Memo - Response to Hearings Panel question

Date:	26 March 2019
To:	Hearings Panel - Proposed Plan Change 1: Waikato and Waipa River Catchments
From:	Mathew McCallum-Clark, Section 42A lead author
Prepared by:	John Hadfield, Senior Scientist, Waikato Regional Council
Subject:	**Groundwater nitrate-nitrogen state and trend in the Healthy Rivers catchments**

Purpose

1. The purpose of this memo is to provide a response to a question from the Hearings Panel regarding the state and trend of nitrate-nitrogen concentrations in the Proposed Plan Change 1 (Healthy Rivers) catchments including the Upper Waikato dated 12 March 2019.

Introduction

2. This response to the above question has been prepared by: John Hadfield, Senior Scientist, Waikato Regional Council.

3. In preparing this response the author has complied with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014.

Response

4. This information is derived from the 56 regional state of environment (SOE) groundwater monitoring wells in the area, including 13 located in the Upper Waikato.

5. The current state of nitrate-N occurrence (based on latest sampling in late 2018) is indicated in Table 1 and the spatial distribution illustrated in Figure 1. Nitrate-N

concentrations are compared with the drinking water guidelines. The maximum acceptable value (MAV) for drinking is 11.3 g m^{-3}. About 11% of wells exceed the MAV in the Healthy Rivers catchments whereas none of the exceedances occur in the Upper Waikato. Substantial impact is also indicated by concentrations above half the MAV (5.65 g m^{-3}). Over 50% of the groundwater wells monitored in the Healthy Rivers catchments have nitrate-N concentrations above half the drinking water guideline concentration.

6. About a third of wells in the Upper Waikato have nitrate-N concentrations over half the drinking water guideline. Approximately a third of the remaining wells in the Upper Waikato and Healthy Rivers catchments have concentrations greater than one but not more than half the MAV. These indicate some land-use influence. Although concentrations are compared to drinking water guidelines, even concentrations well below half MAV may nevertheless be of concern with respect to degradation of receiving surface waters. Wells which have concentrations below 1 g m^{-3} nitrate-N are currently little affected by land-use loading or may reflect anaerobic conditions.

Table 1 The current state (2018) of nitrate-N concentrations in wells in the Healthy Rivers and Upper Waikato catchments

Nitrate-N concentration (g m^{-3})	% Healthy Rivers	% Upper Waikato
> 11.3	10.71	0
> 5.65 to 11.3	41.07	30.77
> 1 to 5.65	26.79	30.77
< 1	21.43	38.46

7. The current distribution of nitrate-N concentrations in Figure 1 shows they are generally higher in the Hamilton Basin and particularly the northern Pukekawa and Pukekohe areas. These are areas of long established intensive land-use. Hydrogeological setting factors are also important in the distribution and are discussed briefly later.

8. Changes in nitrate-N concentration with time within the Healthy Rivers and Upper Waikato catchments have been investigated using Mann-Kendall trend analysis. A total of 21 of the 56 SOE monitoring wells are monitored quarterly and the remaining on an annual basis. Data to 2018 has been used and most of these wells have been monitored for a period of about 20 years, although records vary as indicated in Table 2. The results of the trend analysis are shown in Table 2 and Figure 2. Increasing trends are listed in red in Table 2 and decreasing trends in blue with negative slopes. Well numbers shaded grey are in the Upper Waikato catchment. Grey shaded number of samples (n) indicates where

quarterly monitoring data is available. The results are in order of decreasing median values and where there is no significant trend it is indicated by ns.

