11 July 2023

Pete Ravenscroft
Otago Regional Council

**Analysis of Manuherekia River flow data timeseries**

Dear Pete,

Otago Regional Council (ORC) requested a comparison of the output flow time series data from the GoldSim[1] and TopNet models for estimated natural conditions in the Manuherekia catchment. In particular, a dry year and a wet year were to be included, flows were assessed at Campground, Ophir and Dunstan at Gorge (referred to hereafter as Gorge), and reference is made to flow statistics mentioned in the Manuherekia Joint Hydrology Statement[2].

**Data**

Time series data from the GoldSim model for the "Full Dams no irrigation" scenario [3] (hereafter called the GoldSim model) at the three sites were provided by Ian Lloyd of Davis Ogilvie, and TopNet time series by Dr Christian Zammit of NIWA. Additionally, simulated natural flows at Campground and Ophir from the 2019 NIWA report[4], and recorded flows at the two Dunstan Gorge sites (provided by ORC), were used.

All data were transformed to midnight-midnight daily mean flows. Mean annual low flow statistics were derived from 7-day moving means of the daily time series. Water years are defined as 1 July to 30 June, labelled with the closing year (i.e., the 2018 water year runs from 1 July 2017 to 30 June 2018).

**Low Flow Statistics under Natural Conditions**

Both the TopNet and GoldSim models have been calibrated/optimised for low flow behaviour. Thus, the first comparison is between estimates of the 7-day mean annual low flow (MALF), a useful reference flow for dry periods. Table 1 below shows estimates for the calibration/validation period (2014–2018) and the longer record now available (1974 to 2020).

Within Table 1, the row labelled 'Table 4.9…' provides the numbers from the 2019 NIWA report and are the results of TopNet runs at that time. The 'Simulated Natural' entries refer to estimates derived from measured flows plus water meter data, as described in the 2019 NIWA report, and as used to calibrate the TopNet model

[1] Refers to the Manuherekia Hydrology Model V4 dated September 2022.

[2] Otago Regional Council, 2023. Manuherekia Catchment Hydrology – Joint Expert Statement (DRAFT – February 2023).

[3] This scenario is based on all the dams being set as full on 1 June 1973 (the start of the model run) so they spill throughout the model run, the irrigated area set at zero, no minimum flows applied and the Mount Ida Race operational.

[4] Henderson RD, Zammit, CL, Griffiths J. 2019. CHES Implementation for the Manuherekia River, Otago. Report for Manuherekia TAG. NIWA Client Report 2019294CH for ORC dated September 2019.

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The Booker and Woods[5] estimates are those from a published national statistical model, available at NZ River Maps (niwa.co.nz).

**Table 1: 7-day MALF Natural Flow estimates, in cumecs ($m^3/s$).**

| Location | Gorge | Ophir | Campground |
|---|---|---|---|
| | | 7-day MALF 2014–2018 | |
| GoldSim | 0.65 | 3.0 | 3.6 |
| TopNet | 0.31 | 2.7 | 3.4 |
| Table 4-9 NIWA 2019 | | 2.9 | 3.5 |
| Simulated Natural | | 3.1 | 3.9 |
| | | 7-day MALF 1974–2020 | |
| GoldSim | 0.67 | 3.4 | 4.0 |
| TopNet | 0.49 | 4.5 | 5.5 |
| Table 4-9 NIWA 2019 | | 4.1 | 5.1 |
| Recorded 1974-2010 | 0.67 | | |
| | | | |
| Booker & Woods | 0.65 | 3.1 | 3.9 |

The MALF estimate is the average from a series of annual minima. These generally range from just above the lower quartile flow down to the minimum flow, and thus the mean annual low flow is representative of the lower third to a quarter of the flow range.

The long-term GoldSim 7-day MALF estimates are very close to recorded values at Gorge and national model estimates at Ophir and Campground (Booker and Woods 2014). The long-term (1974–2020) TopNet estimates are higher at Ophir and Campground by 40%, and lower at Gorge by 24%. The TopNet calibration for Dunstan Creek was to a naturalised series at Beatties Road, not at the Gorge recorder.

Apart from the TopNet estimate at Gorge, the short-term estimates for Natural 7-day MALF are within 5% of the national model.

**Mean Flow under Natural Conditions**

Mean flows, from the same sources as for low flows, are presented in Table 2 below.

The GoldSim estimate for long-term mean flow at Gorge is close to the long-term measured value as this series comprises the majority of the GoldSim input for that location. The TopNet estimate is more than 40% higher at the same location, possibly again reflecting the calibration at Beatties Road. At Ophir and Campground, the GoldSim estimates of mean flow are lower than the national model by 2.3 and 5.0 cumecs respectively. However, some of this is attributable to the GoldSim model retaining the diversion of water through the Mount Ida Race. The TopNet estimates for these two sites are higher than the national model by 30% and 10% respectively. Much of this variability will be related to uncertainty in the estimation of floods as the available rainfall inputs are poorly defined, and high flows make up a significant portion of the mean. This aspect is discussed in the 2019 report.

