Appendix A Borelog Geology Interpretation

WS Number	Easting (NZMG)	Northing (NZMG)	Bore Depth (mbgl)	Cased Depth (mbgl)	Static Water Level (mbgl)	Borelog Rating[1]	Bottom Clay (mbgl)	Bottom Wrthd Basalt or Scoria[2] (mbgl)	Bottom Hard Basalt (mbgl)	Bottom Wrthd Basalt or Scoria (mbgl)	Bottom Hard Basalt (mbgl)[3]	Identified Fracture Zones (mbgl)
204046	2612875	6606875	34	9	5.8	5	5.7	8.8	12.8	13.7	32	19.5 - 21.6
205148	2623099	6605800	65	16.5	17	5	3.9	**21.3**	>65			53 - 53.5, 54.8 - 60.3
209570	2624977	6605232	48	12	22	5	1	**2**	31	**34**	36	21 - 22.5
204048	2612900	6603600	25	15.5	13	4	8	15	18	19.5	24	-
204049	2612900	6603600	62	27	39	4	6.5	25.5	35	40	61	-
205047	2614670	6606080	34	6.5	14	4	5.5	*7.6*	31.4	*33*	34.5	-
205071	2616699	6602300	28	9.1	3.6	4	8.8		21.6	**25.6**	30.5	-
205083	2617399	6605000	39	23.7	-	4	12		23.4	*29*	39	-
205086	2616799	6602299	16	3.4	-	4	3.35		7	12.8	14	-
205102	2618899	6605199	55	15.8	19.8	4	0.6	7.6	29.8	33.5	>55	-
205122	2620999	6606499	118	12.2	61	4	9.1		74	**109**	116.7	-
205123	2621300	6606200	98	55.4	79.1	4	2.7	**11.6**	24.4	**93.5**	>98	-
205124	2621099	6605800	80	12.8	48.7	4	2.4	**30.5**	32	**34.1**	53.9	-
205146	2623000	6602799	31	-	DRY	4	4.3		5.4	8.5	>31	8.5 – 12.5
205197	2625337	6605452	60	18	14.5	4	3	**12**	>14.5			-
205268	2627219	6605958	62	14	8.2	4	8.2	12.2	27.4	40	>62	12.2 – 14.6, 23.7 – 27.4, 51.8 – 61.6
205557	2614899	6605899	39	19.6	-	4	6	*12.6*	17	*>39*		19.6 – 24.6
205582	2624700	6605500	89	19.8	21.9	4	9.1	**18.3**	>89			81.9, 84.7, 87
205672	2622999	6605499	56	18	17.5	4	9	**13**	42	**45**	>56	-
205835	2613775	6605674	30	22	6.5	4	1.5		6.5	**13**	22	-
207151	2615499	6601699	57	34	30	4	15.5	**18**			47.5	38 – 39.5, 40 – 41.5, 43.5 – 43.8, 44.5 - 45
209467	2614780	6601336	44	21.6	30.9	4	5.2		>44			-
209537	2619837	6602211	32	31.5	2.5	4	4.5	12	>32			20 - 25

WS Number	Easting (NZMG)	Northing (NZMG)	Bore Depth (mbgl)	Cased Depth (mbgl)	Static Water Level (mbgl)	Borelog Rating[1]	Bottom Clay (mbgl)	Bottom Wrthd Basalt or Scoria[2] (mbgl)	Bottom Hard Basalt (mbgl)	Bottom Wrthd Basalt or Scoria (mbgl)	Bottom Hard Basalt (mbgl)[3]	Identified Fracture Zones (mbgl)
209697	2615332	6605644	43	9	12.2	4	4	**7**	14	**23**	29	-
204045	2612000	6607700	11	6	2	3	2				*10.5*	-
204050	2612900	6603100	31	29	22.7	3	4	8	12	14	31	-
204056	2612999	6606999	30	-	-	3	1.2		14	15.5	>30	28 – 30.2
204057	2612700	6607200	27	17.6	10	3	2	4	16	*19*	>27	-
205038	2613410	6603526	62	27	39	3	6.5	18	40	51	61	-
205044	2614400	6605700	74	20	6	3	10		24	58	65	-
205048	2614700	6606200	32	8.5	2.7	3	6.25		12	26	30	-
205049	2614700	6606300	28	10	3.8	3	1.2	9.7	>28			
205072	2616699	6602300	37	7.9	6.4	3	7.9		14.9	>37		-
205088	2616799	6603500	15	-	3.8	3		12.2			15	-
205093	2617600	6604599	67	16	-	3		**15.2**	>67			-
205096	2618200	6604300	11	8.2	5.5	3	1.2	**5.4**	>11			6.7 – 10
205097	2618400	6604299	42	6.5	6.4	3	6.1		39.6	>42		-
205104	2619199	6602299	66	19.5	18.5	3	4	18.5	>66			-
205108	2619599	6603500	53	10	5	3	4.5	9.5	>53			-
205115	2620087	6605127	65	15.2	-	3	10		>65			60
205117	2620399	6604999	36	7.9	6.1	3	3.9	**8.5**			34.2	-
205118	2620400	6605199	29	8.6	10	3	10.5	**13.4**	>29			-
205126	2621359	6605558	54	-	-	3	9.45	**20.7**	>54			31 – 39
205132	2621399	6605699	54	-	28.5	3	9.4	**20.7**	44.2	**>54**		-
205137	2622700	6606199	39	21.2	31	3	8.7	**26**	>39			33.9
205138	2622799	6604199	65	-	-	3	3.4	**5.7**	>65			-
205145	2622999	6603799	8	-	-	3	2.7	**7**	>8			-
205152	2626499	6605799	68	12	10	3	8		66.7	**>68**		-
205166	2623799	6606099	25	15.2	-	3	3.7	**22**	>25			-

WS Number	Easting (NZMG)	Northing (NZMG)	Bore Depth (mbgl)	Cased Depth (mbgl)	Static Water Level (mbgl)	Borelog Rating[1]	Bottom Clay (mbgl)	Bottom Wrthd Basalt or Scoria[2] (mbgl)	Bottom Hard Basalt (mbgl)	Bottom Wrthd Basalt or Scoria (mbgl)	Bottom Hard Basalt (mbgl)[3]	Identified Fracture Zones (mbgl)
205170	2623899	6605400	35	19	20	3	6.4	9.1	>35			35
205172	2623900	6605500	6	-	-	3	3.6	**5.4**	>6			-
205173	2623900	6606299	90	18.3	22	3	9.1	**18.3**	>90			-
205174	2623899	6606499	25	15.2	15.2	3	3.6	**21.9**	>25			-
205198	2625400	6605000	66	13	7.8	3		**11.5**			61	32 – 35, 49 – 50, 53 – 54, 57 – 58
205206	2625500	6605200	17	12.2	9	3	1.5	**5.1**	>17			-
205211	2625599	6604999	19	-	8	3	3	**12**	>19			-
205238	2626200	6605599	10	10	6	3	2.3	**10**	>10			-
205281	2628300	6603199	27	-	-	3	4.8	No basalt identified – only sandstone				16.2 – 27.4
205520	2626000	6604799	68	14	24	3	1.5	**11**	>68			29 – 34, 63 – 68
205528	2614800	6606100	38	19.6	-	3	4	6	17	19.8	>38	19.6 – 24.6
205529	2617300	6602399	27	18.5	15.5	3		**17.8**	21.5	**>27**		-
205553	2623799	6605000	72	25	35	3	3	**18**	69	**>72**		-
205554	2623700	6605599	67	25	-	3	7	**15**	>67			61 – 67
205555	2620999	6605300	46	22	14	3	7	13	44			-
205562	2616899	6601900	44	3.6	26	3	2		39	**>44**		38.5 – 39
205618	2622300	6606999	80	44.5	34	3	15	**44.5**	>80			-
205620	2614199	6601099	57	15	5.5	3	16		24	**31**	52	52 – 52.5
205671	2619200	6604599	31	10	3.5	3	6	**10**	>31			10 – 22
205688	2620699	6606899	45	12	8.5	3	9				41	-
205691	2621200	6606400	56	13	-	3	13.8		44	**45.7**	55.5	-
205695	2624000	6606000	95	28	24.8	3	2	**2.6**	>95			74 - 93
205700	2619276	6605771	38	29.2	16	3	6	**21**	>38			36 – 37
205707	2620410	6601803	52	7.8	30	3	0.2	**7.5**			26	-
205725	2621400	6605000	68	24	47	3	0.25	**23.5**	>68			38 – 39.5, 50.5 – 66

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205786	2620999	6606099	123	17	79	3	3	**16**	67	**90**	>123	-
205805	2623972	6605181	73	-	52.7	3	3		72	**>73**		-
205816	2613549	6606400	34	4	12	3	0.5				33	-
205829	2619599	6602800	54	24	19	3	7.5		>54			52
205874	2620300	6601599	45	35.5	32.1	3	4.9		>45			36
207153	2615800	6601399	42	10.9	-	3	8.5		13.3	**18.7**	>42	-
207276	2613399	6601299	35	8	12.5	3	7.3		>35			35
207277	2613199	6604500	35	10	26	3	8				33	20 – 30
207279	2623600	6606400	69	11.5	22.3	3	2.5	**5.8**	>69			-
207283	2613540	6601411	31	6	14.5	3	5		>31			24
207285	2613899	6601499	46	9	17	3	7		>46			-
209020	2615203	6606431	47	9.3	6.9	3	4.8		32.5	**>47**		32 – 46
209096	2613700	6606300	8	-	-	3	4.5		5.8	*>8*		6.1 – 8
209097	2613700	6606300	24	-	-	3	4.5		6.4	*8*		6.4 – 8.5
209098	2613700	6606300	9	-	-	3	4.5		6.1	>9		6.1 – 8.5
209099	2613700	6606300	9	-	-	3	4.5		5.7	8	>9	6.1 – 8.5
209166	2612699	6603042	26	6	9.2	3	4.5		12	**19**	>26	-
209209	2612668	6603044	43	15.5	11	3	6		>43			-
209471	2614019	6601405	48	48	27.5	3	15		>48			-
209751	2614082	6606018	25	14.4	14	3	3	**8**	>25			17 – 19.5
204051	2613300	6602600	41	22.5	13.1	2	2.5	12.2	>41			-
204052	2612866	6603577	61	49	37.5	2	8		>61			20 – 61
204066	2615100	6606799	12	2	2.5	2	1.5		11	**>12**		-
205017	2618843	6608938	14	3.9	5.2	2	4		>14			-
205043	2613800	6605400	47	26	24.6	2	4	12	16	28	>47	-
205053	2614899	6605800	41	19.5	28.3	2	4	10.5	>41			-

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205054	2615200	6605300	10	8	0.5	2	6.1		>10			-
205062	2615900	6605300	83	18	8.5	2	1.2		66.75	*68.8*	79.2	-
205073	2616500	6604500	14	4.2	3	2	2	8	>14			-
205074	2616600	6602800	18	-	4.5	2	2.4	>18				-
205079	2616799	6609500	21	12.4	8.2	2	5.8	No basalt identified – only limestone				-
205082	2616699	6604400	66	-	-	2	11.6		>66			-
205089	2616799	6603500	10	-	3.9	2	>10					-
205103	2619000	6604300	58	6.4	-	2			>58			-
205109	2619799	6604700	29	3.9	1.2	2	1.8		>29			-
205110	2619799	6604700	50	39	-	2	25.6		>50			-
205111	2619800	6604900	33	11.8	-	2	10	**10.6**	>33			-
205113	2619900	6601999	58	5.0	9.5	2	2.8	**5.4**	>58			53
205114	2620199	6605000	23	16.5	9.6	2	6	14	16	21	>23	-
205119	2620600	6607200	36	11	-	2		**10.4**	>36			-
205129	2621410	6605510	40	16	-	2		**13.7**	>40			-
205133	2621600	6605500	24	12	15	2	3	**23**	>24			-
205143	2623000	6605300	26	11.5	17	2	9.8	**19.8**	>26			-
205161	2623600	6605099	64	17.6	-	2	17.6		>64			-
205181	2624199	6605299	27	13	19.8	2		**11.6**	>27			-
205190	2624899	6605599	41	24.4	35	2		**24.4**	>41			-
205215	2625799	6605000	19	18	-	2		**>19**				-
205229	2625900	6604800	44	15.2	-	2		**17.6**	>44			-
205230	2625850	6604750	24	18.3	-	2	1.5	**17.35**	>24			-
205233	2625899	6605000	34	14	14	2	29.5		>34			-
205269	2627300	6606600	23	15.8	2.4	2	4.8		6.7	15.8	16.8	15.85 – 16.76
205516	2627499	6609599	38	23	2	2	3		9	30	>38	-

