Appendix A. Flow Calibration Details

A.1 Paraiti (Mangorewa) River at Saunders

Specific discharge for the Paraiti (Mangorewa) River at Saunders site from the initial model calibration was 0.031 $m^3/s/km^2$, which is considerably lower than that calculated for other sites in the Kaituna WMA. This inferred that a proportion of rainfall that infiltrates to groundwater may not be hydraulically connected or returning within the river reach of the gauge, implying that a significant proportion of the overall catchment water balance is not observed at the gauge. This is consistent with the geological properties of the highland Kaituna catchment, which has highly porous pumice soils and geological materials, and deep groundwater.

From a review of digital elevation models and aerial photographs it was hypothesised that a portion of groundwater generated in the headwaters of the Paraiti (Mangorewa) River catchment may actually flow into the Rotorua Lakes rather than discharge into the Paraiti (Mangorewa) River. The average slope in the headwaters is extremely flat (<7.3 degrees), with little indication of drainage direction. To test this hypothesis, flow from a portion of the sub-catchment that could flow to Lake Rotorua equating to 18.75 km^2 (10%) was redirected out of the river catchment to reduce the oversupply by the model.

The change in area reduced the volume of discharge generated in the model, and increased the specific discharge, improving the comparison between measured and modelled flow. It is noted that modifications made to the Paraiti (Mangorewa) River at Saunders sub-catchment area also matched the Kaituna WMA groundwater model boundary in this area, which was provided by BOPRC after the catchment reconfiguration work was undertaken for the SOURCE modelling project.

Although improving the calibration PMs, modifications made to the catchment boundary did not fully address the oversupply of catchment discharge at the gauge and as alluded to above, a further assumption was made that water may be passing under the gauge.

To replicate the inferred loss via deeper groundwater indicated by the low catchment specific discharge, loss nodes were placed in each sub-catchment upstream of the Paraiti (Mangorewa) River at Saunders gauge, excluding SC#10 (this catchment was excluded as it was believed the losses to deeper groundwater were happening in the upper catchments before it flattened out in SC#10). The losses assigned to each node were proportional to the area of each sub-catchment and based on a specific discharge adjustment of an average 0.015 $m^3/s/km^2$, as summarised in **Table E-1**. There is an increased loss in SC#2 due to a downstream discrete observed flow point. The losses were returned to the river in the SC#23 catchment, as discussed in **Section 6.1.2**.

Table E.1. Summary of flow losses to deep groundwater.

SOURCE catchment	Area (km^2)	Flow assigned to loss node (m^3/day)
SC#1	31	30240
SC#2	44	38880
SC#3	59	34560
SC#5	22	6912
SC#6	102	4320
SC#7	11	21600

SOURCE catchment	Area (km^2)	Flow assigned to loss node (m^3/day)
SC#8	26	8640
SC#9	39	33696
SC#11	11	37152

A.2 Waitahanui River at Otamarakau Valley Rd

Analysis of catchment discharge percentage of rainfall at the Waitahanui River at Otamarakau Valley Rd site indicated there were more outputs (discharge) than inputs (rainfall) in this reach (**Section 4.3.6**).

McIntosh (2010) identified that it was likely the Waitahanui River catchment receives discharge from the Lake Rotoehu and Lake Rotoma catchments by way of groundwater throughflow. This inference is supported by electrical conductivity measurements that indicate the Waitahanui River is influenced by discharge coming from Lake Rotoehu (White *et al.*, 2009). White *et al.* (2009) estimated the influence from Lake Rotoehu and the wider catchment flowing directly into the local groundwater system was approximately 2,086 L/s.

Based on these observations it is reasonable to conclude that groundwater recharge from Lake Rotoehu and associated groundwater throughflow is likely to contribute to baseflow discharge in the Waitahanui catchment. To reflect this interaction a lake storage node was configured in the model (SOURCE) with a head dependent relationship and a minimum flow requirement node downstream (**Section 5.1**).

The lake was configured within the model by prescribing the approximate depth and width of the lake, which in turn enables the model to calculate volume of water the lake held. The lake typically was simulated in the model within a 3 m depth range (39-41 m), with the rate of discharge governed by the lake level as shown in **Figure E-1.**

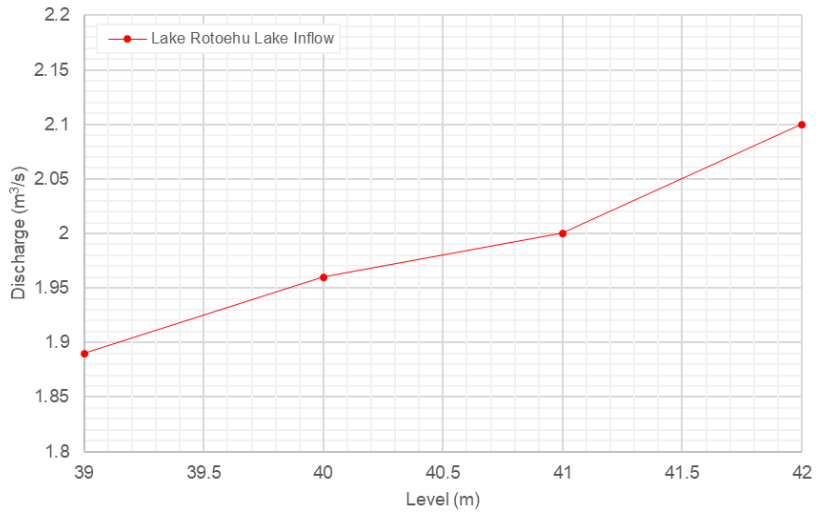

Figure E-1: Waitahanui at Otamarakau Valley Rd Lake Storage Head Dependent Relationship.

The configured contribution of water from Lake Rotoehu improved the flow calibration and decreased the overall discharge as a percentage of rainfall from 107% to 74%.

A.3 Puanene at SH2

The simulated flow of the Puanene River at SH2, was consistently greater than the measured data recorded by the BOPRC. The measured discharge was calculated as 0.008 $m^3/s/km^2$ and 17% of sub-catchment MAP. This suggests a significant proportion of discharge was moving via sub-surface flows, or being lost to the deeper groundwater, and not being captured at the monitoring location.

