STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
GORDON FRANKLIN STUDY AREA
MODEL CALIBRATION

REPORT

MARCH 2023

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Project Tasmanian Strategic Flood Map Gordon Franklin Study Area Model Calibration	**Project Number** **120038**
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**TASMANIAN STRATEGIC FLOOD MAP
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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
DEM	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
RAF	Rafts Adjustment Factor; sub-catchment calibration parameter in ICM
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 Gordon-Franklin study area.

2. STUDY AREA

The Gordon Franklin study area is situated in the South West of Tasmania. The Franklin River is a tributary of the Gordon River. Other large tributaries of the Gordon River include the Denison River and Olga Rivers. Larger tributaries of the Franklin River include Jane River, Andrew River and Collingwood River. The study area also includes several smaller watercourses that discharge directly into the Southern Ocean on the West Coast of Tasmania, and other smaller rivers that discharge into Bathurst Harbour and Port Davey. The study area is part of the Tasmanian Wilderness World Heritage Area and is covered by the Franklin-Gordon Wild Rivers National Park and the Southwest Conservation Area. The only settlement in the area is Strathgordon, which has a population of around 15 people.

The study area includes two large hydro-electricity storages in the headwaters of the Gordon catchment – Lake Gordon and Lake Pedder. The two storages are connected via McPartlans Pass Canal and Lake Pedder diverts water from the headwaters of the Huon and Serpentine Rivers into Lake Gordon via this canal. Lake Gordon and Lake Pedder combined is the largest storage in Hydro Tasmania's system and represents 32.5 % of Tasmania's total energy storage capacity. It is also the largest storage of water in Australia (Hydro Tasmania, 2014). Water from Lake Gordon is used to generate electricity through Gordon Power station, which discharges water into the Gordon River downstream of the dam. There is no spillway associated with Gordon Dam, and water is spilled from the combined Gordon-Pedder system via Lake Pedder into the Serpentine River.

The borders of this study area are defined based on current developed dams rather than the historical natural watersheds. Therefore, there are three dams which sit on the border of this study area. Darwin Dam in the north of the study area impounds Lake Burbury, along with Crotty Dam in the King-Henty Study area. Water stored in Lake Burbury eventually flows down the King River, either through power station operations or spill at Crotty dam, so flows south into the Andrew River are now completely cut off at Darwin Dam. Therefore, this study area is bordered by Darwin Dam which acts as the watershed line. Similarly, Edgar and Scotts Peak Dams on Lake Pedder have cut off –natural catchment areas which would have flown east to the Huon River and now flow west down the Gordon River, so these are included in this study area and were not included in the Huon study.

Larger floods in the study area include the August 2007 and July 2016 flood events.

The Gordon-Franklin study area has an area of 11,014 km^2. The Gordon-Franklin study area and the available gauge information are shown in Figure 1, and landuse in the study area is shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow Data and Level Data

There are five natural gauges with flow data available in the Gordon-Franklin study area, as shown in Table 1. Davey River Below Crossing River gauge is owned by DPIPWE. The remaining gauges are owned and operated by Hydro Tasmania, who supplied timeseries of flows and stage heights, and ratings and gaugings for sites that are currently operating. No recent data was available at the Gordon River below Huntley or Franklin River Below Jane River gauges and these gauges were not used for calibration. There are also two gauges on the Andrew River near Darwin Dam that are believed to be used by Hydro Tasmania for dam safety monitoring, and gauge only a very small catchment area of less than 5 km^2. These gauges were not investigated further for use in this study. There are a number of gauges on the Gordon River downstream of Gordon Power Station. As discharge from the power station can be a large proportion of flow, up to 200 m^3/s, these were not used for calibrating historical events.

Daily lake level and lake volume data was also available for Lake Gordon and Lake Pedder.

Table 1: Flow gauges

Gauge attribute	Davey River Below Crossing River	Gordon River Below Huntley	Franklin River Below Jane River	Franklin River at Mount Fincham Track	Collingwood River b/l Alma
Gauge number	473-1	46-1	183-1	145-1	799-1
Gauge abbreviated name	Davey b/l Crossing	Gordon b/l Huntley	Franklin b/l Jane	Franklin at Fincham	Collingwood b/l Alma
Start date	26/02/1964	21/12/1952	13/05/1957	10/04/1953	18/12/1980
End date	current	02/11/1978	23/01/1979	current	current
Latitude	-43.14	-42.66	-42.47	-42.24	-42.16
Longitude	145.95	146.37	145.76	145.77	145.93
Rating quality	Poor – no gaugings at higher flows and rating extrapolated	Not known	Not known	Poor to Fair – no gaugings at higher flows and rating extrapolated	Good – rating fits through high flow gaugings
Used for calibration	Yes	No	No	Yes	Yes
Assumed local datum 0m in AHD	n/a	n/a	n/a	n/a	n/a
Highest Gauged Level (m local datum)	5.4	Not known	Not known	7.4	5.5
Highest recorded stage height (m local) datum	8.6	12.6	12.6	13.8	6.6
Highest recorded flow (m^3/s)	738	568	2,460	1,123	422
Highest recorded flow date	15/07/2016	18/05/1975	18/05/1975	18/05/1975	20/09/2019

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). The August 2007 and July 2016 events were used in calibration. The July 2016 event was the largest on record at Davey below Crossing gauge and the second largest on record at Franklin at Fincham and Collingwood below Alma gauges. This event is around 1% AEP event at Davey below Crossing, between 1% and 2% AEP at Collingwood below Alma, and between 2% and 3% AEP at Franklin at Fincham.

The August 2007 event was the second largest on record at Davey below Crossing gauge, fourth largest at Franklin at Fincham, and seventh largest at Collingwood below Alma. This event is around 3% AEP at Davey below Crossing, 5% AEP at Franklin at Fincham, and between 10% and 20% AEP at Collingwood below Alma.

Table 2: Summary of the largest events in the Gordon-Franklin study area, selected from the 13 calibration events supplied for the project.

Event name	Used in calibration	Event peak flow (m^3/s) (location)
2007_Aug	Yes	365 (Collingwood b/l Alma)
	Yes	725 (Davey b/l Crossing)
	Yes	950 (Franklin at Fincham)
2016_Jul	Yes	422 (Collingwood b/l Alma)
	Yes	738 (Davey b/l Crossing)
	Yes	992 (Franklin at Fincham)

For the Gordon-Franklin Study area calibration, changes in reservoir volume for Lake Gordon and Lake Pedder were also used in calibration. This additional data was used as the gauged catchment areas are small in relation to the total Gordon River catchment (Table 3), and Lake Gordon and Pedder catchments combined provide data on a larger catchment area.

Table 3: Catchment area to gauge sites

Site	Gauged Area (km^2)	Percent of total study area
Davey below Crossing	689	6%
Collingwood below Alma	268	2%
Franklin at Fincham	774	7%
Lake Pedder	722	7%
Combined Lake Gordon and Lake Pedder	2008	18%

3.1.2. Rating Curve Quality

At Davey below Crossing and Franklin at Fincham, the highest gauging is considerably lower than the highest recorded stage height (Table 1), and the rating has been extrapolated to higher flows. At Collingwood below Alma, there are higher flow gaugings and the rating is considered more reliable. At Davey below Crossing, the flows for both the August 2007 and July 2016 events are available, however were given a code of “unknown” by DPIPWE. This means that the only site with a high flow rating that is considered to be good, Collingwood below Alma, covers only 2% of the study area, which limits the reliability of the model calibration.

It is noted that there is some uncertainty in the reservoir volume data for Lake Gordon and Lake Pedder, as volumes are calculated based on the level to volume ratings for each lake. Lake Pedder in particular has a very small operating range and a very large surface area, so small errors in the water level or the rating can result in larger errors in estimated lake volume.

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 Gordon-Franklin study area (see Data Review Report WMAwater (2020) for details on calibration events).

The AWS and pluvio data were found to be more consistently reliable. 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.

The gauges in and around the Gordon-Franklin study area are shown in Figure 1, and the number of gauges with data available for the calibration events is shown in Table 4. The Gordon-Franklin study area is very large, almost one sixth of the area of Tasmania, so despite having between 7 and 9 sub-daily gauges in the area there is still very high uncertainty in rainfall distribution for this catchment. This is particularly the case as the rain gauges are typically clustered in the north or around the two hydro lakes and along the Gordon River (Figure 1).

Table 4: Available Rainfall Information

Statistic	August 2007	Jul 2016
Number of Sub-daily stations available within the catchment	9	7
Number of daily stations available within the catchment*	4	3
Number of sub-daily surrounding gauges ~15km	10	12
Number of daily surrounding gauges ~15km	5	8
Rainfall Totals within catchment	90-310 mm	50- 270mm
Approximate duration of rainfall event	48 hours	36 hours

*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 2021a, and is summarised below.

1. Daily rainfall data from all gauges within Tasmania was extracted for each of the seven calibration events from 2007 – 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 4.

3.3. Dam Information

Hydro Tasmania operates two very large, interconnected, hydroelectricity dams in the Gordon-Franklin study area. Details are shown in Table 5. The two lakes are connected by McPartlan's Pass Canal. Storage volume curves for Lake Gordon were supplied by Hydro Tasmania. A storage rating curve for Lake Pedder and a McPartlans Pass discharge curve was based on data downloaded from Water Data Online (BoM, 2021). These were coded into the external hydrologic model, and the McPartlans Pass discharge curve was used in the hydrodynamic model where the lakes were modelled as 2D elements and the canal was modelled as a 1D element (refer Section 5.5). Historical lake levels were downloaded from Water Data Online (BoM, 2021) to set the starting level in the lakes for the calibration events.

Table 5: Dam information

Name	Storage FSL (mAHD)	Active Storage Volume at FSL (ML)*
Lake Pedder	308.46	352,774
Lake Gordon	307.85	10,635,551

*Storage volumes on Water Data Online are believed to be water volume within Hydro Tasmania's normal operating levels. There is considerable extra water stored that is not included in the active storage volume, particularly for Lake Pedder.

3.4. Flood Levels and Extents

No information was provided to enable verification of modelled flood levels and extents 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. 2 m DEM subsets were not available at any of the gauges in the study area. The SES state-wide 10 m DEM was clipped to the study area with a buffer zone to ensure 100% active mesh area in the model. The resulting DEM is shown in Diagram 1.

It is noted that the SES state-wide 10 m DEM appears to contain bathymetry through Macquarie Harbour, Lake Pedder, and Lake Gordon (with levels in the DEM as low as -50 mAHD in Macquarie Harbour). The SES state-wide 10 m DEM does not appear to contain bathymetry through Port Davey to Bathurst Harbour, with levels in the DEM set to -10 mAHD.

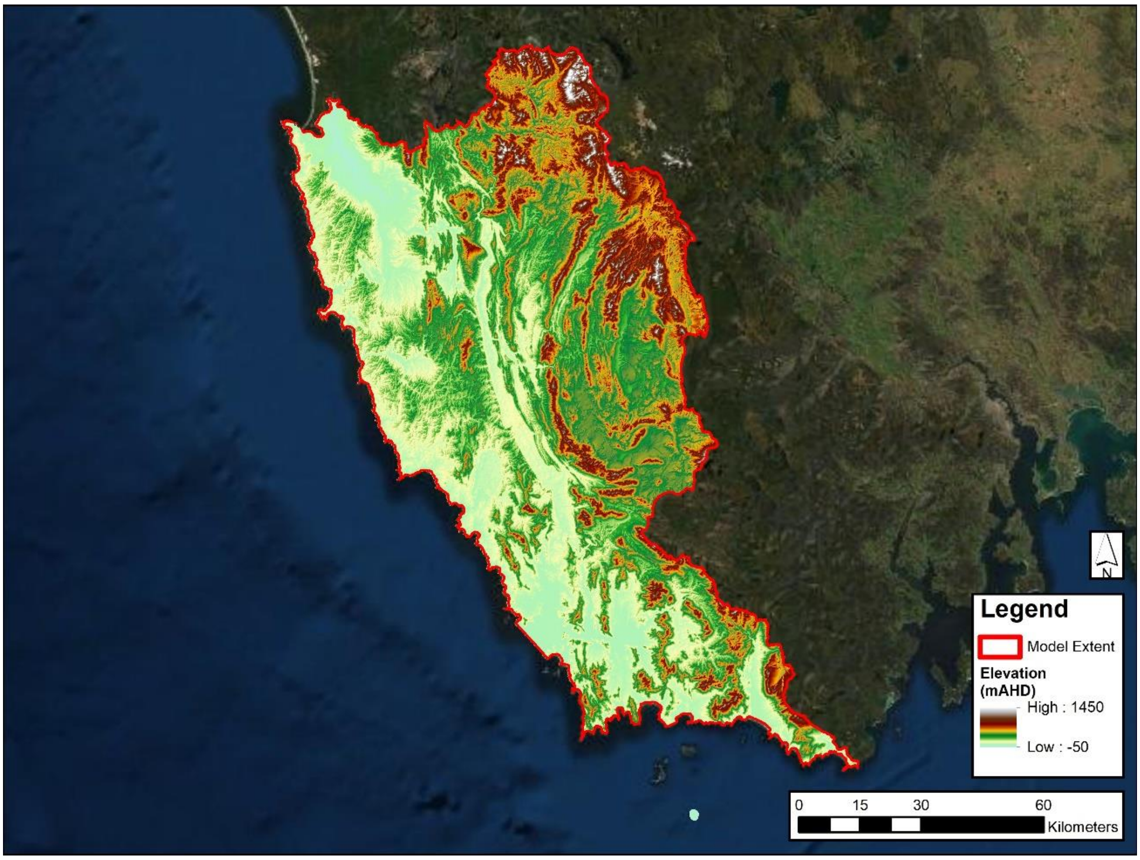

Diagram 1: DEM of the Gordon-Franklin study area

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. The majority of the Gordon-Franklin study area is covered by the ‘Default DEM’, as shown in Diagram 2.

Further discussion on the implications of the ‘Default DEM’ on the outcomes of the hydrodynamic model is provided in Section 6.

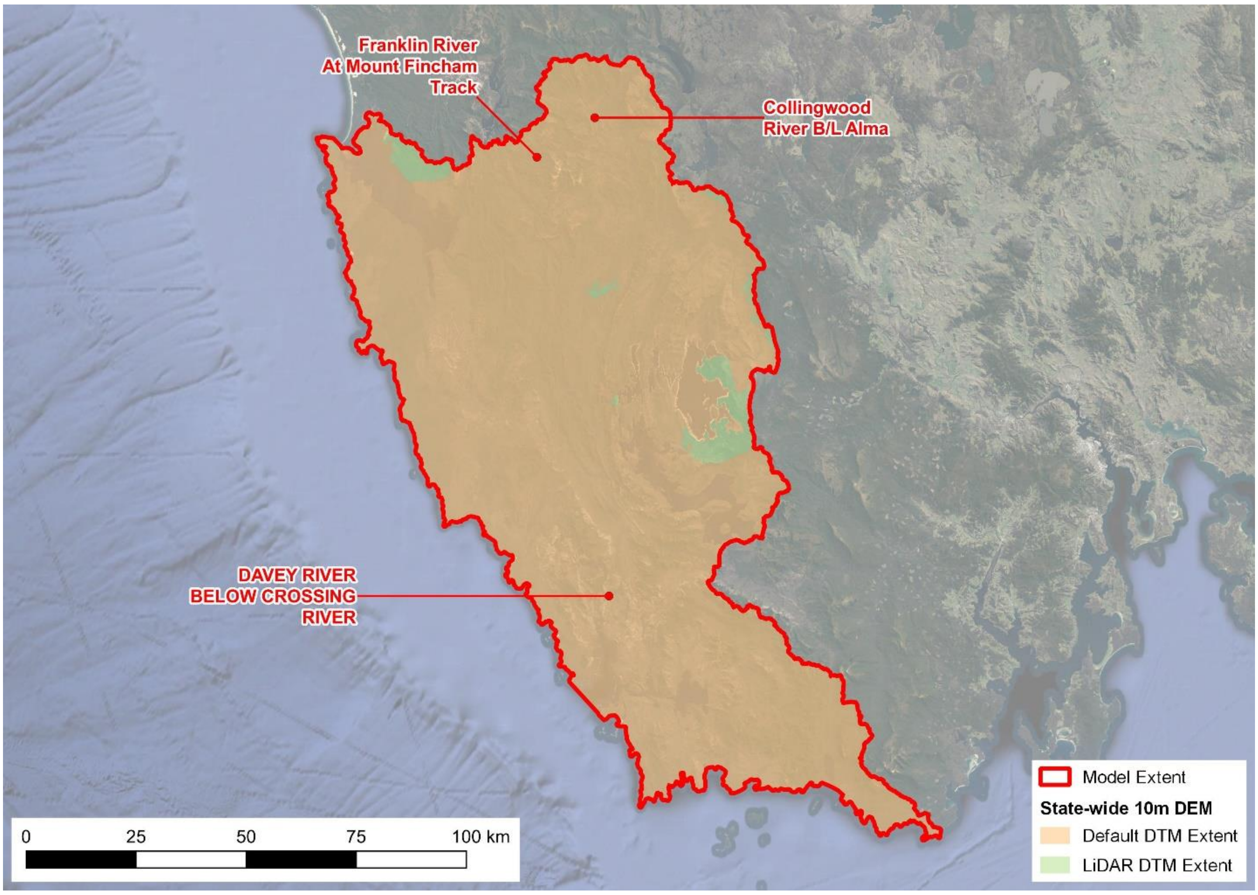

Diagram 2: 'Default DEM' extents for the Gordon-Franklin study area

5.2. Roughness

The base dataset that was used for the roughness of the hydrodynamic model was the SES state-wide roughness grid. This dataset was converted to a set of polygons for each land use and linked to a corresponding friction value (as detailed in the Hydrodynamic Modelling Methods Report, WMA 2021b). The polygons were then cleaned in GIS to ensure that the geometry was valid before being imported into the hydrodynamic model.

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 continuous zone of single roughness of 0.05 for all upper streams was utilised.

The resulting roughness layer is shown in Diagram 3.

