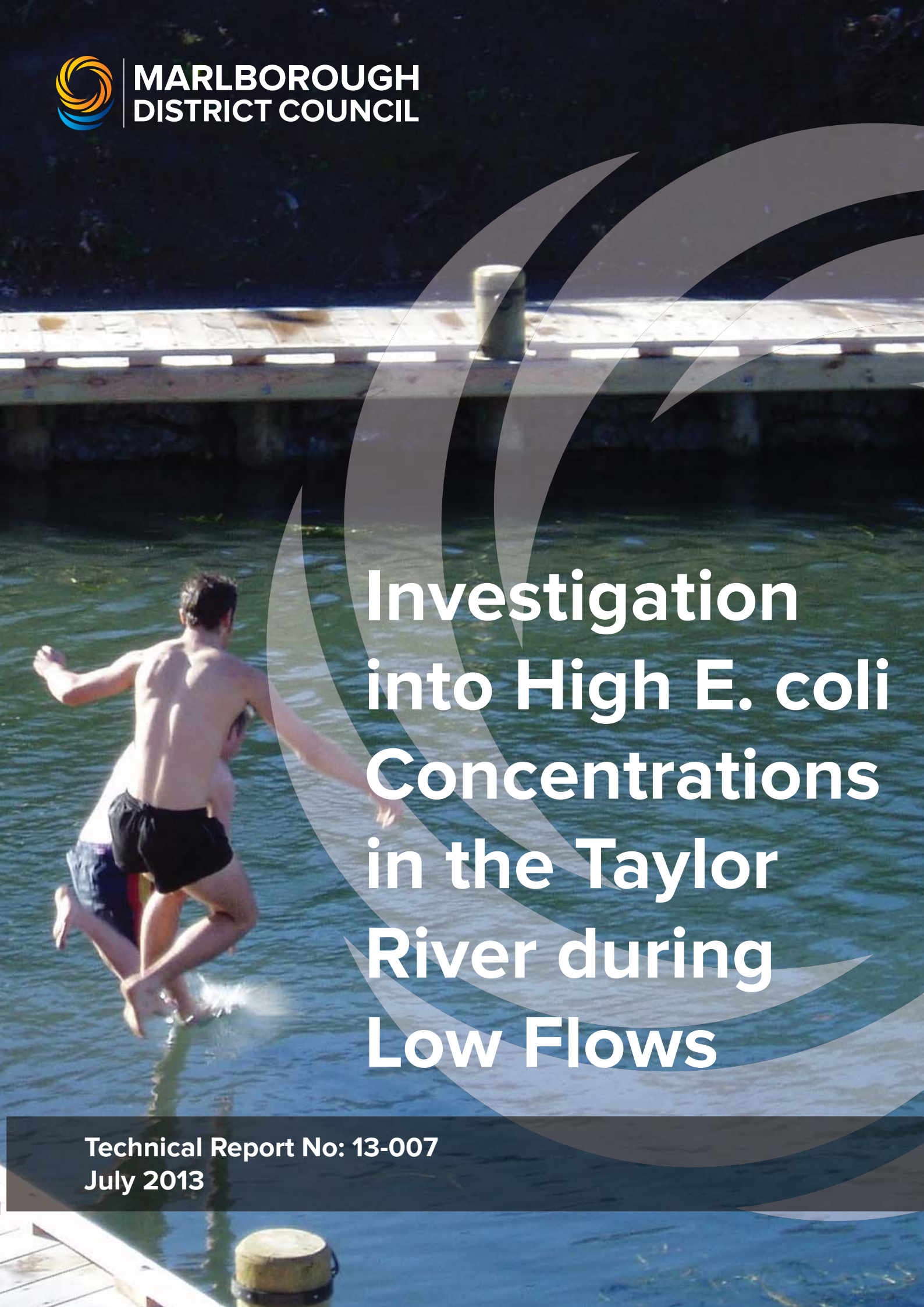
MARLBOROUGH DISTRICT COUNCIL



# Investigation into High E. coli Concentrations in the Taylor River during Low Flows

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# Executive Summary

The Taylor River and its riparian margins are of significant recreational and aesthetic value to the people of Blenheim. The Taylor River and its associated River Reserve are continuously accessed by the public. The river has a high public profile, both as a feature of the town and as a site for recreational water activity like swimming and rafting.

However, there has been mounting concern regarding the water quality of the Taylor River and recent sampling has shown faecal bacteria concentrations regularly exceed values considered safe for contact recreation. Of particular concern are prolonged periods of high E. coli levels **during dry weather conditions**.

The aim of this investigation was to determine the possible sources of faecal contamination during low flows in the Taylor River.

Several sites along the Taylor River and its tributaries were sampled and the concentrations of the faecal indicator bacteria E. coli were measured. Sites with high E. coli levels had additional samples taken and genetic markers were used to determine the source of faecal bacteria. Water Temperature and Specific Conductivity were measured during sampling. Flow gaugings were also carried out at selected sites.

Doctors Creek was found to be the most significant source of E. coli and Turbidity entering the Taylor River. In Doctors Creek itself the Turbidity increases significantly between Wiffen Bridge at the southern end of Bells Road and the confluence with Fairhall Coop Drain. Analysis showed that faecal contamination in Doctors Creek originates mainly from ruminant/bovine sources and wildfowl.

Within the Taylor River Reserve, Dashwood St Drain had the highest E. coli concentrations. It was also the only tributary shown to have significant faecal contamination of human origin. Waterlea Creek was the only other waterway containing faecal bacteria from human sources; however, the signal was faint. Due to the low flow in those drains the effect these two tributaries have on the Taylor's microbiological water quality is localised to their confluence.

Murphys Creek is the largest tributary and supplies the most water to the Taylor River during low flow periods. Its microbiological water quality is generally good. As a result low E. coli concentrations are found in the Taylor downstream of the Murphys Creek confluence. Downstream of Fultons Creek faecal bacteria concentrations in the Taylor River increase again. Microbial Source tracking showed that the majority of faecal bacteria in the lower part of the Taylor originate from wildfowl and dogs.

# Table of Contents

# 1. Introduction

The Taylor River and the associated River Reserve are of significant recreational and aesthetic value for the people of Blenheim. The River Reserve offers a green space to walk, bike or relax and is easily accessible from most parts of the town. The river is used for contact recreational activities like swimming and rafting especially on hot days during summer.

The Taylor River and its tributaries flow through rural land as well as urban Blenheim. As a result there is the potential for contamination of the waterway with faecal bacteria, and consequently a risk to human health from water borne diseases like Campylobacter and Giardia. During the warmer months of the year the Marlborough District Council takes weekly water samples from the Taylor River at Riverside. The samples are analysed for concentrations of faecal bacteria which allow an assessment of the potential health risk to swimmers and other users. If bacteria concentrations are above a recommended level the water is considered unsuitable for contact recreational use and warning signs are placed around the site.

Rivers that have rural as well as residential use in their catchment quite commonly contain high faecal bacteria concentrations during high flows, especially after prolonged periods of dry weather. However, faecal bacteria concentrations in the Taylor River are frequently high during low flows. During those periods the most likely sources include livestock with direct access to the water way, waterfowl and human sewage. The River Reserve is also a popular dog walking destination and canines are frequently seen enjoying themselves in the water, and although the owners are ask to remove the faeces this is not always followed.

In the summer of 2012/2013 the Taylor River at Riverside had the worst microbiological water quality of all sites sampled across Marlborough as part of the recreational water quality program. Warning signs had to be erected around the site for a total of 28 days. This sparked an investigation, the results and findings of the investigation are published in this report.

# 2. Methodology

Several sites along the Taylor River as well as the main tributaries entering the river along the River Reserve were sampled during low flows in January, February and March of 2013. A total of five sampling rounds were carried out. The samples were analysed for the concentration of E. coli by Hill's Laboratory in Blenheim using the Colilert method.

E. coli is an indicator bacterium for the presence of disease causing microorganisms, like Campylobacter, Cryptosporidium and Giardia, associated with faecal contamination. The Ministry for the Environment together with the Ministry of Health have released guidelines allowing an evaluation of the water quality in regard to the risk to human health (Table 1).

| E. coli concentration [E. coli/100mL] | Human Health Risk |
|---|---|
| <260 | **Low** (**Safe** for contact recreation) |
| 260 | Alert Guideline |
| 260 - 550 | **Increased risk** |
| 550 | Action Guideline |
| >550 | **High** (**Unsafe** for conctact recreation) |

**Table 1: National Guidelines for E. coli in Recreational waters**

Water Temperature and Specific Conductivity[1] were measured at each site using a YSI handheld meter and general observations including the Turbidity of the water, presence of waterfowl and stream bed cover were also collected.

The flow of the Taylor River at Hutcheson St Bridge and the major tributaries was measured during one of the sampling runs to determine the relative input of each tributary to the overall flow of the Taylor River. The flow of smaller tributaries was estimated.

The study concentrated on the Taylor River and its tributaries upstream of the State Highway One Bridge at Riverside Park in central Blenheim. During the initial analysis of results it became clear that Doctors Creek was consistently contributing a significant amount of faecal bacteria. Consequently the study area was extended to include parts of Doctors Creek and its tributaries on the later three sampling runs.

