstream of Masterton for a quantitative assessment to be made of their contribution to the risk of waterborne disease.

# 3 HEALTH OF THE COMMUNITY

The following section is an assessment of aspects of community health that may be affected by microorganisms in the Ruamahanga River. This includes an appraisal of the notified disease statistics for pathogens that are potentially waterborne, an assessment of a perceived cluster of non-infectious diseases in the locale and a description of the exposures with which the Ruamahanga River could be associated.

## 3.1 POTENTIALLY WATERBORNE NOTIFIED DISEASE

Information about the occurrence of a number of these potentially waterborne pathogens is available through the EpiSurv notifiable diseases database. The average annual number of notified cases of diseases that are potentially waterborne are given in the following table.

**Table 7 Notified potentially waterborne diseases cases (1997 – 2004)**

| Notified diseases | Wairarapa | | New Zealand | |
|---|---|---|---|---|
| | Notified cases [a] | Average annual cases/100,000 | Notified cases [a] | Average annual cases/100,000 |
| Campylobacteriosis | 657 | 214.7 | 86,719 | 292.3 |
| Cholera | 0 | - | 9 | 0.03 |
| Cryptosporidiosis | 72 | 23.5 | 6,587 | 22.2 |
| Gastroenteritis [b] | 59 | 19.3 | 6,544 | 22.0 |
| Giardiasis | 69 | 22.5 | 14,025 | 47.4 |
| Hepatitis A | 3 | 1.0 | 1,004 | 3.4 |
| Leptospirosis | 7 | 2.3 | 741 | 2.5 |
| Paratyphoid | 0 | - | 178 | 0.6 |
| Salmonellosis | 221 | 72.2 | 13,895 | 46.8 |
| Shigellosis | 8 | 2.6 | 997 | 3.4 |
| Pathogenic *E. coli* [c] | 1 | 0.3 | 534 | 1.8 |
| Typhoid | 1 | 0.3 | 178 | 0.6 |
| Yersiniosis | 22 | 7.2 | 3,697 | 12.5 |

a Average number of cases notified (Data from EpiSurv as at 21 October 2005)

b Only cases from a common source or foodborne intoxication

c Given as "VTEC/STEC infection"

While the average incidence rate of notified cases of cryptosporidiosis, leptospirosis and gastroenteritis from unspecified causes in the Wairarapa does not greatly differ from that nationally, it is lower for campylobacteriosis, giardiasis, hepatitis A, shigellosis, yersiniosis and VTEC/STEC disease. The annual incidence rate is higher in Wairarapa than nationally only for salmonellosis.

Details of the 221 salmonellosis cases recorded in EpiSurv from the Wairarapa district between 1997 and 2004 were examined to investigate the importance of recreational contact with the Ruamahanga River. This was assessed by examination of the source of infection fields within EpiSurv, which comprise the following three components:

- Source of Infection (animal contact, person-to-person, food/water, overseas travel and other sources).
- Likelihood that the nominated source of infection caused the infection (those records marked as "definite" or "suspected" were regarded as being possible causes for the source(s) of infection noted for that record.
- The risk factors that may indicate river recreation (*i.e.* Recreational water contact and River/sea contact) were also noted

A definite or suspected source of infection was noted in 100 (45%) of the salmonellosis records. Of those, food/water was most often (for 52 cases) followed by person-to-person contact (29), animal contact (23), other (13) and overseas travel (8)[2]. However, it is not possible to determine how many of the cases attributed to food/water were from recreational contact rather than contaminated food or drinking-water. This was assessed using the two risk factor fields that were relevant to recreational water contact. Nine cases cited recreational water contact as a risk factor but only five of these noted river or sea contact (the others being overseas and swimming pools). None of the salmonellosis cases mentioned the Ruamahanga River. While not definitive, this is a strong indication that recreational contact with the Ruamahanga River was not a significant cause of salmonellosis reported in the Wairarapa district during 1997-2004.

The trends in the number of notified potentially waterborne disease cases per 100,000 people over recent years are shown in Figures 3 and 4. For most of the notified diseases, the trend in annual incidence rates for the Wairarapa cases generally follows that of the nationally reported cases. However, as one might expect with the much smaller population base in the Wairarapa (*ca*. 1% of the New Zealand population), the incidence rates are less consistent locally than nationally. It is not possible to determine whether the falls in notified campylobacteriosis in 2002 and gastroenteritis of unknown cause in 1998-99, and the increase in salmonellosis in 2000 in the Wairarapa occurred as a result of some change in exposure, varying notification practices or statistical aberrations caused by the small number of notified cases in the Wairarapa.

It is not possible to determine how many of the diseases notified occurred as a result of waterborne exposure or from other exposures (*i.e*. contaminated food, animal contact, person-to-person contact *etc*). Nor would it be possible to determine if any of the notified cases were linked to exposure to the Ruamahanga River.

[2] The total adds up to more than 100 because more than one definite/suspected source if infection are noted for some cases.

**Figure 3 Annual trends in notified enteric diseases in Wairarapa and New Zealand – part 1**

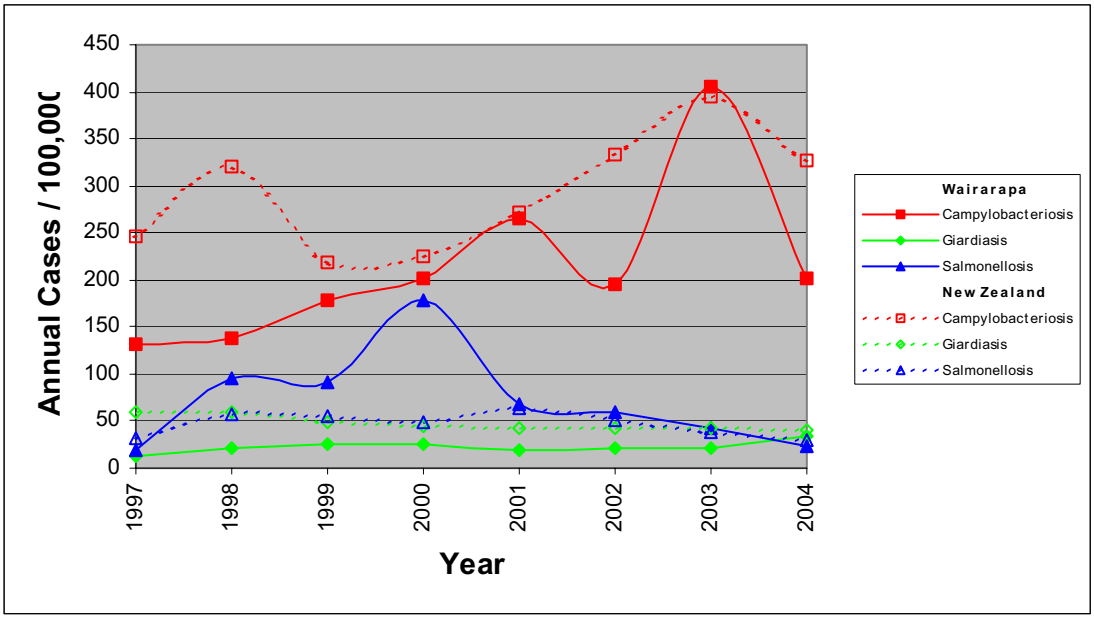
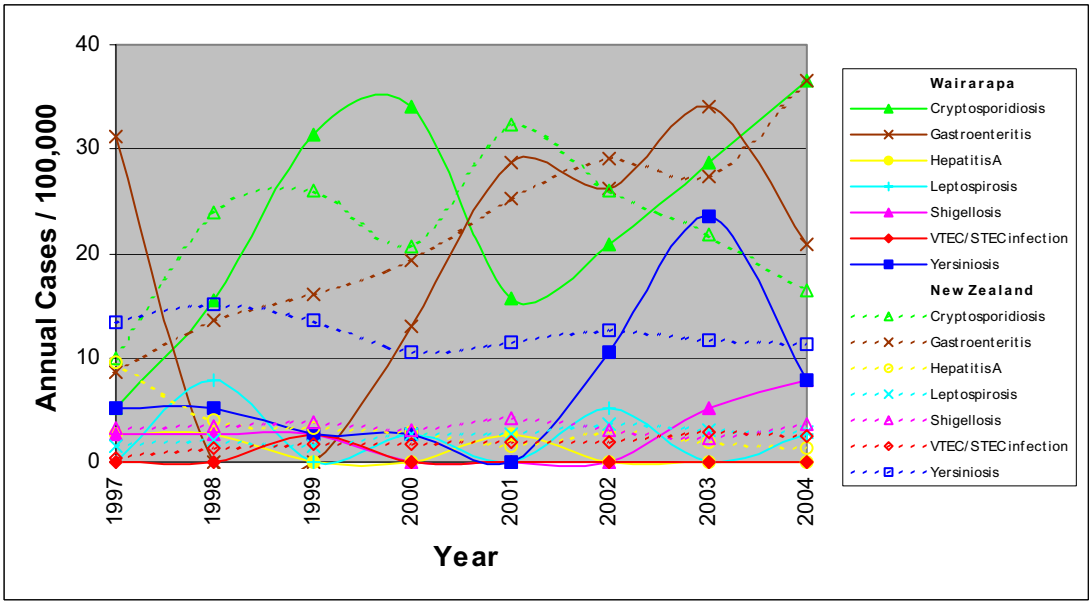



**Figure 4 Annual trends in notified enteric diseases in Wairarapa and New Zealand – part 2**




It should be noted that only a proportion of actual cases are notified. This is caused by: people with (usually milder) symptoms not visiting a GP; GPs not taking clinical specimens for laboratory diagnosis; the causal pathogen not being detected by the laboratory and; failure to notify. Consequently, the number of actual infections will always be higher than the number of notified cases.

While the pathogens listed in Table 7 may be transmitted to people via water, they can also be transmitted via contaminated food, person-to-person contact with another case and, with the exceptions of hepatitis A virus and *Shigella*, which are strictly human pathogens, contact with infected animals/faeces. Of these exposure routes, it

is generally regarded that contaminated food and animal contact are the two most common vehicles of infection for most of these pathogens in developed countries.

## 3.2 NON-INFECTIOUS DISEASE

Community consultation revealed some perceptions of a high rate of cancer and neurological conditions in residents living closest to the oxidation ponds. This concern was investigated by Regional Public Health (Cunningham & McLean, 2006), who concluded that the cases of cancer, multiple sclerosis and Down's syndrome are very unlikely to have been related to exposures from the WWTP or river.

## 3.3 WATERBORNE EXPOSURES

The microbiological quality of water in the Ruamahanga River may impact on human health in three ways. It may cause additional risk of waterborne disease through recreational contact in the river; it may cause additional risk of waterborne disease through contaminated drinking-water within the Ruamahanga catchment and; it may lead to additional risk of disease through consumption of mahinga kai collected from the river. This section assesses the usage of the Ruamahanga River in relation to these exposure routes.

### 3.3.1 Recreational usage of the Ruamahanga River

Six sites on the Ruamahanga River are identified in the Wellington Regional Freshwater Plan (WRC, 1999) as having regionally important amenity and recreational values with the water quality to be managed for contact recreation purposes. These sites are:

- Upper Ruamahanga River to State Highway 2 for "tubing".
- State Highway 2 to the confluence with the Waingawa River for angling.
- Confluence with the Waingawa River to Tuhitarata for canoeing, kayaking and angling.
- Tuhitarata to Lake Onoke for canoeing, kayaking, power boating and angling.
- The Kopuaranga River for angling.
- The Waipoua River for angling.

In summary, the part of the Ruamahanga River that is downstream of the Masterton WWTP has been identified as being important sites of secondary contact recreation. However, Section A8.3 of the Regional Freshwater Plan requires that after reasonable mixing, contaminants must not be likely to cause the water to be rendered unsuitable for bathing (WRC, 1999). This effectively replaces secondary contact recreation with primary contact recreation as the benchmark exposure for health risk assessment.

A number of studies have attempted to quantify the various recreational activities in the Ruamahanga River. These have been reported by Mills (2002) the results of which are reproduced below.

**Table 8 Angler use of the Ruamahanga River**

| Period | Angler Days | |
|---|---|---|
| | 1994/95*[1] | 2001/02*[2] |
| Oct – Nov | 945 | |
| Dec – Jan | 1,951 | |
| Feb – Mar | 2,316 | |
| Apr – May | 1,035 | |
| Jun – Jul | 536 | |
| Aug - Sep | 602 | |
| **Total** | **7,386** | **6,910** |

*[1] Estimates derived from the 1994/95 National Angling Survey (Unwin & Brown, 1998).
*2 Estimated from the 2001/02 National Angling Survey (Unwin & Brown, 2003).

**Table 9 Canoeing and jet boating activity in the Ruamahanga River**

| Activity | Nov 2001 – Apr 2002 |
|---|---|
| Jet boating | 2,040 |
| Kayaking | 3,260 |
| Trout fishing | 20 |

Estimates based on data supplied by local operators (one did not respond). (Mills, 2002).

**Swimming in the Ruamahanga River**

The only swimming data available are those collected for a preliminary assessment of usage of various freshwater swimming sites throughout the country that were being assessed to determine their suitability for inclusion in a study about water quality at freshwater recreation sites (McBride *et al.*, 1996). Data were collected for two sites on the Ruamahanga River (The Cliffs and Morrisons Bush) on five days between 14 January and 11 February 1996.

**Table 10 Swimming in the Ruamahanga River**

| Ruamahanga site | | Number of swimmers | |
|---|---|---|---|
| | Days surveyed | range | mean |
| The Cliffs | 5 | 40 - 250 | 133 |
| Morrisons Bush | 5 | 15 - 250 | 110 |

Overall, the Ruamahanga River is used regularly for both primary and secondary contact recreational activities. The closest designated site of recreational activity involving primary contact is The Cliffs. This site is about 7.8 km downstream of Makoura Stream, the tributary into which the oxidation pond effluent presently discharges. The estimated time it would take for the effluent to reach this site is *ca.* 280 minutes at median flows. By this time the effluent would be fully mixed within the Ruamahanga River. Based on the average daily flows of the Ruamahanga River and Masterton WWTP effluent discharges between January 1997 and September 2005 the dilution factor would range from 0.0771 (1:13) to 0.000448 (1:2232)[3] just above

[3] However, in the proposed new consent conditions the dilution factor will not exceed 0.0333 (1:30).

the convergence of the Ruamahanga and Waingawa Rivers. The effluent dilution will be even greater at The Cliffs, which is situated a little below the convergence.

### 3.3.2 The Ruamahanga River as a drinking-water source

The Ruamahanga River is not listed in the Wellington Regional Freshwater Plan (WRC, 1999) as a water body in which water quality needs to be managed for water supply purposes. There are no registered community drinking-water supplies that are sourced directly from the Ruamahanga River. However, there are a number of supplies that draw water from groundwater that may be close enough to the river for there to be a possible impact on the microbiological quality. These are listed in the following table.

**Table 11 Drinking-water supplies in the Ruamahanga catchment**

| Water supply | Source | Treatment |
|---|---|---|
| Martinborough | Herrick's bore | Untreated |
| Opaki | Opaki well | UV |
| Opaki School | Opaki well, Opaki School | UV |
| Pirinoa | Pirinoa bore | Ozone |
| Rathkeale College | Bell Tower well | Untreated |
| | Cranleigh House well | Untreated |
| | School House | Untreated |

Drinking-water quality monitoring data were reviewed from the seven plants and their associated distribution zones proximal to the Ruamahanga River for microbiological compliance with the DWSNZ:2000 for 2001-2004. These data were obtained from the Water Information New Zealand (WINZ) database and the 2000-2004 Annual Reviews of Drinking-Water Quality (MoH 2002, 2003, 2004 & 2005). Details of compliance and bacteriological analyses of water from the treatment plants and distribution zones are given in Tables 12 and 13.

**Table 12 Treatment plant compliance and *E. coli* monitoring / surveillance**

| Treatment Plant | TP code | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Ruamahanga | TP00635 | 0/56 | 0/57 C | 1/54 | 0/58 C |
| Opaki | TP00626 | 0/12 | 0/12 | 1/11 | 4/64 |
| Opaki School | TP02246 | NT | exempt C | exempt C | exempt C |
| Pirinoa | TP02207 | NT | NT | NT | NT |
| School House * | TP01854 | NT | NT | NT | NT |
| Bell Tower * | TP02314 | NT | NT | NT | NT |
| Cranleigh House * | TP02315 | NT | NT | NT | NT |

* Rathkeale College supplies NT Not tested C Compliance (bacteriological) achieved that year

None of the treatment plants have adequate treatment to comply with the protozoan standards of the DWSNZ:2000.

