BEFORE A COMMISSIONER APPOINTED BY THE OTAGO REGIONAL COUNCIL AND THE CENTRAL OTAGO DISTRICT COUNCIL

IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	applications by Cromwell Certified Concrete Limited for resource consents to expand Amisfield Quarry

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STATEMENT OF EVIDENCE OF MICHAEL CONRAD FREEMAN ON BEHALF OF CROMWELL CERTIFIED CONCRETE LIMITED

(GROUNDWATER)

Dated:30 November 2021

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INTRODUCTION

1 My name is Michael Conrad Freeman. I am a Senior Scientist/Planner with Landpro Limited and have been employed in that role since 2018. I hold the qualifications of BSc Environmental Sciences from the University of Warwick and a PhD in water quality from Massey University. I am a member of the Environmental Institute of Australia and New Zealand, and an Associate Member of the New Zealand Planning Institute. I have over 30 years of experience as an environmental scientist and planner specialising in water resources, particularly groundwater and surface water quality.

2 Before working at Landpro, I worked in a range of roles relating to the investigation, monitoring and management of groundwater resources. I worked as a groundwater water quality scientist for Environment Canterbury in the 1980s and 1990s and was directly involved or supervised numerous investigations of groundwater resources in Canterbury. I also worked as a senior science manager at Environment Canterbury. I worked at AgResearch as a Soil and Water Impact leader and I have worked at various consultancies as an environmental scientist and planner.

3 My role at Landpro involves working on a wide range of groundwater resource issues including assessments of groundwater quality and quantity within Otago, and elsewhere in New Zealand. These include assessing the effects of land use activities on groundwater and the interaction between groundwater and surface waterways. I have extensive experience in Canterbury, Southland and Otago in assessing the effects of groundwater abstraction and discharges on water quantity and quality.

4 I have been involved in many similar proposals to abstract water and to discharge contaminants in Southland, Otago and Canterbury. I have appeared as an expert witness at council and Environment Court hearings since 1986. I have also been involved in a range of council and Environment Court expert witness conferencing.

Involvement in the Proposal

5 I was engaged by Cromwell Certified Concrete Limited to provide advice concerning groundwater matters arising from the proposed expansion of Amisfield Quarry. I prepared the report titled *Assessment of the Effects of Increased Water Take at Amisfield Quarry* dated 19 October 2020, which forms part of the AEE lodged with the applications for resource consents. I also drafted the Section 92 response to the Otago Regional Council signed by myself and Matt Curran dated 1 December 2020. Since then, I have undertaken some further work including writing the report provided to the Councils on 10/11 November 2021.

6 I have inspected the site and the surrounding area, and I am familiar with the area and the hydrogeological setting.

Code of Conduct

7 Whilst this is a Council hearing, I acknowledge that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses, contained in the Environment Court Practice Note 2014. My qualifications as an expert are set out above. Other than where I state that I am relying on the advice of another person, I confirm that the issues addressed in this statement of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF EVIDENCE

8 The purpose of my evidence is to describe the groundwater setting of the proposal and my assessment of the potential effects of the proposal on groundwater and surface water.

9 Specifically, my evidence addresses:

(a) The hydrogeological and hydrological setting of the area around the Amisfield Quarry;

(b) Current quarry operations, as they relate to groundwater;

(c) The quarry expansion proposal, as it relates to groundwater;

(d) The effects of the expansion proposal on groundwater (including nearby local bores) from:

(i) Deepening of the existing quarry;

(ii) Increase in water take from the existing bores;

(iii) Discharge of contaminants from gravel washing to land;

(e) Sections 105 and 107 of the Resource Management Act 1991 (RMA) and specific provisions of the Otago Regional Plan: Water for Otago (RPW), particularly Schedule 5B and Policy 6.4.10B;

(f) Submissions on the expansion proposal which relate to effects on water quality or quantity;

(g) The s42A report(s) and earlier reports prepared by Otago Regional Council (ORC) officers and consultants; and

(h) Consent conditions.

EXPERT WITNESS CONFERENCING

10 On Thursday 25 November, Ms Alexandra Badenhop and I visited the site and met to discuss technical issues relating to groundwater hydrogeology and water quality. A Joint Witness Statement (JWS) is being finalised and will be made available as soon as possible. This evidence takes those discussions into account.

SUMMARY

11 I provide background information on the hydrogeological and hydrological setting that is important to understand the potential significance of both the proposed increased abstraction and the potential effects of the proposal on water quality.

12 My evidence addresses the key potential adverse effects on groundwater levels in bores near the two bores where an increase in abstraction is proposed. While the S42A planning reporting officer, Mr Whyte, considers that the drawdown guideline specified in Schedule 5B of the RPW should be used as a threshold to determine adverse effects, I do not consider that this approach is consistent with either the RPW or the RMA. My assessment considers effects in the context

of the groundwater that would otherwise be available to nearby groundwater users. This assessment concludes that nearby groundwater users have a column of groundwater available to them of approximately 10 m and that the combined effect of the proposed increased abstraction together with the effects of other nearby groundwater abstractions would reduce groundwater levels by less than 1 m. The bores in this location have submersible pumps at the base of bores with 1 to 3 m screens. There would still be a column of water of at least 9 m above the bottom of these bores available for pumping. Therefore, it is virtually certain that the proposed increase in water abstractions would not have a significant adverse effect on existing water users.

13 I have assessed the potential for adverse effects on the Amisfield Burn (main branch and the northern tributary) flows and Lake Dunstan levels. Because the groundwater levels near the abstraction bores are approximately 10 m lower than the height of the bed of the Amisfield Burn (closest main branch) it is very unlikely that there could be a stream depletion effect.

14 I have assessed the potential for the expanded quarrying activities to adversely affect water quality. The combination of the type of contaminants generated by aggregate quarrying activities (silt and sediment), the location in alluvium material that provides a filtration system that effectively removes silt and sediment, and the distances between the quarry activities and neighbouring bores, enables me to conclude that the proposed activities are very unlikely to have an adverse effect on the quality of groundwater abstracted by any neighbour. Monitoring of groundwater quality is proposed and would detect such effects.

15 The annual amount of water applied for is well within the allocation guidelines identified by ORC staff for this groundwater zone.

HYDROGEOLOGICAL AND HYDROLOGICAL SETTING

16 The application site is located in an area known as Mt Pisa. It is located on the lower slopes of terraces that drop down from the Lowburn face of the Pisa Range in the west.

Hydrology – surface water

17 The nearest surface water bodies to the quarry site are a tributary of the Amisfield Burn which was diverted around the site when the quarry was first established, and the main stem of the Amisfield Burn.

18 The existing quarry takes water from two bores. Bore G41/0127 is approximately 55m from the closest part of Amisfield Burn and bore G41/0456 is approximately 230 m from this tributary. Lake Dunstan is located approximately 825 m south-east of those bores.

19 According to the RPW (Schedule 1AA), the Amisfield Burn is known to provide habitat for Koaro, which is identified as having a threat status of 'declining'[1]. Other specific values identified in RWP Schedule 1AA are "Weedfree, Rarefish".

20 The locations of fish species recorded in the last forty years[2] are shown in the following figure.

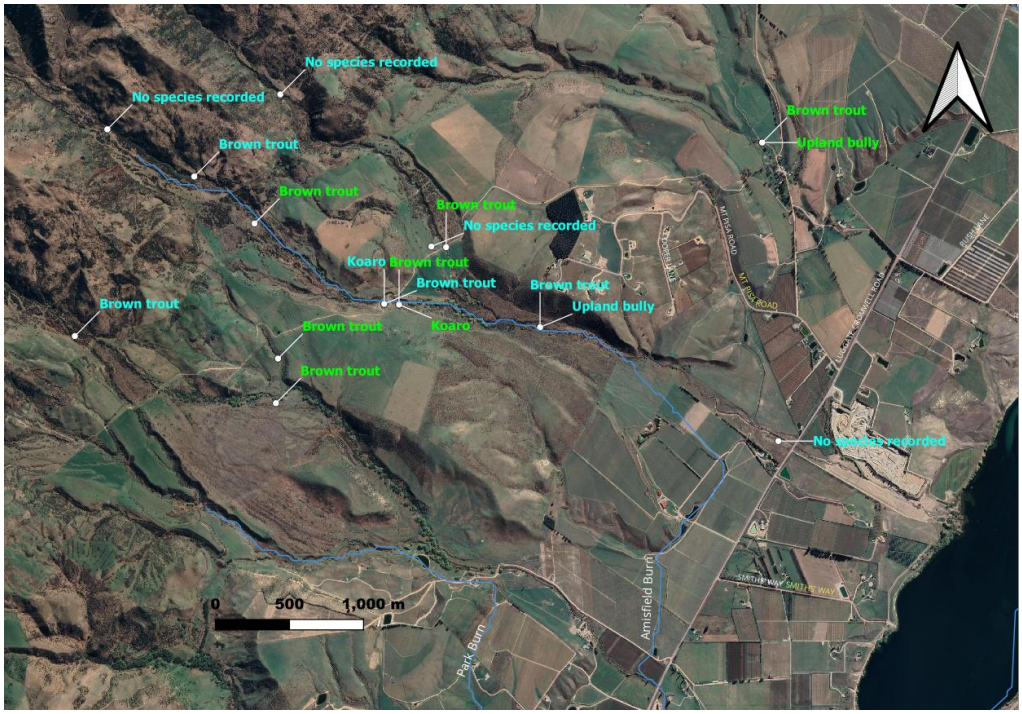

Figure 1 Location of fish species recorded in the catchment (Blue = 2000-2021, Green =1980-2000)

[1] https://www.doc.govt.nz/Documents/science-and-technical/nztcs24entire.pdf
[2] NIWA New Zealand freshwater fish database - https://nzffdms.niwa.co.nz/

Hydrogeology

21 Groundwater in this area has generally been found at adequate yields for irrigation from bores between 30 - 40 m below the natural ground surface with yields and aquifer permeability improving with proximity to Lake Dunstan. The reduction in aquifer permeability away from the lake/former river location is reflected in the very small number of bores west of the state highway.

22 Given the nature of the alluvial deposits in this area and glaciation periods, I am very confident that it is highly unlikely that there are any really extensive separate aquifer layers, i.e., the groundwater is virtually certain to be unconfined(i.e., the groundwater is in contact with the atmosphere and able to rise and fall and be recharged directly by rainfall percolating down into groundwater, in contrast, confined groundwater is overlain with an impermeable layer that restricts direct downward recharge and movement of groundwater upwards and contaminants downwards). There appears to be general agreement[3] between myself and Ms Badenhop, the hydrogeologist S42A reporting officer, that underlying saturated groundwater near the two abstraction bores is between 10 – 15 m thick(i.e., the depth of saturated groundwater, or the height of the column of groundwater from its base to the top of the groundwater is at least 10m).

23 No piezometric contours have been mapped by the ORC in this area. However, topography and rainfall strongly indicate that groundwater flow generally follows the overall topography[4] towards the lake in a south-easterly direction. This is supported by recent surveyed water level measurements (Landpro Surveyor, Geoff Thomas) undertaken for groundwater in bore G41/0456 (within the quarry site) and Lake Dunstan water level at the lake edge by the outlet of the Amisfield Burn on 27 July 2021. That survey[5] showed a 0.91 m drop (194.95 m to 194.04 m RL Dunedin Vertical Datum 1958) over the approximate 825 m from the bore to the lake edge.

24 The approximate direction of groundwater relative to bore locations, topography and Lake Dunstan is illustrated in the following figure.

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3 e3 Scientific, Groundwater Take Effects Assessment Review, 11 November 2020.
4 Freeze, RA, and J.A Cherry, 1979, Ground Water: Prentice-Hall.
5 Original survey data has been provided to Ms Badenhop.

Figure 2: Location of bores and approximate direction of groundwater flow

25 The two groundwater bores within the existing quarry are located approximately 190 m apart. The bores are approximately 25 – 30 m deep and are screened at the base within gravel or sandy gravel strata. Static water levels within those bores have been recorded at around 13.8 m (G41/0127, when drilled in 1995) and 7.1 m (G41/0456, when drilled in 2015) below actual ground level.

26 Hydrogeological characteristics are important aspects of assessing the potential effects of increasing the quantity of increased abstraction. Two key characteristics of an aquifer that are used in modelling effects on other groundwater users and surface water are:

(a) The transmissivity (T, the ease with which water moves through an aquifer); and

(b) The specific yield or storativity (S, the amount of water released from an aquifer when the water level drops).

27 The original (2016) eight-hour pump test indicated a transmissivity of 1,100 m^2/day. This was accepted for the previous water permit application.

28 The ORC has a form (Form 5) that has no status in the RPW, which indicates that water permit applicants should undertake a 48-hour constant rate test and a step drawdown test. The applicant was requested by the ORC to undertake those tests because they are specified in Form 5. However, I do not consider the additional aquifer testing to be essential because: aquifer characteristics had been previously accepted, (there are no established aquifer testing procedures in Otago we rely on guidelines from other regions), and we have aquifer tests from other locations in the wider area. However, I accept that a longer duration aquifer test is generally preferable because it would draw water in from further away from the test bore and could result in higher or lower estimates of aquifer variables. However, I note that the original bore log shows that drawdown had 'flatlined' after five minutes of pumping and had not changed after one hour of pumping. This is most likely the reason that pumping was not continued for 48 hours. Therefore, even if the pumping had continued for the full 48 hours it appears very likely that the groundwater level would not have changed and therefore the original T and S estimates are robust.

29 I have reviewed all the information available to summarise accepted aquifer characteristics in the wider area. Refer Figure 1 in Appendix C to this evidence. This information together with the original review undertaken by PDP strongly supports a conclusion that the transmissivity value of 1,100 m^2/day used in the original application is appropriately conservative. The information from other aquifer tests in the area indicates higher transmissivity which would decrease any potential estimated drawdowns. Later in my evidence, I report on modelling using a range of T and S values to take account of the uncertainties in estimating appropriate values to use.

EXISTING OPERATION

30 At present, the quarry is consented to excavate to a maximum depth of 15 m below ground level. This would allow for excavation of approximately 8 m of gravels in saturated groundwater. Data from the monitoring of groundwater levels in Smiths Way (bore G41/0486) (a range of ~1.2 m) and the controlled range of the levels of Lake Dunstan (1 m) strongly indicate that groundwater levels in the location of the Amisfield Quarry will fluctuate in response to these processes across a similar range, i.e., approximately one metre.

31 The current take and use of water at the quarry are authorised by Otago Regional Council (ORC) water permit RM16.108.01[6] which was granted in 2016 and provides for a take of up to 46 L/s from two bores on the site (G41/0127 and G41/0456) for gravel washing and dust suppression.

32 According to ORC bore data (referenced in my earlier technical report and in the AEE), since RM16.108.01 was granted in 2016, an additional bore (G41/0238) was consented on a property immediately to the north of the quarry, owned by Manukau Fifty Ltd[7]. According to ORC records, that bore is 44.87m deep, and at the time of drilling had a depth to groundwater of 23.5m. It is closer (230 metres) to G41/0456 than the neighbouring bores to the northwest of the property (G41/0220[8] and G41/0321[9]).

33 After the applications were lodged, Amisfield Estate Society Incorporated (AES) contacted the Otago Regional Council to say that it takes water from a bore located at 1180 Luggate-Cromwell Road, bore G41/0005. The Council's GIS database records the bore as owned by the NZ Geological Survey and as being abandoned. The Society's submission states that the bore is located within 200m of the water take that is the subject of the applications. My understanding is that there has been some confusion about bore numbering and the location of the bore that AES takes water from as the bore is located where the ORC database now has assigned bore number G41/0111. The ORC GIS database shows that the distance between the closest Amisfield bore (G41/0127) and G41/0111 is approximately 462 m as shown below.

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6 A copy of RM16.108.01 was included in Appendix A to my technical report and is also attached as Appendix A to my evidence.
7 A submitter on this proposal.
8 ORC database: Water permit 2010.152.V1 held by Wanaka Road Wine Holdings Limited.
9 ORC database: Water permit RM14.211.02 held by Irrigation & Maintenance Limited.

Figure 3 Location diagram showing the distance between some bores

34 Figures 2,3 & 3a shows bores G41/0127 and G41/0456 on the quarry site, as well as the locations of bores in the immediate area according to current ORC records[10].

