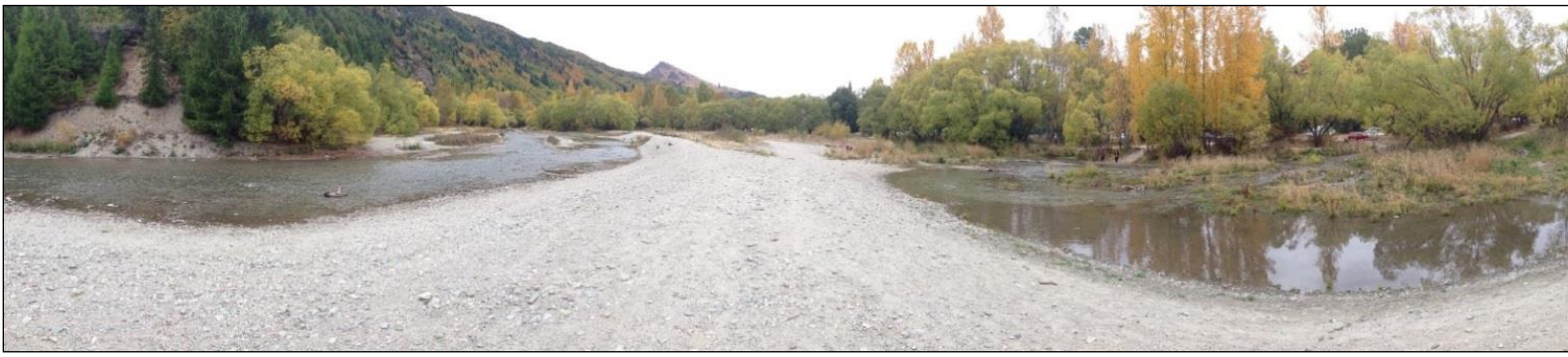
Groundwater Report:
Arrow-Bush Ribbon Aquifer

June 2017



Otago Regional Council

Report writer: Frederika Mourot, Resource Scientist
Subject: Groundwater report: Arrow-Bush Ribbon Aquifer

Date: June 2017

1. Background

The Arrow- Bush Ribbon Aquifer (ABRA) is located within the lower part of the Arrow River Catchment, and along the northern boundary of the former Wakatipu Basin Aquifer, as shown in Figure 1.1:

