Document Id: **A1355395**

MEMORANDUM

To: **Kirstyn Lindsay**

From: **Sarah McCrorie**

Date: **11/06/2020**

Re: **RM20.007 - Amisfield Burn historical water use analysis**

This memorandum is in relation to application RM20007 to replace deemed permits 96320.V1 and 96321.V1 from Amisfield Burn for the purpose of irrigation and stock drinking. Abstraction of water under this permit occurs through water meter WM0964.

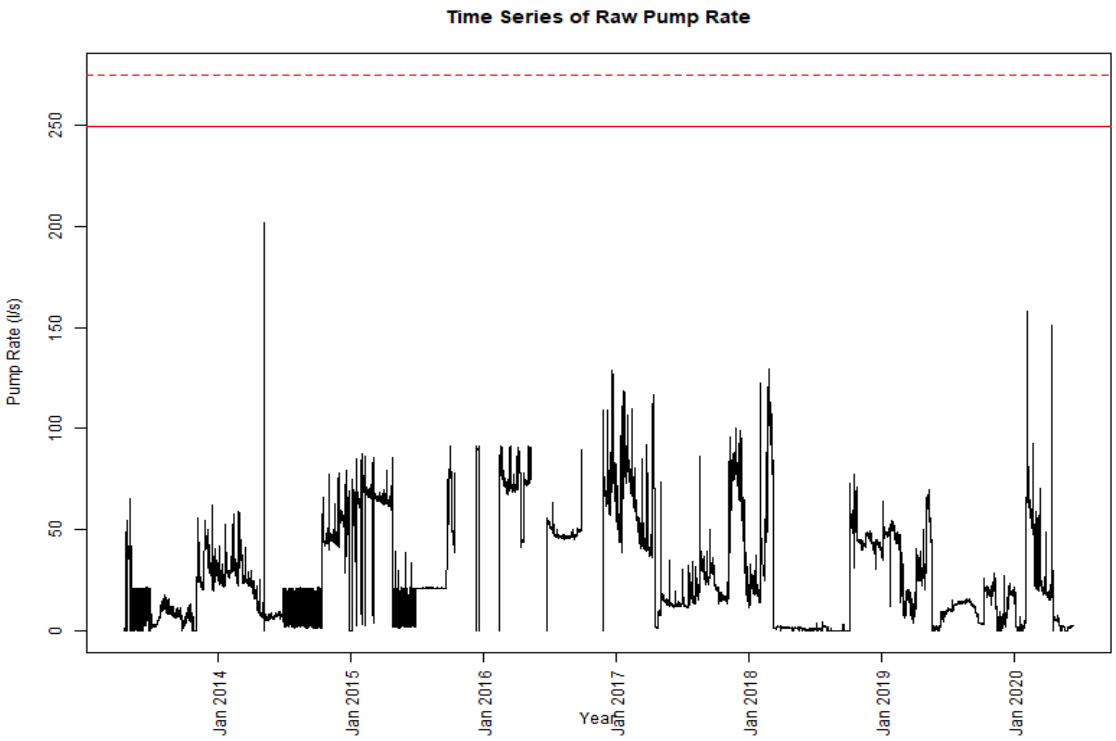
All analyses, graphs, and calculations were performed using RStudio version1.2.5033 and RGui version 3.6.3.

Data taken through WM0964 extends from 19 April 2013 to 10 June 2020 with a total of 57308 hourly measurements.