The elevation profile of the catchment (**Section 4.3.8**) is consistent with this inference (**Figure E-2**). It is assumed that flow from the higher land areas is discharging into the shallow alluvial aquifer as it reaches the low gradient section of the reach.

To reflect this assumption a loss node was configured in SC#77, upstream of the Puanene River at SH2 flow site, with a head dependent relationship between modelled discharge and loss rate, as shown in **Figure E-3**.

Figure E-2. Puanene at SH2 Elevation Profile (Taken from google earth).

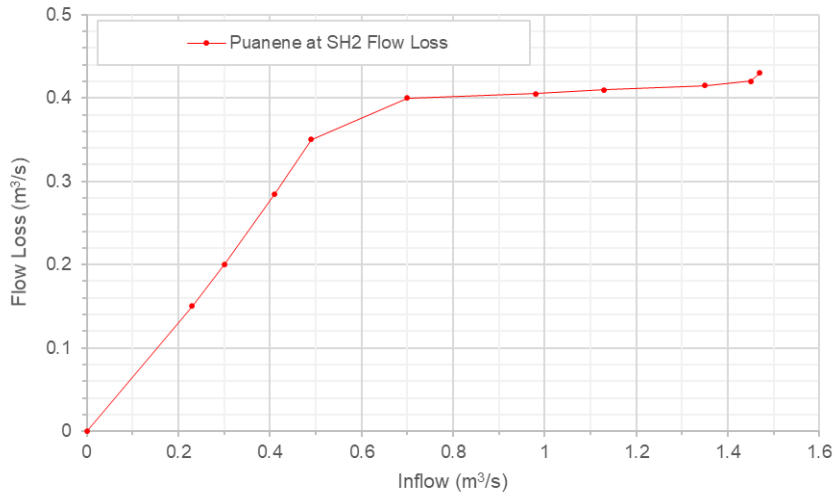

Figure E-3. Puanene at SH2 Head Dependent loss Relationship.

This model configuration enabled a close match between the simulated discharge and measured flow. The water that is removed within the Puanene catchment is assumed to discharge to the seafloor outside the model domain.

A.4 Rangitāiki River at Murupara

As discussed in **Section 6.2.2**, a loss node was required within this catchment to reduce the simulated flows at the gauge into the order of magnitude of flow measured at the gauge (this loss node was applied to SC#77).

Figure E-4 describes the relationship between inflow into the catchment and the amount of loss which will be removed.

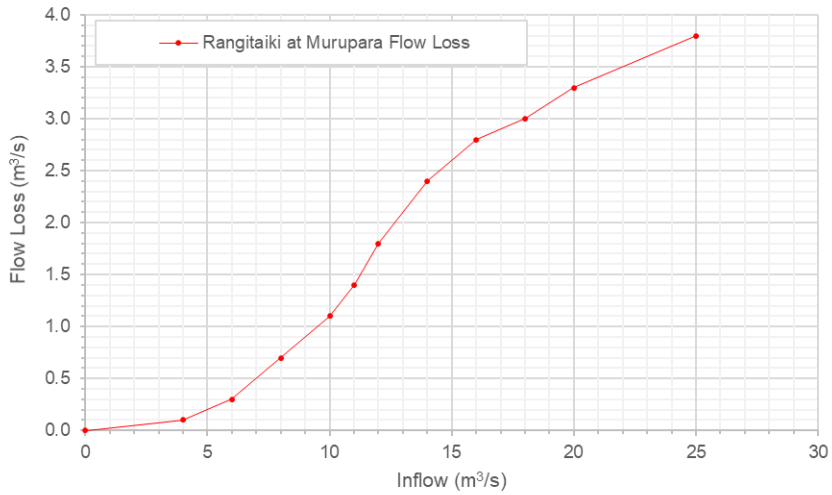

Figure E-4: Rangitāiki at Murupara Head Dependent loss Relationship.

A.5 Lake Aniwhenua

Lake Aniwhenua was configured so that once the storage level reached 50 m, flow was released through the spill with the discharge rate increasing with increasing storage level.

Based on the model results extracted downstream of the dam, the dam discharges water at an average rate of 51.8 m^3/s with a range of between 17.3 to 501.5 m^3/s.

A.6 Lake Matahina

Lake Matahina was configured so that once the storage level reached 77 m, flow was released through the spillway with the discharge rate increasing with increasing storage level.

Lake Matahina was also configured with a minimum flow requirement node. As a result, if the lake storage dropped below the minimum flow all inflows to the lake were discharged.

Based on the model results extracted downstream of the dam, the dam discharges water at an average of 72.2 m^3/s with a range of between 21.9 to 778.6 m^3/s.

A.7 Kaituna Water Management Area Discrete Flow Comparisons

Discrete monitoring locations were used as a secondary flow calibration check. The plotted hydrographs below present a comparison of the measured and modelled flow for the secondary (discrete) monitoring locations in the Kaituna WMA (**Figure E-5** to **Figure E-12)**.

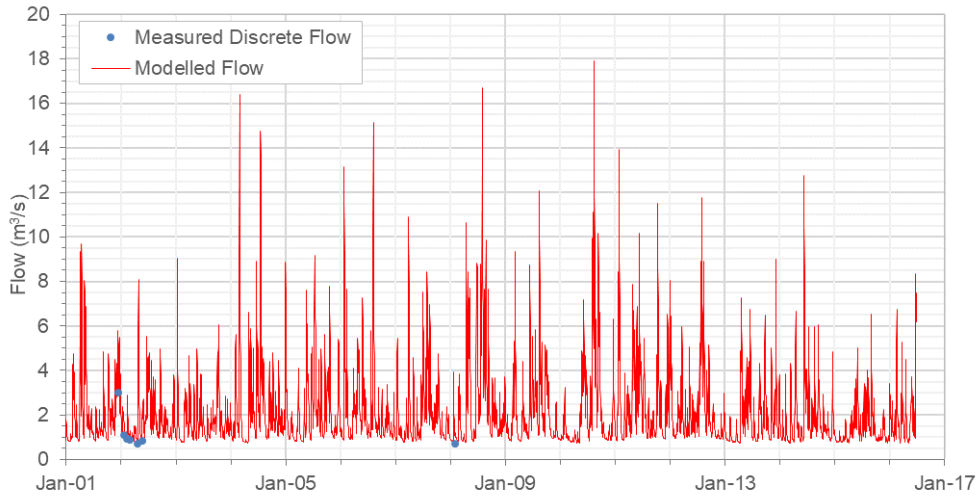

Figure E-5. Comparison of the measured and modelled flow for SCID: 43 Site ID: FO005113

