Hydrogeology Assessment for Proposed Burnham Quarry

Prepared for

Burnham 2020 Ltd

July 2023

PATTLE DELAMORE PARTNERS LTD
Level 2, 134 Oxford Terrace
Christchurch Central, Christchurch 8011
PO Box 389, Christchurch 8140, New Zealand

Office +64 3 **345 7100**
Website **http://www.pdp.co.nz**
Auckland Tauranga **Hamilton** Wellington
Christchurch Invercargill

solutions *for your environment*

Quality Control Sheet

TITLE	Hydrogeology Assessment for Proposed Burnham Quarry
CLIENT	Burnham 2020 Ltd
VERSION	Final
ISSUE DATE	18 July 2023
JOB REFERENCE	C04096400
SOURCE FILE(S)	C04096400R001.docx

DOCUMENT CONTRIBUTORS

Prepared by

SIGNATURE P. F. Callander

Tom Garden

Peter Callander

Reviewed and Approved by

SIGNATURE P. F. Callander

Peter Callander

Limitations:

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Burnham 2020 Ltd [and] [others (not directly contracted by PDP for the work)], including Environment Canterbury. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Burnham 2020 Ltd for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Executive Summary

The proposed quarry will occur within strata described as brownish-grey river alluvium which hosts a groundwater system used by water supply bores and is a source for spring-fed streams further down the plains. Most abstraction bores in the vicinity of the proposed quarry are screened from 25 – 70 m deep, with some deeper bores occurring from 90 – 150 m deep. The water table within the proposed quarry site is estimated to fluctuate from around 8 – 19.5 m deep in the south-east and 16.5 – 28 m deep m deep in the north-west. Monitoring of groundwater quality in the area shows elevated nitrate concentrations, sometimes exceeding the Maximum Acceptable Value in the NZ drinking water standards and occasional detections of *E.coli.* This is typical of the central Canterbury plains due to intensive agriculture land-use activities.

The quarry will excavate to a depth of 1 m above the highest historic groundwater level in the area. This is currently estimated to be an excavation depth of 7 m in the south-east area and 15.5 m in the north-west corner, with an average depth across the entire site of 10.5 m. There is some uncertainty in these predictions of the highest groundwater levels and on-site monitoring bores will allow more refined estimates as the quarrying proceeds. These highest groundwater levels have historically occurred infrequently, with isolated spikes of around 2 months duration occurring at a frequency of less than 1 in 20 years.

The operation of the quarry will strip the topsoil and expose the underlying gravels. This will enhance the infiltration of rainwater and water used in the quarry operation (particularly water used for washing aggregate) so as to increase recharge to the aquifer, whilst also removing the current sources of nitrate and *E. coli* that occur from the on-site farming activity.

The quarry uses some hazardous substances (primarily fuel and lubricating oil for vehicles and machinery) and will also have an on-site wastewater treatment system for their office buildings. These can all be managed to a standard that avoids contamination risks to the underlying aquifer.

The quarry pit will move around the farm with the current farming activity continuing to operate on the areas of the farm prior to them being quarried. At the completion of each quarried section the land surface will be rehabilitated using soils stripped from other parts of the farm so that some form of agricultural use can continue, albeit at a lower elevation. The effect of the quarrying will reduce the thickness of the unsaturated zone strata above the groundwater table. Drainage of nitrates from any post-quarry farming activities are expected to have a similar annual discharge rate to the current farming situation, if the current farming land use was to continue, because there is no significant attenuation of nitrate concentrations through the unsaturated zone, although the nitrate will reach the water table faster than currently occurs. *E. coli* numbers are reduced through the unsaturated zone due to processes such as

by filtration, desiccation and natural die-off over time. These processes will be lessened in the post-quarry environment, due to the decreased distance between the soil and the water table however a modelling assessment of potential flow paths to nearby bores shows that there will still be sufficient removal (on the order of 10 log cycles) to avoid adverse water quality effects.

Table of Contents

Appendices

1.0 Introduction

Burnham 2020 Ltd owns the 362 ha property known as Burnham Farm, shown in Figure 1. It proposes to progressively quarry the property to provide aggregate for construction projects. This report has been prepared by Pattle Delamore Partners Ltd, at the request of Burnham 2020 Ltd, to describe the hydrogeologic setting for the area and to assess the way in which the proposed quarry activity will interact with that hydrogeology.

2.0 Background

Burnham Farm is a modern dairy support block which is irrigated with water formerly supplied by groundwater bores under an existing consent, but more recently supplied by the Central Plains Water (CPW) scheme. The proposed quarry will operate within this farming operation, with around 18 ha utilised for long-term access, administration and aggregate processing facilities and a further 22ha of active quarry workings that will move progressively across the farm area and be rehabilitated at a lower elevation, following the removal of aggregate.

The quarrying activity will strip topsoil from the current farmland and then remove aggregate down to an elevation that is above the highest historical groundwater level for the property. Water supply for the quarrying activity will be sourced from on-site bores and the water will be used for processing plant operations, including the washing of aggregate, dust suppression, wheel washing, supply of water to the administration facilities and incidental irrigation of vegetation associated with the quarry. At the completion of each quarried area the base of the excavation will be reinstated with topsoil. The current farming operation and the associated irrigation of the farm, using water from the CPW scheme, is intended to continue as a land use prior to and alongside quarrying each section of the farm.

Based on this proposed quarrying activity, this report provides the following information:

- A description of the hydrogeologic setting
- An assessment of the expected depth of the quarry excavation, based on currently available information
- An assessment of how the quarrying activities affect the underlying groundwater
- An assessment of how the potential effects from the current farming land use will change following the completion of quarrying

The effects arising from the abstraction of groundwater by the on-site bores to provide the quarry water supply is the subject of a separate assessment report, PDP (2021).

3.0 Hydrogeologic Setting

The Burnham Farm property is located near the middle of the Canterbury Plains, approximately 6.5 km north of the Selwyn/Waikirikiri River and 12.5 km south of the Waimakariri River. The geology of the broader area consists of successive alluvial deposits comprising gravel, sand, silt and clay derived from the Southern Alps and deposited during the Quaternary period. The permeability of the strata is influenced by the age, depth of burial and depositional environment. The aquifers in the region are classified as semi-confined as they are overlain by low permeability fine grained strata (sand, silt and clay-sized particles) through which leakage can occur.

The 1:250,000 geological map of the Christchurch area (Forsyth, Barrell, & Jongens, 2008) describes the underlying geology as brownish-grey river alluvium beneath plains or low-level terraces. The local near surface geology in this area of the plains also consists of remnants of stabilised river (Waimakariri) sands.

The driller’s logs for the water supply bores on the property (Appendix B) are generally consistent with the geological description above. The logs indicate that the strata generally consist of gravels with varying sand and clay content. Near the bottom of the bores, water-bearing sandy gravels were generally encountered, across which screens were placed in each bore.

Groundwater recharge in the area is generally from infiltration of rainfall on the plains and seepage from rivers, particularly the Waimakariri and Selwyn/Waikiriri. ECan regional piezometric contours indicate that the groundwater near the site flows in a generally south-easterly direction.

An assessment of long-term groundwater level records in the area is presented in Appendix C. This information indicates that the level of the water table at the site is expected to fluctuate over a depth range of around 8 – 19.5 m below ground level in the south-east of the site and around 16.5 – 28 m in the north-west of the site (as shown in Figure 5 of Appendix C). Lowest groundwater levels generally occur in late summer and autumn, and highest groundwater levels generally in spring.

A plot of yield versus the screen depth (i.e. depth to the top of the screen) for all bores within 2 km of the supply bores is provided in Figure 2, Appendix A. As shown, bore depths generally fit into two depth ranges, with one group of bores having screen depths of 25 – 70 m bgl and the other having screen depths of 90 – 150 m bgl. There is no clear trend of yield versus depth, however it is clear that there is more variability in yield of the shallower bores (0 – 103 L/s), while the deeper bores tend to be more consistent in their yield (11 -67 L/s).

Private dwellings in the area use groundwater as their source of drinking-water supply (at locations shown by the green dots in Figure 1 of Appendix E). In addition, within 2km of the site boundary, there are three community drinking water source protection zones, which apply to water supplied to communities of a size no less than 25 people, for no fewer than 60 days per year, all are located to the south of the farm property. These are the drinking water supply wells for the Burnham military camp and none of the protection zones intercept the land area of Burnham Farm (also shown in Figure 1 of Appendix E). The community drinking-water source protection zone defines an area where land-use and discharge activities should be carefully managed and monitored so as to minimise contamination risks for the water supply.

The details of these community water supply bores are:

- M36/2694 is located approximately 1200m to the south of Burnham Farm. The community drinking water source protection zone spans towards the north-west direction from the bore. M36/2964 is 24.3m deep.
- BX23/0903 is approximately 600m south-east of the site and is screened between 189 and 195m deep. Due to the depth of this bore it has a small circular source protection zone largely contained within the camp boundary.
- M36/2693, is approximately 900 m south-east of Burnham Farm and is screened between 44.8 and 54.9m deep. Its community drinking water source protection zone extends in a north-west direction and overlaps with the protection zone for bore BX23/0903.

Groundwater Quality

The groundwater quality of the area is typical of the central Canterbury Plains with shallow bores in particular showing the effects from the surrounding agricultural land use resulting in elevated concentrations of nitrate-Nitrogen and occasional detections of *E. coli.*

Groundwater quality data available through ECan in the vicinity of Burnham Farm is largely historical samples collected between 1975 and 1995. These show that 3 of the sampled bores had nitrate-N concentrations above the drinking-water maximum acceptable value (MAV) of 11.3 g/m^3 with an average nitrate-N concentration across all samples of 8 g/m^3.

One pair of bores (M36/4151 and M36/8187) provide a long-term record of nitrate-N concentrations. In 2005 bore M36/4151 (35 m deep) was replaced by bore M36/8187, 48 m deep located approximately 25m northeast of where the unused M36/4151 was located. The data from this pair of bores indicate that the concentrations of nitrate-N are steadily increasing over time, with values around the MAV or 11.3 g/m^3 recorded in 2020 and 2021. This pair of long-term monitoring bores have also had 2 exceedances of the *E. coli* MAV (<1 MPN/100 mL) from 41 samples taken between January 2006 and November 2022. These exceedances occurred during July 2013 and September 2017and recorded values of 1 MPN/100mL.

All other parameters recorded in the ECan groundwater quality data base appear to have remained relatively constant and not unusually elevated through time.

Two bores within Burnham Farm were sampled in late May/ early June 2022 to provide an indication of groundwater quality beneath the site: one shallow bore (M36/5785, screened from 24.7 – 27.7 m deep) and one deep bore (M36/7711, screened from 118.4 – 148.4 m deep). The laboratory analysis reports for these samples are presented in Appendix F. They show the shallow groundwater has generally low concentrations for most parameters although nitrate-N is elevated at 7.5 g/m^3. Total coliforms were detected at 9 MPN/100mL, indicating a pathway for near surface bacteria to reach this shallow groundwater, although none of these were *E. coli* which is the drinking-water standards indicator of a health risk.

Similar, or slightly lower concentrations were recorded in the deep groundwater (bore M36/7711) with the notable differences being nitrate-N at 4.8 g/m^3 and no detections of total coliforms.

4.0 Expected Quarry Depth

The quarry proposes to excavate down to a depth that is 1m above the highest groundwater level that has historically occurred in that area. An assessment of that depth is presented in Appendix C. It uses long-term monitoring records to show that the highest historical groundwater levels (likely the highest since 1951) at the site likely occurred in spring 1978. An extrapolation of the records across monitoring locations shows that the peak groundwater level at the site in spring 1978 is estimated to have ranged from approximately slightly less than 8m below ground level on the southern side of the site, to approximately 16.5 m below ground level in the northern corner of the site. The mean of the peak groundwater level across the site in spring 1978 is estimated to be 11.5 m below ground level.

The groundwater level in spring 1978 is considered to be an appropriate level to use as an estimated maximum groundwater level, for the purposes of maintaining a 1 m buffer from the ground surface to groundwater. However, it must be recognised that the effects of the Central Plains Water Scheme and climate change could cause some difference in future groundwater levels compared to what has been observed in the past. Given that the quarry will progress gradually over several decades, it will be useful to refine the estimated maximum water table depth based on measurements made at the on-site groundwater monitoring bores. It is recommended that this site-specific data should be reviewed at 5 -yearly intervals to update the estimate of the highest historic groundwater level.

After the quarry has excavated down to its maximum depth the surface will be rehabilitated by the placement of a minimum soil thickness (topsoil and subsoil) of 400mm. This final re-established subsoil profile should be predominantly fine matrix soil materials, free of rocks and other coarse materials. It will provide an additional buffer above the estimated highest groundwater level.

It is important to recognise that the highest groundwater levels occur infrequently and for limited periods. So, whilst there is some uncertainty regarding the highest groundwater level, it is helpful to consider the frequency and duration of an extreme high spike in groundwater levels might occur for. This is discussed in section 6.0 of Appendix C, which indicates that the highest estimated groundwater levels will occur at a frequency of less than a 1 in 20-year event and such historical spikes were recorded in only 1 or 2 consecutive monthly measurements. Therefore, such extreme spikes occur infrequently and are of limited duration.

5.0 Assessment of Quarry Activities on Groundwater

As noted above, the excavation activities will commence with the stripping of topsoil, followed by excavation and processing of aggregate and then reinstatement of soil at the lowered, post excavation surface. The key activities that might impact on the underlying groundwater resource are discussed in the following sections.

5.1 Aggregate Extraction

The removal of topsoil and excavation of gravels will change the surface of the ground, which in turn alters the rainfall infiltration which drains down to recharge the underlying groundwater. Under the current agricultural land use, the soils retain much of the rainfall and infiltration is reduced due to the uptake of soil moisture into plants. The water that infiltrates downwards through the soil carries with it nitrates and *E. coli*, which have the potential to contaminate the underlying shallow groundwater.

The removal of the soil during quarrying activities and the exposure of the underlying gravels will promote the infiltration, of both rainwater and water used within the quarry (as described in section 5.2), to the underlying groundwater and will remove the sources of nitrates and *E. coli* that currently occur from the agricultural land use. These changes are considered to make a positive change to the underlying shallow groundwater resource.

5.2 Quarry Water Use

The major use of water at the quarry is for processing aggregate. This mostly drains back to the aquifer when it falls on the ground, or discharges to settling ponds. Most of this water is expected to return to the underlying aquifer. It has primarily been in contact only with uncontaminated natural strata and accordingly is not expected to cause any adverse effect on the underlying aquifer.

Truck washing will occur within fully bunded concrete pads. Truck decks will be cleaned using only clean water. The washwater will primarily contain only fine sediment which will discharge to a sump, with overflow occurring to a soakpit. Body cleaning may involve biodegradable detergents and degreasers and may be expected to pick up hydrocarbons off trucks. This washwater will discharge to a sump and an oil-water interceptor, with the discharge water directed to a vegetated swale and then a soak pit. These discharges will promote the return of the water to the underlying groundwater resource in a manner that avoids adverse water quality effects.

The silt settlement basins also will take water and suspended silt derived from the natural strata. The water will be discharged through the base and sides of the basins, and the sediments and silts will remain in the basins. It may be necessary to clean out the basins as silt and sediment builds up, and these materials will be spread out within the site. Given that the water and suspended sediment are derived from the natural strata within and beneath the site this activity is not expected to cause any adverse effects.

Water used for dust suppression will be sprayed at a rate to help bind surface sediments. It is used during dry, windy weather and will primarily evaporate. It is not expected to drain back to the underlying groundwater.

It is expected that office wastewater will pass through an on-site wastewater treatment system prior to discharge to a subsurface dripline system through landscape and bunded areas located at, or near to, the original ground level in the general vicinity of the office buildings.

5.3 Storage and Use of Hazardous Substances

Storage of hazardous substance on site will be limited to plant and machinery fuel (diesel, unleaded petrol, bioethanol mix, hydrogen, ad-blue, etc.), lubrication (oils and greases), and small quantities of laboratory chemical for use in aggregates compliance testing. Fuel will be kept in double skinned tanks of up to 30,000L. Oil and greases will be stored in specially designed areas within the workshop area of up to 1,000kgs.

Refuelling will occur on paved surfaces draining to oil-water interceptors that discharge to soakpits.

A hazardous substance risk register and management plan will be developed for the site and comply with all relevant legislation.

6.0 Continuation of farming land use on the rehabilitated quarry land

When each section of quarry activity has reached its maximum depth, soil will be re-established and farming activities will recommence, albeit at a lower elevation that is closer to the water table than is currently the case. This will change the way in which any farming land-use will affect the underlying groundwater quality. This has been assessed in two memos, one dealing with nitrate leaching (Appendix D) and one dealing with the migration of *E. coli* (Appendix E).

In the case of nitrate (Appendix D), the annual loss of nitrate into the groundwater will remain largely the same as currently occurs, if the same farming land use were to continue, although the nitrate will reach the water table sooner than under the pre-quarry scenario.

E. coli from the current farming activity is mostly derived from animal excretions, which can migrate downwards through the soil and into the groundwater, particularly due to the extra seepage that occurs during heavy rainfall events. During this migration from the ground surface through the sub-surface environment, *E. coli* numbers are reduced by filtration, desiccation, dispersion, dilution and natural die-off over time. The quarrying activity will reduce the thickness of the unsaturated zone beneath the soil and bring the source of the *E. coli*, at the pasture surface, closer to the saturated groundwater flow system. The effects of this change are assessed in a memo presented in Appendix E. That assessment indicates there will be less reduction of the *E. coli* concentrations through the unsaturated zone between the surface soil profile and the groundwater table than is currently the case, but that there will still be sufficient removal (on the order of 10 log cycles) to avoid adverse water quality effects on neighbouring bores.

It is expected that the rehabilitated quarry land will progressively become available for farming use over the next five or six decades. It is not possible to predict with certainty what that use will be, how it will be undertaken, or under what conditions. Assuming the current use (or other uses with the same or lesser environmental outputs), it is expected that effects on groundwater quality at the completion of the quarrying activity will be within the range of other land-use effects that are typically occurring within the Canterbury region.

7.0 Conclusion

The water table within the proposed quarry site is estimated to fluctuate from around 8 – 19.5 m deep in the south-east and 16.5 – 28 m deep m deep in the north-west. The quarry will excavate to a depth of 1 m above these highest historic groundwater levels, which corresponds to an average excavation depth across the entire site of 10.5 m. There is some uncertainty in these predictions of the highest groundwater levels and on-site monitoring bores will allow more refined estimates as the quarrying proceeds. These highest groundwater levels have historically occurred infrequently, with isolated spikes of around 2 months duration occurring at a frequency of less than 1 in 20 years.

The exposed gravels in the quarry will enhance the infiltration of rainwater and water used in the quarry operation so as to increase recharge to the aquifer, whilst also removing the current sources of nitrate and *E. coli* that occur from the on-site farming activity.

