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Groundwater REPORT

WAIRAU PLAIN DRAINAGE AND GROUNDWATER

PREPARED FOR
Marlborough District Council

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EXECUTIVE SUMMARY

Aqualinc was asked by MDC to undertake literature review to understand rural land drainage on the Wairau Plain, how it has evolved over time, and assess impact on groundwater levels. This request evolved to also understand how groundwater can influence risk, including by retroactively commenting on groundwater level data relative to the July 2022 flood event.

Literature review showed a long but poorly documented history of drainage interventions. Most documentation made general observations of what was done and the observed consequences, not measured impacts. Information was only found on the Marlborough District Council (MDC) managed drainage network; no information was available on privately managed land drainage. This is a significant gap in understanding. Surface drains have been used to decrease ponding and increase hydraulic efficiency. Installation of new surface drains continues to this day on the lower Wairau Plan. Comprehensive field drainage (e.g. tile drains, mole drains, Novaflo^{TM}) preceded the transition to viticulture to control the water table and keep vine roots dry.

The MDC network consists of 195 drains totalling 400 km. Most of the drains are permanent flowing. This suggests widespread and constant groundwater discharge. 53% of the drainage network drains under gravity, 47% of the network requires some level of pumping. Roberts Drain, Rouses Drain, and Chaytors Drain pump stations have been telemetered within the last five years.

Knowledge and consideration of land use, drainage, and groundwater can be highly siloed, as demonstrated by with the 2015 drainage review failing to consider stormwater outfall, but most stormwater discharging to the drains.

Forecasting suggests groundwater levels will rise in response to changes such as sea level rise. Higher groundwater levels will reduce the capacity of the drainage network, requiring more pumping. It will also increase land inundation, requiring additional drainage.

Groundwater is dynamic but our built and engineered environments are either static or only able to tolerate “so much” change before “something has to give”. Failing to account for or underestimating groundwater’s influence within such restricted systems can result in consequences (or risks) ranging from nuisance (e.g. ponding on a lawn) to catastrophic (e.g. widespread damage to property and belongings and displacement of people). A preliminary high-level risk assessment focussing on groundwater suggests there is potentially extremely high risk posed by groundwater.

Review of daily groundwater level data for wells provided by MDC suggests there is evidence in the groundwater level record of levels responding to key interventions (such as the Wairau Valley Scheme). However, this influence cannot be proved conclusively without eliminating other drivers. This data was also reviewed against river and rainfall data for July and August 2022, with July 2022 being the wettest month on record. Groundwater levels responded within a day to repeated rainfall events across July and August, with cumulative groundwater level rises far exceeding that which could occur had rainfall events happened in isolation, with maximum groundwater levels recorded. This would have significantly reduced infiltration capacity, exacerbating and prolonging flooding. This is contrasted to current state data, which shows groundwater levels at or approaching their minimum highlighting the rapid movement of water through the Wairau Aquifer and the importance of effective short-term and long-term water management to best mitigate the extremes of water availability.

Though there is limited data, there is strong anecdotal evidence that land drainage has exerted significant influence over groundwater level. There remain significant information gaps, especially relating to drainage infrastructure and interventions outside of the MDC network.

1 INTRODUCTION

Aqualinc has been engaged by Marlborough District Council (MDC) to document rural land drainage on the Wairau Plain and describe the potential impacts of this drainage on Wairau Plain groundwater levels. This review explicitly excludes analysis of urban drainage and stormwater management.

Aqualinc has also been asked to help MDC better understand how shallow groundwater can pose and exacerbate risk across MDC functions.

Interventions to control or otherwise manage volumes of water are desirable when too much or too little water poses or exacerbates risk. This is inherently a human-based concept. Flooding or drainage “problems” only occur when water is present in volumes that impact people and/or desirable land use. Given this report focuses on land drainage, we frame “problem” volumes of water in negative language, e.g. “excess water”, “drainage issues”. This does not mean the presence of large quantities of freshwater is a bad thing, just in the context with which we are considering it.

1.1 Approach

We reviewed available literature and MDC GIS information to understand land drainage in the Wairau Plain and its evolution through time. Documentation identifies drainage network reviews occurring in 1960 as part of developing the Wairau Valley Scheme, in the early-1990s to inform the 1996 Wairau Drainage Management Plan, and in the mid-2010s to inform asset management planning, with the latter also intended to be used to produce an updated flood protection and drainage plan for 2020-2050 (MDC, 2018), however this did not eventuate. Information on each of these reviews was provided by MDC.

In this report we refer to the “upper” and “lower” Wairau Plain. The upper Wairau Plain can generally be interpreted to be inland of Blenheim (and other urban areas) and State Highway 1. The lower Wairau Plain can generally be interpreted to be coastwards of State Highway 1 plus the Tuamarina Valley.

1.1.1 Drainage Definition

There are many different forms of drainage and interpretations of the term drainage in a water resources and infrastructure context. Drainage can refer to:

- Water movement through the soil profile that leads to land surface recharge,
- Land drainage, or
- Drainage from a water balance perspective.

Within this report, unless otherwise specified, “drainage” refers to land drainage.

1.2 Background

The Wairau Plain is broadly the valley floor coastwards of the Waihopai / Wairau confluence. The Plain is approximately 170 km^2, with most of the Plain below 30 m msl, and a significant area <2 m msl, especially in the Lower Wairau/Dillons Point area (Rae, 1987). Flood control and drainage is provided naturally by rivers and streams. Where this is inadequate to meet the needs and expectations of communities, flood control and drainage schemes have been introduced. The Wairau Plain has a long history of flooding and drainage problems and an equally long record of attempted interventions and resolutions.

Today, MDC staff undertake flood control work to protect assets and infrastructure from damage from flood events. Staff undertake drainage work to remove water from land over the longer term to '*reduce groundwater levels*' and enable land development and use (MDC, 2018). MDC (2018) describes '*a degree of overlap*' between flood control and drainage assets on low-lying land:

> '*Drains and natural watercourses that are specifically excavated to drain otherwise swampy land will also reduce the flood level in storm events, especially where there is good channel capacity and outfall capacity to the main river systems.*' (p. 19)

MDC (1994) comments that:

> '*Improving and maintaining the jigsaw of interlinked modified waterways on the floodplain to an appropriate standard carries with it the responsibility that all river control work on these Wairau floodplain waterways should be planned, promoted, and funded as one scheme*.' (p. 24)

Because of this inherent interconnectedness, it is appropriate to consider drainage activity as also encompassing flood control (and vice versa) as drains and watercourses created to drain otherwise swampy land, will also reduce the flood level in storm events, especially where there is good channel capacity and outfall capacity to the main river systems (MDC, 2015).

1.3 Report Structure

This report is structured as follows:

Section 2: Groundwater of the Wairau Plain is a high-level description of groundwater of the Wairau Plain, describing aquifers and changes in groundwater levels. This enables understanding of the hydrologic setting across which changes occur and enables readers to move into Section 3 with a high-level understanding of the underlying conditions.

Section 3: Land Use, Drainage, and Groundwater describes how land use has developed, how different land uses have required different scales and types of drainage in different locations, and how this development has been observed to impact groundwater levels. Drainage on the Wairau Plain is inherently tied to land use, so though not explicitly within the scope of works, land use is inherently a necessary consideration.

Section 4: Current MDC Drainage Network describes the current MDC drainage network, giving details on the drains, pumps, and floodgates. It also comments on the limitations of the existing network, and knowledge of groundwater by those responsible for managing the network and how this could pose risk.

Section 5: Anticipated Changes to Land Use, Drainage, and Groundwater summarises potential future conditions of land use, drainage, and groundwater based on provided literature and speculates on the appropriateness of a BAU approach to drainage management under these conditions.

Section 6: Groundwater Impact on Risk introduces groundwater as a hazard and describes how groundwater can both pose and exacerbate risk. An initial high-level assessment focussed on groundwater is undertaken to explore what groundwater as a hazard could mean for MDC.

In **Section 7: Quantifying Change** we review daily groundwater level data provided by MDC against key interventions that impacted groundwater level and comment on whether change was observable in hydrographs.

Section 8: Summary summarises Sections 1 through 7.

Section 9: Conclusions lists the key conclusions from this report.

2 GROUNDWATER OF THE WAIRAU PLAIN

Figure 2-1 shows the current MDC groundwater level monitoring network relative to aquifer extent. The Wairau Aquifer underlies a land area of ~14,000 ha and receives constant recharge from the Wairau River. The Wairau Aquifer is unconfined across most of the Wairau Plain. Towards the coast it becomes confined as it is overlain by marine sediment and the Rarangi Shallow Aquifer (<10 m thick). Aquifers, springs, rivers, and wetlands are all connected as part of the hydrological cycle. Changes to water management above ground impacts water below ground, and vice versa.

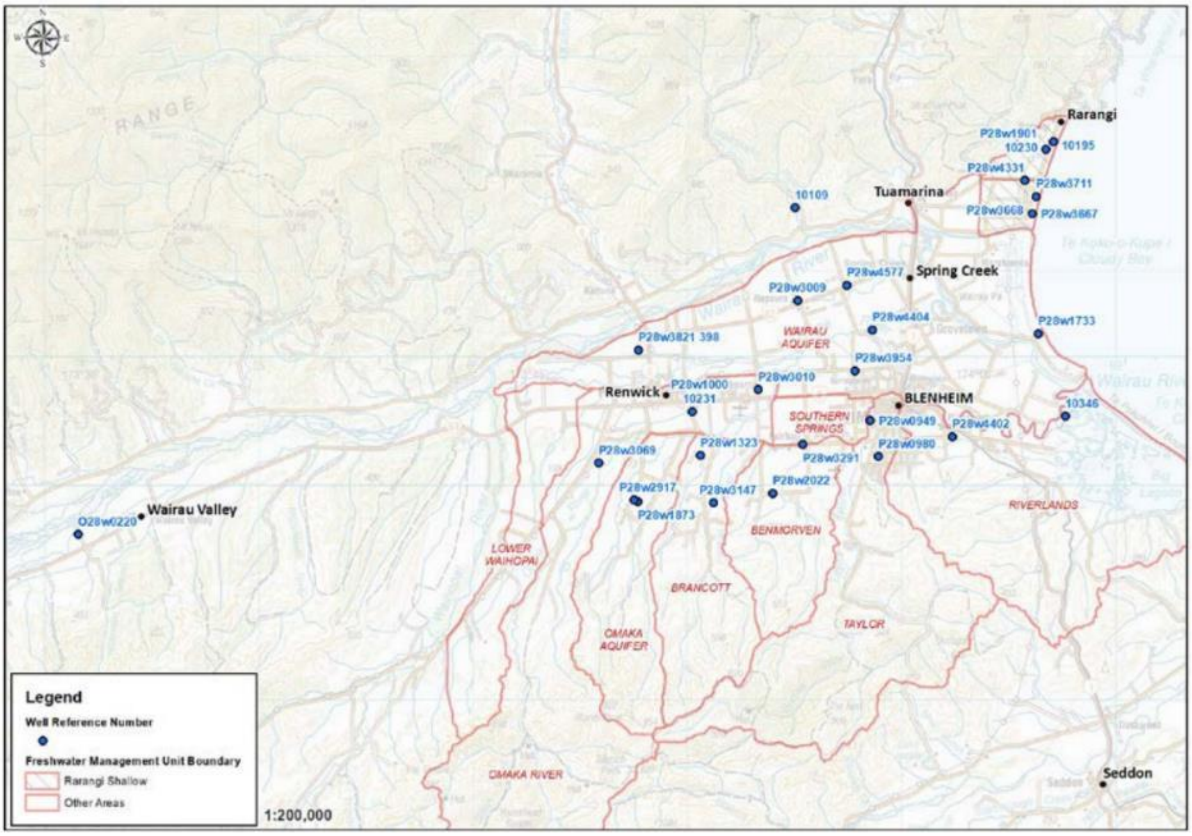

Figure 2-1 Marlborough District Council groundwater level monitoring network relative to aquifer extent (Davidson, 2022)

Nearly all rivers lose significant volumes to groundwater as they flow from the hills onto the Wairau Plain, especially rivers flowing from the Southern Hills, with many of the rivers flowing from the south drying along some of their length. Wilson (2016) identifies three main areas of Wairau Aquifer recharge, as shown in Figure 2-2. Groundwater levels need to be lower than riverbed levels in this area for this recharge to happen. At moderate to high Wairau River flows, the Wairau Aquifer recharge rate is relatively constant at 7 m^3/s (Davidson, 2022), with modelling by Wöhling, et al. (2017) suggesting recharge '*rarely exceeds*' 12 m^3/s. A lesser volume of Wairau Aquifer recharge is sourced from rainfall and tributary rivers (Davidson & Wilson, 2011). Modelling by Wöhling, et al. (2017) suggests that land surface recharge accounts for 1% of the long-term water balance. Contributions from rivers draining the Southern Valley catchments are of increasing importance with distance from the Wairau River and during higher rainfall months. Cunliffe (1988) describes the Wairau Aquifer as sensitive to changes in river flows, including flood flows.

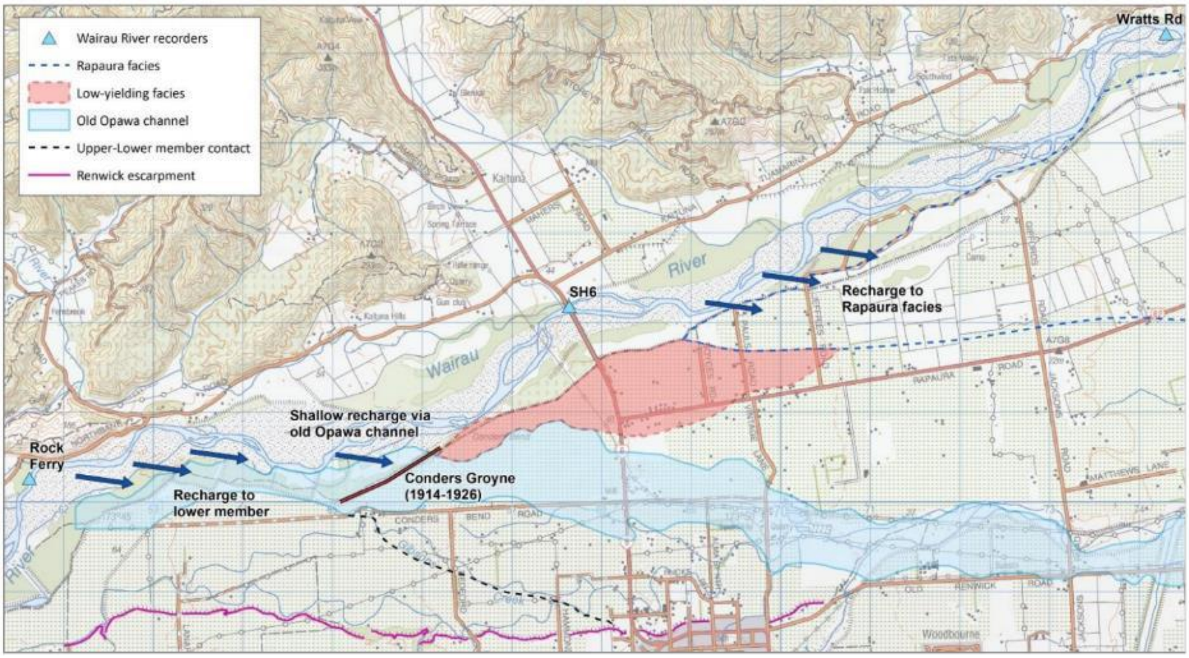

Figure 2-2 Main areas of Wairau Aquifer recharge (Wilson, 2016)

Most Wairau Aquifer water discharges onshore as spring flow, from where the water table intersects the land surface (Figure 2-3) to the coast. The most significant outflows are from Spring Creek (Awarua). Other spring-fed waterways include Dowlings Creek, the Ōpaoa River, Fultons Creek, Murphys Creek, Yelverton Stream and Doctors Creek (Cunliffe, 1988). Under moderate to low flows, the Wairau Aquifer drains faster through its springs than it is recharged, meaning stable groundwater levels are dependent on regular, high Wairau River flows (Davidson & Wilson, 2011). Coastwards of State Highway 1, groundwater discharge to land surface can be from both the Rarangi Shallow Aquifer and confined Wairau Aquifer.

Awarua has the largest flow of all Wairau Aquifer-fed springs, making flow in Awarua a good indicator of the state of the aquifer. 73% of the variation in Awarua flow is explained by changes in groundwater level (Davidson, 2022). Flows in Awarua decreased between 1996 and 2022 at an annual rate of 0.03 m^3/s, or 0.92 m^3/s over ~31 years (Davidson, 2022). Based on an extrapolation of the current rate of flow recession, all spring flow east of State Highway 1 could cease by 2100 (Davidson, 2022).

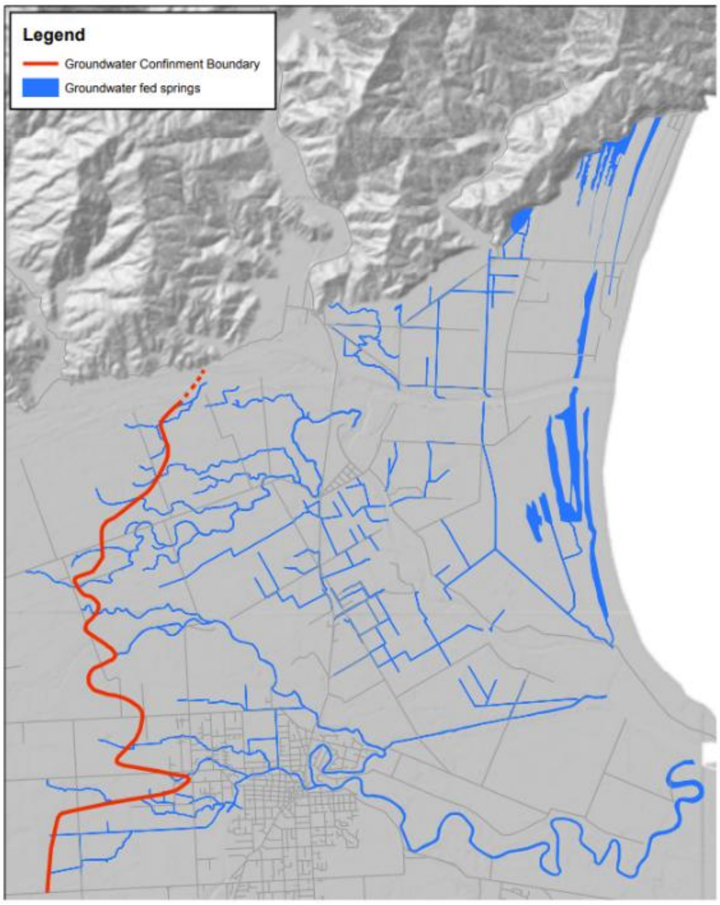

Figure 2-3 Wairau Plain spring belt (red) and groundwater-fed waterways (blue) (Davidson & Wilson, 2011)

2.1 Groundwater Level and Trends

Figure 2-4 shows the general groundwater flow pattern towards the coast. The tight bunching of contours in the upper Plain suggests a steep hydraulic gradient and high groundwater velocity, while the wider spacings towards the coast suggest a much-reduced velocity. Contour sinuosity in the mid Plain area around Hammerichs and O'Dwyers roads reflects discharge to Awarua. Convergence of the contours indicates losses, while divergence means the aquifer is gaining water. The shape of the contours in the Lower Wairau area implies that groundwater flow in the confined aquifer near the coast is focused upwards or offshore. The permeability of gravels located north of the Wairau Diversion channel are significantly lower than those opposite the Wairau River mouth; groundwater flow is more sluggish in northern areas, with lower well yields and older, poorer quality groundwater (Davidson & Wilson, 2011). There is also a vertical pressure gradient in the coastal sector of the Wairau Aquifer, resulting in groundwater discharging onshore as springs/wetlands rather than discharging offshore. The depth to the water table is significantly greater over summer in the west and south of the Wairau Aquifer where rainfall or river recharge is lowest in relation to abstraction and natural drainage.

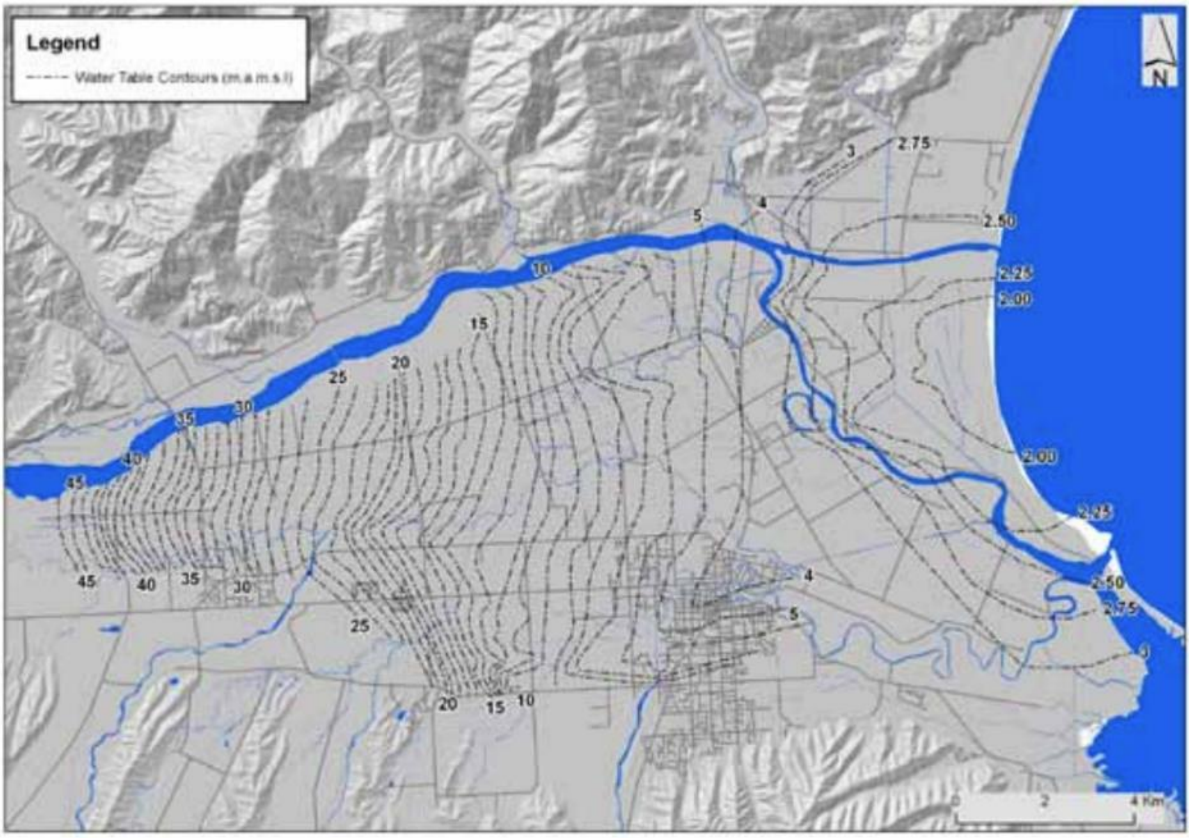

Figure 2-4 Piezometric contours (labels in m msl) based on data collected in March 1978, a relatively dry summer (Davidson & Wilson, 2011)

Wairau Aquifer groundwater levels have been declining for 50 years (Davidson, 2022). This decline was first identified in early 1970s readings from the MDC Conders well and confirmed by a similar trend in groundwater levels in Wratts Road wells. Table 2-1 summarises the state and trends of the Wairau Aquifer, based on MDC monitoring wells (shown in Figure 2-1). All wells show declining level trends. The average groundwater level decline per year decreases with proximity to the coast. All wells show seasonality in the groundwater levels, though the timing of peaks and troughs differs based on relative location, depth, and drivers.

Groundwater level in all wells is impacted by river baseflow, with only some impacted by flood events or rainfall. Davidson (2022) attributes declining trends as being partially attributable to declining Wairau River channel levels and lower Wairau River summer flows, meaning less recharge to the groundwater system from the Wairau River. Except for the coastal sector, there have been no previous connections made between land drainage interventions and changes in groundwater levels. This does not mean that land drainage and/or drainage interventions have not impacted groundwater level, just that the link has not been established.

Figure 2-5 shows the mapped extent and magnitude of tidal impacts on groundwater level. The shape of the contours suggests larger fluctuations beneath the centre of the Wairau Plain, and smaller changes on the margins at Riverlands or Rarangi. Tidal forcing will impact shallow groundwater discharge but will have a lesser impact on discharge from the confined system.

Table 2-1 Summary of Wairau Aquifer level trend and drivers based on Marlborough District Council monitoring wells (as described in Davidson (2022))

Well	Aquifer sector	Record starts	Average level change (mm/year)	Drivers
3821	Recharge	1973	-22	Wairau River + events
3009	Recharge	1996	-10	Rainfall, Wairau River + events
3954	Southern Springs	2002	-7	Rainfall, Wairau River
4577	Northern Springs (semi-confined)	2010	-10	Wairau River + events, spring flows, tides
4404	Central Springs (semi-confined)	2009	-8	Ruakanakana, Ōpaoa River, spring flows
1733	Coastal (confined)	1988	-3	Groundwater pumping, Wairau River + events, drainage, tides, barometric pressure

Figure 2-5 The extent of the tidal influence (contours) on Wairau Plain well (points) groundwater levels (Davidson & Wilson, 2011)

2.2 Other Aquifers

Davidson's (2022) findings of groundwater state and trends for the remaining aquifers in Figure 2-1 are summarised in Table 2-2. There is greater variation in groundwater levels across these aquifers, likely reflecting the more variable conditions. Drainage and pumping have been identified as a much more prominent drivers of groundwater level change in these aquifers.

Table 2-2 Summary of aquifer level, trends, and drivers based on Marlborough District Council monitoring wells (as described in Davidson (2022))

Aquifer	Well count	Level / state	Level trend	Drivers
Riverlands	2	Low	No change to increasing	Groundwater pumping
Taylor	2	Normal to high	No change to increasing[1]	Groundwater pumping, drainage rate
Benmorven	2	Low	Decreasing to increasing[6]	Groundwater pumping
Brancott	2	High	No change to increasing	Fairhall River, rainfall, groundwater pumping, drainage rate
Omaka	2	High	Increasing[6]	Mill Creek, rainfall, groundwater pumping
Omaka River	3	Normal	Decreasing to no change[6]	Omaka River, groundwater pumping, drainage rate
Rarangi	5	Normal	No change to increasing	Rainfall, groundwater pumping, sea level rise, drainage rate

2.3 Summary

The Wairau Aquifer lies beneath the Wairau Plain and is predominantly recharged by the Wairau River. The Wairau Aquifer is unconfined inland, becoming confined towards the coast where it is overlain by marine deposits and the Rarangi Shallow Aquifer. The Wairau Aquifer intersects the land surface inland of Blenheim, with the equivalent of Wairau River recharge discharging as springs from inland of Blenheim towards the coast. Discharge of groundwater to land coastwards of State Highway 1 is from both the Wairau Aquifer and Rarangi Shallow Aquifer. The Wairau Aquifer has had declining groundwater levels across the last 50 years. The greatest declines have been observed inland and decrease with proximity to the coast. Land drainage has not been directly tied to changes in groundwater levels in the Wairau Aquifer but has been elsewhere.

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[1] Additional patterns over shorter record length

3 LAND USE, DRAINAGE, AND GROUNDWATER

Land drainage removes excess water to enable desirable land uses. There have been two major stages of land drainage on the Wairau Plain. The first was the excavation/installation of drainage channels; channelising spring flow and providing efficient water conveyance, resulting in a general lowering of the water table. On the upper Wairau Plain this was undertaken to enable pastoral and arable farming and was largely completed by the 1960s. On the lower Plain, surface drainage interventions began at a similar time to those in the upper Plain and are ongoing today. Active management of drainage channels (e.g. weed clearance) is required to maintain drain effectiveness in many cases. In other cases, failure to properly account for increased land surface runoff from changed land uses (e.g. increased urban area, transition from pasture/arable farming to viticulture) has meant drains are vulnerable to being overwhelmed by outfall.

The second stage of drainage was paddock-scale subsurface drainage, such as tile drains which outfall to drainage channels, from the 1980s to mid-2000s. This only occurred on the upper Plain. This more intense drainage again controlled groundwater levels, enabling the establishment and success of viticultural land use. Land drainage on the lower Plain is still developing to enable further viticultural expansion into marginal areas.

Land drainage on the Wairau Plain over the more than a century consists largely of the following types of drainage channels:

1. **Gravity drainage**: discharging groundwater can be conveyed “naturally” along rivers and drainage channels.
    a. Ongoing maintenance of stream and drainage channels is important, but only significant river floods cause backflow along drains.
        i. Any backflow due to storm run-off is usually of short duration, with significant flooding in localised areas.
    b. Some drainage areas do not discharge to river outfalls, but to lower-lying drainage areas or via control structures which regulate overflows.
2. **Pumped drainage**: areas dependent on pumping stations for land drainage and/or for protection from floods.
    a. Without the provision of pumping facilities these areas would be virtually unproductive and subject to extensive flooding.
    b. Pumping stations are required on drainage channels where high downstream water levels are encountered for long periods of time, to maintain upstream drainage efficiency.
    c. Flooding potential of these areas has increased with the continued development and use of the drainage channel network and increased land surface runoff (e.g. quick flow runoff from vineyards and urban stormwater).
3. **Pump-assisted drainage**: areas assisted by pumping operations to provide for flood mitigation when high river levels close gravity outfalls.
    a. Gravity drainage is usually adequate, but the system can become overwhelmed during events, necessitating pumping.
    b. Maintenance of drainage channels and outfalls important (MDC, 2018; 2015; 1996).

This section compiles information on land drainage in identified literature. Literature only captures information on surface drains managed by regional governing bodies (e.g. MDC). It does not capture information on privately managed drains or on tile drainage.

3.1 Before 1960

Rae & Tozer (1990) describe the pre-human vegetation. A narrow zone of coastal forest occurred on both sides of the Wairau Valley, possibly with a narrow linking band of ngaio around Cloudy Bay. The lower Plain was predominantly flax, raupo, toitoi and cabbage tree swampland. The brackish Wairau lagoon system would have been much as it is today and contained patches of swamp forest. On the upper Plain and into the Southern Valleys was a more open, partly deciduous, forest.

Rae & Tozer (1990) describe Māori as occupying the Wairau Plain ‘*for almost a millennium*’. Māori occupation included permanent settlements, a canal system across the Wairau lagoons, and widespread clearing (using fire) of the lowland podocarp forests of the Wairau Plain some 600-800 years ago, with forests succeeded by grassland and shrubland. Conflict between Māori and Pakeha over ownership of the Wairau Plain was ‘*resolved*’ with the acquisition of the land by the governor in 1847 (Rae & Tozer, 1990), the same year permanent European settlement of the Wairau Plain was achieved.

The historic maximum extent of saturated ground, that is land likely requiring drainage intervention, is perhaps best reflected in the estimated extent of pre-human wetlands as projected by Ausseil, et al. (2008) based on soil information in the Land Resource Inventory. Figure 3-1 shows almost all projected historic wetlands on the lower Plain were swamp-type. Based on classification by Johnson & Gerbeaux (2004), swamps are fed by surface runoff and groundwater, with ‘*the water table usually permanently above some of the ground surface, or periodically above much of it.*’ Marsh-type wetlands are also fed by groundwater or surface water but characterised by moderate-to-great water table/water level fluctuations. Rae & Tozer (1990) describe the wetlands as being fed by the Taylor and Fairhall rivers, springs, and floodwaters. Drainage was therefore deemed necessary by European settlers to enable land use in some places and increase land productivity in others.

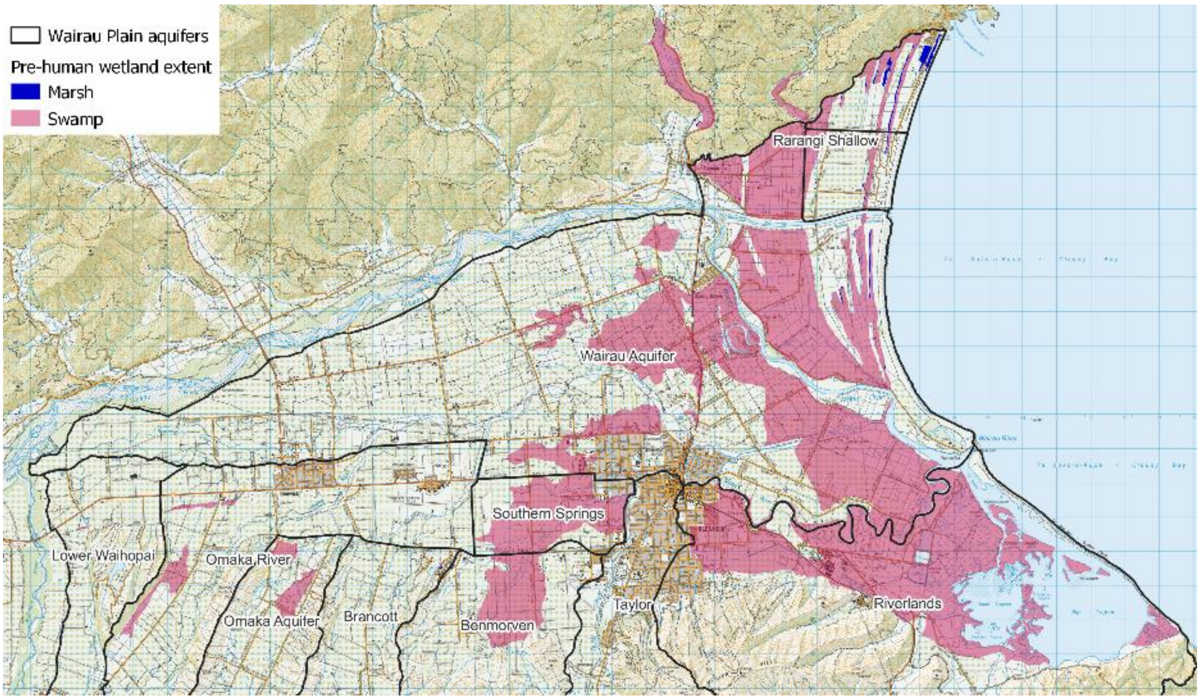

Figure 3-1 Pre-human wetland extent (Ausseil, et al., 2008) compared to aquifer extent

Initial European land uses saw more land clearance (using fire and logging). Early land use on the Wairau Plain was predominantly cropping (cereals and seed crops) and mixed stock uses, with intensification reliant on flood protection and drainage interventions as described above. European settlement saw substantial waterway modification soon after the establishment of Blenheim in the 1850’s because of frequent floods and heavily saturated ground (Rae, 1987). This included diverted and realigned rivers (generally watercourse straightening), stopbanking and land drainage. These interventions made flow paths shorter and gradients steeper, causing sediment to accumulate, resulting in bed aggradation, and reducing the capacity of waterways to convey floodwaters, further amplifying drainage issues. Attempts to "best" manage large river flows and flood flows were contentious; what was good for one community was often detrimental for another. By the 1890's there was a land "shortage", triggering cultivation of "inferior" land. For example, the swampland in the Lower Wairau nearest the bar was drained to enable agricultural use of flat land, which contributed to the demise of the flax fibre industry (Rae & Tozer, 1990).