**Table 13 Distribution zone compliance and *E. coli* monitoring / surveillance**

| Treatment Plant | Zone code | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| Martinborough | MAR003MA | 0/56 | 1/56 | 0/52 C | 0/58 C |

| | | | | | | |
|---|---|---|---|---|---|---|
| Opaki | OPA001OP | 1/10 | 0/1 | 1/3 | 0/3 | |
| Opaki School | OPA005SC | 0/3 | 0/2 | 0/3 | 0/14 | C |
| Pirinoa | PIR004PI | 1/10 | 2/12 | 0/11 | 1/13 | |
| Rathkeale College | RAT005SC | 0/12 | 1/10 | 0/12 | 0/14 | C |

C Compliance (bacteriological) achieved that year.

Rathkeale College and the two Opaki supplies are upstream of the oxidation ponds so cannot be affected by effluent from the Masterton WWTP. Pirinoa is too far downstream to be affected by the Masterton WWTP effluent. Martinborough is also quite a long way downstream and so the possibility of contamination of its groundwater source is negligible. In addition, it also has a water treatment plant that is adequate to comply with the bacteriological requirements of the DWSNZ:2000.

There are a number of private bores in general proximity to the Masterton oxidation ponds (see Appendix 5). These have been assessed by PDP, who concluded that; "The predicted groundwater flow paths post-irrigation indicate that the irrigation will not affect the water quality in neighbouring wells several hundred metres to the south-west."

### 3.3.3 The Ruamahanga River as a source of mahinga kai

Section 4.2 of the Wellington Regional Freshwater Plan (WRC, 1999) includes a policy to manage sites of special value to the tangata whenua, which includes mahinga kai sites.

Increased concentrations of chemical contaminants and waterborne pathogens as a result of the Masterton WWTP discharge to the Ruamahanga River may adversely affect human health via consumption of mahinga kai (aquatic food) collected from the affected part of the river.

There are three main types of mahinga kai that need to be considered separately: fish, shellfish and watercress.

**Fish**

There are a number of fish species taken in the Ruamahanga River, including eels, trout and lamprey. However, the human pathogens of concern do not infect fish. Their presence in or on fish would be limited to contamination of the water in which they live. Consequently, any waterborne pathogens would at worst occur at the same concentration as in the river itself and therefore result in very low risk to people who eat the fish. Cooking would reduce this risk to negligible levels.

If there is a problem of chemical contamination in mahinga kai caused by chemicals discharged from the WWTP then it will first manifest in fish. Acute toxicity is most unlikely as the likelihood of the effluent containing high concentrations of chemical hazard is minimal. If a health risk exists to consumers of mahinga kai it will result from bioaccumulation over a long period of time. For this reason is usual to investigate organisms at the top of the food chain when examining for accumulated toxins. The obvious examples in the Ruamahanga River are trout and eels. There is, however, no indication that trade wastes discharging into Masterton sewers are discharging a significant load of toxins that may give rise to concern with respect to bioaccumulation.

### Shellfish

Filter-feeding shellfish would present a greater health risk because of their feeding habits. They feed by concentrating microorganisms present in water, which can result in large enough concentrations of waterborne pathogens within their gut to cause infection in people who eat shellfish. While cooking would alleviate this risk, it is not unusual for shellfish to be consumed raw. However, shellfish are not known to be present, or to be harvested, in the Ruamahanga River.

### Watercress

Watercress is a plant that commonly grows in slow moving streams throughout New Zealand. Pathogens such as *Campylobacter* have been detected on watercress surveyed at other locations (Edmonds & Hawke, 2004). The risk is alleviated if the plant is cooked but consumption of raw watercress is not uncommon. Watercress does not grow in the Ruamahanga River, which flows too swiftly for it to establish there, but it can be found in the marshy borders of the river and in some of the low-flowing tributaries. Consequently, the expected increase in pathogens in the river emanating from the Masterton WWTP is unlikely to contribute to the health risk from watercress consumption.

### Conclusion

The discharge from the Masterton WWTP is unlikely to cause a measurable increase in health risk via consumption of the mahinga kai present in the Ruamahanga River. The risk of foodborne infectious disease contracted as a result of consuming the only mahinga kai relevant to this situation (*i.e.* fish caught in the lower Ruamahanga River) is likely to be extremely small. The same is probably true for chemical contaminants.

## 3.4 SUMMARY

The incidence of notified infectious diseases in the Wairarapa district is similar to or lower than the national average for all diseases except salmonellosis. While the notified salmonellosis rate in the Wairarapa was 50% higher than the national average for the period 1997-2004, there is no evidence of this being waterborne.

The three potential exposure routes (*i.e*. consumption of drinking-water and mahinga kai, and contact recreational were assessed. There are no community drinking-water supplies sourced from the Ruamahanga River and while Martinborough and Pirinoa draw on groundwater that may be influenced by the Ruamahanga River, these are highly unlikely to be much affected by the Masterton WWTP effluent. None of the types of mahinga kai collected from the Ruamahanga River are likely to be affected by the Masterton WWTP effluent or result in a measurable increase in notified diseases. The greatest potential risk is via recreational water contact. The Ruamahanga River is used for a range of recreational pursuits downstream of Masterton which gives rise to the potential for infectious disease from pathogens entering the river from the WWTP effluent.

# 4 PUBLIC HEALTH RISK ASSESSMENT

## 4.1 INTRODUCTION

This section describes the derivation and outcome of a quantitative health risk assessment on the potential health effects resulting micro-organisms and chemicals discharged from the Masterton Wastewater Treatment Plant (WWTP). The risk assessments for microbiological and chemical hazards are carried out independently.

Risk is the product of hazard and exposure. The greater the hazard and/or exposure, the greater the risk. In this scenario, the hazards are chemicals and pathogens (micro-organisms that can cause infection) present in wastewater. The exposures routes are by ingestion, inhalation or absorption through the skin of effluent-contaminated water and consumption of mahinga kai harvested from these waters. The exposures are the amount of water ingested and/or inhaled and mahinga kai consumed. The risk estimating procedure involves ascribing numerical values to hazard, exposure and infectious doses.[4] In its simplest form, one could get a crude risk estimate to recreational water users by multiplying "average" values of pathogen concentration in the effluent by the river water dilution factor, further multiplication by the "average" volume of water ingested/inhaled during recreational pursuits to give the "average" number of pathogens consumed. This can then be entered into the infectious dose equation[5] for that pathogen to give an "average" risk of infection (although, for technical statistical reasons, it won't be a true average). However, this completely ignores the fact that the risk itself has a distribution of values. Foe example, some days the receiving environment may be quite uncontaminated and so risk will be low, possibly even zero, but on another day there may be appreciable contamination and so the risk higher. So the outcome of the procedure is a risk profile, not a single risk number. Usually the only way to calculate this profile is to use Monte Carlo simulations, which combines the probability distributions around each of these variables instead of "average" values. The outcome of this procedure, when repeated a sufficient number of times (at least 1,000), allows the risk to be expressed as a frequency distribution.

The accuracy of a risk assessment rests upon the availability of suitable hazard and exposure data from which the individual probability distributions are derived. In this risk assessment, which is carried out using the @Risk software package, the probability distributions were estimated thus. Data pertaining to each variable was tested by @Risk to see whether it matched one of a number of defined distribution types. If a match was obtained, the distribution of that variable was described by the distribution name and one or two parameters (*eg* median and standard error). If no match was obtained, empirical distributions were derived from the appropriate data. For example, a rectangular distribution may be appropriate if only the minimum and maximum values are available. However if the most likely value is also known, a triangular distribution is more suitable and a polygonal distribution is used if more than three points are known.

The following elements are used as inputs for the microbiological and chemical risk estimations:

[4] There is no such thing as "the infectious dose". Rather, infectivity increases with dose.
[5] Relating dose to probability of infection.

- microorganisms of public health significance
- chemicals of health significance
- the impact sites
- the concentration of health-related microorganisms and chemicals at the point of discharge
- the rates of survival of pathogens in river water and groundwater
- the dilution of effluent
- the time taken for the effluent plume to reach the impact points
- bioaccumulation in mahinga kai
- guidelines for drinking-water, recreational and shellfish-gathering waters
- infectious doses of the key pathogens
- maximum allowable values (MAVs) of the key chemicals
- exposures
- acceptable risk levels
- existing microbiological and chemical quality of effluent
- predicted microbiological and chemical quality of treated wastewater

It is the aim of the author to make the risk assessment as transparent as possible by showing the data and stating the assumptions upon which the assessment is made. In this report the microbial and chemical risk assessments are carried out separately. The microbiological risk assessment is presented in the first section of this report. The chemical risk assessment is presented in the second section, with reference back to the first section for aspects where commonality exists between the inputs of the microbiological and chemical assessments. An interpretation and discussion of the findings are presented in the third section. Where practicable, the data used in the formulation of the risk models used in the risk assessments are given in the appendices.

## 4.2 MICROBIOLOGICAL RISK ASSESSMENT – METHODS AND ASSUMPTIONS

### 4.2.1 Impact sites

The areas where an effluent plume from the Masterton WWTP outfall is considered to have the potential to impact on public health are listed below and shown on Map 1.

- Rua2 (Wardells Bridge)
- The Cliffs
- Lake Onoke.

The Cliffs is the closest designated contact recreation site used downstream of the point that the treated wastewater from the Masterton WWTP enters the Ruamahanga River. The Cliffs is approximately 8.8 km downstream of the WWTP and the travel

time to this point is approximately 280 minutes at median flows. The treated wastewater is dispersed evenly throughout the river at this point.

Wardells Bridge is included in this assessment because, while there is signage warning against swimming, people have been observed swimming there occasionally. Wardells Bridge is situated approximately 200 m downstream of the point where the WWTP discharges into Makoura Stream and the travel time to this point is approximately 6 minutes at median flows. The treated wastewater is not fully mixed with the river water at this point. The new discharge point is proposed to be 1.3 km upstream of Wardells Bridge and will have a travel time of *ca.* 42 minutes at median flows.

Lake Onoke is the closest site downstream of the Masterton WWTP at which shellfish are collected. This is some 98 km below Masterton and the travel time ranges from approximately 16 hours in flood flow to three days at median flow and longer at lower flows (Mike Gordon, GWRC, pers. comm.).

A number of private water supply bores exist to the southwest of the ponds, the closest of which is approximately 540 m from Pond 3. Groundwater modelling by Pattle Delamore Partners indicates that the proposed irrigation will not create any major changes to the existing groundwater flow patterns and that the irrigated wastewater will not flow towards any neighbouring wells. Regardless of the considerable attenuation of contaminant concentrations shown by the contaminant modelling, the groundwater flow direction means that the proposed irrigation will have no effect on the water quality of neighbouring wells.

### 4.2.2 Microorganisms of Public Health Significance

The microorganisms of potential public health significance that can be associated with sewage effluent are listed in Table 14 (ANZECC & ARMCANZ 2000). However, many of these are not relevant to these particular circumstances, the reasons for their exclusion being given in the table.

**Table 14 Sewage-borne microorganisms of public health significance**

| Pathogen | Include? | Main disease caused | Reason for not including in assessment |
|---|---|---|---|
| **Bacteria** | | | |
| *Campylobacter sp.* | Yes | Gastroenteritis | |
| Pathogenic *E. coli* | No | Gastroenteritis | Low concentration expected in sewage |
| *Legionella pneumophila* | No | Legionnaires' disease | No evidence of infection via recreational water |
| *Leptospira* sp. | No | Leptospirosis | Low concentration expected in sewage |
| *Salmonella* sp. | Yes | Gastroenteritis | |
| *Salmonella typhi* | No | Typhoid fever | Rare in New Zealand |
| *Shigella* sp. | No | Dysentery | Low concentration expected in sewage |
| *Vibrio cholerae* | No | Cholera | Rare in New Zealand |
| *Yersinia enterolitica* | No | Gastroenteritis | Low concentration expected in sewage |
| **Helminths** | | | |
| *Ascaris lumbricoides* | No | Roundworm | Rare in New Zealand |
| *Enterobius vernicularis* | No | Pinworm | Low concentration expected in sewage |
| *Fasciola hepatica* | No | Liver fluke | Rare in New Zealand |
| *Hymnolepis nana* | No | Dwarf tapeworm | Rare in New Zealand |
| *Taenia* sp. | No | Tapeworm | Rare in New Zealand |
| *Trichuris trichiura* | No | Whipworm | Rare in New Zealand |
| **Protozoa** | | | |
| *Balantidium coli* | No | Dysentery | Low concentration expected in sewage |
| *Cryptosporidium* oocysts | Yes | Gastroenteritis | |
| *Entamoeba histolytica* | No | Amoebic dysentery | Rare in New Zealand |
| *Giardia* cysts | Yes | Gastroenteritis | |
| **Viruses** | | | |
| Adenoviruses | Yes | Respiratory disease [a] | |
| Enteroviruses | Yes | Gastroenteritis | |
| Hepatitis A virus | No | Infectious hepatitis | Low concentration expected in sewage |
| Noroviruses [b] | No | Gastroenteritis | No reliable method for viability enumeration |
| Rotavirus | No | Gastroenteritis | No evidence of infection via recreational water |

a Adenoviruses can also cause pneumonia, eye infections and gastroenteritis.
b Formerly known as Norwalk-like viruses.

An indication of the relative significance of pathogens at the local level can be gained from disease notifications. Table 7 shows the annual notified gastrointestinal disease statistics in Wairarapa and New Zealand over the past two years. While an estimated 1-10% of cases are notified, Table 7 provides information on the relative importance of the notifiable gastrointestinal pathogens. However, it should be noted that many of the pathogens listed in Table 14 are not notifiable.

From the annual incidence rates shown in Table 7 it is apparent that the pattern of notified gastrointestinal diseases in the Wairarapa district does not differ greatly from the country as a whole.

### 4.2.3 Microbiological Quality of the Effluent

This risk assessment is based on the concentration of pathogens at the point of exposure. In the absence of sufficient data about pathogen concentrations in receiving water this is estimated from pathogen concentrations in wastewater and the reduction predicted as a result of the WWTP upgrade.

The existing quality of the treated wastewater has been monitored for *E. coli* from October 2000. Prior to that, monthly monitoring of faecal coliforms and enterococci

was carried out between July 1994 and February 2003 with sporadic faecal coliform testing being continued to the present date. In comparison, the concentration of *E. coli* in the effluent is expected to be 330/100mL after the upgrade as this outcome is one of the stated aims of the proposed WWTP upgrade. The only pathogen data for the treated wastewater was obtained for a small baseline survey conducted in October 2005 for pathogens. The complete monitoring data are given in Appendix 4. The concentrations of indicator organisms and pathogens identified in Table 14 are summarised in Table 15.

There is sufficient information about the concentration of indicator organisms in the final effluent to estimate their probability distributions. However, there are insufficient data to do the same for pathogens. Furthermore, all the effluent virus and protozoan parasite concentrations to date have been below the detection limits of the tests. Consequently, alternative sources of effluent pathogen concentrations were sought as a basis for this risk assessment. The only study that appears to be pertinent (*i.e.* surveys of pathogen concentrations from New Zealand wastewater treatment plants that incorporate oxidation ponds) was of the Christchurch WWTP at Bromley, the summary statistics of which are given in Table 16. The sewage treatment process at Bromley differs from that at Masterton in that the effluent passes through trickling filtration and activated sludge before entering the oxidation pond. These steps are estimated to reduce the microbial load by about one order of magnitude.

**Table 15 Microbial quality of existing Masterton WWTP effluent**

| Organsim | Monitoring period | n | Min. | Max. | Median | Geometric Mean |
|---|---|---|---|---|---|---|
| ***Indicator organisms*** | | | | | | |
| *E. coli* (/100mL) | Oct 2000 – Jul 2005 | 118 | 10 | 35,000 | 698 | 614 |
| Faecal coliforms (/100mL) | Jul 1994 – Jul 2005 | 150 | 20 | 150,000 | 1,593 | 1,355 |
| Enterococci (/100mL) | Aug 1994 – Feb 2003 | 98 | 10 | 6,200 | 300 | 277 |
| Somatic coliphage (pfu/100mL) | Oct 2005 | 3 | 80 | 630 | 200 | 216 |
| ***Pathogens*** | | | | | | |
| *Campylobacter* (mpn/100mL) | Oct 2005 | 3 | <3 | <3 | <3 | <3 |
| *Salmonella* (mpn/100mL) | Oct 2005 | 3 | <0.3 | <3 | 0.4 | N/A |
| *Giardia* (cysts/L) | Oct 2005 | 3 | <1 | <1 | <1 | <1 |
| *Cryptosporidium* (oocysts/L) | Oct 2005 | 3 | <1 | <1 | <1 | <1 |
| Adenoviruses ($TCID_{50}$/L) | Oct 2005 | 3 | <5 | <5 | <5 | <5 |
| Enteroviruses (pfu/L) | Oct 2005 | 3 | <5 | <5 | <5 | <5 |

Extensive pathogen testing was conducted at the Mangere WWTP (DRG, 2002). Unfortunately, all samples were taken from the effluent stream prior to the oxidation ponds and, as significant pathogen reduction occurs within oxidation ponds, the pathogen concentration data are not suitable.