35 Water from gravel washing on the site is discharged to land around the washing equipment; water is then directed to the first settlement pond and then via overflow to the second settlement pond. This is authorised by RM16.108.02 and is attached to my evidence as Appendix A. A recent aerial photo of the settling ponds and nearby bores is shown in the following figure.

10 Bore G41/0101 (on the southern boundary of the quarry site) is shown in the ORC's GIS system but I understand that bore was never drilled, and I could not locate it on the site. ORC has been requested to remove the bore from its database or update its information to show that the bore was not drilled. As at November, 2021 the ORC GIS database shows the bore as proposed.

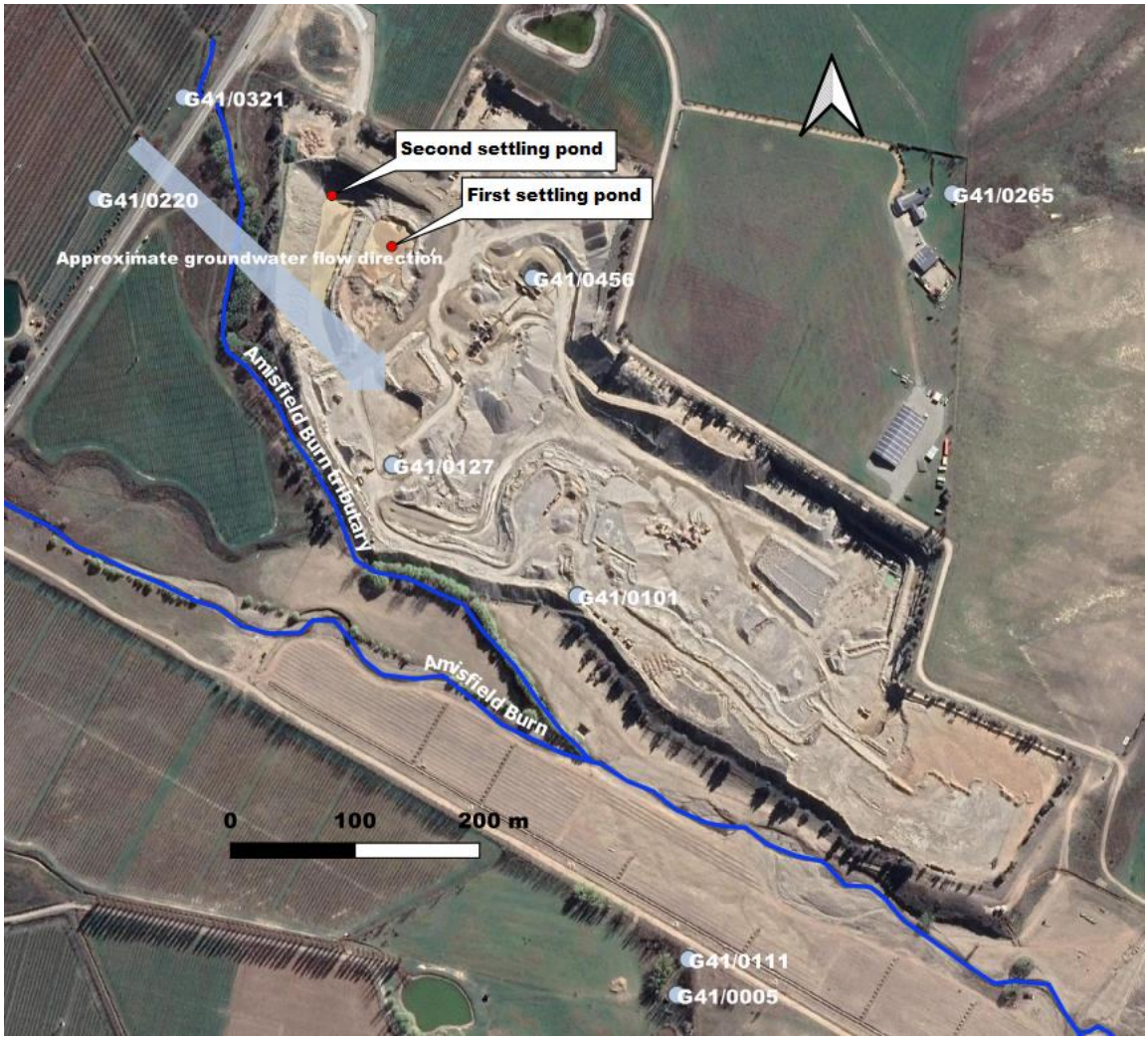

Figure 4: Amisfield quarry showing the location of the settling ponds

36 The following photos show the layout of the two settling ponds and main plant. Water is collected in a sump and discharged via a pipe to the primary settling pond before flowing over and down to the main settling pond.

Figure 4a: Photos of the settling ponds, 25 November 2021

Figure 4b: Photos of the washing area and pipe to settling ponds

37 Both of the current regional resource consents were granted on 20 July 2016 and expire on 21 July 2036.

38 Fuel storage, re-fuelling and spill control procedures are described in the evidence of the quarry manager, Mr Travis Allison.

THE PROPOSAL

39 It is proposed to deepen the existing quarry to the maximum depth of the aggregate resource, which is estimated to extend up to 30 m below ground level. Given the proposed increase in the depth of excavation, it is certain that groundwater will be intercepted. Where groundwater is intercepted, a mobile dragline machine or similar methods will be used to excavate gravel.

40 Where groundwater is exposed, the quarry operation would provide for some backfilling with surplus gravel material generated on-site. My understanding is that clean-filling into groundwater is not proposed.

41 To enable the increased rate of production, it is proposed to increase the total amount of water taken to a maximum instantaneous take of 70 L/s with a maximum daily take of 3,024 m^3/day (i.e., 70 L/s for up to 12 hrs per day, equivalent to a daily average of 35 L/s) and an annual maximum take of 846,720 m^3 (i.e., up to 280 days per year). As lodged, the applications sought to enable 70 l/s to be taken from either bore. However, it is now proposed that the maximum rate of abstraction from bore G41/0127 be limited to 25 l/s, and 45 l/s from bore G41/0456. This refinement reflects

the actual proposed operation and reduces potential drawdown effects on nearby bores, as I discuss in my evidence.

42 A comparison of the existing (consented) and proposed rates of take is set out in Table 1 below.

Table 1 current and proposed groundwater take limits

	Current water take limits	Proposed water take limits
Instantaneous rate (L/s)	46	70
Daily rate (m^3/day)	1620	3,024
Monthly rate (m^3/month)	50,220	93,744
Annual rate (m^3/year)	453600	846,720

43 A portion of the water to be taken will be used for potable use, dust suppression and irrigation. These uses are generally considered to be consumptive as the water will be taken up by plants or evaporated, and therefore will not be returned to the source aquifer. A small proportion of the irrigation water will be returned to groundwater. This is generally accepted as being between 10 and 20% depending on the 'efficiency' of the irrigation system. However, I have assumed that none of the irrigation water returns to groundwater, i.e., I have over-estimated the actual effects on groundwater levels.

44 The vast majority of the water to be abstracted will be used for aggregate washing and will be returned to the aquifer via soakage, particularly at the soakage pond. The proportion of water that is used for washing purposes can be considered largely non-consumptive (see Table 2 below). As described in the evidence of Mr Allison, the washing plant has been fitted with fixed sprinklers which limit water flow to ensure the amount of water used is controlled and restricted to only that necessary.

45 In consultation with Mr Allison, an estimate of the breakdown of water use has been undertaken and is outlined in the following table.

Table 2: Estimated distribution of proposed water take

	Volume (m^3)/day	Percentage of total
Crushing Plant	2,768	91.5%
Water Cart	240 (20 m^3 x 12 times/day)	8%
Irrigation	15	0.5%
Potable Use/Washdown	1 (rounding up)	Negligible

TOTAL:	3,024	100

46 Water from gravel washing will continue to be discharged to the settlement pond but in increased quantities, given the increased volume of water to be abstracted.

AQUIFER CHARACTERISTICS

47 As part of the expert witness conferencing it was agreed that there would be benefit in taking more explicit account of the uncertainties in estimating aquifer characteristics by using a range of transmissivity and specific yield values. Therefore, the following values have been used to assess the potential implications of uncertainties.

Transmissivity: accepted value 1,100 m^2/day, range 300 – 1,500 m^2/day
Storativity: accepted value 0.1, range 0.02 – 0.15

48 These ranges are based on reported values and on modelling undertaken by Ms Badenhof.

EFFECTS

Deepening of the existing quarry

49 Deepening a quarry into groundwater increases the vulnerability of that groundwater to contamination (for example, from hydrocarbons if a fuel line were to rupture, and from unauthorised dumping). However, appropriate precautions and limited site access will reduce those risks to being negligible. There are only a small number of immediately downgradient bores and the overall risks of contaminating groundwater in those bores or Lake Dunstan would be negligible.

50 I understand that normal good management precautions will be taken with all site machinery and refuelling, including restricting refuelling to only occurring at locations on natural ground level, to minimise the potential for petroleum compounds to enter groundwater. The site is securely locked when it is not operating and therefore unauthorised dumping would be highly unlikely.

Increase in water take from existing bores

51 The effects of the existing quantity of water abstraction were assessed and considered to be acceptable when the current water permit was granted in

2016. Stream depletion and bore interference effects were considered when that application was granted, as well as aquifer allocation. Since then the new take from the bore owned by Manukau Fifty has been established. The water permit associated with that bore authorises: up to 78 cubic metres per day of groundwater at a rate of up to 9 litres per second for irrigation, and up to 1440 cubic metres per day at a rate of up to 16.7 litres per second for irrigation and frost fighting of on the 6.5 hectares of vineyard.

Potential adverse effects of the proposed take on the Amisfield Burn

52 The potential stream depletion effects of RM16.108.01 on the Amisfield Burn were considered to be insignificant. This was because of the significant unsaturated gravel separation between the level of the stream and the underlying saturated groundwater.

53 Ms Badenhop's review of my original assessment did not dispute the conclusions that in the vicinity of the abstraction there is a significant unsaturated gap between the bores and the Amisfield Burn (northern branch) i.e., no ability for the abstraction to affect overlying flows. However, her review suggested that it may be possible as the height of the stream drops as it gets closer to the lake that at some point along there that the increased abstraction could have an effect on stream flows.

54 Ms Badenhop and I appear to agree that a distinction needs to be made between the northern branch of the Amisfield Burn and the main branch. Given the height of the northern branch, it appears that concerns about stream depletion will apply only to the main branch of the Amisfield Burn, including after its confluence with the north branch.

55 The abstractions could influence stream flows if there is a physical connection between groundwater and the flows in the stream. The ready movement of water from Lake Dunstan into the permeable alluvial material means that closer to the lake the more there is an opportunity for input from the lake to be the dominant factor affecting groundwater surface water interactions.

56 As part of the previous application, it was agreed that the vertical distance between the Amisfield Burn and the underlying groundwater surface is approximately 20 metres. However, during the expert witness joint site visit on 25 November it was agreed that while there is clearly a significant vertical separation between the bed of the northern branch of the Amisfield Burn that runs alongside the north west boundary of the quarry; the main branch

downstream from the State Highway is lower. As a consequence, the bed of the main branch in this area was surveyed on Friday 26 November 2021 in various publicly accessible locations to better understand the extent of separation between the stream and the underlying groundwater.

57 I received the results of the survey data on Sunday 28 November and have provided that data to Ms Badenhop. The following figure is taken directly from the Excel survey report.

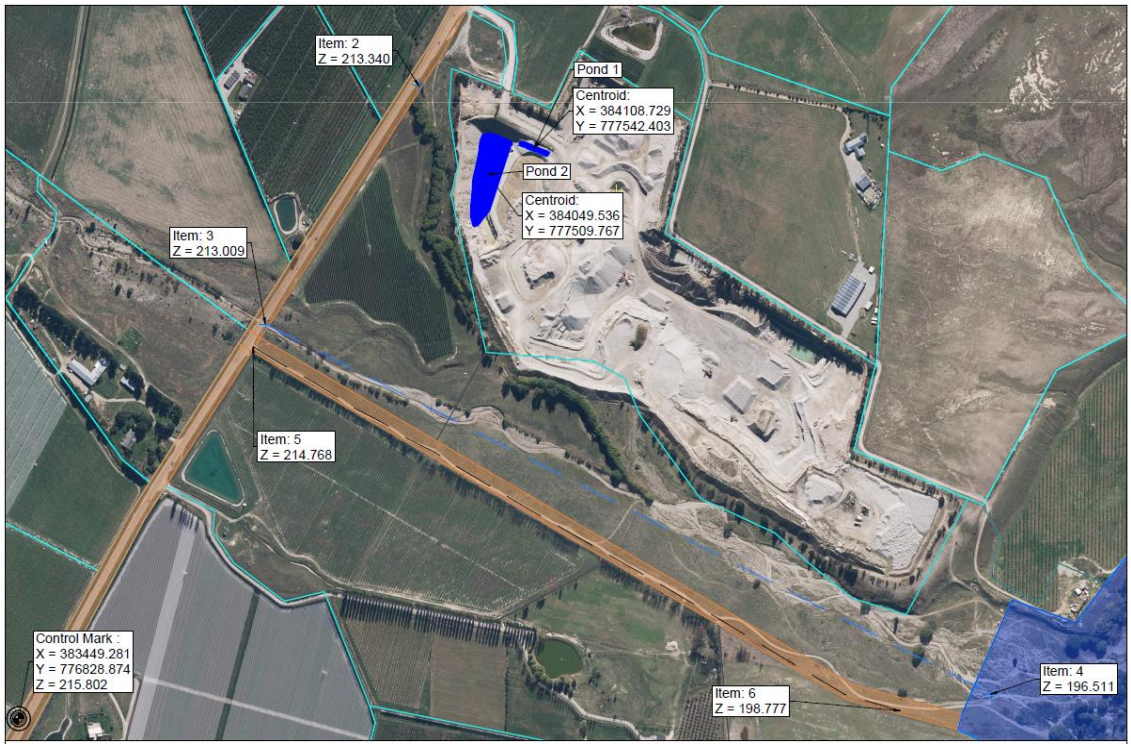

Figure 4c: Summary of survey information of levels of main branch of the Amisfield Burn and settling ponds[11].

58 The survey shows that the bed level of the Amisfield Burn at the SH is 213.009 m and over a distance of approximately 1,000 m drops to 196.511 m approximately 200 m from the edge of Lake Dunstan. Points in between were on private land and were not surveyed. The public road was surveyed as a comparison to identify the extent to which there is a steady gradient over the distance. It appears to be a reasonably consistent gradient along the full distance.

59 At 500 m along that distance or approximately at the location of the confluence of both branches the height of the bed is approximately 205.7 m. The surveyed height of groundwater in bore G41/0456 in July 2021 was 194.95. Remembering that information from the Smiths Way monitoring bore

11 All survey information is relative to Dunedin Vertical Datum 1958.

and Lake Dunstan indicate that background groundwater levels in this area are likely to fluctuate by about 1 m.

60 Therefore, the survey information strongly indicates that there was be a gap of approximately 10 m between the height of groundwater at bore G41/0456 and the bed of this branch of the Amisfield Burn at its closest point to the bore. The gap will decrease as the creek gets closer to the lake but even at the point marked on the above figure close to the lake at 196.511 m where it is possible that groundwater could fluctuate up and interact with the stream bed the distance is over 750 m from bore G41/0456 and the groundwater at that location will be dominated by the influence of Lake Dunstan meaning that it is highly likely that there would be no stream depletion effect.

61 Similarly, the north branch of the Amisfield Burn will be significantly higher than groundwater levels in the pumping bores and would not be subject to a stream depletion effect.

Potential effects on Lake Dunstan

62 Schedule 5A of RPW is specified in Policy 6.4.1A of RPW as a tool for use in allocating a take wholly or partly to groundwater or surface water. This schedule is also included in Rule 12.2.3.2A as a condition to be satisfied to qualify as a restricted discretionary activity. Schedule 5A is also listed in the information that should be provided with an application to take groundwater. The key part of Schedule 5A is reproduced below.

