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DAVIS OGILVIE
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MEMORANDUM

To:	Manuherekia Hydrology Group
From:	Ian Lloyd, Davis Ogilvie
Date:	21 May 2021
Subject:	Manuherekia Hydrology Model –Calibration Memorandum – Final Draft.

1.0 BACKGROUND

This Calibration Memorandum was originally provided to facilitate discussion regarding the Manuherekia Hydrology Model during the meeting of the Manuherekia Hydrology Group on 26 January 2021. It is principally aimed at briefly describing the model build and the calibration/verification process.

An earlier draft of this Calibration Memorandum was circulated to the Manuherekia Hydrology Group immediately prior to their 26 January 2021 meeting. That earlier draft was briefly discussed during the meeting, but no formal comments were received.

The Manuherekia Hydrology Model is to be documented in a formal model report. However, as at 21 May 2021 the model report had not been commissioned. It is anticipated that the contents of this memorandum will feed into the Model Report.

The Otago Regional Council (ORC) are in the process of developing a water management plan for the Manuherekia Catchment and have developed various consultation documents which are scheduled for release on 21 May 2021. In the absence of a Model Report this Calibration Memorandum along with two other memorandums[1] have been updated in order to provide background to ORC's consultation documents. It is noted that the three memorandums were originally produced as internal documents to facilitate discussion and provide model output. They were not intended to be public documents and as such all three updated memorandums continue to be issued as drafts. The Model Report will be the official documentation of the model. This Calibration Memorandum updates and replaces the earlier draft dated 26 January 2021. It has been reviewed internally by Davis Ogilvie but has not been reviewed or formally adopted by the Manuherekia Hydrology Group. At the time of updating this Calibration Memorandum (21 May 2021) the Manuherekia Hydrology Model has not been documented, reviewed nor has it been formally adopted or approved by the Manuherekia Hydrology Group.

[1] An Ecological Memorandum (dated 21 May 2021) which discusses ecological aspect of the Manuherekia Hydrology Model and provides ecological output from the model, and a Scenario Memorandum (dated 21 May 2021) which provides model output requested by ORC in relation to various water management scenarios that were developed by ORC.

2.0 MODEL BUILD

Development of the Manuherekia Hydrology Model was informed by the scoping document dated 6 July 2020[2]. The model is as described in the scoping document (particularly the model logic diagram – a copy of which attached as Appendix 1) with the following minor changes:

(a). Two further small storages were added – the lower Manorburn Dam and the Ida Dam. Both dams were added to better model irrigation and downstream flows.

(b). Ecological parameters were added to allow estimation of habitat area for various species under different flows both at various locations and for various river reaches.

(c). Race losses of 5% of the flow were included from the Bonanza Race back into the Manor Burn.

(d). The Ida Valley Irrigation Scheme area was separated into two parts – Bonanza Race supplied by the Upper Manorburn Dam and the German Hill race supplied by the Poolburn Dam and tributaries. In practice water from the Bonanza Race can also be used to supply the German Hill Race. This ability was excluded from the model, but the irrigated area supplied by each of the two races was adjusted to ensure a similar reliability for the two systems.

Initial model build focused on the Lauder sub-catchment with the Lauder sub-catchment model checked by the GoldSim Technology Group[3] for overall logic. The Lauder sub-catchment model was then replicated and used to build the overall model. Most of the model logic regarding the dams and reservoirs was taken from the earlier Manuherekia GoldSim model initially prepared for the Manuherekia Catchment Water Strategy Group and subsequently updated for Manuherekia River Limited.

3.0 MODEL INPUT DATA AND TIME SERIES

The model input data and time series are predominantly as per the Scoping Document with only minor changes. The input data used is briefly outlined in the following table.

[2] DO, 2020. Manuherekia Catchment GoldSim model- scoping document – revised draft. Memorandum prepared by DO for the ORC and the Manuherekia Hydrology Group dated 6 July 2020.
[3] The GoldSim Technology Group is based in the USA and owns and supports GoldSim software.

Manuherekia Hydrology Model – Input Data		
Input	**Detail**	**Comment**
Input flow series	Falls Dam inflow	Developed by PZB Consulting[4] which updated and extended earlier series developed by RainEffects[5]. Through the calibration process it was revealed that low flows during drought recessions were being slightly overestimated. The final series used was based on the time series developed by PZB Consulting supplemented during low flow periods (< 3 m^3/s) with the lower of the two time series.
	Dunstan at Gorge	Developed by PZB Consulting. In the model a similar catchment yield is assumed from the Gorge site down to the main intake namely OIS's Dunstan Race intake, downstream of the Donald Stuarts Creek confluence.
	Lauder at Cattle Yards	Developed by PZB Consulting. In the model a similar catchment yield is assumed from the Cattle Yards site down to the main intake namely OIS's Lauder Race intake near the exit from the foothills.
	Thomsons at Weir	Developed by PZB Consulting.
	Chatto Creek at confluence	Predominantly (June 1973 to December 2018) developed by NIWA[6]. Extended by DO[7] for the period January 2019 to May 2020 using measured flows at the confluence and the measured water take data and irrigation area supplied by ORC[8] and modelled water take information.
	Upper Manorburn Dam inflow	Predominantly developed by RainEffects with extension etc by PZB Consulting. In the model a similar catchment yield is assumed from Hopes Creek, above Little Valley and the catchment between the Upper Manor Burn Dam and Hopes Creek.
	Poolburn Dam inflows	Developed by PZB Consulting assuming a similar per ha yield as the Upper Manorburn Dam catchment.
	Ida Burn at Mt Ida Race	Developed by DO using measured data extended using the monthly correlations with Falls Dam inflow. In the model a similar catchment yield is assumed for the remainder of the Ida Burn catchment above the Mt Ida Race.
	Mt Ida Race flows	Developed by DO using measured data from Johnsons Weir (accounting for R race) extended using the monthly correlations with Falls Dam Inflow developed by PZB Consulting. In the model it is assumed one third of the flow in the Mt Ida Race is used within the Ida Burn catchment and the remainder is exported out of the Manuherekia catchment (i.e. to the Taieri).
	Dovedale at Willows	Developed by DO using measured data extended using monthly correlation with initially the nearby Gimmer Burn flow record and then the Upper Manorburn Dam inflow.
Dam Information	Storage, outlet and management of the storages.	Taken from the earlier Manuherekia GoldSim model. Through the calibration process the management imposed irrigation restrictions applied in relation to Falls Dam were altered slightly to ensure a better match with both measured water levels in Falls Dam and actual imposed irrigation restrictions.
Irrigation information	Irrigation Demand Series	Unit (per Ha) time series developed by PZB Consulting for both flood and spray irrigation in three locations (Below Ophir, Above Ophir and the Ida Valley) using a soil moisture model, local climate soil and irrigation information.
	Drainage and return water time series	Unit (per Ha) time series developed by PZB Consulting for flood irrigation, spray irrigation and dryland in the three locations.
	Irrigated area, water source and water transfers	Irrigation Maps developed by ORC. Irrigated areas were assigned an irrigation type, a sub-catchment based on physical location (determines reach return water drains to) and a water source. During calibration measured water take data was used to compare with modelled water supply. Modelled supply was initially found to be less than measured take (note both take into account retakes). An additional 2,200 ha of irrigated area was added (Blackstone, Dunstan Flats and Ida Valley) to better match the measured take data.

[4] Peter Brown of PZB Consulting developed the various time series.
[5] Dave Stewart of RainEffects developed the various time series.
[6] Roddy Henderson and Christian Zammit using NIWA's Topnet model
[7] Ian Lloyd of Davis Ogilvie.
[8] Water take data and irrigation maps supplied by Pete Ravenscroft of ORC

4.0 MODEL CALIBRATION / VERIFICATION

The model was calibrated / verified in the following sequence:

(a). Dunstan sub-catchment with consideration of flow at Beattie Road and at the downstream temporary flow recorder at Phil Smith's property.

(b). Lauder sub-catchment with consideration of flow at the Rail Trail.

(c). Thomsons sub-catchment with consideration of flow at SH85.

(d). Chatto sub-catchment with consideration of flow at the Manuherekia confluence.

(e). Manor Burn sub-catchment including the Upper Manor Burn Dam with consideration of the short measured flow record from Hopes Creek and the time series of estimated inflow to the Lower Manor Burn Dam developed by RainEffects.

(f). Pool Burn sub-catchment including the Pool Burn Dam. There is no downstream flow record to calibrate to, although gaugings indicate that during periods of low flow the Pool Burn does not contribute very much flow i.e. < 20 L/s to the Ida Burn.

(g). Ida Burn sub-catchment, which includes the Pool Burn sub-catchment, with consideration of flow at Cob Cottage.

(h). Manuherekia Main Stem from Falls to Ophir including Falls Dam and the various tributary inflows. Calibration considered flow at Ophir and operation of Falls Dam (namely measured water level and known irrigation restrictions).

(i). Manuherekia Main Stem from Ophir to Campground with consideration of flow at Campground.

Initial calibration commenced prior to finalisation of all the input data (namely Chatto Creek, Dovedale Creek and Ida Burn inflow time series). Initial calibration was based on visual curve matching with a focus on lower flows. This initial model was shown to Roddy Henderson of NIWA and Peter Brown of PZB Consulting (27 November 2020), the Manuherekia TAG group (30 November and 1 December 2020) and the Manuherekia MRG group (7 and 8 December 2020). Initial calibration indicated relatively good matching of downstream flows for the tributaries and the main stem. However, the initial calibrated model overestimated water level in the Falls Dam Reservoir and underestimated the associated Falls Dam management imposed irrigation restrictions particularly during drought conditions (i.e. Falls Reservoir was not working hard enough). Subsequently the following changes were made to the model:

I) Chatto Creek, Dovedale Creek and Ida Burn inflow time series were finalised.

II) Water Take Data was analysed and compared with modelled water supply in each sub-catchment resulting in slight adjustments to the irrigated area, in total, a further 2,200 ha of spray irrigated land was included in the model (original irrigation map 24,180 ha irrigated, initial model 25,010 ha irrigated, final model 27,210 ha irrigated).

III) The management imposed irrigation restrictions applied in relation to Falls Dam were reduced slightly allowing harder use of storage at Falls Dam.

IV) Removal of dryland drainage return flow from all catchments – in order to reduce the peaky nature of the modelled flow series.

V) Review of the Falls Dam inflow time series particularly during periods of low flow - resulted in a slightly modified inflow series.

