Groundwater residence time in a dissected and weathered sandstone plateau: Kulnura–Mangrove Mountain aquifer, NSW, Australia

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* Tables S1–3 [indicated by an asterisk (*) in the text and listed at the end of the paper] are Supplementary Papers; copies may be obtained from the Geological Society of Australia's website (www.gsa.org.au), the Australian Journal of Earth Sciences website (www.ajes.com.au) or from the National Library of Australia's Pandora archive (<http://nla.gov.au/nla.arc-25194>).

Table S1 Groundwater wells with number corresponding to the NOW monitoring well number, sampling date, elevation, total well depth, screened interval and abbreviated water type.

Table S2 SIROQUANT calculated proportions (wt%) for the different whole rock samples. Well location can be seen in Figure 1. Qtz = quartz, Clay = kaolinite + illite + interstratified illite/smectite, Goe = goethite, Rut + Ana = rutile + anatase, Sid = siderite, Mic = microcline, others depending on samples are Ank = ankerite, Mus = muscovite, Cal = calcite.

Table S3 Estimated average vertical hydraulic conductivity, K_v , between screens (or the ground surface) where SWL's, apparent ages and samples are available.

REFERENCES

- CENDÓN D. I. & HANKIN S. 2008. The ^{14}C ages for groundwater in the Bangalow and Ourimbah Creek borefields (Gosford, NSW). *ANSTO/C-988*, 24 pp.
- CENDÓN D. I. & HANKIN S. 2009. ^{14}C ages for groundwater in the Narara borefield (Gosford, NSW), *ANSTO/C-1027*, 17 pp.

Table S1 Groundwater wells with number corresponding to the NOW monitoring well number, sampling date, elevation, total well depth, screened interval and abbreviated water type.

Well ID	Sampling Date	Elevation (A.H.D.) m	Depth (m)	Screen (m)	SWL (m toc)	Water type
271008–1/07	31/05/2007	324	51	45–48	20.8	Na–Cl
271008–1/08	3/06/2008				17.0	Na–Cl
271008–2/07	31/05/2007	324	111	105–108	32.6	Ca–HCO ₃
271008–2/08	11/04/2008				12.6	Na–Cl
271008–2/09	19/08/2009				45.1	Na–Cl
271008–2/10	19/02/2010				39.7	Na–Cl
271008–2/12	20/02/2012				10.9	Na–Cl
271009–2/07	1/06/2007	254	100	94–97	21.6	Na–HCO ₃
271009–2/08	11/04/2008				16.6	Na–HCO ₃
271009–3/09	22/10/2009	254	150	141–147	17.8	Na–Cl
271009–3/10	19/02/2010				31.8	Na–Cl
271007–1/07	16/05/2007	314	35	29–32	14.4	Na–Cl
271007–1/08	10/04/2008				11.4	Na–Cl
271007–2/06	11/05/2006	314	70	64–67	25.6	Na–Cl
271007–2/07	16/05/2007				23.2	Na–Cl
271007–2/08	10/04/2008				18.9	Na–Cl
271007–2/09	19/08/2009				20.3	Na–Cl
271007–3/07	16/05/2007	314	111	105–108	36.2	Ca–HCO ₃
271007–3/08	10/04/2008				33.5	Na–HCO ₃
271007–3/09	19/08/2009				30.2	Na–HCO ₃
75012–1/06	3/05/2006	256	45	41–44	13.4	Na–Cl
75012–1/07	15/05/2007				12.1	Na–Cl
75012–1/08	5/03/2008				11.4	Na–Cl
75012–2/06	3/05/2006	256	85	81–84	33.6	Na–HCO ₃
75012–2/07	16/05/2007				30.7	Na–HCO ₃
75012–2/08	5/03/2008				32.1	Na–HCO ₃
75012–2/12	20/02/2012				32.3	Na–HCO ₃
75013–1/06	4/05/2006	287	25	21–24	12.6	Na–Cl
75013–1/07	17/05/2007				12.8	Na–Cl
75013–1/08	6/03/2008				6.8	Na–Cl
75013–2/06	3/05/2006	287	55	51.5–54.5	20.5	Na–Cl
75013–2/07	17/05/2007				19.9	Na–Cl
75013–2/08	6/03/2008				15.9	Na–Cl
75013–3/06	3/05/2006	287	110	106–109	29.4	Ca–HCO ₃
75013–3/07	30/05/2007				28.6	Ca–HCO ₃
75013–3/08	6/03/2008				26.2	Ca–HCO ₃
75014/06	4/05/2006	275	65	61–64	18.0	Mg–HCO ₃