> **5A Schedule of equations to determine stream depletion effects of the take of groundwater**
>
> **Requirement to determine stream depletion on surface water**
> The Bekesi and Hodges[1] equations are used to determine whether a proposed groundwater take may have an effect on nearby surface water that is greater than 5 litres per second.
>
> The Bekesi and Hodges equations are preferred to other equations reported in the literature as they are less demanding of hydrogeological data, and allow a reasonable relationship to be calculated empirically, which can be transposed to determine the threshold distance between the point of groundwater take and the surface water body. These equations consider pumping occurs over 30 days, and assumes a 90 percentile confidence. Which equation is used depends on the proposed maximum rate of take (Q in litres per second):
>
> | | |
> |---|---|
> | Where 5 l/s ≤ Q ≤ 25 l/s | $r = 65 \times Q$ |
> | Where Q > 25 l/s | $r = 1138 \times \log Q$ |
>
> r = distance between abstraction structure and surface water body (metres)
>
> If r is greater than the actual distance from the point of groundwater take to the surface water body, then the stream depletion effect is considered to be greater than 5 litres per second. However, there may be exceptions to the empirical relationship (see below).

63 The intent of this Schedule appears in part to be to calculate "r" using the equation "65xQ" and then compare that calculated value with the actual distance. Using the highest value of 6.75 L/s the calculated "r" value is 6.75 x 65 = 439. This is less than the actual 825 m distance. Similarly, with a total amount of 10.5 L/s the "r" value would be 682.5; still significantly less than 825. The intent of this part of the Schedule appears to be primarily a method for assigning allocation to surface water or groundwater. Schedule 5A indicates that the Jenkins equations should be used to estimate the extent of stream depletion.

64 Potential stream depletion effects of the proposed abstractions were calculated using the Hunt (1999)[12] methodology which is widely utilised to estimate stream depletion effects. The Hunt (1999) methodology is a slightly more refined version of the Jenkins method. The variables used in this method are outlined below.

Table 3: Summary of inputs into stream depletion assessment

Parameter	Value	Comment
Transmissivity (m^2/day)	1,100	Accepted value
Specific yield (storativity)	0.1	Accepted value and typical for alluvial sediments[13]
Streambed conductance (m/day)	100	Relatively high value to reflect potentially significant sediment on lake bed.
Pumping rate (L/s)	6.75 or 3.75	Maximum rate.
Pumping duration (days)	280	As detailed in the outline of the proposal.
Separation distance (L1, m)	825	Distance from Lake
Irrigation efficiency (%)	100	Assumes all water taken is used.
Separation distance L2, m)	825	Needed for the Hunt model. Not a relevant factor because 100% efficiency used.

65 The result of these calculations was that the estimated stream/lake depletion effect of the larger of the two proposed abstractions is 5 L/s and for the smaller abstraction, 3 L/s. The mean annual low flow (MALF) of the Clutha River below the confluence with the Cardrona River (upstream of Lake

12 Hunt, B., 1999; Unsteady Stream Depletion from Ground Water Pumping. Ground Water, 37(1), 98–102.

13 Environment Canterbury, 2000; Guidelines for the Assessment of Groundwater Abstraction Effects on Stream Flow. Environment Canterbury Report ROO/11, June 2000.

Dunstan) has been estimated by the ORC as 121.17 m^3/s (over the period March 1988 – January 2007[14]). Therefore, with a total stream depletion effect of 8 L/s or 0.0066% of the MALF, it is clear that the stream (lake) depletion effect is insignificant.

66 If the agreed range of possible transmissivity and specific yield values are used, the estimated stream/lake depletion ranges as follows:

Table 4: Estimated lake depletion effect for a range of aquifer characteristics

Bore G41/0456 6.75L/s		Transmissivity (m^2/day)		
		300	1,100	1,500
Storativity	0.02	5.2	5.9	6.0
	0.1	3.5	4.9	5.2
	0.15	2.9	4.6	4.8

67 Therefore, it is clear that the range of aquifer characteristics has very little effect on the conclusion that the potential adverse effect on Lake Dunstan would be negligible.

Effects of increased groundwater abstraction on existing groundwater users

68 The bores in the immediate area, and their approximate distances to the bores on the application site, are illustrated in Figure 5 below.

[14] https://www.orc.govt.nz/managing-our-environment/water/water-monitoring-and-alerts/upper-clutha/clutha-below-cardrona-river-confluence.

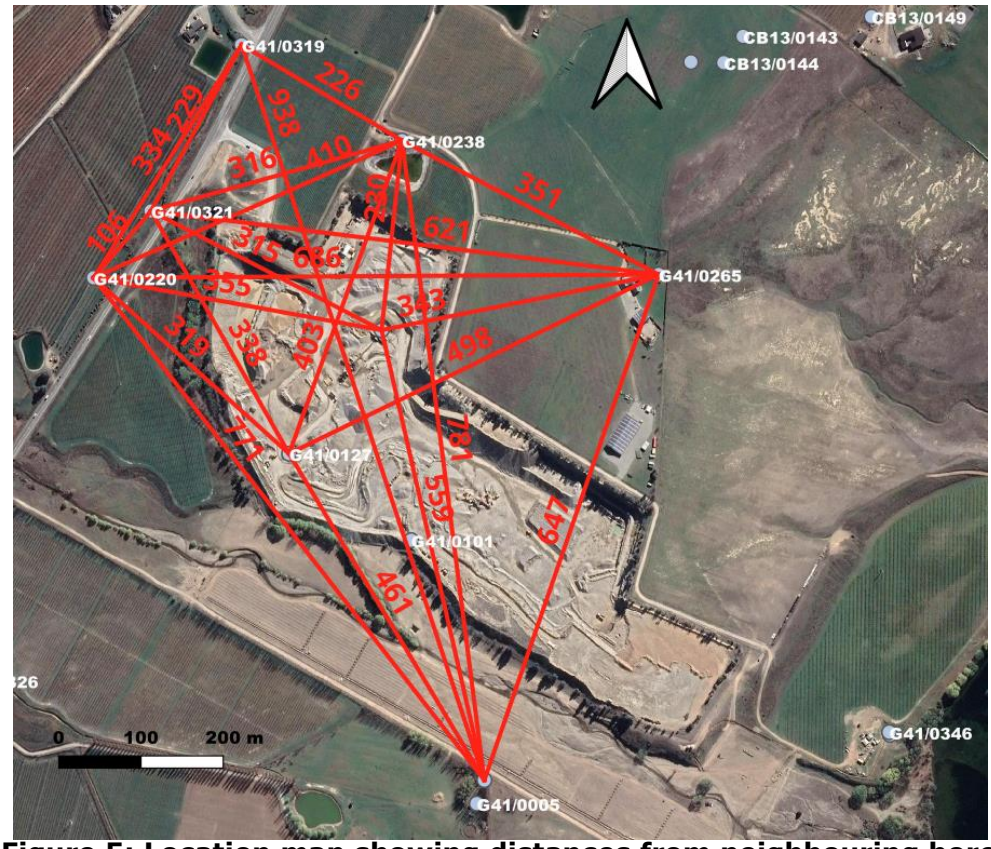

Figure 5: Location map showing distances from neighbouring bores

69 When RM16.108.01 was granted in 2016, the bore interference effects on the closest bores at that time (and of similar depth) (G41/0220 and G41/0321) were estimated to be 0.19 m drawdown, just below the notification interference drawdown threshold of 0.2 m identified in the RPW Schedule 5B.

70 Before undertaking the modelling needed to estimate drawdown effects I think it is important to clarify the context of groundwater drawdown calculations and why I consider that they should be completed within the context of local hydrogeology characteristics and other lawful water takes and the otherwise available groundwater. I do not consider the RPW 'threshold' of 0.2m is an appropriate reference point to assess potential adverse effects (beyond the use as a trigger for identifying persons who may be adversely affected).

The Regional Plan: Water for Otago framework for considering drawdown effects

71 The RPW has one relevant policy that specifically applies to the consideration of effects on existing groundwater abstractions. **Policy 6.4.10B** provides:

"In managing the taking of groundwater, to have regard to avoiding adverse effects on existing groundwater takes, unless the approval of affected persons has been obtained.

Explanation

This policy recognises that the taking of ground water from any aquifer can result in bore interference. Bore interference relates to the temporarily reduced ability of users in a localised area to take water due to the taking of water from another bore reducing the pressure or the level of groundwater. When considering the taking of groundwater, regard will be had to avoiding adverse effects on existing takes. Conditions on a resource consent to take groundwater may include limits on the instantaneous take of groundwater from the bore, in order to maintain existing access to water in neighbouring bores. Schedule 5 identifies formulae that will be applied in order to determine the acceptable level of bore interference.

Principal reasons for adopting

This policy is adopted to maintain, as far as possible, the availability of groundwater at existing bores. This will assist to avoid the potential for conflict among those taking groundwater."

72 The policy is unusual in that it appears to be directing decision-makers to "avoid" adverse effects on existing groundwater takes but the policy is tempered by the direction to "have regard to". There are no rules that provide direction on bore interference effects. The explanation purports to give some status to Schedule 5 formulae to determine "the acceptable level of bore interference".

73 The S42A planning officer appears to consider that Schedule 5B establishes a maximum adverse effect. Schedule 5B is reproduced in part in Appendix D. The purpose of this Schedule is to define the threshold for identification of potentially affected persons for the purpose of notification.

74 The explanation to Policy 6.4.10B refers to Schedule 5 Which is titled "Schedule of limits to instantaneous take of groundwater". Schedule 5B is linked to the RPW provisions in Section 16.3.1 as resource consent information that will be required:

"*5A. In the case of the taking of groundwater, affected parties who are those taking from that aquifer, within a radius r of the proposed pumping bore as specified in Schedule 5B.*

5B. In the case of the taking of groundwater, results of the aquifer test."

75 The current policy provisions do not address the level of adverse effects on existing users which the RPW considers to be acceptable nor do they recognise the complexity of groundwater resources, for example, they do not recognise that the depth of groundwater available (the height of the column of groundwater) can vary significantly from one location to another. More recent regional plans in other regions have responded to the complexity of groundwater management issues and identified both policy and technical guidance that takes this complexity into account (for example, by providing clear levels of protection e.g., 80% of the available drawdown, for bores that fully penetrate an aquifer). The bores in this location appear to fully penetrate the aquifer. However, bore log information quality is extremely variable, which makes it challenging to interpret and compare many bore logs.

76 The current RPW is often misinterpreted to mean that a reduction in groundwater level of 0.2 m in an unconfined aquifer is "acceptable" regardless of the depth of groundwater available in that aquifer. Similarly, this is often misinterpreted as any reduction greater than 0.2 m is not considered to be acceptable. Such interpretations are not consistent with the RPW provisions or the wider RMA planning framework that provides for the consideration of effects on a case by case basis.

77 Firstly, from the perspective of the status and application of the 0.2m drawdown guidance, I consider that the S42A planning report assigns that figure with a status that it does not have. Secondly, and perhaps more importantly, I do not consider that this approach appropriately considers the effects.

78 The implications of this are most apparent when different aquifers are considered and what the effects would be of a drawdown of greater than 0.2 m. There would be a very significant difference in effects for say a 2 m reduction in an aquifer that is on average 2 m thick (saturated groundwater thickness) versus one that is 20 m thick. For the first example the aquifer would be completely depleted and in the second situation, with a pump at the base of the aquifer, the drawdown would likely not be noticed.

79 The 2019 Skelton report on water management in Otago[15] made it clear that the overall current water management regime in Otago needs "…*to develop a fit for purpose freshwater management planning regime that gives effect*

[15] Skelton P (2019) Investigation of Freshwater Management and Allocation Functions at Otago Regional Council - Report to the Minister for the Environment. Wellington: Ministry for the Environment.

to the relevant national instruments and sets a coherent framework for assessing all water consent applications…".

80 I think it is prudent to take a 'first principles' approach to assessing effects and to consider more developed guidance on what level of drawdown effect would be consistent with the RMA.

Assessing the effects of groundwater abstractions on groundwater levels

81 The RPW is effectively a 'first generation' regional plan. Other regions such as Canterbury have developed 'third generation' regional planning frameworks with more detailed provisions that provide detailed technical guidance and a planning framework for bore interference. I appreciate that this proposal is in Otago. However, when considering effects, approaches from other regions can provide useful technical information.

82 For example, in Canterbury (where there has been considerable investment in developing guidelines for determining acceptable bore interference effects), a criterion has been developed which identifies the "protected available drawdown". That is, a drawdown of 20% of the groundwater level that is available for 80% of the time is considered acceptable. This provides protection for groundwater users of 80% of the groundwater level that is exceeded for 80% of the time during proposed water use.

83 The same approach to the definition of acceptable adverse interference effects is used in the Proposed Southland Water and Land Plan (Appendix L.3 Interference effects). The approach is illustrated below.

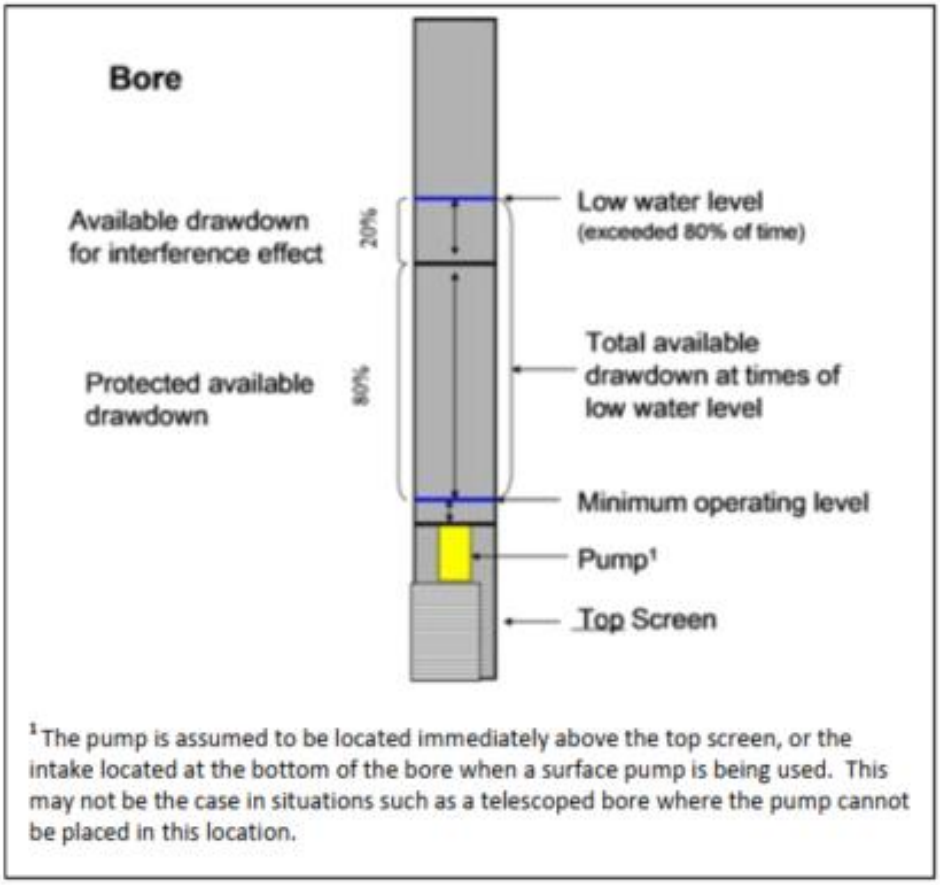

Figure 6: Copy of a representation of 'protected available groundwater'. (Schedule 12 of the Canterbury Land and Water Regional Plan)

84 There appears to be general agreement between Ms Badenhop and me that the available drawdown in the absence of abstractions in the vicinity of bore G41/0238 (the closest bore to G41/0456) is at least 10 m. Bore log information held by the ORC indicates that the depth (or thickness) of available groundwater in the vicinity of the two abstraction bores (G41/0127 and G41/0456) ranges from 11 m to 20 m.

85 Bore logs and available information for this area (from the ORC GIS system) have been considered and assessed against the usual criteria for assessing the effects of drawdown[16]. This assessment is summarised in Table 5 below.

[16] Freeze R & Cherry J (1979) Groundwater, Prentice-Hall.