In addition to analysing the raw data, the following steps were taken:

- Rates less than, or equal to zero were set to NA.
- The maximum average rate of take authorized by the permit this application seeks to replace is 249.8 l/s and water is taken through an open channel. A 10% margin of error was applied to this and rates in excess of 274.78 l/s were set to NA.
- Rates between 249.8l/s and 274.78l/s were set to 249.8l/s.
- The resultant data set had 54383 hourly measurements

A time series showing the pump rate, the maximum consented rate, and the upper error limit is presented below:

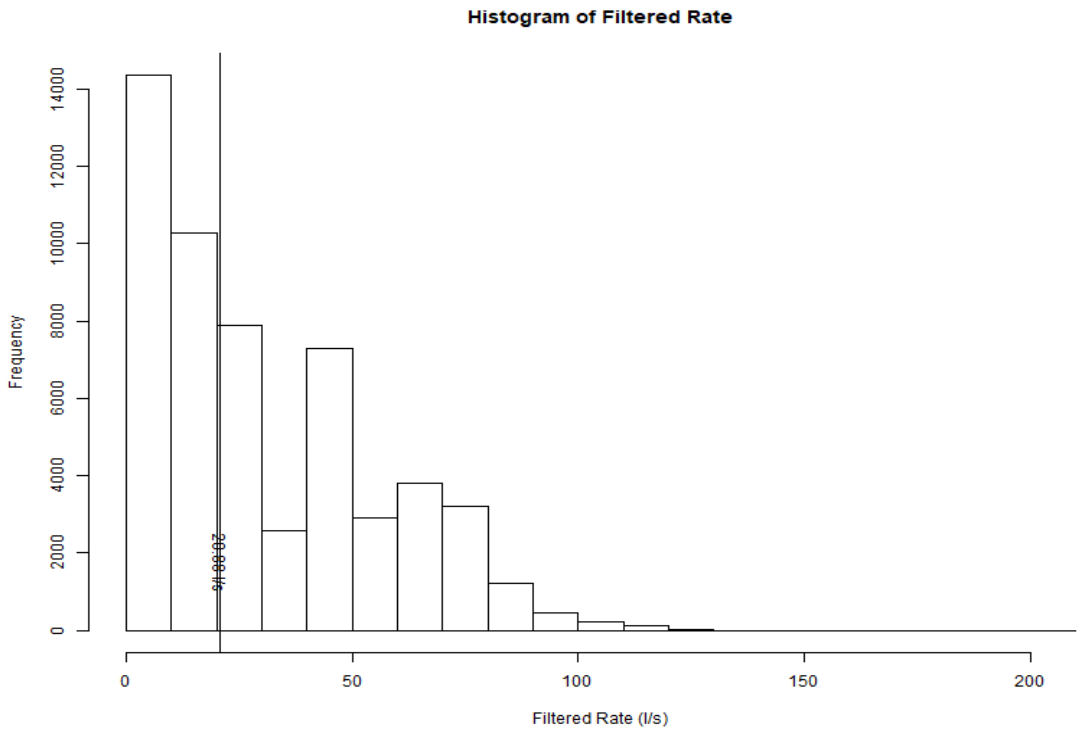


The solid red line represents the consented maximum rate of 249.8 l/s, and the broken red line represents 249.8 + 10% (274.78 l/s).