The use of hazardous substances (primarily fuel and lubricating oil for vehicles and machinery) within the quarry and an on-site wastewater treatment system for the office buildings will be managed to a standard that avoids contamination risks to the underlying aquifer.

Once an area of the farm has been quarried the soil cover will be reinstated and some form of agricultural use will continue, albeit at a lower elevation. The effect of the quarrying will reduce the thickness of the unsaturated zone strata above the groundwater table. Drainage of nitrates from the post-quarry farming activity are expected to have a similar annual discharge rate to the current farming situation, if the current farming land-use were to continue, because there is no significant attenuation of nitrate concentrations through the unsaturated zone, although the nitrate would reach the water table faster than currently occurs. *E. coli* numbers are reduced through the unsaturated zone due to processes such as by filtration, desiccation and natural die-off over time. These processes will be lessened in the post-quarry environment, due to the decreased distance between the soil and the water table however a modelling assessment of potential flow paths to nearby bores shows that there will still be sufficient removal (on the order of 10 log cycles) to avoid adverse water quality effects.

8.0 References

Pattle Delamore Partners Ltd, 2021; Renewal of Resource Consents CRC222536 for Take and Use of Groundwater for Irrigation and CRC221642 for Use of Groundwater for Quarrying Activities

Appendix A: Figures

Farm map showing irrigation types.

FIGURE 1: PLAN SHOWING IRRIGATION TYPES USED ACROSS BURNHAM FARM

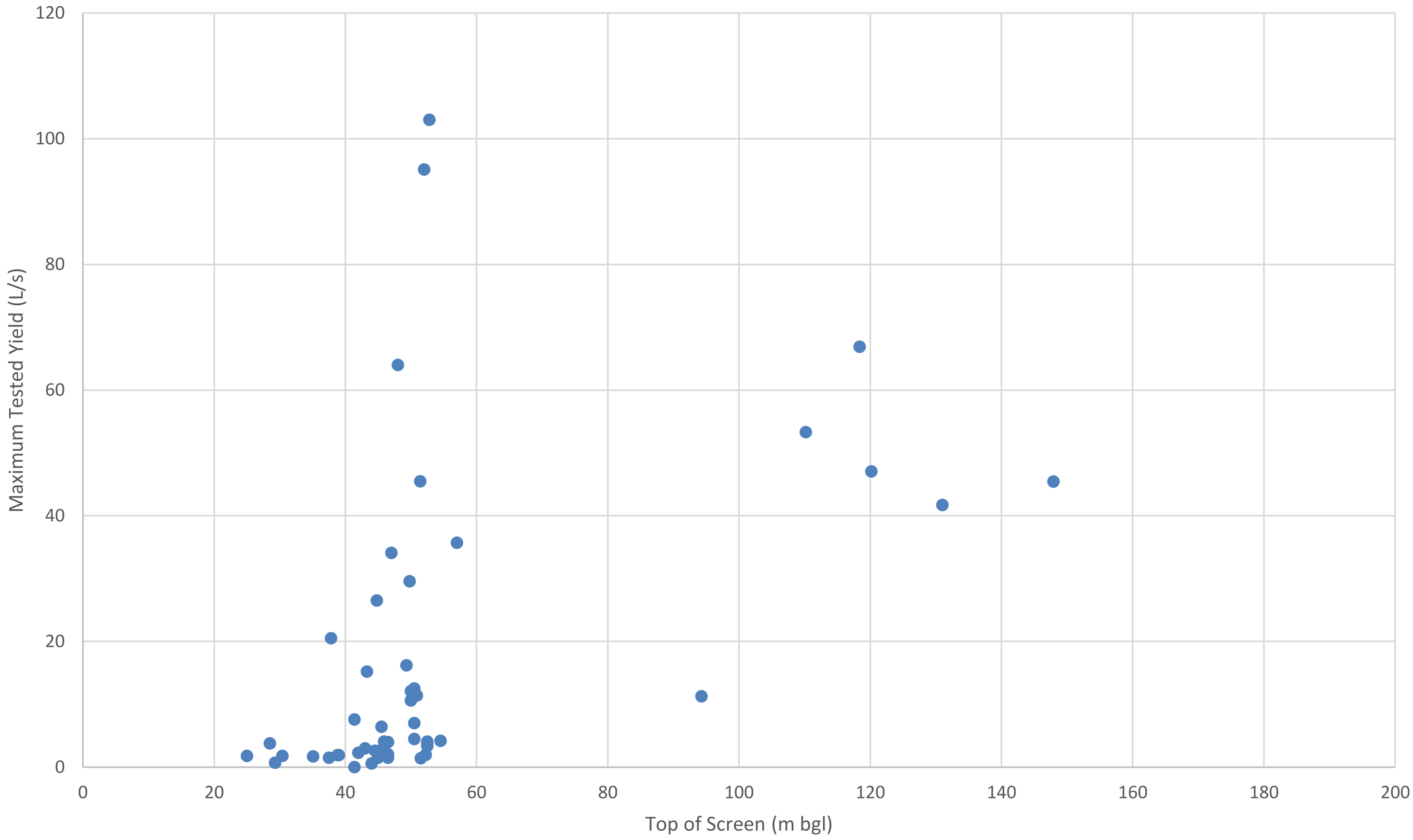


FIGURE 2: SCREEN DEPTH VERSUS YIELD, FOR ALL BORES WIHTIN 2 KM OF SITE

Appendix B: Bore Logs

#1 Well 92 Kw Submersible. #1.

McMILLAN WATER WELLS LTD
120 High Street Southbridge Canterbury – Phone (03) 324 2571 – Fax (03) 324 2431

M36/7713

BORE REPORT-Redevelop and test pump

Client::	Selwyn Plantation Board		
Driller/s:	P Breward	Lot No.:	
Method:	Rotary Percussion	Job No.:	5065
Date Completed:	10/12/07	CRC No.:	CRC042685
Grid Ref:	M36:538-336	Bore No.:	M36/7713
Site Location:	Aylesbury Road		

BORE CONSTRUCTION DETAILS:

Casing

Casing Length (m):

Casing Material: Steel

Top of Casing (m): 0.10 above ground level

Bore

Bore Depth (mbgl): 151.30

Bore Diameter (mm): 300

Telescoped Casing (if applicable)

Diameter (mm)	Length (m)	Set [from ; to] (mbgl)	
300	88.25	0.00	88.25
.250	116.50	85.10	116.56

Screen/s (if applicable) Top of Leader (m): 85.10 Length of Leader (m):

Type	Slot Size (mm)	Diameter (mm)	Length (m)	Set [from : to] (mbgl)	
....					
....					
....					

WATER LEVEL INFORMATION: (at completion of bore) Static Water Level (m): 31.50 below ground level

BORE DEVELOPMENT & TESTING: (if applicable)

Development Duration(hrs): 22.00 Pumping Duration(hrs): 11.00

Flow Rate(gpm)	Draw Down (from SWL) (m)	Duration (hrs)
300	15.40	0.50
400	23.10	0.50
588	42.70	2.00
621 46 l/Sec	46.10	8.00
Flow Shows	42-44 l/Sec	

BORE HEAD SEALING: Sealed: no Sealing Material: na Capped: yes

Riser Colomn 81·2m + Motor Pump.

J:\McMillans\Client Folders\Selwyn Plantation Board\5065.doc

200mm PVC to Cl.wot. 534m.

Bore or Well M36/7713

Well Name :
Owner : Selwyn Plantation Board Limited

Environment Canterbury
Your regional council

Street of Well : Corner Alyesbury & Grange Road
Locality : Burnham
Grid Reference : M36:53637-34192 QAR 3
Location
Ecan Monitoring :
Well Status : Active (exist, present)
Uses : Irrigation

File no : CO6C/21988
Squalarc no :
Tideda no :
Allocation Zone : Selwyn-Waimakariri

Drill Date : 15 Sep 2006
Well Depth : 150.14m -GL
Initial Water Depth : -26.25m -MP
Diameter : 300mm

Measuring Point Alt. : 73.30m MSD QAR 4
Ground Level Around Well : -0.30m -MP
MP Description : TOC

Driller : McMillan Water Wells Ltd
Drilling Method : Rotary/Percussion
Casing Material : Steel
Pump Type :
Yield : 47l/s
Drawdown : 48m
Specific Capacity : 1l/s/m

Aquifer Type :
Aquifer Name :

Reading Count : 0
Strata Logs : 16
Aquifer Test : 0
Isotope Data : 0
Geophysical :
Fossil Data :

Highest GWL :
Lowest GWL :
First Reading :
Last Reading :
Calc. Min. GWL : -23.30m -MP
Last Updated : 08 Apr 2008
Last Field Check :

Screens :
Screen Type : Slotted Casing
Top GL : 120.18m
Bottom GL : 144.14m

Screen Type : Stainless steel
Top GL : 144.14m
Bottom GL : 150.14m

Date	Comments
25 Jul 2005	Awaiting water allocation issues to be resolved.
25 Oct 2006	Gridref changed from: M36:5314-3398 approx 564 metres from consented location BCR confirms. Depth 90 metres deeper than proposed.
09 Jul 2007	Kerry called and said that they have just started developing the well, and getting a pump test next week. I told him to tell us when he has started exercising this bore.
08 Apr 2008	Gridref changed from: M36:5368-3410 re X on topo map.
30 Apr 2008	routine monitoring visit measured flow at 31L/s

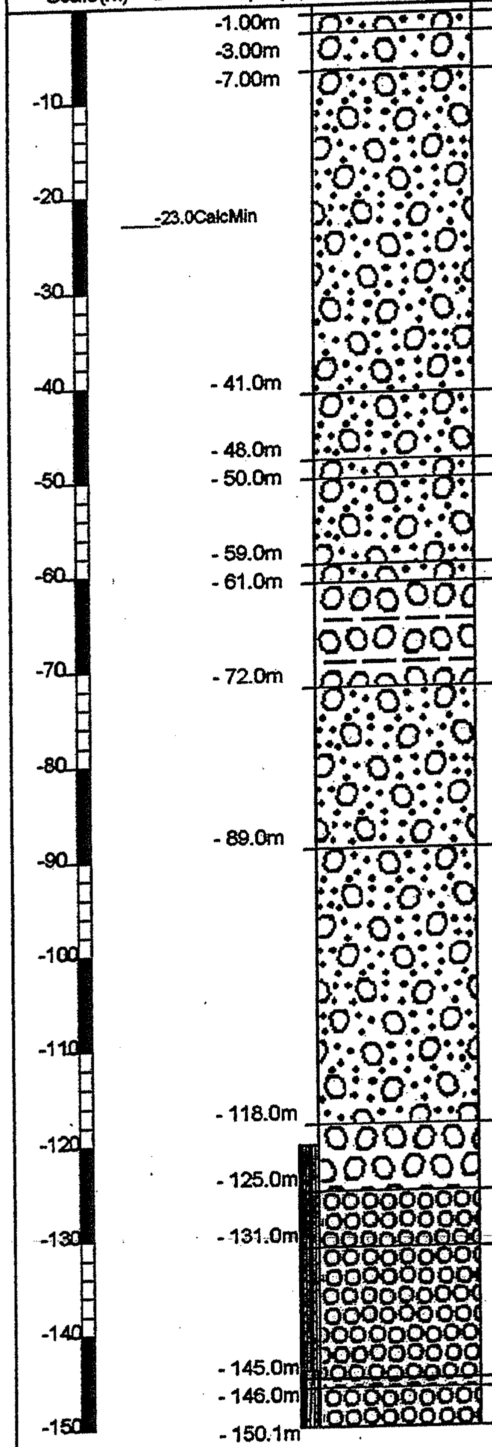
Pivot 1

92 Ha Pivot @ .6 = 55l/Sec.

Borelog for well M36/7713

Gridref: M36:5361-3354 Accuracy : 3 (1=best, 4=worst)
Ground Level Altitude : 72.9 +MSD
Driller : McMillan Water Wells Ltd
Drill Method : Rotary/Percussion
Drill Depth : -150.14m Drill Date : 15/09/2006

Environment Canterbury
Your regional council



Depth(m)	Full Drillers Description	Formation Code
-1.00m	earth	
-3.00m	sandy gravels	
-7.00m	claybound sandy gravels	
- 41.0m	sandy gravels	
- 48.0m	poor sandy gravels	
- 50.0m	claywashed, sandy gravels, good stain	
- 59.0m	free sandy gravels, heavy stain	
- 61.0m	free sandy gravels, good stain	
- 72.0m	clay and gravels	
- 89.0m	freeish, poor sandy gravels	
- 118.0m	freeish sandy gravels	
- 125.0m	free, well stained, large gravels	
- 131.0m	free, well stained gravels	
- 145.0m	freeish, stained gravels	
- 146.0m	clay and gravels	
-150.1m	free, stained gravels	

Burnham # 3 Well.

McMILLAN WATER WELLS LTD
120 High Street Southbridge Canterbury – Phone (03) 324 2571 – Fax (03) 324 2431

M36/7710

BORE REPORT

Client::	Selwyn Plantation Board -	Smith Block	
Driller/s:	V. Vasques Vagas/ P. Breward	Lot No.:	
		Job No.:	6030
Method:	Rotary Percussion	CRC No.:	CRC081840
Date Completed:	27/2/08	Bore No.:	M36/7710
Grid Ref:	M36:52031-34070		
Site Location:	Grange Road, Burnham		

BORE CONSTRUCTION DETAILS:

Casing

Casing Length (m): 118.80

Casing Material: Steel

Top of Casing (m): 0.30 above ground level

Bore

Bore Depth (mbgl): 167.91

Bore Diameter (mm): 300

Telescoped Casing (if applicable)

Diameter (mm)	Length (m)	Set [from ; to] (mbgl)	
300	119.80	0.00	119.80
250	29.91	118.00	147.91

Screen/s (if applicable) Top of Leader (m): 145.913 Length of Leader (m): 2.00

Type	Slot Size (mm)	Diameter (mm)	Length (m)	Set [from ; to] (mbgl)	
Stainless Steel	2.5	200	9.00	147.91	156.91
Slotted Casing	5.0	200	11.00	156.91	167.91

WATER LEVEL INFORMATION: (at completion of bore) Static Water Level (m): 35.50 below ground level

BORE DEVELOPMENT & TESTING: (if applicable)

Development Duration(hrs): 48.50 Pumping Duration(hrs): 25.00

Flow Rate(gpm)	Draw Down (from SWL) (m)	Duration (hrs)
283	19.20	1.00
408	30.40	1.00
500	38.40	1.00
600	47.60	17.75

BORE HEAD SEALING: Sealed: no Sealing Material: na Capped: yes

McMILLAN WATER WELLS LTD
120 High Street Southbridge Canterbury – Phone (03) 324 2571 – Fax (03) 324 2431

BORE REPORT M36/7710

BORELOG:

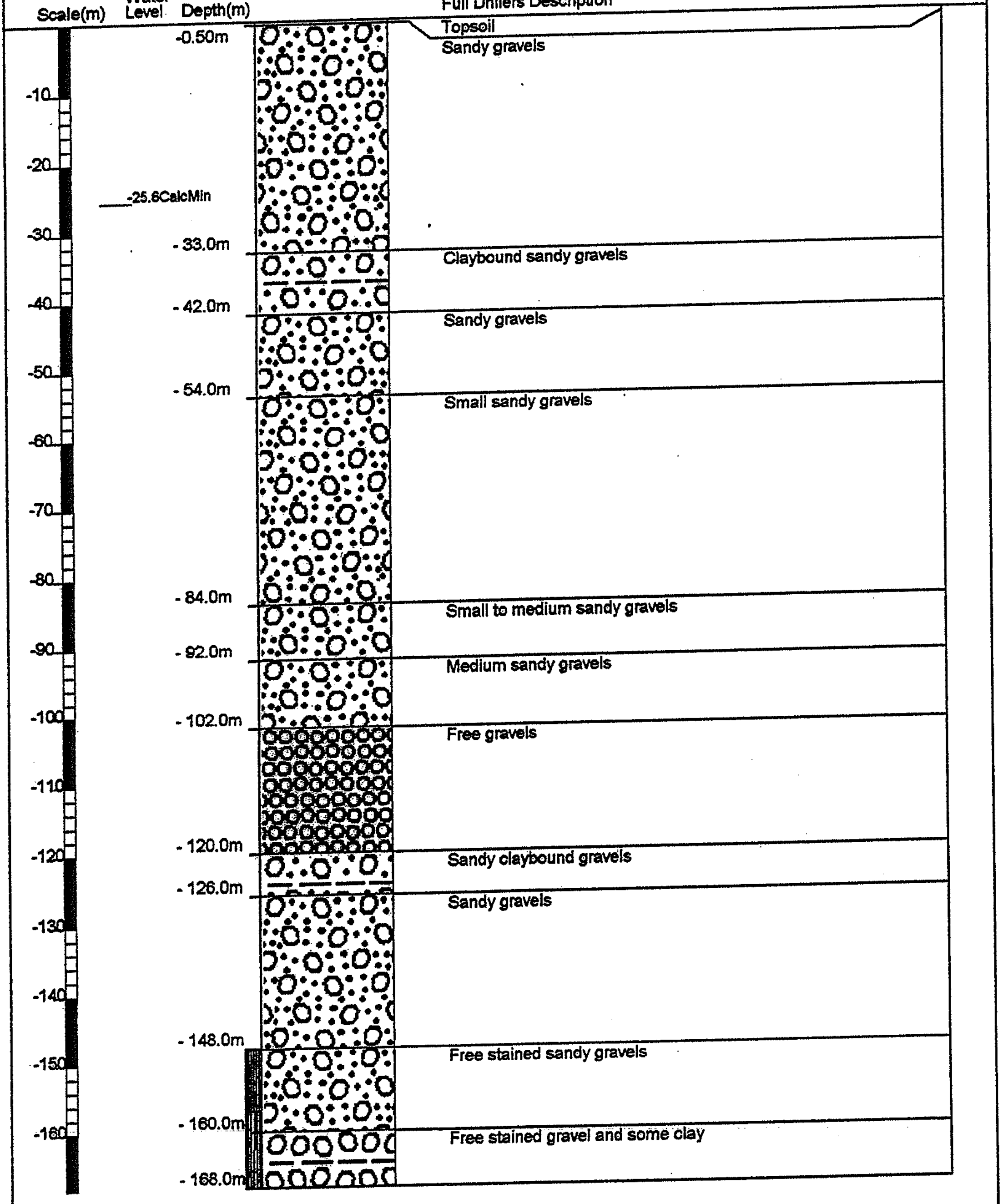
Depth Below Ground (m)		Strata Description	
Top	Bottom	Material: colour, composition, plasticity or particle/grain shape and grading, main soil/rock type, secondary components	WL (mbgl)
0.00	0.50	Top soil	
0.50	33.00	Sandy gravels	
33.00	42.00	Claybound sandy gravels	
42.00	54.00	Sandy gravels	
54.00	84.00	Small sandy gravels	
84.00	92.00	Small to medium sandy gravels	
92.00	102.00	Medium sandy gravels	
102.00	120.00	Free gravels	
120.00	126.00	Sandy claybound gravels	
126.00	148.00	Sandy gravels	
148.00	160.00	Free stained sandy gravels	
160.00	168.00	Free stained gravel and some clay	

ADDITIONAL NOTES: ....