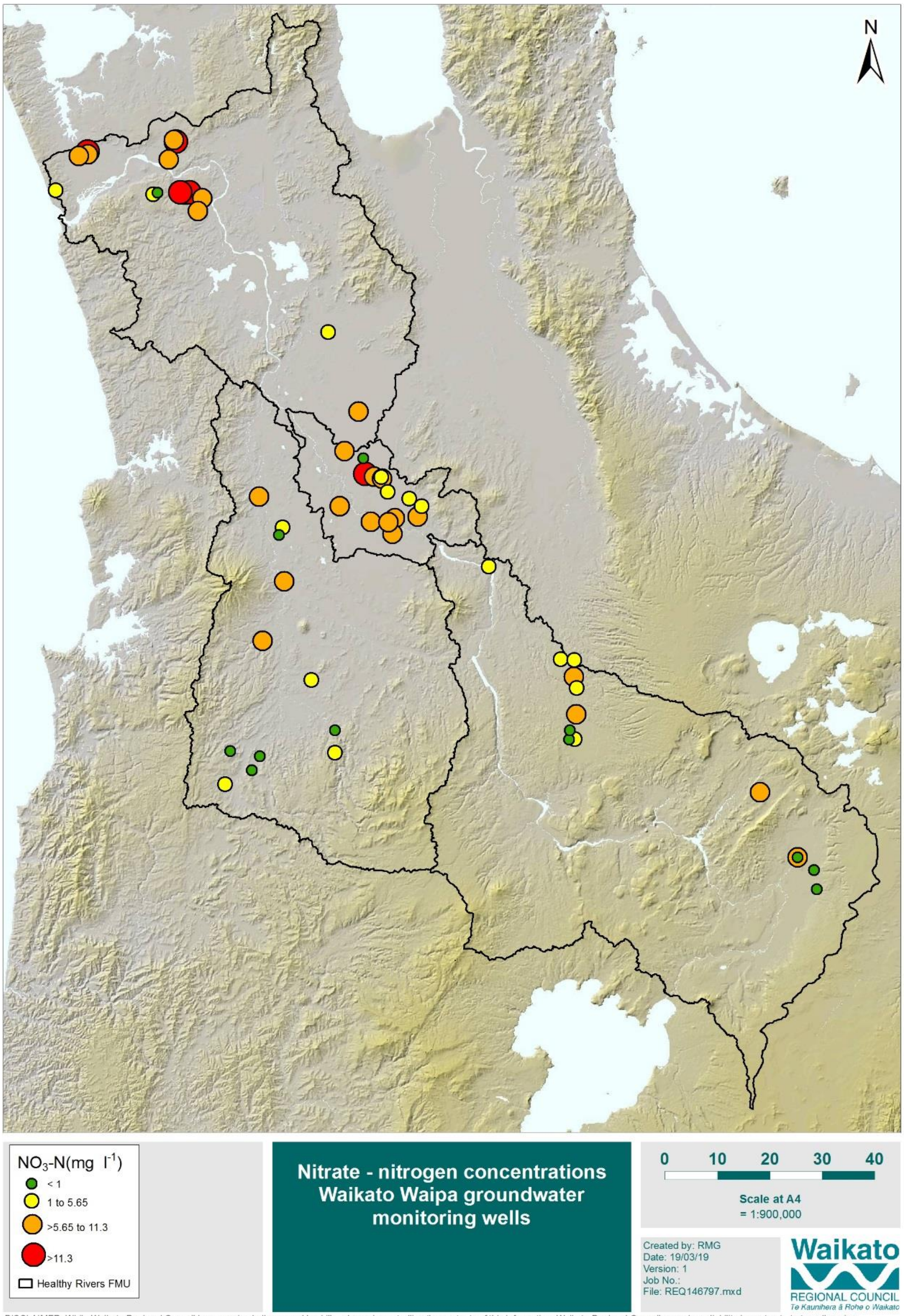

Figure 1 The current distribution (2018) of nitrate-N concentrations in SOE monitoring wells in the Healthy River catchments

Table 2 Mann Kendall analyses of nitrate-N concentration trends in the Healthy Rivers catchments (red indicates increases and blue indicates decreases, ns indicates no significant trend)