Floods saw areas inundated by water, with the December 1939 flood resulting in thousands of hectares under water for up to six weeks (Waters, 1959). Given floodwaters would have receded by this time, the prolonged flooding was no doubt exacerbated by high groundwater levels preventing infiltration and land drainage and resulting in the ponding/daylighting of shallow groundwater in low-lying areas. Rae & Tozer (1990) describe an '*extraordinary effort*' across 100 years to provide land for settlement and security from flooding by undertaking swamp drainage, channelisation, stopbanking, and river diversion.

Dunbar (1958) reports that in 1952 Marlborough County, 5% of total land area was in crops and non-grass pasture, while 18% total land area was sown grass, with 97% of livestock being sheep. Stock water supplies for the pastoral industry relied on the availability of water in watercourses, including drains (Rae, 1987). Dunbar (1958) classified land capability for the Wairau catchment based on soil characteristics, topography, and existing vegetation. Figure 3-2 shows their distribution, and highlights classes II, III and IV land which have areas sub-classified as '*water*' meaning it had excess water, limiting land use intensity. ~7,600 ha or 2% of the Wairau catchment was classified as having this limitation. Dunbar (1958) identified that adequate drainage can aid in soil conservation, and identifies opportunities for tile drainage, hump and hollows to increase pasture establishment, and that '*special problems*' exist in the Tuamarina/Pukaka Class VII areas.

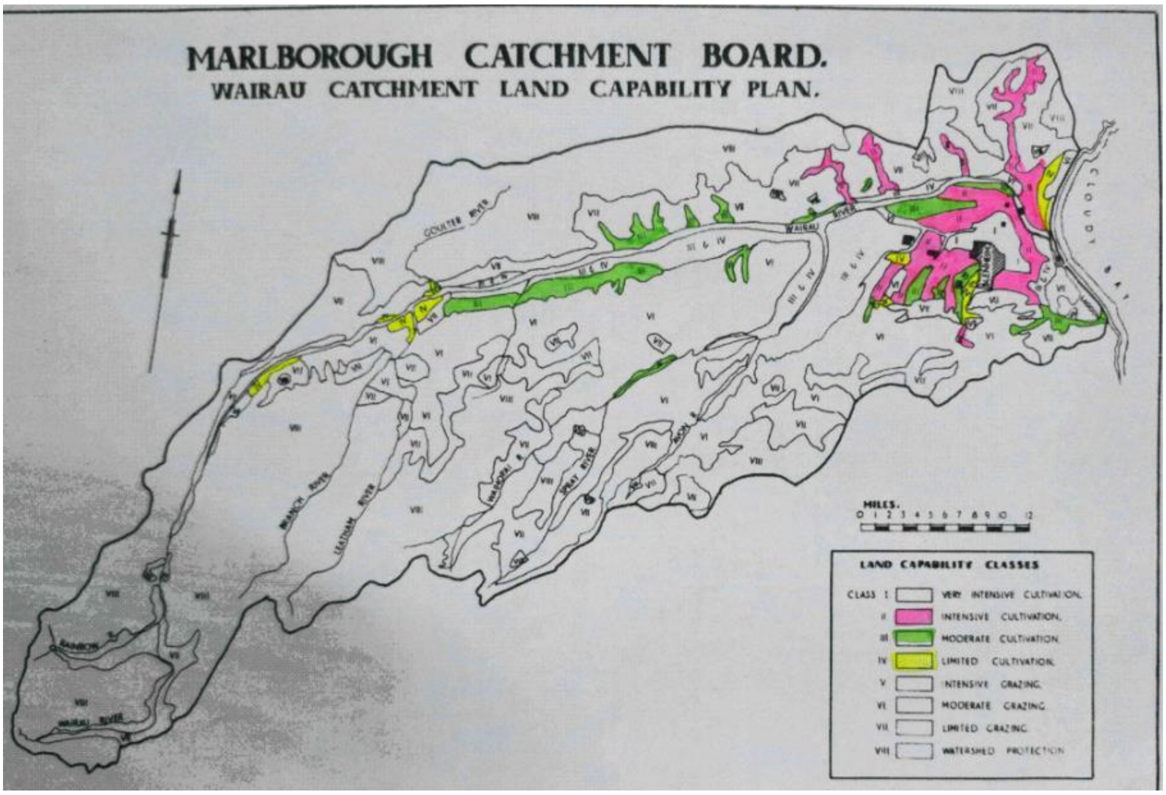

Figure 3-2 1958 land capability distribution for the Wairau Catchment (Dunbar, 1958). Coloured classes indicate where areas of shallow groundwater could occur

The Wairau Plain is a highly modified hydrological environment. Table 3-1 presents a timeline of interventions from the late 1800's until the Wairau Valley Scheme was commissioned in 1960. There is no formal documentation of when every drain was established, just whether it existed at the time of reviews. Many of the drains that form part of the current MDC drainage network were constructed by a Drainage Board (Bezar, 2023; Adams, 2023).

Table 3-1 Timeline of interventions based on descriptions in (Rae, 1987; MDC, 1994)

Year	Intervention
1848	Land survey of the Wairau Plain shows the Opawai River as a second channel of the Wairau River. Downstream of the junction, seepage from the Wairau River is described as causing the Ōpaoa River to flow. Swamps and springs were identified in the Foxes Island-Rapaura area. Wairau riverbed was '*much higher*' than in subsequent decades.
1861	Marlborough Provincial Council attempts and fails to block the Ōpaoa Breach for the first time.
1874	• Spring Creek River Board (SCRB) formed to protect the northern half of the Wairau Plain. • Lower Wairau River Board (LWRB) formed to protect the southern half of the Wairau Plain, including Blenheim and the Lower Wairau, by preventing flow along the Ōpaoa River. • These boards had opposing and '*antagonistic*' approaches to controlling Wairau and Ōpaoa flows.
1875	Omaka River Board formed.
1877	LWRB diverted the Omaka River to flow into the Ōpaoa River.
1877-8	Fairhall Diversion. The Fairhall was a blind river terminating in a swamp between Middle and New Renwick roads. The diversion channelled flow into the old Omaka River channel to remove/reduce flooding risk to Blenheim.
1878	Pukaka River and Drainage Board formed. • The Pukaka was a blind river terminating in a swamp at Pembers Road. • The Pukaka Drain was constructed, discharging to Marukoko Creek. Secondary Roberts Drain was also constructed. • Interventions caused issues in neighbouring Wairau Māori Drainage District. • Landowners of these schemes constructed their own stopbanking. Taylor River diverted to Omaka River.
1879	Injunction to prevent LRWB from closing the Ōpaoa Breach.
1881	Fosters Channel diverted into the Lower Wairau, to '*relieve*' Blenheim of Ōpaoa River floodwater.
1885	Parliamentary Committee investigated '*the river board situation*' and recommended amalgamation. No action was taken.
1900 (approx.)	• SCRB effectively ring-banked its area. • LWRB has many kilometres of stop banks, three major river diversions taking water away from Blenheim, and straightened river channels.
1901	Roses Overflow opened to better protected Blenheim from Ōpaoa floodwater. • Soon showed evidence of '*uncontrolled*' scour. Closing the Ōpaoa Breach resolved this. • Its stop banks were raised to enable it to also take floodwater from Ruakanakana, Omaka River, Fairhall River, and Doctors Creek diversion.
1911	LWRB constructed a groyne at the lower end of the Waihopai River to prevent breakout via Ruakanakana.
1913	Tuamarina River Board formed and erected stop banks which SCRB viewed as a '*threat*' to their safety.
1914	'*Clandestine*' attempt to close the Ōpaoa Breach by LWRB.
1917	Wairau River Commission recommended:

Year	Intervention
	- the Wairau River be '*improved*' to carry all water (so the Ōpaoa did not flow) and establishing a River Board to cover entire Wairau catchment. A parliamentary bill to do this failed. - improvements to the Pukaka drainage system.
1921	Despite the above failure, all River and Drainage Boards were amalgamated into the Wairau River Board. - The Board was to manage the rivers to the largest known flood. - The Board could deal with river channel problems as they arose.
1926	Wairau River Board closed the Ōpaoa Breach.
1931	Fairhall River diverted to the Ōpaoa River.
1953	Wairau River Board realigned Wairau River through Blenheim, steepening the river gradient, causing the channel to accumulate silt and gravel.
1956	Marlborough Catchment Board was formed in response to ongoing frequent (every seven years) and significant flooding.

Rae (1987) identifies the practice of extracting river gravels and river realignment as having potential to decrease groundwater recharge, especially where over-extraction causes the river channel to deepen. Rae (1987) identifies that gravel pits have been filled by both authorised and unauthorised refuse, creating a potentially significant hazard given the lack of success at sealing these pits to prevent groundwater contamination. Davidson (1959) describes shingle movement from Tuamarina into the silt channel as far as the Ferry Bridge as accentuating drainage problems in the lower Tuamarina and Awarua area.

The earliest known mapping of flood and drainage interventions was by Vickerman and Lancaster in 1924, shown in Figure 3-3. This shows some drains and drainage features, such as Co-op Drain to the southeast and Awarua and tributaries. Many of the dashed blue lines in in Figure 3-3 align with current drainage channels, suggesting these features are also drainage features. In 1948 aerial imagery was collected for the Wairau Plain. This will also capture the extent of drainage features. Though collated after 1960, Rae (1987) mapped and timestamped how rivers had been altered, as in Figure 3-4. Where waterways begin mid-Plain, it can be inferred this is spring flow and so the associated waterways are groundwater drainage/discharge features.

Based on an annotated board held by Bezer (2023), the Marlborough Catchment Board managed drainage network in 1960 was the extent shown in Figure 3-5. This consisted of 142 individual drains totalling 172 km.

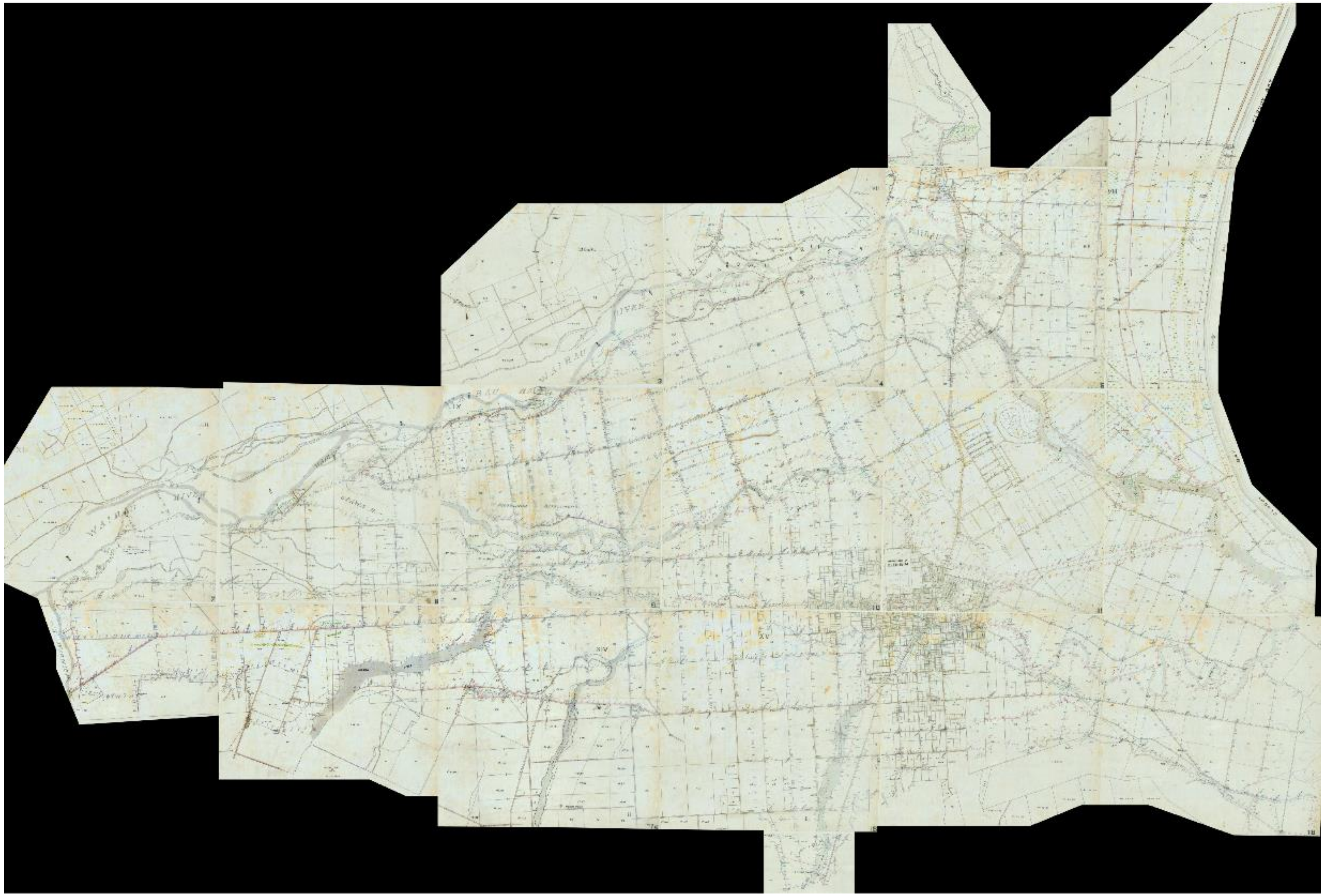

Figure 3-3 Vickerman & Lancaster, 1924 (Henderson, 2023). Solid red lines appear to be flood management infrastructure (e.g. stopbanks), dashed red lines appear to be land elevation, pencil lines appear to be piezo contours, dashed blue lines appear to be minor drainage channels, solid blue or back lines with grey infill appear to be waterways, blue text appears to show both GL (ground level) and WL (water level) elevation, black text appears to be the elevation of culverts, drains, and other points of interest

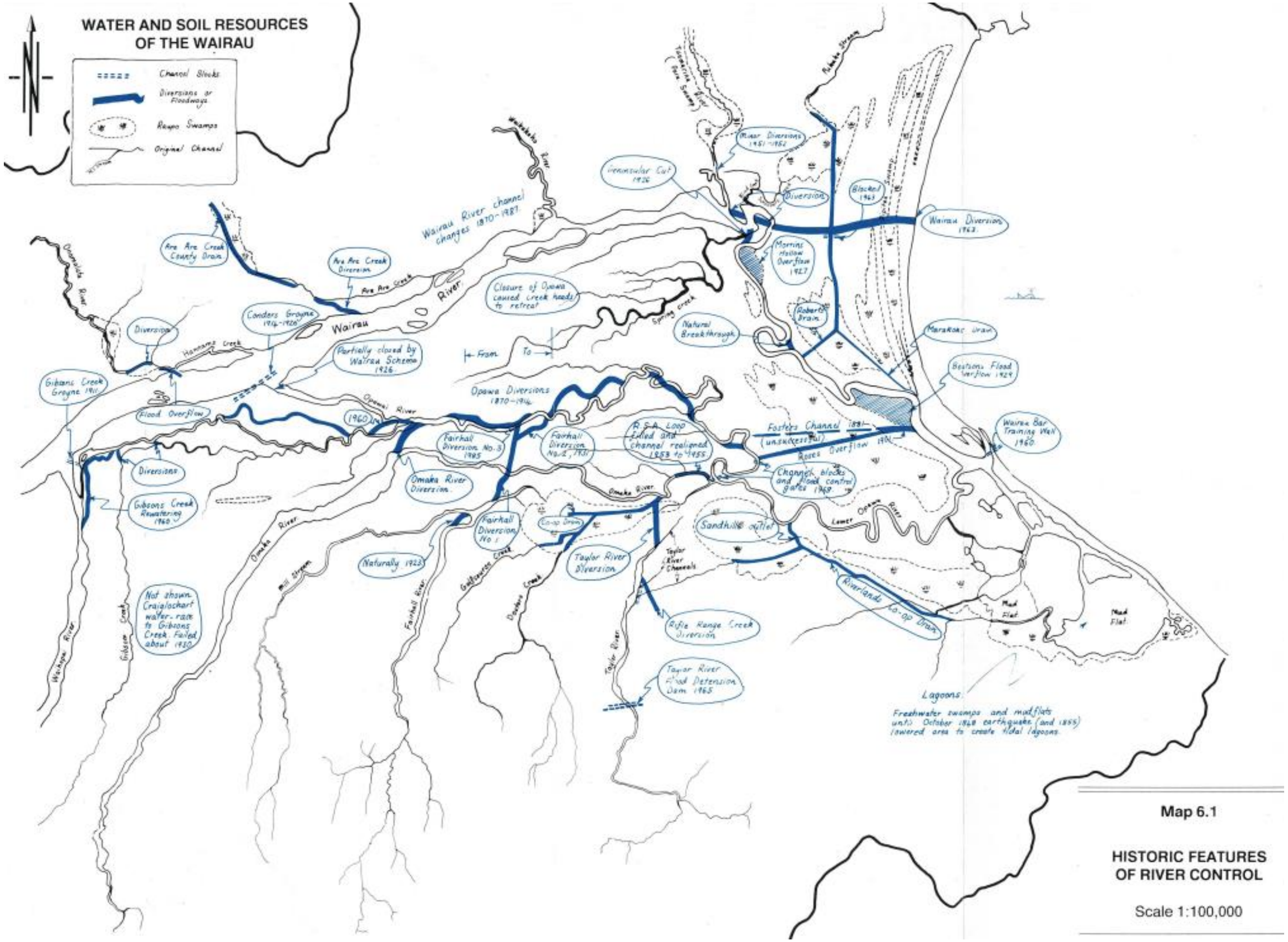

Figure 3-4 Early river management interventions as in Rae (1987). Note: Opawa is Ōpaoa

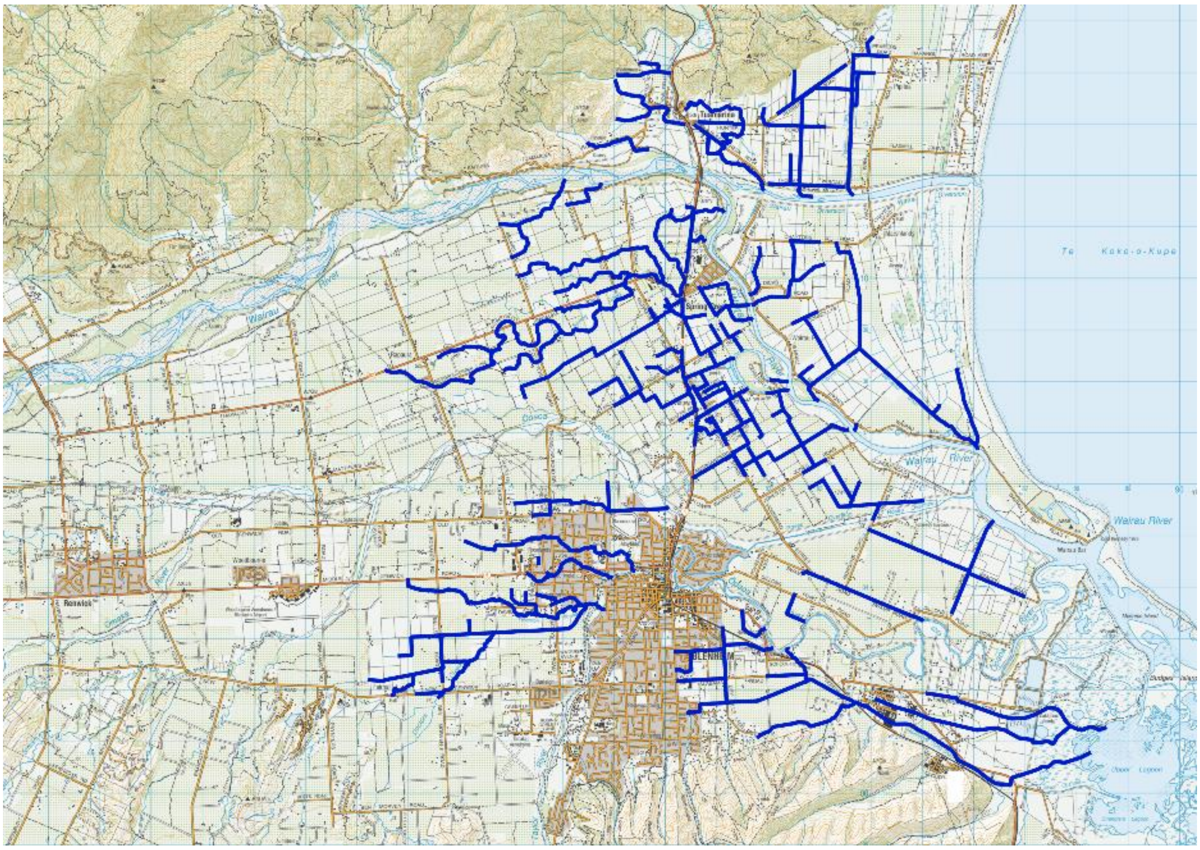

Figure 3-5 Likely 1960 managed drainage extent (based on image board held by Bezer (2023)

3.1.1 Upper Plain

In the upper Plain, the Waihopai and Wairau were prevented from discharging to the Ōpaoa in the 1910's. Gibsons Creek (Ruakanakana) was a side channel of the Waihopai.

The farmland surrounding Ruakanakana was described as '*highly productive*', with a high water table maintained by seepage from the Waihopai. The damming of the Waihopai (into the Ōpaoa) within years caused Ruakanakana to dry and dramatically reduced groundwater recharge and so groundwater discharge, with considerable lowering of the water table, and substantial drying up of springs, streams, and the land in the Renwick-Rapaura areas, causing the drying of wells and failure of crops, and increased fire risk (Marlborough District Council, 1994; Rae, 1987; Davidson, 1959). Ruakanakana was described as usually dry apart from a small length fed by a side stream, with '*considerable*' seepage to groundwater when wet. The production of the area was described as '*a shadow of the earlier days*' (Rae, 1987). Conversely the diversion of the Omaka River is suggested to have increased recharge to groundwater (Rae, 1987).

Most of the agricultural drainage begins where springs begin emerging on the plains. Discharges of groundwater (as springs and wetlands) were channelised with discrete outfalls. Where groundwater had previously discharged to a slow-moving environment such as wetlands, creating highly saturated ground conditions, discharges were now being conveyed efficiently as river and drain flow and discharging into surface waterways. This ready movement of water decreased ground saturation to better enable desirable land uses.

3.1.2 Lower Plain

Changes to surface water flows in the upper Plain required modification of the mid and lower Plain, such as raising stopbanks. Though increased stopbanking enabled greater flood resilience, it amplified drainage issues. Resolutions included pumping drainage (instead of gravity drainage), pumping drains over stopbanks, and draining through stopbanks (e.g. via culverts). Floodgates on culverts prevented backflow of flood waters and tidal waters, further reducing potential for land inundation, and so preserving drainage capacity. Floodgates also impound water behind them, so prolonged periods of closed floodgates can see adverse impacts.

Flooding of the Wairau River south of Bothams Bend seriously impacted direct land drainage, and the drainage capacity of other waterways. This land is described as having '*very high*' production potential, limited by drainage and flood conditions (Davidson, 1959). Davidson (1959) identifies that at least 7,600 ha could have improved production by resolving waterlogging issues driven by high groundwater and impeded internal drainage. Most of this extent surrounds the urban areas (Figure 3-2). Suggested resolutions included increasing the effectiveness of existing drainage, or installing further opens drains or internal drains.

Much of the area coastwards of State Highway 1 is not much higher than sea level. Land drainage is possible in such areas when ground level is higher than groundwater level and groundwater level is higher than sea level. Discharge from the deeper confined system also occurs in this area, adding to land saturation, exacerbating the need for drainage. Because of the similarity between ground elevation, groundwater elevation and tide height, pumped drainage was necessary to remove groundwater from land, with floodgates necessary to prevent floodwaters, high tides and storm surges further impeding drainage. Adequate drainage and 'flushing' irrigation to remove/dilute salts from the soil profile were required to enable agricultural land uses in these lowland areas, however the land uses were not as productive as the comparable practices in the upper Plain.

Rae (1987) identifies a '*substantial concrete lined channel through old sandhills alongside Thomas Road*' as providing the most comprehensive and intensive drainage, giving gravity drainage to the Pembers area into the Wairau River at Bothams Bend, by diverting the Pukaka Stream to Marukoko and Roberts Drain. A drainage pumping station was also installed at Pembers Road which fell into disuse once drainage and peat fires caused the land to sink. Major reconstruction across the late 1950s increased pumping performance capacity, transforming '*extremely wet swampy country of low productivity*' into an area that produces '*perhaps the best wheat crops in Marlborough*' (Davidson, 1959). However, extensive areas of unproductive land remained.

3.2 Wairau Valley Scheme

Before Wairau Valley Scheme (WVS) commenced, ~6,900 ha in the Wairau catchment were identified as inadequately drained, while main river channels were gradually aggrading and regular floods were disrupting communities and agricultural production (Waters, 1959). Waters (1959) describes inadequate drainage maintenance to date, with the build-up of sediment progressively worsening the efficiency of drainage to the point that some areas were experiencing reduced production and others were '*deteriorating to a swamp where a few years ago it gave limited production*'. Davidson (1959) describes

> '*Large areas of the best land have suffered from inadequate drainage and high water tables, and the land capability report puts this area at 17,000 acres* [~6,900 ha].' (p. 7)

At the time the WVS was commissioned, dairy farming was the predominant land use on the Wairau Plain, with other land uses including, beef and sheep farming, and growing of grain and fodder crops, with the latter predominantly grown from Blenheim to the coast (Davidson, 1959). Davidson (1959) describes land use in the northwest and west of the Plain between the Ōpaoa and Wairau rivers and near Rapaura as orchards, the remainder in pastoral or arable land uses. On the lower Wairau Plain, the predominant land use was pastoral animal production with lesser areas supporting the growing of arable crops and seeds.

The WVS was implemented by the Marlborough Catchment Board from 1960 to 1975. The WVS was initiated to achieve '*as far as economically possible*' the prevention of flooding, the provision of adequate drainage, and the stabilisation of all river and stream channels and catchments (Waters, 1959). One of the scheme's objectives was to increase security of landholdings by better managing excess water, including through the provision of adequate drainage to large areas of low-lying lands. Increased security enabled more intensive and extensive farm systems. The WVS was one of the most comprehensive approaches to river management in New Zealand at the time.

The WVS continued the practice of diverting waterways in the upper and lower Plain and expanded the drainage network in the lower Plain. The WVS upgraded flood infrastructure to a 1-in-100-year standard. Soil conservation works in the hills and tributary interventions sought to reduce sediment supply to the Plain (MDC, 1994).

The WVS undertook works to improve 160 km of public drainage (including deepening channels), and installation of some new channels, flood-gated culverts, and pumping stations to provide adequate drainage to facilitate productive land uses (Rae, 1987; MDC, 2018). The Wairau Scheme Report (Davidson, 1959) includes a figure of the Grovetown Drainage Scheme. No other figures in the Report clearly show or identify drainage features, so we cannot know with confidence the composition of the Wairau Plain drainage network at the time of WVS.

Perhaps the most significant feature of the WVS in the context of land drainage was the Wairau Diversion (Figure 3-4). The Wairau Diversion enabled much of the Wairau River flow and, significantly, flood flow, to discharge directly offshore instead of the full flow meandering adjacent to the urban areas to discharge to the lagoon and then offshore. The increased conveyance efficiency of the Wairau River increased velocity and riverbed scour, which lowered the local water table control, lowering groundwater levels. Davidson (1959) suggests the Diversion will '*make possible the efficient functioning of miles of drains that at present do not give efficiency.*' It was not anticipated that siltation caused by the lower flows would cause issues.

The Wairau Diversion reduced surface water levels in the lower Wairau and lower Ōpaoa rivers, reduced flood levels, and considerably improved drainage along the Wairau River, the Ōpaoa River, their associated lagoons and tributaries (including Wairau Pa, Pukaka, Tuamarina, Awarua, Grovetown, Lower Wairau, Riverlands, and Dillons Point), reducing and in cases eliminating backflow (e.g. Awarua and Tuamarina River), flooding, and land drainage issues (e.g. Pukaka) (Marlborough District Council, 1994; Davidson, 1959; Waters, 1959) as

> '…*even small rises in the river seriously affect these low lying but high quality lands, lower levels for all sizes of floods and freshes would greatly improve drainage and reduce backing up.*' (Davidson, 1959, pp. 2, Appendix V)

Waters (1959) stressed the need for reconstruction and maintenance to retain the improvements obtained through WVS upgrades. Waters recommended an annual drainage maintenance programme of £4,200 of works, equivalent to $117,300 today.

Rae (1987) describes drainage works completed as part of the WVS as '*undoubtedly*' causing '*further losses from the groundwater aquifer under the lower valley*.' The reduced flood risk and lower water levels resultant from WVS allowed intensified farming practices (e.g. move from arable to pastoral land uses), improved drainage from the Wairau Diversion, rewatering of Ruakanakana, and side stream and drainage improvements.

Waters (1959) estimated productivity increases resulting from WVS and identified the increased provision of drainage as the greatest factor in increased revenue. Waters (1959) anticipated WVS would greatly increase production, enable intensified farming practices, and increase stability through reduced flooding from both surface and groundwater. The upper Plain was both the most impacted by flooding and the highest producing area. Waters (1959) estimated WVS interventions would increase production by 7.5-10% in the upper Plain, by 25% north of the Ōpaoa River, and by 10% between the Ōpaoa River and Wither Hills. Increases were expected to be greater than this in the lower lying areas.

The first vineyard development on the Wairau Plain was initiated by Montana in 1973.

3.2.1 Upper Plain

Table 3-2 summarises the major interventions on the upper Plain. At the top of the Plain, the Ōpaoa Breach was blocked. This increased flood flows in the Wairau mainstem by 50% and enabled viticultural development of the land around the upper Ōpaoa channel. The WVS increased the capacity of the Wairau River (MDC, 1994). The closure of the Ōpaoa Breach was tied to reduced Wairau Aquifer recharge and groundwater levels in the early 1970s (Davidson & Wilson, 2011).

Table 3-2 Summary of major Wairau Valley Scheme intervention on the upper Wairau Plain (adapted from Davidson (1959))

Waterway	Description
Wairau River – Tuamarina to Waihopai	Bed improvement and channel training works for ~6.5 km above Tuamarina to establish a "single thread channel", and additional bank protections including clearing, planting, and stop banking
Ōpaoa River and Roses Overflow	• Increase stopbank height, clear vegetation and culverts, upgrade floodgates • Construct a small dam across the Ōpaoa River immediately below Roses Overflow to prevent flooding of Blenheim from Taylor River water, while still enabling Ōpaoa River low flow and so effluent discharge
Fairhall River	• Planting, clearance, stopbank maintenance • Remedy channel scour
Omaka River	• Channel training to preserve banks and prevent aggradation • New pump station
Awarua	• Vegetation clearance
Ruakanakana	• Rewatered from the Waihopai. Associated works to facilitate rewatering
Taylor River	• Increase stopbank height • Upgrade culverts and floodgates • Pump stations in urban areas
Doctors Creek	• Flood detention dams in main tributaries • Reconstruct/regrade to desired standard

Ruakanakana was rewatered in 1960 at a rate of 3 m^3/s with an estimated 0.3 m^3/s loss to groundwater (MDC, 2018; Rae, 1987) as one of the earliest projects of the WVS to supply water for irrigation and provide ecological values. To eliminate opposition to the rewatering, the Catchment Board first carried out major drainage works (Rae, 1987). Rae (1987) describes the '*immediate*' impact of the rewatering on groundwater levels as '*dramatic*'. Davidson (1959) anticipated ~1,200 ha would directly benefit from rewatering Ruakanakana via access to stock and spray irrigation water, and up to ~4,000 ha likely to benefit from higher groundwater levels and reliable supply, as far as Rapaura. Some of these farmers also benefited from the rewatering because the increased freshwater flow in Roses Overflow caused the retreat of the saline tidal water. Davidson (1959) stressed that to '*avoid seepage troubles in the lower reaches*" of Ruakanakana the channel must be "*kept in good order*'.

Awarua is described as draining '*2,370 acres* [960 ha] *of high class farming flats*' (Davidson, 1959).

The lower Doctors Creek catchment area is described as a large area of flat, swampy land, subject to frequent overflows, meaning overflows saturates already waterlogged land, reducing production. This land is described as '*rough grazing*' but '*of the highest potential*' (Davidson, 1959). The WVS would reconstruct the channel to give '*generous production increases*' (Davidson, 1959).

The Taylor River was dammed in its upper reaches to reduce urban flooding. The Taylor River flood detention dam intercepted groundwater flows, decreasing recharge to the Wairau Plain via the Taylor Fan (Rae, 1987). Davidson (1959) describes the Taylor, Fairhall, and Omaka rivers as being slow to respond to changes in inputs, mainly due to losses to groundwater as the rivers reach and cross the Wairau Plain; these rivers only flood when the catchment is saturated.

3.2.2 Lower Plain

Table 3-3 summarises the major interventions on the lower Wairau Plain. The WVS interventions were anticipated to increase flood protection and lower both surface water and groundwater levels on the lower Plain. The lowering of the Wairau River level facilitated by the Wairau Diversion enabled agricultural intensification through better flood protection and enhanced drainage.