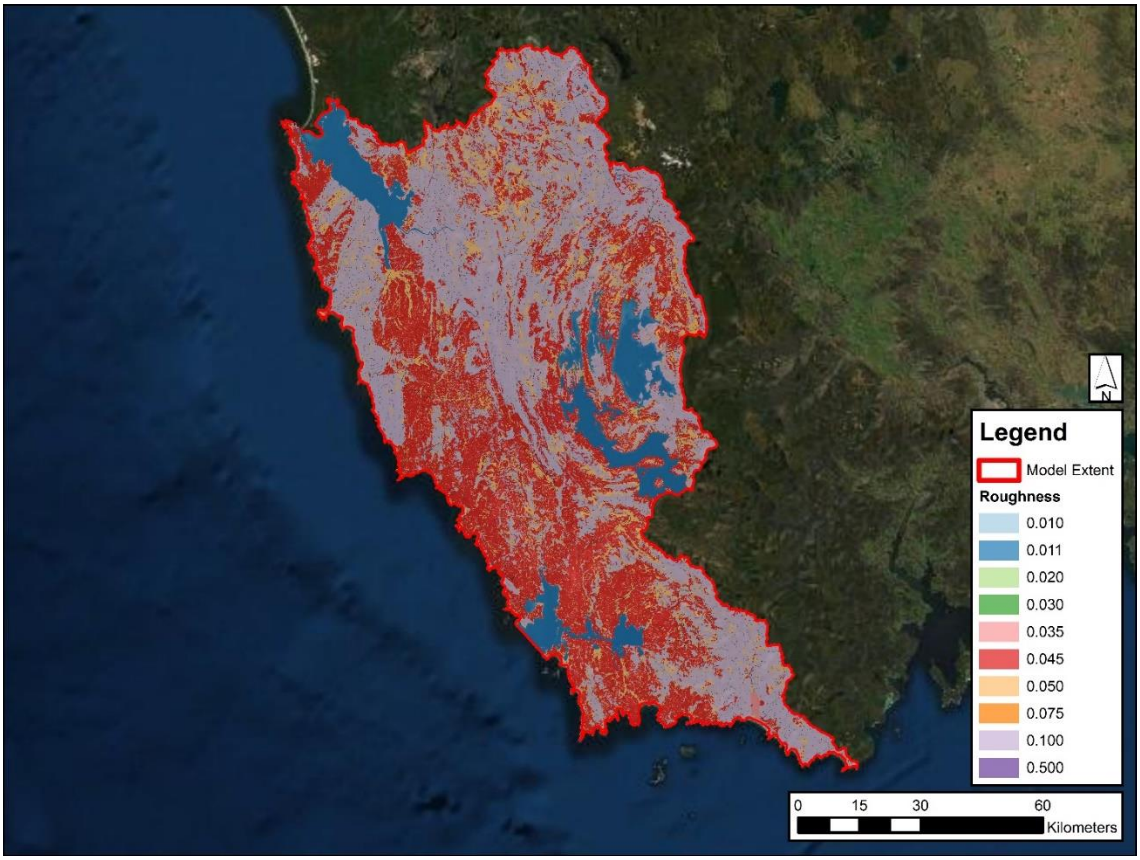

Diagram 3: Roughness layer for the Gordon-Franklin study area

5.3. Meshing

Meshing in the hydrodynamic model was undertaken using mesh zones, with the following rules:

- Base mesh zone – the default mesh size, set to a maximum of 2500 m² and a minimum of 400 m²
- Stream mesh zones – set as an independent mesh zone with a maximum mesh size of 400 m² and a minimum of 100 m²
- Upper stream mesh zones – streamlines of Strahler order 2-5 and Strahler order 6-8 were buffered by 10 m and 20 m either side of the centre line. These zones were then set to a maximum mesh size of 150 m² and a minimum of 100 m². This process was done to ensure that the meshing process did not result in artificial blocking of the flow paths along the upper streams.
- Human Settlement Areas and other areas of interest – set as an independent mesh zone with a maximum area of 100 m² and a minimum of 25 m²

The resulting mesh zones are shown in Diagram 4.

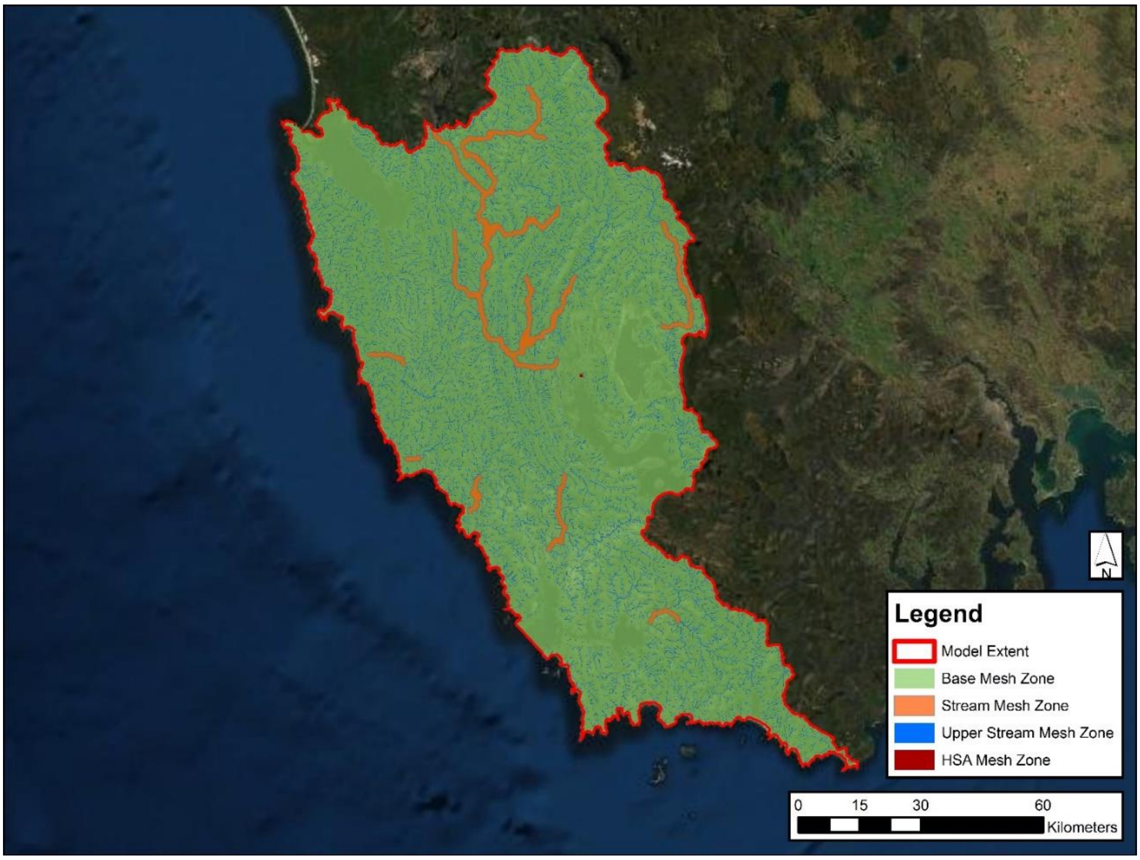

Diagram 4: Mesh zones for the Gordon-Franklin study area

5.4. Structures

No significant bridges or culverts were identified within the study area.

5.5. Dams

Lake Pedder and Lake Gordon were modelled in the hydrodynamic model in the 2D domain, assuming initial conditions at the starting level of the dams, based on historical lake levels from Water Data Online (BoM 2021). McPartlan's Pass Canal was modelled in the hydrodynamic model in the 1D domain, assuming a pump with a head-discharge relationship as per the discharge rating curve of the canal described in Section 3.3.

The dam walls for Serpentine Dam (Lake Pedder) and Gordon Dam (Lake Gordon) were set to the full supply level of the lakes (Table 5). The dam walls for Edgar Dam (Lake Pedder) and Scott's Peak Dam (Lake Pedder) were set to vertical walls by the model extent.

The percent impervious for both lakes was set to 100% in the ICM model.

5.6. Downstream Boundaries

Downstream boundaries were applied at the base of the model to provide the interaction with the tidal zone. Synthetic tide data was provided by the Bureau of Meteorology (BOM) and was used to set a varying tide level for the calibration events. This data was extracted off the coast of Low

Rocky Point at 10 min time increments and was imported into ICM as a time varying boundary condition. Diagram 5 shows an example of the tide data that was extracted for the July 2016 event. Note there is no calibration information to verify the function of the tailwater condition thus no allowance for local storm effects have been undertaken. It is considered the synthetic tide is a reasonable estimation of tailwater levels for the purposes of calibration assessment.

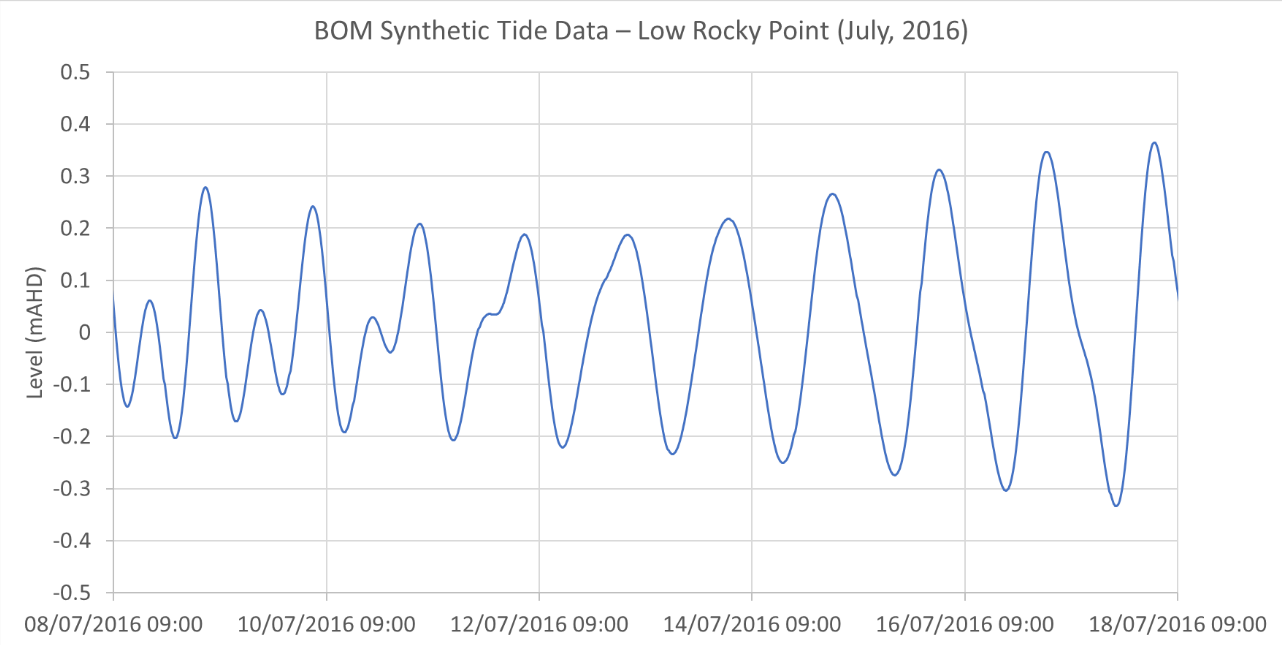

Diagram 5: Synthetic tide data off the coast of Low Rocky Point (July 2016)

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, only 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 resulting RAFTS sub-catchment model setup is shown in Diagram 6. 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.

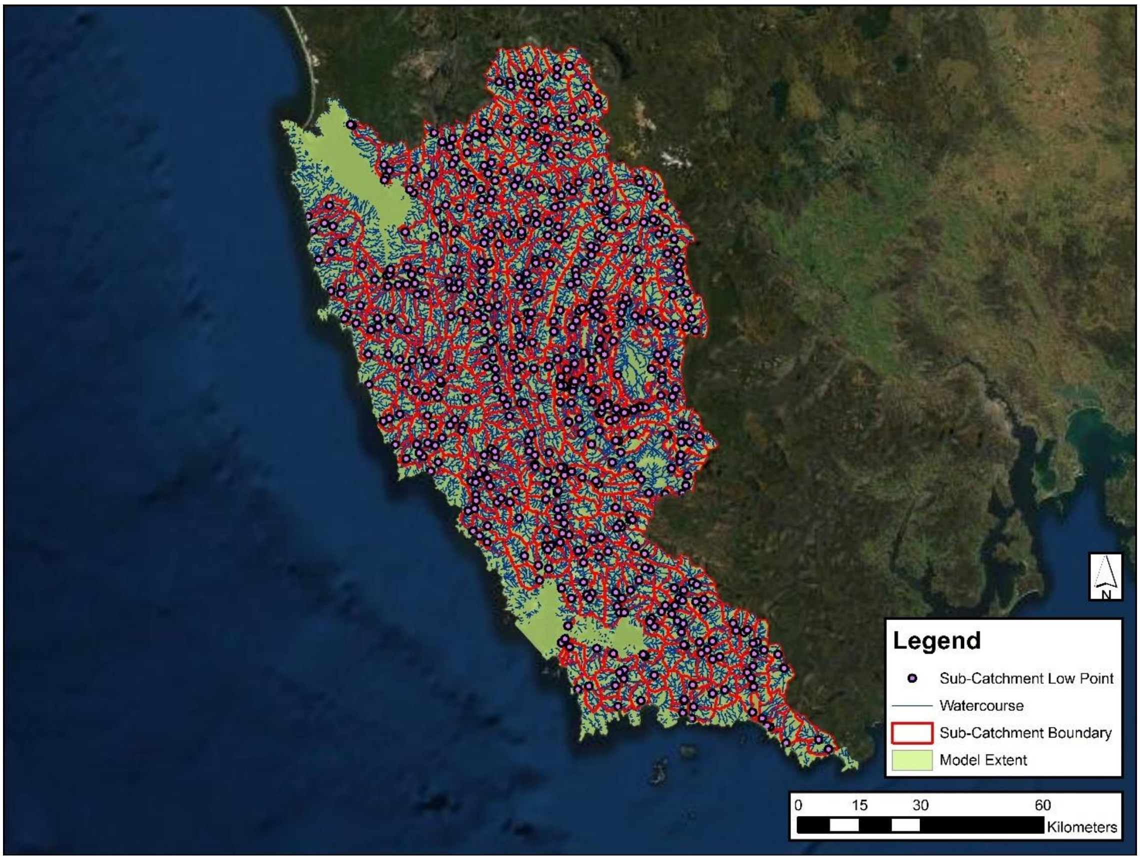

Diagram 6: RAFTS sub-catchment model setup for the Gordon-Franklin study area

6. CALIBRATION RESULTS

Significant unrealistic ponding was identified across the Gordon-Franklin study area in review of the calibration modelling results. Appendix D presents some examples of the ponding issues observed. This ponding is believed to relate to the DEM coverage in this study area, in particular due to the following:

- The majority of the Gordon-Franklin 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 – examples of these instances are shown in Figure D 2 (Map 3), Figure D 3 (Map 2), and Figure D 4 (Map 2)
  - While the 'Default DEM' is hydrologically enforced, the width of the enforcement is insufficient to accurately represent the channel capacity in the area.
- A number of instances were identified where the DEM has insufficient detail to represent the narrowing of a main flow path (such as at gorges) – examples of these instances are shown in Figure D 1 (Map 2 and 3), Figure D 2 (Map 2), Figure D 3 (Map 3), and Figure D 4 (Map 3). The impact of these can be seen in the Appendix C figures at Davey_Crss, Gor604, Gor94 for maps D 1, D 2 and D 3 respectively.

Comparisons of the hydrodynamic model to the external hydrologic model are shown in Appendix C. It is estimated that at least 30% of the expected volume to the Davey River gauge is being 'trapped' within the DEM of the hydrodynamic model (Figure C 1 – Davey_Crss). This issue means that the Davey River component of this study area is not able to be calibrated to at this stage, as presented in Section 6.3.1.

Similarly, in the Gordon River catchment, it is estimated that at least 25% of the expected volume to the outlet of the Gordon River is being 'trapped' within the DEM of the hydrodynamic model (Figure C 1 – Gor605).

Give the issue with the significant ponding, it is proposed that the hydrodynamic model is run with the initial routing and loss parameters derived from the external hydrologic model until such time that improved topographic information is available. It is noted that there may still be difficulties in achieving an appropriate calibration to the Davey River gauge and to the lake levels at that time due to the following issues:

- The results presented herein suggest sparse rainfall data is causing a lack of runoff volume, with flows and levels being underestimated at the Davey River gauge and in Lake Pedder respectively in the calibration events, even with initial and continuing loss set at 0 (Figure C 1 – Davey below Crossing and Lake Pedder).
- The results presented herein also suggest that multiple sets of losses may be required, with levels being overestimated in Lake Gordon in the 2016 event at this stage, although this may relate more to rain gauge coverage than differences in catchment runoff behaviour (Figure C 1 – Lake Gordon).

6.1. Sub-catchment Routing and Loss Parameters

The hydrodynamic model was run with the routing and loss parameters derived from the external hydrologic model. This consists of a single sub-catchment routing parameter across the study area (RAF of 1.0) and a single set of initial and continuing losses (in this case, no initial and continuing losses).

6.2. Initial Conditions

Prefilling of the hydrodynamic model was not undertaken. It is noted that a prefill of the hydrodynamic model at the locations of significant ponding may improve the response of the model at specific locations, however it will also result in spurious results in significant portions of the catchment.

6.3. Gauge Results

Historic event information was available for three of the five gauges within the catchment for the selected calibration events (Davey River below Crossing, Collingwood River below Alma, and Franklin River at Fincham). Historic event information was also available at Lake Pedder and Lake Gordon in the form of daily lake levels.

Historic event information was not available for the remaining two gauges within the catchment as they were closed prior to the selected calibration events (Gordon River below Huntley and Franklin River below Jane).

At this stage only flow comparisons have been presented at each gauge. Plotting of the levels has been omitted due to the poor topographic representation of the system. Mapping of the modelled flood extent across the Gordon-Franklin study area has also been omitted for the same reason.

6.3.1. Davey River Below Crossing River

The modelled and observed flows at the Davey River gauge is shown in Table 6 and Diagram 7 to Diagram 8. The modelled peak flow shows a poor match to the recorded peak flow. This is due to significant unrealistic ponding occurring upstream of the gauge as discussed in Section 6.

A gauge zero for the Davey River gauge was not available from the DPIPWE database.

Table 6: Parameters and results at Davey River Below Crossing River

Statistic	2007 August	2016 July
IL (mm)	0.0	0.0
Average CL (mm/h)	0.0	0.0
RAF	1.0	1.0
Modelled Peak (m^3/s)	342	306
Observed Peak (m^3/s)	725	738
Peak % difference	-53%	-59%
Modelled Volume (GL)	71	51
Observed Volume (GL)	147	122
Volume % difference	-52%	-58%