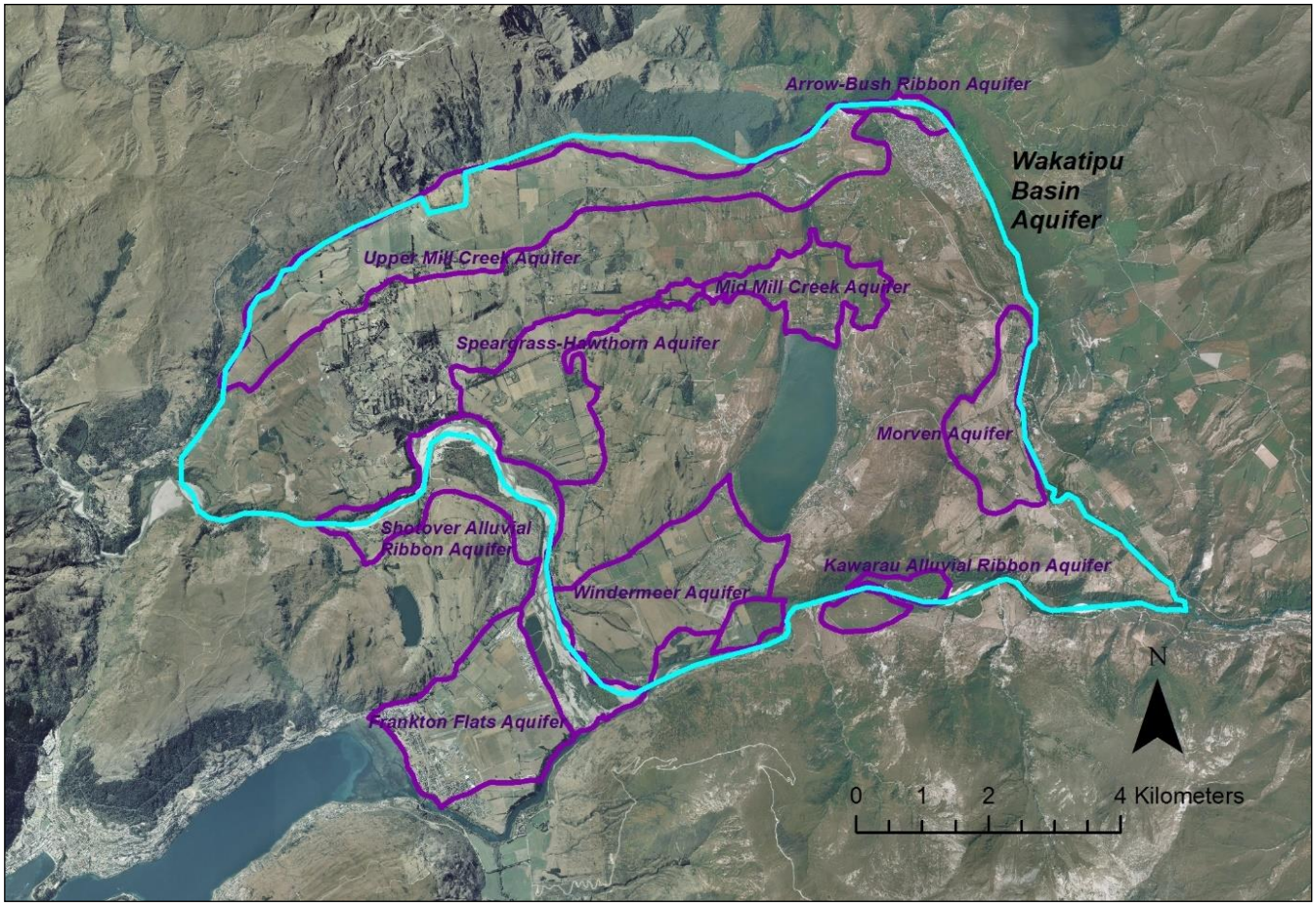


Figure 1.1 Arrow-Bush Ribbon Aquifer Location Map

Slightly upstream of Arrowtown, the Arrow River turns its course. The resulting deceleration has resulted in the aggradation of the level of the bed of the Arrow River and Bush Creek, resulting in the formation of a small alluvial aquifer at the confluence with Bush Creek (ORC, 2014).

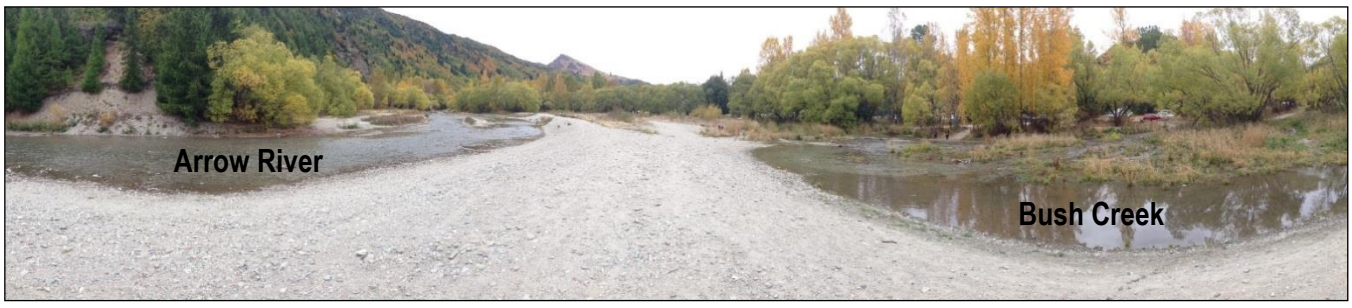


Figure 1.2 Arrow River and Bush Creek Confluence (view looking toward the south)

This aquifer known as Arrow-Bush Ribbon Aquifer is of limited extent, but is nevertheless of local significance as it is supplying drinking water to Arrowtown.

This resource has been briefly described in the ORC “Investigation into the Wakatipu Basin Aquifers” Report, 2014. However, groundwater allocation was not estimated for this aquifer, it was considered as part of the Arrow alluvial ribbon, and therefore to be managed as surface water.

In preparation for a Plan Change for the Arrow River, and to support the Policy development work required, this memorandum aims to provide a summary of the current knowledge of the Arrow-Bush Ribbon Aquifer.

The information presented in this memo was prepared based on existing studies (hydrogeological investigations carried out for a groundwater take consent application for Arrowtown Water Supply), and not on additional recent surveys or monitoring.

2. Drilling Investigations and Aquifer Geometry

The drilling works and subsurface investigation campaigns carried out over the Arrow-Bush Ribbon Aquifer are summarised hereafter:

- In October 1999, the Queenstown Lake District Council (QLDC) drilled a 400 mm diameter well; known as Bore 1 (or F41/0246) to supply drinking water to Arrowtown ;

- Shortly after in December 1999, a subsurface investigation campaign was implemented by Mac Neill Drilling for Duffill Watts & King. Nine boreholes were drilled: along the Bush Creek left bank, at the confluence between Bush Creek - Arrow River, and further down along the Arrow River flood plain;

- In February 2000, using the results of these investigations, another QLDC water supply well, known as Bore 2 (or F41/0258) was drilled, with a diameter of 400 mm ;

- In August 2006: Eight boreholes were drilled by Mac Neill Drilling for Opus, mainly near the confluence of Bush Creek - Arrow River.

The location of these boreholes is given in Figure 2.1, and a summary of the drilling results in Table 3.1 page 9.