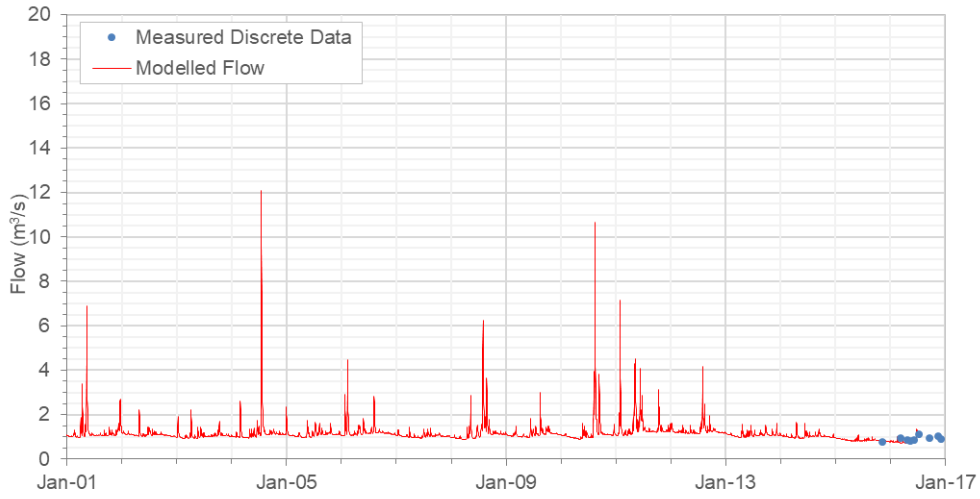

Figure E-6. Comparison of the measured and modelled flow for SCID: 110 Site ID: HM688516

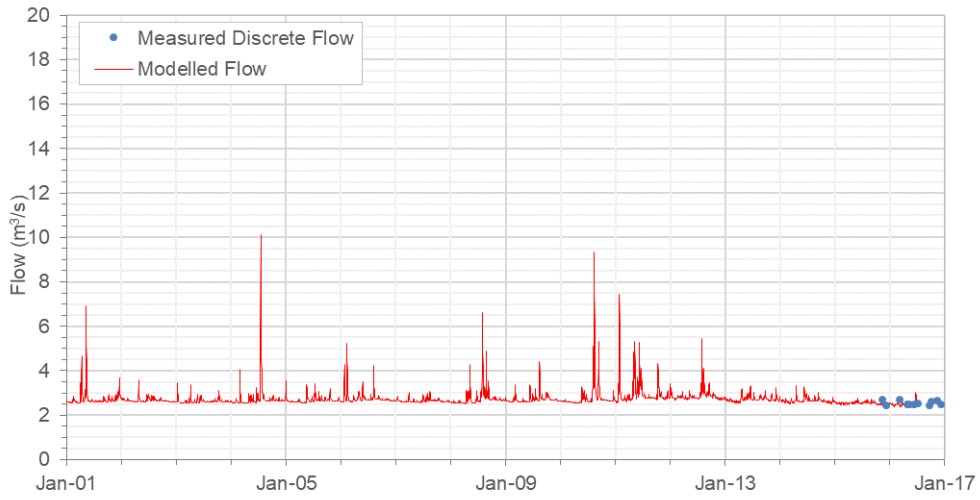

Figure E-7. Comparison of the measured and modelled flow for SCID: 105 Site ID: HM319871.

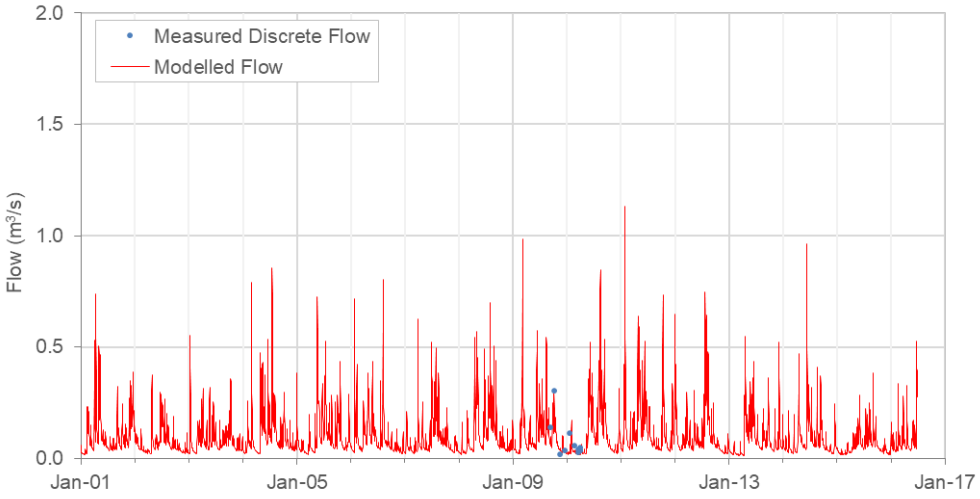

Figure E-8. Comparison of the measured and modelled flow for SCID: 49 Site ID: FO073670.