Table 5: Outline of factors to consider when assessing possible groundwater drawdown

Drawdown interference criteria	Assessment
• The available drawdown, i.e., what depth of groundwater is available	The depth to groundwater in the local area is usually 22 to 24 m deep with bores drilled to 35 to 45 m depth. Therefore, there is usually at least a 10 m 'thickness' of groundwater available. This has been confirmed in the report from e3 Scientific.
• Seasonal groundwater level fluctuations	There is limited information on groundwater level changes. However, information from the nearby Smiths Way monitoring bore[17] and the limited range of the height of Lake Dunstan (varies by about 1 m) indicate that groundwater levels do not change by more than one metre during a year.
• Depth of neighbouring bores	Bore depths are between 33 – 44 m deep below the natural ground surface. Bores closer to the lake are shallower e.g., G41/0111 is 14.8 m deep.
• Depth of screen and pumps	Screens and pumps are in the bottom three metres of bores. The screens vary from about one to three metres in length.
• Self-induced drawdown	There is limited information available, but aquifer test information indicates that this is likely to be relatively small e.g., G41/0238 data indicates a drawdown of 1.75m at a pump rate of 13 L/s.
• Other factors that might affect assumptions inherent in Theis[18] modelling	Proximity to the lake, about 825 m, means that drawdown will be reduced by water moving in from the lake. This will be more pronounced the closer a bore is to the lake.

86 The estimated drawdown effects of the proposed take are outlined in Table 6 below. This approach is a significantly more refined assessment than originally provided that takes account of the maximum abstraction from each pumping bore, rather than assuming that all water could be taken from either bore. This restricts the instantaneous take from bore G41/0456 to 45 L/s and G41/0127 to 25 L/s. The total maximum does not change. This is within the scope of the application and has been formally proffered as a proposed condition.

87 The modelling assumptions using the previously accepted approach of a 30% consumptive take, to assess the effects of pumping from the two bores are as follows:

- 12 hour pumping maximums spread over 24 hours.
- 30% of the take is not returned to groundwater, i.e., 30% modelled as pumped.

[17] Data from Bore G41/0486 on Smiths Way was provided on 16/11/21 by ORC and that shows a variation of approximately 1 m over the period from June 2017 to November 2021. This bore is 28.4 m deep and groundwater is approximately 20 m below the measuring point.

[18] The Theis solution was developed in the 1930s and is used as the fundamental model of the drawdown of groundwater in response to pumping.

- G41/0456 = 45L/s over 12 hours = 22.5 L/s over 24 hours x30% = 6.75 L/s.
- G41/0127 = 25L/s over 12 hours = 12.5 L/s over 24 hours x 30% = 3.75 L/s.
- Transmissivity = 1100 m^2/d, Storativity = 0.1 (values accepted previously by PDP. Evidence from other aquifer tests in the area to use higher values which would decrease drawdown).
- Pumping continuously for 280 days.

88 The assessment is for the total proposed abstraction and not just the additional amount compared to the abstraction already authorised. My understanding is that because there is an existing water permit that does not expire until 2036 the assessment could have considered solely the additional amount.

89 The results of modelling the drawdown caused by pumping from these two bores are outlined in the following table. The Bruce Hunt spreadsheet has been used as made available by Environment Canterbury[19].

Table 6: Bore interference drawdown calculations for the two proposed abstractions

Pumping bores		Affected bores (estimated drawdown in metres)				
		G41/0238	G41/0265	G41/0111	G41/0220	G41/0321
	G41/0456	0.205	0.172	0.132	0.169	0.179
	G41/0127	0.088	0.078	0.082	0.099	0.096
	Total	**0.294**	**0.250**	**0.214**	**0.268**	**0.275**

90 I understand that the planning reporting officer (pages 25 – 28) consider that the RPW Schedule 5B guidance of 0.2 m should be used. However, as explained earlier in this evidence I consider that the 0.2 m threshold identified in RPW Schedule 5B has very limited status beyond being guidance to identify potentially affected persons and is inconsistent with the fundamental effects-based focus of the RMA.

91 Therefore, I have considered a first principles approach alongside the approach that is used in Canterbury and Southland. I have considered the total replacement application rather than just the effects of the additional amount of water sought in addition to that that is already authorised.

19 https://www.ecan.govt.nz/your-region/your-environment/water/tools-and-resources/

92 This approach requires an assessment of not only the proposed abstractions but also other bores affecting groundwater levels. I have therefore also calculated the drawdowns that would be caused by all the other bores within about 600m of the pumping bores. Before these calculations can be done some interpretation of various water permit conditions is required to enable the drawdown effects to be modelled. The interpretations to allow this are detailed below.

Table 7: Summary of bores in the vicinity of Amisfield Quarry bores

Bore	Water take	Purpose	Consented/Estimated take[20]
G41/0220	2010.152.V1	Irrigation & FF	5 L/s for 31 days
G41/0321	RM14.211.02	Community domestic	1.39 L/s
G41/0319	RM14.211.01	Irrigation & FF	16.7 L/s for 52 days
G41/0238	2001.831	Irrigation & FF	78 m^3/d =0.9 L/s, 150 days
G41/0265	2002.430.V1	Domestic & irrigation	2.5 L/s, 150 days
G41/0111	No water permit	Community domestic & irrigation	N/A

93 This information is used to model the drawdown associated with each of those abstractions and is outlined in the following table.

Table 8: Bore interference drawdown calculations for surrounding bores

		Affected bores (estimated drawdown in metres)					
		G41/0220	G41/0321	G41/0319	G41/0238	G41/0265	G41/0111
Pumping bores	G41/0220	N/A	0.133	0.063	0.035	0.025	0.020
	G41/0321	0.058	N/A	0.045	0.039	0.028	0.023
	G41/0319	0.260	0.336	N/A	0.339	0.156	0.076
	G41/0238	0.018	0.020	0.024	N/A	0.019	0.011
	G41/0265	0.033	0.036	0.038	0.053	N/A	0.035
	G41/0111	ND	ND	ND	ND	ND	N/A
	Total	**0.369**	**0.525**	**0.17**	**0.466**	**0.228**	**0.165**

94 The reported depths of these bores and depth to groundwater level are summarised in Ms Badenhop's report dated 11 November 2020 and are not repeated here.

[20] From www.data.orc.govt.nz

95 It is interesting to note that pumping from bore G41/0319 has an estimated drawdown effect on three other bores greater than 0.2 m.

96 No assessment has been done for the abstraction from bore G41/0111 because I understand that there is no water permit for this bore and therefore the amount taken has been assumed to be no more than 25,000 L/day or 0.29 L/s. Therefore, such a small amount has not been modelled. I do not have water meter records to confirm these amounts.

97 These assessments do not take account of the potential influence of the lake as a source of recharge water. This was estimated using an 'image well', a method used for many decades[21]. This allows the effect of the recharge boundary to be accounted for by subtraction of the recharge induced from the lake. Because the distances from the image wells to the affected wells are significant, approximately 1.5 – 2.0 km and the individual effects are relatively small I have simplified this slightly and combined the two image wells to one image well abstracting 10.5 L/s (6.75+3.75). Specific distances for each bore have been estimated using QGIS and Google Maps. The results of these calculations are summarised in the following table.

Table 9: Image bore 'drawdown' effect on surrounding bores

Image bore		Affected bores (estimated +ve drawdown in metres)				
		G41/0238	G41/0265	G41/0111	G41/0220	G41/0321
	Distance	1,700 m	1,400 m	1,300 m	1,950 m	1,950 m
	DD effect	0.072	0.093	0.101	0.058	0.058

98 The location of the image well is illustrated below.

[21] https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1107&context=water_rep

Figure 7: Location of merged image well

99 The results of both sets of drawdown estimates can be combined to assess the overall impact on the depth of available groundwater.

100 The image well analysis has not been undertaken for all the surrounding bores, i.e., an image well has not been included for each of the surrounding bores to assess the recharge effect. This would involve significant further additional analysis. There would be a small recharge effect on those bores. Therefore, the drawdown effect attributed to those abstractions will overestimate actual drawdowns. Excluding that specific recharge effect, the overall estimates of the combined effects are illustrated in the following table.

Table 10: Combined bore interference drawdown calculations for both proposed and surrounding takes and effect of lake recharge (2 bores only)

Pumping bores		Affected bores (estimated drawdown in metres)				
		G41/0238	G41/0265	G41/0111	G41/0220	G41/0321
	G41/0456	0.205	0.172	0.132	0.169	0.179
	G41/0127	0.088	0.078	0.082	0.099	0.096
	Total two bores	**0.294**	**0.250**	**0.214**	**0.268**	**0.275**
	Total other bores	0.466	0.228	0.165	0.369	0.525
	Lake recharge	-0.072	-0.093	-0.101	-0.058	-0.058
	Grand Total	**0.688**	**0.385**	**0.278**	**0.579**	**0.742**
	% of 10m	**6.9%**	**3.9%**	**2.8%**	**5.8%**	**7.4%**

101 This amounts to approximately 4 – 7.5% of the available 10 m of groundwater. Or to put it another way, instead of 10 m of groundwater being available there would be at least 9.25 m of groundwater. The ORC database indicates that bore screens and pumps in this location are at the bottom of bores (no data on the screen location for bore G41/0321). Therefore, the effect of the reduction of available water from 10 m to 9.25 m would be negligible.

102 As a comparison, the Canterbury and Southland frameworks allow for up to a 20% reduction in the amount of available groundwater.

103 A total drawdown of up to 0.75 m or 7.5% of the available 10 m would be an acceptable negligible adverse effect and would not be noticeable by the groundwater users in the context of natural groundwater level variability which is likely to fluctuate by up to 1 m.

104 In addition to this assessment of the cumulative effects of currently authorised abstractions and the full volumes sought (not just the increase above the amounts already authorised until 2036), it is possible to assess the self-induced drawdown in, for example, the two bores with the greatest drawdown. This is outlined in the following table.

Table 11: Combined bore interference drawdown calculations for both proposed and surrounding takes and effect of lake recharge (2 bores only)

Bore	Water take	Modelled self drawdown (m)	Reported pump test drawdown (m)
G41/0321	RM14.211.02 1.39 L/s	0.139	5.32 (1,641.6 L/s)[22]
G41/0238	2001.831 0.9 L/s, 150 days	0.085	1.75 (13 L/s)

105 The addition of the modelled self-drawdown demonstrates that the overall drawdown that includes the effects not only of the proposed abstractions but also all other bores and self-drawdown in the most affected bores would be less than 1 m. In the context of the available groundwater depth being approximately 10 m, this modelling strongly indicates that the adverse effect is highly likely to be negligible.

Alternative drawdown modelling approach and uncertainties

106 As a consequence of expert witness conferencing Ms Badenhop and I agreed that the approach of assuming a 30% consumptive approach with just one set of T and S values is a relatively simplified approach and we can model the effects of discharging the significant majority of the taken water into the settling ponds, primarily the large second pond. This can be done in a manner similar to the image well approach used above to simulate the effect of a recharge source but with the main settling pond being a recharge source.

107 To get an understanding of the implications of this alternative modelling approach and to consider the potential implications of a broad range of aquifer characteristics I have modelled the effects of the take from bore G41/0456 on groundwater levels at bore G41/0238, i.e., the closest bore to the largest take. To take account of the water that is lost at the plant, the water that is lost in evaporation from the ponds, and because the pond is an area rather than a point source, I have assumed that 80% of the abstraction is consumptive and 80% of that is discharged back into groundwater in the second pond, i.e., 18 L/s is taken and 14.4 L/s is discharged back into the aquifer. I have also used T values, 300, 1,100 and 1,500 m^2/day and S values 0.02, 0.1 and 0.15. The results of this modelling are shown below.

[22] The reported pump rate for the reported aquifer test is not reliable. It is virtually certain that the pump test was not undertaken at that rate.

108 The range of transmissivity and specific yield values have been chosen to cover the range of possible values from a joint review of both reported values that I was able to find and estimated values that Ms Badenhop has modelled.

Table 12: Modelled drawdown on bore G41/0238 as a consequence of the proposed abstraction at Bore G41/0456 and recharge at the second settling pond

	Drawdown and recharge (m)					
	Transmissivity (m^2/day)					
	Take from bore			Discharge to pond		
Specific yield	300	1,100	1,500	300	1,100	1,500
0.02	2.140	0.729	0.561	-1.756	-0.596	-0.457
0.1	1.481	0.549	0.428	-1.229	-0.451	-0.351
0.15	1.367	0.503	0.396	-1.097	-0.415	-0.325

Table 13: Overall modelled drawdown on bore G41/0238 as a consequence of the proposed abstraction at Bore G41/0456 and recharge at the second settling pond

	Overall drawdown (m)		
	Transmissivity (m^2/day)		
Specific yield	300	1,100	1,500
0.02	0.384	0.133	0.104
0.1	0.252	0.098	0.077
0.15	0.27	0.088	0.071

109 This modelling has been undertaken to complement the earlier modelling using a different approach and a very wide range of aquifer characteristics. A key useful comparison is to compare the modelled drawdown using the simplified approach and this approach. In the first modelling approach, the estimated drawdown effect on Bore G41/0238 was 0.205 m while the more detailed modelling showed a range of between 0.077 to 0.252 m. All modelling involves significant assumptions and with more time and resources more detailed investigations and modelling could be undertaken. However, the different approaches lend further support to my conclusion that the effects of the proposed abstractions on surrounding groundwater users would be negligible and not noticeable.

110 Submissions have raised a concern that exposure of groundwater in new extraction locations could result in a level of evaporation that could lower groundwater levels. My understanding is that this is a matter that is not related to a potential adverse effect that could be caused by the proposed take and use of water. A land use consent application has been lodged for the excavation of pits and removal of aggregate. As a consequence, the effects that can be considered under that application are restricted as

specified in RPW Rule 14.2.3.1. The effects that can be considered are specified below and do not include the potential effects of evaporation.

"*(a) The potential for contamination of groundwater; and*
(b) The location of the drilling; and
(c) The planned depth of the drilling; and
(d) The management of the drill hole on completion; and
(e) The method of drilling; and
(f) The duration of the resource consent; and
(g) The information and monitoring requirements; and
(h) Any bond; and
(i) The review of conditions of the resource consent."

Groundwater allocation & cumulative groundwater effects

111 The bores within the quarry are located in the "Pisa Groundwater Management Zone" which is currently estimated by ORC staff as being under allocated. This zone has been estimated by ORC staff to have a mean annual recharge of 6.5 million m^3. It is currently (most recent data reported for July 2020) estimated by ORC staff that there is 2,135,128 m^3/yr of water available within this aquifer. This assumes that 453,600 m3 is already allocated for quarry use.

112 The Pisa Groundwater Management Zone (PGMZ) is not defined in the RPW. Schedule 4C of the RPW indicates that "Additional aquifers are added through the plan change process following scientific investigations and consultation with the community and affected parties". The PGMZ has not been added to the RPW via a plan change process.

113 Schedule 4D of the RPW indicates in general terms what matters would be considered when "calculating the mean annual recharge of an aquifer." Therefore, the PGMZ extent, recharge amounts and the allocation amounts are all estimated by ORC staff (as provided for in RPW Policy 6.4.10A2 (b)) and while they are useful, they are not equivalent to aquifer allocations explicitly defined in the RPW.

Discharge of 'contaminants' to land

114 The 'contaminants' in the discharge to land (the soakage pond) will be naturally occurring silts and sands from the washing of gravel, and the sediment will be removed from the water column by settling in the soakage pond and then by the filtering process as water moves through the natural alluvium.

115 Following the close of submissions on the expansion proposal, water quality sampling was done by an independent third party (approved by two submitters - AES and Irrigation and Maintenance) of groundwater from three bores, G41/0321 (upgradient) (the I&M bore), G41/0456 (site bore) and G41/0111 (general downgradient direction) (the AES bore). The results of that monitoring are included in Appendix E.

Analysis of groundwater quality results

116 These results demonstrate that all three samples complied with all the NZ Drinking Water Standards for variables of health significance but none of the three samples complied with the aesthetic guideline values for turbidity and total iron. The aesthetic guidelines do not affect the health suitability of the water. The bore in the quarry had significantly lower concentrations of iron and turbidity than both the upgradient or down-gradient bore. Naturally elevated concentrations of iron in shallow groundwater is a recognised issue in many parts of New Zealand (including Central Otago) that have significant alluvial/fluvial groundwater resources[23]. This is usually caused by the presence of organic material in the aquifer matrix such as plant material laid down many thousands of years ago. The organic material can reduce the dissolved oxygen concentrations that can then result in increased concentrations of dissolved iron that will precipitate out when the water is exposed to a high oxygen environment. In addition, if a bore is in an aquifer with a significant amount of fine sand material that is not screened or filtered out during abstraction, this can raise the turbidity of the water and if those 'fines' have a high iron content this will be revealed in a total iron analysis.

