Flaxbourne Community Irrigation Limited

Flaxbourne Community Irrigation

Groundwater Assessment

June 2018

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

Executive summary

This report documents an assessment of groundwater and surface water effects associated with the proposed groundwater abstraction to supply the Flaxbourne Community Irrigation Scheme. In 2008, FCIL was granted consent for a surface water take from the Waima River at the Narrows to supply the scheme. In recent years, attention has focussed on a groundwater supply in the vicinity of the SH1 Bridge over the Waima River. To date, two groundwater production wells have been drilled and tested with the results of the pump testing discussed in more detail in the attached aquifer test report (Appendix A).

The pump testing indicated:

- The drawdown response of the aquifer was limited in both magnitude and extent. Under the conditions at the time of the test, the aquifer could comfortably yield 130 L/s and would have achieved the design rate of 250 L/s. Under dry summer conditions, the aquifer is expected to perform well and achieve the design yield.
- No hydraulic boundaries were encountered over the duration of the test nor was there any evidence of saline intrusion.
- The pumping test showed that the lower aquifer can be considered to be semi-confined. A strong leakage signature in the pumping test data indicates vertical movement of groundwater is occurring at short time scales; from the shallow gravel aquifer, through the fine grained semi-confining layer to the lower gravel.
- The time series data indicates that the shallow gravel aquifer has a high degree of connection to flows in the Waima River. Concurrent flow gaugings indicate that the river gains and loses water to the shallow gravels (and likely to the deeper aquifer). Therefore, abstraction from the lower gravel aquifer is expected to result in movement of water from the shallow aquifer, and is likely to have some impact on surface water flows.
- Water chemistry analysis confirms a similar source for the river water, shallow and deep groundwater.

The groundwater assessment indicated:

- The effect of the proposed groundwater abstraction on water levels in upstream wells is considered to be negligible after seven days of continuous pumping at the maximum rate of 250 L/s. Over 212 days, the modelled effect is less than 0.5 m. In comparison to the available drawdown it the neighbouring wells, the effect is less than minor.
- Abstraction from the lower aquifer is expected to cause stream flow depletion due to the leaky nature of the semi-confining layer. The potential effects to surface water are however considered to be equivalent or better than those of the currently consented surface water take. As with this surface water take, the effect on the surface water environment is considered to be no more than minor, as the abstraction will have a negligible effect on flood flows that are important for the river ecosystem.
- Saline intrusions is not expected to occur to a significant degree, due to the likely offshore position of the saline interface and persistent hydraulic gradient driving groundwater flow towards the coast.
- The cumulative effect on the freshwater system of the proposed groundwater take is less than the existing surface water take.

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1. Introduction

This report has been prepared by GHD Limited (GHD) for Flaxbourne Community Irrigation Limited (FCIL) to assess the effects of the proposed groundwater take from the aquifer at or about 25 m deep in the vicinity of the State Highway 1 (SH1) Bridge over the Waima (Ure) River.

1.1 Background

FCIL has been exploring options for an irrigation supply for more than 10 years. In 2008, FCIL was granted to consent for a surface water take from the Waima River at the Narrows. This consent (U071402) allowed for up to 520 L/s abstraction from the river subject to flow restrictions and a number of other conditions.

Over the past 10 years, further refinement of the irrigation scheme and consideration of alternate water sources has led to the development of a potential groundwater supply adjacent to the Waima River. Development of the well field to date has been undertaken in two stages. It has included the drilling of two production wells and several monitoring wells, pump testing (bore efficiency and aquifer hydraulics), and monitoring of groundwater levels. A summary of the works completed is provided below (Table 1-1). FCIL propose to surrender the surface water take consent and instead supply the scheme with groundwater.

Following completion of the pumping tests, GHD prepared a technical aquifer test report (GHD 2018, included as Appendix A), which provides analysis and interpretation of the groundwater response to pumping. Aquifer parameters defined in the pump test report are utilised in this groundwater assessment report to assess the effects on the environment and other groundwater uses from the proposed groundwater take.

Table 1-1 Development of FCIL well field – works completed

Stage 1 (2017)	Drilling of a 150 mm investigation well (IW), 300 mm production well (PW1) and two monitoring wells (MW1_S and MW1_D) Step discharge test and 98 hour constant rate test of PW1 Geophysical (resistivity) survey
Stage 2 (2018)	Drilling of a 400 mm production well (PW2) and three monitoring wells (MW2, MW3, MW4) Step discharge tests of PW1 and PW2 7 day constant rate test of PW2 (rate 83 L/s) 7 day well field test of PW1 and PW2 (combined rate 130 L/s)

1.2 Purpose of this report

The purpose of this report is to provide an assessment the effects on the environment and other groundwater uses of a proposed groundwater take in the vicinity of the State Highway 1 Bridge over the Waima (Ure) River.

1.3 Scope and limitations

This report: has been prepared by GHD for Flaxbourne Community Irrigation Limited and *may only be used and relied on by Flaxbourne Community Irrigation Limited for the purpose agreed between GHD and the Flaxbourne Community Irrigation Limited as set out in section 1 of this report.*

GHD otherwise disclaims responsibility to any person other than Flaxbourne Community Irrigation Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s)1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Flaxbourne Community Irrigation Limited and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has not been involved in the preparation of the [insert name of the other document] and has had no contribution to, or review of the [insert name of the other document] *other than in the* [insert name of the document prepared by GHD]*. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the* [insert name of the other document].

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.
Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1.4 Assumptions

- Information provided by MDC is accurate, this includes bore data, flow gauging measurements and factual information provided in third party reports.
- Assumptions relating to the application of analytical solutions are addressed in the technical sections of the attached aquifer test report, and via references.
- The assessment of effects has been completed assuming that the surface water consent U071402 will be surrendered.

2. Description of the Proposal

2.1 Site description

The site is located on the north bank of the Waima River, adjacent to the SH1 Bridge. The site is located 8 km south of Ward, Marlborough (Figure 2-1).

2.2 Existing consent U071402

FCIL was granted consent to take surface water from the Waima River at the Narrows in 2008. Surface water was to be abstracted via a low weir or infiltration gallery for irrigation use for 2500 ha area of pasture, agriculture, horticulture, viticulture and to place in storage. The consent was subject to a number of conditions requiring baseline monitoring of surface water, groundwater, and ecological surveys. The consent was structured in two stages. Stage 1 allowed for an annual abstraction of 3.5 million m^3 at a maximum instantaneous rate of 520 L/s. Following completion of baseline surveys and additional monitoring, the annual abstraction rate may be increased to 5.5 million m^3 (Stage 2) provided the effects of the Stage 1 take could be shown to be no more than minor. Abstraction (both Stage 1 and Stage 2) was subject to seasonal flow restrictions. The Stage 1 abstraction regime is summarised below:

Condition 12

Abstraction shall occur as follows:

a) *Abstraction between 1 January and 31 August*

   i. *At river flows, measured at the Narrows, of less than 149 L/s there is to be no abstraction*

   ii. *At river flows at or above 150 L/s the consent holder may abstract 50 L/s plus 67% of the flow above 150 L/s, as measured at the Narrows.*

b) *In the period 1 September to 31 December*

   i. *At river flows, measured at the Narrows, of less than 149 L/s there is to be no abstraction*

   ii. *At river flows at or above 150 L/s the consent holder may abstract 50 L/s plus 33% of the flow above 150 L/s, as measured at the Narrows.*

2.3 Proposed groundwater supply and irrigation scheme

FCIL propose to take up to 250 L/s from a bore-field comprising 4-5 production wells, to be located on the north side of the Waima River. To date two production wells have been completed on the eastern side of the SH1 Bridge, with a smaller diameter pilot well also installed. It is likely that the remaining production wells will be located in a similar area as the existing wells and may include a well upstream of the rail bridge (near existing monitoring well MW4). All groundwater wells will abstract water from the lower gravel aquifer at or about 25 m – 30 m depth.

