STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
SWAN - APSLEY CATCHMENT
MODEL CALIBRATION

REPORT

MARCH 2023

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Project Tasmanian Strategic Flood Map Swan - Apsley Catchment Model Calibration	**Project Number** **120038**
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Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Draft report for review	Luke Roberts, SES	Sarah Blundy, Audrey Lau	Daniel Wood	Mark Babister	DEC 21
1	Review comments addressed	Luke Roberts, SES	Sarah Blundy, Audrey Lau	Daniel Wood	Mark Babister	FEB 22
2	Report with minor revisions	Chris Irvine, SES	Sarah Blundy, Audrey Lau	Daniel Wood	Mark Babister	MAR 23

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
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
RAF	RAFTS Adjustment Factor
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 Swan - Apsley study area.

2. STUDY AREA

The Swan - Apsley study area is situated in the East of Tasmania. The study area includes the Swan, Apsley, Meredith and Stoney rivers. The study area also includes several smaller watercourses that discharge directly into the Tasman Sea. The Swan River is the largest river in the study area. The Swan River has two major tributaries; the North Swan River rises from Mt St John, whilst the West Swan River rises at Snow Hill. The Swan River flows in a southerly direction, before discharging into Great Oyster Bay. The study area includes large areas of native forest and some forestry plantations in the upper catchment, and cleared areas used for sheep grazing and cropping in the lower catchment. The major towns in the study area include Swansea, Bicheno and Coles Bay.

The Swan Valley Irrigation Scheme operates within the study area. The scheme is operated by Tasmanian Irrigation and sources water via pumping from the Swan River for storage in an off-stream reservoir, Melrose Dam. Water is then released and distributed to irrigators over summer (Tasmanian Irrigation, 2021).

The Swan - Apsley study area has an area of 1430 km^2. The Swan - Apsley study area and the available gauge information are shown in Figure 1. Land use in the study area is shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow and Level Data

There are five flow gauges with data available in the Swan - Apsley study area, that were operational over the period of calibration events (Table 1). These gauges are owned by DPIPWE, who supplied timeseries of flows for each site, and ratings and gaugings for some sites. All gauges other than Goatrock Creek gauge are still operational. There is an additional gauge, Swan River us Tasman Highway, operated by Tasmanian Irrigation, however this site was not operational for the calibration events.

Table 1: Flow gauges

Gauge attribute	SWAN RIVER U/S HARDINGS FALLS	APSLEY RIVER U/S COLES BAY RD	SWAN RIVER AT THE GRANGE	MEREDITH RIVER AT SWANSEA	GOATROCK CREEK D/S McNEILLS RD
Gauge number	2219-1	2204-1	2200-1	2208-1	2213-1
Gauge abbreviated name	Swan u/s Headings	Apsley u/s Coles Bay	Swan at The Grange	Meredith River	Goatrock Creek
Start date	30/06/1983	30/05/1968	26/05/1964	18/03/1970	17/06/1975
End date	current	current	current	current	23/09/1996
Latitude	-41.847	-41.938	-42.045	-42.121	-42.140
Longitude	148.100	148.236	148.076	148.039	147.919
High flow rating quality	Poor - Fair	Fair	Good	Fair	N/A
Used for calibration	Yes	Yes	Yes	Yes	No
Used for FFA	Yes	Yes	Yes	Yes	No
Assumed local datum 0m in AHD	N/A	2.3#	0.1#	13.18##	N/A
Highest gauged level (m local datum)	1.6	4.3	5.8	3.1	unknown
Highest recorded stage height (m local) datum	3.7	5.9	6.7	4.6	1.2
Highest recorded flow (m^3/s)	196	891	1162	366	3
Highest recorded flow date	24/03/2011	27/04/1974	30/05/1969	29/01/2016	01/06/1981

Based on DPIPWE gauge zero with adjustment

Based on DPIPWE gauge zero

3.1.1. Calibration Event Data Availability

Significant flows were recorded in the catchment area for 4 of the 13 flood events selected by the Bureau as calibration events for this project (Table 2). The March 2011 event was excluded from calibration as an initial calibration in the external hydrological model showed that the modelled volume was significantly underestimated when compared with event volumes at the gauges, even when all losses were set to zero. This is considered to be due to the very high rainfall gradient in this event where 170 mm was recorded on the coast, and 465 mm in the hills 7 km inland. Using the methodology to create rainfall surfaces based on gauged data (WMAwater, 2021a), there is not sufficient density of rain gauges to achieve a good representation of the rainfall over the catchment.

The June 2016 event was also excluded from calibration as the same issues occurred in matching volumes, and this event also had a high rainfall gradient. The June 2016 event was also not as large as the others identified.

The May 1969 event was the largest on record at the Swan River at Grange gauge. The January 2016 event was close to a 1% AEP event at Meredith River at Swansea gauge, and was between a 10% and 30 % AEP event at the other gauges.

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

Event name	Used in calibration	Event peak flow (m^3/s) (location)
1969_May	Yes	212 (Apsley u/s Coles Bay) 1162 (Swan at The Grange)
2011_Mar	No	408 (Apsley u/s Coles Bay) 202 (Meredith River) 196 (Swan u/s Headings) 518 (Swan at The Grange)
2016_Jan	Yes	294 (Apsley u/s Coles Bay) 366 (Meredith River) 128 (Swan u/s Headings) 496 (Swan at The Grange)
2016_Jun	No	360 (Apsley u/s Coles Bay) 133 (Meredith River) 134 (Swan u/s Headings) 378 (Swan at The Grange)

3.1.2. Rating Curve Quality

The Swan River at Grange site is well gauged with some higher flow gaugings. The DPIPWE rating is extrapolated at the highest recorded level. To improve the quality of the high flow rating, a theoretical rating was developed using a local hydraulic model (WMAwater, 2021c). This rating curve was used for the January 2016 event (Diagram 1). At this site, there are two distinct sets of gaugings, with a shift between the older and newer gauged data, and a different rating curve was used at the time of the 1969 event (Diagram 2). Therefore the DPIPWE supplied flows were used for the 1969 event.

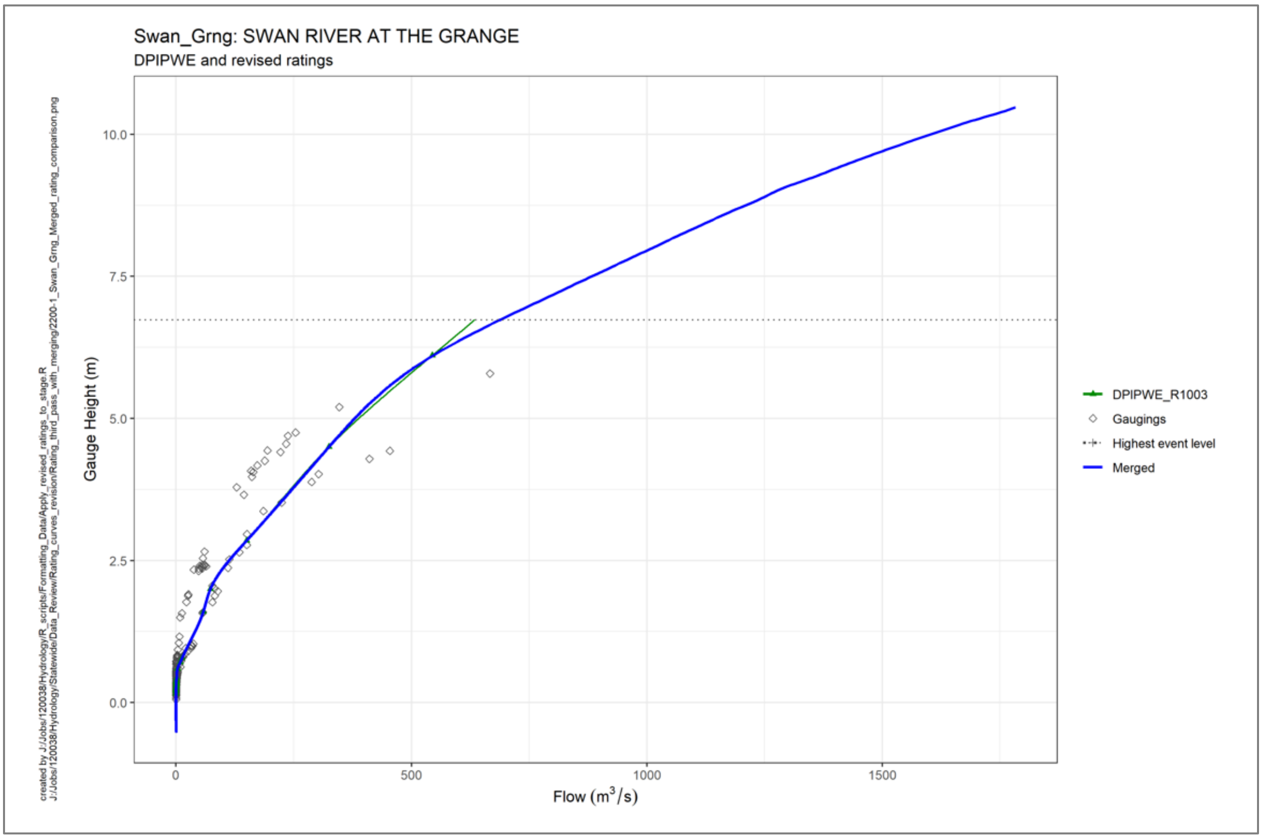

Diagram 1: Swan River at the Grange - revised rating

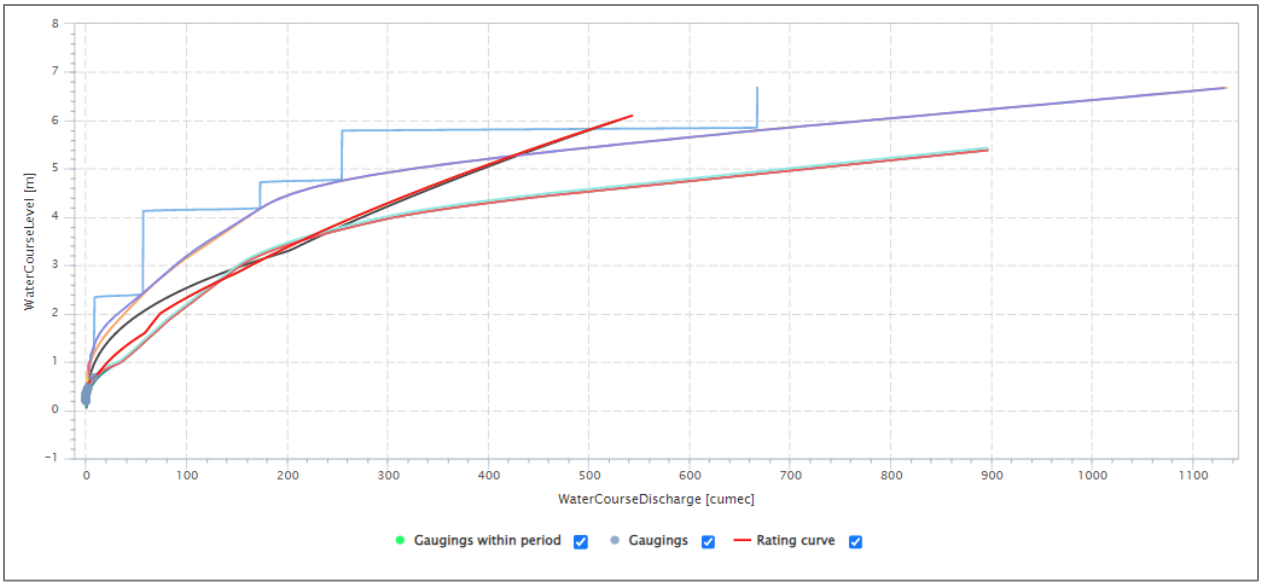

Diagram 2: Swan River at the Grange ratings. Rating applicable in 1969 shown in purple, latest rating shown in red (screenshot from Water Data Online, Bureau of Meteorology, 2021).

The same process was undertaken for the Apsley River upstream Coles Bay rating. The revised rating was used for the 2016 event (Diagram 3), and the DPIPWE derived flows were used for the 1969 event as the ratings were extrapolated very differently to high flows (Diagram 4).

