Mandeville San Dona Groundwater Assessment

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Waimakariri District Council

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29 April 2024

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Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to assess potential groundwater related issues related to the potential development of the Mandeville and San Dona areas of the Waimakariri District and specifically, to address the scope of work as described in this report.

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1. Background

Waimakariri District Council (WDC) are reviewing and updating the Operative Waimakariri District Plan. The Proposed District Plan was notified for submissions in mid-2022, with the further submission period closing on 21 November 2022. WDC engaged Jacobs New Zealand Limited (Jacobs) to provide specialist technical support and to comment on potential flooding and groundwater issues within the Mandeville and San Dona area of the district to support the preparation of a Section 42A report.

1.1 Scope

Our scope of work, as requested by WDC, is outlined as follows:

1. Summarise the present groundwater issues and changes that may have occurred over the last 20 years (anecdotally, the land may have subsided since the Canterbury earthquakes and that area is known for having resurgence issues);
2. Identify potential changes in groundwater levels for the next 30 years given climate change for the general area;
3. Provide comments as to what impacts increased impervious surfaces would have on the local groundwater table and any issues associated with stormwater disposal at San Dona;
4. Provide comment on whether any changes in the groundwater table would increase localised flooding risk;
5. San Dona is on the rural water supply scheme (there is a possibility that the stock water race is removed) and Mandeville isn't (hence the large number of bores), any change in land intensification will result in more groundwater bores tapping into the underlying aquifer. What is the likely impact of more groundwater bores (assuming they sit between 20-30m) on that aquifer and impacts on the groundwater table (assuming they get used for irrigation purposes);
6. Provide comments as to whether any expansion of the Mandeville area to the east, along Tram Road down to the Whites Road intersection, would result in groundwater issues:
    a. Given that most properties have bores, what is the likely impact upon the underlying aquifer,
    b. will localised irrigation cause an increase in shallow groundwater (bearing in mind the stock water race may be removed)?

1.2 Study Area

The study area and sub-areas referred to in this report are shown on Figure 1 and Figure 2.

1.3 Report layout

The existing environment and features relevant to the assessment are summarised in Section 2. Section 3 provides and overview of forecast climate change for the study area, and the groundwater assessment and response to individual scope items are presented in Section 4.

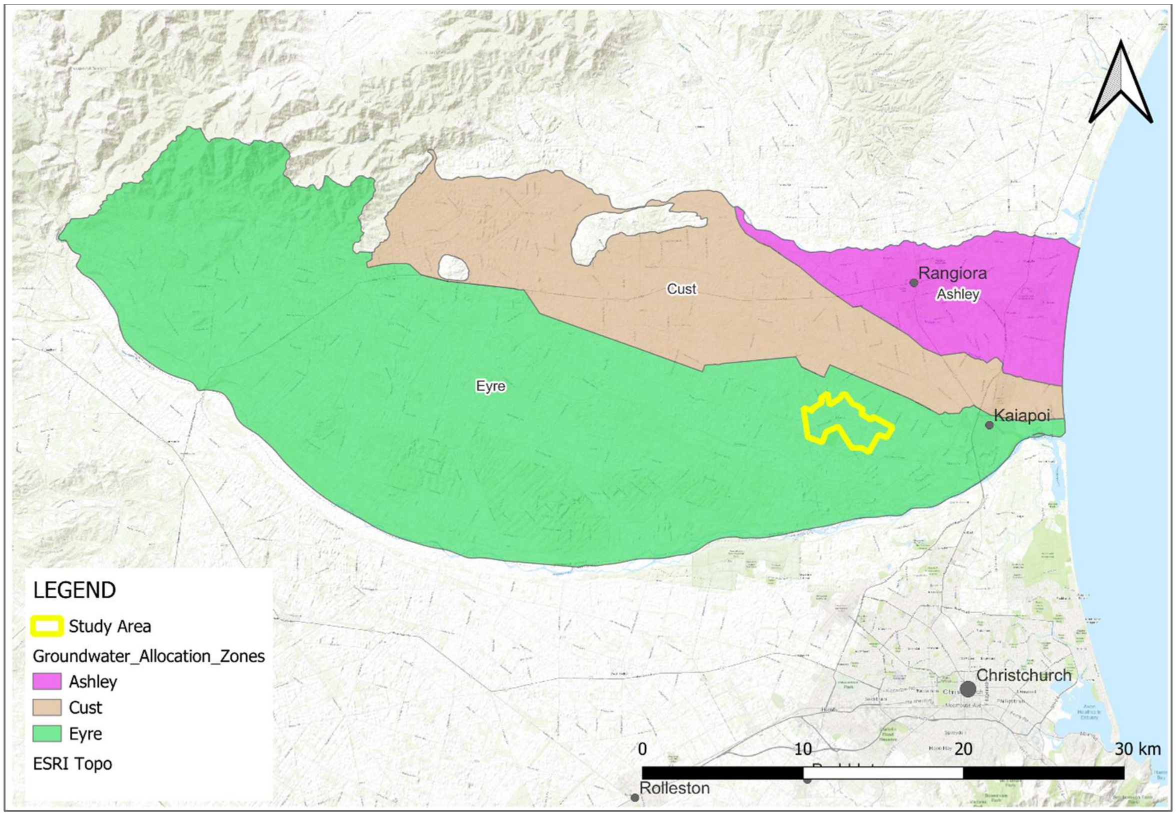

Figure 1. Study Area and Waimakariri-Ashley Groundwater Allocation Zones

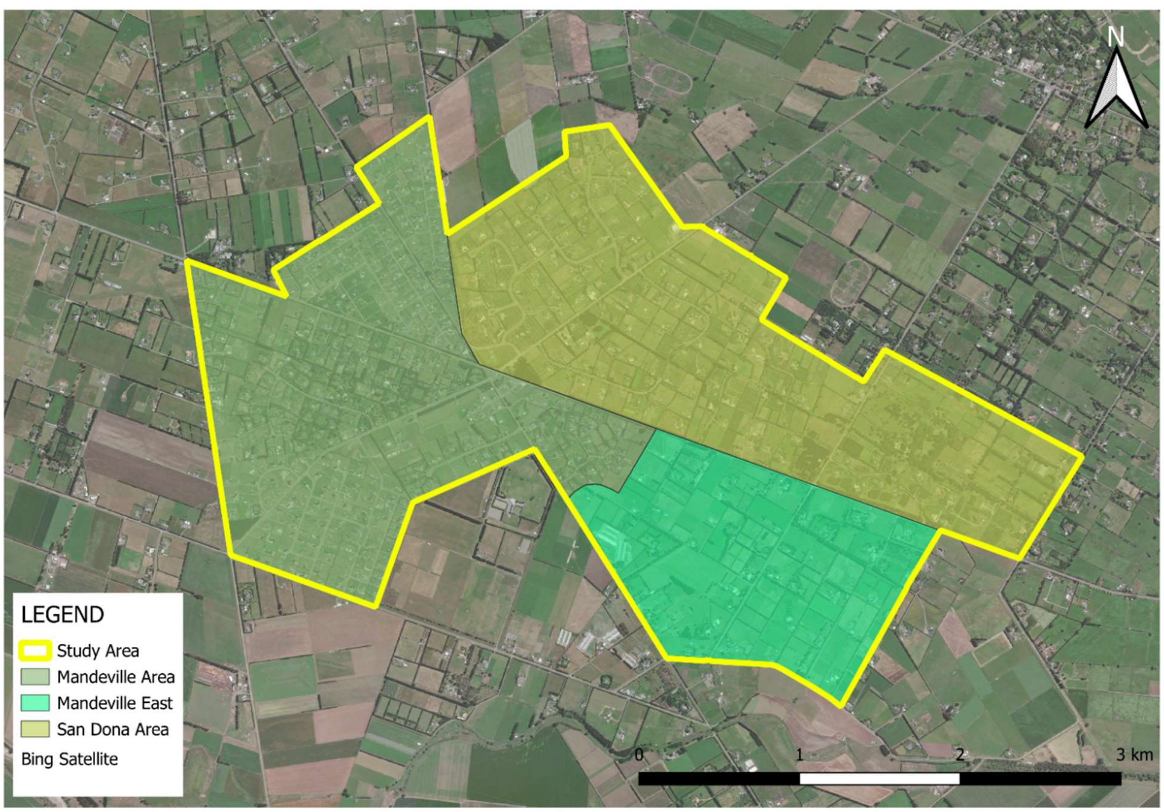

Figure 2. Study Area

2. Existing Environment

2.1 Climate

Average annual rainfall increases from the coast to the inland plains. At Kaiapoi, average annual rainfall is approximately 600 mm per year and near Oxford it is approximately 1,000 mm (Dodson *et al.*, 2012). The closest ECan rain gauge to the study area is located at Threlkelds Road, Ohoka, approximately 4 km northeast of the study area. Average annual rainfall for the period 2006 to 2022 for this rain gauge was approximately 600 mm. Average monthly rainfall is presented on Figure 3.

The graph indicates significant seasonal variation with approximately twice the amount of rain falling in June, as in January. For the period of observation (November 2005 to April 2023), the driest month on average is September and there is also increased rainfall during late spring and early summer.

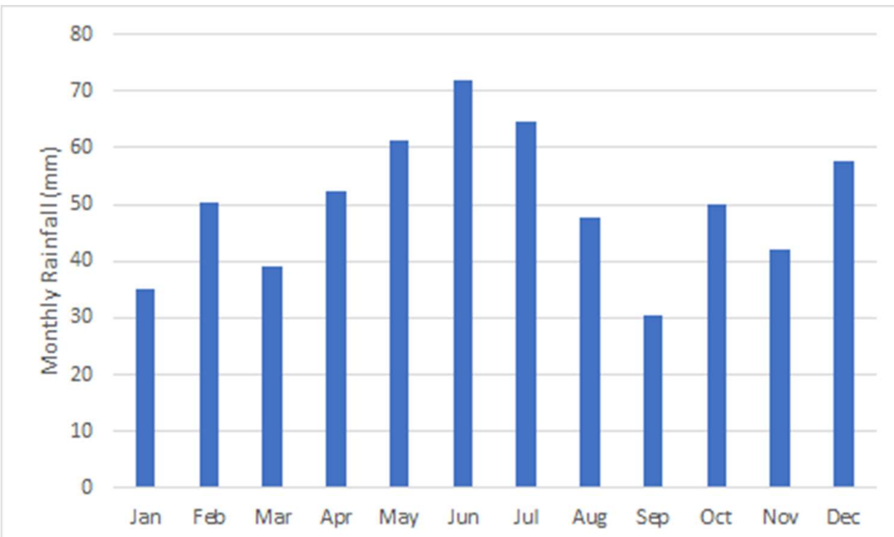

Figure 3. Threlkelds Road Rain Gauge – Average Monthly Rainfall (November 2005 to April 2023)

2.2 Geology and Hydrogeology

The existing groundwater environment is described in detail in Dodson *et al.* (2012) and Dodson (2015).