The data from the recent Bromley study did include samples from the oxidation pond and were considered to estimate pathogen distributions in the risk assessment. However, these data comprised a number of points where the pathogen concentrations fell outside the limits of detection; these values were estimated as half the detection limit. It should be noted that this approach is only valid provided that not too many samples are outside the detection limits – otherwise the integrity of the estimates are

severely compromised. Furthermore, it must be noted that a survey of this nature should be carried out throughout at least an entire year because of the seasonal variation in pathogens in the community and the inherent temporal variability of pathogens in the environment.

Concentrations of *Salmonella*, *Campylobacter*, *Giardia, Cryptosporidium* adenoviruses and enteroviruses were tested in the Bromley oxidation pond effluent in February/March 2005 and the winters of 2002, 2003 and 2004. The summary statistics for indicator and pathogen concentrations are shown in the following table.

**Table 16 Microbial quality of Bromley WWTP effluent**

| Organsim | n | Min. | Max. | Median | Geometric Mean |
|---|---|---|---|---|---|
| *E. coli* (MPN/100mL) | 24 | 26 | 16,000 | 1,000 | 674 |
| *Campylobacter jejuni* (MPN/L) | 11 | <4 | 30 | 4.5 | 6 |
| *Salmonella* (MPN/L) | 30 | <30 | 400 | <30 | 21 |
| *Giardia* (cysts/L) | 23 | 0.005 | 2 | 0.14 | 0.15 |
| *Cryptosporidium* (oocysts/L) | 24 | 0.005 | 3.9 | 0.14 | 0.16 |
| Adenoviruses ($TCID_{50}$/L) | 22 | <0.4 | 8.4 | 0.75 | 1.0 |
| Enteroviruses (PFU/L) | 34 | 0.025 | 114 | 2.3 | 2.4 |

The pathogen concentrations observed in the small survey of oxidation pond effluent at Masterton were lower than the limit of detection and so were not able to be compared directly with those from Bromley. However, an assessment was made using the respective *E. coli* data from Bromley and the extensive monthly sampling data from the Masterton WWTP effluent. The concentrations of *E. coli* in the oxidation pond effluent from these two sites are very similar. The range in effluent *E. coli* concentrations was larger at Masterton than Bromley, which is not surprising given that many more samples were tested at the former. The median and geometric means for *E. coli* were higher at Bromley but by less than half an order of magnitude and not statistically significantly different. Based on this small survey, the concentrations of pathogens in the Masterton WWTP effluent are not likely to be higher than those at Bromley. However, the pathogen concentrations used for this risk assessment were derived from the Bromley data multiplied by ten to account for the possibility of an additional tenfold reduction in microbial load at Bromley resulting from the treatment used there in addition to that used at Masterton. Consequently, while it may appear that using the Bromley pathogen data may result in an overestimation of the risk (although probably not by much), this follows the precautionary approach.

The resultant concentration estimates were used to best-fit frequency distribution models for each pathogen using the @Risk software. To achieve this the concentration data from the Bromley survey had to be amended wherever there was a result below the detection limit (*i.e*. a "less than" result). The standard approach of using the value of half the detection limit was used (*eg*. <3 becomes 1.5). The exception to this rule was where a result was given where the limit of detection for that sample was higher than normal for some reason and would result in a value greater than some of the other test results for that organisms; such data were omitted. The @Risk software was used to determine the best-fit estimates for each of the

pathogen concentrations used in the subsequent modelling, the parameters for which are shown in the following table.

**Table 17 Pathogen distributions derived from the 10xBromley WWTP data**

| Pathogen | Frequency distribution (best-fit pathogen concentration) |
|---|---|
| *Campylobacter jejuni* | Inverse Gauss (μ = 75.696; λ = 8.9561; shift = 18.168) |
| *Salmonella* sp. | Normal (μ = 50.167; σ = 108.37) |
| *Giardia* | Inverse Gauss (μ = 3.6142; λ = 1.5548; shift = -0.18135) |
| *Cryptosporidium* | Lognormal (α = 4.4026; σ = 0.656; shift = -0.019681) |
| Adenoviruses | Inverse Gauss (μ = 17.989; λ = 3.4559; shift = 1.2381) |
| Enteroviruses | Inverse Gauss (μ = 133.61; λ = 11.86; shift = -2.0244) |

### 4.2.4 Survival of microorganisms in the environment

There is much literature about the survival of various microorganisms in water and wastewater. However, one has to deal with the following conundrum when assessing survival literature. Reproducible results are seldom obtained unless the survival experiments are conducted in a laboratory where the various factors that impact on survival can be controlled. However, laboratory-based experiments can bear little relation to the reality of a natural surface water system. In contrast, the estimation of microbial survival in natural conditions may be unique to that particular set of experimental conditions and which are rarely repeatable in the field. Therefore, one must be cautious when comparing the survival rates of different microorganisms between different field experiments. Nevertheless, reliable comparisons can be made where several microorganisms are measured in the same survival trial and broad comparisons can be made between some trials, although too much reliance should not be made on absolute survival rates or decimal reduction times ($T_{90}$ values).

Field and laboratory-based survival experiments have determined that sunlight is the most important factor that influences the survival rate of microorganisms. Other factors include the water temperature and microbiota/nutrient concentrations of the receiving water. Microorganisms generally survive longer in dark, cool conditions where the ambient levels of microorganisms are low. These factors must be taken into account when comparing the survival rates of different microorganisms from different survival experiments. Using survival rates from experiments carried out in the dark in clean water, and with temperature in the normal range for the environment for which the risk assessment is being carried out, would be considered worst-case and is in accordance with the precautionary approach.

Empirical survival data are best drawn from field experiments carried out in environmental conditions that closely resemble those at the assessment site. In the case of groundwater, the conditions would be at temperatures of 10 – 18°C, with a median temperature of *ca*. 15°C, and in the dark.

The measure of survival used in this assessment is the $T_{90}$ value (the time taken to reduce the concentration of the microorganism in question by 90%—a 1-log reduction).

**Table 18 $T_{90}$ values for the key pathogens and indicator organisms**

| Microorganism | $T_{90}$ | Conditions | Reference |
|---|---|---|---|
| *Campylobacter jejuni* | 46-60 h | Dark; 16°C | Terzieva & McFeters, 1991 |
| *Campylobacter jejuni* | 1.02 – 3.23 d | Ambient; 10-20°C | Thomas *et al*., 2002 |
| *Salmonella* sp. | 168-312 h | Dark; 15°C | Evison, 1988 |
| *Salmonella* sp. | 130 h | Diurnal; 18-21°C | Jimenez *et al*., 1989 |
| Poliovirus | 120-240 h | Dark; 15°C | Gordon & Toze, 2003 |
| Poliovirus | 31 h | Diurnal; 12-20°C | O'Brien & Newman, 1977 |
| Adenovirus | 43 - 62 d | Dark; 15°C | Enriquez, 1995 |
| *Cryptosporidium* sp. | 1,000 h | Dark; 15°C | Medema *et al*., 1997 |

For the risk assessment from recreational exposure, there is no need to factor in survival because the travel time in the river between the point of entry of the treated effluent into the Ruamahanga River and the closest designated recreational site downstream (The Cliffs) is a few hours (4.5 hours at median flow). The amount of die-off over such a short period would be small (1-2% for adenoviruses[6]) and has been ignored. However, travel times through the soil and aquifer are more substantial. Consequently, the $T_{90}$ values used were derived from experiments in the dark at temperatures that approximate the groundwater temperatures expected at Masterton.

### 4.2.5 Dilution / Dispersion

At present, treated wastewater is discharged via a pipe into Makoura Stream (a tributary of the Ruamahanga River). However, following the upgrade the treated wastewater will be discharged via three routes: direct discharge into the Ruamahanga River, leakage from the oxidation ponds and land discharge by means of border dyke irrigation, depending on river conditions. As the three disposal routes are completely different they are addressed separately below.

The effluent:river ratio is fundamental to this risk assessment. However, it is important to note that the only river flow data available for this section of the Ruamahanga River was measured at Rua2 (Wardells Bridge). This has two implications to this assessment. First, because The Cliffs (the closest designated recreational site downstream of the outfall) is also downstream of the Waingawa River, the dilution of effluent will be greater than at Wardells Bridge, which is modelled here. While this means that the model will overestimate the risk to swimmers at The Cliffs, it is a precautionary approach. Second, the effluent is not currently completely dispersed by the time it reaches Wardells Bridge[7] but tends to hug the right bank of the river. Without a river transect model at this point, it is not possible to adequately factor this into the risk assessment. The risk assessment is made on the basis of complete mixing of effluent in the river. This means that the risks to swimmers at Wardells Bridge will be underestimated for those using the right (north/west) side of the river and overestimated for those using the left (south/east)

[6] A greater reduction is expected in bright sunlight but it is not possible to provide a quantitative estimate because adenovirus survival data are not available.

[7] This currently the case, but the change in discharge point post-upgrade will result in the treated effluent being fully mixed well before Wardells Bridge.

side of the river. This problem will be obviated after the WWTP upgrade because the effluent will be fully mixed at Wardells Bridge. Neither will this have a bearing at The Cliffs, the primary focus of this assessment, by which point the effluent is also fully mixed.

One of the aims of this report is a comparison of the present and future risks. The present and future risks are estimated using different risk models because of the nature of the discharge and river flow data differ. Consequently, effluent dilutions for the present situation and post-upgrade scenarios are presented separately below.

#### *4.2.5.1 Direct discharge to the Ruamahanga River*

Two factors affect the proportion of microorganisms in the treated wastewater discharged directly into the river that reach the impact areas: dilution and microbial survival rate. In general, the concentration of viable microorganisms reduces with increasing distance between the outfall and impact sites, in terms of both time and physical distance. For Wardells Bridge, being a few minutes downstream of the present discharge, die-off would be negligible and has been ignored. The effect of die-off has also been ignored at The Cliffs because, despite being 7.8 km (280 min) downstream of the discharge point, die-off would still have minimal bearing on the outcome.

*Present situation*

The present dilution of effluent by the river has been modelled using historical data on the relative daily flows using all the flow data for which both effluent and the Ruamahanga River flow at Wardells Bridge are available for the same day. This has been split into two subsets for comparison against the risks estimated for the post-upgrade scenarios.

- A subset of the above dataset when the river was above the trigger level (median) flow of 12.33 $m^3$/sec.
- A subset of the above dataset when the river was below the median flows.

The frequency distributions for these two flow datasets were determined using the best-fit estimates for the daily ratios of effluent : river flow using the @Risk software package. The parameters for the two distributions are shown in the following table.

**Table 19 Effluent dilution distributions based on Masterton data**

| River flow regime | Frequency distribution (best-fit effluent : river flow ratio) |
|---|---|
| Above median flows | Weibull (α = 1.7443; β = 0.0080805; shift = 0.00040964) |
| Below median flows | Lognormal (α = 0.020317; σ = 0.009751; shift = 0.0022108) |

The effluent from the WWTP outfalls presently accounts for 1.2% of the flow (median value) and 5.8% (median value) of the *E. coli* load present at Wardells Bridge. The median contribution of the effluent to the *E. coli* load increases to 13% when the river is at less than median flows. As the river flow drops the proportional contribution of the outfall increases. While the proportion of the pathogen load cannot be estimated due to a paucity of pathogen data in the Ruamahanga River, it is likely to be somewhat higher from the discharge than that for *E. coli* for many of the pathogens assessed. This is particularly so for human enteric viruses, which are present in human but not animal faeces. However, the same may not be true for some

of the other pathogens. For example, *Campylobacter* is commonly found in cow faeces and was detected in 63% of water samples tested in the FMRP survey at Double Bridges, sometimes at high concentrations[8].

*Post-upgrade*

It is proposed that direct discharge into the Ruamahanga River will be governed by the following discharge rules:

- Summer (November – April) – no direct discharge below median flows in the Ruamahanga River.
- Winter (May – October) - no direct discharge below half-median flows in the Ruamahanga River.
- Whenever there is a direct discharge the effluent : river ratio will be 1 : 30 until the maximum effluent discharge rate of 1,200 L/sec is reached.

The effluent dilution distributions derived from PDP modelling for the different discharge regimes are shown in the following table.

**Table 20 Effluent dilution distributions based on PDP Modelling**

| River flow regime | Frequency distribution (best-fit effluent : river flow ratio) |
|---|---|
| Summer - above median flows | Loglogistic (α = 0.00024504; σ = 0.0067052; shift = 1.5963) for viruses<br>Loglogistic (α = 0.00023731; σ = 0.0066128; shift = 1.5753) for bacteria/protozoa |
| Summer - below median flows | BetaGeneral (min = 1.2081; max = 4.8337; α1 = 0.0011491; α2 = 0.011475) for viruses<br>Exponential (β = 0.0016878; shift = 0.0011323) for bacteria/protozoa |
| Winter – above half-median flows | BetaGeneral (min = 1.7729; max = 24.945; α1 = 0.00059962; α2 = 0.15634) for viruses<br>BetaGeneral (min = 1.7747; max = 26.354; α1 = 0.00059656; α2 = 0.16369) for bacteria/protozoa |
| Winter - below half-median flows | InverseGauss (μ = 0.0011953; λ = 0.0021165; shift = 0.0021713) for viruses<br>InverseGauss (μ = 0.0010857; λ = 0.0018093; shift = 0.0020658)) bacteria/protozoa |

Effluent flows include direct river discharge, subsurface flows following effluent irrigation to land and 1,200 $m^3$/day pond leakage.

### *4.2.5.2 Pond leakage*

The present amount of leakage from the oxidation ponds has been estimated at 0-1,700 $m^3$/day with a best estimate of 800 $m^3$/day (PDP, 2006). A separate estimate of 0 – 2,400 $m^3$/day (best estimate of 1,200 $m^3$/day) has also been made for pond leakage after the proposed upgrade. The increased amount results from increased storage times that are required to avoid discharging effluent directly to the river at low flows. This increases the average hydraulic loading in the ponds and therefore is also expected to increase the pond leakage rate.

No estimate has been made so far of the microbiological quality of the leakage material. It is likely that passage of pond effluent through the sediment layer on the bottom of the ponds will filter out many of the microorganisms in the wastewater, particularly those associated with particulate material. However, in the absence of an estimate the precautionary approach has been followed. The risk assessment is made on the assumption that all of the pond leakage material enters the Ruamahanga River

[8] *Campylobacter* exceeded the upper limit of the test of 110/100 mL in four of the 49 FMRP samples.

and that the effect is equivalent to an additional 1,200 – 1,700 $m^3$/day of pond effluent being piped into the river.

#### *4.2.5.3 Land discharge*

When the treated wastewater is discharged onto land, microorganisms are also removed by filtration through the soil and during transport through the aquifer. The dilution and filtration through soil and the aquifer are best dealt with independently. Given the short travel times to the river for the effluent discharged to land the losses due to die-off have been ignored; this follows the precautionary approach.

Losses through the soil were modelled by (Green, 2006) using a static *E. coli* concentration of 1,000/100 mL and 10 adenoviruses/L. The output of this model was used as the input for the groundwater modelling carried out by PDP.

The PDP model was used to estimate the flows and dilution of land-treated effluent re-entering Makoura Stream and the Ruamahanga River. The estimated total daily flow of effluent re-entering the river was 20,100 $m^3$/day. The estimated total daily fluxes of *E. coli* and adenoviruses contained in the land-treated effluent re-entering the river of $2.7 \times 10^8$ *E. coli*/day and $5.96 \times 10^6$ adenoviruses/day. These estimates were based on the assumptions of steady state, no physical removal of microorganisms during passage through the groundwater and $T_{90}$ values of 135 hours and 62 days for *E. coli* and adenovirus respectively[9]. From this one can derive average concentrations of 1.7 *E. coli*/100 mL and 0.37 adenoviruses /L in the land-treated effluent stream as it enters the Ruamahanga River. In comparison, the median concentrations of *E. coli* in the treated effluent and the Ruamahanga River at Rua1 (upstream of the oxidation ponds) are 689 and 45 *E. coli*/100 mL.

From this analysis it is apparent that the contribution of microorganisms to the river via land-treated effluent will be insignificant when direct discharge is occurring simultaneously. Consequently, the contribution of land-treated effluent is not included in the risk assessment except under circumstances when there is no direct discharge of effluent to the river.

The log reductions in *E. coli* and adenovirus concentrations are thus calculated from the input and output concentrations of the PDP model. For *E. coli*, the concentration drops from 1,000/100 mL to 1.7/100 mL after land treatment, a log reduction of 2.8. For adenovirus, the concentration drops from 10/L to 0.37/L after land treatment, a log reduction of 1.4.

At times when direct discharge to the river is not occurring then the risk assessment is based on land discharge and pond leakage only. In these circumstances the risk assessment is made with the following inputs and assumptions:

- Pathogen distributions from Table 17 are used in place of the fixed values of 1,000 *E. coli*/100 mL and 10 adenoviruses/L.
- Applying log reductions (derived above for adenovirus and *E. coli*) of 1.4 for viruses and 2.8 for the bacterial and protozoal pathogens.