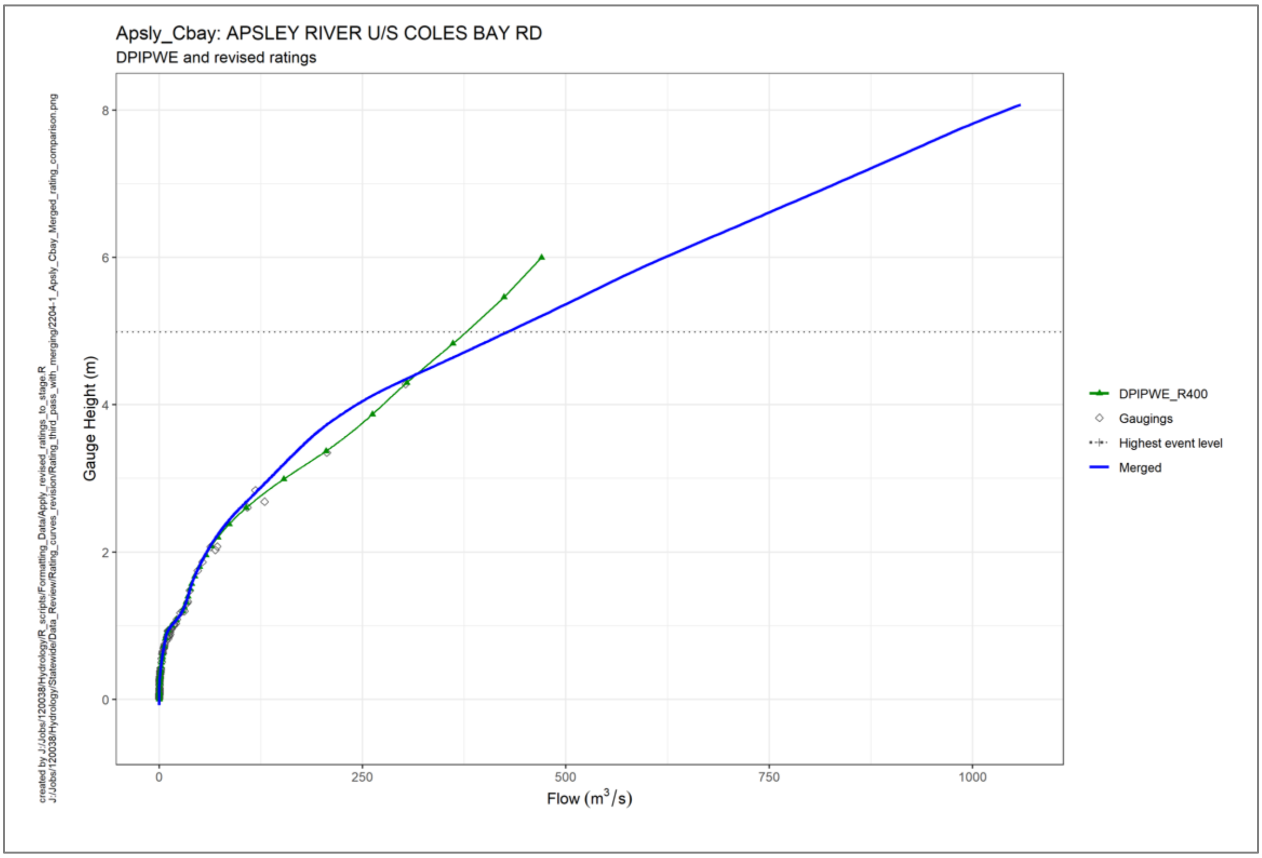

Diagram 3: Apsley River upstream Coles Bay Road - revised rating

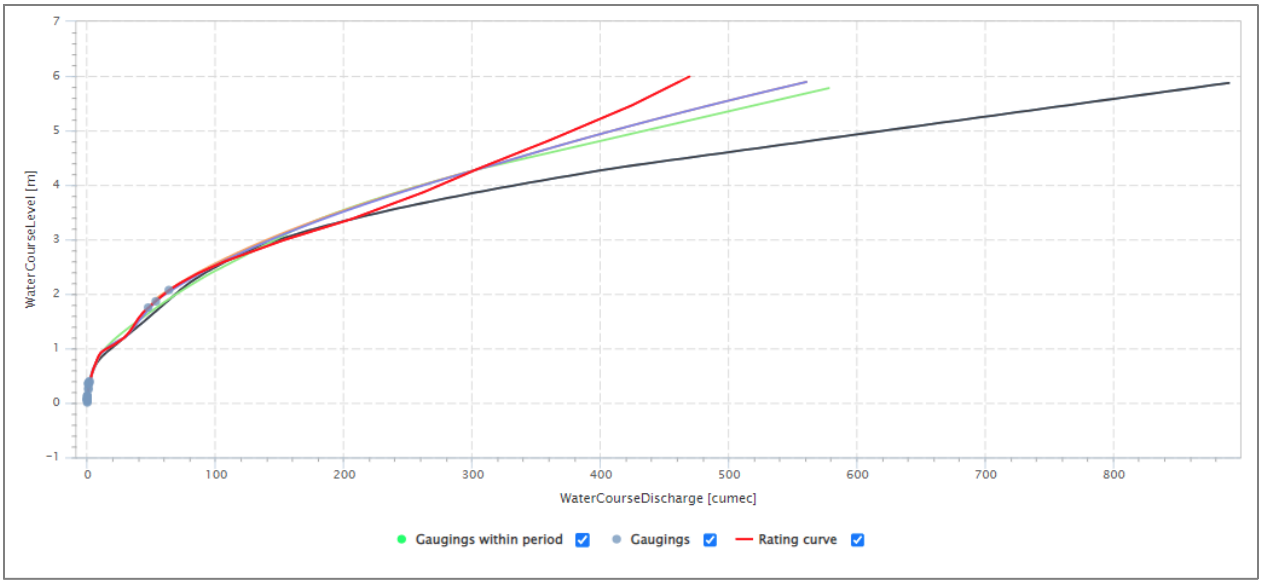

Diagram 4: Apsley River upstream Coles Bay ratings. Rating applicable in 1969 shown in purple, latest rating shown in red (screenshot from Water Data Online, Bureau of Meteorology, 2021).

The gaugings at the Meredith River at Swansea, and the Swan River u/s Hardings Falls sites are all within the channel and are considerably lower than the highest recorded stage height (Table 1). Due to the poor high flow rating at Swan River u/s Hardings Falls, and the fact that it gauges only a small portion of the catchment compared to the Swan River at Grange site, Swan River u/s Hardings Falls was not used in final calibration.

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 Swan-Apsley catchment (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.

There is three sub-daily rain gauges within the study area with available data for the January 2016 calibration event, at Mt St John, Friendly Beaches and Meredith River at Swansea and none for the May 1969 event, however sub-daily gauge data was available in the surrounding area. There were eight or nine daily gauges with available data within the study area for both the calibration events. The gauges in and around the Swan- Apsley study area are shown in Figure 1.

As discussed in Section 3.1.1 the rain gauge coverage for March 2011 and June 2016 was not sufficient to give a reasonable rainfall surface for calibration. While there were 9 or 10 rain gauges available for these events there was a very high rainfall gradient and rainfall recorded further north in the Scamander-Douglas study area suggests there was very strong orographic forcing of the rainfall distribution. All the available rain gauges for March 2011 and all bar one (at Mt St John) for June 2016 were either on the coast or inland valleys so rainfall surfaces derived from these gauges likely significantly underestimate rainfall in the ranges that cover a large proportion of the study area.

Table 3 – Available Rainfall Information

	May 1969	Mar 2011	Jan 2016	Jun 2016
Number of Sub-daily Stations Available within the study area	0	1	3	3
Number of daily Stations Available within the study area*	9	8	8	7
Number of sub-daily surrounding gauges ~15km	1	1	3	3
Number of daily surrounding gauges ~15km	3	3	6	5
Rainfall Totals	110-280 mm	80-210 mm	150-260 mm	120-260 mm
Approx duration of rainfall event (hours)	48 hours	23 hours	50 hours	72 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 2021 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

There are two significant on stream dams identified in the Hydrodynamic Methods Report (WMAwater 2021b) for modelling in the Swan - Apsley study area, operated by TasWater. Swansea Dam near the Meredith River was also identified however this is an off-stream storage so should not have significant impact on floods. There are other farm dams in the study area. These have not been modelled explicitly, and are included in the 2D modelling where they are captured in the DEM. Details are shown in Table 4 (from DPIPWE, 2009).

Table 4: Dam information

Name	Storage Volume (ML)	Crest Length (m)	Spillway Width (m)
Coles Bay Dam	170	195	20
Northern Tin Mine Dam	150	unknown	20

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 four of the gauges in the catchment, with the SES state-wide 10 m DEM used in the remaining 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 5), was then imported into ICM via the grid import interface.

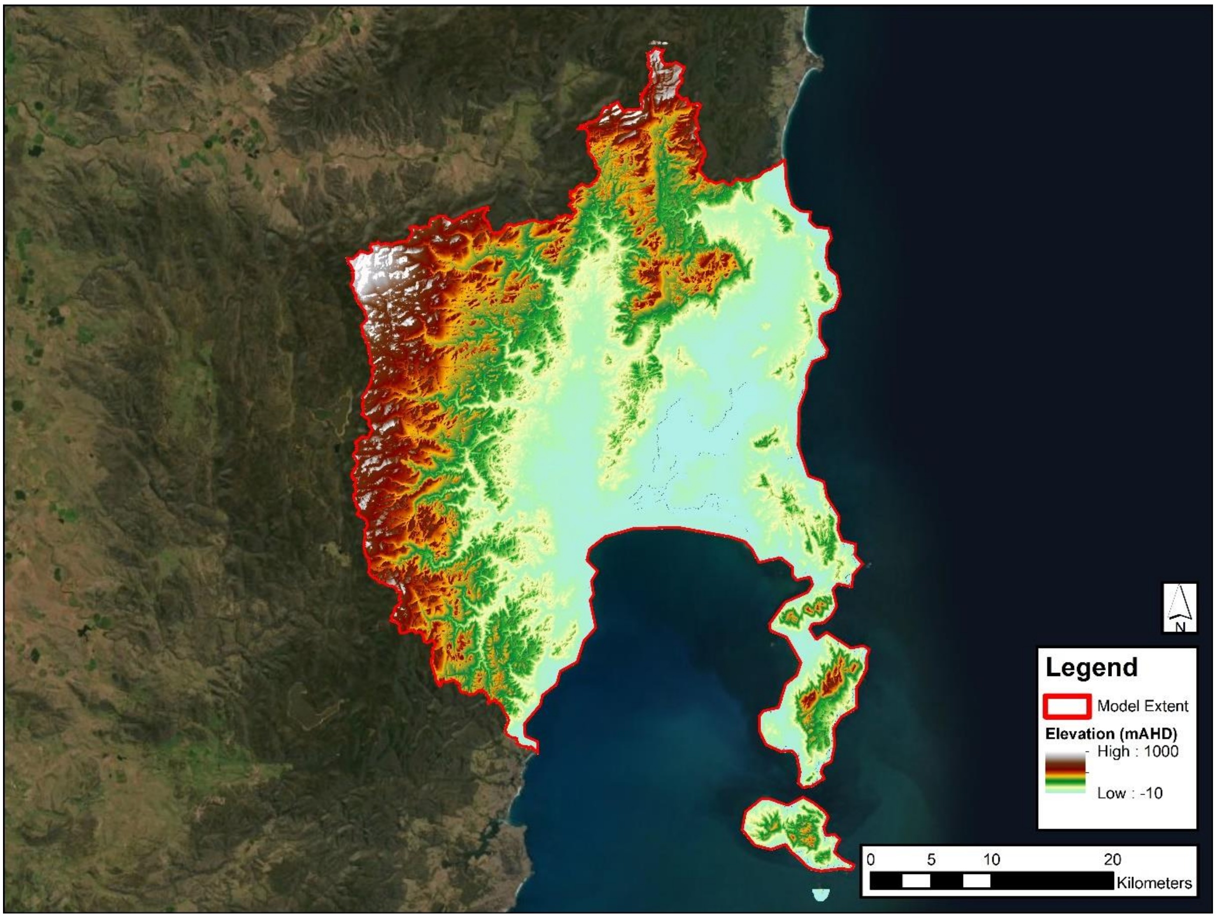

Diagram 5: DEM of the Swan-Apsley catchment

It is noted that the DEM at the Northern Tin Mine Dam and Coles Bay Dam is limited to the ‘Default DTM’ of the state-wide 10 m DEM, which is understood to be comprised primarily of photogrammetric contour data. The ‘Default DTM’ is likely to be a poor representation of the topography of the area.