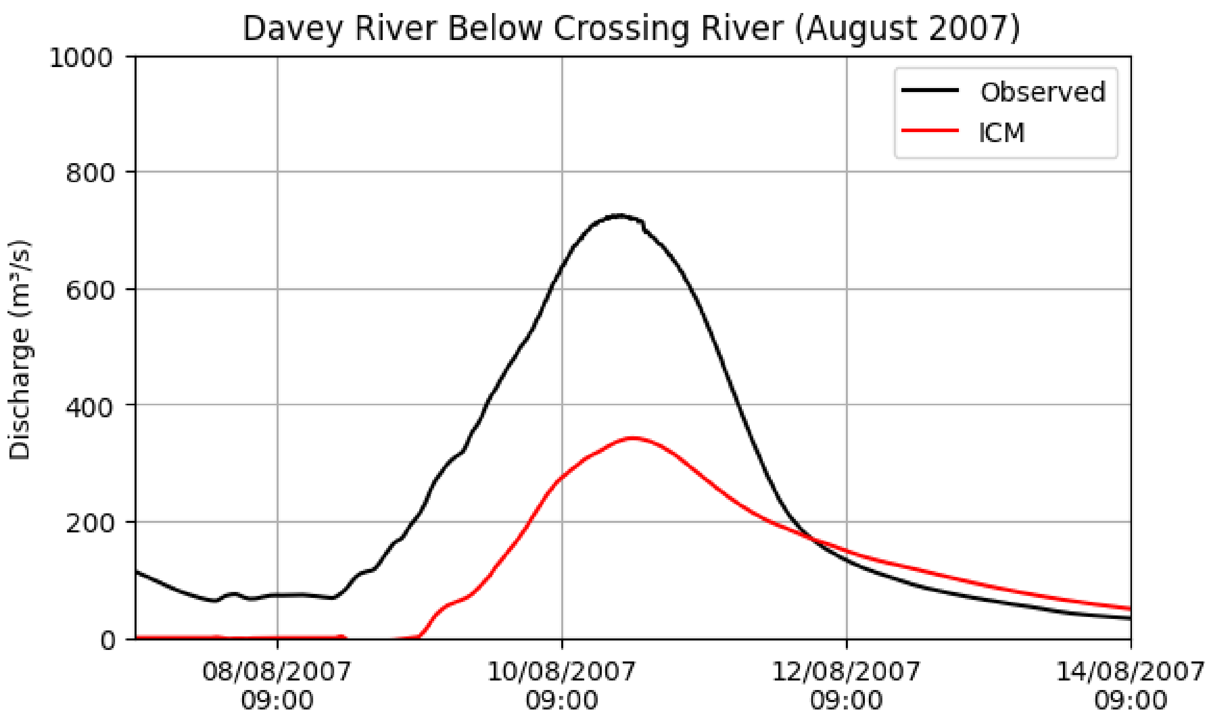

Diagram 7: August 2011 flow comparison at Davey River Below Crossing River

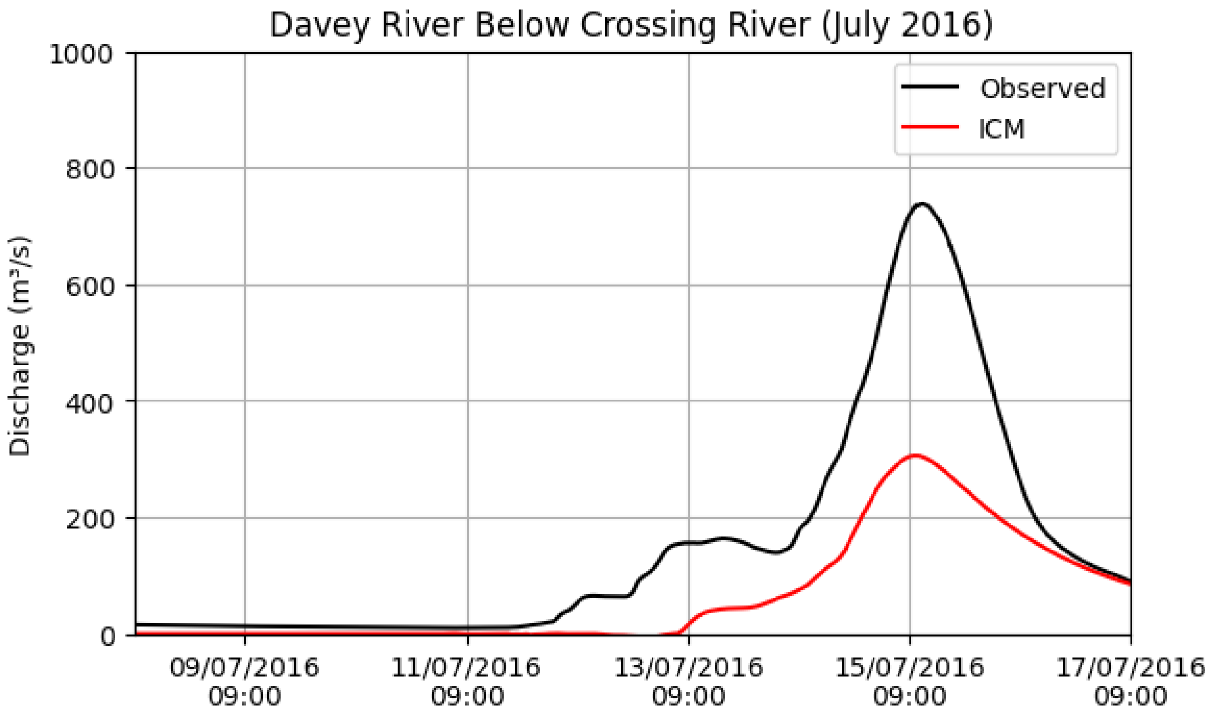

Diagram 8: July 2016 flow comparison at Davey River Below Crossing River

6.3.2. Collingwood River Below Alma

The modelled and observed flows at the Collingwood River gauge are shown in Table 7 and Diagram 9 to Diagram 10. The modelled peak flow shows a fair match to the recorded peak flow and the modelled hydrograph shows a fair match to the timing and shape of the recorded flows.

It is noted that the Collingwood River gauge is in the upper reaches of the Gordon-Franklin study area, where significant ponding in the hydrodynamic model was not observed.

A gauge zero for the Collingwood River gauge was available from the Hydro Tasmania database (334.5 mAHD), however, this level differs to the levels in the Gordon-Franklin DEM (338 to 339 mAHD). As such no level comparisons have been undertaken.

Table 7: Results at Collingwood River below Alma

Statistic	2007 August	2016 July
IL (mm)	0.0	0.0
Average CL (mm/h)	0.0	0.0
RAF	1.0	1.0
Modelled Peak (m^3/s)	343	363
Observed Peak (m^3/s)	365	422
Peak % difference	-6%	-14%
Modelled Volume (GL)	54	41
Observed Volume (GL)	61	44
Volume % difference	-12%	-6%

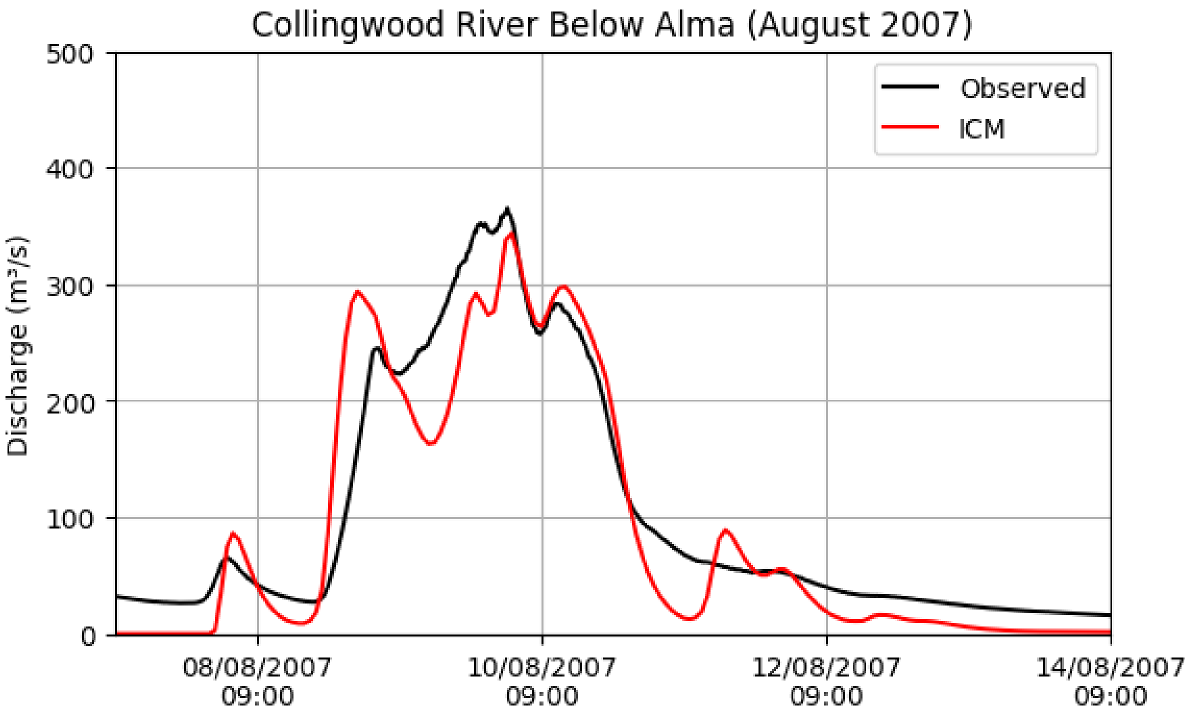

Diagram 9: August 2007 flow comparison at Collingwood River Below Alma

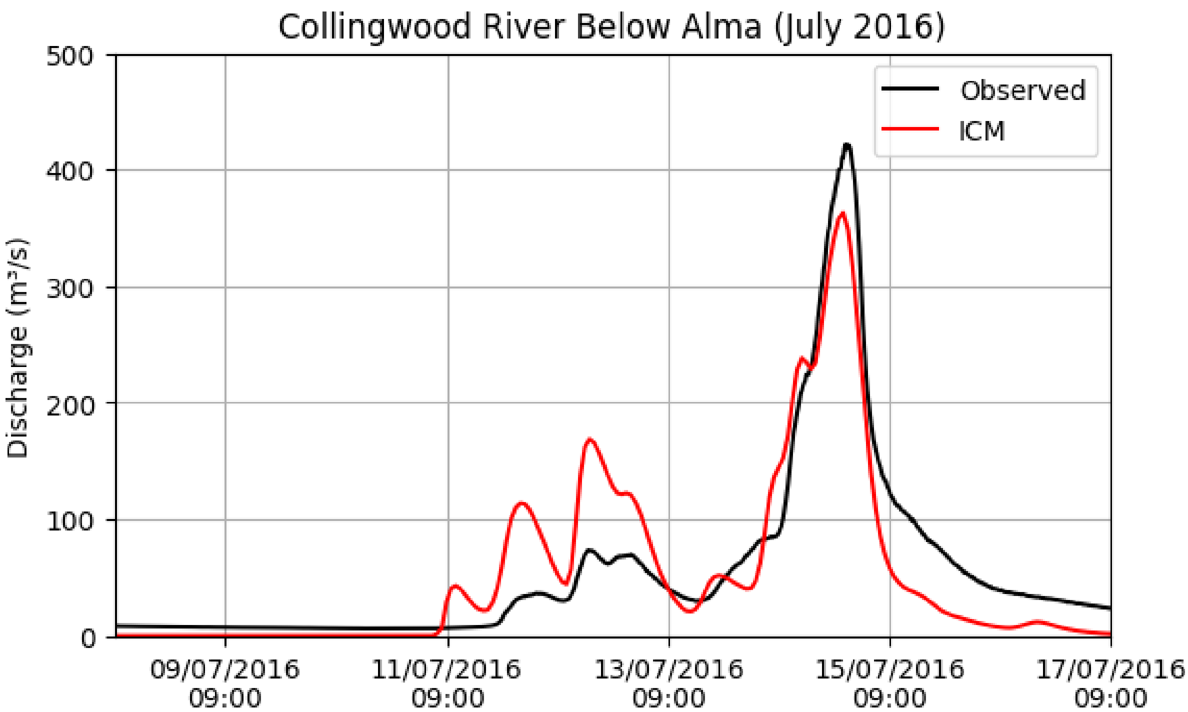

Diagram 10: July 2016 flow comparison at Collingwood River Below Alma

6.3.3. Franklin River at Mount Fincham Track

The modelled and observed flows at the Franklin River at Fincham gauge are shown in Table 8 and Diagram 11 to Diagram 12. The modelled peak flow show a fair match to the recorded peak flow and the modelled hydrographs show a fair match to the timing and shape of the recorded flows.

It is noted that the Franklin River at Fincham gauge is in the upper reaches of the Gordon-Franklin study area, where significant ponding in the hydrodynamic model was not observed.

A gauge zero for the Franklin River at Fincham gauge was available from the Hydro Tasmania database (222.5 mAHD), however, this level differs to the levels in the Gordon-Franklin DEM (226 to 227 mAHD). As such no level comparisons have been undertaken.

Table 8: Results at Franklin River at Mount Fincham Track

Statistic	2007 August	2016 July
IL (mm)	0.0	0.0
Average CL (mm/h)	0.0	0.0
RAF	1.0	1.0
Modelled Peak (m^3/s)	944	853
Observed Peak (m^3/s)	950	992
Peak % difference	-1%	-14%
Modelled Volume (GL)	153	108
Observed Volume (GL)	142	121
Volume % difference	+7%	-11%

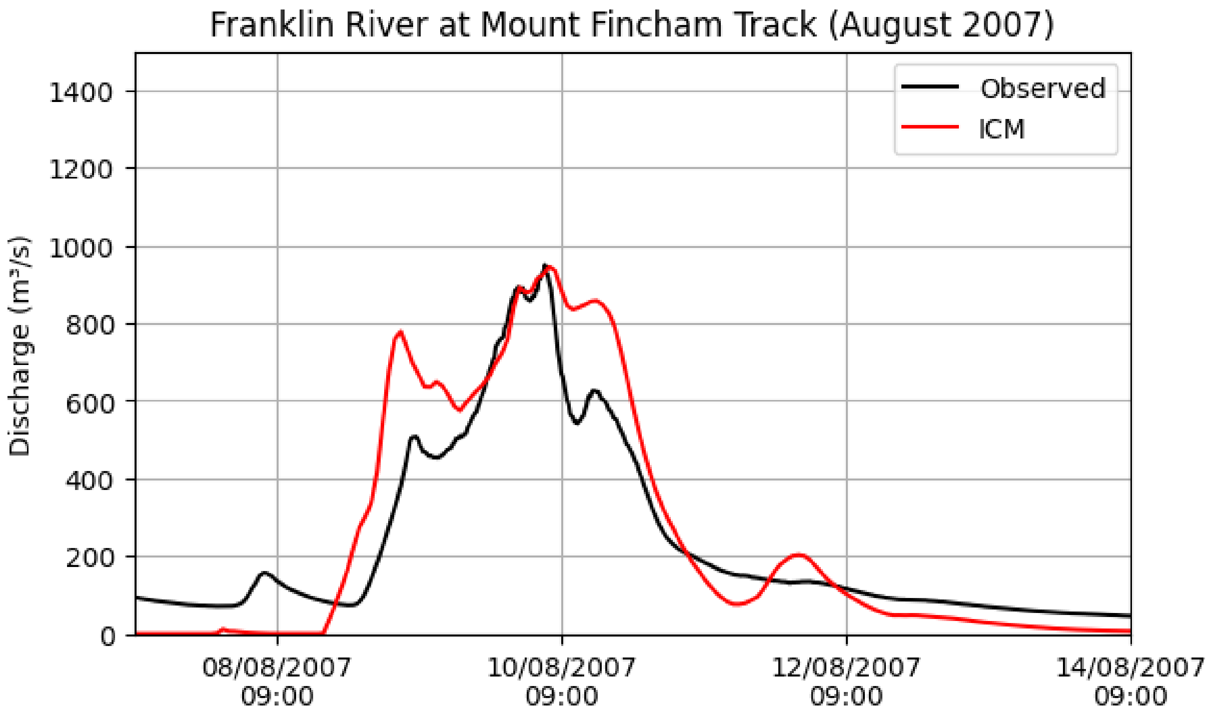

Diagram 11: August 2007 flow comparison at Franklin River at Fincham

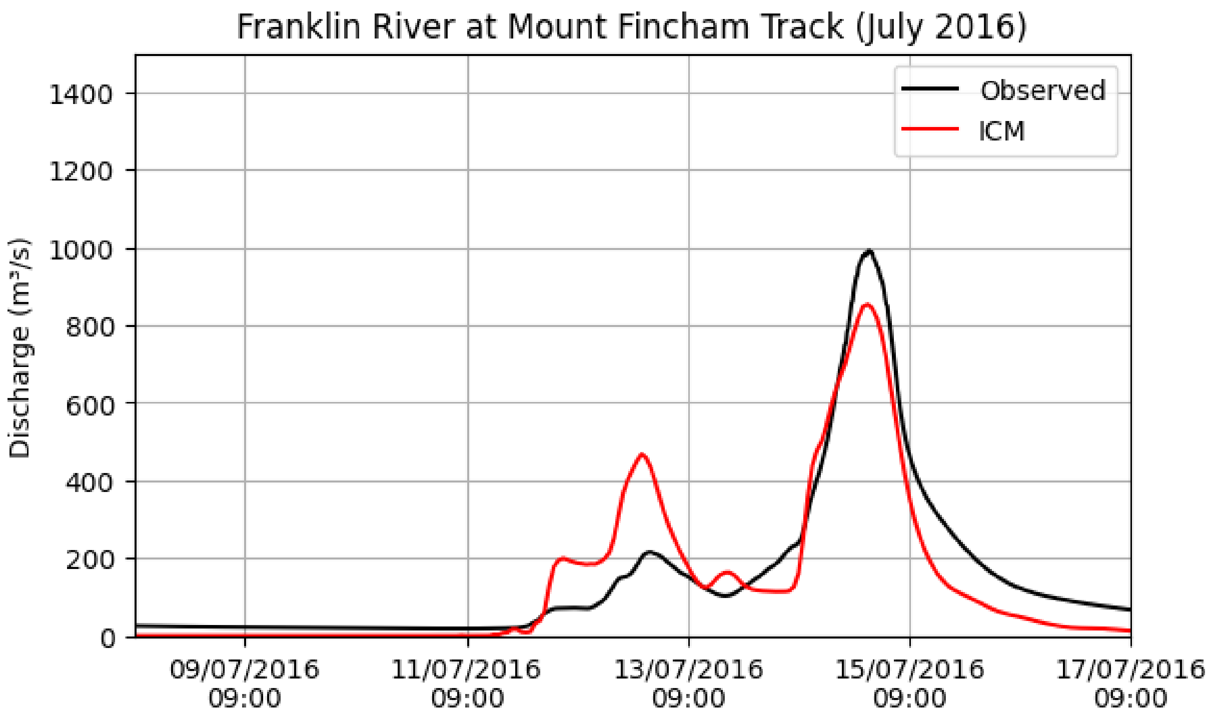

Diagram 12: July 2016 flow comparison at Franklin River at Fincham

6.3.4. Lake Pedder

The modelled and observed levels at Lake Pedder are shown in Table 9 and Diagram 13 to Diagram 14. The modelled levels show a poor match to the recorded daily lake levels, likely due to issues discussed in Section 6, as well as poor representation of rainfall due to the sparse gauge network. There are only two rain gauges that were operating over the Lake Pedder catchment (722 km^2) and the rainfall totals at Strathgordon (276 mm) for the 2007 event were almost twice those at Scotts Peak (144 mm). The difference in volume for the 2007 event equates to approximately 60 mm of rainfall on the Lake Pedder catchment area, and this is considered to be within the uncertainty of the rainfall distribution over the area.