[9] The $T_{90}$ values for *E. coli* and adenovirus survival are also applied to the other bacterial and viral pathogens respectively.

### 4.2.6 Microbial Exposure Pathways

Three types of microbiological and chemical hazards are associated with discharge of effluent into the river and aquifer. These are:

- waterborne disease following recreational use
- disease following consumption of contaminated drinking-water
- food poisoning following consumption of contaminated mahinga kai.

As contact recreation, drinking-water and mahinga kai occur at different locations within the catchment, this risk assessment deals with each separately.

#### *4.2.6.1 Recreational contact*

Recreational use of waterways is often split into two categories: primary and secondary contact activities. Primary contact activities comprise those in which immersion in water is a normal part of that activity (*eg* swimming, diving, surfing etc) or accidental immersion is commonplace (*eg* water skiing). Secondary contact activities comprise other aquatic activities with a lesser degree of contact with the water (*eg* fishing, boating etc).

In the area of potential impact from the Masterton WWTP, both primary and secondary contact recreation activities have been observed. Consequently, the risk assessment for contact recreation is made upon the basis of primary recreational contact, this being the greater risk.

Due to the nature of aquatic recreational activities, exposures are transient. Consequently, this aspect of the risk assessment deals with transient exposures and not long-term exposures. For illness to result from a single exposure the hazard must be at a high enough concentration to cause an acute reaction. The microbial hazards normally associated with wastewater that can cause acute illness are pathogens, which may cause symptoms to susceptible people at very low concentrations.

#### *4.2.6.2 Drinking-water*

None of the five community drinking-water supplies in the Ruamahanga catchment are likely to be adversely affected by treated wastewater from the Masterton WWTP. Of these, the Opaki, Opaki School and Rathkeale College supplies are upstream of the WWTP and so not relevant to this assessment. The Pirinoa and Martinborough supplies are downstream of Masterton but are also downstream of other sources of faecal contamination that are likely to have greater impact than treated wastewater from the Masterton WWTP.

The few private bores close to the ponds are upstream of the groundwater flows and therefore not subject to contamination from the ponds or effluent irrigation.

Drinking-water exposures with public health consequences can be either transient or long-term. The transient exposures to drinking-water normally associated with microorganisms and generally cause acute illness.

#### *4.2.6.3 Mahinga kai*

Increased concentrations of chemical contaminants and waterborne pathogens as a result of the Masterton WWTP discharge to the Ruamahanga River may adversely

affect human health via consumption of mahinga kai (aquatic food) collected from the affected part of the river.

The three main types of mahinga kai of relevance to this risk assessment are fish, shellfish and watercress. The potential exposures via these routes have been discussed in Section 3.3.3. In summary, the discharge from the Masterton WWTP is unlikely to cause a measurable increase in health risk via consumption of the mahinga kai present in the Ruamahanga River. The risk of foodborne infectious disease contracted as a result of consuming the only mahinga kai relevant to this situation (*i.e*. fish caught in the Ruamahanga River in the vicinity of Masterton WWTP) is extremely small.

### 4.2.7 Exposure Assessment

The extent to which the target population is exposed to the hazard is also required as part of the risk assessment. In this instance, the target populations are recreational water users at the closest downstream recreational site, people whose private bore water supplies draw from the aquifer impacted by land disposal of the treated wastewater, and those who consume shellfish gathered from the vicinity of Lake Onoke.

#### *4.2.7.1 Estimated exposure of recreational water users*

- *duration of swimming* as a rectangular distribution with minimum and maximum durations ¼ and 2 hours.
- *volume ingested/inhaled per hour* as a triangular distribution with minimum and maximum volumes = 10.5 and 100.5 mL, with mode = 50.5 mL.[10]

#### *4.2.7.2 Estimated drinking-water exposure*

The WHO estimation of 2 L daily intake of drinking-water is used in this risk assessment (WHO, 2004).

#### *4.2.7.3 Estimated exposure of consumers of fish*

The risk associated with eating fish is a chemical one since fish are normally cooked before consumption and so the microbiological risk is minimal. For an assessment of the risk from chemicals to be made it would be necessary to obtain data on tissue concentrations of chemicals in fish captured in the vicinity of Wardells Bridge.

### 4.2.8 Infectious doses for waterborne pathogens

The infectious dose equations for the pathogens used in this risk assessment are described by the models and parameters shown in Table 21. The endpoint used in the health effects modelling is infection rather than illness for two reasons. First, the dose-response data is somewhat fragile for illness[11] whereas the dose-response data for infection is rather more robust. Second, people who are infected but not ill may

[10] The upper limits refer to swimmers; other recreational users (water skiers, wind surfers) tend to ingest or inhale less water (G. Lewis, University of Auckland, pers. comm.). Note too that Schernewski & Jülich (2001) noted that "10 ml to 100 ml water are incorporated during bathing (Johl *et al*. 1995)."

[11] Examples can be found for three possible alternatives: an increase in the probability of illness with increasing dose (salmonellosis), a decrease with higher doses (campylobacteriosis), and a probability of illness (given infection) independent of the ingested dose (cryptosporidiosis). These alternatives may reflect different modes of interactions between pathogens and hosts (Teunis *et al*. 1996, 1999).

shed the pathogen for some time and so be a source of infection to other people. While the use of infection means that the risk assessment will over-estimate health risks because not all people who are infected will develop symptomatic illness, this is in keeping with the precautionary approach that is generally used in public health.

**Table 21 Infectious dose model parameters used for the key pathogens**

| Pathogen | Model | α | β | *r* | $N_{50}$# |
|---|---|---|---|---|---|
| *Campylobacter* | β-Poisson | 0.145 | 7.58 | | 896 |
| *Salmonella* | β-Poisson | 0.3126 | 2,884 | | 23,600 |
| *Cryptosporidium* | Exponential | | | 0.0042 | 165 |
| *Giardia* | Exponential | | | 0.0199 | 34.8 |
| Hepatitis A virus | Exponential | | | 0.5486 | 1.26 |
| Adenovirus 4 | Exponential | | | 0.4172 | 1.67 |
| Echovirus 12 | Exponential | | | 0.0128 | 54.1 |

Parameters obtained from Haas *et al*., 1999.
* Echovirus 12 is used to represent enteroviruses in this risk assessment
# Derived from $N_{50} = 0.693/r$ (exponential model) or from $N_{50} = \beta(2^{1/\alpha} - 1)$ (beta-Poisson model)

Exponential model: $P_{\text{inf}} = 1 - e^{-rN}$

Beta-Poisson model: $P_{\text{inf}} = 1 - \left[1 + \frac{N}{\beta}\right]^{-\alpha}$

The protozoan and virus dose-response follows the exponential model, which relates the probability of infection ($P_{\text{inf}}$) to the dose ($N$) via a single parameter ($r$) being the probability of infection per ingested or inhaled particle. With this model the median infectious dose ($ID_{50}$ is $N_{50} = -\log_e(0.5)/r = 0.693/r$). This is the dose required to cause infection in half of the exposed population. The bacterial pathogens (*Salmonella* and *Campylobacter*) follow the more complex "beta-Poisson" model, in which r is replaced by the two parameters of the beta distribution (α and β). The median infectious dose is then given by $N_{50} = \beta(2^{1/\alpha} - 1)$.

The following figures are diagrammatic representations of exponential and beta-Poisson dose-response models for viruses and *Campylobacter* respectively. In both dose-response models, increasing the dose results in a greater probability of infection. In the exponential model, it is clear that ingestion of a small number of adenoviruses gives a high probability of infection whereas a much higher dose of enteroviruses is required to achieve the same probability of infection. The main difference between the exponential and beta-Poisson dose-response models is that the probability of infection approaches 1 as the dose increases in the exponential model whereas the beta-Poisson dose-response curve flattens out and may take forever to get to high probabilities.

**Figure 5 Viral dose-response curves**

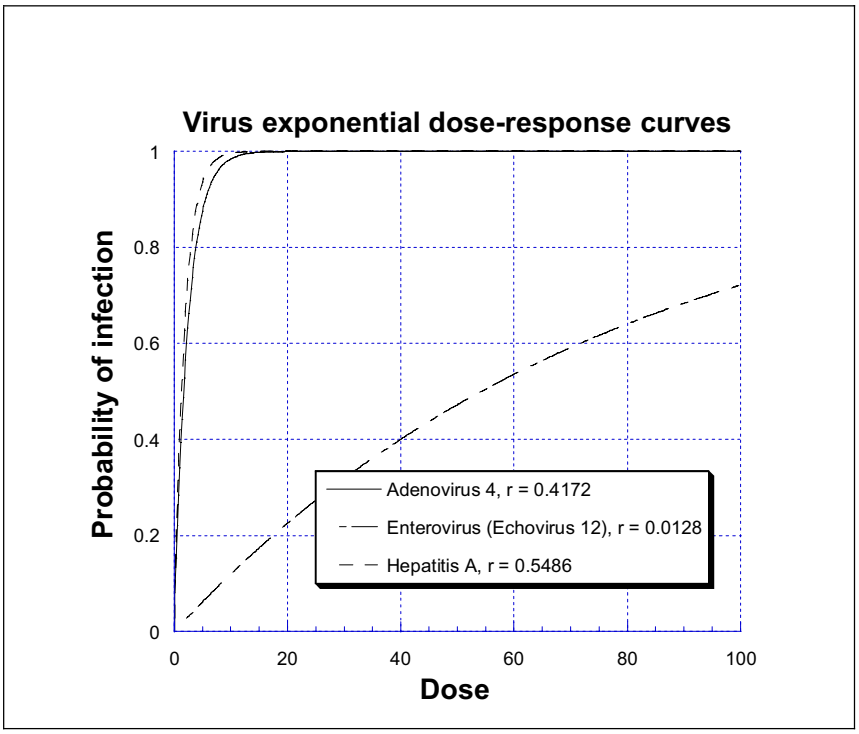
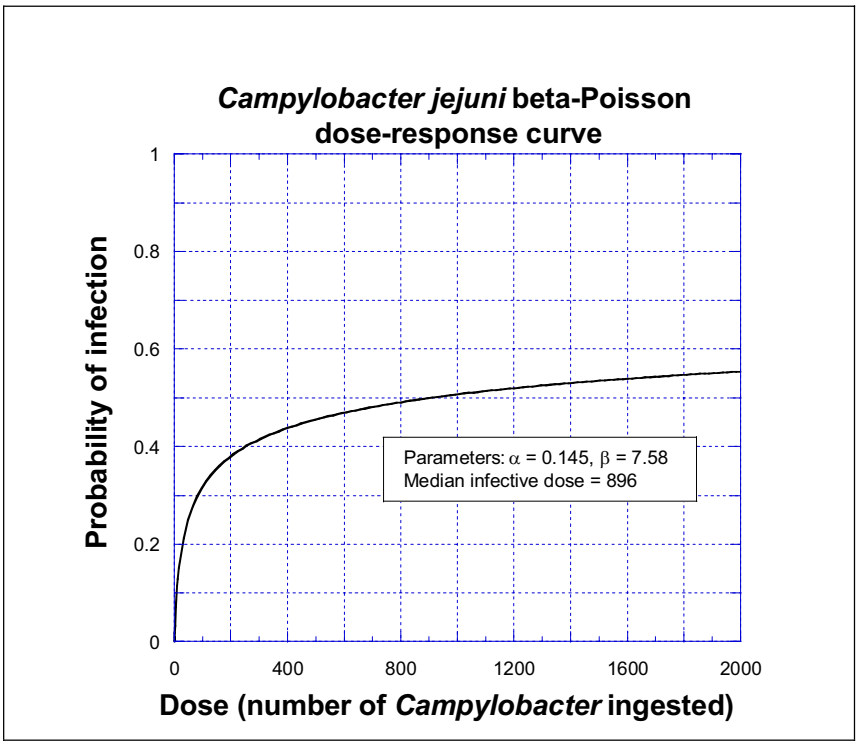



**Figure 6** ***Campylobacter*** **dose-response curve**




### 4.2.9 New Zealand Recreational Water Quality Guidelines

Water quality is generally assessed using the concentrations of faecal indicator organisms. These are microorganisms such as *E. coli*, faecal coliforms and enterococci that are abundant in faeces and are quick and inexpensive to test for in water. Overseas epidemiological studies have determined that a relationship exists between the concentration of indicator organisms in water and illness in recreational water users. It is estimated that a 95$^{th}$ percentile concentration of <130 *E. coli*/100mL

in recreational freshwater corresponds to <0.1% risk of *Campylobacter* infection (MfE/MoH, 2003)[12]. This relationship forms the basis of the New Zealand Recreational Water Quality Guidelines (Table 22). In addition, the guideline limit for faecal coliforms in water in shellfish-gathering areas is a median of 14/100mL with not more that 10% of samples exceeding 43/100mL.

**Table 22 Microbiological Guidelines for Recreational Freshwaters**

| Critical values (*E. coli* / 100 mL) | MAC | Mode (based on single point max. value) | Estimated risk of *Campylobacter* infection (based on 95 percentile *E. coli* value) |
|---|---|---|---|
| ≤130 | A | | <0.1% |
| 131 - 260 | B | Surveillance mode | 0.1 – 1% |
| 261 - 550 | C | Alert mode | 1 – 5% |
| >550 | D | Action mode | >5% |

There are some caveats to these guidelines. First, in receiving waters impacted by a point source effluent discharge mere compliance with limits on indicator bacteria (*i.e. E. coli*) is not a guarantee of safety (MfE/MoH, 2003). Second, monitoring of indicator bacteria should be carried out in conjunction with a sanitary survey because situations may occur where an unacceptable level of risk may be inferred despite *E. coli* concentrations being below the guideline values.

Several waterborne pathogens survive in the environment much longer that the commonly used bacterial indicators. Also, the ratio of indicators to pathogens is variable and likely to have a seasonal effect caused by the seasonal variation in the occurrence of various pathogens in the population whereas no corresponding variation in indicator concentrations is observed. Consequently, it is unlikely that indicator organisms are able to provide a reliable measure of the range of pathogens that might be expected in receiving water (hence the caveat).

In summary, the relationship between indicator organisms and faecal pathogens is neither strong nor consistent enough to enable waterborne pathogens to be predicted from the concentration of indicator organisms in surface waters. Accordingly, risk assessments need to consider the risks of waterborne disease as estimated by both indicator and pathogen concentrations. Consequently, this document follows two risk assessments in parallel:

A. using guideline *E. coli* concentrations based on epidemiological studies and;

B. using estimates of the concentrations of individual pathogens in conjunction with infective dose models.

### 4.2.10 New Zealand Drinking-Water Standards

The maximum acceptable values (MAVs) for the chemicals and micro-organisms that are relevant to exposure via drinking-water consumption are given in the Drinking-Water Standards for New Zealand 2005 (DWSNZ).

[12] The previous New Zealand recreational water guideline was based on an acceptable swimmer illness rate of 8 cases per thousand bathers swimming in fresh water with a running median *E. coli* concentration of 126/100mL, (MfE/MoH, 1999).

It is usual practice to make assessments of the risks from chemicals via the drinking-water exposure route by comparison of the concentrations of the chemicals as measured in the drinking-water with the DWSNZ. However, this approach was not used because this would have entailed an extensive monitoring programme for a potentially large number of drinking-water supplies as well as the likelihood that all the chemicals would fall below the limits of detection due to the large dilution factor. Consequently, the chemicals were measured in oxidation pond effluent and the expected concentration in drinking-water was estimated by applying the appropriate dilution factor. This is a conservative assessment as it assumes no degradation of the chemicals in the water has taken place and is therefore in keeping with the precautionary approach.

## 4.3 QUANTITATIVE MICROBIOLOGICAL HEALTH RISK ASSESSMENT

As previously discussed, the microbial hazards emanating from discharge of wastewater from the Masterton WWTP results in a risk of waterborne disease to those who use the Ruamahanga River during the pursuit of contact recreational activities. The risk of infectious disease via drinking-water or mahinga kai contaminated with pathogens from the WWTP effluent is negligible. Consequently, the following risk assessment is made for recreational contact only.

### 4.3.1 Determination of Health Risk from Contact Recreation

This QHRA for recreational users is based on the following assumptions:

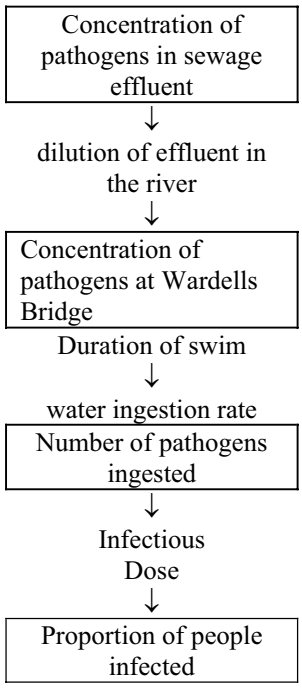
- The pathogen concentrations in the effluent are the same as presently being discharged by the Masterton WWTP. This may cause an over-estimate of the risk because it does not take into account any reduction in concentration of microorganisms resulting from an upgrade of the treatment plant. The pathogen loads used in the assessment were derived from data from a pathogen survey in sewage from Bromley WWTP. Comparison of the Masterton and Bromley *E. coli* data reveals that the effluent quality is not significantly different in terms of *E. coli* concentration. Comparison of the Masterton and Bromley pathogens data suggests that the pathogen load is unlikely to be higher in the Masterton effluent than the Bromley effluent. Using the tenfold Bromley pathogen concentrations in the risk models is unlikely to underestimate the risk from the Masterton WWTP and therefore follows a precautionary approach.
- The closest recreational contact is at Wardells Bridge, by which time the effluent is fully mixed.
- The dilution of the treated wastewater that is proposed to be discharged directly to the river at times of high river flows is based on the modelling under the previously described pre- and post upgrade scenarios. The present risks are assessed separately for above- and below-median flows in the Ruamahanga River. The post-upgrade risks are assessed separately for summer (above and below median flows) and winter (above and below half-median flows) based on PDP modelling.

