

Gellibrand Source Model Development

Technical Report

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1. Introduction

Gellibrand environmental flow recommendations were derived for the waterway in 2006 (EarthTech, 2006) and the estuary in 2008 (Lloyd et al., 2008). These flow recommendations are currently under review by Alluvium, and HARC has been commissioned to extend the current Upper Gellibrand Source model to represent all the desired environmental flow reaches in the Gellibrand system down to the estuary. As part of this work detailed representation of Wannon Waters' Otway supply system has been included in the extended Gellibrand model.

As shown in Figure 1-1, key tributaries that will be included in the environmental flows analysis are Love Creek, Lardners Creek, Carlisle River and Kennedy Creek. Wannon Water and Barwon Water's extractions from the catchment (extraction points for the upper and lower Gellibrand catchment shown in Figure 1-2 and Figure 1-3 respectively) for urban water supply have been considered as part of the Gellibrand Source model development, as well as rural water use including take and use licences groundwater pumping impacts and farm dam impacts.

The environmental flow reaches considered in the development of the full Gellibrand Source model were:

- Reach 1: Love Creek
- Reach 2a: Upper Gellibrand River above Love Creek
- Reach 2b: Upper Gellibrand between Love Creek and Carlise River
- Reach 2c: Lardners Creek
- Reach 3: Carlisle River
- Reach 4: Mid Gellibrand River (between Carlisle River and the Great Ocean Road)
- Reach 5: Kennedys Creek
- Reach 6: Gellibrand River Estuary (below the Great Ocean Road)

In 2024, HARC developed an Upper Gellibrand Source model for Barwon Water terminating at Bunkers Hill. This model was used to assess the resilience of the upper reaches of the Gellibrand River under projected future climate scenarios, and compare these to what is likely to have occurred if Barwon Water never activated the Barwon Downs borefield. Any reference to Upper Gellibrand in this report refers to the existing Source model upstream of Bunkers Hill, lower Gellibrand refers to the Source model extension developed downstream of Bunkers Hill to the estuary as part of this project.

In order to provide documentation for the full model in once place this and later versions of the Technical Report will include documentation of input and model development undertaken in previous projects. This report includes details of the development of the Gellibrand Source model with reference to:

- BW and HARC (2023): Development of inflows to Olangolah Weir and West Gellibrand Reservoir and representation of Barwon Water extractions from the Gellibrand system to Colac
- HARC (2025b): Development of the Gellibrand Source model down to Gellibrand River at Bunkers Hill (235227)
- Extension of the Gellibrand Source model from Gellibrand River at Bunkers Hill down to the estuary undertaken as part of this project

- Development of the Otway Source model for Wannon Water undertaken as part of a parallel project to configure into the Gellibrand Source model

This version of the Technical Report includes:

- Preparation of climate data (Section 2)
- Derivation of demands and catchment impacts including groundwater pumping impacts, rural demands, farm dam impacts and urban demands (Section 3)
- Inflow derivation (Section 4)
- Development of the Gellibrand River Source model (Section 5)
- Representation of Wannon Water's Otway system (Section 6)
- Verification of the Otway system and Gellibrand River system against historic data (Section 7)

Later versions of the Technical Report will also include:

- Scenario modelling including development of alterative inputs (to be completed once inputs and model are reviewed and approved)

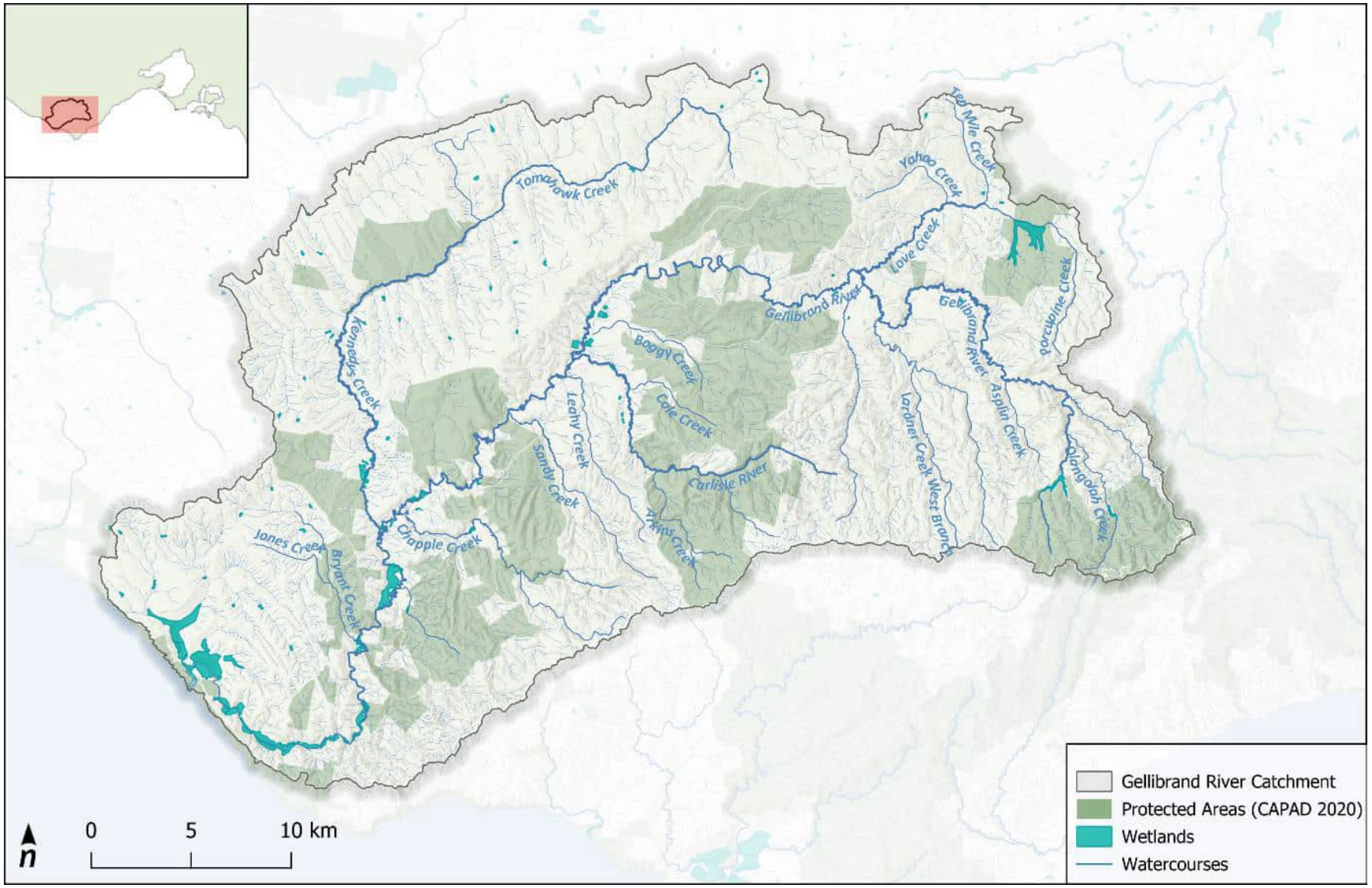


Figure 1-1 Gellibrand River catchment (Source: Alluvium)

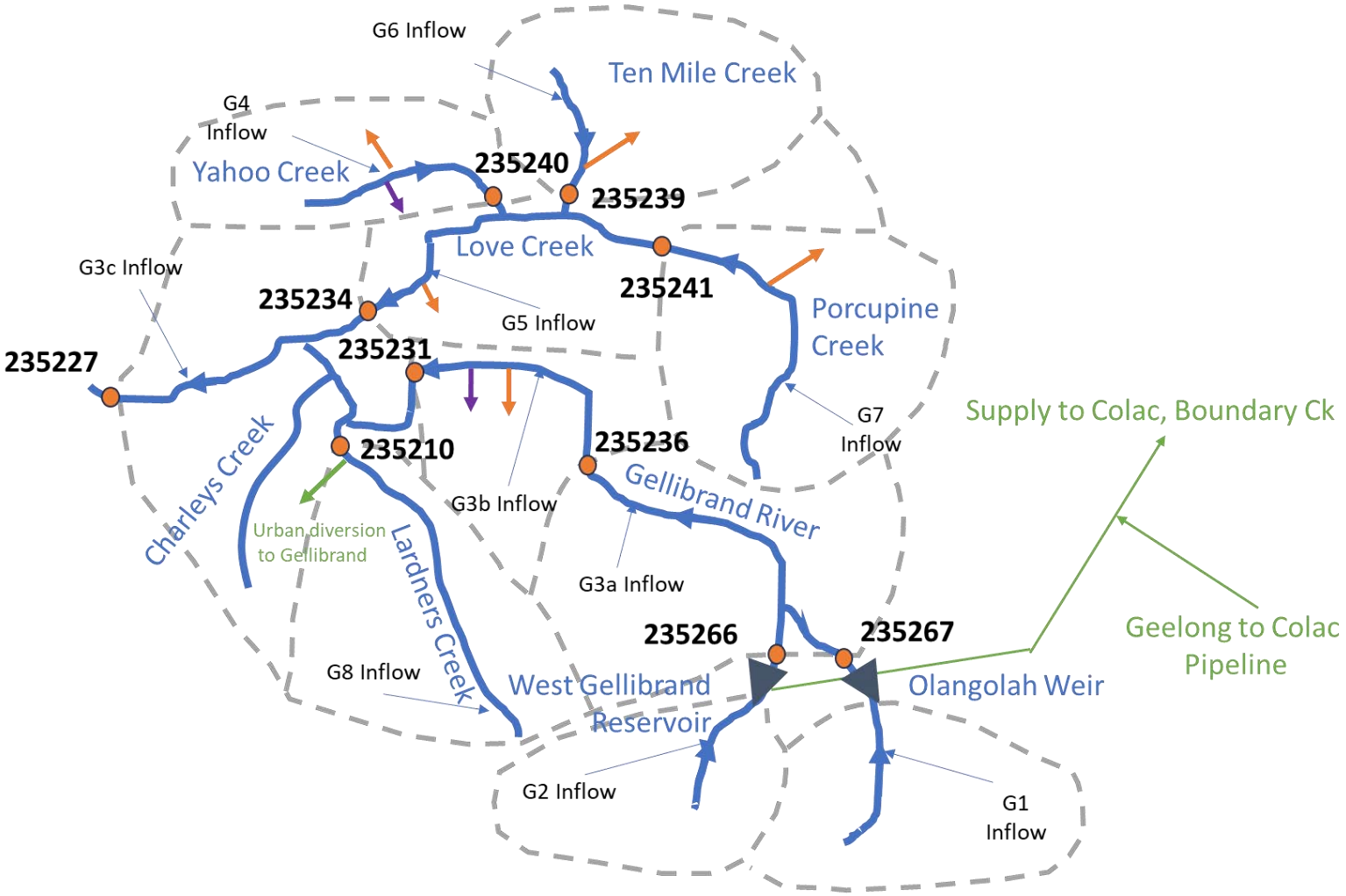


Figure 1-2 Schematic of upper Gellibrand River Source model catchments (BW and HARC, 2024)

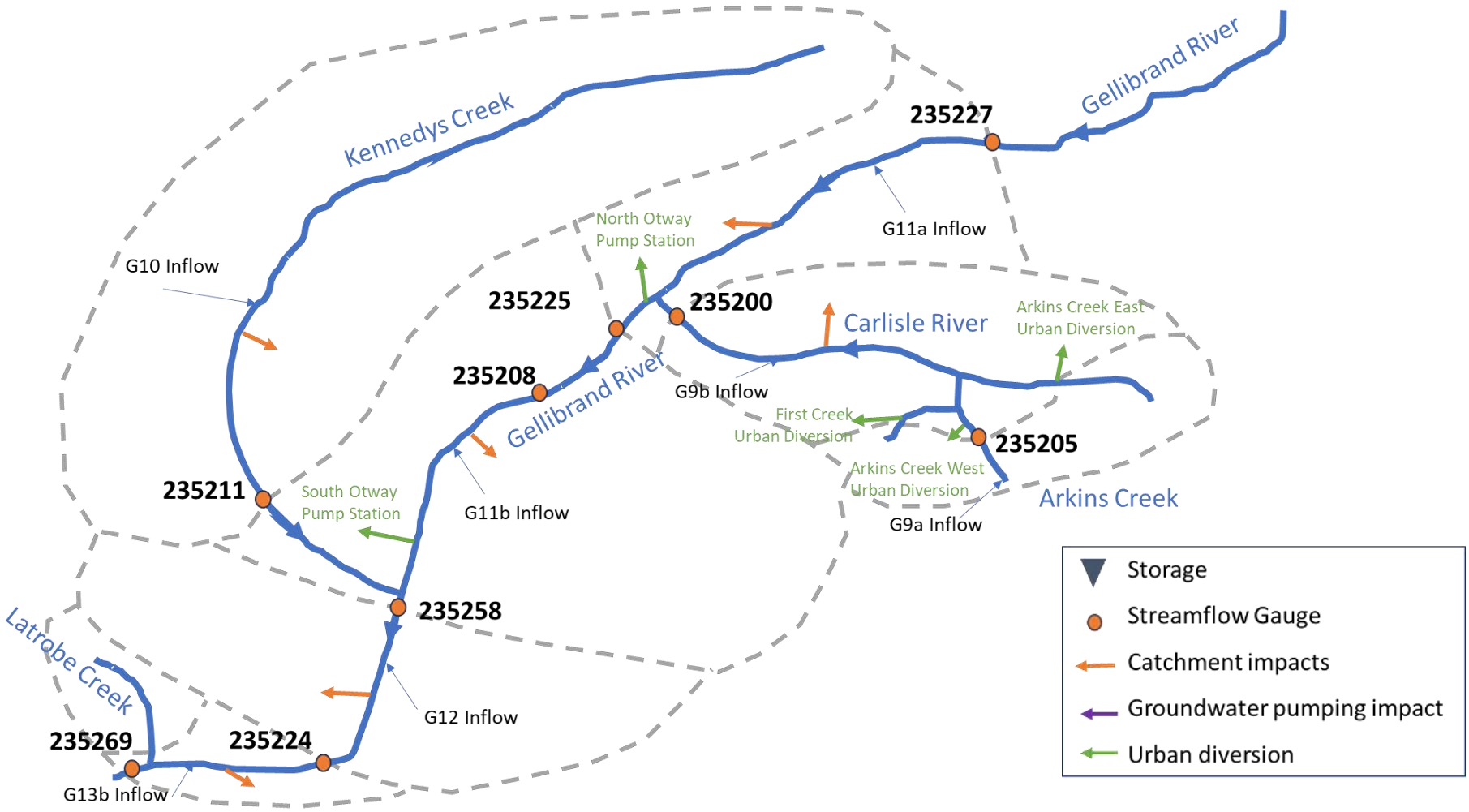


Figure 1-3 Schematic of lower Gellibrand River Source model catchments

2. Climate data preparation

Climate inputs are required for a range of modelling purposes including representing Direct climate impact on storage, for input to rainfall runoff modelling, crop water requirement modelling and modelling of farm dam impacts on inflows.

SILO station point data (formerly referred to as patched point data) at rainfall gauge locations has been adopted, with the climate types used for the various modelling components summarised in Table 2-1. Note that the climate data for irrigation modelling will only be used to derive full level of development irrigation demands as irrigation demands are set to zero for current (Section 3.2).

Thiessen weighted rainfall data has been adopted for this project, which takes into account rainfall behaviour from nearby gauges within and surrounding the catchment of interest. Thiessen weighted data is used in preference to gridded rainfall data as it is not subject to smoothing.

For rainfall runoff modelling, two to three datasets of station point rainfall are input into the rainfall runoff models and are optimised during rainfall runoff modelling until a good fit is achieved with the timing of peaks in observed streamflow. Thiessen weightings are relevant for modelling runoff production or catchment impacts (such as farm dam impacts) that are distributed across a subcatchment.

Table 2-1 Summary of climate types adopted

Process	Rainfall	Evaporation
Rainfall runoff modelling	Thiessen weighted SILO station point rainfall	SILO station point Morton's wet areal evaporation
Irrigation modelling	SILO station point rainfall	SILO station point FAO56 reference crop evapotranspiration
Farm dam modelling	Thiessen weighted SILO station point rainfall	SILO station point Morton's shallow lake evaporation
Direct climate impact on storage	SILO station point rainfall	SILO station point Morton's shallow lake evaporation

The climate gauges adopted to develop inputs to the Gellibrand Source model are summarised in Table 2-2 and shown on the map in Figure 2-1. A number of these gauges were utilised in the previous projects (BW and HARC, 2023, BW and HARC, 2024) in the Upper Gellibrand and therefore have had non-climatic trend removed and are ready for use. These are marked in Table 2-2.

Table 2-2 Summary of rainfall data adopted to develop the Gellibrand Source model

Gauge Number	Gauge Name	De-trended by?	Available Period
089018	Lismore Post Office	Current project (Otway demands)	1919 – current
090000	Allansford	Current project (Otway demands)	1898 - 1966
090003	Barramunga	BW and HARC (2023)	1891 - 1980
090006	Beech Forest	BW and HARC (2023)	1887 - current
090021	Cobden Post office	Current project (Otway demands)	1894 - current
090040	Forrest State Forest	BW and HARC (2023)	1898 - current
090041	Gellibrand River East (Lovat)	BW and HARC (2024)	1898 - 1960
090042	Gellibrand River West	Current project	1915 - current
090058	Torrumbarry	Current project (Otway demands)	1877 - 1955
090071	Princetown	Current project	1901 – current
090077	Terang	Current project (Otway demands)	1896 - current
090083	Weeaproinah	Current project	1901 – 2012
090087	Wyelangta	Current project	1936 – 2019
090134	Gellibrand River Forestry	BW and HARC (2024)	1956 - 2015
090138	Irrewillipe (Tomahawk Creek)	Current project	1965 – current
090139	Chapple Vale	Current project	1914 – 1974
090153	Camperdown Donalds Hill	Current project (Otway demands)	1957 - current
090165	Simpson South	Current project	1968 – current
090174	Colac (Ellimminyt)	BW and HARC (2024)	1983 - 1998
090186	Warrnambool Airport	Current project (Otway demands)	1998 - current

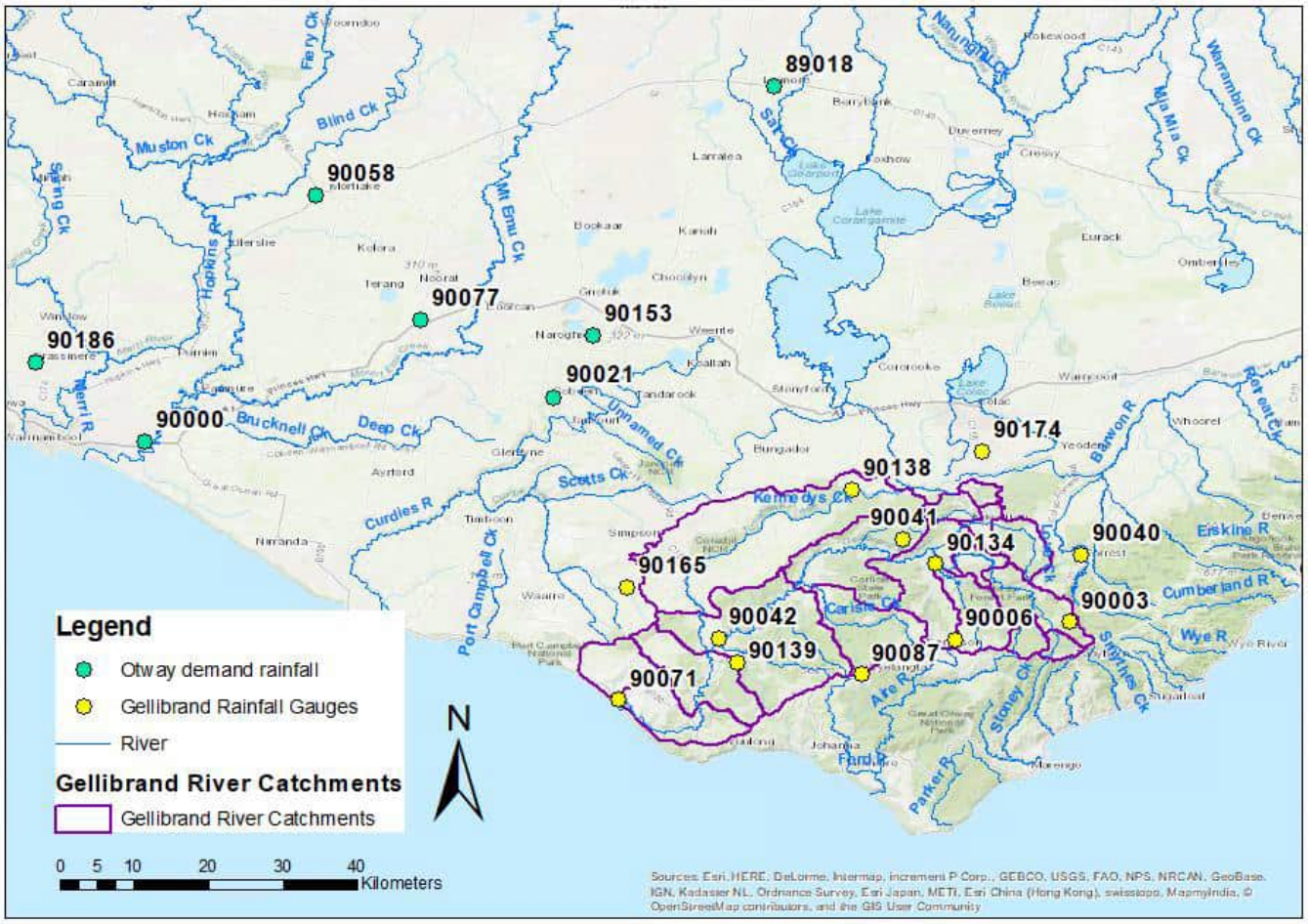


Figure 2-1 Climate gauges in the Gellibrand catchment and used to derive Otway demands

2.1 Removal of non-climatic trend

Non-climatic trends can occur in climate data due to poor infilling and extension, in particular where this process is automated on a large scale such as SILO or AWAP and station coverage is relatively sparse. Non-climatic trends can also occur when there are different collection methods of climate data such as a change in instrumentation, a change in location of the gauge, or interference to the gauge such as changes in vegetation (Lavery, Kariko and Nicholls, 1992).

Detrending is undertaken to remove any non-climatic trends from the rainfall, temperature and calculated evaporation datasets.

2.1.1 Removal of non-climatic trend in rainfall

Rainfall detrending is applied to each site using the district average annual rainfall depths. Rainfall detrending is undertaken by correcting the double mass curve at the primary site so that the cumulative precipitation total at the rainfall site and the cumulative rainfall total from the district average was close to a straight line, with a slope consistent with rainfall over the more recent period.

The rainfall gauges that require checking for non-climatic trend for this project are:

- Gellibrand River West (090042)
- Princetown (090071)
- Weeaproinah (090083)
- Wyelangta (090087)
- Irrewillipe (090138)
- Chapple Vale (090139)
- Simpson South (090165)

Removal of non-climatic trend has been undertaken using the DEECA Climate Detrending Automation Tool developed in 2022. As outlined in the User Guide (DEECA, 2022) the climate detrending tools can be used to automatically analyse the non-climatic trends in rainfall, temperature and evaporation timeseries, when referenced against a timeseries of known high quality.

The rainfall de-trending was undertaken using District Rainfall data as the high-quality data set, and a flag was included in the script to note any anomalous scaling factors. These were then checked manually prior to adoption. The scaling factors derived during rainfall de-trending and applied to raw rainfall can be found in Appendix E.1.

It was found that the de-trended rainfall data was fit for purpose for use in developing the Gellibrand Source model.

2.1.2 Removal of non-climatic trend in evaporation and evapotranspiration

Non-climatic trend exists in temperature data due to changes in instrumentation, data collection or site conditions. As SILO Mortons evaporation and FAO56 evapotranspiration is derived as a function of temperature and solar radiation these datasets can also exhibit non-climatic trend.

The non-climatic trend in SILO station point evaporation, evapotranspiration and temperature data was checked by analysing a double mass curve against the Melbourne high quality temperature dataset, and the cumulative departure from the slope between the 1956 and 1975 period. As outlined in Austin and Szabo (2019), non-climatic trends have occurred in evaporation data prior to 1957 and post 2011. The period prior to 1956 is due to a shift from less sheltered temperature recording equipment to Stevenson thermometer screens after Federation (Ashcroft et.al, 2012).

As shown in Figure 2-2, the evaporation datasets are lower than expected from 2011 onwards. Recent investigations undertaken by HARC for a project in northern Victoria (HARC, DELWP & DPE, 2022) found that a drop in the solar radiation used in calculation of evaporation was causing the drop in Morton evaporation estimation. A data update provided by SILO in November 2023 noted that:

- there has been a decline in the number of observing stations means that the previous cloud oktas/sunshine hours methodology is no longer viable and solar radiation estimates are becoming increasingly biased relative to high quality radiometers.
- Solar radiation data after 1990 is now BoM sourced satellite radiation data. Missing data has been infilled with the previous interpolated radiation data which is calculated from cloud oktas and sunshine hours. Negative satellite radiation estimates and values less than 1MJ/day set to 1MJ.
- New data code introduced to outputs (42) signifying the use of BoM satellite radiation estimate.

Whilst there has been an improvement in SILO evaporation post 2011 since the original investigation in 2019, there is still a large step change in evaporation that is inconsistent with the rest of the record. For this project de-trending was undertaken post 2011 which is considered a conservative approach.

For the purposes of rainfall runoff modelling, de-trending using the DEECA Climate De-Trending Tool (DEECA, 2022) has been applied to the Morton's products shown in Table 2-2. The scaling factors derived during rainfall de-trending and applied to raw rainfall can be found in Appendix E.2 (Morton's Wet Areal Evaporation only).

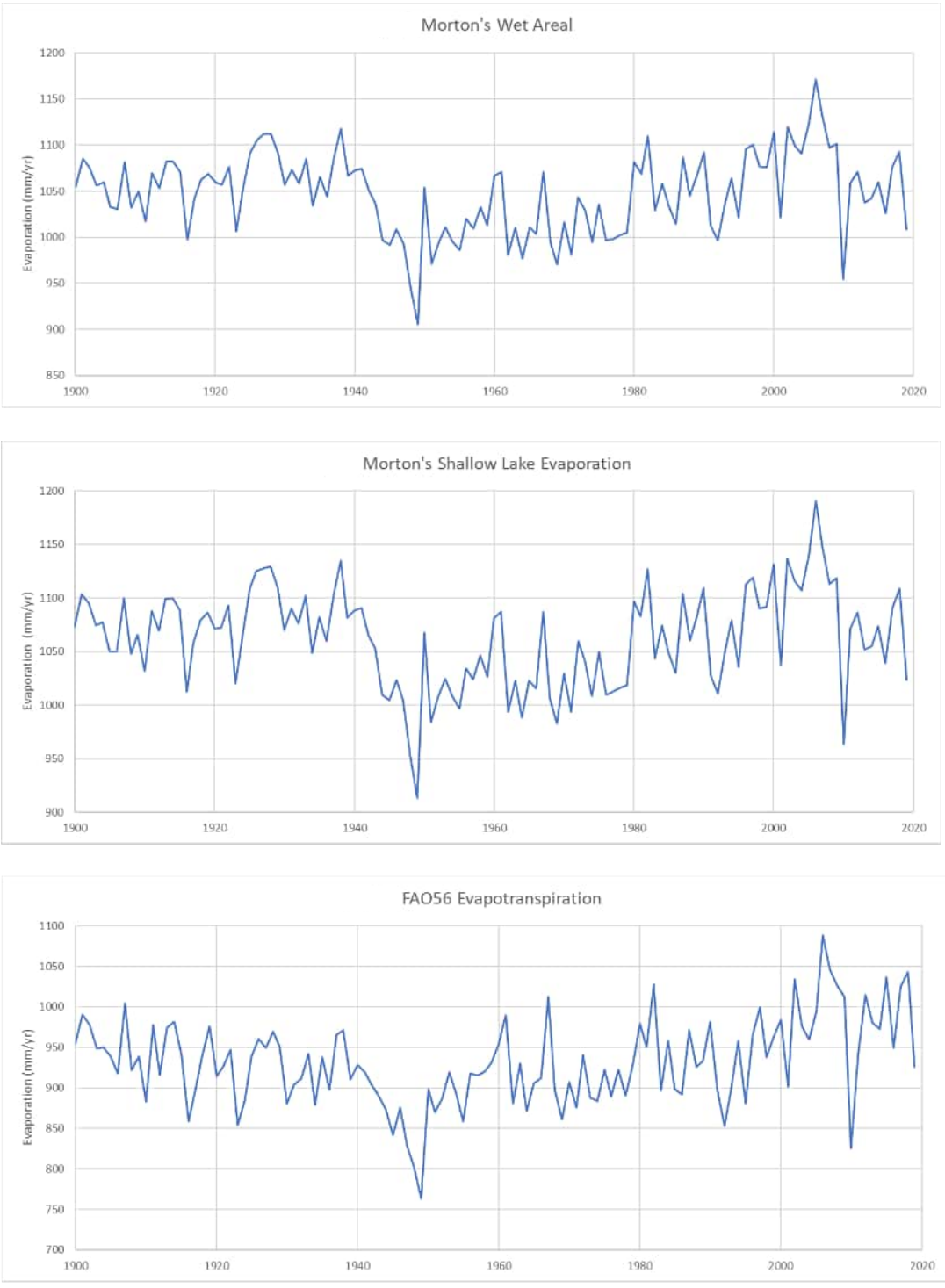


Figure 2-2 Example annual evaporation plots for each evaporation type

3. Derivation of demands and catchment impacts on flow

3.1 Impact of groundwater pumping

Groundwater pumping can impact baseflows. This volume of pumping can be either be fully or partially provided by baseflow, and the pattern of pumping can be subject to smoothing and time lag. The Gellibrand River catchment is subject to three types of groundwater pumping impact, the impact of pumping to supply rural demand, the impact of Barwon Water's historic groundwater pumping activities at Barwon Downs and the impact of Wannon Water's groundwater extraction adjacent to the Carlisle River.

Historic impacts of groundwater pumping need to be taken into account when deriving inflows, while impacts of ongoing groundwater pumping activities are required for input as demands in the Source model.

3.1.1 Impact of rural groundwater pumping

The Victorian Water Accounts note that there is stock and domestic groundwater usage from the Newlingrook Groundwater Management Area (GMA), covering the lower reaches of the Gellibrand River. It was noted that there was 23 ML of usage in the 2022/23 water year and 28 ML of usage in the 2021/22 water year. For a more conservative estimate, current usage is assumed to be 28 ML/yr uniformly disaggregated to daily to represent the stock and domestic groundwater usage. This rural groundwater demand has been allocated to G12, Gellibrand River upstream of Burrupa (235224). To be conservative it is assumed all groundwater pumped is sourced from baseflow.

3.1.2 Impact of Barwon Downs groundwater pumping on upper Gellibrand catchment flows

A significant amount of work has already been undertaken by Barwon Water to assess the impacts caused by Barwon Water's historical groundwater pumping activities at the Barwon Downs borefield. In 2024, HARC on behalf of Barwon Water used these findings to develop the Upper Gellibrand Source model to:

- assess the resilience of these surface water systems under projected future climate scenarios,
- better understand the changes that are likely to occur in response to these climate related influences, and
- compare these changes to what is likely to have occurred if groundwater pumping never occurred.

To do this, groundwater pumping impacts were represented in the most upstream reach, where the Lower Tertiary Aquifer – which was accessed by Barwon Water, outcrops and provides

inflows. These impacts were then routed downstream to account for the potential flow on effects of these impacts.

3.1.2.1 Historic trend in Barwon Downs groundwater pumping impact

The groundwater pumping impact is set to zero prior to pumping related impacts being realised within surface water features in 1997, and the magnitude of daily groundwater pumping impact can be found in Table 3-1 for the two subcatchments.

The assumed trend in historic groundwater pumping impact for Gellibrand River and Yahoo Creek can be found in Figure 3-1. These have been calculated by Barwon Water based on the observed changes in the flow data during and post pumping periods and the current state of knowledge regarding groundwater dynamics within the region.

Current level of development pumping impacts are uniformly applied in the hydrologic models and are noted in Table 3-1.

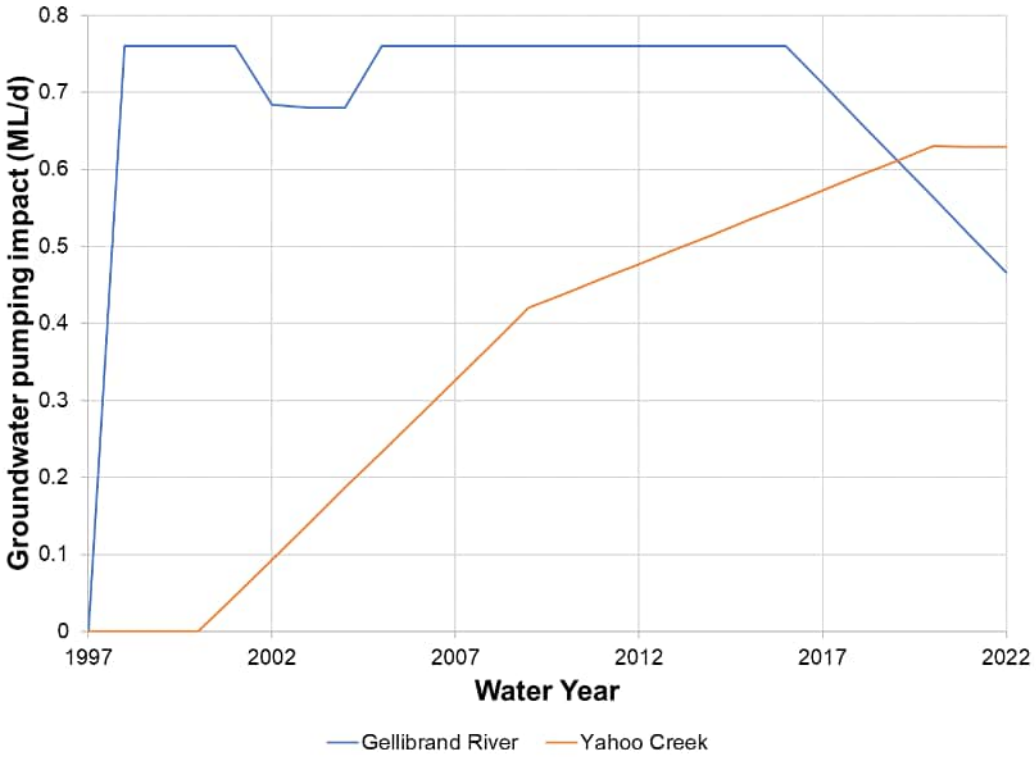


Figure 3-1 Historic groundwater pumping impact for Gellibrand River and Yahoo Creek

Table 3-1 Current and historic daily Barwon Downs groundwater pumping impact assumptions in the Upper Gellibrand

Water Year	G3 Gellibrand River between Colac storages and Bunkers Hill (235227)	G4 Yahoo Creek
Current LOD assumption	**0.47**	**0.63**
1900	0	0
1997	0	0
1998	0.76	0.00
1999	0.76	0.00
2000	0.76	0.00
2001	0.76	0.05
2002	0.68	0.09
2003	0.68	0.14
2004	0.68	0.19
2005	0.76	0.23
2006	0.76	0.28
2007	0.76	0.33
2008	0.76	0.37
2009	0.76	0.42
2010	0.76	0.44
2011	0.76	0.46
2012	0.76	0.48
2013	0.76	0.50
2014	0.76	0.52
2015	0.76	0.53
2016	0.76	0.55
2017	0.71	0.57
2018	0.66	0.59
2019	0.61	0.61
2020	0.56	0.63
2021	0.52	0.63
2022	0.47	0.63

3.1.3 Impact of Carlisle River bores

As outlined in Wannon Water (2016), two Wannon Water bores at Carlisle River were drilled in the early 2000s. Groundwater pumping data is available for these groundwater bores (north and south) from 2001 to 2025, as shown in Figure 3-2 and Figure 3-3. It has been assumed that there is no groundwater pumping impacts prior to 2001. The groundwater licence allow extraction at a maximum of 6 ML/d up to 1,800 ML/yr. The groundwater licence also states groundwater pumping must cease if the water table in Observation bore 8 (shown in Figure 3-4) reaches a trigger level of 23.545 mAHD.

GHD (2014) estimated that 10% of the total volume extracted from the bores is sourced from the Gellibrand River, with the hydrogeological assessment indicating that impacts on surface water would be proportionate to the volume pumped in the given time frame. Therefore, groundwater pumping impacts on Gellibrand River will be calculated as 10% of groundwater pumping from the North and South bore for that given time step. GHD (2014) noted that the lag times were not able to be reviewed due to the monitoring frequency of the groundwater bores. For the purpose of this study, it has been assumed that there is no lag between groundwater pumping and impact to surface water. As check has been made to ensure that baseflow is always greater than the impact of Carlisle River bores to confirm that no smoothing or lag is required between pumping and impact to surface water.

As shown confirmed with Barwon Water, the area impacted by groundwater pumping from the Carlisle River bores is upstream of gauged flow at 235225. Consistent with the approach undertaken for the Upper Gellibrand to represent Barwon Water groundwater pumping impacts (BW and HARC, 2024), the groundwater impacts will be represented at the upstream gauge and routed downstream. The historic groundwater pumping impacts on Gellibrand River (calculated as 10% of groundwater extraction shown in Figure 3-2 and Figure 3-3) that have been adopted when deriving inflows upstream of 235225 are shown in Figure 3-5.

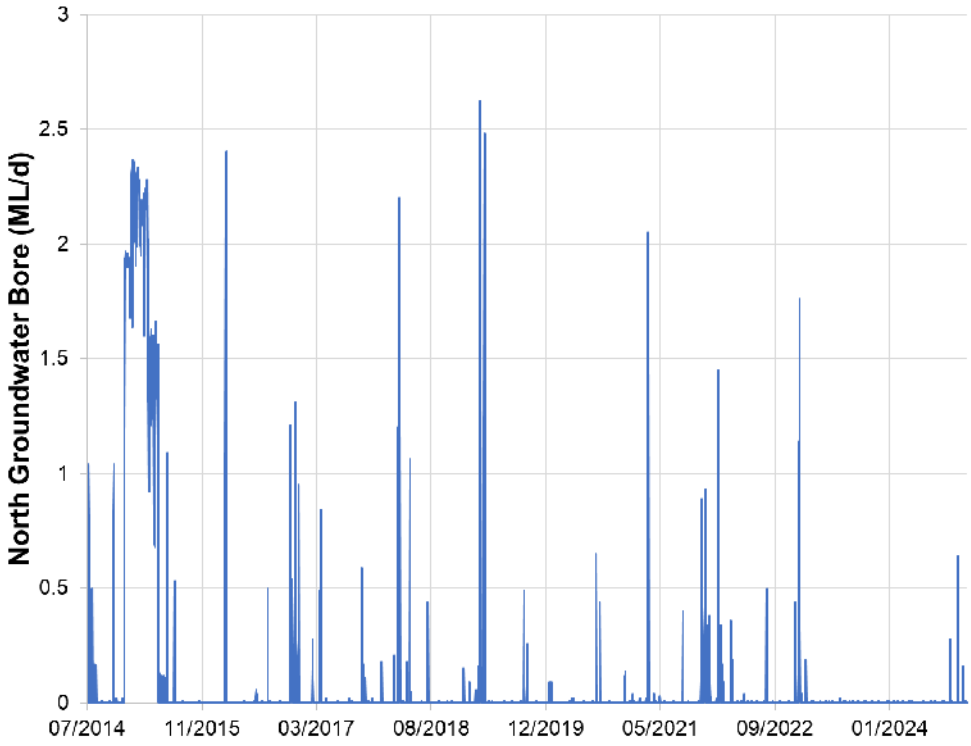


Figure 3-2 Historic north groundwater bore pumping (daily) from 2014 to 2025

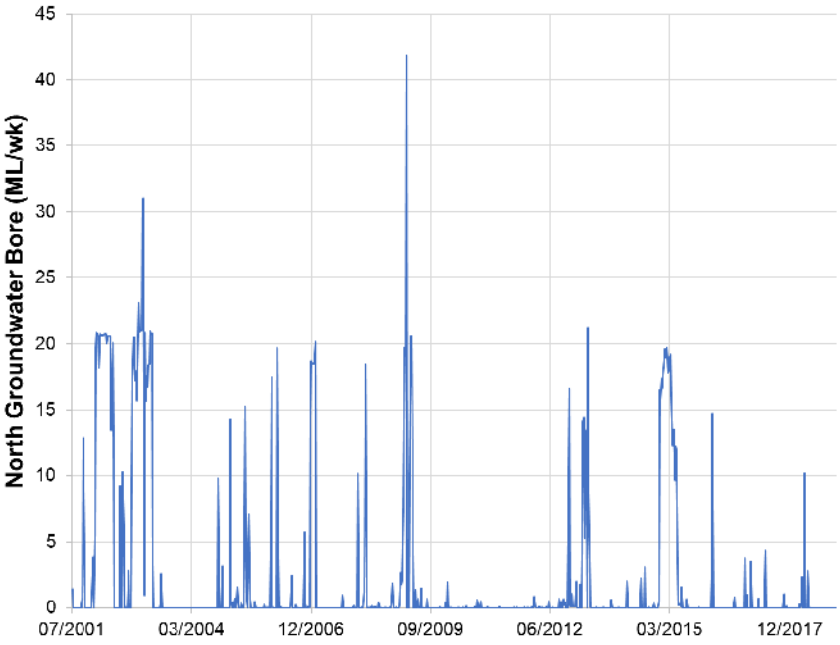


Figure 3-3 Historic north groundwater bore pumping (weekly) from 2001 to 2019



Figure 3-4 Schematic of location of observation bores

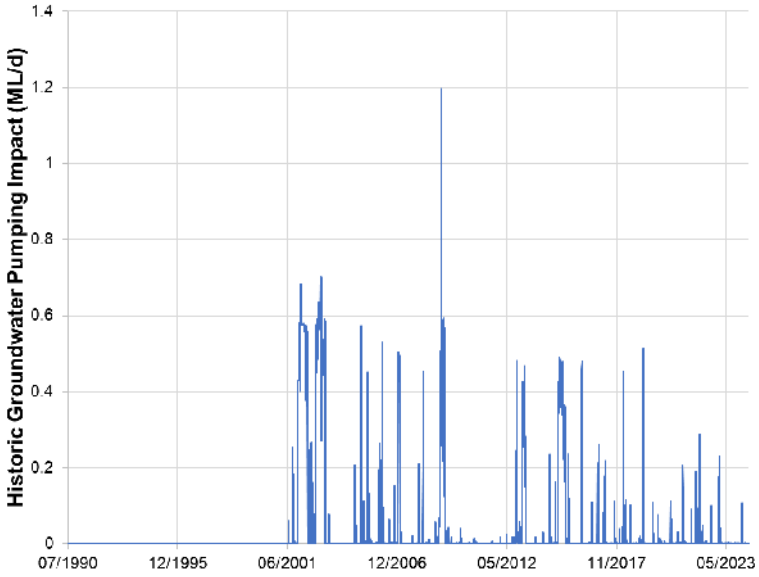


Figure 3-5 Historic groundwater pumping impact assumption

3.2 Rural demands

Rural demands are required at current level of development, historic level of development where they form part of an inflow derivation, and at full uptake and under future climate conditions for scenario modelling.

Current take and use surface water licence volumes have been extracted from the Victorian Water Register and are summarised for each reach in Table 3-2.

As noted in the review of the Gellibrand catchment (HARC, 2025), there is currently negligible direct irrigation usage in the Gellibrand River catchment and therefore, direct irrigation demands are not explicitly represented in the Source models. This is consistent with the assumptions in the upper Gellibrand River.

For this project Southern Rural Water has confirmed that the negligible direct irrigation usage is correct (pers. comm. P. Winbanks, 29/01/2025). SRW also confirmed there is currently zero usage for all on-stream and off-stream winterfill licences in the lower Gellibrand catchment.

To derive the rural demand inputs, it has been assumed that the stock and domestic, dairy, and commercial and industrial licences are all currently active (100% full licence volume uptake) and uniformly used across the year.

Assumptions relating to rural demands under full update and future climate will be discussed in future versions of this report.

Table 3-2 Summary of private diverter licence volumes from the Water Register

Waterway subcatchment		Surface water licence volume (ML/yr)								
		Direct irrigation	Domestic and Stock	Dairy	Industrial and commercial	Off-stream dam all year extraction	Off-stream winterfill (May – Oct)	Off-stream winterfill (Jul – Oct)	On-stream winterfill (Jul – Oct)	Total
G1	Inflow upstream of West Gellibrand Res	0	0	0	0	0	0	0	0	**0**
G2	Inflow upstream of Olangolah Weir	0	0	0	0	0	0	0	0	**0**
G3	Inflow to Gellibrand River downstream of storages and upstream of 235228	153.4	27.2	19.8	3.5	58.0	112	40	0	**416.1**
G4	Yahoo Creek upstream of Kawarren	0	0	0	0	0	0	0	0	**0**
G5	Love Creek upstream of Gellibrand	15	2.2	11.0	0	0	0	0	0	**28.2**
G6	Ten Mile Creek upstream of Kawarren	0	0	0	0	0	0	0	0	**0**
G7	Porcupine Creek upstream of Kawarren	0	0	4.4	0	0	0	0	0	**4.4**
G8	Lardner Creek upstream of Gellibrand	0	2.2	6	0	0	0	0	0	**8.2**
G9	Carlisle River	329.8	2.2	0	0	0	0	159.4	0	**491.4**
G10	Kennedys Creek	24.5	0	13.6	0	18.8	0	80.9	0	**137.8**
G11a	Gellibrand River from Bunkers Hill to ds Carlisle River	529.8	2.2	7.4	0	0	0	0	0	**539.4**
G11b	Gellibrand River from ds Carlisle River to Pump Station	451.4	4.4	30.8	0	0	0	20	0	**506.6**
G12	Gellibrand River from Pump Station to Burrupa	70.2	4.4	8.8	0	0	0	1.3	29.1	**113.8**
G13	Gellibrand River from Burrupa to Princetown	0.0	11	15.5	0	6	0	0	92.8	**125.3**
TOTAL		**1,574.1**	**55.8**	**117.8**	**3.5**	**82.8**	**112**	**301.6**	**121.9**	**2,371.2**

[1]rural demands taken from GHD and DEECA (2022)

3.2.1 Upper Gellibrand River off-stream winterfill demands

3.2.1.1 Current level of development

For the upper Gellibrand River and to undertake climate resilience modelling, the impact of winterfill use (pumping to refill dams) was modelled by BW and HARC (2024) by explicitly representing the three types of winterfill storage and irrigation usage from it based on an irrigation pattern for pasture such that the maximum usage year is equal to the magnitude of licence volume. This along with a maximum pumping rate can then be used to model the pattern of water pumped into the storage from the river to refill it over the next winterfill period. It will be assumed that pumping occurs at the maximum rate from the start of the winterfill period until the storage is filled.

A daily maximum extraction rate and the annual licence volume has been configured into the Upper Gellibrand Source Model and will be discussed during model development.

A pasture crop has been run through PRIDE adopting rainfall and evaporation at 090134 Gellibrand Forestry. A time series of pasture irrigation pattern was extracted from the irrigation model from 1900 to 2022. The irrigation pattern was then scaled until the maximum usage year was the equivalent of the winterfill licence volume. The final irrigation pattern for off-stream winterfill in the upper Gellibrand River can be found in Figure 3-6.

To represent current level of development demands, this irrigation pattern will be configured into the Gellibrand Source model, which will explicitly represent the off-stream winterfill storages.

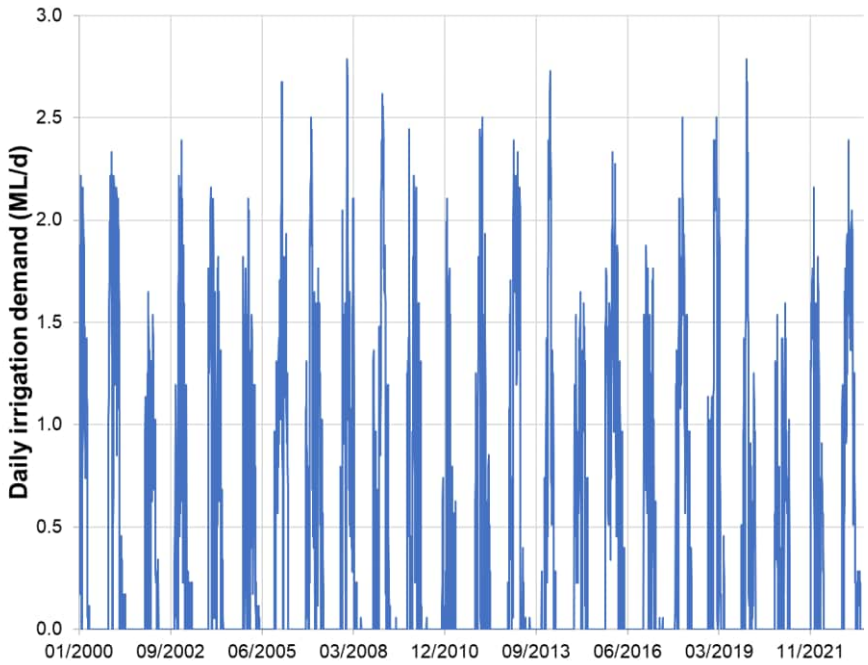


Figure 3-6 Gellibrand River irrigation demand from off-stream winterfill storages

3.2.1.2 Historic extractions from Gellibrand River

The extraction from Gellibrand River over the historic period for the purpose of adding back to the reach balance of G3 (Section 4.3) was calculated by developing a mini Source model to replicate the filling and spilling of the off-stream winterfill storages and extraction from the river based on available upstream flow (gauged flow at 235234 within Love Creek + gauged flow at 235267 within Olangolah Creek downstream of the reservoir + gauged flow at 235266 within the Gellibrand River downstream of the West Gellibrand Reservoir). The mini Source model was run over the reach balance period of 2005 to 2023 and can be found in Figure 3-7. The off-stream winterfill extractions from Gellibrand River to be considered during the G3 reach balance in Section 4.3 was the sum of the extractions for the three winterfill periods and can be shown in Figure 3-8.

No historic trend was required to be applied to the calculated as historic is equal to current over the period of 2005 to 2023.

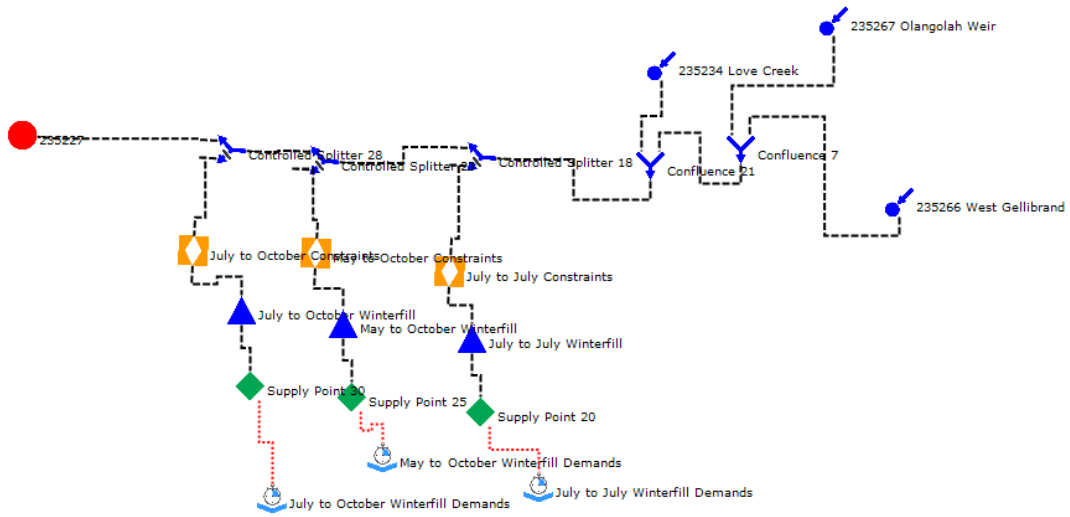


Figure 3-7 Source model used to calculate the historic extractions from Gellibrand River to off-stream winterfill (BW and HARC, 2024)

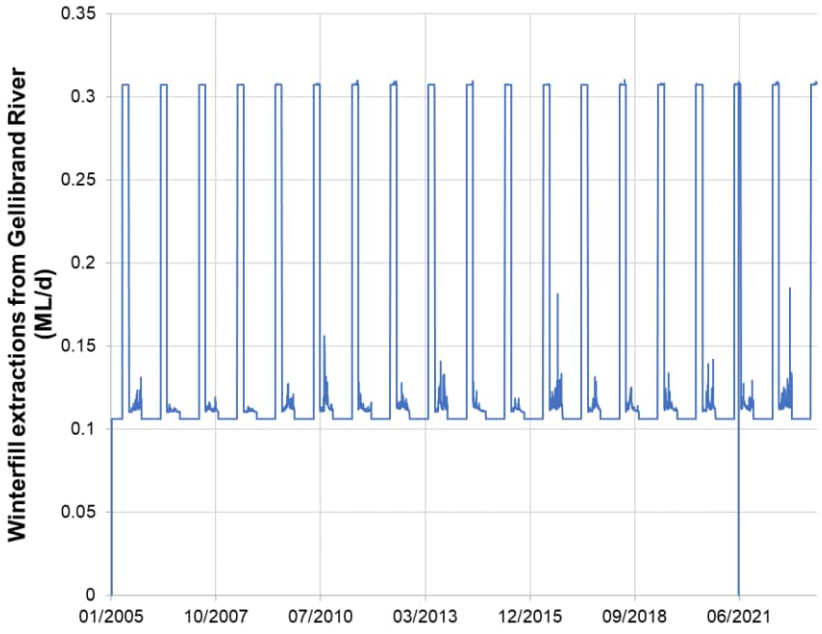


Figure 3-8 Historic off-stream winterfill pumping from Gellibrand River for reach balance (BW and HARC, 2024)

3.3 Farm dam impacts

When incorporating the impact of farm dams on inflow into a hydrologic model, the estimated impact of historic level of development farm dams are added back to partial natural flow to derive unimpacted inflows. These farm dam impacts are added back to the partial natural flows after rainfall runoff modelling has been undertaken.

Current level of development farm dam impacts, and negative impacts represented as farm dam inflows, are configured into the model for the current level of development case. Farm dam impacts under future climate were determined by re-running farm dam impact models with climate change impacted streamflows and climate input. The setup of future farm dam impacts is further discussed in Section 8.1.2.3.

3.3.1 Current level of development

Inflow data

The inflow data derived in Section 4 is adopted in the farm dam models. Note that as the inflow to Gellibrand River (G3) was split upstream and downstream of gauges 235231 and 235236, the farm dam impacts were split into the same subcatchments (G3a, G3b, G3c).

Climate data

Climate inputs to the STEDI model were assumed to be the SILO patched point rainfall and Morton's Shallow Lake Evaporation using the climate gauges outlined in Table 3-6.

Farm dam distribution data

The most recent farm dam distribution layer, developed by DELWP (2012), was adopted to calculate the farm dam distributions for the relevant subcatchments. The farm dams within each gauged catchment were identified using the 'Farm Dam Boundaries' GIS datasets available from www.data.vic.gov.au. These datasets are comprised of polygons and points identifying farm dams, as digitised from aerial imagery over the period 2005 to 2011. Before using these datasets, the following filters were applied, as advised by DEECA:

- Features that overlay a named waterbody in the VicMap hydro dataset were excluded
- Features that are larger than 200 ML were excluded
- Features that are not of an appropriate type (i.e. not 'Rural Storage', 'Town Rural Storage', 'Rural Licensed Storage', 'Rural Irrigation Storage') were excluded
- Duplications of winterfill licence volumes within the farm dam layer (Section 3.2)

Given that the DEECA farm dam distribution layer has not been updated in 2012, further investigations have been made to determine if any additional farm dams need to be included. The DEECA farm dam distribution layer has been overlain over Google Earth Pro (Figure 3-10 with an example of the investigation results in Figure 3-9) and the subcatchments checked for any missing farm dams that have been constructed since 2012.

This investigation found the following additional farm dams:

- 15 additional farm dams in Gellibrand River (G3b) with a total volume of 8.2 ML
- 4 additional farm dams in Love Creek (G5) with a total volume 3.4 ML
- 1 additional farm dam in Ten Mile Creek (G6) with a total volume of 0.15 ML

The number of farm dams since 2012, based on an investigation of Google Earth Pro satellite imagery found only 11.7 ML of farm dam.

The SRW registered licence volumes for farm dams have been checked and it was found that 10.9 ML of additional farm dams have been licensed since 2012, this is comparable to the farm dams found from Google Earth Pro.

The additional farm dam volumes outlined above were added to the dataset, as shown in Table 3-6. The farm dam distributions in each subcatchment can be found in Appendix D.

STEDI also requires sub-catchment areas corresponding to a 100 ML and 5 ML dam. The current update used the assumptions of catchment area of a 5 ML and 100 ML dam of 0.3 km² and 1.4 km² which are estimated as a function of stream density (SKM, 2004).

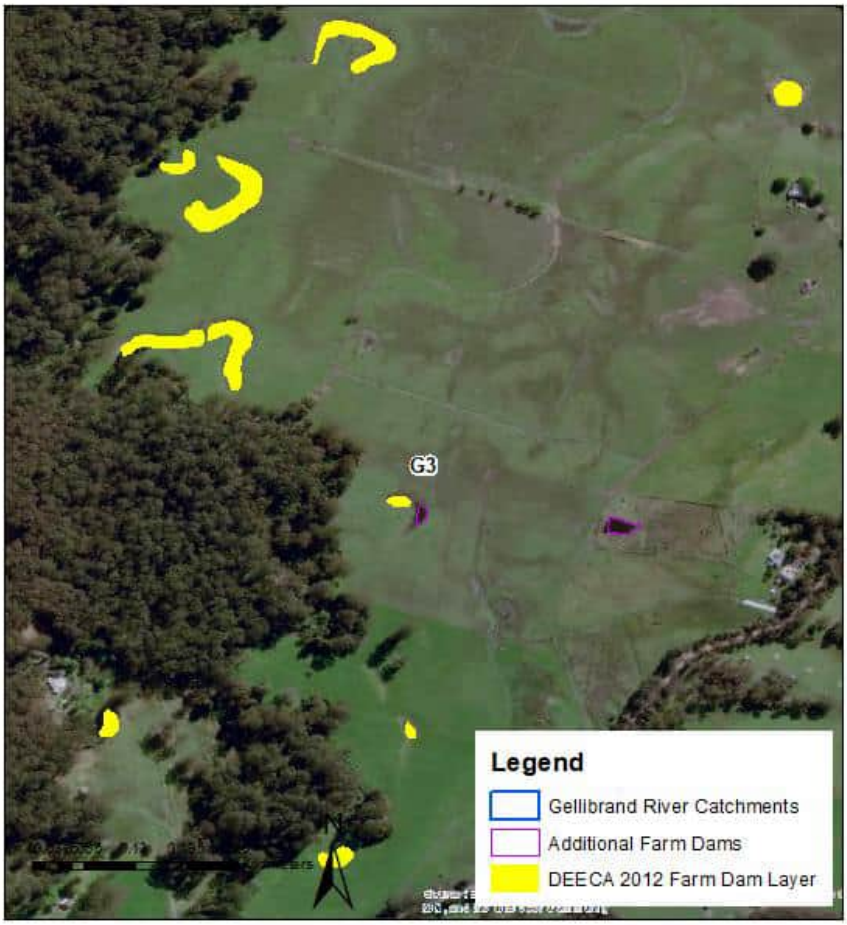


Figure 3-9 Example of new farm dams found when compared to satellite imagery

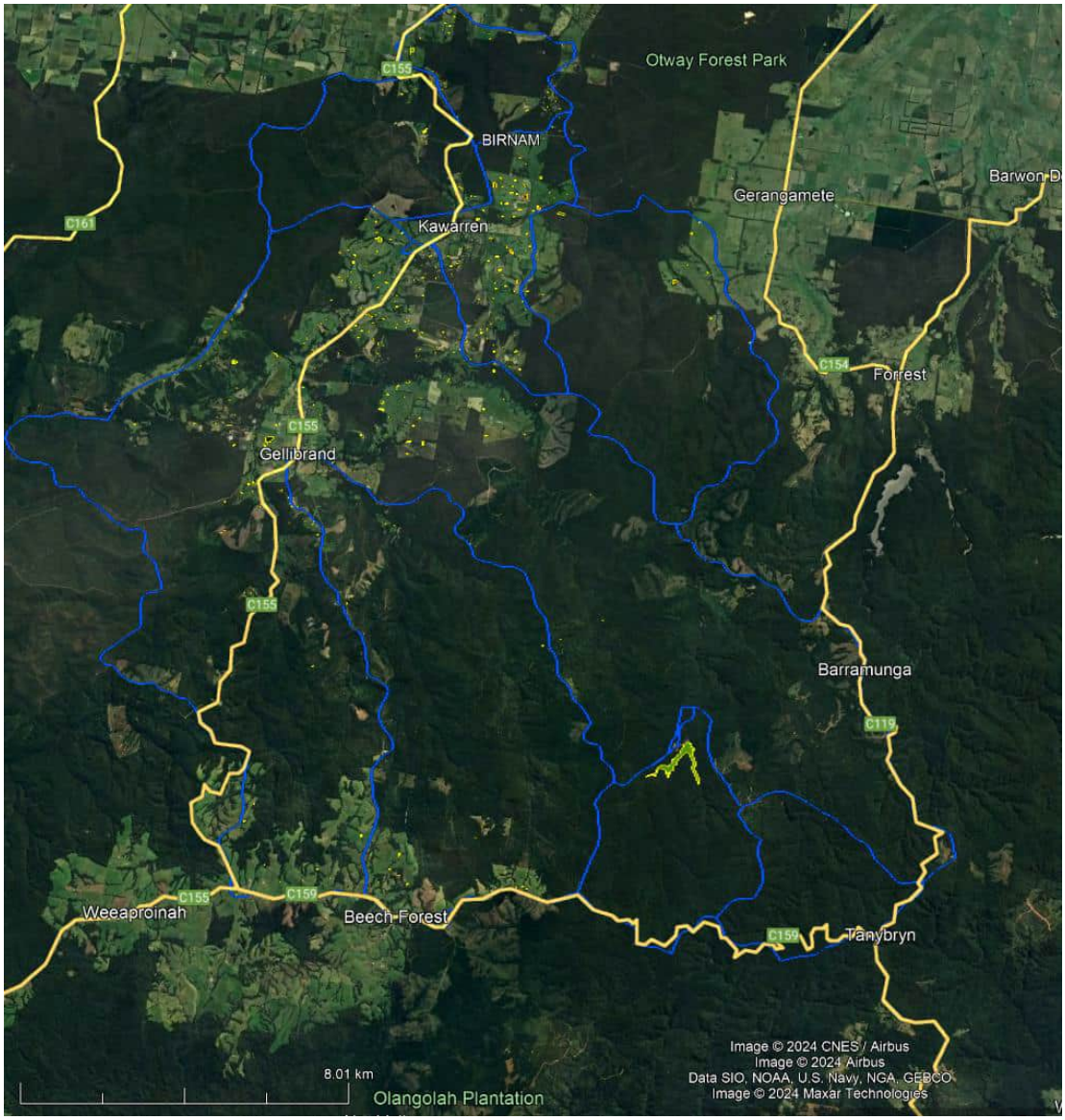


Figure 3-10 Comparison of farm dam distribution from 2012 (shown in yellow) and current satellite imagery

Table 3-3 Summary of farm dam assumptions in the Gellibrand catchment

Subcatchment		Climate gauge	Number of dams	Farm dam volumes			Catchment Area (km²)	Farm dam density (ML/km²)
				DEECA farm dam layer	Additional farm dams since 2012	Total		
G1	Inflow upstream of West Gellibrand Reservoir	090134	0	0	0	0	15.4	0
G2	Inflow upstream of Olangolah Weir	090134	0	0	0	0	11.5	0
G3a	Inflow to Gellibrand River downstream of storages and upstream of 235236	090134	6	1.7	0	1.7	53.2	0.03
G3b	Inflow to Gellibrand River downstream of 235236 and upstream of 235231	090134	38	56.2	0	56.2	16.5	3.4
G3c	Inflow to Gellibrand River downstream of 235231 and upstream of 235227	090134	195	198.5	8.2	206.7	88.5	2.3
G4	Yahoo Creek upstream of Kawarren	090134	22	20.5	0	20.5	17.5	1.2
G5	Love Creek upstream of Gellibrand	090134	105	166.9	3.4	170.3	15.2	11.2
G6	Ten Mile Creek upstream of 235239	090134	35	33.8	0.15	33.9	10.0	3.4
G7	Porcupine Creek upstream of 235240	090134	16	59.5	0	59.5	33.8	1.8
G8	Lardner Creek upstream of Gellibrand	090134	31	14.0	0	14.0	51.8	0.3
G9b	Carlisle River	090042	36	110	0	110	71.3	1.54
G10	Kennedys Creek	090042	1,247	2,590	0	2,590	269.40	9.62
G11a	Gellibrand River from Bunkers Hill to ds Carlisle River	090042	90	110	0	110	101.97	1.08
G11b	Gellibrand River from ds Carlisle River to Pump Station	090042	238	393	0	393	192.24	2.05
G12	Gellibrand River from Pump Station to Burrupa	090042	238	430	0	430	82.07	5.24
G13a	Latrobe Creek and Boggy Creek	090042	507	1,342	0	938.4	57.6	16.2
Total			**2,659**	**5,526**	**11.75**	**5,213**	**1,061**	**Av 4.3**

Dam volumes

Dam volumes are estimated using Fowler et al. (2016). The volume of each dam was calculated based on its apparent surface area using the following equation:

- $V = \frac{A^{1.321}}{9600}$ Equation 3-1

where:

V = farm dam volume (ML)
A = farm dam surface area (m^2)

Demand data

The amount of water used for each dam varies based on its purpose. This was represented by the volume of water used each year as a proportion of dam volume. The demand factors for stock and domestic and irrigation dams were set to 0.5 and 0.83 respectively (Fowler et.al, 2016).

The irrigation demands follow a pattern defined by PRIDE based on the irrigation pattern of perennial pasture, and can be found in Table 3-4 where the monthly distribution is a proportion of the annual total. The D&S demands are applied uniformly throughout the year.

Table 3-4 Irrigation demand pattern adopted in STEDI

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.33	0.29	0.16	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.16

3.3.2 Historic level of development

As for rural demands, an estimate of historic farm dam impact is required to add back to recorded streamflow data used for inflow derivation.

As part of the preliminary investigations for this project, the historic farm dam impact assumptions from the nearby Moorabool catchment (SKM, 2004) were adopted. In this study the volume of farm dams in 1965 was estimated from farm dam volumes and numbers surveyed in 1970, documented in GHD (1987).

It was assumed that that farm dam impacts linearly increase from 0% to 40% of current between 1900 to 1965, then from 40% to 100% of current impact from 1965 to 2004. It is assumed that current impact is representative of farm dam impacts from 2004 to 2023, as shown in Figure 3-11.

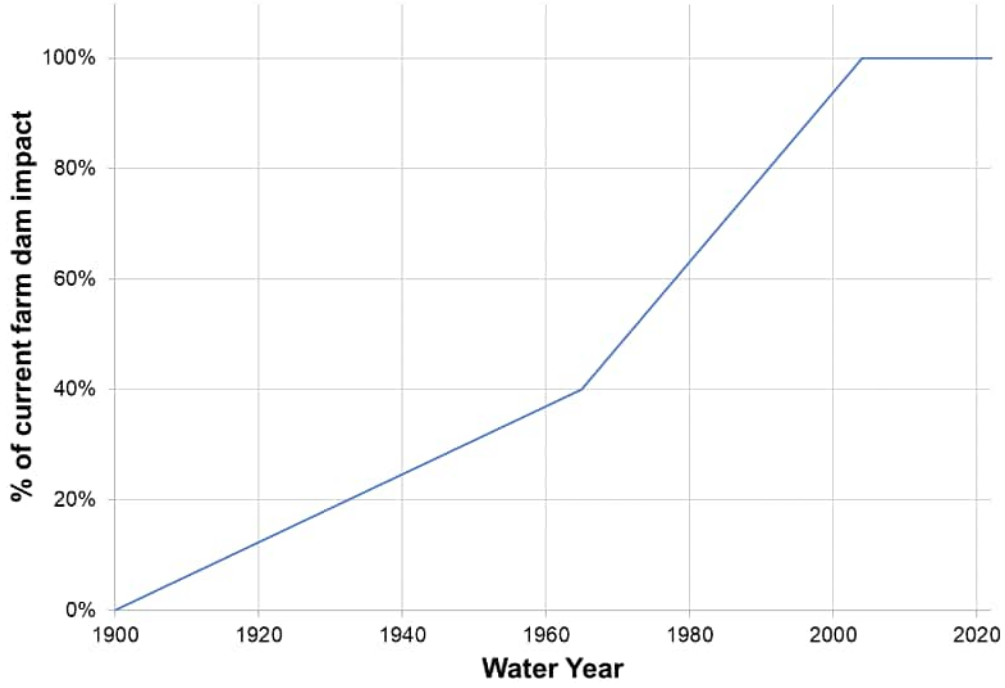


Figure 3-11 Historic farm dam trend (SKM, 2004)

HARC (2020) investigated recent trends in farm dam development over time across Victoria, using a sample tile in Barongarook, near the Gellibrand catchment, as a case study. As shown in Figure 3-12, the farm dam volume growth from 2010/11 to 2014/15 was found to be 0-0.5% for Barongarook. This is consistent with the assumption outlined above that there has been minimal farm dam growth from 2010 to 2022.

It has been assumed that assuming current farm dam volumes back to 2004 is valid, as outlined in Figure 3-11. As well, the farm dam trend prior to 2004 has been adopted.

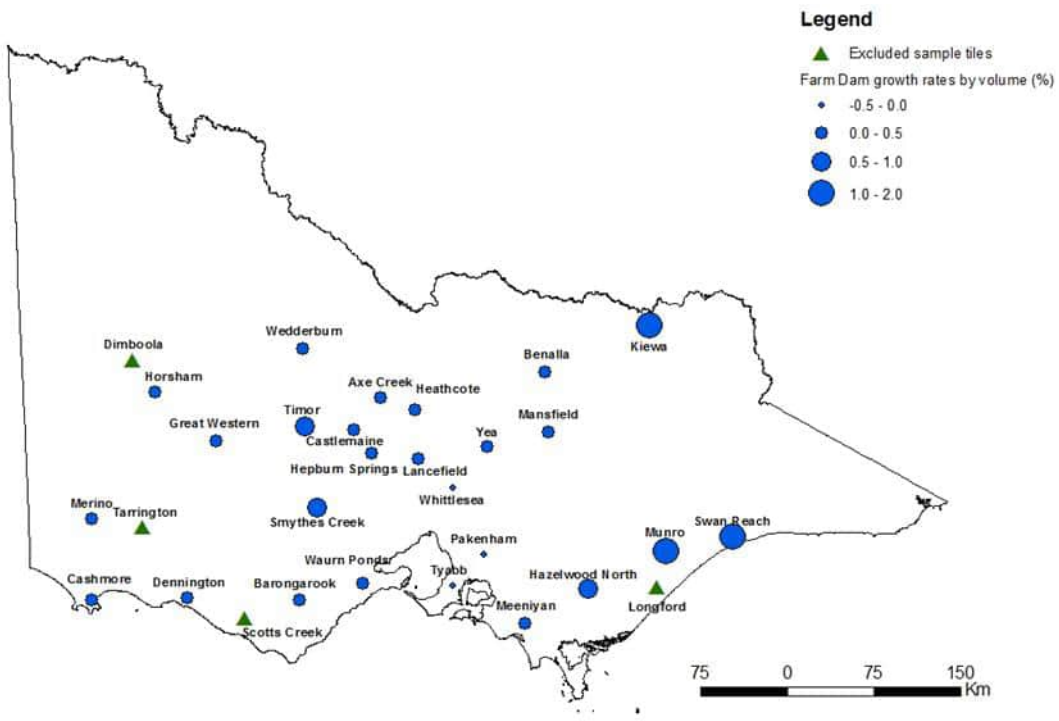


Figure 3-12 Farm dam volume growth rate represented by circle area from 2010/11 to 2014/15 (HARC, 2020)

3.4 Barwon Water demands

The Gellibrand River catchment includes a number of urban demand centres, with water extracted by Barwon Water and Wannon Water as per the Bulk Entitlement rules.

Urban demands are required at current level of development, historic level of development where they form part of an inflow derivation, and at full uptake and under future growth and climate conditions (2040, 2065) for scenario modelling.

Assumptions relating to urban demands under full update and future climate and growth will be discussed in future versions of this report.

3.4.1 Supply to the Geelong- Colac system

Barwon Water transfers from Olangolah Weir and West Gellibrand Reservoir to Colac, which is sometimes supplemented by water supplied from the Geelong system via the Geelong-Colac Pipeline. In 2023, the Geelong Colac Source model was refined by HARC (BW and HARC, 2023), including the development of climate dependent urban demands for Colac and the Geelong system. To correctly represent the Barwon Water supply to Colac from the Gellibrand catchment, a time series of modelled transfers via Geelong Colac Pipeline from the Geelong Colac Source model (BW and HARC, 2023) was configured into the Gellibrand Source model. This time series is available at current level of demand and for each future climate change scenario.

3.4.2 Supply to Gellibrand

Barwon Water is able to extract from Lardner Creek to supply Gellibrand.

An urban demand regression has been calculated over a recent unrestricted period of 2011 to 2023 to calculate monthly demands at Gellibrand for inclusion in the Gellibrand Source model. Monthly data provided by Barwon Water was used to derive the following climate dependent regression for current Gellibrand demands:

Current level of Gellibrand Demand (ML/mth) = 0.0545 x Maximum daily temperature in a month at Colac 090147 factored by 1.2 when maximum daily temperature > 36ºC

The modelled monthly demand has been compared to observed in Figure 3-13 and shows a good correlation. The monthly demand will be uniformly disaggregated to daily for application in the model.

For historic river diversion from Lardner Creek to Gellibrand, metered data was provided by Barwon Water. This has been incorporated into the inflow derivation of Lardner Creek (G8).

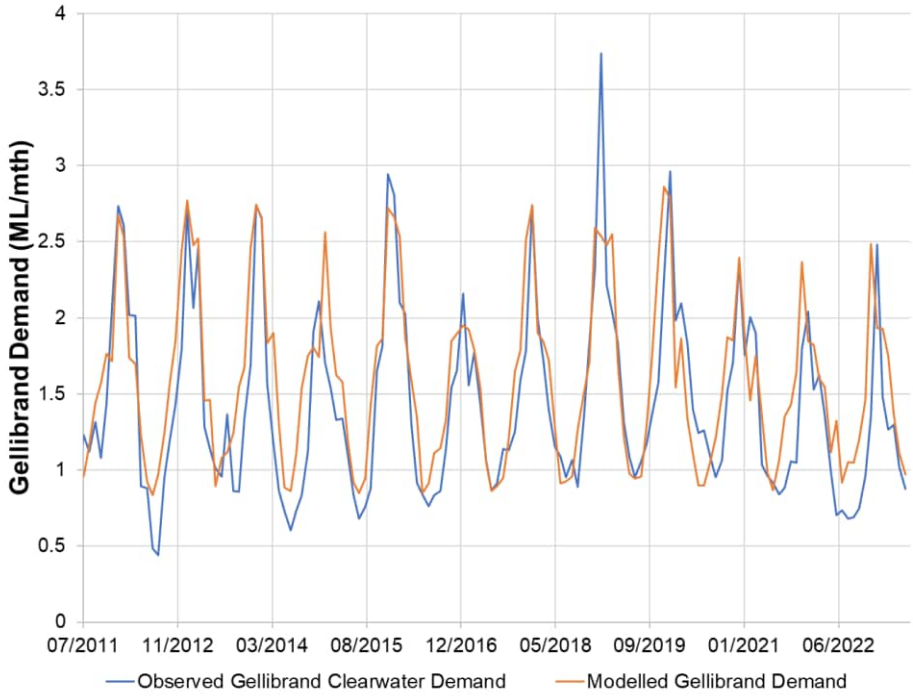


Figure 3-13 Comparison of observed and modelled monthly Gellibrand demand from 2011 to 2023

3.5 Wannon Water demands

This section outlines the derivation of Wannon Water's demand in the Otway supply system. Historic clear water demands for urban, industrial and rural users have been provided by Wannon Water from from 2017/18 to 2023/24 on a monthly timestep. Wannon Water recommended that only data from 2018/19 water year onwards was adopted for demand derivation due to an incomplete number of meters in 2017/18. A calibration period of 1/7/2018 to 30/6/2024 has been used, unless there is a trend in the observed data resulting in the need to calibrate to a shorter period. The calibration periods and trend in data has been confirmed with Wannon Water. In general, demand models were fitted to the period of record felt to be most representative of current level of development demands.

3.5.1 Urban demands

Monthly regressions have been calibrated to model the clear water demand for each demand centre. To calculate daily demands for the Source model, the modelled monthly demand will be uniformly disaggregated to a daily timestep.

The independent variables used in the model are maximum daily temperature in the month and monthly rainfall. The demand estimation was performed using a multiple linear regression relationship of the form:

$$d = C_t \times t^2 + C_r \times r + constant$$

Where: d = *monthly clear water demand (ML)*
t = *mean maximum Temperature (°C)*
r = *monthly Rainfall (mm)*
c_x = *coefficient of variable x*

The Otway system demand model calibrations are summarised in Table 3-5. Where required additional factors were included to increase demand when the temperature is above a certain threshold, as shown in Table 3-5, to be able to achieve the peak demands found in the observed data.

The calibration plots for each demand centre are available in Appendix H. The calibration plots include a monthly and annual comparison between modelled and observed data, as well as a time series of temperature and rainfall.

The following observations have been made with regards to the urban demand calibrations:

- The Allansford Urban calibration in Appendix H.1 was undertaken from 2022 to 2024 and is able to replicate the observe demand pattern, however, overestimates the winter demand in 2023. To capture the winter demand, a repeating series of average monthly demand calculated from 2022 to 2024 was adopted in place of the regression results just for June (8 ML/mth), July (8.3 ML/mth) and August (8.1 ML/mth).
- The Camperdown Urban calibration in Appendix H.2 is able to replicate the peaks and demand pattern of the observed data well. Note that that winter demand is well modelled in the 2023 and 2022, however, slightly underestimated in 2019, 2020 and 2021.
- The Cobden Urban demand regression has been calibrated from 2018 to 2022 to capture the climate driven demand pattern (Appendix H.3). The higher demand from 2022 to 2024 was confirmed by Wannon Water to be due to a leak in the system and not representative of customer behaviour so this data was excluded from the calibration period.
- For Koroit, the higher demand from 2020 to 2024 has been used as the calibration period, as shown in Appendix H.4. The very high demand in summer 2024 and lower winter in 2023 is not able to be replicated or explained by Wannon Water. However, the demand pattern from 2020 to summer 2023 is well modelled. The total Koroit demand (Koroit urban + Bega) was examined to ascertain if a better demand pattern was able to be achieved. However, the erratic pattern was still evident.
- For Lismore and Derrinallum (Appendix H.5), the demand regression has been calibrated from July 2020 to 2024 and is able to achieve a very satisfactory calibration over this period. The peak summer demands are also able to be captured. The anomalous observed demand data in summer 2020 is not able to be replicated and could not be explained by Wannon Water.

- As shown in Appendix H.6, the demand regression is able to replicate the observed demand pattern for Mortlake. Whilst the peaks in 2022 and 2023 are overestimated, the recent higher summer peak in 2024 is well modelled. This is a conservative estimate of demand for Mortlake.
- The recent three years of observed demand for Noorat Glenormiston is able to be modelled by the demand regression, included the higher spring demand in 2023 (Appendix H.7).
- The monthly observed demand pattern for Purnim was difficult to calibrate to, with some peaks underestimated and some winters overestimated. The behaviour of observed winter demands was discussed with Wannon Water and may be due to rural usage within Purnim. The annual calibration of data was found to be satisfactory (Appendix H.8).
- The Simpson demand regression was calibrated from July 2019 to 2024 to exclude the anomalous high demand in the summer of 2019. The demand regression is able to replicate the magnitude of the observed demand satisfactorily (Appendix H.9).
- The Terang monthly observed data is able to be replicated by the modelled demand regression, including satisfactorily modelling the summer peaks (Appendix H.10).
- The Warrnambool demand pattern is able to be replicated, with the exception of a high demand peak in the summer of 2019 (Appendix H.11). Note that two lower demand values in the spring of 2022 and autumn of 2023 are also not replicated by the demand regression. The higher demands in 2023/24 are currently being investigated by Wannon Water and will be updated as a future enhancement.

The comparison of modelled and observed urban demands has been reviewed and approved by Wannon Water.

Table 3-5 Wannon Water urban demand calibration details

Demand Centre	Climate gauge	R^2 of monthly calibration	Over Calibration Period				Calibration parameters				
			Calibration Period	Average annual observed clear water demand (ML/yr)	Average annual modelled clear water demand (ML/yr)	% Volume Bias	C_t	C_r	Constant	Temp cutoff (ºC)	Temp factor
Allansford[1]	090000	0.69	2022 – 2024	82	88	+6%	0.009	-0.009	5.6	24	1.18
Camperdown	090153	0.86	2018 – 2024	363	369	+2%	0.042	-0.025	16.7	24	1.11
Cobden	090021	0.76	2018 - 2022	269	271	+1%	0.032	-0.012	13.4	25.5	1.15
Koroit	090186	0.37	2020 – 2024	304	305	+0%	0.015	-0.030	21.8	NA	NA
Lismore and Derrinallum	089018	0.81	2020 – 2024	85	88	+4%	0.011	-0.011	3.1	24	1.20
Mortlake	090058	0.81	2018 – 2024	170	172	+1%	0.022	-0.036	7.6	25	1.10
Noorat Glenormiston	090077	0.63	2018 – 2024	116	120	+3%	0.012	-0.021	6.6	24	1.20
Purnim	090186	0.33	2018 – 2024	37	38	+3%	0.004	0.004	1.2	24	1.20
Simpson	090042	0.36	2019 – 2024	40	40	0%	0.002	-0.006	3.2	24	1.30
Terang	090077	0.75	2018 – 2024	207	212	+2%	0.016	-0.015	12.4	24	1.15
Warrnambool	090186	0.55	2018 – 2024	3,554	3,603	+1%	0.220	-0.351	237.5	24	1.10

[1]winter demand for Allansford Urban set as a repeating series to pick up higher winter demands. 8 ML/mth in June, 8.3 ML/mth in July and 8.1 ML/mth in August

3.5.1.1 Base demand derivation

Total demand is proposed to be split into a base demand (defined as commercial, industrial, priority green space and in-house use that is not subject to water restrictions) and restrictable demand (assumed to be residential and non-residential outdoor use). The recalibration of urban demand regressions requires the rederivation of base demands.

Across Victoria base demand is generally calculated as 85% of the average winter demand. Previously, Wannon Water has calculated base demand as 20% of residential use based on data collected in Hamilton over the Millennium Drought. Wannon Water has confirmed that the base demand is to be calculated as 85% of the average winter demand for this project.

The base demands for each Otway urban demand are summarised in Table 3-6 and have been calculated over the available modelled current level of development demand period of 1900 to 2024 using historic climate data. That is, demands that would be produced under current usage levels given a repeat of climate since 1900.

The estimated base demand has been compared to the modelled demand in the calibration plots in Appendix H. Base demand has also been calculated as a percentage of the average monthly unrestricted demand to compare to the previous Wannon Water estimate of base demand calculated as 20% of unrestricted demand. As shown in Table 3-6, the base demand is much higher than the previous Wannon Water estimation, which will result in a more conservative estimate of restricted urban demand due to a lower restrictable demand.

The Otway Source model requires base demand to be expressed as a percentage of total demand in a given month. The calculation of restrictable demand and base demand percentage is based on a typical dry year demand. In this case, the 2006/07 drought water year has been adopted. The base demand percentage and restrictable demand can be found in Appendix I.

Table 3-6 Otway System base demands

Urban centre	Average monthly unrestricted demand (ML/mth)	Base demand (ML/mth)	Base demand as % of average monthly unrestricted demand
Allansford	8.8	6.9	79%
Camperdown	30.4	18.1	60%
Cobden	24.5	15.4	63%
Koroit	25.2	18.7	74%
Lismore and Derrinallum	7.4	3.7	50%
Mortlake	14.0	7.7	55%
Noorat Glenormiston	9.9	5.8	59%
Purnim	3.1	2.0	66%
Simpson	3.4	2.4	71%
Terang	17.5	11.8	67%
Warrnambool	295.5	211.3	72%

3.5.2 Industrial demands

Industrial demands have been calculated using a repeating pattern based on monthly average demand over the calibration period. Higher peaks in industrial demand were investigated to determine whether they were resulting from higher temperature. However, it was found that demand peaks were irregular and not able to be correlated to temperature. A comparison of monthly and annual industrial demands can be found in Appendix J. The industrial demands for each month and the comparison to average annual observed demand is summarised in Table 3-7.

The following observations have been made with regards to the industrial demand calibrations:

- For Bega Koroit, there is a change in demand pattern in recent years, particularly lower summer demands (Appendix J.1). However, demand has been calculated over the available period of 2018 to 2024, slightly over estimating demand in the 2023/24 water year.
- For Fonterra Cobden, calibration period was set to 2018 to 2014 to capture earlier higher industrial demand (Appendix J.2).
- For Sungold Allansford, the calibration period was limited to 2021 to 2024 due to an increase in industrial demand in recent years (Appendix J.3). The repeating pattern is able to replicate observed demand during this calibration period.
- The Saputo industrial demand is the largest industrial demand in the Otway system. The comparison between modelled and observed in Appendix J.4 shows that the erratic demand behaviour is able to be replicated.
- The South West Healthcare observed data does not exhibit a well behaving demand pattern and the within year pattern shown in Appendix J.5 has been checked with Wannon Water and confirmed for use.
- The Midfields industrial demand was calibrated from 2022 to 2024 to capture the increase in demand in recent years (Appendix J.6).

The comparison of modelled and observed industrial demands has been reviewed and approved by Wannon Water.

Table 3-7 Wannon Water Industrial demand calibration details

	Bega Koroit	Fonterra Cobden	Sungold Allansford	South West Healthcare	Saputo	Midfields
Calibration period	2018 - 2024	2018-2024	2021-2024	2018 - 2024	2018 - 2024	2022 - 2024
Calculated over calibration period						
Average annual observed demand (ML/yr)	159.7	470.8	60.7	49.7	1142.9	303.0
Average annual modelled demand (ML/yr)	159.6	470.8	61.4	52.7	1157.9	306.7
Volume bias (%)	-0.1%	+0.0%	+1.2%	+6.0%	+1.3%	+1.2%
Monthly industrial demand pattern						
January	13.2	40.3	5.8	5.4	109.5	26.2
February	17.9	34.0	4.9	4.8	83.9	28.2
March	19.1	28.1	5.6	4.9	104.6	28.2
April	15.9	34.5	5.0	4.3	90.3	24.9
May	13.4	40.3	5.0	4.3	59.9	29.3
June	13.3	36.1	5.0	4.2	104.0	27.4
July	12.2	41.9	4.8	3.9	91.9	25.5
August	10.6	40.6	4.9	4.1	100.2	24.7
September	10.1	41.5	4.7	3.8	101.7	16.2
October	11.5	46.1	5.0	4.3	108.9	25.5
November	10.9	42.3	5.0	3.9	105.3	24.5
December	11.5	45.0	5.6	4.7	97.5	25.1

3.5.3 Rural demands

Rural demands were confirmed to be stock and domestic only, so these demands have been calculated using a repeating within year pattern (similar to industrial demands).

Comparison between annual observed and modelled demand shows a slight over estimation of demand (Table 3-8). This is due to the rural demands being increased during drier months based on a temperature threshold to capture peak demands (shown in Table 3-8). A comparison of monthly and annual rural demand is shown in Appendix K. The following has been observed:

- The demand pattern for Camperdown Rural is able to be replicated (Appendix K.1), however, the higher demand in the 2023/2024 water year is underestimated by the demand model.
- The calibration period for Bungador was confined to 2019 to 2024 as the 2018/19 water year was anomalous. The rural demand pattern for Bungador was quite erratic (Appendix K.2). The demand has been confirmed with Wannon Water.

- The demand pattern for Carpendeit is able to be replicated with the exception of very high winter demand in 2023 (Appendix K.3). This has been treated as an anomalous demand and was confirmed with Wannon Water.
- Similar to Bungador, the Cobrico observed demand pattern is quite erratic (Appendix K.4). However, was confirmed with Wannon Water to be the best estimate of demand.
- The high demand in 2018 and 2019 has been removed from the calibration period for Lismore, which has been calibrated to the lower demand from 2020 to 2024 (Appendix K.5).

The rural demand calibrations have been confirmed with Wannon Water.

Table 3-8 Wannon Water rural demand derivation details

	Camperdown Rural	Bungador	Carpendeit	Cobrico	Lismore
Climate gauge	090153	090153	090153	090153	NA
Calibration period	2018 - 2024	2019-2024	2018 - 2024	2022-2024	2020 - 2024
Calculated over calibration period					
Average annual observed demand (ML/yr)	578.3	32.2	54.5	73.1	39.2
Average annual modelled demand (ML/yr)	583.5	32.4	55.5	79.1	40.2
Volume bias (%)	+0.9%	+0.6%	+1.8%	+8.2	+2.6%
Monthly modelled demand (ML/mth)					
January	64.2	3.4	5.9	8.1	3.6
February	56.3	2.9	5.6	6.6	4.1
March	54.7	3.1	6.0	6.9	3.4
April	42.5	2.7	5.1	5.9	3.9
May	39.2	2.7	4.4	6.1	3.4
June	39.4	2.3	3.9	5.6	2.9
July	44.9	2.4	3.3	6.0	2.8
August	42.7	2.3	3.2	6.5	3.5
September	43.5	2.4	3.5	6.3	2.4
October	45.5	2.6	3.7	6.4	3.5
November	48.2	2.7	4.3	7.1	3.1
December	57.2	2.9	5.5	8.3	3.6
Increase in rural demand above temperature threshold					
Temperature Cutoff	25	26	24.5	23	NA
Temperature Factor	1.10	1.03	1.15	1.05	NA

4. Inflow derivation

Inflows have been derived from 1900 to June 2022, constrained by the availability of flow from the Geelong Colac Source model (HARC, 2023).

Inflows for the Gellibrand River have been summarised in Table 4-1, showing the inflow derivation methodology, reference and relevant catchment impacts in that subcatchment. Schematics showing available data in each subcatchment can be found in Figure 4-2 for the Upper Gellibrand and Figure 4-3 for the Lower Gellibrand. A map of the full Gellibrand River catchment can be found in Figure 4-1. Note that in the Upper Gellibrand a number of the tributary inflows have split gauged flow data availability, with data available in the 1980's and 1990's and then a large gap until recent data is available.

Inflow derivation has been undertaken in two steps:

- Extension of partial natural flow (gauged flow or reach balance with rural and groundwater pumping impacts added back) over the model run period of 1900 to 2022 using rainfall runoff models
- Derivation of unimpacted inflow by adding back estimated historic farm dam impacts outlined in Section 3.3.

The unimpacted inflow was derived in each section using the equation outlined below based on the catchment impacts outlined in Table 4-1:

Unimpacted flow = (Gauged or reach balance derived flow + historic rural demands + historic groundwater pumping impact + historic farm dam impact)

Inflows derived as outlined in this section represent the historic climate case. For the purposes of water resources modelling under current and future climate conditions inflows pre 1975 will be adjusted using decile scaling to create the reference inflow data set which will then be factored to derive inflows representing current (2020) and future (2040 and 2065) climate conditions in accordance with the Victorian Climate Change Guidelines (DELWP, 2020).

Table 4-1 Summary of subcatchment inflows and impacts in Gellibrand River and Boundary Creek catchments

Subcatchment		Catchment Area (km²)	Reference	Inflow extension method	Rural demands	Groundwater pumping impact	Farm dam impact	Urban demand
G1	Inflow upstream of West Gellibrand Reservoir	15.4	BW and HARC (2023)	Water balance on storage extended by rainfall runoff model				
G2	Inflow upstream of Olangolah Weir	11.5	BW and HARC (2023)	Water balance on storage extended by rainfall runoff model				
G3a	Inflow to Gellibrand River between Colac storages and damsite G5A (235236)	53.2	BW and HARC (2024) Additional split for current project	Reach balance extended by rainfall runoff model split into three subcatchments at 235231 and 235236			✓	
G3b	Inflow to Gellibrand River between damsite G5A (235236) and Rafferty's Lane (235231)	16.5				✓	✓	
G3c	Inflow to Gellibrand River between Rafferty's Lane (235231) and Bunkers Hill (235227)	88.5			✓		✓	
G4	Yahoo Creek upstream of Kawarren (235240)	17.5	BW and HARC (2024)	Gauged flow extended by rainfall runoff model		✓	✓	
G5	Love Creek upstream of Gellibrand (235234) and downstream of Yahoo, Ten Mile and Porcupine creeks	15.2	BW and HARC (2024)	Reach balance extended by rainfall runoff model	✓		✓	
G6	Ten Mile Creek upstream of Kawarren (235239)	10.0	BW and HARC (2024)	Gauged flow extended by rainfall runoff model			✓	
G7	Porcupine Creek upstream of Kawarren (235241)	33.8	BW and HARC (2024)	Gauged flow extended by rainfall runoff model			✓	
G8	Lardners Creek upstream of Gellibrand (235210)	51.8	BW and HARC (2024)	Gauged flow extended by rainfall runoff model	✓		✓	✓

Subcatchment		Catchment Area (km²)	Reference	Inflow extension method	Rural demands	Groundwater pumping impact	Farm dam impact	Urban demand
G9a	First Creek, Arkins Creek West and Arkins Creek East upstream of diversion weirs	7.7	Current project	Transposed gauge flow at 235205				
G9b	Carlisle River between diversion weirs and Carlisle River (235200)	71.3	Current project	Reach balance between 235205 and 235200 extended by rainfall runoff model	✓		✓	
G10	Kennedys Creek upstream of Kennedys Creek (235211)	269.4	Current project	Gauged flow extended by rainfall runoff model	✓		✓	
G11a	Gellibrand River between Bunkers Hill (235227) and Carlisle River pumping station (235225)	105.0	Current project	Lumped reach balance extended by rainfall runoff model and split by verification to gauged flows	✓	✓	✓	✓
G11b	Gellibrand River between Carlisle River pumping station (235225) and South Otway pumps bridge (235258)	192.2	Current project		✓		✓	✓
G12	Gellibrand River between South Otway pumps bridge (235258) and Burrupa (235224)	82.1	Current project		✓		✓	
G13	Gellibrand River between Burrupa (235224) and Princetown (235269) including Latrobe Creek and Boggy Creek	110.7	Current project	Transposition of flow from a neighbouring catchment verified with a Source model.	✓		✓	

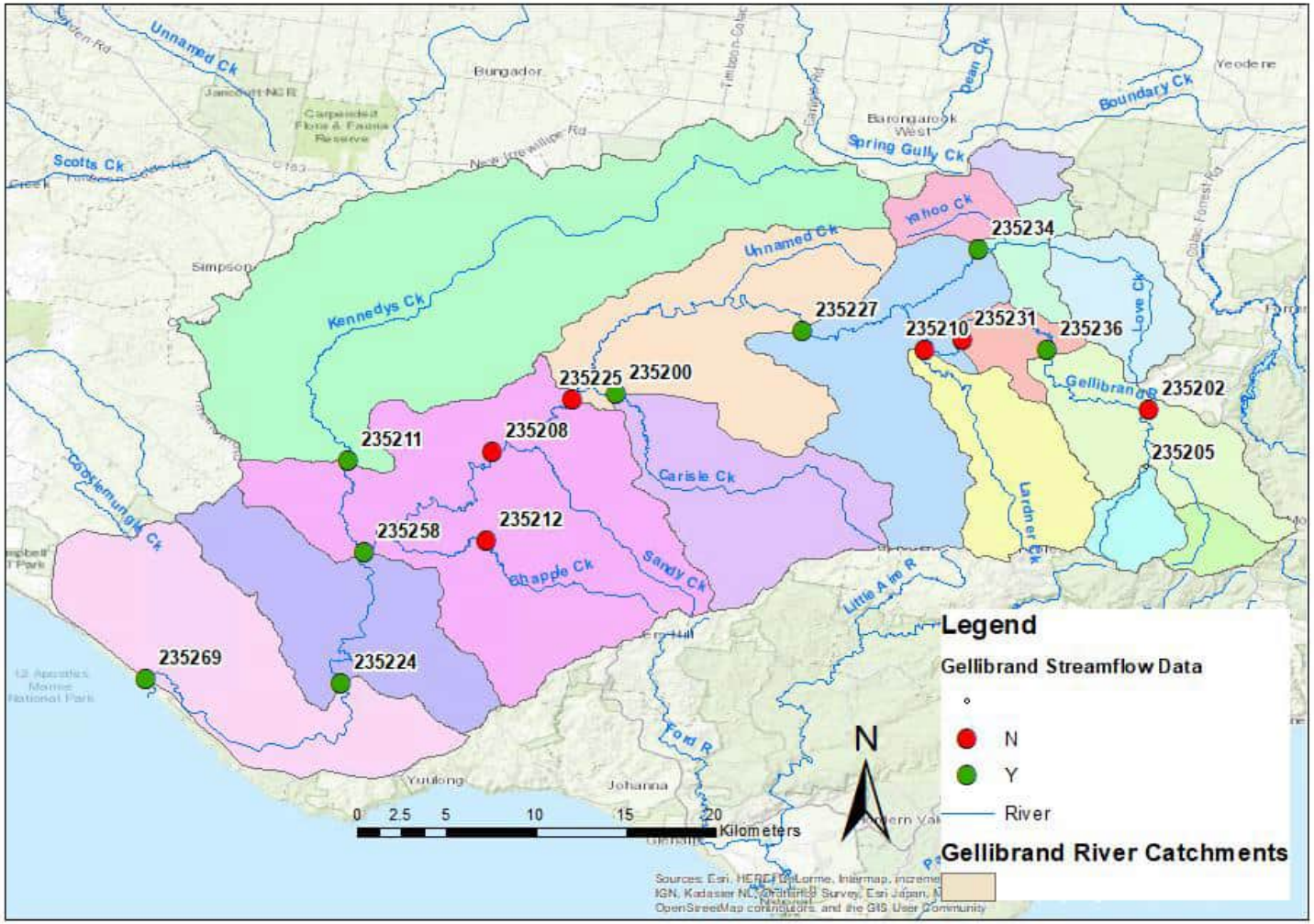


Figure 4-1 Map of Gellibrand River Source model catchments (environmental flow compliance points shown in green)

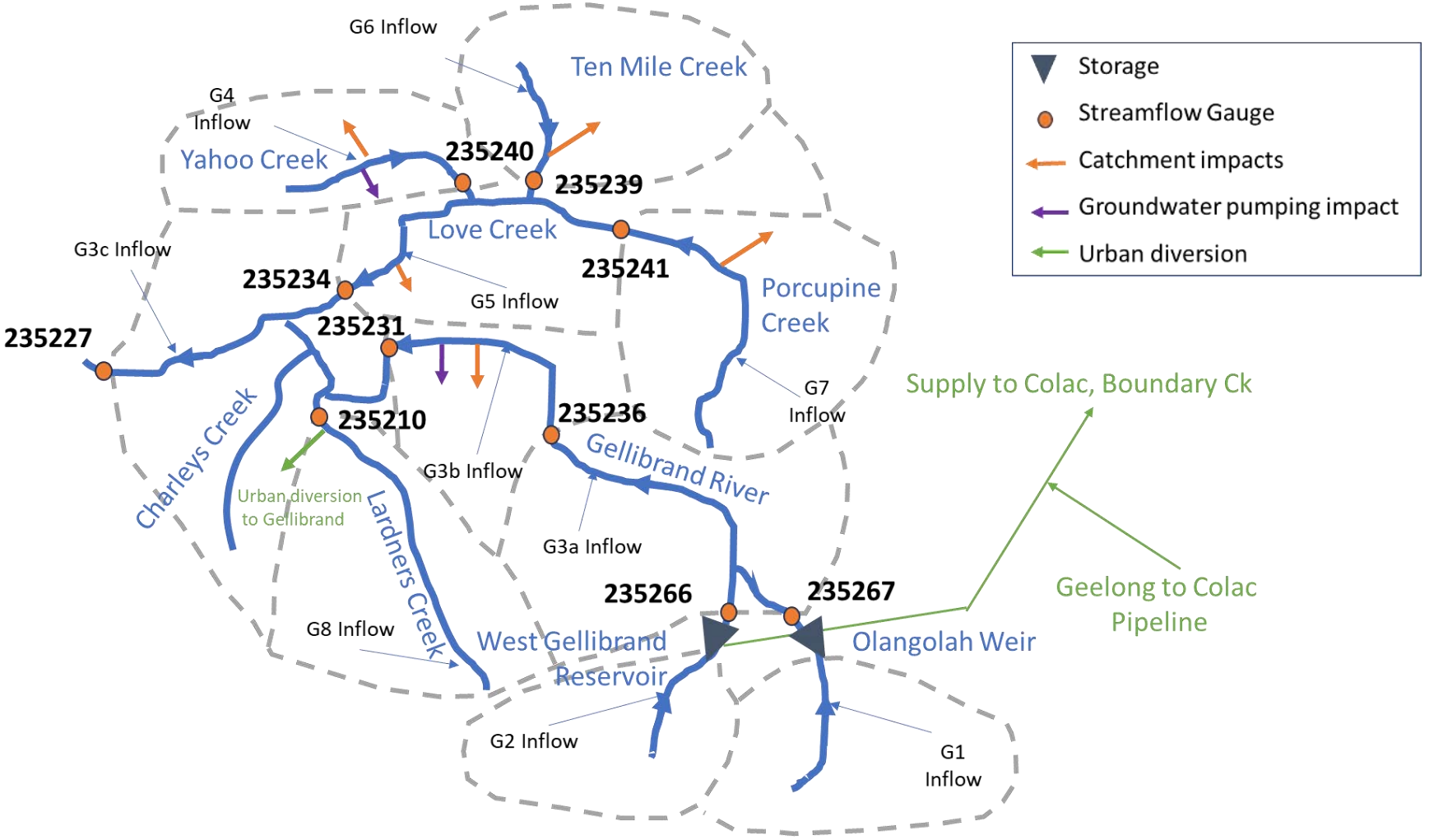


Figure 4-2 Schematic of upper Gellibrand River Source model catchments (BW and HARC, 2024)

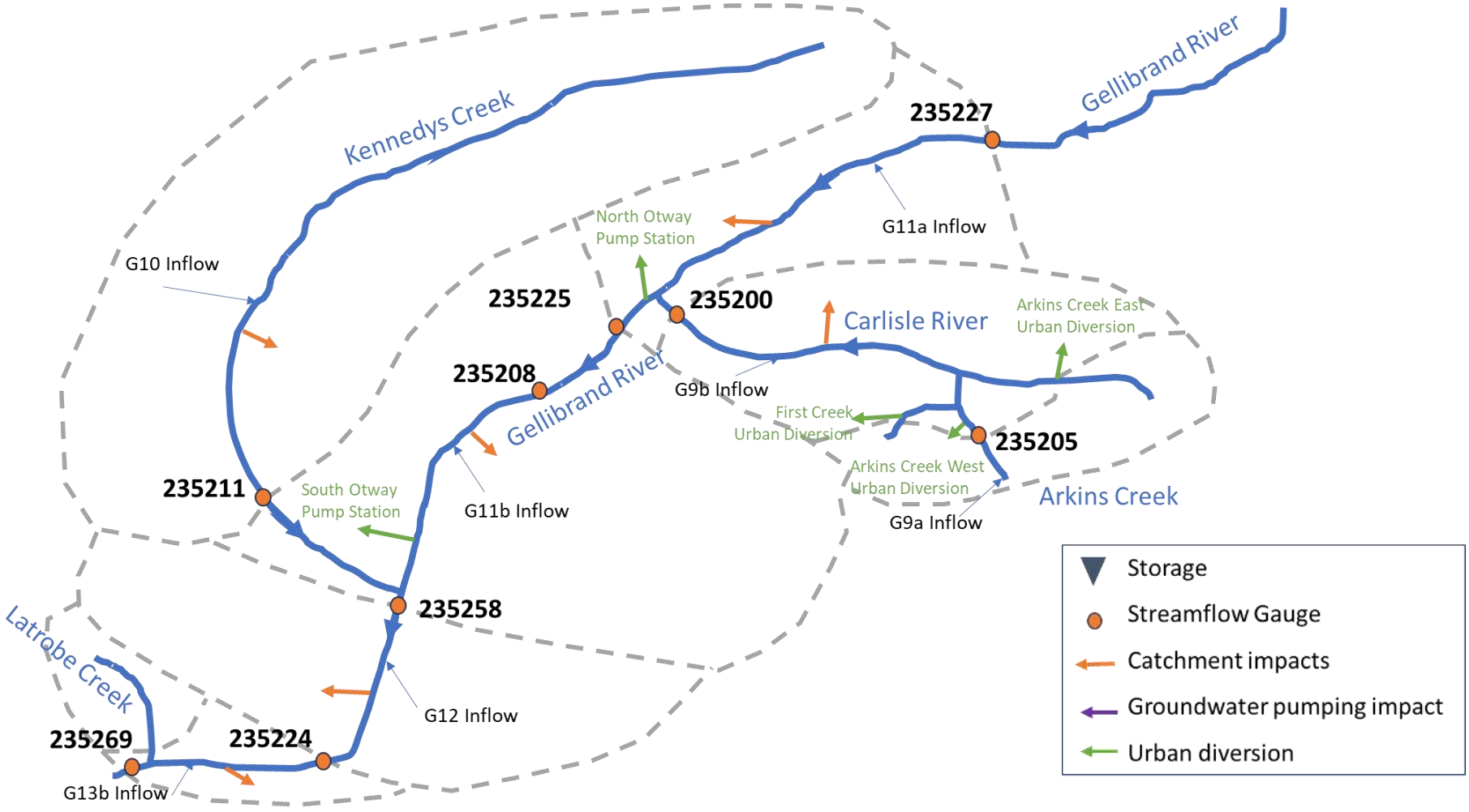


Figure 4-3 Schematic of lower Gellibrand River Source model catchments

4.1 G1 Inflow to West Gellibrand Reservoir

This inflow was recently calculated as part of the Geelong Colac Source model update (BW and HARC, 2023). Each water balance component was critically reviewed prior to adoption. The methodology undertaken was the best practice approach to water balance on storage, as outlined in Szabo et.al (2022).

The inflow to West Gellibrand Reservoir was calculated using a water balance on storage from 2005 to 2022 with the following equation:

$$Inflow = change\ in\ storage + releases\ to\ river + spill\ + Pipe\ extractions\ by\ Barwon\ Water - rainfall\ impact\ on\ storage + evaporation\ impact\ on\ storage$$

Where:

- River releases and spills from Gellibrand Reservoir are measured at gauge 235266 (Gellibrand River d/s West Gellibrand Dam)
- Pipe flow from West Gellibrand has been provided by BW (ME851 FLO01.ANA)
- Rain is the rainfall recorded or estimated at West Gellibrand Reservoir

Evaporation is the Morton's Shallow Lake Evaporation estimated at the Beech Forest rainfall gauge (090006). The inflow was extended prior to 2005 using a rainfall runoff model that was able to achieve a correlation of 0.82 and NSE of 0.67. The rainfall runoff model report card can be found in Appendix C as F18.

The inflow was not required to be further extended to cater for the model run period until June 2022. There are no historical catchment impacts that were required to be added back to the inflow to West Gellibrand Reservoir and the water balance on storage derived flow is representative of unimpacted flow.

4.2 G2 Inflow to Olangolah Weir

Similar to the inflow to West Gellibrand Reservoir, the inflow to Olangolah Weir was calculated by BW and HARC (2023). Similarly, the inflow to Olangolah Weir was calculated using a water balance on storage from 2005 to 2022:

$$Inflow = change\ in\ storage + releases\ to\ river + spill\ + Pipe\ extractions\ by\ Barwon\ Water - rainfall\ impact\ on\ storage + evaporation\ impact\ on\ storage$$

Where:

- River releases from Olangolah Weir and spills are measured at gauge 235267 (Olangolah Creek d/s Olangolah Reservoir)
- Pipe flow from Olangolah has been provided by BW (RE852)
- Rain is the rainfall recorded or estimated at West Gellibrand Reservoir
- Evap is the Morton's Shallow Lake Evaporation estimated at the Beech Forest rainfall gauge (090006)

The inflow was extended prior to 2005 using a rainfall runoff model that was able to achieve a correlation of 0.80 and NSE of 0.62. The rainfall runoff model report card can be found in Appendix C as F19.

The inflow is not required to be further extended to cater for the model run period until June 2022. There are no historical catchment impacts that were required to be added back to the inflow to Olangolah Weir and the water balance on storage derived flow is representative of unimpacted flow.

4.3 G3 Inflow to Gellibrand River downstream of Colac storages and Love Creek

G3 subcatchment represents the inflow to Gellibrand River main stem between West Gellibrand Reservoir, Olangolah Weir and Love Creek and is shown in Figure 4-4. This inflow was originally derived by BW and HARC (2024), however, the split of inflow at gauge 235236 and 235231 was included as part of the current project.

The reach balance has been derived as follows, with details of the derivation available in the subsequent sections:

G3 = Gauged flow at 235227 (Gellibrand River at Bunkers Hill) – Gauged flow at 235234 (Love Creek at Gellibrand) – Gauged flow at 235267 (Olangolah Creek downstream of the Olangolah Reservoir) – Gauged flow at 235266 (Gellibrand River downstream of the West Gellibrand Reservoir) – Gauged flow at 235210 (Lardner Creek at Gellibrand) + historic rural demands + groundwater pumping impacts

Given groundwater pumping impacts primarily occur above the confluence with Love Creek as a result of reduced inflows from Yahoo Creek (Section 3.1) the lumped subcatchment was split at gauge 235231 (Gellibrand River at Rafferty's Lane) and gauge 235236 (dam site). The lumped residual inflow was split as follows, with further details available in Section 4.3.4:

- G3a: Gellibrand River from Olangolah Weir/West Gellibrand Reservoir down to 235236= 44% of total G3 inflow
- G3b: Gellibrand River from 235236 to 235231 = 8% of total G3 inflow
- G3c Gellibrand River downstream of 235231 (Gellibrand River at Rafferty's Lane) and 235210 (Lardner Creek at Gellibrand) and Love Creek downstream of 235234 (Love Creek at Gellibrand) = 48% of total G3 inflow

Note that Charley's Creek is implicitly included in the derivation of residual flow to Gellibrand River. As there is no gauge available on Charley's Creek and minimal private diverters, it has not been separated out and explicitly represented.

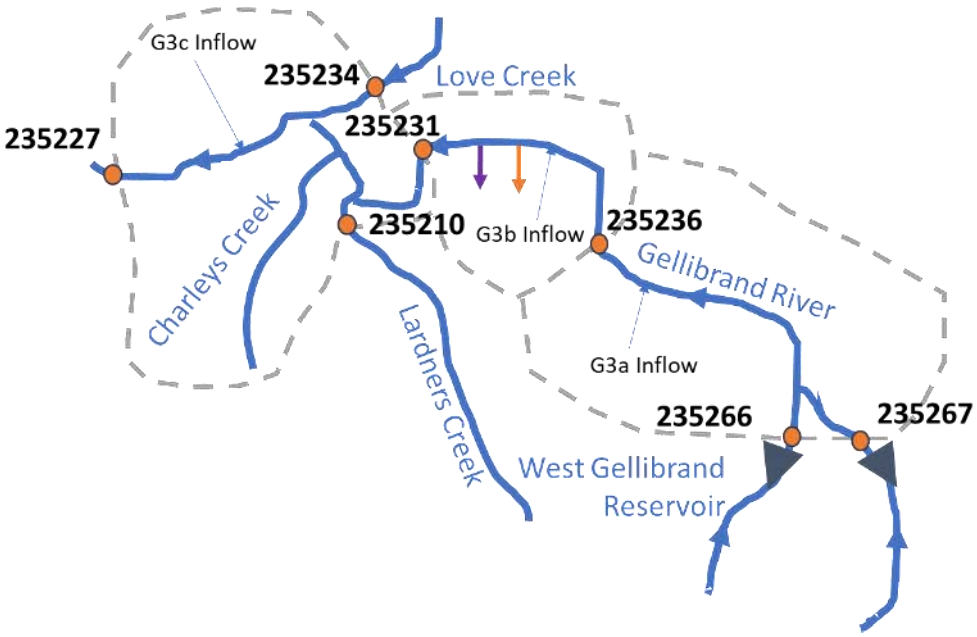


Figure 4-4 Schematic of the reach between Olangolah Weir, West Gellibrand Reservoir, Love creek and Gellibrand River at Bunkers Hill.