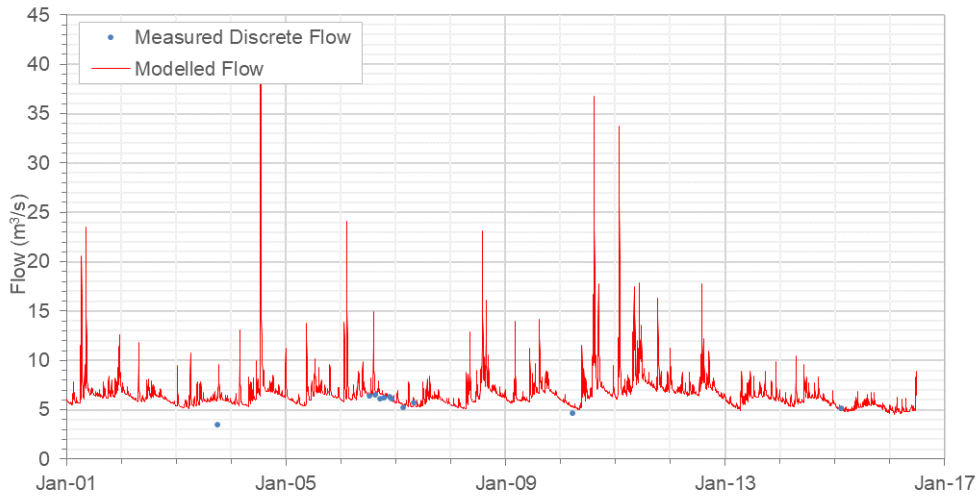

Figure E-9. Comparison of the measured and modelled flow for SCID: 114 Site ID: HN674689.

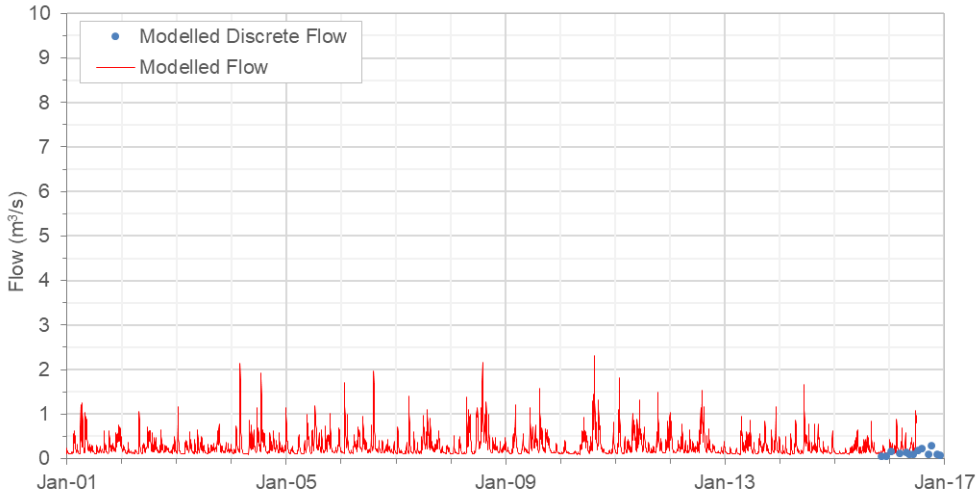

Figure E-10. Comparison of the measured and modelled flow for SCID: 43 Site ID: FO085675.

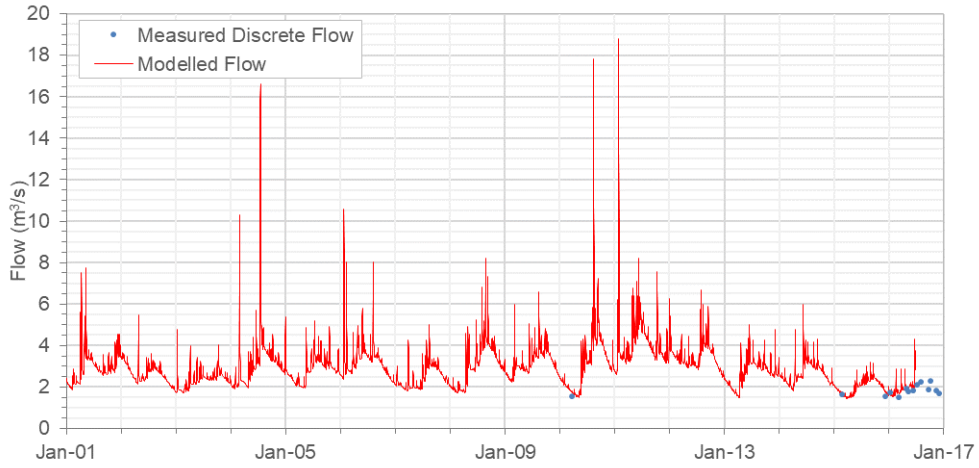

Figure E-11. Comparison of measured and modelled flow for SCID: 73 Site ID: GN178816

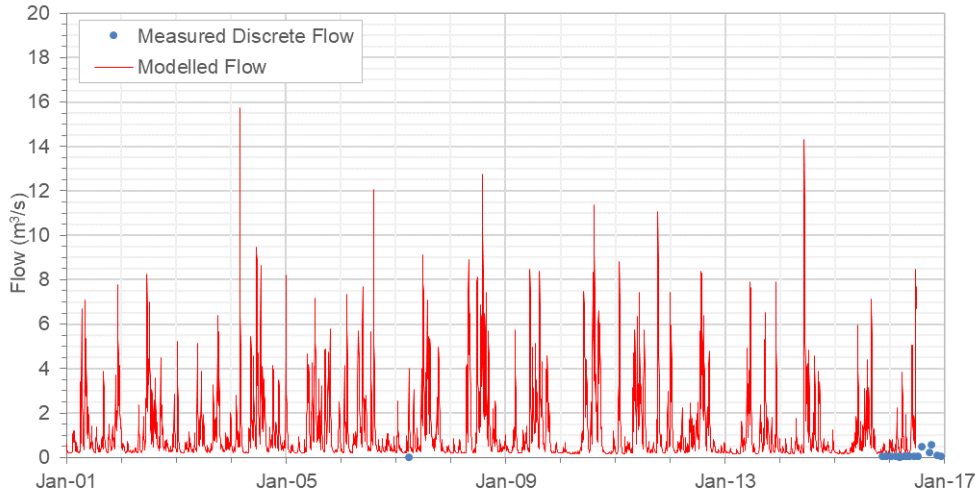

Figure E-12. Comparison of the measured and modelled flow for SCID: 2 Site ID: DM860350.