- Microorganisms do not decay appreciably in the river between the point of entry to the river and upon reaching Wardells Bridge.
- The removal of microorganisms through the soil (*ie* during the vertical movement of treated wastewater following land application until entry to the aquifer) is as estimated by Green (2006).
- The times and dilutions used for the movement of treated wastewater through the aquifer are based on modelling by PDP. The PDP model assumed that there was no physical removal (filtration) of microorganisms during groundwater passage.
- The $T_{90}$ values obtained from the literature that were used to describe the decay of microorganisms in the dark at *ca*. 15°C (see Table 18) are appropriate for the groundwater at this site.
- Exposure is based on primary contact with ingestion being the primary route of infection and all infected people become ill.

The health risks are calculated on the basis of pathogen concentrations and infectious dose parameters given in Table 21.

In addition, the likelihood of the recreational water guideline single sample maximum *E. coli* concentration of 260/100 mL being exceeded at Wardells Bridge is reported.

**Figure 7 Flow Diagram of the Recreational Risk Assessment Procedure**




The risk calculations were carried out using @Risk software (Pallisade Corporation).

The present typical risk of recreational waterborne disease would occur when the river usage is highest. This can be expected in summer when the river is below median flows (*i.e.* when the effluent dilution is expected to be at its lowest). The

model was set up for 1,000 individuals, each of whom was exposed to a random concentration of pathogens emanating from the outfall, all of which survived to reach Wardells Bridge during recreational contact of random duration when a random volume of water was ingested/inhaled. Each of the random values being selected from the frequency distributions described previously. The number of Monte Carlo simulations were increased until there was little appreciable change in the output, at which point the output is said to be converged. This occurred at *ca*. 10,000 iterations.

### 4.3.2 Predicted Health Risk from Contact Recreation

The outputs from 10,000 iterations of the risk model are shown in the following table.

**Table 23 Predicted Waterborne Infections per 1,000 Swimmers at Present (Summer, below median river flows using 10xBromley pathogen concentrations)**

| | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| Percentile* | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| Minimum | 0 | 0 | 0 | 0 | 0 | 0 |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 2 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 50%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 55%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 60%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 65%ile | 4 | 1 | 0 | 0 | 0 | 1 |
| 70%ile | 5 | 1 | 0 | 0 | 0 | 1 |
| 75%ile | 6 | 1 | 0 | 0 | 0 | 2 |
| 80%ile | 8 | 2 | 0 | 0 | 0 | 2 |
| 85%ile | 11 | 2 | 0 | 0 | 0 | 3 |
| 90%ile | 17 | 4 | 0 | 0 | 0 | 4 |
| 95%ile | 31 | 8 | 1 | 0 | 0 | 7 |
| 99%ile | 79 | 31 | 1 | 1 | 1 | 23 |
| Maximum | 286 | 138 | 8 | 1 | 2 | 98 |
| Mean | 7.2961 | 1.8514 | 0.0719 | 0.0197 | 0.0121 | 1.8068 |

* Percent of time that the predicted number of infections are below the stated value.

The above table represents the risk profile to recreational water users under the conditions previously specified. The numbers in the cells of this and similar tables indicate the predicted maximum number of people to become infected with the individual pathogen per 1,000 recreational water users on the percentage of occasions as depicted by the percentile value. From this series of simulations, the infection risks are quite low. The mean number of infections per thousand recreational water users predicted by this model is 7.3. On average, this model predicts that 7.3 cases of adenovirus infection can be expected for every thousand recreational water users at Wardells Bridge[13]. This falls just below the acceptable limit of 8 cases of illness per thousand recreational water users that was cited in the 1999 recreational fresh water guidelines and well short of the 5% infection rate that corresponds to the 95$^{th}$

[13] The risk of infection will be higher at lower flows and if one swims on the right bank at Wardells Bridge where the bulk of the effluent plume occurs at present.

percentile *E. coli* concentration of 550/100 mL cited in the 2003 Recreational Water Quality Guidelines.

This is not to say that higher risks would not occur occasionally. The model predicts that on 5% of occasions, 31 swimmers per thousand would become infected with adenovirus. Enterovirus, *Giardia* and *Campylobacter* infections would occur in eight, one and seven per 1,000 swimmers, respectively (values shown on the 95 percentile row of the previous table). However, it is usual to use the mean number of infected individuals per thousand swimmers to describe the overall risk. This statistic represents the risk to the individual and is sometimes referred to as the individual risk rate (IRR), which is the mean number of infected swimmers/1,000.

To give a more realistic assessment of the health risks from recreational contact, the model was rerun after changing some of the input parameters such as effluent dilution and the method of effluent disposal. This allows one to estimate the health risks for situations that are more realistic than the worst-case scenario described previously. The risks of waterborne infection under the more realistic scenarios are presented in Table 24. In this table the risks are presented as mean values. The more detailed but complex risk profiles for these scenarios are shown in Appendix 10.

**Table 24 Risk per 1,000 Swimmers for Various Scenarios**

| Scenario | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *C. jejuni* |
| A10.1 | **Present situation for below-median flows**<br>Microbe load set at 10 x Bromley distributions (truncated at 0); discharge to river via pipe and 800 m³/d pond leakage; effluent dilutions based on eff:river flow ratios for historical < median river flows (assumes full mixing). | | | | | |
| Mean | 7.2961 | 1.8514 | 0.0719 | 0.0197 | 0.0121 | 1.8068 |
| A10.2 | **Present situation for above-median flows**<br>Microbe load set at 10 x Bromley distributions (truncated at 0); discharge to river via pipe and 800 m³/d pond leakage; effluent dilutions based on eff:river flow ratios for historical > median river flows. | | | | | |
| Mean | 2.5191 | 0.6303 | 0.0257 | 0.0055 | 0.0046 | 0.6238 |
| A10.3 | **Post-upgrade for summer below-median flows**<br>Microbe load set at 10 x Bromley distributions (truncated at 0); discharge to river via land and 1,200 m³/d pond leakage; river : effluent dilutions based on PDP model. | | | | | |
| Mean | 1.0355 | 0.2644 | 0.0074 | 0.0028 | 0.0007 | 0.2225 |
| A10.4 | **Post-upgrade for summer above-median flows**<br>Microbe load set at 10 x Bromley distributions (truncated at 0); discharge to river via pipe, land and 1,200 m³/d pond leakage; river : effluent dilutions based on PDP model. | | | | | |
| Mean | 4.2128 | 1.1496 | 0.0429 | 0.0119 | 0.0068 | 1.1113 |
| A10.5 | **Post-upgrade for winter below-half-median flows**<br>Microbe load set at 10 x Bromley distributions (truncated at 0); discharge to river via land and 1,200 m³/d pond leakage; river : effluent dilutions based on PDP model. | | | | | |
| Mean | 1.0882 | 0.2742 | 0.0114 | 0.0019 | 0.0017 | 0.2636 |
| A10.6 | **Post-upgrade for winter above-half-median flows**<br>Microbe load set at 10 x Bromley distributions (truncated at 0); discharge to river via pipe, land and 1,200 m³/d pond leakage; river : effluent dilutions based on PDP model. | | | | | |
| Mean | 3.4967 | 0.906 | 0.036 | 0.0088 | 0.0047 | 0.8742 |

Comparison of the present and future health risk to river users is best made using estimates based on the present situation for below-median river flows and the post-upgrade summer below-median river flows, the risk estimates for which shown for scenarios A10.1 and A10.3. These represent the times and river conditions when most recreational activity occurs. The models predict that the overall risk of adenovirus infection of swimmers at Wardells Bridge will fall from 7.3 at present to 1.0 per 1,000 under the proposed discharge regime. It should be noted that the risk to swimmers at The Cliffs will be lower than at Wardells Bridge because the effluent at

The Cliffs is further diluted by the Waingawa River and there will be some pathogen die-off on the way.

Examination of the risks to recreational water users, as depicted by the mean risks in the various scenarios, illuminates several features of this analysis. First, the critical pathogen in all scenarios is adenovirus. Second, in terms of the contribution to risk, direct river discharge > pond leakage > land (irrigated) discharge. Third, risks tend to be lowest at lower river flows when no direct discharge occurs.

As the adenoviruses tested in the effluent were human in origin, this means that the pathogen imparting the greatest risk is of human origin. Given that no significant point sources of human faeces are known to occur in the Ruamahanga River upstream of Masterton then there is little likelihood that significant concentrations of human adenoviruses will be there either. This means that the entire risk of adenovirus infection can be ascribed to the Masterton WWTP and this risk will not be added to by adenoviruses already in the river.

Direct discharge to the river is the discharge route that results in the greatest risk.

Pond leakage is estimated to pose a greater risk than land discharge. However, this may be an artefact of the model, which assumes no filtration of micro-organisms as the effluent passes through the floor of the pond. As previously stated, this conservative assumption is necessary given the lack of knowledge about the degree of filtration and is in accordance with the precautionary principle.

Under the present consent, all the effluent is discharge directly to the river via Makoura Stream. With no regulation on the timing of effluent flows, the risk to river users would be greatest at low river flows when effluent dilution would be at its lowest. Discharging more effluent at times of high river flows reduces the risk in two ways. Greater dilution is achieved at flows in excess of 36 $m^3$/sec, when the effluent dilution will exceed 1:30. However, the impact at lower river flows will be lessened when river levels are rising after rain events – this is when river water quality is at its poorest. Also, human exposures are lower at higher flows because most aquatic recreational activity occurs at lower flows.

The estimated risks to river users from pathogens in the effluent associated with the scenarios summarised in Table 24 show that none exceed eight infections per thousand. The highest estimate of infection risk for the present situation at below-median flows is 7.3/1,000. The level of risk for all post-upgrade scenarios would have been considered to be acceptable under the 1999 Recreational Water Standards for fresh waters and falls below the risk associated with the alert level under the 2003 Recreational Water Standards. In comparison, the estimated risks associated with swimming at the lower river flows post-upgrade are about 1/1,000 at Wardells Bridge and lower at The Cliffs.

The above scenarios will underestimate the risk to river users in the event of a significant increase in effluent pathogen concentration. There are two situations that may cause this to occur: increased influent pathogen concentration and reduced treatment efficiency.

Large changes in the concentration of pathogens in sewage influent are only likely in the event of a widespread outbreak of infectious disease in Masterton. In such an event perhaps a 100-fold increase in the concentration of the pathogen causing the outbreak could occur (Dahling *et al*., 1989). An outbreak of such magnitude would

be rare but ought to be apparent to the public health services. In the event of such an outbreak, it would be wise to advise the public against recreational water activities in the river until either the situation has abated or additional treatment can be implemented. However, it is feasible that smaller outbreaks, which may result in perhaps a tenfold increase in the concentration of the causal pathogen, may occur without being detected by the health services.

Reduced sewage treatment occurs from time to time in most wastewater treatment plants, mainly caused by equipment failure or reduced retention times associated with prolonged heavy rain. The magnitude of the resultant increase in pathogen concentration is unlikely to exceed tenfold. An even greater risk would occur should the oxidation pond be breached. However, this would require a catastrophic event such as a flood or earthquake of greater magnitude than has been recorded at Masterton. In any event the situation would be obvious to the treatment plant operator.

In the event of increased risk caused it is important that the public health service is notified promptly and protocols should be in place to ensure this happens. At such times the public health service can instigate additional health protection measures so that the public can be notified and thus protected until the problem is resolved.

### 4.3.3 Predicted Health Risk from Drinking-Water

The population that are potentially affected by contamination of their drinking-water supply are those people living in the vicinity of the WWTP who are on bore water supplies. Contaminants can enter the groundwater aquifer via the river, pond leakage and via border dyke irrigation of the effluent disposal field adjacent to the WWTP. The rate of entry of contaminants to the aquifer was modelled for each of these sources as previously described. A risk assessment would be made using the dilution within the aquifer and travel time to the closest drinking-water well, the removal and decay rate of each pathogen and an estimate of the amount of water consumed. This risk assessment would be carried out for each pathogen on the basis of the total combined concentration from each contaminant source. However, it was not necessary to extrapolate from these data because the modelling carried out by PDP indicated that the groundwater flows of the bores from which drinking-water is extracted are all up-gradient of the oxidation pond and the effluent disposal area and so are not impacted by the effluent.

### 4.3.4 Predicted Health Risk from Shellfish Consumption

The closest downstream location where shellfish are likely to be gathered that may be impacted by contaminants in the Masterton WWTP effluent is Lake Onoke, which is some 98 km downstream of Masterton. Between Masterton and Lake Onoke there are several major point sources of pollution including municipal wastewater from Martinborough, which is in much closer proximity but has a smaller population. In addition a considerable area of the lower Ruamahanga catchment is used for intensive livestock farming and is therefore likely to be affected by a large amount of faecal pollution from non-point sources. Consequently it is considered inappropriate to carry out a quantitative risk assessment when the majority of the microbial load emanates from sources downstream of the Masterton WWTP.

## 4.4 CHEMICAL RISK ASSESSMENT – METHODS AND ASSUMPTIONS

### 4.4.1 Impact sites

The sites relevant to the chemical risk assessment are identical to those discussed in the microbiological risk assessment described previously.

### 4.4.2 Chemical Hazards

An assessment of the chemical hazards in the effluent was made by BCHF. The chemicals can be grouped into the following categories:

- heavy metals -
- Polycyclic aromatic hydrocarbons (PAHs)
- Semi-volatile organic compounds (primarily PAHs, plasticisers, pesticides and phenols)
- Volatile organic compounds (primarily halogenated compounds)

### 4.4.3 Chemical Quality of the Effluent

Chemical analysis was carried out on a sample of pond effluent sampled on 6 December 2004, the results of which are shown in Appendix 6.

An algal bloom occurred in the Masterton WWTP oxidation ponds in 2005 during late summer that caused a visible plume in the Ruamahanga River. As a consequence the concentrations of algal cells and the algal toxin microcystin in pond effluent were monitored in March and April 2005. These data are presented in Appendix 7.

The concentrations of algal cells and microcystin in the oxidation pond were modelled using the @Risk software. The summary statistics and best-fit distributions are shown in the following table.

**Table 25 Summary statistics and best-fit distributions of algae and microcystin in Masterton oxidation pond (March-April 2005)**

| Variable | Units | n | Min. | Max. | Median | Geometric Mean |
|---|---|---|---|---|---|---|
| Algal cells | cells/mL | 4 | 748,536 | 4,204,136 | 1,368,598 | 1,546,075 |
| Microcystin | *u*g/L | 6 | 0.76 | 17.3 | 1.595 | 2.07 |
| | **Distribution** | | **μ** | **λ** | **shift** | |
| Algal cells | Inverse Gauss | | 1,753,738 | 1,975,688 | -241,516 | |
| Microcystin | Inverse Gauss | | 3.4352 | 0.52541 | 0.63977 | |

### 4.4.4 Dilution / Dispersion

As discussed in the analogous section of the microbiological assessment, treated wastewater is presently discharged via a pipe into Makoura Stream. However, the intent is to discharge treated wastewater via three routes: direct discharge into the Ruamahanga River, land discharge by means of border dyke irrigation, depending on river conditions and unintentional leakage from the oxidation ponds. However, the losses of chemicals through land discharge have only been modelled for nitrate and phosphate, which may not be representative of the aforementioned range of chemical hazards. Consequently, the risk assessment is made on the basis that discharge is made directly to the Ruamahanga River, which follows the precautionary approach.

#### *4.4.4.1 Direct discharge to the Ruamahanga River*

As discussed previously, it is proposed that direct discharge into the Ruamahanga River will only occur above the median flow when the dilution will be greater and recreational use minimal. The concentration of chemicals at the impact areas emanating from the direct river discharge is influenced only by the dilution of the effluent by the river. The minimum dilution of treated effluent in the Ruamahanga River is proposed to be 1:30. The same approach to modelling is used as described in the microbiological risk assessment.

### 4.4.5 Chemical Exposure Pathways

As with microbial contaminants, the potential exposure routes are consumption of drinking-water sourced from groundwater, consumption of mahinga kai and ingestion and inhalation during aquatic recreational pursuits. In addition, some chemicals can be absorbed through the skin, so this route must also be considered in a chemical risk assessment.