The study area is located within the Eyre River groundwater allocation zone of the Ashley-Waimakariri plains. Geology is dominated by Quaternary age alluvial deposits, consisting of gravel, sand, silt and clay, formed over the past 1.8 million years.

Most of the Waimakariri River and Ashley River/Rakahuri alluvial fans were deposited during or following glacial periods. More deposition occurred at these times due to the increased erosion of the Southern Alps/Kā Tiritiri o te Moana by glaciers and rivers supplying significant volumes of material and the melting ice supplied large volumes of water.

During interglacial periods sea level rose as the glacial ice caps melted. As the sea rose, it encroached further onto land and marine and marginal marine sediments were deposited over the top of the terrestrial sediments. Bore logs in the coastal plains show that there have been at least four periods when the sea intruded onto the land. The marine and marginal marine deposits are generally less permeable than the terrestrial gravels and act as confining layers resulting in what is known as the coastal confined aquifer system. The inland extent of the coastal confined aquifer is located approximately 5 km east of the study area towards Kaiapoi.

In the study area, aquifers are typically unconfined to semi-confined, becoming increasingly confined with depth due to stratification and inter-fingering silt and sand/gravel deposits, but without the well defined confining layers found further towards the coast.

Review of ECan bore logs indicates that shallow geology in the study area is highly variable even over relatively short distances, representing the highly variable nature of deposition and erosion of braided river channels and over-bank flood deposits.

2.3 Surface Water

The Eyre River and the Cust River (or Cust Main Drain) are the main surface water features bounding the study area, along with a number of smaller streams as depicted on Figure 4. The Eyre River has been diverted from its natural course to the southwest of the study area and now discharges to the Waimakariri River and the Cust River is constrained in a modified channel. The old Eyre River channel runs eastward just south of the study area. The Eyre River tends to flow permanently in the foothills until it reaches the plains and then it is often dry near Oxford, approximately 27 km upstream from the study area, and only flows along its full length once or twice a year (Dodson, 2016).

When the Eyre River does flow along its full length, it loses water to the groundwater system (Sanders, 1997; PDP, 2007; Wilson, 2014) and a number of the intermittent springs also start to flow (Earl, 1997). The Eyre River is an important source of groundwater recharge to its local area.

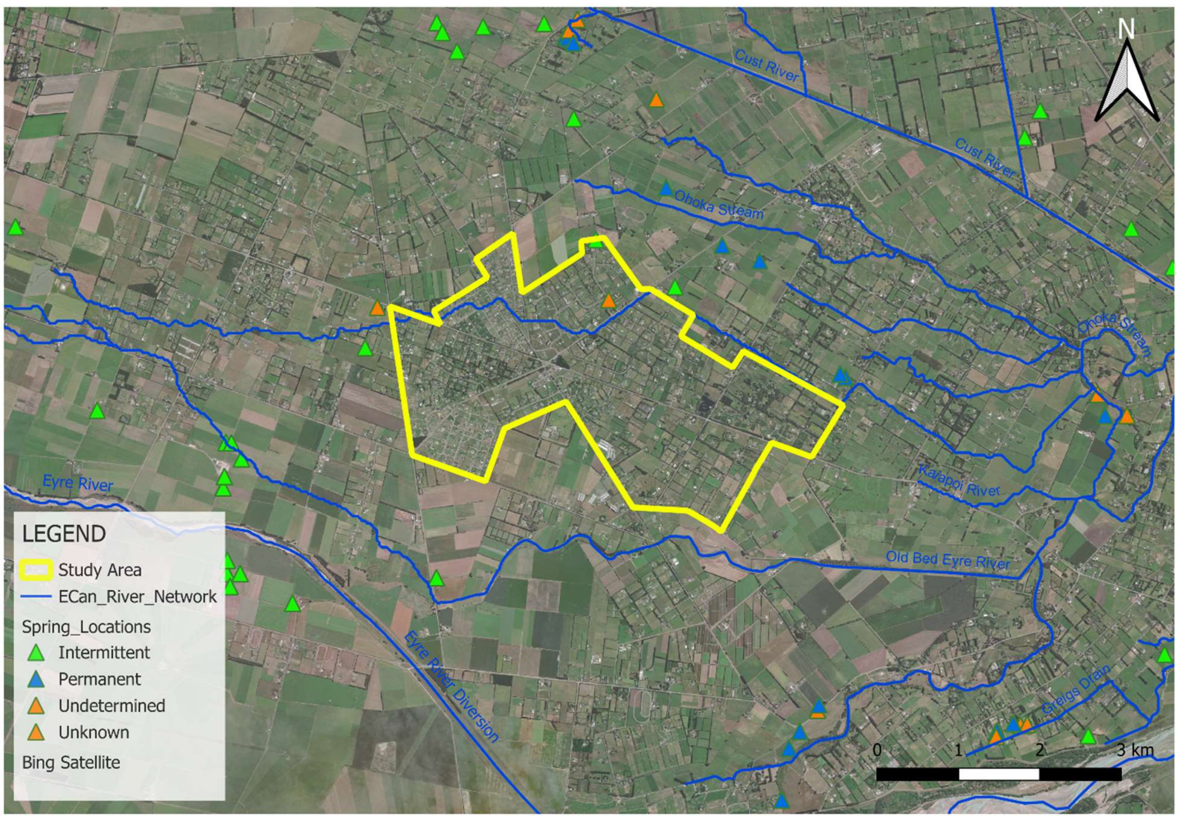

Figure 4. Surface Water Features

2.4 Springs

There are numerous springs in Ashley-Waimakariri plains. ECan recorded spring locations in the vicinity of the study area are shown on Figure 4 and Figure 12.

Springs located near the western edge of the confined aquifer system often have permanent flow and feed the headwaters of the lowland streams. A number of springs recorded as having permanent flow are also located to the northeast of the study area near the head of Ohoka Stream and its tributaries.

Springs in the vicinity of the study are typically recorded as being intermittent and are likely the result of temporarily elevated groundwater levels intersecting topographic low points, or depressions. These depression-type springs typically occur where groundwater intersects the land surface in the unconfined area of the plains. Localised contact springs may also occur where groundwater is forced up by areas of relatively lower permeability sediments.

Earl (1997) mapped a number of springs along the Eyre River. The Eyre springs are recharged by losses from the Eyre River and because river flow is intermittent, the springs also flow intermittently. When the Eyre River does flow along its full length, it loses water to the groundwater system (Sanders, 1997; PDP, 2007; Wilson, 2014) and a number of the intermittent springs also start to flow.

2.5 Water Races

The network of open stock water and irrigation races in and around the study area are presented on Figure 5. The water race locations are from a number of sources, including a 2012 plan of Waimakariri District Water Races[1], and the 1:50,000 New Zealand Drains Centreline topographic data[2].

The stock water scheme on the Ashley-Waimakariri plains commenced in 1896. Davey (2005) reported that there were approximately 1,400 km of unlined stock water races over Eyre River, Cust and Ashley groundwater allocation zones, whereas the Waimakariri District Council website and Stockwater Races Fact Sheet[3] reports approximately 758 km of open races. The difference is likely due to the transition from open water races to piped water supply.

In October 1999, the Waimakariri Irrigation Limited (WIL) irrigation scheme was launched and has undergone phase of expansion over the years. The WIL scheme delivers water to storage ponds, mainly via the existing stock water races, from where it is abstracted for spray irrigation during the irrigation season (1st September to 30th April).

Influence on groundwater levels

Dodson *et al.* (2012) identified ten wells where groundwater levels have risen periodically due to irrigation-induced recharge. The location of these wells are shown on Figure 6 and include 8 wells located within or immediately adjacent to the scheme (as at 2012) and two wells located downgradient of the scheme.

An example hydrograph of a well that is influenced by the WIL scheme is shown in Figure 5-10 (M35/0312, 9 m deep located approximately 3.2 km north of study area). The temporal variation in water levels has decreased since the WIL scheme began. Low summer water levels, such as those seen in the 1980s and in 1998/99, no longer occur. Dodson *et al.* (2012) noted that most wells recorded water level rises between 1 m to 2 m when compared to previous seasonal low groundwater levels. At some locations, where previous groundwater levels showed marked falls during dry periods, the rise in water level was up to 5 m to 10 m (e.g. M35/0143 and M35/0174). The magnitude of rise was noted to decrease with distance from the WIL scheme towards the coast. Further discussion on groundwater levels and responses to the WIL irigation scheme is provided in Section 2.9.

While it is noted that Dodson *et al.* (2012) attribute the reduction in summer low water levels to seepage losses and increased irrigation from the WIL scheme, without knowing individual bore history, such a response could also be partly due to transitioning from reliance on pumped groundwater to use of scheme water. As discussed in Section 2.8 there was a corresponding drop in allocations when the WIL irrigation schemen was introduced.