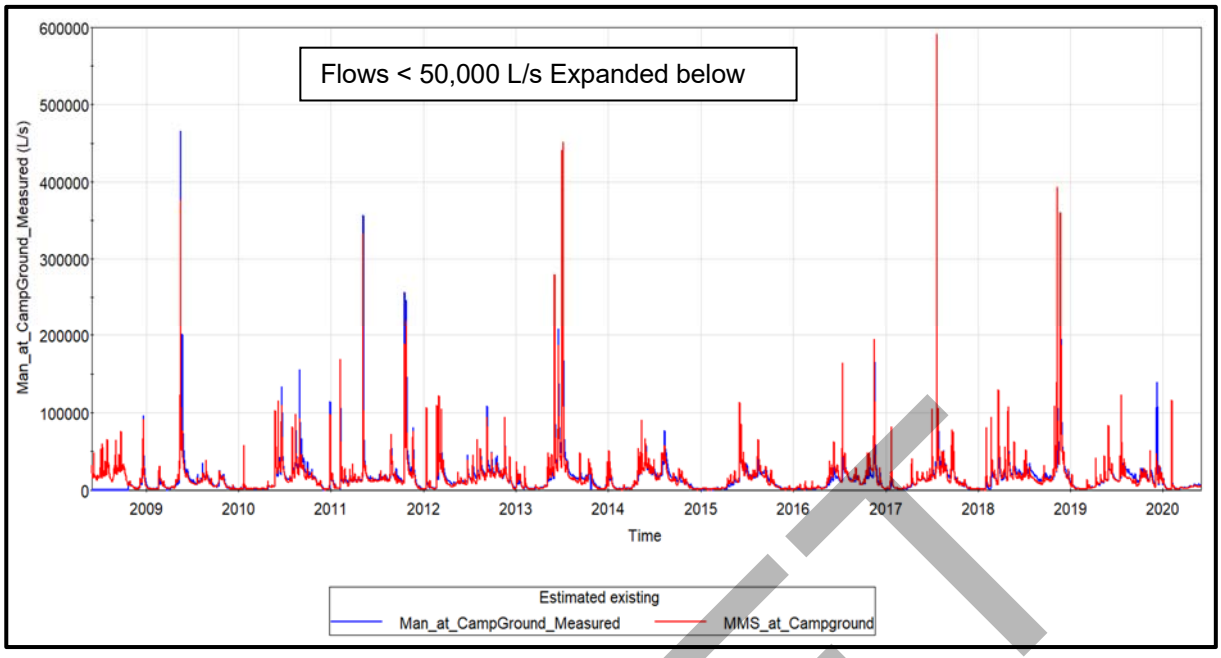
The above changes significantly improved the model's ability to replicate water levels in Falls Dam. Subsequently flow duration curves, cumulative flow and flow statistics namely 7 Day MALF were compared for the modelled and measured data at both Campground and at Ophir. The comparisons were based on periods when there is measured data at both sites (namely October 2008 to May 2020). The following plots and tables summarise the results:

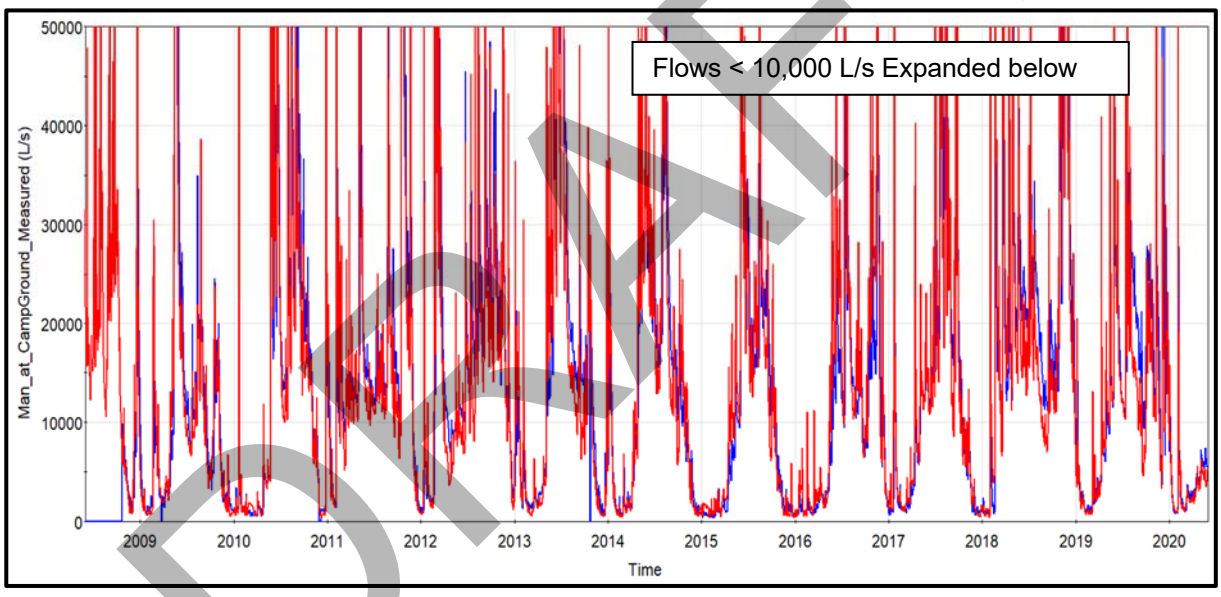
4.1 Campground

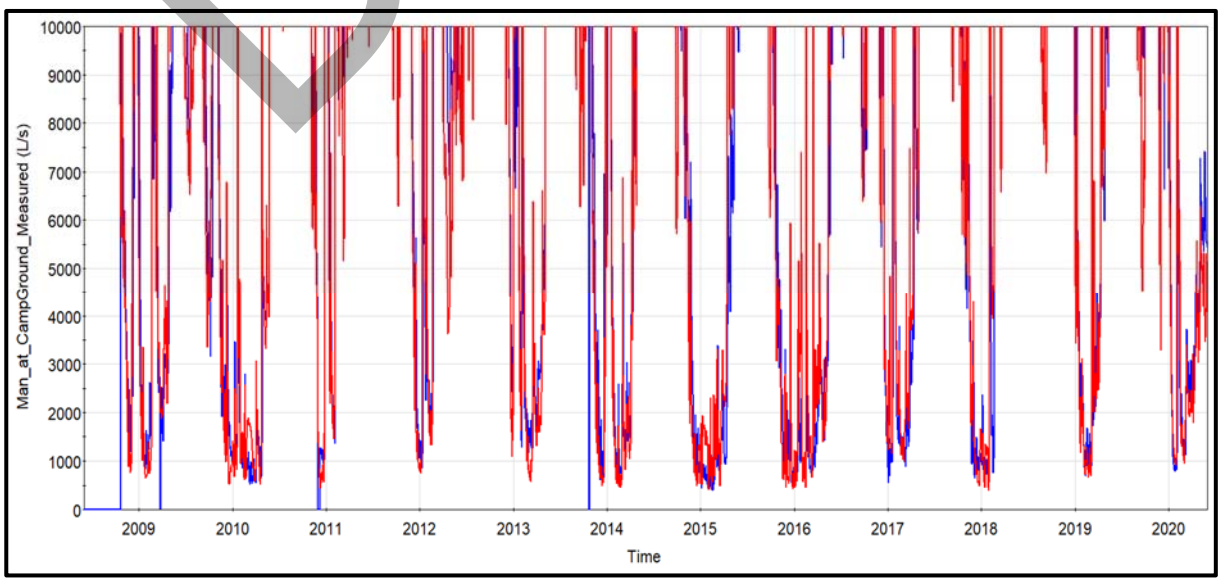
The modelled (red and overlaying) and measured (blue) flow in the Manuherekia River at Campground visually match very well with the modelled flow showing similar flow fluctuations and similar magnitude high and low flows.

The flow duration curves match well particularly for the lower 40% and upper 20% of the flow range. The model tends to underestimate flows through the middle (40% to 80%) of the flow regime. The model tends to slightly underestimate flows below 1,000 L/s (the lower 10%) including 7 day MALF which is considered conservative.

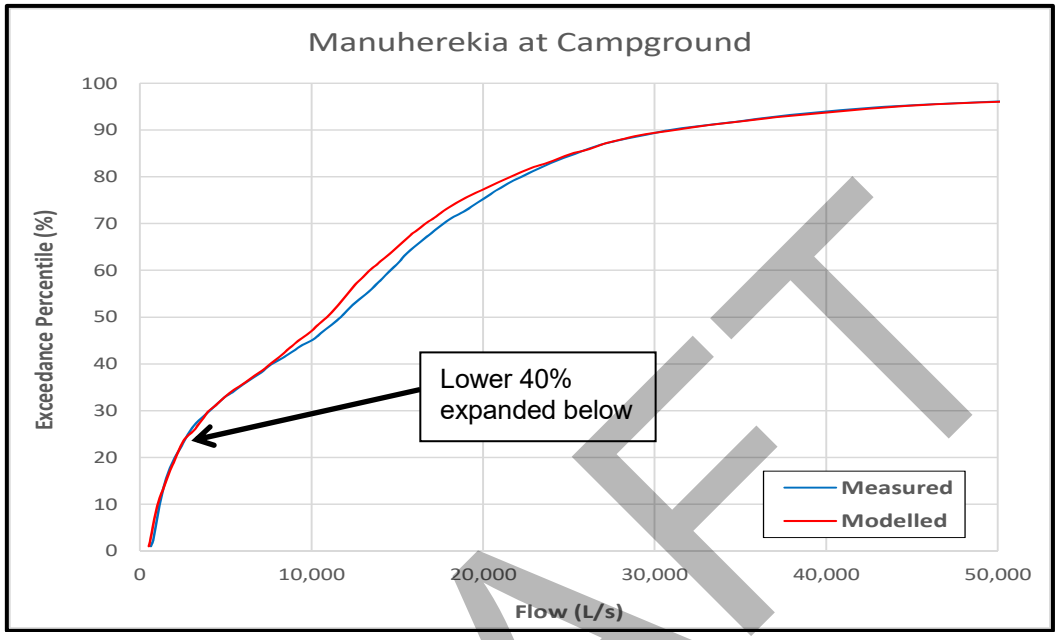
Cumulative flow matches well, with the model tending to slightly underestimate cumulative flow at Campground. This is likely to be in part due to the underestimation of mid-range flow but also is highly affected by large flow events which are difficult to model accurately.