Table 3-3 Summary of major Wairau Valley Scheme intervention on the lower Wairau Plain (adapted from Davidson (1959))

Waterway	Description
Wairau River – Tuamarina to the Mouth	• Constructed a new channel from Bothams Bend to the sea (Wairau Diversion), generally parallel with Thomas Road so that 37% of flows flow down the old channel and 63% flow along the overflow • Stopbanking and channel training
Lower Ōpaoa River	• Stopbanking adjustments • Upgrade culverts and floodgates
Riverlands Co-op Drain	• Reconstruct/regrade drain to desired standard • Stabilise side streams
Pukaka Stream	• Separate Roberts Drain from Pukaka Stream • Install pump stations and floodgates on Roberts Drain and Pukaka outlets to Wairau River • Increase stopbank height
Tuamarina	• Construct low flow channel through Tuamarina Swamp to drain its ~160 ha and enable agricultural land use • Channel improvements above Tuamarina Swamp, along Koromiko Stream, and Speeds Valley

Though the Wairau Diversion was the most significant intervention in the lower Plain, additional work was also scheduled to improve land drainage. Pukaka Stream drains both hill country and ~2,000 ha of '*very flat land*' (Davidson, 1959). Pre-WVS the area was vulnerable to flooding from the Wairau and the Pukaka. Under WVS, Roberts and Pukaka drains could be pumped directly into the Wairau, increasing drainage efficiency to '*complete the transformation of this previously swampy area*' (Davidson, 1959). A further drainage station was built at Thomas Road to pump into the newly built Wairau Diversion. The WVS also increased drainage in the Tuamarina Valley, enabling agricultural expansion. Rae (1987) describes the Tuamarina River as maintaining a '*reasonably consistent*' flow, suggesting constant groundwater inputs.

The Riverlands Co-op Drain was subject to regular overflows from the Ōpaoa River, and sedimentation from Wither Hills. The latter required installation of an additional outlet into the Ōpaoa River in the Sandhills area. The Riverlands Co-op Drain is described as having a flat gradient, partially tidal, with its inadequacies as a drain exacerbating flooding. At the lagoon end, an increase of '*salty land slowly coming into production*' was increasing the back-up and overflow of brackish water into the Drain and increasing seepage of saltwater (Davidson, 1959). The WVS was anticipated to lower water levels at the Drain outlet. This, combined with drain regrading, was anticipated to result in increased drainage efficiency.

At the coast, the Wairau Bar training wall was built in 1960 to obtain a permanent outlet to the sea. This introduced stability to the local hydrologic system, enhancing the tidal range in the lagoons and in the lower river systems, improving drainage outfalls for low lying land (Rae, 1987), and was described as ‘*very worthwhile*’ after earlier being deemed uneconomic (MDC, 1994).

3.3 Post-Wairau Valley Scheme

Table 3-4 compares the composition of the drainage network across 1987-2018, while Figure 3-6 shows the 1987 extent of drainage features, and Figure 3-7 the 2018 extent. These show the Council-maintained network did not necessarily increase substantially in extent across this time, but did increase in capacity, as indicated by the increased provision of pumped drainage. Figure 3-8 shows the areas benefitting from pumped drainage (as indicated by blue and green) in 1994, which is predominantly coastwards of State Highway 1. Despite floodgates, outlets discharging into the sea or larger rivers remained an issue, especially at high tide or in flood conditions when outlet water levels are higher than drain water levels preventing drains from discharging (MDC, 2015).

Table 3-4 Drainage infrastructure in 1987, 1996, and 2018 as described by Rae (1987) and MDC (1996; 2018). Note this reflects drains managed by Catchment Board/Council only, not private drains

	1987 (Rae, 1987)	**1996** (Marlborough District Council, 1996)	**2018** (Marlborough District Council, 2018)
Drain length (km)	160	175	160
Drainage area (ha)	?	10,000	8,000
Total number of pumping stations	23	25	30
Total number of pump stations with control gates or weirs (i.e. water levels need to be above a minimum value or within a specified range for pumping to occur)	?	12	20
Number of pumping stations for agricultural land drainage	?	17	19
Number of culverts (usually flood gated)	?	249	290

Following implementation of the WVS there was a significant intensification of land use, including subdivision and a trend towards viticulture, and an increasing community expectation of a generally high level of service, creating a reliance on adequate and reliable drainage. Despite efforts to improve soil conservation under the WVS, sedimentation and siltation still impacted tributary drainage and the effectiveness of southern drains (MDC, 1994). Not all attempts to improve interventions were successful, with reports indicating that culvert upgrades to bubble grades decreasing conveyance efficiency and increasing local flooding. Flood infrastructure continued to be maintained to a 1-in-100-year ARI[2] standard. The drainage works and watercourse modifications

> ‘…*have in most instances completely altered the channels from their natural shape and form*.’ (MDC, 1996, p. 44)

Rae & Tozer (1990) classified most of the Wairau Plain as highly suitable for pastoral or forestry use and some permanent horticultural crops, and moderately suited to annual cropping. This included much of the vineyard area near Renwick. Approximately 10,000 ha immediately to the north, west and east of Blenheim was classified as ‘*highly prized land*’, very suitable for permanent cropping. Another ~10,000 ha was classed as unsuited to cropping but suited to pastoral or forestry use. Lesser areas were classed as unsuited for cropping, with medium to low suitability for pastoral or forestry use.

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[2] Average recurrence interval, or how often this has potential to occur based on available information

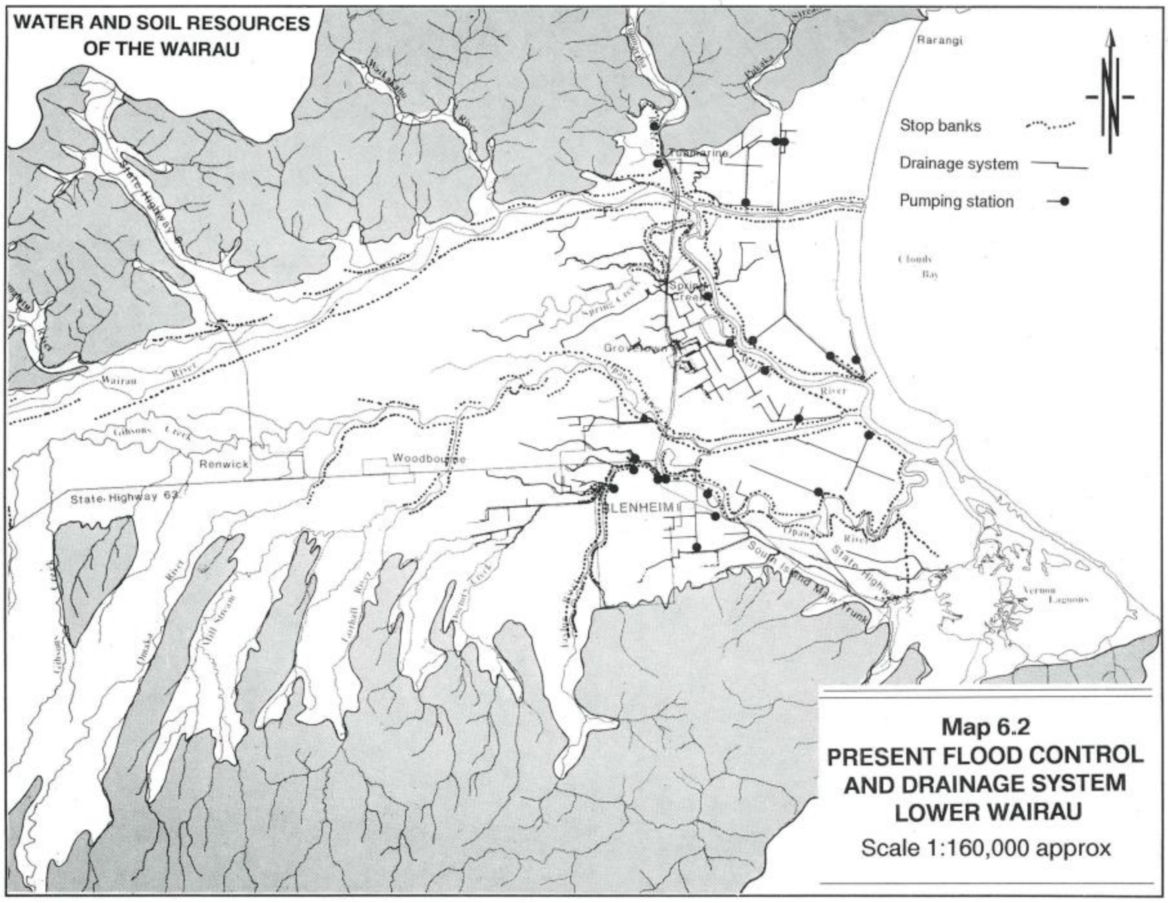

Figure 3-6 Flood control and land drainage structures as at 1987 (Rae, 1987)

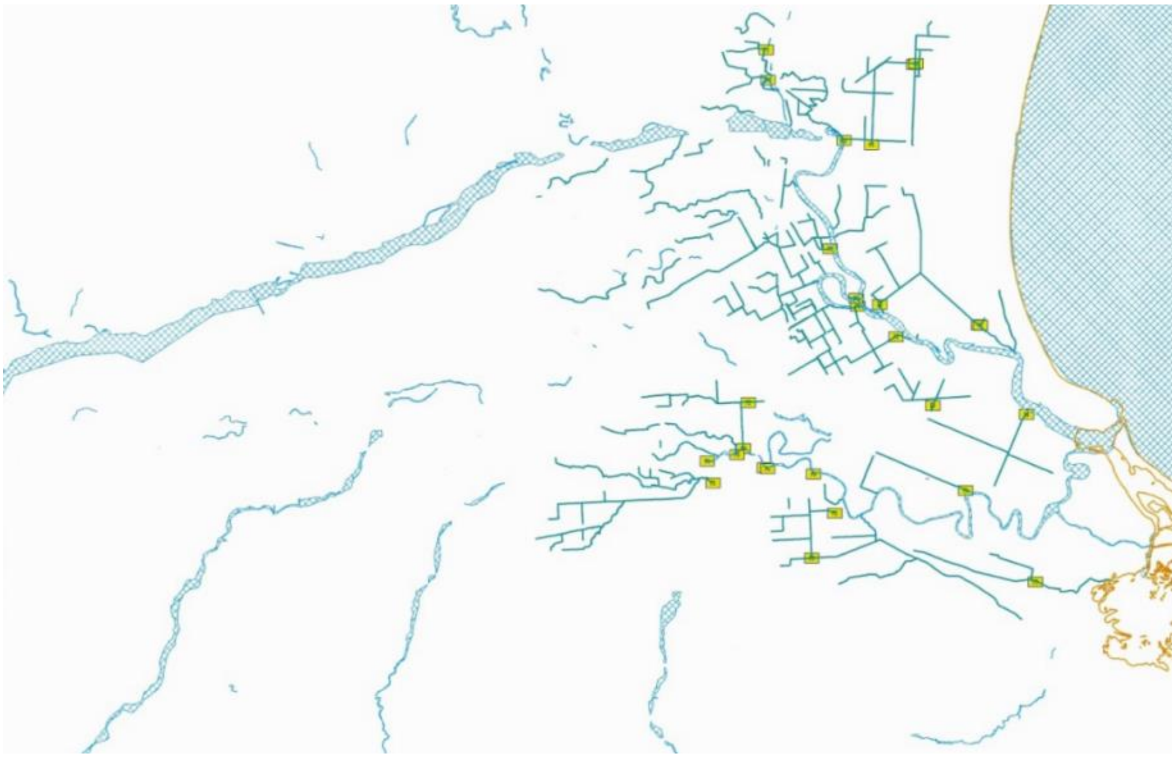

Figure 3-7 Urban and rural drains and pump stations as at 2018 (MDC, 2018). Green lines are drains and green boxes are pump stations

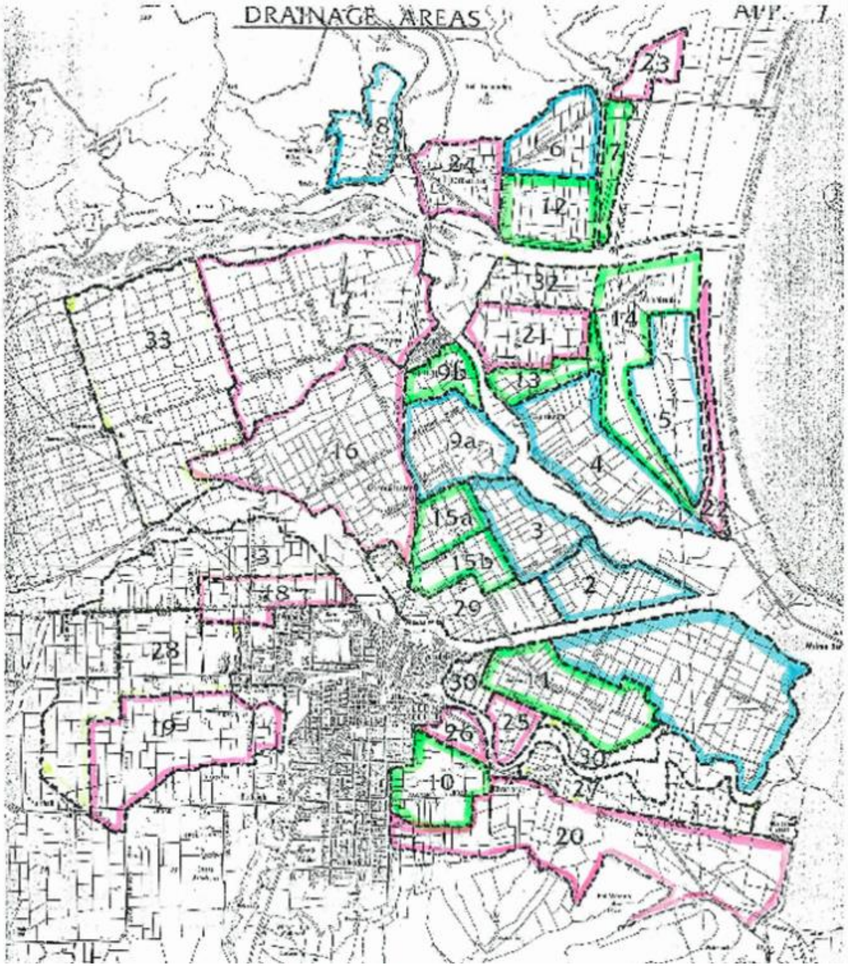

Figure 3-8 Marlborough District Council Drainage areas as at 1994 (MDC, 1994). Pumped drainage areas are identified in blue, pump-assisted drainage areas in green, gravity drainage areas in pink, and contributing drainage catchment areas in yellow/uncoloured

Horticultural land use expanded dramatically, with 1,850 ha in grapes by 2000, 15,900 ha by 2010, and 18,590 ha by 2021 on the Wairau Plain[3]. This shift in land use from being dominated by cropping to being dominated by horticulture was not foreseen at the time the WVS was initiated. Viticulture became the predominant form of horticulture within 20 years. With this shift to viticulture and higher value crops, there was an increased willingness for landowners to improve their own land drainage to protect their investments (Bezar, 2023).

Rae & Tozer (1990) reported the spread of horticulture was limited by high water table, poor drainage, and increasing salinity to the east of Blenheim. In other places, viticultural irrigation resulted in downgradient increases in soil moisture. Rae & Tozer (1990) identify 7.23% of the Wairau catchment as being limited in usability by "wetness" or having a high water table, slow internal drainage, or high flooding vulnerability, with up to 25% (~13,500 ha) of the Wairau Plain unsuited to cultivation due to wetness or stoniness, including to the east and north of Blenheim where there is "excessive" soil moisture that can be overcome with adequate drainage outfalls.

Following drainage problems in winter 1995, the Wairau Drainage Plan 1996 (MDC, 1996) resulted in pumping station upgrades, with initiation of active management of aquatic weeds to enable proper drainage while also providing for ecological values (MDC, 2018). The 1996 Drainage Plan reconfirmed the 1-in-10-year ARI rainfall design as the minimum acceptable standard for the drainage network.

In 2004 when the Southern Valleys Irrigation Scheme was initiated, the need for irrigation was questioned given the "swamp-like" conditions of much of the area.

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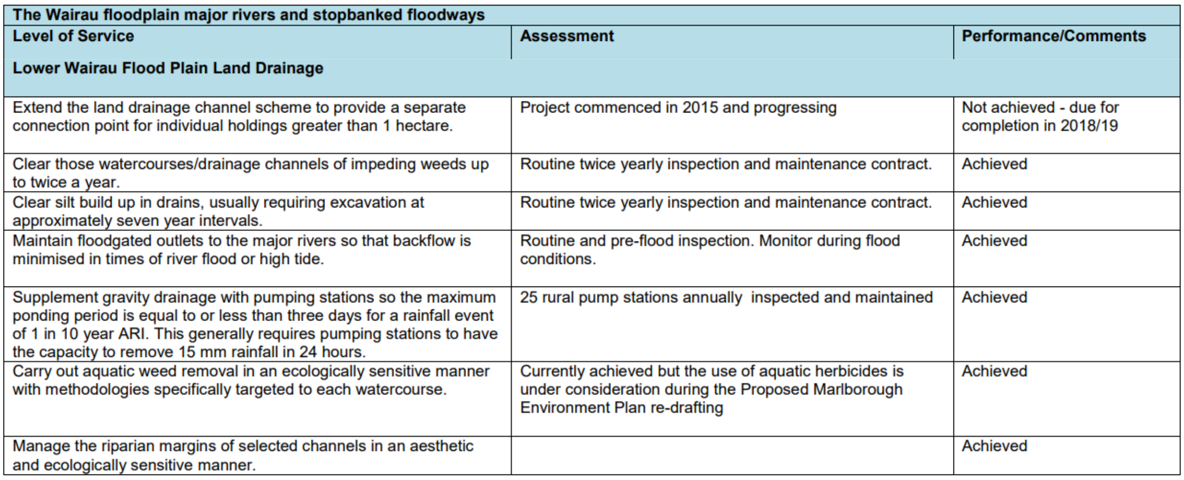
[3] https://www.marlborough.govt.nz/environment/land/land-coverland-use/vineyard-development-areas

The subsequent 2015 review of the drainage network recognised there had been significant intensification of land use: subdivision and a trend towards viticulture, and an expectation of a generally high level of service since the WVS (MDC, 2021). The 2015 review resulted in 15.3 km of drains being added to the MDC network, mostly consisting existing private drains, with a few km of new drains dug. This upgrade enabled:

- Drainage outfall to (nearly) all properties greater than 1 ha within the drainage area (MDC, 2018),
- The ability to (generally) avoid more than 2-3 days of ponding in paddocks in these drainage areas (MDC, 2021),
- Further land use changes and intensification, and
- Rationalised maintenance of drains to ensure the provision of a consistent level of service (MDC, 2018).

The Rivers Asset Management Plan (2018) levels of service (Figure 3-9) gave a statutory backing to the outcomes sought in the 2015 review. The 2015 review did not factor stormwater or increased subdivision/urbanisation into drainage capacity calculations.



The Wairau floodplain major rivers and stopbanked floodways		
Level of Service **Lower Wairau Flood Plain Land Drainage**	**Assessment**	**Performance/Comments**
Extend the land drainage channel scheme to provide a separate connection point for individual holdings greater than 1 hectare.	Project commenced in 2015 and progressing	Not achieved - due for completion in 2018/19
Clear those watercourses/drainage channels of impeding weeds up to twice a year.	Routine twice yearly inspection and maintenance contract.	Achieved
Clear silt build up in drains, usually requiring excavation at approximately seven year intervals.	Routine twice yearly inspection and maintenance contract.	Achieved
Maintain floodgated outlets to the major rivers so that backflow is minimised in times of river flood or high tide.	Routine and pre-flood inspection. Monitor during flood conditions.	Achieved
Supplement gravity drainage with pumping stations so the maximum ponding period is equal to or less than three days for a rainfall event of 1 in 10 year ARI. This generally requires pumping stations to have the capacity to remove 15 mm rainfall in 24 hours.	25 rural pump stations annually inspected and maintained	Achieved
Carry out aquatic weed removal in an ecologically sensitive manner with methodologies specifically targeted to each watercourse.	Currently achieved but the use of aquatic herbicides is under consideration during the Proposed Marlborough Environment Plan re-drafting	Achieved
Manage the riparian margins of selected channels in an aesthetic and ecologically sensitive manner.		Achieved

Figure 3-9 Rivers Asset Management Plan (MDCl, 2018) drainage levels of Service and recent performance assessment (adapted from Rivers Asset Management Plan Table 2-1)

MDC (2018) describe a programme of ongoing drainage maintenance; channel excavation[4], keeping channels clear of aquatic weed and siltation, floodgates, culverts, pumps, and miscellaneous structures. MDC (2015) describe aquatic weeds as a '*major issue*' able to reduce the performance of drains by a factor of ten.

3.3.1 Upper Plain

To facilitate intensification, especially viticultural expansion, extensive field drainage took place. Though this is not mapped, field drainage (tile drains, mole drains, Novaflo^{TM}, etc.) was intensively deployed over large areas that were put into grapes to further lower the water table to keep vine roots dry to ensure plant health and viability. These field drains discharge into the MDC drainage network. In the upper Plain, increasing drain depth perhaps unintentionally increased drain capacity to cope with increased inputs from field drainage. It is likely that landowners have maps of their field drainage to prevent damage and reducing their effectiveness (and so decreasing the value obtained from their

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[4] Deepening existing natural watercourses and/or straightening and diverting watercourses, and/or excavating entirely new drainage channels in locations where surface flow did not previously occur (Marlborough District Council, 2018)

land), however it is equally possible they would be reluctant to share this information with MDC without understanding how the information would be used.

The Wairau between Wratts Road and Waihopai confluence has undergone significant river control works to narrow the channel since 1966. MDC (1994) found no evidence that the river control works had affected groundwater recharge, despite Rae's (1987) earlier concerns of this occurring. Gravel extraction continues to be managed to prevent/limit impact on groundwater recharge (Rae, 1987; MDC, 1994). A 2009 gauging survey by MDC confirmed the Wairau River is losing channel flow at the same rate as in the early 1970's: 7 m^3/s (Davidson & Wilson, 2011), with losses at higher flows reconceptualised to suggest that under flood conditions the rate of leakage is likely to be much higher for short periods due to the increased hydraulic gradient. Rae (1987) found that shallow wells in the Rapaura area were not affected by Wairau floods but were affected by changes in Ruakanakana and the Omaka River, with no measurable loss downstream of Giffords Road.

Rae (1987) reports that Awarua contributes up to 30% of flow in the lower Wairau River above the Ōpaoa confluence at times of low flow, with Stump Creek contributing major inflows at the top of Awarua, and additional significant inflows to Awarua to the Wairau confluence. Inflows into Awarua are '*remarkably constant*', suggesting predominantly groundwater inflows.

Groundwater recharge from Ruakanakana reduced during the 1980s and 1990s due to the natural sealing of the channel bed by fine sediments (Davidson & Wilson, 2011). Rae (1987) describes Ruakanakana as losing on average 37% of its flow to groundwater between the Waihopai input and the State Highway Bridge at Renwick, with further losses downstream of Renwick and flow increases of 300% between O'Dwyer Road and the Grove Road Bridge due to drainage water and groundwater inflows. From 2004, additional rewatering occurred to supply the Southern Valley Irrigation Scheme and to provide continuous flow from source to sea in the Ruakanakana/Ōpaoa system, which did not occur from approximately the 1980's through to 2004 (Davidson, 2023). The degree to which Ruakanakana recharges groundwater depends on the siltation pattern and its removal. MDC (1996) identifies that though rewatering can happen at a rate of 3 m^3/s, it generally happens at a rate of 0.5-1 m^3/s. MDC describes Ruakanakana rewatering as

> *'…of considerable benefit for environmental uses not only of Ruakanakana, but also for the Upper Opawa* [Ōpaoa]*, Opawa* [Ōpaoa] *Loop and Rose's Overflow.'* (MDC, 1994, p. 136)

Since 2000, extensive field drainage was installed in the Bells Road area, where a topographic basin was transformed from dairy farming to intensive viticulture. Field drains discharge into the closest drain, Novaflo^{TM} drains discharge into the Fairhall Co-op Drain year-round, suggesting they are placed well below where the water table would occur without these interceptions. Both the Fairhall Co-op (Figure 3-10) and nearby Douglas 2 Drain are reported to flow year-round (except in extreme circumstances), further supporting the notion of significant volumes of shallow groundwater in this area.

Figure 3-10 Fairhall Co-op Drain at Bells Road (facing up-channel, 27/06/2023)

3.3.2 Lower Plain

Increasing drain depth to lower the water table was not possible in the lower Plain as shallow groundwater level at or near ground level means increasing the depth of drains does not increase drainage capacity. Land drainage was expanded to more areas. Drainage intensification led to greater losses of groundwater from the Wairau Aquifer, especially in the Marshlands area where '*drainage levels have been maintained below sea level and well below the artesian pressure head*' (Rae, 1987). To enable productive land use in many low-lying areas of the lower Plain, it was necessary to "flush" salt from soils.

3.4 Current State

In MDC's 2021-2031 Long-Term Plan (LTP), MDC committed to maintenance '*generally to the east of Blenheim and O'Dwyers Road*' of excavated drains or natural waterways, culverts, and pumping stations to a capacity which enables the removal of up to 15 mm rainfall across 24 hours (MDC, 2021). There is no reference to actions to maintain drainage capacity inland of Blenheim, other than in reference to managing river floodwaters and Ruakanakana rewatering (for irrigation, ecological values and to provide groundwater recharge), despite parts of MDC's managed drainage network being inland of Blenheim (Figure 3-11). None of the drains are artificially lined, except where culverts and structures are installed. Natural lining can occur due to sedimentation and siltation.

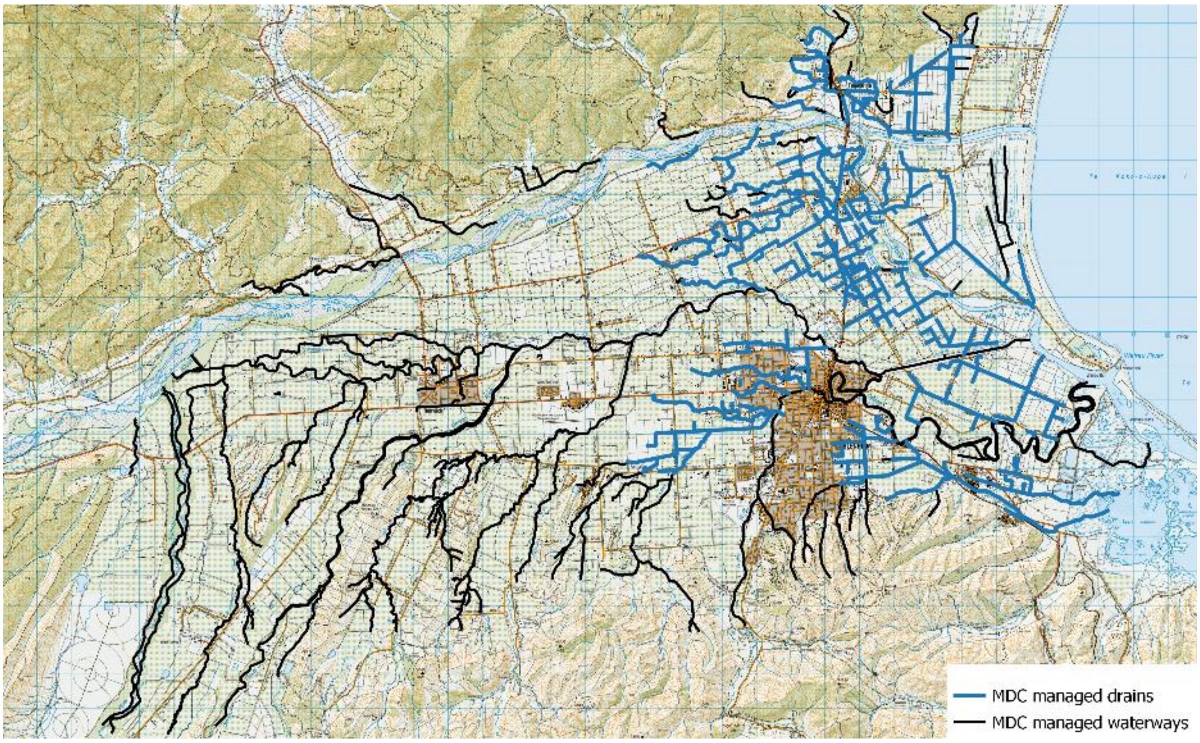


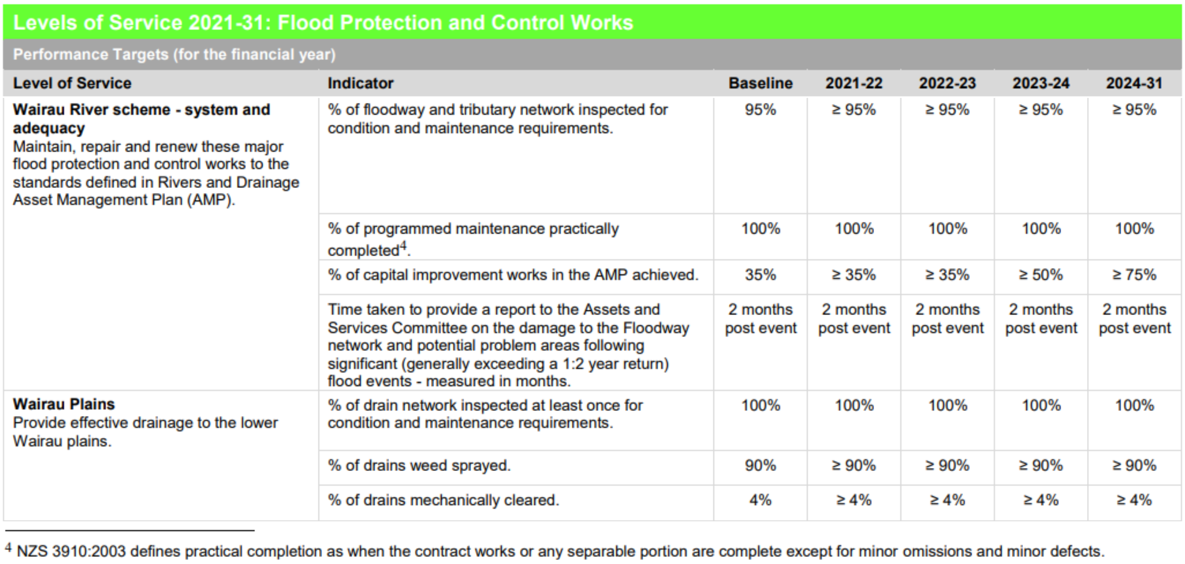
Figure 3-11 Current MDC managed drains and other managed waterways (Henderson, 2023)

Table 3-5 summarises the drainage infrastructure listed in the LTP relative to earlier summaries. The drainage network had slightly extended since 2018, but otherwise remained unchanged. Though floodgates are essential to a properly functioning drainage system they prevent the migration of native fish such as īnanga. The drainage network represents the movement of a significant volume of freshwater. There is very little use of water from this network.

Table 3-5 Table 3-4 updated with 2021 values. Note values reflect drains managed by Catchment Board/Council only, not private drains

	1987 (Rae, 1987)	**1996** (Marlborough District Council, 1996)	**2018** (Marlborough District Council, 2018)	**2021** (Marlborough District Council, 2021)
Drain length (km)	160	175	160	170
Area benefitting from drainage (ha)		10,000	8,000	8,000
Total number of pumping stations	23	25	30	30
Total number of pump stations with control gates or weirs (i.e. water levels need to be above a minimum value or within a specified range for pumping to occur)		12	20	20
Number of pumping stations for agricultural land drainage		17	19	19
Number of culverts (usually flood gated)		249	290	290

The LTP sets two drainage-related levels of service, as shown in Figure 3-12. Across the 2021-2031 LTP, MDC commits to a maximum expenditure of $4.3 M in the 2023-24 financial year and a minimum expenditure of $1.6 M in the 2025-26 financial year on drainage works and infrastructure (MDC, 2021, p. 97).



Levels of Service 2021-31: Flood Protection and Control Works

Performance Targets (for the financial year)

Level of Service	Indicator	Baseline	2021-22	2022-23	2023-24	2024-31
Wairau River scheme - system and adequacy Maintain, repair and renew these major flood protection and control works to the standards defined in Rivers and Drainage Asset Management Plan (AMP).	% of floodway and tributary network inspected for condition and maintenance requirements.	95%	≥ 95%	≥ 95%	≥ 95%	≥ 95%
	% of programmed maintenance practically completed[4].	100%	100%	100%	100%	100%
	% of capital improvement works in the AMP achieved.	35%	≥ 35%	≥ 35%	≥ 50%	≥ 75%
	Time taken to provide a report to the Assets and Services Committee on the damage to the Floodway network and potential problem areas following significant (generally exceeding a 1:2 year return) flood events - measured in months.	2 months post event	2 months post event	2 months post event	2 months post event	2 months post event
Wairau Plains Provide effective drainage to the lower Wairau plains.	% of drain network inspected at least once for condition and maintenance requirements.	100%	100%	100%	100%	100%
	% of drains weed sprayed.	90%	≥ 90%	≥ 90%	≥ 90%	≥ 90%
	% of drains mechanically cleared.	4%	≥ 4%	≥ 4%	≥ 4%	≥ 4%

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[4] NZS 3910:2003 defines practical completion as when the contract works or any separable portion are complete except for minor omissions and minor defects.

Figure 3-12 Drainage-related levels of service in the 2021-2031 Long-Term Plan (Marlborough District Council, 2021, p. 95)

It could be interpreted that MDC is presently required to receive all drainage outfall from private landowners (of properties >1 ha) into their network in all circumstances. This could mean an increased risk of flooding due to capacity constraints, e.g. during high rainfall events. Because we do not know the scale of these inputs, nor where they occur, we cannot quantify how such inputs may impact network capacity and where these impacts are the most severe. Clarity around these levels of service will be of increasing importance into the future due to mounting pressures, including those posed by climate change and constrained rates income.

The MDC Infrastructure Strategy (within the LTP (2021)) identifies the key challenges facing land drainage as:

- The need to meet levels of service in areas where land use has been changed and development is occurring.
    - This is predominantly coastwards of State Highway 1.
- Ratepayers continue to expect a higher standard of flood control and drainage.
- The impacts of climate change on coastal storm waves, sea level rise and flood flows on the effectiveness of the existing land drainage system.