[1] https://www.waimakariri.govt.nz/__data/assets/pdf_file/0023/8951/District-Water-Races.pdf

[2] www.linz.govt.nz/topography/topo-maps/topo50

[3] https://www.waimakariri.govt.nz/__data/assets/pdf_file/0024/69621/Fact-Sheet-Stockwater-Races-July-2019.pdf

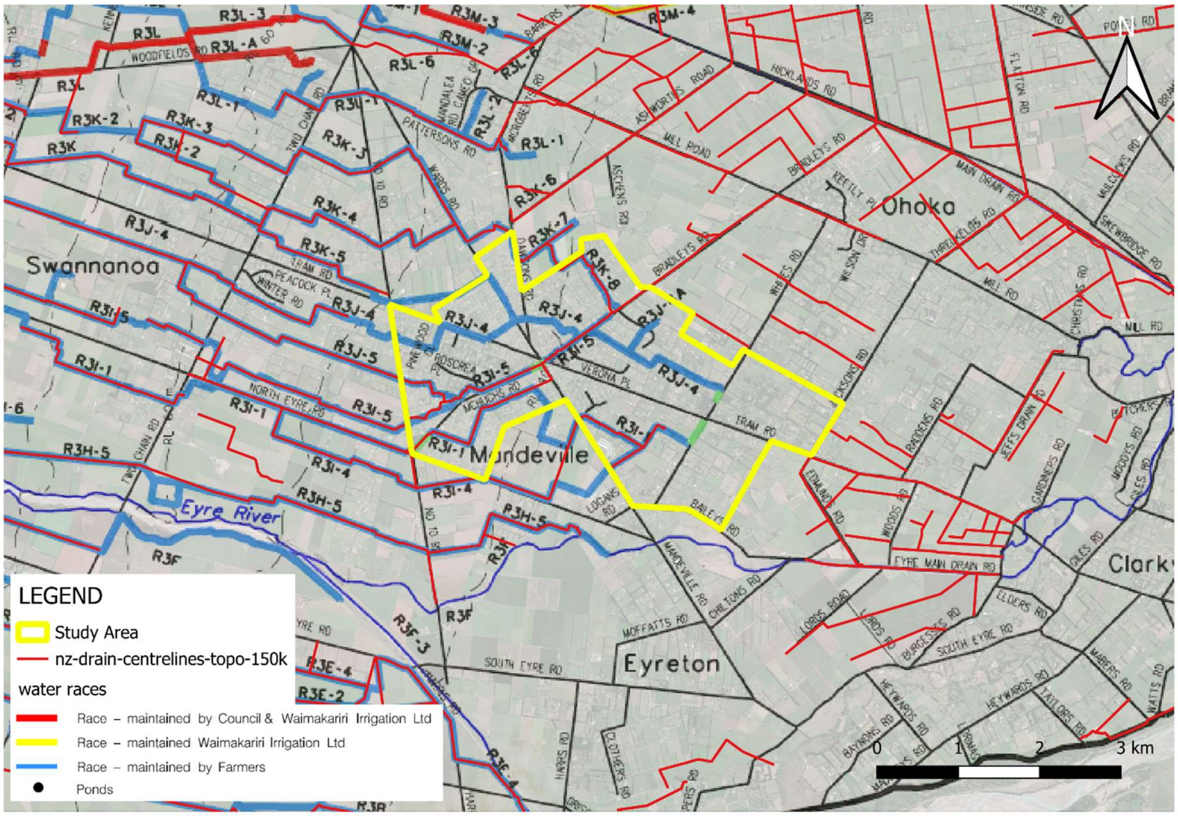

Figure 5. Study Area Water Races

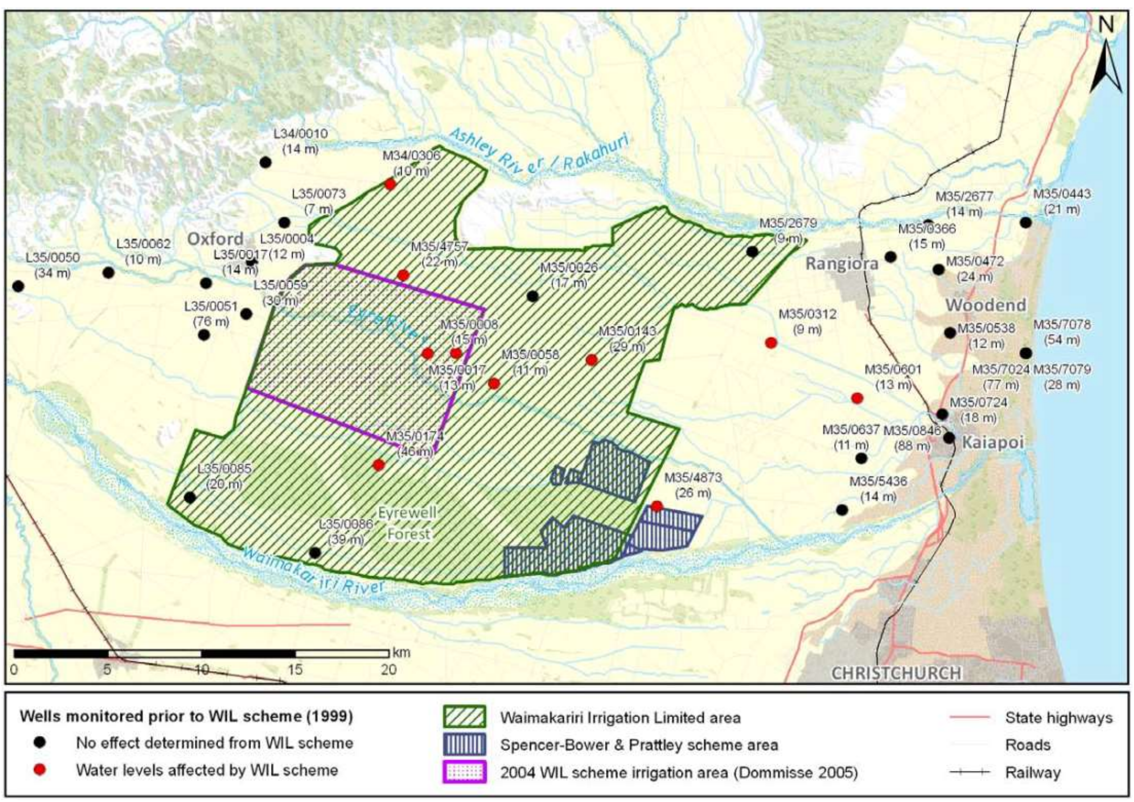

Figure 6. Wells influenced by WIL (Figure 5-9 of Dodson et al. 2012)

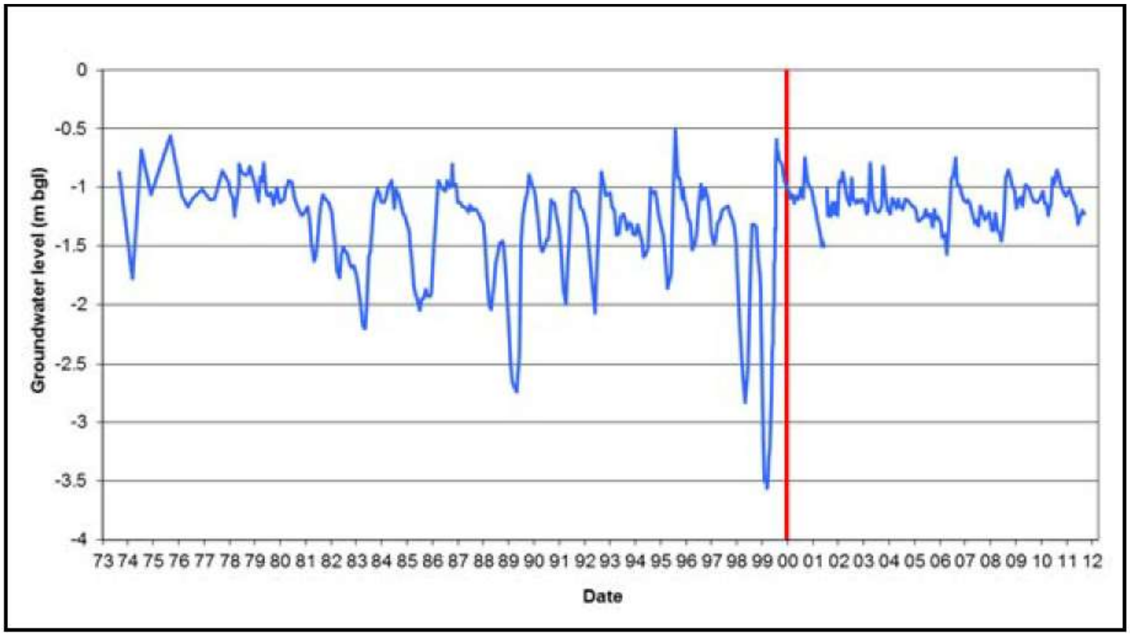

Figure 7. Long term hydrograph for well M35/0312 at Ohaka (Figure 5-10 of Dodson et al. 2012)

2.6 Groundwater Recharge

Groundwater recharge in the Eyre River groundwater allocation zone is dominated by land surface recharge, which comprises a combination of rainfall and irrigation.

The constructed water races also form a significant component of groundwater recharge. Studies in the Canterbury region indicate that between 75% to 90% of total water in the water races is lost to infiltration. Davey (2005) summarises work undertaken looking at the recharge from stock water and irrigation races in the Waimakariri-Ashley Plains and concluded that a loss of 80% was representative for the area.

In their assessment of groundwater quantity in the Waimakariri Zone, Etheridge and Wong (2018) provided updated water budget results for groundwater recharge in the Eyre River GAZ. Key sources of groundwater recharge are as follows:

- Land surface recharge provides 69% of groundwater recharge,
- 22% of recharge comes from surface water (Waimakariri and Eyre Rivers and streams), and
- 10% of recharge comes from water race losses.

Stewart et al. (2002) indicate that recharge in the study area is dominated by rainfall recharge and foothills river runoff. Groundwater ages are of the order of 25 years for shallow (approximately 20 m deep) groundwater and 50 plus years for deeper groundwater (approximately 80 m deep).

The groundwater seepages from water races have been occurring for many decades and in many cases for over 100 years, meaning that historic measurements of shallow groundwater levels will have already included any recharge contribution from the stock water races.