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205518	2625599	6604999	18	13	7.4	2	2	**12**	>18			14 – 18
205558	2619914	6601815	46	39	21.6	2	1.8	**10**	>46			38 – 45
205596	2615199	6604599	104	15	92	2	15		>104			92 – 104
205598	2613399	6601299	31	3	12	2	2.8		>31			8.5
205619	2625199	6604799	65	11	-	2	11		>65			11 – 65
205724	2614478	6606066	46	3	4.5	2	0.6	**12**	>46			39
205741	2621600	6605399	70	24	51	2		**22**	>70			-
205742	2624300	6606199	38	24	18	2		**22**	>38			-
205758	2619500	6605000	32	13.5	5.4	2	13.2		>32			-
205767	2624000	6606799	43	32	6	2	24				32	-
205775	2619776	6601792	30	29.5	5.5	2	6		>30			6 – 15
205785	2612099	6609600	13	4.3	0.5	2	1.5		>13			1.5 – 11.5
207150	2615299	6600899	47	3.8	DRY	2	4		>47			-
207152	2615537	6601447	37			2	8.2		>37			-
207161	2617700	6601600	37	-	-	2	3		>37			-
207182	2624299	6597500	23	3.6	-	2	3	No basalt identified – only limestone				-
207284	2614012	6601406	44	13	24	2			>44			29 – 40
207286	2620700	6607099	41	6	6	2	4		>41			-
209146	2614040	6605679	40	9	15.3	2	4.8		>40			-
209188	2619951	6601631	17	17	6	2	5		>17			13 – 77
209200	2623900	6605900	53	25.3	19.4	2	3	**9.7**	>53			-
209538	2619646	6602398	18	6	8	2	5		>18			-
209539	2619498	6602272	12	7	6	2	5		>12			-
209550	2619841	6604724	32	13.5	5.4	2	13		>32			-
209659	2613386	6601375	35	8.6	12.5	2	4.5		>35			7.3, 35
209874	2613983	6605443	29	29	24	2	1.5		>29			-

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205456	2614799	6608700	9	6.4	-	1	27.4	>9				-
207140	2612977	6601280	21	13.3	12.2	1			>21			-
204044	2611799	6605500	-	-	-	0	No information on borelog					-
204047	2612900	6605200	-	7.6	1.2	0	No geological information on borelog					-
205045	2614500	6605399	1	4.8	-	0	No geological information on borelog					-
205046	2614600	6605500	20	7.9	5.7	0	No geological information on borelog					-
205052	2614799	6604200	21	-	-	0	No geological information on borelog					-
205056	2615300	6605700	27	18.3	16.4	0	No geological information on borelog					-
205066	2615999	6602800	92	50	68.3	0	Borelog illegible					-
205075	2616600	6602400	15	7	3	0	No geological information on borelog					-
205078	2616600	6602600	10	6	2.9	0	No geological information on borelog					-
205087	2616799	6603500	17	-	5.1	0	No geological information on borelog					-
205095	2618000	6602399	-	12.8	-	0	No geological information on borelog					-
205128	2621300	6605099	-	-	-	0	No information on borelog					-
205136	2622500	6606200	67	36	-	0	Borelog illegible					-
205147	2623000	6602799	14	-	-	0	No geological information on borelog					-
205158	2623599	6605800	60	-	-	0	Borelog illegible					-
205171	2623900	6605500	25	17.6	9.7	0	No geological information on borelog					-
205180	2624199	6605299	-	-	-	0	No information on borelog					-
205231	2625800	6604900	17	12.8	12.8	0	No geological information on borelog					-
205232	2625799	6604700	35	17.7	-	0	No geological information on borelog					-
205282	2628300	6603199	11	-	-	0	No geological information on borelog					-
205283	2628300	6603199	13	-	-	0	No geological information on borelog					-
205523	2621300	6605899	93	27	50.7	0	Borelog illegible					-
205803	2622899	6606600	52	-	-	0	No borelog available					-
205804	2623698	6605188	-	-	-	0	No borelog available					-

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205806	2623972	6605181	-	-	-	0	No borelog available					-
205808	2625522	6605046	-	-	-	0	No borelog available					-
205809	2614670	6606080	36	-	-	0	No borelog available					-
205810	2615088	6601495	-	-	-	0	No borelog available					-
205811	2615925	6605315	-	-	-	0	No borelog available					-
205812	2616037	6602749	-	-	-	0	No borelog available					-
205813	2616882	6601302	16	-	-	0	No borelog available					-
205815	2615157	6601367	-	-	-	0	No borelog available					-
205852	2615771	6605174	83	-	-	0	No borelog available					-
205853	2614900	6605699	23	-	-	0	No borelog available					-
205854	2613599	6606800	-	-	-	0	No borelog available					-
207141	2613100	6601599	66	-	-	0	Borelog illegible					-
207154	2615800	6601399	-	18.8	18	0	No geological information on borelog					-
207159	2617199	6600700	16	9	3.6	0	No geological information on borelog					-
207178	2622699	6599500	-	-	-	0	No geological information on borelog					-
207185	2628099	6601499	7	-	2.1	0	No geological information on borelog					-
209112	2615199	6605399	-	-	-	0	No borelog available					-
209132	2616599	6602300	31	-	-	0	No borelog available					-
209133	2616799	6602299	31	-	-	0	No borelog available					-
209136	2616699	6602399	29	-	-	0	No borelog available					-
209141	2617399	660500	39	-	-	0	No borelog available					-
209464	2613935	6601406	39	-	-	0	No borelog available					-
209505	2625108	6605585	-	-	-	0	No borelog available					-
209549	2619980	6604999	29	-	-	0	Borelog illegible					-
209661	2612853	6601359	-	-	-	0	No borelog available					-
209662	2613721	6601079	-	-	-	0	No borelog available					-

WS Number	Easting (NZMG)	Northing (NZMG)	Bore Depth (mbgl)	Cased Depth (mbgl)	Static Water Level (mbgl)	Borelog Rating[1]	Bottom Clay (mbgl)	Bottom Wrthd Basalt or Scoria[2] (mbgl)	Bottom Hard Basalt (mbgl)	Bottom Wrthd Basalt or Scoria (mbgl)	Bottom Hard Basalt (mbgl)[3]	Identified Fracture Zones (mbgl)
209663	2614260	6601267	-	-	-	0	No borelog available					-
209664	2614314	6601210	-	-	-	0	No borelog available					-
209665	2613770	6601409	-	-	-	0	No borelog available					-
209826	2612761	6607143	-	-	-	0	No borelog available					-
209965	2615569	6605067	-	-	-	0	No borelog available					-

Notes: [1] borelog ratings – 0: no borelog available, 1: poor geological information, 5: detailed geological information available.

[2] depths in bold indicate scoria identified within borelog, while depths in bold indicate vesicular basalt.

[3] indicates top of basement, i.e. base of basalt aquifer.

Appendix B Recharge Modelling

The soil moisture water balance model (SMWBM) is a deterministic lumped parameter model originally developed by Pitman (1976) to simulate river flows in South Africa. Modification of these algorithms and reworking of the code into a Windows environment now permits soil moisture accounting and assessment of the various components of the catchment water balance. In this study, the model is used to determine the percolation to groundwater component of the water balance to be applied directly as aquifer recharge to the groundwater model.

The model operates on a maximum timestep of daily during dry days, with smaller timesteps (hourly) implemented on wet days. When a rainday occurs, daily rainfall is disaggregated into the hourly timesteps based on a pre-defined synthetic rainfall distribution, which includes peak intensities during the middle of the storm. The model time stepping ensures that rainfall intensity effects and antecedent catchment conditions are considered in a realistic manner.

The model utilises daily rainfall and mean-monthly evaporation data to calculate soil moisture conditions and rainfall percolation to the aquifer. The model incorporates parameters that characterise the catchment in terms of:

- interception storage,
- evaporation losses,
- soil moisture storage capacity,
- soil infiltration rates,
- soil moisture percolation rates;
- surface runoff (quickflow);
- stream baseflows (groundwater contribution); and
- parameters that govern the recession and/or attenuation of groundwater and surface water flow components, respectively.

The fundamental operation of the model is as follows:

Daily rainfall is disaggregated into hourly intervals when a rainday occurs to allow refined accounting of soil infiltration and evaporation losses. Rainfall received must first fill a nominal interception storage (PI – see below) before reaching the soil zone, where the net rainfall is assessed as part of the runoff/infiltration calculation.

Water that penetrates the soil fills a nominal soil moisture storage zone (ST). This zone is subject to evapotranspiration via root uptake and direct evaporation (R) according to the mean monthly evaporation rate and current soil moisture deficits. The soil moisture zone provides a source of water for deeper percolation to the underlying aquifer, which is governed by the parameters FT and POW.

If disaggregated hourly rainfall is of greater intensity than the calculated hourly infiltration rate (ZMAX, ZMIN) surface runoff occurs. Surface runoff is also governed by two other factors, which are the prevailing soil moisture deficit and the proportion of impervious portions of the catchment directly linked to drainage pathways (AI).

Rainfall of sufficient intensity and duration to fill the soil moisture storage results in excess rainfall that is allocated to either surface runoff or groundwater percolation depending on the soakage and slope characteristics of the catchment (DIV).

Finally, the model produces daily summaries of the various components of the catchment water balance and calculates the combined surface runoff/percolation to groundwater to form a total catchment runoff discharge.

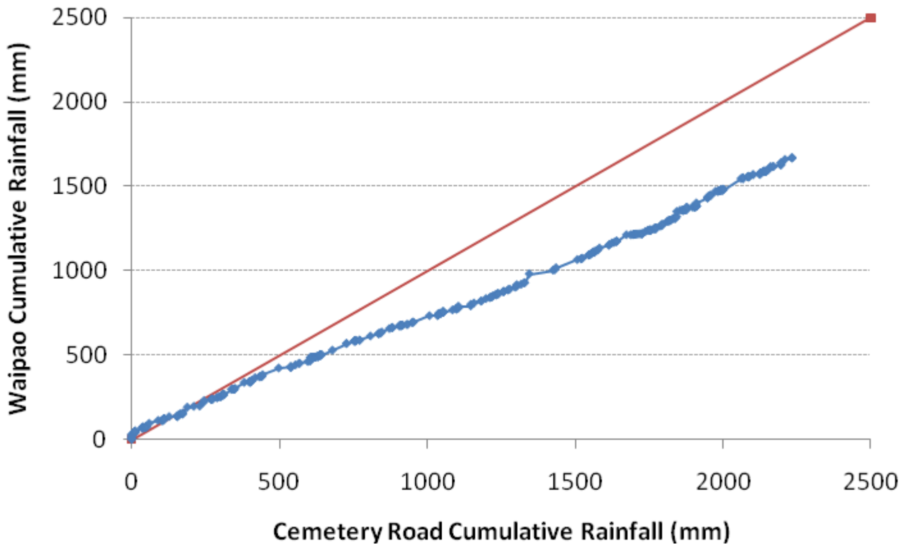
A.1 Model Input

The following data sources were used to obtain input for the model:

Evaporation: Total Penman open water evaporation data was obtained from Station 1287 Whangarei Aero AWS, Network Number A54737.

Rainfall: Rainfall from the Cemetery Road at Mokupara station was selected for inclusion within the SMWBM due to the length of record and minimal data gaps. In order to account for any possible localised rainfall conditions, the Cemetery Road rainfall data was compared with data recorded at the rainfall station beside the streamflow gauge, i.e. Waipoa at Williams site. The cumulative rainfall records for both stations were calculated and compared as shown in **Figure B1**. It was calculated that the Cemetery Road rain gauge recorded higher rainfall (by approximately 1.3) than the Waipoa at Williams site. Therefore, a synthetic rainfall record was developed for Cemetery Road by dividing this rainfall by 1.3.

Streamflow Data: Daily streamflow data from the Northland Regional Council Network Recording Site on the Waipa Draffin Road site was used to calibrate the SMWBM. In addition, low flow spot gauging data collected from site Raumanga at City Weir were used to validate the calibration.



- **Figure B1. Cumulative rainfall comparison between Cemetery Road and Waipao at Williams rainfall stations.**

A.2 Model Parameters

ST: Soil thickness

ST defines the size of the soil moisture store in terms of a depth of water.

