Appendix C – Ecology Assessment

Queenstown Lakes District Council

Wastewater Network Consent: Assessment of Ecological Effects

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Queenstown Lakes District Wastewater Overflow Discharge Network Consent: Assessment of Ecological Effects

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Cover photo (G. Ryder): View of Lake Hāwea from pump station #30, 24 August 2018

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Executive summary

Queenstown Lakes District Council (QLDC) operates wastewater reticulation systems servicing a number of communities in the district including the greater Queenstown area, Wanaka (including Albert Town and Luggate), and Lake Hāwea. With any wastewater scheme, there is the potential for overflows to occur. This Assessment of Ecological Effects presents an assessment of the existing environments where such wastewater overflows may occur, including water quality (including microbiological), ecology, and fisheries, and considers the actual and potential adverse effects of discharges of wastewater to such receiving environments. It was prepared to support the broader Assessment of Environmental Effects prepared for QLDCs Wastewater Overflow Discharge Network Resource Consent application.

Most of the waterways in the Queenstown Lakes District have good to excellent water quality and support highly valued aquatic ecosystems, such as those recognised in the Water Conservation (Kawarau) Order. Lakes Hāwea, Wakatipu and Wanaka are microtrophic, characterised by high water clarity, low nutrients and low algal biomass and large volumes of this very high-quality water from these lakes form the Clutha/Mata-Au and upper Kawarau Rivers. Many of the tributaries of these waterbodies have similarly high water quality, particularly in their upper reaches. There are, however, some exceptions. The Shotover River, for example, has naturally high sediment loads, while water quality in Lake Hayes is poor, having been degraded by historical land-use practices as well as contemporary inputs of nutrients and sediment.

The generally high water quality in many of the waterways in the Queenstown Lakes District means that they are potentially sensitive to inputs of nutrients, sediment and animal or human waste.

The highest risk sites identified were associated with sites near embayments on Lakes Wanaka and Wakatipu (pump stations near Roys Bay and Bremner Bay in Lake Wanaka, Queenstown Bay and Frankton Beach in Lake Wakatipu), pump stations near the shore of Lake Hayes, a pump station near Bullock Creek (Wanaka), one pump station on the banks of Luggate Creek and another in a reserve near the Arrow River. There is also a general risk associated with the presence of a wastewater system in close proximity to waterways, such as in Queenstown and Wanaka. This general risk is likely to be affected by factors such as the density of urban development, topography, proximity to waterways and presence of potential flowpaths to waterbodies (e.g. stormwater systems).

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1. Introduction

Queenstown Lakes District Council (QLDC) operates wastewater reticulation systems servicing a number of communities in the district including the greater Queenstown area, Wanaka (including Albert Town and Luggate) and Lake Hāwea. With any wastewater scheme, there is the potential for overflows to occur. This Assessment of Ecological Effects supports the broader Assessment of Environmental Effects prepared for QLDC's Wastewater Overflow Discharge Network Resource Consent application.

This report presents the available information on the existing environments where wastewater overflows may occur, including water quality (including microbiological), ecology, and fisheries, and assesses the actual and potential adverse effects of discharges of wastewater to these receiving environments. These assessments extend to areas of future development of wastewater systems in the Queenstown Lakes District.

The broader Assessment of Environmental Effects contains a fuller description of the project.

2. Ecological Assessment Methodology

This assessment consisted of a desktop literature review of ecological and water quality information for potential receiving waters along with site visits to 35 sites within the existing wastewater network as well as 12 sites that are part of planned future wastewater systems or that may become part of the QLDC network. In addition, water quality and biomonitoring[1] data received from Otago Regional Council and NIWA was analysed and presented to establish the existing water quality of water bodies.

Water quality outcomes for different water bodies were compared with Schedule 15 of the Otago Regional Plan: Water (RPW) (see Section 2.2).

2.1 Approach to risk assessment

The approach used to assess the ecological risk associated with wastewater overflows to freshwater in this report consisted of two primary considerations:

1) The risk of any wastewater overflow entering freshwater, and

2) The actual and potential effect(s) of wastewater overflows entering freshwater.

The risk of wastewater entering freshwater at the 35 existing sites and 11 potential future sites identified was assessed based on a measurement of the distance from the potential source of wastewater to water. Where a clear flow path was identified during the site visit or from aerial photographs[2], the distance to water was measured along this path. Such flow paths included roadways and stormwater systems, where these discharged to surface waters. Where no clear pathway was identified, the distance to water was measured as the shortest straight-line distance to water considering the local topography (i.e. water cannot flow up hill). The landcover of each potential flow path was also considered based on aerial photographs. Impervious surfaces (e.g. concrete, asphalt) would provide minimal infiltration of wastewater, so would potentially facilitate rapid transport to surface waters, and were therefore were considered to represent a higher risk of wastewater reaching surface waters than vegetated areas (e.g. rank grass). These factors and the resulting level of risk are set out in Table 1 below. While presented as discrete bands in Table 1, these factors are actually continuous variables and the risk of wastewater entering each of the pump stations and other notable parts of the network was considered based on the combination of each of these factors. The assessment of risk set out in Section 6.1 was based on the combination of distance to water, presence of a flow path and the ground cover.

[1] Periphyton and macroinvertebrate monitoring data
[2] QLDC web-based GIS layer

Table 1 Characteristics used to determine the risk of wastewater entering freshwater in this assessment.

Distance to water	Flow path	Ground cover	Risk
>200 m	No	-	Negligible
>200 m	No	Rank grass, thick vegetation	Low
100-200 m	Possible flow path present	Grass, shrubs with good undergrowth	Low-mod
100-200 m	Flow path present	Sparse grass or trees with little undergrowth	Moderate
40-100 m	Flow path present	Gravel, rock, bare soil	Mod-high
0-40 m	Clear flow path present	Impervious (e.g. concrete, asphalt)	High

The actual and potential adverse effects of wastewater overflows on freshwater ecology were based on an assessment of the likely consequences of wastewater overflow to the various types of waterbody (see Section 3 for descriptions of the existing environment for the different types of waterbody found in the Queenstown Lakes District).

This assessment considered the sensitivity of receiving environments (including the capacity to dilute contaminants as well as the existing state of each waterbody) along with the significance of the values in the receiving environment. For rivers, this assessment included consideration of the size of the river (flow) as well as water velocities/channel gradient (which affects the aeration rate and sediment deposition rate) as well as current water quality. In lakes, this assessment included consideration of the size of the lake (volume), residence time of water, exposure of the area that could potentially be affected by an outflow (considering wind directions, currents), tributary inflows and proximity to the lake outlet.

Table 2 below sets out the consequences and resulting level of effects.

Table 2 Description of the assessment of the potential effects of wastewater overflows on freshwater ecosystems.

Oxygen	Sediment		Growths		Odour	Scums/foam	Assessed level of effects
	Sedimentation	Clarity	Fungus	Periphyton			
Oxygen levels unchanged	Limited sedimentation	Water clarity not noticeably changed	No sewage fungus evident	Periphyton similar to areas upstream of overflow	No noticeable odour	No scums or foams	Low
Oxygen levels slightly lower than expected but unlikely to cause any ecological effect	Some localised deposits of fine sediment on channel margins and in backwaters (rivers) or thin layer of sediment on macrophytes or natural substrate in vicinity of overflow	Slight reduction in clarity	Very limited fungus growths in vicinity of overflow	Some moderate growths of algal mats or filamentous algae in the vicinity of overflow	Slight odour in vicinity of overflow	Minor scums or foams in immediate vicinity of overflow	Low-mod
Oxygen levels lower than normal which may cause stress for aquatic organisms	Some sedimentation on channel margins and in backwaters (rivers) or layer of sediment on macrophytes or natural substrate in vicinity of overflow	Obvious reduction in water clarity	Some fungus growth evident in vicinity of overflow	Moderate growths of algal mats or filamentous algae , in the vicinity of overflow	Noticeable odour in vicinity of overflow	Scums/foams evident in vicinity of overflow	Moderate
Oxygen levels at levels that may cause stress for aquatic organisms and lead to mortality if prolonged	Moderate sedimentation, deposited fine sediment covers much of the surface of natural substrate and macrophytes	Noticeable reduction in water clarity	Substantial fungus growth evident, mostly in vicinity of overflow	Moderate to thick growths of algal mats or filamentous algae mostly in the vicinity of overflow	Strong odour in vicinity of overflow	Conspicuous scums/foams in vicinity of overflow	Mod-high
Oxygen concentrations likely to drop to levels that may lead to the death of aquatic organisms	Severe sedimentation, deposited fine sediment completely covers the surface of natural substrate and may smother macrophytes	Marked reduction in water clarity	Substantial growths of sewage fungus extending well beyond the vicinity of overflow	Thick growths of algal mats or filamentous algae extending well beyond the vicinity of overflow	Strong odour extending beyond the vicinity of overflow	Conspicuous scums or foams evident beyond the vicinity of overflow	High

2.2 Statutory considerations

2.2.1 Water Conservation (Kawarau) Order

The Water Conservation (Kawarau) Order (WCO) includes provisions for water bodies that may be affected by the wastewater discharges considered in this report. These are outlined in Schedule 2 of the WCO, attached as Appendix A. Water quality provisions in the Kawarau WCO includes reference to water quality classes from Schedule 3 of the Resource Management Act (see Appendix B for the water quality standards for each of these water quality classes).

2.2.2 Lake Wanaka Preservation Act

The Lake Wanaka Preservation Act 1973 recognises the value the community places on the water quality of Lake Wanaka. Section 4 of the Lake Wanaka Preservation Act 1973 outlines the purposes of the Act, which includes the following purpose:

(d) to maintain and, as far as possible, to improve the quality of water in the lake.

2.2.3 Regional Plan: Water - Schedule 15

Schedule 15 of the RPW describes the characteristics of good water quality in lakes and rivers along with numerical water quality limits and targets for waterbodies across Otago. Table 3 below sets out the numerical water quality limits/targets for receiving water groups (RWGs) in the Queenstown Lakes District. It is worth noting that nitrate-nitrogen and dissolved reactive phosphorus limits apply to flowing water sites (RWGs 2 & 3), while limits on total nitrogen and total phosphorus apply to lakes (RWGs 4 & 5).

The limits/targets in Schedule 15 are not limits that apply to any potential discharge, but rather set out the long-term water quality objectives for receiving waters. As such, Schedule 15 is included here to provide context on the existing state of receiving waters and the long-term objectives for these water bodies.

It is important to note that in river sites these limits/targets apply as 5-year, 80th percentiles when flows are below median flows at the relevant flow reference site. That is, 80% of values collected when flows are at or below the median flow at the appropriate flow reference site over a 5-year period should be below the Schedule 15 limit.

Table 3 Numerical limits and targets for good water quality in lakes and rivers in the Queenstown Lakes District from Schedule 15 of the Otago Regional Plan: Water. RWG = receiving water group, NNN = nitrate-nitrite nitrogen, DRP = dissolved reactive phosphorus.

RWG	NNN mg/L	Total nitrogen mg/L	DRP mg/L	Total phosphorus mg/L	Ammoniacal nitrogen mg/L	*E. coli* cfu[3]/100 mL	Turbidity NTU	Tributaries within QLDC boundary
2	0.075	-	0.01	-	0.1	260	5	Arrow River, Cardrona River, Clutha River (Luggate to sea), Kawarau River (downstream of Shotover confluence), Luggate Creek, Mill Creek, Shotover River
3	0.075	-	0.005	-	0.01	50	3	Clutha River/Mata-Au above Luggate, Dart River, Kawarau River (above Shotover), Matukituki River, tributaries of Lakes Hāwea, Wakatipu & Wanaka
4	-	0.55	-	0.033	0.1	126	5	Lake Hayes
5	-	0.1	-	0.005	0.01	10	3	Lake Hāwea, Lake Wakatipu, Lake Wanaka

[3] Colony forming units. When culturing microbes, it is uncertain if a colony arose from one cell or a group of cells and expressing results as colony-forming units reflects this uncertainty.

3. Receiving environments

3.1 Very large rivers (Clutha/Mata-Au, Kawarau)

The natural values of the Clutha/Mata-Au and Kawarau Rivers from Schedule 1A of the RPW are set out in Appendix C. A number of the outstanding characteristics of the Kawarau River recognised in Schedule 2 of the Kawarau WCO (Appendix A) are presented in Schedule 1A of the RPW. These include the wild and scenic characteristics, natural characteristics, scientific value and recreational values (Appendix A). Schedule 2 also states that water quality is to be managed to Water Quality Class CR (Appendix A).

3.1.1 Ecology

Close to the lake outlets, both the Clutha/Mata-Au and Kawarau Rivers have very high water quality with low nutrients, *E. coli* and turbidity (Appendix D – Figures 1-5) and highly productive ecosystems (particularly in upper Clutha/Mata-Au).

Fish

Longfin eel, kōaro, common bully, upland bully, brown trout have been recorded from both the upper Clutha/Mata-Au and Kawarau Rivers. Rainbow trout, and quinnat salmon have been recorded from the upper Clutha/Mata-Au and are likely to also be present in the Kawarau River. Of the native fish present, longfin eel and kōaro are classified as 'at risk – declining', while common and upland bully are classified as "not threatened" (Dunn et al. 2018).

3.1.2 Fishery

The upper Clutha/Mata-Au is recognised as a nationally significant trout fishery[4] (Otago Fish & Game Council 2015), with in excess of 20,000 angler days recorded in the 2001/2002 and 2007/08 National Angler Surveys, although angler usage was substantially lower in the 2014/15 survey (Unwin 2016). Meanwhile, the Kawarau River supports a locally significant trout fishery with relatively consistent usage by anglers across the three most recent angler surveys.

[4] A naturally self-sustaining trout fishery.

3.2 Medium-large rivers (Hāwea, Shotover)

The natural values of the Hāwea and Shotover Rivers from Schedule 1A of the RPW are set out in Appendix C. A number of the outstanding characteristics of the Shotover River recognised in Schedule 2 of the Kawarau WCO (Appendix A) are presented in Schedule 1A of the RPW. These include the wild and scenic characteristics, natural characteristics (in particular, the high natural sediment load and active delta), scientific value (in particular, the high natural sediment load and active delta) and recreational values (Appendix A). Schedule 2 also states that water quality is to be managed to Water Quality Class CR (Appendix A).

3.2.1 Ecology

The Shotover River has extremely good water quality, with low levels of NNN, ammoniacal nitrogen and dissolved reactive phosphorus at the Bowen's Peak monitoring site (Appendix D – Figures 1-3). Counts of *E. coli* indicate a very low level of faecal contamination, although occasionally *E. coli* counts exceed alert (260 cfu/100 mL) and Action (550 cfu/100 mL) levels (Appendix D – Figure 4). However, the Shotover River carries naturally high loads of suspended sediment (Appendix D – Figure 5), as recognised in Schedule 2 of the Kawarau WCO (Appendix A).

Fish

The Shotover River supports a limited population of native fish, with a single longfin eel caught from the mainstem close to the SH6 bridge and records of kōaro from a number of tributary streams. Brown and rainbow are also present. Meanwhile kōaro, longfin eel, common bully, brown trout and rainbow trout have been recorded from the Hāwea River. Both longfin eel and kōaro are classified as 'at risk – declining' (Dunn *et al.* 2018).

The Hāwea River generally has very low *E*. coli concentrations, with the long-term median concentration of 1.6 cfu/100 mL (Appendix D – Figure 4)and water clarity is generally high, with turbidity ranging from 0.2 to 2 NTU (Appendix D – Figure 5), corresponding to a clarity range of 1.4 to 12.1 m.[5]

3.2.2 Water clarity and colour (hue)

High sediment loads and low water clarity are a feature of the Shotover River (Ludgate & Ryder 2008), as recognised by the WCO – see Appendix A), with the median water clarity (July 2008-December 2017) of less than 1 m (Appendix D – Figure 6). The low water clarity in the Shotover River means that it is unsuitable for swimming most of the

[5] Based on the relationship between turbidity and black disc clarity at the nearby National River Water Quality Network site in the Clutha River at the Luggate Bridge between February 1989 and December 2017. Turbidity and clarity relate to one-another as an inverse power relationship: Clarity = 2.7215 *Turbidity$^{-0.929}$, the R^2 for this relationship is 61.7%.

time naturally (MfE 1994, ANZECC 2000). However, the high sediment loads in the Shotover are natural and its recognised significance for kayaking, rafting and jetboating indicates that the limited visibility in the Shotover does not affect these activities.

3.2.3 Fishery

The Shotover River supports a locally significant trout fishery and angler usage of the Shotover has generally been low, with the exception of the 2001/02 season (Unwin 2016). The trout fishery in the Hāwea River is regionally significant (Otago Fish & Game Council 2015), although there has been a substantial reduction in angler effort since the 2001/02 survey. No international angler effort was record in either river during the 2014/15 season. It is likely that the reduction in angler effort in the Hāwea River is a result of the invasion and establishment of Didymo (*Didymosphenia geminata*). Didymo can reach very high levels of cover and biomass, which is unsightly, can affect macroinvertebrate communities and fish numbers (Jellyman & Harding 2016) and can be a nuisance to anglers by fouling their equipment. Spawning in the Hāwea River is thought to contribute to trout populations in the broader upper Clutha catchment.

3.3 Small-medium rivers

Four small- to moderate-sized rivers flow through or adjacent to urban areas within the Queenstown Lakes District: Arrow River (Arrowtown), Cardrona River (Albert Town), Luggate Creek (Luggate) and Mill Creek (Lake Hayes catchment). The natural values of these waterbodies from Schedule 1A of the RPW are set out in Appendix A.

3.3.1 Ecology

Water quality in the Arrow River is generally good with low concentrations of ammoniacal nitrogen and DRP and *E. coli* (Appendix D – Figures 2-4). NNN concentrations in the lower Arrow River were elevated during the sampling period available (August 1998-June 2014; Appendix D – Figure 1). A substantial amount of water (maximum rate of take of approximately 680 l/s) is abstracted from upstream of Arrowtown by the Arrow Irrigation Company (Olsen *et al.* 2017). Given the magnitude of this abstraction, it is expected to reduce the capacity of the lower river to dilute any inputs of contaminants, especially during the irrigation season (October-April).