75014/08	6/03/2008				14.2	Mg-HCO ₃
75015-1/06	4/05/2006	314	56	52-55	19.0	Na-Cl
75015-1/07	31/05/2007				18.7	Na-Cl
75015-1/08	10/04/2008				14.2	Na-Cl
75015-2/06	4/05/2006	314	100	96-99	30.9	Na-HCO ₃
75015-2/07	31/05/2007				31.0	Na-HCO ₃
75015-2/08	10/04/2008				28.2	Na-HCO ₃
75015-2/09	20/08/2009				28.3	Na-HCO ₃
80163/06	5/05/2006	299	60	51-54	14.2	Na-Cl
80165/06	5/11/2006	196	59.8	53.8-56.8	30.2	Na-Cl
80165/08	3/5/2008				28.7	Na-Cl
80166/06	11/05/2006	196	40.5	34-37	22.0	Na-Cl
80166/08	5/03/2008				20.1	Na-Cl

Table S2 SIROQUANT calculated proportions (wt%) for the different whole rock samples. Well location can be seen in Figure 1. Qtz = quartz, Clay = kaolinite + illite + interstratified illite/smectite, Goe = goethite, Rut + Ana = rutile + anatase, Sid = siderite, Mic = microcline, others depending on samples are Ank = ankerite, Mus = muscovite, Cal = calcite.

GW271007 Depth (m)	Qtz	Clay	Goe	Rut + Ana	Sid	Mic	Other
0.5	84.9	12.3	2.5	0.3			
1.5	86.0	13.7	0.1	0.2			
2.5	68.5	31.2	0.1	0.2			
3.5	82.0	16.5	1.1	0.4			
4.5	77.6	21.5	0.9				
8.5	85.6	13.4	0.3	0.7			
12.5	88.6	10.8	0.2	0.4			
16.5	85.9	13.1	0.7	0.3			
21.5	84.9	14.9	0.1	0.2			
28.5	90.0	9.5	0.2	0.4			
34.5	86.0	13.6		0.5			
36.5	84.8	15.0		0.2			
39.5	82.3	16.4	1.0	0.2			
44.5	99.5	0.2		0.3			
47.5	88.5	10.3	0.8	0.4			
49.5	84.3	14.5		1.1			
51.5	88.0	10.3	1.3	0.4			
55.5	94.3	5.3	0.2	0.2			
62.5	92.4	6.8	0.3	0.5			
65.5	85.2	14.6	0.2				
68.5	86.8	9.8			1.4	1.6	
71.5	79.8	14.2		2.7	3.3		
74.5	74.8	19.0		0.4	4.3	1.4	
77.5	84.2	9.2			0.9	5.6	
81.5	77.2	19.2		0.7	2.4		0.8 Ank
83.5	56.6	30.8		0.1	7.5	4.9	
86.5	57.0	37.8		0.4	4.7		
90.1	75.6	16.8			3.0	4.6	
94.5	81.5	10.1		0.2	3.2	4.9	
97.5	77.1	15.9			4.6	2.4	
99.5	81.4	9.7			0.9	8.0	
102.5	77.7	16.7			3.8	1.8	
104.5	85.7	5.4			2.9	5.9	
106.5	80.4	12.4		1.3	1.8	5.4	
107.5	77.2	12.7			1.9	8.2	