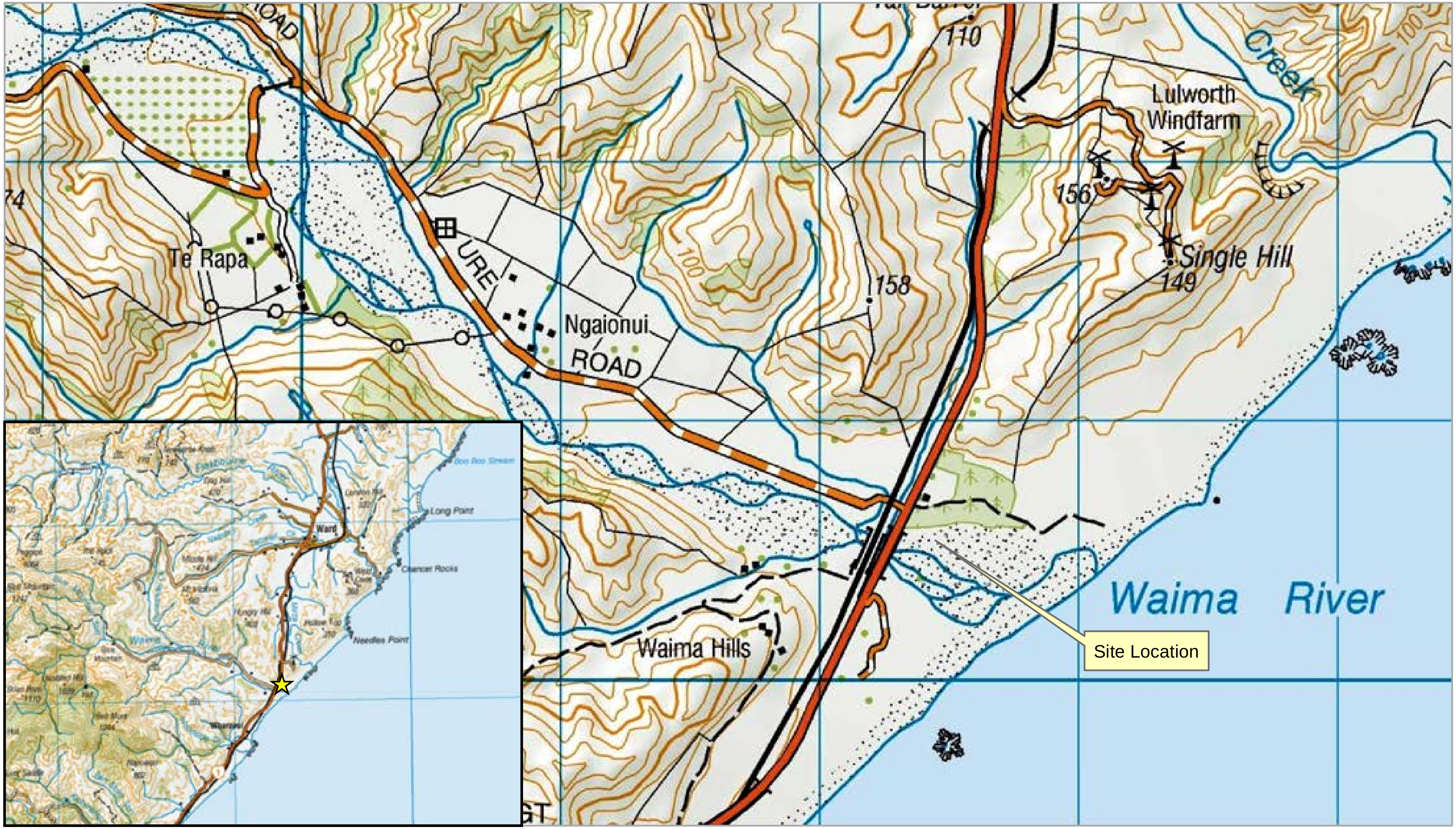
Abstracted groundwater is to be pumped to a buffer tank on a high point, likely to the east of SH1, with sufficient elevation to serve the scheme command area. The bore pumps will operate automatically to provide the required scheme demand, based on the water level in the buffer tank, with one or all of the pumps able to operate, depending on the flow rate required.

Groundwater will predominantly be used to irrigate grapes via a drip irrigation system. The total area covered by the irrigation scheme is expected to be 1100 ha. The estimated 90th percentile monthly irrigation demand has been calculated using the online Irricalc tool[1] and is summarised below. The 250 l/s peak take will therefore be able to provide the estimated average January demand as well as a minimum application rate of 1.83 mm/day (232 l/s). At 250 l/s, the peak system capacity will be an application rate of 2.0 mm/day (or 0.227 l/s/ha) for the 1100 ha command area

Table 2-1 90 Percentile irrigation demand (Irricalc)

Month	Monthly Total (m^3)	Water demand (m^3/h)	Water demand (L/s)
October	99,000	90	25
November	440,000	400	111
December	627,000	570	158
January	704,000	640	178
February	638,000	580	161
March	385,000	350	97
April	121,000	110	31

[1] http://mycatchment.info/



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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
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GHD

Flaxbourne Community Irrigation
Waima Pump Testing

Location Map

Project No. 51-37728
Revision No. A
Date 23/05/2018

FIGURE 2-1

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3. Environmental Setting

3.1 Climate

The east coast of Marlborough is one of New Zealand driest areas due to the rain shadow effect of the Southern Alps and Kaikoura Ranges. The area receives low rainfall and has high evaporation rates. Monthly and annual rainfall recorded at Ward (Chancet) obtained from Niwa's cliflo database[1] are summarised in Table 3-1. Anecdotal evidence (K. Loe, pers comm.) suggests that the rainfall in the upper Waima Valley is higher than recorded at Ward.

Table 3-1 Rainfall statistics Ward 1917-2017

Month	Minimum (mm)	Maximum (mm)	Average (mm)
January	0	232.5	53.5
February	0.4	271.8	54.0
March	5.4	455.2	57.5
April	4.6	238.2	62.0
May	16	262.2	77.7
June	9.9	291.9	71.4
July	4.6	265.3	82.3
August	8.7	214.2	74.7
September	3.6	194	60.2
October	5.1	226.5	60.0
November	4.6	184.1	57.0
December	0	190.5	59.2
Annual	442.5 (1958)	1193.6 (1995)	764.1[1]

[1]Note: Monthly averages do not sum to annual average due to incomplete records in 1953, 1954 and 1975. These three years have not been included in the annual average, although individual months have been included in the monthly average.

[1] www.cliflow.co.nz

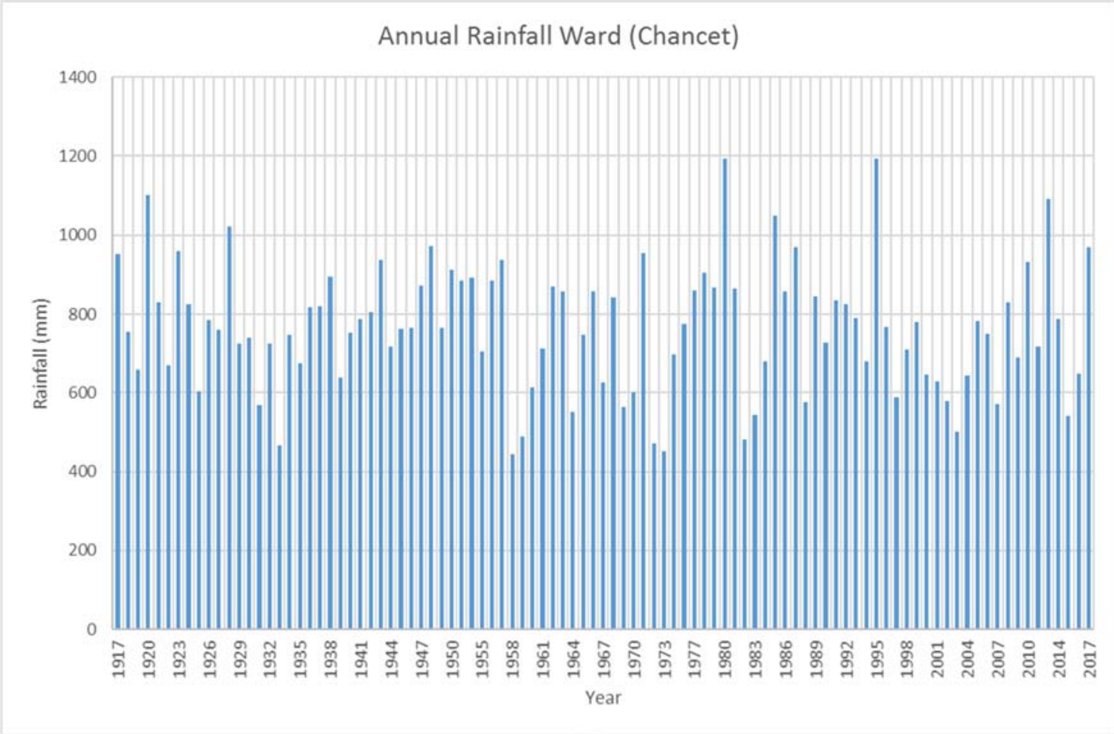


Figure 3-1 Annual rainfall Ward 1917-2017

3.2 Hydrology

The Waima (Ure) River flows from eastward to the coast from its headwaters at the northern end of the Inland and Seaward Kaikoura Range. The river is confined to a narrow bedrock channel in the upper reaches. From Blue Mountain Homestead, the channel gradient flattens and the valley widens with the river taking on a braided form. Surface flow is often absent downstream of “The Narrows” in summer months (Opus, 2017). At the river mouth there is usually tidal pond rather than an estuary. The tidal pond exhibits a high degree of variability in response to the tidal cycle and flow conditions in the river (Opus, 2018). The river mouth is usually closed to the sea due to the presence of a gravel bar. The variable nature of the lower Waima River is demonstrated in the two aerial photos below. These photos were taken in 2010, after an extended dry period and in 2016 after a winter of low-moderate flow events (inferred from Flaxbourne River flow record).

Figure 3-2 Aerial photographs of lower Waima River. Top May 2010, bottom November 2016 (source Google Earth)

Concurrent flow gaugings collected by MDC typically show a reduction in flows from The Narrows to the Ure Road Bridge, the river then gains water in the segment from the Ure Road Bridge to the SH1 Bridge. It is unclear whether this gain is due to recharge from groundwater or from surface water inflows from creeks feeding into the river. Only one set of concurrent flow gaugings has been collected since the 2016 Kaikoura earthquake. This showed a slight gain from the Ure Road Bridge to SH1, contrary to previous trends (pers comm. Val Wadsworth, MDC).