2.7 Groundwater Wells

Wells from the ECan wells data base are shown on Figure 8. Within the study area there are 403 wells on the wells database. Of these wells:

- 334 are recorded as active (exist, present)
- 21 are noted as proposed
- 25 are noted as not used / not drilled
- 18 are noted as no information, expired bore consent
- 4 are noted as buried, capped, or filled in.

Within the study area groundwater wells are mostly concentrated in the Mandeville area where approximately 60% of properties are estimated to have wells.

Wells on Figure 8 are categorised by depth and the distribution of well depths is also plotted on Figure 9.

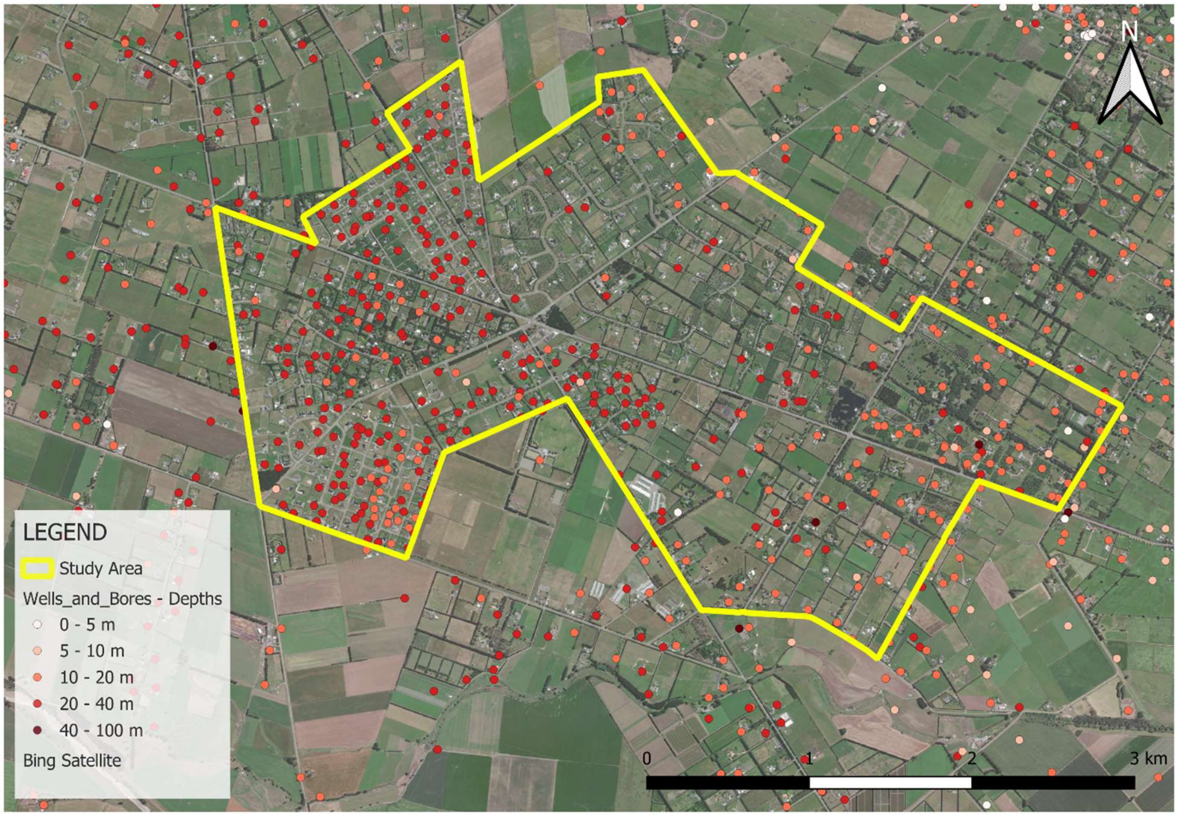

Figure 8. Groundwater Wells

The average depth of wells is approximately 21.5 m, with most wells in the 20 to 25 m depth range (225 wells) or 15 to 20m depth range (106 wells). This is indicative of the relatively accessible and productive shallow aquifers. Only 11 wells are shallower than 10 m and the deepest well is 95 m deep.

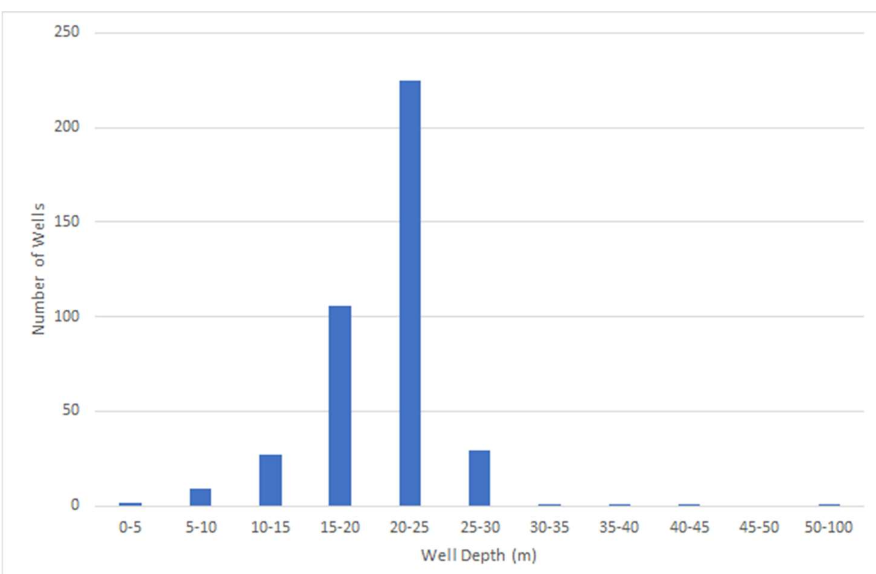

Figure 9. Study Area Well Depths

2.8 Groundwater take consents

The Canterbury Land and Water Regional Plan also allows for the taking of small volumes of groundwater for domestic and stock water uses as a permitted activity for which consents are not required:

5.113 The taking and using of less than 5 L/s and 10 m^3 per property per day of groundwater is a permitted activity, provided the following condition is complied with:

1. The bore, other than a sampling or monitoring bore, is located more than 20 m from the property boundary, or any surface waterbody.

5.114 The taking and using of less than 5 L/s and more than 10 m^3 but less than 100 m^3 per property per day of groundwater on a property more than 20 ha in area is a permitted activity, provided the following conditions are complied with:

1. The bore is located more than 20 m from the property boundary or any surface waterbody.

It is anticipated that the majority of the 334 active wells in the study area (refer Figure 8) are utilised to take groundwater as a permitted activity. In comparison, the number of consented water takes is relatively low, with only 23 consented groundwater takes within the study area (Figure 11). The volume of groundwater takes in the vicinity of the study area are also relatively small (<20,000 m^3/annum).

The Canterbury Land and Water Regional Plan sets the groundwater allocation limit for the Eyre River groundwater allocation zone at 99.07M m^3/year. Etheridge & Wong (2018) note that groundwater allocation in the Waimakariri zone has increased significantly over the last decade (2008 – 2018), and that allocation at the time was at or close to the plan limits, with about 70% of available water having been allocated for the Waimakariri zone as a whole.

Groundwater allocation in the Waimakariri Zone from 1889 to 2015 is shown on Figure 10 and indicates that allocation has increased significantly since 2009 predominantly due to expansion of irrigation in the Eyre River groundwater allocation zone, with a doubling of allocation between 2009 and 2015. The sharp decline in Eyre River allocation in 1999-2000, is attributed to expiry or surrender of groundwater takes for irrigation when the WIL scheme came online.

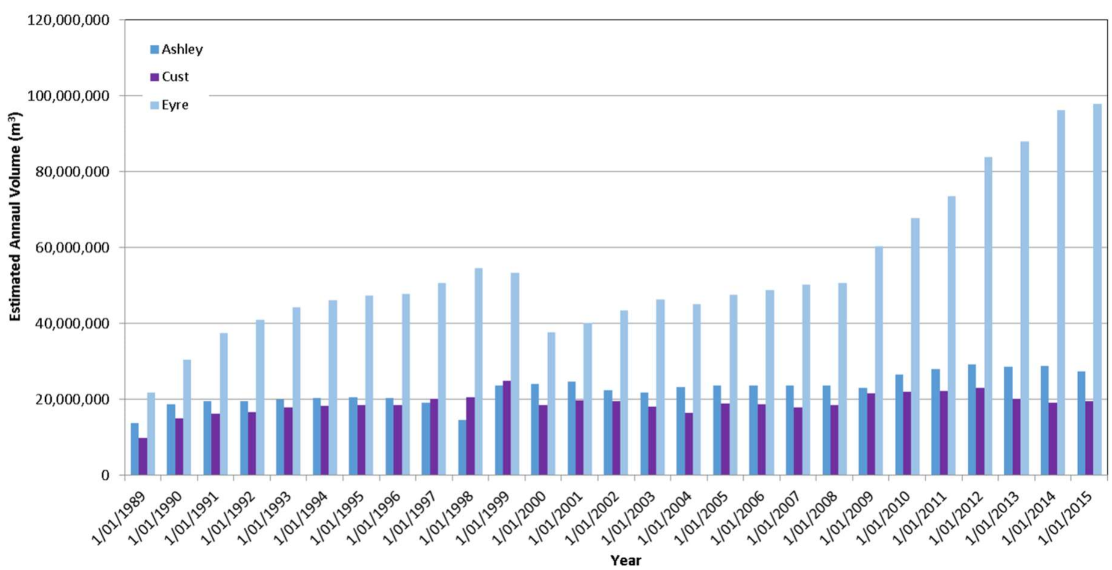

Figure 10. Historical Groundwater Allocation (Figure 2-3 of Etheridge & Wong, 2018)

Groundwater allocation in the Eyre River groundwater allocation zone (as at 2016) was estimated at 111.7M m^3/year, reducing to 100.5M m^3/year when taking stream depletion into account, as such, the Eyre River groundwater allocation zone is over allocated. However, on average, consent holders were estimated to use only about 43% of their consented volumes.