Well	median ($g\ m^{-3}$)	n	p-values %	trend ($g\ m^{-3}\ y^{-1}$)
61_143	25	30	<1	0.73
61_93	24	81	<1	-0.584
61_208	14.5	90	<1	-0.292
70_50	14.15	18	ns	
61_135	14	19	<1	0.584
70_44	13.3	79	<1	-0.6205
69_173	12.8	89	<1	-0.3285
61_280	11.1	42	<1	0.3285
70_22	11	92	<1	-0.2555
67_404	10.7	19	<1	-0.438
66_6	10.5	85	<1	-0.6205
69_374	10.35	30	ns	
61_85	9.7	78	<1	1.095
70_56	9.55	88	<1	-0.1095
70_31	9	16	ns	
69_163	8.1	18	ns	
69_62	7.45	18	ns	
72_3741	7.35	4	ns	
69_295	7.3	17	ns	
61_54	7.295	32	<1	0.4015
65_4	7.21	23	ns	
62_5	7.02	30	ns	
61_19	6.9	32	3.14	0.365
61_126	6.48	90	ns	
72_1564	6.2	17	<1	-0.3285
61_230	6.16	30	<1	0.219
61_113	6.12	94	<1	0.1825
69_365	6.1	89	<1	-0.073
69_81	5.35	88	<1	1.241
67_83	5	17	ns	
67_573	4.98	17	ns	
69_1709	4.93	93	2.02	0.073
61_221	4.87	90	<1	0.1095
70_76	4.38	88	<1	0.073
70_1134	4.25	76	<1	0.292
61_59	4.2	82	<1	0.02555
66_93	4.05	20	ns	
70_47	3.64	89	<1	-0.219
70_74	3.63	89	ns	
67_4	3.55	20	1.8	-0.073

Well	median (g m^{-3})	n	p-values %	trend (g m^{-3} y^{-1})
71_1	3.46	24	<1	0.146
72_4500	3.2	12	ns	
71_4	2.6	23	ns	
61_258	2.5	93	<1	0.1095
70_65	2.36	88	1.7	-0.073
65_6	2.2	23	<1	0.073
69_248	2	31	2.52	-0.219
72_5510	0.95	9	ns	
71_3	0.93	22	ns	
72_2138	0.8	7	ns	
66_92	0.25	20	ns	
66_58	0.155	24	<1	0.00365
61_245	0.15	20	ns	
66_96	0.025	19	ns	
67_483	0.025	19	ns	
71_5	0.025	21	ns	

9. The trend analysis results in Table 2 indicate that there are 18 SOE wells in the Healthy Rivers catchments which have significantly increasing trends and 14 wells which have significantly decreasing trends. In the Upper Waikato, there are two significantly increasing trends and three significantly decreasing trends. The distribution of trends is illustrated in Figure 2 and shows about half the increasing trends are occurring in the northern Pukekohe/Pukekawa areas. The highly variable nature of the results are similar to findings on a national scale. Statistics New Zealand (web link provided) found that for the period 2005-14 nitrate-N concentrations at 26.5 percent worsened (130 wells), 18.9 percent improved (93 sites) and 54.6 percent (268 wells) were indeterminate.

10. There are a large number of factors which may influence groundwater quality. These include variability in land-use, geology, aquifer confinement, well depth, groundwater age and redox conditions (Daughney et al., 2012). The distribution of nitrate-N concentration with well depth is illustrated for the 56 SOE wells in the Healthy Rivers catchments using 2018 data in Figure 3. Although there is no significant linear relationship, higher nitrate-N concentrations tend to occur at depths less than 50 m and often 30 m. Lower nitrogen concentrations also, however, occur at shallow depth dependent on other factors including land-use, water age and redox[1] conditions.

[1] Redox conditions range from aerobic to anaerobic and strongly influence the occurrence of nitrate-N

11. Redox conditions are also been indicated in Figure 3. They are divided into four categories comprising not only aerobic and anaerobic conditions but mixed and indeterminate categories based on the following criteria:

- Aerobic: NH_4, dissolved Fe and dissolved Mn all non-detect and NO_3-N > 1 ppm
- Anaerobic: Two of NH_4, dissolved Fe and dissolved Mn detected and NO_3-N non-detect
- Mixed: Two of NH_4, dissolved Fe and dissolved Mn detected and NO_3 -N detected > 1 ppm
- Indeterminate: not meeting the criteria above

12. The highest nitrate-N concentrations occur in aerobic conditions. There is only one well in this dataset in which there is an anaerobic condition (anaerobic wells plot along the x axis). The indeterminate category includes wells where the groundwater may be older and not yet significantly influenced by land-use.