SL: Soil moisture storage capacity below which percolation ceases

There is a definable soil moisture state below which percolation ceases due to soil moisture retention. For practical purposes this has been assigned zero.

ZMAX & ZMIN: Maximum and minimum soil infiltration rate

ZMAX and ZMIN are nominal maximum and minimum infiltration rates in mm/hr used by the model to calculate the actual infiltration rate ZACT. ZMAX and ZMIN regulate the volume of water entering soil moisture storage and the resulting surface runoff. ZMIN is usually assigned zero. ZMAX is usually assigned the saturated infiltration rate from field testing. ZACT may be greater than ZMAX at the start of a rainfall event. ZACT is usually nearest to ZMAX when soil moisture is nearing maximum capacity.

FT: Percolation rate from soil moisture storage at full capacity

Together with POW, FT (mm/day) controls the rate of percolation to the underlying aquifer system from the soil moisture storage zone. FT is the maximum rate of percolation through the soil zone.

POW: Power of the soil moisture-percolation equation

The parameter POW determines the rate at which percolation diminishes as the soil moisture content is decreased. POW therefore has significant effect on the seasonal distribution and reliability of percolation, as well as the total yield from a catchment.

AI: Impervious portion of catchment

This parameter represents the proportion of impervious zones of the catchment directly linked to drainage pathways (AI).

R: Evaporation-soil moisture relationship

Together with the soil moisture storage parameters ST and SL, R governs the evaporative process within the model. The rate of evapotranspiration is estimated using a linear relationship relating evaporation to the soil moisture status of the soil. As the soil moisture capacity approaches full, evaporation occurs at a near maximum rate based on the mean monthly pan evaporation rate, and as the soil moisture capacity decreases, evaporation decreases linearly according to the predefined function.

DIV: Fraction of excess rainfall allocated directly to groundwater.

DIV has values 0 – 1 and defines the fraction of excess (ponded) water due to saturation of the soil zone to be routed to groundwater or surface water.

TL: Routing coefficient for surface runoff.

TL defines the lag of surface water runoff. This is not necessary to define for this study as we are only interested in the groundwater percolation component of the water balance.

GL: Groundwater recession parameter.

Has no effect in this application of the model as we are only interested in percolation to groundwater, not the discharge of groundwater to surface water bodies.

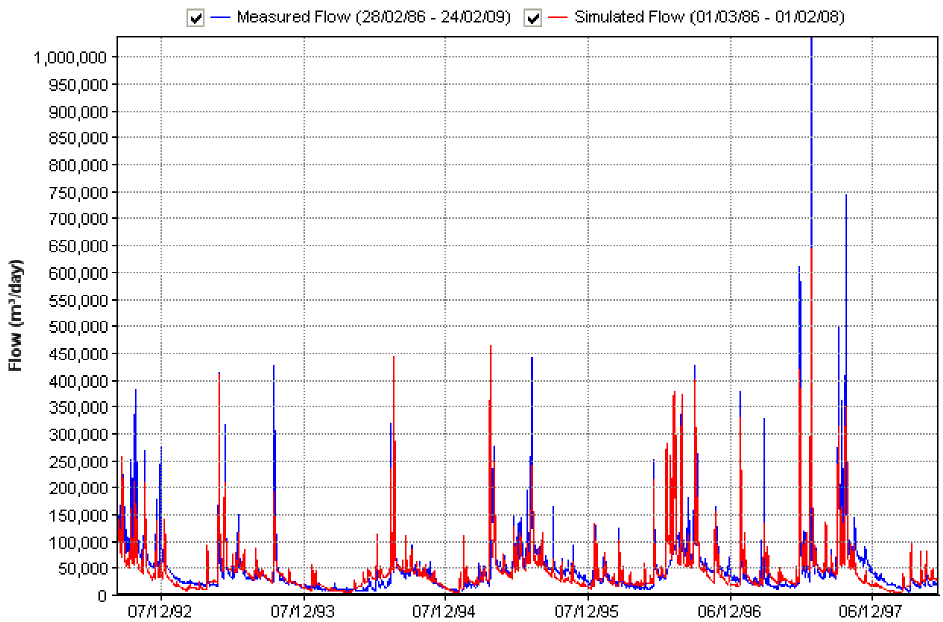
Final model parameters are provided in **Table A1**.

- **Table B1. SMWBM model parameters used for recharge estimation.**

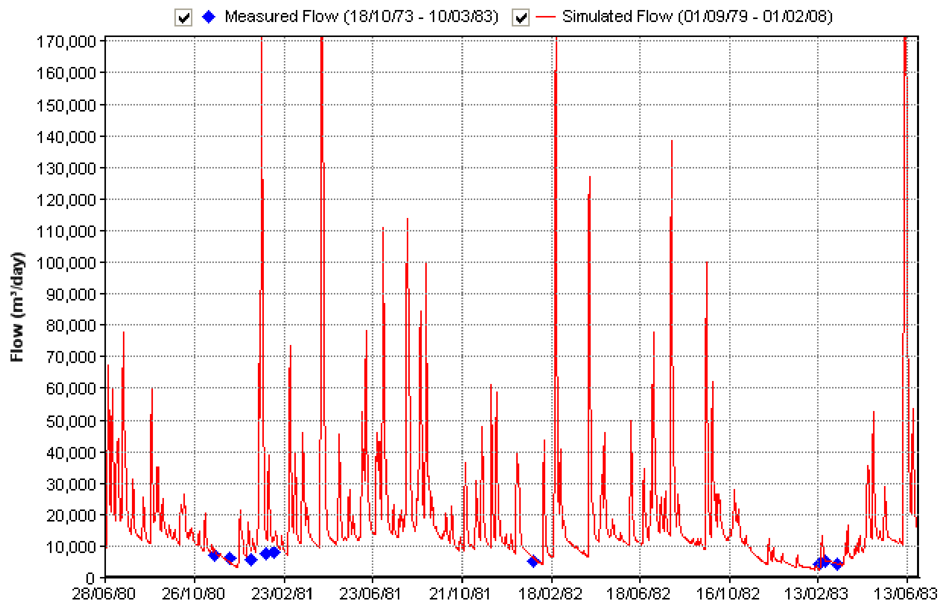
Zone	ST (mm)	Z_{MAX} (mm/hr)	FT (mm/d)	POW	AI	R	DIV
Aquifer Extent	110	8	1.8	0.9	0	0	0

A.3 Model Calibration and Results

Figures B2 and **B3** shows the calibration achieved using SMWBM. Although some peak flows are not accurately simulated, the model reasonably simulates the baseflow component of the flow record, which is of most interest in this study. This calibration was verified by checking the modelled flows against low flow spot gauging within the Raumanga River. The model simulated these low flows with reasonable accuracy.



- **Figure B2. SMWBM calibration graph for Waipa Draffin Road gauging site.**



- **Figure B3. SMWBM calibration graph for Raumanga at City Weir.**

The water balance partitioning from this calibration are shown in **Table B2**.

- **Table B2. Modelled water balance partitioning (%).**

Zone	Interception	Soil Evaporation	Surface Runoff	Groundwater Percolation
Aquifer Extent	20.53	27.77	22.98	29.05

This result indicates that across the aquifer extent, the groundwater recharge will be approximately 29% of the annual rainfall. However, during calibration it became evident that there were different requirements for recharge throughout the model, i.e. in order to simulate spring flows accurately.

Three distinct zones of recharge were assigned to the calibrated model as follows:

1) ***Bulk Aquifer*** – 6% groundwater recharge was assigned to areas where there is high proportion of quickflow. This assumption made is that the majority of rainfall runs across the surface rather than percolating into the groundwater;
2) ***Volcanic Cones*** – 18% groundwater recharge assigned to both the Whatitiri and Maunu cones. These areas were assigned higher recharge as there were less streams originating from these cones, indicating that a higher proportion of rainfall percolates into the groundwater.
3) ***Poroti and Maunu Springs Channel*** – 62% of rainfall was assigned to the Poroti Channel and the 'Tunnel" branch of Maunu Springs. Increased recharge in this area was required to generate the required spring flow from each of these springs and is consistent with a large area of highly permeable material located within the basalt flows.

These zones are shown in **Figure B4**, with specific SMWBM parameters and water balance portioning outlined in **Tables B3** and **B4**. In addition, the recharge assigned to the model for each zone is shown in **Figure B5**.

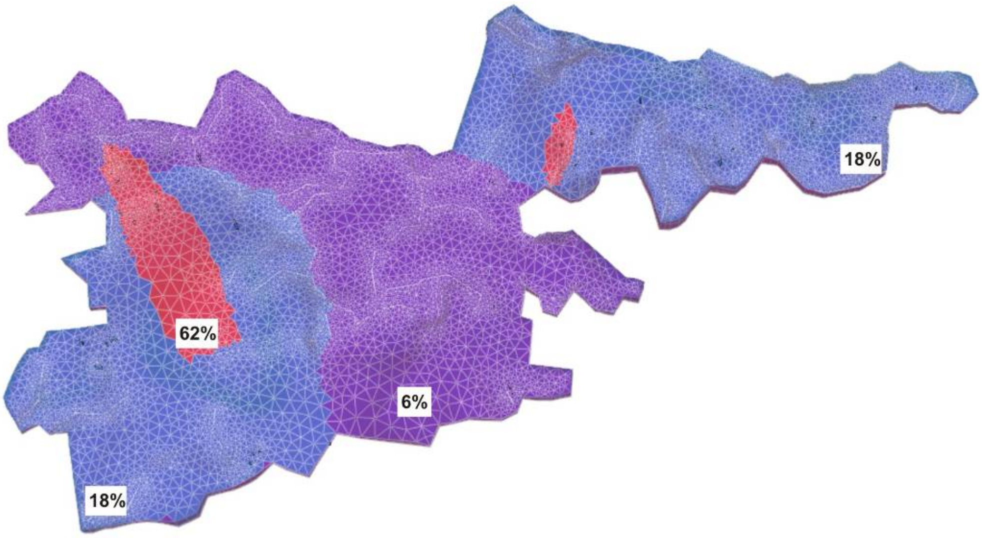


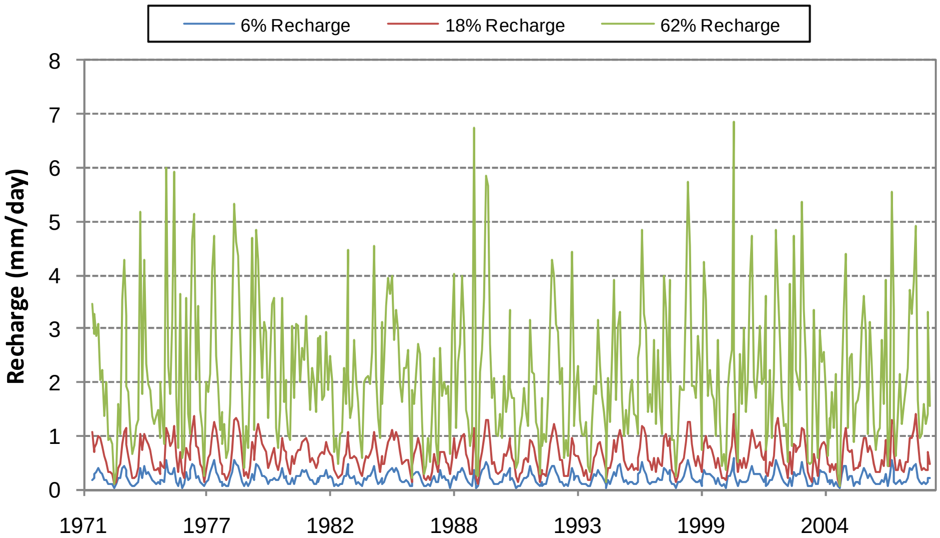
Figure B4. Recharge zones assigned to calibrated model.

Table B3. SMWBM model parameters used for recharge estimation.