### 4.4.6 Chemical Water Quality Guidelines

The following guidelines and standards are pertinent to chemical risk assessment in New Zealand:

- The chemical MAVs for drinking-water are given in Tables 2.2 and 2.3 of the Drinking-water Standards for New Zealand 2005.
- The chemical MAVs for recreational water are given in Tables 5.2.3 and 5.2.4 of the ANZECC Guidelines 2000.

- The ANZECC Guidelines 2000 also refer to a limit for algae in water, above which recreational contact is not recommended. This limit has been set at 15,000 - 20,000 algal cells/mL.
- The WHO Guidelines for safe recreational waters use algal cell counts of 100,000 algal cells/mL, above which there is a moderate probability of adverse health effects. A microcystin concentration of 20 µg/L in the upper 4 m of the water column is tentatively proposed. The guidelines also note that a high probability of adverse health effects can be expected in the event of contact with algal scums.

### 4.4.7 Food Chemical Standards

The maximum acceptable values (MAVs) for the chemicals that are relevant to exposure via consumption of mahinga kai were obtained from the Australia New Zealand Food Standards Code (FSANZ, 2002).

## 4.5 CHEMICAL HEALTH RISK ASSESSMENT

With the exception of algal toxin, most of the chemicals tested fall below the limit of detection. Overall, the results of this analysis indicate that the effluent does not contain high concentrations of the chemicals tested. It is not possible to deduce from a single sample the usual chemical content of the effluent. However, in the absence of more comprehensive data, the chemical risk assessment was made on the basis that these values were typical of the Masterton WWTP effluent.

The results of the chemical analyses are not relevant to all exposure routes. Consequently, separate consideration has been given to exposures via drinking-water, recreational water and mahinga kai.

### 4.5.1 Drinking-water

Drinking-water exposures with public health consequences can be either transient or long-term. Most chemical[14] exposures only manifest following prolonged consumption of contaminated drinking-water and the resultant illness is generally chronic. Consequently, this aspect of the chemical risk assessments deals with long-term exposures to chemical hazards.

The results of chemical analyses of pond effluent collected on 6 December 2004 and microcystin during an algal bloom in the oxidation pond during 2005 form the basis of the risk assessment for chemical hazards in drinking-water. The drinking-water risk assessment is made on the basis of the chemical maximum allowable values (MAVs) as listed in the Drinking-Water Standards for New Zealand:2005 (DWSNZ:2005). The results of the chemical analyses and corresponding drinking-water MAVs that were tested in the pond effluent are presented in Appendix 8. From this it can be seen that none of the MAVs have been exceeded. However, it should be noted that the limits of detection were greater than the MAVs for four chemicals (aldrin + dieldrin, heptachlor and its epoxide, vinyl chloride and hexachlorobenzene). Nevertheless, when the designed minimum 30-fold dilution of effluent by the river was taken into account, none of these four chemicals would have exceeded their

[14] Nitrate, which can have acute effect, is an exception to this.

MAV. There were also 94 chemicals for which drinking-water MAVs exist that were not included in the analysis.

It is not necessary to extrapolate from these data, however, because the modelling carried out by PDP indicates that the groundwater flows of the bores from which drinking-water is extracted are up-gradient of the oxidation pond and the effluent disposal area and so are not impacted by the effluent.

### 4.5.2 Recreational-water

Chemical assessment is made using the guideline values of the chemicals listed in Tables 5.2.3 and 5.2.4 of the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC 2000). The results of the chemical analyses and corresponding ANZECC Guideline values that were tested in the pond effluent are presented in Appendix 9. From this it can be seen that none of the MAVs have been exceeded. However, the limits of detection were greater than the MAVs for two chemicals (benzo(α)pyrene and 1,1-dichloroethene). Nevertheless, when the designed minimum 30-fold dilution of effluent by the river was taken into account, neither of these chemicals would have exceeded the ANZECC Guideline value for recreational water. There were also 71 chemicals for which ANZECC Guideline values exist that were not included in the analysis.

The greatest concentration of microcystin measured in the oxidation pond was 17.3 µg/L. This would be equivalent to a concentration of 0.58 µg/L in the river following the minimum effluent dilution of 1/30. This falls well below the tentative threshold level of 20 µg/L referred to in the WHO guidelines (WHO, 2003)

### 4.5.3 Mahinga kai

The broad types of mahinga kai that occur in rivers are fish, shellfish and edible aquatic plants. Of these, only fish are collected from this location. If there is a problem of chemical contamination in mahinga kai caused by chemicals discharged from the WWTP then it will first manifest in predatory fish. Acute health effects resulting from the ingestion of contaminated mahinga kai is most unlikely as the likelihood of the effluent containing high concentrations of chemical hazard is minimal. If a health risk exists to consumers of mahinga kai it would result from bioaccumulation over a long period of time. For this reason is usual to investigate organisms at the top of the food chain when examining for accumulated toxins. The obvious examples in the Ruamahanga River are trout and eels.

However, measurement of chemicals that can bioaccumulate in mahinga kai raises the following conundrum. None of the organics tested in the pond effluent were above the detection limit. If the samples tested were typical of the effluent quality then none of the chemicals tested are likely to be of concern. However, some of these will bioaccumulate, and the greatest concentrations would occur in old trout and eels, which would have been exposed longest and are at the top of the food chain.

## 4.6 DISCUSSION

This assessment has addressed the potential risks resulting from exposure to chemicals and pathogens emanating from the discharge of effluent from the Masterton WWTP into the Ruamahanga River, such exposure being via accidental ingestion/inhalation during aquatic recreational activities and consumption of drinking-water and mahinga kai.

There is no risk via the drinking-water route. There is no tangible risk of infection via consumption of mahinga kai, nor of chemical toxicity following recreational water contact.

It is not possible to reliably assess the risk from chemicals that may bioaccumulate in mahinga kai harvested in the river due to the limited amount of data available. However, given the nature of the WWTP catchment and the industries within it, it is likely to be a small risk.

The main risk is the potential for waterborne infectious disease associated with recreational activity in the Ruamahanga River downstream of the effluent discharge.

An ongoing problem associated with risk assessment is how to contextualise the risks to the various stakeholders.

The usual way of assessing the risks to recreational water users is to compare them with risks associated with recreational water use as per the Recreational Water Quality Guidelines. The New Zealand guidelines measure health risks from recreational exposure to freshwater in terms of the risk of *Campylobacter* infection, with the alert mode being triggered at an infection rate of 1% (*i.e.* 10/1,000). However, these are disease risks whereas the risk outcome used in this risk assessment is infection, which may or may not manifest as disease. Nevertheless, a risk of infection that is lower than 10/1,000 is generally considered acceptable. The pathogen that consistently gave rise to the highest risk was adenovirus. Consequently, the risk of adenovirus infection was used to assess the risk via recreational contact.

The risk assessment that best reflects the overall situation predicts that under the present direct discharge regime 7.3 persons per 1,000 become infected[15] from recreational activity at Wardells Bridge with water contaminated by effluent from the Masterton WWTP discharge at below-median river flows. However, the risk of infection post-upgrade is expected to fall below one person per 1,000 at The Cliffs for below median river flows in summer. This is a conservative estimate because of the precautionary approach used regarding pond leakage. This is well below the alert limit in the Recreational Water Quality Guidelines.

In the rare event of a community-wide infectious disease outbreak or a breakdown in the sewage treatment process at a time when direct river discharge is occurring, the risk to river users could become unacceptable. In such an event, additional public health measures such as restricting aquatic recreation should be taken to protect the public against waterborne disease and clearance monitoring to demonstrate that the hazard has abated. It is noted that after the upgrade has taken place direct discharge

[15] The risk will increase as the river flow decreases and will be higher for those using the right side of the river where most of the plume occurs at present.

in the summer will only occur at river flows > median, when little contact recreation is expected.

It should be recognised that risk assessments are only as good as the model and can go awry if incorrect assumptions or poor data are used to derive the model. Consequently, some effort has been made to challenge this model.

One potential weakness is the quantity of the pathogen concentration data from which the frequency distributions were derived. The number of effluent pathogen results available from which to derive reliable distributions was quite small. Given that the *E. coli* concentrations were slightly higher in the Bromley effluent (upon which the model was based), as were the pathogen concentrations, we consider the pathogen distributions in the model to be appropriate and the best available. As a precaution against under-estimating the risk the pathogen concentrations used in the risk models these concentrations were multiplied by a factor of ten to account for possible differences in pathogen concentrations in the Bromley and Masterton effluent.

A number of assumptions used in this risk assessment warrant further attention.

There remains a paucity of effluent monitoring data from the existing WWTPs. This means that this risk assessment is based on distributions of chemical and pathogen concentrations that may not be sufficiently robust. This may result in inaccuracies in the risk assessment. This potential deficiency can only be addressed by further effluent monitoring. It is recommended that a programme of effluent testing be established for adenovirus, the pathogen most critical to this risk assessment.

No account was taken of the filtration effect of pathogens during the passage of effluent through the bottom of the oxidation ponds during pond leakage or within the groundwater. It is likely that the removal of microorganisms by these processes would be considerable[16]. However, their omission would result in an overestimation of the risk so is not critical to the outcome of this assessment.

The magnitude of the reduction in microorganisms achieved by land discharge was largely derived from modelling. It would be prudent to conduct post-upgrade monitoring to check the validity of the modelling assumptions.

[16] By following the precautionary (*i.e.* no pathogens retained in the sediment during pond leakage) approach in this assessment the risk of infection at Wardells Bridge was 1/1,000. The risk falls to well below 1/1,000 if a 1-log removal of pathogens occurs during pond leakage.

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## APPENDIX 1 MASTERTON TRADE WASTE REGISTER

| Premise | Type | Class | Waste Description |
|---|---|---|---|
| Animal Hospital | Animals | Small | animal waste products, detergents |
| Chapel St Veterinary Centre | Animals | Small | animal waste products, detergents |
| Masterton Medical | Medical | Small | Antibiotics/narcotics |
| Kuripuni Sports Bar | Hotel/Motels | Medium | beer/detergent direct to sewer |
| Sliderite Manufacturing Ltd | Industrial | Medium | Caustic/salt/soda ash/dyes |
| Wairarapa Powder Coating | Industrial | Medium | Chromates/acids diluted |
| Copthorne Resort Solway Park | Hotel/Motels | Small | Commercial/fats/detergants |
| Qualchem Ltd | Industrial | Small | Detergents to trap to sewer |
| Wakefield Radiology | Medical | Small | developer/fixer/silver |
| Makoura College | School | Small | domestic/pool backwash/lab chemicals |
| Masterton Hospital | Medical | Large | Facilities changed to new Hospital |
| Homestead Tavern | Hotel/Motels | Medium | Fats/detergent to grease trap |
| Golden Shears Tavern | Restaurant | Small | Fats/detergent to grease trap |
| Anderson Meats | Butchers | Small | fats/detergents GT |
| Neate CL Ltd | Butchers | Small | fats/detergents GT |
| Solway Butchery | Butchers | Small | fats/detergents GT |
| Kuripuni New World | Supermarkets | Medium | fats/oils/detergents |
| New World Church Street | Supermarkets | Medium | fats/oils/detergents |
| Woolworths | Supermarkets | Medium | fats/oils/detergents |
| Writeprice Food Barn | Supermarkets | Medium | fats/oils/detergents |
| David Dew Funeral Services Ltd | Funeral Director | Small | formaldehyde/body fluids to sewer |
| Wairarapa Funeral Services | Funeral Director | Small | formaldehyde/body fluids to sewer |
| Breadcraft | Bakers | Large | grease/fat |
| Kuripuni Hot Bread shop | Bakers | Small | grease/fat no trap |
| Lansdowne Sammies | Bakers | Small | grease/fat no trap |
| Masterton Bakery & Coffee Shop | Bakers | Small | grease/fat no trap |
| Solway Pie shop | Bakers | Small | grease/fat no trap |
| Ten o'clock Cookie Bakery & Café | Bakers | Small | grease/fat no trap |
| Wairarapa Bakery | Bakers | Small | grease/fat no trap |
| A1 takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Baldees Café | Restaurant | Small | grease/oils/hot water >50° |
| Basils Fish Supply | Restaurant | Small | grease/oils/hot water >50° |
| Burridges Restaurant | Restaurant | Small | grease/oils/hot water >50° |
| Café Arakai | Restaurant | Small | grease/oils/hot water >50° |
| Café Cecile | Restaurant | Small | grease/oils/hot water >50° |
| Café de corale | Restaurant | Small | grease/oils/hot water >50° |
| Café Solway | Restaurant | Small | grease/oils/hot water >50° |
| Café Strada | Restaurant | Small | grease/oils/hot water >50° |
| Chans Restaurant | Restaurant | Small | grease/oils/hot water >50° |
| Chriscelles - UCOL @ Wairarapa | Restaurant | Small | grease/oils/hot water >50° |
| Cobb & Co | Restaurant | Medium | grease/oils/hot water >50° |
| Crème on Top | Restaurant | Small | grease/oils/hot water >50° |
| Crying Onion takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Essential Foods | Restaurant | Small | grease/oils/hot water >50° |
| Express Lunchbar | Restaurant | Small | grease/oils/hot water >50° |
| Food for Thought | Restaurant | Small | grease/oils/hot water >50° |
| Four Seasons Takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Hong Kong takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Java House | Restaurant | Small | grease/oils/hot water >50° |
| Joxer Daleys | Restaurant | Small | grease/oils/hot water >50° |
| KFC | Restaurant | Medium | grease/oils/hot water >50° |
| Kuripuni Takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Macs Fresh Fish & Chips | Restaurant | Small | grease/oils/hot water >50° |
| Makoura College Canteen | Restaurant | Small | grease/oils/hot water >50° |
| **Premise** | **Type** | **Class** | **Waste Description** |

| Masterton Club | Restaurant | Small | grease/oils/hot water >50° |
|---|---|---|---|
| Masterton Cosmopolitan Club | Restaurant | Medium | grease/oils/hot water >50° |
| McDonalds | Restaurant | Medium | grease/oils/hot water >50° |
| Mollies Cafe' | Restaurant | Small | grease/oils/hot water >50° |
| Mr Chips Chinese Takeaway | Restaurant | Small | grease/oils/hot water >50° |
| Pizza Hut | Restaurant | Medium | grease/oils/hot water >50° |
| Rumblin Tum Takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Rutenes takeaways | Restaurant | Small | grease/oils/hot water >50° |
| Sanctum Restaurant | Restaurant | Small | grease/oils/hot water >50° |
| Seasons restaurant on Solstone | Restaurant | Small | grease/oils/hot water >50° |
| Stellar bar & restaurant | Restaurant | Small | grease/oils/hot water >50° |
| The Green Frog | Restaurant | Small | grease/oils/hot water >50° |
| The Horse & Hound Café & Bar | Restaurant | Small | grease/oils/hot water >50° |
| The Perky Pukeko | Restaurant | Small | grease/oils/hot water >50° |
| Tulloch Lodge café restaurant & bar | Restaurant | Small | grease/oils/hot water >50° |
| Wairarapa Services & Citizens Club | Restaurant | Small | grease/oils/hot water >50° |
| Waldorf Restaurant | Restaurant | Small | grease/oils/hot water >50° |
| Café Trocadero | Restaurant | Small | grease/oils/hot water >50°/ grease convertor |
| MINT | Restaurant | Small | grease/oils/hot water >50°/ grease convertor |
| Kountry Kafe | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Lansdowne House | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Lunch Box | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Masterton Golf Club | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Masterton Kebab House | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Plaza India Bistro & Tandoor Ltd | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Russian Jacks Café | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| True Blue Café 2002 | Restaurant | Small | grease/oils/hot water >50°/No grease trap |
| Hospital Laboratory | Scientific | Medium | grease/oils/lab chemical/commercial |
| Solway College | School | Small | grease/oils/lab chemicals/commercial/pool backwash |
| St Mathews Collegiate School | School | Small | grease/oils/lab chemicals/commercial/pool backwash |
| UCOL | School | Small | grease/oils/lab chemicals/commercial/pool backwash |
| Wairarapa College | School | Small | grease/oils/lab chemicals/commercial/pool backwash |
| Chanel College | School | Small | grease/oils/lab chemicals/domestic |
| Abbeyfield House for Elederly People | Rest Homes | Small | Grease/oils/large domestic |
| Aversham House | Rest Homes | Small | Grease/oils/large domestic |
| Cornwall Rest Homes | Rest Homes | Small | Grease/oils/large domestic |
| Glenwood Hospital | Rest Homes | Small | Grease/oils/large domestic |
| Kandahar Elderly Care | Rest Homes | Small | Grease/oils/large domestic |
| Landsdowne Court | Rest Homes | Small | Grease/oils/large domestic |
| Lyndale Rest Homes | Rest Homes | Small | Grease/oils/large domestic |
| Hansells (NZ) Ltd | Industrial | Large | Hot wash/sugars/colourants |
| Kuripuni Medical Centre | Medical | Small | Hotwater >50° autoclave |
| Pride Drycleaners Ltd | Laundromats/Drycleaners | Small | Hotwater/detergent >50°C |
| Taylors Dry cleaners | Laundromats/Drycleaners | Small | Hotwater/detergent >50°C |
| Wairarapa Laundry | Laundromats/Drycleaners | Small | Hotwater/detergent >50°C |
| Lambert Engineers Ltd | Engineers | Small | Hydrocarbons |
| Hireworld | Industrial | Small | Hydrocarbons |
| Dans Mufflers & Auto shop | Automotive repair | Small | Hydrocarbons/dangerous goods |
| Fagan Motors Ltd | Automotive repair | Medium | Hydrocarbons/dangerous goods |
| Fagan Motors Ltd | Automotive repair | Medium | Hydrocarbons/dangerous goods |
| Herrieck Richard Transport repairs | Automotive repair | Medium | Hydrocarbons/dangerous goods |
| Kuripuni Auto Services | Automotive repair | Small | Hydrocarbons/dangerous goods |
| Majestic Motors | Automotive repair | Small | Hydrocarbons/dangerous goods |
| McKenzie Motors | Automotive repair | Small | Hydrocarbons/dangerous goods |
| Solway Auto Services | Automotive repair | Small | Hydrocarbons/dangerous goods |
| Southey Honda & Nissan | Automotive repair | Small | Hydrocarbons/dangerous goods |
| TRC Toyota | Automotive repair | Small | Hydrocarbons/dangerous goods |
| Tunnell Tyres & Garage Ltd | Automotive repair | Small | Hydrocarbons/dangerous goods |
| **Premise** | **Type** | **Class** | **Waste Description** |