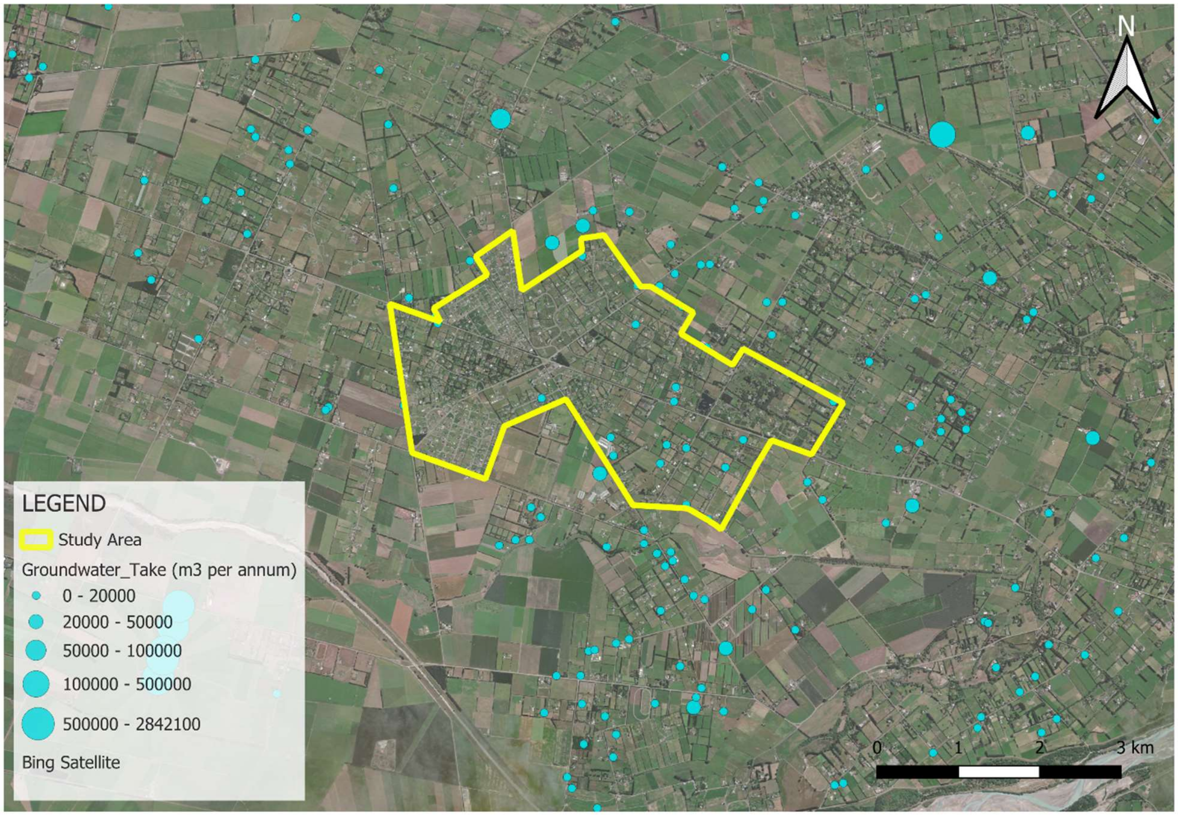

Figure 11. Consented Groundwater Takes

2.9 Groundwater levels and flow directions

The groundwater flow direction in the study area is typically east-southeast to eastwards, towards the coast. Long term median groundwater contours (pre-2016) are provided on Figure 12 and show that groundwater levels typically range from approximately 40 m elevation in the west of the study area to 15 m elevation in the east, equivalent to a hydraulic gradient of approximately 0.0045 m/m.

ECan monitor several groundwater wells in the vicinity of the study area (Figure 12), key wells of relevance to the study area include:

- M35/0222, located approximately 4 km upgradient of the study area
- M35/0637, located approximately 2 km downgradient of the study area, and
- M35/0596, located approximately 1 km to the northeast of the study area.

A further monitoring well M35/0143 is located approximately 11 km northwest of the study area along Tram Road (not shown on Figure 12).

Water levels are also monitored at the Whites Road Reserve (BW24/0321) located within the study area. Whites Road Reserve is a former gravel extraction pit that is now flooded. Water levels have been monitored for comparison to local shallow groundwater levels.

Each of these sites are manually monitored, notionally at monthly intervals. Hydrographs for these monitoring bores are provided on Figure 13 and Figure 14.

The hydrographs also display long term rainfall trends represented by the cumulative rainfall deficit (CRD). CRD is a measure of the cumulative departure from long term average rainfall where rainfall below the long term average rainfall is a deficit and rainfall above the long term average is a surplus. A sustained downwards trend of the CRD curve is indicative of sustained below average rainfall and the slope of the curve is indicative of the magnitude of the departure from average conditions. Conversely, a predominantly upwards sloping curve is indicative of above average rainfall conditions, and a predominantly horizontal trend indicates prevailing average rainfall conditions. The date of commencement of the WIL irrigations scheme (October 1999) is also indicated.

Figure 12. Groundwater Features

M35/0222

The hydrograph for M35/0222 is shown on Figure 13.

M35/0222 is 12.6 m deep. There are 322 water level observations for M35/0222, dated from March 1995 to April 2023. Water levels are observed to range from 4.59 to 11.9 mbgl with an average of 8.88 mbgl. The seasonal range in fluctuation is relatively large and typically of the order of 3 m to 4 m, with an overall range in observed water levels of 7.31 m.

M35/0222 displays a relatively close correlation with CRD, albeit with relatively large short-term fluctuations. The large magnitude of fluctuations may be indicative of a low storage in the aquifer (specific yield) but may also be influenced by localised groundwater abstraction as there are two other bores in close proximity.

No significant influence of the introduction of the WIL irrigation scheme is noted.

M35/0143

The hydrograph for M35/0143 is also shown on Figure 13.

M35/0143 is 29 m deep. There are 670 water level observations for M35/0143 ranging from September 1977 to April 2023. Water levels are observed to range from 7.23 to 27.6 mbgl with an average of 15.41 mbgl. The seasonal range in fluctuation is very pronounced and likely due to abstraction from the well.

Following the introduction of the WIL irrigation scheme, there is a considerable reduction in low water levels. Following the introduction of the scheme there was a period of approximately 15 years of gradually increasing water levels despite below average rainfall conditions. Prior to the introduction of the WIL irrigation scheme, water levels were typically around 5 m lower than those observed at M35/0222. Since the introduction of the scheme water levels have increased and the difference compared to M35/0222 has reduced to the order of 2-3 m.

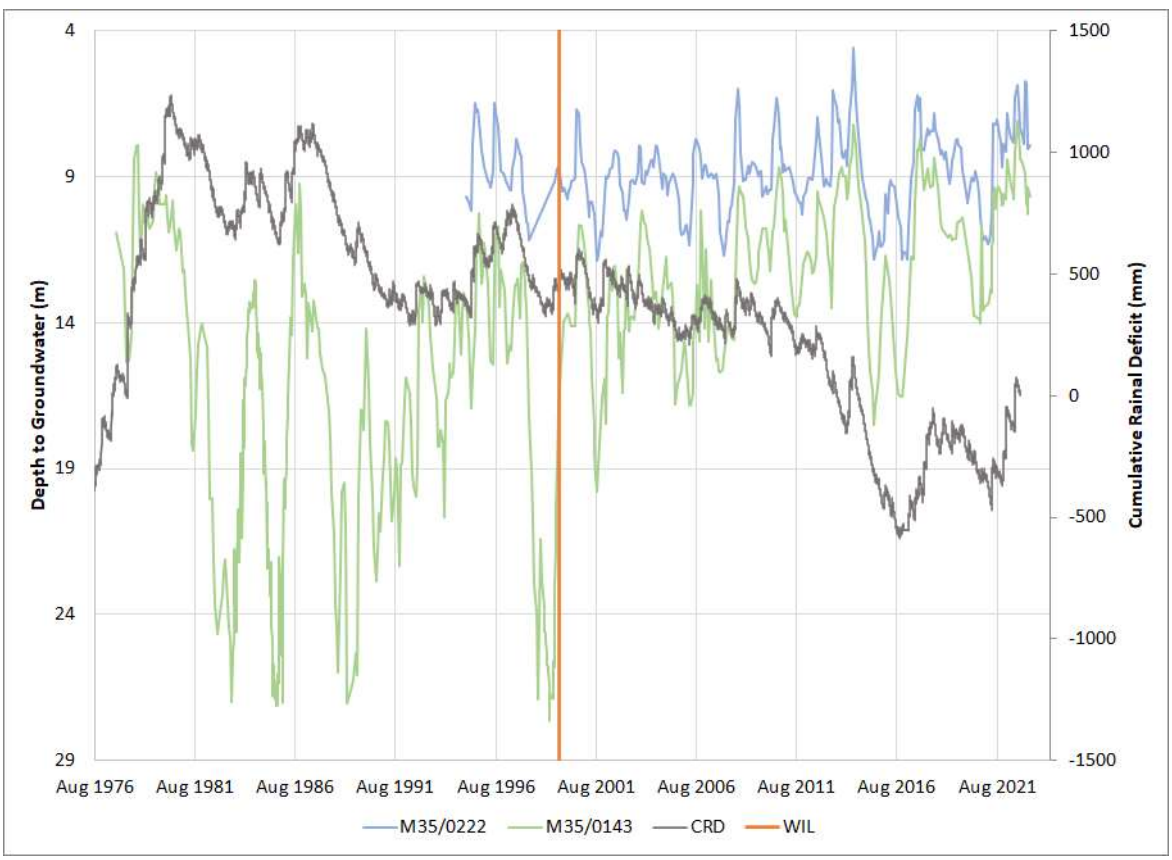

Figure 13. Groundwater level Hydrographs – M35/0222 and M35/0143

M35/0596

The hydrograph for M35/0596 is shown on Figure 14.

M35/0596 is 2.9 m deep. There are 1154 water level observations for M35/0596 ranging from September 1977 to April 2023, with consistent data collection from July 1999. The high number of water level observations is due to a period of automated daily recordings from December 2009 to May 2012. Water levels are observed to range from 0.12 to 1.4 mbgl with an average of 0.64 mbgl. The seasonal range in fluctuation is relatively small at approximately 0.2 m to 0.4 m, with an overall range in observed water levels of 1.28 m.

