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The data presented in this Report are available to GNS Science for other use from March 2011

BIBLIOGRAPHIC REFERENCE

Stewart, M.K.; 2011. Improved Understanding of Groundwater Movement and Age in the Aquifers of the Waimea Plains, *GNS Science Consultancy Report 2011/55*. 10p.

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1.0 INTRODUCTION

Envirolink grant (924-TSDC72) has funded the collation and review of past tritium and CFC data held in the GNS Science database for aquifers of the Waimea Plains. This review and the conclusions from it are given below with the aim of contributing to better understanding and management of the aquifers by Tasman District Council staff.

2.0 TRITIUM RESULTS

The locations of the wells sampled are given in Fig. 1, and the results of the tritium measurements in Table 1. The wells were sampled at various times between 1972 and 1999. Aquifers sampled include the Appleby Gravel Unconfined Aquifer (AGUA) along the Waimea River, Hope Minor Confined and Unconfined Aquifers (HU) in the centre and eastern side of the plains, the Upper Confined Aquifer (UCA) and the Lower Confined Aquifer (LCA) which were delineated by previous workers.

Mean residence times (MRTs) were determined for four wells for which there is a time sequence of tritium measurements (TDC208, 32, 14, 255), these all tap the LCA. The data are plotted in Figs 2a-d together with the input concentrations (rainfall) and simulations using the exponential piston flow model (EPM). It can be seen that the simulations fit the data very well and yield well-defined MRTs. The EPM models have high degrees of mixing of young and old water (with f values of 85-100%). Well TDC208 contains very young water (MRT ~ 8 months), TDC32 has MRT of 31 years, and TDC14 and 255 have much older waters with MRTs of 110 and >150 years respectively.

Applying the same EPM models to the other wells for which there is only one tritium measurement per well, yields the MRTs given in Table 1. The three HU wells (TDC777, 162, 141) yield relatively young MRTs (17 -0.1 years) as expected, as also do the two AGUA wells (TDC263 and 802). Two wells were sampled in the UCA (TDC59 and 37). TDC59 is in the upstream part of the aquifer, and contains older water (36 years) and moderate nitrate concentration compared with TDC37 which has very young MRT (~0 years) and high nitrate. The high nitrate water in the UCA appears to be moving slowly towards the coast (from 1978 and 1986 nitrate surveys), but the recharge of the water at TDC37 occurred very recently.

The MRTs, $\text{NO}_3\text{-N}$ concentrations and $\delta^{18}\text{O}$ values are plotted against distance along the aquifer in Figs. 3a-c. The distance along the aquifer from the gorge (inland) end was determined from the map. The MRTs show a very clear and distinctive pattern with distance. Ages decrease from 70 years along the aquifer to about the 5 km point (where the age is 8 months for well TDC208) and then increase strongly towards the sea with the offshore wells (Bells Island TDC14 and Rabbit Island TDC255) having the oldest ages (greater than 100 years). All of the data fit this trend remarkably well except those for wells TDC109 and TDC31. TDC109 is situated close to the west side of the LCA aquifer and therefore is away from the main flow towards the coast (and the probable source of the young water on the east side of the aquifer). TDC31 is close to TDC32, but may tap a less permeable part of the aquifer.

The NO₃-N concentrations show a similar clear trend despite the limited data with high values around 5-6 km along the aquifer and low values at the ends (Fig. 3b). I have no data for TDC109 and 31.

The δ¹⁸O values also show a clear trend with distance along the aquifer, except for well TDC109. (TDC31 was not analysed for δ¹⁸O). The Waimea River has mean δ¹⁸O of -7.2‰, while rainfall on the plains has a mean of -6.2‰. The pattern in Fig. 3c shows increasing recharge from rainfall towards the central part of the aquifer, while river recharge is important at the ends of the aquifer. TDC109 does not fit the trend and shows river recharge around 8 km along the aquifer, but on the west side.