Table 9: Parameters and results at Lake Pedder

Statistic	2007 August	2016 July
IL (mm)	0.0	0.0
Average CL (mm/h)	0.0	0.0
RAF	1.0	1.0
Modelled peak (mAHD)	307.75	308.20
Observed peak (mAHD)	307.93	308.31
Peak difference (m)	-0.18 m	-0.11 m

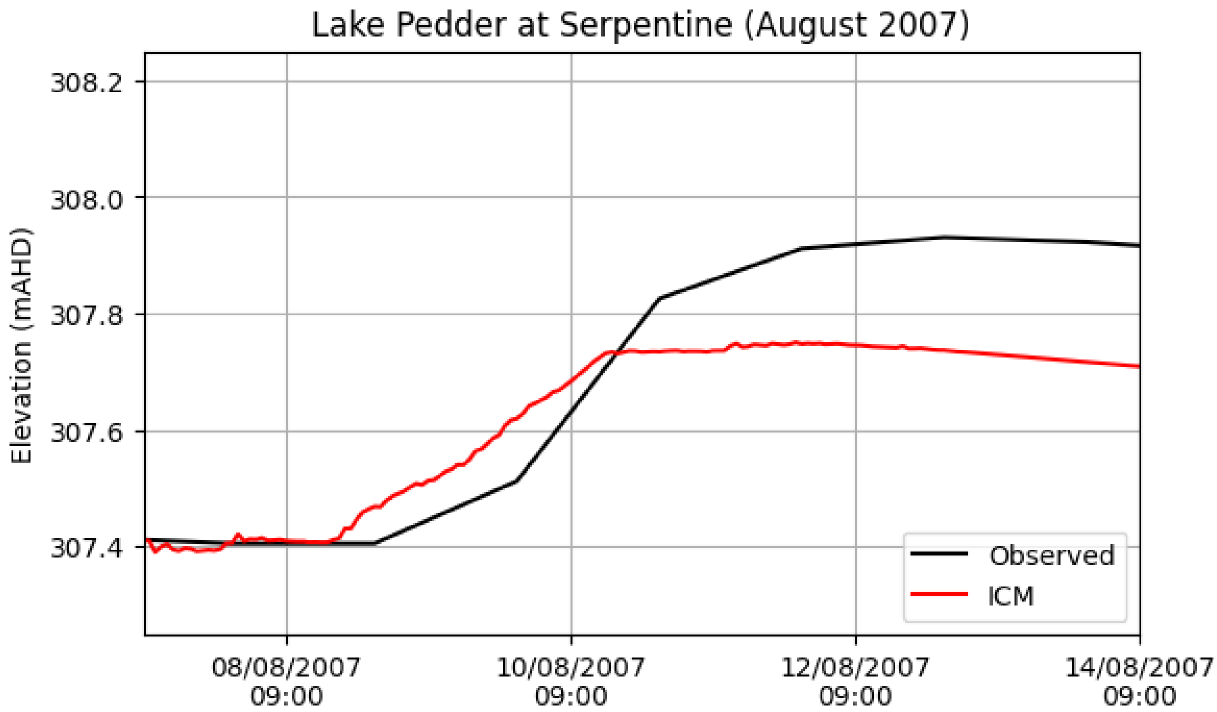

Diagram 13: August 2007 water level comparison at Lake Pedder

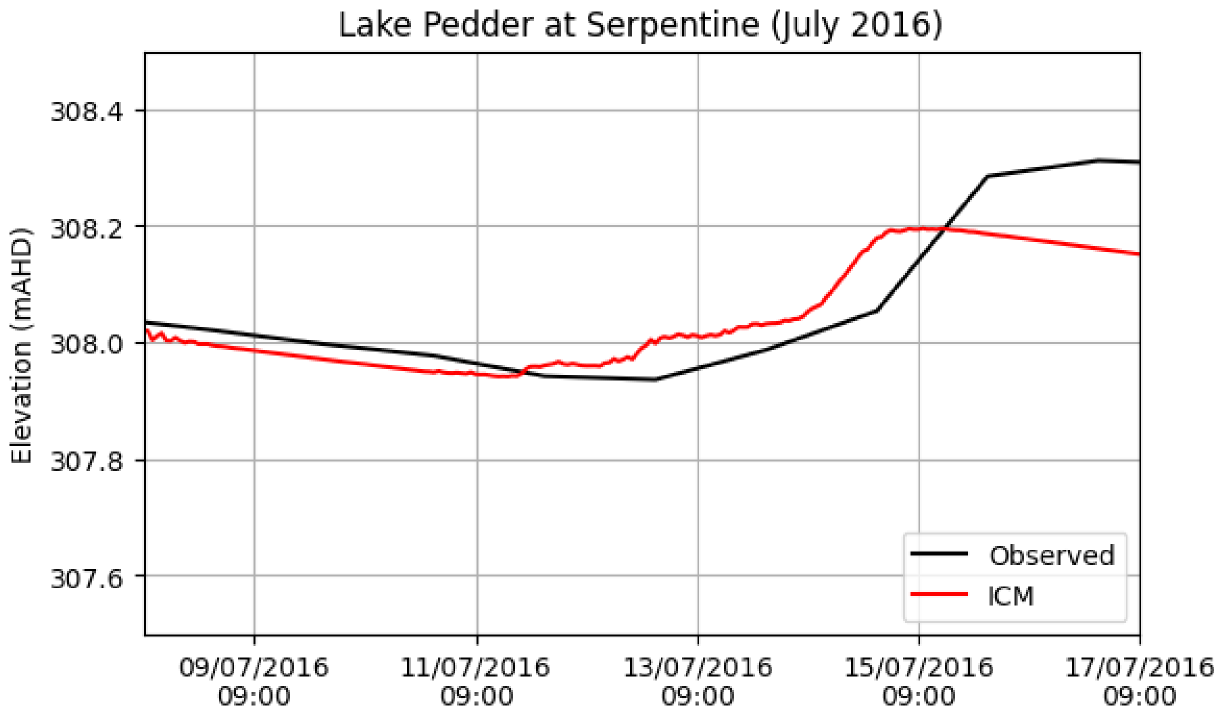

Diagram 14: July 2016 water level comparison at Lake Pedder

6.3.5. Lake Gordon

The modelled and observed levels at Lake Gordon are shown in Table 10 and Diagram 16 to Diagram 17. The modelled levels show a poor match to the recorded daily lake levels.

It is estimated that at least 50% of the expected volume into Lake Gordon via the Gordon River is being 'trapped' within the DEM of the hydrodynamic model (Figure C 1 – Gordon_Hntl). Despite this volume deficit, the model produced elevated levels in Lake Gordon in comparison to the observed (Figure C 1 – Gor468) for the July 2016 event. This is attributed to differences in the stage-storage relationship of the two models, with the hydrodynamic model based on the DEM and external hydrological model based on the Hydro Tasmania rating. This difference in storage volume means the ICM model shows a greater lake level increase, despite lower total inflow volumes to the storage. Diagram 15 shows the relative storage across the levels covered in both calibration runs. Given the larger scale issues with the DEM and rainfall inputs that impact on level replication at the lakes, at this stage it was not considered necessary to utilise alternative methods of assessment, such as inclusion of the lakes as 1D elements.

Table 10: Parameters and results at Lake Gordon

Statistic	2007 August	2016 July
IL (mm)	0.0	0.0
Average CL (mm/h)	0.0	0.0
RAF	1.0	1.0
Modelled peak (mAHD)	271.44	270.39
Observed peak (mAHD)	271.59	270.21
Peak difference (m)	-0.15 m	+0.18 m

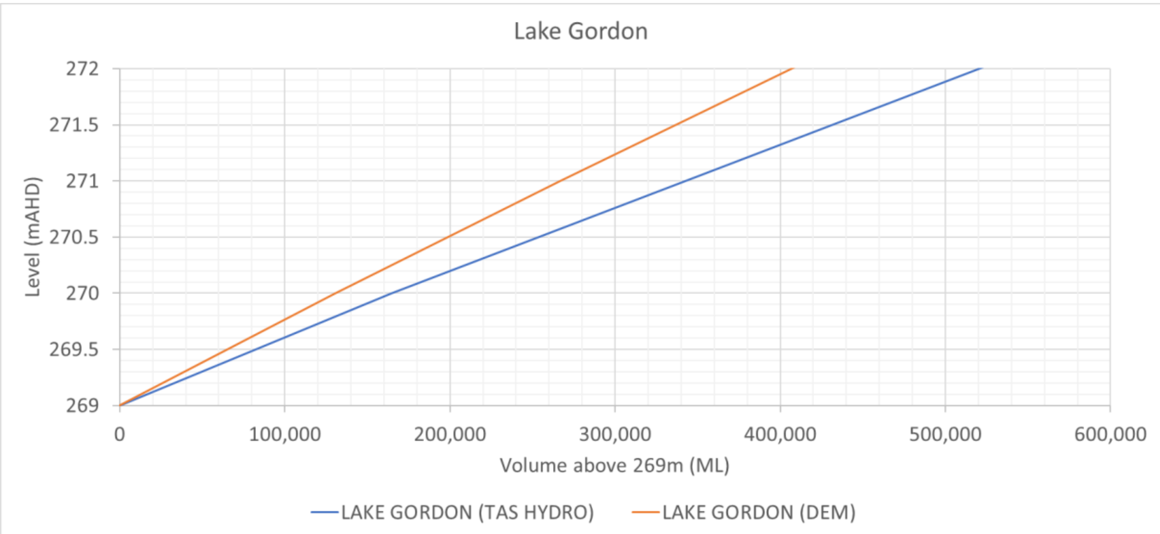

Diagram 15 Lake Gordon relative storage above 269.0 mAHD in the provided Hydro Tasmania rating curve and within the DEM surface.

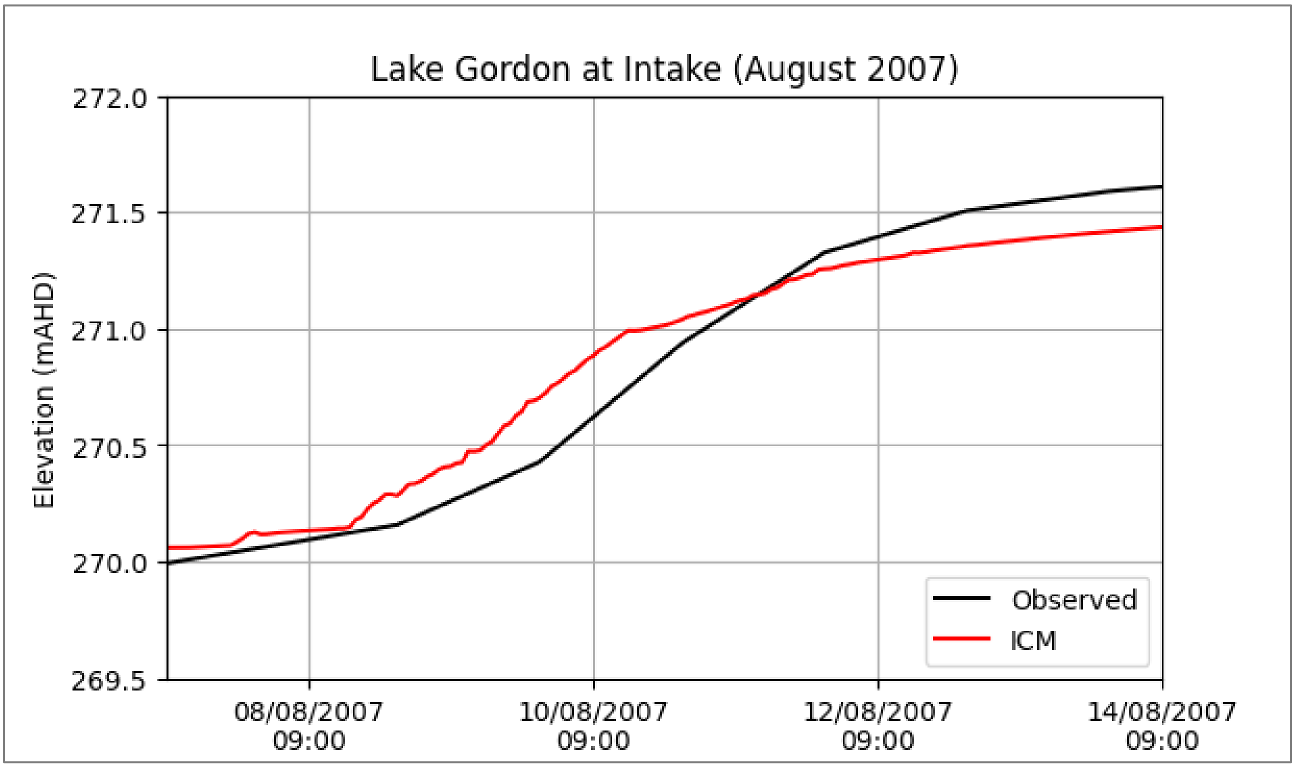

Diagram 16: August 2007 water level comparison at Lake Gordon

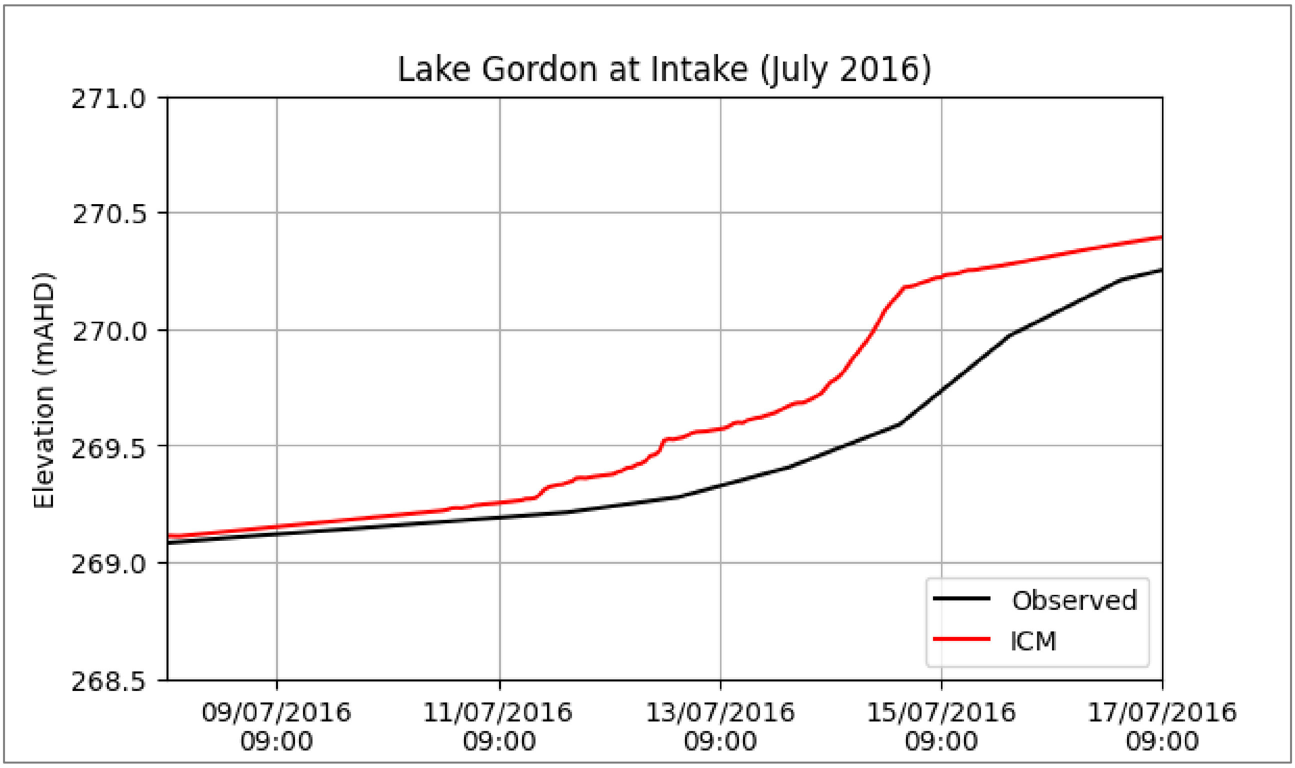

Diagram 17: July 2016 water level comparison at Lake Gordon

6.4. Comparison to Previous Studies

No previous studies of use were identified for the Gordon-Franklin study area.

6.5. Identified Issues

Early in the calibration process, it was identified that there would be significant challenges in achieving a reasonable calibration to the locations of interest and a reasonable match to the external hydrologic model due to the quality of the DEM. If further modelling is required in this area it is recommended that future works aim to address this issue through access to improved topographic data (such as LiDAR capture). Access to improved topographic data will also allow for the plotting of the levels at the gauges and the mapping of the modelled flood extents across the Gordon-Franklin study area, which have been omitted at this stage.

If future modelling is undertaken in this study area, it would be worthwhile obtaining power station data from Hydro Tasmania if possible. This would allow for calibration to gauges on the Gordon River downstream of the power station.

Sparse rainfall gauge coverage across the study area means that there is a very high level of uncertainty in the representation of rainfall in the model inputs.

7. UNCERTAINTY ASESSMENT

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. The August 2007 and July 2016 events were used in calibration.

Flow data was available at three gauges for the calibration events, however these gauges gauge relatively small areas of the overall catchment. There were no flood extents or depths available in this catchment.

The hydrodynamic modelling for this study area is considered to be very poor. This is due to issues with the DEM, which result in unrealistic results when modelling at this coarse scale. 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. The majority of the Gordon-Franklin 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 uncertainty assessment for the modelling is shown in Table 11 and Appendix B, however the assessment is limited to a comparison of flows at gauges as gauge levels were not consistent with the DEM.

Table 11: Uncertainty assessment for Gordon Franklin River catchment model

Category	Quality statement
Hydrology – rainfall input quality	The quality of the rainfall data overall is considered to be poor. The Gordon-Franklin study area is very large so, despite having between 7 and 9 sub-daily gauges in the area, there is still very high uncertainty in rainfall distribution for this catchment. This is particularly the case as the rain gauges are clustered in the north, around the two hydro lakes and along the Gordon River.
Hydrology – observed flows	At Davey below Crossing and Franklin at Fincham, the highest gauging is considerably lower than the highest recorded stage height, and the rating has been extrapolated to higher flows. These ratings are considered to be poor. At Collingwood below Alma, there are higher flow gaugings and the rating is considered more reliable, and has been classified as good, however this gauges only 2% of the total study area.
Hydrology – calibration events	The July 2016 event was the largest on record at Davey below Crossing gauge and the second largest on record at Franklin at Fincham and Collingwood below Alma gauges. The August 2007 event was the second largest on record at Davey below Crossing gauge, fourth largest at Franklin at Fincham, and seventh largest at Collingwood below Alma.
Hydrology – calibration results	The hydrology calibration was considered to provide a poor match to observed flows at the Davey at Crossing gauge due to issues with ponding in the model above the gauge, associated with the DEM resolution. The modelled flows showed a good to very good match to observed flows at the Collingwood below Alma and Franklin at Fincham sites.

Category	Quality statement
DEM 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. The majority of the Gordon-Franklin study area is covered by the 'Default DEM'. No 2m DEM was available in the catchment. 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 (such as at gorges).
DEM waterways	No bathymetric data was available and waterway definition was based on the default DEM. The representation of waterways is considered to be poor.
Hydrodynamic – calibration results, peak levels	Levels are not presented over the study area due to the significant issues introduced to the modelled through the DEM.
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

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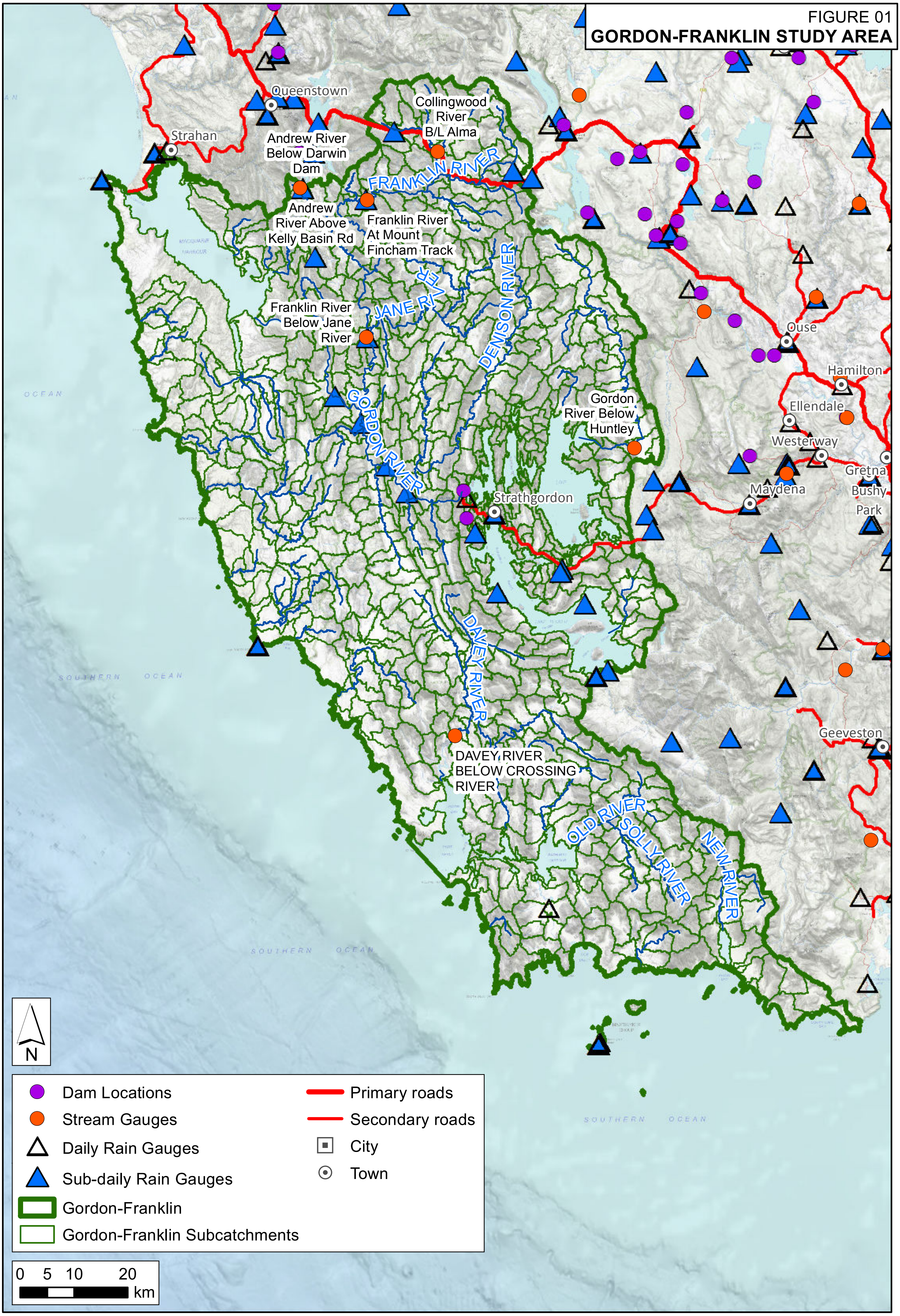
Figures