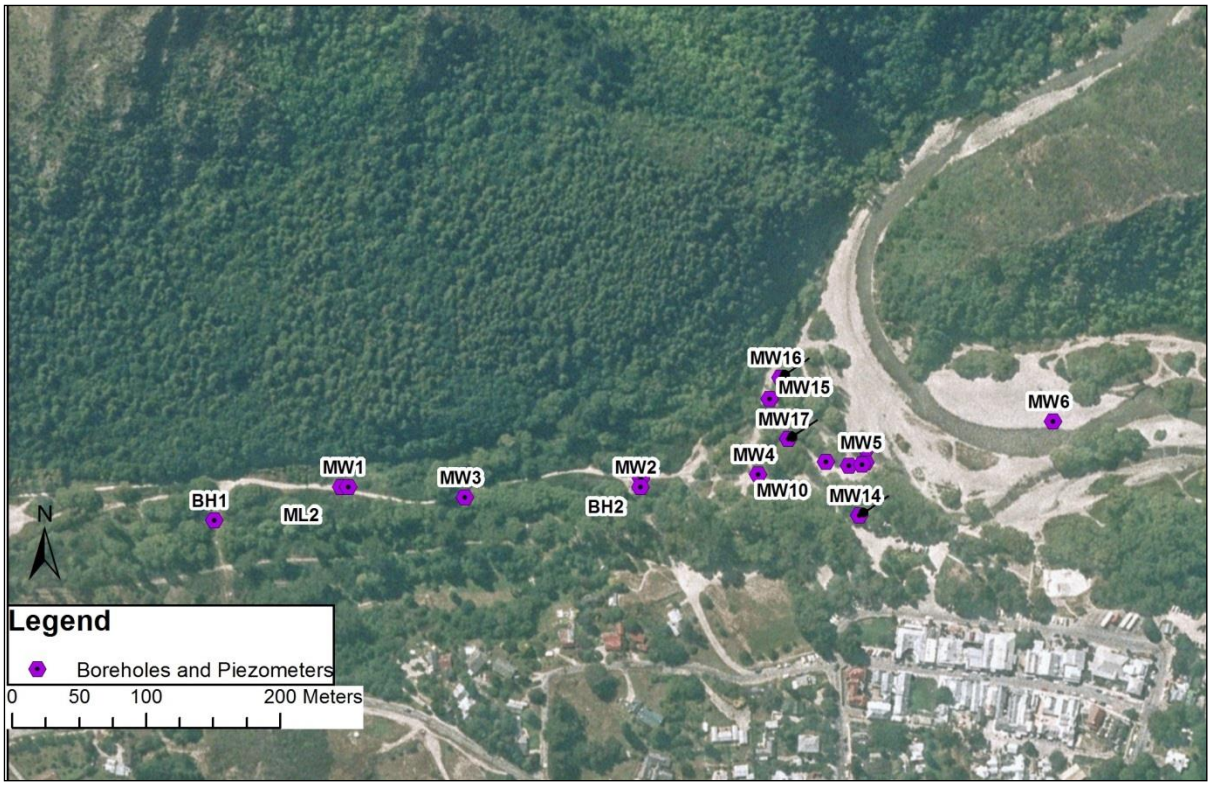


Figure 2.1 Location of the boreholes drilled over the Arrow-Bush Ribbon Aquifer

In July 2014, the "Investigation into the Wakatipu Basin Aquifers Report" set coarse boundaries for the Arrow-Bush Ribbon Aquifer. Shortly after (August 2014), refined boundaries were proposed to better match the physical boundaries and especially the topography, as illustrated in Figure 2.2.