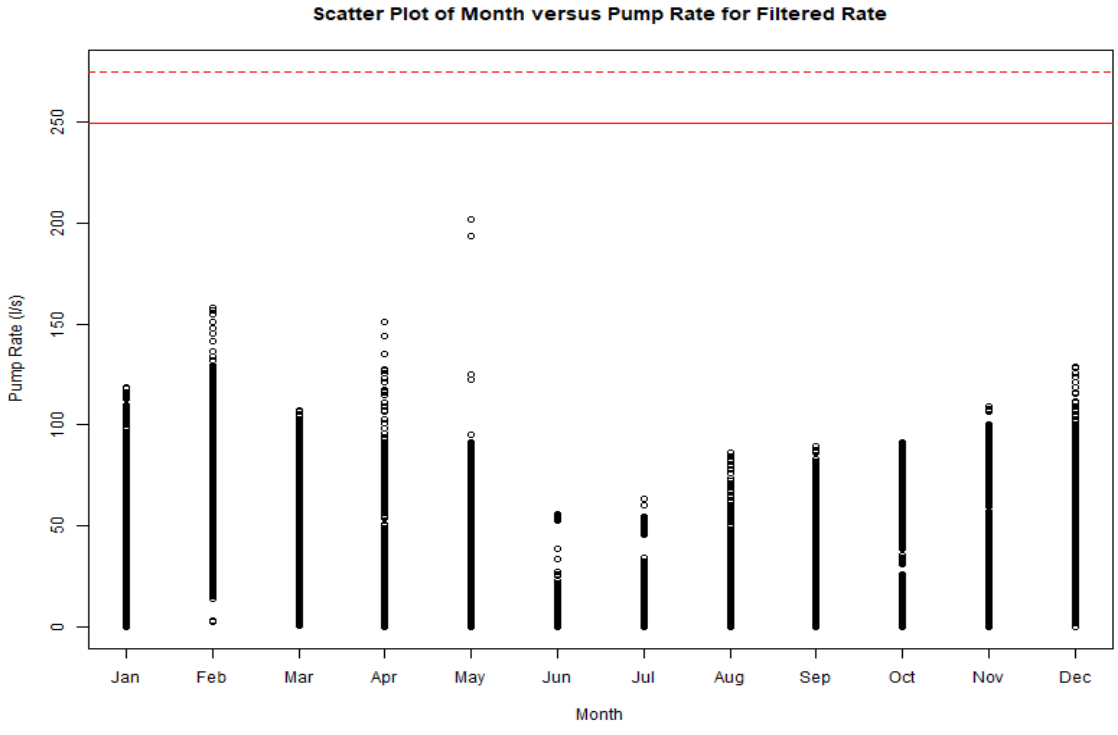
There is no consistent pattern distinguishable in the raw time series graph.

The filtered data set contains 54,383 measurements with an average take of 30.4 l/s, a median rate of take of 20.9 l/s, and a modal (most common) rate of take of 20.87 l/s.

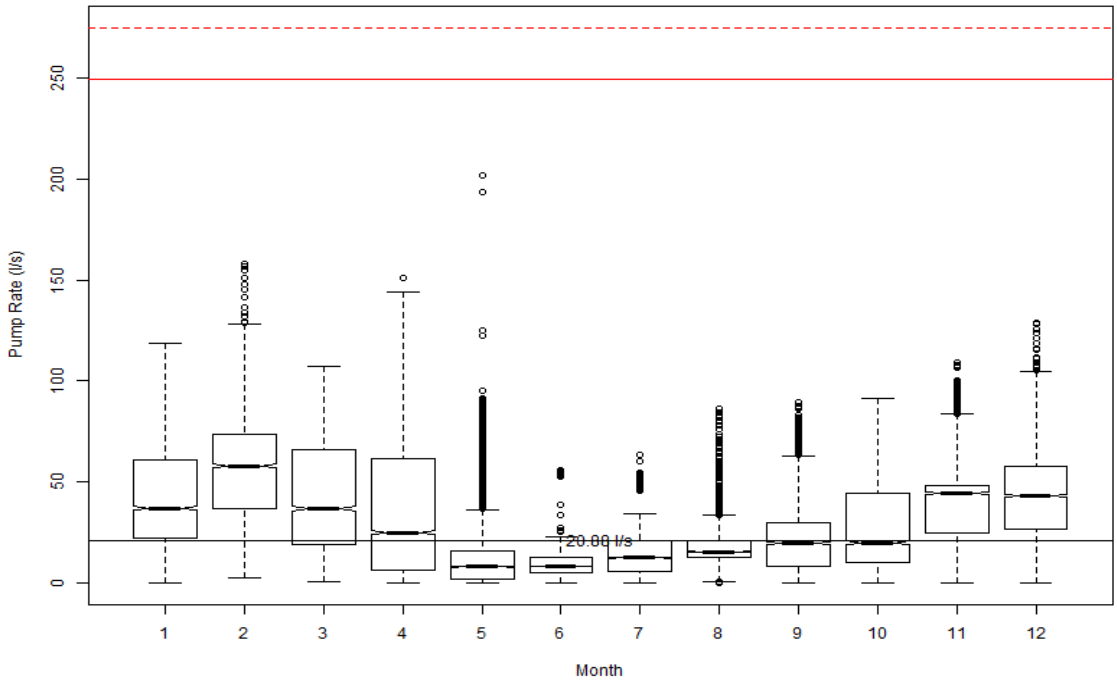
The histogram is positively skew with a bimodal element. There is a major peak at 0-10 l/s and a smaller peak at 40-50 l/s, this would be consistent with a lower rate of rate stock drinking most of the time and higher rate of take for irrigation some of the time.