The estimates of the short-term mean flows are closer to those of the national model, but subject to the same caveats as for the long-term estimates.

[5] Booker DJ, Woods RA. 2014. Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. *Journal of Hydrology* **508**:227-239.

**Table 2: Mean Natural Flow estimates, in cumecs ($m^3/s$).**

| Locations | Gorge | Ophir | Campground |
|---|---|---|---|
| | | Mean flow 2014-2018 | |
| GoldSim | 2.6 | 15.2 | 18.7 |
| TopNet | 2.3 | 16.9 | 20.7 |
| Table 4-9 NIWA 2019 | | 22.5 | 27.1 |
| Simulated Natural | | 15.9 | 19.5 |
| | | Mean flow 1974-2020 | |
| GoldSim | 2.4 | 13.6 | 17.3 |
| TopNet | 2.9 | 20.3 | 24.8 |
| Table 4-9 NIWA 2019 | | 26.1 | 30.8 |
| Recorded 1974-2010 | 2.2 | | |
| Booker & Woods | 2.0 | 15.9 | 22.3 |

**Dry Year Example**

Figure 1 below shows hydrographs for the three sites for the water year 2014–15. This year had the 5th, 3rd and 3rd lowest low-flow from 47 years at Gorge, Ophir and Campground respectively, averaged over all available model runs.

- At Gorge, there are no recorded data in this year. The differences between the GoldSim and TopNet flows are indicative of the different source inputs for the models (flow data and rain data respectively), the uncertainties in the Gorge flow input time series used in the GoldSim model, and the fact that the TopNet model was calibrated to a site downstream with assumptions about the water meter data.
- At Ophir, the GoldSim and the Simulated Natural flow agree closely, where the TopNet flows are often underestimating flow. However, this difference declines during the lowest flow period, reflecting the TopNet calibration to low flows.
- At Campground, the situation is similar to that at Ophir, with all flow series close at the lowest flow.

For each site, there are flood events that are represented in one or two models but not in all.

