Notes on derived tributary series

Information paper

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Market Analytics

Contents

1 Introduction

1.1 Tributaries can contribute significant flows into hydro schemes. These tributary flows generally enter the system below significant controlled storage and must be used for generation, spilled, or managed within the smaller reservoirs.

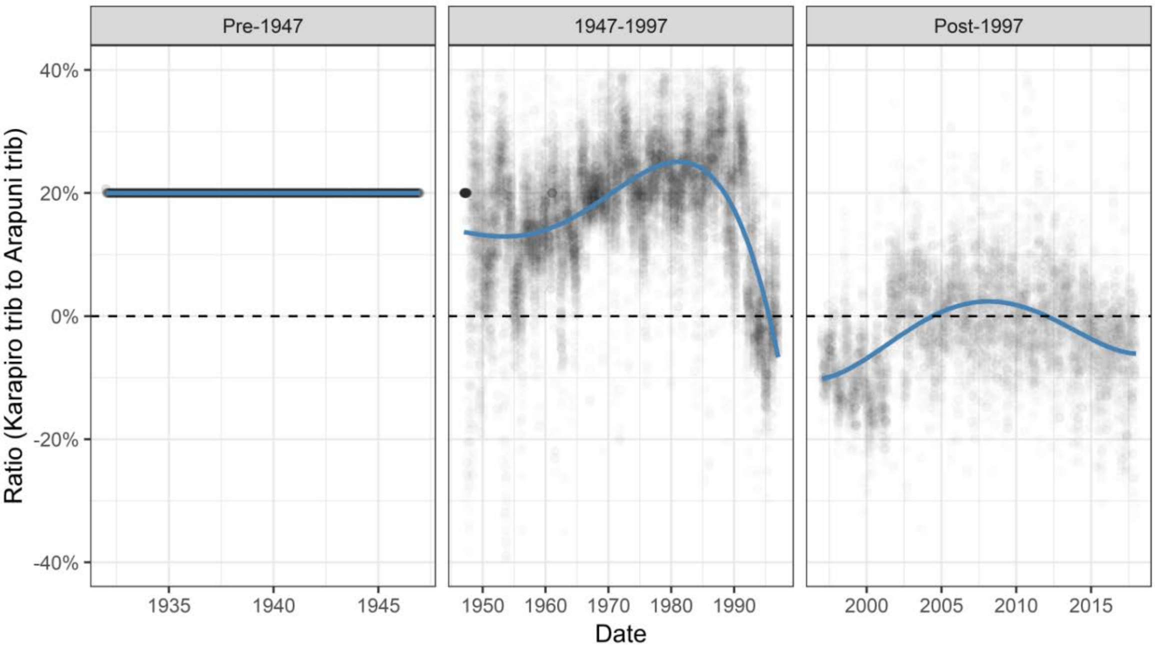
1.2 Several tributary flow series are provided as part of the HMD. However, as noted in Report 2 (flows methodology and description), robust series through time can be difficult to establish. Simple subtraction between series to derive intermediate contributions can result in negative flows.

1.3 Of course, negative flows can't happen in reality and including them in modelling makes little sense. The following sections outline the approach the Authority has taken to derive tributary flow series from the HMD series for our modelling.

2 Waikato tributary flow series

2.1 Two tributary flow series are included in the HMD dataset for total tributary flow on the Waikato River. These are the total Waikato tributary flow to Arapuni, and the total Waikato tributary flow to Karapiro. However, subtracting the Arapuni series from the Karapiro series results in sustained periods of negative flows.

Figure 1: Waikato tributary flow at Karapiro relative to Arapuni



Source: Electricity Authority

Notes: 1. Seven day moving average of Waikato tributary flow at Karapiro (92714.1) divided by seven day moving average of Waikato tributary flow at Arapuni (92724.1) minus 1

2.2 The approach the Authority has taken is to treat each tributary series as an observation of a system for which we already have a model. In this way, we can gain value from each independent, although uncertain, observation. To the best of our knowledge we have no reason to trust one measure more than the other.

2.3 Previously mean station outflows across the scheme had been used to define the model, but even these proved unreliable and resulted in negative flows[1] (ie less outflow from a downstream station than the upstream station). This reflects the uncertainty in station flow measurements.