The data clearly shows that rainfall recharge occurs in the Hope region from the overlying Hope Gravels (and probably from the UCA to the LCA). Rainfall recharge carries nitrate into the system. For the UCA, well TDC37 is clearly in the region of greatest recharge and nitrate input, and likewise TDC208 for the LCA. TDC208 has been in this position for the entire period 1972-1999. The very young ages of TDC37 and 208 show that recharge from the surface is direct and consistent from year to year (also shown by their large CFC-12 concentrations below). The ¹⁵N results (not included here) also bear on the source of the nitrate.

3.0 CFC RESULTS

MRTs estimated from the CFC measurements from 1998 and 1999 do not agree well with the tritium results. Applying the same EPM models as were used to determine the tritium MRTs leads to contrary results for some wells where both the tritium and CFC concentrations were measured (Table 2). Many of the samples (and probably all of them) contain excess CFC-12 (some massively). Some of the Waimea Plains samples had the highest CFC-12 concentrations we have ever measured. Apart from the samples containing more CFC-12 than could have come from the atmosphere (i.e. those containing excess CFC-12), all of the others gave younger ages than would be estimated from the CFC-11 concentrations showing that they are also contaminated in CFC-12 to a lesser degree. The source of the CFC-12 contamination is probably agricultural chemicals used on the plains.

Although less prone to contamination, the CFC-11 results are not very satisfactory either. No excess concentrations were observed, but there is still poor agreement with the tritium results for several wells. When the CFC-12 results are demonstrably contaminated, it appears that the CFC-11 results are also likely to be disturbed.

Looking at the results in detail in Table 2, TDC802 from the unconfined Appleby Aquifer shows agreement between the tritium and CFC-11 MRTs, and the CFC-12 concentration is only mildly in excess. It appears that the CFC-11 concentration is about right, because the well is not badly contaminated in CFC-12. In the Upper Confined Aquifer, TDC59 is slightly contaminated with CFCs and the tritium and CFC-11 MRTs shows moderate agreement (36 to 48 years), while TDC37 is massively contaminated and its tritium and CFC-11 MRTs are completely different (0 compared with 68 years). In the Lower Confined Aquifer, both TDC208 and 32 are badly contaminated and there is poor agreement between the tritium and CFC-11 MRTs (with TDC208 being the worse), and TDC14 and 255 are moderately contaminated and their CFC-11 MRTs are much younger than their tritium MRTs.

My conclusion is that only the tritium results can be relied on for dating the groundwater in the Waimea Plains, and that the CFC results are unreliable especially when the CFC-12 is badly contaminated. Note that the EPM models that give the best fits to the tritium data have high degrees of mixing of young and old water (i.e. f values ranging from 85-100%). This explains why excess CFCs have contaminated even the oldest samples (e.g. TDC 14 and 255) in the plains.