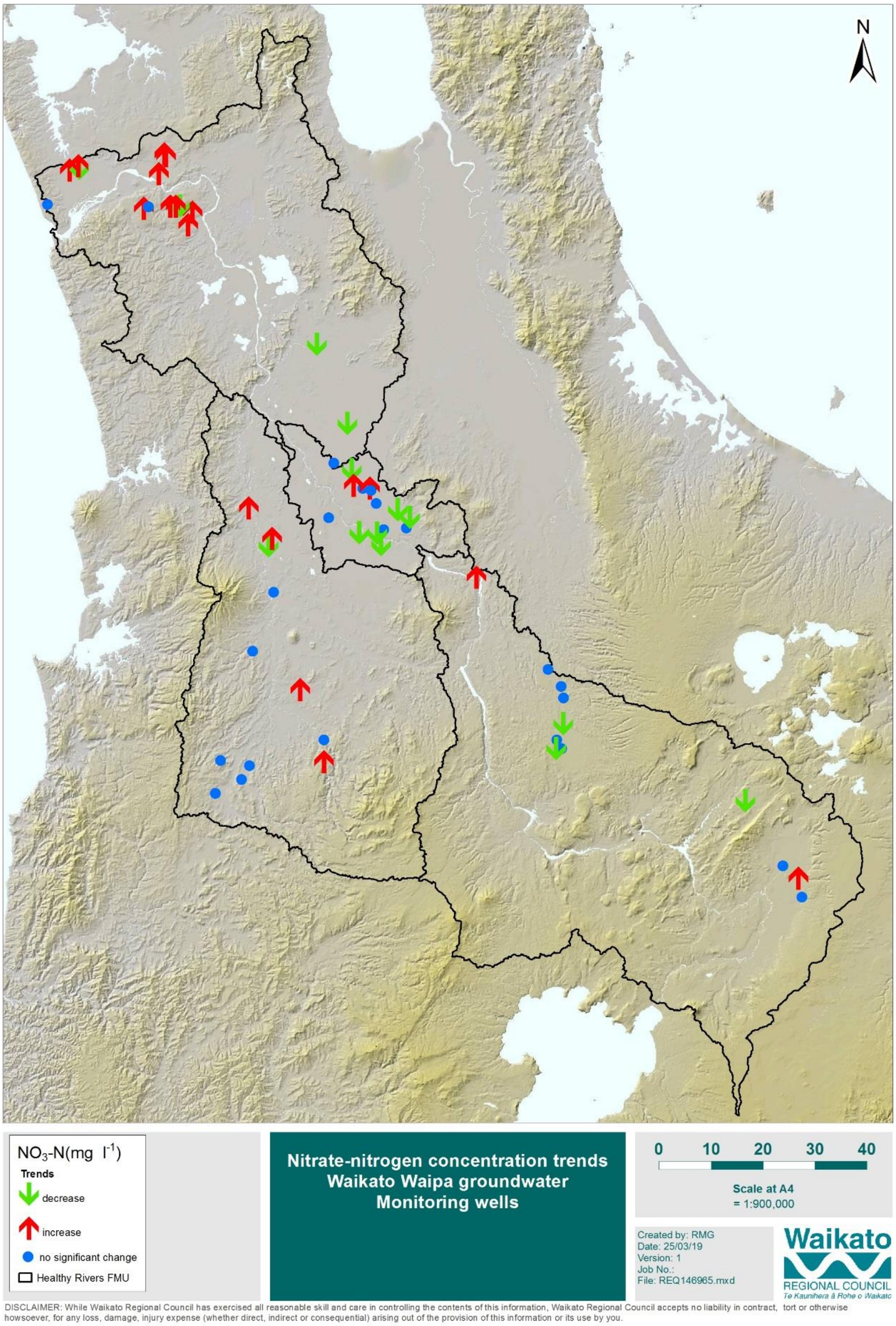

Figure 2 Nitrate-N concentration trends in SOE monitoring wells in the Healthy River catchments