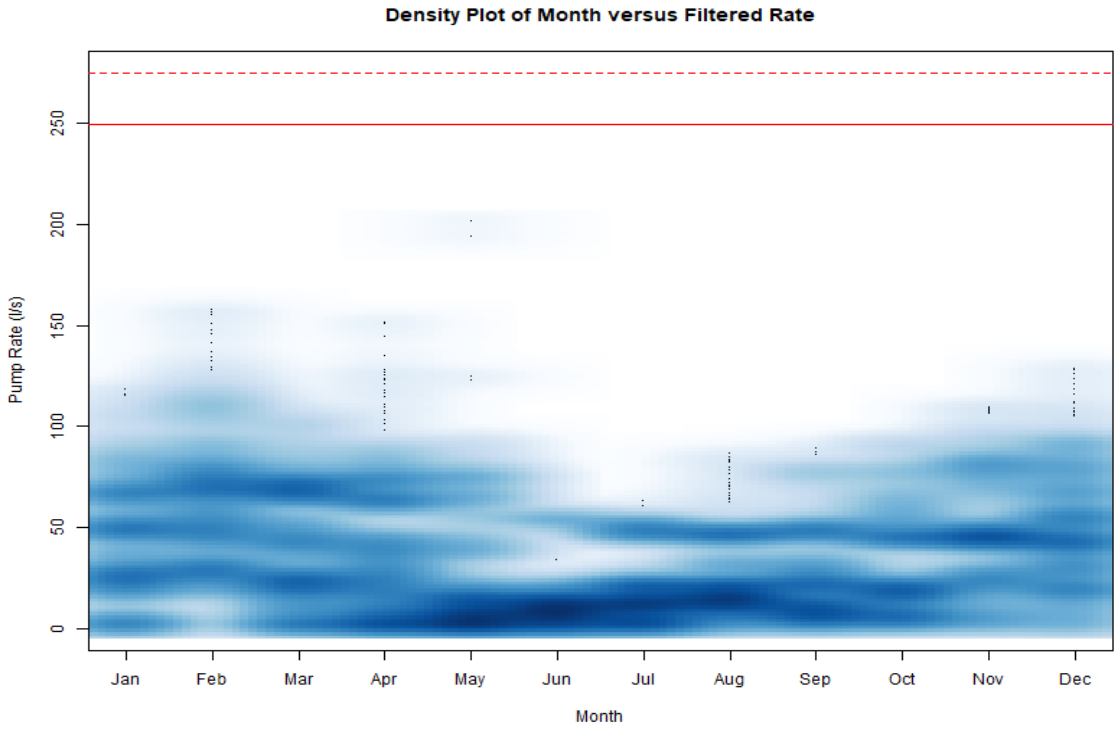
The scatter plot below shows higher rates of take are likely to occur between November and April, which is consistent with irrigation. The lower rates during the off-season are consistent with stock drinking.



It can be seen on the box plot below the rates of take are more likely to be above the average rate of take between November and April. This is consistent with irrigation.



The density plot supports the data from the box plot.



The high use data set was selected by filtering for those months in which the median usage exceeded the median for the filtered data set. The mean for the high use data set is 42.2l/s, the median is 42.62 l/s and the modal value is 0.12 l/s.