Borelog for well M36/7710

Gridref: M36:52031-34070 Accuracy : 2 (1=high, 5=low)
Ground Level Altitude : 77.7 +MSD
Driller : McMillan Water Wells Ltd
Drill Method : Rotary/Percussion
Drill Depth : -168m Drill Date : 27/02/2008

Environment Canterbury



Depth(m)	Full Drillers Description	Formation Code
-0.50m	Topsoil	
-33.0m	Sandy gravels	
-42.0m	Claybound sandy gravels	
-54.0m	Sandy gravels	
-84.0m	Small sandy gravels	
-92.0m	Small to medium sandy gravels	
-102.0m	Medium sandy gravels	
-120.0m	Free gravels	
-126.0m	Sandy claybound gravels	
-148.0m	Sandy gravels	
-160.0m	Free stained sandy gravels	
-168.0m	Free stained gravel and some clay	

Burnham. # 2 well.

McMILLAN WATER WELLS LTD
120 High Street Southbridge Canterbury – Phone (03) 324 2571 – Fax (03) 324 2431

McMILLAN

M36/7711

BORE REPORT

Client::	URS		
Driller/s:	V.vasquez / M.Ducan	Lot No.:	
....		Job No.:	4674
Method:	Rotary Percussion	CRC No.:	CRC042685
Date Completed:	28/6/07	Bore No.:	M36/7711
Grid Ref:	M36:5266-3504		
Site Location:	Smiths Block - Aylesbury Rd, Burnham		

BORE CONSTRUCTION DETAILS:

<u>Casing</u>
Casing Length (m): 100.87
Casing Material: Steel
Top of Casing (m): 0.30 above ground level

Bore
Bore Depth (mbgl): 148.38
Bore Diameter (mm): 300

<u>Telescoped Casing</u> (if applicable)

Diameter (mm)	Length (m)	Set [from ; to] (mbgl)	
300	100.87	0.00	100.87

Screen/s (if applicable) Top of Leader (m): 97.88 Length of Leader (m): 2.50

Type	Slot Size (mm)	Diameter (mm)	Length (m)	Set [from : to] (mbgl)	
Stainless Steel	2.5	200	6.00	148.38	142.38
Slotted Casing	5.0	200	24.00	142.38	118.38
Blank	0	200	18.00	118.38	100.38

WATER LEVEL INFORMATION: (at completion of bore) Static Water Level (m): 33.16 below ground level

14m

BORE DEVELOPMENT & TESTING: (if applicable)

Development Duration(hrs): 40.50 Pumping Duration(hrs): 12.00

Flow Rate(gpm) (l/m)	Draw Down (from SWL) (m)	Duration (hrs)
396 = 1499	4.44	1.00
529 2002	47.92	1.00
577 2184	8.82	1.00
725 2744	13.12	1.00
83 3343	19.39	3

BORE HEAD SEALING: Sealed: yes/no Sealing Material: .... Capped: yes/no

Bore or Well M36/7711

Environment Canterbury
Your regional council

Well Name :
Owner : Selwyn Plantation Board Limited

Street of Well : Corner Alyesbury & Grange Road
Locality : Burnham
Grid Reference : M36:52660-35040 QAR 2
Location
Ecan Monitoring :
Well Status : Active (exist, present)
Uses : Irrigation

File no : CO6C/21988
Squalarc no :
Tideda no :
Allocation Zone : Selwyn-Waimakariri

Drill Date : 28 Jun 2007
Well Depth : 148.38m -GL
Initial Water Depth : -33.46m -MP
Diameter : 300mm

Measuring Point Alt. : 81.00m MSD QAR 4
Ground Level Around Well : -0.30m -MP
MP Description : ToC

Driller : McMillan Water Wells Ltd
Drilling Method : Rotary/Percussion
Casing Material : Steel
Pump Type :
Yield : 67l/s
Drawdown : 19m
Specific Capacity : 7l/s/m

Aquifer Type :
Aquifer Name :

Reading Count : 0
Strata Logs : 14
Aquifer Test : 1
Isotope Data : 0
Geophysical :
Fossil Data :

Highest GWL :
Lowest GWL :
First Reading :
Last Reading :
Calc. Min. GWL : -28.20m -MP
Last Updated : 19 Nov 2007
Last Field Check :

Screens :
Screen Type : Slotted Casing
Top GL : 118.38m
Bottom GL : 142.38m

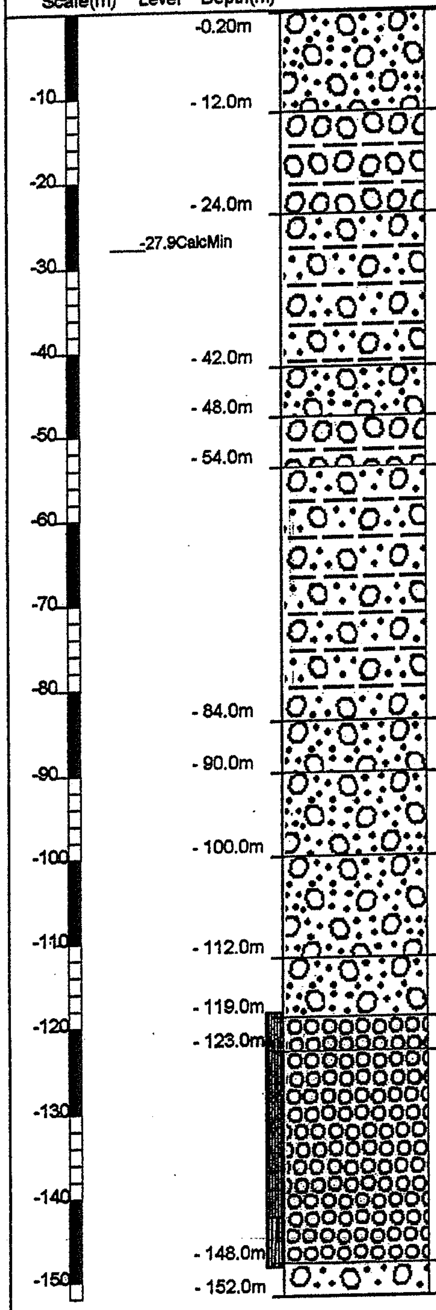
Screen Type : Stainless steel
Top GL : 142.38m
Bottom GL : 148.38m

Date	Comments
25 Jul 2005	Awaiting water allocation issues to be resolved.
17 Oct 2007	Gridref changed from: M36:5268-3507, new gridref from BCR
30 Jan 2009	Looks like a typo on BCR in the step test data - cahnged drawdown from 17.92 to 7.92 which fits dd curve

Borelog for well M36/7711

Gridref: M36:52660-35040 Accuracy : 2 (1=best, 4=worst)
Ground Level Altitude : 80.7 +MSD
Driller : McMillan Water Wells Ltd
Drill Method : Rotary/Percussion
Drill Depth : -152m Drill Date : 28/06/2007

Environment Canterbury
Your regional council



Depth(m)	Full Drillers Description	Formation Code
-0.20m	earth	
	sandy gravels	
- 12.0m	claybound gravels	
- 24.0m	sandy clay-bound gravels	
- 42.0m	freeish sandy gravels	
- 48.0m	claybound gravels	
- 54.0m	sandy clay-bound gravels	
- 84.0m	sandy gravels	
- 90.0m	freeish sandy gravels	
- 100.0m	sandy med sized gravels	
- 112.0m	freeish sandy gravels	
- 119.0m	free stained gravels	
- 123.0m	free medium & large stained gravels	
- 148.0m	claybound sandy gravels	
- 152.0m		

Burnham #4 Well.

Bore Report

McMILLAN DRILLING SERVICES

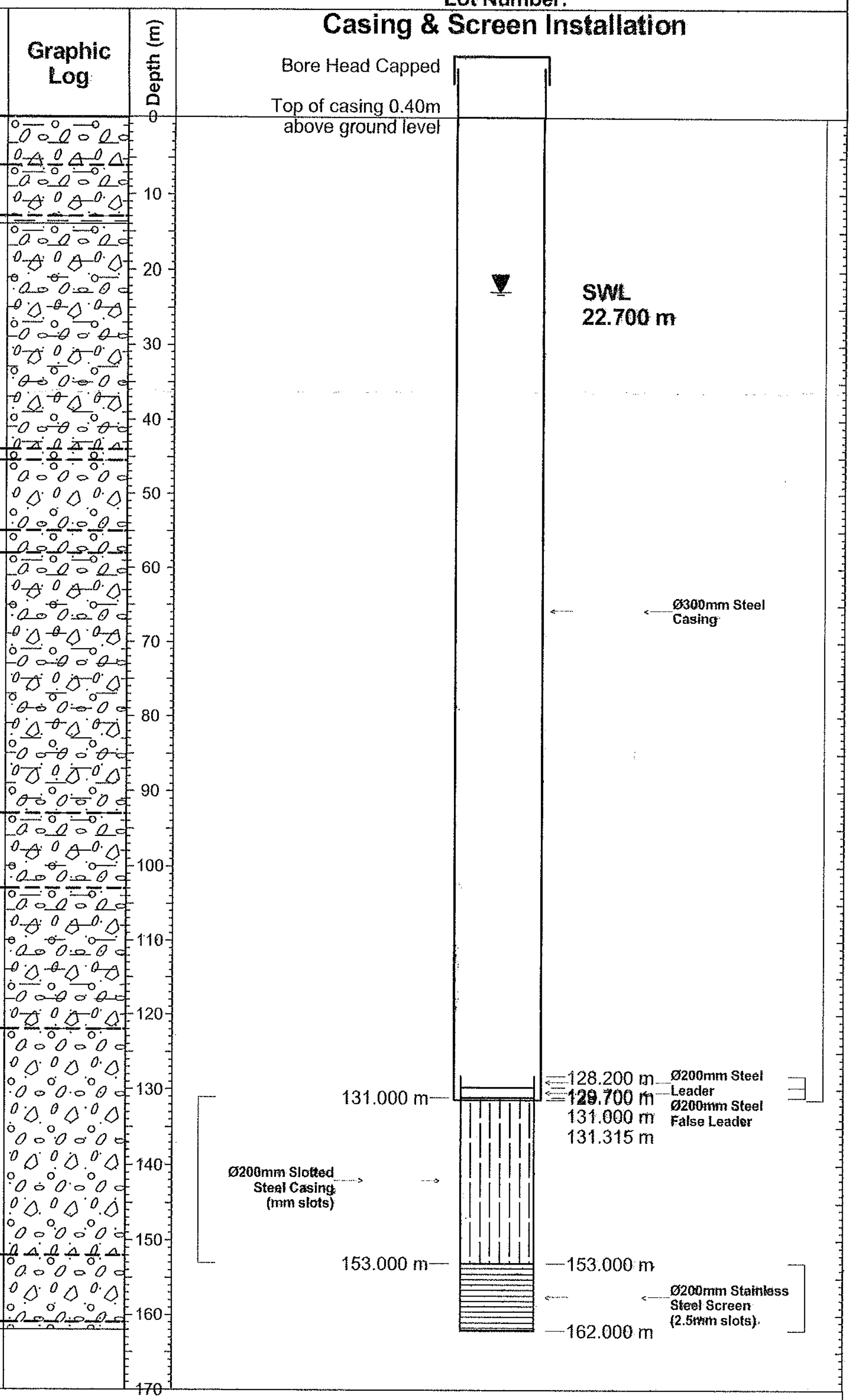
Client:	Leo Donkers Burnham Farm Ltd	**Bore No.:** M36/7712 **Job No.:** 7924

Project: Drilling of New 12" (300mm) Well
Site Location: Aylesbury Road, BURNHAM
Driller(s): S. Lane
Method: Rotary Percussion

Date Completed: 5/11/2010
Grid Reference: M36:52574-33618
Consent No.: CRC103909
Lot Number:

Material Description	Depth (m)
Earth	0.20
Angular Claybound GRAVELS	6.00
Small subangular Claybound Sandy GRAVELS	13.00
Red/brown CLAY	14.00
Small/medium subangular Claybound Sandy GRAVELS	44.00
Medium smooth Sandy GRAVELS	45.50
Medium smooth free Sandy GRAVELS	55.00
Medium subangular Claybound Sandy GRAVELS	58.00
Small mixed Sandy GRAVELS with Clay	93.00
Small to medium Sandy GRAVELS with Clay	103.00
Small to medium very Sandy GRAVELS, some Clay	122.00
Medium rounded Sandy GRAVELS	152.00
Smooth round free Sandy GRAVELS	161.00
Smooth round GRAVELS, some Clay	162.00
Beyond depth drilled	

Casing & Screen Installation



Remarks:

Bore Diameter (mm): 300
Static Water Level (SWL) (m): 22.7
Total Bore Depth (m): 162
Total Depth Drilled (m): 162

Development Duration (hr):	Flow Rate (gpm)	Flow Rate (l/sec)	Draw Down (m)	Duration (hr)
64.5	275	20.8	28.250	1.00
	346	26.2	35.760	1.00
Pumping Duration (hr):	408	30.9	43.090	1.00
10.25	483	36.6	52.570	1.00
	550	41.7	62.700	6.25

Report Created: 18/11/2010 9:56:48 a.m.

Appendix C: Preliminary Assessment of Highest Water Table Level

PATTLE DELAMORE PARTNERS LTD
Level 2, 134 Oxford Terrace
Christchurch Central, Christchurch 8011
PO Box 389, Christchurch 8140, New Zealand

Office+64 3 **345 7100**
Web **www.pdp.co.nz**
Auckland Tauranga Hamilton Wellington
Christchurch Invercargill

solutions for your environment

29 May 2023

Dan McGregor
Senior Project and Resource Adviser
Winstone Aggregates Ltd
PO Box 17-195
Greenlane
AUCKLAND 1546

Dear Dan,

BURNHAM QUARRY HIGHEST WATER TABLE ASSESSMENT

1.0 Introduction

Burnham 2020 Ltd proposes to develop a new quarry within the Burnham Farm property bounded by Grange Road and Aylesbury Road, near Burnham on the central Canterbury Plains.
Pattle Delamore Partners (PDP) has been engaged by Burnham 2020 Ltd to use the currently available data to assess the highest historical groundwater level, which is likely to be a limit imposed on the depth of the proposed excavations, and the likely highest future groundwater level beneath the site, which is relevant to the finished post-quarry elevation of the farm, so as to minimise the risk of groundwater inundation of the future land use. For example, at the present time it is considered that the land use at the site could be returned to agriculture after quarrying ceases, and the agricultural viability of the land could be adversely affected if inundation by groundwater were to occur. It is recognised that the currently available on-site data has only been monitored over a short period of time and therefore considerable extrapolation is required across monitored datasets to assess the highest groundwater level. However, the proposed quarry will develop gradually over a period of decades, which will provide ample opportunity for more refined estimates of the highest groundwater level to be determined in the years ahead based on longer term measurements from on-site bores.

This assessment uses a comparison of on-site shallow groundwater level monitoring data to nearby long-term groundwater level monitoring bores to produce extrapolated long-term groundwater level records, in order to estimate the highest historical groundwater levels and to contour these across the site.

This memo describes:

- The details of the groundwater level monitoring bores at the site.
- Details of nearby long-term groundwater level monitoring bores.
- Comparison of the on-site groundwater level monitoring record with the nearby long-term groundwater level monitoring bores, and creation of long-term extrapolated groundwater level records for the site.
- Assessment of the highest estimated historical groundwater level across the site.

- A consideration of the factors that might influence the highest groundwater level across the site in the future.

2.0 On-Site Groundwater Level Monitoring Bores

Three shallow groundwater monitoring bores are located on the site with transducer groundwater level monitoring records, with details provided in Table 1 below. Bore M36/5785 is a long-term existing shallow monitoring bore, while bores BX23/1342 and BX1343 were drilled for monitoring relating to the proposed quarry. Figure 1 shows the locations of these bores. There are also five water supply bores on the site that are more than 100 m deep. Due to the depth of these bores and the downwards hydraulic gradient at the site, the water levels measured in these bores are not appropriate to use for assessing the depth and seasonal fluctuations of the water table. Two additional shallow bores (BX23/1398 and BX23/1399) have recently been installed in the southwest and southeast corners of the site, and transducers were installed in these bores in May 2023. The groundwater level records from these bores will be used to create extrapolated records in the future and further refine the assessment detailed in this memo.

Table 1: Details of On-Site Monitoring Bores

Bore ID	Depth (m bgl[1])	Screened interval (m bgl[1])	Date drilled	Start of transducer record
Bores with transducer records used to develop extrapolated records				
M36/5785	27.7	24.7 – 27.7	Unknown (prior to 25/10/2006)	14/4/2022
BX23/1342	37.13	7.06 – 37.13	24/8/2022	9/9/2022
BX23/1343	34.19	4.11 – 34.19	30/8/2022	9/9/2022
Recently drilled bores				
BX23/1398	23.20	3.20 – 23.2	27/3/2023	10/05/2023
BX23/1399	31.68	3.50 – 31.68	28/3/2023	10/05/2023

Notes:

1. *Metres below ground level.*

Figure 1: Site location, and the location of monitoring bores used for creation of extrapolated groundwater long-term groundwater level records for the site.

Figure 2 shows the available transducer groundwater level data from each of the shallow monitoring bores on the site for which data is available. The data shows that the highest groundwater level was 8.7m bgl on the 6th of August 2022, recorded in bore M36/5785. This peak was not recorded in bores BX23/1342 and BX23/1343 as they had not yet been drilled at that time. The highest groundwater levels recorded in these bores were recorded on the 12th September 2022 and were 18.0m bgl in BX23/1342 and 14.2m bgl in BX23/1343. The transducer records presented in Figure 2 show that groundwater levels increase in depth towards the northwest. Note that the water level record in bore BX23/1343 stops on 15 December 2022 because the water level dropped below the level at which the transducer was positioned.