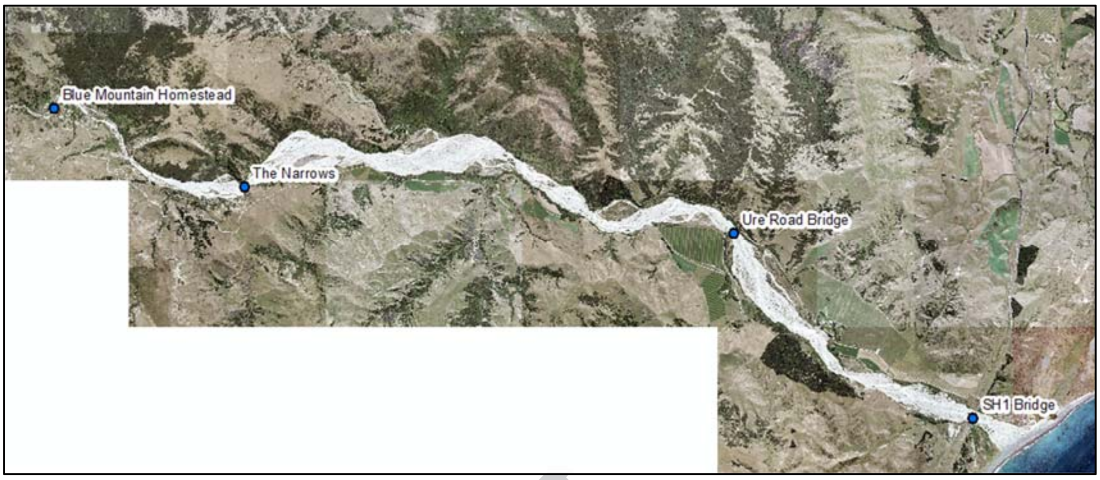


Figure 3-3 Waima River Gauging Locations

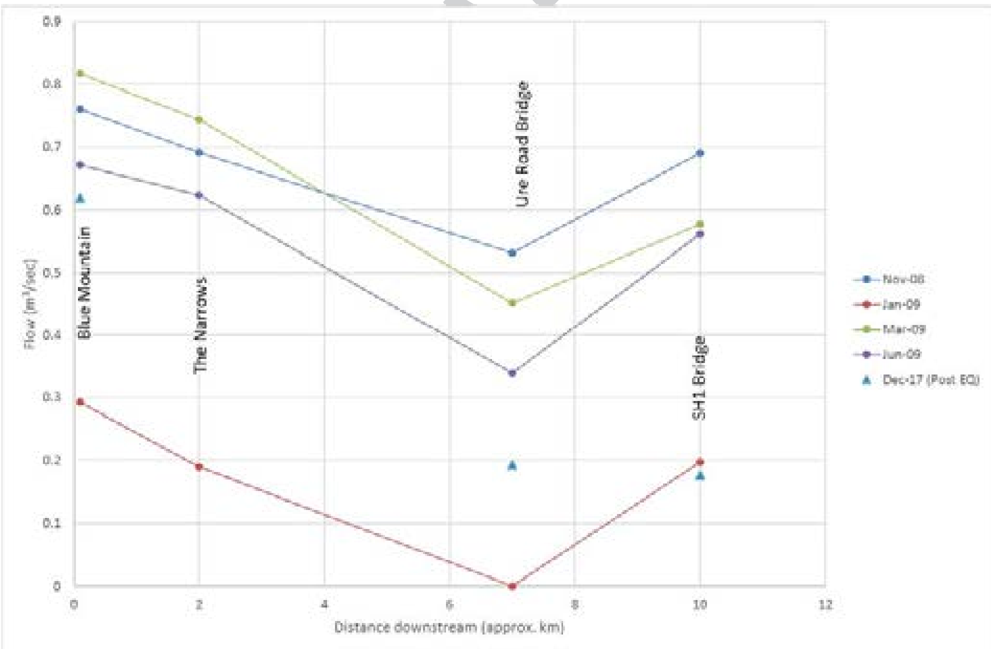


Figure 3-4 Waima River Flow Gauging (source MDC)

3.2.1 Surface water monitoring during pump tests

Surface water monitoring during the FCIL pump test program included flow measurements (collected by MDC) and monitoring of water level changes at a fixed point. Flow and level measurements were collected in the Waima River (above SH1 bridge) and in a drain that flows into the River immediately upstream of the Bridge. Flow measurements are summarised in Table 3-2. Continuous water level measurements recorded with a pressure transducer during the testing period are included in the Aquifer Test report (Appendix A).

The data show relatively stable water levels in the side drain. The Waima River plot shows a rapid response to rainfall events, and similar flow patterns to the nearby Flaxbourne River. An exception is a flood event in the Flaxbourne River record (25 March 2018) that was not recorded by the Waima River level logger. This flood event does correlate with rainfall in Ward and a water level rise in the shallow groundwater wells MW3 and MW1_S. The absence of a water level response in the river transducer is likely due to the braided nature of the river, where the majority of the flow may have flowed down a different braid.

Table 3-2 Flow gauging (source MDC)

Date	Waima River	Side Drain
19/03/2018	400 L/s	14 L/s
4/04/2018	394 L/s	11 L/s
20/04/2018	723 L/s	11 L/s

3.2.2 Flaxbourne River

The Flaxbourne River is the nearest river monitored regularly by MDC, located approximately 10 km north of the Waima River. The Flaxbourne arises in the inland Kaikoura Range flowing east, then southeast towards the coast. In absence of regular monitoring data for the Waima River, the Flaxbourne River is considered to be a best approximation for flows in the Waima. However, during dry periods the Flaxbourne can drop down to 5-10 L/s but does not go dry unlike the Waima River. Additionally, there are several gaps in the Flaxbourne record (Figure 3-5) due to damage to the control weir (where the monitoring gauge is located) caused by flood events. For these reasons, there is some uncertainty with correlating of Waima River and Flaxbourne River for very low and very high flow scenarios.

Figure 3-6 shows the correlation between the Flaxbourne and Corrie Downs and the Waima River at SH1 Bridge for mid-range flow. For most records, the correlation provides a flow rate within the similar range (both over and under estimating) to the actual measured flow rate. However, the correlation wildly overestimates the flow during the February 2009 and January 2018 flow gaugings. To partially account for low flows and dry conditions in the Waima River, a second correlation was completed with the intercept forced through zero. While the R^2 value is low (0.68), this correlation is considered to be very conservative as it will almost always underestimates the flow in the Waima River.