Additional samples were taken from the tributaries of the Taylor River that had E. coli concentrations exceeding the Alert Guideline as well as the Taylor River at Riverside. These samples were sent to the Cawthron Laboratory in Nelson for Microbial Source tracking analysis. Microbial Source tracking analysis uses genetic markers to identify the species of animals that are contributing to the source of the faecal bacteria in the sample.

# 3. Results

The Results of the study are outlined below. Maps showing the Water Temperature and Specific Conductivity measurements as well E. coli concentrations can be found in the Appendices 1 to 3. There are two maps for each of the parameters (Figure 1)

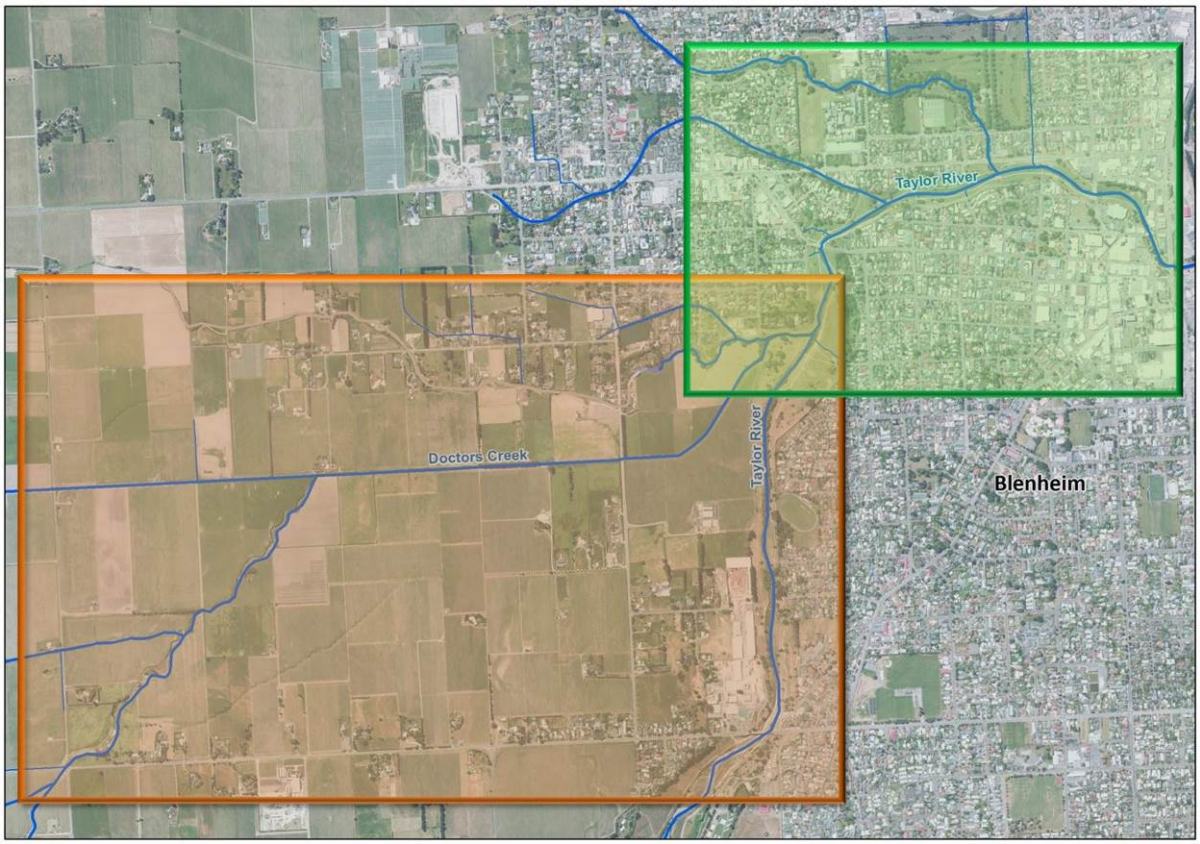


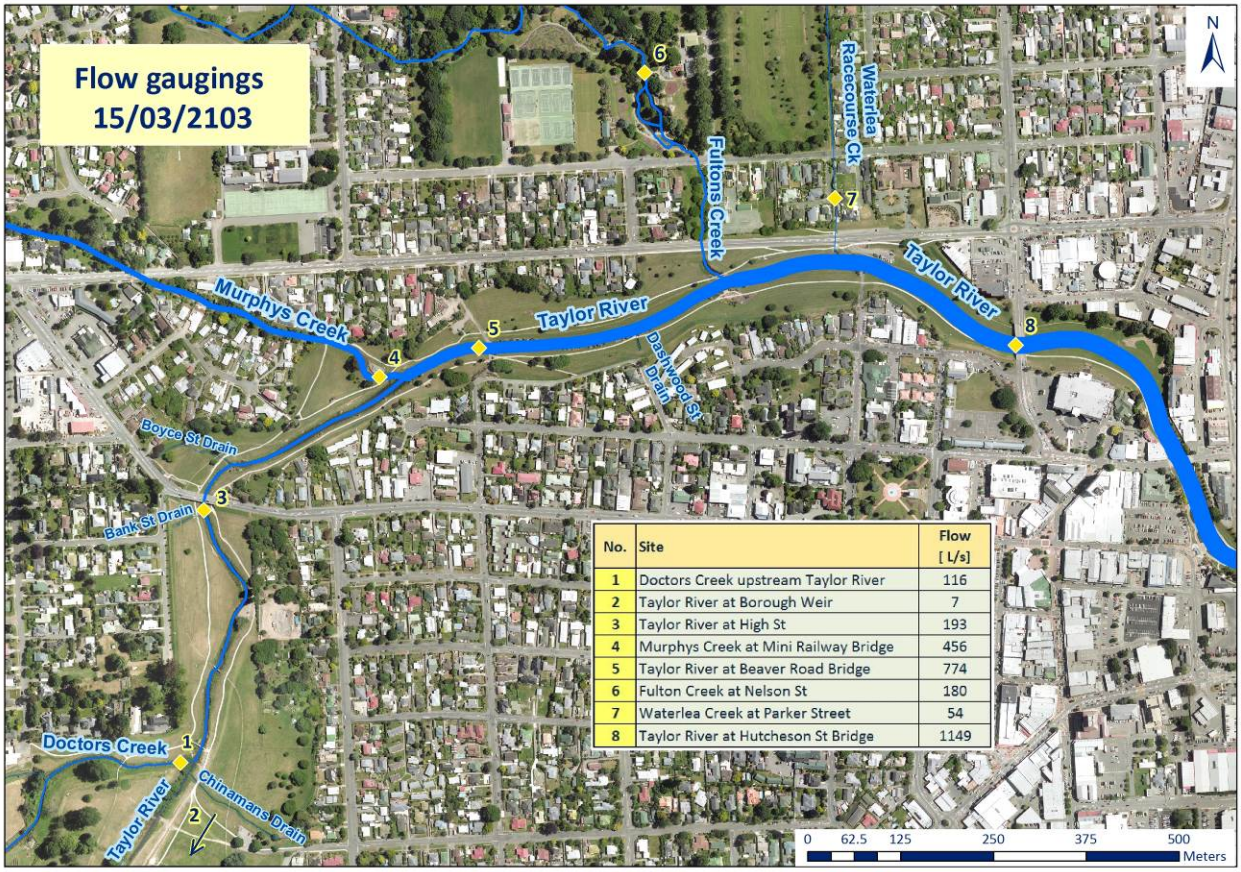

**Figure 1: Outlines of the maps showing the results for Water Temperature, Specific Conductivity and E. coli concentration that can be found in the Appendices.**

[1] Conductivity at 25°C

## 3.1. Flow

Simultaneous flow gaugings of the main tributaries and the Taylor River at Hutcheson St Bridge were carried out on 28/02/2013. Murphys Creek had the highest flow with 490L/s, which was more than double that of the other Taylor tributaries. The flows from Doctors Creek and Fulton Creek were comparable with 180L/s and 190L/s respectively. Of the main tributaries Waterlea Creek had the lowest flow with 50L/s. Analysis of earlier gaugings showed a similar pattern.

Another gauging round was carried out on 15/03/2013 shortly after the study was concluded, but flows were similar and the flow of two additional sites along the Taylor River was measured (Figure 2).




| No. | Site | Flow [ L/s] |
|---|---|---|
| 1 | Doctors Creek upstream Taylor River | 116 |
| 2 | Taylor River at Borough Weir | 7 |
| 3 | Taylor River at High St | 193 |
| 4 | Murphys Creek at Mini Railway Bridge | 456 |
| 5 | Taylor River at Beaver Road Bridge | 774 |
| 6 | Fulton Creek at Nelson St | 180 |
| 7 | Waterlea Creek at Parker Street | 54 |
| 8 | Taylor River at Hutcheson St Bridge | 1149 |

**Figure 2: Flow of the Taylor River and its tributaries based on gaugings carried out on 15/03/2013[2]. The width of the river line is proportional to the flow.**

The flow of the Taylor River upstream of Doctors Creek regularly reduces to less than 10L/s during summer and was contributing very little water to the system. This meant by the time the river had moved its way downstream to the Hutcheson St Bridge the flow increased 100 fold to 1150L/s. The majority of the additional water originated from Murphys Creek and Fultons Creek. Additional sub-surface flow also contributes a significant amount of water[3]. Most other drains had very small flows with Dashwood St Drain in the higher range and Chinamans and Bank St Drain in the lower ranges.