117 The results are consistent with the total suspended solids (TSS) analyses that have been undertaken quarterly since December 2016 on groundwater from bores G41/0127, G41/0456 and G41/0220 that consistently showed TSS below the detection limit of 3 g/m^3 for all three bores.

118 Given the nature of the alluvial deposits in this area and glaciation periods, I am confident that it is highly unlikely that there are any really extensive separate aquifer layers. Therefore any contaminants that enter groundwater will be able to move both horizontally and vertically downwards. I have extensive experience of groundwater quality monitoring and investigations in Canterbury and I have observed and read reports of significantly different groundwater quality from bores in similar aquifers the same depth 20 m apart

[23] Haughey CJ (2003) Iron and manganese in New Zealand's groundwater, Journal of Hydrology 42, 11-26.

that was most likely caused by ancient localised deposits of plant material in the aquifer matrix. However, there are other possible causes of high iron concentrations in groundwater samples e.g., rusting iron casing components.

119 There is an apparent trend of a reduction in concentrations of many key water quality variables moving towards the lake. With only one set of data taken on one day, it would be premature to make any definitive conclusions, but the data does strongly indicate that bores closer to the lake have lower concentrations of, for example, major cations (calcium and magnesium) and anions (nitrate and sulphate). This is not unexpected given the permeable nature of alluvial material close to the lake, and the expected difference in the quality of groundwater that is sourced primarily from precipitation percolating through the ground in contrast to Lake Dunstan water which is formed primarily by higher altitude precipitation with less migration through sub-surface alluvial.

120 This conclusion is supported by the very limited amount of water quality sampling undertaken of bores close to Lake Dunstan. For example, Rekker (2012)[24] reported the chloride concentration of groundwater in a bore approximately 350 m from the Lake Dunstan of 1.0 g/m^3, similar to concentrations found from the bores closer to the lake in the Amisfield Quarry area.

121 Similarly, Pollock (2012)[25] found chloride concentrations of the Clutha River/Mata Au near Alexandra to be approximately 0.6 g/m^3 while nearby groundwater from community water supply bores had significantly higher (1.7 – 5.2 g/m^3) chloride concentrations.

122 The results for both the upgradient bore and the downgradient bore show higher turbidity and iron concentrations than the Amisfield Quarry bore (G41/0456). This is highly likely to be a consequence of localised reduced dissolved oxygen concentrations and/or localised fine sediment being entrained into the bore supply.

Analysis of filter and sediment results

123 At the same time as groundwater samples were taken for analysis, a sample of sediment from the second quarry settling pond was taken and a sample of a wool filter used with bore G41/0321. The purpose of the wool filter is

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24 Rekker J (2012) Cromwell Terrace Aquifer Study, ORC Report, October 2012.

25 Pollock SJ (2012) Assessing Groundwater/Surface Water Connectivity and the Effect on Groundwater Quality in Alexandra, Central Otago, MSc Thesis, University of Otago.

presumably to reduce the turbidity of the water ultimately used. The filter 'cake' was separated from the wool filter material by Hill Laboratories. There are many commercial treatment/filtration options to reduce bore water turbidity. I do not have sufficient knowledge of the effectiveness of different systems to comment on the suitability of a wool filter.

124 The location of settling ponds and bores are shown in the following figure.

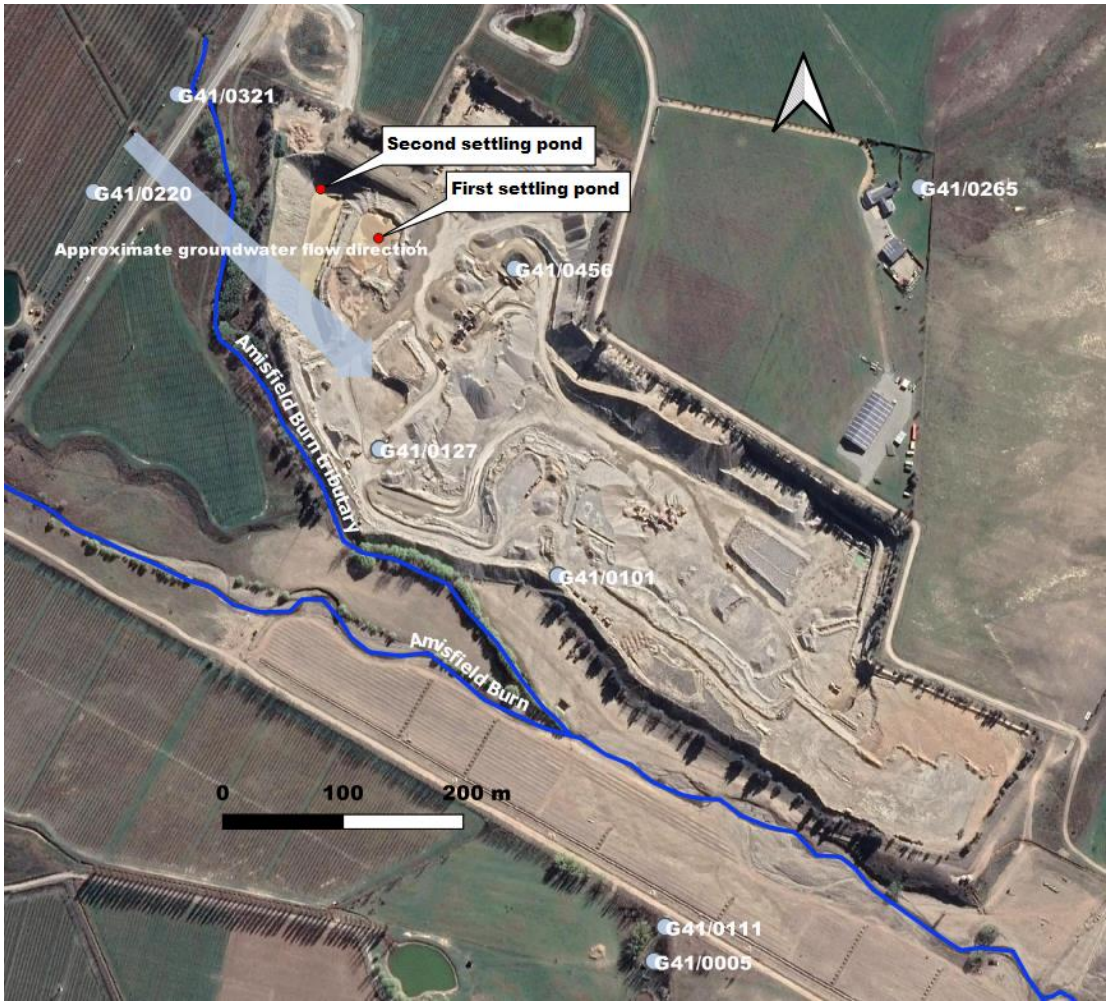

Figure 8: Location of settling ponds and bores

Table 14: Results from sampling of pond sediment and bore filter cake on 5 October 2021 (units mg/kg)

	Filter sample	Pond sediment	Reference Soil standards*
Total iron	38,000	15,200	N/A
Total arsenic	24	6	70
Total cadmium	< 0.3	< 0.10	1,300
Total chromium	69	7	6,300
Total copper	55	15	>10,000
Total lead	123	20	3,300
Total nickel	19	10	3,000
Total zinc	490	36	35,000

* NES Soil Contaminant Standards for commercial land use except for Ni & Zn which are Australian NEPM concentration triggers for investigation for residential land.

125 The results reflect the groundwater quality sample results, particularly with high concentrations of iron in the filter cake as well as comparatively high concentrations of chromium, lead and zinc compared to the pond sediment sample. These high concentrations are likely to be a consequence of organic material in the alluvium that cause a reduction in dissolved oxygen concentrations which in turn cause various metals to be dissolved. When that low oxygen water is exposed to air, the metals precipitate out of solution and will be caught on the filter. It is also possible that a combination of the alluvial fines, bore development and screen result in a greater proportion of 'fines' being pumped into the filter.

126 It is very unlikely[26] that the high concentrations of metals in the filter sample could have been caused by settling pond activities at the quarry because even though the settling pond water surfaces are higher (see 26 November survey results) than the screen depth for bore G41/0321 they are down-gradient, fine material would have to travel through over 100 m of sand and gravel and the pond sediment has substantially lower metal concentrations.

127 My experiences of similar groundwater quality issues lead me to conclude that it is likely that the high concentrations of metals in the filter sample are caused by a combination of localised reduced dissolved oxygen concentrations (which causes many metals to be dissolved and then precipitate out once the water is exposed to air) and/or localised fine sediment being pulled into the bore as a consequence of either poor bore development and/or bore deterioration.

[26] IPCC terminology is used. Exceptionally unlikely = <1% probability. Very unlikely = 0 – 10% probability, ... Very likely =>90% probability, Virtually certain = 99 – 100% probability.

128 These localised groundwater quality problems are normally solved by either treatment and/or filtration, rehabilitation of a bore, and/or installing a new bore.

129 The data in Table 2 are compared with the NES[27] Soil Contaminant Standards purely as a reference point to assist in interpreting the significance or relevance of the results. The values included are those used to determine the suitability of soils on sites used for commercial/industrial purposes. The results demonstrate that either material would be acceptable if it was placed on a commercial/industrial site.

Conclusions on current water quality effects

130 The results of the groundwater quality monitoring indicate that groundwater in the area of the Amisfield Quarry is influenced by Lake Dunstan with groundwater from bore G41/0111 having lower concentrations of key water quality variables than groundwater from bores further inland. Groundwater from the bore upgradient from the quarry, G41/0321, and bore G41/0111 downgradient from the quarry had relatively high turbidity and iron concentrations that are likely caused by localised aquifer matrix characteristics, by bore development/screen issues and/or bore/screen deterioration.

131 It is exceptionally unlikely that the relatively high turbidity and iron concentrations found in groundwater from bore G41/0321 were caused by activities at Amisfield Quarry. Similarly, it is exceptionally unlikely that the high concentrations of metals in the filter sample could have been caused by settling pond activities at the quarry.

132 It is very unlikely that the relatively high turbidity and iron concentrations found in groundwater from bore G41/0111 were caused by activities at Amisfield Quarry.

133 All the groundwater samples complied with the NZ Drinking Water Standards Maximum Acceptable Values.

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[27] National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health.

Soakage ponds, extraction of gravel from below groundwater and groundwater levels

134 Provided that the soakage ponds continue to be maintained and on-site precautions continue to be undertaken, it is virtually certain that groundwater quality in the area would continue to be unaffected by quarry operations.

135 Provided the quarry operations continue to occur in a pit well below the natural ground surface it would be virtually impossible for sediment-laden water to spill over into either the Amisfield Burn or Lake Dunstan. The proposed resource consent conditions[28] also provide an assurance of this.

136 The extraction of gravel from below groundwater levels as proposed does increase the potential vulnerability of that groundwater to contamination. However, the proposed conditions including post-extraction site management conditions mean that the risk would be reduced to an acceptable minimum.

137 The proposed increase in abstraction amounts would increase the amount of existing authorised localised drawdown. However, as stated earlier in this evidence, the scale of that effect is negligible and because of the significant gap between the ground surface and the underlying groundwater level, this small reduction in localised groundwater levels cannot cause land surface contaminants to enter groundwater.

RMA/RPW MATTERS

RMA Section 105

138 Section 105 of the RMA requires that when considering an application for a discharge permit to do something that would contravene section 15 of the Act, the consent authority must, in addition to the matters in section 104(1), have regard to—

(a) the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and

(b) the applicant's reasons for the proposed choice; and

(c) any possible alternative methods of discharge, including discharge into any other receiving environment.

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[28] Proposed conditions are contained in the planning evidence of Mr Curran.

139 The nature of the discharge (into a settlement pond so that sediment is filtered) and the sensitivity of the receiving environment has been considered in my assessment of effects. I understand that there are no practicable alternatives to this method of discharge. The applicant's method of discharge, the natural filtering capacity of the alluvium material in the quarry area, and monitoring undertaken that indicates no adverse effects on groundwater quality. The proposed conditions of consent include a wide range of operational controls and monitoring that provide a high level of assurance that no significant adverse effects would occur. These proposed conditions include review conditions. The s42A planning report agrees that the proposed method of discharge is appropriate.[29]

RMA Section 107

140 Section 107 of the RMA provides that a discharge permit shall not be granted (with certain exceptions) if, after reasonable mixing, a contaminant or water discharge is likely to give rise to all or any of the following effects in receiving waters:

(a) The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;

(b) Any conspicuous change in the colour or visual clarity;

(c) Any emission of objectionable odour;

(d) The rendering of freshwater unsuitable for consumption by farm animals; and

(e) Any significant adverse effects on aquatic life.

141 I am confident that the proposed discharge would not result in any of the Section 107 adverse effects in any water that would generally be considered to be a receiving water. The s42A planning report agrees[30].

SUBMISSIONS

142 Some of the submissions on the resource consent applications to the ORC raise concerns about groundwater effects, in particular the submissions by Amisfield Estate Society Incorporated (AES), and Irrigation & Maintenance Limited. Some matters raised in those submission have been addressed in

29 Page 64
30 Page 65

the response to a Section 92 request for further information (a copy of which is contained in Appendix C) and the further information provided by the applicant on 10/11 November 2021. Separate submissions have also been lodged by people who refer to being members of the Amisfield Estate Society. Those submissions generally raise similar issues to the Society's submission, with some exceptions which I address below.

143 Irrigation and Maintenance Limited hold a water permit to take water from bore G41/0321 upgradient from the quarry (see Figure 2). Amisfield Estate Society appears to take water from bore G41/0111 which is roughly down-gradient from the quarry (see Figure 2).

144 The key issues identified in these submissions that are relevant to my areas of expertise can be summarised as concerns about:

- potential effects on groundwater levels and access to water, and
- potential contamination of water either via the soakage pond or through on-site activities such as via the use, storage or transport of fuel.

145 I have been addressed both of these matters earlier in my evidence.

Amisfield Estate Society Incorporated

146 AES and any users of its bore were considered by the Regional Council to be an affected party on the basis of a technical audit undertaken by E3 Scientific on behalf of the Council's Resource Science Unit. The notification report states that the audit confirmed that the drawdown effect on G41/0111 is 3.75, that G41/0111 is located adjacent to G41/0005 and therefore is likely to experience drawdown effects of greater than 0.2m.

147 However, the re-notification memorandum misinterpreted parts of the technical review undertaken by Ms Badenhop. Her assessment did not confirm a drawdown effect of 3.75 m on bore G41/0111. Ms Badenhop simply estimated the **available** drawdown of that bore (and others) in Table 1 in her report. The numbers in Ms Badenhop's Table 1 are not an estimated drawdown caused by the proposed pumping of the quarry bores. My assessment of the potential drawdown of groundwater levels at the surrounding bores is included earlier in my evidence.

148 AES is concerned that water levels within the aquifer are not reduced as a result of drawdown such that the Society's access to water is compromised.

Its submission states that it considers that due to a lack of site-specific pump testing, there is a degree of uncertainty about this such that a precautionary approach should be taken and careful monitoring required. My assessment of drawdown includes conservative assumptions and the lack of an additional aquifer test for the two bores is not material. As my earlier evidence states, I am confident that adverse effects on water levels in the AES bore would be insignificant.

149 AES also seek that a range of conditions be imposed. The applicant has been in directly contact with Society about these. For completeness, the conditions suggested by the Society in its submission are reproduced below.

(a) Groundwater quality monitoring should also include analysis in accordance with the New Zealand Drinking Water Standards.

(b) Monitoring frequency to be increased to monthly to ensure early detection of contaminants;

(c) Requirement for CCC to provide alternative source of drinking water for the Society or treatment facilities in the event that their activities cause contamination of the

Societies drinking water source that results in a failure to meet the New Zealand Drinking Water Standards.

(d) Requirement for groundwater sampling to be carried out by a suitably qualified independent person.

(e) Requirement for results of groundwater monitoring results to be provided to the Amisfield Estate Society immediately, but no later than a week following their receipt by the consent holder.