M35/0596 shows a relatively close correlation to CRD but with accentuated short term water level declines. The closest bore to M35/0596 is over 200 m away so these declines are likely the result of periods of reduced recharge and relatively low storage, although they are significantly smaller in magnitude compared to those observed at M35/0222.

There is insufficient data prior to the introduction of the WIL irrigation scheme to assess any change in groundwater response.

M35/0637

The hydrograph for M35/0637 is shown on Figure 14.

M35/0637 is 10.7 m deep. There are 589 water level observations for M35/0637 ranging from September 1977 to April 2023. Water levels are observed to range from 0.27 to 0.71 mbgl with an average of 0.50 mbgl. The seasonal range in fluctuation is relatively small at approximately 0.2 m, with an overall range in observed water levels of 0.44 m.

M35/0596 shows a close correlation to CRD. Following the introduction of the WIL irrigation scheme there does appear to be a slight change in groundwater response, with the magnitude of fluctuation post WIL slightly diminished and the response to sustained periods of below average rainfall is less accentuated. This is likely due to the offsetting effect of increased irrigation during these periods.

However, average water levels in the 15 years pre- and post-WIL only indicate an approximate 0.05 m increase in average water levels.

M35/0596 appears to show an increased response to sustained periods of below average rainfall in the last 10 years, this is considered to be the result of increased groundwater abstraction.

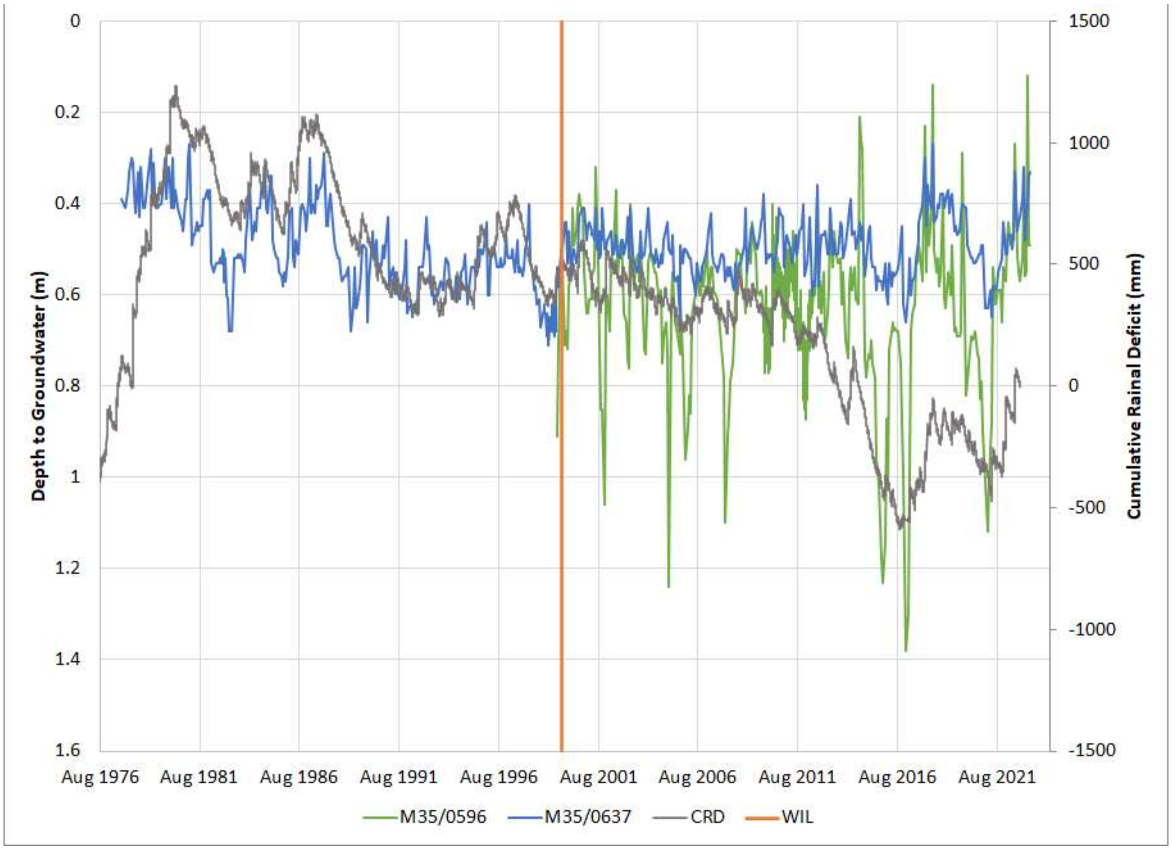

Figure 14. Groundwater level Hydrographs – M35/0596 and M35/0637

2.9.1 Water level response to WIL irrigation scheme

A statistic summary of water level data pre- and post-WIL irrigation scheme is provided on Table 1 and summarised below. It is noted that other influences such a rainfall recharge and bore pumping can also influence bore responses.

M35/0143 shows an increase in shallow water levels, a significant decrease in deep water levels and corresponding reduction in range of water level following the introduction of the WIL scheme. Water level trends transition from declining to increasing.

M35/0312 shows no significant change in shallow water levels following the introduction of the WIL scheme, but does have an overall decrease in average and deep water levels and a corresponding reduction in range of water levels. Water level trends transition from declining to marginally increasing.

M35/0637 shows no significant change in shallow water levels or average water levels following the introduction of the WIL scheme; however, there is a slight reduction in deep water levels and corresponding slight reduction in range of water levels. Water level trends transition from declining to increasing.

Table 1. Pre- and Post- WIL Water level statistics

Statistic	Pre-WIL	Post-WIL	Difference
M35-0143			
Number of measurements	385	285	-
5th Percentile (shallow groundwater) (mbgl)	10.49	8.45	2.04
Average water level (mbgl)	17.87	12.09	5.78
95th Percentile (deep groundwater) (mbgl)	26.66	16.44	10.23
Range (m)	16.18	7.99	8.19 (51%)
Trend	declining	increasing	-
M35/0312			
Number of measurements	287	295	-
5th Percentile (shallow groundwater) (mbgl)	1.18	1.10	0.08
Average water level (mbgl)	1.72	1.39	0.33
95th Percentile (deep groundwater) (mbgl)	3.00	1.66	1.33
Range (m)	1.82	0.57	1.25 (69%)
Trend	declining	minor increase	-
M35/0637			
Number of measurements	297	292	-
5th Percentile (shallow groundwater) (mbgl)	0.33	0.39	-0.06
Average water level (mbgl)	0.51	0.49	0.01
95th Percentile (deep groundwater) (mbgl)	0.67	0.59	0.08
Range (m)	0.34	0.20	0.14 (41%)
Trend	declining	increasing	-

2.10 Groundwater Resurgence

Along with other localities within the district, Mandeville and nearby Ohoka have experienced issues with groundwater resurgence compounding impacts from surface flooding.

High groundwater levels and groundwater resurgence can result in reduced capacity of stormwater systems, with drains already partly full before intense rainfall events resulting in drainage systems that are quickly overwhelmed. Elevated groundwater levels can also result in reduced infiltration, which exacerbates surface runoff and flooding, and prevents ponded water from infiltrating so that water can take weeks to drain away.

There is no reliable long term record of groundwater resurgence events; however, notable occurrences of widespread groundwater resurgence issues occurred in June 2014 and July 2022.

Purton and Cleary (2015) noted that following the June 2014 event, high groundwater and flooding caused problems with the pumped septic tank wastewater systems in Mandeville. Groundwater flowed into the systems, causing the private pumps and the downstream Council pump station to run continuously and the systems to overflow. Approximately 50 houses reported not having any wastewater disposal and more are understood to have had problems that were not reported.

Groundwater level hydrographs for M35/0143 and M35/0222, located approximately 11 km and 4 km upgradient of the study area, respectively, are shown on Figure 15. The timings of the June 2014 and July 2022 groundwater resurgence events are also indicated.

Purton and Cleary (2015) note that while M35/0143 is located a considerable distance upgradient of the study area, when water levels at M35/0143 reach 10 mbgl, the water table in Mandeville is generally at or above the ground surface. During times when the water table is at these high levels, groundwater emerges, ponds and flows via overland flow paths throughout these areas and the groundwater resurgence flow can be sustained for many months.

From review of the hydrograph for M35/0143 (Figure 15) water levels can be maintained above 10 mbgl for a year or more at a time, so it is likely that the threshold level at M35/0143 for groundwater resurgence in the study area is at a shallower level (potentially approximately 8-9 mbgl). Corresponding water levels at M35/0222 indicate that there have been 10 to 12 similar occurrences of elevated water levels over the past 28 years of observation that may also have resulted in groundwater resurgence in the study area, suggesting a relatively frequent recurrence.

A recent study into coastal groundwater flooding frequency in the Waimakariri District (Jacobs, 2022) noted that the indicative annual recurrence interval for rainfall events leading to groundwater resurgence ranged from 8.5 to 18 years for the June 2014 event and from 4 to 12 years for the July 2022 event.