Apart from the site immediately upstream of the Taylor River the flow of Doctors Creek and its tributaries was not measured as part of this investigation. Nevertheless it became clear that a considerable amount of groundwater was rising to the surface west of Bells Road. All three sites along Bells Road had very

[2] The Flow for the Taylor River at Borough Weir is based on a rating

[3] Peter Davidson - personal comment

little flow, but the flow of both Fairhall Coop Drain and Doctors Creek had increased substantially at their confluence.

## 3.2. Water Temperature

Water Temperatures ranged from 13.7$^{o}$C to 24.6 $^{o}$C with higher values in the Doctors Creek catchment. The maximum Temperature along the River Reserve was 18.5 $^{o}$C resulting in a very small Water Temperature range of 4.8$^{o}$C for that part of the study area. The northern tributaries had the lowest Water Temperatures due to a combination of cooler groundwater entering the streams and the abundance of trees along the stream edges preventing the warming of the water by sunlight.

Although a significant amount of groundwater was entering Doctors Creek and its tributaries the lack of shade led to the higher Water Temperatures observed. While vegetation along the Taylor River provides little shading the frequent influx of cool water from its tributaries along the River Reserve kept Water Temperatures cooler than in Doctors Creek.

## 3.3. Conductivity

Specific Conductivities in Doctors Creek and its tributaries were mostly higher than in the Taylor River and its tributaries within the River Reserve. The exception was Chinamans Drain with Conductivities around 190µS/cm which was comparable with Doctors Creek. Waterlea Creek on the other hand had the lowest Conductivity with an average of 120.9µS/cm. The average Specific Conductivity of the sites downstream of the Taylor River/Doctors Creek confluence ranged between 144.1µS/cm to 164.8µS/cm meaning that the difference was very small with about 20µS/cm.

The greatest variability in Specific Conductivity between sampling dates was observed in Fairhall School Creek, Doctors Creek at Wiffen Bridge and Bank St Drain, with the Doctors Creek site also consistently having the highest Conductivity with values greater than 400µS/cm. All three sites had very little flow when the measurements were taken. The variability in Bank St Drain was due to one of the four samples having a Specific Conductivity 30% lower than the other three samples, the Water Temperature on that particular occasion was slightly higher, but the 0.2$^{o}$C increase cannot be considered significant.

## 3.4. Turbidity

Turbidity was assessed visually and values were given based on a rank system consisting of four values (clear, slightly turbid, turbid, very turbid). Generally, water clarity did not vary significantly between different samples from the same site.

Doctors Creek upstream of the confluence with Fairhall Coop Drain was consistently the most turbid site during the study, but upstream at Wiffen Bridge, Doctors Creek was flowing clear and Fairhall School Creek which flows into Doctors Creek about half way between the two sites also had clear water at the Bells Road site (Figure 3). There was a significant influx of fine sediment into Doctors Creek within this 1.5km reach of the Creek resulting in a knee deep layer of fine sediment covering the Creek bed upstream of Fairhall Coop Drain. Although there was some fine sediment covering the bed at the other sites the hard stream bed consisting of small stones was clearly visible. Cattle could be seen entering Doctors Creek between Fairhall School Creek and Fairhall Coop Drain while fences prevented stock entering Fairhall Coop Drain which was only slightly turbid. The destabilisation of the stream bank by cattle is a possible source of the high sediment content of Doctors Creek; however, channel modifications of Doctors Creek upstream of Wiffen Bridge might also be a major source of fine sediment which is washed downstream during flood events. The Taylor River characterisation study planned will provide more information on the origins of fine sediment in Doctors Creek.

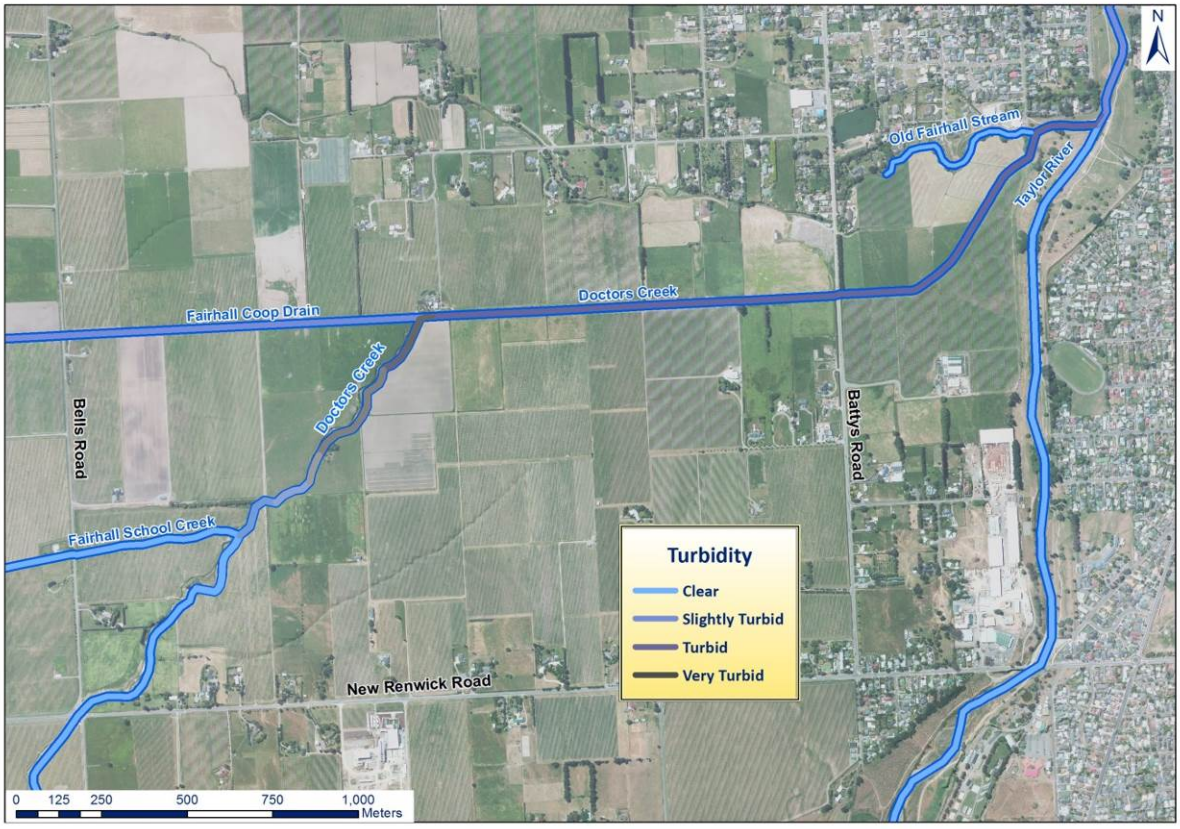



**Figure 3: Turbidity of the water in Doctors Creek and its tributaries based on observations during sampling.**

At the other three sites along Doctors Creek downstream of the confluence with Fairhall Coop Drain, the water was still slightly turbid or turbid and subsequently impacted on the water clarity of the Taylor River. Yet, by the time the water had reached the confluence with Murphys Creek the water was clear again.

The bed of Fultons Creek immediately upstream of its confluence with the Taylor River is covered with a layer of fine sediment which is deposited due to the widening of the stream and the consequent reduction in water velocity. The water generally appeared clear, but ducks or dogs entering the stream can easily dislodge the sediment and cause an increase in Turbidity. This might contribute to the higher amount of fine sediment covering the Taylor River in the lower reaches, but its contribution are likely to be minor. As the Taylor River moves its way to the East the velocity of the water is decreasing and the amount of oxygen weed covering the Riverbed increases. Both are major contributing factors to the increase in fine sediment cover in the lower reach of the River. Dogs are often seen playing in the Taylor River and Ducks are regularly seen around the Water Fountain at the Riverside park. Both animals cause the fine sediment on the Riverbed to be moved back into the water column and are subsequently the cause for a localised increase in Turbidity in the lower Taylor River.

## 3.5. E. coli concentrations

Fairhall Coop Drain, Doctors Creek upstream of Fairhall Coop Drain, Old Fairhall Stream and Dashwood St Drain recorded the highest E. coli concentrations. Fairhall Coop Drain at Bells Road had the highest E. coli concentrations with levels in excess of 2500 E. coli/100mL in both samples. The source of the faecal contamination was not obvious from the sample site and will be investigated as part of the Taylor River Characterisation Study.

Doctors Creek was the main contributor of faecal contamination downstream of its confluence with the Taylor River, but bacterial levels reduce quickly downstream.

The three main tributaries flowing into the Taylor River from the north are Murphys Creek, Fultons Creek and Waterlea Creek. Murphys Creek, which provides the greatest amount of water during dry periods has relatively good microbiological water quality most of the time, but had elevated E. coli concentrations in one of the samples. Faecal bacteria concentrations in Fultons Creek were only slightly higher than in Murphys Creek despite the large numbers of Ducks living on the Pond in Pollard Park which is part the of Fultons Creek system. Waterlea Creek had the highest E. coli concentrations, but also the lowest flow of these three tributaries.