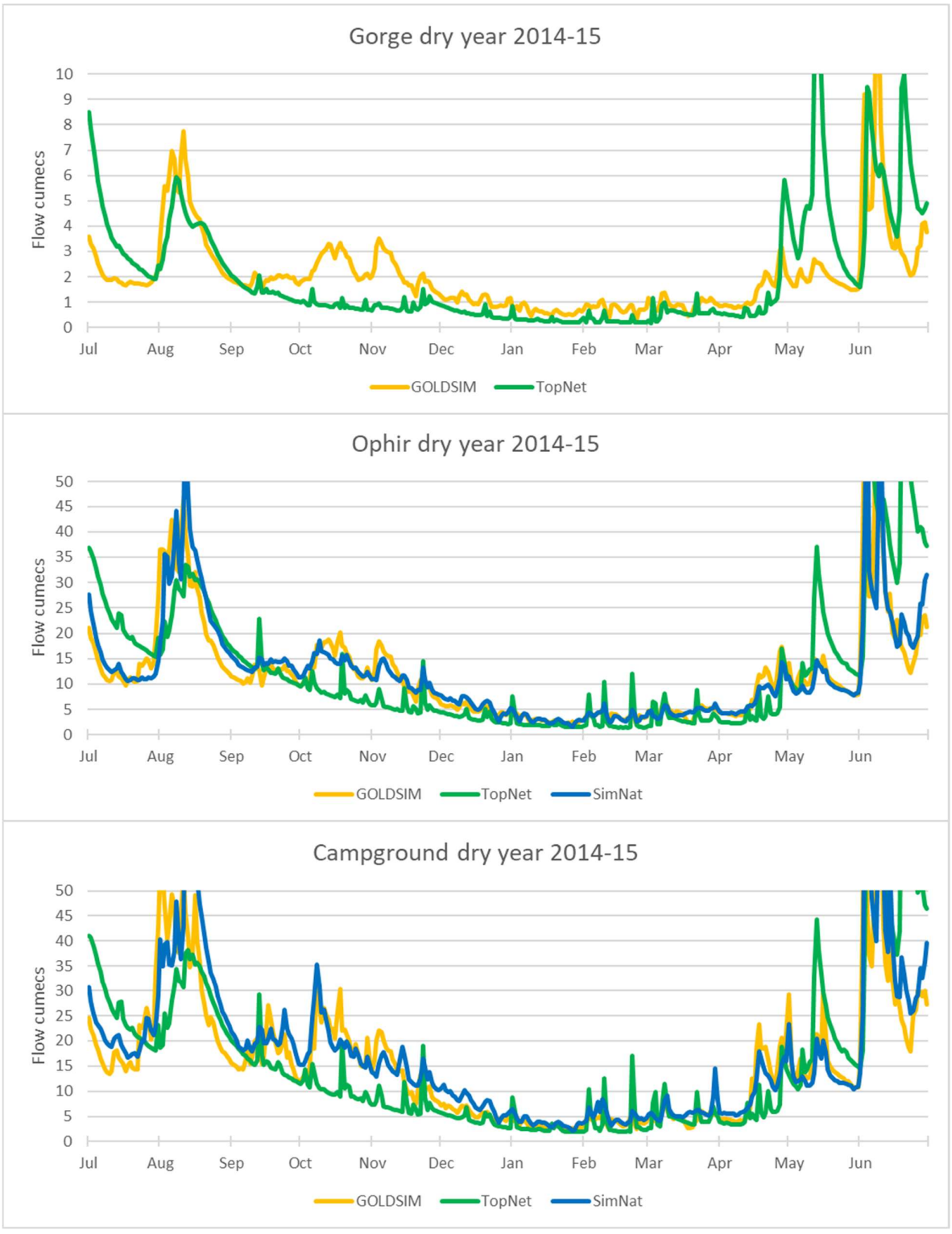



**Figure 1: Dry year modelled flows from GoldSim and TopNet at Gorge, Ophir and Campground sites compared with Simulated Natural (SimNat) where data were available.**

**Wet Year Example**

Figure 2 below shows hydrographs for the three sites for the water year 2016–17. This year had the 11$^{th}$, 11$^{th}$ and 9$^{th}$ highest low flow from 47 years at Gorge, Ophir and Campground respectively averaged over all available model runs.

- At Gorge. there are no recorded data in this year. The differences between the GoldSim and TopNet flows are indicative of the different source inputs for the models (flow data and rain data respectively), the uncertainties in the Gorge flow input time series used in the GoldSim model, and the fact that the TopNet model was calibrated to a site downstream with assumptions about the water meter data. Nevertheless, the lowest flows in this wetter year are similar, although there are several events and recessions that are quite different between the models.
- As for the dry year example above, at Ophir and Campground the lowest flows are well modelled, but the TopNet series are quite different during and immediately after events. With larger events and overall wetter catchments, and calibrations based on low flows, it is no surprise that the TopNet model performs less well than one based on flow data.

