Christchurch Water Supplies Water Safety Plan

Volume B: Christchurch/Lyttelton Water Safety Plan

Christchurch City Council

Revision 6

May 2022

Christchurch City Council

Water safety plan requirements are provided in two parts. This volume (Volume B) covers information that is specific to the Christchurch/Lyttelton water supply.

This information is to be read alongside Volume A which contains the water safety plan components that are common to all of the Council's water supplies (TRIM: 22/438283).

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1 Commitment to Drinking Water Quality Management

Detailed information relating to the relationship of the Water Safety Plan to Organisational Policy and Strategy and the Drinking water Quality Statement is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM22/438283).

Volume A of the Water Safety Plan also contains information relating to engaging stakeholders. This includes the key stakeholders with responsibilities for managing activities in the catchment that may influence source water quality, or be affected by decisions or activities of the drinking-water supplies within the Council's jurisdiction. Volume C contains more specific information regarding the aquifer sources that provide the water for Christchurch's supply. A more detailed source risk management plan is a requirement of the Water Services Act (section 31 (1)i. Some of the information from Volume C is also included in Volume B to provide completeness for those wanting to just have some background source information.

External contacts specific to the Christchurch/Lyttelton Harbour Basin Water Safety Plan are provided in Table 1-1.

Table 1-1: Key external stakeholders

Stakeholder	Position	Name
HDM Professional Services Panel[1]	CH2M Beca AECOM GHD Stantec Jacobs Opus	[redacted]
Ministry of Education	Director of Education for Canterbury	
Ngāi Tūāhuriri Rūnanga	Tuahiwi Marae	
Te Hapū o Ngāti Wheke	Rapaki Marae	

Detailed information engaging communities, including public consultation, incidents and emergencies, and customer complaints is provided in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

A summary of policy documents specific to the Christchurch/Lyttelton Harbour Basin water supply is provided in Table 1-2.

1 http://intranet.ccc.govt.nz/Teams/CityServices/3WatersWaste/HDMPanels/Information%20Library/3%20Waters%20HDM%20Consultant%20Contact%20Details.pdf

Table 1-2: Policy documents and resources related to water supply

Name	Description	Document Location
Christchurch City and Lyttelton Harbour Basin Site Specific Risk Management Plans	Provides an overview of the pump stations and site specific documents and resources, risks and improvement tables.	TRIM://19/1174477 (register of site specific risk management plans with TRIM links to each plan)
Potable Water Zone Manual (draft 2019)	General information for the operation of any potable water zone, and the specific zone manuals contain information for the operation of specific zones	TRIM://19/1054164 - Potable Water Zone Manual TRIM://18/935286 - Rawhiti Zone Manual TRIM://19/1155848 - Central Zone Manual TRIM://19/1276106 - North Western Zone Manual TRIM://19/1299556 - Western Zone Manual TRIM://19/1290242 - Parklands Zone Manual TRIM://19/1295736 - Riccarton Zone Manual TRIM://19/1205333 - Independent Zone Manual TRIM://19/1187529 - Ferrymead Zone Manual TRIM://19/1298110 - Rocky Zone Manual TRIM://19/1208640 - Lyttelton Harbour Zone Manual
Water Supply Well Head Security Assessments and Well Information	Well head assessments carried out by Beca and PDP in accordance with DWSNZ requirements, other asset information about water supply wells in Christchurch	TRIM://18/422884 Well head security and Remediation – Master Well List
Water Supply Overview Map Christchurch and Lyttelton Harbour	Map showing the Council water supply schemes (refer also to Council's GIS SmartMap for current information)	TRIM://17/737163 (Christchurch) TRIM://17/737180 (Lyttelton Harbour Basin)
Christchurch Water and Wastewater System Key Documents	Document with Trim links to relevant water supply and wastewater related information (maps, schematics, engineering plans)	TRIM://12/706966
Citycare Contractor's Plans for the Christchurch/ Lyttelton Harbour Basin water supply	Overarching Contractor's Plans for the Christchurch/Lyttelton water supplies which outlines the methodologies and resources that Citycare Water use to maintain the network.	TRIM://19/1034969 - Potable water pump station maintenance TRIM://19/1034961 - Reservoir maintenance TRIM://19/1034951 - Water reticulation network planned and reactive maintenance TRIM://19/1034976 - Below and above ground well heads maintenance

2 Description of the Drinking Water Supply System

2.1 Overview

Christchurch City is situated on the flat alluvial Canterbury plains, bounded by the Port Hills to the south and the Pacific Ocean to the east. The city lies above the Christchurch West-Melton Aquifer System. Figure 2-1 provides a 3D schematic of the Canterbury Plains and Figure 2-2 provides a simplified schematic of the Christchurch-West Melton groundwater system. About three quarters of the aquifer system is recharged by seepage from the Waimakariri River and the remainder by infiltrating rainfall on the plains to the west and north of the city (see Figure 2-3). Groundwater modelling by GNS in 2018 found that an area north of the Waimakariri River could also contribute to Christchurch's aquifers[2]. The groundwater system is discussed in more detail in section 2.3.

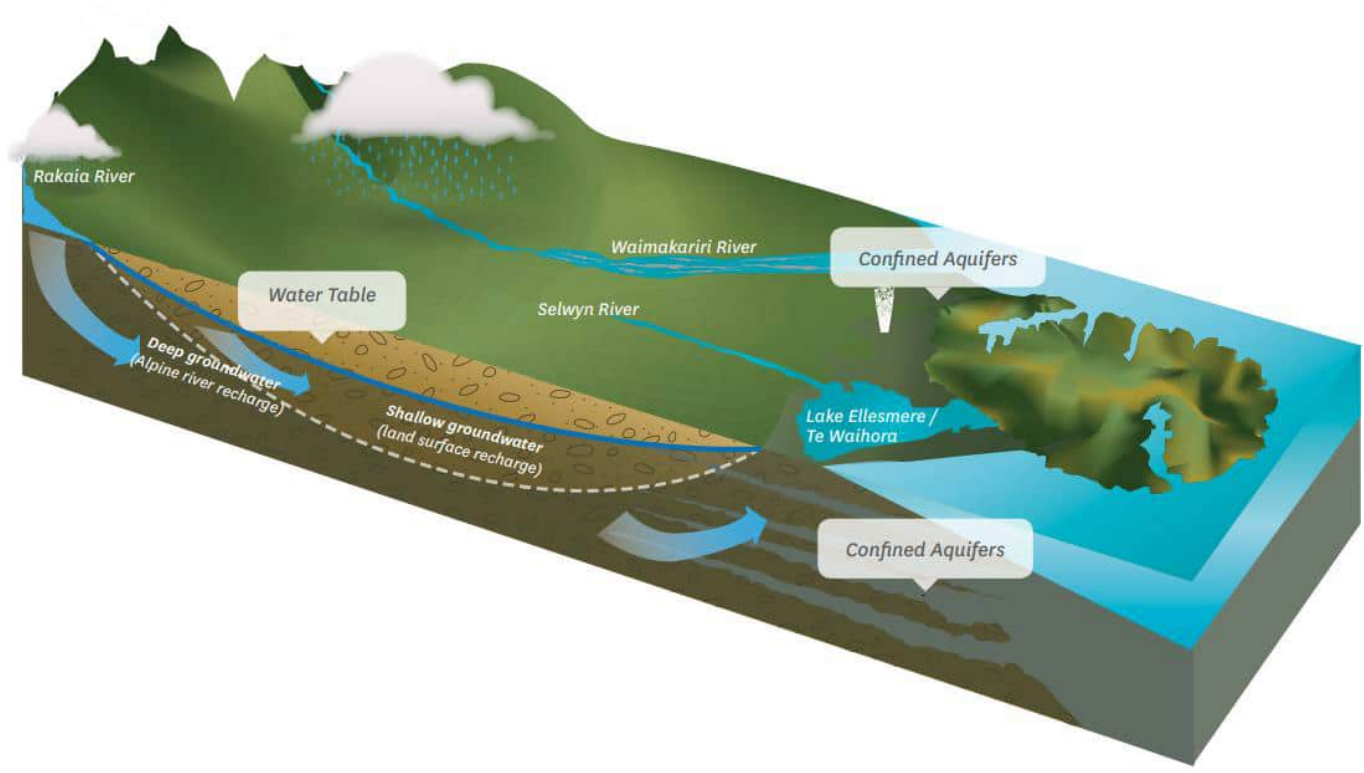


Figure 2-1: 3D Schematic of the Canterbury Plains

[2] Hemmings, B.J.C, Moore, C.R., Knowling, M.J (2018) Calibration constrained Monte Carlo uncertainty analysis of groundwater flow and contaminant transport models for the Waimakariri-Ashley region of the Canterbury Plains. Lower Hutt (NZ): GNS Science https://api.ecan.govt.nz/TrimPublicAPI/documents/download/3632774

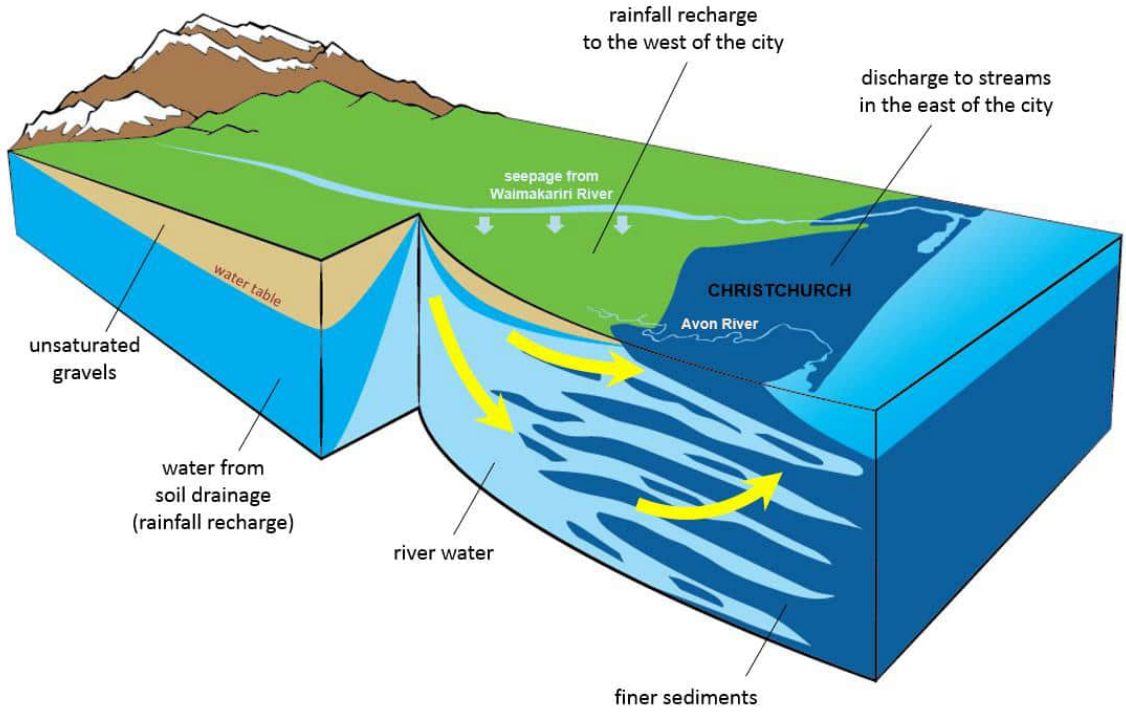


Figure 2-2: Schematic of the Christchurch-West Melton Groundwater System

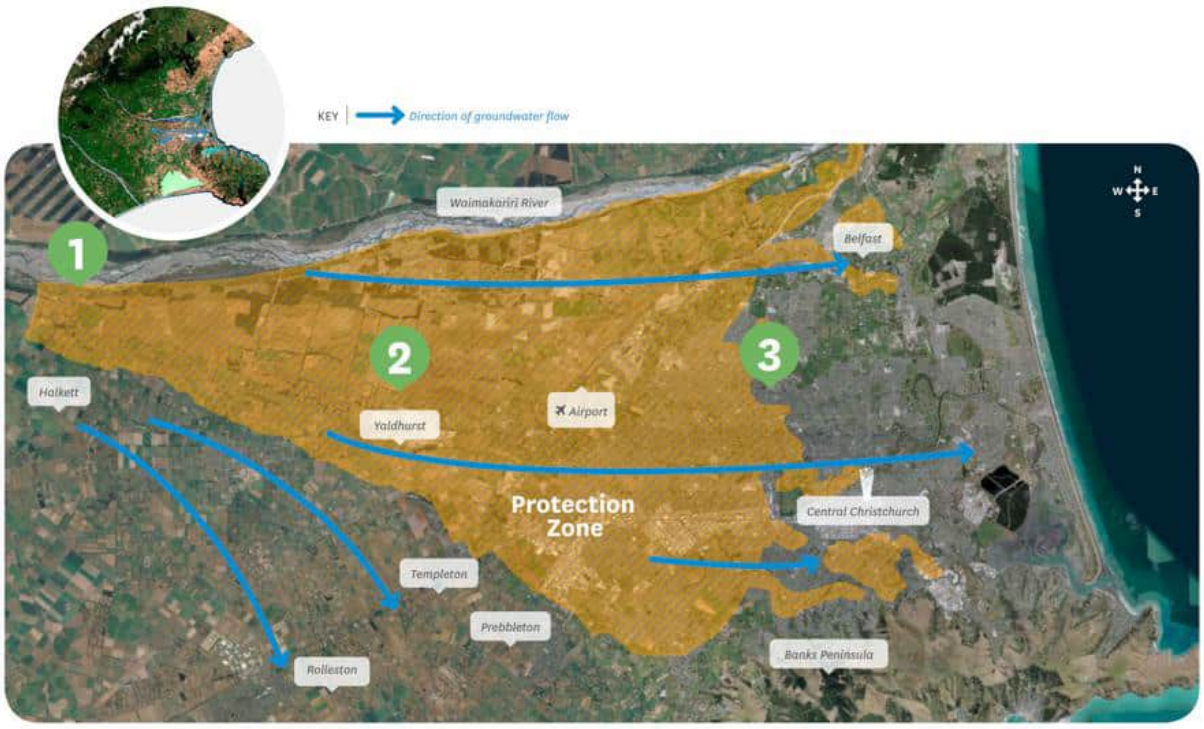


Figure 2-3: Where does Christchurch's water come from?[3]

[3] Map and commentary from ECan website https://www.ECan.govt.nz/your-region/your-environment/water/drinking-water-quality/ accessed 16/11/2020.

Notes accompanying Figure 2-3:

1: Downstream of this point, some of the water in the river begins to flow into the gravels of the plains, topping up the aquifers on which Christchurch depends for its drinking water.

2: Environment Canterbury owns a significant amount of land in this area. The land is managed to ensure it is used for appropriate purposes that won't have an adverse impact on Christchurch's groundwater.

3: Flow through the gravels is at about 25m a day, groundwater takes a few years to reach the zone from which Christchurch takes its drinking water.

Public water supply began later in Christchurch than most New Zealand cities because an adequate supply could be obtained relatively easily from private wells. Today, about half of the groundwater taken from the Christchurch West-Melton aquifers is taken for public supply, with the remainder taken from private wells for industrial and agricultural purposes. Water for the public supply is pumped from confined aquifers to the city's residential and commercial water users via 142 wells, at 50 primary pump station sites, into 1,648 kilometres of water mains and 1,600 kilometres of submains throughout the city.

Christchurch City is currently divided into two registered community drinking water supplies and seven supply zones: Central, West, Parklands, Riccarton, Northwest, Rawhiti, Ferrymead and Brooklands/Kainga.

The Christchurch City pressure zones (excluding the Lyttelton Harbour Basin) are based on previous network boundaries operated by the various authorities that merged in 1989 to form the new Christchurch City Council. The zones are operated at different pressures and can be interconnected, in an emergency, by opening valves at zone boundaries; or split into smaller zones, by closing specifically labelled earthquake emergency zone valves.

Lyttelton Harbour Basin became a Christchurch City Council water supply when the Banks Peninsula District Council (BPDC) was amalgamated with Christchurch City Council in 2006. The Lyttelton supply consists of one registered community drinking water supply and three supply zones that operate independently: Lyttelton, Governors Bay and Diamond Harbour.

The Lyttelton supply sources its water from the Christchurch Central/Ferrymead water supply zone and distributes water via 69 km of water mains and 18 km of submains. Scruttons and Ferrymead booster pump stations and pipelines through both the road and rail tunnels provide redundancy for the supply to Lyttelton. The Lyttelton sub-zones are based on geographical constraints. Reservoirs provide a steady supply to each sub-zone and some storage in the case of an interrupted supply.

A summary of the key features of the Christchurch and Lyttelton Harbour Basin water supplies is given in Table 2-1. Table 2-2 lists the supplies covered by this water safety plan.

Table 2-1: Summary statistics for the Christchurch/ Lyttelton water supplies

	Christchurch	Lyttelton Harbour Basin	Total
Population served	383,445	5,854	389,299
Annual water extracted (m^3/year)	56,401,570		56,401,570
Average daily extraction (m^3/day)	154,103		154,103
Maximum daily extraction (m^3/day)	275,737		275,737
Minimum daily extraction (m^3/day)	116,729		116,729
Primary (source) pump stations (in service)	50	-	50
Secondary (lift) pump stations	41	13	54
Number of wells	143		143
Well depths (m)	28 – 232		28 – 232

	Christchurch	Lyttelton Harbour Basin	Total
Water treatment plants	1 (Main Pumps UV)	0	1
Storage reservoirs	50 reservoirs at 39 sites	18 reservoirs at 15 sites	68 reservoirs at 54 sites
Suction tanks	23	0	23
Length of water mains (km)	1,682	81	1,763
Length of water submains (km)	1,643	19	1,662
Total length of water pipes (km)	3,325	100	3,425
Number of connections to the system	130,707	2,017	132,724

Notes:

- Population data from the Ministry of Health register of community drinking water supplies
- Water extraction data is for the financial year 1 July 2019 – 30 June 2020. Lyttelton Harbour Basin is supplied from Christchurch Ferrymead and has no wells of its own.
- Pump station and well information from TRIM 18/422884. Excludes pump station and wells currently under construction (Ben Rarere) and suction tanks that are not in service (Averill and Jeffreys).
- Reticulation information from TRIM 20/1460293

There are 50 reservoirs at 39 reservoir sites on the Christchurch side of the Port Hills and 18 reservoirs at 15 sites in Lyttelton Harbour Basin. There are a total of 25 suction tanks at primary pump stations in Christchurch City but only 23 are currently in use. Water supply overview maps are shown in Figure 2-6 and Figure 2-7 which are also available in Trim: Christchurch City: 17/737163 , Lyttelton Harbour Basin: 17/737180.

The individual system components are further described in sections 2.2 to 2.5.

Table 2-2: Registered Supplies and Associated Zones, Treatment Plants and Sources

Water Supply	Distribution Zone	Distribution Zone Code	Population	Plant Associated with Zone	Treatment Plant Code	Source Name	Source Code
CHR001	Central	CHR001CE	158,250	Central Christchurch	TP00179	Central CHCH, Aquifer 1 Central CHCH, Aquifer 2 Central CHCH, Aquifer 3 Central CHCH, Aquifer 4 Central CHCH, Aquifer 5	G00118 G00119 G00120 G00121 G01602
				Main Pumps	TP04053	Central CHCH, Aquifer 1	G00118
	Parklands	CHR001PA	20,139	Parklands	TP00182	Parklands, Aquifer 2 Parklands, Aquifer 3 Parklands, Aquifer 4	G00126 G03132 G00127
	West	CHR001WE	57,811	West	TP00183	West CHCH, Aquifer 2 West CHCH, Aquifer 3 West CHCH, Aquifer 4	G00128 G01601 G02147
	Riccarton	CHR001RI	11,771	Riccarton	TP00185	Riccarton, Aquifer 2 Riccarton, Aquifer 4	G00131 G01599
	Northwest	CHR001NO	86,160	Northwest	TP00181	NW CHCH, Aquifer 1 NW CHCH, Aquifer 2 NW CHCH, Aquifer 3 NW CHCH, Aquifer 4 NW CHCH, Aquifer 5	G00122 G00123 G02162 G01598 G00125
	Rawhiti	CHR001RA	30,838	Rawhiti	TP04061	Rawhiti Aquifer 2 Rawhiti Aquifer 3 Rawhiti Aquifer 4 Rawhiti Aquifer 5	G03098 G03099 G03100 G03101
	Ferrymead	CHR001FE	16,847	Ferrymead	TP04060	Ferrymead Aquifer 1 Ferrymead Aquifer 4 Ferrymead Aquifer 5	G03095 G03096 G03097
Lyttelton LYT001	Lyttelton	LYT001LY	3,273				
	Governors Bay	LYT001GO	880				
	Diamond Harbour	LYT001DI	1,701				
BRO012	Brooklands / Kainga	BRO012BR	1,629	Brooklands / Kainga	TP00964	Brooklands Kainga Aquifer 2	G00581

Note: The term treatment plant is used for consistency with the drinking water register, even though treatment is not necessarily present. In Christchurch, treatment plant is taken to apply to pump stations.

2.2 System flow diagram

Effective system management requires a detailed understanding of the water supply system from catchment to consumer. The purpose of this diagram is to ensure that all elements of the supply are assessed for risk and the presence (or absence) of barriers to contamination can be clearly identified.

Figure 2-4 provides a high level overview of Christchurch's water supply.

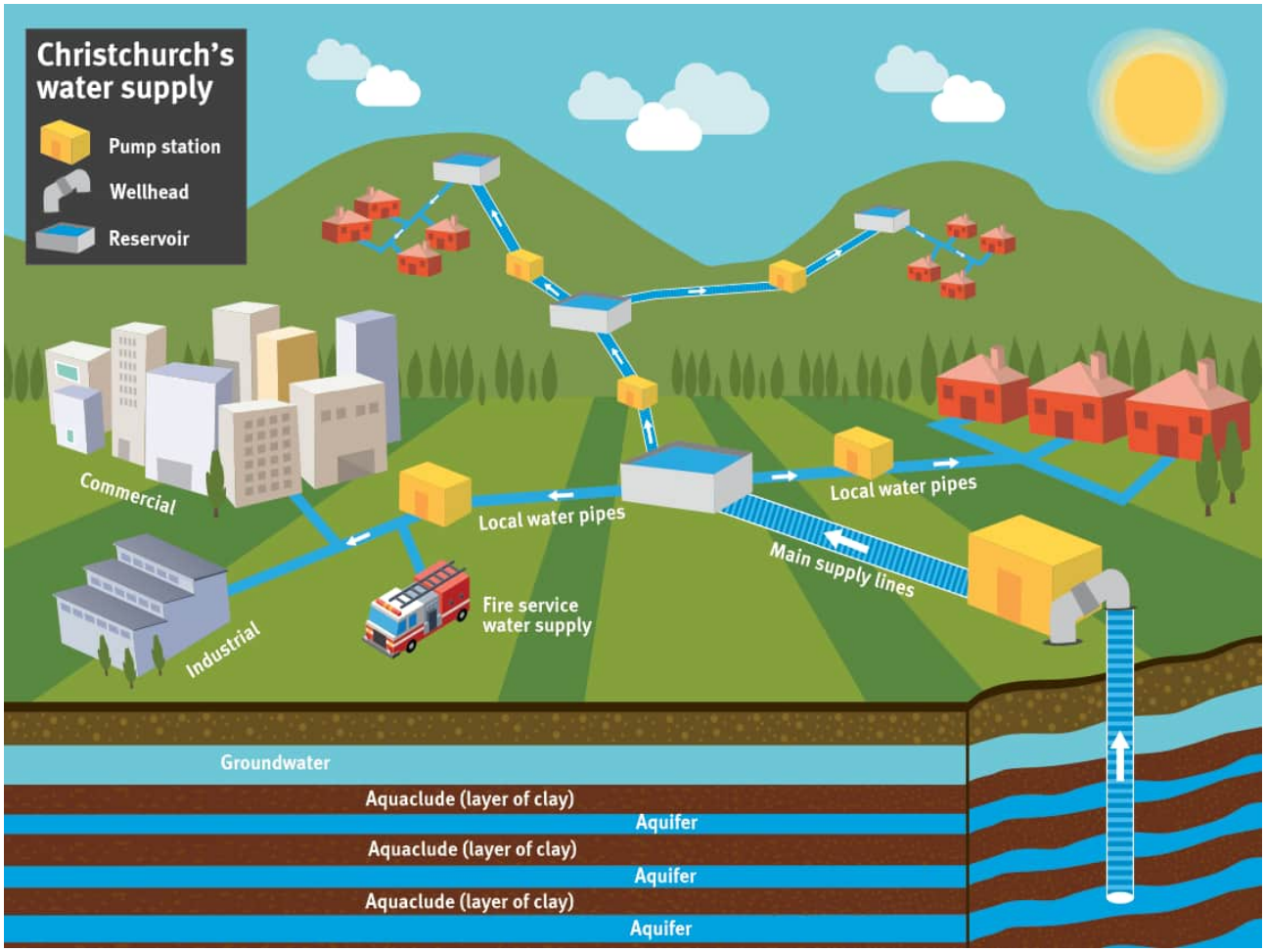


Figure 2-4: Christchurch's water supply system

A system flow diagram for the Christchurch and Lyttelton water supplies is shown in Figure 2-5. Table 2-3 provides a detailed overview of this information by supply zone.

Schematics with key characteristics for individual zones are included in section 6.1.2 of Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283)

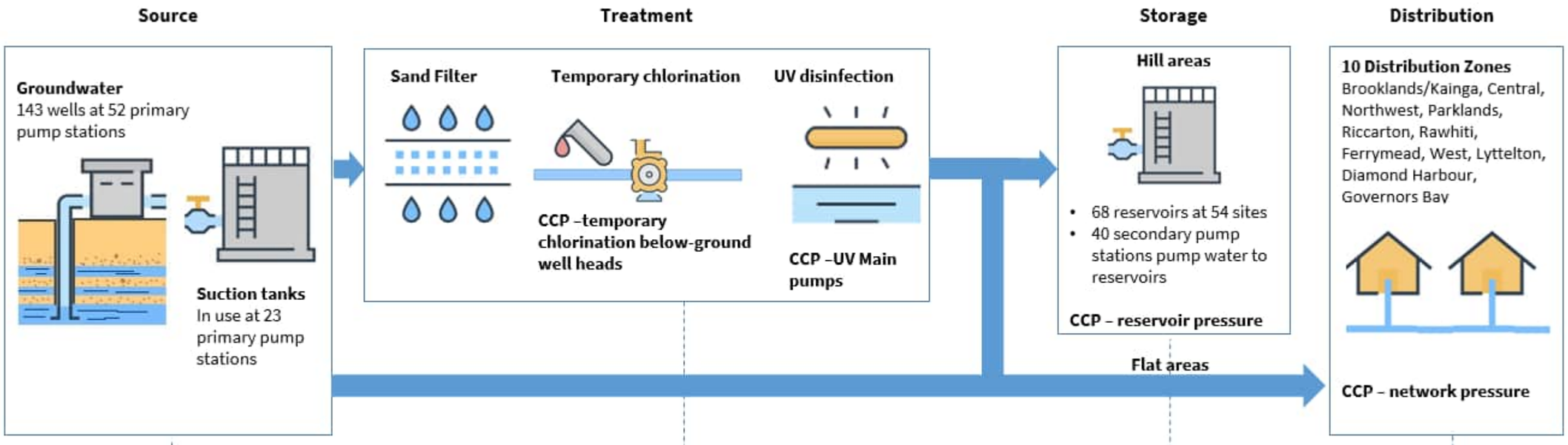


Figure 2-5: Schematic of the Christchurch City and Lyttelton Harbour Basin water supplies

Table 2-3: Water supply zone, pump stations and wells – summary of information

Key

Secure above ground well
Well turned off, to be abandoned
Below-ground well which meets DWSNZ secure bore water criterion 2 but will be replaced in the medium-term (new pump station)
Well isolated, currently being replaced or on medium-term replacement programme
Below-ground well which meets DWSNZ secure bore water criterion 2 but will be raised above ground in short-term
Newly drilled well, not yet in service

Supply Zone	Station Name	PS Number	Number of wells in each aquifer					Total Wells	Comments	Artesian / Non-artesian	Suction Tank	Main Supply to reservoirs
			1	2	3	4	5					
Brooklands / Kainga	Brooklands	PS1066		1 1				1	Well 2 currently isolated	Non-artesian		
	Kainga	PS1067		1				1		Non-artesian		
Central	Addington	PS1001				2		2		Artesian		
	Aldwins	PS1002	1			2		3	Well 3 currently isolated	Artesian		
	Averill	PS1005	1	1		1		3	Well 2 (aquifer 1) not in use. Pump station will be replaced in the long-term	Artesian	Yes	
	Blighs	PS1007				1		1		Non-artesian	Yes	
	Grassmere	PS1014			2		1	3		Non-artesian	Yes	
	Hillmorton	PS1016				2		2	Well 1 abandoned	Non-artesian	Yes	
	Hills	PS1017			2	1		3		Artesian and non-artesian	Yes	
	Kerrs	PS1022				2		2		Artesian		
	Main Pumps	PS1024	6					6		Non-artesian	Yes	Yes
	Mays	PS1026		1		1		2		Artesian and non-artesian	Yes	
	Montreal	PS1027	1			1		2		Non-artesian		
	Palatine	PS1028	1					1		Non-artesian		
	Spreydon	PS1030	1	1	1	2		5		Artesian and non-artesian	Yes	
	Sydenham	PS1031		1		1	2	4		Artesian and non-artesian	Yes	
	Tanner	PS1095	2					2		Non-artesian		
	Trafalgar	PS1035				2	1	3		Artesian	Yes	
	Worcester	PS1037				2		2		Artesian		
Ferrymead	St Johns	PS1063				2	1	3		Artesian	Yes	Yes
	Woolston	PS1065	1			2		3		Artesian and non-artesian	Yes	Yes
Northwest	Auburn	PS1068		1			1	2	Well 3 isolated	Artesian	Yes	
	Avonhead	PS1068			1	1		2		Non-artesian		
	Belfast	PS1070	1		1	1		3		Artesian		
	Burnside	PS1071				3	3	6		Non-artesian		
	Crosbie	PS1072				2	1	3		Non-artesian		
	Farrington	PS1073			3	1	1	5		Non-artesian		
	Gardiners	PS1125				1	1	2		Non-artesian	Yes	
	Grampian	PS1074		1	1	1		3		Non-artesian	Yes	
	Jeffreys	PS1076			1		1	2	Wells 7 & 8 are drilled but not developed	Artesian and non-artesian	Yes	
	Redwood	PS1077	2					2	Wells 3 and 4 currently being drilled	Non-artesian		
	Thompsons	PS1078				2		2		Non-artesian		
	Wrights	PS1080			1	1		2		Non-artesian		
Parklands	Burwood	PS1081				2		2		Artesian		
	Mairehau	PS1083				1		1		Artesian		
	Marshlands	PS1084				2		2		Artesian		
	Parklands	PS1085		2		1		3		Artesian		
	Prestons	PS1123		2	1	1		4		Artesian and non-artesian	Yes	
Rawhiti	Aston	PS1004		1		1		2		Artesian		
	Ben Rarere	PS1126				2		2	Under construction	Non-artesian		
	Carters	PS1008		1		3		4		Artesian and non-artesian	Yes	
	Effingham	PS1010		2		1		3		Artesian		
	Estuary	PS1012		1		1		2		Artesian and non-artesian	Yes	
	Keyes	PS1119		2		1		3		Artesian	Yes	
	Lake Terrace	PS1023			1	1	1	3		Artesian and non-artesian	Yes	
Riccarton	Picton	PS1088		1		2		3		Artesian		
	Tara	PS1089				1		1		Non-artesian		
West	Denton	PS1099		1	4			5		Non-artesian	Yes	
	Dunbars	PS1102		3		1		4		Non-artesian	Yes	Yes
	Sockburn	PS1109		6				6		Non-artesian	Yes	
	Wilmers	PS1117				2		2		Non-artesian	Yes	Yes

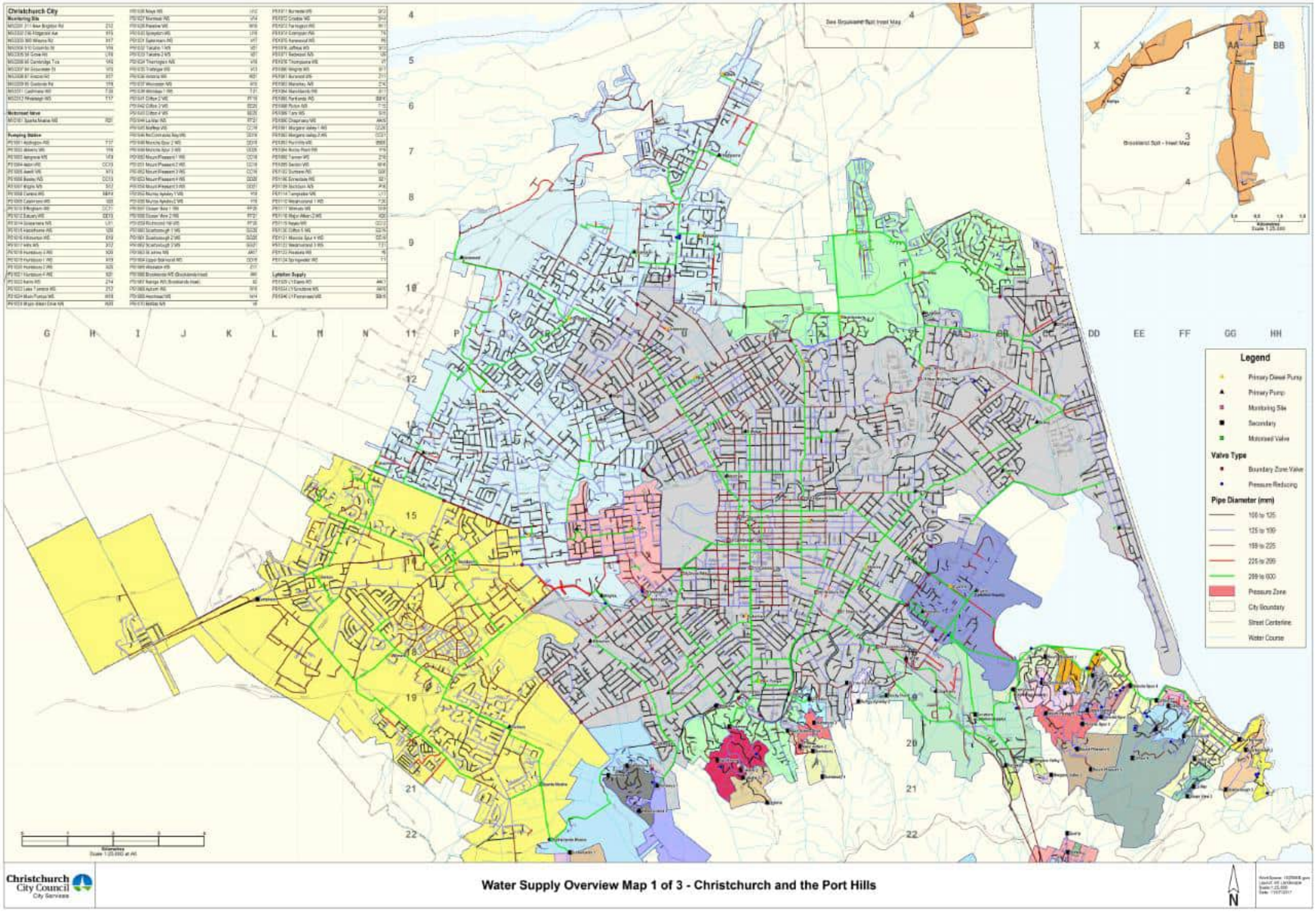


Figure 2-6: Water Supply Overview Map – Christchurch and the Port Hills

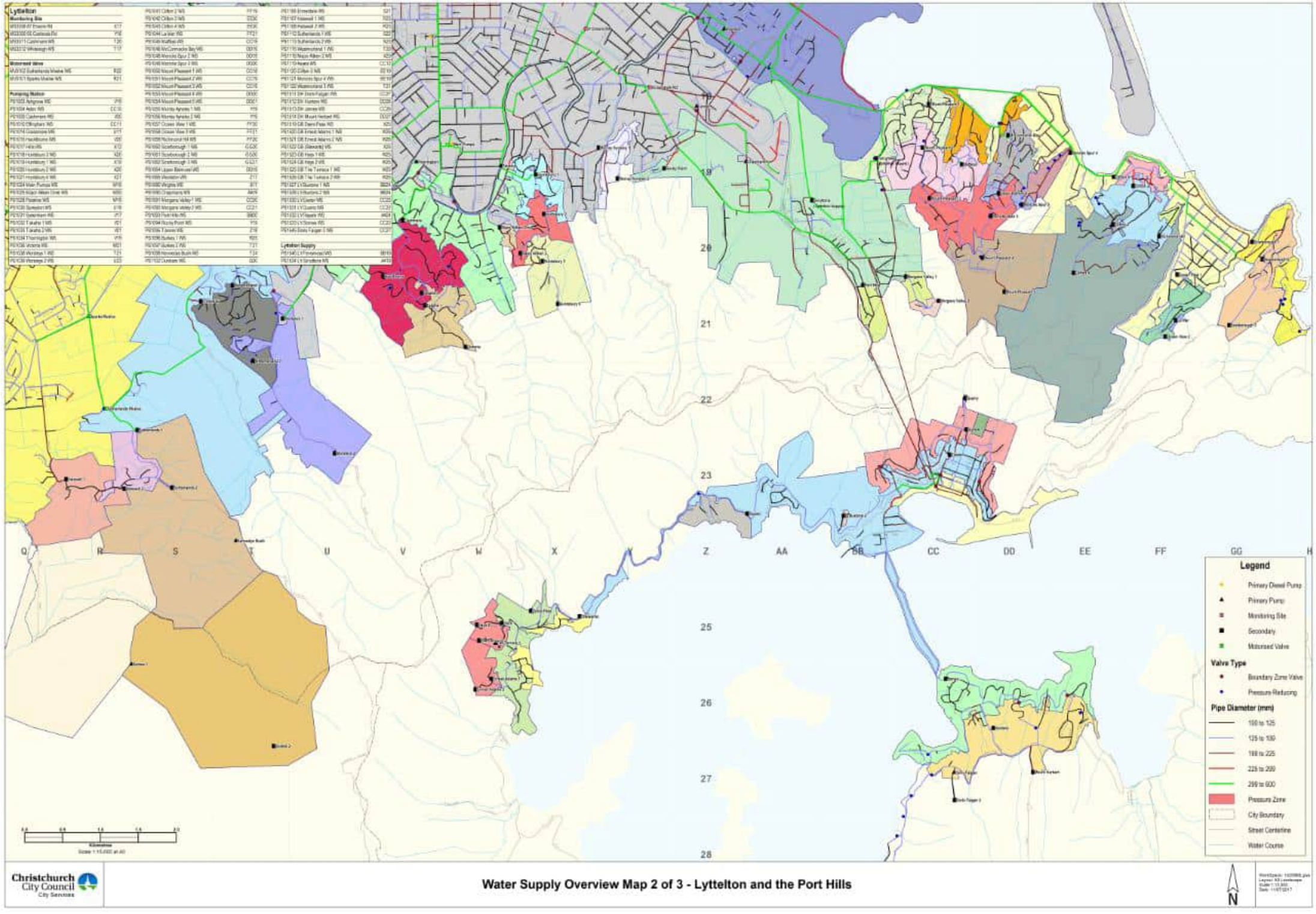


Figure 2-7: Water Supply Overview Map – Lyttelton and the Port Hills

2.3 Source catchment, well characteristics and source water risk management

2.3.1 Source catchment

The Christchurch City and Lyttelton Harbour Basin water supply is sourced entirely from the Christchurch-West Melton groundwater system. It comprises late Quarternary deposits of postglacial and interglacial fluvial gravels. Towards the coast, these gravels are interbedded with fine sand, silt, peat and clay deposits, together with marine, estuarine and lagoon sediments which accumulated during fluctuating climatic periods of the last 1 million years.

Figure 2-8 shows the sequence and nomenclature of the late-Quarternary deposits underlying Christchurch. Flowing artesian aquifers underlie the area from the coast extending inland to Papanui, Fendalton and Riccarton. Five known aquifers are present to a depth of over 200 metres.

Figure 2-9 illustrates the recharge sources of the upper aquifers of the Christchurch-West Melton groundwater system and shows the western limit of groundwater confinement in the first confined aquifer (Riccarton Gravel), indicated by the 3 metre isopach (thickness) line.

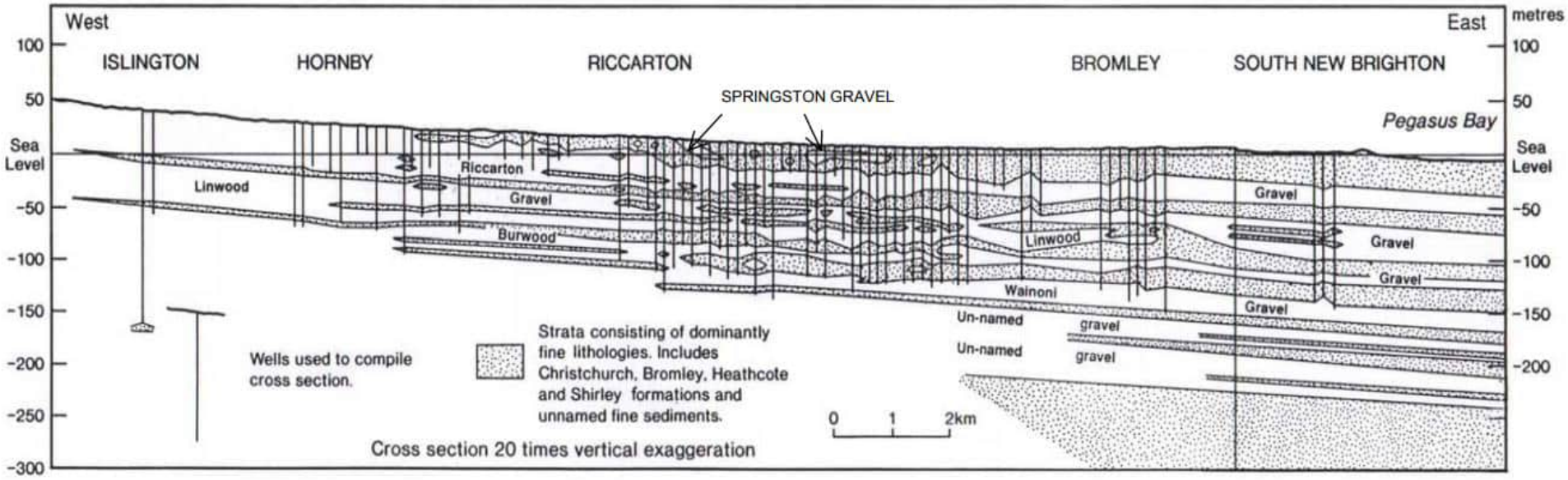
The principal aquifers are in outwash and reworked gravel deposits. The intervening silt, sand, and peat layers confine the groundwater.[4] The overlying confining sediments (Christchurch Formation) increase in thickness eastwards of 3 metre isopach line and are about 30 – 40 metres thick at the coast.

Recharge of the Christchurch-West Melton groundwater system occurs in the unconfined areas primarily from drainage from the Waimakariri River and rainfall on the plains. About three quarters of groundwater is recharged by Waimakariri River, with rainfall derived infiltration providing the remainder.

A contributing source of groundwater to the deep aquifers in the northeast part of the confined zone is deep flow beneath the Waimakariri riverbed from north of the Waimakariri River. This is based on groundwater modelling undertaken by GNS for Environment Canterbury and is described in the Waimakariri Land and Water Solutions Programme – Options and Solutions Assessment – Nitrate Management (Kreleger & Etheridge, 2019)[5]. The source area north of the Waimakariri River is shown in Figure 2-10. There is a risk that nitrate concentrations could increase in the Christchurch water supply in the future as a result of intensive land use north of the Waimakariri River. The Council made a submission and presented evidence on Plan Change 7 of the Land and Water Regional Plan on this matter, advocating for more stringent controls on land use and an accelerated programme to reduce nitrate leaching from farms in this groundwater source area.

[4] S.A. Hayward, 2002. Christchurch-West Melton Groundwater Quality: a review of groundwater quality monitoring data from January 1986 to March 2002. Report No U02/47: https://api.ECan.govt.nz/TrimPublicAPI/documents/download/454603

[5] Kreleger & Etheridge, 2019: Waimakariri Land and Water Solutions Programme – Options and Solutions Assessment – Nitrate Management: https://api.ECan.govt.nz/TrimPublicAPI/documents/download/3626251



Stratigraphy of the Christchurch – West Melton groundwater system (Brown and Weeber, 1992)

Riccarton gravel – Aquifer 1
Linwood gravel – Aquifer 2
Burwood gravel – Aquifer 3
Wainoni gravel – Aquifer 4
Un-named gravel – Aquifer 5

Figure 2-8: Stratigraphy of the Christchurch–West Melton Groundwater System

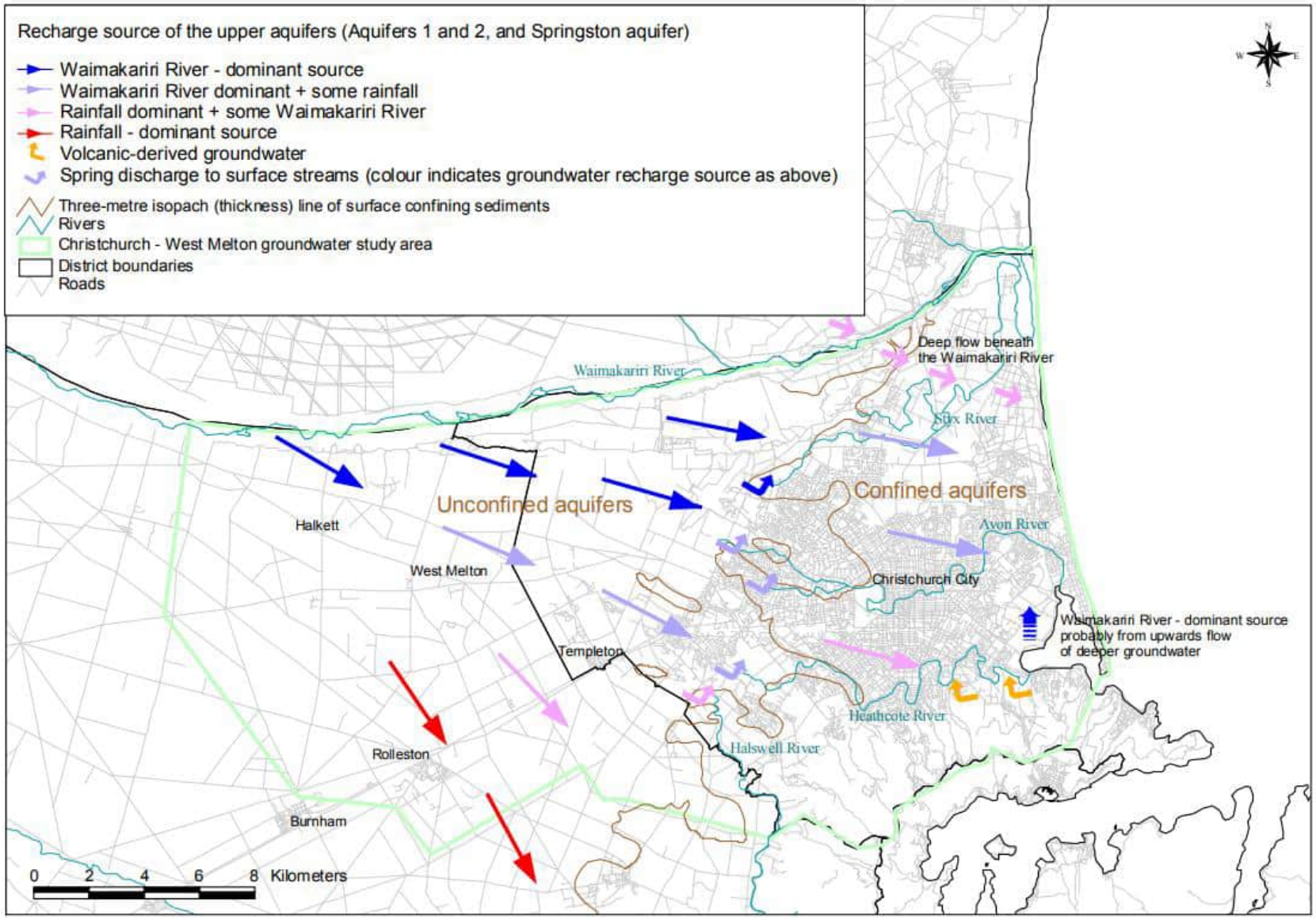


Figure 2-9: Recharge Sources of the Upper Aquifers of the Christchurch-West Melton Groundwater System

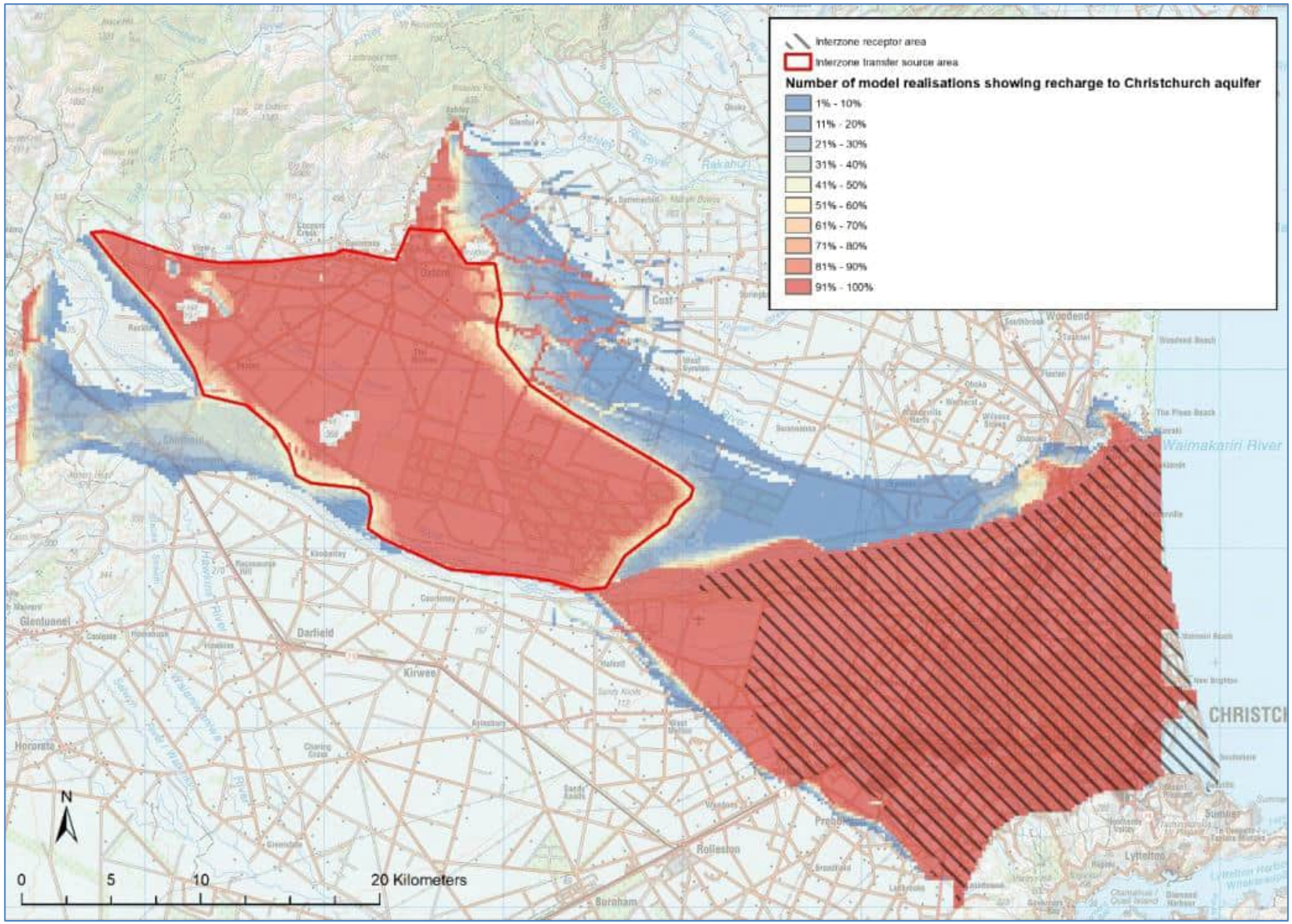


Figure 2-10: Waimakariri Recharge Sources of the Christchurch Groundwater System

The risk of surface or climatic influences on the aquifers is related to the thickness of the confining layer, the presence (or absence) of an upwards hydraulic gradient and the length of flow paths leading to any water supply well.

As illustrated in Figure 2-8 and Figure 2-9, Aquifer 1, the shallowest aquifer in the system, is protected from surface and climatic influences in the east of the city by a thick, low permeability layer. It has less protection in the west of the city where the confining layers are thinner, and in the Heathcote-Woolston area where the aquifers thin out and pinch adjacent to the low permeability volcanic rock. The extent of the 3-metre isopach (thickness) line of surface confining sediments is shown in Figure 2-9. Shallow wells located to the east of this line are considered unlikely to be affected by surface or climatic influences, and shallow wells located to the west of this line are considered more susceptible to surface or climatic influences.

Aquifers 2, 3, 4 and 5 are considered unlikely to be affected by surface or climatic influences at all locations throughout the city as groundwater modelling has shown that an upward hydraulic gradient exists in those deeper aquifers, as shown by monitoring.

2.3.2 Water supply wells

There are 142 operational wells supplying water to Christchurch City and to Lyttelton Harbour Basin (see TRIM 18/422884 for information about each well).

Water is abstracted at 50 primary pump station sites under groundwater take consent CRC191331[6]. Appendix A – CRC191331 Schedule 1 – lists all wells currently included in this global consent.

At each of these sites there is between one and six wells. The wells are typically 200 and 300 mm in diameter and the wells are drilled to depths ranging from 28 m to 232 m. Wells are fully cased and screened in the last 5 to 10 m of the total well depth. All wells, except those indicated in Table 2-3, have above-ground well heads and have been grouted between the inner and outer casing.

The water supply demand base load is usually obtained from the deeper aquifer at each site, often free flowing into a suction tank if the wells are artesian. The supply is supplemented by the shallower aquifers and using submersible pumps during high demand periods. Suction tanks at some sites help balance the flow between wells in different aquifers, provide storage for short-term peaks, reduce surges on wells, and settle any sand that may come from the well.

The Council is reducing the amount of water drawn from Aquifer 1 by using the deeper wells at each pump station first and drilling deeper wells to replace shallow wells. In 2004/5, approximately 30% of Christchurch's water supply was drawn from Aquifer 1. This reduced to 11% in 2019/20. The percentage will reduce further as more Aquifer 1 wells are replaced with deeper wells.

As illustrated in Figure 2-8 and Figure 2-9, the Christchurch water supply is most vulnerable to contamination in the north-western parts of the city because the shallow Aquifer 1 in the north-west is protected by a thin confining layer. In 2004/5, approximately 60% of Northwest Christchurch's water supply was drawn from Aquifer 1. This reduced to 3% in 2018/19. This is due to the Council's well deepening programme in the Northwest zone which is almost complete. The remaining Aquifer 1 wells at Belfast and Redwood pump stations are no longer being used and deeper wells are being drilled to replace them.

[6] https://www.ECan.govt.nz/data/consent-search/consentdetails/CRC191331/CRC191331

Table 2-4 compares the total volume (cubic metres) from each aquifer for each supply zone [7] for the period 1 July 2019 to 30 June 2020.

Table 2-4: Total annual volume from Christchurch City aquifers m³)

	Aquifer 1	Aquifer 2	Aquifer 3	Aquifer 4	Aquifer 5	Total Flow
2004/5						
Brooklands / Kainga	0	526,101	0	0	0	**526,101**
Central	8,629,552	3,405,413	947,512	14,047,668	1,208,902	**28,239,047**
Northwest	6,059,958	198,596	0	0	3,863,059	**10,121,613**
Parklands	0	833,966	0	1,095,283	0	**1,929,249**
Riccarton	5,319	33,411	0	1,428,881	0	**1,467,611**
Rocky Point	315,813	0	0	0	0	**315,813**
West	0	6,864,392	1,154,690	0	0	**8,019,082**
Total Flows	**15,010,642**	**11,861,879**	**2,102,202**	**16,571,832**	**5,071,961**	**50,618,516**
Percentage	**30%**	**23%**	**4%**	**33%**	**10%**	
2019/20						
Brooklands / Kainga	0	272,185	0	0	0	**272,185**
Central	4,982,442	1,848,037	3,049,807	12,755,950	2,064,024	**24,700,260**
Ferrymead	1,151,183	0	0	2,427,411	742,844	**4,321,438**
Northwest	88,483	271,781	686,170	3,649,121	4,267,981	**8,963,536**
Parklands	0	124,437	350,284	430,787	1,353,143	**2,258,651**
Rawhiti	0	903,841	47,329	2,553,949	9,800	**3,514,919**
Riccarton	0	311,237	0	1,229,794	0	**1,541,031**
West	0	3,851,559	4,419,523	2,001,506	0	**10,272,587**
Total	**6,222,109**	**7,583,077**	**8,553,113**	**25,048,516**	**8,437,792**	**55,844,607**
Percentage	**11%**	**14%**	**15%**	**45%**	**15%**	

Christchurch's drinking water source is protected by rules in the Canterbury Land and Water Regional Plan (LWRP)[8], which controls land-use to minimise the risk of contamination. Much of the recharge area for Christchurch's aquifers south of the Waimakariri River is used for very low intensity stock grazing and recreational parks.

The groundwater is of good natural quality and has consistently complied with secure bore water criterion 3 (absence of E. coli), discussed further in section 2.8. Until 22 December 2017 – with the exception of 22 shallow wells in unconfined aquifers in the Northwest zone – it met the provisionally secure bore water status of the DWSNZ, which meant that no treatment was required to comply with DWSNZ. In the more risk averse post-Havelock North environment, the expert well head security assessment of bores in late 2017 found that the well heads assessed were not secure, and so provisionally secure status was lost.

[7] Data from 'Report on "Secure" Status of Christchurch City Council Water Supply Wells', PDP, September 2005.

[8] https://www.ECan.govt.nz/your-region/plans-strategies-and-bylaws/canterbury-land-and-water-regional-plan/canterbury-land-and-water-regional-plan/

2.3.3 Site-specific investigations

Over the years the Council has commissioned a significant number of site investigations which contribute to the improved understanding of site specific risks. Investigations include desktop based contamination pre-screening reports, preliminary site investigations and detailed site investigations for sites where further information was deemed necessary. In addition to contamination assessments, mapping of wastewater defects near water supply wells was undertaken. The Council has also commissioned city-wide groundwater modelling, described in section 2.3.7, and groundwater age dating, summarised in section 2.3.8.

The investigations have been summarised in TRIM 20/1427862 which provides a detailed breakdown of investigations undertaken at each pump station site and an overall assessment of the contamination risk to shallow groundwater and the contamination risk to the deeper aquifer(s) used for public water supply. While the contamination risk to shallow groundwater ranges between low and moderate-high, the contamination risk to the deeper aquifers used for public water supply has been assessed as low.

2.3.4 Assessment of the potential effects of catchment land-use on the wells

The Technical Guidelines for Drinking Water Source Protection Zones[9] (PDP, 2018) outlines the method for assessing contamination risks to drinking water sources by assessing:

- the source of contamination
- the receptor that may be adversely affected by the contamination
- the pathway that allows the contaminant to reach the receptor.

For a risk to be present, all three components – source, pathway and receptor – must be present. The risk can be managed by eliminating one of these three components or to make the pathway between the source of contamination and receptor contain sufficient barriers so that the risk of an adverse effect on the drinking water supply is acceptable.

In the Christchurch/Lyttelton context, the receptor that may be adversely affected by contamination are the water supply wells. The sources of contamination that are present within the wider recharge area could introduce different types of contaminants to the well are described in TRIM 20/1427862 and are summarised in Table 2-5.

Table 2-5: Summary of potential contamination sources in the water supply catchment

Contamination Source	Types of Contaminants
Low intensity farming (outskirts of Christchurch)	Bacteria, Protozoa, Agrichemicals, Nitrate
Discharges – animal effluent	Bacteria, Protozoa, Nitrate
Reticulated wastewater network	Bacteria, Protozoa, Viruses
Residential/commercial/industrial on-site stormwater disposal	Bacteria, Chemicals
Historic landfills and contaminated sites	Bacteria, Chemicals
Roading infrastructure	Chemicals

[9] PDP, 2018: Technical Guidelines for Drinking Water Source Protection Zones: https://www.mfe.govt.nz/publications/fresh-water/technical-guidelines-drinking-water-source-protection-zones

2.3.5 Contaminant pathway and attenuation

According to the PDP guideline an effective barrier in the pathway between the contamination source and the receptor is attenuation of the contaminant between the source of contamination and the well.

Longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of:

- Dispersion and dilution
- Filtration and adsorption
- Bio-degradation and chemical transformation
- Pathogen die-off.

Pathogenic water-borne viruses are associated with human and animal effluent. Viruses are smaller than bacteria and protozoa and therefore more difficult to remove through natural filtration in the soil layer and vadose zone. Therefore it can be concluded that if appropriate virus attenuation is achieved then appropriate bacteria and protozoa attenuation is achieved as well.

Viruses can survive sewage treatment processes and be transported in water moving through the soil and the unsaturated material beneath and then laterally with groundwater flow. The concentration of viruses is reduced at each stage of the transportation process.

The Guidelines for Separation Distances Based on Virus Transport Between On-site Domestic Wastewater Systems and Wells[10] (ESR, 2010) provides a methodology for estimating the reduction in virus concentrations in each of the four stages of the virus transport which are illustrated in Figure 2-11. Reduction is dependent on separation distances between a land treatment area (contaminant source) and drinking water sources, and the soil conditions. While there are few domestic wastewater systems in the urban Christchurch and Lyttelton areas the same concept could apply to wastewater originating from broken wastewater pipes.

[10]ESR, 2010: Guidelines for separation distances based on virus transport between on-site domestic wastewater systems and wells: https://www.envirolink.govt.nz/assets/Envirolink/Guidelines-for-separation-distances-based-on-virus-transport-.pdf

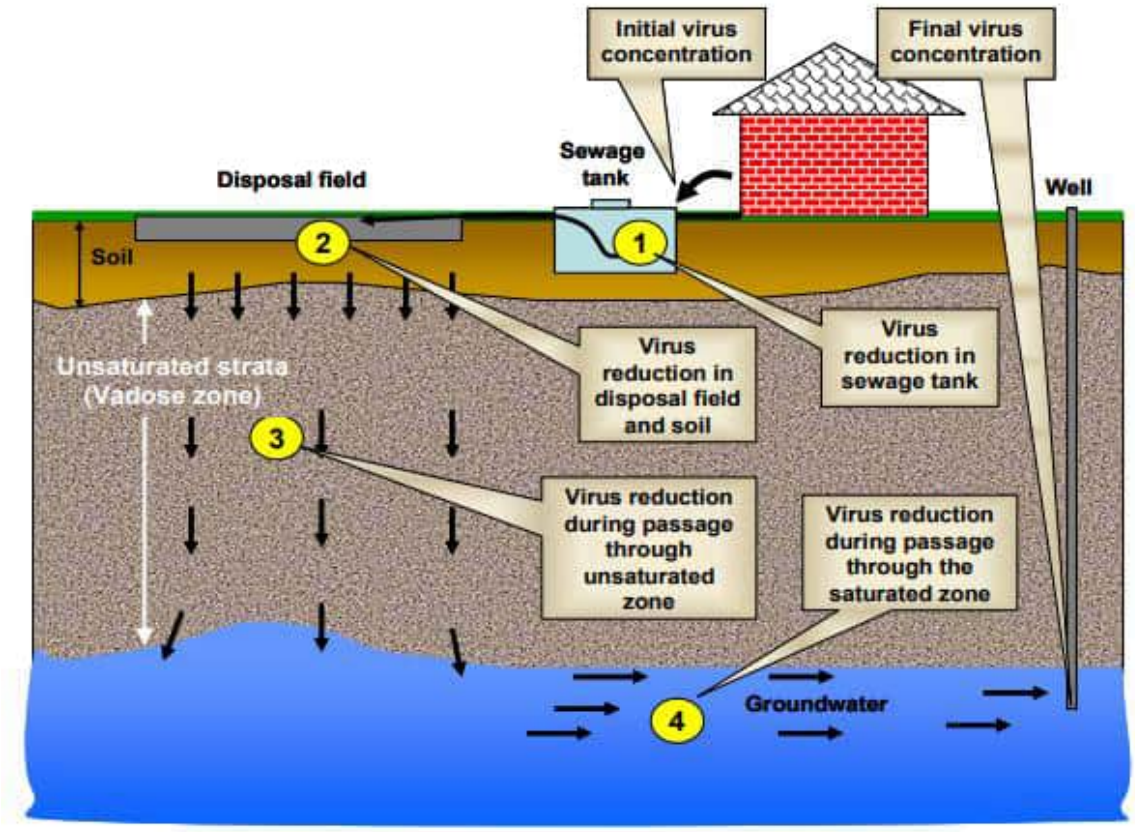


Figure 2-11: Components of virus removal between the sewage tank and abstraction point (ESR, 2010)

Separation distance to nearest wastewater discharge is based on a 2019 report which mapped wastewater pipe defects – established by CCTV inspections – in the vicinity of water supply pump stations and wells.