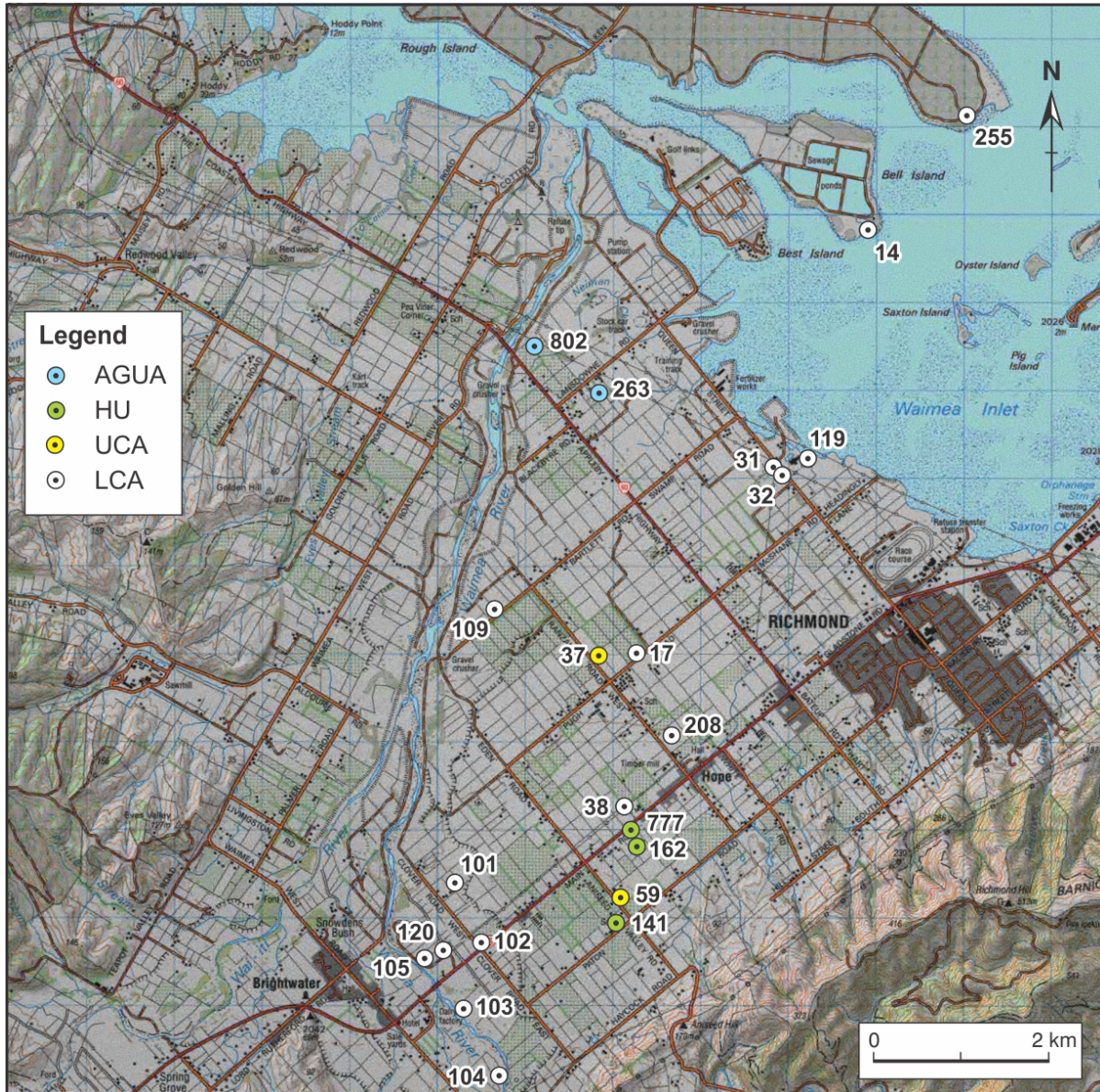


Figure 1 Map of the Waimea Plains showing the locations of the wells sampled for tritium measurements.

Table 1: Tritium concentrations and well details for groundwater samples from the Waimea Plains groundwater system.

