STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
KING-HENTY STUDY AREA MODEL CALIBRATION

REPORT

MAY 2023

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Project Tasmanian Strategic Flood Map King-Henty Study Area Model Calibration	**Project Number** **120038**
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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ALS	Airborne Laser Scanning
AMS	Annual Maximum Series
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ATP	Areal Temporal Patterns
AWAP	Australian Water Availability Project
AWS	Automatic Weather Station
Bureau/BoM	Bureau of Meteorology
C	Lag parameter in WBNM
CFEV	Conservation of Freshwater Ecosystem Values (DPIPWE)
CL	Continuing Loss
DEM	Digital Elevation Model
DPIPWE	Department of Primary Industries, Water and Environment
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
FFA	Flood Frequency Analysis
FLIKE	Software for flood frequency analysis
FSL	Full Supply Level
GIS	Geographic Information System
GEV	Generalised Extreme Value distribution
GPS	Global Positioning System
HSA	Human Settlement Area
ICM	Infoworks ICM software (Innovyze)
IDW	Inverse Distance Weighting
IL	Initial Loss
IFD	Intensity, Frequency and Duration (Rainfall)
LiDAR	Light Detection and Ranging
mAHD	meters above Australian Height Datum
PERN	Catchment routing parameter in RAFTS
Pluvi	Pluviograph – Rain gauge with ability to record rain in real time
QAQC	Quality assurance and quality control
R	Channel routing parameter in WMAWater RAFTS WBNM hybrid model
RAFTS	hydrologic model
SCE	Shuffled Complex Evolution
SES	State Emergency Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydrodynamic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

1. INTRODUCTION

Flooding occurs regularly throughout Tasmania; the Bureau of Meteorology describes numerous major flood events that have occurred since the early 1800s. Following the 2016 Tasmanian floods, the need for state and local governments, communities and emergency response agencies to better understand flooding in Tasmania was identified. Improved flood intelligence would allow for targeted and appropriate investment in flood recovery and increased community resilience to future flood events. The Independent Review into the Tasmanian Floods of June and July 2016 found that there were gaps in flood studies and flood plans over Tasmania, both in comprehensiveness and currency.

The objectives of the Tasmanian Strategic Flood Mapping Project are to assist flood affected communities to recover from the 2016 floods through a better understanding of flood behaviour, and to increase the resilience of Tasmanian communities to future flood events. The targeted outcomes of the project are that post-flood recovery will be informed by up-to-date flood risk information, ownership of flood risk is appropriately allocated, flood risk can be included in investment decisions, and responsibility for flood mitigation costs can be appropriately allocated.

The Tasmanian Flood Mapping Project aims to address the objectives and outcomes by:

- providing communities with access to a high resolution digital terrain model that can be used for flood modelling, through collection of LiDAR data over Tasmania
- developing state-wide Strategic Flood Maps to support flood risk assessment and post event analysis and
- partnering with Local Government to deliver detailed flood studies and evacuation planning for communities with highest flood risk that do not have a current flood study.

This project addresses the second component of the Tasmanian Flood Mapping Project, the development of state-wide Strategic Flood Maps.

This report describes the calibration of hydrologic and hydrodynamic flood models for the King-Henty study area.

2. STUDY AREA

The King-Henty River study area is situated in western Tasmania. The major rivers in the study area are Pieman River, Henty River, Little Henty River and King River. There are a number of smaller rivers and creeks in the study area which discharge directly into the Southern Ocean. The study area includes the Pieman-Anthony, King and Margaret hydroelectricity schemes and the larger rivers are heavily regulated due to the associated dams and diversions. The Lake Margaret scheme dates back to 1914, whilst the other hydroelectric schemes in the study area were developed in the 1970s – 1980s.

The Pieman River rises in the west of the Central Plateau, in the Cradle Mountain Lake St Clair National Park, and flows in a generally westerly direction to discharge into the Southern Ocean at Pieman Head. The main tributaries of the Pieman River include Mackintosh River, Murchison River, Savage River, Huskisson River, Anthony River and Whyte River. The Pieman River and some of its major tributaries are regulated by dams and diversions constructed for the Pieman-Anthony hydroelectric scheme. The dams form lakes including Lake Murchison, Lake Mackintosh, Lake Rosebery, Lake Pieman, and Lake Plimsoll.

The Henty River rises on the southern slopes of Mount Read and flows in a southerly direction to the confluence with the Yolande River, where it then flows west to discharge into the Southern Ocean south of Trial Harbour. The upper reaches of the Henty River and its tributaries include Lake Henty, Whitespur Lake and Lake Newton, which form part of the Pieman-Anthony hydroelectricity scheme. Lake Margaret, on the Yolande River provides storage for the Lake Margaret hydroelectricity scheme.

The King River rises in the Franklin-Gordon Wild Rivers National Park. The upper reaches of the King River are impounded by Crotty Dam, which forms Lake Burbury as part of the King River hydroelectricity scheme. From Lake Burbury, the King Rivers flows in a westerly direction to discharge into Macquarie Harbour south of Strahan. The major tributary of the King River is the Queen River.

The study area includes large areas of national park in the upper catchment, with some areas of farmland in the lower catchment. The majority of Tasmania’s mining industry operates within the study area, mining ores and minerals including copper, zinc, lead and gold. The study area is generally sparsely populated other than the towns of Zeehan, Queenstown and Strahan. Queenstown is the largest town, with a population of approximately 1,800 people.

Large floods in the study area include the August 1970, May 1994 and August 2007 flood events.

The King-Henty study area has an area of 5,955 km^2. The King-Henty study area and the available gauge information are shown in Figure 1. Landuse in the King-Henty study area is shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow Data and Level Data

There are five gauges with natural flow data available in the King-Henty study area (Table 1), and none of these gauges are still operating. There are a number of other gauges on very small hydro pickups or heavily regulated waterways which were not considered appropriate for calibration. Whyte River A/B Rocky River gauge is owned by DNRE. The remaining gauges are owned and operated by Hydro Tasmania, who supplied timeseries of flows and stage heights. The gauges on the Mackintosh River and Murchison River operated prior to the construction of Mackintosh and Murchison dams, and are now in the area either inundated or at least influenced by Mackintosh Reservoir.

Table 1: Flow gauges

Gauge attribute	Mackintosh River Below Sophia River	Murchison River Above Sterling	Que River b/l Bulgobac Creek	Que River at Murchison Highway	Whyte River A/B Rocky River
Gauge number	149-1	148-1	472-1	1061-1	350-1
Gauge abbreviated name	Mackintosh River	Murchison River	Que River b/l Bulgobac	Que River at Murchinson	Whyte River
Start date	08/04/1954	08/02/1955	22/10/1963	18/03/1987	50/05/1960
End date	11/09/1980	05/07/1983	03/10/1995	28/10/2010	16/06/1992
Latitude	-41.721	-41.761	-41.615	-41.577	-41.62
Longitude	145.629	145.628	145.577	145.683	145.18
High flow rating quality	Unknown	Unknown	Unknown	Unknown	Unknown
Used for calibration	Yes*	Yes*	Yes	Yes	No
Assumed local datum 0m in AHD	N/A	N/A	342.5	606.58	32.48
Highest Gauged Level (m local datum)	Unknown	Unknown	Unknown	Unknown	Unknown
Highest recorded stage height (m local datum)	6.79	9.46	3.03	2.11	6.0
Highest recorded flow (m^3/s)	723	1163	116	26	319
Highest recorded stage height date	24/08/1970	18/05/1975	15/08/1991	20/11/1987	28/04/1974
Highest recorded flow date	24/08/1970	18/05/1975	15/08/1991	20/11/1987	28/14/1974

* Hydrology only as now inundated by Mackintosh Dam

3.1.1. Calibration Event Data Availability

Significant flows were recorded in the catchment area for 2 of the 13 flood events selected by the Bureau as calibration events for this project (Table 2). However, due to very significant changes in regulation of the catchment, the older event in 1970 was of limited value for calibration of the hydrodynamic model. Therefore, therefore an additional event in May 1994 was selected (WMAwater 2021d). As well as limited stream flow data, recorded spill at the major dams, particularly in the Pieman Scheme, were used for event calibration as their pickup covers a much larger proportion of the study area, and spillway rating curves are typically more reliable than stream gauges in high flows. Lake Burbury on the King River did not spill for any calibration events. The August 2007 and May 1994 events were the largest two spill events on record at all the Pieman Scheme gauges and in the top 5 in the Anthony system. The August 1970 event was the largest on record at the Mackintosh gauge. There is no consistent stream or spillway flow data available for both the 1970 and later 1994 and 2007 events to assess their relative significance based on recorded data, however modelled results suggest that the 1970 event was between the magnitudes of the 1994 and 2007 events.

Table 2: Summary of the largest events in the King-Henty study area

Event name	Used for calibration	Event peak flow (m^3/s) (location)
1970_Aug	Yes	723 (Mackintosh River) 954 (Murchison River)
1994_May	Yes	85 (Que River below Bulgobac) 23 (Que River at Murchinson)
2007_Aug	Yes	21 (Que River at Murchinson)

3.1.2. Rating Curve Quality

There was no information available about the rating curves at any of the gauges used in this study area.

3.2. Historic Rainfall Data

Rainfall data was provided by Bureau of Meteorology as part of the initial project data. The data provided included sub-daily rainfall timeseries data from four different sources: Automatic Weather Station (AWS) data, pluvio data, rolling accumulated rainfall from the Bureau's flood warning network, and 10 minutely accumulation from the Bureau's flood warning network. The datasets were in different formats and required processing to a common format before they could be used to produce rainfall inputs to the model. Rainfall data was provided for 13 events identified by the Bureau of Meteorology for use as calibration events for this project, although not all 13 events have data available or were significant events in the King-Henty study area (see Data Review Report WMAwater (2020) for details on calibration events). The 1994 calibration event at this site was selected as an additional event for calibration (WMAwater 2021d).

The AWS and pluvio data were found to be the most consistently reliable data. Where multiple data sources were available at the same site, AWS or pluvio data were prioritised for use over the event or accum data. Data that was recorded less frequently than at 3 hour intervals was excluded from the analysis.

A summary of the rain gauges for this study area is shown in Table 3. Given the relative remoteness of the study area there is fairly good coverage of sub-daily rain gauges as there are a significant number of Hydro-Tasmania gauges in the catchment. Both the events in May 1994 and August 2007 had very widespread high rainfalls with the highest rainfalls in the south and east of the catchments, and lower rainfall totals in the north-west (around Whyte River), with fairly gradual rainfall gradients (Figure 4 and Figure 5) . The August 1970 had a steep rainfall gradient with very high rainfalls in the far east (mainly in the Mackintosh and Murchison catchments) and much lower rainfall through the remainder of the study area (Figure 5). The gauges in and around the King-Henty study area are shown in Figure 1.

Table 3: Available Rainfall Information

	August 1970	**May 1994**	**August 2007**
Number of Sub-daily Stations Available within the study area	6	10	21
Number of daily Stations Available within the study area	11	10	8
Number of sub-daily surrounding gauges ~15km	5	9	10
Number of daily surrounding gauges ~15km	3	3	5
Rainfall Totals	70-310 mm	80-220 mm	100-290 mm
Approx duration of rainfall event (hours)	72	72	48

*The number of daily gauges does not include daily gauges co-located with an active sub-daily gauge

The daily and sub-daily rain gauge data were used to create rainfall surfaces for each of the selected calibration events using an inverse distance weighting method. The method is described in detail in WMAwater 2021 and is summarised below.

1. Daily rainfall data from all gauges within Tasmania was extracted for each of the seven calibration events from 2000 – 2018
2. Rudimentary QAQC and infilling of daily record was undertaken
3. Daily rainfall surfaces for each event were fitted using all daily and available pluviograph data, using Inverse Distance Weighting (IDW)
4. Sub-catchment rainfall depths were calculated from all grid cells within the sub-catchment using areal weighted averages
5. Daily data in each sub-catchment was disaggregated using the temporal pattern from gauge assigned using Thiessen polygon method.

The rainfall surfaces for the selected calibration events are shown in Figure 3 to Figure 5.

3.3. Dam information

The King-Henty study area covers several of Hydro Tasmania's hydropower schemes; the Yolande, King, Anthony and Pieman Schemes. Details of the major dams are shown in Table 4. This means a number of the rivers are highly regulated, with dams and water diversions. The majority of dams in the study area were constructed since the 1970 calibration event. As the ICM modelling was undertaken using a current DTM, this event is modelled with the current (2022) infrastructure so will not replicate historic flows in impacted catchments. However for calibration in the external hydrological models, the dams were removed to allow for calibration at gauges now inundated by Lake Mackintosh.

The scope of this project is not to accurately model Hydro Tasmania's operations, therefore in most cases the diversions are not included in the model as they are not significant compared to flood flows. Water from Lake Burbury is diverted through a tunnel to John Butters Power Station. As no spill was observed from this lake and changes in flow due to power station operations are not within the scope of this project, this diversion was not modelled.

The dams in the Upper Anthony (Henty, White Spur, Newton) were allowed to spill in the model. There is a diversion (Henty Canal) that transfers water from these lakes to Lake Plimsoll. These lakes spill into a different river basin than the diversion, however flood operating rules would be used if there was a large flood event, and this may change the volume of water diverted. The catchments of the Upper Anthony lakes represent only a small portion of the Henty River catchment and the spills from the Upper Anthony lakes do not impact any human settlement areas. Therefore the diversion into Lake Plimsoll has not been modelled.

There is a diversion from Lake Plimsoll into Lake Murchison, which was not modelled. Lake Plimsoll spills into a tributary of the Anthony River that drains to Lake Murchison, so the overall impact of this is expected to be minor. Sophia Tunnel can transfer over $100m^3/s$ from Lake Murchison to Lake Mackintosh. As spillway discharge from Lake Murchison and Mackintosh were major calibration points, this diversion was included in the model, assuming a constant flow of $100m^3/s$. This was an estimated flow based on local knowledge as no data about the diversion was available. The remainder of the power stations discharge directly downstream of the dams, so combined spillway and power station outflows were used for calibration.

Table 4: Dam information

Name	Storage FSL (mAHD)	Active Storage Volume at FSL (ML)*	Date constructed
Lake Burbury	235.3	510,000	1991
Lake Margaret	662.4	15,300	1918
Lake Newton	480.0	2070	1989
Lake Plimsoll	513.1	22,200	1993
White Spur Pond	521.7	1760	1989
Lake Henty	523.0	360	1988
Lake Murchison	241.0	62,600	1982
Lake Mackintosh	229.0	273,000	1981
Lake Rosebery	159.4	51,200	1983
Lake Pieman	97.5.0	100,000	1986

* Storage volumes are believed to be water volume within Hydro Tasmania's normal operating levels. There could be considerable extra water stored that is not included in the active storage volume

3.4. Flood Levels and Extents

There was no information on flood levels or extents provided for this study area.

4. METHODOLOGY OVERVIEW

The hydrological and hydrodynamic model calibration methodology has been outlined in the Hydrology Methods Report (WMAwater, 2021a) and the Hydrodynamic Methods Report (WMAwater 2021b). Details on the methods are only included in this report where they deviate from the methods described in these reports or are specific for this catchment.

The modelling method includes the following steps:

- Data preparation
  - Extraction and collation of rainfall data for identified calibration events
  - Gridding rainfall data across each catchment
  - Extraction of flow data for identified calibration events at each flow site, and assessment of suitability of this data for calibration
- Hydrologic modelling
  - Identification of flow gauge locations
  - Identification of dam and diversion locations
  - Sub-catchment delineation in GIS
  - Inclusion of dam storage and spillway ratings where required and available
  - Event calibration for routing and losses using automated external RAFTS modelling tool. Output event sub-catchment rainfalls, routing parameters and event losses for input to ICM model
  - Running event calibration through ICM RAFTS model to provide sub-catchment pickups for direct input into ICM hydrodynamic model
  - As required, revise hydrologic parameters within ICM-RAFTS to obtain good match to historic flood information provided
  - Once a good match is achieved, provide ICM-RAFTS modified hydrologic parameters back to the external hydrologic model to ensure consistency
  - As required, confirm the response between the external hydrologic model and ICM hydrodynamic model is consistent to enable design event analysis
- Hydrodynamic modelling in ICM
  - Importing base DEM
  - Setting roughness values, referencing calibrated PERN value from hydrologic model
  - Meshing
  - Incorporation of structures
  - Setting up rainfall inputs (depth and temporal pattern), losses and dam/diversion outflows from the hydrologic model
  - Calibration model runs
  - Compare model results with hydrologic model runs and calibration points
- Model iteration (if necessary)
  - Adjust routing parameters values in both external and ICM RAFTS hydrologic model if necessary, based on results of hydrodynamic model calibration
  - Rerun hydrologic models for calibration events
  - Set roughness values in hydrodynamic model
  - Rerun hydrodynamic model for calibration events

5. HYDRODYNAMIC MODEL SETUP

5.1. Digital Elevation Model (DEM)

The base dataset that was used for the digital elevation model (DEM) of the hydrodynamic model was the SES state-wide 10 m DEM merged with 2 m DEM subsets at the gauges (where available). 2 m DEM subsets were available at two of the gauges used for calibration in the study area. The merged DEM was then clipped to the study area with a buffer zone to ensure 100% active mesh area in the model.

Where no terrain information was available in the tidal zones, a ground level of -10 mAHD was applied in GIS to the clipped DEM. The resulting DEM (Diagram 1), was then imported into ICM via the grid import interface.

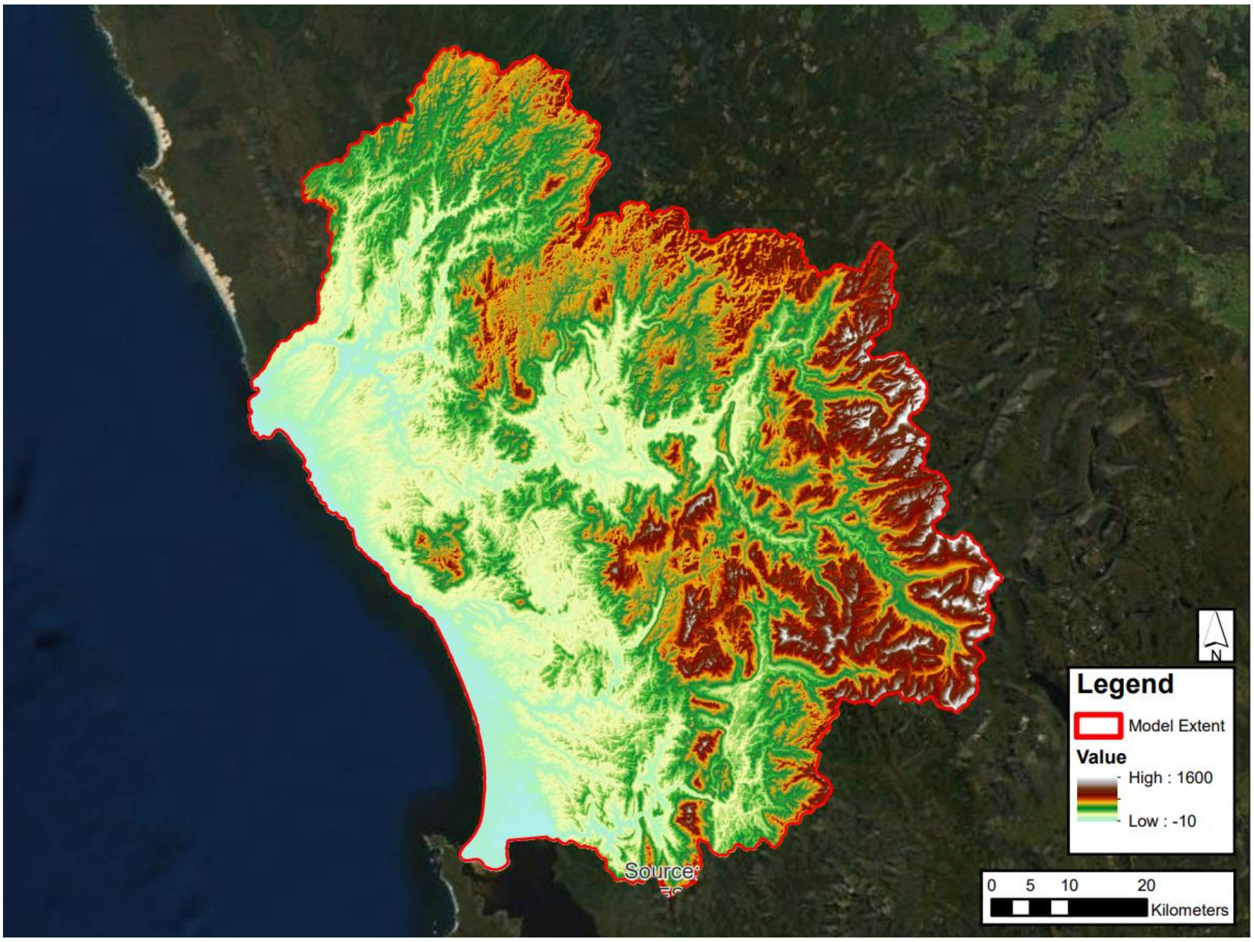

Diagram 1: DEM of the King-Henty study area

The 'Default DTM' is understood to be comprised primarily of photogrammetric contour data and is widespread in this catchment (Diagram 2). The 'Default DTM' is therefore likely to be a poor representation of the topography of the area. Large areas of the King-Henty catchment are covered by the Default DTM.

The edge artifacts between LiDAR and Default DTM cause artificial depressions when the levels are not aligned (Appendix D). Further discussion on the implications of the 'Default DEM' on the outcomes of the hydrodynamic model is provided in Section 6.4.

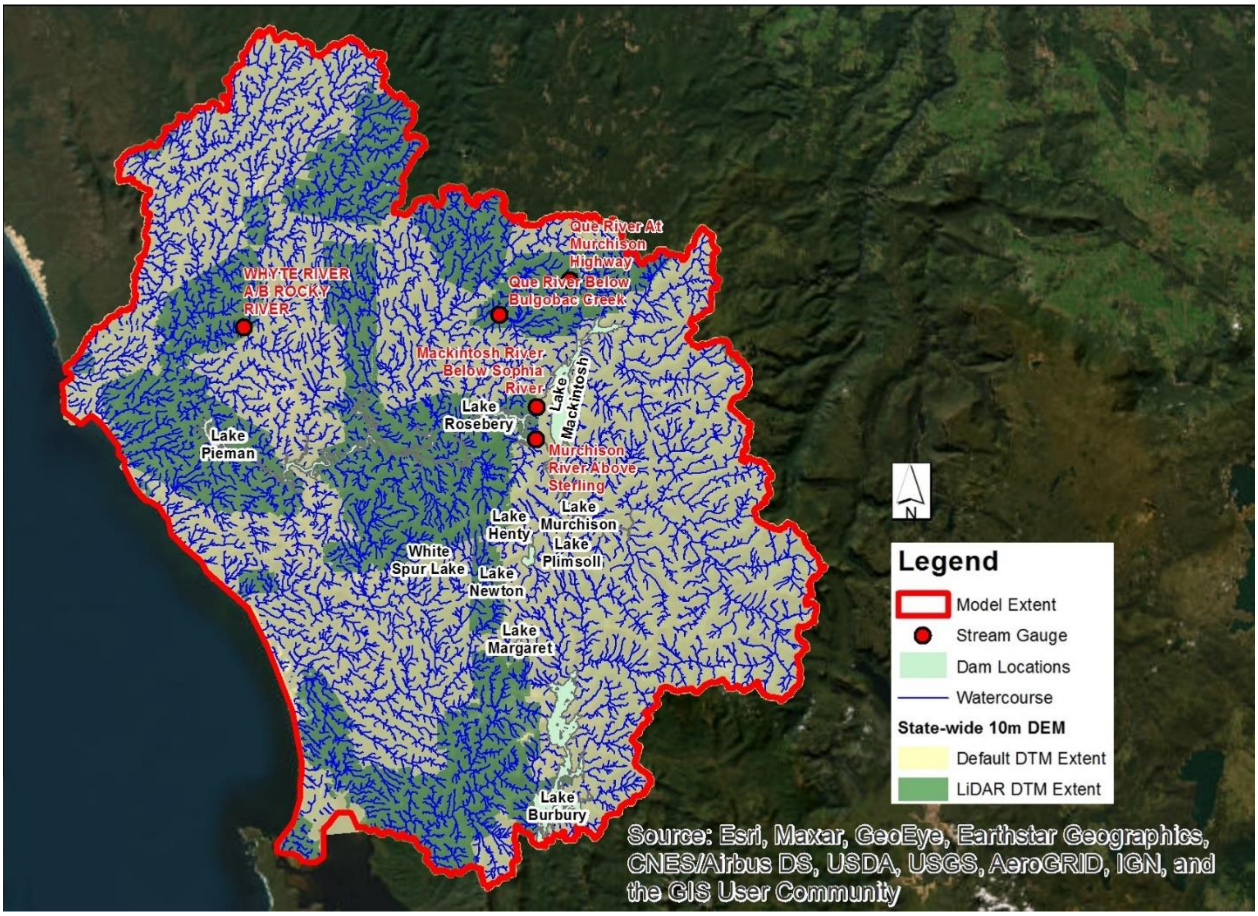

Diagram 2: 'Default DTM' extents for the King-Henty study area

5.2. Roughness

The base information for the roughness grid was the roughness raster provided by SES for this project. The whole of state dataset was converted to a set of polygons for each land use zone in GIS, and the dataset was cleaned to ensure that the geometry was valid. This data was then exported as a csv file to link land use to friction values.

It is noted that at this stage the roughness values for streams vary greatly with sections of Manning's n of 0.1 crossing streams in many locations. This issue is an artefact of the simplification of the roughness layer when it is converted into triangles. Where the issue was severe, a 30 m buffered zone of single roughness of 0.05 for all upper streams was utilised.

The roughness layer in ICM is shown in Diagram 3.