Table 2-6 summarises the parameters used to estimate virus transport and log reduction. Two wells are presented as examples: a non-artesian shallow aquifer 1 well (Montreal well 2) representing the worst case scenario, and the shallowest aquifer 2 well (Dunbars well 3) which will be a representation of the most vulnerable well when all aquifer 1 wells have been replaced (except Main Pumps which have UV treatment). The bore logs shows a clay layer between 0.3m and 3m depth which potentially provides additional protection. However, the extent of these confining layers over the source protection zone is not known and therefore has not been considered in the assessment. Separation distance to nearest wastewater discharge is based on a 2019 report which mapped wastewater pipe defects – established by CCTV inspections – in the vicinity of water supply pump stations and wells.

Table 2-6: Parameters Used to Estimate Viral Log Reduction

Parameter	Montreal well 2 (M35/2325, 32m)	Dunbars well 3 (M36/4333, 53m)	Data Source
Soil material	Kaiapoi*ƒ* mottled-weathered fluvial recent soil	Kaiapoi*ƒ* mottled-weathered fluvial recent soil	• S-Map (Manaaki Whenua – Landcare Research)
Soil depth	1.2 m	No information	Well bore log
Aquifer type	Non-flowing artesian	Non-flowing artesian	Well bore log
Vadose zone material	Clay	Clay	Well bore log

Parameter	Montreal well 2 (M35/2325, 32m)	Dunbars well 3 (M36/4333, 53m)	Data Source
Vadose zone thickness	1.1 m	1.3 m	ECan data / well bore log
Saturated zone material	Gravel, sand and clay	Gravel, pug	Well bore log
Depth to first groundwater	1.1 m	1.3 m	ECan data / well bore log
Separation distance to nearest up-gradient medium or high risk wastewater pipe	100 m	180 m	Beca Wastewater Pipeline Assessment (TRIM 20/21388)

Figure 2-12 from the ESR guideline provides the estimated virus log removal in relation to the separation distance to the nearest effluent disposal system for a gravel aquifer with gravel vadose zone. This table shows that:

For Montreal well 2, with a 100 m separation distance to the nearest up-gradient medium or high risk wastewater pipe, virus removal in the vadose and saturated zone can be expected to be at least 1.9 log.

For Dunbars well 3, with a 180 m separation distance to the nearest up-gradient medium or high risk wastewater pipe, virus removal in the vadose and saturated zone can be expected to be at least 2.2 log.

The above assessment represents the minimum expected log removal as it does not take into account any additional attenuation and protection due to confining layers which are present in the Christchurch/West Melton aquifer system. Protection due to confining layers is more accurately assessed by groundwater modelling which is discussed in section 0.

Log Reduction Table 1 **Vadose zone: Gravel - Saturated zone: Gravel**

Vadose Zone Thickness (m)	Separation Distance (m)													
	40	50	60	80	100	150	200	250	300	400	500	600	800	1000
1	1.5	1.6	1.6	1.7	1.9	2.0	2.3	2.5	2.6	2.9	3.2	3.4	3.8	4.2
2	1.7	1.8	1.8	2.0	2.1	2.3	2.6	2.7	2.9	3.2	3.5	3.7	4.1	4.5
3	1.9	2.0	2.1	2.2	2.3	2.5	2.9	3.0	3.2	3.5	3.7	4.0	4.4	4.8
4	2.1	2.2	2.2	2.4	2.5	2.7	3.1	3.2	3.4	3.7	4.0	4.2	4.7	5.1
5	2.3	2.4	2.4	2.6	2.7	2.9	3.3	3.4	3.6	3.9	4.2	4.4	4.9	5.4
6	2.4	2.5	2.6	2.8	2.9	3.1	3.5	3.6	3.8	4.1	4.5	4.7	5.2	5.6
7	2.6	2.7	2.8	2.9	3.1	3.3	3.6	3.8	4.0	4.3	4.6	4.8	5.3	5.8
8	2.8	2.8	2.9	3.0	3.2	3.4	3.8	4.0	4.2	4.5	4.8	5.0	5.6	6.1
9	2.9	3.0	3.0	3.2	3.4	3.7	4.0	4.1	4.3	4.7	5.0	5.2	5.7	6.3
10	3.1	3.2	3.2	3.4	3.5	3.8	4.2	4.3	4.5	4.8	5.2	5.5	6.0	6.4
15	3.7	3.9	3.9	4.0	4.2	4.5	5.0	5.1	5.3	5.7	6.0	6.2	6.9	7.4
20	4.5	4.6	4.6	4.8	4.9	5.3	5.7	5.9	6.1	6.6	6.9	7.2	7.8	8.3
25	5.2	5.3	5.3	5.5	5.7	5.9	6.5	6.7	7.0	7.3	7.7	8.1	8.6	9.3
30	5.9	5.9	6.1	6.3	6.4	6.8	7.3	7.4	7.8	8.1	8.5	8.8	9.6	10.1
35	6.6	6.7	6.8	6.9	7.2	7.6	8.1	8.3	8.6	9.1	9.4	9.7	10.5	11.0
40	7.4	7.6	7.7	7.9	8.0	8.4	8.9	9.0	9.4	9.9	10.4	10.7	11.3	12.1
45	8.2	8.4	8.5	8.7	8.9	9.2	9.8	10.0	10.3	10.8	11.3	11.6	12.3	12.9
50	9.1	9.1	9.2	9.4	9.6	10.1	10.7	10.8	11.1	11.6	12.1	12.4	13.0	14.0
55	9.9	10.0	10.1	10.4	10.4	10.8	11.4	11.7	11.9	12.4	12.9	13.3	14.2	14.7
60	10.7	10.9	10.8	11.0	11.2	11.6	12.3	12.4	12.9	13.3	13.5	14.5	15.0	15.7
65	11.5	11.7	11.6	11.9	12.2	12.5	13.1	13.4	13.7	14.1	14.6	15.2	16.1	16.9
70	12.4	12.4	12.5	12.8	13.0	13.3	14.2	14.3	14.6	15.2	15.6	16.0	17.0	17.8
75	13.1	13.3	13.4	13.5	13.8	14.2	14.9	15.1	15.4	15.9	16.7	16.6	17.4	18.5
80	13.9	14.1	14.1	14.2	14.5	14.9	15.7	15.9	16.3	16.6	17.2	17.5	18.5	19.3

Figure 2-12: Virus Log Removal Based on Separation Distance

2.3.6 Main Pumps PS Sources and Protozoa Risk

At the Main Pumps pump station, there are six source wells which all access aquifer 1 via wells of less than 30 meters in depth (summarised in Table 2.7). The Draft Drinking Water Quality Assurance Rules (October 2021) list in section 10.8.1 the various classes and required protozoa treatment levels for each. Wells without a sanitary bore head required a minimum protozoa treatment barrier of 4 logs. This may be reduced to 3-log if the source water risk management plan for the supply provides evidence that the source water has a low risk of protozoa contamination. The discussions in sections 2.3.4 and 2.3.5 above

indicate that sources of protozoa are unlikely in the residential/commercial catchment. Between August 2018 and July 2019, twenty eight samples were taken from Main Pumps sources and tested for giardia. Results confirmed that under the Drinking-water Standards for New Zealand that three log credit treatment was required, UV treatment has been installed at Main Pumps since late 2019.

Table 2.7: Main Pumps well information

Well No	Well Name	ECan well ID	Depth (m)	Aquifer	Year drilled	Wellhead construction	Consented maximum weekly volume by aquifer (m^3)	Max tested yield	Non Artesian or Artesian	Last wellhead security assessment	Wellhead Secure (yes/no)
Well-01	Main Pumps Stn Well-01	M36/4591	29	1	1993	Below ground	212,688	80 L/s	Non-Artesian	15/834399	No
Well-02	Main Pumps Stn Well-02	M36/2828	29	1	1984	Below ground		68 L/s	Non-Artesian		No
Well-03	Main Pumps Stn Well-03	M36/1356	28	1	1924	Above ground		No info	Non-Artesian		No
Well-04	Main Pumps Stn Well-04	M36/1363	29	1	1966	Below ground		159 L/s	Non-Artesian		No
Well-05	Main Pumps Stn Well-05	M36/1195	29	1	1973	Below ground		116 L/s	Non-Artesian		No
Well-06	Main Pumps Stn Well-06	M36/0985	29	1	1975	Below ground		49 L/s	Non-Artesian		No

2.3.7 Private wells and groundwater modelling

The Council works with Environment Canterbury to identify private bores that may provide pathways to contamination if not adequately decommissioned. A summary (Environment Canterbury) of private bores that are assumed to be in use, including their function and depth, is presented in Figure 2-13. A GIS app has been produced that allows a visual identification and assessment of private bores in the vicinity of Council water supply bores. An example map is provided in Figure 2-14.

		Well Depth (m)							
		<20	20<= x <50	50<= x < 100	100<= x < 140	140<= x <180	180<=		
Wells By Function	Well Function	Shallow Unconfined	Aquifer 1	Aquifer 2	Aquifer 3	Aquifer 4	Aquifer 5	Unknown	Grand Total
22.8%	Water Level Observation	1,342	217	23	9	2	-	37	**1,630**
16.6%	Geotechnical Investigation	846	308	4	2	3	-	28	**1,191**
12.0%	Domestic Supply	247	384	72	12	-	-	143	**858**
8.8%	Irrigation	186	370	37	10	-	1	23	**627**
3.8%	Domestic and Stockwater	50	174	30	1	-	1	13	**269**
3.5%	Commercial / Industrial	50	126	40	17	7	-	14	**254**
3.4%	Sewer Flushing	14	77	60	6	-	-	86	**243**
29.1%	Other	473	576	462	159	33	4	378	**2,085**
100.0%	**Grand Total**	**3,208**	**2,232**	**728**	**216**	**45**	**6**	**722**	**7,157**
	Wells By Aquifer	44.8%	31.2%	10.2%	3.0%	0.6%	0.1%	10.1%	100.0%

Figure 2-13: Private wells assumed to be in use

Groundwater modelling is currently being undertaken by Aqualinc to determine whether the source water for each well complies with DWSNZ secure bore water criterion 1 (absence of young water). The methodology has been developed with input from a technical panel of modelling experts. Several modelling scenarios with particle backward tracking are tested on two pump station sites: Effingham pump station, representing the eastern parts of Christchurch with artesian wells and thick confining layers; and Denton pump station, representing the western parts of Christchurch with non-artesian wells and non-homogenous confining layers:

Baseline model representing the current best prediction of actual groundwater conditions based on the Weir (2018) model, with the modification that the higher 90 percentile flow rates are used rather than the long-term average flow rates which results in larger drawdowns in the pumped layers which influences the vertical gradients between those layers and the surface.

Locally punctured aquitards which may arise due to:

- Fractures in the aquitard due to (say) seismic activity
- Old lamp posts, building piles, rotting tree roots, extracted bores, etc.
- Old river incisions
- Areas of naturally thinning aquitards at a local scale that are too small to identify in bore logs.

Leaky bores that could transmit water rapidly from the uppermost saturated layer through to the pumped layer due to:

- Unsealed bores
- Multi-screened bores that hydraulically span shallow and deeper layers
- Gravel pits, building basements and other surface excavations.

Reduced coastal confining layer extent with the inland extent of aquitards reduced by 2 km (i.e. moved closer to the coast).

Modelling of wells at Denton (unconfined) and Effingham (confined) pump stations confirmed that no particles reach the bores within one year of entering shallow groundwater for any of these scenarios. These results provide confirmation that private bores near Council water supply wells are unlikely to provide a pathway for contamination and are therefore unlikely to affect water quality.

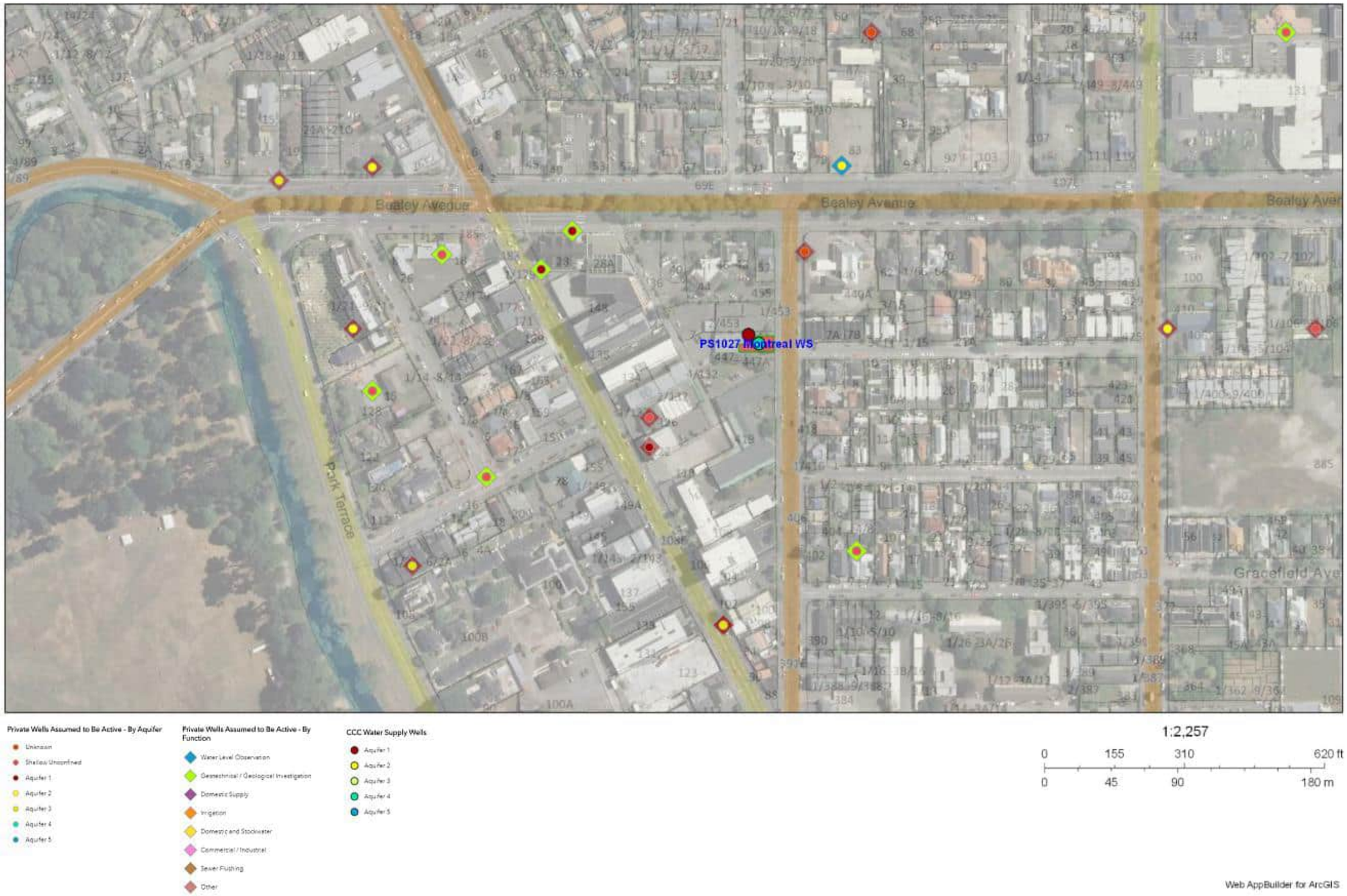


Figure 2-14: Example Map of Private Bores Near CCC Water Supply Wells

2.3.8 Groundwater residence time

Considerable work has also been undertaken in ground water residence time: both as part of the demonstration of the previous secure source criteria that Christchurch source waters previously held and also some collaborative studies with other agencies such as ECan and Aqualinc. More detail of this work is to be found in Volume C – Source Risk Management Plan (TRIM 22/438290).

2.3.9 Conclusion

Sections 2.1 to 2.3.8 provide information that the risk of contamination by pathogenic organisms is unlikely. This is evidenced by groundwater age dating and groundwater modelling which has been examined across the entire city. The estimated viral log reduction presented in section 2.3.4 provides further assurance that the groundwater used for public water supply is protected from contamination.

2.4 Pump stations

The Christchurch City water supply has 50 primary pump stations to extract the water from wells and 41 secondary stations, which boost pressure at critical points, mostly lift stations to supply water to properties on the hills and to fill reservoirs.

Lyttelton Harbour Basin supply is connected to the Christchurch Central/Ferrymead zone via two booster stations, the Scruttons booster station and the Ferrymead booster station, built in 2011.

In Christchurch City, each zone is fed by primary pump stations that pump from one or more wells. These stations are distributed throughout the city, providing efficient delivery of water at a relatively even pressure within each zone. As the pressure in the system falls and rises, pumps are switched on and off by a combination of automatic and manual controls via the central control room, staffed 24 hours a day and 7 days a week. The pressure in the water mains gently fluctuates throughout the day depending on demand.

Approximately 50% of the primary pump stations have a standby diesel generator in case of power failure. Riccarton, Northwest, Parklands and Brooklands/Kainga rely solely on suction tanks and diesel-powered pumps and generators for emergency supply, as they don't have hill reservoirs for storage. These stations also have sufficient pumping capacity to meet instantaneous peaks. Zones that have the Port Hills immediately to the south (Central, Woolston, Rocky Point and West) have their pressure controlled by the levels of the bulk-storage reservoirs on the hills that provide for emergencies and assist in meeting peak demand.

Secondary pump stations pump water to higher levels, usually to a reservoir on the hills, and rely on reservoir storage. They do not have standby generators although there is a mobile diesel powered pump available.

Pumping capacity at all sites is adequate to meet average and peak instantaneous demands, where no storage is provided, and average and peak daily demands, where bulk storage is available.

Figure 2-15 lists all primary pump stations by pressure zone and provides some well information. A more comprehensive list is saved in TRIM 19/1022400.

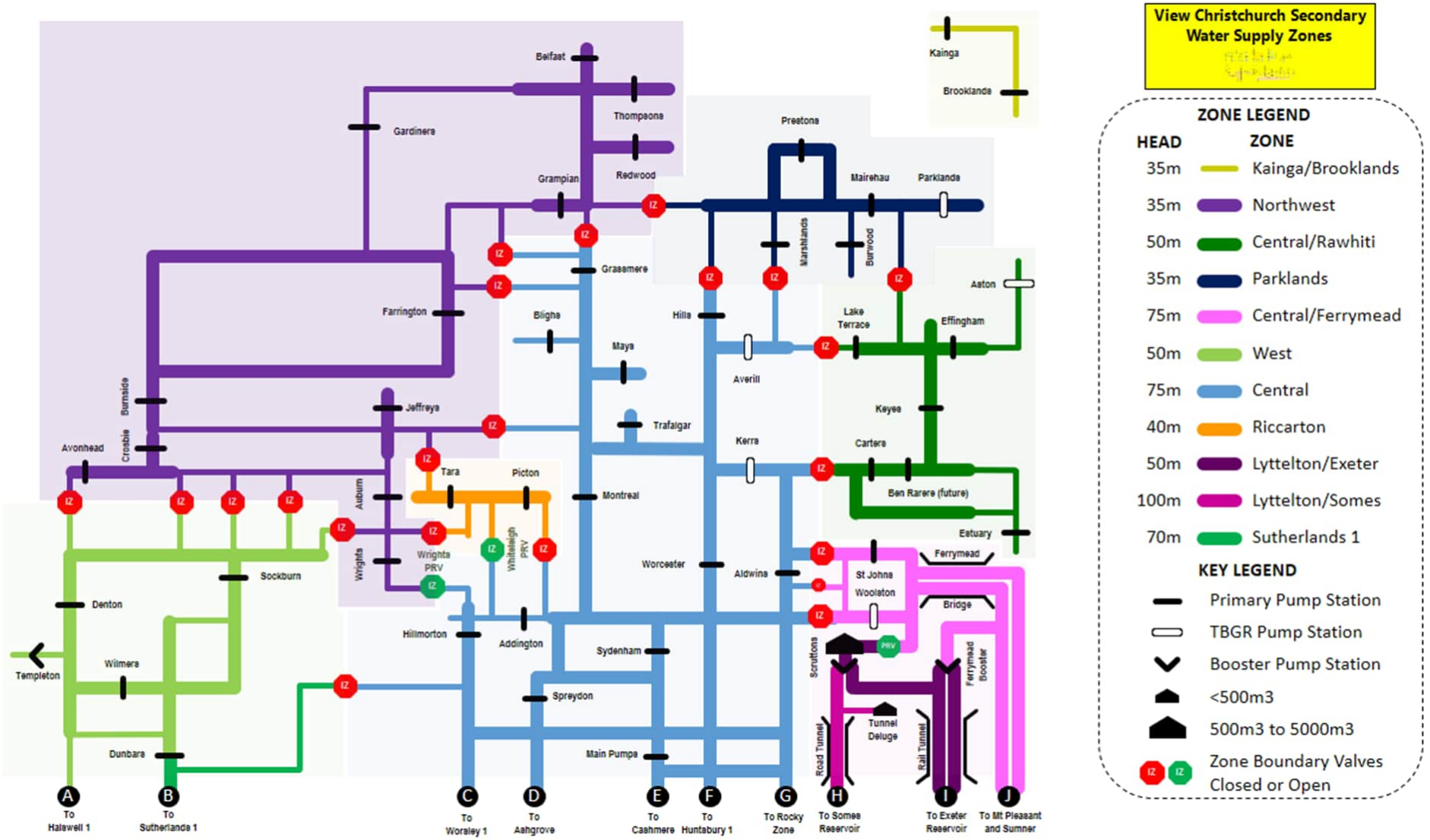


Figure 2-15: Primary pump stations by pressure zones

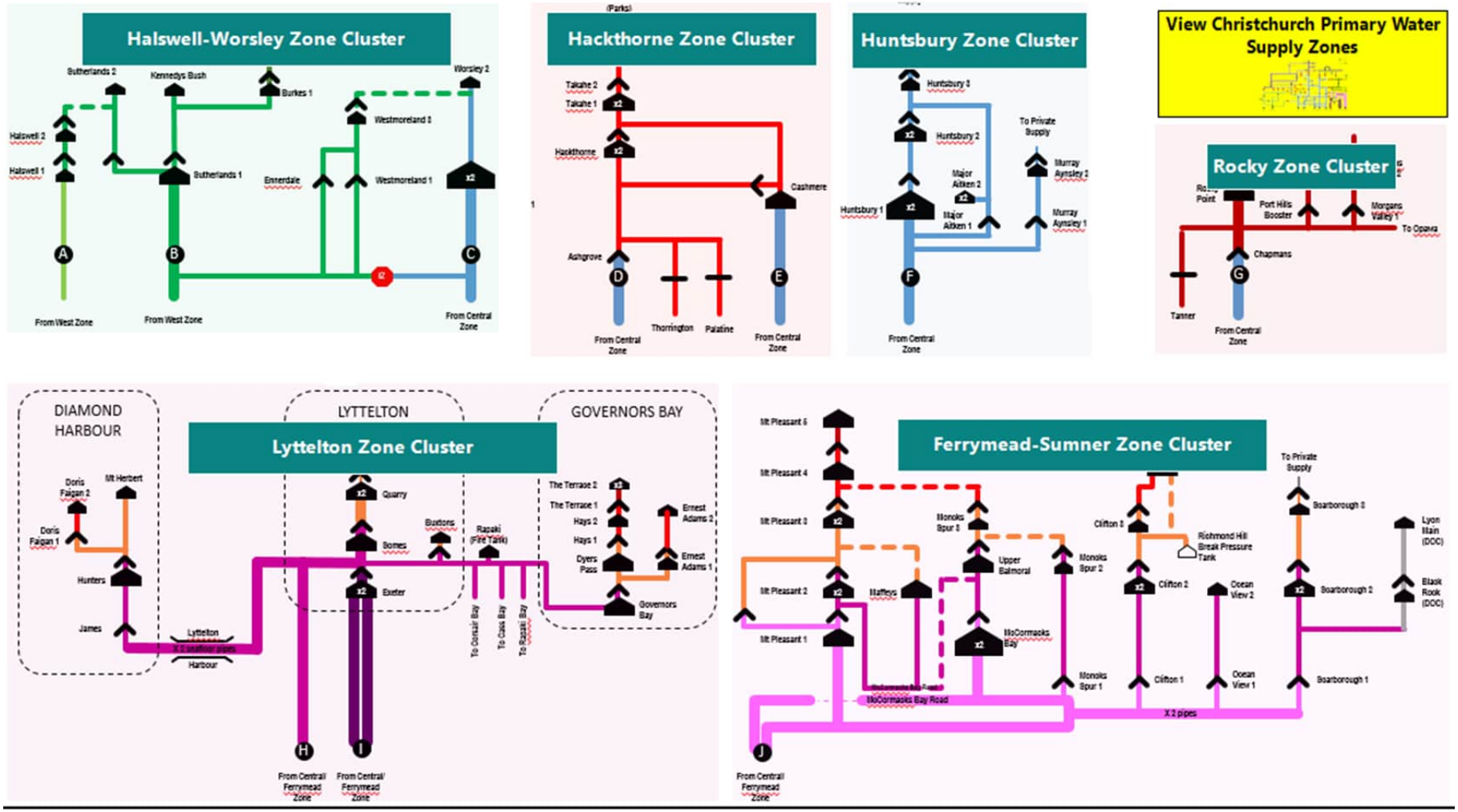


Figure 2-16: Secondary Water Supply zones

Water treatment

2.4.1 Ultraviolet treatment

An ultraviolet (UV) treatment plant was installed and commissioned at Main Pumps station in 2019. The site takes water from six Aquifer 1 wells. While age dating, undertaken in 2017, found that the water is more than one year old and therefore complies with DWSNZ bore water security criterion 1, the Council decided to install UV disinfection at Main Pumps in late 2019 as an additional barrier. This is because Main Pumps station is a large and critical pump station and because of its location at the foot of the Port Hills where there are no deeper aquifers at the site. The UV treatment provides 3-log protozoa removal and delivers a minimum UV dose of 40 mJ/cm^2 at a flow rate of 370 L/s through each of the two reactors which are installed as a duty/standby arrangement. The UV treatment system is monitored in accordance with DWSNZ requirements. Relevant documents are listed in TRIM 20/327732.

2.4.2 Temporary chlorination

Between March and May 2018, temporary chlorination was introduced at primary pump stations to address the risk of contamination via an insecure bore. This was in response to well heads not being signed off as secure and the consequential loss of secure bore water status under the current DWSNZ. Hypochlorite is dosed on the discharge line from the pump station.

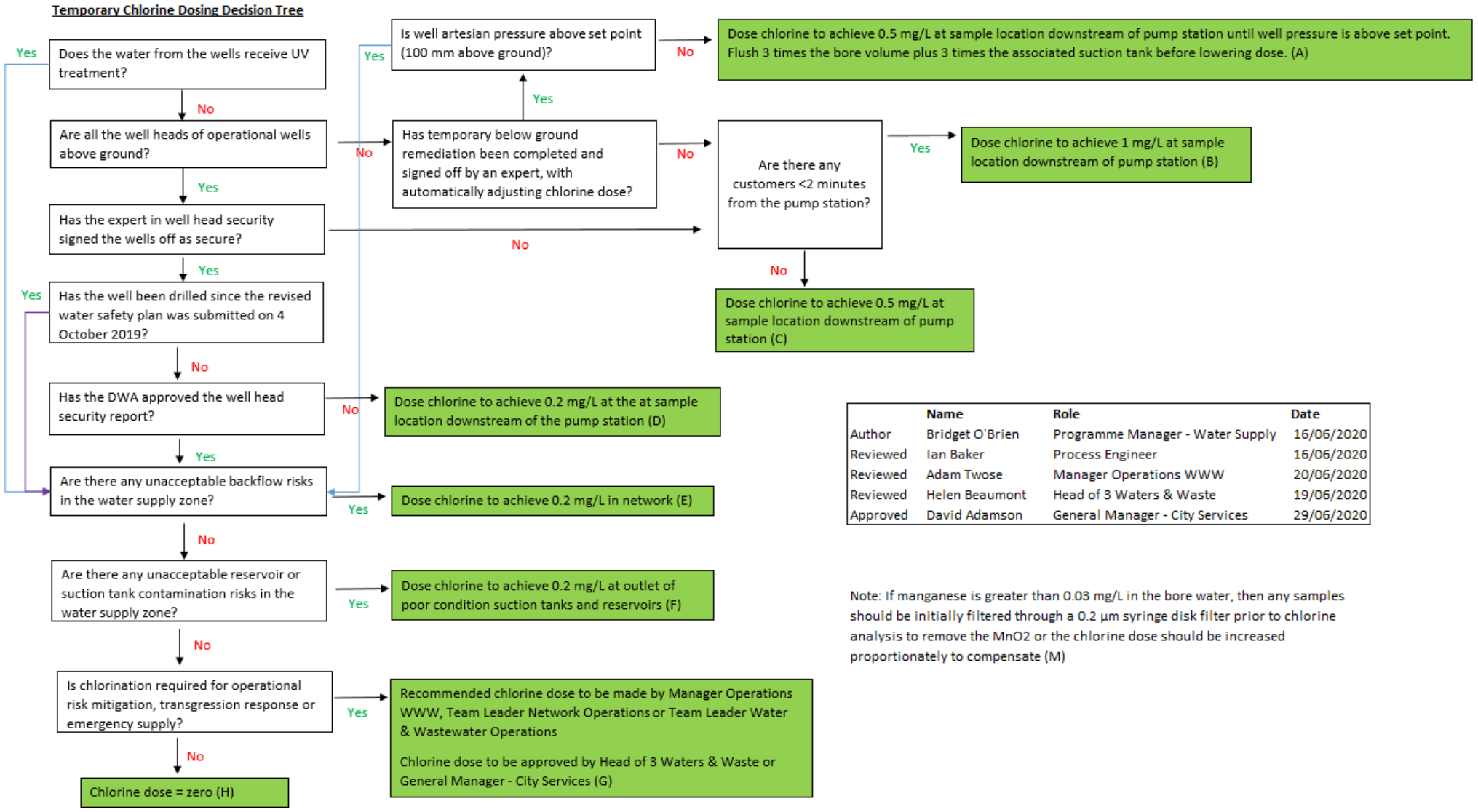
The chlorine dose is expressed as a CT value – the product of the concentration of chlorine (mg/l) and the contact time (minutes) with the water. Initially this dose was at a level of 1.0 milligram per litre (mg/L) after a one minute contact time (ct of 1 mg/L.min), on the advice of an independent expert. Upon review with the expert, a dose of 0.5 mg/L was agreed where the first consumer was at least 2 minutes away from the point of chlorination (this has the same ct). Where the minimum contact time to the first consumer was within 2 minutes of the pump station as shown by modelling, work was done on the local pipework to increase the time to 2 minutes, where possible.

When temporary chlorination was being implemented, there were four pump stations where all wells had been drilled since the earthquakes and had above ground wellheads that met DWSNZ Criterion 2 for bore water security (Estuary, Keyes, Gardiners and Prestons). Temporary chlorination was therefore not implemented at these pump stations.

Since implementing temporary chlorination, Council staff have varied the chlorine dosage according to the progress of the wellhead remediation works and an assessment of risk at each pump station and water supply zone. The decision making rationale for chlorine dosing at each pump station is set out in TRIM 20/342293 and is shown in Figure 2-17.

On 13 December 2020, 19% of the water delivered to the network had no chlorine treatment, 71% was dosed at 0.2 mg/L and 10% dosed at 0.5 to 1 mg/L. The chlorination status of each pump station and the status of each well is shown on a dynamic map on the Council website[11].

[11] https://ccc.govt.nz/services/water-and-drainage/water-supply/water-chlorination/



	Name	Role	Date
Author	Bridget O'Brien	Programme Manager - Water Supply	16/06/2020
Reviewed	Ian Baker	Process Engineer	16/06/2020
Reviewed	Adam Twose	Manager Operations WWW	20/06/2020
Reviewed	Helen Beaumont	Head of 3 Waters & Waste	19/06/2020
Approved	David Adamson	General Manager - City Services	29/06/2020

Note: If manganese is greater than 0.03 mg/L in the bore water, then any samples should be initially filtered through a 0.2 µm syringe disk filter prior to chlorine analysis to remove the MnO_2 or the chlorine dose should be increased proportionately to compensate (M)

Figure 2-17: Temporary Chlorine Dosing Decision Tree

2.5 SCADA control measures and alarms

Information relating to SCADA Control Measures and Alarms is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

2.6 Distribution system

2.6.1 Supply zones

An interactive map of the Christchurch/Lyttelton water supply network is available on the Network Operations intranet page[12]. The water supply primary zones are shown in Figures 2.17 – 2.20 and the secondary zones are shown in Appendix B. Staff can drill down into individual pump stations and reservoirs to find TRIM links to relevant information about each of them.

Detailed system schematics showing primary pump stations, wells and connecting mains are currently being developed for individual supply zones and some sub-zones. So far, the schematics for Northwest, Ferrymead, Rawhiti and Hackthorne have been finalised. More will be developed and will be available in TRIM: FOLDER09/2246 (Water Supply Systems).

- Figure 2-18 – Northwest: 18/927171
- Figure 2-19:– Ferrymead – Lyttelton Harbour Basin: 19/349006
- Figure 2-20 – Rawhiti: 18/1006613
- Figure 2-21 – Hackthorne: 19/985079

Appendix B provides additional schematics of reservoirs, secondary pump stations and principal connecting mains. These schematics also can be found in TRIM:

- Taylors Mistake to Mt Pleasant: 19/181535
- Murray Aynsley to Worsleys Spur: 19/181549
- Heathcote and Cashmere: 19/181569
- West Zone: 19/181574
- Lyttelton Harbour Basin: 19/181578
- Temporary Emergency / Earthquake Zones: 11/457724 (spreadsheet with valve lists: 18/746334)

The key features of each pressure zone are summarised in Table 2.9 which lists the Christchurch pressure zones with their standard operating pressures, the reservoirs servicing each zone, the approximate population served and the typical annual water consumption in each zone.

Table 2.10 provides a list of high water users, including the type of activity on site and average use. This knowledge is useful in planning for work to be undertaken within the network.

12 http://intranet.ccc.govt.nz/Teams/InfrastructurePlanningRegulatory/3WatersWaste/NetOps/SitePages/Water%20Supply%20Primary%20Zones.aspx

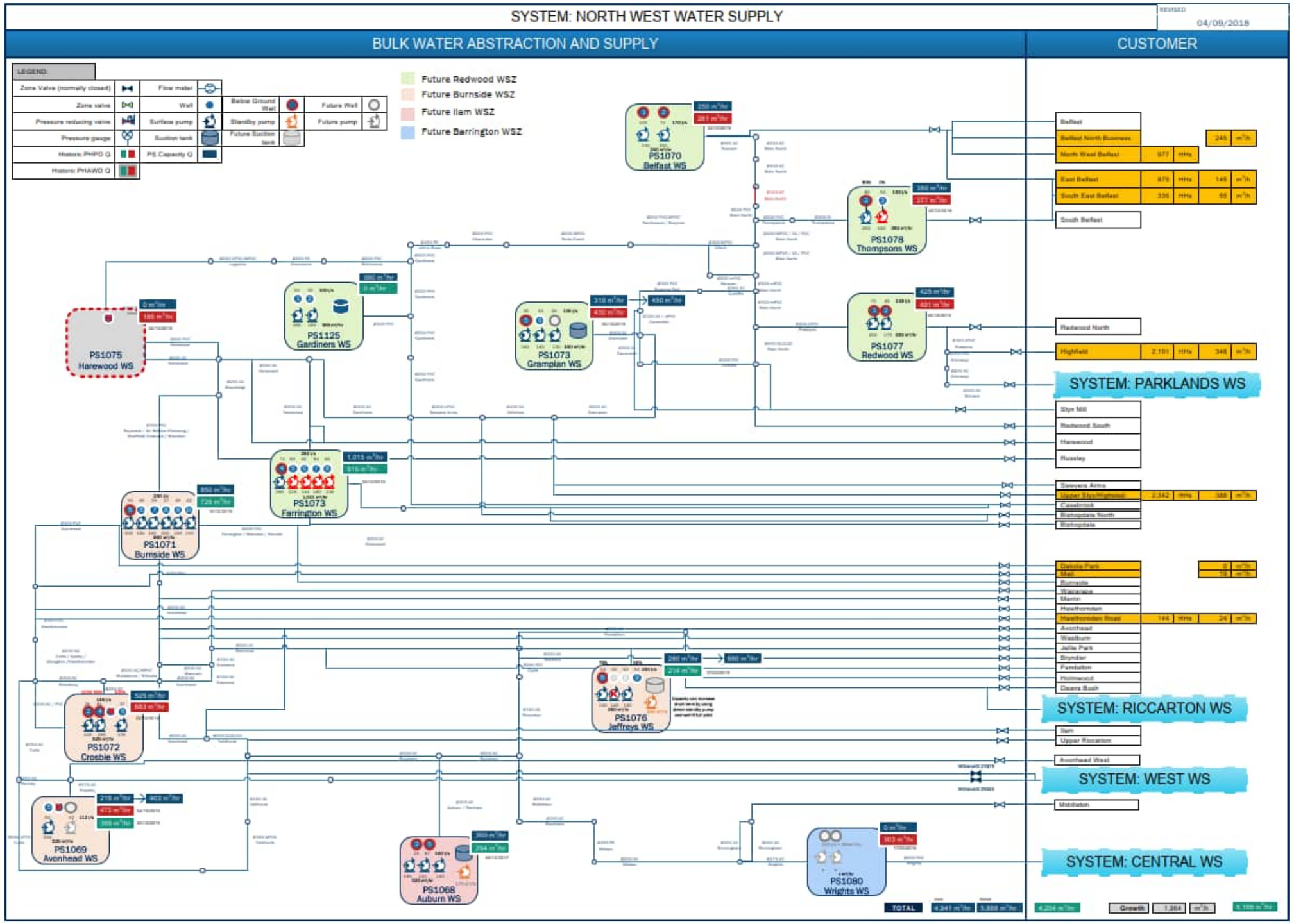


Figure 2-18: System schematic – Northwest

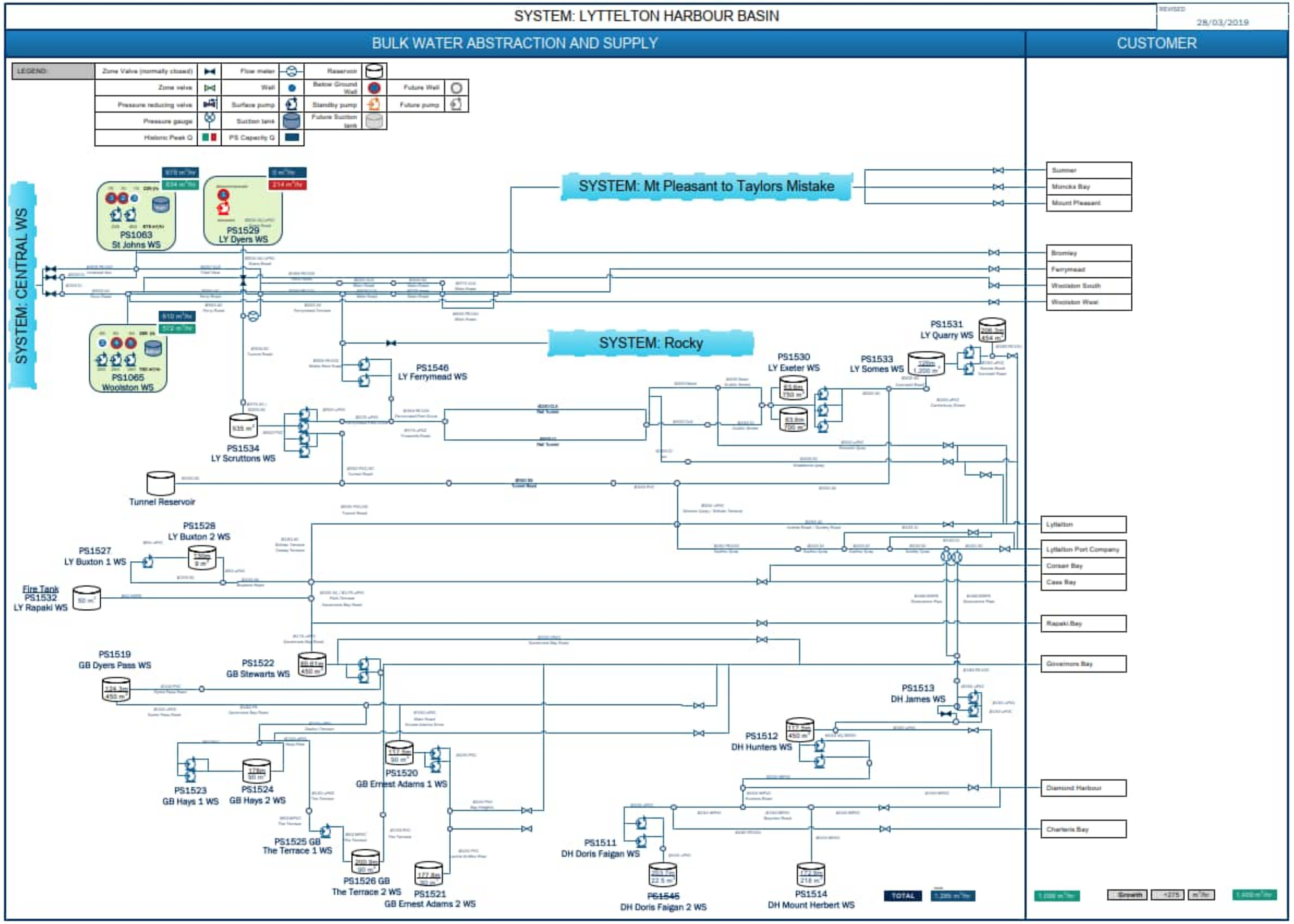


Figure 2-19: System schematic – Ferrymead – Lyttelton Harbour Basin

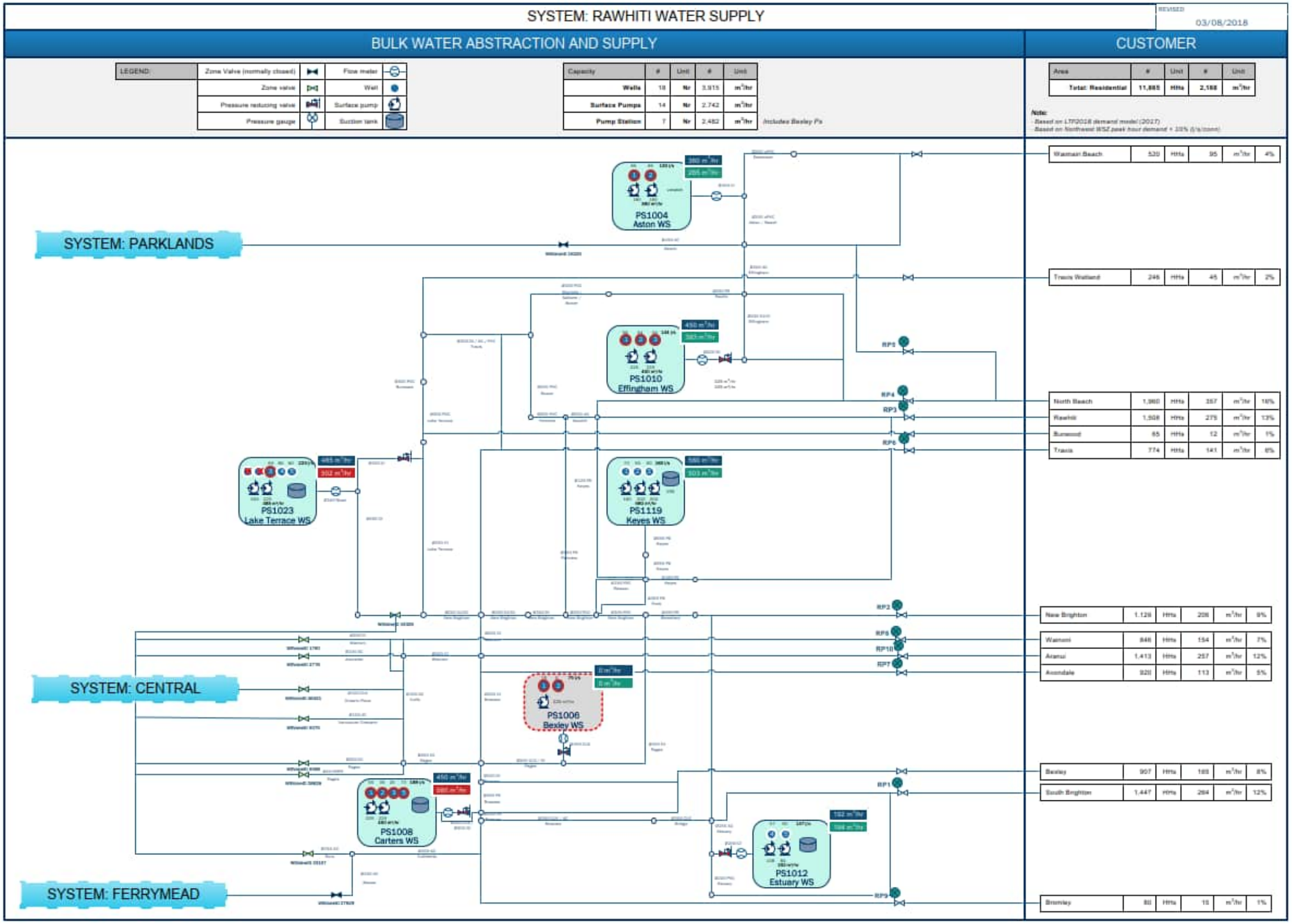


Figure 2-20: System schematic – Rawhiti

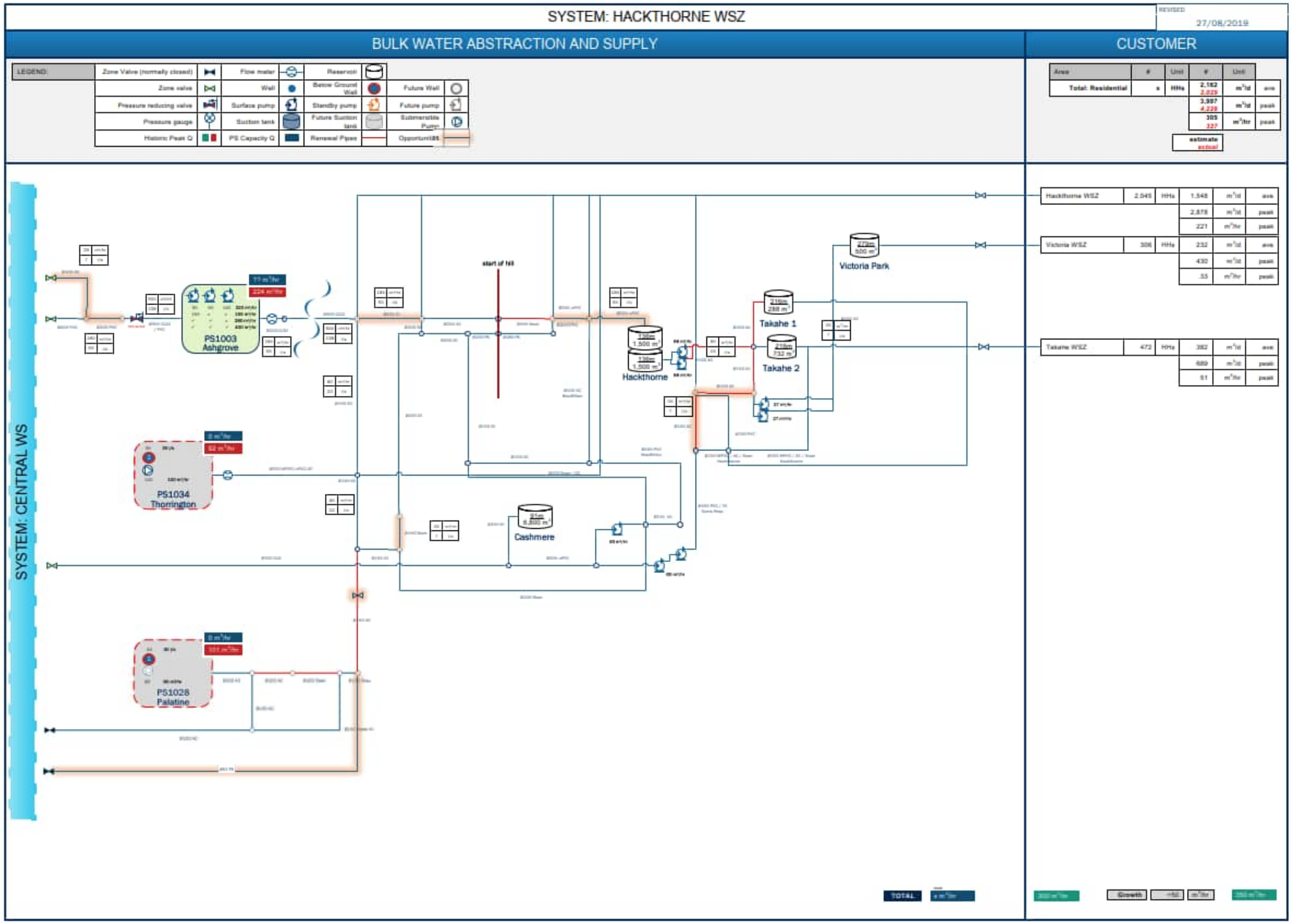


Figure 2-21: System schematic – Hackthorne

Table 2.9: Supply zones, pressure and reservoirs

Water Supply	Zone	Supply Pressure (kPa)	Population Served	Typical Annual Water Consumption (m^3)	Reservoirs	Reservoir Elevation (Christchurch Drainage Board Datum)
Christchurch CHR001	Central	600 – 1,240	158,250	24,700,260	Rocky Point	94m
					Morgans Valley 2	124m
					Murray Aynsley 2	117m
					Huntsbury 1, 2, 3 & 4	91m, 163m, 201m, 257m
					Major Aitken 2	143m
					Cashmere	91m
					Hackthorne	136m
					Takahe	216m
					Victoria	279m
					Worsley 1 & 2	91m, 229m
	West	360 – 660	57,811	10,272,587	Westmorland 3	145m
					Sutherlands 1 & 2	91m, 182m
					Halswell 1 & 2	70m, 122m
					Kennedys Bush	232m
					Burkes Track 1 & 2	209m, 422m
	Ferrymead	600 – 820	16,847	4,321,438	Mt Pleasant 1, 2, 3, 4 & 5	55m, 121m, 205m, 298m, 353m
					Maffeys	121m
					Upper Balmoral	165m
					McCormacks Bay	80m
					Moncks Spur 2 & 3	166m, 226m
					Clifton 2, 3 & 4	133m, 199m, 281m
					Ocean View 2	97m
					Scarborough 2 & 3	149m,214m
	Rawhiti	400 – 550	30,838	3,514,919	-	-
	Parklands	380 – 440	20,139	2,258,651	-	-
	Riccarton	500 – 600	11,771	1,541,031	-	-
	Northwest	310 – 510	86,160	8,963,536	-	-
Brooklands/Kainga BRO012	Brooklands/Kainga	350 – 380	1,629	272,185	-	-
	Lyttelton	250 – 1150	3,273	757,982	Exeter	64m

Water Supply	Zone	Supply Pressure (kPa)	Population Served	Typical Annual Water Consumption (m^3)	Reservoirs	Reservoir Elevation (Christchurch Drainage Board Datum)
Lyttelton LYT001					Somes	126m
					Buxtons 2	130m
					Quarry	206m
	Governors Bay	300 – 800	880	192,947	Stewarts	81m
					Dyers Pass	124m
					Ernest Adams 1 & 2	118m, 178m
					Hayes 2	178m
					The Terrace 2	201m
	Diamond Harbour	200 - 800	1,701	231,540	Hunters	118m
					Mt Herbert	173m
					Doris Faigan 2	204m

Table 2.10: Key high water consumers >150 m³/day

Pressure Zone	Company	Street	Activity	Daily Use (m³)
Central	Windsorcare	Horseshoe Lake Road	Retirement home	151
	Wesley Care	Harewood Road	Retirement home	152
	Ministry of Education	Hagley Avenue	Education	155
	Park Lane Retirement Village Ltd	Whiteleigh Avenue	Retirement home	159
	Aromaunga Baxter Flowers	Bridle Path Road	Wholesale florist	166
	Canterbury District Health Board	Riccarton Avenue	Hospital	177
	Christchurch Top 10 Holiday Park	Meadow Street	Accommodation	189
	Palm Grove Village Ltd	Marshland Road	Retirement home	190
	ARA Institute of Canterbury Ltd	Madras Street	Education	190
	Christchurch City Council	Riccarton Avenue	Park	208
	Christchurch City Council	Domain Terrace	Park	211
	Kainga Ora - Homes and Communities	Fitzgerald Avenue	Social Housing	216
	Southern Cross Hospital	Bealey Avenue	Hospital	290
	St George's Hospital	Leinster Road	Hospital	313
	Northlands Mall	Main North Road	Shopping centre	335
	Ministry of Education / Christchurch City Council	Langdons Road	Education / pool	343
	Winstone Wallboards Ltd	Opawa Road	Building products manufacturing	533
	St Andrews College	Papanui Road	Education	546
	Alsco NZ Ltd	Kingsley Street	Commercial laundry	602
	Christchurch City Council	Hagley Avenue	Park	761
	Pharmazen Ltd	Port Hills Road	Pharmaceutical manufacturing	1,111
	Canterbury District Health Board	Sylvan Street	Hospital	1,701
Ferrymead	Wallace Corporation Ltd	Newtown Street	Tannery	159
	Christchurch City Council	Metro Place	Refuse station	814
Lyttelton	Lyttelton Port Company	Godley Quay	Port	471
Northwest	Expol Ltd	March Place	Building products manufacturing	160
	Bush Inn Mall	Waimairi Road	Shopping centre	216
	Commodore Airport Hotel	Memorial Avenue	Accommodation	293
	Christchurch City Council	Greers Road	Pool	466
	NZ Yarn Ltd	Sheffield Crescent	Wool manufacturing/processing	478
	George Weston Foods NZ Ltd	Wairakei Road	Food manufacturing/processing	503
	University of Canterbury	Ilam Road	Education	509
Parklands	Canterbury District Health Board	Mairehau Road	Hospital	150
Rawhiti	Ministry of Education	Shortland Street	Education	171
	Aroma NZ Ltd	Senior Place	Pharmaceutical manufacturing	270
	Christchurch City Council	Travis Road	Pool	286
	Ministry of Education	Travis Road	Education	366
Riccarton	Ministry of Education	Matai Street East	Education	155
	Westfield Mall	Riccarton Road	Shopping centre	196

Pressure Zone	Company	Street	Activity	Daily Use (m^3)
	Chateau on the Park	Deans Avenue	Hotel	286
West	Hamilton Jet Ltd	Lunns Road	Marine propulsion systems	152
	Racecourse Hotel	Racecourse Road	Accommodation	153
	Christchurch Ready-Mix Concrete Ltd	Branston Street	Concrete manufacturing	156
	Altus NZ Ltd	Pilkington Way	Aluminium manufacturing	173
	Metro Glass Ltd	Halswell Junction Road	Window manufacturing	174
	Opal Kiwi Packaging Ltd	Branston Street	Fiber packaging manufacturing	185
	Ryman Healthcare Ltd	Woodcote Avenue	Retirement home	217
	Tegel Foods Ltd	Produce Place	Food manufacturing/processing	220
	Rubber Developments Ltd	Klondyke Drive	Rubber manufacturing	222
	Skellerup Industries Ltd	Hayton Road	Rubber manufacturing	238
	Dairyworks Ltd	Halswell Junction Road	Food manufacturing/processing	292
	Ministry of Education	Waterloo Road	Education	303
	AW Fraser Ltd	Lunns Road	Metal manufacturing	348
	Christchurch City Council	Halswell Road	Pool	368
	Christchurch City Council	Parkhouse Road	Refuse station	371
	Foodstuffs South Island Ltd	Paradyne Place	Food manufacturing/processing	377
	Americold NZ Ltd	Smarts Road	Cold storage	388
	Humes Ltd	Carmen Road	Concrete manufacturing	464
	Apparelmaster Christchurch	Ballarat Way	Commercial laundry	547
	Hexion NZ Ltd	Waterloo Road	Chemical manufacturing	671
	United Fisheries Ltd	Parkhouse Road	Food manufacturing/processing	693
	Life Technologies New Zealand Ltd	Brixton Street	Science	729
	Christchurch City Council	Wigram Road	A&P showgrounds	759
	Meadow Mushrooms Ltd	Wilmers Road	Food manufacturing/processing	1,346

Source: Quarterly high water consumers and commercial users lists, usage > 150 m^3/day (TRIM 20/1546005)

2.6.2 Storage reservoirs

There are 50 reservoirs at 39 reservoir sites along the Port Hills and 18 reservoirs at 15 reservoir sites in Lyttelton Harbour Basin. There are 25 suction tanks at primary pump stations in Christchurch City with 23 in use (tanks at Averill and Jeffreys pump stations are not in service) (Figure 2-22).

Suction tanks are located at primary pump stations associated with wells in the flat parts of the city and provide for 1 to 3 hour peak flow balancing for reticulation pumps that pump water from the suction tank into the network. They also function as sand settlement devices. Newer tanks are sized to provide both functions.

Reservoirs are located on the hills and provide pressure and diurnal flow balancing by returning water stored at high elevations back into the water network by gravity. Most reservoirs provide at least an average day's storage for the associated pressure zone. In normal operation, pump stations have sufficient capacity to return reservoirs to 100% full during the night of the peak demand day of summer. Reservoir outages for maintenance is planned for lower demand periods.

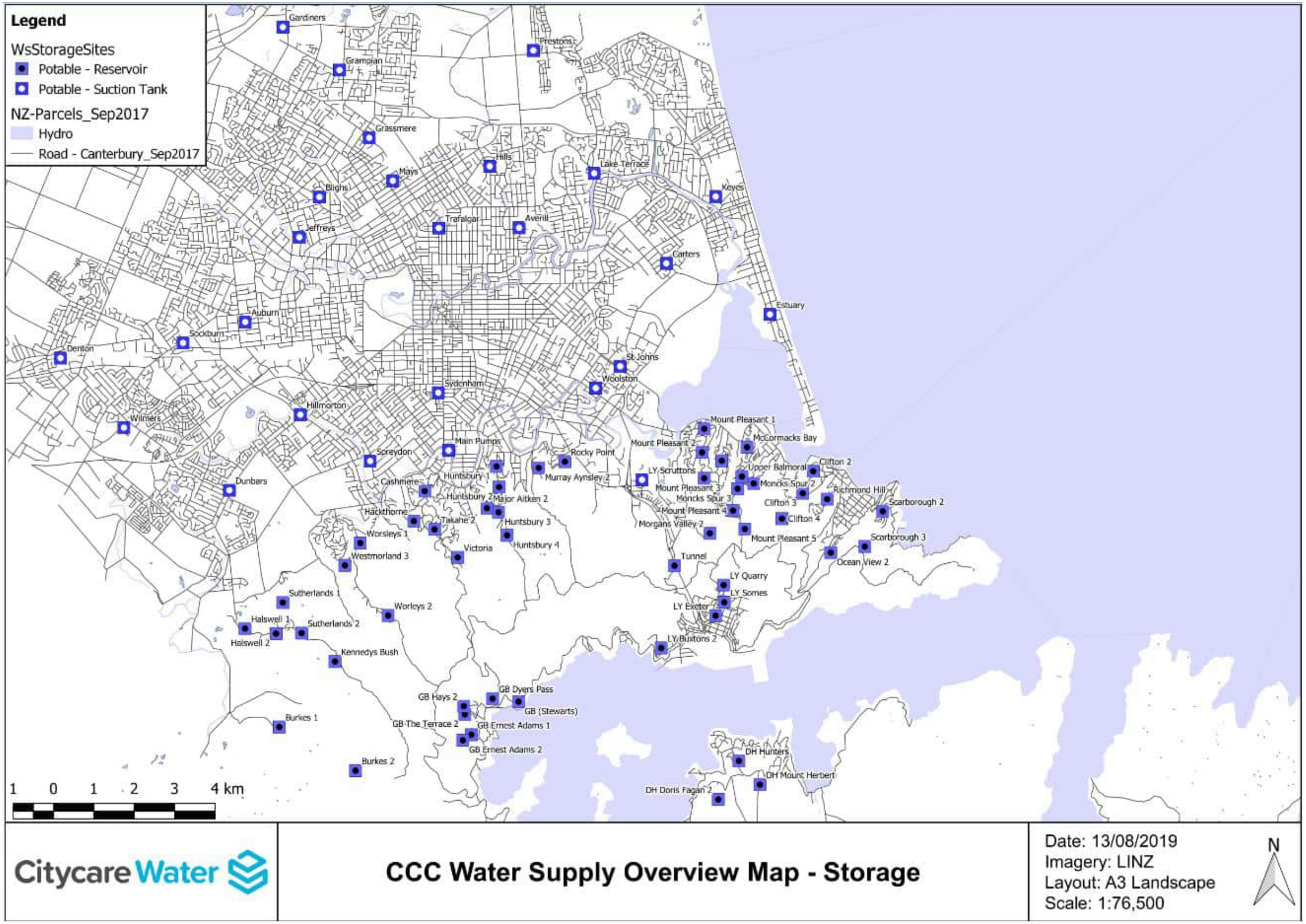


Figure 2-22: CCC Water Supply Storage Reservoirs and Suction Tanks

In some cases there is a series of up to four reservoirs at successively higher elevations to service properties further up the hill, with water pumped up from one reservoir to the next.

Most reservoirs on the hills are located fully above ground. A small number have one wall partially built into the sloping terrain. Examples are provided in Figure 2-23 and Figure 2-24.

Figure 2-23: Example of above-ground reservoir – Worsleys 2 reservoir

Figure 2-24: Example of reservoir partially built into hill – Sutherlands 1 Reservoir

All suction tanks at primary pump stations in the flat part of the city are above ground, except for the tanks at Main Pumps, Grampian and Auburn pump stations.

In 2018 Citycare undertook external condition assessments on reservoirs and suction tanks in the water supply network (refer to TRIM 19/1026197 and 19/1004870 and the summary presented in Appendix B. Results of microbial sampling were reviewed from 2008 and weighting given where occurrences of total coliforms or E.coli had been recorded. Based on these assessments a reservoir and suction tank priority list was prepared for the programming of comprehensive external and internal inspections, and repairs; and the criteria for condition assessments revised (refer to TRIM 20/847952 and 19/1031722).

This revised criteria is referred to as the 'Demonstrably Safe' criteria. It covers infrastructure assessment of up to 30 items, both external and internal, and ranks them against detailed guidelines that grade the conditions from 1 to 5 (1 is typically 'No defects' and 5 represents 'major potential contamination pathway'). The first 20 of the 30 items are deemed to require a condition grade of at least 3 for the tank to be signed off as meeting the demonstrably safe criteria. Reporting against the criteria includes detailing how many items scored grade 4 or 5 and an average weighted grading for each tank, therefore it represents the maximum risk. After this infrastructure assessment is finished, a water quality risk assessment is undertaken considering all preventive measures and the residual risk scored. This procedure ensures that all inherent risks are well managed and the tank can be safely operated without a chlorine residual.

Detailed external and internal condition assessments were carried out on eleven reservoirs and suction tanks in 2020, prioritised because of known poor condition and/or poor bacteriological results. The key findings are summarised in Table 2-7 as an example of the detail and content. Further data is stored in TRIM 20/847952. A further eight prioritised tanks were internally inspected late in the winter of 2021, with

work to address risks and defects undertaken while the tank was out of service if possible. Results from the work are available in the project management folder CP503658-01. Beca consultants were contracted to complete external inspections of all reservoirs and suction tanks during 2021. A master list that holds relevant information for all reservoirs and suction tanks is TRIM21/1706559 . An ambitious programme of internally inspecting up to 30 tanks is planned for 2022.