Percentiles are not a percentage of the maximum rate, but rather the rate that is exceeded x% of the time. Percentiles are calculated by ranking the data from lowest to highest and taking the weighted average of the nth highest and the n+1th highest values. The 80th percentile is the pump rate that is exceeded 20% of the time. The 90th percentile is the pumping rate that is exceeded 10% of the time. The 95th Percentile is exceeded 5% of the time. What this means in terms of the analysis is that if the applicant is pumping at the maximum consented rate more than 5% of the time, the 95th percentile will equal the maximum consented rate. If they are pumping at the maximum consented rate more than 10% of the time, the 90th percentile will equal the maximum consented rate. If they are pumping at the maximum consented rate more than 20% of the time, then the 80th percentile will equal the maximum consented rate. In practical terms if the applicant is pumping 24 hours/day and 2160 hours for a 90-day season then:

- The 80th percentile is the rate that is exceeded for 5 hours per day, or 432 hours per season.
- The 90th percentile is the rate that is exceeded for 2.5 hours per day, or 216 hours per season.
- The 95th percentile is the rate that is exceeded for 1.5 hours per day, or 108 hours per season.

What this means is that if a consent holder is consistently using their maximum consented rate for more than 5%, 10%, or 20% of the time they are pumping, it will show up in the table of percentiles.

The 80th, 90th, and 95th percentiles for the flow rate were calculated, without modelling the distribution, for the raw data set, the filtered data set, and the high rate data set. The results are presented to three significant figures below.

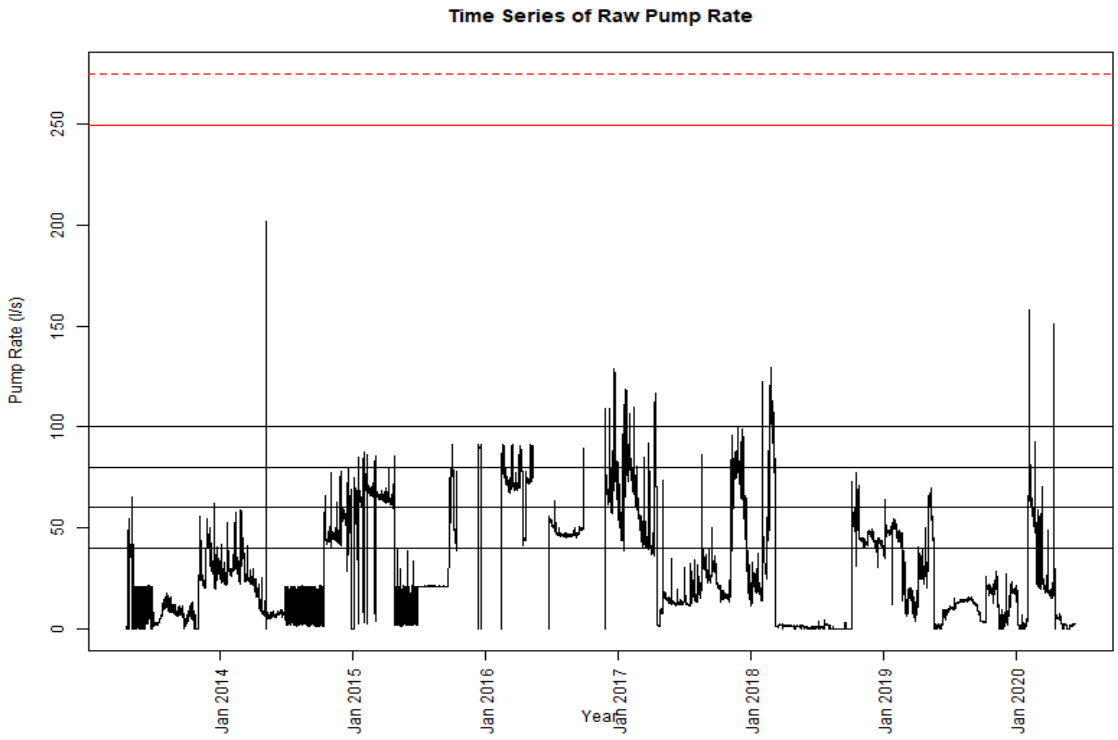
	80th %ile	90th %ile	95th %ile
Raw rate	51.2	68.8	76.7
Filtered rate	52.8	69.6	77.3
High use rate	68	76.2	83.3