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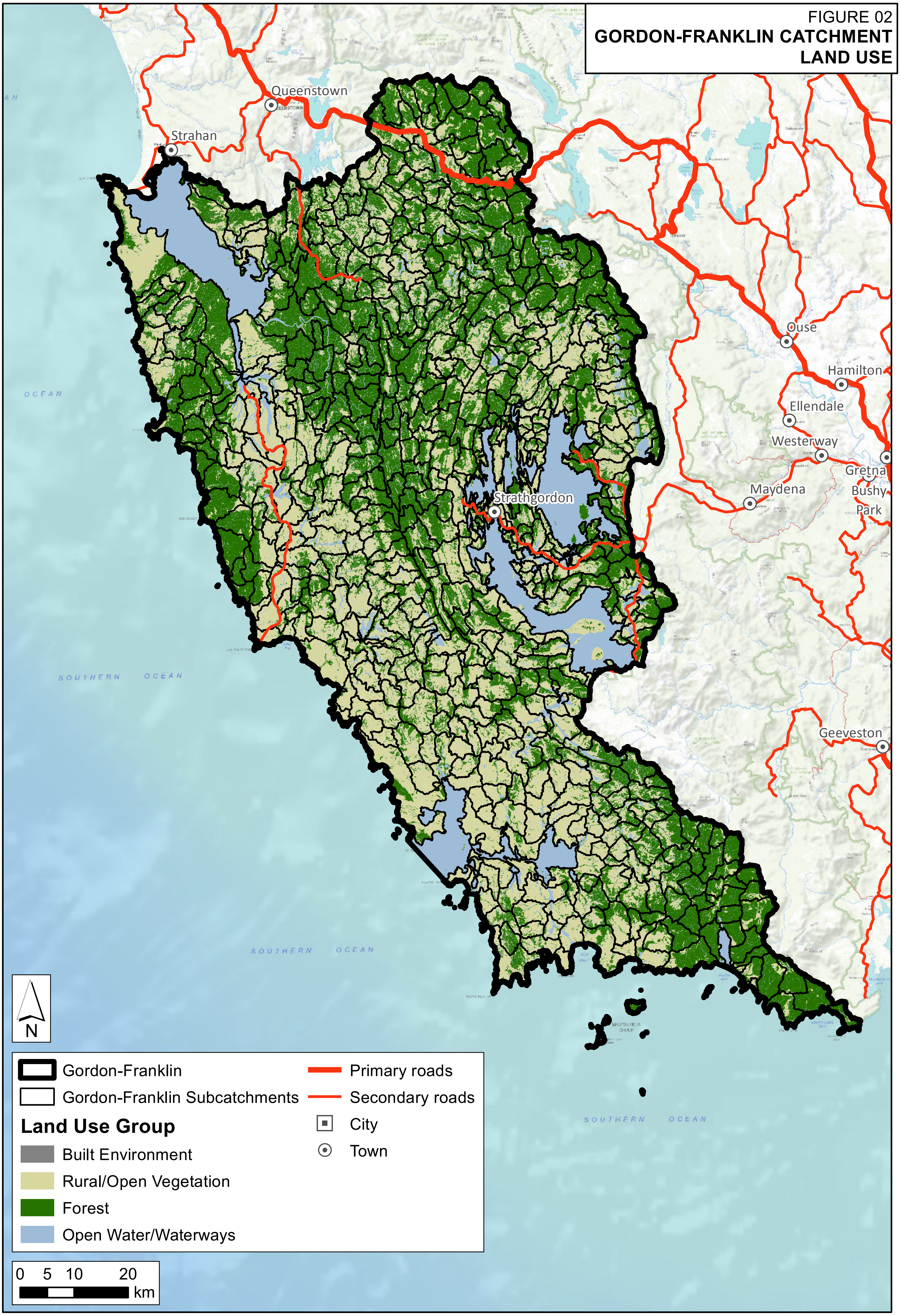

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FIGURE 3
GORDON−FRANKLIN STUDY AREA
RAINFALL 2007_AUG

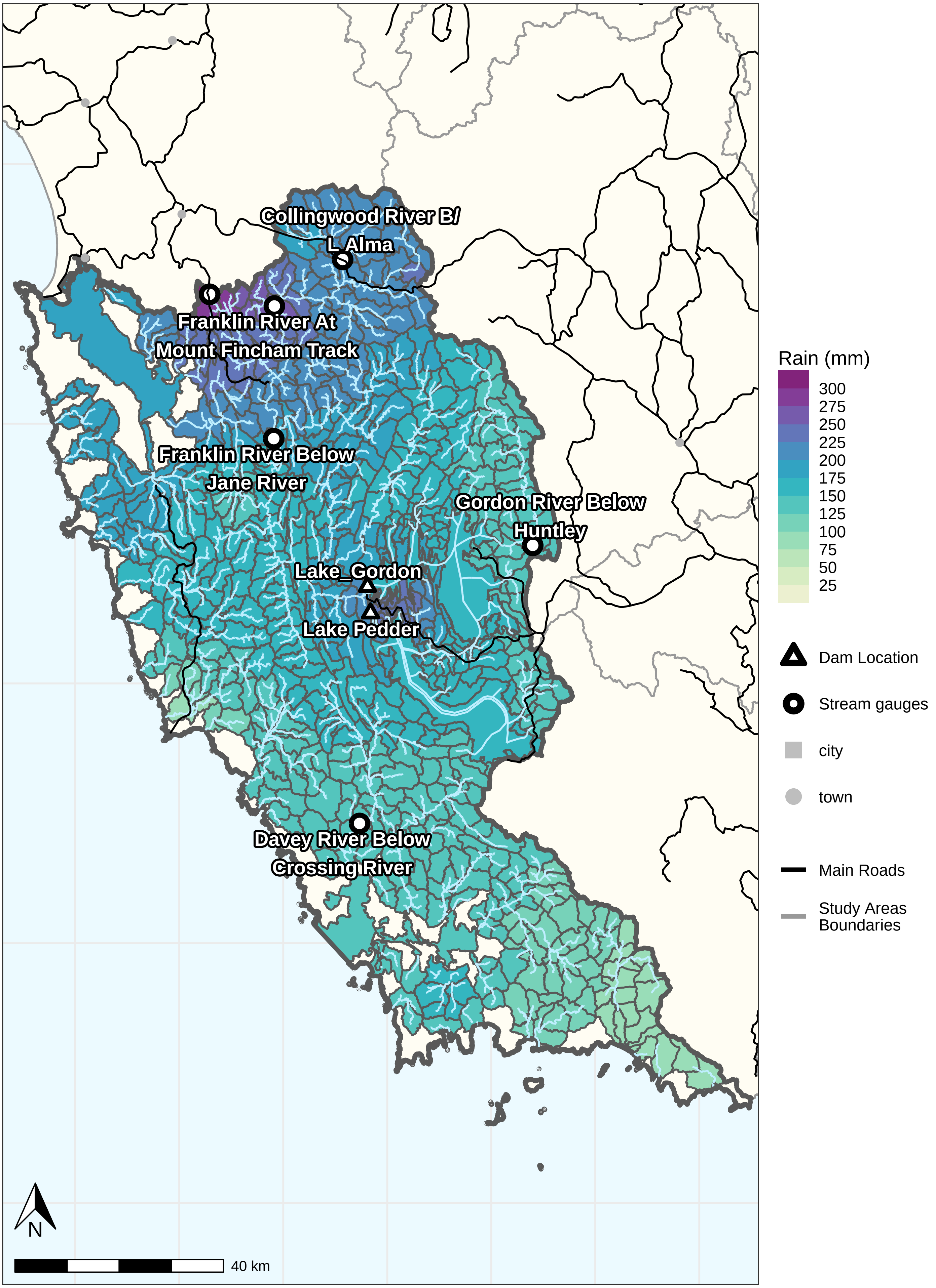

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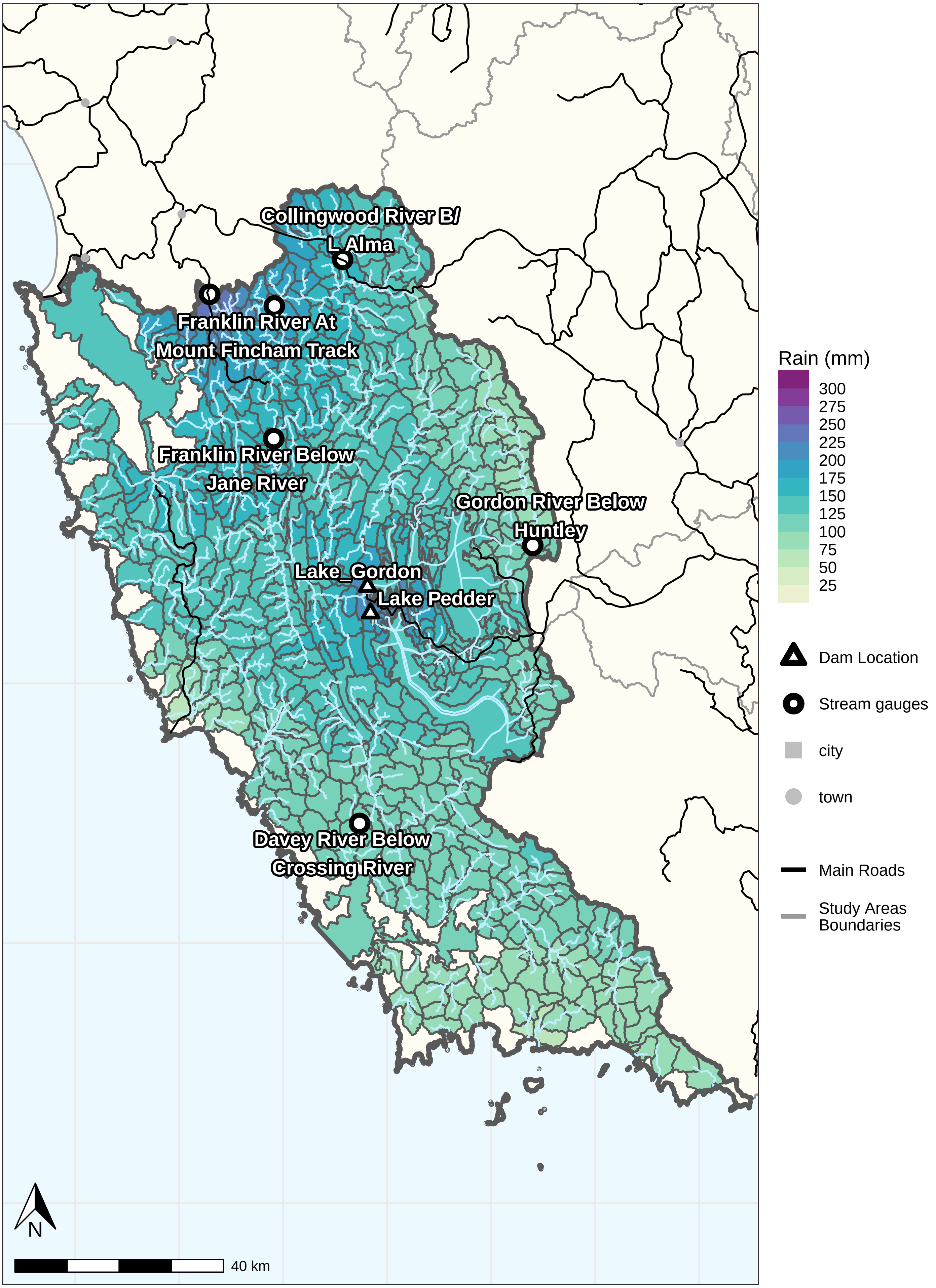
FIGURE 4
GORDON−FRANKLIN STUDY AREA
RAINFALL 2016_JUL



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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

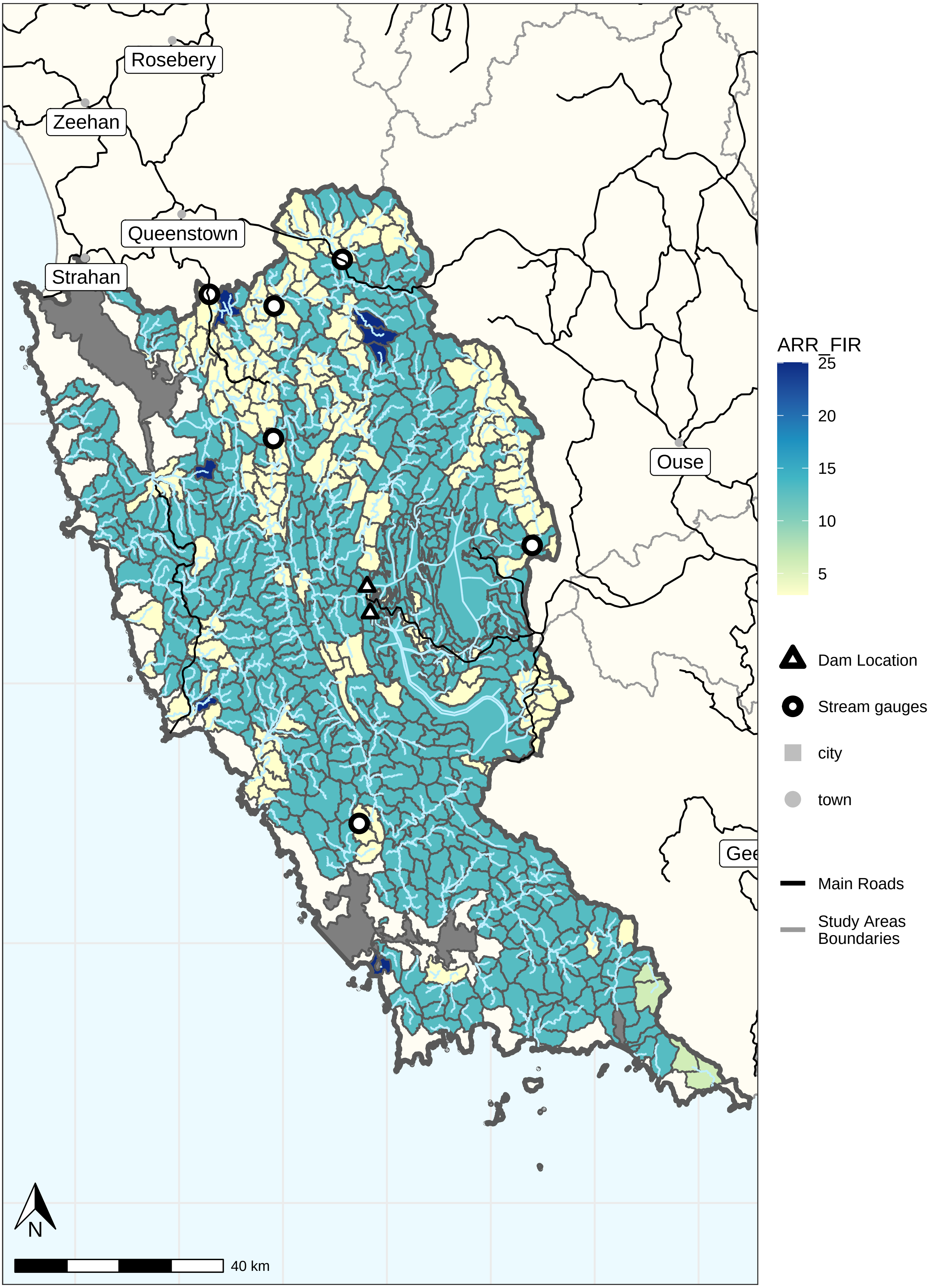

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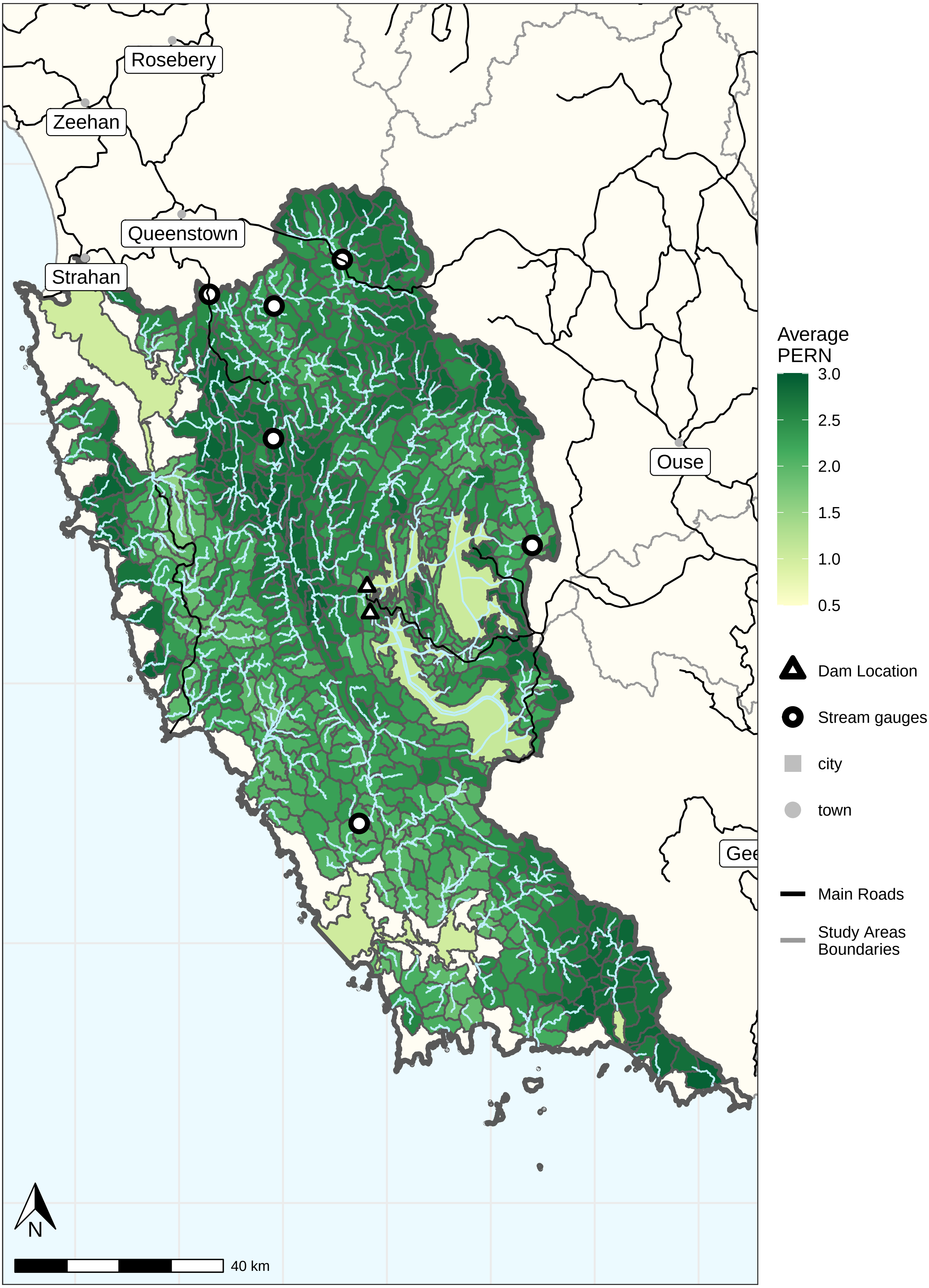
FIGURE A2

GORDON−FRANKLIN 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 where applicable to all gauges or events. In terms of the rainfall input quality, while there are pluviometers and daily gauges within the catchment, the overall quality of the rainfall data is considered to be poor, as the density of rain gauges is not considered sufficient to represent rainfalls over the entire catchment. In other cases, the following shading is used to highlight relevant statements:

- For observed flow rating description, Davey below Crossing and Franklin at Fincham are shown in orange shading, Collingwood below Alma is shown in blue shading.