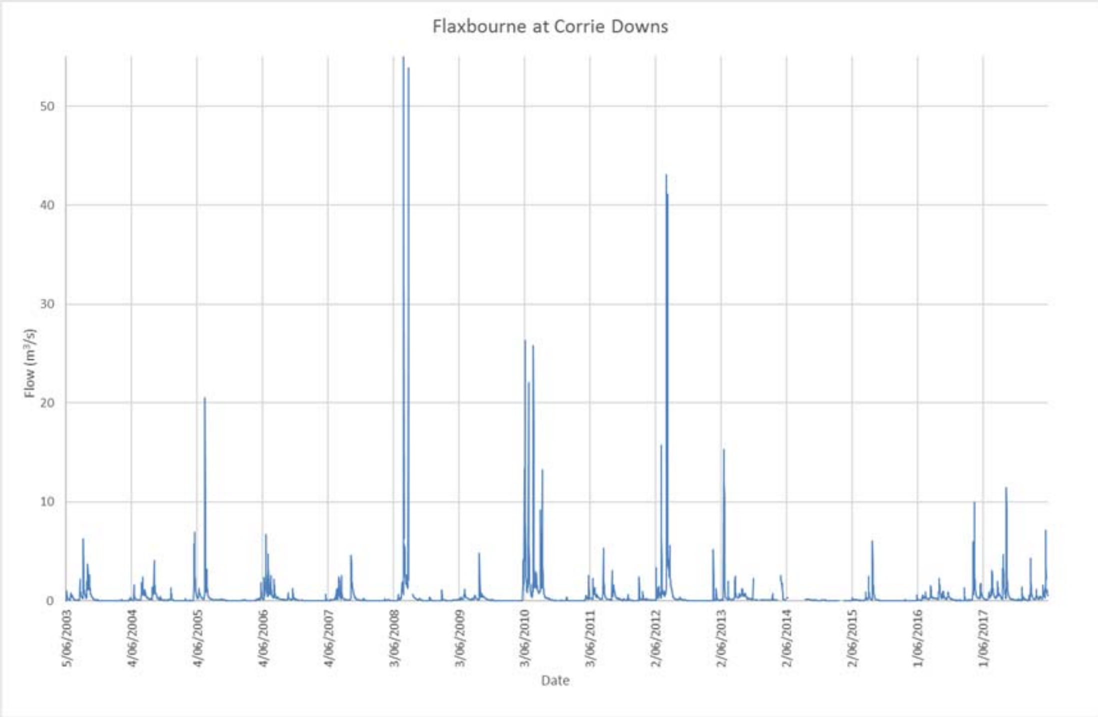


Figure 3-5 Flaxbourne River flow at Corrie Downs 2003-2018. Source MDC

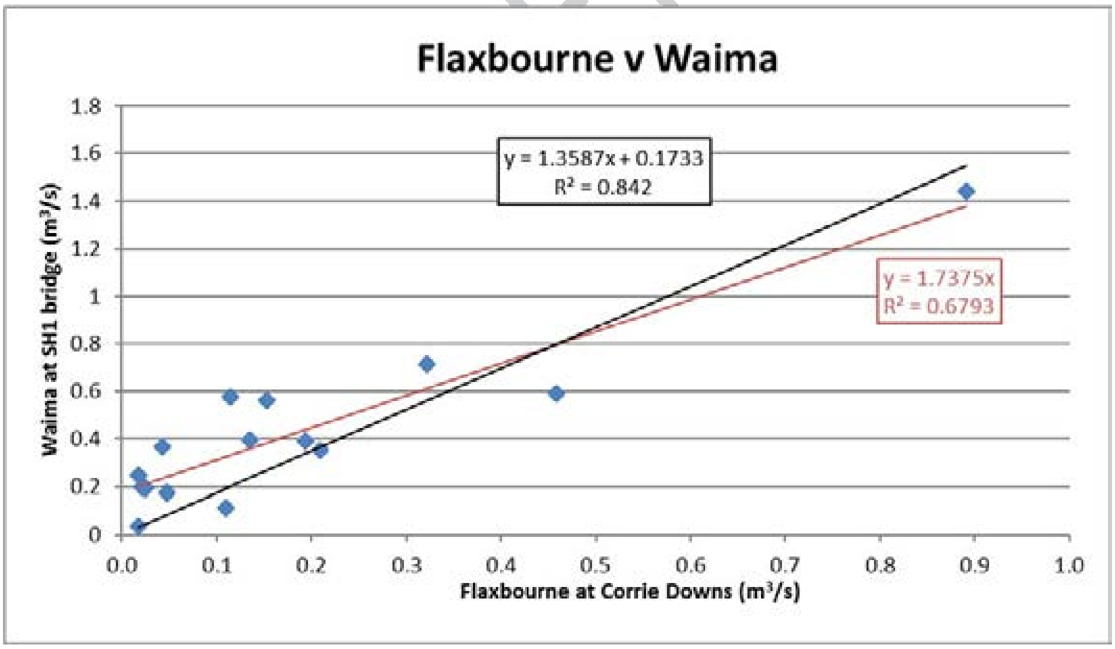


Figure 3-6 Flaxbourne and Waima correlation

The percentage exceedance for both synthetic Waima flow records is shown graphically in Figure 3-7. This graph shows that 40% of the time, modelled flow in the Waima River (at SH1 bridge) is 250 L/s or less for the $R^2 = 0.84$ correlation (100 L/s for the $R^2 = 0.64$).

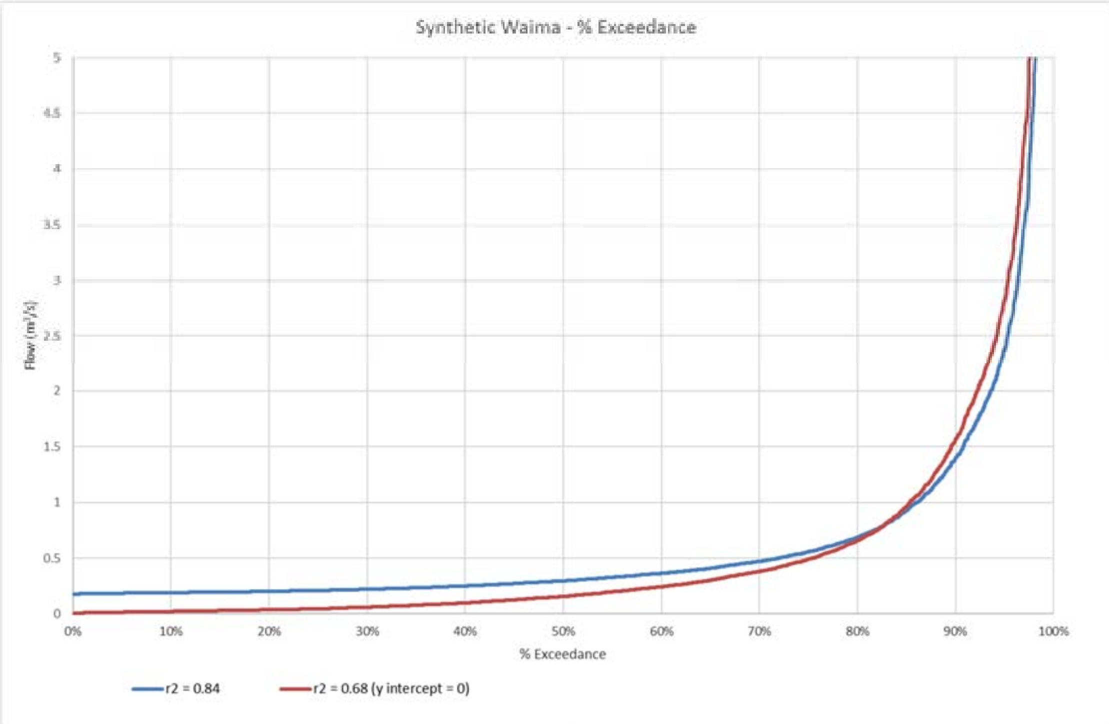


Figure 3-7 Percentage exceedance synthetic Waima River (at SH1 bridge) flow record

3.3 Geology

The geology of the lower Waima River valley comprises Quaternary alluvium underlain by mudstone and sandstone of the Pahau Terrane (Rattenbury *et al*, 2006). Pahau Terrane mudstone and sandstones form the hills to the north and south of the river. The geology of the upper catchment is complex due to numerous faults bisecting the area. The upper catchment is dominated by limestone; however, several other sedimentary rock types (predominantly marine origin) are present.

Few bores have been drilled in the Waima Valley area. The available bore logs show that the Waima Valley alluvium can be divided into three main layers, a shallow gravel, a finer grained layer with silt, clay and claybound gravels and a lower gravel. While there is variability in the thickness and material composition of the fine grained layer, it is present in all bore logs. This indicates that the fine grained layer is reasonably extensive throughout the lower Waima Valley. This unit has been described as clay on many of the FCIL bore logs. However, a sample provided to GHD is best described as a sandy silt. Around PW1 and MW1 this layer appears to be sandier, and is described on the drilling logs as marine sand.

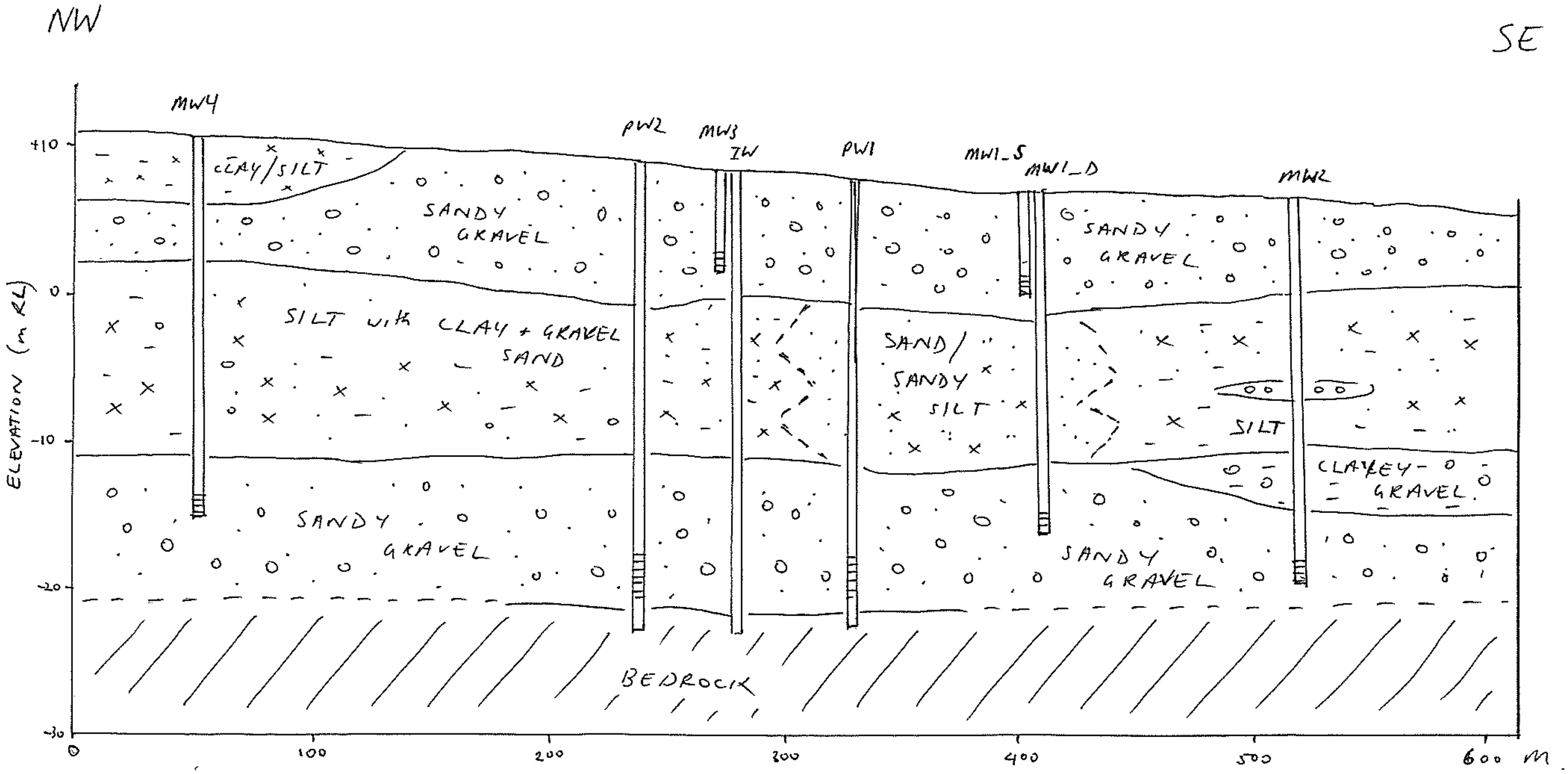
The main water-bearing layer generally occurs at the base of the lower gravels. Geophysical information suggests that the lower gravels are absent on the south side of the river (Opus, 2017). The geology encountered at the test site is summarised in Table 3-3 and Table 3-4. The geology of the bore field area is shown in the cross section in Figure 3-8. This cross section shows the lower gravel aquifer pinching out towards the coast, with MW2 having only a ~5 m thickness of sandy gravels.