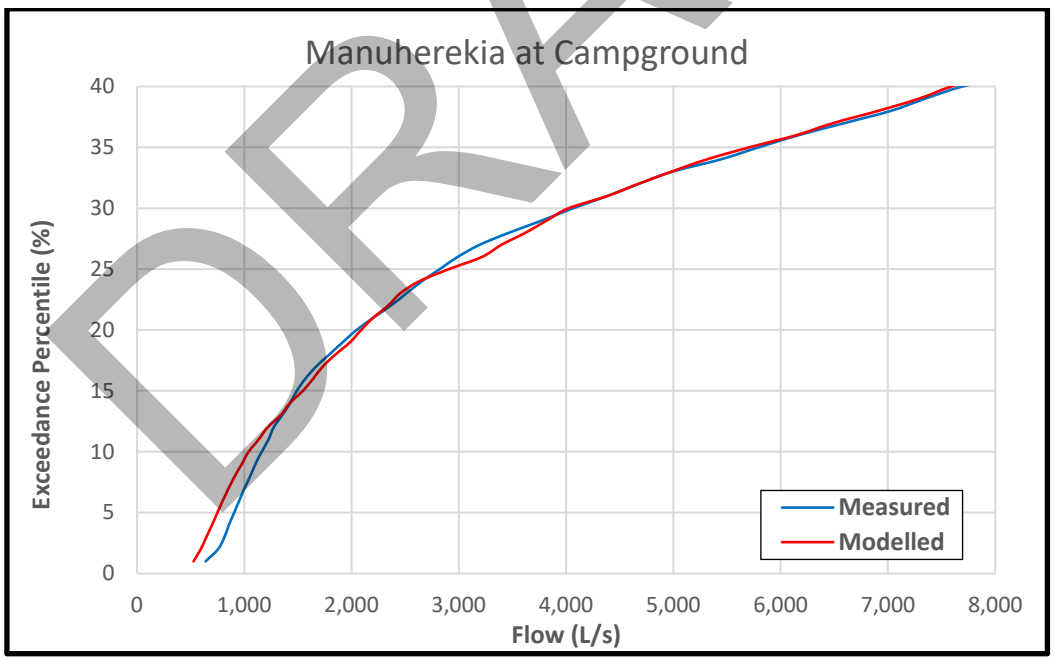


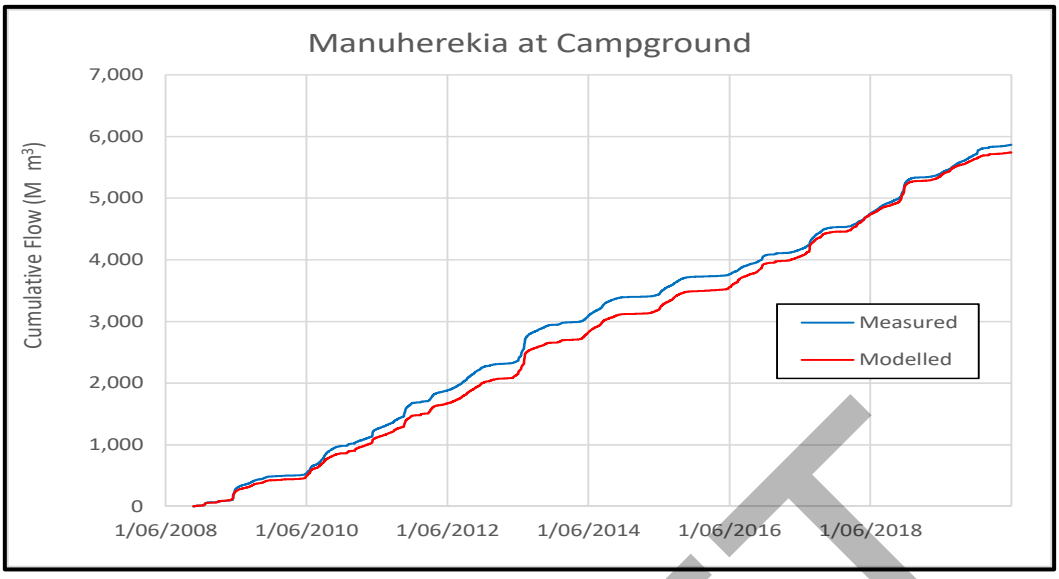




Campground	**7 Day MALF** (October 2008-May 2020) (L/s) for complete hydrological years (1 June to 31 May) only
Measured	887
Modelled	721





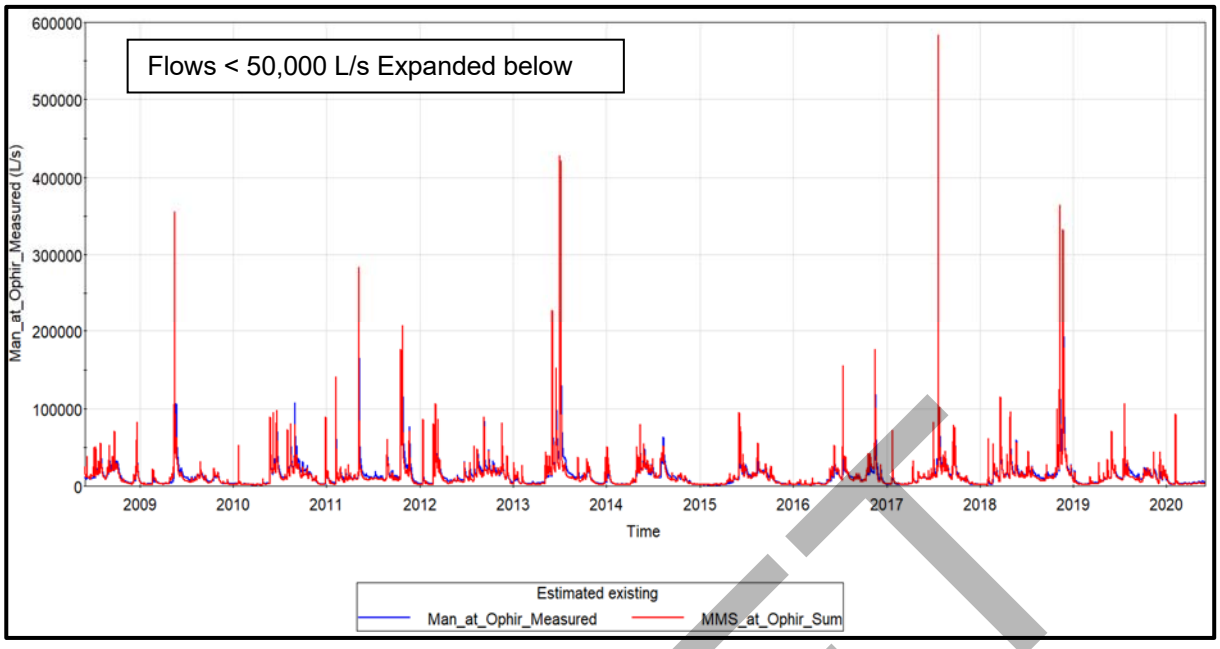


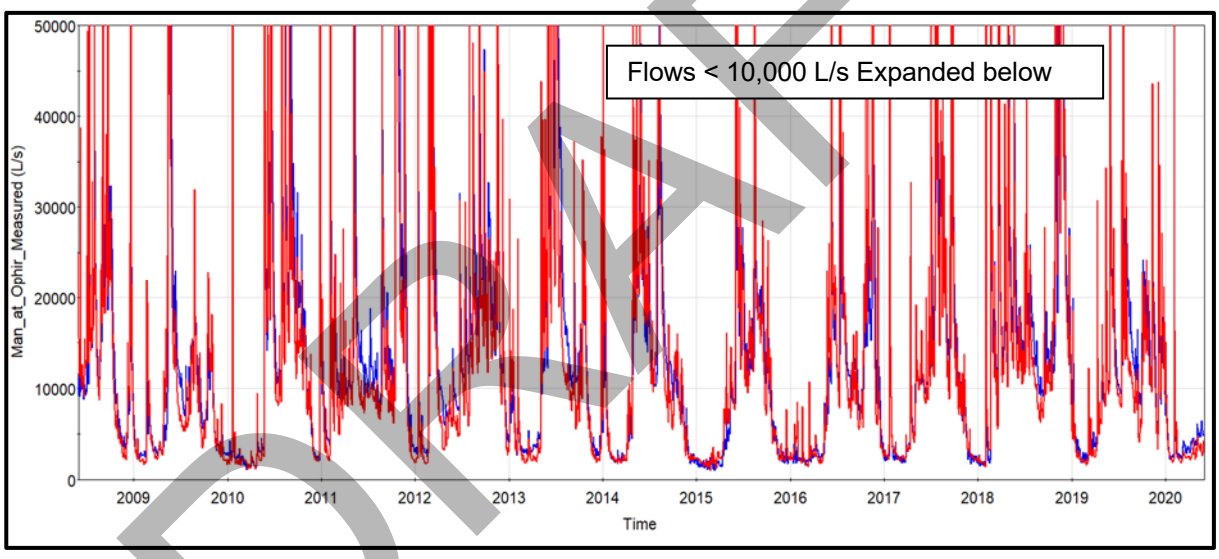
4.2 Ophir

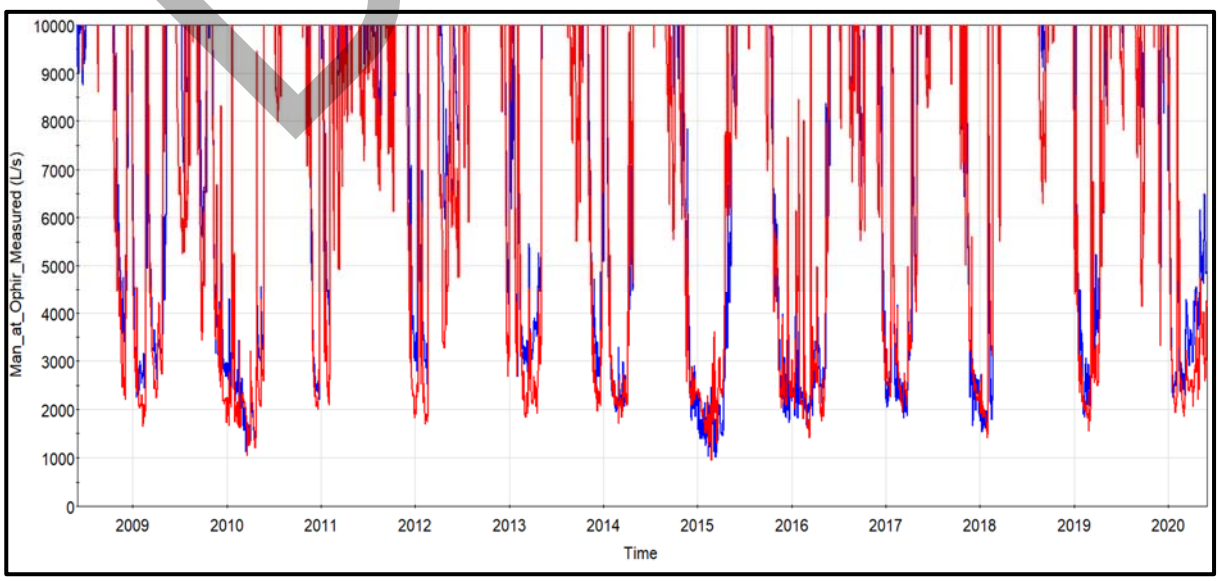
The modelled (red and overlaying) and measured (blue) flow in the Manuherekia River at Ophir visually match very well with the modelled flow showing similar flow fluctuations and similar magnitude high and low flows.