Zone	ST (mm)	Z_{MAX} (mm/hr)	FT (mm/d)	POW	AI	R	DIV
Bulk Aquifer	20	1	0.8	0.9	0	0	0
Volcanic Cones	100	2	2	0.9	0	0	0
Poroti/Maunu Springs Channel	110	10	10	0.9	0	0	0

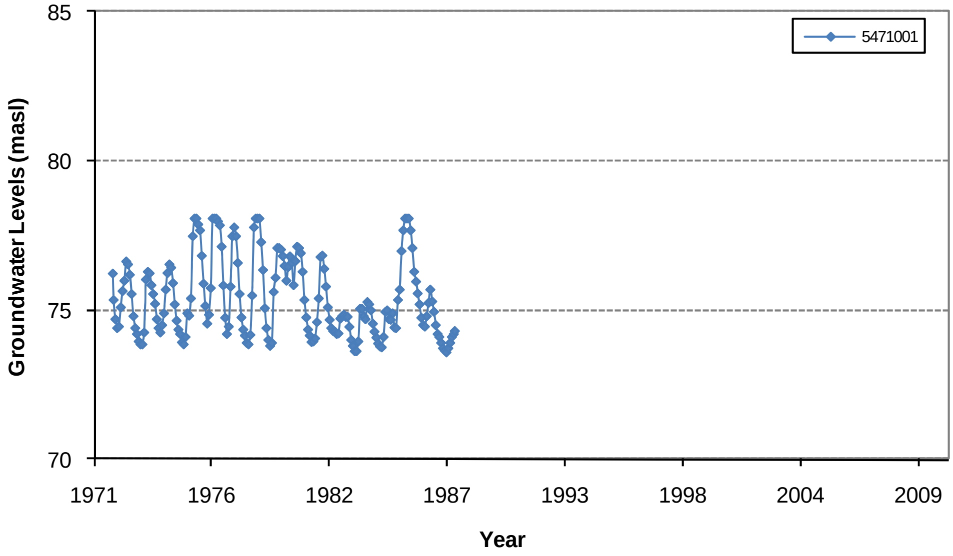
TableB4. Calibrated modelled water balance partitioning (%).

Zone	Interception	Soil Evaporation	Surface Runoff	Groundwater Percolation
Bulk Aquifer	13	16	65	6
Volcanic Cones	20	15	47	18
Poroti/Maunu Springs Channel	20	11	7	62

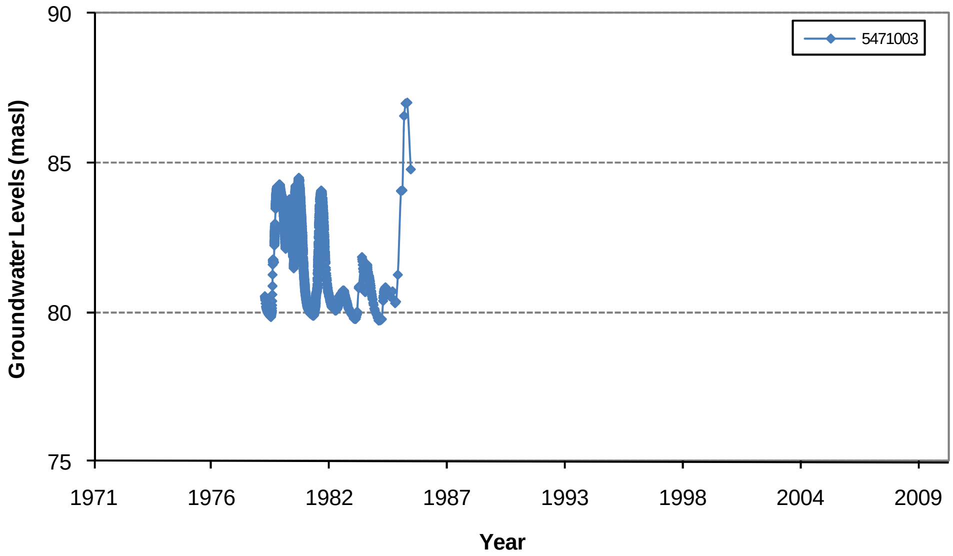


- **Figure B5. Actual recharge assigned to calibrated model for each zone.**

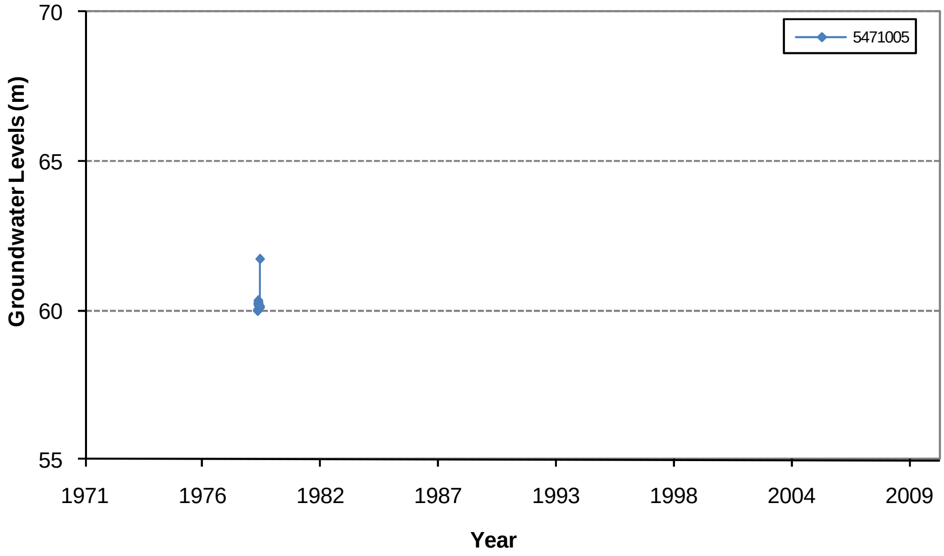
Appendix C Groundwater Level Monitoring Data



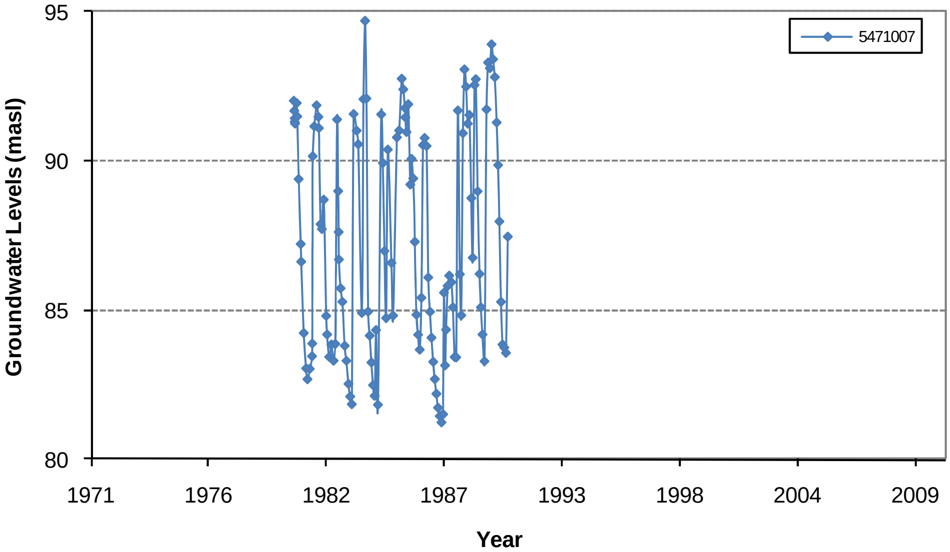
- **Figure B1. Poroti Springs (site number 5471001) hydrograph.**



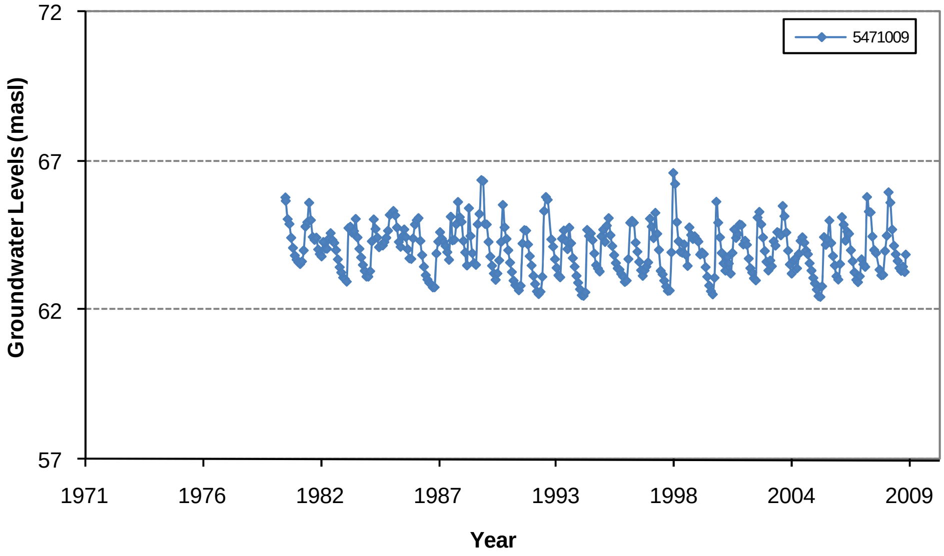
- **Figure B2. Poroti Road (site number 5471003) hydrograph.**



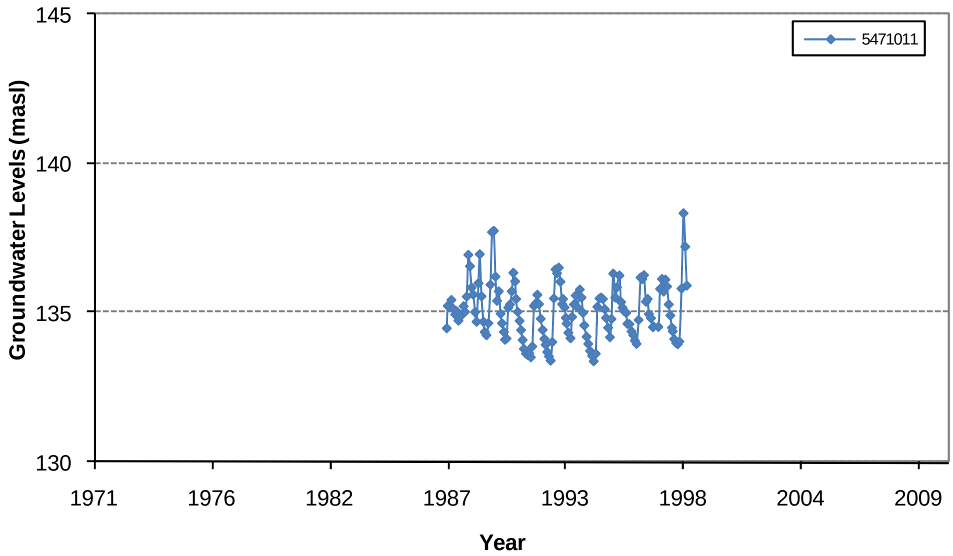
▪ **Figure B3. Cutforths (site number 5471005) hydrograph.**



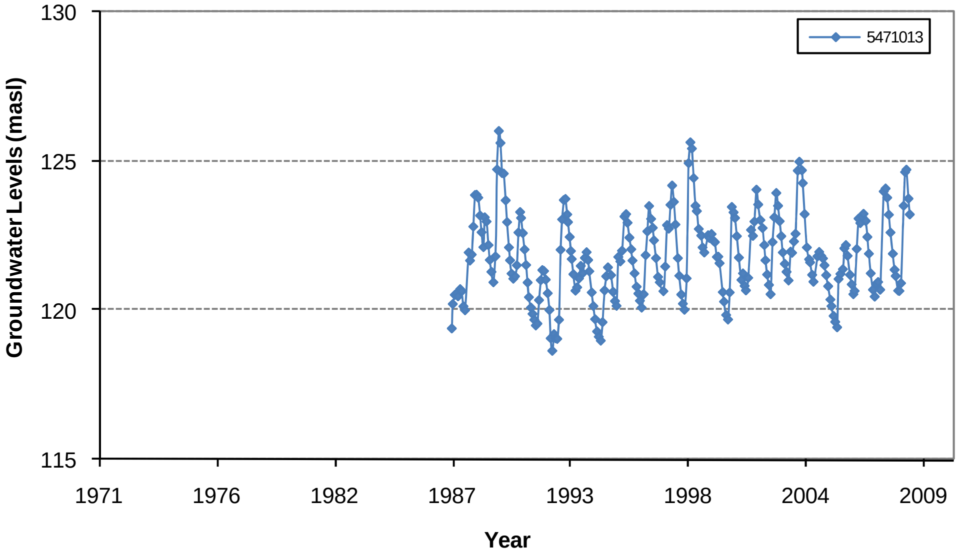
▪ **Figure B4. Whatitiri Wines (site number 5471007) hydrograph.**