GW271012 Depth (m)	Qtz	Clay	Goe	Rut + Ana	Sid	Mic	Other
0.5	87.9	9.9	1.6	0.7			
1.25	93.0	5.2	1.2	0.5			
1.75	86.7	12.9		0.4			
2.5	88.9	7.5	3.0	0.5			
3.5	85.1	14.4	0.1	0.4			
4.5	67.8	31.6	0.4	0.3			
5.5	83.7	15.1	1.0	0.3			
6.5	83.7	14.7	1.2	0.5			
7.5	82.5	16.7	0.5	0.3			
8.5	85.0	14.0		0.9			
9.5	85.7	13.5	0.6	0.2			
10.5	86.9	12.7	0.1	0.3			
11.5	88.8	10.5	0.1	0.4			
12.5	45.6	54.5					
13.5	59.6	40.2	0.2				
14.5	90.2	9.4	0.4				
15.5	58.6	41.4					
16.5	82.4	16.9	0.3	0.4			
17.5	87.1	10.8	1.6	0.5			
19.5	87.6	10.0	2.0	0.4			
21.5	85.8	13.1	0.2	0.9			
23.5	56.7	41.4	1.8	0.1			
25.5	42.3	15.7	41.8		0.1		
27.5	90.4	8.2	0.7	0.6			
29.5	92.6	6.7	0.1				
31.5	91.8	6.9	0.5	0.8			
33.5	91.1	8.2	0.1	0.7			
35.5	87.1	10.7	1.4	0.8			
37.5	79.4	11.2			4.3	5.0	
39.5	77.9	10.0			4.9	7.2	
41.5	65.7	19.7			8.6	5.9	
43.5	71.1	14.5		0.4	9.7	4.3	
45.5	70.2	15.0			8.4	6.4	
47.5	87.5	4.5			1.3	6.8	
49.5	79.5	12.7			0.9	6.5	
50.5	71.0	17.9			3.6	7.5	
52.5	69.5	18.2			4.0	8.3	
53.5	68.8	20.7			5.0	5.4	

GW271008 Depth (m)	Qtz	Clay	Goe	Rut + Ana	Sid	Other
0.5	62.6	23.0	12.6	1.8		
1.5	79.4	18.4	1.2	0.9		
2.5	59	41.0		0		
3.5	64.4	35.5		0.1		
4.5	72.2	27.6		0.3		
5.5	80.1	13.0	4.1	0		
8.5	82.8	14.1	3.1	0.1		
10.5	80.9	18.5	0.5	0.1		
14.5	86.1	13.5	0.3	0		
15.5	87.4	11.6	0.9	0		
16.5	75.0	23.3	1.2	0.5		
19.5	87.8	11.1	0.3	0.1		
25.5	74.1	24	1.1	0.8		
30.5	82.8	15.7	0.9	0.6		
35.5	84.2	13.7	1.2	0.8		
40.5	87.7	10.9	0.8	0.7		
45.5	90.2	8.1	1.0	0.8		
50.5	88.3	10.0	1.1	0.7		
55.5	84.7	13.3	1.1	0.8		
59.5	79.4	19.1	0.7	0.9		
62.5	81.6	13.7		1.9	1.0	
65.5	81.0	17.3	0.8	0.9		
68.5	80.9	16.9	1.1	1.1		
70.5	69.1	29.2	1.1	0.5	0.1	
75.5	82.9	15.6	0.9	0.7		
80.5	83.1	14.6	1.6	0.9		
84.5	77.4	19.4	2.7	0.6		
86.5	79.1	19.1	1.2	0.5		
91.5	84.9	13.1	0.9	0.7	0.3	
95.5	75.1	20.8	1.0	0.6	2.5	
96.5	74.1	21.1	0.5	1.0	3.2	
97.5	56.2	33.8	0.7	2.0	7.4	
100.5	67.3	24.2	0.5	1.0	6.9	
103.5	65.8	26.0	0.5	0.8	6.9	
105.5	70.1	24.7	0.6	0.9	3.7	
107.5	72.3	23.3	0.2	1.6	2.5	
110.5	78.3	18.7	0.4	0.8	1.7	