The flow duration curves match well particularly for the lower 10% and upper 20% of the flow range flows. The model tends to underestimate flows through the middle (10% to 80%) of the flow regime. The model underestimates 7 day MALF which is considered conservative.

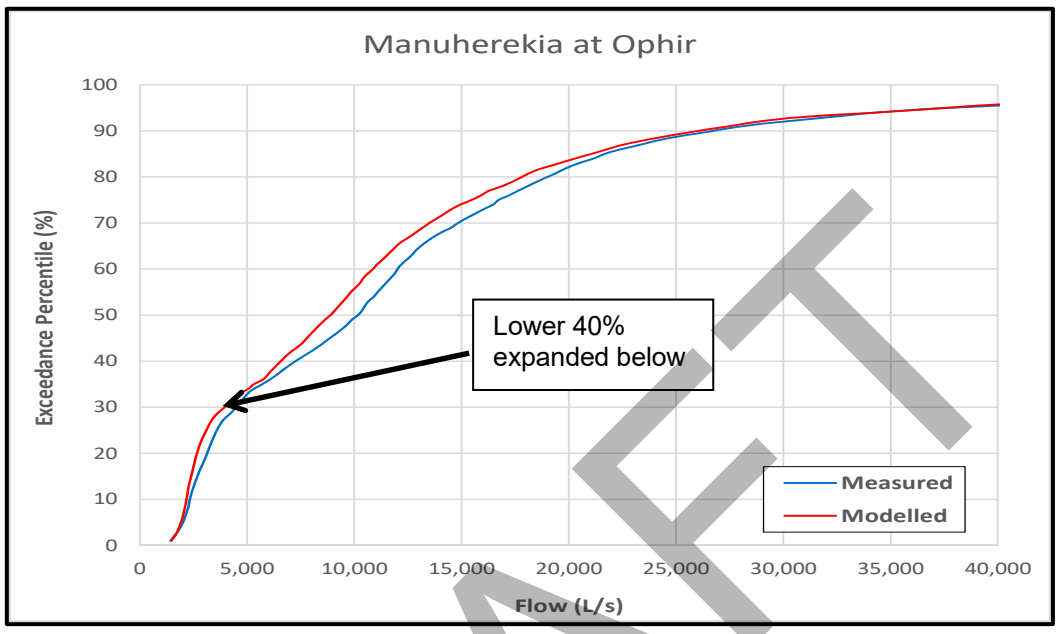
Cumulative flow matches well, with the model tending to slightly underestimate cumulative flow at Ophir. This is likely to be in part due to the underestimation of mid-range flow but also is highly affected by large flow events which are difficult to model accurately.

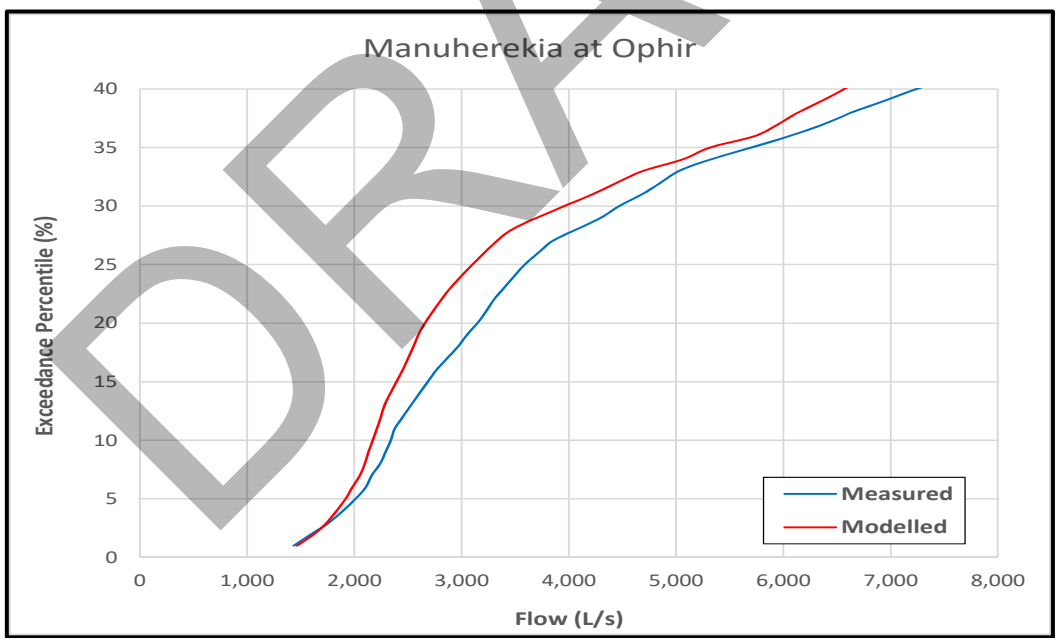


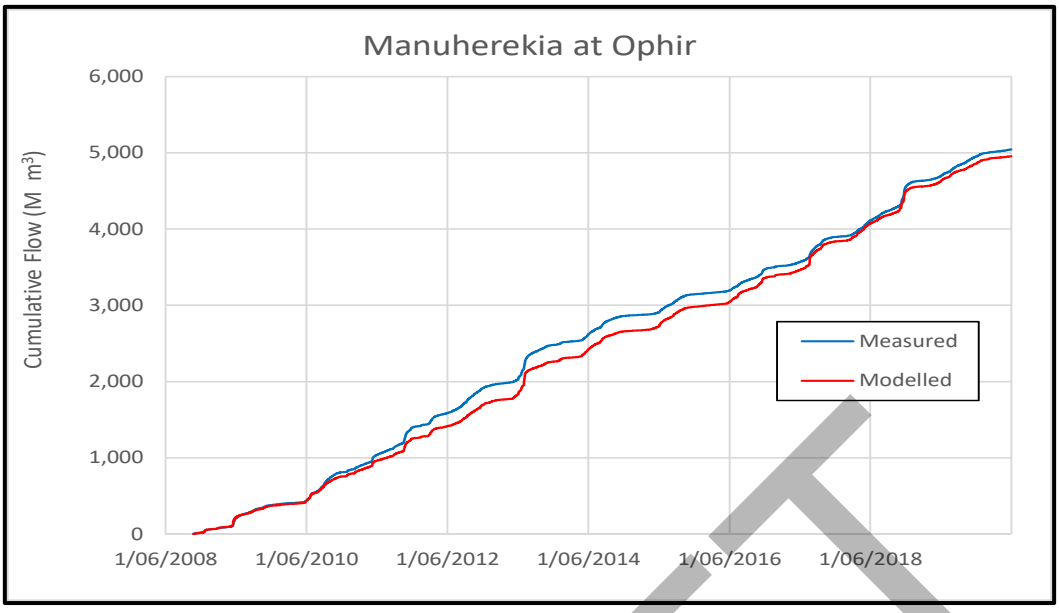




Ophir	**7 Day MALF** (October 2008-May 2020) (L/s) for complete hydrological years (1 June to 31 May) only
Measured	2055
Modelled	1701