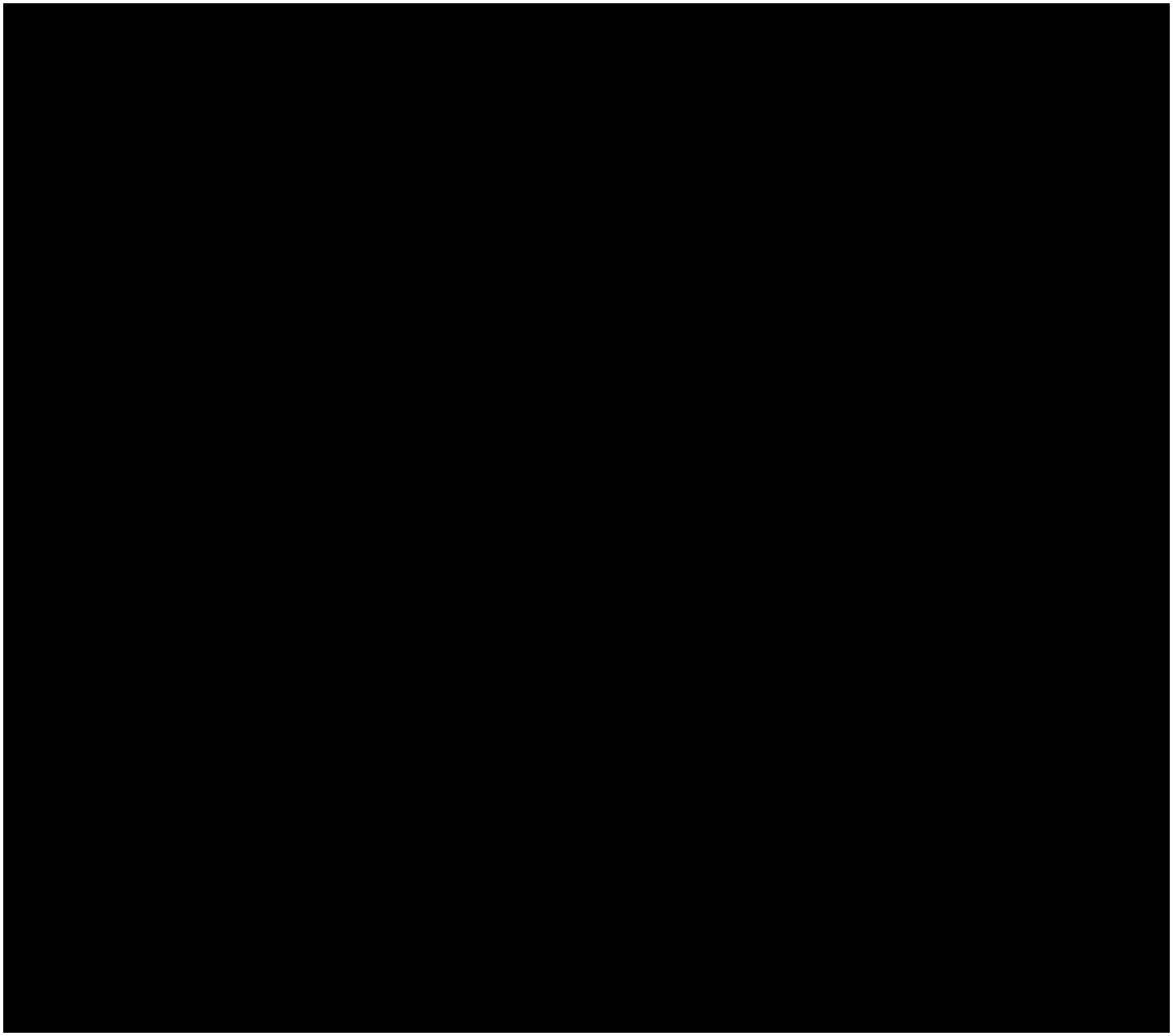
The detailed condition assessments will continue until all reservoirs have been assessed. Several specific projects are currently underway and further remedial work is being scoped by the Three Waters Asset Management Team.

There are several circular reservoirs, with multi segmented roofs, that have a significant length of roof joint known to be susceptible to cracking and pose a risk for rainwater water intrusion. Examples are the suction tanks at Denton and Sockburn which have had water quality transgressions in the past. Some remedial work has taken place and the detailed work is being scoped as part of the wider reservoir and suction tank programme.

The Council's actions with regard to reservoir and suction tank risks are further discussed in Section 3.4.1.

Table 2-7: 2020 Detailed Reservoir Condition Assessment Summary

Reservoir Name	Water Supply Zone	Inspection Date	Report Record Number	Walls Above Ground (all materials)	Walls Partially or Fully Buried Below Ground	Roof	Floor	Internal Lining	Controlled Openings	Penetrations Through Walls / Roof	Pipework Internal (Internal / in tank pipework)	Internal Inspection and Cleaning	Overflow & Vents	Surface Water Contamination	Flooding Risk	Site / Ground Conditions	[redacted]	Pipework External (from wells / to pump station / network)	Structural Integrity	Slope Stability / Geotech	Reservoir Access - External	Reservoir Access - Internal	Reservoir Access - Site
Reservoirs that could supply more than 5,000 people																							
Hackthorne Reservoir 2	Central	5/02/2020	20/1480876	5	5	4	4	5	2	2	3	4	4	4	1	4		2	4	2	3	3	1
Suction tanks that could supply more than 5,000 people																							
Grassmere Suction Tank	Central	9/06/2020	20/1480777	2	2	4	2	n/a	not graded	4	3	2	4	3	3	2		not assessed	3	2	2	3	2
Mays Suction Tank	Central	13/10/2020	20/1480955	5	5	5	2	n/a	4	5	4	2	5	3	4	5		3	3	2	3	4	1
Estuary Suction Tank	Rawhiti	14/09/2020	20/1480369	4	n/a	5	2	n/a	4	4	3	2	5	2	3	3		2	5	2	3	3	1
Keyes Suction Tank	Rawhiti	14/01/2020	20/1481108	4	4	4	to be confirmed	to be confirmed	4	4	2	2	to be confirmed	3	not assessed	not		1	1	3	1	1	1
Sockburn Suction Tank	West	14/01/2020	20/1481083	4	n/a	4	3	3	4	3	4	3	to be confirmed	3	to be confirmed	4		not assessed	3	1	3	2	1
Gardiners Suction Tank	Northwest	1/10/2020	20/1481131	2	n/a	2	4	n/a	2	1	2	1	5	4	not assessed	1		5	1	1	1	3	1
Reservoirs that could supply less than 5,000 people																							
Mt Pleasant 3 Reservoir 1	Ferrymead	24/09/2020	20/1481018	3	4	3	4	n/a	4	5	4	3	4	3	1	4		2	5	2	4	3	1
Mt Pleasant 3 Reservoir 2	Ferrymead	8/10/2020	20/1481042	4	n/a	3	2	n/a	3	1	3	3	2	3	1	3		3	4	3	3	3	1
Quarry Reservoir 2	Lyttelton	3/03/2020	20/1481150	5	5	5	4	n/a	3	3	4	2	4	4	1	2		not assessed	3	3	3	3	4
Halswell 2 Reservoir	West	17/09/2020	20/1481064	5	4	3	2	n/a	2	4	3	2	3	3	1	5		3	5	3	3	4	1



2.6.4 Distribution network

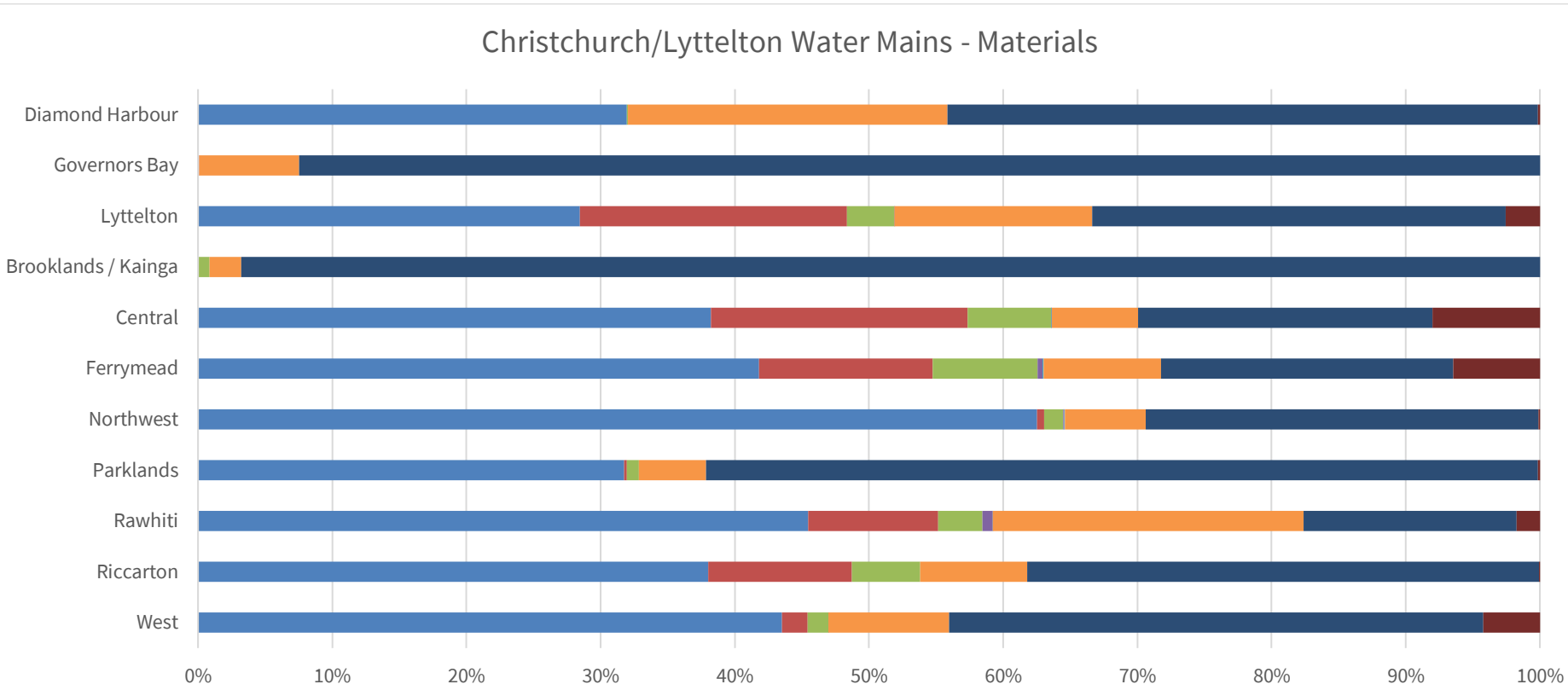
Table 2-8 and Table 2-9 and Figure 2-25 to Figure 2-28 summarise the distribution network characteristics including pipe materials and decade of installation. The combined length of water supply mains (mains with fire hydrants and trunk mains) in Christchurch and Lyttelton is approximately 1,763 km and the length of submains (including crossovers) is 1,662 km. Mains range in size from 80mm to 600mm diameter but are typically 200mm to 300mm diameter. Submains range in size from 25mm to 63mm diameter. Comprehensive data is found in TRIM 20/1460293.

Table 2-8: Christchurch City Distribution Network Characteristics

			Breakdown By Zone							
Water Supply Zone	**Total Christchurch**		**Brooklands / Kainga**	**Central**	**Ferrymead**	**Northwest**	**Parklands**	**Rawhiti**	**Riccarton**	**West**
Water Mains and Submains										
Length of water mains (m)	**1,681,735**		14,647	630,266	115,091	335,019	91,097	129,777	36,827	329,010
Length of water submains (m)	**1,643,220**		9,181	690,850	88,864	292,260	90,486	154,812	30,226	286,541
Water Connections										
Number of Residential Metered Water Connections	**118,092**	**90.3%**	447	48,039	6,344	25,435	6,409	10,479	2,747	18,192
Number of Standard Commercial Water Connections	**11,822**	**9.0%**	28	6,185	751	1,710	144	441	600	1,963
Number of High Use Commercial Water Connections	**698**	**0.5%**	0	356	44	118	14	31	17	118
Number of Unmetered On-Demand Water Connections	**16**	**0.0%**	0	1	0	6	0	0	0	9
Number of Restricted Water Connections	**79**	**0.1%**	0	3	0	9	0	0	1	66
Total Number of Water Connections	**130,707**		**475**	**54,584**	**7,139**	**27,278**	**6,567**	**10,951**	**3,365**	**20,348**
Calculated Population (2.5 persons per connection)	**326,768**		1,188	136,460	17,848	68,195	16,418	27,378	8,413	50,870
MoH Register Population	**383,445**		1,629	158,250	16,847	86,160	20,139	30,838	11,771	57,811

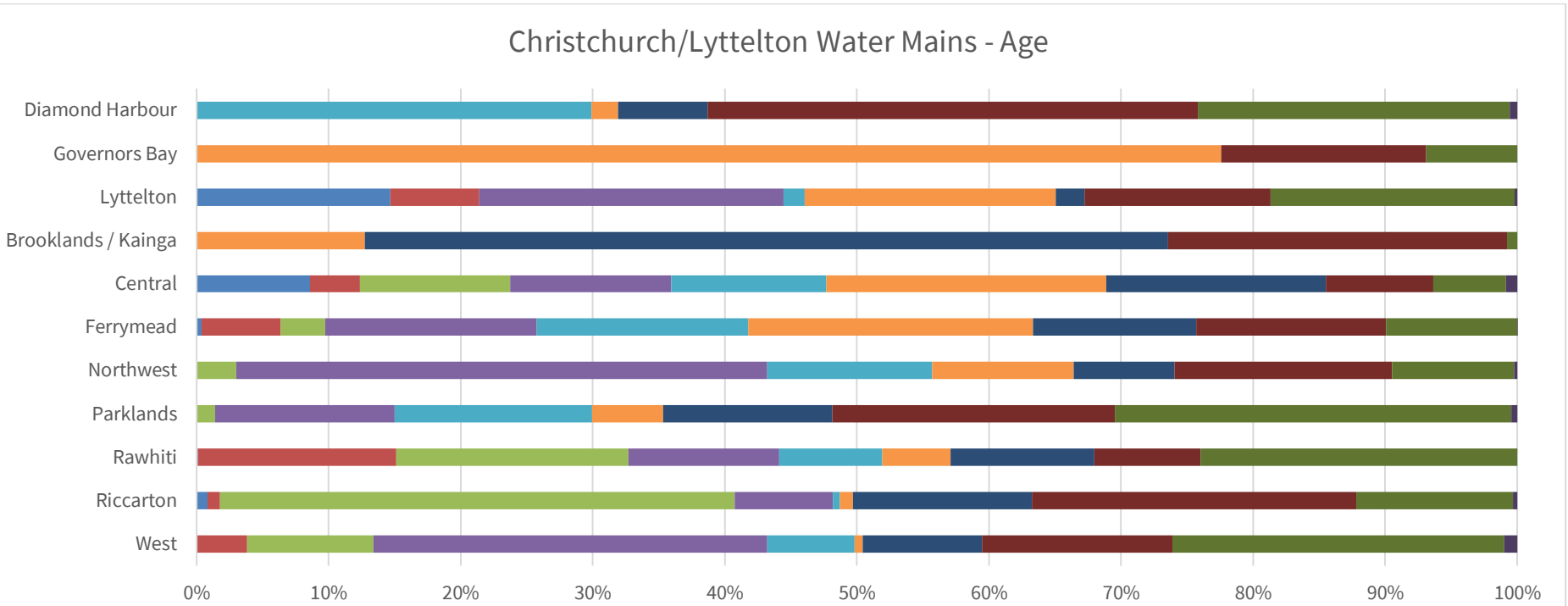
Table 2-9: Lyttelton Harbour Basin Distribution Network Characteristics

			Breakdown By Zone		
Water Supply Zone	**Total Lyttelton**		**Lyttelton**	**Governors Bay**	**Diamond Harbour**
Water Mains and Submains					
Length of water mains (m)	**81,110**		49,213	9,851	22,047
Length of water submains (m)	**19,288**		10,778	2,902	5,608
Water Connections					
Number of Residential Metered Water Connections	**465**	**23.1%**	179	32	254
Number of Standard Commercial Water Connections	**130**	**6.4%**	101	8	21
Number of High Use Commercial Water Connections	**19**	**0.9%**	19	0	0
Number of Unmetered On-Demand Water Connections	**1,401**	**69.5%**	753	290	358
Number of Restricted Water Connections	**2**	**0.1%**	0	0	2
Total Number of Water Connections	**2,017**		**1,052**	**330**	**635**
Calculated Population (2.5 persons per connection)	**5,043**		2,630	825	1,588
MoH Register Population	**5,854**		3,273	880	1,701



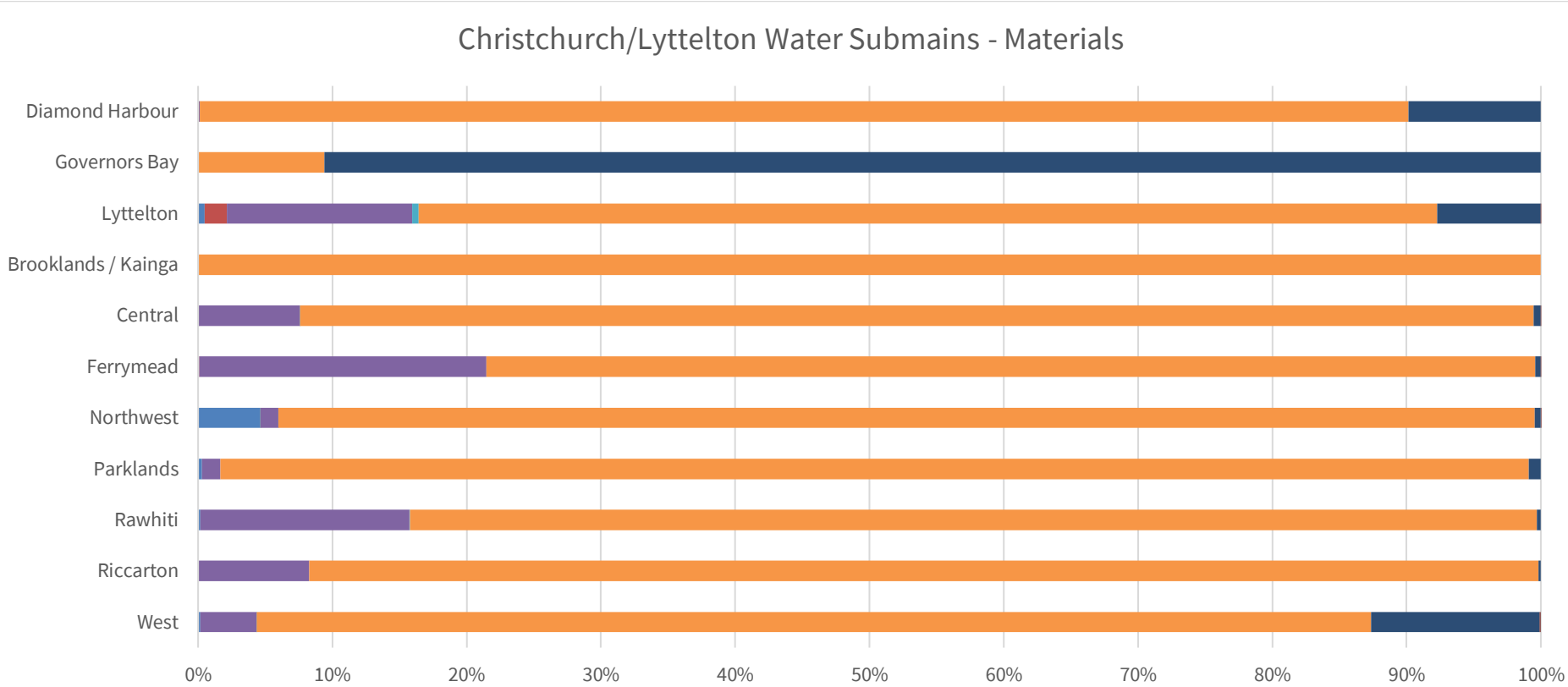
	West	Riccarton	Rawhiti	Parklands	Northwest	Ferrymead	Central	Brooklands / Kainga	Lyttelton	Governors Bay	Diamond Harbour
Asbestos Cement	44%	38%	45%	32%	63%	42%	38%	0%	28%	0%	32%
Cast Iron	2%	11%	10%	0%	1%	13%	19%	0%	20%	0%	0%
Ductile Iron	2%	5%	3%	1%	1%	8%	6%	1%	4%	0%	0%
Galvanised Iron	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Polyethylene	9%	8%	23%	5%	6%	9%	6%	2%	15%	7%	24%
PVC	40%	38%	16%	62%	29%	22%	22%	97%	31%	92%	44%
Steel	4%	0%	2%	0%	0%	6%	8%	0%	3%	0%	0%

Figure 2-25: Water main materials – breakdown by zone



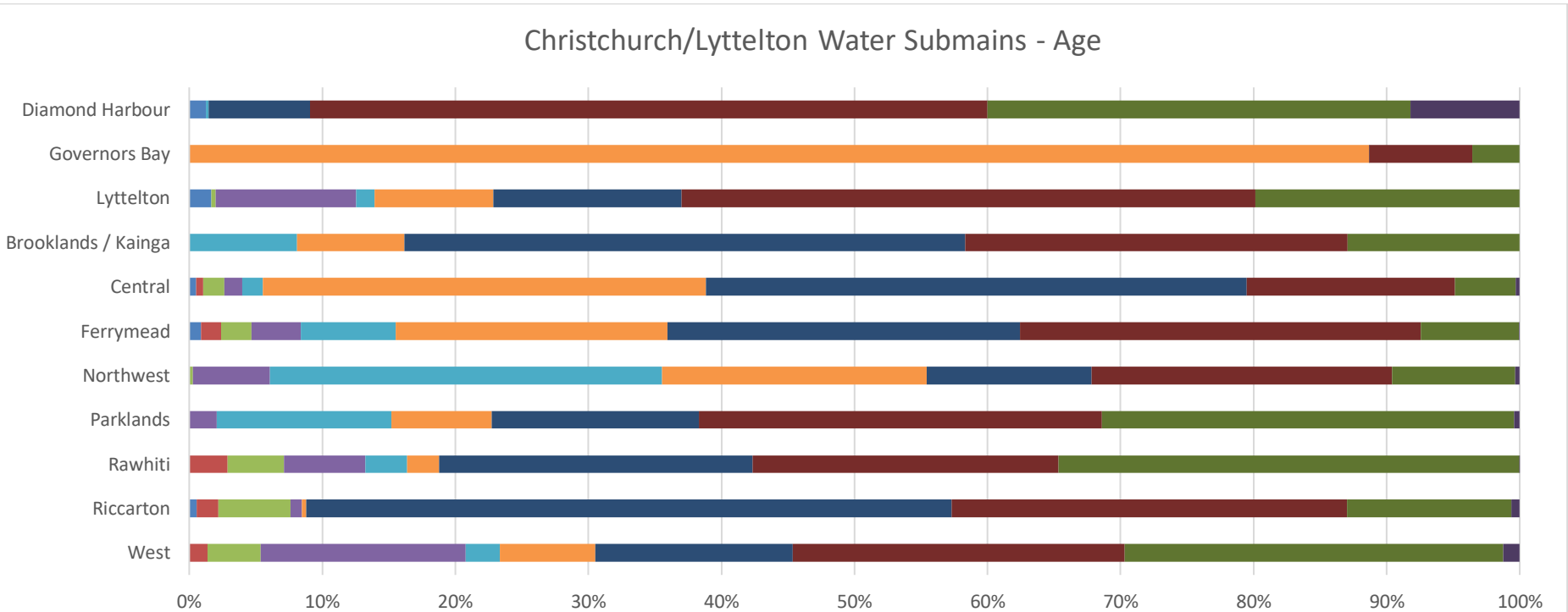
	West	Riccarton	Rawhiti	Parklands	Northwest	Ferrymead	Central	Brooklands / Kainga	Lyttelton	Governors Bay	Diamond Harbour
Pre-1940s	0%	1%	0%	0%	0%	0%	9%	0%	15%	0%	0%
1940s	4%	1%	15%	0%	0%	6%	4%	0%	7%	0%	0%
1950s	10%	39%	18%	1%	3%	3%	11%	0%	0%	0%	0%
1960s	30%	7%	11%	14%	40%	16%	12%	0%	23%	0%	0%
1970s	7%	1%	8%	15%	12%	16%	12%	0%	2%	0%	30%
1980s	1%	1%	5%	5%	11%	22%	21%	13%	19%	78%	2%
1990s	9%	14%	11%	13%	8%	12%	17%	61%	2%	0%	7%
2000s	14%	25%	8%	21%	16%	14%	8%	26%	14%	15%	37%
2010s	25%	12%	24%	30%	9%	10%	6%	1%	18%	7%	24%
2020s	1%	0%	0%	0%	0%	0%	1%	0%	0%	0%	1%

Figure 2-26: Water main age – breakdown by zone



	West	Riccarton	Rawhiti	Parklands	Northwest	Ferrymead	Central	Brooklands / Kainga	Lyttelton	Governors Bay	Diamond Harbour
Asbestos Cement	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%
Cast Iron	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%
Ductile Iron	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Galvanised Iron	4%	8%	16%	1%	1%	21%	8%	0%	14%	0%	0%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Polyethylene	83%	92%	84%	97%	94%	78%	92%	100%	76%	9%	90%
PVC	13%	0%	0%	1%	0%	0%	1%	0%	8%	91%	10%
Steel	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 2-27: Water submain materials – breakdown by zone



	West	Riccarton	Rawhiti	Parklands	Northwest	Ferrymead	Central	Brooklands / Kainga	Lyttelton	Governors Bay	Diamond Harbour
Pre-1940s	0%	1%	0%	0%	0%	1%	1%	0%	2%	0%	1%
1940s	1%	2%	3%	0%	0%	2%	1%	0%	0%	0%	0%
1950s	4%	5%	4%	0%	0%	2%	2%	0%	0%	0%	0%
1960s	15%	1%	6%	2%	6%	4%	1%	0%	11%	0%	0%
1970s	3%	0%	3%	13%	30%	7%	2%	8%	1%	0%	0%
1980s	7%	0%	2%	8%	20%	20%	33%	8%	9%	89%	0%
1990s	15%	49%	24%	16%	12%	27%	41%	42%	14%	0%	8%
2000s	25%	30%	23%	30%	23%	30%	16%	29%	43%	8%	51%
2010s	28%	12%	35%	31%	9%	7%	5%	13%	20%	4%	32%
2020s	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	8%

Figure 2-28: Water submain age – breakdown by zone

In 2018 the Council commissioned a study of western European medium sized cities that do not normally operate their water supply systems with a residual disinfectant.[13]

The study focused on several cities in Holland that rely on groundwater sources and non-chlorinated distribution systems. It provides information on the typical source conditions and source water quality parameters, and details the methods used to control real and potential contamination risks in the distribution system.

The study includes a comparison of pipe materials which is shown in Table 2-10 and Figure 2-29. It can be seen that Christchurch has a slightly higher proportion of resilient pipe materials (PVC and PE) than Holland.

Table 2-10: Water Supply Pipe Material Comparison between Christchurch and Holland

Pipe Material	Holland, km	Holland, %	Christchurch, km	Christchurch, %
PVC	62,445	52%	574	17%
PE	8,691	7%	1,539	45%
AC	30,812	26%	820	24%
Cast Iron	9,294	8%	176	5%
Ductile CI	3,330	3%	64	2%
Steel	2,561	2%	226	7%
Concrete	871	1%	0	0%
Other	1,142	1%	0.1	0%
Total	**119,146**	**100%**	**3,399**	**100%**

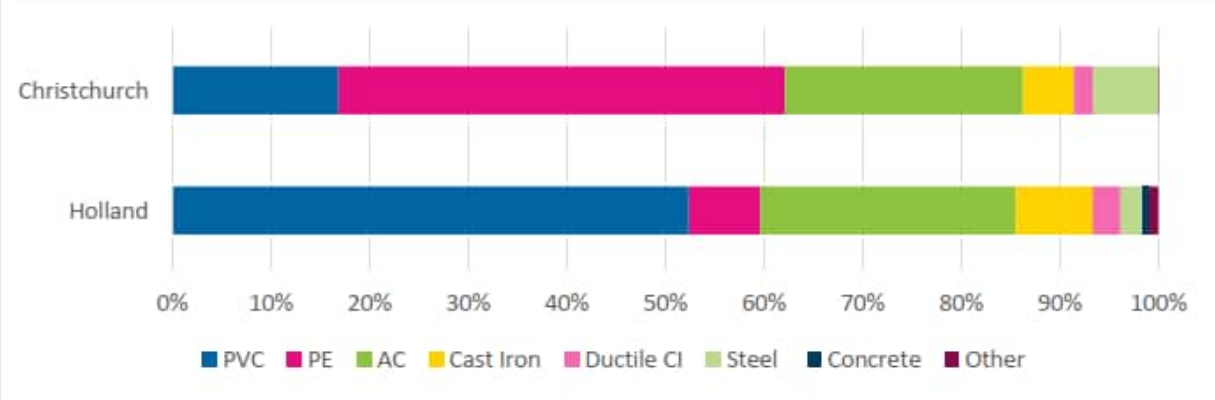


Figure 2-29: Water supply pipe material comparison between Christchurch and Holland

There is a high level of redundancy in the system and the effect of pump station or pipe failures has been mitigated by the grid nature of the network, the ability to feed zones from a neighbouring zone, and duplication of trunk mains. Additional improvements were undertaken after the earthquakes for increased resilience and these have been incorporated into the Council's key infrastructure design and construction documents (IDS and CSS).

[13] Non-Chlorinated Case Studies Report, GHD, 2018. TRIM 18/756438.

The Council undertook a trial of high speed pressure sensing and acoustic monitoring of the network in the Riccarton water supply zone and about a third of the Northwest water supply zone (approximately 11% of the city) for 19 months from February 2017 to September 2018. The purpose of the trial was to characterise pressure transients and to detect leaks. Pressure was monitored 265 times per second at 26 monitoring sites, along with acoustic monitoring for leak detection. An analysis of the results found that there were only 12 instances of zero or negative pressure, all appearing to be associated with pipes isolated for repair. TRIM://19/102928 for the project closeout report and TRIM://19/955889 for the analysis of zero and negative pressures. While the trial did not cover the whole city, this is good evidence that zero or negative pressure is a rare occurrence in Christchurch.

2.6.5 System water loss and leakage

Information relating to the system water loss and leakage work and contract is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283 .

For the Christchurch/Lyttelton Harbour water supply, there are 180 water loss zones that can be temporarily isolated by closing valves so that there is only one single feed into the zone at which point the nightflow is measured. The zones range in size between 40 to over 2,000 water connections / properties. Figure 2-30 shows the extent of the zones. The different colours on the map correspond to the different water supply zones.

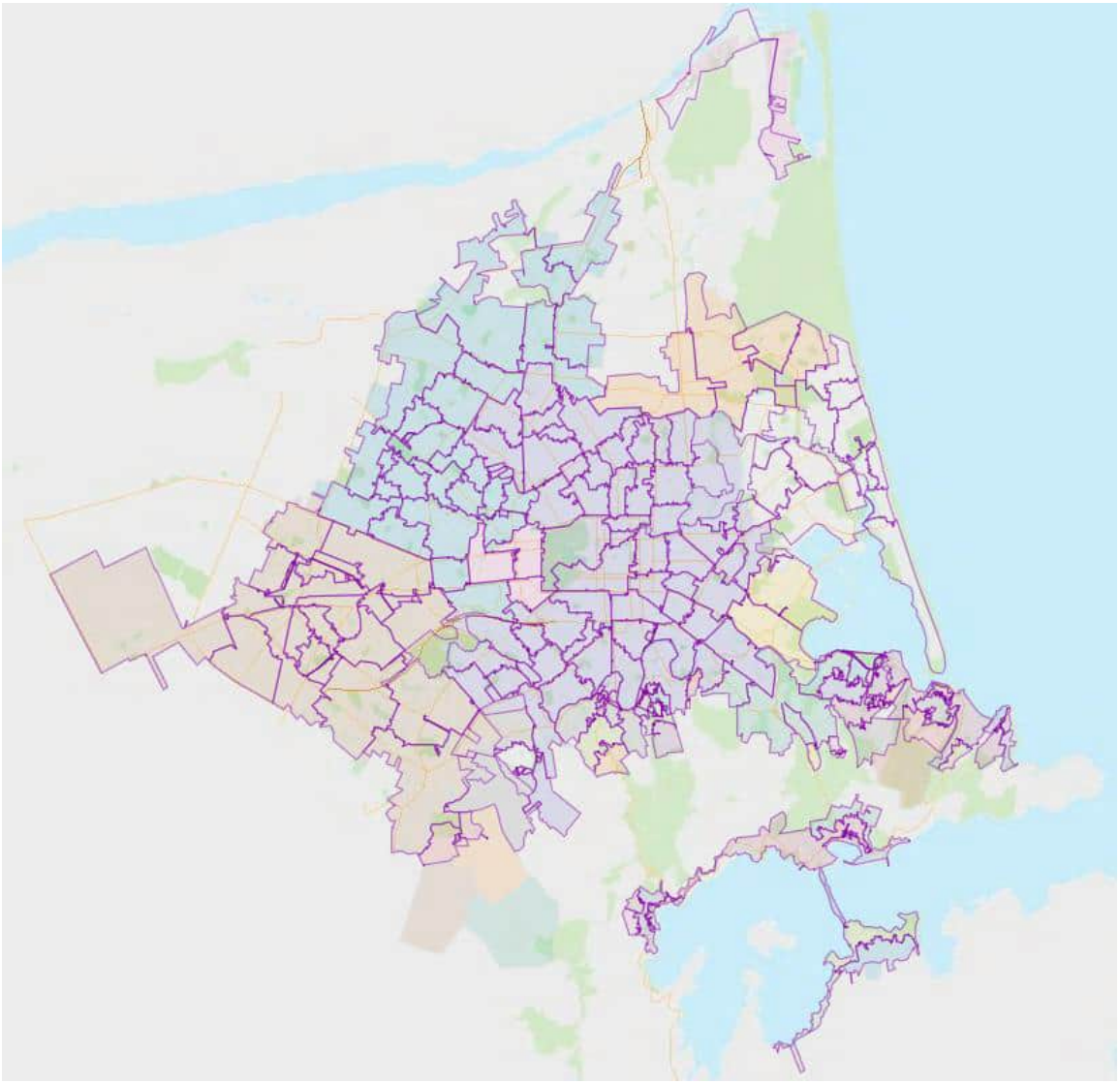


Figure 2-30: Water loss zones overview map

The Council recognises the benefits of pressure management and rezoning. Reconfiguring eight supply zones into 14 more evenly sized zones and lowering the pressures in the east and central parts of the city (to bring them in line with other zones) would result in even sized zones with consistent operating pressures. Pressure management and rezoning brings a number of benefits:

- Optimal pressure management
- Reduced pipe burst frequency
- Reduced water leakage
- Reduced pressure transients and improved stability of supply
- Opportunity to isolate an area in the event of an emergency.

The Rawhiti pressure management trial will aid the decision making in re-configuring the network into more manageable pressure zones. If the water supply re-zoning project goes ahead (after conclusion of the Rawhiti trial and approval by the Elected Members) then options to provide smarter measurement of water losses will be included in the scope of the re-zoning.

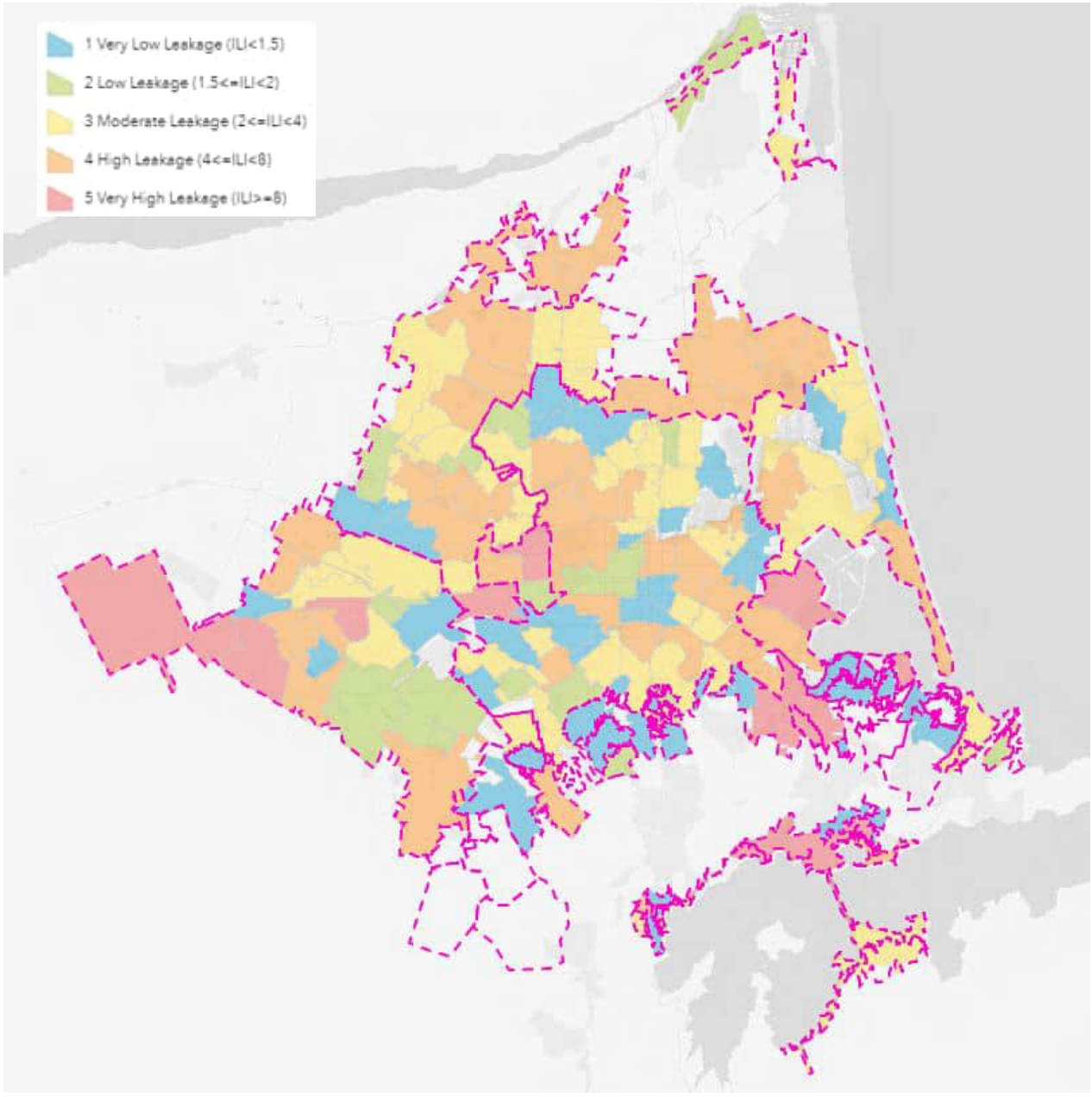


Figure 2-31: Infrastructure Leakage Index (ILI) By Water Loss Zone

2.7 Asset Assessment and Intervention Framework

The Council's Asset Assessment and Intervention Framework (AAIF) is explained in detail in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

AAIF information is available on a GIS dashboard:
(https://gis.ccc.govt.nz/portal/apps/opsdashboard/index.html#/120e360f35934ddf9d65eb32c1127a2b).

Figure 2-32 shows the dashboard for water loss zone Central 1 which includes asset information along with likelihood of failure and infrastructure leakage index data. Further maps can be produced from the CCC GIS Portal.

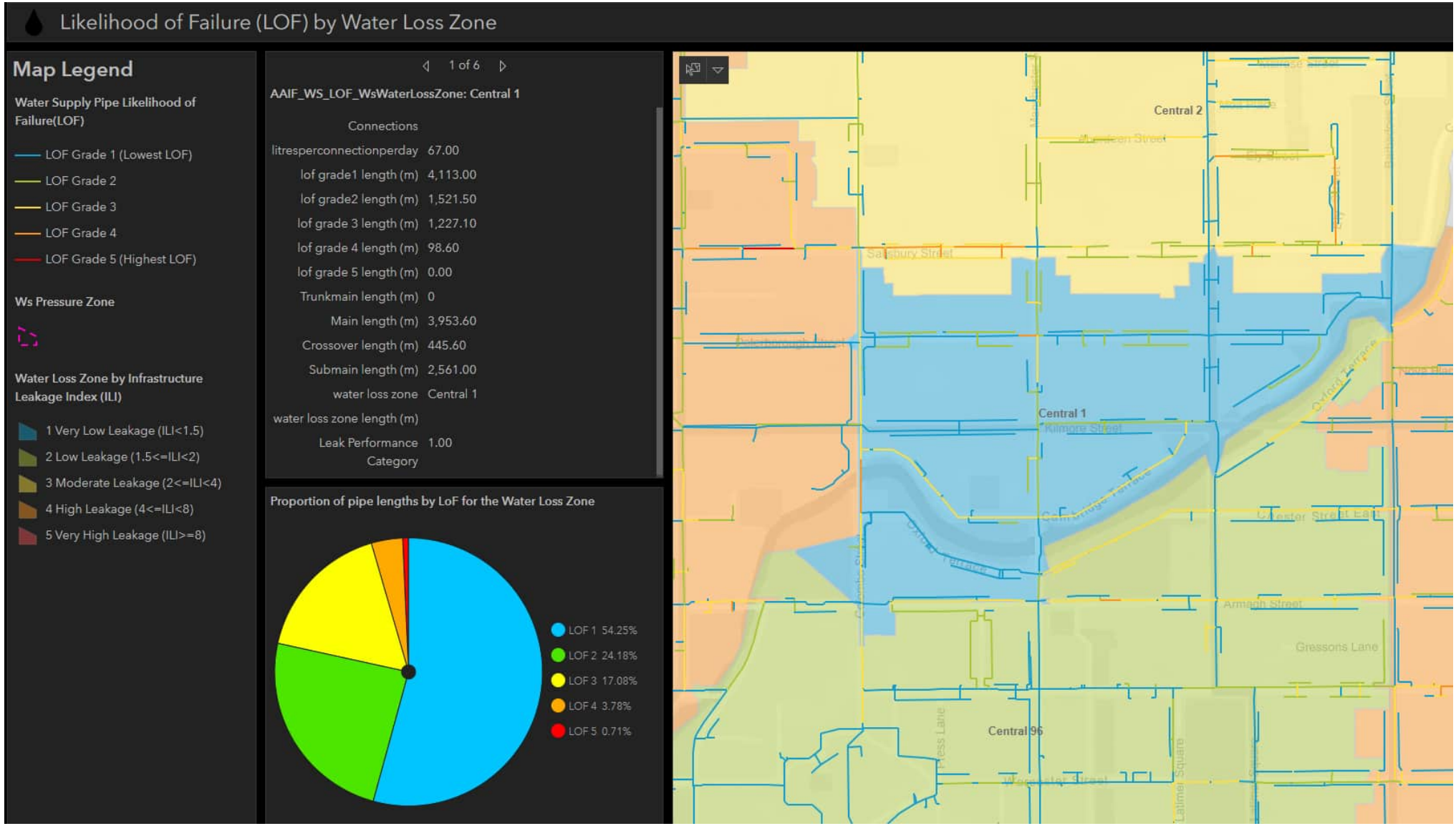


Figure 2-32: Water loss zone Central 1 showing AAIF likelihood of failure for pipes and infrastructure leakage index (ILI)

Currently overall 12.93% per cent of pipes are classified as being very poor condition (grade 5 – expected to fail in 5 years). This comprises 14.11% of water mains/trunk mains and 4.95% of submains and crossovers. Although there is a renewals programme in place, the change in focus following the Canterbury Earthquakes from replacement to repair has resulted in a slowing in the pipe renewal programme. While the network of water supply pipes is inherently safe, so long as the pressure within the network remains higher than that of the surrounding groundwater, any pipe failure can lead to a drop in pressure in the network and a consequential risk of contamination occurring. Repairs to the water supply pipes are another potential cause of contamination in the network.

There are a number of initiatives in place to minimise the risk of contamination in the network which are summarised in Section 4.

2.7.1 Asset renewals

Significant recent and current renewals and water supply improvements are shown in Table 2-11. Replacing assets in poor condition, and built to older standards, with new assets built to current standards in the IDS and CSS improves water safety.

Table 2-11: Significant renewals and water supply improvements

Category	Project Description	Improvement
New primary water pump stations	Ben Rarere Pump Station (Central zone)	Replacement for earthquake damaged Bexley Pump Station
	Gardiners Pump Station (Northwest zone)	Deeper wells, new suction tank and new pump station to replace the shallow well Harewood PS and to provide for growth
	Keyes Pump Station (Central zone)	Replacement for Palmers Pump Station
	Prestons Pump Station (Parklands zone)	Allowance for growth, new PS and wells has enabled decommissioning of two old pump stations and three wells (Mairehau and Burwood)
	Wilmers Pump Station (West zone)	Allowance for growth
	Wrights Pump Station (Northwest zone)	Replacement for old Wrights PS which had elevated nitrates
Northwest DWSNZ upgrade	Drilling of 22 deep wells to replace 16 shallow wells	Decommissioning of vulnerable shallow wells in the northwest area
Well replacements	Grassmere well 1 replacement	Replacing vulnerable shallow wells with deeper secure wells
	Belfast well 1 replacement	
	Mays well 3 replacement	
	Redwood PS	
	Spreydon well 2 and 3	
	Blighs Road well 3	
Water supply reservoir roof lining	The roofs of 20 reservoirs were improved by installing a flexible, waterproof liner in 2016 and 2017.	Prevents contamination of storage reservoirs.
Sydneham and Jeffreys Road PS	Suction tank replacements currently progressing	Existing suction tanks old, prevention of contamination.
Quarry reservoirs (2) Lyttelton	Repair and relining	Prevents contamination

Category	Project Description	Improvement
Completed new water supply mains	Ferrymead Booster PS: 1255 m of DN355 PE100 installed during 2013 which supplies the Exeter Reservoir and Low Level Pressure Zone in Lyttelton through the Rail Tunnel pipelines.	This supplies the Port of Lyttelton and the Fuel Tank Farm which are listed as lifeline entities in the Civil Defence Emergency Management Act 2002.
	Gardiners Rd: 662 m of DN355 PE100 and DN300 PVC-U installed	To provide connectivity for the new Gardiners pump station and to increase capacity of the existing DN200 PVC pipeline.
	Halswell Junction Rd: 2007 m of new DN560 PE100 and DN450 DI trunk main installed during 2013 and 2014	To service growth areas in Southwest Christchurch.
	Main Rd, Sumner: 785 m of new DN250 PE100 duplication main installed during 2018	Improved redundancy and resilience.
	Marshland Rd: 1360 m of DN355 PE100 or DN300 DI new pipeline installed between 2014 and 2016	Provide connectivity between the Prestons, Marshland and Mairehau Pump Stations within the Parklands Pressure Zone.
Completed water main renewals	Bealey Ave: 415 m of DN150 steel pipe was renewed in 2016 with DN250 PE100	To provides service to Southern Cross Hospital
	Bridge St along each side of the Avon River Estuary Bridge: 75 m of DN355 PE100 installed by SCIRT as part of bridge reconstruction works during 2015.	To strengthen an essential lifeline.
	Cannon Hill Cres: approximately 1300 m of DN250 PE100 installed in 2018. This main was upsized as it is the backup supply to Heathcote Valley and the Rocky Zone	To improve redundancy within the Rocky Zone which is highly industrial and commercial.
	Ferrymead Bridge: 272 m of DN355 PE100 twin mains installed during 2015	To replace existing mains for major lifelines project supplying potable water to hill and coastal suburbs east of the bridge
	Governors Bay Rd: 576 m of DN250 PE100 installed in 2019.	To strengthen the supply to Governors Bay.
	Governors Bay Rd: 668 m of DN180 PE100 installed in 2016.	To strengthen the supply to Governors Bay.
	Linwood Ave: 304 m of DN355 PE100 replaced DN250 steel pipe during 2015 and 2016.	To replace old pipes with more resilient pipe material and to improve capacity.
	Lyttelton Port Fuel Tank Farm Area: 1130 m of DN250 PE100 or DN200 DI pipes installed in 2016.	To renew old, hydraulically under sized pipes servicing the Fuel Tank Farm area of the Lyttelton Port. This pipeline is also important as the only feed to supply Diamond Harbour.
	Lyttelton Road Tunnel Pipeline: Approximately 1260 m of DN300 stainless steel pipe installed mostly in 2019 within Lyttelton Road Tunnel	To provide increased capacity for the NZTA deluge system which also provides the additional benefit of increasing hydraulic capacity for supplying potable water to Lyttelton.
	Manchester St: 589 m of DN355 PE100 installed by SCIRT during 2015.	To upsize and replace AC pipe damaged during the earthquakes within the CBD.
	Matipo St: 88 m of DN355 PE100 installed during 2016	Upsizing required as part of the Rezoning project in an industrial / commercial area.
	New Brighton Rd across and in the vicinity of Pages Rd Bridge: 131 m of DN355 PE100 / DN315 PE100 / DN300 PVC-U installed during 2016 in conjunction with bridge repair works.	To strengthen an essential lifeline.
	Quarry Reservoirs (Lyttelton High Level Zone) Pumping Main – 227 m of DN150 AC pipeline renewed in 2017 with DN180 PE100.	The pipeline is the only feed to the Quarry Reservoirs

Category	Project Description	Improvement
	Riccarton Ave: 284 m of DN150 CI pipe was renewed in 2016 with DN355 PE100	To replace an old main and provide adequate supply and fire flow to Christchurch Hospital.
	Riccarton Rd: 545 m of DN355 or DN250 PE100 pipeline replaced DN150 AC pipe during 2017 and 2018.	To replace old pipes with more resilient pipe material and to improve capacity and connectivity.

2.7.2 Water supply budget

This information is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283

2.8 Water quality characteristics

The drinking water compliance monitoring regime is carried out in accordance with the requirements set out in DWSNZ and is specific to each pressure zone as it is dependent on the population served. The drinking water compliance monitoring schedules are stored in TRIM FOLDER09/2233.

The Drinking Water Sampling Manual is located in TRIM FOLDER12/1026. The Council also undertakes an annual monitoring programme of the chemical composition at various wells as described in Section 2.8.3.

2.8.1 Bacteria

Council monitors bacterial compliance by taking samples from pump stations, storage reservoirs and private customer taps. A project is currently underway to install dedicated sampling bollards (CP503579) across the city.

Until 31 January 2018 each pump station was sampled at least once per month with the exception of the Northwest zone, which was sampled daily. This exceeded the DWSNZ requirement for monthly monitoring of secure groundwater. Sampling currently covers at least one pump station from each zone each day. Each pump station within a zone is sampled at least once per month. Each reservoir is also sampled at least once every month. All samples are enumerated for E. coli and total coliforms.

Sampling is continuing to considerably exceed the minimum DWSNZ frequency requirements. Table 2-12 which provides a breakdown of sample numbers for the financial year 2019/20 (1 July 2019 – 30 June 2020). Sample results are stored in Council's QLims laboratory management system and are also saved in Drinking Water Online (and previously Water Information New Zealand).

Table 2-12: Minimum and Actual Number of E. coli Samples Taken in 2020/21

Supply Name	Registration Code	Location	Population	Minimum Annual Samples Required (DWSNZ Tables 4.2a and 4.3a)	Actual No. Samples Taken	% of DWSNZ Requirement
Brooklands/Kainga	BRO012BR	Distribution	1,629	52	85	163
	TP00964	TP (source)		104	108	103
Central	CHR001CE	Distribution	158,250	388	645	166
	TP00179	TP (source)		365	488	133
Main Pumps	TP04053	TP (source)		n/a (uses bacterial compliance criterion 5 UV treatment but 61 E. coli samples taken)		
Rawhiti	CHR001RA	Distribution	30,838	124	189	152
	TP04061	TP (source)		365	467	127
Parklands	CHR001PA	Distribution	20,139	88	159	180
	TP00182	TP (source)		365	399	109

Supply Name	Registration Code	Location	Population	Minimum Annual Samples Required (DWSNZ Tables 4.2a and 4.3a)	Actual No. Samples Taken	% of DWSNZ Requirement
Riccarton	CHR001RI	Distribution	11,771	64	121	189
	TP00185	TP (source)		365	398	109
West	CHR001WE	Distribution	57,811	148	291	196
	TP00183	TP (source)		365	386	108
Northwest	CHR001NO	Distribution	86,160	232	415	178
	TP00181	TP (source)		365	464	127
Lyttelton	LYT001LY	Distribution	3,273	52	202	388
Governors Bay	LYT001GO	Distribution	880	52	133	255
Diamond Harbour	LYT001DI	Distribution	1,701	52	112	215

The source water quality is considered to be very good, confirmed by the fact that the Christchurch water supplies have a long-term excellent compliance history for bacterial parameters which is reported by the Ministry of Health in the annual compliance report (refer to Section 2.9.1).

There has been a small number of E. coli detections at pump stations that could exclusively be traced back to issues with suction tanks and/or sampling point contamination. Examples of such detections are Picton pump station (17/11/2019), Keyes pump station (20/12/2019), Sockburn pump station (23/2/2020), Denton pump station (25/11/2020) and Grampian pump station (13/08/21). None of these detections occurred in source water samples taken directly from wellheads but in samples taken at other locations at the pump station site such as the surface pumps which pump into the reticulation system.

An example of this is the E. coli detection in a sample collected from the Pump 1 sampling point at Denton pump station on 11 February 2018 (West water supply zone). The sampling point is downstream from the suction tank. Two samples were taken and enumerated at the time (one compliance sample and one quality control sample) – E. coli was present at a concentration of 1 MPN/100mL in one sample and absent from the second sample. It was raining at the time but, according to the sampling technician, the sample had not been impacted.

Council staff followed the agreed transgression procedure. Actions included:

- Isolating the pump station from the network
- Notifying Taumata Arowai
- Sampling of the suction tank prior to chlorination
- Chlorinating the suction tank
- Sampling of all wells that feed into the suction tank
- Sampling in the distribution system
- Sampling of other pump stations in the West zone (Sockburn and Wilmers)
- Flushing in the reticulation system from around the station on an ‘outside to in’ basis (from about 600 m radius) to bring water from the other pump stations (Sockburn and Wilmers) in the zone toward it.
- Inspecting the Denton suction tank roof for leaks using a Remote Operated Vehicle and putting water on the roof to check for leaks (after cleaning and chlorinating).

None of the 72 subsequent corrective action samples contained E. coli. The suction tank inspection identified some issues with the roof and repairs were carried out immediately, prior to bringing the pump station back into service. Full details about this transgression can be found in TRIM 19/1088933.

On 25th December 2020 E. coli was found in a sample collected from the Denton pump station. The investigation report found that the condition of the suction tank was the likely cause of the transgression. No E Coli was found in any of the five wells that serve the pump station. Full details about this transgression can be found in the SITREP (refer to TRIM 20/1477218) and investigation report (TRIM://21/364469).

E. coli transgressions at storage reservoirs triggered the reservoir roof improvement programme where the roofs of vulnerable reservoirs were coated with an epoxy lining to seal small cracks and prevent the ingress of surface water. Additional repairs, including the more complex repairs to the Denton suction tank, and other reservoirs that require work to address issues identified in the Citycare reservoir condition report (refer to TRIM 19/1026197 and the summary presented in Appendix B). The subsequent refinement of the Demonstrably Safe criteria and detailed condition assessments carried out by consulting engineers will be used to plan and execute a range of suction tank and reservoir renewal projects, with a total budget of $8 million in draft Long Term Plan for financial years 2020/21-30 (see also section 2.7.2).

There have been occasional transgressions of E. coli in the distribution system but the number of transgressions are well within the current DWSNZ permissible range and the Council has always been able to trace the event back to the underlying cause. All transgressions are resolved in an efficient manner, following DWSNZ protocols. An exception to this was the E. coli transgression in the Brooklands/Kainga distribution on 18 April 2019 (Good Friday) where a reduced number of staff were on call resulted in delayed flushing of the distribution system. Since this incident several lessons learnt workshops were undertaken – with one being attended by the DWA – and new procedures implemented. This is further described in Section 2.8.6.

Table 2-13 provides a summary of E. coli transgressions since financial year 2012/13. In financial years 2012/13 to 2017/18, E. coli transgressions were recorded as 'Events' in Water Information New Zealand (WINZ) where details on the actions carried out, sampling undertaken and the likely cause of the transgression were recorded. An export of the E. coli transgression events history is stored in TRIM 19/1094604. Since financial year 2018/19 until late 2021, E. coli transgression events are recorded in Drinking Water Online (DWO), the web-based system which replaces WINZ. All information was able to be readily accessed by the Drinking Water Assessor at https://drinkingwateronline.nz, in section 'Investigations'.

DWSNZ currently permit E. coli exceedances (transgression events), provided that the target benchmark (MAV) is not being exceeded more than 5% of the time. DWSNZ Table A1.1 shows the relationship between the number of E. coli samples taken and the allowable exceedances.

Figure 2-33 to Figure 2-35 provide the history of allowed versus actual E. coli transgression events for Christchurch City treatment plants (TP) – actually pump stations but called treatment plants for the purposes of the drinking water register – Christchurch City distribution system and Lyttelton Harbour Basin distribution system between FY 2012/13 and FY 2019/20. Only data for full financial years is represented as sample numbers were officially validated by the Drinking Water Assessor in the annual drinking water compliance survey which takes place in July each year for the previous financial year. The graphs illustrate an excellent track record of high quality water being delivered to water consumers.

Table 2-13: E. coli transgression events between FY 2012/13 and FY 2020/21

Supply Name	Location	DWO Code	FY 2012/13 Transgression Details	FY 2013/14 Transgression Details	FY 2014/15 Transgression Details	FY 2015/16 Transgression Details	FY 2016/17 Transgression Details	FY 2017/18 Transgression Details	FY 2018/19 Transgression Details	FY 2019/20 Transgression Details	FY 2020/21 Transgression Details
Brooklands/ Kainga	Distribution	BRO012BR							• 18 April 2019: 159 Kainga Rd (Community Centre)		
Brooklands/ Kainga	TP (source)	TP00964									
Central	Distribution	CHR001CE	• 2/9/2012: Huntsbury 2 reservoir • 24/5/2013: Murray Aynsley 2 reservoir	• 15/10/2013: Takahe reservoir • 6/3/2014: Takahe reservoir (storm) • 7/3/2014: Scarborough 2 reservoir (storm) • 19/3/2014: Hackthorne reservoir • 11/4/2014: Scarborough 3 reservoir • 26/4/2014: Murray Aynsley 2 reservoir • 8/5/2014: Takahe reservoir	• 8/3/2015: 89 St Andrews Hill Rd • 10/3/2015: Huntsbury 4 reservoir • 4/4/2015: Major Aitken 2 reservoir	• 4/1/2016: Major Aitken 2 reservoir • 18/1/2016: Mt Pleasant 1 reservoir	• 28/2/2017: Scarborough 2 reservoir • 29/3/2017: Mt Pleasant 3 reservoir (non-routine sample after roof lining)	• 22/3/2018: 72 Greenhaven Dr			
Central	TP (source)	TP00179		• 6/3/2014: Main PS Well 2 (storm)						• 20/12/2019: Keyes PS (Pump 1)	
Diamond Harbour	Distribution	LYT001DI	• 17/1/2013: 61 Waipapa Ave		• 23/12/2014: Stoddard reserve			• 19/12/2017: Doris Faigan 2 reservoir			
Governors Bay	Distribution	LYT001GO		• 8/4/2014: Fire Station	• 30/1/2015: Hayes 2 reservoir		• 18/4/17: Hays 2 reservoir				
Lyttelton	Distribution	LYT001LY		• 6/1/2014: Somes reservoir • 6/3/2014: Quarry reservoir (storm)		• 5/4/2016: Buxtons 2 reservoir		• 7/11/2017: Scruttons PS (suction tank)			

Supply Name	Location	DWO Code	FY 2012/13 Transgression Details	FY 2013/14 Transgression Details	FY 2014/15 Transgression Details	FY 2015/16 Transgression Details	FY 2016/17 Transgression Details	FY 2017/18 Transgression Details	FY 2018/19 Transgression Details	FY 2019/20 Transgression Details	FY 2020/21 Transgression Details
				• 7/3/2014: Tunnel reservoir (storm)							
Northwest	Distribution	CHR001NO	• 21/1/2013: 5 Barlow St • 17/6/2013: 366 Sawyers Arms Rd	• 5/3/2014: 582 Harewood Rd • 30/4/2014: 22A Belfast Rd • 6/3/2014: Grampian suction tank (storm) • 8/5/2014: 12C Darroch St		• 31/5/16: 151 Greers Rd	• 12/12/2016: Grampian PS (suction tank) • 2/1/2017: Grampian PS (suction tank)	• 23/7/2017: Grampian PS (suction tank)			13/8/21 Grampian PS (suction tank)
Northwest	TP (source)	TP00181	*• 1/3/2013: Grampian PS well 5 (well decommissioned)*		*• 27/4/2015: Harewood PS well 1 (well decommissioned)*	• 18/2/2016: Burnside PS (pump sampling point) • 26/3/2016: Burnside PS (pump sampling point)					
Parklands	Distribution	CHR001PA									
Parklands	TP (source)	TP00182									
Riccarton	Distribution	CHR001RI									
Riccarton	TP (source)	TP00185								• 17/11/2019: Picton PS	
Rocky Point	Distribution	CHR001RP			• 10/4/2015: Morgans Valley 2 reservoir			• 6/3/2018: 10 Chapmans Rd			
Rocky Point	TP (source)	TP00184									
West	Distribution	CHR001WE	• 9/1/2013: 84 Carmen Rd • 7/2/2013: Burkes 1 reservoir	• 6/3/2014: Burkes Track 2 reservoir (storm) • 9/3/2014: 14 English St	• 20/9/2014: Kennedys Bush reservoir	• 16/3/2016: Burkes Track 2 reservoir • 18/3/2016:		• 6/3/2018: 123 Main South Rd • 19/3/2018: Burkes			

Supply Name	Location	DWO Code	FY 2012/13 Transgression Details	FY 2013/14 Transgression Details	FY 2014/15 Transgression Details	FY 2015/16 Transgression Details	FY 2016/17 Transgression Details	FY 2017/18 Transgression Details	FY 2018/19 Transgression Details	FY 2019/20 Transgression Details	FY 2020/21 Transgression Details
				• 19/3/2014: Halswell 1 reservoir • 14/4/2014: Sutherlands 2 reservoir		Halswell 1 reservoir		Track 2 reservoir			
West	TP (source)	TP00183	• 9/2/2013: Dunbars PS (suction tank)					• 11/2/2018: Denton PS (suction tank) • 22/2/2018: Dunbars PS (suction tank)	• 8 March 2019: Sockburn PS (suction tank)	• 23/2/2020: Sockburn PS (Pump 2)	• 20/11/2020: Denton PS (Pump 1) and 25/12/20 (Suction tank)
Ferrymead	Distribution	CHR001FE									
Ferrymead	TP (source)	TP04060									
Rawhiti	Distribution	CHR001RA									
Rawhiti	TP (source)	TP04061									

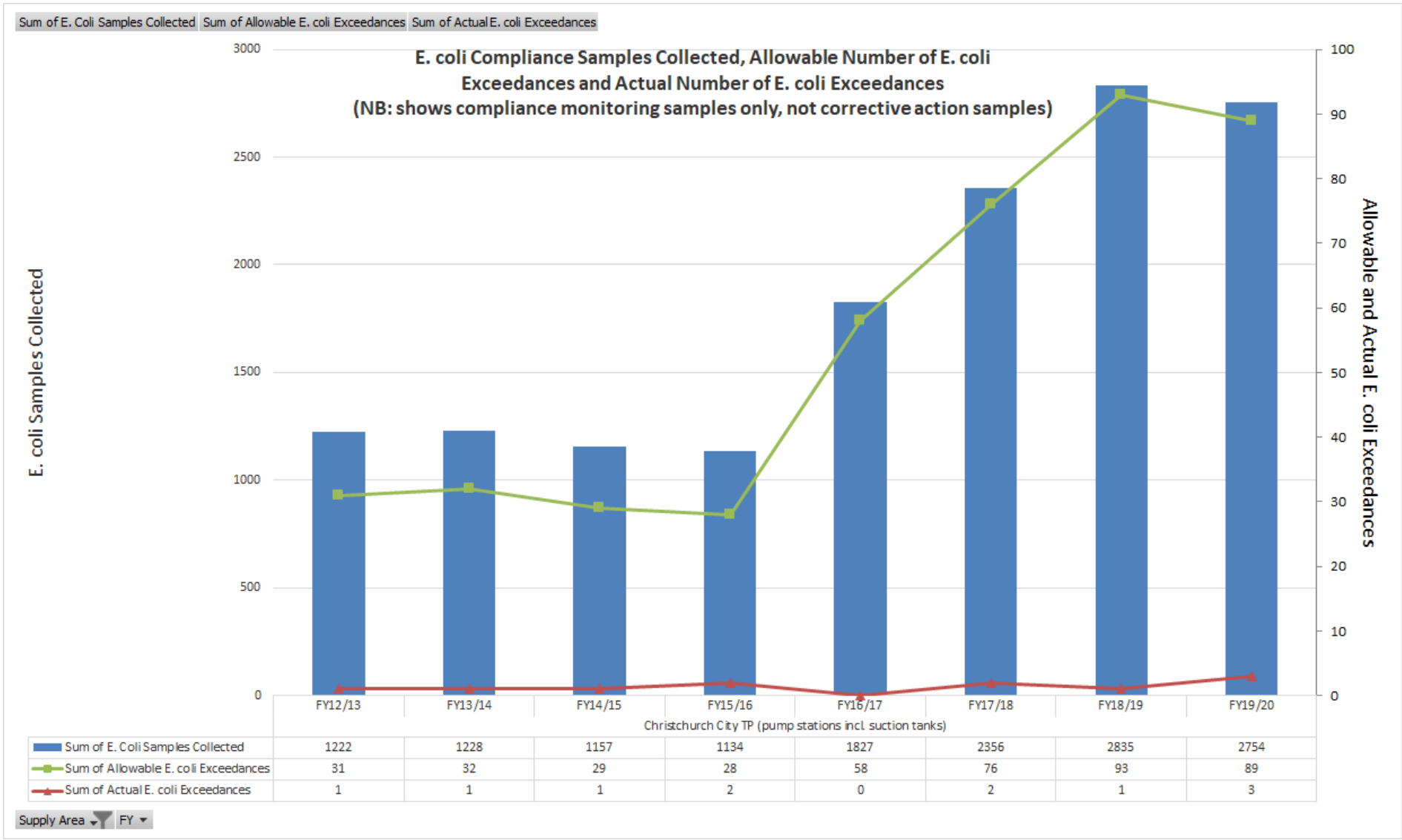


Figure 2-33: Christchurch City Treatment Plants – E. coli compliance samples collected (blue), allowable number of E. coli exceedances (green) and actual number of E. coli exceedances (red)

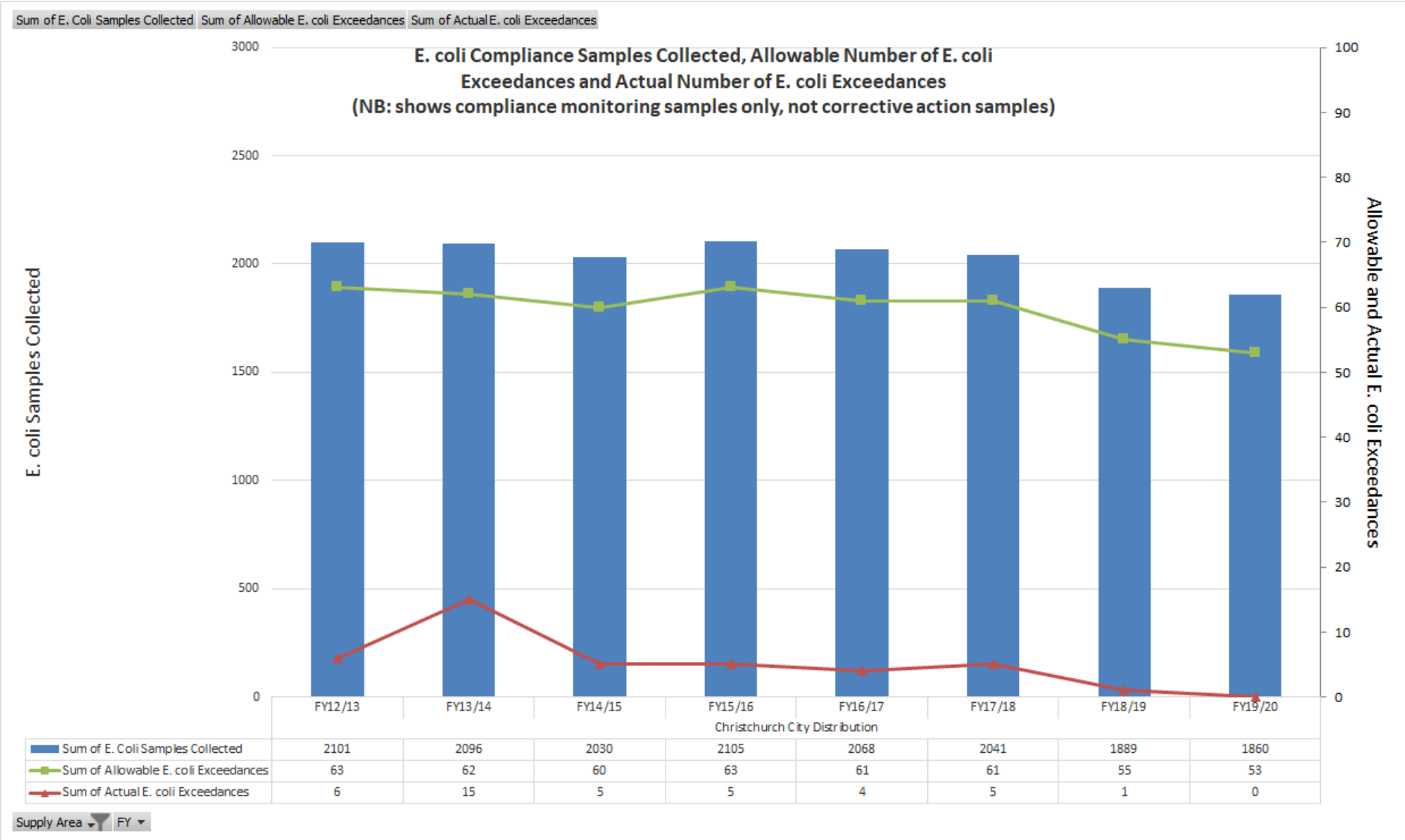
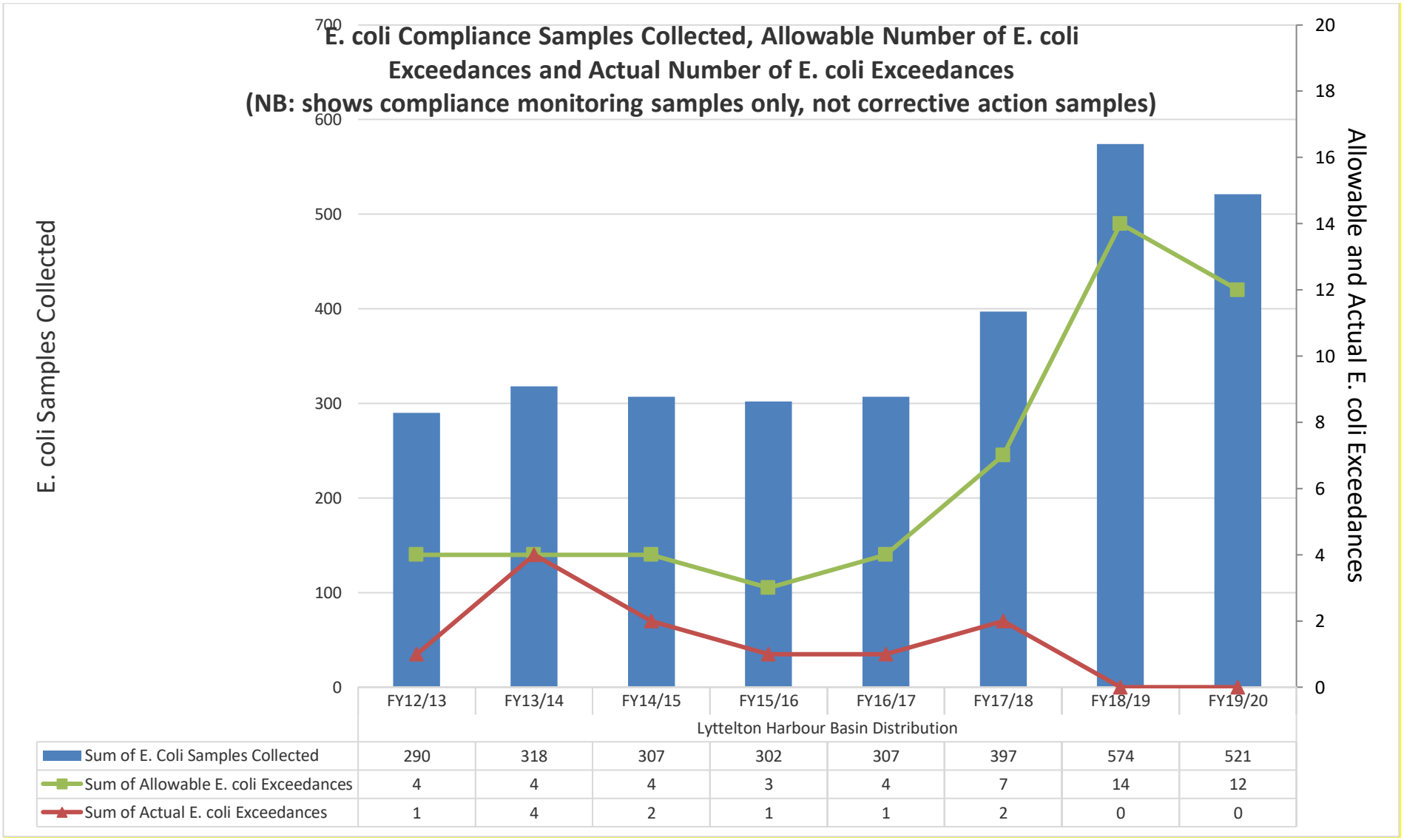


Figure 2-34: Christchurch City Distribution Network – E. coli compliance samples collected (blue), allowable number of E. coli exceedances (green) and actual number of E. coli exceedances (red)



	FY12/13	FY13/14	FY14/15	FY15/16	FY16/17	FY17/18	FY18/19	FY19/20
Sum of E. Coli Samples Collected	290	318	307	302	307	397	574	521
Sum of Allowable E. coli Exceedances	4	4	4	3	4	7	14	12
Sum of Actual E. coli Exceedances	1	4	2	1	1	2	0	0

Figure 2-35: Lyttelton Harbour Basin Distribution – E. coli compliance samples collected (blue), allowable number of E. coli exceedances (green) and actual number of E. coli exceedances (red)

2.8.2 Protozoa

The Council undertook a comprehensive protozoa monitoring programme in 2018 and 2019. Fortnightly samples were taken from shallow wells and analysed for Cryptosporidium and Giardia. Samples were collected in accordance with DWSNZ requirements and covered different weather patterns. No protozoa were found in any of the samples. The data was used to confirm the Protozoa log credit treatment requirement for the UV treatment plant at Main pump station which treats water from six Aquifer 1 wells. The sampling results are saved in TRIM 19/1037925.