A recent catchment water quality study found that water quality in the Cardrona River is generally high, with very low levels of ammoniacal nitrogen and dissolved reactive phosphorus (Appendix D – Figures 2-3; Olsen, 2016). However, concentrations of NNN exceeded the Schedule 15 limit in the lower Cardrona River (Olsen 2016).

Concentrations of NNN at the Mount Barker monitoring site were elevated (Appendix D – Figure 1).

Concentrations of NNN (Appendix D – Figure 1) and ammoniacal nitrogen (Appendix D – Figure 2) in Luggate Creek were typically low, while concentrations of DRP were relatively high (Appendix D – Figure 3) and exceed the Schedule 15 target (0.0152 mg/L cf. 0.01 mg/L[6]). Concentrations of *E. coli* in Luggate Creek were generally low, although they can exceed guidelines for contact recreation at times, usually in association with high rainfall and high flow events (Appendix D – Figure 4). Turbidity in Luggate Creek was generally low (Appendix D – Figure 5).

Water quality in Mill Creek, does not meet the Schedule 15 targets (see Table 3[7]) for NNN (0.36 mg/L cf. 0.075 mg/L) and *E. coli* (440 cfu/100 mL cf. 260 cfu/100 mL)[8] (Appendix D – Figures 1 & 4). However, dissolved reactive phosphorus concentrations (0.008 mg/L cf. 0.01 mg/L) and turbidity (4.11 NTU cf. 5.0 NTU) are within the Schedule 15 limit[8] (Appendix D – Figures 3 & 5).

Fish

Arrow River – The Arrow River supports a limited population of native fish, with a single record of kōaro from close to the confluence of Soho Creek, and it appears that the abundance of kōaro in the Arrow catchment is very low (Olsen *et al.* 2017). Brown trout and rainbow trout can be locally abundant in the Arrow River and in the Soho Creek sub-catchment. Kōaro is classified as ‘at risk – declining’ (Dunn *et al.* 2018).

Cardrona – Fish populations include longfin eels, kōaro, upland bullies and Clutha flathead galaxias (*Galaxias* sp. D) as well as brown and rainbow trout (Ravenscroft *et al.* 2017). Clutha flathead galaxias are classified as ‘nationally critical’, the highest threat classification in New Zealand, while longfin eels and kōaro are classified as ‘at risk – declining’ (Dunn *et al.* 2018). Clutha flathead galaxias are mostly found in tributaries of the Cardrona where trout are not present, with the exception of the lower reach between the Mount Barker flow monitoring site and the SH8 bridge where limited numbers of Clutha flathead galaxias have been recorded.

Luggate Creek – Brown trout, rainbow trout and kōaro have been recorded from the Luggate Creek catchment. Kōaro is classified as ‘at risk – declining’ (Dunn *et al.* 2018).

Mill Creek – Common bully, kōaro, brown trout and perch (*Perca fluviatilis*) have been recorded from the Lake Hayes catchment[9], although perch are likely to be mainly confined to Lake Hayes. Populations of kōaro and common bully are landlocked. Kōaro are classified as “at risk – declining”, while common bully are not considered to be

[6] http://archive.orc.govt.nz/Documents/Publications/Research%20And%20Technical/surface-water-quality/2016/2016%20SOE%20report%20card.pdf
[7] On page 7
[8] https://www.orc.govt.nz/media/6120/2018-wq-report-card-arrow-basin-pdf.pdf
[9] New Zealand Freshwater Fish Database, records downloaded 8 August 2018

threatened (Dunn *et al.* 2018).

Macroinvertebrates

No macroinvertebrate data are available for the Arrow River. However, macroinvertebrate communities collected from the Cardrona River at Mount Barker between 2001 and 2015 were consistent with good to excellent water quality, and have been stable over this period (Olsen 2016). Olsen (2016) undertook macroinvertebrate surveys throughout the Cardrona catchment, with communities in the upper Cardrona River and tributaries (all upstream of Mount Barker) in October 2014 consistent with good water quality, although sites below Mount Barker indicated that water/habitat quality was fair. Macroinvertebrate sampling in February 2015 followed a similar pattern, but the macroinvertebrate community at most sites included a greater proportion of taxa that are tolerant of poor water quality, probably the result of the low, stable flows and warmer water temperatures before this sampling occasion.

Macroinvertebrate sampling in Luggate Creek at the SH6 bridge is undertaken annually as part of ORC's State of the Environment (SoE) monitoring programme. Macroinvertebrate community index (MCI) scores for this site over the last 10 years have consistently been between 100 and 112, indicating good water/habitat quality.

3.3.2 Faecal indicator bacteria

At low flows, *E. coli* concentrations are generally low at most sites in the Cardrona River (Olsen 2016). *E. coli* counts in SoE samples from the Cardrona River at Mount Barker (2007-2016) show that 3% of readings were above "action" level (>550 cfu/100 mL) and only 6% of readings were above "alert" level (>260 cfu/100 mL) (Appendix D – Figure 4). It is likely that some or all of these readings are attributable to high flows at the time of sampling.

Similarly, *E. coli* counts in SoE samples from Luggate Creek at the SH6 bridge (2007-2016) show that 2% of readings were above "action" level (>550 cfu/100 mL) and only 5% of readings were above "alert" level (>260 cfu/100 mL)(Appendix D – Figure 4). Again, it is likely that some or all of these elevated readings are likely to be attributable to high flows at the time of sampling.

3.3.3 Fishery

Both the Arrow and Cardrona Rivers support locally significant fisheries, although the proximity of the Arrow River to the tourist towns of Arrowtown and Queenstown means that it is especially popular with international anglers (Unwin 2016). Most angler effort in both these fisheries is early in the fishing season (November-April for the Arrow River, October-April for the Cardrona River) and likely reflects anglers targeting post-spawn adult fish before they drop back into the Clutha/Mata-Au (Cardrona) or Kawarau (Arrow)

Rivers as flows drop (Unwin 2016). No angler effort has been recorded from Luggate Creek in any of the National Angler Surveys (Unwin 2016).

3.4 Streams

A number of small streams flow through the urban areas of Wanaka and Queenstown including Bullock Creek, Horne Creek and numerous other small tributaries. Of these, Schedule 1A of the RPW identifies both Bullock Creek and Horne Creek as having significant habitat for trout spawning and juvenile rearing, and as having a significant presence of trout (in the lower reaches of Horne Creek) (Appendix C). Furthermore, Horne Creek is also identified as having unimpeded access through to Lake Wakatipu and being free of weeds (Appendix C).

There is limited information on the water quality and ecology of these smaller streams. Despite their small size, these smaller streams may carry contaminants to larger water bodies.

3.4.1 Ecology

Fish

Native fish potentially present include longfin eel, kōaro (especially lake tributaries), common bully (lakes tributaries) and upland bully[10]. Clutha flathead galaxias are potentially present in tributaries of upper Clutha River[11], particularly where trout are absent. Clutha flathead galaxias are classified as 'nationally critical', the highest threat classification in New Zealand, while longfin eels and kōaro are classified as 'at risk – declining' (Dunn *et al*. 2018).

Many of the small tributary streams of the upper Clutha and Lakes Hāwea, Wakatipu and Wanaka provide habitat for trout spawning and are likely to be recruitment sources for trout populations in larger receiving water bodies.

3.5 Large lakes (Lakes Hāwea, Wakatipu and Wanaka)

Lakes Hāwea, Wakatipu and Wanaka are large (141-291 km^2), deep (311-392 m maximum depth) glacial lakes fed by large alpine rivers that drain from the Southern Alps and foothill ranges. Their catchments are dominated by steep alpine areas that are very sparsely populated, with the only major settlements being located close to the outlets of each lake: Hāwea, Queenstown and Wanaka, respectively. In the Wakatipu

[10] New Zealand Freshwater Fish Database, records downloaded 8 August 2018
[11] New Zealand Freshwater Fish Database, records downloaded 8 August 2018

catchment there are settlements (Glenorchy and Kingston) at either end of the lake.

These three large lakes are renowned for the high quality of their water, especially their clear waters and the blue hue of their water which, in part, results from the high clarity of their water (Appendix D – Figure 7). This high clarity is due, in part, to low nutrient availability (Appendix D – Figures 8-9) which results in these lakes supporting a low biomass of phytoplankton (Appendix D – Figure 10). All three of these lakes can be classified as microtrophic systems.[12]

High water clarity also allows high penetration of ultra-violet radiation into the water, killing bacteria, which results in very low *E. coli* concentrations (Appendix D – Figure 11). These characteristics are reflected in the Schedule 15 limits for these water bodies (Table 3).

3.5.1 Ecology

Fish

Fish populations include longfin eel (*Anguilla dieffenbachii*), kōaro (*Galaxias brevipinnis*), common bully (*Gobiomorphus cotidianus*), upland bully (*Gobiomorphus breviceps*), brown trout (*Salmo trutta*), rainbow trout (*Onchorhynchus mykiss*) and quinnat salmon (*Onchorhynchus tshawytscha*)[13]. Populations of kōaro and common bully are landlocked. Longfin eel and kōaro are classified as "at risk – declining", while other native species are not considered to be threatened (Dunn *et al.* 2018).

Macroinvertebrates

Macroinvertebrate communities of Lakes Hāwea, Wakatipu and Wanaka have been surveyed on a number of occasions by various researchers (Biggs & Malthus 1982, Stark 1993, Kelly & Hawes 2005, Thompson & Ryder 2008). The results of these studies suggest that these lakes support similar macroinvertebrate communities, with snails (*Potamopyrgus antipodarum*, *Gyraulus*, *Lymnaea* and *Physa*), chironomid midges (*Chironomus*, Orthocladiinae, Tanypodinae), worms (Oligochaeta, Nematoda) and caddis flies (especially the purse-cased caddis *Paroxyethira*) among the most common taxa collected. Kelly & Hawes (2005) found exotic macrophyte beds supported higher macroinvertebrate densities and diversity than native macrophyte beds.

Freshwater mussels (*Echydridella menziesii*) are present in Lakes Hāwea, Wakatipu and Wanaka (Thompson & Ryder 2002, Goldsmith *et al.* 2007) and are listed as "at risk – declining" by Grainger *et al.* (2014).

[12] Microtrophic (a trophic level of less than 2) is defined as lakes with very good water quality. Such lakes are clear and blue with very low levels of nutrients and algae (https://www.lawa.org.nz)
[13] New Zealand Freshwater Fish Database, records downloaded 8 August 2018

Macrophytes

One measure of the ecological condition of lakes is LakeSPI (Lake Submerged Plant Indicators) based on the composition of native and invasive plants (Clayton & Edwards 2006). The LakeSPI score for Lakes Wakatipu and Wanaka indicate that they are in 'excellent' condition, although the macrophyte community of Lake Wakatipu is in better condition, with a very high native condition and a low level of invasive impact (Table 4). In comparison, Lake Wanaka has a slightly lower overall LakeSPI, slightly lower native condition and higher invasive impact, with two invasive oxygen weeds present: *Elodea* and *Lagarosiphon*, while only *Elodea canadiensis* is present in Lake Wakatipu (Table 4).

Table 4 Macrophyte survey data for Lakes Wakatipu and Wanaka. Data from https://lakespi.niwa.co.nz/

Lake	Native submerged plants recorded	Invasive submerged plants recorded	Max depth (m) of submerged aquatic plants				LakeSPI		
			Year	Native plants	Charophyte meadows	Invasive	LakeSPI	Native condition	Invasive impact
Lake Wakatipu	Charophyte meadow	*Elodea*	2001	35	25	-	98	97	0
	Native pondweeds		1992	50	50	8	90	93	13
	Native milfoils		1982	45	45	7	94	95	6
	Isoetes								
	Charophyte species								
	Turf community								
Lake Wanaka	Charophyte meadow	*Elodea*	2011	20	18	8	81	87	25
	Native pondweeds	*Lagarosiphon*	2001	20	20	-	80	81	19
	Native milfoils		1982	35	25	-	94	91	0
	Isoetes								
	Charophyte species								
	Turf community								

Clayton *et al.* (1986) sampled macrophytes to the maximum vegetation depth (where possible) at various sites in Lake Hāwea, with a maximum depth of 36 m sampled. Stark (1993) recorded the macrophyte species present in samples taken from a range of depths (up to 4 m in Lakes Hāwea and Wanaka and up to 6 m in Lake Wakatipu). Kelly & Hawes (2005) collected samples from between 3-5 m in Lake Wanaka. Thompson & Ryder (2008) collected macrophyte and macroinvertebrate samples at depths of between 1-12 m in Lakes Hāwea and Wanaka.

Most of the macrophyte species recorded from each lake (

Table 5) were native and not threatened (based on Lange *et al.* 2013). However, Stark (1993) recorded the quillwort *Isoetes kirkii*, which is classified as 'at risk – declining', from both Lakes Wakatipu and Wanaka, although Kelly & Hawes (2005) recorded *Isoetes alpinus* from Lake Wanaka. *Isoetes alpinus* is classified as not threatened (Lange *et al.* 2013). Stark (1993) also recorded the marsh arrow grass *Triglochin palustris* from Lake Wanaka, which is classified as 'threatened – nationally critical' (Lange *et al.* 2013).

The presence of Maniototo button daisy *Leptinella maniototo* and curly dock *Rumex crispus* in shallow (<1 m) parts of Lake Hāwea probably reflect the variability of water levels resulting from the management of Lake Hāwea for hydroelectric power generation. Maniototo button daisy is often found growing close to water, in ephemeral wetlands and at sites subject to seasonal flooding and drying episodes.[14]

All three lakes support deep water bryophyte (mosses and liverworts) communities. In Lake Hāwea these occur to 35 m, in Lake Wakatipu to 60 m and down to 50 m in Lake Wanaka (de Winton & Beever 2004). Coffey and Clayton (1988b) recorded bryophytes to a maximum depth of 70 m in Lake Wakatipu, while de Winton and Beever (2004) found bryophytes to a maximum depth of 60m, with the average maximum depth limit of 41.5m. These communities require very high water clarity and are rare internationally.

[14] http://www.nzpcn.org.nz/flora_details.aspx?ID=913

Table 5 Macrophyte taxa recorded from Lakes Hāwea, Wakatipu and Wanaka by [1] = Clayton et al. 1986, [2] = Stark (1993), [3] = Kelly & Hawes (2005) and [4] = Thompson & Ryder (2008).

Lake Hāwea	Lake Wakatipu	Lake Wanaka
Chara corallina[1,2,4]	*Chara corallina*[2]	*Chara corallina*[2,4]
Chara braunii[1]	*Chara fibrosa*[2]	*Chara fibrosa*[2]
Crassula sinclairii[2]	*Nitella* spp. [2]	*Nitella pseudoflabellata*[4].
Elodea canadensis[2,4]†	*Elatine gratioloides*[2]	*Nitella hookeri*[4]
Glossostigma diandrum[2]	*Glossostigma diandrum*[2]	*Nitella hyalina*[4]
Glossostigma elatiinoides[2]	*Isoetes kirkii*[2] ‡	*Elatine gratioloides*[2]
?Juncus sp.[2]	*Lilaeopsis* sp. [2]	*Elodea canadensis*[2,3,4]†
Leptinella maniototo[2]*	*Myriophyllum triphyllum*[2]	*Glossostigma elatinoides*[4]
Lilaeopsis sp.[2]	*Pilularia novae-zelandiae*[2]	*Glossostigma diandrum*[2]
Myriophyllum aquaticum[4]	*Potamogeton cheesemanii*[2]	*Isoetes alpinus*[3]
Myriophyllum triphyllum[2,4]	Moss (*Lycopodium* spp.) [2]	*Isocetes kirkii*[2,4] ‡
Pilularia novae-zelandiae[2]		*?Juncus* sp.[2]
Potamogeton cheesemanii[2,4]		*Lagarosiphon major*[3,4]†
Rumex crispus[2]*		*Lilaeopsis ruthiana*[4]
Moss (*Lycopodium* spp.)[2]		*Myriophyllum aquaticum*[4]
Nitella hooker[1,4]		*Myriophyllum pedunculatum*[2]
Nitella hyalina[4]		*Myriophyllum triphyllum*[2,3,4]
Nitella pseudoflabellata[1,4]		*Pilularia novae-zelandiae*[2]
		Potamogeton cheesemanii[2,3,4]
		Ranunculus limosella[2]
		Triglochin palustris[2] §
		Moss (*Lycopodium* spp.)[2,4]
		Lagarosiphon major[3,4]

* Not typically a submerged aquatic macrophyte
† Invasive species
‡ Native, at risk – declining
§ Native, threatened – nationally critical

3.5.2 Faecal indicator bacteria

Recreation monitoring in Lake Hāwea (December 2014-March 2018) indicates that the microbial water quality is excellent, with low overall risk for contact recreation, with all readings over the last three years being <50 cfu/100mL. Similarly, limited sampling water quality in Roys Bay in Lake Wanaka (December 2017 – March 2018), indicates that *E. coli* concentrations are generally low (<72 cfu/100 mL), representing a low overall risk for contact recreation. However, contact recreation sampling at Lake Wanaka at the Township site in 2014-15 resulted in two samples that exceeded 550 cfu/100mL[15], while all samples collected over the 2015/16 contact recreation season were below

[15] http://archive.orc.govt.nz/Documents/Publications/Research%20And%20Technical/surface-water-quality/2015/2014%202015%20Contact%20Rec%20report%20card.pdf

550 cfu/100 mL[16]. Recent sampling in Lake Wakatipu shows that whilst the water quality in the Frankton Arm generally has a high level of compliance with guidelines for contact recreation, two values were recorded during the 2017/18 season that exceeded 550 cfu/100 mL ('Action' level[17]) and one value was recorded that was between 260 and 550 cfu/100 mL ('Alert' level[17]). One other non-compliance was recorded in the 2015/16 bathing season, with an 'Alert' level reading recorded on 25 January 2016.

3.5.3 Fisheries

All three lakes support nationally significant fisheries for trout and salmon (Otago Fish & Game 2015). Angler usage is very high in all three lakes, although the level of use estimated for the 2014/15 season was lower than in the 2007/08 season in Lakes Hāwea and Wanaka, while effort in Lake Wakatipu has been more consistent through time (Unwin 2016).