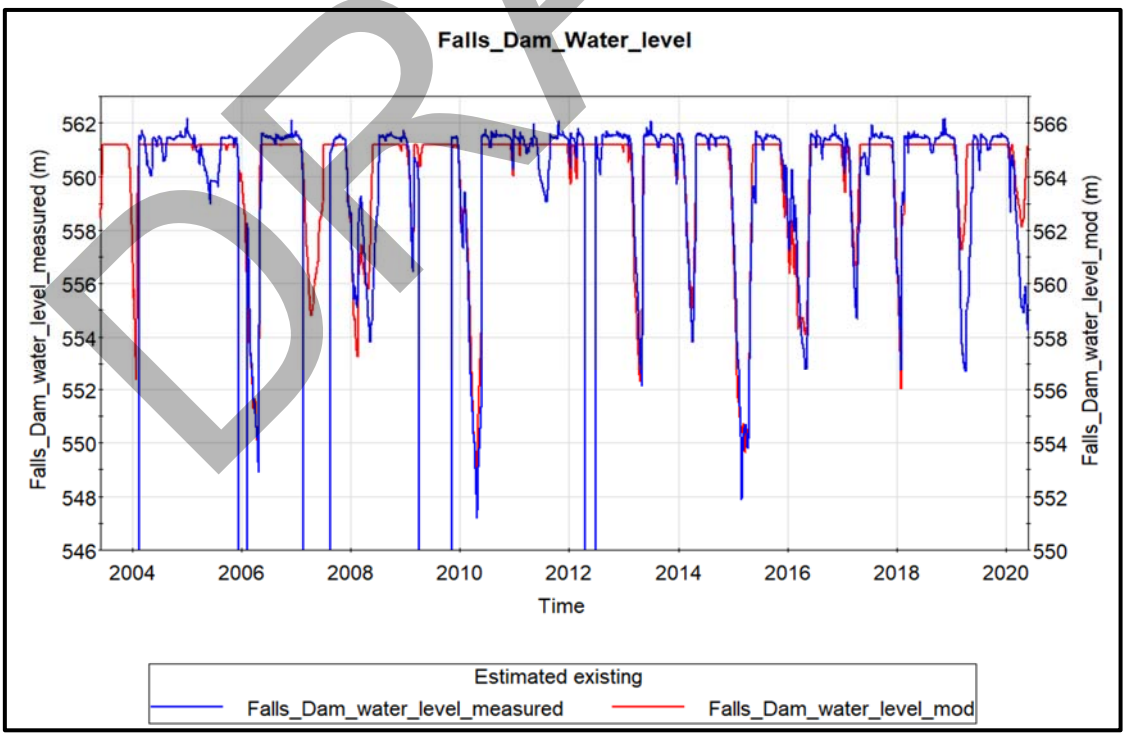


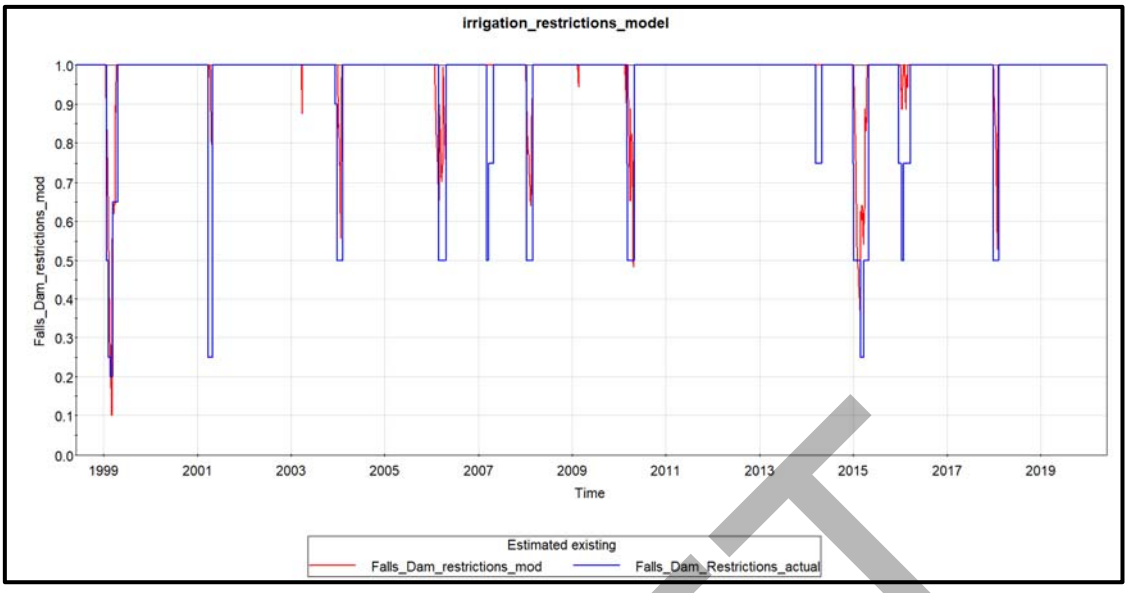




4.3 Falls Dam Operation

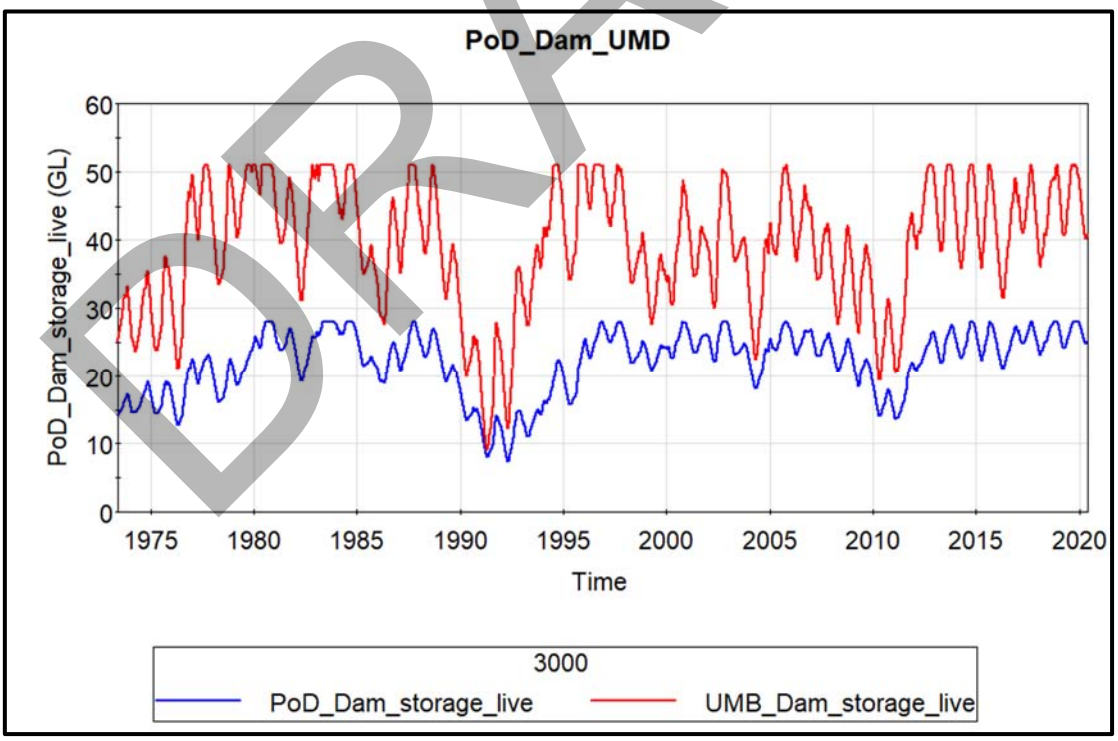
Comparison plots from the model are shown below for Water Level in Falls Dam and Irrigation Restrictions. In both cases actual measured data is shown in blue and modelled in red, (note the measured data in blue overlays the modelled data in red). In both cases the modelled data is considered a good visual match to the measured data.





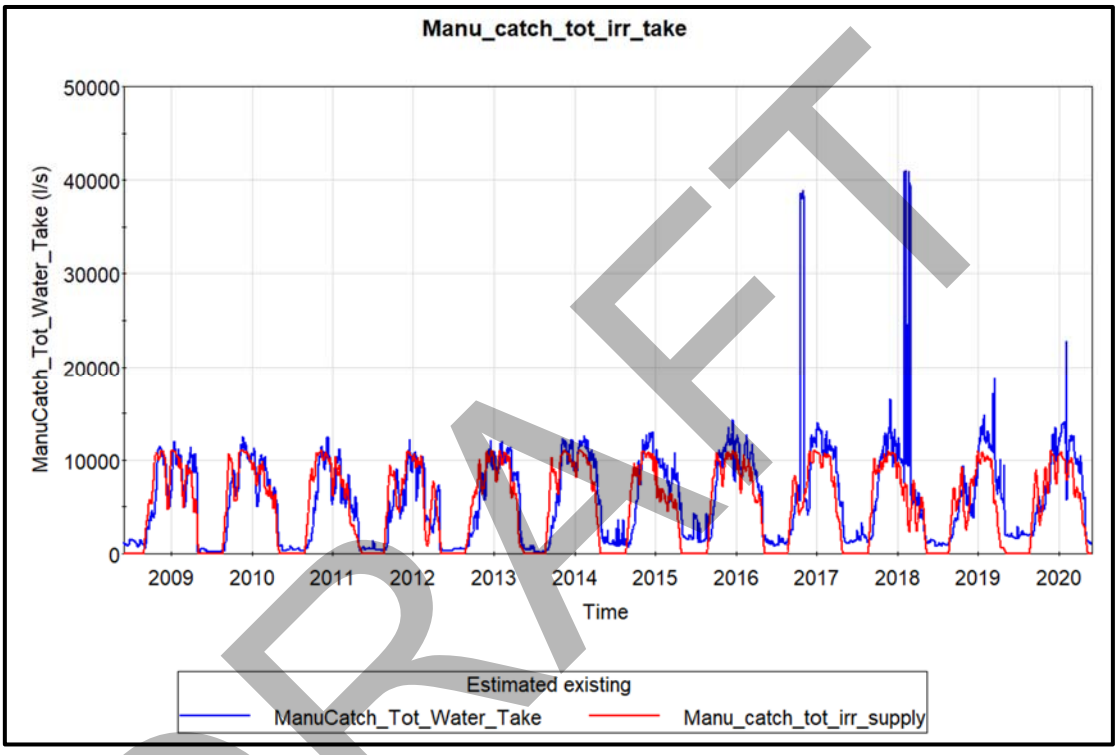
4.4 Ida Valley Storage Operation

A plot of modelled live storage in both the Poolburn (blue) and the Upper Manorburn (red) reservoirs is shown below. There is limited measured data available for either reservoir, however modelled storage fluctuates as expected.



4.5 Total Catchment Water Supply

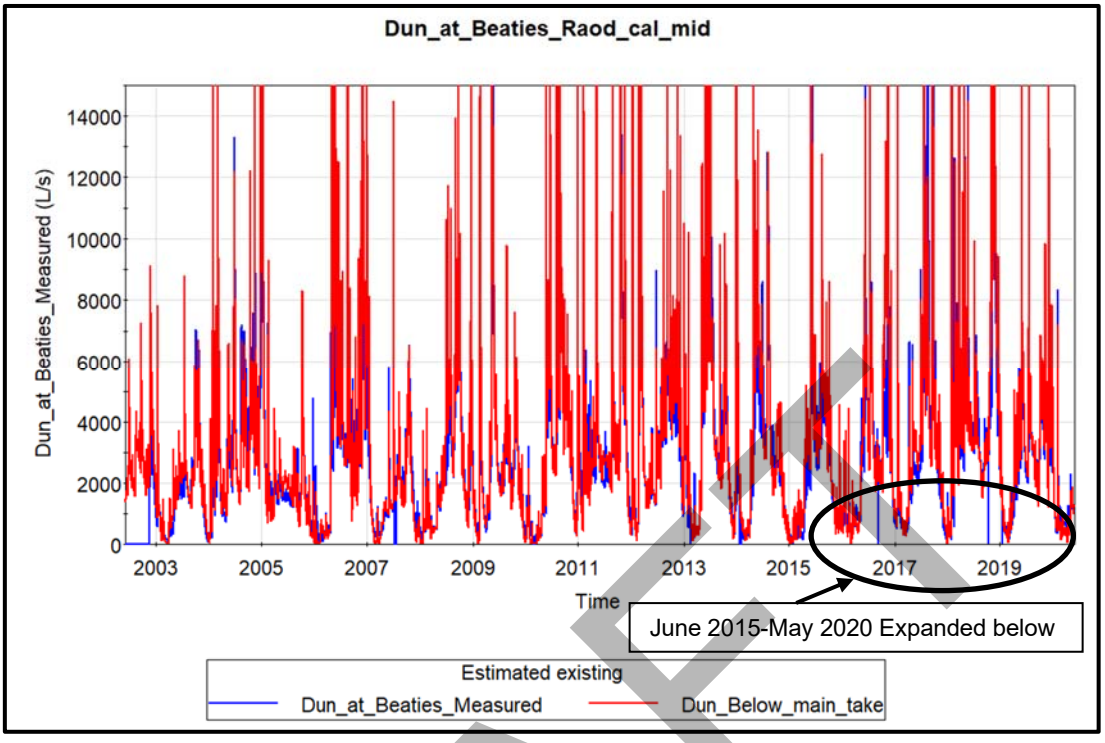
A comparison plot of total measured take (blue) and modelled water supply (red) for the catchment is shown below (note the modelled data in red overlays the measured data in blue). In both cases retakes have been excluded. The extreme peaks in the measured data are expected to be erroneous. The modelled take generally matches the measured take reasonably well although the modelled take does not include winter takes and underestimates the peak measured take particularly since 2014.