In Moulting Bay Lagoon area, the elevation in the DEM has been set to -10 m. If bathymetry becomes available for this area, it would be worthwhile revising the DEM as this is not consistent with on-ground conditions.

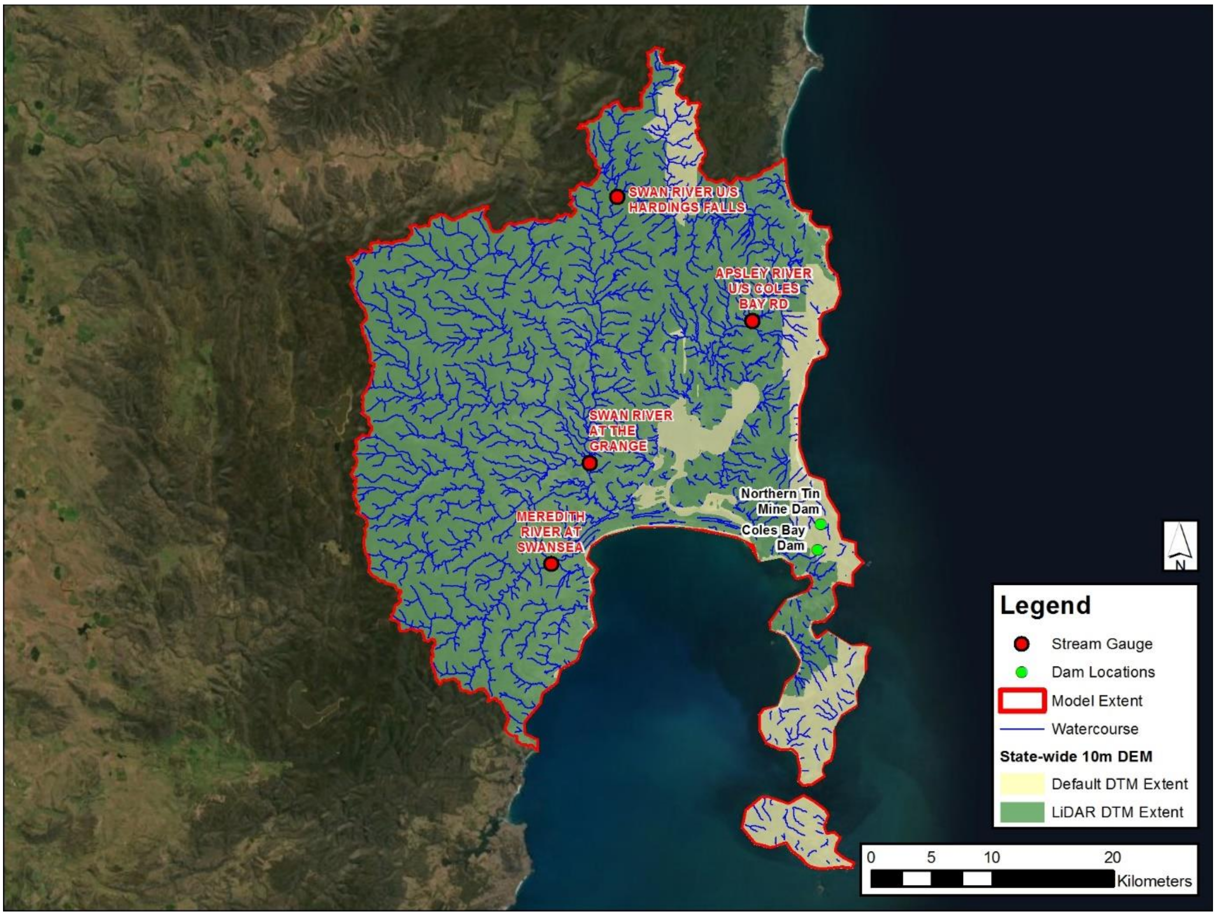

Diagram 6: 'Default DTM' extents for the Swan-Apsley catchment

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 20 m buffered zone of single roughness of 0.05 for all upper streams was utilised.

This change will be revised on a case-by-case basis in future assessments as it is managing a very specific issue. The values derived are shown in the 'Hydrodynamic Modelling Report'. The roughness layer in ICM is shown in Diagram 7.

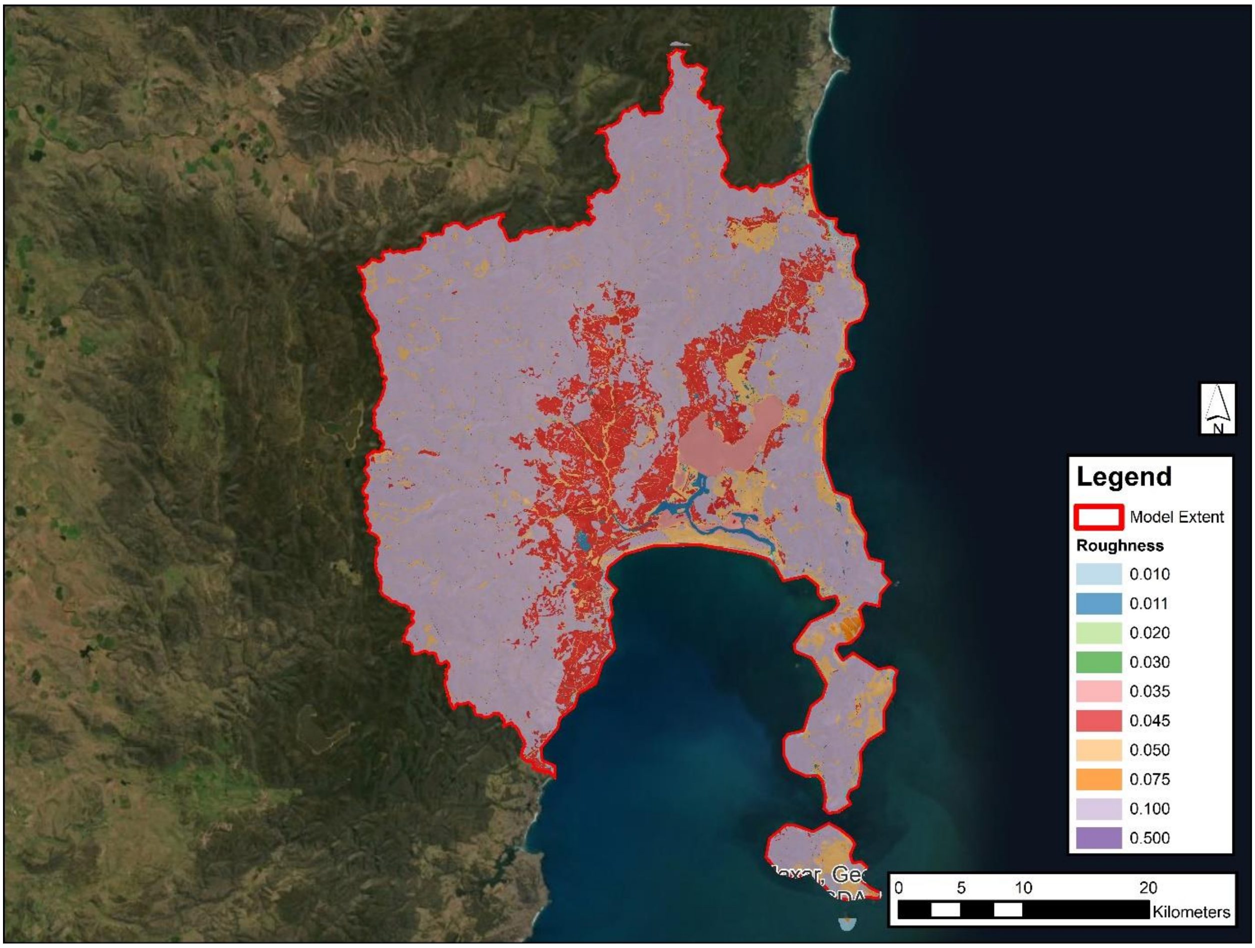

Diagram 7: Roughness layer for the Swan-Apsley catchment

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 40 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 Swan-Apsley catchment are shown in Diagram 8.

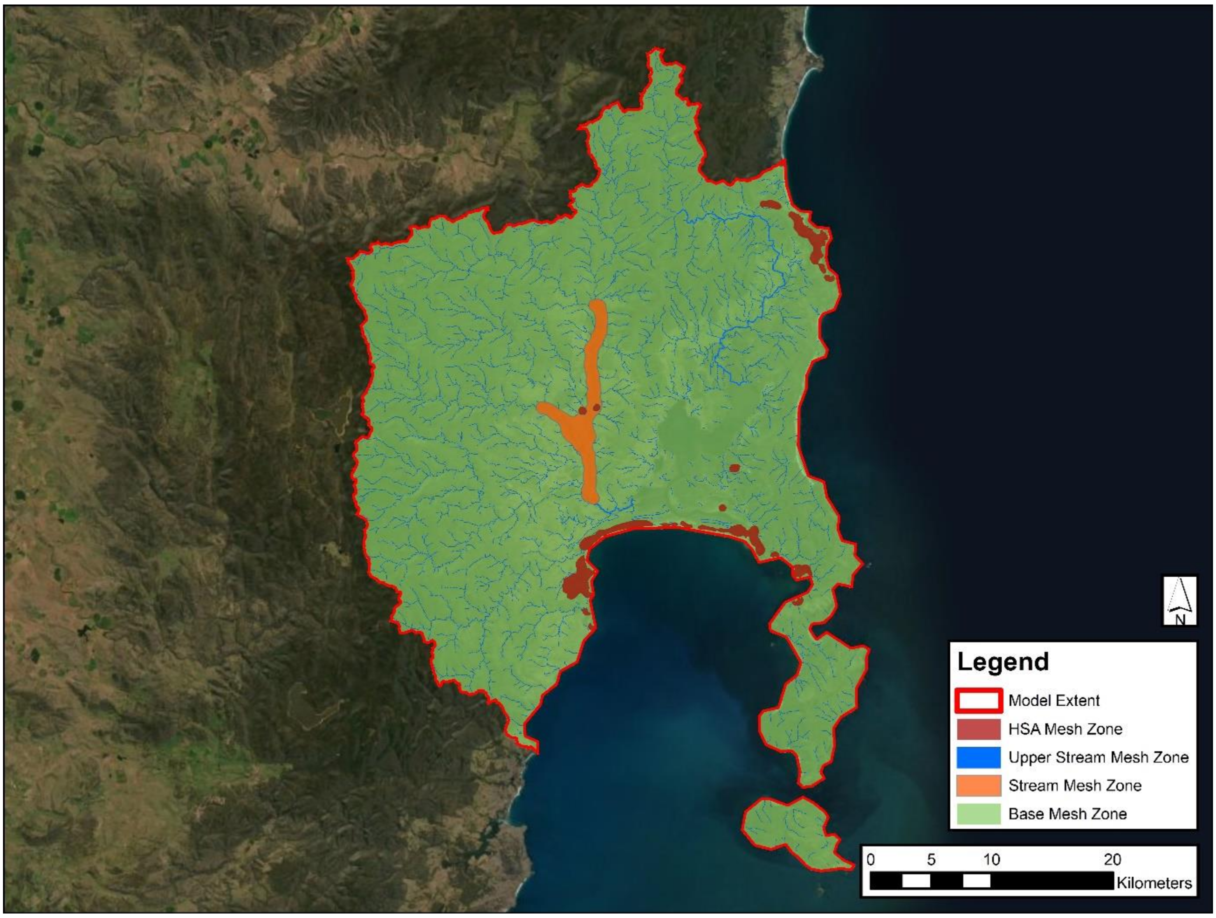

Diagram 8: Mesh zones for the Swan-Apsley catchment

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 Swan-Apsley catchment a total of 10 bridges longer than 30 m were identified and imported into the hydrodynamic model.

These include:

- Tasman Highway at Stony River
- Tasman Highway at Meredith River
- Tasman Highway at Wye River
- Tasman Highway at Cygnet River
- Tasman Highway at Swan River
- Tasman Highway at Apsley River

Further discussion on this process is provided in the Hydrodynamic Modelling Methods Report.

No major culverts were identified.