| | | | |
|---|---|---|---|
| Waggs of Masterton | Automotive repair | Medium | Hydrocarbons/dangerous goods |
| Wairarapa Engine Rebuilders | Automotive repair | Small | Hydrocarbons/dangerous goods |
| Juken Nissho Ltd | Industrial | Large | Large domestic |
| Masterton Motor Lodge | Hotel/Motels | Medium | Large domestic/fats, grease/oils/hot water >50° |
| Metlifecare | Rest Homes | Medium | Large domestic/grease/oils |
| Langlands Motorcycles | Automotive repair | Small | oil/detergents/sediment |
| Masterton Motorcycles | Automotive repair | Small | oil/detergents/sediment |
| Paul Croft Motors | Automotive repair | Small | oil/detergents/sediment |
| Pope David Transport | Automotive repair | Medium | oil/detergents/sediment |
| Tranzit Coachlines | Automotive repair | Medium | oil/detergents/sediment |
| Faulknors | Service Stations | Medium | oil/detergents/sediment |
| Gull Petroleum (NZ) Ltd | Service Stations | Medium | oil/detergents/sediment |
| Kuripuni Service Station | Service Stations | Medium | oil/detergents/sediment |
| Nicks Auto Services | Service Stations | Medium | oil/detergents/sediment |
| Parkview Motors Ltd | Service Stations | Medium | oil/detergents/sediment |
| Shell Chapel St | Service Stations | Medium | oil/detergents/sediment |
| Solway Service Station (2000) Ltd | Service Stations | Medium | oil/detergents/sediment |
| Toms Auto Services | Service Stations | Medium | oil/detergents/sediment |
| Western Automart (1992) Ltd | Service Stations | Medium | oil/detergents/sediment |
| Carshine | Vehicle Washing | Small | oil/detergents/sediment |
| Feron Logging | Vehicle Washing | Large | oil/detergents/sediment |
| Superior Car Valet | Vehicle Washing | Small | oil/detergents/sediment |
| Genesis Energy Recreation Centre | Miscellaneous | Large | Pool backwash |
| Selina Sutherland Hospital | Medical | Large | Same as Masterton Hospital |
| Combined Products 94 | Industrial | Medium | Sea food/washdown to sewer |
| Greenlees Print | Printers | Medium | Silver/devolpers/cleaners |
| Printcraft '81 Ltd | Printers | Medium | Silver/devolpers/cleaners |
| Webstar | Printers | Large | Silver/devolpers/cleaners |
| Kodak Express | Photo labs | Small | small amounts of developer. No Ag recovery |
| Wairarapa Camera Services Ltd | Photo labs | Small | small amounts of developer. Ag recovery |
| The Doctors | Medical | Small | Small amounts of waste |
| The Olive Press Ltd | Industrial | Medium | Starch-laiden slurry |
| Farmers Transport | Fertiliser | Large | washdown to traps & sewer |
| Astrolite Motor Bodies Ltd | Industrial | Large | Zinc/acid |

## APPENDIX 2 GWRC MONITORING SITES IN THE RUAMAHANGA CATCHMENT

| Site | Southing | Easting | Period | Tested |
|---|---|---|---|---|
| ***Recreational Sites (summer monitoring only)*** | | | | |
| Ruamahanga @ Double Bridges | 2734363 | 6033494 | Nov 01 – present | *E. coli* |
| Ruamahanga @ Te Ore Ore | 2735543 | 6024638 | Nov 01 – present | *E. coli* |
| Ruamahanga @ The Cliffs | 2731492 | 6013902 | Nov 01 – present | *E. coli* |
| Ruamahanga @ Kokotau | 2725774 | 6008913 | Nov 01 – present | *E. coli* |
| Ruamahanga @ Morrisons Bush | 2718938 | 6002829 | Nov 01 – present | *E. coli* |
| Ruamahanga @ Waihenga | 2714631 | 5998182 | Nov 01 – present | *E. coli* |
| Waingawa @ Kaituna | 2720341 | 6032867 | Nov 01 – present | *E. coli* |
| Waingawa @ South Road | 2739565 | 6022599 | Nov 01 – present | *E. coli* |
| Waiohine @ SH2 | 2719683 | 6013431 | Nov 01 – present | *E. coli* |
| ***State of the Environment Sites*** | | | | |
| Ruamahanga @ McLays | 2727428 | 6047462 | Sep 03 - present | FC, *E. coli* |
| Ruamahanga @ Te Ore Ore | 2735588 | 6024740 | Feb 97 – present | FC, *E. coli* |
| Ruamahanga @ Gladstone Bridge | 2731125 | 6011816 | Feb 97 – present | FC, *E. coli* |
| Ruamahanga @ Pukio | 2707855 | 5992730 | Sep 03 – present | FC, *E. coli* |
| Ruamahanga @ Mt Bruce | 2730943 | 6045091 | Feb 97 – Jun 03 | FC, *E. coli* |
| Ruamahanga @ Double Bridges | 2734400 | 6033500 | Feb 97 – Jun 03 | FC, *E. coli* |
| Ruamahanga @ Waihenga Bridge | 2714692 | 5998188 | Feb 97 – Jun 03 | FC, *E. coli* |
| Waingawa @ South Rd | 2730731 | 6022370 | Feb 97 – present | FC, *E. coli* |
| Waingawa @ Gorge | 2711907 | 6017714 | Aug 94 – present | FC, *E. coli* |
| Waiohine @ Bicknells | 2721009 | 6009379 | Feb 97 – present | FC, *E. coli* |

## APPENDIX 3 RESULTS OF FMRP SURVEY OF THE RUAMAHANGA RIVER AT DOUBLE BRIDGES

| Sampling Date | *E. coli* | *C. perfringens* spores | Somatic coliphage | FRNA phage | *Salmonella* | *Campylobacter* | Enterovirus RT-PCR | Adenovirus PCR | *Giardia* APHA/IMS | *Cryptosporidium* APHA/IMS |
|---|---|---|---|---|---|---|---|---|---|---|
| QA | (MPN/100mL) | (CFU/100mL) | (PFU/100mL) | (PFU/100mL) | (MPN/litre) | (MPN/100mL) | (P/A in 1L) | (P/A in 1L) | (cysts/100L) | (oocysts/100L) |
| 4-May-98 | 120 | 2 | 3 | <1 | <1 | 1.8 | - | - | 9.7 | <1 |
| 4-May-98 | 22 | 0.9 | 2 | <1 | <1 | 4.6 | - | - | 7.2 | <1 |
| 11-May-98 | 23 | 4.5 | 2 | <1 | <1 | 0.6 | - | - | 2.4 | <1 |
| 11-May-98 | 21 | 4.5 | 0.4 | <1 | 1 | 0.6 | - | - | 12.3 | <1 |
| 25-May-98 | 65 | 0.9 | 10 | <1 | <1 | >110 | - | - | 3.5 | <1 |
| 25-May-98 | 31.3 | 0.9 | <1 | <1 | <1 | 4.6 | - | - | 2.5 | <1 |
| 2-Jun-98 | 48.8 | 0.9 | 21 | 3 | <1 | 9.5 | + | - | <1 | <1 |
| 2-Jun-98 | 178.9 | 6.8 | 12 | 14 | <1 | 46.2 | + | - | <1 | <1 |
| 15-Jun-98 | 137.4 | 0.9 | 6 | <1 | <1 | 109.9 | - | - | 1.1 | <1 |
| 15-Jun-98 | 73.8 | 2 | 8 | <1 | 20 | 150 | - | - | 2.3 | <1 |
| 22-Jun-98 | 47.1 | 0.9 | 5 | 10 | <1 | 7.8 | - | - | <1 | <1 |
| 22-Jun-98 | 22.6 | 1.8 | 1 | 1 | <1 | 1.8 | - | - | <1 | <1 |
| 6-Jul-98 | 56.5 | <1 | 1 | <1 | <1 | 0.6 | - | - | <1 | 4 |
| 6-Jul-98 | 30.5 | <1 | 2 | <1 | <1 | 0.6 | - | - | <1 | 2 |
| 13-Jul-98 | 50.4 | 15 | 1 | <1 | 170 | 4.6 | - | - | <1 | <1 |
| 13-Jul-98 | 17.5 | 8 | <1 | 1 | 10 | 0.6 | + | - | <1 | <1 |
| 27-Jul-98 | 81.3 | 1 | 9 | <1 | 10 | 24 | - | - | 4.9 | 14 |
| 27-Jul-98 | 238.2 | 1 | 1 | <1 | 20 | 109.9 | - | - | 6.0 | <1 |
| 3-Aug-98 | 18.5 | 2 | 2 | <1 | <1 | 4.6 | - | - | <1 | <1 |
| 3-Aug-98 | 8.6 | <1 | <1 | <1 | <1 | 1.3 | - | - | <1 | <1 |
| 18-Jan-99 | 920.8 | <1 | 5 | <1 | <1.2 | <0.3 | + | - | <1 | <1 |
| 11-Jan-99 | 920.8 | <1 | 68 | <1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 26-Jan-99 | 488.4 | <1 | 1 | <1 | <1.2 | 0.6 | - | - | <1 | <1 |
| 8-Feb-99 | 137.6 | <1 | 5 | <1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 22-Feb-99 | 177 | <1 | 12 | 2 | <1.2 | <0.3 | - | + | <1 | <1 |

| Sampling Date | *E. coli* | *C. perfringens* spores | Somatic coliphage | FRNA phage | *Salmonella* | *Campylobacter* | Enterovirus RT-PCR | Adenovirus PCR | *Giardia* APHA/IMS | *Cryptosporidium* APHA/IMS |
|---|---|---|---|---|---|---|---|---|---|---|
| QA | (MPN/100mL) | (CFU/100mL) | (PFU/100mL) | (PFU/100mL) | (MPN/litre) | (MPN/100mL) | (P/A in 1L) | (P/A in 1L) | (cysts/100L) | (oocysts/100L) |
| 8-Mar-99 | 461.1 | <1 | 11 | <1 | <1.2 | 1.2 | + | + | <1 | <1 |
| 22-Mar-99 | 343.3 | 1 | 53 | 2 | <1.2 | >110 | - | + | 2 | <1 |
| 6-Apr-99 | 307.6 | <1 | 75 | <1 | <1.2 | >110 | - | + | <1 | <1 |
| 19-Apr-99 | 119.1 | <1 | 81 | <1 | <1.2 | >110 | - | - | <1 | <1 |
| 3-May-99 | 307.6 | <1 | 59 | 23 | <1.2 | <0.3 | - | - | <1 | <1 |
| 17-May-99 | 152.9 | <1 | 77 | 7 | <1.2 | 0.6 | - | - | <1 | <1 |
| 31-May-99 | 59.8 | 1 | 3 | <1 | <1.2 | 3.6 | - | - | <1 | <1 |
| 14-Jun-99 | 90.6 | <1 | 3 | <1 | <1.2 | 23.7 | - | - | <1 | <1 |
| 28-Jun-99 | 36.4 | <1 | 5 | <1 | <1.2 | 1.2 | - | - | <1 | <1 |
| 9-Aug-99 | 73.8 | <1 | 8 | 2 | <1.2 | 1.8 | + | + | <1 | <1 |
| 23-Aug-99 | 17.1 | 4 | 6 | <1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 6-Sep-99 | 39.3 | 1 | 17 | <1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 20-Sep-99 | 62.7 | 2 | 1 | 1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 4-Oct-99 | 32.3 | <1 | 17 | <1 | <1.2 | <0.3 | - | + | <1 | <1 |
| 18-Oct-99 | 18.7 | <1 | 2 | <1 | <1.2 | 0.6 | + | + | <1 | <1 |
| 1-Nov-99 | 25 | <1 | 2 | <1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 15-Nov-99 | 41.9 | <1 | 3 | 3 | <1.2 | <0.3 | - | - | <1 | <1 |
| 29-Nov-99 | 2419.17 | 1 | 308 | 13 | <1.2 | 9 | - | - | <1 | <1 |
| 13-Dec-99 | 166.9 | 1 | 52 | 2 | <1.2 | 0.6 | - | + | <1 | <1 |
| 5-Jan-00 | 101.9 | 1 | 47 | <1 | <1.2 | 3.9 | + | - | <1 | <1 |
| 17-Jan-00 | 53 | <1 | 2 | <1 | <1.2 | <0.3 | - | - | <1 | <1 |
| 31-Jan-00 | 365.4 | <1 | 64 | <1 | <1.2 | <0.3 | + | - | <1 | <1 |
| 14-Feb-00 | 93.3 | 1 | 3 | <1 | <1.2 | 0.3 | - | + | <1 | <1 |
| 28-Feb-00 | 187.2 | 1 | 2 | 1 | <1.2 | 0.3 | + | + | <1 | <1 |

## APPENDIX 4 BCHF SAMPLING DATA

| Date | | Sample No. | *E. coli* MPN/100mL | Somatic coliphage pfu/100mL | *Salmonella* MPN/100mL | *Campylobacter* MPN/100mL | Enterovirus pfu/L | Adenovirus $TCID_{50}$/L | *Giardia* cysts/10L | *Cryptosporidium* oocysts/10L |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Surface water samples** | | | | | | | | | |
| 5/10/2005 | Ruamahanga River | RUA1 | 1,300 | 650 | <0.3 | 0.9 | <1 | <1 | <1 | <1 |
| 5/10/2005 | Ruamahanga River | RUA2 | 2,600 | 1,110 | <0.3 | 1.5 | <1 | <1 | <1 | <1 |
| 11/10/2005 | Ruamahanga River | RUA1 | 360 | 160 | <0.3 | 2.3 | <1 | <1 | <1 | 1 |
| 11/10/2005 | Ruamahanga River | RUA2 | 610 | 290 | <0.3 | 9.3 | <1 | <1 | <1 | 3 |
| 17/10/2005 | Ruamahanga River | RUA1 | 130 | 60 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| 17/10/2005 | Ruamahanga River | RUA 7 | 800 | 91 | <0.3 | 110 | <1 | <1 | <1 | <1 |
| 17/10/2005 | Ruamahanga River | RUA2 | 290 | 120 | <0.3 | 24 | <1 | <1 | <1 | <1 |
| 17/10/2005 | Makoura Stream | MAK1 | 52 | 3,880 | <0.3 | <0.3 | <1 | <1 | <1 | 1 |
| 17/10/2005 | Makoura Stream | MAK2 | 720 | 1,130 | <0.3 | 24 | <1 | <1 | <1 | <1 |
| | **Groundwater samples** | | | | | | | | | |
| 6/10/2005 | g/w in effluent field | HB1 | <10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| 6/10/2005 | g/w in effluent field | HB3 | 10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| 6/10/2005 | g/w in effluent field | HB4 | <10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| 6/10/2005 | g/w in effluent field | HB6 | <10 | 20 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| 6/10/2005 | g/w in effluent field | HB11 | <10 | <1 | <0.3 | <0.3 | <1 | <1 | <1 | <1 |
| | **Pond effluent samples** | | | | | | | | cysts/L | oocysts/L |
| 5/10/2005 | Pond effluent | | 740 | 630 | <3 | <3 | <5 | <5 | <1 | <1 |
| 11/10/2005 | Pond effluent | | 410 | 80 | <0.3 | <3 | <5 | <5 | <1 | <1 |
| 17/10/2005 | Pond effluent | | 840 | 200 | 0.4 | <3 | <5 | <5 | <1 | <1 |
| | **Pond sludge samples** | | | | | | pfu/g | $TCID_{50}$/5g | cysts/100g | oocysts/100g |
| 17/10/2005 | pond 1 | | 82,000 | 11,100 | <18 | 2,300 | 0.5 | <1 | <1 | <1 |
| 17/10/2005 | pond 2 | | 7,800 | 2,500 | <18 | <18 | 0.5 | <1 | <1 | <1 |