The Kawarau WCO recognises the fishery in Lake Wakatipu as being an outstanding characteristic (Appendix A).

3.5.4 Water clarity and colour (hue)

Scenic values have been identified as outstanding in all three lakes, particularly the colour of their water (Schedule 1A of the RPW). The colour of water is affected by the absorption and scattering of light. In very clear water, longer wavelengths of light (red, yellow, green) are absorbed by water molecules, while shorter wavelengths (blue) penetrate the water to a greater extent and are more likely to be scattered and reach the eye of an observer, giving very clear water a blue hue. The introduction of sediment particles, particulate or dissolved organic matter and phytoplankton can alter the hue by absorbing and/or scattering different wavelengths of light, giving the water a green, yellow or brown hue. As noted in section 2.1, the blue hues of Lakes Hāwea, Wakatipu and Wanaka partly result from the very high clarity of their waters, with low amounts of suspended sediment and low phytoplankton biomass, especially in the main bodies of these large lakes.

[16] http://archive.orc.govt.nz/Documents/Publications/Research%20And%20Technical/surface-water-quality/2016/Contact%20Recreation%20report%20card%202015-16.pdf
[17] Ministry for the Environment & Ministry of Health (2002). Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment, Wellington. See Appendix C for an outline of the alert levels for freshwater contact recreation monitoring.

3.6 Medium lakes (Lake Hayes)

Lake Hayes is a medium-sized lake with an area of 276 ha and a maximum depth of 33 m. It is a nutrient-rich lake (eutrophic[18] – Figures 1-4) as a result of historic catchment development (including top dressing) and land-use intensification as well as contemporary activities in its catchment, which results in periodic algal blooms and fish kills.

Schedule 1A of the Otago Regional Plan: Water identifies the following values for Lake Hayes: Weed free (absence of aquatic pest plants (eg *Lagarosiphon*) identified in the Pest Management Strategy for Otago 2009[19]), significant presence of eel and significant presence of trout.

3.6.1 Ecology

Water quality in the main tributary to the lake, Mill Creek, does not meet the Schedule 15 targets (see Table 3[20]) for NNN (0.36 mg/L cf. 0.075 mg/L) and *E. coli* (440 cfu/100 mL cf. 260 cfu/100 mL). However, dissolved reactive phosphorus concentrations are within the Schedule 15 limit (0.008 mg/L cf. 0.01 mg/L). The current water quality in Lake Hayes (Appendix D – Figures 7-11) likely reflects the combined effects of contemporary nitrogen discharges in combination with the internal load of phosphorus from historic land-use practices.

Fish

Common bully, kōaro, brown trout and perch (*Perca fluviatilis*) have been recorded from the Lake Hayes catchment[21]. Populations of kōaro and common bully are landlocked. Kōaro are classified as “at risk – declining”, while common bully are not considered to be threatened (Dunn *et al.* 2018).

Invertebrates

Freshwater mussels (*Echydridella menziesii*) are recorded as present in Lakes Hayes in the New Zealand freshwater fish database and are listed as “at risk – declining” by Grainger *et al.* (2014).

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[18] The LAWA website defines a Eutrophic lake as one having an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes the shallow waters of oxygen in summer resulting in death of animal life.
[19] Although see Section 3.6.1 – Macrophytes. The invasive macrophytes *Elodea canadensis* and *Ranunculus trichophyllus* are present in Lake Hayes.
[20] Page 7
[21] New Zealand Freshwater Fish Database, records downloaded 8 August 2018

Macrophytes

The LakeSPI score for Lake Hayes based on a survey in 2001 indicates that it was in 'moderate' condition, with an overall score of 26%, a native condition score of 14% and an invasive impact score of 69%[22]. These scores represent the dominance of the macrophyte community of Lake Hayes by invasive species. Despite Schedule 1A of the RPW listing Lake Hayes as "Weed free", the invasive macrophytes *Elodea canadensis* and *Ranunculus trichophyllus* are present.

3.6.2 Faecal indicator bacteria

ORC monitors water quality for suitability for contact recreation at one site for Lake Hayes – Lake Hayes at Mill Creek shallows. This site generally has a high level of compliance with guidelines for contact recreation (Appendix D – Figure 11), although in the 2017/18 season three values were recorded that exceeded 550 cfu/100 mL ('Action' level) and four values were recorded that were between 260 and 550 cfu/100 mL ('Alert' level). Single values in the 2015/16 and 2016/17 seasons also reached the 'Alert' level reading.

Lake Hayes also periodically has blooms of potentially toxic cyanobacteria (*Anabaena*), which can pose a risk to recreational users and has resulted in health warnings to avoid contact with its waters being issued.

[22] https://lakespi.niwa.co.nz/lake/54190

3.6.3 Fishery

Lake Hayes supports a regionally significant fishery for trout and wildlife habitat (Otago Fish & Game 2015). European perch are also present and contribute to the fishery. Angler usage of Lake Hayes has declined since the 2001/2002 National Angler Survey (Unwin 2016).

3.6.4 Water clarity and colour (hue)

Low water clarity (Appendix D – Figure 7), particularly associated with algal blooms, can detract from the scenic value of Lake Hayes at times.

4. Characteristics of wastewater

This section explains the characteristics of wastewater.

4.1 Organic matter

Organic matter is a major constituent of wastewater and comes from human faeces, food waste and soaps (MfE 2003).

4.2 Suspended solids

The term suspended solids refers to particulate matter larger than 2 µm and includes inorganic and organic material. The organic component of total suspended solids (TSS) can be determined by the loss of mass on ignition at a temperature of 550-600°C – termed the volatile fraction (VSS). The difference between TSS and VSS of a sample represents the inorganic fraction. The concentration of suspended solids in wastewater can exceed 200 mg/L.

4.3 Nutrients

The major nutrients present in wastewater are nitrogen and phosphorus, which are both produced by the breakdown of organic matter. Nitrogen is also present as urea in the urine of humans, which can be converted to ammonia/ammonium ions in water, which is usually rapidly oxidised to nitrate in high-oxygen aquatic environments. Phosphorus is also present in some detergents and these can be a source of phosphorus in wastewater. Typical concentrations of nitrogen and phosphorus in wastewater are 40 mg/L and 15 mg/L, respectively.

4.4 Others

Wastewater can also contain a range of other contaminants including metals (especially from trade waste), industrial or household chemicals (e.g. surfactants), as well as chemicals that may interfere with the physiology of organisms exposed to them (e.g. endocrine disruptors).

5. Ecological impacts of wastewater discharges entering freshwater

5.1 Organic matter

The introduction of wastewater rich in organic matter, along with high loads of bacteria, can lead to high biochemical oxygen demand (BOD) as oxygen is consumed during the aerobic breakdown of organic matter. This can lead to low oxygen in the receiving environment, especially when there is little aeration or inflows of oxygenated water. The BOD_5 of untreated wastewater is around 200–300 g/m^3, while the BOD_5 for a healthy aquatic ecosystem would be less than 5 g/m^3 (MfE 2003) and probably less than 1 g/m^3 for the larger alpine lakes of the Queenstown Lakes District. Organic matter occurs in dissolved or particulate forms and both can affect the colour and/or clarity of water by affecting how light is scattered and/or absorbed. Organic matter usually absorbs longer wavelength light (red, yellow) giving the water a red, brown or yellow appearance, while particles suspended in the water increase the scattering of light, reducing light penetration (see Section 3).

High concentrations of organic matter can fuel the growth of fungal growths, such as the aptly named "sewage fungus". Sewage fungus refers to the growth of a community dominated by heterotrophic[23] organisms, fed by organic matter-rich discharges. In instances of the prolonged discharge of untreated wastewater, sewage fungus can rapidly grow to cover the stream bed, excluding other types of periphyton, reducing oxygen concentrations, causing unpleasant odours when river levels drop and leading to changes in macroinvertebrate communities.

5.2 Suspended solids

Suspended solids have direct and indirect adverse effects on aquatic ecosystems and these effects can vary depending on the organic content. The adverse effects of organic matter are covered in Section 5.1. High suspended solid concentrations can lead to sedimentation of gill surfaces (of fish and invertebrates), the smothering of eggs or redds (nests), abrasive damage of skin or respiratory surfaces. Indirect effects include changes in invertebrate prey resulting from sedimentation of substrate.

Suspended sediment (and organic matter) can also lead to changes in the clarity and colour of receiving waters, with flow-on effects on ecosystems. For example, reduced water clarity can reduce the effective feeding range of trout and salmon by reducing their ability to see and intercept prey. Changes in clarity and water colour can also reduce light penetration, which can affect the depth range of macrophytes and

[23] Heterotrophic organisms are unable to manufacture their own food from simple chemical compounds, so consume organic matter, which is then broken down

periphyton.

5.3 Nutrients

5.3.1 Nutrient enrichment

Both nitrogen and phosphorus are essential nutrients for plant growth, but as their concentrations increase, they can lead to excessive growths of macrophytes and periphyton.

Nitrate is usually the predominant form of bioavailable nitrogen in freshwater and is, therefore, an important indicator of nutrient enrichment of freshwater systems and the effects of nitrate enrichment would be expected to be seen at concentrations far below the concentrations at which the toxic effects of nitrate are expected to be observed (see 'Nitrate toxicity' below). Schedule 15 of the RPW sets out limits for NNN for receiving environments in various parts of Otago (Table 3). The limit for RWGs 2 and 3 (0.075 mg/L) is lower than the ANZECC (2000) guideline for upland rivers (0.167 mg/L), reflecting the very low levels of NNN in water bodies in these parts of Otago, including most of the rivers and streams in the Queenstown Lakes District. Of the river/stream sites in the Queenstown Lakes District sampled by ORC as part of State of the Environment monitoring, only Mill Creek fails to meet the Schedule 15 limit for nitrate-nitrate. In addition, inputs of groundwater to the lower Cardrona River (from the SH6 bridge downstream) mean that NNN concentrations in this section of the Cardrona are also likely to exceed the Schedule 15 limit.

Phosphorus is a limiting nutrient in many Otago rivers and any increase in the concentration of dissolved reactive phosphorus is expected to increase the rate of the accrual of periphyton biomass, increasing the potential for the nuisance growths.

Because of the retention and complex internal cycling of nutrients in lakes, limits are usually applied on total nutrient concentrations. Therefore, the addition of any nutrients in whatever form (dissolved, organic, particulate) to lakes is expected to increase the productivity of the receiving water, reflected in higher phytoplankton biomass.

Wastewater typically has low concentrations of nitrate-nitrogen, with most of the nitrogen occurring as ammoniacal nitrogen. However, any ammoniacal nitrogen is expected to be rapidly oxidised under the conditions found in most surface water receiving environments in the Queenstown Lakes District. Inputs of nitrogen have the potential to impact the ecosystem values of these waterbodies by significantly increasing the concentration of bioavailable nitrogen (especially compared to the very low background levels of nitrate nitrogen), with effects including localised proliferations of periphyton and phytoplankton. Excessive growth of periphyton can lead it to over-grow macrophytes and lead to the macrophytes dying-off. However, given that the duration of any overflow is expected to be short, this limits the potential for such discharges to affect aquatic ecosystems.

5.3.2 Nitrogen toxicity

In addition to being an essential nutrient, the two primary forms of nitrogen in freshwater can also be toxic to aquatic life. Ammoniacal nitrogen occurs in two forms in freshwater: free (unionised) ammonia (NH_3) and ammonium ions (NH_4^+), with these two forms occurring in equilibrium with the balance between the two forms determined by water temperature and pH (ANZECC 2000[24]). Of the two forms, unionised ammonia is more toxic to aquatic life. The discharge of untreated wastewater to freshwater is expected to be a significant source of ammoniacal nitrogen.

The National Policy Statement for Freshwater Management (NPS: FM, 2014, amended 2017) National Objectives Framework (NOF) sets out attribute states for ammonia toxicity, with "A" band concentrations being set to protect 99% species protection level, with an annual median of ≤0.03 mg NH_4-N/L and annual maximum value of ≤0.05 mg NH_4-N/L, with both values being based on pH 8 and temperature of 20°C[25]. All waterbodies considered here are in A-band for ammonia toxicity, with the exception of Lake Hayes, which would be in Band B (based on annual maximum ammoniacal nitrogen concentrations). The Schedule 15 limits for ammoniacal nitrogen in the RPW (Table 3) are well below those in the NOF and the limits for Receiving Water Groups 3 and 5 are equivalent to the ANZECC (2000) guidelines for upland rivers (0.01 mg/L), while the limit for Receiving Water Groups 1, 2 and 5 (0.1 mg/L) exceeds the ANZECC (2000) guidelines for upland (0.01 mg/L) and lowland rivers (0.021 mg/L). Therefore, the input of significant concentrations of ammoniacal nitrogen from wastewater overflows have the potential to impact the ecosystem values of these waterbodies (due to low background ammoniacal nitrogen and resulting presence of sensitive species). However, the duration of any overflow is expected to be short, limiting the potential for any acute toxic effect of such discharges.

Oxidised forms of nitrogen are also toxic to aquatic life. Of these nitrite (NO_2^-) is the more toxic form, although it is rare to observe appreciable concentrations of nitrite ions in oxic surface freshwaters, as it is usually rapidly oxidised to nitrate under such conditions. However, nitrate (NO_3^- is also toxic to aquatic life at sufficient concentrations and is also included in the NOF[26], with an annual median value of ≤1 mg NO_3-N/L and annual 95th percentile of ≤1.5 mg NO_3-N/L representing "A" band. All waterbodies considered here would be in A-band for nitrate toxicity. The nitrate bands in the NOF relate to nitrate toxicity, not the ecosystem effects of nitrate enrichment. Nitrate toxicity refers to the direct effect of nitrate on organisms causing mortality while nitrate can also indirectly affect aquatic ecosystems through its role as a nutrient for aquatic plant life. Nitrate enrichment can lead to prolific growths of

[24] Section 8.3.7.2
[25] Compliance with numeric attribute states should be undertaken after pH adjustment.
[26] The NOF values for nitrate relate to nitrate toxicity, not to effects relating to it as a nutrient.

aquatic plants (including periphyton and phytoplankton) with flow-on ecosystem effects.

5.4 Others

Wastewater can also contain a range of other contaminants including metals (especially from trade waste), industrial or household chemicals (e.g. surfactants), as well as chemicals that may interfere with the physiology of organisms exposed to them (e.g. endocrine disruptors).

Table 6 Summary of actual and potential adverse effects of wastewater discharges to freshwaters

Potential effect	Description
Oxygen depletion	High biochemical oxygen demand may cause depletion of oxygen in vicinity of discharge, particularly where limited current/mixing leads to low dispersion. This can lead to oxygen stress in fish and invertebrates.
Sediment:	
Sedimentation	Potential for direct or indirect effects. Direct effects include sedimentation of gill surfaces or smothering of eggs or redds (nests), abrasive damage of skin or respiratory surfaces. Indirect effects may include changes in invertebrate prey resulting from sedimentation of substrate.
Clarity	Suspended sediment (and organic matter) can lead to changes in the clarity and colour of receiving waters.
Growths:	
Fungus	Wastewater contains high levels of organic matter, which can lead to growths of heterotrophic organisms, such as sewage fungus.
Algae	The high concentrations of nutrients (nitrogen and phosphorus) in wastewater can lead to proliferation of filamentous algae.
Pathogens	Wastewater contains human waste, which contains bacteria, protozoa and viruses that can lead to illness in humans and other mammals that ingest contaminated water.
Odour	At high concentrations, wastewater can give water an unpleasant odour.
Scums/foam	Dissolved organic matter, surfactants and oils in wastewater can lead to the formation of scums and foams in receiving waters.
Endocrine disruptors	Wastewater can contain hormones (e.g. from contraceptive pills) or other chemicals that can disrupt the physiology of aquatic organisms.

6. Risk and effects assessment

6.1 Assessment of risk of wastewater overflows entering freshwater

The first part of the risk and effects assessment was to assess each identified potential overflow location for the risk of wastewater entering surface waterbodies based on the distance to water, presence of surface flow paths and land cover (as described in Section 2.1).

The results of this risk assessment for the 35 locations within the wastewater network and 12 future sites assessed is presented in Table 8. Most of these locations were pump stations but also included engineered overflow points, manholes and pipe crossings.

Ten sites were identified as "high risk" of wastewater entering surface waters in the event of a discharge (Table 8). These sites included pump stations at Lake Wanaka, Bullock Creek, Luggate Creek, a roadside drain that enters the Arrow River, a small stream that enters Lake Wakatipu at Sunshine Bay, Lake Wakatipu, Lake Hayes, Stone Creek and Buckler Burn (Table 8). Sixteen sites with moderate-high risk were identified in Lake Wanaka, Luggate Creek, Shotover River, several sites around Lake Wakatipu (including the Frankton Arm and at Kingston), Mill Creek, Lake Hayes, Stone Creek and Buckler Burn (Table 8).

Seven sites were identified as having a "negligible" risk of wastewater entering water (Table 8) due to their distance from surface waterbodies, a lack of obvious surface flowpath, and the presence of surfaces that will reduce the likelihood of wastewater reaching surface waterbodies (see Table 1). Sites assessed as having a negligible risk included at two locations within the lower Cardrona catchment, two sites in Luggate Creek, one location at Bush Creek (Arrow catchment) and two sites at Lake Hawea (Table 8).

6.2 Assessment of adverse effects of wastewater overflows on receiving environments

6.2.1 Large rivers (Kawarau & Clutha/Mata-Au)

These rivers contain low levels of nutrients, *E. coli* and suspended sediments and support significant ecological values, however their large flows (and therefore considerable dilution capacity) means that they are generally relatively insensitive to wastewater discharges, and adverse effects on river biota due to a very occasional, short-term discharge of untreated wastewater are correspondingly unlikely.