(f) Monitoring of groundwater draw down level during bore operation at least weekly for the first 36 months following exercise of the new consents and quarterly thereafter to ensure actual draw down effects are consistent with modelled effects.

(g) Requirement for Amisfield Estate Society to be notified immediately if a hazardous substance spill occurs at the site.

(h) Prohibition on importation of soils or other materials for storage or disposal at the site. If importation is intended then testing of material to be deposited at the site to ensure it qualifies as clean fill and does not contain contaminants that may affect ground water quality and requirements to maintain records of the material received including the volume and the location of its deposit.

(i) Machinery refuelling to take place on impermeable and bunded surface with stormwater to be captured and monitored for contaminants prior to discharge.

(j) Truck washdown to occur on an impermeable surface and bunded surface with washdown/stormwater captured and appropriately treated prior to discharge.

(k) A specific review condition be imposed in the event that groundwater quality monitoring indicates that the discharge consent is having an effect on groundwater quality.

(l) That all existing seepage ponds to be lined and water discharged through a filter system so no contaminated water is leached back into the ground, any contaminated material is removed from site and disposed as per best practice.

(m) Appropriate site perimeter fencing established for public safety purposes.

(n) Consideration be given to granting a shorter-term consent in recognition of the need for the ORC to implement the NPSFM. It is anticipated that by the time this matter is heard the new proposed regional policy statement will be available which is likely provide further guidance on an appropriate term.

150 In my opinion, the conditions proposed by the applicant (attached to the planning evidence of Mr Curran) appropriately address all potential adverse effects on groundwater and surface water quality and quantity.

151 Groundwater quality testing conditions are proposed. A proposed condition (2) in the draft regional land use consent proposes to monitor a comprehensive suite of groundwater quality variables at bore G41/0111 and a new piezometer to be installed in a more directly downgradient direction. A similar condition is proposed for the discharge permit to monitor suspended sediment and turbidity in G41/0220 and G41/0456. It also replicates an equivalent condition of the existing discharge permit.

152 Condition 9 of the draft land use consent requires the submission of a Quarry Management Plan. This plan will detail the methods of operation for the quarry including re-fuelling, spill management and desludging of the sediment pond.

153 All of the bores in this area are relatively shallow, in permeable unconfined groundwater and because the surface soils are generally relatively thin, contaminants on the ground upgradient from the quarry such as faecal material from stock will result in microorganisms of potential health significance being washed down into groundwater. Therefore, all the bores in this wider area are vulnerable to a level of risk of microbiological contamination as a consequence of the wider agricultural land use. This proposal does not increase that risk.

154 Many of the proposed conditions are either not practicable (monitoring drawdowns), not warranted (lining settlement ponds and monthly monitoring) or have been addressed by the proposed conditions (e.g., proposed addition of a new monitoring bore and inclusion of a requirement for analysis of the full NZ Drinking Water Standard suite of variables).

Irrigation and Maintenance Limited

155 The concerns raised by Irrigation and Maintenance about the quality of water in bore G41/0321 and potential effects on groundwater levels have been addressed earlier in this evidence.

PROPOSED CONDITIONS

156 A number of conditions have been proposed (Mr Curran's evidence) to monitor the effectiveness of the methods proposed to maintain water quality

and quantity. These conditions include limits on the instantaneous, daily and monthly amounts of water that can be taken from each bore as well as the annual limit of water that can be taken by both bores cumulatively. I have reviewed those conditions and with a minor change consider that they are generally appropriate.

157 As a consequence of expert witness conferencing, Ms Badenhop and I agree that instead of using Bore G41/0456 as a monitoring bore it would be more robust to install one to two dedicated (narrow diameter) down-gradient groundwater quality monitoring piezometer(s) that could be used to monitor groundwater quality. The key advantage of this approach would be the ability to align the location better with the most likely down-gradient direction.

SECTION 42A OFFICERS' REPORTS

158 The planning S42A report makes number of conclusions based on mis-interpretation of the technical information, the planning framework, and both my and Ms Badenhop's reports. Two key issues are outlined below:

Table 15: Key conclusions on groundwater matters in the S42A planning report

Statements in S42A planning report	Comments
Page 26 "Alexandra Badenhop… confirmed drawdown effects on G41/0111 is 3.75m…"	My Whyte appears to have misinterpreted the comment in Table 1 of Ms Badenhop's report dated 11 November 2020 that summarised an estimate of the "available drawdown". Ms Badenhop's report, dated 9 July 2020, states "…*Cromwell Certified Concrete groundwater abstraction is unlikely to significantly interfere with the AESI bore. This is based on the take being only 37% consumptive. However, even if the take is 50% consumptive, it is unlikely to have a significant effect."*
Page 27 "Figure 7: location of bores that are likely to experience drawdown effects greater than 0.2 m"	The misinterpretation of Ms Badenhop's table (reproduced in Mr Whyte's report as Table 11), provision of Figure 7 ("*Location of bores that are likely to experience drawdown effects greater than 0.2 m*") and subsequent comments mean that the subsequent assessment against policy provisions are not based on the actual drawdown estimates and need to be revised.

Misinterpretation of the operation and status of Policy 6.4.10B and Schedule 5B	See paragraphs X - Y

CONCLUSIONS

159 The Pisa Groundwater Management Zone has been delineated and estimated by ORC staff to have a mean annual recharge of 6.5 million m^3. It is currently (most recent data reported for July 2020) estimated by ORC staff that there is 2,135,128 m^3/yr of water available within this aquifer. This includes 453,600 m^3 already allocated for quarry use. Therefore, there is ample available groundwater for allocation of the 846,720 m^3 sought from this zone.

160 Compared to a situation with no abstractions from these two bores (G41/0127 and G41/0456), the proposal would result in an estimated reduction of less than 1 m of the available groundwater depth in the closest bores. This would reduce the column of groundwater level in those bores from approximately 10 m to 9 m. Even with the additional effect of self-induced drawdown in those nearby bores, and considering annual fluctuations of groundwater, with bores screened in the lower 3 m of the bore, this reduction would be negligible. Therefore, it is virtually certain that the proposed increase in water abstractions would not have a significant adverse effect on existing water users.

161 Groundwater in this location is well below the level of the Amisfield Burn and sufficiently distant from Lake Dunstan such that it is very unlikely that the proposed abstractions would have an adverse effect on these water bodies.

162 Subject to the proposed conditions, it is very unlikely that there would be any significant adverse effects on groundwater quality or surface water quality.

Mike Freeman

30 November 2021

Appendix A Copies of ORC water permit and discharge permit

Our Reference: A919731

Consent No. RM16.108.01

WATER PERMIT

Pursuant to Section 104C of the Resource Management Act 1991, the Otago Regional Council grants consent to:

Name: Cromwell Certified Concrete Limited

Address: Wright Stephenson House, 585 Great South Road, Penrose, Auckland

To take and use ground water

for the purpose of gravel washing and dust suppression

For a term expiring 21 July 2036

Location of Point of Abstraction: Cromwell, approximately 360 metres east northeast of the intersection of Luggate-Cromwell Road (State Highway 6) and Amisfield Road

Cromwell, approximately 500 metres east northeast of the intersection of Luggate-Cromwell Road (State Highway 6) and Amisfield Road

Legal Description of land at point of abstraction: Lot 8 DP 301379

Legal Description of land (s) where water is to be used: Lot 8 DP 301379 and other land as advised in writing to the Consent Authority

Map Reference at point of abstraction: NZTM 2000 E1305397 N5017068

NZTM 2000 E1305502 N5017223

Conditions

Specific

1. This permit shall not commence until Water Permit 2004.294.V1 has been surrendered or expired.

2. If this consent is not given effect to within a period of two years from the date of commencement of this consent, this consent shall lapse under section 125 of the Resource Management Act 1991.

3. (a) The rate of abstraction shall not exceed 15 litres per second from bore G41/0127 and 31 litres per second from bore G41/0456;
(b) 1,620 cubic metres per day;
(c) 50,220 cubic metres per month;
(d) 453,600 cubic metres per year.

4. This permit shall be exercised in conjunction with Discharge Permit RM16.108.02.

5. This permit shall be exercised or suspended in accordance with any Council approved rationing regime that applies to the Pisa Groundwater Management Zone.

Performance Monitoring

6. (a)The consent holder shall install a water meter to record the water take, within an error accuracy range of +/- 5% over the meter's nominal flow range, and a telemetry compatible datalogger with at least 24 months data storage and a telemetry unit to record the rate and volume of take, and the date and time this water was taken.
(b)The datalogger shall record the date, time and flow in litres per second.
(c) Data shall be provided once daily to the Consent Authority by means of telemetry. The consent holder shall ensure data compatibility with the Consent Authority's time-series database.
(d) The water meter shall be installed in a straight length of pipe, before any diversion of water occurs. The straight length of pipe shall be part of the pump outlet plumbing, easily accessible, have no fittings and obstructions in it. There shall be a straight length of pipe on either side of the water meter: on the upstream side there shall be a distance that is 10 times the diameter of the pipe and on the downstream side there shall be a distance of 5 times the diameter of the pipe.
(e) The consent holder shall ensure the full operation of the water meter, datalogger and telemetry unit at all times during the exercise of this consent. All malfunctions of the water meter and/or datalogger and/or telemetry unit during the exercise of this consent shall be reported to the Consent Authority within 5 working days of observation and appropriate repairs shall be performed within 5 working days. Once the malfunction has been remedied, a Water Measuring Device Verification Form completed with photographic evidence must be submitted to the Consent Authority within 5 working days of the completion of repairs.
(f) The installation of the water meter, datalogger and telemetry unit shall be

completed to full and accurate operation within 1 month of the exercise of the consent. The consent holder shall forward a copy of the installation certificate to the Consent Authority within one month of installing the water meter datalogger and telemetry unit.

(g) (i) If a mechanical insert water meter is installed it shall be verified for accuracy each and every year from the first exercise of this consent.
(ii) Any electromagnetic or ultrasonic flow meter shall be verified for accuracy every five years from the first exercise of this consent.
(iii) Each verification shall be undertaken by a Consent Authority approved operator and a Water Measuring Device Verification Form shall be completed and submitted to the Consent Authority with receipts of service within 5 working days of the verification being performed, and at any time upon request.

General

7. The consent holder shall take all practicable steps to ensure that:
(a) there is no leakage from pipes and structures;
(b) there is no run off of irrigation water either on site or off site.
(c) a back flow preventer device is fitted to prevent any contaminants from being drawn into the source of the water.

8. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the conditions of this consent for the purpose of imposing aquifer restriction levels, if and when an operative regional plan sets aquifer restriction levels.

9. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the conditions of this consent within 3 months of each anniversary of the commencement of this consent for the purpose of:
(a) adjusting the consented rate or volume of water under condition 3, should monitoring under condition 5 or future changes in water use indicate that the consented rate or volume is not able to be fully utilised; or
(b) determining whether the conditions of this consent are adequate to deal with any adverse effect on the environment which may arise from the exercise of the consent and which it is appropriate to deal with at a later stage; or
(c) ensuring the conditions of this consent are consistent with any National Environmental Standards Regulations, relevant plans and/or the Otago Regional Policy Statement; or;
(d) adjusting or altering the method of water take data recording and transmission.

10. Copies of the results of any water quality analyses performed on the groundwater shall be forwarded to the Consent Authority within two weeks of the analysis being undertaken.

Notes to Consent Holder

1. *If you require a replacement permit upon the expiry date of this permit, any new application should be lodged at least 6 months prior to the expiry date of this permit. Applying at least 6 months before the expiry date may enable you to continue to exercise this permit until a decision is made, and any appeals are resolved, on the replacement application.*

2. *The water meter, datalogger and telemetry unit should be safely accessible by the Consent Authority and its contractors at all times.*

Issued at Dunedin this 20th day of July 2016.

Christopher P. Shaw
Manager Consents

Our Reference: A919731

Consent No. RM16.108.02

DISCHARGE PERMIT

Pursuant to Section 104B of the Resource Management Act 1991, the Otago Regional Council grants consent to:

Name: Cromwell Certified Concrete Limited

Address: Wright Stephenson House, 585 Great South Road, Penrose, Auckland

To discharge contaminants to land

for the purpose of gravel washing and dust suppression

For a term expiring 21 July 2036.

Location of consent activity: Cromwell, approximately 360 metres east northeast of the intersection of Luggate-Cromwell Road (State Highway 6) and Amisfield Road

Legal description of consent location: Lot 6 DP 301379

Map Reference: NZTM 2000 E1305397 N5017068

Conditions

Specific

1. This permit shall not commence until Water Permit 2004.294.V1 has been surrendered or expired.

2. The volume of water discharged shall not exceed:
   (a) 1,620 cubic metres per day;
   (b) 50,220 cubic metres per month; and
   (c) 453,600 cubic metres per year.

3. No contaminants other than silt and sediment shall be discharged into the Pisa Groundwater Management Zone.

4. Settlement ponds shall be maintained in an efficient operating condition at all times, including at least:
   (a) Three monthly inspections of settling ponds; and
   (b) Pond desludging as necessary.

5. The consent holder shall ensure that there is no direct discharge to any surface watercourse.

Performance Monitoring

6. Quarterly monitoring of suspended sediment concentrations shall be undertaken at bores: G41/0101, G41/0456, and an up-gradient bore for the purpose of comparison, either G41/0220 or G41/0321.
   (a) The applicant should provide details of the construction of the bores from which monitoring is undertaken, including filter pack and development; and
   (b) The sampling method to monitor suspended sediment concentrations should be non-intrusive, e.g. hydrosleeve or low flow monitoring, to ensure that sediment is not re-suspended during sampling or that down gradient clean water is not brought into the bore in a manner that could cause dilution.

General

7. The water conveyancing system shall be maintained to minimise water leakage.

8. This consent shall not be exercised to the detriment of any existing lawful water user.

9. The consent holder shall ensure that the discharge authorised by this consent does not cause any flooding, erosion, scouring, land instability or property damage. Should such effects occur due to the exercise of this consent, the consent holder shall, if so required by the Consent Authority and at no cost to the Consent Authority, take all such action as the Consent Authority may require to remedy any such damage.