5.5. Downstream Boundaries

Downstream boundaries were 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) and was used to set a varying tide level for the calibration events. This data was extracted off the coast of The Nuggets at 10 min time increments and was imported into ICM as a time varying boundary condition. Diagram 9 shows an example of the synthetic tide data that was extracted off the coast of The Nuggets for the June 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.

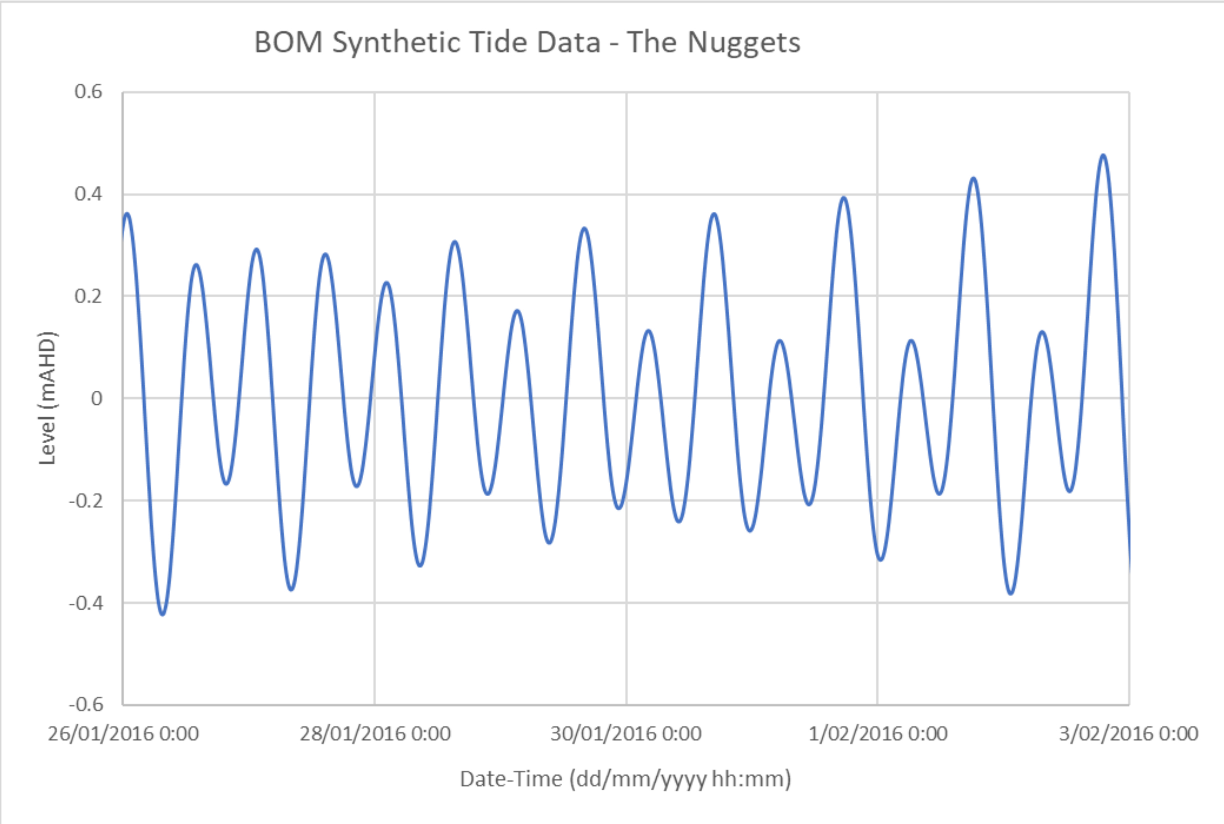

Diagram 9: Synthetic tide data off the coast of The Nuggets (Jan, 2016)

5.6. 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.

5.6.1. 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 Swan-Apsley catchment is shown in Diagram 10. 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.

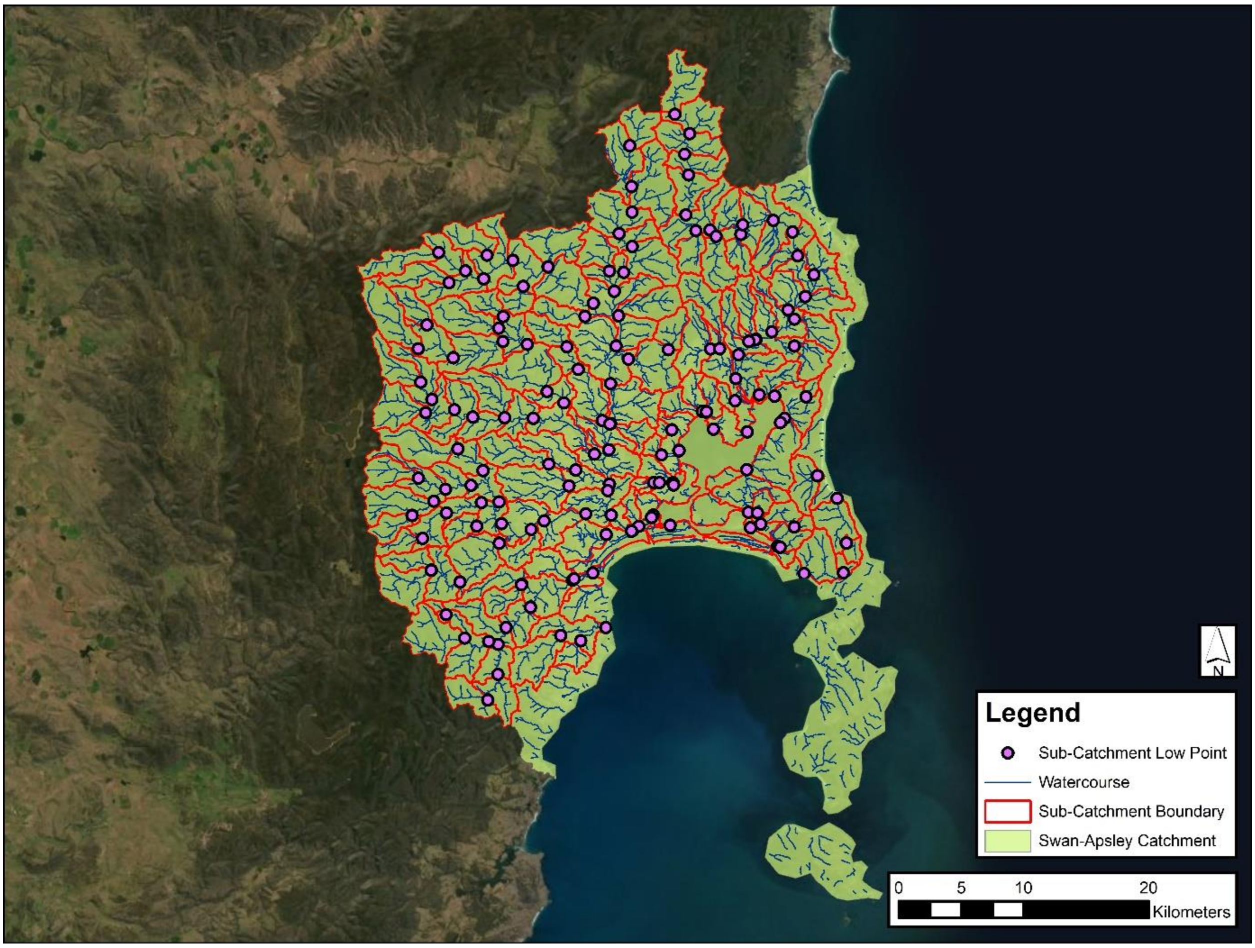

Diagram 10: RAFTS sub-catchment model setup in ICM for the Swan-Apsley catchment

6. CALIBRATION RESULTS

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. The calibrated loss parameters were consistent at all gauges for each event and are summarised in this section. Initial calibration of the model indicated that two RAF values were required in the model to give a good comparison to the observed data. The sub-catchment routing parameters adopted for the Swan-Apsley study area are shown in Diagram 11.

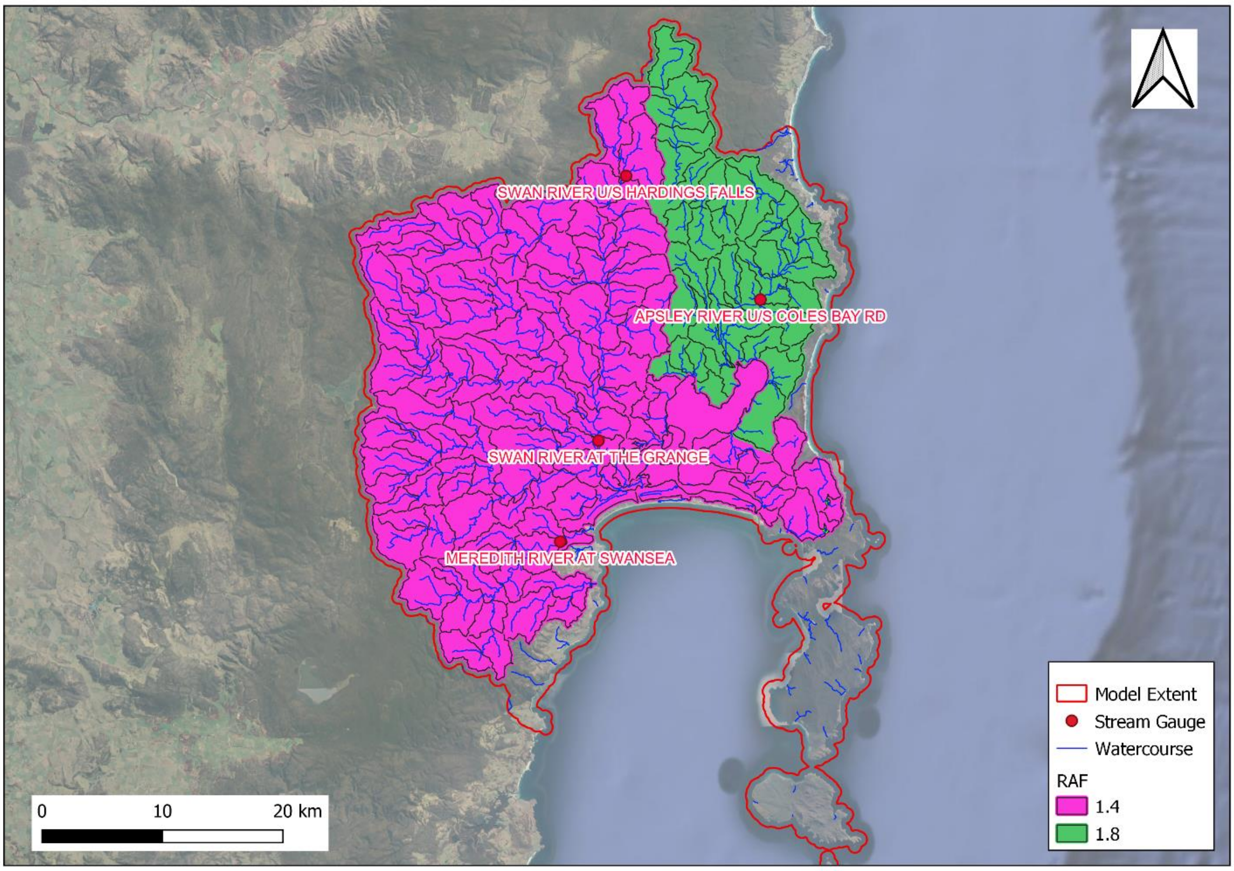

Diagram 11: RAF Factors utilised within Calibration Modelling

The ICM model was run with the routing and loss parameters derived from the external hydrologic model and the calibration process was undertaken for each calibration event. Prefilling of the model was not undertaken as this was not deemed to be required based on the results of the calibration events.

Within the catchment there are three (3) gauges where historic event information is present and appropriate calibration data exists. Each gauge has varying quality however and, as such, different outcomes were achieved depending on the limitations present at each gauge. The following sections outline the results and limitations of calibration at each gauge.

Mapping of the peak flood depths from the calibrated ICM model for each calibration event can be found in Figure 5 and Figure 6.

6.1. Gauge Results

6.1.1. Apsley River U/S Coles Bay Road

The modelled peak flows for the May 1969 and January 2016 events at the Apsley River U/S Coles Bay Road gauge show a good match to the recorded peak flows (Table 5). The modelled hydrographs also show a good match in terms of timing and shape to the recorded hydrograph at the peak of the events, as shown in Diagram 12 and Diagram 13.