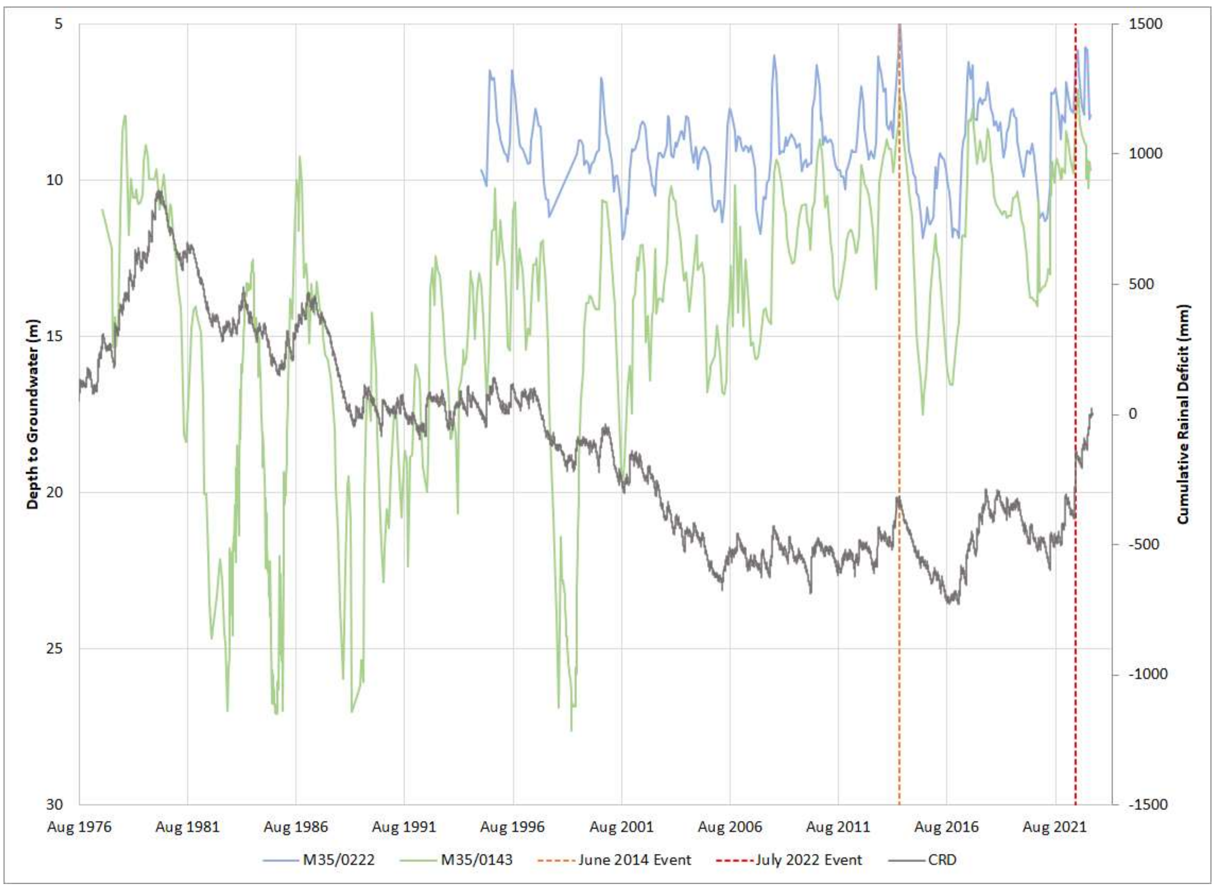

Figure 15. Groundwater level Hydrographs – M35/0222 and M35/0143

2.11 Land Subsidence

Anecdotally, it has been suggested that the study area may have experienced land subsidence due to earthquakes with a corresponding influence on groundwater levels. The potential for earthquake subsidence has been assessed through geodetic survey mark survey data.

The LINZ Geodetic database[4] lists five geodetic markers surrounding the study area that have a local vertical accuracy of 0.003 m (3 mm) and have historical vertical survey data that cover the periods of the Canterbury and Kaikoura Earthquakes. The locations of the geodetic survey marks are shown on Figure 16.

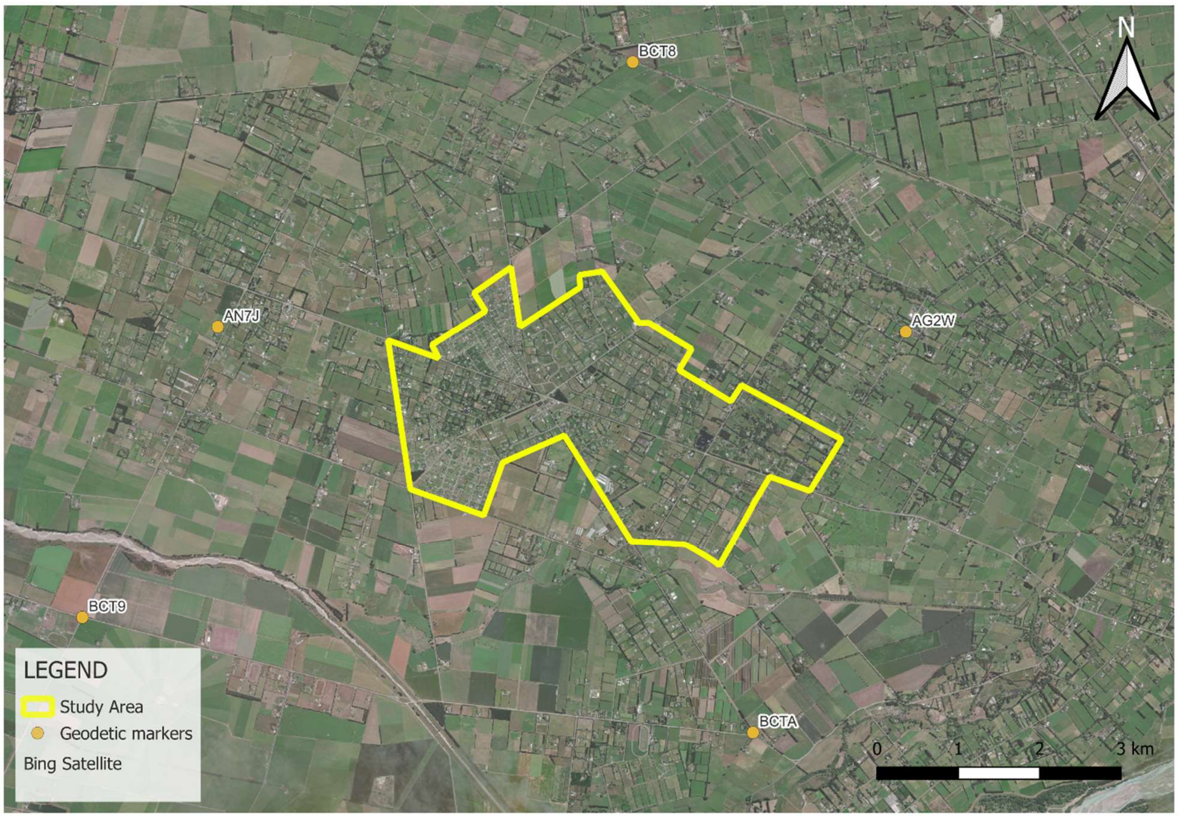

Figure 16. Geodetic Survey Marks

Key Earthquake dates are as follows:

- Darfield earthquake – 4 September 2010
- Christchurch earthquake – 22 February 2011
- Kaikoura earthquake – 14 November 2016

There is insufficient data to distinguish between the Darfield and Christchurch earthquakes and the cumulative vertical displacement from both earthquakes are presented as post Christchurch earthquake displacement.

For estimation of vertical displacement the following calculations have been undertaken:

- Post Christchurch earthquake displacement
  - Average post Christchurch earthquake elevations (14 Dec 2013 to 30 Jun 2016) minus pre earthquake elevation (28 Jul 1999)

[4] https://www.geodesy.linz.govt.nz/gdb/?mode=gmap

- Post Kaikoura earthquake displacement
  - Average post Kaikoura earthquake elevations (14 Jan 2018 to 30 Nov 2018) minus average post Christchurch earthquake elevations
- Total displacement
  - Post Christchurch earthquake displacement plus post Kaikoura earthquake displacement.

Survey elevations are provided on Table 2 and average vertical movements are presented on Table 3. A negative vertical movement is indicative of net downwards displacement (subsidence). All elevations are New Zealand Vertical Datum 2016 (NZVD).

The total average displacement is indicated to be of the order of 0.104 m (10.4 cm) with marginally more subsidence attributable to the Kaikoura earthquake than to the Christchurch earthquakes.

In general, given the relatively small magnitudes and relatively uniform regional nature of the displacement, no significant re-equilibration of groundwater levels is anticipated, the magnitude of vertical displacement is not expected to have a significant influence on groundwater levels.

Table 2. Geodetic marker elevation data

Geodetic marker	Surveys Dates / Elevation (m NZVD)							
	28/07/99	14/12/13	15/12/13	1/07/14	30/06/16	14/01/18	14/01/18	30/11/18
AG2W	26.244	26.212	26.214	-	26.174	26.138	26.146	26.147
AN7J	73.317	73.282	73.274	73.263	73.236	73.203	73.207	73.211
BCT8	47.823	47.792	47.788	-	47.756	47.720	47.728	47.729
BCT9	76.894	76.857	76.850	-	76.820	76.788	76.790	76.796
BCTA	31.690	31.655	31.658	31.653	31.612	31.578	31.577	31.586

Table 3. Average vertical movement

	Christchurch EQ	Kaikoura EQ	Total
AG2W	-0.044	-0.056	-0.100
AN7J	-0.053	-0.057	-0.110
BCT8	-0.044	-0.053	-0.097
BCT9	-0.052	-0.051	-0.103
BCTA	-0.046	-0.064	-0.110
Average	-0.048	-0.056	-0.104

3. Climate Change

One of the key uncertainties with respect to future groundwater availability is the response of groundwater to climate change.

The forecast effects of climate change for the Waimakariri District and in Canterbury in general are summarised in the Waimakariri District Climate Change Scenario: Technical Report (NIWA, 2022) and Canterbury Climate Change Risk Assessment (Tonkin & Taylor, 2022).

NIWA (2022) provide the following synopsis for future climate scenarios for the Waimakariri District:

Mean air temperature

- Mid-century mean air temperature is projected to increase by 0.8 °C (RCP4.5) to 0.9 °C (RCP8.5)
- End-century mean air temperature is projected to increase by 1.2 °C (RCP4.5) to 2.4 °C (RCP8.5)
- Largest increase in mean air temperature is projected in high-elevation regions.
- Changes in mean temperature are projected to be uniform across seasons.

Hot days

- Mid-century hot days are projected to increase by 13 (RCP4.5) to 15 (RCP8.5) days per year.
- End-century hot days are expected to increase by 20 (RCP4.5) to 44 (RCP8.5) days per year.
- 44 additional hot days would represent a tripling of historical hot days for the district on average.