A summary of rates and volumes for the period 1 July 2012 to 30 June 2017, prepared according to proposed Method 10.A.4 is presented below:

	Max Take Rate	Max Daily Volume	Max Monthly Volume	Max Annual Volume
2012/2013	65.3	5080	57400	109000
2013/2014	202	4460	90200	541000
2014/2015	87.6	6680	176000	1090000

	Max Take Rate	Max Daily Volume	Max Monthly Volume	Max Annual Volume
2015/2016	91	7840	193000	829000
2016/2017	129	9240	2e+05	1270000
Mean	115	6660	143000	767000

A time series with reference lines at 40 l/s, 60 l/s, 80 l/s, & 100 l/s is presented below to provide context for the percentiles and where they sit in relation to the history of taking by the resource consent holder.



The number of days in each month of the historical record that the 80th, 90th, and 95th percentiles have been exceeded for all three data sets is presented below:

51.2 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	1	2	0	0	0	0	0	4	1
2014	1	2	1	0	1	0	0	0	0	1	5	27
2015	27	28	31	28	0	0	0	0	6	10	NA	4
2016	NA	14	31	25	11	8	7	0	2	NA	6	31
2017	30	28	12	9	1	0	0	2	0	0	25	18
2018	0	17	9	0	0	0	0	0	0	22	0	0
2019	8	4	0	0	13	0	0	0	0	0	0	0
2020	1	24	3	2	0	0	NA	NA	NA	NA	NA	NA

68.8 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	3	3
2015	11	24	6	7	0	0	0	0	5	9	NA	4
2016	NA	14	31	25	11	0	0	0	2	NA	6	28
2017	20	19	3	5	1	0	0	1	0	0	25	12
2018	0	12	9	0	0	0	0	0	0	6	0	0
2019	0	0	0	0	1	0	0	0	0	0	0	0
2020	0	8	1	2	0	0	NA	NA	NA	NA	NA	NA

76.7 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	2	1
2015	4	6	3	3	0	0	0	0	4	8	NA	4

76.7 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	NA	12	3	10	7	0	0	0	2	NA	4	18
2017	17	12	3	4	0	0	0	1	0	0	24	11
2018	0	12	7	0	0	0	0	0	0	1	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	6	0	2	0	0	NA	NA	NA	NA	NA	NA

52.8 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	1	2	0	0	0	0	0	3	1
2014	1	2	1	0	1	0	0	0	0	1	5	26
2015	27	28	31	28	0	0	0	0	6	10	NA	4
2016	NA	14	31	25	11	8	3	0	2	NA	6	31
2017	29	28	10	9	1	0	0	2	0	0	25	18
2018	0	17	9	0	0	0	0	0	0	21	0	0
2019	5	1	0	0	13	0	0	0	0	0	0	0
2020	1	23	3	2	0	0	NA	NA	NA	NA	NA	NA

69.6 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	3	2
2015	9	20	5	7	0	0	0	0	5	9	NA	4
2016	NA	14	31	25	11	0	0	0	2	NA	6	25
2017	19	19	3	5	1	0	0	1	0	0	25	12
2018	0	12	8	0	0	0	0	0	0	5	0	0
2019	0	0	0	0	1	0	0	0	0	0	0	0
2020	0	8	1	2	0	0	NA	NA	NA	NA	NA	NA