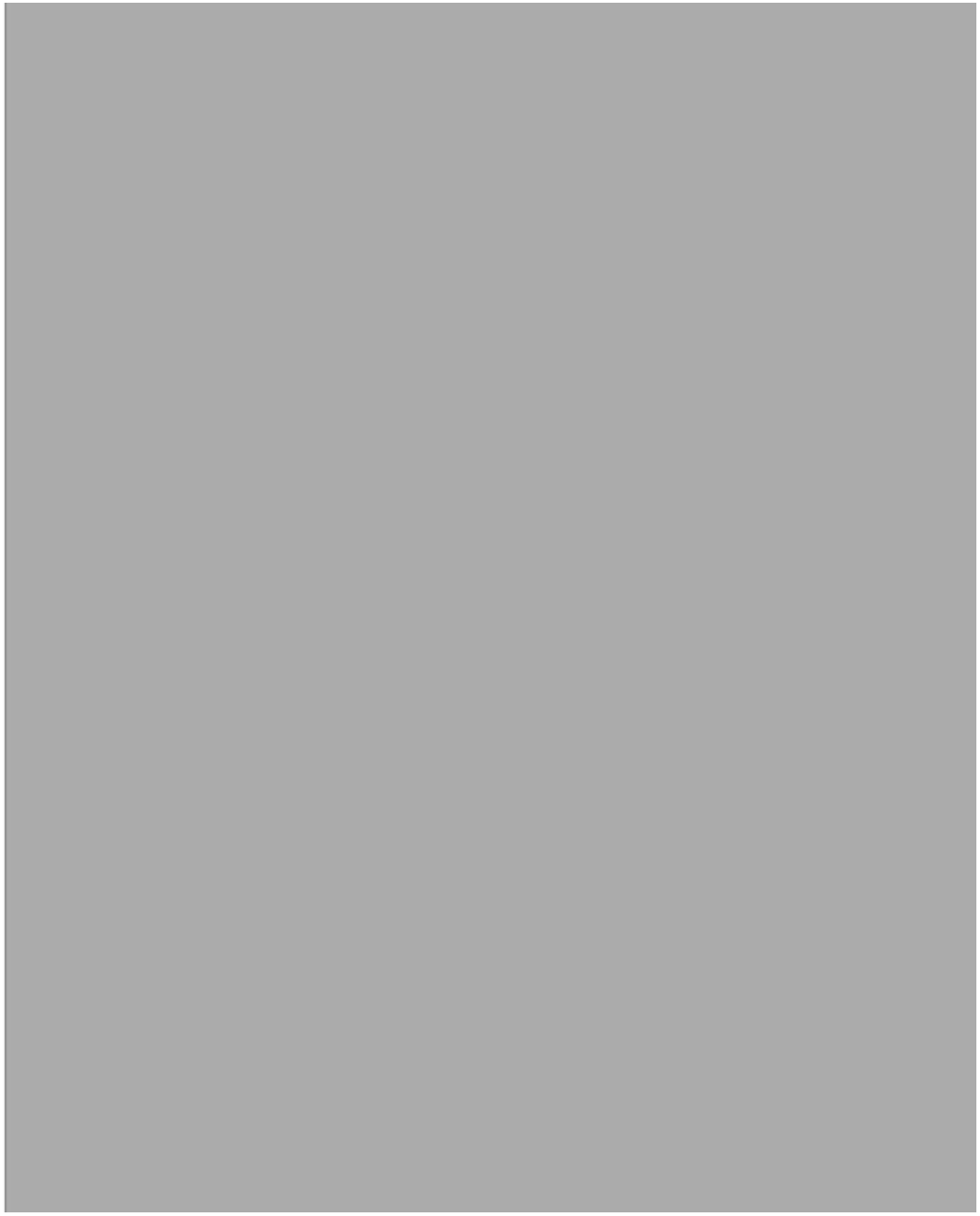
Review

10. The Consent Authority may, in accordance with Sections 128 and 129 of the Resource Management Act 1991, serve notice on the consent holder of its intention to review the conditions of this consent within 3 months of each anniversary of the commencement of this consent for the purpose of:
    (a) adjusting the consented rate of water under condition x, should future changes in water use indicate that the consented rate is not able to be fully utilised; or
    (b) determining whether the conditions of this consent are adequate to deal with any adverse effect on the environment which may arise from the exercise of the consent and which it is appropriate to deal with at a later stage; or

(c) ensuring the conditions of this consent are consistent with any National Environmental Standards; or
(d) Imposing, adjusting or altering a method of water take data measuring, recording and transmission.

Issued at Dunedin this 20th day of July 2016.
Reissued at Dunedin this 29th day of April 2019 to correct a minor typographical error in Condition 6.

Joanna Gilroy
Manager Consents

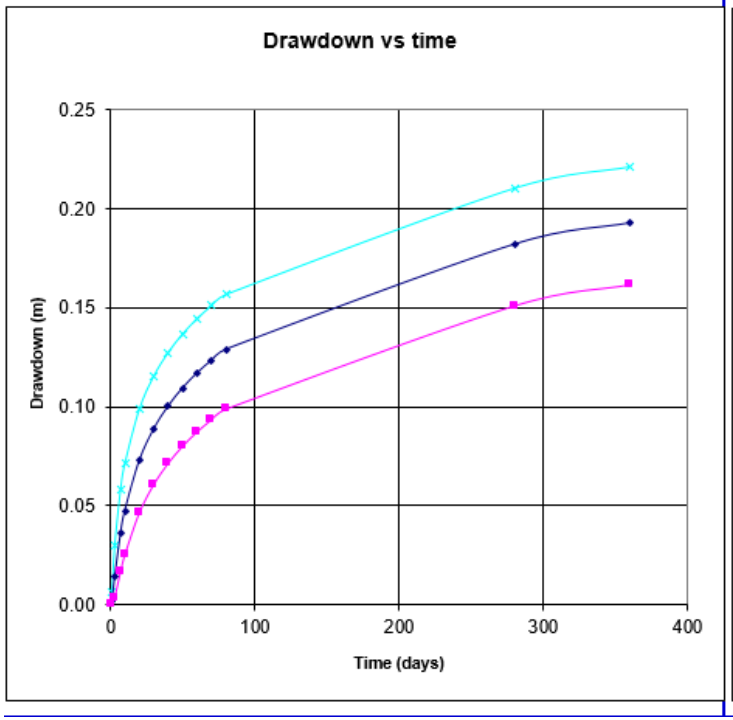


Appendix B Bore interference modelling data - original (additional available on request)

Time-drawdown calculations using Theis equation

Aquifer parameters		
T	1100	m2/d
S	0.1	
B		
Pumping rate		
Q	6.9	l/s

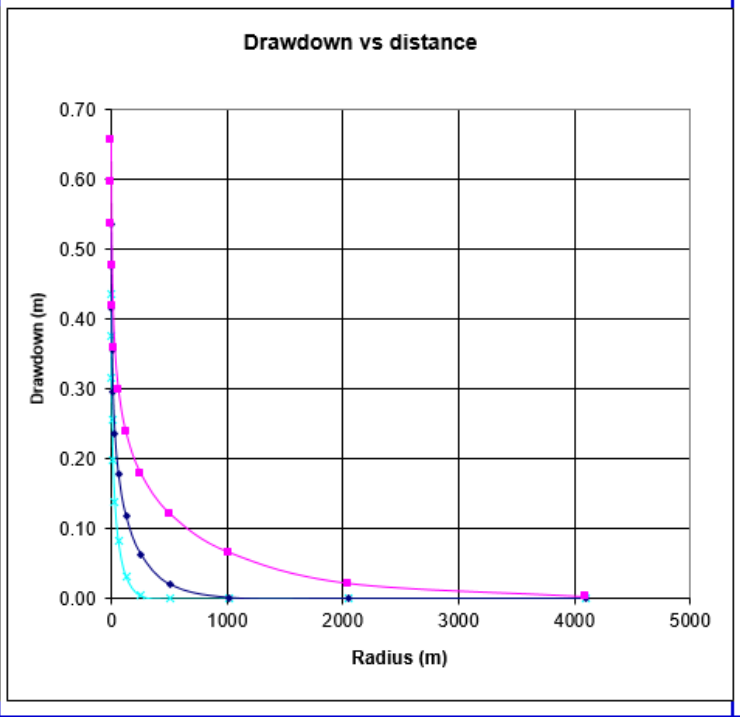
Radius (m)	230	320	461
Time (days)	Drawdown (m)	Drawdown (m)	Drawdown (m)
1	0.007	0.001	0.000
3	0.030	0.014	0.004
7	0.058	0.036	0.016
10	0.072	0.047	0.025
20	0.099	0.073	0.046
30	0.116	0.089	0.061
40	0.128	0.100	0.071
50	0.137	0.109	0.080
60	0.145	0.117	0.087
70	0.151	0.123	0.093
80	0.157	0.129	0.099
280	0.210	0.182	0.151
360	0.221	0.193	0.162



Distance-drawdown calculations using Theis equation

Aquifer parameters		
T	1100	m2/d
S	0.1	
B		
Pumping rate		
Q	6.9	l/s

Time (days)	1	10	165
Radius (m)	Drawdown (m)	Drawdown (m)	Drawdown (m)
1	0.436	0.536	0.656
2	0.376	0.476	0.597
4	0.317	0.416	0.537
8	0.257	0.356	0.477
16	0.197	0.296	0.417
32	0.138	0.237	0.358
64	0.081	0.177	0.298
128	0.032	0.119	0.238
256	0.004	0.063	0.179
512	0.000	0.020	0.120
1024	-	0.001	0.065
2048	-	0.000	0.021
4096	-	-	0.001



Appendix C: Copy of response to Section 92 request for further information

1 December 2020

Landpro Reference: 19474
Council Reference: RM20.360

Attention: Sarah Davidson
Otago Regional Council
Via email

Dear Sarah

Request for Further Information under Section 92(1) of the Resource Management Act 1991 – Cromwell Certified Concrete

Thank you for your request for further information request dated 12 November 2020. This is our response.

1 Pumping test

"*Please provide a pumping test that meets ORC Form 5 requirements specified on Page 18 of Form 5 for the proposed increased groundwater take. Specific requirements for takes greater than 750m3/day are a 48-hour constant rate pumping test undertaken at the maximum proposed rate. Water level monitoring should include drawdown and recovery in the pumped bore and at least two observation bores within the area of localized drawdown. Static levels must also be monitored for 24 hours prior to the commencement of the test, and a step drawdown aquifer test must be taken with a minimum of 4, 1-hour pumping steps followed by measurement of recovery. An interpretation of the test by a suitably qualified and experienced person must also be provided.*"

We understand that you are effectively asking for further information on aquifer characteristics. You refer to specific pumping tests as "requirements". However, as we understand the situation there is no current regional plan provision that provides for such specific pumping tests to be undertaken as a requirement. The Otago Regional Council (ORC) is entitled to request further information but a specific method in an application form is not a legal "requirement".

We appreciate that under RMA Section 67(g) regional plans can specify information to be included in resource consent applications. However, our understanding of RMA Section 92 is that further information requests should:

- "directly relate to the actual and potential effects of the proposed activity on the environment and how any adverse effects may be avoided, remedied or mitigated
- be focused and lead to a better understanding of the nature of the proposed activity
- consider the implications of affected persons excluding trade competitors or the effects of trade competition (s104(3)(a)(i))
- where necessary, clarify aspects of the proposal to understand its likely effects and ensure that conditions are reasonable."[31]

[31] https://www.qualityplanning.org.nz/node/565

You will appreciate that a key purpose of a pumping test is to estimate the hydraulic properties of an aquifer to then use that information to assess potential bore interference and stream depletion. In that context it is generally accepted that it is useful to complement any pumping test result with other pumping test information and a broad understanding of the hydrogeology of an area. A pumping test was provided, reviewed by PDP, and accepted for this bore five years ago. It is not reasonable or justifiable to do another aquifer test because of an increase in the amount of water sought. An increase in the amount of water proposed to be taken from a bore in this location is highly unlikely to change the hydraulic properties of the aquifer.

We do accept that ORC needs reassurance that the aquifer characteristics are robustly determined and the subsequent assessments are similarly robust. To assist with that we have carefully reviewed all the aquifer test information that we have for this area.

We have also made a request for aquifer test information from bores in this location held only by ORC. However, it appears that it is currently not possible to obtain aquifer test information for bores in this location from ORC. The following figure summarises the information for other bores that Landpro currently has available for the area.

Figure 1 Illustration of bores with aquifer testing information

This information together with the original review undertaken by PDP strongly support a conclusion that the transmissivity value of 1,100 m^2/day used in the original application is appropriately conservative. The above information would support the choice of a higher transmissivity which would decrease the estimated drawdown. Consequently we consider that our original conclusions about effects on neighbouring bore are valid and this additional assessment strongly indicates that our assessment of the level of drawdown almost certainly over-estimates the drawdown effects on neighbouring bores.

We consider that there is a sufficient body of information to be able to draw a robust conclusion about the level of adverse effects on groundwater levels in neighbouring bores and an additional aquifer test is not warranted.

We consider that the information provided here satisfies your request for further information. If you do not consider that this is the case could you let us know.

2 Breakdown of water use

"The stated water use in the application specifies water will be used for gravel washing, dust suppression and irrigation, and potable use. No breakdown of the different uses has been provided to demonstrate the likely percentage of consumptive use. Please provide this breakdown."

An assessment of the breakdown of water use has been undertaken and is outlined in the following table.

	Volume (m^3)/day	Percentage of total
Crushing Plant	2,768	91.5%
Water Cart	240 (20m^3 x 12 times/day)	8%
Irrigation	15	0.5%
Potable Use/Washdown	1 (rounding up)	Negligible
TOTAL:	3,024	100

The reason for requesting this information was not specified. However, we assume that it was to assist in estimating the proportion of water that is likely to be returned to the aquifer. This is discussed in the next section.

3 Soakage pit operation and evaporation losses

"*The application notes soakage pits are used, where groundwater is returned to the source aquifer. Please provide more information on the operation of the soakage pits, including evaporation losses*."

The soakage pits receive runoff washwater from the crushing operations as illustrated in the aerial photo below. Runoff water is directed firstly to the eastern smaller pond and then on to the western elongated rectangular pond. Sediment that collects in the first pond is used for backfill on site or sale. The pits have operated successfully for many years with minimal maintenance. You will be aware that there is a programme of

groundwater quality monitoring to assess the potential for sediment to travel into groundwater. I have seen the groundwater quality monitoring results that demonstrate that this is not happening.

Figure 1: Aerial image of the soakage ponds with adjacent crushing plant

You have asked about evaporation losses. The graph below illustrates the monthly balance at Cromwell between rainfall and evapotranspiration.

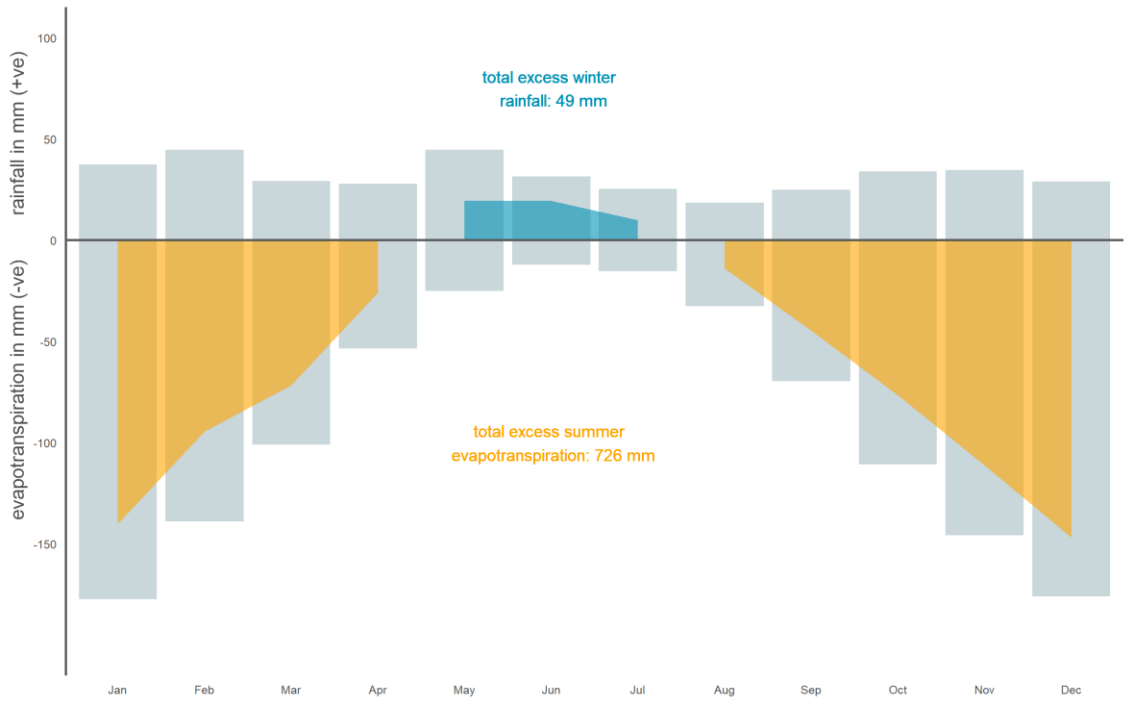


Figure 2: Average monthly climate data for Cromwell (evapotranspiration significantly exceeding rainfall during the summer months) Data source: NIWA Cliflo database, Cromwell EWS station, May 2006-December 2018.

Grow Otago[32] estimates the soil moisture deficit to be an annual mean of approximately 420 mm and the total area of the soakage pits is approximately 4,140 m^2. Therefore on average the ponds will lose approximately 1,739 m^3/year as evaporation.

As noted above, we assume that the reason that this information has been requested is because the reviewer expressed concerns that there should be a more accurate estimate made of return flows.

The daily water applied to land either as aggregate washing or via the water tank keep dust down is approximately 3,000 m^3/day and use the Grow Otago maximum (1950 – 1984) monthly soil moisture deficit for January of 175 mm. Then if we increase the evaporation up to 185 mm to take account of some climate change and/or a really hot and windy January. Then if we assume that evaporation occurred over this whole area, up to about 60,000 m^2 we would have:

Input ~ say 30 days x 3,000 = 90,000 m^3

Evaporation ~ 185 mm over say an evaporation surface area of 60,000 m^2 = 11,100 m^3

This indicates that about 12% of the water applied to land would evaporate in the hottest month of the year, with about 88% going back into the aquifer.