Diagram 14 and Diagram 15 show the water level responses for the calibration events at the gauge. A gauge zero was available from the DPIPWE database however it was one metre above the ground levels in the area. The gauge zero level was lowered by 1 m to provide a better estimation of the actual level at this location.
The results indicate a generally good match to the recorded flows and levels at the gauge, with a slight underestimation of flow and level for the January 2016 event.

Table 5: Calibrated parameters and discharge at Apsley River U/S Coles Bay Road

Statistic	1969 May	2016 Jan
IL	20	84
Average CL	0.04	0.35
Modelled Peak (m^3/s)	201	265
Observed Peak (m^3/s)	213	280
Peak % difference	-5%	-6%
Modelled Volume (ML)	21,049	14,542
Observed Volume (ML)	20,643	17,016
Volume % difference	2%	-15%
Modelled peak (mAHD)	5.82	6.12
Observed peak (mAHD)	5.71	6.53
Peak difference (m)	0.11	-0.41

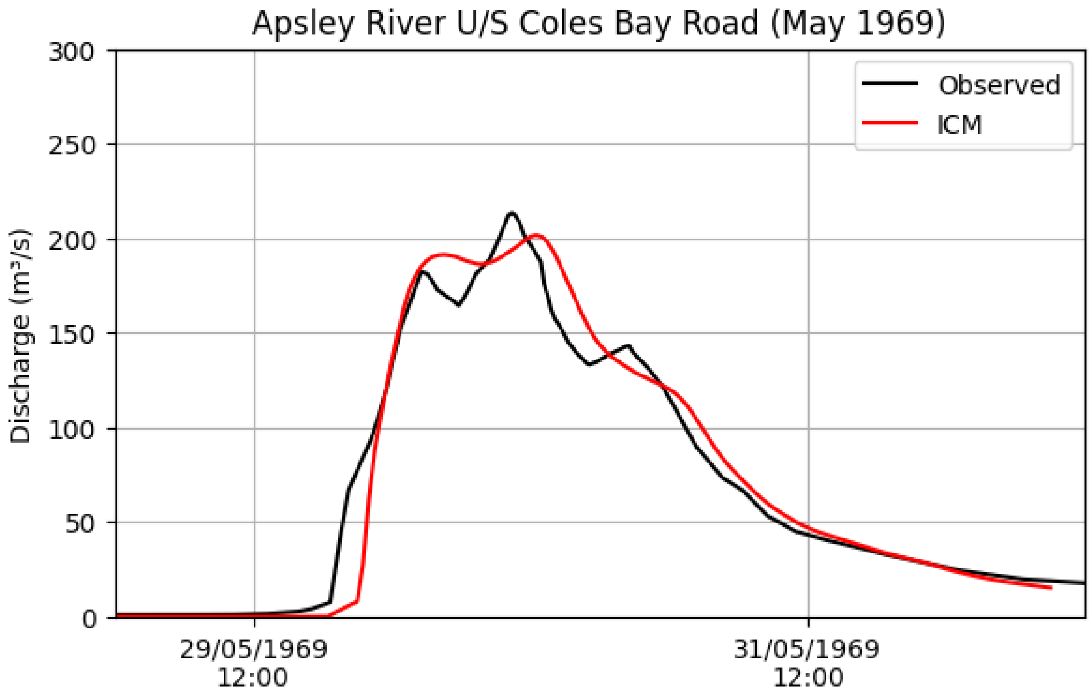

Diagram 12: May 1969 flow comparison at Apsley River U/S Coles Bay Road

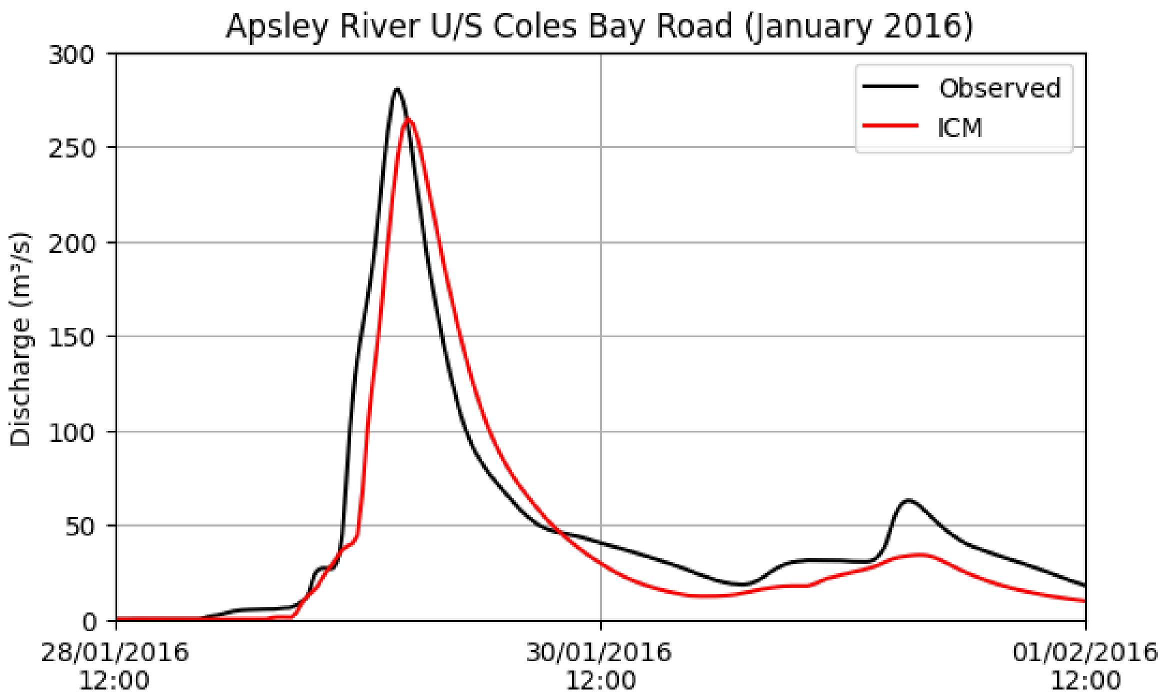

Diagram 13: January 2016 flow comparison at Apsley River U/S Coles Bay Road

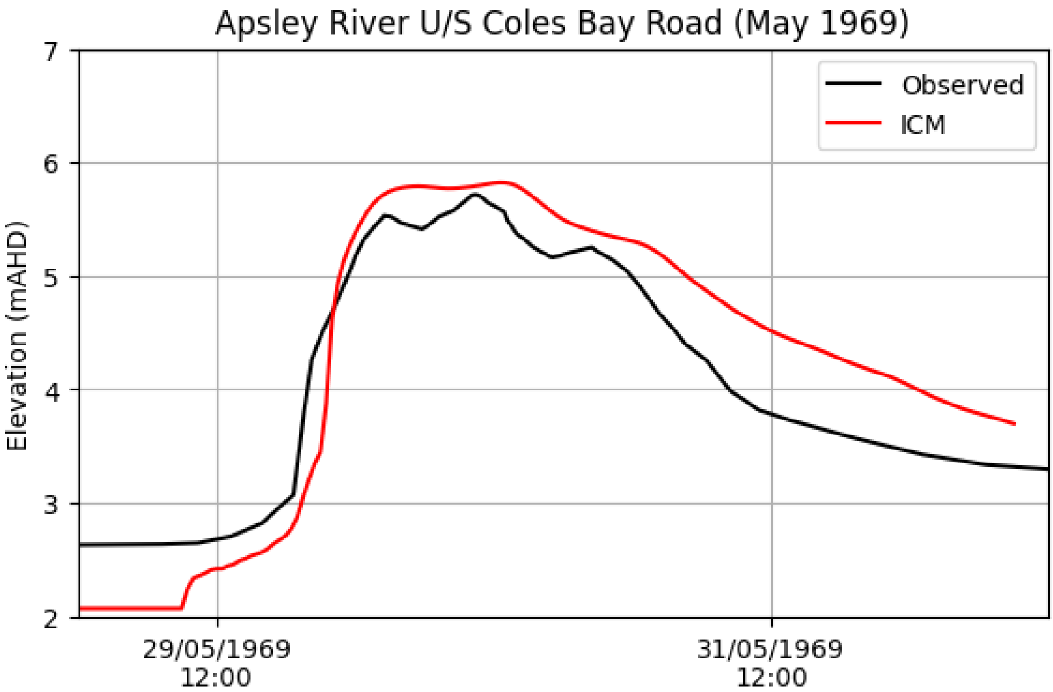

Diagram 14: May 1969 water level comparison at Apsley River U/S Coles Bay Road (assumed gauge zero)

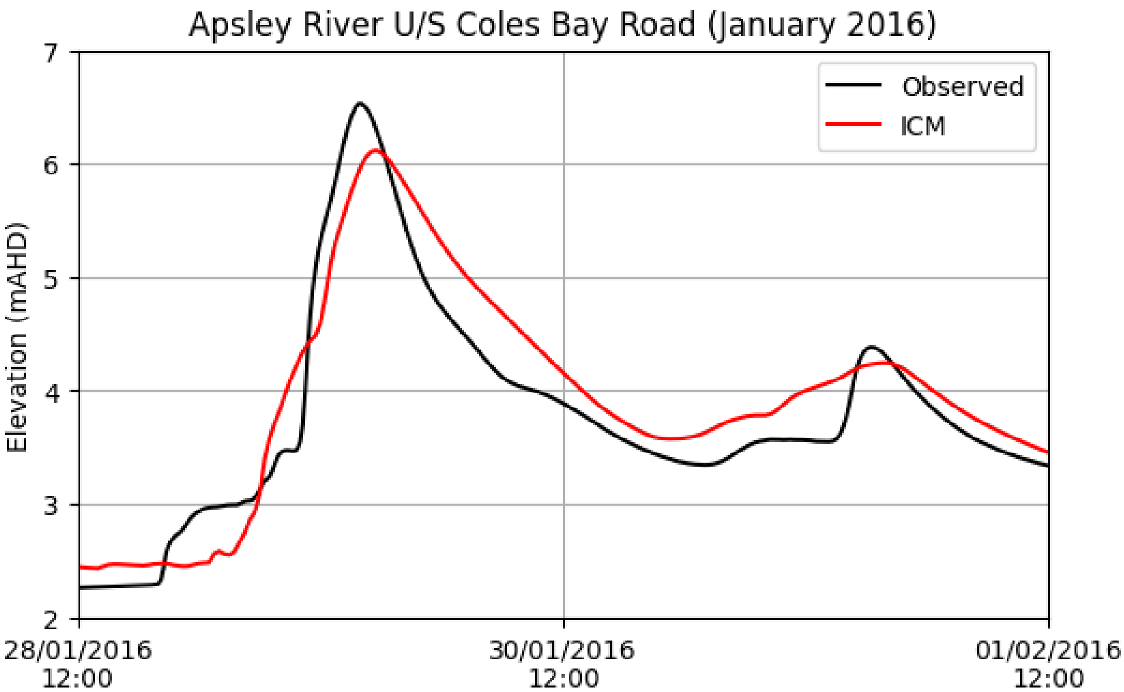

Diagram 15: January 2016 water level comparison at Apsley River U/S Coles Bay Road (assumed gauge zero)

6.1.2. Swan River at The Grange

The modelled peak flows for the May 1969 and January 2016 events at the Swan River at The Grange show poor match to the recorded peak flow (Table 6). The modelled hydrograph also shows a poor match in terms of timing and shape to the recorded hydrograph at the peak of the event, as shown in Diagram 16 and Diagram 18.

When comparing levels it is apparent that there is likely a discrepancy in the gauge zero at this location, with a good match to level and shape present in the May1969 event. This indicates that the likely mismatch in flows is due to the rating at this site for this event. There is considerable uncertainty in the level to flow rating at this site for the 1969 event. As discussed in Section 3.1.2, there is a wide scatter in the gaugings at this site and significant changes in the ratings over time. If the revised rating was applied for the 1969 event, there is a far better match between modelled and observed flows (Diagram 17).