The Council's protozoa monitoring results are well aligned with the results of the Ministry of Health's national baseline monitoring for protozoa in natural waters. The paper *Re-assessment of the Risks of Protozoa in New Zealand's Natural Waters*[14] shows that in eight years of protozoal monitoring none of the samples collected from shallow groundwater/spring sites have contained protozoa although 8% of samples contained E. coli. These sites were deliberately selected by the Ministry of Health because they were shallow or not secure, and had a history of occasionally containing E. coli.

2.8.3 Chemical determinands

The Council performs groundwater chemistry monitoring to improve understanding of groundwater quality. The water from each aquifer at each pump station site has historically been tested on a 5-year rolling programme. The Council has also established close working relationships with Environment Canterbury who is responsible for monitoring and safe guarding the general quality of Canterbury groundwater. Exchanges of water quality data take place on a regular basis.

In 2019 the Council commissioned a source water hydrochemistry assessment to determine geochemical variation across sites so that recharge sources could be better understood. The report (TRIM 19/1064915) confirmed that some bores that take water close to the foothills of Banks Peninsula (e.g. Palatine Well 1(no longer in use)) have a geochemical 'finger print' of water emerging from the volcanic rocks whereas other bores showed similar geochemistry to bores located in the alluvial plains aquifer system.

The Council has mapped the concentrations of key determinands in Christchurch's water supply wells. Figure 2-36 provides an example map. More maps are provided in Appendix D.

A comprehensive summary of all chemistry data is saved in TRIM 19/1083022.

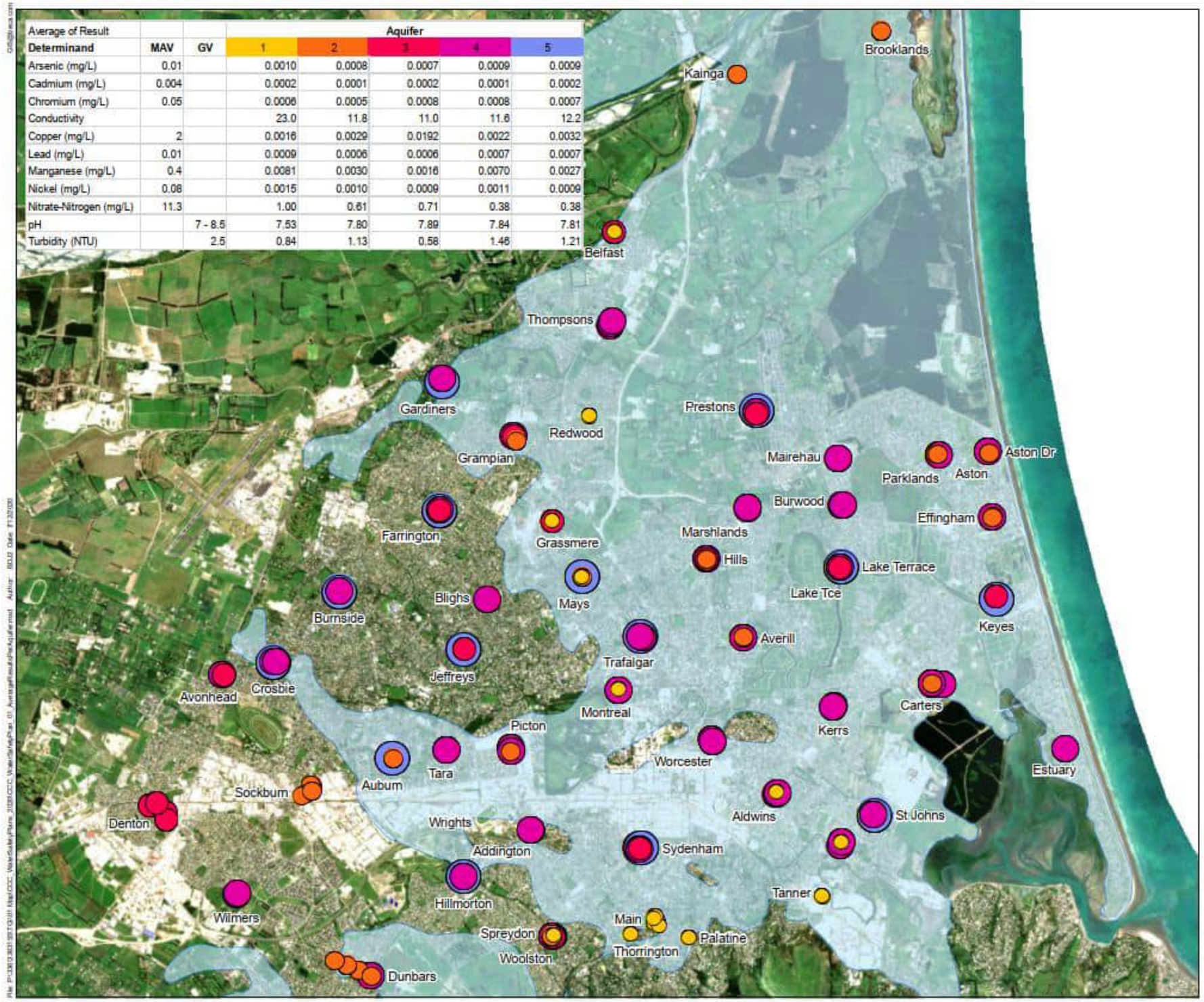
The following observations can be made:

- Cadmium: there were six cadmium results from 2009 where the chosen analytical detection limit (0.005 mg/L) was higher than the DWSNZ maximum acceptable value (MAV) (0.004 mg/L). More recent testing at those sites confirms that cadmium concentrations are below 50% MAV.
- Lead: there were two samples from wells at Spreydon pump station (0.051 mg/L in 2009) and Addington pump station (0.0066 mg/L in 2011) that were >50% MAV (0.005 mg/L). More recent testing at those sites confirms that lead concentrations are below 50% MAV.
- The chemistry data shows that all other results for tested parameters with a MAV were either below the detection limit or, where the result was above the detection limit, below 50% MAV.
- Conductivity: as outlined above, the well at Palatine has higher conductivity as it has a geochemical 'finger print' of water emerging from the volcanic rocks

[14] https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=3362

- Turbidity: sites where elevated turbidity has been observed (usually during start-up of the well pump) have sand filters or suction tanks that help settle out particles.
- pH: there are several wells with pH greater than the DWSNZ guideline value (GV) of 8.5 (at Spreydon, Brooklands, Montreal, Picton, Tara, Mairehau and Parklands pump stations). There are also several wells with pH below the GV of 7.0 (Lake Terrace, Carters, Kerrs, Spreydon, Main Pumps, St Johns, Picton and Sockburn). At most sites, water from different wells (and depths) is mixed prior to distribution in the network which generally results in the pH falling within the DWSNZ guideline range of 7.0 – 8.5. The distribution system pH data is contained within TRIM 19/1083022.
- Nitrate-nitrogen: while all sample results are well below the MAV of 11.3 mg/L there is an emerging trend of rising concentrations across the district. This is illustrated in Figure 2-37 which shows the maximum concentrations of nitrate-nitrogen in Council water supply wells for 2008–2020 and mean nitrate-nitrogen concentrations in private wells, collected by Environment Canterbury between 1957 and 2020. The map clearly shows that these elevated concentrations are associated with dairy farming on the Canterbury Plains.

Average of Result			Aquifer				
Determinand	**MAV**	**GV**	1	2	3	4	5
Arsenic (mg/L)	0.01		0.0010	0.0008	0.0007	0.0009	0.0009
Cadmium (mg/L)	0.004		0.0002	0.0001	0.0002	0.0001	0.0002
Chromium (mg/L)	0.05		0.0006	0.0005	0.0008	0.0008	0.0007
Conductivity			23.0	11.8	11.0	11.6	12.2
Copper (mg/L)	2		0.0016	0.0029	0.0192	0.0022	0.0032
Lead (mg/L)	0.01		0.0009	0.0006	0.0006	0.0007	0.0007
Manganese (mg/L)	0.4		0.0081	0.0030	0.0016	0.0070	0.0027
Nickel (mg/L)	0.08		0.0015	0.0010	0.0009	0.0011	0.0009
Nitrate-Nitrogen (mg/L)	11.3		1.00	0.61	0.71	0.38	0.38
pH		7 - 8.5	7.53	7.80	7.89	7.84	7.81
Turbidity (NTU)		2.5	0.84	1.13	0.58	1.46	1.21



Average Results for Each Aquifer 2008 - 2020

Aquifer

- 1
- 2
- 3
- 4
- 5

Coastal Confined Gravel Aquifer System

This map contains data derived in part or wholly from sources other than Beca, and therefore, no representations or warranties are made by Beca as to the accuracy or completeness of this information.

Map intended for distribution as a PDF document.
Scale may be incorrect when printed.

Map Scale @ A4: 1:100,000

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Client: Christchurch City Council
Discipline: GIS
Project: HDW WHSIP Delivery
Drawing No: GIS-3383155-WSP-01

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Figure 2-36: Average Concentrations of Select Chemical Determinands in Each Aquifer 2008 – 2020

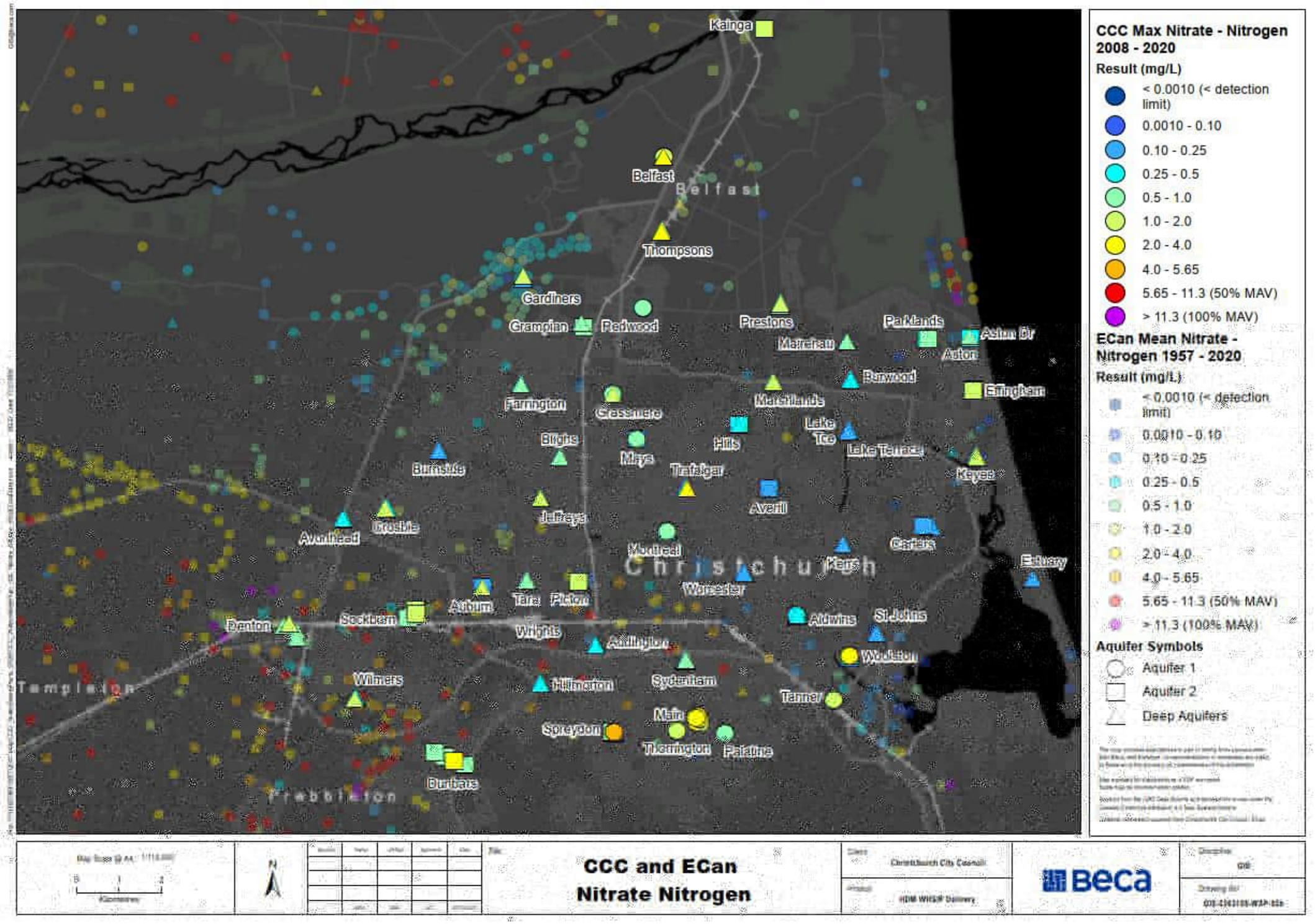

Figure 2-37: Nitrate-Nitrogen Concentrations – CCC Max 2008 – 2020 and Environment Canterbury Mean 1957 – 2020

2.8.4 Radiological determinands

Drinking-water may contain radioactive substances (radionuclides) that could present a risk to human health. The Council tests groundwater from all five aquifers on an annual basis, in accordance with DWSNZ Section 9. Table 2-14 shows the 2020 sampling results. A full summary of results is saved in TRIM 19/1037907.

Table 2-14: Radiological Sampling Results

Pressure Zone	Pump Station	Well	Depth	Aquifer	Determinand	Result	Units	Date
Central	Montreal	Well 2	32	1	Radon-222	11.5 ± 1.5	Bq/L	13/10/2020
Central	Montreal	Well 2	32	1	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Central	Montreal	Well 2	32	1	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Central	Montreal	Well 2	32	1	Radon-222	12.1+/-1.5	Bq/L	30/11/2021
Central	Montreal	Well 2	32	1	Total Alpha Concentration	<0.040	Bq/L	30/11/2021
Ferrymead	Woolston	Well 3	34	1	Radon-222	23.8 ± 2.6	Bq/L	21/10/2020
Ferrymead	Woolston	Well 3	34	1	Total Alpha Concentration	0.047 ± 0.014	Bq/L	21/10/2020
Ferrymead	Woolston	Well 3	34	1	Total Beta Concentration	<0.15	Bq/L	21/10/2020
Rawhiti	Keyes	Well 1	97	2	Radon-222	17.7 ± 2.0	Bq/L	13/10/2020
Rawhiti	Keyes	Well 1	97	2	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Rawhiti	Keyes	Well 1	97	2	Total Beta Concentration	<0.15	Bq/L	13/10/2020
West	Sockburn	Well 5	76	2	Radon-222	30.9 ± 3.2	Bq/L	21/10/2020
West	Sockburn	Well 5	76	2	Total Alpha Concentration	0.062 ± 0.015	Bq/L	21/10/2020
West	Sockburn	Well 5	76	2	Total Beta Concentration	<0.15	Bq/L	21/10/2020
West	Sockburn	Well 5	76	2	Radon-222	29.4 ± 3.0	Bq/L	10/12/2020
West	Sockburn	Well 5	76	2	Total Alpha Concentration	<0.031	Bq/L	10/12/2020
West	Sockburn	Well 5	76	2	Total Beta Concentration	<0.15	Bq/L	10/12/2020
Central	Hills	Well 5	116	3	Radon-222	20.7 ± 2.3	Bq/L	13/10/2020
Central	Hills	Well 5	116	3	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Central	Hills	Well 5	116	3	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Central	Hills	Well 7	82	3	Radon-222	18.3+/-2.0	Bq/L	13/11/2021
Central	Hills	Well 7	82	3	Total Alpha Concentration	<0.040	Bq/L	13/11/2021
Central	Hills	Well 7	82	3	Total Beta Concentration	<0.20	Bq/L	13/11/2021
Northwest	Farrington	Well 7	107	3	Radon-222	25.7 ± 2.8	Bq/L	22/10/2020
Northwest	Farrington	Well 7	107	3	Total Alpha Concentration	<0.031	Bq/L	22/10/2020
Northwest	Farrington	Well 7	107	3	Total Beta Concentration	<0.15	Bq/L	22/10/2020
Northwest	Wrights	Well 5	126	3	Radon-222	19.2 ± 2.2	Bq/L	13/10/2020
Northwest	Wrights	Well 5	126	3	Total Alpha Concentration	0.023 ± 0.012	Bq/L	13/10/2020
Northwest	Wrights	Well 5	126	3	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Central	Hillmorton	Well 2	123	4	Radon-222	15.1 ± 1.8	Bq/L	13/10/2020
Central	Hillmorton	Well 2	123	4	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Central	Hillmorton	Well 2	123	4	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Parklands	Marshlands	Well 2	150	4	Radon-222	25.9 ± 2.8	Bq/L	21/10/2020
Parklands	Marshlands	Well 2	150	4	Total Alpha Concentration	0.055 ± 0.015	Bq/L	21/10/2020
Parklands	Marshlands	Well 2	150	4	Total Beta Concentration	<0.15	Bq/L	21/10/2020
Parklands	Marshlands	Well 2	150	4	Radon-222	24.1 ± 2.5	Bq/L	10/12/2020
Parklands	Marshlands	Well 2	150	4	Total Alpha Concentration	<0.031	Bq/L	10/12/2020
Parklands	Marshlands	Well 2	150	4	Total Beta Concentration	<0.15	Bq/L	10/12/2020
Rawhiti	Keyes	Well 2	151	4	Radon-222	16.8 ± 2.0	Bq/L	13/10/2020
Rawhiti	Keyes	Well 2	151	4	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Rawhiti	Keyes	Well 2	151	4	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Central	Sydenham	Well 6	166	5	Radon-222	24.4 ± 2.7	Bq/L	21/10/2020
Central	Sydenham	Well 6	166	5	Total Alpha Concentration	0.065 ± 0.016	Bq/L	21/10/2020
Central	Sydenham	Well 6	166	5	Total Beta Concentration	<0.15	Bq/L	21/10/2020
Central	Sydenham	Well 6	166	5	Radon-222	25.2 ± 2.6	Bq/L	10/12/2020

Central	Sydenham	Well 6	166	5	Total Alpha Concentration	<0.031	Bq/L	10/12/2020
Central	Sydenham	Well 6	166	5	Total Beta Concentration	<0.15	Bq/L	10/12/2020
Northwest	Burnside	Well 10	202	5	Radon-222	16.5 ± 1.9	Bq/L	13/10/2020
Northwest	Burnside	Well 10	202	5	Total Alpha Concentration	<0.032	Bq/L	13/10/2020
Northwest	Burnside	Well 10	202	5	Total Beta Concentration	<0.15	Bq/L	13/10/2020
Brooklands Kainga	Kainga	Well 1	92	2	Radon-222	32.0+/-3.3	Bq/L	19/12/2021
Brooklands Kainga	Kainga	Well 1	92	2	Total Alpha Concentration	<0.040	Bq/L	19/12/2021
Brooklands Kainga	Kainga	Well 1	92	2	Total Beta Concentration	0.142+/-0.099	Bq/L	19/12/2021
Northwest	Auburn	Well 5	177	5	Radon-222	27.0+/-2.9	Bq/L	19/10/2021
Northwest	Auburn	Well 5	177	5	Total Alpha Concentration	0.03+/-0.020	Bq/L	19/10/2021
Northwest	Auburn	Well 5	177	5	Total Beta Concentration	<0.20	Bq/L	19/10/2021
Northwest	Gardiners	Well 1	232	5	Radon-222	25.7+/-2.8	Bq/L	19/10/2021
Northwest	Gardiners	Well 1	232	5	Total Alpha Concentration	<0.040	Bq/L	19/10/2021
Northwest	Gardiners	Well 1	232	5	Total Beta Concentration	<0.20	Bq/L	19/10/2021
Parklands	Prestons	Well 2	124	3	Radon-222	16.2+/-1.9	Bq/L	30/11/2021
Parklands	Prestons	Well 2	124	3	Total Alpha Concentration	<0.040	Bq/L	30/11/2021
Parklands	Prestons	Well 2	124	3	Total Beta Concentration	<0.20	Bq/L	30/11/2021
West	Wilmers	Well 1	150	4	Radon-222	24.0+/-2.6	Bq/L	30/11/2021
West	Wilmers	Well 1	150	4	Total Alpha Concentration	<0.040	Bq/L	30/11/2021
West	Wilmers	Well 1	150	4	Total Beta Concentration	<0.20	Bq/L	30/11/2021
Riccarton	Picton	Well 1	126	4	Radon-222	18.7+/-2.2	Bq/Kg	19/10/2021
Riccarton	Picton	Well 1	126	4	Total Alpha Concentration	<0.040	Bq/L	19/10/2021
Riccarton	Picton	Well 1	126	4	Total Beta Concentration	<0.20	Bq/L	19/10/2021
Ferrymead	Woolston	Well 3	34	1	Radon-222	9.0+/-1.3	Bq/L	30/11/2021
Ferrymead	Woolston	Well 3	34	1	Total Alpha Concentration	0.03+/-0.019	Bq/L	30/11/2021
Ferrymead	Woolston	Well 3	34	1	Total Beta Concentration	<0.20	Bq/L	30/11/2021
Rawhiti	Keyes	Well 1	97	2	Radon-222	21.0+/-2.4	Bq/L	19/10/2021
Rawhiti	Keyes	Well 1	97	2	Total Alpha Concentration	<0.040	Bq/L	19/10/2021
Rawhiti	Keyes	Well 1	97	2	Total Beta Concentration	<0.20	Bq/L	19/10/2021

The Total Alpha Concentration in three sample results was found to be greater than 50% MAV (0.05 Bg/L) with results between 0.055 and 0.065 (± 0.016) Bq/L. These results should be interpreted in the light of the World Health Organization 'Guidelines for Drinking-water Quality 4th Edition 2017'[15] which sets a screening value of 0.5 Bq/L for Total Alpha Activity, below which no further action is required. Furthermore, the WHO publication 'Management of Radioactivity in Drinking-water'[16] states that any health effects from radionuclides in drinking water are normally small, compared with the risks from microorganisms and chemicals, and will not be acute or immediate. Except in unusual circumstances, the radiation dose resulting from the ingestion of radionuclides in drinking-water is much lower than that received from other sources of radiation. Since the 2020 results are approximately 9 times lower than the WHO screening value it has been concluded that these concentrations pose no health risk. Repeat samples taken in December 2020 were all below 50% MAV.

[15] https://www.who.int/publications/i/item/9789241549950

[16] https://www.who.int/publications/i/item/9789241513746

2.8.5 Priority 2 determinands, disinfection by-products and other sampling

Disinfection by-product sampling was undertaken in June 2018 across the Christchurch and Lyttelton water supplies. There were no results that caused concerns. The data is stored in TRIM 18/916182. In early 2021 the Council will undertook another round of comprehensive disinfection by-products sampling across Christchurch. The sampling programme is contained in TRIM 20/1342771, again no results of concern were found, sampling results can be reviewed in TRIM 21/1390441.

Sampling for asbestos fibres in the distribution network was undertaken in December 2017. One out of 16 samples contained <1mm x 1mm chrysotile (white asbestos) and the assessment concluded that there was no health risk present. Sampling results and conclusion are contained in TRIM 20/1605086.

2.8.6 Water quality incidents and responses

This information is provided in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

2.9 Compliance with Drinking Water Standards for New Zealand (DWSNZ)

The DWSNZ set out the standards for drinking-water constituents or properties (determinands) and the criteria used to demonstrate whether a water supply complies with these standards. DWSNZ also contain population based criteria for monitoring and requirements for removal of microbiological contamination and protozoa.

Compliance with these standards was assessed annually by the Drinking Water Assessor and published in the Ministry of Health (MoH) Annual Report on Drinking-water Quality. With the recent change to Taumata Arowai as the regulator Council is continuing to undertaken quarterly internal compliance assessments to assess and record DWS compliance.

2.9.1 Compliance History

Table 2-15 to Table 2-18 summarise the compliance history for the Christchurch City and Lyttelton Harbour Basin water supplies, as published in the Ministry of Health's annual reports.

Table 2-15: Bacterial Compliance Summary

		Bacterial Compliance The MoH reports assess bacteriological monitoring and achievement solely for the distribution zones, on the basis that this best represents the water quality as received by consumers. However, water suppliers are also required to assess bacteriological compliance at the treatment plant.								
Zone Code	**Distribution Zone**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
BRO012BR	Brooklands / Kainga	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001CE	Central	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001PA	Parklands	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001RI	Riccarton	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001RP	Rocky Point	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001WE	West	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001NO	Northwest	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001FE	Ferrymead	n/a (zone newly registered in 2020/21)								☑
CHR001RA	Rawhiti	n/a (zone newly registered in 2020/21)								☑
LYT001LY	Lyttelton	☑	☒	☑	☑	☑	☑	☑	☑	☑
LYT001GO	Governors Bay	☑	☑	☑	☑	☑	☑	☑	☑	☑
LYT001DI	Diamond Harbour	☑	☑	☑	☑	☑	☑	☑	☑	☑

The bacterial compliance summary shows that:

- The Council has a strong track record of supplying compliant water to the community
- Lyttelton did not meet bacterial compliance in 2013/14 due to E. coli transgressions at reservoirs that occurred after a significant storm event. Two of the three affected reservoirs were repaired and the third reservoir has been replaced.

Table 2-16: Protozoal Compliance Summary

		Protozoal Compliance Protozoal achievement is assessed only at the treatment plant. Because the MoH reports are distribution zone-based, a zone was determined to achieve the protozoal standards if all treatment plants supplying the zone during the reporting period achieved the protozoal standards.								
Zone Code	**Distribution Zone**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
BRO012BR	Brooklands / Kainga	☑	☑	☑	☑	☑	☒	☒	☒	☒
CHR001CE	Central	☑	☑	☑	☑	☑	☒	☒	☒	☒
CHR001CE	Central								☑ (Main Pumps TP)	☑ (Main Pumps TP)
CHR001PA	Parklands	☑	☑	☑	☑	☑	☒	☒	☒	☒
CHR001RI	Riccarton	☑	☑	☑	☑	☑	☒	☒	☒	☒
CHR001RP	Rocky Point	☑	☑	☑	☑	☑	☒	☒	☒	☒
CHR001WE	West	☑	☑	☑	☑	☑	☒	☒	☒	☒
CHR001NO	Northwest	☒	☒	☒	☒	☒	☒	☒	☒	☒
CHR001FE	Ferrymead	n/a (zone newly registered in 2020/21)								☒
CHR001RA	Rawhiti	n/a (zone newly registered in 2020/21)								☒
LYT001LY	Lyttelton	☑	☑	☑	☑	☑	☒	☒	☒	☒
LYT001GO	Governors Bay	☑	☑	☑	☑	☑	☒	☒	☒	☒
LYT001DI	Diamond Harbour	☑	☑	☑	☑	☑	☒	☒	☒	☒

The protozoal compliance summary shows that:

- Until 2017/18, all supplies apart from the Northwest had provisional protozoal compliance
- The Northwest zone has not had protozoal compliance due to its shallow wells in an unconfined aquifer. A well replacement programme to replace 22 wells with deeper secure wells is almost complete, with just the two wells at Redwood left to replace, due for completion in 2022.
- All other Christchurch distribution zones lost protozoal compliance in 2017 when the expert found that none of the well heads assessed met DWSNZ secure bore water criterion 2, and as a consequence provisionally secure bore water status was revoked by the DWA. The well head security remediation programme to upgrade all well heads was undertaken in 2018-2020 and is now complete.

Even though the supplies do not meet the protozoa requirements of DWSNZ for technical reasons, no protozoa have been detected in samples (refer to data summarised in TRIM 19/1037925). The Council will apply to the DWA for secure bore water status for distribution zones where all wells meet all three criteria for secure bore water status. This is discussed in more detail in section 2.9.2.

Table 2-17: Chemical compliance summary

		Chemical Compliance								
Zone Code	**Distribution Zone**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
BRO012BR	Brooklands / Kainga	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001CE	Central	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001PA	Parklands	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001RI	Riccarton	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001RP	Rocky Point	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001WE	West	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001NO	Northwest	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001FE	Ferrymead	n/a (zone newly registered in 2020/21)								☑
CHR001RA	Rawhiti	n/a (zone newly registered in 2020/21)								☑
LYT001LY	Lyttelton	☑	☑	☑	☑	☑	☑	☑	☑	☑
LYT001GO	Governors Bay	☑	☑	☑	☑	☑	☑	☑	☑	☑
LYT001DI	Diamond Harbour	☑	☑	☑	☑	☑	☑	☑	☑	☑

All supplies are fully compliant with respect to the chemical compliance requirements of DWSNZ.

Table 2-18: Health Act compliance summary

		Health Act Compliance								
Zone Code	**Distribution Zone**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**
BRO012BR	Brooklands / Kainga	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001CE	Central	☑	☑	☒	☑	☒	☒	☑	☑	☑
CHR001PA	Parklands	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001RI	Riccarton	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001RP	Rocky Point	☑	☑	☑	☑	☑	☑	☑	☑	☑
CHR001WE	West	☑	☑	☑	☑	☒	☑	☑	☑	☑
CHR001NO	Northwest	☑	☑	☑	☑	☒	☑	☑	☑	☑
CHR001FE	Ferrymead	n/a (zone newly registered in 2020/21)								☑
CHR001RA	Rawhiti	n/a (zone newly registered in 2020/21)								☑
LYT001LY	Lyttelton	☑	☑	☑	☑	☑	☑	☑	☑	☑
LYT001GO	Governors Bay	☑	☑	☑	☑	☑	☑	☑	☑	☑
LYT001DI	Diamond Harbour	☑	☑	☑	☑	☑	☑	☑	☑	☑

There were several instances where compliance with Health Act requirements were not achieved. All instances relate to Section 69S (3) (b) where Council failed to notify the Medical Officer of Health of water supply interruptions greater than 8 hours prior to the interruption occurring (for planned interruptions) or within 24 hours after the interruption occurred (for unplanned interruptions). These non-compliances were addressed by procedural improvements, which are documented in processes *CSWS 015 Manage Planned Water Shut Off* and *CSWS 017 Manage Unplanned Emergency Water Supply Shut Off*.

In the 2020/21 year a 'potential breech' of the Health Act duties was identified by the DWA due to the treatment plants being non-compliant with respect to protozoa and so failing to meet Section 69V – Duty to comply with the Drinking Water Standards. This was escalated to a Designated Officer at Canterbury District Health Board to determine whether an offence had occurred, no further action has been taken.

2.9.2 Secure bore water

DWSNZ allows for secure bore water to be supplied untreated if the following criteria are met:

1. The bore water must not be directly affected by surface or climatic influences (i.e. the water is at least a year old, by which time any pathogens will have died)

2. The well head must provide satisfactory protection to prevent contamination of the water supply
3. E. coli must be absent in the bore water.

Until 22 December 2017 all Christchurch City and Lyttelton Harbour Basin water supplies, except Northwest Christchurch, had provisionally secure groundwater status which meant that no treatment was required. In Northwest Christchurch, a programme had been underway since 2012 to replace the shallow wells which did not meet the secure criteria with deeper wells, with the last two wells due for completion in 2019.

In accordance with the DWSNZ, the security of all water supply wells needs to be assessed by an expert in well head security assessments every five years. To demonstrate compliance with Criterion 2, the Council commissions external experts to assess the security of approximately 20% of its wells each year.

The well head inspections of 25 well heads undertaken in November 2017 found none of those well heads met Criterion 2 of the secure bore criteria in DWSNZ. Previous inspections had found that the wells did meet Criterion 2. The contrast reflected a more rigorous application of the DWSNZ applied by different experts following the Havelock North Drinking Water Inquiry. These assessments were discussed at a meeting attended by the Drinking Water Assessor, the authors of the well head inspection reports and Council technical staff on 19 December 2017.

On 22 December 2017 senior Council staff met with the Drinking Water Assessor and the Canterbury Medical Officer of Health to discuss implications of the Director-General of Health's statement issued on 20 December 2017 which brought the responsibilities under the Health Act and the DWSNZ to the attention of drinking water suppliers. At this meeting the Drinking Water Assessor indicated that in light of the Director-General of Health's statement and the findings included in recent draft reports on well head security, the groundwater security status for the Christchurch and Brooklands/Kainga water supplies would be changed from 'provisionally secure' to 'non-secure'. The letter confirming the change was received by staff later that afternoon, and stated that this meant the Council no longer complied with the DWSNZ for protozoa.

The Council was briefed on this issue and on 25 January 2018 approved a programme to improve the security of below ground well heads and to implement temporary chlorination, until the well heads were made secure. The purpose of the temporary chlorination was to mitigate the risk of contamination of the source water via unsecure well heads. This current temporary chlorination regime is described in Section 2.4.2.

The chlorination status of each pump station and the status of each well is shown on a dynamic map on the Council website: https://ccc.govt.nz/services/water-and-drainage/water-supply/water-chlorination/.

Work is underway to re-confirm compliance with DWSNZ bore water security criteria 1 and 2.

2.9.3 Bore water security Criterion 1

The Council will demonstrate the absence of surface influences (DWSNZ bore water security criterion 1) by groundwater age determinations and hydrogeological modelling:

- 17 groundwater samples from various aquifers were collected in July and September 2017 as part of a joint agency project (Environment Canterbury and CCC) and a report on groundwater age was issued in June 2018
- 7 groundwater samples were collected in late October 2018 and a report was issued in July 2019.
- 58 groundwater samples were collected in 2020.
- A further 10 groundwater samples were collected in early 2021 (awaiting results).

All sample results are summarised in Section 2.3.8. They confirm that all wells – except for three shallow wells in the Northwest zone which have been decommissioned and will be replaced by deep wells – meet the DWSNZ Criterion 1 requirements.

- Aqualinc, a specialist groundwater modelling provider has been engaged for groundwater modelling services. The modelling methodology has been subject to several iterations and reviews by a technical peer review panel of experts from ESR. This peer review is supported by the DWA and Ministry of Health. Modelling has now been completed. Groundwater age data determined by sampling will be compared with the modelling results.
- Upon successful completion of the modelling a report will be issued and this will be used to supplement evidence to determine the Class of water (December 2021 Draft Assurance Rules section 10.8.1).

2.9.4 Bore water security Criterion 2

To meet bore water security criterion 2, a comprehensive programme of works was undertaken in 2018-2020 (refer to Section 2.9.3) to upgrade wells to meet the existing Drinking Water Standards and to provide future proofing for likely more stringent DWSNZ requirements. Wellhead security assessments were carried out by an expert to confirm that the newly converted well heads and newly drilled wells meet DWSNZ bore water security criterion 2.

The Well Head Security Improvement Programme was a large undertaking to upgrade all of the city's wells not just to comply with Criterion 2 of the bore security criteria in DWSNZ, but to be in line with best practice and the anticipated changes to the DWSNZ.

This has included upgrading as many wells as possible from below-ground well heads to above-ground well heads. The Council has a standard design, developed in the late 2000s, for an above-ground well head that meets the rigorous interpretation of DWSNZ Criterion 2. During the 2010/11 earthquakes, wells built to the newer Council standard design performed well and, post-earthquake, the design required only minor amendments. This was reviewed and updated again at the start of the Well Head Security Improvement Programme and this design formed the basis of the upgrades. A functional design brief was developed and was issued to each design team to communicate the design process and requirements. The standard design provided consistency across sites and design teams. It was modified at each site to specify the orientation of the well head, the below-ground connection detail and altering the size of the well head to suit smaller wells and/or pumps.

The key points of the standard design for the Well head Security Improvement Programme are:

- Above ground well head design
- Retrofit grout seal around well casing
- Backflow prevention
- Seismic design
- Flow meters and level monitoring
- Bird-proofing.

Temporary below-ground remediation work was agreed with the expert to be acceptable for two years where the following criteria could be met:

- Artesian pressure remaining 0.1m above ground as the artesian pressure prevents contaminants entering the water supply. In the case of flooding above this level, the well would need to be isolated. Council flood modelling is undertaken using 50 year

and 200 year flood scenarios and modelling shows that none of the wells in this category are affected by the 50 year annual recurrence interval (ARI) flood.

- Chlorine dosing to remain on standby in case of artesian pressure dropping below 0.1m above-ground level
- Automatic re-starting of chlorine dosing based on local pressure readings
- Well head chamber upgrades to be effected including sealing the well chambers, wet floor alarms and sump pumps
- Air valves raised above 100-year flood level to mitigate inundation risk, in accordance with DWSNZ Guidelines Chapter 3, Figure 3.2 (sanitary protection of a typical bore)[17].

Seven well heads at three pump stations (Parklands, Averill and Kerrs) have received temporary below ground remediation. The wellheads at Aston and Woolston have recently been raised. Averill and Kerrs are old pump stations and need replacing. Replacement pump stations with new wells are planned to be complete by 2026 and 2027 respectively. It has been agreed with the well head security expert that the below-ground wells can remain in service until they are replaced, as that is the most prudent approach.

The network controllers will only use wells that are not yet secure if there is a significant additional demand for water (due to an event such as a major fire or a mains break) or if there is an infrastructure failure or power outage affecting our pump stations.

The DWSNZ currently require an expert in well head security to certify a well head as meeting the requirements of Criterion 2 for bore water security (a similar requirement for a Sanitary Bore head is included in the draft Drinking Water Quality Assurance Rules (Dec 2021)). Once all the well heads at a pump station have been signed off by the expert as meeting Criterion 2 or non-secure wells have been isolated, temporary chlorination will be turned off or reduced to 0.2 mg/L depending on the outcome of a risk assessment and depending on risk assessment of other hazards in the distribution zone.

2.9.5 Bore Water Security Criterion 3

When the secure bore status was removed on 22 December 2017 the then DWA (from Canterbury District Health Board, Community & Public Health) verbally confirmed that the loss was due to the bores not meeting bore water security criterion 2 and that bore water security criterion 3 was still satisfied by Council's ongoing drinking water monitoring programme as shown in Table 2-15.

[17] https://www.health.govt.nz/system/files/documents/publications/dwg-ch3-water-sources-jun19.pdf

3 Hazards and Hazardous Event Identification and Risk Assessment

The overarching Council risk assessment methodology and information relating to risk assessment, uncertainty and acceptability is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

The live Risk Table and associated Improvement Tables are located in TRIM: 20/714310.

Consideration was given to plausible combinations of hazards or hazardous events that result in an increased level of risk to the water quality. These combinations of hazards are presented in Section 3.3.

3.1 Site specific risk management plans

The Council has developed risk management plans for all primary pump stations and is currently also developing them for reservoirs. These plans provide information about the characteristics, features and risks that are unique and specific to the site. They also include site-specific documents, resources and risk and improvement tables. Where risks common to several pump station sites are described in the risk assessment table in section 3.2, the rating in the risk assessment table represents the worst case from the site-specific risk management plans.

TRIM://19/1174477 provides a register of site specific risk management plans with TRIM links to each plan). Table 3-1 lists the persons involved in the preparation of the site specific risk management plans.

Table 3-1: Staff involved in the preparation of site-specific risk management plans

Name	Position	Team	Organisation
Deepak Chouhan	Engineering Officer – Water Supply	Quality & Compliance	CCC
Melissa Patterson	Engineering Officer – Water Services	Water Services	CCC
Daniela Murugesh	Water Supply Security Engineer	Quality & Compliance	CCC
Sarah Hemmingsen	Senior Advisor Operational Policy	Quality & Compliance	CCC
Chris Mallet	Senior Network Controller	Network Operations	CCC
Grant Fraser	Senior Network Controller	Network Operations	CCC
Bruce West	Network Controller	Network Operations	CCC
Jess Carruthers	Network Operations Engineer	Network Operations	CCC
Ian Baker	Process Engineer	Network Operations	CCC
Andrew Batchelor	Contract Supervisor Reticulation & Maintenance	Water & Wastewater Operations	CCC
Graham Wardman	Contract Supervisor Reticulation & Maintenance	Water & Wastewater Operations	CCC
Zefanja Potgieter	Senior Resource Advisor	Asset Planning Water & Wastewater	CCC
Gijs Hovens	Team Leader Network Operations	Network Operations	CCC
Jeanette Gower	Team Leader Water & Wastewater Operations	Water & Wastewater Operations	CCC
Tim Drennan	Manager Service Excellence	Service Excellence	CCC
Veronica Zefferino	Team Leader Quality & Compliance	Quality & Compliance	CCC
Mayank Katira	Senior Asset Systems & Information Specialist	Asset Information Management	CCC

Name	Position	Team	Organisation
Craig McCauley	Asset Engineer Reticulation	3WW Asset Management	CCC
Irmana Garcia-Sampedro	Strategic Asset Engineer	Asset Information Management	CCC
Dale McEntee	Resource Consent Compliance Coordinator	Quality & Compliance	CCC
Grant Deeney	Project Manager	Water Supply & Wastewater Delivery	CCC
Prawindra Mukhia	Senior Project Manager	Water Supply & Wastewater Delivery	CCC
Mark Johnson	Team Leader 3WW Asset Management	3WW Asset Management	CCC
Mark Mullen	Team Leader Stormwater & Waterways Operations	Stormwater & Waterways Operations	CCC
Tallat Mehmood	Team Leader Water Supply & Wastewater Delivery	Water Supply & Wastewater Delivery	CCC
Don Gracia	Senior Engineer Mechanical	Technical Services & Design	CCC
Andrew Choe	Asset Systems & Information Specialist	Asset Information Management	CCC
Iris Brookland	Senior Technical Engineer Land Drainage	Stormwater & Waterways Operations	CCC
Kenton Winckles	Asset Engineer Mechanical/Civil	3WW Asset Management	CCC
Kawal Singh	Assistant Engineer Water/Environmental	Asset Planning Stormwater & Waterways	CCC
Julia Valigore	Specialist Advisor – Water/Environmental	Quality & Compliance	CCC
Grant Burgess	Engineering Officer Instrumentation, Electrical & Control	3WW Instrumentation, Electrical & Control	CCC
Nick Reuther	Senior Consent Planner		ECan
Jeff Gibson	Pump and Storage Field Staff		Citycare
Chris Barron	Pump and Storage Manager		Citycare

3.2 Risk Assessment Table

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Source - Groundwater	Source water (aquifer) receives chemical contamination	1.01	• Contaminated sites close enough to potentially affect groundwater quality • Consented activities, with non-conforming behaviour or poor consent conditions • Unconsented activities • Chemical/diesel spillage seeps into aquifer	☐	☐	☑	☐	Likely	Assumes: Unconfined aquifers, unsecure well heads, inadequate land use controls to protect aquifers from contamination, location and status of private wells unknown.	Major	Chronic harm to people (long-term exceedance of long-term chemical MAV). Most contaminants will appear over long period of time, contaminants appearing more suddenly likely to be hydrocarbons e.g. failed buried tank. Health impacts for hydrocarbons somewhat self-limiting due to taste and odour issues (people will avoid drinking very bad tasting or smelling water).	Extreme	• Routine inspection and maintenance of water supply assets • Building consent and HSNO processes and associated inspections • ECan groundwater quality monitoring reports • Well head security assessments • Pre-screening/ PSI/DSI Assessments • Site Specific Risk Management Plans • Water quality monitoring • Water supply connection application process • Customer complaints • Water quality monitoring • Listed Land Use Register (LLUR) of Hazardous Activities and Industries and List (HAIL) sites • Groundwater modelling	• Engagement with resource consent applications • Building consent and HSNO processes and associated inspections • Trade waste and stormwater audits • Liaison with ECan • Liaison with Council Contaminated Sites Officers • Programme to replace shallow wells with deep wells • CCC fuel tanks are all above ground • Well head security improvement programme • PSI/DSI Assessments • Monitoring known Council-owned assets that present a contamination risk • Controls under Land and Water Regional Plan and Christchurch District Plan • 3-yearly certification of fuel tanks • Mass balance checks on diesel volumes • Confined aquifer system • Dangerous goods	Unlikely	Depth to aquifer, and confining layers reduces influence from surface. Source aquifers have a significant depth of confining materials and often an upward artesian head. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation	Major	Rolling 5-yearly testing regime of all PS shows no history of chemical contamination in past 10 years. ECan's Land and Water Regional Plan (LWRP), Christchurch District Plan and other regulations manage activities to reduce risks to aquifers. Pre-screening for potential contamination undertaken for every pump station site in 2018 and 2019, and where required, followed up with preliminary site investigations and detailed site investigations including recommended remedial measures and shallow groundwater quality monitoring. Site-specific safety plan reviews include review of land use, and no contaminating activities identified in past 5 years. Majority of source aquifers believed to be too deep for contamination by nearby sites. Not all abandoned	Medium	Confident	Acceptable	CI03 PI14

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														legislation • Adoption of UKWIR guidelines for assessment of contaminated land • Maintain contamination monitoring, risk assessment and reactive processes				wells are mapped by ECan.				
Source - Groundwater	Source water (aquifer) receives microbial contamination from untreated wastewater	1.02	• Broken or leaking wastewater pipes • Wastewater overflows • Septic tanks	☑	☑	☐	☐	Likely	Assumes: Poor condition wastewater network, frequent overflows and poor condition septic tanks in close proximity to water supply wells, unconfined aquifers, young water in wells, shallow unsecure drinking water supply wells	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Alert from CDHB about illness in the community • Customer complaints • Well head security assessments • Site Specific Risk Management Plans • Pre-screening/ PSI/DSI Assessments • Routine inspection and maintenance of water supply assets • Water quality monitoring • Groundwater modelling • Groundwater age dating • Wastewater pipe defect mapping • Wastewater overflow monitoring and modelling	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with resource consent applications • Routine inspection and maintenance of water supply assets • Building consent process and associated inspections • Trade waste and stormwater audits • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • PSI/DSI Assessments • Monitoring known Council-owned assets that present a contamination risk • Controls under Land and Water Regional Plan and	Rare	Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history demonstrates DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off	Catastrophic		Medium	Reliable	Acceptable	CI03

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														Christchurch District Plan • Confined aquifer system • Reduced abstraction from shallow wells • Good asset records							
Source - Groundwater	Source water (aquifer) receives chemical or microbial contamination	1.03	Abandoned or improperly decommissioned private wells	☑	☑	☑	☐	Likely	Assumes: Poor condition private wells provide a direct contamination route to the aquifer, unconfined aquifers, no artesian pressure, young water in wells, shallow unsecure drinking water supply wells	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Alert from CDHB about illness in the community • Customer complaints • Well head security assessments • Site Specific Risk Management Plans • Pre-screening/ PSI/DSI Assessments • Routine inspection and maintenance of water supply assets • Water quality monitoring • Groundwater modelling • Groundwater age dating • Monitoring known Council-owned assets that present a contamination risk • ECan well data for private wells	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with resource consent applications • Routine inspection and maintenance of water supply assets • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • Controls under Land and Water Regional Plan • Confined aquifer system • Reduced abstraction from shallow wells • Good asset records	Rare	Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history demonstrates DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Initial groundwater modelling with simulated aquifer punctures (e.g. private well contamination path) for Effingham and Denton wells concluded that no young water would reach the wells. Location of private wells in relation to CCC water supply wells has been mapped and is also considered during wellhead security assessments. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a	Catastrophic		Medium	Reliable	Acceptable	CI03 CI04 PI16

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)										
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
																contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Source - Groundwater	Source water (aquifer) receives discharge from domestic or industrial processes, either directly or indirectly (excluding septic tanks)	1.04	Ground-source heating and cooling systems not maintained and causing heat exchanger fluids to contaminate the source water.	☐	☐	☑	☐	Possible		Major	Exceedance of the chemical MAV that affects <5,000 people	High	• Maintain contamination monitoring, risk assessment and reactive processes • Routine inspection and maintenance of water supply assets • Building consent process and associated inspections • Resource consent process and associated monitoring • Well head security assessments • Pre-screening/ PSI/DSI Assessments • Site Specific Risk Management Plans • Water quality monitoring • Customer complaints	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with Resource Consent applications • Building consent process and associated inspections • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • Pre-screening/PSI/DSI Assessments • Controls under Land and Water Regional Plan • Confined aquifer system • Double skinned heat exchangers prevent loss of heating/cooling fluid into aquifer	Unlikely	Most ground source heating systems have been installed post-earthquakes and mostly in the Central city and are discharging into aquifer 1. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation	Major	Reduced abstraction from aquifer 1 for public water supply means less people potentially affected.	Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Source - Groundwater	Water supply well receives water affected by microbial contamination from animals	1.05	Water abstracted from the well is less than 1 year old and animals are present in the 1-year source area	☑	☑	☐	☐	Likely	Assumes: Unrestricted land use in close proximity to water supply wells, unconfined aquifers, no artesian pressure, young water in wells, shallow unsecure drinking water supply wells.	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Well head security assessments • Site Specific Risk Management Plans • Water quality monitoring • Age dating of groundwater • Groundwater modelling • Routine inspection and maintenance of water supply assets	• Maintain contamination monitoring, risk assessment and reactive processes • Engagement with resource consent applications • Routine inspection and maintenance of water supply assets • Liaison with ECan • Programme to replace shallow wells with deep wells • Well head security improvement programme • Pre-screening/PSI/DSI Assessments • Controls under Land and Water Regional Plan and Christchurch District Plan • Confined aquifer system • Good asset records	Rare	Depth to aquifer, and confining layers reduces influence from surface Microbial monitoring history demonstrates DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Aqualinc modelling of 1 year travel times found that only wells at Main Pumps(aquifer 1) and Dunbars (aquifer 2) had travel times that reached the surface.	Catastrophic		Medium	Reliable	Acceptable	
Source - Groundwater	Water supply well receives water affected by agricultural land use and chemicals (e.g. nitrate)	1.06	• Application of fertiliser in the catchment or recharge zone • Land use intensification e.g. dairy conversions.	☐	☐	☑	☐	Possible	Assumes: Unrestricted land use in source water area	Major	Chronic harm to people (long-term exceedance of long-term chemical MAV).	High	• Groundwater modelling • Water quality monitoring • ECan groundwater quality modelling and monitoring reports	• Maintain contamination monitoring, risk assessment and reactive processes • Canterbury Water Management Strategy • Liaison with ECan • Controls under Land and Water Regional Plan • NES Freshwater 2020 limits land	Unlikely	5-yearly chemical monitoring of wells shows low levels of nitrate. Majority of Christchurch groundwater is sourced from the Waimakariri River which has a very low nitrate concentration. Groundwater modelling for ECan LWRP Plan Change 7	Major		Medium	Reliable	Acceptable	CI03 PI14

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														use intensification • Confined aquifer system • Submissions on Land and Water Regional Plan Changes		shows increasing nitrates from north of the Waimakariri river in the long term but still below MAV.						
Source - Groundwater	Groundwater nitrate concentrations much lower than the DWSNZ MAV may cause an increase in colorectal cancer rates	1.07	• Application of fertiliser in the catchment or recharge zone • Land use intensification e.g. dairy conversions.			☑		Rare	• Epidemiological studies have shown that nitrate may be a contributing factor to colorectal cancer at concentrations of less than 10% of the current MAV. • Groundwater modelling predicts increased nitrate concentrations from north of the Waimakariri river entering the deeper aquifers of the Christchurch West Melton groundwater system.	Major	Chronic harm to people	Low	• Water quality monitoring • Alert from CDHB about illness in the community • Epidemiological studies	• Maintain contamination monitoring, risk assessment and reactive processes • Canterbury Water Management Strategy • Liaison with ECan • Controls under Land and Water Regional Plan • NES Freshwater 2020 limits land use intensification • Confined aquifer system • Submissions on Land and Water Regional Plan Changes	Rare		Major		Low	Estimate	Acceptable	PI14 PI19 PI20
Source - Groundwater	Water supply well is affected by saline water intrusion	1.08	Shallow well near the coast could draw saline groundwater	☐	☐	☑	☐	Possible	Assumes: Shallow drinking water supply wells near the coast, unconfined aquifer, no alternative pump stations for supply	Major	Systems significantly compromised and abnormal operation	High	• Water quality monitoring • Customer complaints	• No shallow wells near coast • System redundancy	Unlikely	Shallow water supply wells near coast have been decommissioned and replaced with deeper wells. Monitoring data shows low conductivity and salinity	Minor		Low	Reliable	Acceptable	CI03 PI14
Source - Groundwater	Not enough source water available for abstraction	1.09	• Resource consent limitations: insufficient upper limit on global water take consent • Water availability reduces over	☐	☐	☐	☑	Possible	Assumes: Insufficient head room in Council's water take consent, insufficient control on other groundwater takes, increasing demand due to population growth, climate change and increasing	Catastrophic	Major disruption of service (over 24 hours and >500,000 customer hours)	High	• Groundwater take flow monitoring • Groundwater level monitoring • Water supply model for current and future demand scenarios	• Sufficient headroom in Council's groundwater take consent • Engagement with resource consent applications • Liaison with ECan • Controls under	Rare	ECan data shows that there is sufficient water in the aquifers and the only permissible consumptive use for new groundwater take consents is for community drinking water supplies.	Catastrophic		Medium	Confident	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
			time due to more groundwater take consents issued to private well owners • Ground-source heating and cooling systems abstract too much water from deeper aquifers used for public water supply • Increased demand for water due to population growth, leakage and climate change						leakage due to deteriorating water supply pipe network					Land and Water Regional Plan • Annual water conservation campaign • Water restrictions if required • Masterplan for growth areas		Infrastructure for growth is already provided for the next years with budget in the Long Term Plan and Infrastructure Strategy for water supply infrastructure for growth. Global groundwater consent is approx. 72 million m^3 per year whereas current take is approx. 50 million m^3 per year.						
Source - Groundwater	Not enough source water available for abstraction	1.10	Water abstraction / pumping exceeds recharge rates or causes well to collapse	☐	☐	☐	☑	Possible	Assumes: Over pumping of the well beyond its capacity, no alternative pump stations for supply	Moderate	Significant modification to normal operation but manageable (as only one well affected)	Medium	• SCADA alarms and associated maintenance • Groundwater level monitoring • Groundwater take flow monitoring • SCADA alarms	• Network Control staffing and processes • Step tests and sand tests undertaken during well development to determine the safe pumping rate for each well • Flow limiters on some wells • System redundancy	Unlikely		Moderate		Medium	Reliable	Acceptable	PI07
Source - Groundwater	Emerging contaminants affect drinking water supply wells	1.11	• PFOS and PFOA used in fire-retardant foams, particularly in Wigram and area around the airport • PFOS/PFOA	☐	☐	☑	☐	Possible	Assumes: Use of PFOS and PFOA in source water catchments, unconfined aquifers, no artesian pressure, shallow unsecure drinking water supply wells.	Major	Exceedance of the chemical or radiological MAV that affects <5,000 people	High	• Test for PFOS and PFOA • PFAS Joint Agency Working Group	• Confined aquifer system • Programme to replace shallow wells with deep wells • Well head security improvement programme	Rare	There are no water supply wells near Wigram and the airport. 27 Washbournes Rd located hydraulically down-gradient from Sockburn pump station.	Major		Low	Estimate	Acceptable	PI14

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
			found in shallow groundwater at [redacted] (information provided by ECan)											• Pre-screening/PSI/DSI Assessments		Testing in distribution system showed no presence of PFOS/PFOA Testing by Christchurch International Airport Ltd and FENZ has not found any contamination. Depth to aquifer, and confining layers reduces influence from surface. Source aquifers have a significant depth of confining materials and often an upward artesian head. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation					
Source - Groundwater	Radioactivity in the groundwater affects drinking water supply wells	1.12	Principally by: • leaching of radionuclides from rocks and soils into water • deposition of radionuclides from the atmosphere.	☐	☐	☑	☐	Unlikely	According to DWSNZ Guidelines chapter 9, naturally occurring radionuclides from both these sources account for almost the entire radioactivity present in New Zealand drinking-waters. Concentrations are as	Moderate	According to DWSNZ Guidelines chapter 9, in the radiological context, the MAV is intended to indicate a level above which the radioactive content of the water should be investigated further and an assessment of all relevant radiological	Medium	• Water quality monitoring		Unlikely	Is naturally occurring radiation which cannot be prevented. Annual radiological sampling has not detected any concentrations exceeding the MAV (highest concentration was approx. 55-65%	Moderate		Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
									variable as the nature of the soils and rocks themselves.		issues undertaken. The MAV is thus more of a guideline than necessarily an absolute maximum. It is also intended to be clear however, that at levels below the MAV, there is no need for further assessment.					MAV for total alpha activity).						
Treatment	Contaminated water getting into the bore/ well from the surface	2.01	• Contamination sources (e.g. stock) too close to the well head • Below-ground wellhead not secure (leaking cable glands etc.) • Well head is below-ground and has water ponding • Well is in low lying land or flood prone area	☑	☑	☑	☐	Likely	Assumes: Contamination sources in close proximity to water supply wells, unconfined aquifers, young water in wells, flood prone wells, shallow unsecure drinking water supply wells with poor condition below ground well heads	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Routine inspection and maintenance of water supply assets • Well head security assessments • Pre-screening/ PSI/DSI Assessments • Site Specific Risk Management Plans • Customer complaints • Water quality monitoring	• Routine inspection and maintenance of water supply assets • Programme to replace shallow wells with deep wells • Well head security improvement programme • Confined aquifer system • Majority of well heads fenced off or inside locked chamber • Temporary chlorination of unsecure wells with below ground well heads • Wells in locations vulnerable to flooding are turned off when heavy rain is forecast • UV treatment at Main Pumps	Rare	Wells mostly in urban and suburban areas with no stock nearby. Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history and age dating of water has shown no concerning data DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Site specific risk management plans looked at this for each site in 2019 and 2020. No more flood prone wells except Main Pumps wells which are UV treated. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and	Catastrophic		Medium	Confident	Acceptable	CI03 PI10