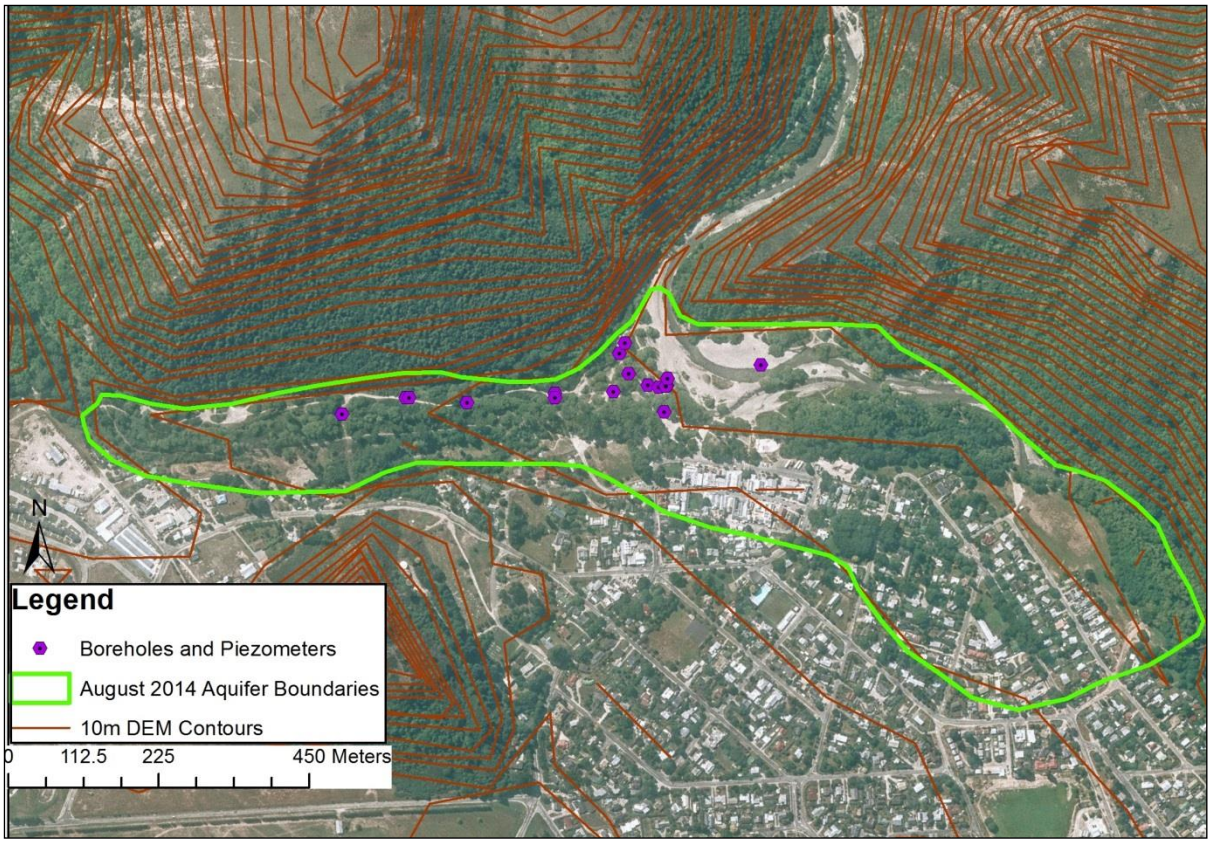


Figure 2.2 Arrow-Bush Ribbon Aquifer Boundaries

The aquifer is located between the emergence of Bush Creek from a schist rock gorge for its western boundary to approximately Ford Street alignment for its lower and eastern extent, with a length of about 1.7 kilometres and an approximate area of 40 hectares.

Its location in the narrow Bush Creek valley limits its lateral extent in the upper part with an approximate width of 150m. The aquifer widens in the Arrow Valley, with an approximate width of 360m in its lower part.

Figure 2.3 represents a simplistic cross section (not to scale and very approximate) of the valley containing the upper part of the Arrow-Bush Ribbon Aquifer:

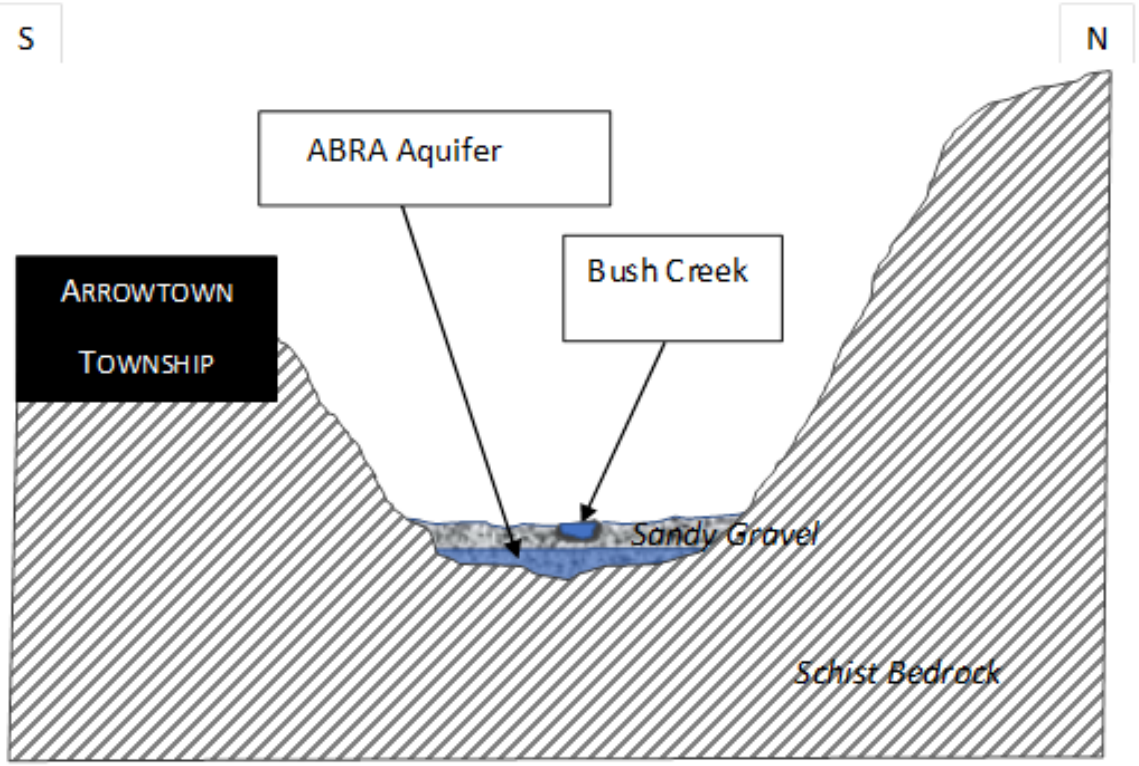


Figure 2.3 Simplistic Cross section of upper part of the ABRA

Photographs taken during a site visit carried out on the 11th April 2017 are presented in Figure 2.4 and provide an overview of the area of interest.