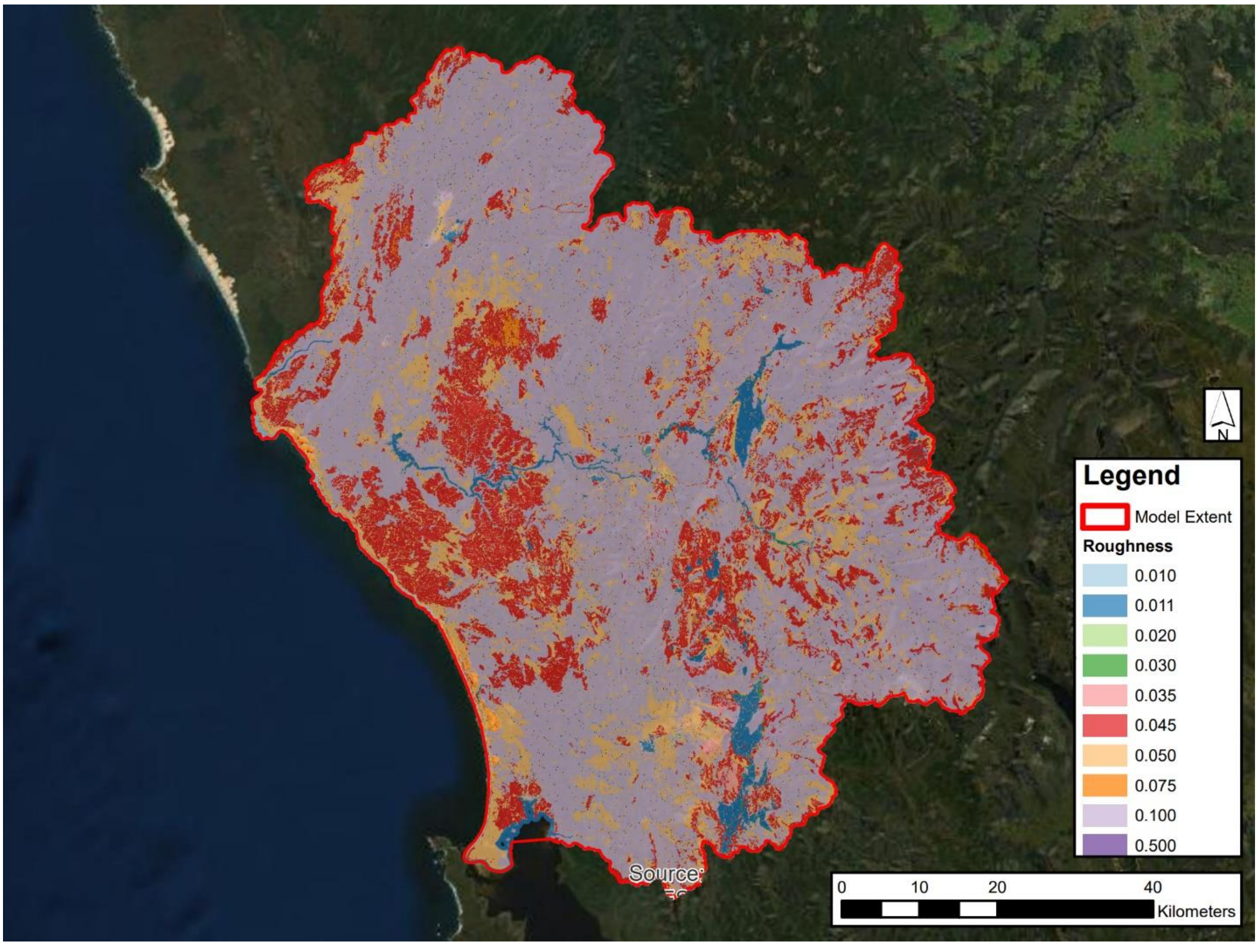

Diagram 3: Roughness layer for the King-Henty study area

5.3. Meshing

Meshing in ICM was undertaken using zones, with the following rules:

- Base 2D zone – regional extent mesh size set to a maximum of 2500 m^2 with a minimum of 400 m^2
- Stream zone – set as an independent area with a maximum mesh size of 400 m^2 and a

minimum of 100 m^2

- Human Settlement Area – set as an independent mesh zone with a maximum area of 100 m^2 and a minimum of 25 m^2
- Upper stream reaches – streamlines of Strahler order 2-5 were buffered by 10 m either side of the centre line with Strahler order 6-8 buffered by 20 m either side of the centre line and incorporated into the hydrodynamic model as a mesh zone. The mesh zones had a maximum area of 150 m^2. This process was to ensure that the meshing process did not result in artificial blocking of the flow paths along main stream lines.

The resulting mesh zones for the King-Henty study area are shown in Diagram 4.

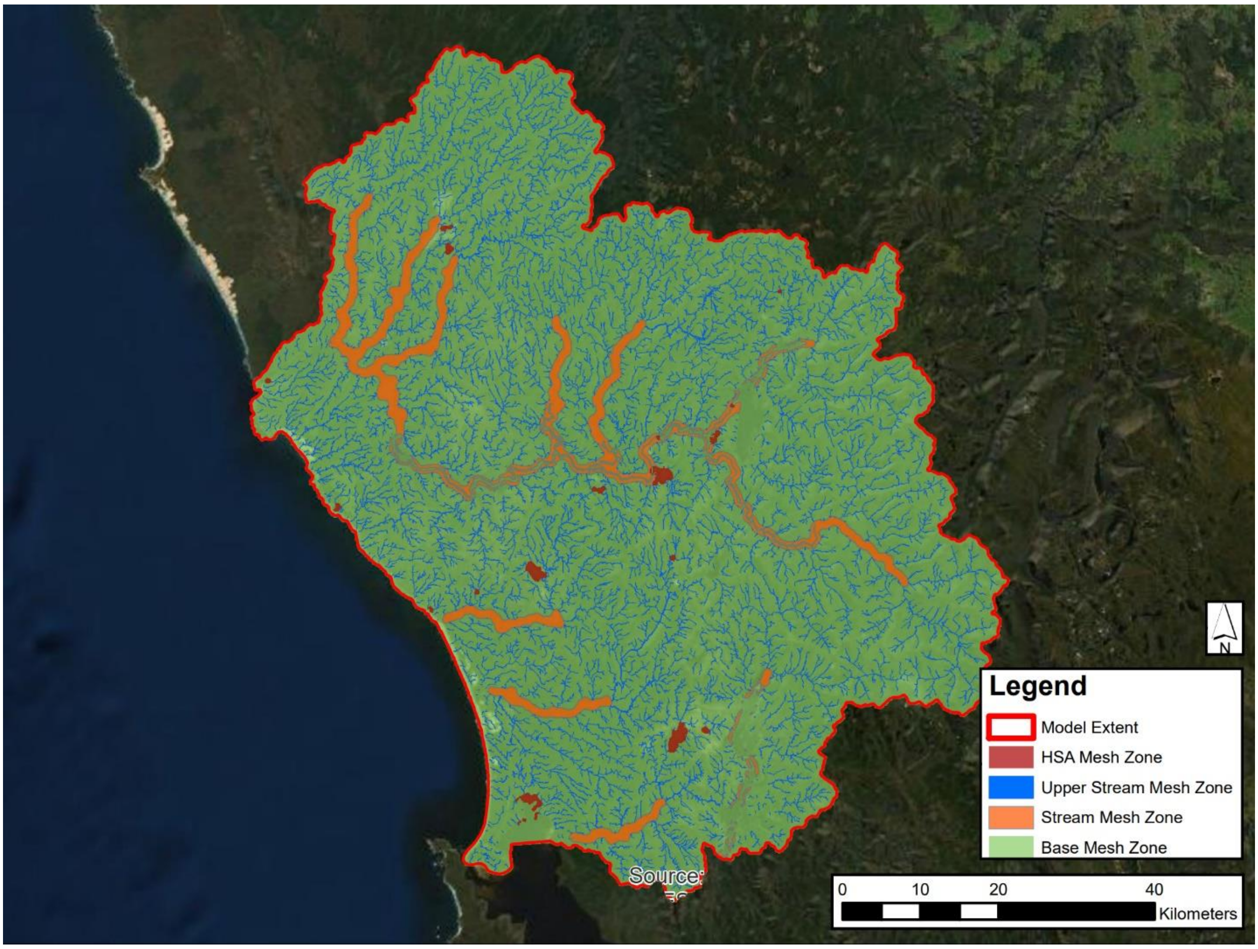

Diagram 4: Mesh zones for the King-Henty study area

5.4. Structures

Bridges are represented within the ICM model as linear 2D bridge structures, using the SES state-wide bridge database for location and reach of associated structures.

For the King-Henty study area, a total of 13 bridges longer than 30 m were identified and imported into the hydrodynamic model. These include:

- A few railway bridges crossing King River,

- Henty River at Henty Road,
- Huskisson River at Pieman Road,
- King River at Mount Jukes Road.

Further discussion on this process is provided in the Hydrodynamic Modelling Methods Report (WMAwater, 2021b).

No major culverts were identified.

5.5. Dams and Storage areas

Ten lakes (Section 3.3) were modelled in the hydrodynamic model in the 2D domain as 1D elements, assuming initial conditions at the starting level of the dams, based on historical lake levels from Water Data Online (BoM 2021). Sophia Tunnel, connecting Lake Murchison to Lake Mackintosh, was modelled in the hydrodynamic model in the 1D domain, with a constant 100 m^3/s flow, except for the August 1970 calibration event as the tunnel did not exist at that time.

The dam walls were modelled as 1D/2D connection boundaries around the lakes. The dam wall is set to about the same height of the highest available spillway rating curves for dams when there was no relevant information available. The dam walls of Pieman Lake (Reece Dam), Lake Rosebery (Bastyan Dam), Lake Mackintosh, Lake Murchison and Plimsoll Lake were set to the crest level (Section 3.3).

5.6. Downstream Boundaries

The downstream boundary was applied at the base of the model to provide interaction with the tidal zone. Synthetic tide data was provided by the Bureau of Meteorology (BOM) for the original 13 calibration event and was used to set a varying tide level for the calibration events. This data was extracted off the coast of the Trial Harbour at 10 min time increments and was imported into ICM as a time varying boundary condition. Synthetic tide data was not available for the May 1994 event as it was selected as a calibration event at a later stage (Section 3.2), therefore observed tide data from the Burnie gauge was used for this event (Bureau of Meteorology 2021). Diagram 5 and Diagram 6 show examples of the observed and synthetic tide data that was extracted for the calibration events.

Note there is no calibration information to verify the function of the tailwater condition, thus no allowance for local storm effects has been undertaken. It is considered the observed and synthetic tide data are reasonable estimations of tailwater levels for the purposes of calibration assessment.

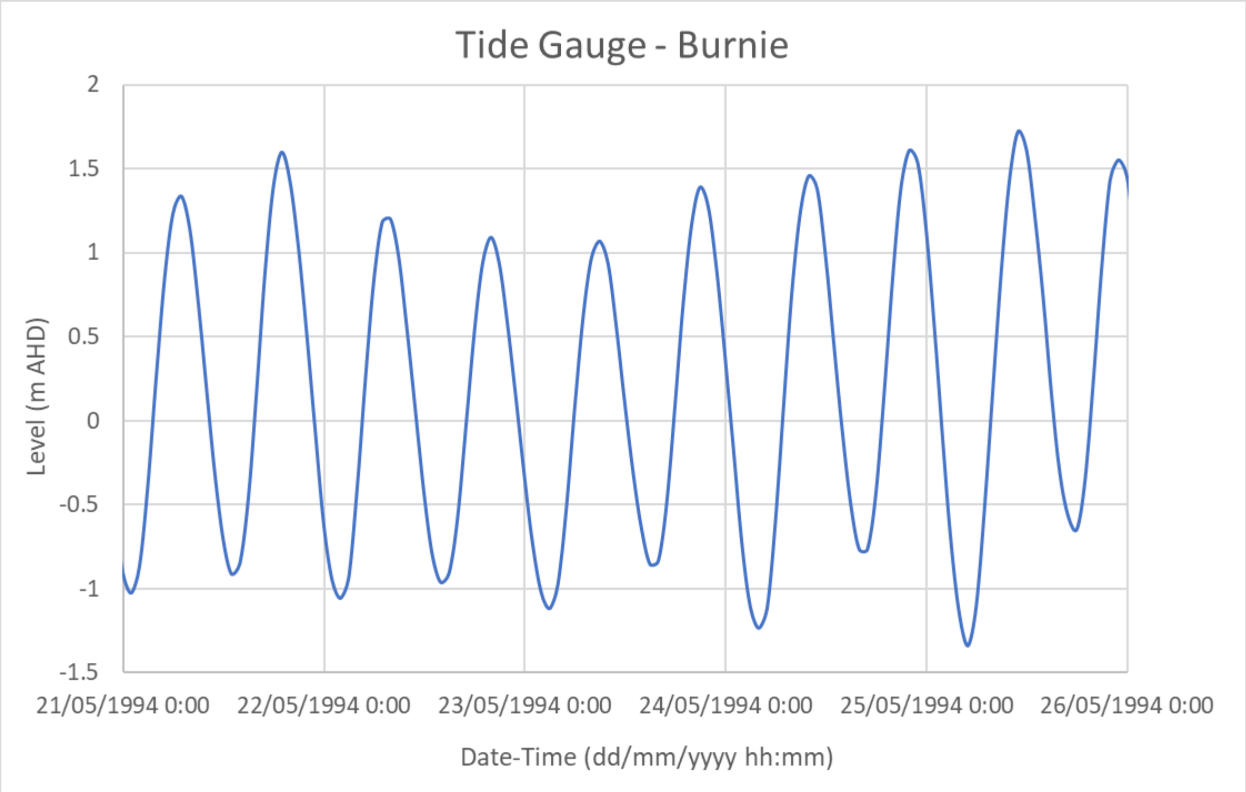

Diagram 5: Observed tide data from the Burnie tide gauge for the May 1994 calibration event

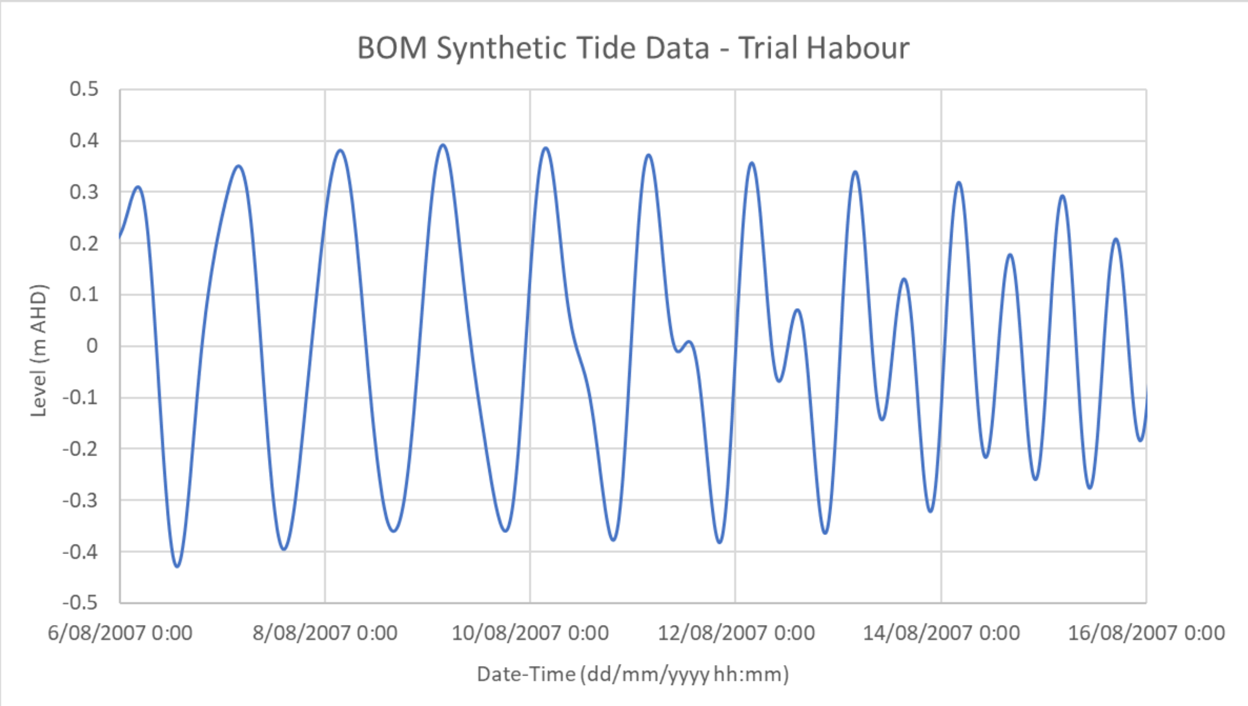

Diagram 6: Synthetic tide data off the coast of the Trial Habour for the August 2007 calibration event

5.7. Flow Application for Hydrodynamic Modelling

Two approaches were used for application of flow in ICM:

- ICM-RAFTS sub-catchment routing, applied to each sub-catchment in the model at the

downstream end of the sub-catchment
- Direct rainfall to model overland flow (short duration events).

The reason for using two approaches is to enable the model to be run efficiently for longer durations by limiting the number of cells wet, focusing on the major tributary flooding while also ensuring the local areas in the upper tributaries are mapped for short duration flooding.

The two flow scenarios sit within the same ICM hydrodynamic model as alternative flow condition scenarios (base and direct rainfall). For the calibration events, the ICM-RAFTS approach is used, where the rainfall information is derived from rainfall files created by the hydrologic model.

For the design events, an envelope of the ICM-RAFTS approach and the design rainfall approach will be used. Rainfall and temporal pattern information derived from the ARR datahub will be used to establish the design rainfall and temporal pattern information for the ICM-RAFTS approach and a synthetic, duration independent storm will be used to assess a range of storm durations and temporal patterns in a singular rainfall event for the design rainfall approach.

5.7.1. ICM-RAFTS Sub-catchment Routing

For the ICM-RAFTS sub-catchment routing, the RAFTS model within ICM was used to calculate the hydrologic routing at each sub-catchment. Rainfalls, model information and model parameters developed through the external hydrologic model were imported into ICM through the open data input tool.

The information imported into ICM included:

- Sub-catchment name
- Slope
- PERN
- RAF
- Initial and Continuing Loss
- Sub-catchment rainfalls (for calibration events)

Each sub-catchment is connected directly to the 2D mesh surface at the downstream end of the catchment. The RAFTS sub-catchment model setup in ICM for the King-Henty study area is shown in Diagram 7. Figure A 1 and Figure A 2 show the hydrological soil groups used to distribute the CL and the average PERN used for each sub-catchment.

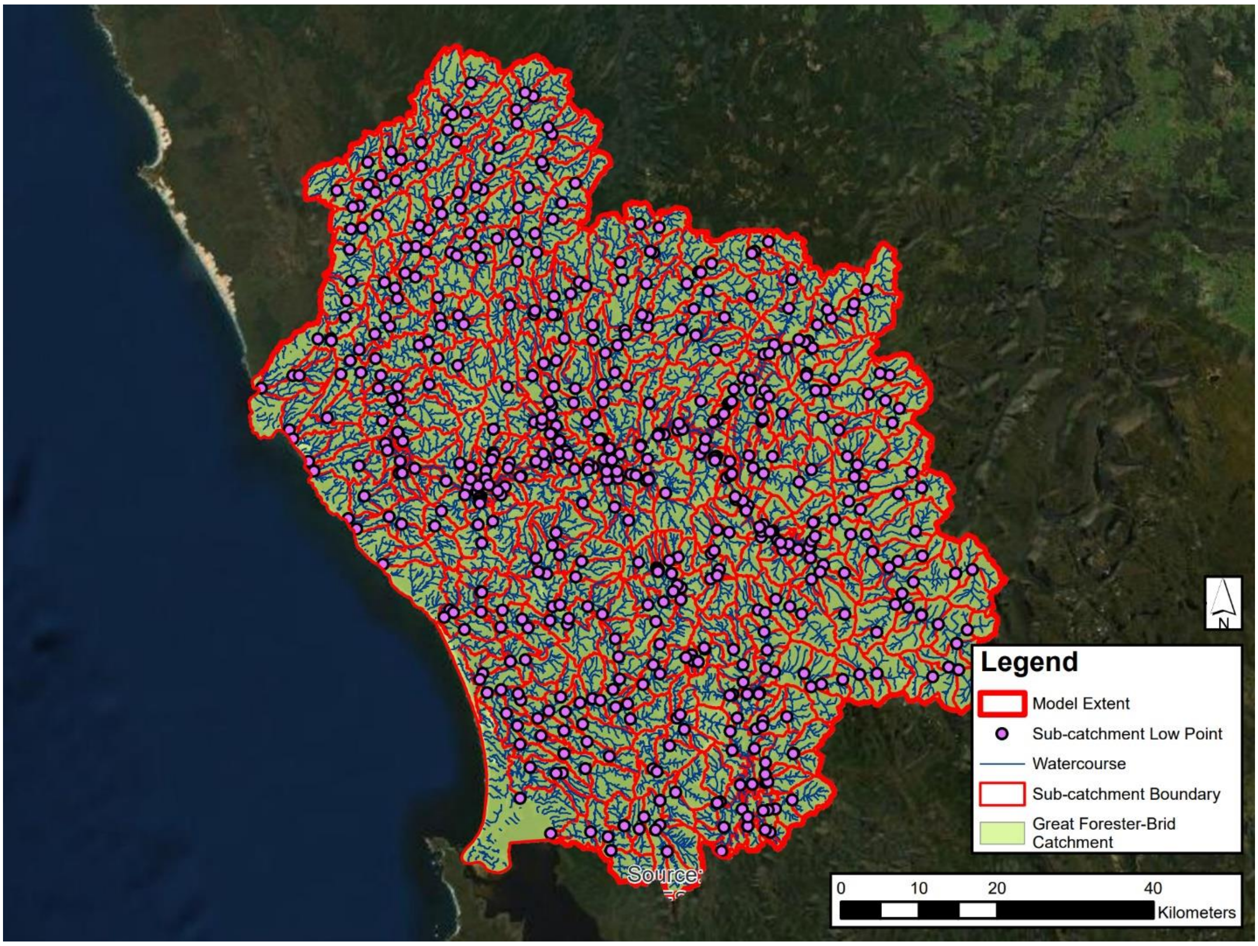

Diagram 7: RAFTS sub-catchment model setup in ICM for the King-Henty study area

6. CALIBRATION RESULTS

Significant unrealistic ponding, and incorrect and disconnected flow paths were identified across the King-Henty study area in review of the calibration modelling results. Appendix D presents some examples of the issues observed. This ponding is believed to relate to the DEM coverage in this study area. A large portion of the King-Henty catchment DEM was constructed from the 'Default DEM' of the SES state-wide 10 m DEM (which it is understood was constructed from the interpolation of circa 1950 contouring of aerial imagery). This introduced the following issues:

- A number of instances were identified where this process has introduced a constriction along main flow paths
- While the 'Default DEM' is hydrologically enforced, the width of the enforcement is insufficient to accurately represent the channel capacity in the area.

Comparisons of the hydrodynamic model to the external hydrologic model are shown in Appendix C. An example of where the expected volume is 'trapped' within the DEM of the hydrodynamic model is shown at sub-catchment KiH486.

Given the issue with the significant ponding, no mapping was done for this study area. Calibration was undertaken at the flow gauges and to lake levels and spills where possible.

6.1. Sub-catchment Routing and Loss Parameters

The ICM model was run with the routing and loss parameters derived from the external hydrologic model and the calibration process for each calibration event.

To prevent the overfitting of parameters, a single IL and scaling to the default CLs (based on the soil types as described in the Hydrology Methods Report (2021a)) was used across the entire study area. It is acknowledged that there are some locations where flows are under or overestimated. Varying losses across the catchment could improve the fit at some of these locations, however, variability in model performance may also be due to quality of recorded flow data and capturing of observed rainfalls so a study-area wide calibration was adopted. The calibrated loss parameters are summarised in Section 6.3.

No changes were required to the RAF routing parameter for this study area. Upon completion of the calibration assessment the external hydrologic model and the ICM model flow results were compared to ensure results were comparable. A summary of this review is presented in Appendix C.

6.2. Initial Conditions

Prefilling of the model was undertaken based on the calibration modelling. Without prefilling, some artificial depression storage occurs due to irregularities in the DTM, which significantly affected the flows at the gauge sites. Even with prefilling, some flows was still caught-up in artificial depressions due to the quality of the DTM.

6.3. Gauge Results

In general, it is considered that a reasonable calibration has been achieved, considering no gauge zero and rating curves were available at the gauges.

Historic event information was available for four of the five gauges within the catchment for the selected calibration events (Mackintosh River Below Sophia River, Murchison River Above Sterling, Que River below Bulgobac Creek, Que River at Murchison Highway). However, the Mackintosh River Below Sophia River is within the 1D Dam modelling area and the Murchison River above Sterling is outside the main flow path in 2D modelling. Therefore, they are not included in the results section below. These four gauges were used in the calibration in the external hydrology.

Mapping of the modelled flood extent across the King-Henty study area has been omitted due to the poor quality of DTM and the limitations of the modelling approach (See Section 6.4).

6.3.1. Que River At Murchison Highway

The modelled and observed peak flows for the May 1994 and August 2007 calibration events at the Que River at Murchison Highway gauge are presented in Table 5 and Diagram 8 to Diagram 9. The modelled and observed peak water elevation for the May 1994 and August 2007 calibration events at the Que River at Murchison Highway gauge are presented in Diagram 10 and Diagram 11. The modelled peak flow shows a fair match to the recorded peak flow and a good match to the observed and modelled water level.

A gauge zero for the Que River at Murchison Highway gauge was not available from the Hydro Tasmania. Therefore, the assumed gauge zero is obtained from the hydrodynamic mesh level.