Table 3-3 PW1 Bore log

Depth	Description
0 – 0.4	Brown silt, white and grey gravels
0.4 – 8.1	Grey and white gravels, water bearing
8.1 – 19.6	Grey marine sand
19.6 – 28.6	Brown and white medium gravels, some yellow clay, water bearing
28.6 – 29.9	Grey clay (Papa)

Table 3-4 PW2 Bore log

Depth	Description
0 – 0.2	Brown silt
0.2 – 9.4	White and grey medium gravel to medium sand
9.4 – 21.6	Grey clay, some white and grey medium gravels
21.6 – 28.9	White grey and blue medium gravel to medium sand, good water bearing
28.6 – 29.9	Grey medium gravels and grey clay



NW
SE
MW4
PW2
MW3
IW
PW1
MW1_S
MW1_D
MW2
CLAY/SILT
SANDY GRAVEL
SILT with CLAY + GRAVEL SAND
SAND/SANDY SILT
SILT
CLAYEY-GRAVEL
SANDY GRAVEL
BEDROCK
ELEVATION (m RL)
+10
0
-10
-20
-30
0
100
200
300
400
500
600 m.

3.4 Hydrogeology

Groundwater in the Waima Valley occurs in two main aquifers, a shallow unconfined aquifer in the upper gravels (<10 m deep) and deeper gravel aquifer (>20 m deep). The shallow gravel aquifer is hydraulically connected to the Waima River. Concurrent water level measurements of the shallow and lower gravel aquifers (MW1_S and MW1_D) indicate a downward hydraulic gradient in the vicinity of the SH1 Bridge. Bore logs records, aquifer response to pumping and tidal response indicate that the lower gravel aquifer is semi-confined.

3.4.1 Existing Groundwater Takes

MDC records indicate that groundwater is abstracted from four wells in the Waima Valley, with details provided in Table 3-5. Pump test information is not available for these wells. Most of the wells are screened in the lower gravels, at depths greater than 23 m. P29w/0113 is screened from 14.1 m depth (lower gravel). Groundwater levels recorded on the bore logs are shallow, between 0.85 m and 4.5 m below ground level. Groundwater levels in the Buick wells typically vary between 5 m (winter) and 15 m (dry summer) below ground level (Mr Buick pers comm.)

Table 3-5 Groundwater take consents in the Waima Valley

Consent Number	Well Number	Maximum Abstraction (m^3/day)	Bore Owner
U120387	P29w/0141	1285	Rudd
U120386	P29w/0141	880	Hungry Hill Ltd.
U110175	P29w/0112	600	Buick (Te Rapa)
	P29w/0113	1100	
U000564	P29w/0090	360	Buick (Te Rapa)

3.5 Water Chemistry

To ascertain if there were any significant chemical differences between the surface water, shallow groundwater, and the deeper groundwater, water samples were collected during the testing period and analysed for major cations and anions.

The major ion chemistry was plotted on a piper Tri-linear plot (Figure 3-9). Water samples were collected from the deep aquifer (wells PW1 and PW2), the shallow unconfined aquifer (well MW3) and two surface water samples (from the Waima River and side drain). All samples have a very similar chemistry, with a strong calcium carbonate signature, indicative of the limestone catchment. There does not appear to be significant chemical evolution occurring between the shallow and deep samples, suggesting that flow paths are short and interaction between surface water, shallow groundwater, and deep groundwater occurs. Laboratory reports are included in Appendix B.

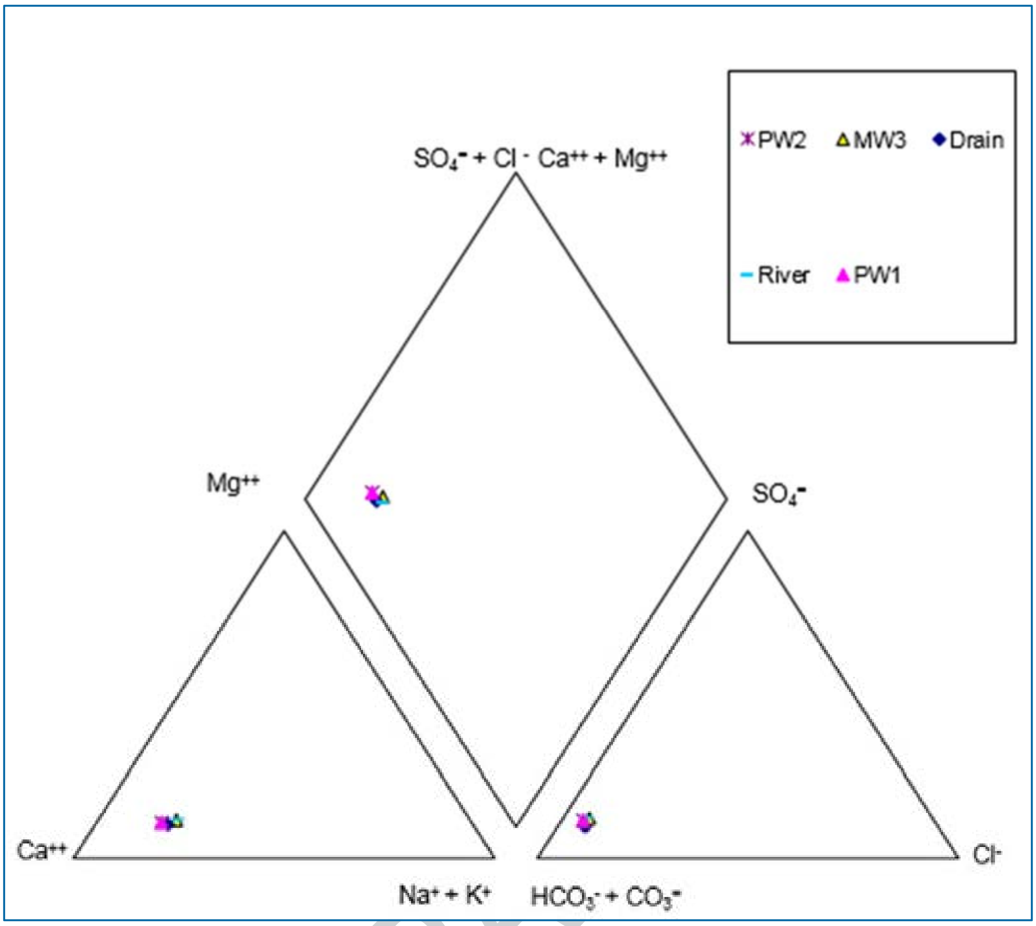
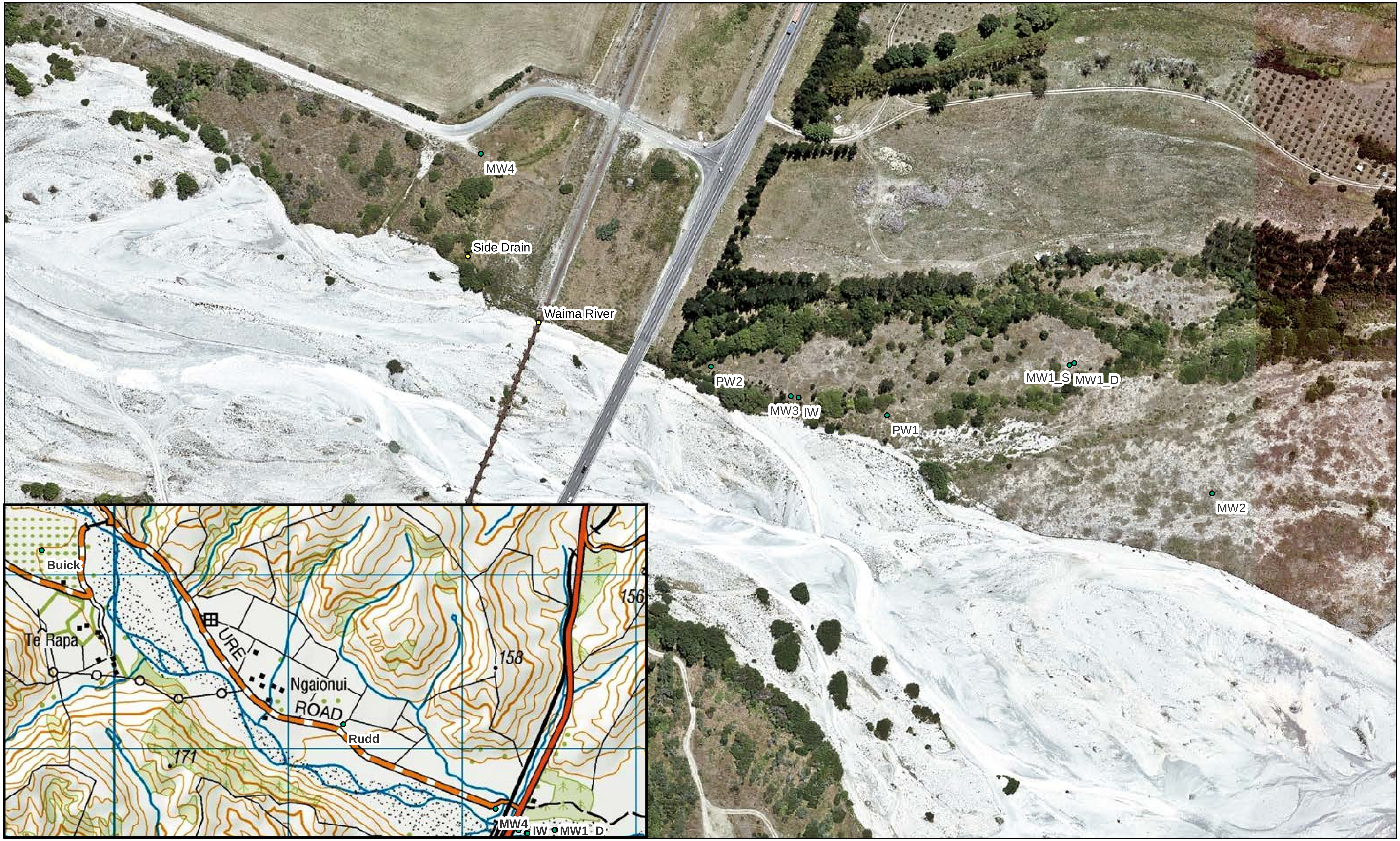