Of the smaller Taylor River tributaries Dashwood St Drain, which flows into the Taylor River downstream of Murphys Creek, had the highest E. coli levels. Half of the samples taken had concentrations in excess of the Action Guideline. Boyce St Drain also had faecal bacteria concentrations exceeding the Action Guideline on two occasions. The other two small streams, Bank St Drain and Chinamans Drains, had generally low E. coli concentrations.

Of all the samples taken from the Taylor River during this investigation the water from the site immediately upstream of Fultons Creek had the best microbiological water quality.

### 3.5.1. E. coli sources

Faecal contamination in Doctors Creek and Old Fairhall Stream originated from ruminant sources and wildfowl which is not surprising considering the rural nature of most of the catchment. Waterlea Creek, Fultons Creek and the Taylor River at Riverside also tested positive for ruminant or bovine sources however their presence was classified as faint. Only Waterlea Creek and Dashwood St Drain contained faecal contamination of human origin. While the signal was faint for Waterlea Creek, analysis of water from Dashwood St Drain showed a significant presence of human faecal bacteria[4]. Wildfowl was a significant contributor to high E. coli concentrations in four of the seven sites tested[5], while faecal bacteria originating from dogs were found at the two sites furthest downstream, Waterlea Creek and Taylor River at Riverside. For the sample taken from Boyce St Drain no matching markers could be found.

### 3.5.2. E. coli concentrations and Conductivity/Water Temperature

There was no correlation between Specific Conductivity and E. coli concentration for either individual samples from each of the sites or for the averages between sites. The same was found when analysing the last three years of weekly summer sampling carried out at the Taylor River at Riverside.

Sewage inflow, but also other direct discharges might result in a localised change in water temperature. This was not observed, even for the two waterways, Dashwood St Drain and Waterlea Creek that were found to contain faecal bacteria of human origin. Water temperatures were predominantly dictated by the inflow of groundwater and the warming of the water by sunlight when the waterway was not shaded. Generally water temperature between samples from the same site varied very little and the variation present was not correlated to E. coli concentrations.

### 3.5.3. E. coli concentrations and Turbidity

Turbidity greatly influences the concentration of E. coli because the bacteria die off quickly when exposed to direct sunlight.

Turbidity is known to increase when significant numbers of stock or other animals move through or along a stream, or wastewater is discharged directly into a waterway. Nevertheless no correlation between E. coli concentrations and Turbidity was found, either between sites or the samples from the same site. For example the water in Dashwood St Drain and Old Fairhall Stream was clear during all sampling runs, but both streams had some of the greatest ranges in E. coli concentrations with values as low as 74 E.coli/100mL and as high as 1539 E.coli/100mL.

[4] The sources of human sewage are being investigated

[5] Fultons Creek, Waterlea Creek, Doctors Creek and Taylor River at Riverside

# 4. Conclusion – Microbiological Water Quality of the Taylor River at Low Flows

The map in Appendix 4 shows the distribution of E. coli concentrations in the Taylor River and its tributaries.

The Taylor River upstream of Doctors Creek is not spring fed, but its tributaries sampled as part of this study are. As a result during summer low flows, the good microbiological water quality of the upper Taylor River has little impact compared to Doctors Creek, which has much higher flows but also considerably higher faecal bacteria concentrations. Microbial Source Tracking of the faecal bacteria in Doctors Creek points to contamination coming from ruminant sources in the rural catchments, particularly cattle in Old Fairhall Stream. Wildfowl is also contributing.

By the time the water reaches the confluence with Murphys Creek the water is clearer and the lack of shading, although resulting in an increase in water temperature, contributes to the reduction of E. coli concentrations as the bacteria are quickly killed when exposed to direct sunlight.

Murphys Creek is the tributary adding the most amount of water to the system and its clear water with generally low E. coli concentrations has a positive effect on the microbiological water quality of the Taylor River downstream of the confluence. However, there appear to be occasional spikes in the level of faecal bacteria in Murphys Creek which are not indicated by an increase in Turbidity or a change in either Water Temperature or Specific Conductivity. The apparent sporadic nature of these elevated E. coli concentrations makes an investigation into the source(s) difficult. Nevertheless, because the microbiological water quality of Murphys Creek has such a great influence on the water quality of the Taylor River the source(s) of faecal contamination should be studied.

The large Duck population living on the Fultons Creek Pond in Pollard Park was thought to be one of the major sources of high E. coli numbers in the Taylor River. Surprisingly the 150 – 200 Ducks had a minor impact on the microbiological water quality. In none of the five samples taken were E. coli levels exceeding the Action Guideline which indicates unsafe concentrations. Microbial Source Tracking in a sample from Fultons Creek upstream of the Taylor River confluence showed the expected wildfowl source, but also a faint ruminant and bovine source. During dry periods the flow in Fultons Creek is less than half that of Murphys Creek which means although E. coli concentrations in Fultons Creek are generally elevated the effect on the Taylor River is minor.

Faecal contamination in Dashwood St Drain and Waterlea Creek are at least partly of human origin and therefore generally pose a greater risk to human health than other sources. Nevertheless the occasionally very high E. coli concentrations in Dashwood St Drain and generally elevated E. coli levels in Waterlea Creek have only localised effects, due to the comparatively low flows in these two tributaries. Nonetheless the sources of human faecal bacteria need to investigated and mitigated especially in Waterlea Creek which is accessible to the public for most of its length. Waterlea Creek also had a faint bovine source, but the majority of faecal contamination originates from wildfowl and dogs.

Microbial Source Tracking of a sample from the Taylor River at Riverside, showed that wildfowl and dogs were the main sources of faecal contamination. This means the increase in E. coli concentrations in the Taylor River from the Hutcheson St Bridge to the Riverside site is probably due to a combination of dog faeces on the water's edge and the more than 30 ducks living along this stretch of the river. The banks of the Taylor River are a popular dog walking destination and the car park just upstream of the Hutcheson St Bridge is a popular starting point for these walks. Owners are asked to remove the droppings of their animals; however, it is not uncommon to see dog faeces left on the banks very close to the river's edge[6]. Removing the faeces of their canine companions, while enjoying the walk along the river, is an important contribution to looking after the river and maintaining its value.

[6] It should be noted that the majority of dog owners are conscientious and only a small number are neglecting their responsibilities

Correlations analysis showed neither Conductivity nor Water Temperature can be used as a predictor for E. coli concentrations and although Turbidity greatly influences the survival of E. coli in the water column there was no correlation with the level of faecal contamination. As a result we are as yet unable to estimate the level of faecal contamination in the Taylor River using field measurements and observations only. Samples still need to be taken and incubated for 24 hours before the concentration of faecal bacteria is known.