Table 5: Calibrated parameters and discharge at Que River At Murchison Highway

Statistic	1994 May	2007 Aug
IL (mm)	20	5
Average CL (mm/h)	0	0.4
Modelled Peak (m^3/s)	27.05	24.05
Observed Peak (m^3/s)	22.95	21.17
Peak % difference	18%	14%
Modelled Volume (GL)	2.87	2.81
Observed Volume (GL)	3.38	2.69
Volume % difference	-15%	4%
Modelled peak (mAHD)	608.4	608.35
Observed peak (mAHD)	608.6	608.56
Peak difference (m)	-0.2	-0.21

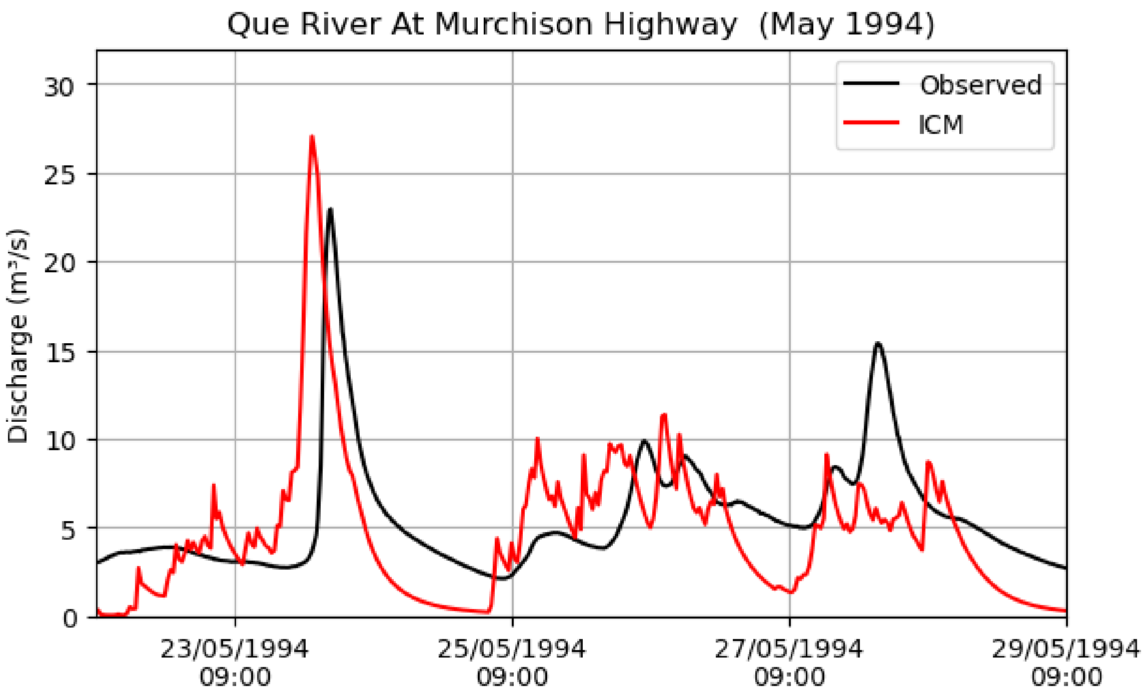

Diagram 8: May 1994 flow comparison at Que River At Murchison Highway

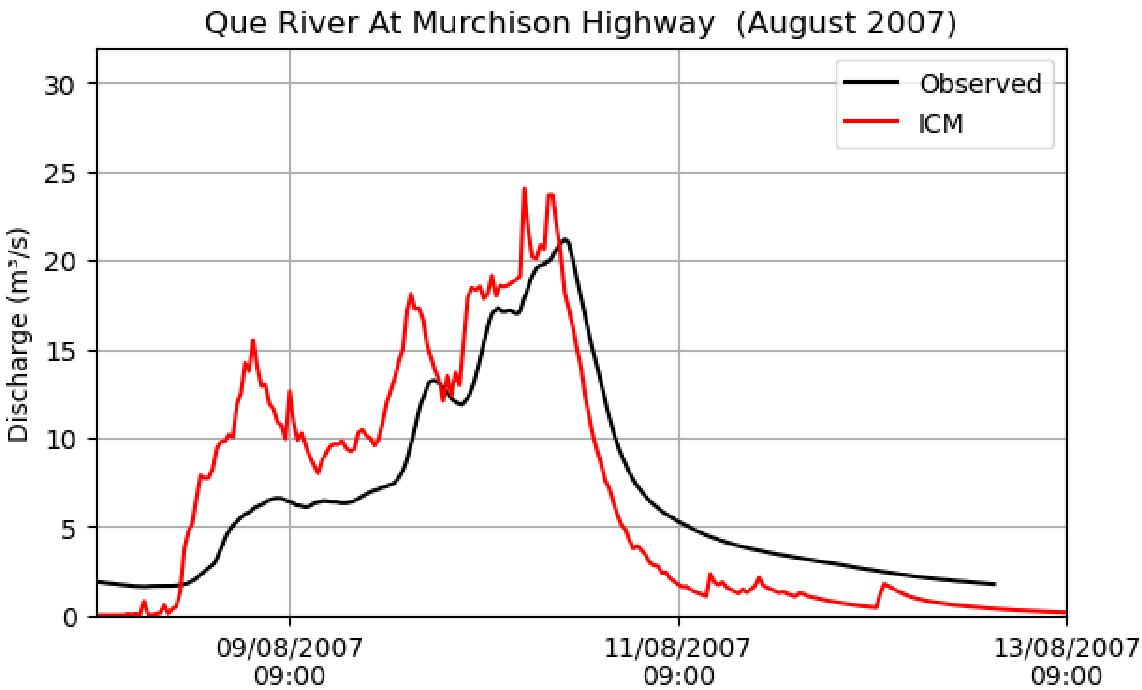

Diagram 9: August 2007 flow comparison at Que River At Murchison Highway

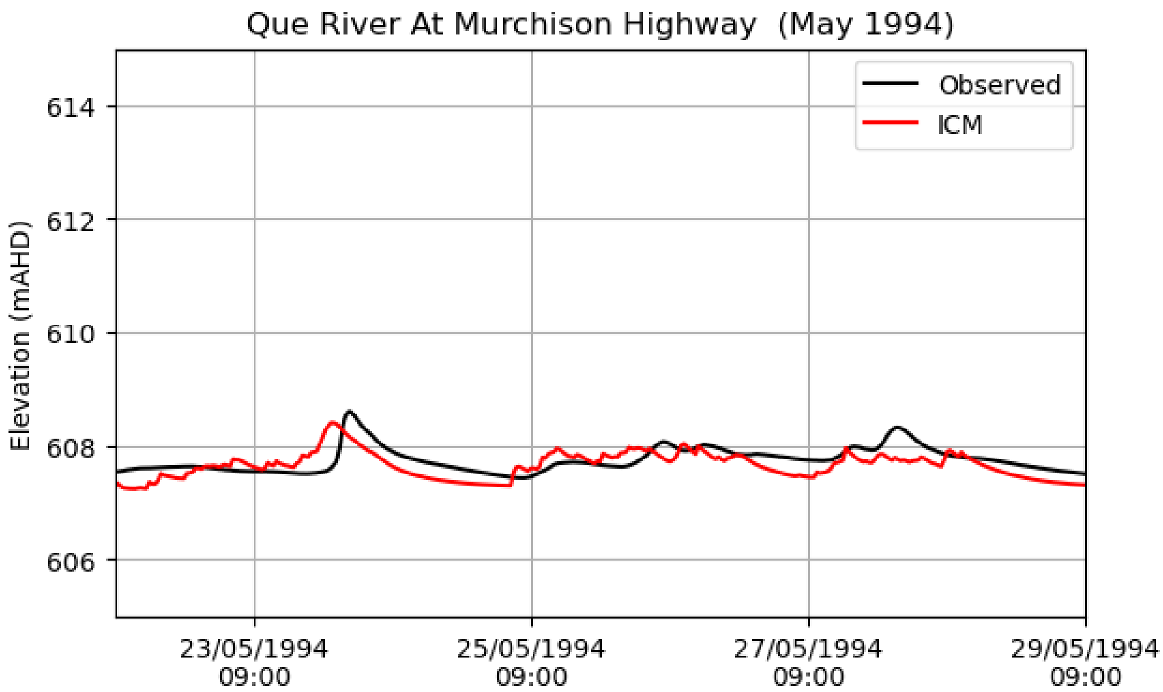

Diagram 10: May 1994 water level comparison at Que River At Murchison Highway (assumed gauge zero)

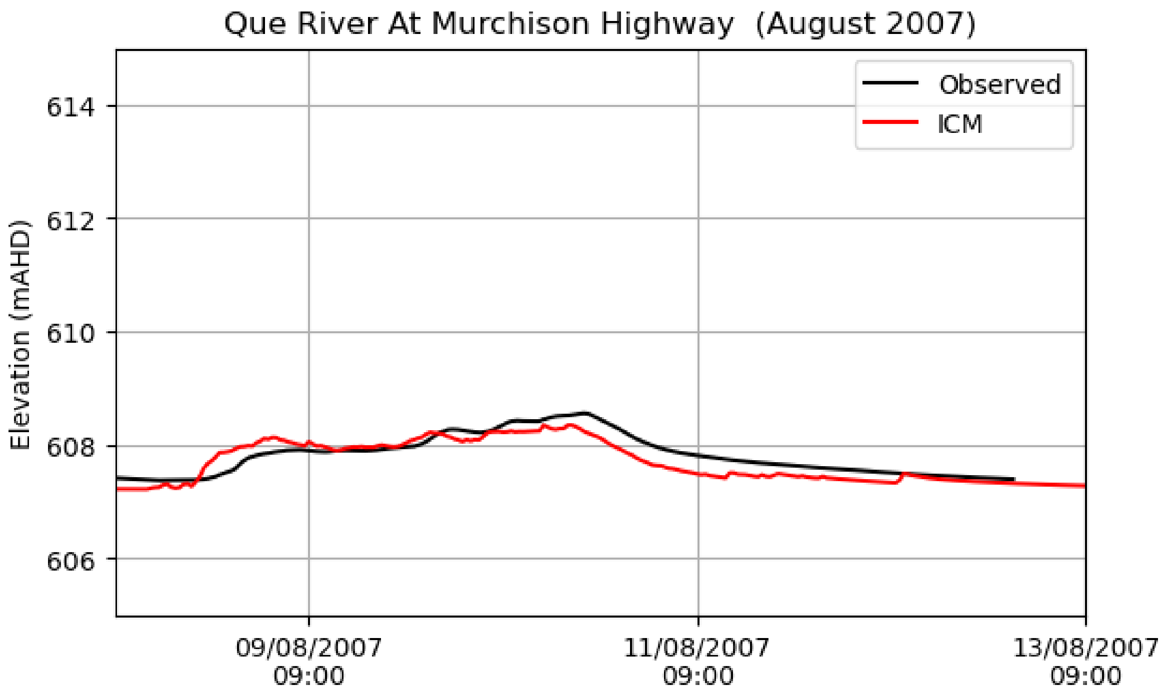

Diagram 11: August 2007 water level comparison at Que River At Murchison Highway (assumed gauge zero)

6.3.2. Que River Below Bulgobac Creek

At this gauge, data was available for one calibration event, May 1994. The modelled and observed flows at the Que River Below Bulgobac Creek gauge are shown in Table 6 and Diagram 12. The modelled and observed peak water elevation for the May 1994 calibration events at the Que River at Murchison Highway gauge are presented in Diagram 13.

The modelled flows show a poor match to the gauge flows. The quality of the rating at this site is not known, and the gauge zero is also not available. The assumed gauge zero was adopted based on the hydrodynamic mesh.

Table 6: Calibrated parameters and discharge at Que River Below Bulgobac Creek

Statistic	1994 May
IL (mm)	20
Average CL (mm/h)	0
Modelled Peak (m^3/s)	170.57
Observed Peak (m^3/s)	84.99
Peak % difference	101%
Modelled Volume (GL)	21.29
Observed Volume (GL)	19.88
Volume % difference	7%
Modelled peak (mAHD)	345.26
Observed peak (mAHD)	345.24
Peak difference (m)	0.02

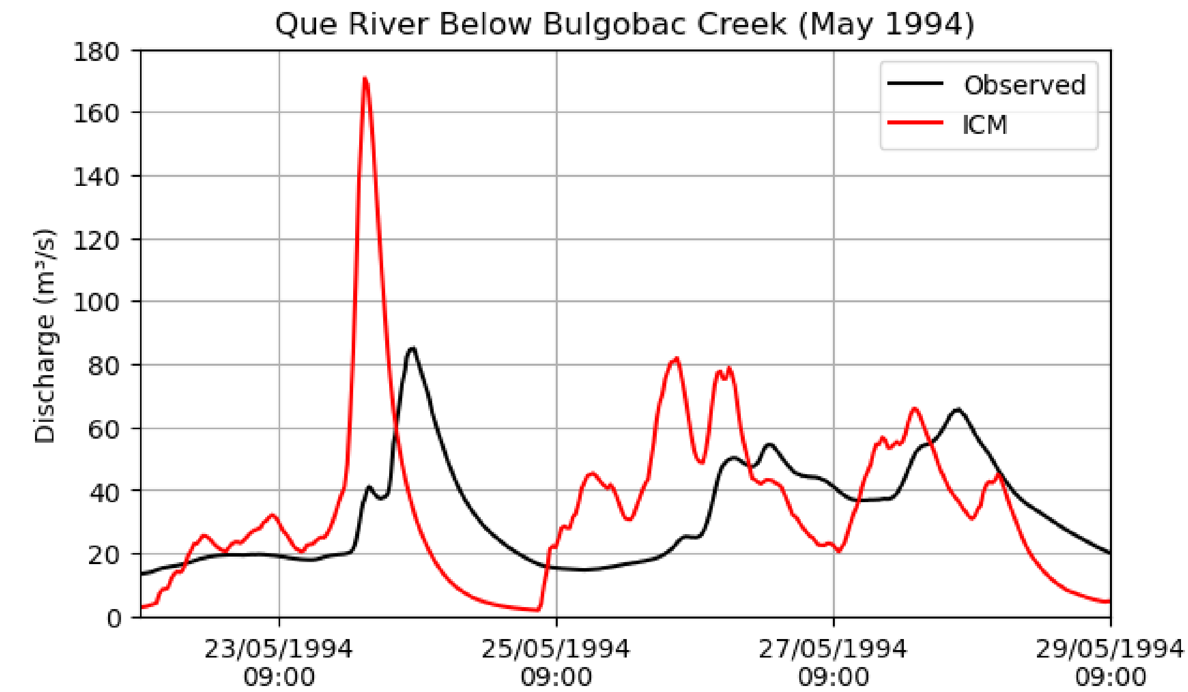

Diagram 12: May 1994 flow comparison at Que River Below Bulgobac Creek

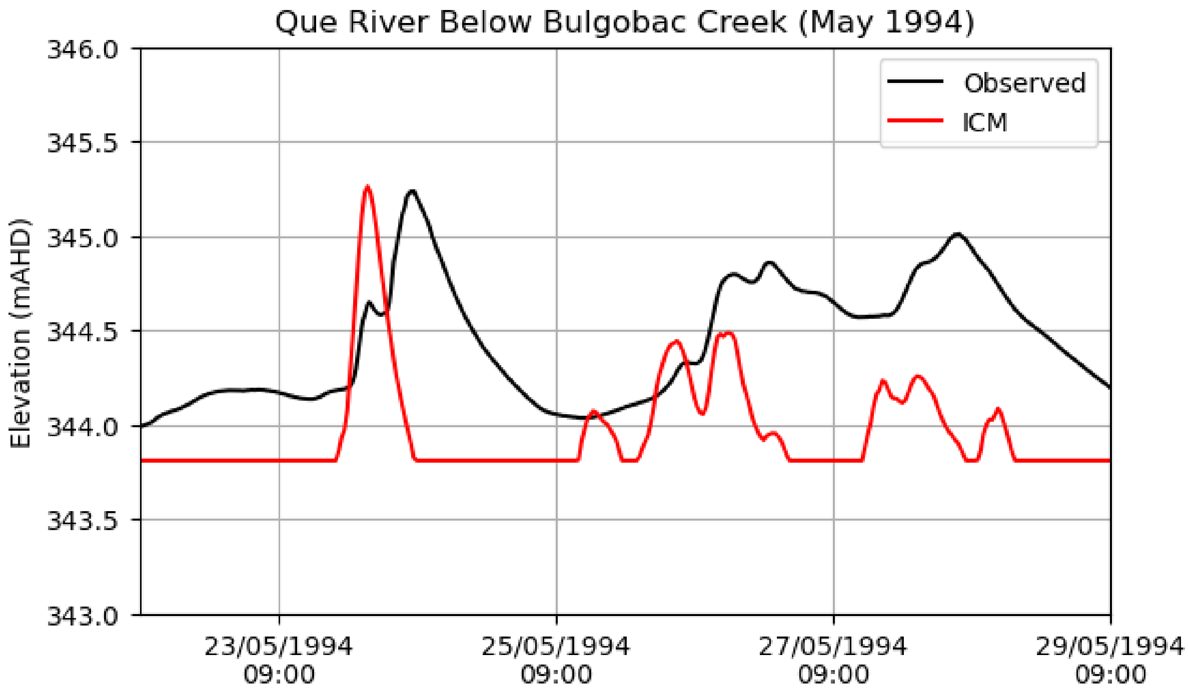

Diagram 13: May 1994 water level comparison at Que River Below Bulgobac Creek (assumed gauge zero)

6.3.3. Lake Mackintosh

The modelled and observed spills from Lake Mackintosh are shown in Table 7, Diagram 14 and Diagram 15. Observed spills in this case also include flows through the power station. Note that the modelled spills for 1994 event are assumed to be based on daily data. The modelled flows show a good match to the recorded spills for the 1994 event, but show a relatively poor match for the 2007 event. The poor match in 2007 is due to power station operation. The power station was in operation at the start of the event, which drew down the lake level. This was not included in the model. A comparison of modelled lake levels is shown in Diagram 16.

Table 7: Parameters and results at Lake Mackintosh

Statistic	1994 May	2007 August
Modelled peak (m^3/s)	373.78	308.48
Observed peak (m^3/s)	349.33	242.26
Peak difference (%)	7%	27%
Modelled Volume (GL)	75.64	42.47
Observed Volume (GL)	59.85	64.44
Volume % difference	26%	-34%

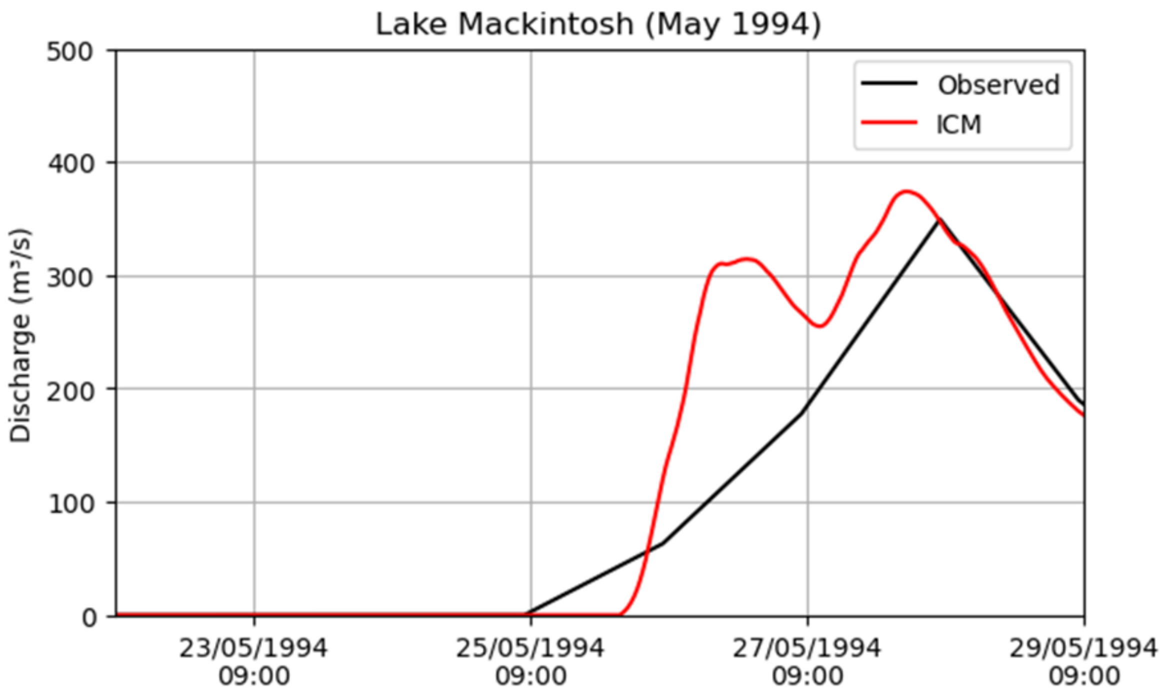

Diagram 14: May 1994 Lake Mackintosh spill comparison

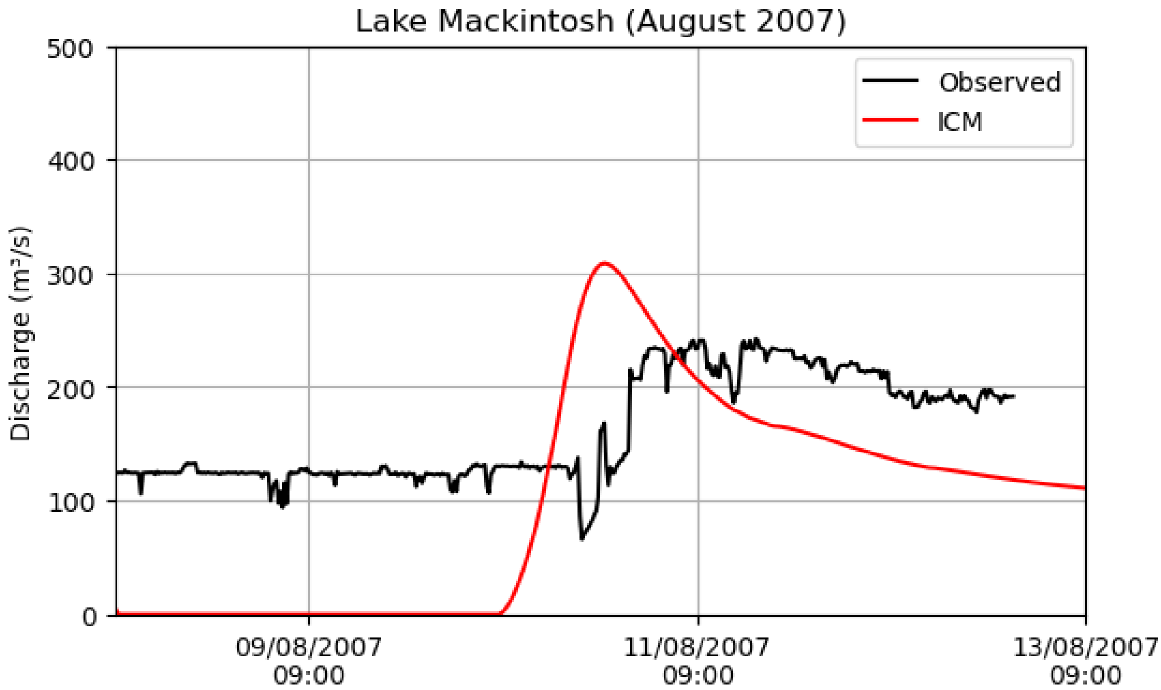

Diagram 15: August 2007 Lake Mackintosh spill

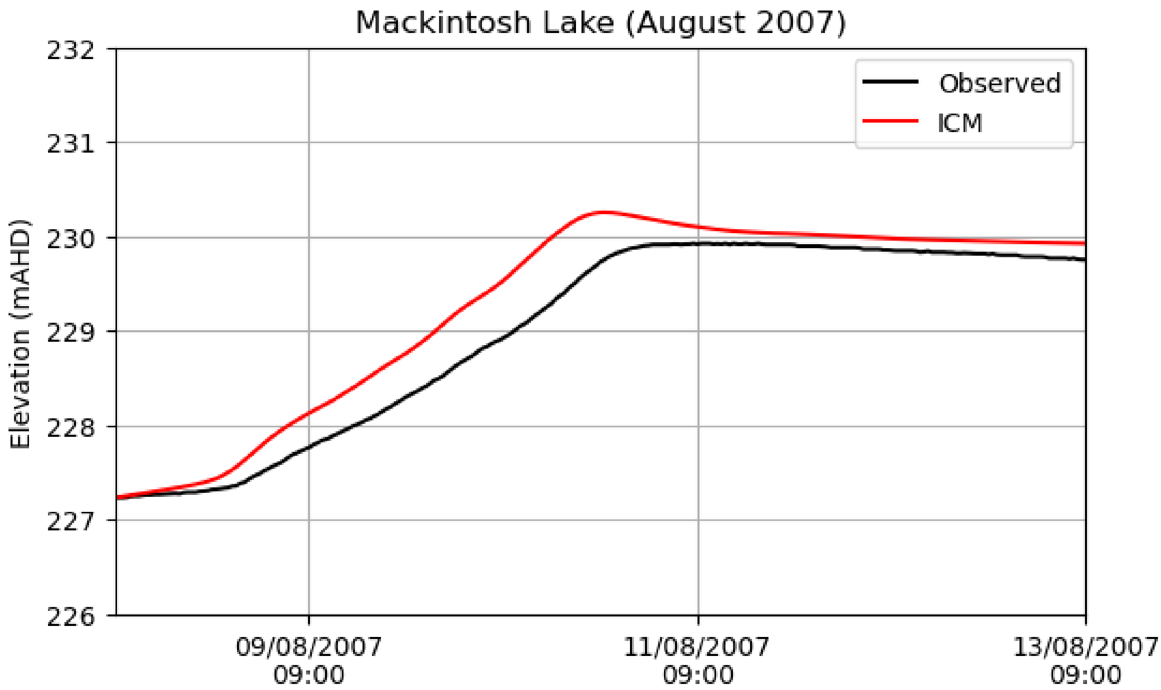

Diagram 16: August 2007 Lake Mackintosh lake level

6.3.4. Lake Murchison

The modelled and observed spills from Lake Murchison are shown in Table 8 and Diagram 17 and Diagram 18. The modelled spills show a good match to the observed spills.