> ‘*Average sea levels are predicted to rise by 0.3 m by 2050, which will impact on drainage gravity outfalls and require more pumping, alter general water table levels, and may increase saline intrusion in the very low-lying areas. Sea level rise is also likely to lead to an increase in wave lap type erosion in the lower reaches of the Wairau and Opawa* [Ōpaoa] *Rivers*.’ (MDC, 2021, p. 267)

Adding to drainage capacity concerns is the volume of runoff from vineyards in comparison to more traditional land uses. Observation indicates that that conversion of land to vineyards had resulted in a very engineered landscape, with land recontoured to maximise runoff, and soil compaction further contributing to increased runoff. MDC (2021) reports that vineyard developments appear to be causing increased runoff and suggests the need to manage this, including with larger culvert sizes and increased maintenance of the drainage channels. In places, drainage has moved from being drainage to storage, particularly in vineyard areas. Previously drains might just been a wet channel that would allow the water to naturally drain off. Because vineyards have increased runoff velocity and volume, drains are increasingly managed to provide storage in a flood. There’s also the challenge of encroachment of land, with landowners wanting productive use of “their” land up to the margins of waterways and drains, meaning there is an increased expectation that MDC prevents any flooding from their drainage network as it would directly impact production, where previously there may have been a “buffer” or informal fairway area.

There remain areas of the Wairau Plain that is water-short and other areas that are waterlogged; a great dichotomy over a short distance.

As demand to increase land productivity increases, landowners will be seeking to improve and use increasingly marginal areas, likely requiring additional drainage, discharging into drains or key Wairau Plain floodways’ (e.g. Ōpaoa, Wairau, Taylor rivers). MDC will have to decide whether the current levels of service remain appropriate; is it MDC’s responsibility to provide drainage outfall for all properties >1 ha in all circumstances?

3.4.1 Upper Plain

At the very top of the Plain, groundwater tends to be 3 - 10 m bgl so land drainage is not necessary. The decline in groundwater levels in this area is generally attributed to declining Wairau riverbed level.

Ruakanakana has a highly silted water column along its length due to the sediment load of its source the Waihopai.

Giffords Creek is considered the head of Awarua. Awarua used to flow continuously from Giffords Creek along its length but is now usually dry until the Tennis Club.

The Fairhall Co-op Drain flows permanently. There are large springs in the Murrays Road area. This area overlies the semi-confined aquifer, with spring discharge year-round, contributing a significant input into the drains.

Many landowners “pipe” springs (i.e. field drainage) that emerge on their land into the MDC drainage network. New springs emerging on developed land is not uncommon.

3.4.2 Lower Plain

In the last five years, telemetry has been installed on the ‘*important*’ pump stations: Roberts, Chaytors, and Rouses. It is reported that this data has not been interrogated in any meaningful way. There is no information on the proportion of time floodgates are open vs closed (i.e. drains are discharging or not). This could potentially be inferred from pump on vs off status from the telemetry information.

Much of the land in the low-lying Pembers Road, Wairau Pa, Lower Wairau, and Dillons Point areas have recently (in the last five or so years) been converted to vineyard. These areas require significant pumping to enable such land use, however groundwater level remains close to ground level, as shown in Figure 3-13. By necessity, heavy machinery has tracks rather than tyres to prevent bogging in the soft ground. Water in these areas tends to pond on the ground as there is no capacity in the soil for infiltration due to high groundwater levels. Low-lying areas tend to have ~500 mm separation between ground level and groundwater level. In the Wairau Pa area.

Pembers Road drain is already demonstrating capacity constraints, due to it providing drainage both for low-lying land and for hill country runoff.

Though no other drains are yet exceeding capacity, drains in lowland areas do not have capacity for increased inflows. Increasing drainage depth will not increase drain capacity and could decrease capacity by encouraging increased inflows. Lateral expansion is an option. However, as these drains are predominantly roadside, this will mean encroachment on private land. Lowland drains tend to have beds that are below sea level, meaning they can only discharge under pumping and only when floodgates permit, e.g. at low tide and low river flows.

Figure 3-13 Pickerings Drain (left) and Pembers Road Drain (right) as viewed from Pembers Road on 27/06/2023 showing how close the water table is to ground level. The pipe discharge into Pickerings Drain (left) is a constant inflow from private land drainage

In the Swamp Road area, hump and hollows have been infilled to recontour the land for viticulture, reportedly without installing field drainage. This resulted in increased private pumping of water into the MDC drainage network without a commensurate increase in MDC network capacity. There is no gravity drainage in areas such as Swamp Road, meaning any increases in volumes within the MDC drainage network means an increase in costs associated with running and maintaining the MDC pumping stations.

Subdivision of the Hardings Road area was possible under MDC plans. This occurred despite concerns raised by some staff regarding operational feasibility. This area had no provision for stormwater, and very high groundwater levels which limits the options and operation of septic systems. As this area does not have pumped drainage, it is reported that water ponds, draining very slowly.

Low-lying coastal landholders are reported to need to regularly “flush” their land of salt (due to existing tidal ingress) to avoid loss of productivity. Reportedly there is not concern about the effects of saline intrusion or sea level rise on the security and productivity of such low-lying land as “Council” has always been responsive to fixing and addressing issues.

The very shallow groundwater levels in coastal and low-lying areas, and increasing land and production values, have resulted in significant pressure on MDC drainage staff to maintain “adequate” drain function. The level of rating is contributing to an expectation from landholders that MDC drainage prevents all private land flooding; not just groundwater flooding caused by high water tables, but flooding from high rainfall and river flows too.

3.5 Summary

The hydrologic environment of the Wairau Plain is heavily modified to efficiently convey excess water offshore and enable desirable land uses. The flood and drainage management networks are inherently interconnected and backflow prevention is crucial to ensuring flood flows and tides do not compromise the drainage network.

River diversions and channel modifications have changed groundwater recharge regimes. The exact nature of this change is unquantified but broadly inferred in available literature, with increased groundwater recharge in some places and decreased groundwater recharge in others.

Interventions along the coastline enabled the Wairau River to discharge directly offshore instead of meandering to a lagoon terminus. This also lowered groundwater levels in tributary catchments and enabled more land drainage and intensified land use.

In the mid Plain, groundwater discharges to the surface from the unconfined Wairau Aquifer where the water table intersects the falling land gradient. In the lower Plain, groundwater at ground level is from both unconfined deposits and the increasingly confined Wairau Aquifer. Effective drainage needs to effectively manage both sources of saturation. Excavation (including for drainage) must be careful to not disturb confining materials as this can increase discharge from the (semi-)confined Wairau Aquifer, increasing saturation, and increasing the need for drainage while reducing drainage capacity. The relative contribution of discharge from these groundwater sources is unquantified.

Reviewed literature describes surface drainage interventions operated by regional governing bodies (e.g. MDC). The MDC drainage network is expansive, with land being drained both under gravity and via pumping. There is known to be additional drain network and tile drainage than what we have described.

Drainage has evolved to exert potentially significant control over groundwater levels across the Wairau Plain to support increasingly valuable land uses. Without drainage, most of the Wairau Plain would not be able to sustain current land uses and occupation. Drains also act as outfall for stormwater and private drainage to enable current land uses.

4 CURRENT MARLBOROUGH DISTRICT COUNCIL DRAINAGE NETWORK

Figure 4-1 shows the current MDC drainage network. This consists of 200 km of drains, 195 individually named drains, and 30 pump stations.

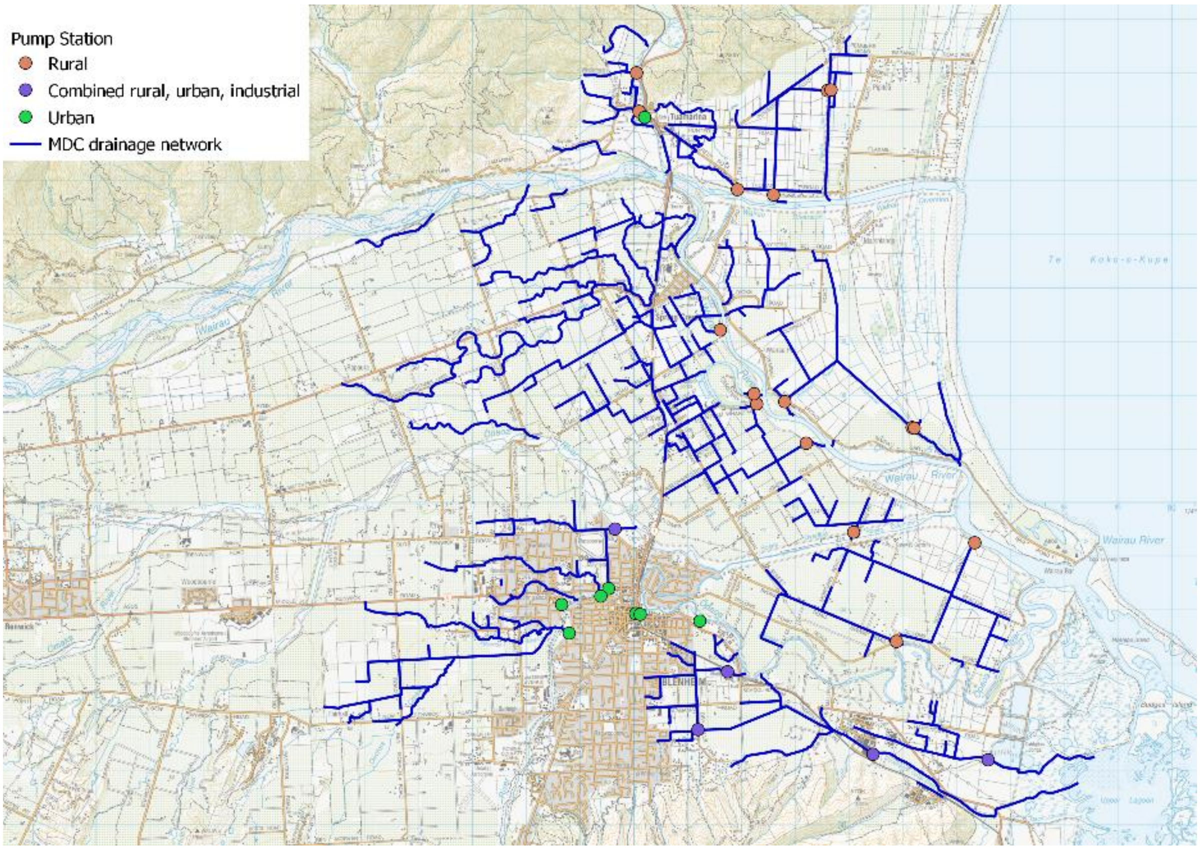

Figure 4-1 Marlborough District Council drainage network (Henderson, 2023; Bezar, 2023)

In 2018, MDC estimated it would spend $44 M on river control and drainage on the Wairau Plain across the coming ten years (MDC, 2018); $11 M capital expenditure on drainage, $18 M capital expenditure on flood protection, and $15 M operational expenditure on '*Wairau floodplain drainage*' (MDC, 2018, p. 4) which likely captures both land drainage and flood protection works.

Table 7-1 of MDC's 2018 Rivers Asset Management Plan (MDC, 2018, p. 78) suggest MDC has reliable to highly reliable information on its rural drains, culverts, pump stations, pumps, and floodgates, but notes data management deficiencies. As part of this project, we asked for information on the age of the rural drains so we could better understand the development of drainage and the MDC drainage network through time. We were advised MDC did not have record of when the drains were installed. This is contrary to the Asset Management Plan, which rates asset data on the age of rural drains as a "B", as defined below.

> '*B = Reliable. Data is based on sound records, procedures, investigations, and analysis, and documented properly but has minor shortcomings, for example some data is old, some documentation is missing and/or reliance is placed on unconfirmed reports or extrapolation. Dataset is complete and estimated to be accurate to +/- 10%.*'
> (MDC, 2018, p. 79)

The drainage network level of service is to manage a 1-in-10-year ARI rainfall event. Depending on the receiving environment such an event can have differing impacts at different times. It is unknown if this volume is updated based on land use change and so different runoff volumes, or how often it is updated with new rainfall data that shift the 1-in-10 ARI event threshold. Increased impermeability through urbanisation and soil compaction means a 1-in-10-year rainfall event today could generate higher volumes and velocities of runoff than a 1-in-10-year rainfall event 30 years ago.

4.1 Drains

Figure 4-2 shows the drainage network by receiving waterway. 41% of the drainage network discharges into the Lower Wairau River, 13% of the network discharges into the Upper Lagoon and into the Ōpaoa River, 12% into the Taylor River, 10% into the Wairau Diversion, 7% into the Wairau River, and 3% into Roses overflow. This does not consider the volume of water discharging from the drainage network.

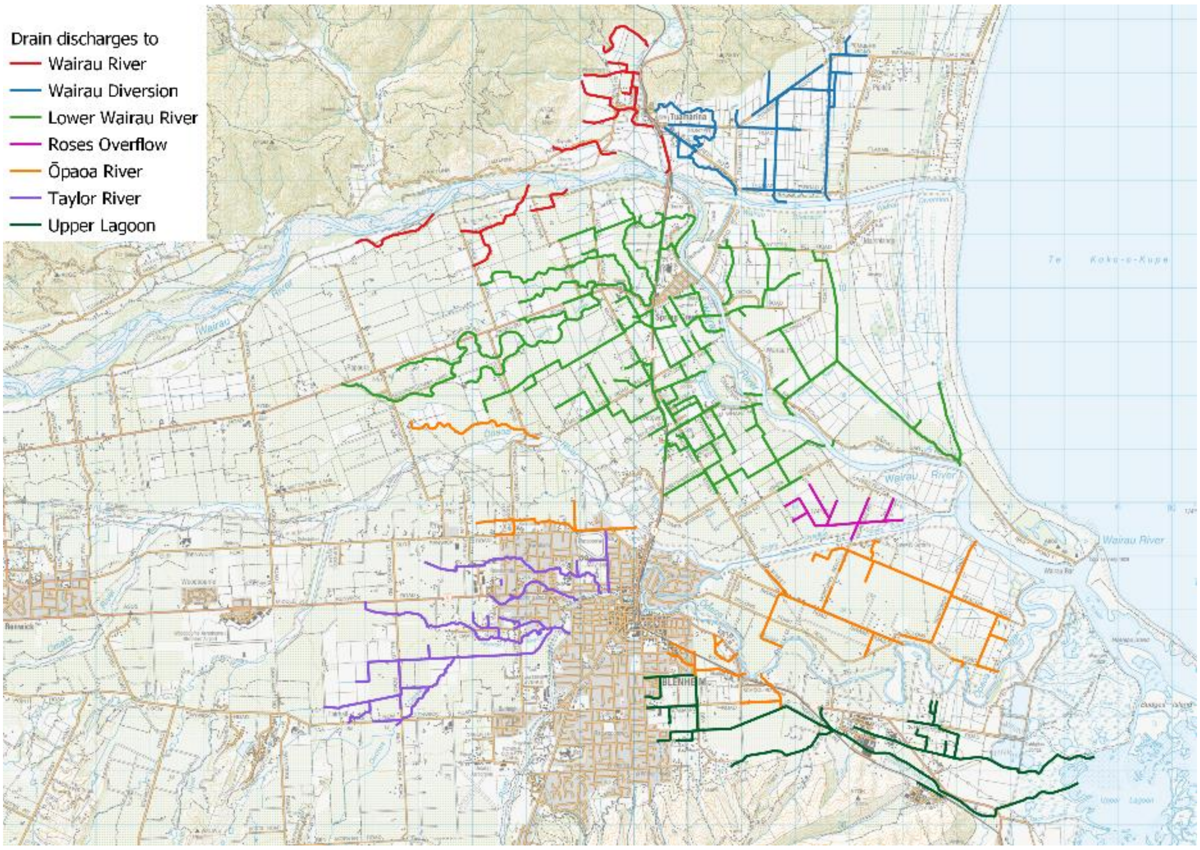

Figure 4-2 Marlborough District Council drains (Henderson, 2023) by discharge location

Figure 4-3 shows the drainage network by catchment as defined in the 2018 Asset Management Plan (MDC, 2018, pp. 111-114) and extrapolated to drains not listed in this document. 19% of MDC drains are in the Grovetown drainage catchment, 16% are in the Spring Creek and Riverlands catchments, 11% are in the Pembers catchment, while the remaining six catchments have 4-8% of the drainage network. Again, this does not account for drainage volume. Though the Riverlands catchment has 11% of the drainage network, it could easily have significantly more or less of the network drainage volume.

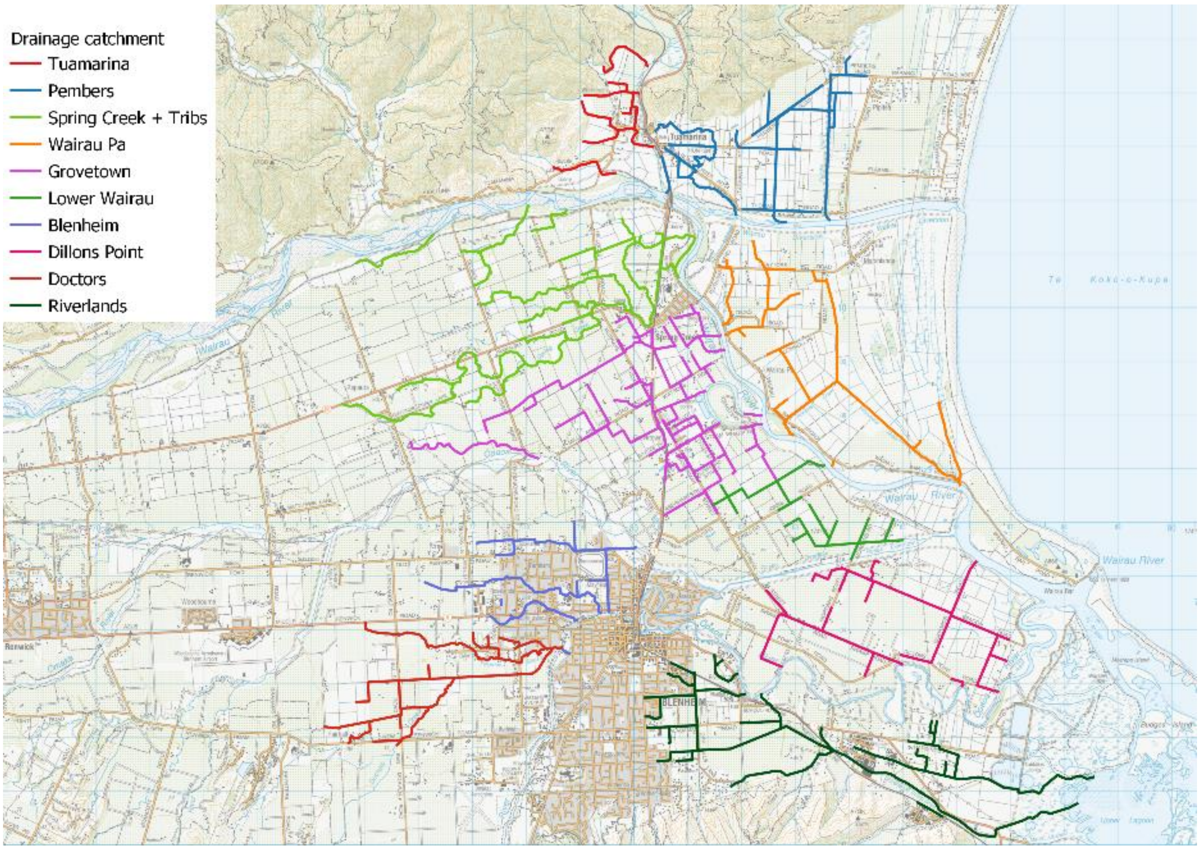

Figure 4-3 Marlborough District Council drains (Henderson, 2023) classified based on 2018 Asset Management Plan catchments (Marlborough District Council, 2018, pp. 111-114)

Figure 4-4 shows the MDC drainage network by flow permanence (as defined in MDC (2018) and by Bezar (2023); Appendix A lists this for each drain) and underlying aquifer type. Table 4-1 shows that 73% of the MDC drainage network is permanently flowing, 18% is ephemeral, and 9% is usually dry. Most of the drainage length is permanent flowing across the confined aquifer. This suggests widespread and constant discharge from the confined system.

Bezar (2023) advises that MDC has many drain bed/invert levels from drain surveys, some dating back to the Wairau Valley Scheme. Drain beds/inverts are around 13 m msl at the network’s inland extent. Many drains near the coast have inverts below mean sea level (Bezar, 2023). Land drainage in such areas would not be possible without pumping.

Figure 4-5 summarises contributors to MDC drain flows. Drain baseflow is sustained by groundwater. Drains receive inflows of stormwater and from private drainage (other drainage channels and field drainage) to remove excess water and enable desired land use. Drains also receive direct contributions from rainfall and other waterways. Inflows must be less than drain volume to prevent flooding. Pumping can be used to control the volume/level of water in a drain and alleviate risk of flooding.

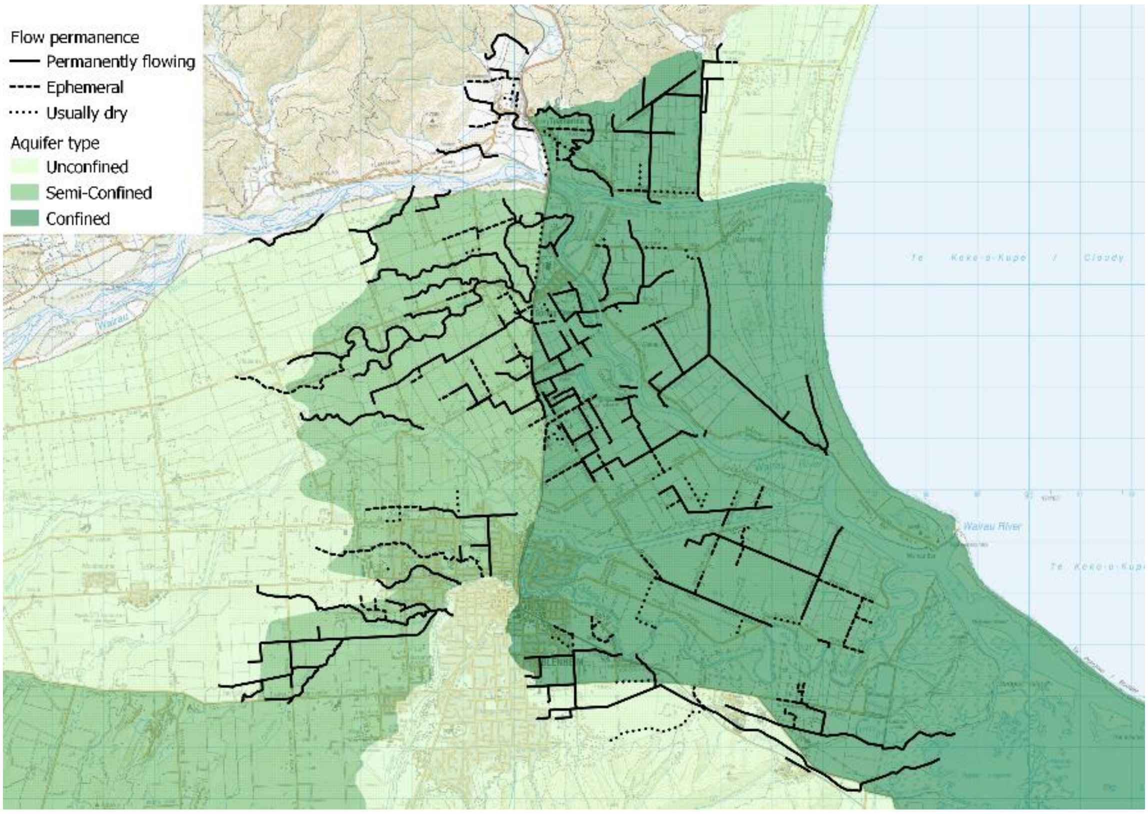

Figure 4-4 Marlborough District Council drainage network flow permanence and underlying aquifer type (based on information provided by Henderson (2023) and Bezar (2023))

Table 4-1 Percentage of total drain length across each flow permanence class and aquifer type shown in Figure 4-4

Aquifer type	Permanent flow	Ephemeral	Usually dry	Total
Confined	33%	8%	5%	**46%**
Semi-Confined	16%	5%	2%	**23%**
Unconfined	21%	4%	1%	**26%**
Outside aquifer extent	3%	1%	1%	**5%**
Total	**73%**	**18%**	**9%**	**100%**

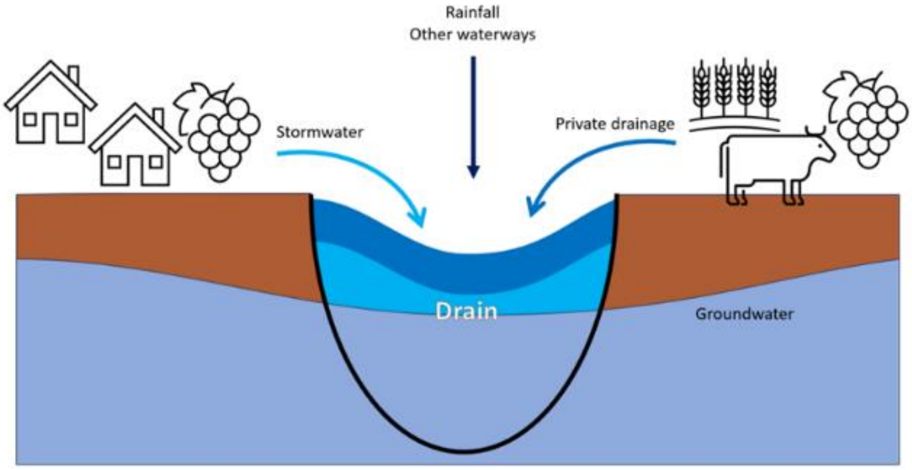

Figure 4-5 Contributors to drain flows

4.2 Pump Stations

MDC's Rivers Group has 30 pump stations in its asset schedule (Bezar, 2023). Sixteen pump stations facilitate rural drainage only, five facilitate rural drainage and prevent urban and industrial flooding by removing stormwater and mitigating the impacts of river flooding, while the remaining nine provide urban drainage by removing stormwater and mitigating the impacts of river flooding. This report focuses on the 21 pump stations that service rural areas. In its Rivers Asset Management Plan (MDC, 2018) MDC acknowledges the use of pump stations to lower the water table in such areas.

Figure 4-6 shows the current MDC drainage network by drainage discharge type (Appendix A lists this for each drain). 53% of the network drains under gravity; that is, there is adequate fall and capacity in the network that no other assistance is required to remove excess water. 47% of the network requires some level of pumping to maintain adequate drainage.

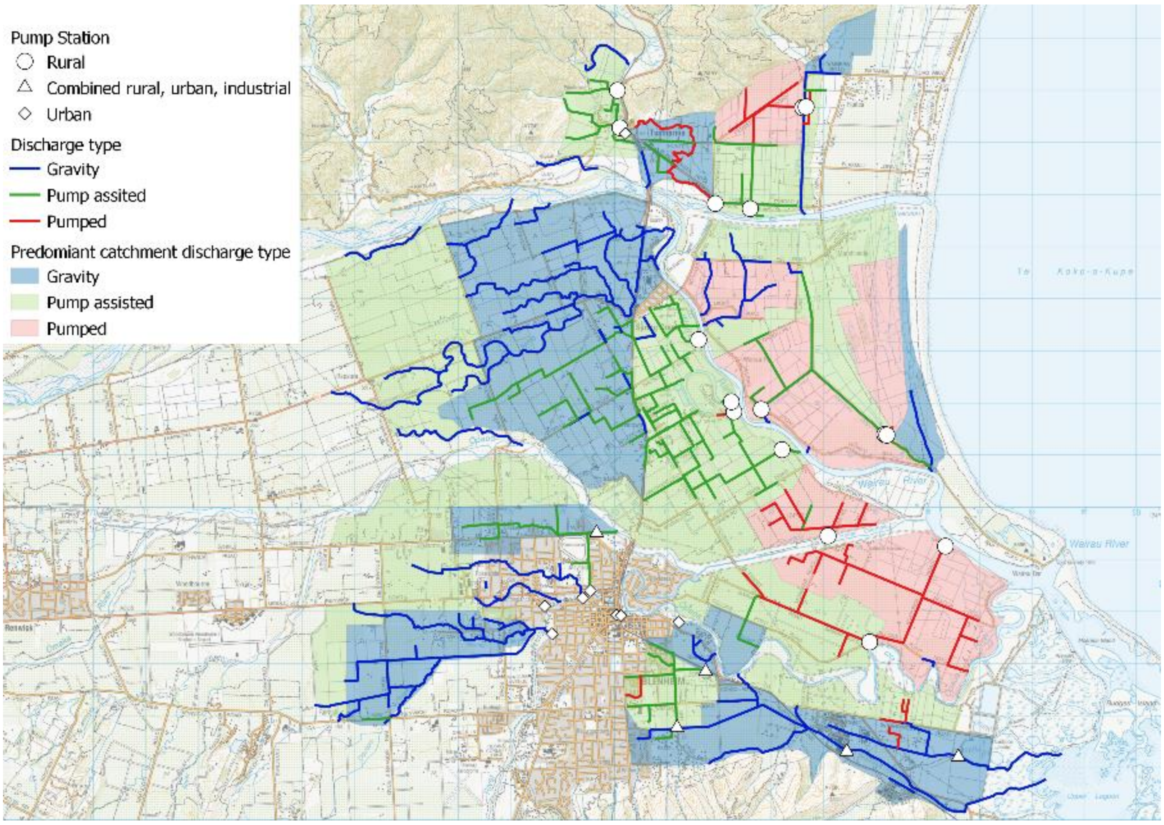

Figure 4-6 Marlborough District Council drainage network and catchments by discharge type (based on information provided by Henderson (2023) and Bezar (2023))

Figure 4-7 shows MDC pumping stations by drainage catchment as defined in MDC (2018). Spring Creek and Doctors are the only catchments drained entirely under gravity; all other catchments have some degree of pumped drainage. Under its Rivers Asset Management Plan and 2021 LTP MDC aims to have pump stations performing so

> '…*maximum ponding period is equal to or less than three days for a rainfall event of 1 in 10 year ARI. This generally requires pumping stations to have the capacity to remove 15 mm rainfall in 24 hours*.' (MDC, 2018, p. 22; 2021, p. 91)

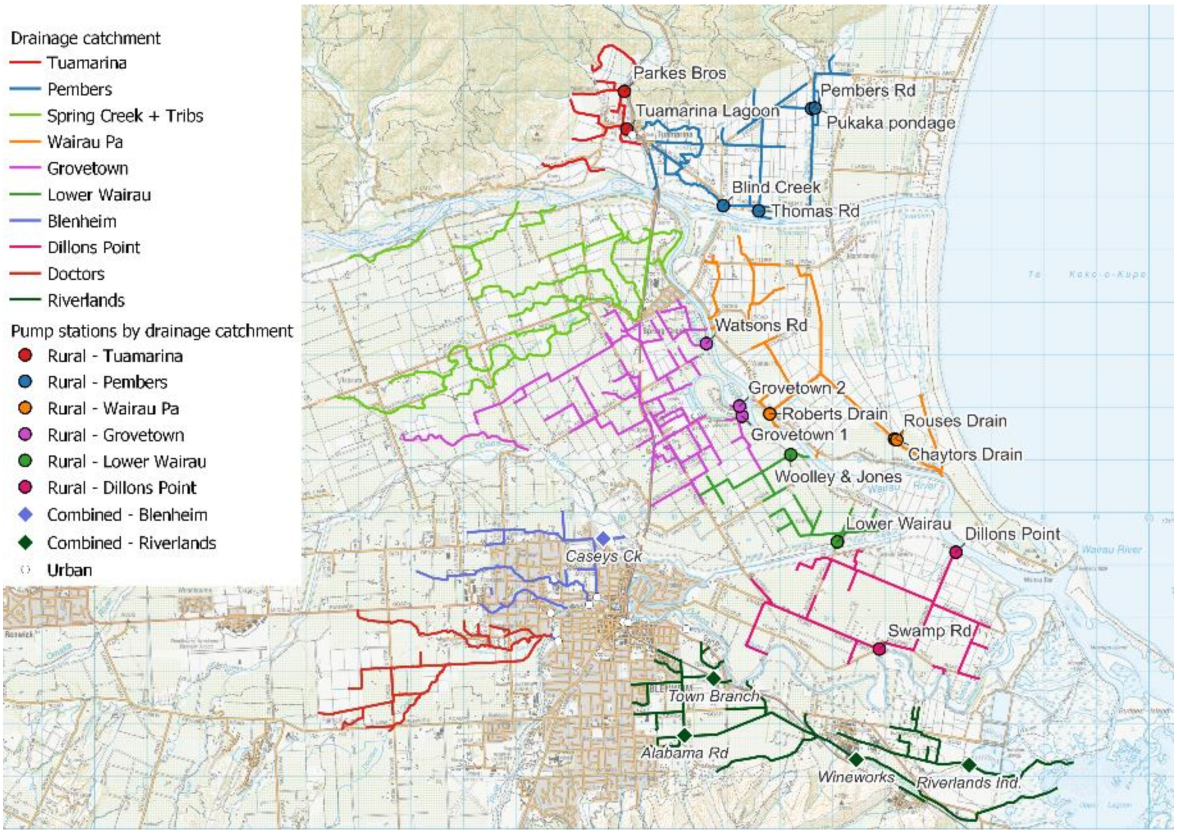

Figure 4-7 Marlborough District Council rural and combined pump stations (Henderson, 2023) classified based on 2018 Asset Management Plan catchments (MDC, 2018, pp. 111-114)

Table 4-2 gives further information on the rural and combined pumping stations. This shows that 52% (11) of stations meet this requirement, 33% (seven) of stations do not, and 14% (three) of pumping stations do not have a drainage capability defined. Almost all pumping stations were constructed between 1957 and 1984 with most (57% or 12) constructed during implementation of the WVS (1960-1975). Three stations have been constructed this century in areas of increased urban and industrial development. Based on the values in Table 4-2, at least 5,313 ha of rural land benefits from pumped drainage. Anecdotal information suggests the Pembers and Roberts drains pumping stations operate longer now than they did historically, as their function has transitioned away from providing capacity to manage floodwaters, to predominantly managing land drainage.

As described in Section 3.4.2, the Roberts, Rouses, and Chaytors drain pump stations in the Wairau Pa drainage district (Figure 4-7) have been telemetered within the last five years. The collection of this data, and consideration of it alongside other monitoring data, can give insight into pumping and environmental regimes. Another benefit to MDC of knowing the total rate of discharge from pumped drainage stations is to confirm the quantum of discharge from the confined Wairau Aquifer in summer/drier months when there are minimal other drain inflows (e.g., rain, stormwater), as this is the part of the overall Wairau Aquifer water balance that is least certain.