Flat along the left bank of Bush Creek, over the upper part of the ABRA

Bush Creek downstream the gorge

Schist Outcrop near the gorge

Bush Creek near the confluence

Sandy gravels near the confluence

Arrow River at the confluence with Bush Creek

Bush Creek at the confluence with Arrow River

Arrow River downstream the confluence

Arrow River at the ABRA lower boundary

Figure 2.4 Site Photos (11/04/2017)

3. Geological Layout and Drilling Materials

The GNS Geological Map (1:250 000 Geological Map of New Zealand - QMAP) is outlining the geological units identified within the area of interest, as shown in Figure 3.1.

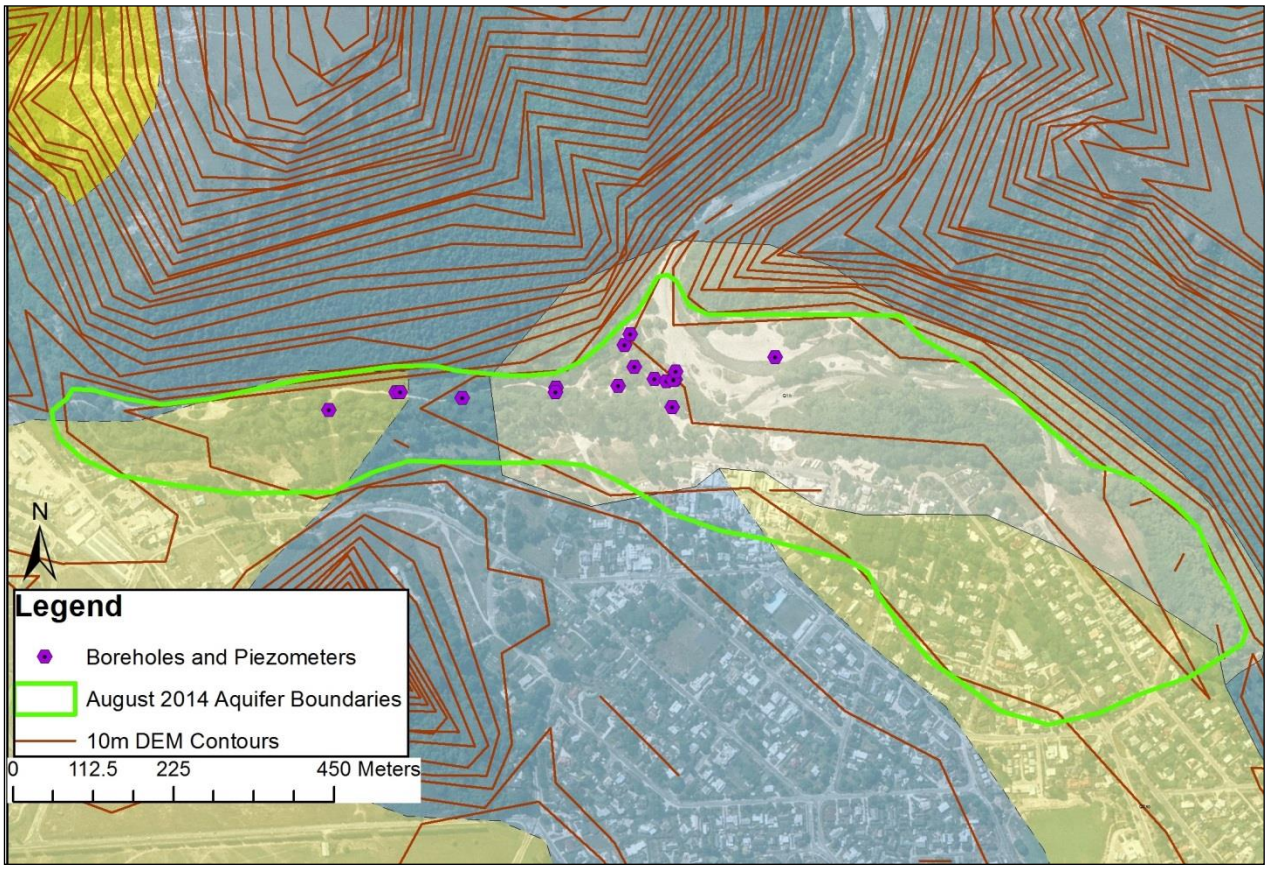


Figure 3.1 Geological Map of the area

According to the GNS Q Map, the Arrow-Bush Ribbon Aquifer is made of:

- Late Pleistocene outwash deposit, described as generally unweathered, well sorted, loose, sandy to bouldery gravel forming large terraces and outwash plains;
- Holocene mining waste, described as well sorted sandy quartz, schist & sandstone gravels in dredge tailings and sluicing deposits; anthropomorphic fossils ;
- And underlain/surrounded by Pelitic Schist (Rakaia terrane), described as very well segregated and laminated; abundant pelitic & subordinate psammitic greyschist; minor greenschist & metachert.