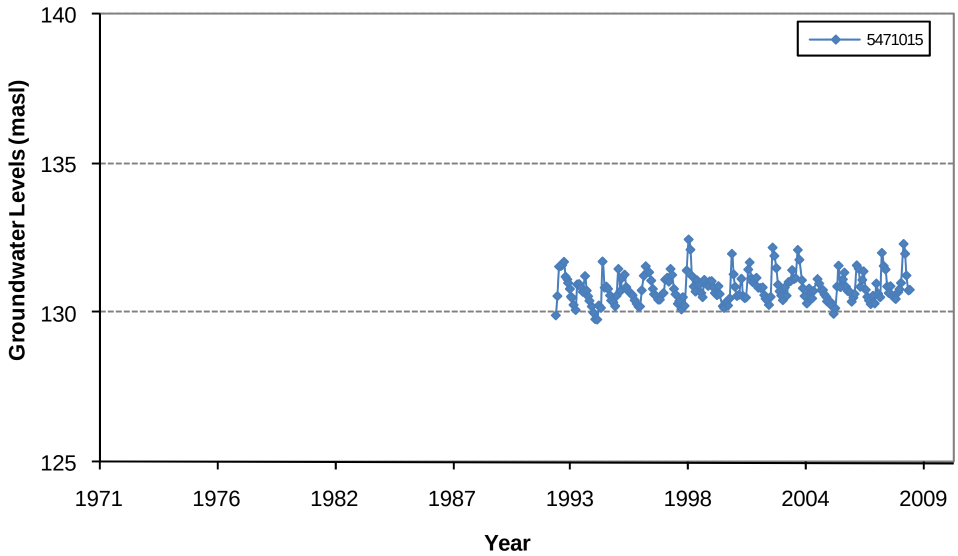
■ **Figure B5. Poroti West (site number 5471009) hydrograph.**



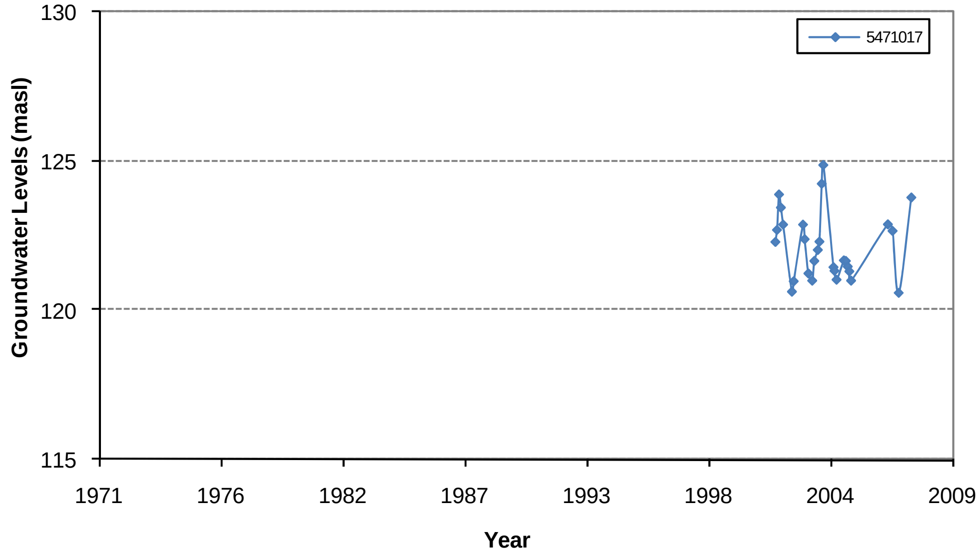
■ **Figure B6. Cochcranes (site number 5471011) hydrograph.**



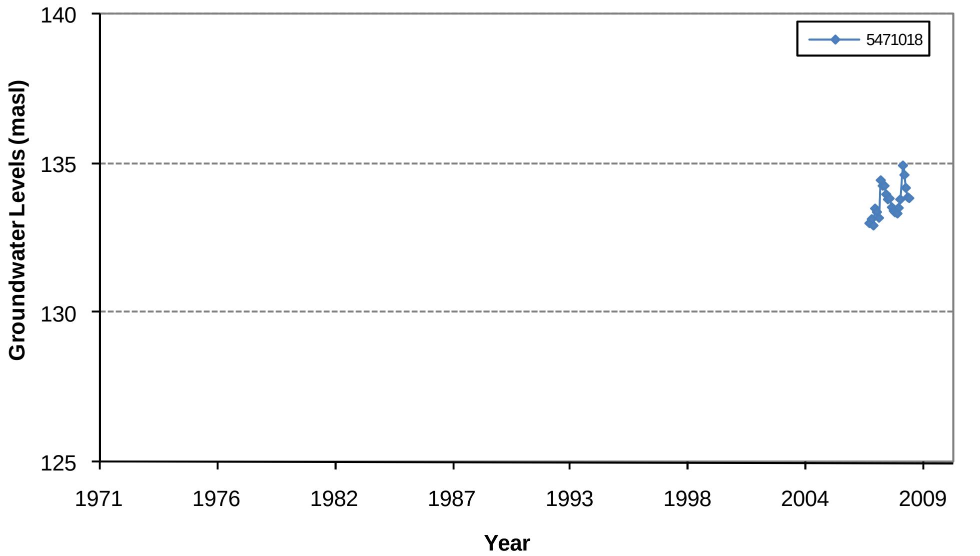
■ **Figure B7. Tanekaha Orchards (site number 5471013) hydrograph.**



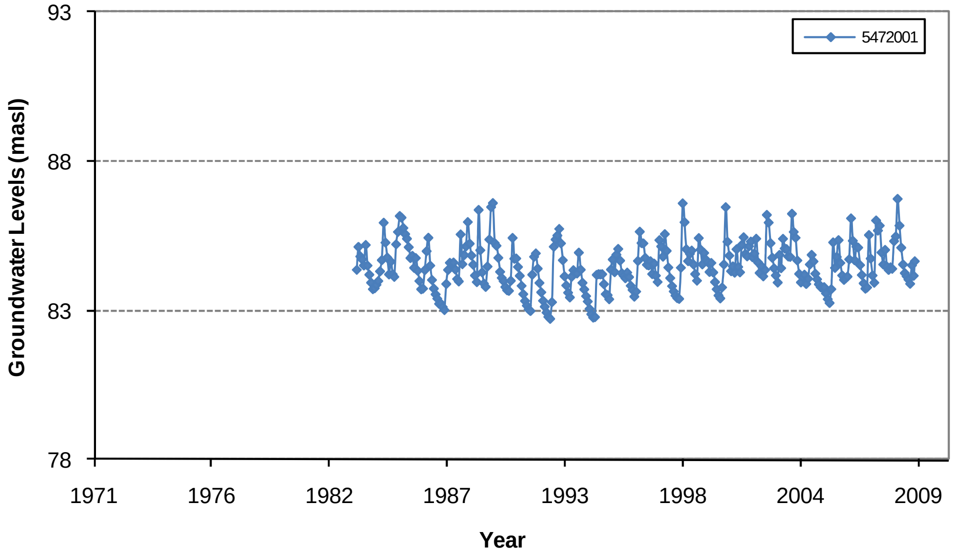
■ **Figure B8. Martins (site number 5471015) hydrograph.**



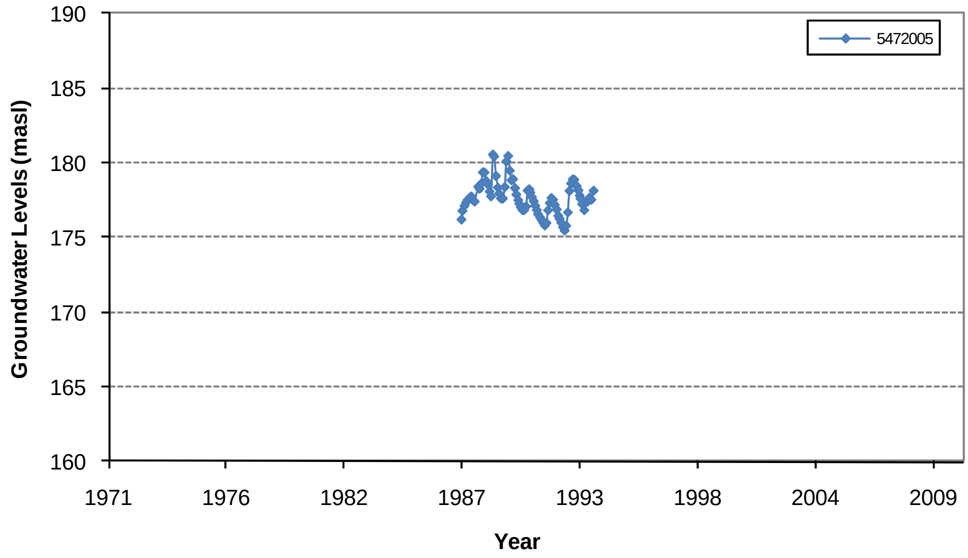
- **Figure B9. Angelo (site number 5471017) hydrograph.**



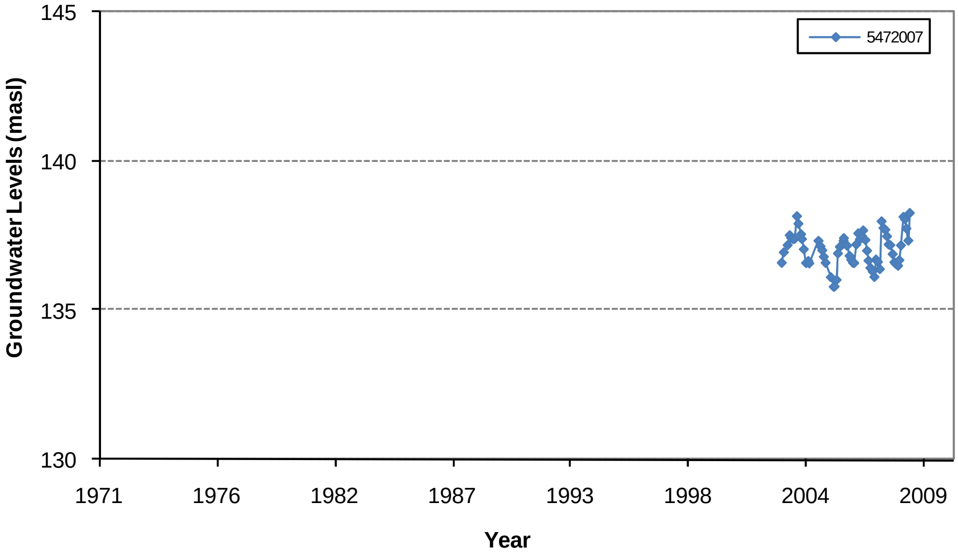
- **Figure B10. Pukeatua Road (site number 5471018) hydrograph.**



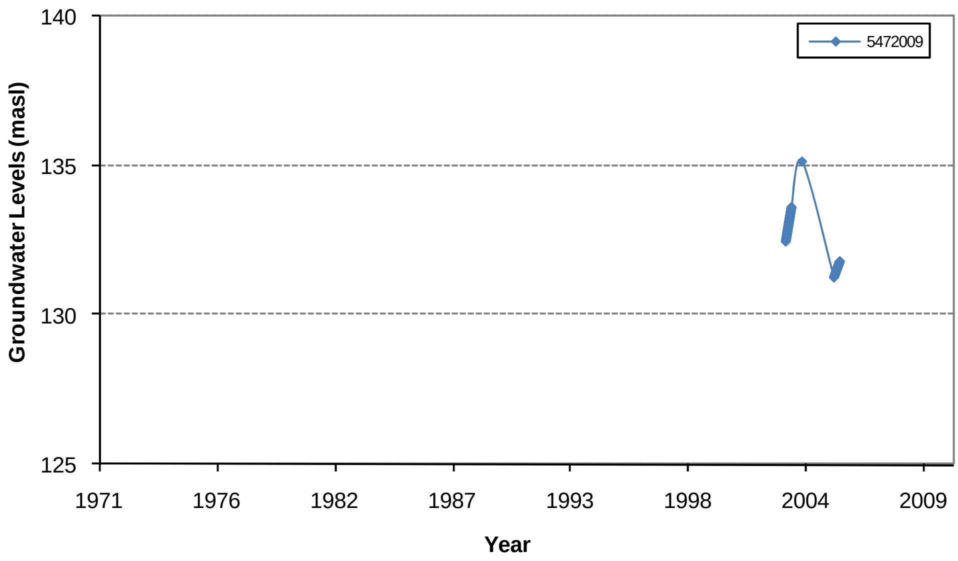
▪ **Figure B11. Puriri Park (site number 5472001) hydrograph.**



▪ **Figure B12. Atkins (site number 5472005) hydrograph.**



■ **Figure B13. Campbell (site number 5472007) hydrograph.**



■ **Figure B14. Foster (site number 5472009) hydrograph.**

Appendix D Bulk Aquifer Parameter Calibration

The geology of the Maunu-Maungatapere-Whatitiri aquifer system is highly variable given fractured nature of the three primary basalt flows. Adding this level of variability and complexity into a groundwater model from the beginning can lead to issues during calibration. Hence, the first stage of calibration for this project was to obtain a calibration for the bulk aquifer, i.e. using the same hydraulic parameters over large areas of the model to represent the general aquifer conceptualisation.