Three pump stations near the Clutha River were identified as having a moderate to high risk of wastewater entering the river in the case of overflow (Table 8), although the risks of adverse ecological effects associated with such a discharge are assessed as being low given the large flow of the upper Clutha River and high velocity water, which will rapidly dilute and disperse contaminants (Table 7). One pump station near the Kawarau River was identified as having a low to moderate risk of wastewater entering the river in the case of overflow due to the distance to water (52 m), and groundcover of rank grass (Table 8), and the risks of adverse ecological effects associated with such a discharge are also assessed as being low to moderate given the large flow of the Kawarau (Table 8).

Included in the future developments to the QLDC wastewater network assessed was a proposed wastewater pipeline from Lake Hāwea village to a wastewater treatment plant at Wanaka Airport, including a pipe bridge across the Clutha River. In the event of a breach of this pipe, there would be a high risk of wastewater entering the Clutha River, but the risks of adverse ecological effects associated with such a discharge are assessed as being low given the large flow of the Clutha River at this location. It would be expected that with adequate maintenance, the risk of such a breach would be extremely low, although this was beyond the scope of this assessment.

6.2.2 Medium-Large rivers (Hāwea & Shotover Rivers)

Both the Hāwea and Shotover Rivers contain low levels of nutrients and *E. coli*, although the Shotover can carry high loads of suspended sediments. The large flows (and therefore dilution capacity) of these rivers mean that they are also expected to generally be relatively insensitive to wastewater discharges.

One pump station near the Shotover River was identified as having a moderate to high risk of wastewater entering the river in the case of overflow due to its proximity of the pump station to the river, the steepness of the slope between the pump station and the river and the vegetation in the area being pine trees (with limited understory) (Table 8). However, the risks of adverse ecological effects associated with such a discharge are assessed as being low-moderate due to the large flow, high water velocities and naturally high sediment load in the Shotover River (Table 7).

Development of the alluvial flats on the true left (north) bank of the Lower Shotover has resulted in wastewater infrastructure being in relatively close proximity to the Shotover River. However, there is a low risk of wastewater reaching the Shotover (as a result of distance, lack of clear flowpaths and vegetation in the area) and the size and high sediment load of the lower Shotover (Table 8), the risk associated with waste water discharging to the lower Shotover was assessed as being low to moderate.

One pump station near the Hāwea River was identified as having a negligible risk of wastewater entering the river in the case of overflow due to it being a long distance from surface water and the lack of clear flowpaths to the Hāwea (Table 8).

6.2.3 Small-medium rivers

Low levels of nutrients, *E. coli* and suspended sediments in these rivers mean that they are expected to be highly sensitive to inputs of nutrients, microbes and sediments in wastewater discharges during periods of low flows. However, this is expected to be less of a risk during periods of higher flows, when there will be greater dilution with high quality water from the upper catchments. Flows in these rivers are highly seasonal, with the lowest flows occurring in summer and autumn months (Olsen et al. 2017, Ravenscroft et al. 2017).

Mill Creek has high levels of nitrogen, *E. coli* and suspended sediments and the bed of Mill Creek is dominated by fine sediments. As a result, it is not expected to be as sensitive to wastewater discharges as many other waterways within the QLDC district. However, given that Mill Creek discharges to Lake Hayes (approximately 2.5 km downstream), any nutrients or sediment that enters Mill Creek will contribute to nutrient and sediment loads to Lake Hayes, which will contribute to the continuation of poor water quality in Lake Hayes. There may be some attenuation of nitrogen before it enters Lakes Hayes (such as denitrification), but it is not possible to estimate the extent to which this may occur. Any phosphorus or sediments contributed to Mill Creek are expected to enter Lake Hayes.

Two pump stations near the Cardrona River were assessed as having a negligible risk of wastewater entering water due to the distance from and the lack of clear flowpaths to the nearest surface water (Table 8). A wastewater pipeline from Cardrona Village to a proposed wastewater disposal area near the ski field access road was assessed as a potential future addition to the QLDC wastewater network. Generally, the risk of wastewater from this pipeline entering surface water is assessed as being low, as the pipeline is to be buried alongside the path of Cardrona Valley Road. However, the pipe will cross several small streams, which discharge to the Cardrona a short distance downstream of the road. Therefore, the risk of wastewater entering water is generally assessed as low, but will be high where pipes cross tributary streams. The ecological risk associated with a discharge of wastewater to these small tributaries is assessed as high, with a moderate risk associated with such a discharge then entering the Cardrona River.

Of the four pump stations near to Luggate Creek, two stations were a considerable distance from the creek and were assessed as having a negligible risk of wastewater entering water as a result (Table 8). However, one pump station was assessed as having a moderate risk and another as having a high risk (Table 8). Luggate Creek has a minimum flow of 180 l/s (Schedule 2A of the RPW), meaning that the river has limited capacity to dilute any wastewater discharges when at low flows and there is moderate to high risk of adverse effects if one occurs (Table 7).

A pump station near Mill Creek has been identified as having a moderate-high probability of wastewater entering water in the case of overflow, while the ecological risks associated with such as discharge are assessed as being moderate, but with high risks of localised effects in Mill Creek (Table 7). The risk associated with the discharge of nutrients and sediment entering Lake Hayes is assessed in Section 6.2.6 and Table 7.

One other pump station was assessed as having a moderate risk of wastewater entering the Arrow River in the event of an overflow (Table 8), and the risk of potential adverse ecological effects associated with such a discharge is assessed as being moderate (Table 7).

Included in assessments was a proposed wastewater pipeline from Glenorchy to a proposed wastewater disposal area near the Glenorchy Airport. Generally, the risk of wastewater from this pipeline entering surface water is assessed as being low, as the pipeline is to be buried alongside the path of the Glenorchy-Queenstown Road. However, the pipe will cross the Buckler Burn, most likely under the existing road bridge. The vegetation under the Buckler Burn bridge is sparse, with the area under the bridge being dominated by steep bedrock. The risk associated with this pipeline will generally be low, but will be high where it crosses any streams. The size of the Buckler Burn means there is a moderate risk of ecological effects arising from the discharge of wastewater.

6.2.4 Streams and small rivers

Most small streams in the Queenstown Lakes District are expected to contain low levels of nutrients, *E. coli* and suspended sediments and they are expected to be highly sensitive to wastewater discharges. These streams are expected to provide habitat for trout spawning and rearing, and those that are close to large lakes are expected to support kōaro. Most of these values are not expected to be significantly affected by infrequent wastewater discharges, although there may be more sensitive receiving waters downstream (e.g. tributaries of the lakes). However, a lack of dilution means that any discharge has potential to impart significant, short-term, effects on local water quality and ecological values (Table 7).

Pump stations near Bullock Creek, an unnamed tributary of Lake Wakatipu near Fernhill and an unnamed tributary of the Arrow River, have been identified as having a moderate-high probability of wastewater entering water in the case of overflow (Table 8). Bullock Creek (Wanaka) flows through a highly built up area and is highly accessible and supports high values. Given its small size and high values, the risks associated with any wastewater discharges are high (Table 7).

The small roadside drain near Arrowtown has very limited flow, but is not expected to contain significant values. The main risk associated with a discharge from this pump station is if wastewater was to be flushed downstream into areas with higher values, including the Arrow River itself (3 km downstream).

It was also identified that in the case of an overflow at the pump station in Fernhill, it would be likely to enter a small unnamed tributary of Sunshine Bay in Lake Wakatipu.

Given the small flow of this stream, the risk of adverse effects from an overflow is potentially high as this small stream is likely to provide habitat for kōaro which could be affected. This stream also enters Lake Wakatipu, and therefore any overflow may also affect the ecological values in a localised area of the lake.

The risks associated with a proposed pipeline from Jacks Point to Frankton was included in these assessments. Generally, the risk of wastewater from this pipeline entering surface water is assessed as being low, as the pipeline is to be buried along a formed track. However, the pipe will cross a number of ephemeral streams that were dry during my site visit and were also dry at the time that GoogleMaps StreetView imagery was captured in August 2017. Whilst there is high risk of wastewater entering the bed of these streams in the event of a ruptured pipe, given they are ephemeral, the risk of wastewater entering surface water is assessed as low to moderate (Table 7). Given these streams appear to be ephemeral, they are unlikely to support significant aquatic values, and so the ecological risk associated with any wastewater discharge is assessed as being low.

Included in assessments was a proposed wastewater pipeline from Glenorchy to a proposed wastewater disposal area near the Glenorchy Airport. Generally, the risk of wastewater from this pipeline entering surface water is assessed as being low, as the pipeline is to be buried alongside the path of the Glenorchy-Queenstown Road. However, the pipe will cross Stone Creek, most likely under the existing road bridge. The vegetation under the bridge is sparse and relatively steep. The size of Stone Creek means there is a moderate to high risk of ecological effects arising from the discharge of wastewater.

Current development in Luggate is on the true left (west) side of Dead Horse Creek. However, development of the true right (east) side of Dead Horse Creek is underway and the wastewater network will cross Dead Horse Creek to connect to the greater wastewater network in Luggate. Given that this will involve a wastewater pipe crossing Dead Horse Creek, there is a high probability of wastewater entering Dead Horse Creek in the event of a leak. Given the small size of Dead Horse Creek, the risk of ecological effects arising from such a leak is assessed as being moderate to high.

It is proposed that wastewater from Luggate will be connected to a wastewater treatment plant near Wanaka Airport. Given that this will involve a wastewater pipe crossing Luggate Creek, there is a high probability of wastewater entering Luggate Creek in the event of a leak. The risk of ecological effects arising from such a leak is assessed as being moderate. Based on field visits and consideration of topographical maps and aerial photographs, it does not appear that the proposed pipeline will cross any other surface waterbodies.

6.2.5 Large lakes

The very low levels of nutrients, *E. coli* and suspended sediments in these lakes means that they are expected to be highly sensitive to the local effects of wastewater discharges. All three large lakes support significant ecological values. Whilst individual wastewater overflows are not expected to adversely affect the overall health of these lakes, they may cause significant, localised adverse effects in the vicinity of the discharge. The areal extent of a wastewater plume and its associated effects on water quality and aquatic biota, and the duration of those effects, are highly variable and dependent on a range of factors, including the volume of the discharge, the prevailing weather (e.g., calm lake conditions versus significant wind and wave action, river flow), local topography (e.g., shallow versus deep bed profiles) and currents, etc.

Twelve pump stations near these lakes have been identified as having a moderate to high probability of wastewater entering surface water in the case of overflow (Table 8). The local risks associated with the discharge of wastewater are higher at a number of sites in these lakes due to local features that reduce the potential for dilution and/or dispersion (e.g. embayments) (Table 7). Notable sites include Roys Bay and Bremner Bay in Lake Wanaka, Queenstown Bay and Frankton Beach in Lake Wakatipu.

Whilst occasional discharges of wastewater are unlikely to contribute significantly to overall nutrient concentrations in these lakes individually, cumulatively they will contribute the overall nutrient load to these lakes. The cumulative effect of multiple discharges is difficult to assess without information on the frequency, volume and nutrient loads of the discharges. Given the extremely low nutrient concentrations in these lakes, even seemingly small individual discharges may contribute significant nutrient loads to these systems and may contribute to eutrophication, at least locally. Having said that, most likely scenarios for discharges to large lakes are likely to be short-term in nature. The contribution of such discharges to the overall nutrient loads of these lakes would be minimised by minimising the frequency, duration and volume of such discharges.

6.2.6 Medium lakes (Lake Hayes)

The high levels of nutrients in Lake Hayes mean that it is expected to be less sensitive to individual discharges of nutrients and sediment than lower-nutrient lakes, although wastewater discharges may have localised effects in the immediate vicinity of the discharge point.

Two pump stations near Lake Hayes have been identified as having a moderate-high probability of wastewater entering the lake in the case of overflow (Table 8). Both have localised risks associated with the discharge of wastewater, particularly localised sedimentation, deoxygenation within any wastewater plume and the risk of the proliferation of periphyton in the event of a prolonged discharge. Wildlife, particularly waterfowl, are often abundant in the shallows in the vicinity of Mill Creek.

A pump station near Mill Creek has been identified as having a moderate-high probability of wastewater entering water in the case of overflow (see Section 6.2.3).

Given that Mill Creek discharges to Lake Hayes (approximately 2.5 km downstream), any nutrients or sediment that enters Mill Creek is expected to contribute to nutrient and sediment loads to Lake Hayes, which will contribute to the continuation of poor water quality in Lake Hayes. There may be some attenuation of nitrogen before it enters Lakes Hayes (such as denitrification), but it is not possible to estimate the extent to which this may occur. Any phosphorus or sediments contributed to Mill Creek are expected, ultimately, to enter Lake Hayes.

Table 7 Summary of the assessment of the risks associated with each of the potential effects of wastewater discharges to freshwaters.

Potential effect		**Large lakes**	**Lake Hayes**	**Streams**	**Small-medium rivers**	**Medium-large rivers**	**Large rivers**	**Values potentially affected**
Oxygen		Low, but high locally	Mod-high	Mod-high	Moderate	Low-moderate	Low	Fish, invertebrates
Sediment	Sedimentation	Low-moderate, but high locally	Mod-high	Mod-high	Moderate	Low-moderate	Low	Fish, invertebrates, macrophytes
	Clarity	Low, but high locally	Low, but high locally	Moderate	Low-moderate	Low	Low	Fish, macrophytes, aesthetics
Growths	Fungus	Low	Low	Moderate	Low-moderate	Low	Low	Fish, invertebrates, macrophytes
	Periphyton/ phytoplankton	Moderate	Moderate	Moderate	Moderate	Low-moderate	Low	Fish, invertebrates, macrophytes
Odour		Moderate	Moderate	Mod-high	Moderate	Moderate	Moderate	Aesthetic
Scums/foam		Moderate	Mod-high	High	Mod-high	Moderate	Low-moderate	Aesthetic

Table 8 Risk assessment associated with potential discharge points from QLDC wastewater infrastructure.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Probability of waste water entering water	Risk associated with wastewater discharge
1	Wanaka	16	Lake Wanaka	Pump station on Lakeside Road on lake shore.	High	Moderate, but high locally
2	Wanaka	110	Lake Wanaka (Bremner Bay)	Pump station near the end of Waimana Place.	Low-mod	Moderate, but high locally
3	Wanaka	30	Lake Wanaka (Eely Point)	Pump station near Eely Point Access track.	Mod-high	Moderate, but high locally
4	Wanaka	120	Lake Wanaka (Roys Bay)	Pump station on Dungarvon Street. Possible stormwater route or along road.	Mod-high	Moderate, but high locally
5	Wanaka	105	Lake Wanaka (Roys Bay)	Pump station near Edgewater Resort.	Moderate	Moderate, but high locally
6	Wanaka	71	Bullock Creek	Pump station on Dungarvon Street.	High	Mod-high
7	Wanaka	210*	Cardrona River	Pump station on Riverbank Road.	Negligible	Moderate
8	Clutha outlet	70	Clutha River	Pump station at end of Clutha Outlet Road.	Mod-high	Low-mod
9	Albert Town	650	Cardrona River	Pump station on Albert Town-Lake Hāwea Road.	Negligible	Moderate
10	Albert Town	25	Clutha River	Pump station on Wicklow Terrace.	Mod-high	Low-mod
11	Albert Town	120	Clutha River	Pump station on Gunn Road.	Low-mod	Low-mod
12	Albert Town	114	Clutha River	Pump station on Alison Avenue.	Mod-high	Low-mod
13	Albert Town	70	Clutha River	Pump station on Alison Avenue.	Moderate	Low-mod
14	Luggate	400	Luggate Creek	Pump station on Pisa Road.	Negligible	Moderate
15	Luggate	374	Luggate Creek	Pump station on Alice Burn Drive (unformed).	Negligible	Moderate
16	Luggate	110	Luggate Creek	Pump station on Harris Place.	Moderate	Moderate
17	Luggate	15	Luggate Creek	Pump station on river bank near Church Road.	High	Mod-high
18	Arrowtown	42	Arrow River	Pump station on bank near Alexander Place above river.	Mod-high	Mod-high
19	Arrowtown	3	Roadside drain/Arrow River	Pump station near McDonnell Road.	High	Mod-high
20	Arrowtown	425	Bush Creek	Pump station beside Essex Avenue.	Negligible	Moderate
21	Arthur's Point	292	Shotover River	Pump station beside Atley Road.	Low	Low-mod
22	Arthur's Point	8	Shotover River	Pump station beside Oxenbridge Tunnel Road on bank of Shotover River.	Mod-high	Low-mod
23	Queenstown	34	Lake Wakatipu (Queenstown Bay)	Pump station on Marine Parade beside lake shore.	High	Moderate, but high locally

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Probability of waste water entering water	Risk associated with wastewater discharge
24	Queenstown	23/150	Small stream, Lake Wakatipu (Sunshine Bay)	Pump station on track off Glenorchy-Queenstown Road.	High	Moderate, but high locally
25	Queenstown	60	Lake Wakatipu (Frankton Arm)	Pump station on lake shore on Shoreline Road at Frankton Beach.	Mod-high	Moderate, but high locally
26	Queenstown	10	Lake Wakatipu (Frankton Arm)	Sewer main with overflow on lake shore on Allan Cresent at Frankton Beach.	High	Moderate, but high locally
27	Queenstown	25	Lake Wakatipu	Pump station beside Park Street.	High	Moderate, but high locally
28	Queenstown	25	Lake Wakatipu	Pump station on vehicle track off Cedar Drive.	Mod-high	Moderate, but high locally
29	Queenstown	52	Kawarau River	Pump station on vehicle track at end of Riverside Road.	Mod-high	Low-mod
30	Lake Hayes	84	Lake Hayes	Pump station beside access road to Mill Creek shallows.	Mod-high	Mod-high
31	Lake Hayes	13	Lake Hayes	Pump station on shore of Lake Hayes beside access track and carpark off Arrowtown-Lake Hayes Road.	High	Mod-high
32	Lake Hāwea	52	Lake Hāwea	Pump station on Hawea Esplanade Road near shoreline of Lake Hāwea.	Moderate	Moderate, but high locally
33	Lake Hāwea	98	Lake Hāwea	Pump station near Scotts Beach Road near shoreline of Lake Hāwea. No obvious flow path to lake.	Moderate	Moderate, but high locally
34	Lake Hāwea	380	Hāwea River	Pump station near Domain Road.	Negligible	Low-mod
35	Lake Hāwea	990	Lake Hāwea	Pump station on Cemetery Road.	Negligible	Moderate
36	Kingston	36	Lake Wakatipu	PROPOSED - Pump station at lakefront park across from Gloucester Street.	Moderate	Low-moderate, but high locally
37	Kingston	30	Lake Wakatipu	PROPOSED - Pump station at lakefront park across from Cornwall and Oxford Street.	Mod-high	Low-moderate, but high locally
38	Jacks Point	0	Various ephemeral creeks	PROPOSED - pipeline from Jacks Point to Frankton.	Low-mod	Low
39	Lower Shotover	>150	Shotover River	PROPOSED - wastewater network infrastructure for development on low-lying land on true left of the Shotover River	Low	Low-mod
40	Glenorchy	0 (pipe crossing)	Stone Creek	PROPOSED - pipeline from Glenorchy to potential disposal site at Glenorchy airport.	High	Moderate, but high locally