# 5. References

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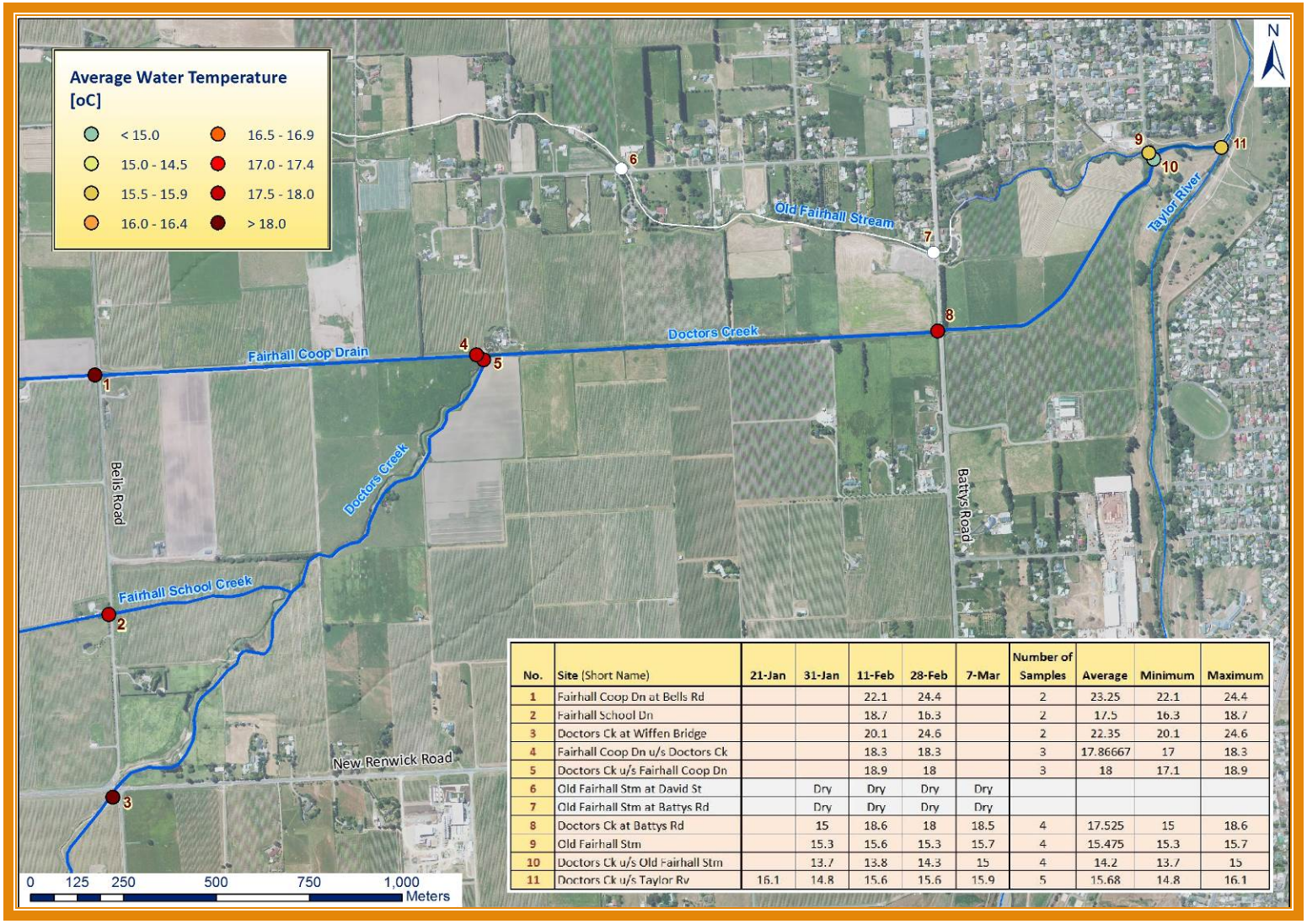
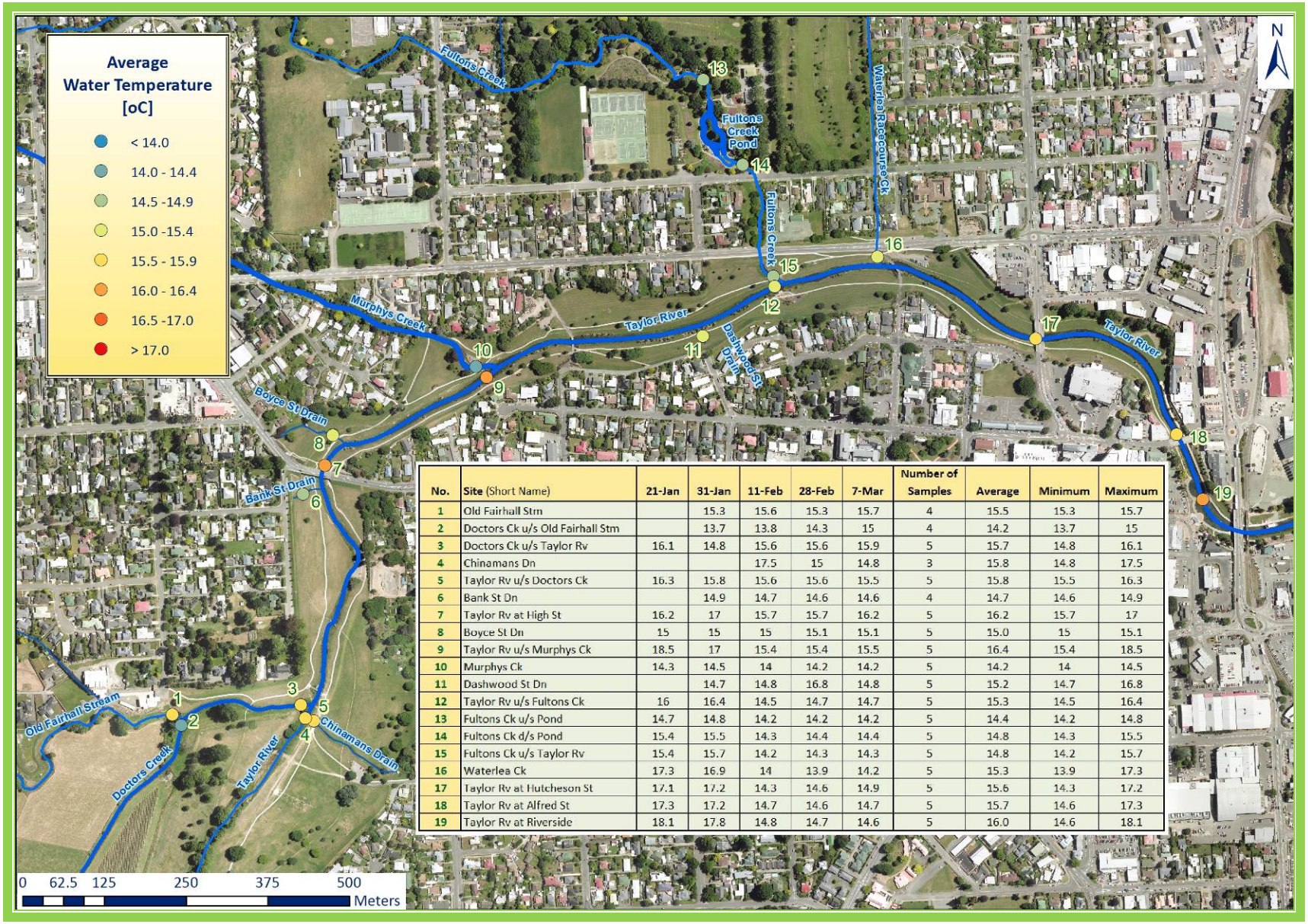
Scott, T.M., Rose, J.B., Jenkins, T.M., and Lukasik, J. (2013) *Microbial Source Tracking: Current Methodology and Future Directions.* Applied and Environmental Microbiology