Well	Well	Date	Grid	Screened	Distance	Tritium	MRT	f	$\delta^{18}\text{O}$	Cl	SO ₄	NO ₃ -N
TDC#		Collected	Reference	Depth m	km	TR	yr	%	‰	mg/L	mg/L	mg/L
<i>Unconfined Aquifers (AGUA & HU)</i>												
777	Groundwater	19/12/72	S20/506192	12.2		15.2 ± 0.9	0.5	100	-6.2			
162	Groundwater	19/12/72	S20/505188	24.0-25.3		10.0 ± 0.6	17	100	-6.3			
141	Hope School	19/12/72	S20/505180	18.3		14.2 ± 0.9	0.1	100	-6.4			
263	Groundwater	19/12/72	S20/502246	2.1		18.6 ± 1.1	2	100	-6.7			
802	Waiwest	14/06/99	N27/21258816			2.40 ± .07	~0	100	-6.6	11.3	8.3	1.3
<i>Upper Confined Aquifer (UCA)</i>												
59	Zwart	14/06/99	N27/22018222			1.52 ± 0.05	36	98	-6.3			9.0
37	Milson	14/06/99	N27/21858498			2.05 ± 0.06	~0	100	-6.2	16.7	34.0	19.4
<i>Lower Confined Aquifer (LCA)</i>												
104	Baigents	3/02/75	S20/48931595	25.3 - 26.2	0.0	1.9 ± 0.2	71	90	-7.0			
103	Waimea County	26/2/75	S20/48561700	29.3 - 30.5	0.7	3.0 ± 0.4	62	94	-6.6			
105	Railway	3/08/75	S20/47981757	27.4 - 32.9	1.5	4.6 ± 0.4	42	96	-6.7			1.7
101	Sowman No. 1	14/2/75	S20/48261862	28.7-34.1	1.6	5.8 ± 0.8	33	98	-6.7			1.9
120	Near 105	31/1/78	S20/48001756	30.0-34.3	1.7	4.3 ± 0.3	41	96	--			
102	Sowman No. 2	24/2/75	S20/48721774	29.6 - 33.2	2.5	7.5 ± 0.6	22	99	-6.8			1.1
38	Woodford	30/8/73	S20/506194	31.7-32.6	4.3	13.4 ± 0.8	10	100	--			
208	Ranzau Rd	19/12/72	N27/22688409	33.5	5.2	15.8 ± 1.0	1	100	-6.4			
208		14/3/83				3.93 ± 0.20			-6.5			
208		15/06/99				2.16 ± 0.06			-6.5			20.4
109	Bartletts Rd	16/4/75	S20/48852176	29.9-30.5	5.4	1.4 ± 0.4	78	89	-7.4			
17	Pughs Rd	17/11/72	S20/508216	33.5	5.7	10.5 ± 0.6	16	100	-6.6			
32	RBC#2	17/11/72	N27/23768724	32.0-38.1	8.2	6.4 ± 0.4	31	98	-6.7			
32		16/4/75				6.0 ± 0.5			-6.4			
32		14/06/99				1.70 ± 0.05			-6.4	16.0	22.0	13.2
31	RBC#3	14/3/83		31.6-37.9	8.3	2.28 ± 0.15	66	92	--			10.0
119	Chipmill	26/6/86		31.0-39.6	8.5	2.67 ± 0.19	41	96	-6.3			14.0
14	Bells Island	15/3/83	N27/25008984	38.5-54.0	11.2	0.71 ± 0.14	110	85	-7.0			
14		27/6/86				1.02 ± 0.10			-7.0			
14		14/06/99				0.488 ± 0.023			-7.0			5.7
255	Rabbit Island	3/02/83	N27/26279131	47.0-56.6	12.9	-0.14 ± 0.11	150	85	-7.1			
255		20/11/86				0.07 ± 0.09			-7.1			3.2

Table 2: Comparison of mean residence times (MRTs) from tritium and CFC measurements.

Well	EPM	Tritium		CFC-11		CFC-12	
No.	f	Concentration	MRT	Concentration	MRT	Concentration	MRT
TDC#	%	TU	yr	pptv	yr	pptv	yr
<i>Appleby Aquifer (AGUA)</i>							
802	100	2.40	~0	271.6	~0	696.0	Excess
<i>Upper Confined Aquifer (UCA)</i>							
59	98	1.52	36	95.2	48	546.5	~0
37	100	2.05	~0	71.4	68	14,245	Excess
<i>Lower Confined Aquifer (LCA)</i>							
208	100	2.16	1	97.8	46	4,259.0	Excess
32	98	1.7	31	89.7	50	2,322.0	Excess
14	85	0.488	110	55.5	63	579.0	~0
255	85	--	>150	55.9	57	210.3	32