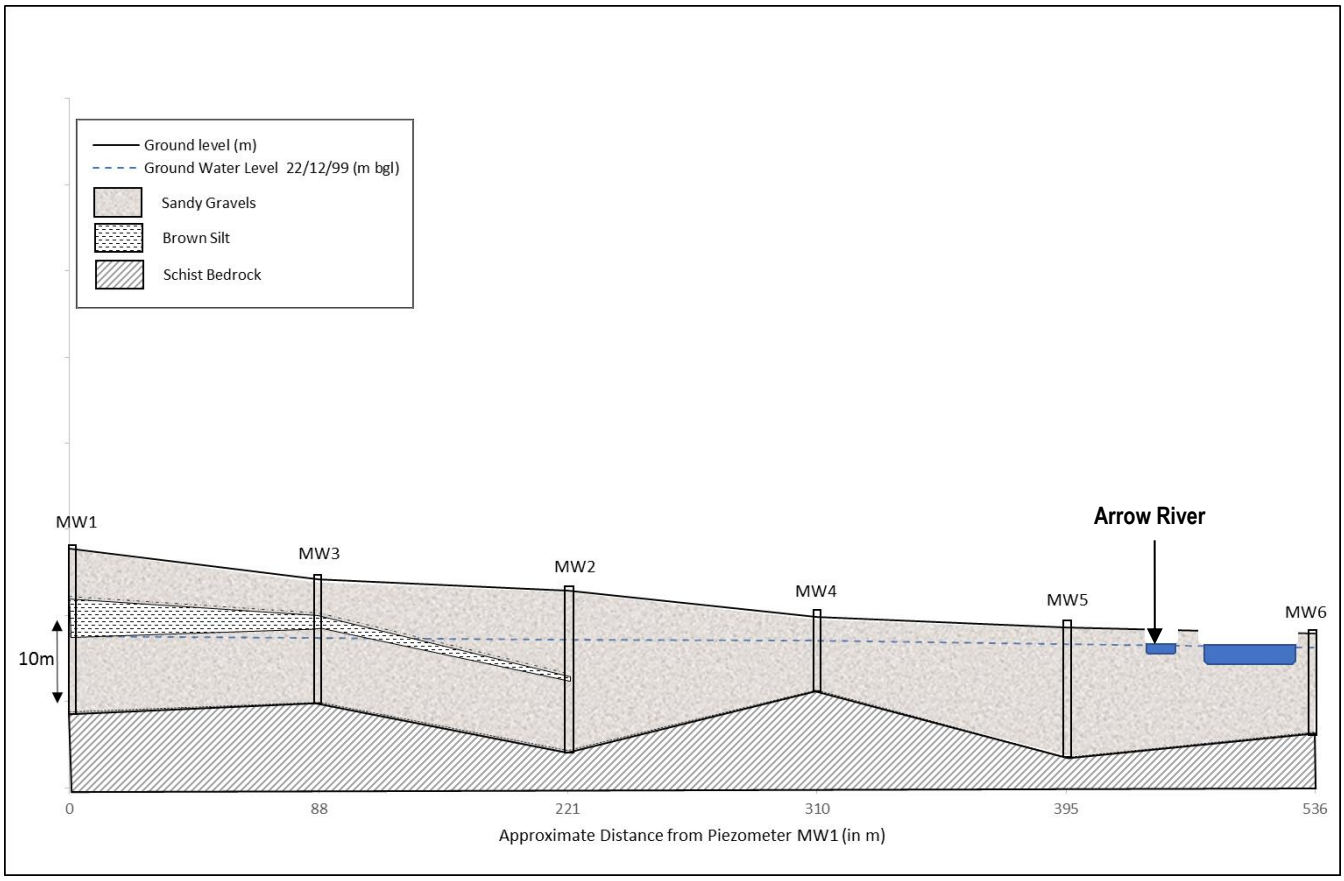
Over the two drilling campaigns, the materials encountered were:

- Sandy gravels (with a variable thickness of 9-19m for the upper part of the aquifer, and 2-11m near the confluence),
- Underlain by a schist bedrock (with a variable depth of 4.5-19m) identified as moderately to highly weathered.
- A silty horizon has also been identified during the drilling of a couple of bores (with a variable thickness of 0.2-4.4m).