GW271009 Depth (m)	Qtz	Clay	Goe	Rut + Ana	Sid	Other
0.5	69.4	21.4	8.4	0.8		
1.5	69.1	21.2	8.7	0.9		
2.5	73.4	24.8	1.5	0.3		
3.5	59.0	39.1	1.8	0.1		
4.5	72.9	26.3	0.7	0		
5.5	85.7	9.2	4.3	0.8		
8.5	80.0	13.3	5.6	1.1		
11.5	91.2	6.2	1.7	0.9		
17.5	87.1	11.5	0.5	0.8		
20.5	89.1	9.6	0.6	0.7		
27.5	80.0	18.2	0.9	0.8		
30.5	67.8	30.9	0.5	0.9		
33.5	87.7	10.9	0.7	0.8		
35.5	87.4	10.9	0.9	0.8		
38.5	85.7	12.8	0.9	0.6		
43.5	89.1	8.4	0.8	0.8	0.9	
49.5	86.3	11.5	1.1	1.0		
54.5	83.1	12.6	0.5	1.0	2.7	
59.5	78.4	10.3	0.5	0.5	10.2	
65.5	72.1	19.9	0.6	0.6	6.7	
70.5	75.5	20.3	0.6	1.0	2.7	
75.5	59.5	31.4		1.2	8.0	
80.5	68.0	25.1	0.6	1.2	5.2	
85.5	74.7	15.5	0.3	0.7	8.7	
90.5	71.4	23.7	0.8	1.0	3.1	
95.5	87.6	9.5	0.2	0.7	2.0	
100.5	80.4	14.4	0.3	0.4	4.4	
105.5	76.5	17.9	0.7	1.0	4.0	
110.5	90.7	7.6		0.7	1.0	
115.5	75.8	18.3	0.2	0.7	5.0	
119.5	71.5	20.3	0.7	1.3	6.3	
125.5	74.7	18.5	0.6	1.0	5.2	
130.5	57.4	29.0		1.0	7.7	4.8 Mus, Cal,
135.5	88.1	9.4	0.1	0.8	1.7	
140.5	86.7	10.3	0.4	0.8	1.8	
142.5	76.9	17.2		0.9	4.9	
144.5	80.6	12.6	0.5	1.0	5.4	
148.5	86.0	10.3	0.4	0.8	2.5	

Table S3 Estimated average vertical hydraulic conductivity, K_v , between screens (or the ground surface) where SWL's, apparent ages and samples are available.

Well group number	271008	271007	75015	80163	75013	75014	75012	271009	80166	80165
Surface AHD (m)	324	314	314	299	287	275	256	254	196	196
No. samples	n = 2	n = 2	n = 3	n = 1	n = 3	n = 2	n = 3		n = 2	n = 2
Average K_v (m/s)	3.1E-08	1.9E-08	9.9E-10	1.50E-08	6.0E-08	4.5E-11	4.8E-08		4.2E-09	2.1E-10
Std Dev	8E-09	5E-09	1.6E-10	n/a	2.7E-08	1E-12	4E-09		2E-10	6E-11
Shallow screen AHD (m)	277.5	283.5	260.5	246.5	264.5	212.5	213.5	n/a	160.5	140.7
No. samples	n = 1	n = 2	n = 3		n = 3		n = 3	n = 2		
Average K_v (m/s)	2.8E-10	7.4E-10	9.6E-11		5.6E-08		3.5E-11	6.7E-10		
Std Dev	n/a	6E-11	8E-12		6E-09		3E-12	9E-11		
Intermediate screen AHD (m)	217.5	248.5	216.5		234		173.5	158.5		
No. samples		n = 3			n = 3			n/a		
Average K_v (m/s)		2.4E-10			2.9E-10					
Std Dev		1.2E-10			3E-11					
Deep screen AHD (m)		207.5			179.5			110		

Estimation of K_v was simply based on the Darcy equation:

$$v = -K_v \Delta H \Delta L$$

Where Darcy's specific discharge, v , is proportional to head differences ΔH , and (for vertical velocities) inversely proportional to the difference in depths, ΔL . Apparent vertical velocity between the middle of each screened interval or the soil profile is simply $\Delta L \Delta t$, where Δt is the difference in corrected ages. Assuming uniform sandstone porosity, θ , of 15%, to convert vertical velocity to specific discharge gives:

$$\Delta L \Delta t \cdot \theta = -K_v \Delta H \Delta L$$

Therefore:

$$K_v = \Delta L \Delta t \cdot \Delta L \Delta H \times 0.15$$