4.3.1 Critical input analysis

The streamflow gauges were checked by analysing the gaugings versus ratings plot to determine the uncertainty in gauged flows used in the reach balance analysis. The downstream gauge 235227 (Gellibrand River at Bunkers Hill) is well rated for all flows, as shown in Figure 4-5. The Love Creek gauge analysis is undertaken in Section 4.5 and the Lardner Creek gauge analysis in Section 4.8..

The upstream gauges in Gellibrand River that are directly downstream of Olangolah Weir and West Gellibrand Reservoir (235266 and 235267) show that the rating is extrapolated for flows above 200 ML/d (Figure 4-6 and Figure 4-7). Any anomalous reach balance results will be further investigated for the upstream flows above this magnitude.

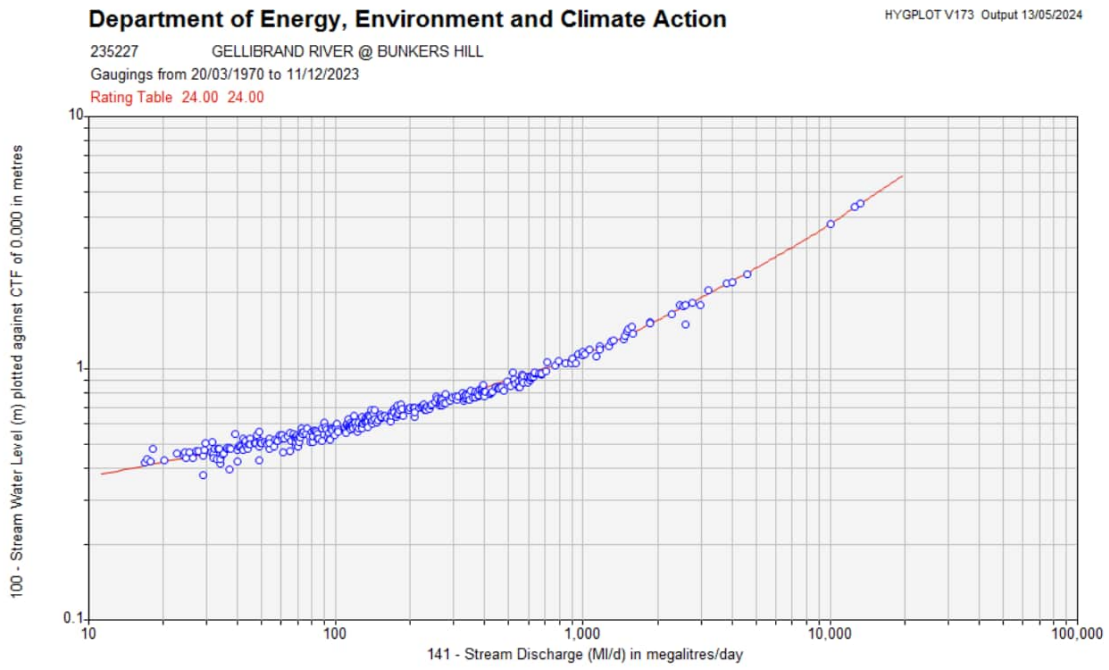


Figure 4-5 Gaugings vs ratings for 235227 (Gellibrand River at Bunkers Hill) - sourced from WMIS

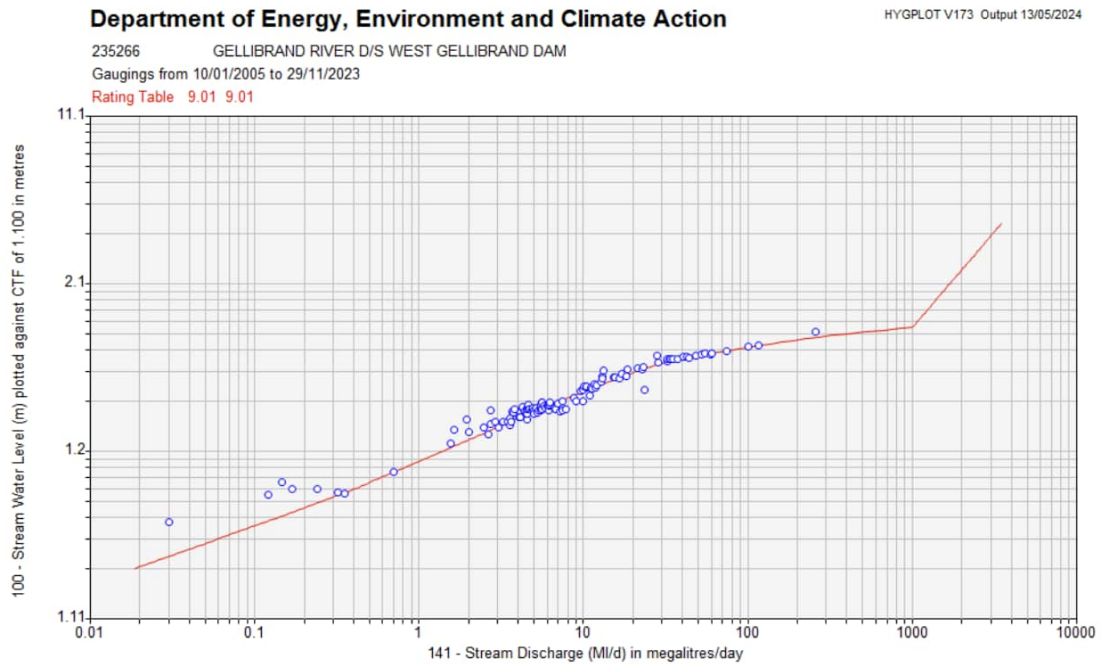


Figure 4-6 Gaugings vs ratings for 235266 (Gellibrand River downstream of the West Gellibrand Reservoir) - sourced from WMIS

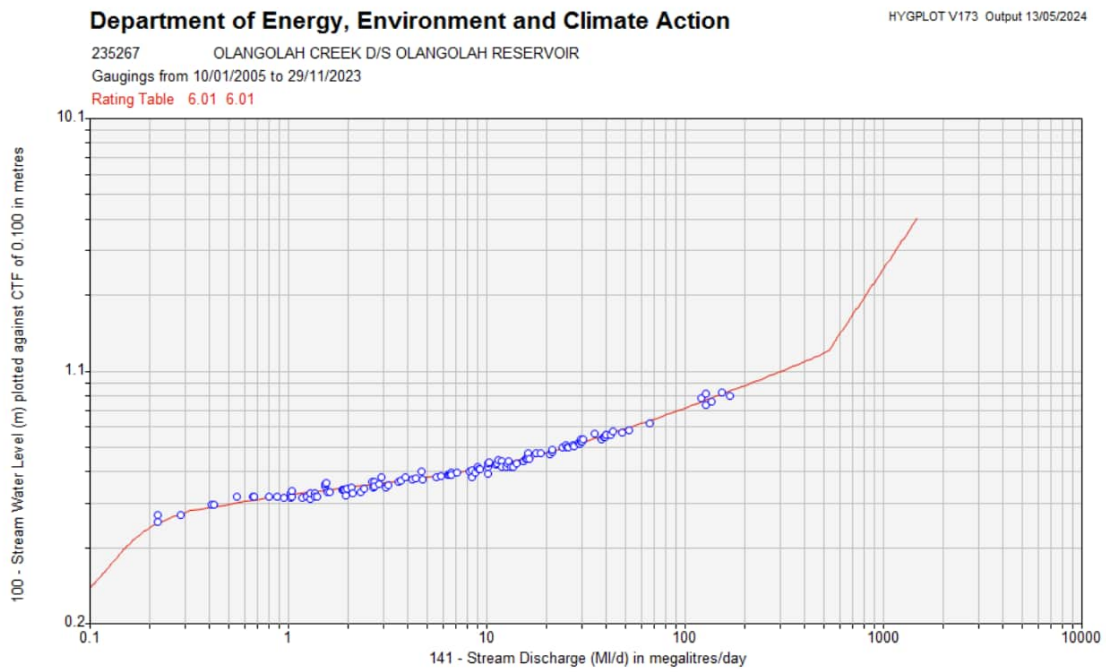


Figure 4-7 Gaugings vs ratings for 235267 (Olangolah Creek downstream of the Olangolah Reservoir - sourced from WMIS

4.3.2 Residual flow calculation

4.3.2.1 Flow routing

To calculate the residual inflow to Gellibrand River between the West Gellibrand Reservoir (235266), Olangolah Reservoir (235267), Love Creek at Gellibrand (235234) and Gellibrand River at Bunkers Hill (235227), the upstream flow was routed down to the downstream end of the reach by calculating the travel time between these locations.

Prior to the reach balance calculation, the following historic diversions were removed from the upstream end:

- Estimated historic groundwater pumping impact calculated in Section 3.1

The following rural demands were included in the downstream end of the reach balance:

- 27.2 ML/yr of stock and domestic demand
- 25.8 ML/yr of dairy demand
- 3.5 ML/yr of commercial and industrial demand

Off-stream winterfill demands were also considered during the reach balance and calculated as outlined in Section 3.2.1. Based on spatial analysis, these off-stream winterfill licences were extracting from the Gellibrand River main stem and closer to the downstream end of the reach.

The reach balance was setup as follows:

$Q_{upstream}$ = Q_{235266} + Q_{235267}+ Q_{235210}+ Q_{235234} - historic groundwater pumping impact
$Q_{downstream}$ = Q_{235227} + historic off-stream winterfill demands + historic rural demands

Concurrent data was available from 2005 to 2023. Travel time between upstream and downstream flows and the number of events in each flow range is shown in Figure 4-8.

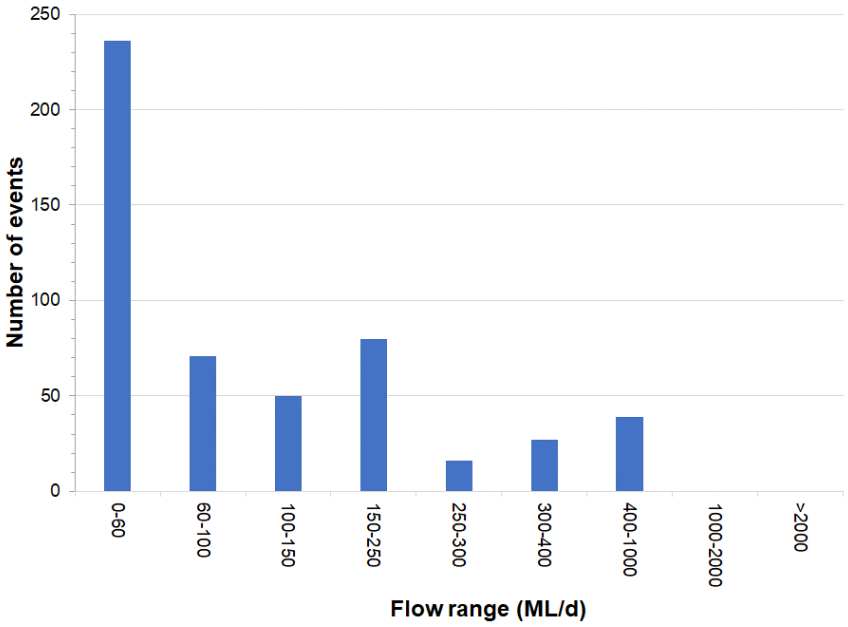


Figure 4-8 Histogram of flow events for Gellibrand River downstream of storages and Love Creek

A piecewise routing relationship derived for different flow groups is shown in Table 4-2.

Table 4-2 Travel time parameters for piecewise routing for Gellibrand River downstream of storages and Love Creek

Upstream Flow (235267 + 235266 + 235234) ML/d	Travel Time (days)
0	1.4
30	1.0
40	0.9
50	0.8
120	0.8
140	0.6
200	0.4
250	0.4
400	0.2
999999	0.2

4.3.2.2 Reach losses

During the development of the Gellibrand River Source model, it was found that a small loss was required downstream of the Love Creek and Gellibrand River confluence to achieve a satisfactory calibration between gauged and modelled flow in Gellibrand River at Bunkers Hill. The final loss adopted in the Gellibrand River Source model is summarised in Table 4-3.

Table 4-3 Gellibrand River loss function

Upstream flow (ML/d)	Loss (ML/d)
0	0
50	5
150	0

4.3.3 Rainfall runoff modelling

A Sacramento rainfall runoff model was initially calibrated using FORS to extend the G3 calculated residual flow prior to the reach balance period. Morton's Wet Areal Evaporation at the Gellibrand River Forestry gauge location (090134) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment (32% of Beech Forest rainfall gauge (090006) and 64% of Gellibrand River East rainfall gauge (090041)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-4, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

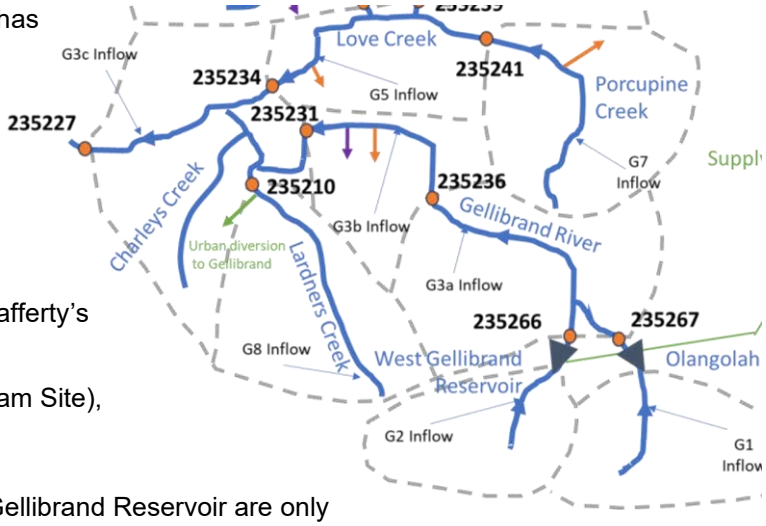
Whilst the Sacramento rainfall runoff model is able to produce better statistics, the GR4J rainfall runoff model has been adopted as it is able to produce a better flow duration curve comparison, and comparison to the flow pattern.

Table 4-4 Comparison of Sacramento and GR4J RR model fits for G3

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.89	0.88
Coefficient of determination (r^2)	0.80	0.78
NSE	0.79	0.77
Average annual observed flow (ML/yr)	41,634.1	41,634.1
Average annual modelled flow (ML/yr)	41,519.0	41,640.6
% bias	-0.3%	-0.0%
Flow duration curve fit?	Good flow duration curve fit	Very satisfactory flow duration curve fit
Time series fit?	Slight overestimation of droughts	Droughts and flow recessions are well modelled

4.3.4 Reach balance split

A mini Source model of the Gellibrand River has been used to verify the residual flow for G3 (Gellibrand River downstream of storages and Love Creek) and to refine the split of this inflow into three required for this project.



The inflow was split at two key gauges:

- Gauge 235231 (Gellibrand River at Rafferty's Lane), available from 2022 to 2023.
- Gauge 235236 (Gellibrand River at Dam Site), available from 1981 to 1990

Gauged releases from Olangolah Weir and Gellibrand Reservoir are only available from 2005 to date. Therefore, the gauged data was utilised to split the Gellibrand River inflow upstream of 235231. The inflow upstream of 235231 was then further split at gauge 235236 (refer to schematic in Figure 4-4) to better represent groundwater pumping impacts and so that flow at key environmental flow locations can be modelled.

Since the gauged releases from Olangolah Wier and Gellibrand Reservoir are not available over the gauged period for 235236 of 1981 to 1990, modelled releases based on current Barwon Water extractions and passing flow requirements were used to estimate the split of inflow upstream of gauge 235236. It is acknowledged that this estimate could be more refined if historic releases from storage were available.

The inflow split based on catchment area was refined to produce a better estimation of flow at 235231 and 235236 and as a result, G3 was split as follows:

- G3a: Gellibrand River from Olangolah Weir/West Gellibrand Reservoir down to 235236= 44% of total G3 inflow
- G3b: Gellibrand River from 235236 to 235231 = 8% of total G3 inflow
- G3c Gellibrand River downstream of 235231 (Gellibrand River at Rafferty's Lane) and 235210 (Lardner Creek at Gellibrand) and Love Creek downstream of 235234 (Love Creek at Gellibrand) = 48% of total G3 inflow

Modelled and gauged flow was compared at the following locations:

- Gellibrand River at Bunkers Hill at 235227 from 2005 to 2023
- Gellibrand River at Rafferty's Lane at 235231 from 2022 to 2023
- Gellibrand River at Dam Site at 235236 from 1981 to 1990

The gauged flow at 235231 (Gellibrand River at Rafferty's Lane) was used to verify the split of the Gellibrand River upstream and downstream of Love Creek confluence. The reach balance comparison at 235231 (Gellibrand River at Rafferty's Lane) and 235227 (Gellibrand River at Bunkers Hill) has been summarised in Table 4-5.

The split of the catchment at 235231 (Gellibrand River at Rafferty's Lane) shows that a 0% volume bias is able to be achieved, and correlation of 0.92. The time series comparison in Figure 4-9 shows that the magnitude of flow and flow pattern at 235231 (Gellibrand River at Rafferty's Lane) is able to be replicated.

A very good correlation was able to be achieved between modelled and gauged flow at 235227 (Gellibrand River at Bunkers Hill), with a correlation of 0.99 and volume bias of 0.8%. The comparison of modelled and gauged flow at 235227 (Gellibrand River at Bunkers Hill) produced a very satisfactory flow duration curve comparison (Figure 4-11). The time series was also checked for key droughts and found to be able to satisfactorily replicate the 2006/07 Drought (Figure 4-14).

As part of this project, an additional split was included at 235236 (Gellibrand River at Dam Site) to accommodate the estimation of flow at an additional environmental flow location. As shown in Table 4-5, over the comparison period of 1981 to 1990, a correlation of 0.78 and volume bias less than 1% was able to be achieved. The flow comparison in Figure 4-10 shows that the use of modelled releases from Olangolah Weir and West Gellibrand Reservoir in the absence of observed data is resulting in an underestimate of high flow releases by the model. However, the flow pattern is able to be replicated.

Table 4-5 Summary of reach balance comparison results between modelled and gauged flow

	235227 (Gellibrand River at Bunkers Hill)	235231 (Gellibrand River at Rafferty's Lane)	235236 (Gellibrand River at Dam Site)
Comparison Period	2005-2023	2022-2023	1981 - 1990
Correlation (r)	0.99	0.92	0.78
Coefficient of determination (r^2)	0.99	0.85	0.61
NSE daily	0.99	0.84	0.60
% Volume bias	0.8%	0.1%	0.6%

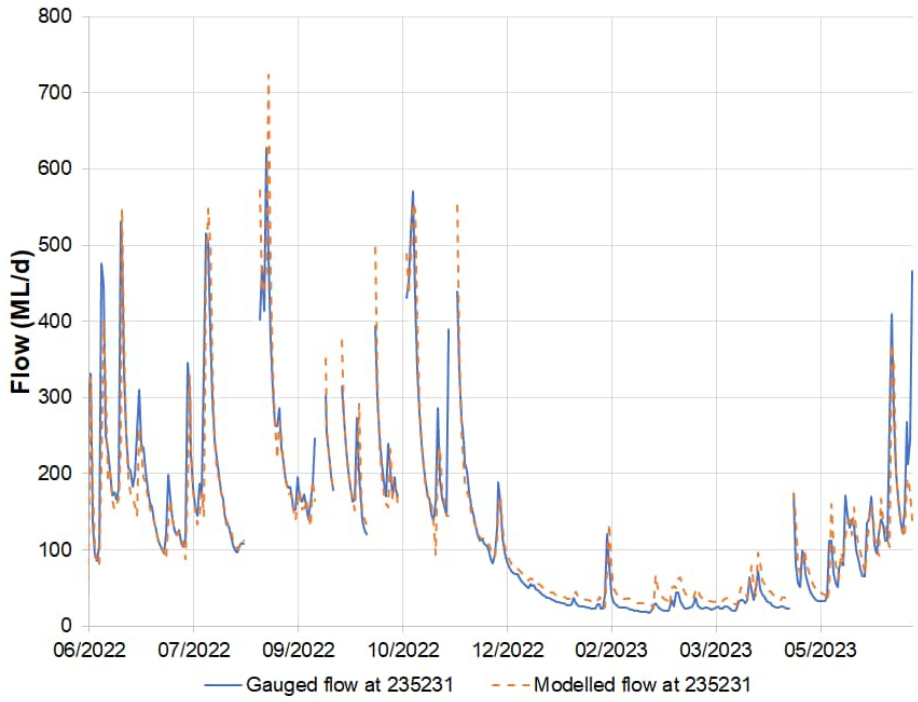


Figure 4-9 Comparison of gauged and modelled flow at 235231 (Gellibrand River at Rafferty's Lane)

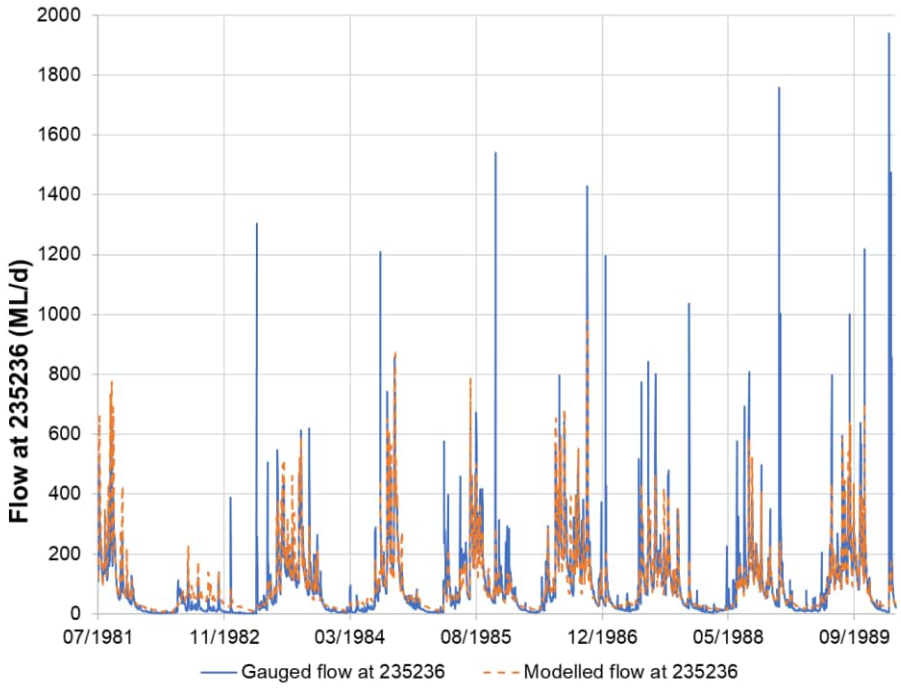


Figure 4-10 Comparison of gauged and modelled flow at 235236 (Gellibrand River d/s dam stie)

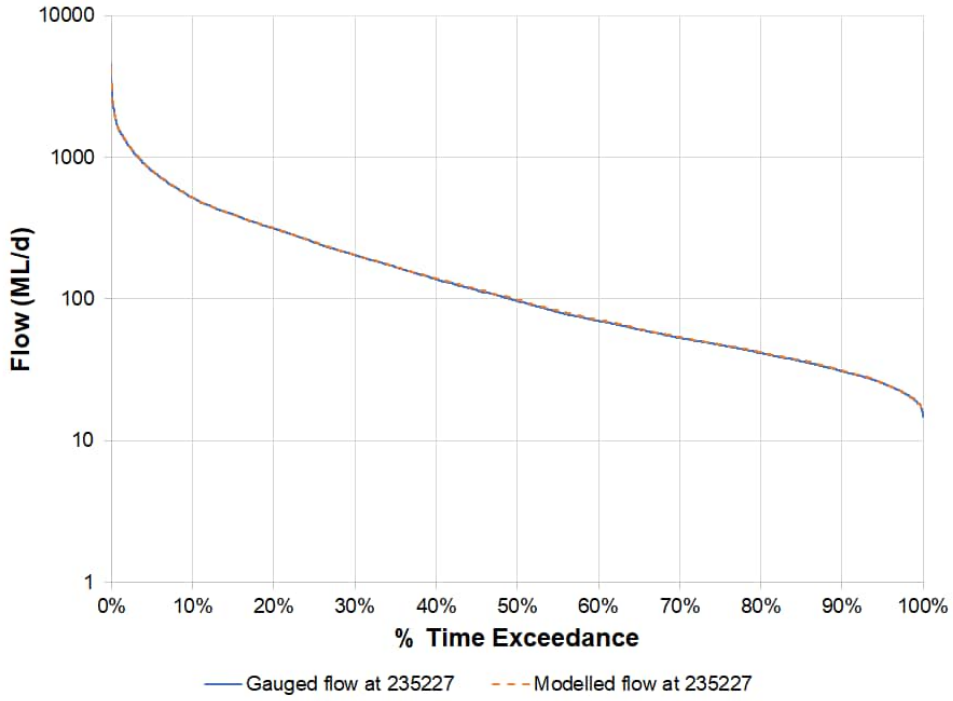


Figure 4-11 Flow duration curve comparison between gauged and modelled flow at 235227 (Gellibrand River at Bunkers Hill) calculated from 2005 to 2023

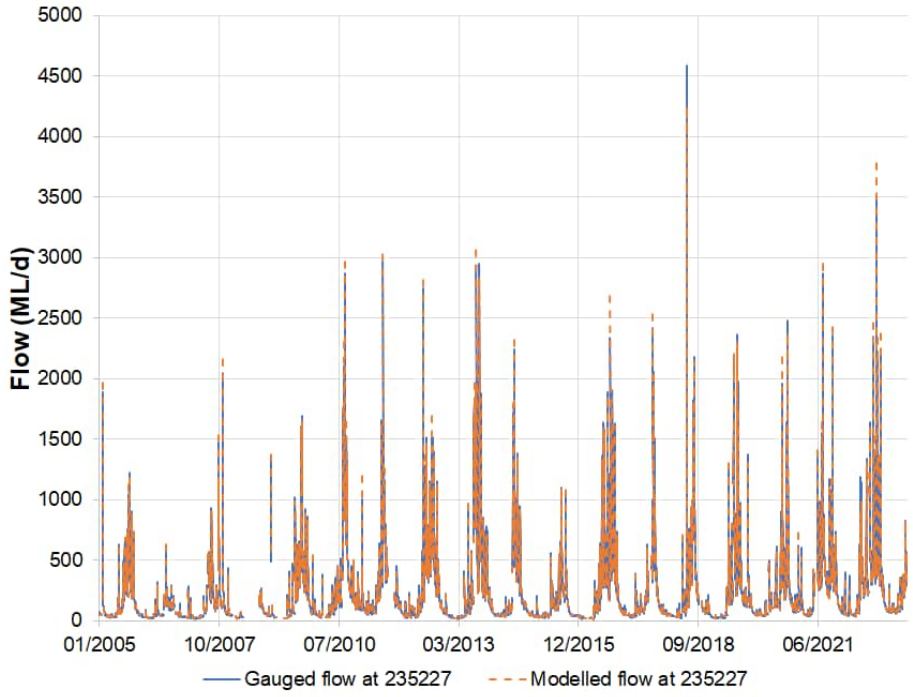


Figure 4-12 Comparison of gauged and modelled flow at 235227 (Gellibrand River at Bunkers Hill)

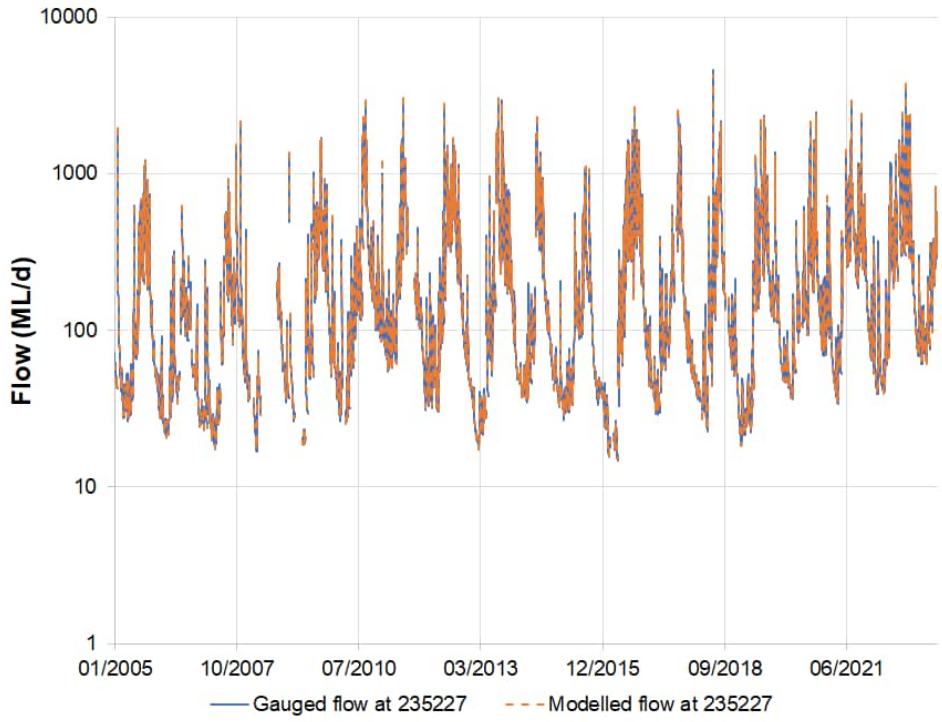


Figure 4-13 Comparison of gauged and modelled flow at 235227 (Gellibrand River at Bunkers Hill) – log

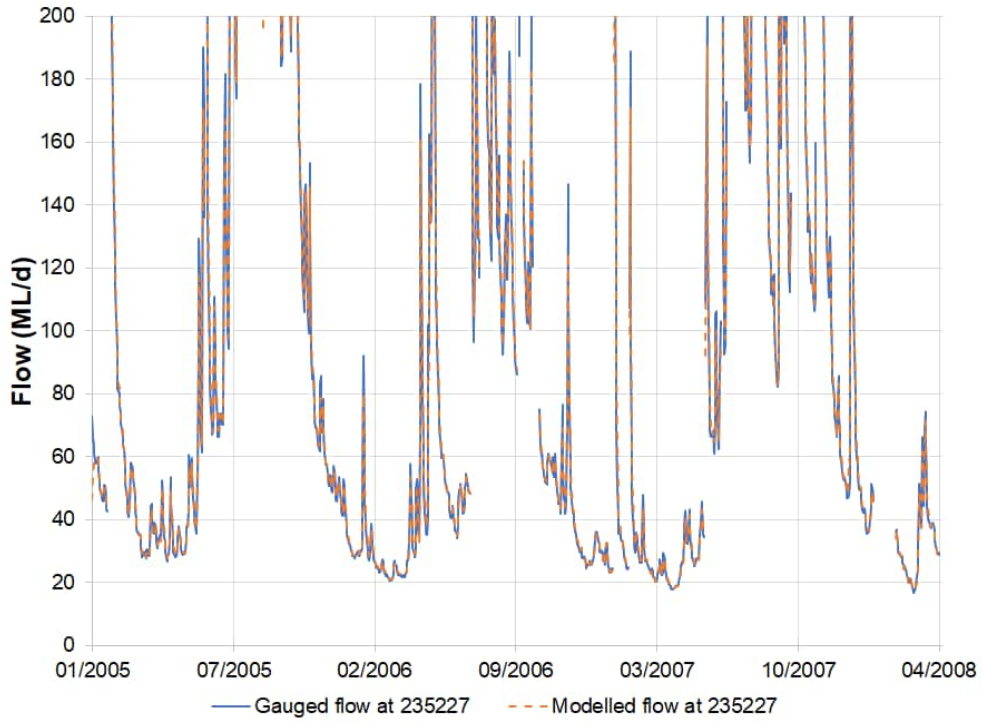


Figure 4-14 Comparison of gauged and modelled flow at 235227 (Gellibrand River at Bunkers Hill) for the 2006/07 Drought

4.4 G4 Yahoo Creek upstream of 235240

The inflow to Yahoo Creek is calculated using gauged flow 235240 (Yahoo Creek at Kawarren) and derived by BW and HARC (2024). Gauged flow is available from 1985 to 1996 and then again from 2018 to 2023. The gaugings vs ratings plot for 235240 (Yahoo Creek at Kawarren) in Figure 4-15 shows that flow in Yahoo Creek is not well rated above 100 ML/d. Neither of these data periods was recorded using daily staff readings.

Prior to rainfall runoff modelling, the following catchment impacts were added back to Yahoo Creek to derive partial natural flow (shown in Figure 4-16):

- Daily groundwater pumping impact as outlined in Table 3-1 in Section 3.1.2.1

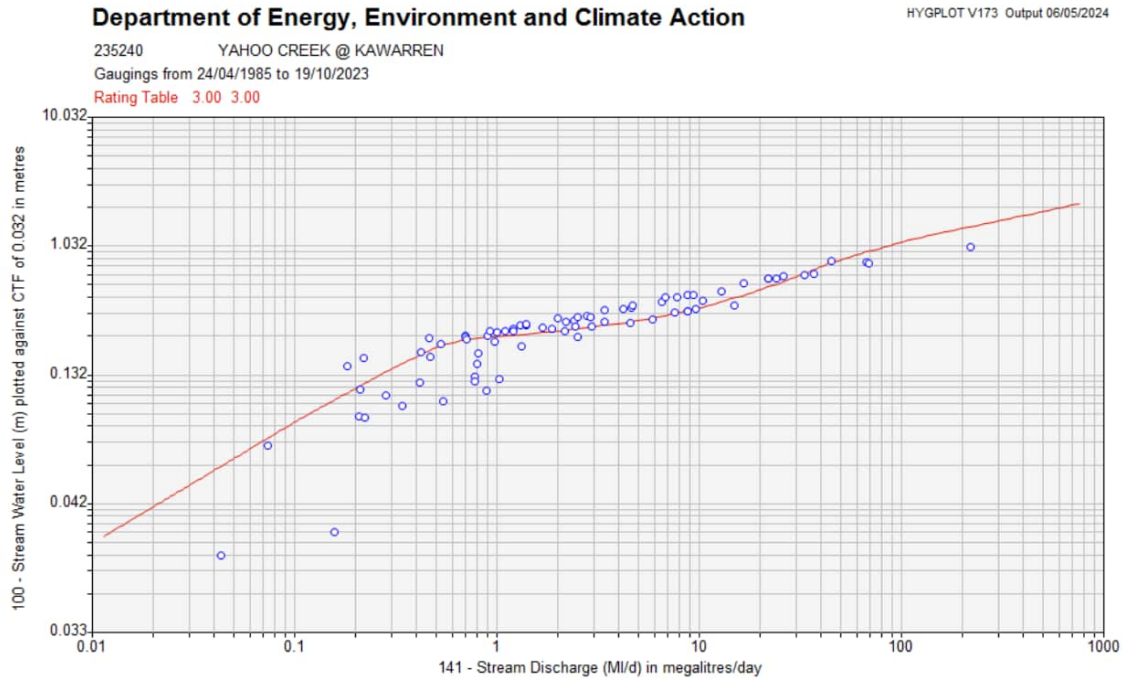


Figure 4-15 Gaugings vs Ratings plot for 235240 (Yahoo Creek at Kawarren)

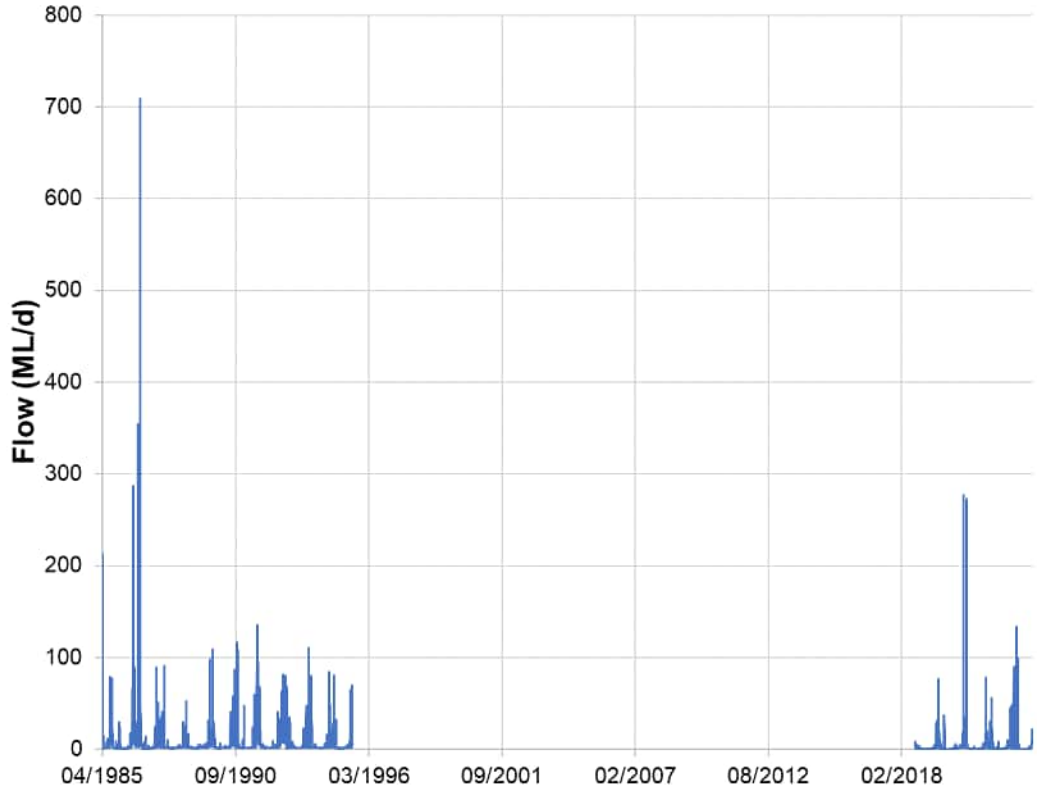


Figure 4-16 Partial natural flow at 235240 (Yahoo Creek at Kawarren)

A rainfall runoff model was used to extend and infill partial natural flow at 235240 (Yahoo Creek at Kawarren) over the period of 1985 to 2023. A Sacramento rainfall runoff model was initially calibrated using FORS over the entire available period to ensure that the rainfall weightings are optimised to the full dataset. Morton's wet areal evapotranspiration over land at the Gellibrand River Forestry gauge

location (090134) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment (8.5% of Gellibrand River Forestry rainfall gauge (090134), 26% of Kawarren rainfall (community data) and 51% of Colac (090174)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

During the preliminary rainfall runoff modelling process, anomalous flows above 250 ML/d in the 1980s (Figure 4-16) were removed from the rainfall runoff model as it did not match the pattern of rainfall (NSE < 0.3) and exceeded the rating table (Figure 4-15).

The statistics of both calibrations have been compared in Table 4-6, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the GR4J rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the GR4J rainfall runoff model has been adopted over the Sacramento model.

Table 4-6 Comparison of Sacramento and GR4J RR model fits for G4

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.75	0.83
Coefficient of determination (r^2)	0.56	0.69
NSE	0.48	0.63
Average annual observed flow (ML/yr)	1,783.6	1,980.6
Average annual modelled flow (ML/yr)	1,782.7	1,982.3
% bias	-0.1%	0.0%
Flow duration curve fit?	Slight mismatch with the flow duration curve comparison	Very satisfactory flow duration curve comparison
Time series fit?	Flow recession not well modelled	Droughts are well modelled

To derive unimpacted flow, the following was required to be added back to the extended gauged flow at Yahoo Creek:

- 20.5 ML of farm dam impacts as outlined in Section 3.3

4.4.1 Yahoo Creek gauged flow update

Since the inflow derivation of Yahoo Creek was undertaken by HARC (2025a), the gauged flow in Yahoo Creek at Kawarren (235240) has been revised by ALS to account for known issues that weren't picked up in the original QC process. This data has been recently downloaded and compared to the gauged flow used by HARC (2025a) that was extracted from WMIS in 2023. Over the concurrent period of 2018 to June 2022, there was a less than 0.2% difference in the mean annual flow between the two Yahoo Creek datasets.

As shown in Figure 4-17 and Figure 4-18, there are minimal differences between the two datasets. This shows that the rainfall runoff model calibrated by HARC (2025a) remains fit for purpose for extending and infilling partial natural flow in Yahoo Creek at Kawarren.

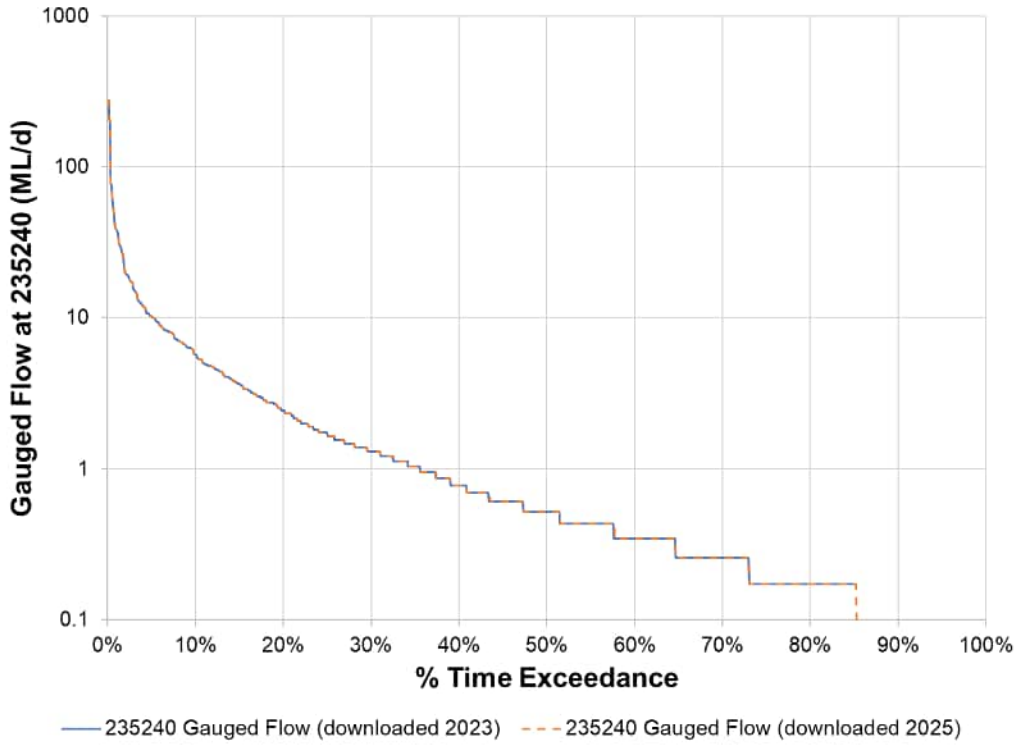


Figure 4-17 Flow duration curve comparison between 2023 and 2025 data for gauged flow in Yahoo Creek (calculated from 2018 to 2022)

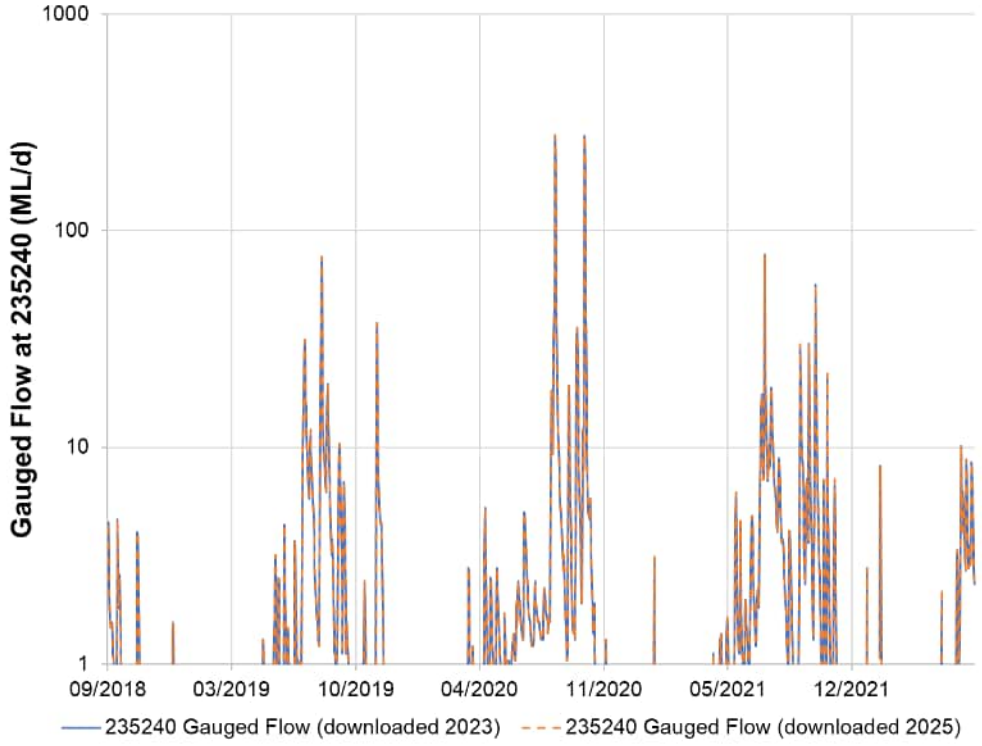


Figure 4-18 Log time series comparison between 2023 and 2025 data for gauged flow in Yahoo Creek

4.5 G5 Love Creek downstream of Yahoo Creek, Ten Mile Creek and Porcupine Creek

G5 subcatchment represents the inflow to Love Creek between Yahoo Creek, Porcupine Creek and Ten Mile Creek, and is shown in Figure 4-19. This inflow was derived by BW and HARC (2024).

The reach balance has been derived as follows, with details of the derivation available in the subsequent sections:

G5 = Gauged flow at 235234 (Love Creek at Gellibrand) – Gauged flow at 235239 (Ten Mile Creek at Kawarren) – Gauged flow at 235240 (Yahoo Creek at Kawarren)– Gauged flow at 235241 (Porcupine Creek at Kawarren) + historic rural demands

To be able to maximise the availability of gauged flow in Love Creek, the extended gauged flow in Yahoo Creek (Section 4.4), Porcupine Creek (Section 4.7) and Ten Mile Creek (Section 4.6) have been utilised.

The following historic rural demands were added back to the reach balance to calculate the residual flow:

- 2.2 ML of domestic and stock (Section 3.2)
- 11 ML of dairy (Section 3.2)

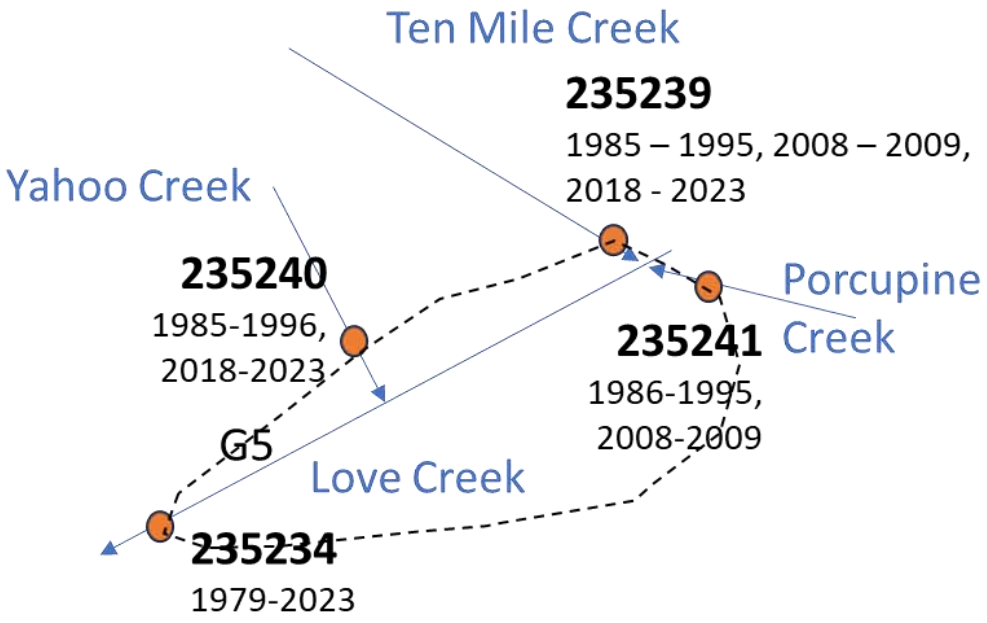


Figure 4-19 Schematic of Love Creek

4.5.1 Critical input analysis

The streamflow gauges were checked by analysing the gaugings versus ratings plot to determine the uncertainty of gauged flows. The upstream gauges are analysed in the subsequent tributary inflow sections. The gaugings versus ratings plot for 235234 *(Love Creek at Gellibrand)* in Figure 4-20 shows

that the gauged is not well gauged for flows less than 1 ML/d and the rest of the flow magnitudes are well rated.

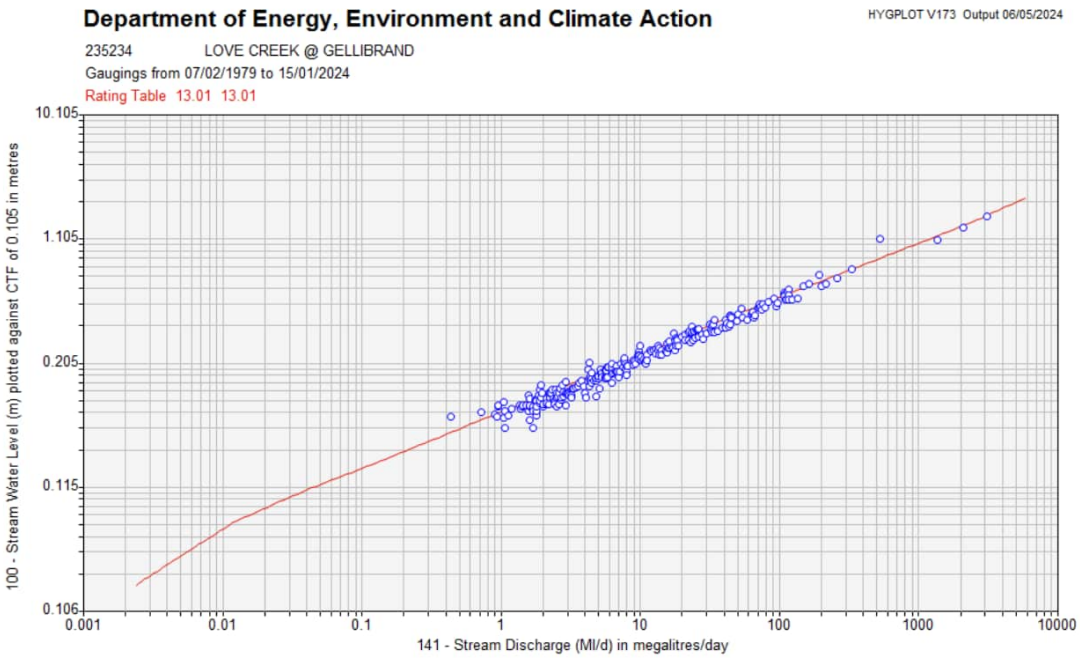


Figure 4-20 Gaugings vs Ratings plots for 235234 *(Love Creek at Gellibrand)*

4.5.2 Residual flow calculation

4.5.2.1 Flow routing

To calculate the residual inflow to Love Creek between Ten Mile Creek (235239), Porcupine Creek (235241) and Yahoo Creek (235240). The reach balance was setup as follows:

$Q_{upstream} = Q_{235239} + Q_{235241} +$ historic rural demands
$Q_{downstream} = Q_{235234} - Q_{235240}$

Concurrent data was available from 1979 to 2022. The upstream flow was routed down to the downstream end of the reach by calculating the travel time between these locations. It was found that there was no lag in the subcatchment, with a travel time of zero calculated.

4.5.2.2 Reach losses

The reach losses for Love Creek were calculated using the reach balance check in Section 4.5.4 and is summarised in Table 4-7.

Table 4-7 Love Creek loss table

Upstream flow (ML/d)	Loss (ML/d)
0	0.0
2	1.8
3	1.9
5	2.2
10	2.5
20	0.0
50	0.0

4.5.3 Rainfall runoff modelling

A Sacramento rainfall runoff model was initially calibrated using FORS to extend the G5 calculated residual flow prior to the reach balance period. The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The calibration statistics for the Sacramento and GR4J rainfall runoff models can be found in Table 4-8, and it was found that the rainfall runoff model calibrations were unsatisfactory.

A transposition of upstream gauged flow was instead investigated in Section 4.5.4.

Table 4-8 Comparison of Sacramento and GR4J RR model fits for G5

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.59	0.53
Coefficient of determination (r^2)	0.35	0.28
NSE	0.30	0.08
Average annual observed flow (ML/yr)	2,239.8	2,239.8
Average annual modelled flow (ML/yr)	2,240.9	2,242.2
% bias	0.0%	0.1%

4.5.4 Source reach balance check

A Source model of Love Creek, as shown in Figure 4-21, was used to transpose partial natural flow at an upstream gauge until a good comparison was able to be achieved for 235234 (Love Creek at Gellibrand). The gauged flow for Yahoo Creek, Ten Mile Creek and Porcupine Creek was configured as the upstream tributary inflows and all tested until a suitable transposition was achieved.

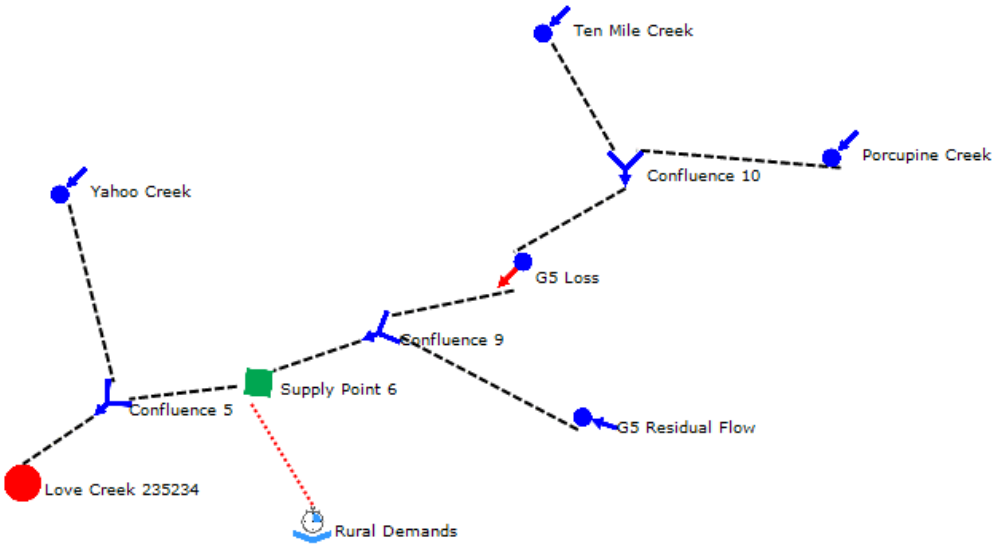


Figure 4-21 Love Creek between 235234 and Ten Mile Creek, Porcupine Creek and Yahoo Creek

It was found that the best transposition of upstream flow to represent the residual flow to Love Creek was:

G5 = 1.15 x Partial natural flow for G6

The reach balance comparison in Love Creek at 235234 (Love Creek at Gellibrand) has been summarised in Table 4-9. A good correlation was able to be achieved between modelled and gauged flow at 235234 with the transposition of Ten Mile Creek flow, with a correlation of 0.92 and volume bias of 0.0%. The very satisfactory flow duration curve comparison can be found in Figure 4-22. The time series was also checked for key droughts and found to be able to satisfactorily replicate the 2006/07 Drought (Figure 4-25).

Table 4-9 Summary of reach balance comparison results between modelled and gauged flow

	Love Creek at 235234 (Love Creek at Gellibrand)
Comparison Period	1979-2022
Correlation (r)	0.92
Coefficient of determination (r^2)	0.84
NSE daily	0.84
Average annual gauged flow (ML/yr)	7,841
Average annual modelled flow (ML/yr)	7,844
% Volume bias	0.0%

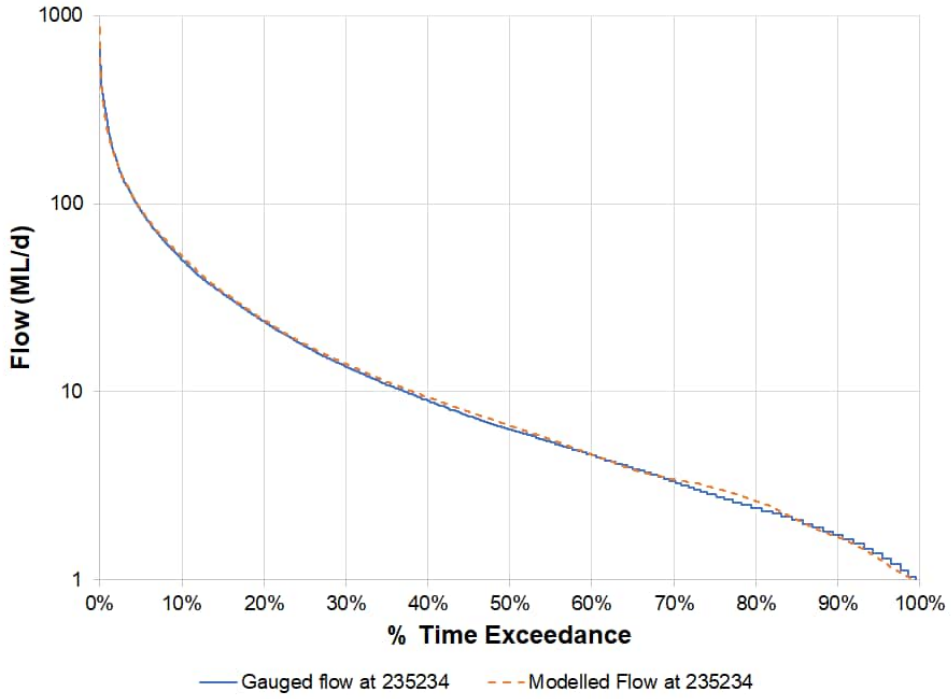


Figure 4-22 Flow duration curve comparison between gauged and modelled flow at 235234 (Love Creek at Gellibrand) calculated from 1979 to 2022

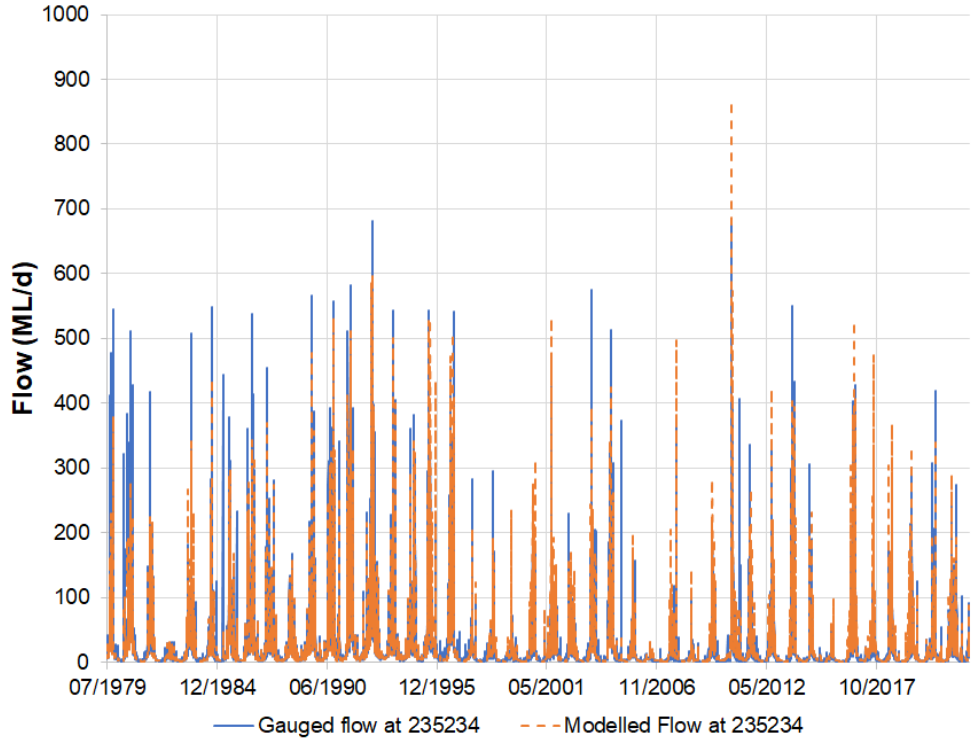


Figure 4-23 Comparison of gauged and modelled flow at 235234 (Love Creek at Gellibrand)

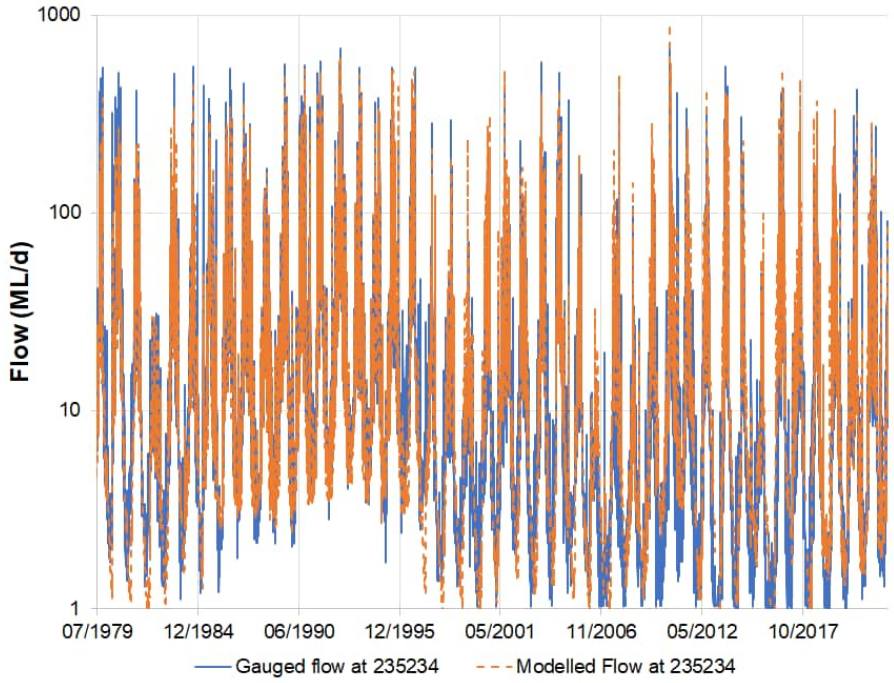


Figure 4-24 Comparison of gauged and modelled flow at 235234 (Love Creek at Gellibrand) – log

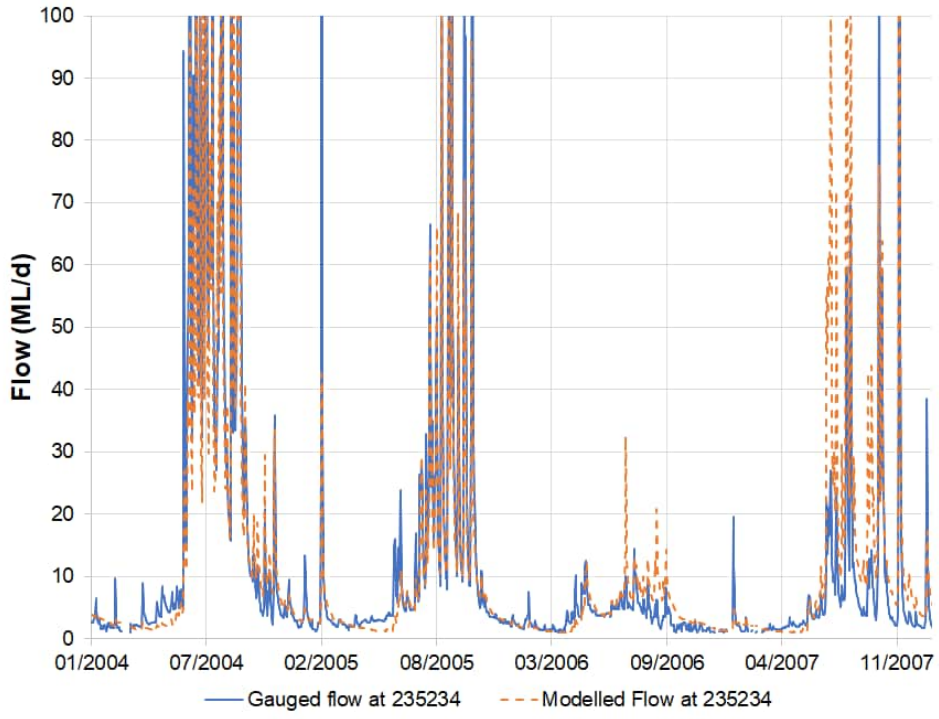


Figure 4-25 Comparison of gauged and modelled flow at 235234 (Love Creek at Gellibrand) for the 2006/07 Drought

4.6 G6 Ten Mile Creek upstream of 235239

The inflow to Ten Mile Creek is calculated using gauged flow at (235239 (Ten Mile Creek at Kawarren). Gauged flow is available from 1985 to 1995, briefly in 2008, and then again from 2018 to 2023 (as shown in Figure 4-26). Neither of these data periods was recorded using daily staff readings. This inflow was derived by BW and HARC (2024).

The gaugings vs ratings plot for 235239 (Ten Mile Creek at Kawarren) in Figure 4-27 shows that flow in Ten Mile Creek is well rated above 100 ML/d.

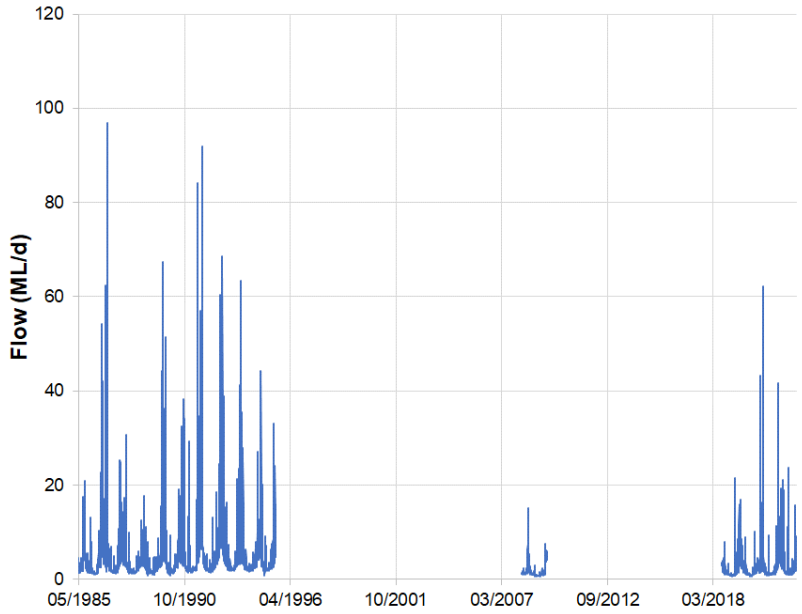


Figure 4-26 Gauged flow at 235239 (Ten Mile Creek at Kawarren)

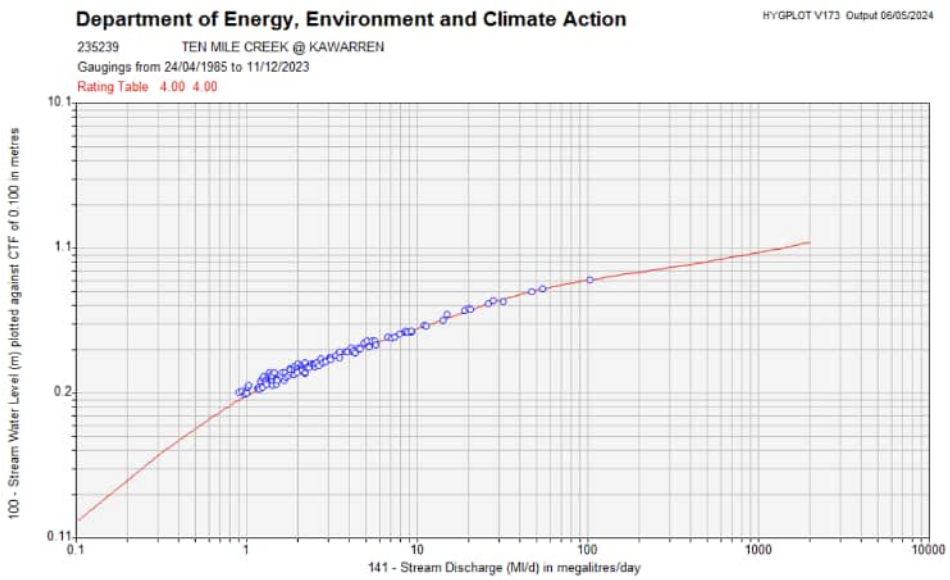


Figure 4-27 Gaugings vs Ratings plot for 235239 (Ten Mile Creek at Kawarren)

A rainfall runoff model was used to extend and infill gauged flow at 235239 (Ten Mile Creek at Kawarren). No rural demands or groundwater pumping impacts were required to be added back to gauged flow prior to rainfall runoff modelling.

A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to the gauge period and in the gap between 1996 and 2018. Morton's wet areal evapotranspiration over land at 090134 (Gellibrand River Forestry) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment (30% of Kawarren rainfall and 59% of Colac (090174)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-10, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the GR4J rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the GR4J rainfall runoff model has adopted over the Sacramento model.

Overall, there seems to be a higher base flow in the earlier period pre Millennium Drought (Figure 4-28), which has not bounced post Millennium Drought (Figure 4-29). As a result, the rainfall runoff model is underestimating the earlier flow period and slightly overestimating current flows. It should be noted that any inaccuracy in this will be captured in the residual flow downstream (G5 Love Creek upstream of 235234 (Love Creek at Gellibrand)). The recent period of 4 years is not a long enough period for a valid rainfall runoff model to be calibrated to the drier flow.

Table 4-10 Comparison of Sacramento and GR4J RR model fits for G6

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.80	0.83
Coefficient of determination (r^2)	0.63	0.70
NSE	0.59	0.65
Average annual observed flow (ML/yr)	1,405.9	1,405.9
Average annual modelled flow (ML/yr)	1,405.9	1,405.8
% bias	0.0%	0.0%
Flow duration curve fit?	Slight mismatch in the flow duration curve	Flow duration curve is well modelled
Time series fit?	Low flow pattern is not well modelled	Flow pattern is well modelled

To derive unimpacted flow, the following was required to be added back to the extended partial natural flow at Ten Mile Creek:

- 33.8 ML of farm dam impacts as outlined in Section 3.3

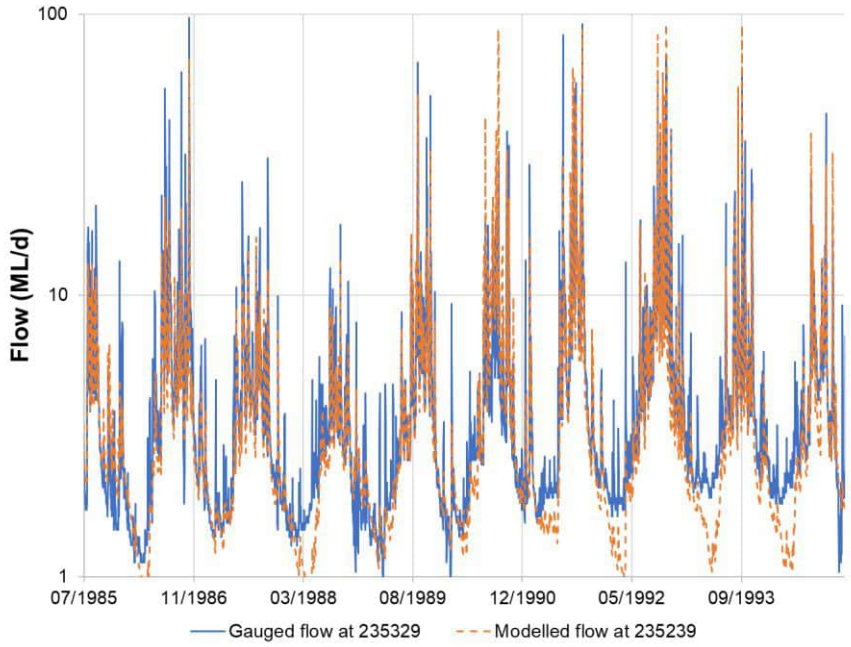


Figure 4-28 Comparison of gauged and modelled flow 235239 (Ten Mile Creek at Kawarren) (log scale) from 1985 to 1995

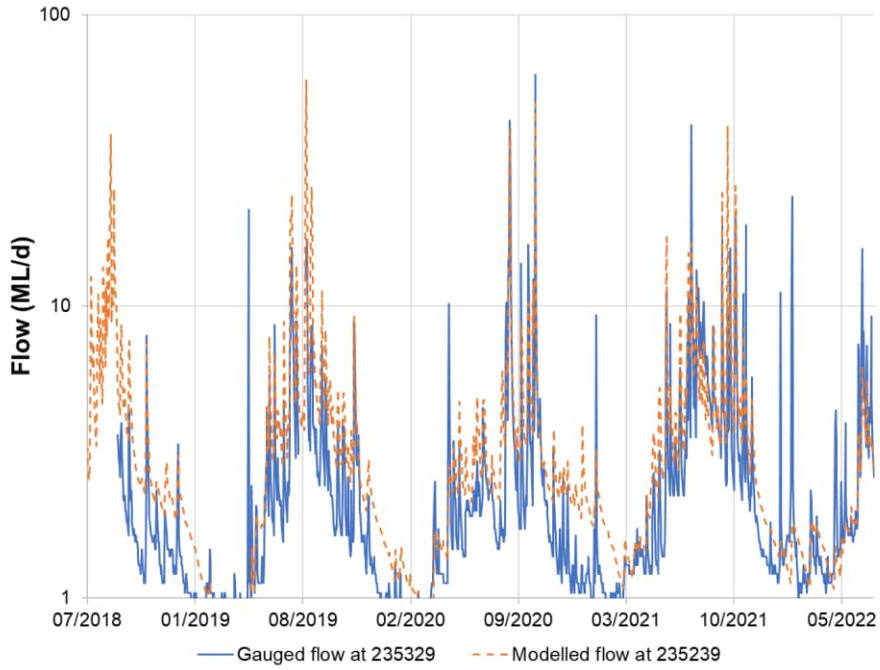


Figure 4-29 Comparison of gauged and modelled flow at 235239 (Ten Mile Creek at Kawarren) (log scale) from 2018 to 2022

4.7 G7 Porcupine Creek upstream of 235241

The inflow to Porcupine Creek is calculated using gauged flow at 235241 (Porcupine Creek at Kawarren). Gauged flow is available from 1985 to 1995, and then briefly in 2008 (as shown in Figure 4-30). This inflow was derived by BW and HARC (2024).

The gaugings vs ratings plot for 235241 in Figure 4-31 shows that flow in Porcupine Creek is not well rated above 500 ML/d. Given that the flows are unrated above 500 ML/d, the flow above 600 ML/d in 1986 was removed from the time series after the preliminary rainfall runoff modelling resulted in a mismatch of high flows.

Prior to rainfall runoff modelling, the following was added back to Porcupine Creek to derive partial natural flow:

- 4.4 ML of dairy demand (Section 3.2).

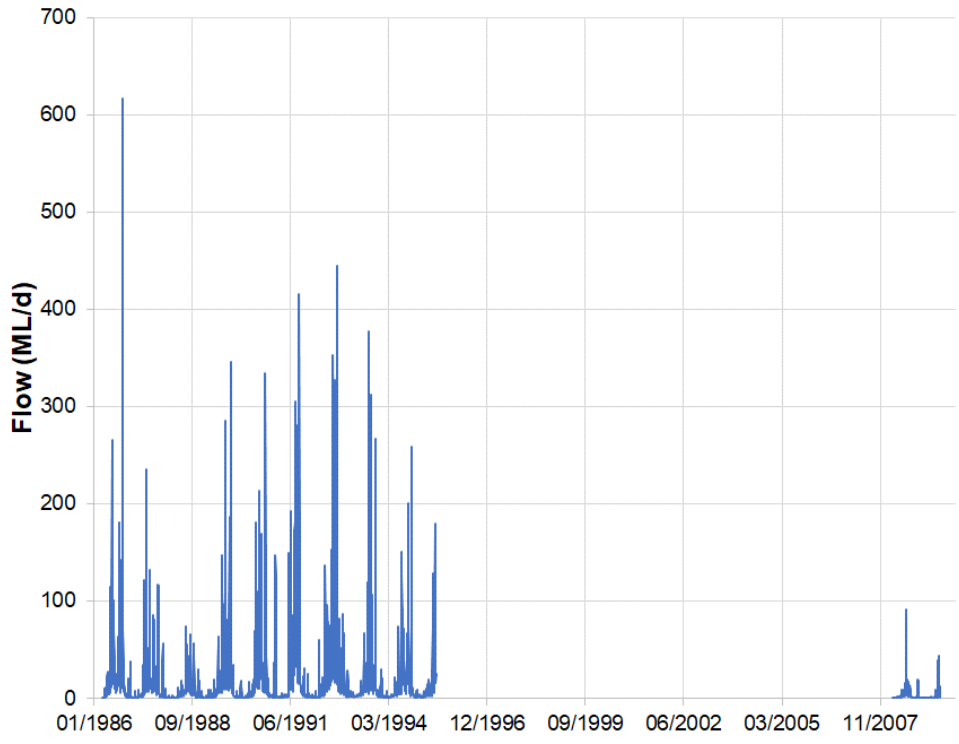


Figure 4-30 Gauged flow in Porcupine Creek at 235241 (Porcupine Creek at Kawarren)

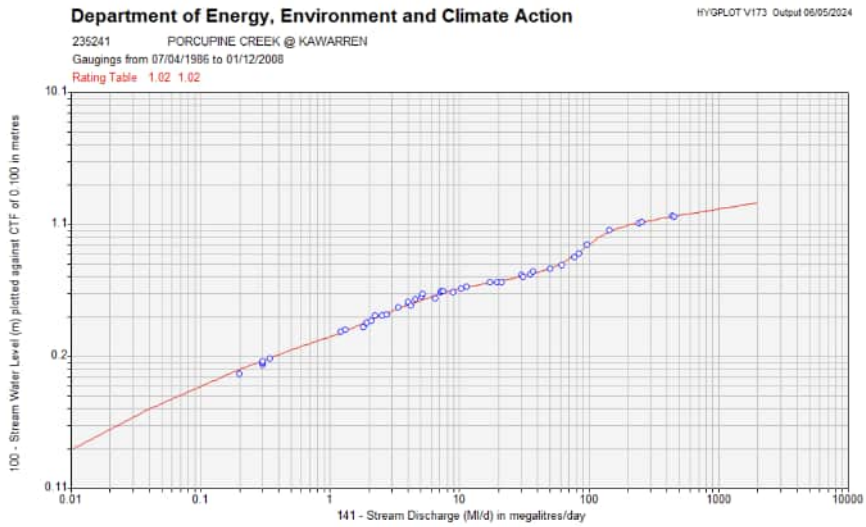


Figure 4-31 Gaugings vs Ratings plot for 235241 (Porcupine Creek at Kawarren)

A rainfall runoff model was used to extend and infill gauged flow at 235241 (Porcupine Creek at Kawarren). A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to and after the gauge period. Morton's wet areal evapotranspiration over land at 090134 (Gellibrand River Forestry) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment (8.5% of Gellibrand River Forestry (090134), 26% of Kawarren rainfall and 51% of Colac (090174)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-11, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the GR4J rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the GR4J rainfall runoff model has been adopted over the Sacramento model.

Table 4-11 Comparison of Sacramento and GR4J RR model fits for G7

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.89	0.92
Coefficient of determination (r^2)	0.79	0.85
NSE	0.77	0.84
Average annual observed flow (ML/yr)	5,481.1	5,481.1
Average annual modelled flow (ML/yr)	5,480.2	5,481.2
% bias	0.0%	0.0%
Flow duration curve fit?	Satisfactory flow duration curve comparison	Satisfactory flow duration curve comparison
Time series fit?	Flow recessions are overestimated	Flow pattern well modelled

To derive unimpacted flow, the following was required to be added back to the extended gauged flow at Porcupine Creek:

- 59.5 ML of farm dam impacts as outlined in Section 3.3.

4.8 G8 Lardner Creek upstream of 235210

The inflow to Lardner Creek is calculated using gauged flow at 235210 (Lardner Creek at Gellibrand). Gauged flow is available from 1964 to 2023 (as shown in Figure 4-32). The gaugings vs ratings plot for 235210 in Figure 4-33 shows that there have been a number of rating curves developed over time. This inflow was derived by BW and HARC (2024).

The Barwon Water extractions from Lardner Creek to Gellibrand are required to be added back to gauged flow in Lardner Creek at Gellibrand. Raw water extractions are available from 2001 to 2023, as provided by Barwon Water (WP853- Figure 4-34). As shown in Figure 4-35, the magnitude of the Barwon Water extractions compared to low flows in Lardner's Creek is very small. Given that gauged flow in Lardner's Creek is available from 1964 to 2023, the Barwon Water extractions from Lardner's Creek have been extended prior to 2001 using the demand regression outlined in Section 3.4.

Prior to rainfall runoff modelling, the following was added back to Lardner Creek to derive partial natural flow:

- 6 ML of dairy demand (Section 3.2).
- 2.2 ML of domestic and stock (Section 3.2)

The final equation for calculating partial natural flow in Lardner Creek at Gellibrand (Subcatchment G8) is:

Inflow to Lardners Creek = Gauged flow at 235210 + Barwon Water urban extractions + historic rural demands

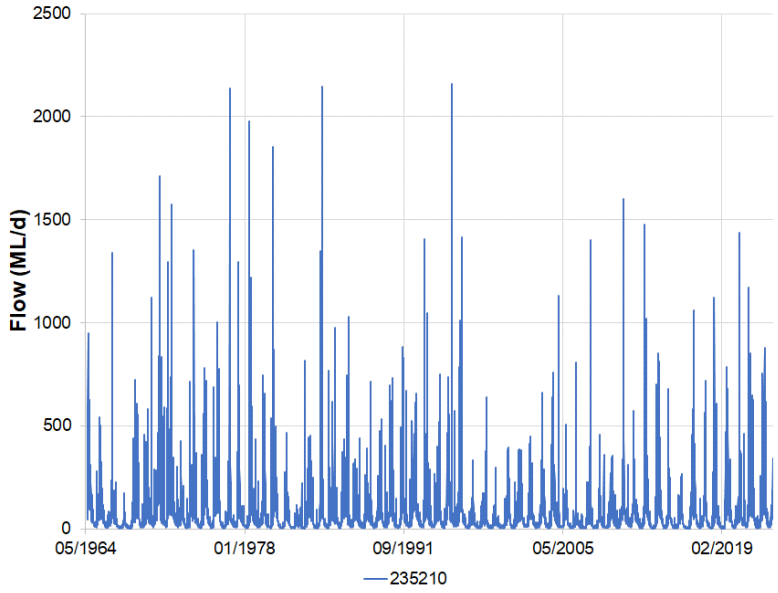


Figure 4-32 Gauged flow in Lardner Creek at 235210 (Lardner Creek at Gellibrand)

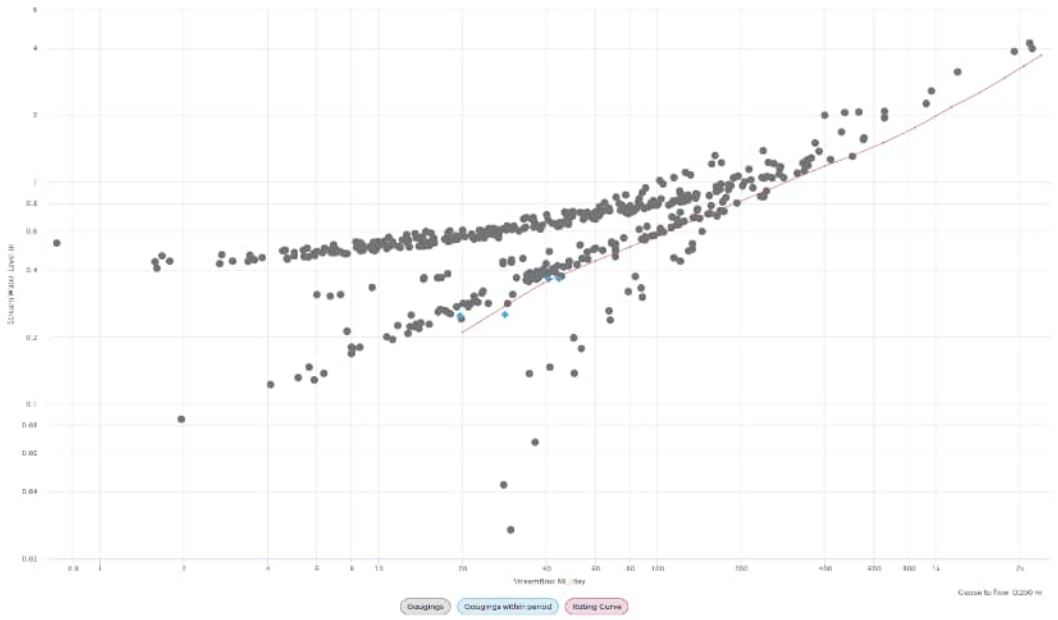


Figure 4-33 Gaugings vs Ratings plot for 235210 (Lardner Creek at Gellibrand)

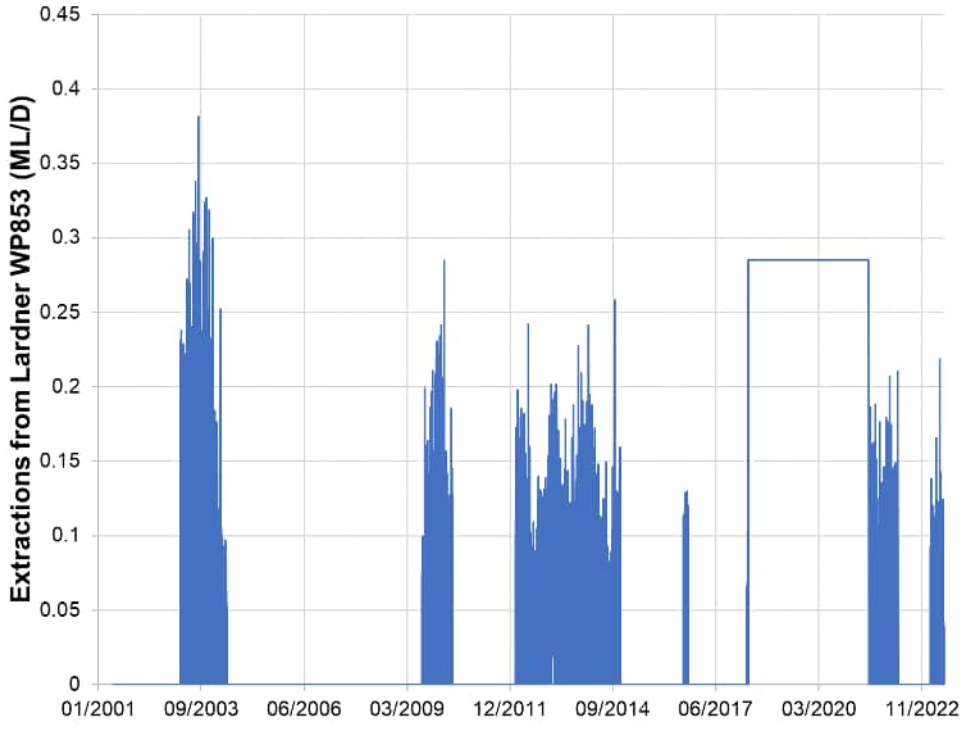


Figure 4-34 Extractions from Lardner Creek to Gellibrand- BW gauge WP853

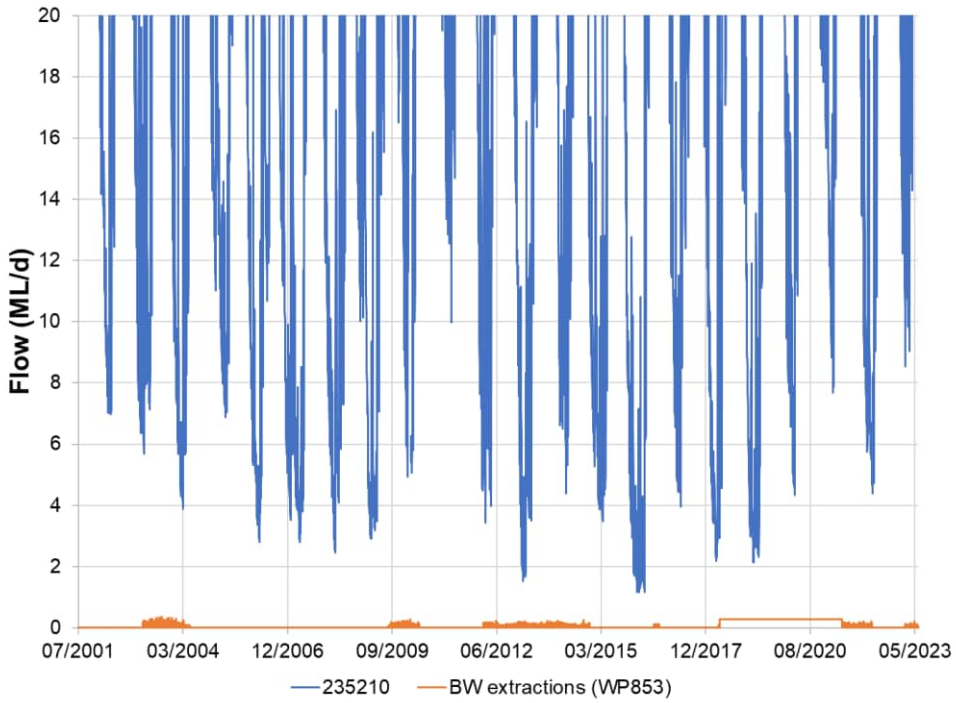


Figure 4-35 Comparison of gauged flow at 235210 (Lardner Creek) and Barwon Water extractions

A rainfall runoff model was used to extend and infill gauged flow at 235210 (Lardners Creek at Gellibrand). A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to and after the gauge period. Morton's wet areal evapotranspiration over land at 090134 (Gellibrand River Forestry) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment ((35% of Beech Forest rainfall gauge (090006) and 69% of Gellibrand River East rainfall gauge (090041)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-12, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the GR4J rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the GR4J rainfall runoff model has been adopted over the Sacramento model.

Table 4-12 Comparison of Sacramento and GR4J RR model fits for G8

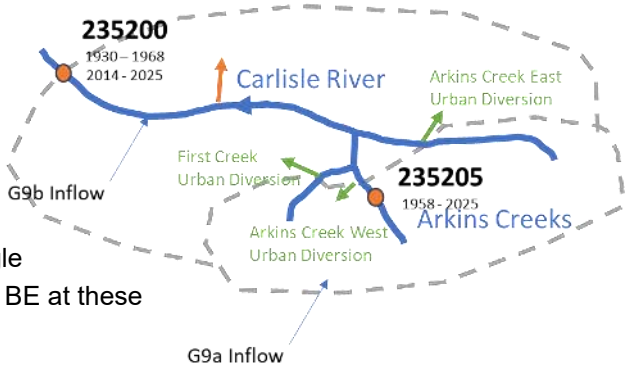
Statistics	Sacramento RR model	GR4J RR model
Correlation	0.89	0.90
Coefficient of determination (r^2)	0.79	0.80
NSE	0.78	0.80
Average annual observed flow (ML/yr)	22,902.4	22,902.4
Average annual modelled flow (ML/yr)	22,904.6	22,900.4
% bias	0.0%	0.0%
Flow duration curve fit?	Satisfactory flow duration curve comparison	Satisfactory flow duration curve comparison
Time series fit?	Flow recessions are overestimated, slight over estimation of droughts	Flow pattern well modelled, slight overestimation of droughts

To derive unimpacted flow, the following was required to be added back to the extended gauged flow at Lardners Creek:

- 14 ML of farm dam impacts as outlined in Section 3.3.

4.9 G9 Carlisle River upstream of 235200

Carlisle River is a key tributary of the Gellibrand River upstream of the North Otway Pump Station. Wannon Water diverts from First Creek and Arkins Creek East and West at the top of the Carlisle River catchment. Wannon Water diverts any available water from these creeks and therefore, it was appropriate to lump the inflow upstream of the 3 urban diversion points into a single inflow (G9a). There is no passing flow requirement in the BE at these diversion points.



As outlined in the review report, the Carlisle River inflows upstream and downstream of the diversion weirs has been calculated as follows:

- A daily rainfall runoff model was calibrated to gauged flow at 235205 to derive flow from 1900 to 2025
- The 235205 inflow was transposed across to the catchment upstream of Arkins East and First Creek diversion weirs by proportion of catchment area. This derived the G9a inflow.
- G9b inflow was calculated as reach balance between G9a (total inflow to Arkins East and West, and First Creek diversion weirs) and gauged flow at 235200. It is acknowledged that the urban diversions are embedded in the gauged flow data and implicitly accounted for.
- A daily rainfall runoff model was calibrated the calculated reach balance derived inflow to G9b (1930 – 1968 and 2014 – 2025)
- A Source model is developed from 2014 to 2025 with historic river diversions, estimated inflow upstream of the diversion weirs, estimated travel time and losses. This reach balance check is used to check the derivation of G9b inflow by comparing modelled and gauged flow at the downstream end, 235200.

4.9.1 Critical input analysis

4.9.1.1 Streamflow data

Data is available on WMIS at 235200 from 1930 to 1968. More recent data is available from Southern Rural Water at gauge 235200C from 2014 to 2025. The Carlisle River dataset in Figure 4-36 is shown to be consistent between the two datasets. No gauging versus rating curve is available for 235200C. This was confirmed with SRW (pers. comm L. Snow, 7/5/2025), noting that SonTek IQ instrumentation is used to acquire level and flows. The device is placed on the stream and uses velocity beams and a pressure sensor to measure water. The beam and sensor work together to measure level and from the preloaded cross section it determines a flow rate.

Gauged flow in Arkins Creek West Branch at Wyelangta (235205) is available from 1958 to 2025. The gaugings versus ratings plot in Figure 4-37 shows that the gauge is well rated for flows less than 400 ML/d. As shown in Figure 4-38, the flow in Arkins Creek West Branch is less than 400 ML/d and is therefore, considered good quality data.

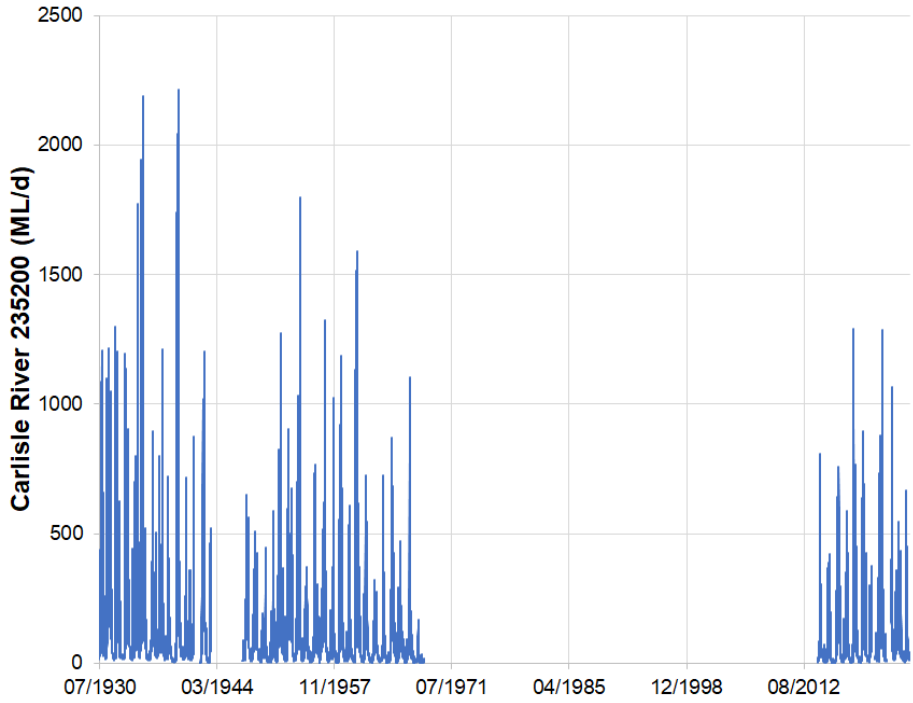


Figure 4-36 Streamflow in Carlisle River at Carlisle (235200)

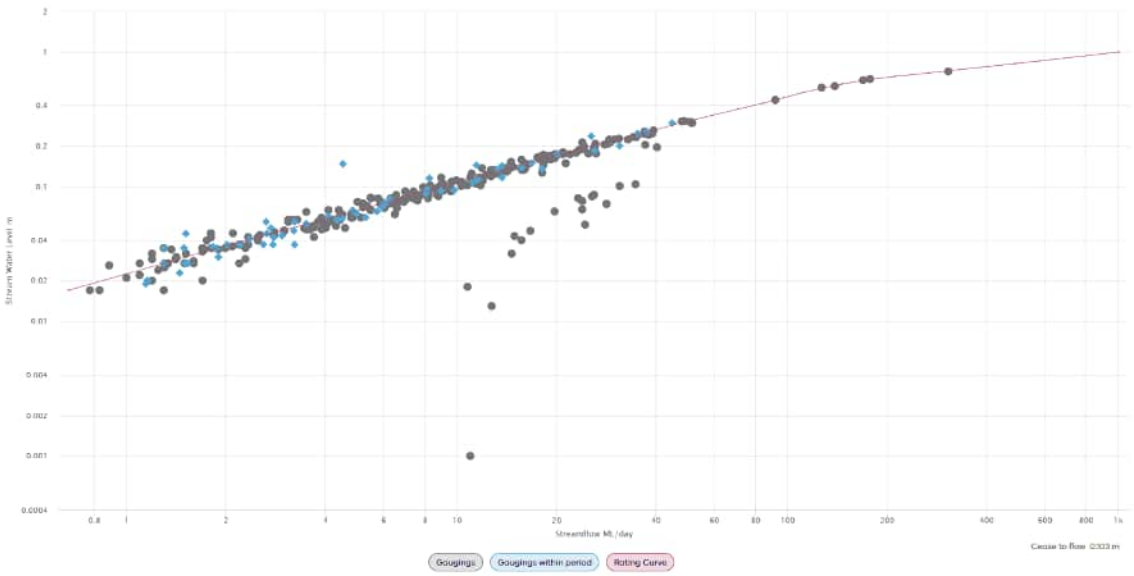


Figure 4-37 Gaugings vs rating plot for 235205 Arkins Creek West Branch

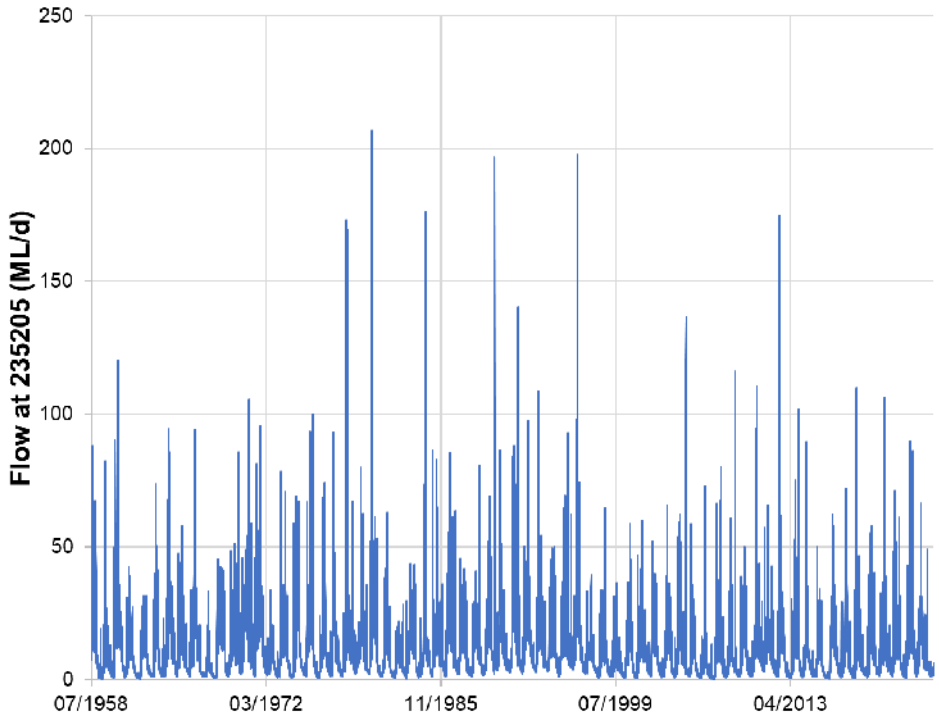


Figure 4-38 Streamflow in Arkins Creek West Branch (235205)

4.9.1.2 Urban diversions

Wannon Water can supply their Otway system from three surface water sources from the Arkins Creek catchment. Urban surface water diversion data was provided by Wannon Water to inform the historic diversions from the Gellibrand River catchment and are summarised in Table 4-13.

Inflows to Carlisle River catchment will be derived both upstream and downstream of the urban diversion points and the urban diversion data will be used to inform this analysis. The weekly data

available from 1993 to 2018 will be uniformly disaggregated to daily prior to adoption. Any daily data available will be used as a first priority to the weekly data when adopting for input derivation.

Table 4-13 Summary of available diversion data as provided by Wannon Water

Data	Timestep	Available period	Use	Figure Reference
Arkins First Creek Weir	Daily	April 2017 to January 2025	Derive current extractions from Arkins Creek, historic data for inflow derivation	Figure 4-42
	Weekly	July 1993 to May 2018		Figure 4-39
Arkins West Creek Weir	Daily	March 2017 to January 2025	Derive current extractions from Arkins Creek, historic data for inflow derivation	Figure 4-40
	Weekly	July 1993 to May 2018		Figure 4-39
Arkins East Creek Weir	Daily	March 2017 to January 2025	Derive current extractions from Arkins Creek, historic data for inflow derivation	Figure 4-41
	Weekly	July 1993 to May 2018		Figure 4-39

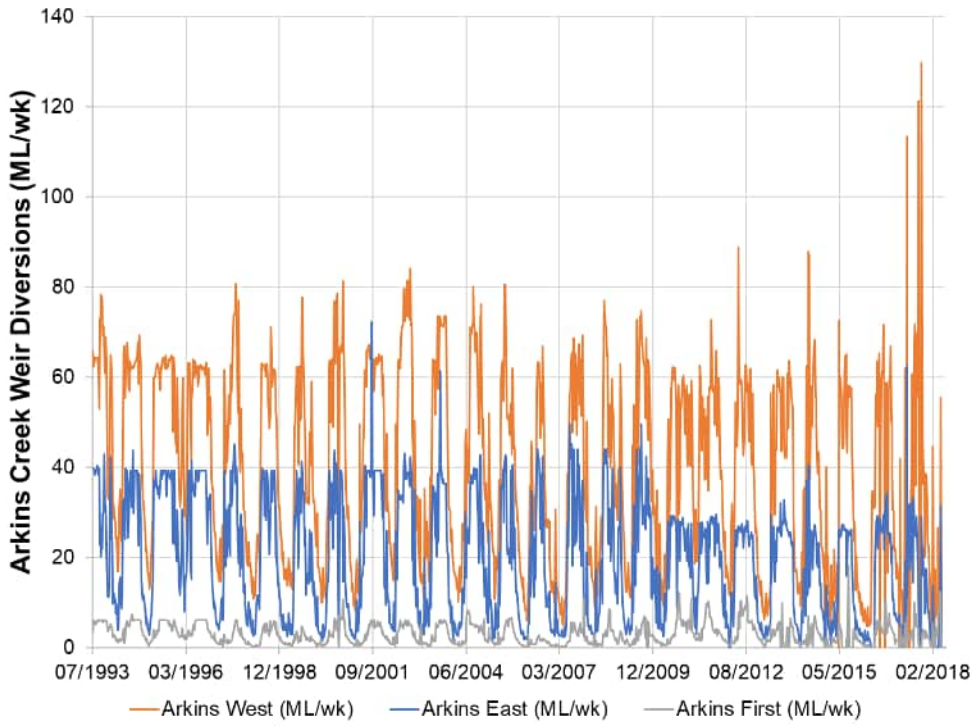


Figure 4-39 Historic weekly diversions from the Arkins Creek diversion weirs from 1993 to 2018

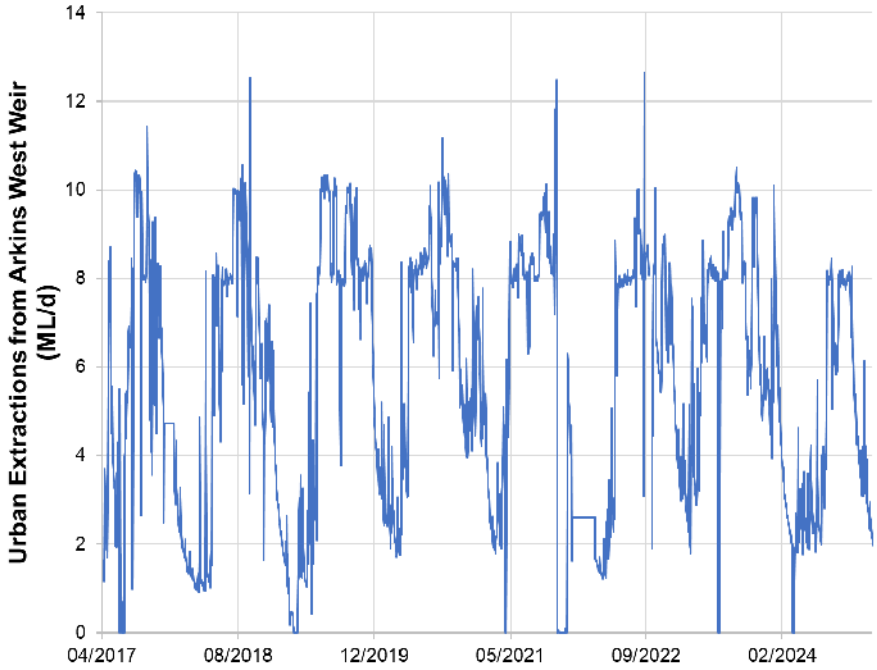


Figure 4-40 Historic Arkins West Wannon Water extractions

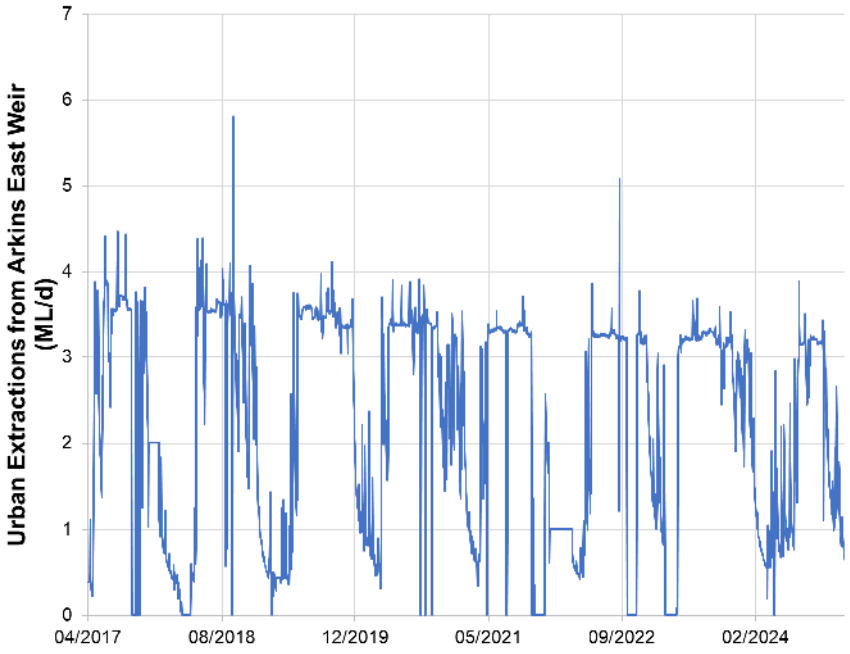


Figure 4-41 Historic Arkins East Wannon Water extractions

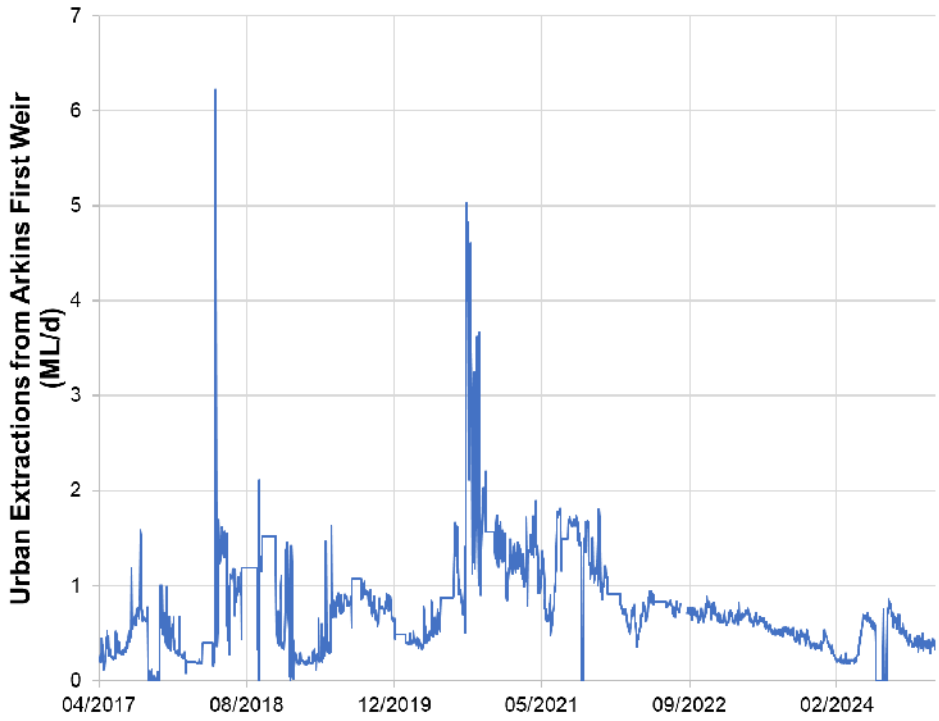


Figure 4-42 Historic Arkins First Wannon Water extractions

4.9.2 Derivation of inflow upstream of Wannon Water urban diversions (G9a)

The inflow upstream of Wannon Water urban diversions has been calculated using gauged flow at 235205 (Arkins Creek West Branch at Wyelangta) and transposing to Arkins Creek East Branch and First Creek on the basis of catchment area. Given the small catchment area of the Arkins Creek catchment, all rural demands for G9 have been applied to G9b, downstream of the diversion weirs. The catchment area of the Arkins Creek Water Supply Reserve is 7.7 km^2, and includes Arkins Creek West and East Branches and First Creek upstream of the diversion weirs. This area is made up of 470 ha of reforested land and 300 ha of crown land, as noted by the Otway Ranges Environment Network[1]. This G9a inflow catchment area of 7.7 km^2 was confirmed using spatial analysis.

The inflow to Arkins Creek West Branch at 235205 has a catchment area of 4.4 km^2. Therefore, to derive inflows to G9a, the following transposition by catchment area is assumed:

G9a Inflow to First Creek, Arkins Creek West and East Branch = 1.75 x Gauged flow at 235205

The transposition factor was sanity checked by comparing the total inflows upstream of First Creek, Arkins Creek West and East Branch diversions weirs (G9a inflow) to the total Wannon Water urban diversions from 3 weirs. As shown in Figure 4-43, the derived inflow is greater than the urban diversions, and it able to replicate the pattern of diversions, particularly during the low flow period.