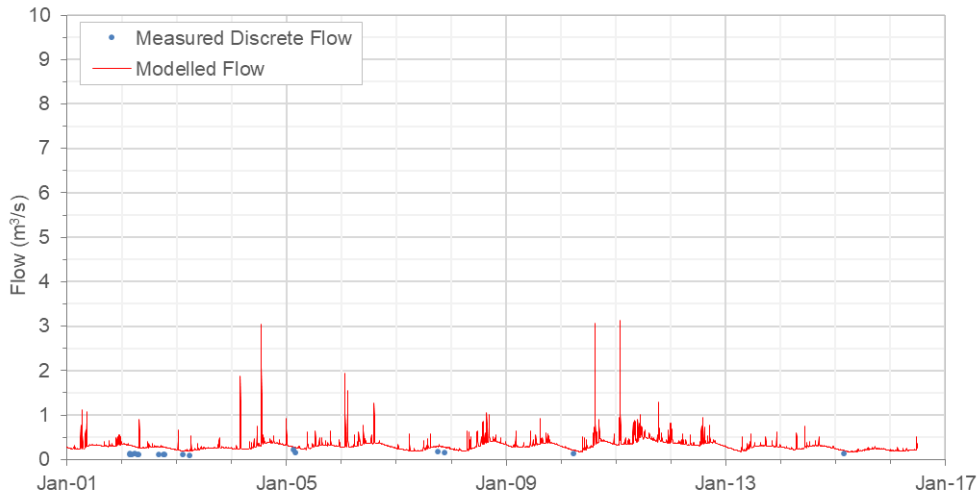

Figure E-13. Comparison of the measured and modelled flow for SCID: 81 Site ID: GN198111.

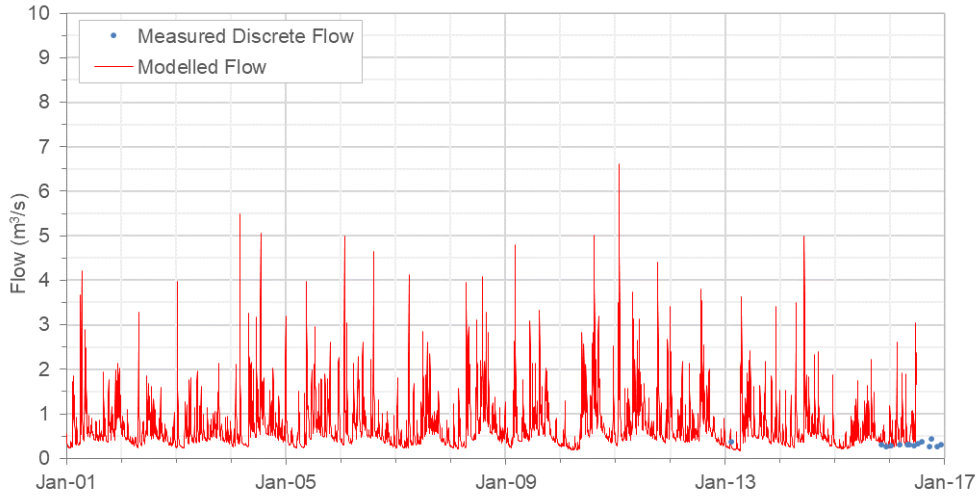

Figure E-14. Comparison of measured and modelled flow for SCID: 41 Site ID: FO210321.

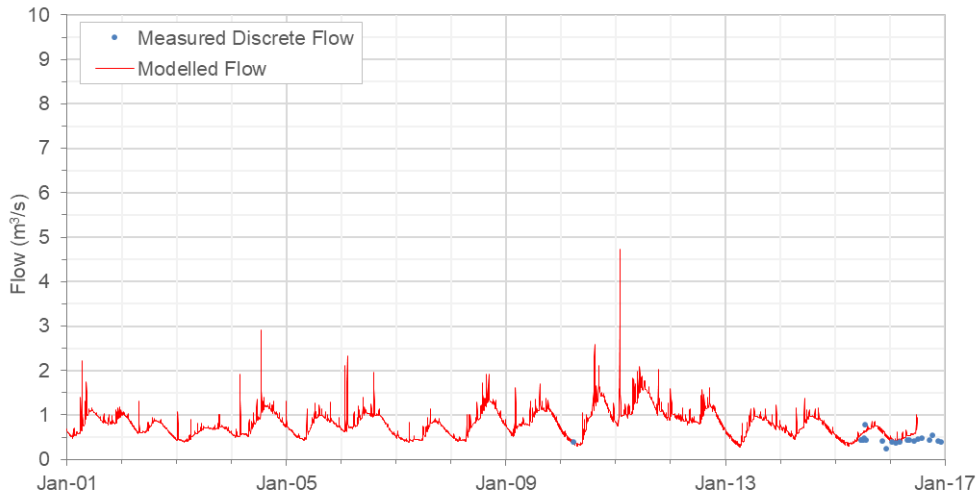

Figure E-15. Comparison of the measured and modelled flow for SCID: 82 Site ID: GN647803.

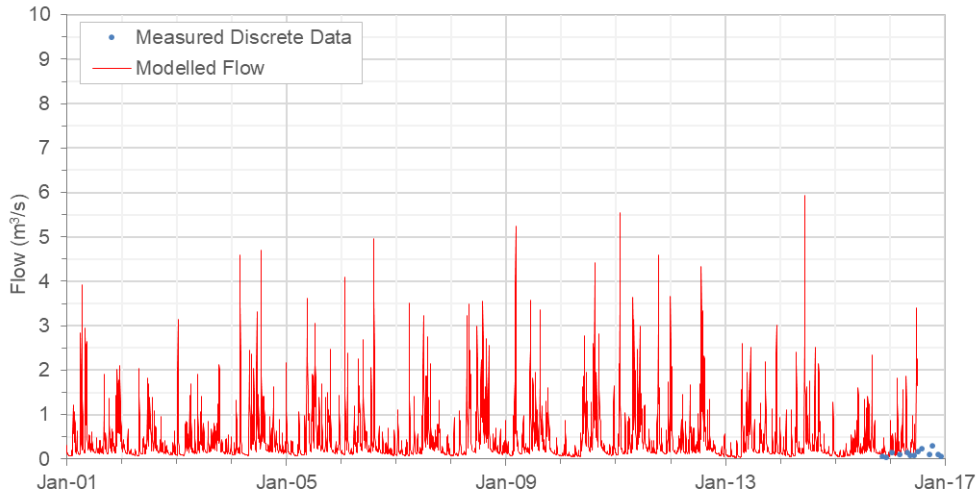

Figure E-16. Comparison of the measured and modelled flow for SCID: 49 Site ID: FO085678.