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
																dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Treatment	Contaminated water getting into the bore/ well from the surface	2.02	Shallow well is situated near a waterway with potential hydraulic connection to it	☑	☑	☑	☐	Likely	Assumes: Waterways in close proximity to water supply wells, unconfined aquifers, young water in wells, flood prone wells, shallow unsecure drinking water supply wells with poor condition well heads	Catastrophic		Extreme	• Alert from CDHB about illness in the community • Customer complaints • Well head security assessments • Site Specific Risk Management Plans • Routine inspection and maintenance of water supply assets • Water quality monitoring • Groundwater modelling • Groundwater age dating	• Programme to replace shallow wells with deep wells • Well head security improvement programme • Temporary chlorination of unsecure wells with below ground well heads • UV treatment at Main Pumps	Rare	Microbial monitoring history and age dating of water has shown no concerning data DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Remaining shallow wells near a waterway are either treated (Main Pumps, UV treatment) or currently isolated (Palatine) and would only be put back in service during a peak demand day with temporary chlorination activated. The shallow well at Palatine will be abandoned when replacement well has been drilled. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution	Catastrophic		Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
																• Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Treatment	Contaminated water getting into the bore/ well from the piped network (backflow)	2.03	Backflow from piped network (not all bores equipped with backflow prevention devices)	☑	☑	☑	☐	Possible		Moderate	If contaminated water from the distribution system was able to get into the bore then this would result into a minor contamination due to significant dilution.	Medium	• Routine inspection and maintenance of water supply assets • Backflow prevention audits • Water quality monitoring • Well head security assessments • Site Specific Risk Management Plans	• Pump with non-return valve fitted • Air gaps in suction tanks • Non-return valves installed on outflows • Well head security improvement programme • Positive hydraulic pressure on artesian wells	Unlikely		Moderate		Medium	Reliable	Acceptable	
Treatment	Water is unable to be pumped from wells	2.04	Pump failure - Christchurch City	☐	☐	☐	☑	Likely	Assumes: Poor condition pumps, no standby pumps or spares, no redundancy in water supply network, no storage available	Moderate	Significant modification to normal operation but manageable	High	• SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Customer complaints	• Network Control staffing and processes • Routine inspection and maintenance of water supply assets • Proactive and reactive maintenance by Contractor • Water supply asset renewals programmes • System redundancy • Standby pumps • Contractor maintains stock of critical parts and fittings • Storage in suction tanks and reservoirs • Contract plans • Use of tankered water	Unlikely	Standby pumps at major stations Good redundancy in system due to integrated network.	Moderate		Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Treatment	Water is unable to be pumped from wells	2.05	[redacted]	☐	☐	☐	☑	Likely	Assumes: Poor condition pumps, no standby pumps or spares, no redundancy in water supply network, no storage available	Major	[redacted]	Extreme	• SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Customer complaints	• Network Control staffing and processes • Routine inspection and maintenance of water supply assets • Proactive and reactive maintenance by Contractor • Contractor maintains stock of critical parts and fittings • Water supply asset renewals programmes • System redundancy • Standby pumps • Two connections between Lyttelton Harbour Basin and city networks • Storage in suction tanks and reservoirs • Contract plans • Use of tankered water	Unlikely	Standby pumps at major stations. Two pipelines to Lyttelton through road and rail tunnels. New stainless steel pipe through road tunnel. Two submarine pipelines to Diamond Harbour. Reservoirs in Lyttelton Harbour Basin can continue to supply water during a pump outage.	Major		Medium	Reliable	Acceptable	
Treatment	Water is unable to be pumped from wells	2.06	Power failure	☐	☐	☐	☑	Possible	Assumes: No standby generators, no redundancy in water supply network, no storage available	Major	Systems significantly compromised and abnormal operation. Multiple pump stations could be affected by a power failure.	High	• SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Planned outage alerts	• Network Control staffing and processes • Diesel generators and diesel pumps at many pump stations • Mobile generators • Storage in suction tanks and reservoirs • System redundancy • Supply from	Possible	Post-earthquake Orion upgraded the power system to create a resilient ring feed for the city.	Minor	Ability to run the entire city on generators (on ripple control) unless it is a peak day in which case demand is down as customers can't use appliances due to power failure and so demand for water will be lower.	Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														neighbouring zones • Proactive and reactive maintenance by Contractor • Contract plans • Use of tankered water								
Treatment	Water is unable to be pumped from wells	2.07	Catastrophic failure due to natural hazards (e.g. floods, earthquakes)	☐	☐	☐	☑	Unlikely		Catastrophic	Complete failure of systems. High level of monitoring and incident management required. Major disruption of service (over 24 hours and >500,000 customer hours). A natural disaster could affect multiple wells at the same time	High	• Natural disaster (earthquake/ flood) • Severe weather warning	• Emergency Management and Business Continuity Plans in place • Participation in Canterbury Drinking Water Reference Group • System redundancy • Storage in suction tanks and reservoirs • IDS and CSS specify resilient materials and design • Seismic valves on reservoirs • Use of sub-zones • Use of tankered water	Unlikely		Major	System redundancy means that water can be supplied from other wells and reservoirs. Worst affected areas can be valved off in sub-zones so that less people are affected. Infrastructure built since the earthquakes is much more resilient. Water can be provided by tankers in an emergency.	Medium	Reliable	Acceptable	
Treatment	Water is unable to be pumped from wells	2.08	Damage to the pump or well head	☐	☐	☐	☑	Possible		Moderate	Significant modification to normal operation but manageable. Likely to only affect one or two wells at a time	Medium	• SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets	• Network Control staffing and processes • Standard secure design for new well heads • System redundancy • Well head security improvement programme • Majority of well heads fenced off or	Unlikely		Moderate		Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														inside locked chamber								
Treatment	Introduction of contaminating material into the pump station pipework	2.09	Significant pressure fluctuations resulting in negative pressure in poor condition pump station pipework allows contamination to enter, pump station supplies >5,000 people	☑	☐	☑	☐	Possible	Assumes: Poor condition pump station pipe work, poor control of pump stop/start (no variable speed drive or soft starter), contaminated shallow groundwater	Major	Minor microbial contamination that affects >5,000 people. Contamination in ground water expected to be low	High	• SCADA alarms and associated maintenance • Pressure monitoring	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' register • Network Control staffing and processes • Audits of all contractors' maintenance protocols and activities, and staff training • Water supply asset renewals programmes • Emergency Management and Business Continuity Plans in place • Proactive and reactive maintenance by Contractor • Backflow prevention devices • Variable speed drives or soft starters on most pumps • Post-repair disinfection and water quality testing • Contract plans • Contractor stand-down for specific diseases	Unlikely	Low level of unexplained transgressions at pump stations.	Major		Medium	Reliable	Acceptable	CI03 PI07

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Treatment	Introduction of contaminating material into the pump station pipework	2.10	Significant pressure fluctuations resulting in negative pressure in poor condition pump station pipework allows contamination to enter, pump station supplies <5,000 people	☑	☐	☑	☐	Possible	Assumes: Poor condition pump station pipe work, poor control of pump stop/start (no variable speed drive or soft starter), contaminated shallow groundwater	Moderate	Minor microbial contamination that affects <5,000 people. Contamination in ground water expected to be low	Medium	• SCADA alarms and associated maintenance • Pressure monitoring	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' register • Network Control staffing and processes • Audits of all contractors' maintenance protocols and activities, and staff training • Water supply asset renewals programmes • Emergency Management and Business Continuity Plans in place • Proactive and reactive maintenance by Contractor • Backflow prevention devices • Variable speed drives or soft starters on most pumps • Post-repair disinfection and water quality testing • Contract plans • Contractor stand-down for specific diseases	Possible	Low level of unexplained transgressions at pump stations.	Moderate		Medium	Reliable	Acceptable	CI03 PI07
Treatment	Introduction of contaminating material into the	2.11	Standard hygiene practices not adhered to by	☑	☑	☑	☐	Likely	Assumes: No standard hygiene practices, unqualified and inexperienced	Major	Minor microbial contamination that affects >5,000 people.	Extreme	• Maintain contamination monitoring, risk assessment and	• Approved Water Installer schemes • Audits of all contractors'	Possible	Audit of contractors controls risk of poor behaviour.	Moderate		Medium	Reliable	Acceptable	PI12

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
	pump station pipework		maintenance contractor and/or subcontractors						contractors, contaminating material in work site		Contaminants likely to be at low concentrations.		reactive processes • Water quality monitoring • QA checks	maintenance protocols and activities, and staff training • Construction monitoring to ensure compliance • Maintenance contractor chain of cleanliness • Chlorination and water quality testing required before assets are brought back into service. • Contract plans • Contractor stand-down for specific diseases • Permit to Work process		Major works require a permit to work and associated commissioning procedures which include water quality sampling and chlorination.						
Treatment	Introduction of contaminating material into the pump station pipework	2.12	Sand ingress from over-pumping of wells or failure of sand filters.			☑	☒	Likely		Minor	Local exceedance of aesthetic GV (turbidity)	Medium	• Customer complaints • Water quality monitoring	• Network Control staffing and processes • Encourage water conservation • System redundancy • Step tests and sand tests undertaken during well development to determine the safe pumping rate for each well • Monitor pumping rates • Sand filters and/or suction tanks to settle out sand"	Possible	Experienced network controllers maintain sustainable pumping rates to prevent over-pumping.	Minor		Medium	Reliable	Acceptable	PI10

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Treatment	Temporary chlorination: Failure to adequately disinfect with chlorine	2.13	Equipment set up or failure, supplied hypochlorite or operator error leads to under-dosing in the network	☑	☐	☐	☐	Almost Certain	Assumes: Poorly designed and installed chlorination equipment, incompetent operators, temporary nature of the dosing systems means that the target dose is not always achieved.	Catastrophic	Assumes source water contamination. Some pump stations supply >5,000 people.	Extreme	• Water quality monitoring • Staff and maintenance contractor observations	• Maintain contamination monitoring, risk assessment and reactive processes • Programme to replace shallow wells with deep wells • Confined aquifer system • Well head security improvement programme • Proactive and reactive maintenance by Contractor • O&M manuals and SOPs	Rare	DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells.	Catastrophic		Medium	Confident	Acceptable	
Treatment	Temporary chlorination: Contamination of the water supply with excessive chlorine.	2.14	Equipment failure, supplied hypochlorite or operator error leads to over-dosing, exceeding the MAV (5 mg/l).	☐	☐	☑	☐	Almost Certain	Assumes: Poorly designed and installed chlorination equipment, incompetent operators, temporary nature of the dosing systems means that the target dose is not always achieved.	Major	Exceedance of the chemical MAV that affects <5,000 people	Extreme	• Alert from CDHB about illness/injury in the community • Customer complaints • Water quality monitoring • Staff and maintenance contractor observations	• Maintain contamination monitoring, risk assessment and reactive processes • Audits of all contractors' maintenance protocols and activities, and staff training • Proactive and reactive maintenance programmes • O&M manuals and SOPs and SOPs Tracking of chlorine delivery to site with comparison of previous demand	Unlikely		Major		Medium	Reliable	Acceptable	
Treatment	Formation of disinfection by-products due to chlorination	2.15	Chlorine dose reacting with existing biofilm and mineral deposits	☐	☐	☑	☐	Possible		Major	Exceedance of the chemical MAV that affects >5,000 people	High	• Customer complaints • Water quality monitoring	• O&M manuals and SOPs • Proactive and reactive maintenance	Rare	Sampling found low level of by-products below 50% MAV. Potential for by-product formation	Major		Low	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														programmes • Maintain contamination monitoring, risk assessment and reactive processes		was assessed and is considered low due to good source water quality.						
Treatment	Cross-contamination between Council wastewater and water supply facilities	2.16	• Service person (e.g. electrical contractor) services both wastewater and water supply sites and transfers contamination water supply station or wellhead. • Tara PS building contains both water supply and wastewater electrical and control services, risk of cross-contamination	☑	☐	☑	☐	Possible	Has the potential to cause microbial contamination of surfaces rather than components that are in contact with the water.	Major	Major microbial contamination, possibly deaths expected, that affects <5,000 people.	Medium	• Water quality monitoring • Alert from CDHB about illness in the community • Customer complaints	• Audits of contractors' maintenance protocols and activities, and staff training • Permit to Work process • Maintenance contractor chain of cleanliness • Signage and specific SOPs at Tara Pump Station	Unlikely	All contractors working on Council water supply and wastewater assets have to undertake induction training which raises awareness of contamination risk.	Major		Medium	Reliable	Acceptable	PI11
Treatment	Turbidity and turbidimeter issues at the UV treatment plant (only relevant to Main Pumps UV plant)	2.17	• High turbidity water from groundwater water source • Turbidity meter failure • Turbidity meter not calibrated	☑	☑	☑	☐	Possible		Major	Has the potential to cause minor microbial contamination affecting >5,000 people as good quality groundwater is used as the sole source for the UV treatment plant.	High	• SCADA alarms • Water Outlook compliance report • Water quality monitoring • Alert from CDHB about illness in the community • Customer complaints	• Confined aquifer system • Groundwater source with low turbidity • Suction tank allows particles to settle out prior to UV treatment • If turbidity exceeds 2 NTU for a 3 minute period the pumps will automatically stop and the UV plant will shut down • Treatment plant automatically shuts down under	Possible	Source groundwater of very high quality with low turbidity. Suction tank helps settle out solids prior to UV treatment. Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history and age dating of water has shown no concerning data DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence	Moderate	Automatic plant shut down on adverse conditions. System redundancy means that distribution zone can be supplied from other pump stations and reservoirs.	Medium	Confident	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														low intensity, high flow, pressure transient or loss of power • 14 other primary stations within the Central zone can supply water if Main Pumps shuts down as a result of a UV failure • Storage in reservoirs and suction tanks • Weekly validation of turbidity meter, quarterly calibration		of young water in operational wells. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Treatment	UV System operating outside of validated conditions (only relevant to Main Pumps UV plant)	2.18	• There is no deactivation of bacteria and protozoa because the UV system does not work or inadequate UV intensity at the required wavelength • Too much flow passing through • UV ineffective because turbidity is too high • UV lamp fails	☑	☑	☐	☐	Possible		Major	Has the potential to cause minor microbial contamination affecting >5,000 people as good quality groundwater is used as the sole source for the UV treatment plant.	High	• SCADA alarms • Water quality monitoring • Staff and maintenance contractor observations • Water Outlook compliance report • Alert from CDHB about illness in the community • Customer complaints	• Confined aquifer system • Two UV units operate on a duty/standby arrangement • Routine cleaning and maintenance schedule for lamp sleeves and UV sensor • Regular replacement of UV lamps • Flow moderated UV dose • Treatment plant automatically shuts down under low intensity, high flow, pressure transient or loss of power • 14 other primary stations within the Central zone can supply water in the	Unlikely	Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history and age dating of water has shown no concerning data DWSNZ bacterial compliance for the last 5 years. Groundwater age dating shows absence of young water in operational wells. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution	Insignificant	Automatic plant shut down on adverse conditions. System redundancy means that distribution zone can be supplied from other pump stations and reservoirs.	Low	Confident	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														event of a UV failure at Main Pumps • Storage in reservoirs and suction tanks • Plant complies with the DWSNZ requirements and is third party accredited		• Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Treatment	Failure of the UV system (only relevant to Main Pumps UV plant)	2.19	UV quartz sleeve failure releases mercury vapour and quartz glass into the water in the distribution system	☐	☐	☑	☐	Possible		Major	Exceedance of the chemical MAV that affects >5,000 people	High	• SCADA alarms • Inspections • Alert from CDHB about illness in the community • Customer complaints	• Pressure switch • Treatment plant automatically shuts down under low intensity, high flow, pressure transient or loss of power • 14 other primary stations within the Central zone can supply water in the event of a UV failure at Main Pumps • Storage in reservoirs and suction tanks	Unlikely	Regular maintenance and lamp replacement schedule (based on lamp hours)	Major	Plant will immediately shut down in case of a UV lamp failure (causing low intensity)	Medium	Confident	Acceptable	
Treatment	Failure of the UV system (only relevant to Main Pumps UV plant)	2.20	Disinfection stops due to power failure	☑	☑	☐	☐	Possible		Major	Minor microbial contamination that affects >5,000 people	High	• SCADA alarms • Power outage map • Notifications from power company for scheduled power outages • Water quality monitoring • Alert from CDHB about illness in the community • Customer complaints	• Confined aquifer system • Diesel generator on site • Station will stop completely until the diesel generator has been started and accepts load. • The UV valves will be closed and the UV warmup cycle will begin again and the pumps can be operated once the UV is ready. • 14 other primary	Unlikely	Diesel generator on site. Post-earthquake Orion upgraded the power system to create a resilient ring feed for the city. Depth to aquifer, and confining layers reduces influence from surface. Microbial monitoring history and age dating of water has shown no concerning data DWSNZ bacterial compliance for the last 5 years.	Insignificant	Automatic plant shut down on adverse conditions. System redundancy means that distribution zone can be supplied from other pump stations and reservoirs.	Low		Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														stations within the Central zone can supply water in the event of a UV failure at Main Pumps • Storage in reservoirs and suction tanks		Groundwater age dating shows absence of young water in operational wells. Deep water supply wells with longer migration pathways present greater potential for attenuation of the concentration of a contaminant due to naturally occurring processes of: • Dispersion and dilution • Filtration and adsorption • Bio-degradation and chemical transformation • Pathogen die-off						
Storage and Suction Tanks	Not enough water in storage to meet demand (only relevant to hill reservoir zones in: • Central • Ferrymead • West • Lyttelton • Governors Bay • Diamond Harbour)	3.01	• Peak water usage exceeds reservoir capacity • Major fire-fighting	☐	☐	☐	☑	Possible		Major	Systems significantly compromised and abnormal operation. High level of monitoring and incident management required. Major disruption of service (8 to 24 hours and 20,000 to 500,000 customer hours).	High	• SCADA alarms and associated maintenance • Alert from CDHB about illness in the community • Customer complaints • Staff and maintenance contractor observations	• Maintain contamination monitoring, risk assessment and reactive processes • Network Control staffing and processes • Water restrictions procedure • Encourage water conservation • System redundancy • Emergency Management and Business Continuity Plans in place • Use of modelling data to identify areas with insufficient capacity for fire-fighting	Unlikely	2017 Port Hills fire the only recent example of this. Ability to monitor levels and restrict use reduces likelihood of shortage	Major	Drinking water can be supplied by tanker in emergency situations	Medium	Reliable	Acceptable	PI07

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														• Maintain fire-fighting reserve in all reservoirs • Use of tankered water • Alternative water sources for fire-fighting e.g. sea								
Storage and Suction Tanks	Introduction of contaminating material into storage tank (only relevant to: Hill reservoir zones in: • Central • Ferrymead • West • Lyttelton • Governors Bay • Diamond Harbour Suction tanks in: • Central • Ferrymead • West • Northwest • Parklands • Rawhiti)	3.02	Sampling procedures cause contamination (dip sample)	☑	☐	☐	☐	Possible		Major	Minor microbial contamination that affects >5,000 people. Potential amount of contaminant very small.	High	• Water quality monitoring • Alert from CDHB about illness in the community • Customer complaints • External sampling points on reservoirs • Routine inspection and maintenance of water supply assets	• Maintain contamination monitoring, risk assessment and reactive processes • Audits of all contractors' maintenance protocols and activities, and staff training • Training / certification of staff undertaking water quality monitoring • CCC Laboratory is IANZ accredited • Reservoir cleaning • Contract plans	Unlikely	Some reservoirs / suction tanks do not have a sample tap so must be dipped. Most do have sample taps, and history is of low level of unexplained transgressions. Staff training reduces likelihood of mistakes, and inspection/maintenance ensures sample taps are in good order	Major		Medium	Reliable	Acceptable	PI17
Storage and Suction Tanks	Introduction of contaminating material into distribution system (service reservoir) (only relevant to: Hill reservoir zones in: • Central • Ferrymead • West • Lyttelton • Governors Bay • Diamond Harbour	3.03	Leaching and/or corrosion from reservoir construction materials	☐	☐	☑	☐	Likely	Assumes: Poor condition reservoirs and suction tanks made from inappropriate materials which leach chemical contaminants into the water supply	Moderate	Exceedance of half the chemical MAV that affects >5,000 people	High	• Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Water quality monitoring	• Maintain contamination monitoring, risk assessment and reactive processes • Audits of all contractors' maintenance protocols and activities, and staff training • Approved materials' list and requirements • Inspection/approval of subdivision	Possible	No history of contamination from this cause. Condition inspections occur 5-yearly on average	Moderate		Medium	Reliable	Acceptable	PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
	Suction tanks in: • Central • Ferrymead • West • Northwest • Parklands • Rawhiti)													and Council capital works • Water supply asset renewals programmes • IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • Reservoirs and suction tanks are made from materials which do not leach contaminants • Reservoir cleaning • Contract plans							
Storage and Suction Tanks	Major microbial contamination of storage tank serving >5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying >5,000 people)	3.04	[redacted]	☑	☑	☐	☐	Almost Certain	[redacted]	Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people	Extreme	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Comprehensive condition assessments of high risk reservoirs and suction tanks • ROV camera inspections	• Maintain contamination monitoring, risk assessment and reactive processes • SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Approved materials' list and requirements • Inspection/approval of subdivision and Council capital works • Water supply asset renewals programmes • IDS	Unlikely	Installation of mesh on vents has been completed on all storage tanks. There are 3 overflows which still require further improvements. This reduces the amount of contaminating material that could be introduced to minor microbial contamination.	Major	Temporary chlorination of affected tanks until repairs are undertaken reduces the likelihood of the contamination occurring and the severity of the consequence (change from major to minor contamination)	Medium	Reliable	Acceptable	CI01 CI02 CI06 PI02 PI04 PI10 PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														(Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • Reservoir cleaning • Contract plans • Water supply asset renewals programme								
Storage and Suction Tanks	Major microbial contamination of storage tank serving <5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying <5,000 people)	3.05	[redacted]	☑	☑	☐	☐	Almost Certain	[redacted]	Major	Major microbial contamination, possibly deaths expected, that affects <5,000 people	Extreme	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Comprehensive condition assessments of high risk reservoirs and suction tanks • ROV camera inspections	• Maintain contamination monitoring, risk assessment and reactive processes • SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Approved materials' list and requirements • Inspection/approval of subdivision and Council capital works • Water supply asset renewals programmes • IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • ROV camera inspections	Unlikely	[redacted]	Moderate	Temporary chlorination of affected tanks until repairs are undertaken reduces the likelihood of the contamination occurring and the severity of the consequence (change from major to minor contamination)	Medium	Reliable	Acceptable	CI01 CI02 CI06 PI02 PI04 PI10 PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														• Reservoir cleaning • Contract plans • Water supply asset renewals programme								
Storage and Suction Tanks	Major microbial contamination of storage tank serving >5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying >5,000 people)	3.06	Cracks in roof or below ground walls allow contaminated water to enter	☑	☑	☐	☐	Almost Certain		Catastrophic	Major microbial contamination, possibly deaths expected, that affects >5,000 people. Cracks in roof or below ground walls have the potential to allow major contamination to enter the tank (e.g. via bird excrement on the roof or shallow contaminated groundwater).	Extreme	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Comprehensive condition assessments of high risk reservoirs and suction tanks • ROV camera inspections	• Maintain contamination monitoring, risk assessment and reactive processes • SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Temporary chlorination of poor condition reservoirs and suction tanks until repairs/upgrades have been completed • Chlorine spraying on selected reservoir roofs • Approved materials' list and requirements • Inspection/approval of subdivision and Council capital works • Water supply asset renewals programmes • IDS (Infrastructure Design Standards) and CSS (Construction Standard	Possible	2020 Comprehensive Reservoir Condition assessment incorporating microbial results with inspections leading to prioritised list for internal inspections and Water Supply Security Work Stream 1 - Reservoirs and Suction tanks Master sheet tracks Reservoir/Suction tank programme TRIM 21/1706559	Major	Temporary chlorination of affected tanks until repairs are undertaken reduces the likelihood of the contamination occurring and the severity of the consequence (change from major to minor contamination)	High	Reliable	**Unacceptable**	CI01 CI02 CI06 PI02 PI04 PI10 PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														Specifications) requirements • ROV camera inspections • Reservoir cleaning • Contract plans								
Storage and Suction Tanks	Major microbial contamination of storage tank serving <5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying <5,000 people)	3.07	Cracks in roof or below ground walls allow contaminated water to enter	☑	☑	☐	☐	Almost Certain	Assumes: Poor condition reservoirs with cracks that allow contaminants to enter, large amounts of contaminants present, no maintenance or temporary chlorination	Major	Major microbial contamination, possibly deaths expected, that affects <5,000 people. Cracks in roof or below ground walls have the potential to allow major contamination to enter the tank (e.g. bird excrement enters through the roof or shallow contaminated groundwater). Gravity and rain (on roof) and groundwater upward pressure play a role.	Extreme	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Comprehensive condition assessments of high risk reservoirs and suction tanks • ROV camera inspections	• Maintain contamination monitoring, risk assessment and reactive processes • SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Temporary chlorination of poor condition reservoirs and suction tanks until repairs/upgrades have been completed • Chlorine spraying on selected reservoir roofs • Approved materials' list and requirements • Inspection/approval of subdivision and Council capital works • Water supply asset renewals programmes • IDS (Infrastructure Design Standards) and CSS (Construction	Possible	2020 Comprehensive Reservoir Condition assessment incorporating microbial results with inspections leading to prioritised list for internal inspections and Water Supply Security Work Stream 1 - Reservoirs and Suction tanks Master sheet tracks Reservoir/Suction tank programme TRIM 21/1706559 E. coli transgression associated with Quarry and Burkes 2.	Moderate	Temporary chlorination of affected tanks until repairs are undertaken reduces the likelihood of the contamination occurring and the severity of the consequence (change from major to minor contamination)	Medium	Reliable	Acceptable	CI01 CI02 CI06 PI02 PI04 PI10 PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														Standard Specifications) requirements • ROV camera inspections • Reservoir cleaning • Contract plans • Reservoir roof sealing programme							
Storage and Suction Tanks	Minor microbial contamination of storage tank serving >5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying >5,000 people)	3.08	Cracks in structure - other than cracks in roof or below ground walls - allow contaminated water to enter	☑	☑	☐	☐	Likely	Assumes: Poor condition reservoirs with cracks that allow contaminants to enter, small amounts of contaminants present, no maintenance or temporary chlorination. Cracks in structure other than in roof or below ground walls have the potential for only minor contamination to enter the tank (e.g. vertical crack). Gravity, rain and groundwater upward pressure have no impact.	Major	Minor microbial contamination that affects >5,000 people	Extreme	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Comprehensive condition assessments of high risk reservoirs and suction tanks • ROV camera inspections	• Maintain contamination monitoring, risk assessment and reactive processes • SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Temporary chlorination of poor condition reservoirs and suction tanks until repairs/upgrades have been completed • Chlorine spraying on small number of selected reservoir roofs • Approved materials' list and requirements • Inspection/approval of subdivision and Council capital works • Water supply asset renewals programmes • IDS	Possible	2020 Comprehensive Reservoir Condition assessment: Several reservoirs were assessed as grade 4 or 5 for exterior wall condition: Hackthorne. Several suction tanks were assessed as grade 4 or 5 for exterior wall condition: Mays, Estuary, Keyes, Sockburn.	Moderate	Temporary chlorination of affected tanks until repairs are undertaken reduces the likelihood of the contamination occurring and the severity of the consequence	Medium	Reliable	Acceptable	CI01 CI02 CI06 PI02 PI04 PI10 PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														(Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • ROV camera inspections • Reservoir cleaning • Contract plans • Reservoir roof sealing programme								
Storage and Suction Tanks	Minor microbial contamination of storage tank serving <5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying <5,000 people)	3.09	Cracks in structure - other than cracks in roof or below ground walls - allow contaminated water to enter	☐	☐	☐	☐	Likely	Assumes: Poor condition reservoirs with cracks that allow contaminants to enter, small amounts of contaminants present, no maintenance or temporary chlorination. Cracks in structure other than in roof or below ground walls have the potential for only minor contamination to enter the tank (e.g. vertical crack). Gravity, rain and groundwater upward pressure have no impact.	Moderate	Minor microbial contamination that affects >5,000 people	High	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Alert from CDHB about illness in the community • Customer complaints • Comprehensive condition assessments of high risk reservoirs and suction tanks • ROV camera inspections	• Maintain contamination monitoring, risk assessment and reactive processes • SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Chlorine spraying on selected reservoir roofs • Approved materials' list and requirements • Inspection/approval of subdivision and Council capital works • Water supply asset renewals programmes • IDS (Infrastructure Design Standards) and CSS (Construction Standard	Possible	2020 Comprehensive Reservoir Condition assessment: Several reservoirs were assessed as grade 4 or 5 for exterior wall condition: Mt Pleasant 3, Quarry, Halswell 2	Minor	Temporary chlorination of affected tanks until repairs are undertaken reduces the likelihood of the contamination occurring and the severity of the consequence	Medium	Reliable	Acceptable	CI01 CI02 CI06 PI02 PI04 PI10 PI17

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														Specifications) requirements • ROV camera inspections • Reservoir cleaning • Contract plans • Reservoir roof sealing programme								
Storage and Suction Tanks	Development or resuspension of sediment within tank or reservoir (only relevant to: Hill reservoir zones in: • Central • Ferrymead • West • Lyttelton • Governors Bay • Diamond Harbour Suction tanks in: • Central • Ferrymead • West • Northwest • Parklands • Rawhiti)	3.10	Sediment accumulation and release	☐	☐	☑	☐	Likely	Assumes: Poor quality groundwater source with high turbidity, no measures to remove turbidity, poor operation of reservoirs which encourages. Development of sediment is almost certain, but has no impact until re-suspension. Re-suspension occurs during peak use (generally yearly).	Moderate	In isolation, consequence would be minor, but these events tend to occur in summer peak use, when all plant is required to be operational. Assumes multiple tanks are affected at the same time, which would cause a widespread exceedance of the GV (turbidity).	High	• SCADA alarms and associated maintenance • Customer complaints • Routine inspection and maintenance of water supply assets • Water quality monitoring • Level sensors • ROV camera inspections	• High quality groundwater with low level of turbidity • Sand filters and/or suction tanks to settle out sand • Step tests and sand tests undertaken during well development to determine the safe pumping rate for each well • Maintain contamination monitoring, risk assessment and reactive processes • Network Control staffing and processes • Proactive and reactive maintenance • Reservoir cleaning	Unlikely	Network Controllers maintain minimum water level in tank to prevent sediment resuspension.	Minor	Following complaints, the reservoir can be isolated and cleaned, and reticulation flushed	Medium	Reliable	Acceptable	
Distribution System	Introduction of contaminating material into the distribution system	4.01	Defective water supply pipe or fitting (low level leakage).	☑	☑	☑	☐	Almost Certain	Assumes: Very poor condition pipes with high rates of leakage, contaminated shallow groundwater surrounding pipe, episodes of negative pressure in the pipe	Major	Minor microbial contamination that affects >5,000 people Low level leakage has the potential to cause a minor contamination event.	Extreme	• SCADA alarms and associated maintenance • Water loss and leak detection contract • Alert from CDHB about illness in the community • Customer complaints • Staff and	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' register • Network Control staffing and	Unlikely	Contractor audit lowers likelihood of poor valve shut off practice or poor cleanliness. Low level of unexplained transgressions and none were related to distribution network	Major	Flushing and chlorination of repairs reduce potential contamination.	Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
													maintenance contractor observations	processes • Audits of all contractors' maintenance protocols and activities, and staff training • Water supply asset renewals programmes • Water loss and leak detection contract • Water supply asset renewal programme • Maintenance contractor chain of cleanliness • Post-repair disinfection and water quality testing • Contract plans • Contractor stand-down for specific diseases • Constant positive pressure in the network		condition (even in areas with high levels of leakage). Positive pressure prevents contamination entering the network. Negative pressure events of very short duration, as shown in high speed pressure sensing trials (transient fluctuation). Minor leaks are repaired under pressure.						
Distribution System	Introduction of contaminating material into the distribution system	4.02	• Burst water main on the flat. • Accidental contractor damage to a pipe on the flat.	☑	☑	☑	☐	Almost Certain	Assumes: Very poor condition pipes prone to bursting, contaminated shallow groundwater surrounding pipe, episodes of negative pressure in the pipe, third party contractors unaware of pipe locations, major pipe failure affects a large number of people	Major	Minor microbial contamination that affects >5,000 people	Extreme	• SCADA alarms and associated maintenance • Customer complaints • Staff and maintenance contractor observations • Reports of illness	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' register • Network Control staffing and processes • Audits of all contractors' maintenance protocols and activities, and staff training	Unlikely	Positive pressure prevents contamination entering the network. Negative pressure events of very short duration, as shown in high speed pressure sensing trials (transient fluctuation). Low number of unexplained transgressions in the distribution system.	Major	Pipe has to be isolated / valved off for repair so a limited area is affected. Rapid identification of the issue is likely - due to lost water complaints. Flushing and chlorination of repairs reduce potential contamination.	Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														• Water supply asset renewals programmes • Maintenance contractor chain of cleanliness • Availability of drainage and water supply plans • Good asset records • Post-repair disinfection and water quality testing • Contract plans • Contractor stand-down for specific diseases • Constant positive pressure in the network • Use of approved chlorination contractors									
Distribution System	Introduction of contaminating material into the distribution system (only relevant to reservoir zones in: • Central • Ferrymead • West • Lyttelton • Governors Bay • Diamond Harbour)	4.03	• Burst water main on the hills or pipe suppling hill areas or reservoirs. • Accidental contractor damage to a pipe on the hills or supplies hill areas or reservoirs.	☑	☑	☑	☐	Likely	Assumes: Very poor condition pipes prone to bursting, contaminated shallow groundwater surrounding pipe, third party contractors unaware of pipe locations major pipe failure affects a large number of people. Smaller geographic area than flat parts of Christchurch and Lyttelton Harbour Basin so service strikes and pipe bursts are less frequent.	Major	Minor microbial contamination that affects >5,000 people	Extreme	• SCADA alarms and associated maintenance • Network Control staffing and processes • Customer complaints • Staff and maintenance contractor observations • Reports of illness	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' register • SCADA alarms and associated maintenance • Network Control staffing and processes • Audits of all contractors' maintenance protocols and activities, and staff training • Water supply asset renewals	Unlikely	Low number of unexplained transgressions in the distribution system. Maintenance contractor is aware of the correct sequence for closing valves to isolate a broken pipe on the hill for repair. Deeper groundwater levels on the hill so less chance of contaminated groundwater reaching the broken pipe.	Major	Pipe has to be isolated/ valved off for repair so a limited area is affected. Rapid identification of the issue is likely - due to lost water complaints and reservoir level monitoring and alarms. Maintenance contractor required to respond within 1 hour for urgent repairs. Flushing and chlorination of	Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														programmes • Emergency Management and Business Continuity Plans in place • Maintenance contractor chain of cleanliness • Availability of drainage and water supply plans • Post-repair disinfection and water quality testing • Contract plans • Contractor stand-down for specific diseases • Use of approved chlorination contractors					repairs reduce potential contamination.				
Distribution System	Introduction of contaminating material into the distribution system	4.04	Cross connections between water supply and pressurised stormwater/ wastewater pipes in the distribution system	☑	☑	☑	☐	Possible	Some services very close together - increasing risk of misidentification more of a risk in new subdivisions	Major	Major microbial contamination, possibly deaths expected, that affects <5,000 people. Issue localised, so <5,000 people.	High	• Building consent process and associated inspections • Customer complaints • Water quality monitoring • Construction audits • Reports of illness	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' and Drainlayers' register • Approved materials' list and requirements • IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • Good asset records • Availability of drainage and water	Unlikely	Authorised Water Installer and Drainlayer schemes ensure that competence of contractors is high. Approved materials ensures right labelling of pipes (colour coding on pipes). Water supply network under pressure at all times therefore contractor would be unable to make a connection by accident.	Major	Inspections may spot cross connection before significant flow occurs, and trigger remedial work	Medium	Reliable	Acceptable	PI12

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														supply plans • Construction audits								
Distribution System	Introduction of contaminating material into the distribution system	4.05	• Standard hygiene practices not adhered to by maintenance contractor and other authorised water supply installers. • Inadequate disinfection of new or repaired pipework.	☑	☑	☐	☐	Almost Certain	Assumes: No standard hygiene practices, unqualified and inexperienced contractors, contaminating material in work site	Moderate	Minor microbial contamination that affects <5,000 people. Generally contained, and low level of contaminant.	High	• Water quality monitoring • QA checks • Construction audits • Customer complaints • Reports of illness	• Approved Water Supply Installers' register • Audits of all contractors' maintenance protocols and activities, and staff training • Evidence of qualifications at time of recruitment and contract award • Permit to Work process • Maintenance contractor chain of cleanliness • Construction audits • Post-repair disinfection and water quality testing • Contract plans • Contractor stand-down for specific diseases • Use of approved chlorination contractors	Unlikely	Water sampling after repairs shows no contamination Water supply maintenance teams solely work on water supply. New pipework and repairs are required to be chlorinated. Authorised Water Installer scheme ensure that competence of contractors is high and 3 strikes system encourages good workmanship	Moderate		Medium	Reliable	Acceptable	PI12
Distribution System	Introduction of contaminating material into the distribution system	4.06	Repair or illegal connection by unauthorised contractors	☑	☑	☑	☐	Likely	Assumes: No standard hygiene practices, unqualified and inexperienced contractors, contaminating material in work site	Moderate	Minor microbial contamination that affects <5,000 people. Localised and low volume related to quick leak repairs or illegal connections to smaller diameter pipes have the potential to cause a	High	• Water quality monitoring • Routine inspection and maintenance of water supply assets • Water quality monitoring • Construction audits • Staff and maintenance	• Approved Water Supply Installers' register • Council Bylaw • Permit to Work process	Possible	Contractors are aware of CCC requirements and consequences if not adhering to them.	Moderate		Medium	Reliable	Acceptable	PI12

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
											minor contamination affecting <5,000 people.		contractor observations • Building consent process and associated inspections • Water loss and leak detection contract									
Distribution System	Introduction of contaminating material into the distribution system	4.07	Inadequate flushing and hygiene procedures during commissioning of new mains, after pipe repairs or during contamination event response.	☑	☑	☑	☐	Likely	Assumes: No standard hygiene practices, unqualified and inexperienced contractors, contaminating material in work site	Major	Minor microbial contamination that affects >5,000 people.	Extreme	• Routine inspection and maintenance of water supply assets • Water quality monitoring • Report of procedural breach by maintenance contractor	• Approved Water Supply Installers' register • Audits of all contractors' maintenance protocols and activities, and staff training • Inspection/approval of subdivision and Council capital works • Permit to Work process • IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • Water quality monitoring • Use of approved chlorination contractors	Possible	Approved and audited contractors only. Work is inspected, and water tested before livening new main to reticulation.	Moderate	Mandatory disinfection of pipework reduces the consequence	Medium	Reliable	Acceptable	
Distribution System	Introduction of contaminating material into the distribution system	4.08	Corrosion and deterioration of pipes (galvanised iron, cast iron and asbestos cement pipes)	☐	☐	☑	☐	Possible	Corrosion or pipe deterioration causes dirty water complaints	Moderate	Widespread exceedance of aesthetic GV	Medium	• Customer complaints • Analysis of pipe samples • Annual well head sampling • 2018 asbestos testing returned no results of concern	• Maintain contamination monitoring, risk assessment and reactive processes • Water supply asset renewals programmes • Mixed source water keeps pH within	Unlikely	pH in network within GV range reduces likelihood of corrosion and deterioration.	Moderate		Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														recommended range								
Distribution System	Introduction of contaminating material into the distribution system (only relevant to certain pipes in: • Central • Lyttelton • Riccarton • Rawhiti)	4.09	Leaching of lead from lead jointed pipes	☐	☐	☑	☐	Possible	2019 and 2020 results returned several results which exceeded the MAV and half the MAV. 2020/21 surveys using 24hr sampling show no exceedence	Moderate	Possible harm to people (short-term exceedance of long-term chemical MAV). According to WHO information (https://www.who.int/ipcs/features/lead..pdf?ua=1) lead is classified as a chronic or cumulative toxin. Chronic exposure is defined as continuous or repeated contact with a toxic substance over a long period of time (months or years).	Medium	• Water quality monitoring • Analysis of pipe samples	• Maintain contamination monitoring, risk assessment and reactive processes • Water supply asset renewals programmes	Unlikely	•Sampling programme 2021 using 24 hr sampling has found there has not been a continuous exposure to high levels of lead at any of the sites investigated	Moderate		Medium	Reliable	Acceptable	CI05 CI08 PI01 PI05
Distribution System	Introduction of contaminating material into the distribution system	4.10	Contaminants (hydrocarbons) permeate through pipe walls where plastic pipe is installed in contaminated land	☐	☐	☑	☐	Possible		Moderate	Exceedance of the chemical MAV that affects <5,000 people. Somewhat self-limiting as consumers will avoid drinking foul smelling water.	Medium	• Water quality monitoring • Customer complaints • Resource consent applications	• Engagement with resource consent applications • Building consent and HSNO processes and associated inspections • Maintain contamination monitoring, risk assessment and reactive processes • Approved materials' list and requirements • IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • Adoption of	Unlikely	Assessment carried out at consent stage and CSS/IDS require use of pipe materials that are fit for the intended purpose. History of few complaints of this type.	Moderate		Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														UKWIR guidelines for assessment of contaminated land • Water supply asset renewals programmes								
Distribution System	No flow through trunk main for prolonged period	4.11	Major trunk main break	☐	☐	☐	☑	Likely	Assumes deteriorating network and no maintenance and no on-call maintenance contractor.	Major	Major disruption of service (8 to 24 hours and 20,000 to 500,000 customer hours)	Extreme	• SCADA alarms and associated maintenance • Customer complaints • Staff and maintenance contractor observations	• Maintain contamination monitoring, risk assessment and reactive processes • Approved Water Supply Installers' register • Network Control staffing and processes • Audits of all contractors' maintenance protocols and activities, and staff training • Water supply asset renewals programmes • System redundancy • Emergency Management and Business Continuity Plans in place • Contractor maintains stock of critical parts and fittings • Availability of drainage and water supply plans • Storage in reservoirs and suction tanks • Contract plans • Use of tankered water.	Possible	There are only a few areas served by a single trunk main, so normally it would be possible to continue supplying water via an alternative main. If necessary, tankered water could be provided.	Moderate	Alarms and network controller response will trigger early response. Reservoir supply likely to cover repair period. Maintenance contractor required to respond to urgent jobs within 1 hour. Maintenance contractor required to keep critical spare parts in stock.	Medium	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Distribution System	Interruption to supply to Lyttelton harbour basin (only relevant to: • Lyttelton • Governors Bay • Diamond Harbour)	4.12	[redacted]	☐	☐	☐	☑	Possible	New (2019), larger stainless steel pipe through road tunnel. Served by Scruttons booster station. Dual supply pipes through rail tunnel provide alternative supply route. Served by Ferrymead booster station. [redacted]	Catastrophic	Catastrophic consequence if all supply mains to Lyttelton were unavailable.	High	• SCADA alarms and associated maintenance • Routine inspection and maintenance of water supply assets • Customer complaints	• SCADA alarms and associated maintenance • Network Control staffing and processes • Reactive maintenance by Contractor • Contractor maintains stock of critical parts and fittings • Council Bylaw • Water supply asset renewals programmes • Asset replacement programme • Emergency Management and Business Continuity Plans in place • Use of tankered water • Water shut offs monitored	Possible	New (2019), larger stainless steel pipe through road tunnel. Served by Scruttons booster station.	Moderate	Reduced consequence due to redundancy in the system by means of dual supply pipes through rail tunnel providing alternative supply route. Served by Ferrymead booster station. Also ability to fill reservoirs using water tankers.	Medium	Reliable	Acceptable	PI05
Distribution System	Reduced supply to Lyttelton harbour basin (only relevant to: • Lyttelton • Governors Bay • Diamond Harbour)	4.13	Kiwi Rail demands removal of Lyttelton rail tunnel trunk mains	☐	☐	☐	☑	Possible	Kiwi Rail had previously indicated that they would like CCC to remove the pipes from the rail tunnel in the near future. The agreement allows them to require this within a 3-month notice period.	Catastrophic	Opus modelling confirms that peak demand cannot be met without the rail tunnel pipelines. Requires trunk main upgrade on either side of the road tunnel or new supply line across the hill. Lyttelton Port is a lifeline and must have continuous water supply.	High	• Request from Kiwi Rail to remove trunk main	• Network Control staffing and processes • Water restrictions procedure • Customer complaints • Water supply model • Communication with Kiwi Rail • Upgraded pipe in road tunnel • Staff and maintenance contractor observations • Reports of illness	Unlikely	Lyttelton water supply alternative pipeline options report has been completed with the conclusion that an alternative water supply route would be very high. Discussions with Kiwi Rail are positive and Council is now investigating a replacement pipe in the tunnel which would require a structural liner so that the pipe can be	Major	Response plan allows for feed to lower reservoir within notice period from Kiwi Rail.	Medium	Reliable	Acceptable	PI05

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
																supported at a high level (off centre to no interfere with possible future electrification of the train service.						
Distribution System	No flow through trunk main for prolonged period (only relevant to Diamond Harbour)	4.14	Submarine pipelines to Diamond Harbour damaged	☐	☐	☐	☑	Unlikely	Damage has occurred once since pipelines laid. Neither pipeline was broken beyond use. Could be vulnerable to dredging.	Catastrophic	If both lines broken, no reticulated supply to Diamond Harbour for several weeks. 1 month equals 1m customer hours (population of 1,000).	High	• SCADA alarms and associated maintenance • Customer complaints	• Water restrictions procedure • Use of tankered water • Redundancy within reservoir network • Annual inspection of submarine pipelines	Unlikely	Dual submarine pipelines, it is unlikely that both pipelines would be affected at the same time.	Major	Combination of use restriction and tankered supply reduce impact	Medium	Reliable	Acceptable	
Distribution System	Development of sediment or biofilm	4.15	• Sediment allowed to develop • Not enough water turnover in dead ends of network	☐	☐	☑	☐	Likely	Sediment resuspension occurs only during peak demand periods.	Minor	Potential local exceedance of GV due to containment in dead end.	Medium	• Water quality sampling • Customer complaints	• Maintain contamination monitoring, risk assessment and reactive processes • IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements • Asset replacement programme • Flushing as required	Likely		Minor	2014 comparative testing showed quality in dead ends was not different from well-flushed areas	Medium	Reliable	Acceptable	
Distribution System	Introduction of contamination due to no / inadequate / faulty / incorrectly installed backflow prevention device	4.16	High hazard commercial and industrial sites (incl. WWTP): Unintentional backflow event due to backflow prevention device not actually connected, connected improperly, or	☑	☑		☐	Likely		Major	Greater range of contaminants combined with higher pressure at commercial and industrial properties and a larger volume of contaminants could cause a major contamination event affecting >5,000 people	Extreme	• Water loss and leak detection contract • Customer complaints • IQP Inspections/Testing • Backflow event causes water quality issue • Water quality sampling	• Building consent process and associated inspections • Council Bylaw • Backflow prevention audits • Assessment for backflow risk at the building consent and water connection application stage • Backflow	Unlikely	Targeted backflow prevention installation and education programme underway	Major		High	Reliable	**Acceptable**	CI06 PI03

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)										
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
			no backflow prevention device fitted.											prevention devices • Staff and maintenance contractor observations • CCC-owned at risk properties have appropriate backflow devices installed • Backflow survey programme								
Distribution System	Introduction of contamination due to no / inadequate / faulty / incorrectly installed backflow prevention device	4.17	High hazard commercial and industrial sites (incl. WWTP): Unintentional backflow event due to backflow prevention device not actually connected, connected improperly, or no backflow prevention device fitted.			☑		Likely		Major	Greater range of contaminants combined with higher pressure at commercial and industrial properties and a larger volume of contaminants could cause a major contamination event affecting >5,000 people		•Water loss and leak detection contract • Customer complaints • IQP Inspections/Testing • Backflow event causes water quality issue • Water quality sampling	• Building consent process and associated inspections • Council Bylaw • Backflow prevention audits • Assessment for backflow risk at the building consent and water connection application stage • Backflow prevention devices • Staff and maintenance contractor observations • CCC-owned at risk properties have appropriate backflow devices installed • Backflow survey programme	Unlikely	Targeted backflow prevention installation and education programme underway. Very few industries with a microbiological risk that would affect >5000 people	Major		Medium	Reliable	Acceptable	
Distribution System	Introduction of contamination due to no / inadequate / faulty / incorrectly installed backflow	4.17	Medium hazard commercial sites: Unintentional backflow event due to backflow prevention device not actually	☑	☐	☑	☐	Likely		Major	Reduced range of contaminants combined with lower volume of contaminants could cause a minor contamination event affecting >5,000 people	Extreme	• Water loss and leak detection contract • Customer complaints • IQP Inspections/Testing • Backflow event causes water quality issue	• Building consent process and associated inspections • Trade waste and stormwater audits • Council Bylaw • Backflow prevention audits	Unlikely		Major		Medium	Reliable	Acceptable	CI06 PI03

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
	prevention device		connected, connected improperly, or no backflow prevention device fitted.										• Water quality sampling	• Assessment for backflow risk at the building consent and water connection application stage • Backflow prevention devices • Staff and maintenance contractor observations • CCC-owned at risk properties have appropriate backflow devices installed • Backflow survey programme • Constant positive pressure in the network								
Distribution System	[redacted]																					
Distribution																						

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
[redacted]																						
Distribution System																						
Distribution																						

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
[redacted]																						
Systems and Processes	Incorrect or inadequate water quality data used for supply management	5.01	Inappropriate or incorrect sampling methods / equipment calibration / laboratory tests used	□	□	□	□	Likely		Minor		Medium	• Review of unusual sample results • IANZ audit of laboratory	• Sampling and laboratory staff are adequately trained in sampling techniques and proficiency is maintained • Laboratory is IANZ accredited • Laboratory is approved by the Ministry of Health for drinking water testing • The maintenance contractor receives training by the Council drinking water sampling officers	Possible	Lake Tce well 5 sample result incident in October 2020 makes the likelihood Possible (occurs several times in a 5- year period)	Minor		Medium	Reliable	Acceptable	
Systems and Processes	Incorrect or inadequate water quality data used for supply management	5.02	Inadequate or incorrect monitoring records and record keeping	□	□	□	□	Likely		Moderate		High	• Drinking water compliance audits identify missing or incorrect sample results	• Laboratory is IANZ accredited • Laboratory uses a recognised laboratory data management system (QLIMS) • Council uses Drinking Water Online to store drinking water monitoring data	Possible	Drinking water online currently used but unknown availability beyond June 2022, council needs new system for demonstrating compliance and also improved scheduling with more complex monitoring.	Moderate		Medium	Estimate	Unacceptable	P116
Systems and	Incorrect or inadequate water quality data used for	5.03	Failure of data loggers at pump stations or reservoir sites	□	□	□	□	Possible		Minor		Medium	• SCADA alarms • Inspection picks up unusual or no readings	• Regular servicing and calibration of data loggers	Unlikely		Minor		Low	Reliable	Acceptable	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
	supply management												• Water quality monitoring									
Systems and	Incorrect or inadequate water quality data used for supply management	5.04	Not enough sampling points in the distribution system where there are several branches/legs	☐	☐	☐	☐	Possible		Insignificant		Low	• Sample result	• Monitoring programme ensures the sampling point locations are sufficiently comprehensive	Possible		Insignificant		Low	Reliable	Acceptable	
Systems and Processes	Civil emergency	5.05	Earthquake or other large scale disruption	☐	☐	☐	☑	Unlikely		Catastrophic		High	• Earthquake, tsunami or other large scale disruption occurs • Severe weather warnings • Tsunami warning sirens	• Contingency Plans and Emergency Business Continuity Plans • Strong working relationships with other Civil Defence agencies • Support via the Canterbury Drinking Water Reference Group (CDWRG) • Use of tankered water • SCADA alarms and associated maintenance • Network Control staffing and processes • Audits of all contractors' maintenance protocols and activities, and staff training • Post-earthquake recovery and improvement work • Good asset records • Staff and	Unlikely		Catastrophic		High	Reliable	**Unacceptable**	

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
														maintenance contractor observations • Standby chlorination systems • Contract plans • System redundancy								
Systems and Processes	Civil emergency	5.06	Vandalism (e.g. graffiti, equipment damage), applies to source, treatment and distribution facilities	☑	☑	☑	☑	Almost Certain		Minor		High	• SCADA indicates unauthorised entry to site. • Reported by contractor or residents.	• Contingency Plans and Emergency Business Continuity Plans. • Strong working relationships with other Civil Defence agencies. • Support via the Canterbury Drinking Water Reference Group (CDWRG) • Use of tankered water • Access hatches are alarmed and have padlocks.	Likely	Vandalism other than graffiti is uncommon. All Pump Stations have secure locks. Some are fenced.	Minor	Response by Network Controllers to hatch alarms triggers risk assessment / response processes - limiting impact.	Medium	Reliable	Acceptable	PI09
Systems and Processes	Civil emergency	5.07	[redacted]	☑	☑	☐	☐	Rare		Catastrophic		Medium	• Water quality monitoring • Reports of illness.	• Contingency Plans and Emergency Business Continuity Plan. [redacted] • Support via the Canterbury Drinking Water Reference Group (CDWRG) • Use of tankered water	Rare		Catastrophic		Medium	Reliable	Acceptable	PI09

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)								
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
Systems and	Contractor and other management issues	5.08	Structural failure of system component	☐	☐	☐	☐	Unlikely		Minor		Low	• SCADA alarms. • Contractor reports	• Monitor condition of system components (ongoing).	Rare		Minor		Low	Reliable	Acceptable	
Systems and Processes	Contractor and other management issues	5.09	Inadequate monitoring or poor response to alarms	☐	☐	☐	☐	Possible		Moderate		Medium	• SCADA alarms. • Third party audits	• Contract plans with required response times (1 hour for alarms). • Network control room also monitors alarms 24/7 • There is also the second on-call person who receives the alarms if missed by Citycare/contractor and control room. • Contractor has backup contractor resources available. • Duty rosters in place 24/7.	Unlikely		Minor		Low	Reliable	Acceptable	PI06 PI07 PI08
Systems and Processes	Contractor and other management issues	5.10	Inadequate QA / management systems	☐	☐	☐	☐	Possible		Minor		Medium	• Third party audits	• Contract audits and QA. • Laboratory is IANZ accredited • Laboratory is approved by the Ministry of Health for drinking water testing • Training/certification of staff undertaking Water quality monitoring • Construction audits	Unlikely		Minor		Low	Reliable	Acceptable	CI07 PI06 PI08 PI10 PI11
Systems and	Asset data issues	5.11	Inaccurate as-built information being received and input into				☑	Possible		Minor	Could cause moderate disruption to service if wrong asset data used for maintenance work	Medium	• Contractor reports • Third party audits	• Contract audits and QA • IDS (Infrastructure Design Standards)	Unlikely	Only approved and audited contractors who are aware of Council requirements can carry out works	Minor		Low	Estimate	Acceptable	P21

	Hazardous Event			Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Supply Element	Event Description	Cause No.	Possible Causes	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics / Radioactivity	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
			Council's Asset Information Systems and GIS due to automated data process with inadequate quality assurance processes in place.											and CSS (Construction Standard Specifications) requirements • Approved Water Supply Installers' and Drainlayers' registers		and submit as built information.						

3.3 Plausible Combinations of Hazards

Hazardous Event Combination				Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Combination	Event Description	Hazard 1	Hazard 2	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
PC1	Contamination of distribution system	Burst water main on the flat. Accidental contractor damage to a pipe on the flat.	Broken wastewater pipe nearby	☑	☑	☑	☑	Almost Certain		Catastrophic	major microbial contamination, potentially >5,000 people affected	Extreme	• Staff/Maintenance contractor observations • Customer complaints • Network Control staffing and processes • Reports of illness • Water quality monitoring	• Audits of all contractors' maintenance protocols and activities, and staff training • SCADA alarms and associated maintenance • Maintain contamination monitoring, risk assessment and reactive processes • Network Control staffing and processes • Water supply asset renewals programmes • Maintenance contractor chain of cleanliness • Authorised Drainlayer / Approved Water Installer schemes • Contractor stand-down for specific diseases • Post-repair disinfection and water quality testing • Contract plans • Availability of drainage and water supply plans • Constant positive pressure in the network • Design as per CSS/IDS	Unlikely	Low level of unexplained transgressions. Although a broken water main and a broken wastewater main were found to be in close proximity in Diamond Harbour in July 2018 no contamination or E. coli transgression was found. A precautionary boil water notice was issued.	Major	Reduced consequence as constant positive pressure in pipes ensures that no contamination can enter the pipeline. Valving off of immediate area ensures that a minimum number of people is affected.	Medium	Confident	Acceptable	
PC2	Contamination of distribution system	Microbial contamination identified in distribution system	Incorrect flushing procedure distributes contamination further and affects >5,000 people	☑	☑	☑	☐	Possible		Catastrophic	major microbial contamination, potentially >5,000 people affected	High	• Staff/Maintenance contractor observations • Customer complaints • Network Control staffing and processes • Reports of illness	• Audits of all contractors' maintenance protocols and activities, and staff training • SCADA alarms and associated maintenance • Maintain contamination monitoring, risk assessment and reactive processes • Network Control staffing and processes • Maintenance contractor chain of cleanliness • Authorised Drainlayer / Approved Water Installer schemes • Contractor stand-down for specific diseases • Post-repair disinfection and water quality testing • Contract plans • Availability of drainage and water supply plans • Constant positive pressure in the network	Unlikely	Low level of unexplained transgressions. Flushing plans are developed by experienced CCC staff and are accompanied by detailed flushing instructions (TRIM 20/1254928)	Major	The purpose of flushing is to reduce the affected area. Flushing plans are developed by experienced CCC staff who understand the network. Therefore <5,000 people affected.	Medium	Confident	Acceptable	

Hazardous Event Combination				Hazards				MAXIMUM Risk (with no preventive measures in place and all barriers failing)					RESIDUAL Risk (with existing preventive measures)									
Combination	Event Description	Hazard 1	Hazard 2	Bacteria / Viruses	Protozoa	Chemicals / Aesthetics	Disruption to Supply	MAX Likelihood	Assessment Rationale - Likelihood	MAX Consequence	Assessment Rationale - Consequence	Maximum (unmitigated) Risk	Event Detection Measures	Preventive Measures	RES Likelihood	Assessment Rationale - Modified Likelihood	RES Consequence	Assessment Rationale - Modified Consequence	Residual Risk	Level of Uncertainty	Risk Acceptability	Improvement Plan Reference
PC3	Unable to supply water to meet demand	Not enough source water available for abstraction	Major fire or major civil emergency	☐	☐	☐	☑	Possible		Catastrophic		High	• Reduced abstraction rates • Water supply model • Natural disaster (flood, earthquake)	• Engagement with Resource Consent applications • Liaison with ECan • Priority given to drinking water groundwater take consent • Masterplan for growth areas • Network Control staffing and processes • Use of modelling data to identify areas with insufficient capacity for fire-fighting • Maintain fire-fighting reserve in all reservoirs • Tankered water • Alternative water sources for fire-fighting e.g. sea • System redundancy • Supply from neighbouring zones • Earthquake/Flood/Natural Disaster • Emergency Management and Business Continuity Plans in place	Unlikely	Ability to monitor levels and restrict use reduces likelihood of shortage. ECan data shows that there is sufficient water in the aquifers and priority is given to community drinking water supplies. Infrastructure for growth is already provided for the next years with budget in the Long Term Plan for water supply infrastructure for growth. Global groundwater consent is approx. 72m m^3 per year whereas current take is approx. 50m m^3.	Major	Port Hills fire 2017 the only recent example of a major fire. Although the water levels in some top level reservoirs dropped significantly due to fire fighting the Network Controllers and CCC Operations & Maintenance staff were able to direct fire fighters to suitable water take sites (hydrants in the flat rather than hydrants on the hills) so that water demand was able to be managed.	Medium	Confident	Acceptable	
PC4		Damaged or burst water main	Wet weather event, contaminated flood waters nearby	☑	☑	☑	☑	Possible		Catastrophic	major microbial contamination, potentially >5,000 people affected	High	• Staff/Maintenance contractor observations • Customer complaints • Network Control staffing and processes • Reports of illness • Natural disaster (flood, earthquake) • Severe weather warning	• Audits of all contractors' maintenance protocols and activities, and staff training • SCADA alarms and associated maintenance • Maintain contamination monitoring, risk assessment and reactive processes • Network Control staffing and processes • Water supply asset renewals programmes • Maintenance contractor chain of cleanliness • Authorised Drainlayer / Approved Water Installer schemes • Contractor stand-down for specific diseases • Post-repair disinfection and water quality testing • Contract plans • Availability of drainage and water supply plans • Constant positive pressure in the network	Unlikely	Low level of unexplained transgressions. Although service strikes occur on a daily basis, positive pressure prevents contamination entering the network.	Major	Reduced consequence as constant positive pressure in pipes ensures that no contamination can enter the pipeline. Valving off of immediate area ensures that a minimum number of people is affected.	Medium	Confident	Acceptable	

3.4 Unacceptable risks

The assessment of risk acceptability and level of uncertainty in Section 3.2 has identified four risks that the Council considers unacceptable, as listed in Table 3-2. Existing programmes and measures are also outlined below Table 3-2. Additional improvements to address risk are outlined in Section 5.1.

Table 3-2: Unacceptable risk from Christchurch/Lyttelton risk assessment

Supply Element	Event Description	Cause No.	Possible Causes
Storage and Suction Tanks	Major microbial contamination of storage tank serving >5,000 people (Refer to WSP Appendix C for reservoirs and suction tanks supplying >5,000 people)	3.06	Cracks in roof or below ground walls allow contaminated water to enter
Systems and Processes	Incorrect or inadequate water quality data used for supply management	5.02	Inadequate or incorrect monitoring records and record keeping. Drinking water online currently used but unknown availability beyond June 2022, council needs new system for demonstrating compliance and also improved scheduling with more complex monitoring.
Systems and Processes	Civil emergency	5.05	Earthquake or other large scale disruption

3.4.1 Risk Cause 3.06 – Major microbial contamination of storage tank

Contamination could enter reservoirs and suction tanks via cracks in the roof or below ground walls and cause major microbial contamination of the water supply, for reservoirs and tanks that serve more than 5,000 people. Progress on reservoir condition assessments is presented in Section 2.6.2 and summarised below.

The key short and medium term actions being undertaken to improve information associated with the risk and actions to reduce the risk are:

- Detailed internal and external inspections completed on five reservoirs and six suction tanks in 2020. The remediation programme for the inspected sites has been determined and initiated for these 11 tanks. Information is contained in TRIM 20/847952.
- In 2021, all reservoirs and suctions tanks in Christchurch had external inspections completed and eight had internal inspections (and in some cases remedial work) completed. Results from the work are available in the project management folder CP503658-01.
- A master list that holds relevant information for all reservoirs and suction tanks is TRIM21/1706559 . An ambitious programme of internally inspecting up to 30 tanks is planned for 2022.
- One reservoir has been replaced (Richmond Hill tank).
- Continuation of temporary chlorination at pump stations feeding reservoirs and suction tanks with poor condition roofs or below ground walls, with the target being 0.2 mg/L at the outlet of the tank.

The longer term improvement actions are:

- Undertake a comprehensive condition assessment of all suction tanks and reservoirs using recently revised condition assessment criteria, with a focus on high risk tanks. 'High Risk' determination comes from reviewing the external inspections and any relevant bacterial monitoring results.
- Develop a prioritised remediation programme to address contamination risks identified in the comprehensive condition assessment (priority given to worst condition and for reservoirs/suction tanks serving more than 5,000 people).
- Improve maintenance contract clauses to ensure that contractor regularly carries out visual and physical inspections of all water supply assets, including well heads and reservoirs.
- Making use of technology such as ROV inspections.
- Develop site-specific risk management plans for reservoir sites.

3.4.2 Risk Cause 5.02 - Incorrect or inadequate water quality data used for supply management

Drinking water online currently used but unknown availability beyond June 2022, council needs a new system for demonstrating compliance and also improved scheduling with more complex monitoring.

3.4.1 Risk Cause 5.05 – Civil Emergency

An earthquake or other large scale event could lead to a major disruption of service over 24 hours, requiring high level of monitoring and operational incident management. As earthquakes or other large scale natural events are somewhat unpredictable, the initial response and associated disruption will almost always take longer than 24 hours therefore the residual risk rating remains High. Since all of the Council's water safety plan improvement actions contribute to a safer water supply in terms of public health and water supply operations, no additional improvements have been assigned to this risk.

3.4.2 Risk Cause 4.09 – Lead in the distribution system (risk now rescored as acceptable)

Following the risk assessment in 2019 where the potential for lead leaching from lead-jointed pipes (pre 1940s cast iron pipes) into the water supply was found to be uncertain, the Council undertook water sampling for lead from areas served by lead-jointed pipes in Lyttelton in September 2019. A further sampling programme was undertaken in November 2019 on the water from lead jointed pipes including one of the Lyttelton rail tunnel pipelines, pipes in Lyttelton and Christchurch city. Some results had elevated levels of lead with some exceeding DWSNZ maximum acceptable value (MAV, 0.01 mg/L) and 50% MAV (0.005 mg/L), although lead concentrations were variable and no location consistently exceeded 50% MAV.

According to WHO information[18] lead is classified as a chronic or cumulative toxin. Chronic exposure is defined as continuous or repeated contact with a toxic substance over a long period of time (months or years).

In a 2020 sampling round undertaken in Akaroa where 26 samples were taken at regular intervals over a 24-hour period only one sample exceeded the MAV, 11 samples were below 50% MAV and 14 samples below the detection limit. This suggests that there is no chronic exposure to potentially harmful concentrations of lead on that pipe. This sampling approach was then applied to lead-jointed pipes in Christchurch and Lyttelton.