[1] Otway Ranges Environment Network, Arkins Creek Catchment: https://oren.org.au/campaign/threatareas/arkins.htm

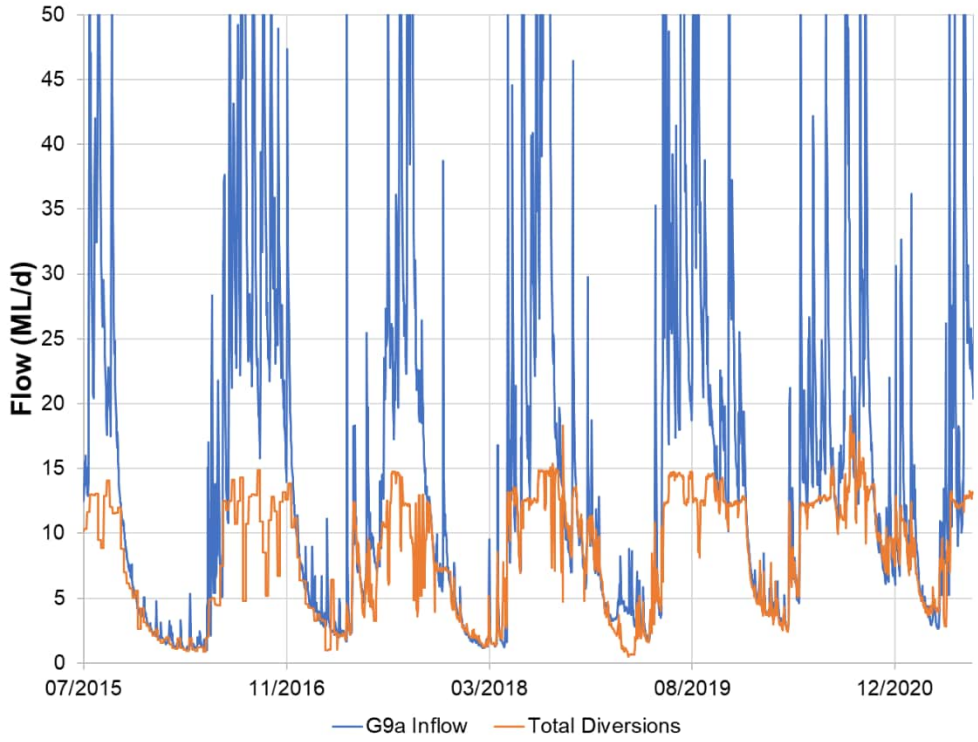


Figure 4-43 Comparison of historic diversions from Arkins Creek West, Arkins Creek East and First Creek to derived G9a inflow

Gauged flow at available at 235205 from 1958 to 2025. A rainfall runoff model was used to extend and infill gauged flow at 235205 (Arkins Creek West). A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to and after the gauge period. Morton's wet areal evapotranspiration over land at 090042 (Gellibrand River West) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment (48% of Gellibrand River West rainfall gauge (090042), 24% of Beech Forest rainfall gauge (090006) and 48% of Wyelangta rainfall gauge (090083)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-14, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the Sacramento rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the Sacramento rainfall runoff model has been adopted over the GR4J model.

The Sacramento rainfall runoff modelled flow was used to extend gauged flow at 235205. This long-term time series from 1900 to 2025 was then transposed to represent G9a inflows.

Table 4-14 Comparison of Sacramento and GR4J RR model fits for 235205

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.91	0.90
Coefficient of determination (r^2)	0.82	0.81
NSE	0.82	0.80
Average annual observed flow (ML/yr)	4,004.2	4,004.0
Average annual modelled flow (ML/yr)	4,004.2	3,989
% bias	0.0%	0.4%
Flow duration curve fit?	Very good flow duration curve comparison	Very good flow duration curve comparison
Time series fit?	Flow pattern and low flow well modelled	Slight over estimation of low flows

4.9.3 Derivation of inflow between Wannon Water urban diversions and 235200 (G9b)

The residual inflow to Carlisle River between Wannon Water urban diversion weirs and 235200 was derived using a reach balance over the available gauge period for 235200 (1930 – 1968, 2014 -2025). Urban diversions at Arkins Creek East, Arkins Creek West and First Creek were available from Wannon Water from 2014 to 2025. However, diversions were not available from 1930 to 1968. It has been assumed that the magnitude of these diversions is negligible compared to the total Carlisle River inflow.

It is recommended that as more data is collected at 235200C by Southern Rural Water that the reach balance is checked and refined if required.

4.9.3.1 Reach balance approach

4.9.3.1.1 Flow routing

To calculate the travel time between the urban diversion weirs on Arkins Creek (East and West) and First Creek down to Carlisle River at 235200, a reach balance was set up and upstream flow routed down to the downstream end. The reach balance was set up as follows:

$Q_{upstream} = Q_{235205\ transposed\ to\ Arkins/First\ Creeks}$ – urban diversions at Arkins Creek East – urban diversions at Arkins Creek West – urban diversions at First Creek
$Q_{downstream} = Q_{235200}$ + historic rural diversions

A concurrent period of 1930 to 1968 and 2014 to 2025 was available for the travel time calculation. The flow routing approach resulted in a piecewise routing relationship derived for different flow groups is shown in Table 4-2.

Table 4-15 Travel time parameters for piecewise routing for Carlisle River downstream of diversion weirs

Upstream Flow (G9a inflow) ML/d	Travel Time (days)
0	0.6
50	0.6
60	0.6
80	0.4
999999	0.4

4.9.3.1.2 Reach losses

During the reach balance calculations, it was found that a small loss was required downstream of the Wannon Water urban diversions to achieve a satisfactory calibration between gauged and modelled flow in Carlisle River at 235200. The final loss adopted in the G9b inflow derivation is summarised in Table 4-16

Table 4-16 Carlisle River loss function

Upstream flow (ML/d)	Loss (ML/d)
0	0
1	0.52
2	0.77
10	0.35
20	0.03
50	0

4.9.3.2 Rainfall runoff modelling

The calculated residual inflow for G9b was available from 1930 to 1968 and from 2014 to 2025. A rainfall runoff model was used to extend and infill gauged flow at 235200. A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to and after the gauge period. Morton's wet areal evapotranspiration over land at 090042 (Gellibrand River West) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment (55% of Gellibrand River West rainfall gauge (090042), 17% of Beech Forest rainfall gauge (090006) and 34% of Gellibrand Forestry (090041)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-17, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the GR4J rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the GR4J rainfall runoff model has been adopted over the Sacramento model.

Table 4-17 Comparison of Sacramento and GR4J RR model fits for G9b residual inflow

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.73	0.73
Coefficient of determination (r^2)	0.53	0.54
NSE	0.46	0.47
Average annual observed flow (ML/yr)	28,657.7	28,657.7
Average annual modelled flow (ML/yr)	28,655.3	28,680.6
% bias	0.0%	0.1%
Flow duration curve fit?	Slight over estimation of mid-range flows	Flow duration curve well modelled
Time series fit?	Flow recessions not well modelled	Flow patterns are well replicated

4.9.4 Source balance check

A Source model was developed to check the derivation of inflows upstream of the diversion weirs from Arkins Creek West Branch, Arkins Creek East Branch and First Creek (G9a) and the residual inflow to Carlisle River (G9b). A schematic of the Source model developed can be shown in Figure 4-44 and is available over the concurrent period of 2014 to 2025.

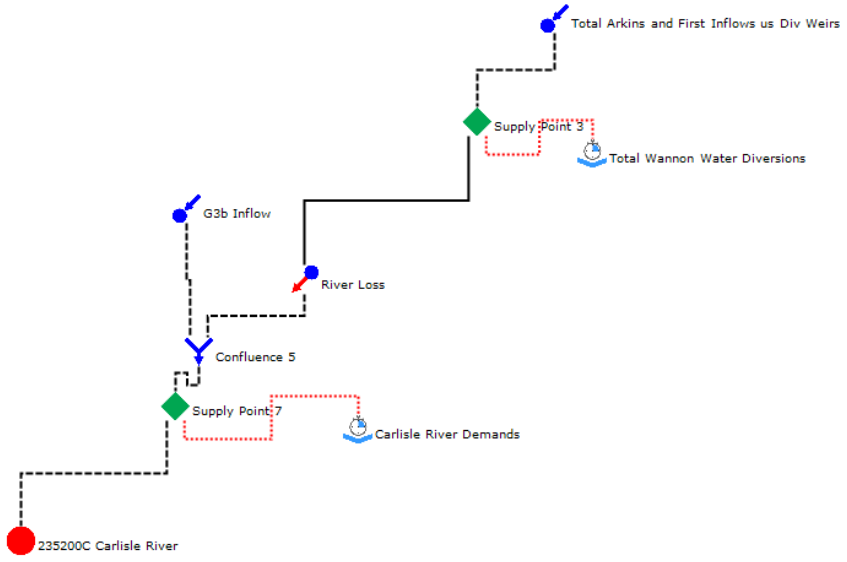


Figure 4-44 Schematic of the Carlisle River reach balance

The derived inflows to Carlisle River were able to achieve a very satisfactory comparison between gauged flow and modelled flow was able to be achieved at 235200 (Table 4-18). The magnitude and flow pattern of gauged flow at 235200 was able to be replicated (Figure 4-45 for linear time series and Figure 4-46 for flow duration curve). The low flow comparison in Figure 4-47 shows that the inflows calculated are able to replicate water availability in Carlisle River at 235200 with consideration for upstream Wannon Water urban extractions.

To derive unimpacted flow to Carlisle River downstream of Wannon Water diversion weirs, the following was required to be added back:

- 110 ML of farm dam impacts as outlined in Section 3.3.

Table 4-18 Summary of reach balance comparison results between modelled and gauged flow

	235200 (Carlisle River at Carlisle)
Comparison Period	2014 - 2025
Correlation (r)	0.99
Coefficient of determination (r^2)	0.99
NSE daily	0.99
% Volume bias	0.4%

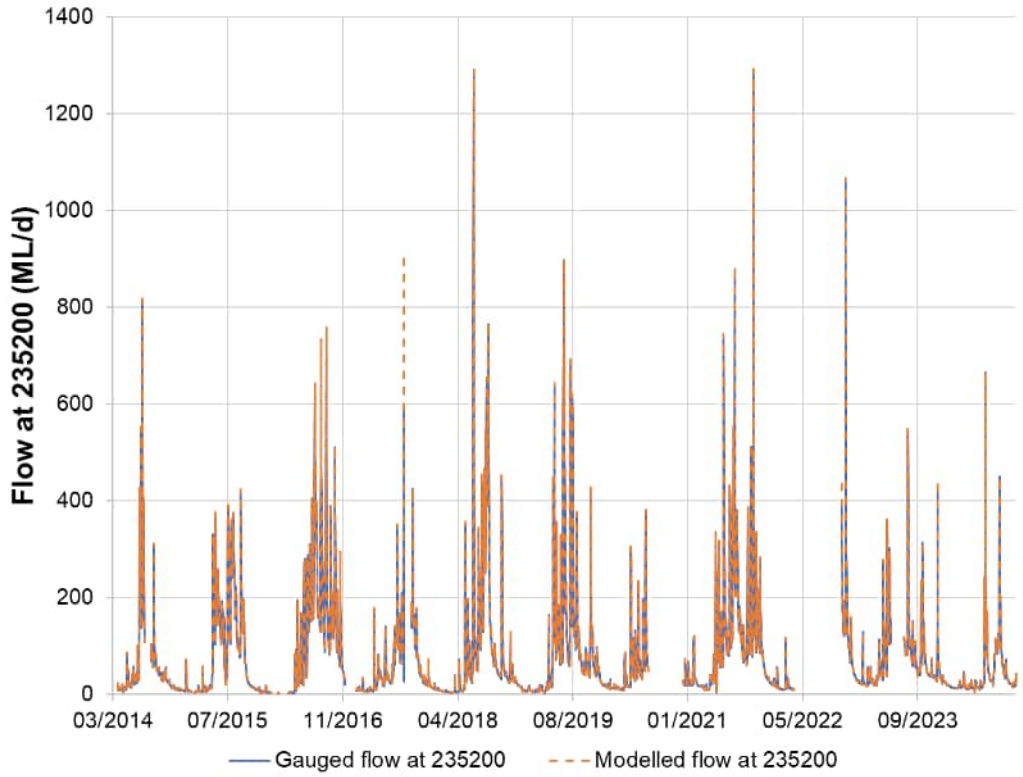


Figure 4-45 Linear time series comparison between gauged and modelled flow at 235200

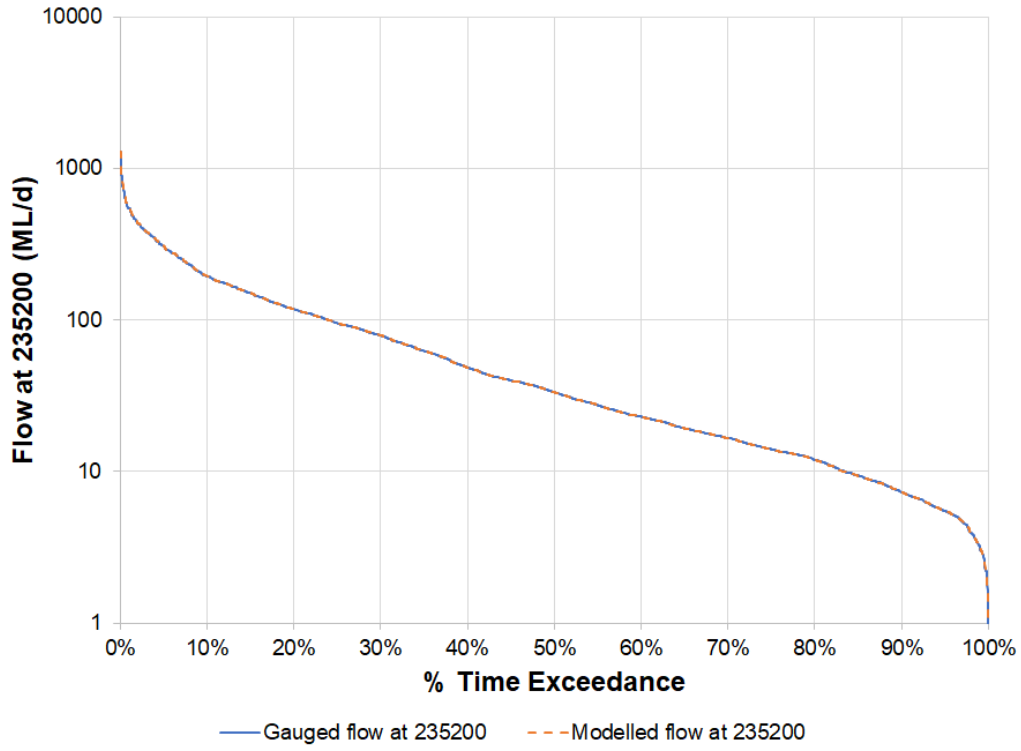


Figure 4-46 Flow duration curve comparison between gauged and modelled flow at 235200

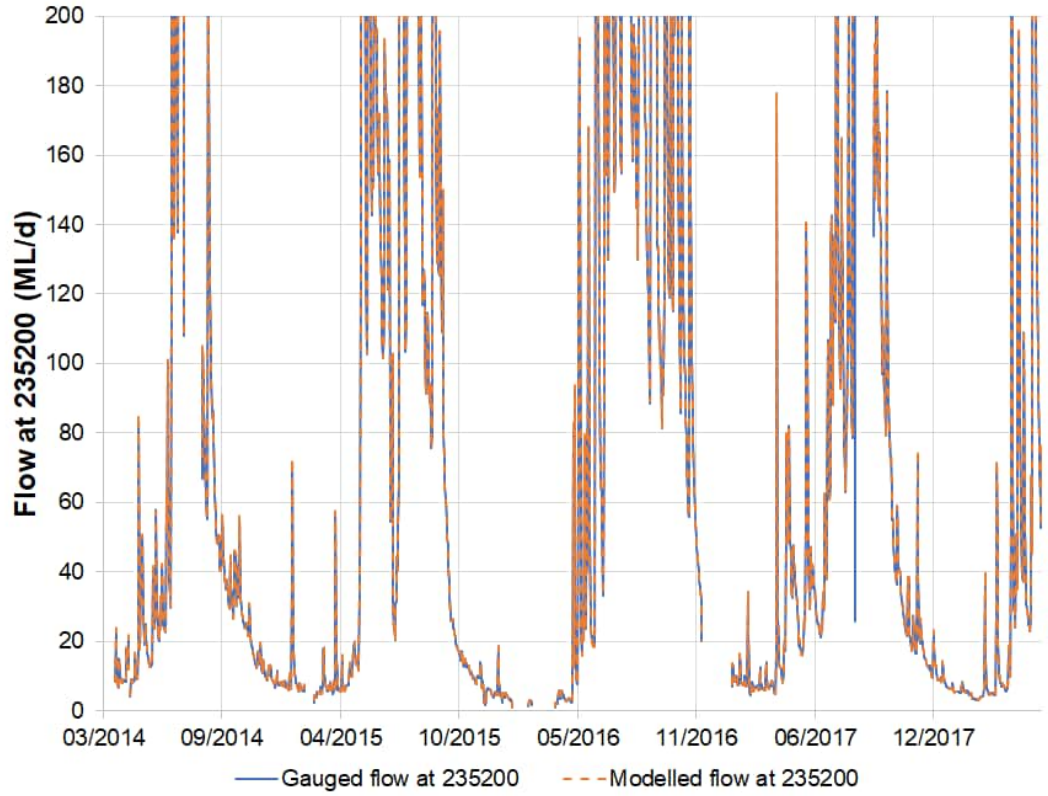


Figure 4-47 Low flow comparison between gauged and modelled flow at 235200

4.10 G10 Kennedys Creek upstream of 235211

The inflow to Kennedys Creek is calculated using gauged flow at 235211 (Kennedys Creek at Kennedys Creek). Gauged flow is available from 1964 to 2024 (as shown in Figure 4-48). The gaugings versus ratings plot for 235211 in Figure 4-49 shows that there have been a number of rating curves developed over time suggesting that the cross section at the gauge location has also changed over time. Prior to rainfall runoff modelling, the following was added back to Kennedys Creek to derive partial natural flow:

- 13.6 ML/yr of domestic and stock demand (Section 3.2)

The final equation for calculating partial natural flow in Kennedys Creek (Subcatchment G10) is:

Inflow to Kennedys Creek = Gauged flow at 235211 + historic rural demands

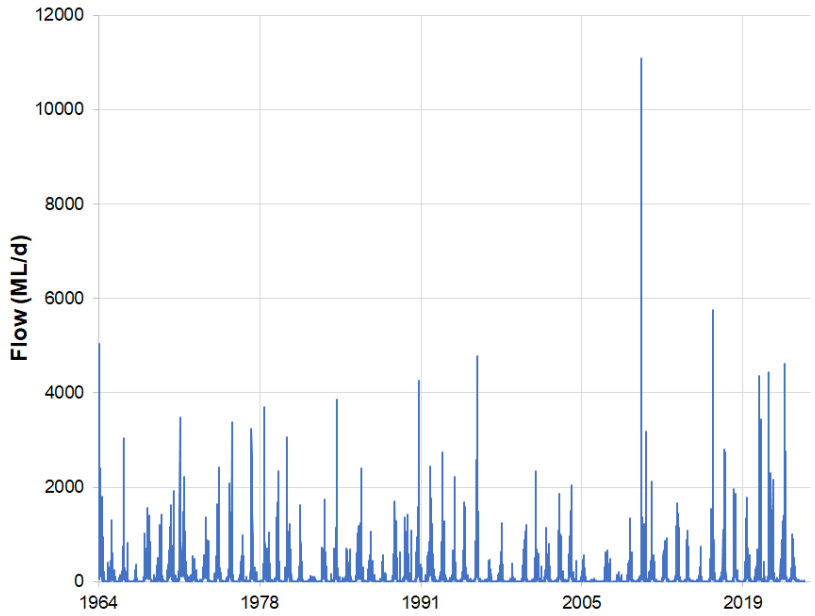


Figure 4-48 Gauged flow in Kennedys Creek at 235211 (Kennedys Creek at Kennedys Creek)

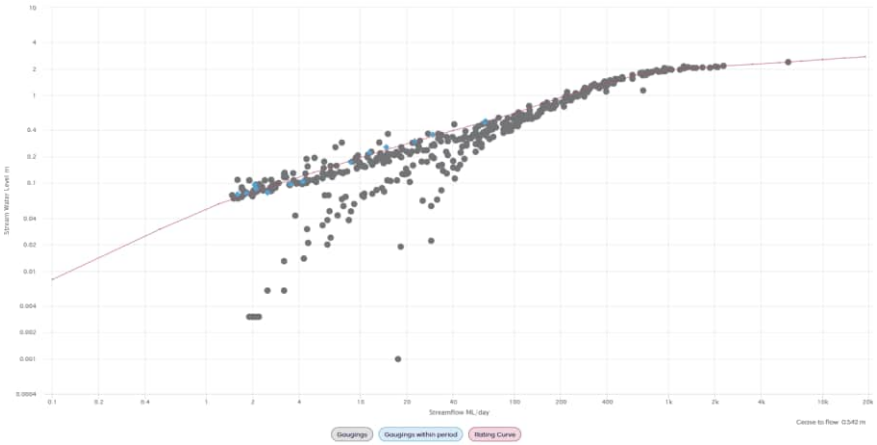


Figure 4-49 Gaugings vs Ratings plot for 235211 (Kennedys Creek)

A rainfall runoff model was used to extend and infill gauged flow at 235211 (Kennedys Creek). A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to and after the gauge period. Morton's wet areal evapotranspiration over land at 090042 (Gellibrand River West) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment ((37% of Gellibrand River West rainfall gauge (090042), 17% of Irrewillpe rainfall gauge (090138) and 35% of Simpson South rainfall gauge (090165)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-19, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the GR4J rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the GR4J rainfall runoff model has been adopted over the Sacramento model.

Table 4-19 Comparison of Sacramento and GR4J RR model fits for G10

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.87	0.87
Coefficient of determination (r^2)	0.76	0.76
NSE	0.74	0.76
Average annual observed flow (ML/yr)	38,550.5	38,550.5
Average annual modelled flow (ML/yr)	38,550.5	38,565.6
% bias	0.0%	0.0%
Flow duration curve fit?	Slight mismatch of flow duration curve	Good flow duration curve comparison
Time series fit?	Over estimation of low flows and erratic streamflow behaviour	Flow pattern well replicated. Slight over estimation of droughts

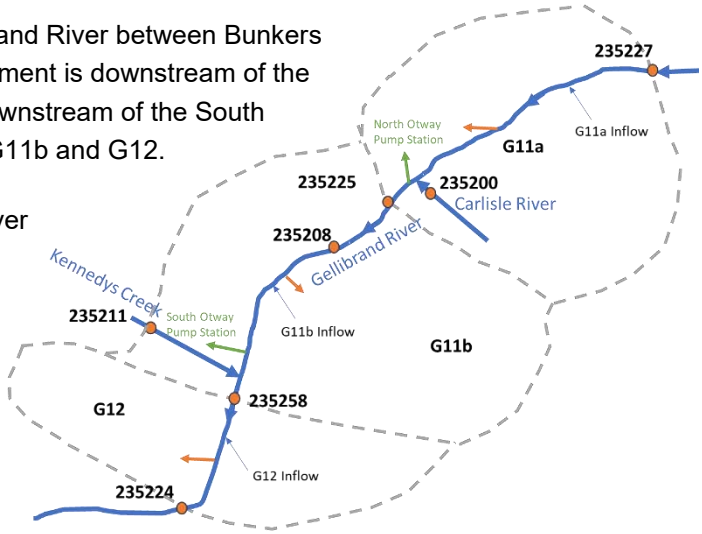
To derive unimpacted flow, the following was required to be added back to the extended gauged flow at Kennedys Creek:

- Impacts of 2,590 ML of farm dams as outlined in Section 3.3.

Note that there is high farm dam density in Kennedy's Creek (shown in Section 3.3) which would increasing low flow periods when added back to derive unimpacted flows to Kennedy's Creek.

4.11 G11 G12 Gellibrand River between Bunkers Hill (235227) and Burrupa (235224)

G11 and G12 represents the residual inflow into Gellibrand River between Bunkers Hill (235227) and Burrupa (235224). The G11 subcatchment is downstream of the North Otway pump station (235225) while the gauge downstream of the South Otway pump station (235258) forms the split between G11b and G12.



Wannon Water is able to extract from the Gellibrand River at North Otway Pump Station and South Otway Pump Station. Gauges available downstream of North Otway Pump Station and North Otway Pump Station are 235225 and 235258 respectively. The streamflow data as these gauges has been further analysed in Section 4.11.1.1.

Initially, it was intended that individual reach balances would be undertaken for the 3 subcatchments: G11a, G11b and G12. However, the quality of the available streamflow data resulted in very anomalous results. This is further discussed in Section 4.11.2.

The final input derivation approach adopted was as follows:

- Lump the subcatchments together to derive a residual flow from Bunkers Hill (235227) and Burrupa (235224)
- Calculate travel time and losses based on the lumped catchment and then split based on reach length (Section 4.11.3)
- Extend the lumped residual inflow using a rainfall runoff model (Section 4.11.4)
- Split the lumped residual inflow into the individual subcatchments using a Source model to split the residual flow to match gauged flow at 235225, 235258 and 235224 (Section 4.11.5)

4.11.1 Critical input analysis

4.11.1.1 Streamflow data

A number of streamflow gauges are considered for the reach balance between Bunkers Hill (235227) and Burrupa (235224). The critical analysis and streamflow data preparation for the following gauges has previously been reviewed as follows:

- Gellibrand River at Bunkers Hill (235227): Section 4.3.1
- Carlisle River at Carlisle (235200): Section 4.9.1.1
- Kennedys Creek (235211): Section 4.10

Gauged flow in Gellibrand River at Burrupa (235224) is available from 1969 to 2025. It was confirmed with ALS that 235224 can be influenced by backwater effects when the estuary mouth is closed. ALS utilises water levels at 235269A (Princetown) as a reference for the build-up and release of water once the mouth is re-opened. ALS adopt a quality code of 160 to indicate a back-up of water impacting gauged flow at Burrupa (235224). The datapoints with a quality code of 160 have been removed from the gauged flow at Burrupa to ensure that a dataset that is not impacted by backwater effects is

adopted for the residual flow calculation. The gaugings vs ratings plot for 235224 in Figure 4-50 shows that the gauge is well rated for flow up to 20,000 ML/d.

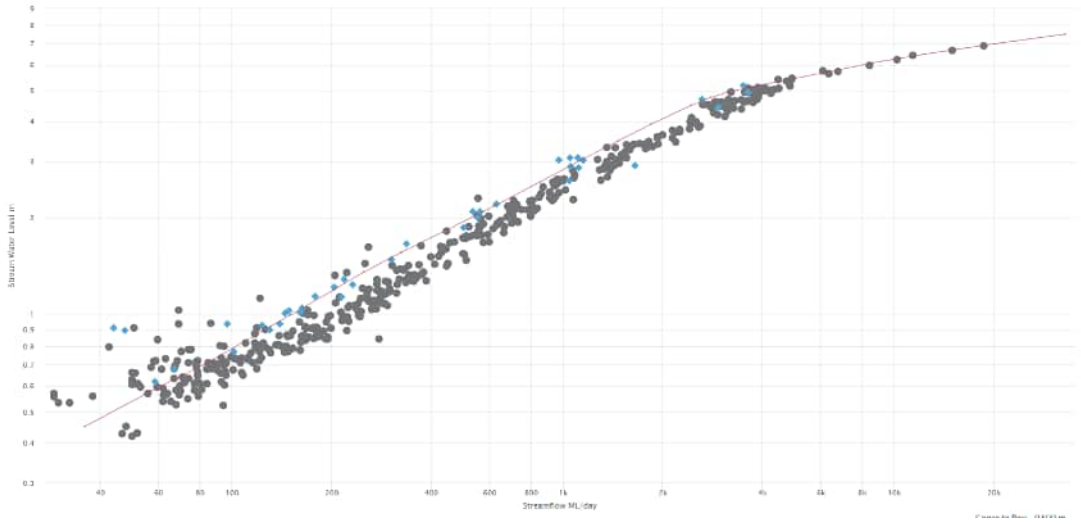


Figure 4-50 Gaugings vs ratings plot for 235224 (Gellibrand River at Burrupa)

Gauged flow is available downstream of urban extractions at North (235225) and South (235258) Otway Pump Station from 1999 to date. Wannon Water has noted that both gauges are flooded for nearly 50% of days and consequently, missing key winter flows. This is evident in the gaugings versus rating plots (Figure 4-51 for 235225 and Figure 4-52 for 235258) where the rating table is exceeded at 150 ML/d for 235225 and 200 ML/d for 235258. Due to the low quality of this streamflow data, ALS has not released flows that exceed the rating curve. However, for the purpose of this project, raw data was sourced for both gauges and is shown in Figure 4-53 for 235225 and Figure 4-54 for 235258. This data was investigated for adoption however, produced very anomalous results (further discussed in Section 4.11.2).

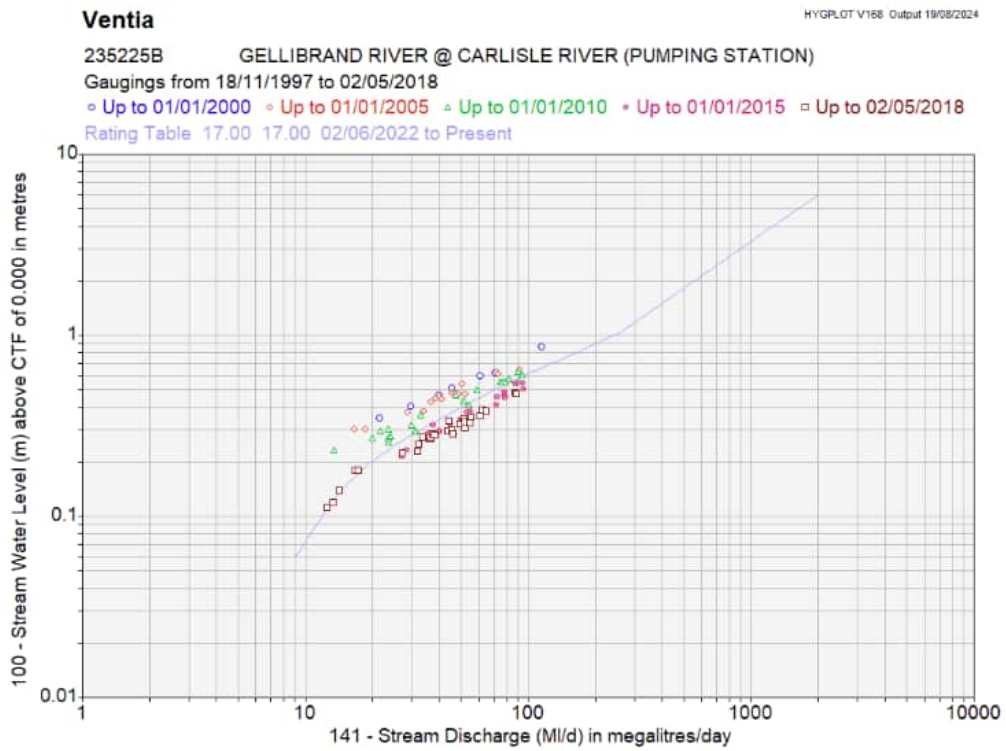


Figure 4-51 Gaugings vs Ratings plot for Gellibrand River at Carlisle River Pumping Station (235225B)



Figure 4-52 Gaugings vs Ratings plot for Gellibrand River d/s South Otway Pumps bridge (235258A)

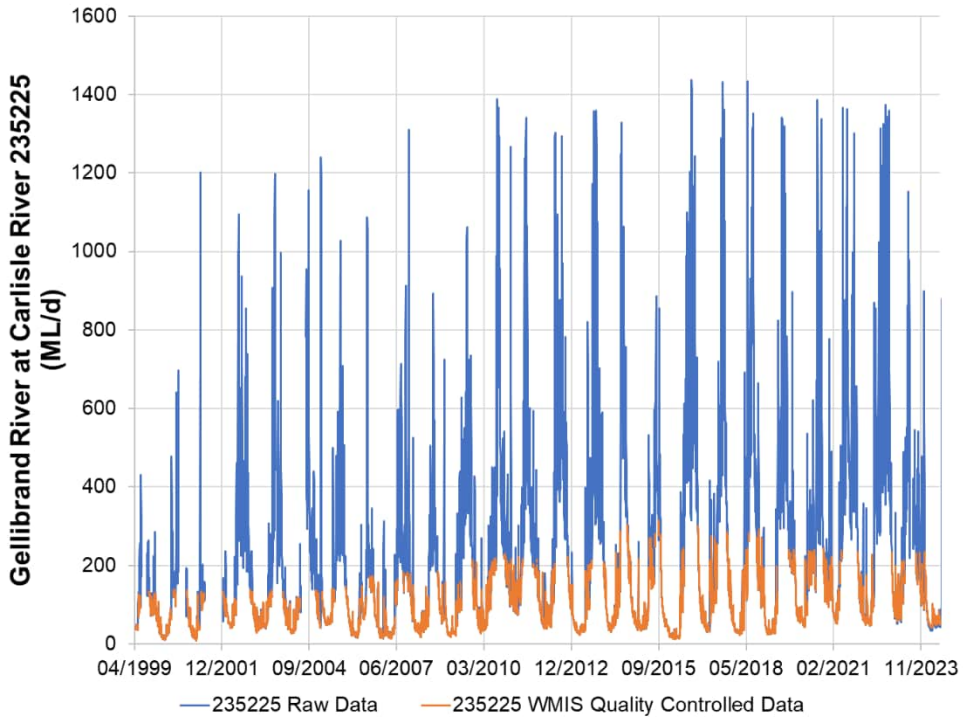


Figure 4-53 Streamflow in the Gellibrand River at Carlisle River (235225)

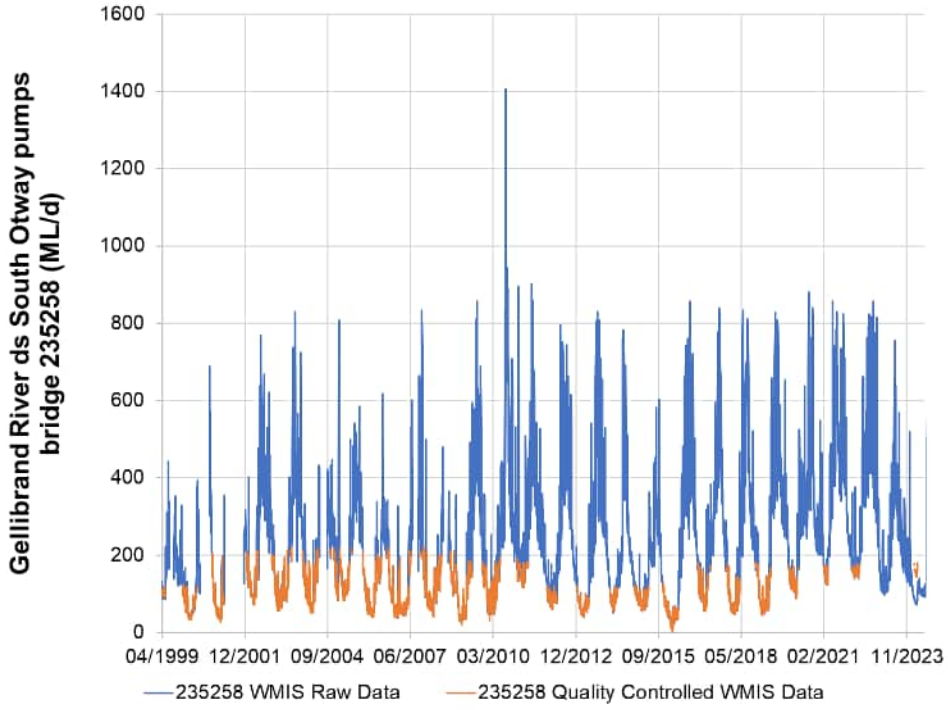


Figure 4-54 Streamflow in the Gellibrand River d/s south Otway pumps bridge (235258)

4.11.1.2 Urban diversions

Wannon Water provided historic urban diversion data for North Otway Pump Station and South Otway Pump Station back to 1970. Diversion data prior to 2017 for North Otway Pump Station and 2014 for

South Otway Pump Station was available on a weekly timestep which was uniformly disaggregated to daily.

The historic urban extractions adopted in the calculation of residual inflow to Gellibrand River can be found in Figure 4-55 for North Otway Pump Station and Figure 4-56 for South Otway Pump Station.

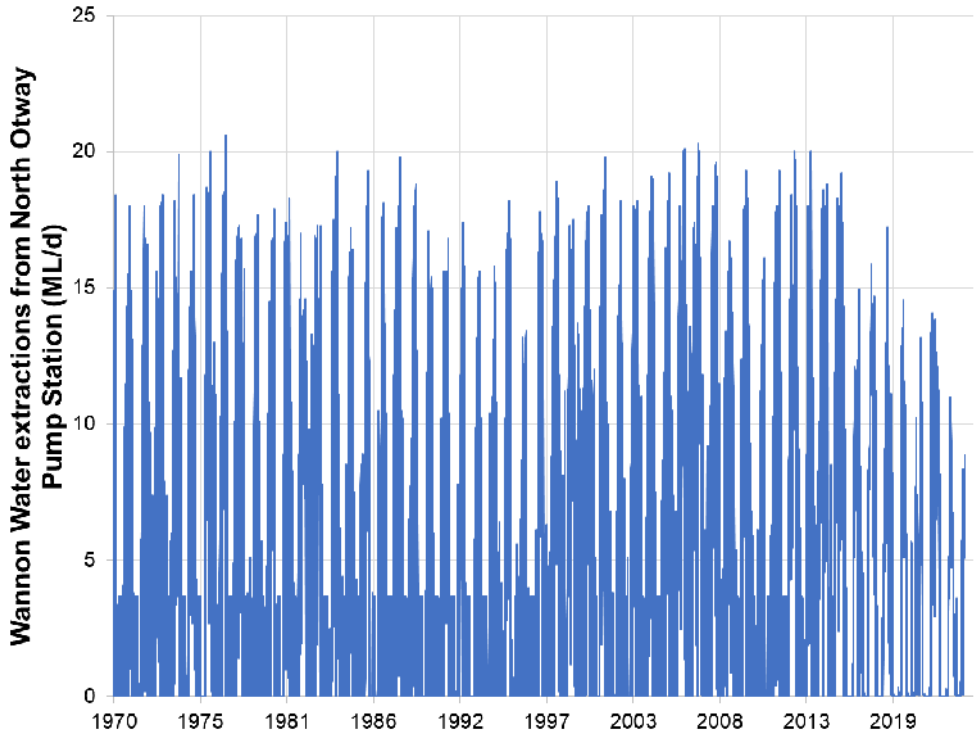


Figure 4-55 Historic Wannon Water diversions from North Otway Pump Station

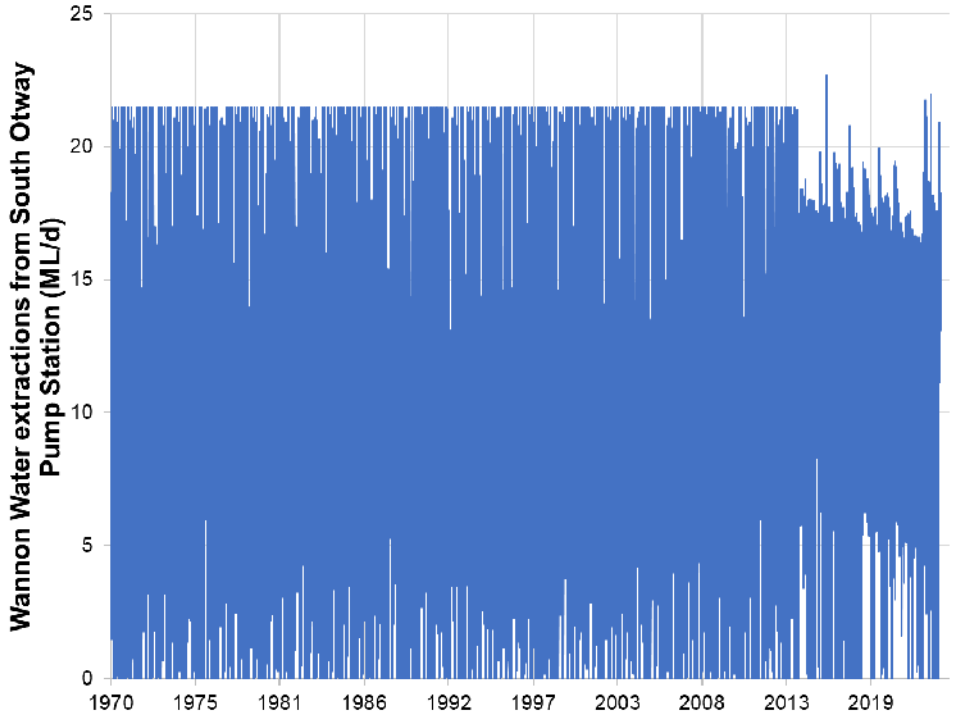


Figure 4-56 Historic Wannon Water diversions from South Otway Pump Station

4.11.2 Preliminary reach balance investigations

As proposed in the review report (HARC, 2025), reach balances were intended to be undertaken separately for G11a (Gellibrand River from Bunkers Hill to 235225), G11b (Gellibrand River from 235225 to 235258) and G12 (Gellibrand River from 235258 to Burrupa). However, the missing data for flows above 150 ML/d at 235225 and above 200 ML/d for 235258 made the routing of upstream flow to downstream flow to calculate travel time difficult. Also, the residual flow derived using the available data did not produce a realistic flow pattern.

An attempt was made to adopt the unverified raw data for 235225 and 235258 such that a more complete dataset was available for the individual reach balances. However, the raw data was found to be unreliable for mid to high range flows, the gauged flow at 235225 was less than the upstream gauged flow at 235227 (Figure 4-57). For a gaining river such as the Gellibrand River, it is expected that the river losses would not be substantial enough to reduce high flows that significantly (small losses shown in the upper Gellibrand River in Section 4.3.2.2). Therefore, the raw data at 235225 was deemed to be unusable and only the quality controlled data was adopted for this analysis.

Given that individual reach balances were not able to be undertaken due to available streamflow data, a lumped approach to derive a residual flow from high quality gauges Bunkers Hill (235227) and Burrupa (235224) was explored.

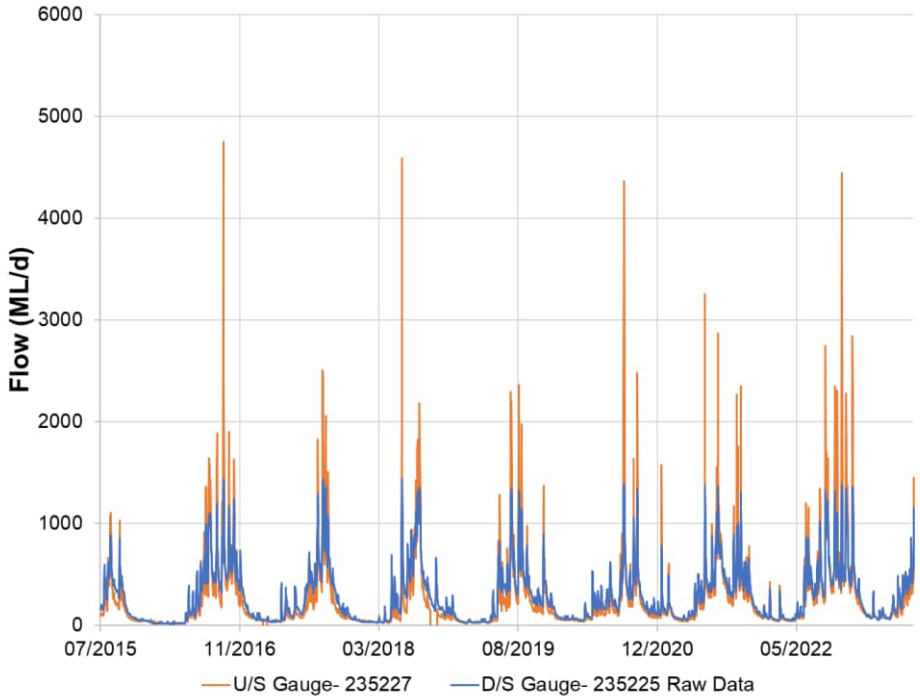


Figure 4-57 Comparison of gauged flow at 235227 (upstream) to raw data at 235225 (downstream)

4.11.3 Lumped reach balance approach

4.11.3.1 Flow routing

To calculate the residual inflow to Gellibrand River between Bunkers Hill (235227) and Burrupa (235224), the upstream flow was routed down to the downstream end of the reach by calculating the travel time between these locations.

Prior to the reach balance calculation, the following historic diversions were incorporated:

- Estimated historic groundwater pumping impact from Carlisle River bores calculated in Section 3.1.3
- Historic rural groundwater demands as outlined in Section 3.1.1
- Wannon Water urban extractions from North Otway Pump Station (Section 4.11.1)
- Wannon Water urban extractions from South Otway Pump Station (Section 4.11.1)
- Historic rural demands for G11a, G11b and G12 as outlined in Section 3.2.3.1

The reach balance was setup as follows:

$Q_{upstream} = Q_{235227} + Q_{235200+}$ - historic groundwater pumping impact – historic G11a rural demands – North Otway pump station extractions
$Q_{downstream} = Q_{235224} - Q_{235211}$ + historic G11b rural demands + historic G12 rural surface water and groundwater demands + South Otway pump station extractions

Concurrent data was available from 1970 to 2023. Travel time between upstream and downstream flows and the number of events in each flow range is shown in Figure 4-58.

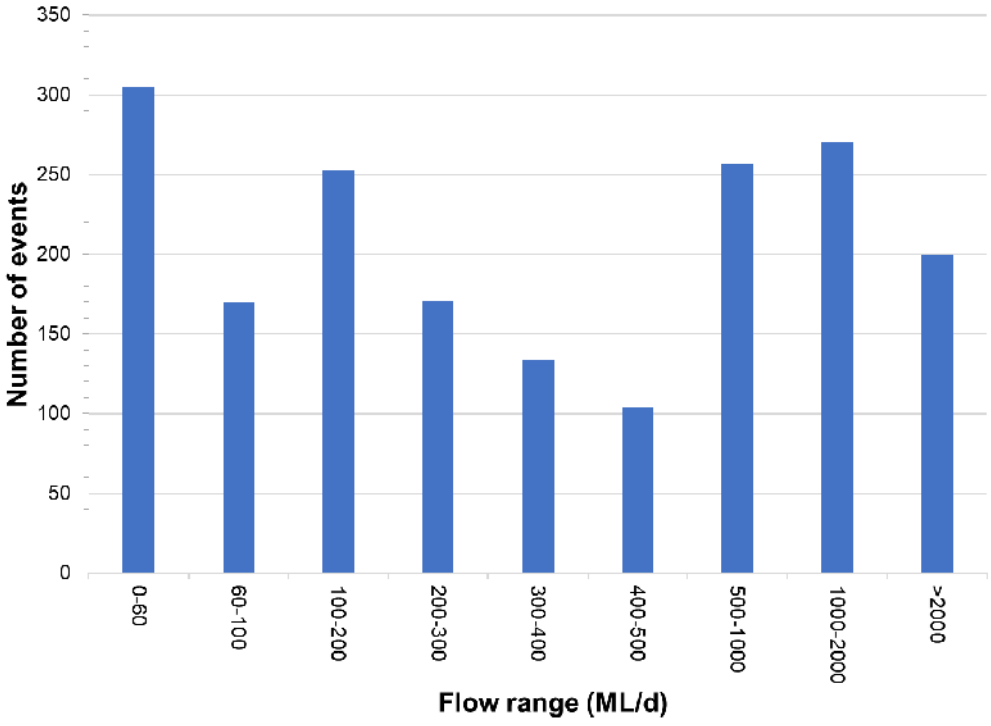


Figure 4-58 Histogram of flow events for Gellibrand River from Bunkers Hill to Burrupa

A piecewise routing relationship derived for different flow groups is shown in Table 4-20. The total travel time for Gellibrand River from Bunkers Hill (235227) to Burrupa (235224) was split at North Otway Pump Station (NOPS- 235225) and South Otway Pump Station (SOPS- 235258) by proportion of reach length. The travel time for each subcatchment was verified during the Source reach balance check in Section 4.11.5 which demonstrated the modelled peaks were able to match the timing of observed high flow events.

Table 4-20 Travel time parameters for piecewise routing for Gellibrand River from Bunkers Hill to Burrupa

Upstream Flow ML/d	Travel Time (days)			
	Total Gellibrand River from Bunkers Hill to Burrupa	Bunkers Hill to NOPS (G11a)	NOPS to SOPS (G11b)	SOPS to Burrupa (G12)
0	2.4	0.65	1.22	0.53
40	2.4	0.65	1.22	0.53
100	2.4	0.65	1.22	0.53
120	2.1	0.57	1.07	0.46
140	1.7	0.46	0.87	0.37
200	1.6	0.43	0.85	0.35
250	1.4	0.38	0.71	0.31
1,000	1.4	0.38	0.71	0.31
2,500	1.4	0.38	0.71	0.31
999999	1.4	0.38	0.71	0.31

4.11.3.2 Reach losses

The residual flow calculation produced negative inflows 2.5% of the time. The negatives were included in the derivation of the loss function. There were a number of negatives produced during the winter months due to mismatched timing of peaks and gauge rating table issues that were not included in the analysis, but either adjusted or set as missing.

The reach loss was derived as a percentage of upstream flow (235227). A loss function was then fitted to this data (Figure 4-59) and applied in the Source model as a loss table. The loss function was refined during the Source model balance check and the final result shown in Table 4-21. As part of the Source model balance check in Section 4.11.5, it was found that the river loss function was best applied in G12, directly upstream of Burrupa. This approach was able to produce very satisfactory comparison between gauged and modelled flow at all streamflow gauges verified between Bunkers Hill and Burrupa (further information in Section 4.11.5).

Table 4-21 Gellibrand River upstream of Burrupa loss function

Upstream flow (ML/d)	Loss upstream of Burrupa 235224 (ML/d)
0	0.00
20	20
50	10
100	12
250	17
500	27
1000	0.00
999999	0.00

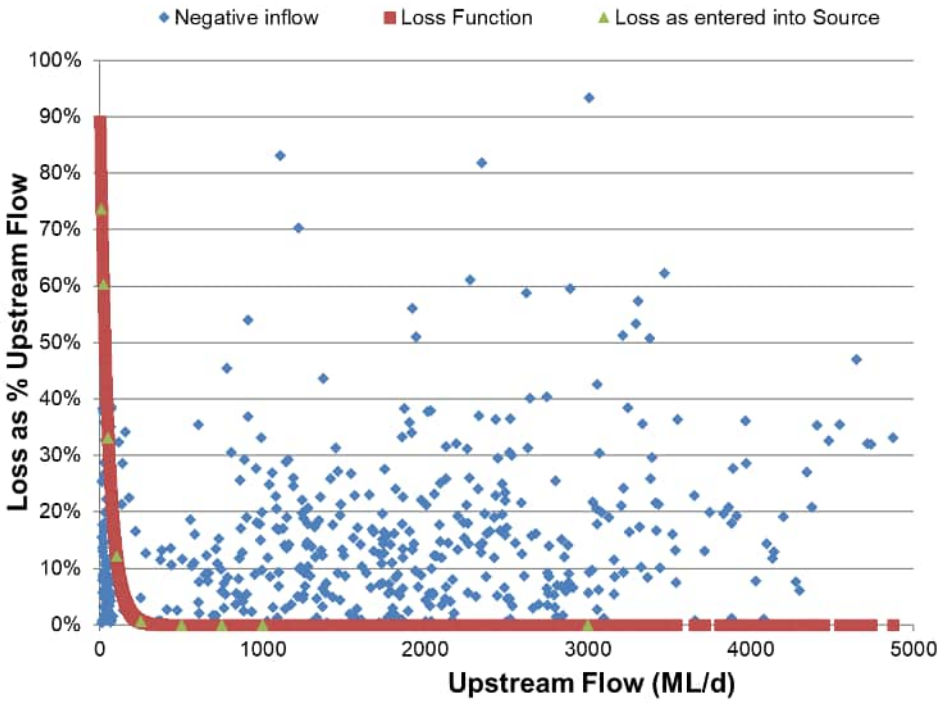


Figure 4-59 Lower Gellibrand River reach loss function

4.11.4 Rainfall runoff modelling

A rainfall runoff model was used to extend and infill the residual flow calculated from Bunkers Hill (235227) to Burrupa (235224). A Sacramento rainfall runoff model was initially calibrated using FORS to extend the recorded flow prior to and after the gauge period. Morton's wet areal evapotranspiration over land at 090042 (Gellibrand River West) was adopted, and FORS was used to optimise the rainfall weightings for this subcatchment ((2% of Gellibrand River West rainfall gauge (090042), 31% of Gellibrand River East Lovat rainfall gauge (090041) and 62% of Chapple Vale rainfall gauge (090139)). The optimised rainfall weightings were then input to a GR4J rainfall runoff model using Source, with a loss node configured.

The statistics of both calibrations have been compared in Table 4-22, with the GR4J report card in Appendix A and Sacramento report card in Appendix B.

As the Sacramento rainfall runoff model is able to produce a better flow duration curve comparison, statistics and comparison to the flow pattern, the Sacramento rainfall runoff model has been adopted over the GR4J rainfall runoff model.

Table 4-22 Comparison of Sacramento and GR4J RR model fits for G11 G12

Statistics	Sacramento RR model	GR4J RR model
Correlation	0.70	0.65
Coefficient of determination (r^2)	0.49	0.42
NSE	0.41	0.32
Average annual observed flow (ML/yr)	93,755.2	93,612.6
Average annual modelled flow (ML/yr)	93,846.9	93,655.1
% bias	0.1%	0.0%
Flow duration curve fit?	Very good flow duration curve comparison	Very good flow duration curve comparison
Time series fit?	Flow recessions slightly over estimated however, flow pattern is well modelled	Flow recession is lagged and not representative of flow pattern

4.11.5 Source reach balance split

The residual flow derived for G11 and G12 was split into the three subcatchments using a Source model (schematic shown in Figure 4-60), with the inflow split adjusted until a good comparison was able to be achieved at the following locations:

- Gellibrand River at North Otway Pump Station (235225)
- Gellibrand River at South Otway Pump Station (235258)
- Gellibrand River at Burrupa (235224)

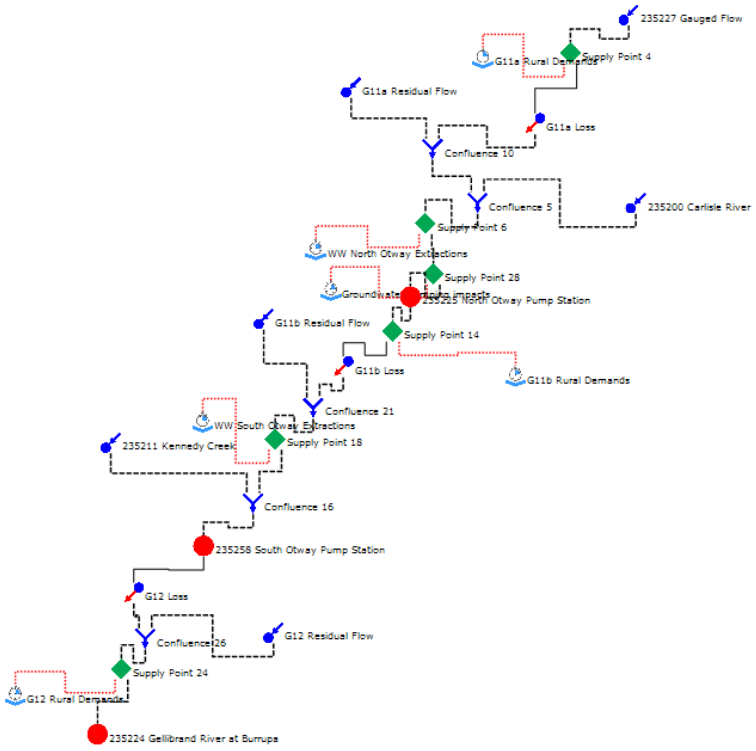


Figure 4-60 Schematic of the lower Gellibrand River reach balance

As outlined in Section 4.11.1.1, only low flows are considered high quality flows in Gellibrand River at North Otway Pump Station (235225) and South Otway Pump Station (235258), therefore, only low flows were used for the reach balance split.

An iterative approach was used to estimate subcatchment inflows as follows:

- Gellibrand River between Bunkers Hill and North Otway (G11a): *0.07 x G11 G12 Residual Flow*
- Gellibrand River between North Otway and South Otway Pump Stations (G11b): *0.53 x G11 G12 Residual Flow*
- Gellibrand River between South Otway and Burrupa (G12): *0.40 x G11 G12 Residual Flow*

The small transposition factor for G11a was able to produce the best comparison between gauged and modelled flow at Noth Otway Pump Station (Table 4-23), however, produced a lower specific yield than surrounding subcatchments. This is further discussed in Section 4.13.

The split of the residual flow into the individual subcatchments was able to produce very satisfactory results when compared to gauged flow in the Gellibrand River. As shown in Table 4-23, a 0% volume bias between gauged and modelled flow was able to be achieved at all key gauges, as well as high correlations. The flow duration curve comparisons in Figure 4-61 (235225), Figure 4-64 (235258) and Figure 4-67 (235224) show that the full range of flow magnitudes in the observed data are replicated by the modelled flow. In particular, matching the available low flow data at gauge 235225 and gauge 235258 gives confidence that the availability of water in the Gellibrand River for Wannon Water urban diversions at North and South Otway Pump Station is well represented (Figure 4-63 for NOPS, Figure 4-66 for SOPS).

Further verification of inflow estimations will be undertaken during the development of the Gellibrand Source model.

To derive unimpacted flow to Gellibrand River, the following estimated historic farm dam impacts were added back (as outlined in Section 3.3):

- Impact of 110 ML of farm dams in G11a
- Impact of 393 ML of farm dams in G11b
- Impact of 430 ML of farm dams in G12

Table 4-23 Summary of reach balance comparison results between modelled and gauged flow

	Gellibrand River at North Otway Pump Station	Gellibrand River at South Otway Pump Station	Gellibrand River at Burrupa
Gauge Number	235225	235258	235224
Comparison Period	1999 - 2024	1999 - 2024	1970 - 2024
Correlation (r)	0.93	0.81	0.96
Coefficient of determination (r^2)	0.86	0.66	0.92
NSE daily	0.86	0.60	0.91
% Volume bias	0.0%	0.3%	0.2%

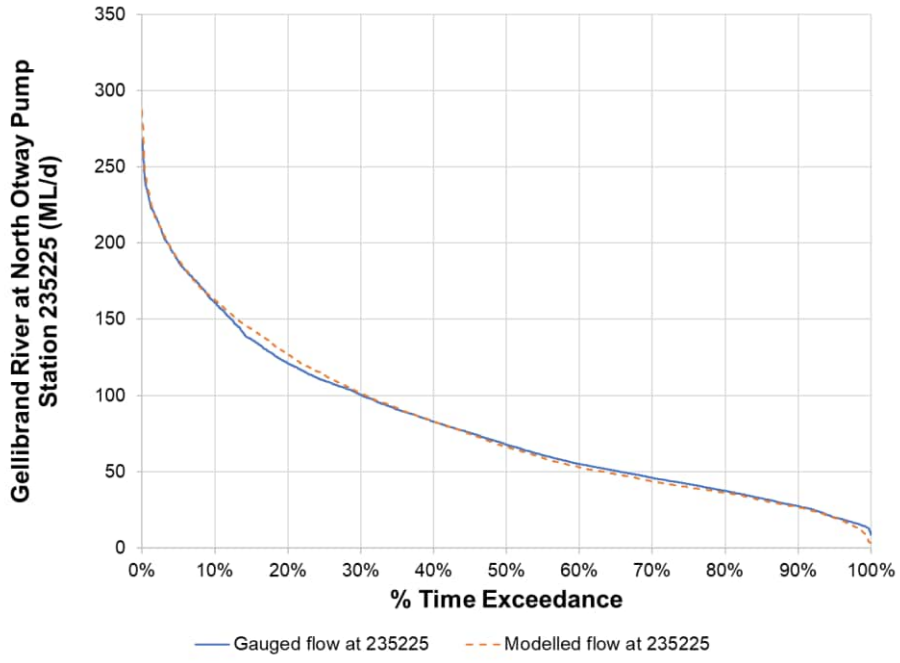


Figure 4-61 Flow duration curve comparison in Gellibrand River at North Otway Pump Station (235225)

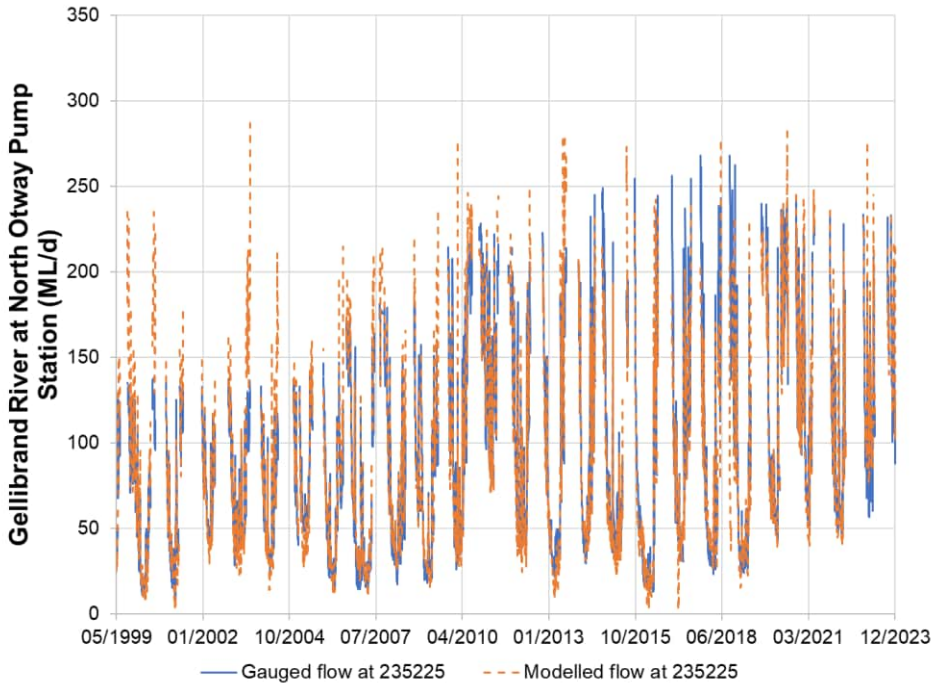


Figure 4-62 Time series comparison in Gellibrand River at North Otway Pump Station (235225)

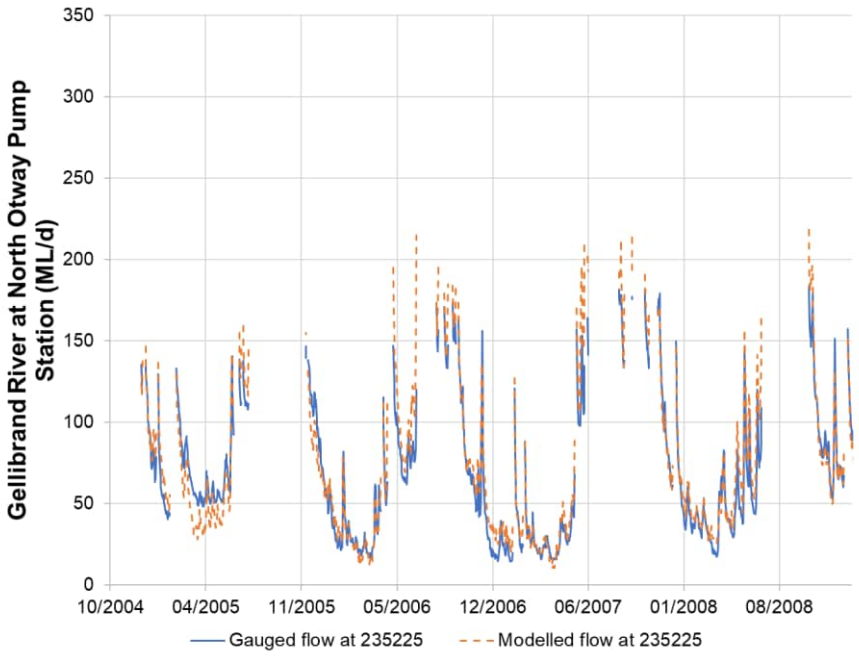


Figure 4-63 Millennium Drought Time series comparison in Gellibrand River at North Otway Pump Station (235225)

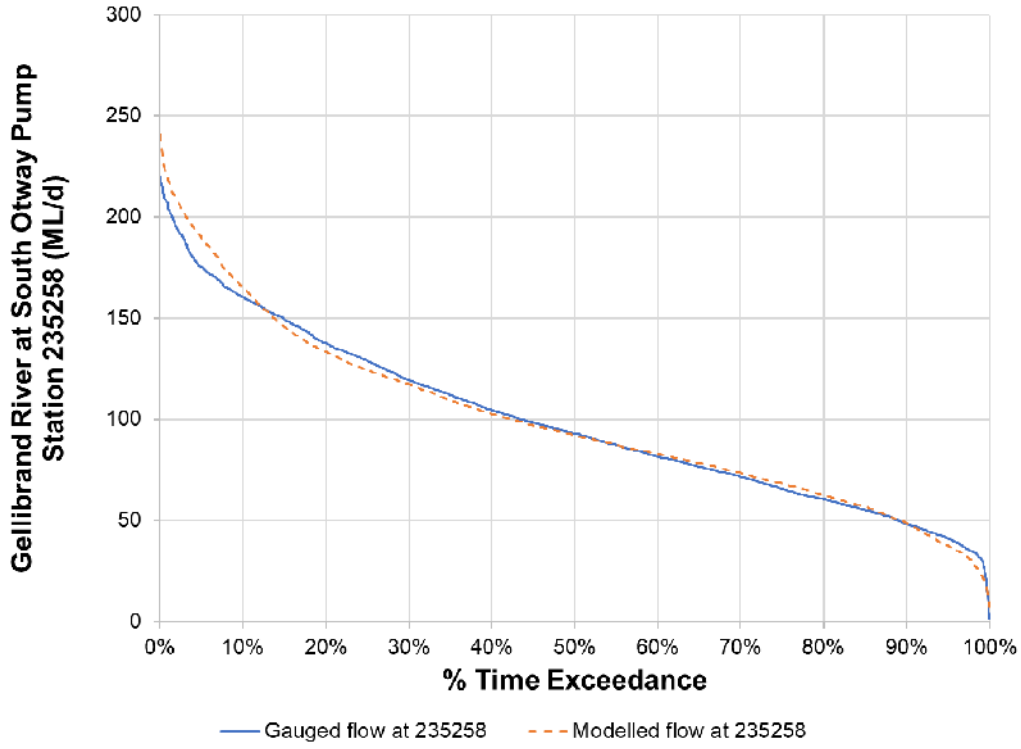


Figure 4-64 Flow duration curve comparison in Gellibrand River at South Otway Pump Station (235258)

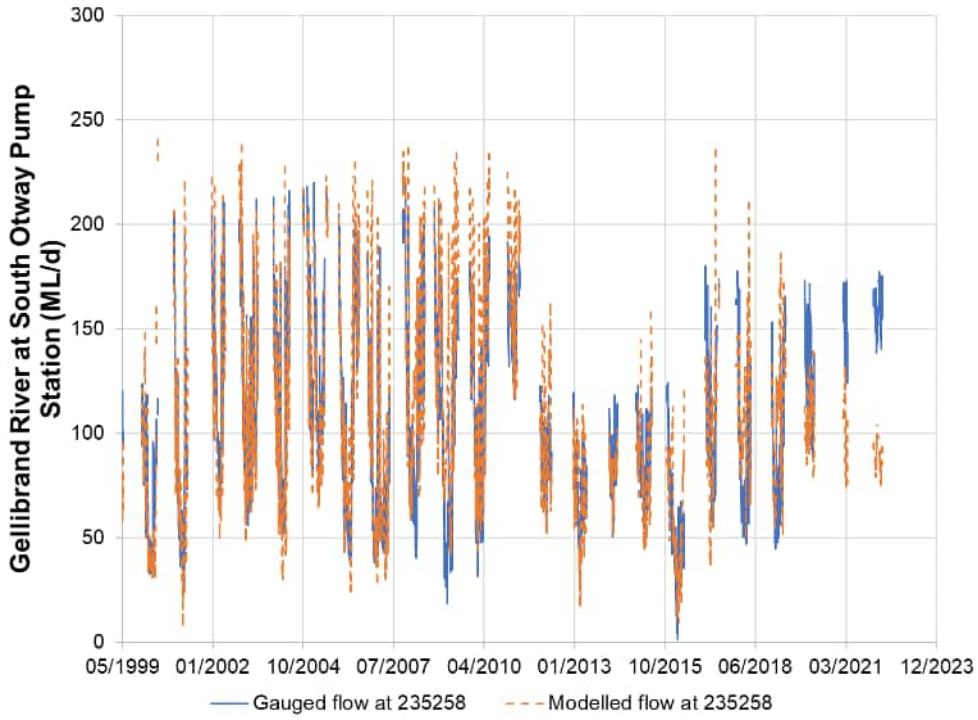


Figure 4-65 Time series comparison in Gellibrand River at South Otway Pump Station (235258)

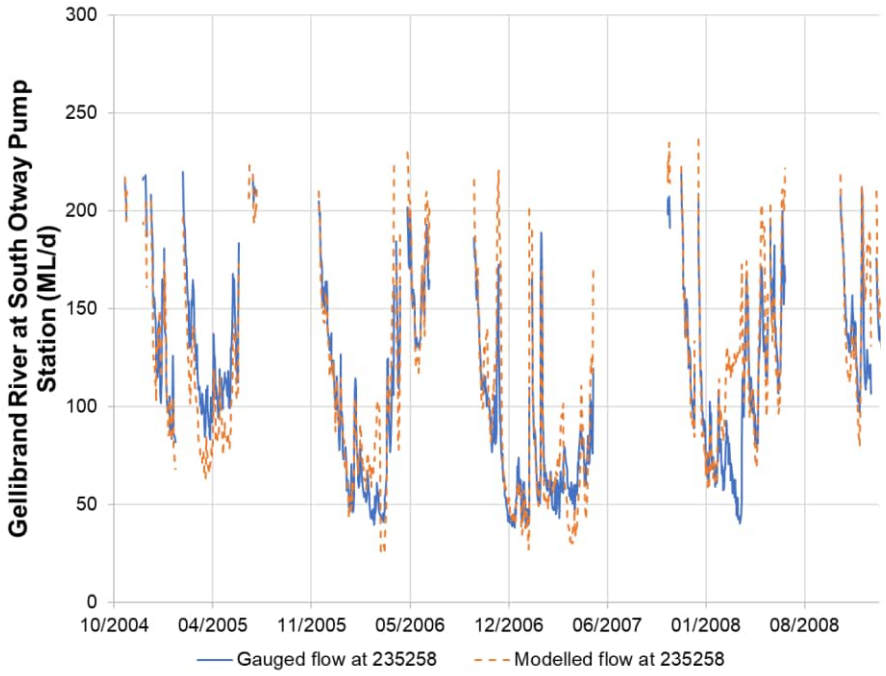


Figure 4-66 Millennium Drought Time series comparison in Gellibrand River at South Otway Pump Station (235258)

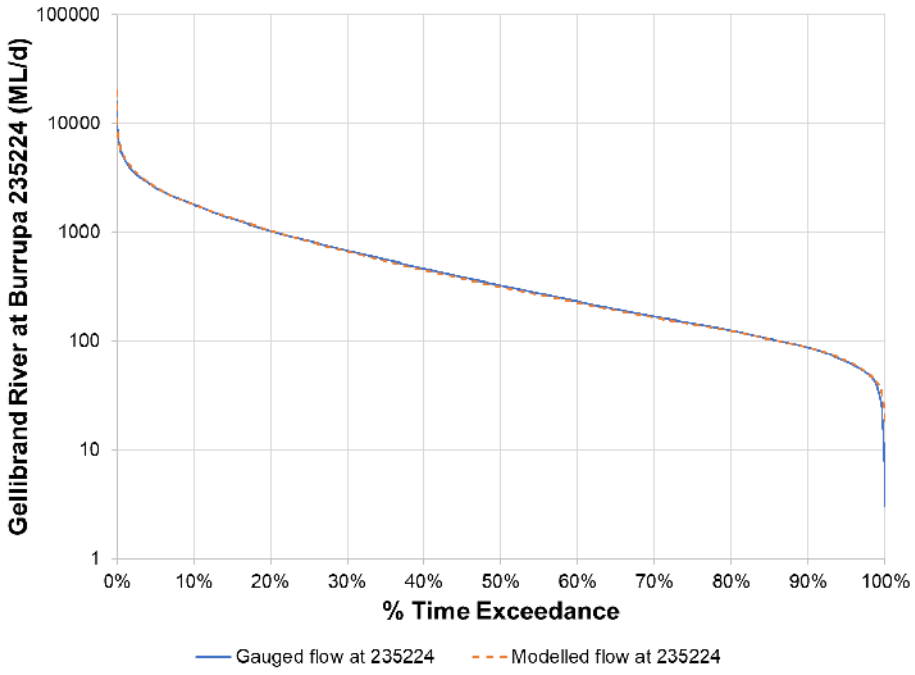


Figure 4-67 Flow duration curve comparison in Gellibrand River at Burrupa (235224)

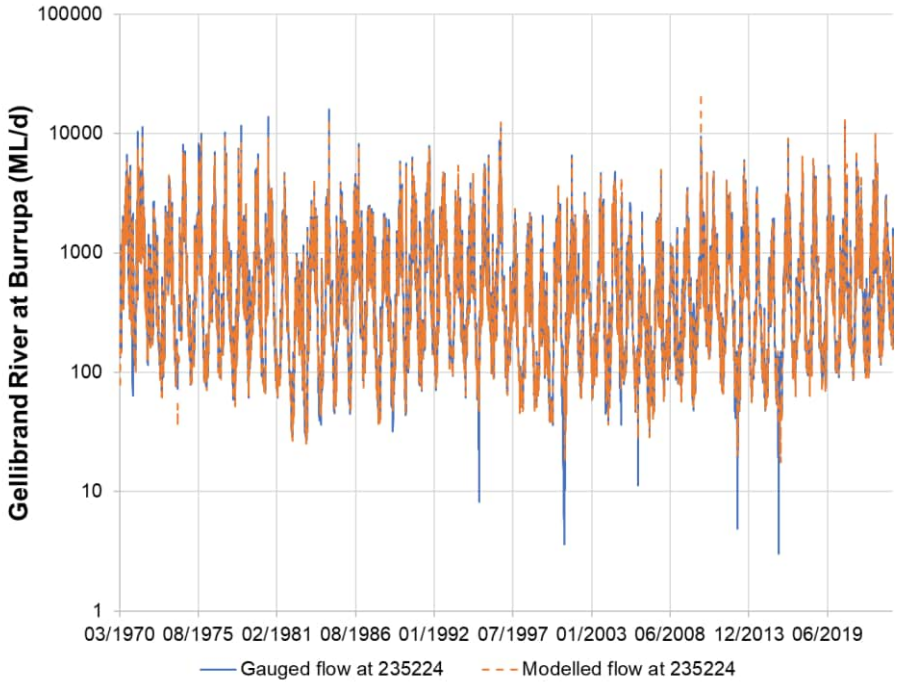


Figure 4-68 Log time series comparison in Gellibrand River at Burrupa (235224)

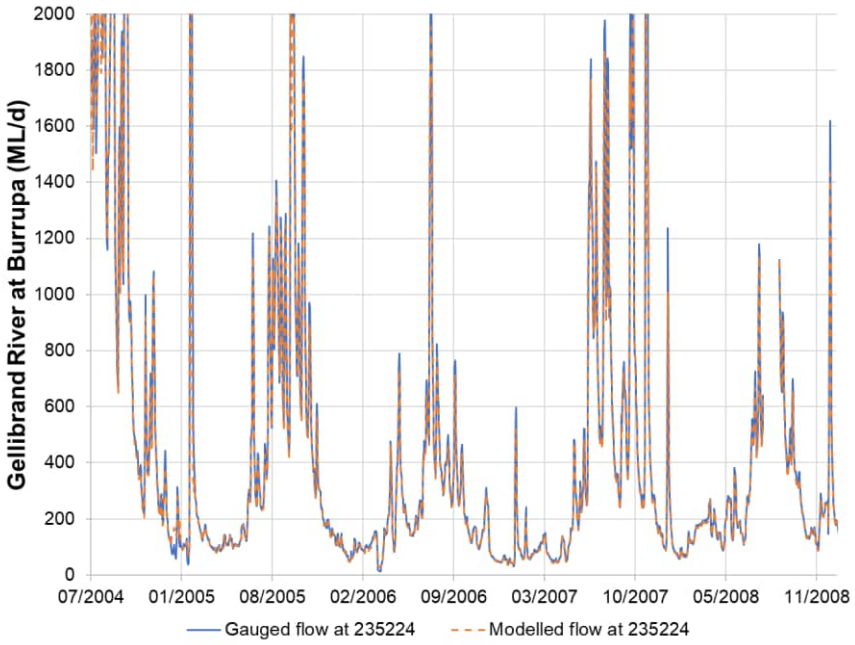
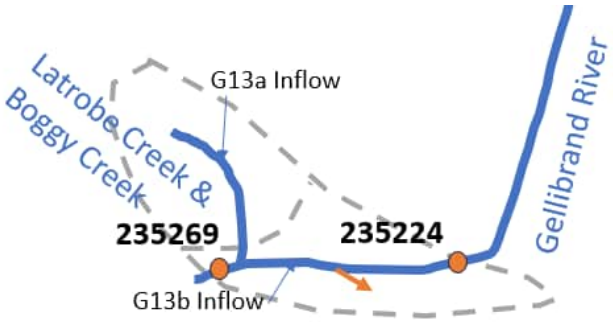


Figure 4-69 Millennium Drought time series comparison in Gellibrand River at Burrupa (235224)

4.12 G13 Gellibrand River Estuary

G13 represents the residual inflow to the Gellibrand River estuary, including Latrobe Creek and Boggy Creek. Level data (only) is available in the Gellibrand River at Princetown (235269) from 2008 to 2025, which has been identified as an environmental flow compliance location.



Alluvium (2017) noted that there is a significant tributary inflow (Latrobe Creek) to the estuary, approximately 1.25 km upstream of the estuary mouth, upstream of Princetown. Corangamite Catchment Management Authority (CCMA) also noted that Boggy Creek is a contributor to the Gellibrand River upstream of Princetown (pers. comm R. Jackson, 07/05/2025) and has been included in the tributary calculation.

The tributary inflow from Latrobe Creek and Boggy Creek has been separated from the residual inflow to the estuary, calculated as a transposition from neighbouring catchment Kennedy's Creek based on catchment area:

G13a Latrobe Creek inflow = (57.6/269.4) x Kennedys Creek inflow

To investigate whether there is appreciable inflow to Gellibrand River downstream of Latrobe Creek, Boggy Creek and Burrupa (235224), concurrent water level data at Princetown (235269) and Burrupa (235224) gauges was compared over the period 2008 to 2024.

As shown in Figure 4-70, there does not appear to be a distinctive increase in water level at Princetown (235269) during the high flows events clearly shown at Burrupa (235224). This implies that the Gellibrand River between Burrupa and the Estuary is not a gaining reach and it is appropriate to assume that residual inflows are zero. This is also a more conservative estimate of water availability at the Princetown gauge for the purpose of environmental flow compliance.

This assumption has been checked with Corangamite Catchment Management Authority. It was noted that there may be gains from groundwater in the Gellibrand River (pers. comm R. Jackson, 07/05/2025), this will be further investigated during the model development phase.

Given the lack of data available for loss derivation, it will be assumed that the loss function derived upstream of Burrupa (235224) is able to be applied in G13b, scaled down by magnitude of relative reach length.

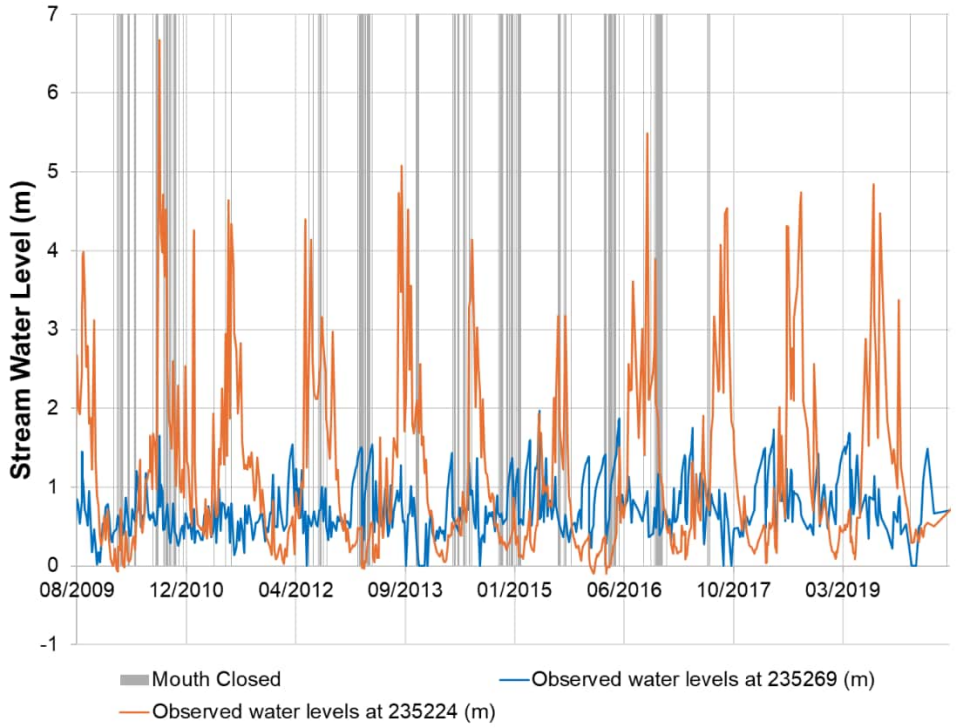


Figure 4-70 Comparison of observed water levels at Princetown (235269) and Burrupa (235269)

4.13 Specific yield check

A specific yield check was undertaken after the impact of farm dam impacts being added back to the partial natural flows and natural flows were derived. River losses were also subtracted from the partial natural flows prior to specific yield being calculated (only relevant for Love Creek, Carlisle River and Gellibrand River main stem). The specific yield check is used to validate the magnitude of flow calculated, with the expectation that specific yield generally decreases from upstream to downstream in a catchment.

The summary of specific yield in Table 4-24 and Figure 5-1 show the following:

- As expected, the specific yield of the unregulated catchments upstream of Olangolah Weir, Lardner Creek, Carlisle River and West Gellibrand Reservoir are much higher than the downstream catchments.
- Porcupine Creek and Ten Mile Creek have a higher specific yield than Yahoo Creek and Love Creek downstream.
- Kennedy's Creek and Latrobe Creek have a comparable specific yield to neighbouring ephemeral creeks Porcupine Creek and Ten Mile Creek.

The specific yield for Gellibrand River main stem is highest directly downstream of the storages and slowly decreases from upstream to downstream in the upper Gellibrand.

However, when splitting the residual inflow calculated for the lower Gellibrand River between Bunkers Hill and Burrupa, it was found that the best comparison to gauged flow at the Otway Pumping Stations was achieved by having a lower specific yield for G11a (Gellibrand River between Bunkers Hill and

North Otway Pump Stations). This resulted in a higher specific yield for G12 when allocating the remaining lumped residual flow for G11 G12 to this subcatchment, as shown in Figure 5-1.

The lumped catchment G11 G12 has a specific yield of 248 ML/km^2, which is consistent with the specific yields calculated for the upper Gellibrand. By modelling inflows upstream of North Otway and South Otway Pump Stations to match the gauged flow rather split by proportion of catchment area, a better estimate of water available for urban extractions is able to be achieved.

Additional gauged data is available to validate the specific yield estimations in the lower Gellibrand River. Gauged flow is available at Carlisle (235208- shown on Figure 5-1), downstream of the North Otway Pump Station gauge 235225, from 1964 to 1991. Specific yield was calculated from Bunkers Hill (235227) to Carlisle (235208) and Carlisle (235208) to Burrupa (235224) over a concurrent period of 1970 to 1991. The specific yield was calculated as follows:

- 235227 to 235208: 136 ML/km^2
- 235208 to 235224: 340 ML/km^2

This check independently verifies that the catchment directly downstream of Bunkers Hill (235227) is lower yielding than the catchment directly upstream of Burrupa (235224). This is consistent with the calculated results in Table 4-24 and also consistent with the specific yield for Yahoo Creek and Love Creek.

Table 4-24 Specific yield for each subcatchment calculated based on partial natural flow from 1900 to 2022

Subcatchment		Mean annual flow (ML/yr)	Catchment Area (km^2)	Specific Yield (ML/km^2)
G1	Inflow upstream of West Gellibrand Reservoir	10,289	15.4	668
G2	Inflow upstream of Olangolah Weir	8,427	11.5	733
G3a	Inflow to Gellibrand River downstream of storages and upstream of 235236	25,275	53.2	475
G3b	Inflow to Gellibrand River downstream of 235236 and upstream of 235231	4,616	16.5	280
G3c	Inflow to Gellibrand River downstream of 235231 and upstream of 235227	26,947	88.5	304
G4	Yahoo Creek upstream of Kawarren (235240)	1,771	17.5	101
G5	Love Creek upstream of Gellibrand (235234) and downstream of Yahoo, Ten Mile and Porcupine	1,238	15.2	81
G6	Ten Mile Creek upstream of 235239	1,470	10.0	147
G7	Porcupine Creek upstream of 235241	5,582	33.8	165
G8	Lardners Creek upstream of 235210	25,415	51.8	491
G9a	Carlisle River upstream of urban diversions weirs	7,395	7.7	960
G9b	Carlisle River upstream of 235200 and downstream of diversion weirs	29,810	71.3	418
G10	Kennedys Creek upstream of 235211	39,580	269.4	147
G11a	Gellibrand River from Bunkers Hill (235227) to downstream Carlisle River (235225)	6,879	105.0	66
G11b	Gellibrand River from ds Carlisle River (235225) to Pump Station (235258)	51,849	192.2	270
G12	Gellibrand River from Pump Station (235258) to Burrupa (235224)	33,485	82.1	408
G13a	Latrobe Creek and Boggy Creek	8,610	57.6	149
G13b	Gellibrand River from Burrupa (235224) to Princetown (235269) downstream of Latrobe Creek	0	56.4	0
	Total	**288,639**	**1,155**	**250**

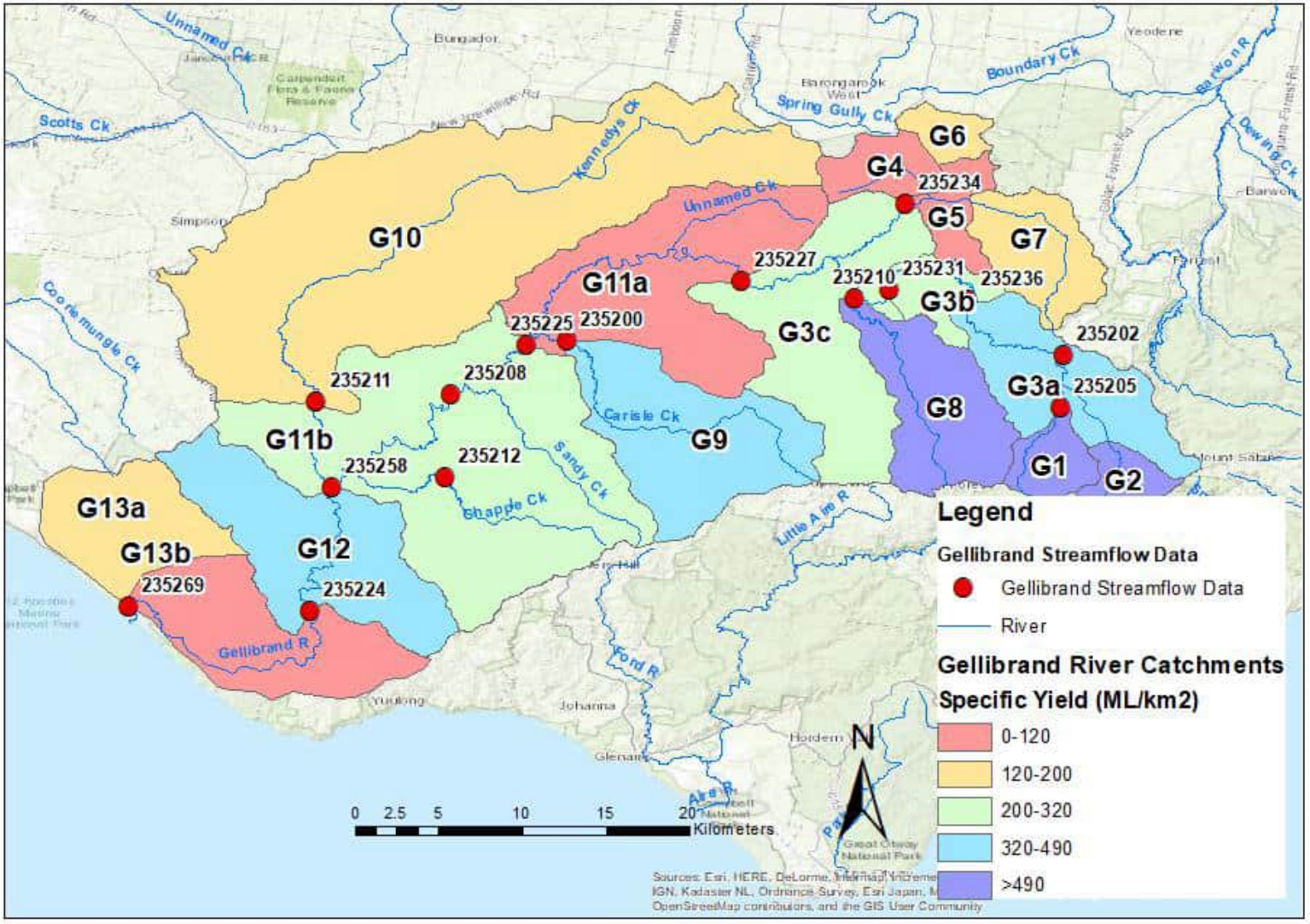


Figure 4-71 Specific yield map of the Gellibrand River catchment

5. Gellibrand Source model development

This section outlines the setup of the Gellibrand Source model, excluding the configuration of the Otway Source model (outlined below in Section 6).

5.1 Physical layout

The Gellibrand Source model has been developed based on the subcatchments, demands and catchment impacts shown in the schematic in Figure 5-1 for the Upper Gellibrand catchment upstream of Bunkers Hill (235227) and Figure 5-2 for the lower Gellibrand catchment from Bunkers Hill to Princetown (235269). Demands and catchment impacts include the impact of groundwater pumping, farm dam impacts, rural demands and urban demands.

The inflow to Gellibrand River downstream of the Colac storages and upstream of Bunkers Hill has been split at gauge 235231 (Gellibrand River at Rafferty's Lane) so that the impacts of groundwater pumping could be configured upstream of this point. The impact of groundwater pumping has been set at current level of development, assuming a daily impact of 0.63 ML/d for Yahoo Creek and 0.47 ML/d for Gellibrand River (as outlined in Section 3.1).

The inflow to Gellibrand River downstream of the Colac storages were further split at gauge 235236 to accommodate the environmental flow reaches outlined in Section 5.7.

The inflow in the lower Gellibrand has been split upstream of both South Otway Pump Station and North Otway Pump Station to represent water available for Wannon Water diversions. As well, the Arkins Creek East and West and First Creek inflows upstream of Wannon Water diversions have been represented as a single inflow, with Wannon Water able to extract all available water up to a daily extraction limit.

The flow routing and losses for Gellibrand River upstream of Bunkers Hill, Love Creek and Carlisle River are summarised in Section 4.3, Section 4.5 and Section 4.9 respectively. Routing and losses in the lower Gellibrand upstream of Burrupa are available in Section 4.11

Barwon Water transfers from Olangolah Weir and West Gellibrand Reservoir to Colac were configured based on a time series of modelled extractions from the Geelong Colac Source model (BW and HARC, 2023). The time series has been extracted for each climate scenario and configured into the Gellibrand Source model. It is recommended that the modelled extractions from the Geelong Colac Source model are updated when future model refinements are undertaken.

As outlined in Section 4.12, it has been assumed that there are no residual catchment inflows to the estuary between Burrupa and Princetown, with the exception of inflows from Latrobe Creek. The representation of the back up of water in the estuary when the estuary mouth is closed is not included in the model.

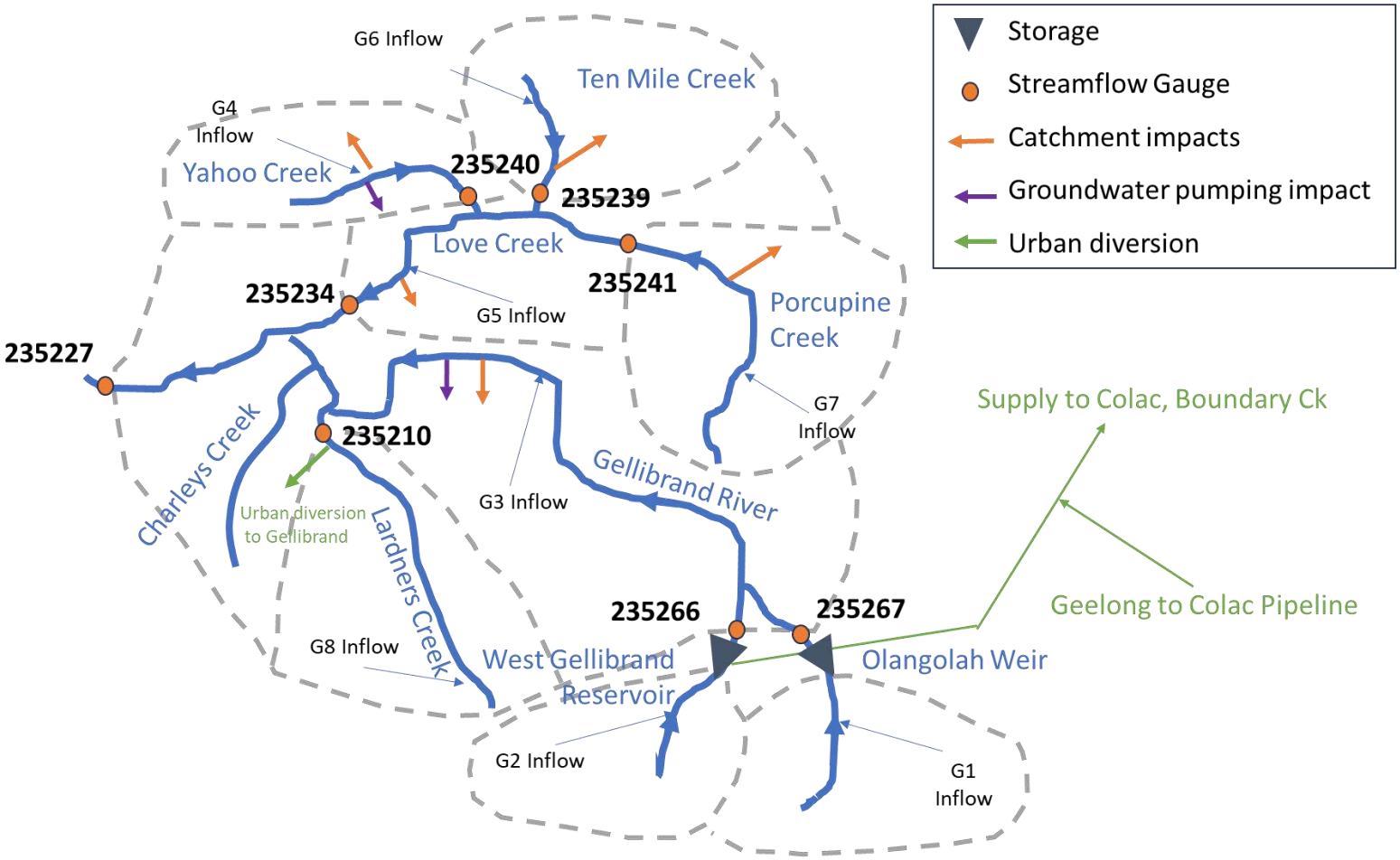


Figure 5-1 Schematic of the Gellibrand Source model

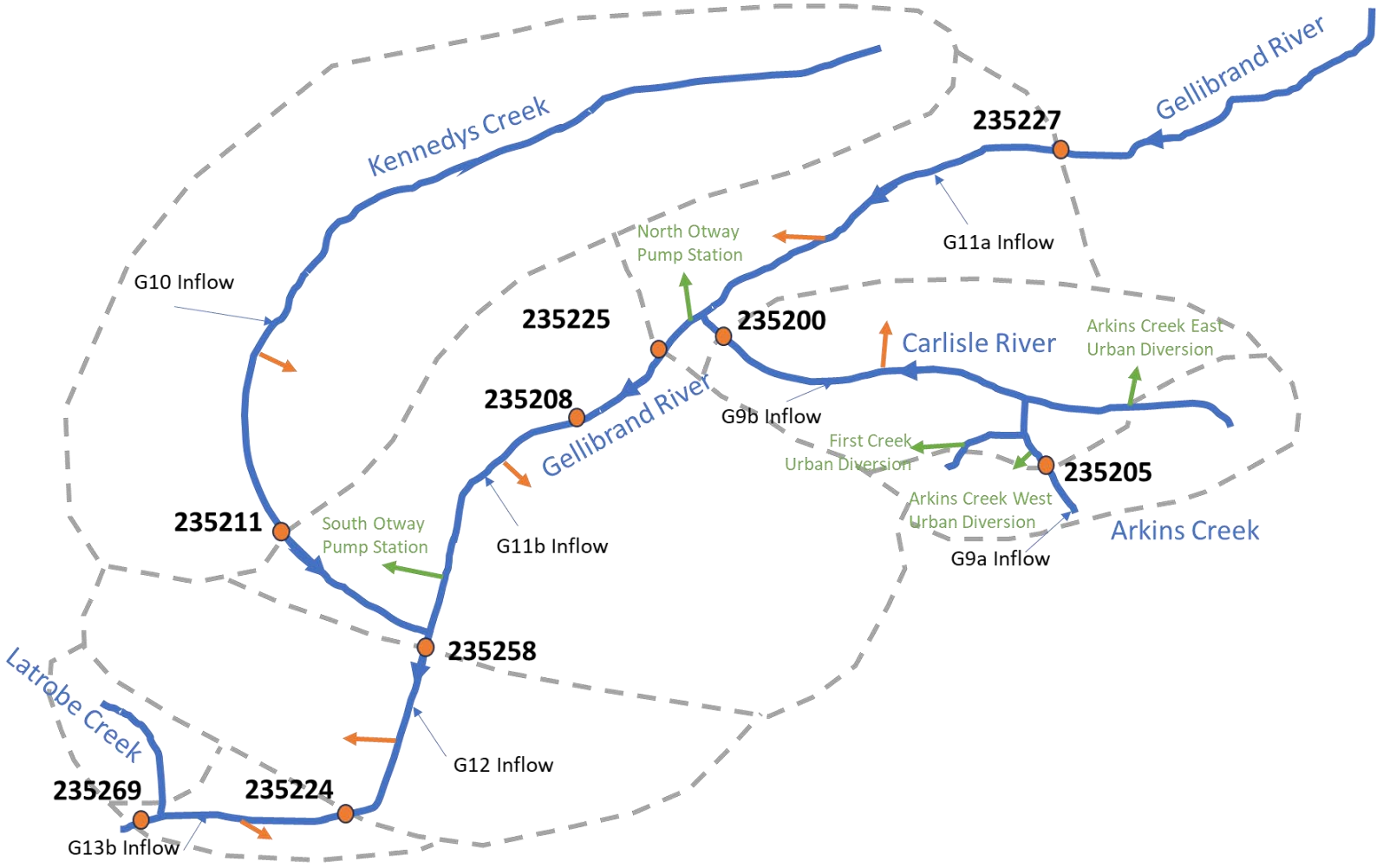


Figure 5-2 Schematic of lower Gellibrand River Source model catchments

5.2 Storages

West Gellibrand Reservoir and Olangolah Weir have been configured into the Gellibrand Source model consistent with the Geelong Colac Source model (BW and HARC, 2023). A summary of the storage details is available in Table 5-1, with rating curves available in BW and HARC (2023). A time series of rainfall and evaporation at Beech Forest (090006) has been configured to represent climate impacts on storage.

Table 5-1 Summary of storage details

Modelled storage	Full Supply Volume (ML)	Surface area at capacity (ha)	Dead storage (ML)
West Gellibrand Reservoir	1,860	21	65
Olangolah Weir	129	7	0

5.3 Minimum passing flow requirements

The minimum passing flow requirements downstream of Olangolah Weir and West Gellibrand Reservoir are taken from Bulk Entitlement (Colac) Amendment Order 2003. The passing flows have been configured downstream of the storages as follows:

- Olangolah Weir passing flow = 1 ML/d or natural
- West Gellibrand Reservoir passing flow = 5 ML/d or natural

There are no passing flow requirements for the urban extractions from Lardner Creek, Arkins Creek or First Creek.

5.4 Winterfill demands

5.4.1 Upper Gellibrand

As outlined in Section 3.2.1.1, it was found that there has been very low usage of off-stream winterfill licences on the Gellibrand River above Bunkers Hill in the period after the Millennium Drought. Given that the current usage is very low, it was agreed with Barwon Water to model the impact of winterfill use (either offstream winterfill pumping to refill dams or onstream winterfill capturing upstream flows) by explicitly representing the three types of winterfill storage and irrigation usage from those storages based on an irrigation pattern for pasture, such that the maximum usage year is equal to the magnitude of licence volume. This along with a maximum pumping rate can then be used to model the pattern of water pumped into the storage from the river to refill it over the next winterfill period. It will be assumed that pumping occurs at the maximum rate from the start of the winterfill period until the storage is filled.

The maximum extraction rate for each off-stream winterfill licence on the Gellibrand River was confirmed with Southern Rural Water and is summarised in Table 5-2.

Table 5-2 Gellibrand River above Bunkers Hill off-stream dam maximum extraction rate

BEE	Annual Licence Volume (ML)	Maximum Extraction Rate (ML/d)	Usage period
BEE022814	58 ML	1 ML/d	July to June
BEE027073	12 ML	1 ML/d	May to October
BEE031157	40 ML	1.5 ML/d	July to October
BEE031642	100 ML	1 ML/d	May to October

A schematic of the winterfill pumping setup in the Gellibrand Source model can be found in Figure 5-3, showing that a different storage is used to represent each diversion period set to the winterfill licence volume.

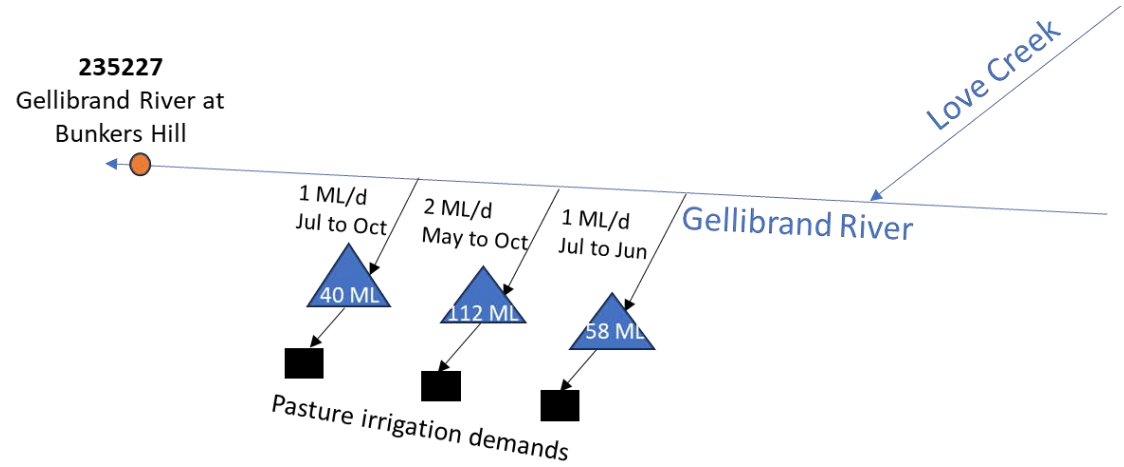


Figure 5-3 Schematic of winterfill setup in Gellibrand Source model

5.4.2 Lower Gellibrand

As outlined in Section 3.2, there is no current on-stream winterfill usage demands in the Gellibrand River downstream of Bunkers Hill. Therefore, winterfill demands were not required to be represented in the lower Gellibrand.

5.5 Rural restrictions

As outlined in Southern Rural Water's Otway Coast Basin Local Management Plan (2014), irrigation licence holders (direct and winterfill) are subject to a five-stage roster and restriction process. The Gellibrand River is divided into three zones which are summarised in Table 5-3. The daily flow at compliance points is calculated as a 7-day rolling average, noting that Gellibrand River at Bunkers Hill is the compliance point for both Zone 1 and Zone 2. Other licence types (such as stock and domestic, commercial and industrial) are not impacted by rural restrictions.

Table 5-3 Summary of Southern Rural Water Otway direct irrigation Restriction Zones (SRW, 2014)

Zone		Subcatchments	Compliance points
Zone 1	Below North Otway Pump Station (NOPS)	G10, G11b, G12, G13	Gellibrand River at Bunkers Hill (235227)
Zone 2	Upstream of North Otway Pump Station (excluding Carlisle River)	G1, G2, G3, G4, G5, G6, G1, G8, G11a	Gellibrand River at Bunkers Hill (235227)

Zone 3	Carlisle River	G9	Carlisle River at Carlisle (235200)

For direct irrigators, SRW (2014) outlines a percentage of maximum diversion rate for each restriction level based on a 7-day rolling average flow trigger at the given compliance point (summarised in Table 5-4). Note that the restrictions for Stage 2 and Stage 3 in the Carlisle River zone are based on the same 7-day rolling average trigger as Stage 4. Therefore, direct irrigation restrictions have been setup for Carlisle River to go from Stage 1 to Stage 4 (25% maximum extraction rate).

For winterfill irrigators a ban is imposed when flow drops below 350 ML/d at Bunkers Hill (zones 1 & 2) or 80 ML/d at Carlislie (zone 3).

Table 5-4 Rural restrictions in Otway coast

Restriction level	% of maximum diversion rate	Flow trigger (7-day rolling average) in ML/d		
		Zone 1	Zone 2	Zone 3
Stage 1	100%	22.5	27.5	8.1
Stage 2	75%	17.5	22.5	NA
Stage 3	50%	15	20	NA
Stage 4	25%	12.5	17.5	6.6
Stage 5	0%	10	15	6.1
Winterfill	0%	350 ML/d	350 ML/d	80 ML/d

5.6 Urban supply to Gellibrand

5.6.1 Extraction from Lardner Creek

As outlined in the Bulk Entitlement (Gellibrand) Conversion Order 1997, Barwon Water is entitled to extract up to 60 ML/yr from Lardners Creek at a maximum daily rate of 0.43 ML/d. There is no passing flow requirement for the urban extractions.

5.6.2 Urban restrictions

For a conservative estimate of water availability in Lardner Creek, urban restrictions for Gellibrand have not been configured into the Gellibrand Source model.

5.7 Environmental flows

The environmental flow reaches have been defined consistent with EarthTech (2006), including some additional environmental flow compliance locations as shown in Table 5-5. These environmental flow compliance points are shown in Figure 5-4 and were determined in collaboration with Alluvium and key stakeholders. The Gellibrand Source model has been setup such that each of the environmental flow compliance points are represented.

Table 5-5 Summary of environmental flow reaches

Environmental flow reach	Reach	Environmental flow compliance point
1	Love Creek catchment	Love Creek at Gellibrand (235234)

Environmental flow reach	Reach	Environmental flow compliance point
2a	Upper Gellibrand to Love Creek confluence	Gellibrand River d/s dam site (235236)
2b	Upper Gellibrand to Carlisle River confluence	Gellibrand River at Bunkers Hill (235227)
2c	Lardner Creek	Lardner Creek at Gellibrand (235210)
3	Carlisle River	Carlisle River at Carlisle River (235200)
4	Mid Gellibrand River	Gellibrand River at Burrupa (235224)
4	Mid Gellibrand River	Gellibrand River d/s South Otway Pumps Bridge (235258)
5	Kennedys Creek	Kennedys Creek at Kennedy Creek (235211)
6	Gellibrand River Estuary	Gellibrand River at Princetown (235269)

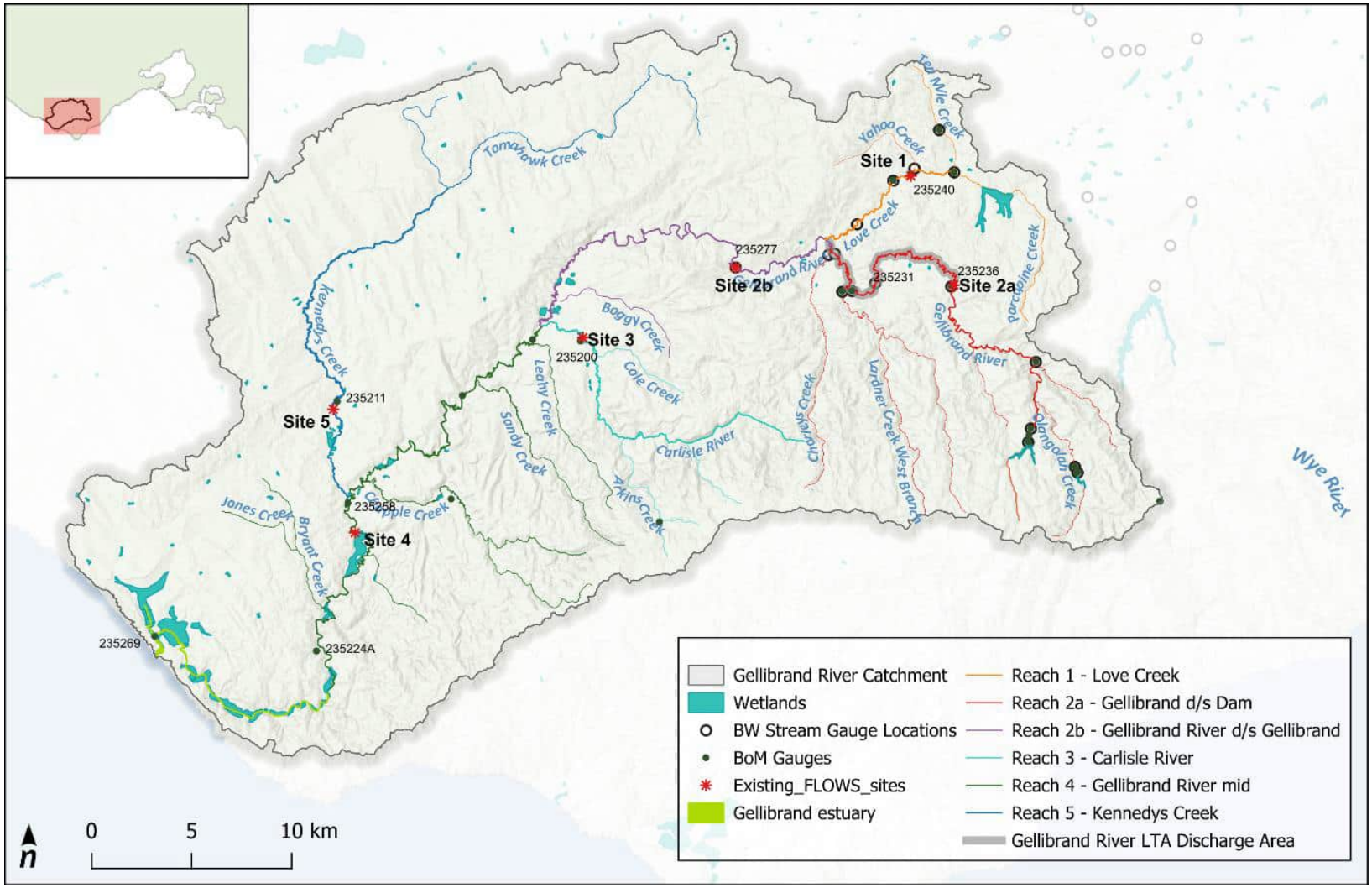


Figure 5-4 Map of environmental reaches and flow compliance locations (Source: Alluvium)

5.7.1 Environmental flow recommendations

Environmental flow recommendations for the Gellibrand catchment were previously made by EarthTech in 2006 and will be updated by Alluvium as part of the current project. The EarthTech (2006) flow recommendations outlined below have been configured in the Environmental Flow Nodes at each compliance point, with the option to be updated with new recommendations later in this project. Some key considerations for the specification of environmental flows in the Gellibrand Source model are:

- A minimum interval of 7 days between spells has been assumed (as recommended by EarthTech, 2006)
- Target compliance of 80% has been assumed for all Environmental Flow Nodes. This means that the success criteria for flow components within the nodes will be set to 80% for target magnitude, duration and volume.

As no environmental entitlements are held in the Gellibrand system, ordering has not been switched on for the Environmental Flow Nodes and their setup will only be used to inform environmental flow compliance.