2.4 The model we've used is to prorate the total tributary flows based on the catchment area for each reservoir in the Waikato hydro system. Clearly this is a very simple model, ignoring temporal aspects of river flow and differences in rainfall. This approach assumes rainfall is equally likely and evenly spread across wider catchment when considered over the longer term.

2.5 Most modelling is long-term in nature, the flow data has a daily resolution, and modelling generally operates in weekly time steps to serve peak, off peak, and shoulder load blocks. For these reasons we believe that prorating across catchments is appropriate. The spreading of tributary flows across the catchment may reduce the spilled volumes within the modelled system as it reduces the severity of localised events. However, this shortcoming is not a new and arises from the modelled time scales anyway.

2.6 The Arapuni series is the longer of the two Waikato series and prior to 1947 is the source used to derive the Karapiro series (by scaling by 20%). After 1947, both series are derived from station outflows and give rise to the unusually variable results through time as illustrated in Figure 1.

2.7 With reference to Table 1, dividing the Karapiro series by 1.23 gives a second series for Arapuni that fits our flow model. The mean of these two Arapuni series is then scaled using the factors in Table 1 to derive the tributary flow for each reservoir in the Waikato scheme.

Table 1: Waikato catchment areas and derived tributary factors

Catchment	Total catchment area (square km)	Total tributary catchment area (square km)	Tributary factor
Lake Taupo (Taupomoana)	3,438		
Lake Aratiatia	3,562	124	0.03
Lake Ohakuri	5,050	1,612	0.45
Lake Atiamuri	5,357	1,919	0.54
Lake Whakamaru	5,861	2,423	0.68
Lake Maraetai	6,522	3,084	0.86
Lake Waipapa	6,777	3,339	0.93
Lake Arapuni	7,022	3,584	1.00
Lake Karapiro	7,853	4,415	1.23

Source: Opus and the Electricity Authority

3 Waitaki tributary flow series

3.1 Three tributary flow series are also included in the HMD for the Waitaki scheme. These are the total tributary flows to Benmore (via two different approaches) and total tributary flows to the Waitaki station.

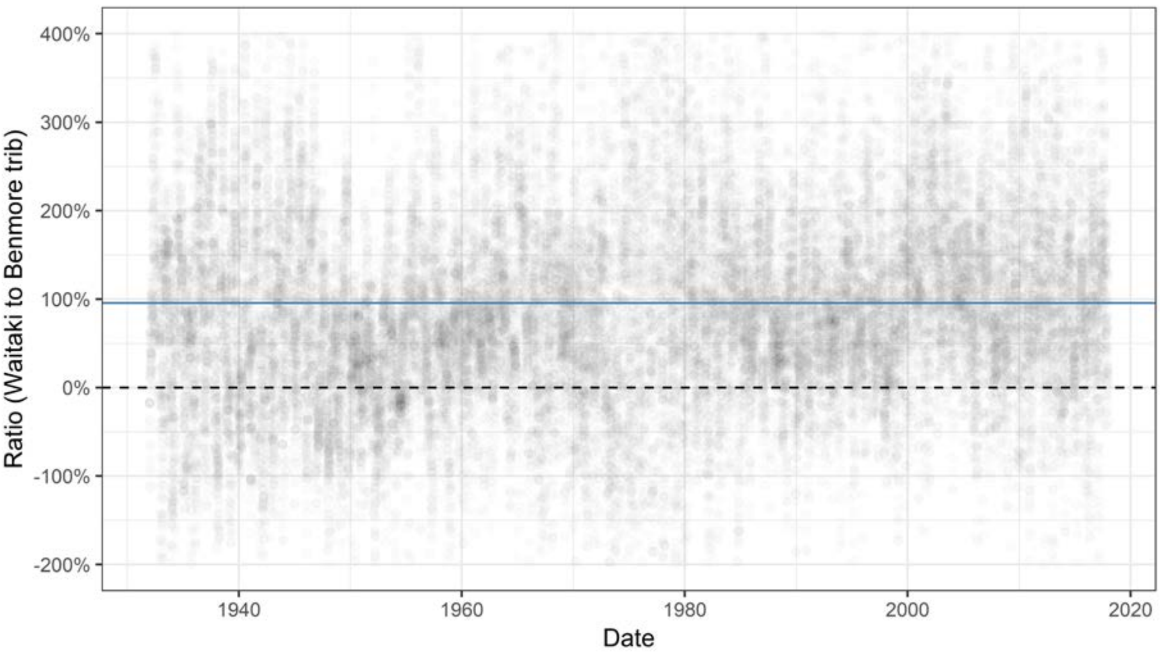
1 See table 4.1 in Report 2, 2018.