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Probability of waste water entering water	Risk associated with wastewater discharge
41	Glenorchy	0 (pipe crossing)	Buckler Burn	PROPOSED - pipeline from Glenorchy to potential disposal site at Glenorchy airport.	High	Moderate, but high locally
42	Cardrona	15	Cardrona River	PROPOSED - pipeline from Cardrona township to potential disposal site at skifield turn-off.	Low-high	Low-mod
43	Clutha near Wanaka airport	0 (pipe crossing)	Clutha River	PROPOSED - pipeline from Hāwea township to potential disposal site at Wanaka airport.	Low-high	Low
44	Luggate	0 (pipe crossing)	Luggate Creek	PROPOSED - pipeline from Luggate township to potential disposal site at Wanaka airport.	Low-high	Moderate
45	Luggate	0 (pipe crossing)	Dead Horse Creek	PROPOSED - wastewater from developments to east of Luggate township.	Low-high	Mod-high
46	Glendhu Bay	>55	Lake Wanaka (Glendhu Bay)	PROPOSED - Glendhu Bay campground	Moderate	Moderate, but high locally
47	Mill Creek	12	Mill Creek	PROPOSED - Pump station at Millbrook, near 18th hole.	Mod-high	Moderate
			Lake Hayes			Mod-high

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Appendix A

Water Conservation (Kawarau) Order – Schedule 2

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Schedule 2
Waters to be protected

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All map references are NZMS 1 unless otherwise stated

Waters	Outstanding characteristics	Restrictions and prohibitions
Kawarau River mainstem from Scrubby Stream to Lake Wakatipu control gates (S133:940715 to S132:615707)	(c) wild and scenic characteristics; (c) natural characteristics, in particular the return flow in the upper section when the Shotover River is in high flood; (d) scientific values, in particular the return flow in the upper section when the Shotover River is in high flood; (e) recreational purposes, in particular rafting, jetboating, and kayaking.	(i) no damming allowed; (ii) water quality to be managed to Class CR standard.
Nevis River mainstem gorge from Nevis Crossing to Kawarau River confluence (NZTM: 5002690.6 N, 1287862.0 E to 4989927.5 N, 1285354.6 E)	(a) native fishery habitat (non-migratory galaxiids); (c) wild and scenic characteristics; (e) recreational purposes, in particular fishing and kayaking.	(i) no damming or diversion allowed; (ii) water quality to be managed to Class CR, Class F, and Class FS standards.

Waters	Outstanding characteristics	Restrictions and prohibitions
	(f) historical purposes, in particular goldmining.	
Dart River mainstem from Lake Wakatipu to confluence with Beans Burn (at or about S122:291916 to S113:226162)	(a) habitat for wildlife; (c) scenic characteristics; (c) natural characteristics, in particular natural turbidity; (d) scientific value, in particular natural turbidity; (g) significance in accordance with tikanga Maori, in particular sites at the mouth of the river.	(i) no damming allowed; (ii) braiding of water to be maintained.
Rees River mainstem from Lake Wakatipu to confluence with Hunter (at or about S123:301915 to S114:363204)	(a) habitat for wildlife; (c) scenic characteristics; (g) significance in accordance with tikanga Maori, in particular sites at the mouth of the river.	(i) no damming allowed; (ii) braiding of water to be maintained.
Diamond Lake, Diamond Creek, and Reid Lake (at or about S122:290050; S122:299036 to S123:305987)	(a) habitat for wildlife and quinnat salmon; (b) fishery.	(i) no damming allowed; (ii) fish passage to be maintained; (iii) water quality to be managed to Class F and Class FS standards.

Waters	**Outstanding characteristics**	**Restrictions and prohibitions**
Lake Wakatipu (from outlet at control gates (S132:615707) to confluences of Dart River (at or about S122:291916) and Rees River (at or about S123:301915) and including whole lake)	(b) fishery; (c) scenic characteristics; (d) scientific value, in particular water clarity, and bryophyte community; (e) recreational purposes, in particular boating; (g) significance in accordance with tikanga Maori, in particular sites at the head of the lake, and the legend of the lake itself.	(i) fish passage to be maintained; (ii) water quality to be managed to Class AE, Class CR, Class F, and Class FS standards.
Lochy River mainstem (S132:592511 to S142:328409 and S142:307380)	(b) fishery; (e) recreational purposes, in particular fishing.	(i) fish passage to be maintained; (ii) water quality to be managed to Class F and Class FS standards.
Von River mainstem (S132:353629 to S141:288380 and S131:216620)	(b) fishery; (e) recreational purposes, in particular fishing.	(i) fish passage to be maintained; (ii) water quality to be managed to Class F and Class FS standards.

Key:

Outstanding characteristics (s 199(2)(b) and (c) of Act):

(a) as habitat for terrestrial or aquatic organisms:

(b) as a fishery:

(c) for its wild, scenic or other natural characteristics:
(d) for scientific and ecological values:
(e) for recreational purposes:
(f) for historical purposes:
(g) for significance in accordance with tikanga Maori.

Restrictions and prohibitions:

References to classes are Water quality classes as in Schedule 3 of the Act.

Schedule 2: amended, on 12 December 2013, by clause 5 of the Water Conservation (Kawarau) Amendment Order 2013 (SR 2013/450).

Appendix B

Water Quality Classes

Schedule 2 of the Water Conservation (Kawarau) Order (WCO) outlines water quality classes for 'Waters to be protected', including the Kawarau River (Class CR), Shotover River (Class CR) and Lake Wakatipu (Classes AE, CR , F, FS). These water quality classes relate to Schedule 3 of the RMA and the relevant ones are outlined below:

1 Class AE Water (being water managed for aquatic ecosystem purposes)

(1) The natural temperature of the water shall not be changed by more than 3° Celsius.

(2) The following shall not be allowed if they have an adverse effect on aquatic life:

(a) any pH change:

(b) any increase in the deposition of matter on the bed of the water body or coastal water:

(c) any discharge of a contaminant into the water.

(3) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.

(4) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.

2 Class F Water (being water managed for fishery purposes)

(1) The natural temperature of the water—

(a) shall not be changed by more than 3° Celsius; and

(b) shall not exceed 25° Celsius.

(2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.

(3) Fish shall not be rendered unsuitable for human consumption by the presence of contaminants.

3 Class FS Water (being water managed for fish spawning purposes)

(1) The natural temperature of the water shall not be changed by more than 3° Celsius. The temperature of the water shall not adversely affect the spawning of the specified fish species during the spawning season.

(2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.

(3) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.

5 Class CR Water (being water managed for contact recreation purposes)

(1) The visual clarity of the water shall not be so low as to be unsuitable for bathing.

(2) The water shall not be rendered unsuitable for bathing by the presence of contaminants.

(3) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.

Appendix C

Schedule 1A of RPW

Table 9 Natural values of waterbodies potentially affected by wastewater overflows in the Queenstown Lakes District from Schedule 1A of the RPW.

Water body	Ecosystem Values	Outstanding natural feature or landscape	Significant indigenous vegetation and significant habitat of indigenous fauna	Areas with a high degree of naturalness
Arrow River	Psize, Psand, Ppass, Pgravel, Hspawn, Hjuve, Weedfree, Trout	-	-	A high degree of naturalness above 900 m asl.
Bullock Creek	Hspawn(t), Hjuve(t), Trout			
Cardrona River	Pboulder, Psand, Pgravel, Hspawn, Hjuve, Weedfree, Trout, Eel, Rarefish. Invrare (mid to upper reaches)	-	Significant habitat for flathead galaxiid	A high degree of naturalness above 900 m asl.
Clutha River/Mata-Au *between Alexandra and Lake Wanaka*	Psize, Prock, Pgravel, Hspawn(t&s), Hriparian, Hjuve(t&s), Trout, Eel, Salmon, Rarefish, Birddiv	-	Significant habitat for flathead galaxiid (tributaries).	-
Kawarau River *between Lake Dunstan and Lake Wakatipu*	Psize, Pgravel, Prock, Trout, Salmon, Eel, Rarefish. Weedfree upstream of Lake Dunstan	Outstanding: (a) for its wild, scenic characteristics; (b) natural characteristics, in particular the return flow in the upper section when the Shotover River is in flood; (c) for scientific values, in particular the return flow in the upper section when the Shotover is in flood; (d) for recreational purposes, in particular rafting, jet boating and kayaking. Spectacular and rugged river gorge, schistose landscape, fast flowing white water and rapids, old gold sluicing landscape, from confluence with Arrow River to Lake Dunstan.	Significant habitat for kōaro including many tributaries.	-
Hāwea River	Psize, Weedfree, Hspawn, Hjuve, Trout, Salmon, Eel	-	-	-

Table 9 Natural values of waterbodies potentially affected by wastewater overflows in the Queenstown Lakes District from Schedule 1A of the RPW.

Water body	Ecosystem Values	Outstanding natural feature or landscape	Significant indigenous vegetation and significant habitat of indigenous fauna	Areas with a high degree of naturalness
Lake Hāwea	Psize, Psand, Weedfree, Hjuve(t&s), Eel, Trout, Salmon	Scenic values within the wider landscape context of the surrounding mountains, particularly colour of the water.		
Lake Hayes	Psand, Psilt, Weedfree, Hriparian, Eel, Trout			
Horne Creek	Weedfree. Hspawn(t), Hjuve(t), Ppass, Trout in lower reaches			
Luggate Creek	Weedfree, Rarefish. Invrare upstream of F40: 040924		Significant habitat for koaro	-
Mill Creek	Pgravel, Psand, Hspawn, Hjuve, Weedfree, Rarefish		*Significant habitat* for roundhead galaxiid.	A high degree of naturalness above 900 metres asl.
Shotover River	Pgravel, Pboulder, Psand, Prock, Psize, Weedfree, Hriparian, Birddiv, Birdrare	Outstanding: (a) for its wild and scenic characteristics; (b) for its natural characteristics, in particular the high natural sediment load and active delta at confluence with Kawarau River; (c) scientific value, in particular the high natural sediment load and active delta at confluence with Kawarau River; (d) for recreational purposes, in particular rafting, kayaking and jet boating; (e) for historical purposes, in particular gold mining. Spectacular and rugged river gorge, schistose landscape, fast flowing white water and rapids, old gold sluicing landscape, in main stem between confluence with Iron Stone Stream and Arthur Point. Wild and scenic characteristics, from confluence with Iron Stone Stream to its source	Lochnagar and Lake Creek, outstanding: (a) Essential characteristics that determine the ecosystem's integrity, form, functioning and resilience. Significant habitat: Areas of importance to internationally uncommon species - black fronted tern, banded dotterel - in main stem between Arthur Point and its source.	A high degree of naturalness above 900 metres asl.

Table 9 Natural values of waterbodies potentially affected by wastewater overflows in the Queenstown Lakes District from Schedule 1A of the RPW.

Water body	Ecosystem Values	Outstanding natural feature or landscape	Significant indigenous vegetation and significant habitat of indigenous fauna	Areas with a high degree of naturalness
Lake Wakatipu	Psize, Ppland, Weedfree, Hjuve(t&s), Hriparian, Eel, Trout, Salmon, Sigveg, Rarefish, Invrare	Outstanding: (a) as a fishery; (b) for its scenic characteristics; (c) for scientific value, in particular water clarity, and bryophyte community; (d) for recreational purposes, in particular boating; (e) for historical purposes; (f) for significance in accordance with tikanga Maori, in particular sites at the head of the lakes, and the legend of the lake itself. Scenic values within the wider landscape context of the surrounding mountains, particularly: - clear blue colour of the water, - river deltas, and beaches, particularly uncommon beach features between Rat Point and White Point	Significant habitat for koaro including many tributaries. Significant vegetation: Rare association of aquatic plants.	A high degree of naturalness above 900 m asl.
Lake Wanaka	Psize, Psand, Eel, Trout, Salmon, Sigveg, Rarefish, Invrare	Scenic values within the wider landscape context of the surrounding mountains, particularly the unmodified lake level, water quality and colour of the water.	Significant vegetation: Rare association of aquatic plants.	

Appendix D

Water quality figures - Rivers

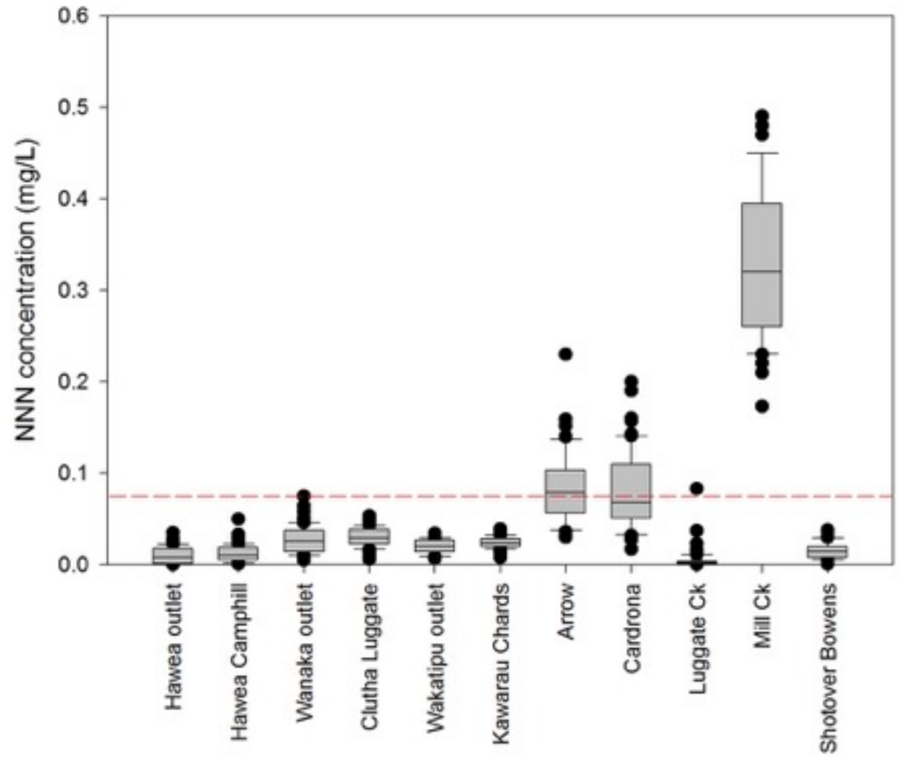

Figure 1 NNN concentrations in river sites. Data courtesy of Otago Regional Council. The dashed red line represents the Schedule 15 limit/target.

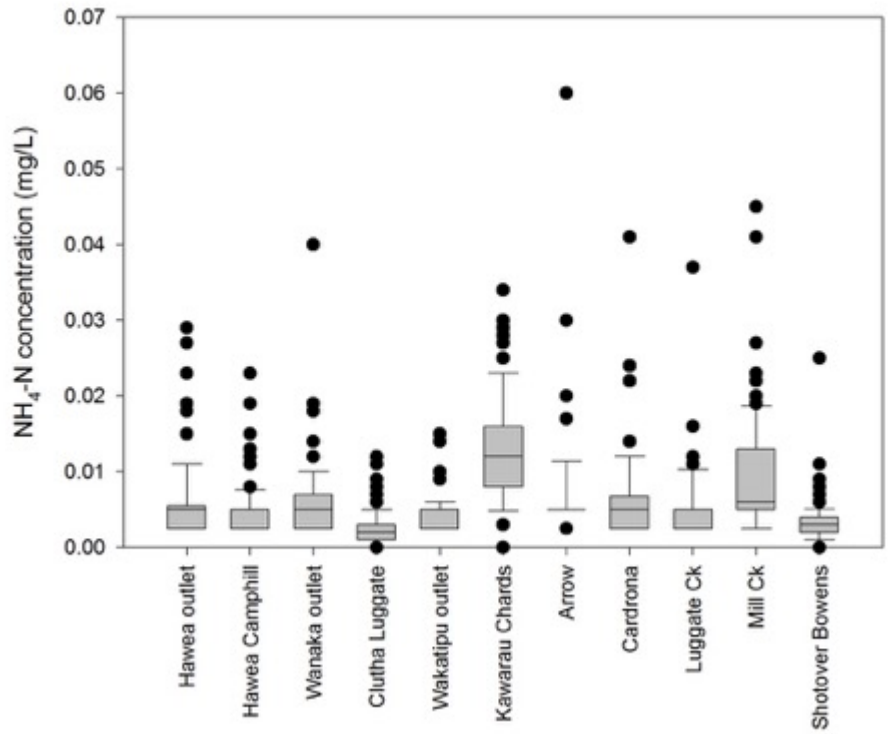

Figure 2 *NH_4-N concentrations in riv er sites. Data courtesy of Otago Regional Council. The Schedule 15 limit for all sites is 0.1 mg/L.*