# 6. Appendices

## 6.1. Appendix 1: Average Water Temperatures in the Taylor River and its Tributaries

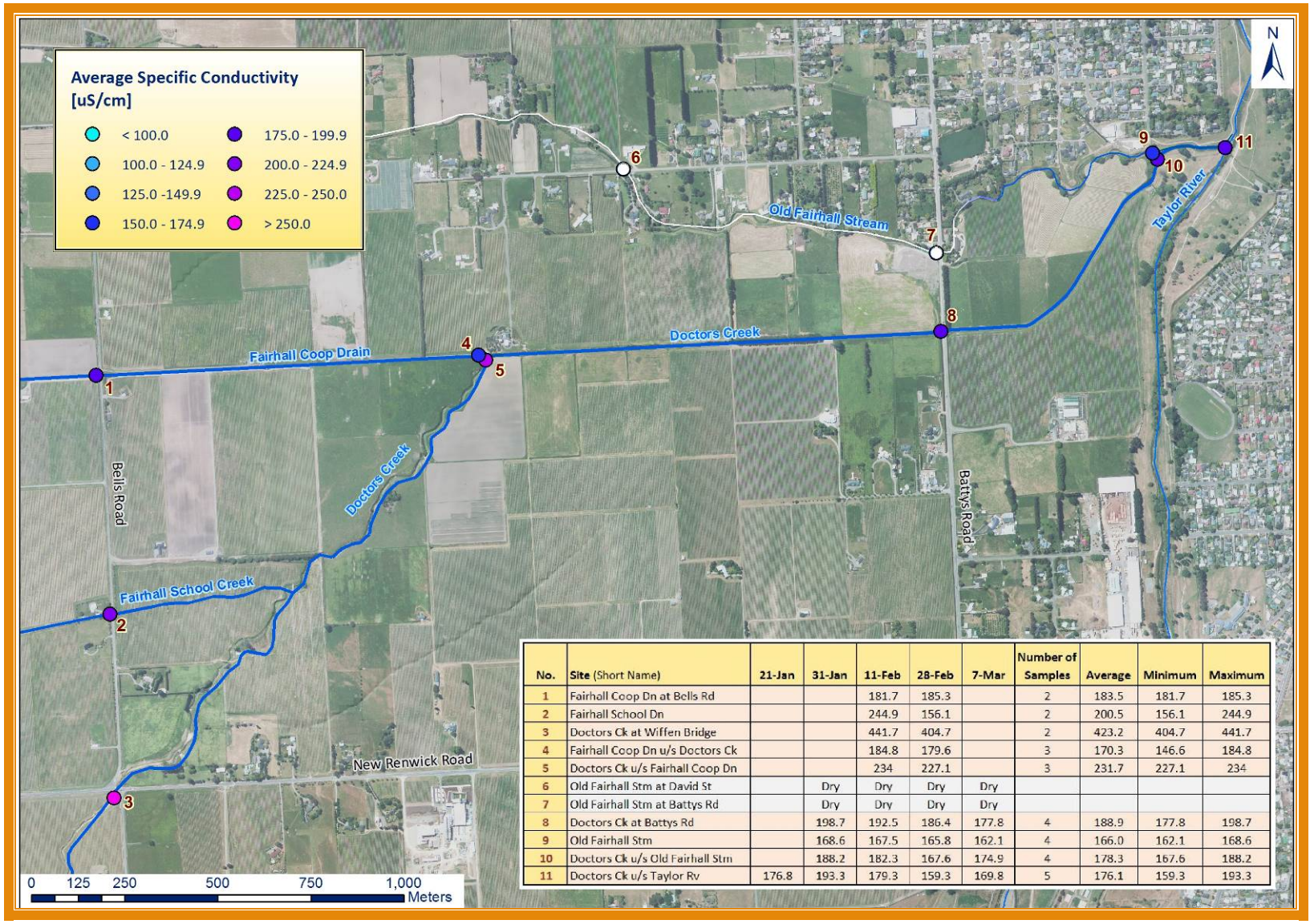



| No. | Site (Short Name) | 21-Jan | 31-Jan | 11-Feb | 28-Feb | 7-Mar | Number of Samples | Average | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Fairhall Coop Dn at Bells Rd | | | 22.1 | 24.4 | | 2 | 23.25 | 22.1 | 24.4 |
| 2 | Fairhall School Dn | | | 18.7 | 16.3 | | 2 | 17.5 | 16.3 | 18.7 |
| 3 | Doctors Ck at Wiffen Bridge | | | 20.1 | 24.6 | | 2 | 22.35 | 20.1 | 24.6 |
| 4 | Fairhall Coop Dn u/s Doctors Ck | | | 18.3 | 18.3 | | 3 | 17.86667 | 17 | 18.3 |
| 5 | Doctors Ck u/s Fairhall Coop Dn | | | 18.9 | 18 | | 3 | 18 | 17.1 | 18.9 |
| 6 | Old Fairhall Stm at David St | | Dry | Dry | Dry | Dry | | | | |
| 7 | Old Fairhall Stm at Battys Rd | | Dry | Dry | Dry | Dry | | | | |
| 8 | Doctors Ck at Battys Rd | | 15 | 18.6 | 18 | 18.5 | 4 | 17.525 | 15 | 18.6 |
| 9 | Old Fairhall Stm | | 15.3 | 15.6 | 15.3 | 15.7 | 4 | 15.475 | 15.3 | 15.7 |
| 10 | Doctors Ck u/s Old Fairhall Stm | | 13.7 | 13.8 | 14.3 | 15 | 4 | 14.2 | 13.7 | 15 |
| 11 | Doctors Ck u/s Taylor Rv | 16.1 | 14.8 | 15.6 | 15.6 | 15.9 | 5 | 15.68 | 14.8 | 16.1 |

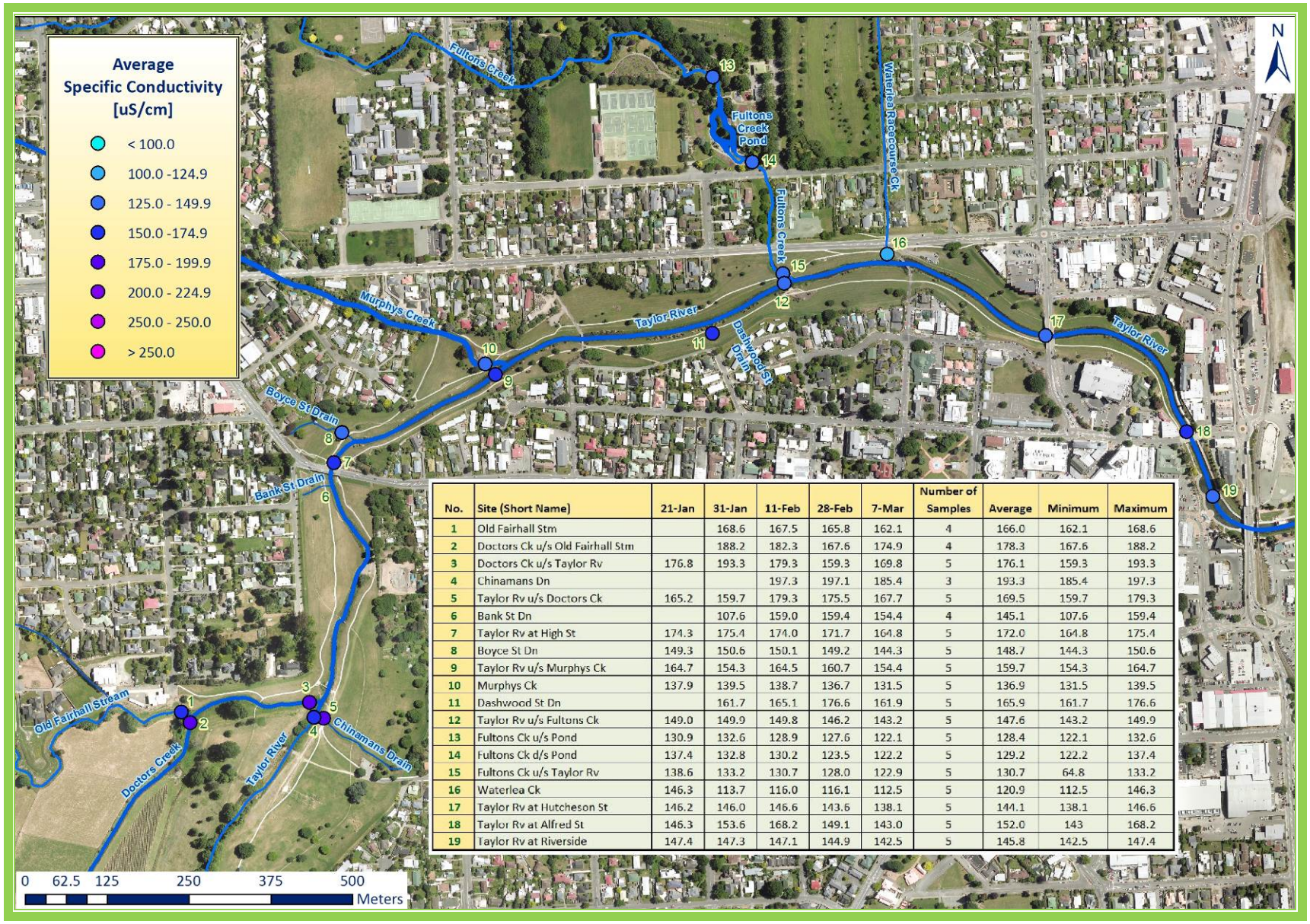



| No. | Site (Short Name) | 21-Jan | 31-Jan | 11-Feb | 28-Feb | 7-Mar | Number of Samples | Average | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Old Fairhall Stm | | 15.3 | 15.6 | 15.3 | 15.7 | 4 | 15.5 | 15.3 | 15.7 |
| 2 | Doctors Ck u/s Old Fairhall Stm | | 13.7 | 13.8 | 14.3 | 15 | 4 | 14.2 | 13.7 | 15 |
| 3 | Doctors Ck u/s Taylor Rv | 16.1 | 14.8 | 15.6 | 15.6 | 15.9 | 5 | 15.7 | 14.8 | 16.1 |
| 4 | Chinamans Dn | | | 17.5 | 15 | 14.8 | 3 | 15.8 | 14.8 | 17.5 |
| 5 | Taylor Rv u/s Doctors Ck | 16.3 | 15.8 | 15.6 | 15.6 | 15.5 | 5 | 15.8 | 15.5 | 16.3 |
| 6 | Bank St Dn | | 14.9 | 14.7 | 14.6 | 14.6 | 4 | 14.7 | 14.6 | 14.9 |
| 7 | Taylor Rv at High St | 16.2 | 17 | 15.7 | 15.7 | 16.2 | 5 | 16.2 | 15.7 | 17 |
| 8 | Boyce St Dn | 15 | 15 | 15 | 15.1 | 15.1 | 5 | 15.0 | 15 | 15.1 |
| 9 | Taylor Rv u/s Murphys Ck | 18.5 | 17 | 15.4 | 15.4 | 15.5 | 5 | 16.4 | 15.4 | 18.5 |
| 10 | Murphys Ck | 14.3 | 14.5 | 14 | 14.2 | 14.2 | 5 | 14.2 | 14 | 14.5 |
| 11 | Dashwood St Dn | | 14.7 | 14.8 | 16.8 | 14.8 | 5 | 15.2 | 14.7 | 16.8 |
| 12 | Taylor Rv u/s Fultons Ck | 16 | 16.4 | 14.5 | 14.7 | 14.7 | 5 | 15.3 | 14.5 | 16.4 |
| 13 | Fultons Ck u/s Pond | 14.7 | 14.8 | 14.2 | 14.2 | 14.2 | 5 | 14.4 | 14.2 | 14.8 |
| 14 | Fultons Ck d/s Pond | 15.4 | 15.5 | 14.3 | 14.4 | 14.4 | 5 | 14.8 | 14.3 | 15.5 |
| 15 | Fultons Ck u/s Taylor Rv | 15.4 | 15.7 | 14.2 | 14.3 | 14.3 | 5 | 14.8 | 14.2 | 15.7 |
| 16 | Waterlea Ck | 17.3 | 16.9 | 14 | 13.9 | 14.2 | 5 | 15.3 | 13.9 | 17.3 |
| 17 | Taylor Rv at Hutcheson St | 17.1 | 17.2 | 14.3 | 14.6 | 14.9 | 5 | 15.6 | 14.3 | 17.2 |
| 18 | Taylor Rv at Alfred St | 17.3 | 17.2 | 14.7 | 14.6 | 14.7 | 5 | 15.7 | 14.6 | 17.3 |
| 19 | Taylor Rv at Riverside | 18.1 | 17.8 | 14.8 | 14.7 | 14.6 | 5 | 16.0 | 14.6 | 18.1 |