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 300km2 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% AEP	Between 10% and 5% AEP	Between 5% and 2% AEP or within largest 4 events on record	Larger than 2% AEP or within largest 2 events on record

Table B 2 shows the hydrology calibration quality rating. The following shading is used to highlight relevant statements:

- Davey below crossing in orange shading
- Franklin at Fincham and Collingwood below Alma are shown in blue shading.

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. DEM Uncertainty

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

Table B 3: DEM rating

Category	Rating				
	Poor	**Fair**	**Good**	**Very good**	**Excellent**
DEM 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
DEM 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

Appendix C

APPENDIX C. EXTERNAL HYDROLOGY MODEL AND ICM HYDRODYNAMIC MODEL COMPARISON

Figure C 1: Event hydrographs

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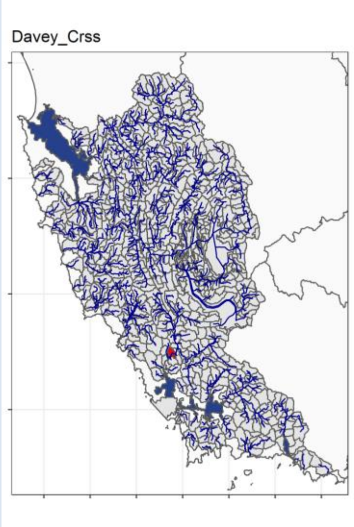
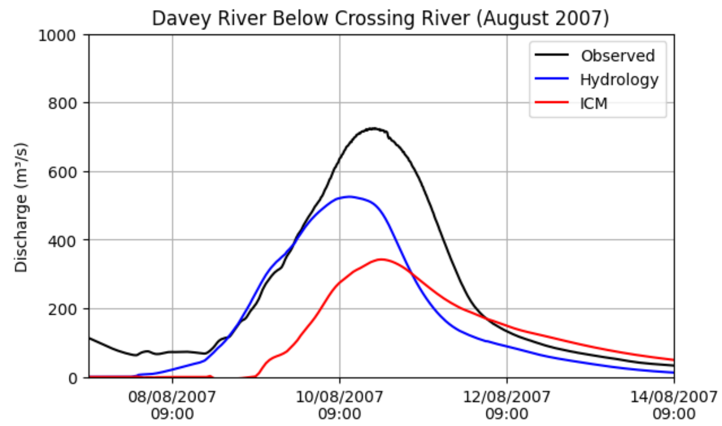
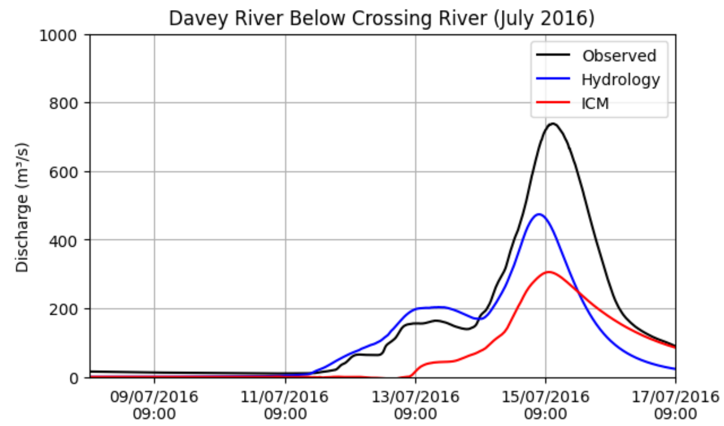
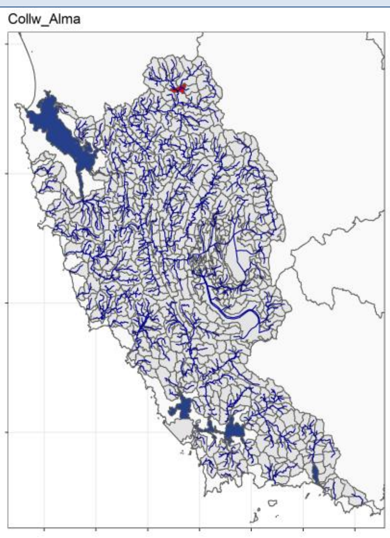
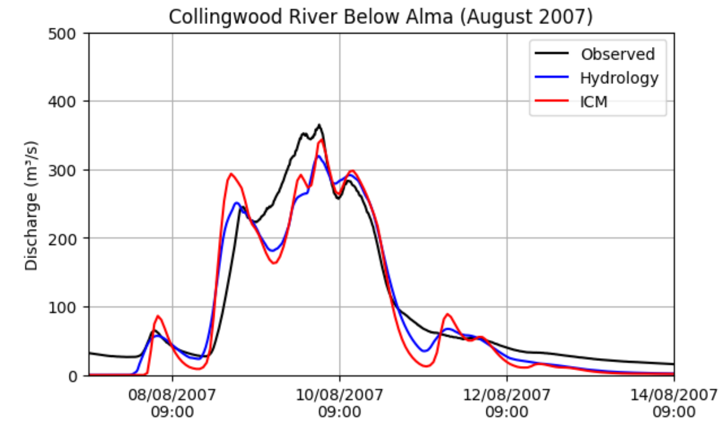
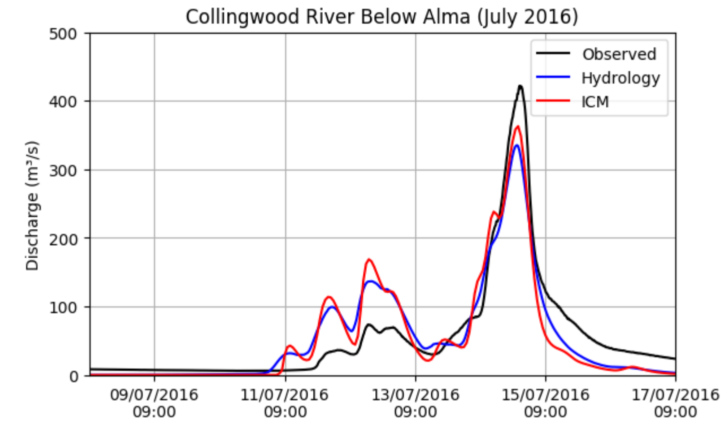
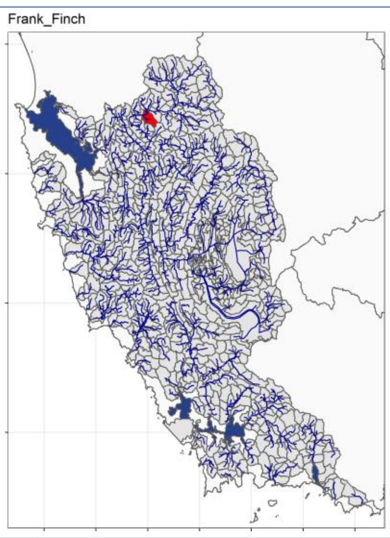
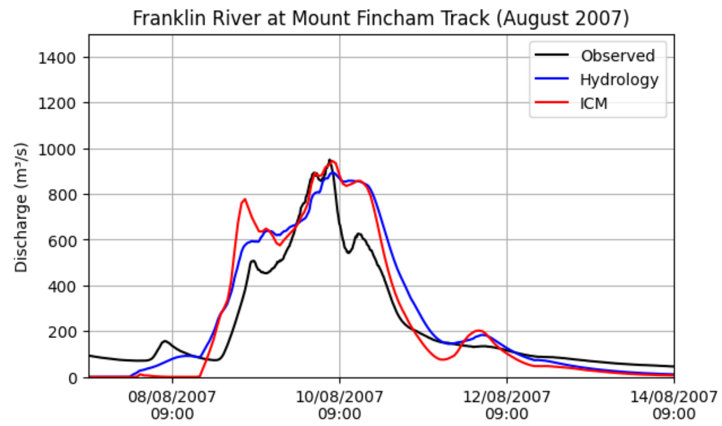
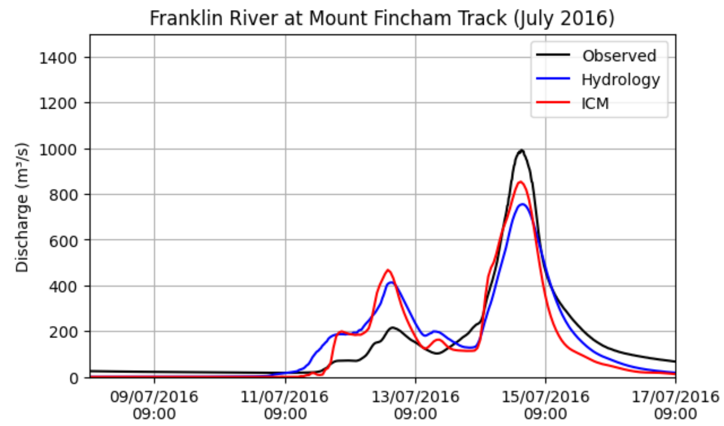
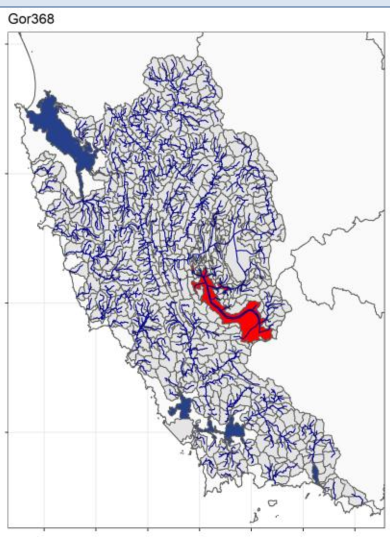
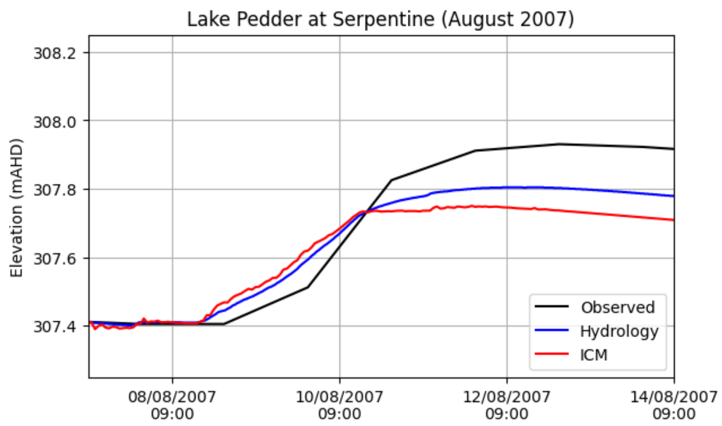
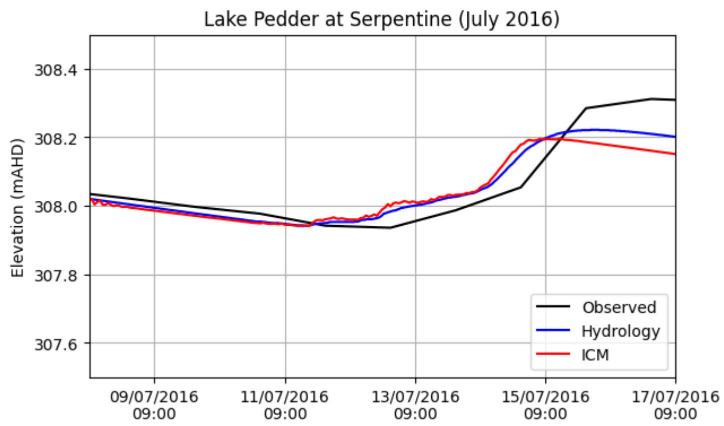
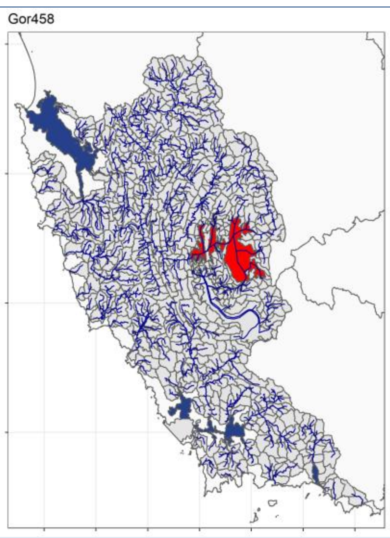
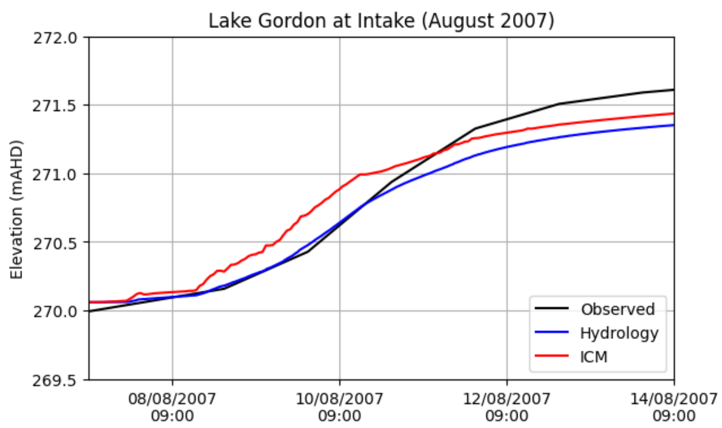
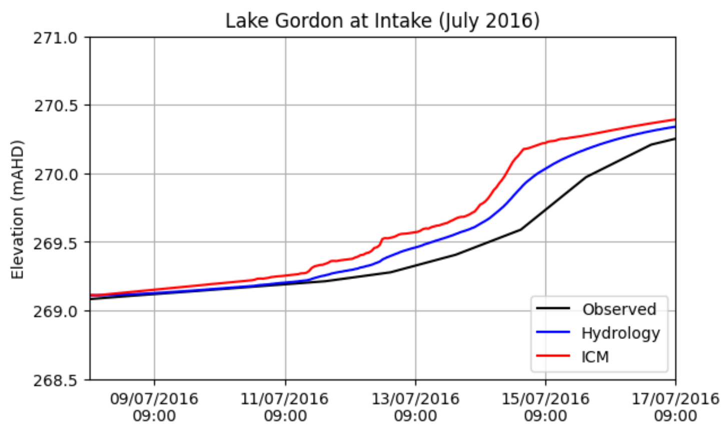
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
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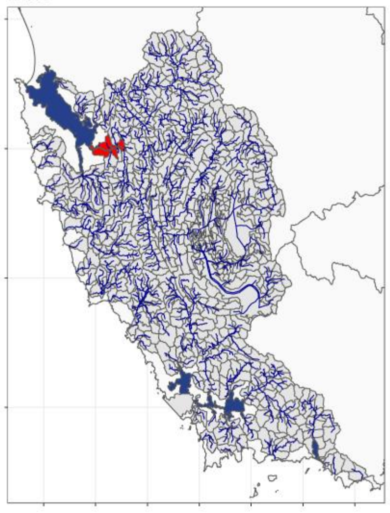

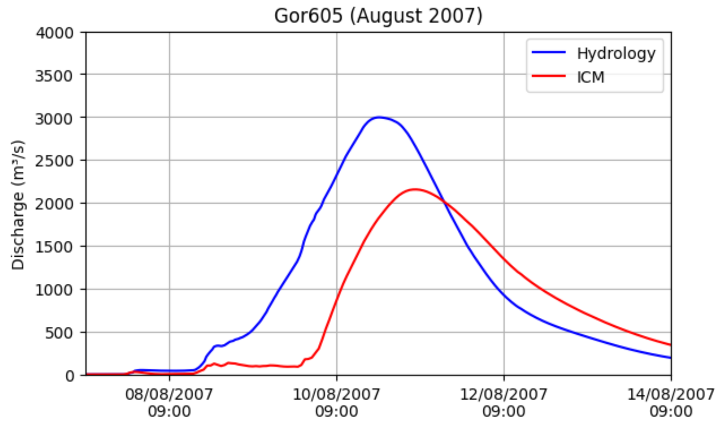

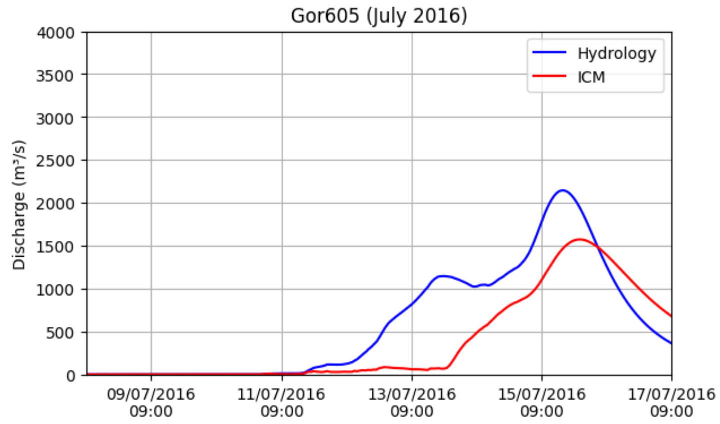

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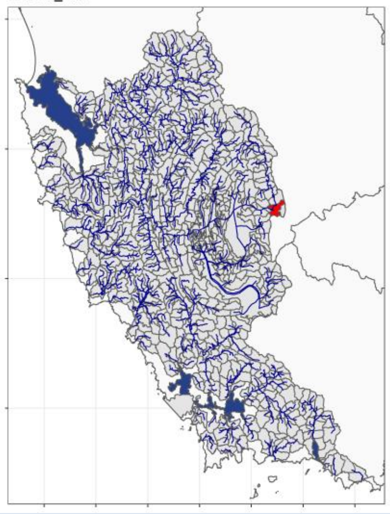

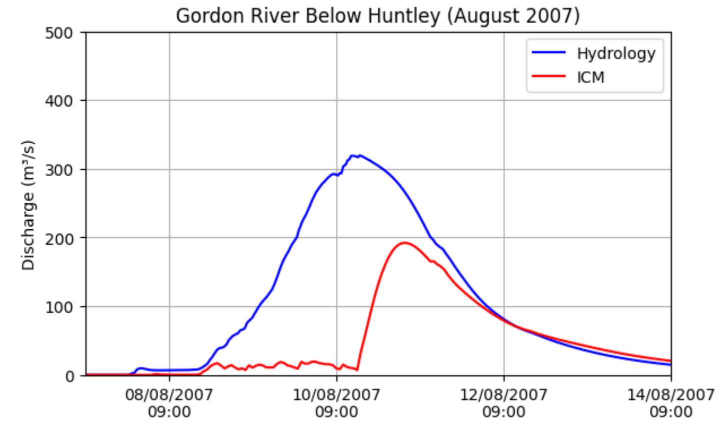

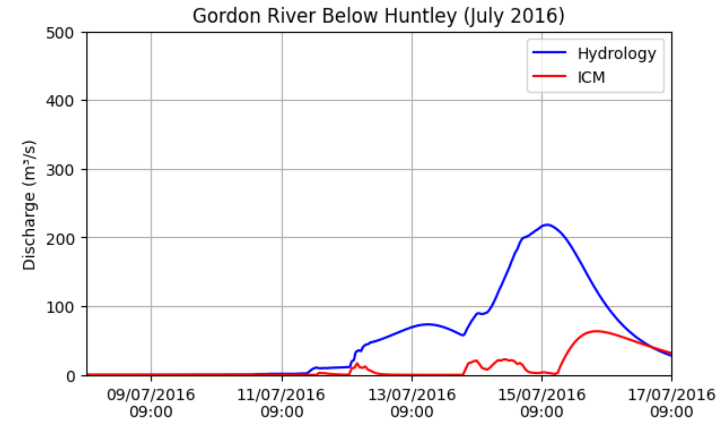

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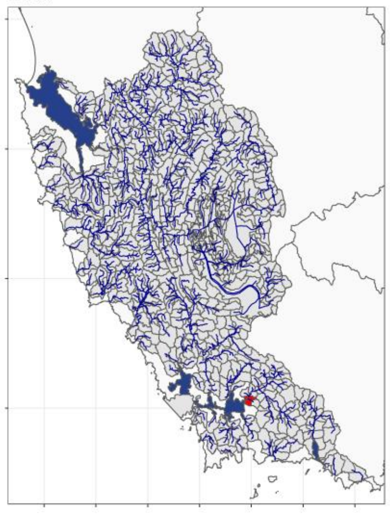