Table 5-6 Reach 1: Love Creek Catchment environmental flow recommendations

Period	Component	Flow Magnitude	Frequency	Duration
December to May	Low flow	6 ML/d or natural	Continuous	Continuous
December to May	Low flow fresh	8.6 ML/d	5 per year	4 days
December to May	Low flow fresh	26 ML/d	2 per year	2 days
June to November	High flow	26 ML/d or natural	Continuous	Continuous
June to November	High flow fresh	86.4 ML/d	5 per year	5 days
Anytime	Annual flood	518.4 ML/d	1 per year	3 days
Anytime	Overbank	1,000 ML/d	1 every 2 years	1 day
Anytime	Overbank	1,728 ML/d	1 every 10 years	1 day

Table 5-7 Reach 2a: Gellibrand River at James Access Bridge environmental flow recommendations

Period	Component	Flow Magnitude	Frequency	Duration
December to May	Low flow	8.6 ML/d or natural	Continuous	Continuous
December to May	Low flow fresh	22 ML/d	4 per year	4 days
December to May	Low flow fresh	173 ML/d	2 per year	2 days
June to November	High flow	130 ML/d or natural	Continuous	Continuous
June to November	High flow fresh	260 ML/d	5 per year	5 days
Anytime	Bankfull	2,000 ML/d	2 every 3 years	1 day
Anytime	Overbank	3,500 ML/d	1 every 5 years	1 day

Table 5-8 Reach 2b: Gellibrand River at Bunkers Hill environmental flow recommendations

Period	Component	Flow Magnitude	Frequency	Duration
December to May	Low flow	13 ML/d or natural	Continuous	Continuous
December to May	Low flow fresh	86.4 ML/d	5 per year	4 days
December to May	Low flow fresh	260 ML/d	2 per year	2 days
June to November	High flow	173 ML/d or natural	Continuous	Continuous
June to November	High flow fresh	1,901 ML/d	2 per year (1 in June, 1 in October)	2 days
Anytime	Overbank	5,184 ML/d	1 every 2 years	1 day

Table 5-9 Reach 3: Carlisle River environmental flow recommendations

Period	Component	Flow Magnitude	Frequency	Duration
December to May	Low flow	5.2 ML/d or natural	Continuous	Continuous
December to May	Low flow fresh	61 ML/d	1 per year	2 days
December to May	Low flow fresh	121 ML/d	1 per year	2 days
June to November	High flow	61 ML/d or natural	Continuous	Continuous
June to November	High flow fresh	372 ML/d	2 per year	2 days
Anytime	Overbank	1,106 ML/d	1 every 10 years	1 day

Table 5-10 Reach 4: Mid Gellibrand River environmental flow recommendations

Period	Component	Flow Magnitude	Frequency	Duration
December to May	Low flow	86.4 ML/d or natural	Continuous	Continuous
December to May	Low flow fresh	260 ML/d	4 per year	4 days
June to November	High flow	260 ML/d or natural	Continuous	Continuous
June to November	High flow fresh	3,284 ML/d	3 per year	3 days
Anytime	Annual Flood	6,048 ML/d	1 per year	3 days
Anytime	Overbank	12,960 ML/d	1 every 3 years	1 day

Table 5-11 Reach 5: Kennedys Creek environmental flow recommendations

Period	Component	Flow Magnitude	Frequency	Duration
December to May	Low flow	2 ML/d or natural	Continuous	Continuous
December to May	Low flow fresh	35 ML/d	3 per year	5 days
June to November	High flow	35 ML/d or natural	Continuous	Continuous
June to November	High flow fresh	259 ML/d	4 per year	3 days

Anytime	Overbank	1,728 ML/d	1 per year	2 days

5.7.2 Rates of rise and fall

Rates of rise and fall must be configured for the low flow fresh and high flow fresh flow components to regulate the fluctuations in flow. The rates of rise and fall as recommended by EarthTech (2006) in Table 5-12 have been configured in the Gellibrand Source model.

Table 5-12 Rates of rise and fall (EarthTech, 2006) expressed as a change in discharge of the event divided by the length of the event

Reach	Component	Average rate of rise (ML/day/day)	Average rate of fall (ML/day/day)
1 Love Creek	Low flow fresh	13	4
	High flow fresh	61	32
2a Gellibrand River at James Access Bridge	Low flow fresh	26	20
	High flow fresh	102	61
2b Gellibrand River at Bunkers Hill	Low flow fresh	74	32
	High flow fresh	265	144
3 Carlisle River	Low flow fresh	11	5
	High flow fresh	37	20
4 Gellibrand River Mid Reach	Low flow fresh	123	50
	High flow fresh	562	274
5 Kennedys Creek	Low flow fresh	14	6
	High flow fresh	120	65

5.7.2.1 Estuary environmental flow recommendations

Estuary environmental flow recommendations have been investigated over a number of projects, with difficulty in formulating flow recommendation due to the absence of an available hydrological model.

EarthTech (2006) made the following recommendations:

- Late winter to early spring flushing flows: 1,500 ML/d to 2,000 ML/d for 2 to 3 days in July to October
- Summer and autumn low flows: diversion of water should cease when flows fall to 100 ML/d to reduce the occurrence of estuary mouth closure
- Flow variability by allowing the naturally occurring flows less than the 100 ML/d recommendation. Periods of high flow in summer and autumn at their natural frequency and timing to mimic natural freshes.

The estuary flow recommendations were further developed by Lloyd et al in 2008 as follows:

- 100 ML/d baseflow from June to November to maintain the salt wedge dynamics. This ensures that bank stability in the upper estuary and suspended sediment dynamics in the middle estuary are maintained
- 100 ML/d baseflow from December to May to minimise the probability of the mouth closure.
- High (Bankfull) flow for at least 1 day a year to maintain the channel and floodplain morphology of all parts of the estuary, including scour of the sandy delta at the entrance.

It has been assumed for the development of the Gellibrand Source model that the estuary flow recommendations will be based on a flow rate at Burrupa.

The key recommendation is the requirement for 100 ML/d in the Gellibrand estuary, with EarthTech (2006) recommending that upstream diversions are ceased to ensure this happens. This is further discussed in the pump stop investigations in Section 5.7.3.

5.7.3 Pump stop investigations

The Gellibrand River estuary is an Intermittently Closed and Open Lake and Lagoon (ICOLL) estuary and is considered a wave dominated estuary (Corangamite CMA, 2023). The estuary can be closed due to wave height and wave direction, contributing to sand build-up at the estuary mouth causing a closure. The closure of the estuary mouth for prolonged periods of time can cause a threat of flooding and damage to agricultural land and infrastructure, in particular the Great Ocean Road. When these threats occur, an artificial opening can be attempted. However, artificial openings can contribute to adverse environmental outcomes such as fish deaths, which are dependent on the factors of tidal exchange, catchment inflows and presence of anoxic water on the floodplain (Corangamite CMA, 2023). To avoid this, management intervention, such as requesting Wannon Water to cease pumping to allow for greater flow rates, occurs.

As outlined in Corangamite CMA (2023), a short term management action is to reduce extractions for short periods of time (e.g. two days). The South Otway Pump Station extractions may be reduced from 17 ML/d to 0 ML/d, while the North Otway Pump Station may be reduced from 10 ML/d to 6 ML/d. There are a number of factors that Wannon Water consider when assessing a pump stop request from Corangamite CMA, in particular the current water availability condition in the Otway system.

Corangamite CMA have noted that there have been just three pump stop requests on record (pers. comm R. Jackson, 02/04/2025). These are outlined below:

- 10th March 2022- the estuary ended up opening naturally, no management action undertaken
- 19th April 2024- Wannon Water responded that from 7am Saturday 20th April 2024 to 11pm Sunday 21st April 2024, minimal extraction will occur from NOPS (3-4 ML/d). However, South Otway Pump Station continued to pump at a rate of 15-17 ML/d.
- 24th January 2025- No reduction of Wannon Water extractions from pump stop request due to the low Wannon Water storage levels.

Given that no direct pumping was stopped for the March 2022 and January 2025 requests, only the April 2024 request was further analysed for potential representation in the Source model.

As shown in Figure 5-5, there is a two day reduction of Wannon Water extractions at North Otway Pump Station after the pump stop request is made in 19th April 2024. Extractions reduce from 10 ML/d to 6.3 ML/d. This reduction allows an increase in flow in Gellibrand River at Burrupa from very minimal flow to 174 ML/d at the peak of the flow event. The flow in the Gellibrand River at Burrupa then falls over the next fortnight from 174 ML/d to 120 ML/d by the start of May.

Note that the streamflow data in Gellibrand River at Burrupa (235224) prior to 19th April 2024 has a quality code of 160 from the Water Measurement Information System (WMIS), which indicates the impact of downstream tidal influence backing up water the gauge. Therefore the improvement of flow in the Gellibrand River due to the pump stop is not able to be fully understood as the data prior to the pump stop request is not reliable.

At the time when the April 2024 pump stop was requested, Wannon Water Otway storages were 78% full. In January 2025 when the pump stop request was not granted, Wannon Water Otway storages were between 75% and 77% full. Presumably the time of year, i.e. the fact that Wannon Water was in its highest demand period would have influenced this decision, whereas in April periods of high demand would have passed.

Given there is only a single pump stop event that has occurred, and the river flow data prior to the pump stop is unreliable, a relationship between flow data, estuary mouth conditions and Wannon Water available storage volume could not be derived. It is recommended that this investigation is repeated once there is more data available. Given the infrequent occurrences of the pump stop request, the need to represent it in the Gellibrand Source model will be discussed further with Corangamite CMA and Wannon Water.

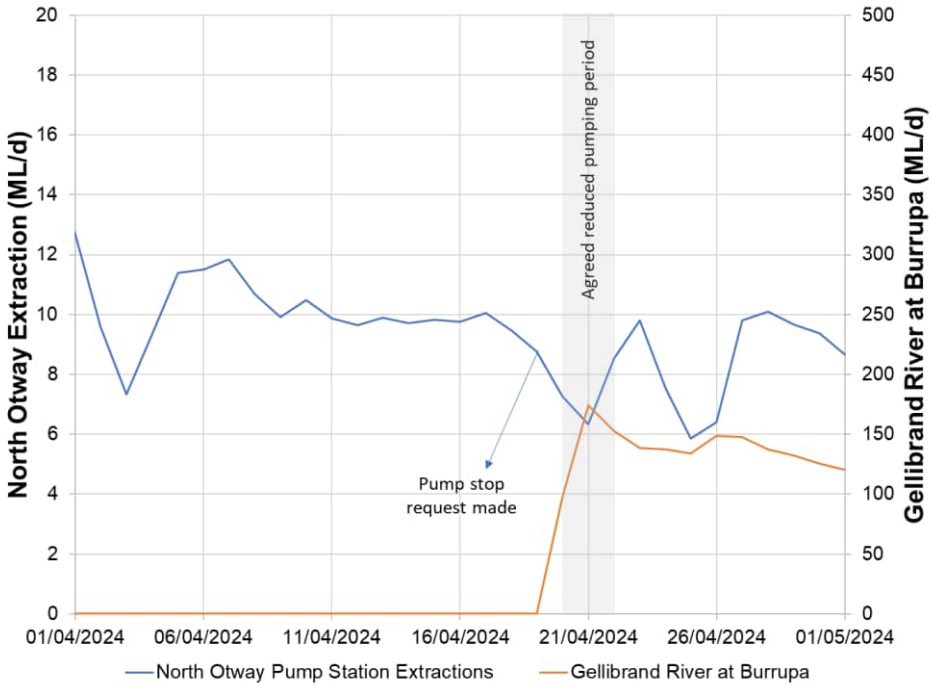


Figure 5-5 Comparison of North Otway extractions and flow in the Gellibrand River at Burrupa (235224)

6. Otway supply system representation

The Otway supply system representation in the existing Source model (GHD, 2019) has been updated in collaboration with Wannon Water to ensure an accurate representation of extractions from Gellibrand River to supply the Otway system. System layout is shown in Figure 6-1. Note that GHD (2019) has labelled the Dales Road Basins as Warrnambool Storage and Mt Ewen Reservoir as Ewens Hill Reservoir.

6.1 Storage representation

6.1.1 Storage characteristics

The details of the storages in the Otway system are summarised in Table 6-1 and have been confirmed by Wannon Water, including the high dead storage volumes. Storage rating tables are available in Appendix G.

6.1.2 Storage targets and drawdown priorities

The model has been set up to transfer and distribute water across storages to minimise pumping costs based on reservoir storage targets and transfer rules (refer Section 6.4.3. Each storage, with the exception of Cobden Storage, has been set up to be supplied as the same priority. Cobden Storage has been configured as a higher priority and so is supplied first.

Storage operating targets for each storage were provided by Wannon Water and summarised in Table 6-2. During the model verification process, storage operating targets were updated to achieve satisfactory comparisons to observed Otway system storage volumes (as outlined in Section 7.2). The updated storage operating targets that replicate historic storage behaviour are shown in Table 6-3 and have been adopted in the Gellibrand Source model.

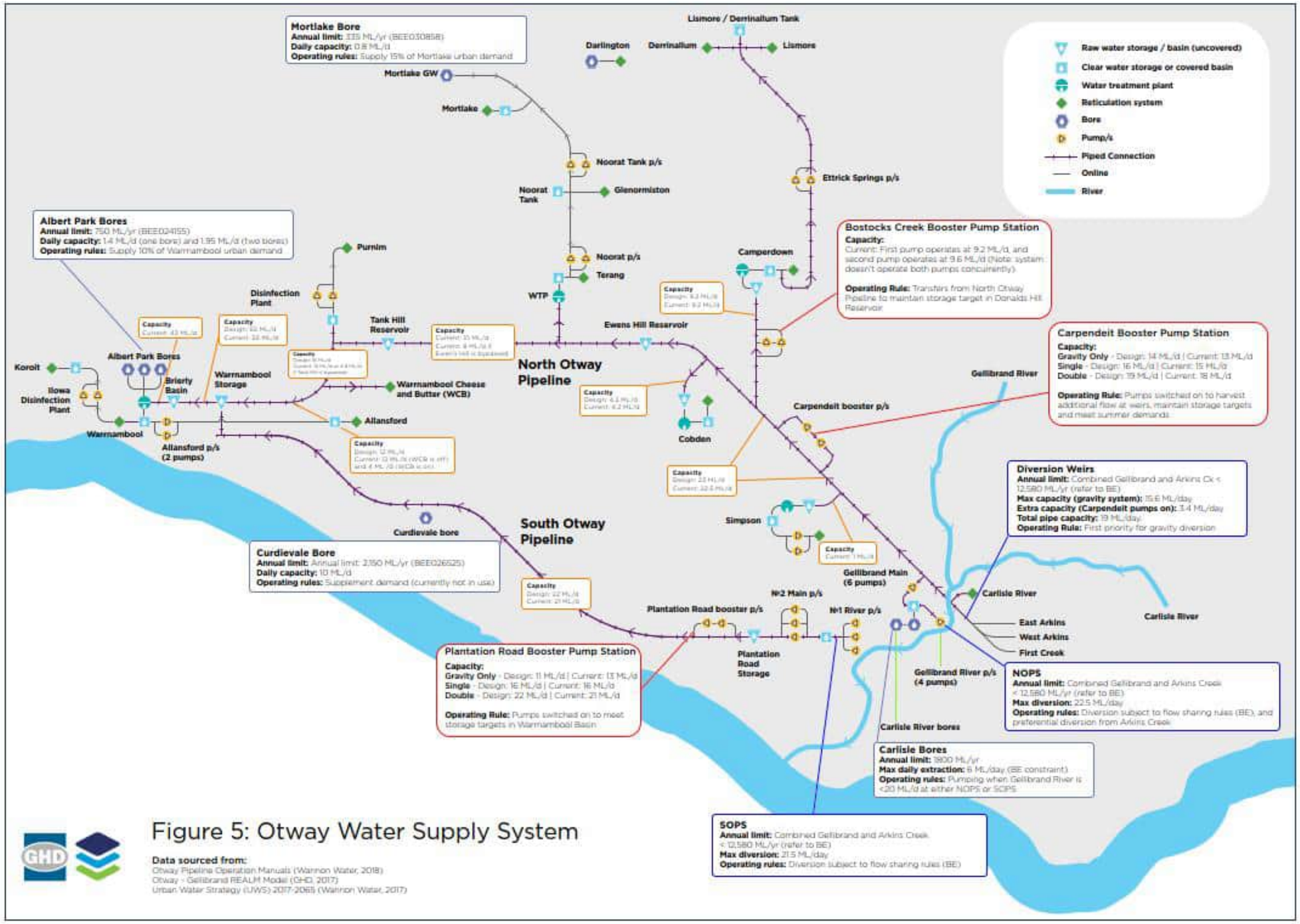


Figure 5: Otway Water Supply System

Data sourced from:
Otway Pipeline Operation Manuals (Wannon Water, 2018)
Otway - Gellibrand REALM Model (GHD, 2017)
Urban Water Strategy (UWS) 2017-2065 (Wannon Water, 2017)

Figure 6-1 Otway Supply System (GHD, 2019)

Table 6-1 Summary of Wannon Water storage details

Storage	Capacity (ML)	Dead storage (ML)	Outlet capacity (ML/d)	Supplied from	Supply to	Gauge used to represent climate impacts on storage
Brierly Basin	51.7	20	43 ML/d	Warrnambool Storage / Dales Road Basins	Warrnambool and Allansford	Warrnambool Airport (090186)
Dales Road Basins	620	74	55 ML/d	North Otway Pipeline South Otway Pipeline	Brierly Basin	Warrnambool Airport (090186)
Plantation Road Basin	100	40	21 ML/d	South Otway Pipeline	South Otway Pipeline	Cobden Post Office (090021)
Tank Hill Reservoir	774	280	12 ML/d	North Otway Pipeline	Purnim Dales Road Basins	Terang (090077)
Cobden Basin	51	16.7	4.2 ML/d	North Otway Pipeline	Cobden	Cobden Post Office (090021)
Donalds Hill Storage	207	38	9.2 ML/d	North Otway Pipeline	Camperdown Lismore and Derrinalum	Camperdown Post Office (090011)
Simpson Storage	34	17	1 ML/d	North Otway Pipeline	Simpson	Cobden Post Office (090021)
Mt Ewen Reservoir	625	202	10 ML/d	North Otway Pipeline	Terang Tank Hill Reservoir	Terang (090077)

Table 6-2 Otway system current operating storage targets as provided by Wannon Water

Month	Storage Operational Target Volume (ML)							
	Brierly Basin	Cobden Basin	Simpson Basin	Plantation Road Storage Basin	Dales Road Basin	Tank Hill Storage Basin	Ewens Reservoir	Donalds Hill Storage
Storage full supply volume (ML)	**51.7**	**51**	**34**	**100**	**620**	**774**	**625**	**207**
January	40	45	30	70	460	562	469	190
February	40	45	30	70	328	473	428	190
March	40	45	30	70	232	442	419	190
April	40	45	30	70	200	489	468	190
May	40	45	30	70	250	557	440	190
June	40	45	30	70	330	625	423	190
July	40	45	30	70	400	682	475	190
August	40	45	30	70	445	730	568	190
September	40	45	30	70	485	735	598	190
October	40	45	30	70	530	741	600	190
November	40	45	30	70	575	715	600	190
December	40	45	30	70	568	650	576	190

Table 6-3 Otway system current operating storage targets as updated during model verification

Month	Storage Operational Target Volume (ML)							
	Brierly Basin	Cobden Basin	Simpson Basin	Plantation Road Storage Basin	Dales Road Basin	Tank Hill Storage Basin	Ewens Reservoir	Donalds Hill Storage
Storage full supply volume (ML)	**51.7**	**51**	**34**	**100**	**620**	**774**	**625**	**207**
January	40	45	30	70	497	670	553	160
February	40	45	30	70	495	634	539	160
March	40	45	30	70	411	614	524	160
April	40	45	30	70	394	599	523	160
May	40	45	30	70	407	636	515	160
June	40	45	30	70	422	667	534	160
July	40	45	30	70	484	659	532	160
August	40	45	30	70	513	677	563	160
September	40	45	30	70	524	699	592	160
October	40	45	30	70	540	719	602	160
November	40	45	30	70	524	707	590	160
December	40	45	30	70	527	698	582	160

6.2 Bulk Entitlement rules

As outlined in the Bulk Entitlement (Otway System) Conversion Order 1998, Wannon Water's bulk entitlement allows for a combined 22.5 ML/d to be extracted from the North Otway Pump Station and Arkins diversion weirs (Arkins Creek West, Arkins Creek East and First Creek). Up to 21.5 ML/d can also be extracted via the South Otway Pump Station. Wannon Water is constrained by a combined annual Bulk Entitlement limit for all Gellibrand River diversions of 12,580 ML/yr.

The maximum extraction rate as outlined in the Bulk Entitlement rules has been configured on the diversion from the Gellibrand River, however the lower pipeline capacity outlined in Section 6.3 constraints the water able to be diverted daily.

As outlined in the Bulk Entitlement (Otway System) Conversion Order 1998, maximum extraction rates for Wannon Water are dependent on upstream flow as outlined below. These extraction limits effectively ensure a passing flow except when upstream flows are 12 ML/d or less in which case Wannon Water can extract all flow.

If the flow upstream of North Otway Pumping Station is:

- Greater than 54.9 ML/d, combined extraction of 22.5 ML/d allowed
- Greater than 44.9 ML/d, combined extraction of 20 ML/d allowed
- Greater than 22.5 ML/d, combined extraction of 17.5 ML/d allowed
- Greater than 12 ML/d, combined extraction of 12 ML/d allowed
- Less than 12 ML/d, combined extraction of 12 ML/d allowed

If the flow upstream of South Otway Pumping Station is:

- Greater than 41.2 ML/d, combined extraction of 21.5 ML/d allowed
- Greater than 32.7 ML/d, combined extraction of 19 ML/d allowed
- Greater than 22 ML/d, combined extraction of 17 ML/d allowed
- Greater than 12 ML/d, combined extraction of 12 ML/d allowed
- Less than 12 ML/d, combined extraction of 12 ML/d allowed

This maximum extraction has been set up on the controlled splitter used to configure the diversion from the Gellibrand River at North Otway Pump Station and South Otway Pump Station.

6.3 Pipeline and booster pump capacities

The pipeline capacities for the Otway system outlined in Table 6-4 have been reviewed and confirmed by Wannon Water. The corresponding function used to set up the pipeline and booster pump capacities are also noted in Table 6-4 to streamline future updates.

Plantation Road booster pumps are used to supply additional water to Warrnambool storage when gravity supply is inadequate. Wannon Water advised that:

- If the Warrnambool demand is less than 11 ML/d, then only the gravity fed supply is occurring at a rate of up to 11 ML/d

- If the Warrnambool demand is between 11 ML/d and 14 ML/d, then a single booster pump is added giving a combined maximum capacity of 14 ML/d
- If the Warrnambool demand is greater than 14 ML/d, then both booster pumps are used giving a combined capacity of up to 16 ML/d.

Table 6-4 Otway system pipeline and booster pump capacities

Pipeline and booster pump	Maximum capacity (ML/d)	Function
Arkins Creek Diversions	13 ML/d	*$f_ArkinsCreek_DiversionCapacity*
North Otway Pipeline	17 ML/d	*$f_NorthOtway_DiversionCapacity*
South Otway Pipeline	16.5 ML/d	*$f_SouthOtway_DiversionCapacity*
Simpsons offtake	1 ML/d	*$f_Simpson_DiversionCapacity*
Cobden offtake	4.2 ML/d	*$f_Cobden_DiversionCapacity*
Mt Ewen Reservoir to Tank Hill Reservoir	8 ML/d	*$f_MtEwen_TankHill_Capacity*
Tank Hill Reservoir to Warrnambool Dairy	12 ML/d	*$f_TankHill_WarrnamboolDairy_Capacity*
Warrnambool Dairy to Dales Rd Basins	4 ML/d	*$f_WarrnamboolDairy_DalesRd_Capacity*
Dales Rd Basins to Brierly Basin	55 ML/d	*$f_DalesRd_BrierlyBasin_Capacity*
Brierly Basins to Warrnambool	43 ML/d	*$f_BrierlyBasins_Warrnambool_Capacity*
Plantation Road Booster Pumps ds Planation Rd Basin	Max 16 ML/d	*$f_PlantationRoadBoosterPump_Capacity*
Carpendeit Booster Pumps d/s Simpsons Storage offtake	17 ML/d	*$f_CarpendeitBoosterPumps_Capacity*
Bostocks Booster Pumps to Donald's Hill Storage	9 ML/d	*$f_BostockBoosterPumps_Capacity*

6.4 Urban system configuration

6.4.1 Groundwater supply sources

The Otway system is able to access supplementary groundwater supply from the Carlisle River bores (at North Otway Pump Station), Mortlake bores, Albert Park bores in Warrnambool and Curdievale bore on the South Otway pipeline (currently switched off in the Otway Source model). The groundwater pumping rules summarised in Table 6-5 have been confirmed with Wannon Water.

Wannon Water noted that Curdievale bore will be ready for use in 18 months and has been included in the Source model with the following rules:

Curdievale Groundwater Bore Extraction = up to 10 ML/d when flow in the Gellibrand River downstream of SOPS is less than 60 ML/d

The current Source model setup suggests that Mortlake bores supply 15% of Mortlake urban demand. The 2022 Drought Preparedness Plan outlines that the Otway supply to Mortlake is shandied with 17% groundwater. The 2022 DPP confirms that the groundwater bores at Albert Park supply approximately 10% of Warrnambool supplied water. These operating rules were confirmed with Wannon Water.

Table 6-5 Groundwater pumping rules for Otway system

Groundwater Source	Licence	No of bores	Annual limit (ML)	Daily capacity (ML/d)	Operating Rules
Albert Park Bores (Warrnambool)	BEE024155	3	750	1.4 ML/d (one bore) 1.95 ML/d (two bores)	Supply 10%of Warrnambool urban demands
Mortlake Bores	BEE030858	2	335	0.8 ML/d	Supply 15% of Mortlake urban demand
Carlisle Bores	BEE029488	2	1800	6 ML/d	Pumping occurs when flow in the Gellibrand River is less than 20 ML/d at either NOPS or SOPS
Curdievale Bore	BEE026252	1	2,150 ML/yr	9 ML/d	up to 10 ML/d when flow in the Gellibrand River downstream of SOPS is less than 60 ML/d

6.4.2 Warrnambool roof water harvesting

The 2022 Wannon Water Drought Preparedness Plan notes that the Warrnambool Roofwater harvesting project was completed in 2011 and is able to supply additional water to Brierly Basin.

Recorded total inflow to Brierly Basin from the Warrnambool Roofwater harvesting project was available from 2015 to 2024 and compared against rainfall data at Warrnambool Airport (090186). A monthly regression showed a strong correlation (Figure 6-2) between rainfall depth and roofwater harvesting volume. Roofwater harvesting was estimated as follows:

Monthly Roofwater Harvesting (ML/mth) = 0.0682 x Monthly Rainfall at Warrnambool (mm/mth)

The monthly comparison of estimated and observed roofwater harvesting in Figure 6-3 shows that the observed pattern is able to be replicated. This was verified on a daily timestep (Figure 6-4) showing that the monthly regression when applied daily is able to estimate the magnitude and timing of daily roofwater harvesting contribution to Brierly Basin.

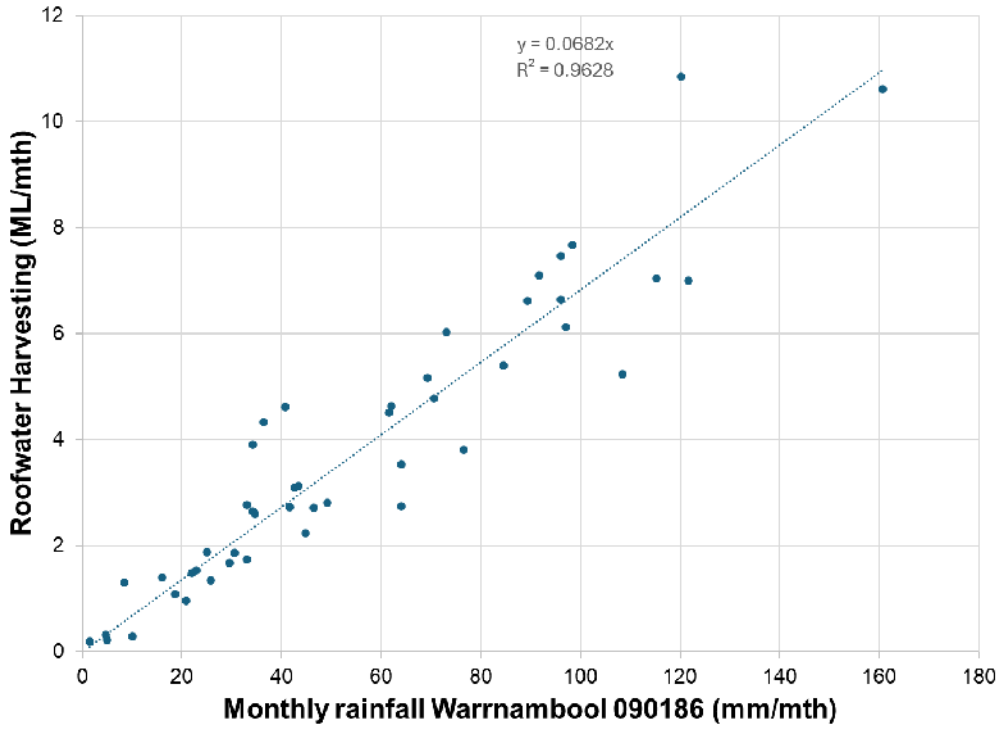


Figure 6-2 Monthly regression of Warrnambool rainfall (090186) and roofwater harvesting

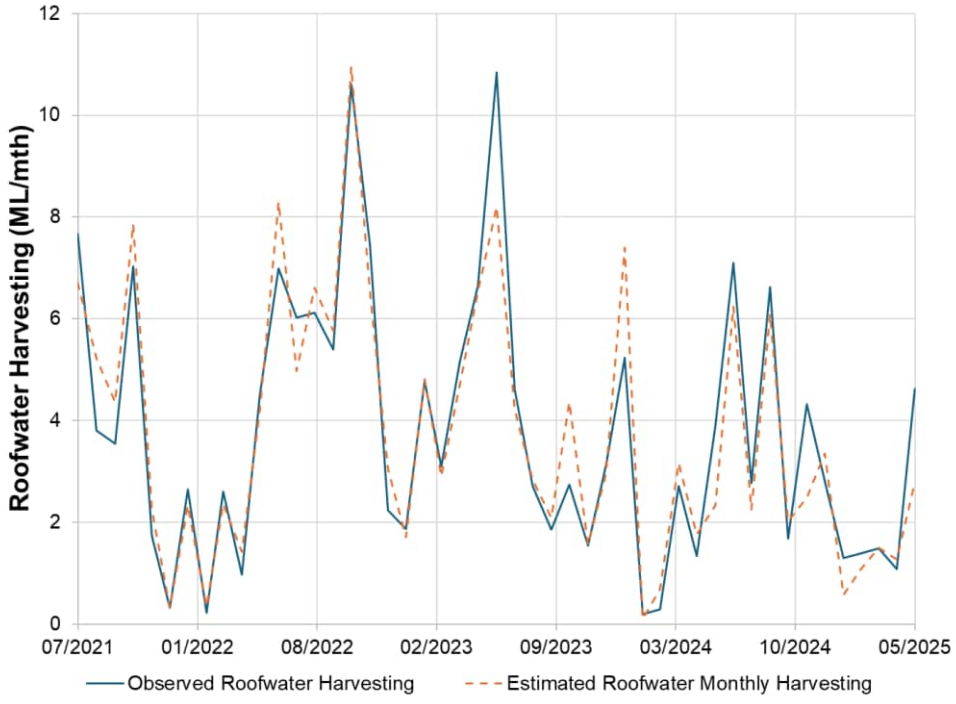


Figure 6-3 Monthly comparison of estimated and observed roofwater harvesting contribution to Brierly Basin

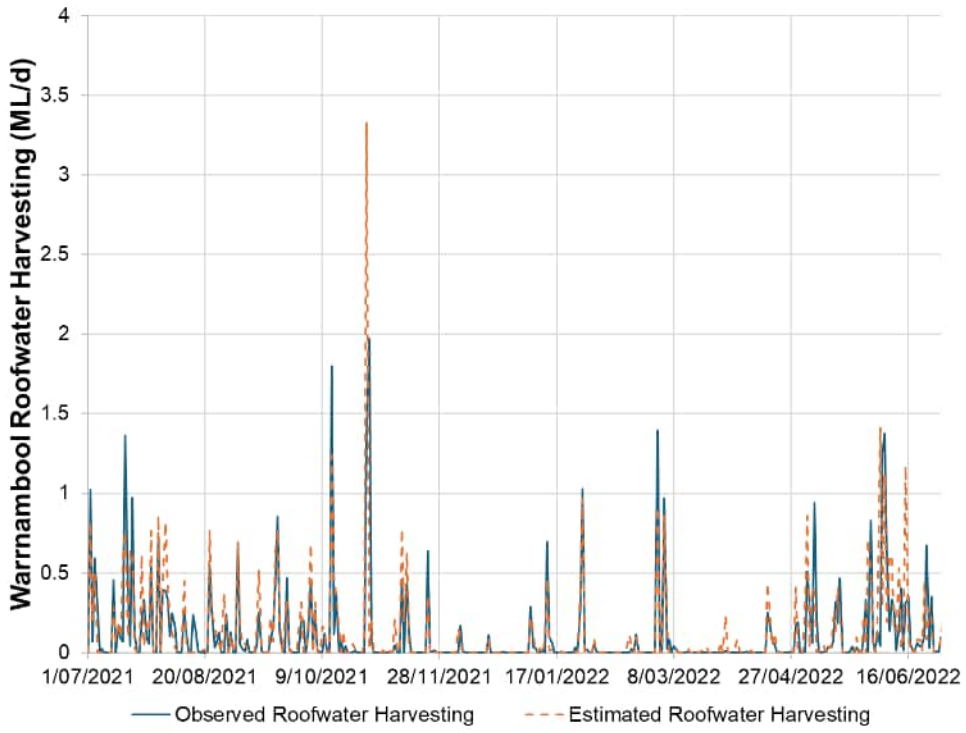


Figure 6-4 Daily comparison of estimated and observed roofwater harvesting contribution to Brierly Basin

6.4.3 Urban extraction rules

The Otway system has been set up to extract all available water under the Bulk Entitlement Rules from Gellibrand River and Arkins Creek where storage capacity exists. The extraction of water is driven by the storage target rules outlined in Section 6.1.2.

It is noted that to minimise pumping costs water is extracted first from Arkins Creek via gravity and then supplemented by pumping from North Otway Pump Station. Wannon Water advised that the North Otway Pump Station is not utilised in the winter and Wannon Water harvests from the Arkins Creek diversion weirs only (pers. comm B. Clingin, 02/07/2025). This is evident in the observed North Otway Pumping data (Figure 6-5) and therefore, no North Otway Pumping occurs from June to October in the model. This was further verified by comparing modelled North Otway extractions to observed in Section 7.2.

Wannon Water prioritise pumping from South Otway Pump Station to supply Plantation Basin and Warrnambool demands. Wannon Water extract flow from the Gellibrand River via South Otway Pump Station when it's available to be held in Plantation Basin, Dales Road Basins or Brierly Basin.

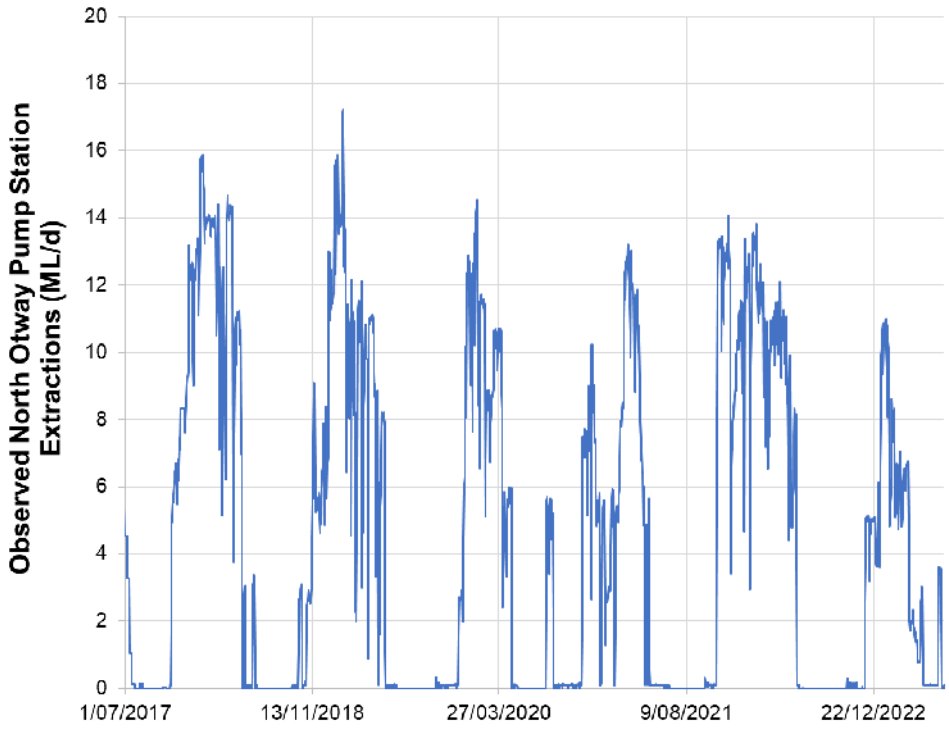


Figure 6-5 Historic North Otway Pump Station extractions

6.4.4 Urban restrictions

Restrictions in the Otway system are implemented in accordance with restriction rule curves based on the total volume in storage. The following reduction in restrictable demands is applied when restrictions are triggered:

- Stage 1 = 14% reduction in restrictable demand
- Stage 2 = 44% reduction in restrictable demand
- Stage 3 = 67% reduction in restrictable demand
- Stage 4 = 98% reduction in restrictable demand

The restriction curves taken from GHD (2017), with Stage 1 configured in the Otway Source model (GHD, 2021), are based on total storage volume and can be found in Table 6-6. Restriction curves will be updated for the upcoming Urban Water Strategy and Drought Preparedness Plan.

Restrictions are only applied to the urban demands, not industrial or rural demands. The setup of the rural system is further described in Section 6.5.

Table 6-6 Otway urban restriction curves

Month	Total Storage Volume (ML)			
	Stage 1	Stage 2	Stage 3	Stage 4
January	1,624	1,475	1,322	1,173
February	1,359	1,235	1,106	982
March	1,231	1,118	1,002	889

April	1,224	1,112	996	884
May	1,349	1,225	1,098	974
June	1,448	1,315	1,179	1,046
July	1,547	1,405	1,259	1,117
August	1,705	1,549	1,388	1,232
September	1,792	1,628	1,458	1,294
October	1,804	1,639	1,468	1,303
November	1,809	1,643	1,472	1,306
December	1,769	1,607	1,439	1,277

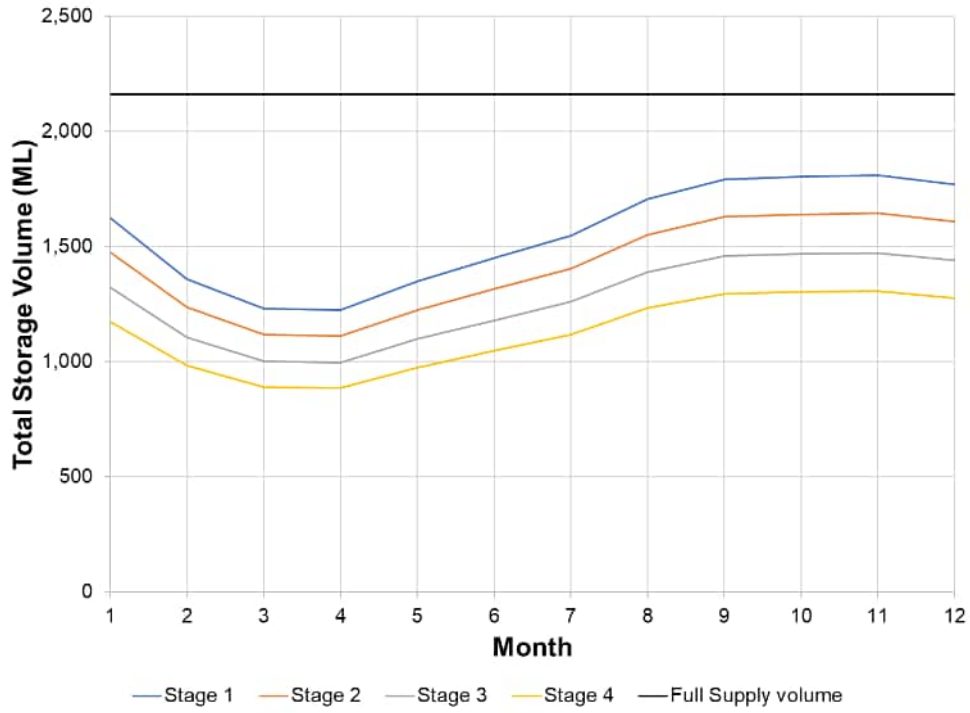


Figure 6-6 Otway urban restriction curves

6.4.5 Urban system losses

Losses are configured in the Otway system to represent pipeline losses and treatment plant losses. The treatment plant losses for Warrnambool, Simpson, Terang, Camperdown and Cobden have been updated by comparing recent raw water and clear water data. The updated losses can be found in Table 6-7.

Note also that there was previously a loss of 13% of South Otway Pipeline (GHD, 2017), however, this level of loss was found to result in overestimated extractions from South Otway Pump Station when compared to historic data. When the South Otway Pipeline loss was set to zero as part of historic verification (Section 7.2), a 0% volume bias was able to be achieved when comparing historic and modelled extractions from South Otway Pump Station.

Losses have been summarised in Table 6-7. The magnitude of the system losses were verified by comparing the sum of WTP losses and system losses to the Victorian Annual Water Accounts. The sum of the modelled WTP loss (329 ML) and system distribution loss (444 ML) equated to 1,136 ML,

only 0.7% less than the system losses reported for Otway by the Victorian Water Accounts (1,144 ML).

As well, the 2022 Wannon Water Annual Water strategy notes that system losses are defined as water lost while being transferred from the water source to the water treatment plant, such as leaking through transfer pipes. In 2020/21, the system losses upstream of WTPs was reported to be 700 ML in the 2022 Wannon Water Urban Water Strategy, which is comparable to the modelled system distribution losses outlined above. The update of the WTP losses and use of the 2022 Urban Water Strategy system distribution losses were able to achieve a very good comparison between modelled and gauged extractions from the Gellibrand River system (Section 7.2.1).

Table 6-7 Summary of urban system losses as configured in the Otway Source model

Infrastructure	Loss type	Loss (%)
North Otway pipeline downstream of NOPS	Pipeline loss	14%
North Otway pipeline between Ewens Hill Reservoir and Tankhill Reservoir	Pipeline loss	7%
Simpson supply system	Water treatment plant loss	14.4%
Cobden supply system	Water treatment plant loss	2%
Camperdown supply system	Water treatment plant loss	4.2%
Terang supply system	Water treatment plant loss	13.2%
Purnim supply system	Water treatment plant loss	2%
Warrnambool supply system	Water treatment plant loss	4.1%

6.5 Rural system configuration

Rural demands are supplied from the Otway system and North and South Otway pipelines. These demands have been summarised in Section 3.5.3 and outlined below:

- Bungador Rural
- Carpendeit Rural
- Cobrico Rural
- Camperdown Rural
- Lismore Rural

The locations of these rural demands from various supply systems has been confirmed by Wannon Water. Carpendit and Bungador rural demands are directly downstream of the Carpendit Booster Pumps and Cobrico extracts water upstream of Tank Hill Reservoir.

7. Gellibrand Source model verification

The verification of the Gellibrand Source model has been undertaken by comparing to historic data over a recent period and split into two sections:

- Verification of flow along the Gellibrand River (with historic urban extractions configured)
- Verification of Wannon Water extractions from Gellibrand River, and Wannon Water storage volumes

It is noted that the Upper Gellibrand component of the model has previously been verified as part of BW and HARC (2024) so was not further reported here.

7.1 Verification of Gellibrand River

The Gellibrand Source model was verified by comparing historic gauged flow to modelled flow at the following locations:

- Gellibrand River at Bunkers Hill (235227)
- Carlisle River at Carlisle (235200)
- Gellibrand River at Burrupa (235224)

Note that for Gellibrand River at Burrupa (235224), any periods where the gauge is impacted by tidal influences have been excluded (Section 4.11.1.1).

The verification for the Gellibrand River Source model has been undertaken over the period 1993 to 2022, constrained by the availability of Wannon Water urban extractions and storage releases from West Gellibrand Reservoir and Olangolah Weir. This verification period captures a range of wet and dry periods including the Millennium Drought.

It is understood that operating rules and demand levels over the period from 1993 to date will have changed and will not necessarily correspond to current level of development demands and operating rules. Therefore the following historic data was configured into the Gellibrand Source model for the verification:

- Groundwater pumping impacts (from Barwon Water's historic groundwater pumping activities and Wannon Water's ongoing groundwater pumping activities)
- Recorded extractions at Wannon Water North Otway and South Otway pump stations
- Recorded extractions at Wannon Water Arkins Creek diversions weirs
- Recorded releases from West Gellibrand Reservoir and Olangolah Weir

The comparison of modelled and gauged flow can be found in Table 7-1, showing very satisfactory correlations (>0.90) and NSE daily statistics (>0.8) for each of the key flow locations. As well, the volume bias for each gauge location is less than 0.5%, showing that the model is able to replicate the magnitude of historic flows. This is shown by the flow duration curve comparison of gauged and modelled flow in the Gellibrand River at Burrupa (Figure 7-1). A comparison between modelled and gauged flow for Carlisle River at Carlisle (235200) and Gellibrand River at Bunkers Hill (235227) can be found in Appendix F.

Table 7-1 Summary of comparison results between daily modelled and gauged flow

	Gellibrand River at Bunkers Hill	Carlisle River at Carlisle	Gellibrand River at Burrupa
Comparison Period	*1993 – 2022*	*2014 – 2022*	*1993-2022*
Gauge Number	*235227*	*235200*	*235224*
Correlation (r)	0.95	0.99	0.93
Coefficient of determination (r^2)	0.90	0.98	0.86
Kling Gupta Efficiency (KGE)	0.95	0.99	0.89
NSE daily	0.90	0.98	0.84
Average annual gauged flow (ML/yr)	82,046	30,011	219,474
Average annual modelled flow (ML/yr)	81,959	30,126	219,107
% Volume bias	-0.1%	+0.4%	-0.2%

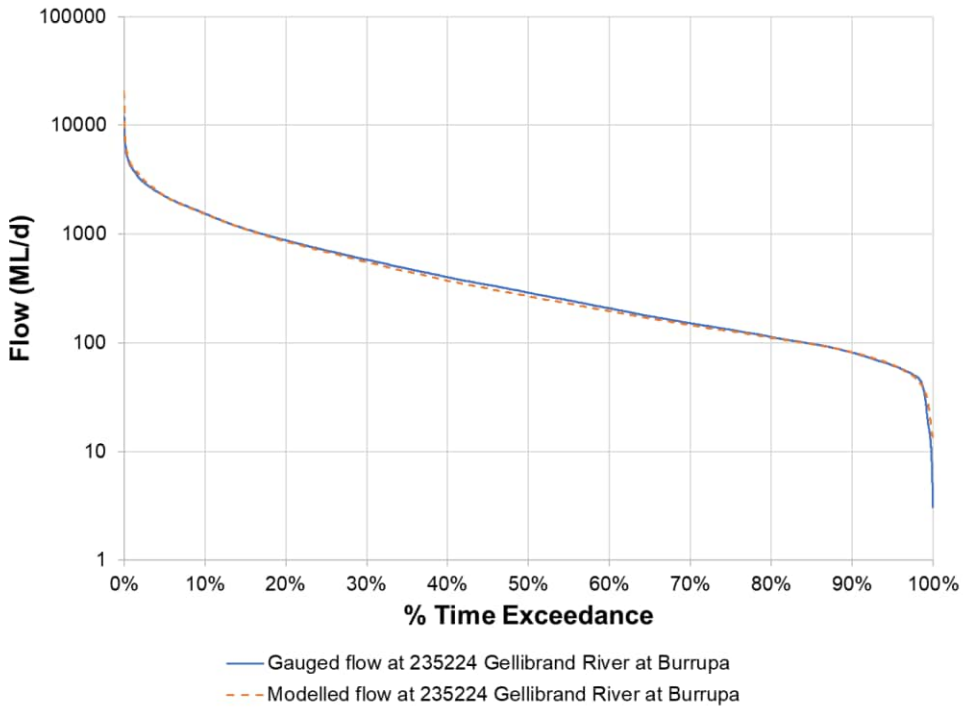


Figure 7-1 Flow duration curve comparison between gauged and modelled flow in the Gellibrand River at Burrupa (235224)

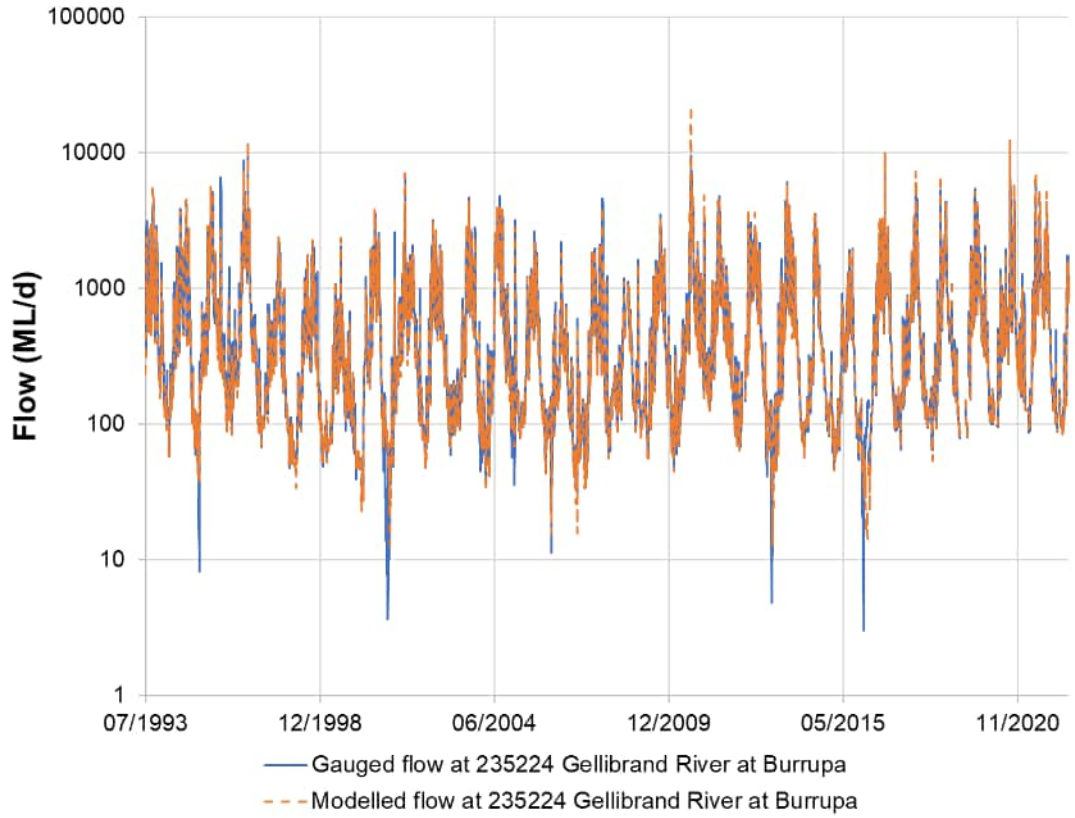


Figure 7-2 Log time series comparison between gauged and modelled flow in the Gellibrand River at Burrupa (235224)

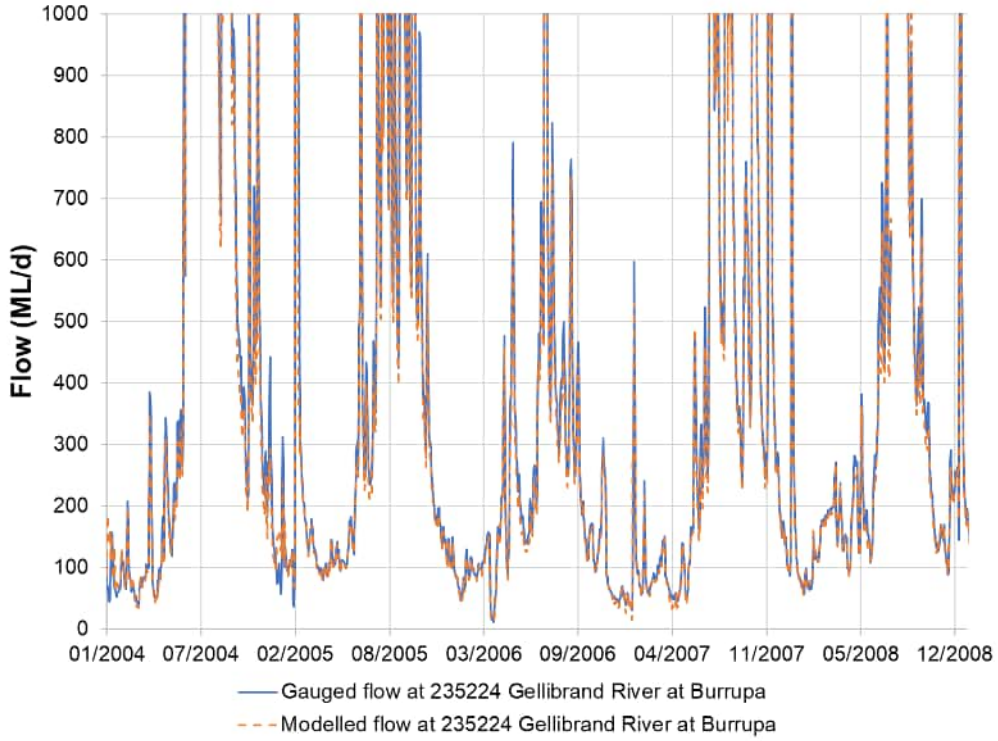


Figure 7-3 Drought linear time series comparison between gauged and modelled flow in the Gellibrand River at Burrupa (235224)

7.2 Verification of Otway system

The verification for the Otway system has been undertaken from July 2018 to June 2022, constrained by the availability of recorded Wannon Water clearwater demands by demand type. To undertake the verification of the Otway system, historic urban, industrial and rural clearwater demands were configured into the Gellibrand Source model. The Wannon Water extractions from the Gellibrand catchment and Wannon Water storage traces were investigated to assess performance of the Otway system.

7.2.1 Wannon Water extractions

Daily recorded and modelled Wannon Water extractions have been compared to verify the magnitude and split of extractions from the Gellibrand catchment. These are summarised in Table 7-2. Daily and monthly comparison plots are also available below.

Table 7-2 Comparison of modelled and observed Wannon Water extractions from Gellibrand catchment

Urban extraction location	Correlation	Average annual observed flow (ML/yr)	Average annual modelled flow (ML/yr)	Volume bias (%)
Arkins Weirs	0.82	3,297	3,307	+0.3%
North Otway Pump Station	0.83	1,647	1,677	+0.3%
South Otway Pump Station	0.14	4,032	4,000	-0.5%

The modelled extractions from the Arkins Weirs (Arkins Creek West, Arkins Creek East and First Creek diversion weirs) were compared to historic and found to be able to be replicated (correlation of 0.82 and <1% volume bias- Table 7-2). The comparison of daily flow in Figure 7-4, shows that the time of extractions is satisfactory, however, the extractions in the model are limited to 13 ML/d, which was advised by Wannon Water to be current operational extraction limit. The monthly comparison for Arkins Weirs in Figure 7-5 was found to be very satisfactory.

The timing of extractions from North Otway Pump Station were confirmed with Wannon Water, who rely on the weirs primarily for harvest during the winter months. Therefore, the model was set up such that there are no extractions from North Otway Pump Station from June to October. As shown in Figure 7-6 (daily) and Figure 7-7 (monthly), this assumption was able to replicate the historic extractions from North Otway Pump Station. As well, the correlation on a daily timestep for the comparison was found to be satisfactory (0.83- Table 7-2), with a volume bias of less than 1%.

Daily historic extractions from South Otway Pump Station are very erratic (Figure 7-8) and were not well replicated by the modelled extractions (more smoothed output). This has resulted in a low daily correlation between observed and modelled South Otway Pump Station Extractions (0.14-Table 7-2). However, the volume bias (<1%) and monthly comparison in Figure 7-9 show that the overall magnitude of diversions from South Otway Pump Station are able to be replicated by the Source model.

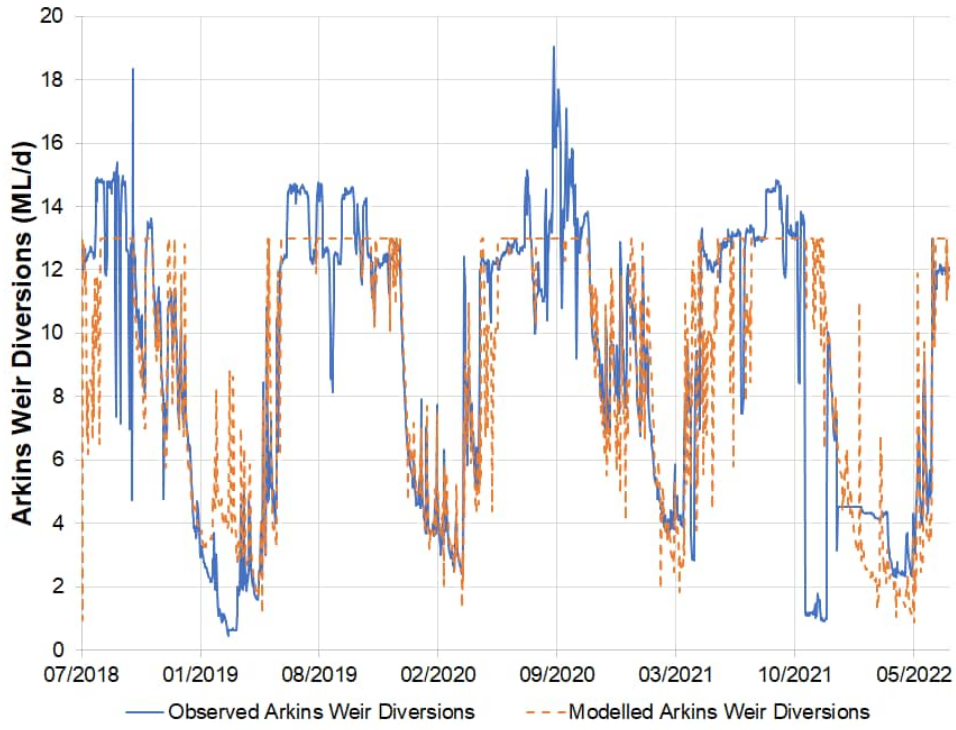


Figure 7-4 Daily comparison of observed and modelled diversions from Arkins Weirs (total)

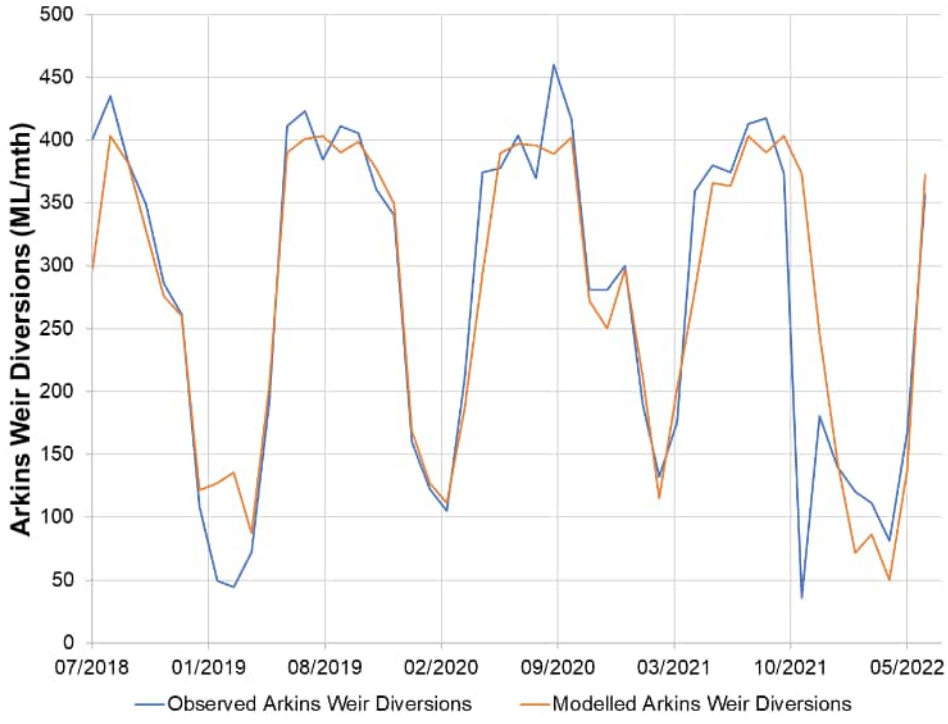


Figure 7-5 Monthly comparison of observed and modelled diversions from Arkins Weirs (total)

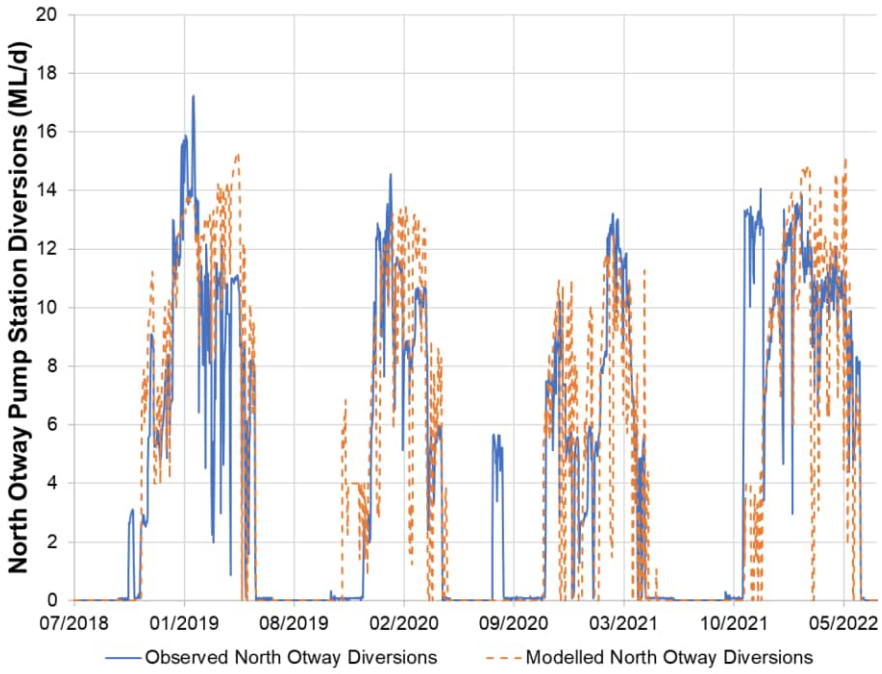


Figure 7-6 Daily comparison of observed and modelled diversions from North Otway Pump Station

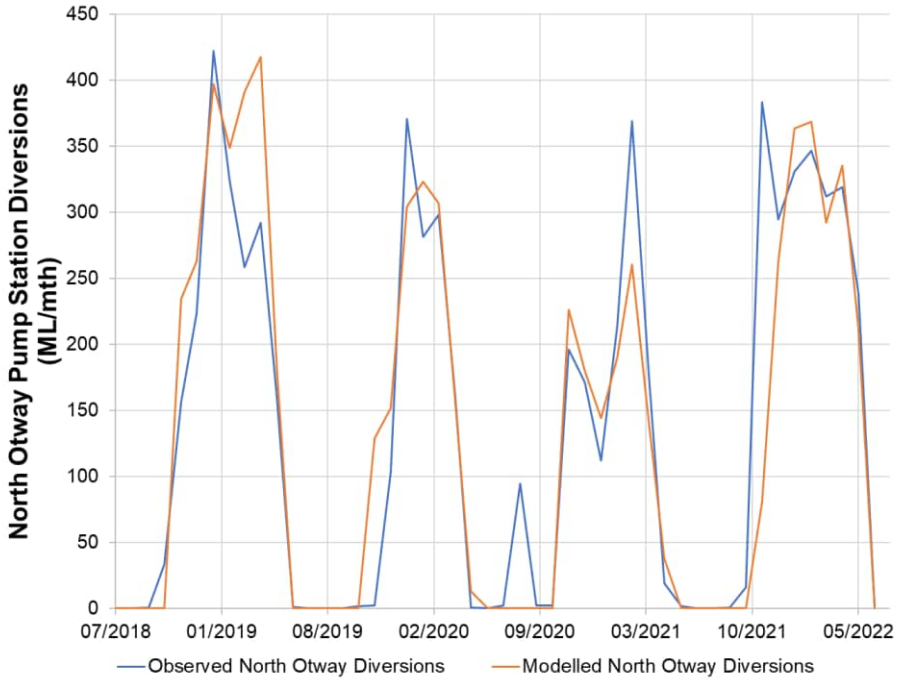


Figure 7-7 Monthly comparison of observed and modelled diversions from North Otway Pump Station

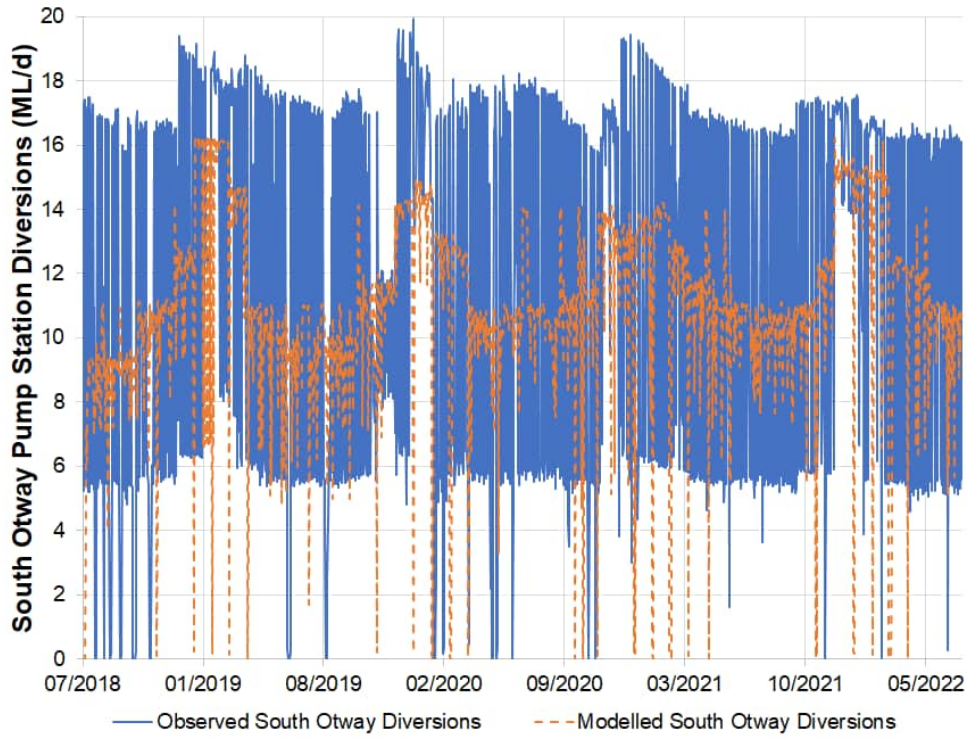


Figure 7-8 Daily comparison of observed and modelled diversions from South Otway Pump Station

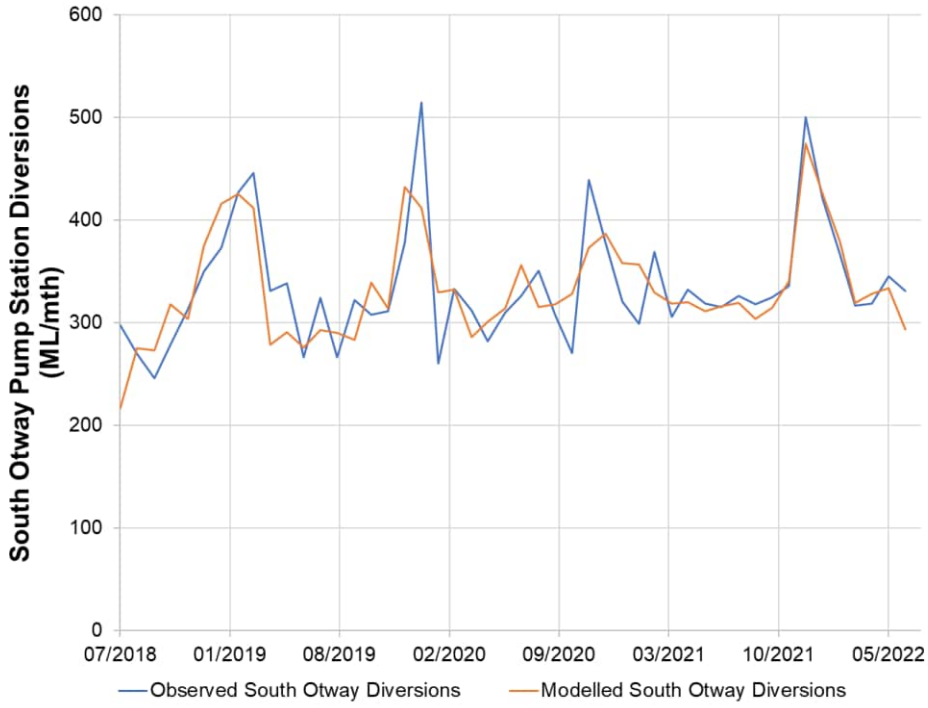


Figure 7-9 Monthly comparison of observed and modelled diversions from South Otway Pump Station

7.2.2 Wannon Water storage volumes

The comparison of Wannon Water modelled storage volumes to observed shows that the transfer of water through the Otway system is well modelled. As noted in Section 6.1.2, operating targets were updated during the model verification process to better reflect historic behaviour.

The comparison of total Otway system storage in Figure 7-10 shows that the availability of water for Wannon Water in the Otway system is very well modelled and able to be replicated. As the key storage upstream of Warrnambool, the total Dales Road Basins were closely analysed to ensure a good comparison between modelled and observed was achieved. As shown in Figure 7-11, the historic total Dales Road Basin storage volumes were able to be replicated by the model, particularly for the recent years. Similarly, the comparison between observed and modelled storage volume for Mt Ewen Reservoir is very satisfactory (Figure 7-13).

From 2018 to early 2020, the Tank Hill Reservoir storage volume is overestimated, with greater historic drawdown (Figure 7-12). However, the model is able to replicate the storage volume over recent years. The reason for the reduction in storage in Tank Hill Reservoir will be checked with Wannon Water.

As shown in Figure 7-14, there is a step change in storage operating targets in Donalds Hill Reservoir, down to approximately 160 ML. The operating target in the model was updated to reflect the recent storage volume, underestimating the period prior to 2019. The reason for the reduction in storage in Donalds Hill Reservoir will be checked with Wannon Water.

The historic storage trace for Plantation Road storage is quite erratic, as shown in Figure 7-15. This was not able to be replicated by the model, which kept Plantation Road Basin at constant storage volume of 70 ML.

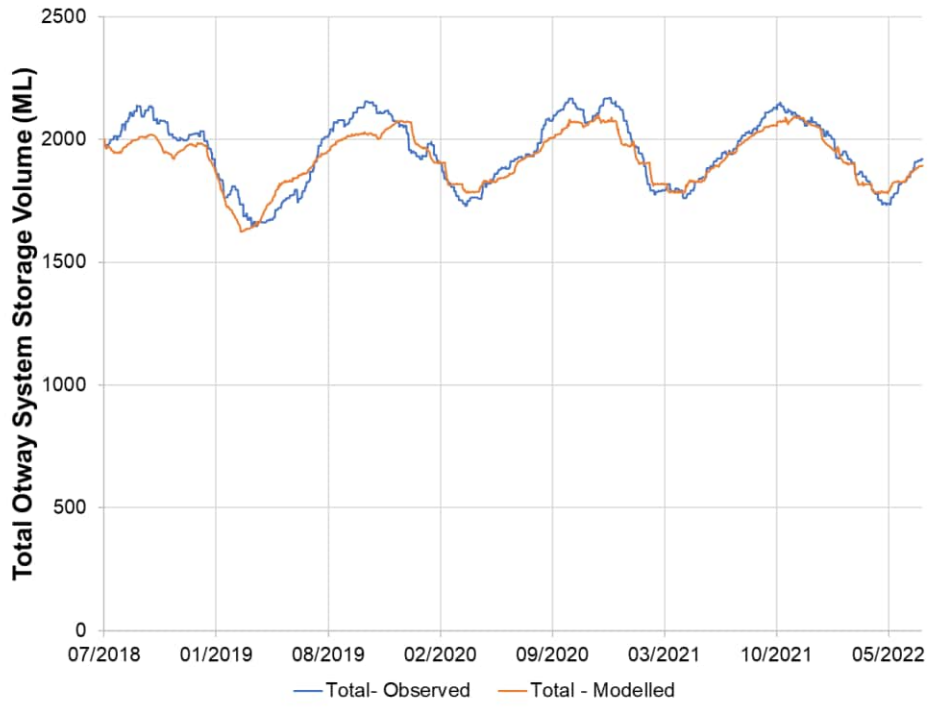


Figure 7-10 Comparison of observed and modelled Otway Total System Storage

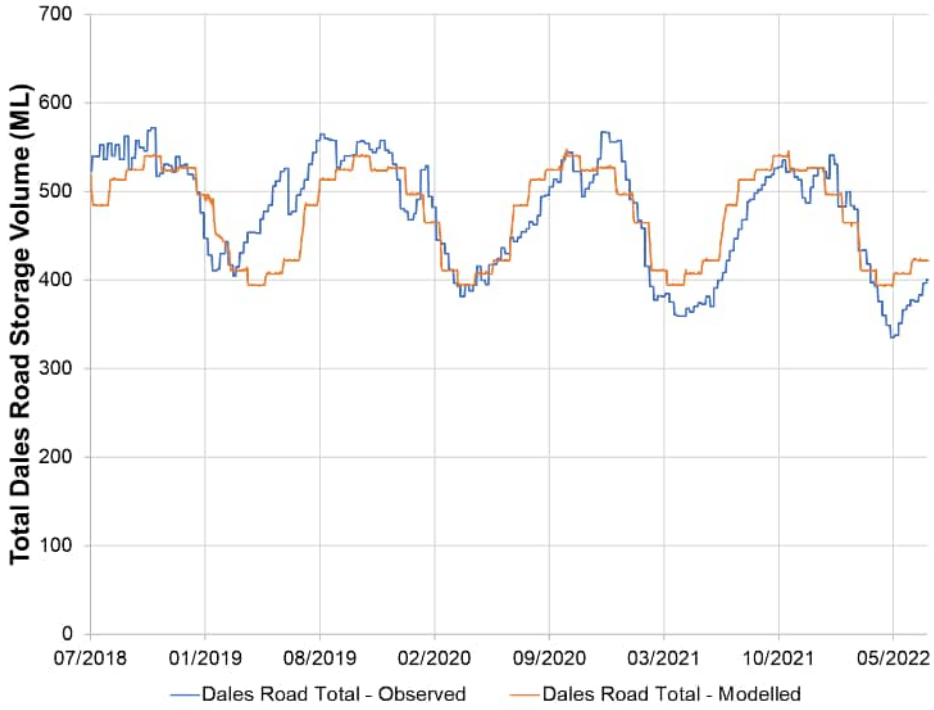


Figure 7-11 Comparison of observed and modelled Total Dales Road Basins storage volume

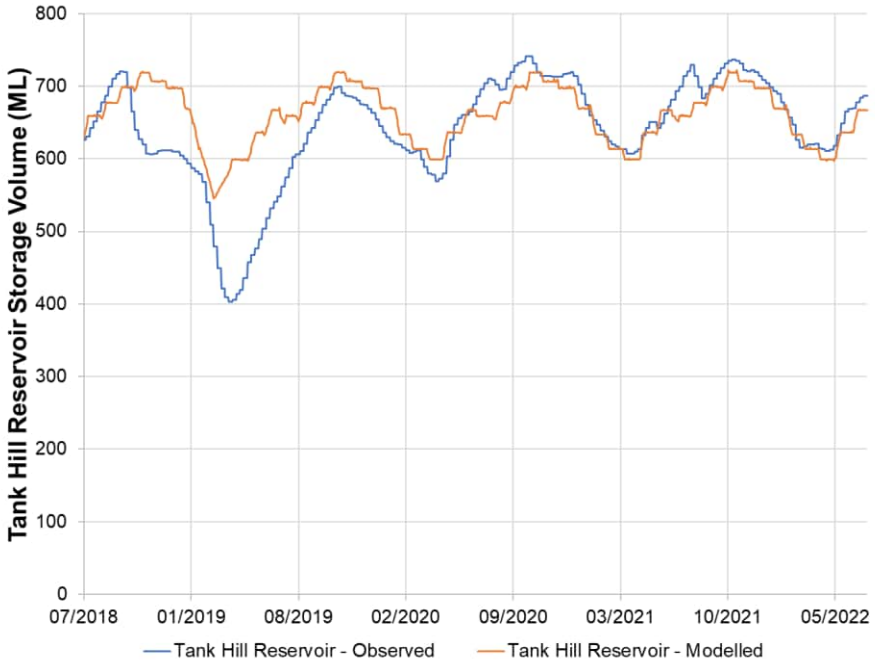


Figure 7-12 Comparison of observed and modelled Tank Hill Reservoir storage volume

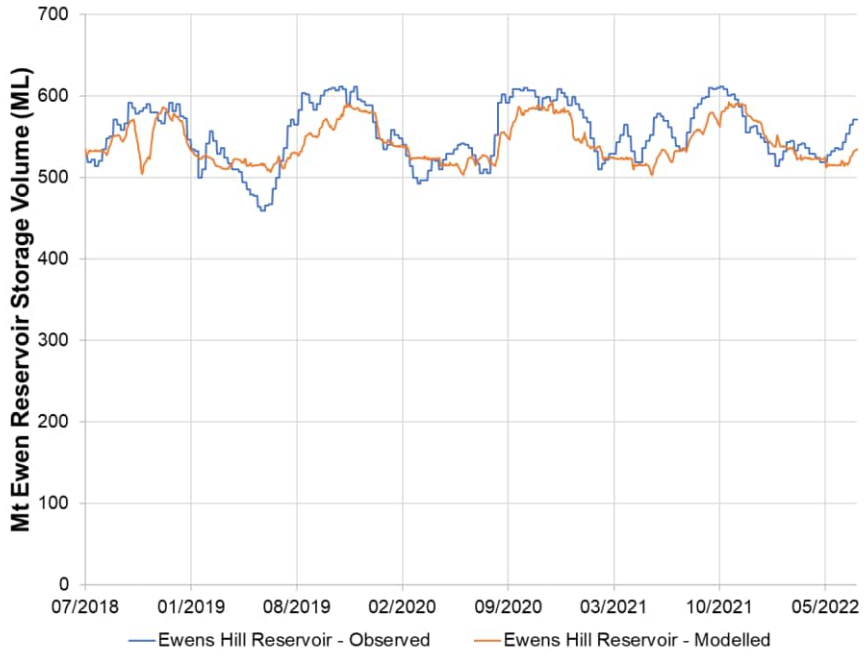


Figure 7-13 Comparison of observed and modelled Mt Ewen Reservoir storage volume

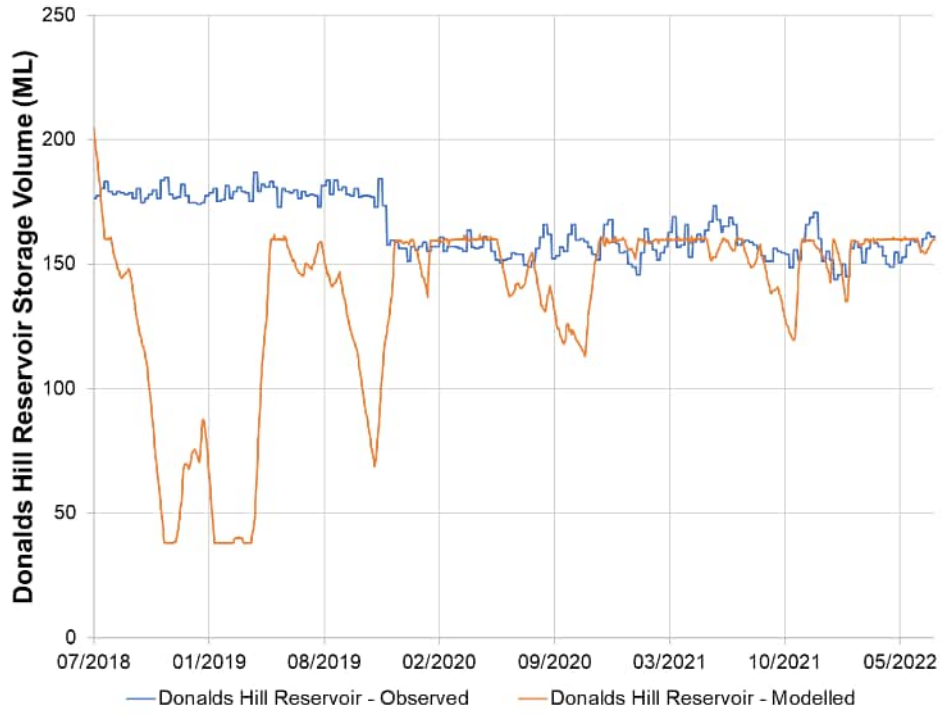


Figure 7-14 Comparison of observed and modelled Donalds Hill Reservoir storage volume

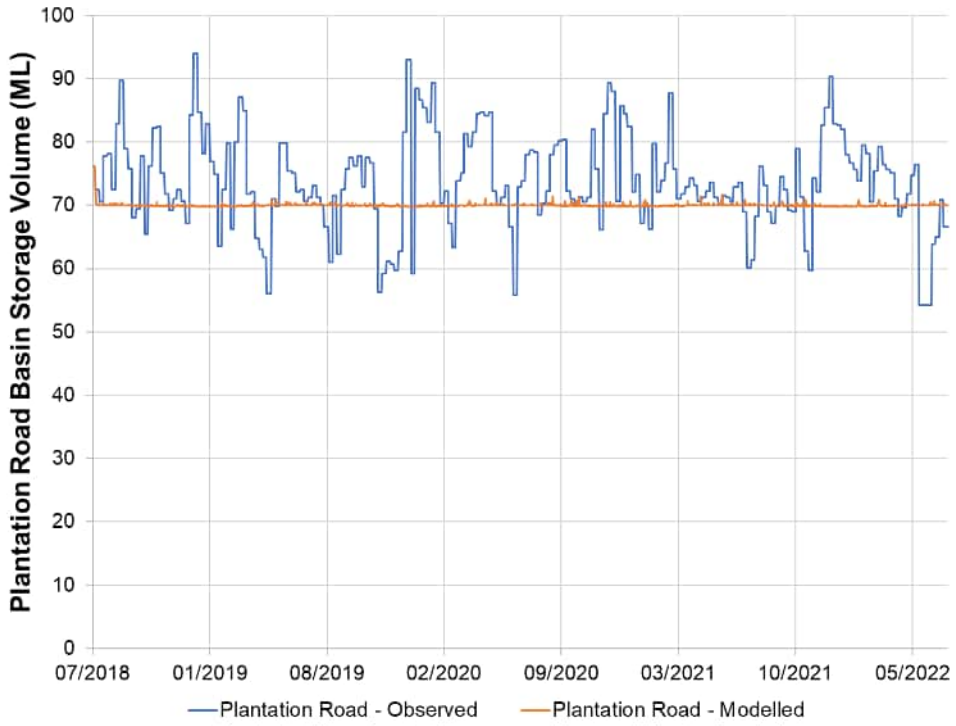


Figure 7-15 Comparison of observed and modelled Plantation Basin storage volume

8. Scenario modelling

To inform the Gellibrand FLOWS study, the following scenarios have been modelled under the full suite of future climate cases:

- Current daily flows
- Unimpacted daily flows
- Full use of licence volumes of rural sleeper licences (no change to urbans) including the additional 1 GL of winterfill entitlement made available after the 2011 WRSWS
- Full use of licence volumes of rural sleeper licences including the additional 1 GL of winterfill entitlement made available after the 2011 WRSWS and urban demands at yield

For the future climate cases in 2040 and 2065, the corresponding 2040 and 2065 level of development urban demand is adopted based on urban growth assumptions. This is further discussed in Section 8.1.2.1.

Yield is defined as the average annual demand that can be supplied at the preferred level of service. The preferred level of service for the Otway system is 95% annual reliability and no breach to the drought reserve volume. The preferred level of service for Barwon Water systems is 95% monthly reliability and no breach to the drought reserve volume in Colac.

It is important to note that for the scenarios where urban demands are at yield, the 2040 or 2065 yield can be less than the 2040 or 2065 level of development demand, because the preferred level of service criteria is breached under these demand levels.

For example, for the 2065 high climate change scenario:

- 2065 level of development demand for Barwon Water is 3,160 ML/yr and Wannon Water is 9,362 ML/yr. This represents the take from the Gellibrand River system assuming population growth by 2065 under 2065 high climate change impacts. When the model is run with this demand level preferred level of service criteria are breached.
- 2065 yield for Barwon Water is 2,849 ML/yr and for Wannon Water is 5,548 ML/yr. This represents the demand that can be taken from the Gellibrand River system without breaching the preferred level of service criteria under 2065 high climate change impacts.

8.1 Scenario modelling input preparation

8.1.1 Climate cases

To inform the Gellibrand FLOWS study, daily flows are required under current and future climate conditions. Climate and inflow inputs to the model were adjusted to represent the following climate change cases, as recommended by the *Guidelines for Assessing the Impact of Climate Change in Water Availability in Victoria* (DELWP, 2020):

- Baseline or reference climate (pre-1975 adjusted)
- Step climate change (pre-1997 adjusted)
- RCP 8.5 2020 Low climate change scenario
- RCP 8.5 2020 Medium climate change scenario

- RCP 8.5 2020 High climate change scenario
- RCP 8.5 2040 Low climate change scenario
- RCP 8.5 2040 Medium climate change scenario
- RCP 8.5 2040 High climate change scenario
- RCP 8.5 2065 Low climate change scenario
- RCP 8.5 2065 Medium climate change scenario
- RCP 8.5 2065 High climate change scenario

As outlined in DELWP (2020), the baseline and step climate cases are developed by applying seasonal decile scaling prior to 1975 and 1997 respectively to produce a stationary dataset that is representative of more recent climate behaviour. Seasonal scaling applied was for two seasons: warm (November to March) and cool (April to October). Climate change factors outlined in DELWP (2020) are then applied to the reference climate time series to produce the required climate change inputs.

Note that at the time of the Gellibrand FLOWS study, the 2025 Climate Change Guidelines were not yet released. It is recommended that the climate change assumptions are updated in the next iteration of the Gellibrand FLOWS study to reflect up to date future climate assumptions.

8.1.2 Demand scenarios

8.1.2.1 Urban demands

Barwon Water

Barwon Water supplies both Colac and Gellibrand from this system. Barwon Water's future surface water harvesting in 2040 and 2065 accounts for population growth and the impacts of climate change on BW storages. This remains below the maximum take limits outlined in BW's Bulk Entitlements. As confirmed with Barwon Water (pers. comm C. McTaggart, 29/11/2024), it has been assumed that Gellibrand's current population of 73 grows by 4.1% in 2040 and 9.6% in 2065. For Colac, a medium growth has been assumed. It is assumed that the demand grows by 27.6% by 2040 and 41.1% by 2065.

Wannon Water

Wannon Water future demand growth was adopted from the 2022 Wannon Water Urban Water Strategy. Baseline growth assumed as increase in Wannon Water demand of 20.5% by 2040 and 44.6% by 2065. It is noted that the 2065 demand assumptions for Wannon Water remain below the maximum annual limit as outlined in the Otway Bulk Entitlement rules.

8.1.2.1.1 Urban demand assumptions at yield

Urban demands at yield represent the long term average take of the Barwon Water and Wannon Water urban systems that just meets the preferred level of service criteria.

As previously stated, for some future demand scenarios, the demand at 2040 and 2065 exceed the required level of service criteria (e.g. restrictions triggered too frequently) and therefore, for these scenarios, the urban demand at yield is less than the future demand. Note that all future urban

demand magnitudes at yield remain below the Barwon Water and Wannon Water annual Bulk Entitlement limits.

Barwon Water

To derive yield the following preferred level of service criteria was confirmed with Barwon Water:

- Restriction frequency does not exceed 5% for model run period. This has been calculated using percentage of months with restrictions
- Total Colac storage volume does not drop below the contingency storage volume which is set at 209 ML for Colac

Due to the minimal impact of supply to Gellibrand on the Gellibrand system (annual Bulk Entitlement limit of 60 ML/yr less than 0.2% of annual flow in the Lardner Creek at 2065 high climate change scenario), demand at yield has been set at 2040 and 2065 levels of Gellibrand demand.

Wannon Water

To derive yield, the level of service criteria assumed is consistent with the 2022 Wannon Water Urban Water Strategy:

- 95% annual reliability (restrictions no more than 1 in 20 years)
- No Stage 4 restrictions

8.1.2.2 Rural demands

Full level of development rural demands assume that the full licenced volume of all licence holders is used, including sleeper licences. In addition an extra 1 GL of winterfill entitlement (July to October) is assumed, as this volume was made available to the Gellibrand River catchment in the 2011 Western Region Sustainable Water Strategy (Action 7.1 Revised caps on the amount of unallocated surface water available for winterfill diversions in Otways catchments).

At current level of development, unrestricted rural demands extract approximately 320 ML/yr. Under full level of development rural demands, including the additional 1 GL of winterfill entitlement, the unrestricted rural demands increase to approximately 2,700 ML/yr.

8.1.2.3 Farm dam impacts

Farm dams intercept and harvest catchment runoff, impacting the natural flow regime, particularly during dry periods. Farm dam impacts have been derived using the current distribution of farm dams in the Boundary Creek and Gellibrand River catchments, and their growth considered as part of future climate change scenarios. Based on investigations carried out in HARC (2020) for 2040 and 2065, the impact of stock and domestic (<5 ML) farm dams was increased as per Table 8-1 across all Gellibrand River subcatchments.

Table 8-1 Domestic and stock farm dam growth assumptions calculated in HARC (2020) and associated farm dam volumes in the Gellibrand and Boundary catchments

Level of development	% increase in stock and domestic farm dams per year[1] in Love Creek	Total farm dam volume in Gellibrand River catchment (ML)
Current	0	5,213 ML
2040	0.3%	5,694 ML
2065	1.4%	6,542 ML

[1]increase every year from 2020 to 2040 and 2065

The impact of farm dams in future was determined using inflows under current inflows. The increase in farm dams impacts due to reduced inflows under future climate has not been modelled.

8.1.2.4 Barwon Downs groundwater pumping impacts

It has been assumed that in 2040 and 2065 groundwater discharge from the Lower Tertiary Aquifer into receiving waterways (Yahoo Creek and Gellibrand River upstream of Bunkers Hill) is nearing pre-pumping levels. Groundwater levels are considered to have recovered after pumping when levels return to 90% of their pre pumping levels. This is indicative of what successful remediation would look like and is consistent with the assumptions adopted in BW and HARC (2024). It has been assumed that the impact of Carlisle River bore groundwater pumping on the Gellibrand River remains unchanged in 2040 and 2065.

8.2 Scenario modelling results

The following scenarios have been modelled under the full suite of future climate change cases:

- Current daily flows
- Unimpacted daily flows
- Full use of licence volumes of rural sleeper licences (no change to urbans)
- Full use of licence volumes of rural sleeper licences and urban demands at yield

Gellibrand system water balances for each climate change case and level of development scenario are available in Appendix L.

8.2.1 Urban extractions from Gellibrand River system

The Barwon Water and Wannon Water urban extractions were compared for each climate change scenario and level of development scenario. The Barwon Water extractions represent the sum of urban extractions from West Gellibrand Reservoir and Olangolah Weir for transfer to Colac, and Lardner Creek to supply Gellibrand.

The comparison of average annual Barwon Water extractions is summarised in Table 8-2, showing that there are no changes to Barwon Water extractions under a full uptake of rural demand scenario. At yield Barwon Water extractions are greater than 2020 and 2040 level of demand for Colac. However, in 2065 yield is less than 2065 demand. This shows that the preferred level of service criteria are breached by 2065 and augmentation is required before then to restore level of service.

There are no shortfalls in supply of Barwon Water extractions under current or yield assumptions.

Table 8-2 Comparison of average annual Barwon Water extractions from 1900 to 2022 for each climate case

Climate change scenario	Average annual Barwon Water extractions from 1900 to 2022 (ML/yr)				
	Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows	Scenario 3: Full uptake of rural demands	Scenario 4: Full uptake of rural demands and urban demands at yield	
Historic	3,625	0	3,625	4,220	+16.4%
Post-1975	3,631	0	3,631	4,208	+15.9%
Post-1997	3,617	0	3,617	3,997	+10.5%
RCP 8.5 2020 Low	3,660	0	3,660,	4,354	+19.0%
RCP 8.5 2020 Med	3,606	0	3,606	4,059	+12.6%
RCP 8.5 2020 High	3,473	0	3,473	3,679	+5.9%
RCP 8.5 2040 Low	4,248	0	4,248	4,362	+2.7%
RCP 8.5 2040 Med	3,977	0	3,977	3,971	-0.2%
RCP 8.5 2040 High	3,469	0	3,469	3,477	+0.2%
RCP 8.5 2065 Low	4,303	0	4,303	4,156	-3.4%
RCP 8.5 2065 Med	3,947	0	3,947	3,619	-8.3%
RCP 8.5 2065 High	3,160	0	3,160	2,849	-9.8%

The Wannon Water extractions represent the sum of urban extractions from Arkins Creek diversion weirs, North Otway Pump Station and South Otway Pump Station for transfer to the Otway supply system. The comparison of average annual Wannon Water extractions is summarised in Table 8-3.

There is a 1% reduction in supply to the Otway system when there is a full uptake of rural demands. This reduction in supply was further investigated and the increased supply of rural demands increased the magnitude of river losses, accounting for 50% of the average annual magnitude of reduction of supply to the Otway system. The remaining deficit in supply to the Otway system is due to increased farm dam impacts and increased winterfill usage.

When demands are set to yield Wannon Water extractions are greater than 2020 level of demand for the Otway system. However, by 2040, the yield is less than 2030 demand for all climate change scenarios. This shows that the preferred level of service criteria are breached by 2040 and augmentation is required before then to restore level of service.

Under 2065 high climate change scenario and 2065 level of Wannon Water demands the average annual shortfalls in the Wannon Water system are as follows:

- 11 ML/yr demand shortfall for Industrial Saputo demand
- 89 ML/yr demand shortfall for Lismore Derrinalum demand
- 403 ML/yr demand shortfall for Rural Camperdown demands
- 30 ML/yr demand shortfall for Rural Lismore Derrinalum demand
- 354 ML/yr demand shortfall for Urban Camperdown demand

This shows that under a drier climate scenario, the Otway system requires augmentation and system upgrades to provide 2065 level of demand.

Table 8-3 Comparison of average annual Wannon Water extractions from 1900 to 2022 for each climate case

Climate change scenario	Average annual Wannon Water extractions from 1900 to 2022 (ML/yr)					
	Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows	Scenario 3: Full uptake of rural demands		Scenario 4: Full uptake of rural demands and urban demands at yield	
Historic	8,773	0	8,696	-0.9%	10,170	+15.9%
Post-1975	8,783	0	8,705	-0.9%	9,916	+12.9%
Post-1997	8,809	0	8,722	-1.0%	9,454	+7.3%
RCP 8.5 2020 Low	8,977	0	8,900	-0.9%	9,974	+11.1%
RCP 8.5 2020 Med	8,888	0	8,802	-1.0%	9,750	+9.7%
RCP 8.5 2020 High	8,724	0	8,633	-1.0%	9,446	+8.3%
RCP 8.5 2040 Low	10,068	0	9,992	-0.8%	10,010	-0.6%
RCP 8.5 2040 Med	9,871	0	9,778	-0.9%	9,743	-1.3%
RCP 8.5 2040 High	9,455	0	9,360	-1.0%	8,042	-14.9%
RCP 8.5 2065 Low	10,463	0	10,374	-0.9%	9,789	-6.4%
RCP 8.5 2065 Med	10,231	0	10,142	-0.9%	9,386	-8.3%
RCP 8.5 2065 High	9,362	0	9,282	-0.9%	5,548	-40.7%

8.2.2 Rural extractions from the Gellibrand River system

As shown in Table 8-4, at current level of development, average annual rural extractions are consistently 310 – 316 ML/yr regardless of the climate change case suggesting that water availability is not limiting under climate change for these small demands. Current rural usage is not impacted by rural restrictions as they are primarily industrial and stock and domestic licence holders who are not subject to restrictions.

Under full level of development the winterfill and direct irrigation licence holders are subject to the rural restrictions outlined in Section 5.5. There is a decline in average annual rural extractions under drier future climate change scenarios due to a combination of increased rural restrictions and reduced water availability. Under full uptake average annual rural demand is consistently ~2,100 to ~2,300 ML/yr greater than current usage. There is no difference in rural demand supplied if urbans are at yield.

There are no shortfalls in rural demand under current rural usage assumptions. Under the full uptake of rural demands scenario, there are no shortfalls for the Low and Medium climate change scenarios. However, for the 2065 high climate change scenario, there is an average shortfall of 6 ML/yr in Latrobe Creek and 3 ML/yr in Kennedy Creek.

Table 8-4 Comparison of average annual rural extractions from 1900 to 2022 for each climate case

Climate change scenario	Average annual rural extractions from 1900 to 2022 (ML/yr)				
	Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows	Scenario 3: Full uptake of rural demands	Scenario 4: Full uptake of rural demands and urban demands at yield	
Historic	316	0	2,610	2,610	+2.3 GL
Post-1975	316	0	2,597	2,597	+2.3 GL
Post-1997	316	0	2,572	2,572	+2.3 GL

RCP 8.5 2020 Low	316	0	2,605	2,605	+2.3 GL
RCP 8.5 2020 Med	316	0	2,588	2,588	+2.3 GL
RCP 8.5 2020 High	316	0	2,557	2,557	+2.2 GL
RCP 8.5 2040 Low	316	0	2,614	2,614	+2.3 GL
RCP 8.5 2040 Med	315	0	2,584	2,584	+2.3 GL
RCP 8.5 2040 High	313	0	2,516	2,516	+2.2 GL
RCP 8.5 2065 Low	315	0	2,589	2,589	+2.3 GL
RCP 8.5 2065 Med	314	0	2,554	2,554	+2.2 GL
RCP 8.5 2065 High	310	0	2,389	2,390	+2.1 GL

8.2.3 Flow at key compliance points

As part of the modelling component of the Gellibrand FLOWS study, electronic files have been provided to Alluvium for each environmental flow compliance point and scenario outlined Table 8-5. For the purpose of this modelling report, the 2020, 2040 and 2065 Medium Climate Change Scenario flows have been compared for each environmental flow compliance point, with an extended analysis provided for the Reach 6 compliance point (Gellibrand River at Princetown) in Section 8.2.3.1.

As shown in Table 8-5, under the 2020 Medium Climate Change Scenario there is a greater reduction in flow in the Gellibrand River when urban demands are at yield when compared to the 2040 Medium (Table 8-6) or 2065 Medium (Table 8-7) climate change scenarios. This is due to Barwon Water and Wannon Water extractions at yield resulting in less urban extractions than the 2040 and 2065 demand. Whereas for current (2020), the system is not currently at yield and demand is increased until the level of service criteria is exceeded. The full uptake of rural demands results in a nearly 1% difference in flows across the Gellibrand system.

Table 8-5 Summary of flow at key compliance locations under 2020 Medium Climate Change Scenario

Env flow reach	Environmental flow compliance point	Average annual flow from 1900 to 2022 (ML/yr)						
		Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows		Scenario 3: Full uptake of rural demands		Scenario 4: Full uptake of rural demands and urban demands at yield	
1	Love Creek at Gellibrand (235234)	7,776	8,247	+6.1%	7,768	-0.1%	7,768	-0.1%
2a	Gellibrand River d/s dam site (235236)	32,830	36,302	+10.6%	32,830	0.0%	32,386	-1.4%
2b	Gellibrand River at Bunkers Hill (235227)	86,102	90,672	+5.3%	84,813	-1.5%	84,365	-2.0%
2c	Lardner Creek at Gellibrand (235210)	20,887	20,924	+0.2%	20,887	0.0%	20,887	0.0%
3	Carlisle River at Carlisle River (235200)	28,961	32,273	+11.4%	28,701	-0.9%	28,635	-1.1%
4	Gellibrand River at Burrupa (235224)	225,802	241,781	+7.1%	223,688	-0.9%	222,286	-1.6%
4	Gellibrand River d/s South Otway Pumps Bridge (235258)	195,573	211,374	+8.1%	193,552	-1.0%	192,163	-1.7%
5	Kennedys Creek at Kennedy Creek (235211)	33,996	35,928	+5.7%	33,964	-0.1%	33,964	-0.1%
6	Gellibrand River at Princetown (235269)	232,985	249,720	+7.2%	230,773	-0.9%	229,371	-1.6%

Table 8-6 Summary of flow at key compliance locations under 2040 Medium Climate Change Scenario

Env flow reach	Environmental flow compliance point	Average annual flow from 1900 to 2022 (ML/yr)						
		Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows		Scenario 3: Full uptake of rural demands		Scenario 4: Full uptake of rural demands and urban demands at yield	
1	Love Creek at Gellibrand (235234)	7,676	7,954	+3.6%	7,669	-0.1%	7,669	-0.1%
2a	Gellibrand River d/s dam site (235236)	31,241	35,092	+12.3%	31,241	0.0%	31,251	0.0%
2b	Gellibrand River at Bunkers Hill (235227)	82,973	87,599	+5.6%	81,684	-1.6%	81,693	-1.5%
2c	Lardner Creek at Gellibrand (235210)	20,188	20,226	+0.2%	20,188	0.0%	20,188	0.0%
3	Carlisle River at Carlisle River (235200)	27,832	31,191	+12.1%	27,574	-0.9%	27,585	-0.9%
4	Gellibrand River at Burrupa (235224)	216,275	233,491	+8.0%	214,165	-1.0%	214,207	-1.0%
4	Gellibrand River d/s South Otway Pumps Bridge (235258)	187,272	204,272	+9.1%	185,260	-1.1%	185,304	-1.1%
5	Kennedys Creek at Kennedy Creek (235211)	32,680	34,730	+6.3%	32,649	-0.1%	32,649	-0.1%
6	Gellibrand River at Princetown (235269)	222,888	241,165	+8.2%	220,682	-1.0%	220,723	-1.0%

Table 8-7 Summary of flow at key compliance locations under 2065 Medium Climate Change Scenario

Env flow reach	Environmental flow compliance point	Average annual flow from 1900 to 2022 (ML/yr)						
		Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows		Scenario 3: Full uptake of rural demands		Scenario 4: Full uptake of rural demands and urban demands at yield	
1	Love Creek at Gellibrand (235234)	6,855	7,168	+4.6%	6,849	-0.1%	6,849	-0.1%
2a	Gellibrand River d/s dam site (235236)	27,992	31,840	+13.7%	27,992	0.0%	28,332	+1.2%
2b	Gellibrand River at Bunkers Hill (235227)	74,632	79,345	+6.3%	73,349	-1.7%	73,691	-1.3%
2c	Lardner Creek at Gellibrand (235210)	18,307	18,352	+0.2%	18,308	0.0%	18,308	0.0%
3	Carlisle River at Carlisle River (235200)	25,040	28,281	+12.9%	24,791	-1.0%	24,828	-0.8%
4	Gellibrand River at Burrupa (235224)	192,944	211,213	+9.5%	190,849	-1.1%	191,947	-0.5%
4	Gellibrand River d/s South Otway Pumps Bridge (235258)	167,247	185,187	+10.7%	165,260	-1.2%	166,356	-0.5%
5	Kennedys Creek at Kennedy Creek (235211)	29,032	31,512	+8.5%	29,000	-0.1%	29,000	-0.1%
6	Gellibrand River at Princetown (235269)	198,714	218,176	+9.8%	196,523	-1.1%	197,620	-0.6%

8.2.3.1 Flow in Gellibrand River at Princetown

The average annual flow in the Gellibrand River at Princetown is compared for all scenarios in Table 8-8. For the unimpacted scenario, flow in the Gellibrand River at Princetown is 6% to 14% greater than the current daily flows, showing the impact of rural and urban extractions and impoundments on flows in the river.

Under the full uptake of rural demands flow in the Gellibrand River at Princetown decreases by 1% and up to 1.6% when assuming full rural uptake and urban demands at yield. There is an increase in flow in the Gellibrand River at Princetown for the 2065 High climate change scenario as the Barwon Water and Wannon Water extractions at yield are less than 2065 demand.

Table 8-8 Comparison of average annual flow in Gellibrand River at Princetown from 1900 to 2022 for each climate case

Climate change scenario	Average annual flow in Gellibrand River at Princetown from 1900 to 2022 (ML/yr)						
	Scenario 1: Current daily flows	Scenario 2: Unimpacted Flows		Scenario 3: Full uptake of rural demands		Scenario 4: Full uptake of rural demands and urban demands at yield	
Historic	273,772	290,016	+5.9%	271,538	-0.8%	269,473	-1.6%
Post-1975	243,911	260,415	+6.8%	241,685	-0.9%	239,896	-1.6%
Post-1997	214,397	231,029	+7.8%	212,203	-1.0%	211,087	-1.5%
RCP 8.5 2020 Low	253,192	270,041	+6.7%	250,962	-0.9%	249,191	-1.6%
RCP 8.5 2020 Med	232,985	249,720	+7.2%	230,773	-0.9%	229,371	-1.6%
RCP 8.5 2020 High	206,239	222,720	+8.0%	204,050	-1.1%	203,027	-1.6%
RCP 8.5 2040 Low	259,364	278,062	+7.2%	257,127	-0.9%	256,990	-0.9%
RCP 8.5 2040 Med	222,888	241,165	+8.2%	220,682	-1.0%	220,723	-1.0%
RCP 8.5 2040 High	175,356	192,789	+9.9%	173,204	-1.2%	174,520	-0.5%
RCP 8.5 2065 Low	227,843	247,849	+8.8%	225,628	-1.0%	226,368	-0.6%
RCP 8.5 2065 Med	198,714	218,176	+9.8%	196,523	-1.1%	197,620	-0.6%
RCP 8.5 2065 High	130,580	148,434	+13.7%	128,578	-1.5%	132,607	+1.6%

The flow exceedance curves for in the Gellibrand River at Princetown have been compared for the medium climate change case under current demand in Figure 8-1. The figure shows the reduction in flow under 2065 climate change impacts compared to current (2020) climate.

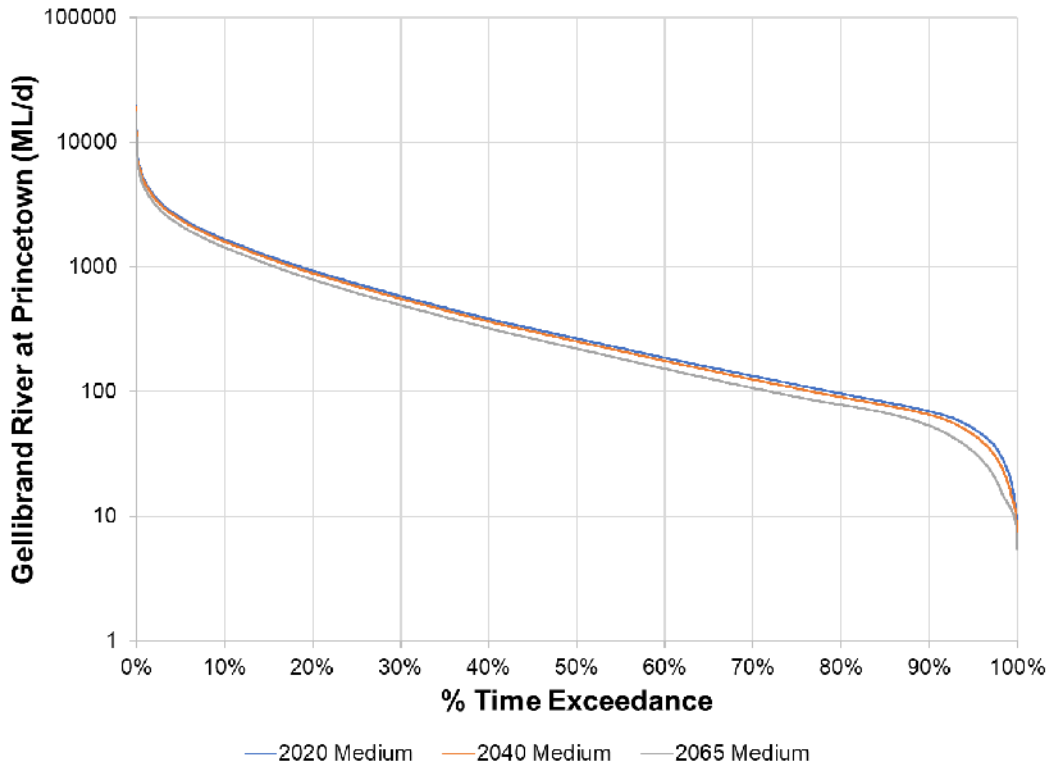


Figure 8-1 Comparison of current level of development flows in the Gellibrand River at Princetown for medium climate change scenarios

The subsequent flow duration curves show the impact of the various levels of development for 2020 medium (Figure 8-2), 2040 medium (Figure 8-3) and 2065 medium (Figure 8-4) climate change. Flow in Gellibrand River for the unimpacted scenario is greater for flows less than 1000 ML/d when compared to the impacted scenarios. The full uptake of rural demands reduces flow in the Gellibrand River at Princetown for flow less than 100 ML/d.