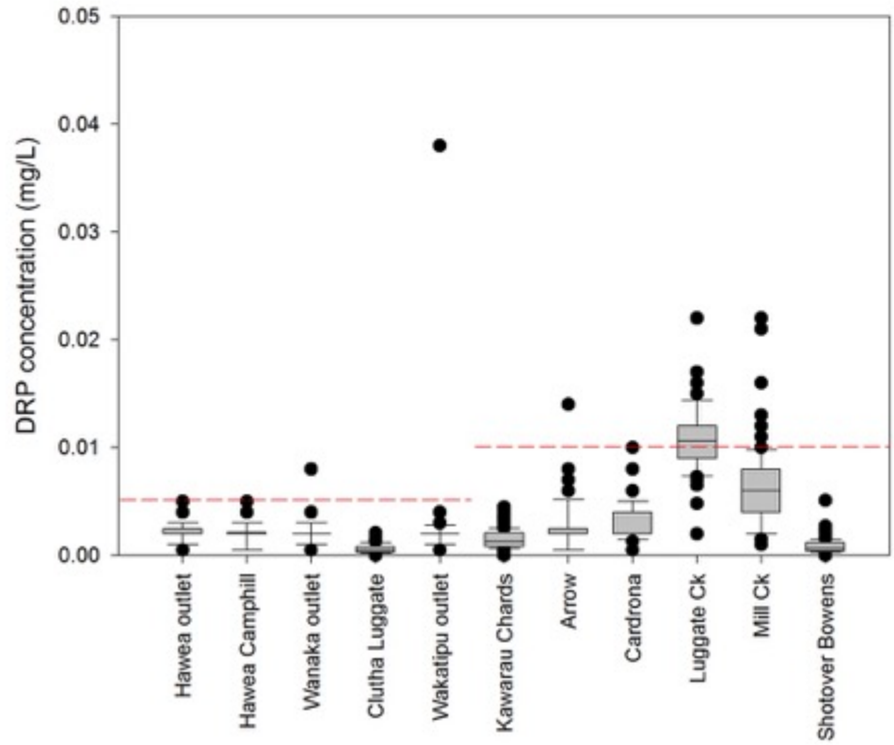

Figure 3 *DRP concentrations in river sites. Data courtesy of Otago Regional Council. Dashed red lines represent the Schedule 15 limit/target.*

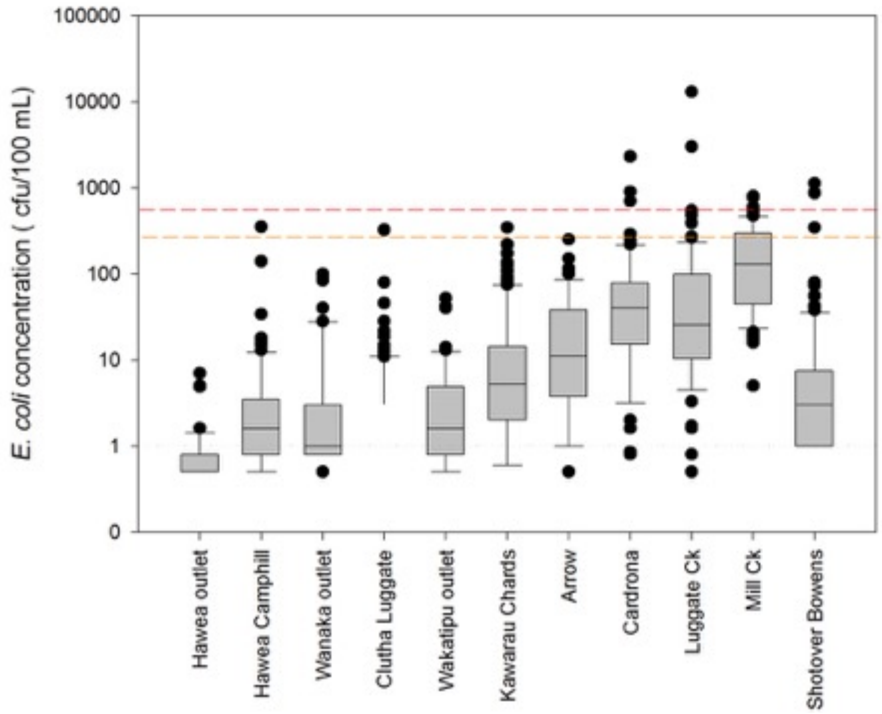

Figure 4 Counts of E. coli for river sites. Data courtesy of Otago Regional Council. The orange dashed line indicates the threshold for "alert" (orange) mode and the red dashed line indicates the threshold for "Action" mode based on MfE & MoH (2000).

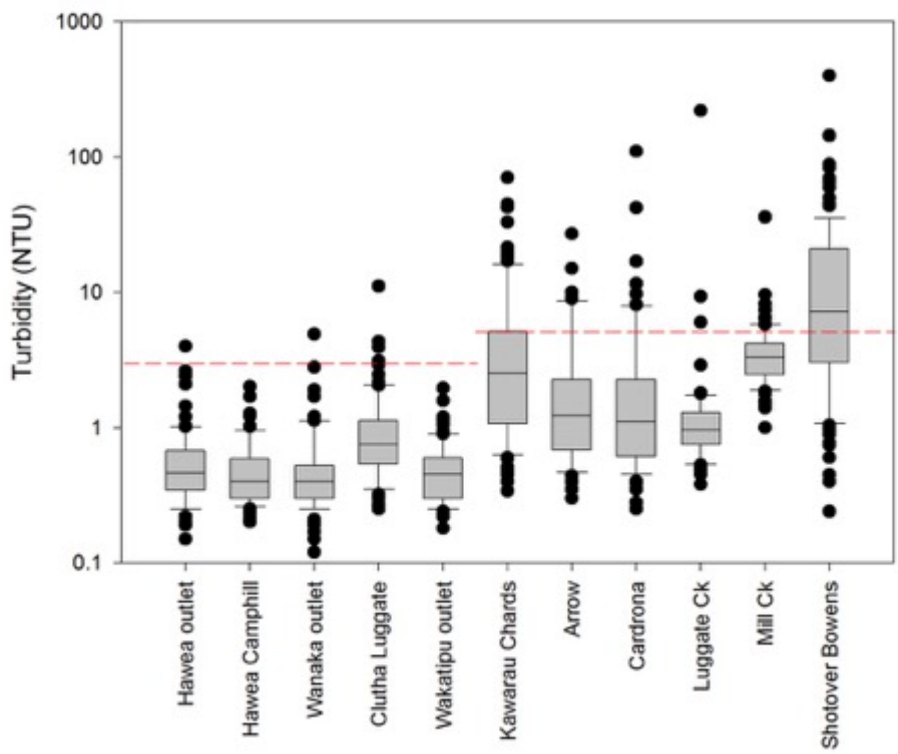

Figure 5 Turbidity at river sites. Data courtesy of Otago Regional Council. Dashed red lines represent the Schedule 15 limit/target.

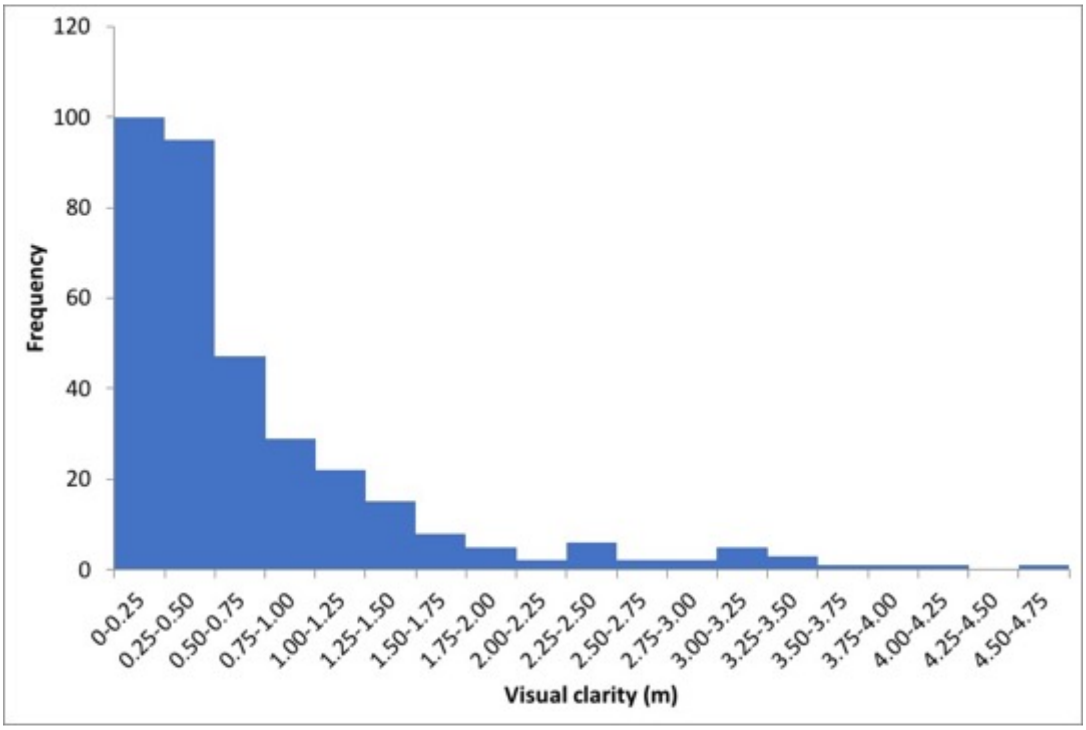

Figure 6 Histogram of visual clarity in the Shotover River at Bowen's Peak between February 1989 and December 2017. Data courtesy of NIWA.

Water quality figures - Lakes

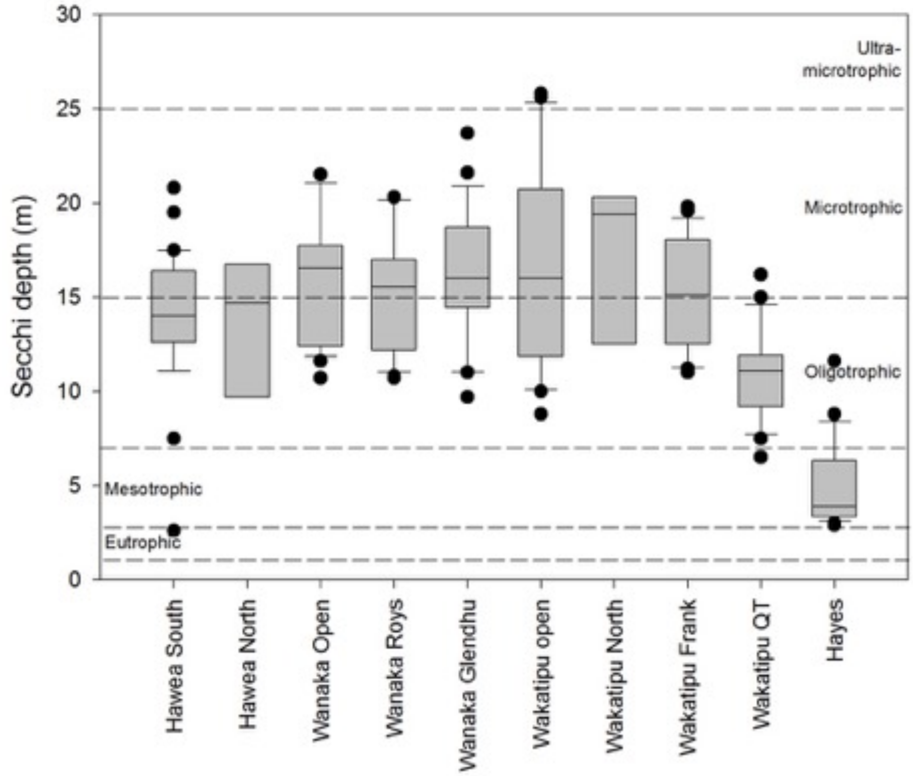

Figure 7 Water clarity (as measured by Secchi disc) at sites in Lakes Hāwea, Wanaka, Wakatipu and Hayes. Data courtesy of Otago Regional Council (ORC).

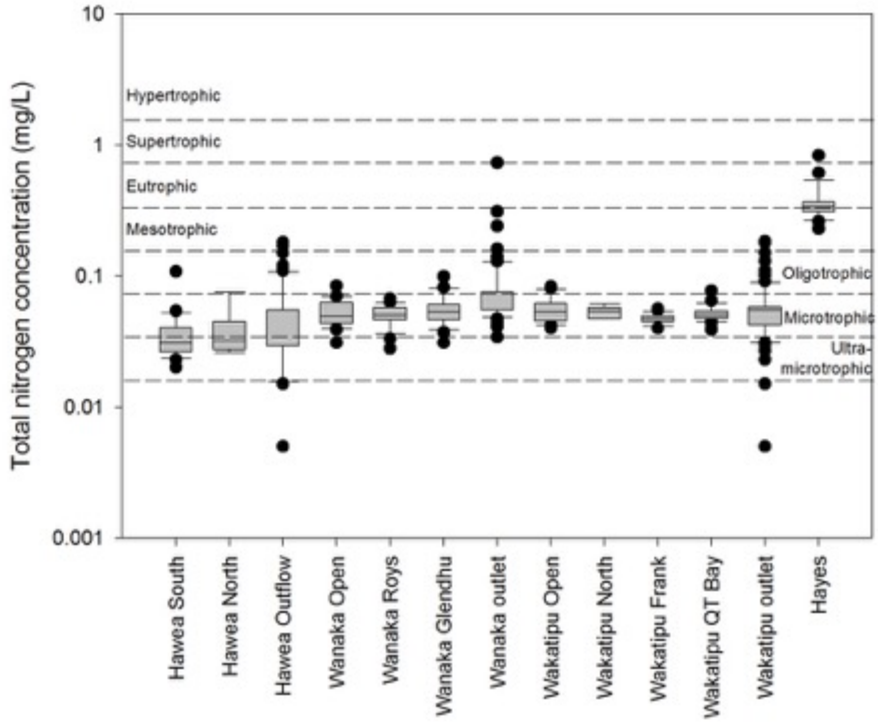

Figure 8 Total nitrogen concentrations (note logarithmic scale) at sites in Lakes Hāwea, Wanaka, Wakatipu and Hayes. Data courtesy o f Otago Regional Council. Concentrations for all sites are for samples taken at 10 m water depth, except for outlet sites.

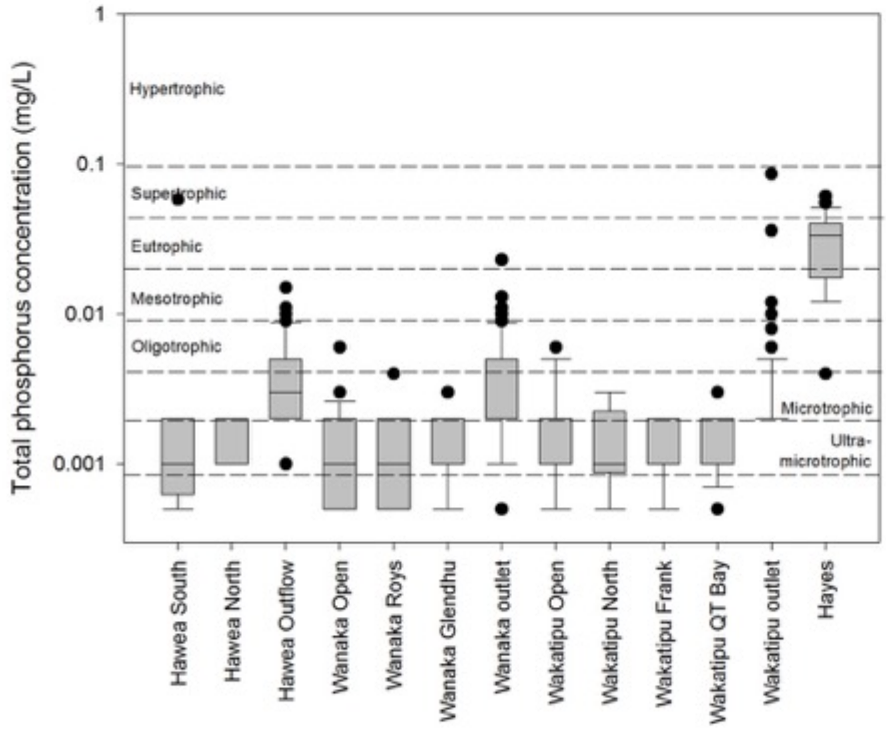

Figure 9 Total phosphorus concentrations (note logarithmic scale) at sites in Lakes Hāwea, Wanaka, Wakatipu and Hayes. Data courtesy of Otago Regional Council. Concentrations for all sites are for samples taken at 10 m water depth, except for outlet sites.