Since February 2021, in-depth lead and other chemical sampling and testing was undertaken using an automatic 24-hour sampling set-up. These samples were collected from private properties, connected to the old cast iron pipes. The automatic sampling machine collected samples every hour over a 24-hour period.

[18] https://www.who.int/ipcs/features/lead..pdf?ua=1

Each site therefore providing 24 different results for a 24-hour cycle. In summary, the 9-month long lead sampling programme collected and analyses 3672 samples in total.

Sampling sites and process	Pre 1940's Cast Iron pipes		1940-1950 CI pipes	Total
	Christchurch	Lyttelton		
Sampling sites	120	12	23	155
Sample process in lab	2832	288	552	3672

Out of 3672 only three samples exceeds the MAV. In all instances, only the first sample out of 24 exceeded the MAV. After changing the flushing time from 2 minutes to 10 minutes, none of the sampling undertaken exceeded the MAV. This suggests that the risk to the water supply from lead leaching from Lead-joined Cast Iron pipes is low.

All the lead result are stored in Trim 21/207012. The Arc GIS web map has been developed during the sampling programme to visualize the location of the pipes. The link to the web page is

https://gis.ccc.govt.nz/portal/home/webmap/viewer.html?webmap=37b0218c974647dab5f46f9cdeb28cb0

The longer term improvement actions are:

- Investigate options for replacing the cast iron rail tunnel trunk mains to Lyttelton.
- Accelerate replacement of lead jointed pipes via the water supply mains renewal programme.

3.4.3 Risk Cause 4.16 – Contamination due to inadequate backflow prevention (risk now scored as acceptable)

A lack of adequate backflow prevention could result in microbial or chemical contamination of the water supply and the consequence could be catastrophic if backflow was from a high hazard site.

Under section 69ZZZ of the Health Act, the Council may install a backflow prevention device on the public side of the point of supply, or allow the property owner to install backflow prevention device on their property.

The Council has had a long running programme to audit and improve backflow prevention, with a focus on high hazard sites. Backflow prevention is assessed and installed as required for building consents and new water supply connections.

While almost all water meters 38 mm diameter or smaller have at least a non-testable single check valve and provide some level of backflow prevention, there are 827 commercial water meters that are larger than this.

Backflow from high hazard sites and medium hazard sites with a meter diameter <38mm were identified as unacceptable risks in the 2019 risk assessment. To better understand the extent of the risk, an audit of all commercial properties which the Council did not have backflow prevention device records for, was undertaken in late 2019. Over 10,000 properties were checked to determine their backflow hazard and whether or not a backflow prevention device was present at the boundary. This found 5% of commercial connections were high hazard and did not have a boundary device, and 14% of medium hazard commercial connections did not have a boundary device. All properties with inadequate backflow prevention are having a backflow prevention device installed at the boundary. Details of the investigation, options considered and approved approach are described in two internal memos (TRIM 20/36833 and 20/953799). Rolling out the programme has now addressed all connections which had scored as unacceptable within the risk assessment.

The key short and medium term actions being undertaken to improve information associated with the risk and actions to reduce the risk are:

- Three additional full time staff members to administer and manage the backflow prevention programme
- In unchlorinated zones, all high hazard connections and medium hazard connections >38mm have backflow devices
- Letters are being sent to medium risk properties, and those properties where the risk may increase if the use was to change(ie the district plan allows for industrial use), informing them of the obligation to install a backflow device that is appropriate for the level of risk
- Review the bylaw to improve its robustness relating to backflow (currently underway)
- Continuation of temporary chlorination at pump stations feeding zones with inadequate backflow prevention on high hazard connections and medium hazard connections >38mm with the FAC target being 0.2 mg/L in the distribution network.

The longer term improvement action is:

- Create a system to collate and report on information about the backflow risk, backflow prevention device and annual testing records for all commercial properties (work underway).

4 Existing Preventive Measures and Barriers to Contamination

4.1 Introduction

The overarching information relating to existing preventive measures, barriers to contamination and additional mitigation measures is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

4.2 Preventing hazards entering the raw water

Groundwater source and security

Sections 2.3, 2.8 and 2.9 provide in-depth information about groundwater source, source quality and security.

Aquifers 2, 3, 4 and 5 are considered unlikely to be affected by surface or climatic influences at all locations throughout the city as groundwater modelling has shown that confining layers protect those aquifers and an upward hydraulic gradient exists in those deeper aquifers. The Council has significantly reduced abstraction from Aquifer 1 wells by drilling deep replacement wells in the northwest parts of the city where the surface confining layer above aquifer 1 is less than 3 m thick.

Extensive monitoring has confirmed the absence of protozoa in the groundwater.

The Christchurch/West Melton confined aquifer system is therefore considered to be an effective barrier to contamination.

Well head security

Section 2.9.3 provides a detailed description of the Council's Well Head Security Improvement Programme to upgrade all of the city's wells to comply with Criterion 2 of the bore security criteria in DWSNZ, and to be in line with best practice and the anticipated changes to the DWSNZ.

Having secure well heads that meet best practice is therefore considered to be an effective barrier to contamination.

Backflow prevention at pump stations

At Council's primary pump station sites, suction tanks with air gaps protect the source water from backflow from the distribution system. At sites with no a suction tank, backflow prevention and monitoring is provided by a combination of means:

- Artesian wells provide a constant positive head
- Non-artesian wells have a non-return valve in the submersible pump set
- Non-return valves installed on the headworks
- Pump station flow meters provide continuous monitoring and feedback on flows, and a backflow event can be quickly identified as it would result in reverse flow through the meter.

4.3 Removing particles and hazardous chemicals from the water

The confined aquifers which are the source of Christchurch's water naturally filter the water, removing particles from it.

No hazardous chemicals have been detected in the groundwater, so no treatment of these is required.

4.4 Killing or inactivating pathogens in the water

Previous groundwater modelling and age dating of the groundwater that is taken from Christchurch water supply wells shows that the water in all wells that are in use is at least one year old (refer to **Error! Reference s ource not found.**), by which time all pathogens will have been killed or inactivated. Microbial monitoring of source water over the last five years has demonstrated continued compliance with Criterion 3 of the DWSNZ bore water security criteria.

While three Aquifer 1 wells had age dating which was inconclusive and may have water which is less than one year old (Belfast and Redwood), these wells have been removed from service. The Council has continued with plans to replace these wells with deeper, secure wells in 2020 and 2021. In the meantime, the wells will not be used unless absolutely necessary (e.g. for peak demand) and when they are used the water will be treated with a chlorine dose of 0.5 mg/L. Aquifer 1 wells at Grassmere and Mays pump stations were replaced with deep wells in 2020.

While recent age dating of groundwater in Aquifer 1 at Main Pumps found that the water is more than one year old and complies with DWSNZ bore water security criterion 1, the Council decided to install UV disinfection at Main Pumps as an additional barrier. This is because it is a large and critical pump station and because of its location at the foot of the Port Hills where there are no deeper aquifers to take water from.

Aquifer 1 wells at Palatine and Thorrington are not in use and are prioritised to be decommissioned within the next year.

Once the above replacement deeper wells are drilled, this will leave just five Aquifer 1 wells: one each at Aldwins (headworks removed and not currently in use), Montreal (age dating found a minimum groundwater age of 26 years), Woolston (minimum groundwater age of 12 years) and two wells at Tanner pump station (minimum groundwater age of 52.5 years).

4.5 Maintaining the quality of the water in the distribution system

Chlorination

Presently temporary chlorination systems are installed to protect against microbial risks that are currently assessed as unacceptable.

Chlorination will not prevent contamination events and may not render harmless all pathogens that present a risk to human health. Christchurch City has adopted a vigilant monitoring and rapid response system with defined procedures instead of disinfection to avoid any complacency that disinfection may prevent contamination.

Storage reservoirs

The reservoirs in the network are covered and enclosed to prevent ingress of rainwater or contaminants and to exclude birds and vermin. These measures provide a partial barrier against recontamination of water following treatment. Reservoirs are inspected and repaired or upgraded as required. Further information is provided in Section 2.6.1.

Backflow prevention

The Council has identified backflow prevention as an important way of reducing the risk of contamination in the water supply.

The likelihood of backflow occurring in the Christchurch City and Lyttelton Harbour Basin reticulation networks is considered unlikely because the zones operate at high pressures and pressures do not fluctuate greatly, however, the consequence could be catastrophic even with temporary chlorination and therefore prevention and monitoring are the best defences to reduce this risk.

The system is also at risk from industries that use a higher water pressure in their processing than the distribution network, such as the local cement factory. For these properties, it is critical that adequate backflow prevention is installed.

Please refer to section 3.4.3 for the steps that the Council has taken and is taking to reduce this risk.

4.6 Summary of existing preventive measures

Table 4-1 provides a summary of the existing preventive measures for hazards and hazardous events and the barriers that are in place.

Table 4-1: Summary of Preventive Measures and Barriers to Contamination

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
24/7 network monitoring, control and operations	SCADA alarms and associated maintenance	Council has an in-house team dedicated to SCADA maintenance.	☑	☐	☐	☑	☐	☐	Full
24/7 network monitoring, control and operations	Network Control staffing and processes	SCADA alarms are monitored 24/365 by a dedicated in-house team of Network Controllers. Training consists of 3-6 months on-the-job training and assessment by peers.	☐	☐	☐	☑	☐	☐	Full
24/7 network monitoring, control and operations	Flow limiters	Control the water flow rate to prevent over pumping of the well	☐	☐	☐	☑	☐	☐	Full
24/7 network monitoring, control and operations	Severe weather warning	Emergency shut off for flood prone below ground well heads at risk ahead of weather events TRIM20/650821)	☐	☐	☐	☐	☑	☑	Partial
24/7 network monitoring, control and operations	Maintenance of Pump Station VSDs / Soft Starters	Allows pump speed to be adjusted to reduce pressure spikes and fluctuations, reducing negative or low pressure so contamination path is negated	☐	☐	☐	☑	☐	☐	Partial
24/7 network monitoring, control and operations	Maintain fire-fighting reserve in all reservoirs	SCADA monitoring of reservoir levels by network controllers	☐	☐	☐	☑	☐	☐	Full
24/7 network monitoring, control and operations	Duty rosters in place 24/7	Ensures network is monitored and alarms responded to	☐	☐	☐	☑	☑	☑	Full
24/7 network monitoring, control and operations	Monitor pumping rates	Prevents over-pumping of wells	☐	☐	☐	☐	☑	☑	Partial
24/7 network monitoring, control and operations	Mixed source water keeps pH within recommended range		☐	☐	☐	☑	☐	☐	Full
Approved contractors	Approved Water Supply Installers' register	Includes 3 strikes system for poor behaviour and hygiene working requirements, appropriate qualification and training.	☑	☐	☐	☑	☐	☐	Full
Approved contractors	Maintenance contractor chain of cleanliness	Contract clause 12 ‘Cleanliness, Hygiene and Contamination Certificate’ outlines the contractor’s obligations	☐	☐	☐	☑	☐	☐	Full
Approved contractors	Post-repair disinfection and water quality testing	Contract requirements for: - Disinfection of fittings and tools - Sterilisation of new pipework (including chlorination requirements) - bacteriological sampling and testing before being cleared for consumption	☐	☑	☑	☑	☐	☐	Full
Approved contractors	Contractor stand-down for specific diseases	Requirement in Schedule D - Terms and Conditions for Christchurch City Council Authorised Water Supply Installers to prevent transfer of illness through supply	☑	☐	☐	☑	☐	☐	Full
Approved contractors	Evidence of qualifications at time of recruitment and contract award	Ensures staff have appropriate qualifications to work on the water supply network	☐	☐	☐	☑	☐	☐	Full
Approved contractors	Use of approved chlorination contractors	CSS requirement for the disinfection of new and repaired pipework.	☑	☐	☐	☑	☐	☐	Full
Approved contractors	Maintenance contractor required to hold NZQA recognised qualification	Ensures staff have appropriate qualifications to work on the water supply network	☑	☐	☐	☑	☐	☐	Full

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Asset maintenance - inspections and scheduled maintenance	Routine inspection and maintenance of water supply assets	Citycare maintain and follow a schedule of 'Rounds' to maintain assets. Checklists are completed for each round.	☐	☐	☐	☑	☐	☐	Full
Asset maintenance - inspections and scheduled maintenance	Chlorine spraying on selected reservoir roofs	Roofs of vulnerable reservoirs are sprayed and scrubbed to remove solids and sterilise the surface. This measure has been implemented until the reservoir can be repaired or renewed.	☐	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Proactive and reactive maintenance by Contractor	Maintenance as per the requirements of the three waters and waste maintenance contract	☑	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Contractor maintains stock of critical parts and fittings	Stock is held at Pages Road, and a stock list provided by Citycare to CCC annually. Emphasis is on keeping stock for odd sized mains and fittings.	☐	☐	☐	☑	☐	☐	Full
Asset maintenance - inspections and scheduled maintenance	ROV camera inspections	Able to put the ROV into reservoirs to check internal condition	☐	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Reservoir cleaning	Reduces risk of reservoir contamination	☐	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Maintenance programmes	Ensures equipment is correctly maintained and performance monitored	☑	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Staff/Maintenance contractor observations	Damage to infrastructure or changes to water in network able to be investigated	☑	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Contract plans	Outline the methodologies and resources that Citycare Water use to maintain the Network.	☐	☐	☐	☑	☐	☐	Partial
Asset maintenance - inspections and scheduled maintenance	Reservoir roof sealing programme	Condition assessment of mesh for specific reservoirs and suction tanks	☑	☐	☐	☑	☐	☐	Partial
Asset Management	Good asset records	Assists in understanding the location, age and condition of infrastructure	☑	☐	☐	☑	☐	☐	Partial
Asset Management	Availability of drainage and water supply plans	Asset information also available on Canterbury Maps and CCC website.	☑	☐	☐	☑	☐	☐	Partial
Asset Management	O&M manuals and SOPs	Operations and maintenance manuals and standard operating procedures	☐	☐	☑	☑	☐	☐	Partial
Asset Management	Water supply asset renewals programmes	Including Capital Works Programme to repair or replace significantly damaged pipes, proactive and reactive asset renewals	☑	☐	☐	☑	☐	☐	Partial
Asset Management	Asset replacement programme	Asset upgrades planned to maintain ability to maintain public water supply. AAIF used for planning.	☑	☐	☐	☑	☐	☐	Partial
Asset Management	Water loss and leak detection contract	This contract measures unaccountable-for water in the network and helps identify leaks and potential issues in the network such as cross-connections and illegal connections.	☑	☐	☐	☑	☐	☐	Partial
Asset Management	Monitoring known Council-owned assets that present a contamination risk	This includes CCTV and condition assessments for wastewater pipes, landfill monitoring etc.	☑	☐	☐	☑	☐	☐	Partial
Asset Management	CCTV inspection of wells	CCTV inspections of well through WHSIP programme	☑	☐	☐	☐	☐	☐	Partial

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Asset Management	WW defect mapping	Identifies risk areas	☑	☐	☐	☑	☐	☐	Partial
Asset Management	Analysis of pipe samples	Samples of pipes replaced in the network are assessed to monitor assess corrosion and deterioration of pipes across city.	☐	☐	☐	☑	☐	☐	Partial
Asset Management	Annual inspection of submarine pipelines	condition assessment to maintain supply	☐	☐	☐	☑	☐	☐	Full
Asset management	Council uses Drinking Water Online to store drinking water monitoring data.		☐	☐	☐	☐	☐	☐	Partial
Asset planning	Water supply model	Used to assess current demand and system's ability to cope with future growth and also to plan shut downs and operations.	☐	☐	☐	☑	☐	☐	Full
Asset planning	Use of modelling data to identify areas with insufficient capacity for fire fighting	Identifies areas where drinking water may need to be supplied by tanker (for small reservoirs only), limiting duration of time without water in the event of significant firefighting requirements	☐	☐	☐	☑	☐	☐	Full
Asset planning	Pressure management trial in Rawhiti Zone	Lower pressure reduces leakage, pipe breaks. Potentially will be rolled out city-wide	☐	☐	☐	☑	☐	☐	Partial
Asset planning	Masterplan for growth areas	Early identification of growth areas for the city and indicative water supply and infrastructure requirements and accounted for in current water take consent	☐	☐	☐	☑	☐	☐	Full
Backflow prevention	Backflow prevention audits	These audits help identify potential high risk water consumers and contamination issues and require the installation of appropriate backflow prevention devices.	☐	☐	☐	☑	☐	☐	Partial
Backflow prevention	Assessment for backflow risk at the building consent and water connection application stage	The water connection application process includes an assessment of backflow risk for commercial and industrial connections	☑	☐	☐	☑	☐	☐	Full
Backflow prevention	Backflow prevention devices	Includes pump stations and water supply connections. Annual testing by IQP.	☑	☐	☐	☑	☐	☐	Partial
Backflow prevention	CCC-owned at risk properties have appropriate backflow devices installed	Prevents unintentional backflow event	☑	☐	☐	☑	☐	☐	Partial
Backflow prevention	Backflow programme	Programme to confirm presence of backflow devices including installing devices where not present and documenting.	☑	☐	☐	☑	☐	☐	Partial
Backflow prevention	Air gaps in suction tanks	Prevents contaminated water getting into the bore/well from the network	☑	☐	☐	☐	☐	☐	Partial
Backflow prevention	Non-return valves installed on wells	Prevents contaminated water getting into the bore/well from the network	☑	☐	☐	☐	☐	☐	Partial
Business continuity plans	Earthquake/Flood/Natural Disaster	Business Continuity Plans and procedures	☑	☐	☐	☑	☐	☐	Partial
Business continuity plans	Emergency Management and Business Continuity Plans in place	Council has a comprehensive register of emergency management and business continuity processes and plans	☐	☐	☐	☐	☐	☐	Partial

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Communications and customer feedback	Customer complaints	Including residents reporting broken pipes, low pressure, taste and odour etc.	☐	☐	☐	☑	☐	☐	Event Detection
Communications and customer feedback	Encourage water conservation	Work undertaken to encourage consumers to reduce their water consumption	☐	☐	☐	☑	☐	☐	Partial
Communications and customer feedback	Planned outage alerts	Where there will be no water supply available in a particular area for a planned period, water supply shut off notices created and delivered a minimum of 24 hours in advance of the shut off occurring.	☐	☐	☐	☑	☐	☐	Full
Communications and customer feedback	Reports of illness	Identifies issue that requires further investigation	☐	☐	☐	☑	☐	☐	Event Detection
Communications and customer feedback	Report of procedural breach by maintenance contractor		☑	☐	☐	☑	☐	☐	Event Detection
Communications and customer feedback	Observations by other contractors	Damage to infrastructure or changes to water in network able to be investigated	☑	☐	☐	☑	☐	☐	Event Detection
Communications and customer feedback	Reports/Observations by members of the public	Damage to infrastructure or changes to water in network able to be investigated	☑	☐	☐	☑	☐	☐	Event Detection
Confined aquifer system	Confined aquifer system	Confined aquifer system provides an effective barrier to contamination.	☑	☑	☑	☐	☐	☐	Full
Confined aquifer system	Groundwater modelling	Hydrogeological modelling to demonstrate the absence of surface influences as required for DWSNZ groundwater security criterion 1 in conjunction with age dating of groundwater	☑	☑	☑	☐	☐	☐	Partial
Confined aquifer system	Positive hydraulic pressure on artesian wells	Prevents contaminated water getting into the bore/well	☑	☐	☐	☐	☐	☐	Partial
Confined aquifer system	Age dating of groundwater	To demonstrate the absence of surface influences as required for DWSNZ groundwater security criterion 1 in conjunction with hydrogeological modelling	☑	☑	☑	☑	☐	☐	Full
Contract auditing and QA	Audits of all contractors' maintenance protocols and activities, and staff training	Monthly joint audits between the Council and Citycare to ensure appropriate processes and procedures are followed and identifies areas where improvements may be required	☐	☐	☐	☑	☐	☐	Partial
Legislation, Council bylaw, plans and standards	Water restrictions procedure	Restriction processes are triggered by a number of conditions related to pressure and reserve volume.	☐	☐	☐	☑	☐	☐	Partial
Legislation, Council bylaw, plans and standards	Council Bylaw	Water Supply, Wastewater and Stormwater Bylaw 2014	☑	☐	☐	☑	☐	☐	Full
Council QA and Construction Requirements	Building consent process and associated inspections	Building work involving new or altered 3-waters connections is inspected as part of the consent process	☑	☐	☐	☑	☐	☐	Full
Council QA and Construction Requirements	Approved materials' list and requirements	Ensuring right labelling of pipes, use of appropriate materials (barrier pipe in contaminated areas), pipes and fittings that are approved for use in potable water supplies.	☑	☐	☐	☑	☐	☐	Full

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Council QA and Construction Requirements	Inspection/approval of subdivision and Council capital works	Work has to comply with Council design and construction requirements.	☐	☐	☐	☑	☐	☐	Full
Legislation, Council bylaw, plans and standards	IDS (Infrastructure Design Standards) and CSS (Construction Standard Specifications) requirements	This includes use of approved materials that are safe to use in contact with drinking water and pipework and reservoir specific safety measures (mesh on vents, seals on hatches, external sample taps etc.). Also minimum separation distances between water supply pipes and other pipes.	☑	☐	☐	☑	☐	☐	Full
Council QA and Construction Requirements	Standard secure design for new well heads	The Council has a standard design, developed in the late 2000s, for an above-ground well head that meets the rigorous interpretation of DWSNZ Criterion 2 to provide consistency across sites and design teams.	☑	☐	☐	☐	☐	☐	Full
Council QA and Construction Requirements	QA checks	Ensures appropriate processes and procedures are followed and identifies areas where improvements may be required	☑	☐	☐	☑	☐	☐	Partial
Council QA and Construction Requirements	External sampling points on reservoirs	Reduces risk of contamination from sampling	☐	☐	☐	☑	☐	☐	Partial
Council QA and Construction Requirements	Construction audits	Ensure correct construction techniques and materials used	☑	☐	☐	☑	☐	☐	Partial
Council QA and Construction Requirements	Adoption of UKWIR guidelines for assessment of contaminated land	provides guidance on and assessments of land condition and ensuring correct materials are selected for water pipes and components to be used to protect the quality of drinking water whilst taking into account the service life of the water distribution system.	☑	☐	☐	☑	☐	☐	Full
Council QA and Construction Requirements	Established standpipe hire process	Includes hire of standpipes to contractors through a contract agent; standpipes have testable Backflow Prevention device and water meter fitted; illegal standpipes confiscated	☐	☐	☐	☑	☐	☐	Full
Council QA and Construction Requirements	Third party audits	Ensures appropriate processes and procedures are followed and identifies areas where improvements may be required	☐	☐	☐	☑	☐	☐	Partial
Council QA and Construction Requirements	IQP Inspections/Testing	Ensures appropriate processes and procedures are followed and identifies areas where improvements may be required	☐	☐	☐	☑	☐	☐	Full
Council QA and Construction Requirements	Post-earthquake recovery and improvement work	Additional improvements were undertaken after the earthquakes for increased resilience	☑	☐	☐	☑	☐	☐	Partial
Council QA and Construction Requirements	Sand filters and/or suction tanks to settle out sand	Prevents sands from entering distribution network	☐	☑	☐	☐	☐	☐	Partial
Health & Safety regulations, systems and processes	CCC fuel tanks are all above ground	Above ground structure allows for the easy detection of leaks or deterioration	☑	☐	☐	☐	☐	☐	Full
Health & Safety regulations, systems and processes	3-yearly certification of fuel tanks	To comply with Health and Safety at Work (Hazardous Substances–Validity Periods of Compliance	☑	☐	☐	☐	☐	☐	Full

			Preventive measure contributes to barrier				CCC measures		
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		Certificates for Stationary Container Systems) Safe Work Instrument							
Health & Safety regulations, systems and processes	Mass balance checks on diesel volumes	Used to asses or identify if there is a tank leak.	☑	☐	☐	☐	☐	☐	Partial
Health & Safety regulations, systems and processes	Hazardous substances legislation	Applicable to fuel tanks and chemicals used in water supply operations.	☑	☐	☐	☑	☐	☐	Full
Operations and maintenance contract	Contract audits and QA.		☑	☐	☑	☑	☑	☑	Partial
Operations and maintenance contract	Contract plans and response (1 hour for alarms), Network control room also monitors alarms 24/7. There is also the second on-call person who receives the alarms if missed by Citycare/contractor and control room.		☐	☐	☐	☑	☑	☑	Full
Operations and maintenance contract	Contractor has backup contractor resources available. Third party contractor resources available to assist with DWSNZ compliance matters Council EI&C team can maintain the communications systems		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Contractor response time to SCADA alerts is a contractual key performance indicator (i.e. high priority).		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Contractor stand-down for specific diseases.		☐	☐	☐	☑	☐	☑	Full
Operations and maintenance contract	Duty rosters in place 24/7.		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Flushing programme (flushing as required).		☐	☐	☐	☑	☐	☑	Partial
Operations and maintenance contract	Maintenance Contractor (Citycare Water) and Authorised Installer System required to have an NZQA recognised qualification (L3 or L4) or working towards the qualification (under supervision).		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Maintenance contractor follows 'chain of cleanliness'.		☐	☐	☐	☑	☐	☑	Full
Operations and maintenance contract	Maintenance contractor follows contractor plans and uses disinfection when carrying out repairs.		☐	☐	☐	☑	☐	☑	Partial
Operations and maintenance contract	Maintenance of reservoirs if inspections identify the need for remedial works		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Minimum operating level in the reservoir is maintained to prevent resuspension of any sediment		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Pipe fittings for major mains are required to be kept in stock.		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Pump on VSD and can be ramped down.		☐	☐	☐	☑	☐	☑	Partial

			Preventive measure contributes to barrier				CCC measures		
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Operations and maintenance contract	Regular checks ensure site security measures are in place (ongoing).		☐	☐	☐	☑	☐	☑	Partial
Operations and maintenance contract	Regular checks of reservoir ensure that tank lids, overflow pipes etc. are well maintained and have vermin protection in place		☐	☐	☐	☑	☐	☑	Partial
Operations and maintenance contract	Regular servicing and calibration of data loggers		☐	☐	☐	☐	☑	☑	Partial
Operations and maintenance contract	Reservoir cleaning as per the contractor plan.		☐	☐	☐	☑	☑	☑	Partial
Operations and maintenance contract	Reservoir roof chlorine spraying programme (when deemed necessary).		☐	☐	☐	☑	☐	☑	Partial
Operations and maintenance contract	ROV camera inspections.		☐	☐	☐	☑	☐	☑	Partial
Operations and maintenance contract	Trained operators		☐	☐	☐	☐	☐	☑	Partial
Operations and maintenance contract	Use of tankered water: supply agreement in place with PROTRANZ		☐	☐	☐	☑	☑	☑	Full
Positive pressure prevents contamination entering the network.	Constant positive pressure in the network	Positive pressure prevents contamination entering the network.	☐	☐	☐	☑	☐	☐	Full
Regional Council planning, rules and cooperation	Engagement with Resource Consent applications	Engagement with ECan on resource consents in supply protection zone reduces risk of polluting activities.	☑	☐	☐	☐	☐	☐	Partial
Regional Council planning, rules and cooperation	Liaison with ECan	Liaison includes: - Water Issues Management group: bimonthly meeting of senior managers from Environment Canterbury and our Council to identify and resolve any issues that arise with respect to the management of three waters services and their impact on the environment - 3 waters management zone committee - Quarterly meetings with ECan compliance monitoring staff to discuss issues with resource consents compliance - review and submissions on ECan resource consent applications - participation in the Canterbury Drinking Water Reference Group	☑	☐	☐	☐	☐	☐	Partial
Regional Council planning, rules and cooperation	Council consulted on resource consents	Council receives 'interested party' notification from ECan on issues where the Council is deemed to have a general interest in a consent application, even where the consent is non-notified, and able to send comments. The Council also submits where it has 'affected party' status.	☑	☐	☐	☐	☐	☐	Partial
Regional Council planning, rules and cooperation	ECan GIS data for potential contaminated sites	ECan holds information identifying if land has previously been used for hazardous activities	☑	☐	☐	☐	☐	☐	Partial

			Preventive measure contributes to barrier				CCC measures		
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		and industries. Testing is often required to confirm contamination.							
Regional Council planning, rules and cooperation	ECan Source Protection Zone	Source water is protected by rules in the Canterbury Land & Water Regional Plan.	☑	☐	☐	☐	☐	☐	Full
Regional Council planning, rules and cooperation	Controls under Land and Water Regional Plan	Includes rules relating to heat exchangers and no new groundwater take consents other than for group and community drinking water supplies and non-consumptive uses, and flow limits on wells.	☑	☐	☐	☐	☐	☐	Partial
Regional Council planning, rules and cooperation	Flow monitoring and reporting	By ECan or Council	☐	☐	☐	☑	☐	☐	Event Detection
Regional Council planning, rules and cooperation	ECan undertake modelling and investigations	ECan undertakes groundwater modelling and monitoring throughout the region. Most recent modelling is groundwater flow under the Waimakariri River	☑	☐	☐	☐	☐	☐	Partial
Regional Council planning, rules and cooperation	Submission on Land and Water Regional Plan	Council submits on LWRP and changes to chapters that have potential to impact on water quality and quality for public supply purposes e.g. protecting source water quality	☑	☐	☐	☐	☐	☐	Partial
Regional Council planning, rules and cooperation	Priority given to drinking water groundwater take consent	LWRP states - In general, no additional water is to be allocated from the Christchurch West-Melton Groundwater Allocation Zone shown on the Planning Maps except for group or community water supply as set out in Rule 5.115 or for non-consumptive taking and use as set out in Rules 5.131 and 5.132.	☐	☐	☐	☑	☐	☐	Full
Safe heat exchanger design	[redacted]		☐	☐	☐	☑	☐	☐	Full
Safe heat exchanger design			☐	☐	☐	☑	☐	☐	Full
Secure well heads	Well casing grouting and sealing programme	Part of the Wellhead improvement programme to prevent the ingress of water and/or contaminants	☑	☐	☐	☐	☐	☐	Full

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Secure well heads	Well head security assessments	Includes assessment of contamination potential of any sites within 400m of well head and CCC-owned wells in vicinity of water supply wells	☑	☐	☐	☐	☐	☐	Full
Secure well heads	PSI/DSI Assessments	Assessment to understand contamination risk from contamination to groundwater	☐	☐	☐	☐	☐	☐	Full
Secure well heads	Level sensors	Measures the water level in the wells	☑	☐	☐	☑	☐	☐	Event Detection
Secure well heads	Pump with non-return valve fitted	Non-artesian wells have a non-return valve in the submersible pump set to prevent contaminated water entering the bore/well	☑	☐	☐	☐	☐	☐	Full
Secure well heads	Drilling of Deep Wells	Programme to reduce the amount of water drawn from Aquifer 1, particularly in the Northwest zone, where there is only a thin confining layer	☑	☐	☐	☐	☐	☐	Full
Council QA and construction requirements	Majority of well heads fenced off or inside locked chamber	includes fencing around pump station	☑	☐	☐	☐	☐	☐	Partial
Council QA and construction requirements	Access hatches are alarmed and have padlocks.	Prevents unauthorised access and damage to equipment	☑	☐	☐	☑	☐	☐	Full
Site specific risk management plans	Site Specific Risk Management Plans	Every pump station has its own Site Specific Risk Management Plan that provides an overview of the pump station and site specific documents and resources, risks and improvement tables	☑	☐	☐	☑	☐	☐	Full
Stakeholder engagement, communication and collaboration	Support via the Canterbury Drinking Water Reference Group (CDWRG)	Council, ECan, CDHB and other Canterbury territorial authorities are members of the Canterbury Drinking Water Reference Group (CDWRG) reports to the Chief Executives' and Mayor Forums. CWMRG shares information and advice, reports on public drinking water supplies, co-ordinates contingency planning and makes joint or shares submissions on matters of interest. Builds good relationships with our neighbouring authorities makes it easier for us to call on them for support when needed (e.g. in an emergency).	☑	☐	☐	☑	☐	☐	Partial
Stakeholder engagement, communication and collaboration	PFAS Joint Agency Working Group	Allows council to draw on expertise of others and understand risk potential (e.g. draw on testing by other agencies (CIAL and FENZ) which found no contamination)	☑	☐	☐	☐	☐	☐	Partial
Stakeholder engagement, communication and collaboration	NEW - liaison with the DWA and Medical Officer of Health		☐	☐	☐	☐	☐	☐	Partial
Stakeholder engagement, communication and collaboration	Liaison with Council Contaminated Sites Officers	These officers are responsible for application of the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health at Territorial Authority level	☑	☐	☐	☐	☐	☐	Partial

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Stakeholder engagement, communication and collaboration	Communication with Kiwi Rail	Ability to work collaboratively to develop solution without reduced supply to LHB	☐	☐	☐	☑	☐	☐	Partial
Stakeholder engagement, communication and collaboration	Notification from NZTA	NZTA notifies Council of use of tunnel deluge system	☑	☐	☐	☑	☐	☐	Full
Stakeholder engagement, communication and collaboration	SLA between NZTA and CCC	Includes procedure for operating the deluge system. Also covers roles and responsibilities around maintenance, testing and reporting.	☑	☐	☐	☑	☐	☐	Full
Stakeholder engagement, communication and collaboration	Strong working relationships with other Civil Defence agencies	Able to assist to provide public water supply as soon as possible after a natural disaster	☐	☐	☐	☑	☐	☐	Partial
Stakeholder engagement, communication and collaboration	Trade waste and stormwater audits	These audits (carried out by 3WW Technical Services staff) help identify potential contamination issues.	☑	☐	☐	☑	☐	☐	Partial
System redundancy	Upgraded pipe in road tunnel	Ability to supply more water through road tunnel would limit impact of loss of pipe in rail tunnel	☐	☐	☐	☑	☐	☐	Partial
System redundancy	System redundancy	multiple wells and pump stations in zones	☐	☐	☐	☐	☐	☐	Full
System redundancy	Multiple connections between LHB and city networks	LHB water supplied by city network. Multiple connections reduces risk of loss of water for maintenance and repairs	☐	☐	☐	☑	☐	☐	Full
System redundancy	Mobile generators	Mobile diesel powered pump available for secondary pump stations (usually for reservoirs)	☐	☐	☐	☐	☐	☐	Partial
System redundancy	Supply from neighbouring zones	Pressure zones across the network can be interconnected in an emergency by opening valves at zone boundaries	☐	☐	☐	☑	☐	☐	Partial
System redundancy	Diesel generators	Approximately 50% of the primary pumping stations have a standby diesel generator in case of power failure	☐	☐	☐	☐	☐	☐	Partial
System redundancy	Use of sub-zones	Pressure zones across the network can be interconnected in an emergency by opening valves at zone boundaries split into smaller zones by closing specifically labelled earthquake emergency zone valves	☐	☐	☐	☐	☐	☐	Full
System redundancy	Redundancy within reservoir network	suction tanks and storage reservoirs provide storage	☐	☐	☐	☑	☐	☐	Full
System redundancy	Back-up generators fully operational	Reduces downtime in providing power to pumping stations in case of power failure	☐	☐	☐	☐	☐	☐	Full
System redundancy	Standby pumps	At major stations in case of failure	☐	☐	☐	☐	☐	☐	Partial
System redundancy	Seismic valves	Emergency valve that isolates reservoirs following a seismic event to prevent loss of water from potential pipe breakage	☐	☐	☐	☐	☐	☐	Partial
System redundancy	Alternative water sources for fire-fighting e.g. sea	Reduces the impact on areas with insufficient capacity for fire-fighting during peak water usage	☐	☐	☐	☑	☐	☐	Full

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Temporary chlorination	Standby chlorination systems	Used to provide public water supply as soon as possible after a natural disaster	☐	☐	☑	☑	☐	☐	Partial
Temporary chlorination	Temporary chlorination of wells	Temporary chlorination at un-remediated or at-risk wells that currently don't meet DWSNZ bore security criterion 2	☐	☐	☑	☑	☐	☐	Partial
Water quality monitoring	2018 Asbestos Testing returned negative results	Samples of pipes replaced in the network are assessed to monitor assess corrosion and deterioration of pipes across city.	☐	☐	☐	☑	☐	☐	Partial
Water quality monitoring	Microbiological testing of drinking water	Scheduled microbiological testing is performed by the Council laboratory. Samples are enumerated for E. coli and Total Coliforms.	☐	☐	☐	☑	☐	☐	Event Detection
Water quality monitoring	Water quality monitoring	Includes testing for disinfection by-products, FAC etc. and also monitoring undertaken by ECan	☑	☐	☐	☑	☐	☐	Event Detection
Water quality monitoring	5-yearly chemical monitoring of water supply wells	Council performs annual groundwater chemistry monitoring to better understand groundwater quality. The water from each aquifer at each pump station site is tested on a 5-year rolling programme.	☐	☐	☐	☑	☐	☐	Event Detection
Water quality monitoring	Test for PFOS and PFOA	Emerging contaminant used in fire-retardant foam identified. No city water supply wells near CIAL or Wigram	☑	☐	☐	☐	☐	☐	Event Detection
Water quality monitoring	CCC Laboratory is IANZ accredited	Formal recognition that the Laboratory has been independently assessed and passed by an authoritative accreditation body.	☐	☐	☐	☑	☐	☐	Full
Water quality monitoring	Annual well head sampling	Annual monitoring programme of the chemical composition of various wells	☑	☐	☐	☑	☐	☐	Event Detection
Water quality monitoring	Laboratory uses a recognised laboratory data management system (QLIMS).		☐	☐	☐	☐	☑	☑	Full
Water quality monitoring	Laboratory is approved by the Ministry of Health for drinking water testing		☐	☐	☐	☐	☑	☑	Full
Water quality monitoring	Monitoring programme ensures the sampling point locations are sufficiently comprehensive.		☐	☐	☐	☐	☐	☑	Partial
Water quality monitoring	Sample points are maintained and correct procedures are followed (ongoing)		☐	☐	☐	☑	☐	☑	Partial
Water quality monitoring	Sampling and laboratory staff are adequately trained in sampling techniques and proficiency is maintained	Routine microbiological sampling and testing is performed by Council lab, which is IANZ accredited. Some sampling for operational and treatment process monitoring on Banks Peninsula and in Christchurch is performed by CCL staff (verified by the DWA who signs off the CCL staff as 'competent' for undertaking the sampling and equipment calibration).	☐	☐	☐	☑	☐	☑	Partial
Water quality monitoring	The maintenance contractor receives training by the Council drinking water sampling officers		☐	☐	☐	☑	☐	☑	Partial
Water quality monitoring	Training/certification of staff undertaking Water quality monitoring					☑	☐	☑	Partial

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
Water treatment	If turbidity exceeds 2 NTU for a 3 minute period the pumps will stop, the UV plant will shut down			☑	☑	☐	☐	☑	Partial
Water treatment	Treatment plant shutdown under low intensity, high flow, pressure transient or loss of power			☑	☑	☐	☐	☑	Partial
Water treatment	Two UV units operate on a duty/standby arrangement					☐	☐	☑	Partial
Water treatment	Routine cleaning and maintenance schedule for lamp sleeves and UV sensor					☐	☐	☑	Partial
Water treatment	Regular replacement of UV lamps					☐	☐	☑	Partial
Water treatment	Flow moderated UV dose					☐	☐	☑	Partial
Water treatment	Plant complies with the DWSNZ requirements and is third party accredited			☐	☑	☐	☐	☑	Partial
Water treatment	Pressure switch					☐	☐	☑	Partial
Water treatment	Diesel generator on site					☐	☐	☑	Partial
Water treatment	Station will stop completely until the diesel generator has been started and accepts load.					☐	☐	☑	Partial
Water treatment	The UV valves will be closed and the UV warmup cycle will begin again and the pumps can be operated once the UV is ready.					☐	☐	☑	Partial
Water supply procedures and processes	Water shut offs monitored	To manage compliance with section 69S (3) (b) of the Health Act (notify the Medical Officer of Health of water supply interruptions greater than 8 hours prior to the interruption occurring (for planned interruptions) or within 24 hours after the interruption occurred (for unplanned interruptions).	☐	☐	☐	☑	☐	☐	Partial
Water supply procedures and processes	Permit to Work process	The permit to work process was put in place so that Council has visibility of what is happening in the networks, can notify the maintenance contractor of work carried out by others, in case an after-hours response is required, and can notify the applicant of any special conditions and precautions they should take in doing the work and any contingencies and remedial actions required.	☐	☐	☐	☑	☐	☐	Full
Water supply procedures and processes	Wells in locations vulnerable to flooding are turned off when heavy rain is forecast	Process for turning off below ground wells that may be at risk of flooding or inundation during a wet weather event to remove risk of contamination (TRIM20/650821)	☑	☐	☐	☑	☐	☐	Partial
Water supply procedures and processes	Maintain contamination monitoring, risk assessment and reactive processes	Reactive processes reduce extent of contamination impact by ensuring that alerts and alarms are monitored, risks assessed and	☐	☐	☐	☑	☐	☐	Partial

			Preventive measure contributes to barrier				CCC measures		
Preventive Measure Category	**Existing Preventive Measure**	**Description**	**Prevent hazards entering the raw water**	**Remove particles and hazardous chemicals from the water**	**Kill or inactivate pathogens in the water**	**Maintain the quality of the water in the distribution system**	**Maintain water supply to consumers**	**Operate plant and distribution system safely and efficiently**	**Full / Partial Barrier?**
		appropriate response actions taken. Refer Transgression Response processes.							
Well head security improvement programme (WHSIP)	Reduced abstraction from shallow wells	Work is being undertaken to replace wells drawing water from the shallowest aquifer (Aquifer 1) where there is only a thin confining layer where possible	☑	☐	☑	☐	☐	☐	Partial
Well head security improvement programme (WHSIP)	Conversion to above ground well head	Programme of work to convert below ground well heads to above grounds well heads to reduce risk of contamination	☑	☐	☐	☐	☐	☐	Partial
Well head security improvement programme (WHSIP)	Well Head Security Improvement Programme (WHSIP)	Includes grouting and sealing, raising wellheads above ground, abandoning wells and drilling deeper wells, backflow prevention.	☑	☐	☐	☐	☐	☐	Partial

4.7 Effectiveness of preventive measures

Based on the information presented in in the risk assessment table (Section 3.2) and in Sections 4.2 to 4.6, the Council considers that there are adequate preventive measures in place that contribute to the effectiveness and maintain the integrity of each of the four types of barriers.

Type of Barrier	Statement on Effectiveness of Existing Preventive Measures
Preventing hazards entering the raw water.	Adequate existing preventive measures due to confined aquifer system, source water quality and CCC monitoring.
Removing particles and hazardous chemicals from the water.	Adequate existing preventive measures due to confined aquifer system and source water quality and CCC monitoring.
Killing or inactivating pathogens in the water.	Adequate existing preventive measures due to confined aquifer system and source water quality and CCC monitoring.
Maintaining the quality of the water in the distribution system.	Additional improvements are proposed, refer to Table 5-1, Table 5-2 and Table 5-5.

Notwithstanding the above statement Council has identified several areas for improvement which are outlined in Section 4.8.

4.8 Turning off temporary chlorination

Temporary chlorination is currently being turned off once the following criteria are met:

- All contributing wells at a pump station meet Criterion 2 for bore water security in DWSNZ, as determined by an expert in well head security, or have been isolated
- Suction tanks and reservoirs supplying >5,000 people within the zone of influence of the pump station have condition grade 3 or better for hatch and seals, mesh on vents, mesh on overflows, roof condition and below ground wall condition
- Within the zone of influence of the pump station, appropriate backflow prevention is installed and functioning for all sites with a high risk of microbial contamination.

Information on improvement measures for all risks and timeframes, including those to further reduce acceptable risks, is provided in section 4.8.

5 Identification of Additional Preventive Measures and Improvement Plan

5.1 Improvements to address unacceptable risks

Section 3.2, the Christchurch/Lyttelton Harbour Basin risk assessment table, includes an assessment of each risk's acceptability in light of the associated uncertainty. The following tables outline the improvements to address the seven unacceptable risks discussed in section 3.4.

Improvement plan items were prioritised in the risk assessment workshops and highest priority given to those improvements that address unacceptable risks. It is expected that upon completion and implementation of the improvement items the risk acceptability for currently unacceptable risks will change to acceptable due to:

A better understanding of the risk profile and associated data and processes which improves the level of uncertainty; and/or
An improved residual likelihood due to capital works and/or operational/procedural improvements; and/or
An improved residual consequence due to capital works and/or operational/procedural improvements.

Table 5-1: Improvements to address risk 3.06 – Major microbial contamination of storage tank

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
CI01 - Repair reservoirs and suction tanks	Structural repairs to reservoir walls, roofs, floors. Work package being identified in project CPMS 50446 WS Suction Tank/ Reservoir Renewals.	3.04 3.05 3.06 3.07 3.08 3.09	Sharmin Eswardatt, 3WW Project Management	$2,000,000	FY2020/21 and 2021/22	1
CI02 - Improve security at reservoirs	Install alarms at hatches at those reservoirs and suction tanks which don't have them. May also include other security and safety measures, software and hardware upgrades as deemed necessary.	3.04 3.05 3.06 3.07 3.08 3.09	Karn Snyder-Bishop, 3WW Asset Management	$200,000	FY2020/21 and 2021/22	1

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
CI06 - Temporary chlorination to provide a chlorine residual in the affected part distribution system	Chlorination of parts of the distribution system until unacceptable microbial risks have been mitigated.	3.04 3.05 3.06 3.07 4.17 4.18	Adam Twose, 3WW Operations	TBC	Until unacceptable risks causing potential microbial contamination have been mitigated.	1
PI02 - Undertake increased inspection and monitoring at-risk reservoirs and increase monitoring frequency at those sites	Identification of reservoirs that would benefit from more frequent inspections and monitoring until they have been repaired and/or improved.	3.04 3.05 3.06 3.07 3.08 3.09	Deepak Chouhan, 3WW Quality & Compliance	Staff time	Ongoing	1
PI04 - Comprehensive condition assessment inspection programme for reservoirs and suction tanks	Investigate additional inspections for reservoirs and suction tanks that are more vulnerable.	3.04 3.05 3.06 3.07 3.08 3.09	Angus Buxton, 3WW Asset Management	Staff time	Ongoing	1
PI10 - Improve maintenance contract clauses to ensure that contractor regularly carries out visual and physical inspections of all water supply assets including well heads and reservoirs. Includes the use of refined electronic checksheets for regular inspections.	Review of maintenance contract prior to going out for tender.	2.01 2.12 3.04 3.05 3.06 3.07 3.08 3.09 5.05	Tim Drennan, 3WW Manager Service Excellence	Staff time	Will be aligned with the preparation of new tender documents for the future 3 Waters operations and maintenance contract	1

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
PI17 - Develop site specific risk management plans (SSRMPs) for reservoir sites	An expansion of the Site Specific Risk Management Plans currently in place for pump stations to include reservoirs	3.02 3.03 3.04 3.05 3.06 3.07 3.08 3.09	Deepak Chouhan, 3WW Quality & Compliance	Staff time	FY2020/21 and 2021/22	1

Table 5-2: Improvements to address risk 4.09 – Lead in the distribution system

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
CI05 - Replace where necessary lead jointed cast iron pipe.	Renewals required depending on the outcomes of PI1.	4.09	Craig McCauley, 3WW Asset Management	TBC	LTP	1
CI08 - Reduce number of connections to pre-1940 lead jointed mains by providing alternative connections. CPMS ID 58162 WS Mains Renewal - London, Canterbury, Dublin, Oxford, Norwich, Gladstone, Exeter and Donald	Where non-lead jointed pipes are nearby, provide connections to these instead	4.09	Peter McConnell, 3WW Project Management	$1,200,000	FY2020/21	1
PI01 - Investigate lead contamination associated with lead jointed cast iron pipes.	Includes testing and providing alternative water supply if necessary.	4.09	Jeanette Gower, 3WW Water & Wastewater Operations	$60,000	FY2020/21 and 2021/22	1 (Completed)

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
PI05 - Options study Lyttelton Harbour Basin water supply source	• Continue to investigate options for replacing the rail tunnel trunk mains to Lyttelton Harbour Basin. • Consider duplicating trunk mains in some parts of Lyttelton Harbour Basin, particularly the trunk main between Lyttelton and Governors Bay	4.12 4.13	Michele McDonald, 3WW Asset Planning Water & Wastewater	$60,000	FY 2020/21 and 2021/22	2

Table 5-3: Improvements to Address Risk 4.16 – Contamination due to inadequate backflow prevention

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
CI06 - Temporary chlorination to provide a chlorine residual in the affected part distribution system	Chlorination of parts of the distribution system until unacceptable microbial risks have been mitigated.	3.04 3.05 3.06 3.07 4.17 4.18	Adam Twose, 3WW Operations	TBC	Until the risk profiles for currently unacceptable risks causing potential microbial contamination have been improved to acceptable.	1
PI03 - Proactive backflow prevention programme	Continue improving the proactive backflow prevention programme, educate customers, create a system to enable reporting on backflow prevention.	4.16 4.17 4.18	Will Rowson, 3WW Water Services	Staff time	Backflow prevention devices on all high hazard sites : end 2020 Backflow prevention devices on all medium hazard sites where connection is >38 mm: mid-2021 Backflow	1

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
					reporting system: by end 2022	

Table 5-4: Improvements to Address Risk 5.02 Incorrect or inadequate water quality data used for supply management

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
P116	Investigating a number of options – external providers/other council systems or a custom system provided by external consultants or internal IT (preference)	5.01 5.02 5.03 5.04	Veronica Zefferino 3WW Quality and Compliance	TBC	1st July 2022 (existing systems can continue to operate)	1

All improvement items in the tables above have been assigned the highest priority. The responsibility for ensuring progress on the improvement, the timeframe for the improvement, and possible practical steps to carry out the improvement are also included in the tables. To ensure that the work is undertaken, responsibilities have been assigned to the relevant Council staff. Roles and responsibilities are likely to change and therefore are required to be checked as part of the annual internal water safety plan review process. Senior management has endorsed these improvements approving the full water safety plan, reflected in the signatures provided on page 2.

5.2 Potential additional improvements

The Council continuously works to improve water supply delivery and has identified additional areas where procedural improvements could be implemented. These items have a lower priority than those in Table 5-1, Table 5-2 and Table 5-3 and will be addressed when and if staff resources and funding is available. The timeframes presented in Table 5-5 are estimates only.

Table 5-5: Potential Additional Improvements

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
CI03 - Smart water monitoring (e.g. pressure transient, leak detection and water quality)	Smart water strategy and request for proposal for smart network monitoring will identify preferred technology. Tender and pilot in the Rawhiti zone	1.01 1.02 1.03 1.06 1.08 2.01 2.09 2.10 PC1 PC2 PC3 PC4	Irmana Garcia Sampedro, 3WW Project Management / Michele McDonald, 3WW Asset Planning Water & Wastewater	$2,000,000	FY2020/21 and 2021/22	2
CI04 - Well decommissioning	Investigate and confirm that CCC owned wells which are no longer in service are decommissioned in line with good practice and that well status records are passed on to ECan	1.03	Don Gracia, CCC Technical Services & Design Unit	TBC	FY2020/21 and 2021/22	2
CI07 - Install additional dedicated sampling points throughout the distribution system. CPMS ID 56258 WS Drinking Water Sampling Point Installations and 41252 Programme - WS Drinking Water Sampling Point Installations	Dedicated sampling points to replace private external taps which are currently used for sampling. This would aid the establishment of water quality trends.	5.05	Veronica Zefferino, 3WW Quality & Compliance	$150,000	Starting FY2020/21, multi-year programme	3
PI06 - Staff induction and ongoing training programme for water supply staff	Develop an induction and ongoing training programme to increase awareness of the importance of public water supply, water safety plan and public health	5.04 5.05 PC2 PC3 PC4	Helen Beaumont, Head of 3WW	TBC	FY 2020/21 and 2021/22	2

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
	risks that can arise when things go wrong.					
PI07 - Develop procedural documents for network control operations	Documentation outlining how network controllers operate the different water supply zones. Includes response to SCADA alarms.	1.10 2.09 2.10 3.01 5.04 PC3 PC4	Gijs Hovens, 3WW Network Operations	Staff time	FY 2020/21 and 2021/22	2
PI08 - Create procedural documents for Critical Control Points	Procedural documents that detail corrective actions that are triggered by exceeding target criteria or critical limits	5.04 5.05	Gijs Hovens, 3WW Network Operations	Staff time	FY 2020/21 and 2021/22	3
PI09 - Operational security audits at water supply sites (pump stations and reservoirs)	Review and document security procedures relating to water supply sites including investigation of installing security cameras at reservoirs and pump stations, fencing etc.	5.02 5.03	Gijs Hovens, 3WW Network Operations (audits) / Tallat Mehmood, 3WW Project Management (capital works)	Staff time (audits) / LTP funds (tbc)	Ongoing	2
PI12 - Engage with contractors and authorised water supply installers	Educate contractors on water supply risks and issues.	2.11 4.04 4.05 4.06 PC1 PC2 PC4	Will Rowson, 3WW Water Services / Jeanette Gower, 3WW Water & Wastewater Operations	Staff time	Ongoing	3

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
PI13 - Develop and implement a quality management system for all drinking water supply processes.	To be rolled out across all CCC owned and operated water supplies.		Veronica Zefferino, 3WW Quality & Compliance	Staff Time	FY2020/21 and FY2021/22	2
PI14 - Carry out the 'Priority 2 Determinand' identification programme as per the 2012 MoH guideline	Likely to be sampling programme of water supply wells and monitoring of key parameters in the distribution system, including nitrate.	1.01 1.06 1.08 1.11	Daniela Murugesh, 3WW Quality & Compliance	$40,000	FY2020/21 and 2021/22	2
PI15 - Investigate removing heat exchange connections at CCC facilities.	• Investigate whether heat exchange need can be met by separate well or alternative connection design at Pioneer Pool and South Library. • Review all pump stations to ensure not present at any other locations (apart from Gardiners PS)	4.20	Mike Bourke, 3WW Asset Planning Water & Wastewater	Staff time	FY2020/21 and 2021/22	2
PI16 - Work with ECan to strengthen information relating to private bores	When ECan undertake a review of the Christchurch - West Melton zone of the Land and Water Regional Plan, the Council has an opportunity advocate for strengthening the requirements around requirements for decommissioning bores and record management of this information.	1.03	Dale McEntee, 3WW Quality & Compliance	Staff time	FY2020/21 and 2021/22	2

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
	While this is important for CCC, it is also likely to be a regional issue.					
PI18 - Commissioning and handover process and associated documentation	Ensure that evidence of all water safety plan quality assurance checks is provided before operational handover of assets		Gijs Hovens, 3WW Network Operations	Staff time	FY2020/21 and 2021/22	2
PI19 - Monitor health evidence and work with Ministry of Health and Taumata Arowai on adding a long-term MAV for nitrate to the drinking-water standards.		1.07	3WW Asset Planning Water & Wastewater	Staff time	FY2020/21 and 2021/22	3
PI20 - When drilling new and replacement wells, target aquifers with low nitrate concentrations.		1.07	Veronica Zefferino 3WW Quality and Compliance Angus Buxton, 3WW Asset Management	Staff time	FY2020/21 and 2021/22	3

Improvement Item	Notes	Risk References	Contact Person / Responsible	Estimated Cost	Timeframe	Priority 1 = high 2 = medium 3 = low
PI21 - Improve automated BIM process.	Includes implementing adequate quality assurance processing and data auditing.	5.11	Steve Sullivan, Manager Asset Systems & Information, Asset Management	Staff time	FY2020/21 and 2021/22	3

The improvement tables are saved in TRIM 20/714310.

6 Operational Procedures

Information relating to system operations, maintenance and reporting for the Christchurch/Lyttelton Harbour Basin water supply is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

6.1.1 Operational set points

There are operational set points for reservoirs levels and pressure within the reticulation network. This information is continuously monitored through the network SCADA by the network controllers 24 hours a day, 7 days a week.

Reservoir levels are generally maintained between 80-100% full. SCADA alarms are set at 110% to avoid overflowing. Generally, if a reservoir level drops to 70% full, actions are focused on refilling the reservoir. If a reservoir drops to 50% full, there is a risk of running out of water and the response action is to create an alert to the rostered on-call manager and to bring additional pump stations into service to refill the reservoir.

This is different from a sudden, unexpected drop in reservoir level. A response in this situation depends on the reservoir and would indicate a large leak in the reservoir, or in the reticulation supplied by the reservoir. If this happens, network controllers dispatch a contractor to investigate, and if necessary isolate the leak, while focussing on maintaining reticulation pressure by starting pumps as necessary. If there are common sense actions available to network controllers (such as closing a valve or stopping pumps) that can reduce the flow of water without sacrificing network pressure, these would be taken.

Pressure within the reticulation network varies between operating zones as shown in Table 2.9. Each part of the network has a nominal operating pressure and network controllers aim to operate around that value. There are overpressure alarms shown on the SCADA. These levels are set between operational and technical staff based on an assessment of what pressures start to increase the incidence of pipe failures. This is dependent on the age and condition of the reticulation network in the water supply zone.

The SCADA system will also show an alarm if the pressure gets too low. Pumps automatically start if the pressure gets too low. An alarm is triggered if the pump does not start and the network controller response is to retry starting the pump, start a different pump, and if those are unsuccessful call the maintenance contractor to investigate the problem with the pump.

6.1.2 Maintenance monitoring and inspection

Copies of the check sheets used by Citycare, including well head/well inspections, reservoirs, suction tanks and pump station buildings can be found in TRIM: 19/1039731. The data is uploaded into Citycare's Event Manager and available to Council staff who have access to the system. An example output generated from the check sheets can be found in TRIM: 19/1066632. An example of the monthly Pumps Inspection Round Completion Reports can be found in TRIM: 19/1064311.

6.2 Operational and Maintenance Staff Training

Key Council staff and Citycare Water staff training information is provided in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

6.3 Critical Control Points for the Christchurch/Lyttelton Harbour Basin water supplies

6.3.1 Introduction

The Council has identified the following as critical control points (CCPs) for the Christchurch/Lyttelton water supplies:

- Critical Control Point 1 – Network Pressure
- Critical Control Point 2 – Reservoir Level
- Critical Control Point 3 – Temporary Chlorination of Below-Ground Wellheads.

The following sections provide details on each critical control point including the monitoring procedures and the necessary corrective actions to be taken when monitoring indicates that the critical limits have been exceeded.

Corrective actions for parameters outside the normal operating ranges are outlined in the respective Critical Control Point Sections 6.3.2 to 6.3.4.

Exceeding a critical limit may also trigger incidents and response plans as outlined in Section 8.

The Critical Control Point for Main Pumps UV Disinfection is included in the Main Pumps site specific risk management plan in TRIM 20/1501365.

6.3.2 Critical Control Point 1 – network pressure

General

Adequate system pressure is required to achieve customer levels of service. System pressures lower than the target and action limits increases the potential for contamination through leaks and unintentional backflow. System pressures higher than the target and action limits increase the risk of damage to the pipe network and thus the risk for introduction of contaminants into the system.

Critical Limits

Operational day-to-day monitoring of control process:	
What	• Pressure
When	• Continuous
Where	• Pump station outlet
How	• Pressure measurement
Who	• Automatic/SCADA
Records	• Automatic (Network Controller)

Process performance criteria at the operational monitoring point:		**Correction if performance criteria are not met:**
Target:	All pump stations have different target pressures, action limits and critical limits which are captured in document 'Critical Control Points Targets by Pump Station and Reservoir/Suction Tank'. This document is reviewed and updated as and when required. Refer to TRIM 20/1291758.	Duty Network Controller checks that pressures are within expected range.
Action Limits		Use SCADA to review pumping activity trend. Alter pumping at affected station and other stations in the zone to compensate. Check if pressure drop is due to peak demand and will replenish when peak period is over. Check current permitted valve isolations (Permits to Work). Send out Pump Station Maintenance Team to check pumps for airlocks and sand filter (if present) pressure differential. Send Water & Wastewater Operations Team to check other network valves and if there is a high water use occurring from point source (large water leak).
Critical Limits		All of the above actions, plus: Escalate by informing Team Leader Network Operations, Manager Operations WWW and Manager Service Excellence. Check for industrial commercial properties that could have pumping operations on site, i.e. backflow/back pressure. For near or total pressure loss notify Fire and Emergency NZ. Use specialist contractors to identify large unseen leaks or draw off. For pressures <280 kPa notify the CCC call centre and communicate with the public through CCC Communications Team

6.3.3 Critical Control Point 2 – reservoir level

General

- A sudden or unexplained drop in a reservoir water level indicates an unusually high demand in the network, or a large water main leak or burst.
- Excessive drops in reservoir water levels have the potential to stir up sediments from the reservoir bottom and may result in turbid water being distributed in the network.
- Excessive reservoir level drops may also result in loss of water and shortage in the distribution zone if the reservoir cannot be filled in time.
- Excessive reservoir filling can cause water to be lost out of overflow pipes and potential damage to reservoir.

Critical Limits

Operational day-to-day monitoring of control process:	
What	• Reservoir level
When	• Continuous
Where	• Reservoir
How	• Level measurement
Who	• Automatic/SCADA
Records	• Automatic (Network Controller)

Process performance criteria at the operational monitoring point:		**Correction if performance criteria are not met:**
Target:	All pump stations have different targets, action limits and critical limits which are captured in document 'Critical Control Points Targets by Pump Station and Reservoir/Suction Tank'. This document is being reviewed and updated as and when required. Refer to TRIM 20/1291758.	Duty Network Controller checks levels are within expected range.
Action Limits		Use SCADA to review pumping activity trend. Supply the zone from alternative pumping stations (if water level issue at suction tank). Check that reservoir level controls and settings are correct. Check if water use is due to peak demand and will replenish when peak period is over. Check current valve isolations (Permits to Work). Send out Pump Station Maintenance Team to check downstream pump Send Water & Wastewater Operations Team to check if there is a high water use occurring from point source (large water leak, fire). Introduce water restrictions if reservoirs not able to refill for 3 consecutive days and other demand criteria are met.
Critical Limits		All of the above actions, plus: Escalate by informing Team Leader Network Operations or Manager Operations WWW. For near or total pressure loss notify Fire and Emergency NZ. For "no water" notify call centre and communicate with the public through CCC Communications Team. Organise water carrier truck to fill reservoir or provide water for the public.

6.3.4 Critical Control Point 3 – temporary chlorination of below-ground well heads

General

The water is chlorinated at below-ground well head locations to minimise any risks that may be associated with well heads that are located in a below-ground chamber until such time when those well heads are converted to above-ground structures. This CCP is also supplemented during wet weather events by an SOP that sees regular well head inspections during and after the event and increased levels of chlorination at affected pump stations (refer TRIM 20/650821 Section 4.2).

Critical Control Point Objectives

Inform of any corrective action necessary ensure that the temporary chlorination process meets the minimum requirements.

Critical Limits

Operational day-to-day monitoring of control process:	
What	• Manual Monitoring of Free Available Chlorine (FAC)
When	• Daily
Where	• Sampling point installed downstream from the chlorine injection point (sampling after 2 minutes contact time)
How	• Chlorine Dosing
Who	• Maintenance Contractor
Records	• Manual readings (Citycare report)

Process performance criteria at the operational monitoring point:		**Correction if performance criteria are not met:**
Target:	FAC target range is 0.15-0.4 mg/L	Take additional consecutive samples.
Action Limit	1 sample > 1.4 mg/L FAC OR 3 consecutive samples <0.4 mg/L FAC	Resample FAC Inspect chlorination equipment and adjust/repair if required Citycare to complete solutions report with recommendation to CCC
Critical Limit	3 consecutive samples < 0.15 mg/L FAC	All of the action limit actions, plus: Targeted FAC and E. coli sampling programme with pump station on/off Inspect chlorination equipment and adjust/repair if required Escalate by informing Team Leader Water & Wastewater Operations or Manager Operations WWW. Complete solutions report with recommendation to CCC
Critical Limit	1 sample > 5 mg/L FAC	All of the action limit actions, plus: Isolate pump station Sample FAC in reticulation and flush until FAC <5 mg/L Escalate by informing Team Leader Water & Wastewater Operations or Manager Operations WWW. Notify call centre and Drinking Water Assessor

6.3.5 Supporting programmes for Critical Control Points:

The following measures are in place to ensure that the critical control points are monitored and managed within the critical limits:

1. Maintenance Contractor's Standard Operating Procedure that outlines actions and limits specific to a specific target dosing rate. Refer to TRIM 19/1122734.
2. Laboratory sampling for E. coli and total coliforms with transgression reporting to Internal Transgression Group and Taumata Arowai to ensure that exceedances of action and critical limits do not have a negative impact on public health and water supply operations.
3. Notification and liaison with Taumata Arowai for non-microbial transgressions and serious incidents.
4. The Council has a comprehensive register of procedural documents and contingency plans that – depending on the nature of the exceedance – may be activated. Refer to the index of procedural documents in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283). CSWS 046 (Assess Risk of Drinking water Contamination) is the starting point for most water supply incidents.

6.4 Corrective actions

Corrective actions for parameters outside the normal operating ranges are outlined in the respective Critical Control Point sections 6.3.2 to 6.3.4.

7 Verification Monitoring Programme

Information relating to drinking-water quality and compliance monitoring, consumer satisfaction, and short-term evaluation of results is provided in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

8 Management of Incidents and Emergencies

Information on incident and emergency response plans, an index of procedural documents and levels of emergency is provided in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

8.1 Previous incidents and emergencies

The review of previous incidents and emergencies assists with identifying the types of incidents and emergencies that may occur, and the impact that they are likely to have on the water supply. Those that have affected the Christchurch and Lyttelton Harbour Basin water supplies are summarised in Table 8-1.