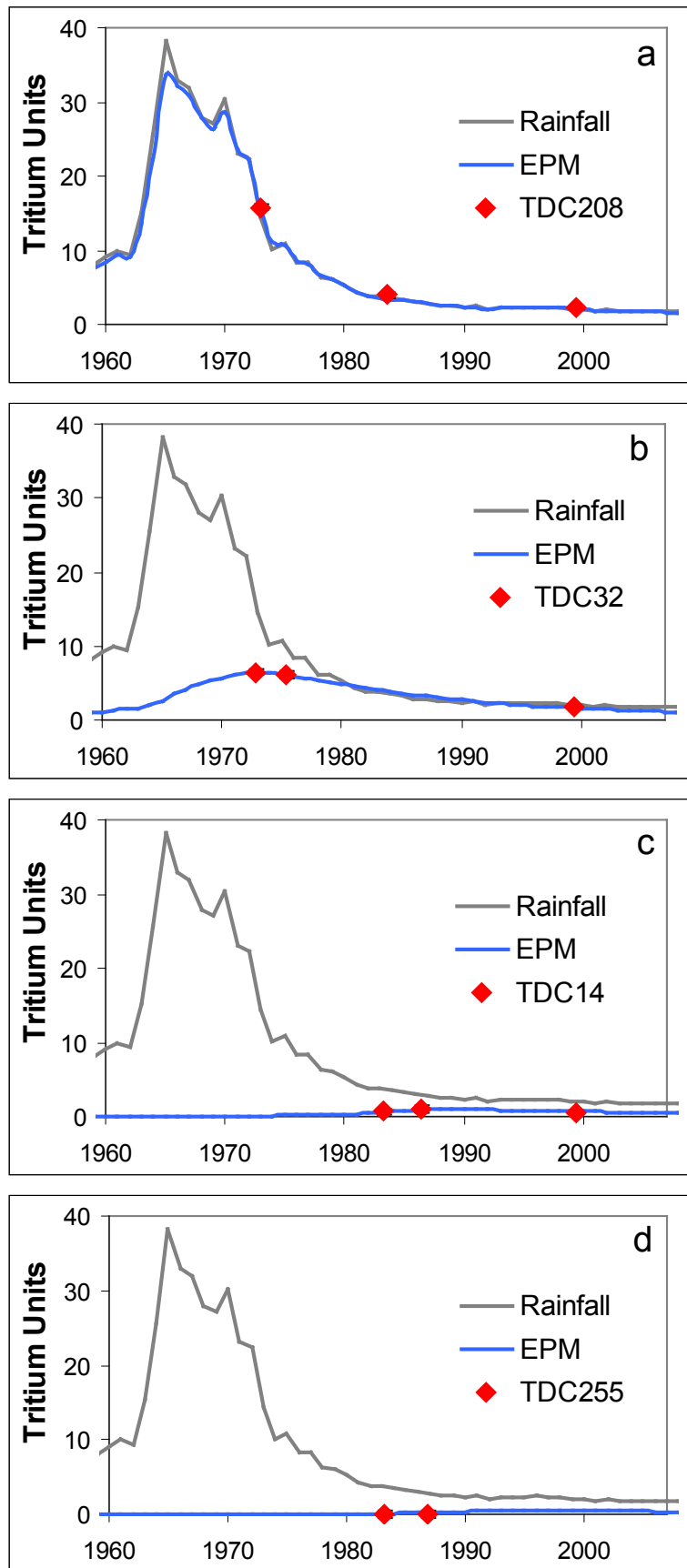


Fig. 2a-d: Tritium measurements and age simulations for wells TDC208, 32, 14 and 255.