## 6.2. Appendix 2: Average Specific Conductivity in the Taylor River and its Tributaries

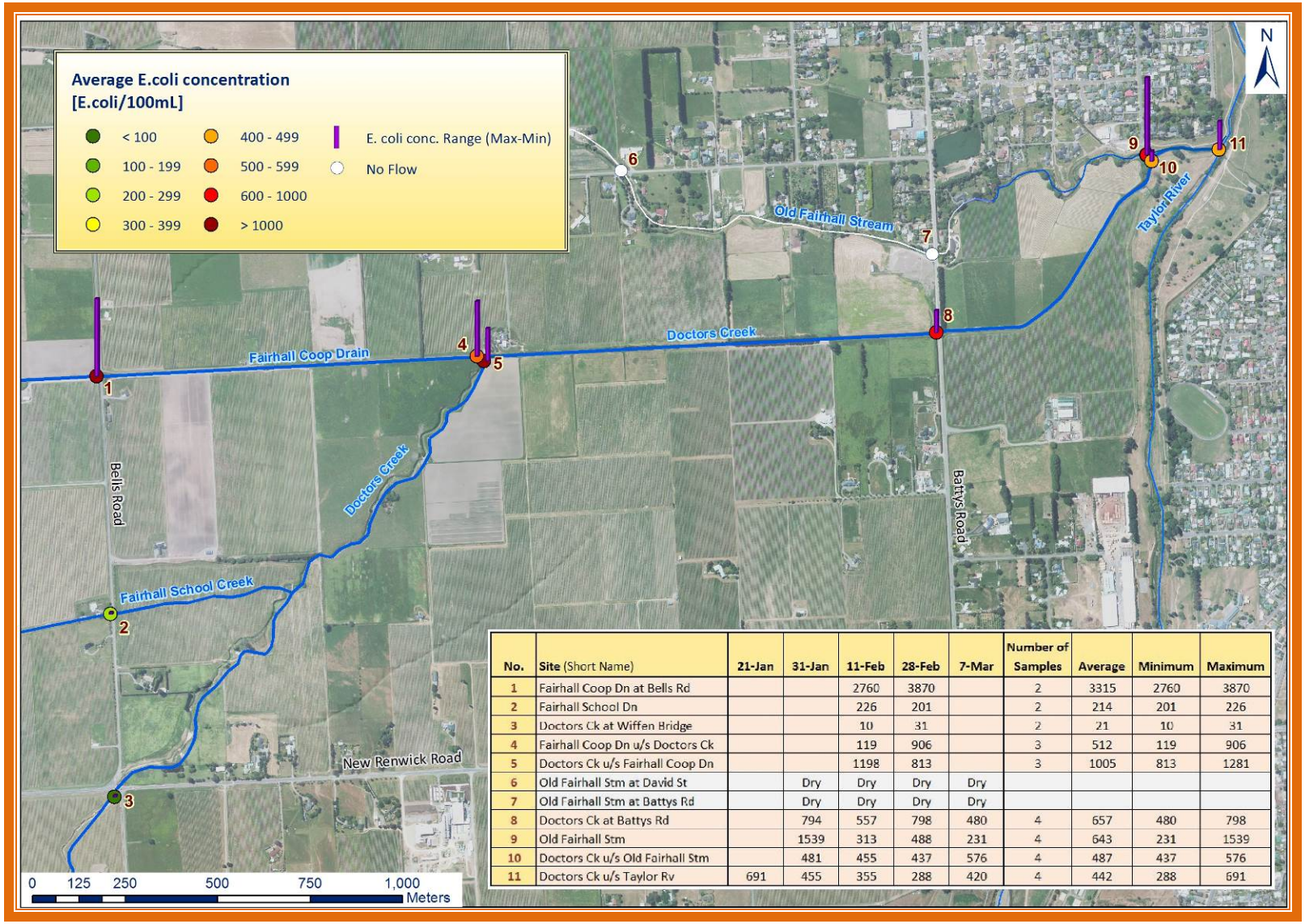



| No. | Site (Short Name) | 21-Jan | 31-Jan | 11-Feb | 28-Feb | 7-Mar | Number of Samples | Average | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Fairhall Coop Dn at Bells Rd | | | 181.7 | 185.3 | | 2 | 183.5 | 181.7 | 185.3 |
| 2 | Fairhall School Dn | | | 244.9 | 156.1 | | 2 | 200.5 | 156.1 | 244.9 |
| 3 | Doctors Ck at Wiffen Bridge | | | 441.7 | 404.7 | | 2 | 423.2 | 404.7 | 441.7 |
| 4 | Fairhall Coop Dn u/s Doctors Ck | | | 184.8 | 179.6 | | 3 | 170.3 | 146.6 | 184.8 |
| 5 | Doctors Ck u/s Fairhall Coop Dn | | | 234 | 227.1 | | 3 | 231.7 | 227.1 | 234 |
| 6 | Old Fairhall Stm at David St | | Dry | Dry | Dry | Dry | | | | |
| 7 | Old Fairhall Stm at Battys Rd | | Dry | Dry | Dry | Dry | | | | |
| 8 | Doctors Ck at Battys Rd | | 198.7 | 192.5 | 186.4 | 177.8 | 4 | 188.9 | 177.8 | 198.7 |
| 9 | Old Fairhall Stm | | 168.6 | 167.5 | 165.8 | 162.1 | 4 | 166.0 | 162.1 | 168.6 |
| 10 | Doctors Ck u/s Old Fairhall Stm | | 188.2 | 182.3 | 167.6 | 174.9 | 4 | 178.3 | 167.6 | 188.2 |
| 11 | Doctors Ck u/s Taylor Rv | 176.8 | 193.3 | 179.3 | 159.3 | 169.8 | 5 | 176.1 | 159.3 | 193.3 |




| No. | Site (Short Name) | 21-Jan | 31-Jan | 11-Feb | 28-Feb | 7-Mar | Number of Samples | Average | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Old Fairhall Stm | | 168.6 | 167.5 | 165.8 | 162.1 | 4 | 166.0 | 162.1 | 168.6 |
| 2 | Doctors Ck u/s Old Fairhall Stm | | 188.2 | 182.3 | 167.6 | 174.9 | 4 | 178.3 | 167.6 | 188.2 |
| 3 | Doctors Ck u/s Taylor Rv | 176.8 | 193.3 | 179.3 | 159.3 | 169.8 | 5 | 176.1 | 159.3 | 193.3 |
| 4 | Chinamans Dn | | | 197.3 | 197.1 | 185.4 | 3 | 193.3 | 185.4 | 197.3 |
| 5 | Taylor Rv u/s Doctors Ck | 165.2 | 159.7 | 179.3 | 175.5 | 167.7 | 5 | 169.5 | 159.7 | 179.3 |
| 6 | Bank St Dn | | 107.6 | 159.0 | 159.4 | 154.4 | 4 | 145.1 | 107.6 | 159.4 |
| 7 | Taylor Rv at High St | 174.3 | 175.4 | 174.0 | 171.7 | 164.8 | 5 | 172.0 | 164.8 | 175.4 |
| 8 | Boyce St Dn | 149.3 | 150.6 | 150.1 | 149.2 | 144.3 | 5 | 148.7 | 144.3 | 150.6 |
| 9 | Taylor Rv u/s Murphys Ck | 164.7 | 154.3 | 164.5 | 160.7 | 154.4 | 5 | 159.7 | 154.3 | 164.7 |
| 10 | Murphys Ck | 137.9 | 139.5 | 138.7 | 136.7 | 131.5 | 5 | 136.9 | 131.5 | 139.5 |
| 11 | Dashwood St Dn | | 161.7 | 165.1 | 176.6 | 161.9 | 5 | 165.9 | 161.7 | 176.6 |
| 12 | Taylor Rv u/s Fultons Ck | 149.0 | 149.9 | 149.8 | 146.2 | 143.2 | 5 | 147.6 | 143.2 | 149.9 |
| 13 | Fultons Ck u/s Pond | 130.9 | 132.6 | 128.9 | 127.6 | 122.1 | 5 | 128.4 | 122.1 | 132.6 |
| 14 | Fultons Ck d/s Pond | 137.4 | 132.8 | 130.2 | 123.5 | 122.2 | 5 | 129.2 | 122.2 | 137.4 |
| 15 | Fultons Ck u/s Taylor Rv | 138.6 | 133.2 | 130.7 | 128.0 | 122.9 | 5 | 130.7 | 64.8 | 133.2 |
| 16 | Waterlea Ck | 146.3 | 113.7 | 116.0 | 116.1 | 112.5 | 5 | 120.9 | 112.5 | 146.3 |
| 17 | Taylor Rv at Hutcheson St | 146.2 | 146.0 | 146.6 | 143.6 | 138.1 | 5 | 144.1 | 138.1 | 146.6 |
| 18 | Taylor Rv at Alfred St | 146.3 | 153.6 | 168.2 | 149.1 | 143.0 | 5 | 152.0 | 143 | 168.2 |
| 19 | Taylor Rv at Riverside | 147.4 | 147.3 | 147.1 | 144.9 | 142.5 | 5 | 145.8 | 142.5 | 147.4 |