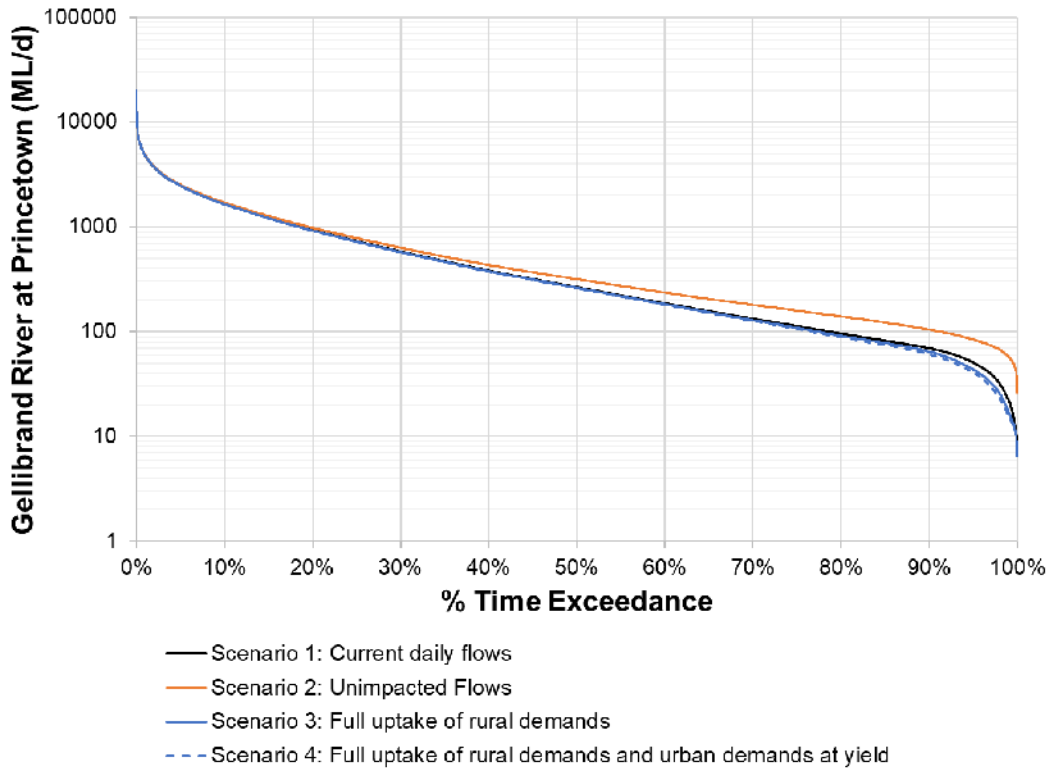


Figure 8-2 Comparison of flows in the Gellibrand River at Princetown for 2020 medium climate change scenario

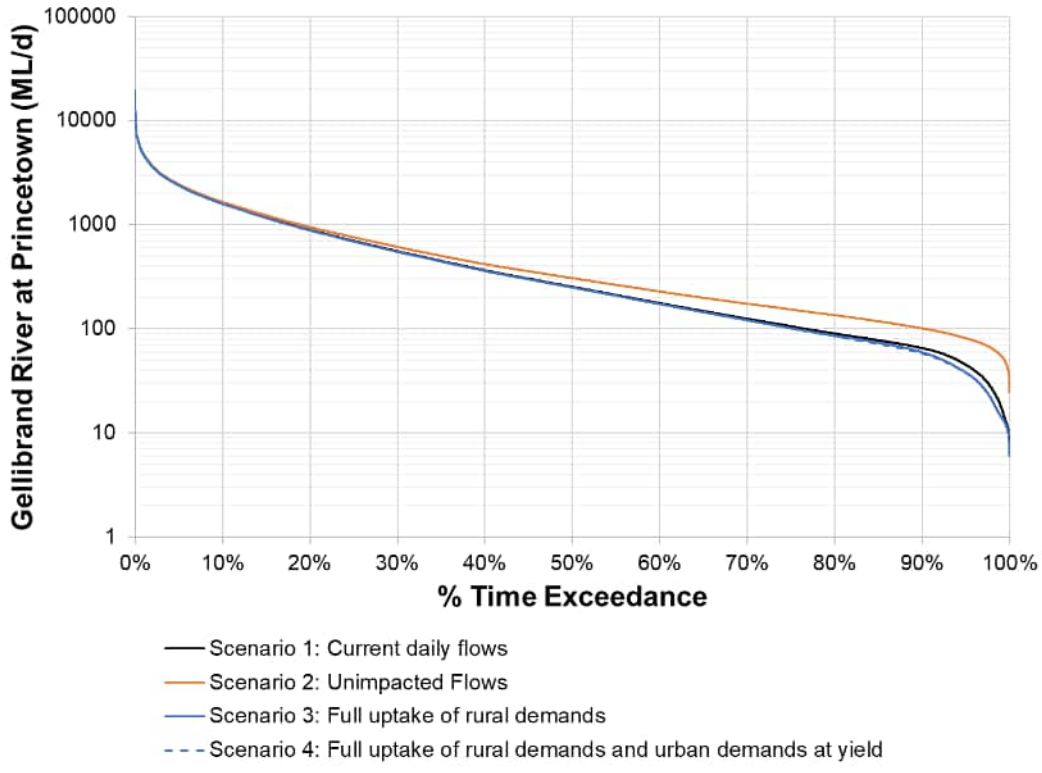


Figure 8-3 Comparison of flows in the Gellibrand River at Princetown for 2040 medium climate change scenario

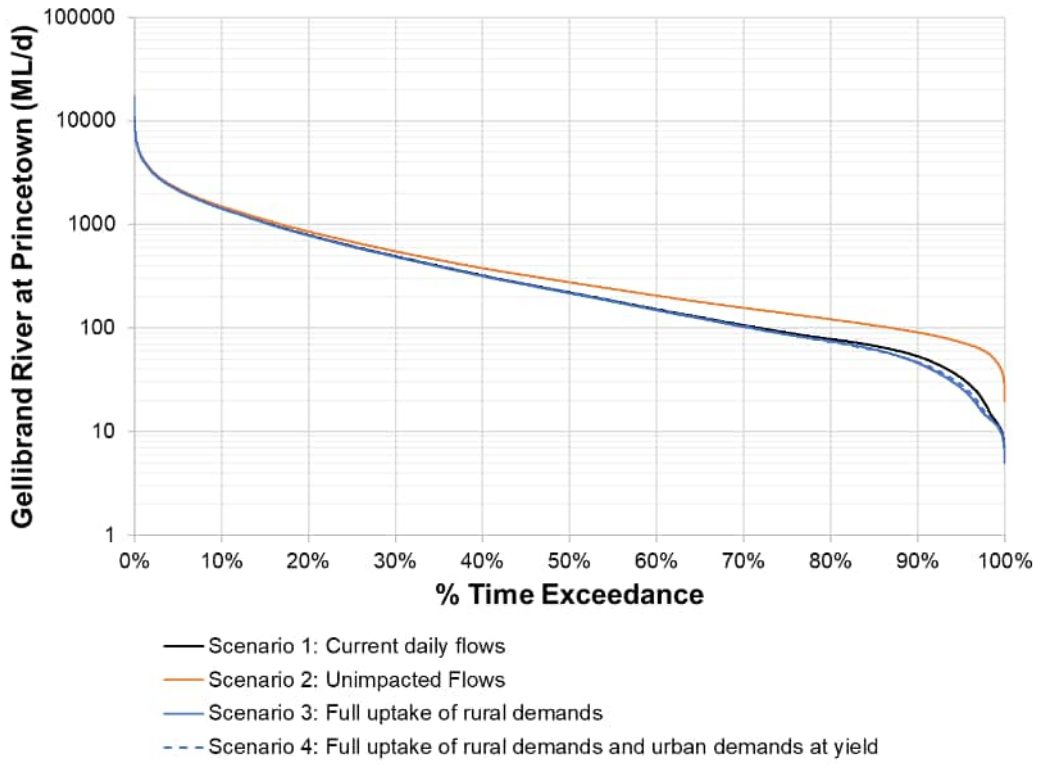


Figure 8-4 Comparison of flows in the Gellibrand River at Princetown for 2065 medium climate change scenario

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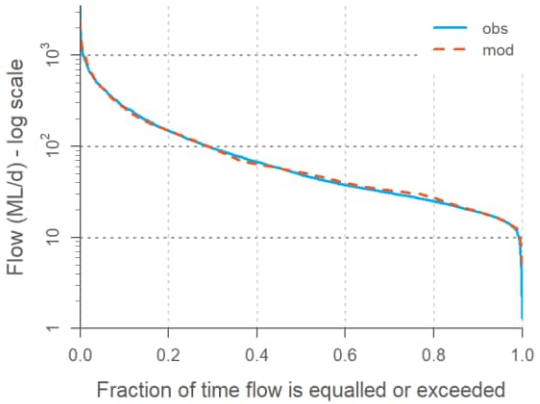
Appendix A GR4J Rainfall runoff model report cards

Subcatchment G3

Period of analysis: 12/01/2005 to 30/06/2022

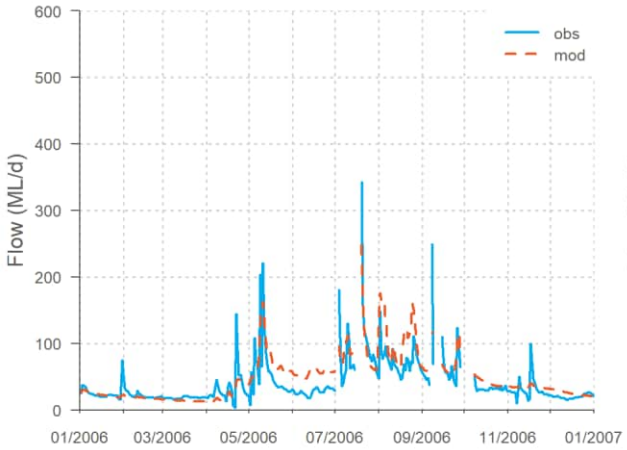
(Observed flow is available for 90.8% of days in this period)

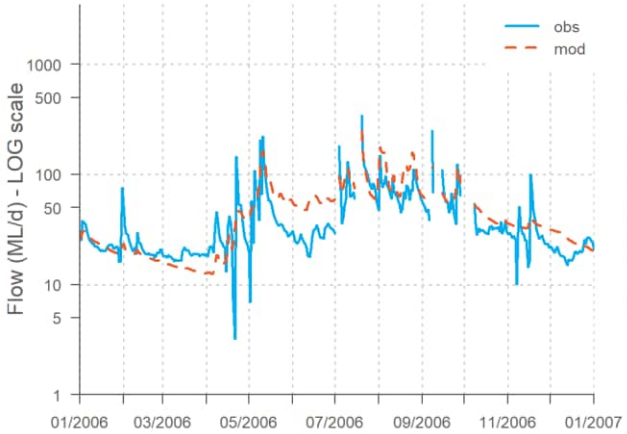
Exceedance curve



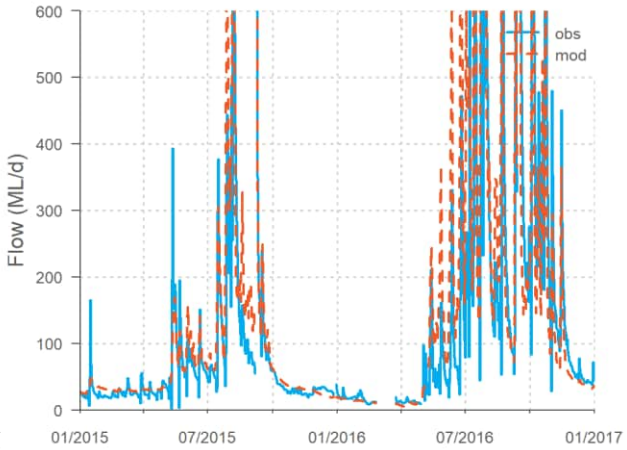
Statistics	Value
Correlation	0.88
Coefficient of determination	0.78
NSE daily	0.77
NSE monthly	0.90
Specific yield (mm)	198.3
Average annual modelled flow (ML/yr)	41,640.6
Average annual observed flow (ML/yr)	41,634.1
% Difference	0.0%
Runoff coefficient	0.20

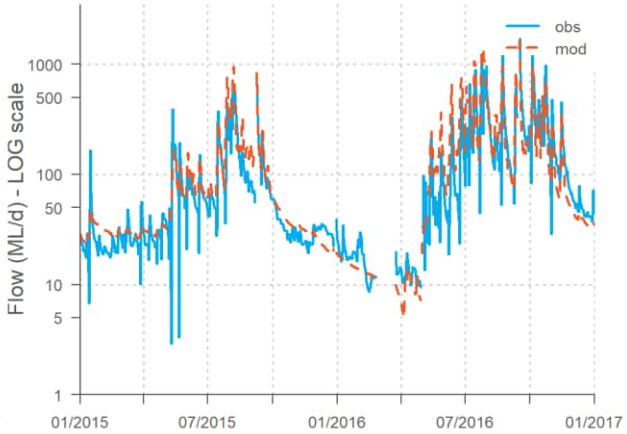
06/07 Drought

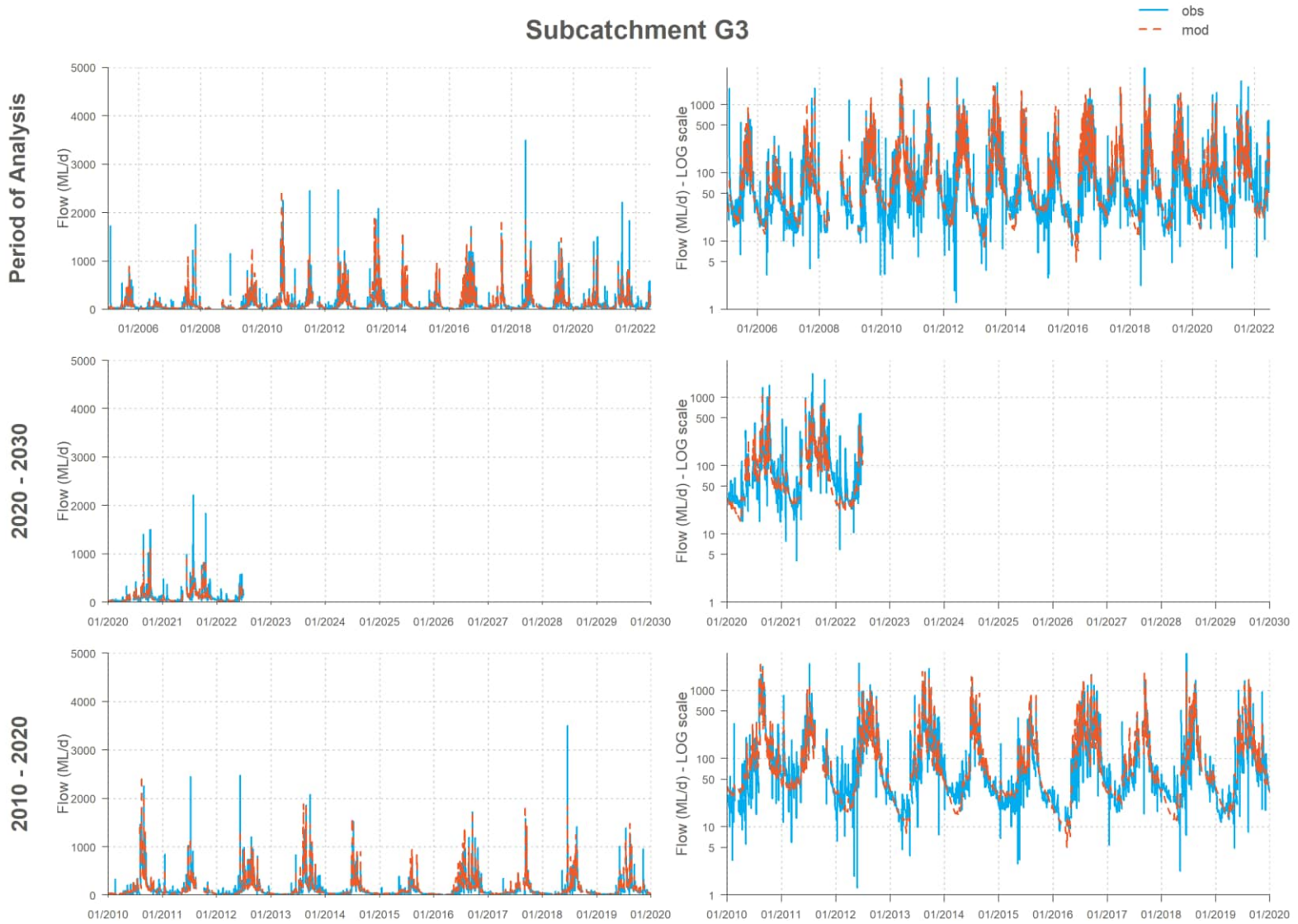


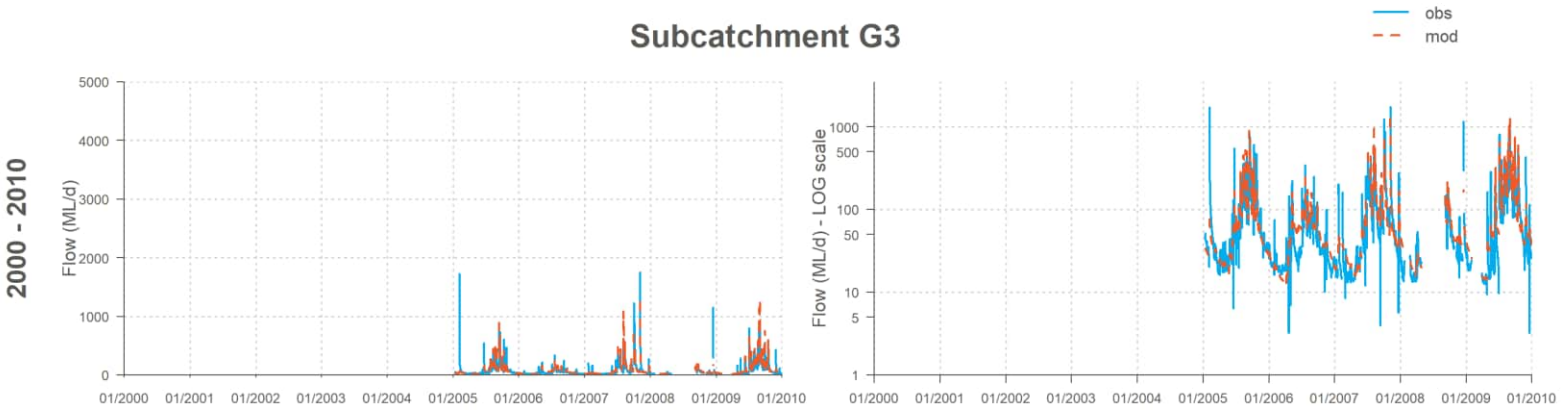


15/16 Drought





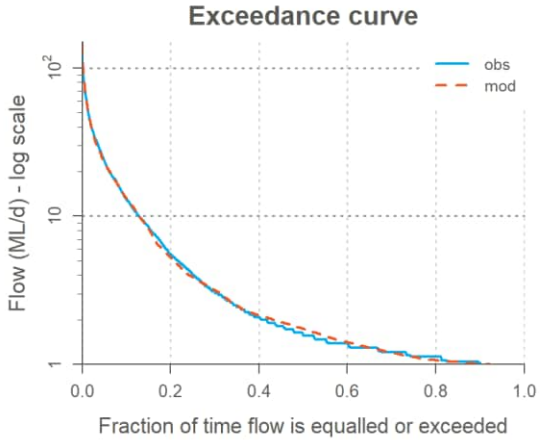

Subcatchment G3
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale


Subcatchment G3
obs
mod
2000 - 2010
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
01/2009
01/2010

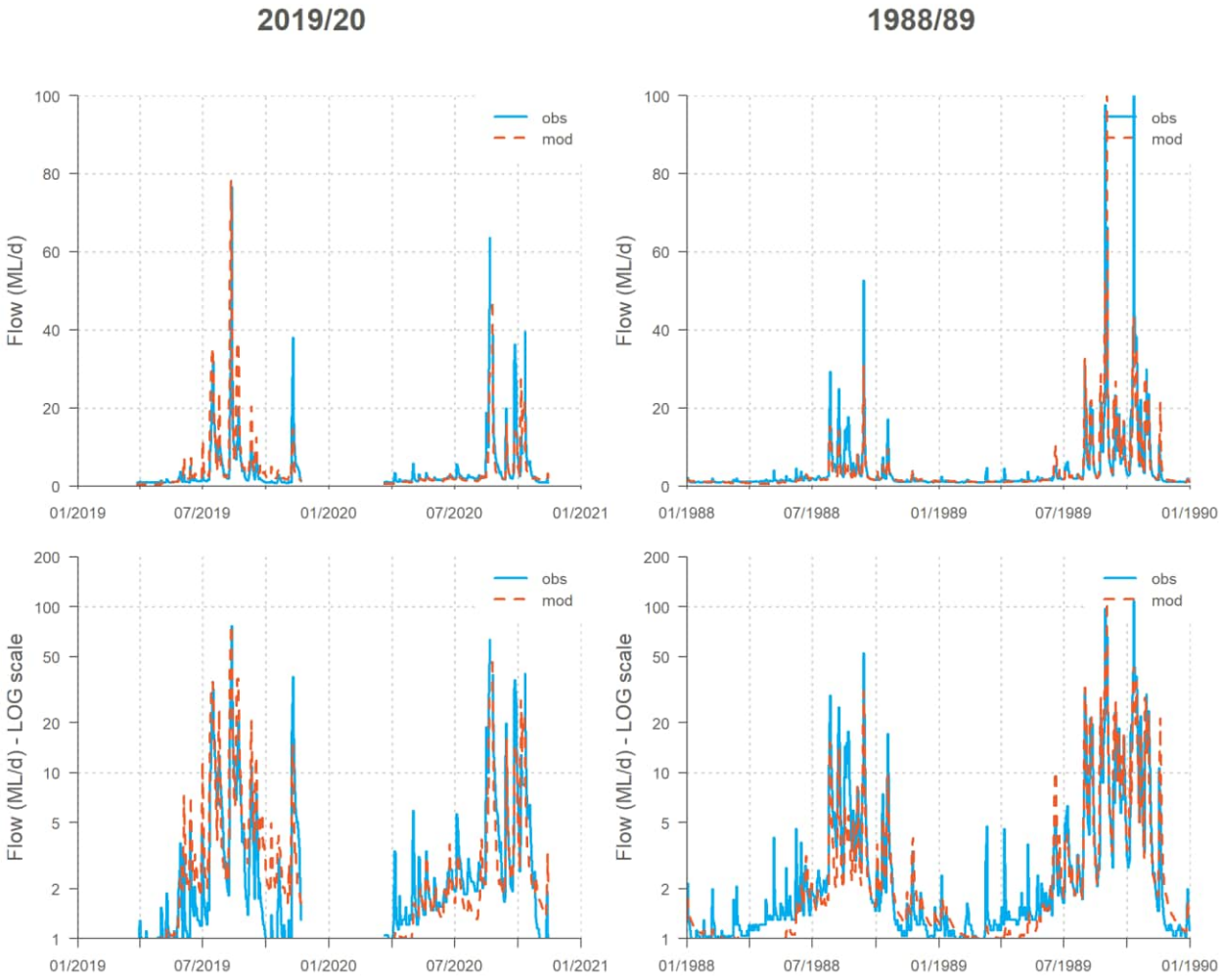
Subcatchment G4

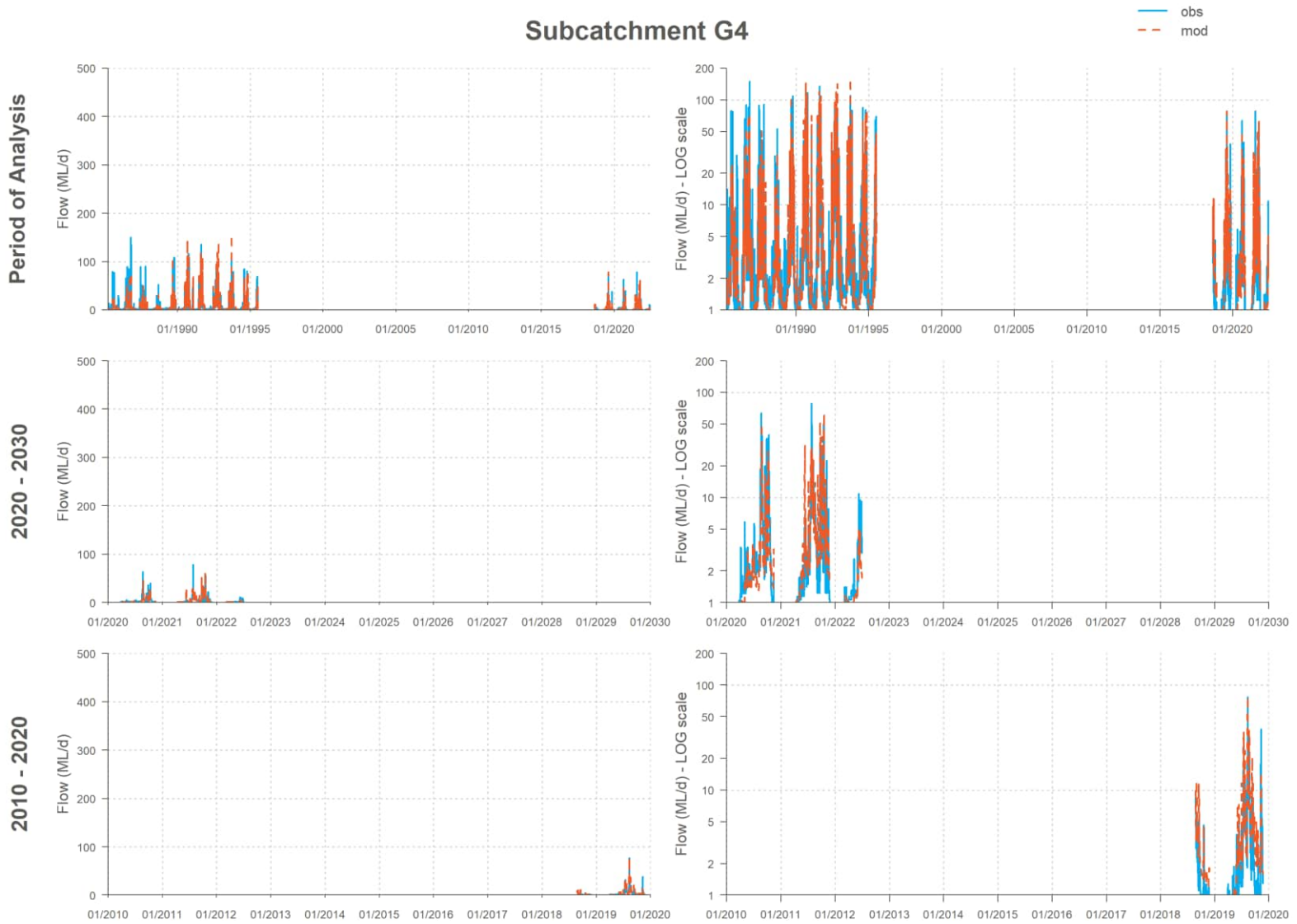
Period of analysis: 27/03/1985 to 30/06/2022

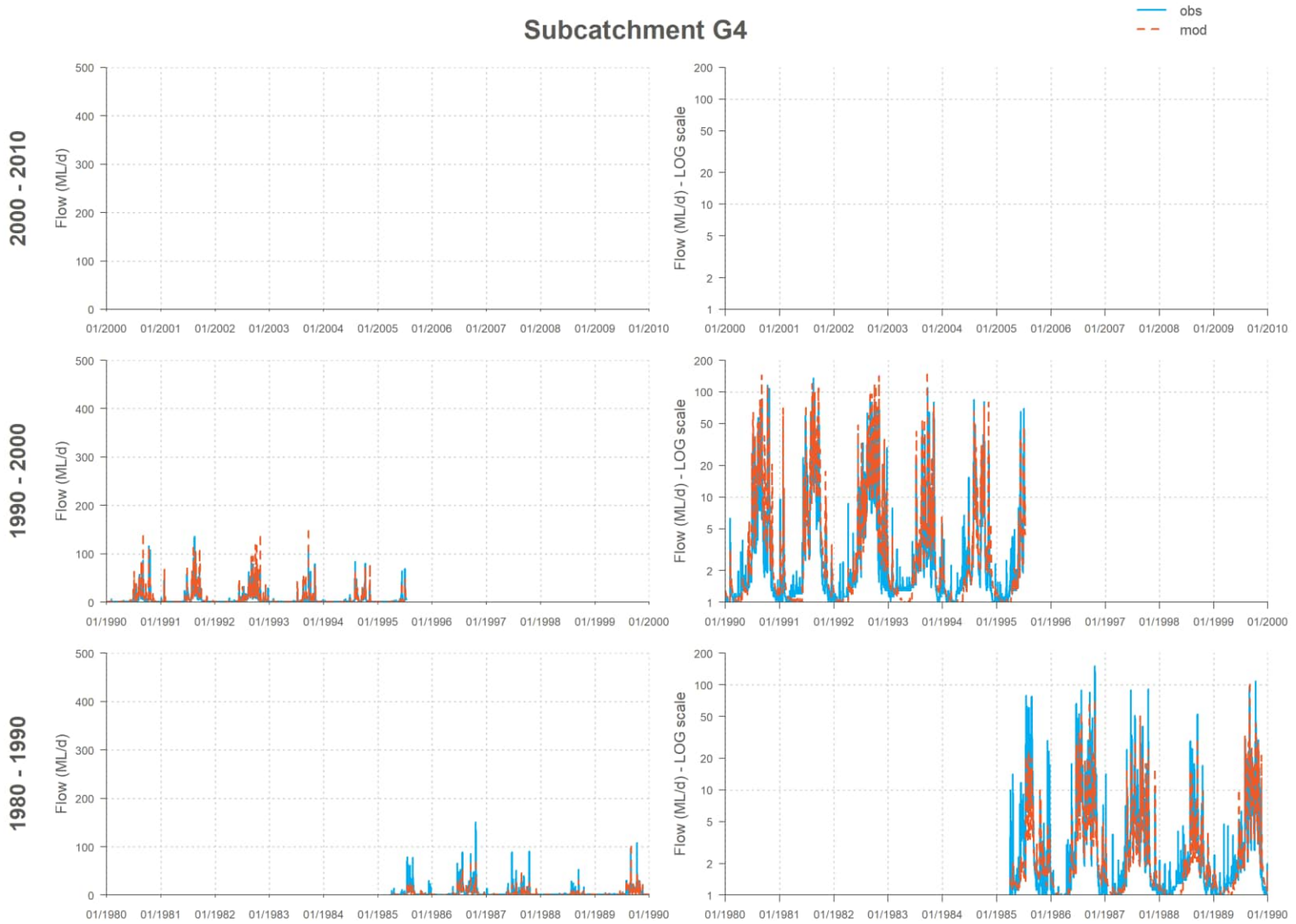
(Observed flow is available for 34.3% of days in this period)



Statistics	Value
Correlation	0.83
Coefficient of determination	0.69
NSE daily	0.65
NSE monthly	0.74
Specific yield (mm)	113.3
Average annual modelled flow (ML/yr)	1,982.3
Average annual observed flow (ML/yr)	1,980.6
% Difference	0.1%
Runoff coefficient	0.13



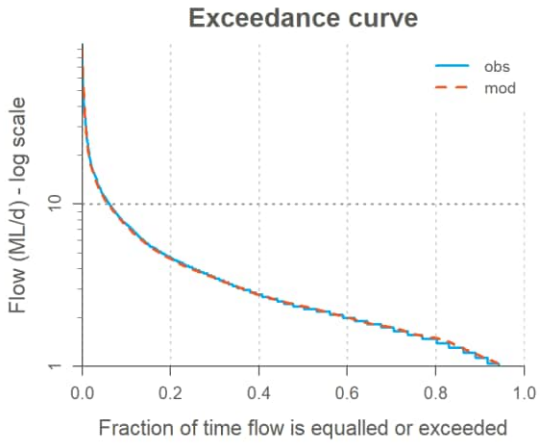

Subcatchment G4
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1990
01/1995
01/2000
01/2005
01/2010
01/2015
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2016
01/2017
01/2018
01/2019


Subcatchment G4
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000 01/2001 01/2002 01/2003 01/2004 01/2005 01/2006 01/2007 01/2008 01/2009 01/2010
01/1990 01/1991 01/1992 01/1993 01/1994 01/1995 01/1996 01/1997 01/1998 01/1999 01/2000
01/1980 01/1981 01/1982 01/1983 01/1984 01/1985 01/1986 01/1987 01/1988 01/1989 01/1990

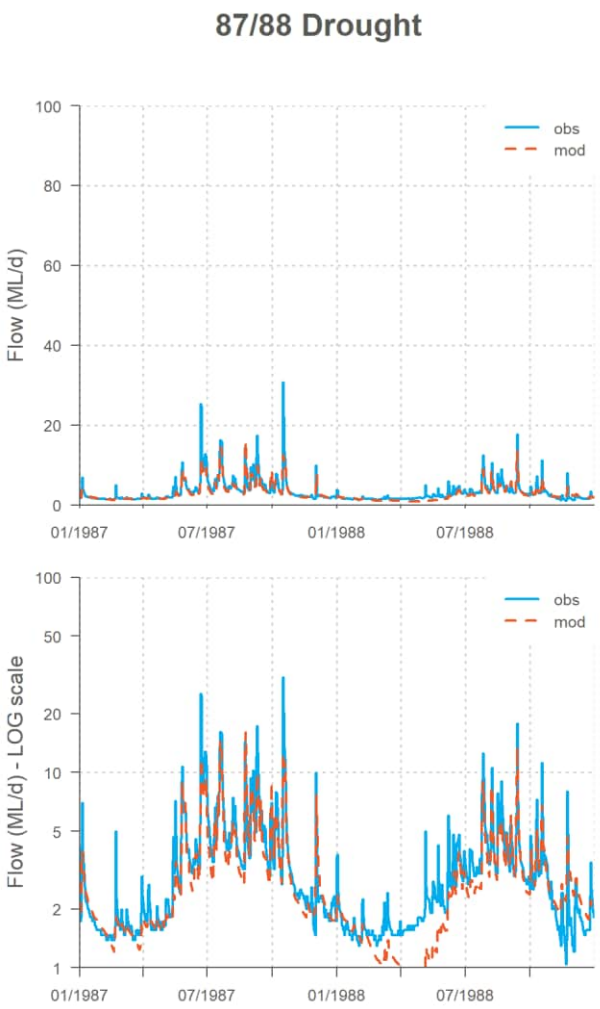
Subcatchment G6

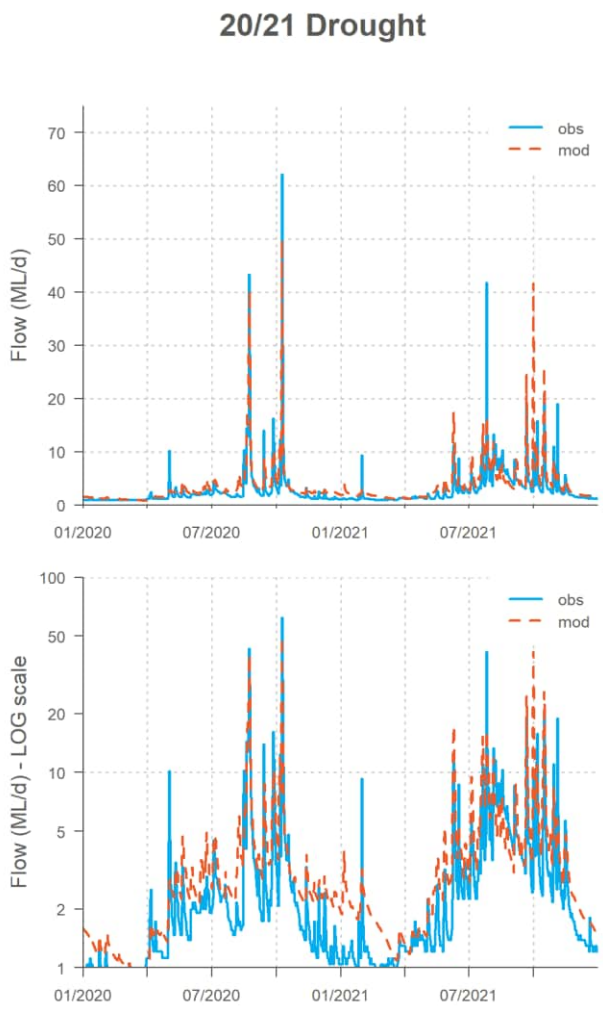
Period of analysis: 19/04/1985 to 30/06/2022

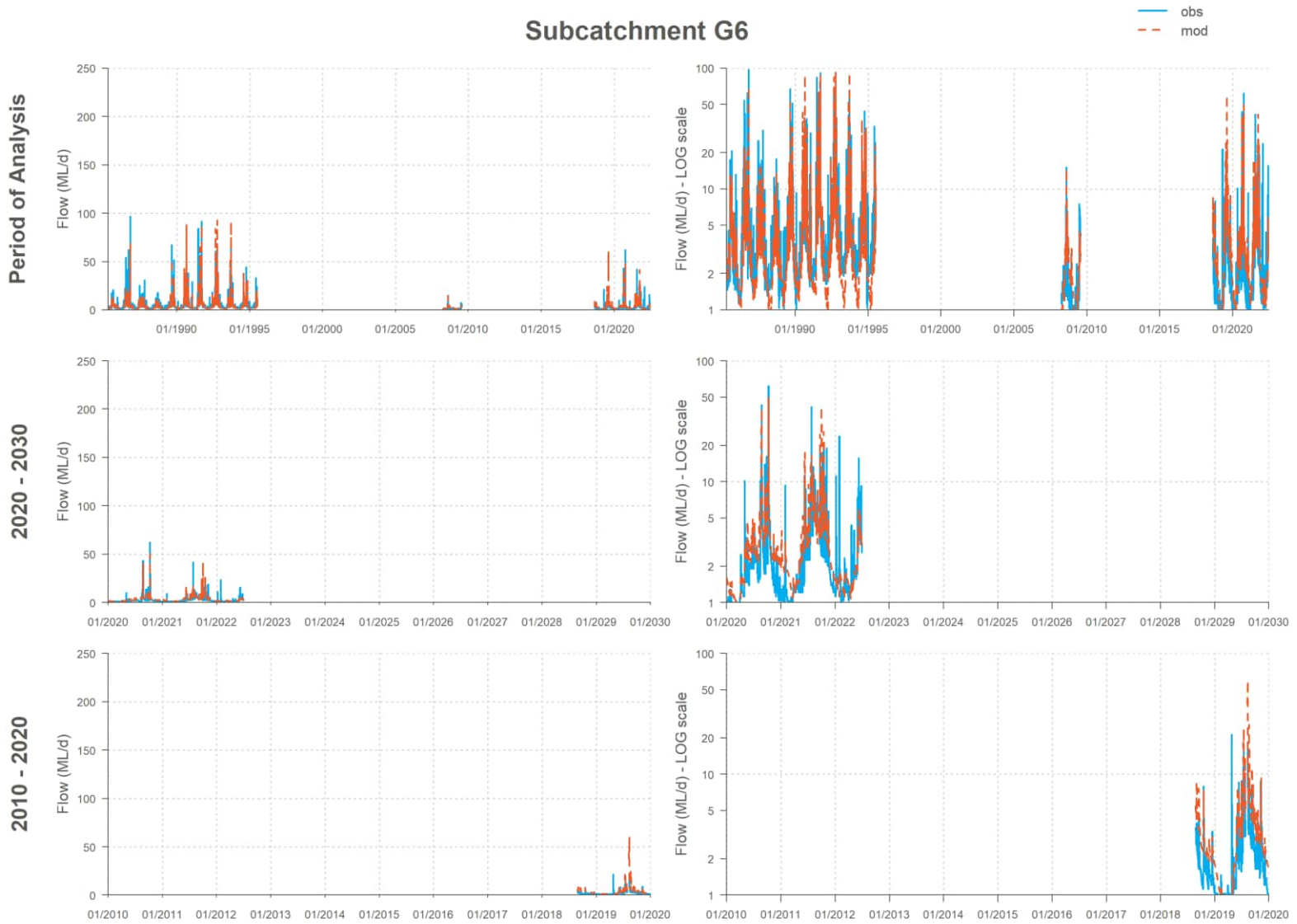
(Observed flow is available for 41.3% of days in this period)

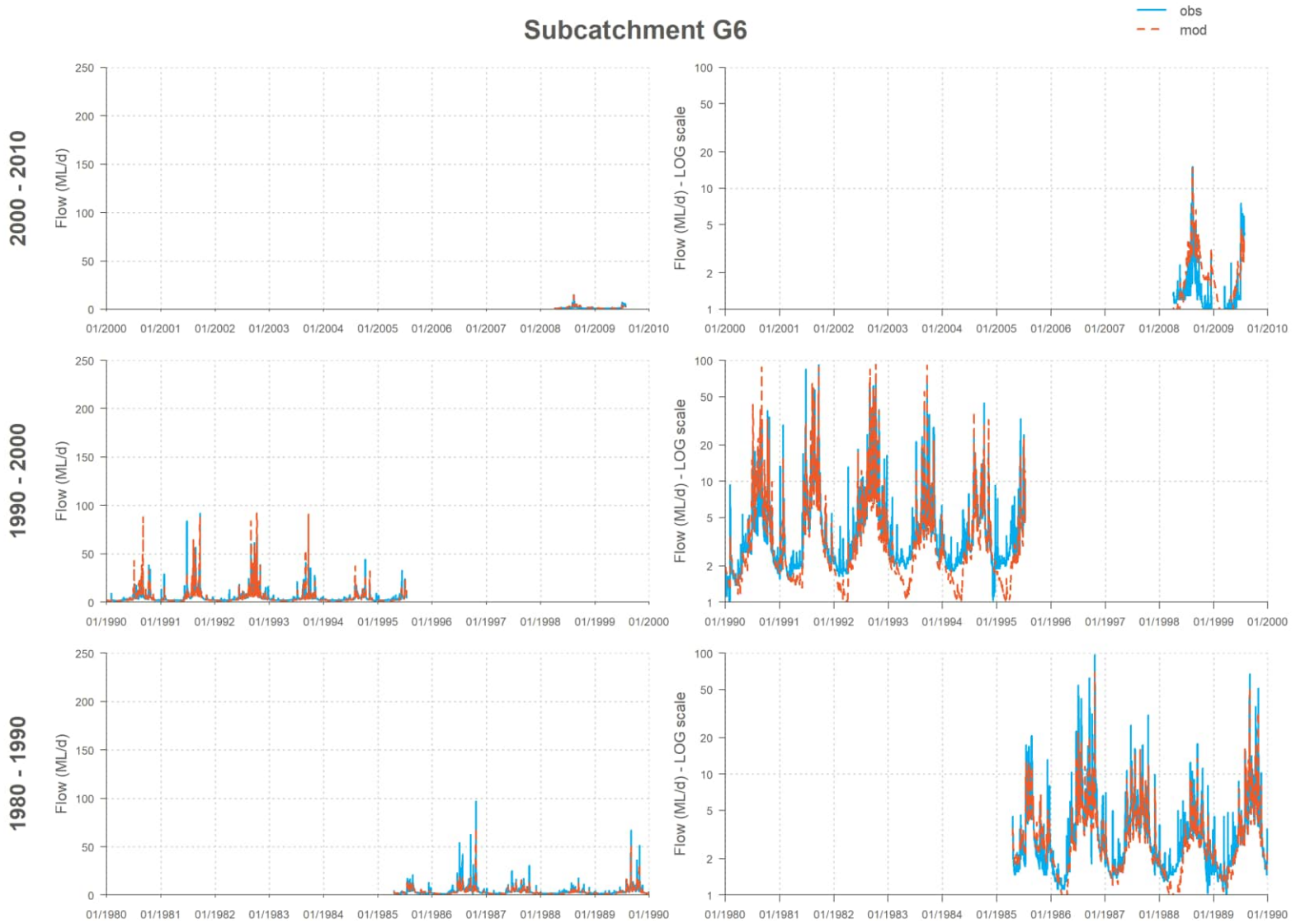


Statistics	Value
Correlation	0.83
Coefficient of determination	0.70
NSE daily	0.65
NSE monthly	0.84
Specific yield (mm)	140.6
Average annual modelled flow (ML/yr)	1,405.8
Average annual observed flow (ML/yr)	1,405.9
% Difference	-0.0%
Runoff coefficient	0.16





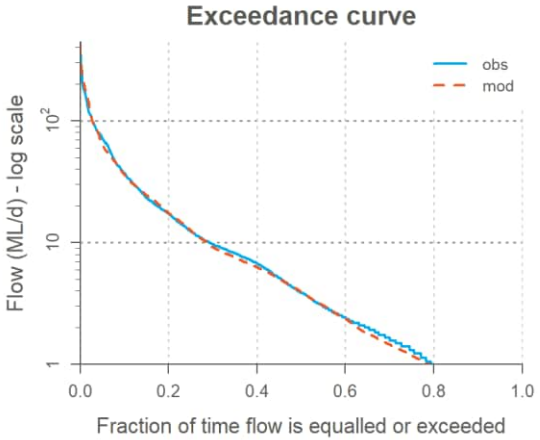

Subcatchment G6
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale


Subcatchment G6
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale

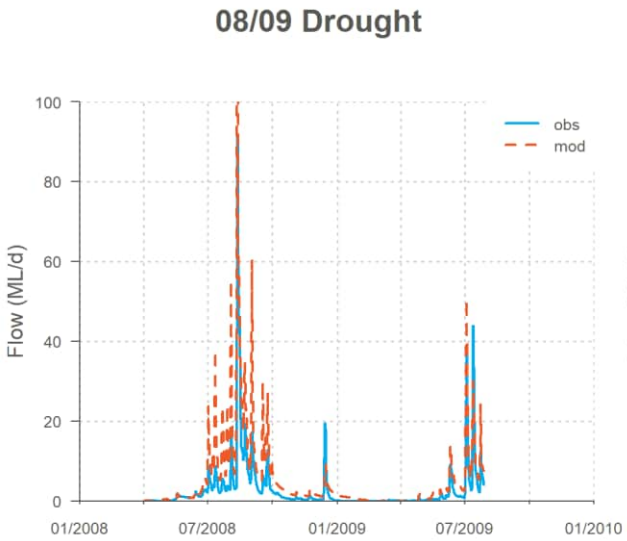
Subcatchment G7

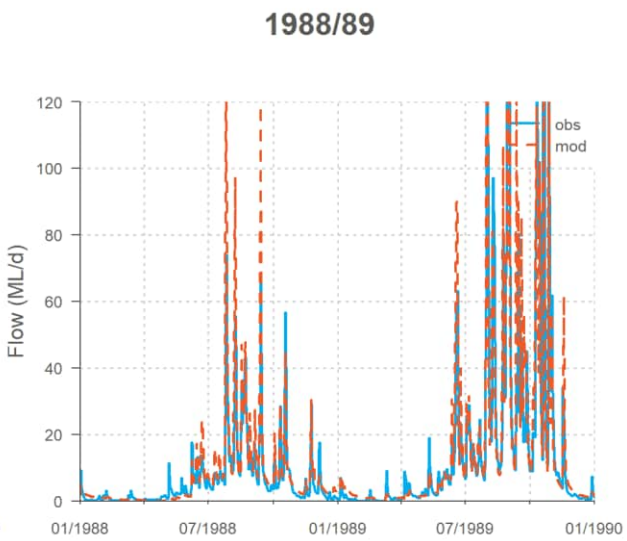
Period of analysis: 26/03/1986 to 28/07/2009

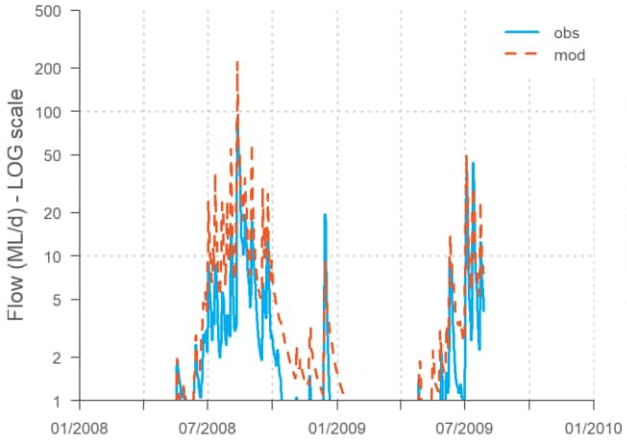
(Observed flow is available for 45.5% of days in this period)

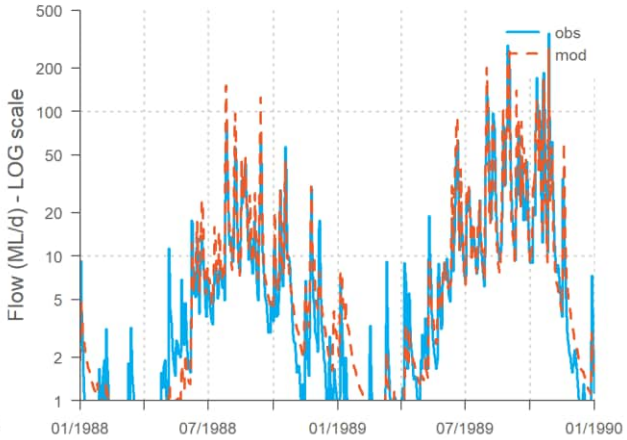


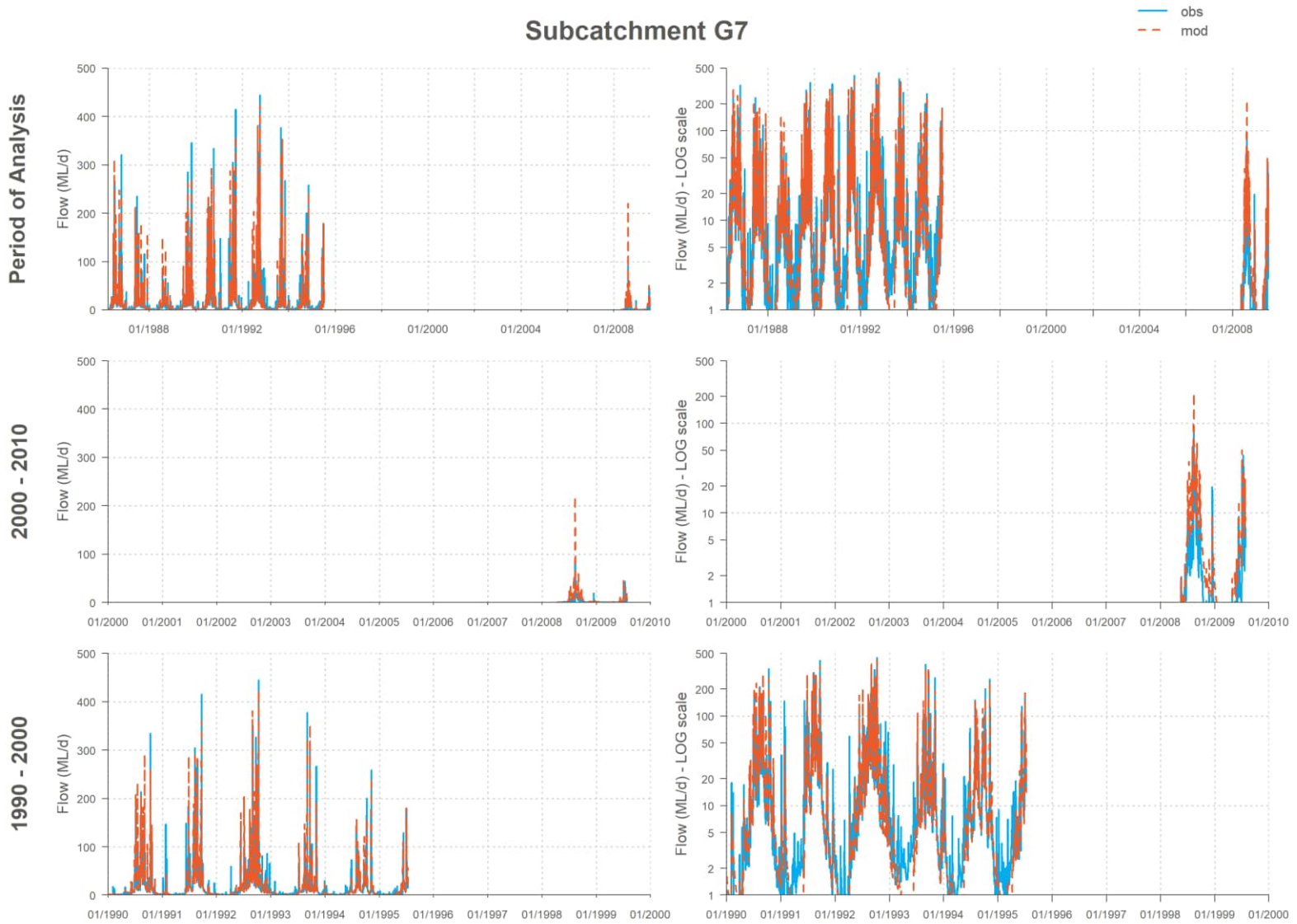
Statistics	Value
Correlation	0.92
Coefficient of determination	0.85
NSE daily	0.84
NSE monthly	0.95
Specific yield (mm)	162.2
Average annual modelled flow (ML/yr)	5,481.2
Average annual observed flow (ML/yr)	5,481.1
% Difference	0.0%
Runoff coefficient	0.17

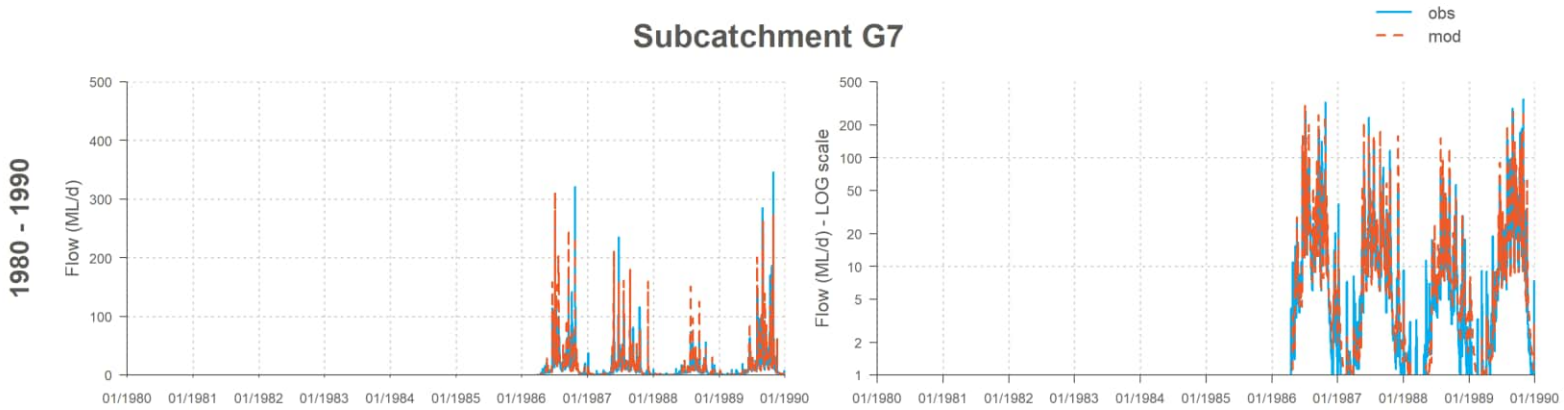








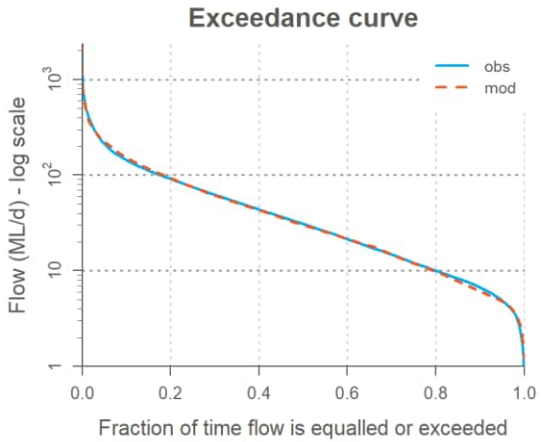

Subcatchment G7
obs
mod
Period of Analysis
2000 - 2010
1990 - 2000
Flow (ML/d)
Flow (ML/d) - LOG scale


Subcatchment G7
obs
mod
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
500
400
300
200
100
0
50
20
10
5
2
1
01/1980
01/1981
01/1982
01/1983
01/1984
01/1985
01/1986
01/1987
01/1988
01/1989
01/1990

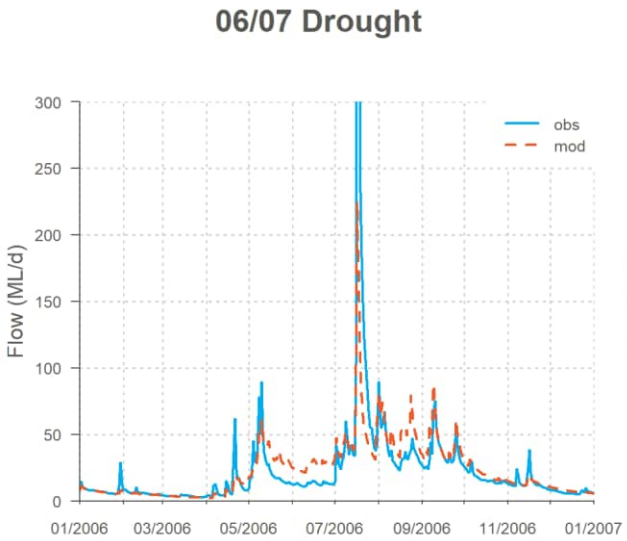
Subcatchment G8

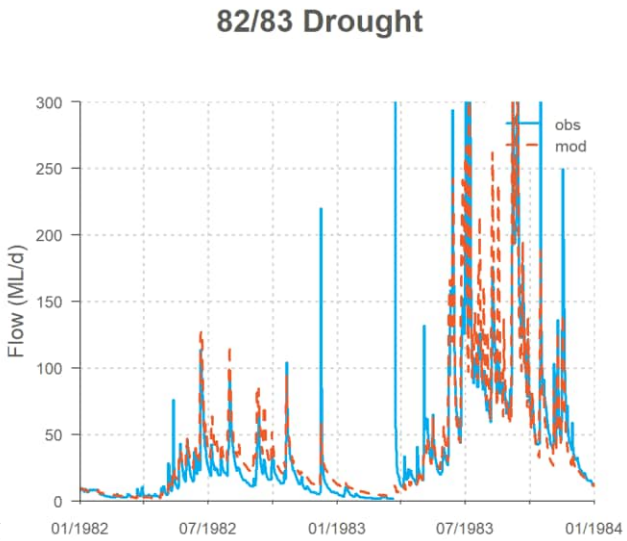
Period of analysis: 19/06/1964 to 30/06/2022

(Observed flow is available for 99.7% of days in this period)

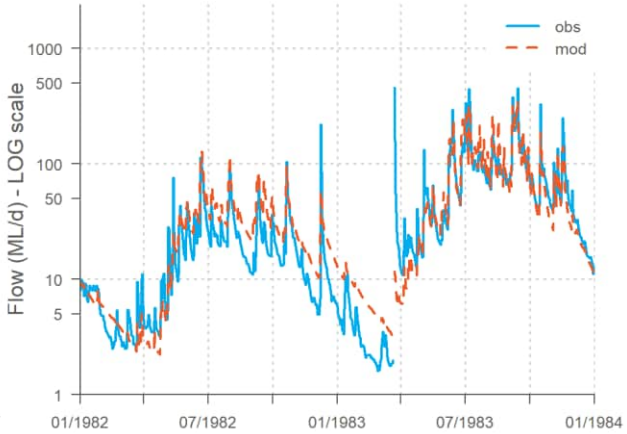


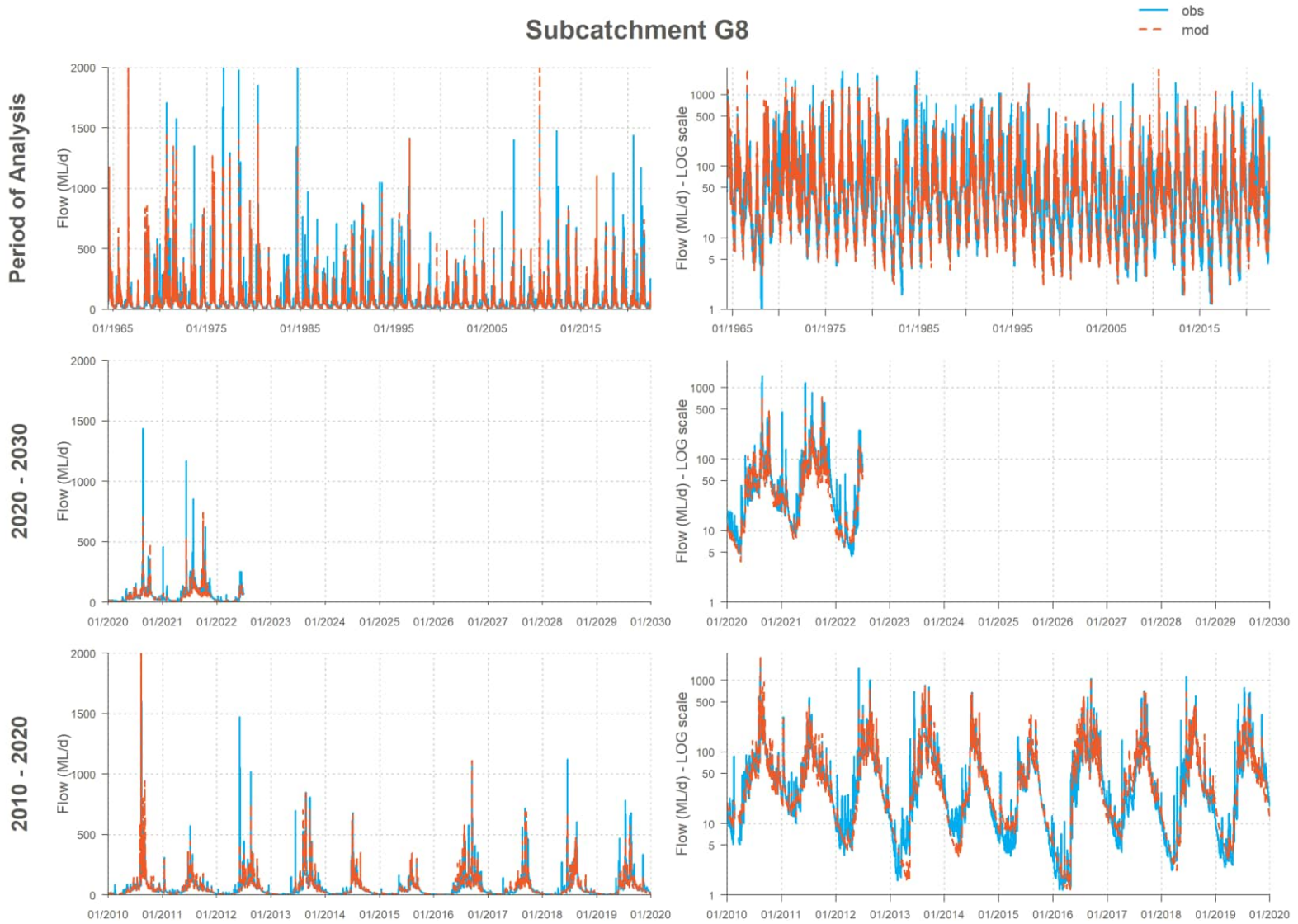
Statistics	Value
Correlation	0.90
Coefficient of determination	0.80
NSE daily	0.80
NSE monthly	0.92
Specific yield (mm)	442.1
Average annual modelled flow (ML/yr)	22,900.4
Average annual observed flow (ML/yr)	22,902.4
% Difference	-0.0%
Runoff coefficient	0.35

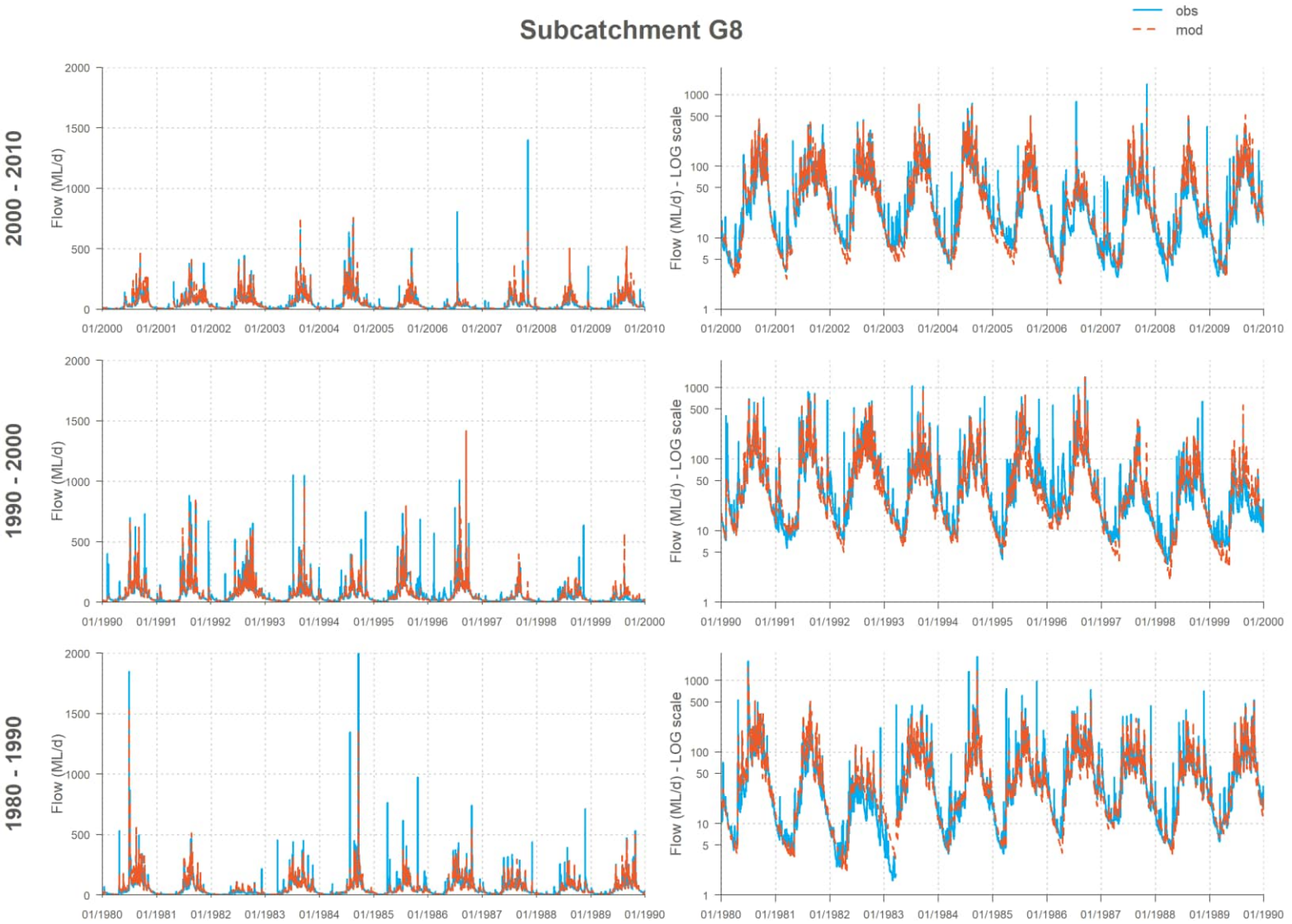


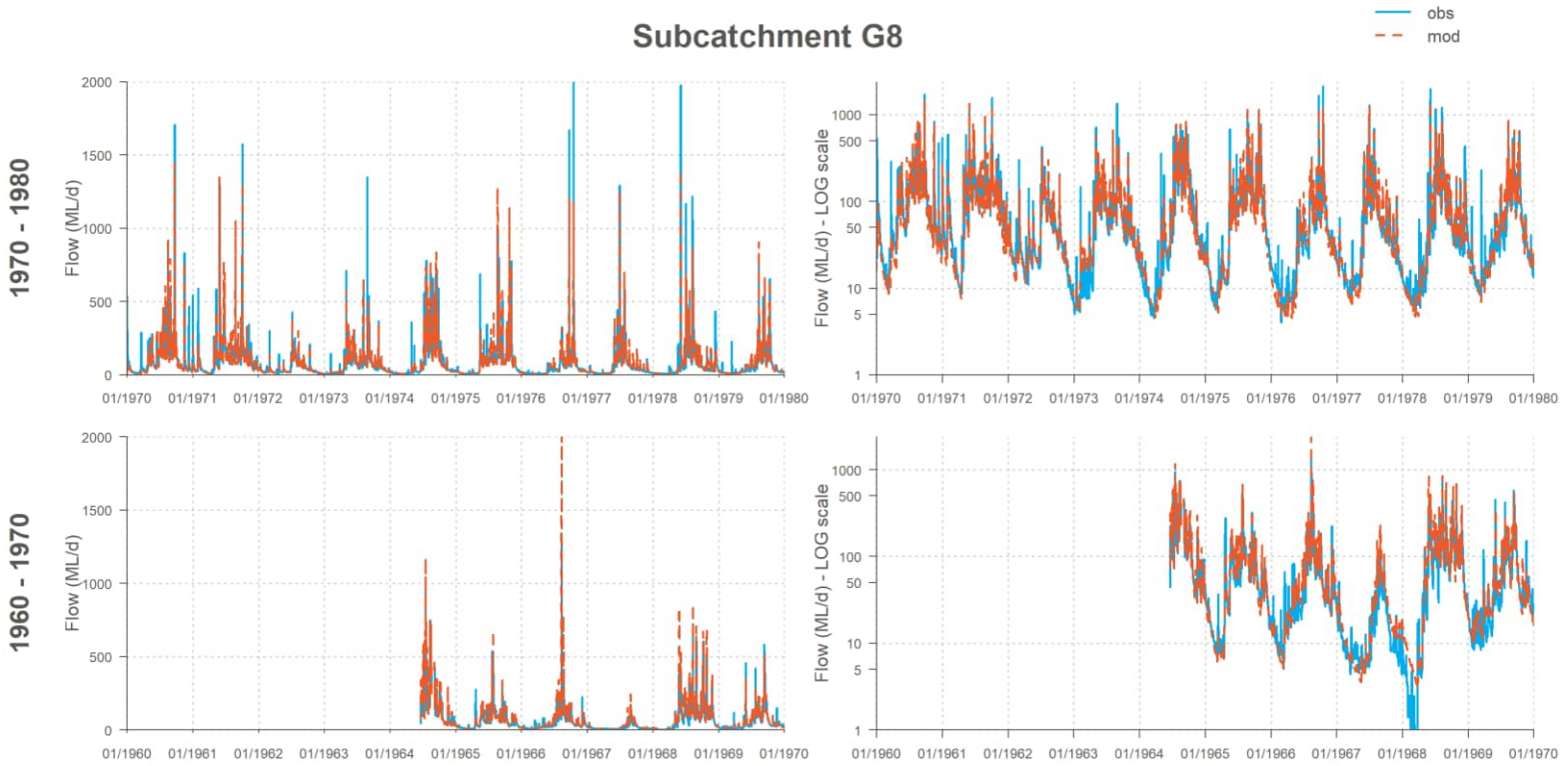







Subcatchment G8
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1965
01/1975
01/1985
01/1995
01/2005
01/2015
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
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01/2018
01/2019
01/2020

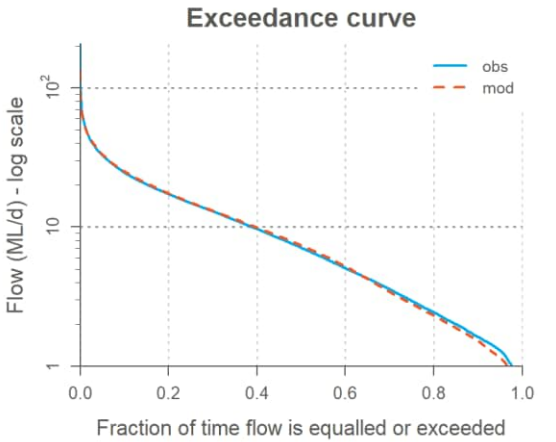

Subcatchment G8
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale


Subcatchment G8
obs
mod
1970 - 1980
1960 - 1970
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1970 01/1971 01/1972 01/1973 01/1974 01/1975 01/1976 01/1977 01/1978 01/1979 01/1980
01/1960 01/1961 01/1962 01/1963 01/1964 01/1965 01/1966 01/1967 01/1968 01/1969 01/1970

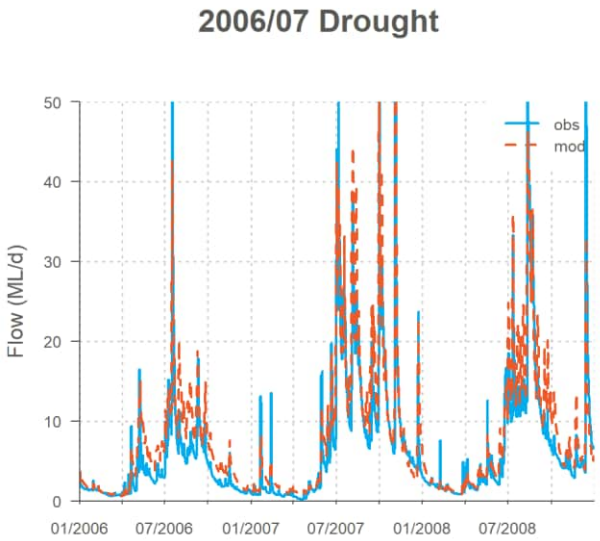
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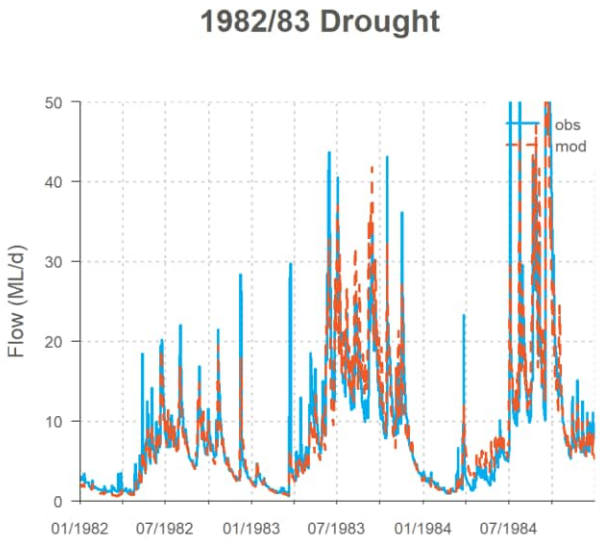
Period of analysis: 15/02/1958 to 30/06/2024

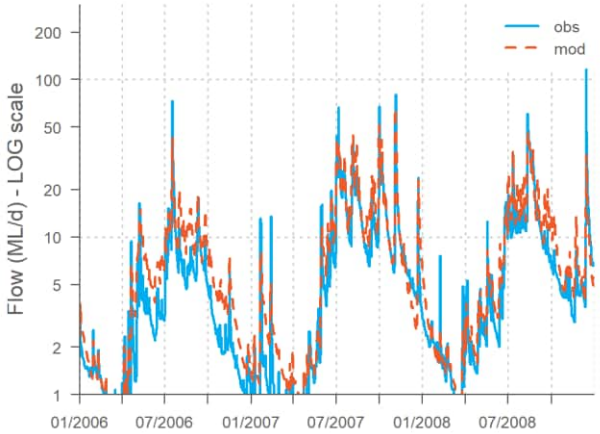
(Observed flow is available for 100.0% of days in this period)

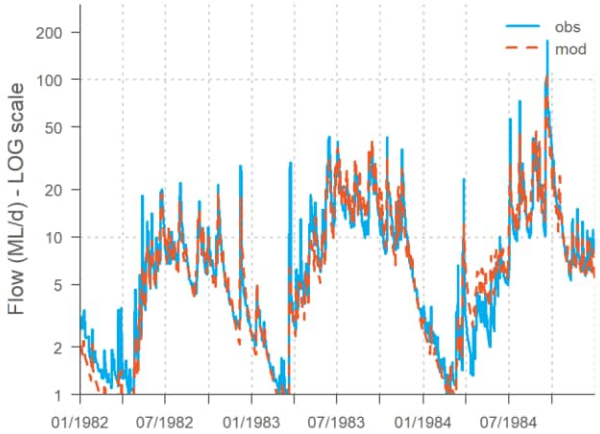


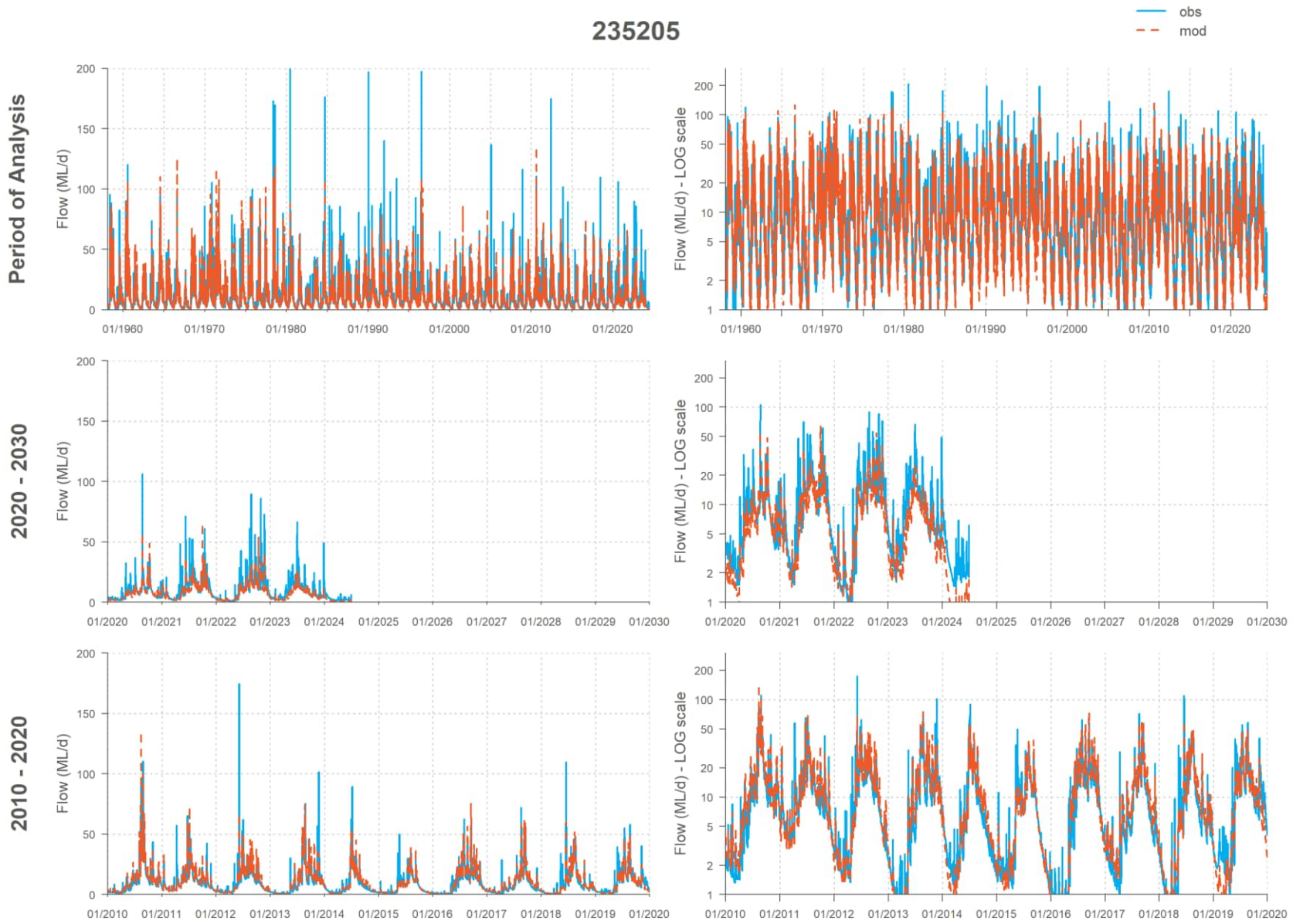
Statistics	Value
Correlation	0.90
Coefficient of determination	0.81
NSE daily	0.80
NSE monthly	0.91
Specific yield (mm)	910.0
Average annual modelled flow (ML/yr)	4,004.0
Average annual observed flow (ML/yr)	3,989.0
% Difference	0.4%
Runoff coefficient	0.51

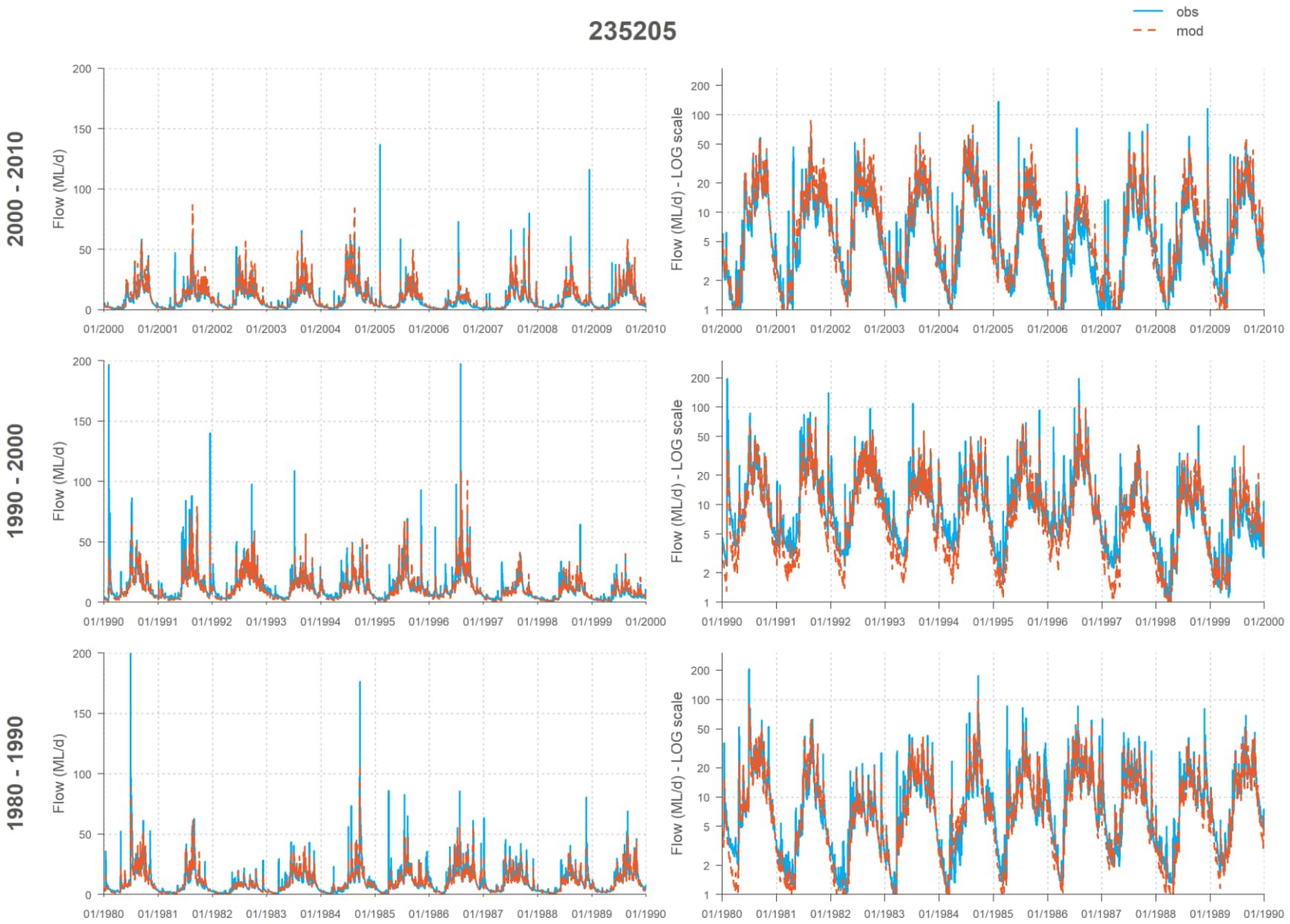


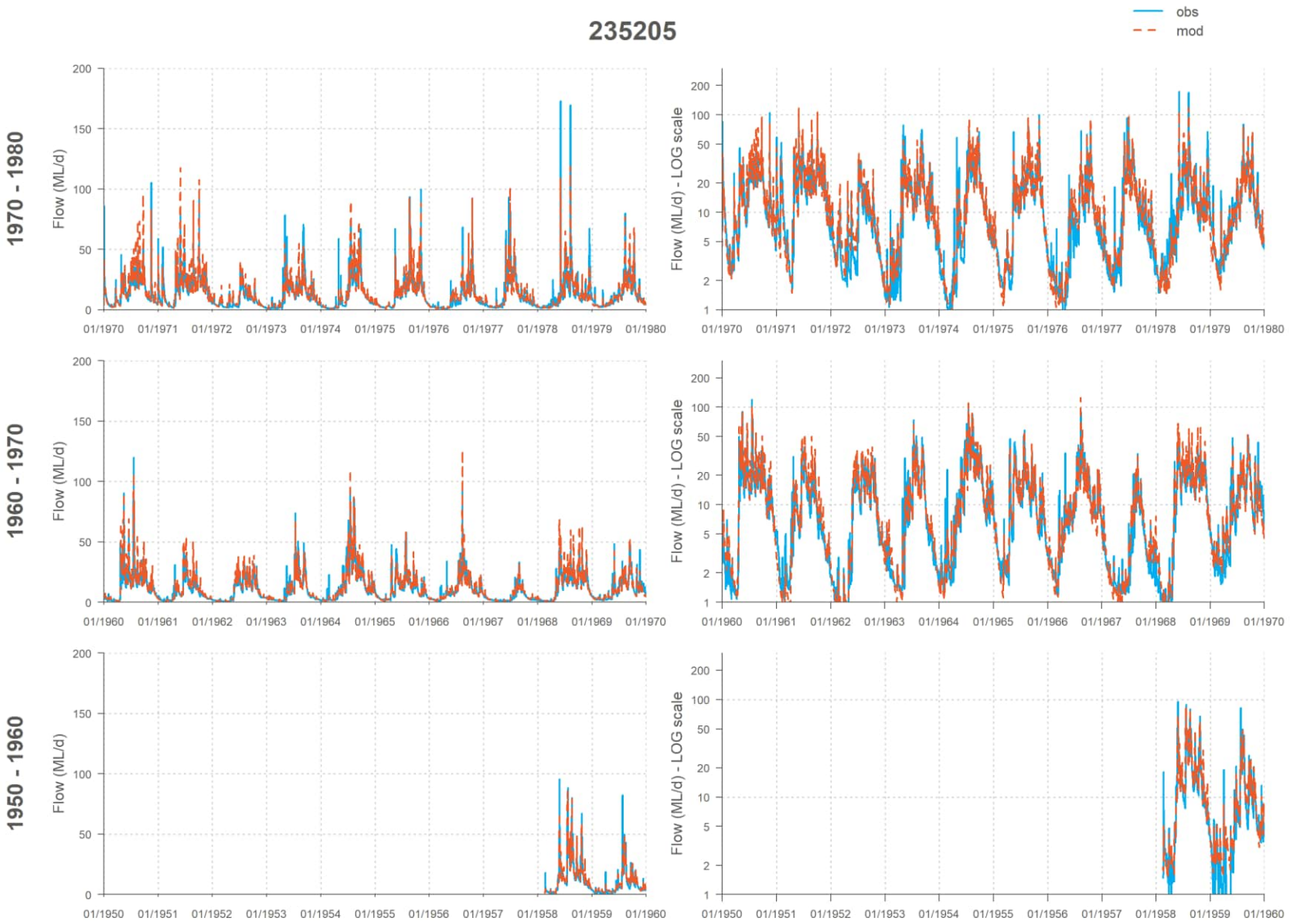







235205
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1960
01/1970
01/1980
01/1990
01/2000
01/2010
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019

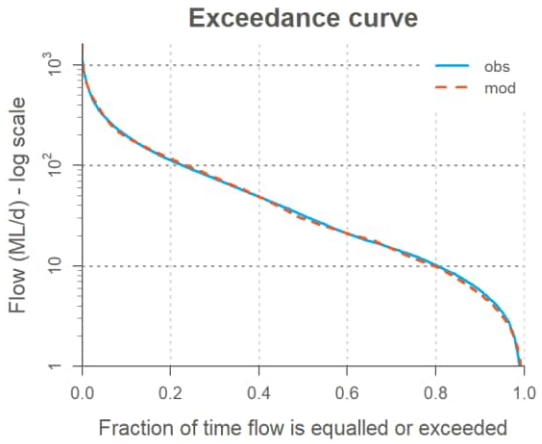

235205
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000 01/2001 01/2002 01/2003 01/2004 01/2005 01/2006 01/2007 01/2008 01/2009 01/2010
01/1990 01/1991 01/1992 01/1993 01/1994 01/1995 01/1996 01/1997 01/1998 01/1999 01/2000
01/1980 01/1981 01/1982 01/1983 01/1984 01/1985 01/1986 01/1987 01/1988 01/1989 01/1990


235205
obs
mod
1970 - 1980
1960 - 1970
1950 - 1960
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1970 01/1971 01/1972 01/1973 01/1974 01/1975 01/1976 01/1977 01/1978 01/1979 01/1980
01/1960 01/1961 01/1962 01/1963 01/1964 01/1965 01/1966 01/1967 01/1968 01/1969 01/1970
01/1950 01/1951 01/1952 01/1953 01/1954 01/1955 01/1956 01/1957 01/1958 01/1959 01/1960

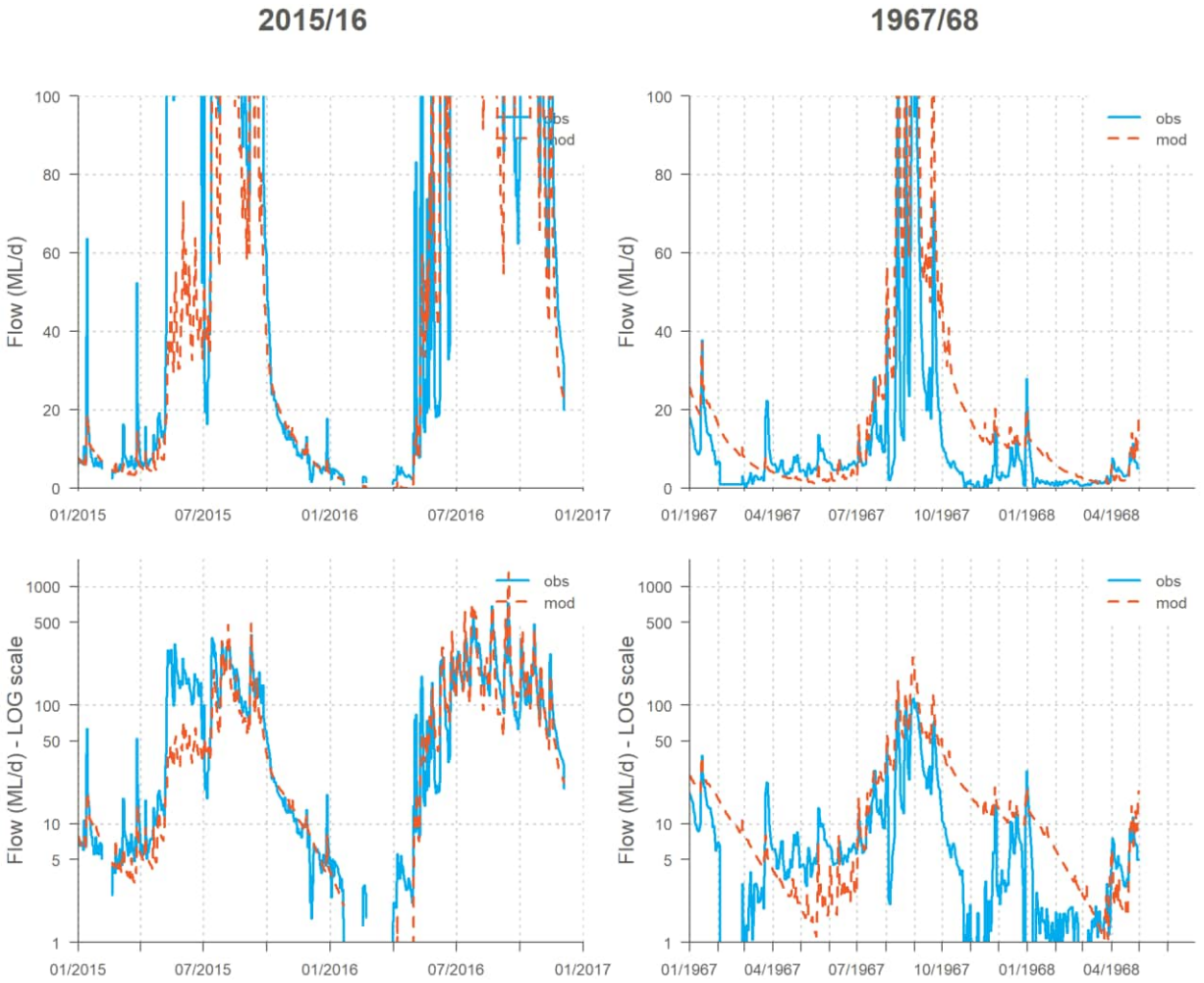
G9b Inflow

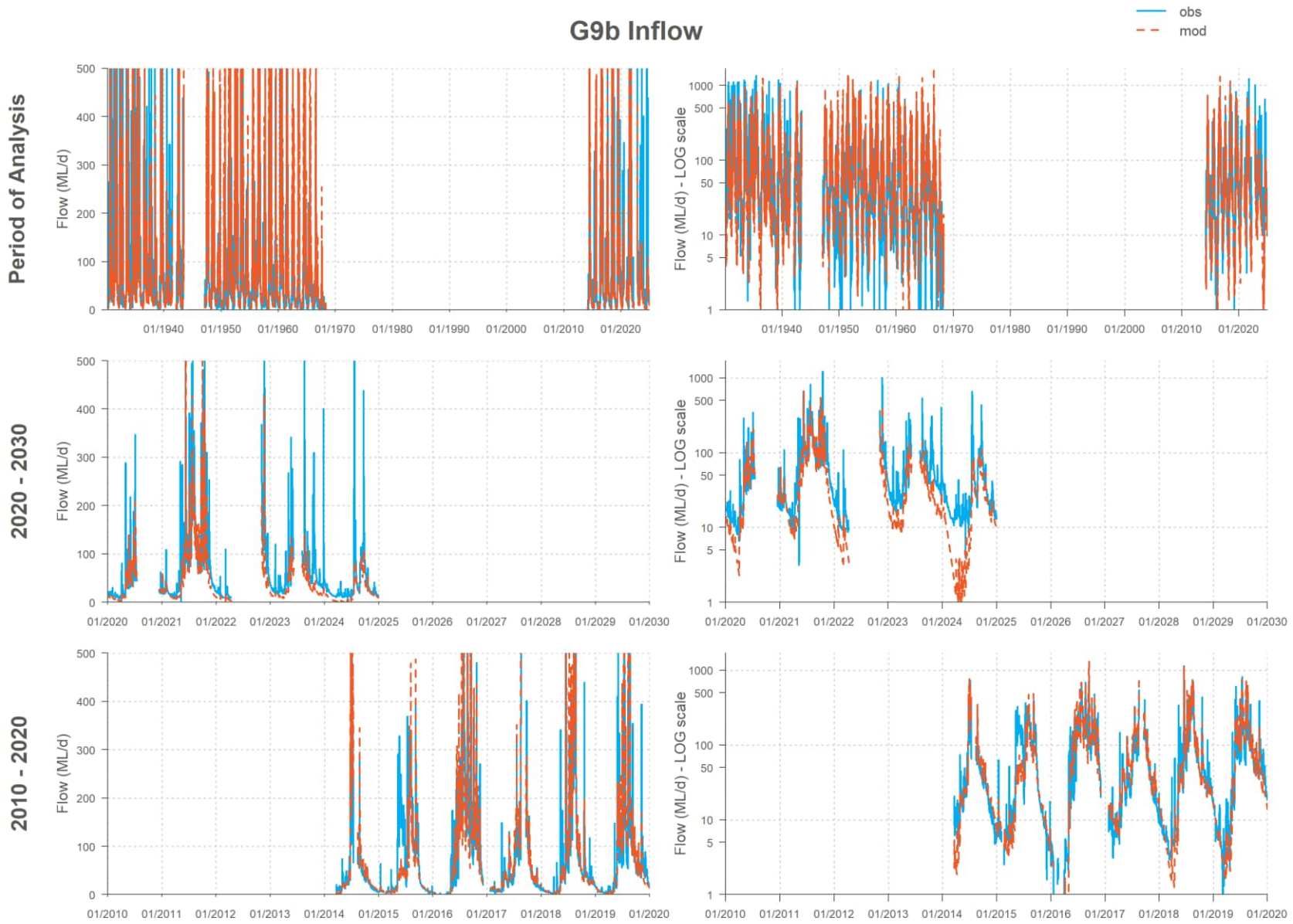
Period of analysis: 03/03/1930 to 31/12/2024

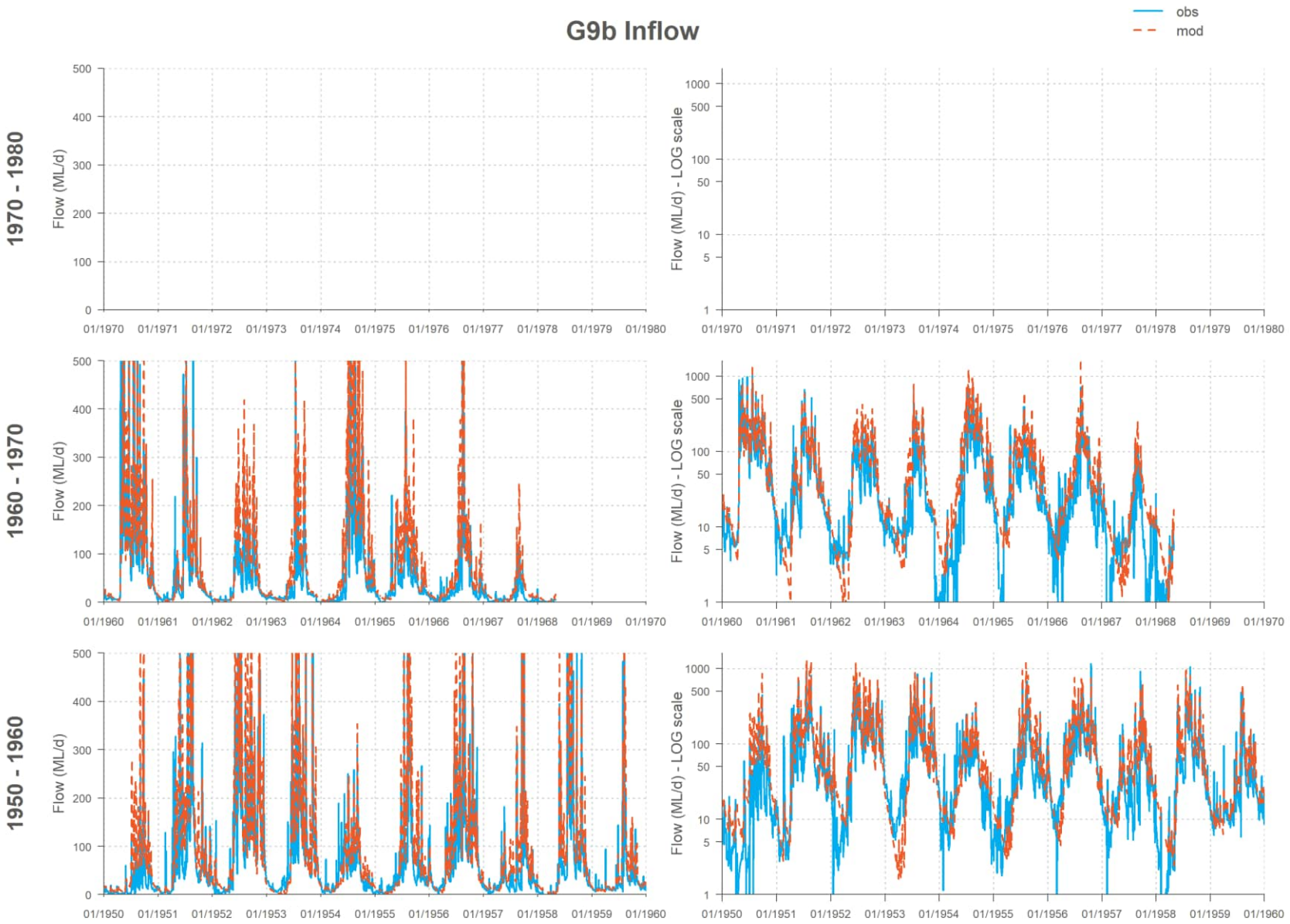
(Observed flow is available for 45.2% of days in this period)

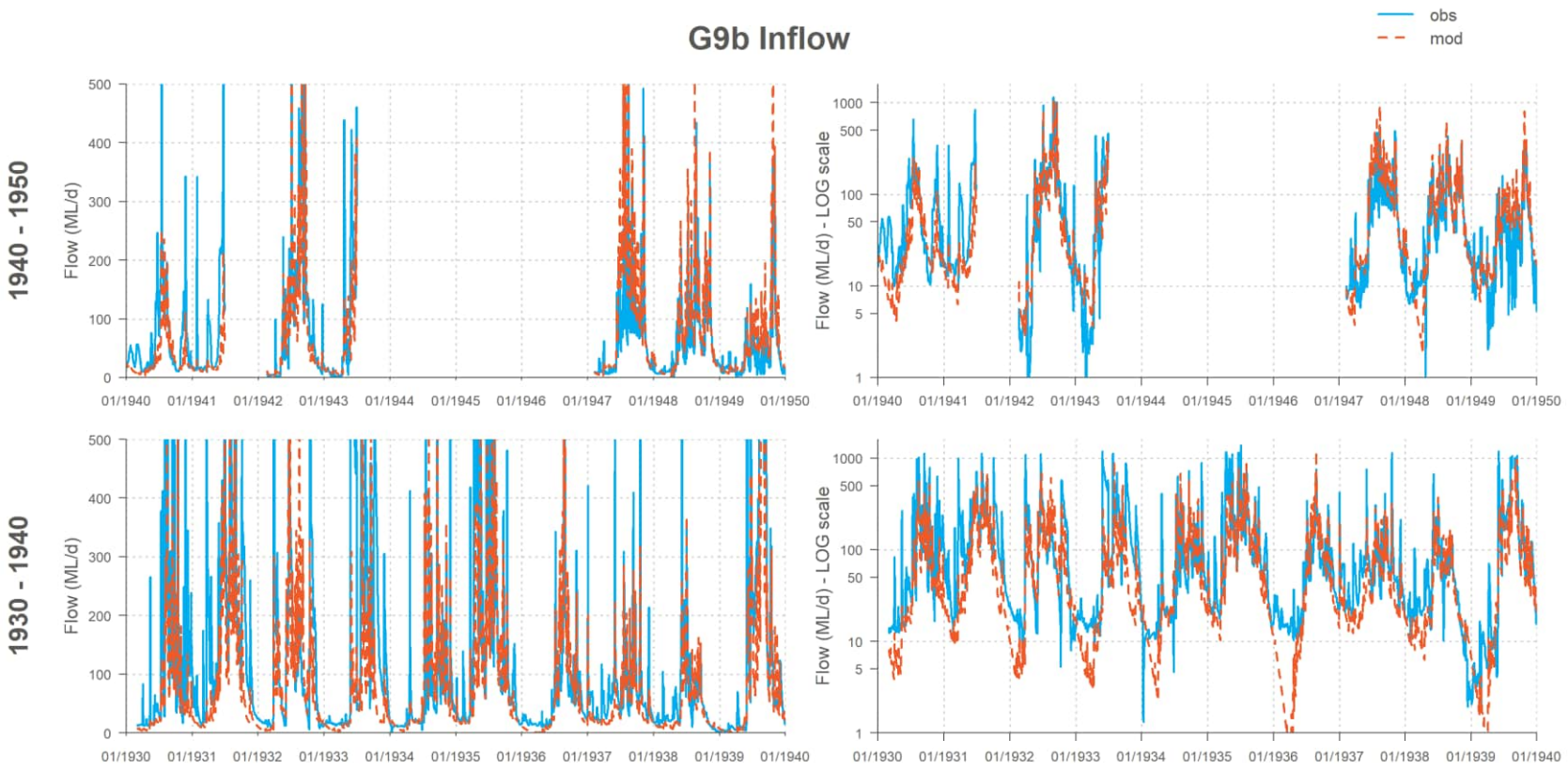


Statistics	Value
Correlation	0.73
Coefficient of determination	0.54
NSE daily	0.47
NSE monthly	0.54
Specific yield (mm)	367.7
Average annual modelled flow (ML/yr)	28,680.6
Average annual observed flow (ML/yr)	28,657.7
% Difference	0.1%
Runoff coefficient	0.30




G9b Inflow
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1940
01/1950
01/1960
01/1970
01/1980
01/1990
01/2000
01/2010
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019

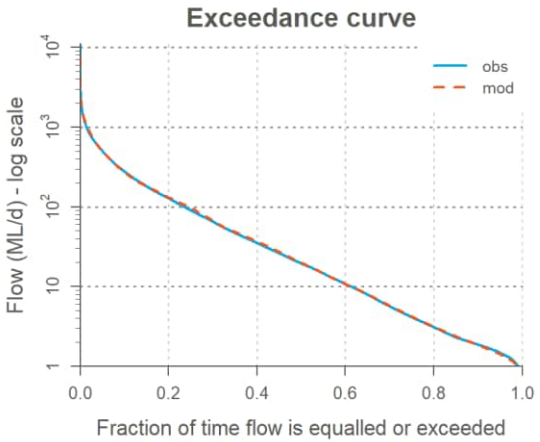

G9b Inflow
obs
mod
1970 - 1980
1960 - 1970
1950 - 1960
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1970 01/1971 01/1972 01/1973 01/1974 01/1975 01/1976 01/1977 01/1978 01/1979 01/1980
01/1960 01/1961 01/1962 01/1963 01/1964 01/1965 01/1966 01/1967 01/1968 01/1969 01/1970
01/1950 01/1951 01/1952 01/1953 01/1954 01/1955 01/1956 01/1957 01/1958 01/1959 01/1960


G9b Inflow
obs
mod
1940 - 1950
1930 - 1940
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1940 01/1941 01/1942 01/1943 01/1944 01/1945 01/1946 01/1947 01/1948 01/1949 01/1950
01/1930 01/1931 01/1932 01/1933 01/1934 01/1935 01/1936 01/1937 01/1938 01/1939 01/1940

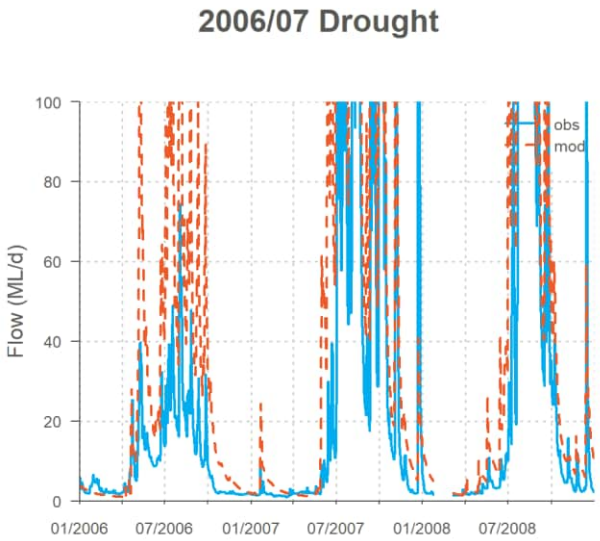
Subcatchment G10

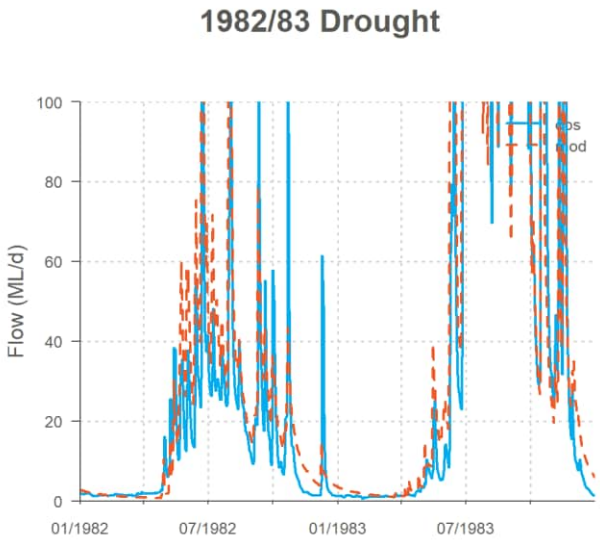
Period of analysis: 19/06/1964 to 30/06/2024

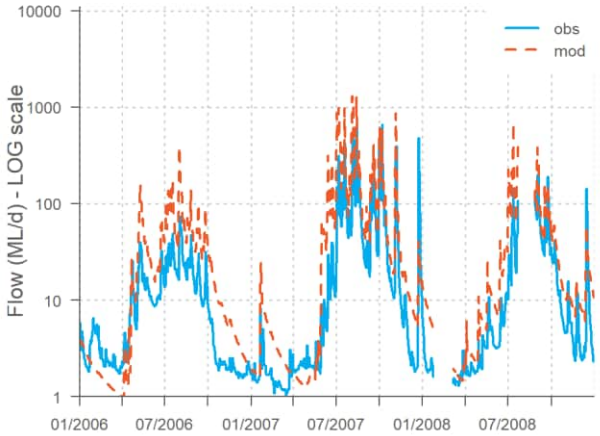
(Observed flow is available for 99.5% of days in this period)

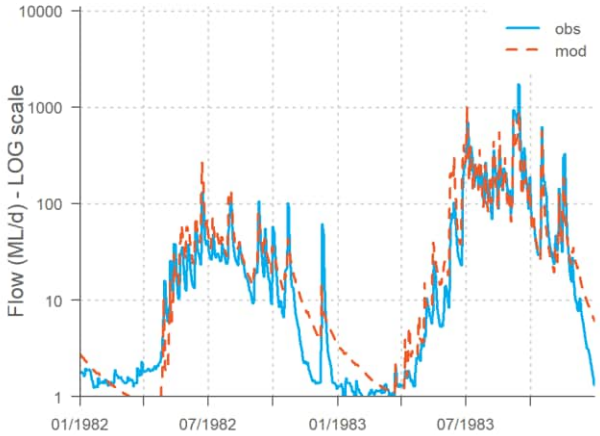


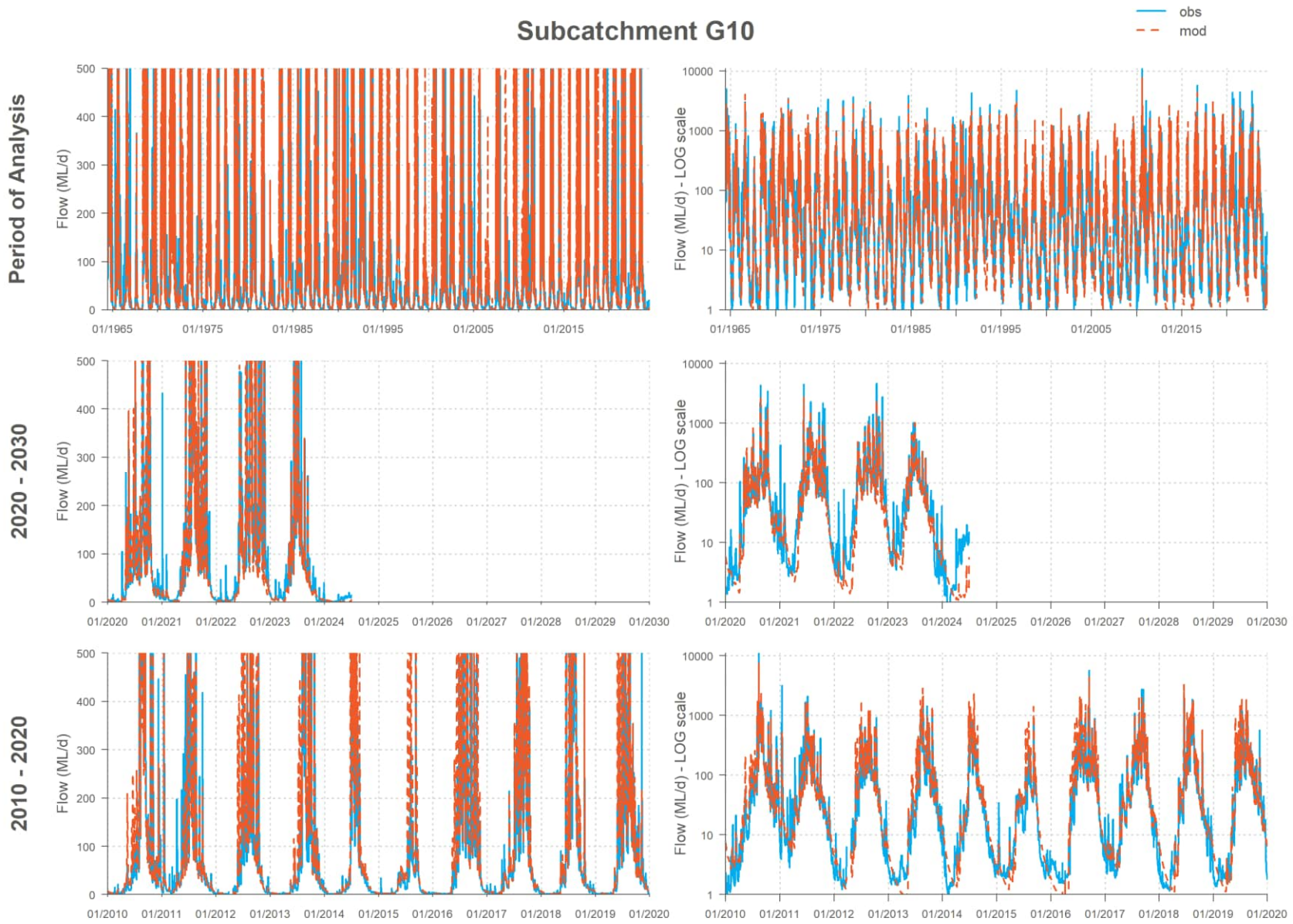
Statistics	Value
Correlation	0.87
Coefficient of determination	0.76
NSE daily	0.76
NSE monthly	0.89
Specific yield (mm)	143.2
Average annual modelled flow (ML/yr)	38,565.6
Average annual observed flow (ML/yr)	38,550.5
% Difference	0.0%
Runoff coefficient	0.16