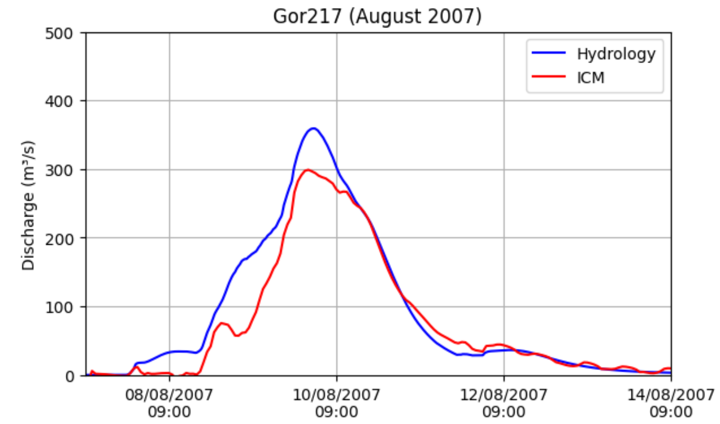

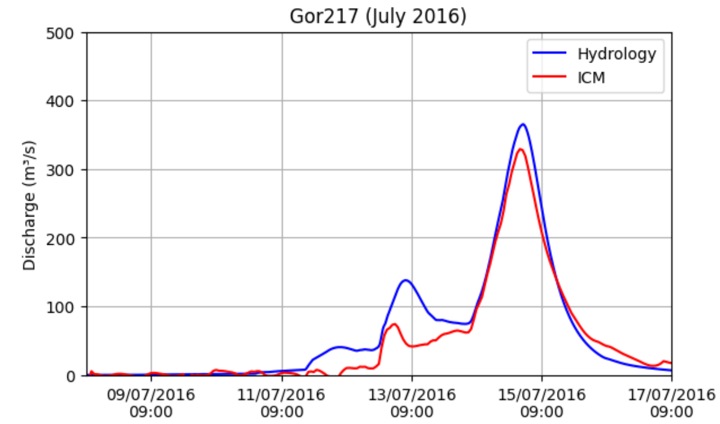

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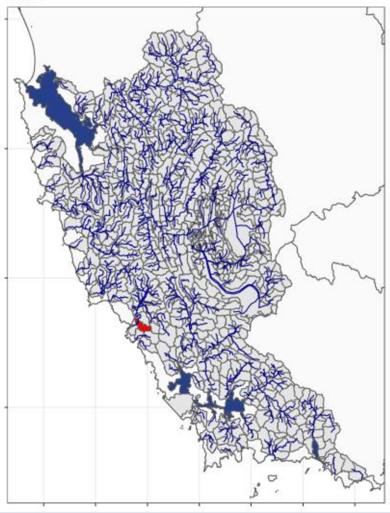

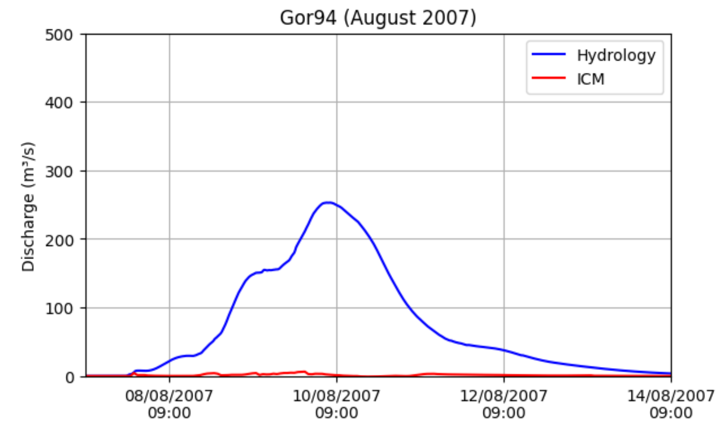

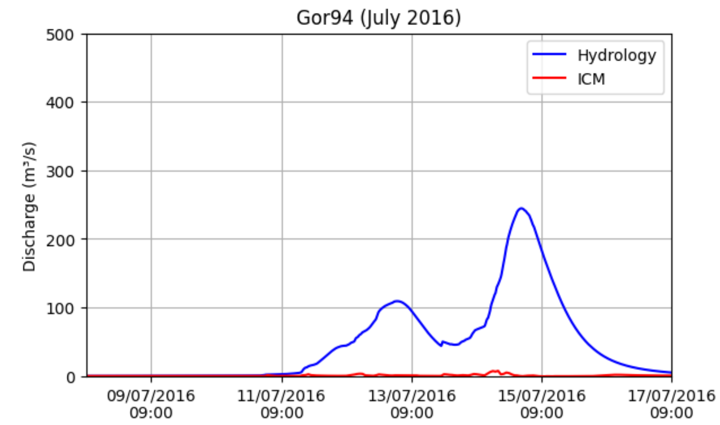

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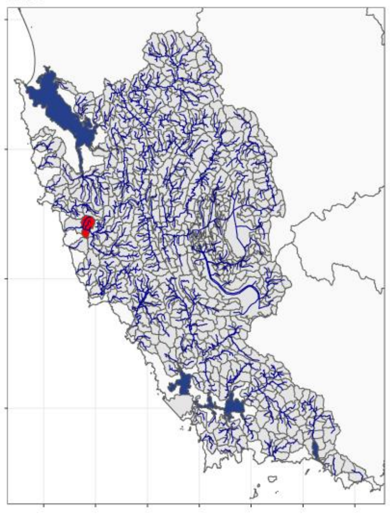

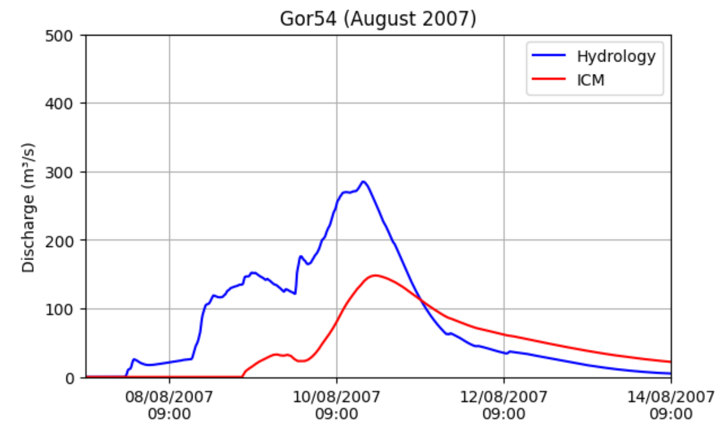

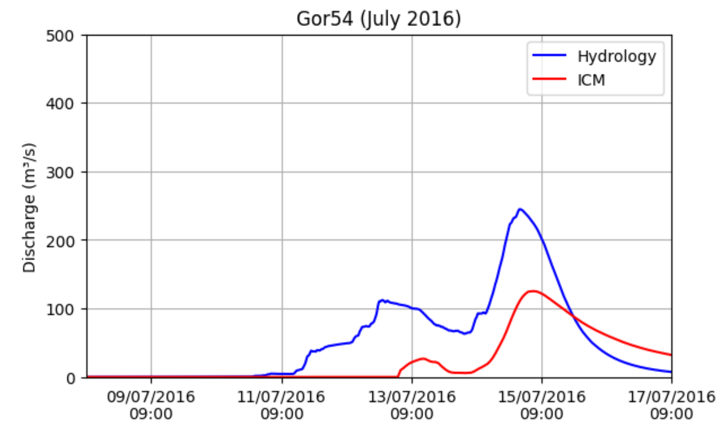

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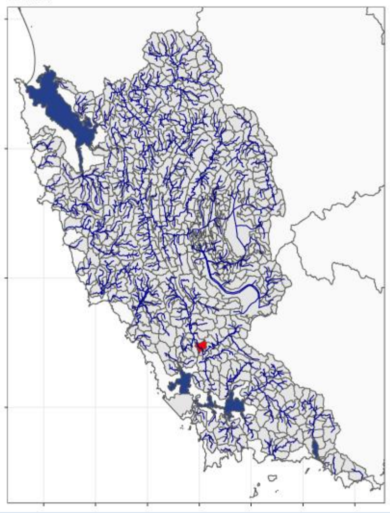

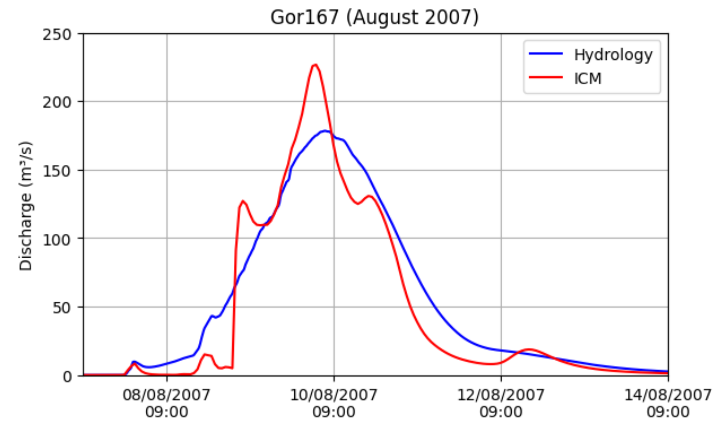

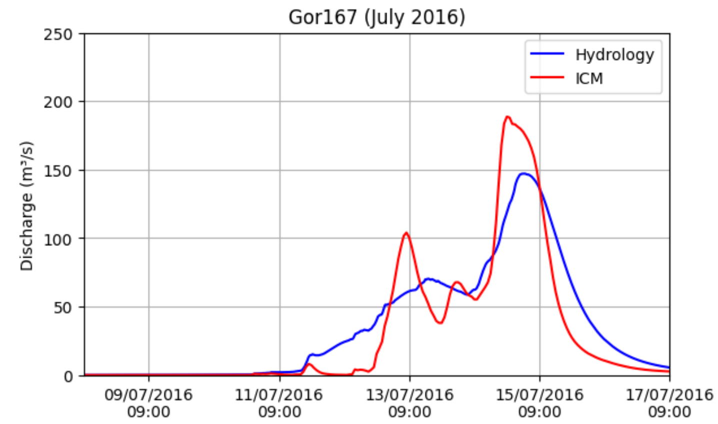

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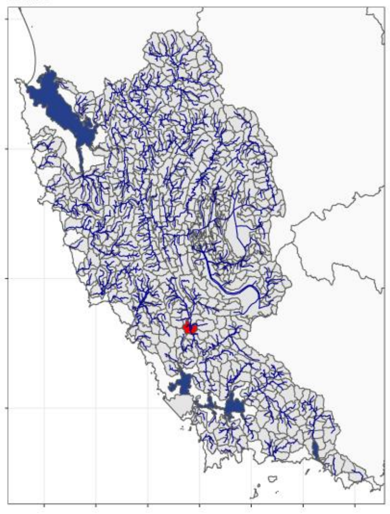

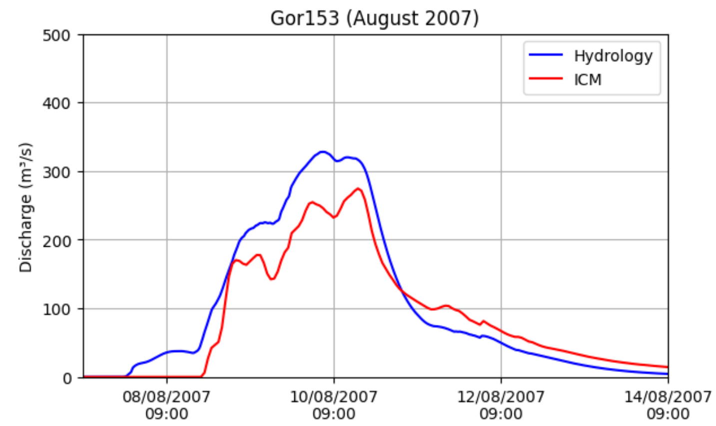

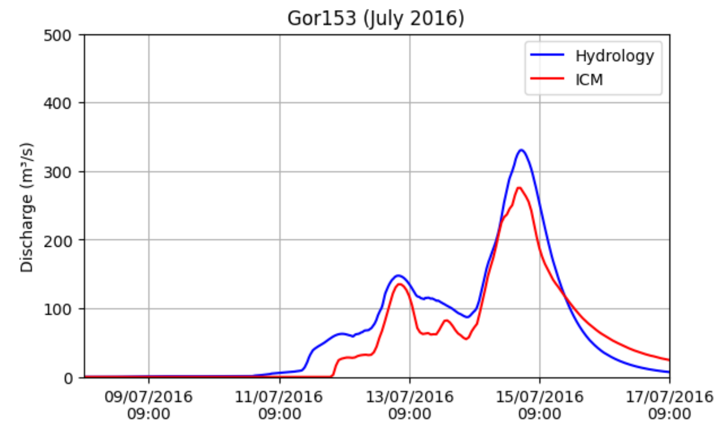

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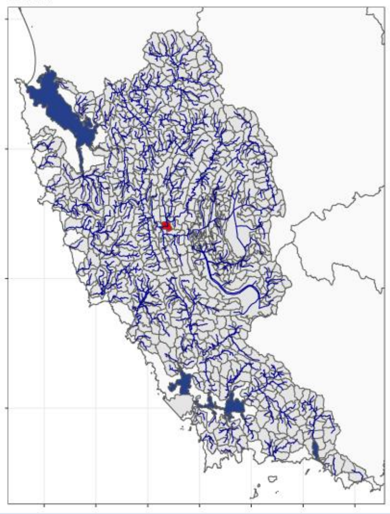

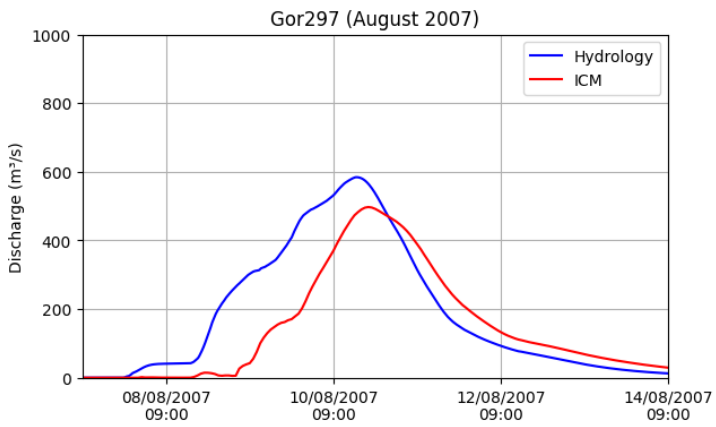

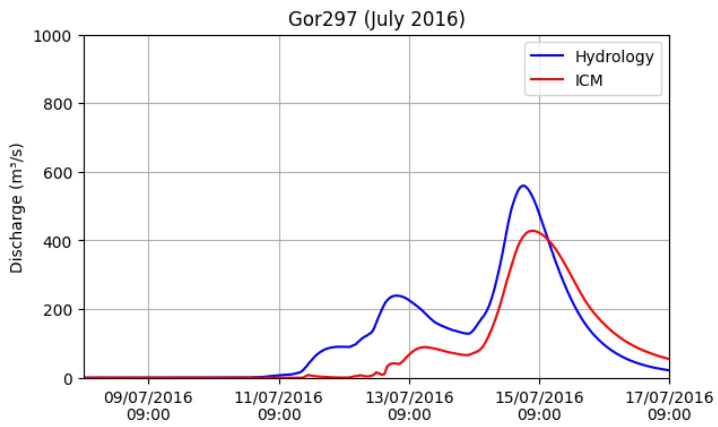

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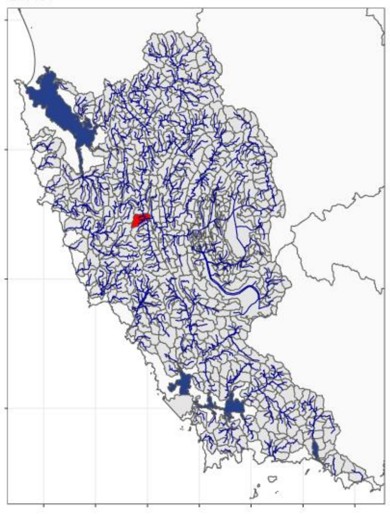

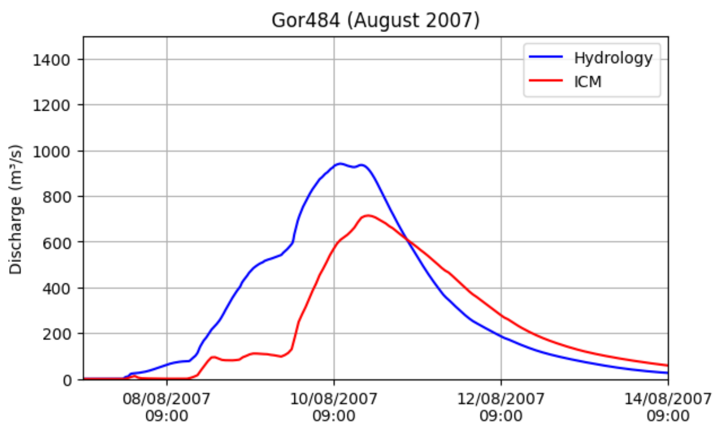

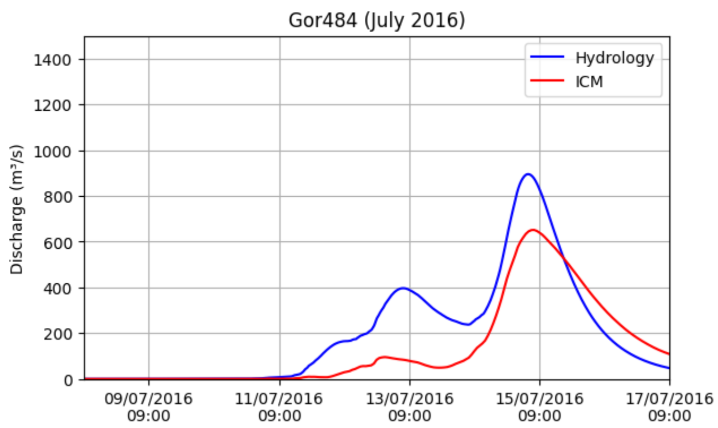

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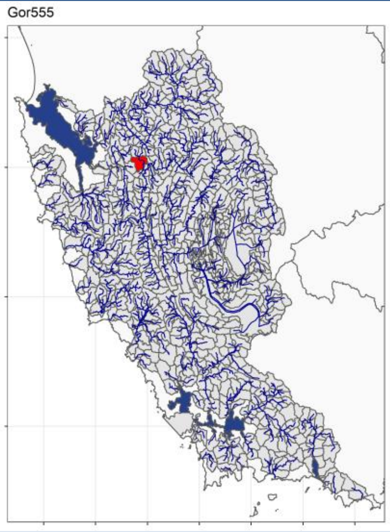