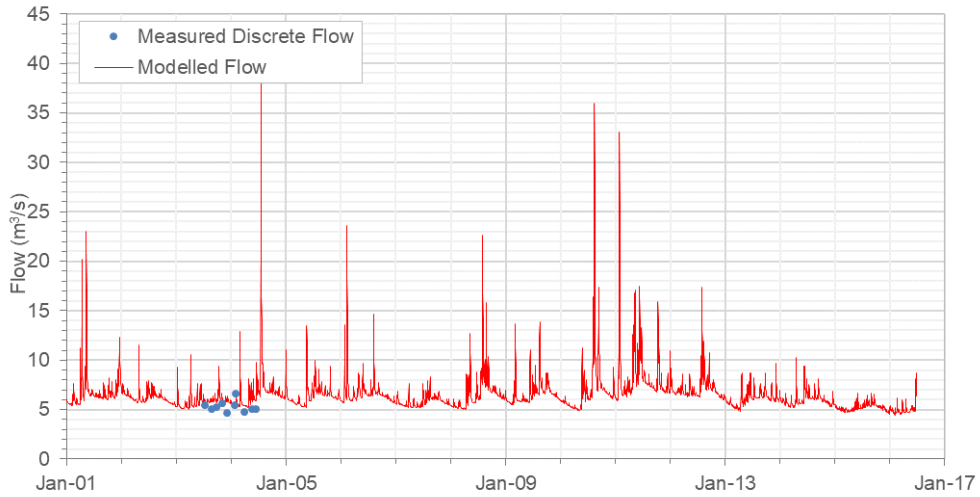

Figure E-17. Comparison of measured and modelled flow for SCID: 114 Site ID: HN643644.

Table E-2. Discrete measured vs modelled flow statistics (m^3/s) in the Kaituna WMA.

Site Name	Site Code	SC#	Type	Mean	Min	50%ile	Max	RMS error
Raparapahoe at No. 4 Road Bridge	FO005113	43	Measured	1.1	0.7	0.9	3.0	1.18
			Modelled	1.7	0.8	1.1	3.8	
Morepara at u/s Pikowai Road	HM688516	110	Measured	0.9	0.8	0.9	0.9	2.58
			Modelled	0.8	0.7	0.7	0.8	
Waitahanui at u/s Campbell Road	HM319871	105	Measured	2.5	2.4	2.5	2.7	1.13
			Modelled	2.5	2.4	2.5	2.5	
Kopuaroa at Above Waikoura Confluence	FO073670	49	Measured	0.1	0.0	0.0	0.3	0.61
			Modelled	0.0	0.0	0.0	0.2	
Waitahanui at Otamarakau Marae	HN674689	114	Measured	5.6	3.5	6.0	6.6	1.19
			Modelled	6.2	5.0	6.4	6.8	
Kirikiri at Manoeka Rd	FO085675	43	Measured	0.1	0.0	0.1	0.2	1.81
			Modelled	0.2	0.1	0.1	0.2	
Pokopoko at Black Rd	GN178816	73	Measured	1.7	1.5	1.7	1.9	1.26
			Modelled	1.8	1.6	1.8	2.1	
Paraiti (Mangorewa) at Old Tauranga Road	DM860350	2	Measured	0.0	0.0	0.0	0.1	31.34
			Modelled	0.4	0.2	0.3	1.1	
Waiari R/B Tributary at U/S Waiari Confluence	GN198111	71	Measured	0.1	0.1	0.1	0.2	4.35
			Modelled	0.3	0.2	0.3	0.3	
Ohineangaanga at SH2	FO210321	41	Measured	0.3	0.2	0.3	0.4	8.95
			Modelled	0.4	0.1	0.4	1.1	
Wharere at SH 2 Bridge	GN647803	82	Measured	0.4	0.0	0.4	0.8	1.70
			Modelled	0.5	0.0	0.6	1.0	
Kopuaroa at SH2	FO085678	49	Measured	0.1	0.0	0.1	0.2	3.04
			Modelled	0.2	0.1	0.1	0.4	
Waitahanui at SH 2	HN643644	114	Measured	5.4	4.1	5.4	6.6	2.22
			Modelled	6.3	4.7	5.9	9.6	

A.8 Rangitāiki Water Management Area Discrete Flow Comparisons

Discrete monitoring locations were used as a secondary flow calibration check. The plotted hydrographs below present a comparison of the measured and modelled flow for the secondary (discrete) monitoring locations in the Rangitāiki WMA (**Figure E-21** to **Figure E-24**).

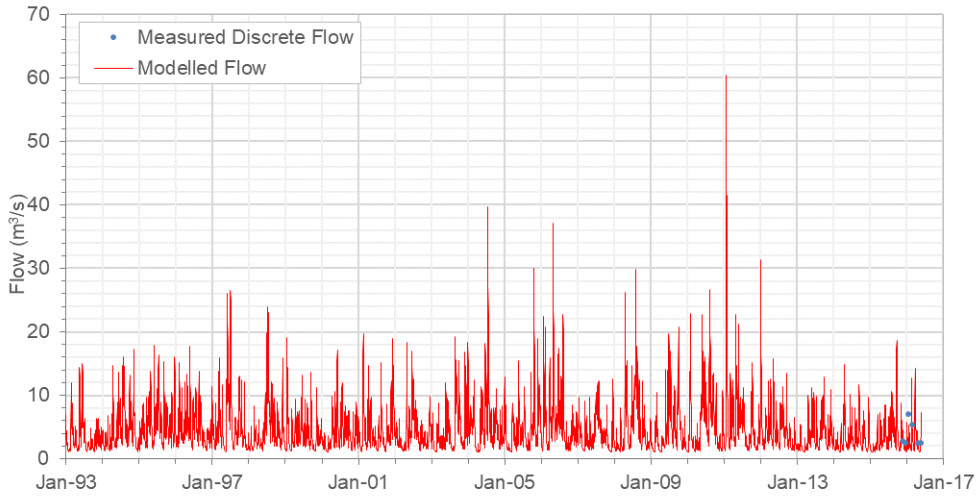

Figure E-18. Comparison of the measured and modelled flow for SC#42. Site ID: IE250425.