Table 8: Parameters and results at Lake Murchison

Statistic	1994 May	2007 August
Modelled peak (m^3/s)	678.37	882.52
Observed peak (m^3/s)	619.4	902.85
Peak difference (%)	10%	-2%
Modelled Volume (GL)	171.83	147.5
Observed Volume (GL)	175.93	149.77
Volume % difference	-2%	-2%

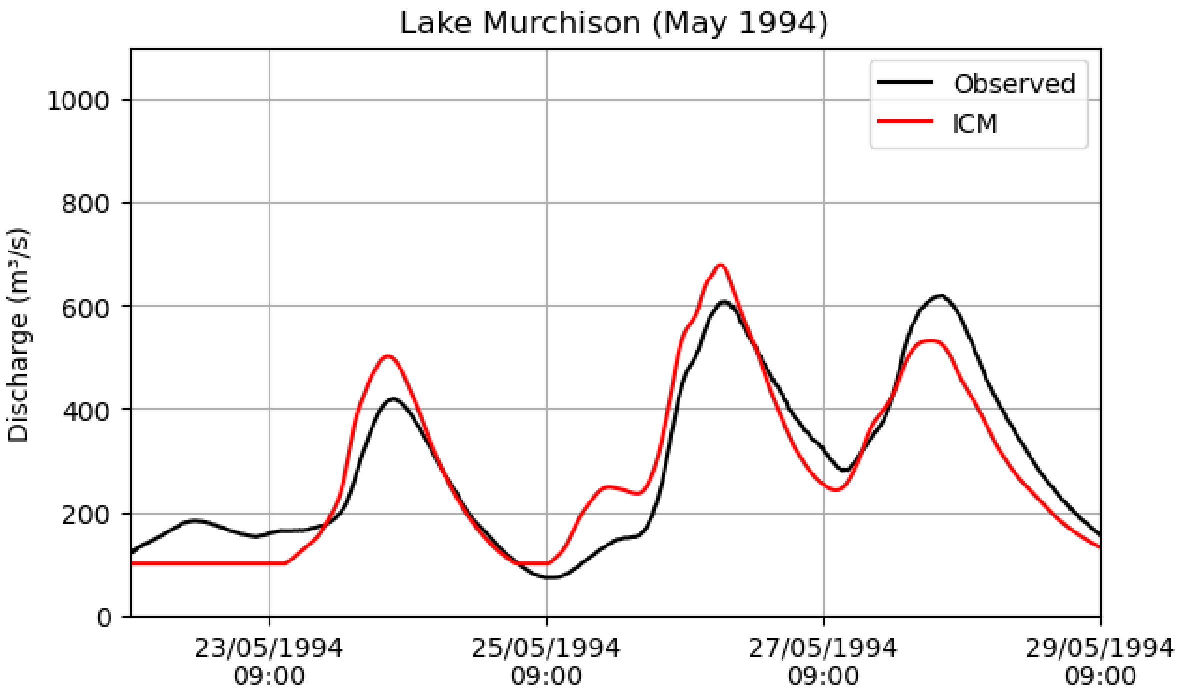

Diagram 17: May 1994 spill comparison at Lake Murchison

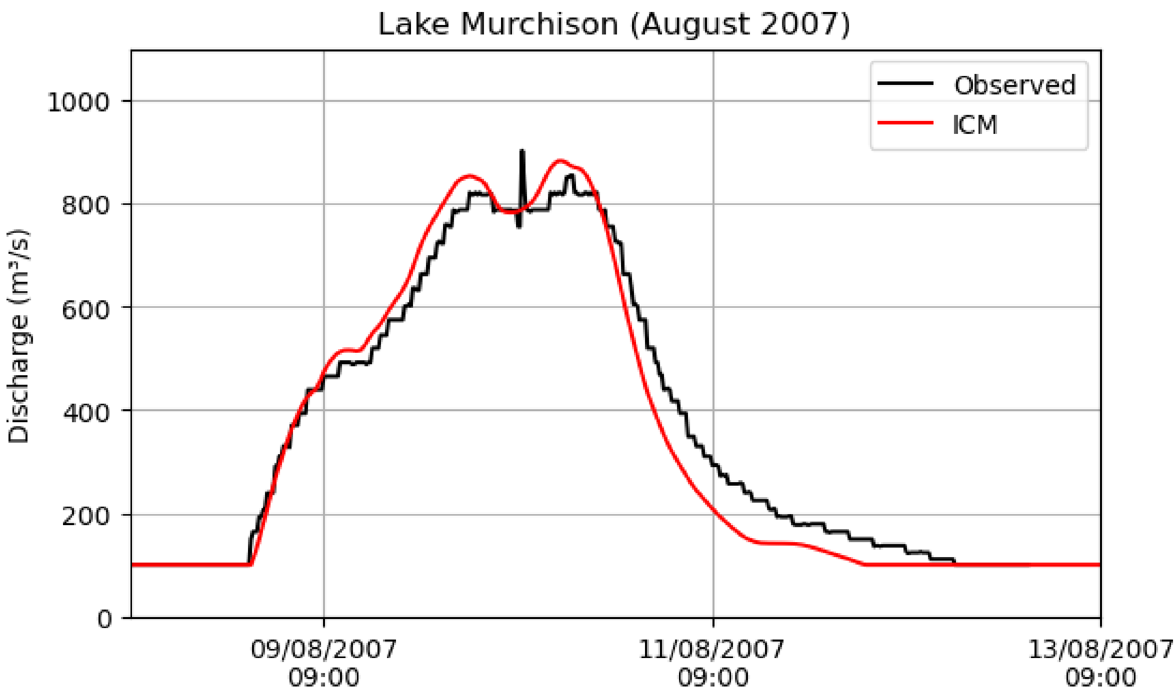

Diagram 18: August 2007 spill comparison at Lake Murchison

6.3.5. Lake Rosebery

The modelled and observed spills from Lake Rosebery are shown in Table 9 and Diagram 19 and Diagram 21. Note that the observed spills in this case include power station flows, and that the observed flows for 1994 are based on daily values. Whilst there are discrepancies between the modelled and observed flows due to assumptions around operation, the modelled and observed lake levels show a fair match in 1994 and compare well in 2007 (

Diagram 20, Diagram 22).

Table 9: Parameters and results at Lake Rosebery

Statistic	1994 May	2007 August
Modelled peak (m^3/s)	861.48	1061.67
Observed peak (m^3/s)	1099.92	1138.11
Peak difference (%)	-22%	-7%
Modelled Volume (GL)	207.95	155.95
Observed Volume (GL)	293.08	214.58
Volume % difference	-29%	-27%

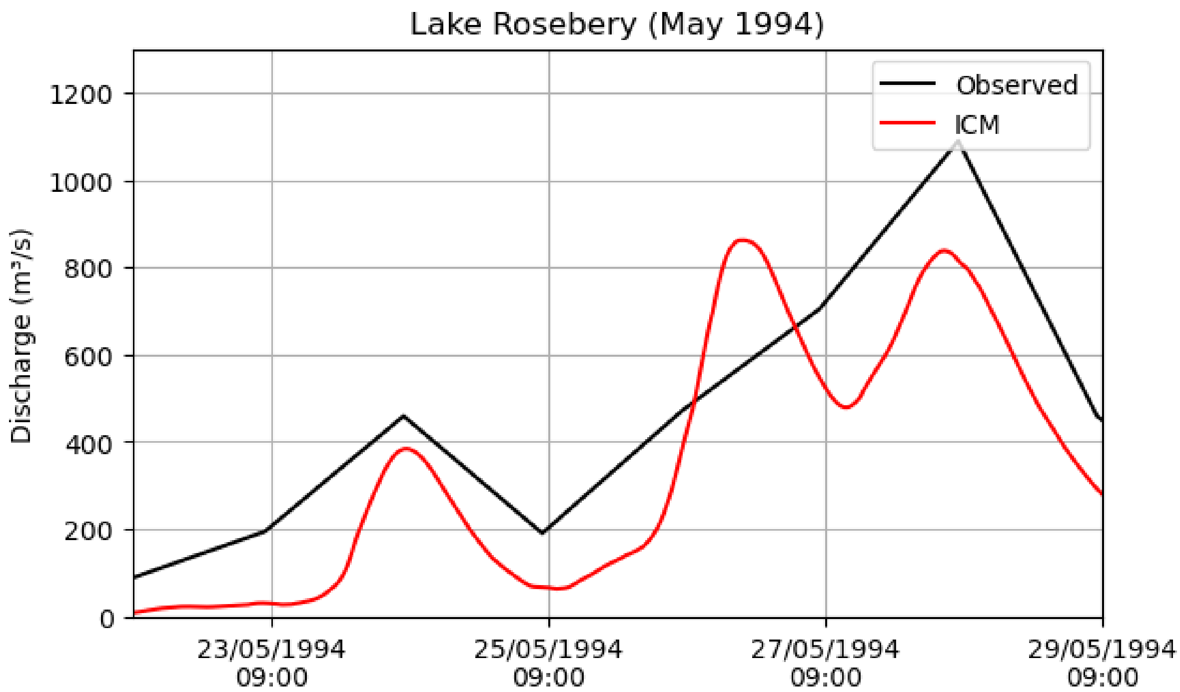

Diagram 19: May 1994 spill comparison at Lake Rosebery

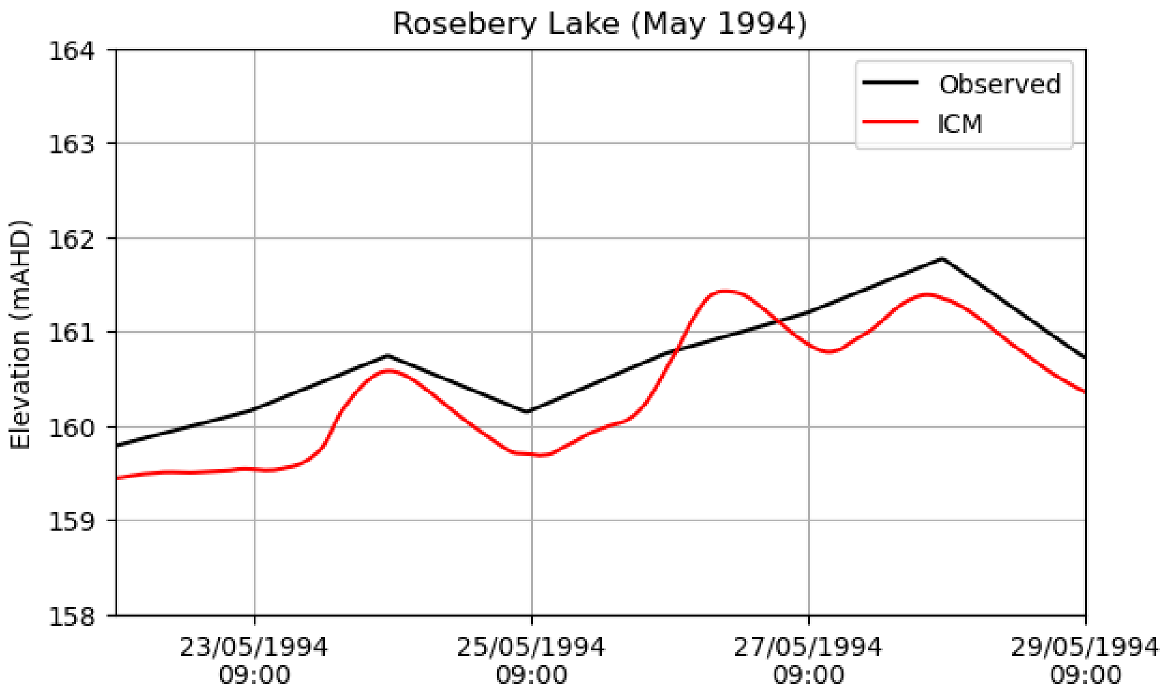

Diagram 20: May 1994 Lake Rosebery lake level

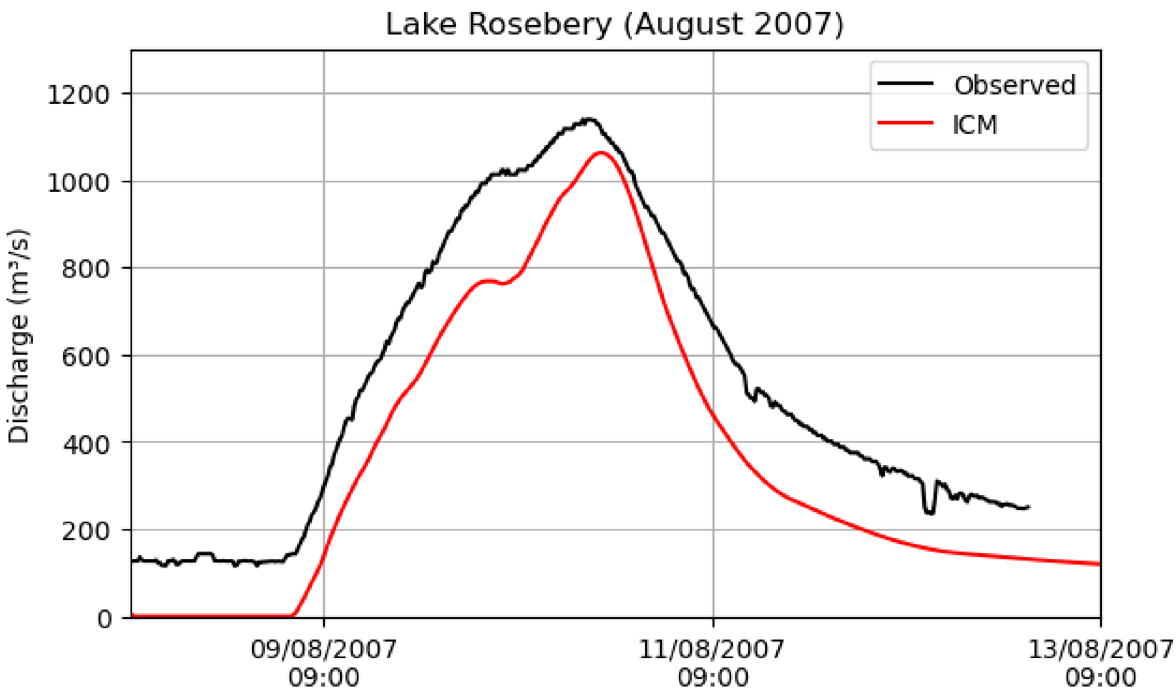

Diagram 21: August 2007 flow discharge comparison at Lake Rosebery

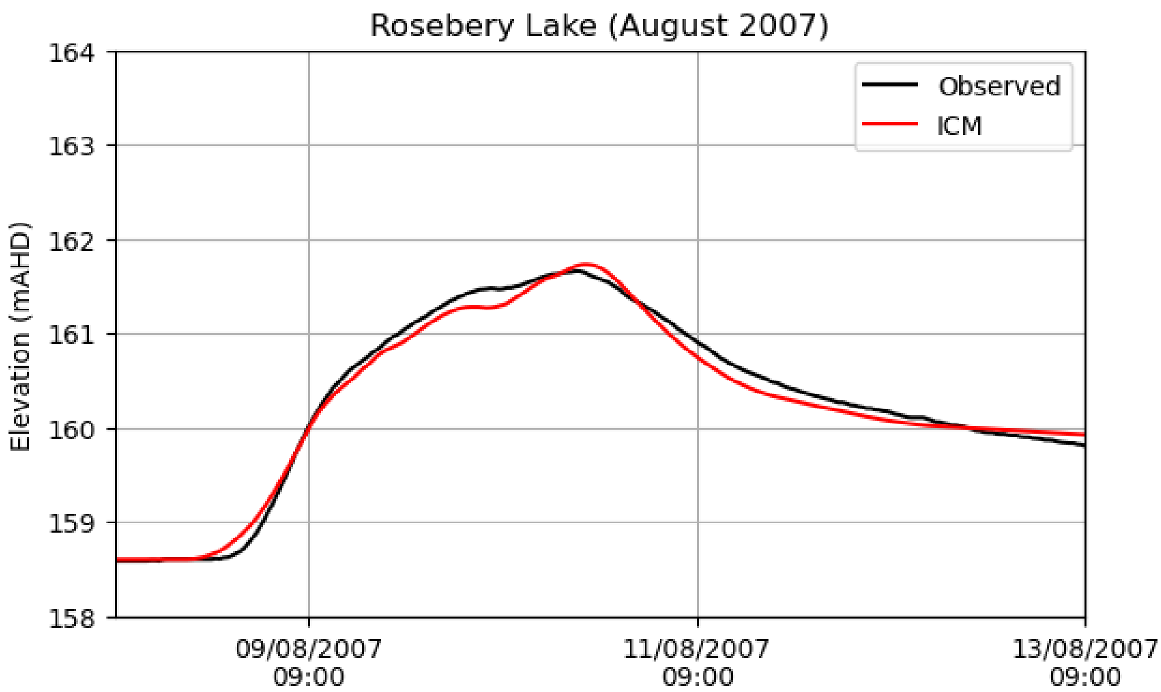

Diagram 22: August 2007 Lake Rosebery lake level

6.3.6. Lake Pieman

The modelled and observed peak discharge flows at Lake Pieman are shown in Table 10 and Diagram 23 to Diagram 25. Note that power station flows are included in the Lake Pieman discharge flows in the 2007 event.

The modelled flows show a good match to the recorded daily lake levels.

Table 10: Parameters and results at Lake Pieman

Statistic	1994 May	2007 August
Modelled peak (m^3/s)	1223.92	1530.79
Observed peak (m^3/s)	1435.2	1913.77
Peak difference (%)	-15%	-20%
Modelled Volume (GL)	340.32	228.83
Observed Volume (GL)	300.78	360.32
Volume % difference	13%	-36%

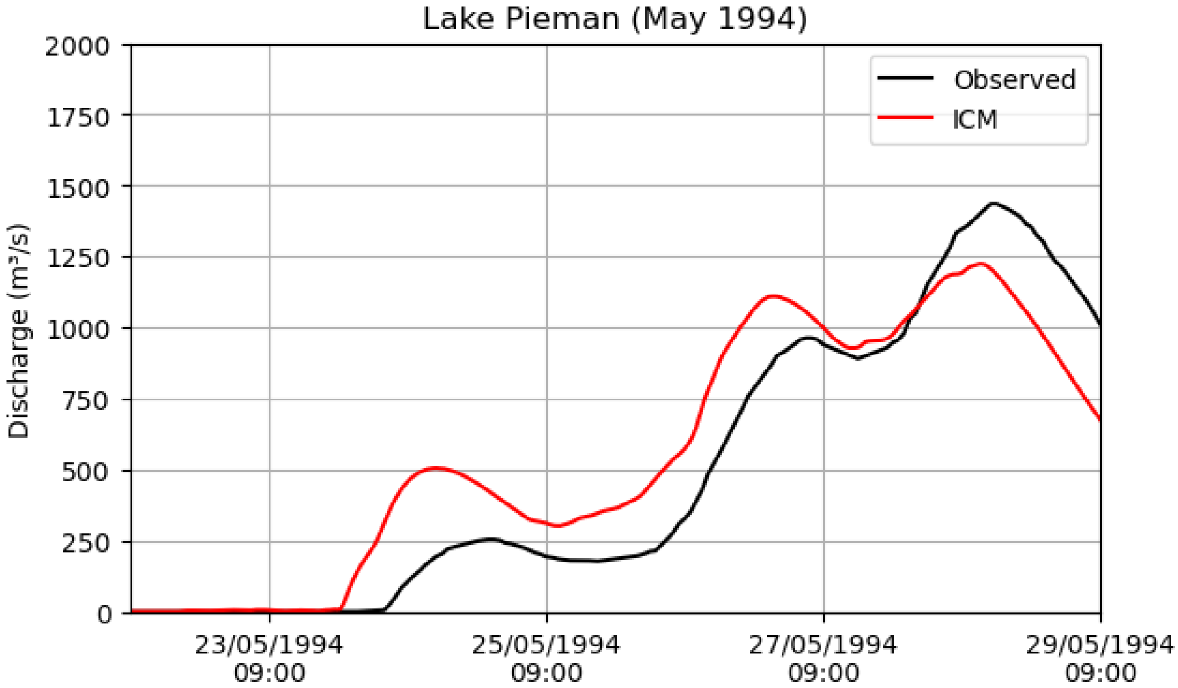

Diagram 23: May 1994 spill comparison at Lake Pieman

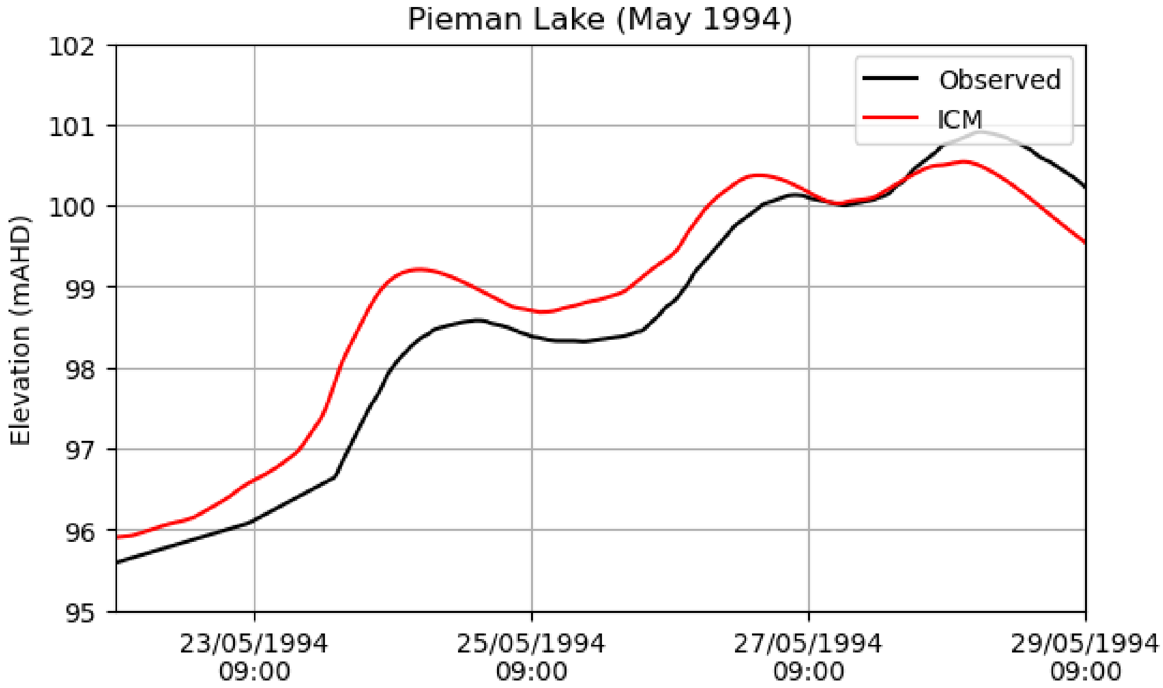

Diagram 24: May 1994 Lake Pieman lake level

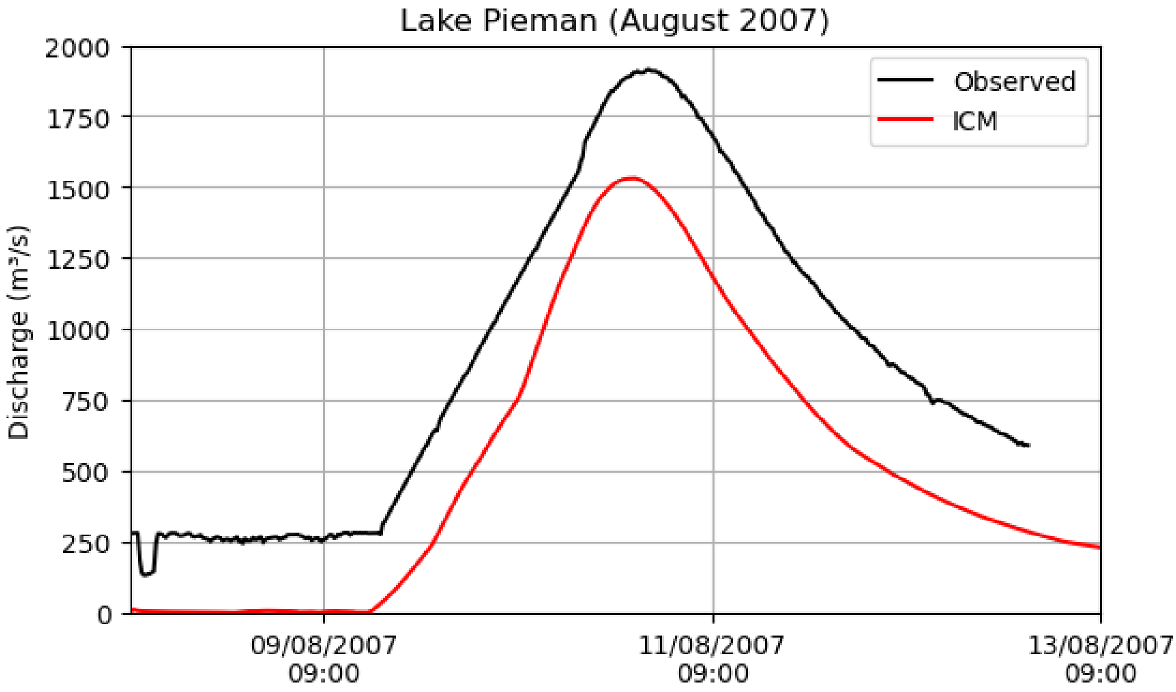

Diagram 25: August 2007 spill comparison at Lake Pieman

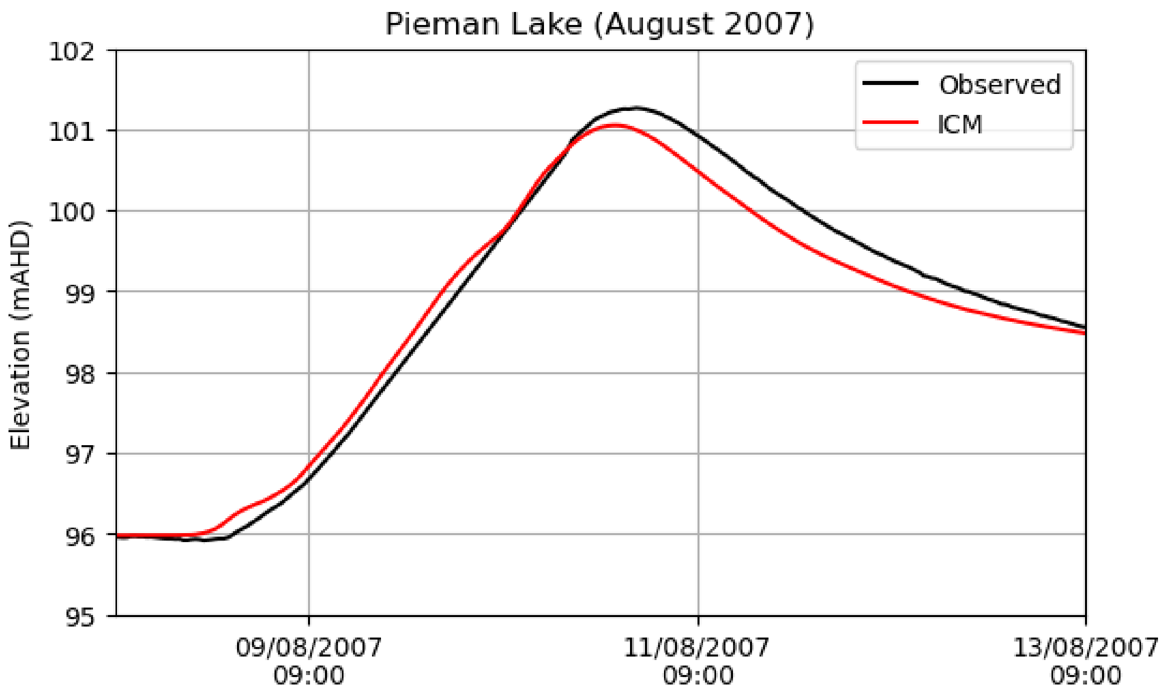

Diagram 26: August 2007 Lake Pieman lake level

6.3.7. Lake Margaret

The modelled and observed levels at Lake Margaret are shown in Table 11 and Diagram 27 for the August 2007 event. The modelled levels show a good match to the recorded lake levels.