Borehole Id.	Drilling Date	Groundwater Level (m)	Date of the measurement	Depth to bedrock (m)	Saturated thickness of sand and gravels (m)	Presence of a silty horizon	Depth of the bottom of a silty horizon (m)	Thickness of a silty horizon (m)
Bore 1	26/10/1999	Unknown - No Bore Log available						
Bore 2	6/02/2000							
Piezo L2	likely Oct.99							
MW1	17/12/1999	10.15	23/12/1999	19	8.85	Yes	9.9	4.4
MW3	17/12/1999	6.85	22/12/1999	14.3	7.45	Yes	5.4	1.5
MW2	17/12/1999	5.7	24/12/1999	18.6	12.9	Yes	10.2	0.6
MW4	17/12/1999	2.75	22/12/1999	8.5	5.75	No		
MW5	17/12/1999	2	22/12/1999	15.1	13.1	No		
MW6	18/12/1999	1.6	22/12/1999	11.4	9.8	No		
MW10	2/08/2006	3.17	2/08/2006	6.5	3.33	No		
MW11	2/08/2006	3.14	2/08/2006	7.4	4.26	Yes	5.2	0.2
MW12	2/08/2006	2.8	2/08/2006	9.3	6.5	No		
MW13	2/08/2006	2.7	2/08/2006	13.4	10.7	No		
MW14	2/08/2006	2.9	2/08/2006	4.5	1.6	No		
MW15	2/08/2006	3.4	2/08/2006	12.1	8.7	No		
MW16	3/08/2006	2.7	3/08/2006	7.4	4.7	No		
MW17	3/08/2006	3.45	3/08/2006	11.3	7.85	Yes	3.4	0.3

Table 3.1 Summary of the results of drilling investigations in the Arrow-Bush Ribbon Aquifer, including material encountered (depths are given in meter below ground).

Based on these results a schematic longitudinal cross section for the upper part of the aquifer has been sketched in Figure 3.2:



Comment: Bore locations are given on Figure 2.1

Figure 3.2 Longitudinal Cross Section of the ABRA Upper Part

These results show that the aquifer thickness is quite variable over the aquifer. The QLDC water Supply Bore 2 has been drilled near MW2, where the saturated sandy gravels thickness was the largest (MW5 site was recommended too).

The Borehole MW3 is located over the part shown as “Schist” on the geological map (Figure 3.1), however the drilling materials found were outwash deposits over the schist basement, which is more elevated in this area compared to MW1 and MW2.

In summary, the aquifer seems to be quite heterogeneous, with the presence of silty lenses and semi-confined parts. Former river channels filled with higher permeability material may also exist near the confluence.

4. Groundwater levels and Aquifer Properties

It appears that groundwater levels are not continuously recorded within the Arrow-Bush Ribbon Aquifer.

However, the drilling investigations carried out in 2000 and 2006 have provided one-time measurements of the position of the water table. While supplying no indication of the likely seasonal variation, these depths to groundwater still give valuable information.
Interestingly, Duffill Watts & King, 2000 noticed that the static water level dropped 800mm between January and March 2000 near MW2, and that this fluctuation was likely influenced by the water level in the Arrow River.

According to the drilling results, the water table was found to be deeper on the western part of the aquifer (a groundwater level of 10.15 m below ground level (bgl) was measured on the 22/12/99 in the piezometer MW1) and shallower near the confluence (a groundwater level of 1.6 m bgl was measured on the 22/12/99 in MW6). This difference can be linked to the ground surface elevation which is slightly above 410 m for MW1 and around 400 m for MW6.
Kingett Mitchell, 2005 has interpreted that the Bush Creek was not connected to the local water table until near confluence, while the Arrow River was.

Several aquifer tests have been carried out on different bores located within the Arrow-Bush Ribbon Aquifer, the detail is listed in Table 4.1:

Date	Bore tested	Duration (hours)	Pumping Rate (L/s)	Transmissivity (m^2/d)	Specific Yield/Storativity	Tests interpreted by
Early 2000	Bore 1, Test bore near MW2	1-48	18.6-50	1,296-8,550	0.08	Duffill Watts & King
July 2000	Bore 2	48	125	Results not available		Duffill Watts & King

Comment: The aquifer test data are not available and these interpretation results have not been checked

Table 4.1 Summary of the Aquifer tests

Duffill Watts & King, 2000 indicated that, while pumping Bore 1 at 50 L/s for over 40 hours, a sudden increase in drawdown was observed. Their interpretation was that the aquifer storage capacity has become exhausted.

From the aquifer tests results and through-flow calculation within the aquifer, Opus, 2006 concluded that to be able to draw high yields from the Arrow-Bush Ribbon Aquifer, the production bores have to be located near the confluence between Bush Creek and the Arrow River to induce stream depletion and infiltrate water from the Arrow River.