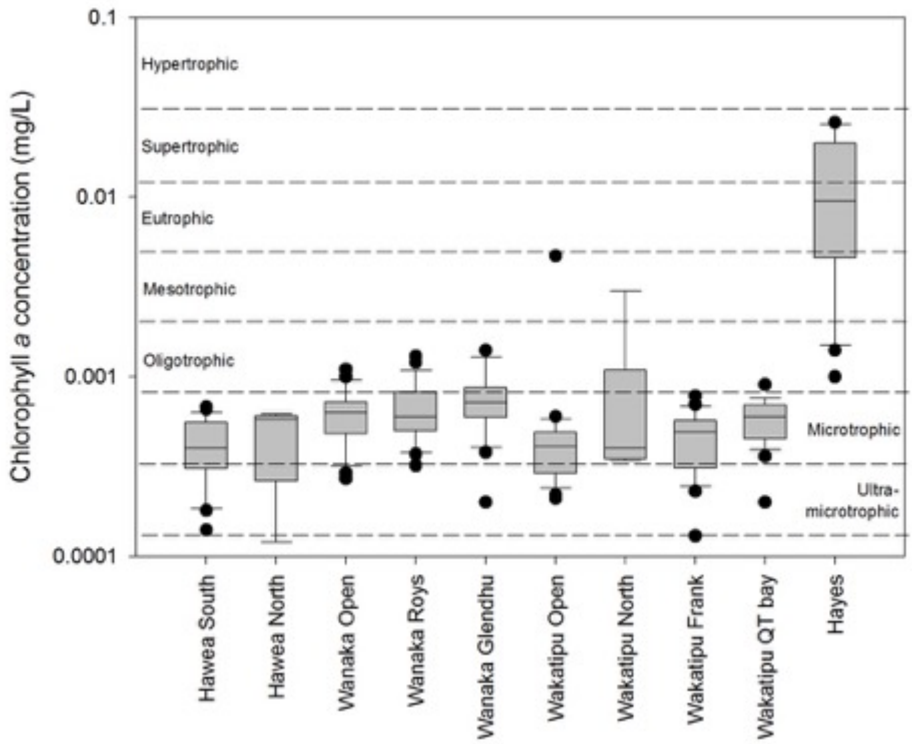

Figure 10 *Chlorophyll* a *concentration (note logarithmic scale) at sites in Lakes Hāwea, Wanaka, Wakatipu and Hayes. Data courtesy of Otago Regional Council. Concentrations for all sites are for samples taken at 10 m water depth.*

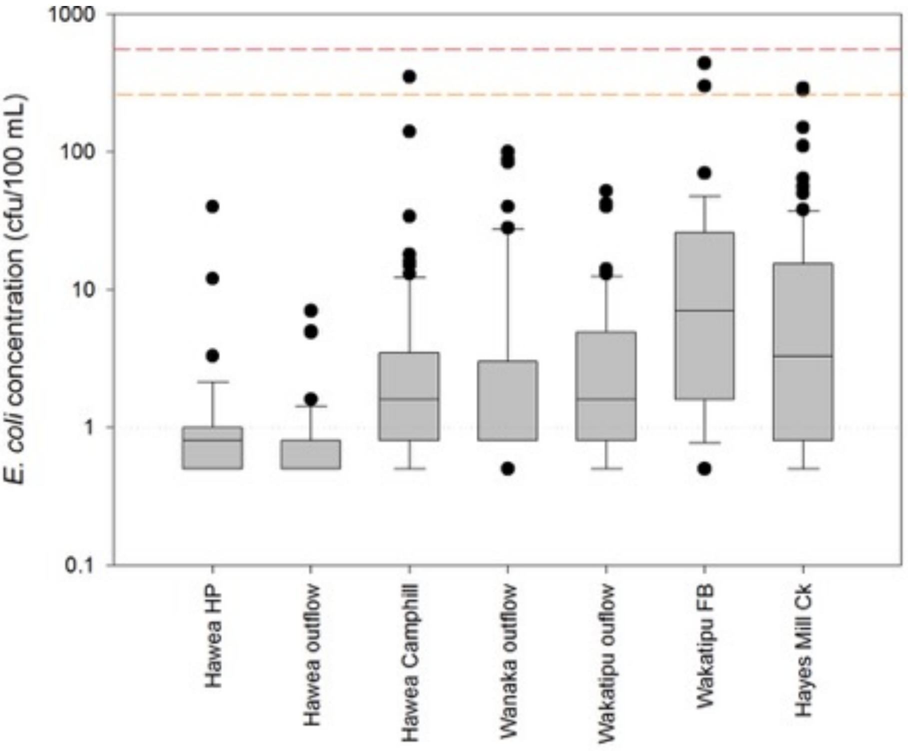

Figure 11 *Counts of E. coli at sites in Lakes Hāwea, Wanaka, Wakatipu and Hayes. Data courtesy of Otago Regional Council. The orange dashed line indicates the threshold for "alert" (orange) mode and the red dashed line indicates the threshold for "Action" mode based on MfE & MoH (2000). Hawea HP = Lake Hāwea at Holiday Park, Wakatipu FB = Lake Wakatipu at Frankton Bay.*

Appendix E

Water quality monitoring sites

Data for most sites were from State of the Environment monitoring undertaken by Otago Regional Council. Data for Clutha River at Luggate Bridge, Kawarau River at Chard Rd and Shotover at Bowen's Peak were downloaded from the NIWA Hydro Web Portal for Hydrometric and Water Quality data (https://hydrowebportal.niwa.co.nz/).

Table 10 Water quality data used in the preparation of this report, including site location and data period.

Site	Type	Location (NZTM)		Data period used	
		Easting	Northing	Start date	End date
Lake Hāwea South Open Water 10m	Lake	1304091	5060812	21/09/16	21/03/18
Lake Hāwea North Open Water 10m	Lake	1306729	5069868	17/02/17	22/02/18
Lake Wakatipu Open Water 10m	Lake	1259057	5001176	22/09/16	20/03/18
Lake Wakatipu North Open Water 10m	Lake	1242128	4997920	16/02/17	20/02/18
Lake Wakatipu at Frankton Arm 10m	Lake	1261119	5004619	22/09/16	20/03/18
Lake Wakatipu at Queenstown Bay 10m	Lake	1257916	5003815	22/09/16	20/03/18
Lake Wanaka Open Water 10m	Lake	1290615	5047684	21/09/16	21/03/18
Lake Wanaka at Roy's Bay 10m	Lake	1292418	5044082	21/09/16	21/03/18
Lake Wanaka at Glendu Bay 10m	Lake	1284603	5046355	21/09/16	21/03/18
Lake Hayes at Mid Lake 10m	Lake	1269730	5010987	22/09/16	9/04/18
Lake Hāwea at Holiday Park	Contact rec.	1302356	5053823	1/12/14	22/03/16
Lake Wakatipu at Frankton Bay	Contact rec.	1263337	5005985	1/12/14	22/03/16
Lake Hayes at Mill Creek Shallows	Contact rec.	1269921	5011934	5/01/12	22/03/16
Lake Hāwea Outflow at Dam	Outlet	1302520	5053536	16/02/12	21/05/18
Lake Wanaka at Outlet	Outlet	1294718	5047186	12/02/12	21/05/18
Lake Wakatipu at Outflow	Outlet	1263310	5005041	28/02/12	17/05/18
Arrow at Morven Ferry Road	River	1273547	5009605	12/08/98	13/06/14
Cardrona at Mt Barker	River			26/07/13	21/05/18
Hāwea at Camphill Bridge	River	1302363	5049022	16/02/12	21/05/18
Luggate Creek at SH6 Bridge	River	1304632	5038216	16/02/12	21/05/18
Mill Creek at Fish Trap	River	1269921	5012135	10/01/12	17/05/18
Clutha River at Luggate Bridge (AX1)	River	1305428	5040400	15/07/08	12/12/17
Kawarau River at Chard Rd (AX2)	River	1274418	5008062	15/07/08	12/12/17
Shotover River at Bowens Peak (AX3)	River	1262194	5009251	15/07/08	12/12/17

Appendix F

Locations of network features considered

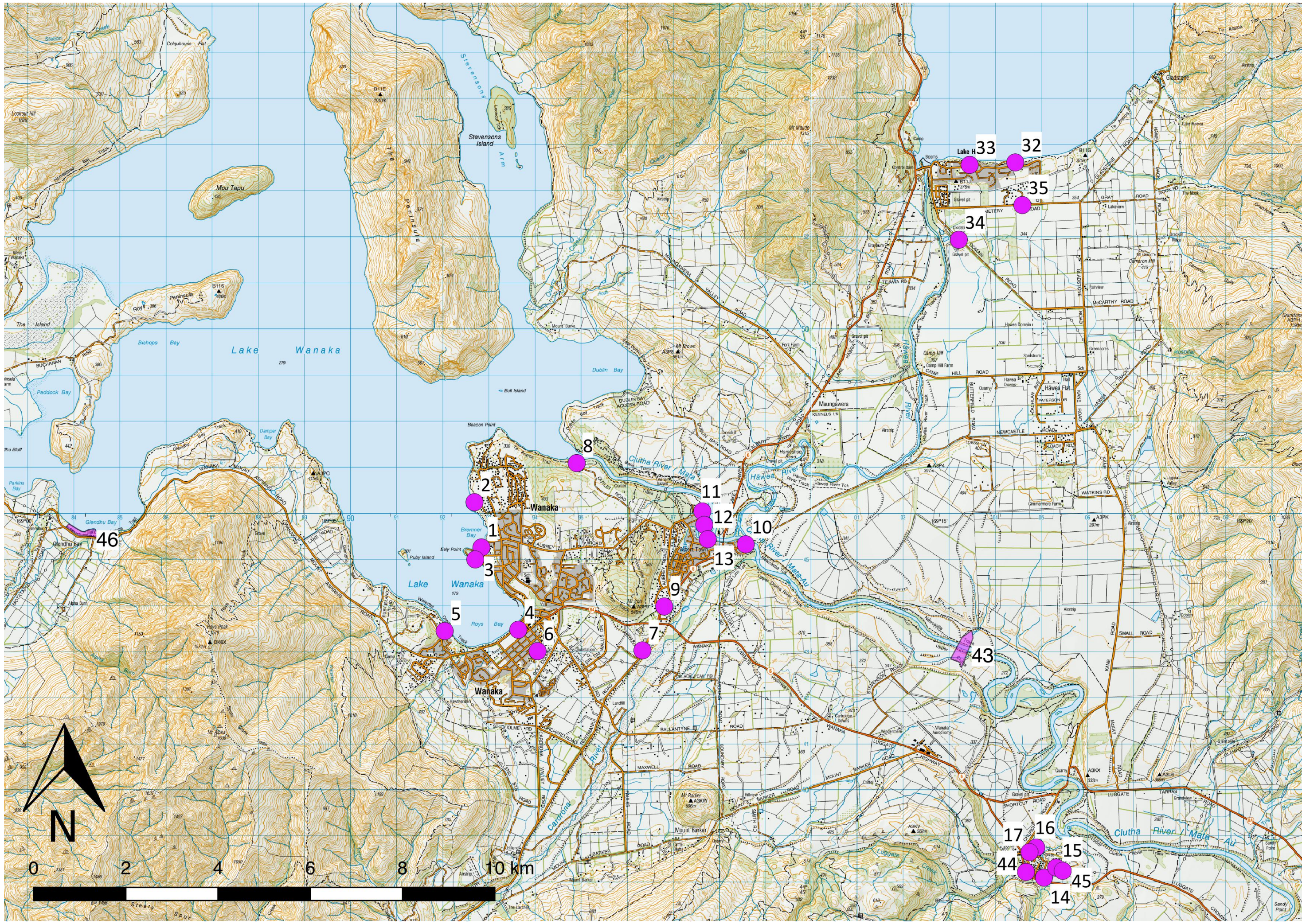

Figure 12 Location of Pump Stations in the Wanaka/Hāwea area.

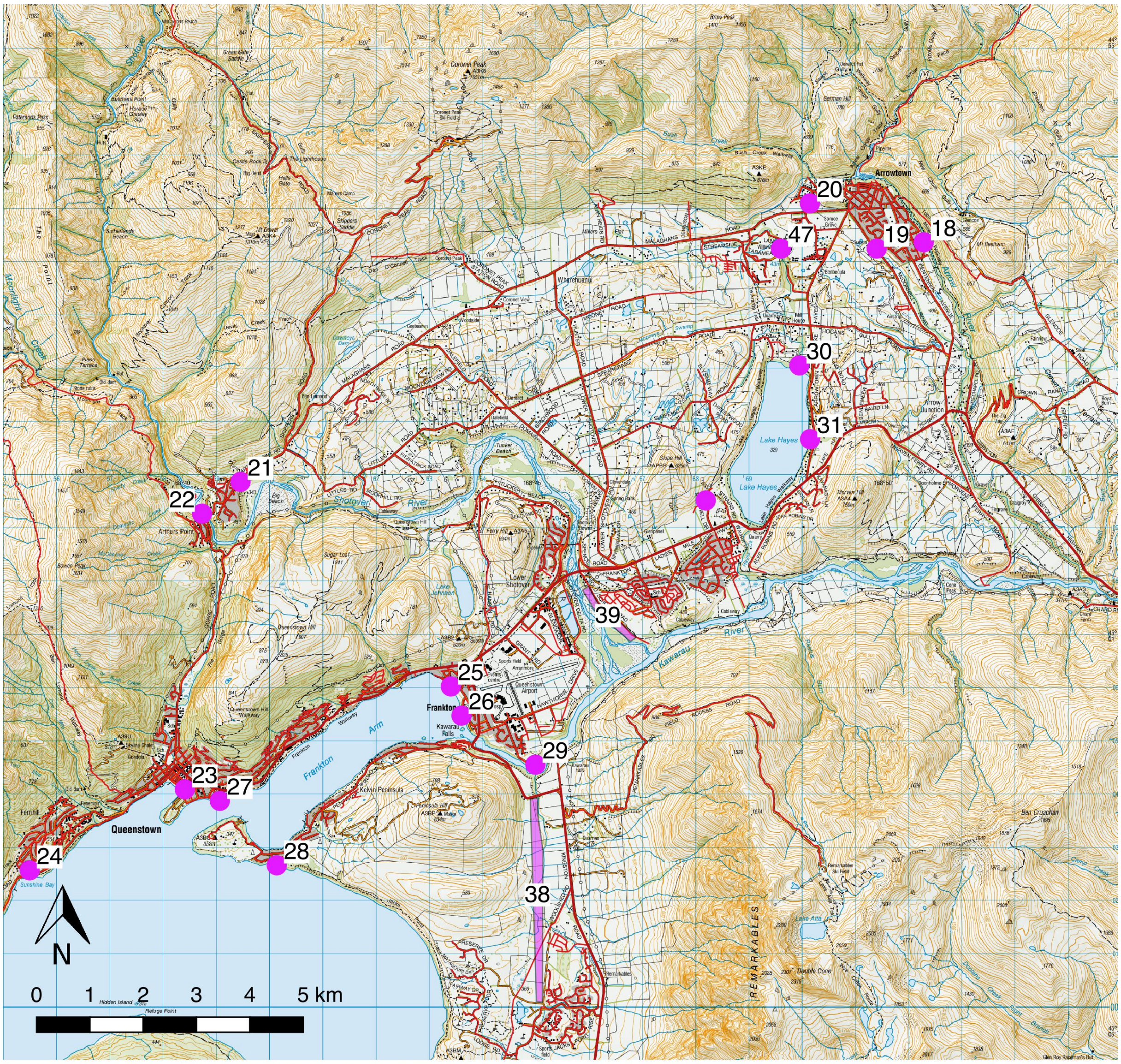

Figure 13 Location of Pump Stations in the Queenstown area.

Figure 14 Location of Pump Stations in Kingston.

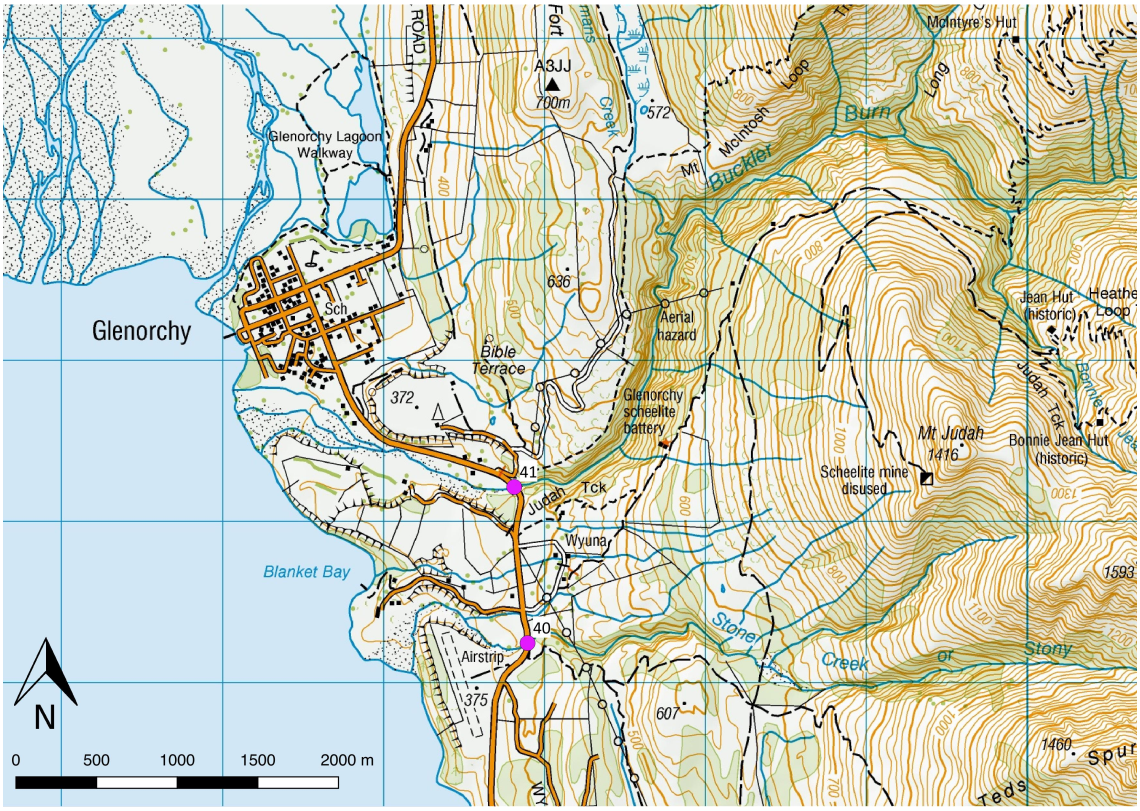

Figure 15 Location of Pump Stations in the Glenorchy area.