Table 4-2 Pumping station descriptions based on Rivers and Drains Asset Management Plans (MDC, 1996; 2018). Drainage capability refers to the daily rainfall rate the pump station can manage

Drainage catchment	Pumping station	Established (year)	Catchment area (ha)	Max pumping (L/min)	Drainage capability (rainfall mm/day)	Pumping control range (mm msl)	Description
Tuamarina	Parkes Bros	1970		17,400	22.6	3 k	• Provides supplementary pumping to a rural residential area in times of heavy rain. • Additional residential development has increased reliance.
	Tuamarina Lagoon	1970		25,000	22.6	2.5 k – 3.5 k	• Hill country and flatlands catchment. • Significant lagoon storage for floodwater from hill run-off.
Pembers	Pembers Road	1957	203[5]	31,800	12.7	400 – 1,200	• Combined pumping with Thomas Road station gives a combined drainage capability of 25.6 mm/day.
	Pukaka Pondage	1972	120	25,000	29.8		• Primarily constructed to minimise flooding from Pukaka Stream spillway.
	Blind Creek	1970	186	25,000	19.3	800 – 1,400	• Relieves flooding more so than supports drainage. • Flooding is limited by the channel storage available and good gravity drainage during the lower stages of a Wairau River flood. • Provides drainage for the rural area and the township of Tuamarina.
	Thomas Road	1970	192	59,100	260	700 – 1,200	• Drainage capability from the combined pumping of Pembers and Thomas Road stations is the highest of any rural pump stations. • Significant gravity outflow available to the Wairau Diversion during low Wairau flows. • Ongoing functioning is described as “critical” to the area (including Pembers Road).
Wairau Pa	Roberts Drain	1968	275	43,000	22.52	-200 – 400	• Significant spring inflow and habitat values. • Any lowering of pumping levels significantly increases the power usage as effective gravity drainage is lost during the low tide cycle. Further lowering of pumping levels is not recommended due to significant spring inflow to the system.
	Chaytors Drain	1961	500	36,000	10.5		• Mitigates flooding. • No gravity drainage is available.
	Rouses Drain	1965	390	24,000	8.9	-300 – 300	• Serves a very low-lying area of land. • Drainage inflows from the Roberts Drain area to the north are controlled by a weir structure. Drainage water levels are approximately 400 mm higher within Roberts Drain due

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[5] Rural area 203 ha, hill country 165 ha

Drainage catchment	Pumping station	Established (year)	Catchment area (ha)	Max pumping (L/min)	Drainage capability (rainfall mm/day)	Pumping control range (mm msl)	Description
							to major spring inflows. Level control is necessary for drainage and to reduce spring inflow rates.
Grovetown	Watsons Road	1984	140	43,000	18.5		• Drains a small rural catchment and provides for the discharge of excess stormwater from Spring Creek township. • Flood protection pumping station with gravity drainage at times of normal flows. • Pumping station design and capacity has been integrated with the stormwater piping disposal system within Spring Creek township. • Provides storage for run-off water within a “control environment” in the event of a major spillage of contaminants from the industrial area of Spring Creek.
	Grovetown 1	1961	1,200	74,000	8.8	300 – 900	• Grovetown stormwater is a minor input. • Improved drainage efficiencies mean run-off is being rapidly transferred to the low-lying Grovetown urban area, increasing its flooding risk.
	Grovetown 2	2000		74,000	8.8	300 – 900	• Improved drainage efficiencies mean run-off is being rapidly transferred to the low-lying Grovetown urban area, increasing its flooding risk.
Lower Wairau	Wooley & Jones	1972	300	36,000	17.3	0 – 400	• An essential component of providing drainage relief is the blocking of overland flood flows from the Grovetown Lagoon.
	Lower Wairau	1957	212	30,250	14	300 - 600	• Can function at low velocities and water levels. • Gravity drainage is available at low tide to Roses Overflow.
Dillons Point	Dillons Point	1959	695	48,000	10.25	0 – 600	• Large catchment with very low flow gradients and low-level pumping. • Gravity drainage to Wairau River not usually available due to low pumping levels. • Considerable pumping is required when the Wairau Bar mouth is closed, with drain water levels generally 600 mm msl. • Serious risk of saltwater intrusion if pumping increases.
	Swamp Road	1978	320	36,000	16.2	350 – 600	• No gravity drainage.
Blenheim (combined)	Caseys Creek	1970	110[6]	24,000	18.4		• Increasingly urban catchment.

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[6] Rural area 120 ha, urban area 10 ha

Drainage catchment	Pumping station	Established (year)	Catchment area (ha)	Max pumping (L/min)	Drainage capability (rainfall mm/day)	Pumping control range (mm msl)	Description
							- Undersized. - Gravity drainage to the Ōpaoa is available except during major flood events.
Riverlands (combined)	Town Branch	1983	50[7]	54,000			- Also provides for emergency pumping of sewage to the river. - Undersized.
	Alabama Road	1963	140[8]	31,800	36.5		- Drainage area integrated into Town Branch.
	Wine Works	2015	10.2	6,000		850-1,050	
	Riverlands Industrial	2004	280[9]	77,000		0 – 2k	

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[7] Rural area 50 ha, urban area 150 ha

[8] Rural area 140 ha, urban area 80 ha

[9] Rural area 280 ha, industrial area 52 ha

4.3 Flood Gates

There are 290 culverts on the drainage network, 249 of which are flood-gated (generally under stop banks) as part of the drainage network (MDC, 2018). MDC maintains these flood gated outlets to minimise backflow in times of river flood and during high tide. Figure 4-8 shows MDC floodgates by drainage catchment.

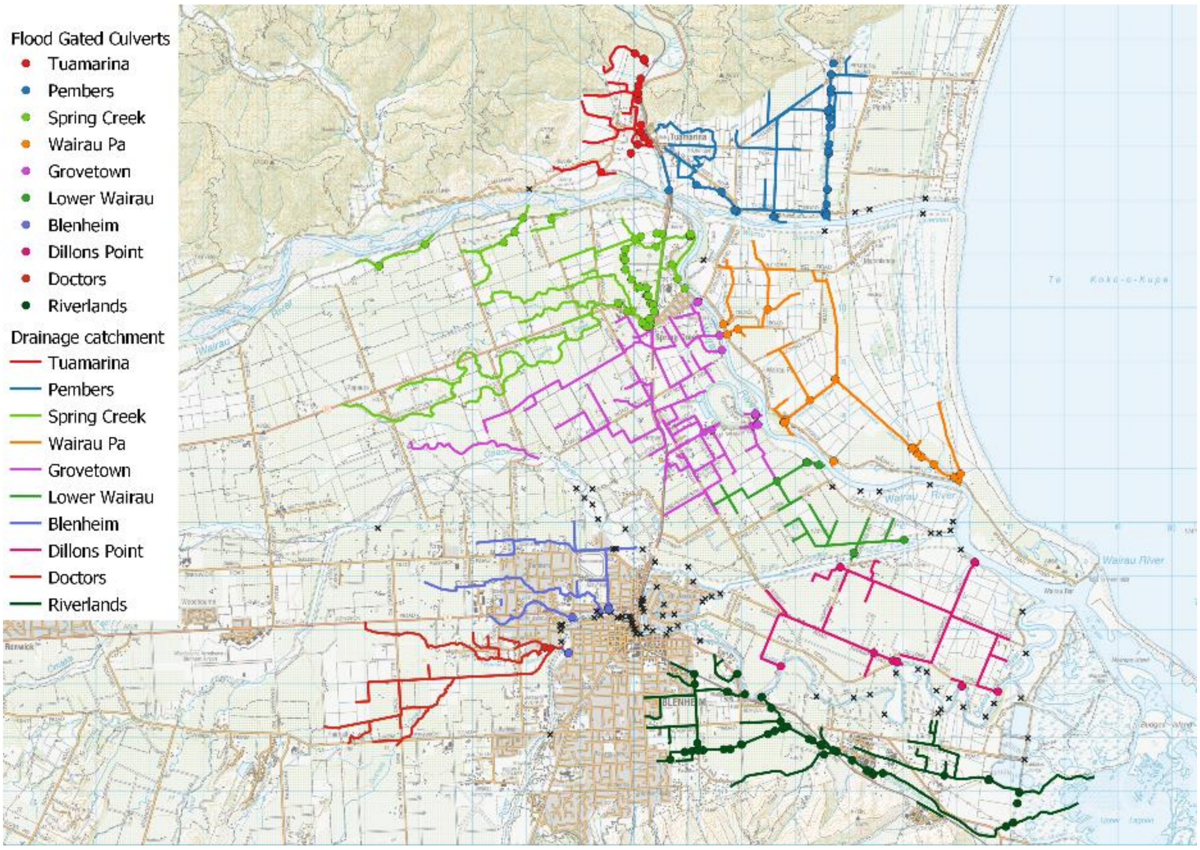

Figure 4-8 Marlborough District Council floodgates (Henderson, 2023) classified based on drainage district. Those outside a drainage district are shown as black crosses

Table 4-3 shows floodgate type by catchment. MDC GIS data contains 357 floodgates, 251 of which are within a drainage area, compared to 249 total previously reported (MDC, 2018). The Riverlands drainage area has the most floodgates, and Doctors drainage area the least. Steel McEwan floodgates[10] are the most common type. There is no information on how often floodgates are closed, how long they are closed for, or the impact this has on land drainage.

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[10] https://macewans.co.nz/wp-content/uploads/Flood-Gates.pdf

Table 4-3 Floodgate type (Henderson, 2023) by drainage catchment

Catchment	Aluminium	Concrete	Fibreglass	Steel	Steel MacEwan	Wooden	Unspecified	Total
Tuamarina	-	-	3	5	11	1	-	**20**
Pembers	-	-	1	8	24	1	-	**34**
Spring Creek	-	9	2	15	12	6	-	**44**
Wairau Pa	1	-	6	3	13	2	-	**25**
Grovetown	2	-	3	3	5	4	-	**17**
Lower Wairau	1	-	3	4	3	-	-	**11**
Blenheim	-	-	-	1	9	2	-	**12**
Dillons Point	2	-	2	2	8	-	-	**14**
Doctors	-	-	-	-	2	-	-	**2**
Riverlands	-	-	21	12	37	2	-	**72**
Total	*6*	*9*	*41*	*53*	*124*	*18*	-	***251***
Outside drainage area	2	-	9	17	72	3	3	**106**
Total	**8**	**9**	**50**	**70**	**196**	**21**	**3**	**357**

4.4 Network Limitations

As discussed in Section 3.3, the 2015 review of the drainage network did not account for stormwater inputs. Increased urbanisation and vineyard expansion has increased impervious areas and soil compaction, increasing land surface runoff. This means increased volumes of outfall. The drainage network is reportedly already vulnerable to failures during intense and/or prolonged rainfall events in areas such as Camerons Creek.

In coastal areas, drain beds are already below sea level. This means they can only discharge at low tide. Sea level rise could mean low tides are higher than drain levels and prevent discharge occurring. More information is needed to assess this risk.

The volume of water moving through the network needs to be better understood. Table 4-2 shows many stations are well below MDCs goal capacity of being able to remove 15 mm rainfall in 24 hours. MDC (2018) identifies that some pump stations are already inadequate to remove existing drainage volumes regardless of this goal capacity.

5 ANTICIPATED CHANGES TO LAND USE, DRAINAGE, AND GROUNDWATER

Given the Wairau River recharges groundwater at a constant rate (MDC, 1994), anticipated increases in rainfall and river flows under climate change do not necessarily mean increased groundwater discharge and so drain discharge. Increased water demand may negate anticipated increases in groundwater level in some places. In other areas, sea level rise may necessitate increased pumping to lower higher water tables, or water level increases may reach a stage where managed retreat needs to be considered.

It is increasingly being found that it's not the scale of the events, but the frequency and duration of events that is causing the issues.

Changes will be measurable but gradual, almost imperceptible to the public, unless they are directly impacted (e.g. flooding). This means there will be a reluctance to increase expenditure or undertake actions to adapt to the changing risk profile.

5.1 Impacts of Sea Level Rise

Investigation of the potential effects of climate change on Wairau Plain groundwater by Weir & Davidson (2016) found sea level rise is likely to increase flow in coastal springs (due to increased aquifer pressures), adversely affecting coastal land use.

Average sea level is predicted to rise by 0.3 m by 2050 (MDC, 2015). This could erode the coastline and inhibit the discharge of rivers and drains, increasing backflow, reducing the capacity for gravity drainage, increasing pumping requirements, altering water table levels, and increasing saline intrusion in very low-lying areas. As the sea level rises, pumped outfalls are also likely to be required to assist with drainage of flat, low-lying land where gravity drainage was previously available (MDC, 2015).

PDP (2021) found sea level could rise by 1.15 m by 2100, moving the saltwater-freshwater interface in the Rarangi Shallow Aquifer inland by up to 50 m in the north and by up to 20 m in the south and central areas. This movement was described as unlikely to cause long-term saline intrusion issues in and of itself. Storm surges were identified as a key mechanism for causing saline ingress and seawater inundation.

In the Pembers Road area, the drainage network is already under huge pressure. There is concern that the backflow potentially induced by sea level rise will require significant pumping. Sea level rise could limit both groundwater and surface water discharges offshore, increase ponding and inundation in low-lying areas, increase salinisation, and see loss of coastal lands to the sea.

There could come a point where drainage, and therefore existing and/or intended land use (including Council's wastewater treatment facility) is no longer viable. This lack of viability could be determined economically (e.g. protection costs are prohibitive), by physical or environmental constraints (e.g. sea level rise has meant an area is no longer accessible), or by change processes that are unable to be foreseen or managed.

5.2 Impacts of Rainfall

MDC (2021) reports that more frequent high intensity rainfall events will:

- Place greater demands on the stormwater system, stressing urban drainage reticulation,
- Inundate detention areas, limiting their effectiveness, and
- Test the capacity of existing drainage and flood infrastructure.

To cope with increased rainfall, MDC (2021) recommend constructing larger drainage channels, increasing the height of stop banks, and increasing stopbanking, which may not be economically attractive in all cases. This appears to consider rainfall's impact on surface water only, not on groundwater.

MDC (2021) also anticipates increased water use and demand due to changes in rainfall pattern. Given the Wairau Plain already experiences water scarcity, it is in the best interest of the region to discharge "excess" water offshore instead of harvesting it?

Weir & Davidson (2016) identified potential reductions in Wairau River flows, decreasing groundwater recharge and associated groundwater levels and discharges (e.g. Awarua) flow, and identified potential decreased land surface recharge, further decreasing groundwater recharge and therefore discharges.

5.3 Impacts on Drainage

Increased pumping to increase the rate of water discharging offshore can only be part of a solution (it is not necessarily an infinitely scalable tool, e.g. due to cost). Networks are always going to have limits. Increasing land drainage or drainage capacity will not necessarily resolve drainage issues. Increasing groundwater drainage in coastal areas could also increase saltwater intrusion. In lowland areas, the effectiveness of deepening drains to increase capacity[11] is limited by confining material; once a confining layer is breached, groundwater discharge increases.

MDC (2021) recommends increased use of pumping to mitigate the impacts of sea level rise and assist with drainage of flat, low-lying land on the Lower Wairau Plain that can no longer be gravity drained. As discharges are currently flood-gated rather than outfalls, it is possible that to maintain drainage discharge with sea level rise, significant upgrades to pump capacity would be required to overcome the differences in head.

Additional drainage to facilitate new land uses or mitigate the impacts of larger change processes may reduce reliability of other groundwater abstractions, impact the behaviour of natural springs, degrade the local environment, or may encourage salt-water intrusion into the aquifer in areas close to the sea (MDC, 2018). There are no "barriers" to sea level rise beyond the "protection" that may be provided by stopbanks.

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[11] In low-lying areas, MDC drains are predominantly located on roadsides. The easiest means of increasing drain size is to deepen the drain, as to expand laterally would by necessity be into private land and thereby require some form of acquisition or permission

6 GROUNDWATERS' IMPACT ON RISK

In this report we have referenced how changes in groundwater levels can change relative risk. Within this section we further explore how groundwater can influence risk profiles. **This is not intended to be a comprehensive risk assessment. It highlights areas of risk consistent with the focus of this investigation.**

We acknowledge and apply the common definitions of a hazard being *something that could cause harm*, with risk being *the degree of likelihood harm will be caused*. Groundwater can be a hazard; it can also impact other hazards raising their relative risk. Table 6-1 explores how groundwater flooding as a hazard intersects with different hazard types. Groundwater flooding is where groundwater is present at or above ground level where it is not otherwise expected to be present. Groundwater flooding is considered largely a physical hazard that can create chemical/biological and psychosocial hazards. The scale and extent of groundwater flooding impacts how much of a risk it poses. Where surface water flooding can last for hours to days, groundwater flooding can last days to months.

Table 6-1 Types of hazards and how they can result from groundwater flooding

Hazard type	Hazard description	Groundwater flooding hazards
Safety	Factor that causes direct harm to an individual.	• Drowning.
Chemical/biological	Substances and their products that can cause harm.	• Mobilisation of contaminants in groundwater.
Physical	Environmental factors that can cause harm.	• Inundation of property. • Household isolation. • Reduced access to property or inability for others reach your property.
Psychosocial	Things that impact mental health and wellbeing.	• Mental and financial strain of repeat/prolonged floodings on property. • Impacts on community cohesion and accessibility through disruption.

Globally, groundwater has been ignored or underplayed as a hazard or as an influence on risk, largely considered "out of sight, out of mind". Groundwater is dynamic, responding to changes in drivers[12]. However, our built and engineered environments are either static or only able to tolerate "so much" change before "something has to give". Failing to account for, or underestimating groundwater's influence within such restricted systems can therefore result in consequences (or risks) ranging from nuisance (e.g. ponding on a lawn) to catastrophic (e.g. sink holes).

Giving proper consideration and regard to groundwater can increase the resilience and cost effectiveness of decision-making, especially regarding infrastructure and the built environment. For example, understanding groundwater dynamics can help engineers:

- Design infrastructure that mitigates the impact of flooding. For example, the design of stormwater detention basins requires an understanding of local groundwater dynamics (e.g., how deep could we make a basin without intercepting groundwater?);

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[12] Drivers include: changes in sea level (including tides, storm surges, and sea level rise), the rate at which groundwater is recharged by rainfall, groundwater-surface water exchanges, and changes to land (e.g. changes to hydraulic conductivity and topography via ground disturbance such as excavation and earthquakes)

- Identify where subsurface infrastructure system capacity is being compromised by the ingress of groundwater, and;
- Assess the long-term viability of, or cost of maintaining sub-surface infrastructure including water supply wells, septic tanks, and three waters systems.

6.1 Shallow Groundwater in Urban Areas

In urban areas, large areas of impermeable surface limits groundwater recharge and so increases surface runoff. Infrastructure and associated ground disturbance can also disrupt groundwater flow paths and alter hydraulic conductivities. If not explicitly considering groundwater, MDC and developers are potentially exacerbating risks in the built environment, including (but not limited) to foundations and subsurface infrastructure, which could be compromised by exposure to shallow groundwater, causing materials to deteriorate at a faster rate, meaning shorter viable lifespans and higher costs.

The MDC LTP recognised the insufficient stormwater provision in the drainage network described in Section 3.3 as an emerging issue/expected change and provides budget to increase pumping and channel capacity.

6.2 Subsurface Infrastructure

Groundwater can both infiltrate subsurface networks and can receive discharges from subsurface infrastructure networks, such as stormwater systems. It can also interact with and compromise . Figure 6-1 shows how higher groundwater levels can impact urban infrastructure. Bosserelle, et al. (2022) undertook a literature review to present a summary of the actual impacts of shallow coastal groundwater on subsurface urban infrastructure, including potential impacts from sea level rise.

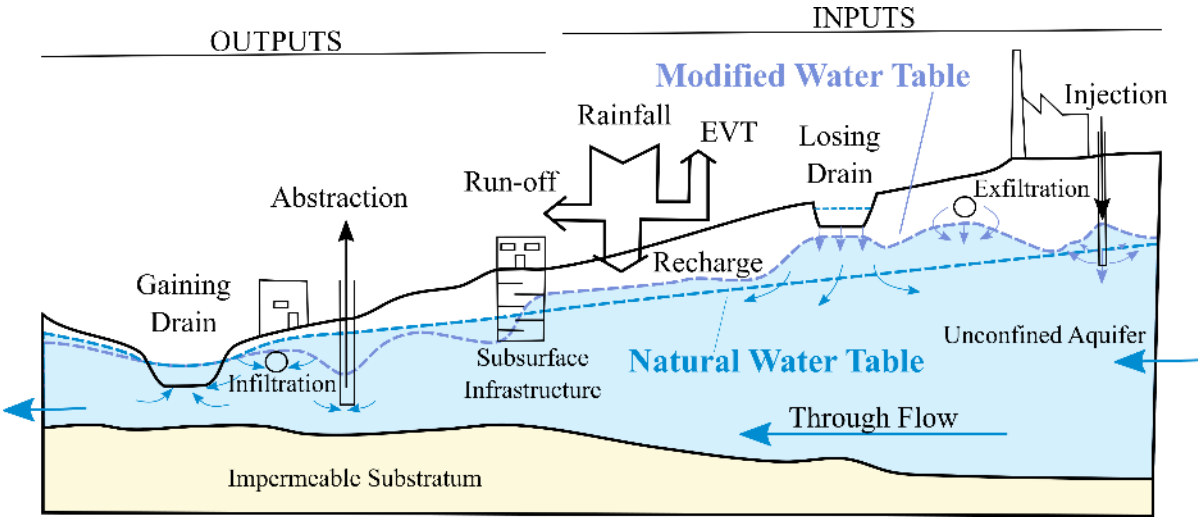

Figure 6-1 Diagrammatic exploration of the impacts of higher groundwater levels in an urban coastal environment (Bosserelle, 2020)

Bosserelle, et al. (2022) found that groundwater generally infiltrates subsurface infrastructure, allowing groundwater to drain further downgradient more efficiently than would occur under natural conditions. This drainage can artificially lower the water table. Repairing assets to prevent this ingress can create unintended adverse impacts. The loss of efficient groundwater drainage increases groundwater levels, potentially causing problems with groundwater infiltration into other infrastructure and flooding problems.

The drivers and impacts of the highly modified subsurface environment on coastal groundwater fluctuations are poorly understood worldwide (Bosserelle, et al. 2022). It is possible that subsurface infrastructure is controlling groundwater level in Blenheim. Infrastructure upgrades would prevent this ingress, increasing the volume of water in the environment and so raising groundwater levels. Groundwater flooding may occur infrequently during extreme events (e.g., high tide coinciding with heavy rainfall), coinciding with surface and marine flooding. However, large inflows of groundwater into the network would also undermine the network performance and increase likelihood of failures and flooding in storm events.

As sea level rises and climate changes, depth to groundwater level will also change. Subsurface infrastructure and underground services must be made resilient to floods, and changes in temperature and humidity to ensure continued levels of service to dependent communities. Because of the potential changes to groundwater levels into the future, flood mitigation options and building and infrastructure practices that are viable now may cease to be so within the lifetime of civil infrastructure assets.

6.3 Surface Water

The most obvious way groundwater impacts risk is how it can impact surface flooding. Changes in groundwater levels over time (days, weeks, seasons, etc.) play a critical role in flood flows.

The interaction between surface water, run-off, and groundwater can significantly affect the movement and quantity of floodwater. Key reasons why groundwater dynamics are an important part of understand flood flows include:

- Depth to the water table, and how this varies (e.g. during a storm event), can significantly affect the amount of water that infiltrates into the ground. The higher the water table, the lower the capacity of the ground to store rainfall. When the soil is saturated, the depth to the water table is zero, and almost all rainfall ponds and runs off. Thus, higher groundwater levels generally result in higher peak flood flows and higher flood volumes.
- Conversely, groundwater can act as a storage reservoir for floodwater. If the water table is far below the ground, and the infiltration rate is high enough, surface water can infiltrate to recharge groundwater. This stored water is released gradually into the surface water system (or offshore), reducing waterway peak flow, and sustaining river baseflow over the longer term.

Figure 6-2 shows how groundwater and surface water can interact. If groundwater levels rise high enough, flow gradients can reverse, meaning losing or disconnected streams become gaining streams. Given MDCs drains are acting as gaining streams, increases of groundwater levels could mean the network no longer has capacity to take other inflows.

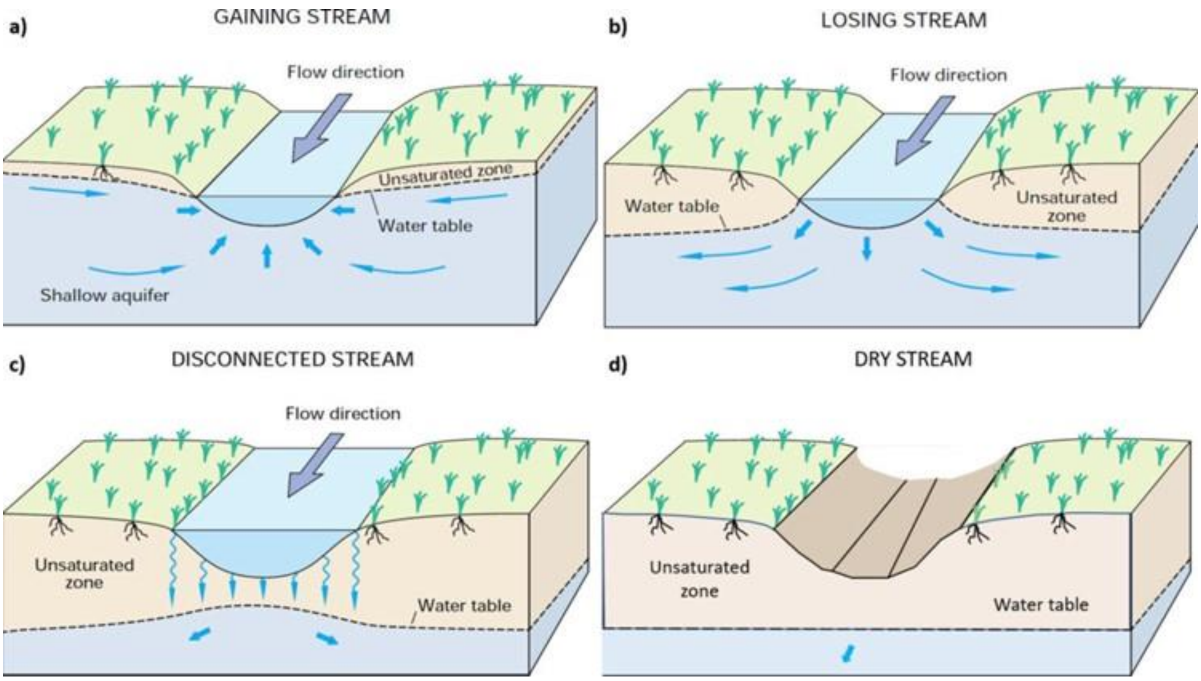

Figure 6-2 How groundwater and surface water can interact (Poeter, et al., 2020)

6.4 Seawater

In a coastal environment there are many factors that interact and influence groundwater level and there is significant uncertainty about the exact nature of these interactions and their net impact. Groundwater ultimately discharges offshore. A groundwater system and its connected water bodies are influenced by tides and waves (Figure 6-3). Anderson (2017) describes tides and waves as acting like a pump, with tidal amplitudes of between 1.0-2.5 m able to increase groundwater levels within 100 m of a tidal estuary or ocean by 0.2-1.8 m above mean sea level, depending on aquifer characteristics. Wave action (coastal storms) can raise groundwater levels even higher, as demonstrated in Figure 6-3.

Sea level rise increases groundwater level, as seen in Figure 6-4. Beyond the immediate impacts of higher sea levels, higher sea levels move the saltwater/freshwater interface further landward and upward, accelerating saltwater intrusion (which can be further exacerbated by groundwater abstraction), and raise the water table, which can:

- Increase the size of existing surface water features and induce groundwater inundation, including the creation of new wetlands, limiting the usability of land,
- Reduce the functionality and stability, and/or result in damage of surface and subsurface infrastructure (e.g. septic tanks, building foundations, landfills, horizontal services), and mobilise associated contaminants,
- Reduce the functionality of unlined and poorly lined water conveyance and storage systems (such as stormwater basins and drainage channels),
- Increase soil salinity and soil moisture to the point it decreases the viability of existing land uses,
- Destabilise existing ecological communities and create opportunities for new communities,
- Reduce the availability of potable groundwater (Jamaluddin, et al. 2016; Bosserelle, et al. 2022).

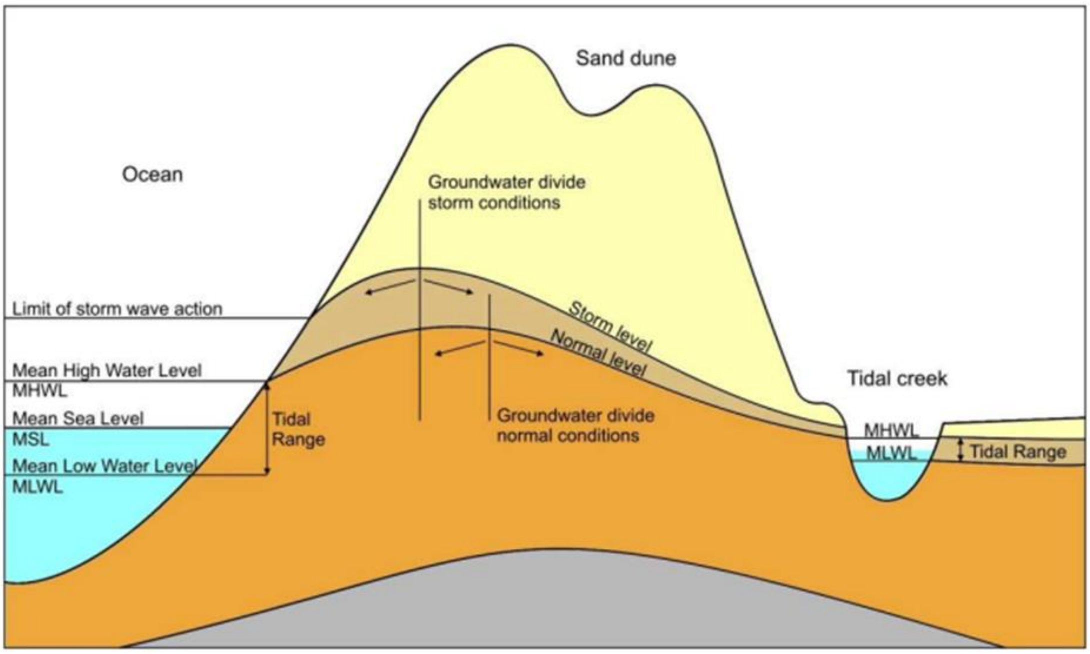

Figure 6-3 Elevation of coastal groundwater by tide and wave action (Anderson, 2017)

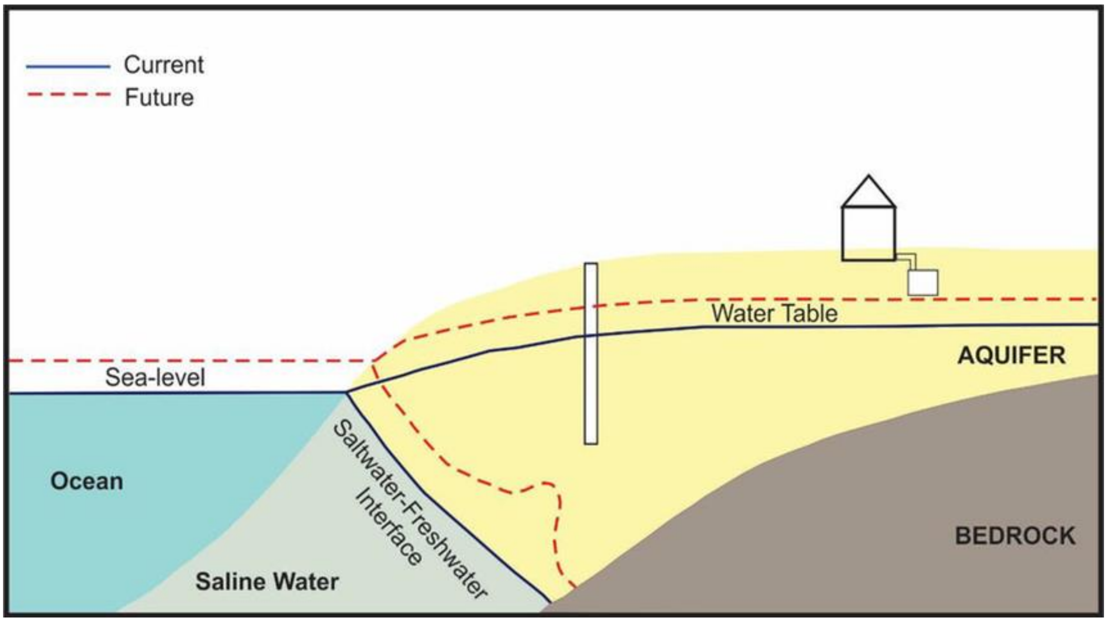

Figure 6-4 Conceptual diagram of the impacts of sea level rise at coastal aquifer area (Jamaluddin, et al. 2016)

There are many factors at play that influence groundwater level in the coastal area. Because the interaction of these factors is poorly understood (including in international literature), there is significant uncertainty associated with predicting what changes will occur and what their net effects may be.

6.5 Controlling Groundwater Level

Drains across the Wairau Plain already function to control groundwater level. Groundwater abstraction can lower the water table locally, creating a cone of depression. Multiple cones of depression can create a regionally lowered water table. If groundwater is taken at sufficient rate and volume, pumping can reduce flow in hydraulically connected surface waterways and induce seawater intrusion. Groundwater can also be strategically pumped to lower the water table to protect assets and reduce the risk of groundwater flooding (Bosserelle, et al. 2022).

6.6 Preliminary Groundwater-Focussed Risk Assessment

Focussing on shallow groundwater in rural areas serviced by the MDC drainage network, we identified the potential groundwater hazards and potential groundwater-influenced hazards listed in Table 6-2. The risks associated with these potential hazards are described and their indicative risk score listed based on description in Table 6-3. Table 6-2 suggests there is potentially extremely high risk posed by groundwater itself, such as high groundwater level compromising the economic productivity of the Wairau Plain, and in how it interacts with other hazards, e.g. sea level rise. The relative risk posed by each potential hazard depends on location.