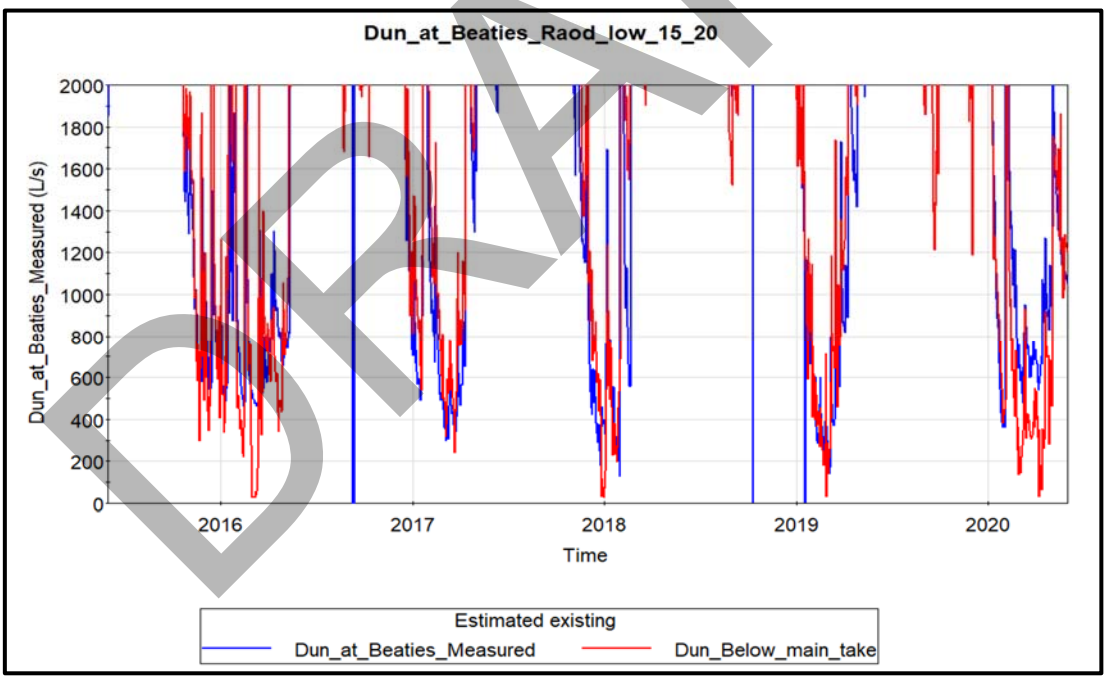


4.6 Tributary Flows

Comparison plots of measured flow (blue) and modelled flow (red) for Dunstan Creek at Beattie Road, Lauder at Rail Trail, Thompsons at SH85, Chatto at Confluence, Manor Burn inflow to the Lower Manorburn Dam and Ida Burn at Cob Cottage are shown below. In all cases the modelled data in red overlays the measured data in blue.

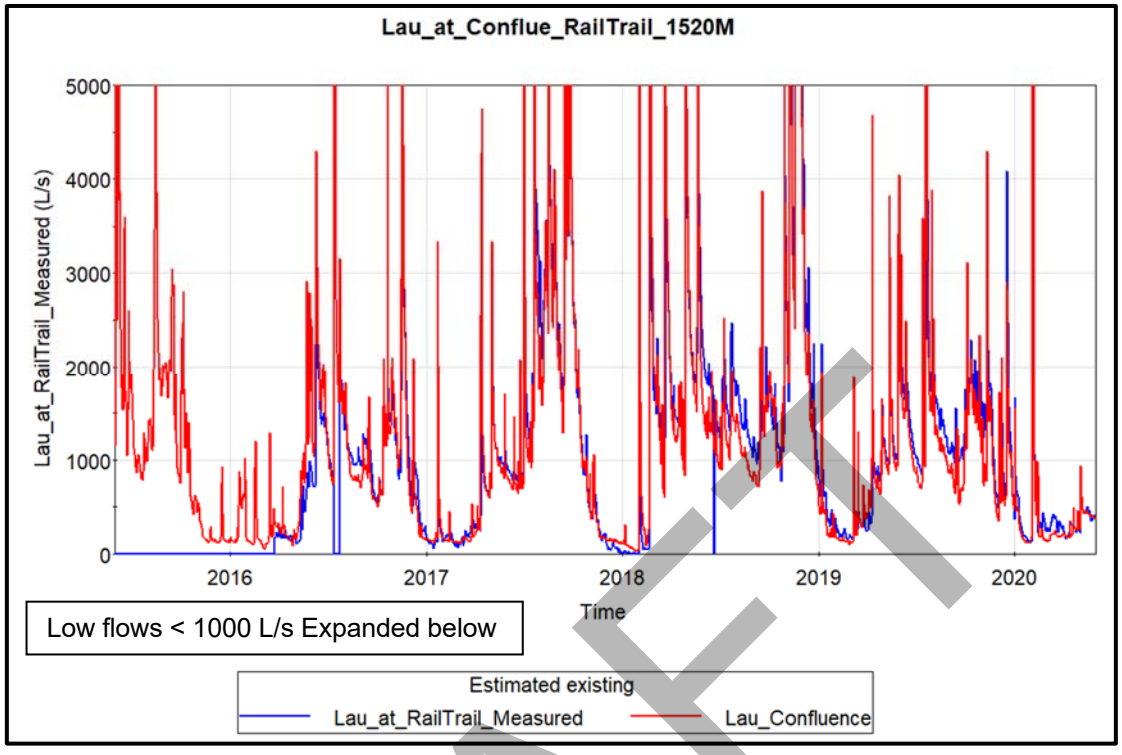
Dunstan Creek

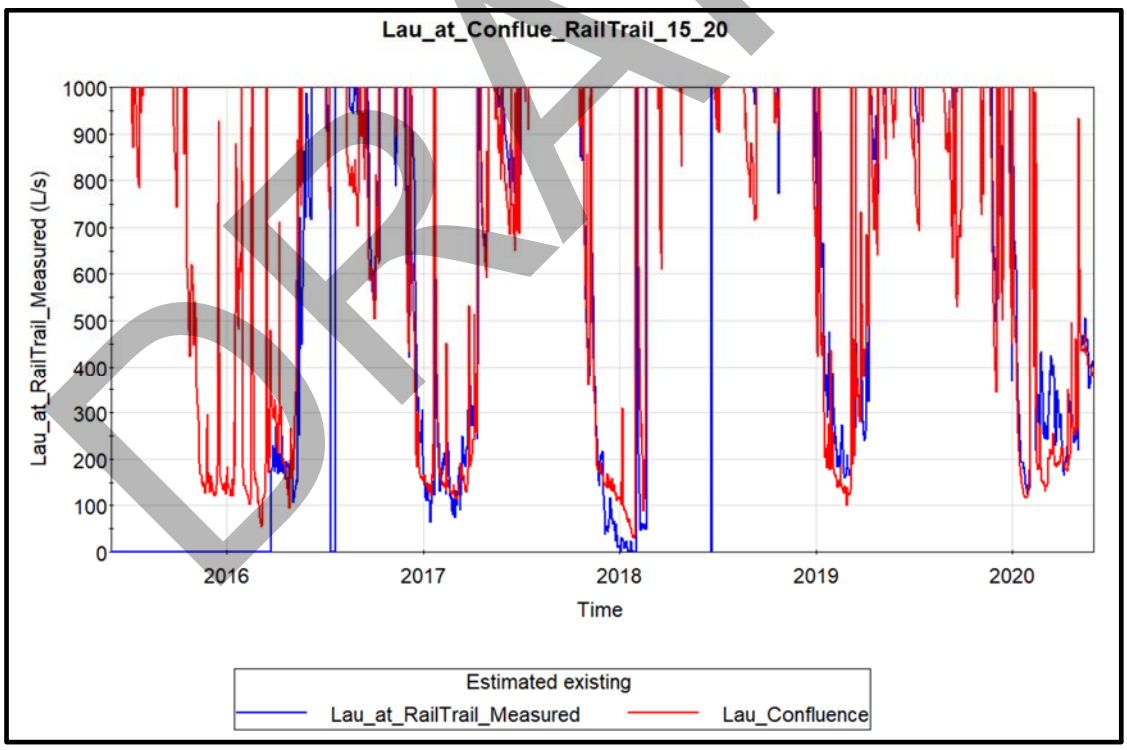




Modelled flow in Dunstan Creek at Beaties Road is considered a good visual match to the measured data and shows similar flow fluctuations. The modelled flow slightly underestimates extreme low flows which is considered conservative. Beaties Road is located part way down the Dunstan Creek catchment which is difficult to replicate in the model as the model is focused on estimating flow in the tributaries at their confluence with the Manuherekia River. Unfortunately, there is very limited measured flow data from the bottom of Dunstan Creek above its confluence with the Manuherekia River.