The amounts taken for irrigation and potable water use are negligible.

[32] http://growotago.orc.govt.nz/docs/climate_tables.html

While the above calculations are crude they do strongly indicate that the amount of consumptive water use will be significantly less than 20%. Therefore, the earlier estimates of 30% consumptive use is still supported as a conservative estimate of water use.

4 Assessment of effects of flows further downstream in the Amisfield Burn

"*As the Amisfield Burn flows towards Lake Dunstan, the depth to groundwater decreases and it may become connected to groundwater. The Amisfield Burn is identified in Schedule 1A of the Regional Plan: Water for Otago (RPW) and provides habitat for koaro. Please provide an assessment of effects of the increased groundwater take on the flow further downstream of the Amisfield Burn, as this could impact spawning fish species*."

Our original report stated "*At the time of the assessment in 2016, stream depletion and aquifer allocation effects were considered to be insignificant. That situation will not change as a consequence of the proposed increase in abstraction. The evidence that the vertical distance between the Amisfield Burn and the underlying groundwater surface is approximately 20 metres has not changed. Therefore, this means that it is virtually certain that there is no connection between the underlying groundwater and the Amisfield Burn*." That situation has not changed.

You may be aware of some commonly used stream depletion guidelines[33] that use a rule of thumb of twice the width of a stream and five times the depth of water in the stream. Using these would also strongly indicate that the abstractions could not affect a stream so far above groundwater levels.

If the abstraction of water occurred closer to Lake Dunstan the distance between the Amisfield Burn and groundwater would be less but the proposal is to abstract water from the current bore locations not from bore locations closer to the lake.

[33] Smith M (2009) Techniques for evaluating stream depletion effect: A supplement to the guidelines for the assessment of groundwater abstraction effects on stream flow(2000), Report No. R09/53, Environment Canterbury.

Figure 3 Illustration showing bore locations and Amisfield Burn (bore locations from ORC GIS, including bore G41/0101 that does not exist)

We think that the question is assuming that there would be some physical connection between groundwater and the overlying Amisfield Burn. However, the technical evidence does not support this. Evidence provided by Pattle Delamore Partners for the ORC at a recent resource consent hearing[34] supports this view. Those authors stated: "*A review of bores on the ORC database shows that the closest potentially effected (sic) bores are generally in the vicinity of SH6 flanking each side of the Amisfield Burn. These bores are around 30 m deep (within the area of Late Pleistocene and Holocene gravelly river deposits at the land surface) with relatively deep groundwater levels up to about 20 m bgl. The bores transition to have slightly shallower depths with shallower depth to groundwater observations toward Lake Dunstan in the vicinity of the Amisfield Burn. This is most notably demonstrated by bore G41/0346 (15 m deep with a 3.5 m depth to groundwater) adjacent to Lake Dunstan and the Amisfield Burn point of discharge into the lake*."

Therefore, it would take more than 400 m towards the lake before the depth to groundwater would even approach the ECan 'rule of thumb' depth of 10 m (five time the 2 metre width of the Amisfield Burn) to groundwater. Even then stream depletion still needs a physical connection. If there is approximately 10 m of unsaturated gravelly alluvium between groundwater and the overlying stream this would not provide a physical mechanism for a groundwater abstraction to affect surface water 10 metres above.

[34] https://www.orc.govt.nz/media/8962/rm20007-smallburn_limited-groundwater-assessment.pdf

Therefore after further analysis of the available information we consider that there is extremely strong evidence that the proposed abstraction will not adversely affects flows at any point in the Amisfield Burn.

5 Permitted activity

"*The taking of up to 1000 m3/day, at a maximum rate of take of 100 l/s from Lake Dunstan is a permitted activity under Rule 12.1.2.2 of the RPW. It has been observed that the water levels in the mine pit pond fluctuate in response to changes in the water level in Lake Dunstan. Please provide an assessment against this Rule, to determine if the activity is permitted under this Rule*."

We are not aware of any study that has been undertaken on levels in the soakage ponds and Lake Dunstan levels. However, we would expect there to be a relationship given the porosity of the aquifer and the proximity to the lake.

The fact that there is likely to be a relationship between the soakage pond levels and the level of water in Laker Dunstan is not evidence to extend the definition of Lake Dunstan for the purpose of the Regional Plan: Water for Otago (RPW) Rule 12.1.2.2. We don't consider that any reasonable interpretation of RPW Rule 12.1.2.2 could extend the definition of Lake Dunstan to include a pond 900 metres away from the lake. So we do not consider that the proposed take is a permitted activity under RPW Rule 12.1.2.2.

6 Other matters

Bore interference and Bore G41/0456 pump test

The e3 Scientific report (thanks for providing that) refers to a pump test of G41/0456 while the earlier ORC report referred to a pumping test on G41/0455. There may be a bore numbering error in the earlier report. We have attached a copy of the full original pumping test as Appendix A.

The basis for assessing effects on persons

We note that the e3 Scientific report states that the Landpro assessment of effects should not be considered and instead "*Regardless of this, the significance of bore interference must be determined based on the provisions of the current Regional Water Plan for Otago…*" Just in case any weight is given to this comment; this is not an accurate statement of the requirements of the RMA notification provisions. Those provisions, particularly Section 95E, require an assessment of effects not simply a comparison with a methodology in a regional plan schedule that is specific to the RPW information requirements. We are not aware of any case law that supports the view that a method specified in a plan for information provision overrides the requirement of the RMA to consider effects.

Kind Regards

Mike Freeman
Senior Scientist/Planner

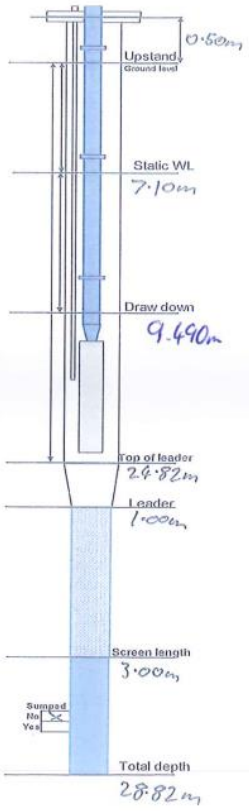
Matt Curran
Senior Planner

Appendix A Copy of full pumping test for bore G41/0456

mcneill — DRILLING ■ DISTRIBUTION ■ PUMPING — SINCE 1918

Client Name:	Amisfield Quarry (Mcneill's)	Home No.	
		Cell No.	
Address	1248 Cromwell – Kingsgate Hwy	Consent No.	
	SH8 Cromwell		
Grid Reference	E- 1305502	N- 5017223	
Driller	Neil Simmons		
Machine/Rig:	DR24	Fleet No. 282	
Drill Method:	Rotary / reverse		
Bore diameter mm	300mm		
Start date:	19/11/15	Finish Date: 20/11/15	
Development Hours:	5.25	Development Method: air surge	
Screen Slot: 2.5 mm	ID 2.56 mm	OD 2.73 mm	
PVC slotted	Top m	Bottom m	
Total casing used:	26.27 m	Total Depth: 28.82 m	
Sump length: N/A	m	Sump Diameter:	mm
Test Pumping	Air lifted	Pumped ✓	Rate: 25.5 LPS
Test Pump period	8 Hrs	Pump intake: 25m	m
Bacterial Water test	Yes	No	
Chemical Water test	Yes	No	
Casing top sealed	Yes ✓	No	
Impervious seal al ground	Yes	No	
Over Drilled	Yes	No ✓	m

Comments:
0–22.2 Gravels
22.2–24 Sandy Gravels
24–28.9 Gravels



Type of Test: 8 hour test

Project: Amisfield Quarry

Name of abstraction well: 12" Main — Location GPS: E1305502

Name of observation well: — Location GPS: N 5017223

Distance of observation well from abstraction well:

Depth: 28.82m — Diameter: 12"

Lining details: Casing: Steel

Perforations / screen: 2.5m slots 3m S/S

Date of test: Start: 1/12/15 — Finish: 1/12/15

Pump: Type: 2/ Plunger — Depth of pump inlet: 25m

Initial water level: 7.290m — Above / below datum: 500m

Datum point: 500m — Above / below ground level:

Logger serial no: — Logger level below datum:

Observers: Richard Cook

Remarks:

Weather: Hot with some Wind No Rain

Date	Actual Time	Intervals Hours	Elapsed Time (t) (min)	Water level above / below datum (m)	Change in water levels (s)	Remarks
1/9/15	6.40			7.290		
	6.41		1	9.510	2.220	
	6.42		2	9.430	.080	
	6.43		3	9.420	.010	
	6.44		4	9.425	.005	
	6.45		5	9.425	Nil	25.3 LPS
	6.50		10	9.440	.015	25.3 LPS
	6.55		15	9.445	.005	25.3 LPS
	7.00		20	9.445	Nil	25.4 LPS
	7.05		25	9.450	.005	25.4 LPS
	7.10		30	9.455	.005	25.4 LPS
	7.20		40	9.460	.005	25.5 LPS
	7.30		50	9.460	Nil	25.6 LPS
	7.40	1	60	9.465	.005	25.6 LPS

Date	Actual Time	Intervals Hours	Elapsed Time (t) (min)	Water level above / below datum (m)	Change in water levels (s)	Remarks
	8.10			9.465	Nil	25.5 LPS
	8.40			9.475	.010	25.5 LPS
	9.10			9.480	.005	25.6 LPS
	9.40			9.480	Nil	25.5 LPS
	10.10			9.485	.005	25.5 LPS
	10.40			9.485	Nil	25.5 LPS
	11.10			9.485	Nil	25.4 LPS
	11.40			9.485	Nil	25.5 LPS
	12.10 pm			9.490	.005	25.5 LPS
	12.40			9.490	Nil	25.5 LPS
	1.10			9.490	Nil	25.5 LPS
	1.40			9.490	Nil	25.5 LPS
	2.10			9.490	Nil	25.5 LPS
	2.40			9.490	Nil	25.5 LPS

Recovery Data

Type of Test: 8 Low test

Project: Amisfield Quarry

Name of abstraction well: 12" Main Location GPS: E1305502

Name of observation well: .. Location GPS: N5017223

Distance of observation well from abstraction well: ..

Static Water Level: 7.290 Pumping Drawdown: 9.490 90 percent of recovery: ..

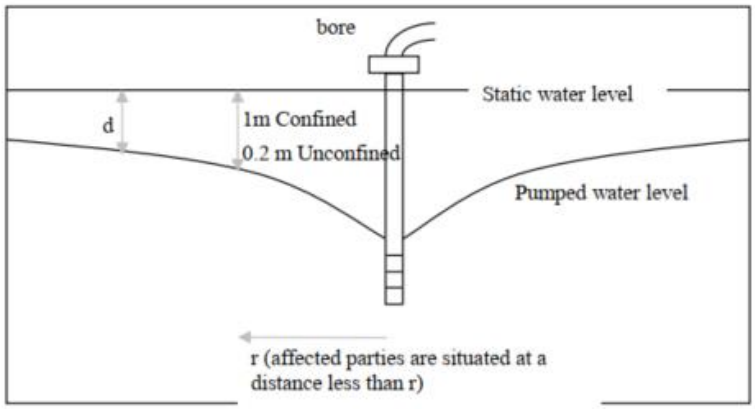
Date	Actual Time	Elapsed Time (t) (min)	Water level above / below datum (m)	Change in water levels (s)	Remarks
1/12/15	2.40pm	0 sec	9.490		
		.10 sec	7.560	1.93	
		20 sec			
		30 sec	7.410	.150	
		40 sec	7.340	.070	
		50 sec	7.330	.010	
	2.41	1 minute	7.330	Nil	
	2.42	2 minutes	7.325	.005	
	2.43	3 minutes	7.325	Nil	
	2.44	4 minutes	7.320	.005	
	2.45	5 minutes	7.320	Nil	
	2.46	6 minutes	7.320	Nil	
	2.47	7 minutes	7.320	Nil	
	2.48	8 minutes	7.320	Nil	
	2.49	9 minutes	7.320	Nil	
	2.50	10 minutes	7.320	Nil	
	2.51	11 minutes	7.320	Nil	
	2.52	12 minutes	7.320	Nil	
	2.53	13 minutes	7.320	Nil	
	2.54	14 minutes	7.320	Nil	

Date	Actual Time	Elapsed Time (t) (min)	Water level above / below datum (m)	Change in water levels (s)	Remarks	Date
	2.55	15 minutes	7.320	Nil		
	3.00	20 minutes	7.320	Nil		
	3.05	25 minutes	7.320	Nil		
	3.10	30 minutes	7.320	Nil		
	3.15	35 minutes	7.320	Nil		
	3.20	40 minutes	7.320	Nil		
	3.25	45 minutes	7.320	Nil		
	3.30	50 minutes	7.320	Nil		
	3.35	55 minutes	7.320	Nil		
	3.40	60 minutes	7.320	Nil		

Appendix D: Regional Plan: Water for Otago, Schedule 5B

5B Schedule of method for identifying groundwater takes potentially affected by bore interference

This schedule is the method for identifying parties likely to be affected by bore interference when a new application to take groundwater is received. The significance of any interference may result in limits being placed through conditions on permits to take groundwater, depending on distance from another bore, and may limit the instantaneous take of groundwater from any one bore in order to maintain existing access to water.



The radius will be determined using a significant interference of $d \geq 1$ m for confined aquifers or $d \geq 0.2$ m for unconfined aquifers, and the 'Theis' equation:

$$d = QW(u)/4\pi T \text{ where } u=r^2S/4Tt$$

Also where:

d is the interference

Q is the pumping rate from the bore

W(u) is the "well equation", approximated by a Taylor series:

$-0.5772 - \ln(u) + u - u2/2 \cdot 2! + u3/3 \cdot 3! - \ldots$

r is the distance from the pumping bore

S is specific yield/storativity of the unconfined/confined aquifer

t is the time or duration of pumping

T is the transmissivity of the aquifer

For clarification, the variables required for the 'Theis' equation will be quantified as follows:

Q from the consent application: maximum daily volume

r from maps, aerial photos, or preferably GPS coordinates

T and S from pumping tests or conservative estimates

t (in days) from consent application: maximum annual volume divided by the maximum daily volume

If a variable cannot be estimated from the consent application or the applicant did not supply the information, the Council will estimate it on an environmentally conservative basis.

Appendix E: Water quality sample results for samples taken on 5 October 2021 (units g/m^3, except where indicated)

Water quality variables	G41/0321	G41/0456	G41/0111	NZ Drinking water Stds
pH (no units)	7.8	7.7	7.6	7.0 – 8.5
Electrical conductivity (mS/m)	13.3	12.2	5.8	N/A
Total suspended solids	5	<3	6	N/A
Turbidity (NTU)	19	3.1	16.5	2.5
Total alkalinity	64	56	27	N/A
Free CO_2	2.1	2.3	1.2	N/A
Total hardness	55	50	25	200
Electrical conductivity (mS/m)	13.3	12.2	5.8	N/A
Approx. total dissolved salts	89	82	39	1,000
Total boron	0.0143	0.0085	< 0.0053	1.4
Total calcium	15.5	15.2	8	N/A
Total iron	3.8	0.78	2.7	0.2
Total magnesium	4	3.1	1.36	N/A
Total manganese	0.023	0.074	0.0189	0.04
Total potassium	0.93	1	0.53	N/A
Total sodium	6.3	4.9	1.65	200
Chloride	1.3	1.1	0.7	250
Nitrate-N	0.24	0.37	0.06	11.3
Sulphate	2.2	2.9	1.8	250
Total arsenic	< 0.0011	< 0.0011	< 0.0011	0.01
Total cadmium	< 0.000053	< 0.000053	< 0.000053	0.004
Total chromium	< 0.00053	< 0.00053	< 0.00053	0.05
Total copper	< 0.00053	< 0.00053	0.00087	2 (1)
Total lead	0.00144	0.00061	0.00022	0.01
Total nickel	0.0007	< 0.00053	0.00076	0.08
Total zinc	0.97	0.53	0.0013	1.5

NZ Drinking Water Standards – Orange shaded = MAV (Maximum acceptable value – health significance)
Green shaded = guideline values for aesthetic reasons
Red text = exceedance of aesthetic guidelines.