77.3 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	2	1
2015	4	4	3	3	0	0	0	0	4	8	NA	4
2016	NA	11	3	10	7	0	0	0	2	NA	4	18
2017	16	12	3	4	0	0	0	1	0	0	24	11
2018	0	12	7	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	6	0	2	0	0	NA	NA	NA	NA	NA	NA

68 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	3	3
2015	13	27	8	8	0	0	0	0	5	9	NA	4
2016	NA	14	31	25	11	0	0	0	2	NA	6	28
2017	20	20	4	5	1	0	0	1	0	0	25	12
2018	0	12	9	0	0	0	0	0	0	8	0	0
2019	0	0	0	0	2	0	0	0	0	0	0	0
2020	0	9	1	2	0	0	NA	NA	NA	NA	NA	NA

76.2 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	2	1
2015	5	6	3	4	0	0	0	0	4	8	NA	4
2016	NA	12	4	11	7	0	0	0	2	NA	4	19
2017	17	14	3	4	0	0	0	1	0	0	24	11
2018	0	12	7	0	0	0	0	0	0	2	0	0

76.2 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	6	0	2	0	0	NA	NA	NA	NA	NA	NA

83.3 l/s	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	1	0	0	0	0	0	0	0
2015	3	3	1	1	0	0	0	0	0	5	NA	4
2016	NA	6	2	5	6	0	0	0	1	NA	3	11
2017	10	6	3	3	0	0	0	1	0	0	12	9
2018	0	12	6	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	4	0	2	0	0	NA	NA	NA	NA	NA	NA

A summary of daily volumes, in m^3, filtered for a maximum daily take of 21600 m^3 and then rounded to three significant figures is presented below:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	10.4	1480	85.1	20.4	2.1	4.62	24.6	4.92	0.9	44.6	26.1	10.4
Mean	3340	4960	3470	2760	1430	818	1400	1780	1870	2340	3590	3850
Median	3150	5010	3280	2240	751	727	1020	1270	1210	1680	3800	3750
80%	5660	6470	5980	5470	2020	1080	1800	2820	3100	3960	4460	5700
90%	5960	7500	6210	6260	4890	1170	4050	4000	4200	5170	6840	6790
95%	6750	8410	6460	6560	6020	1330	4360	4020	4280	5640	7070	7170
Max	9240	10300	9090	7860	6900	4700	4600	5690	6690	7840	8650	8960

A summary of monthly volumes based on daily volumes that have been filtered for a maximum daily take of 21600m^3 and then rounded to three significant figures is presented below.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	NA	NA	NA	19800	57400	31800	11300	30500	17400	13100	63600	90200
2014	77200	73100	78700	45700	21300	18800	27200	26800	23000	69000	119000	132000
2015	142000	167000	176000	155000	24800	24900	54600	55900	78300	84700	NA	NA
2016	NA	83500	193000	179000	72200	28000	131000	124000	118000	NA	36500	2e+05
2017	184000	178000	131000	92800	41700	32900	40200	70800	74200	47200	169000	145000
2018	59700	150000	74400	3500	2800	1490	3010	965	121	129000	116000	115000
2019	126000	97400	34100	70500	83800	14400	30500	38200	24000	40200	27600	36100
2020	9270	149000	64400	40200	3860	1550	NA	NA	NA	NA	NA	NA

In summary:

- The seasonal pattern is consistent with irrigation.
- The pattern of taking indicates that water is also being taken for stock drinking water.
- The maximum volume taken in any day is 10,300 m^3
- The maximum volume taken in any month is 200,000 m^3.
- The maximum taken in any irrigation year is 1,269,900 m^3
- The applicant has applied for 97.3 l/s with a ±10% accuracy.
- The maximum average calculated in accordance with Method 10.A.4 is 115 l/s, which exceeds what the applicant has applied for.
- The lowest rate that can be taken and still in the range 97.3 l/s ±10% is 88.5 l/s which does not include any of the percentiles.