Table 11: Parameters and results at Lake Margaret

Statistic	2007 August
IL (mm)	0.0
Average CL (mm/h)	0.0
RAF	1.0
Modelled peak (mAHD)	662.96
Observed peak (mAHD)	663.03
Peak difference (m)	0.07

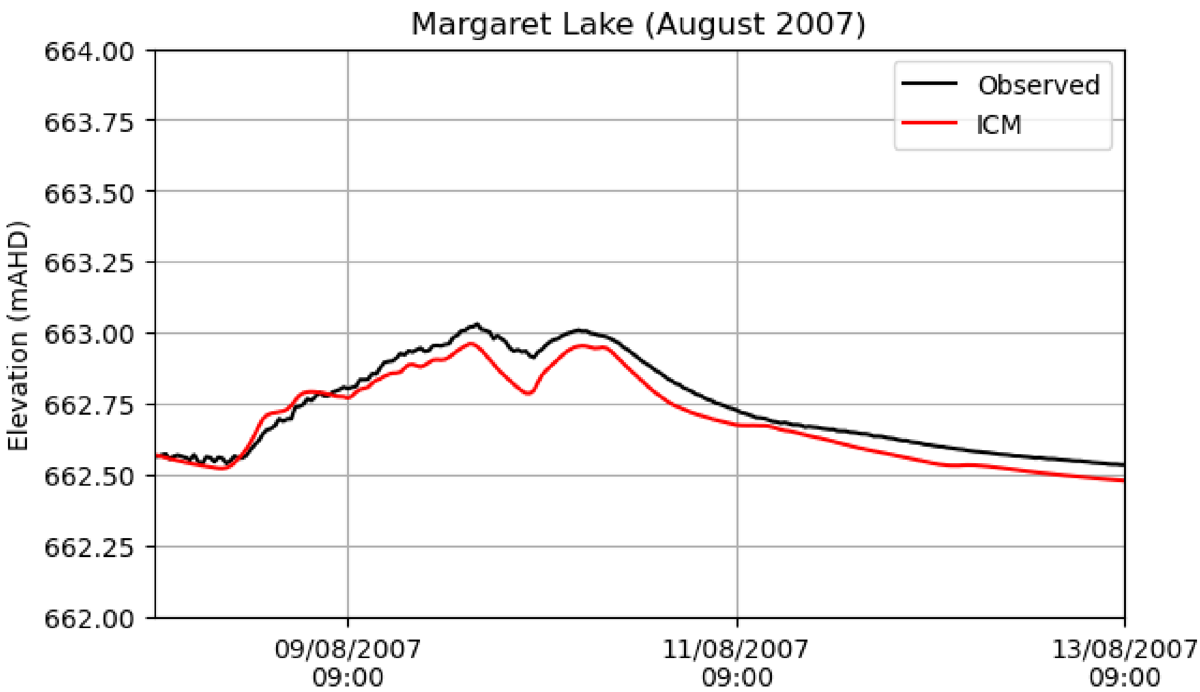

Diagram 27: August 2007 water level comparison at Margaret Lake

6.3.8. Lake Burbury

The modelled and observed levels at Lake Burbury are shown in Table 12 and Diagram 28 to Diagram 29. The modelled levels show a fair to good match to the recorded daily lake levels. It is noted that some of the flow paths upstream of Lake Burbury are disconnected in the DTM, resulting in some flows in the catchment not reaching the lake in the 2007 event.

Table 12: Parameters and results at Lake Burbury

Statistic	1994 May	2007 August
IL (mm)	0.0	0.0
Average CL (mm/h)	0.0	0.0
RAF	1.0	1.0
Modelled peak (mAHD)	234.19	230.57
Observed peak (mAHD)	234.29	231.21
Peak difference (m)	0.1	0.64

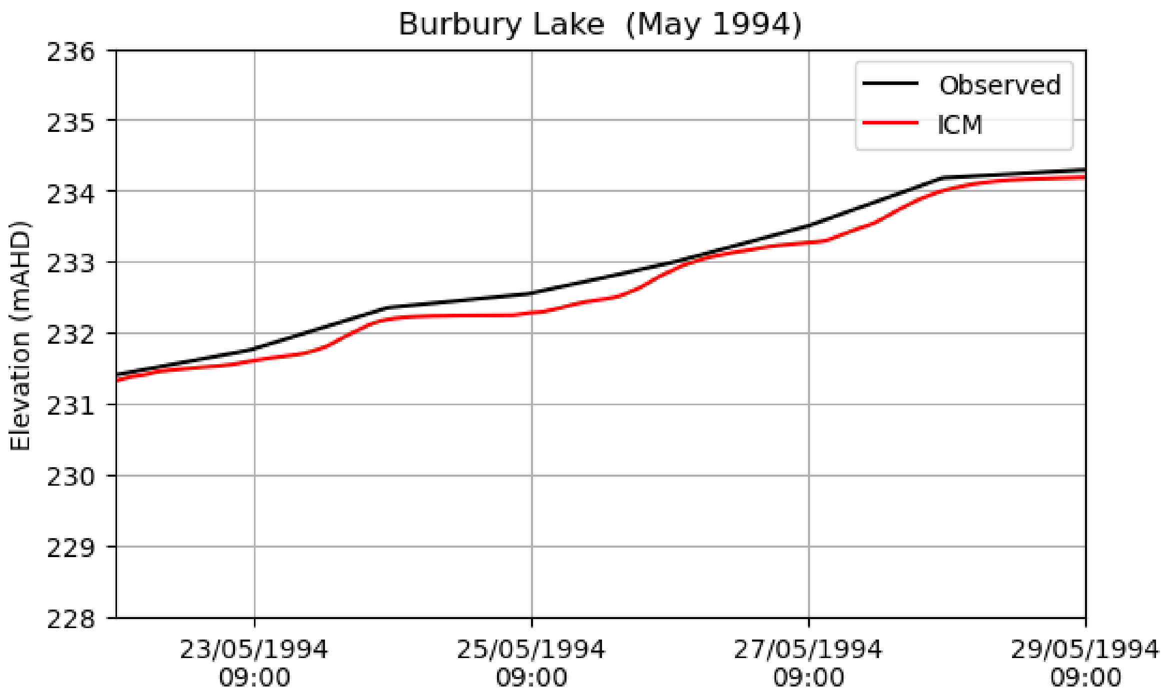

Diagram 28: May 1994 water level comparison at Lake Burbury

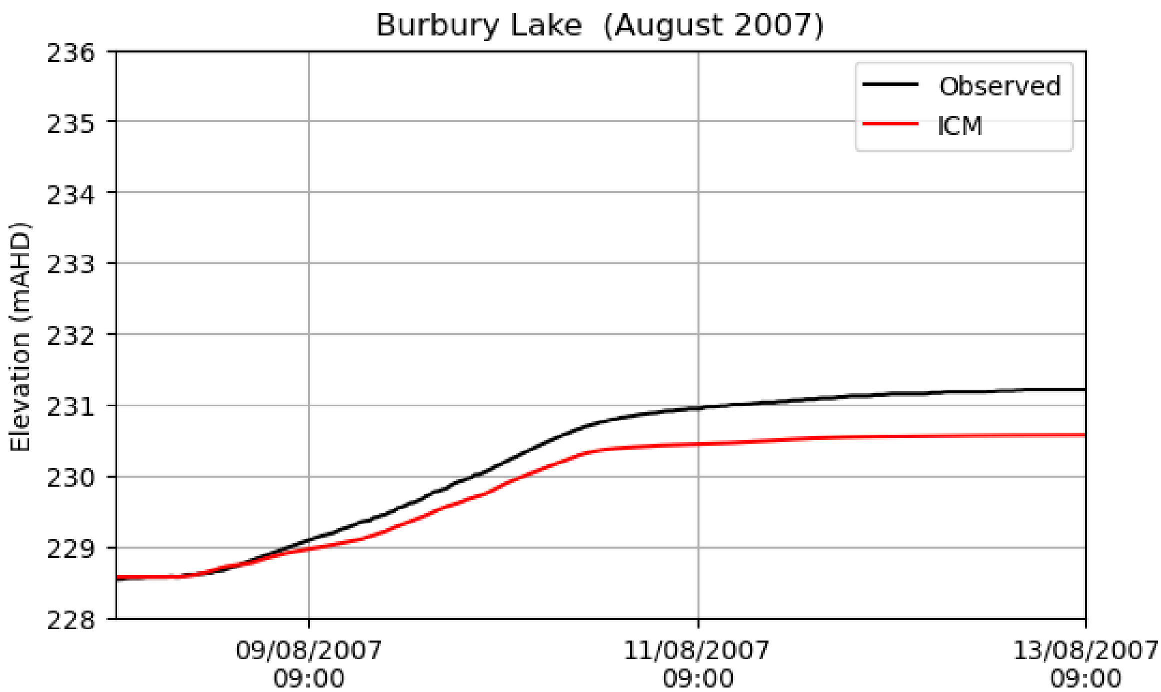

Diagram 29: August 2007 water level comparison at Lake Burbury

6.4. Identified Issues

Whilst it was possible to achieve a reasonable calibration at some gauges and storages, it was identified early in the mapping process that the quality of the DEM results in unrealistic ponding and incorrect flow paths throughout the catchment.

The diversions and power station operation that are part of the hydro-electric power schemes in this study area also introduce errors into the modelling as these are not modelled in detail for this strategic mapping study, as per the agreed methodology. If further modelling is required in this area, it is recommended that future works aim to access improved topographic data (such as LiDAR capture). Access to improved topographic data may allow for the mapping of the modelled flood extents across the King-Henty study area, which have been omitted at this stage. If detailed flood mapping is required in this area in future, it is recommended that details on the operation of the hydro-electricity system are included in the model.

7. UNCERTAINTY ASESSMENT

Flow data was available at four gauges for the calibration events, however two of them are not used in the hydrodynamic model because they are outside of the 2D flow paths. There were no flood survey extents or depths available in this catchment. The Whyte River A/B Rocky River gauge was available in 1970 event but the event was small so it was not used in the calibration.

The hydrodynamic modelling for this study area is generally considered to be poor. A large portion of the King-Henty study area is covered by the 'Default DEM'. This has resulted in significant unrealistic ponding in the model, to the extent that it was not possible to produce acceptable flood mapping using the regional flood modelling methodology agreed for this project.

The diversions and power station operations that are part of the hydro-electric power schemes in this study area also introduce errors into the modelling as these are not modelled in detail for this strategic mapping study, as per the agreed methodology.

There were no flood extents or depths available in this catchment.

The uncertainty assessment for the modelling is shown in Table 13 and Appendix B.

Table 13: Uncertainty assessment for King-Henty study area model

Category	Quality statement
Hydrology – rainfall input quality	The quality of the rainfall data is generally very good to excellent, with good coverage of both sub-daily and data rainfall gauges for the calibration events.
Hydrology – observed flows	No information was available on the rating curves at the gauges.
Hydrology – calibration events	The August 2007 and May 1994 events were the largest two spill events on record at all the Pieman Scheme gauges and in the top 5 in the Anthony system.
Hydrology – calibration results	The hydrology calibration generally provided a good match to peak flows, except at Que River Below Bulgobac Creek where the fit was poor. The quality of the data and the rating at this site is not known. Hydrograph volume was generally well represented in the model once power station flows from the lakes were taken into account.
DTM definition	The DEM definition is considered to be poor. The SES state-wide 10 m DEM consists of a 'Default DEM' that is state-wide and a 'LiDAR DEM' that covers the areas where LiDAR data was available at the time. A large portion of the King-Henty study area is covered by the 'Default DEM'. It was found that there were significant issues with the DEM, in particular constrictions are present along main flow paths, the width of the hydrologic enforcement is insufficient to accurately represent the channel capacity, and there are areas where the DEM has insufficient detail to represent the narrowing of a main flow path.
DTM waterways	No bathymetric data was available and waterway definition was based on the LiDAR to water surface. The representation of waterways is

	considered to be poor.
Hydrodynamic – overall calibration results	Calibration results generally indicate a fair to good correlation between recorded and modelled levels at the gauges and comparison to lake levels, considering that hydro operations were not modelled. There is uncertainty in the gauge zero values at all gauges, and these were derived from the DTM.
Hydrodynamic – calibration results, flood extents	No flood extents were available in this study area
Hydrodynamic – calibration results, flood depths	No flood depths were available in this study area

8. REFERENCES

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WMAwater (2021d): Tasmanian Strategic Flood Map, Addition Calibration Event Rainfalls, Nov 2021.

Figures

FIGURE 01
KING-HENTY STUDY AREA

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J:\Jobs\120038\GIS\Group_3_Catchment_Figures\Figure02_King-Henty_Catchment_Land_Use_SubOutline.mxd

FIGURE 03

KING−HENTY STUDY AREA

RAINFALL 1994_MAY

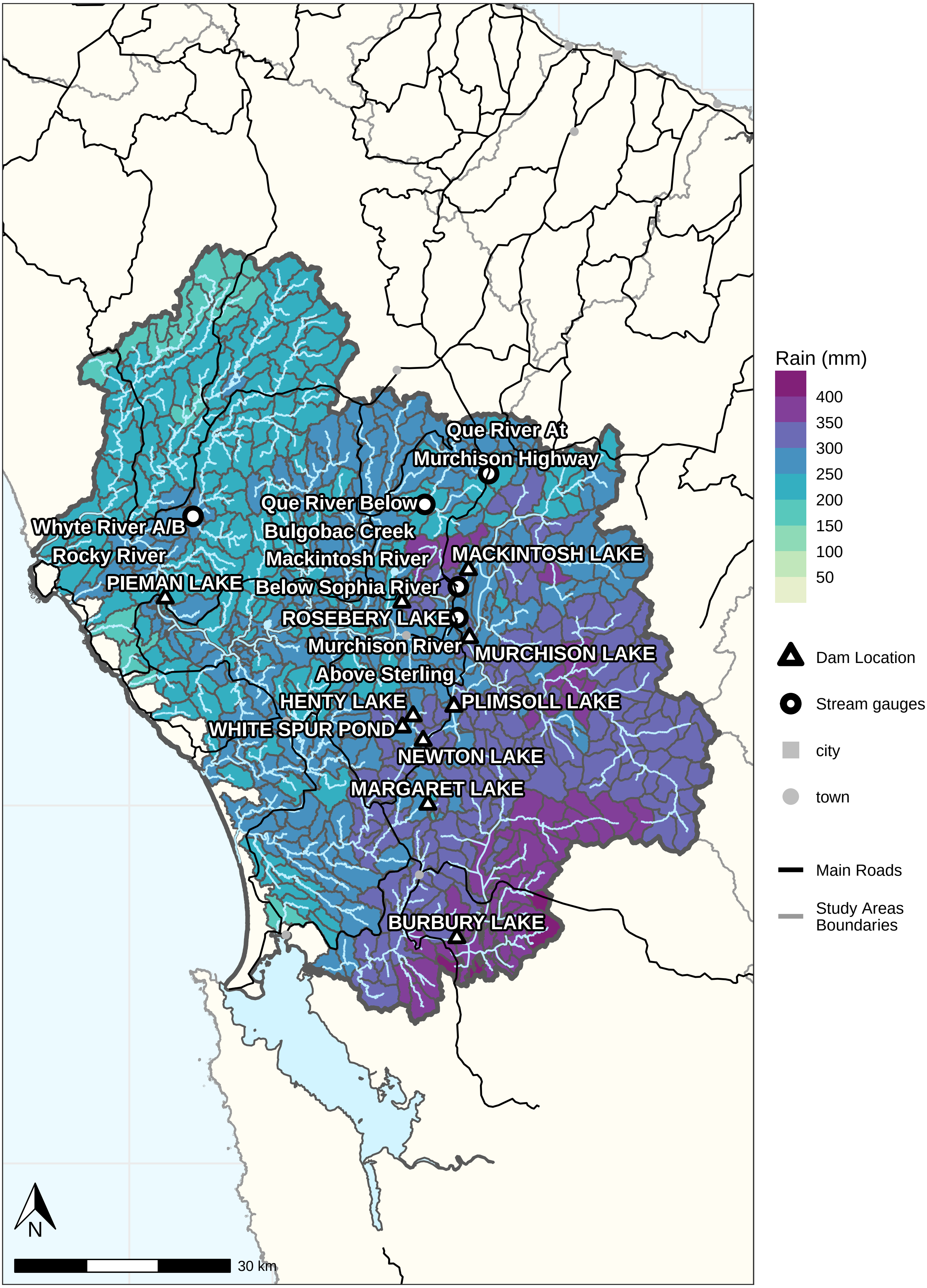

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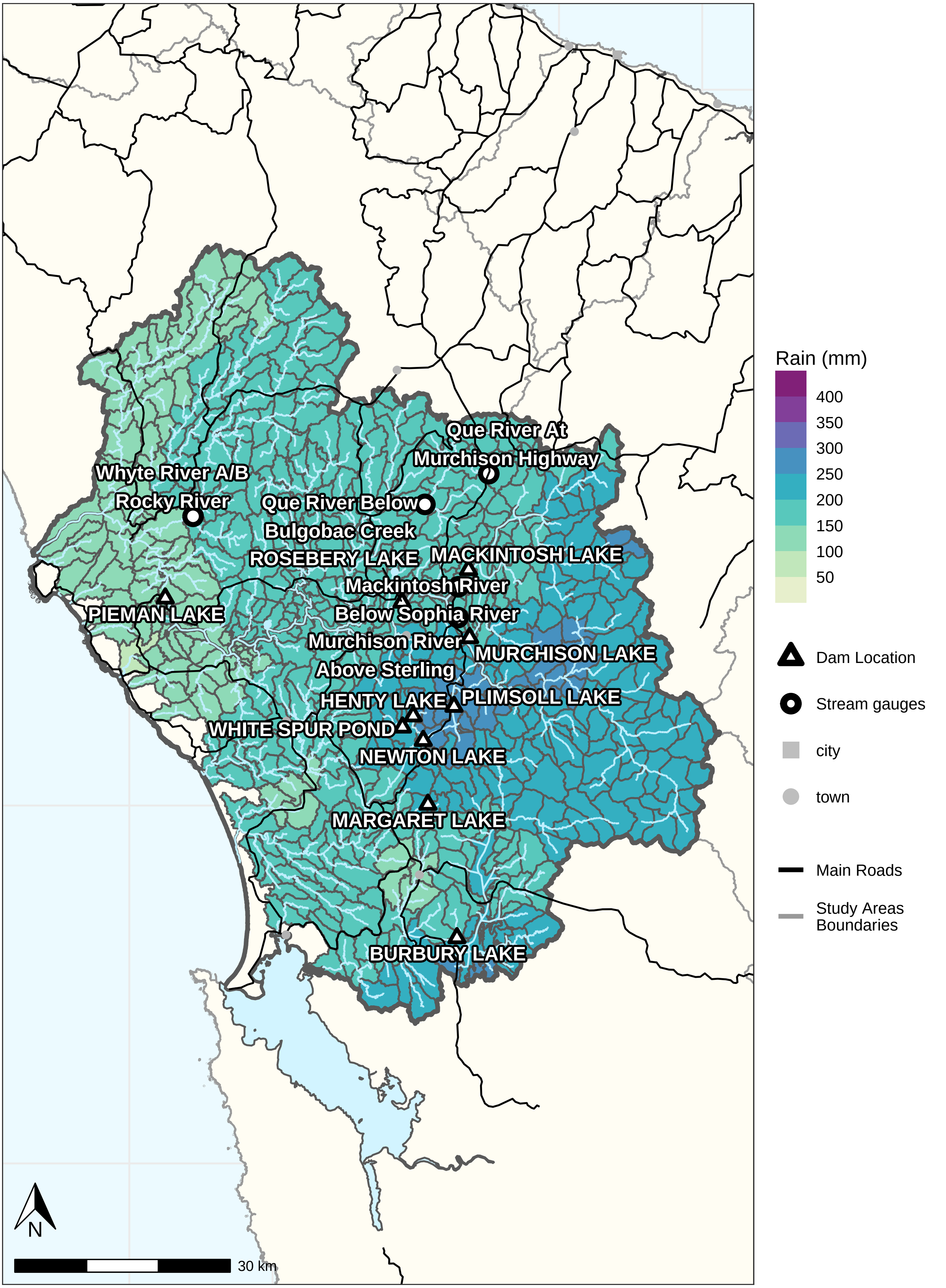
FIGURE 04

KING−HENTY STUDY AREA

RAINFALL 2007_AUG



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Appendix A

APPENDIX A. AVALIABLE DATA

A.1. Sub catchment data

FIGURE A1

HYDROLOGICAL SOIL GROUP MAPPING

DOMINANT SUBCATCHMENT SOIL INFILTRATION RATE

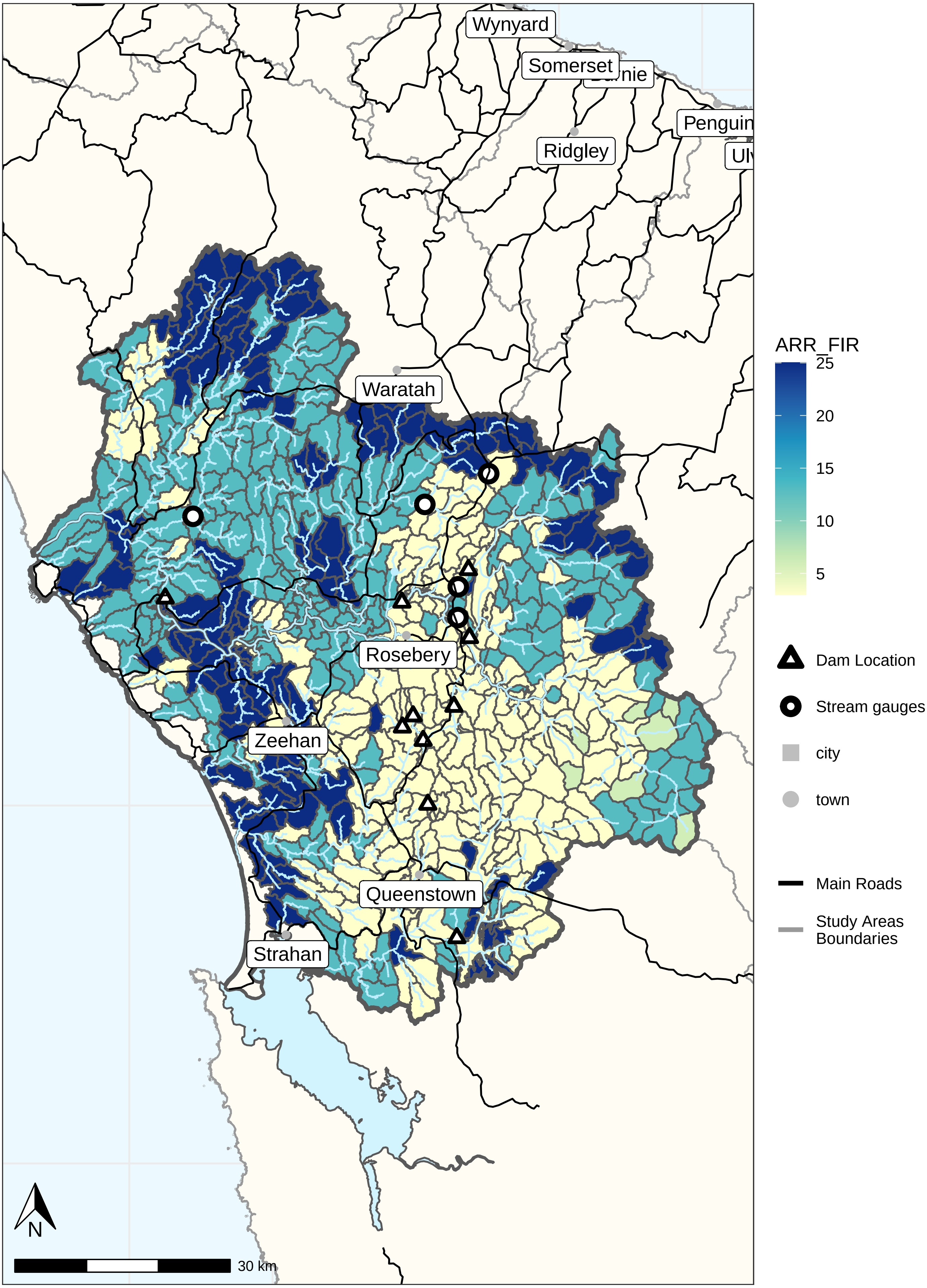

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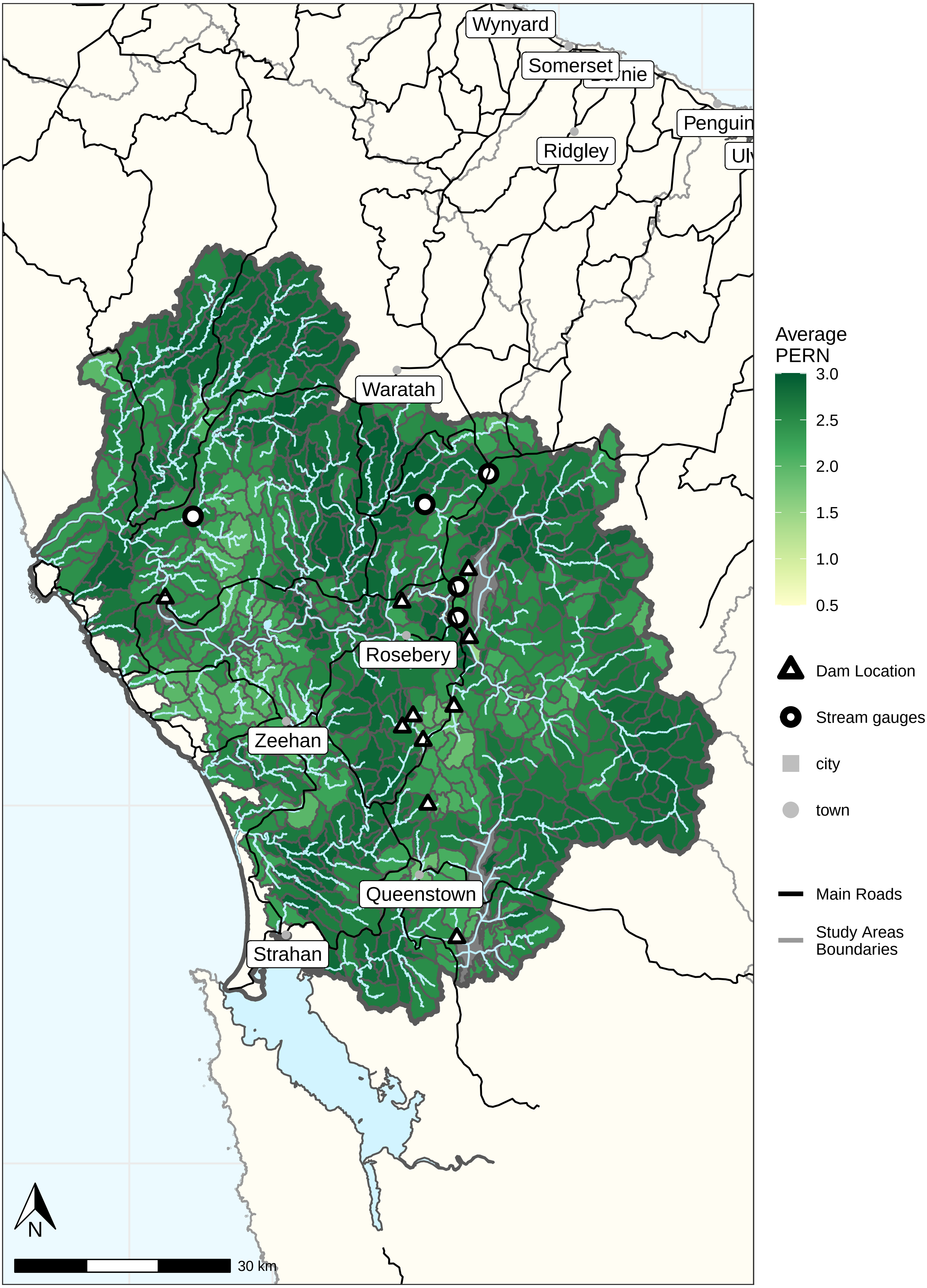
FIGURE A2

KING−HENTY STUDY AREA

SUBCATCHMENT AVERAGE PERN



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Appendix B

APPENDIX B. UNCERTAINTY ANALYSIS

B.1. Hydrologic Model Uncertainty

Table B 1 shows the calibration event rating. Green shading is used to highlight relevant statements. No information was available on the gauge ratings, so this has not been assessed.