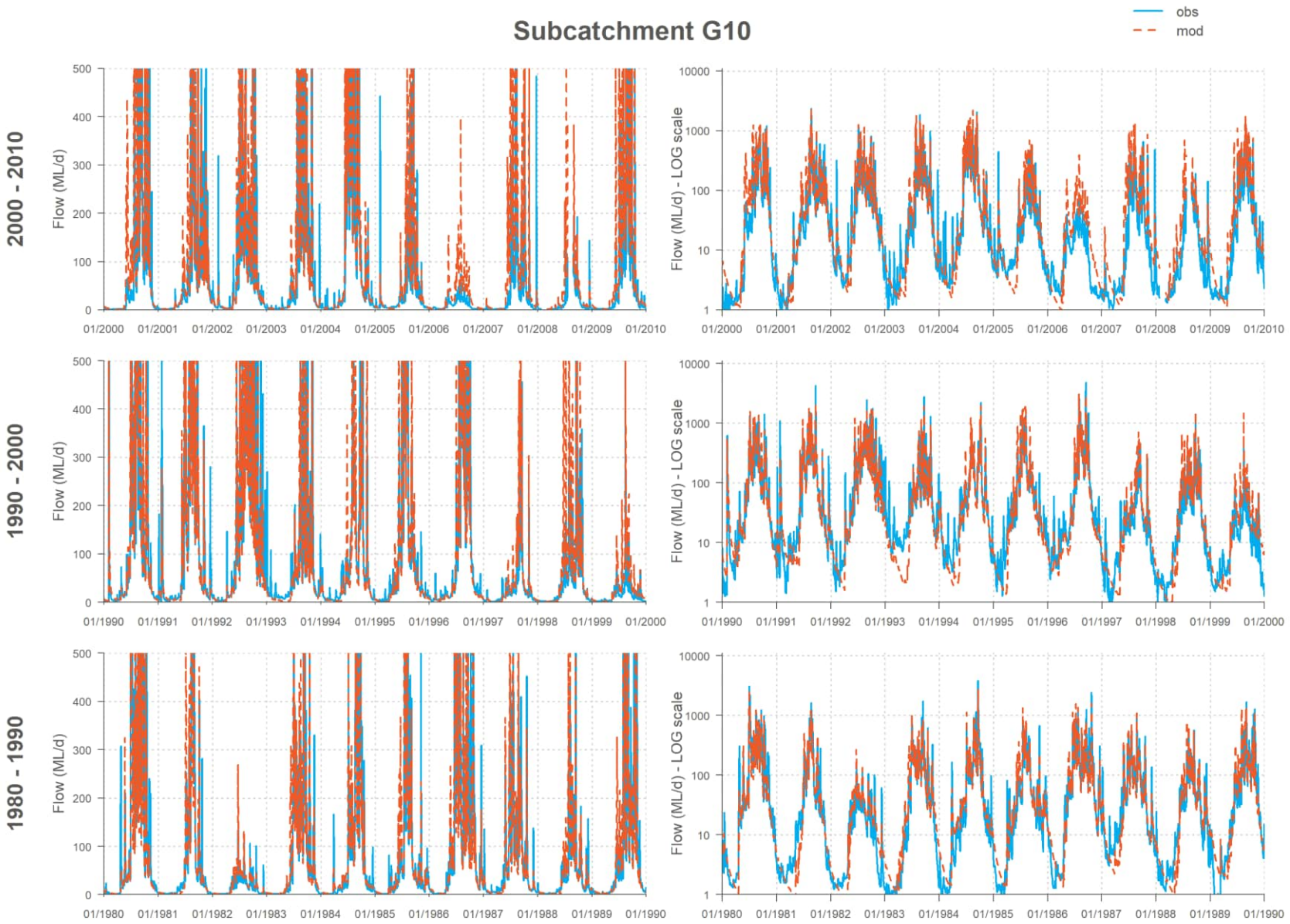


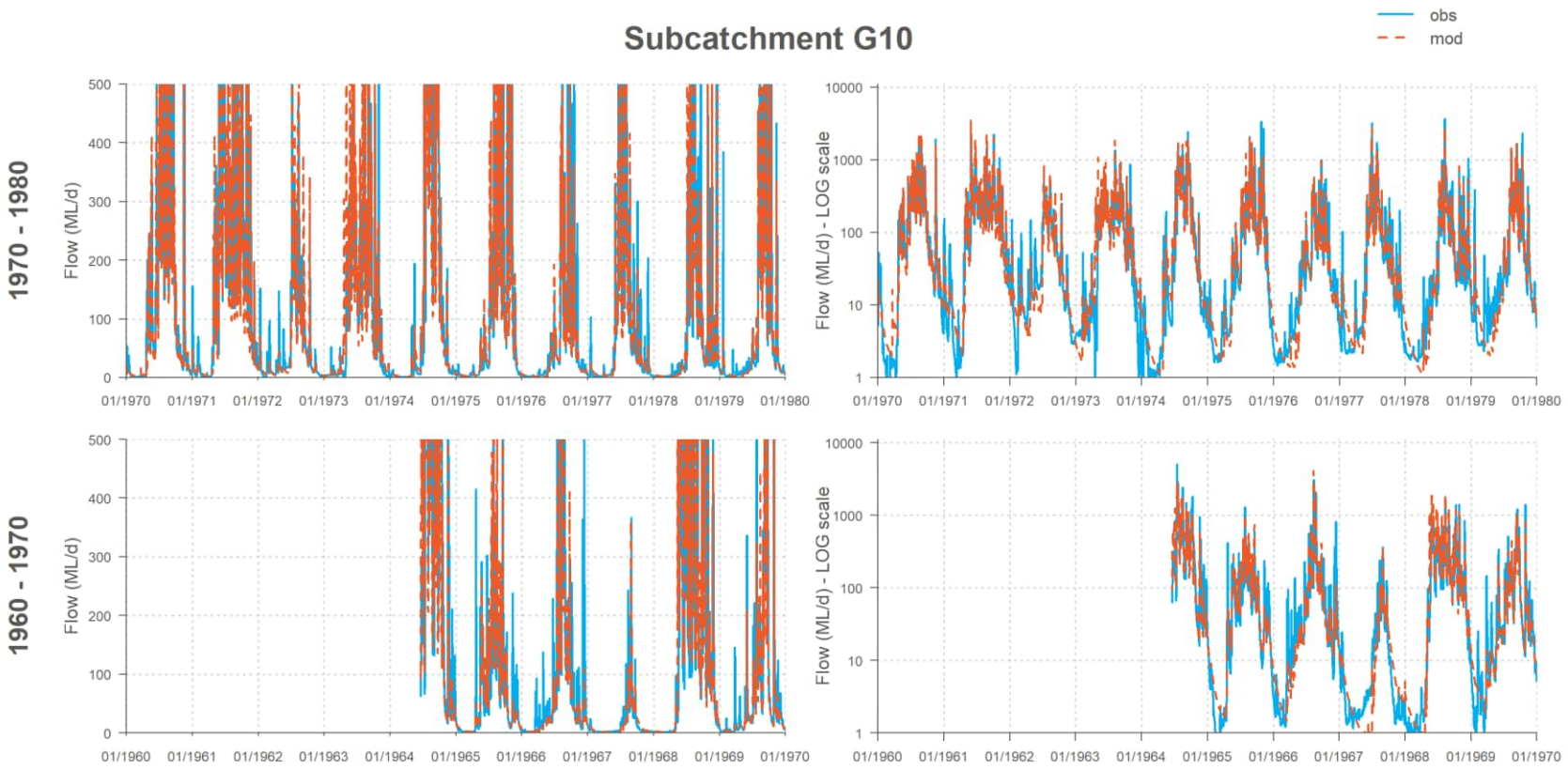







Subcatchment G10
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale

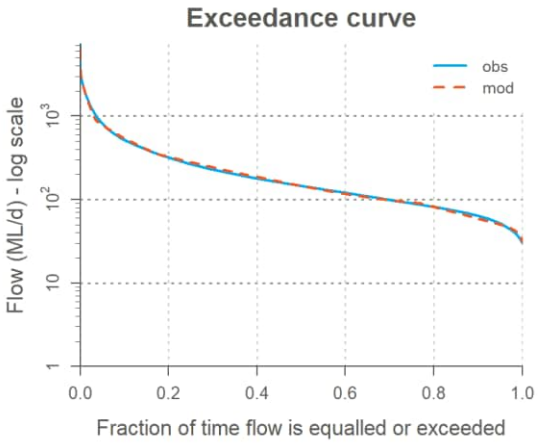

Subcatchment G10
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
0
100
200
300
400
500
1
10
100
1000
10000
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
01/2009
01/2010
01/1990
01/1991
01/1992
01/1993
01/1994
01/1995
01/1996
01/1997
01/1998
01/1999
01/2000
01/1980
01/1981
01/1982
01/1983
01/1984
01/1985
01/1986
01/1987
01/1988
01/1989
01/1990


Subcatchment G10
obs
mod
1970 - 1980
1960 - 1970
Flow (ML/d)
Flow (ML/d) - LOG scale
0
100
200
300
400
500
1
10
100
1000
10000
01/1960
01/1961
01/1962
01/1963
01/1964
01/1965
01/1966
01/1967
01/1968
01/1969
01/1970
01/1971
01/1972
01/1973
01/1974
01/1975
01/1976
01/1977
01/1978
01/1979
01/1980

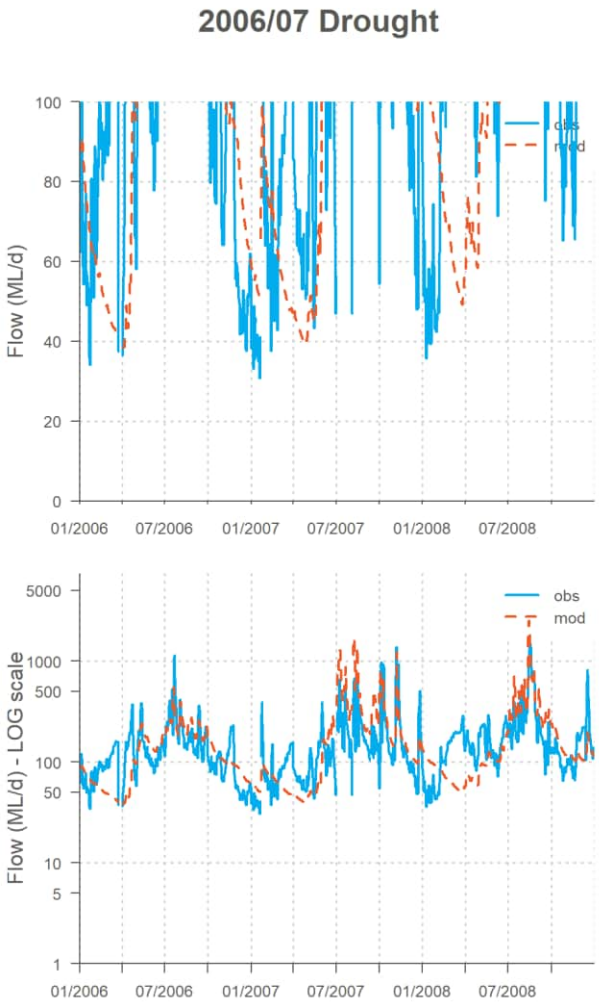
Subcatchment G11 G12

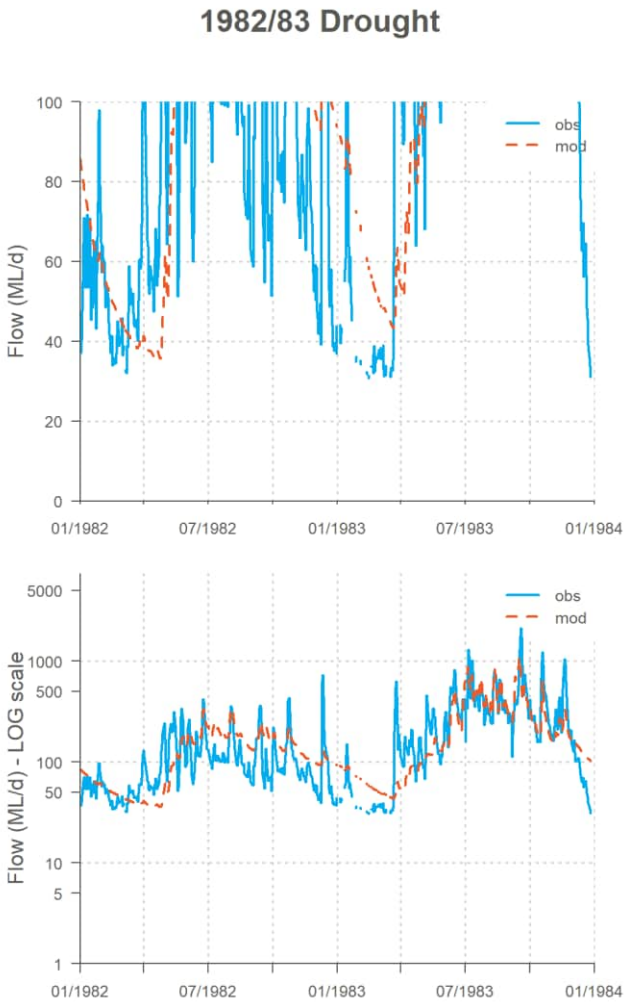
Period of analysis: 12/03/1970 to 31/12/2023

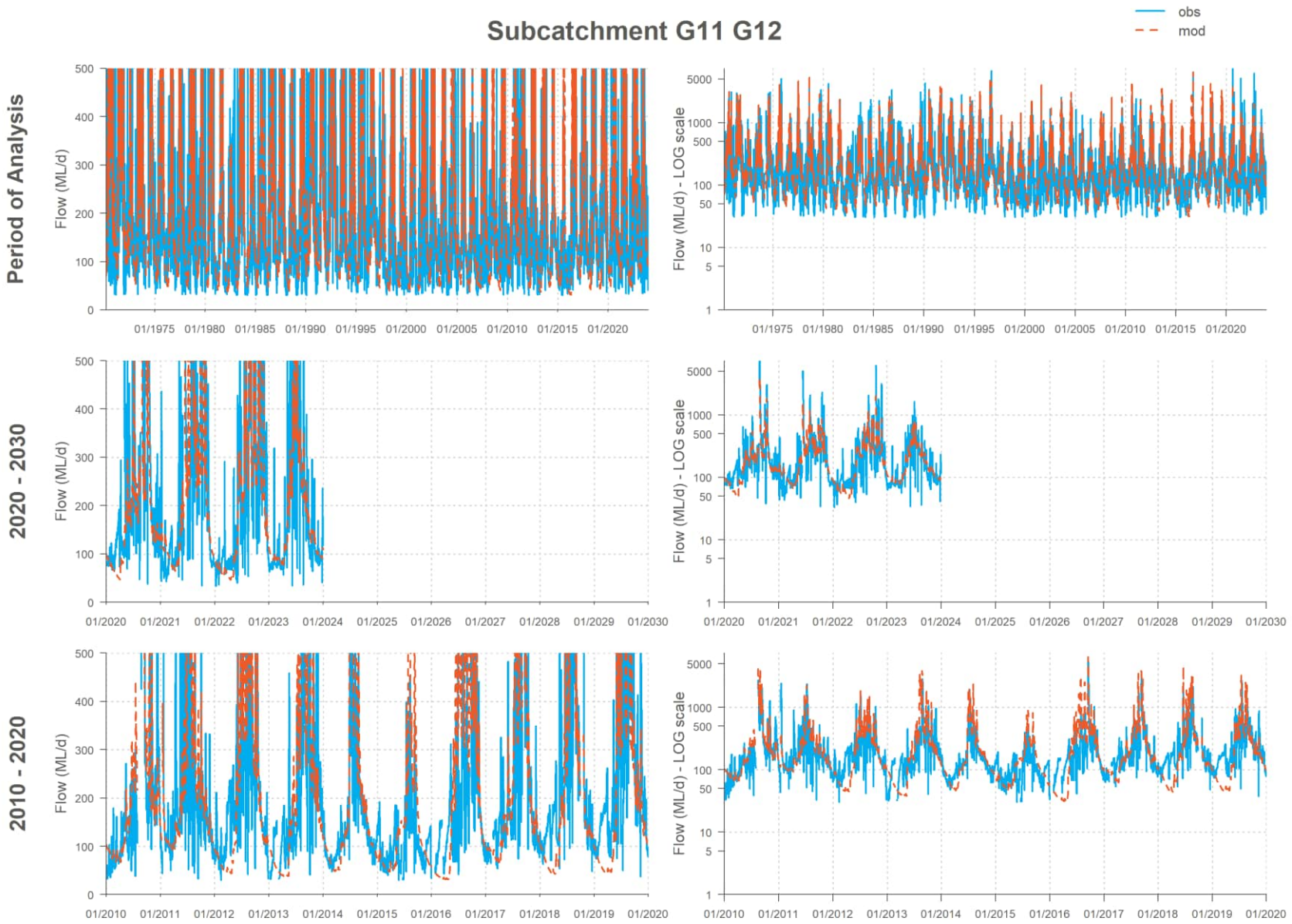
(Observed flow is available for 96.8% of days in this period)

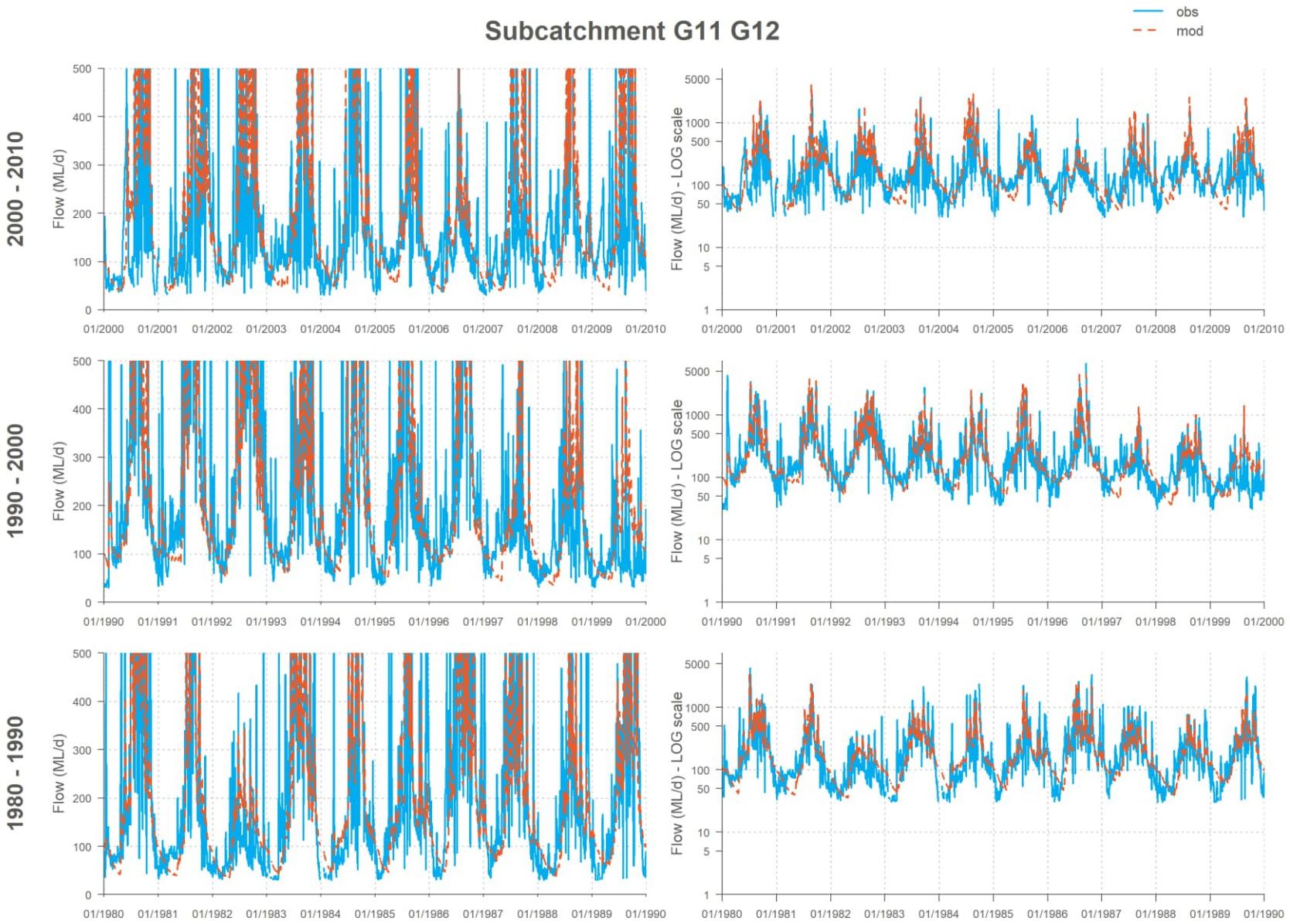


Statistics	Value
Correlation	0.65
Coefficient of determination	0.42
NSE daily	0.32
NSE monthly	0.63
Specific yield (mm)	246.9
Average annual modelled flow (ML/yr)	93,655.1
Average annual observed flow (ML/yr)	93,612.6
% Difference	0.0%
Runoff coefficient	0.24






Subcatchment G11 G12
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1975 01/1980 01/1985 01/1990 01/1995 01/2000 01/2005 01/2010 01/2015 01/2020
01/2020 01/2021 01/2022 01/2023 01/2024 01/2025 01/2026 01/2027 01/2028 01/2029 01/2030
01/2010 01/2011 01/2012 01/2013 01/2014 01/2015 01/2016 01/2017 01/2018 01/2019 01/2020

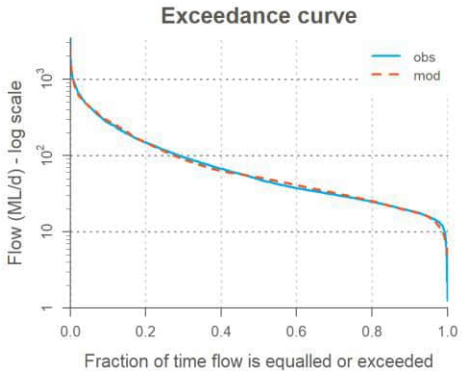

Subcatchment G11 G12
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale

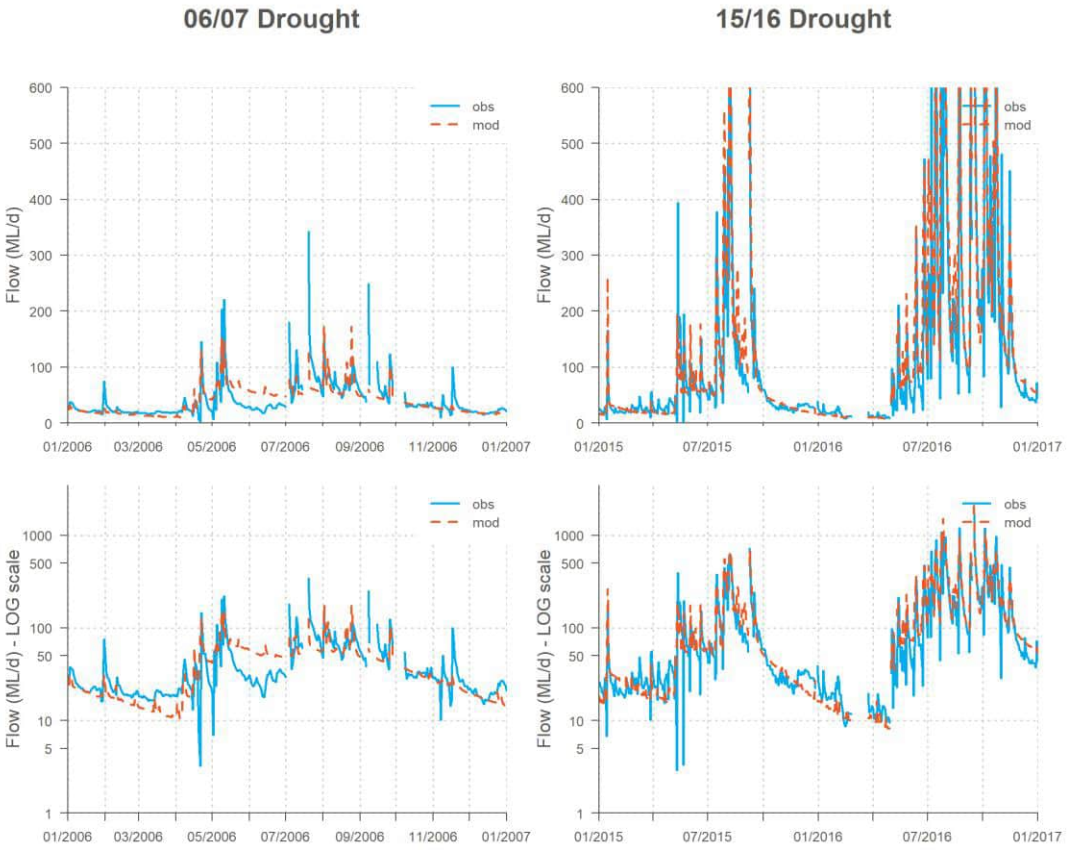
Appendix B Sacramento Rainfall runoff model report cards

Subcatchment G3

Period of analysis: 12/01/2005 to 30/06/2022

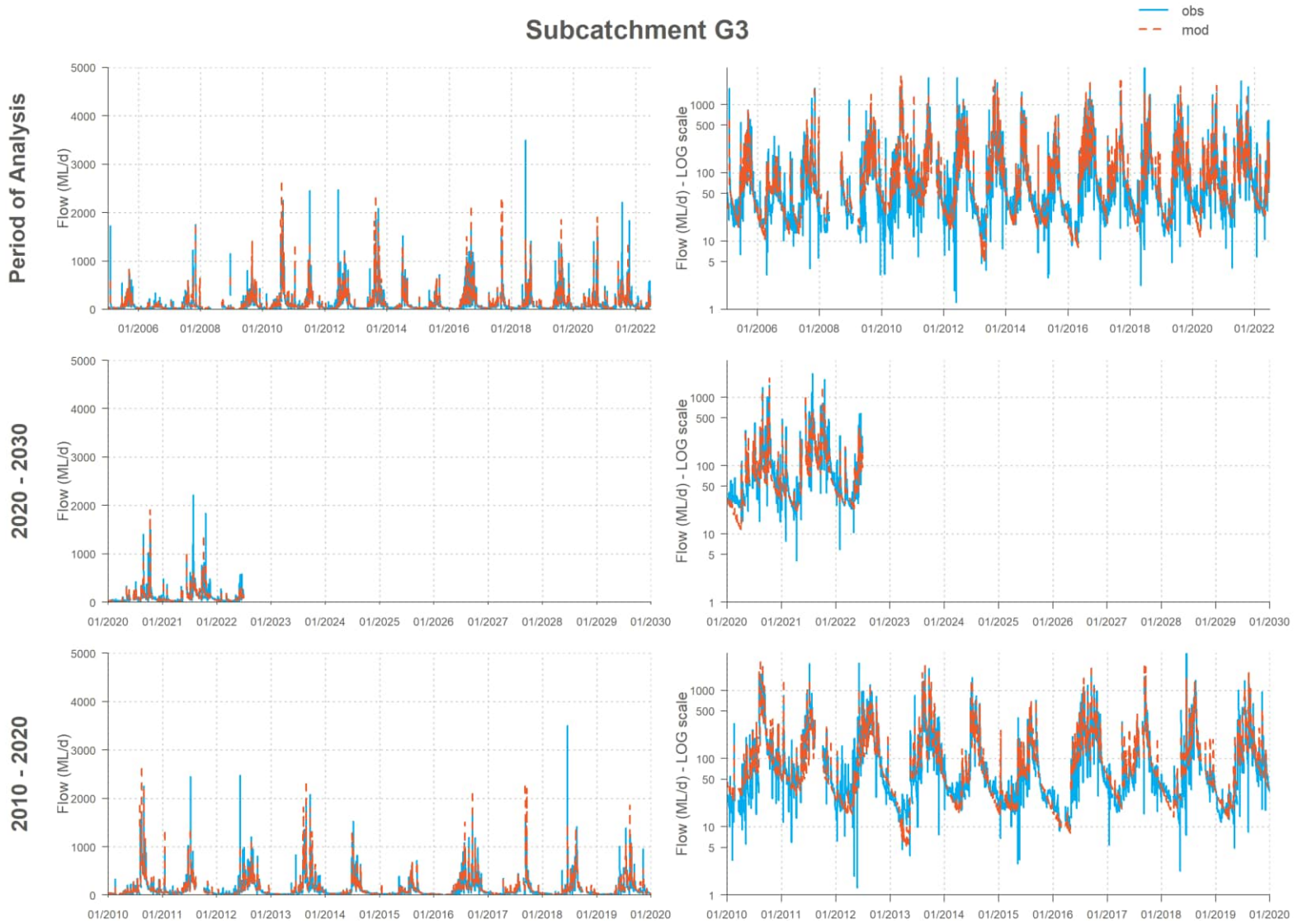
(Observed flow is available for 90.8% of days in this period)

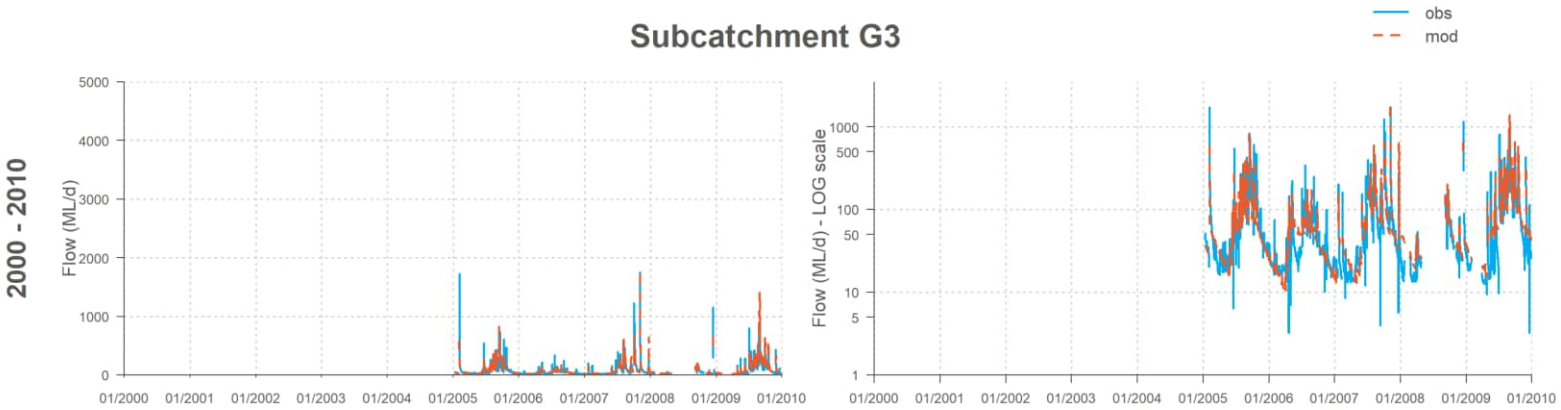




Statistics	Value
Correlation	0.89
Coefficient of determination	0.80
NSE daily	0.79
NSE monthly	0.93
Specific yield (mm)	262.3
Average annual modelled flow (ML/yr)	41,519.0
Average annual observed flow (ML/yr)	41,634.1
% Difference	-0.3%
Runoff coefficient	0.27
% Surface runoff	7.4%
% Interflow	48.3%
% Baseflow	44.3%

	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1	uh2
Value	0.95	6.7e-04	0.32	0.64	0.0013	143.5	137.2	2.4e-04	0.015	374.7	0.0042	0.24	3.1	2.5e-04	0.0014	9.7e-04	24.6	0.19	27.4	221.6	0e+00	0.76	0.24
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1	1

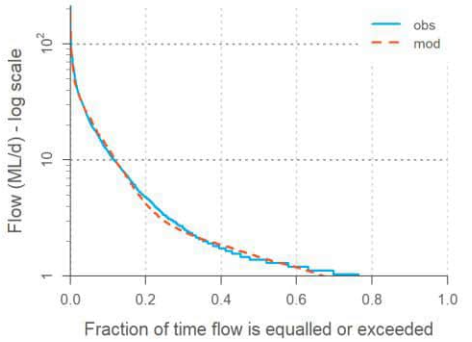

Subcatchment G3
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale


Subcatchment G3
obs
mod
2000 - 2010
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
01/2009
01/2010

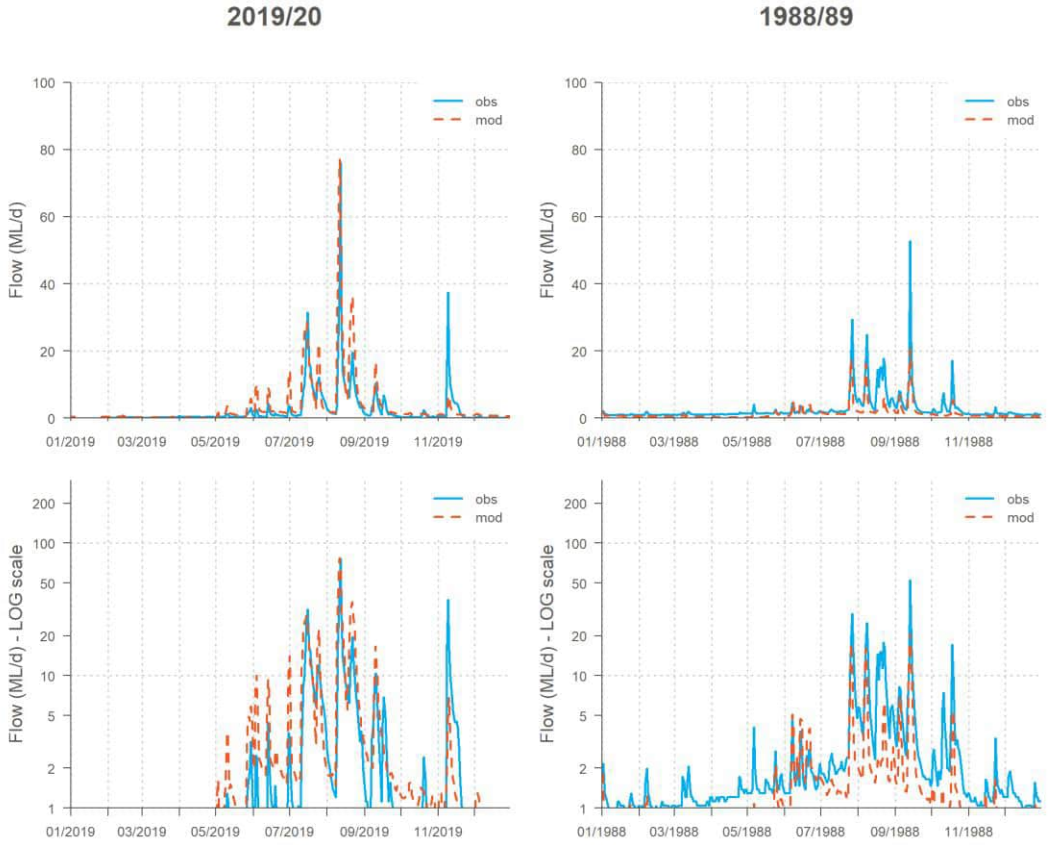
Subcatchment G4

Period of analysis: 27/03/1985 to 30/06/2022

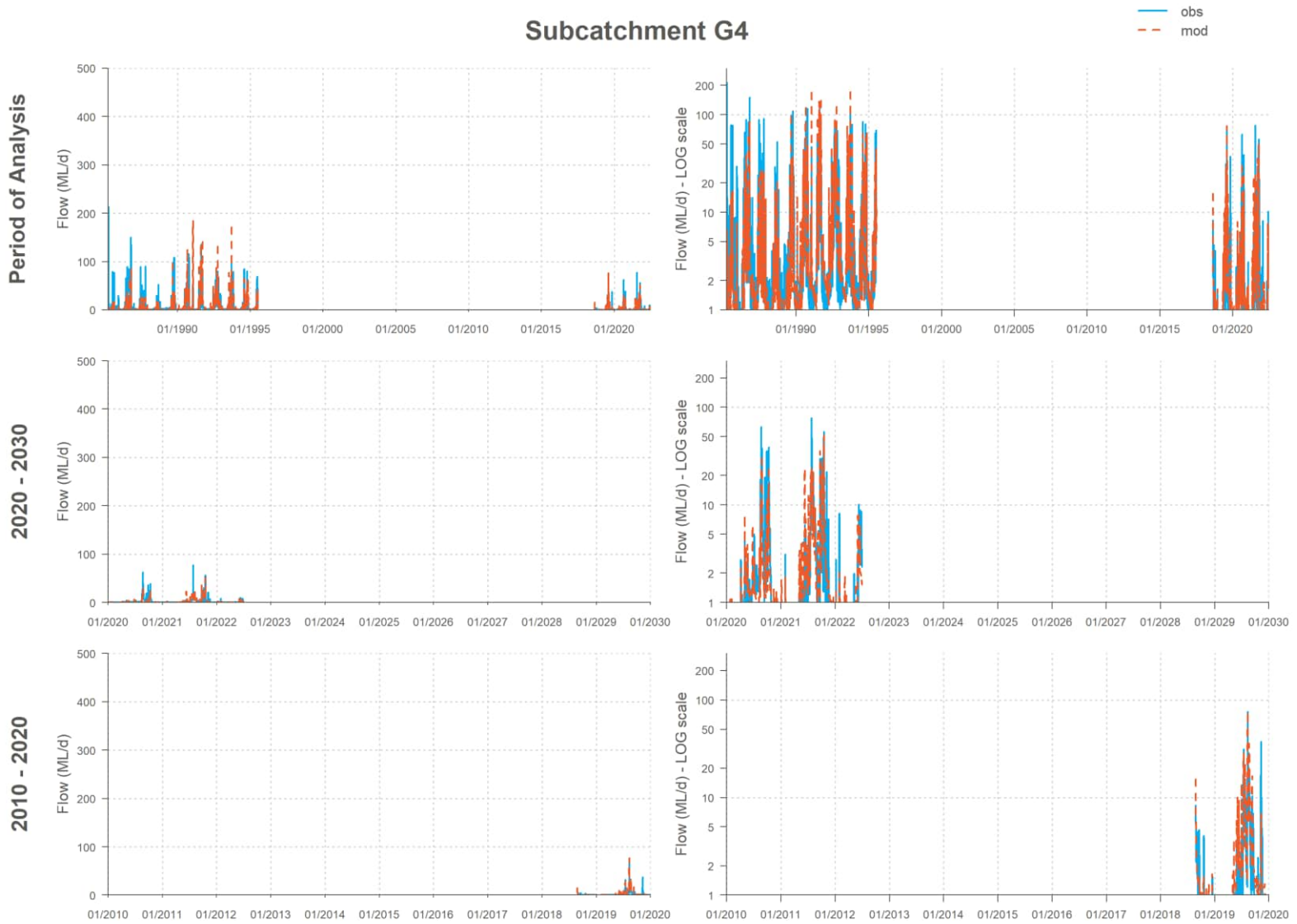
(Observed flow is available for 37.7% of days in this period)

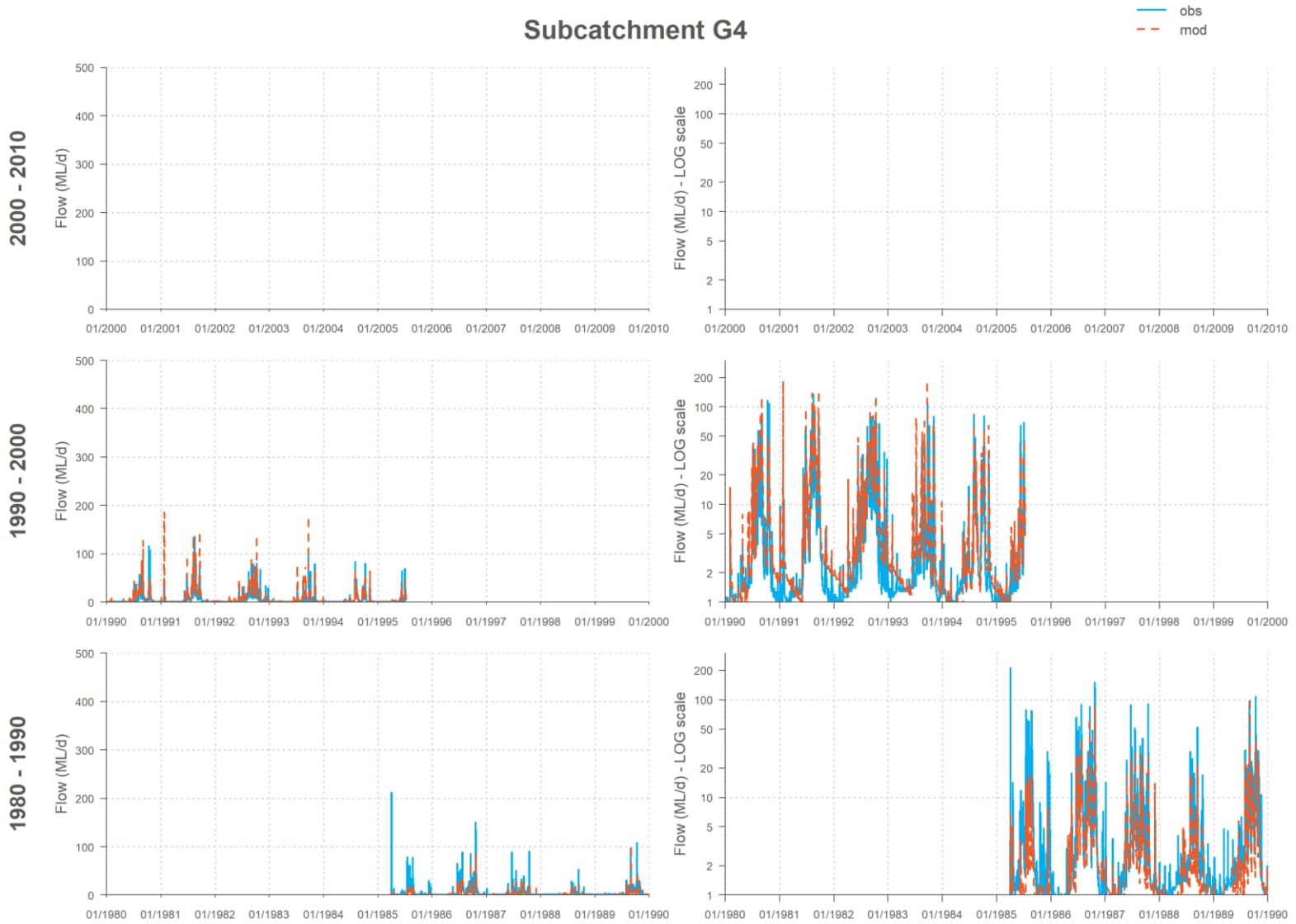


Statistics	Value
Correlation	0.75
Coefficient of determination	0.56
NSE daily	0.48
NSE monthly	0.62
Specific yield (mm)	101.9
Average annual modelled flow (ML/yr)	1,782.7
Average annual observed flow (ML/yr)	1,783.6
% Difference	-0.1%
Runoff coefficient	0.12
% Surface runoff	9.6%
% Interflow	53.4%
% Baseflow	36.9%



	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	0.86	0.086	0.26	0.52	0.0013	207.0	4.2	0.0019	0.098	223.6	0.0042	0.21	3.2	2.5e-04	0.0014	0.10	17.4	0.20	42.8	232.5	0.52	0.48
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1

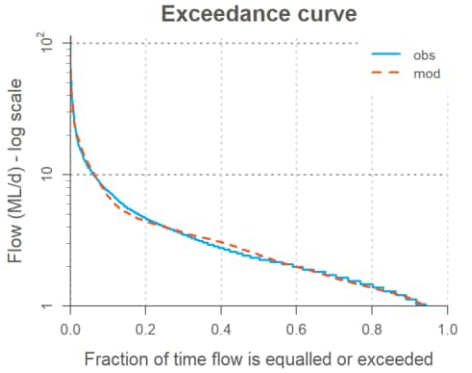

Subcatchment G4
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1990
01/1995
01/2000
01/2005
01/2010
01/2015
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2016
01/2017
01/2018
01/2019


Subcatchment G4
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale

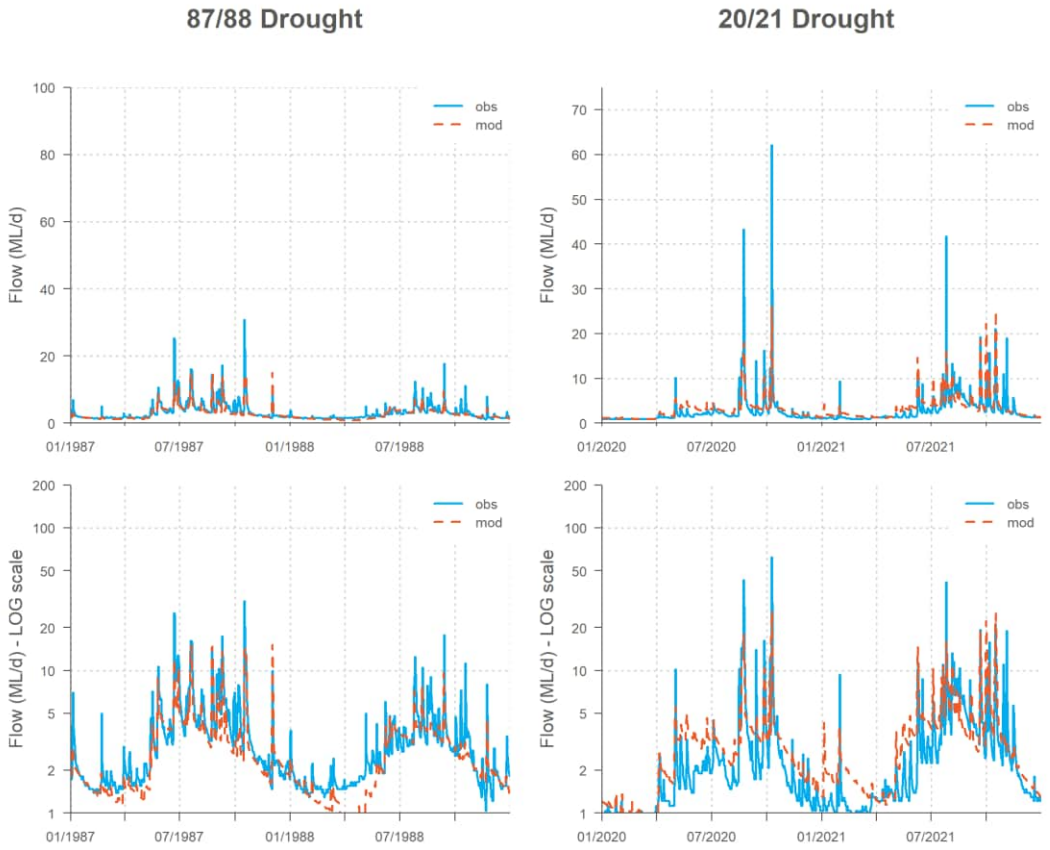
Subcatchment G6

Period of analysis: 19/04/1985 to 30/06/2022

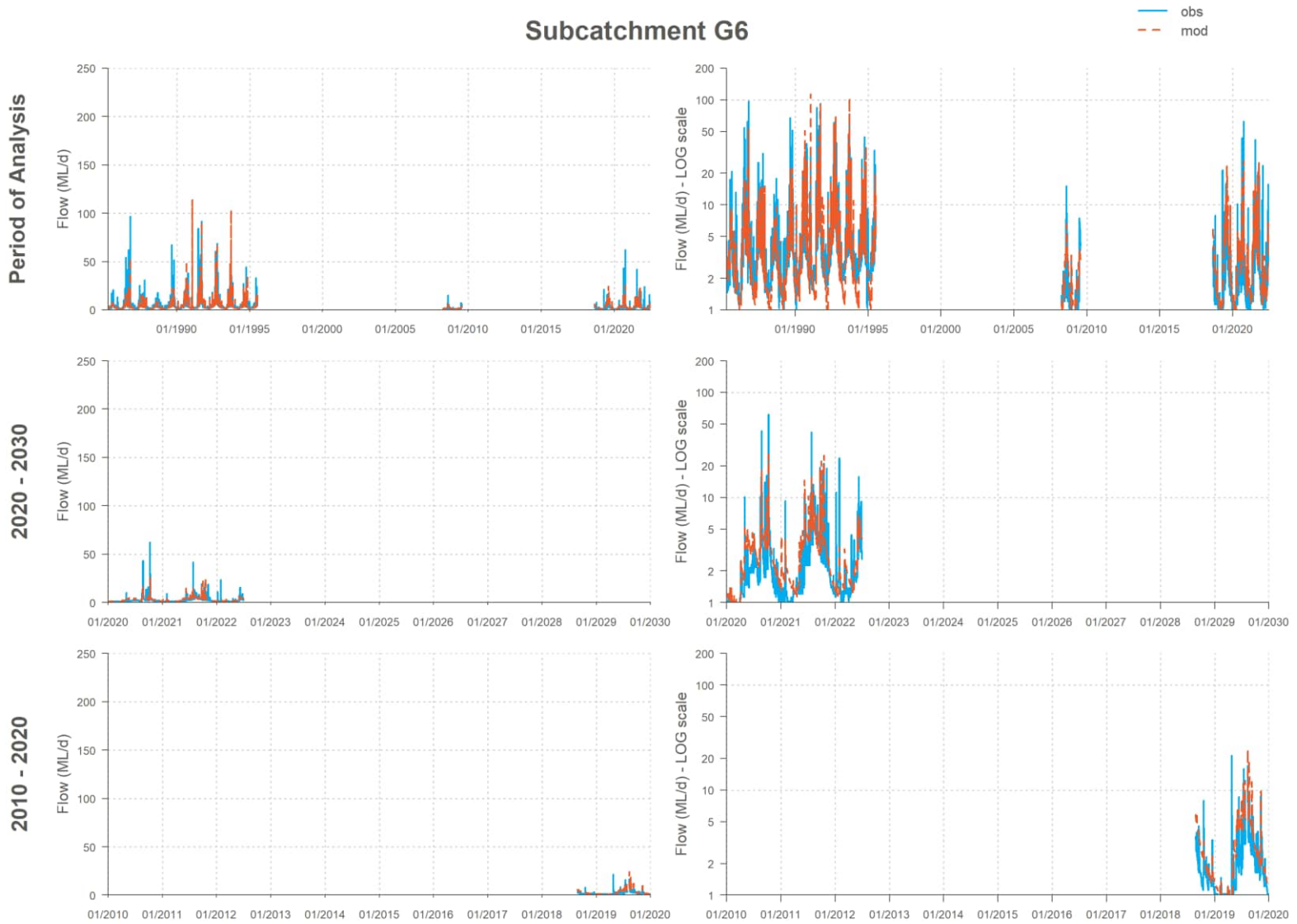
(Observed flow is available for 41.3% of days in this period)

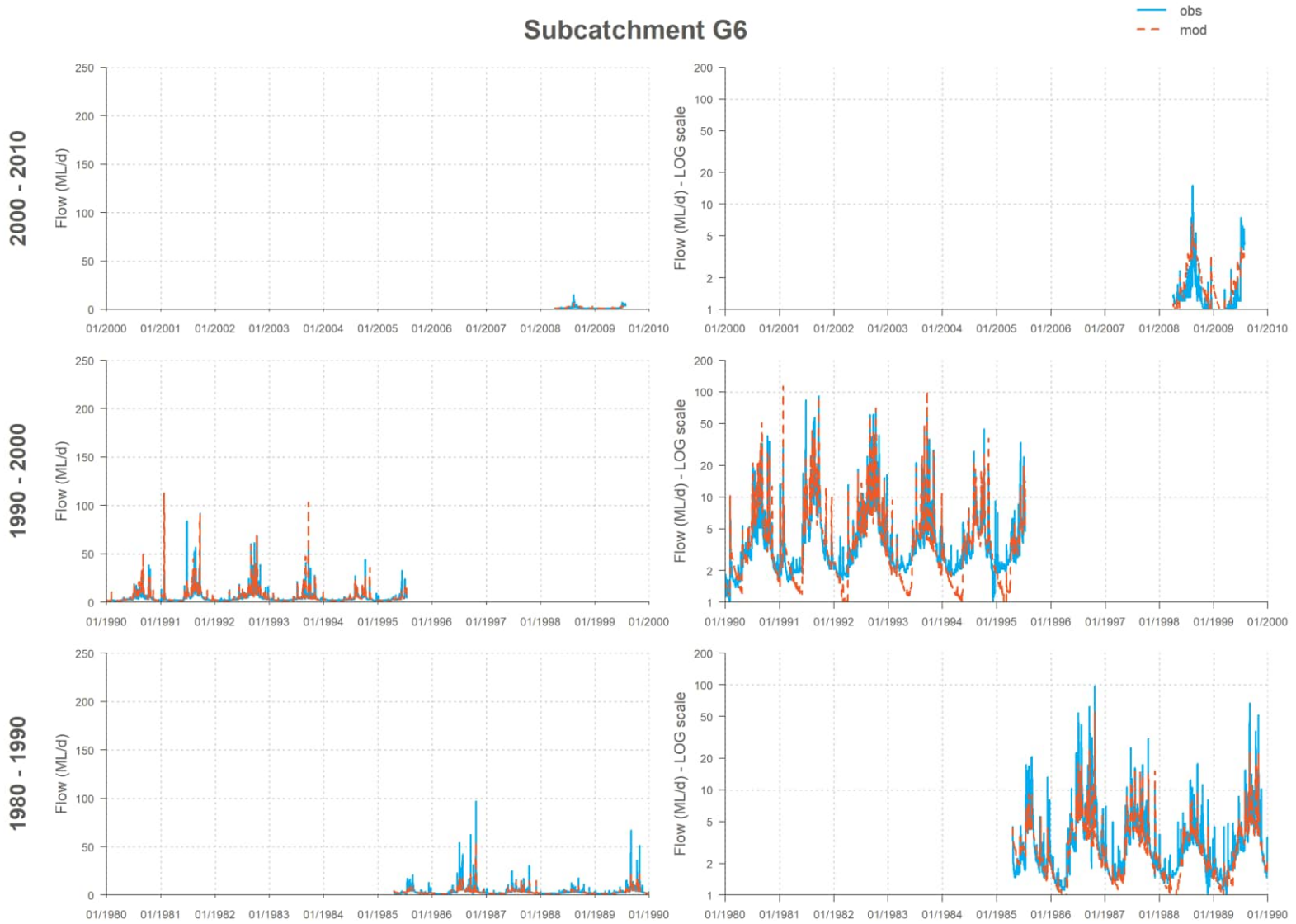


Statistics	Value
Correlation	0.80
Coefficient of determination	0.63
NSE daily	0.59
NSE monthly	0.80
Specific yield (mm)	140.6
Average annual modelled flow (ML/yr)	1,405.9
Average annual observed flow (ML/yr)	1,405.9
% Difference	-0.0%
Runoff coefficient	0.16
% Surface runoff	5.7%
% Interflow	27.1%
% Baseflow	67.2%



	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	0.90	0.33	0.19	0.38	0.0013	300.0	94.1	4.3e-04	0.026	409.6	0.0042	0.26	3.8	2.5e-04	0.0014	1e-05	19.1	0.21	25.8	446.1	0.63	0.37
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1


Subcatchment G6
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1990
01/1995
01/2000
01/2005
01/2010
01/2015
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2016
01/2017
01/2018
01/2019

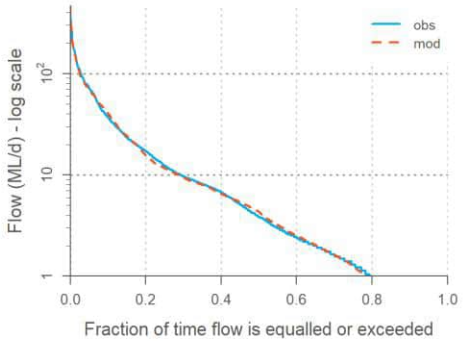

Subcatchment G6
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale

Subcatchment G7

Period of analysis: 26/03/1986 to 28/07/2009

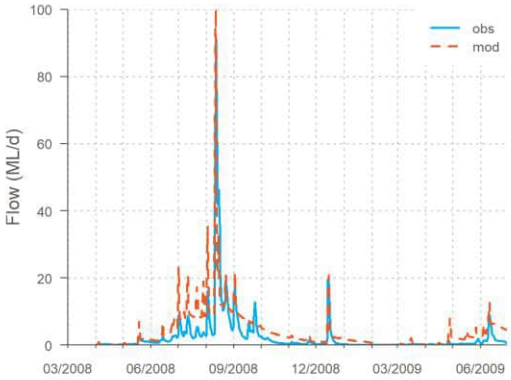
(Observed flow is available for 45.5% of days in this period)

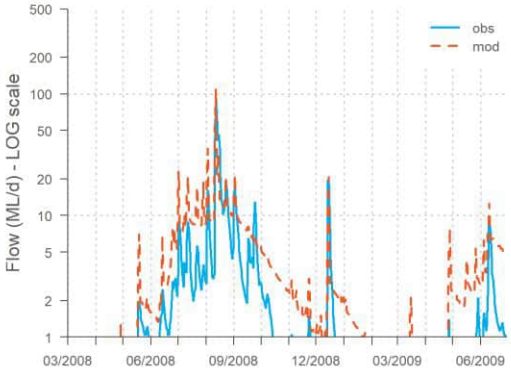
Exceedance curve



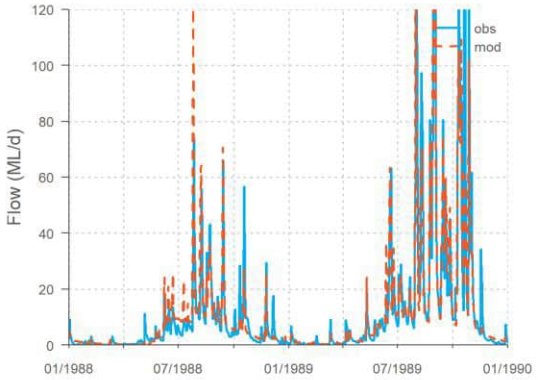
Statistics	Value
Correlation	0.89
Coefficient of determination	0.79
NSE daily	0.77
NSE monthly	0.95
Specific yield (mm)	162.1
Average annual modelled flow (ML/yr)	5,480.2
Average annual observed flow (ML/yr)	5,481.1
% Difference	-0.0%
Runoff coefficient	0.17
% Surface runoff	16.1%
% Interflow	53.4%
% Baseflow	30.5%

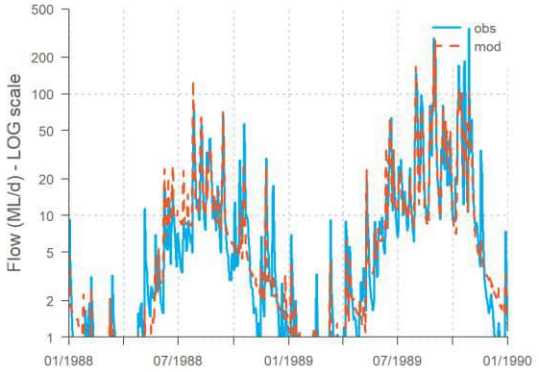
08/09 Drought



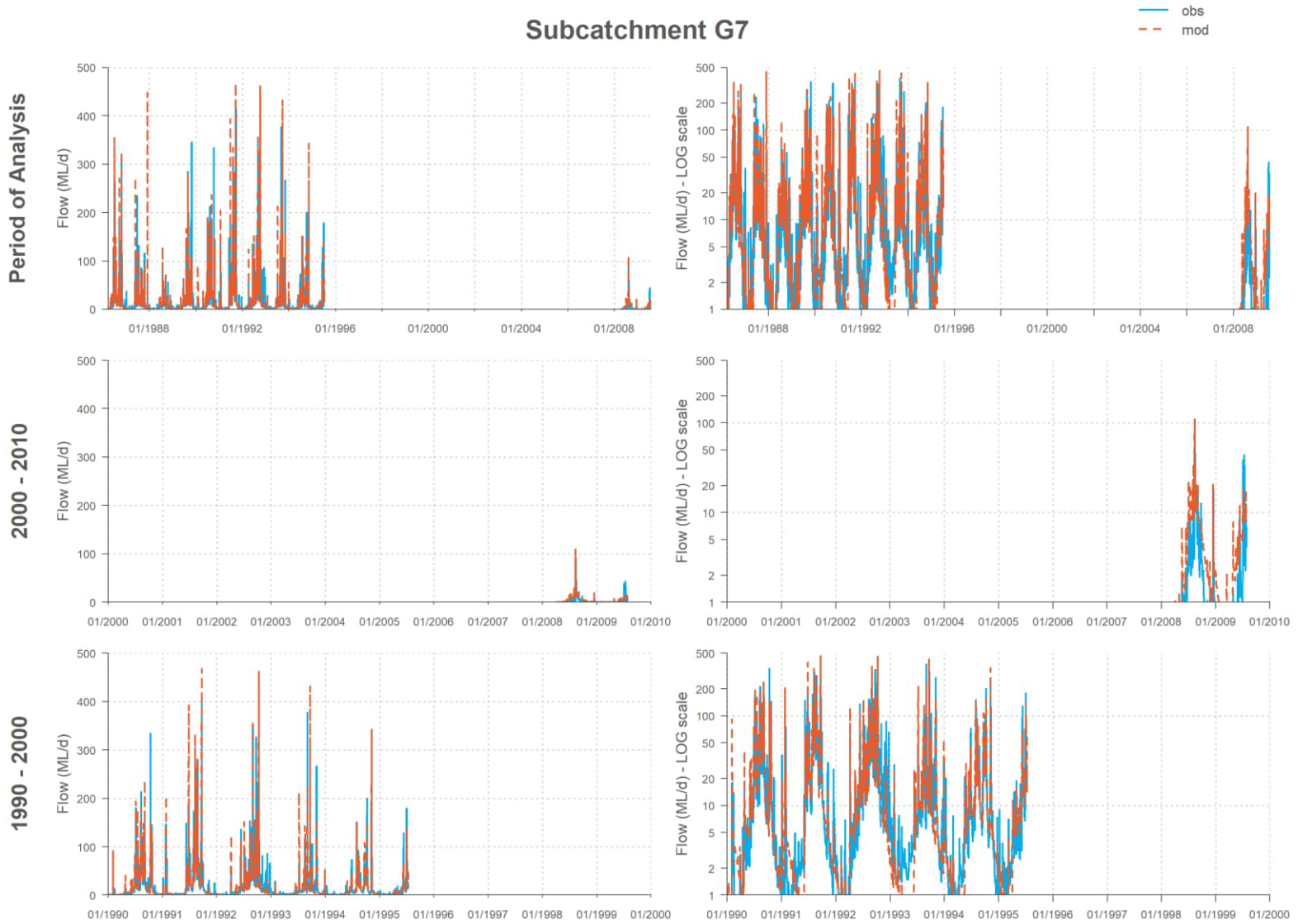


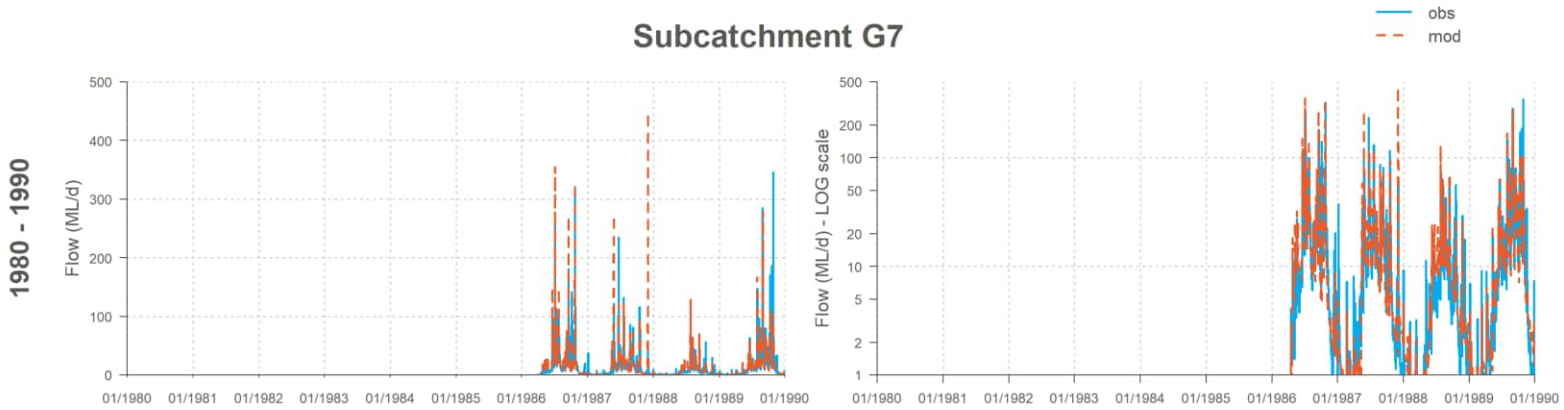
1988/89





	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	0.98	0.057	0.31	0.62	0.0013	73.7	66.0	6.3e-05	0.026	371.5	0.0042	0.17	2.6	2.5e-04	0.0014	0.0043	15.3	0.25	47.6	118.2	0.31	0.69
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1

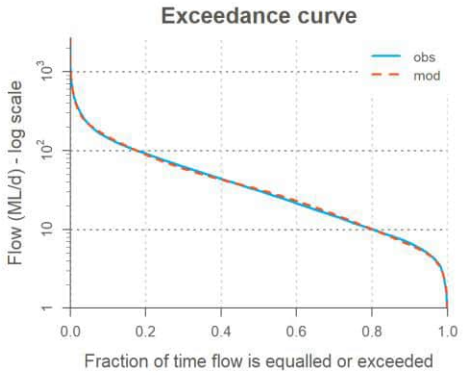

Subcatchment G7
obs
mod
Period of Analysis
2000 - 2010
1990 - 2000
Flow (ML/d)
Flow (ML/d) - LOG scale

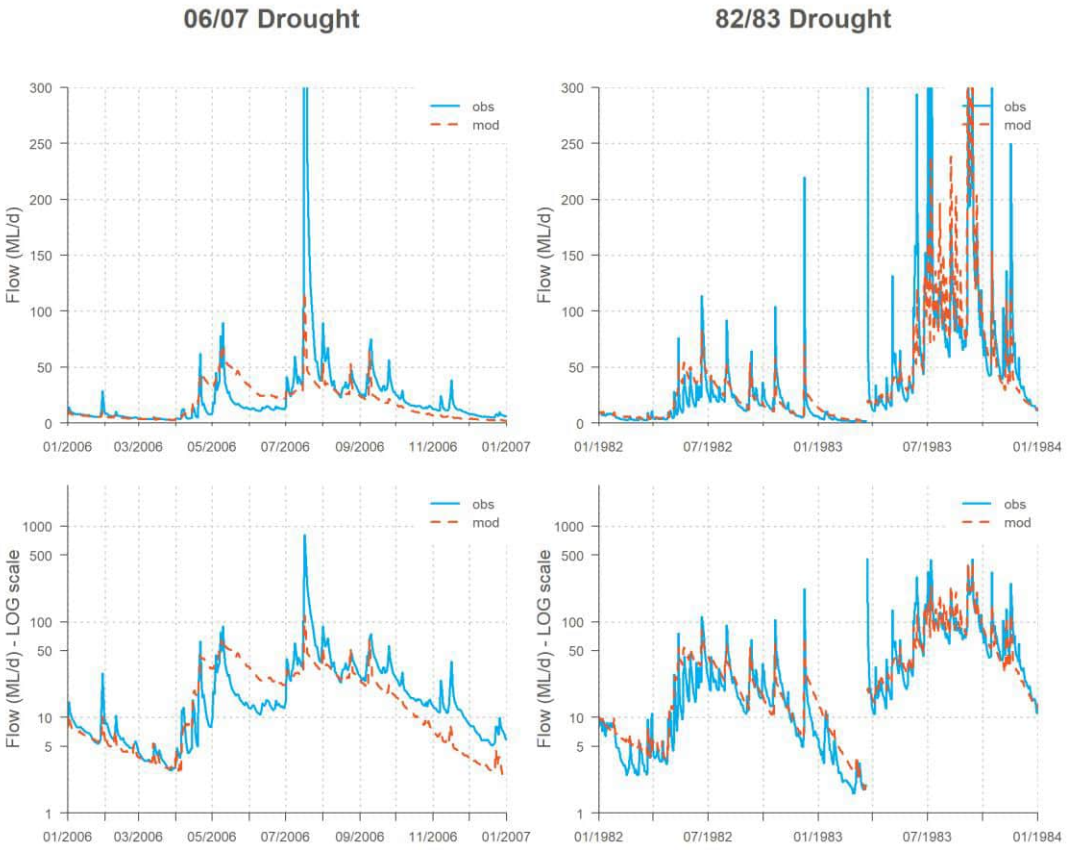

Subcatchment G7
obs
mod
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
500
400
300
200
100
0
50
20
10
5
2
1
01/1980
01/1981
01/1982
01/1983
01/1984
01/1985
01/1986
01/1987
01/1988
01/1989
01/1990

Subcatchment G8

Period of analysis: 19/06/1964 to 30/06/2022

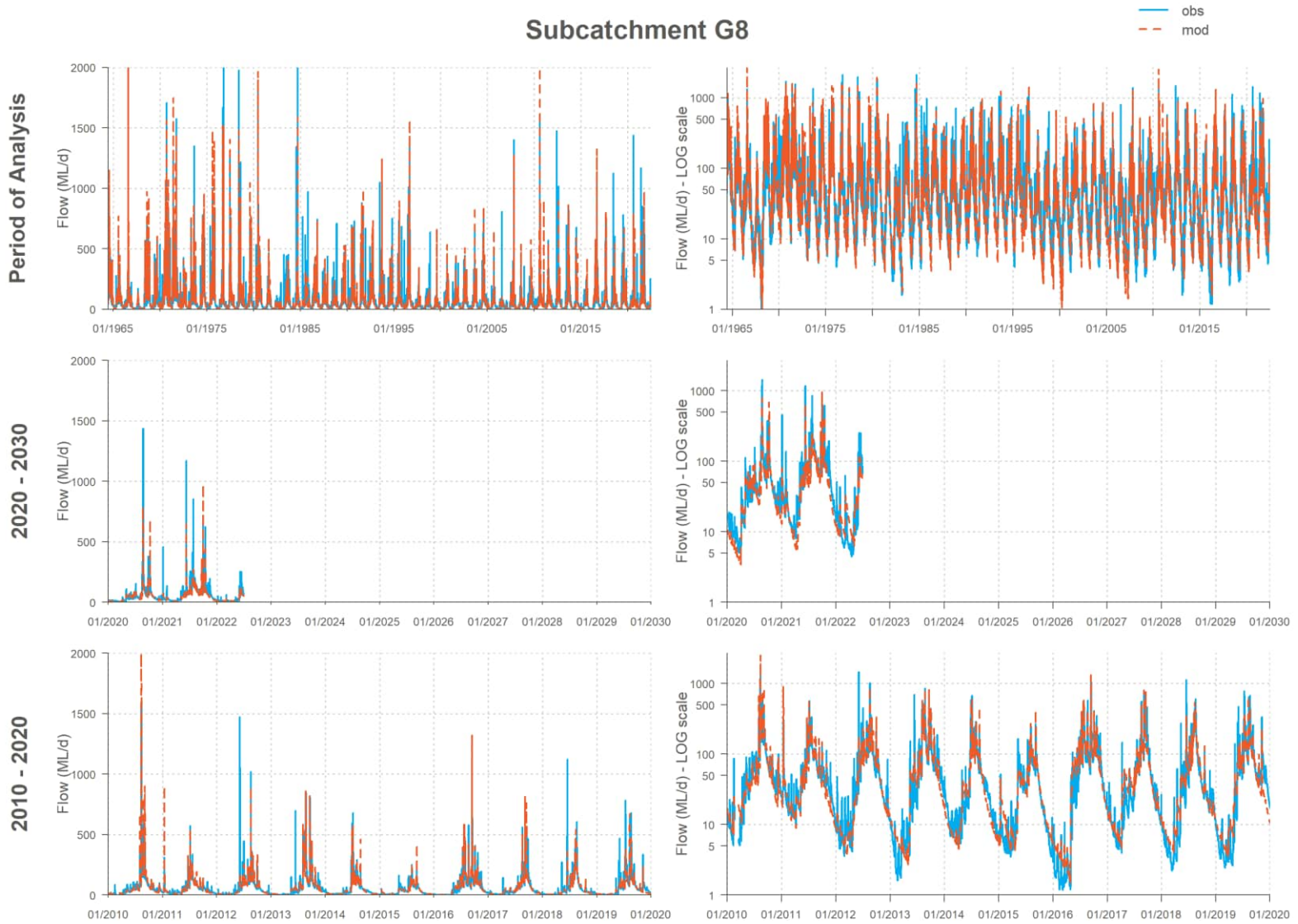
(Observed flow is available for 99.7% of days in this period)

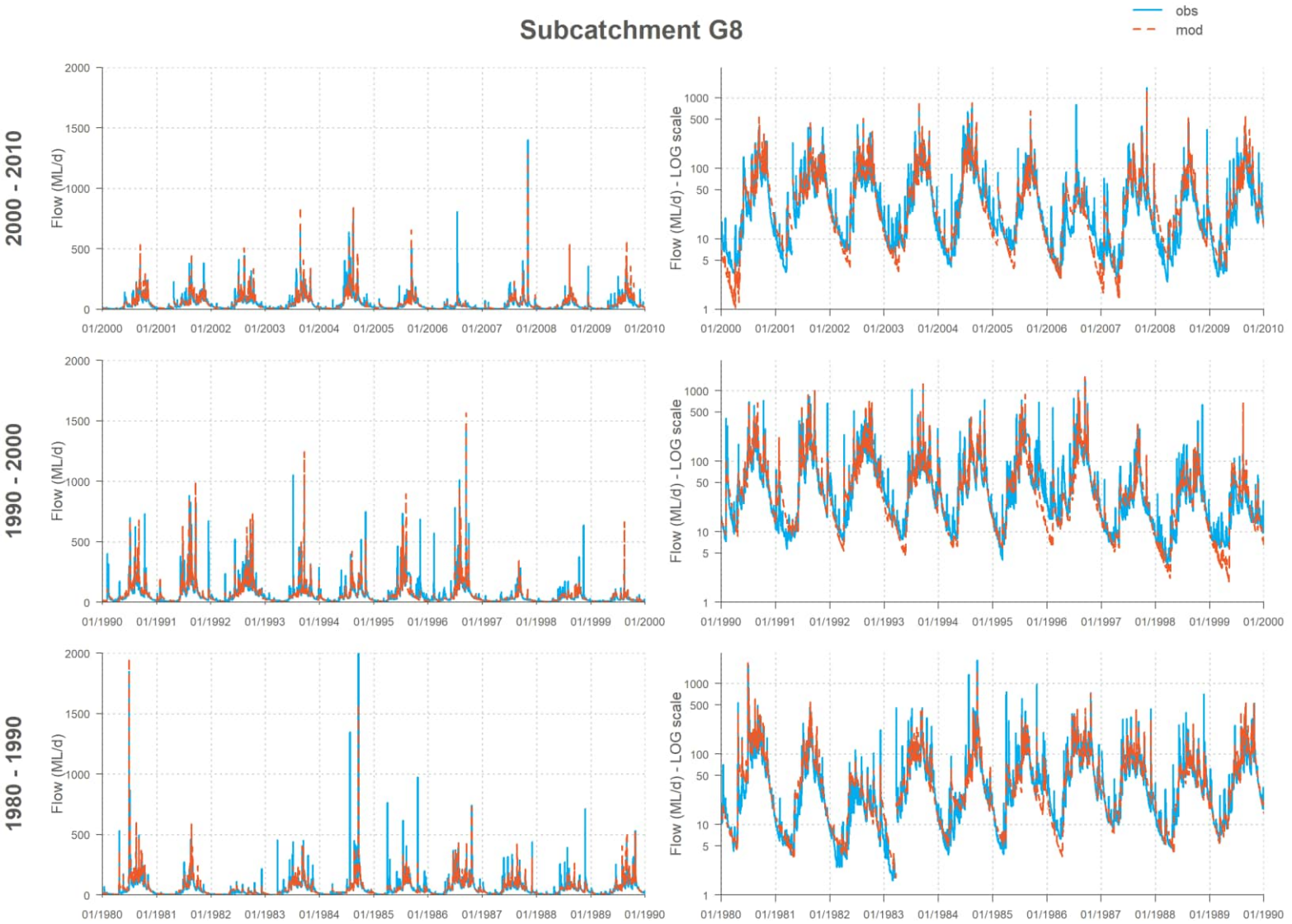


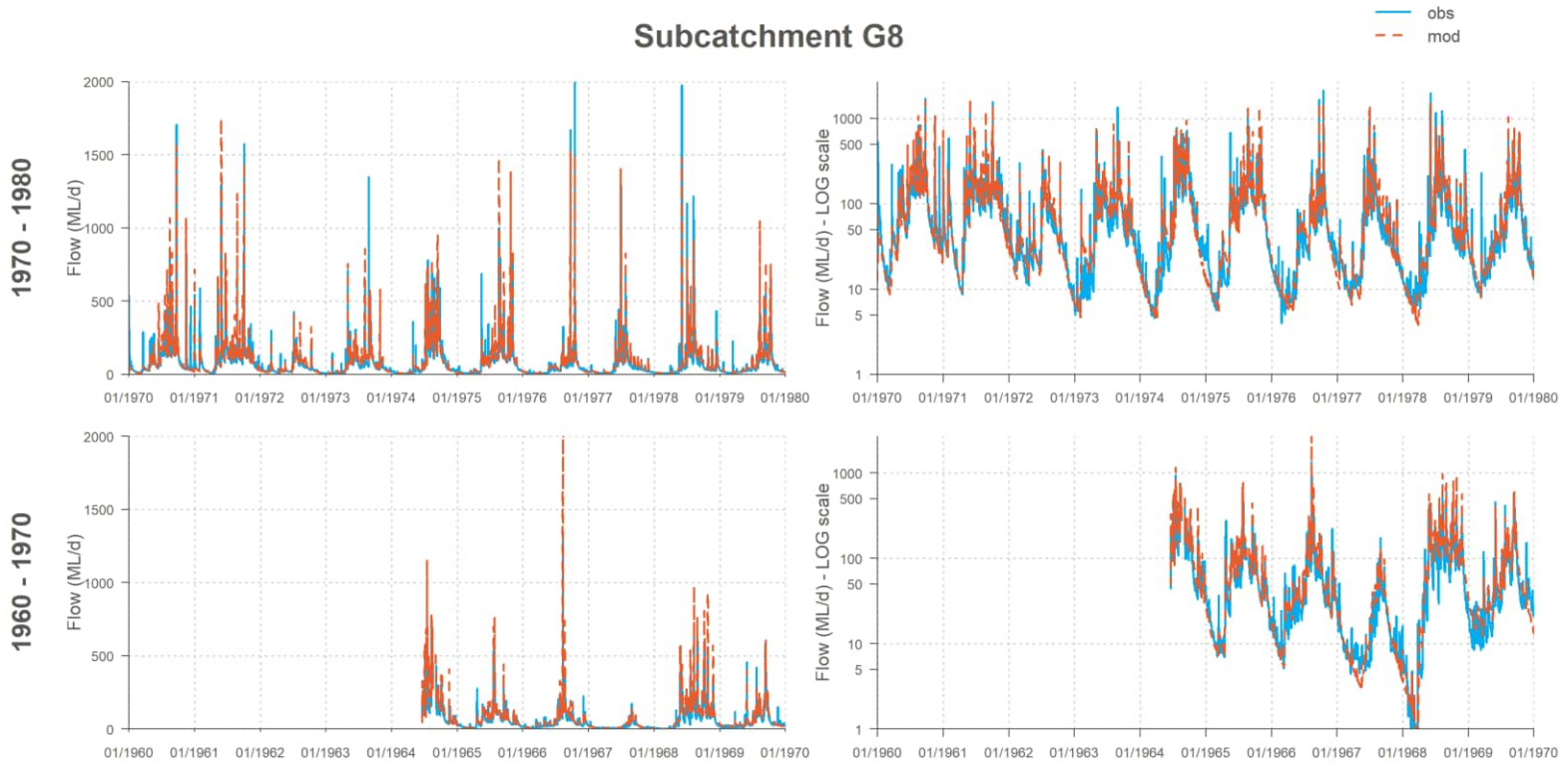


Statistics	Value
Correlation	0.89
Coefficient of determination	0.79
NSE daily	0.78
NSE monthly	0.90
Specific yield (mm)	442.1
Average annual modelled flow (ML/yr)	22,901.6
Average annual observed flow (ML/yr)	22,902.4
% Difference	-0.0%
Runoff coefficient	0.35
% Surface runoff	11.3%
% Interflow	24.7%
% Baseflow	64.0%

	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	1.0	0.0023	0.34	0.69	0.0013	103.5	97.3	0.004	0.043	251.6	0.0042	0.42	2.8	2.5e-04	0.0014	0.10	18.0	0.25	41.6	84.2	0.78	0.22
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1


Subcatchment G8
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1965
01/1975
01/1985
01/1995
01/2005
01/2015
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
01/2020

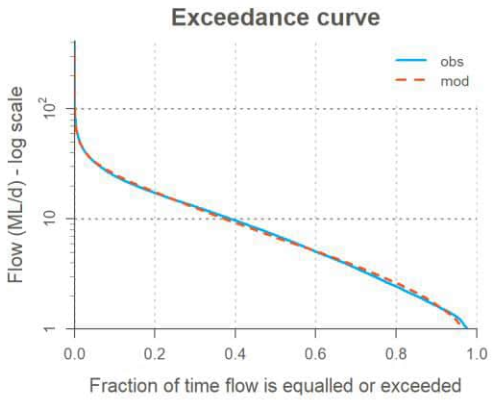

Subcatchment G8
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000 01/2001 01/2002 01/2003 01/2004 01/2005 01/2006 01/2007 01/2008 01/2009 01/2010
01/1990 01/1991 01/1992 01/1993 01/1994 01/1995 01/1996 01/1997 01/1998 01/1999 01/2000
01/1980 01/1981 01/1982 01/1983 01/1984 01/1985 01/1986 01/1987 01/1988 01/1989 01/1990


Subcatchment G8
obs
mod
1970 - 1980
1960 - 1970
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1970 01/1971 01/1972 01/1973 01/1974 01/1975 01/1976 01/1977 01/1978 01/1979 01/1980
01/1960 01/1961 01/1962 01/1963 01/1964 01/1965 01/1966 01/1967 01/1968 01/1969 01/1970

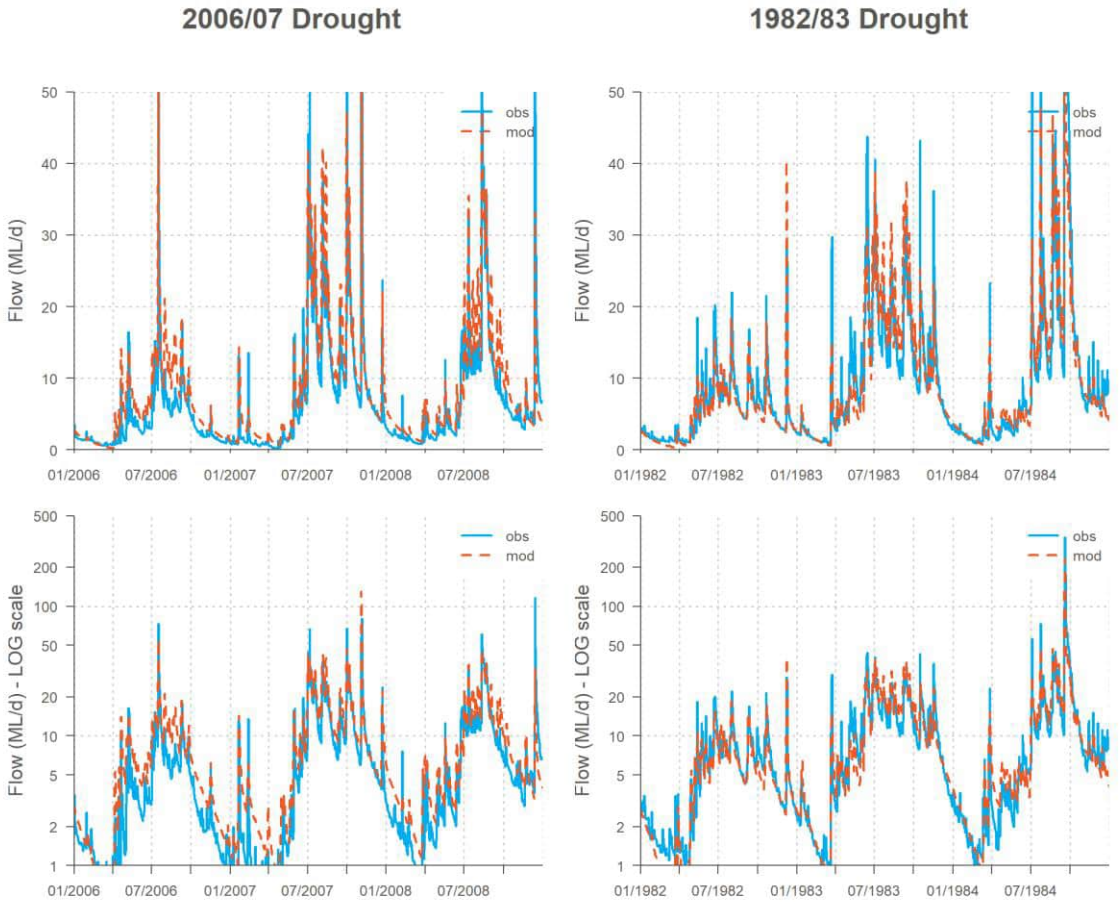
235205

Period of analysis: 15/02/1958 to 30/06/2024

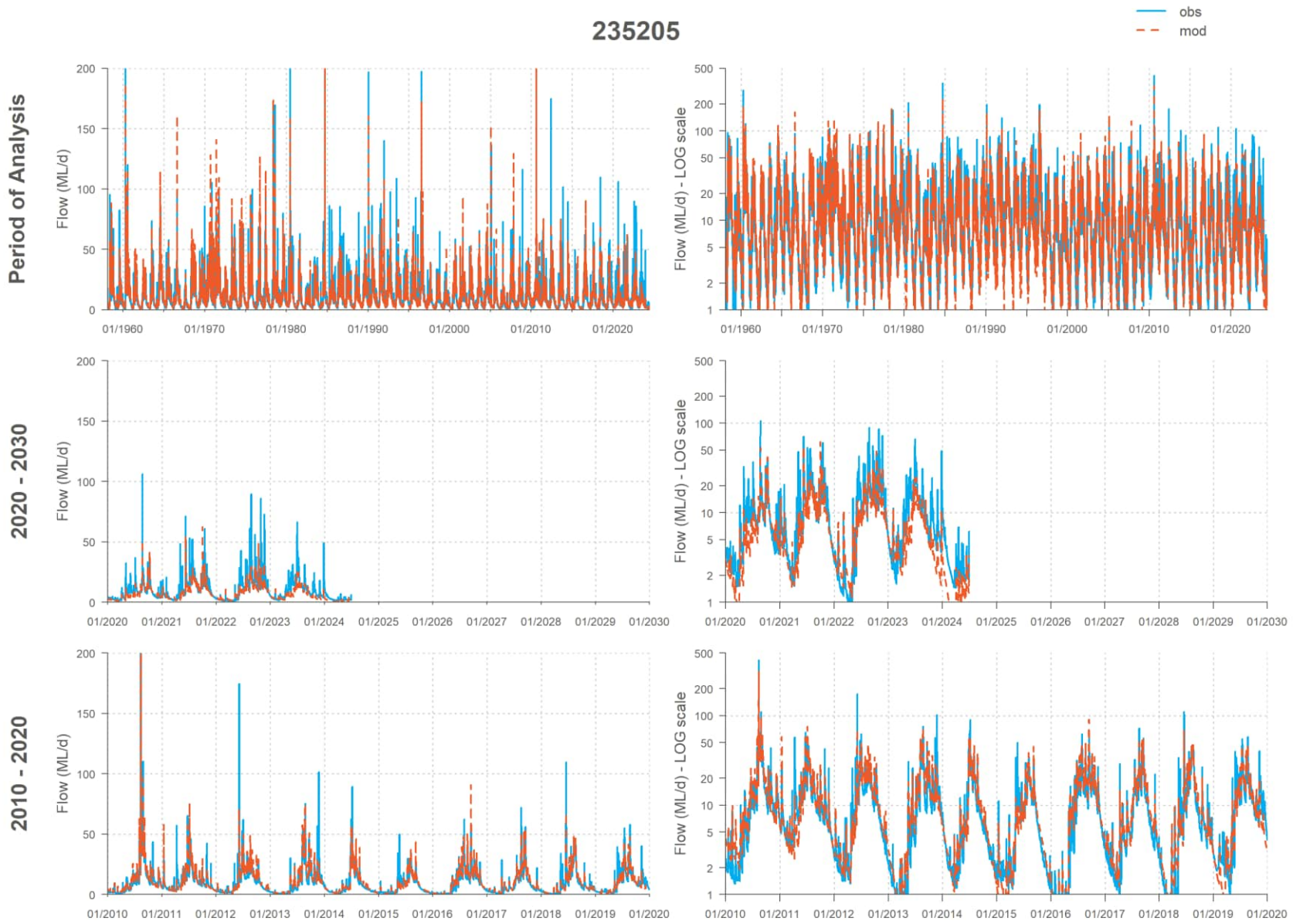
(Observed flow is available for 100.0% of days in this period)

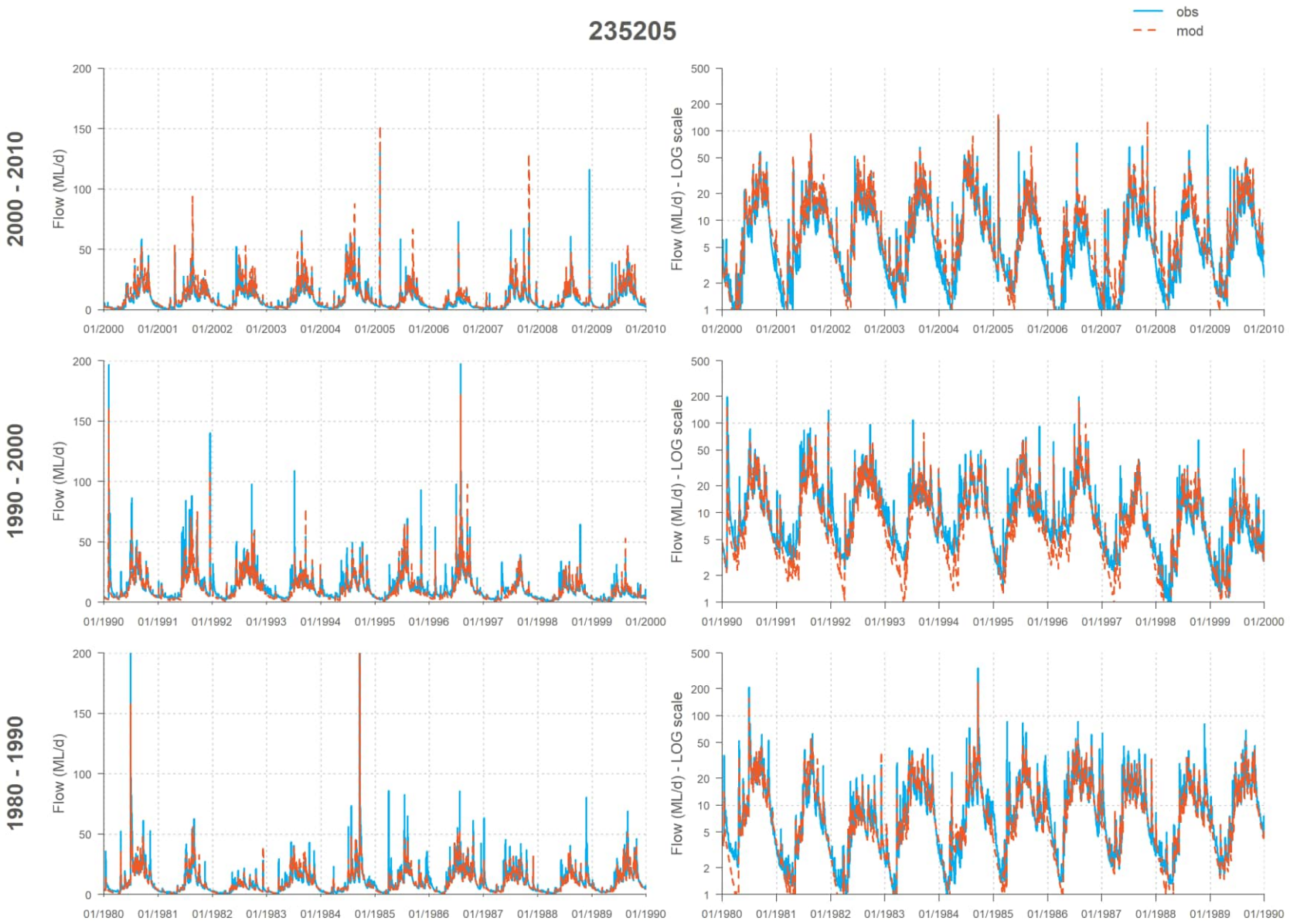


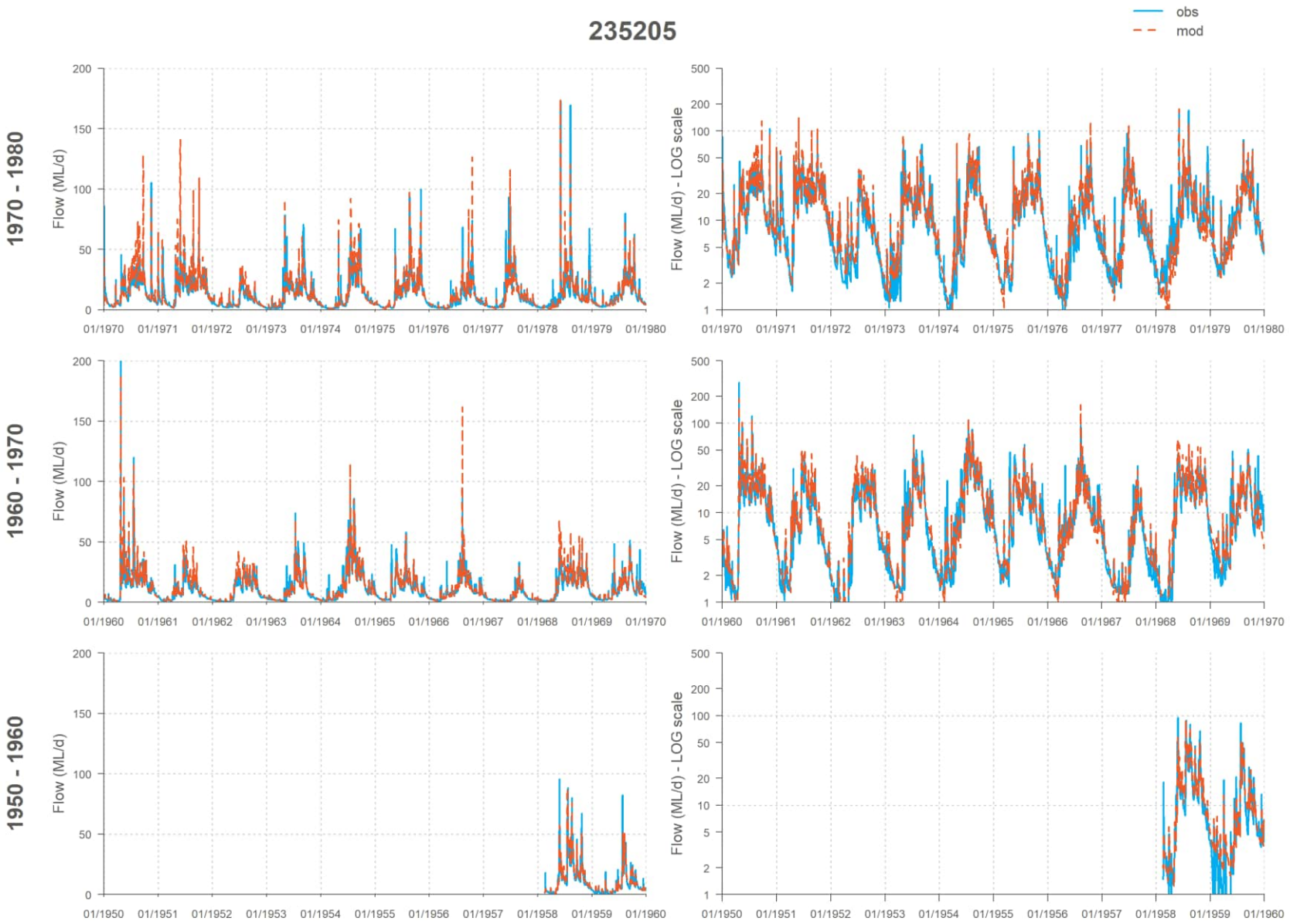
Statistics	Value
Correlation	0.91
Coefficient of determination	0.82
NSE daily	0.82
NSE monthly	0.90
Specific yield (mm)	910.0
Average annual modelled flow (ML/yr)	4,004.2
Average annual observed flow (ML/yr)	4,004.2
% Difference	-0.0%
Runoff coefficient	0.51
% Surface runoff	4.2%
% Interflow	6.0%
% Baseflow	89.9%



	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	1.2	0.48	0.24	0.48	0.0013	257.7	41.1	0.018	0.29	245.8	0.0042	0.44	1.2	2.5e-04	0.0014	0.10	15.5	0.33	24.3	6.2	0.61	0.38
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1


235205
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1960
01/1970
01/1980
01/1990
01/2000
01/2010
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019


235205
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000 01/2001 01/2002 01/2003 01/2004 01/2005 01/2006 01/2007 01/2008 01/2009 01/2010
01/1990 01/1991 01/1992 01/1993 01/1994 01/1995 01/1996 01/1997 01/1998 01/1999 01/2000
01/1980 01/1981 01/1982 01/1983 01/1984 01/1985 01/1986 01/1987 01/1988 01/1989 01/1990

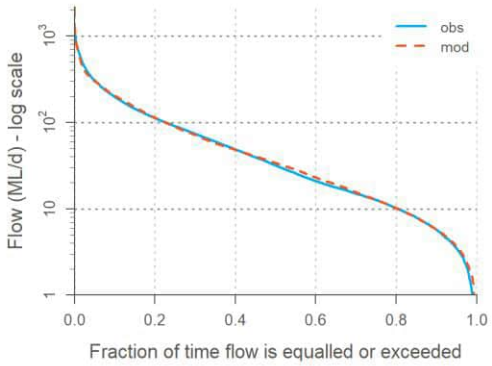

235205
obs
mod
1970 - 1980
1960 - 1970
1950 - 1960
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1970 01/1971 01/1972 01/1973 01/1974 01/1975 01/1976 01/1977 01/1978 01/1979 01/1980
01/1960 01/1961 01/1962 01/1963 01/1964 01/1965 01/1966 01/1967 01/1968 01/1969 01/1970
01/1950 01/1951 01/1952 01/1953 01/1954 01/1955 01/1956 01/1957 01/1958 01/1959 01/1960

G9b Inflow

Period of analysis: 03/03/1930 to 31/12/2024

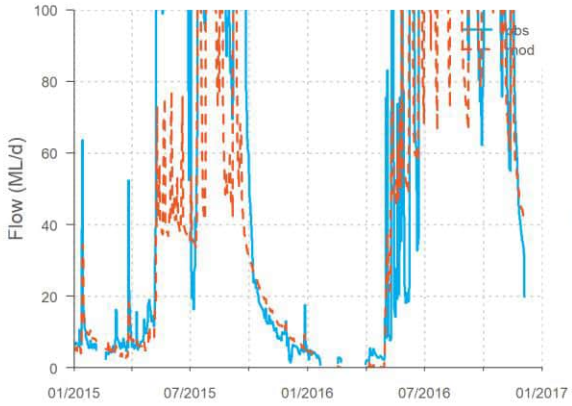
(Observed flow is available for 45.2% of days in this period)

Exceedance curve



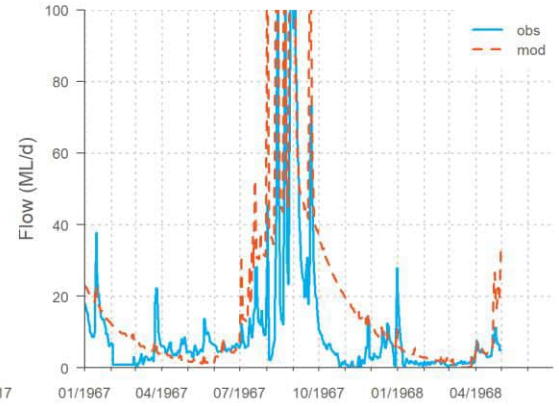
Statistics	Value
Correlation	0.73
Coefficient of determination	0.53
NSE daily	0.46
NSE monthly	0.57
Specific yield (mm)	367.4
Average annual modelled flow (ML/yr)	28,655.3
Average annual observed flow (ML/yr)	28,657.7
% Difference	-0.0%
Runoff coefficient	0.30
% Surface runoff	9.3%
% Interflow	46.3%
% Baseflow	44.4%

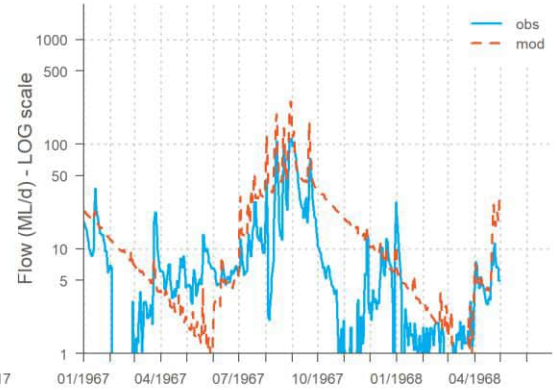
2015/16



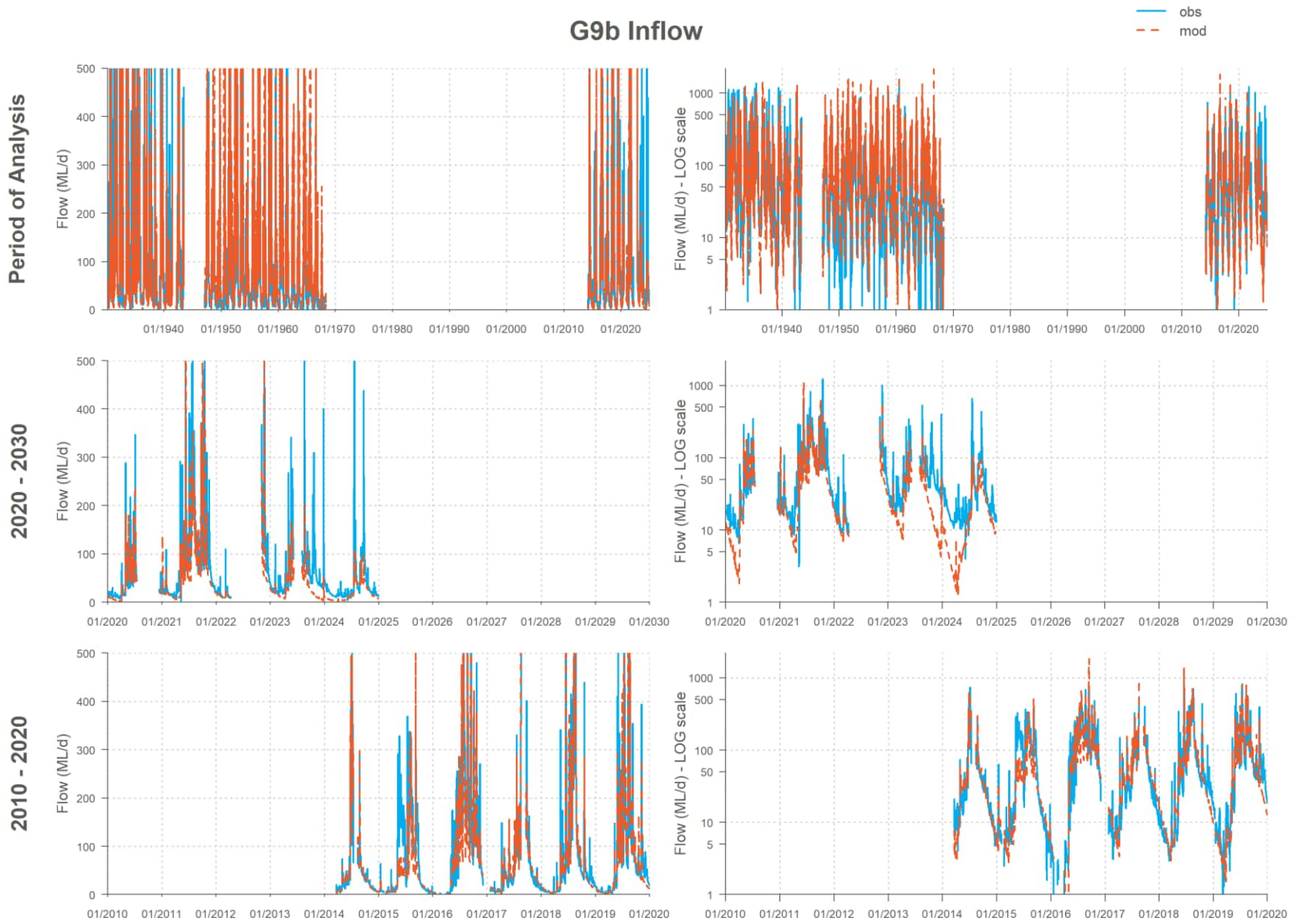


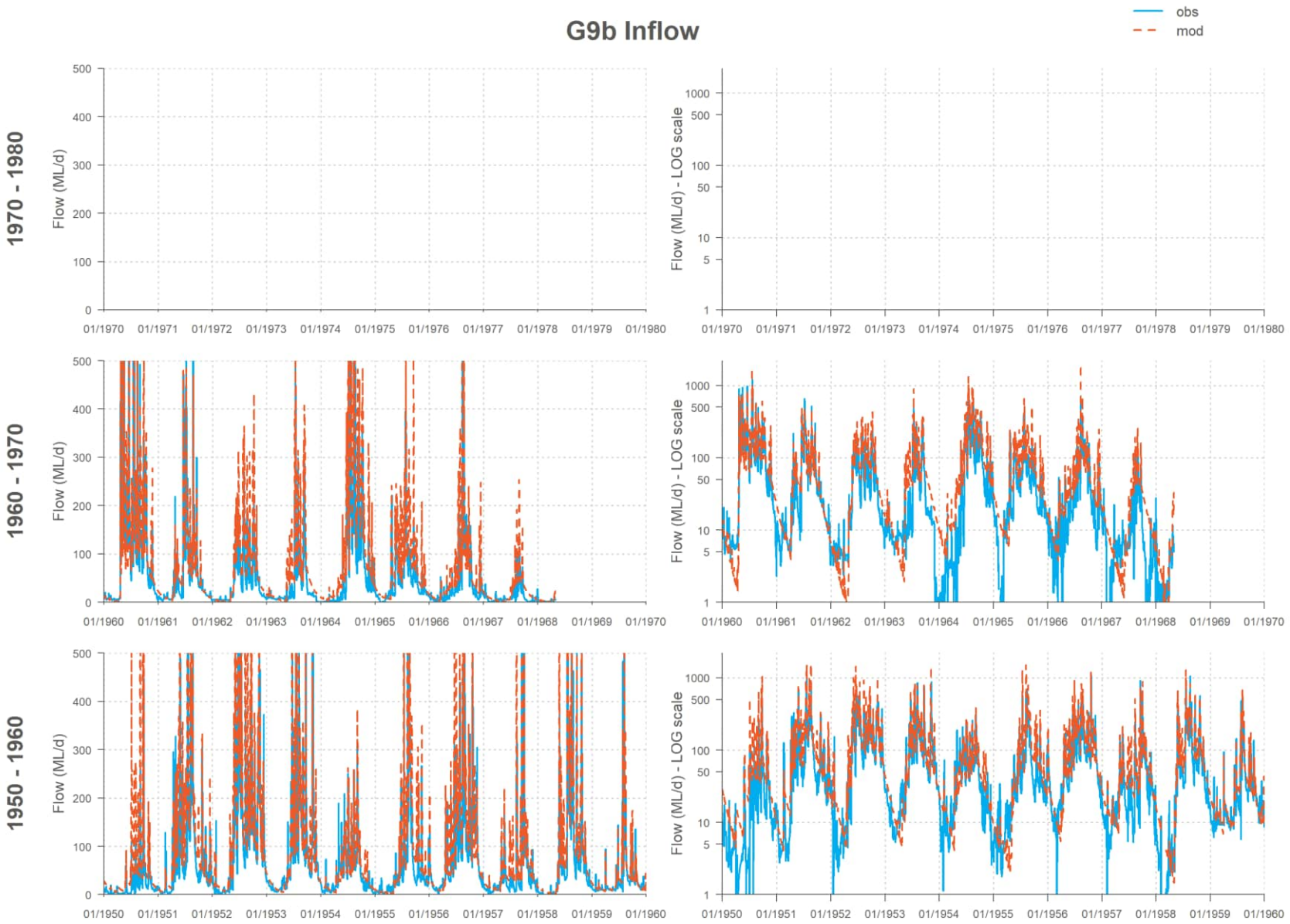
1967/68

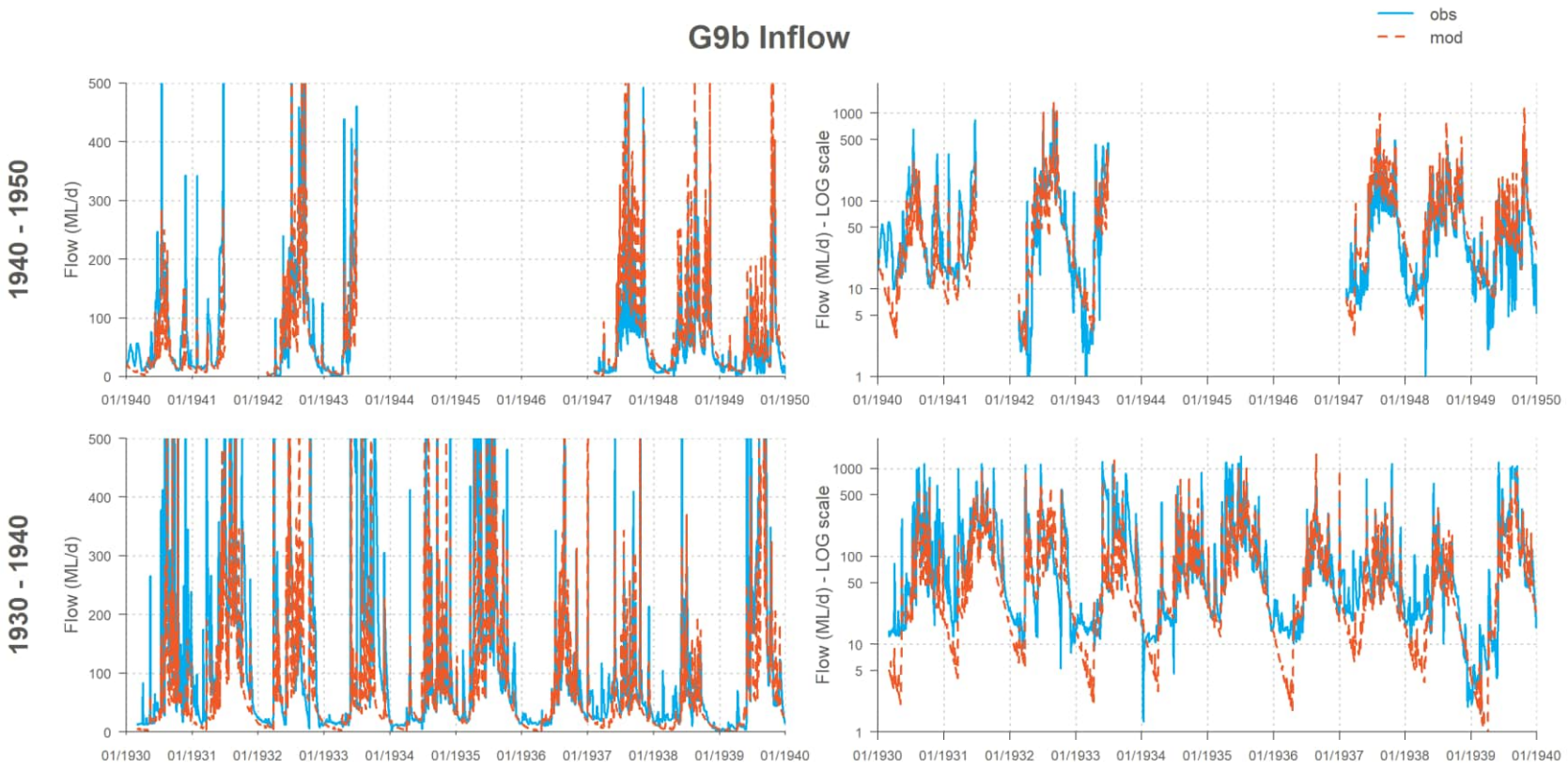




	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	1.1	0.55	0.17	0.34	0.0013	159.2	177.8	2.3e-05	0.019	314.4	0.0042	0.33	3.9	2.5e-04	0.0014	0.0084	23.4	0.25	50.1	265.9	0.45	0.55
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1


G9b Inflow
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1940
01/1950
01/1960
01/1970
01/1980
01/1990
01/2000
01/2010
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019

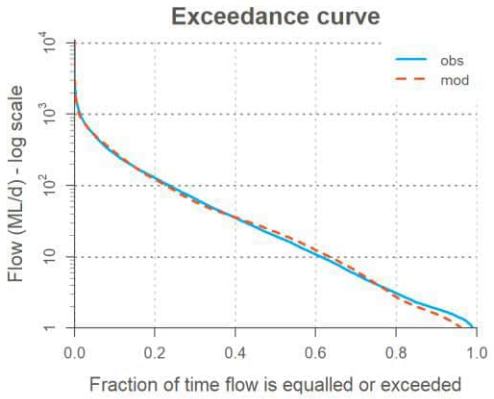

G9b Inflow
obs
mod
1970 - 1980
1960 - 1970
1950 - 1960
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1970 01/1971 01/1972 01/1973 01/1974 01/1975 01/1976 01/1977 01/1978 01/1979 01/1980
01/1960 01/1961 01/1962 01/1963 01/1964 01/1965 01/1966 01/1967 01/1968 01/1969 01/1970
01/1950 01/1951 01/1952 01/1953 01/1954 01/1955 01/1956 01/1957 01/1958 01/1959 01/1960