Hydraulic parameters were assigned for the three primary basalt flows in the aquifer, i.e. the Maunu, Maungatapere and Whatitiri basalt flows. These parameters were assigned based on the knowledge of the occurrence of scoria, weathering or fractures within the basalt flows. The final hydraulic parameters used for the calibration are outlined in **Table D1**. In general the selected hydraulic conductivities used within the model are lower than those calculated from aquifer testing. However, this is expected as the bores used for aquifer testing would be abstracting water from the permeable regions of the aquifer, (i.e. fracture zones) and hence aquifer test results would be skewed towards successful bores with higher permeability.

A groundwater recharge of 6% of annual rainfall, which is within the estimated range for recharge into basalt, was assigned for the entire model domain.

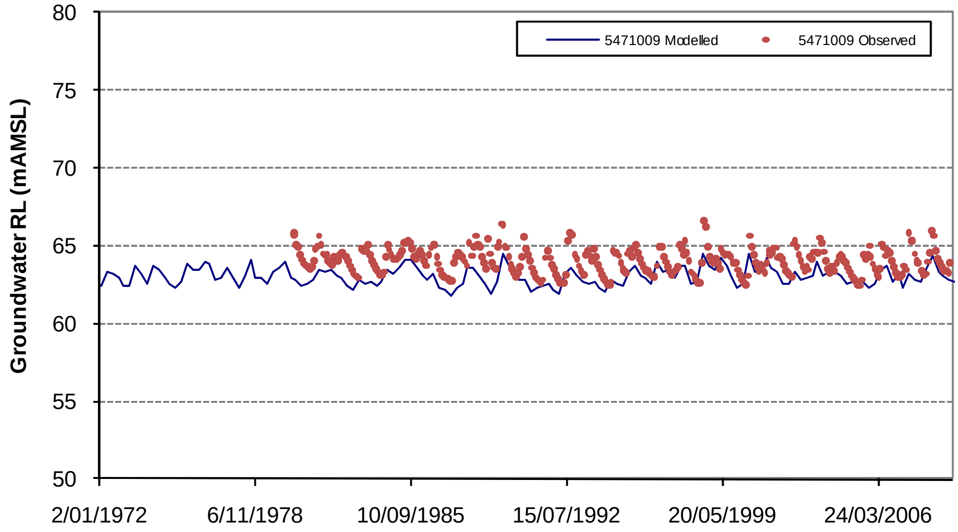
- **Table D1. Calibrated model parameters (based on primary basalt flows)**

Geology	Kx (m/s)	Vertical Anistropy	Sy	Ss
Maunu Flow				
Volcanic Clay	3×10^{-6}	10	0.01	8×10^{-6}
Scoria/Weathered Basalt	1×10^{-5}	3	0.01	8×10^{-6}
Fractured Basalt	1×10^{-6}	10	0.01	8×10^{-6}
Maungatapere Flow				
Volcanic Clay	3×10^{-6}	10	0.01	8×10^{-6}
Scoria/Weathered Basalt	1×10^{-5}	3	0.01	8×10^{-6}
Fractured Basalt	9×10^{-6}	10	0.01	8×10^{-6}
Whatitiri Flow				
Volcanic Clay	3×10^{-6}	10	0.01	8×10^{-6}
Weathered Basalt	3×10^{-6}	10	0.01	8×10^{-6}
Fractured Basalt	8×10^{-6}	10	0.01	8×10^{-6}

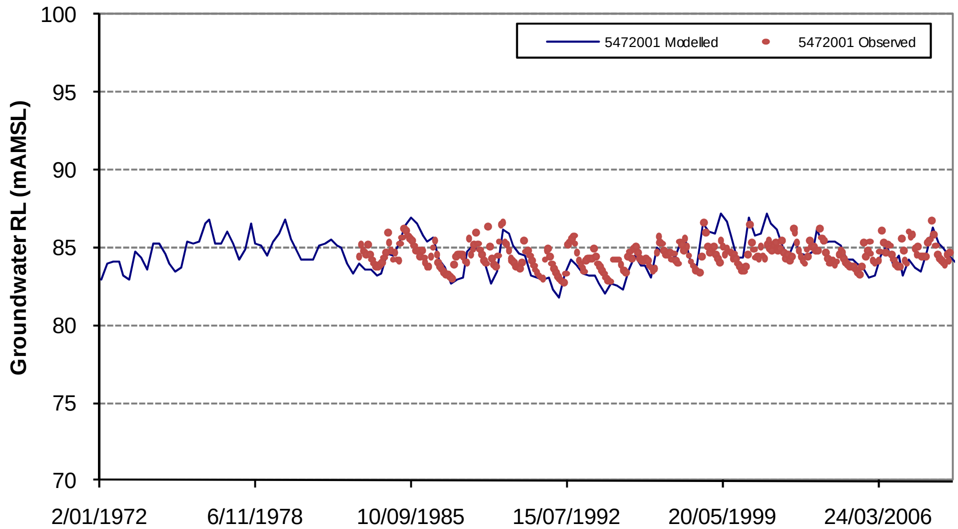
In order to assess the calibration of the model, the simulated groundwater levels were compared with those obtained from the Northland Regional Council monitoring bores. The model simulated the groundwater levels at the location of these monitoring bores with reasonable accuracy, particularly at

SKM

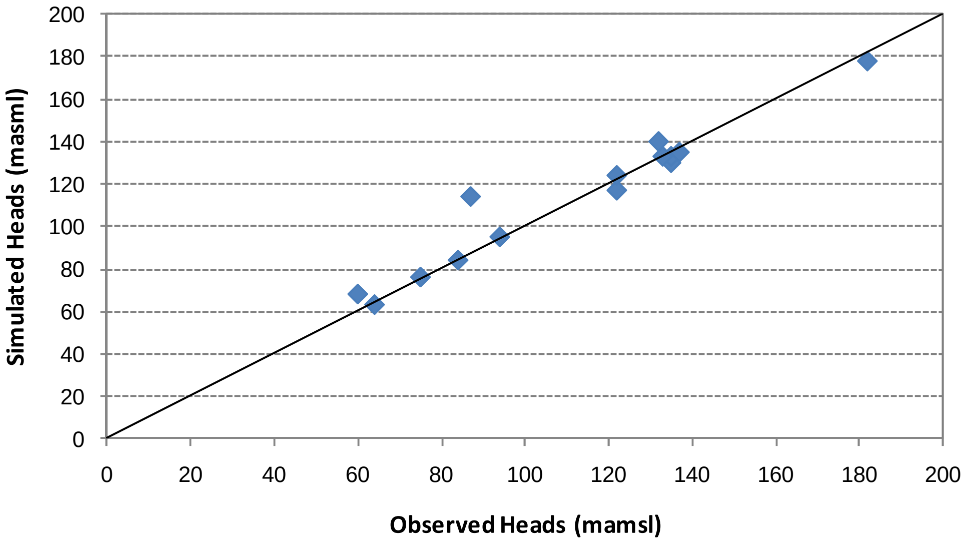
the western and eastern discharge areas of the aquifer, i.e. the location of 5471009 (**Figure D1**) and 5472001 (**Figure D2**). In addition, the hydraulic gradient of the aquifer system was being simulated with reasonable accuracy as shown by the plot of average simulated and observed groundwater levels in **Figure D3**.



- **Figure D1. Modelled and Observed Heads for 5471009**

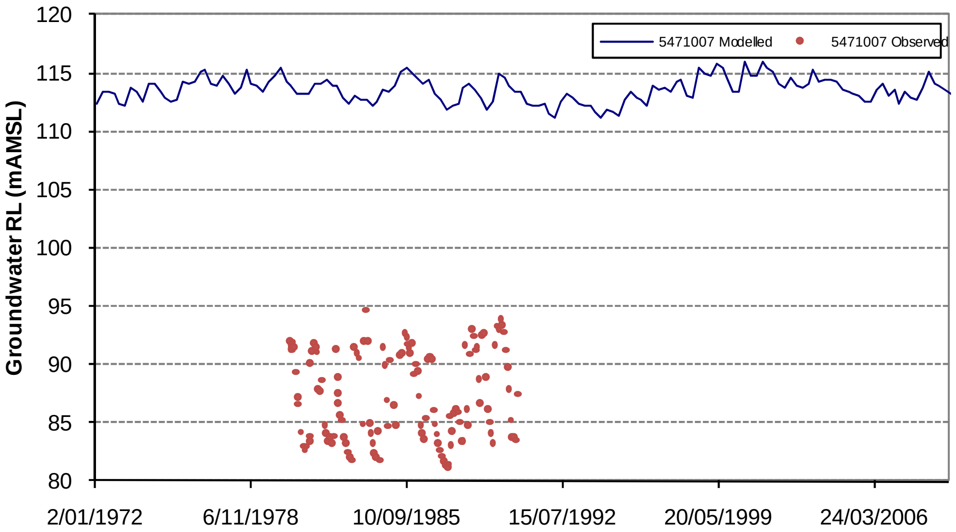


- **Figure D2. Modelled and Observed Heads for 5472001**



- **Figure D3. Average Observed and Simulated Heads**

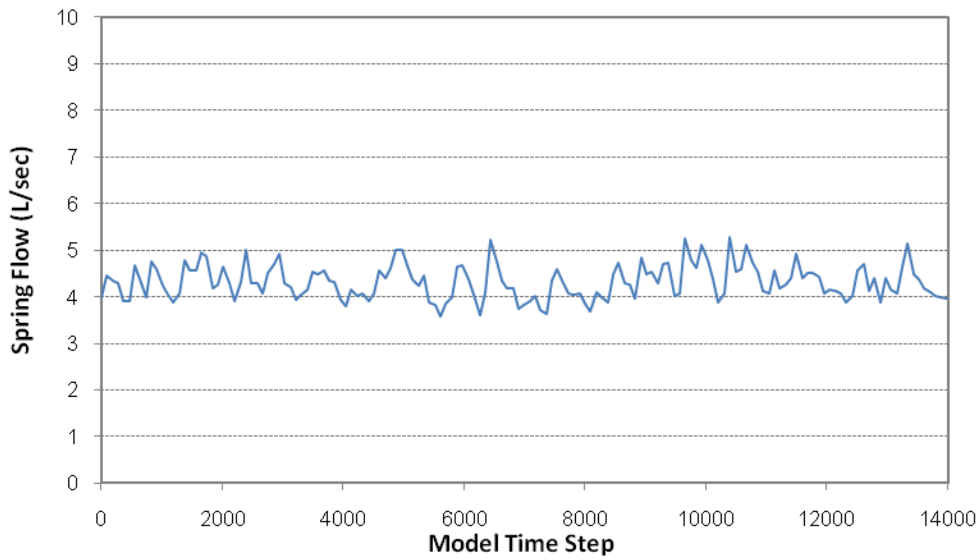
However, the groundwater levels and response to recharge was not accurately simulated in some bores. In particular the groundwater levels within monitoring bore 5471007 were simulated approximately 25 metres too high (**Figure D4**) This is shown as the largest anomaly in **Figure D3**. In addition only 2 m oscillations were simulated, while the observed data clearly shows oscillations of over 10 m. One potential reason for this discrepancy would be if abstraction had occurred in the area which was not included in the model. However, a review of abstraction in the area found that the closest abstraction bore was having a minimal affect on groundwater levels within this bore, thus the large oscillations must be naturally occurring and are likely the result of a high fracture zone within the basalt.