3.2 The description of the files in the HMD need to be carefully read as the correct treatment depends on how the model of the hydrological system is set up. The Authority has included Lake Ohau as a reservoir in our river system models. However, the Lake Benmore tributary flow (98615.2) series includes Ohau flow and therefore it must be subtracted.

3.3 For Lake Benmore tributary flows we have used Benmore tributary flows (98615.2) which excludes Tekapo spill and then we subtract Ohau natural flows (98614.3). Tekapo spill and the required spill from Lake Ohau to Lake Ruataniwha are accounted for within our river model. For more information on hydro constraints see the infrastructure and hydro constraints file in part one of the HMD.

3.4 Figure 2 illustrates total Waitaki tributary flows at Waitaki relative to Benmore. We've fitted a horizontal line to illustrate the average scaling between the two series. However, the scaling shows tributary flows below Benmore being almost 100 percent of the tributary flows above Benmore and this situation seems unusual.

Figure 2: Waitaki tributary flow at Waitaki relative to Benmore



Source: Electricity Authority

Notes: 1. Seven day moving average of Waitaki tributary flow at Waitaki (98714.2) divided by seven day moving average of Waitaki tributary flow at Benmore (98615.2). Ohau inflows (98614.3) have been removed from each series.

3.5 Given the Benmore tributary catchment typically receives rainfall from a more westerly weather pattern and the lower Waitaki from the an easterly one, using an area based model to derive local reservoir inflows like the Waikato system seems unlikely to be accurate.

3.6 The mean station outflows for the Waitaki system are provided in Table 4.2 in Report 2 flow series description and methodology. From the spill dataset we can derive a mean spill flow from Tekapo into the Tekapo River of 4.8 cumecs average since 1980. Thus, removing Tekapo mean spill, Pukaki and Ohau mean outflow from the Benmore mean outflow series in the HMD leaves us with a mean flow of 65.1 cumecs from tributary flow into Benmore. Subtracting the Benmore mean total flow from the Waitaki mean total flow gives a residual outflow of 18.2 cumecs due to tributary flows between Benmore and Waitaki (or 28 percent of tributary flows into Benmore).

3.7 Using the same method, we can split this tributary flow across Aviemore and Waitaki reservoirs. The flow between Waitaki and Aviemore is 8.3 percent (5.4 cumecs mean flow) and Waitaki is 19.7 percent (12.8 cumecs mean flow) of the tributary flow into Lake Benmore.

3.8 This method assumes that tributary flows are correlated between the upper and lower Waitaki which may not be the case. Generally, the tributary flows are small when compared to the catchments Ohau, Pukaki and Tekapo. The Waitaki tributary series in the HMD is not used in our modelling at this time.

4 Clutha tributary flow series

4.1 Within the Clutha catchments Lake Hawea is controlled, while Lakes Wanaka and Wakatipu are uncontrolled. The Roxburgh tributary flow series (99110.1) includes all uncontrolled inflow. In addition the HMD also includes a series for the uncontrolled outflow from Lake Wanaka (9154.1). Given we include Lake Wanaka separately in our modelled system we subtract it from the Roxburgh tributary series to avoid double counting this inflow.

4.2 We use an historic ratio derived from mean station outflows to apportion the remaining tributary flow into the Clutha system. Of the Clutha tributary flow at Roxburgh, 96.7 per cent is enters above the Clyde dam, with 3.3 per cent due to tributary flow between Clyde and Roxburgh.

4.3 We intend to review this ratio during the next update.

5 Updates

5.1 Unless we have a better alternative, we’ll continue to update these derived series using the methods outline above with each HMD release.

5.2 Please let us know if you have ideas about how the flow series in the HMD might be improved.