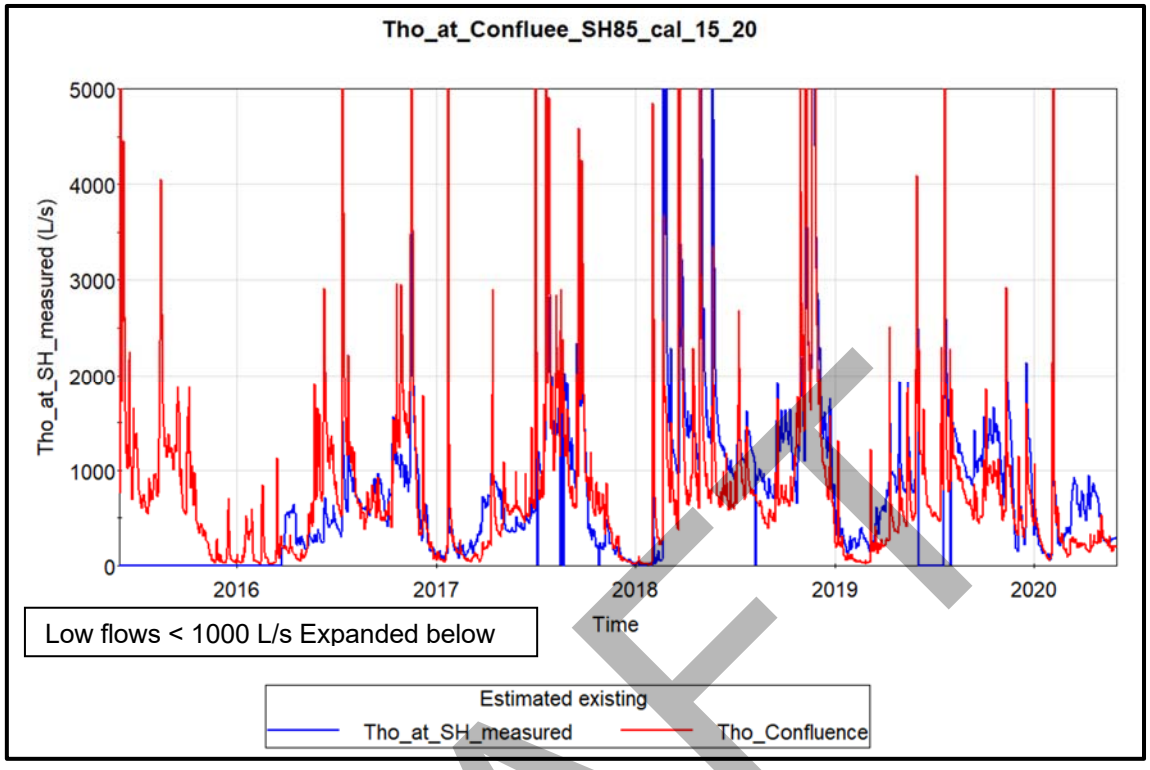
Lauder Creek

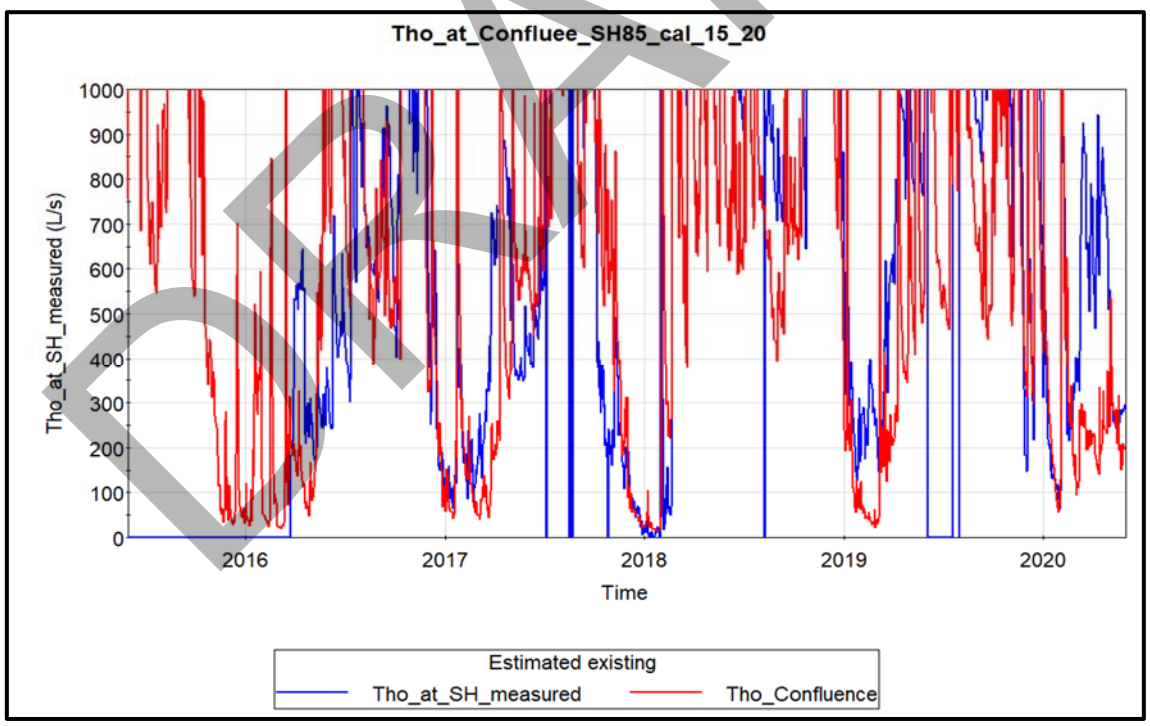




Modelled flow in Lauder Creek at the Rail Trail is considered a good visual match to the measured data and shows similar flow fluctuations. The modelled low flows are of a similar magnitude to the measured low flows.

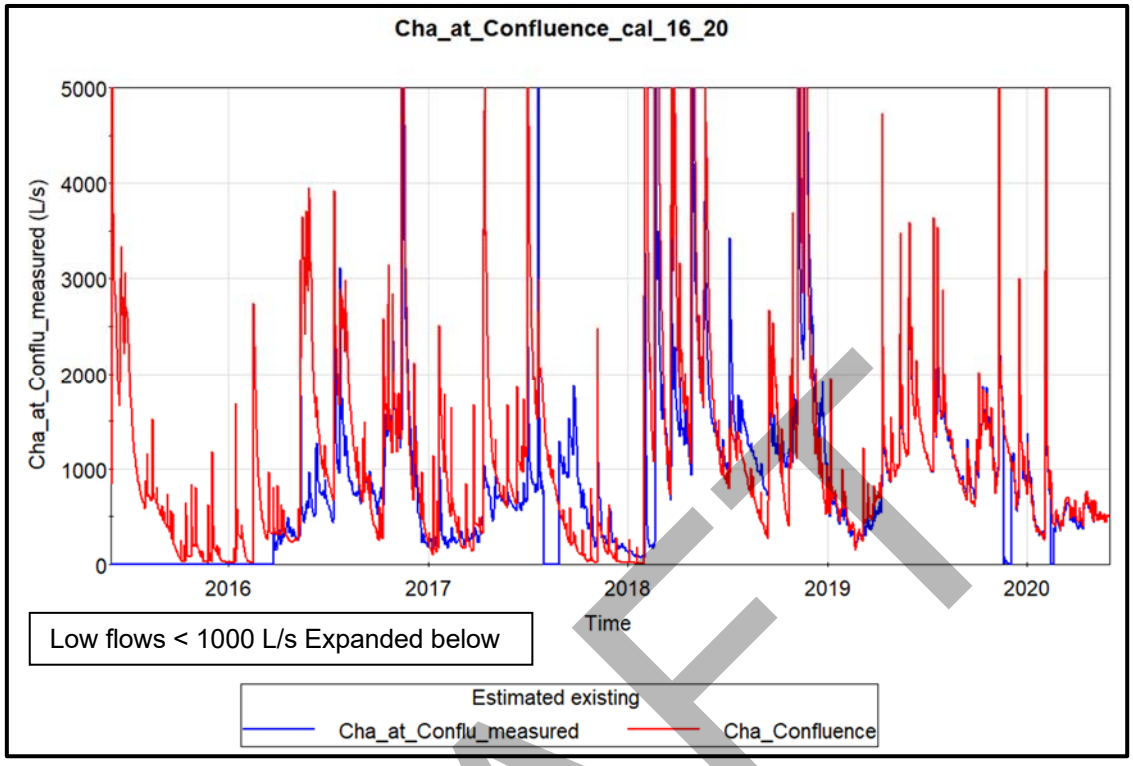
Thomsons Creek

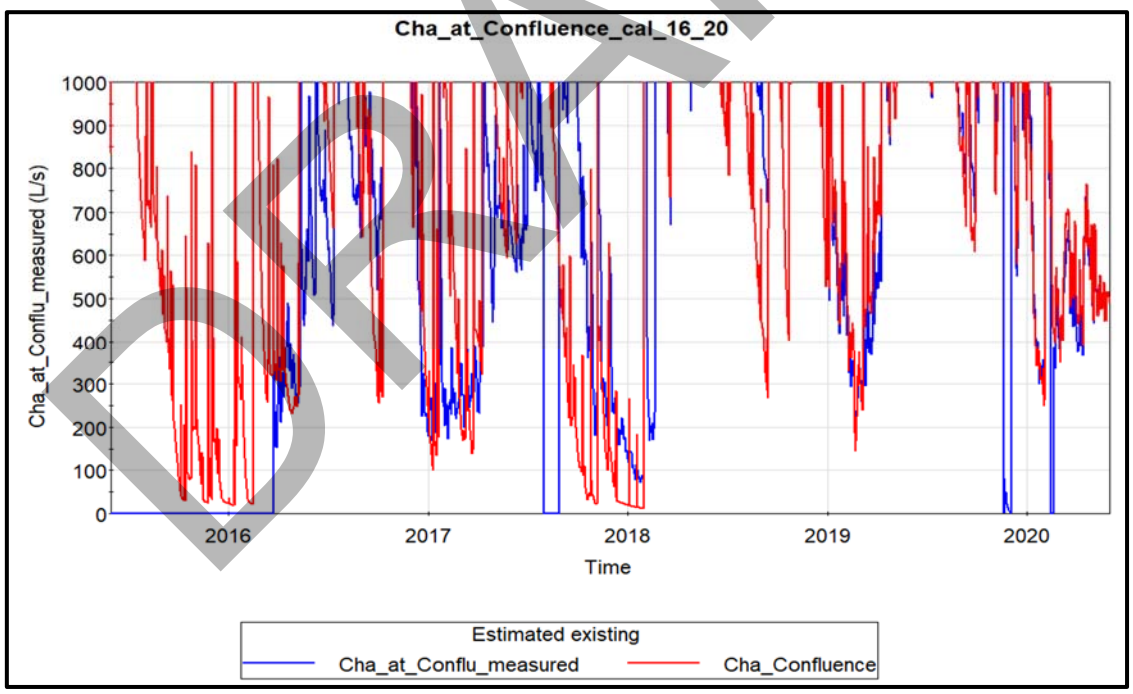




Modelled flow in Thomsons Creek at SH85 is considered a reasonable visual match to the measured data and generally shows similar flow fluctuations. The modelled low flows are of a similar magnitude to the measured low flows. Overall the match (modelled versus measured) for Thomsons Creek is not as good as for Lauder Creek which is expected to be due to the more complex hydrology of the Thomsons Creek catchment and particularly the amount of irrigation water which is imported to and exported from the sub-catchment.