Mean rainfall

- Mid-century rainfall is projected to increase for both RCP 4.5 and RCP 8.5.
- Increased rainfall is projected across the lower altitude plains and coastal areas, and no change (or slight decreases) in annual rainfall are projected in the western high-altitude zones.
- Seasonal trends in projected rainfall change are broadly consistent with the annual change, except spring which has inconsistencies in spatial pattern and the variability of change signal.

Dry days

- Dry days are projected to increase slightly in the upper elevations and decrease in the coastal regions and inland plains.

Extreme heavy rainfall

- Extreme rainfall will likely increase by approximately 7% per 1 °C of climate warming.
- However, shorter duration rainfall events (e.g., hourly) could increase by as much as 15% per 1 °C of climate warming.

Soil moisture deficit days

- Mid-century soil moisture deficit days are projected to decrease by 2 (RCP8.5) to 5 (RCP4.5) days per year.
- End-century soil moisture deficit days are expected to increase by 3 (RCP4.5) to 2 (RCP8.5) days per year.
- Mid-century soil moisture deficit days will likely decrease consistently across the district.
- End-century soil moisture deficit days will likely increase consistently across the district, except in the coastal zone and higher elevation regions.

Potential evapotranspiration deficit

- Mid-century accumulated annual potential evaporation deficit is projected to increase by 75.7 mm (RCP8.5) to 91.2 mm (RCP4.5). *[average 0.21 to 0.25 mm/day].*
- End-century accumulated annual potential evaporation deficit is expected to increase by 88.9 mm (RCP4.5) to 97.6 mm (RCP8.5). *[average 0.24 to 0.27 mm/day].*
- Upper mountainous regions and the Lees valley may see an increase in PED of approximately 15-30 mm greater than the lowland plains.

Relative Humidity

- Mid-century relative humidity is projected to decrease by 0.8% (RCP4.5) to 0.9% (RCP8.5).
- End-century relative humidity is expected to decrease by 1.1% (RCP4.5) to 2.2% (RCP8.5).

- The largest reductions in relative humidity are projected to occur in the Lees Valley region and the higher elevation areas, with generally smaller reductions projected near the coast.
- Relative humidity will decrease most notably during winter and spring.

River flow - Waimakariri and Ashley/Rakahuri Rivers

- Hydrological simulations suggest that mid-century mean flow could remain largely unchanged.
- For the end-century period mean flow will likely remain largely unchanged under the RCP4.5 scenario and slightly increase by 5-10% under the RCP8.5.
- Mean annual low flow in the district is generally projected to decrease by mid-century by upwards of 20% under both RCP4.5 and RCP8.5 scenarios
- By the end-century, mean annual low flow could decrease by 20-50% across the district

In summary, weather patterns are expected to become more volatile. Annual average temperatures are expected to increase with more extreme warm temperatures. Mean annual rainfall is predicted to increase with more frequent heavy rainfall events. Despite this, the district is likely to experience more frequent and prolonged droughts due to increased evapotranspiration. As a result, more water is likely to be needed for irrigation.

Tonkin & Taylor (2022) note that with changes in rainfall trends of wetter winters and drier summers, there may be associated impacts on groundwater. With potentially higher water tables in the winter and lower water tables in the summer. Increased likelihood of drought has potential to reduce aquifer recharge and lower water tables while increasing demand on aquifers for irrigation. Shallow aquifers, and those with naturally fast responses to rainfall, are likely to be most sensitive.

4. Assessment

Summarise the present groundwater issues and changes that may have occurred over the last 20 years (anecdotally the land may have subsided since the Canterbury earthquakes and that area is known for having resurgence issues);

Groundwater Allocation

The study area has experienced increased demand for groundwater associated with changing farming practices and urban expansion. Groundwater allocation has increased considerably since allocation limits were introduced in 2004 and the Eyre GAZ is currently over allocated.

However, despite the increased groundwater usage, Etheridge and Wong (2018) note that overall, the significant increase in groundwater abstraction in the Waimakariri zone since 1999 (principally in the Eyre River GAZ) has not caused significant widespread declines in groundwater levels across the zone. This is likely to be due to the mitigating effects of increased irrigation resulting in increased land surface recharge and ongoing stock water race losses on groundwater abstraction.

It is noted that groundwater takes as a permitted activity associated with takes for domestic or stock water supply are not subject to allocation limits.

As consent holders are estimated to use only about approximately 43% of their consented volumes, there is potential for groundwater abstraction to more than double under the current allocation limits.

Groundwater Resurgence

Groundwater resurgence in the study area has resulted in exacerbated and prolonged surface flooding and disruption of stormwater and wastewater disposal systems.

Land Subsidence

There is no indication that land subsidence has affected the overall groundwater regime of the area. Due to the ubiquitous nature and relatively small magnitude of the subsidence, and the distance from and elevation above the coast, the water table is not anticipated to have undergone any substantial post subsidence re-equilibration, and relative to ground surface, is likely to remain relatively unchanged.

Identify potential changes in groundwater levels for the next 30 years given climate change for the general area;

Mid-century climate change is projected to include increased mean temperature, increased mean rainfall on the lower plains area (with no change to upper plains), increased evapotranspiration and potential evaporation deficit, and increased seasonality of rainfall bringing with it increased likelihood of severe weather events, including flood and drought.

The increase in potential evapotranspiration deficit means that on average there will be less deep drainage of soil water resulting in lower rates of recharge and a corresponding increase in demand for irrigation. However, as the plains area is relatively receptive to infiltration, large volumes of recharge will still be received during larger rainfall events, acting as a top up for the shallow aquifers.

The overall response for the study area is likely to be an increase in the magnitude of seasonal groundwater fluctuations with lower summer low water levels and potentially similar or greater winter high water levels.

Provide comments as to what impacts increased impervious surfaces would have on the local groundwater table and any issues associated with stormwater disposal at San Dona;

Increased impervious surfaces would result in increased and more rapid runoff, meaning less direct infiltration to groundwater and more rapid loading of stormwater systems. However it is noted that the study area and San Dona area are only a small proportion of the overall Eyre River groundwater management zone area, at 1.6% and 0.6% respectively. Changes within these areas may have a small influence on local groundwater levels, but the upgradient catchment area of the broader Eyre River groundwater management zone is anticipated to have the greater influence.

For stormwater disposal, development plans would need to account for the anticipated runoff and whether the increased volume can be accommodated in the existing Ohoka drainage scheme.

Provide comment on whether any changes in the groundwater table would increase localised flooding risk;

Increased or elevated groundwater levels would increase the risk of groundwater resurgence and flooding, and climate change is considered to have the greatest potential to result in increased seasonal groundwater levels.

Other elements such as removal of water races, reduction in rural irrigation, increased groundwater abstraction, and reduced recharge due to impervious surfaces may result in locally reduced water levels, while stormwater infiltration and domestic irrigation will act to partly offset these effects. However, as previously discussed, the study area and areas of potential development and housing intensification, are only relatively small in comparison to the broader groundwater allocation zone, so any localised effects will be offset, or dampened by more regional groundwater responses.

San Dona is on the rural water supply scheme (there is a possibility that the stock water race is removed) and Mandeville isn't (hence the large number of bores), any change in land intensification will result in more groundwater bores tapping into the underlying aquifer. What is the likely impact of more groundwater bores (assuming they sit between 20-30m) on that aquifer and impacts on the groundwater table (assuming they get used for irrigation purposes);

Direct quantification of the potential impact of increased bore density and groundwater abstraction would require a more detailed analytical or numerical modelling assessment, and historically there isn't sufficient local monitoring data to assess the impacts of past housing intensification. However, the long term record for M35/0637 (Figure 14), located approximately 5 km downgradient of the more intensely developed and groundwater bore intensive Mandeville area, does not show any significant long term change in water levels other than trends driven by climate or attributable to the introduction of the WIL irrigation scheme. This would suggest that, regionally, the intensification of housing and increased abstraction of groundwater as a permitted activity has not significantly affected the regional groundwater system.

The likely impact of more groundwater bores abstracting from the shallow alluvial aquifer would be a net take, or loss of water from the aquifer. Assuming a relatively uniform year-round domestic demand and increased summer demand for watering and irrigation, the increased abstraction would act to accentuate seasonal water level fluctuations. Given that the groundwater management zone is over allocated, any future takes will be limited by the permitted activity rules and constrained to a maximum volume om 10 m^3 per day (for a property less than 20 Ha), which is equivalent to a continuous rate of take of approximately 0.1 L/s. This is not considered to be a significant rate of take even when considering cumulative abstraction over hundreds of households. When considering hydraulic conductivity values typical of Quaternary alluvial deposits, this rate of abstraction would only result in localised drawdown of the order of tens of centimetres, or less.

The majority of abstracted groundwater would be expected to be lost either through domestic use, as loss to wastewater, or through direct evaporation or evapotranspiration from irrigation. Poorly managed irrigation does have potential to result in deep drainage and some recycling of groundwater to the water table; however, this is not expected to be a significant component of the overall take.

There is indication in a number of bore logs of relatively shallow low permeability layers, typically indicated as yellow clay-bound or clayey gravels. These layers may have potential for development of shallow perched groundwater layers during high rainfall events or through infiltration from persistent over-irrigation. However it is noted that these layers are not ubiquitous and are not indicated as being regionally extensive, so any perching effects would be expected to be localised.

Provide comments as to whether any expansion of the Mandeville area to the east along Tram Road down to the Whites Road intersection would result in groundwater issues

a) **given that most properties have bores what is the likely impact upon the underlying aquifer,**

b) **will localised irrigation cause an increase in shallow groundwater (bearing in mind the stock water race may be removed?**

Likely impacts for groundwater resulting from expansion to the east of Mandeville along Tram Road are the same as those previously described for San Dona.

Assuming that irrigation water is locally sourced shallow groundwater, as previously described, deep infiltration and recycling of groundwater is only anticipated to comprise a small proportion of the overall groundwater take. The overall effect is anticipated to be a net groundwater take and reduction in groundwater levels; however, this is also not anticipated to be significant.

Properly managed irrigation should also limit the potential for deep drainage and recharge to groundwater.

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