Table 8-1: Previous Significant Incidents and Emergencies

Incident	Impact on Supply	Improvements/Lessons Learned
Canterbury Earthquakes 2010/11	Significant damage to reticulation network and some reservoirs. Several areas with major water outages. Boil water notice issued and water tankers provided emergency supplies. Many wells increased in turbidity and had to be redeveloped. Several pump stations and wells were destroyed beyond repair (Palmers and Bexley pump stations). Water carriers were used to fill the reservoirs.	Ability to create sub-zones to limit the areas that were affected by major water outages. Importance of resilient water supply infrastructure and power supply to enable water pumping and distribution. Council's IDS and CSS were updated to incorporate designs that are resilient to earthquakes.
2017 Port Hills fires	Several top tier reservoirs got drained in a short period of time due to fire fighters taking water from hydrants in the reservoir zones.	Better communication with Fire & Emergency NZ (FENZ) including advising FENZ where to take water from (hydrants in the flat parts at the foot of the Port Hills as draw off won't affect reservoirs)
E. coli transgressions The most significant E. coli transgression in recent years in terms of operational disruption was the Keyes pump station transgression in December 2018, which turned out to be wind blown contamination into the sample bottle.	Several E. coli transgressions over the years due to various reasons. Generally no impact on the supply in terms of water quantity due to the resilient nature of the distribution system with multiple pump stations being able to contribute to the demand in the zone. (Keyes pump station transgression: a precautionary boil water notice was issued for the entire Rawhiti zone. Sampling and investigations continued for several weeks)	Some transgressions could have possibly been prevented if operational maintenance budget was better funded (e.g. more frequent cleaning of pump station buildings may have prevented the Keyes pump station transgression and more proactive repairs on reservoir roofs may have prevented the recent Denton pump station transgression). There is also scope to improve water quality sampling

Incident	Impact on Supply	Improvements/Lessons Learned
		procedures and communication between teams to ensure that samples are taken from the most appropriate and representative sampling points.
Diamond Harbour boil water notice in July 2018 due to broken wastewater pipe nearby	Disruption to day to day operations due to ongoing flushing and investigations.	Importance of good asset records and maintenance.
Mt Pleasant 2 reservoir zone loss of water service in February 2019 due to the presence of multiple closed network valves which should have been open.	Precautionary boil water notice was issued. Significant disruption to day to day operations due to investigations.	Importance of good asset and complaint records. Better valve lock out and documentation system has been developed.
[redacted]		
Belfast turbidity event September 2020	Disruption to day to day operations due to ongoing flushing and investigations.	Council Permit to Work process needs improvement including clear communication channels.
Lake Terrace well 5 lead sampling result in November 2020 (>MAV) which turned out to be an analytical laboratory error	Station was shut down during the investigation, station unable to contribute to zone.	Importance of diligent laboratory chain of custody and analytical methods.
Denton PS transgression Dec 2020	Initial isolation of PS, suction tank, remained off line during repairs for over a year.	Vulnerability of suction tanks and importance of on going comprehensive inspection/maintenance
Grampian PS transgression August 2021	Suction tank off line for just over a month. Programmed for longer term replacement.	On going vulnerability of below ground suction tanks

9 Documenting and Reporting

Detailed information on the management of documentation and records and reporting is provided in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

10 Investigations

10.1 Investigative studies

For the Christchurch/Lyttelton Harbour Basin water supply, the following investigations are currently being undertaken:

10.1.1 Leaching of Lead from lead-jointed pipes

The potential for lead leaching from lead-jointed pipes into the water supply was assessed in the 2019 Christchurch/Lyttelton water safety plan risk assessment workshops as an unacceptable risk. Since there was no comprehensive data available the Council started lead sampling in Christchurch, Lyttelton and Akaroa in September 2019. Initially manual spot sampling was undertaken, but to enable a better understanding of realistic exposures as patterns of demand vary throughout the day automatic sampling over a 24hr period was used. Sampling was undertaken in Akaroa, Christchurch and Lyttelton and targeted areas with cast iron pipes, reticulation dead ends and high residence times for water. For the locations investigated several samples were taken from the same sampling site (2019 manual spot sampling) or an entire sampling sequence was undertaken (2020 samples). The results indicate that there has not been a continuous exposure to high levels of lead at any of the sites investigated. In 2021 the sampling programme has been completed with a further 155 sampling sites with a total of 3672 individual samples analysed at the laboratory.

10.1.2 Smart Network Opportunities

- Smart network opportunities – looking at opportunities for network improvements, e.g. pressure transient monitoring, acoustic leak detection and smart water meters.

10.1.3 Reservoirs and Suction Tanks

- Reservoirs and suction tanks – comprehensive condition assessments of all reservoirs and suction tanks. The inspection programme informs the subsequent programme of repair.
- More frequent sampling of nitrate in water supply wells and the distribution system to better understand the nitrate concentrations being supplied to consumers.

The above investigations are also included in the improvement plan (refer to Section 5.2).

The Council is also undertaking additional investigations to aid compliance with DWSNZ secure bore water criterion 1:

- Groundwater modelling - hydrogeological modelling to establish the security of the groundwater used for water supply and to demonstrate the lack of surface or climatic influences.
- Groundwater age testing – to confirm the average age of the groundwater in the tested bores and that the fraction of the water with age less than one year meets the requirements of DWSNZ bore water security criterion 1.

10.2 Validation of equipment, processes and practice

Validation of equipment is being undertaken by Citycare Water under the maintenance contract. The contractor's plan and associated standard operating procedures (SOPs) detail the calibration and maintenance requirements are provided in Volume A: Components Common to All Water Supplies Water

Safety Plan (TRIM 22/438283). Table 10-1 and Table 10.2 summarise the Council's processes in relation to validation of equipment, processes and practices for the Christchurch/Lyttelton water supplies.

For the temporary chlorination, calibration verification is performed every morning on the day of sampling, and the instrument (Lovibond MD100 photometer) is calibrated every six months by Thermo Fisher Scientific. The SOP (TRIM: 19/1127007) describes the calibration procedure for Citycare field staff and CCC laboratory staff taking and analysing water samples for pH, FAC (free available chlorine), TAC (total available chlorine) and break point titration to ensure chlorination targets are being met. There is also a SOP for managing responses to FAC samples outside the limits agreed with the Council (TRIM: 19/1127045).

Sand filter maintenance is undertaken annually by Citycare. The SOP (TRIM: 19/1121541) outlines the pump stations in scope and the correct procedure to follow.

Citycare are responsible for the annual testing of backflow prevention devices fitted at pump stations, treatment plants and well heads. The SOP (TRIM: 19/1121527) outlines the main actions to be undertaken and the testing standard information. An example of the check certificate is in TRIM: 19/1133544.

The Council uses SAP asset management systems to manage all low voltage (24V and below) instrumentation and communication equipment installed at Council facilities and this will typically include:

- Milltronics level controllers
- Flowmeters
- Radios and radio network
- Radio transmitting units (RTUs)
- Pressure transducers
- Level transducers
- Variable speed drive (VSD) configuration
- Float switches
- Earthquake sensors and equipment
- Instrumentation
- Loggers

Assets are loaded into SAP and have appropriate preventative maintenance tasks assigned to them at suitable intervals. Examples of the SAP preventative maintenance "call" sheets and associated checklists are provided in TRIM: 19/1133511. Pump stations have annual electrical checks, an example of the check sheets for the Farrington Pump Station is provided in TRIM: 19/1133417. The Operations Control Room and dedicated 24/7 callout staff may also add reactive maintenance tasks as necessary.

The Council has a general methodology agreement with Environment Canterbury for the Council's water takes (TRIM 14/664240). This agreement covers compliance with Water Takes Regulations and includes guidance on meters to be used, where they are to be fitted and verification methodology requirements. While there is a five yearly re-verification process, there is an expectation that the Council will use its real-time continuous monitoring to identify conditions that will affect flow meter measurement accuracies and address them at the time. An annual water take summary report is also required to be produced with supporting compliance data for each bore. These reports are found in TRIM FOLDER10/38.

The process of confirming groundwater security for the Christchurch City and Lyttelton supplies is outlined in section 2.9 to ensure compliance with the DWSNZ.

Table 10-1: Validation of existing systems and equipment

What requires validation	Details (validation aspects/location etc.)	Frequency	Procedure	Responsibility
Secure bore water status	• Groundwater age dating and modelling (DWSNZ secure bore criterion 1) • Secure bore head assessment (DWSNZ secure bore criterion 2) • E. coli absent from groundwater (DWSNZ secure bore criterion 3)	• Every 5 years • Every 5 years • Ongoing	As per DWSNZ section 4.5 / New Quality Assurance Rules	3 Waters & Waste Quality & Compliance team
Asset replacements (e.g. well pump)	• Pump settings against target flow rates and consent conditions • SCADA alarm settings	Annually or when there is a change in settings or replacement of plant equipment and/or electrical systems)	As per the equipment manufacturer's directions	Operational Delivery Lead – Water Treatment together with Citycare
Temporary chlorination equipment	• Station flow rates • Chlorine dose rate • Reticulation FAC results	Monthly checks or when there is a change in settings	As per the equipment manufacturer's directions	Citycare
Flow meters	• Well flow meters (for ECan consent purposes) • Station flow meters (for operational purposes)	Annually	As per the equipment manufacturer's directions	Network Operations team
Pressure transmitters	At pump station sites	• At least annually. • Also undertaken for any fault or if required as part of troubleshooting.	• As per Electrical, Instrumentation and Control staff experience and competence. • Results are stored on the SCADA drive: \\ccity.biz\fileserver\tww	Electrical, Instrumentation and Control team
Level transmitters	At reservoir sites	• At least annually. • Also undertaken for any fault or if required as part of troubleshooting.	• As per Electrical, Instrumentation and Control staff experience and competence. • Results are stored on the SCADA drive: \\ccity.biz\fileserver\tww	Electrical, Instrumentation and Control team

What requires validation	Details (validation aspects/location etc.)	Frequency	Procedure	Responsibility
UV reactors (Main Pumps site)	• Operating flow • UV dose • UVT	As per DWSNZ section 5.16.2	As per DWSNZ section 5.16.2/ New T3 Quality Assurance Rules	Network Operations team
Turbidity meter calibrations (Main Pumps site)	• Treatment process	3 monthly	Weekly	Network Operations team
Wells, pump stations and reservoir sites	Maintenance contractor inspections to check operating conditions and processes	Annually	As per instructions given by Operations and Maintenance Team and Network Operations	• Operations team • Network Operations team

Table 10-2: Validation of new systems and equipment

What requires validation	Details (validation aspects/location etc.)	Frequency	Procedure	Responsibility
New treatment or operational assets	Refer DWSNZ requirements for pre-validation to acceptable international standard	Prior to purchase	Pre-validation by manufacturer - As per requirements of DWSNZ /Quality Assurance Rules	Capital Works Project Manager or Operational Delivery Lead - Water Treatment
	Operating within pre-validated conditions (treatment system specific but could include flowrate, turbidity, pH, UVT etc.)	At commissioning (before being brought online to supply customers)	Treatment system specific – refer commissioning report	Capital Works Project Manager or Operational Delivery Lead - Water Treatment

11 Oversight, Review and Continual Improvement

All information on the long-term evaluation of results, internal audit and external of drinking water quality management, and review by Senior Leadership information is available in Volume A: Components Common to All Water Supplies Water Safety Plan (TRIM 22/438283).

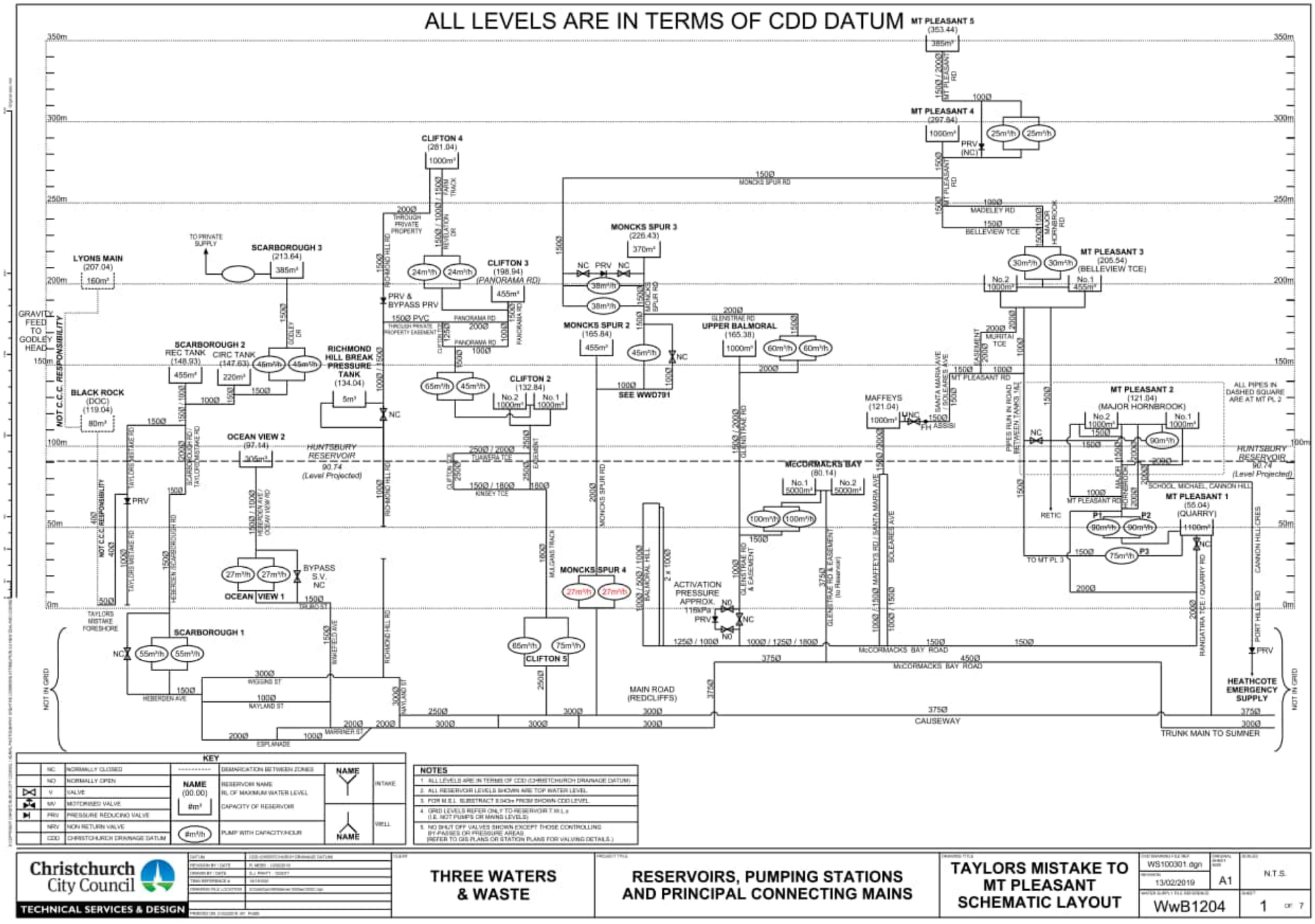
Appendix A CRC204470: Authorised Water Take Bores and Rates of Take

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
PS1001: Addington	Addington Stn Well-01	M35/2270	4	42,350			1568420	-5178474
	Addington Stn Well-02	M35/2787					1568414	-5178457
PS1002: Aldwins	Aldwins Stn Well-01	M35/2587	4	70,000			1573194	-5179193
	Aldwins Stn Well-02	M35/3813					1573165	-5179174
	Aldwins Stn Well-03	M35/8147	1	42,336			1573178	-5179203
PS1004: Aston Drive	Aston Stn Well-01	M35/7215	4	39,312			1577279	-5185757
	Aston Stn Well-02	M35/7216	2	39,312			1577258	-5185779
PS1068: Auburn	Auburn Stn Well-05	M35/7600	5	45,500	972,000		1565741	-5179851
PS1005: Averill	Averill Stn Well-02	M35/2159	1	7,623			1572555	-5182178
	Averill Stn Well-03	M35/2403	2	14,000			1572533	-5182178
	Averill Stn Well-01	M35/1976	4	28,000			1572545	-5182178
	Averill Stn Well-04	M35/1870					1572529	-5182166
PS1069: Avonhead	Avonhead Stn Well-05	BX23/0428	4	33250			1562480	-5181459
	Avonhead Stn Well-07	BX23/0430	5+	33250			1562453	-5181473
PS1070: Belfast	Belfast Stn Well-02	M35/10632	3	35,000			1570028	-5190029
	Belfast Stn Well-03	BX24/2762	4	44,150			1570035	-5190030
PS1006: Bexley Rd	Bexley Stn Well-01	M35/2266	4	45,500			1576927	-5182380
PS1007: Blighs	Blighs Stn Well-03	M35/6203	2	18,144			1567650	-5182963
	Blighs Stn Well-04	BX24/0965	3	28,000			1567578	-5182936
PS1066: Brooklands	Brooklands Stn Well-01	M35/7180	2	13,860			1575198	-5193914
	Brooklands Stn Well-02	M35/7291					1575139	-5193923
PS1071: Burnside	Burnside Stn Well-05	M35/9439	5	62,000			1564762	-5183107
	Burnside Stn Well-07	BX24/0188					1564735	-5183038
	Burnside Stn Well-10	BX24/0191					1564725	-5183010
	Burnside Stn Well-06	BX24/0187	4	44,000			1564718	-5183078
	Burnside Stn Well-08	BX24/0189					1564698	-5183051
	Burnside Stn Well-09	BX24/0190					1564699	-5183050
PS1081: Burwood	Burwood Stn Well-01	M35/3660	2	16,429			1574434	-5184750
	Burwood Stn Well-02	M35/4133	4				1574458	-5184757
	Burwood Stn Well-03	M35/1546					1574476	-5184770
PS1008: Carters	Carters Stn Well-01	M35/2789	4	76,020			1576180	-5181300
	Carters Stn Well-03	M35/2555					1576189	-5181294
	Carters Stn Well-05	M35/10928					1576383	-5181270
	Carters Stn Well-02	M35/2790	2	17,500			1576181	-5181309
PS1072: Crosbie	Crosbie Stn Well-02	M35/6040	5	25,200			1563443	-5181714
	Crosbie Stn Well-05	BX23/0227	5+	21,000			1563421	-5181729
	Crosbie Stn Well-04	M35/18384	4	49,980			1563481	-5181717
	Crosbie Stn Well-06	BX23/0228					1563437	-5181715
PS1100: Denton Park	Denton Main South Well-01	M35/1865	3	105,000			1561363	-5178795
	Denton Stn Well-02	M35/1866					1561046	-5178936
	Denton Stn Well-01	M35/3547					1561181	-5178980
	Denton Main South Well-02	M35/3546					1561370	-5178679
	Denton Amyes Well-01	M35/1864	2	13,104			1561619	-5178526
PS1102: Dunbars Rd	Dunbars Stn Well-01	M36/4053	2	133,000			1565342	-5175647
	Dunbars 56P Well-01(dunbars 3)	M36/4052					1565084	-5175757
	Dunbars 32P Well-01 (dunbars well 2)	M36/4333					1564862	-5175849
	Dunbars 85 Well-01(Dunbars well 4)	M36/3060					1564622	-5175939
	Dunbars Stn Well-05	M36/8019	4	37,800			1565311	-5175651
PS1010: Effingham	Effingham Stn Well-01	M35/1554	4	24,500			1577348	-5184510
	Effingham Stn Well-02	M35/1606	2	53,466			1577344	-5184524
	Effingham Stn Well-03	M35/2609	4				1577354	-5184523
PS1012: Estuary	Estuary Stn Well-04	BX24/0412	2	31,500			1578629	-5180019
	Estuary Stn Well-05	BX24/1210	4	10,500			1578760	-5180048
PS1073: Farrington	Farrington Stn Well-04	M35/9440	5	30,200			1566661	-5184646
	Farrington Stn Well-05	BX24/0192	3	51,400			1566673	-5184622
	Farrington Stn Well-06	BX24/0193					1566674	-5184625
	Farrington Stn Well-07	BX24/0194					1566689	-5184647
	Farrington Stn Well-08	BX24/0195	4	24,400			1566658	-5184645
PS1125: Gardiners	Gardiners Well-01	BX24/1311	5+	27,000			1566708	-5187208
	Gardiners Well-02	BX24/1312	4	23,000			1566701	-5187153
PS1074: Grampian	Grampian Stn Well-05	M35/8660	2	21,168			1568136	-5185992

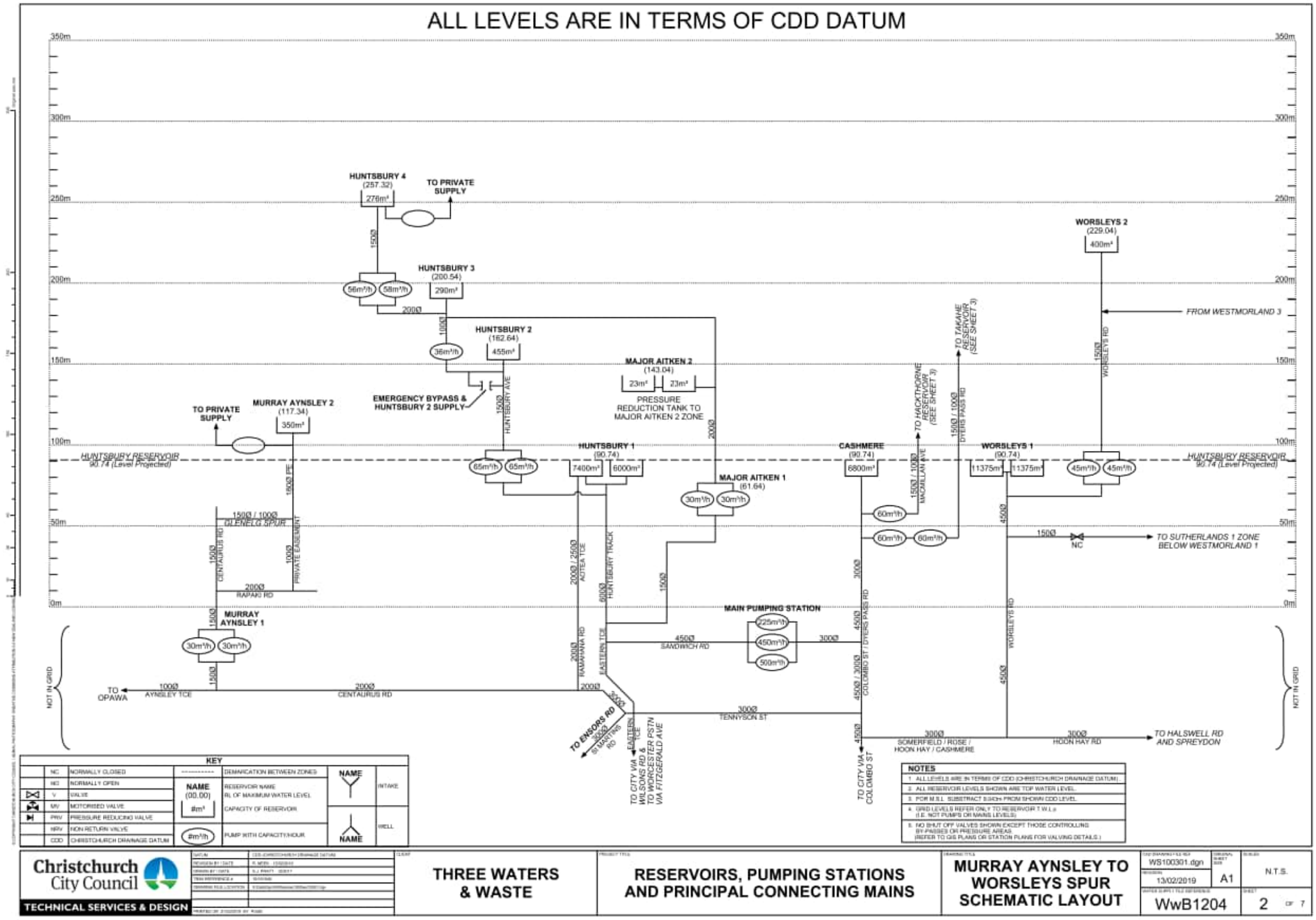
CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
	Grampian Stn Well-06	BX24/1327	3	48,000			1568088	-5186064
	Grampian Stn Well-07	BX24/1328					1568089	-5186084
PS1014: Grassmere	Grassmere Stn Well-01	M35/1476	1	28,000			1568832	-5184433
	Grassmere Stn Well-02	M35/1475	3	30,548			1568832	-5184426
	Grassmere Stn Well-03	M35/8087	4	45,360			1568839	-5184430
PS1016: Hillmorton	Hillmorton Stn Well-01	M36/0981	5	7,637			1567121	-5177567
	Hillmorton Stn Well-02	M36/1058	4	71,365			1567120	-5177568
	Hillmorton Stn Well-04	M36/4073					1567239	-5177644
PS1017: Hills Rd	Hills Stn Well-06	BX24/0457	4	28,000			1571817	-5183705
	Hills Stn Well-07	BX24/0350	2	21,000			1571819	-5183689
	Hills Stn Well-05	M35/10325	3	28,000			1571818	-5183696
PS1076: Jeffreys Rd	Jeffreys Stn Well-06	M35/6667	5	39,312			1567124	-5181957
	Jeffreys Stn Well-07	BX24/0533	4	18,000			1567080	-5181960
	Jeffreys Stn Well-08	BX24/0532	2	23,000			1567080	-5181950
	Jeffreys Stn Well-09	BX24/0534	3	18,718			1567120	-5181950
PS1067: Kainga	Kainga Stn Well-01	M35/6213	2	9,100			1572410	-5193067
PS1022: Kerrs Rd	Kerrs Stn Well-01	M35/2152	4	58,065			1574276	-5180860
	Kerrs Stn Well-02	M35/2241					1574287	-5180863
PS1119: Keyes	Keyes Stn Well-02	M35/18733	4	31,500			1577414	-5182970
	Keyes Stn Well-01	M35/18732	2	50,120			1577432	-5182927
	Keyes Stn Well-03	M35/18734					1577566	-5182999
PS1023: Lake Terrace	Lake Terrace Stn Well-03	M35/2260	4	66,752			1574392	-5183543
	Lake Terrace Stn Well-04	M35/18398	5	39,690			1574423	-5183561
	Lake Terrace Stn Well-05	BX24/0993	3	21,000			1574409	5183550
PS1529: Ly Dyers	LY Dyers Stn Well	M35/5135	4	41,204			1575622	-5178663
PS1024: Main Pumps	Main Pumps Stn Well-01	M36/4591	1	212,688			1570884	-5176731
	Main Pumps Stn Well-02	M36/2828					1570840	-5176812
	Main Pumps Stn Well-03	M36/1356					1570904	-5176629
	Main Pumps Stn Well-04	M36/1195					1570803	-5176810
	Main Pumps Stn Well-05	M36/0985					1570811	-5176673
	Main Pumps Stn Well-06	M36/1363					1570805	-5176753
PS1083: Mairehau	Mairehau Stn Well-01	M35/5830	4	45,360			1574361	-5185638
PS1084: Marshlands	Marshlands Stn Well-01	M35/7813	4	90,720			1572635	-5184704
	Marshlands Stn Well-02	M35/7814					1572622	-5184707
PS1026: Mays Rd	Mays Stn Well-04	M35/2494	2	76,202			1569403	-5183360
	Mays Stn Well-02	M35/1945					1569403	-5183362
	Mays Stn Well-03	M35/1944	1	45,360			1569403	-5183363
	Mays Stn Well-05	M35/7319	5	36,288			1569413	-5183358
PS1027: Montreal St	Montreal Stn Well-01	M35/2243	4	76,202			1570123	-5181177
	Montreal Stn Well-02	M35/2325	1				1570116	-5181183
PS1028: Palatine	Palatine Stn Well-01	M36/1197	1	14,000			1571483	-5176387
PS1085: Parklands	Parklands Stn Well-01	M35/3446	4	43,400			1576297	-5185725
	Parklands Stn Well-02	M35/3128	2	67,060			1576256	-5185733
	Parklands Stn Well-03	M35/7746					1576305	-5185714
PS1088: Picton Ave	Picton Stn Well-01	M35/8897	4	28,224			1568037	-5179984
	Picton Stn Well-02	M35/8896					1568040	-5180058
	Picton Stn Well-03	M35/8898	2	10,080			1568023	-5179980
PS1123: Prestons	Prestons Stn Well-01	BX24/0624	2	30,000			1572776	-5186506
	Prestons Stn Well-02	BX24/0625	3	23,000			1572781	-5186545
	Prestons Stn Well-03	BX24/0626	4	48,000			1572795	-5186582
	Prestons Stn Well-04	BX24/0627	2				1572942	-5186595
PS1077: Redwood	Redwood Stn Well-02	M35/5251	1	42,000			1569561	-5186447
	Redwood Stn Well-01	M35/5573					1569552	-5186469
PS1109: Sockburn	Sockburn Stn Well-01	M35/1859	2	182,000			1564187	-5179227
	Sockburn Stn Well-02	M35/1860					1564183	-5179350
	Sockburn Weaver Well-01	M35/2272					1564081	-5179452
	Sockburn Weaver Well-02	M35/2273					1564102	-5179548
	Sockburn Blenheim Well-01	M35/2274					1564080	-5179181
	Sockburn Blenheim Well-02	M35/2275					1563991	-5179124
PS1030: Spreydon	Spreydon Stn Well-02	M36/1225	1	21,000			1568860	-5176421
	Spreydon Stn Well-06	M36/8288	2	31,500	1,010,000		1568820	-5176409
	Spreydon Stn Well-03	M36/1210	4	46,900			1568852	-5176397
	Spreydon Stn Well-04	M36/1055					1568837	-5176407
	Spreydon Stn Well-05	M36/1619					1568855	-5176426
PS1063: St Johns	St Johns Stn Well-01	M35/2554	4	112,000			1575043	-5178769
	St Johns Stn Well-02	M35/2805					1575038	-5178766

CRC191331 - Schedule 1 - Authorised Water Take Bores and Rates of Take								
Pump Station	**Description**	**ECan Bore Number**	**Aqu.**	**Max. Weekly Volume (m^3)**	**Max. 150 Day Volume (m^3)**	**Max. Annual Volume (m^3)**	**New Zealand Transverse Mercator NZTM mE**	**New Zealand Transverse Mercator NZTM mN**
	St Johns Stn Well-03	M35/18432	5				1575066	-5178758
PS1031: Sydenham	Sydenham Stn Well-05	M36/0967	4	27,800	2,245,000		1570548	-5178108
	Sydenham Stn Well-07	M36/20670	2	27,216			1570568	-5178118
	Sydenham Stn Well-06	M36/4565	5	84,672			1570527	-5178102
	Sydenham Stn Well-08	M36/20671					1570528	-5178127
PS1089: Tara	Tara Stn Well-04	M35/6945	4	29,484			1566784	-5180000
PS1095: Tanner	Tanner Stn Well-02	M36/1915	1	26,610		362,912	1574058	-5177188
	Tanner Stn Well-03	M36/20729				362,912	1574431	-5178228
PS1078: Thompsons Rd	Thompsons Stn Well-02	M35/8972	4	78,400	1,400,000		1569969	-5188255
	Thompsons Stn Well-03	BX24/0153	5				1569999	-5188293
PS1034: Thorrington	Thorrington Stn Well-01	M36/2195	1	14,000			1570359	-5176442
PS1035: Trafalgar	Trafalgar Stn Well-05	M35/2556	4	36,316	1,361,000		1570536	-5182198
	Trafalgar Stn Well-06	M35/8452					1570577	-5182184
	Trafalgar Stn Well-07	BX24/0348	5	27,384			1570539	-5182199
PS1037: Worcester	Worcester Stn Well-01	M35/9289	4	98,000			1571935	-5180186
	Worcester Stn Well-02	M35/9290					1571925	-5180216
PS1117: Wilmers Rd	Wilmers Stn Well-01	M36/20556	4	113,400			1562746	-5177258
	Wilmers Stn Well-02	M36/20557					1562731	-5177210
	Wilmers Stn Well-03	M36/20558					1562552	-5177159
	Wilmers Stn Well-04	M36/20559					1562542	-5177159
PS1065: Woolston	Woolston Stn Well-04	M36/1030	4	26,460			1574429	-5178236
	Woolston Stn Well-03	M36/1045	1	21,000		150,000	1574424	-5178232
	Woolston Stn Well-05	M36/5838	4	30,240			1574409	-5178186
Ruru Cemetery	Ruru Cemetery	BX24/0346		3,150		43,000	1574939	-5179549
PS1080: Wrights	Wrights Stn Well-05	BX24/1678	4	29,064			1567356	-5178607
	Wrights Stn Well-06	BX24/1679	5	30,744			1567377	-5178563
PS1126: Ben Rarere	Ben Rarere Stn Well-01	BX24/1710	4	42,336			1575521	-5182357
	Ben Rarere Stn Well-02	BX24/171	4	42,336			1575557	-5182356

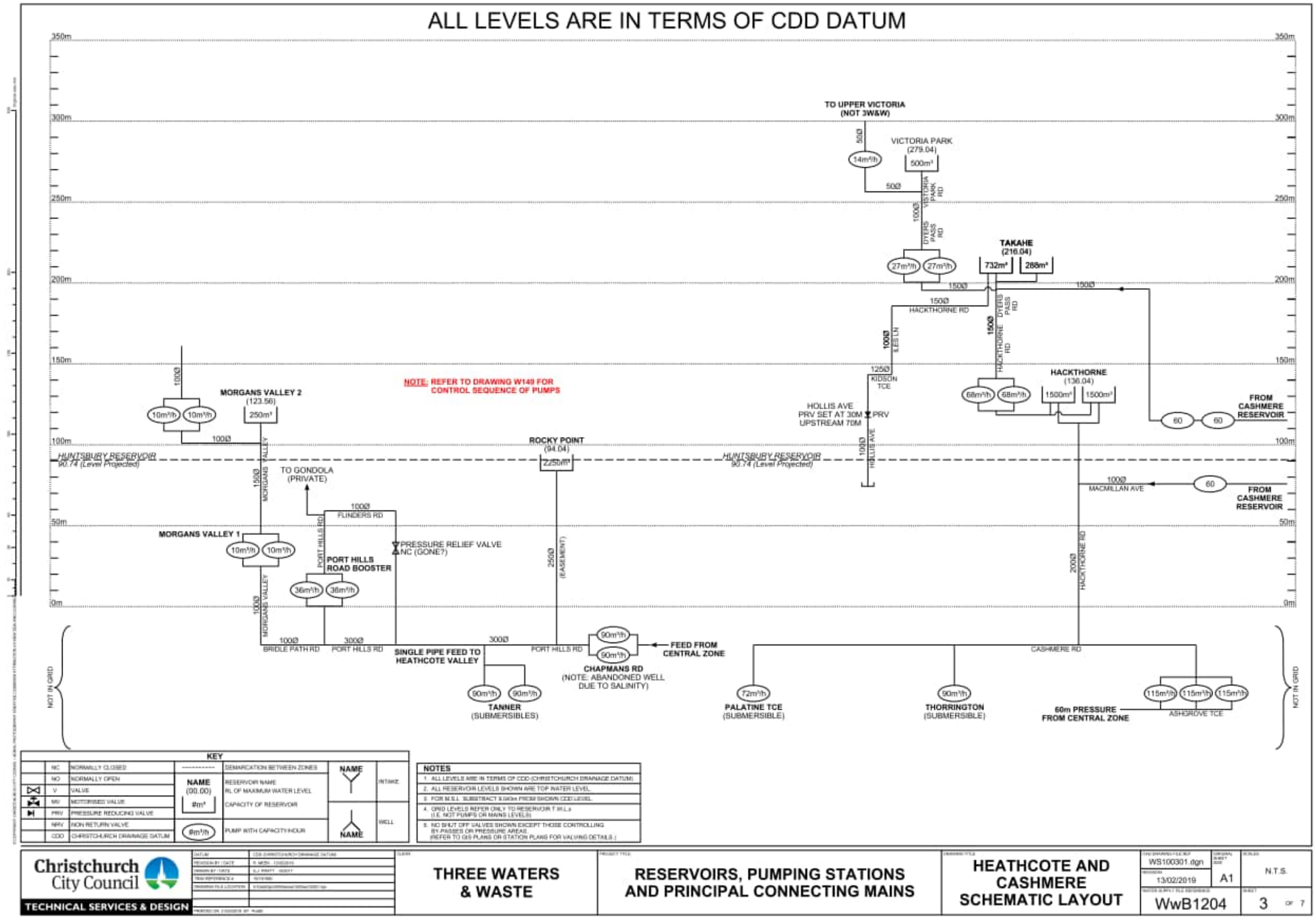
Appendix B Schematics of Reservoirs, Secondary Pumping Stations and Connecting Mains



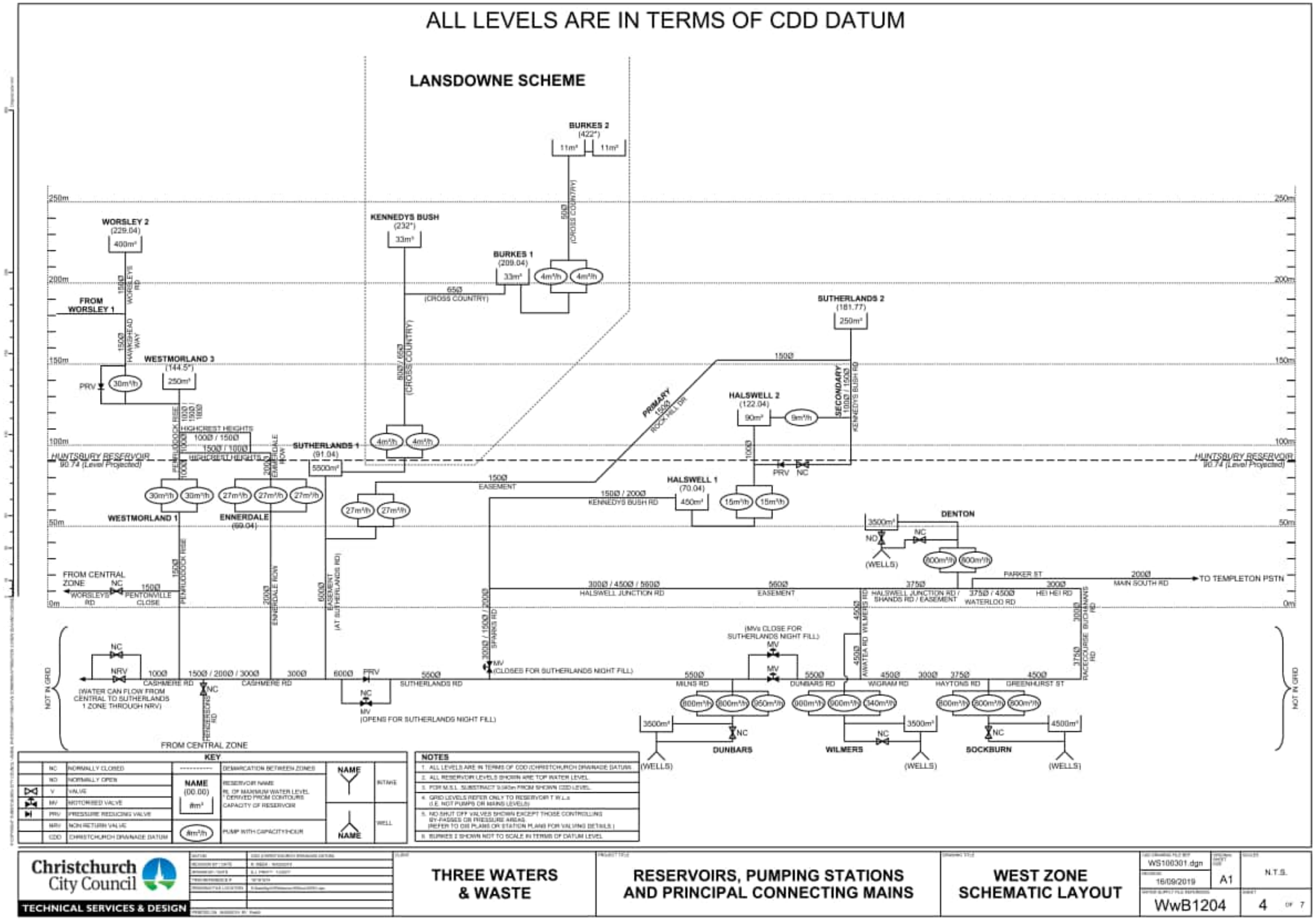
Reservoirs, Pumping Stations and Principal Connecting Mains – Taylors Mistake to Mt Pleasant



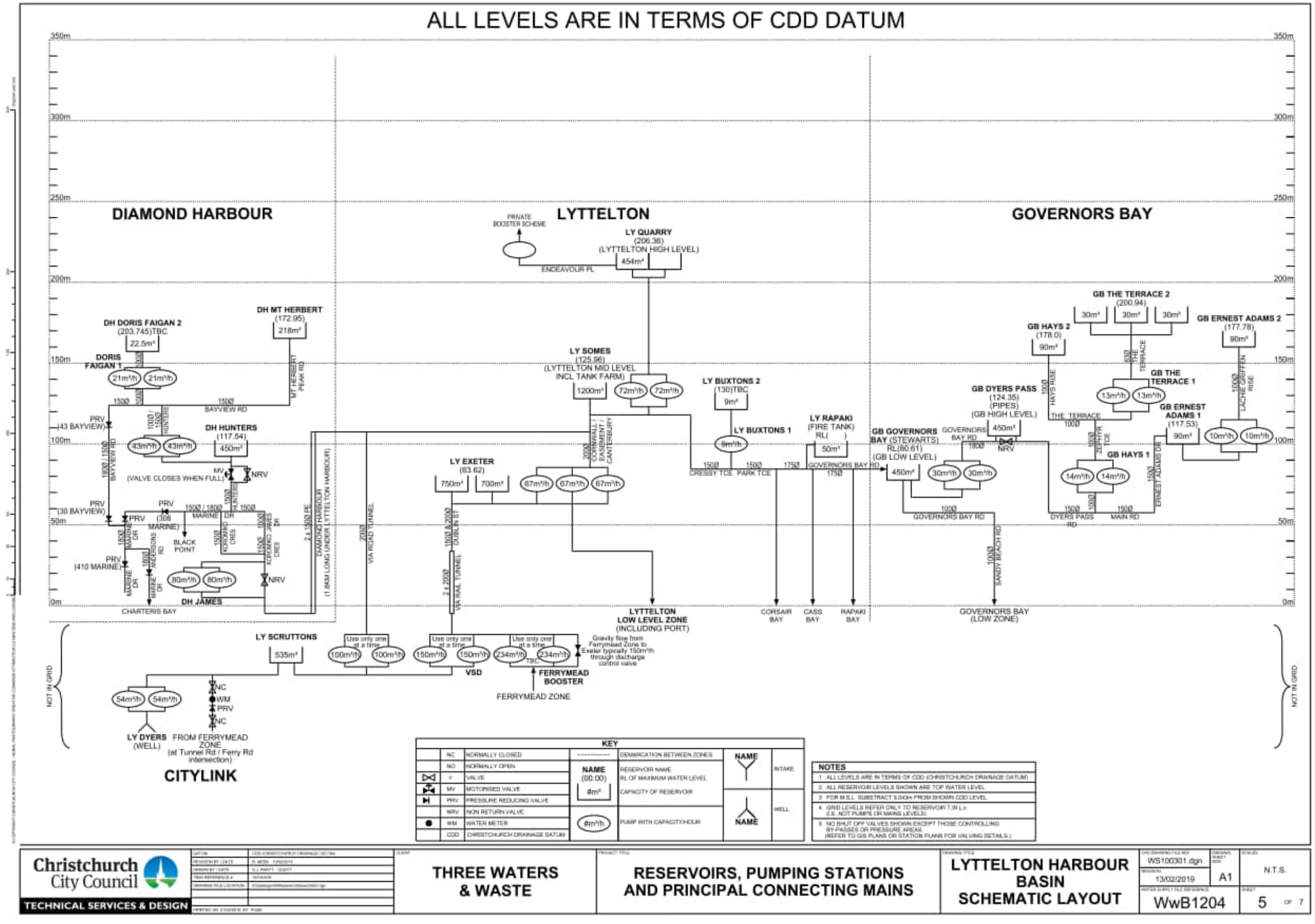
Reservoirs, Pumping Stations and Principal Connecting Mains – Murray Aynsley to Worsley Spur



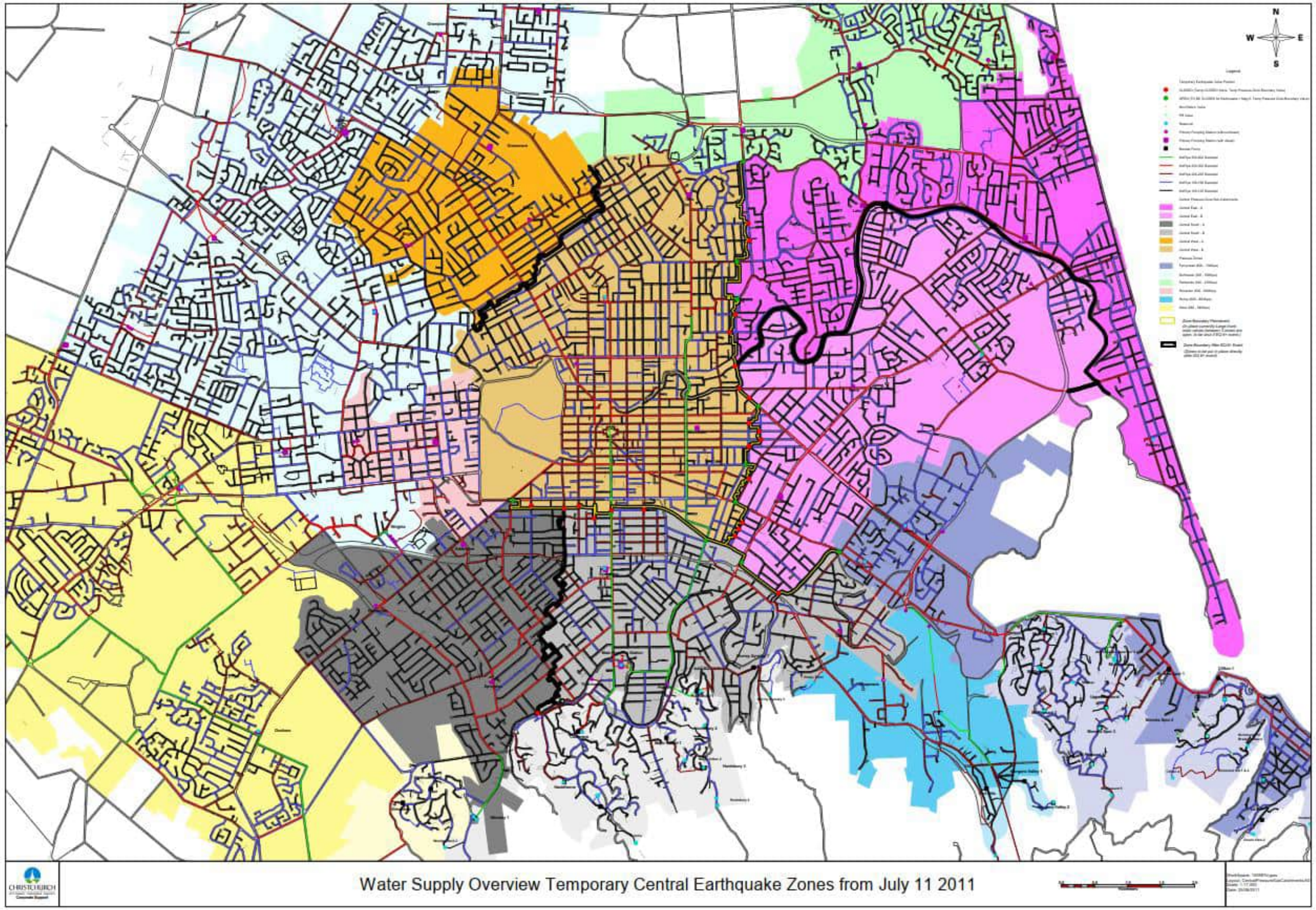
Reservoirs, Pumping Stations and Principal Connecting Mains – Heathcote and Cashmere



Reservoirs, Pumping Stations and Principal Connecting Mains – West Zone



Reservoirs, Pumping Stations and Principal Connecting Mains – Lyttelton Harbour Basin



Temporary Central Emergency / Earthquake Zones

Appendix C Citycare Reservoir and Suction Tank Condition Assessment Summary

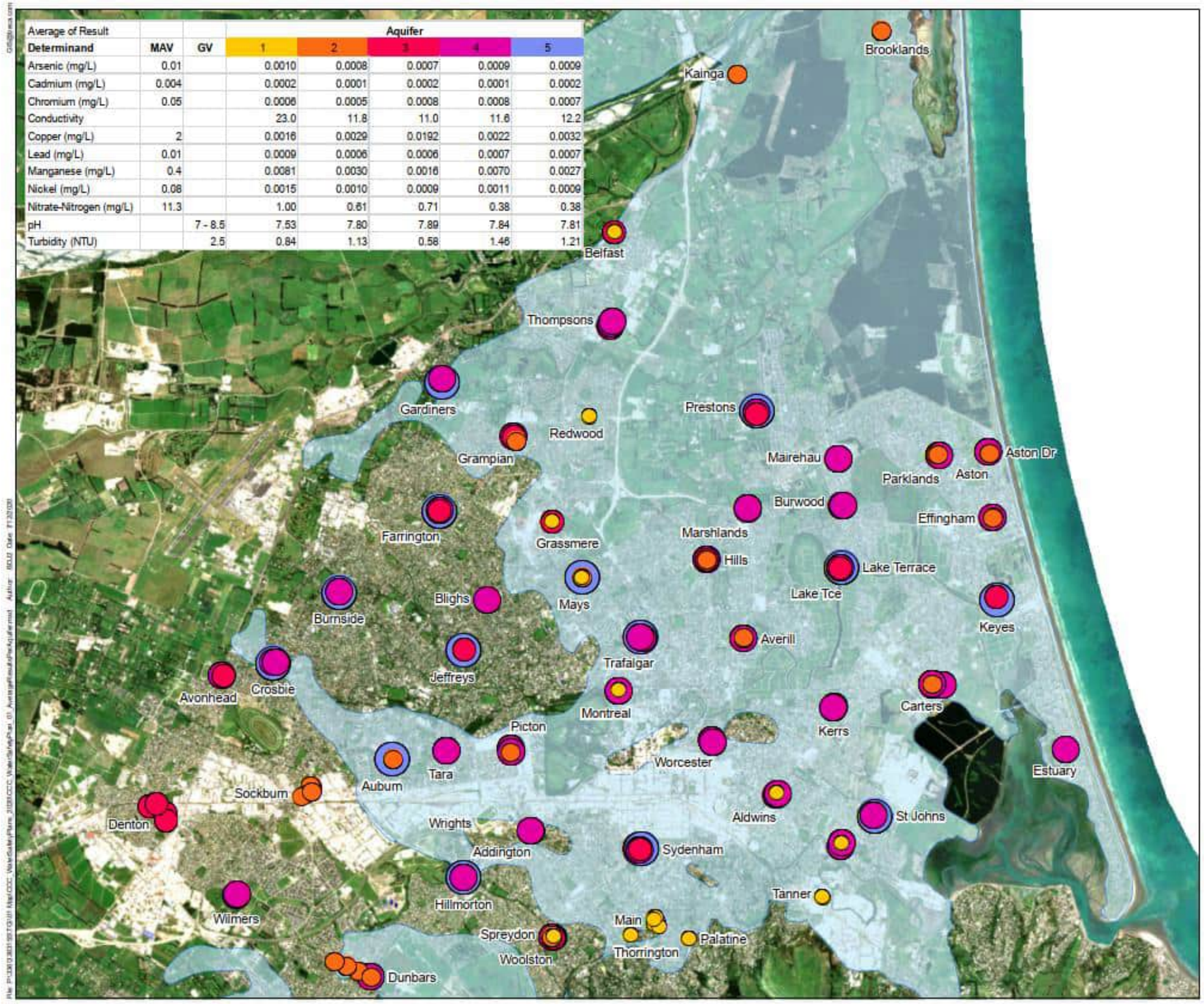
TRIM reference: 19/1004870

Reservoir Name	Water Supply Zone	Commission Date	Construction Material	Capacity (m^3)	Date	External Grounds		Internal Grounds					Storage Structure									Operations			
						Security	Evidence of Trespassing	Animal Droppings	Slaters, insects, spiders	Water pooling	Ground grading	Vegetation	Exterior ladder condition -	Exterior ladder condition -	Working at height	Exterior wall condition	Roof condition	Level sticks (B.P.)	Anchor points or handrail	Hatch and seals condition	Mesh on vents	Mesh on overflow	Sample points condition	Sample points security	Water level devices	Security on Hatches
Reservoirs that could supply more than 5,000 people																									
CASHMERE WS	Central	2008	Concrete	6,800	21/11/17		4	3	3	2	2	2	N/A	N/A	4	N/A	3	N/A	4		N/A	N/A	2	3	2	
HACKTHORNE WS Tank 1	Central	1974	Concrete	1,500	21/06/17		1	2	5	1	1	2	N/A	N/A	N/A	3	4	N/A	3		1	1	N/A	N/A	1	
HACKTHORNE WS Tank 2	Central	1974	Concrete	1,500	21/06/17		1	2	3	5	1	1	N/A	N/A	N/A	5	3	N/A	3		1	1	N/A	N/A	1	
HUNTSBURY 1 WS Tank 1 and Tank 2	Central	2011/2015	Concrete	13,400	26/04/18		2	3	3	3	3	4	2	2	3	3	3	N/A	3		3	4	3	3	3	
LY EXETER WS Tank 1 and Tank 2	Lyttelton	1997/2003	Concrete	1,450	13/02/18		3	2	2	3	2	3	3	3	4	4	3	N/A	3		2	N/A	3	4	3	
LY SCRUTTONS WS	Lyttelton	1994	Concrete	535	13/02/18		2	3	3	4	3	3	2	2	3	3	3	N/A	N/A		3	N/A	N/A	N/A	2	
LY SOMES WS	Lyttelton	1997	Concrete	1,200	13/02/18		4	4	2	5	2	3	2	2	4	5	3	N/A	3		N/A	N/A	3	3	3	
MCCORMACKS BAY WS Tank 1	Ferrymead	1983	Concrete	5,000	29/11/17		3	3	3	3	3	3	3	3	3	2	2	N/A	3		N/A	N/A	3	3	3	
MCCORMACKS BAY WS Tank 2	Ferrymead	1995	Concrete	5,000	29/11/17		3	3	3	3	3	3	3	3	3	3	2	N/A	3		N/A	3	N/A	N/A	3	
MOUNT PLEASANT 1 WS	Ferrymead	1947	Concrete	1,100	29/11/17		3	3	3	3	3	3	3	3	3	3	2	N/A	3		N/A	N/A	3	3	3	
SUTHERLANDS 1 WS	West	1986	Concrete	5,500	19/12/17		3	4	3	3	3	2	N/A	N/A	N/A	3	2	N/A	N/A		3	N/A	N/A	N/A	3	
WORSLEYS 1 WS Tank 1	Central	1968	Concrete	11,375	30/01/18		2	2	3	4	3	4	2	2	2	3	3	N/A	5		N/A	N/A	3	3	2	
WORSLEYS 1 WS Tank 2	Central	2003	Concrete	11,375	30/01/18		3	2	3	4	3	4	2	2	2	3	3	N/A	3		N/A	N/A	3	3	1	
Reservoirs that supply less than 5,000 people																									
BURKES 1 WS	West	2017	Polyethylene	33	21/06/17		3	2	3	2	2	3	2	2	3	1	1	N/A	N/A		N/A	N/A	2	2	2	
BURKES 2 WS Tank 1	West	1985	Concrete	11	12/02/18		2	4	3	2	2	3	3	3	4	3	3	N/A	5		N/A	N/A	3	3	N/A	
BURKES 2 WS Tank 2	West	1985	Concrete	11	12/02/18		2	4	3	2	2	3	3	3	4	3	3	N/A	4		N/A	2	3	3	N/A	
CLIFTON 2 WS - Tank 1 & Tank 2	Ferrymead	1975	Concrete	2,000	13/09/17		3	3	3	3	3	3	3	2	3	3	3	N/A	4		N/A	N/A	3	2	3	
CLIFTON 3 WS	Ferrymead	1947	Concrete	455	13/09/17		3	3	3	3	2	2	2	3	4	3	3	N/A	3		N/A	N/A	3	3	3	
CLIFTON 4 WS	Ferrymead	1988	Concrete	1,000	24/08/17		3	3	3	2	3	2	4	3	3	3	2	N/A	3		N/A	N/A	3	3	3	
DH DORIS FAIGAN 2 WS	Diamond Harbour	2009	Concrete	23	20/12/17		4	5	2	3	3	3	3	3	3	3	3	N/A	4		N/A	2	3	3	N/A	
DH HUNTERS WS	Diamond Harbour	1998	Concrete	450	8/12/17		3	3	3	3	3	2	3	3	3	3	2	N/A	3		4	N/A	3	3	3	
DH MOUNT HERBERT WS	Diamond Harbour	1998	Steel	218	8/12/17		3	3	3	3	3	2	3	3	3	2	3	N/A	N/A		3	3	3	3	3	
GB (STEWARTS) WS	Governors Bay	1989	Concrete	450	11/12/17		3	3	3	3	3	4	N/A	N/A	N/A	3	2	N/A	N/A		N/A	N/A	3	4	3	
GB DYERS PASS WS	Governors Bay	1989	Concrete	450	11/12/17		3	3	3	3	3	3	3	3	3	3	3	N/A	3		N/A	N/A	3	3	N/A	
GB ERNEST ADAMS 1 WS	Governors Bay	1989	Concrete	90	8/12/17		3	3	3	3	3	3	N/A	N/A	N/A	2	3	N/A	N/A		N/A	4	3	3	N/A	
GB ERNEST ADAMS 2 WS	Governors Bay	1990	Concrete	90	8/12/17		3	2	2	3	3	3	3	3	3	2	2	N/A	N/A		N/A	2	3	3	N/A	
GB HAYS 2 WS	Governors Bay	1989	Polyethylene	90	11/12/17		3	2	2	3	3	3	3	3	3	N/A	N/A	N/A	N/A		N/A	N/A	3	3	N/A	
GB THE TERRACE 2 WS Tank 1 & Tank 2 & Tank 3	Governors Bay	2006	Polyethylene	90	15/11/18		2	2	4	2	3	3	N/A	N/A	N/A	2	2	N/A	N/A		3	N/A	4	2	N/A	
HALSWELL 1 WS	West	1958	Concrete	450	6/12/17		3	3	3	3	3	3	3	3	3	5	1	N/A	3		N/A	N/A	3	3	3	
HALSWELL 2 WS	West	1948	Concrete	90	15/12/17		3	2	2	3	3	4	N/A	N/A	N/A	5	2	N/A	N/A		N/A	3	3	3	N/A	
HUNTSBURY 2 WS	Central	1947	Concrete	455	24/07/17		3	3	3	3	3	3	4	3	5	3	3	N/A	4		N/A	N/A	2	1	3	
HUNTSBURY 3 WS	Central	1998	Concrete	290	24/07/17		3	1	1	1	3	3	3	3	3	3	1	N/A	3		1	N/A	1	1	3	
HUNTSBURY 4 WS	Central	2004	Concrete	276	24/07/17		3	1	4	3	3	3	3	3	3	3	3	N/A	3		3	N/A	3	3	3	
KENNEDYS BUSH WS	West	2015	Concrete	33	15/11/18		2	1	5	2	3	2	3	2	N/A	3	2	N/A	N/A		2	N/A	2	1	N/A	
LY BUXTONS 2 WS	Lyttelton	1980	Concrete	9	11/12/17		3	3	3	3	3	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	3	3	N/A	
LY QUARRY WS	Lyttelton	1930	Concrete	454	28/11/17		4	4	3	3	3	3	3	3	3	5	5	N/A	3		3	N/A	3	3	N/A	
LY RAPAKI WS (fire only)	Lyttelton	1950	Concrete	50	1/12/17		3	3	3	3	3	3	N/A	N/A	N/A	3	3	N/A	N/A		N/A	N/A	3	3	N/A	
MAFFEYS WS	Ferrymead	1974	Concrete	1,000	29/11/17		3	3	3	3	3	3	N/A	N/A	N/A	3	3	N/A	N/A		N/A	N/A	3	3	3	
MAJOR AITKEN 2 WS Tank 1	Central	1997	Concrete	23	1/02/18		2	2	2	3	2	2	N/A	N/A	N/A	4	3	N/A	N/A		2	N/A	N/A	N/A	N/A	
MAJOR AITKEN 2 WS Tank 2	Central	1997	Concrete	23	1/02/18		2	2	2	4	2	3	N/A	N/A	N/A	5	2	N/A	N/A		3	N/A	N/A	N/A	N/A	
MONCKS SPUR 2 WS	Ferrymead	1947	Concrete	455	15/09/17		3	3	3	2	2	3	N/A	N/A	3	3	3	N/A	4		N/A	N/A	3	3	3	
MONCKS SPUR 3 WS	Ferrymead	2001	Concrete	370	15/09/17		3	3	4	3	3	3	2	2	3	2	3	N/A	3		4	N/A	3	3	3	
MORGANS VALLEY 2 WS	Central	2004	Concrete	250	13/02/18		2	2	2	3	2	2	2	2	3	2	2	N/A	3		2	N/A	3	3	2	

Reservoir Name	Water Supply Zone	Commission Date	Construction Material	Capacity (m³)	Date	External Grounds		Internal Grounds					Storage Structure									Operations			
						Security	Evidence of Trespassing	Animal Droppings	Slaters, insects, spiders	Water pooling	Ground grading	Vegetation	Exterior ladder condition -	Exterior ladder condition -	Working at height	Exterior wall condition	Roof condition	Level sticks (B.P.)	Anchor points or handrail	Hatch and seals condition	Mesh on vents	Mesh on overflow	Sample points condition	Sample points security	Water level devices	Security on Hatches
MOUNT PLEASANT 2 WS Tank 1 & Tank 2	Ferrymead	1957	Concrete	2,000	21/06/17		1	3	3	3	3	3	4	5	5	3	4	N/A	4		N/A	N/A	2	2	1	
MOUNT PLEASANT 3 WS Tank 1 & Tank 2	Ferrymead	1970	Concrete	1,455	25/07/17		4	4	3	3	3	3	3	3	3	3	2	N/A	3		N/A	N/A	1	1	3	
MOUNT PLEASANT 4 WS	Ferrymead	1964	Concrete	1,000	25/07/17		5	5	3	4	3	3	N/A	N/A	4	3	3	N/A	4		N/A	N/A	3	1	3	
MOUNT PLEASANT 5 WS	Ferrymead	2001	Concrete	385	7/07/17		3	2	3	3	3	1	2	3	3	1	1	N/A	3		N/A	N/A	3	4	1	
MURRAY AYNSLEY 2 WS	Central	2001	Concrete	350	4/12/17		3	3	3	3	3	3	N/A	N/A	N/A	N/A	2	N/A	N/A		N/A	N/A	3	3	3	
OCEAN VIEW 2 WS	Ferrymead	1958	Concrete	305	24/08/17		3	3	3	4	3	3	3	3	5	3	3	N/A	5		N/A	N/A	3	N/A	3	
RICHMOND HILL WS	Ferrymead	1975	Concrete	5	23/11/17		3	3	4	3	3	5	N/A	N/A	N/A	4	4	N/A	N/A		N/A	N/A	3	4	N/A	
ROCKY POINT WS	Central	1993	Concrete	2,250	31/01/18		4	2	2	2	2	2	2	2	2	3	3	N/A	3		N/A	N/A	2	2	2	
SCARBOROUGH 2 WS Tank 1 & Tank 2	Ferrymead	1956	Concrete	675	23/08/17		3	3	3	2	3	3	3	3	2	3	3	N/A	2		2	N/A	3	3	3	
SCARBOROUGH 3 WS	Ferrymead	1992	Concrete	385	23/08/17		2	3	3	4	4	3	2	3	3	3	3	N/A	3		N/A	N/A	3	3	3	
SUTHERLANDS 2 WS	West	2004	Concrete	250	19/12/17		4	4	5	3	3	2	3	3	3	2	2	N/A	4		4	N/A	3	3	3	
TAKAHE 2 WS Tank 1	Central	1965	Concrete	732	31/01/18		N/A	2	2	2	2	3	N/A	N/A	N/A	N/A	1	N/A	2		N/A	N/A	N/A	N/A	N/A	
TAKAHE 2 WS Tank 2	Central	1985	Concrete	288	31/01/18		4	2	2	2	2	3	N/A	N/A	3	4	2	N/A	2		N/A	N/A	N/A	N/A	N/A	
UPPER BALMORAL WS	Ferrymead	1985	Concrete	1,000	15/09/17		3	3	4	3	3	3	3	3	3	4	3	N/A	3		N/A	N/A	3	3	3	
VICTORIA WS	Central	2013	Concrete	500	19/12/17		4	2	4	3	3	2	3	3	4	2	1	N/A	2		N/A	2	N/A	N/A	2	
WESTMORLAND 3 WS	West	2015	Concrete	250	31/01/18		1	1	4	3	3	2	2	2	3	2	2	N/A	2		2	2	2	3	2	
WORSLEYS 2 WS	Central	2003	Concrete	400	30/01/18		4	2	3	2	3	4	3	5	3	2	2	N/A	3		N/A	N/A	2	2	2	
Suction tanks (at primary pump stations) that could supply more than 5,000 people																									
AUBURN WS	Northwest	1968	Concrete		13/09/17		2	3	3	3	3	2	N/A	N/A	N/A	N/A	3	N/A	N/A		N/A	N/A	3	2	3	
BLIGHS WS	Central	1953	Concrete	180	22/08/17		3	2	2	3	2	3	3	3	2	2	3	N/A	3		N/A	N/A	3	3	3	
CARTERS WS	Rawhiti	1960	Concrete		12/07/17		4	4	3	3	3	3	3	3	2	4	3	N/A	3		N/A	N/A	3	3	1	
DENTON WS	West	1982	Concrete	3,500	12/02/18		3	3	4	3	3	4	2	2	3	3	3	N/A	4		2	N/A	2	2	2	
DUNBARS WS	West	1990	Concrete		16/11/17		4	3	4	3	3	2	2	2	2	3	3	N/A	3		2	N/A	3	3	3	
ESTUARY WS	Rawhiti	1953	Concrete	180	1/12/17		3	3	3	3	3	3	3	3	3	4	3	N/A	4		N/A	N/A	3	3	3	
GRAMPIAN WS	Northwest	1957	Concrete		24/11/17		3	3	3	3	3	3	3	3	3	N/A	2	N/A	N/A		2	N/A	3	3	3	
GRASSMERE WS	Central	1957	Concrete	350	27/07/17		3	3	3	4	3	3	1	1	2	2	2	N/A	2		N/A	N/A	3	2	2	
HILLMORTON WS	Central	1956	Concrete		12/02/18		N/A	2	2	2	3	3	3	2	4	4	3	N/A	3		3	N/A	3	3	2	
HILLS WS	Central	1954	Concrete	300	24/11/17		3				3												4	3		
KEYES WS	Rawhiti	2012	Concrete		24/11/17		3	3	3	3	3	3	3	3	3	2	2	N/A	3		N/A	2	3	3	3	
LAKE TERRACE WS	Rawhiti	1956	Concrete		22/08/17		3	3	3	2	2	2	4	3	5	4	3	N/A	5		N/A	N/A	3	3	3	
MAIN PUMPS WS	Central	1956	Concrete		1/02/18		2	3	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3		N/A	N/A	N/A	N/A	N/A	
MAYS WS	Central	1928	Concrete	350	27/07/17		2	2	3	2	2	3	1	1	2	2	2	N/A	2		N/A	N/A	2	2	2	
PRESTONS WS	Parklands	2016	Concrete	500	14/11/18		2	2	2	3	2	2	1	1	1	2	1	N/A	1		1	N/A	1	1	1	
SOCKBURN MAIN WS	West	1980	Concrete	4,500	7/02/18		4	2	3	3	3	4	3	3	3	3	3		3		N/A	N/A	3	3	2	
SPREYDON WS	Central	1949	Concrete		13/09/17		3	3	3	3	3	3	3	2	3	2	3	N/A	4		N/A	N/A	3	2	3	
ST JOHNS WS	Ferrymead	1958	Concrete		7/07/17		1	3	3	2	3	3	3	3	4	3	3	N/A	5		N/A	N/A	3	1	2	
SYDENHAM WS	Central	2013	Polyethylene	650	1/02/18		2	2	3	3	3	3	2	2	3	3	3	N/A	N/A		N/A	N/A	2	2	2	
TRAFALGAR WS	Central	1950	Concrete	250	27/07/17		3	3	3	3	3	3	4	1	4	2	3	N/A	4		N/A	N/A	3	2	3	
WILMERS WS	West	2014	Concrete		16/11/17		2	2	2	3	3	3	2	1	3	2	2	N/A	3		N/A	3	3	2	3	
WOOLSTON WS	Ferrymead	2000	Concrete	400	12/07/17		2	3	3	3	3	3	4	3	4	1	3	N/A	3		1	N/A	3	3	1	
Suction tanks (at primary pump stations) that supply less than 5,000 people																									
AVERILL WS	Northwest	1939	Concrete		24/11/17								N/A	N/A	N/A			N/A					3	3		
JEFFREYS WS	Northwest	1965	Concrete	220	7/02/18		2	2	2	2	2	3	N/A	N/A	N/A	3	3	N/A	N/A		N/A	N/A	2	2	3	
TARA WS	Riccarton	1950	Concrete	140	7/02/18		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A	