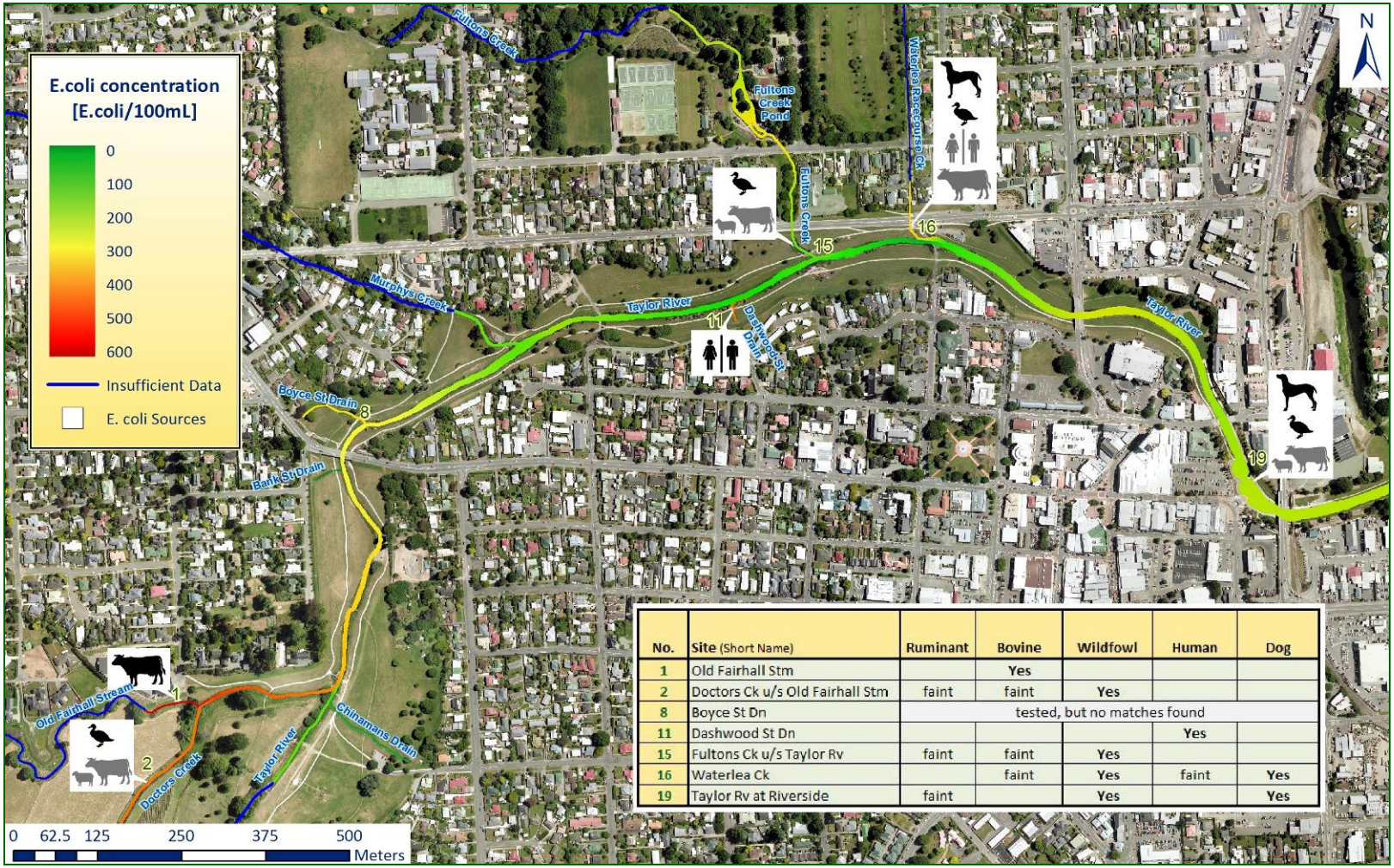
## 6.3. Appendix 3: E. coli concentrations in the Taylor River and its Tributaries




| No. | Site (Short Name) | 21-Jan | 31-Jan | 11-Feb | 28-Feb | 7-Mar | Number of Samples | Average | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Fairhall Coop Dn at Bells Rd | | | 2760 | 3870 | | 2 | 3315 | 2760 | 3870 |
| 2 | Fairhall School Dn | | | 226 | 201 | | 2 | 214 | 201 | 226 |
| 3 | Doctors Ck at Wiffen Bridge | | | 10 | 31 | | 2 | 21 | 10 | 31 |
| 4 | Fairhall Coop Dn u/s Doctors Ck | | | 119 | 906 | | 3 | 512 | 119 | 906 |
| 5 | Doctors Ck u/s Fairhall Coop Dn | | | 1198 | 813 | | 3 | 1005 | 813 | 1281 |
| 6 | Old Fairhall Stm at David St | | Dry | Dry | Dry | Dry | | | | |
| 7 | Old Fairhall Stm at Battys Rd | | Dry | Dry | Dry | Dry | | | | |
| 8 | Doctors Ck at Battys Rd | | 794 | 557 | 798 | 480 | 4 | 657 | 480 | 798 |
| 9 | Old Fairhall Stm | | 1539 | 313 | 488 | 231 | 4 | 643 | 231 | 1539 |
| 10 | Doctors Ck u/s Old Fairhall Stm | | 481 | 455 | 437 | 576 | 4 | 487 | 437 | 576 |
| 11 | Doctors Ck u/s Taylor Rv | 691 | 455 | 355 | 288 | 420 | 4 | 442 | 288 | 691 |


| No. | Site (Short Name) | 21-Jan | 31-Jan | 11-Feb | 28-Feb | 7-Mar | Number of Samples | Average | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Old Fairhall Stm | | 1539 | 313 | 488 | 231 | 4 | 643 | 231 | 1539 |
| 2 | Doctors Ck u/s Old Fairhall Stm | | 481 | 455 | 437 | 576 | 4 | 487 | 437 | 576 |
| 3 | Doctors Ck u/s Taylor Rv | 691 | 455 | 355 | 288 | 420 | 4 | 442 | 288 | 691 |
| 4 | Chinamans Dn | | | 85 | 30 | 10 | 4 | 42 | 10 | 148 |
| 5 | Taylor Rv u/s Doctors Ck | 206 | 213 | 216 | 63 | 97 | 5 | 159 | 63 | 216 |
| 6 | Bank St Dn | | 75 | 41 | 5 | 148 | 3 | 69 | 10 | 85 |
| 7 | Taylor Rv at High St | 556 | 313 | 259 | 203 | 197 | 5 | 306 | 197 | 556 |
| 8 | Boyce St Dn | 602 | 75 | 148 | 97 | 512 | 5 | 287 | 75 | 602 |
| 9 | Taylor Rv u/s Murphys Ck | 97 | 97 | 50 | 345 | 187 | 5 | 155 | 50 | 345 |
| 10 | Murphys Ck | 404 | 135 | 145 | 218 | 134 | 5 | 207 | 134 | 404 |
| 11 | Dashwood St Dn | | 187 | 882 | 1014 | 74 | 5 | 539 | 74 | 1014 |
| 12 | Taylor Rv u/s Fultons Ck | 110 | 98 | 185 | 63 | 74 | 5 | 106 | 63 | 185 |
| 13 | Fultons Ck u/s Pond | 279 | 373 | 148 | 216 | 135 | 5 | 230 | 135 | 373 |
| 14 | Fultons Ck d/s Pond | 341 | 292 | 226 | 336 | 85 | 5 | 256 | 85 | 341 |
| 15 | Fultons Ck u/s Taylor Rv | 175 | 98 | 110 | 243 | 135 | 5 | 152 | 98 | 243 |
| 16 | Waterlea Ck | 189 | 537 | 238 | 404 | 315 | 5 | 337 | 189 | 537 |
| 17 | Taylor Rv at Hutcheson St | 233 | 98 | 332 | 298 | 250 | 5 | 242 | 98 | 332 |
| 18 | Taylor Rv at Alfred St | 75 | 171 | 231 | 288 | 259 | 5 | 205 | 86 | 288 |
| 19 | Taylor Rv at Riverside | 75 | 181 | 288 | 265 | 279 | 5 | 218 | 75 | 288 |

## 6.4. Appendix 4: Modelled E. coli concentrations[7] and Microbial Source Tracking results




| No. | Site (Short Name) | Ruminant | Bovine | Wildfowl | Human | Dog |
|---|---|---|---|---|---|---|
| 1 | Old Fairhall Stm | | Yes | | | |
| 2 | Doctors Ck u/s Old Fairhall Stm | faint | faint | Yes | | |
| 8 | Boyce St Dn | tested, but no matches found | | | | |
| 11 | Dashwood St Dn | | | | Yes | |
| 15 | Fultons Ck u/s Taylor Rv | faint | faint | Yes | | |
| 16 | Waterlea Ck | | faint | Yes | faint | Yes |
| 19 | Taylor Rv at Riverside | faint | | Yes | | Yes |

[7] Based on average E. coli concentrations, flow patterns and die-off due to direct sunlight exposure