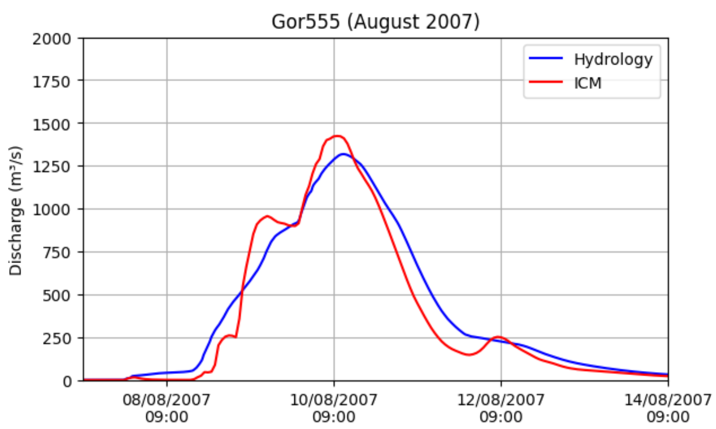

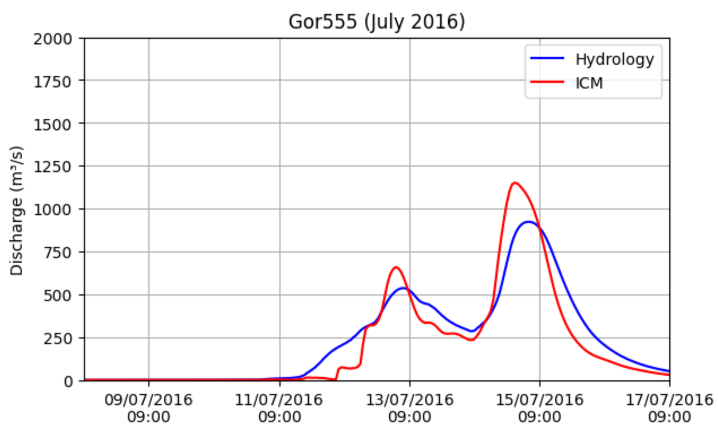

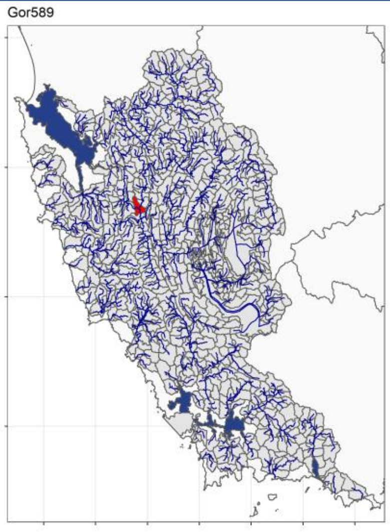
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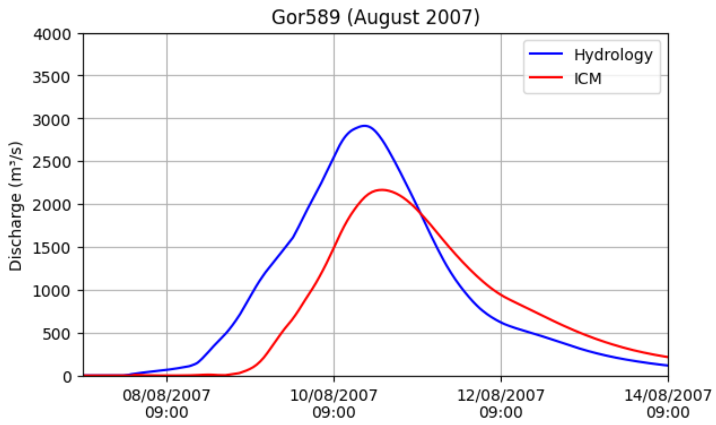
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Discharge (m³/s)
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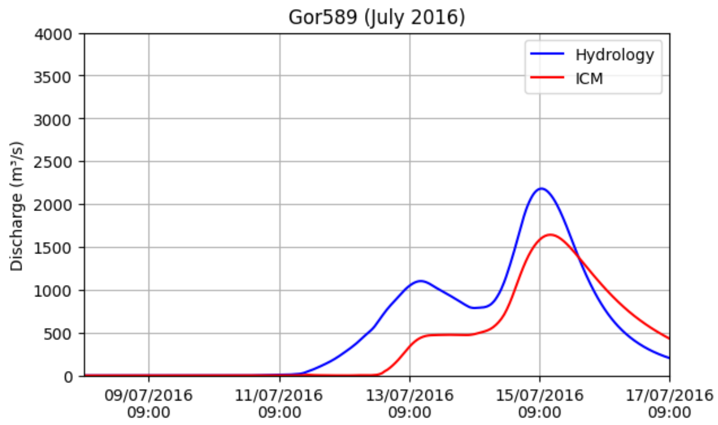
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Appendix D

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

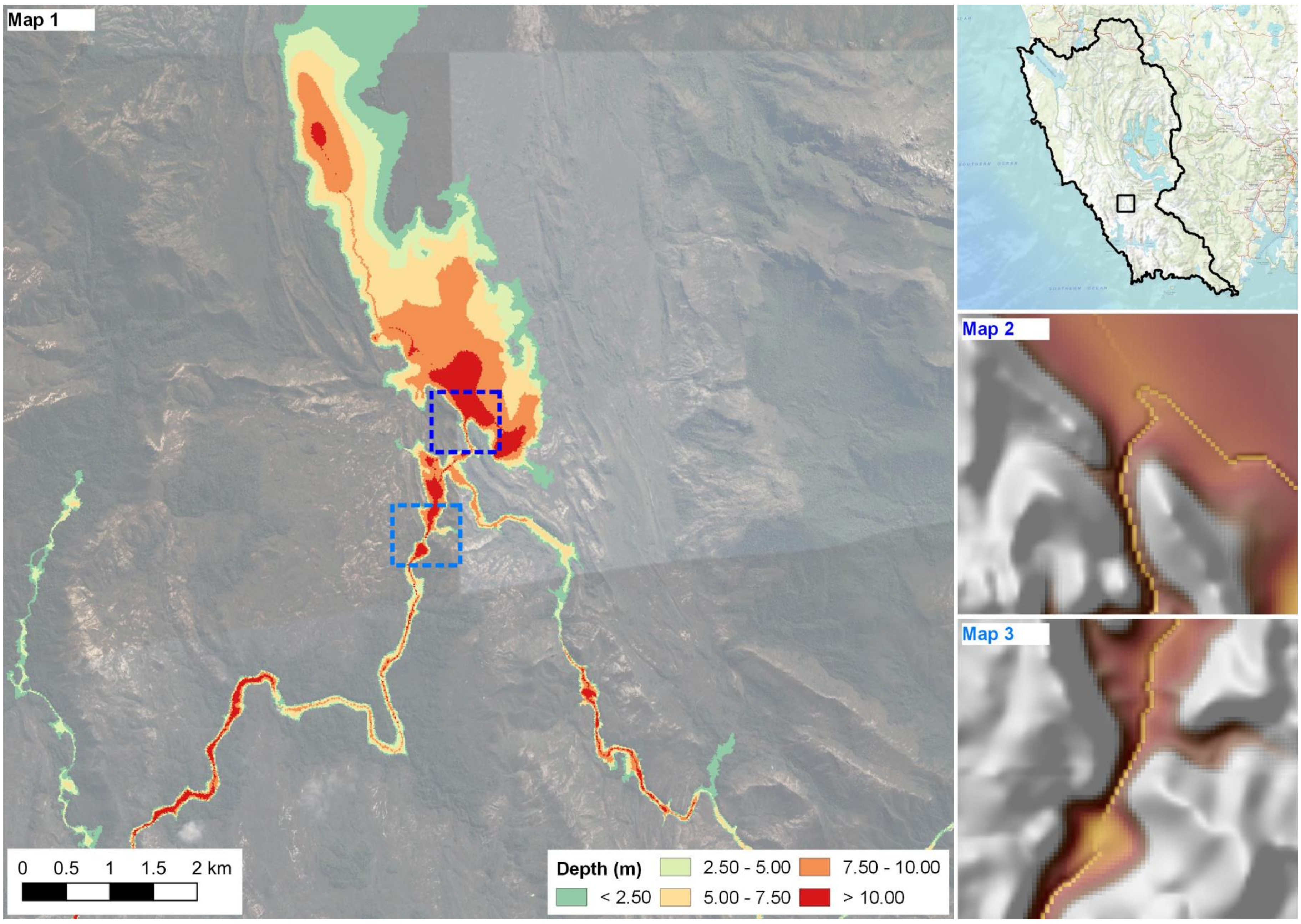

Figure D 1: Significant ponding along Davey River

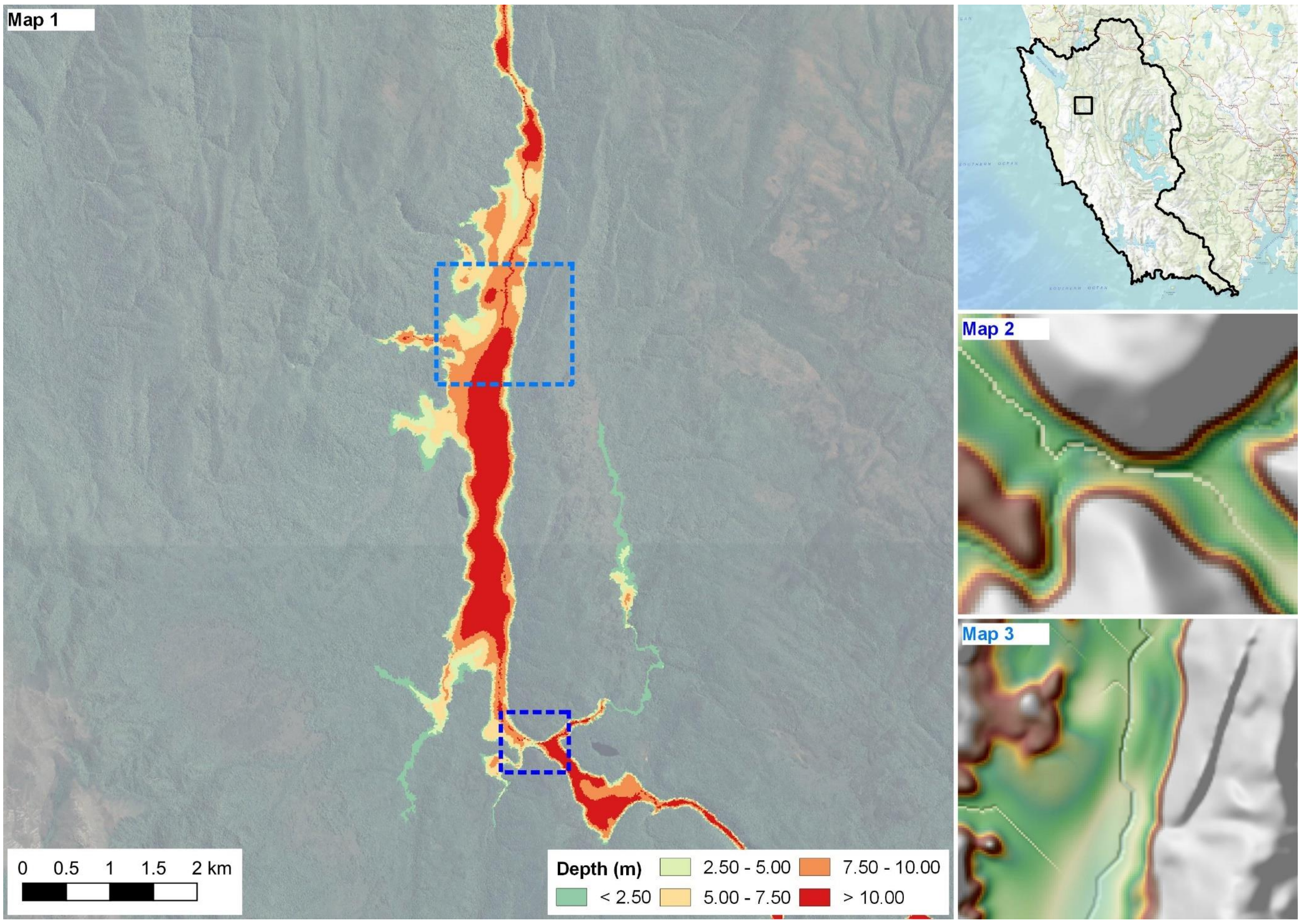

Figure D 2: Significant ponding along Gordon River

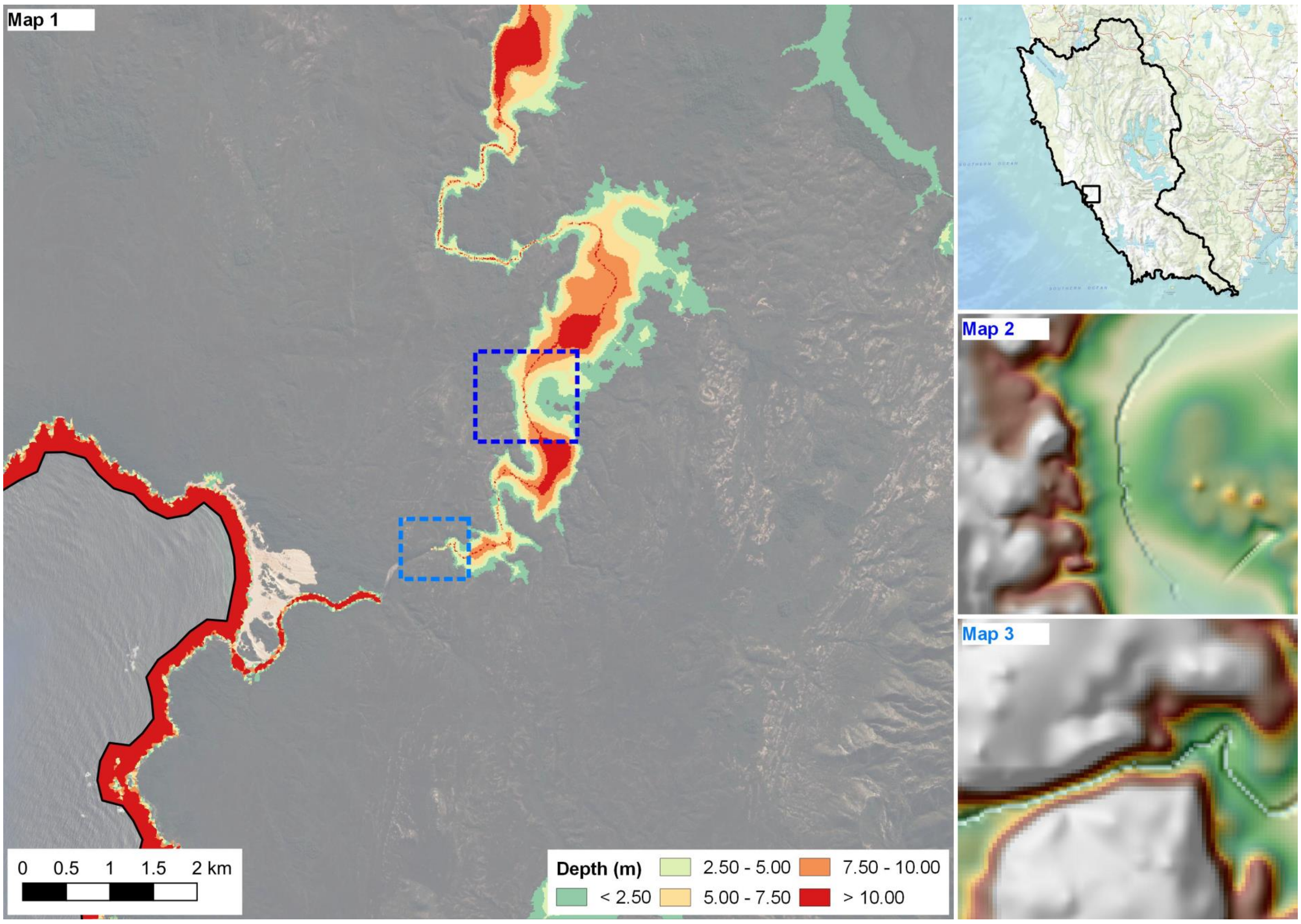

Figure D 3: Significant ponding along Giblin River

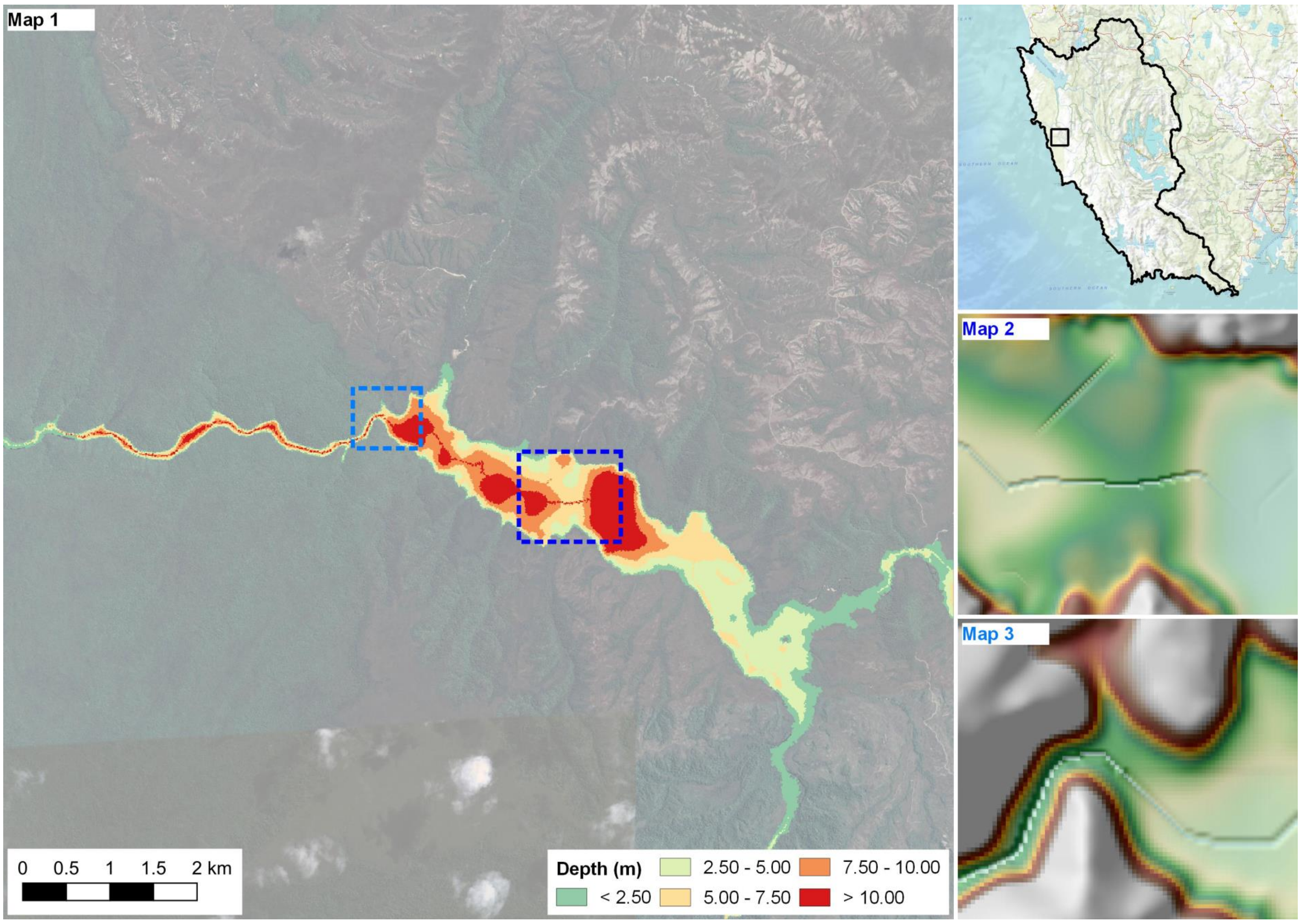

Figure D 4: Significant ponding along Wanderer River