Appendix D Key Chemical Determinands

Average of Result			Aquifer				
Determinand	**MAV**	**GV**	1	2	3	4	5
Arsenic (mg/L)	0.01		0.0010	0.0008	0.0007	0.0009	0.0009
Cadmium (mg/L)	0.004		0.0002	0.0001	0.0002	0.0001	0.0002
Chromium (mg/L)	0.05		0.0006	0.0005	0.0008	0.0008	0.0007
Conductivity			23.0	11.8	11.0	11.6	12.2
Copper (mg/L)	2		0.0016	0.0029	0.0192	0.0022	0.0032
Lead (mg/L)	0.01		0.0009	0.0006	0.0006	0.0007	0.0007
Manganese (mg/L)	0.4		0.0081	0.0030	0.0016	0.0070	0.0027
Nickel (mg/L)	0.08		0.0015	0.0010	0.0009	0.0011	0.0009
Nitrate-Nitrogen (mg/L)	11.3		1.00	0.61	0.71	0.38	0.38
pH		7 - 8.5	7.53	7.80	7.89	7.84	7.81
Turbidity (NTU)		2.5	0.84	1.13	0.58	1.46	1.21



Average Results for Each Aquifer 2008 - 2020

Aquifer

- 1
- 2
- 3
- 4
- 5

Coastal Confined Gravel Aquifer System

Map Scale @ A4: 1:100,000

0 1 2

Kilometres

N

Client: Christchurch City Council

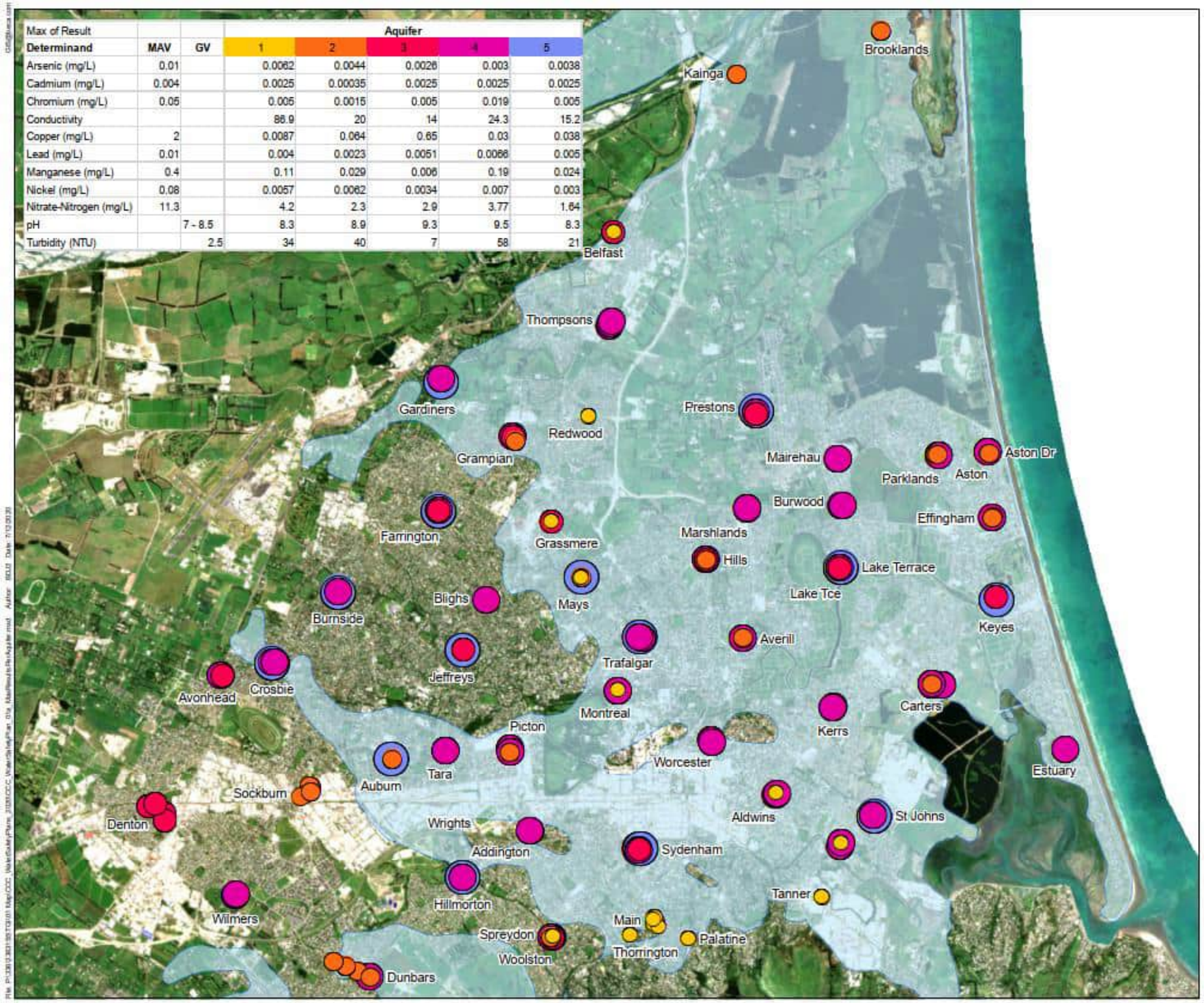
Discipline: GIS

Project: HDW WHSIP Delivery

Drawing No: GIS-336315-WSP-01

Beca

Max of Result			Aquifer				
Determinand	MAV	GV	1	2	3	4	5
Arsenic (mg/L)	0.01		0.0062	0.0044	0.0026	0.003	0.0038
Cadmium (mg/L)	0.004		0.0025	0.00035	0.0025	0.0025	0.0025
Chromium (mg/L)	0.05		0.005	0.0015	0.005	0.019	0.005
Conductivity			86.9	20	14	24.3	15.2
Copper (mg/L)	2		0.0087	0.064	0.65	0.03	0.038
Lead (mg/L)	0.01		0.004	0.0023	0.0051	0.0066	0.005
Manganese (mg/L)	0.4		0.11	0.029	0.006	0.19	0.024
Nickel (mg/L)	0.08		0.0057	0.0062	0.0034	0.007	0.003
Nitrate-Nitrogen (mg/L)	11.3		4.2	2.3	2.9	3.77	1.64
pH		7 - 8.5	8.3	8.9	9.3	9.5	8.3
Turbidity (NTU)		2.5	34	40	7	58	21



Maximum Results for Each Aquifer 2008 - 2020

Aquifer

- 1
- 2
- 3
- 4
- 5

Coastal Confined Gravel Aquifer System

Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

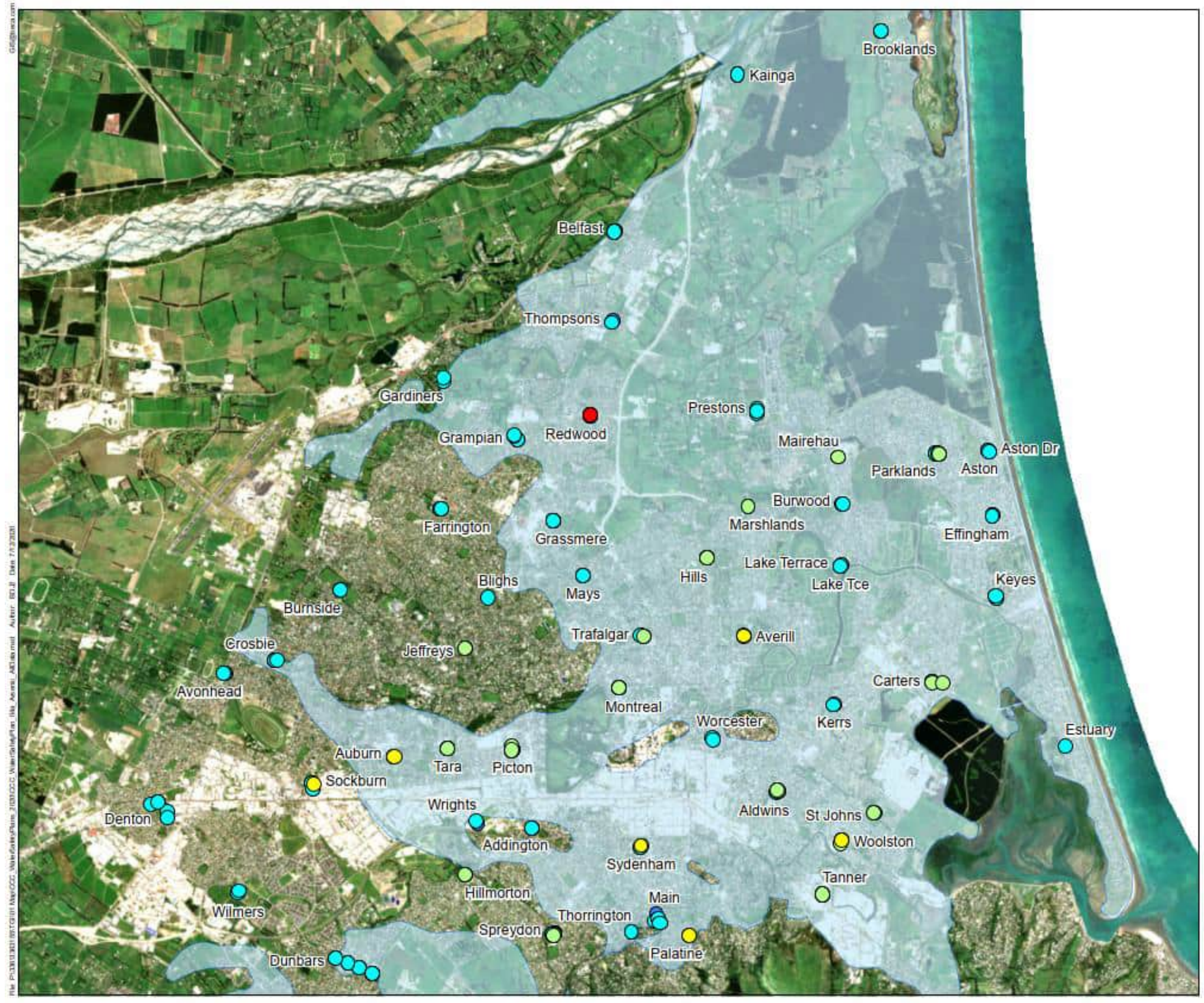
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSP Delivery

Drawing No: GIS-3362155-WSP-01a

Beca



Maximum Arsenic 2008 - 2020

Arsenic

Result (mg/L)

- < 0.00010 (< detection limit)
- 0.0001 - 0.0005
- 0.0005 - 0.001
- 0.001 - 0.003
- 0.003 - 0.005
- 0.005 - 0.01 (50% MAV)
- > 0.01 (100% MAV)
- Coastal Confined Gravel Aquifer System

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0 1 2
Kilometres

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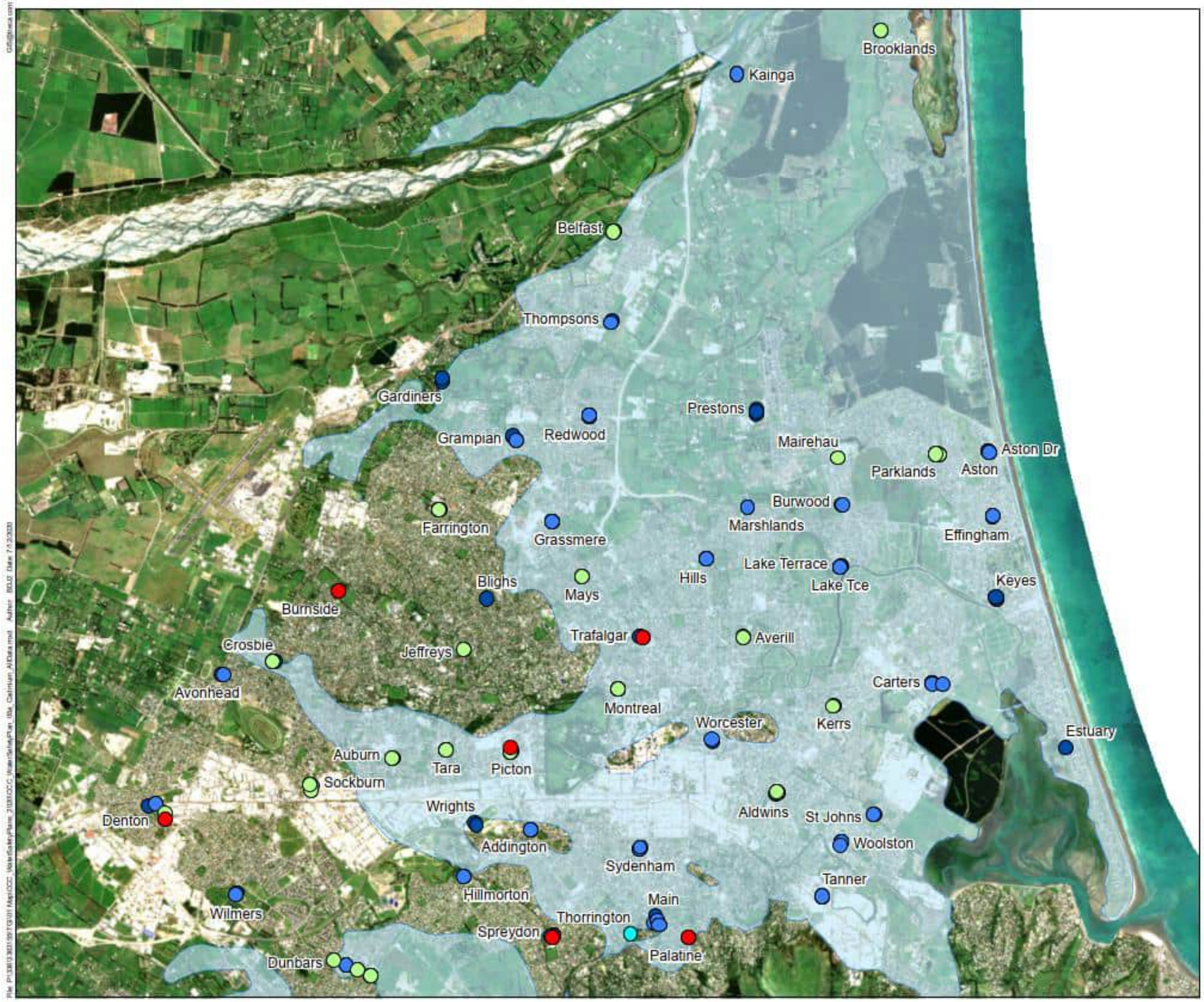
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSIP Delivery

Drawing No: GIS-3363155-WSP-04a

Beca



Maximum Cadmium 2008 - 2020

Cadmium

Result (mg/L)

- < 0.000053 (< detection limit)
- 0.000053 - 0.0001
- 0.0001 - 0.0002
- 0.0002 - 0.0004
- 0.0004 - 0.002
- 0.002 - 0.004 (50% MAV)
- > 0.004 (100% MAV)
- Coastal Confined Gravel Aquifer System

The six samples that fall into the '>50% MAV band' all had results '< detection limit' with the detection limit being 0.005 mg/L. In accordance with DWSNZ guidelines section 10.5.2.3 half the detection limit was used as the value to create the maps.

Map Scale @ A4: 1:100,000

0 1 2

Kilometres

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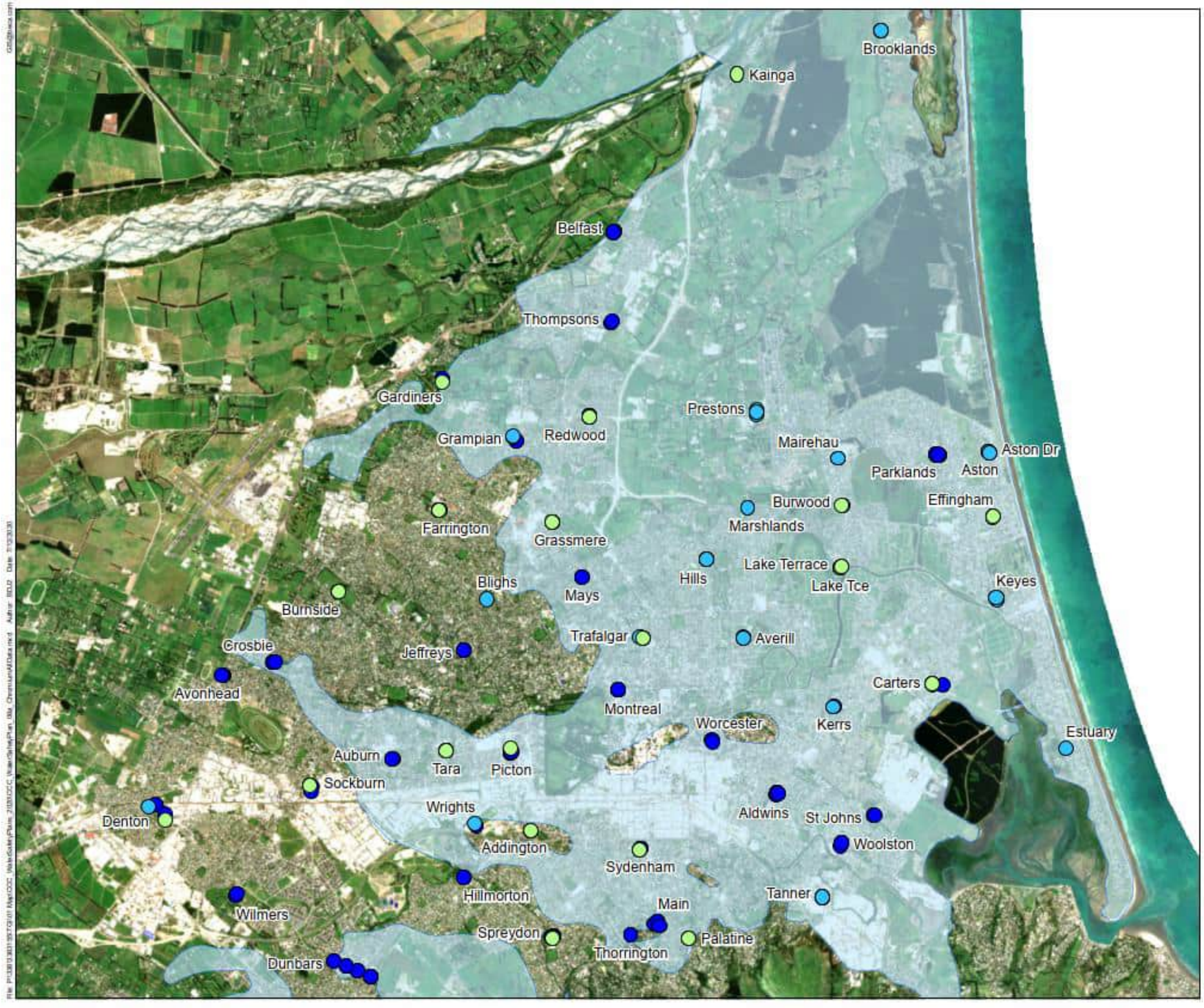
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSIP Delivery

Drawing No: GIS-3363155-WSP-05a

Beca



Maximum Chromium 2008 - 2020

Chromium

Result (mg/L)

- < 0.00053 (< detection limit)
- 0.00053 - 0.001
- 0.001 - 0.025
- 0.025 - 0.05 (50% MAV)
- > 0.05 (100% MAV)
- Coastal Confined Gravel Aquifer System

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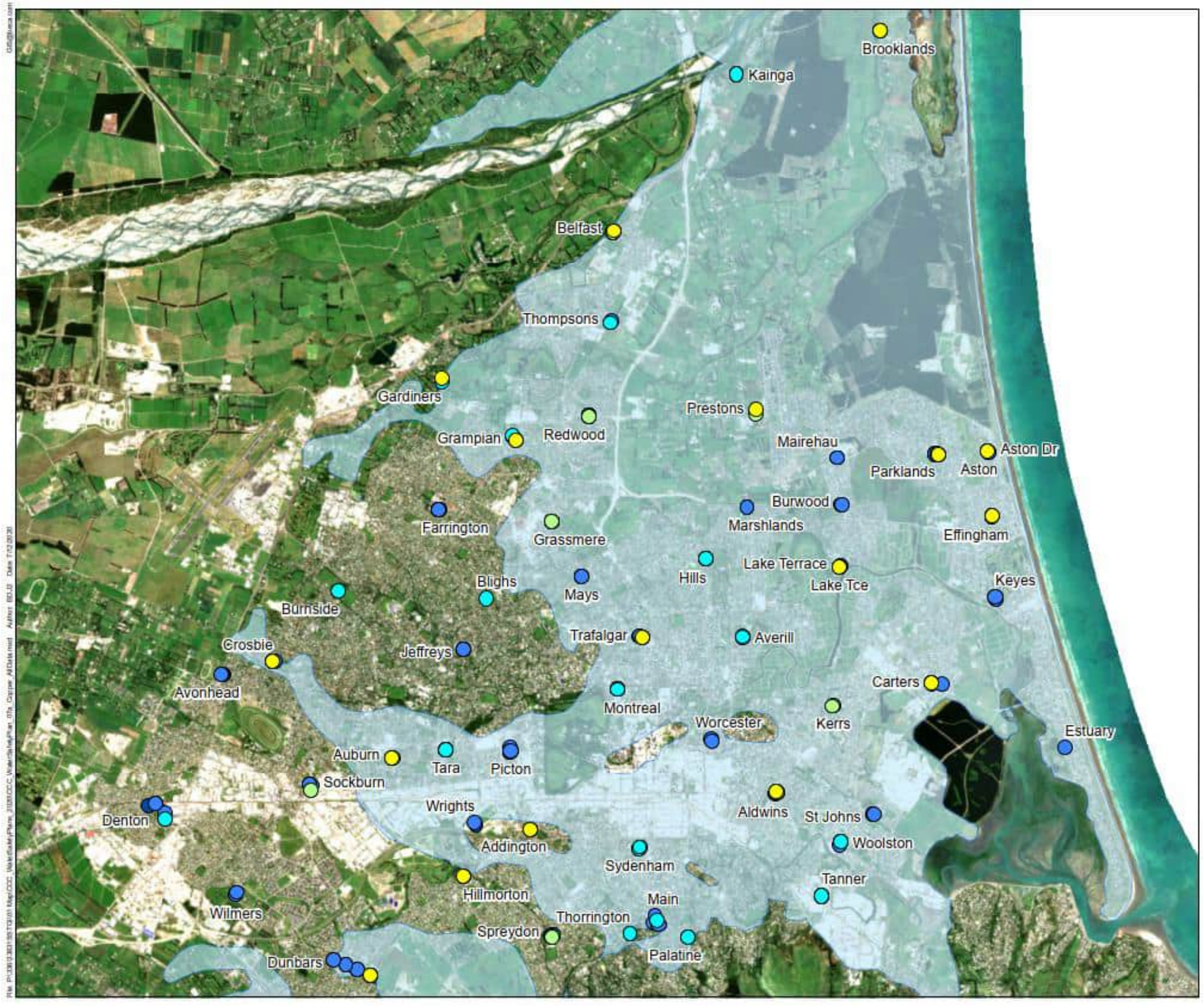
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSP Delivery

Drawing No: GIS-3363155-WSP-06a

Beca



Maximum Copper 2008 - 2020

Copper

Result (mg/L)

- < 0.00053 (< detection limit)
- 0.00053 - 0.0015
- 0.0015 - 0.0035
- 0.0035 - 0.007
- 0.007 - 1.00
- 1.00 - 2.00 (50% MAV)
- > 2.00 (100% MAV)
- Coastal Confined Gravel Aquifer System

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0 1 2
Kilometres

N

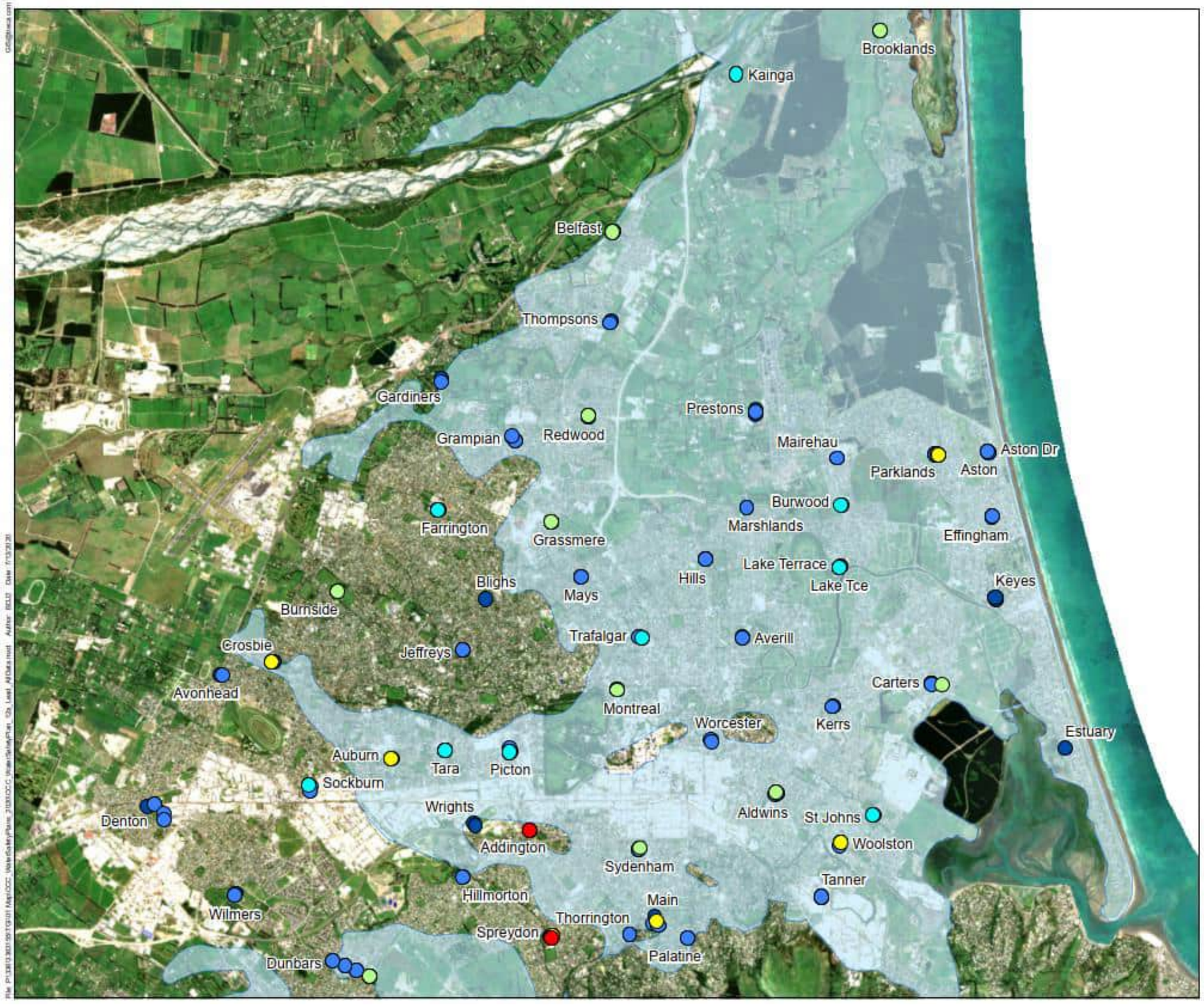
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSP Delivery

Drawing No: GIS-3362155-WSP-67a

Beca



Maximum Lead 2008 - 2020

Lead

Result (mg/L)

- < 0.00011 (< detection limit)
- 0.00011 - 0.0008
- 0.0008 - 0.0015
- 0.0015 - 0.0025
- 0.0025 - 0.005
- 0.005 - 0.01 (50% MAV)
- > 0.01 (100% MAV)
- Coastal Confined Gravel Aquifer System

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0 1 2
Kilometres

N

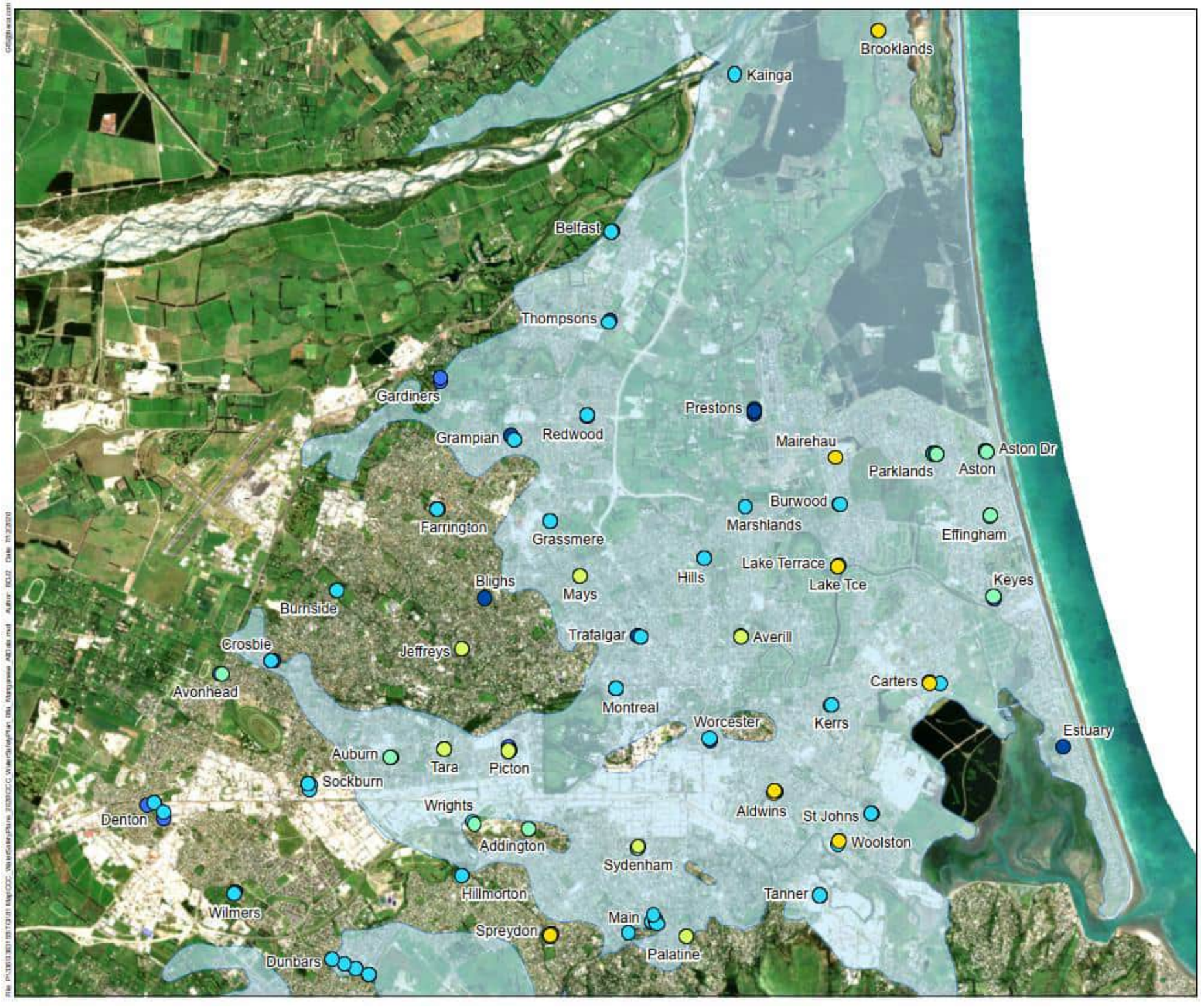
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSP Delivery

Drawing No: GIS-3362155-WSP-12a

Beca



Maximum Manganese 2008 - 2020

Manganese

Result (mg/L)

- < 0.00010 (< detection level)
- 0.0001 - 0.00053
- 0.00053 - 0.005
- 0.005 - 0.01
- 0.01 - 0.025
- 0.025 - 0.2
- 0.2 - 0.4 (50% MAV)
- > 0.4 (100% MAV)
- Coastal Confined Gravel Aquifer System

Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

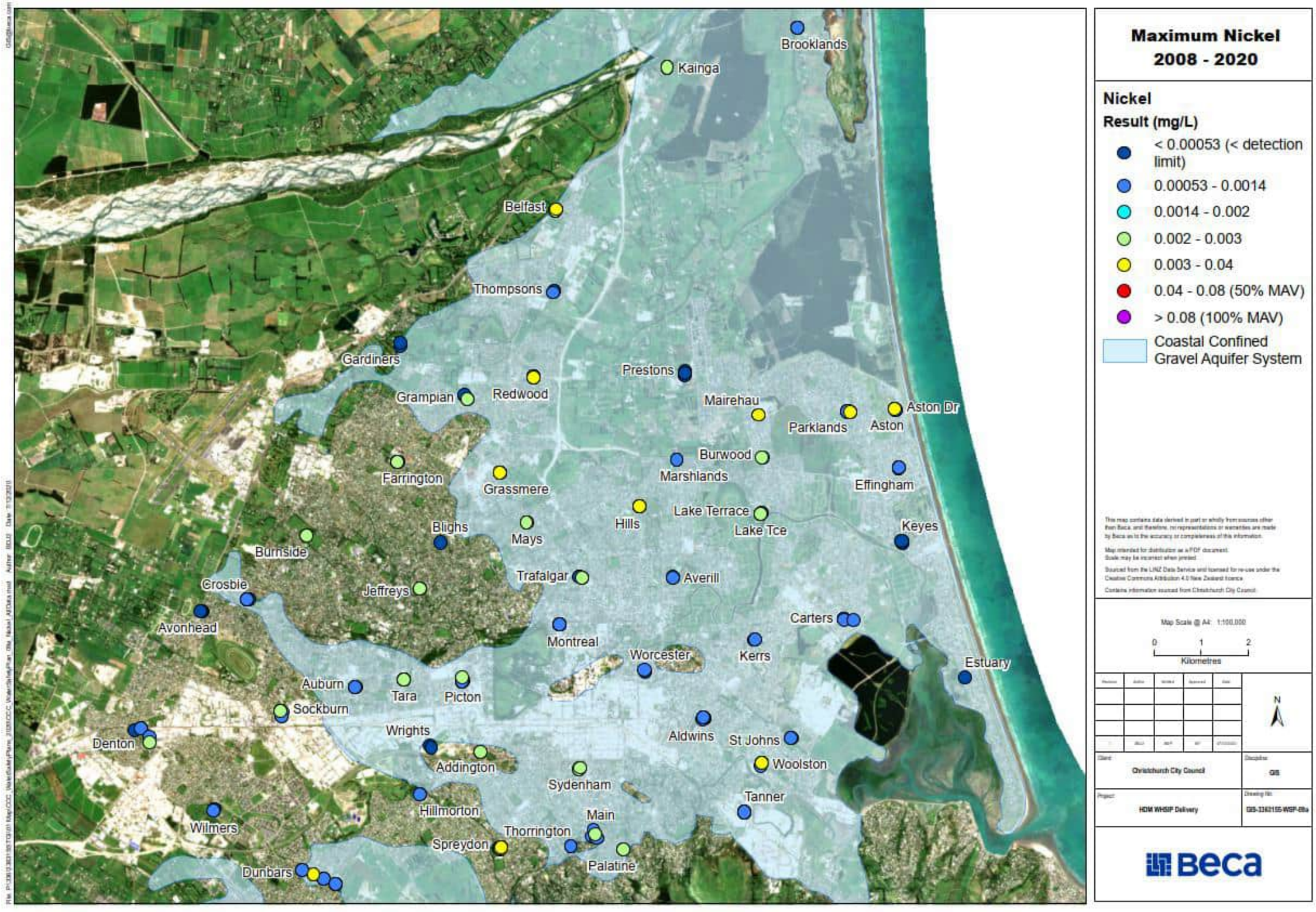
Client: Christchurch City Council

Discipline: GIS

Project: HDW WHSP Delivery

Drawing No: GIS-3363155-WSP-08a

Beca



Maximum Nickel 2008 - 2020

Nickel

Result (mg/L)

- < 0.00053 (< detection limit)
- 0.00053 - 0.0014
- 0.0014 - 0.002
- 0.002 - 0.003
- 0.003 - 0.04
- 0.04 - 0.08 (50% MAV)
- > 0.08 (100% MAV)
- Coastal Confined Gravel Aquifer System

Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

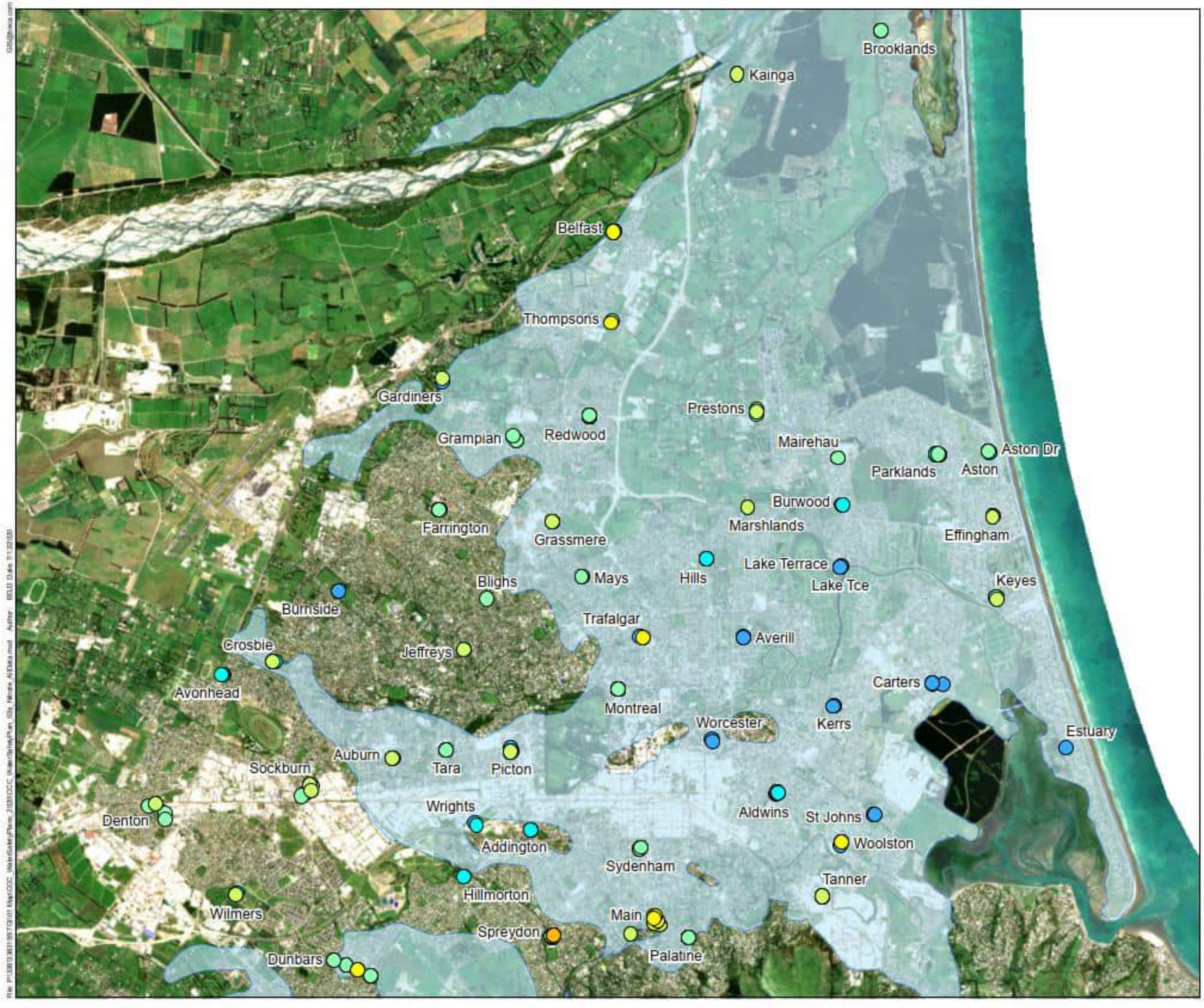
Client: Christchurch City Council

Discipline: GIS

Project: HDM WHSP Delivery

Drawing No: GIS-3362155-WSP-89a

Beca



Maximum Nitrate Nitrogen 2008 - 2020

Nitrate - Nitrogen Result (mg/L)

- < 0.0010 (< detection limit)
- 0.0010 - 0.10
- 0.10 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- 4.0 - 5.65
- 5.65 - 11.3 (50% MAV)
- > 11.3 (100% MAV)
- Coastal Confined Gravel Aquifer System

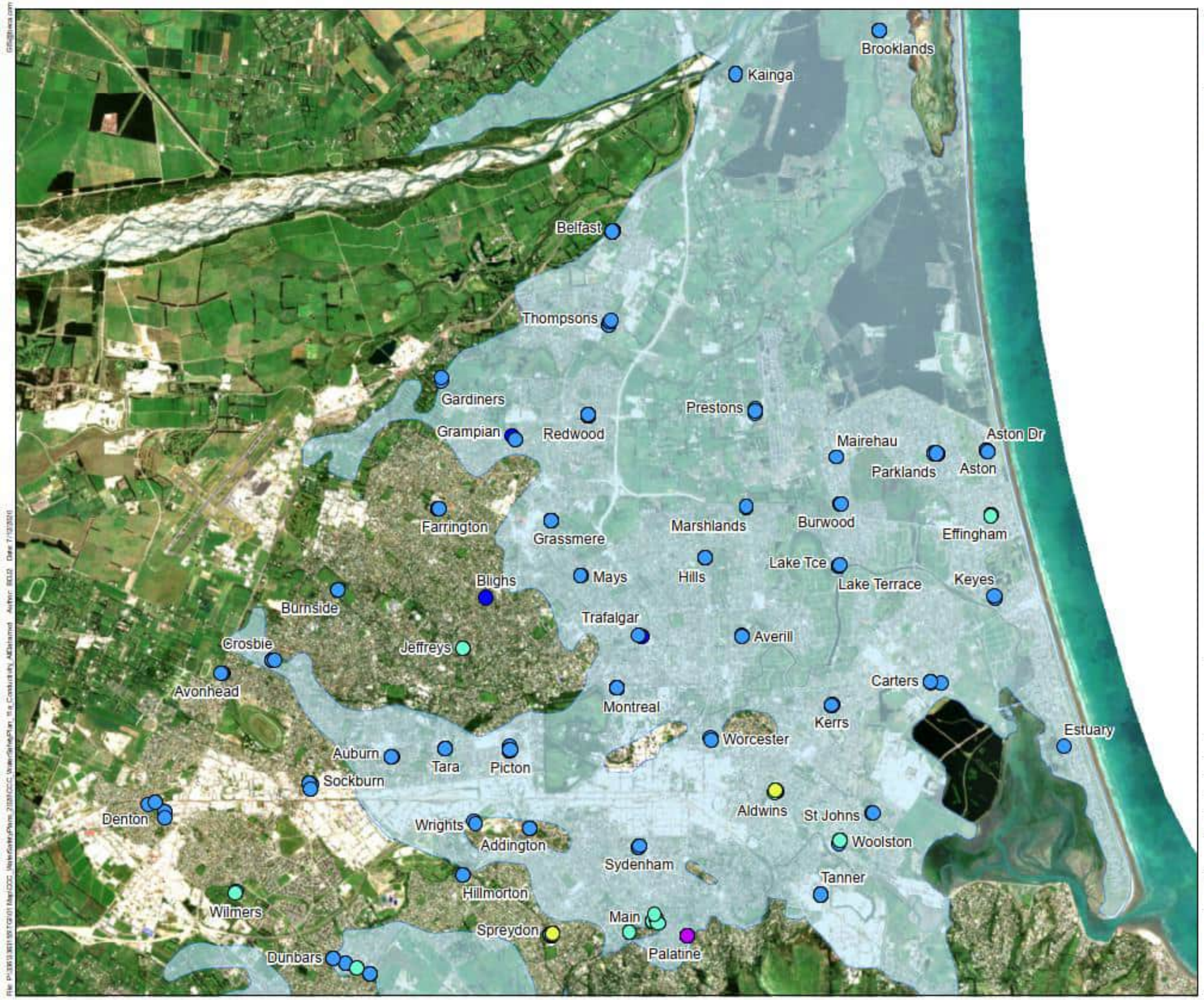
Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

Client: Christchurch City Council
Discipline: GIS
Project: HDW WHSP Delivery
Drawing No: GIS-3363155-WSP-02a

Beca



Maximum Conductivity 2008 - 2020

Conductivity Result

- < 10
- 10 - 15
- 15 - 25
- 25 - 50
- 50 - 70
- 70 - 90
- Coastal Confined Gravel Aquifer System

Elevated electrical conductivity at Palatine is likely due to its proximity to Banks Peninsula. A review of the geochemical make-up of the bore water at Palatine shows similarities with other bores located across Banks Peninsula*1.

**1 Beca, 2019. Water Quality Review for Christchurch and Banks Peninsula - Source Water Finger Printing. Letter Report to Christchurch City Council, 4 April 2019.*

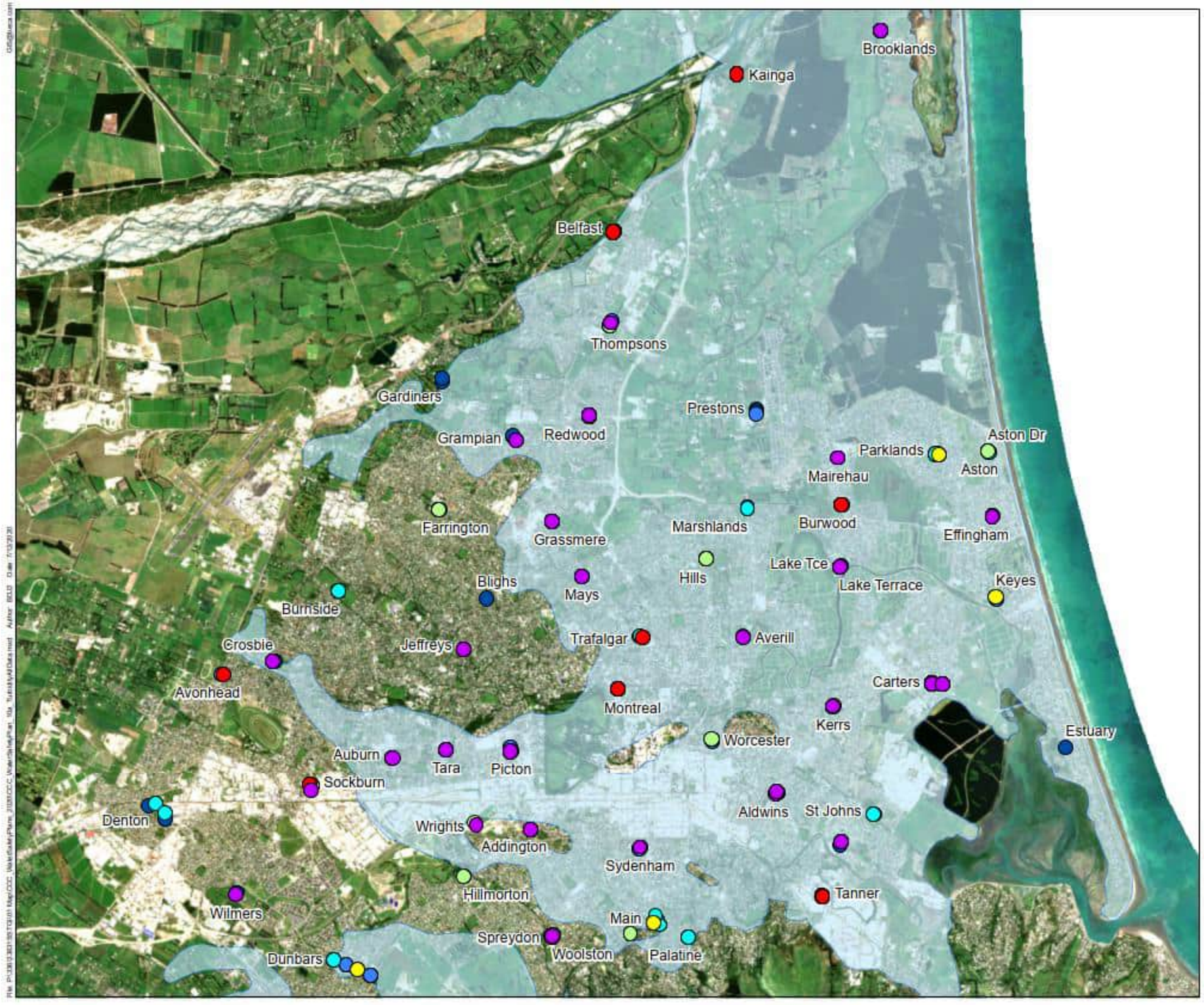
Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

Client: Christchurch City Council
Discipline: GIS
Project: HDM WHSIP Delivery
Drawing No: GIS-3263155-WSP-11a

Beca



Maximum Turbidity 2008 - 2020

Turbidity
Result (NTU)

- 0.015 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 1.25
- 1.25 - 2.5 (50% GV)
- >2.5 (100% GV)
- Coastal Confined Gravel Aquifer System

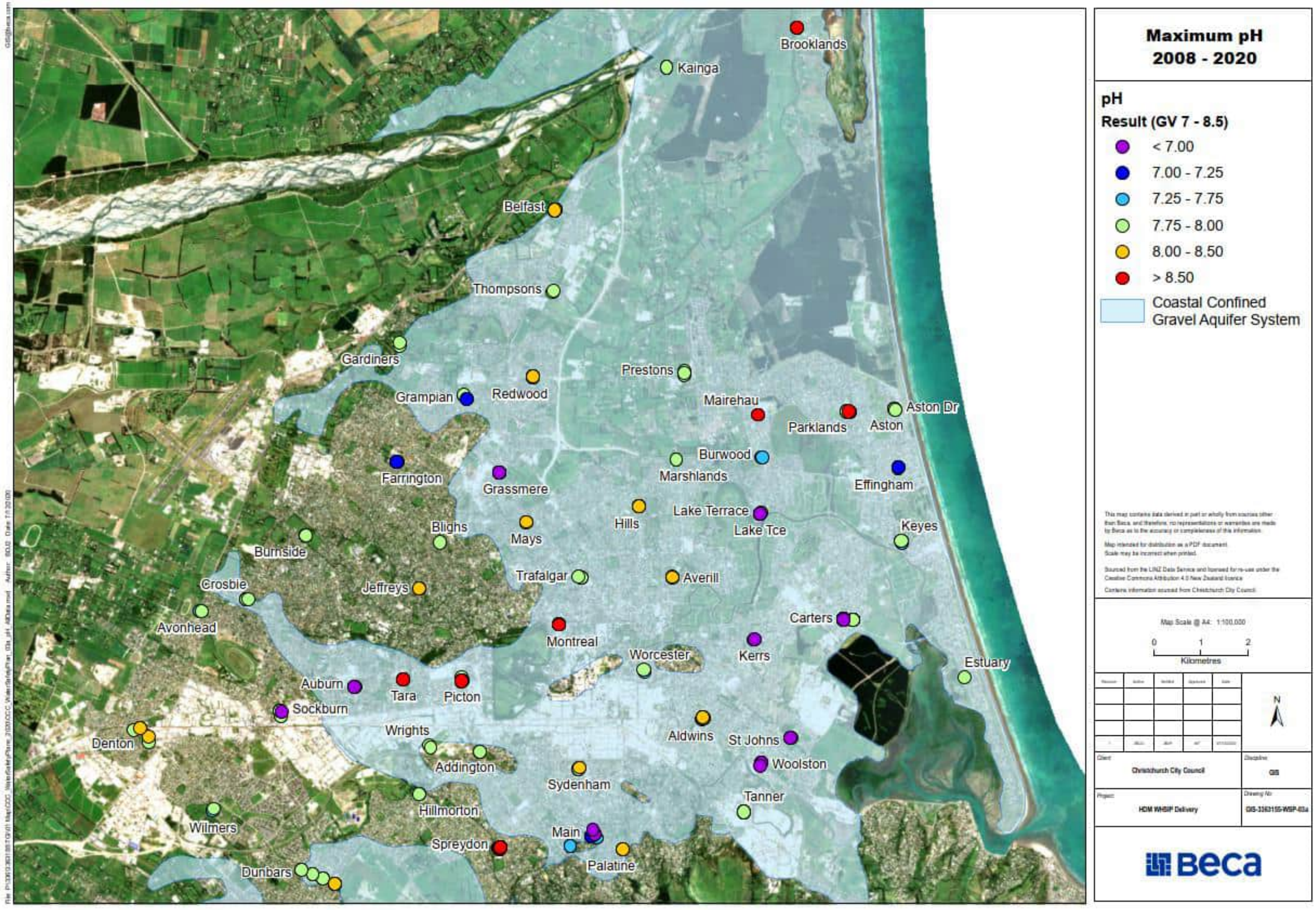
Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

Client: Christchurch City Council
Discipline: GIS
Project: HDM WHSP Delivery
Drawing No: GIS-3362155-WSP-10a

Beca



Maximum pH
2008 - 2020

pH
Result (GV 7 - 8.5)

- < 7.00
- 7.00 - 7.25
- 7.25 - 7.75
- 7.75 - 8.00
- 8.00 - 8.50
- > 8.50
- Coastal Confined Gravel Aquifer System

Map Scale @ A4: 1:100,000

0 1 2
Kilometres

N

Client: Christchurch City Council
Discipline: GIS
Project: HDM WHSIP Delivery
Drawing No: GIS-3362155-WSP-03a

Beca

Appendix E Risk Assessment Workshop Attendees

Workshop 1: 18 March 2019

Name	Position and Organisation	Organisation	Team
Daniela Murugesh	Asset Engineer - Water & Wastewater	CCC	3WW Asset Management
Kenton Winckles	Asset Engineer Mechanical/Civil	CCC	3WW Asset Management
Karn Snyder-Bishop	Principal Electrical & SCADA Engineer	CCC	3WW Asset Management
Mark Johnson	Team Leader Asset Management	CCC	3WW Asset Management
Bridget O'Brien	Programme Manager	CCC	3WW
Mike Bourke	Senior Technician	CCC	Asset Planning Water & Waste
John Moore	Planning and Delivery Manager	CCC	Planning and Delivery
Helen Beaumont	Head of 3 Waters and Waste	CCC	3WW
Will Rowson	Manager Technical Services	CCC	Technical Services
Melissa Patterson	Asset Engineer Planning	CCC	Technical Services
Dale McEntee	Resource Consent Compliance Coordinator	CCC	3WW
Adam Twose	Manager Operations	CCC	3WW Operations
Rob Meek	Senior Advisor	CCC	Reticulation & Maintenance
Sarah Hemmingsen	Senior Advisor	CCC	3WW
[redacted]	Consultant Engineer	Reeftide Environmental & Projects Ltd	
[redacted]	Advisor	Ministry of Health	
[redacted]	Drinking Water Assessor	CDHB	
[redacted]	Treatment Plant Manager	Citycare	
[redacted]	Pump and Storage Manager	Citycare	
[redacted]	Contract Manager	Citycare	

Workshop 2: 30 August 2019

Name	Position	Organisation	Team
Daniela Murugesh	Asset Engineer - Water & Wastewater	CCC	3WW Asset Management
Karn Snyder-Bishop	Principal Electrical & SCADA Engineer	CCC	3WW Asset Management
Bridget O'Brien	Programme Manager	CCC	3WW
Tim Drennan	Manager Reticulation and Maintenance	CCC	Reticulation & Maintenance
Helen Beaumont	Head of 3 Waters and Waste	CCC	3WW
Adam Twose	Manager Operations	CCC	3WW Operations
Rob Meek	Senior Advisor Reticulation & Maintenance	CCC	Reticulation & Maintenance
John Moore	Planning and Delivery Manager	CCC	Planning and Delivery Manager
Gijs Hovens	Team Leader Network Control	CCC	Network Control
Ian Baker	Operational Delivery Lead - Water Treatment	CCC	Network Operations
Peter Milligan	Continuous Improvement Specialist	CCC	
Isabel Carlyon	Business Analyst – Contractor	CCC	3WW
[redacted]	Drinking Water Assessor	CDHB	
[redacted]	Medical Officer of Health	CDHB	
[redacted]		BECA	
[redacted]	Contract Manager	Citycare	
[redacted]	Maintenance Manager	Citycare	

Workshop 3: 6 September 2019

Name	Position	Organisation	Team
Daniela Murugesh	Asset Engineer - Water & Wastewater	CCC	3WW Asset Management
Karn Snyder-Bishop	Principal Electrical & SCADA Engineer	CCC	3WW Asset Management
Bridget O'Brien	Programme Manager	CCC	3WW
Tim Drennan	Manager Reticulation and Maintenance	CCC	Reticulation and Maintenance
Adam Twose	Manager Operations	CCC	3WW Operations
Rob Meek	Senior Advisor Reticulation & Maintenance	CCC	Reticulation and Maintenance
Gijs Hovens	Team Leader Network Control	CCC	Network Operations
David Adamson	General Manager – City Services	CCC	City Services
Isabel Carlyon	Business Analyst – Contractor	CCC	3WW
[redacted]		BECA	
[redacted]	Contract Manager	Citycare	
[redacted]	Maintenance Manager	Citycare	

Workshop 4: 18 June 2020

Name	Position	Organisation	Team
Adam Twose	Manager Operations	CCC	3WW Operations
[redacted]	Operations Manager	Citycare	
Angus Buxton	Asset Engineer Mechanical / Civil	CCC	3WW Asset Management
Bridget O'Brien	Programme Manager Water Supply	CCC	3WW
Bruce West	Network Controller	CCC	Network Operations
Chris Mance	Senior Advisor Reticulation & Maintenance	CCC	Water & Wastewater Operations
Dale McEntee	Resource Consent Compliance Coordinator	CCC	Quality & Compliance
Daniela Murugesh	Water Supply Security Engineer	CCC	Quality & Compliance
David Adamson	General Manager City Services	CCC	City Services
Deepak Chouhan	Assistant Engineer, Water TP	CCC	Network Operations
Gijs Hovens	Team Leader Network Operations	CCC	Network Operations
Graham Wardman	Contract Supervisor – Reticulation & Maintenance	CCC	Water & Wastewater Operations
Ian Baker	Process Engineer	CCC	Network Operations
Helen Beaumont	Head of 3 Waters and Waste	CCC	3WW
[redacted]	Digital Networks Manager	Citycare	
Kenton Winckles	Asset Engineer Mechanical / Civil	CCC	3WW Asset Management
Mark Johnson	Team Leader Asset Management	CCC	3WW Asset Management
Melissa Patterson	Team Leader Quality & Compliance	CCC	Quality & Compliance
Sarah Hemmingsen	Senior Advisor Operational Policy	CCC	Quality & Compliance
Tim Drennan	Manager Service Excellence	CCC	3WW
Will Rowson	Team Leader Water Services	CCC	Water Services

Workshop 5: 24 June 2020

Name	Position	Organisation	Team
Adam Twose	Manager Operations	CCC	3WW Operations
[redacted]	Operations Manager	Citycare	
Andrew Batchelor	Contract Supervisor - Reticulation & Maintenance	CCC	Water & Wastewater Operations
Angus Buxton	Asset Engineer Mechanical / Civil	CCC	3WW Asset Management
Bridget O'Brien	Programme Manager Water Supply	CCC	3WW
Bruce West	Network Controller	CCC	Network Operations
Chris Mance	Senior Advisor Reticulation & Maintenance	CCC	Water & Wastewater Operations
Dale McEntee	Resource Consent Compliance Coordinator	CCC	Quality & Compliance
Daniela Murugesh	Water Supply Security Engineer	CCC	Quality & Compliance
David Adamson	General Manager City Services	CCC	City Services
Gijs Hovens	Team Leader Network Operations	CCC	Network Operations
Ian Baker	Process Engineer	CCC	Network Operations
Helen Beaumont	Head of 3 Waters and Waste	CCC	3WW
[redacted]	Digital Networks Manager	Citycare	
Kenton Winckles	Asset Engineer Mechanical / Civil	CCC	3WW Asset Management
Mark Johnson	Team Leader Asset Management	CCC	3WW Asset Management
Melissa Patterson	Team Leader Quality & Compliance	CCC	Quality & Compliance
Sarah Hemmingsen	Senior Advisor Operational Policy	CCC	Quality & Compliance
Will Rowson	Team Leader Water Services	CCC	Water Services

Workshop 6: 10 July 2020

Name	Position	Organisation	Team
[redacted]	Operations Manager	Citycare	
Andrew Batchelor	Contract Supervisor - Reticulation & Maintenance	CCC	Water & Wastewater Operations
Bridget O'Brien	Programme Manager Water Supply	CCC	3WW
Bruce West	Network Controller	CCC	Network Operations
Chris Mance	Senior Advisor Reticulation & Maintenance	CCC	Water & Wastewater Operations
Dale McEntee	Resource Consent Compliance Coordinator	CCC	Quality & Compliance
Daniela Murugesh	Water Supply Security Engineer	CCC	Quality & Compliance
David Adamson	General Manager City Services	CCC	City Services
Deepak Chouhan	Engineering Officer – Water Supply	CCC	Quality & Compliance
Gijs Hovens	Team Leader Network Operations	CCC	Network Operations
Melissa Patterson	Team Leader Quality & Compliance	CCC	Quality & Compliance
Sarah Hemmingsen	Senior Advisor Operational Policy	CCC	Quality & Compliance
Will Rowson	Team Leader Water Services	CCC	Water Services

Risk Review Update meeting: 6th December 2021

Name	Position	Organisation	Team
Judy Williamson	Water Supply Security Specialist	CCC	3WW
Veronica Zefferino	Team Lead – Quality and Compliance	CCC	3WW
Tim Drennan	Manager Service Excellence	CCC	3WW
Helen Beaumont	Head of Three Waters	CCC	3WW