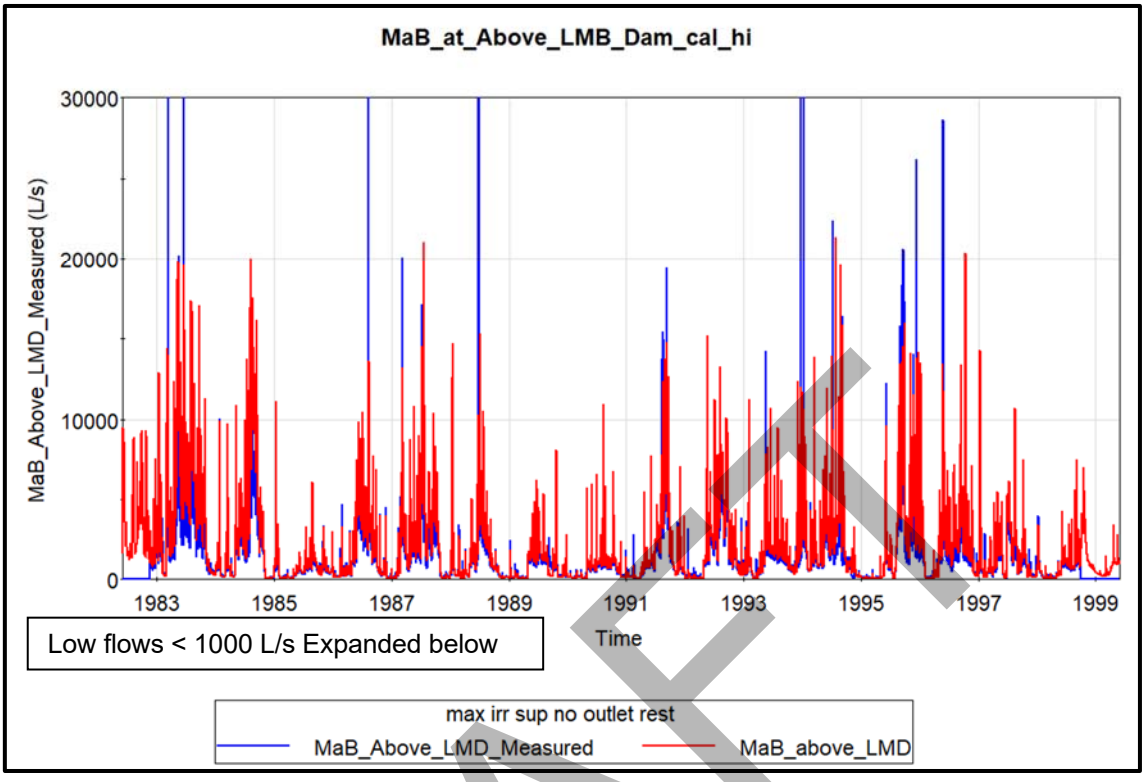
Chatto Creek

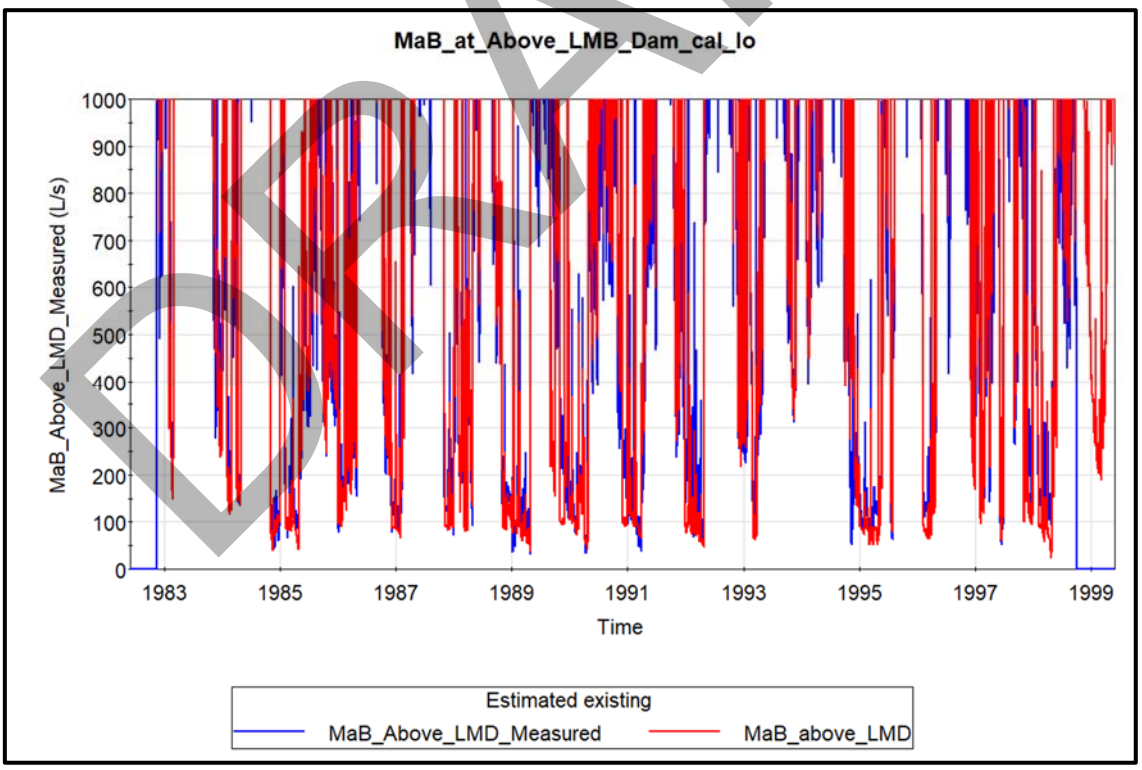




Modelled flow in Chatto Creek at its confluence with the Manuherekia River is considered a reasonable visual match to the measured data although modelled flow fluctuates more than measured flow and low flows tend to be underestimated. Overall the match (modelled versus measured) for Chatto Creek is not as good as for either Lauder Creek or Thomsons Creek which is expected to be predominantly due to uncertainties in the input flow series used for Chatto Creek (i.e. flow above the irrigation takes) which is due to there being very limited measured flow data from the catchment.

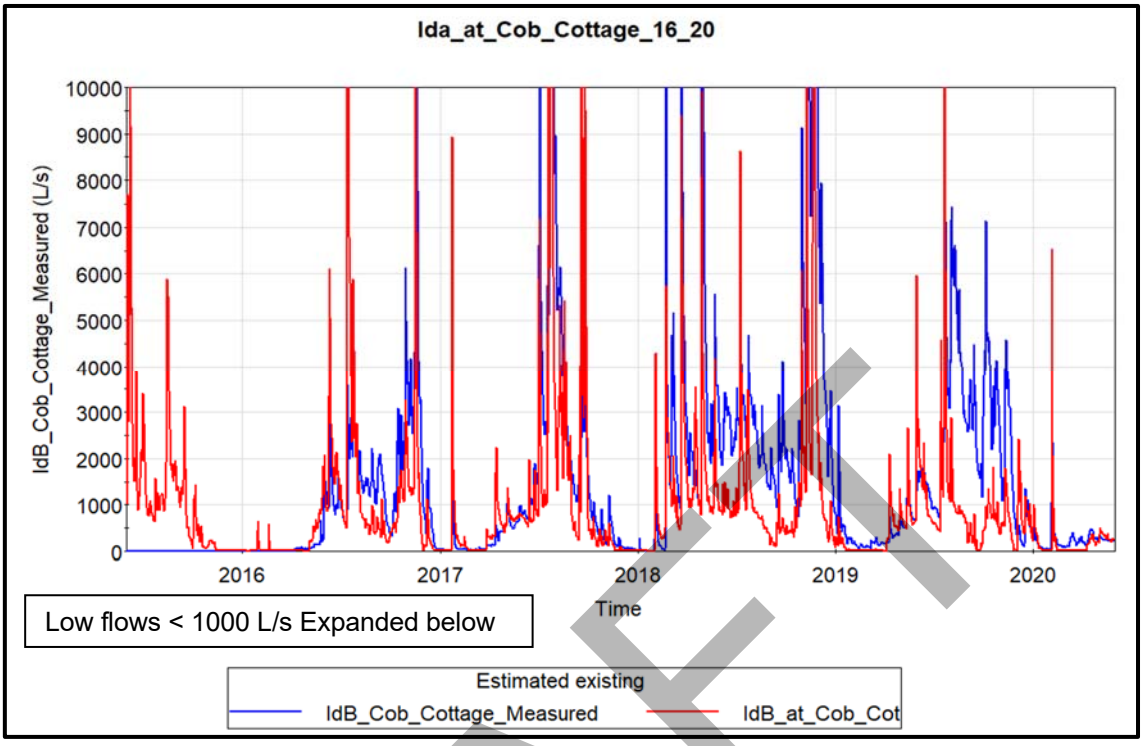
Manor Burn

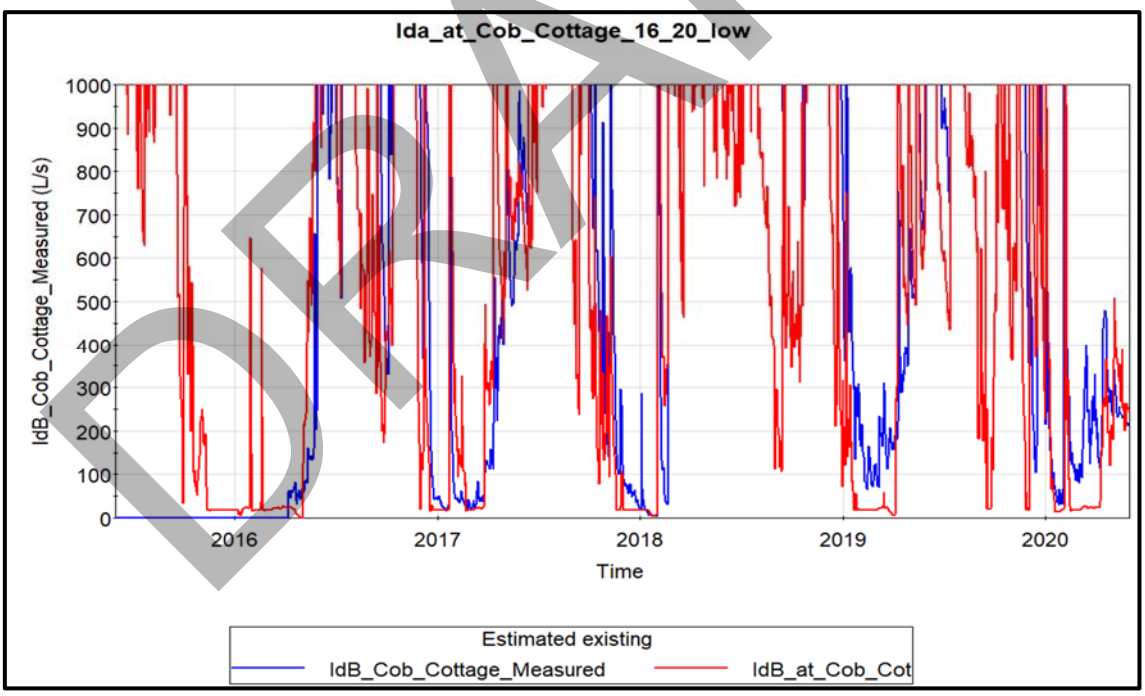




There is very limited measured data available for the Manor Burn catchment and as such it is not possible to calibrate and verify this part of the model. However, modelled flow in the Manor Burn above the Lower Manorburn Dam is considered a reasonable visual match to the modelled flow series produced by RainEffects.

Ida Burn





Modelled flow in the Ida Burn at Cob Cottage is considered a reasonable visual match to the measured data although modelled flow fluctuates more than measured flow and low flows tend to be underestimated. Overall the match (modelled versus measured) for Ida Burn is not as good as for either Lauder Creek or Thomsons Creek which is expected to be predominantly due to uncertainties in the input flow series used for the Ida Burn and its main tributary the Pool Burn (i.e. flow above the irrigation takes) which is due to there being very limited measured flow data from the catchment.

5.0 MODEL USE

At the time of the draft memorandum (25 January 2021) the model had, at ORC's request, been used to assess eight future water management scenarios developed by ORC. Model output from the eight scenarios was used in economic assessments. Subsequently the model has, at ORC's request, been used to assess numerous additional scenarios and has been used in several meetings and workshops.

Due to the complexity of the model and how the model adjusts to changes care is required when developing scenarios and assessing model output.

6.0 CLOSURE

The Manuherekia Hydrology Model has not yet been documented, reviewed nor has it been formally adopted or approved by the Manuherekia Hydrology Group. It has been constructed using all the available hydrological data and current understanding of the catchment. It has been developed to suitably replicate the hydrology of the Manuherekia catchment and to allow potential future water management scenarios to be assessed. Based on the model calibration / verification results outlined above the Manuherekia Hydrology Model is considered to suitably replicate the catchments hydrology and current water management regime.

Yours faithfully,
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APPENDIX 1 – Model Logic Diagram

Figure 1: Manuherekia Catchment GoldSim Model – Model Logic Diagram