Table 6: Calibrated parameters and discharge at Swan River at The Grange

Statistic	1969 May	2016 Jan
IL	0	84
Average CL	0	3.64
Modelled Peak (m^3/s)	646	636
Observed Peak (m^3/s)	1162	486
Peak % difference	-44%	31%
Modelled Volume (ML)	77,793	23,538
Observed Volume (ML)	102,111	33,860
Volume % difference	-24%	-30%
Modelled peak (mAHD)	6.72	6.57
Observed peak (mAHD)	6.84	5.88
Peak difference (m)	-0.12	0.69

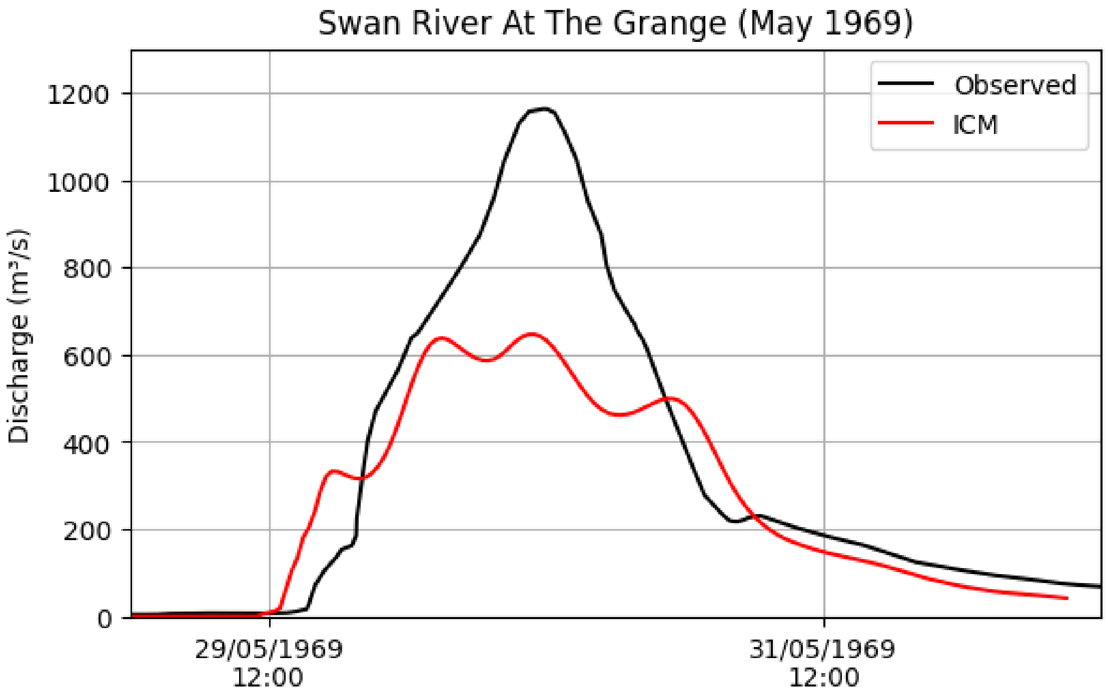

Diagram 16: May 1969 flow comparison at Swan River at The Grange – DPIPWE rating

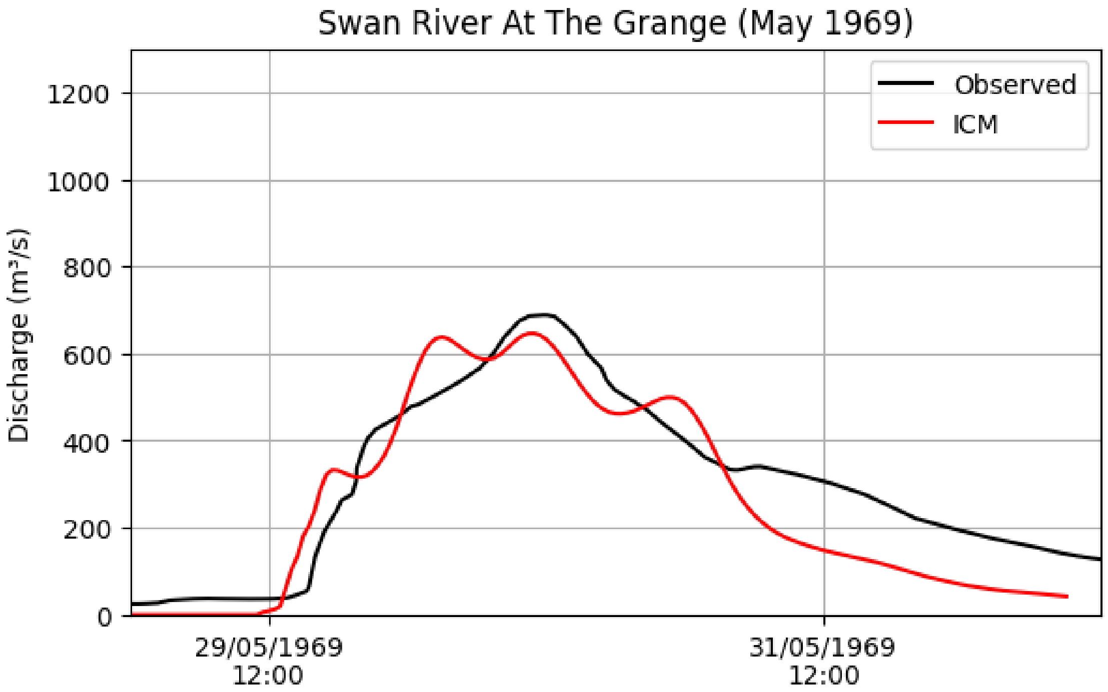

Diagram 17: May 1969 flow comparison at Swan River at The Grange – revised rating

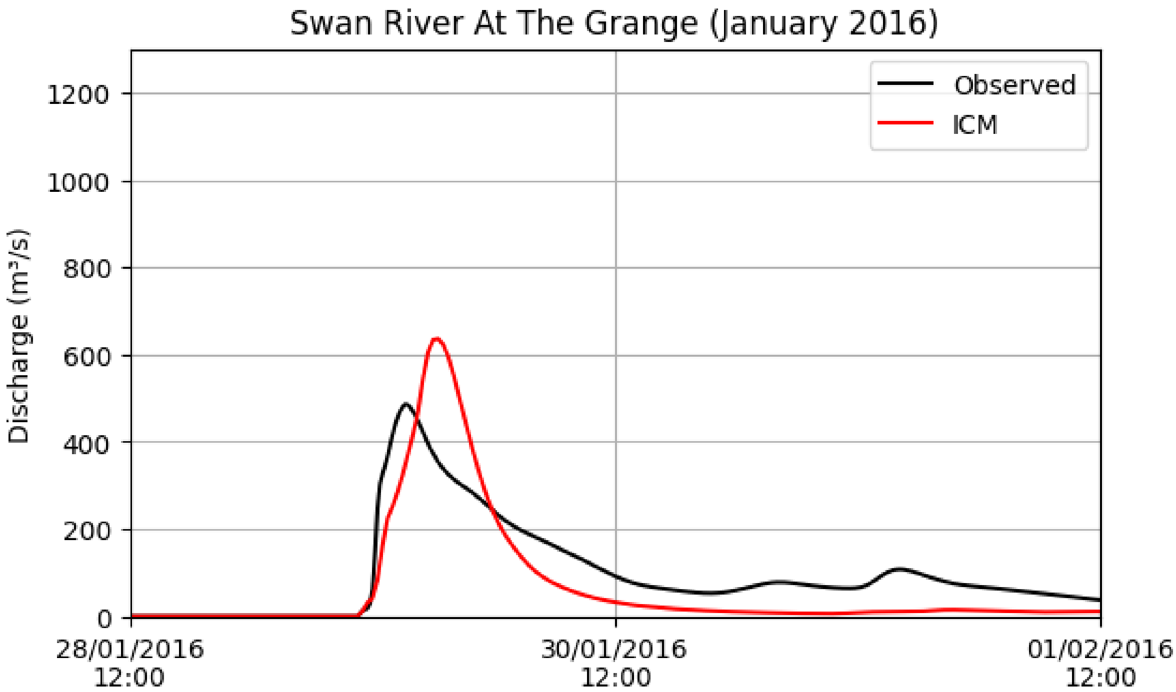

Diagram 18: January 2016 flow comparison at Swan River at The Grange

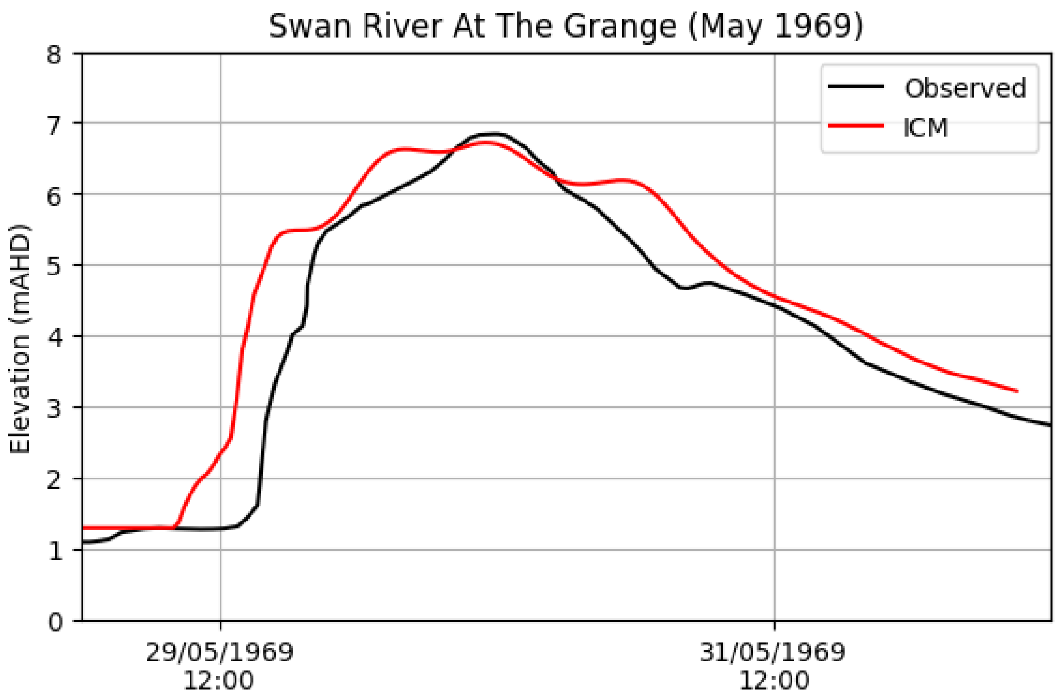

Diagram 19: May 1969 water level comparison at Swan River at The Grange (assumed gauge zero)

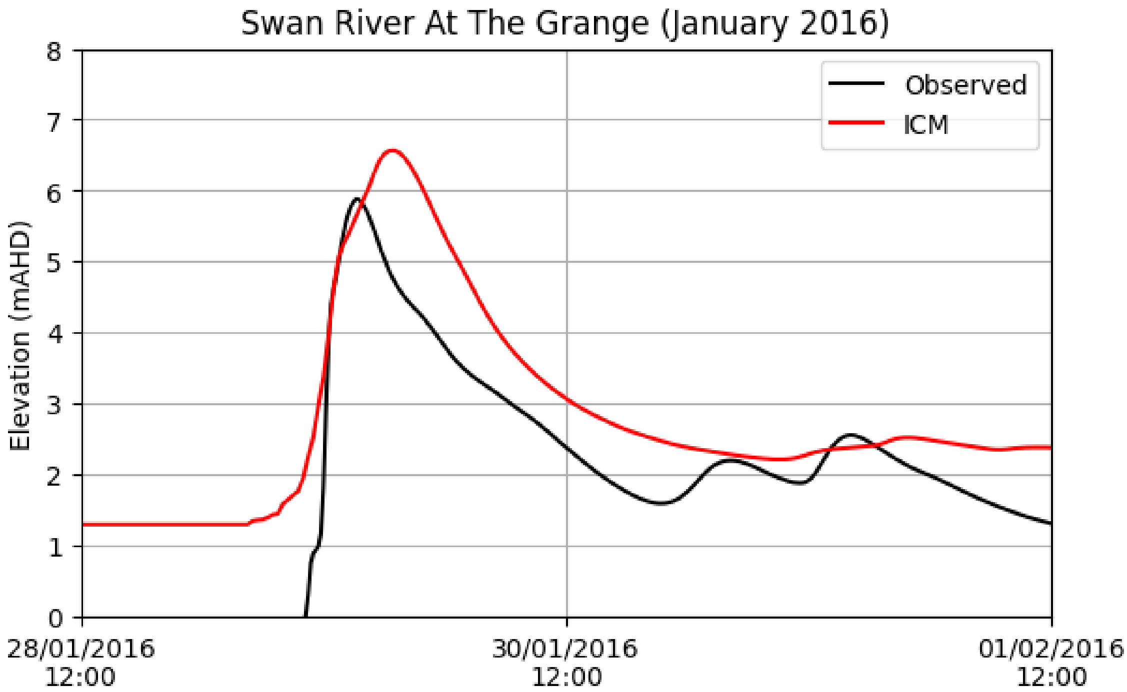

Diagram 20: January 2016 water level comparison at Swan River at The Grange (assumed gauge zero)

The continuing loss used for the January 2016 event is considerably higher for this catchment compared to the Apsley River catchment. This is likely due to the uncertainties in the distribution of rainfall over the study area, as discussed in Section 3.2, and limitations of the DEM. Even with a very low continuing loss, the model was unable to reach the peak flow at the Apsley River gauge, whereas modelled peak flows and levels were high compared to observed with a larger continuing loss at Swan River at the Grange gauge. The overestimation of flows and levels for the January 2016 event is also due to lack of definition of the waterway bathymetry in the DEM. The observed flows and levels for this event (using the updated rating curve) and flows and levels from the ICM model show this issue (Diagram 21), which is particularly evident at lower water levels.