G9b Inflow
obs
mod
1940 - 1950
1930 - 1940
Flow (ML/d)
Flow (ML/d) - LOG scale
0
100
200
300
400
500
1
5
10
50
100
500
1000
01/1930
01/1931
01/1932
01/1933
01/1934
01/1935
01/1936
01/1937
01/1938
01/1939
01/1940
01/1941
01/1942
01/1943
01/1944
01/1945
01/1946
01/1947
01/1948
01/1949
01/1950

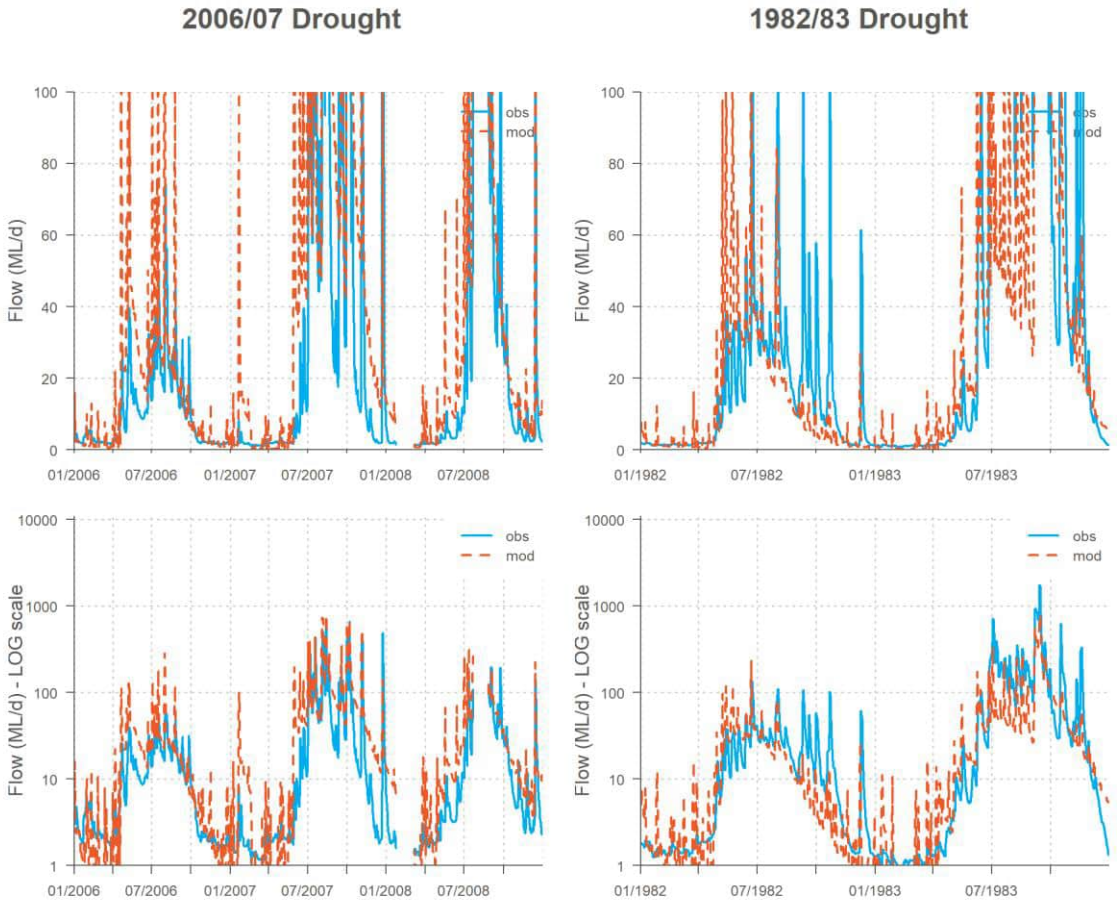
Subcatchment G10

Period of analysis: 19/06/1964 to 30/06/2024

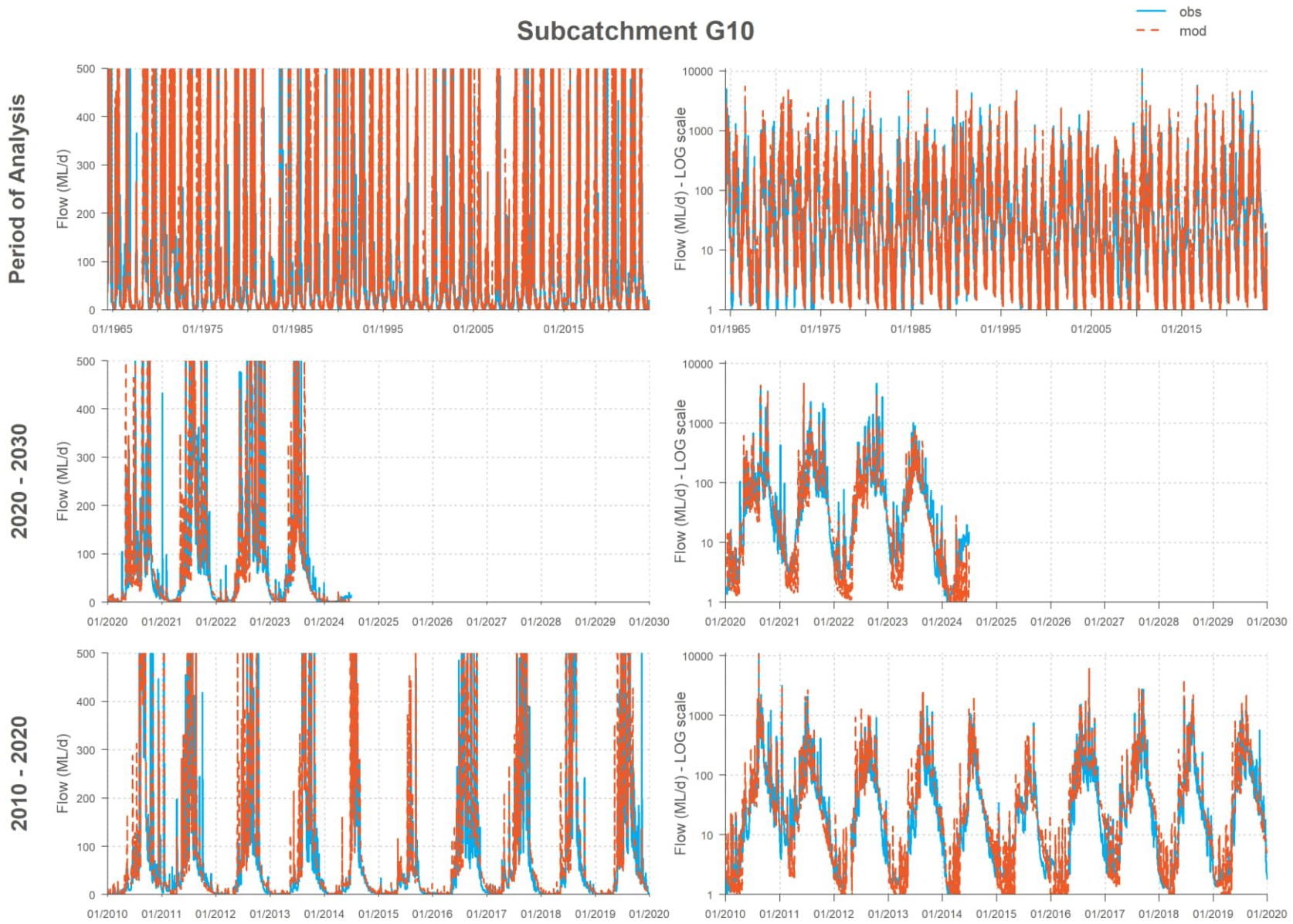
(Observed flow is available for 99.5% of days in this period)

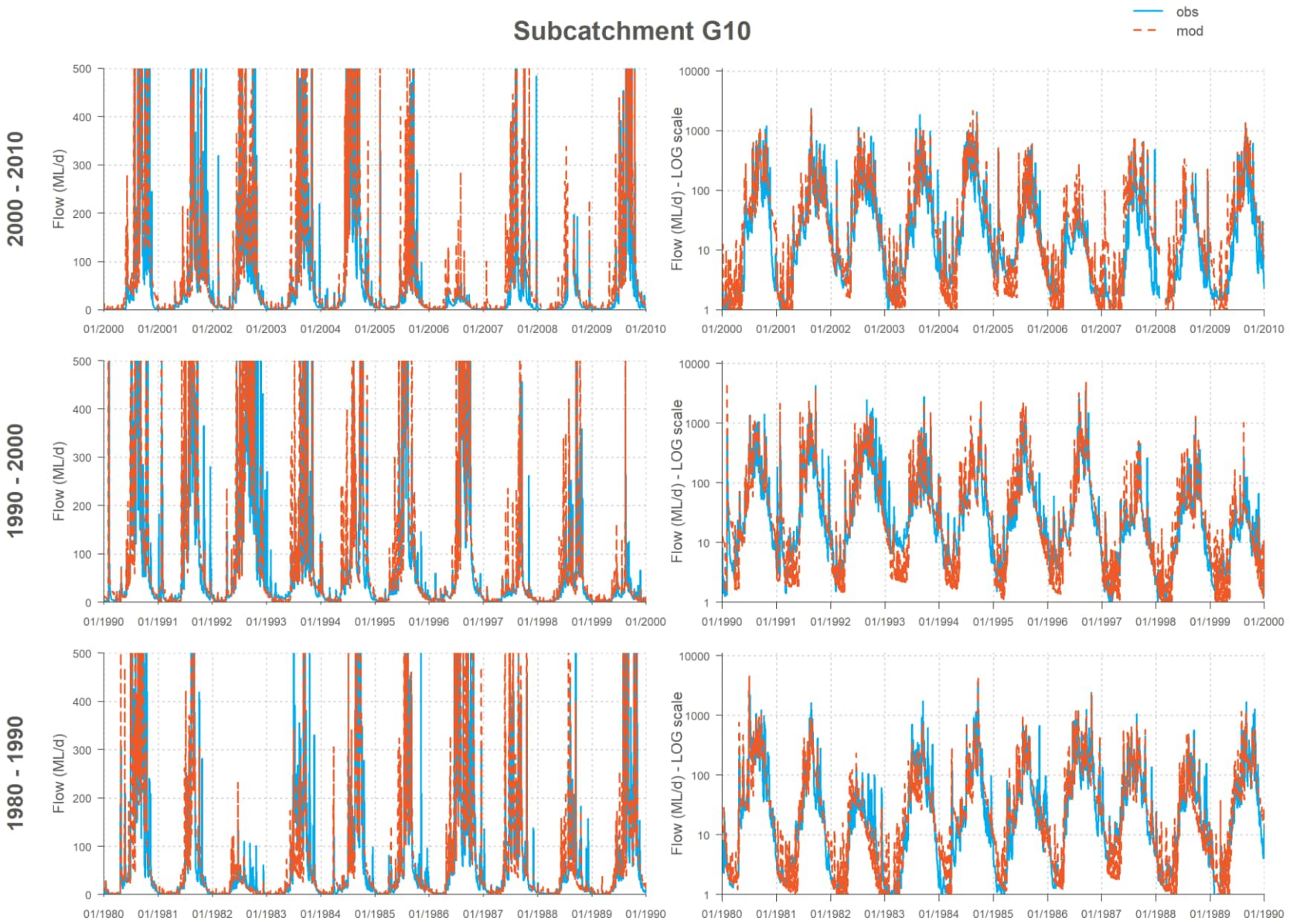


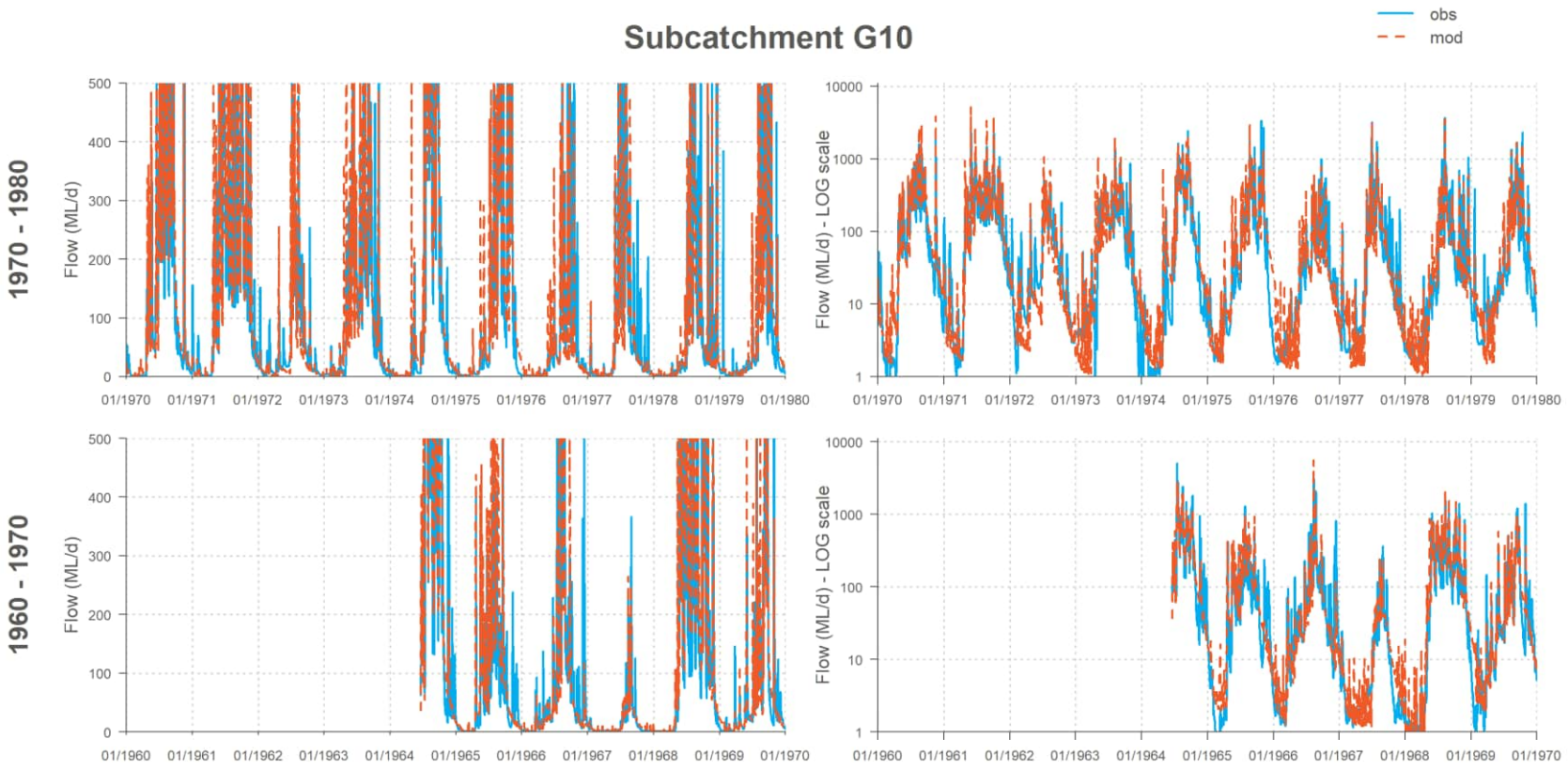
Statistics	Value
Correlation	0.87
Coefficient of determination	0.76
NSE daily	0.74
NSE monthly	0.91
Specific yield (mm)	143.1
Average annual modelled flow (ML/yr)	38,550.5
Average annual observed flow (ML/yr)	38,550.5
% Difference	0.0%
Runoff coefficient	0.16
% Surface runoff	11.1%
% Interflow	53.7%
% Baseflow	35.2%



	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1
Value	0.89	0.37	0.17	0.35	0.0013	300.0	55.0	1.1e-04	0.036	242.7	0.0042	0.16	3.0	2.5e-04	0.0014	0.016	17.8	0.24	63.3	168.0	0.23	0.77
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1


Subcatchment G10
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
01/1965
01/1975
01/1985
01/1995
01/2005
01/2015
01/2020
01/2021
01/2022
01/2023
01/2024
01/2025
01/2026
01/2027
01/2028
01/2029
01/2030
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
01/2020

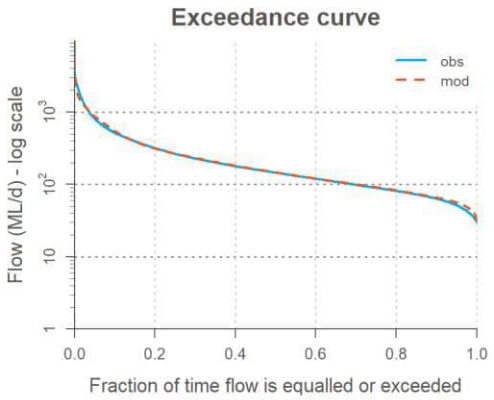

Subcatchment G10
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale
0
100
200
300
400
500
1
10
100
1000
10000
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
01/2009
01/2010
01/1990
01/1991
01/1992
01/1993
01/1994
01/1995
01/1996
01/1997
01/1998
01/1999
01/2000
01/1980
01/1981
01/1982
01/1983
01/1984
01/1985
01/1986
01/1987
01/1988
01/1989
01/1990


Subcatchment G10
obs
mod
1970 - 1980
1960 - 1970
Flow (ML/d)
Flow (ML/d) - LOG scale
0
100
200
300
400
500
1
10
100
1000
10000
01/1960
01/1961
01/1962
01/1963
01/1964
01/1965
01/1966
01/1967
01/1968
01/1969
01/1970
01/1971
01/1972
01/1973
01/1974
01/1975
01/1976
01/1977
01/1978
01/1979
01/1980

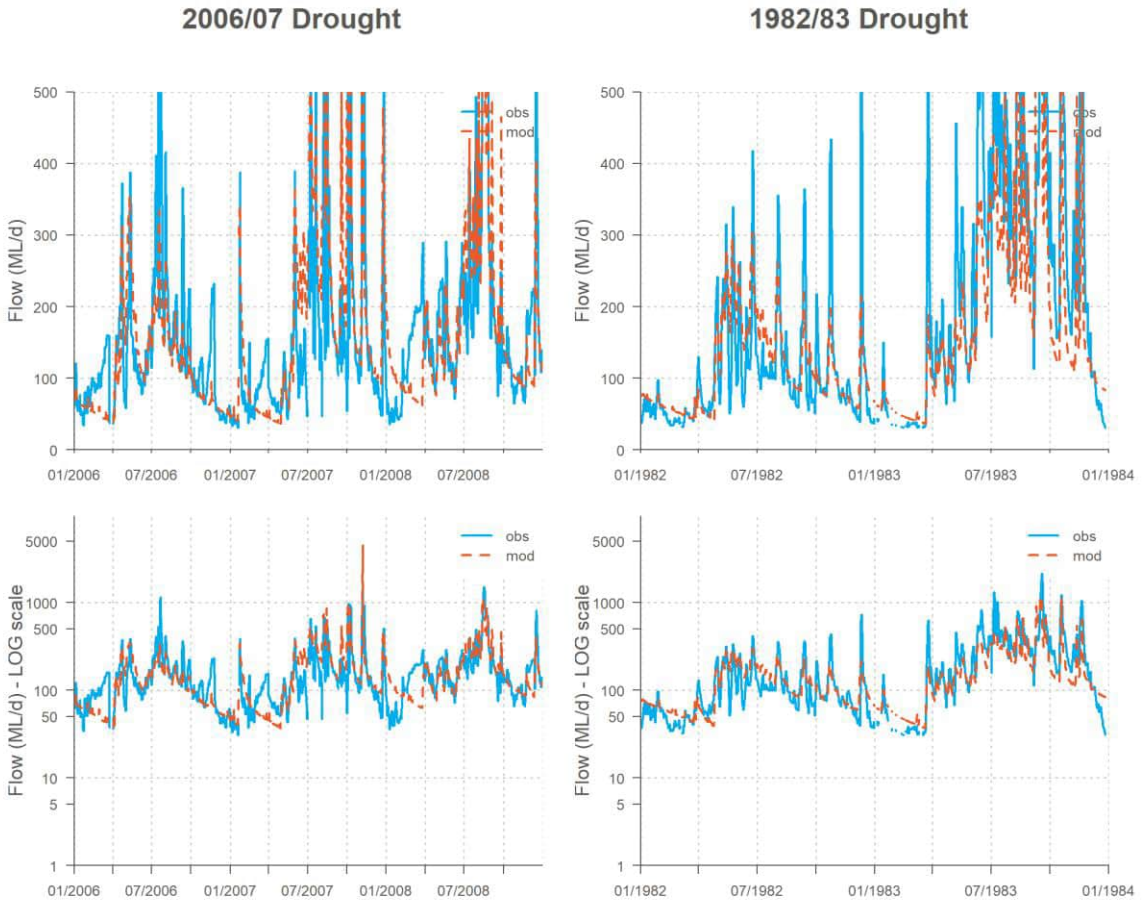
Subcatchment G11 G12

Period of analysis: 12/03/1970 to 31/12/2023

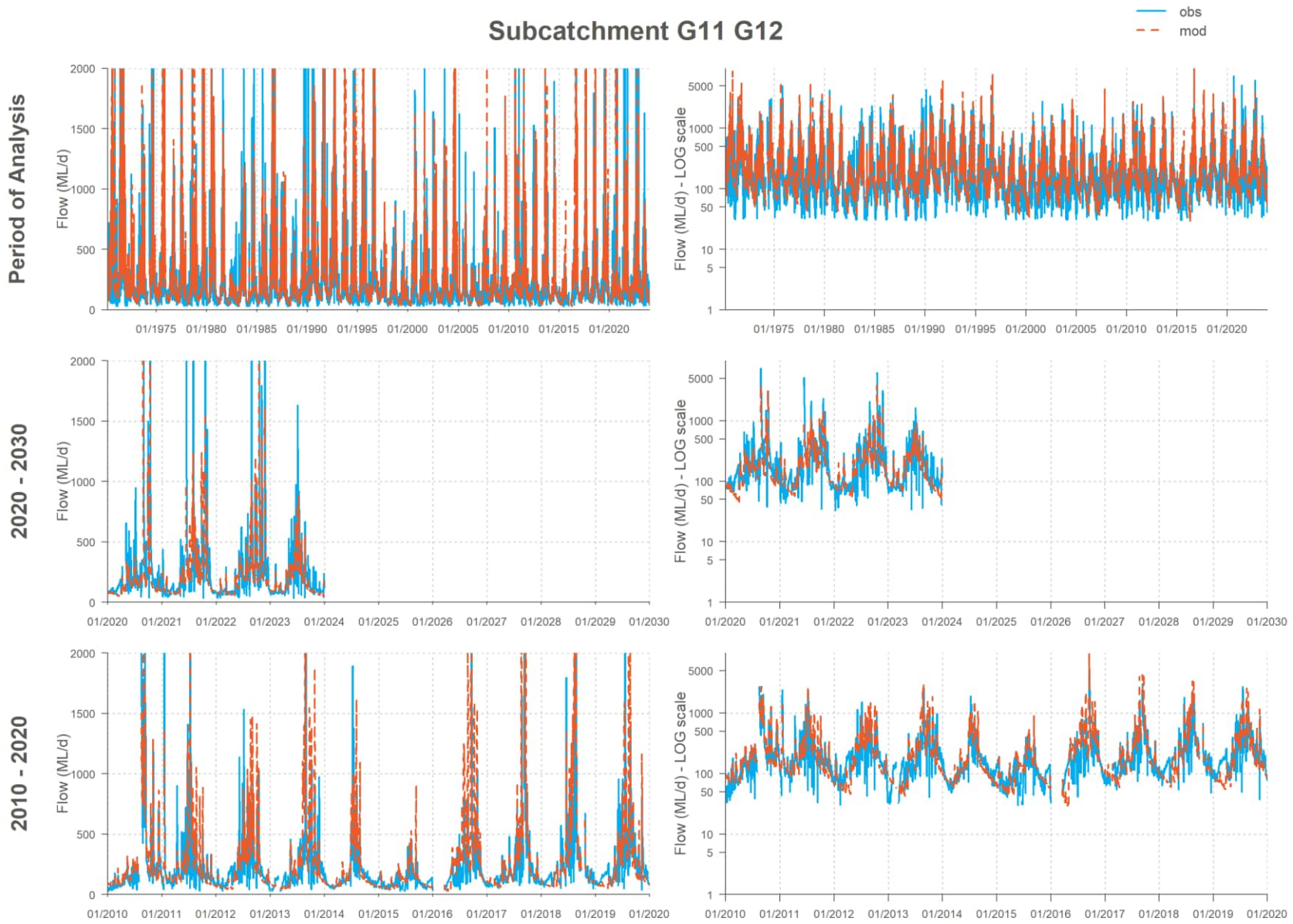
(Observed flow is available for 96.6% of days in this period)

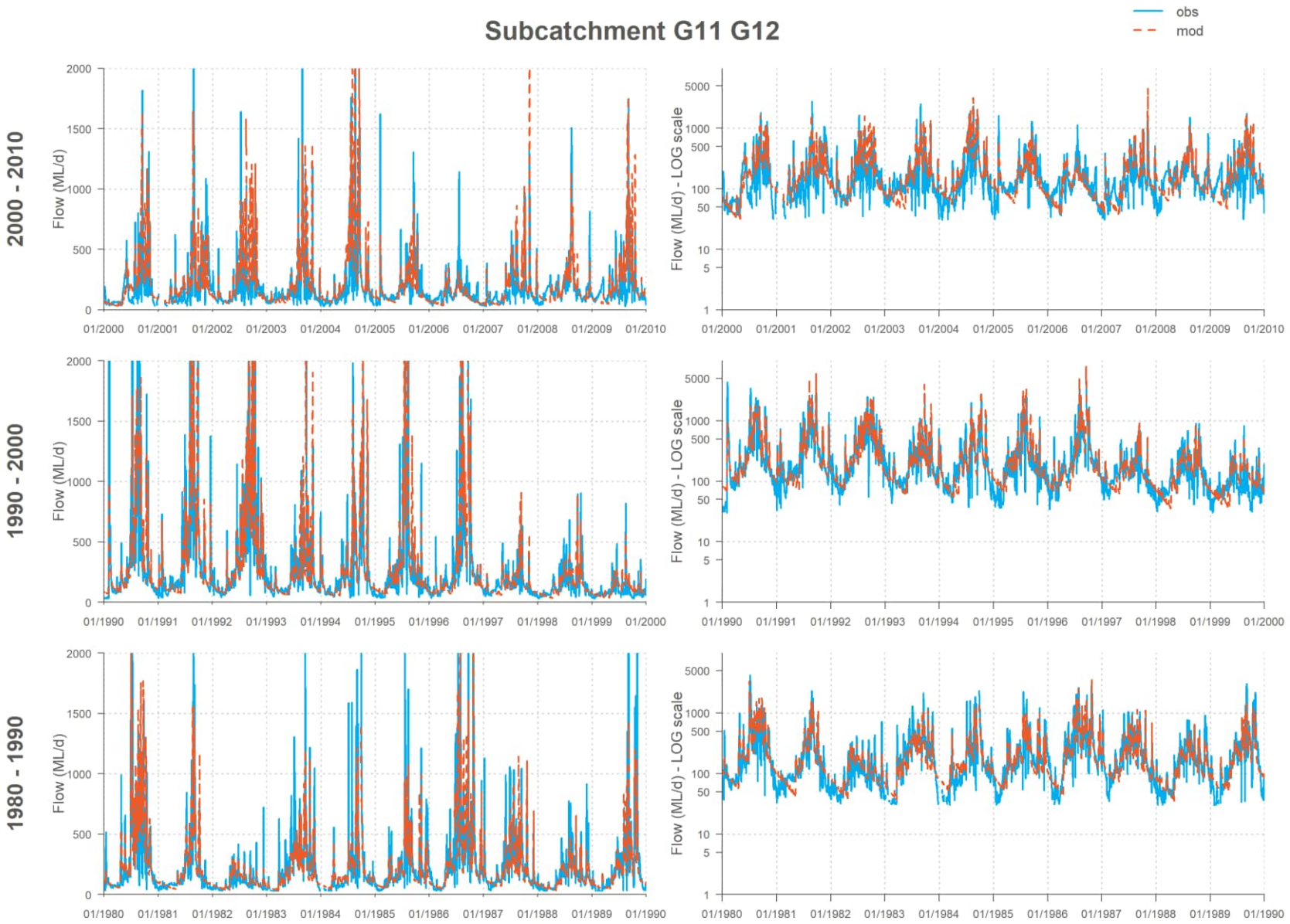


Statistics	Value
Correlation	0.70
Coefficient of determination	0.49
NSE daily	0.41
NSE monthly	0.76
Specific yield (mm)	247.4
Average annual modelled flow (ML/yr)	93,846.9
Average annual observed flow (ML/yr)	93,755.2
% Difference	0.1%
Runoff coefficient	0.24
% Surface runoff	4.8%
% Interflow	28.8%
% Baseflow	66.3%

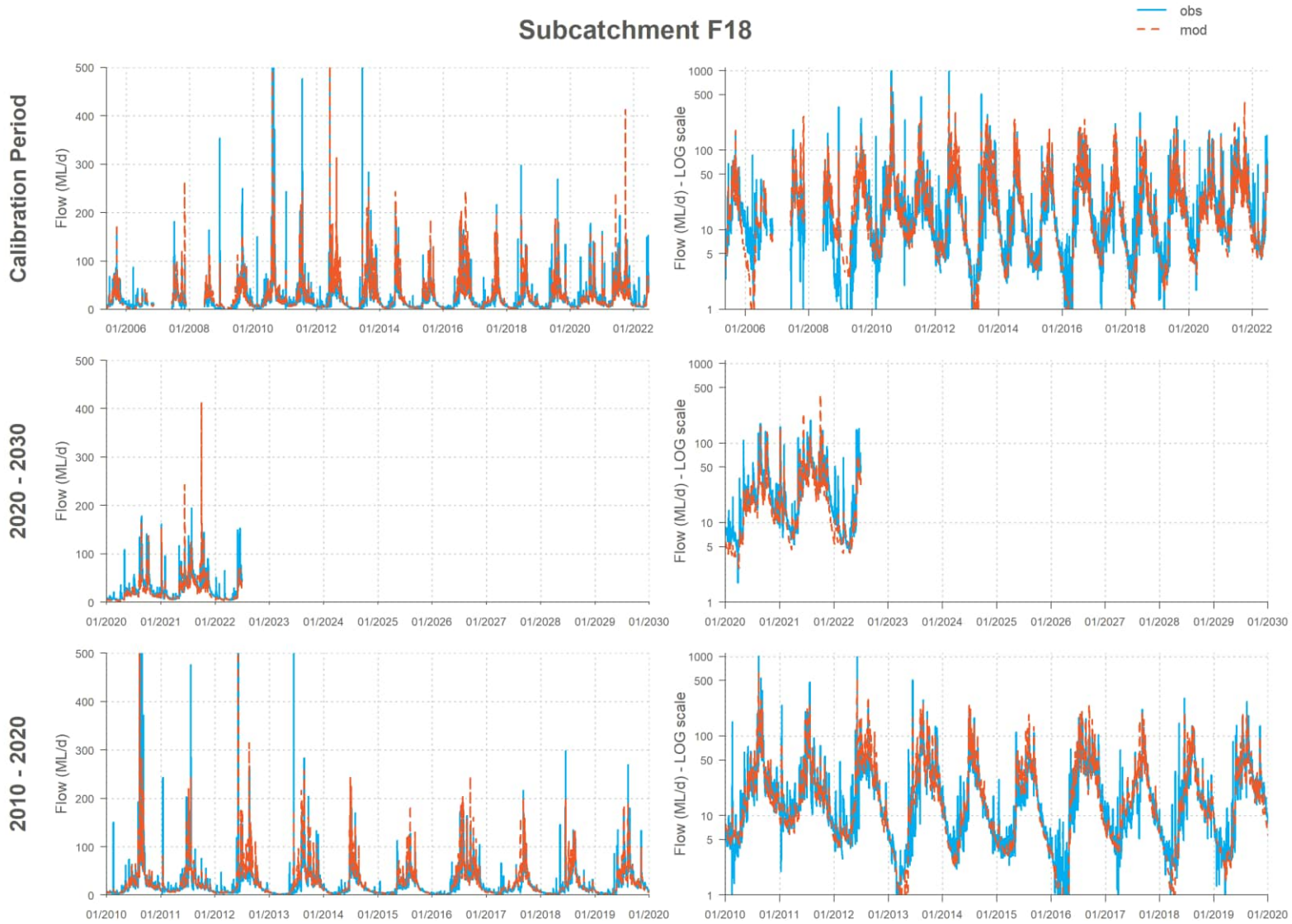


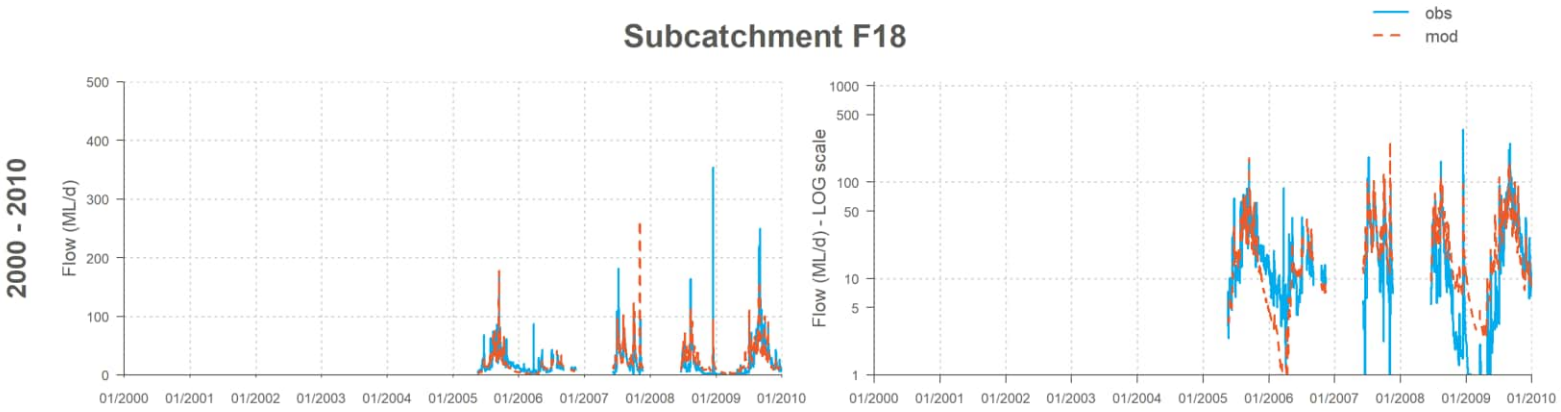
	Rfsum	Rf1	Rf2	Rf3	adimp	lzfpm	lzfsm	lzpk	lzsk	lztwm	pctim	pfree	rexp	sarva	side	ssout	uzfwm	uzk	uztwm	zperc	uh0	uh1	uh2	uh3
Value	0.94	0.021	0.31	0.62	0.0013	116.5	31.0	0.006	0.12	410.7	0.0042	0.32	4.0	2.5e-04	0.0014	0.019	22.4	0.20	21.4	600.0	0e+00	0e+00	0.22	0.78
Tpcl.min	0.7	0	0	0	0	40	15	0.001	0.03	75	0	0	0	0	0	0	10	0.2	25	0	0	0	0	NA
Tpcl.max	3	3	3	3	0.2	600	300	0.015	0.2	300	0.05	0.5	3	0.1	0.8	0.1	75	0.5	125	80	1	1	1	NA


Subcatchment G11 G12
obs
mod
Period of Analysis
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale
2000
1500
1000
500
0
5000
100
50
10
5
1
01/1975 01/1980 01/1985 01/1990 01/1995 01/2000 01/2005 01/2010 01/2015 01/2020
01/2020 01/2021 01/2022 01/2023 01/2024 01/2025 01/2026 01/2027 01/2028 01/2029 01/2030
01/2010 01/2011 01/2012 01/2013 01/2014 01/2015 01/2016 01/2017 01/2018 01/2019 01/2020


Subcatchment G11 G12
obs
mod
2000 - 2010
1990 - 2000
1980 - 1990
Flow (ML/d)
Flow (ML/d) - LOG scale

Appendix C BW and HARC (2023) rainfall runoff model report cards

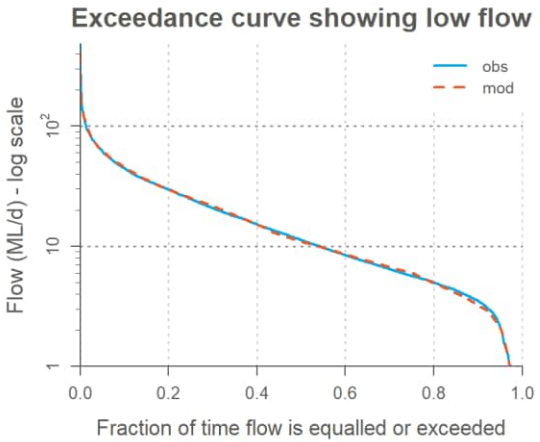

Subcatchment F18
obs
mod
Calibration Period
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale


Subcatchment F18
obs
mod
2000 - 2010
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
01/2009
01/2010

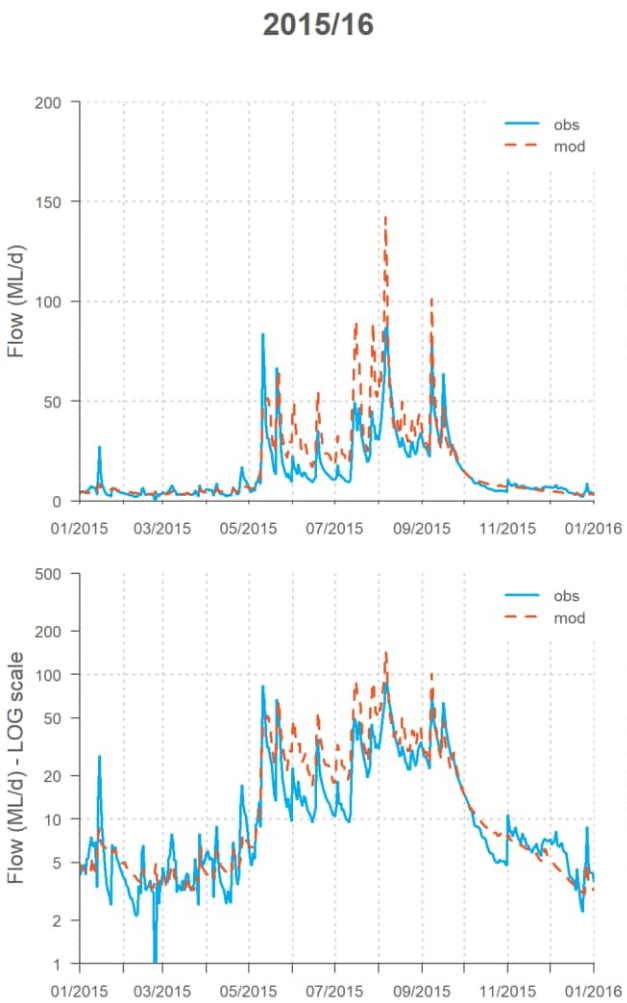
Subcatchment F19

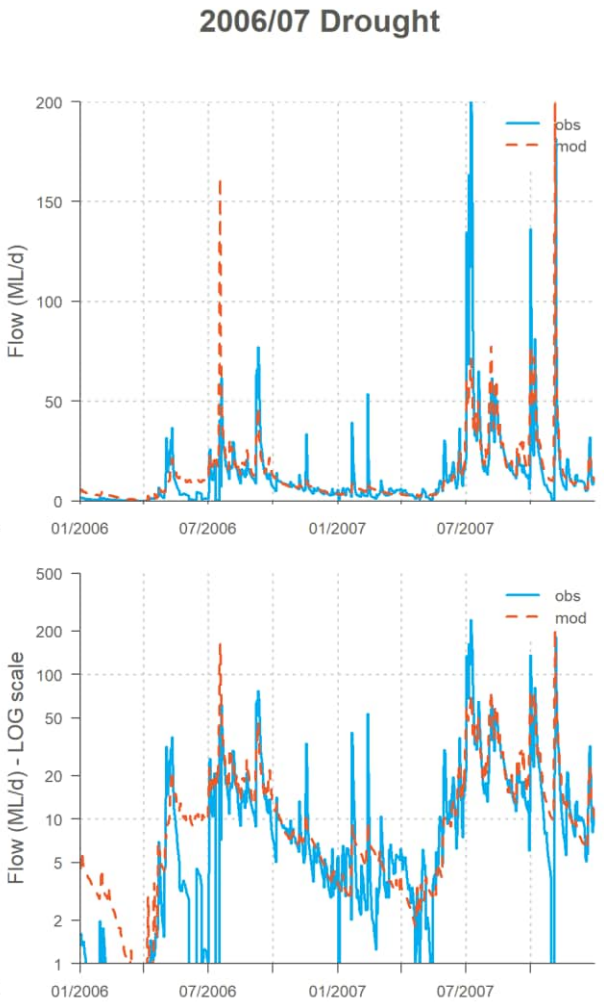
Period of analysis: 11/06/2005 to 30/06/2022

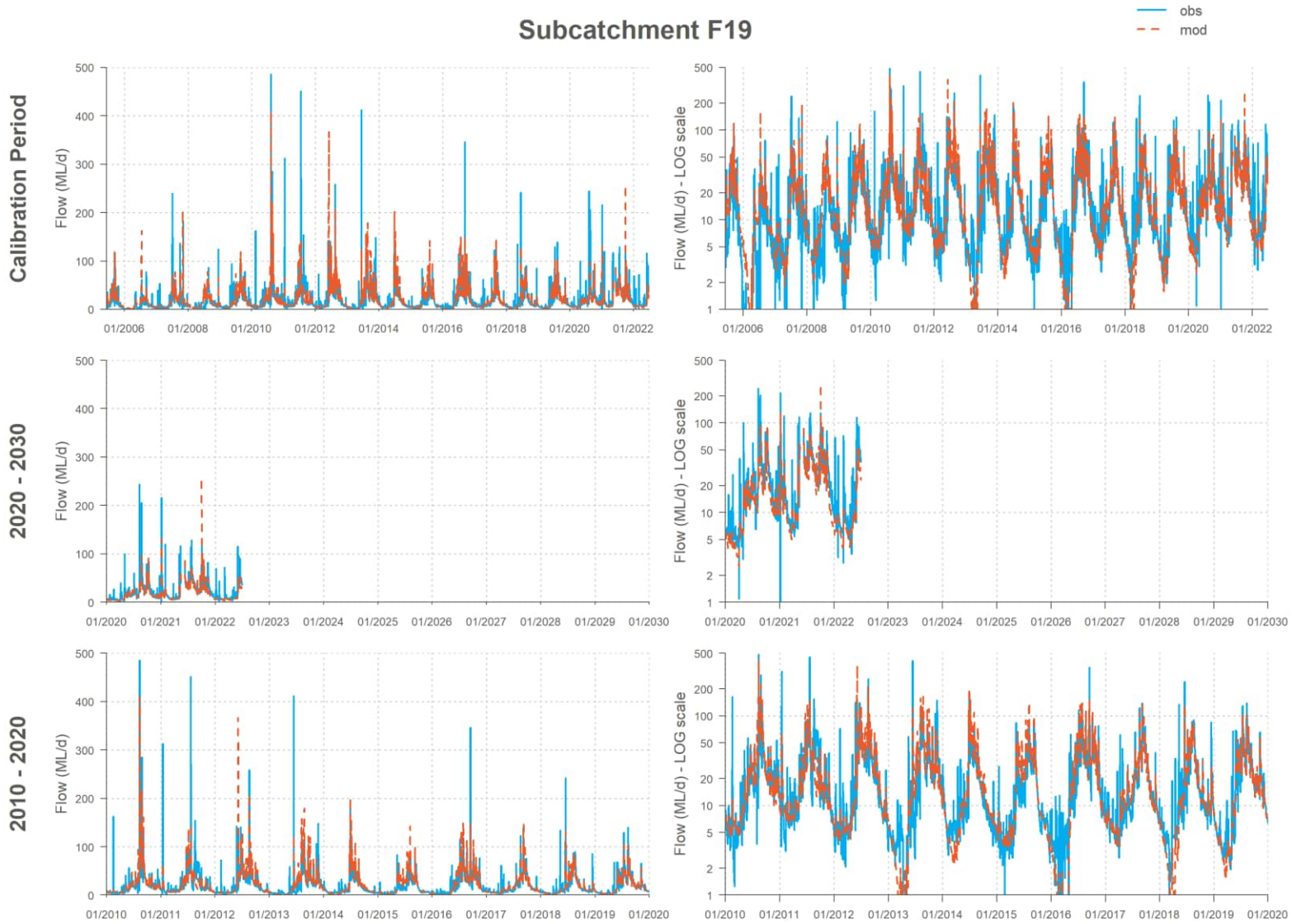
(Observed flow is available for 99.2% of days in this period)

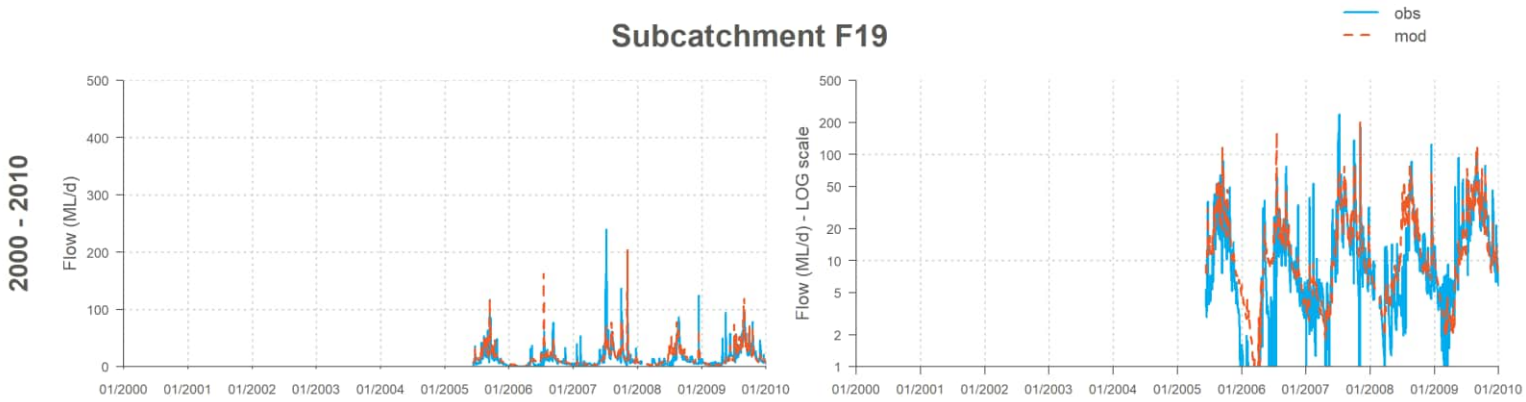


Statistics	Value
Correlation	0.80
Coefficient of determination	0.64
NSE daily	0.62
NSE monthly	0.79
Specific yield (mm)	662.8
Average annual modelled flow (ML/yr)	7,153.4
Average annual observed flow (ML/yr)	7,152.2
% Difference	0.0%
Runoff coefficient	0.43

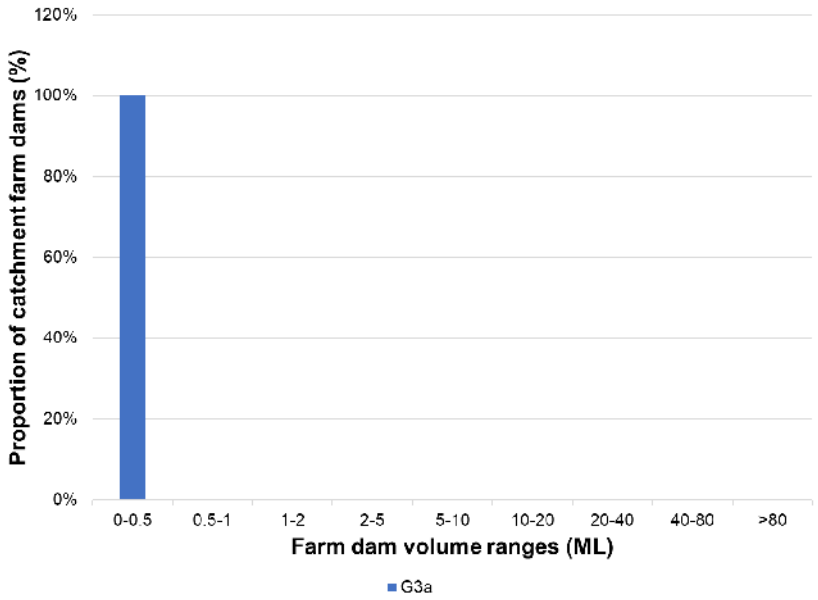


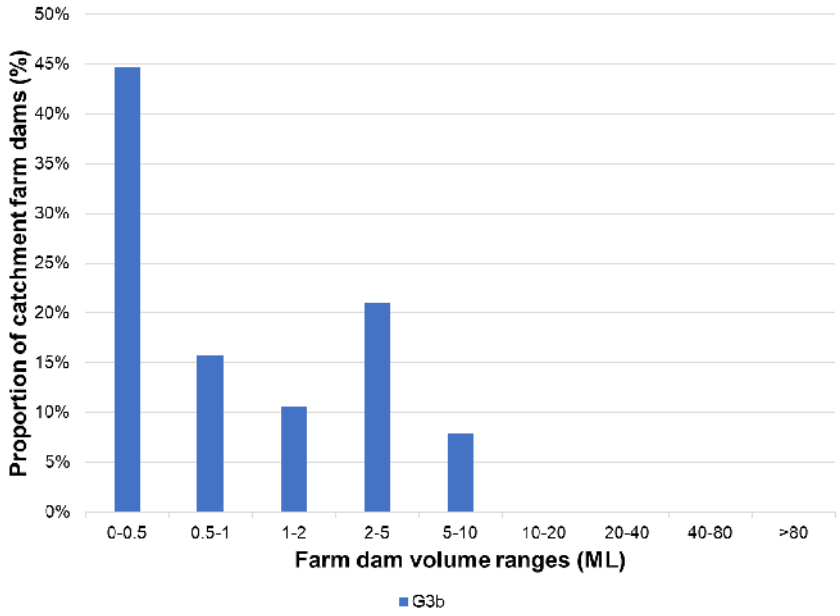


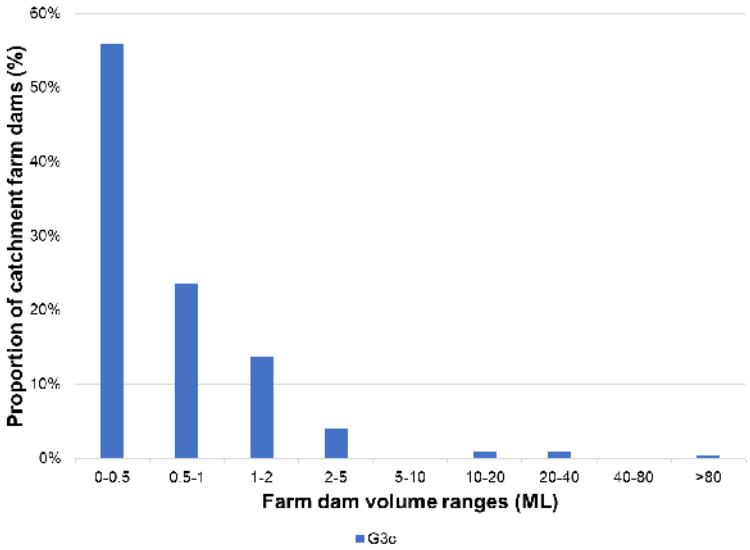

Subcatchment F19
obs
mod
Calibration Period
2020 - 2030
2010 - 2020
Flow (ML/d)
Flow (ML/d) - LOG scale

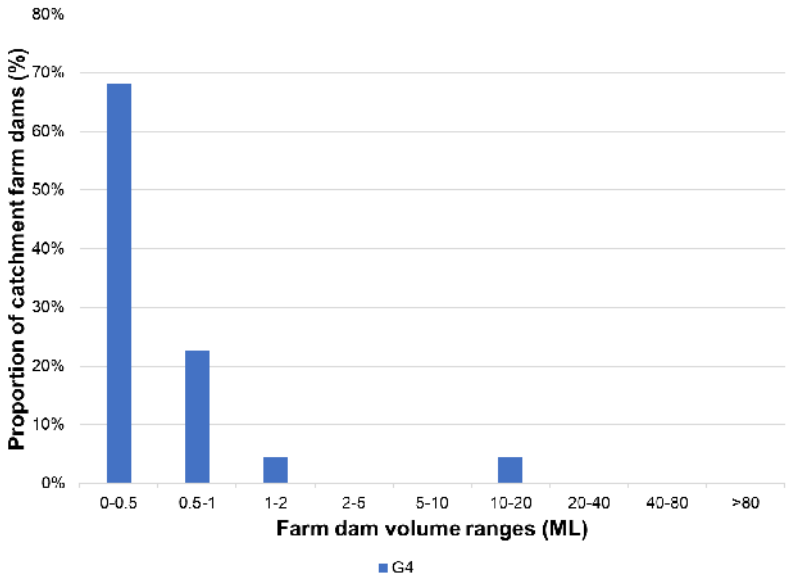

Subcatchment F19
obs
mod
2000 - 2010
Flow (ML/d)
Flow (ML/d) - LOG scale
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
01/2007
01/2008
01/2009
01/2010

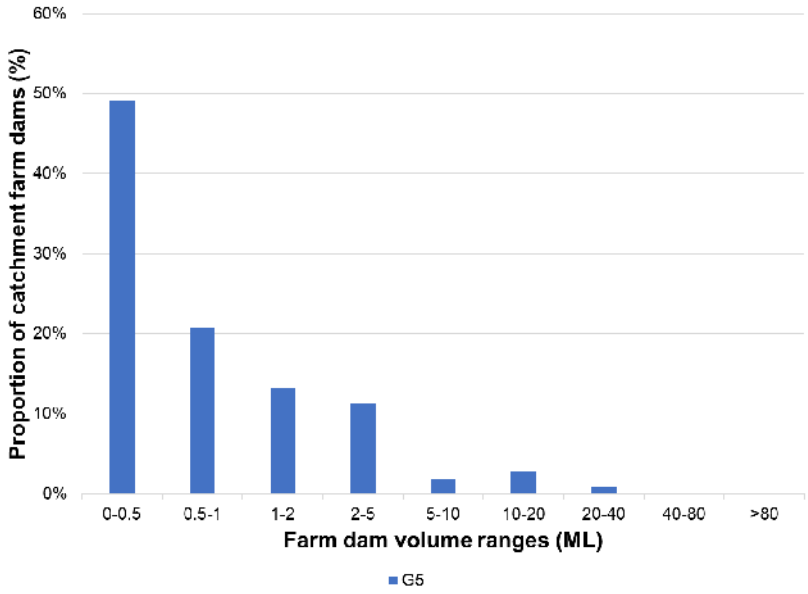
Appendix D Farm dam distributions

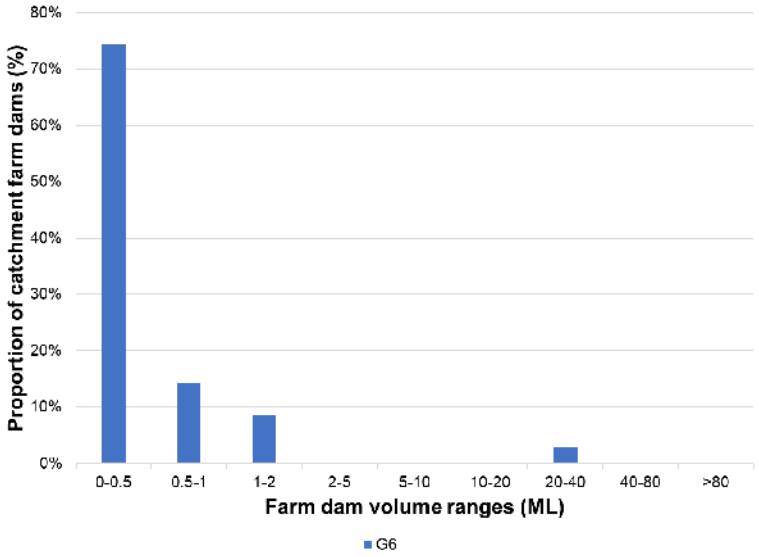


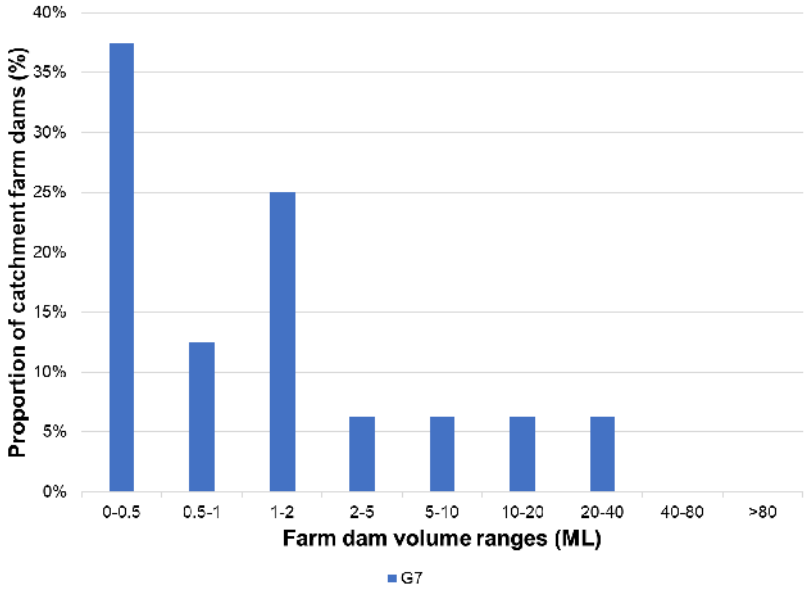


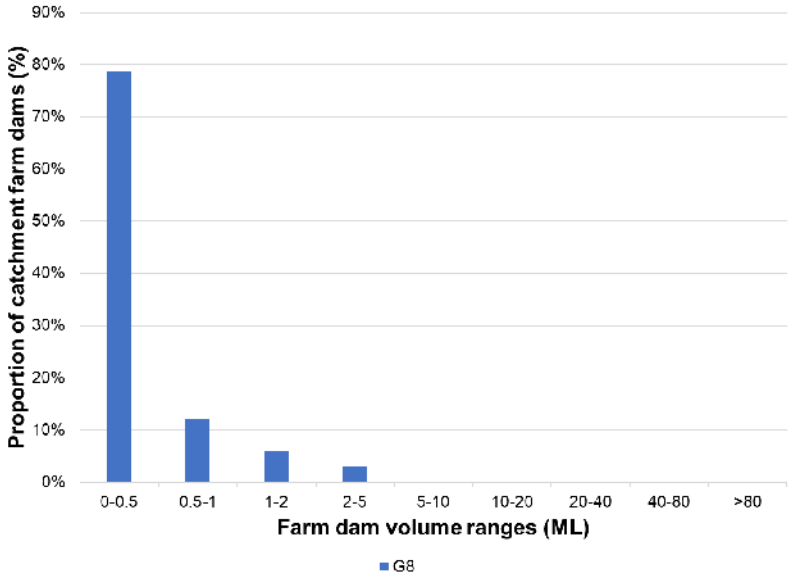

60%
50%
40%
30%
20%
10%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G3c

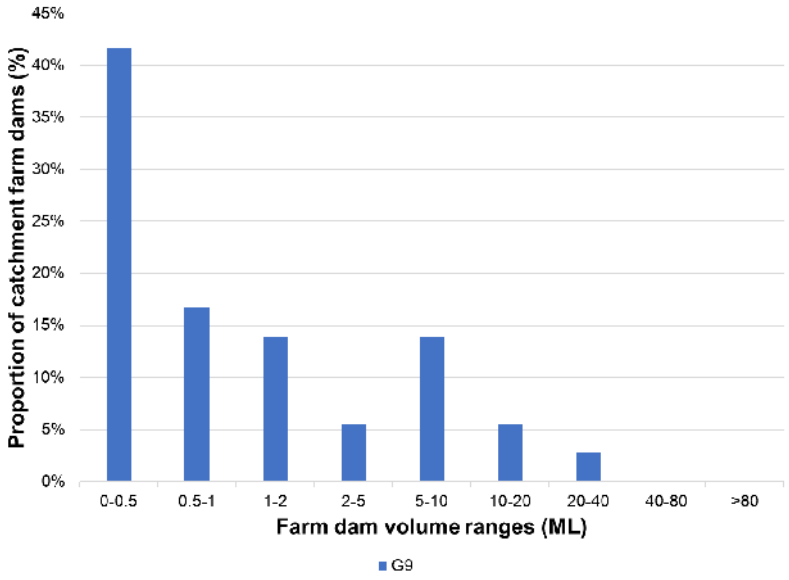

80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G4

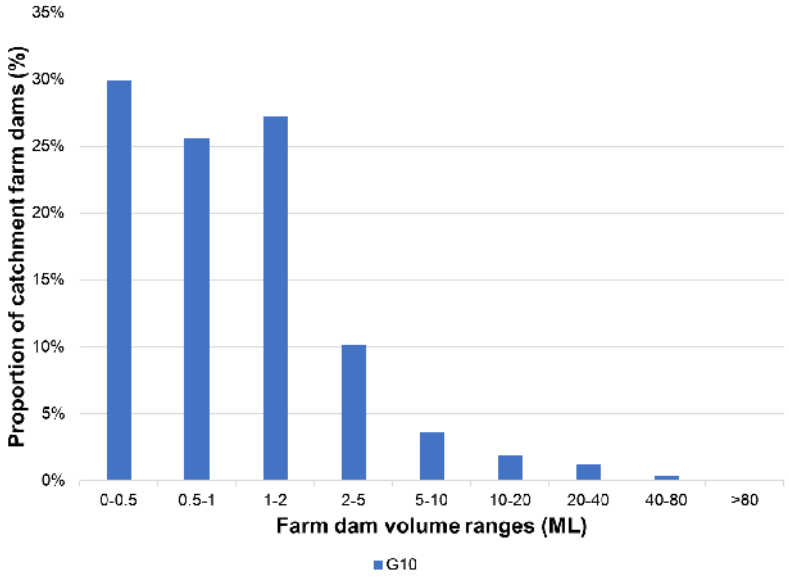

60%
50%
40%
30%
20%
10%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G5

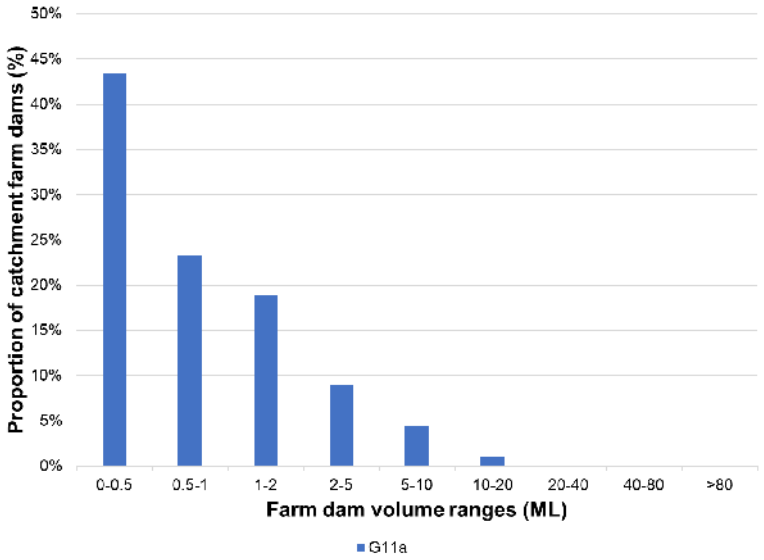

80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G6

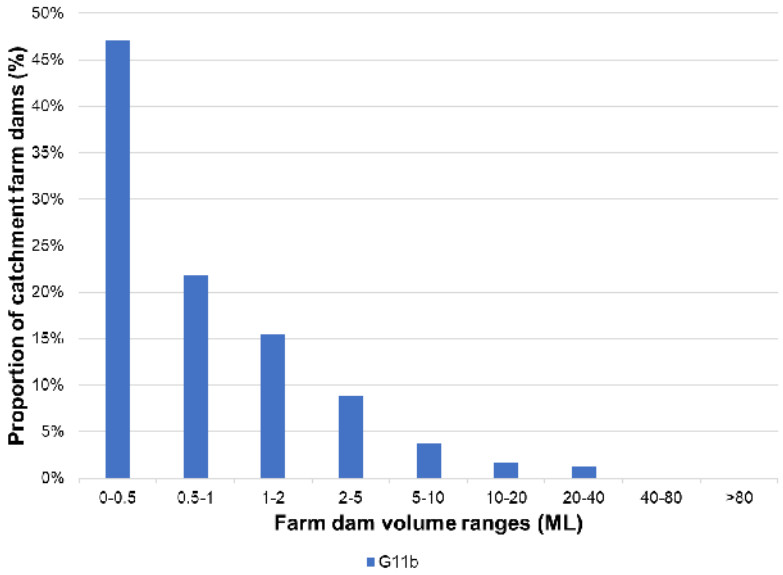

40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G7

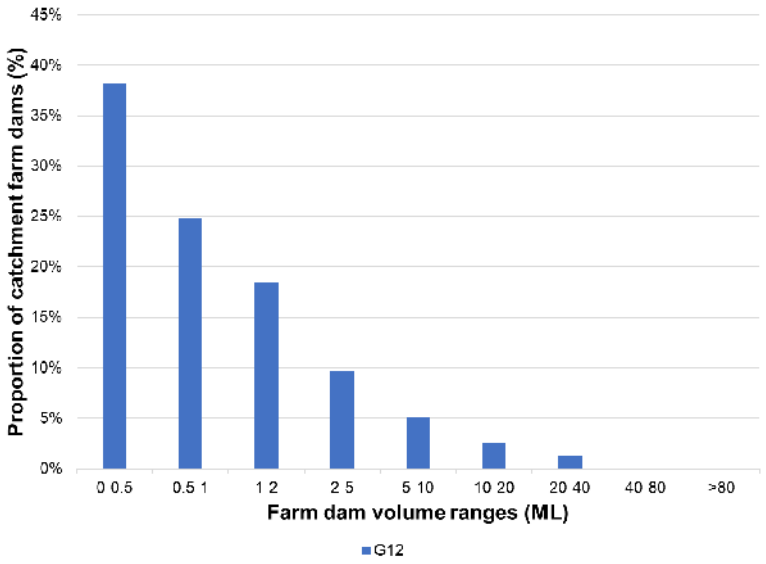

90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G8

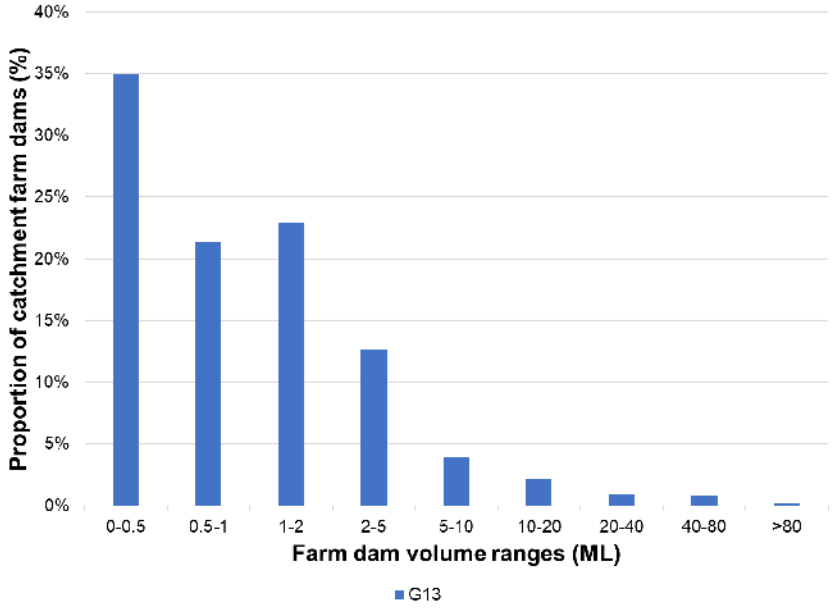

45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G9


35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G10


50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G11a


50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G11b


45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0 0.5
0.5 1
1 2
2 5
5 10
10 20
20 40
40 80
>80
Farm dam volume ranges (ML)
G12

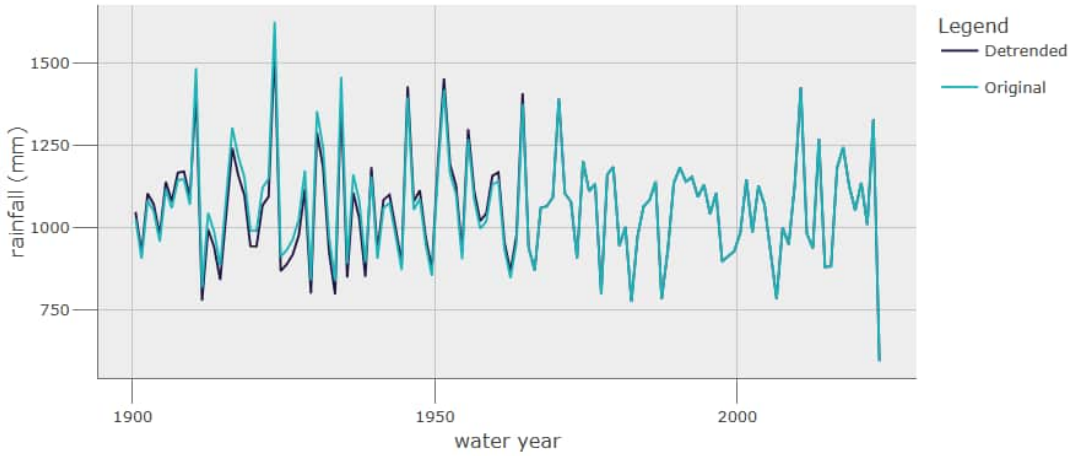

40%
35%
30%
25%
20%
15%
10%
5%
0%
Proportion of catchment farm dams (%)
0-0.5
0.5-1
1-2
2-5
5-10
10-20
20-40
40-80
>80
Farm dam volume ranges (ML)
G13

Appendix E Climate detrending plots

E.1 Rainfall detrending plots

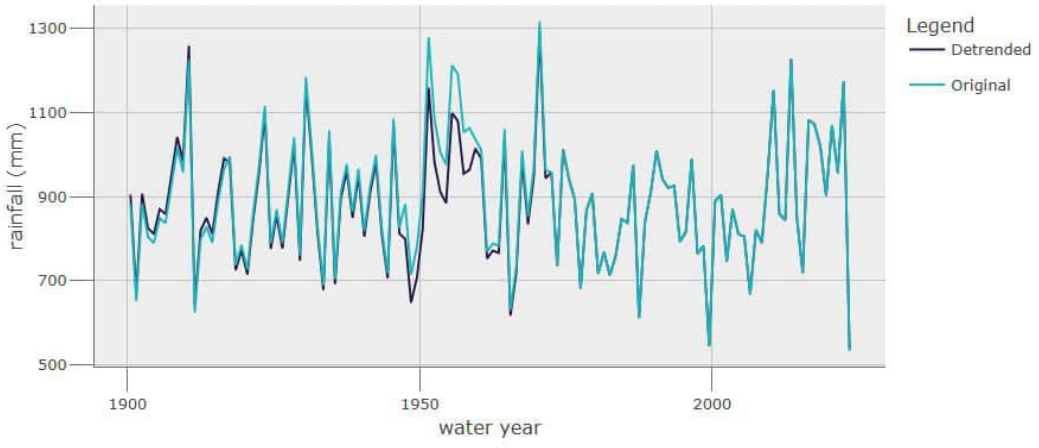
Gauge 090042

Breakpoint Year	Period Slope	Correction Factor
1889	0.9745	1.020
1910	1.0436	0.9525
1939	0.9713	1.0234
1965	0.9940	1.0000



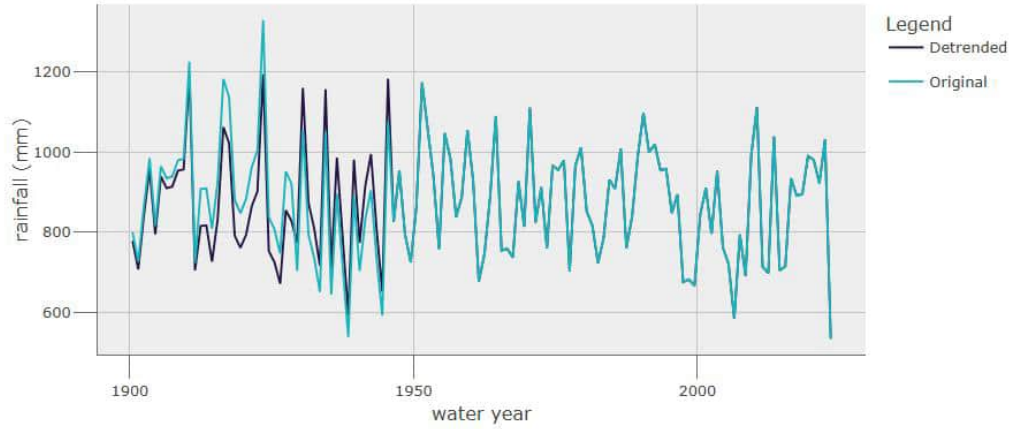
Gauge 090071

Breakpoint Year	Period Slope	Correction Factor
1889	0.9621	1.0262
1917	1.0036	0.9836
1947	1.0889	0.9066
1959	1.0083	0.9791
1972	0.9872	1.0000



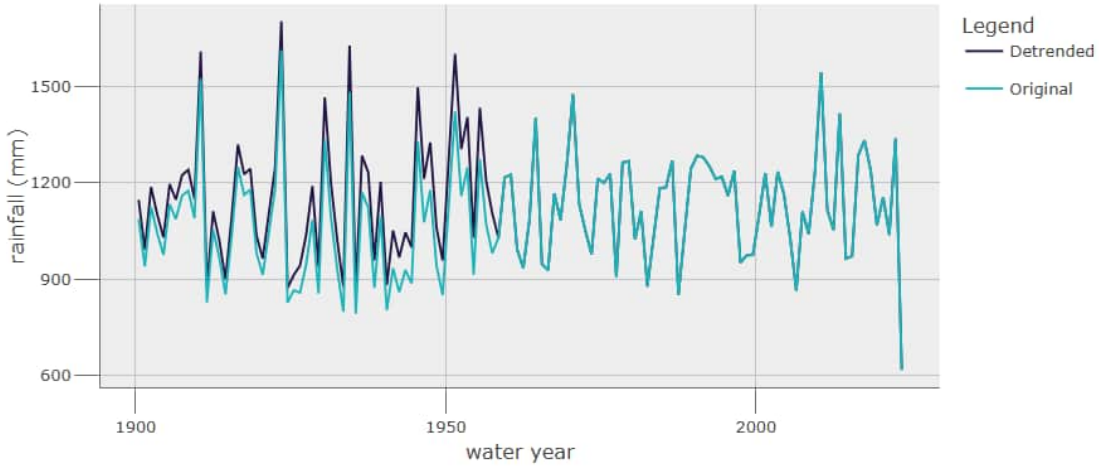
Gauge 090138

Breakpoint Year	Period Slope	Correction Factor
1889	1.0228	0.9734
1912	1.1082	0.8984
1929	0.9048	1.1003
1946	0.9956	1.0000



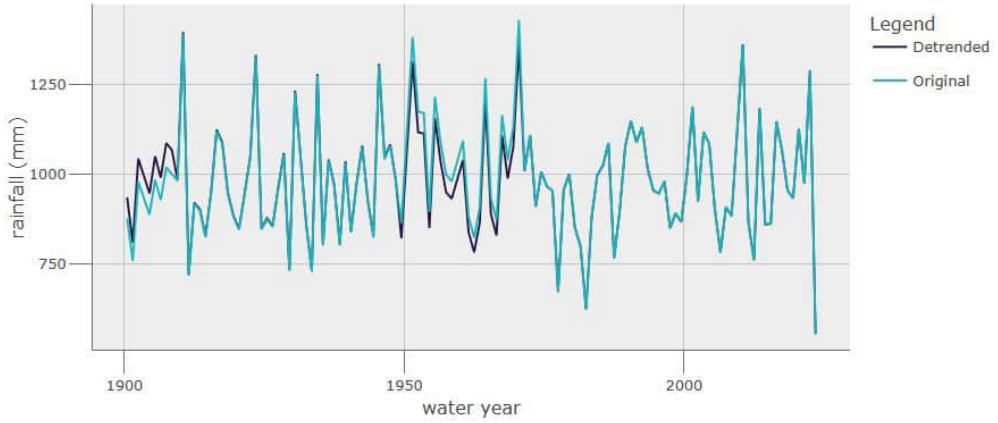
Gauge 090139

Breakpoint Year	Period Slope	Correction Factor
1889	0.9861	1.055
1926	0.9484	1.097
1941	0.9243	1.126
1958	1.0407	1.000



Gauge 090139

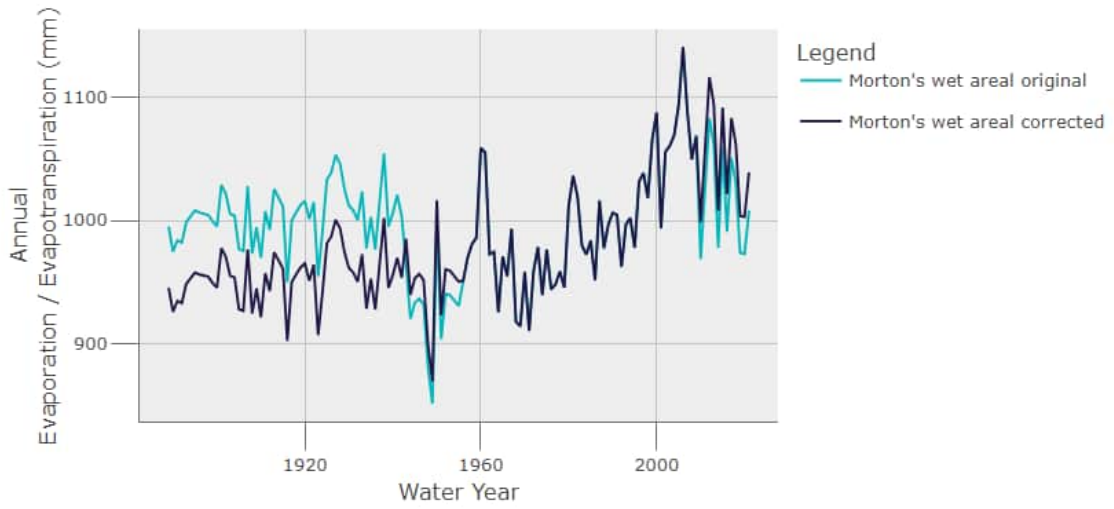
Breakpoint Year	Period Slope	Correction Factor
1889	0.9345	1.0668
1909	0.9933	1.0037
1949	1.0486	0.9508
1974	0.9970	1.0000



E.2 Morton's Wet Areal Evaporation detrending plots

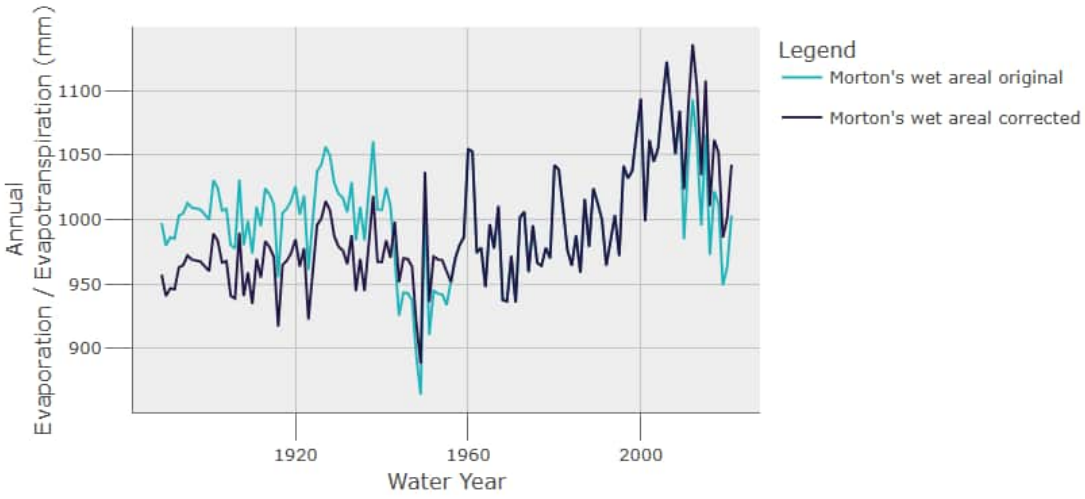
Gauge 090134

Breakpoint Year	Period Slope	Correction Factor
1889	4.377	0.95
1942	4.071	1.02
1956	4.158	1.00
1976	4.288	1.00
2010	4.159	1.03



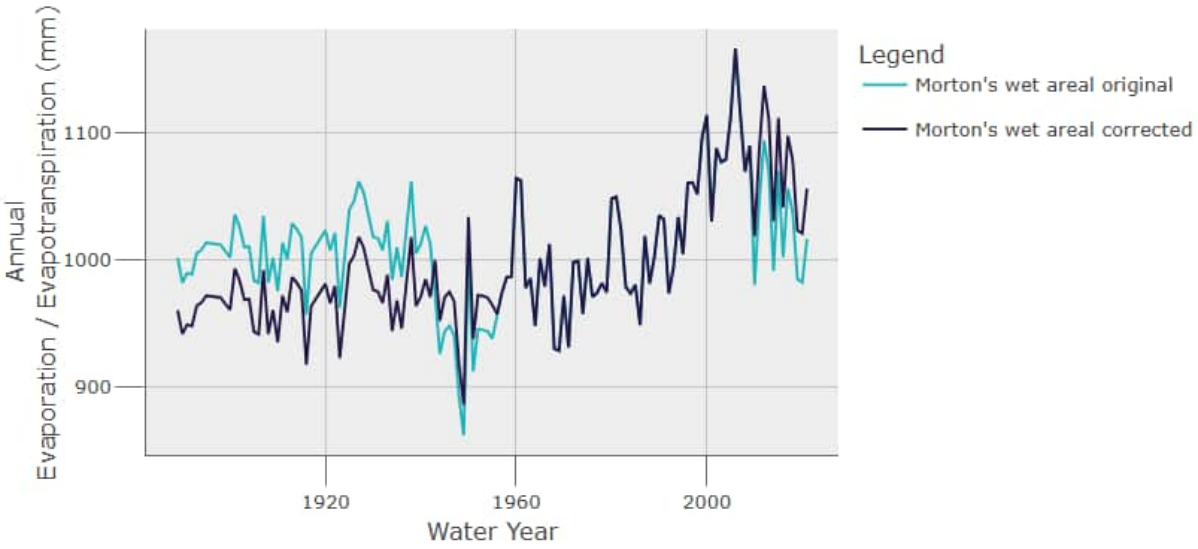
Gauge 090042

Breakpoint Year	Period Slope	Correction Factor
1889	4.396	0.960
1943	4.105	1.028
1956	4.220	1.000
1976	4.301	1.000
2010	4.139	1.039



Gauge 090138

Breakpoint Year	Period Slope	Correction Factor
1889	4.409	0.9588
1943	4.111	1.0282
1956	4.227	1.0000
1976	4.367	1.0000
2010	4.202	1.0393

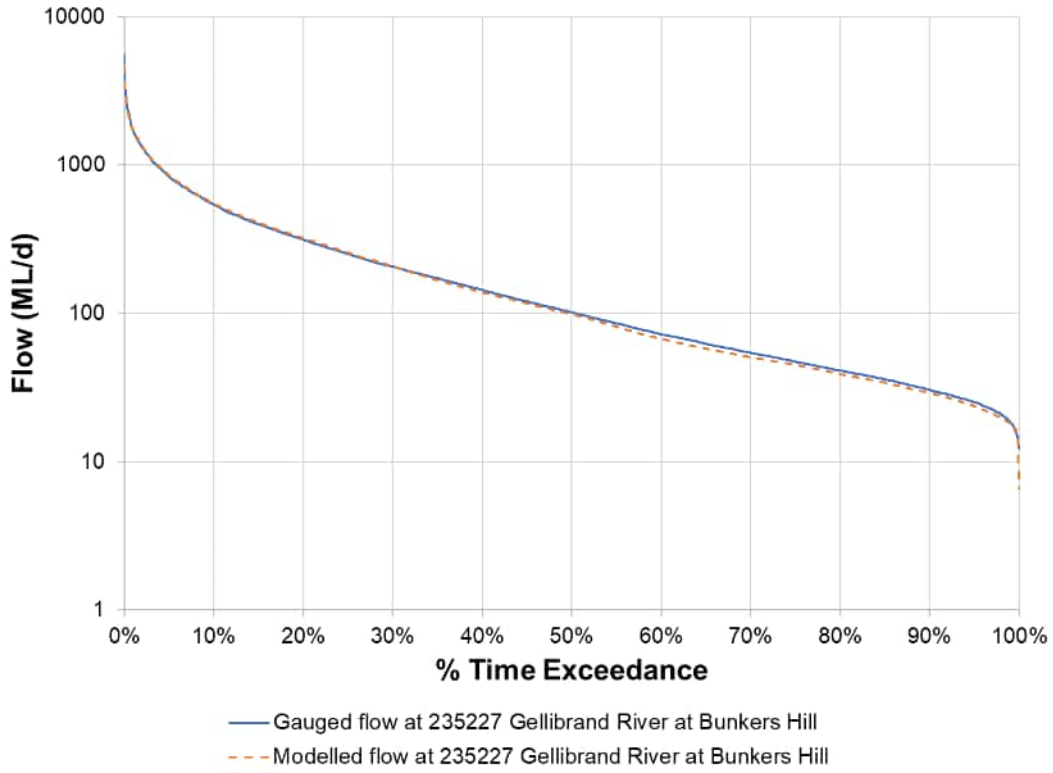


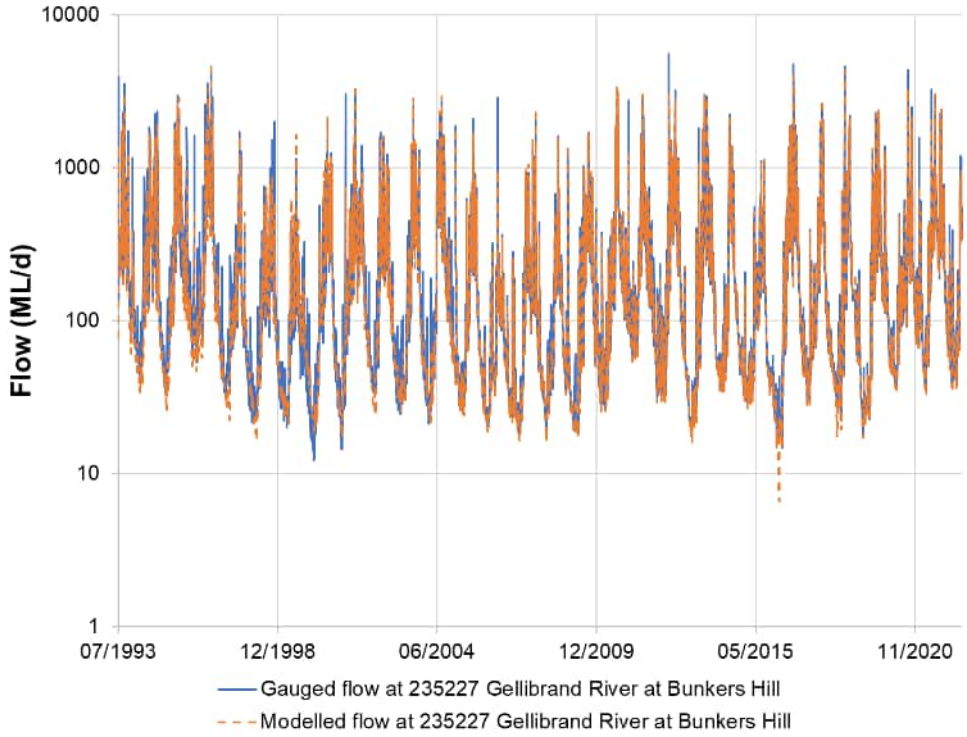
Appendix F Source model verification plots

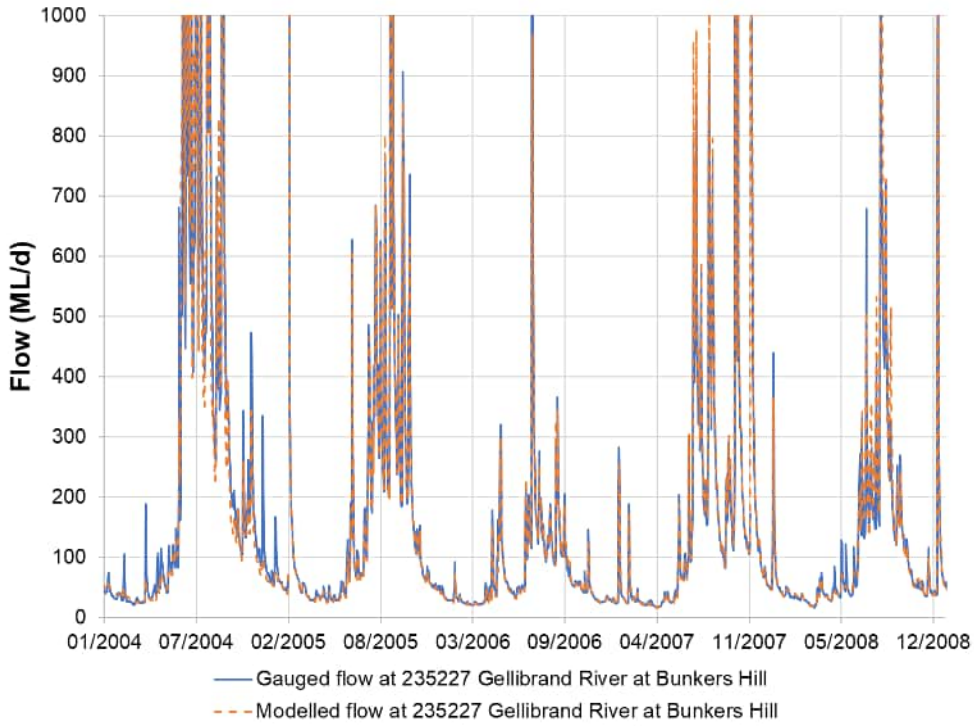
This appendix shows additional Gellibrand Source model verification plots:

- Flow duration curve comparison
- Log time series comparison
- Low flow period (Millennium Drought if available) comparison

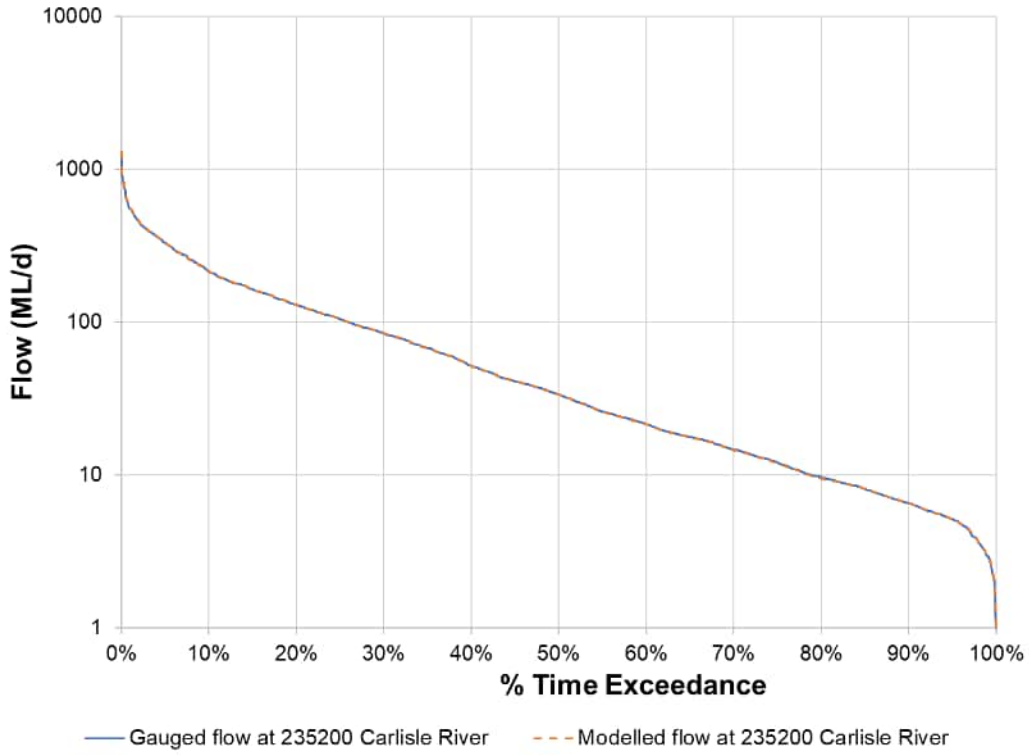
F.1 Gellibrand River at Bunkers Hill (235227)

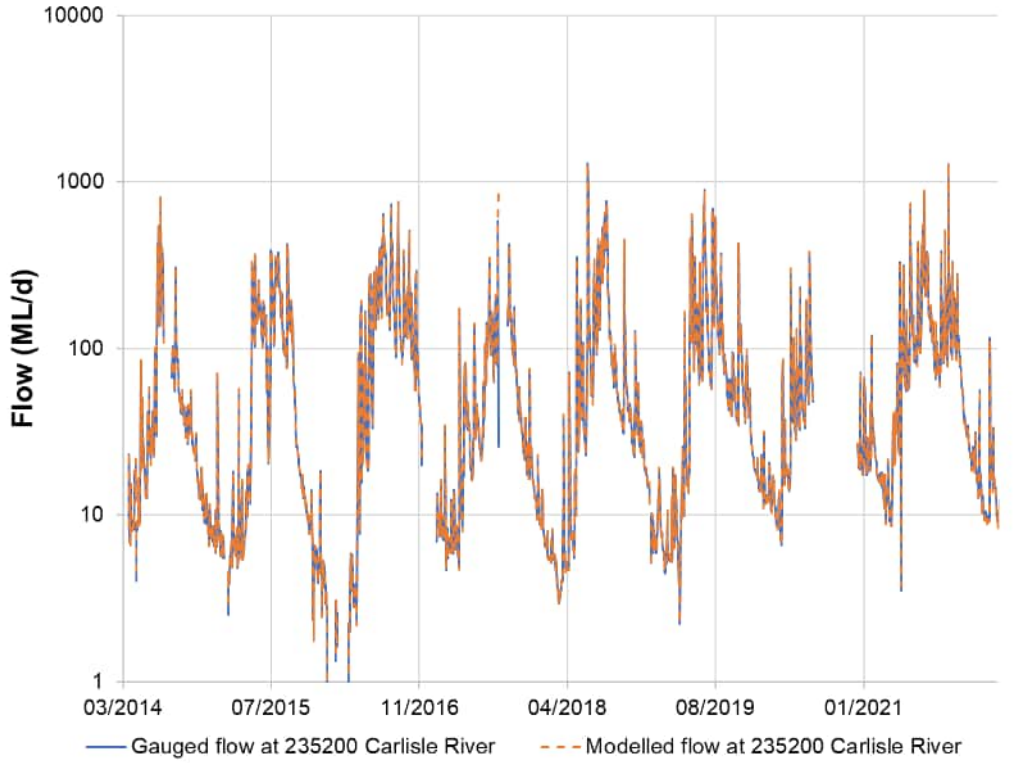


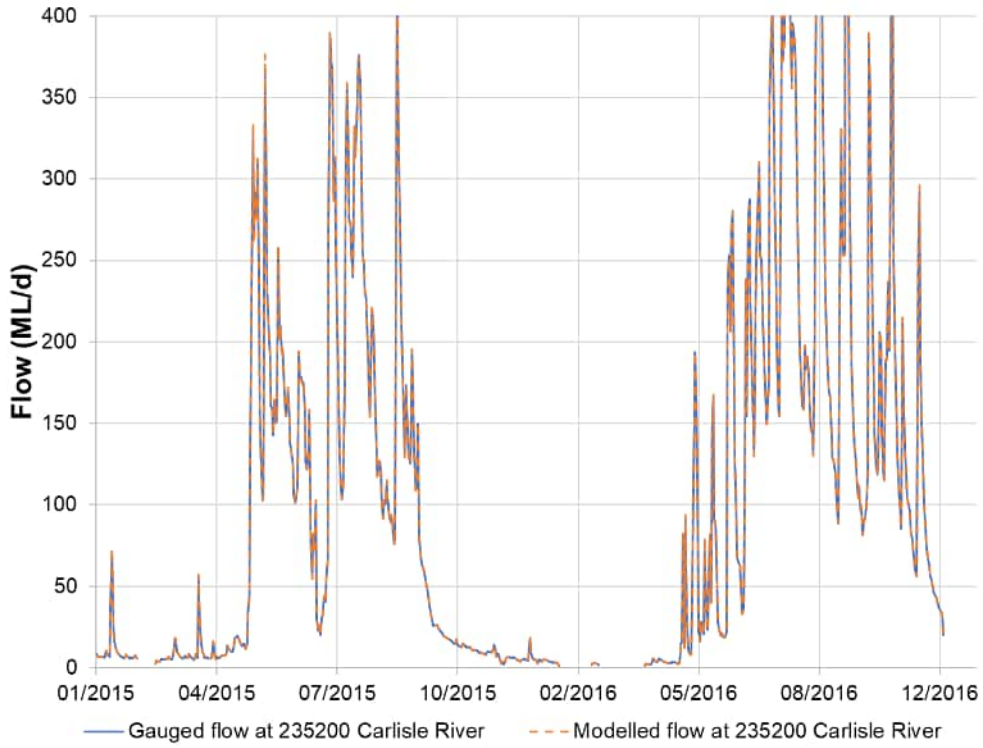

10000
1000
100
10
1
Flow (ML/d)
07/1993
12/1998
06/2004
12/2009
05/2015
11/2020
Gauged flow at 235227 Gellibrand River at Bunkers Hill
Modelled flow at 235227 Gellibrand River at Bunkers Hill


1000
900
800
700
600
500
400
300
200
100
0
Flow (ML/d)
01/2004
07/2004
02/2005
08/2005
03/2006
09/2006
04/2007
11/2007
05/2008
12/2008
Gauged flow at 235227 Gellibrand River at Bunkers Hill
Modelled flow at 235227 Gellibrand River at Bunkers Hill

F.2 Carlisle River at Carlisle (235200)






400
350
300
250
200
150
100
50
0
Flow (ML/d)
01/2015
04/2015
07/2015
10/2015
02/2016
05/2016
08/2016
12/2016
Gauged flow at 235200 Carlisle River
Modelled flow at 235200 Carlisle River

Appendix G Storage rating curves

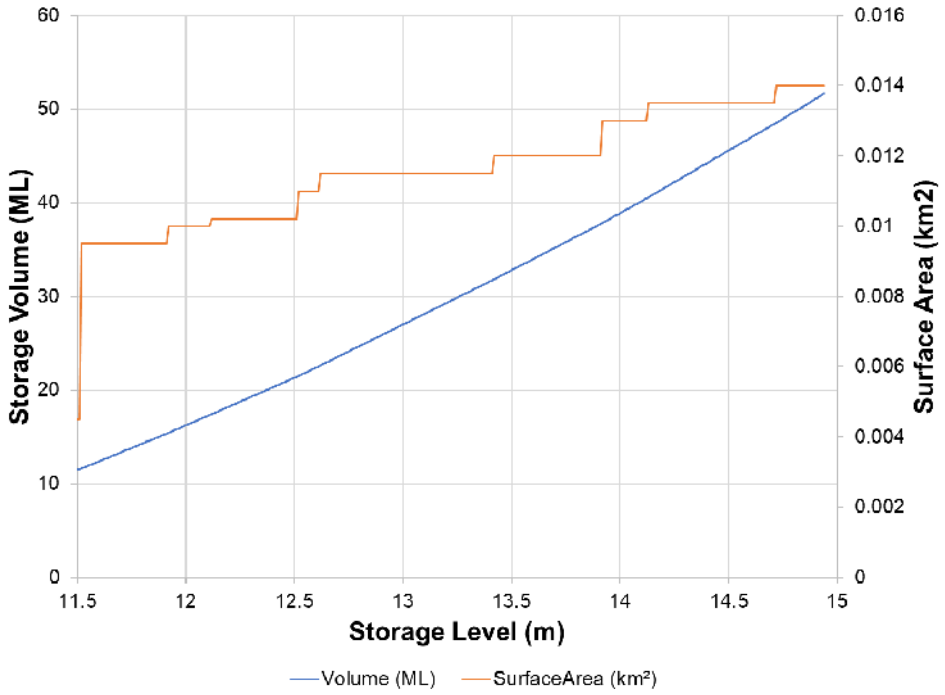


Figure 9-1 Brierly Basin Storage Rating Curve

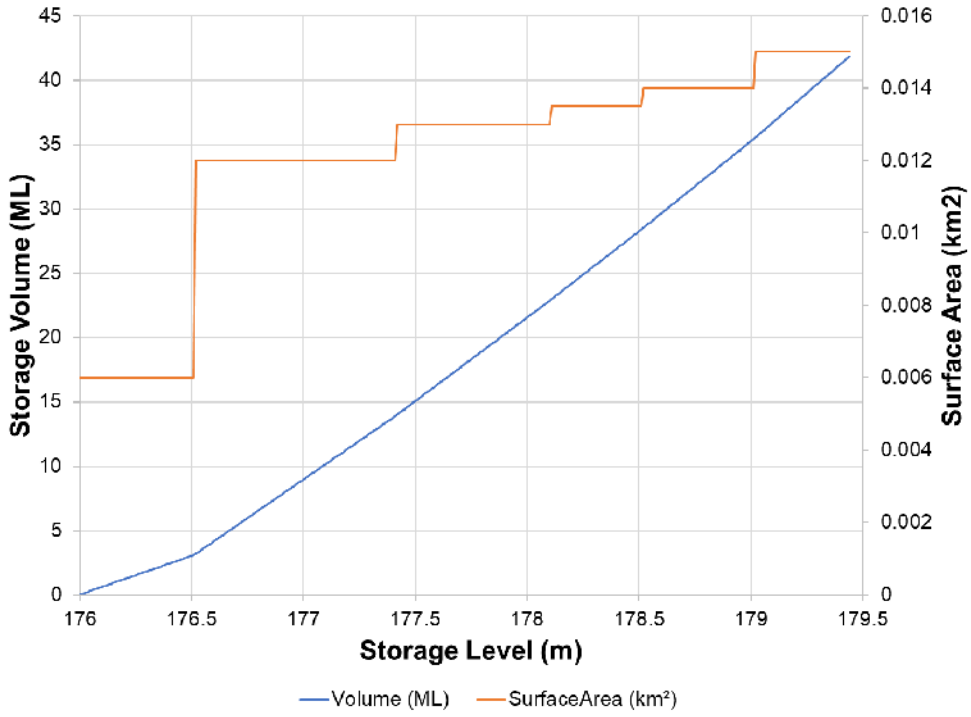


Figure 9-2 Cobden Storage Rating Curve

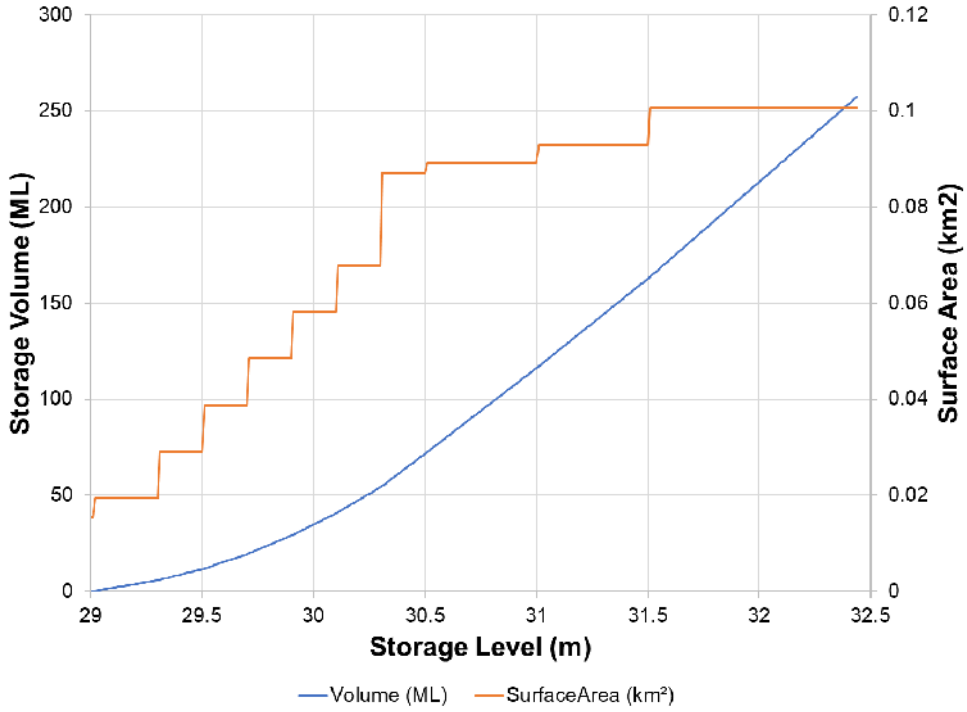


Figure 9-3 Dales Road Basin Storage Rating Curve

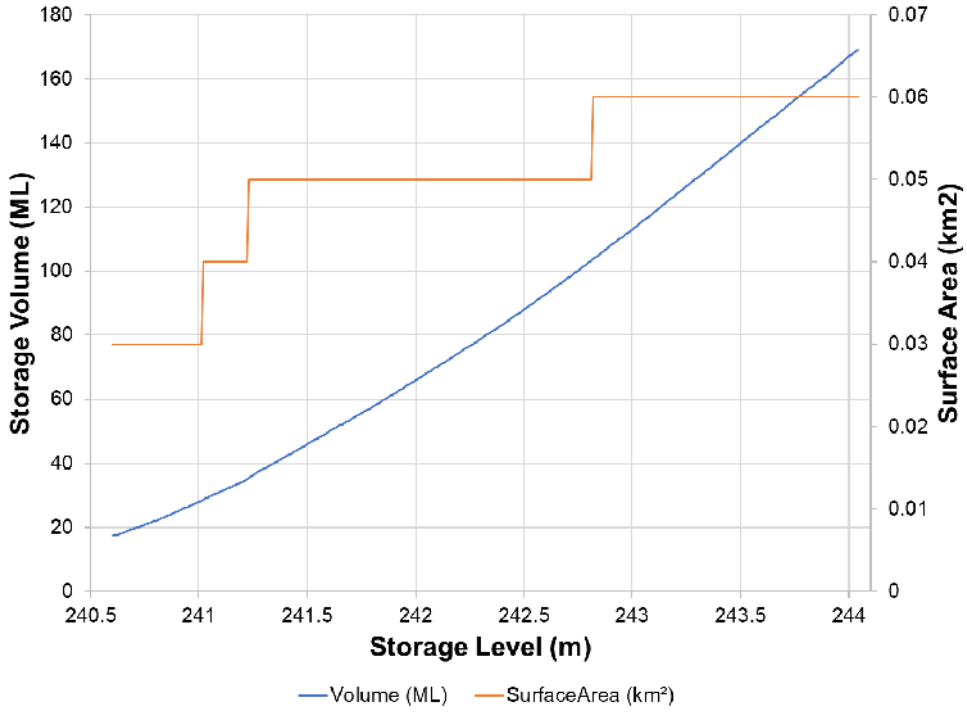


Figure 9-4 Donalds Hill Basin Storage Rating Curve

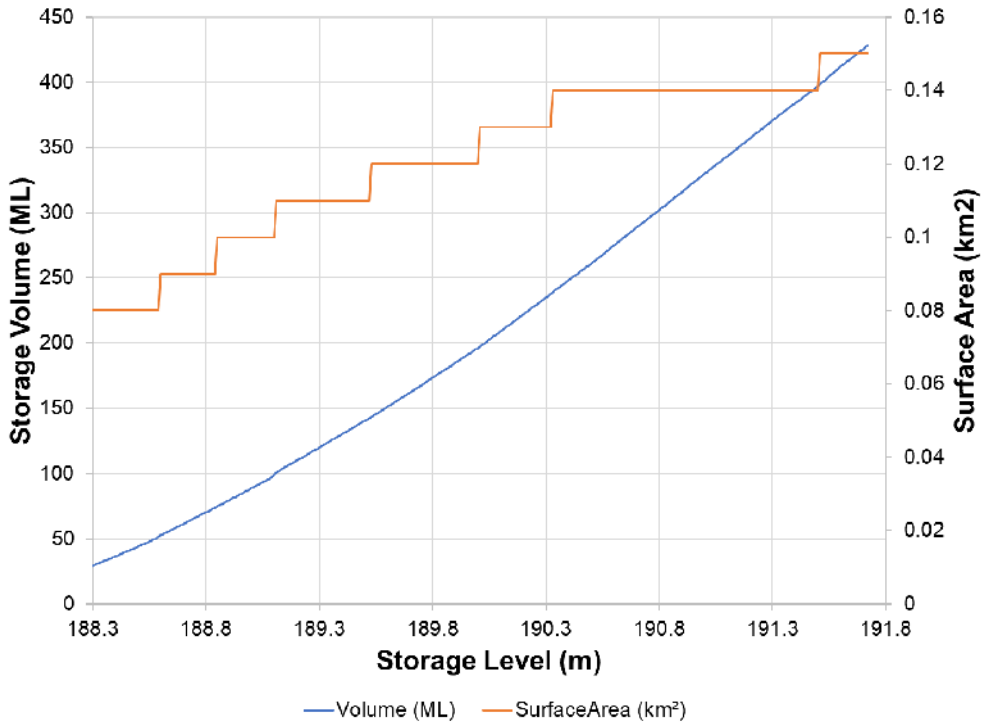


Figure 9-5 Mt Ewen Basin Storage Rating Curve

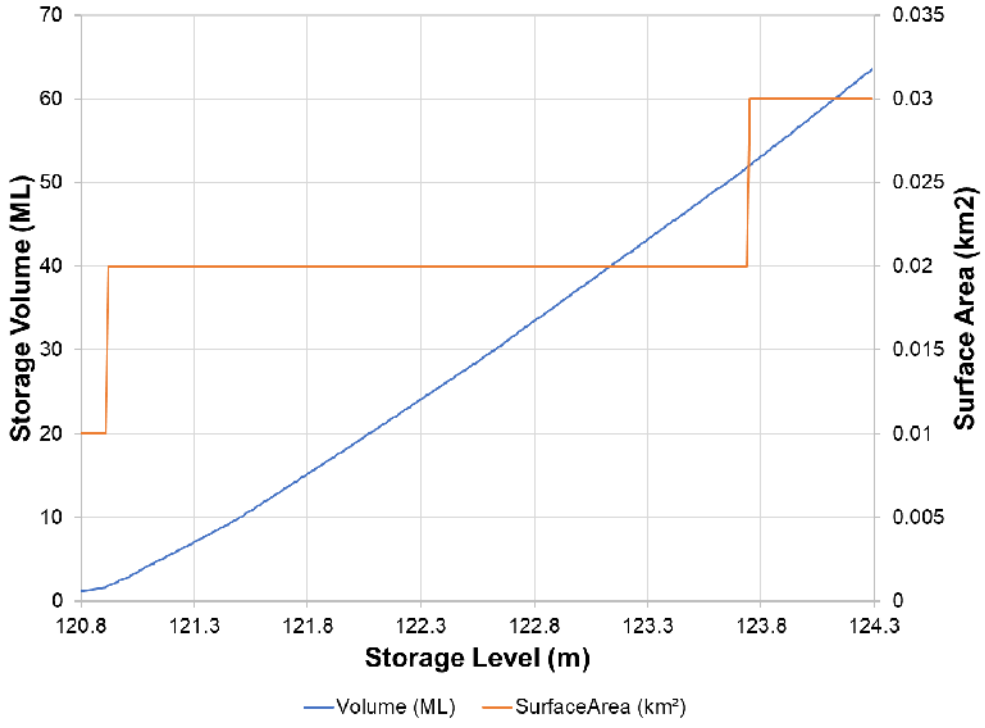


Figure 9-6 Plantation Road Basin Storage Rating Curve

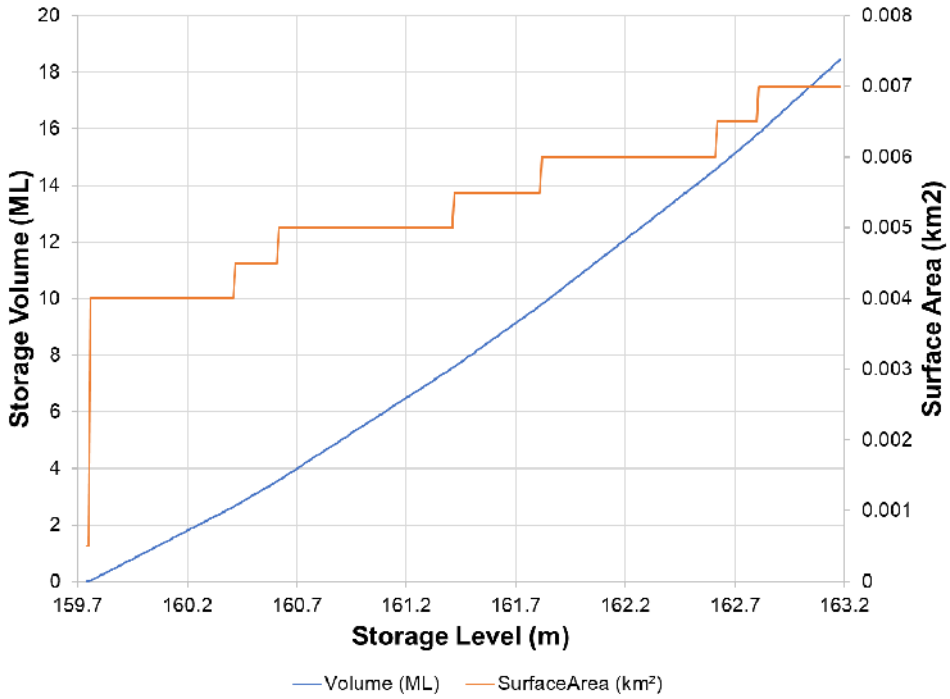


Figure 9-7 Simpson Basin Storage Rating Curve

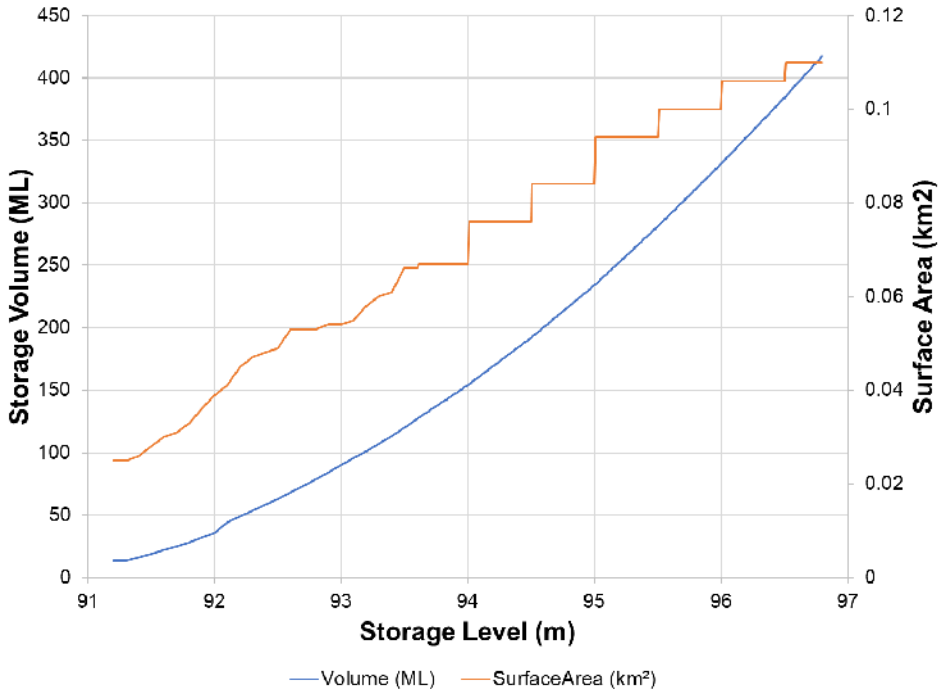
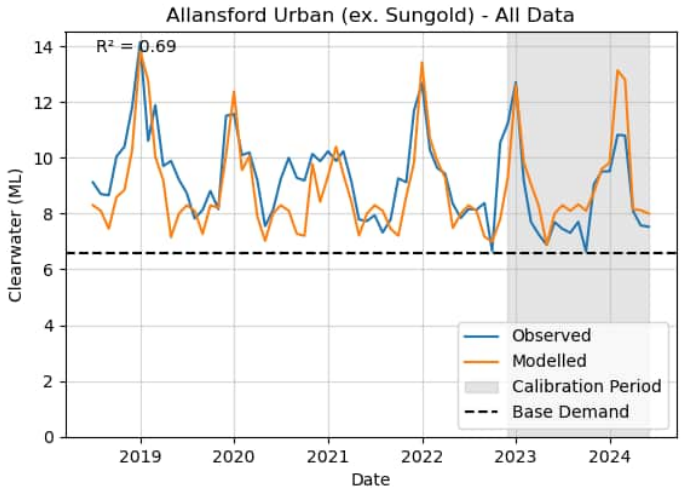
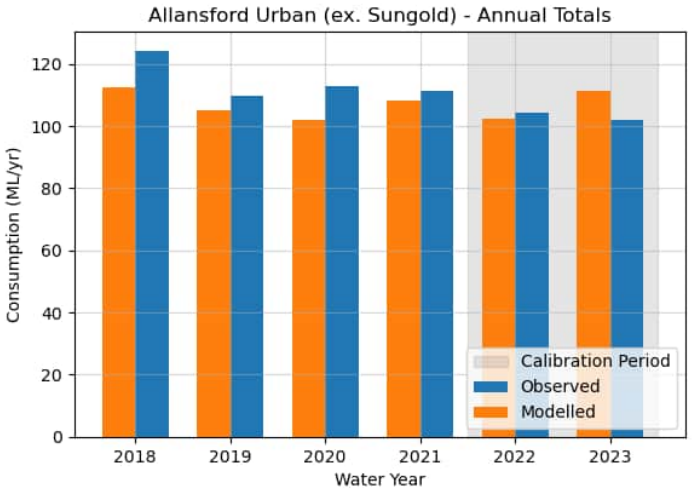