We stress that this is an initial screening. This risk assessment should be considered indicative only. We do not have confidence all groundwater risks or groundwater-influenced risks have been identified and adequately quantified.

Table 6-2 Risk classification of identified and potential groundwater and groundwater-influenced hazards. Indicative risk is based on Table 6-3. These risk assessments should be considered indicative only; they are not comprehensive or robust

Potential hazard	Potential hazard description	Risk description	Indicative risk (Likelihood x Consequence)
High groundwater levels	Widespread elevation of water table impacting existing land uses	• Increased potential for liquefaction. • Decreased capacity for land infiltration. Can cause the failure of stormwater and septic systems, and compromise roading networks. • Vines now “get their feet wet.” Loss of productivity triggering economic downturn if impacts cannot be mitigated. • Increased expectations of the drainage network with limited capacity to deliver. • Loss of capacity of the drainage network, meaning: ○ More ponding of water on land, increasing flooding risk and damaging infrastructure. ○ Increased drainage network pumping increasing operational and maintenance costs. ○ Increased risk of flooding, increased flood extent and prolonged flooding events. • Lack of understanding and acknowledgement of the risks associated with high groundwater levels.	Extremely high risk (4 x 5)
	Very high groundwater level limits the ability for rainfall to infiltrate and increases rainfall inundation	• Rainfall is quick to pond/runoff, increasing land inundation, river flows, and pressure on stormwater and drainage networks. • Reduced use of or access to property. • Community and business disruption. • Psychosocial impacts from inability to use land/operate business, potential recovery. • Potential financial and economic impacts on insurance, rates, and from recovery. • More areas could have very high groundwater levels with sea level rise and other climate change impacts meaning even less rainfall infiltration and greater ponding and/or runoff.	High (5 x 2)

Potential hazard	Potential hazard description	Risk description	Indicative risk (Likelihood x Consequence)
Low groundwater levels	Widespread decline of water table impacting existing land and water use	Lower groundwater levels can: • Result in wells running dry, reducing reliability of supply of drinking and irrigation water. ○ This can increase costs of obtaining water, including securing a secure alternate supply or deepening of wells. ○ This can reduce the productivity of land, creating flow-on economic impacts. The severity of this depends on the scale of water stress. • Increase irrigation requirements, resulting in even lower groundwater levels. • Decrease groundwater discharge in spring-fed streams. This could diminish ecological values. • Increase risk of saline intrusion.	Extremely high risk (5 x 4)
Groundwater flooding	Groundwater can be at or above ground level	• Reduced use of or access to property. • Community and business disruption. • Psychosocial impacts from inability to use land/operate business, potential recovery. • Potential financial and economic impacts on insurance, rates, and from recovery. • More areas could have groundwater at or near the surface with sea level rise and other climate change impacts meaning more groundwater flooding. This could reduce productivity or increase community expectation on the level of drainage provided.	High (5 x 2)
	Infiltration capacity increases inland as the depth to groundwater increases. This means increased recharge could occur at the top of the plain when there is no/limited capacity at the bottom of the plain	• Increased scale of groundwater flooding. Risks in above cell exacerbated.	Moderate (4 x 2)

Potential hazard	Potential hazard description	Risk description	Indicative risk (Likelihood x Consequence)
Increased surface water flows and flooding	Where surface water discharges to groundwater, elevated groundwater levels could limit or prevent these discharges	• Surface water flow is retained in waterways, increasing flow, and potentially contributing to flooding. • Reduced use of or access to property. • Community and business disruption. • Psychosocial impacts from inability to use land/operate business, potential recovery. • Potential financial and economic impacts on insurance, rates, and from recovery.	High (3 x 4)
	Where groundwater discharges to surface water, elevated groundwater levels could increase discharges to surface water	• Surface water flow is increased, potentially contributing to flooding. • Reduced use of or access to property. • Community and business disruption. • Psychosocial impacts from inability to use land/operate business, potential recovery. • Potential financial and economic impacts on insurance, rates, and from recovery.	High (3 x 4)
Infrastructure failure	It is likely there is widespread draining of groundwater via unsecure reticulated networks, reducing baseline capacity	• Reduced capacity means the system is less able to cope with rainfall events, and is more likely to fail, exacerbating inundation. • If high rainfall coincides with high river flows and high tide, the impacts on the stormwater system are exacerbated, causing more widespread inundation and network damage. • Wastewater overflows could result in human exposure to contaminants. • Increased costs due to more failures and repairs ○ Increased rates. ○ MDC may need to reprioritise expenditure to meet rising costs, impacting delivery of other services. • MDC unable to meet levels of service.	Very high (5 x 3)

Potential hazard	Potential hazard description	Risk description	Indicative risk (Likelihood x Consequence)
	Infrastructure submerged in groundwater	- As per above cell, plus: - Both intermittent and prolonged submersion can reduce infrastructure integrity, requiring more repairs and increasing the frequency and scale of failures. - Groundwater undermining horizontal infrastructure such as roads. - Groundwater inundating private infrastructure such as septic systems. - Increasing maintenance and repair costs. - Psychosocial impacts from inability to use land/operate business, potential recovery.	High (3 x 4)
Groundwater contamination	High groundwater levels are more likely to intercept and mobilise contaminants, such as from unsecure wastewater systems and landfills	- High groundwater levels increase the likelihood of mobilisation of contaminants, likelihood of exposure and potential for harm.	Low (2 x 2)
Sea level rise	Higher sea level amplifies the impact of groundwater level changes	- Freshwater/saltwater interface moves further onshore and becomes shallower, increasing salinisation, impacting existing land uses and water users, and accelerating asset degradation. - Low tides are higher constraining the ability of drains and rivers to discharge offshore. ○ The beds of coastal drains are already below sea level and operating on an ~500 mm threshold meaning their discharge will be further inhibited without intervention. ○ Floodgates will be closed for longer, increasing ponding and limiting event storage behind them. - Waterways backup further, meaning impacts are felt further onshore. - Aquifer pressure increases, increasing groundwater level and spring discharges, increasing flooding and land saturation, decreasing the viability of existing land uses. - More pumping is necessary.	Very high (4 X 4)

Table 6-3 Risk matrix

0-2	Very Low Risk
3-4	Low Risk
5-9	Moderate Risk
10-14	High Risk
15-19	Very High Risk
20-25	Extremely High Risk

		CONSEQUENCE				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
LIKELIHOOD	Almost certain 5	5	10	15	20	25
	Likely 4	4	8	12	16	20
	Possible 3	3	6	9	12	15
	Unlikely 2	2	4	6	8	10
	Very unlikely 1	1	2	3	4	5

7 QUANTIFYING CHANGE

As per Section 2.1, MDC reports their monitoring wells show declining groundwater levels, with greater declines seen inland. MDC provided daily groundwater levels and ground level in metres vertical datum for wells in Table 7-1 (Figure 7-1). We subtracted ground level from groundwater level to give depth to groundwater, or groundwater level in metres relative to ground level. In this section we use data form these wells to understand how the Wairau and Rarangi aquifers are potentially responding to changes.

Table 7-1 Wells and daily data record provided by Marlborough District Council. LVD is local vertical datum

Well name	MDC ID	Well depth (m)	Ground level (m LVD)	Record
Conders	P28w/3821	20	39.9	2001-present
	P28w/0398	10	39.9	1982-2001
Wratts Road	P28w/3009	6	14.8	1996-present
	P28w/0238			1958-1996
Woodbourne	P28w/3010		22.5	1996-present
	P28w/0594	12	21.2	1971-1997
Coastal Bar	P28w/1733		3	1988-present
Rarangi Golf Course	P28w/10230/1901		4.1	1998-present

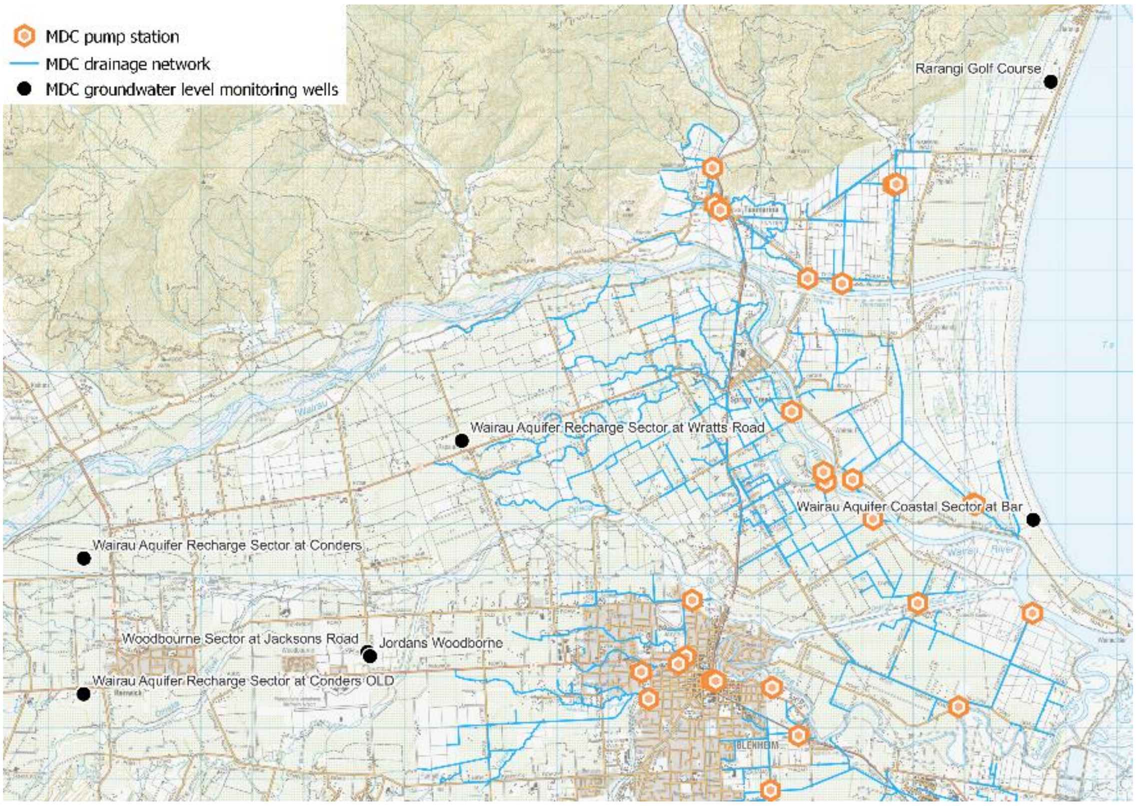

Figure 7-1 Marlborough District Council monitoring sites with provided monitoring data relative to the drainage network

Figure 7-2 through Figure 7-6 show groundwater levels from the wells in Table 7-1/Figure 7-1 with overall groundwater level trend in each well compared to piecewise linear regression plotted relative to the below significant occurrences; in other words, data for each well was fitted with a linear trendline for periods between the below events:

- WVS: (Wairau Valley Scheme) across a 15-year work programme many interventions occurred that saw changes to groundwater management and drainage including the Ruakananaka rewatering, the Wairau Diversion, and drainage improvements.
- Viticulture: The transition to viticulture commenced in 1973 but began in earnest in the 1980's through to the mid-2000's. This increased land drainage, increased water use, and decreased groundwater recharge.
- Drainage review: the 1996 drainage review saw actions to improve drainage performance.
- SVIS: (Southern Valley Irrigation Scheme) increased rewatering of Ruakanakana and increased water use.
- Drainage review: the 2015 drainage review saw actions to improve drainage performance.

Note the following interpretations do not account for all potential influencing factors. To better understand trends and drivers, additional data such as rainfall, water use, river flow, etc. should be considered alongside groundwater level.

All wells have very flashy hydrographs. Conders (Figure 7-2) appears to have a signal reflecting both river recharge and seasonal patterns. Wratts Road (Figure 7-4) signal appears to be river recharge dominated. Woodbourne (Figure 7-3), Rarangi Golf (Figure 7-5), and Coastal Bar (Figure 7-6) have a predominantly seasonal signal, with values for Coastal Bar potentially also showing tidal or pumping impacts, given proximity to both influences (Figure 7-1). The lack of sustained groundwater level recovery following events suggests little aquifer storage and rapidly moving groundwater. As the data are daily values, we do not necessarily see responses to shorter-term drivers such as tides.

Conders (Figure 7-2) and Wratts Road (Figure 7-4) wells show an overall trend of groundwater levels declining (becoming deeper) over time, except in recent years where they have had extraordinarily high (shallow) groundwater levels. The wells at Woodbourne (Figure 7-3) appear to have little net change in groundwater level across the entire record; in recent years groundwater level appears to have been becoming shallower. Coastal Bar (Figure 7-6) and Rarangi Golf (Figure 7-5) both show an overall trend of groundwater levels becoming shallower. Almost all current wells had their highest recorded groundwater level in 2022.

Figure 7-2 shows groundwater levels at Conders deepen to the early-90's, this could be driven by changes in land use and associated changes to drainage and water use. Levels increase, becoming shallower, to the mid-90's where the 1996 drainage review appears to have seen successful intervention to deepen and stabilise groundwater levels. This control appears to be further assisted by SVIS coming online. Since 2015 groundwater levels have generally become shallower, reaching their highest recorded levels in 2022.

Figure 7-3 shows groundwater levels at Woodbourne appear to become shallower until the 1996 drainage review where they deepened substantially, though this interpretation is complicated by the transition to a new monitoring well. Groundwater levels were reasonably stable until 2015, where groundwater levels have become shallower progressively since, including reaching highest recorded groundwater level in 2022.

Wratts Road is the only site that has data going back to WVS (Figure 7-4). Data appear to indicate groundwater level became shallower across the early 1960's. This could be due to WVS interventions such as the Ruakanakana rewatering increasing groundwater recharge, and so groundwater levels. Levels appear to reach equilibrium, then generally deepen from the mid-1970's through to the early-1990's. This could reflect the expansion of viticulture and the associated reduction of recharge and increase of drainage. Groundwater levels become shallower to the mid-1990's where the drainage review appears to have resulted in deepening groundwater levels, though this interpretation is complicated by the transition to a new monitoring well. Counterintuitively, the 2015 drainage review also appears to align with a trend towards groundwater levels becoming shallower, with highest recorded levels in the new Wratts Road well recorded in 2022.

Figure 7-5 show groundwater has been becoming shallower at Rarangi across the record length. Levels were largely stable, with a slight increase until approximately 2007. Groundwater level appears to be rising more quickly in recent years, with the highest recorded groundwater level in 2022.

Figure 7-6 show groundwater has been becoming slightly shallower at the Coastal Bar across the record length. There is very little response to key interventions. Unlike the other wells, groundwater levels have been relatively stable since 2015.

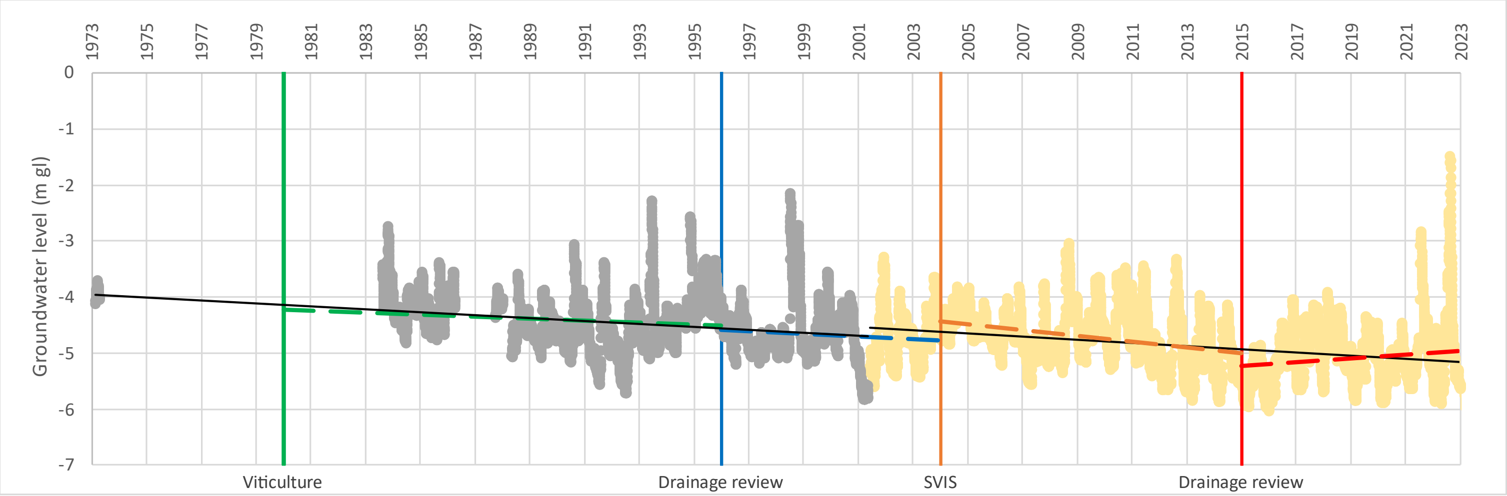

Figure 7-2 Monitoring wells P28w/0398 (grey) and P28w/3821 (yellow) at Conders data, trendline for all data (black), and colour coded significant events that could have impacted groundwater levels (vertical lines as labelled (SVIS: Southern Valleys Irrigation Scheme)), with trendlines in the same colour

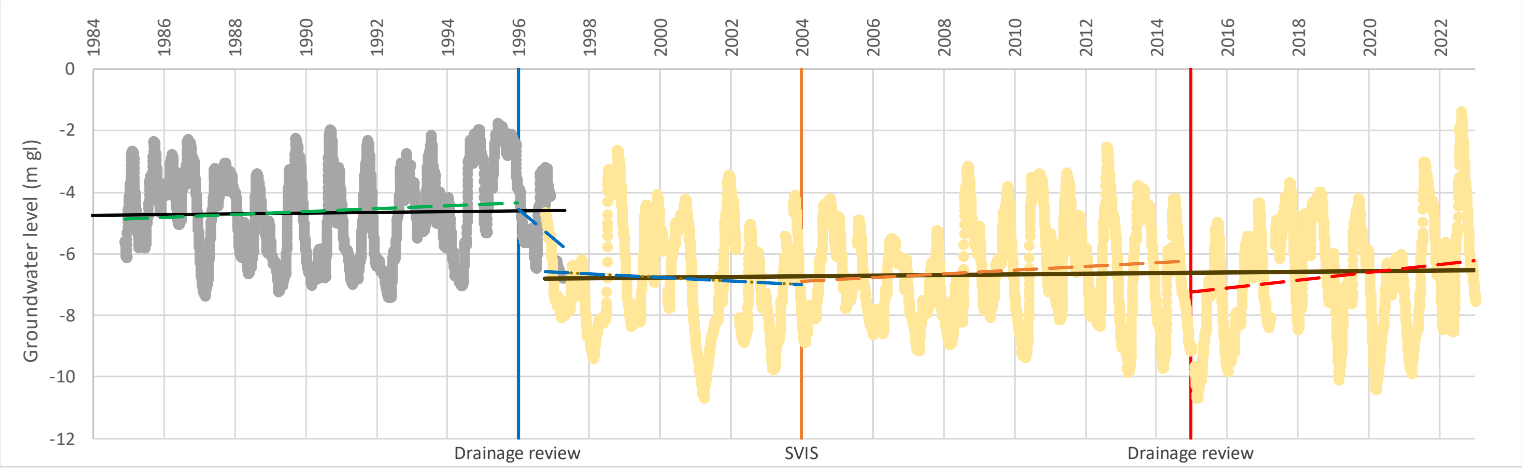

Figure 7-3 Monitoring wells P28w/0594 (grey) and P28w/3010 (yellow) at Woodbourne data, trendline for all data (black/yellow-black), and colour coded significant events that could have impacted groundwater levels (vertical lines as labelled (SVIS: Southern Valleys Irrigation Scheme)), with trendlines in the same colour

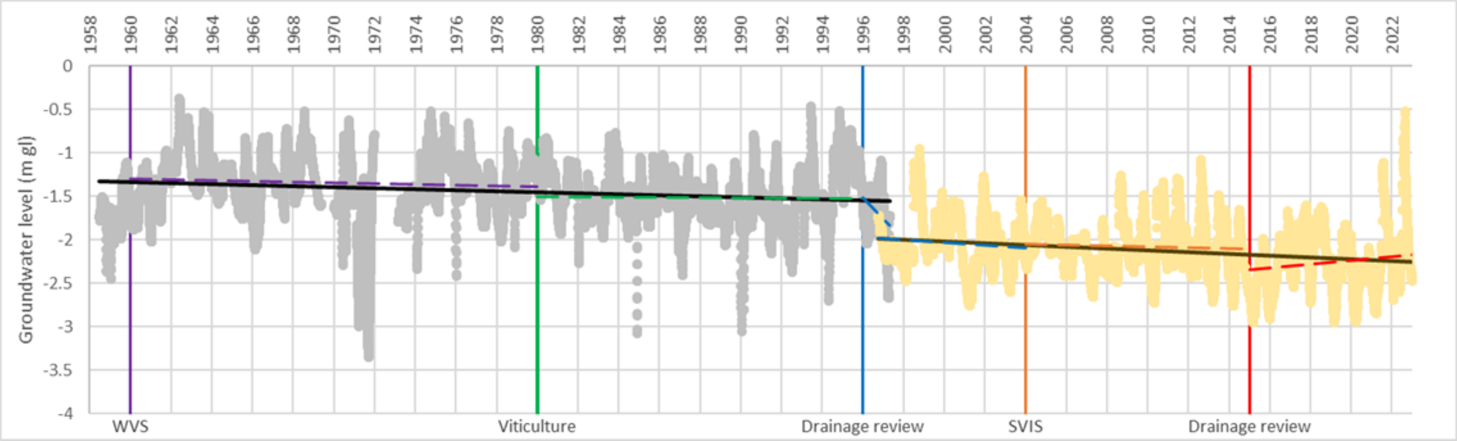

Figure 7-4 Monitoring wells P28w/0238 (grey) and P28w/3009 (yellow) at Wratts Road data, trendline for all data (black/yellow-black), and colour coded significant events that could have impacted groundwater levels (vertical lines as labelled (SVIS: Southern Valleys Irrigation Scheme)), with trendlines in the same colour

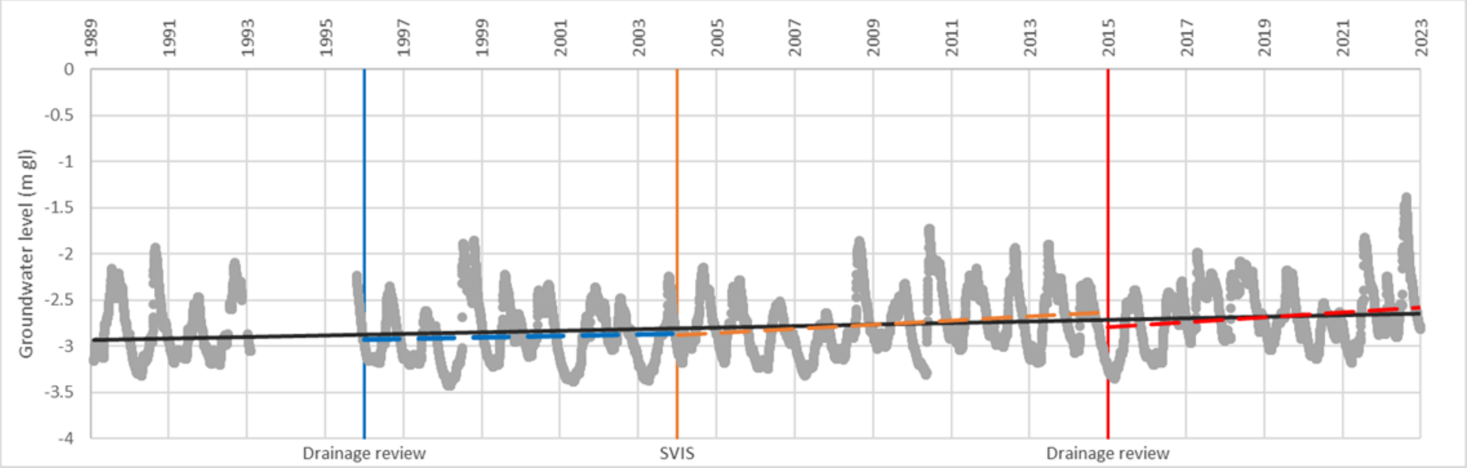

Figure 7-5 Monitoring well P28w/1901-10230 at Rarangi Golf Course data (grey), trendline for all data (black), and colour coded significant events that could have impacted groundwater levels (vertical lines as labelled (SVIS: Southern Valleys Irrigation Scheme)), with trendlines in the same colour

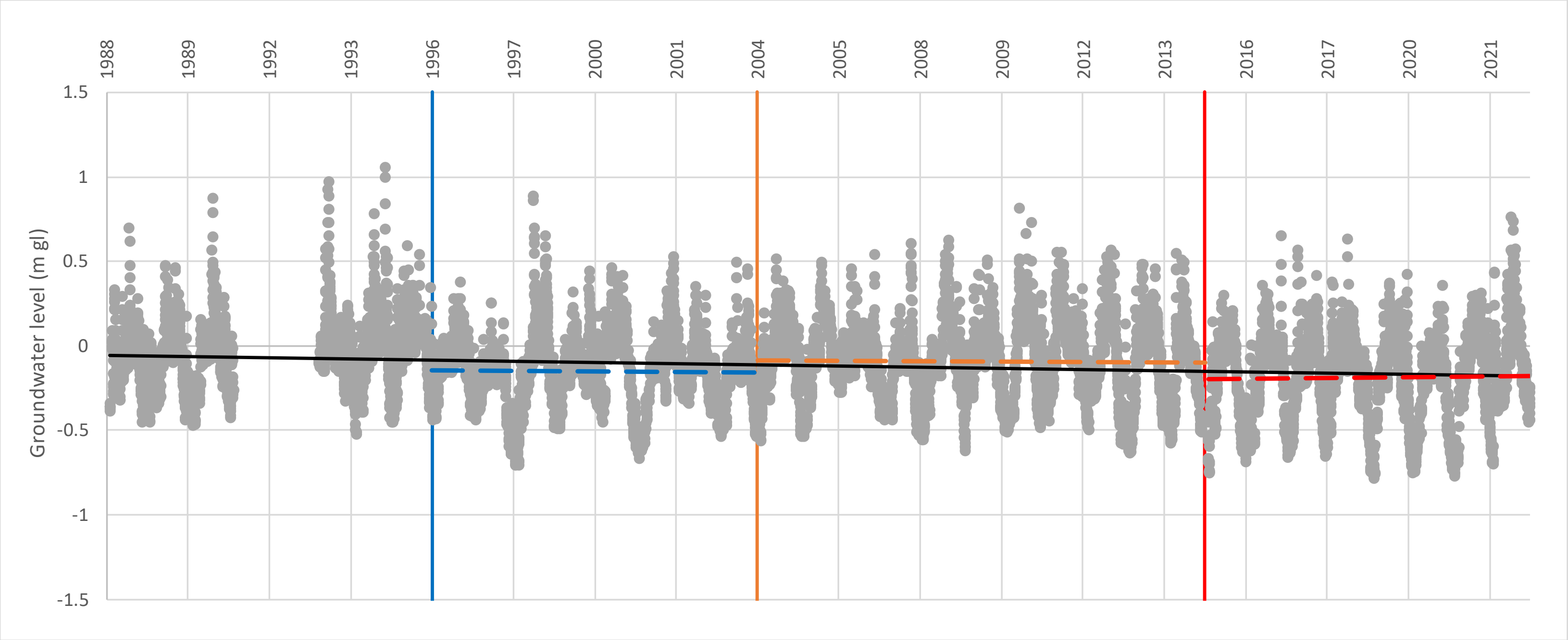

Figure 7-6 Monitoring well P28w/1733 at Coastal Bar data (grey), trendline for all data (black), and colour coded significant events that could have impacted groundwater levels (vertical lines as labelled (SVIS: Southern Valleys Irrigation Scheme)), with trendlines in the same colour

7.1 July 2022

July 2022 was Blenheim’s wettest month on record, with 220.6 mm cumulative rainfall, equivalent to 35% average annual rainfall, and 342% of July’s long-term average rainfall rate of 64.5 mm (Tomlinson, 2022). 12 July 2022 saw 65.4 mm of rainfall in 24 hours. Figure 7-7 shows the response of wells to July rainfall in the context of the calendar year, while Figure 7-8 shows July and August 2022 data. Before the July event(s), groundwater levels across most wells had begun increasing following a period of general decline. This is perhaps clearest in in the Conders data where levels went from ~8 m bgl in early June to ~6 m bgl before the 12 July event.

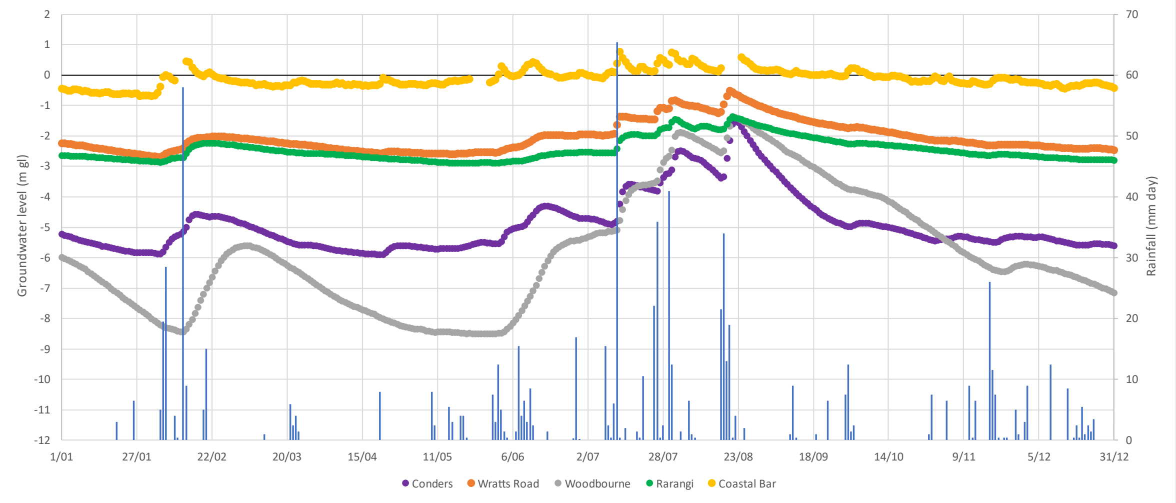

Figure 7-7 2022 Groundwater levels plotted against rainfall recorded at the Blenheim at Marlborough District Council rainfall station

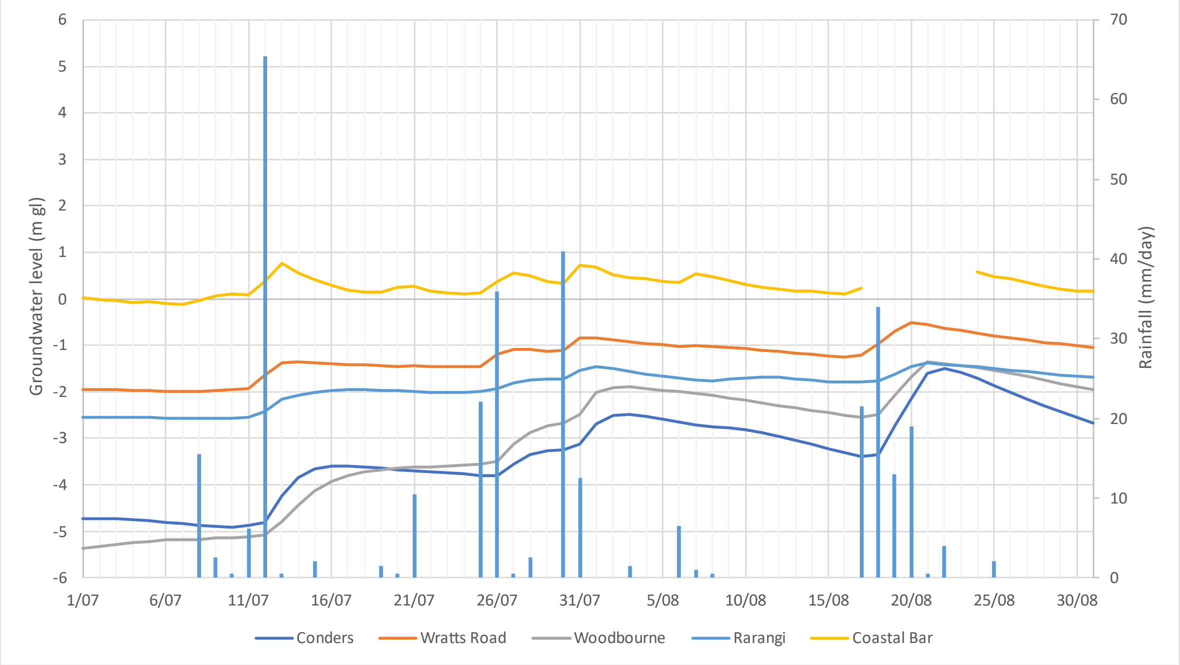

Figure 7-8 July and August 2022 Groundwater levels plotted against rainfall recorded at the Blenheim at Marlborough District Council rainfall station

Figure 7-8 shows that groundwater levels responded to rainfall on 12 July, with Conders and Woodbourne groundwater levels becoming significantly shallower from 12 July. Groundwater levels at Wratts Road, Rarangi, and Coastal Bar begun climbing on 11 July, likely in response to the cumulative rainfall the days preceding. Wells generally sustained their groundwater level increases following the 12 July event. Additional rainfall on 26 and 30 July saw additional groundwater level increases across all wells. These increases effectively "stacked" atop one another, meaning the cumulative rise in groundwater resulted in groundwater levels that were shallower than would have occurred had any one of these events happened in isolation. It also meant that elevated groundwater levels were sustained for longer than a single recharge event. Figure 7-8 shows groundwater levels were declining again until the rainfall event across 17-22 August which saw groundwater levels increase to levels similar to those that occurred in July.