## APPENDIX 5 MAP OF BORES IN THE VICINITY OF THE MASTERTON WWTP

## APPENDIX 6 RESULTS OF CHEMICAL ANALYSES FROM MASTERTON OXIDATION POND

# Hill Laboratories

RJ Hill Laboratories Limited

RECEIVED 09 NOV 2005

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**Client:** Beca Carter Hollings & Ferner Ltd
**Address:** P O Box 3942,
WELLINGTON
**Contact:** Barry Strong S Kerr

**Laboratory No:** 393966
**Date Registered:** 18/10/2005
**Date Completed:** 7/11/2005
**Page Number:** 1 of 11

**Amended Report:** *This is an amended report which replaces a report issued on the 27/10/2005. Following a query from the client the sampling date for samples 393966/7 – 9(PNK4926 – PNK4928) has been changed from '17/11/05' to '17/10/05'.*

**Client's Reference: Extra ex Beca Wtn**

***The results for the analyses you requested are as follows:***

**Sample Type: Environmental Solids, Sludge**

| Sample Name | Lab No | Dry Matter (g/100g as rcvd) |
|---|---|---|
| PNK4928 Pond 2 17/10/05 | 393966/9 | 5.9 |

**Volatile organic compounds (VOC)**

| Sample Name | PNK4928 Pond 2 17/10/05 |
|---|---|
| Lab No | 393966/9 |
| Units | (mg/kg dry wt) |
| Dichlorodifluoromethane | < 10 |
| Chloromethane | < 10 |
| Vinyl chloride | < 10 |
| Bromomethane | < 10 |
| Chloroethane | < 10 |
| Trichlorofluoromethane | < 10 |
| 1,1-Dichloroethene | < 10 |
| Carbon disulphide | < 100 |
| 1,1,2-Trichlorotrifluoroethane (Freon 113) | < 100 |
| Dichloromethane (Methylene chloride) | < 200 |
| trans-1,2-Dichloroethene | < 10 |
| 1,1-Dichloroethane | < 10 |
| 2-Butanone (MEK) | < 100 |
| cis-1,2-Dichloroethene | < 10 |
| 2,2-Dichloropropane | < 10 |
| Chloroform (Trichloromethane) | < 10 |
| 1,1,1-Trichloroethane | < 10 |

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised. The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

## APPENDIX 7 ALGAE AND MICROCYSTIN CONCENTRATIONS IN MASTERTON OXIDATION POND EFFLUENT

| Date | Algae (cells/mL) | Microcystin (µg/L) |
|---|---|---|
| 6 March 2005 | | 17.3 |
| 18 March 2005 | 1,608,196 | 0.76 |
| 21 March 2005 | 4,204,136 | 1.86 |
| 4 April 2005 | 1,164,000 | 1.2 |
| 12 April 2005 | 1,129,000 | 1.33 |
| 18 April 2005 | 748,536 | 2.0 |

## APPENDIX 8 CHEMICAL CONTENT OF MASTERTON WWTP EFFLUENT WITH CORRESPONDING MAVS AS LISTED IN THE DWSNZ:2005

| Chemical | Concentration in effluent (mg/L) | DWSNZ:2005 MAV (mg/L) | |
|---|---|---|---|
| arsenic | <0.001 | 0.01 | P |
| cadmium | <0.00005 | 0.004 | |
| chromium | <0.0005 | 0.05 | |
| copper | 0.0071 | 2 | |
| lead | 0.0005 | 0.01 | |
| mercury | <0.00008 | 0.002 | |
| nickel | 0.0009 | 0.02 | P |
| silver | 0.0027 | 0.1 | P |
| 1,1,1-trichloroethane | <0.0005 | 2 | P |
| 1,1-dichloroethene | <0.0005 | 0.03 | |
| 1,2-dibromo-3-chloropropane | <0.0005 | 0.001 | |
| 1,2-dibromoethane | <0.0005 | 0.0004 | |
| 1,2-dichlorobenzene | <0.0002 | 1.5 | <0.0005 |
| 1,2-dichloroethane | <0.0005 | 0.03 | |
| 1,2-dichloroethene | <0.0005 | 0.06 | cis |
| 1,2-dichloropropane | <0.0005 | 0.05 | P |
| 1,3-dichloropropene | <0.0005 | 0.02 | each |
| 1,4-dichlorobenzene | <0.0002 | 0.4 | <0.0005 |
| aldrin + dieldrin | **<0.0002** | 0.00004 | each |
| benzene | <0.0005 | 0.01 | |
| benzo(a))pyrene | <0.0001 | 0.0007 | |
| bromoform | <0.0005 | 0.1 | |
| carbon tetrachloride | <0.0005 | 0.005 | |
| chloroform | <0.0005 | 0.2 | |
| DDT + isomers | <0.0004 | 0.001 | (4,4'-DDT) |
| dibromochloromethane | <0.0005 | 0.15 | |
| dichloromethane | <0.01 | 0.02 | |
| endosulfan | <0.0004 | 0.02 | P |
| endrin | <0.0002 | 0.001 | |
| ethylbenzene | <0.0005 | 0.3 | |
| fluoranthene | <0.0001 | 0.004 | P |
| heptachlor and its epoxide | **<0.0002** | 0.00004 | P: each |
| hexachlorobenzene | **<0.0002** | 0.0001 | P |
| hexachlorobutadiene | <0.0002 | 0.0007 | <0.0005 |
| lindane | <0.0002 | 0.002 | |
| styrene | <0.0005 | 0.03 | |
| tetrachloroethene | <0.0005 | 0.05 | |
| toluene | <0.0005 | 0.8 | |
| trichlorobenzenes | <0.0005 | 0.03 | P: each (1,2,4; 1,2,3) |
| trichloroethene | <0.0005 | 0.08 | P |
| vinyl chloride | **<0.0005** | 0.0003 | |
| xylenes (total) | <0.0005 | 0.6 | (m+p & o) |

P = Provisional MAV

The following are chemicals for which MAVs are specified in the DWSNZ:2005 but for which no monitoring information is available:

antimony, barium, beryllium, boron, bromate, chlorate, chlorine, chlorite, cyanide, cyanogen chloride, fluoride, lithium, manganese, molybdenum, monochloramine, nitrite, selenium, uranium, acrylamide, alachlor, aldicarb, anatoxin-a & a(s), atrazine, azinphos methyl, bentazone, bromacil, bromodichloromethane, carbofuran, chlordane, chlorotoluron, chlorpyriphos, cyanazine, cylindrospermopsin, 2,4-D, 2,4-DB,

di(2-ethylhexyl)adipate, di(2-ethylhexyl)phthalate, diazinon, dibromoacetonitrile, dichloroacetic acid, dichloroacetonitrile, dichlorprop, dimethoate, diquat, diuron, EDTA, epichlorohydrin, fenoprop, formaldehyde, hexazinone, homoanatoxin-a, homoanatoxin-a, isoproturon, malathion, MCPA, MCPB, mecoprop, metalaxyl, methoxychlor, methyl parathion, metolachlor, metribuzin, microcystins, molinate, monochloroacetic acid, monochlorobenzene, nitrilotriacetic acid, nodularin, oryzalin, oxadiazon, pendimethalin, pentachlorophenol, permethrin, phenylphenol, picloram, pirimiphos methyl, primisulfuron methyl, procymidone, propanil, propazine, pyridate, pyriproxifen, paxitoxins, pimazine, 2,4,5-T, terbacil, terbuthylazine, thiabendazole, tributyltin oxide, trichloroacetaldehyde, trichloroacetic acid, 2,4,6-trichlorophenol, triclopyr, trifluralin, 1080.

## APPENDIX 9 CHEMICAL CONTENT OF MASTERTON WWTP EFFLUENT WITH CORRESPONDING ANZECC GUIDELINE VALUES FOR RECREATIONAL WATER

| Chemical | Concentration in effluent (mg/L) | ANZECC Guideline (mg/L) | |
|---|---|---|---|
| arsenic | <0.001 | 0.05 | complied |
| cadmium | <0.00005 | 0.005 | complied |
| chromium | <0.0005 | 0.05 | complied |
| copper | 0.0071 | 1 | complied |
| lead | 0.0005 | 0.05 | complied |
| mercury | <0.00008 | 0.001 | complied |
| nickel | 0.0009 | 0.1 | complied |
| silver | 0.0027 | 0.05 | complied |
| aldrin | <0.0002 | 0.001 | complied |
| dieldrin | <0.0002 | 0.001 | complied |
| benzene | <0.0005 | 0.01 | complied |
| benzo(a))pyrene | **<0.0001** | 0.00001 | unknown |
| carbon tetrachloride | <0.0005 | 0.003 | complied |
| DDT + isomers | <0.0004 | 0.003 | complied |
| 1,2-dichloroethane | <0.0005 | 0.01 | complied |
| 1,1-dichloroethene | **<0.0005** | 0.0003 | unknown |
| endosulfan | <0.0004 | 0.04 | complied |
| endrin | <0.0002 | 0.001 | complied |
| heptachlor and its epoxide | <0.0002 | 0.003 | complied |
| lindane | <0.0002 | 0.01 | complied |
| tetrachloroethene | <0.0005 | 0.01 | complied |
| trichloroethene | <0.0005 | 0.03 | complied |

The following are chemicals for which MAVs are specified in the ANZECC 2000 Guidelines for Recreational Water but for which no monitoring information is available: acephate, alachlor, amitrol, asulam, azinphos methyl, barban, barium, bentazone, bioresmethrin, boron, bromacil, bromophos-ethyl, bromoxynil, carbaryl, carbendazim, carbofuran, carbophenothion, chlordane, chlordimeform, chlorfenvinphos, chloroxuron, chlorpyriphos, clopzralid, cyhexatin, cemeton, cicamba, cichlobenil, cyanide, diazinon, 2,4-D, 3,6-dichloiopicolinic acid, dichlorvos, diclofop-methyl, dicifol, difenzoquat, dimethoate, diquat, disulfoton, diuron, DPA, endothal, EPTC, ethion, ethoprophos, fenchlorphos, fenitrothion, fenoprop, fensulfothion, febvalerate, flamprop-methyl, fluometuron, formothion, fosamine (ammonium salt), glyphosate, heptachlor, hexaflurate, hexazinone, maldison, manganese, methidathion, methomyl, metolachlor, mevinphos, molinate, monocrotophus, nabam, nitralin, nitrate, omethoate, oryzalin, paraquat, parathion, parathion-methyl, pendimethalin, pentachlorophenol, perfluidone, permethrin, picloram, piperonyl butoxide, pirimicarb, pirimiphos-ethyl, pirimiphos methyl, polychlorinated biphenyls, profenfos, promecarb, propanil, propargite, propoxur, pyrazophos, quintozene, selenium, sulprofos, temephos, 2,3,4,6-tetrachlorophenol, thiobencarb, thiometon, thiophanate, thiram, trichlorofon, 2,4,5-T, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, triclopyr, trifluralinbenomyl.

## APPENDIX 10 RISK PROFILES

### Table A10.1 Risk Profile for Recreational use at Wardells Bridge

(Present situation, below-median flows)

| Percentile* | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 2 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 50%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 55%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 60%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 65%ile | 4 | 1 | 0 | 0 | 0 | 1 |
| 70%ile | 5 | 1 | 0 | 0 | 0 | 1 |
| 75%ile | 6 | 1 | 0 | 0 | 0 | 2 |
| 80%ile | 8 | 2 | 0 | 0 | 0 | 2 |
| 85%ile | 11 | 2 | 0 | 0 | 0 | 3 |
| 90%ile | 17 | 4 | 0 | 0 | 0 | 4 |
| 95%ile | 31 | 8 | 1 | 0 | 0 | 7 |
| 99%ile | 79 | 31 | 1 | 1 | 1 | 23 |
| Maximum | 286 | 138 | 8 | 1 | 2 | 98 |
| Mean | 7.2961 | 1.8514 | 0.0719 | 0.0197 | 0.0121 | 1.8068 |

### Table A10.2 Risk Profile for Recreational use at Wardells Bridge

(Present situation, above-median flows)

| Percentile* | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 50%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 55%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 60%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 65%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 70%ile | 2 | 0 | 0 | 0 | 0 | 0 |
| 75%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 80%ile | 3 | 1 | 0 | 0 | 0 | 1 |
| 85%ile | 4 | 1 | 0 | 0 | 0 | 1 |
| 90%ile | 6 | 1 | 0 | 0 | 0 | 2 |
| 95%ile | 11 | 3 | 0 | 0 | 0 | 3 |
| 99%ile | 32 | 11 | 1 | 0 | 0 | 9 |
| Maximum | 137 | 88 | 2 | 1 | 1 | 58 |
| Mean | 2.5191 | 0.6303 | 0.0257 | 0.0055 | 0.0046 | 0.6238 |

* Percent of time that the predicted number of infections are below the stated value.

## Table A10.3 Risk Profile for Recreational use at Wardells Bridge

(Post-upgrade summer below median flows)

| Percentile* | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 50%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 55%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 60%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 65%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 70%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 75%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 80%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 85%ile | 2 | 0 | 0 | 0 | 0 | 0 |
| 90%ile | 3 | 1 | 0 | 0 | 0 | 1 |
| 95%ile | 5 | 1 | 0 | 0 | 0 | 1 |
| 99%ile | 11 | 5 | 0 | 0 | 0 | 3 |
| Maximum | 48 | 25 | 1 | 1 | 1 | 17 |
| Mean | 1.0355 | 0.2644 | 0.0074 | 0.0028 | 0.0007 | 0.2225 |

## Table A10.4 Risk Profile for Recreational use at Wardells Bridge

(Post-upgrade summer above median flows)

| Percentile* | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 50%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 55%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 60%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 65%ile | 2 | 0 | 0 | 0 | 0 | 0 |
| 70%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 75%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 80%ile | 4 | 1 | 0 | 0 | 0 | 1 |
| 85%ile | 5 | 1 | 0 | 0 | 0 | 2 |
| 90%ile | 8 | 2 | 0 | 0 | 0 | 2 |
| 95%ile | 16 | 4 | 0 | 0 | 0 | 4 |
| 99%ile | 57 | 18 | 1 | 1 | 0 | 15 |
| Maximum | 608 | 418 | 7 | 4 | 4 | 258 |
| Mean | 4.2128 | 1.1496 | 0.0429 | 0.0119 | 0.0068 | 1.1113 |

* Percent of time that the predicted number of infections are below the stated value.

## Table A10.5 Risk Profile for Recreational use at Wardells Bridge

(Post-upgrade winter below half-median flows)

| | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| Percentile* | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 50%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 55%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 60%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 65%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 70%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 75%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 80%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 85%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 90%ile | 3 | 1 | 0 | 0 | 0 | 1 |
| 95%ile | 5 | 1 | 0 | 0 | 0 | 1 |
| 99%ile | 12 | 5 | 1 | 0 | 0 | 4 |
| Maximum | 45 | 46 | 2 | 1 | 1 | 16 |
| Mean | 1.0882 | 0.2742 | 0.0114 | 0.0019 | 0.0017 | 0.2636 |

## Table 10.6 Risk Profile for Recreational use at Wardells Bridge

(Post-upgrade winter above half-median flows)

| | Pathogen | | | | | |
|---|---|---|---|---|---|---|
| Percentile* | Adenovirus | Enterovirus | *Giardia* | *Cryptosporidium* | *Salmonella* | *Campylobacter* |
| 5%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 10%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 15%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 20%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 25%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 30%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 35%ile | 0 | 0 | 0 | 0 | 0 | 0 |
| 40%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 45%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 50%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 55%ile | 1 | 0 | 0 | 0 | 0 | 0 |
| 60%ile | 2 | 0 | 0 | 0 | 0 | 0 |
| 65%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 70%ile | 2 | 0 | 0 | 0 | 0 | 1 |
| 75%ile | 3 | 0 | 0 | 0 | 0 | 1 |
| 80%ile | 4 | 1 | 0 | 0 | 0 | 1 |
| 85%ile | 5 | 1 | 0 | 0 | 0 | 1 |
| 90%ile | 8 | 2 | 0 | 0 | 0 | 2 |
| 95%ile | 15 | 4 | 0 | 0 | 0 | 4 |
| 99%ile | 41 | 15 | 1 | 0 | 0 | 11 |
| Maximum | 315 | 203 | 4 | 1 | 1 | 54 |
| Mean | 3.4967 | 0.906 | 0.036 | 0.0088 | 0.0047 | 0.8742 |

* Percent of time that the predicted number of infections are below the stated value.