Table B 1: Hydrology calibration event rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
Rainfall input quality	Nearest pluvi > 15 km from catchment in unrepresentative location	Nearest pluvi > 15km from the catchment in similar climate area	Pluvi within the catchment or within 15km	1 pluvi within or very near catchment for each 300km^2 of catchment area	1 pluvi within catchment for each 150km^2 of catchment area (spaced out)
	No daily rainfall sites within 15 km of catchment	No daily rainfall sites within 10 km of catchment	One daily rainfall site within 10 km of catchment in similar climate area	multiple gauges within 15km in different directions	multiple gauges within 10km in different directions
	Known high rainfall gradients (from BoM or investigation of surrounding gauges)	Known rainfall gradients for calibration events	No known large spatial variation in event rainfall relative to gauges	Event rainfall known to be generally spatially uniform if catchment is large, or well represented by raingauges	Event rainfall known to be spatially uniform if catchment is large, or well represented by raingauges
Observed flows	Highest gauging within channel and flow breaks out of channel at high flows.	Rating or gauging info unavailable, but flow contained in channel.	Calibration event is out of channel, good set of gaugings but no gaugings out of channel	Calibration event is out of channel, site has been gauged out of channel during different rating period (with changes at top end)	Calibration event is out of channel, site has been gauged during applicable rating period out of channel
	Rating extrapolated with no consideration for shape of cross section	Rating extrapolated with no consideration for shape of cross section	Rating shows consideration to shape of cross section	Rating shows consideration to shape of cross section	Rating shows consideration to shape of cross section
Calibration events	Smaller than 20% AEP	Between 20% and 10%	Between 10% and 5%	Between 5% and 2% AEP	Larger than 2% AEP or

		AEP	AEP	or within largest 4 events on record	within largest 2 events on record

Table B 2 shows the hydrology calibration quality rating. Green shading is used to highlight relevant statements. Note that "flow" includes spills from lakes where power station flows did not impact on observed discharges from lakes (spill only).

Table B 2: Hydrology calibration quality rating

Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
Hydrology calibration results – peak flow	Peak varies by more than 30%	Peak within 30% of observed	Peak within 20% of observed	Peak within 15% of observed	Peak within 10% of observed
Hydrology calibration results – hydrograph volume	Volume varies by more than 30%	Volume within 30% of observed	Volume within 20% of observed	Volume within 15% of observed	Volume within 10% of observed
Hydrology calibration results – hydrograph shape	Poor match to shape – modelled event routing does not match observed	Modelled and observed hydrographs have some similarities in shape	General characteristics of the modelled and observed hydrograph shape match in either rising limb or falling limb	Shape of the event generally matches well in rising and falling limbs	Shape of the event matches well including rising and falling limbs and recession

B.2. DTM Uncertainty

The overall study area DTM quality rating is shown in Table B 3 with green shading.

Table B 3: DTM rating

Category	Rating				
	Poor	Fair	Good	Very good	Excellent
DTM definition	Low resolution	Low resolution	High resolution at HSA/gauges	High resolution in HSA	High resolution in >60% of catchment
	Minimal Ground Control Points (GCP)	Minimal GCP	Reasonable GCP coverage	Good GCP coverage	Good GCP coverage
DTM waterways	Bathymetrical data unavailable	Bathymetrical data poor – e.g. LiDAR with estimated bathymetric information	Bathymetrical data reasonable	Bathymetrical data good	Detailed bathymetrical survey data available

B.3. Hydrodynamic Modelling Uncertainty

The hydrodynamic calibration event rating is shown in Table B 4, with relevant statements highlighted in green.

Table B 4: Hydrodynamic calibration event rating

Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
Calibration flood levels	Water level gauge data not available	Water level gauge data available	Water level gauge data available	Water level gauge data available	Water level gauge data available
		gauge zero level inferred	gauge zero level is known	gauge zero level is known	gauge zero level is known
		Sporadic water level gauge data available for event, low confidence in data	Reasonable confidence in gauged levels based on review of historic data	Good confidence in gauged levels based on review of historic data	Gauge is known to be regularly calibrated and of good quality (e.g. BOM flood warning sites)
Calibration flood depths	No survey extent available	Survey extent available with high uncertainty – few survey points and mostly interpolated	Survey extent available with medium uncertainty – survey points in critical areas, significant areas interpolated	Survey extent available with reasonable certainty – many survey points and limited interpolation	Survey extent available with survey points in all critical areas and limited interpolation

The hydrodynamic calibration event rating is shown in Table B 5 with relevant statements highlighted in green. No flood extents or survey points were available for comparison.

Table B 5: Hydrodynamic calibration quality rating

Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
Hydrodynamic calibration - peak levels	Peak level > +/- 1m of observed	Peak level within +/- 0.5m of observed	Peak within +/-0.5m of observed	Peak within +/-0.3m of observed	Peak within +/- 0.3m of observed
Hydrodynamic calibration – flood extents	Extent > 50m difference from observed	Extent lies within +/- 50m of recorded	Extent lies within +/- 20m of recorded	Extent lies within +/- 10m of recorded	Extent lies within +/- 5m of recorded
Hydrodynamic calibration - depths	Depth within > +/- 1m of Survey	Depth within +/- 1 m of Survey	Depth within +/- 0.5m of Survey	Depth within +/- 0.3m of Survey	Depth within +/- 0.3m of Survey