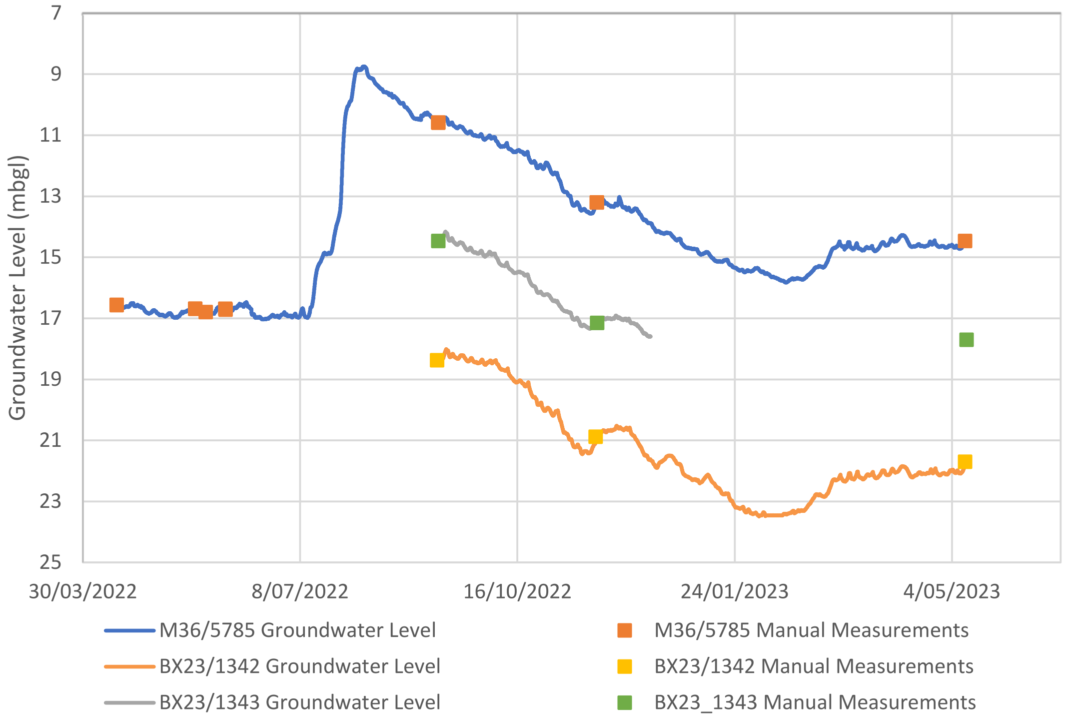


Figure 2: Transducer records from shallow onsite monitoring bores.

3.0 Nearby Long-Term Monitoring Bores

Burnham Farm is located in a transition zone between a shallow aquifer to the east, that thins and pinches out as water levels become deeper in a westerly direction across Burnham Farm, as shown by the summary map attached to a large group of Selwyn Waimakariri groundwater allocation zone consents and reproduced below as Figure 3 (i.e. the blue dotted line that passes through the south-eastern corner of the site shows the western extent of aquifer A1) and indicates that monitoring bore M356/5785 is within that shallow aquifer, but that the shallow aquifer may not be present across the remainder of the farm to the north and west. A conservative assessment will be to assume that the shallow aquifer could extend all the way across the farm and to use a long-term monitoring bore to the east, within that shallow aquifer, to simulate the long-term on-site water levels.

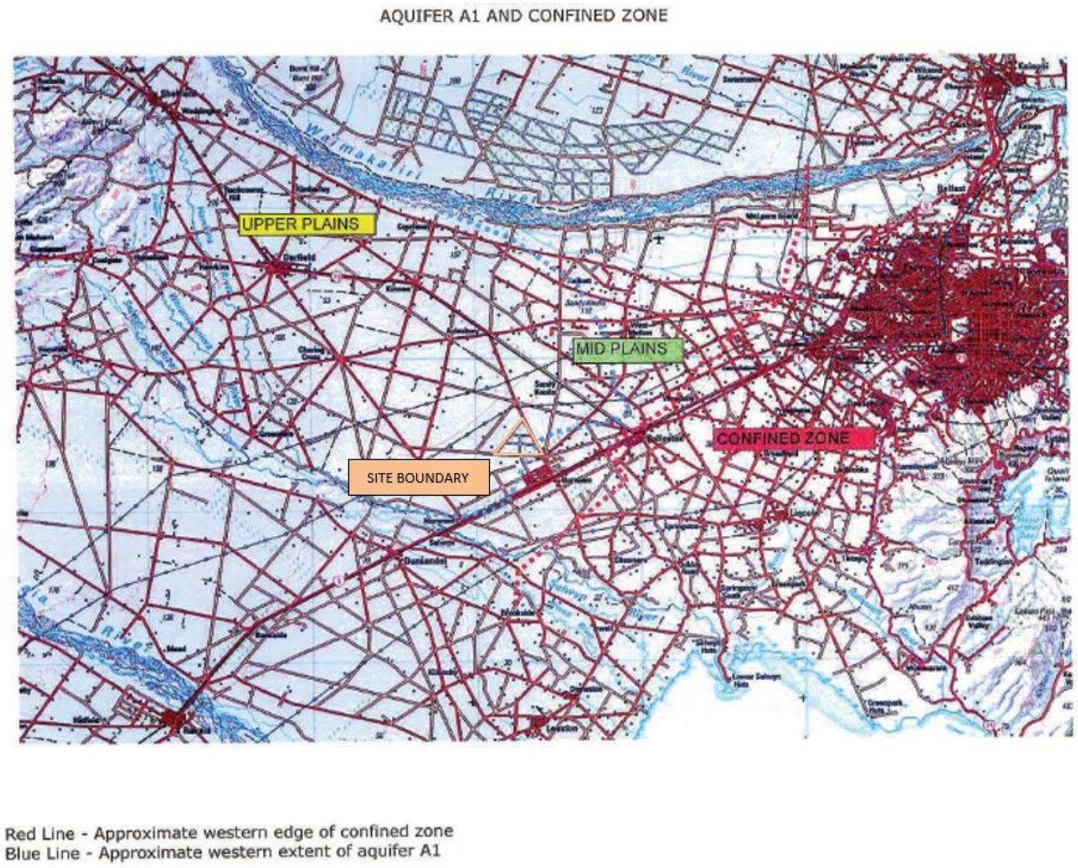


Figure 3: Selwyn Waimakariri Aquifer Zones

A review of Environment Canterbury (ECan) long-term monitoring bores shows that monitoring bore M36/0217 is most appropriate for the creation of long-term extrapolated groundwater records for the shallow bores on the site. It is 40.5 m deep, located approximately 9.5 km east of the site (as shown in Figure 1) and has a long-term record, from 1974 to 2023. Groundwater levels are generally between 20 and 12 m bgl. Groundwater levels tend to peak in spring, with the highest recorded groundwater level being on 27th September 1978 at 10.31 m bgl. The next three highest groundwater level measurements were recorded in September 1975, 1974 and 1977 respectively. It is noted that groundwater levels appear to have been measured on a 6-monthly basis in the 1970s, therefore the absolute highest groundwater level may not have been recorded in this bore. Figure 4 shows the water level record from bore M36/0217.

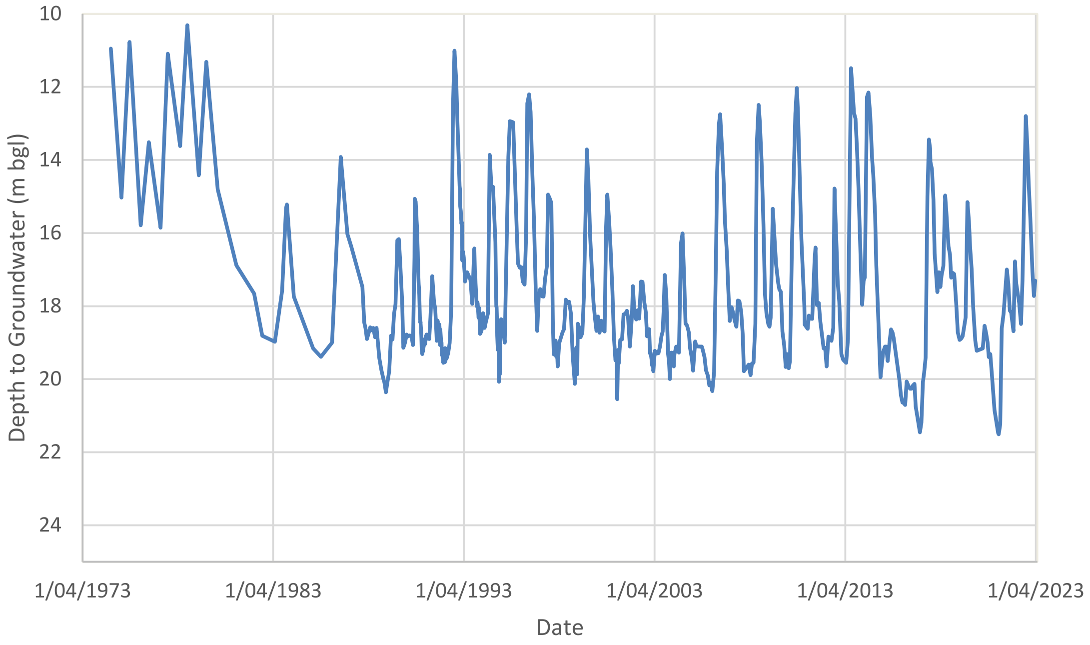


Figure 4: Groundwater level records for nearby long-term monitoring bore M36/0217.

4.0 Extrapolated Long-Term Groundwater Level Record

An extrapolated long-term groundwater level record for the shallow bores on site can be constructed by comparing the long-term monitoring bore record from M36/0217 to the three on-site monitoring bores.

As the time that each reading was taken was not recorded by ECan, it is assumed that each measurement at the monitoring bores was taken at midday. Using these measurements, regression tests can be run between the two data sets. The three regression tests all returned an R^2 value above 0.96. This shows that the data used in the test is a reliable match to the regression model. However, it should be noted that due to the relatively short period of monitoring on the site, only ten measurements from M36/5785 are available for comparison, seven measurements from M36/1342 and four measurements from BX23/1343. Table 2 shows the equations produced from the regression test and the regression plots are appended at the end of this letter. Using these three equations, records from all three onsite bores can be extended back to 1974. Figure 5 shows the extrapolated record constructed using the equations in Table 2 and as elevations in Figure 6.

The peak groundwater level was in September 1978 for all three onsite wells. The extrapolated record shows levels of 8.53 m bgl and 61.83 m RL at M36/5785; 16.42 m bgl and 69.05 m RL at BX23/1342; 12.144 m bgl and 65.73 m RL. Other notable peaks occurred in September 1975, October 1992 and August 2013.

Table 2: Details of Regression Relationships between M36/0217 and Onsite Monitoring Bores

Bore ID	Comparison bore	Equation	R^2 value	Minimum/ Maximum depth to groundwater at comparison bore (m bgl)	Minimum/ Maximum inferred depth to groundwater at on-site bore (m bgl)	Estimated maximum groundwater elevation at on-site bore (mRL)
M36/5785	M36/0217	$y = 0.9916x - 1.6922$	0.9461	10.31/ 21.51	8.53/ 20.03	61.83
BX23/1342	M36/0217	$y = 0.9368x + 6.7587$	0.9130	10.31/ 21.51	16.42/ 26.91	69.05
BX23/1343	M36/0217	$y = 1.0732x + 1.0796$	0.9575	10.31/ 21.51	12.144/ 24.16	65.73

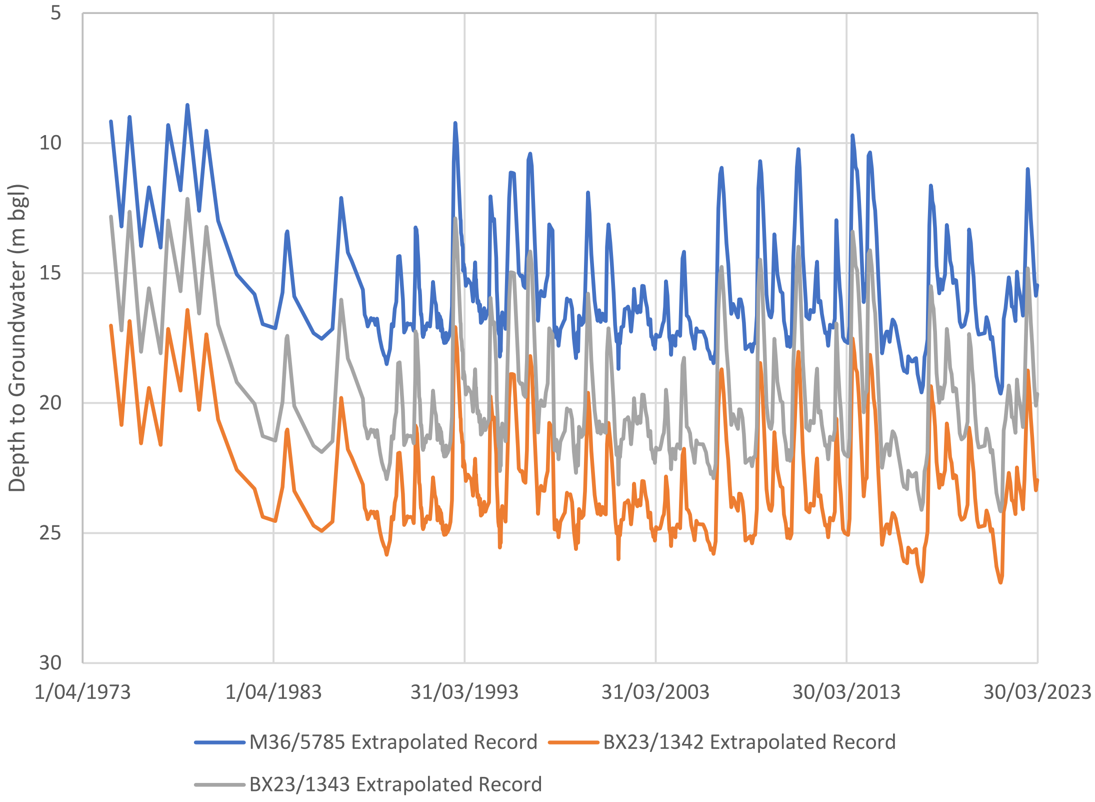


Figure 5: Extrapolated records (m bgl) based on M36/0217

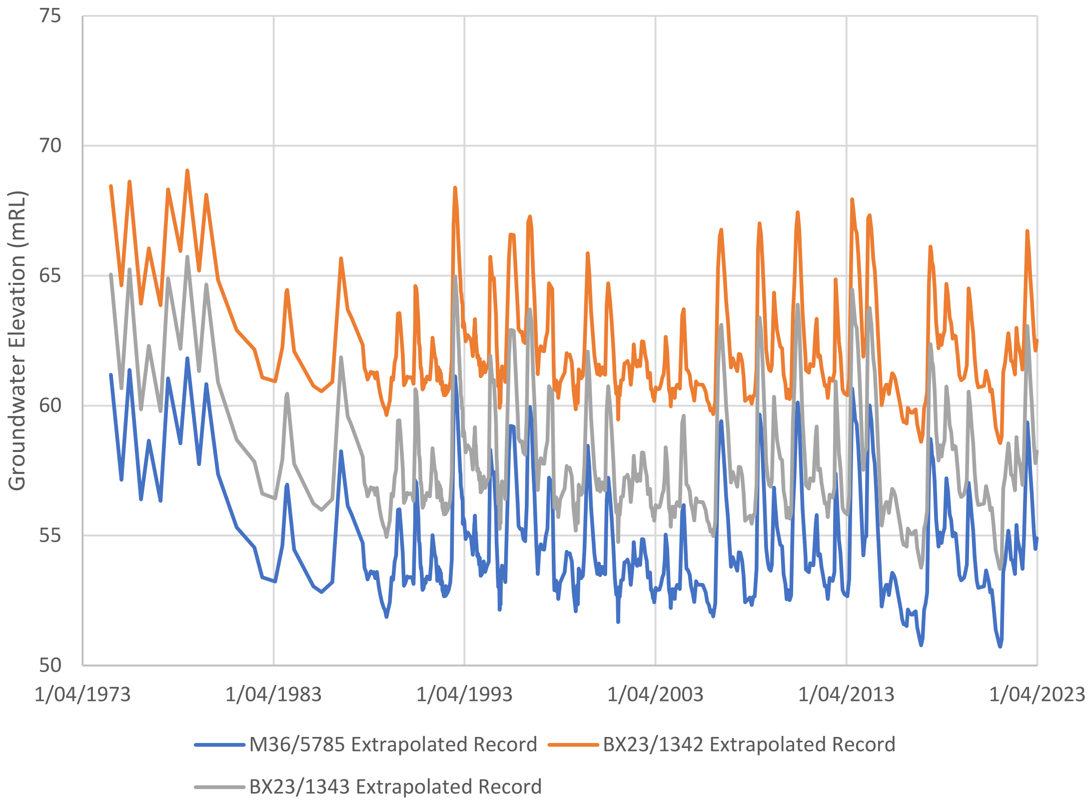


Figure 6: Extrapolated records (groundwater elevation) based on M36/0217

5.0 Highest Groundwater Table Assessment

Table 3 shows data from nearby ECan shallow monitoring bores (current and former) that have records that include the period in spring 1978. As with bore M36/0217 described in Section 4.0 above, all of the bores in Table 3 recorded their maximum groundwater level in spring 1978, and given the combined period of monitoring from all of the bores listed in Table 3 it can be inferred that the groundwater level peak at this period was the highest since at least 1951 (72 years). Therefore, the estimated groundwater level in spring 1978 is considered appropriate for estimating the highest historical groundwater level across the site.

Table 3: Details of Monitoring Bores

Bore ID	Depth (m bgl)	Minimum depth to water (m bgl)	Ground elevation from LiDAR (m RL)	Start of record	End of record	Date of highest groundwater level
L36/0087	58.50	24.42	105.39	04/01/1978	02/09/2003	06/11/1978
L36/0100	57.30	22.08	104.15	02/05/1978	07/06/1989	25/09/1978
M35/1000	48.80	18.36	104.54	23/09/1974	14/12/2022	26/09/1978
M36/0007	15.2	5.38	62.24	27/07/1951	2/08/1984	24/07/1978
M36/0039	39.40	9.19	66.98	26/09/1978	03/09/2003	26/09/1978
M36/0045	44.5	5.36	70.46	23/09/1974	3/09/2003	1/10/1978
M36/0049	27.1	8.14	71.05	27/09/1978	19/08/1991	27/09/1978
M36/0217	40.5	10.31	52.41	24/09/1974	16/11/2022	27/09/1978
M36/0255	24.4	5.78	43.18	14/04/1975	23/07/2018	27/09/1978
M36/0259	61.60	9.7	49.98	23/09/1974	12/05/2008	29/09/1978
M36/0451	44.50	2.61	51.59	20/09/1976	01/09/2003	27/09/1978
M36/0048	58	24.54	102.93	21/09/1976	7/05/1987	6/11/1978
M36/0046	43.8	7.6	77.73	23/09/1974	31/01/1995	27/09/1978
L36/0093	61.9	23.03	103.23	4/01/1978	8/01/1992	6/11/1978
M36/0040	59.4	27.34	106.8	1/02/1976	1/09/2020	6/11/1978

Many bores were only measured 6-monthly or quarterly in the 1970s, therefore the actual peak groundwater level in 1978 may not have been recorded for these bores, as the measurements for these bores were made in late September, which is generally a time of high groundwater levels but may not represent the peak level during that year. Of the nearby monitoring bores that were measured more frequently at that time, one shows higher water levels prior to late September (M36/0007, 0.6 m higher on 24/07/1978), while the other 3 show higher water levels later than late September when all other bores had their highest water levels measured (M36/0045, 0.36 m higher on 1/10/1978; L36/0087, 1.26 m higher on 6/11/1978 and L36/0100, 1.25 m higher on 6/11/1978). In order to account for this, the measured groundwater level from September 1978 in each bore that was not measured monthly was manually adjusted to a higher level, with the amount of adjustment based on best judgement by comparison to the amount that groundwater levels increased after September 1978 in bores that were measured more frequently at that time. The magnitude of adjustment varied from 0.1 m for the most downgradient bores, to 0.6 m for bore BX23/1342 at the upgradient end of Burnham Farm. Bore M36/5785 was adjusted by 0.2 m while BX23/1343 was adjusted by 0.3 m.