Figure 3-9 Piper plot of water samples collected from Waima surface water and groundwater

3.6 FCIL Wells and Pump Testing

To date, development of the bore field adjacent to the Waima River has been undertaken in two stages. The first stage was overseen by Opus International Consultants (2017). GHD has been involved in the second stage of works since January 2018. A summary of the works completed is provided in Table 3-7. All wells have been drilled by Butt Drilling. Bore logs are provided in the attached pump test report (Appendix A).



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0 10 20 40 60 80

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD2000 New Zealand Transverse Mercator 2000

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LEGEND

- Project wells
- Surface water monitoring

Flaxbourne Community Irrigation Ltd
Waima Pump Testing

Job Number	51-37728
Revision	A
Date	14 Jun 2018

Wells and Surface Water Monitoring

Figure 3-10

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Level 3 138 Victoria Street Christchurch 8141 New Zealand **T** 64 3 378 0900 **F** 64 3 377 8575 **E** chcmail@ghd.com **W** www.ghd.com

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:dmains

Table 3-6 Specifications of pumped well and observation wells used in pumping test

Well	MDC well number	Designation	Easting (NZTM)	Northing (NZTM)	Elevation[1]	Distance to PW2 (m)	Top of screen (m)	Depth (m)	Diameter (mm)	Static Water Level[2] (m btoc[3])
PW1	10842	Pumped well	1692428	5360507	7.5	105	25.62	29.86	300	2.57
PW2	10925	Pumped well	1692326	5360539	8	-	25.97	30.44	400	2.20
IW	10795	Observation well	1692377	5360517	8	55	24.2	31.7	150	2.34
MW1_D	10843	Observation well	1692535	5360536	7	205	23.95	25.45	100	1.96
MW1_S	10894	Observation well	1692535	5360537	7	210	6.6	7.6	100	1.60
MW2	10926	Observation well	1692615	5360462	6	300	24.88	25.88	100	2.41
MW3	10927	Observation well	1692374	5360519	8	50	6.51	7.51	100	2.09
MW4	10928	Observation well	1692194	5360658	10.5	180	24.82	25.82	100	2.97
Rudd	P29w/0141	Observation well	1691325	5361149	18	1,180	23.5	26.5	300	1.02
Buick	P29w/0090	Observation well	1689585	5362153	36	3,180	25	28	150	5.40

[1] Estimated from MDC 1 m contours (LIDAR 1 m East Coast, captured Dec 2016-Jan 2017)

[2] Recorded 03/04/2018 prior to PW2 constant rate test

[3] Metres below top of casing

Table 3-7 Summary of works

Stage 1 (2017)	Drilling of a 150 mm investigation well (IW), 300 mm production well (PW1) and two monitoring wells (MW1_S and MW1_D) Step discharge test and 98 hour constant rate test of PW1 Geophysical (resistivity) survey
Stage 2 (2018)	Drilling of a 400 mm production well (PW2) and three monitoring wells (MW2, MW3, MW4) Step discharge tests of PW1 and PW2 7 day constant rate test of PW2 (rate 83 L/s) 7 day well field test of PW1 and PW2 (combined rate 130 L/s)

3.6.1 Pumping testing summary

The results of the pumping tests are detailed in the attached report (Appendix A). Both wells tested are high yielding with limited lateral drawdown. The pumping tests showed that the lower aquifer can be considered to be semi-confined. A strong leakage signature in the pump test data indicates vertical movement of groundwater is occurring at short time scales; from the shallow gravel aquifer, through the fine grained layer to the lower gravel. Furthermore, the time series data indicates that the shallow gravel aquifer has a high degree of connection to the Waima River. Concurrent flow gaugings indicate that the river gains and looses water to the shallow gravels (and likely to the deeper aquifer). Therefore, abstraction from the lower gravel aquifer is expected to result in movement of water from the shallow aquifer, and is likely to have some impact on surface water flows.

As noted in section 3.3 the lower gravel aquifer appears to be pinch (decrease in thickness) towards the cost, this is demonstrated by the low transmissivity value of 870 m^2/day in MW2.

Predicting Seasonal Pumping Effects

The results of the pumping tests are used to predict the seasonal effects of abstracting up to 250 L/s on the aquifer, surface water, and neighbouring water uses.

For the purposes of predicting the long term effects the following parameters are considered to represent the hydraulic properties of the aquifer (Table 3-8).

Table 3-8 Aquifer parameters

Parameter	Representative value	Range	Geomean
Transmissivity (m^2/day)	4,000	870 - 4,940	2,900
Storativity	7.5×10^{-5}	$4.6 \times 10^{-5} – 1.7 \times 10^{-4}$	7.5×10^{-5}

4. Assessment

4.1 Introduction

An initial conceptual model of the groundwater system was developed based on information presented in Section 3 and the results of the pump testing. A high-level water balance was calculated for catchment. The conceptual model, water balance and aquifer properties defined in the pump test report were used to assess the effects of the proposed groundwater take on the environment.

4.2 Conceptual Model

The conceptual model of the groundwater system is presented in the pumping test report (Appendix A) and summarised as follows:

- High degree of connection between the Waima River and the shallow gravel aquifer. Flow gauging indicates that flow is lost from the River to the shallow gravel as the valley widens above the Ure Road Bridge. An increase in river flow at the SH1 Bridge is likely to be a combination of tributary inflow and recharge from shallow groundwater as the valley (and gravel aquifer) narrows.
- Recharge to the lower aquifer is from vertical leakage from the shallow gravel (and connected river) through the semi-confining layer. The downward hydraulic gradients between the aquifers persist in the vicinity of SH1 bridge.
- Groundwater discharge is likely to be via springs/seeps in the sea floor, with hydraulic connection evidenced as tidal response in the lower aquifer.
- Groundwater chemistry indicates a similar source, with little difference between groundwater and surface water chemistry.

4.3 Water Balance

A high level water balance was developed to quantify the flux of water in the surface and groundwater system. This water balance uses concurrent flow gaugings collected by MDC in 2008 and 2009 under moderate[2] flow conditions. Groundwater flow in the shallow and lower gravel aquifers was estimated using the Darcy flow equation (Eqn 1) and aquifer transmissivity calculated from pump testing.

$$Q = KiA \qquad (1)$$

Where:

Q = flow

K = hydraulic conductivity

i = hydraulic gradient

A = area

Parameters used in the flow equation are included in Table 4-1. The water balance is summarised in Table 4-2.

[2] Excludes flood events and low flow periods (when river by Ure Bridge is dry)

Table 4-1 Parameters used in Darcy flow equation

	The Narrows	Ure Bridge	SH1 Bridge	Comments
Valley width (m)	50	700	600	Approximate
Elevation (m)	80	34	8	Approximate, assumes water table elevation close to surface
Gradient	0.01	0.009	0.008	
Lower Aq K (m/day)	400			Based on pump test analysis
Lower Aq thickness (m)	n/a	3	10	
Shallow Aq K (m/day)	1000			Based on Hunt, 2003 analysis
Shallow Aq thickness (m)	2	6	6	

Table 4-2 Waima Valley water balance

Location	Groundwater[1] (L/s)	Surface Water (L/s)	Total (L/s)	Difference from upstream (L/s)
Blue Mountain	-	690	690	
The Narrows	10	620	630	-60
Ure Bridge	530	350	880	+250
SH1 Bridge	580	550	1,130	+250

[1]Combined shallow and lower aquifer flux

4.4 Assessment of Effects

MDC does not specify how to assess the effects of groundwater abstraction on existing users.