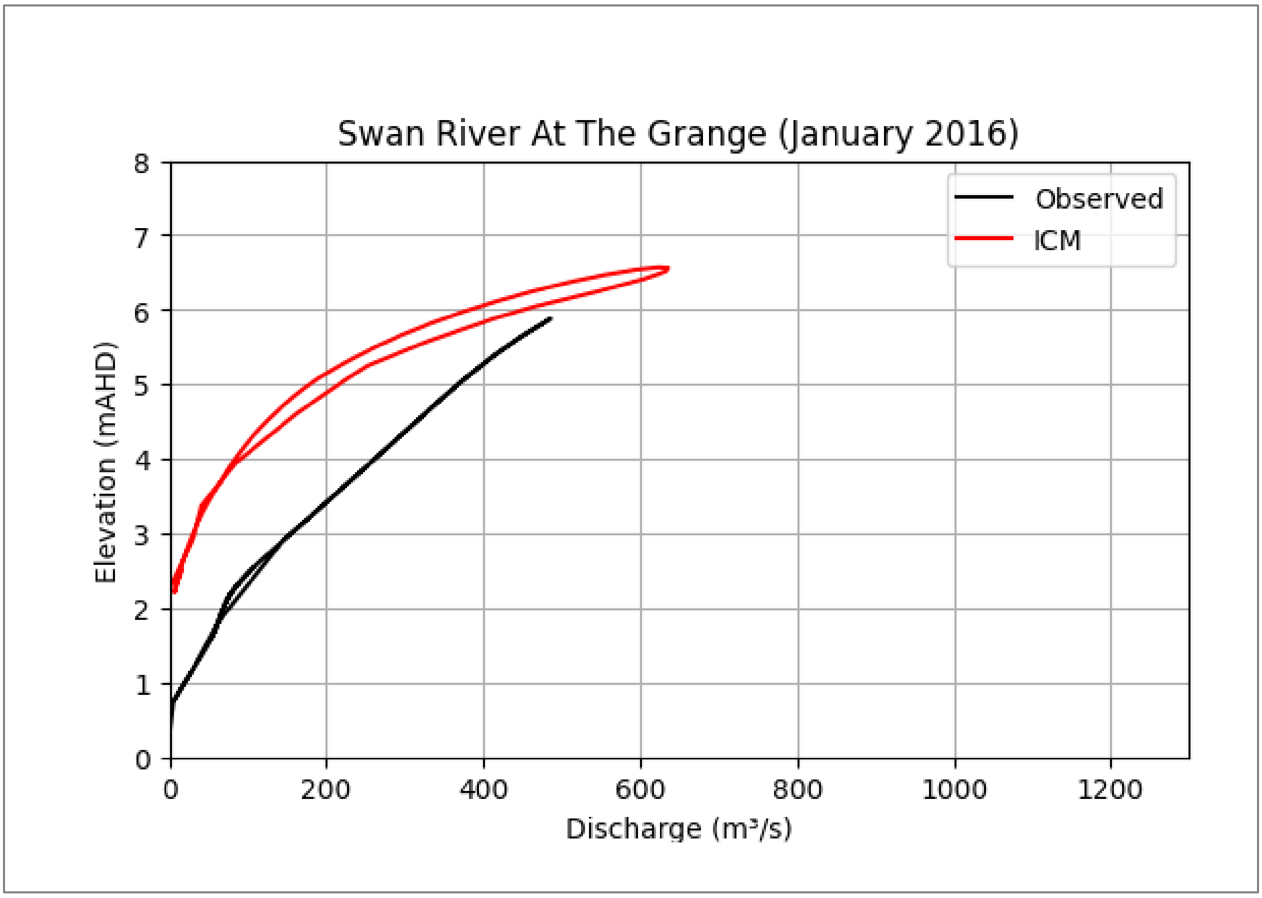

Diagram 21: ICM and observed water levels and flows, Swan River at the Grange, January 2016

6.1.3. Meredith River at Swansea

A flow and water level comparison was undertaken at the Meredith River at Swansea gauge for the January 2016 event. A gauge zero of 13.18 mAHD was provided for this gauge from the DPIPWE database and utilised for this assessment. The continuing loss is reasonably consistent with that applied at the Swan River gauge for the same event.

Table 7: Calibrated parameters results comparison at Meredith River At Swansea

Statistic	2016 Jan
IL	68
Average CL	3.8
Modelled Peak (m^3/s)	374
Observed Peak (m^3/s)	366
Peak % difference	2%
Modelled Volume (ML)	6,599
Observed Volume (ML)	7,150
Volume % difference	-8%
Modelled peak (mAHD)	18.30
Observed peak (mAHD)	17.82
Peak difference (m)	0.48

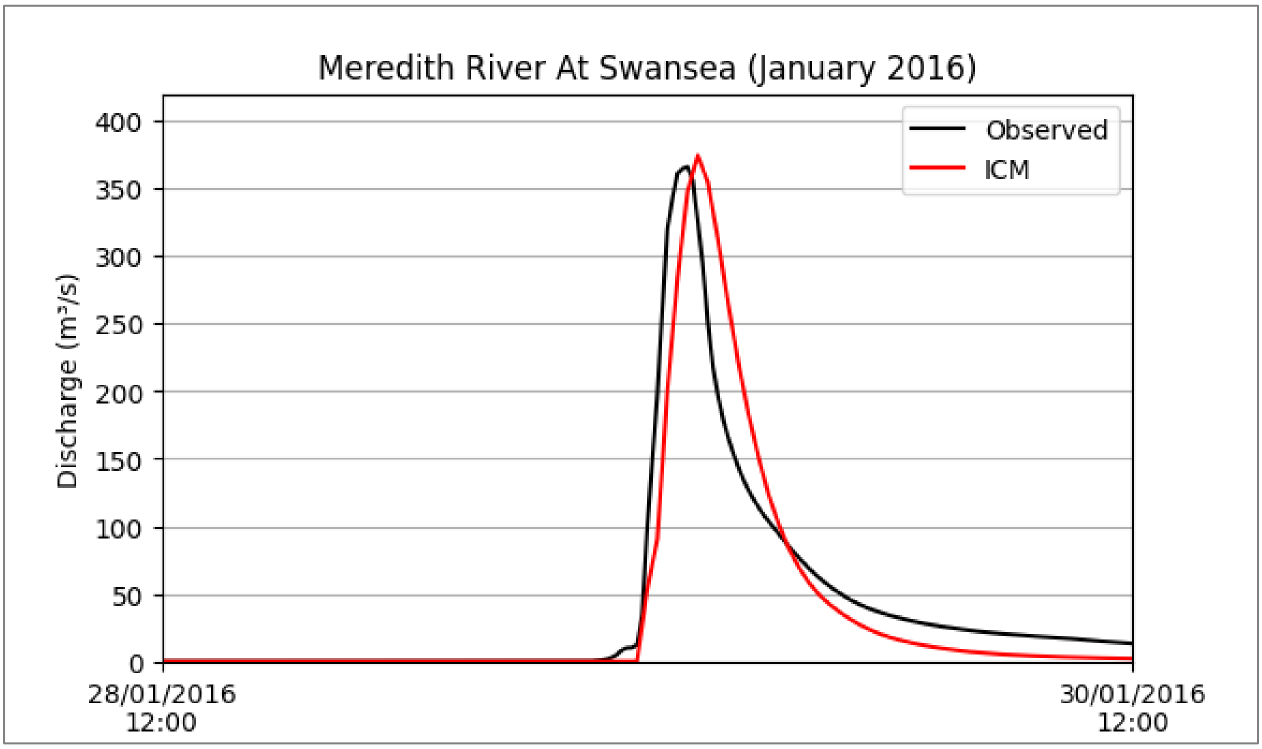

Diagram 22: January 2016 flow comparison at at Meredith River At Swansea

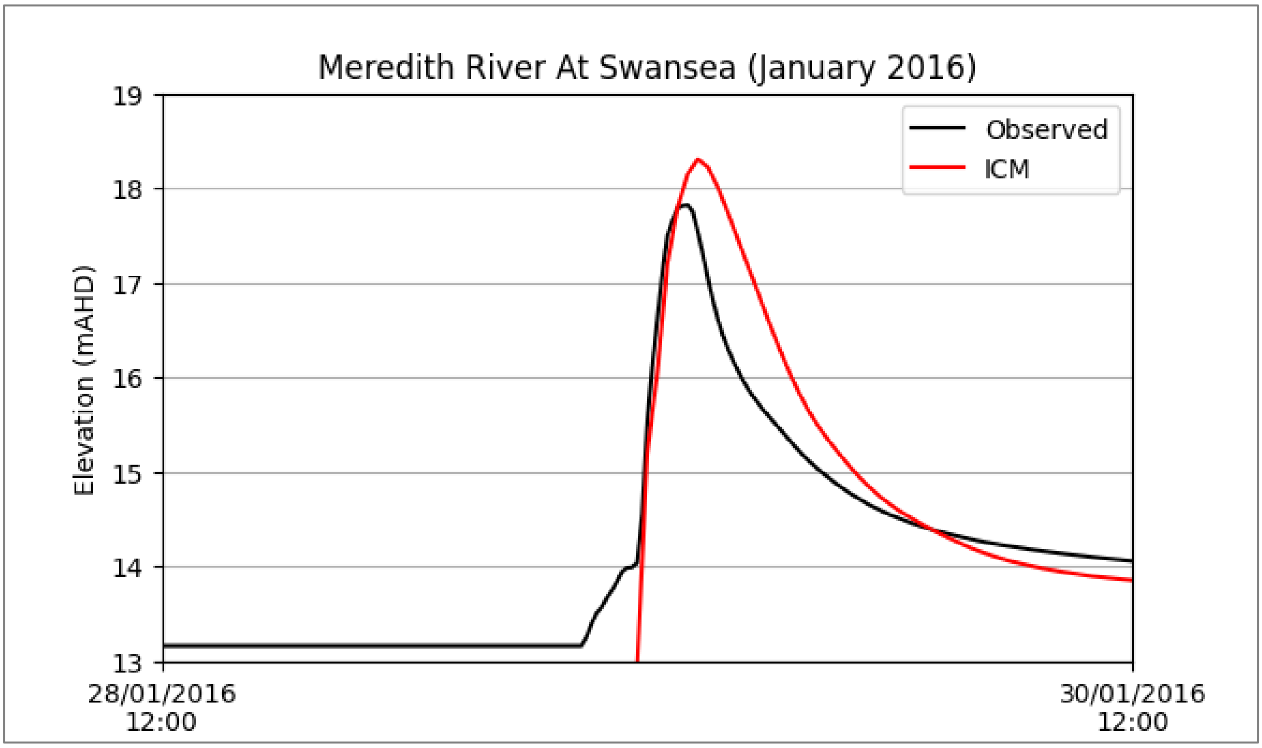

Diagram 23: January 2016 water level comparison at Swan River At The Grange (assumed gauge zero)

6.2. Identified Issues

In lieu of the June 2016 flood survey, a high-level review of the modelled flood extents was undertaken to identify potential issues that may need to be addressed.