- **Figure D4. Modelled and Observed Heads for 5471007**

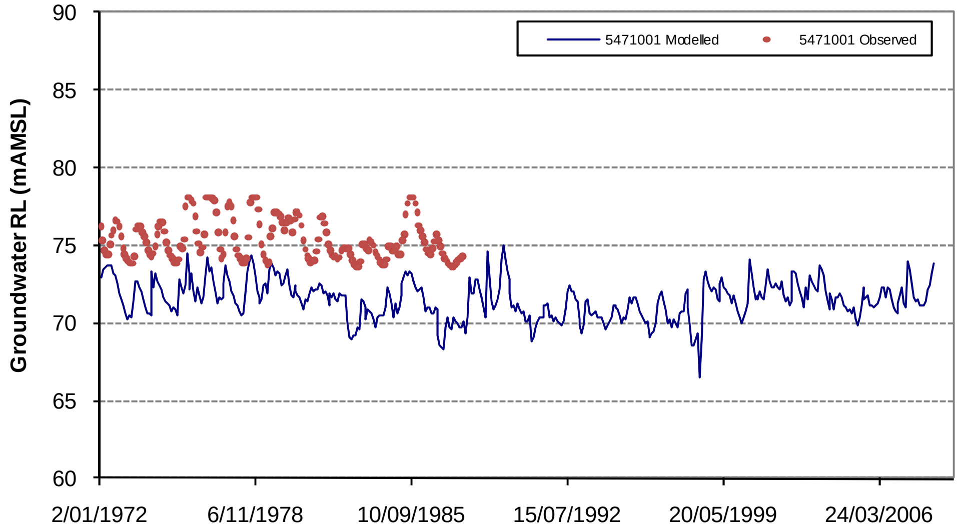
In addition to reviewing the simulated groundwater levels from the calibrated model, the simulated flows from Poroti Springs were reviewed. Roke (1983) outlined gauged spring flows in Poroti Springs of up to 400 L/sec. **Figure D5** shows the Poroti Spring flows simulated by the model. It can be seen the model is simulating flows of between 3.8 and 5.1 L/sec, which is several orders of magnitude lower than the actual spring flows. This shows that even though the majority of groundwater levels were being simulated with reasonable accuracy using the bulk parameters, obviously areas of highly fractured and hence permeable areas are present in the aquifer. This is consistent with the findings of Roke (1983) who stated that the source of flow to Poroti Springs was from a “channel” in the basalt.

Given the findings of this initial calibration, additional calibration was undertaken on the model through increasing the complexity of the geology through incorporating areas of high permeability and recharge. This calibration is described in the main body of this document in **Section 5.3**.

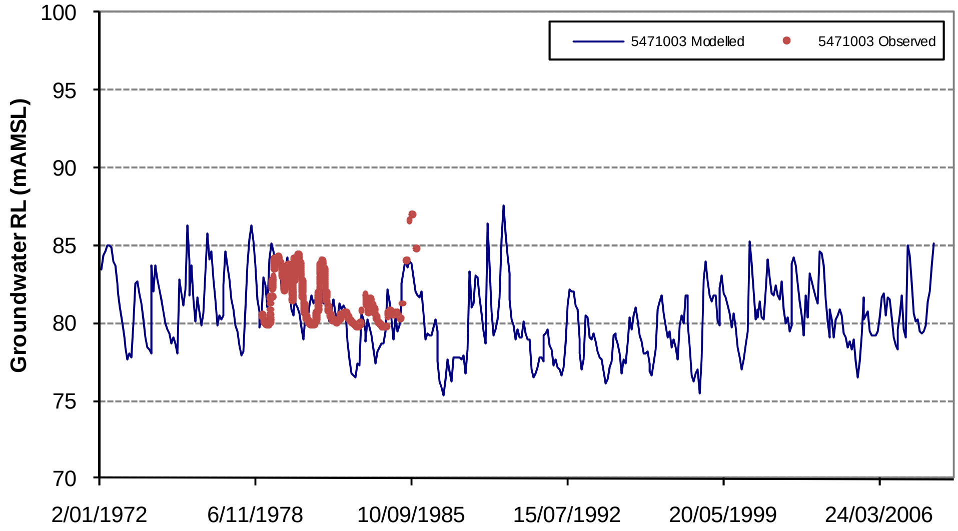


- **Figure D5. Modelled Poroti Spring Flows**

Appendix E Calibrated Model Hydrographs



- **Figure E1. Modelled and observed heads for Poroti Springs (site number 5471001).**



- **Figure E2. Modelled and observed heads for Poroti Road (site number 5471003).**

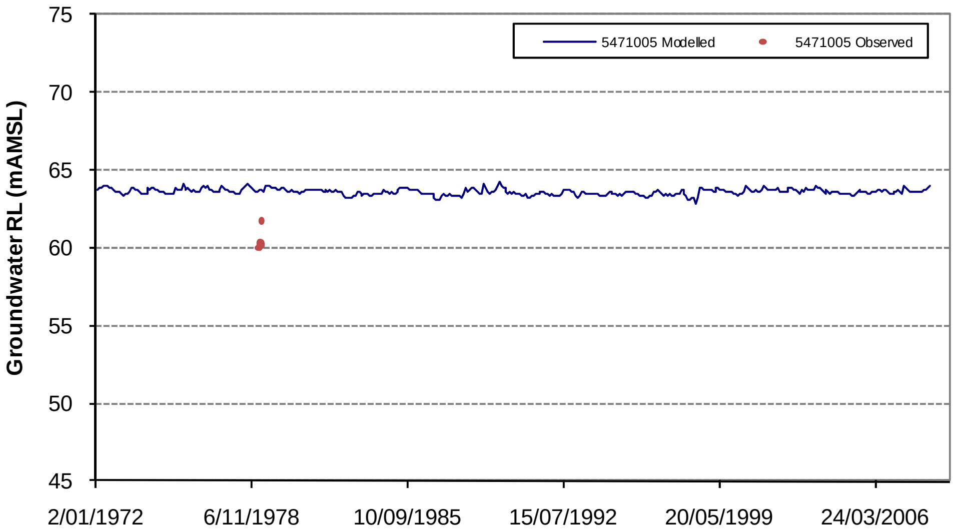


Figure E3. Modelled and observed heads for Cutforths (site number 5471005).

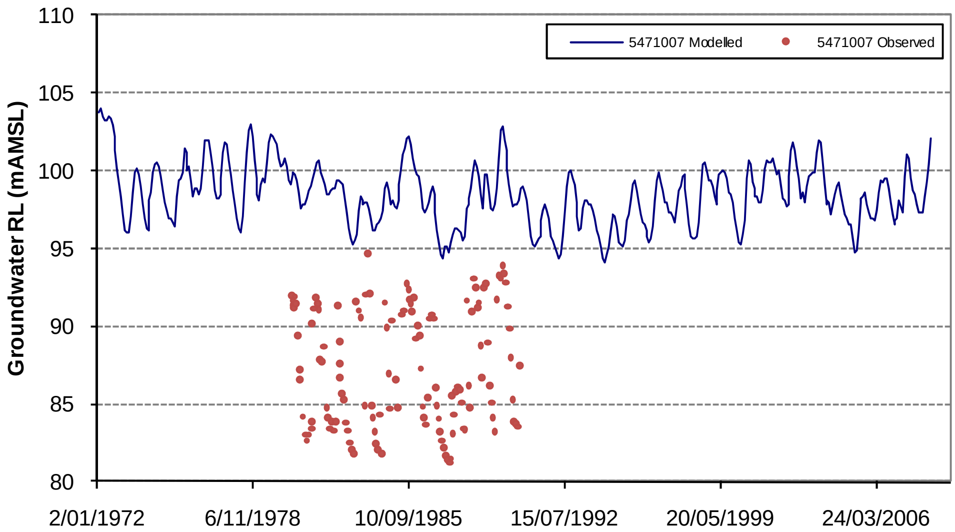
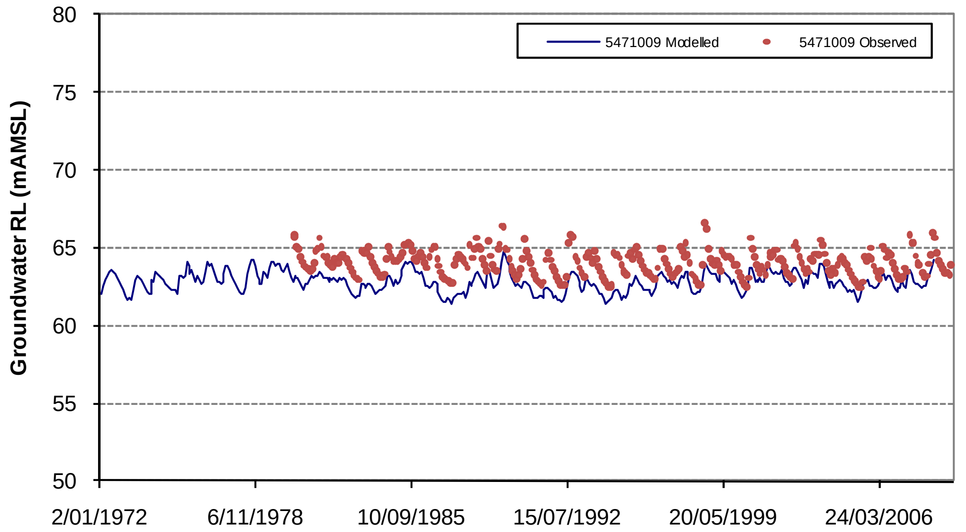
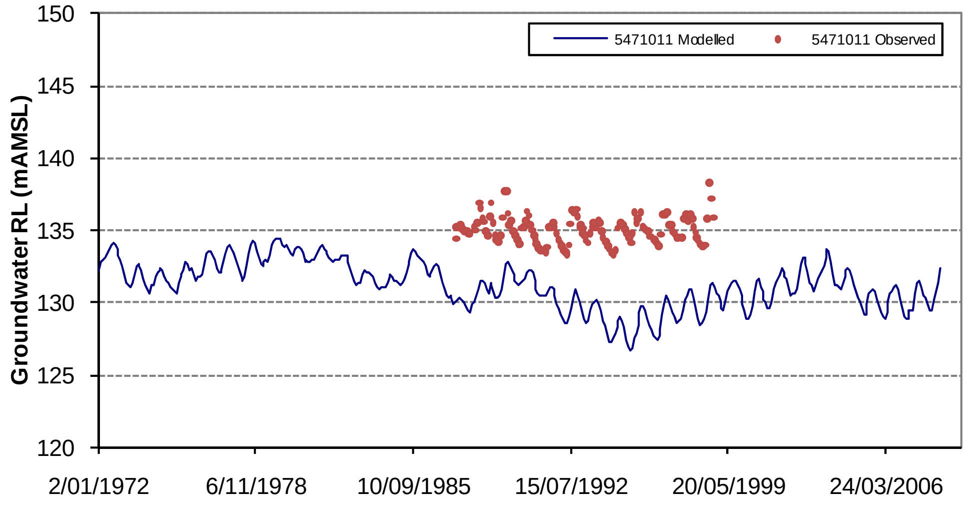


Figure E4. Modelled and observed heads for Whatitiri Wines (site number 5471007).



- **Figure E5. Modelled and observed heads for Poroti West (site number 5471009).**



- **Figure E6. Modelled and observed heads for Cochcranes (site number 5471011).**

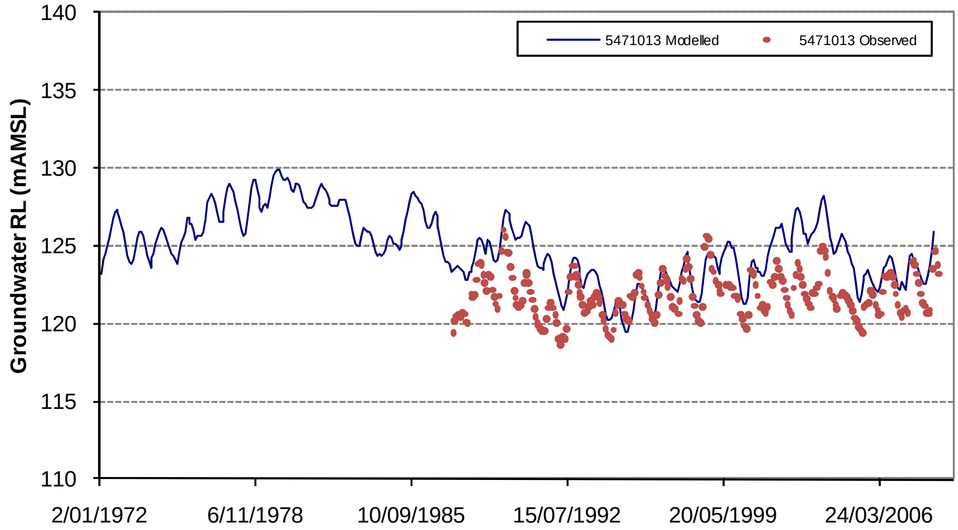


Figure E7. Modelled and observed heads for Tanekaha Orchards (site number 5471013).