The minimum depth to groundwater was converted to peak groundwater elevation by using LiDAR to determine the ground elevation at each bore location. The peak measured groundwater elevation from each of these bores, as well as the peak inferred groundwater elevation estimated in the onsite shallow monitoring bores and bore M36/0465 using extrapolated records (described in section 4.0 above because these bores were not measured in 1978), was contoured to provide a map of the estimated highest groundwater level in 1978, as shown in Figure 7 below.

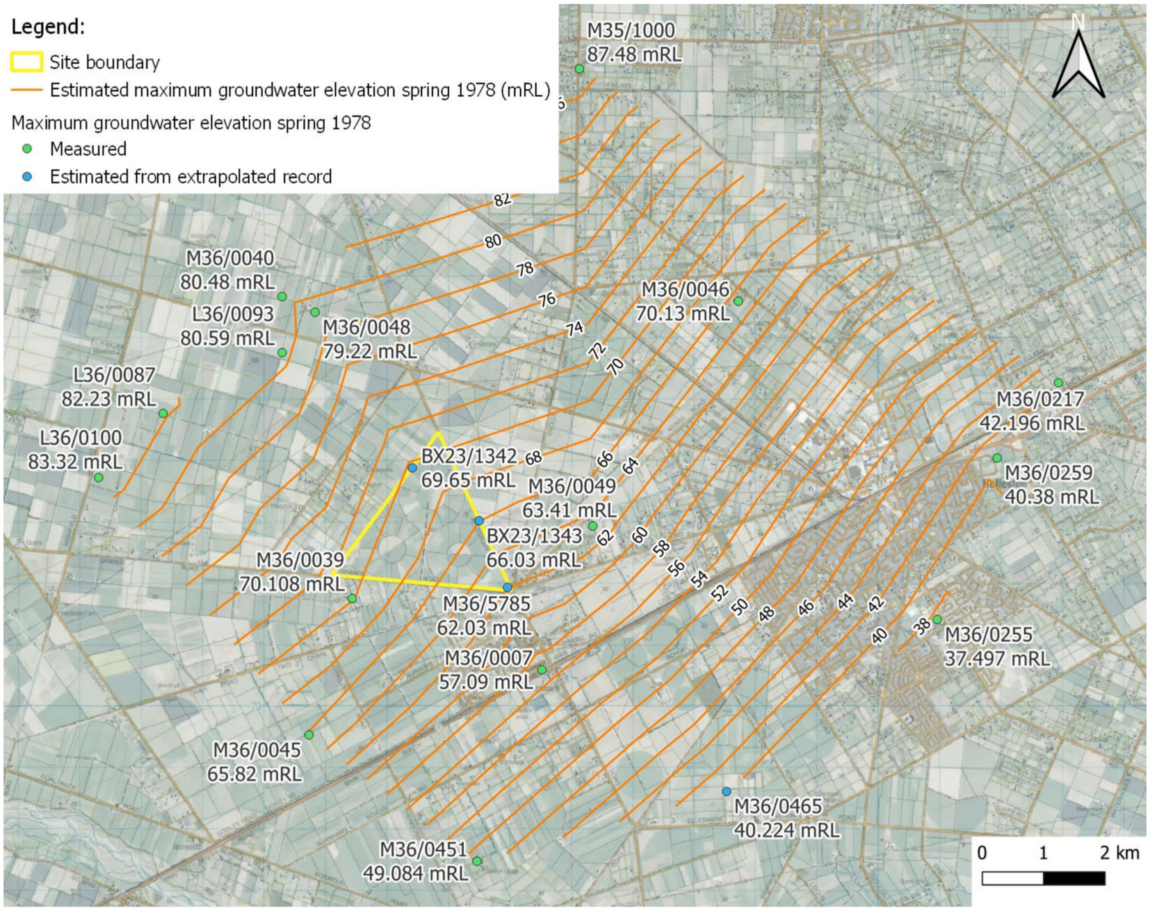


Figure 7: Piezometric contours of the estimated maximum groundwater elevation in spring 1978, based on measured groundwater levels and levels estimated from extrapolated records. 6-monthly and quarterly measurements manually adjusted as described in text above.

The piezometric contours are consistent with our conceptual understanding of the groundwater flow direction at the site. The contours presented in Figure 7 were used to estimate the depth to minimum depth groundwater across the site in 1978 by subtracting the estimated piezometric surface from the LiDAR digital elevation model. The resulting estimated peak depth to water contours (smoothed for clarity) are presented in Figure 8 below. The estimated minimum and maximum depth to groundwater in spring 1978 was slightly less than 8.0 m bgl on the southern side of the site, and approximately 16.5 m bgl in the northern corner of the site, respectively. The calculated mean depth to groundwater in spring 1978 across the site was 11.5 m bgl, which would correspond to a mean excavation depth of 10.5 m in order to maintain a 1 m clearance above the highest estimated groundwater level, based on the inferred level reached in spring 1978.

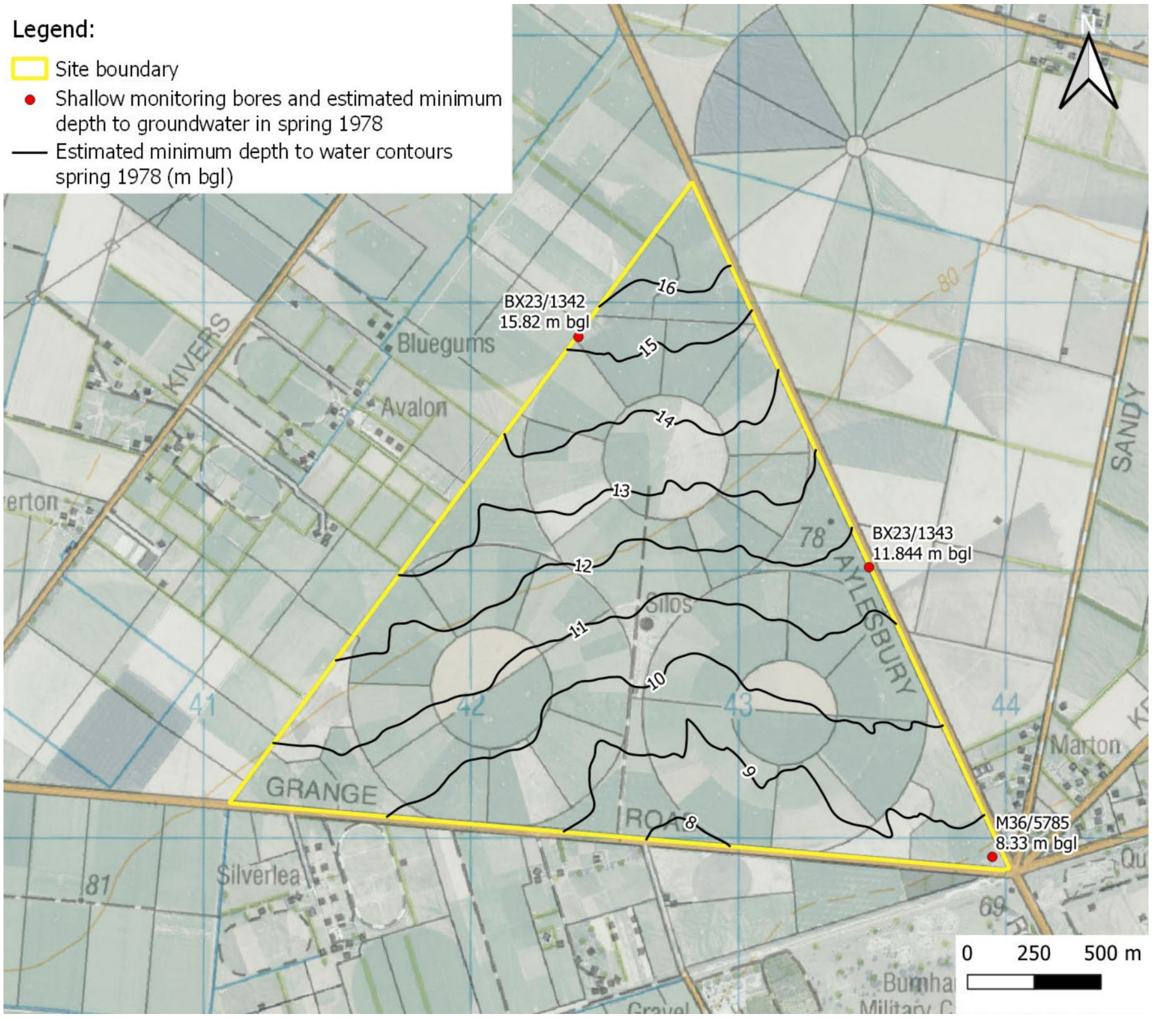


Figure 8: Contours of the estimated depth to groundwater across the site at the time of highest recorded groundwater levels in spring 1978.

It should be noted that it is possible that groundwater levels could peak at a higher level in the future than they did in 1978. Peak groundwater levels in 2022 were similar to the levels in 1978 but generally slightly lower, e.g. the peak 1978 level in bore M36/0217 was approximately 1.5 m higher than in 2022. The Central Plains Water (CPW) Scheme commenced the supply of water into this area in October 2018, so has now been operating for five complete irrigation seasons. This could contribute to groundwater levels being higher than has previously occurred, due to its use of Rakaia River water that brings more water into the area and reduced abstraction from groundwater.

Future groundwater levels could also be affected by climate change, although the likely effect of climate change on groundwater levels in Canterbury is highly uncertain. Temperature is projected to increase, which will generally increase evapotranspiration. A recent report by NIWA indicates that summer rainfall is projected to stay the same or slightly decrease (0 – 5%) on the central Canterbury Plains, however winter rainfall is projected to increase by 5 – 10% (NIWA, 2020). Flood flows in large alpine rivers are projected to increase, however Burnham Farm is in a part of the Canterbury Plains that is not expected to receive significant natural recharge from the Waimakariri River or Rakaia River. In light of the above projections, it is difficult to determine whether climate change will cause groundwater levels to generally increase or decrease, however it is possible that any increase in winter rainfall could cause isolated winter "spikes" in groundwater levels to become higher.

6.0 Percent Exceedance

Given the uncertainty in the evaluation of the highest groundwater level, it is useful to consider the estimated probability of high groundwater levels occurring, so as to indicate the significance of any unexpected spikes in high groundwater levels. The simulated annual maximum groundwater level for each of the three on-site monitoring bores has been evaluated to generate extreme value distributions for estimating the 1 in 5 year, 1 in 10 year and 1 in 20 year high groundwater level statistic, as provided in Table 4 below. There are many extreme value distributions to choose from, however the generalised extreme value (GEV) distribution (Rao and Hamed, 2000) shows a good fit to the extrapolated record data for each on-site bore.

Table 4: High Groundwater Level Estimated Return Periods for On-Site Bores

Bore	**Estimated annual highest groundwater level (m bgl) [1]**		
	1 in 5 year	**1 in 10 year**	**1 in 20 year**
M36/5785	11.0	9.8	8.8
BX23/1342	18.7	17.6	16.6
BX23/1343	14.8	13.5	12.4

Notes:

1. Based on extrapolated record from bore M36/0217 and a generalised extreme value (GEV) distribution.

The highest groundwater level contoured in in Figure 8 is less frequent than a 1 in 20 year event.

It is also useful to consider the amount of time that levels are generally at a peak. As an example, for bore BX23/1343, when the extrapolated groundwater record estimates groundwater levels higher than 14.0 m (between a 1 in 5 year and 1 in 10 year level), the groundwater level “spike” generally lasts two months or less, for example in 1992 levels higher than 14.0 m were only recorded in October and November of that year, and in 2010 only one monthly measurement (in September) was recorded above 14.0 m.

As groundwater monitoring continues at the site, a greater understanding of the range of seasonal fluctuations will be gained, and more robust extrapolated groundwater records will be able to be created to refine the estimates presented in this letter.

7.0 Conclusions

In summary, the results of the assessment described in this letter are as follows:

- The creation of extrapolated long-term groundwater level records indicates that the highest historical groundwater levels (likely the highest since 1951) at the site likely occurred in spring 1978.
- The peak groundwater level at the site in spring 1978 is estimated to have ranged from approximately slightly less than 8.0 m below ground level on the southern side of the site, to approximately 16.5 m below ground level in the northern corner of the site. The mean of the peak groundwater level across the site in spring 1978 is estimated to be 11.5 m below ground level.

- The groundwater level in spring 1978 may be an appropriate level to use as an estimated maximum groundwater level, for the purposes of maintaining a 1 m buffer from the ground surface to groundwater. However, it must be recognised that the effects of the Central Plains Water Scheme and climate change could cause some difference in future groundwater levels compared to what has been observed in the past.
- The proposed quarry will develop gradually over a long period of time which will allow for the assessment described in this letter to be repeated, and to become more robust, as further groundwater level monitoring data becomes available from ongoing monitoring at the site.

8.0 References

Ministry for the Environment. (2018). *Climate change projections for the Canterbury region*. Retrieved from https://environment.govt.nz/facts-and-science/climate-change/impacts-of-climate-change-per-region/projections-canterbury-region/

NIWA. (2020). *Climate change projections for the Canterbury Region. NIWA client report 2019339WN.*

Rao, A. R., & Hamed, K. H. (2000). Extreme Value Distributions. In *Flood Frequency Analysis* (pp. 207-255). Boca Raton: CRC Press.

9.0 Limitations

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Winstone Aggregates Ltd and others (not directly contracted by PDP for the work), including Environment Canterbury. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Winstone Aggregates Ltd for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