The abstraction of groundwater can result in the following environmental effects:

- Drawdown effects on existing users affecting their reliability of supply;
- Effects on surface water flows;
- Effects on the saline/freshwater interface;
- Cumulative effects of the abstraction on the water balance.

4.4.1 Planning assessment

The Wairau/Awatere Resource Management Plan (WAP) and the Proposed Marlborough Environment Plan (MEP) both contain rules relating to the take and use of freshwater. While the MEP is currently in the hearing and submission phase, rules applying to the take and use of water had legal effect as of 9 June 2016. The proposed abstraction of groundwater for irrigation use is not classified as permitted, controlled or prohibited in either of the plans. Under Rule 27.1.2.4 of the WAP the groundwater take is classified as a non-complying activity. In the MEP the activity is classified as Discretionary (Rule 2.5.2). Relevant policies are discussed further in the following sections.

4.4.2 Effects on other groundwater users

There are no specific rules relating to interference effects on other groundwater users. The following policies are applicable.

Wairau Awatere Resource Plan

Policy 6.3.1.1.7

To ensure that new bores, intakes, and dams are located and operated to avoid, remedy or mitigate interference effects on other water users.

Proposed Marlborough Environment Plan

Policy 5.3.11 – Have regard to the potential for any take of water to adversely affect the ability of an existing water user to continue taking water and mitigate any adverse effects by limiting, where necessary, the instantaneous rate of take.

Policy 5.3.13 – While seeking to manage interference effects between groundwater users, recognise that it is unreasonable to protect an existing take of groundwater when the bore does not fully penetrate the aquifer.

Neither plan specifies methodology for calculating interference effects on other groundwater users.

The abstraction of groundwater results in the reduction in groundwater head as the drawdown cone radiates from the pumped well. Where the lateral extent of the drawdown intercepts a neighbouring well, the magnitude of the effect is determined by the duration of the pumping (i.e. how long the effect occurs), the pumping effect of the neighbouring well (i.e. self-induced drawdown effects), existing cumulative drawdown effects, and natural groundwater level fluctuations.

The drawdown effects can be characterised into:

1. Short-term pumping effects; drawdown effects from abstracting at a maximum rate over a period of seven days (Q_7).
2. Seasonal pumping effects; drawdown effects from abstracting at a seasonal average rate over a period of 212 days (Q_{212}).

The aquifer testing undertaken (Appendix A) demonstrates the pumping effects on the aquifer system after seven days of continuous pumping at 130 L/s. Based on the conditions at the time of the test there were negligible effects on neighbouring bores. However, a conservative approach would be to assume the abstraction occurred during a period of no flow in the Waima River and seasonally low groundwater levels.

To assess the effects of the short term and seasonal pumping effects of the proposed abstraction an analytical model (Hunt, 2003) was used to predict direct drawdown effects on neighbouring wells. The analytical model was developed using the hydraulic parameters determined from the pump test (Table 4-3).

In addition to the short term (Q_7) and seasonal pumping (Q_{212}) effects, a third scenario was considered, with this simulating 30 days of pumping (Q_{30}) at the maximum rate while the river is dry. This scenario is considered to provide a highly conservative assessment, as the Waima River is only occasionally dry at the SH1 Bridge.

Table 4-3 Parameters used in interference effects assessment

Parameter	Value	Comment
Pumping rate – 7 days	250 L/s	FCIL demand maximum
Q_{212}	165 L/s	Seasonal demand over 212 days
Transmissivity	4,000 m^2/day	Representative value from pump testing
Storativity	7×10^{-5}	Average value from pump testing
Streambed conductance (λ)	2	Midrange value from pump testing

Table 4-4 Modelling interference effect on other groundwater users

Well		Interference effect (m)	Self induced drawdown[1] (m)	Total drawdown (m)	Available drawdown[2] (m)
Rudd	Q_7 (250 L/s)	0.1	0.5	0.6	21.5
	Q_{30} (250 L/s) dry river	0.2		0.7	
	Q_{212} (165 L/s)	0.4		0.9	
Buick	Q_7 (250 L/s)	0.00	0.1	0.1	18.5
	Q_{30} (250 L/s) dry river	0.01		0.1	
	Q_{212} (165 L/s)	0.05		0.1	

[1]Based on water level variation attributed to pumping (observed in logger record Feb-Apr 2008)

[2]Based on average water level March-April 2018 and a depth 1 m above screen (from bore log). Mr Buick indicated that the static water level drops to 15 mbgl during dry summers.

Interference effects in upstream wells is predicted to be negligible after seven days of continuous pumping at the maximum rate of 250 L/s. Over 212 days, the modelled effect is less than 0.5 m. In comparison to the available drawdown it the neighbouring wells, the effect is less than minor.

4.4.3 Effects of surface water

The pumping tests have shown that the aquifer is semi confined. Abstraction from the lower aquifer will increase vertical movement of water from the shallow gravel aquifer down through semi confining layer. The shallow gravel aquifer is in direct hydraulic connection with flows in the Waima River, therefore abstraction from the lower gravel aquifer is expected to influence flows in the river to some extent. However, the influence on the shallow aquifer will be distributed across a broad area, reflecting the radius of influence of pumping in the lower aquifer. This distribution of greater leakage will mean water will be drawn from not only the river, but also from shallow groundwater distant from the river. In addition, the broadly distributed influence and thickness of the semi-confining layer is expected to buffer the potential effects of drawdown during particularly dry periods. .

The distribution of greater leakage is expected to result in net effects on the Waima River, associated with groundwater abstraction, being less than the equivalent surface water take from the river. However, to provide for average long term effects, the proposed water take is considered in the context of the river and shallow groundwater system water balance.

Both the WAP and MEP include several policies relating to the use of fresh water, with an emphasis on safeguarding the life supporting capacity of the river. To do this MDC has specified annual allocation limits and flow restrictions on many freshwater management units (FMU, includes surface and groundwater resources). The Waima River is not included the list of FMU's with an annual allocation or flow restriction (Appendix 6, MEP).

Applicable policies include:

Wairau/Awatere Resource Plan

Policy 6.2.1.1.2

To maintain groundwater levels and flows at levels which safeguard the life supporting capacity of the resource by setting and enforcing Sustainable Flow Regimes (SFRs) in m^3 */year.*

Marlborough Environment Plan

Objective 5.6 – Ensure that the taking of groundwater does not cause significant adverse effects on river flow.

Policy 5.6.1 – Unless there is an identified aquifer dominant Freshwater Management Unit, all water within a catchment will be managed as a surface water resource. This means that the minimum flow, management flow and allocation limit established for the river dominant Freshwater Management Unit will also apply to groundwater takes.

There is limited information on flows in the Waima River. In Section 3, we attempt to correlate flows recorded in the Waima River at the SH1 Bridge to the Flaxbourne River at Corrie Downs. However, this correlation is poor and likely to underestimate flows in the Waima River. A similar correlation was presented in evidence supporting the original surface water take (U071402), except between the Waima River at the Narrows and the Flaxbourne River at Corrie Downs. This correlation was used to predict flows in the Waima 95% of the time but again underestimated flows. The key difference between the Narrows and the SH1 Bridge is that the river loses water to ground in the mid and lower reaches, consequently the river is often dry around the Ure Rd Bridge and less frequently around the SH1 Bridge. The spatial and temporal extent of the dry part of the river varies from year to year depending on climatic conditions. The past two years have been relatively wet, with approximately 400 L/s flow recorded at the SH1 Bridge during March 2018, typically a dry part of the year.

The effect of abstraction on river flows was assessed using the Hunt (2003) analytical solution. A key component of this solution is the streambed conductance (lamda, λ) which takes into account the width of the river (flowing water), permeability and thickness of the streambed. The pump testing analysis indicated that a streambed conductance of 2 (based on a stream width of 10 m) was appropriate to analyse the results. When the river is dry the streambed conductance is effectively zero, in flood events the streambed conductance is higher, as the width of water increases. This analysis approach results in an increased stream depletion as lamda is increased. However, while the amount of water (L/s) that leaks from the river increases during high flow events, the proportion of river flow is less as demonstrated by Figure 4-1.