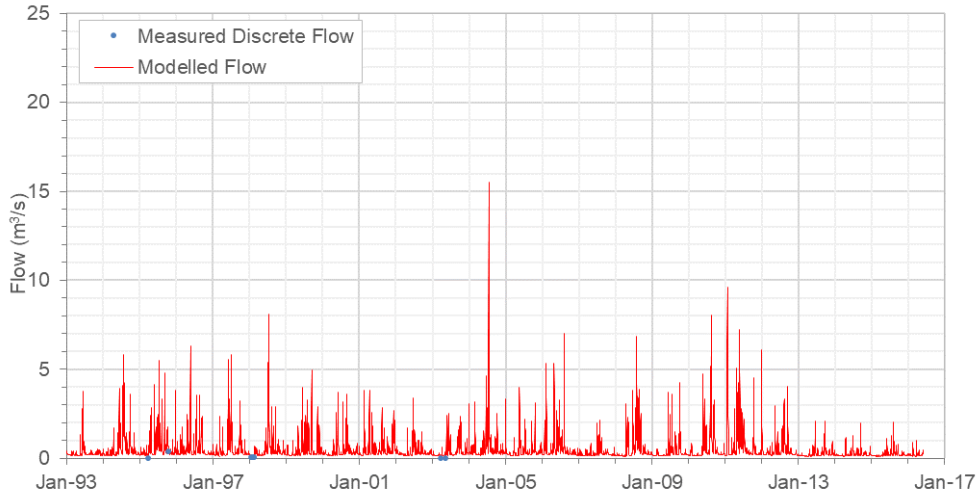

Figure E-19. Comparison of the measured and modelled flow for SC#75. Site ID: IH791208.

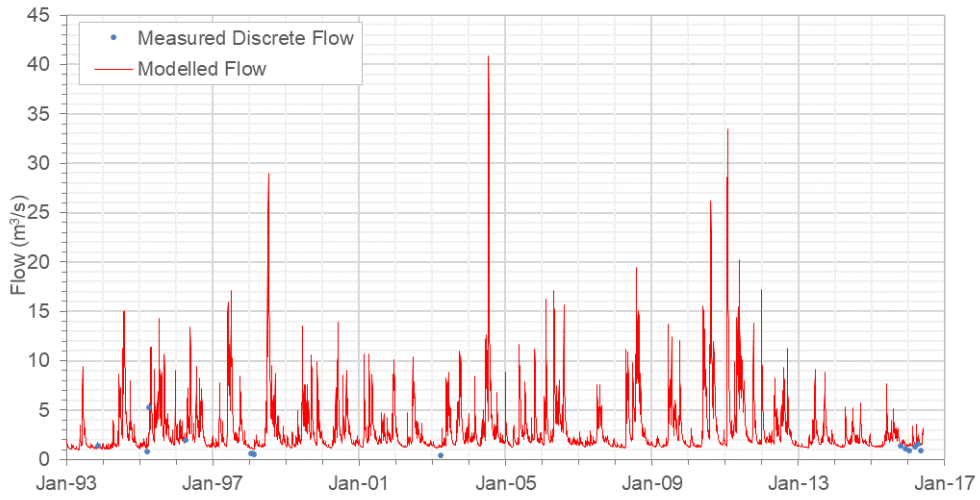

Figure E-20. Comparison of the measured and modelled flow forSC#52. Site ID: IH893640.

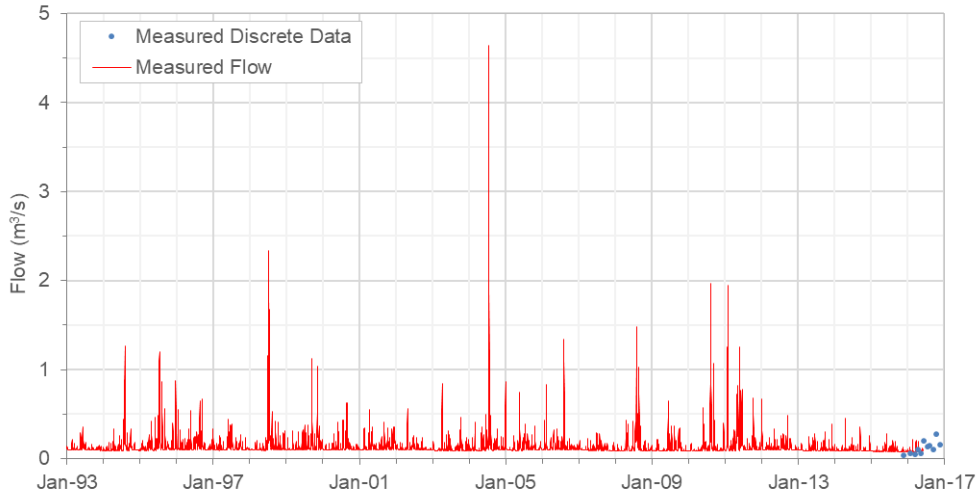

Figure E-21. Comparison of the measured and modelled flow for SC#32. Site ID: JJ633547.