Yours faithfully

PATTLE DELAMORE PARTNERS LIMITED

Prepared by

Tom Garden

Hydrogeologist

Reviewed and Approved by

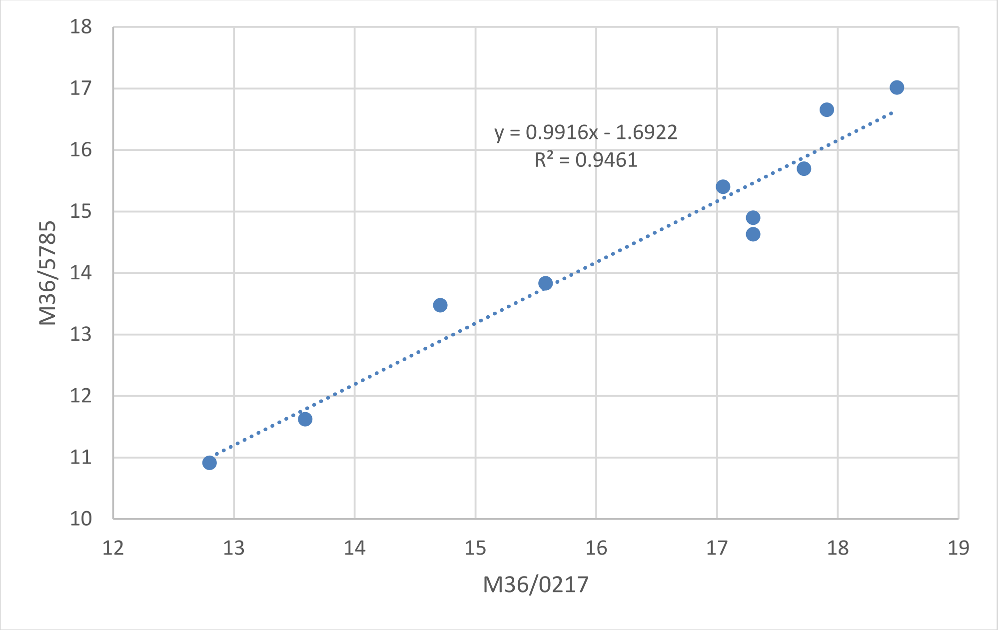
P. F. Callander

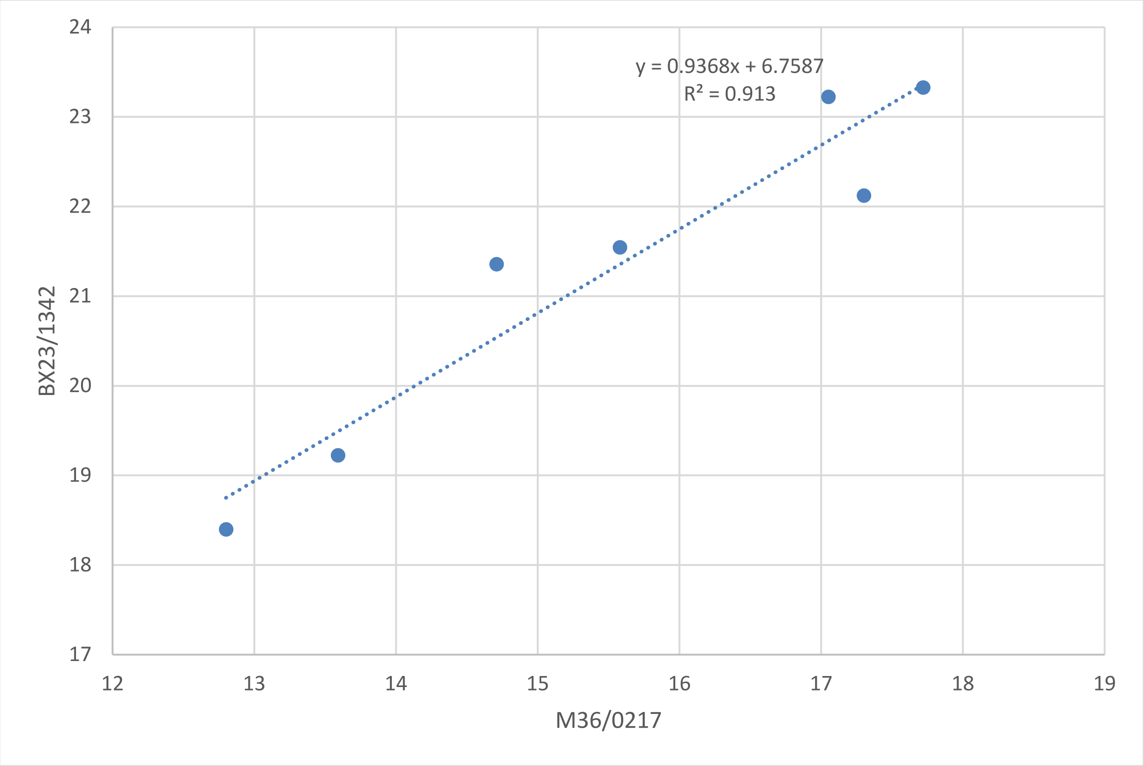
Peter Callander

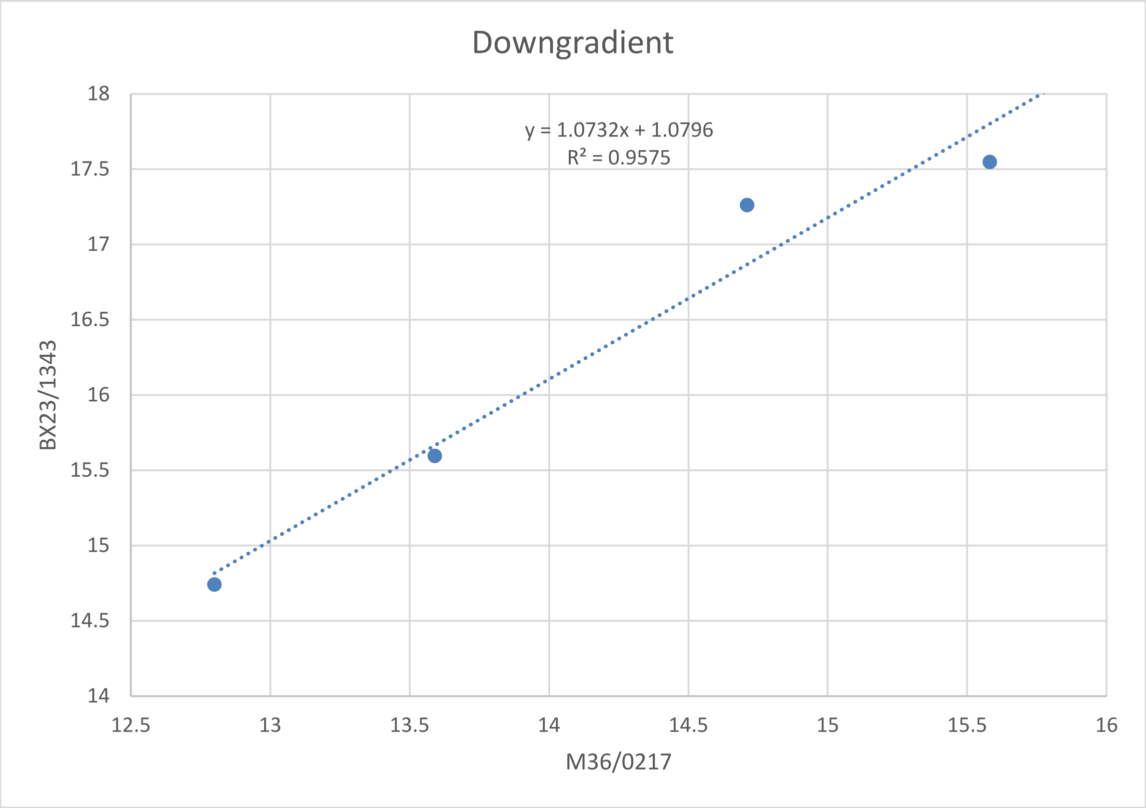
Technical Director-Water Resources

Appendix A: Regression Plots

M36/0217 – onsite bore comparisons






Downgradient
y = 1.0732x + 1.0796
R^2 = 0.9575
18
17.5
17
16.5
16
15.5
15
14.5
14
BX23/1343
12.5
13
13.5
14
14.5
15
15.5
16
M36/0217

Appendix D: Assessment of Proposed Quarry Effects on Nitrate Leaching to Groundwater

Pattle Delamore Partners Limited

TECHNICAL MEMORANDUM

INVESTIGATION	Nitrate leaching assessment for proposed Burnham Quarry and Farm	**PROJECT**	Renewal of Resource Consents CRC222536 and CRC221642 for Take and Use of Groundwater
CLIENT	**Burnham 2020 Ltd**	**PROJECT NO**	C04096400
CLIENT CONTACT	Dan McGregor	**PREPARED BY**	Peter Callander
DATE	15 November 2022	**SIGNATURE**	P. F. Callander

1.0 Introduction

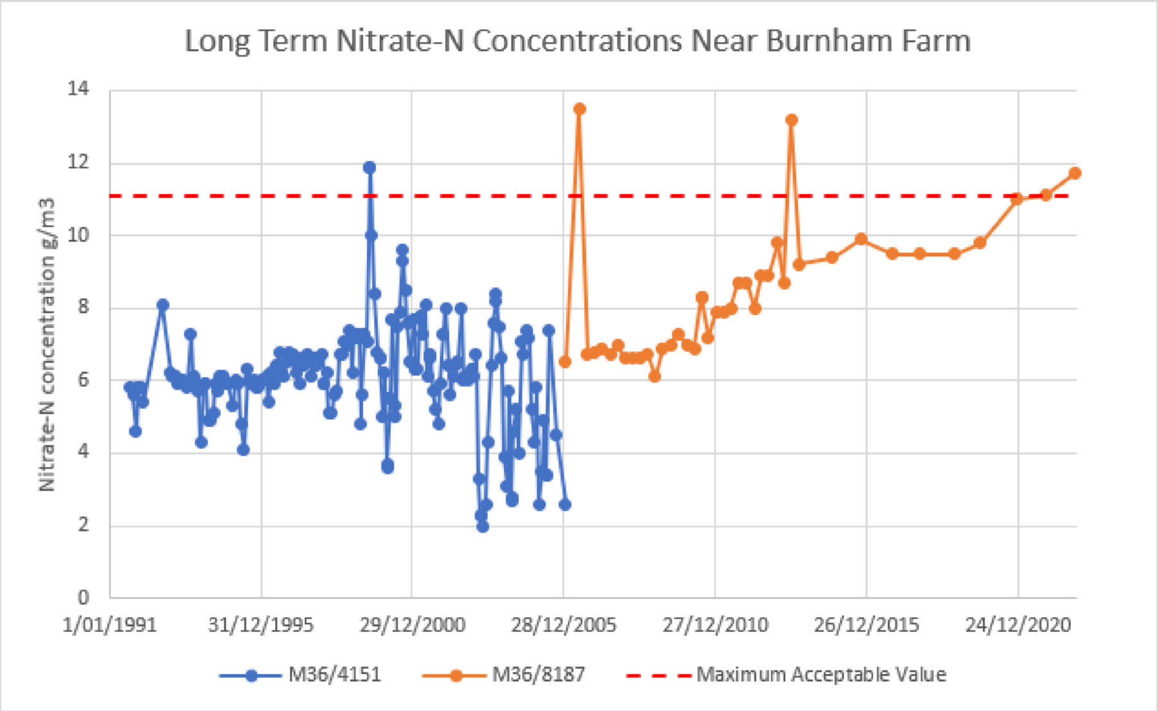
Burnham Farm is a modern irrigated dairy support block with approximately 70 paddocks covering an area of 362 ha. It is currently in pasture and kale crops for winter feed and is being grazed by one- and two-year old dairy heifer replacements. It is proposed to progressively quarry the property and return the land for farming activities, at a lower elevation compared to its current elevation. During a project planning workshop on 28 September, a question was raised as to how these changes in land use would affect the leaching of nitrogen into the underlying groundwater. This memo has been prepared to consider those changes.

The groundwater underlying the farm is part of an alluvial gravel aquifer system that is used by neighbouring property owners who abstract groundwater from wells on their properties to provide a source of drinking-water. Further down the plains (around 10 kilometres away), the groundwater also provides a source of water to spring-fed streams.

Nitrate is the common form of nitrogen that leaches from agricultural land use activities and at elevated concentrations it can cause adverse effects for both drinking-water supplies and spring-fed streams. A maximum acceptable value of 11.3 g/m^3 is specified for nitrate-N in the Drinking-water Standards for New Zealand 2005 (revised 2018). The NPSFM specifies an annual median nitrate-N concentration of 2.4 g/m^3 as the national bottom line for rivers.

2.0 Current Nitrate-N concentrations in groundwater

ECans groundwater quality database in the vicinity of Burnham Farm has mostly older groundwater samples collected between 1975 and 1995. These have average nitrate-N concentrations of 8 g/m^3, with 22 of the 138 samples (drawn from 3 bores) exceeding the MAV of 11.3 g/m^3. However, one pair of bores has a longer-term record. Bore M36/4151 is located on Kerrs Road, near the south-east corner from Burnham Farm. It is 31 m deep, but around 2005 it experienced low water levels and was replaced by bore M36/8187, which is 48 m deep, located around 25m to the north-east of M36/4151. The nitrate-N samples from this bore are plotted below and show a steadily increasing trend with the measurements in 2020 and 2021 all being around the MAV of 11.3 g/m^3.



A recent sample has been collected on 3 June 2022 from shallow bore M36/5785 (screened from 24.7 – 27.7 m deep) located in the south-eastern corner of Burnham Farm which had a nitrate-N concentration of 7.8 g/m^3.

3.0 N-leaching from current farming activities

The leaching of nitrogen from farm activities is typically quantified using the Overseer model. Whilst the accuracy of this model is sometimes questioned, it still provides a useful point of comparison of the relative change between different types of land-use.

The farm is irrigated by Central Plains Water Limited and comes under their nutrient load and environmental management plan. The property has a farm environment plan (FEP), regular audits and for the year ending 2020 the nutrient loss was 31 kg N/ha/yr and nitrogen drainage below the plant root zone is estimated at 16 g/m^3(Overseer v 6.4.3). This loss of nitrogen will typically be in the form of nitrate. The farm currently has 32 ha of kale (8% of the farm) for intensive winter grazing and this increases the nitrogen losses.

These reported losses from the farm soils leach downwards from the soil profile into the underlying groundwater. The geology of the broader area consists of successive alluvial deposits comprising gravel, sand, silt and clay sized particles. Long-term groundwater level records are available from several ECan monitoring wells in the vicinity. These show that seasonal variations in groundwater levels of around 11 m are common, with lowest groundwater levels generally occurring in late summer and autumn, and highest groundwater levels generally in spring. The available data indicates that the highest groundwater level may be around 16.5 m below ground level in the north of the site and around 8 m below ground level in the south-east area of the site.

Nitrate is highly soluble and does not adhere to sedimentary particles. Therefore, it will be present in the pore water that moves downward through the unsaturated zone towards the underlying water table. This subsurface drainage pathway can be divided into three categories, as shown in the Following Table.

Table 1. Subsurface environment below the soil zone

Zones of saturated strata beneath Burnham Farm	Approximate depth range of each zone	
	Prior to quarrying	Following quarrying
Permanently unsaturated strata above the highest groundwater level	0 – 16.5 m	0 - 1 m
Intermittently saturated strata within the range of water table fluctuations	8 – 28 m	1 – 12m
Permanently saturated strata below the lowest groundwater level	>28m	>12 m

As shown by the Table above, the proposed quarry will reduce this vertical separation distance to the highest groundwater level to around 1 m when the quarried area is restored to pasture.

4.0 N-leaching during quarrying

During quarrying, up to 40 ha of the property will be utilised for that purpose at any one time, of which 22 ha will occupy the active quarry workings that will progressively move throughout the farm area and the remaining 18 ha will be at a fixed location for access, administration and processing facilities. The area of the farm in which quarry activities are occurring will have a low nitrogen leaching rate, related to the nitrogen content in rainfall and any additional input and take-up from planted areas.

The estimated reduction in nitrate leaching due to the change from farming to quarrying is summarised in the following Table and shows a significant (10 times) decrease of around 1100 kg N/year in the N loss to groundwater due to the change in land use. Compared to the overall current annual N loss from Burnham Farm, estimated to be 11,222 kg of N (31 kg N/ha/yr over 362 ha) a reduction of 1100 kg corresponds to a 10% decrease.

Table 2. Comparison of N loss from the land surface

	N loss from current land use	N loss from associated quarry activities
Area	40 ha	40 ha
N Loss Rate	31 kg N/ha/year	3 kg N/ha/year[1]
Total N entering groundwater	1240 kg	120 kg

Notes:

1. *Parfitt et al (2008) suggest rainfall loading rates of 1 – 5 kg N/ha/yr and it is assumed that little modification to this rainfall may occur within the quarried area.*

The migration of the nitrate into the groundwater occurs due to downward migration of infiltrating rainwater and by inundation of the strata when the water table rises. These natural processes of water and associated nitrate migrating down to the water table will continue during the quarrying activity.

The moisture that is within the quarried strata will contain nitrate from the farming activity that was occurring prior to the commencement of quarrying. The quarried strata will be processed on site by washing the different sized particles and silt laden water will be pumped into settling ponds or spread out over land as part of the quarry rehabilitation. The volume of pore water in the unsaturated zone will be relatively small, with the active quarry area (22 ha) occupying only 6% of the Burnham Farm property. Furthermore, the infiltrating wash water occurring within this small working area will be quite localised and will not cause any significant rise in the groundwater levels. This process of washing the strata will therefore have a much smaller effect on the overall volume of nitrate that would enter the groundwater compared to what would occur from a rainfall event, which has a much wider scale of impact, both in terms of the area over which the rainfall occurs and the rise in the water table that results.

Consequently, the main effect on nitrate losses during the quarrying activity is the decrease in nitrogen leaching achieved by the interruption of the farming activity, as summarised in Table 2 above.

5.0 **N-Leaching post quarrying**

At the completion of quarrying the land is expected to return to some form of agricultural activity. For the purposes of this assessment we have assumed that the current farming practice will be resumed. The thickness of the permanently unsaturated zone (above the highest water table level) will be reduced from the current depth range of around 8 –16.5 m across the farm to a depth of around 1 m. The thickness of the intermittently saturated zone within which the water table fluctuates will remain unchanged at around 11.5 m, as will the N loss through the soil if the current land-use activity continues. Similarly, the mobilisation of nitrate into the groundwater system when the water table rises will continue as it does at present. However, instead of having 8– 28 m of strata above the water table this will be reduced to a depth of 1 – 12 m, depending on where the groundwater level is at any particular point in time. Consequently, the farm soils will be closer to the water table.

No significant attenuation of nitrate happens within this unsaturated zone therefore it is expected that the same mass of nitrate will reach the water table, but it will reach the intermittently saturated zone and the water table more quickly, due to the shorter travel distance to the water table. This is expected to be a small change that will not noticeably change the groundwater quality of the area.

6.0 **CONCLUSION**

Current nitrate-N concentrations in groundwater in the Burnham Farm area can occur at magnitudes around the Maximum Acceptable Value in the NZ Drinking-Water Standards. Farming activities such as those at Burnham Farm contribute to these elevated nitrate concentrations in groundwater. During quarrying activities that source of nitrate will significantly decrease.

Once the quarried area has been rehabilitated the soil surface will be closer to the water table but will still be above the highest estimated water table level. The mobilisation of nitrates into the groundwater when the water table rises, will still occur as it does at present. There is very little removal of nitrate once it leaches below the soil zone. Consequently, following the rehabilitation of the quarried land, annual losses of nitrate to groundwater will be similar to current losses if the same agricultural land use practices continue into the future. The main difference will be that the nitrate will have reached the groundwater sooner than is currently the case.

7.0 REFERENCES

Parfitt, R.L.; Baisden, W.T.; Schipper, L.A, & Mackay, A.D. (2008) Nitrogen inputs and outputs for New Zealand at national and regional scales: Past, present and future scenarios, Journal of the Royal Society of New Zealand, 38:2, 71-87, DOI: 10.1080/03014220809510547

This memorandum has been prepared by Pattle Delamore Partners (PDP) on the specific instructions of Burnham 2020 Ltd for the limited purposes described in the memorandum. PDP accepts no liability if the memorandum is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

This memorandum has been prepared by PDP on the basis of information provided by Burnham 2020 Ltd and others (not directly contracted by PDP for the work), including Environment Canterbury and McMillan Drilling. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the memorandum. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

Appendix E: Assessment of Proposed Quarry Effects on *E. coli* Migration into Groundwater

Pattle Delamore Partners Limited

TECHNICAL MEMORANDUM

INVESTIGATION	*E. coli* migration assessment for Burnham Farm	**PROJECT**	Renewal of Resource Consents CRC222536 and CRC221642 for Take and Use of Groundwater
CLIENT	**Burnham 2020 Ltd**	**PROJECT NO**	C04096400
CLIENT CONTACT		**PREPARED BY**	Neil Thomas
DATE	10 November 2022	**SIGNATURE**	

1.0 Introduction

Burnham Farm is a modern irrigated dairy support block with approximately 70 paddocks covering an area of 362 ha. It is currently in pasture and kale crops for winter feed and is being grazed by one- and two-year old dairy heifer replacements. The presence of stock creates a source of *E. coli* that can migrate downwards to the underlying groundwater system, particularly during heavy rainfall events. The groundwater underlying the farm is part of an alluvial gravel aquifer system that is used by neighbouring property owner who abstract groundwater from wells on their properties to provide a source of drinking-water. During this migration from the ground surface through the sub-surface environment, *E. coli* numbers are reduced by filtration, desiccation, dispersion, dilution and natural die-off over time. These processes operate in differing degrees as the *E. coli* move through the soil profile, the unsaturated subsurface zone and finally through the water saturated groundwater system.

A proposed quarry at Burnham Farm will reduce the thickness of the unsaturated zone and bring the source of the *E. coli*, at the pasture surface, closer to the saturated groundwater flow system. Pattle Delamore Partners (PDP) have prepared this memorandum to describe the change in *E. coli* attenuation rates and the change in contamination risks on drinking-water supply wells that arises from the proposed quarry at Burnham Farm.

2.0 Hydrogeologic Setting

Burnham Farm is located near the middle of the Canterbury Plains, approximately 6.5 km north of the Selwyn/Waikirikiri River and 12.5 km south of the Waimakariri River. The geology of the broader area consists of successive alluvial deposits comprising gravel, sand, silt and clay derived from the Southern Alps and deposited during the Quaternary period. The permeability of the strata is influenced by the age, depth of burial and depositional environment. The aquifers in the region are generally semi-confined.

The 1:250,000 geological map of the Christchurch area (Forsyth, Barrell, & Jongens, 2008) describes the underlying geology as brownish-grey river alluvium beneath plains or low-level terraces. The local near surface geology in this area of the plains also consists of remnants of stabilised river (Waimakariri) sands.

The driller’s logs for wells in the area are generally consistent with the geological description above. The logs indicate that the strata generally consist of gravels with varying sand and clay content.

Groundwater recharge in the area is generally from rainfall and seepage from rivers, particularly the Waimakariri and Selwyn/Waikirikiri. Environment Canterbury (ECan) regional piezometric contours indicate that the groundwater near the site flows in a generally south-easterly direction.

Long-term groundwater level records are available from several ECan monitoring wells in the vicinity. These show that seasonal variations in groundwater levels of up to 10 m are common, with lowest groundwater levels generally occurring in late summer and autumn, and highest groundwater levels generally in spring. The available data indicates that the highest groundwater level may be around 16.5 m below ground level in the north of the site and around 8 m below ground level in the south-east corner of the site. The proposed quarry may reduce this vertical separation distance to the highest groundwater level to around 1.5 m when the quarried area is restored to pasture.