The analytical solution presented in Jenkins (1977) has been used to estimate the stream depletion on the Arrow River induced by the existing water supply Bore 2.
Various aquifer parameters have been tested to assess the percentage of depletion after 3, 10 and 90 days. The results are presented in Table 4.2:

	Transmissivity (m^2/d)	**Specific Yield/ Storativity S=0.08**			**Specific Yield/ Storativity S=0.2***		
		Depletion Rate after 3 days	**Depletion Rate after 10 days**	**Depletion Rate after 90 days**	**Depletion Rate after 3 days**	**Depletion Rate after 10 days**	**Depletion Rate after 90 days**
Bore 2, $Q=3,000m^3/d$, ≈250m from confluence	T=8,500	75.4%	86.4%	95.4%	62.1%	78.6%	92.8%
	T=1,300	42.3%	66.1%	88.4%	20.6%	48.8%	81.7%

* *A specific yield value of 0.2 has also been tested, as representative for unconfined coarse gravel aquifers according to the literature (Morris and Johnson 1967).*

Table 4.2 Stream Depletion Effects

After 10 days, according to the different sets of aquifer parameters tested previously, the depletion effects on the Arrow River could reach between 49 to 86% for the Bore 2.

5. Current Water Allocation

Currently, there is one water take Permit 2007.049 (QLDC Arrowtown Water Supply) within the aquifer, which has been allocated as surface water and will expire on 10/01/2021.

This Consent is to use surface water as primary allocation from the confluence of Bush Creek and the Arrow River for the purpose of community supply. With the following maximum volumes:

- 108 litres per second;
- 7,800 cubic metres per day;
- 234,000 cubic metres per month; and
- 1,105,200 cubic metres between 1 September and 31 August in the following year.

This Permit allows abstracting groundwater from:

- Bore 1: Bush Creek, approximately 600 metres west of its confluence with the Arrow River;
- Bore 2: Approximately 250 metres west of the confluence of Bush Creek and the Arrow River;
- Bore MW15: Approximately 170 metres North West of the confluence of Bush Creek and the Arrow River.

To our knowledge, at the time of writing, the production bore near the piezometer MW15 has not been drilled yet. Figure 5.1 gives an overview of the current QLDC supply bores: Bore 1 (ORC Bore Tag F41/0246) and Bore 2 (ORC Bore Tag F41/0258).

QLDC Main Water Supply Bore 2 with piezometer MW2 and Bush Creek in the background

QLDC Water Bore 1 and Pump House, Bush Creek in the foreground

Figure 5.1 Photographs of the QLDC Production Bores

According to a discussion with a former QLDC Environmental Consent Manager, Bore 2 is the main water supply, while Bore 1 is only used during peak demand. The preferred option to upgrade the capacity of the drinking water supply would be to install a larger capacity pump in Bore 2 and become less reliant on Bore 1.

In 2014, a Water Supply Safety Plan was submitted by the QLDC, and the risks of contamination for the resource were listed. It was recognised that there was a poor understanding of the recharge zone, and a poor identification of source protection zones.

Of particular interest, this document identified amongst others the potential contamination risks which may arise from the up-gradient Industrial Park, a Council wastewater pipe within 40m from the bore field, and a stormwater discharge in Bush Creek 150m upstream of the bore.

As visible in Figure 5.1, the bore head of the main drinking water supply (Bore 2) is not fenced from animal and from the public, although located in a highly frequented recreational area.

6. Recommendations for Allocation Management

According to the information presented in the previous section, it seems obvious that the water abstracted from Bore 2 (and possibly Bore 15 in the future) has a significant surface water origin component. Therefore, managing this resource as surface water would be a logical approach.

However, for the upper part of the aquifer (for example Bore 1), a pump test has shown that the aquifer storage capacity might be limited, and apparently no recharge from the surface water bodies has been identified so far.

Nevertheless, considering that:

- The current knowledge of the aquifer (and especially the recharge processes and interactions with the surface water bodies) is limited;
- And that the Arrow River Resource is currently over-allocated;

It is recommended that the Arrow-Bush Ribbon Aquifer is managed as surface water, as this would prevent any further allocation of the resource, and protect it until further scientific investigations are carried out to justify an alternative approach to allocation.

7. Other Recommendations

A complete aquifer study would help to have a better understanding of the aquifer extent, capacity, recharge zones and processes, as well as of the aquifer dynamics, including the surface water and groundwater interactions and the effects of abstraction.

This study would have to be based on monitoring data such as continuous groundwater level within the aquifer and stage/flow monitoring sites on the surface water bodies.

Regarding the security of the supply, it appears that the whole drinking water resource is withdrawn from the Arrow-Bush Ribbon Aquifer, which is possibly vulnerable to contamination. QLDC has identified the risks and should therefore undertake the preventive measures and corrective actions to upgrade the resource protection, as the supply borefield is poorly secured at the moment.

References

Duffill Watts & King (2000) – *Arrowtown Water Supply Upgrade Options* – Reference W275-52

Kingett Mitchell J. (2005) – *Arrowtown Water Supply Options, Preliminary Groundwater Assessment* – Report Letter.

OPUS (2006) - *Hydrogeological Assessment, Water Supply Upgrade* – Reference -6-CDQ11.00

Otago Regional Council (ORC) 2014 - *Investigation into the Wakatipu Basin Aquifers* - ISBN 978-0-478-37673-9