The higher groundwater levels are, the more groundwater discharges to drains. The higher the groundwater baseflow in a drain, the lower the capacity of the drain to receive other inflows such as stormwater (as demonstrated in Figure 4-5). Excluding Coastal Bar, the highest groundwater levels following 12 July rainfall were reached on 20 August at Wratts Road (0.5 m bgl), 21 August at Woodbourne and Rarangi (both 1.4 m bgl), and 22 August at Conders (1.5 m bgl), 39-41 days after the rainfall event. The prolonged and repeated groundwater levels meant there was less capacity for infiltration, exacerbating and prolonging flooding. Between 12 July and 31 August, groundwater level exceeded the 95th percentile[13] 65% of the time at Coastal Bar, 35% of the time at Conders, 31% of the time at Woodbourne, and 24% of the time at Wratts Road and Rarangi. This stresses that this was a period of very high groundwater levels, limiting infiltration capacity, reducing drain capacity, and exacerbating flooding. At Coastal Bar, groundwater levels were above ground level from 9 July to 18 September; 71 continuous days. This is one of the longest periods of sustain groundwater level above ground level on record of this well. Groundwater levels were not continuously below ground level again until 8 October, 91 days since 9 July. Rarangi had groundwater levels within 1 m of ground level for 18 days across July and August. This would have resulted in significant discharges to the drainage network, meaning very limited capacity for other inflows, and so would have exacerbated flooding depth and duration.

Appendix B shows net groundwater level change across all July's for current monitoring wells, while Figure 7-9 compares July 22 trends in the target wells. This shows that before 12 July 2022 groundwater levels were generally increasing (becoming shallower) at Woodbourne, deepening at Conders and Coastal Bar, and relatively stable at Wratts Road and Rarangi. There was a significant increase in groundwater levels in these wells coinciding with the 12 July event, with groundwater levels generally sustained (except for Coastal Bar) until they increase again following the 26 and 30 July rainfall events, with measurable decline in the Conders well. Appendix B shows that though the scale of groundwater rise is not unprecedented, having repeated, significant rises that have a cumulative impact on groundwater levels across almost the entire Wairau Plain during July is unusual. Conders has deepening groundwater levels in July more often than not (19 of 36 (47%) Julys on record), while Wratts Road, Woodbourne, Rarangi, and Coastal Bar had increasing (becoming shallower) groundwater levels in July more often than not (56%, 77%, 71%, and 61% respectively). Of the 25 years with July data for all four current wells, this is the 8th time Wratts Road, Woodbourne, and Rarangi have had increasing groundwater levels in July, meaning it happens <⅓ of the time.

Figure 7-10 compares groundwater level to Wairau River discharge (Figure 7-1) across 2022. This shows that increased flows appear to coincide in increases in groundwater levels in Conders, Wratts Road, and Woodbourne wells. The similarity of response suggests they are part of the same system. This is a much more usual and expected relationship. A similar relationship is seen between Rarangi Golf Course well and stage height at Pipitea wetland (Figure 7-11) where groundwater level has a delayed and subdued response to the changes of stage height in the wetland. The similarity of response suggests they are part of the same system. Coastal Bar is the outlier, likely due to its coastal location and so tidal controls on groundwater level.

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[13] The groundwater level only exceeded 5% of the time, based on daily data to end 2021.

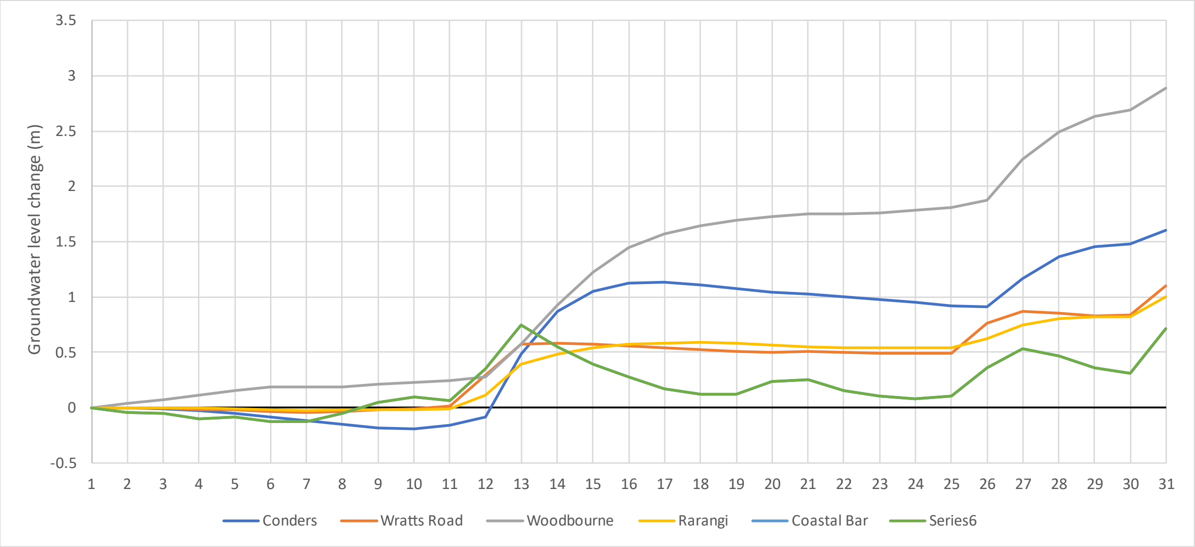

Figure 7-9 Net groundwater level change in Marlborough District Council Monitoring wells across July 2022

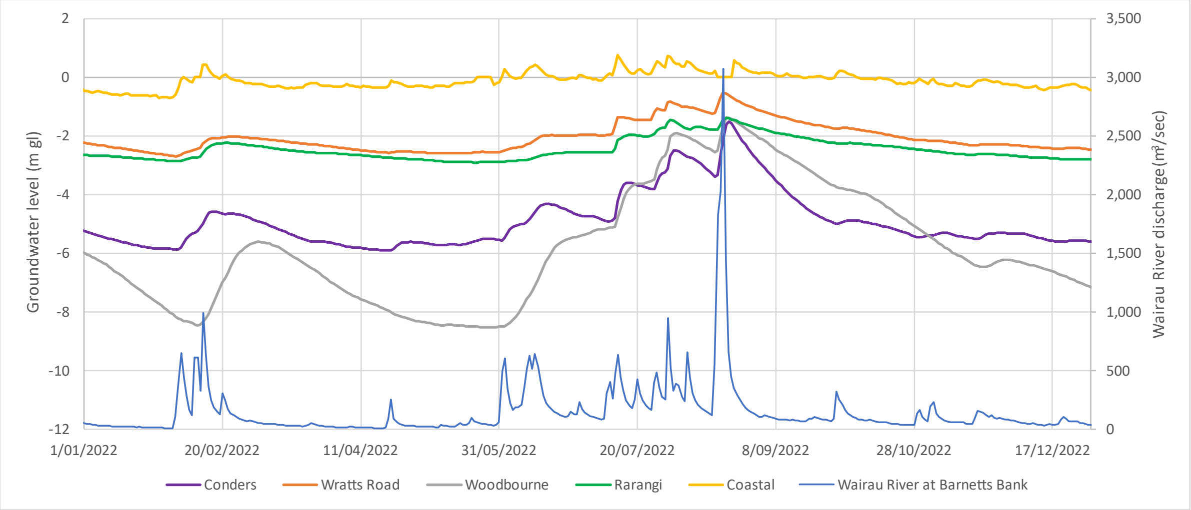

Figure 7-10 Groundwater level and Wairau River discharge in 2022

Table 7-2 compares pre-July 2022 groundwater level ranges to those observed in July 2022. This shows that though there was record rainfall, the net groundwater level increase across July was not record-setting in all cases, though it did exceed 95th percentile range in all wells. This is a significant change that would drastically impact local hydraulics and so exacerbate the scale and duration of flooding. This highlights the importance of considering other factors including (but not limited to):

- Rainfall intensity and duration. A high rainfall intensity (large volume over a short time) will see greater land surface runoff and so less opportunity for groundwater recharge and groundwater levels to increase. The same volume over a longer time gives greater opportunity for groundwater recharge and so has greater potential for groundwater level increase.
- Land use changes. The increase in vineyard area, permanent crops, and impermeable urban area, has increased soil compaction and land surface runoff compared to more “traditional” pastoral and arable land uses, meaning less potential for rainfall infiltration and groundwater recharge than may have happened had the same event happened 80 years ago.
- Groundwater level and soil saturation prior to events. High groundwater levels and soil saturation before rainfall means there is less capacity for infiltration, so groundwater levels do not respond as much as if soil saturation and groundwater levels were lower.

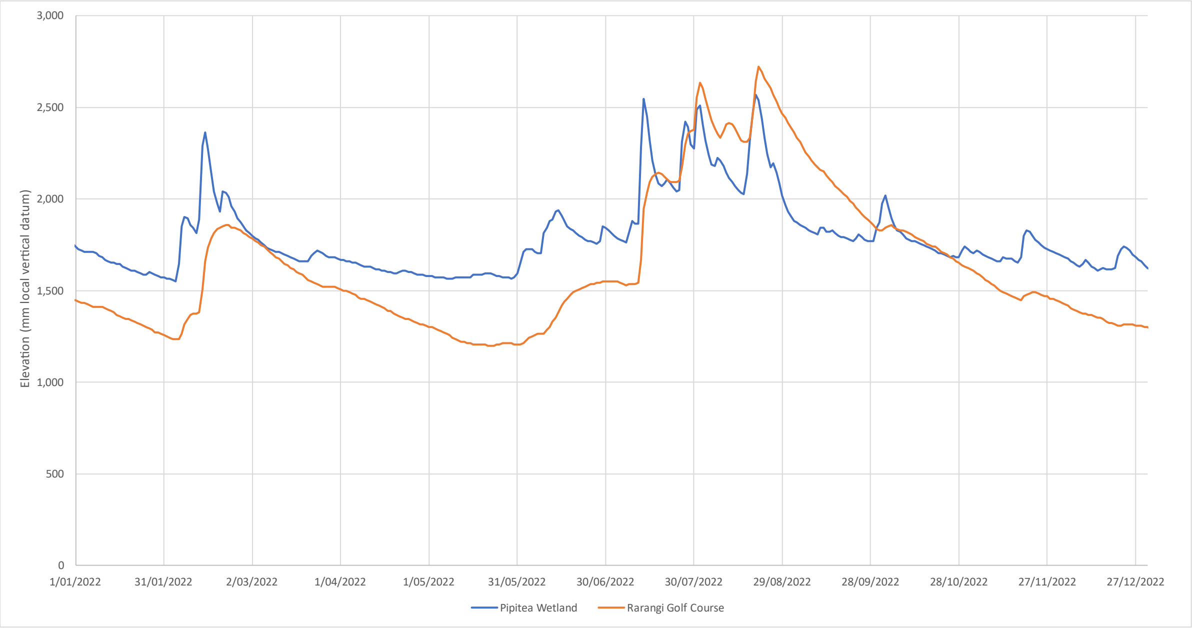

Figure 7-11 Stage height at Pipitea Wetland compared to groundwater level in Rarangi Golf Course well (~1,750 m separation) across 2022 daily data

Table 7-2 Summary of groundwater level ranges for July for each well using pre-2022 data for current wells only (i.e. if the well replaced an old one, the old data is not considered). All values in metres

Well name	Min range	5th percentile range	Average range	95th percentile range	Max range	July 2022 range	2022 range is above previous
Conders	0.27	0.27	0.68	1.12	2.05	**1.8**	95p
Wratts Road	0.06	0.10	0.32	0.93	1.00	**1.1**	Max
Woodbourne	0.11	0.20	1.05	2.79	4.50	**2.9**	95p
Coastal Bar	0.15	0.20	0.43	0.83	0.88	**0.9**	Max
Rarangi Golf Course	0.06	0.07	0.27	0.67	1.13	**1.0**	95p

7.2 Current state

Figure 7-12 through Figure 7-16 shows envelope plots for these wells to early August 2023. Envelope plots show current groundwater level against historical distribution. In all wells except Coastal Bar, August and September 2022 saw record setting high groundwater levels. The “snowballing” effect of multiple recharge events over a short time, including the intense recharge of July 2022, enabled these high levels to be reached. Had any of these events happened in isolation, or at a different time of the year (e.g. summer) the impacts on groundwater level would have been significantly more subdued, and it is unlikely these record levels would have been achieved.

There is a marked contrast between July 2022 groundwater levels (in grey) and July 2023 groundwater levels (in blue). Currently, Wairau Aquifer storage in its upper extent is “empty” as indicated by record low levels at in the Conders well (blue line, Figure 7-12), approaching “empty” at Wratts Road (Figure 7-14) and the Coastal Bar (Figure 7-16), and below median for Woodbourne and Rarangi, in direct contrast to the record high groundwater levels at the same time last year. This acutely demonstrates the limited storage and fast throughflow in the Wairau Aquifer. There is significant year-to-year variability; a year with high groundwater recharge does not bring the Wairau Aquifer back into long-term “balance”, this can only be done through shorter term management approaches.

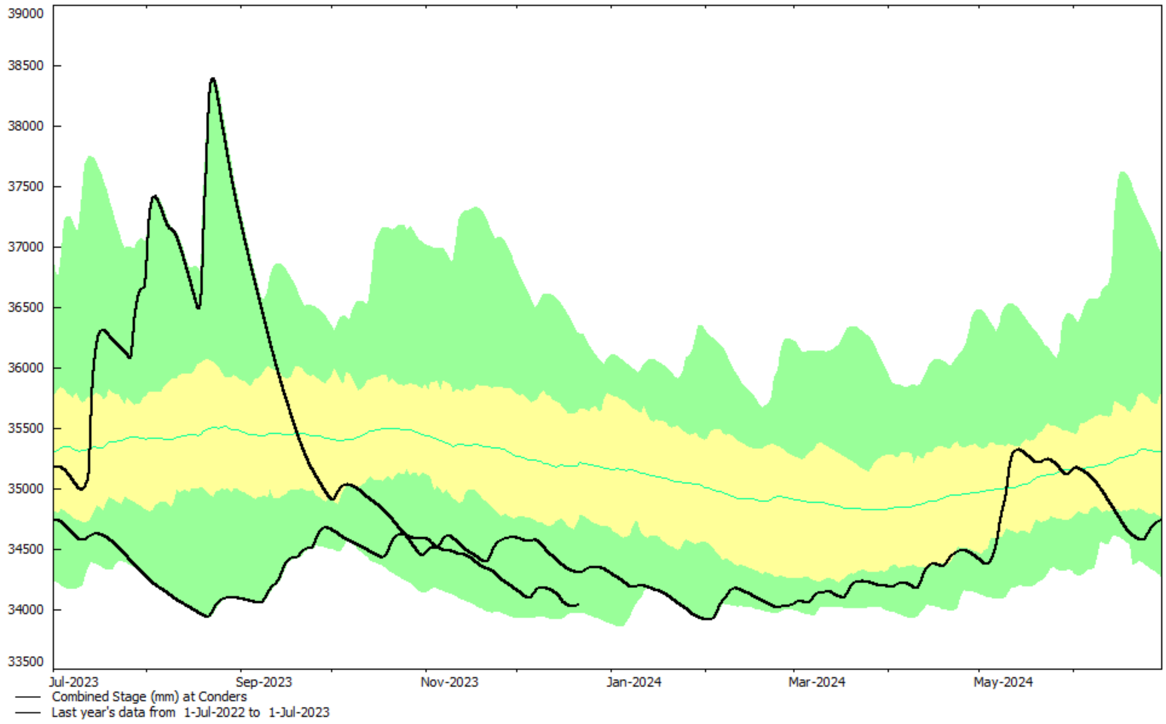

*Figure 7-12 Envelope plot of Conders well in mm local vertical datum based on continuous daily observations since 1982. Blue line: current water year groundwater level; grey line: previous water year groundwater level; green line: median groundwater level; yellow area: 60% groundwater level distribution; green area: total groundwater level distribution (**source**)*

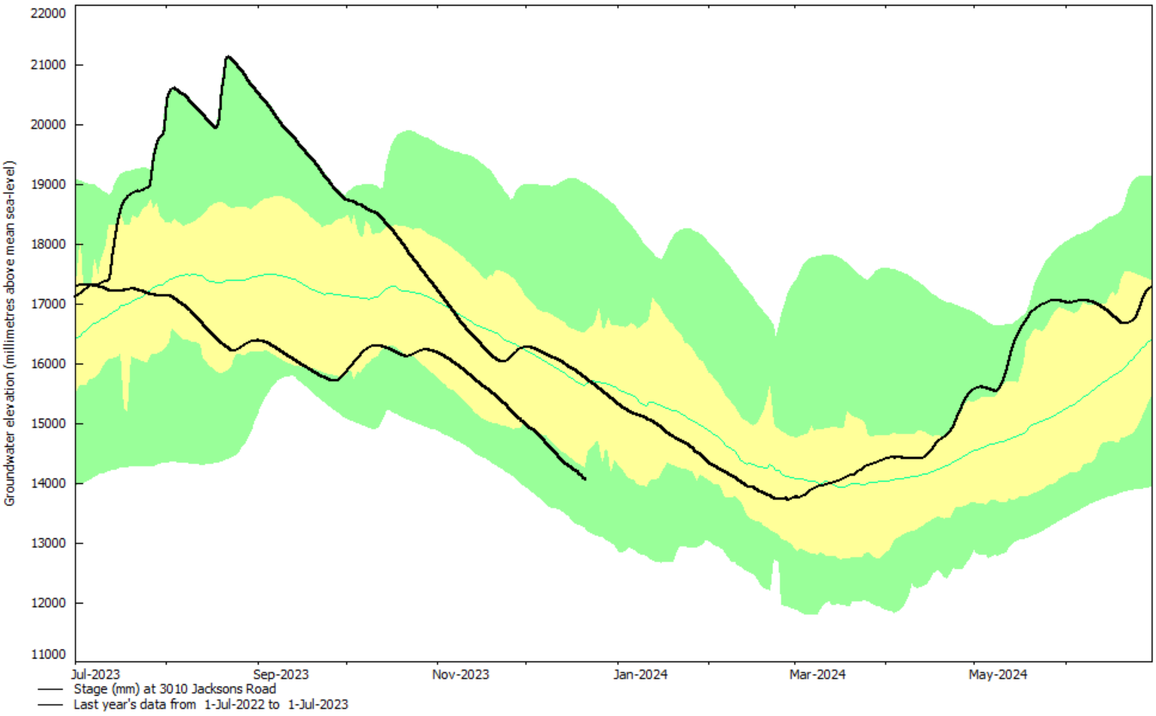

*Figure 7-13 Envelope plot of Woodbourne well in mm local vertical datum based on continuous daily observations since 1996. Blue line: current water year groundwater level; grey line: previous water year groundwater level; green line: median groundwater level; yellow area: 60% groundwater level distribution; green area: total groundwater level distribution (**source**)*

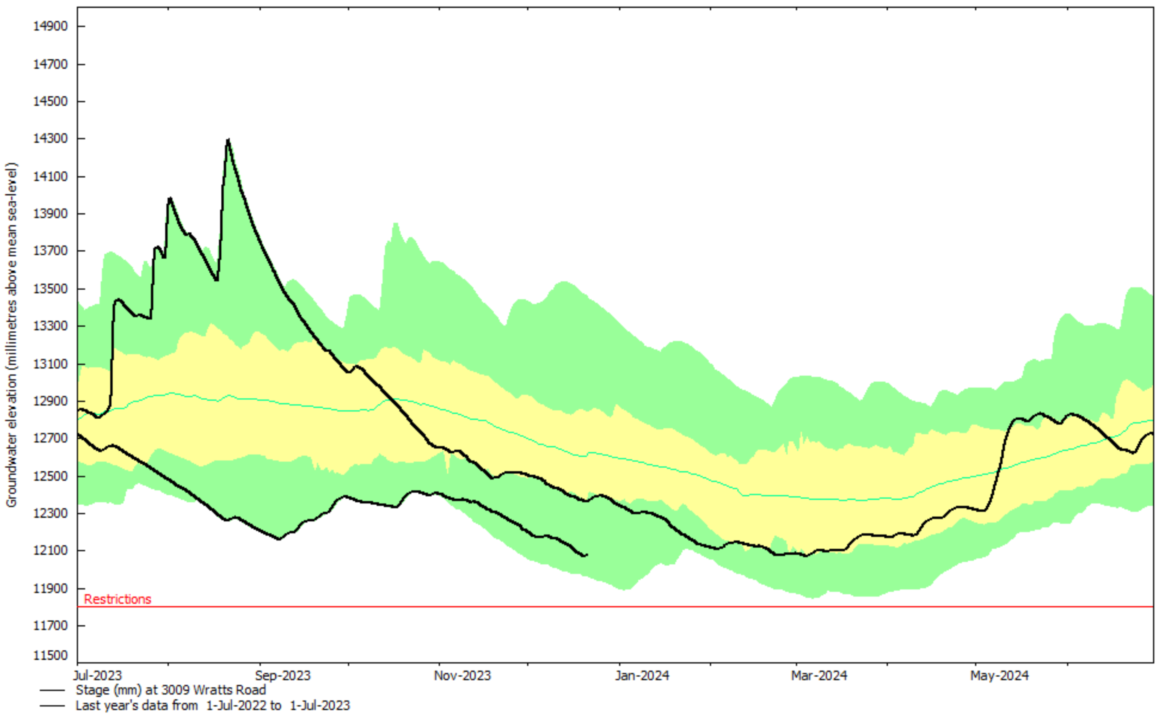

*Figure 7-14 Envelope plot of Wratts Road well in mm local vertical datum based on continuous daily observations since 1996. Blue line: current water year groundwater level; grey line: previous water year groundwater level; green line: median groundwater level; yellow area: 60% groundwater level distribution; green area: total groundwater level distribution (**source**)*

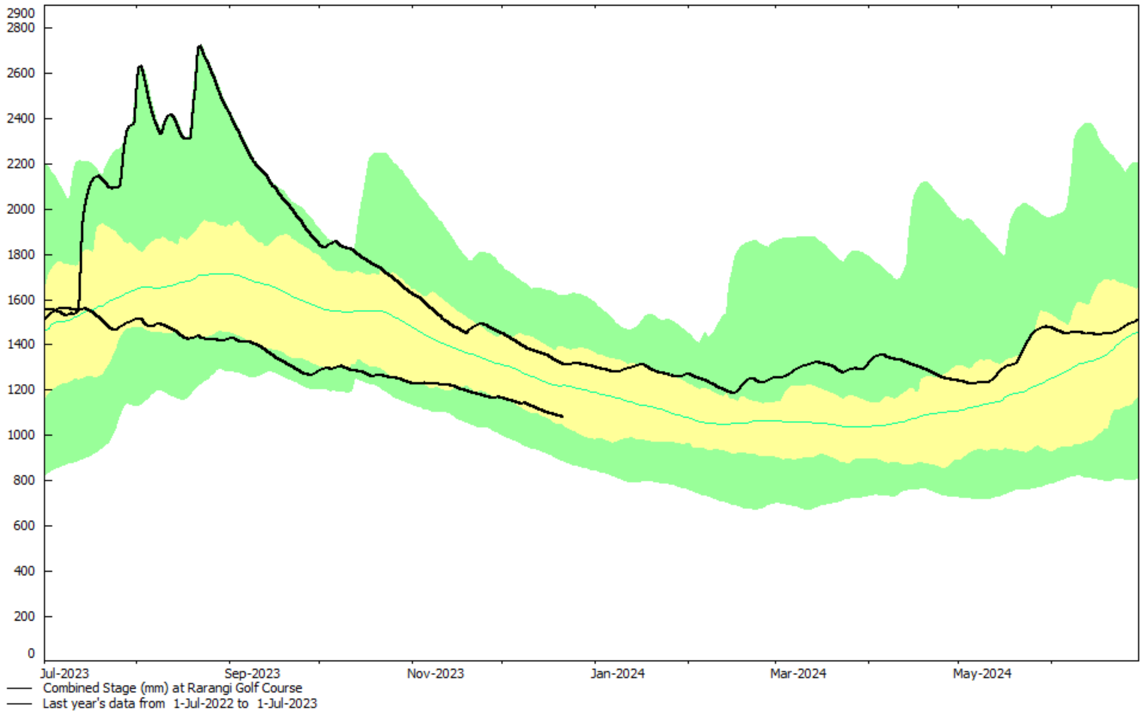

*Figure 7-15 Envelope plot of Rarangi Golf Club well in mm local vertical datum based on continuous daily observations since 1989. Blue line: current water year groundwater level; grey line: previous water year groundwater level; green line: median groundwater level; yellow area: 60% groundwater level distribution; green area: total groundwater level distribution (**source**)*

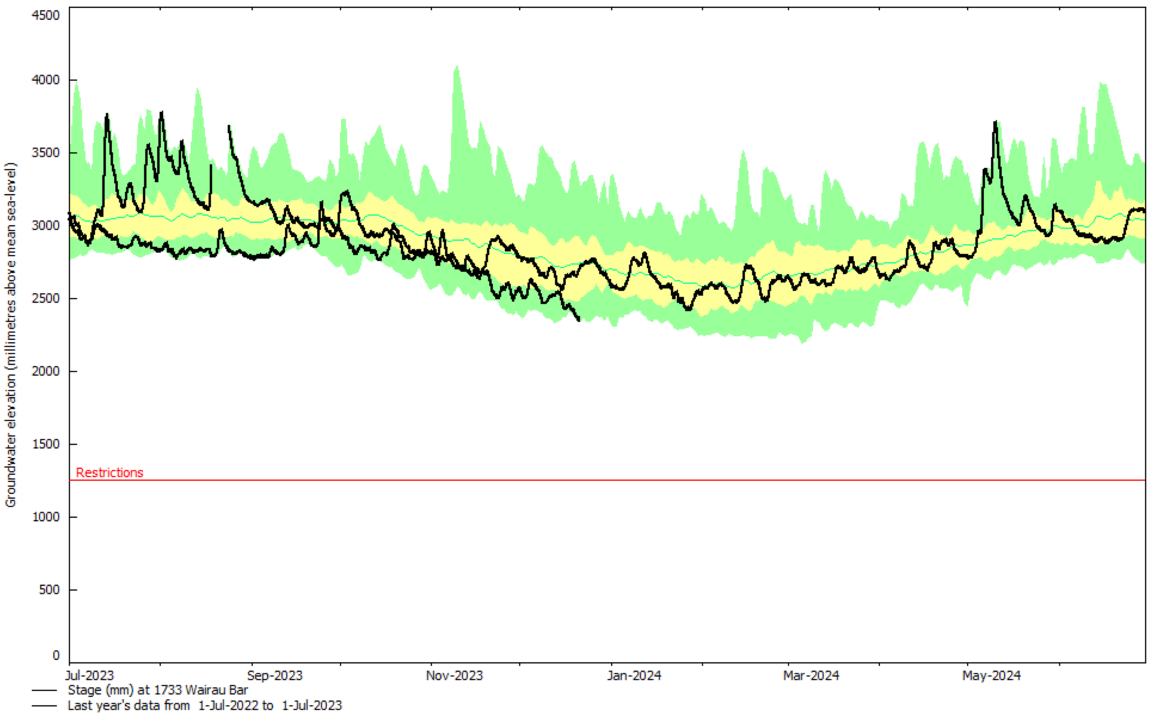

*Figure 7-16 Envelope plot of Coastal Bar well in mm local vertical datum based on continuous daily observations since 1988. Blue line: current water year groundwater level; grey line: previous water year groundwater level; green line: median groundwater level; yellow area: 60% groundwater level distribution; green area: total groundwater level distribution (**source**)*

8 SUMMARY

Section 1 introduces this report and the Wairau Plain. This report was to document the evolution of Wairau Plain land drainage and how this may have impacted groundwater levels by consulting MDC staff and reviewing provided literature. As the project commenced, the scope widened to also consider how groundwater can exacerbate risks.

Section 2 is a high-level description of groundwater of the Wairau Plain. The Wairau Aquifer is unconfined inland, becoming confined towards the coast where it is overlain by confining marine deposits and the Rarangi Shallow Aquifer. The Wairau Aquifer intersects the land surface inland of Blenheim, with the equivalent of Wairau River recharge discharging as springs from inland of Blenheim towards the coast, with discharge to land coastwards of State Highway 1 from both the confined Wairau Aquifer and unconfined Rarangi Shallow Aquifer. The Wairau Aquifer has had declining groundwater levels across the last 50 years. Land drainage has not been directly tied to changes in groundwater levels in the Wairau Aquifer but has in other aquifers.

Section 3 explores land use, drainage, and groundwater level from pre-European settlement to present. The hydrologic environment of the Wairau Plain is heavily modified to efficiently convey excess water offshore and enable desirable land uses. The flood and drainage management networks are inherently interconnected, and backflow prevention is crucial to ensuring flood flows and tides do not compromise the drainage network. River diversions and channel modifications have changed groundwater recharge regimes. The exact nature of this change is unquantified but broadly inferred in available literature, with increased groundwater recharge in some places and decreased groundwater recharge in others. The MDC drainage network is expansive, with land being drained both under gravity and via pumping. There is known to be additional privately managed drain network and tile drainage than what we have described. Drainage has evolved to exert potentially significant control over groundwater levels across the Wairau Plain to support increasingly valuable land uses. Without drainage, most of the Wairau Plain would not be able to sustain current land uses and occupation.

Section 4 describes the current MDC drainage network, based on GIS data and feedback from Bezar (2023). MDC's drainage network consists of 195 drains totalling 400 km. Most of the drainage length is permanently flowing across the confined aquifer. This suggests widespread and constant groundwater discharge. 53% of the drainage network drains under gravity, 47% of the network requires some level of pumping. MDC's drainage network has 30 pump stations, 16 facilitate rural drainage while an additional five stations facilitate rural and other drainage. Almost all pumping stations were constructed between 1957 and 1984 with most (57% or 12) constructed during WVS (1960-1975). Three stations have been constructed this century in areas of increased urban and industrial development. At least 5,313 ha of rural land benefits from pumped drainage. Roberts, Rouses, and Chaytors drain pump stations have been telemetered within the last five years though this data has not been reviewed. There are 290 culverts on the drainage network, 249 of which are flood gated to limit/prevent backflow.

Section 4 also describes the current state of knowledge regarding land use, drainage, and groundwater.

Section 5 summarises potential future conditions of land use, drainage, and groundwater based on provided literature. Sea level rise is anticipated to increase groundwater levels, spring discharge, and increase backflow along waterways. There is likely to be increased demand for pumped drainage, especially in lower-lying areas, to try and maintain BAU. Changes in rainfall pattern will likely result in increased runoff, exacerbating flooding issues. Both sea level rise and changes in rainfall pattern will likely increase pressure on MDC's drainage network.

Section 6 introduces groundwater as a potential hazard and describes how groundwater can both pose and exacerbate risk. Groundwater is dynamic but our built and engineered environments are either static or only able to tolerate "so much" change before "something has to give". Failing to account for or underestimating groundwater's influence within such restricted systems can result in consequences (or risks) ranging from nuisance (e.g. ponding on a lawn) to catastrophic (e.g. widespread economic impact).

In Section 7 we review daily groundwater level data provided by MDC against key land drainage interventions that impacted groundwater level. Inconsistent monitoring wells limited the interpretations able to be made. Interventions were able to be associated with changes in groundwater level in at least one well.

In Section 7 we also review data for July 2022, Blenheim’s wettest month on record. Groundwater levels responded within a day to repeated rainfall events across July and August, with cumulative groundwater level rises far exceeding that which could occur had rainfall events happened in isolation, with maximum groundwater levels recorded. This would have exacerbated and prolonged flooding. This is contrasted to current state data, which shows groundwater levels at or approaching their minimum highlighting the rapid movement of water through the Wairau Aquifer and the importance of effective short-term and long-term water management to best mitigate the extremes of water availability.

9 CONCLUSIONS

This report constitutes the first comprehensive description of the MDC drainage network since former Marlborough Catchment Board Chief Engineer P. A. Thomson compiled his 1987 Operational Exposition. In this respect, this report represents an invaluable resource in both documenting changes and capturing the current state of drainage on the Wairau Plain.

Though there is limited data, there is strong anecdotal evidence that land drainage has exerted significant influence over groundwater level. We compiled a timeline of changes to the Wairau Plain and described the concurrent evolution of the drainage network at a high level, including observations on the impacts of these changes to groundwater level. Anecdotal evidence is an invaluable resource to understanding the development of drainage and drainage management due to limited reporting. However there remains significant information gaps, especially relating to drainage infrastructure and interventions outside of the MDC network. Private surface drains are widespread and tile drainage is reportedly common in the upper Plain beneath vineyards.

We describe the MDC drainage network based on available information, classifying drains, describing pump stations, and understanding flood gate function. We comment on whether groundwater monitoring data indicates changes in trends based on major interventions, and how records capture July 2022 events.