Figure 1 shows the location of drinking-water supply wells on ECan's wells database, located within 1km of the proposed quarry property boundary. It also includes the Community Drinking-water Protection Zones that apply to water supplied for communities no fewer than 25 people for not less than 60 days each calendar year. These are the supply wells for the Burnham military camp and define zones where special land use measures may be required to protect the wells from contamination risks from contaminant sources such as *E. coli*. None of these protection zones extend into Burnham Farm.

The nearest downgradient wells are around 65 m from the Burnham Farm property boundary and around 150 m in the downgradient flow direction. They abstract groundwater from a variety of depths. A histogram of the well intake depths for all recorded drinking-water supply wells within 1 km of the Burnham Farm property is presented in Figure 2. It shows that the shallowest drinking water supply wells abstract from the 25 – 30 m depth range, although most wells are in the range of 40 – 55 m deep. Wells in the shallower depth range will be at greatest risk of *E. coli* contamination. Details of the community supply wells in the area, i.e. those for the Burnham military camp are summarised in Table 1.

Table 1: Community Drinking-Water Supply Wells for Burnham Military Camp

Well	Screen Interval (m bgl)	Diameter (mm)	Date-Drilled	Tested Yield (L/s)	Drawdown (m)
BX23/0903	189 - 195	300	26/4/2019	Unknown	Unknown
M36/2693	44.8 – 54.9	200	19/9/1957	26.5	8.5
M36/2694	24.3 [1]	150	Unknown	Unknown	Unknown

Notes:

1. *Well depth (screen interval unknown).*

3.0 *E. coli* Removal Rates

This section of the memo describes the various *E. coli* removal rates that apply to the Burnham Farm property, based on information presented in Schijven, J., Pang, L., and Ying, G.G. (2017).

The drinking water standard (NZDWS, 2018) for *E. coli* is <1 cfu/100 ml i.e. *E. coli* should not be detected in drinking water samples to comply with the drinking water standards. Therefore, the cumulative removal of *E. coli* along the pathway from the source to a downgradient well needs to reduce the concentrations from contaminant sources to < 1 cfu/100ml.

The source concentration of *E. coli* in paddocks that are used for agriculture, including dairy farming, is not well defined. However, some indication of the likely concentrations can be derived from information on *E. coli* concentration in untreated wastewater, for example septic tanks. Pang (2005) indicates that typical *E. coli* concentrations in raw effluent from septic tanks are around 1×10^6 cfu/100 ml. Likewise, concentrations of *E. coli* observed in dairy farm effluent ponds in New Zealand was recorded at concentrations up to 6×10^7 cfu/100 ml (Donnison, 2011). Therefore, concentrations would need to reduce by at least 8 log cycles to achieve the drinking water standards. This standard has been used in the following assessment, noting that source concentrations within paddocks are likely to be less than those observed in untreated wastewater and dairy farm effluent ponds.

There are three main components of bacterial removal as it travels from the surface to a well used to take groundwater:

- Removal as bacteria travel downwards through the soil directly underlying the source
- Removal as bacteria travel through the unsaturated zone between the soil and saturated strata
- Removal along a groundwater flow path between the source and a well.

The following sections of this memo discuss each of these components in more detail.

3.1 Soil

The top-soil over most of Burnham Farm is described from test pits as a dark brown sandy gravelly silt, well graded, sand, fine to coarse gravel, fine to coarse, rounded to subrounded slightly weathered Greywacke with organics, roots and wood fragments. The average topsoil thickness is 0.3 – 0.4 m.

S-Map (Manaaki Whenua Landcare Research) have mapped the area at 1:50,000 and have identified the soil siblings within the map unit, as described in Table 2. The profile available water (PAW) is a measure of the capacity of the soil sibling to store water that is potentially available for plant growth.

Table 2: Soil Siblings (S-map)

S-Map name	% of soil	Depth	Texture	Drainage class	PAW at 60 cm (mm)	Soil Order
Lismore_1a.1	80	Shallow	silt	Well drained	93	Brown
Lismore_2a.1	10	Shallow	silt	Well drained	75	Brown
Templeton_9a.1	10	Moderately Deep	silt	Well drained	105	Pallic

The proportions of soil siblings may vary across the property as indicated by percentage of stones found in the soil and the depth of topsoil.

Table 3 in Schijven et al (2017) presents bacterial removal rates for various types of soil. The soils at Burnham Farm that best match those reported rates are considered to correspond to a “shallow silt loam over gravel” which have a reported average bacterial removal rate of 4.04 $\log_{10}$/m. This soil type at Burnham farm, representing both topsoil and sub-soil, occurs over a thickness of 0.6 m so actual removal rates average 2.4 $\log_{10}$.

Following the completion of quarrying, existing soils from the farm will be stripped and placed over the quarried areas. Crops will be planted to help develop the soil structure and it is expected that 1 – 2 years after the completion of quarrying the soil will have similar bacterial removal rates to those that currently exist through the topsoil. For the purposes of a conservative assessment, we have assumed that the post-quarry soil is only 0.3 m thick, due to uncertainty regarding the sub-soil layer.

3.2 Unsaturated Zone

The unsaturated zone describes the strata that exists between the soil zone and the saturated groundwater zone. At present the available information indicates that this extends to a depth of around 8 – 28 m below ground level, depending on the elevation of the water table, which fluctuates seasonally. At the completion of quarrying the thickness of this zone could be reduced to a depth of around 1 – 11 m. It comprises the natural alluvial deposits of gravel, sand, silt and clay. Table 5 in Schijven et al (2017) report bacterial removal rates in the unsaturated zone. Their dataset is somewhat limited and because of that, it will be conservative to assume that this zone comprises coarse gravel. The reported bacterial removal rates average 0.44 $\log_{10}$/m.

3.3 Saturated Zone

The saturated groundwater flow system also comprises a mixture of natural alluvial deposits of gravel, sand, silt and clay. For lateral transport it will be conservative to assume transport occurs within coarse gravels, which are laid down on a general horizontal plain orientation. Table 7 in Schijven et al (2017) report bacterial removal rates in saturated aquifer strata. For tracer tests in uncontaminated coarse gravels the reported bacterial removal rates are around 0.02 $\log_{10}$/m for lateral transport. However, the intake zone for drinking-water supply wells occur several metres below the water table. As shown in Figure 2, the shallower wells occur at depths of 25 m (around 15 m below the shallowest water level and 5 m below the deepest water levels, with most well intakes being a further 15 m deeper than that). Therefore, any *E. coli* must migrate downwards through the strata, which will involve a longer flow path and the occurrence of at least some finer grained layers, which will increase removal rates, although quantification of vertical migration in the saturated zone is not described in Schijven et al (2017).

In order to assess vertical migration a 3-d analytical contaminant transport equation has been used (Hunt 2012). The removal rates for coarse clean gravel aquifers described in Schijven et. al., (2017) include those based on experiments described in Pang (1998). Other experiments are also described in Schijven et. al (2017) but we have used the Pang (1998) example as this is the best documented and also appears to best match analytical models for contaminant transport. Other experiments (Sinton, 2000) appear to have missed the peaks in breakthrough curves meaning that the results are less reliable. The experiments in Pang (1998) used an injection source of *B.subtilis* bacteria and an array of monitoring wells up to 85 m downgradient from the source. Concentrations were recorded at the water table in each of the downgradient wells and the reduction in concentrations of bacteria on a per metre basis was calculated, together with other aquifer parameters including flow velocities, retardation coefficients and dispersion. Therefore, the analytical model has been set up to replicate the results of the experiment, using similar aquifer parameters. A table showing the parameters used in the analytical model is provided in Appendix A, which also shows the parameters derived from observations in Pang (1998). Figure 3 shows the results of the analytical model compared to the Pang (1998) experimental results. In general, these indicate a close match.

The analytical model uses a decay rate of 2.4 log/day, which was adjusted to match the observed data, including the timing of the observed breakthrough curves. Although this parameter is labelled as a decay rate in the model, it takes on a surrogate role for bacterial filtration through the aquifer on the basis that travel time corresponds to distance travelled through the strata, resulting in more filtration with more distance travelled. Therefore, its value is not precisely analogous to a decay rate. However, we note that the bacteria chosen for the experiment described in Pang (1998) (*B. subtillis* spores) has a relatively low die off rate. Therefore, the results of the analytical model to bacteria such as *E. coli* are conservative because these would be expected to decay at a greater rate.

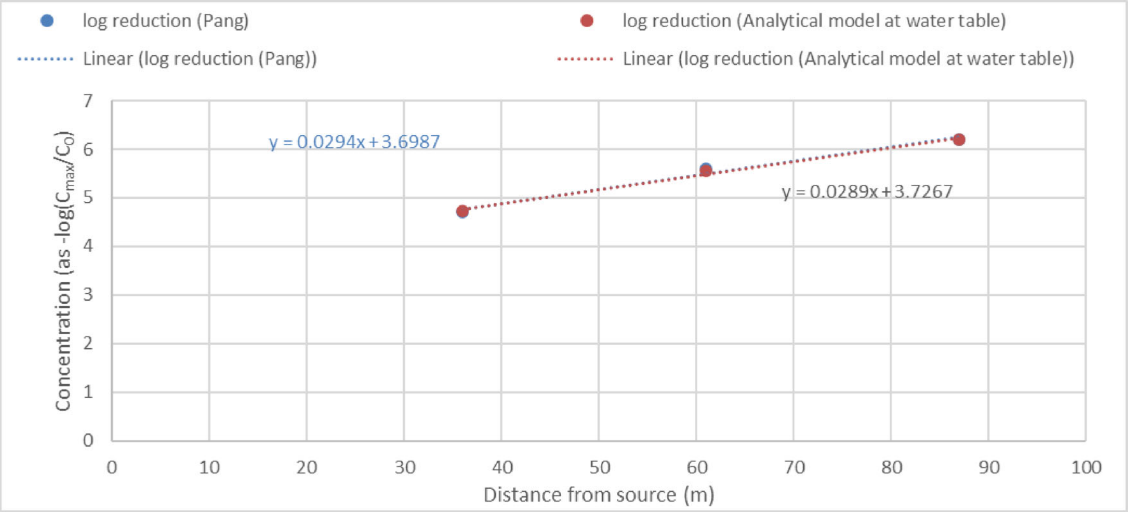


Figure 3: Modelled and observed (Pang, 1998) log reduction with distance from a source

The log removal rates in Pang (1998) are calculated as the slope of the line of best fit between the observed reduction in concentrations at different distances from the source along a flow path but does not include the reduction between the source and the closest monitoring well. Pang (1998) indicates a value of 0.031 log/m, whereas the analytical model indicates a value of 0.029 log/m (giving a 2.52 log reduction over 87 m). Given the close match between the observed results and the results from the analytical model, the results from the analytical model have been extrapolated to a distance of 150 m and a depth of 5 - 15 m below the water table (depending on low water level or high water level conditions).

The analytical model results indicates that the log reduction rate calculated over a distance of 87 m does not remain constant and reduces with increasing distance from the source. At a distance of 150 m, the model indicates an average log reduction rate of 0.022 log/m compared to 0.029 log/m at a distance of 87 m. Therefore, at the water table, the analytical model predicts a total log reduction of 3.3 at 150 m.

The analytical model indicates that at times of high water levels (when the shallowest well intakes are 15 m below the water table) an additional 7.7 log reduction would be expected to occur beyond the 3.3 log reduction at a distance of 150 m at the water table. At times of low water level (when the shallowest well intakes are around 5 m below the water table) the analytical model indicates an additional 1.0 log reduction would be expected to occur beyond the 3.3 log reduction at a distance of 150 m at the water table.

3.4 Combined Removal Rates

Tables 3 and 4 summarise the removal rates described in the preceding sections and combines them to indicate the overall removal rate for the current situation and for the post-quarry situation. Table 3 presents the bacterial removal rates under high water table conditions, while Table 4 presents the bacterial removal rates under low water table conditions

Table 3: Bacterial Removal Rates (under high/shallow water table conditions)

Zone	Prior to Quarrying			Post-quarry rehabilitation		
	Travel Distance (m)	Removal (log10)	Cumulative removal (log10)	Travel Distance (m)	Removal Rate (log10)	Cumulative removal (log10)
Soil Zone: shallow silt loam over gravel – vertical transport	0.6	2.4	2.4	0.3	1.2	1.2
Unsaturated Zone: coarse gravel – vertical transport	10	4.4	6.8	1	0.4	1.7
Saturated Zone: coarse gravel – lateral transport	150	3.3	10.1	150	3.3	5.0
Saturated Zone: coarse gravel – vertical transport	15	7.7	17.8	15	7.7	12.6

Table 4: Bacterial Removal Rates (under low/deep water table conditions)

Zone	Prior to Quarrying			Post-quarry rehabilitation		
	Travel Distance (m)	Removal (log10)	Cumulative removal (log10)	Travel Distance (m)	Removal Rate (log10)	Cumulative removal (log10)
Soil Zone: shallow silt loam over gravel – vertical transport	0.6	2.4	2.4	0.3	1.2	1.2
Unsaturated Zone: coarse gravel – vertical transport	20	8.8	11.2	11	4.8	6.1
Saturated Zone: coarse gravel – lateral transport	150	3.3	14.5	150	3.3	9.4
Saturated Zone: coarse gravel – vertical transport	5	1.0	15.5	5	1.0	10.4

The individual components of the removal processes are summarised in Figures 4 and 5 below. This indicates that the removal rates are reduced by around 5 orders of magnitude due to the lower ground surface, which is a result of the reduced thickness of the unsaturated zone once the quarry is rehabilitated.

However, while the cumulative log reduction is reduced because of the quarry and its rehabilitation, the cumulative log reduction reaches a minimum of 10.4 log cycles at a distance of 150 m from the property, which is the distance to the nearest water supply well. This reduction is still significantly in excess of the 8 log cycle reduction required to reduce concentrations to the drinking water standard (as illustrated in Figure 6 and 7). Therefore, the risk to downgradient wells, while elevated, remains acceptable.

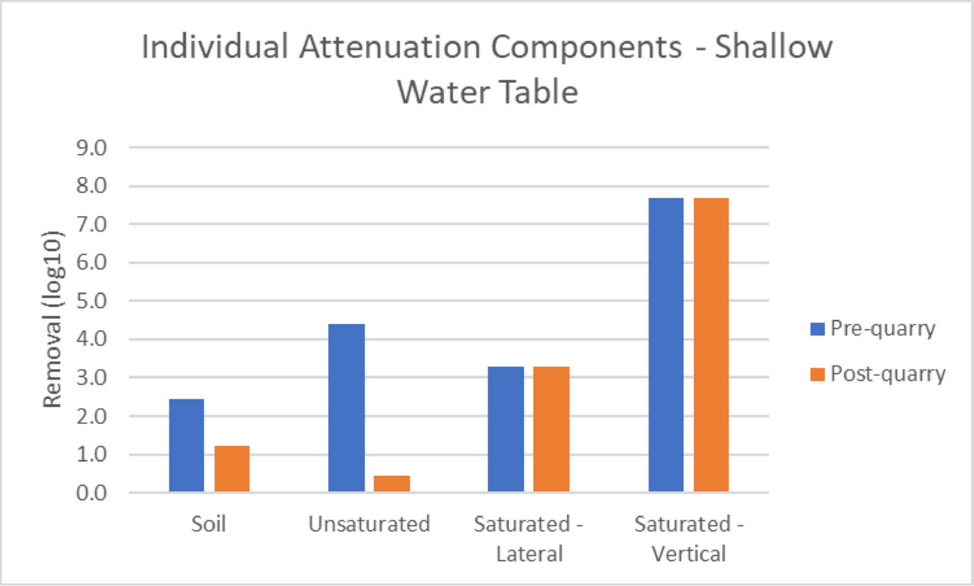


Figure 4: Bacterial removal rates for pre and post quarry under high water table conditions

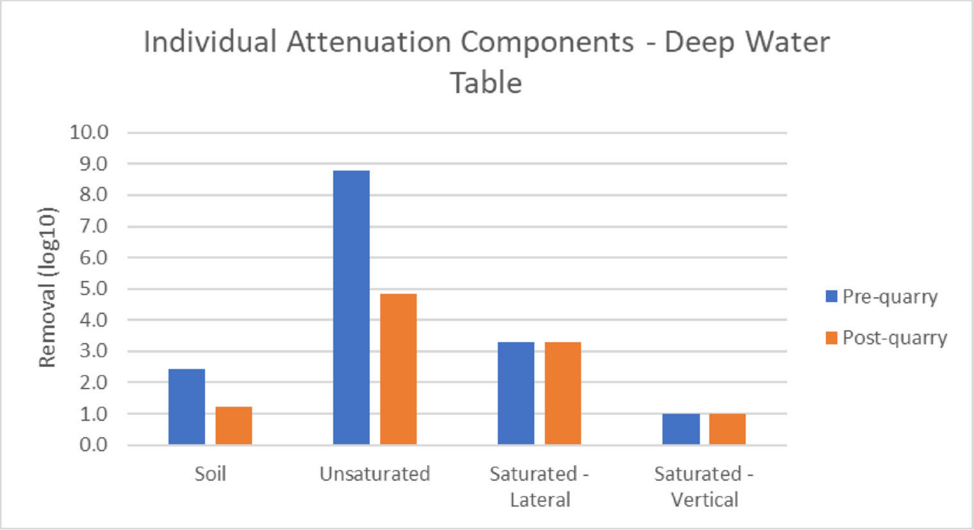


Figure 5: Bacterial removal rates for pre and post quarry under low water table conditions

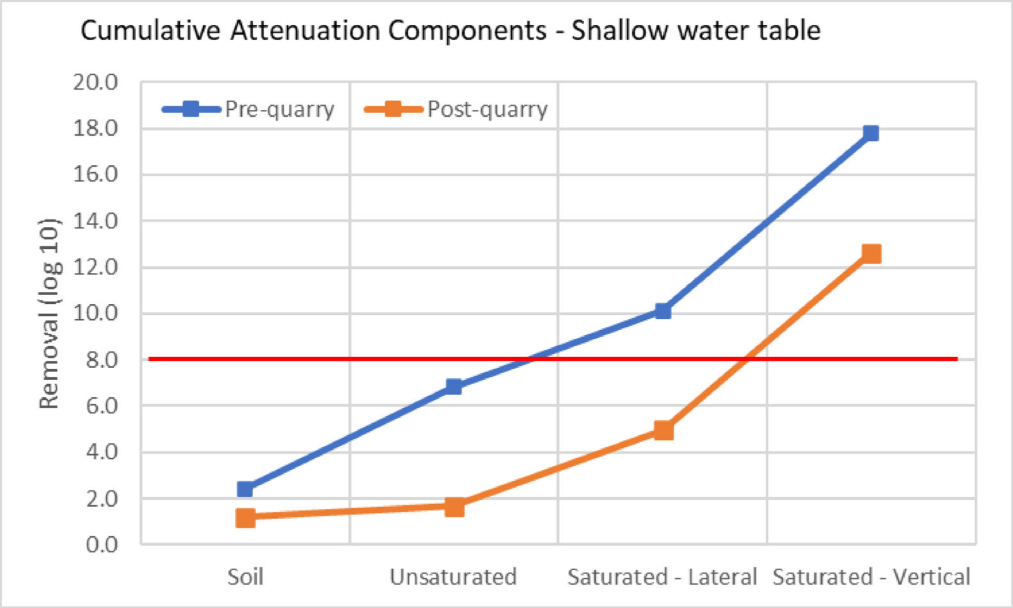


Figure 6: Cumulative bacterial removal rates for pre and post quarry under high (shallow) water table conditions