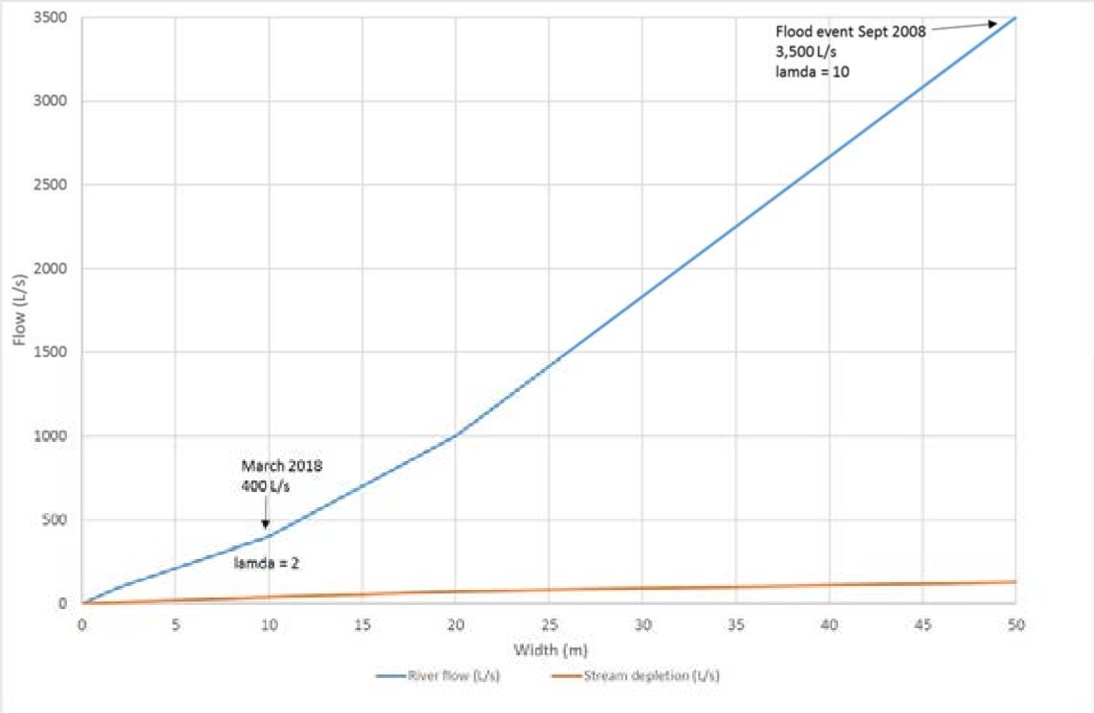

Figure 4-1 Example scenario demonstrating effect of stream width on calculated stream depletion

The analytical solution predicts that as the flow in the river decreases, the effect of groundwater abstraction increases (as a proportion of flow) until the river goes dry. At that point, the abstraction is solely from groundwater with an increased rate of the drawdown in the aquifer. When a flood event occurs in the river this recharges the shallow unconfined aquifer with a proportion of leakage to the lower aquifer. Therefore, due to the variability of the flow regime it is difficult to predict the actual stream depletion at any one time. However, it is likely that during dry years the proposed groundwater abstraction will cause the river to go dry slightly earlier than would occur naturally. This effect is likely to be comparable or less than the impact of the consented surface water take at the Narrows.

Consent U071402 allows for 50 L/s to be abstracted from the river when flow is greater than 149 L/s at the Narrows. At the minimum limit, this would effectively reduce the flow in the river from 150 L/s to 100 L/s at the Narrows. Concurrent flow gaugings (MDC) indicate that flow decreases downstream to the Ure Rd bridge before increasing again at SH1 to a flow slightly less (typically 50-100 L/s) than recorded at the Narrows. Based on these flow gaugings it is likely that the river would already be dry at Ure Rd Bridge prior to the application of the minimum flow restriction. The effect on the flow at the SH1 Bridge is less clear, but it is likely that the surface water take from the Narrows would result in the river going dry slightly earlier than would occur under natural flow conditions.

As discussed in Section 3, the lower reaches of the Waima River are ephemeral with surface flow absent often absent in summer. Additionally, a gravel bar, only breached in large flood events, usually blocks the river mouth. Due to these limitations, fish and eel species are rare in the Waima River (Opus, 2008). The U071402 decision documents indicates that river birds, including species in decline, are known to feed and nest in the river. The presence of an open cobbled riverbed with little or no vegetation is important for breeding. Vegetation can build up during sustained periods of low flow, but is cleared out during flood events (U071402 decision documents). The effect of the proposed groundwater abstraction on flood flows is negligible. In the 2007 hearing, the commissioner concluded that neither the freshwater ecosystem, nor the life-supporting capacity of the river, would be significantly affected.

Overall, the proposed groundwater abstraction is likely to cause the Waima River to, on average, go dry slightly earlier than would occur naturally. The effect is likely to be less or equivalent to the existing surface water take. However, the effect on the surface water environment is no more than minor as the groundwater abstraction will have a negligible effect on flood flows that are important for the river ecosystem.

4.4.4 Saline Intrusion Effects

Abstraction of groundwater has the potential to affect the position of the fresh water / saline interface and lead to saltwater contamination of the aquifer. This is not directly addressed in the regional plan policies but is included as a component in setting minimum levels for freshwater management units (FMU). The Waima River is not included the list of FMU's (Appendix 6, MEP).

Wairau /Awatere Resource Management Plan

Policy 6.2.1.1.7 To set the SFR for fresh groundwater resources to:

• Prevent damage to the physical structure of the aquifer such as compaction, in particular those areas such as the Southern Valleys Management Zone;

• Prevent reductions in the quantity of spring flows, eg. Spring Creek from the Wairau Aquifer;

• Prevent a landward shift of the seawater/freshwater interface;

• Protect the instream ecology; and

• Provide for maintenance or enhancement of water quality.

Marlborough Environment Plan

Policy 5.2.11 – Set specific minimum levels for Freshwater Management Units dominated by aquifers to:

(a) prevent physical damage to the structure of the aquifer;

(b) prevent headwater recession of spring flows;

(c) prevent a landward shift in the seawater/freshwater interface and the potential for saltwater contamination of the aquifer;

(d) maintain natural and human use values of rivers and wetlands where groundwater is physically connected and contributes significantly to flow in the surface waterbody;

(e) maintain groundwater quality; and

(f) prevent long-term decline in aquifer levels that compromises the matters set out in (a) to (e).

Due to the freshwater recharge to the system, it is likely that the fresh water - saline interface is positioned offshore. Groundwater conductivity was monitored in the closest monitoring well to the coast (MW2) throughout the pump testing program. No increase in groundwater conductivity was apparent during pumping of the lower aquifer. Instead, a gradual decrease in groundwater conductivity was observed over a 48 day period as the well stabilised following drilling and development. Given the likely position of the interface and the groundwater setting, saline intrusion effects are unlikely to be an issue at the site. However, monitoring of groundwater quality (conductivity) in MW2 during the irrigation season is proposed to provide further confidence.

4.4.5 Cumulative effects

Cumulative abstraction of groundwater has the potential to cause a decline in groundwater levels where the total volume of water exceeds the natural inputs (recharge to the system).

The water balance presented in Section 4.3 indicates that there is in excess of 1000 L/s flux through the surface water-groundwater system in the Waima Valley under moderate flow conditions. The water flux will be considerably higher during flood events, which will act to recharge the groundwater system. Existing up-gradient groundwater consents allow for up to 49 L/s to be taken from the aquifer. The cumulative effect of the existing and proposed groundwater takes on the water balance is less than a third of the water flow through the system. The cumulative effect on the freshwater system of the proposed groundwater take is less than the existing surface water take.

5. Summary

This report documents an assessment of groundwater and surface water effects associated with the proposed groundwater abstraction to supply the Flaxbourne Community Irrigation Scheme. In 2008, FCIL was granted consent for a surface water take from the Waima River at the Narrows to supply the scheme. In recent years, attention has focussed on a groundwater supply in the vicinity of the SH1 Bridge over the Waima River. To date, two groundwater production wells have been drilled and tested with the results of the pump testing discussed in more detail in the attached aquifer test report (Appendix A).

The pump testing indicated:

- The drawdown response of the aquifer was limited in both magnitude and extent. Under the conditions at the time of the test, the aquifer could comfortably yield 130 L/s and would have achieved the design rate of 250 L/s. Under dry summer conditions, the aquifer is expected to perform well and achieve the design yield.
- No hydraulic boundaries were encountered over the duration of the test nor was there any evidence of saline intrusion.
- The pumping test showed that the lower aquifer can be considered to be semi-confined. A strong leakage signature in the pumping test data indicates vertical movement of groundwater is occurring at short time scales; from the shallow gravel aquifer, through the fine grained semi-confining layer to the lower gravel.
- The time series data indicates that the shallow gravel aquifer has a high degree of connection to flows in the Waima River. Concurrent flow gaugings indicate that the river gains and loses water to the shallow gravels (and likely to the deeper aquifer). Therefore, abstraction from the lower gravel aquifer is expected to result in movement of water from the shallow aquifer, and is likely to have some impact on surface water flows.
- Water chemistry analysis confirms a similar source for the river water, shallow and deep groundwater.

The groundwater assessment indicated:

- The effect of the proposed groundwater abstraction on water levels in upstream wells is considered to be negligible after seven days of continuous pumping at the maximum rate of 250 L/s. Over 212 days, the modelled effect is less than 0.5 m. In comparison to the available drawdown it the neighbouring wells, the effect is less than minor.
- Abstraction from the lower aquifer is expected to cause stream flow depletion due to the leaky nature of the semi-confining layer. The potential effects to surface water are however considered to be equivalent or better than those of the currently consented surface water take. As with this surface water take, the effect on the surface water environment is considered to be no more than minor, as the abstraction will have a negligible effect on flood flows that are important for the river ecosystem.
- Saline intrusions is not expected to occur to a significant degree, due to the likely offshore position of the saline interface and persistent hydraulic gradient driving groundwater flow towards the coast.
- The cumulative effect on the freshwater system of the proposed groundwater take is less than the existing surface water take.

6. References

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Appendices

Appendix A – Aquifer Test Report

Appendix B – Laboratory Report

GHD

Level 3
138 Victoria Street
T: 64 3 378 0900   F: E: chcmail@ghd.com

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