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Appendix A: Marlborough District Council Managed Drains by Discharge Type and Flow Permanence

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Abbatoir Outlet	142	-	Permanently flowing	348	Riverlands	Ōpaoa River
Adams Lane	112	Gravity	Usually Dry	176	Blenheim	Taylor River
Adrians	162	Pump assisted	Usually Dry	273	Tuamarina	Wairau River
Aireys	39	Pump assisted	Ephemeral	487	Woolley & Jones	Lower Wairau River
Alabama Road	135	Pump assisted	Permanently flowing	1,045	Riverlands	Upper Lagoon
Aubreys	37	Pump assisted	Usually Dry	484	Woolley & Jones	Roses Overflow
Awarua Park	72	Pump assisted	Ephemeral	449	Grovetown	Lower Wairau River
Barnetts Creek	42	Pump assisted	Ephemeral	845	Tuamarina	Wairau River
Bells Rd No 1	118	Gravity	Permanently flowing	507	Doctors	Taylor River
Bells Rd No 2	119	Gravity	Permanently flowing	242	Doctors	Taylor River
Blind Creek	17	Pumped	Permanently flowing	5,325	Pembers	Wairau Diversion
Blind Rd	18	Pump assisted	Usually Dry	705	Pembers	Wairau Diversion
Boundary Drain	169	Pumped	Ephemeral	793	Swamp Road	Ōpaoa River
Bowns Creek	53	Gravity	Permanently flowing	985	Spring Creek	Wairau River
Bruces	27	Pump assisted	Permanently flowing	400	Pembers	Wairau Diversion
Bullets Drain	182	Gravity	Ephemeral	794	Spring Creek	Lower Wairau River
Byrnes	172	Pumped	Ephemeral	329	Swamp Road	Ōpaoa River
Camerons Creek	125	Gravity	Permanently flowing	1,045	Doctors	Taylor River
Campbells	191	Pumped	Ephemeral	310	Woolley & Jones	Roses Overflow
Caseys Drain A	106	Pump assisted	Permanently flowing	2,535	Blenheim	Ōpaoa River
Caseys Drain B	107	Pump assisted	Ephemeral	1,207	Blenheim	Ōpaoa River
Chaytors Pump	12	Pumped	Permanently flowing	200	Wairau Pa	Lower Wairau River
Chinamans Drain	105	Gravity	Permanently flowing	164	Blenheim	Taylor River
Cloudy Bay	198	Gravity	Permanently flowing	521	Riverlands	Upper Lagoon
Cobb Cottage Drain	184	Gravity	Ephemeral	492	Riverlands	Upper Lagoon
Connollys Rd	13	Pump assisted	Ephemeral	493	Wairau Pa	Lower Wairau River
Cooper & Morrison	111	Pump assisted	Usually Dry	544	Blenheim	Ōpaoa River
Corrys Outlet	15	Gravity	Permanently flowing	100	Wairau Pa	Lower Wairau River

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Cow Creek	43	Gravity	Permanently flowing	1,370	Tuamarina	Wairau River
Cravens Creek	52	Gravity	Permanently flowing	1,758	Spring Creek	Wairau River
Cresswells	5	Gravity	Usually Dry	400	Wairau Pa	Lower Wairau River
David St	126	Gravity	Permanently flowing	98	Doctors	Taylor River
De Castros	134	Pump assisted	Usually Dry	605	Riverlands	Ōpaoa River
Dentons Creek	57	Gravity	Permanently flowing	1,276	Spring Creek	Lower Wairau River
Dicks Drain	6	Pump assisted	Permanently flowing	1,170	Wairau Pa	Lower Wairau River
Dillons Point	173	Pumped	Ephemeral	737	Swamp Road	Ōpaoa River
Doctors Creek	115	Gravity	Permanently flowing	3,957	Doctors	Taylor River
Dodsons	187	Pump assisted	Ephemeral	420	Grovetown	Lower Wairau River
Dooles	31	Pump assisted	Ephemeral	533	Pembers	Wairau Diversion
Douglas No 2	117	Gravity	Permanently flowing	245	Doctors	Taylor River
Dowlings Creek	154	Gravity	Permanently flowing	2,928	Grovetown	Ōpaoa River
Dr A	83	Pumped	Permanently flowing	1,086	Grovetown	Lower Wairau River
Dr B	70	Pump assisted	Permanently flowing	313	Grovetown	Lower Wairau River
Dr C	86	Pump assisted	Permanently flowing	1,005	Grovetown	Lower Wairau River
Dr C 1	87	Pump assisted	Usually Dry	160	Grovetown	Lower Wairau River
Dr D	88	Pump assisted	Permanently flowing	1,410	Grovetown	Lower Wairau River
Dr D 1	89	Pump assisted	Usually Dry	184	Grovetown	Lower Wairau River
Dr D 2	90	Pump assisted	Ephemeral	442	Grovetown	Lower Wairau River
Dr Evans	30	Pump assisted	Usually Dry	859	Pembers	Wairau Diversion
Dr F	92	Pump assisted	Ephemeral	1,634	Grovetown	Lower Wairau River
Dr G	93	Pump assisted	Ephemeral	820	Grovetown	Lower Wairau River
Dr H	94	Pump assisted	Permanently flowing	749	Grovetown	Lower Wairau River
Dr H 1	95	Pump assisted	Ephemeral	725	Woolley & Jones	Lower Wairau River
Dr H 2	97	Pump assisted	Ephemeral	401	Grovetown	Lower Wairau River
Dr I	96	Pump assisted	Ephemeral	915	Grovetown	Lower Wairau River
Dr J	104	Pump assisted	Permanently flowing	600	Grovetown	Lower Wairau River
Dr K	98	Pump assisted	Permanently flowing	785	Grovetown	Lower Wairau River
Dr M	99	Pump assisted	Permanently flowing	1,045	Grovetown	Lower Wairau River

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Dr N	78	Pump assisted	Permanently flowing	3,655	Grovetown	Lower Wairau River
Dr N 1	79	Gravity	Permanently flowing	409	Grovetown	Lower Wairau River
Dr N 2	91	Pump assisted	Ephemeral	886	Grovetown	Lower Wairau River
Dr N Extn	179	Pump assisted	Ephemeral	310	Grovetown	Lower Wairau River
Dr O	69	Pump assisted	Permanently flowing	5,322	Grovetown	Lower Wairau River
Dr O 1	102	Pump assisted	Ephemeral	326	Grovetown	Lower Wairau River
Dr P	71	Gravity	Permanently flowing	240	Grovetown	Lower Wairau River
Dr Q	80	Pump assisted	Permanently flowing	768	Grovetown	Lower Wairau River
Dr R	81	Pump assisted	Permanently flowing	1,210	Grovetown	Lower Wairau River
Dr S	100	Pump assisted	Ephemeral	605	Grovetown	Lower Wairau River
Dr V	101	Pump assisted	Usually Dry	565	Grovetown	Lower Wairau River
Dr W	75	Gravity	Ephemeral	390	Grovetown	Lower Wairau River
Dr W extn	146	Gravity	Usually Dry	404	Grovetown	Lower Wairau River
Dr X	76	Pump assisted	Permanently flowing	649	Grovetown	Lower Wairau River
Dr Y	77	Pump assisted	Permanently flowing	847	Grovetown	Lower Wairau River
Dr Z	82	Pump assisted	Permanently flowing	518	Grovetown	Lower Wairau River
Dungys	155	Pump assisted	Permanently flowing	458	Riverlands	Upper Lagoon
Dunkinsons Creek	3	Gravity	Permanently flowing	2,010	Wairau Pa	Lower Wairau River
Eyles	49	Pumped	Ephemeral	1,161	Swamp Road	Ōpaoa River
Fairhall Co-op	116	Gravity	Permanently flowing	2,255	Doctors	Taylor River
Fairhall School Creek	127	Gravity	Permanently Flowing	845	Doctors	Taylor River
Flat Lands	188	Pumped	Ephemeral	423	Riverlands	Upper Lagoon
Footes	54	Gravity	Permanently flowing	905	Spring Creek	Wairau River
Frosts	48	Pumped	Permanently flowing	2,112	Swamp Road	Ōpaoa River
Fultons Creek	108	Gravity	Ephemeral	4,104	Blenheim	Taylor River
Fultons Creek West Arm	164	Gravity	Permanently flowing	289	Blenheim	Taylor River
Ganes Creek	56	Gravity	Permanently flowing	1,100	Spring Creek	Lower Wairau River
Garths	170	Pumped	Ephemeral	462	Swamp Road	Ōpaoa River
Giesens	144	Pumped	Usually Dry	458	Swamp Road	Ōpaoa River
Giffords Creek	60	Gravity	Ephemeral	2,808	Spring Creek	Lower Wairau River
Glovers	38	Pumped	Usually Dry	730	Woolley & Jones	Roses Overflow

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Golf Course Creek	120	Gravity	Permanently flowing	2,096	Doctors	Taylor River
Gundys	28	Pump assisted	Usually Dry	563	Pembers	Wairau Diversion
Halls Creek	152	Gravity	Permanently flowing	540	Spring Creek	Lower Wairau River
Harris Drain	165	Gravity	Ephemeral	172	Wairau Pa	Lower Wairau River
Harvey Rices	139	Gravity	Permanently flowing	2,736	Riverlands	Upper Lagoon
Hastilows Creek	41	Pump assisted	Permanently flowing	2,115	Tuamarina	Wairau River
Hill	22	Pumped	Permanently flowing	592	Pembers	Wairau Diversion
Hillocks Rd Drain	183	Gravity	Ephemeral	910	Spring Creek	Lower Wairau River
Hocquards	132	Gravity	Usually Dry	750	Riverlands	Ōpaoa River
Hoddies	176	Pump assisted	Ephemeral	529	Grovetown	Lower Wairau River
Hollis Creek	61	Gravity	Permanently flowing	1,780	Spring Creek	Lower Wairau River
Hollow	166	Gravity	Ephemeral	217	Wairau Pa	Lower Wairau River
Hunters Rd	19	Pump assisted	Permanently flowing	1,468	Pembers	Wairau Diversion
Industrial Drain	137	Gravity	Permanently flowing	750	Riverlands	Upper Lagoon
James Culvert	190	Pump assisted	Ephemeral	25	Riverlands	Ōpaoa River
Jeffries	47	Pumped	Permanently flowing	1,930	Swamp Road	Ōpaoa River
Jeffries Extn	171	Pumped	Usually Dry	712	Swamp Road	Ōpaoa River
Jims Drain	202	Pumped	Ephemeral	572	Riverlands	Upper Lagoon
Jones Rd	33	Pump assisted	Usually Dry	724	Woolley & Jones	Lower Wairau River
Kennedys	63	Pump assisted	Permanently flowing	1,770	Grovetown	Lower Wairau River
Kennedys Extn	156	Pump assisted	Permanently flowing	284	Grovetown	Lower Wairau River
Larges	200	Gravity	Usually Dry	400	Spring Creek	Lower Wairau River
Lower Wairau	34	Pumped	Permanently flowing	2,815	Woolley & Jones	Roses Overflow
Lower Wairau Pump	35	Pumped	Permanently flowing	320	Woolley & Jones	Roses Overflow
Mapps Waterway	130	Gravity	Usually Dry	2,164	Riverlands	Upper Lagoon
Marris Creek	151	Gravity	Permanently flowing	1,900	Spring Creek	Wairau River
Marukoko	11	Pump assisted	Permanently flowing	3,015	Wairau Pa	Lower Wairau River
Mills & Ford	180	Pump assisted	Ephemeral	302	Grovetown	Lower Wairau River
Miltons Drain	177	Pump assisted	Ephemeral	290	Grovetown	Lower Wairau River
Moorlands Outlet	192	Gravity	Permanently flowing	289	Swamp Road	Ōpaoa River
Morgans Rd	168	Pumped	Ephemeral	396	Swamp Road	Ōpaoa River

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Morrisons	121	Pump assisted	Permanently flowing	512	Doctors	Taylor River
Murphys Creek	109	Gravity	Permanently flowing	2,090	Blenheim	Taylor River
Murrays Rd Sth	85	Gravity	Usually Dry	296	Grovetown	Lower Wairau River
Murrays Road E	74	Gravity	Usually Dry	800	Grovetown	Lower Wairau River
Murrays Road W	73	Gravity	Permanently flowing	820	Grovetown	Lower Wairau River
Neals Drain	174	Pumped	Permanently flowing	869	Swamp Road	Ōpaoa River
No Name	196	-	-	270	Riverlands	Upper Lagoon
Nursery Drain	194	Pumped	Ephemeral	481	Swamp Road	Ōpaoa River
Old Fairhall Creek	122	Gravity	Permanently flowing	4,504	Doctors	Taylor River
Old Renwick Rd	110	Pump assisted	Usually Dry	645	Blenheim	Ōpaoa River
O'Regans	178	Pump assisted	Ephemeral	361	Grovetown	Lower Wairau River
Osgoods	124	Gravity	Ephemeral	204	Doctors	Taylor River
Pa Drain	7	Pump assisted	Permanently flowing	610	Wairau Pa	Lower Wairau River
Parkes Bros Drain	161	Pump assisted	Permanently flowing	1,207	Tuamarina	Wairau River
Parkes Drain	44	Pump assisted	Ephemeral	1,014	Tuamarina	Wairau River
Pembers Rd	20	Pumped	Permanently flowing	1,608	Pembers	Wairau Diversion
Peters	26	Pump assisted	Usually Dry	121	Pembers	Wairau Diversion
Pickerings	21	Pumped	Permanently flowing	1,591	Pembers	Wairau Diversion
Pipitea Creek	14	Gravity	Permanently flowing	1,625	Wairau Pa	Lower Wairau River
Polo Field	186	Pump assisted	Permanently flowing	323	Riverlands	Upper Lagoon
Pukaka	10	Pump assisted	Permanently flowing	1,951	Wairau Pa	Lower Wairau River
Pukaka Pondage	29	Pumped	Permanently flowing	733	Pembers	Wairau Diversion
Pukaka Stream	25	Gravity	Permanently flowing	2,736	Pembers	Wairau Diversion
Pukematai	195	Gravity	Permanently flowing	613	Wairau Pa	Lower Wairau River
Quarry Drain	23	Gravity	Permanently flowing	668	Pembers	Wairau Diversion
Railway	133	Pump assisted	Usually Dry	304	Riverlands	Ōpaoa River
Rapuara Rd	58	Gravity	Ephemeral	565	Spring Creek	Lower Wairau River
Rarangi Rd	2	Gravity	Usually Dry	548	Wairau Pa	Lower Wairau River
Rarangi Rd Nth	149	Gravity	Ephemeral	500	Pembers	Wairau Diversion
Rays Drain	175	Pumped	Ephemeral	440	Woolley & Jones	Roses Overflow
Rileys	136	Pump assisted	Permanently flowing	725	Riverlands	Upper Lagoon

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Riverlands Co-op	128	Gravity	Permanently flowing	8,886	Riverlands	Upper Lagoon
Riverlands Industrial	140	Gravity	Permanently flowing	5,120	Riverlands	Upper Lagoon
Roberts Drain	9	Pump assisted	Permanently flowing	1,460	Wairau Pa	Lower Wairau River
Roberts Outlet Drain	8	Gravity	Permanently flowing	339	Wairau Pa	Lower Wairau River
Roses Creek	55	Gravity	Permanently flowing	3,802	Spring Creek	Lower Wairau River
Sadds	84	Pump assisted	Permanently flowing	1,408	Grovetown	Lower Wairau River
Sadds East	159	Pump assisted	Permanently flowing	225	Grovetown	Lower Wairau River
Sandhills Outlet	129	Gravity	Permanently flowing	845	Riverlands	Ōpaoa River
SH No 1	143	Gravity	Usually Dry	708	Pembers	Wairau River
Smith & Dicks	4	Gravity	Permanently flowing	705	Wairau Pa	Lower Wairau River
Snowdens	138	Gravity	Ephemeral	905	Riverlands	Ōpaoa River
Spring Creek	0	Gravity	Permanently flowing	11,732	Spring Creek	Lower Wairau River
Spring Creek Res East	65	Gravity	Permanently flowing	251	Spring Creek	Lower Wairau River
Spring Creek Res West	66	Gravity	Permanently flowing	250	Spring Creek	Lower Wairau River
Staces	103	Gravity	Permanently flowing	360	Grovetown	Lower Wairau River
Steves Drain	203	Gravity	Ephemeral	167	Riverlands	Ōpaoa River
Stringers	193	Pumped	Ephemeral	683	Swamp Road	Ōpaoa River
Stuart St	189	Pump assisted	Ephemeral	462	Riverlands	Ōpaoa River
Sutherlands	36	Pumped	Usually Dry	489	Woolley & Jones	Roses Overflow
Swamp Rd	46	Pumped	Permanently flowing	2,515	Swamp Road	Ōpaoa River
Thomas Rd	24	Pump assisted	Permanently flowing	1,850	Pembers	Wairau Diversion
Thomas Rd Sth	157	Pump assisted	Ephemeral	577	Pembers	Wairau Diversion
Town Abattoir Branch	142	Pump assisted	Permanently flowing	720	Riverlands	Ōpaoa River
Town Branch	131	Pump assisted	Permanently flowing	2,055	Riverlands	Upper Lagoon
Township Drain	16	Pump assisted	Ephemeral	867	Pembers	Wairau Diversion
Upper Dentons	181	Gravity	Permanently flowing	630	Spring Creek	Lower Wairau River
Upper Dillons 1	50	Pump assisted	Usually Dry	508	Swamp Road	Ōpaoa River
Upper Dillons 2	51	Pump assisted	Usually Dry	827	Swamp Road	Ōpaoa River
Upper Harvey Rices	185	Pumped	Ephemeral	374	Riverlands	Upper Lagoon
Vickerman St	167	Pumped	Ephemeral	630	Swamp Road	Ōpaoa River
Wakefield St	148	Pump assisted	Usually Dry	850	Tuamarina	Wairau River
Wakefield St West	160	Pump assisted	Ephemeral	155	Tuamarina	Wairau River

Name	Drain Number	Outlet Type	Flow Regime	Drain Length (m)	Drainage Catchment	Discharges To
Wallace Overflow	67	Pump assisted	Permanently flowing	164	Grovetown	Lower Wairau River
Wallaces	62	Pump assisted	Permanently flowing	1,208	Grovetown	Lower Wairau River
Waterfall Creek	40	Gravity	Permanently flowing	1,410	Tuamarina	Wairau River
Waterlea Creek North	163	Pump assisted	Permanently flowing	333	Blenheim	Taylor River
Waterlea Racecourse Creek	147	Pump assisted	Permanently flowing	1,140	Blenheim	Taylor River
Wells Drain	1	Gravity	Permanently flowing	1,163	Wairau Pa	Lower Wairau River
Wells Extn	215	Gravity	Usually Dry	205	Wairau Pa	Lower Wairau River
Whites Drain	64	Gravity	Usually Dry	1,220	Spring Creek	Lower Wairau River
Whites Drain East	158	Gravity	Permanently flowing	372	Spring Creek	Lower Wairau River
Willies Drain	197	Pumped	Ephemeral	435	Riverlands	Upper Lagoon
Woolley & Jones	32	Pump assisted	Permanently flowing	2,462	Woolley & Jones	Lower Wairau River
Yelverton	123	Gravity	Ephemeral	849	Doctors	Taylor River

Appendix B: July Groundwater Level Change Plots

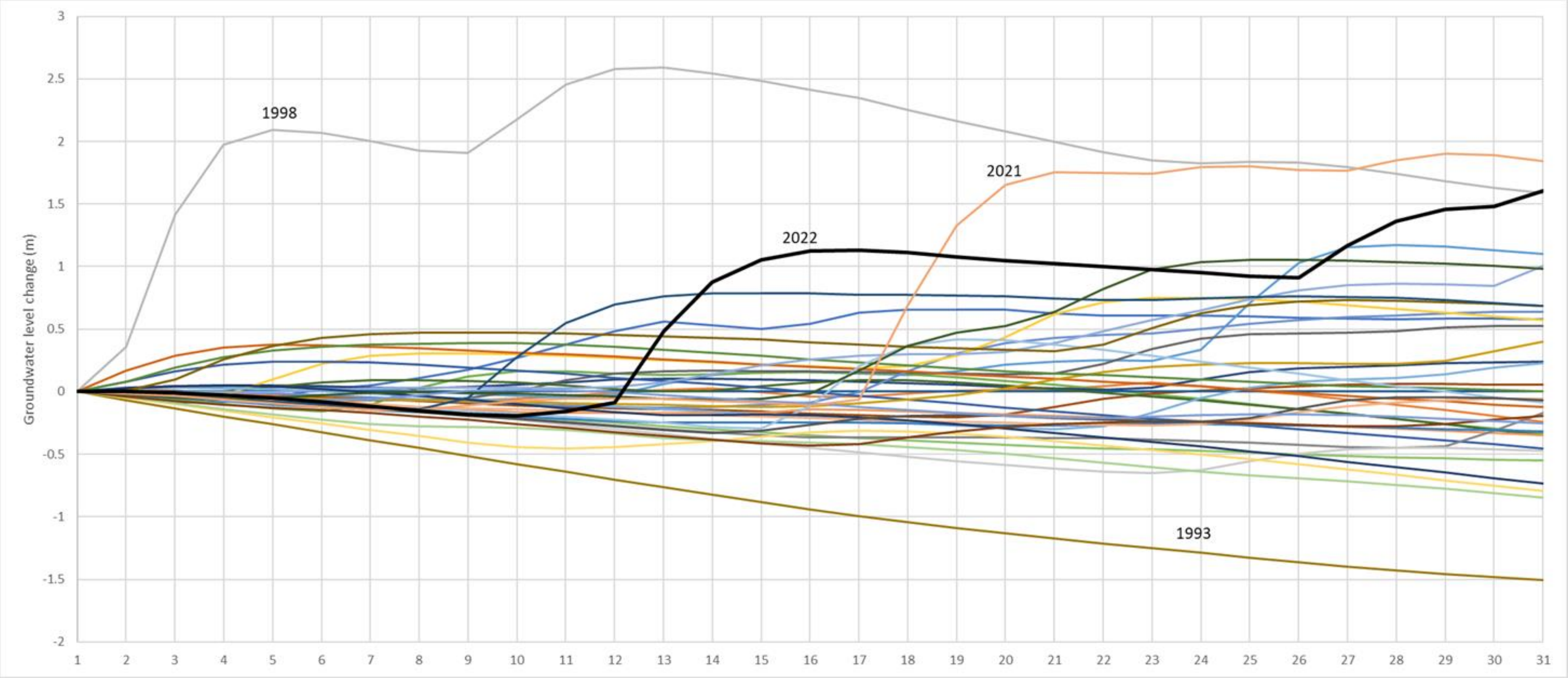

Figure 10-1 Groundwater level change across July by year at Conders

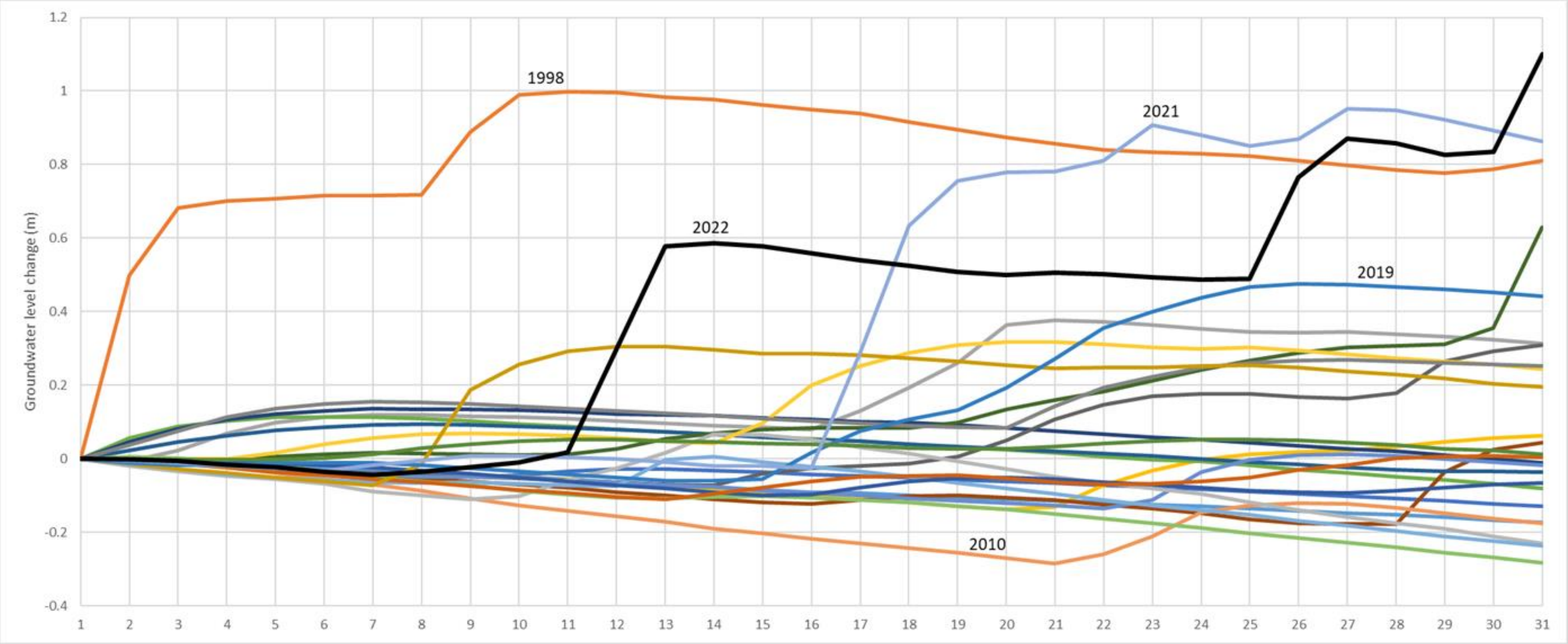

Figure 10-2 Groundwater level change across July by year at Wratts Road (current well only)

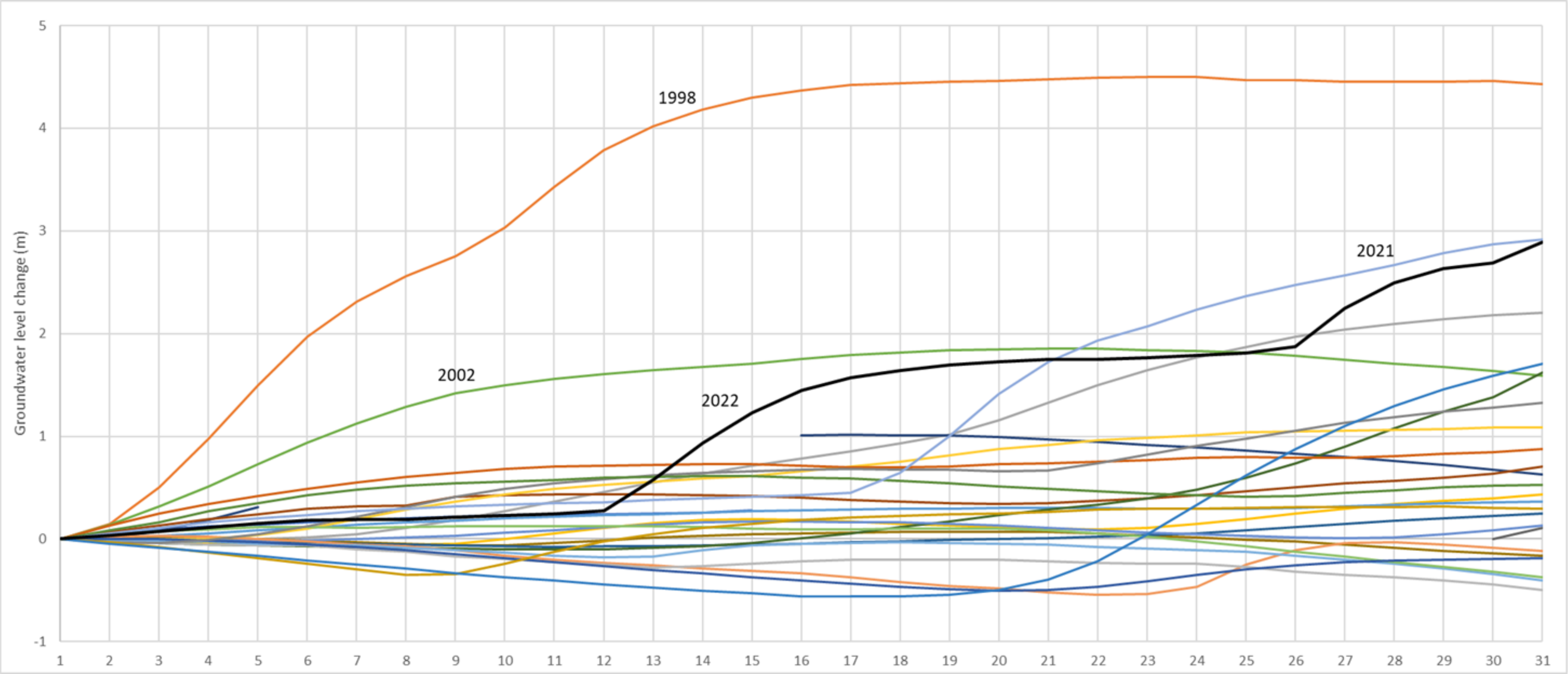

Figure 10-3 Groundwater level change across July by year at Woodbourne (current well only)

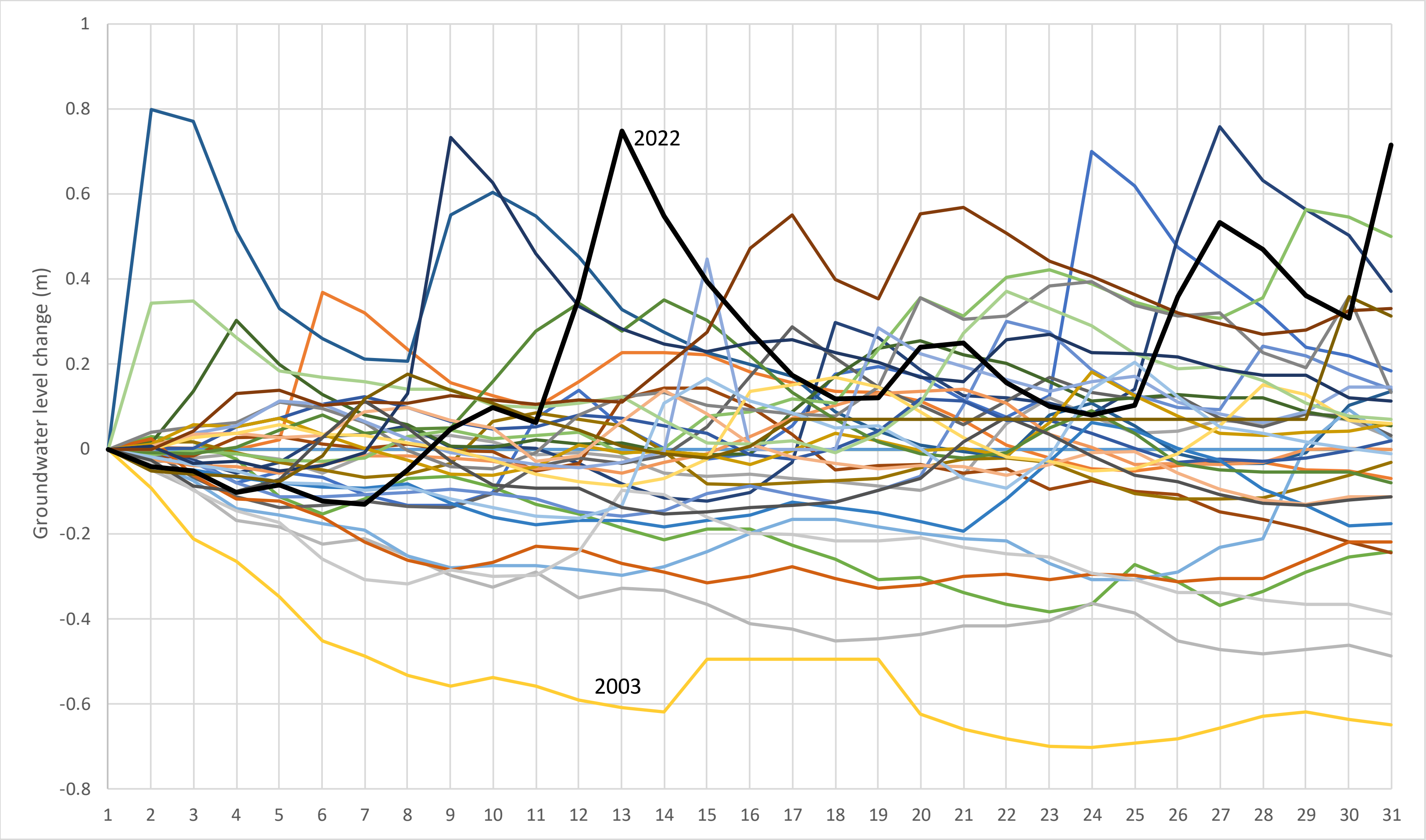

Figure 10-4 Groundwater level change across July by year at Coastal Bar

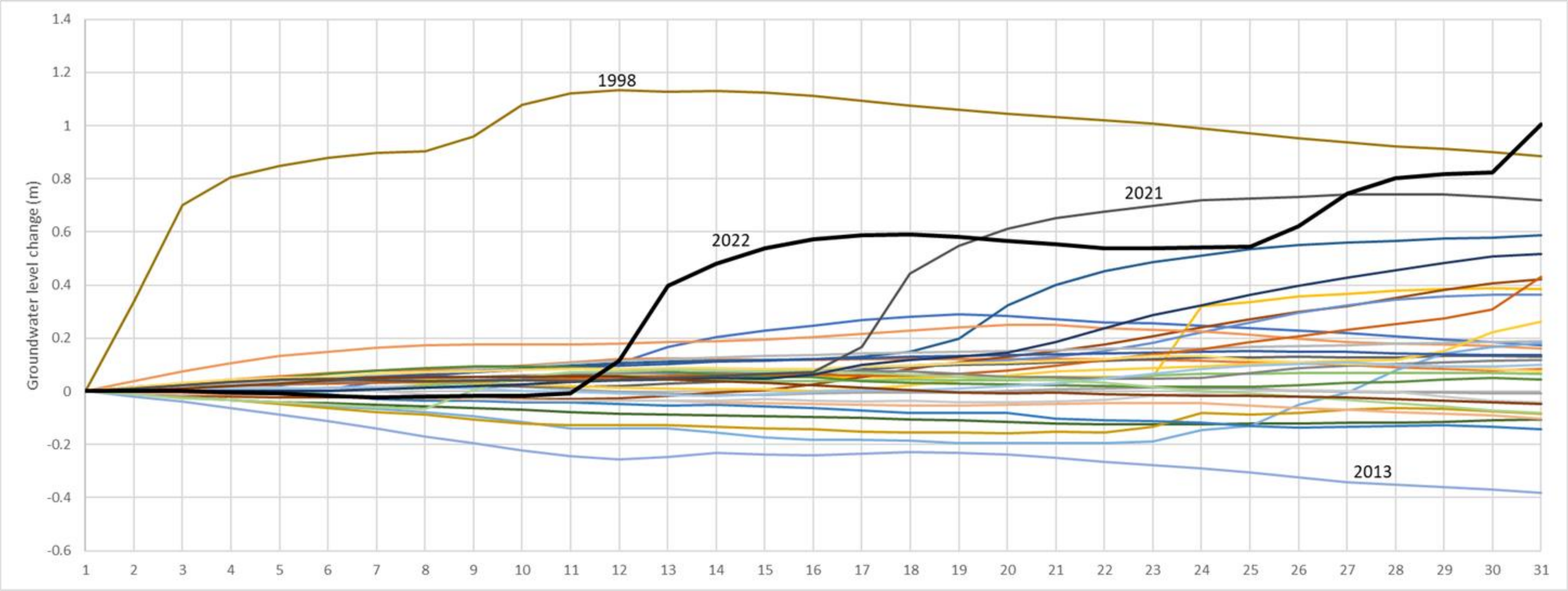

Figure 10-5 Groundwater level change across July by year at Rarangi