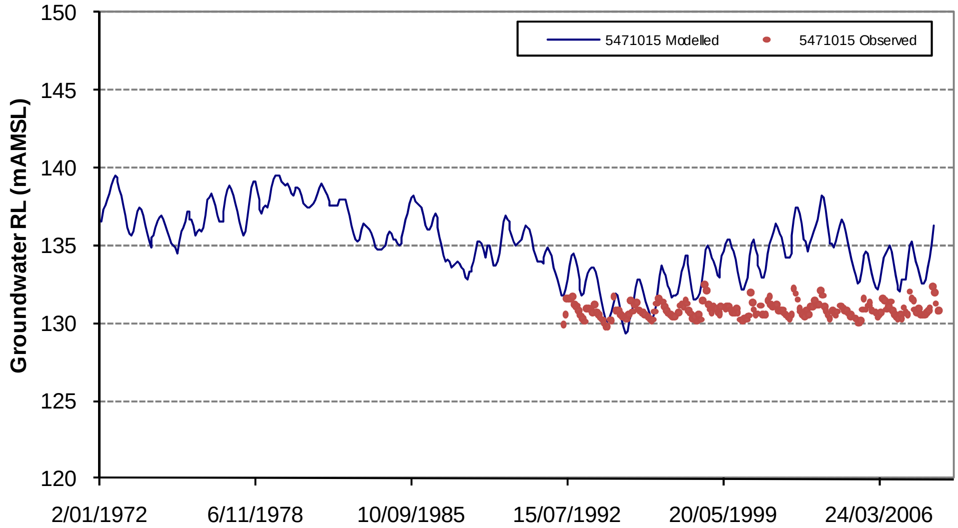
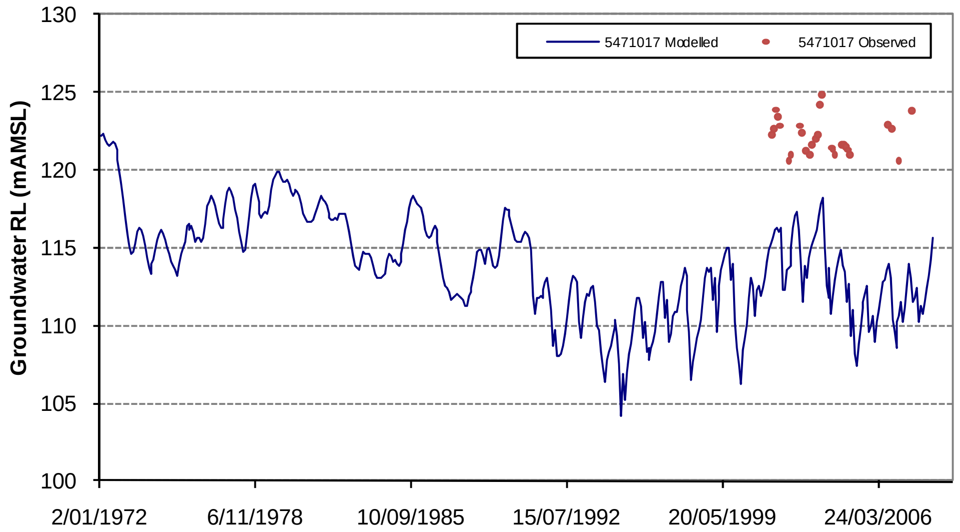
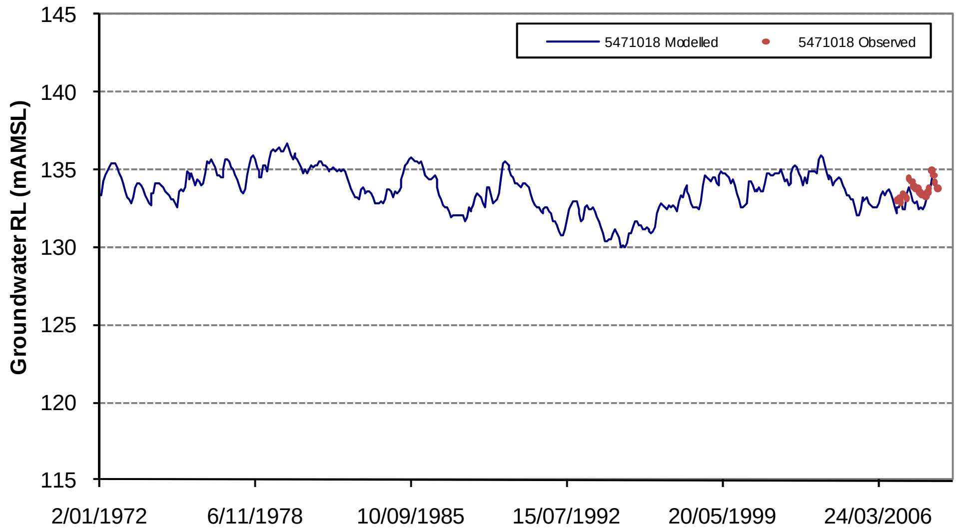


Figure E8. Modelled and observed heads for Martins (site number 5471015).



- **Figure E9. Modelled and observed heads for Angelo (site number 5471017).**



- **Figure E10. Modelled and observed heads for Pukeatua Road (site number 5471018).**

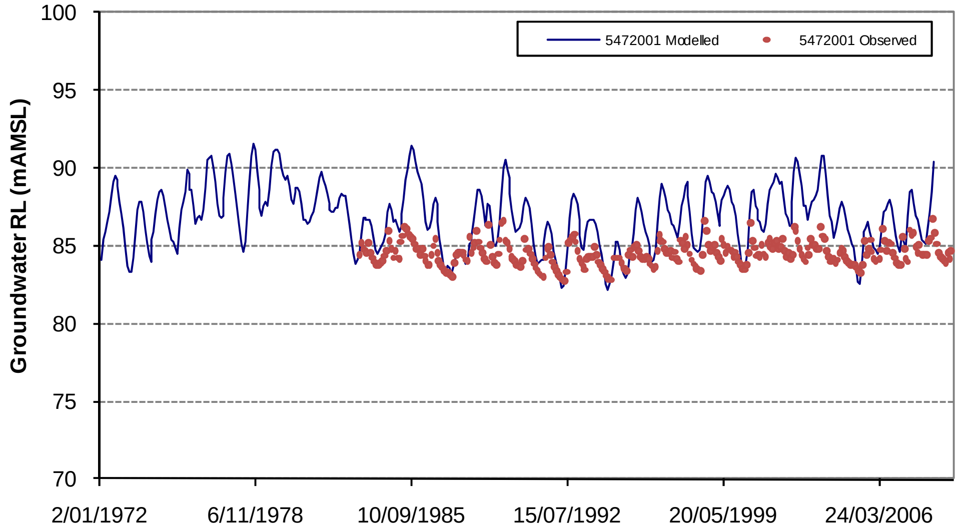


Figure E11. Modelled and observed for Puriri Park (site number 5472001).

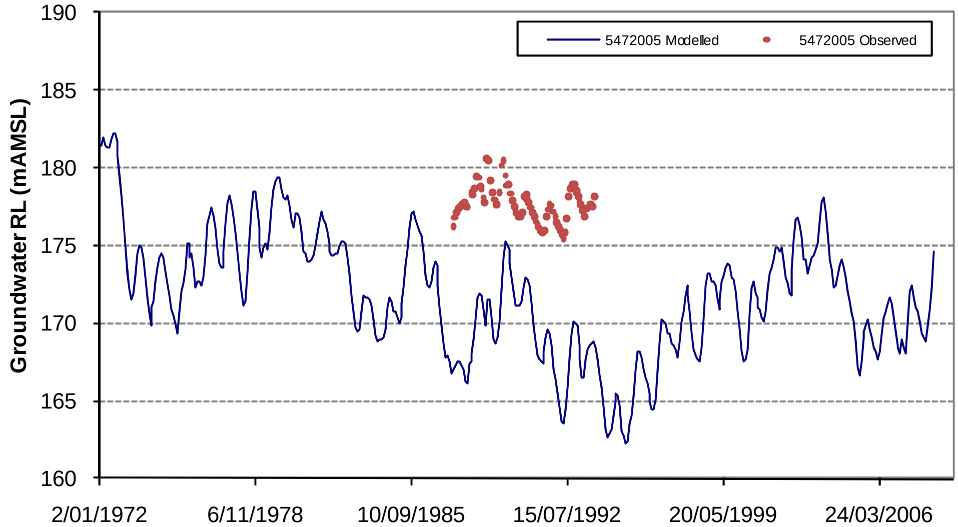


Figure E12. Modelled and observed for Atkins (site number 5472005).

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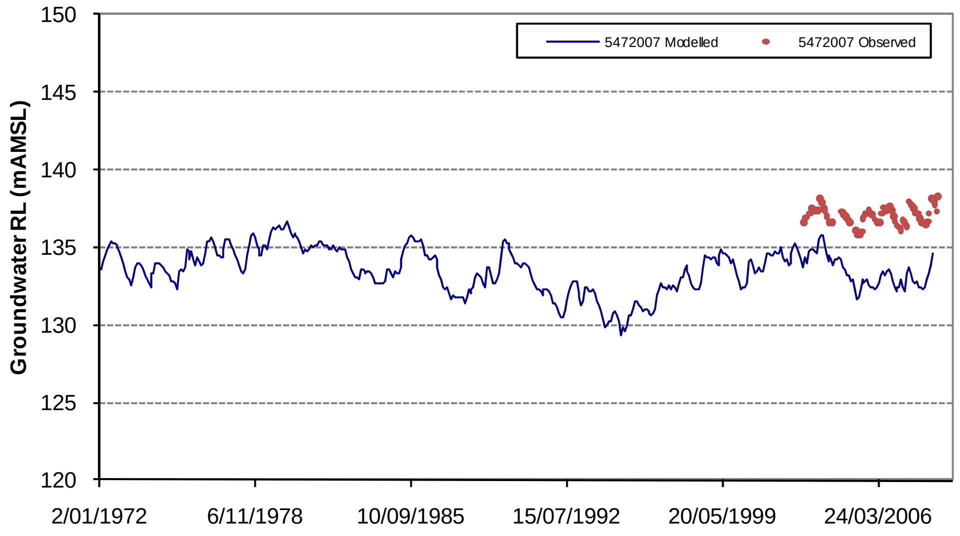
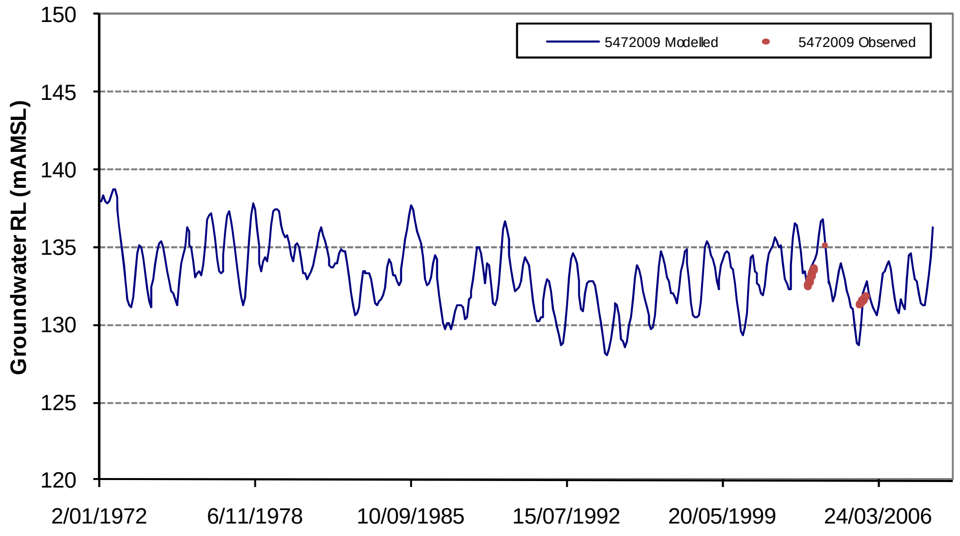


- **Figure E13. Modelled and observed for Campbell (site number 5472007).**



- **Figure E14. Modelled and observed for Foster (site number 5472009).**