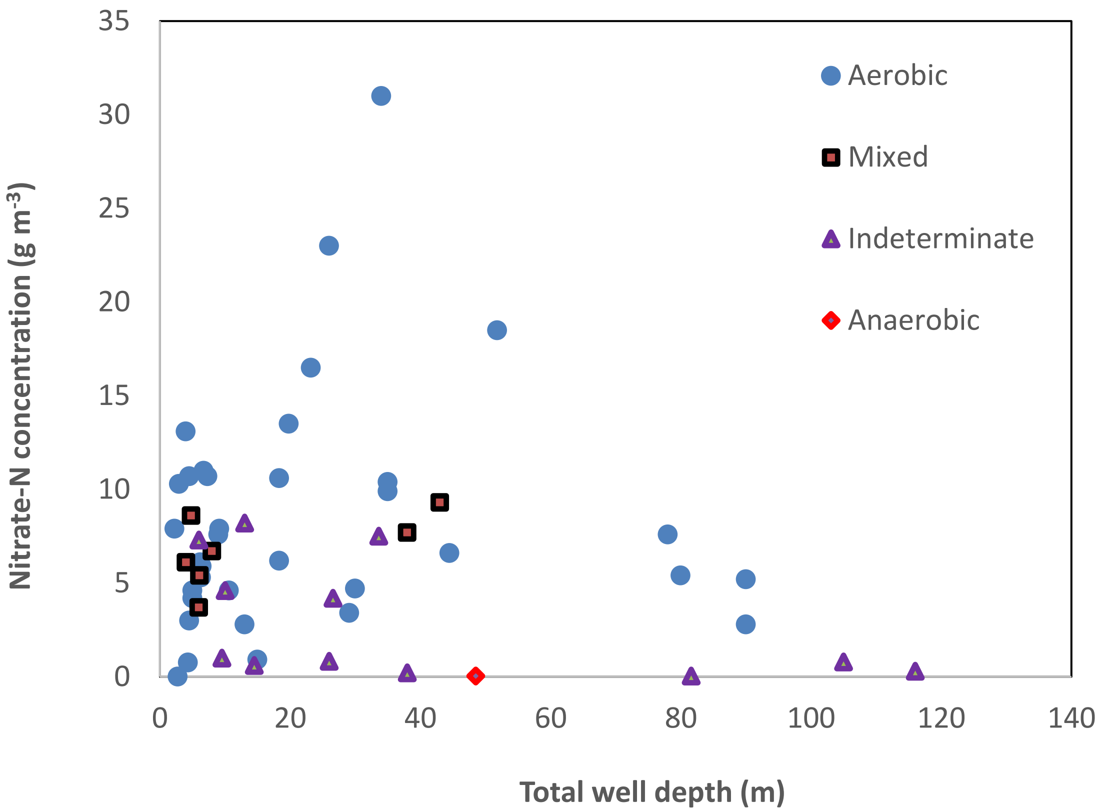

Figure 3 Nitrate- N concentrations versus well depth categorised by redox conditions

13. Nitrate-N concentrations have also been plotted against groundwater age in Figure 4. This is for the 28 wells for which groundwater age analysis is available. Analysis is based on tritium, CFC[2] and SF_6[3] concentrations. Groundwater age (expressed here as mean residence time) is similar to well depth in that there is no simple linear relationship with nitrate concentration. Instead there is again a wedge shaped distribution. This reflects that although higher nitrate-N concentrations tend to occur in younger groundwater, low concentrations may also occur e.g. where there is relatively low intensity land use or anaerobic conditions.

14. Although nitrate-N transport through the groundwater system is complex there are some useful investigative approaches. Three dimensional numerical groundwater flow and contaminant (nitrogen) transport modelling (some of which has been undertaken for the

[2] Chlorofluorocarbons are anthropogenic, atmospheric tracers which may be used to assist groundwater age determination

[3] Sulphur hexafluoride is also predominantly an anthropogenic, atmospheric tracer used to assist in confirming groundwater age

Upper Waikato) enables nitrogen migration from land-use leaching to receiving water to be studied. Determining the relative flux contribution of groundwaters to receiving surface waters is an important consideration. Another fundamentally important aspect is estimating the extent of attenuation, which for nitrate is strongly related to the distribution of redox conditions. Surface water quality trends, particularly in the baseflow dominated Upper Waikato are an integrated representation of groundwater input. Hydrograph separation assisted by chemistry and water age information provides useful insight into flowpath contributions (Woodward and Stenger, 2018).