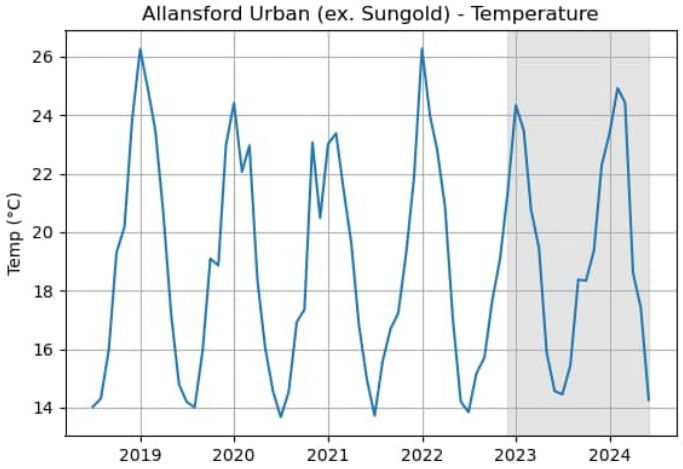
Figure 9-8 Tank Hill Reservoir Storage Rating Curve

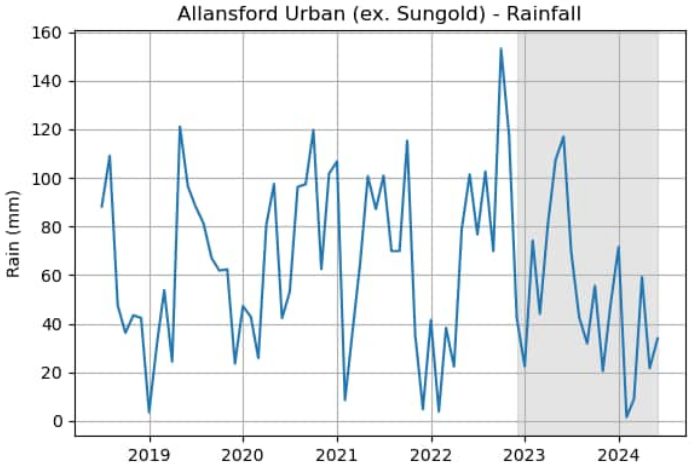
Appendix H Wannon Water urban demand regression plots

H.1 Allansford urban

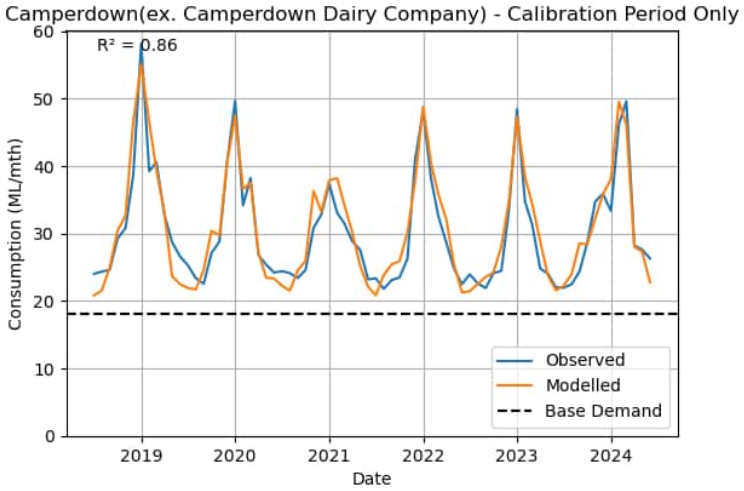


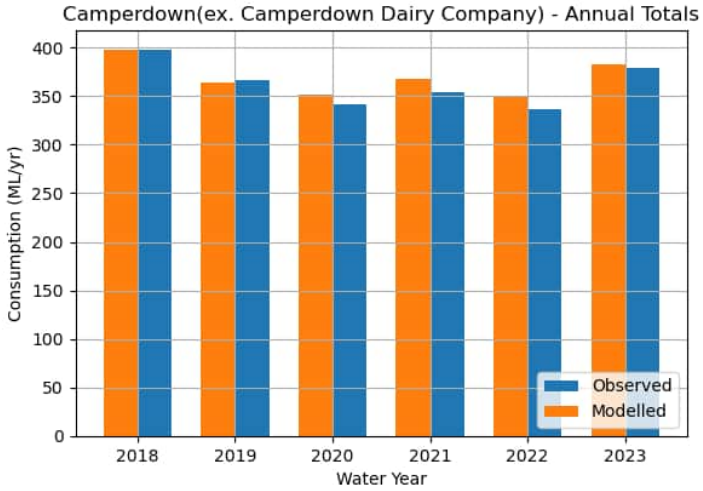


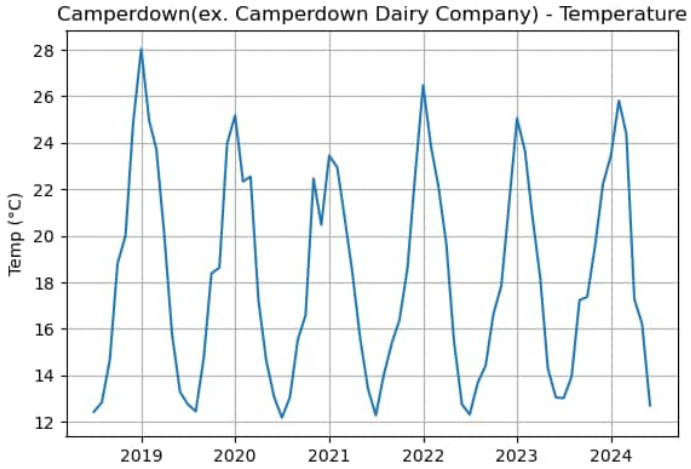


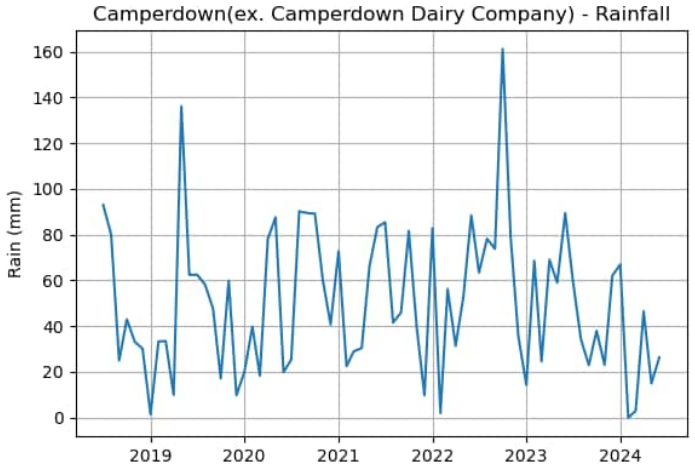


H.2 Camperdown urban

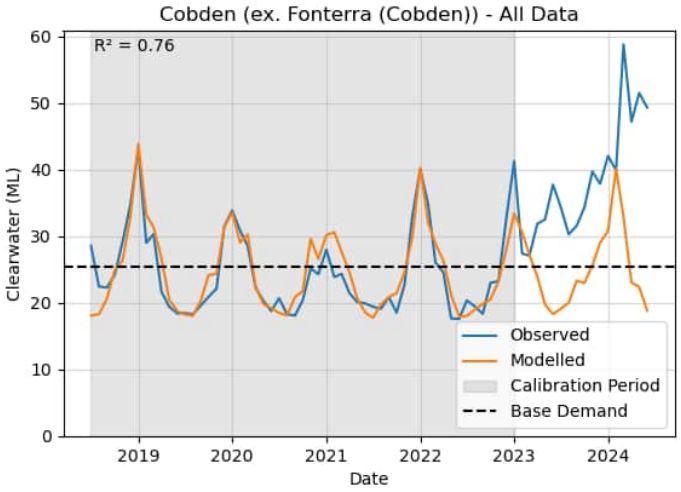


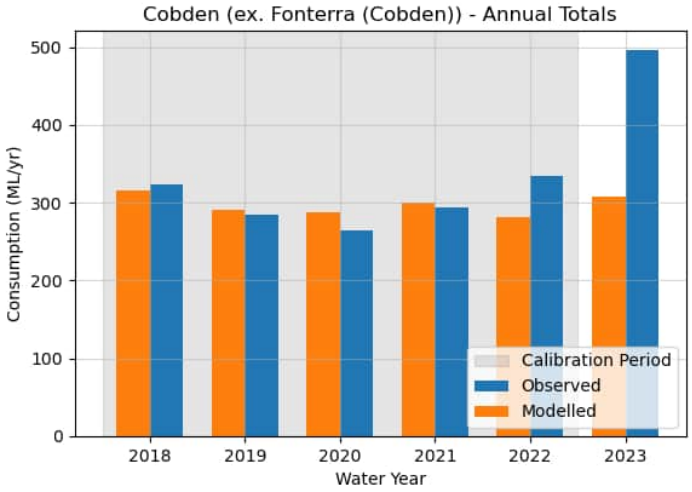


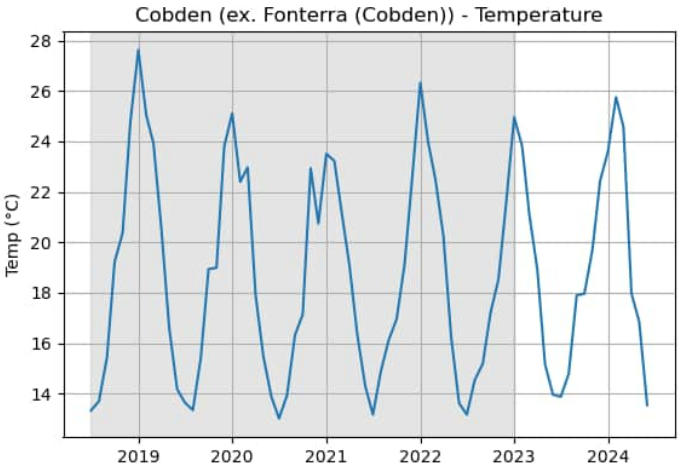


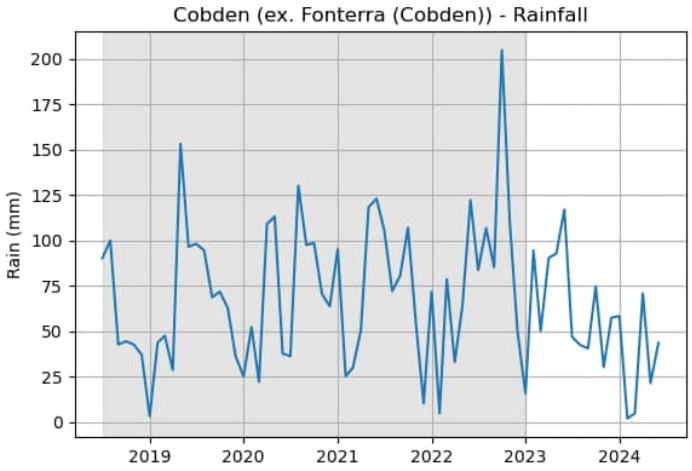


H.3 Cobden urban

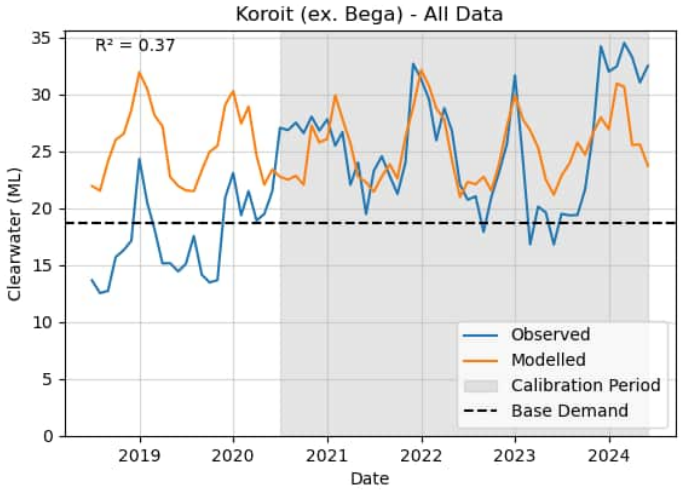


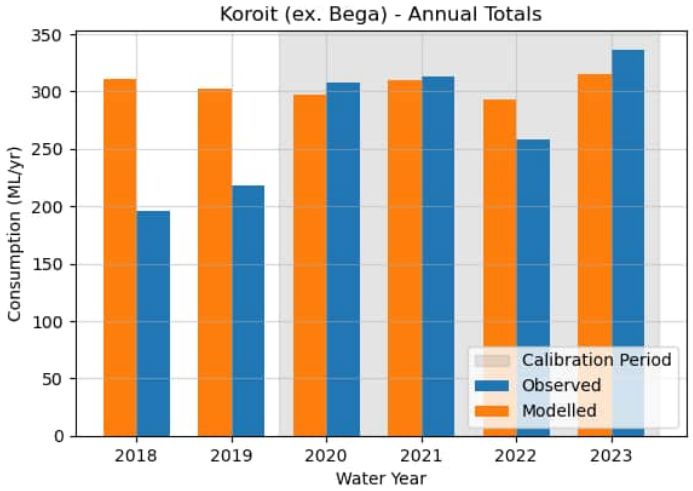


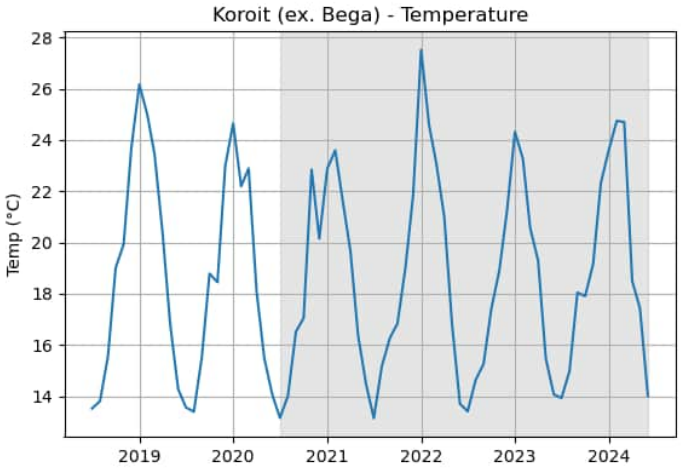


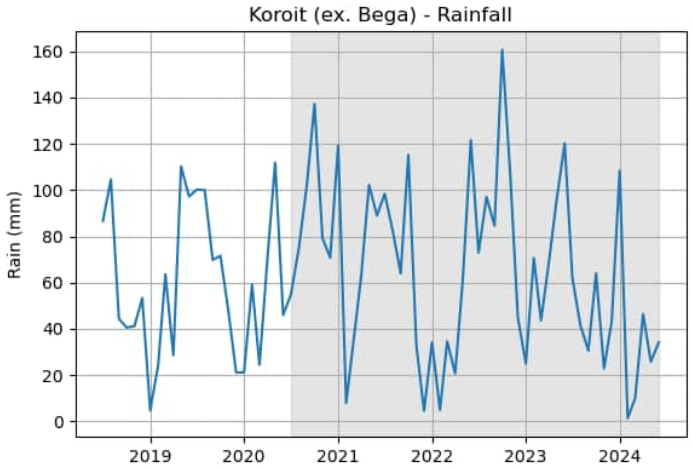


H.4 Koroit urban

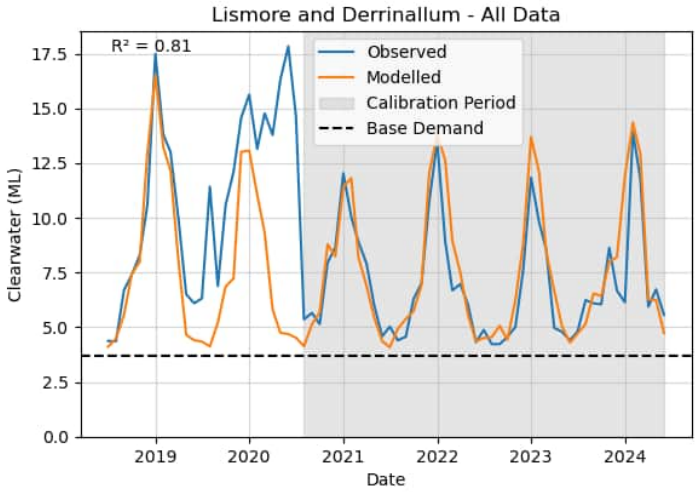


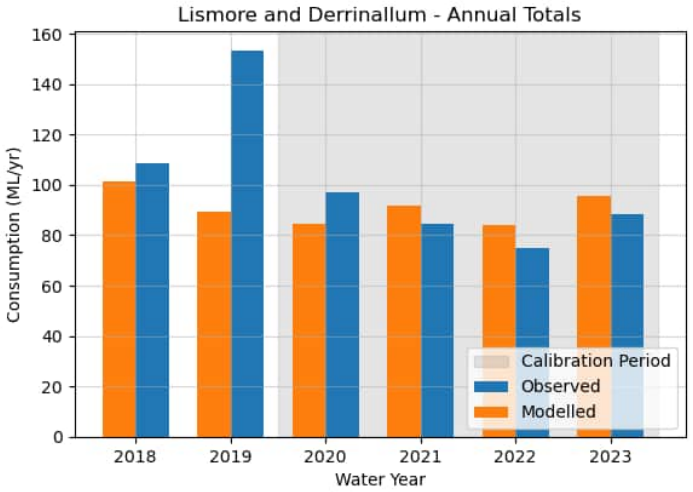


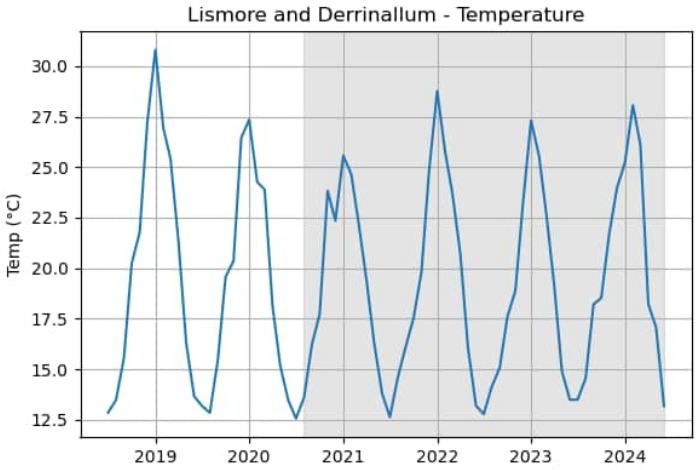


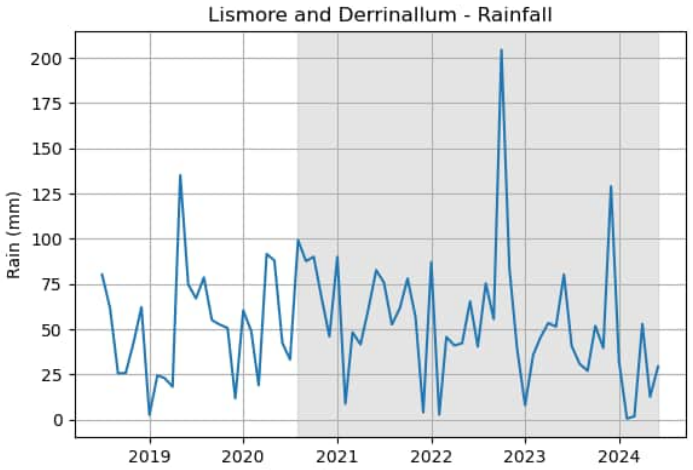


H.5 Lismore and Derrinallum urban

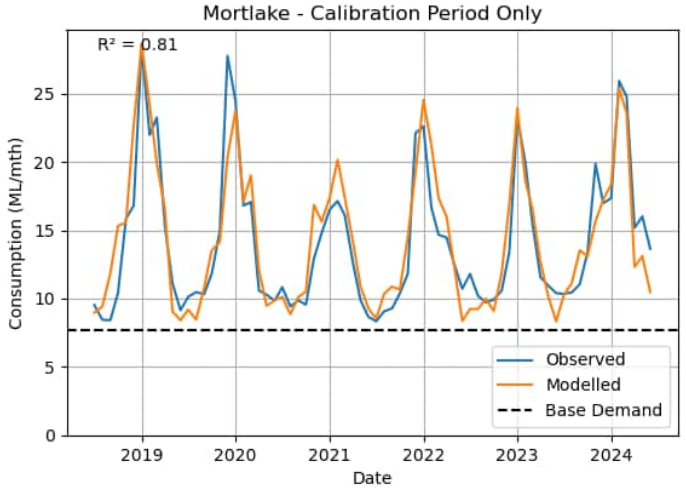


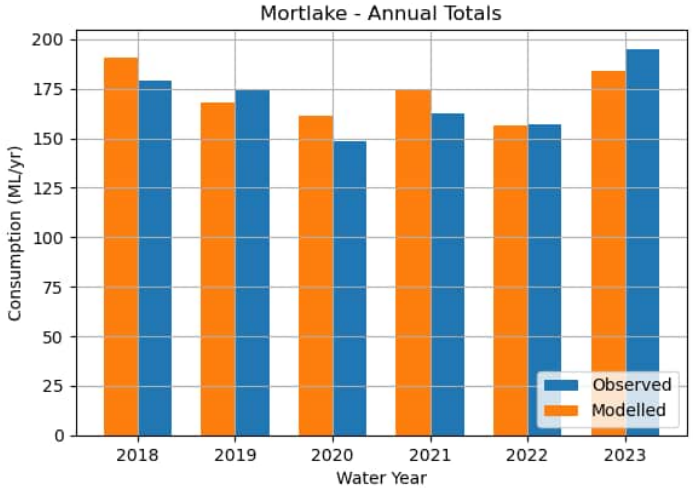


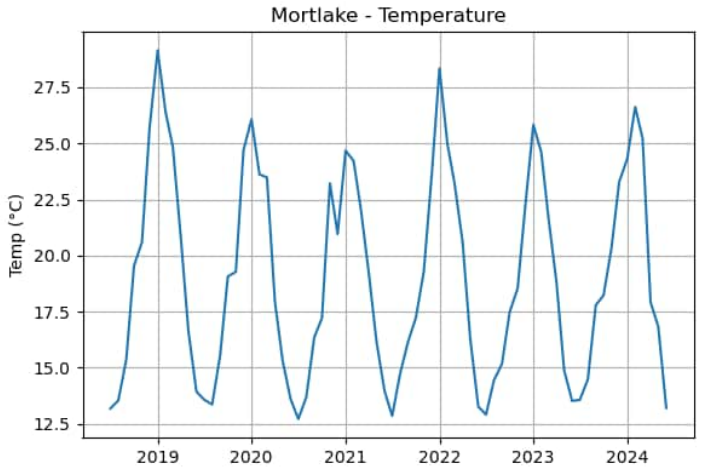


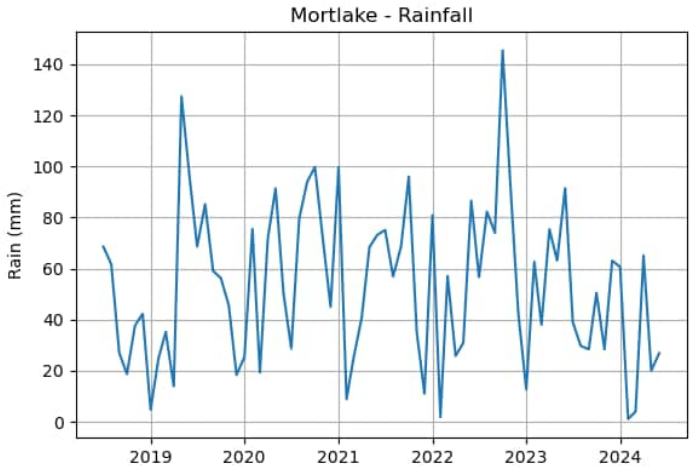


H.6 Mortlake urban

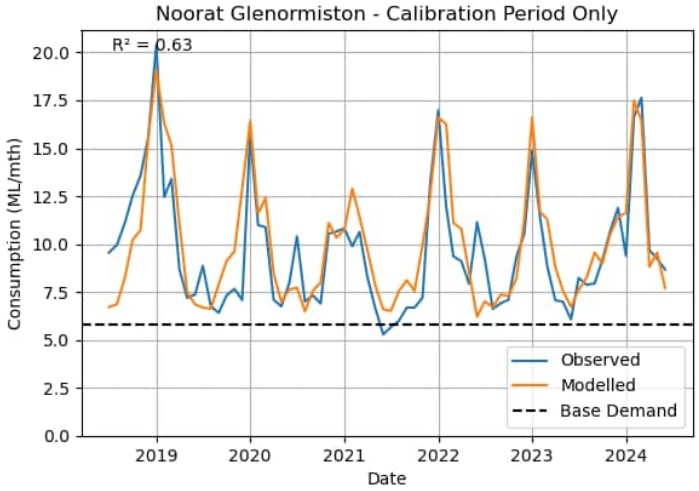


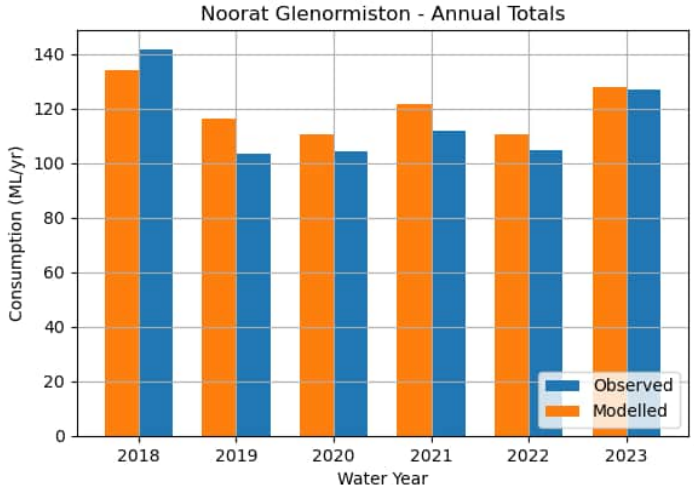


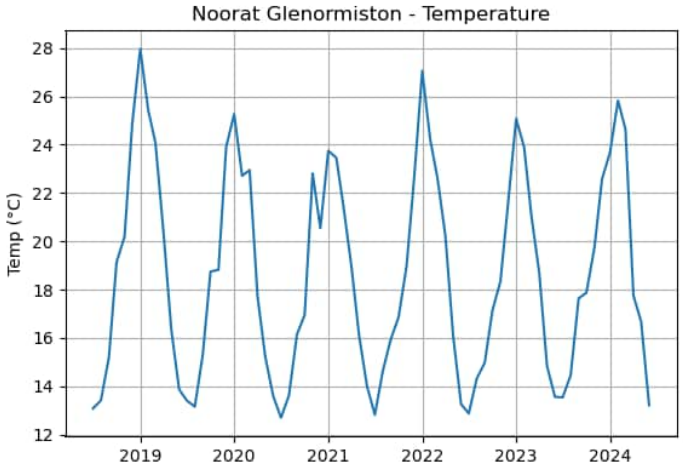


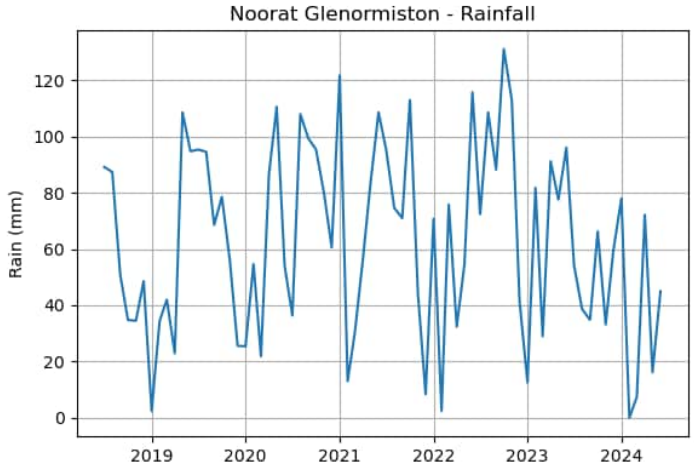


H.7 Noorat Glenormiston urban

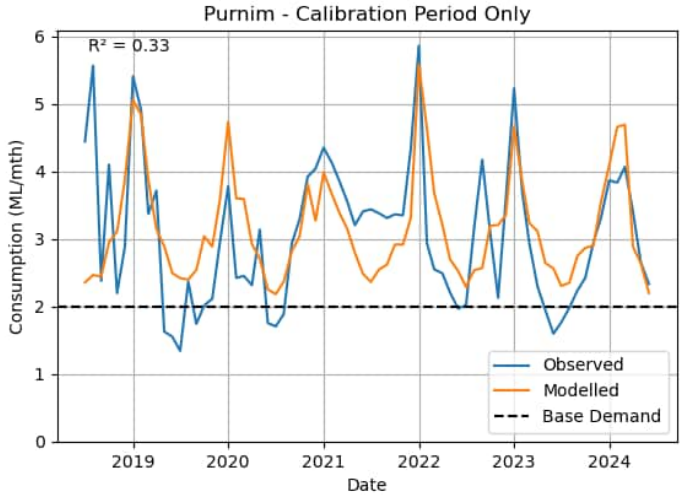


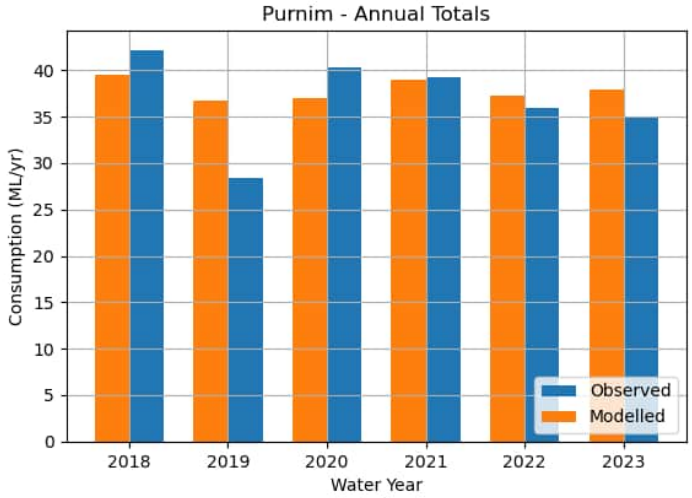


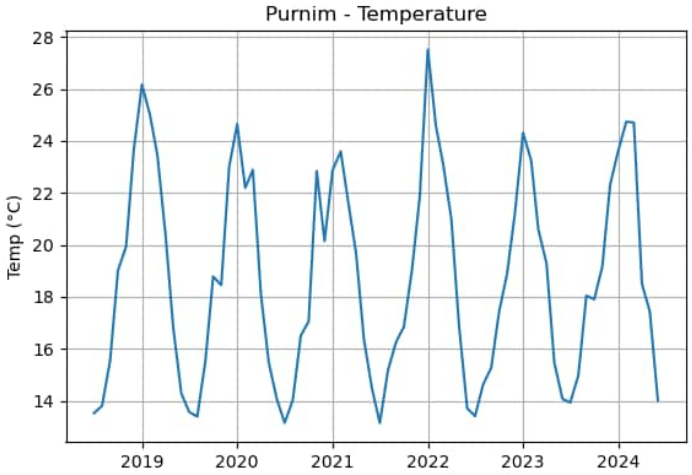


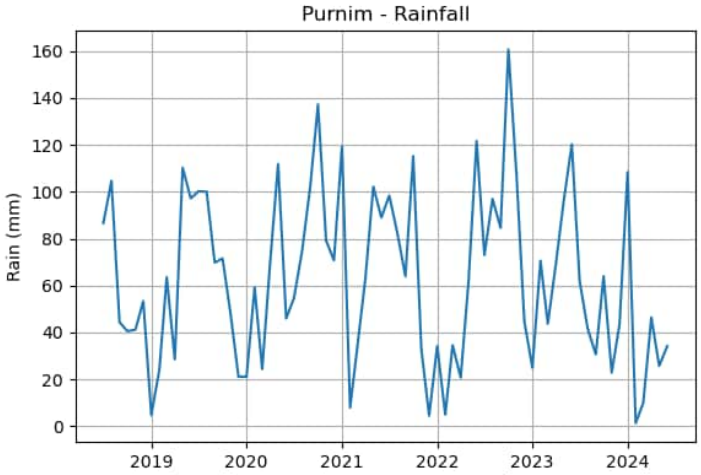


H.8 Purnim urban

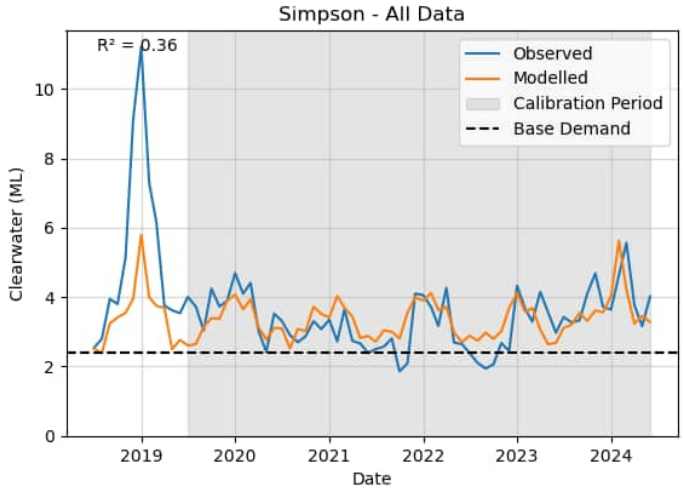


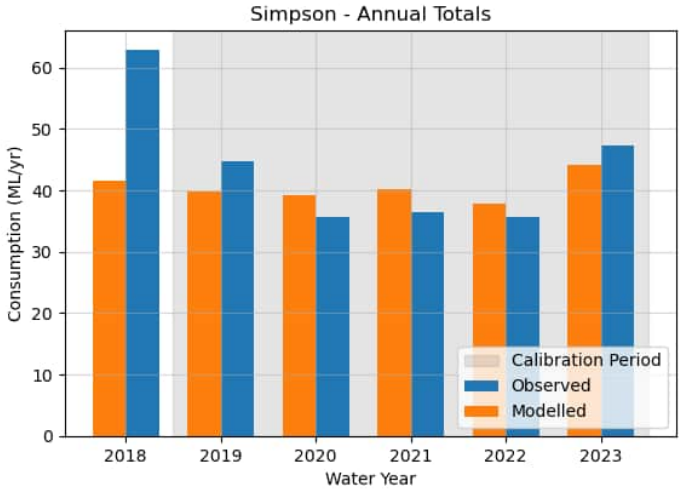


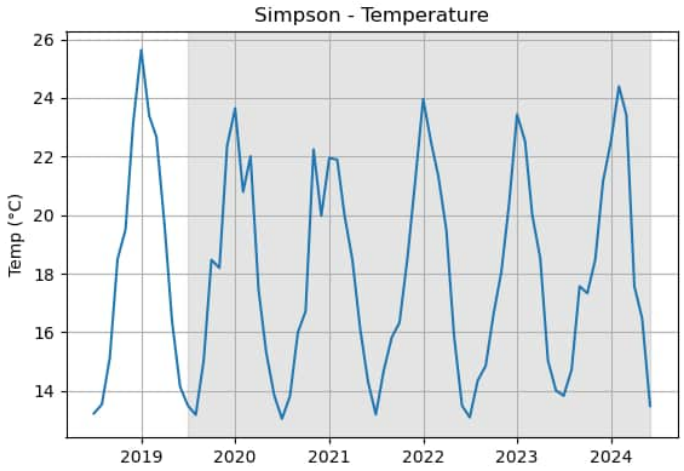


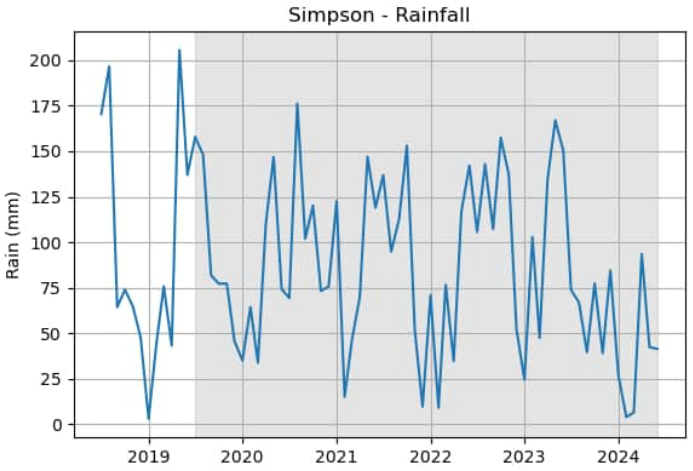


H.9 Simpson urban

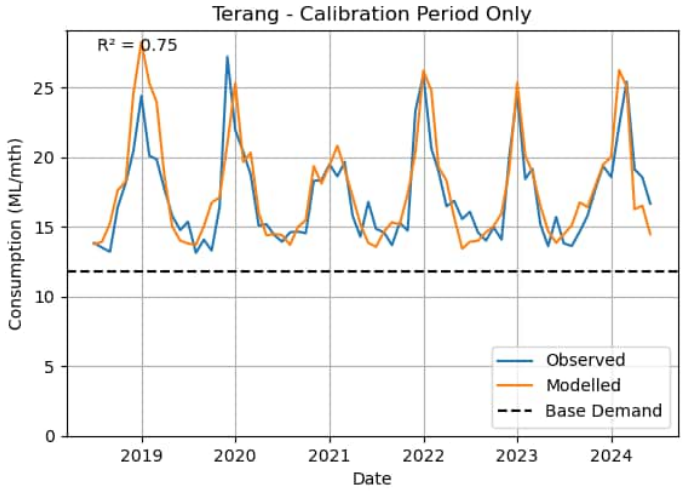


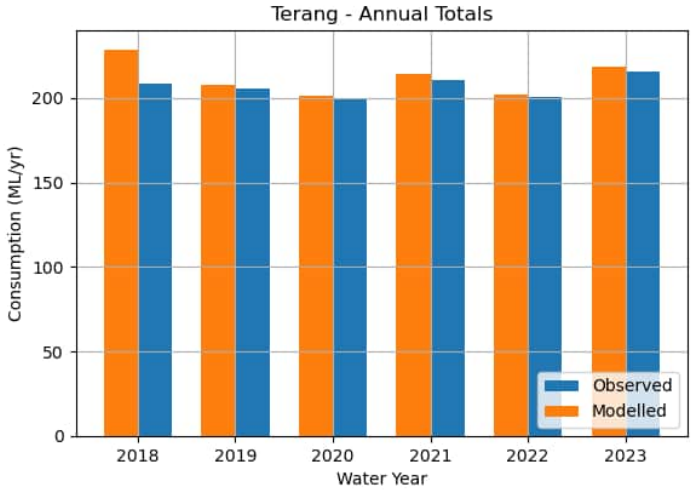


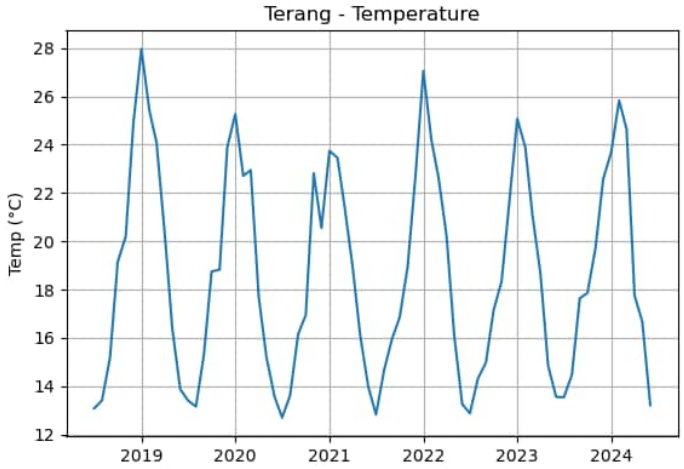


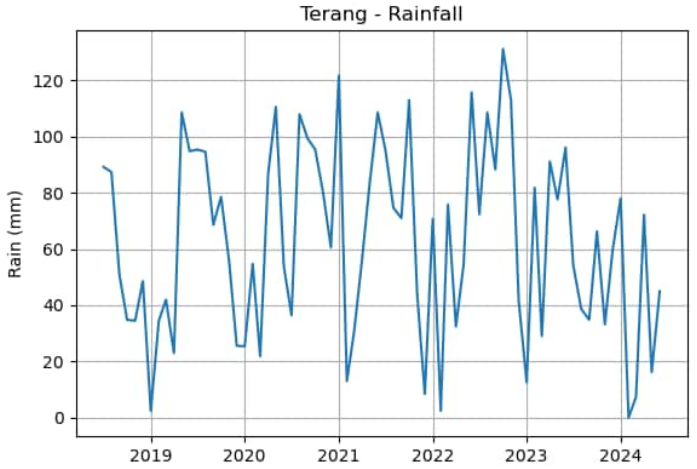


H.10 Terang urban

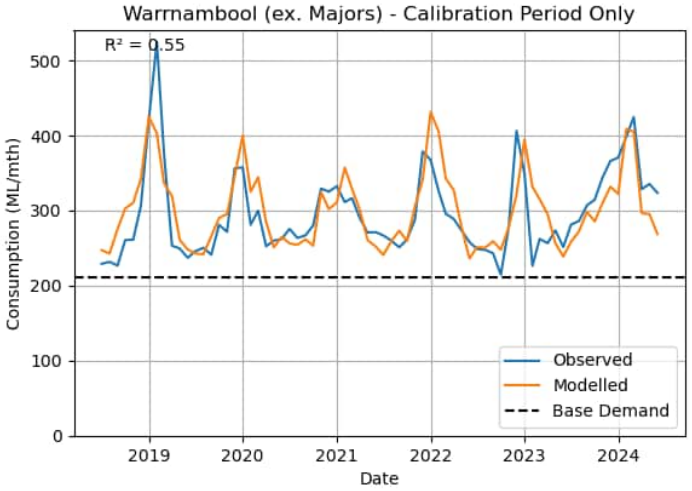


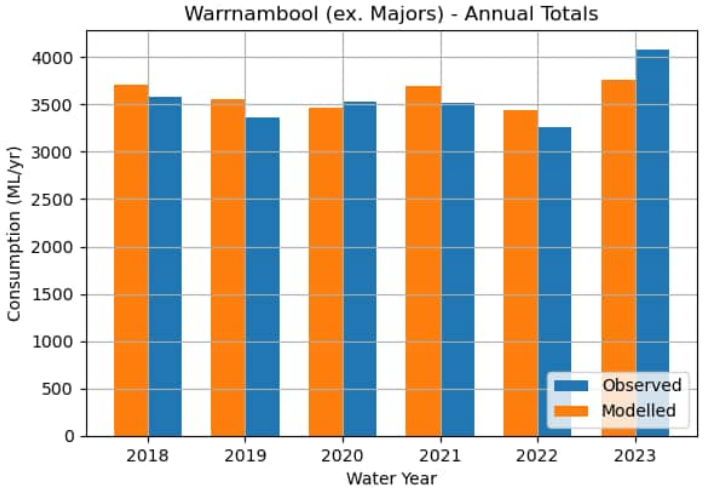


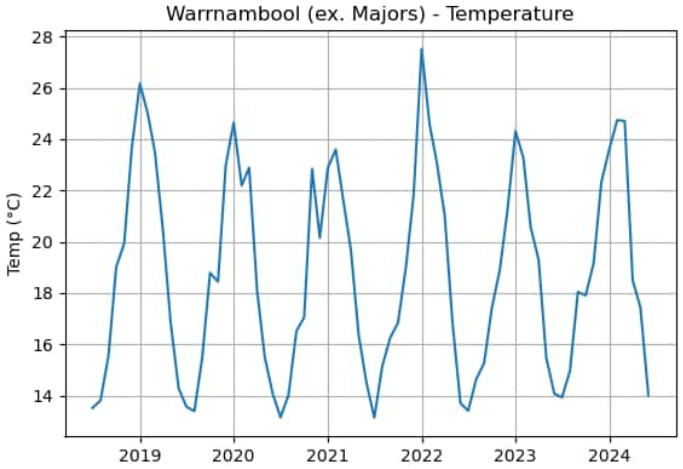


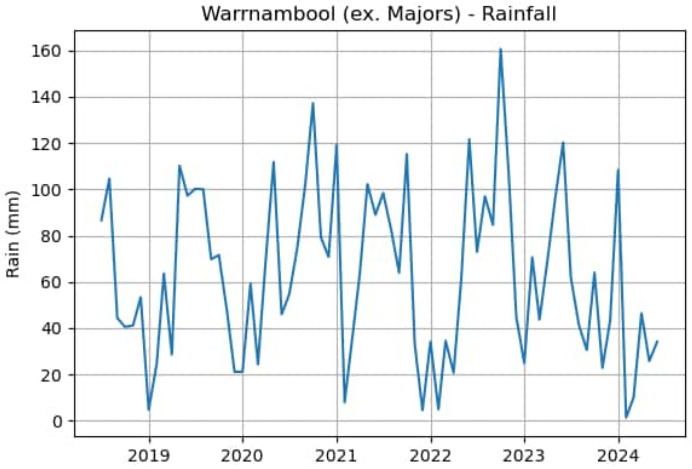


H.11 Warrnambool urban









Appendix I Calculation of base demand percentage

The Otway Source model requires base demand to be expressed as a percentage of design drought demand in a given month. The calculation of restrictable demand and base demand percentage is based on a typical dry year demand. In this case, the 2006/07 drought water year has been adopted to calculate the base demand as a percentage of drought demand in a given month. The base demand percentage and restrictable demand has been calculated and reported for each urban demand centre for input into the Otway Source model.

Table 9-1 Allansford urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	12.1	6.9	5.1	57%
February	13.4	6.9	6.5	52%
March	10.2	6.9	3.3	68%
April	9.3	6.9	2.3	75%
May	7.4	6.9	0.5	93%
June	8.1	6.9	1.1	86%
July	8.4	6.9	1.4	83%
August	8.1	6.9	1.1	86%
September	7.5	6.9	0.5	93%
October	8.7	6.9	1.7	80%
November	9.3	6.9	2.3	75%
December	10.2	6.9	3.3	68%

Table 9-2 Camperdown urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	45.0	18.1	26.8	40%
February	51.2	18.1	33.1	35%
March	39.1	18.1	20.9	46%
April	33.6	18.1	15.5	54%
May	26.7	18.1	8.5	68%
June	21.0	18.1	2.9	86%
July	21.4	18.1	3.3	85%
August	24.2	18.1	6.0	75%
September	26.4	18.1	8.3	69%
October	31.6	18.1	13.5	57%
November	34.8	18.1	16.7	52%
December	37.8	18.1	19.7	48%

Table 9-3 Cobden urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	32.2	15.4	16.8	48%
February	41.4	15.4	26.0	37%
March	31.0	15.4	15.6	50%
April	27.3	15.4	11.9	56%
May	22.0	15.4	6.6	70%
June	17.4	15.4	2.0	89%
July	18.0	15.4	2.6	86%
August	19.8	15.4	4.4	78%
September	21.9	15.4	6.5	70%
October	25.7	15.4	10.3	60%
November	27.3	15.4	11.9	56%
December	30.1	15.4	14.7	51%

Table 9-4 Koroit urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	28.2	18.7	9.5	66%
February	31.6	18.7	12.9	59%
March	29.1	18.7	10.4	64%
April	27.3	18.7	8.6	69%
May	22.9	18.7	4.2	82%
June	21.0	18.7	2.3	89%
July	22.3	18.7	3.6	84%
August	24.2	18.7	5.5	77%
September	23.7	18.7	5.0	79%
October	26.7	18.7	7.9	70%
November	27.6	18.7	8.9	68%
December	29.5	18.7	10.7	64%

Table 9-5 Lismore and Derrinallum urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	28.2	3.7	8.7	30%
February	31.6	3.7	11.1	25%
March	29.1	3.7	8.1	32%
April	27.3	3.7	4.1	48%
May	22.9	3.7	1.9	67%
June	21.0	3.7	0.5	88%
July	22.3	3.7	0.6	86%
August	24.2	3.7	1.6	70%
September	23.7	3.7	2.3	62%
October	26.7	3.7	4.0	48%
November	27.6	3.7	5.3	41%
December	29.5	3.7	8.1	32%

Table 9-6 Mortlake urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	21.7	7.7	14.0	35%
February	27.4	7.7	19.8	28%
March	20.2	7.7	12.5	38%
April	16.2	7.7	8.5	47%
May	11.5	7.7	3.8	67%
June	9.0	7.7	1.3	85%
July	9.3	7.7	1.6	83%
August	11.5	7.7	3.8	67%
September	12.6	7.7	4.9	61%
October	16.1	7.7	8.4	48%
November	18.0	7.7	10.3	43%
December	19.8	7.7	12.2	39%

Table 9-7 Noorat Glenormiston urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	14.6	5.8	8.7	40%
February	18.2	5.8	12.4	32%
March	12.7	5.8	6.9	46%
April	11.1	5.8	5.3	53%
May	8.4	5.8	2.5	70%
June	6.9	5.8	1.1	85%
July	7.1	5.8	1.3	82%
August	8.4	5.8	2.5	70%
September	8.7	5.8	2.9	67%
October	10.5	5.8	4.7	55%
November	11.7	5.8	5.9	50%
December	12.4	5.8	6.6	47%

Table 9-8 Purnim urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	5.3	2.0	3.2	39%
February	5.0	2.0	3.0	41%
March	3.7	2.0	1.7	55%
April	3.3	2.0	1.3	62%
May	3.1	2.0	1.1	66%
June	2.4	2.0	0.4	85%
July	2.2	2.0	0.1	94%
August	2.5	2.0	0.4	82%
September	2.7	2.0	0.7	76%
October	2.8	2.0	0.7	73%
November	3.3	2.0	1.3	62%
December	3.7	2.0	1.7	55%

Table 9-9 Simpson urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	3.4	2.4	1.0	70%
February	5.6	2.4	3.2	43%
March	4.0	2.4	1.6	59%
April	3.6	2.4	1.2	66%
May	3.1	2.4	0.7	77%
June	2.7	2.4	0.3	88%
July	3.1	2.4	0.7	77%
August	3.1	2.4	0.7	77%
September	3.3	2.4	0.9	72%
October	3.7	2.4	1.3	64%
November	3.6	2.4	1.2	66%
December	4.0	2.4	1.6	59%

Table 9-10 Terang urban base demand assumptions (ML/mth)

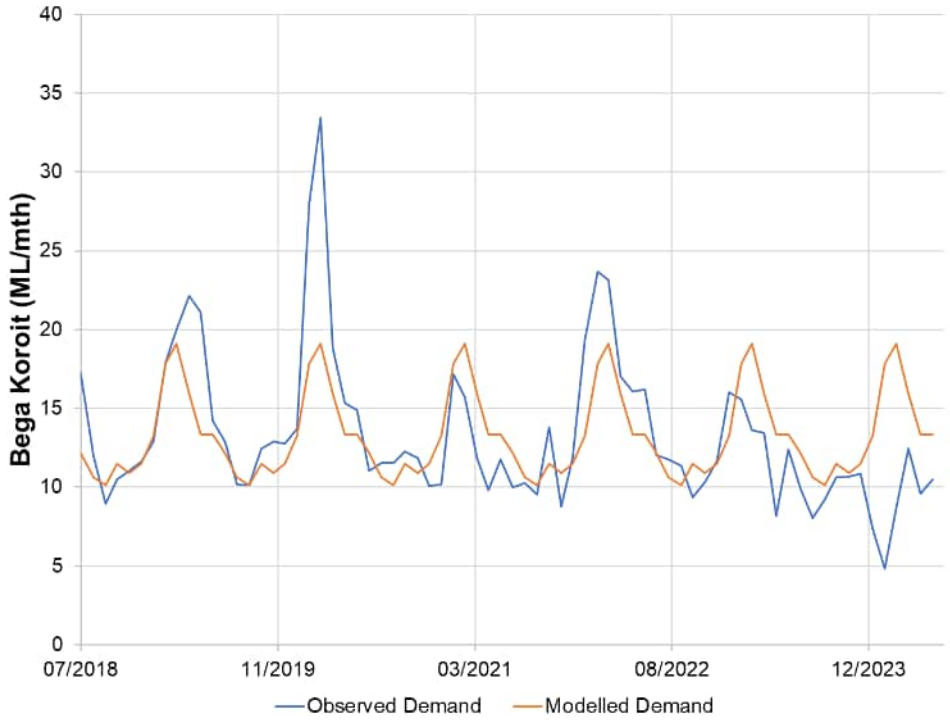
Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	24.2	11.8	12.4	49%
February	27.2	11.8	15.4	43%
March	20.8	11.8	9.0	57%
April	18.9	11.8	7.1	62%
May	15.8	11.8	4.0	75%
June	13.8	11.8	2.0	85%
July	14.0	11.8	2.2	85%
August	15.2	11.8	3.4	78%
September	15.9	11.8	4.1	74%
October	18.0	11.8	6.2	66%
November	19.2	11.8	7.4	61%
December	20.5	11.8	8.7	58%

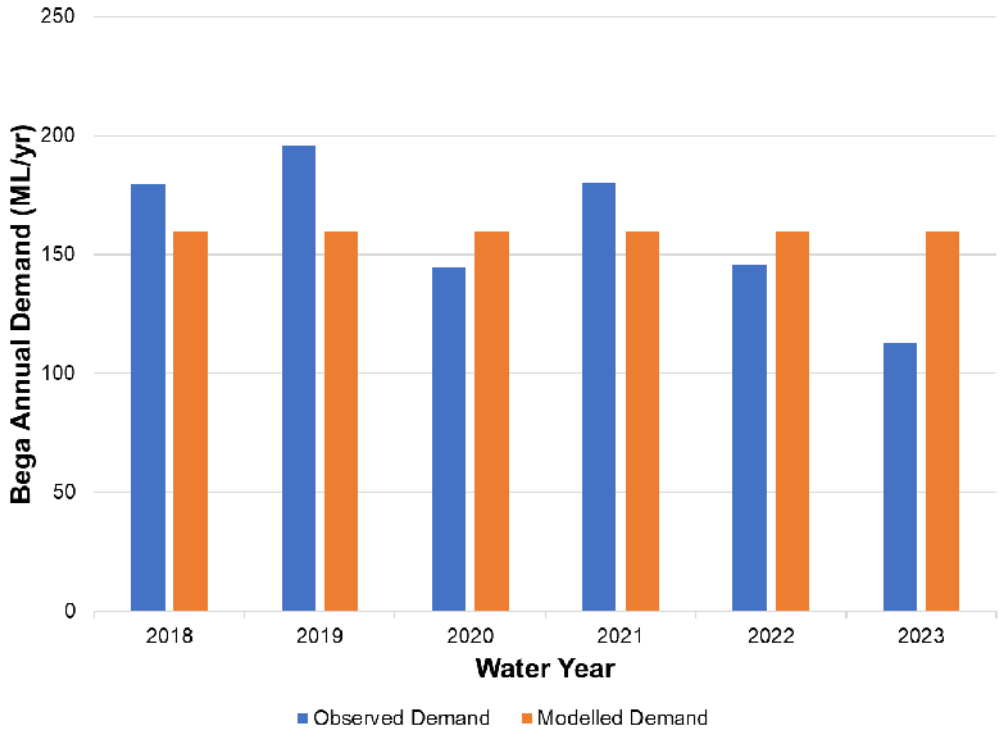
Table 9-11 Warrnambool urban base demand assumptions (ML/mth)

Month	Drought period (06/07) monthly demand (ML/mth)	Base demand (unrestrictable demand)	Restrictable demand (ML/mth)	Base demand as percentage of drought demand (%)
January	376.0	211.3	164.7	56%
February	422.8	211.3	211.5	50%
March	346.6	211.3	135.3	61%
April	320.7	211.3	109.4	66%
May	264.7	211.3	53.4	80%
June	236.1	211.3	24.8	89%
July	250.5	211.3	39.2	84%
August	276.2	211.3	64.9	77%
September	271.8	211.3	60.5	78%
October	309.4	211.3	98.1	68%
November	324.6	211.3	113.3	65%
December	353.1	211.3	141.8	60%

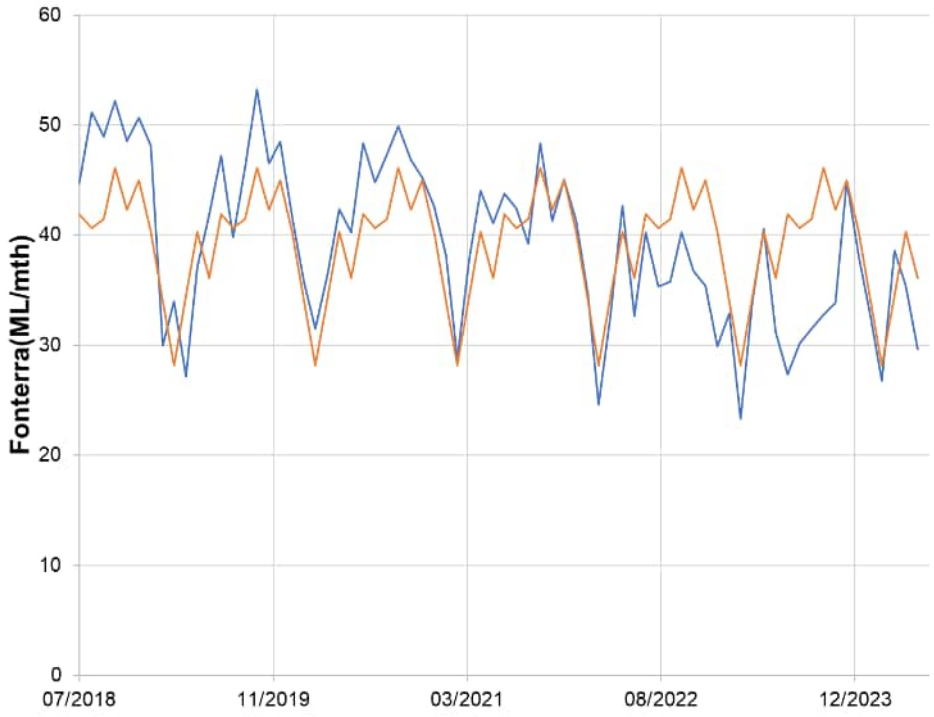
Appendix J Wannon Water Industrial Demand Regression Plots

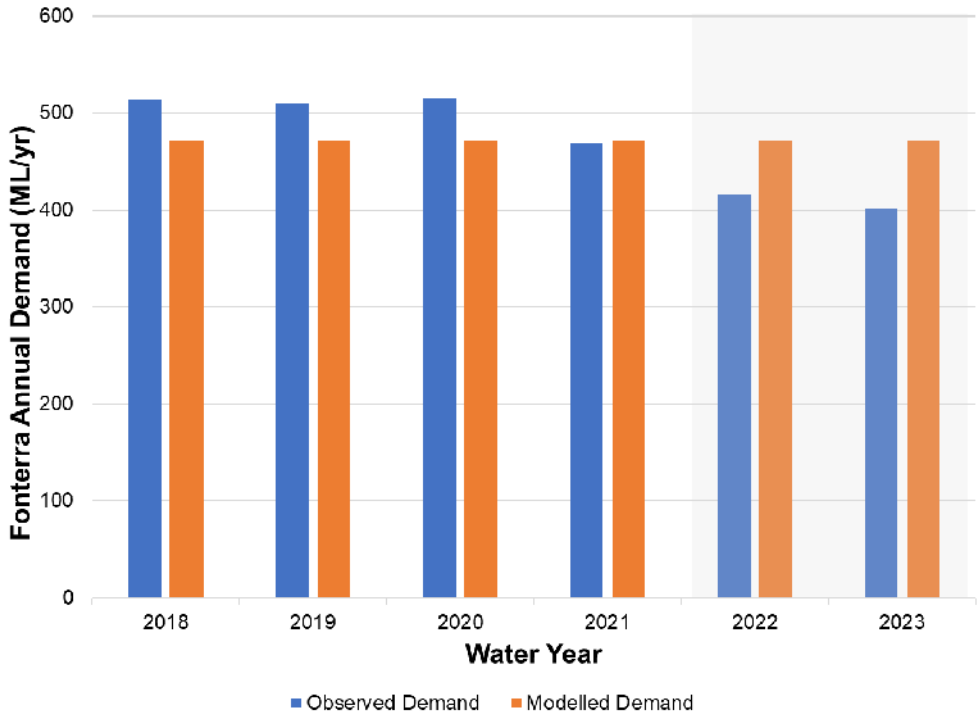
J.1 Bega Industrial Demand



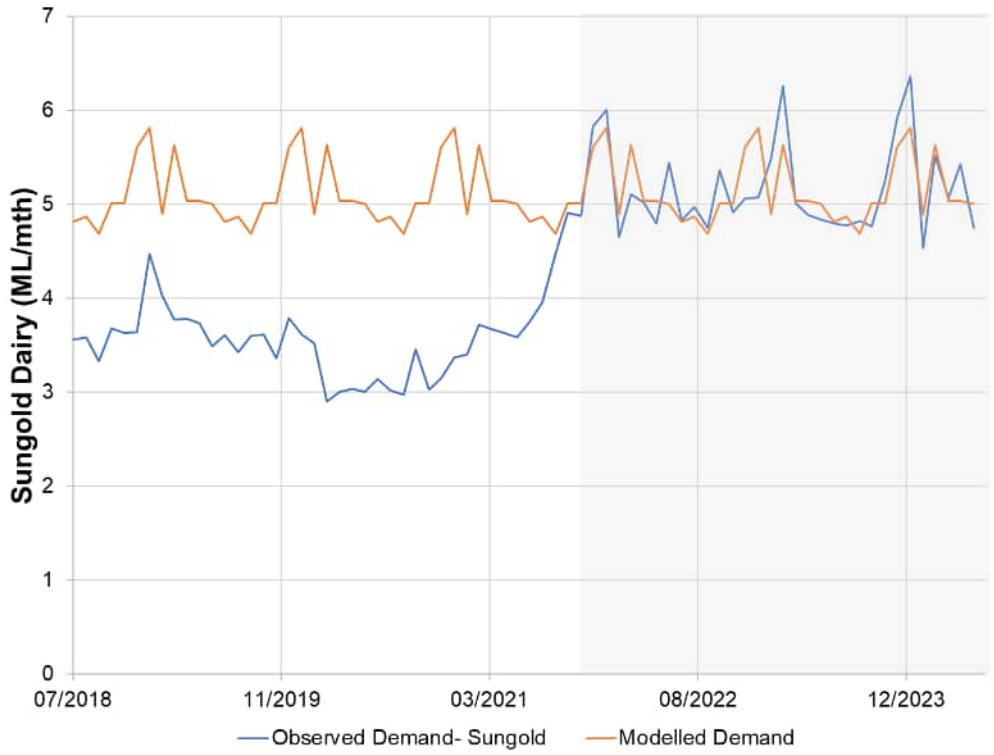


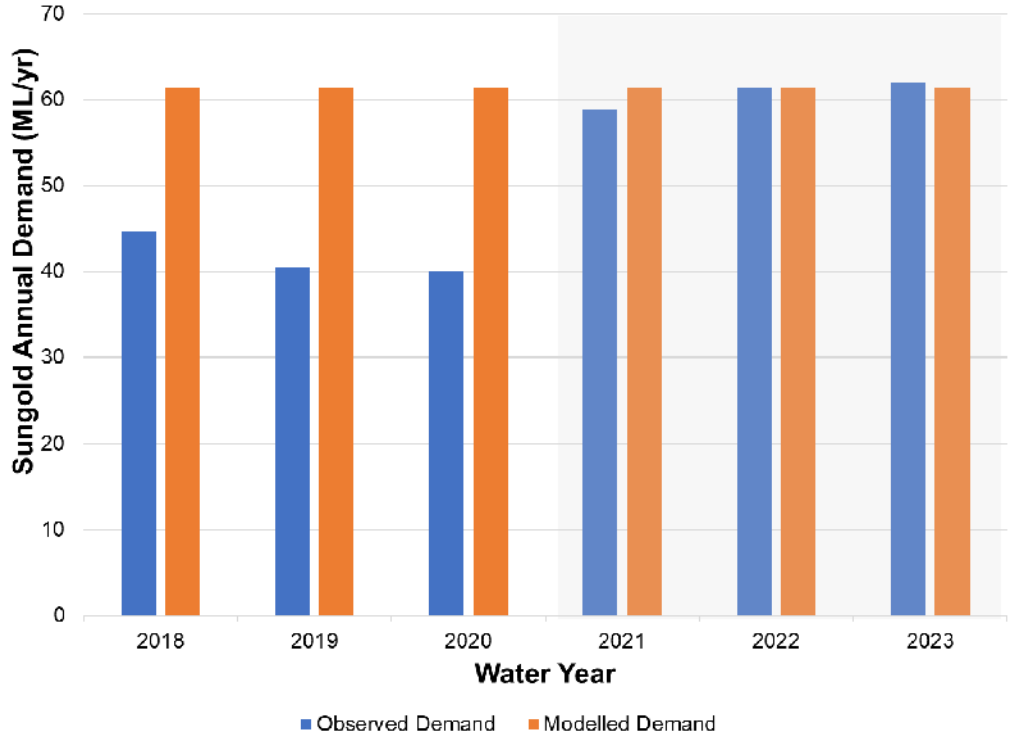
J.2 Fonterra Industrial Demand





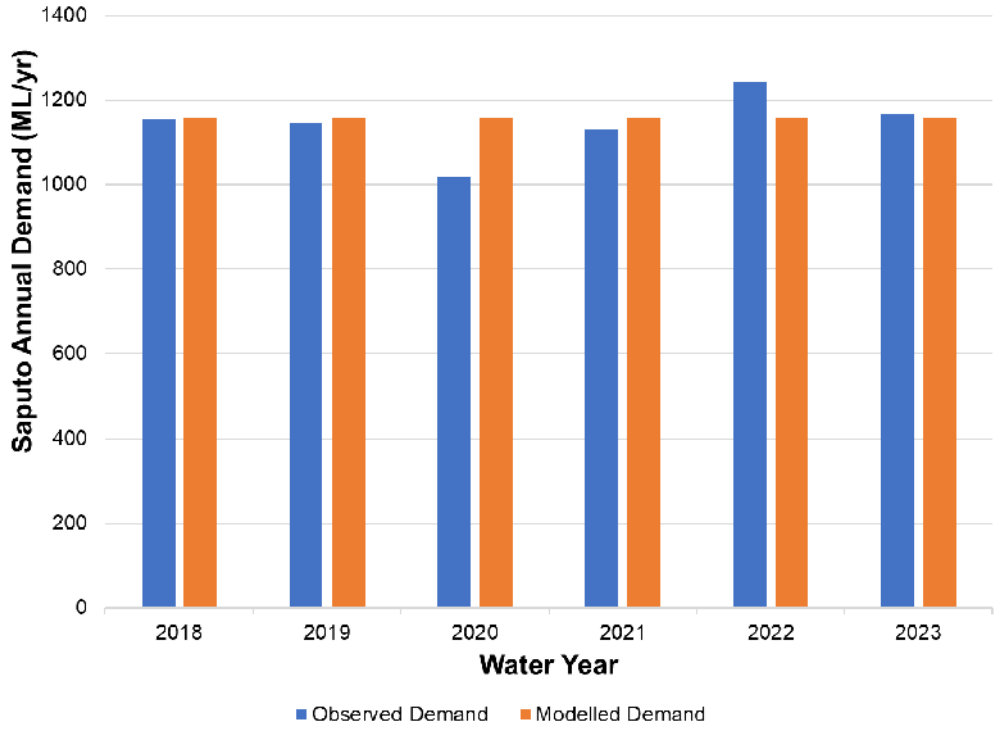
J.3 Sungold Industrial Demand



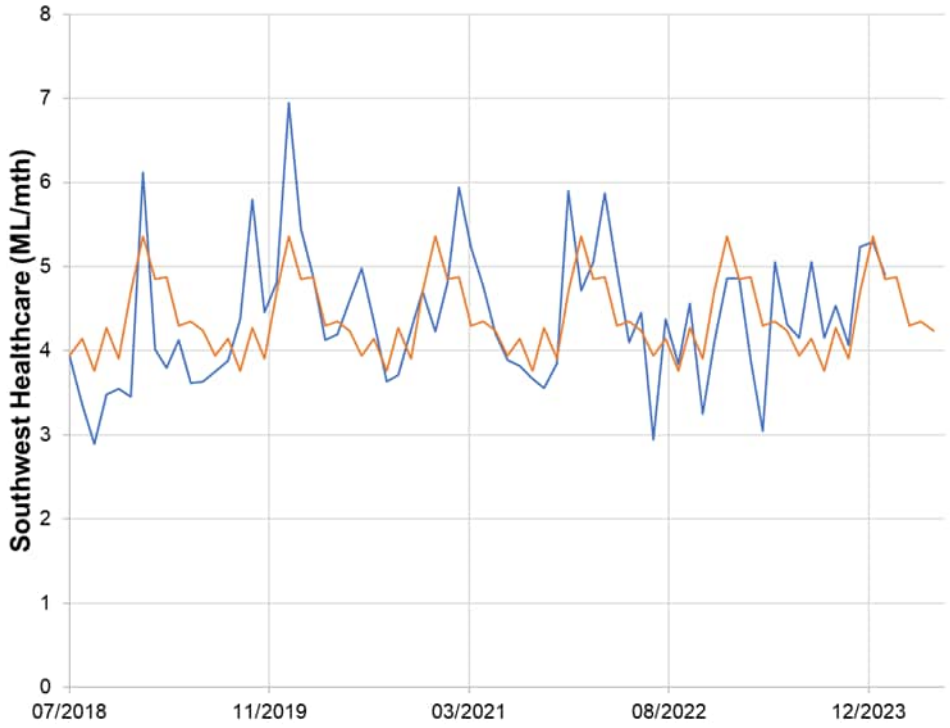


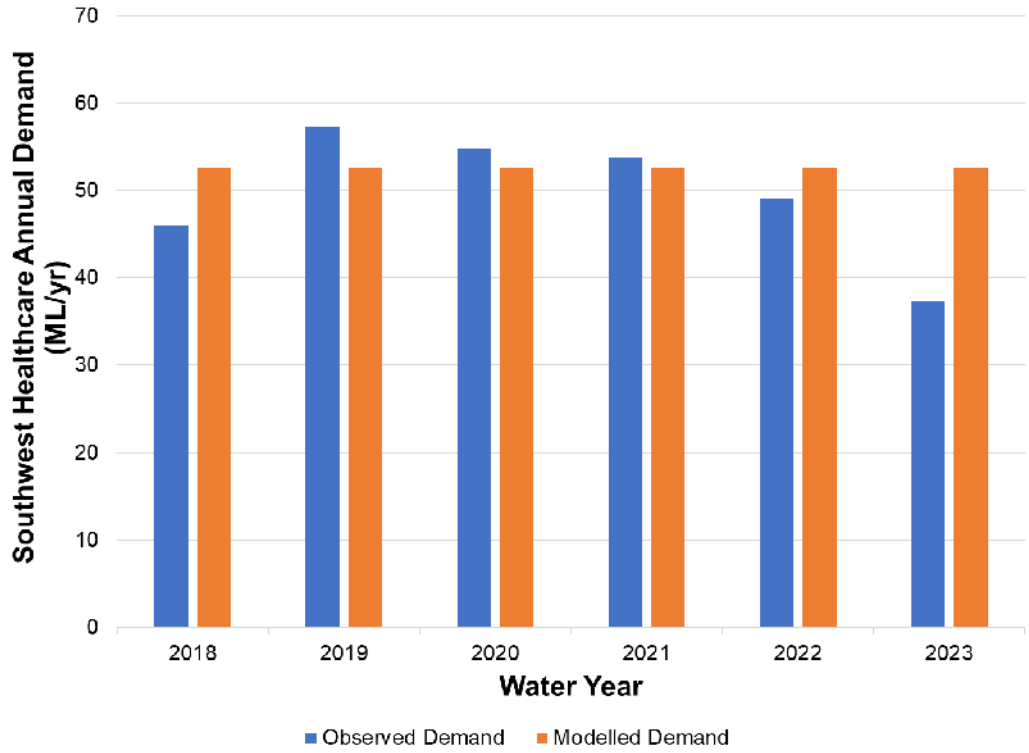
J.4 Saputo Industrial Demand



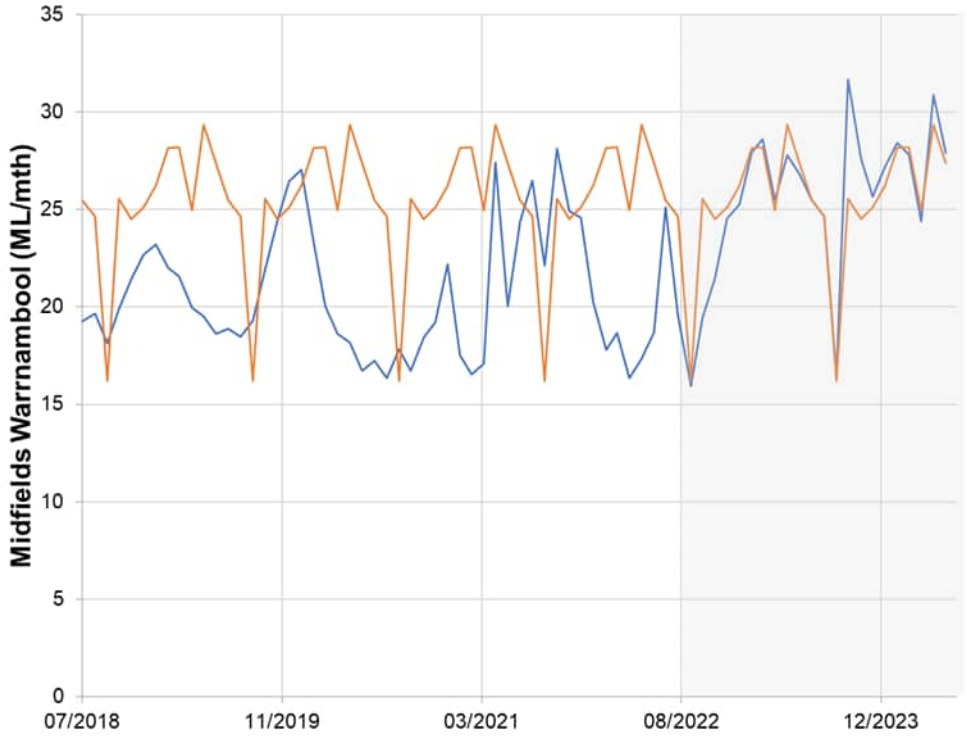


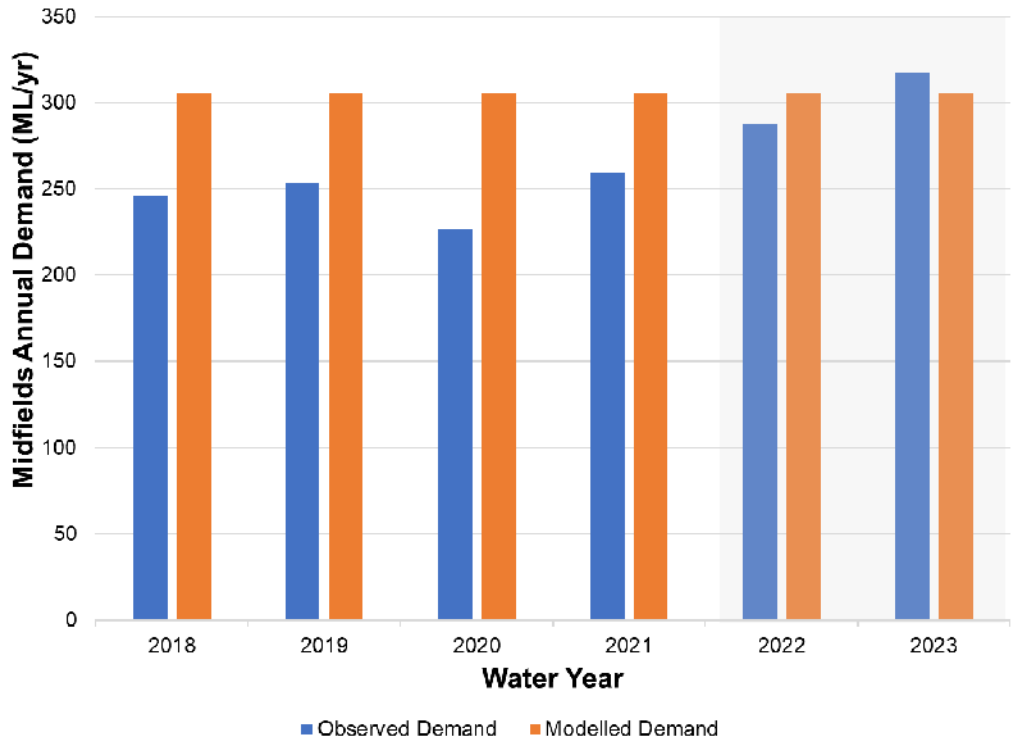
J.5 Southwest Healthcare Industrial Demand





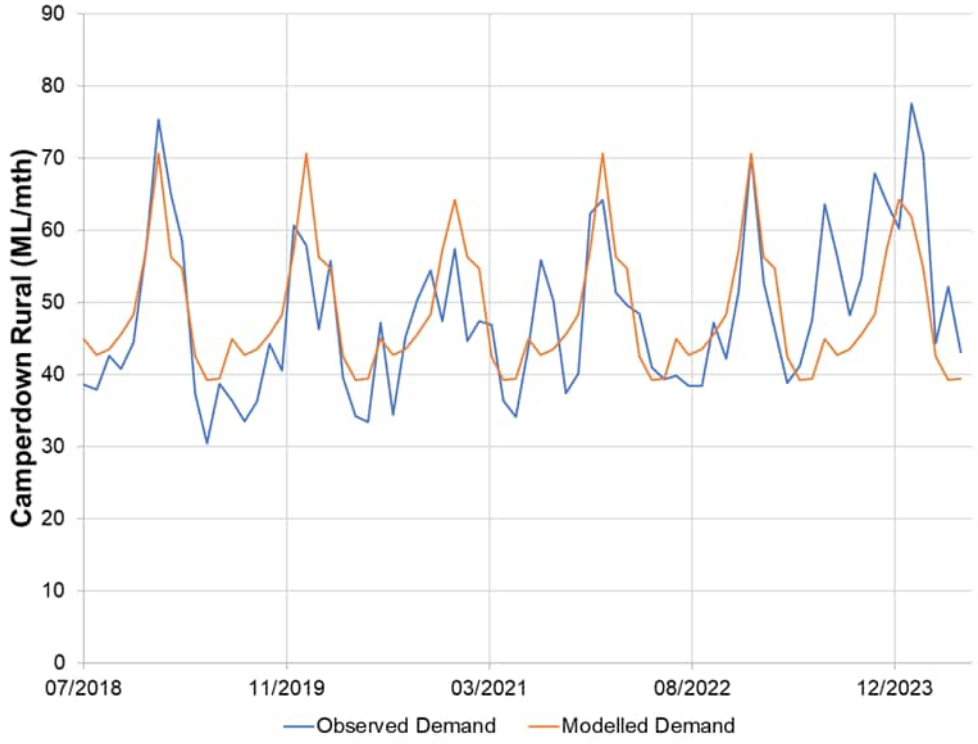
J.6 Midfields Warrnambool Industrial Demand

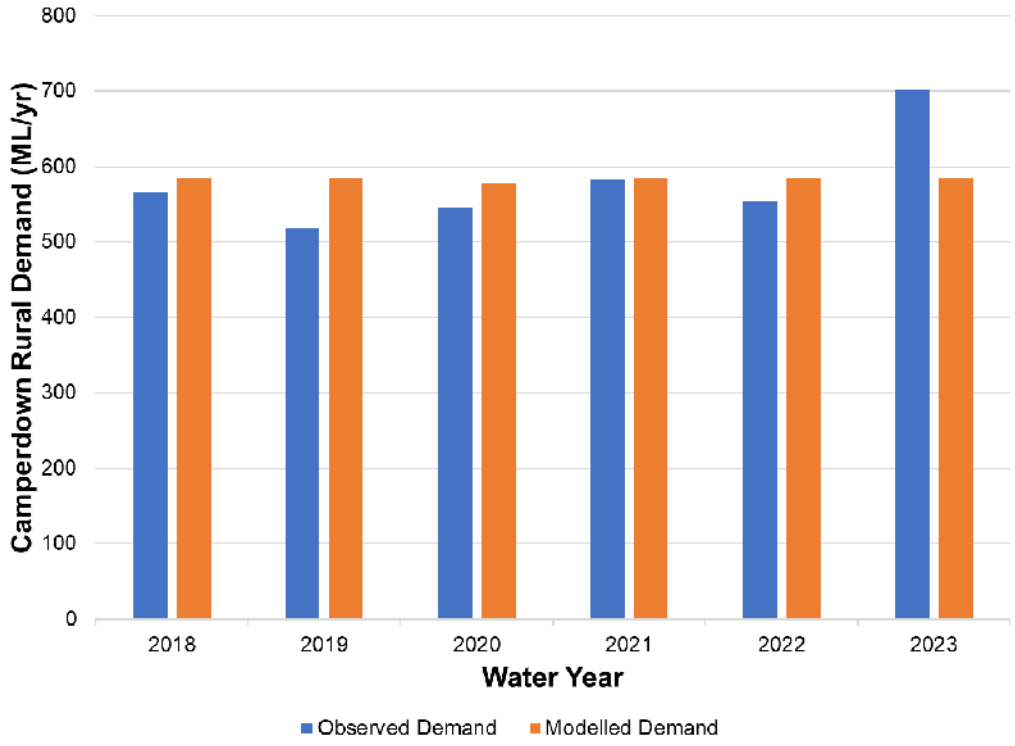




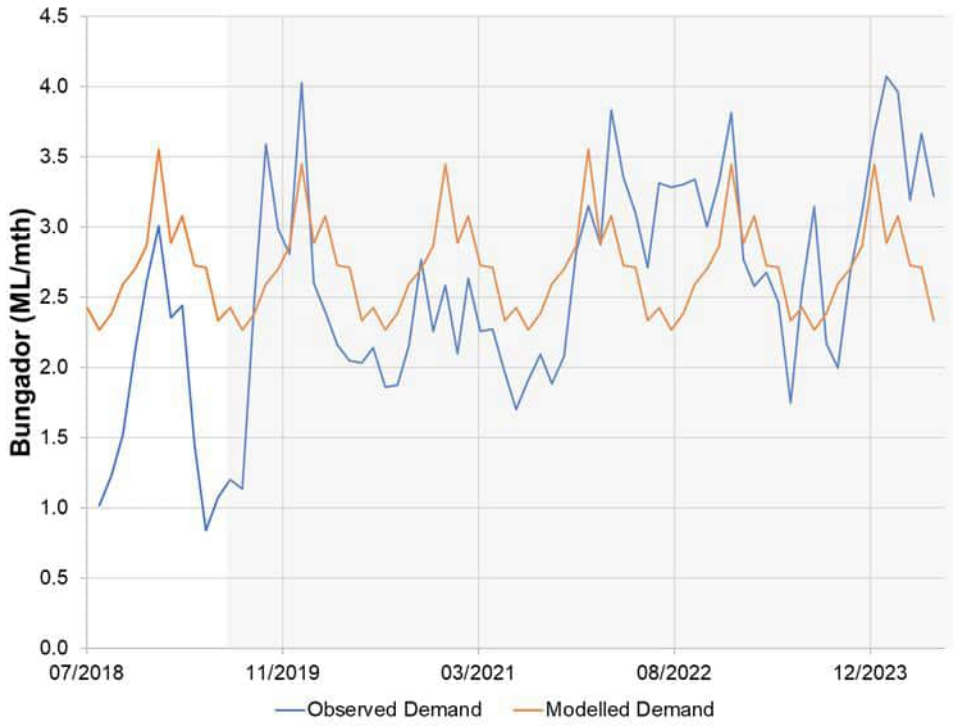
Appendix K Annual Rural Demand Regression Plots

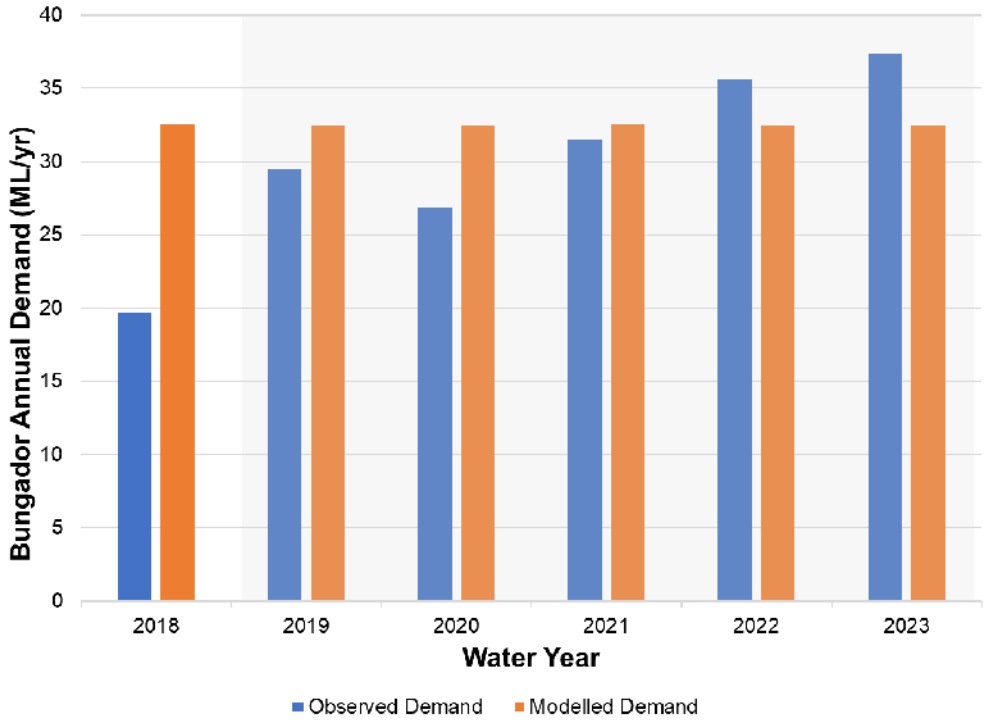
K.1 Camperdown Rural Demand



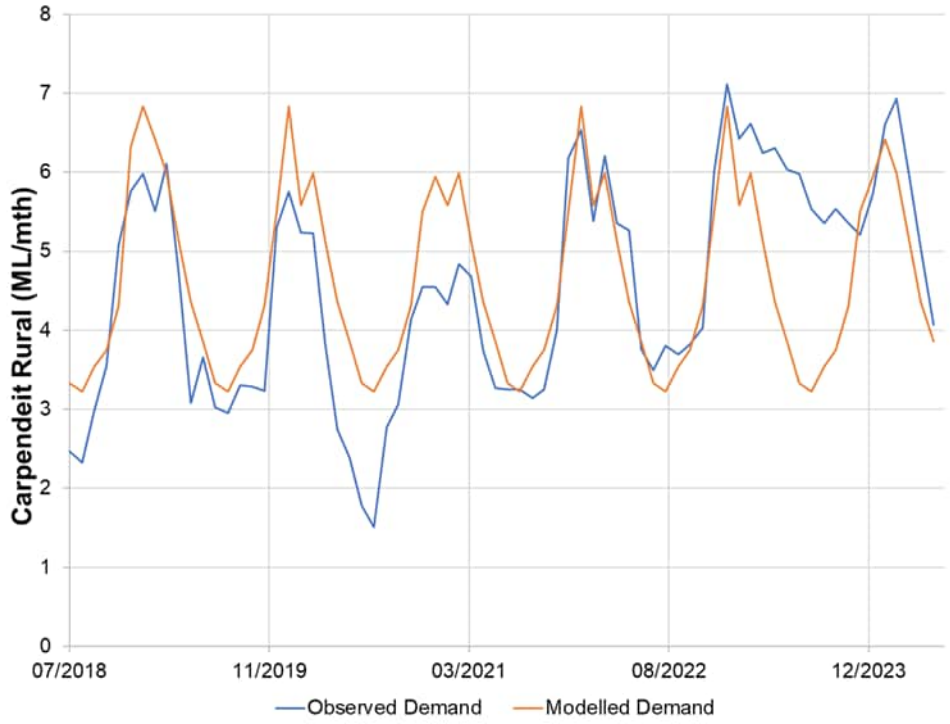


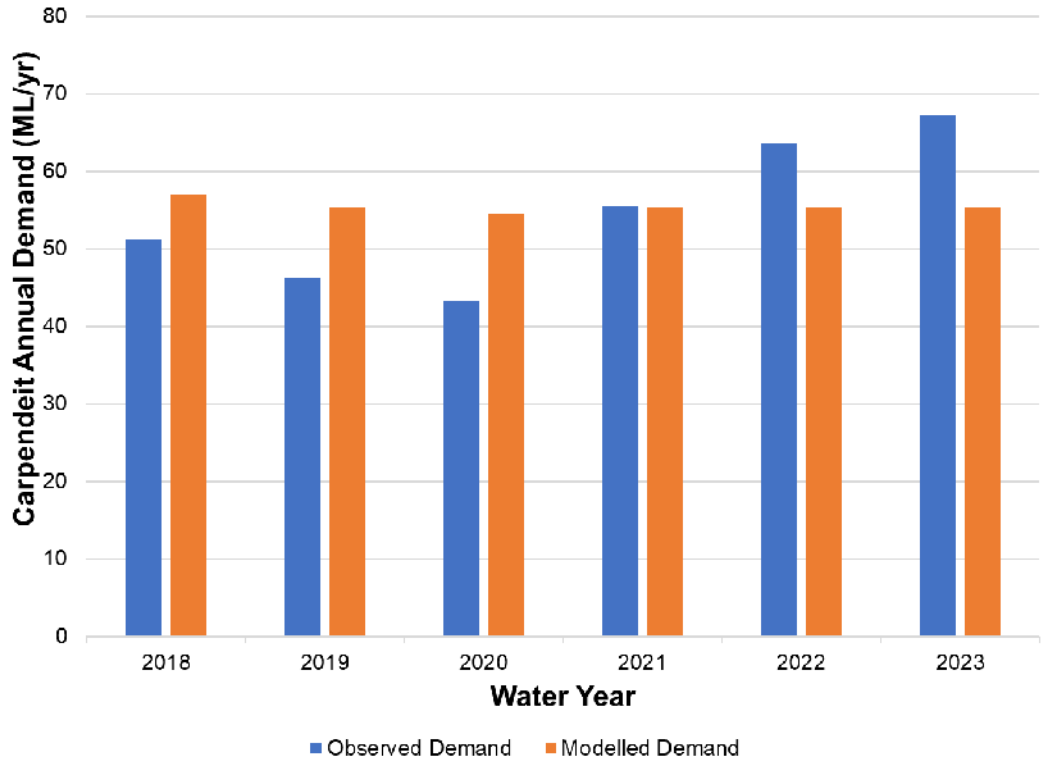
K.2 Bungador Rural Demand



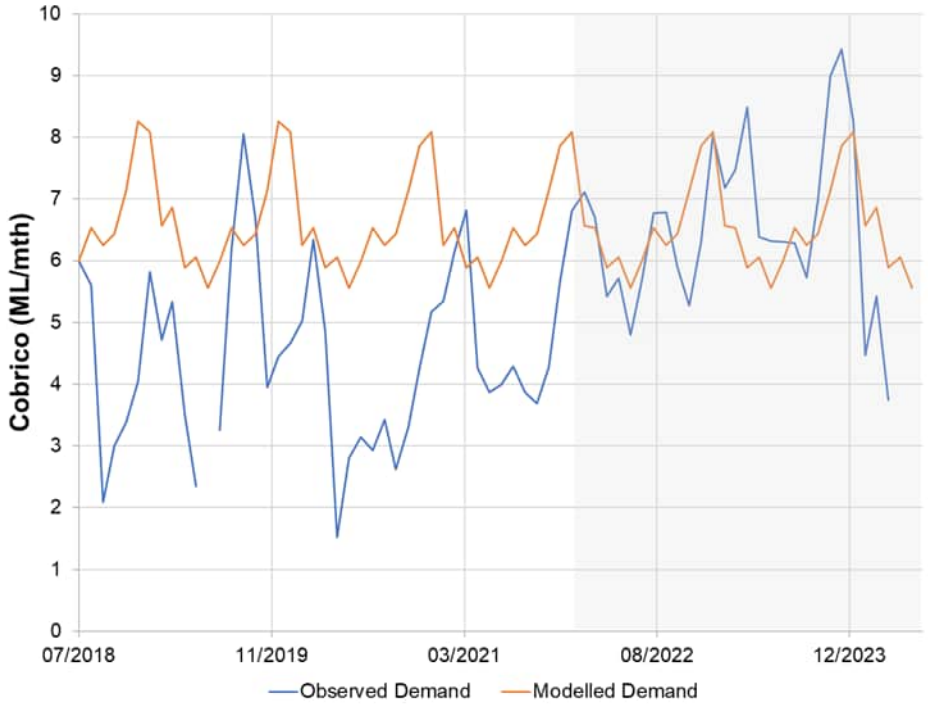


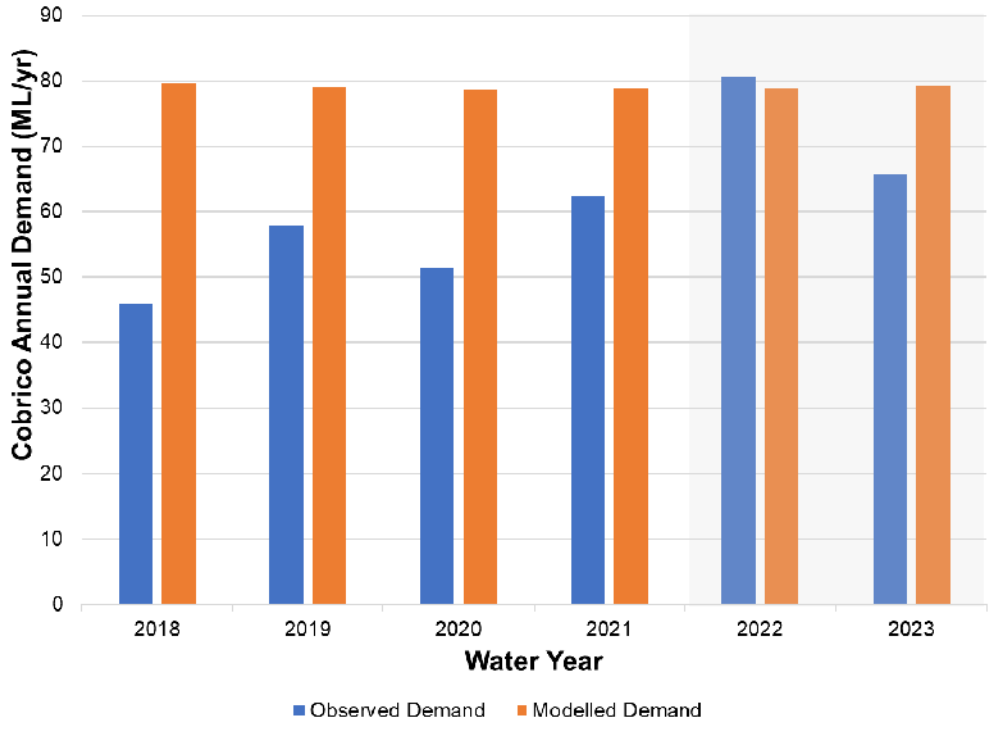
K.3 Carpendeit Rural Demand



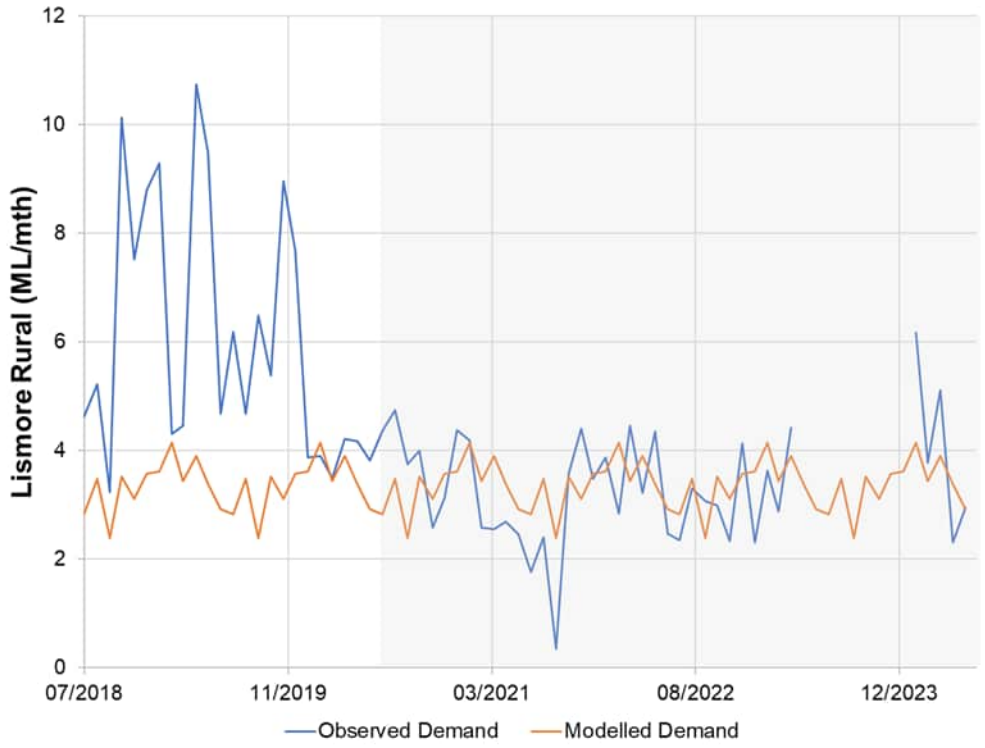


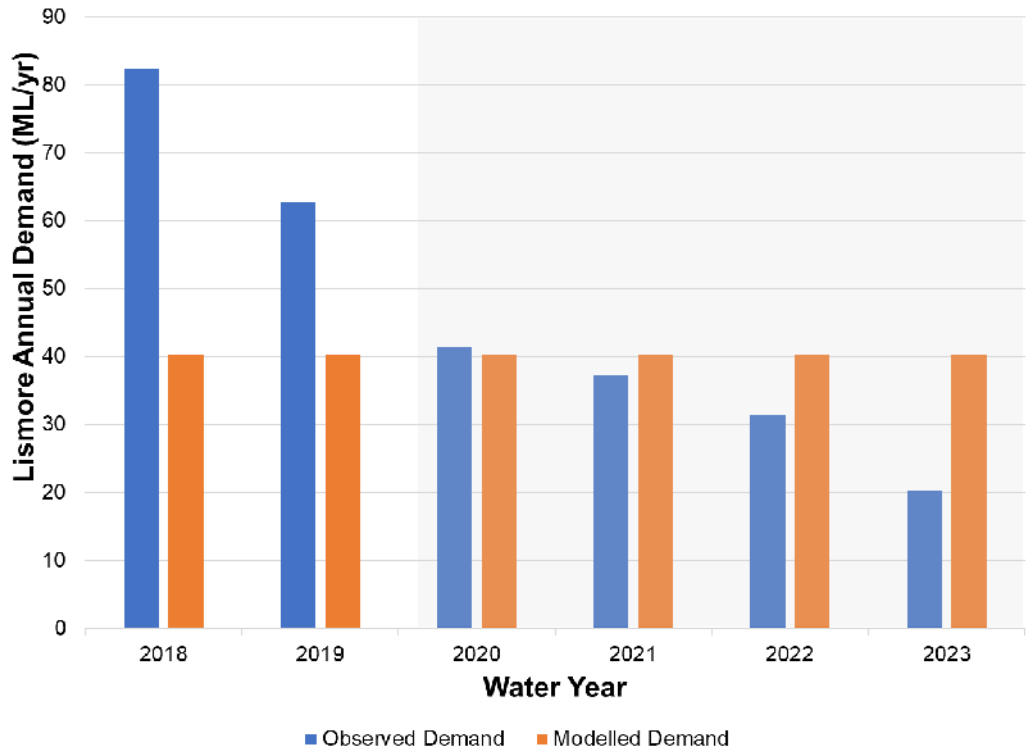
K.4 Cobrico Rural Demand





K.5 Lismore Rural Demand





Appendix L Scenario modelling water balances

Table 9-12 Current level of development Gellibrand River system water balance

	Historic	Post-1975 Baseline	Post-1997 Step	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
				Low	Med	High	Low	Med	High	Low	Med	High
Inflows	**297,204**	**267,843**	**238,559**	**277,377**	**257,119**	**230,197**	**285,332**	**248,547**	**200,301**	**255,194**	**225,606**	**156,035**
Catchment Inflows	295,936	266,554	237,319	276,150	255,892	228,970	284,147	247,362	199,116	254,026	224,439	154,868
Farm Dam inflows	1,268	1,289	1,241	1,227	1,227	1,227	1,185	1,185	1,185	1,167	1,167	1,167
Demands	**17,895**	**18,142**	**18,221**	**18,430**	**18,287**	**17,988**	**20,242**	**19,763**	**18,793**	**21,493**	**20,873**	**19,045**
Wannon Water Extractions	8,773	8,783	8,809	8,977	8,888	8,724	10,068	9,871	9,455	10,463	10,231	9,362
Barwon Water Extractions	3,625	3,631	3,617	3,660	3,606	3,473	4,248	3,977	3,469	4,303	3,947	3,160
Rural Demands	316	316	316	316	316	316	316	315	313	315	314	310
Farm Dam Impacts	4,781	5,013	5,081	5,078	5,078	5,077	5,570	5,559	5,512	6,371	6,339	6,159
Groundwater pumping impacts	399	399	399	400	399	398	41	42	45	42	43	54
Losses	**5,530**	**5,785**	**5,934**	**5,748**	**5,840**	**5,965**	**5,719**	**5,890**	**6,147**	**5,852**	**6,014**	**6,406**
River Losses	5,706	5,918	6,043	5,884	5,957	6,059	5,863	5,998	6,207	5,973	6,093	6,409
Net Evap	-176	-133	-108	-136	-117	-95	-144	-107	-60	-120	-80	-2
Outflow	**273,772**	**243,910**	**214,397**	**253,192**	**232,985**	**206,238**	**259,364**	**222,888**	**175,356**	**227,842**	**198,713**	**130,580**
Gellibrand River at Princetown	273,772	243,911	214,397	253,192	232,985	206,239	259,364	222,888	175,356	227,843	198,714	130,580
Change in storage	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12
Balance error (%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 9-13 Full rural level of development Gellibrand River system water balance

	Historic	Post-1975 Baseline	Post-1997 Step	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
				Low	Med	High	Low	Med	High	Low	Med	High
Inflows	**297,204**	**267,843**	**238,559**	**277,377**	**257,119**	**230,197**	**285,332**	**248,547**	**200,301**	**255,194**	**225,606**	**156,035**
Catchment Inflows	295,936	266,554	237,319	276,150	255,892	228,970	284,147	247,362	199,116	254,026	224,439	154,868
Farm Dam inflows	1,268	1,289	1,241	1,227	1,227	1,227	1,185	1,185	1,185	1,167	1,167	1,167
Demands	**20,112**	**20,346**	**20,391**	**20,642**	**20,473**	**20,139**	**22,463**	**21,938**	**20,901**	**23,677**	**23,023**	**21,030**
Wannon Water Extractions	8,696	8,705	8,722	8,900	8,802	8,633	9,992	9,778	9,360	10,374	10,142	9,282
Barwon Water Extractions	3,625	3,631	3,617	3,660	3,606	3,473	4,248	3,977	3,469	4,303	3,947	3,160
Rural Demands	2,610	2,597	2,572	2,605	2,588	2,557	2,614	2,584	2,516	2,589	2,554	2,389
Farm Dam Impacts	4,781	5,013	5,081	5,078	5,078	5,077	5,569	5,557	5,510	6,369	6,337	6,142
Groundwater pumping impacts	400	400	399	400	399	399	41	42	46	42	44	57
Losses	**5,548**	**5,806**	**5,959**	**5,766**	**5,866**	**6,002**	**5,735**	**5,921**	**6,192**	**5,882**	**6,055**	**6,423**
River Losses	5,723	5,939	6,068	5,902	5,983	6,097	5,879	6,029	6,252	6,003	6,134	6,426
Net Evap	-176	-133	-108	-136	-117	-95	-144	-107	-60	-120	-80	-2
Outflow	**271,538**	**241,685**	**212,203**	**250,962**	**230,773**	**204,050**	**257,127**	**220,682**	**173,203**	**225,628**	**196,523**	**128,578**
Gellibrand River at Princetown	271,538	241,685	212,203	250,962	230,773	204,050	257,127	220,682	173,204	225,628	196,523	128,578
Change in storage	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-4
Balance error (%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 9-14 Full rural and urban level of development Gellibrand River system water balance

	Historic	Post-1975 Baseline	Post-1997 Step	RCP 8.5 2020 Climate Change			RCP 8.5 2040 Climate Change			RCP 8.5 2065 Climate Change		
				Low	Med	High	Low	Med	High	Low	Med	High
Inflows	**297,204**	**267,843**	**238,559**	**277,377**	**257,119**	**230,197**	**285,332**	**248,547**	**200,301**	**255,194**	**225,606**	**156,035**
Catchment Inflows	295,936	266,554	237,319	276,150	255,892	228,970	284,147	247,362	199,116	254,026	224,439	154,868
Farm Dam inflows	1,268	1,289	1,241	1,227	1,227	1,227	1,185	1,185	1,185	1,167	1,167	1,167
Demands	**22,180**	**22,134**	**21,503**	**22,411**	**21,874**	**21,157**	**22,596**	**21,898**	**19,591**	**22,945**	**21,940**	**16,987**
Wannon Water Extractions	10,170	9,916	9,454	9,974	9,750	9,446	10,010	9,743	8,042	9,789	9,386	5,548
Barwon Water Extractions	4,220	4,208	3,997	4,354	4,059	3,679	4,362	3,971	3,477	4,156	3,619	2,849
Rural Demands	2,610	2,597	2,572	2,605	2,588	2,557	2,614	2,584	2,516	2,589	2,554	2,390
Farm Dam Impacts	4,781	5,013	5,081	5,078	5,078	5,077	5,569	5,557	5,510	6,369	6,337	6,142
Groundwater pumping impacts	400	400	399	400	400	399	41	42	47	42	44	57
Losses	**5,544**	**5,808**	**5,964**	**5,768**	**5,867**	**6,007**	**5,739**	**5,920**	**6,185**	**5,875**	**6,041**	**6,442**
River Losses	5,729	5,949	6,080	5,911	5,992	6,107	5,885	6,031	6,250	6,004	6,132	6,459
Net Evap	-185	-141	-116	-143	-124	-100	-146	-111	-65	-129	-91	-17
Outflow	**269,473**	**239,896**	**211,087**	**249,191**	**229,371**	**203,027**	**256,990**	**220,723**	**174,519**	**226,368**	**197,620**	**132,603**
Gellibrand River at Princetown	269,473	239,896	211,087	249,191	229,371	203,027	256,990	220,723	174,520	226,368	197,620	132,607
Change in storage	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-4
Balance error (%)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%