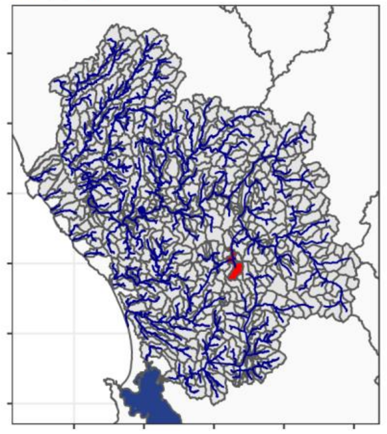
Appendix C

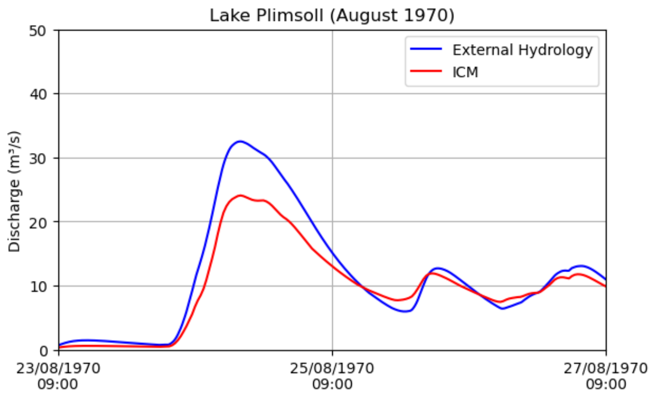
APPENDIX C. EXTERNAL HYDROLOGY MODEL TO ICM HYDRAULIC MODEL COMPARISON CHARTS

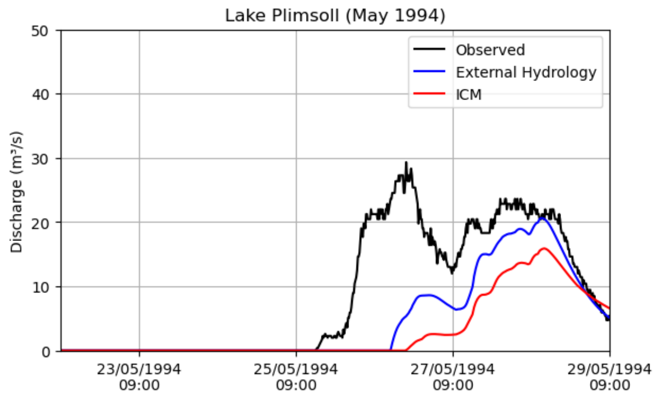
Figure C 1 Event hydrographs

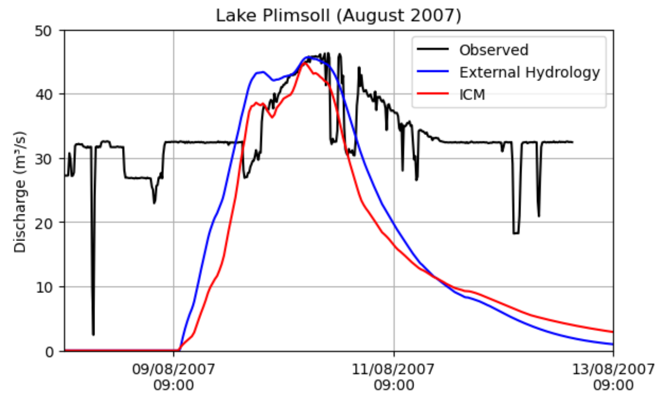
	August 1970	May 1994	August 2007

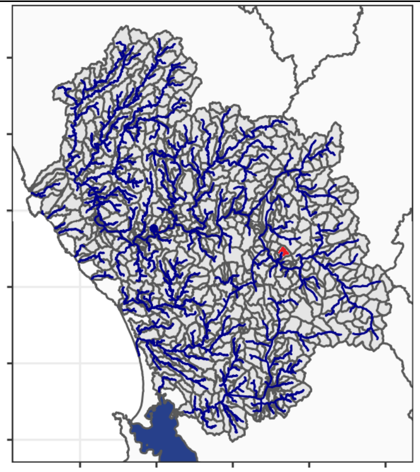
2c_Plmsl_Lake

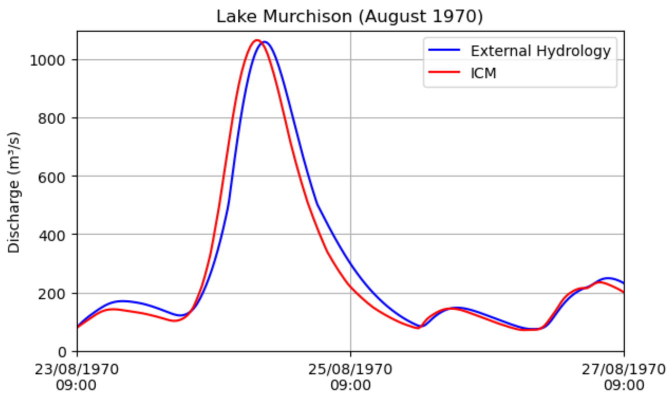


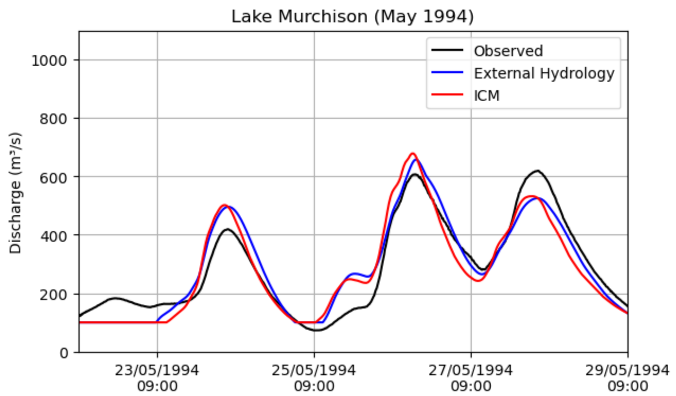


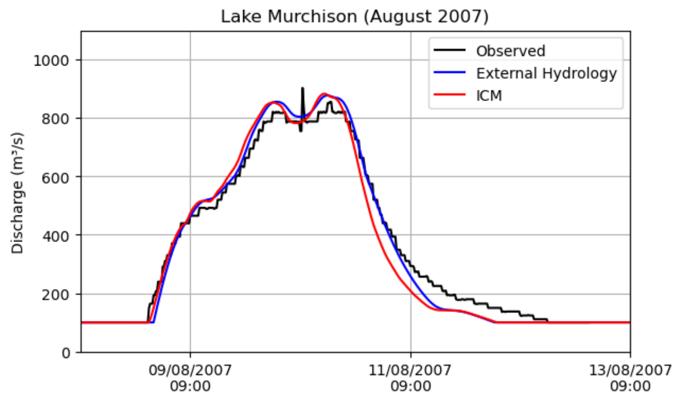


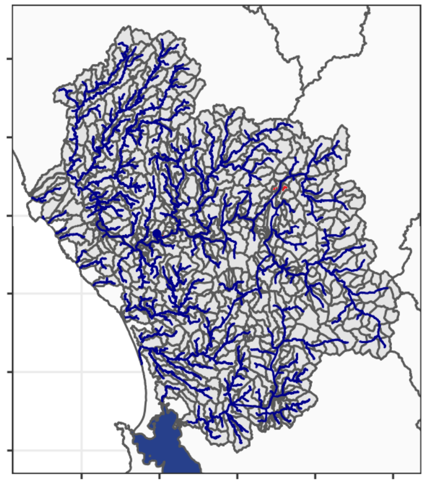


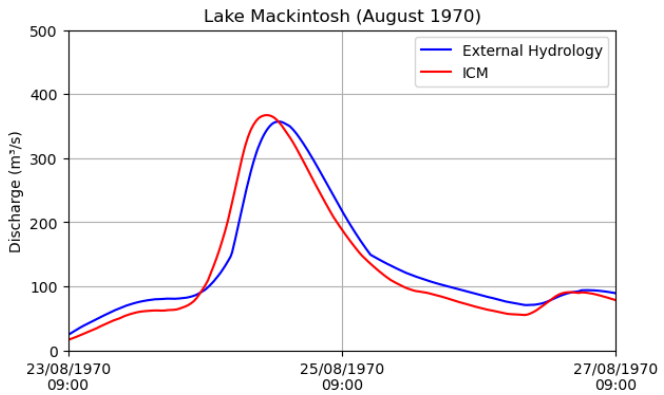


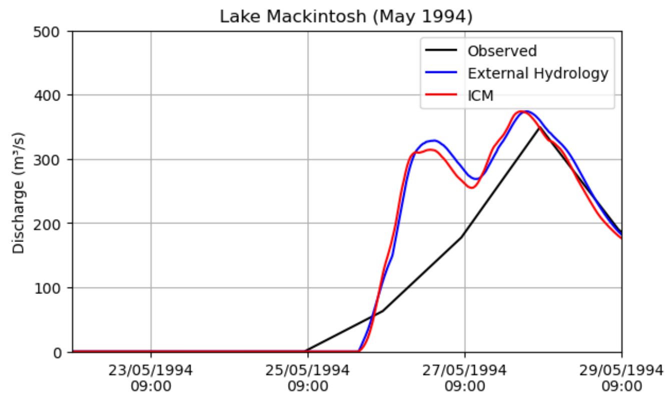


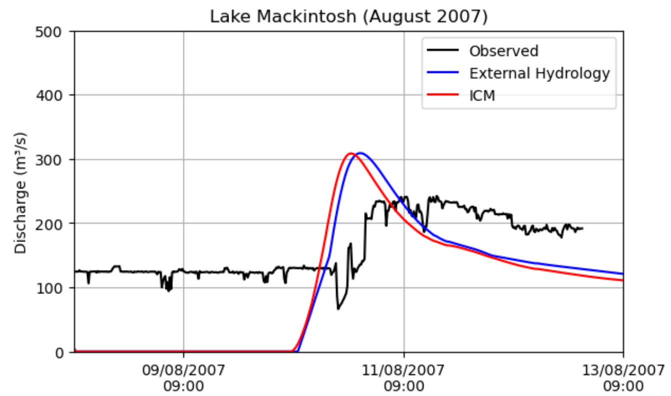


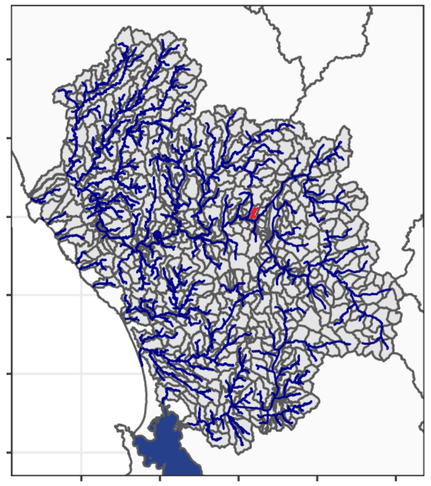


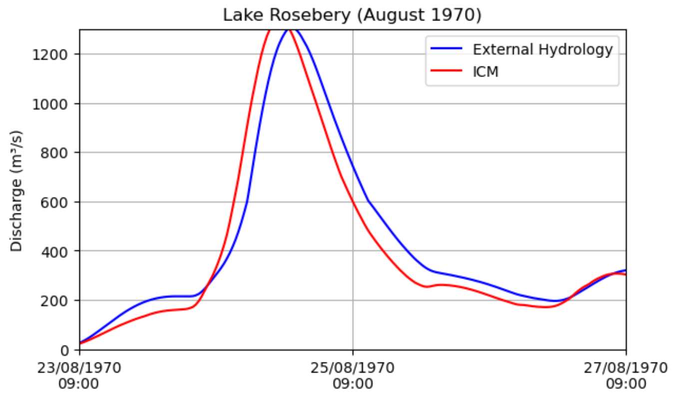


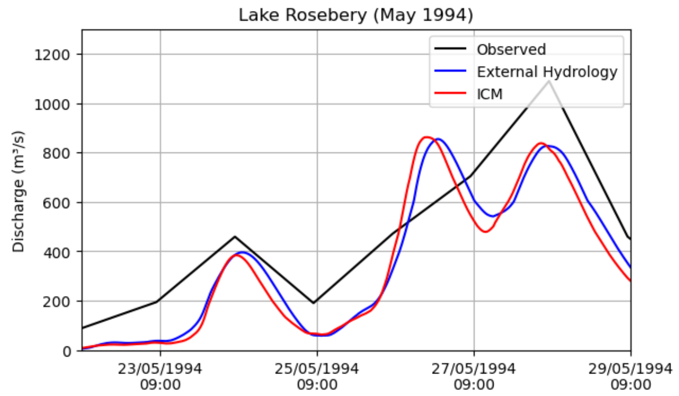


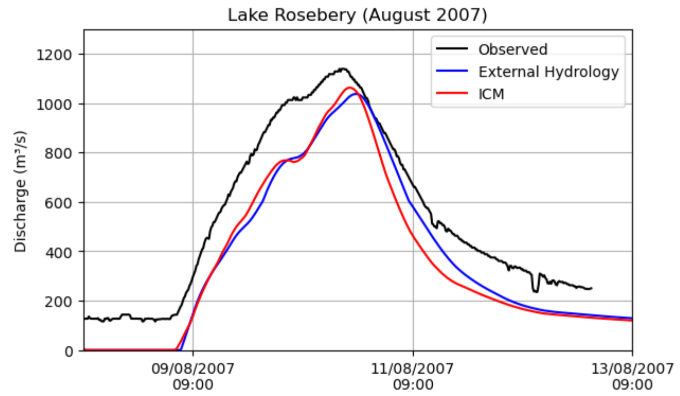




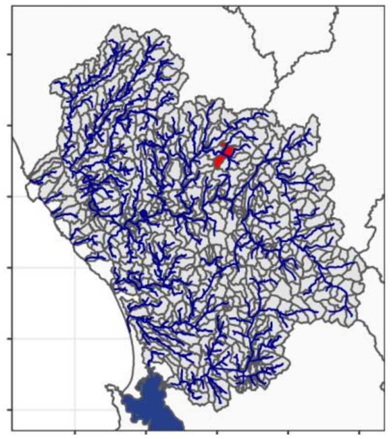


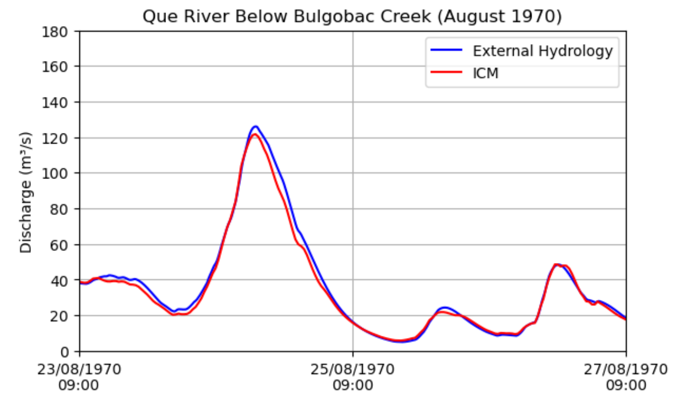


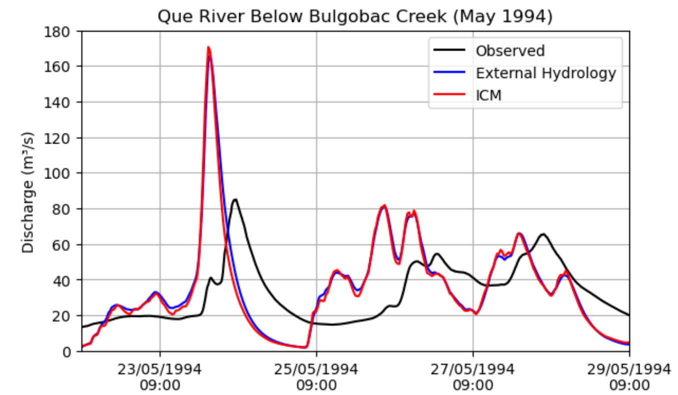


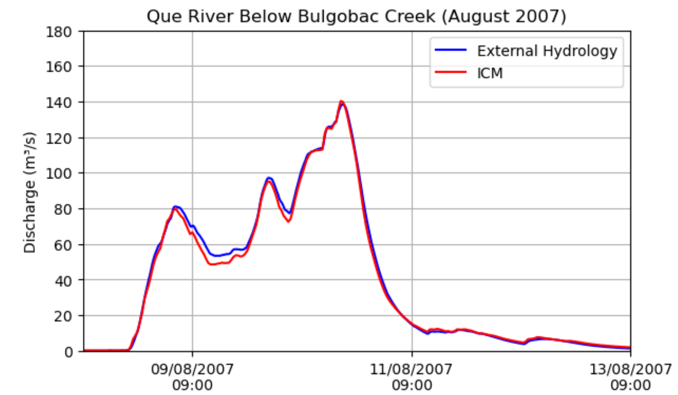


1f_Que_Blgb

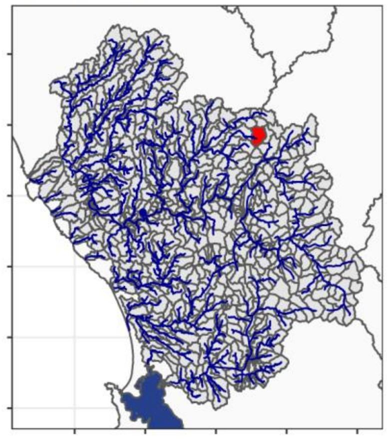


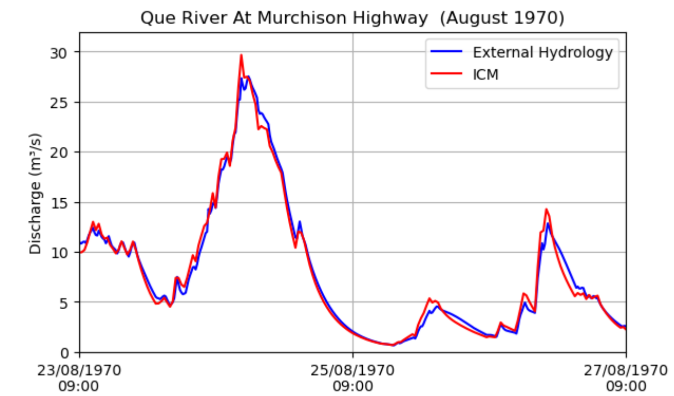


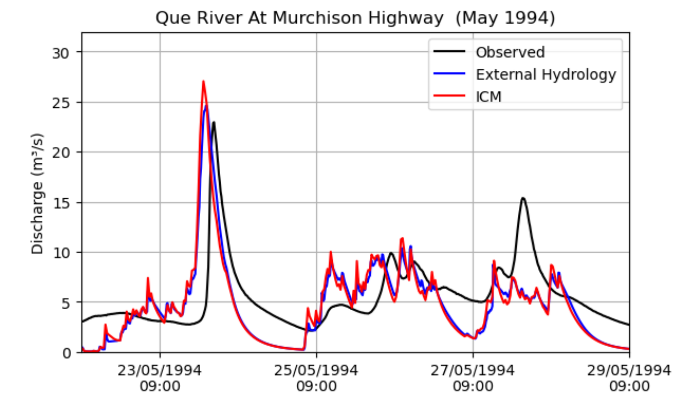


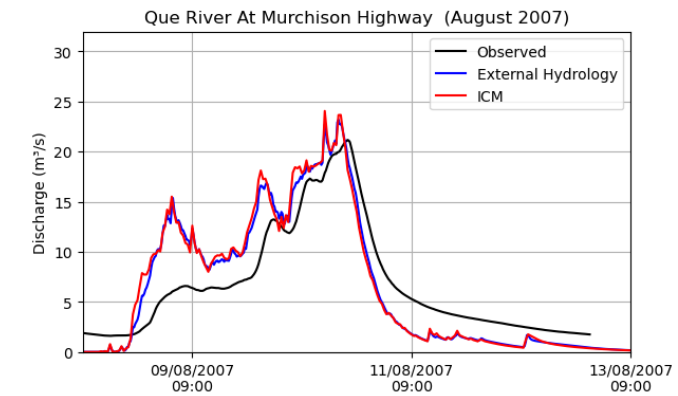


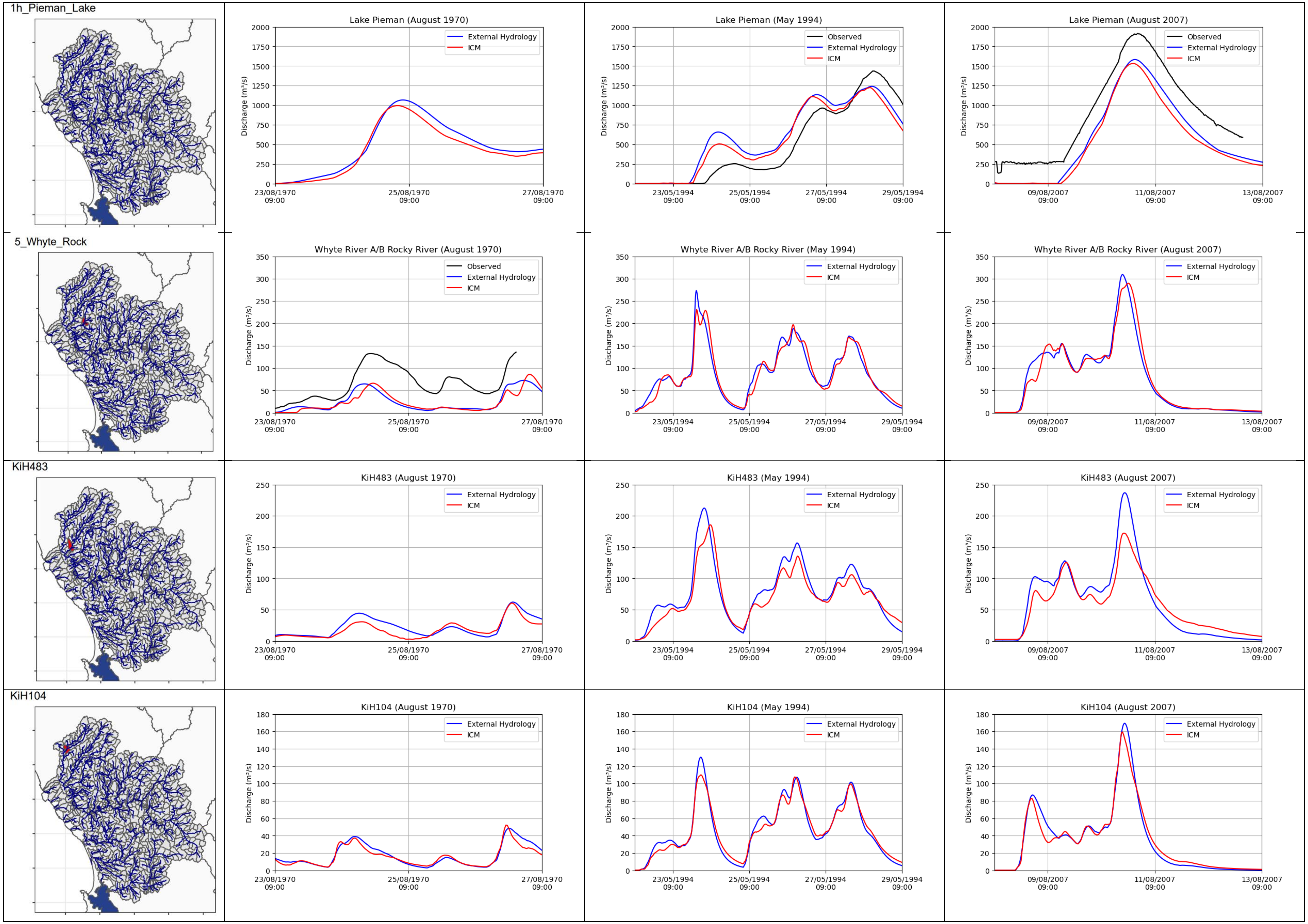
1e_Que_MurHwy










1h_Pieman_Lake
Lake Pieman (August 1970)
Lake Pieman (May 1994)
Lake Pieman (August 2007)
5_Whyte_Rock
Whyte River A/B Rocky River (August 1970)
Whyte River A/B Rocky River (May 1994)
Whyte River A/B Rocky River (August 2007)
KiH483
KiH483 (August 1970)
KiH483 (May 1994)
KiH483 (August 2007)
KiH104
KiH104 (August 1970)
KiH104 (May 1994)
KiH104 (August 2007)
Observed
External Hydrology
ICM
Discharge (m³/s)
23/08/1970 09:00
25/08/1970 09:00
27/08/1970 09:00
23/05/1994 09:00
25/05/1994 09:00
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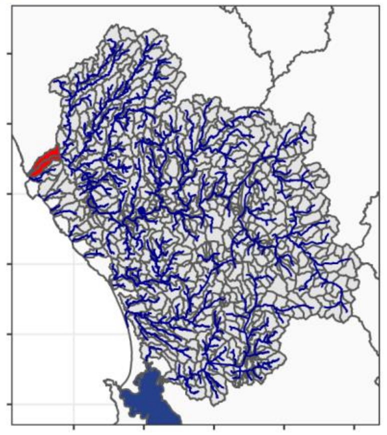
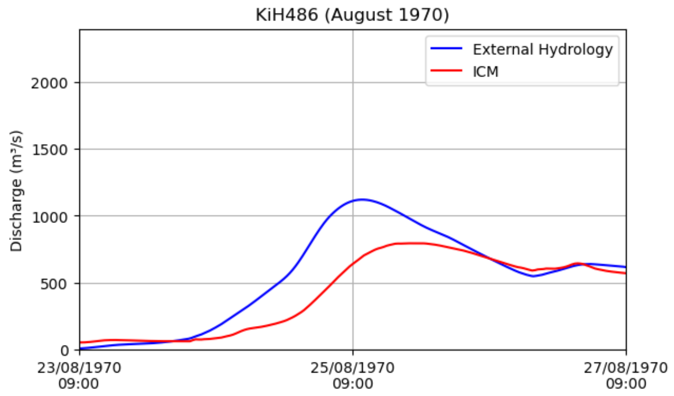
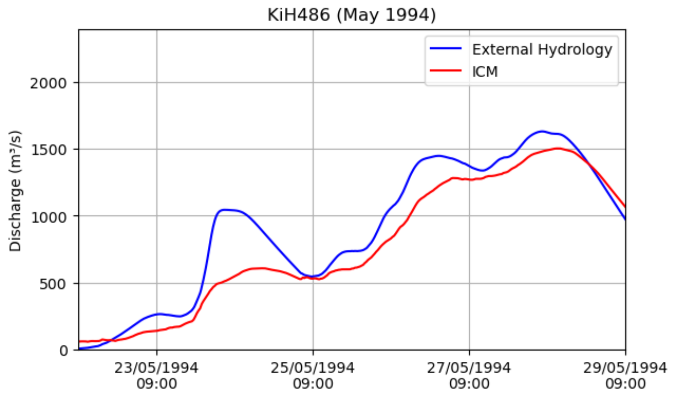
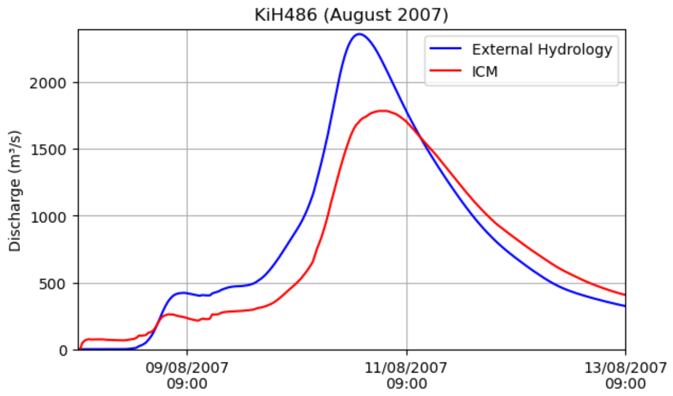
29/05/1994 09:00
09/08/2007 09:00
11/08/2007 09:00
13/08/2007 09:00

KiH486









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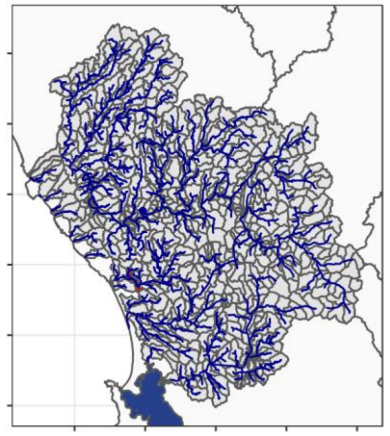
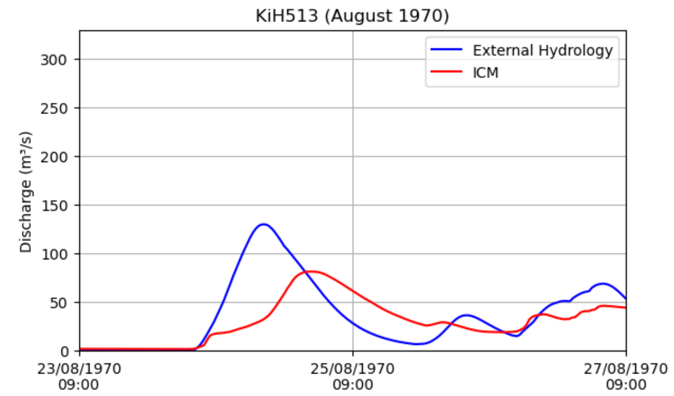
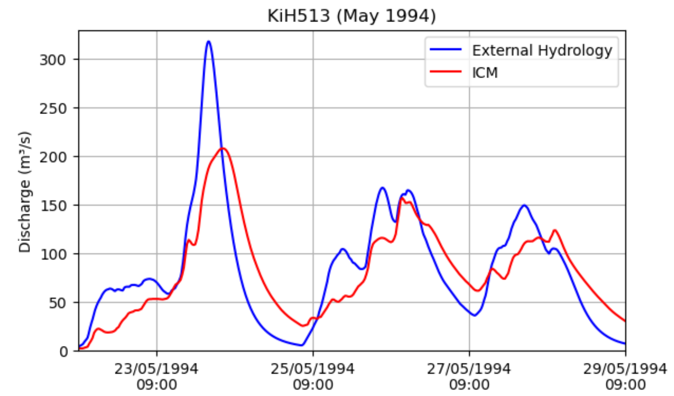
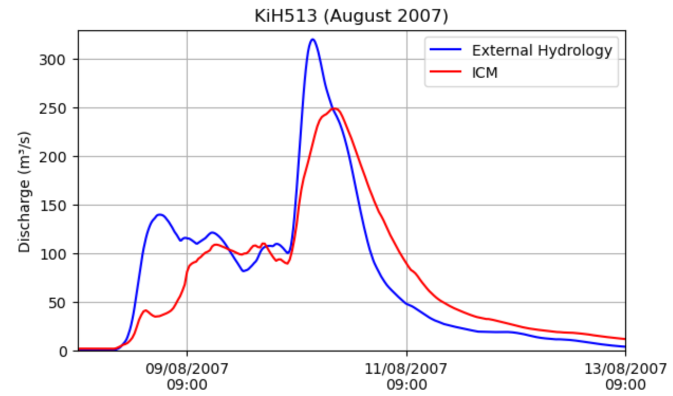
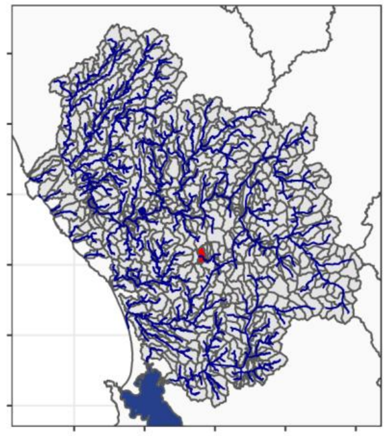