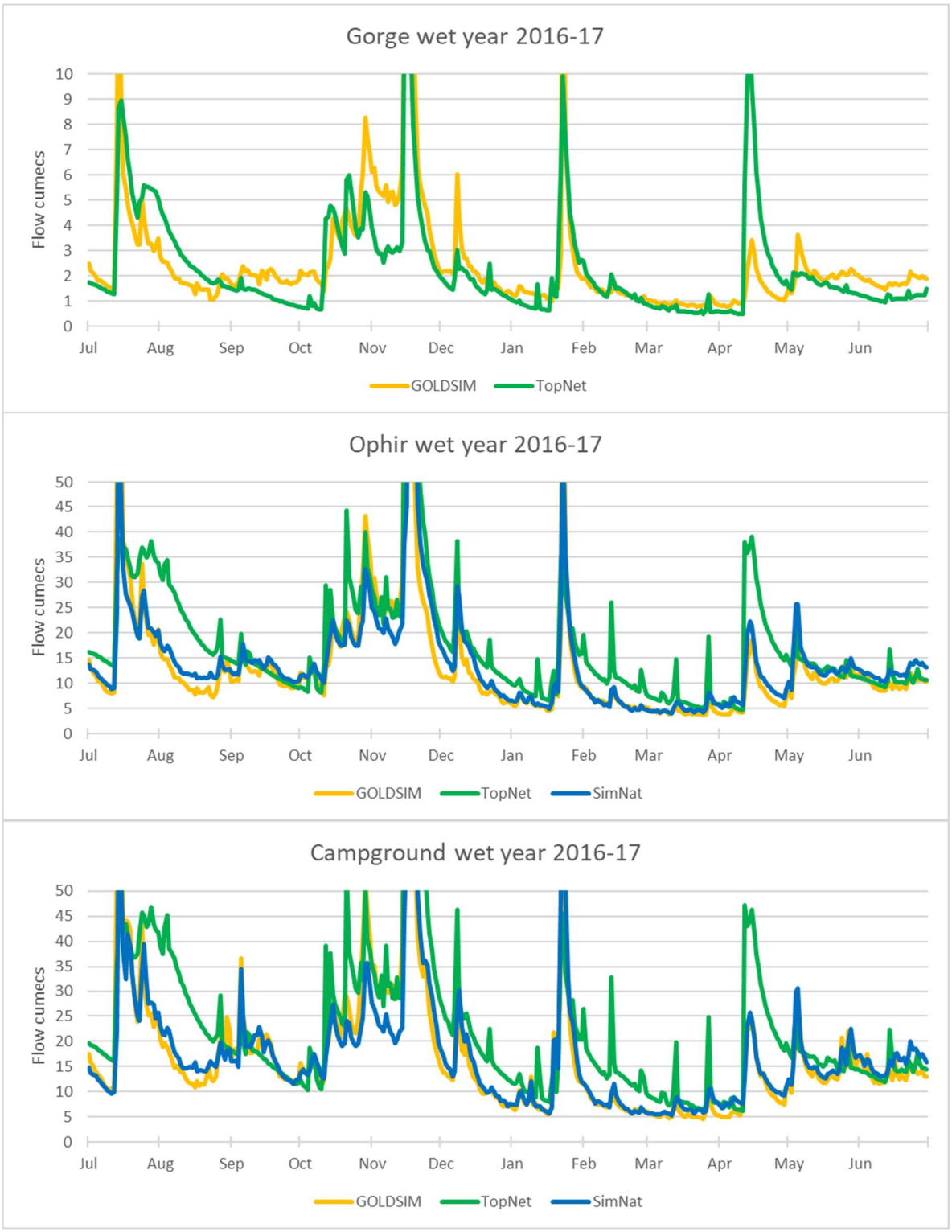



**Figure 2: Wet year modelled flows from GoldSim and TopNet at Gorge, Ophir and Campground sites compared with Simulated Natural (SimNat) where data were available.**

**Conclusions**

The statistics of mean flow and low flow from the described model time series are substantially the same as those reported in the Joint Hydrology Statement. In general, the GoldSim model is closer than the TopNet model to the 7-day MALF estimates of Natural Flow derived from other sources, such as the national model and the Simulated Natural flow series. This reflects the use of flow data as input rather than rainfall.

Low flows are better represented than mean flows. The TopNet model is less reliable for mean to high flows since it was calibrated on low flows, and the rainfall input time series is based on few in-catchment gauges. The GoldSim model "Status Quo" scenario was verified against water levels in Falls Dam and also water take data, and generally simulates the overall system well, including flood flows into the main reservoirs.

It is noted that to assess the potential impact of climate change on future water resource availability, the current GoldSim model would not be appropriate as it is dependent on historical flow data (current climate), and its irrigation demand assumptions would need modification.

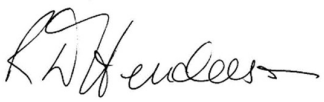
Because of the foundation of the GoldSim model on flow data and existing irrigation infrastructure, caution is warranted about its use as a 'natural' flow simulation tool, because the observed flows are highly affected by the catchment water use. Modelling the 'natural' condition is thus, far from the assumptions on which the GoldSim model was built. The suggestion in the Joint Hydrology Statement was that estimates of natural behaviour using GoldSim may be uncertain by at least ±20%, and the variation in estimates of 7-day MALF and mean flow described above would support this as a minimum uncertainty. While generalised statistics such as 7-day MALF can be produced, any use of model output to focus on extreme low flows or rely on detailed sequences of flow at particular locations, should be discouraged.

The models, but particularly the GoldSim model, are well suited to answering questions of sensitivity of flow controls at points of interest and assessing low flow issues. Because the GoldSim model is built on a framework of recorded data and estimated water use by irrigators it is the best way to assess the impacts of variations in conditions across the catchment.

However, I believe overall the GoldSim model is fit for its original purpose and endorse the reviewers' statement:

> *...the model is fit for the purpose of understanding the flow and its allocation across the catchment and we do not specify any changes be made to the model or flow series i.e., we support the flow time series produced by the model*[6].

Yours sincerely



Roddy Henderson
Hydrologist

[6] Mager, S and Griffiths, J. 2022. Review of the Manuherekia Hydrology Model. A report prepared by Sarah Mager (University of Otago) and James Griffiths (NIWA) for ORC

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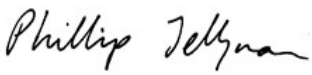
| Revision | Description | Date |
|---|---|---|
| Version 1.0 | Final version sent to client | 27 June 2023 |
| Version 2.0 | Client and Ian Lloyd feedback incorporated | 11 July 2023 |

| Quality Assurance Statement | | |
|---|---|---|
|  | Reviewed by: | Jim Griffiths |
|  | Formatting checked by: | Rachel Wright |
|  | Approved for release by: | Phillip Jellyman |