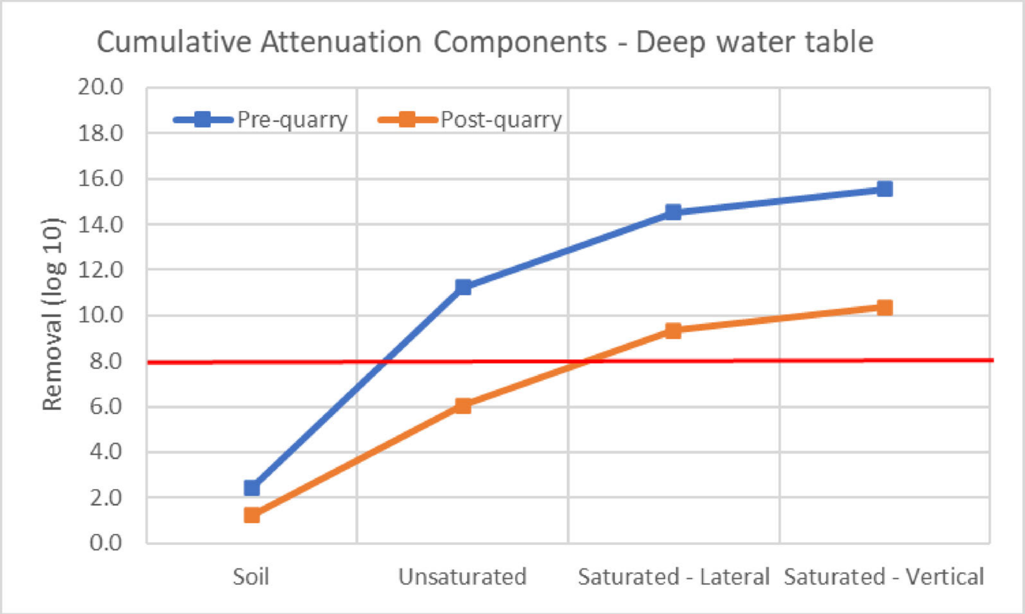


Figure 7: Cumulative bacterial removal rates for pre and post quarry under low (deep) water table conditions

4.0 CONCLUSION

Based on conservative examples of *E. coli* sources from farming activities it is expected that concentrations on the soil surface need to reduce by at least 8 log cycles to achieve the drinking water standards. This reduction in *E. coli* concentrations occurs as they migrate through the soil profile, the unsaturated strata and the underlying saturated groundwater system below the water table. The development of a quarry reduces the amount of *E. coli* reduction that occurs within the unsaturated zone. Assessments of the amount of post-quarry reduction to the nearest neighbouring domestic water supply wells to Burnham Farm is on the order of 5 log cycles, but the post-quarry ground conditions are still expected to achieve at least 10 log cycles removal between the farm and the closest bore 150 m downgradient, which is greater than the required value of 8 log cycles. On that basis it is expected that the current stocking land use can continue following the completion of quarrying without adversely affecting nearby drinking-water supply wells.

5.0 REFERENCES

Donnison, A., Ross, C., & McGowan, A. (2011). Escherichia coli and Campylobacter in two conventional Waikato dairy farm effluent ponds. New Zealand Journal of Agricultural Research, 54(2).

Hunt, B. (2012). *Groundwater Analysis Using Functions.xls.* Christchurch: University of Canterbury.

Pang, L., Close, M., & Noonan, M. (1998). Rhodamine WT and Bacillus subtilis Transport through an Alluvial Gravel Aquifer. *Groundwater, 36*(1).

Schijven, J., Pang, L., & Ying, G. (2017). Evaluation of subsurface microbial transport using microbial indicators, surrogates and tracers. In J. B. Rose, & B. Jiménez-Cisneros, *Global Water Pathogens; Part 2 Indicators and Microbial.* Michigan State University; UNESCO.

Sinton, L., Noonan, M., Finlay , R., Pang , L., & Close, M. (2000). Transport and attenuation of bacteria and bacteriophages in an alluvial gravel aquifer. *New Zealand Journal of Marine and Freshwater Research, 34*(1), 175-186.

This memorandum has been prepared by Pattle Delamore Partners (PDP) on the specific instructions of Burnham 2020 Ltd for the limited purposes described in the memorandum. PDP accepts no liability if the memorandum is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

This memorandum has been prepared by PDP on the basis of information provided by Burnham 2020 Ltd and others (not directly contracted by PDP for the work), including Environment Canterbury and McMillan Drilling. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the memorandum. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

Appendix A:

Table A1: Model Parameters

Parameter	Pang (1998)	Analytical Model
Flow velocity (m/day)	50 to 85	70
Longitudinal dispersivity (α_x) at 36 m	0.38 – 1.65	1
Longitudinal dispersivity (α_x) at 61 m	0.06 – 2.41	1.5
Longitudinal dispersivity (α_x) at 87 m	0.2 – 0.3	1.8
Longitudinal dispersivity (α_x) at 150 m		2
Lateral (α_y) at 150 m		0.2
Vertical (α_z) at 150 m		0.02
Decay rate (log/day)	0.23 – 9.4	2.4
Retardation factor	0.75 – 1.13	0.8
Porosity	0.2	0.2
Input flux (cfu)	5.2×10^{11}	5.2×10^{11}

Appendix F: Groundwater Quality Sample Results from Burnham Farm

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T **0508 HILL LAB** (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Pattle Delamore Partners Limited	**Lab No:**	3000105 DWAPv1
Contact:	Mr Peter Callander C/- Pattle Delamore Partners Limited PO Box 389 Christchurch 8140	**Date Received:**	27-May-2022
		Date Reported:	02-Jun-2022
		Quote No:	118028
		Order No:	
		Client Reference:	C04096400
		Submitted By:	Mr Peter Callander

Sample Type: Aqueous

Sample Name:		M36/7711 27-May-2022 10:30 am	**Guideline Value**	**Maximum Acceptable Values (MAV)**
Lab Number:		3000105.1		
Individual Tests				
Total Nitrogen	g/m^3	4.6	-	-
Total Ammoniacal-N	g/m^3	< 0.010	< 1.2	-
Nitrite-N	g/m^3	< 0.002	-	0.06 0.91 (short term)
Nitrate-N + Nitrite-N	g/m^3	4.6	-	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	< 0.10	-	-
Routine Water + E.coli profile Kit				
Escherichia coli	MPN / 100mL	< 1	-	< 1
Routine Water Profile				
Turbidity	NTU	1.15	< 2.5	-
pH	pH Units	7.8	7.0 - 8.5	-
Total Alkalinity	g/m^3 as $CaCO_3$	43	-	-
Free Carbon Dioxide	g/m^3 at 25°C	1.5	-	-
Total Hardness	g/m^3 as $CaCO_3$	55	< 200	-
Electrical Conductivity (EC)	mS/m	16.1	-	-
Electrical Conductivity (EC)	µS/cm	161	-	-
Approx Total Dissolved Salts	g/m^3	108	< 1000	-
Total Arsenic	g/m^3	< 0.0011	-	0.01
Total Boron	g/m^3	0.021	-	1.4
Total Calcium	g/m^3	16.8	-	-
Total Copper	g/m^3	< 0.00053	< 1	2
Total Iron	g/m^3	0.036	< 0.2	-
Total Lead	g/m^3	< 0.00011	-	0.01
Total Magnesium	g/m^3	3.0	-	-
Total Manganese	g/m^3	0.00107	< 0.04 (Staining) < 0.10 (Taste)	0.4
Total Potassium	g/m^3	0.99	-	-
Total Sodium	g/m^3	9.0	< 200	-
Total Zinc	g/m^3	< 0.0011	< 1.5	-
Chloride	g/m^3	9.8	< 250	-
Nitrate-N	g/m^3	4.8	-	11.3
Sulphate	g/m^3	2.8	< 250	-
Total Coliforms and E.coli				
Total Coliforms	MPN / 100mL	< 1	-	-
Escherichia coli	MPN / 100mL	< 1	-	< 1

Note: The Guideline Values and Maximum Acceptable Values (MAV) are taken from the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)', Ministry of Health. Copies of this publication are available from https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018

The Maximum Acceptable Values (MAVs) have been defined by the Ministry of Health for parameters of health significance and should not be exceeded. The Guideline Values are the limits for aesthetic determinands that, if exceeded, may render the water unattractive to consumers.

Note that the units g/m³ are the same as mg/L and ppm.

Routine Water Assessment for Sample No 3000105.1 - M36/7711 27-May-2022 10:30 am

pH/Alkalinity and Corrosiveness Assessment

The pH of a water sample is a measure of its acidity or basicity. Waters with a low pH can be corrosive and those with a high pH can promote scale formation in pipes and hot water cylinders.
The guideline level for pH in drinking water is 7.0-8.5. Below this range the water will be corrosive and may cause problems with disinfection if such treatment is used.

The alkalinity of a water is a measure of its acid neutralising capacity and is usually related to the concentration of carbonate, bicarbonate and hydroxide. Low alkalinities (25 g/m^3) promote corrosion and high alkalinities can cause problems with scale formation in metal pipes and tanks.

The pH of this water is within the NZ Drinking Water Guidelines, the ideal range being 7.0 to 8.0.
With the pH and alkalinity levels found, it is unlikely this water will be corrosive towards metal piping and fixtures.

Hardness/Total Dissolved Salts Assessment

The water contains a low amount of dissolved solids and would be regarded as being slightly hard.

Nitrate Assessment

Nitrate-nitrogen at elevated levels is considered undesirable in natural waters as this element can cause a health disorder called methaemaglobinaemia. Very young infants (less than six months old) are especially vulnerable. The Drinking-water Standards for New Zealand 2005 (Revised 2018) suggests a maximum permissible level of 11.3 g/m^3 as Nitrate-nitrogen (50 g/m^3 as Nitrate).

Nitrate-nitrogen was detected in this water but at such a low level to not be of concern.

Boron Assessment

Boron may be present in natural waters and if present at high concentrations can be toxic to plants.
Boron was found at a low level in this water but would not give any cause for concern.

Metals Assessment

Iron and manganese are two problem elements that commonly occur in natural waters. These elements may cause unsightly stains and produce a brown/black precipitate. Iron is not toxic but manganese, at concentrations above 0.5 g/m^3, may adversely affect health. At concentrations below this it may cause stains on clothing and sanitary ware.

Iron was found in this water at a low level.
Manganese was found in this water at a low level.
Treatment to remove iron and/or manganese should not be necessary.

Bacteriological Tests

The NZ Drinking Water Standards state that there should be no Escherichia coli (E coli) in water used for human consumption. The presence of these organisms would indicate that other pathogens of faecal origin may be present.
Results obtained for Total Coliforms are only significant if the sample has not also been tested for E coli.

Escherichia coli was not detected in this sample.

Final Assessment

All parameters tested for meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 23rd ed. 2017.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	1 µS/cm	1
Approx Total Dissolved Salts	Calculation: from Electrical Conductivity.	2 g/m^3	1
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1
Total Boron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0053 g/m^3	1
Total Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1
Total Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Manganese	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1
Total Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1
Chloride	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3. In-house calculation.	0.05 g/m^3	1
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Nitrate-N	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1
Routine Water Profile		-	1
Total Coliforms and E.coli			
Total Coliforms	MPN count using Colilert 18 (Incubated at 35°C for 18 hours) and 51 wells. Analysed at Hill Laboratories - Microbiology; 101c Waterloo Road, Hornby, Christchurch. APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1
Escherichia coli	MPN count using Colilert 18 (Incubated at 35°C for 18 hours) and 51 wells. Analysed at Hill Laboratories - Microbiology; 101c Waterloo Road, Hornby, Christchurch. APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 27-May-2022 and 02-Jun-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Martin Cowell - BSc
Client Services Manager - Environmental

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T **0508 HILL LAB** (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

DWAPv1

Client:	Pattle Delamore Partners Limited	**Lab No:**	3007066
Contact:	Mr Peter Callander C/- Pattle Delamore Partners Limited PO Box 389 Christchurch 8140	**Date Received:**	03-Jun-2022
		Date Reported:	13-Jun-2022
		Quote No:	118028
		Order No:	
		Client Reference:	C04096400
		Submitted By:	Mr Peter Callander

Sample Type: Aqueous

	Sample Name:	M36/5785 03-Jun-2022 3:08 pm	**Guideline Value**	**Maximum Acceptable Values (MAV)**
	Lab Number:	3007066.1		
Individual Tests				
Total Nitrogen	g/m^3	7.8	-	-
Total Ammoniacal-N	g/m^3	< 0.010	< 1.2	-
Nitrite-N	g/m^3	< 0.002	-	0.06 0.91 (short term)
Nitrate-N + Nitrite-N	g/m^3	7.7	-	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	< 0.10	-	-
Routine Water + E.coli profile Kit				
Escherichia coli	MPN / 100mL	< 1	-	< 1
Routine Water Profile				
Turbidity	NTU	0.84	< 2.5	-
pH	pH Units	7.6	7.0 - 8.5	-
Total Alkalinity	g/m^3 as $CaCO_3$	38	-	-
Free Carbon Dioxide	g/m^3 at 25°C	1.8	-	-
Total Hardness	g/m^3 as $CaCO_3$	57	< 200	-
Electrical Conductivity (EC)	mS/m	18.5	-	-
Electrical Conductivity (EC)	µS/cm	185	-	-
Approx Total Dissolved Salts	g/m^3	124	< 1000	-
Total Arsenic	g/m^3	< 0.0011	-	0.01
Total Boron	g/m^3	0.0181	-	1.4
Total Calcium	g/m^3	14.6	-	-
Total Copper	g/m^3	< 0.00053	< 1	2
Total Iron	g/m^3	0.027	< 0.2	-
Total Lead	g/m^3	< 0.00011	-	0.01
Total Magnesium	g/m^3	4.9	-	-
Total Manganese	g/m^3	< 0.00053	< 0.04 (Staining) < 0.10 (Taste)	0.4
Total Potassium	g/m^3	1.21	-	-
Total Sodium	g/m^3	10.4	< 200	-
Total Zinc	g/m^3	< 0.0011	< 1.5	-
Chloride	g/m^3	11.2	< 250	-
Nitrate-N	g/m^3	7.5	-	11.3
Sulphate	g/m^3	3.2	< 250	-
Total Coliforms and E.coli				
Total Coliforms	MPN / 100mL	9	-	-
Escherichia coli	MPN / 100mL	< 1	-	< 1

Note: The Guideline Values and Maximum Acceptable Values (MAV) are taken from the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)', Ministry of Health. Copies of this publication are available from https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018

The Maximum Acceptable Values (MAVs) have been defined by the Ministry of Health for parameters of health significance and should not be exceeded. The Guideline Values are the limits for aesthetic determinands that, if exceeded, may render the water unattractive to consumers.

Note that the units g/m³ are the same as mg/L and ppm.

Routine Water Assessment for Sample No 3007066.1 - M36/5785 03-Jun-2022 3:08 pm

pH/Alkalinity and Corrosiveness Assessment

The pH of a water sample is a measure of its acidity or basicity. Waters with a low pH can be corrosive and those with a high pH can promote scale formation in pipes and hot water cylinders.
The guideline level for pH in drinking water is 7.0-8.5. Below this range the water will be corrosive and may cause problems with disinfection if such treatment is used.

The alkalinity of a water is a measure of its acid neutralising capacity and is usually related to the concentration of carbonate, bicarbonate and hydroxide. Low alkalinities (25 g/m^3) promote corrosion and high alkalinities can cause problems with scale formation in metal pipes and tanks.

The pH of this water is within the NZ Drinking Water Guidelines, the ideal range being 7.0 to 8.0.
With the pH and alkalinity levels found, it is unlikely this water will be corrosive towards metal piping and fixtures.

Hardness/Total Dissolved Salts Assessment

The water contains a low amount of dissolved solids and would be regarded as being slightly hard.

Nitrate Assessment

Nitrate-nitrogen at elevated levels is considered undesirable in natural waters as this element can cause a health disorder called methaemaglobinaemia. Very young infants (less than six months old) are especially vulnerable. The Drinking-water Standards for New Zealand 2005 (Revised 2018) suggests a maximum permissible level of 11.3 g/m^3 as Nitrate-nitrogen (50 g/m^3 as Nitrate).

Nitrate-nitrogen was detected at a moderate level.

Boron Assessment

Boron may be present in natural waters and if present at high concentrations can be toxic to plants.
Boron was found at a low level in this water but would not give any cause for concern.

Metals Assessment

Iron and manganese are two problem elements that commonly occur in natural waters. These elements may cause unsightly stains and produce a brown/black precipitate. Iron is not toxic but manganese, at concentrations above 0.5 g/m^3, may adversely affect health. At concentrations below this it may cause stains on clothing and sanitary ware.

Iron was found in this water at a low level.
Manganese was not detected in the water.
Treatment to remove iron and/or manganese should not be necessary.

Bacteriological Tests

The NZ Drinking Water Standards state that there should be no Escherichia coli (E coli) in water used for human consumption. The presence of these organisms would indicate that other pathogens of faecal origin may be present.
Results obtained for Total Coliforms are only significant if the sample has not also been tested for E coli.

Escherichia coli was not detected in this sample.

Final Assessment

All parameters tested for meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch.	-	1
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1
Turbidity	Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1
pH	pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 23rd ed. 2017.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	1 µS/cm	1
Approx Total Dissolved Salts	Calculation: from Electrical Conductivity.	2 g/m^3	1
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1
Total Boron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0053 g/m^3	1
Total Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1
Total Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Manganese	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1
Total Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1
Chloride	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3. In-house calculation.	0.05 g/m^3	1
Total Ammoniacal-N	Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1
Nitrite-N	Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Nitrate-N	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m^3	1
Nitrate-N + Nitrite-N	Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1
Sulphate	Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1
Routine Water Profile		-	1
Total Coliforms and E.coli			
Total Coliforms	MPN count using Colilert 18 (Incubated at 35°C for 18 hours) and 97 wells. Analysed at Hill Laboratories - Microbiology; 101c Waterloo Road, Hornby, Christchurch. APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1
Escherichia coli	MPN count using Colilert 18 (Incubated at 35°C for 18 hours) and 97 wells. Analysed at Hill Laboratories - Microbiology; 101c Waterloo Road, Hornby, Christchurch. APHA 9223 B 23rd ed. 2017.	1 MPN / 100mL	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 04-Jun-2022 and 13-Jun-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

K Harrison

Kim Harrison MSc
Client Services Manager - Environmental