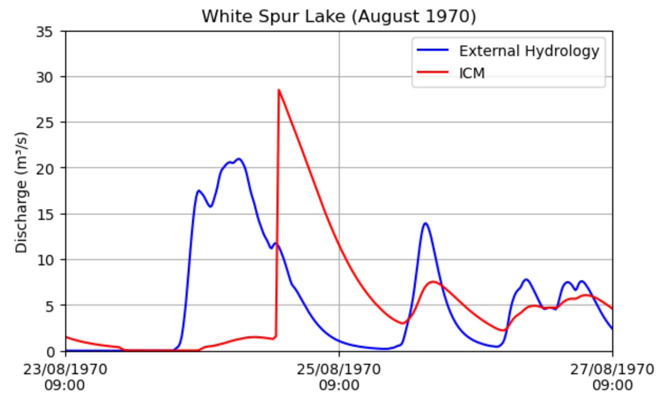


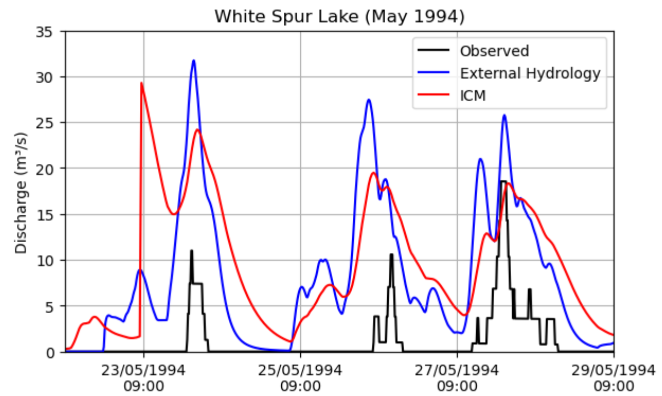


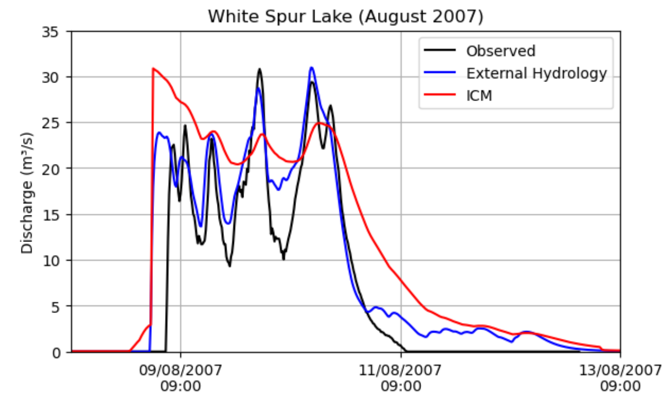


2b_White_Pnd

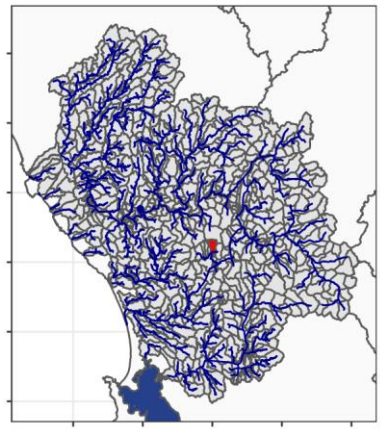


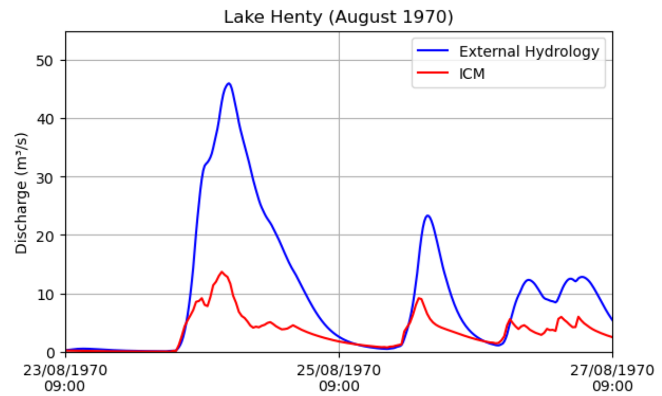


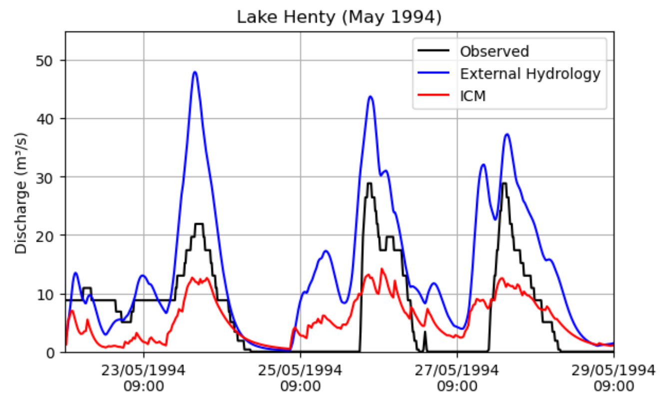


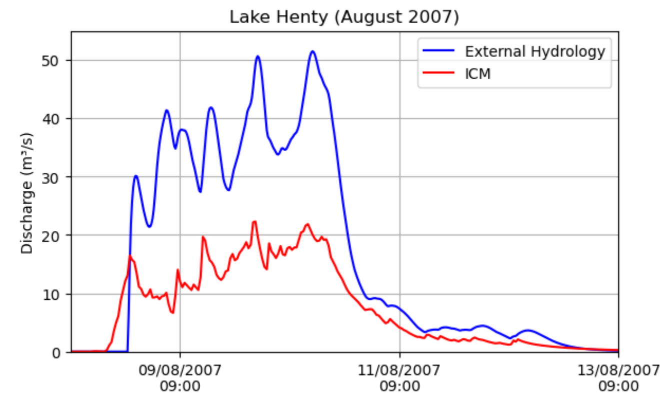


2a_Henty_Lake

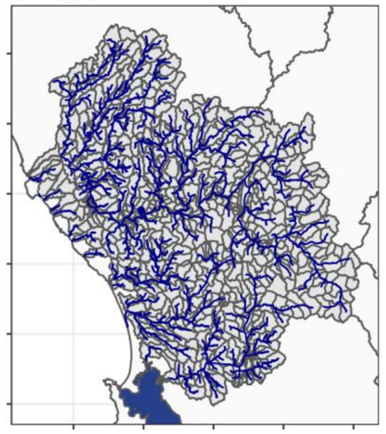


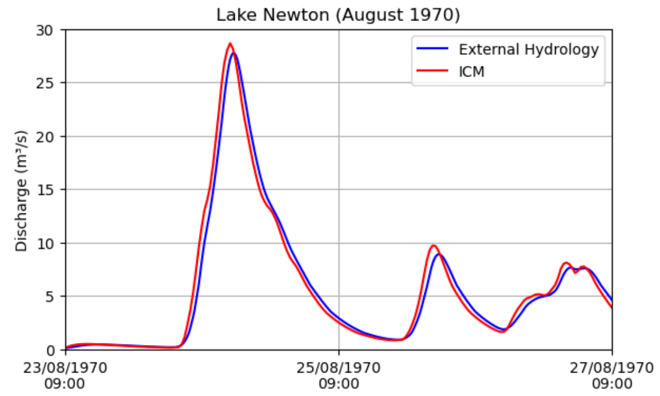


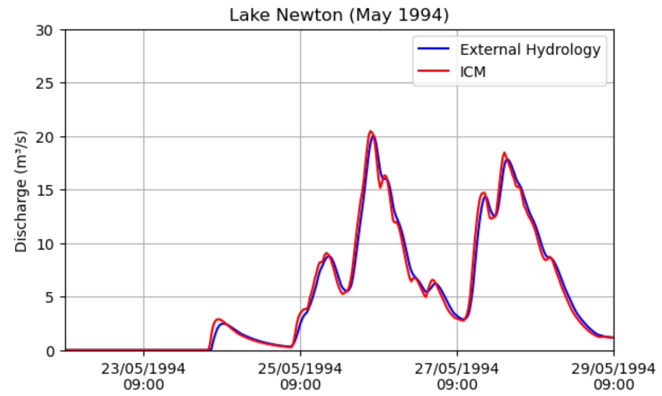


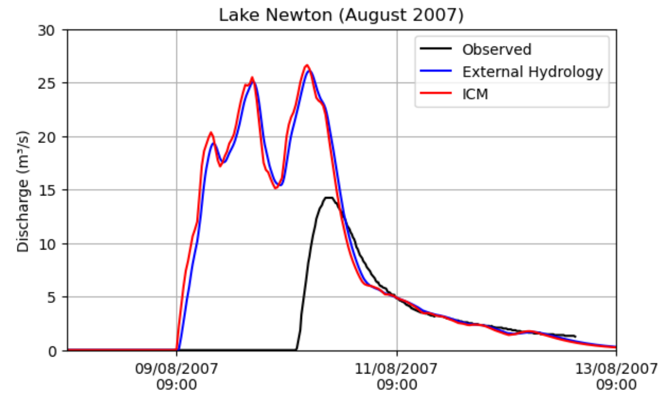


2c_Nwton_Lake

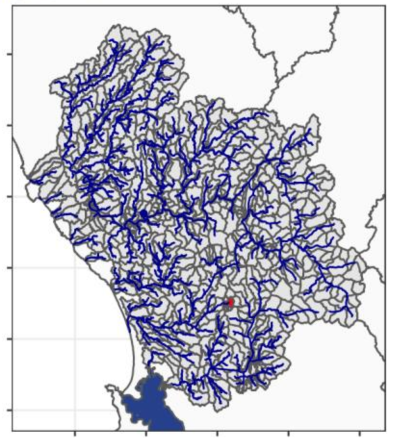


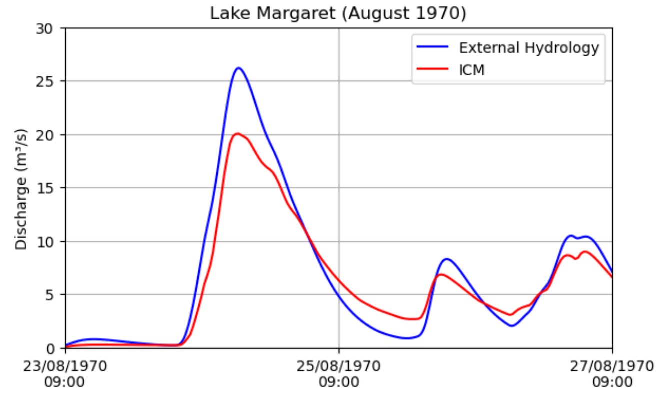


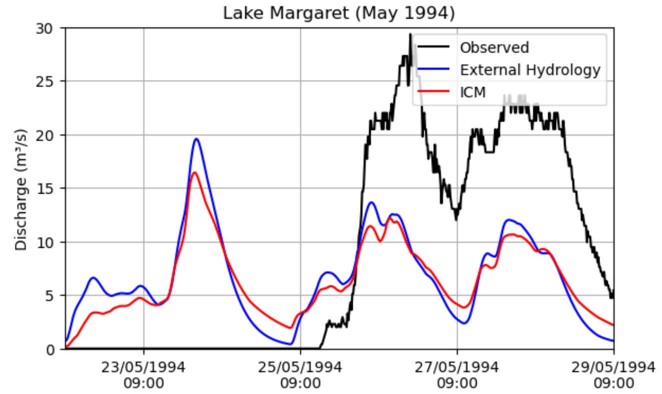


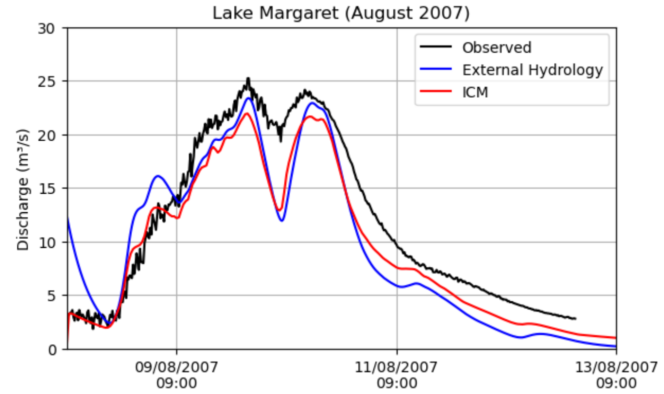


3_Mrgrt_Lake

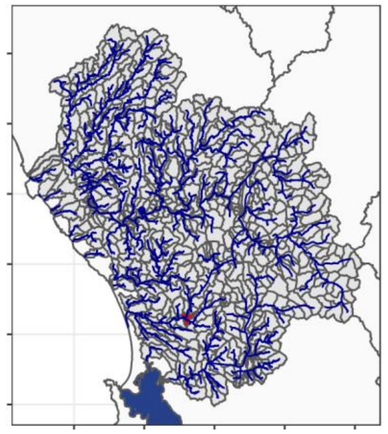


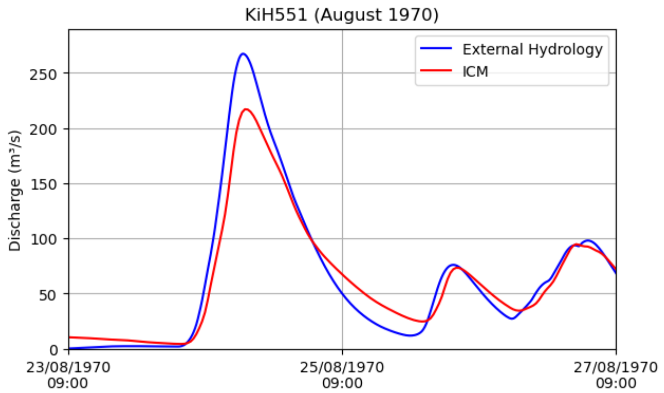


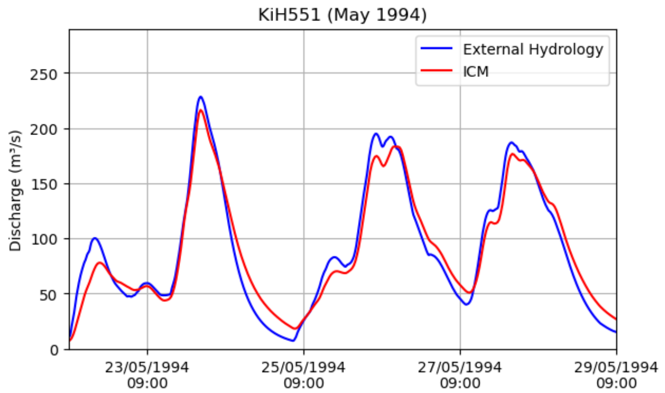


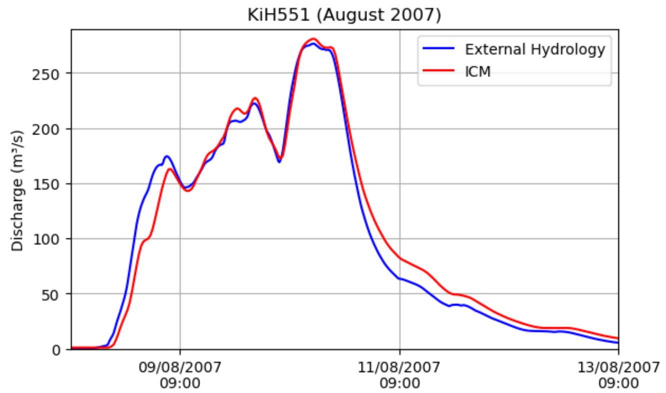


KiH551

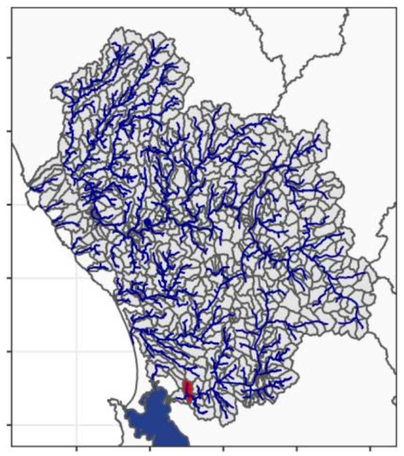


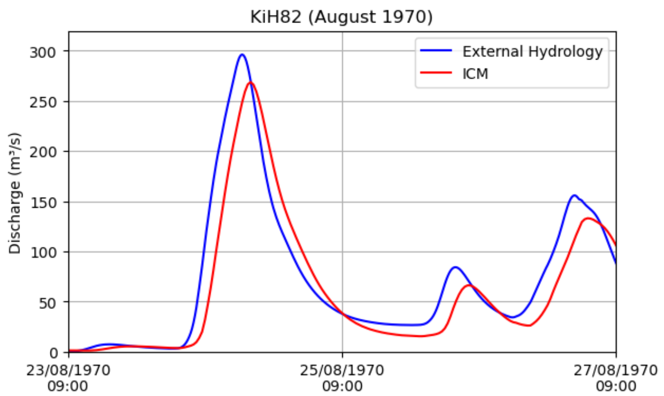


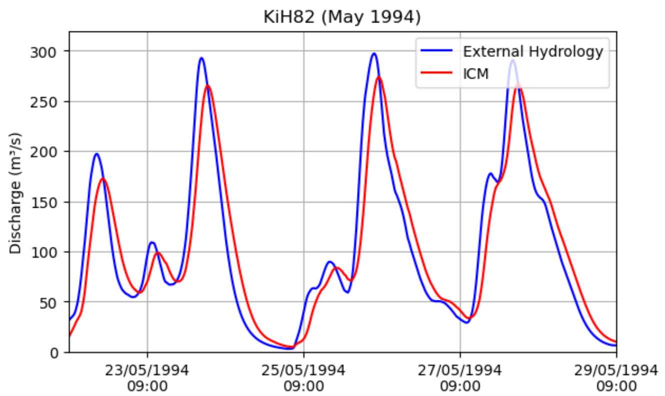


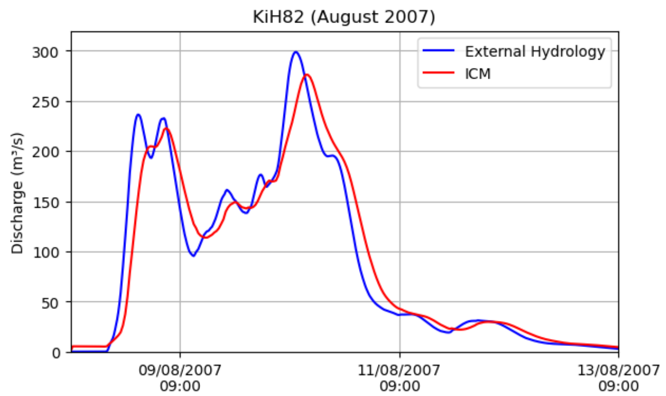


KiH82

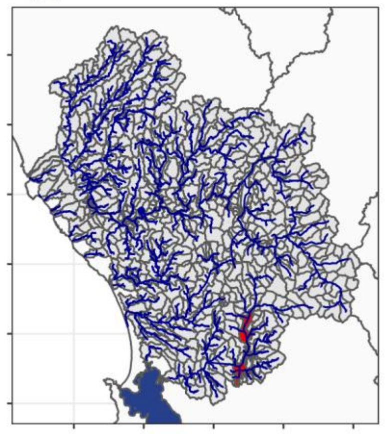


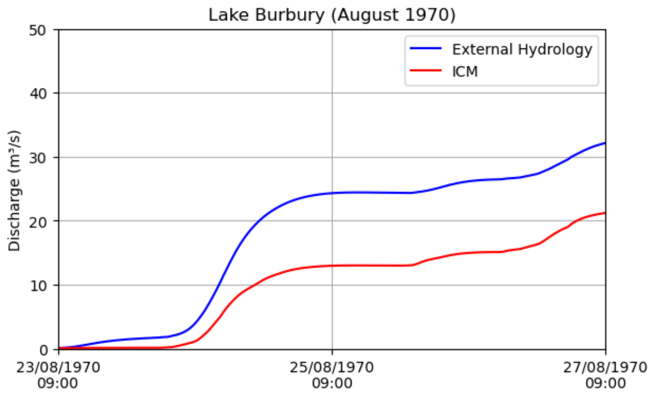


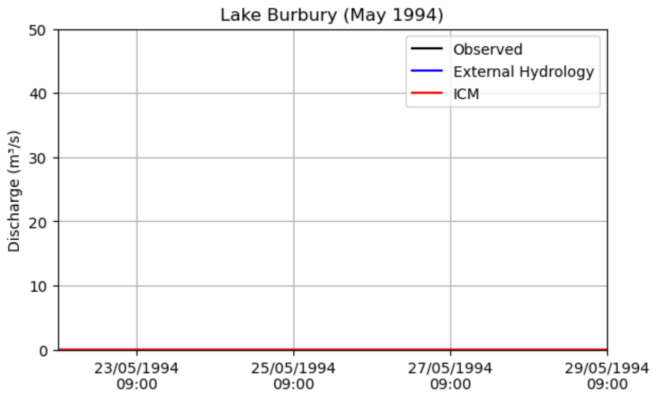


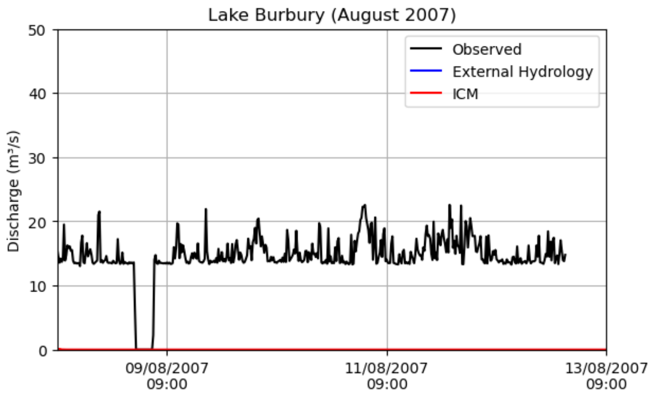


4_Burby_Lake



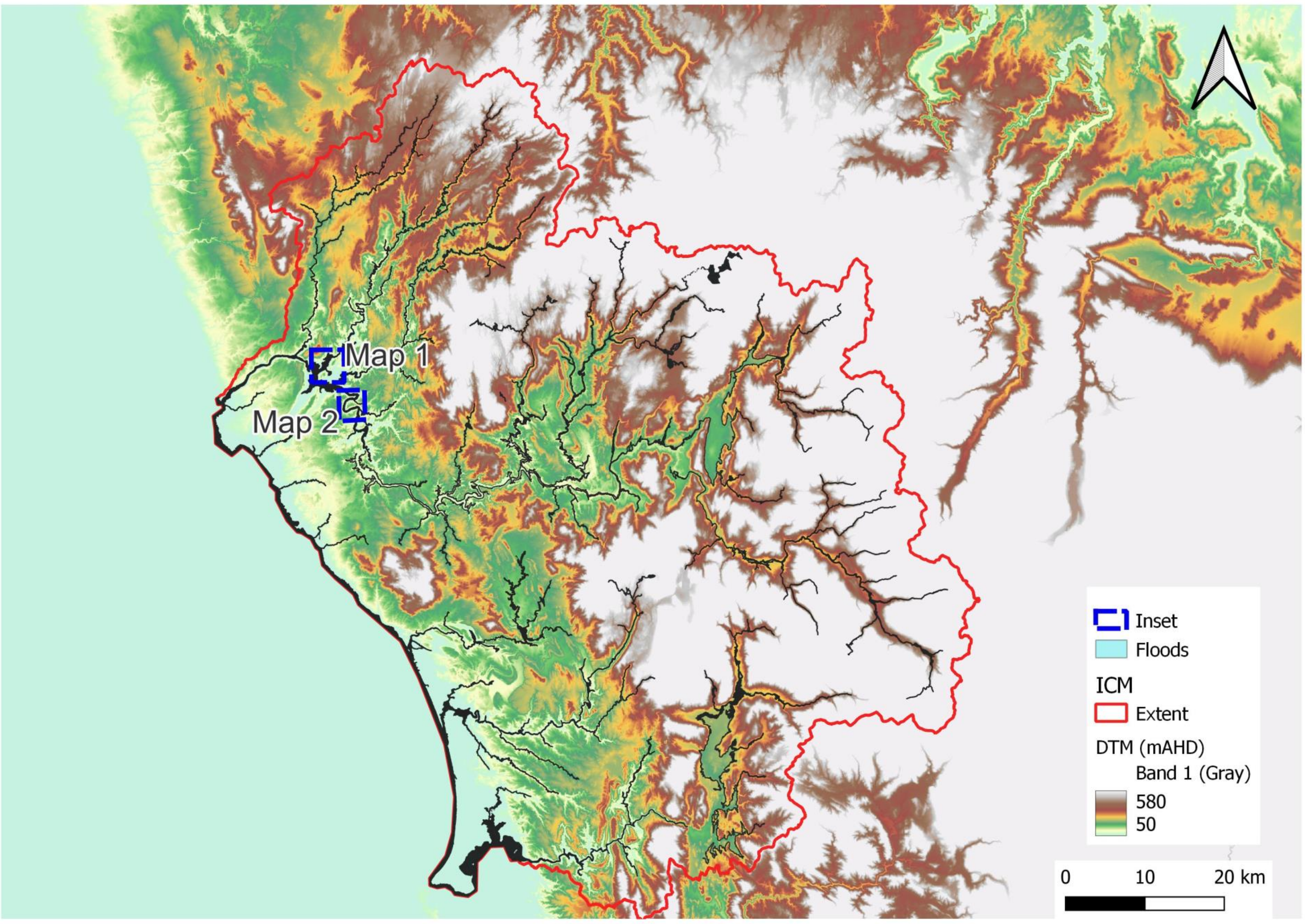

Lake Burbury (August 1970)
External Hydrology
ICM
Discharge (m³/s)
23/08/1970 09:00
25/08/1970 09:00
27/08/1970 09:00


Lake Burbury (May 1994)
Observed
External Hydrology
ICM
Discharge (m³/s)
23/05/1994 09:00
25/05/1994 09:00
27/05/1994 09:00
29/05/1994 09:00

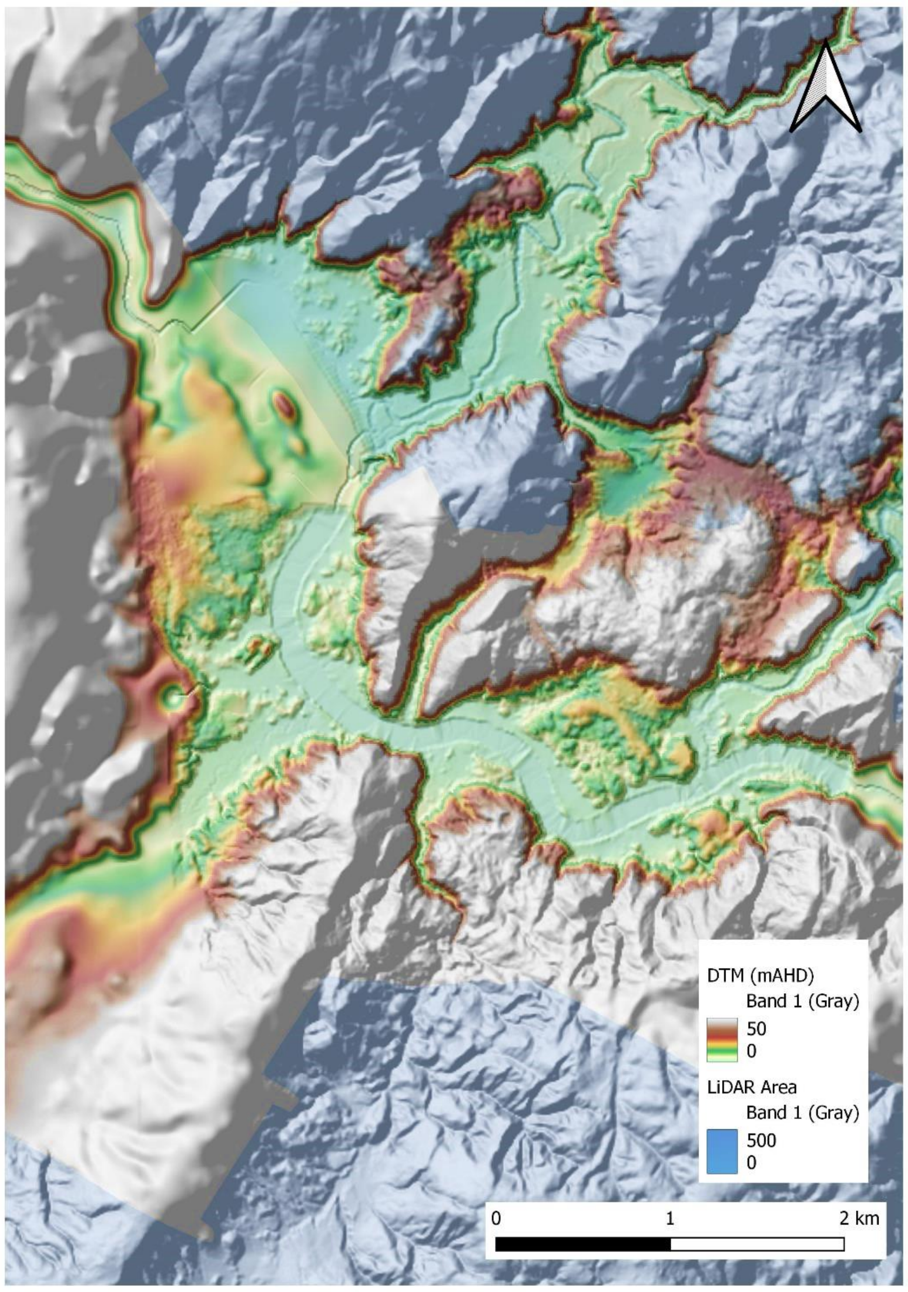

Lake Burbury (August 2007)
Observed
External Hydrology
ICM
Discharge (m³/s)
09/08/2007 09:00
11/08/2007 09:00
13/08/2007 09:00

Appendix D

APPENDIX D. EXAMPLES OF SIGNIFICANT PONDING IN THE ICM HYDRODYNAMIC MODEL



Map 1



Map 2

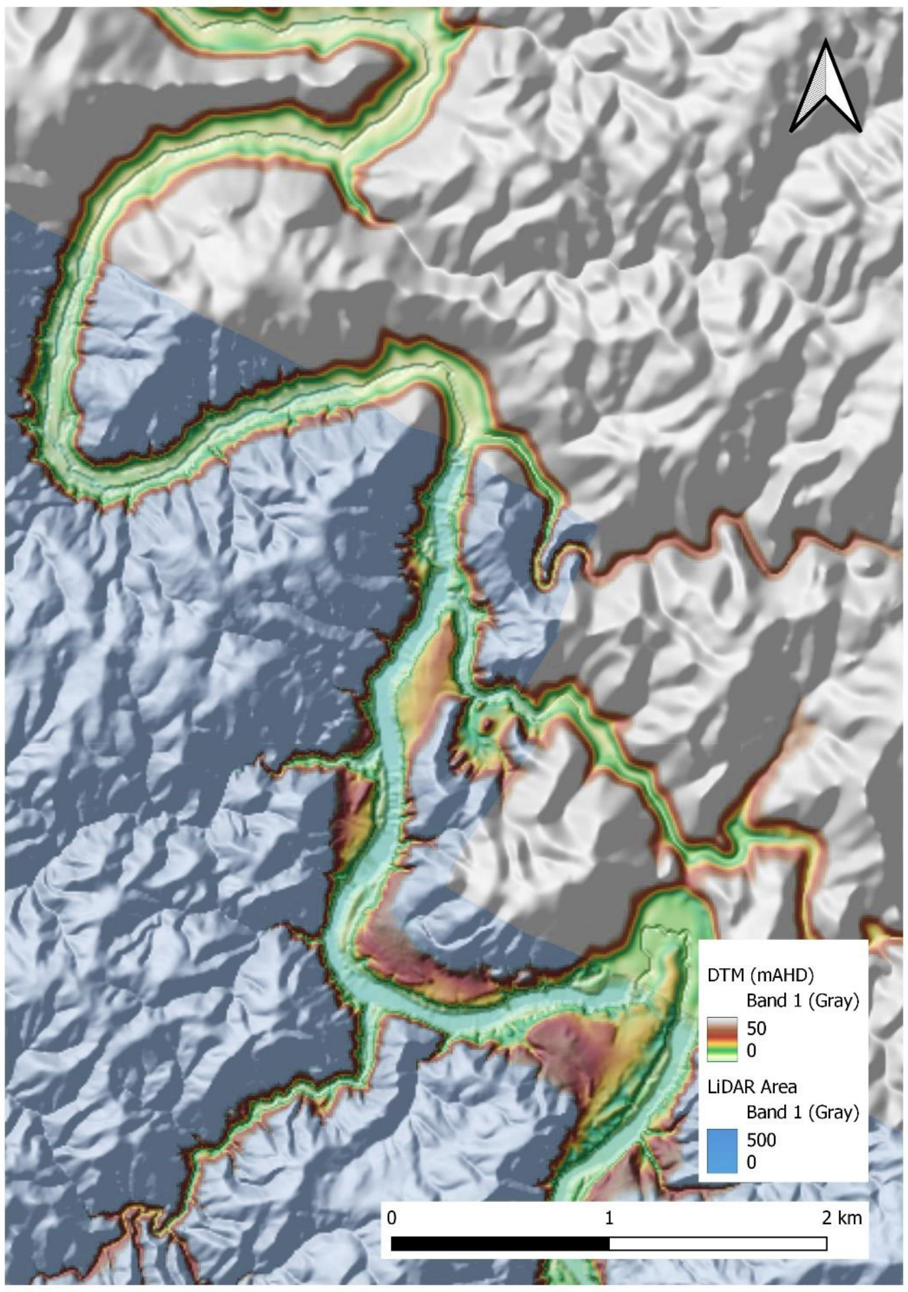


Figure D 1: DTM artifacts created artificial depressions.

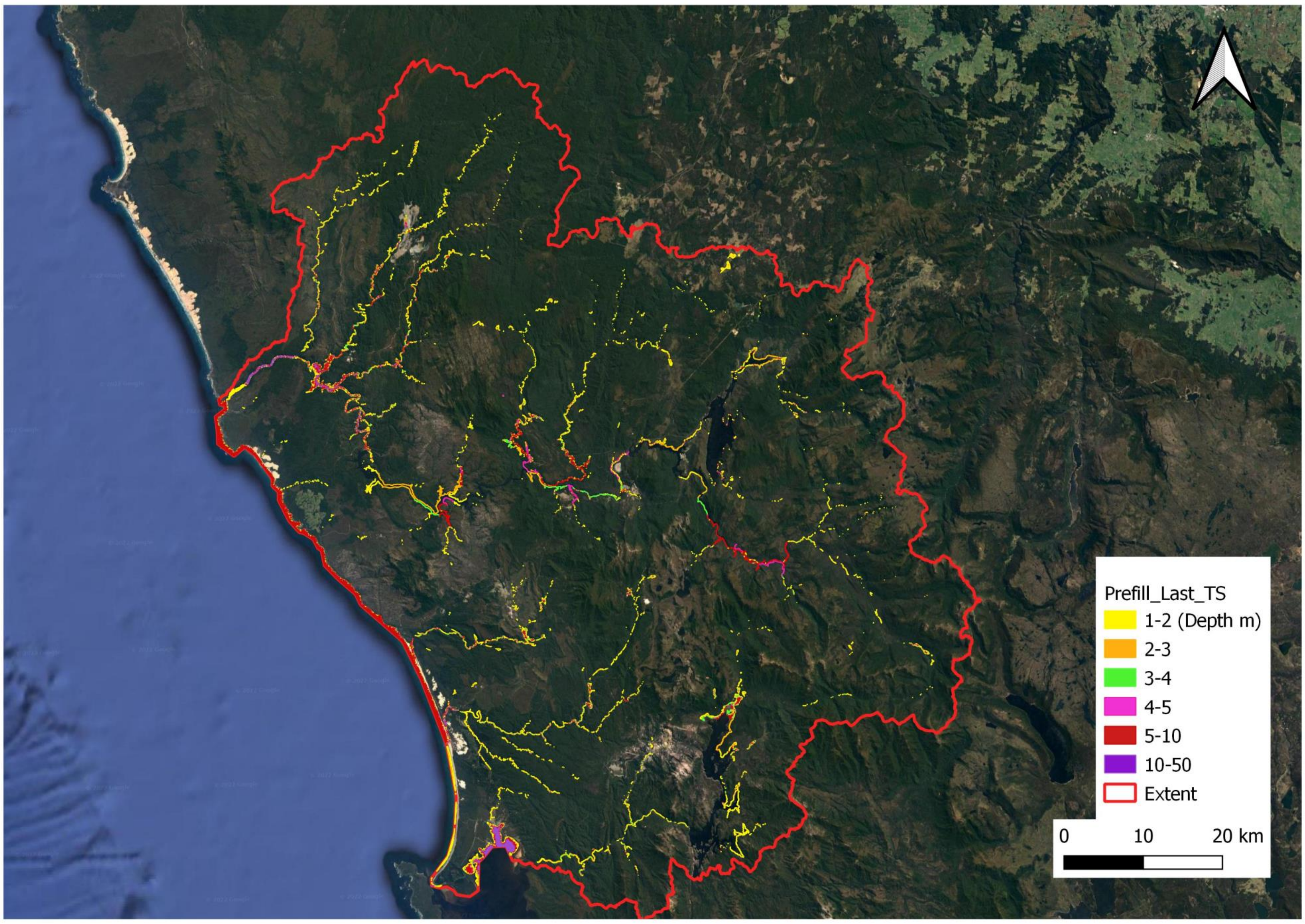


Figure D 2: Example of ponding in the model