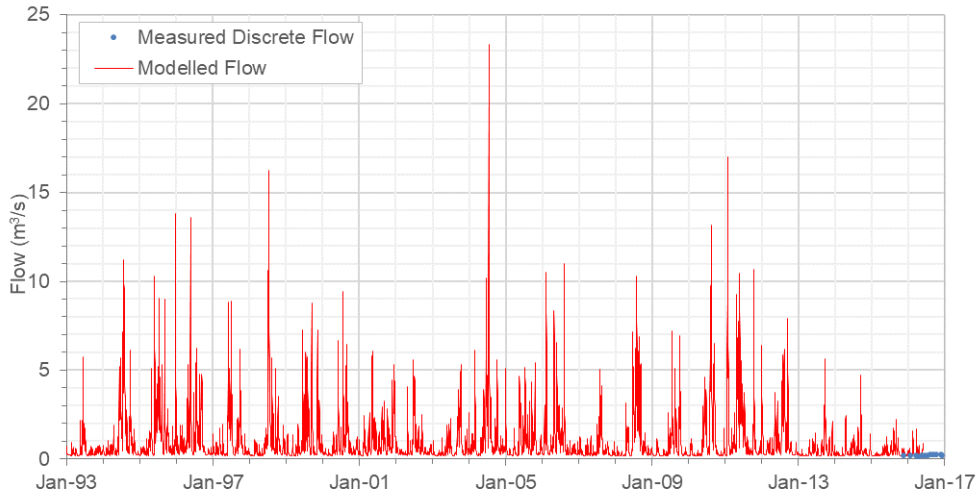

Figure E-22. Comparison of the measured and modelled flow for SC#70. Site ID: IH701900.

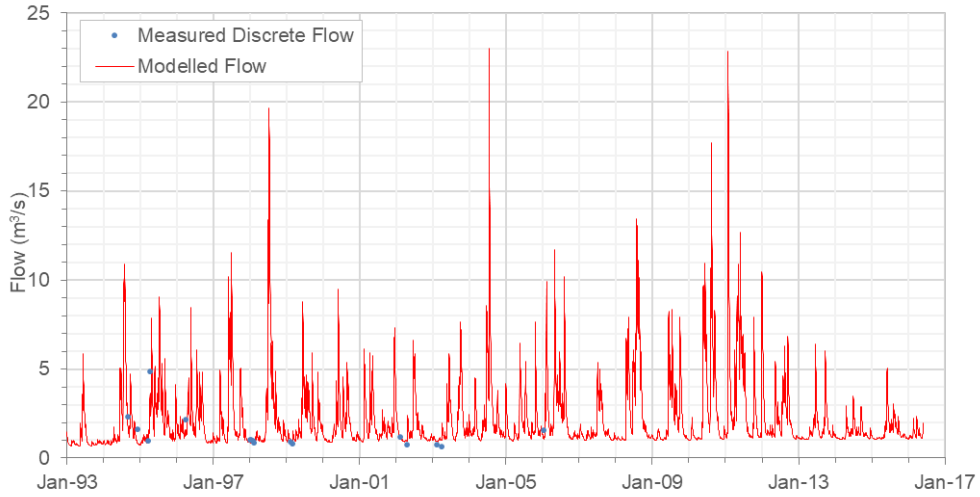

Figure E-23. Comparison of the measured and modelled flow for SC#51. Site ID: JH44716.

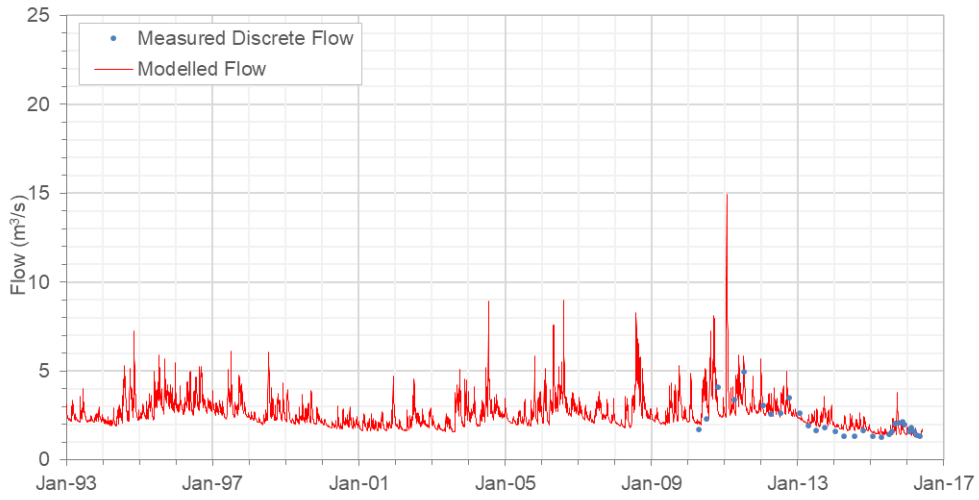

Figure E-24. Comparison of the measured and modelled flow for SC#6. Site ID: FD445529

Table E-3. Discrete measured vs modelled flow statistics (m^3/s) in the Rangitāiki WMA.

Site Name	Site Code	SC#	Type	Mean	Min	50%ile	Max	RMSE
Whirinaki u/s Waiparera confluence	IE250425	41	Measured	3.8	2.5	2.7	7.1	3.24
			Modelled	3.2	1.2	2.9	4.9	
Mangamate at U/S Ruarepuae Confluence	IH791208	75	Measured	0.1	0.0	0.1	0.4	0.23
			Modelled	0.3	0.1	0.2	0.9	
Horomanga at Galatea Rd	IH893640	52	Measured	1.3	0.5	1.0	5.3	0.43
			Modelled	1.7	1.1	1.4	5.4	
Waikuku d/s Galatea Rd	JJ633547	32	Measured	0.1	0.0	0.1	0.1	0.03
			Modelled	0.1	0.1	0.1	0.1	
Ngatamawahine u/s Kopuriki Rd	IH701900	70	Measured	0.2	0.2	0.2	0.2	0.12
			Modelled	0.2	0.1	0.2	0.3	
Horomanga at Above Quarry	JH447165	51	Measured	1.4	0.7	1.0	4.9	0.55
			Modelled	1.1	0.8	0.9	3.3	
Otamatea at Wairere Rd	FD445529	6	Measured	2.1	1.3	1.8	5.0	0.56
			Modelled	2.2	1.3	2.0	4.6	