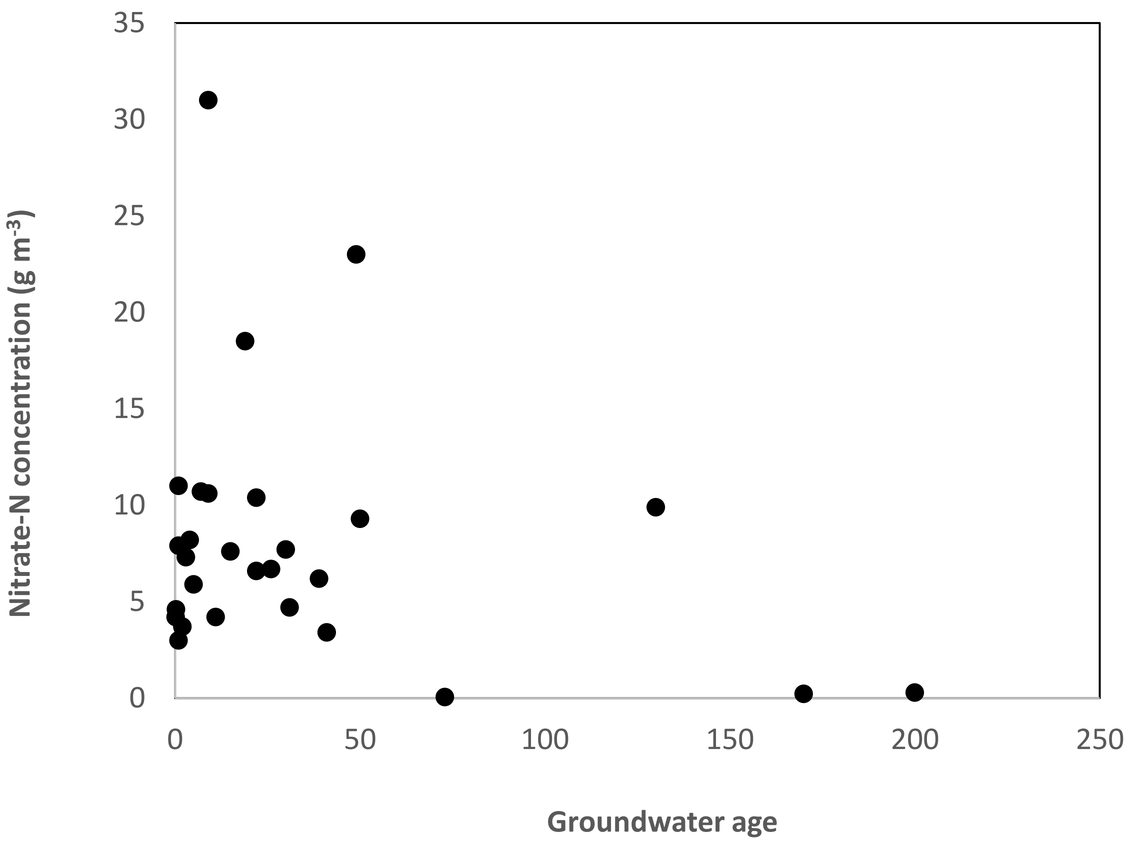

Figure 4 Nitrate- N concentrations versus groundwater age (expressed as mean residence time)

15. Five yearly surveys of groundwater quality in the Upper Waikato are planned using a larger number of monitoring wells, similar to the work undertaken in the summer of 2014-2015. The first of these will be undertaken beginning at the end of this year.

Data caveats

16. The data used in this response is derived using a national protocol and are? QA/QC checked as part of the database management.

Availability of all data used to the public

17. The data used in this response is derived from WRC state of environment (SOE) monitoring records which are publicly available on request and reported in the environmental indicators on the WRC website.

References

Daughney, C.J., Raiber, M., Moreau-Fournier, M., Morgenstern, U., and Van der Raaij, R., 2012: Use of hierarchical cluster analysis to assess the representativeness of a baseline groundwater quality monitoring network: comparison of New Zealand's national and regional groundwater monitoring programs. Hydrogeology Journal (2012) 20: 185–200.

Statistics New Zealand web link: http://archive.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/groundwater-quality.aspx

Woodward S.J.R. and Stenger, R., 2018: Bayesian chemistry-assisted hydrograph separation (BACH) and nutrient load partitioning from monthly stream phosphorus and nitrogen concentrations. Stochastic Environmental Research and Risk Assessment (2018) 32:3475–350.