Appendix F

Risk Assessment

Table 11 Risk assessment for each of the locations assessed including the risk of wastewater entering surace water and the risks associated with wastewater discharges to that receiving environment type.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Distance to water	Flow path	Risk associated with vegetation/surface permeability	Probability of waste water entering water	Notes	Receiving environment type	Risk associated with wastewater discharge
1	Wanaka	16	Lake Wanaka	Pump station on Lakeside Road on lake shore.	High	Yes	High	**High**	No vegetation	Large lake	**Moderate, but high locally**
2	Wanaka	110	Lake Wanaka (Bremner Bay)	Pump station near the end of Waimana Place.	Low-mod	No	Low-mod	**Low-mod**	Rank grass and scrub.	Large lake	**Moderate, but high locally**
3	Wanaka	30	Lake Wanaka (Eely Point)	Pump station near Eely Point Access track.	High	Yes	Moderate	**Mod-high**	Grass berm and beach.	Large lake	**Moderate, but high locally**
4	Wanaka	120	Lake Wanaka (Roys Bay)	Pump station on Dungarvon Street. Possible stormwater route or along road.	Moderate	Potential	Moderate	**Mod-high**	Possible stormwater route.	Large lake	**Moderate, but high locally**
5	Wanaka	105	Lake Wanaka (Roys Bay)	Pump station near Edgewater Resort.	Moderate	Potential	Moderate	**Moderate**	Possible flow path to pond, then on to lake.	Large lake	**Moderate, but high locally**
6	Wanaka	71	Bullock Creek	Pump station on Dungarvon Street.	Mod-high	Potential	High	**High**	Possible stormwater route or along road.	Stream	**Mod-high**
7	Wanaka	210*	Cardrona River	Pump station on Riverbank Road.	Low	No	Low	**Negligible**	No obvious surfacewater bodies nearby.	Small-medium river	**Moderate**
8	Clutha outlet	70	Clutha River	Pump station at end of Clutha Outlet Road.	Mod-high	Yes	Mod-high	**Mod-high**	Gravel tracks, grass and gravel.	Large river	**Low-mod**
9	Albert Town	650	Cardrona River	Pump station on Albert Town-Lake Hāwea Road.	Negligible	No	Low	**Negligible**	No obvious surfacewater bodies nearby.	Small-medium river	**Moderate**
10	Albert Town	25	Clutha River	Pump station on Wicklow Terrace.	High	No	Moderate	**Mod-high**	On grass-covered bank of Clutha River	Large river	**Low-mod**
11	Albert Town	120	Clutha River	Pump station on Gunn Road.	Low-mod	No	Low	**Low-mod**	Gravel road to Clutha, but no clear slope/flowpath to Clutha.	Large river	**Low-mod**
12	Albert Town	114	Clutha River	Pump station on Alison Avenue.	Mod-high	Yes	Moderate	**Mod-high**	Paddock and trees between pumpstation and Clutha River.	Large river	**Low-mod**
13	Albert Town	70	Clutha River	Pump station on Alison Avenue.	Moderate	Yes	Low	**Moderate**	Residential section between pumpstation and Clutha River.	Large river	**Low-mod**

Table 11 Risk assessment for each of the locations assessed including the risk of wastewater entering surace water and the risks associated with wastewater discharges to that receiving environment type.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Distance to water	Flow path	Risk associated with vegetation/surface permeability	Probability of waste water entering water	Notes	Receiving environment type	Risk associated with wastewater discharge
14	Luggate	400	Luggate Creek	Pump station on Pisa Road.	Negligible	No	Low	**Negligible**	No obvious surfacewater bodies nearby.	Small-medium river	**Moderate**
15	Luggate	374	Luggate Creek	Pump station on Alice Burn Drive (unformed).	Negligible	No	Low	**Negligible**	No obvious surfacewater bodies nearby.	Small-medium river	**Moderate**
16	Luggate	110	Luggate Creek	Pump station on Harris Place.	Moderate	Potential	Mod-high	**Moderate**	Grass and gravel tracks. Possible stormwater route to Luggate Creek.	Small-medium river	**Moderate**
17	Luggate	15	Luggate Creek	Pump station on river bank near Church Road.	Mod-high	Yes	Moderate	**High**	Grass and willows on bank.	Small-medium river	**Mod-high**
18	Arrowtown	42	Arrow River	Pump station on bank near Alexander Place above river.	Mod-high	Potential	Moderate	**Mod-high**	Grass, willows and gravel tracks on bank.	Small-medium river	**Mod-high**
19	Arrowtown	3	Roadside drain/Arrow River	Pump station near McDonnell Road.	High	Yes	Mod-high	**High**	Small roadside ditch nearby, which ultimately flows into the Arrow River (3 km downstream).	Small-medium river	**Mod-high**
20	Arrowtown	425	Bush Creek	Pump station beside Essex Avenue.	Negligible	No	Low	**Negligible**	Grass and small trees. No surfacewater bodies nearby.	Stream	**Moderate**
21	Arthur's Point	292	Shotover River	Pump station beside Atley Road.	Low	No	Low	**Low**	Bush and paddock.	Medium-large river	**Low-mod**
22	Arthur's Point	8	Shotover River	Pump station beside Oxenbridge Tunnel Road on bank of Shotover River.	High	Yes	Low-mod	**Mod-high**	Pine trees, gorse and broom.	Medium-large river	**Low-mod**
23	Queenstown	34	Lake Wakatipu (Queenstown Bay)	Pump station on Marine Parade beside lake shore.	High	Yes	Mod-high	**High**	On lake shoreline, gravel beach to Queenstown Bay.	Large lake	**Moderate, but high locally**
24	Queenstown	23/150	Small stream, Lake Wakatipu (Sunshine Bay)	Pump station on track off Glenorchy-Queenstown Road.	High	Yes	Low-high	**High**	Small stream nearby, which flows into Sunshine Bay.	Stream/large lake	**Moderate, but high locally**

Table 11 Risk assessment for each of the locations assessed including the risk of wastewater entering surace water and the risks associated with wastewater discharges to that receiving environment type.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Distance to water	Flow path	Risk associated with vegetation/surface permeability	Probability of waste water entering water	Notes	Receiving environment type	Risk associated with wastewater discharge
25	Queenstown	60	Lake Wakatipu (Frankton Arm)	Pump station on lake shore on Shoreline Road at Frankton Beach.	Mod-high	Yes	Mod-high	**Mod-high**	On lake shoreline, gravel beach to Frankton Beach.	Large lake	**Moderate, but high locally**
26	Queenstown	10	Lake Wakatipu (Frankton Arm)	Sewer main with overflow on lake shore on Allan Cresent at Frankton Beach.	High	Yes	Mod-high	**High**	Road/parking area and grass.	Large lake	**Moderate, but high locally**
27	Queenstown	25	Lake Wakatipu	Pump station beside Park Street.	High	Yes	Mod-high	**High**	Road, grass, trees and gravel.	Large lake	**Moderate, but high locally**
28	Queenstown	25	Lake Wakatipu	Pump station on vehicle track off Cedar Drive.	High	Yes	Moderate	**Mod-high**	Grass, trees and gravel.	Large lake	**Moderate, but high locally**
29	Queenstown	52	Kawarau River	Pump station on vehicle track at end of Riverside Road.	Mod-high	Yes	Moderate	**Mod-high**	Grass and gravel.	Large river	**Low-mod**
30	Lake Hayes	84	Lake Hayes	Pump station beside access road to Mill Creek shallows.	Mod-high	Yes	Mod-high	**Mod-high**	Road and grass.	Lake Hayes	**Mod-high**
31	Lake Hayes	13	Lake Hayes	Pump station on shore of Lake Hayes beside access track and carpark off Arrowtown-Lake Hayes Road.	High	Yes	Mod-high	**High**	Grass.	Lake Hayes	**Mod-high**
32	Lake Hāwea	52	Lake Hāwea	Pump station on Hawea Esplanade Road near shoreline of Lake Hāwea.	Mod-high	No	Moderate	**Moderate**	Near shoreline of Lake Hāwea	Large lake	**Moderate, but high locally**
33	Lake Hāwea	98	Lake Hāwea	Pump station near Scotts Beach Road near shoreline of Lake Hāwea. No obvious flow path to lake.	Mod-high	No	Moderate	**Moderate**	Near shoreline of Lake Hāwea. No obvious flowpath to lake.	Large lake	**Moderate, but high locally**
34	Lake Hāwea	380	Hāwea River	Pump station near Domain Road.	Low	No	Low	**Negligible**	No obvious flow path to river, paddocks and scrub.	Medium-large river	**Low-mod**
35	Lake Hāwea	990	Lake Hāwea	Pump station on Cemetery Road.	Low	No	Low	**Negligible**	No obvious surface water bodies in vicinity.	Large lake	**Moderate**

Table 11 Risk assessment for each of the locations assessed including the risk of wastewater entering surace water and the risks associated with wastewater discharges to that receiving environment type.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Distance to water	Flow path	Risk associated with vegetation/surface permeability	Probability of waste water entering water	Notes	Receiving environment type	Risk associated with wastewater discharge
36	Kingston	36	Lake Wakatipu	PROPOSED - Pump station at lakefront park across from Gloucester Street.	High	No	Low-mod	**Moderate**	In close proximity to shoreline of Lake Wakatipu, but natural topography would result in ponding on grassed area between road and lake.	Large lake	**Low-moderate, but high locally**
37	Kingston	30	Lake Wakatipu	PROPOSED - Pump station at lakefront park across from Cornwall and Oxford Street.	High	Potential	Low-mod	**Mod-high**	In close proximity to shoreline of Lake Wakatipu, but natural topography would result in ponding on grassed area between road and lake. Stormwater drain may provide flow path to lake.	Large lake	**Low-moderate, but high locally**
38	Jacks Point	0	Various ephemeral creeks	PROPOSED - pipeline from Jacks Point to Frankton.	High	Yes	Low-mod	**Low-mod**	Several small ephemeral creeks crossed by potential pipeline route. Vegetation ranges from rank grass to vehicle track.	Streams	**Low**
39	Lower Shotover	>150	Shotover River	PROPOSED - wastewater network infrastructure for development on low-lying land on true left of the Shotover River	Low	No	Low-mod	**Low**	Willow and scrub. No clear flowpaths to lower Shotover River.	Medium-large river	**Low-mod**

Table 11 Risk assessment for each of the locations assessed including the risk of wastewater entering surace water and the risks associated with wastewater discharges to that receiving environment type.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Distance to water	Flow path	Risk associated with vegetation/surface permeability	Probability of waste water entering water	Notes	Receiving environment type	Risk associated with wastewater discharge
40	Glenorchy	0 (pipe crossing)	Stone Creek	PROPOSED - pipeline from Glenorchy to potential disposal site at Glenorchy airport.	High	Yes	High	**High**	Pipe crossing under Glenorchy-Queenstown bridge. Rank grass on upstream side, broom scrub on downstream. Bare ground under bridge.	Stream	**Mod-high**
41	Glenorchy	0 (pipe crossing)	Buckler Burn	PROPOSED - pipeline from Glenorchy to potential disposal site at Glenorchy airport.	High	Yes	High	**High**	Pipe crossing under Glenorchy-Queenstown bridge. Beech forest on upstream side, willow and scrub on downstream. Bare ground under bridge.	Small-medium river	**Moderate, but high locally**
42	Cardrona	15	Cardrona River	PROPOSED - pipeline from Cardrona township to potential disposal site at skifield turn-off.	Low-High	No	Low-High	**Low-high**	Vegetation generally rank grass or pasture. Pipeline would cross several tributaries, higher risk at pipe crossings in case of leak.	Small-medium river	**Moderate, but high locally**
43	Clutha near Wanaka airport	0 (pipe crossing)	Clutha River	PROPOSED - pipeline from Hāwea township to potential disposal site at Wanaka airport.	Low-High	Yes	Low-mod	**Low-high**	Vegetation generally rank grass or pasture. Pipeline would cross water race near Butterfield Road-Newcastle Road.	Large River	**Low**
44	Luggate	0 (pipe crossing)	Luggate Creek	PROPOSED - pipeline from Luggate township to potential disposal site at Wanaka airport.	Low-High	Yes	Low-High	**Low-high**	Pipeline to cross Luggate Creek.	Small-medium river	**Moderate**

Table 11 Risk assessment for each of the locations assessed including the risk of wastewater entering surace water and the risks associated with wastewater discharges to that receiving environment type.

Pump station	Area	Distance to water (m)	Receiving water body/bodies	Description	Distance to water	Flow path	Risk associated with vegetation/surface permeability	Probability of waste water entering water	Notes	Receiving environment type	Risk associated with wastewater discharge
45	Luggate	0 (pipe crossing)	Dead Horse Creek	PROPOSED - wastewater from developments to east of Luggate township.	Low-High	Yes	Low-High	**Low-high**	Pipeline to cross Dead Horse Creek.	Stream	**Mod-high**
46	Glendhu Bay	>55	Lake Wanaka (Glendhu Bay)	PROPOSED - Glendhu Bay campground	Moderate	Yes	Low-mod	**Moderate**	Infrastructure along access track. Vegetation mostly short grass.	Large lake	**Moderate, but high locally**
47	Mill Creek	12	Mill Creek	PROPOSED - Pump station at Millbrook, near 18th hole.	High	Yes	Low-mod	**Mod-high**	Vegetation short grass (golf course).	Small-medium river	**Moderate, but high locally**
										Lake Hayes	**Mod-high**

Appendix G Site photos

Pump station 1

Figure 15 Pump station 1 on shoreline of Lake Wanaka at Bremner Bay.

Figure 16 Shoreline of Lake Wanaka at Bremner Bay near Pump station 1.

Pump station 2

Figure 17 Pump station 2 at the end of Waimana Place near Lake Wanaka.

Figure 18 Track leading from the end of Waimana Place to Lake Wanaka.

Figure 19 Shoreline of Lake Wanaka near Pump station 2.

Pump station 3

Figure 20 Pump station 3 located at Eely Point with Lake Wanaka in background.

Figure 21 Lake Wanaka at Eely Point near Pump Station 3.

Pump station 4

Figure 22   Pump station 4 on Dungarvon Street near Roy's Bay, Lake Wanaka.

Figure 23   Lake Wanaka at Roy's Bay near Pump station 4.

Pump station 6

Figure 24 Pump station 6 on Dungarvon Street near Bullock Creek.

Figure 25 Bullock Creek downstream of Dungarvon Street near Pump Station 6.

Pump station 10

Figure 26 Pump station 10 on Wicklow Terrace (Albert Town) with Clutha River in background.

Figure 27 Upper Clutha River near Pump station 10 on Wicklow Terrace, Albert Town.

Pump station 11

Figure 28 Pump station 11 on Gunn Road, Albert Town.

Figure 29 Access track from Gunn Road near Pump station 11 with Clutha River in background.

Pump station 12

Figure 30 Pump station 12 on Alison Avenue, Albert Town.

Figure 31 Reserve between Pump Station 12 and the Clutha River.

Pump station 16

Figure 32 Pump station 16 on Harris Place, Luggate.

Figure 33 Walkway to Luggate Creek from near Pump station 16 on Harris Place, Luggate.

Figure 34 View of Luggate Creek from end of walkway from Harris Place.

Pump station 17

Figure 35 View of pump station 17 near Church Street, Luggate from the true right bank of Luggate Creek.

Figure 36 Luggate Creek near Pump Station 17.

Pump station 18

Figure 37 Pump Station 18 near Alexander Place, Arrow Town.

Figure 38 View to Arrow River near Pump Station 18, Arrow Town.

Pump station 19

Figure 39 Pump station 19 beside McDonnell Road, Arrow Town.

Figure 40 Roadside ditch beside McDonnell Road, Arrow Town near Pump station 19.

Figure 41 Roadside ditch beside McDonnell Road, Arrow Town near Pump station 19.

Pump station 20

Figure 42 Pump station 20 beside Essex Avenue, Arrow Town.

Figure 43 Pump station 20 beside Essex Avenue, Arrow Town.

Pump station 21

Figure 44 Pump station 21 beside Atley Road, Arthurs Point near the Shotover River.

Figure 45 View to the Shotover River near Pump Station 21 on Atley Road, Arthurs Point.

Pump station 22

Figure 46 View towards Pump Station 22 (Oxenbridge Tunnel Road) from the opposite (true left) bank of the Shotover River.

Pump station 23

Figure 47 Pump Station 23 on Marine Parade on the shore of Queenstown Bay, Lake Wakatipu.

Figure 48 Shoreline of Queenstown Bay, Lake Wakatipu beside Pump Station 23, looking north-west.

Figure 49 Shoreline of Queenstown Bay, Lake Wakatipu beside Pump Station 23, looking south-east.

Pump station 24

Figure 50 Pump Station 24 near Glenorchy-Queenstown Road.

Figure 51 Small unnamed stream near Pump Station 24, off Glenorchy-Queenstown Road, Fernhill.

Pump station 25

Figure 52 Pump Station 25 on the shore of Lake Wakatipu at Frankton Beach.

Figure 53 Shoreline of Lake Wakatipu at Frankton Beach near Pump Station 25.

Pump station 26

Figure 54 Area of sewer main with overflow on lake shore of Lake Wakatipu at Frankton Beach on Allan Cresent.

Figure 55 Area of sewer main with overflow on lake shore of Lake Wakatipu at Frankton Beach on Allan Cresent.

Pump station 30

Figure 56 Pump Station 30 (foreground) looking towards Lake Hayes.

Figure 57 View towards Lake Hayes from Pump Station 30.

Pump station 31

Pump station on shore of Lake Hayes beside access track.

Figure 58 Pump Station 31 with Lake Hayes in the background.

Figure 59 Lake Hayes shoreline near Pump Station 31.

Pump station 32

Figure 60   Pump Station 32 on Hāwea esplanade track on the shore of Lake Hāwea.

Figure 61   View from Pump Station 32 towards Lake Hāwea.

Pump station 33

Figure 62 Pump Station 33 on Scotts Beach Road on the shore of Lake Hāwea.

Figure 63 View towards Lake Hāwea from Pump Station 33.

Pump station 34

Figure 64 Pump Station 34 on Domain Road near Lake Hāwea.

Pump station 35

Figure 65 Pump Station 35 on Cemetery Road near Lake Hāwea.

Kingston

Figure 66 Location of proposed pump station 36 at Kingston across from Gloucester Street.

Figure 67 Location of proposed pump station 37 at Kingston at the intersection of Cornwall and Oxford Streets.

Lower Shotover

Figure 68 Low-lying terrace near the lower Shotover River (to the right of the willows on the right-hand side of the photograph).

Glenorchy

Figure 691 Buckler Burn below the Glenorchy-Queenstown Road bridge.

Clutha River near Wanaka airport

Figure 70 Clutha River near the proposed pipe bridge from Lake Hāwea village to a treatment plant near Wanaka airport.

Luggate – Dead Horse Creek

Figure 71 Dead Horse Creek upstream of Alice Burn Drive.

Figure 72 Dead Horse Creek downstream of the State Highway 6 bridge.

Glendhu Bay

Figure 73 Glendhu Bay campground.

Figure 74 Glendhu Bay campground.

Figure 75 Alpha Burn where it passes through the Glendhu Bay campground before entering Lake Wanaka.

Mill Creek

Figure 71 Mill Creek upstream of Taramea, downstream of pump station 47.