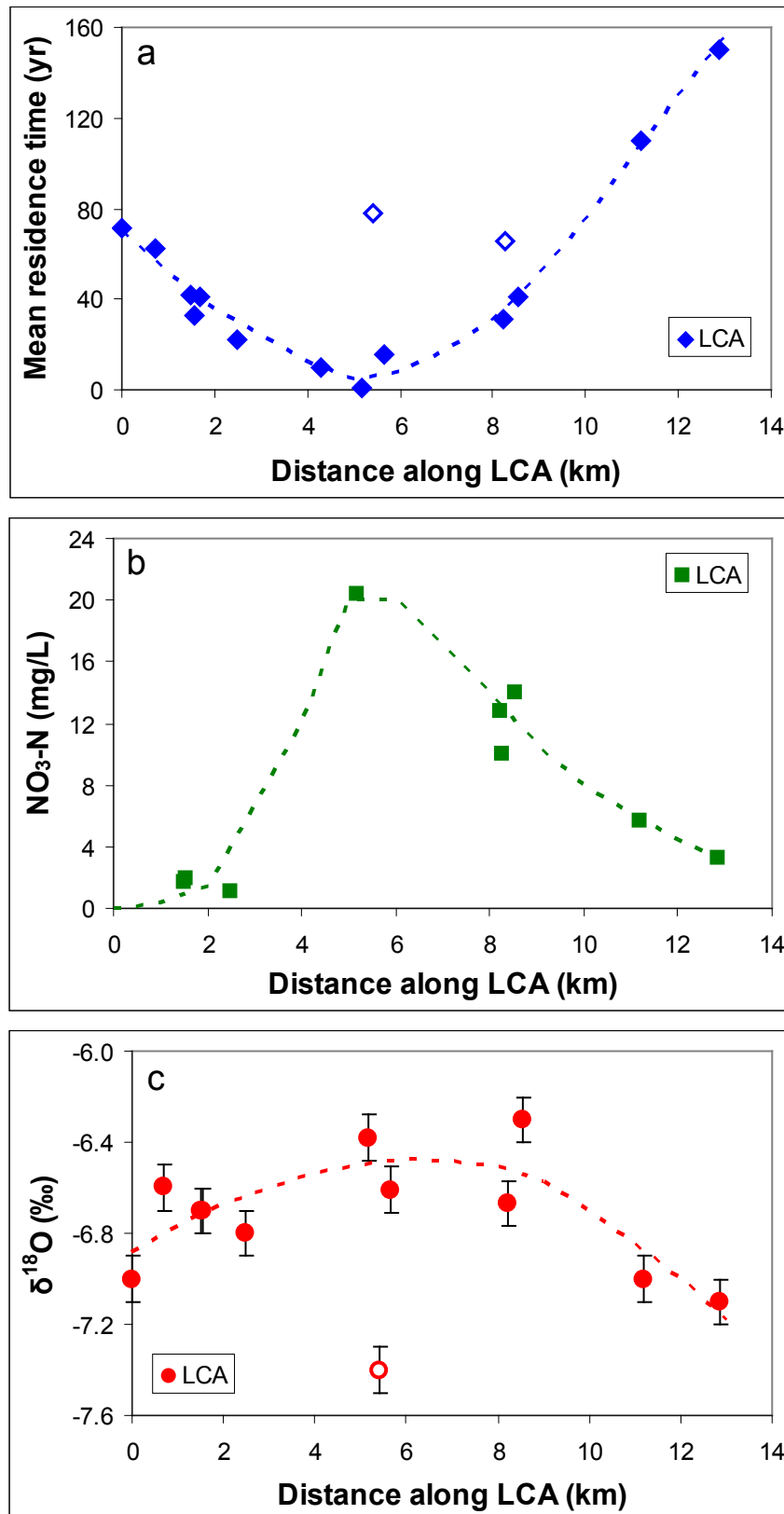


Fig. 3a-c: Plots of mean residence time, NO₃-N, and δ¹⁸O versus distance along the Lower Confined Aquifer from the gorge end. Open symbols mark outliers to the trends.



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