The following issues were identified, which should be investigated further if future detailed analysis is undertaken:

- The DEM in some areas of the catchment, specifically in the lower reaches of the catchment, are limited to the 'Default DTM' of the state-wide 10 m DEM. Future LiDAR capture would likely improve the representation of these areas within the model.
- Other than for Swan River at The Grange gauge, there are no high flow gaugings at any of the gauges and there is considered to be a high degree of uncertainty in the rating curves at high flows.
- The waterway definition at the Swan River at The Grange gauge site is not well captured in the DEM and this results in inaccuracy in the modelled flows and levels at this site.
- Use of the applicable DPIPWE level to flow rating at the Swan River at The Grange site for the May 1969 event resulted in very high flow estimates, whilst application of the revised rating resulted in a close match to modelled flows. Consideration of the appropriate rating to use at this site will be required when undertaking flood frequency analysis at this site in the design modelling phase.
- There is a high rainfall gradient in large rainfall events over this catchment, which is not well captured by the raingauge network. This results in a high level of uncertainty in the rainfalls used for calibration events.

7. UNCERTAINTY ASESSMENT

Significant flows were recorded in the catchment area for 4 of the 13 flood events selected by the Bureau as calibration events for this project however the March 2011 and June 2016 events were excluded from calibration as there is not sufficient density of rain gauges to achieve a good representation of the rainfall over the catchment. The May 1969 and January 2016 events were used in calibration.

The uncertainty assessment for the modelling is shown in Table 8 and Appendix B.

Table 8: Uncertainty assessment for Swan-Apsley study area model

Category	Quality statement
Hydrology – rainfall input quality	The rainfall quality for the two calibration events is generally poor to fair, with one sub-daily rainfall gauges providing information for each calibration event, and 8 or 9 daily rainfall gauges within the catchment. However, there is a steep rainfall gradient from the coast to the hills in the west of the catchment and the rain gauge network is not considered to fully capture the spatial rainfall variability.
Hydrology – observed flows	There are four flow gauges within the catchment that were operating during the January 2016 calibration event. The ratings at Swan River at The Grange and Apsley River Upstream Coles Bay Road were extended using a local hydraulic model and the revised ratings are considered to be very good for the January 2016 event. The high flow ratings at the Meredith River at Swansea, and the Swan River u/s Hardings Falls sites are considered poor as all gaugings are within the channel and are considerably lower than the highest recorded stage height. Only Swan River at the Grange and Apsley River Upstream Coles Bay Road were operating for the 1969 event, and the DPIPWE ratings were used for this event. These are considered to be poor to fair.
Hydrology – calibration events	The May 1969 event was the largest on record at the Swan River at Grange gauge. The January 2016 event was close to a 1% AEP event at Meredith River at Swansea gauge, and was between a 10% and 30 % AEP event at the other gauges.
Hydrology – calibration results	The hydrology calibration was considered to provide a very good to excellent match to peak flows and volume at Apsley River upstream Coles Bay Rd and Meredith River at Swansea gauges, with differences of less than 6% between modelled and observed peaks. The modelled flows at the Swan River at The Grange showed a poor match to observed flows. This is likely due to the quality of the flow rating for the 1969 event, and there is some uncertainty about the quality of the flow data and the rainfall over the catchment for the January 2016 event.
DTM definition	The 2 m DEM provided by SES was utilised to inform levels within the catchment at the gagues. The 10 m DEM was used in the remainder of the catchment.
DTM waterways	No bathymetric data was available and waterway definition was based on the LiDAR to water surface. This impacted the accuracy of definition of waterways which resulted in poor replication of low to medium flows and levels in the model at Swan River at The Grange gauge.

Category	Quality statement
Hydrodynamic – observed flood depths	No surveyed flood levels were available in this area. Comparisons were made to gauge levels, with gauge zero inferred from the DEM and DPIPWE gauge zero information.
Hydrodynamic – overall calibration results	Calibration results within the hydrodynamic model generally indicate a fair to good correlation between recorded and modelled levels for infrequent events.
Hydrodynamic – calibration results, peak levels	Model calibration to peak levels at the gauges was considered to be fair to good, levels generally within 0.5 m of observed at all gauges.
Hydrodynamic – calibration results, flood extents	No observed flood extents were available in this area
Hydrodynamic – calibration results, flood depths	No observed flood depths were available in this area

8. REFERENCES

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Figures

FIGURE 01
SWAN-APSLEY STUDY AREA

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FIGURE 02
SWAN-APSLEY CATCHMENT LAND USE

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FIGURE 03
SWAN−APSLEY STUDY AREA
RAINFALL 1969_MAY

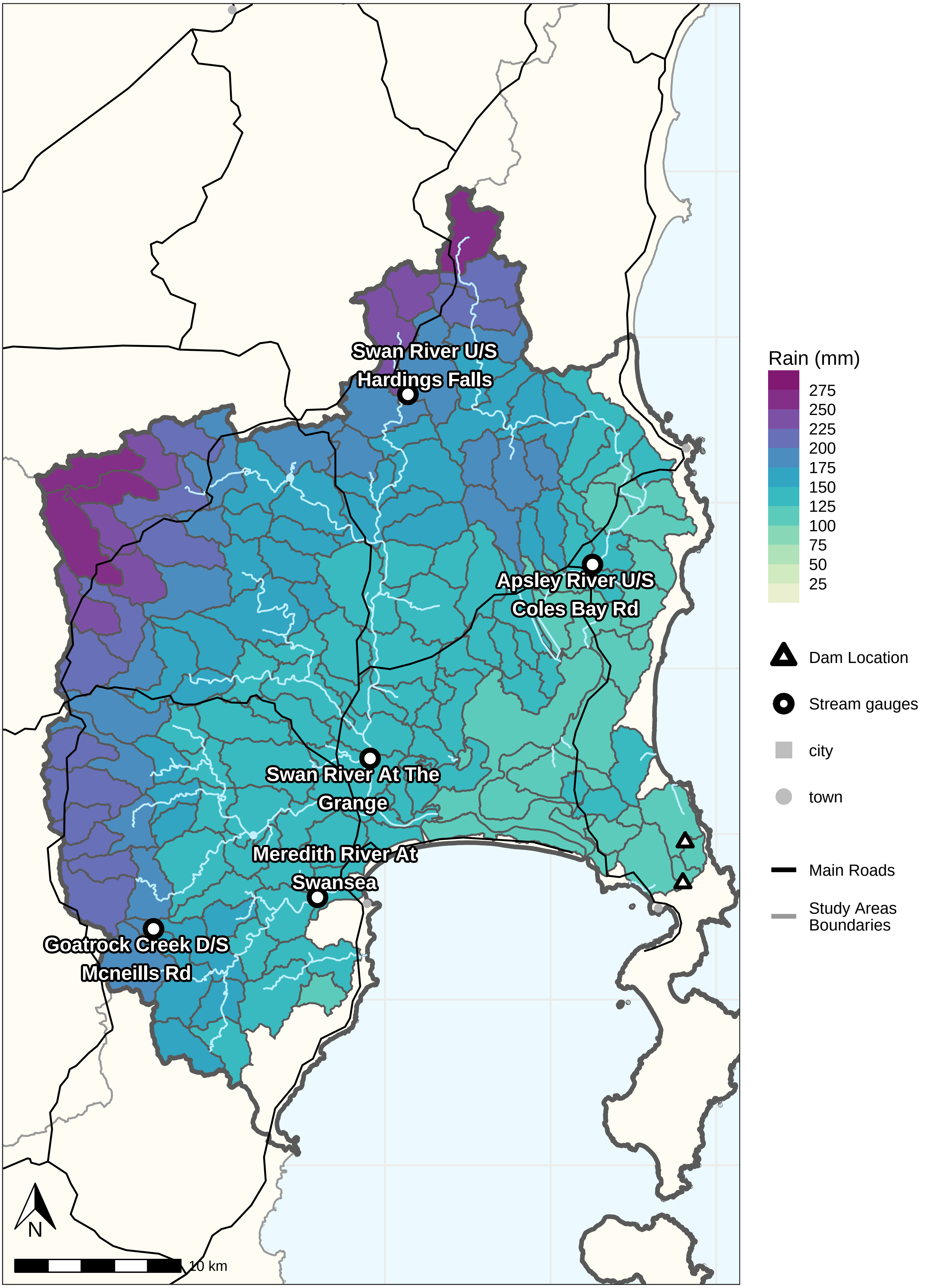

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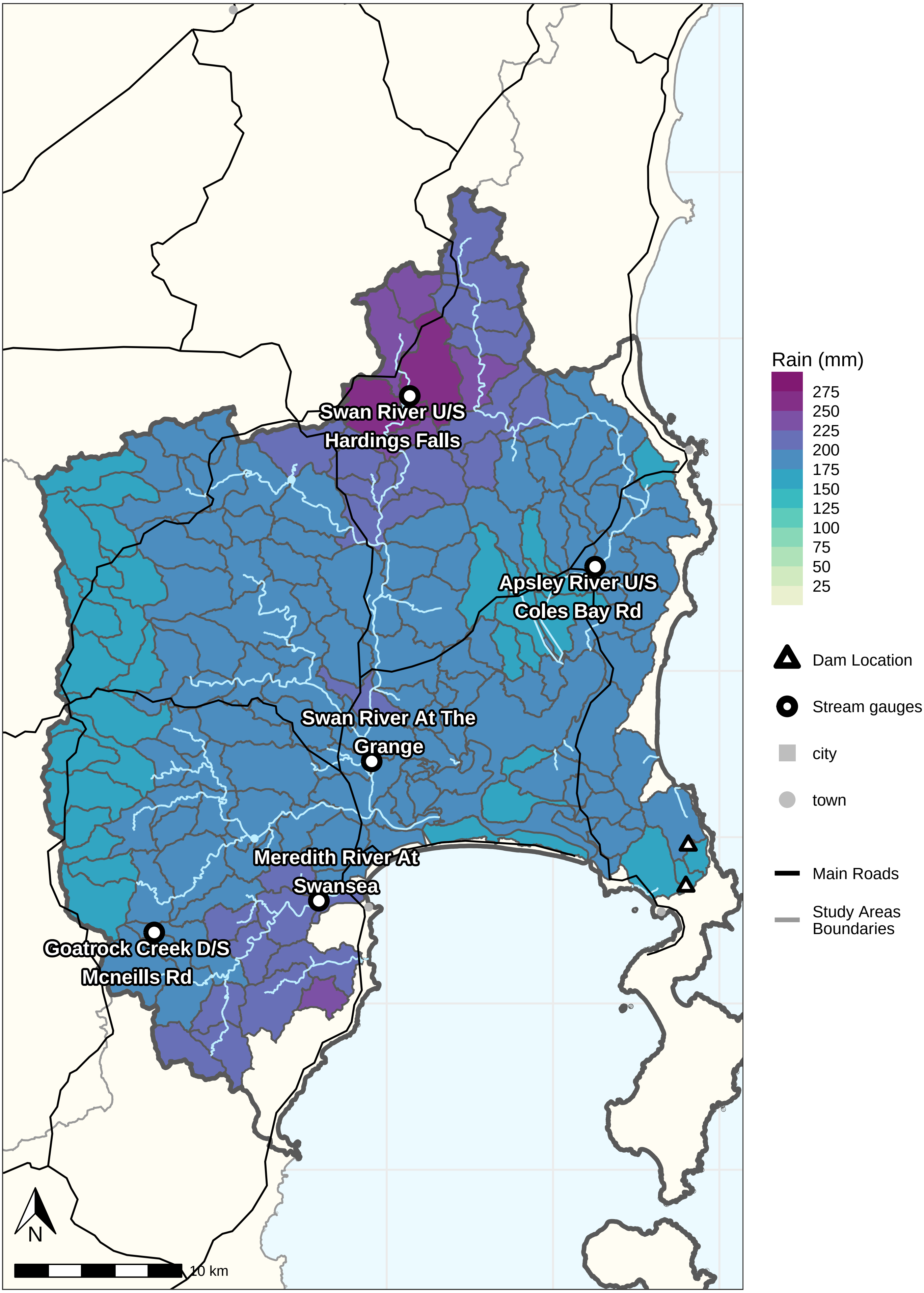
FIGURE 04

SWAN−APSLEY STUDY AREA

RAINFALL 2016_JAN



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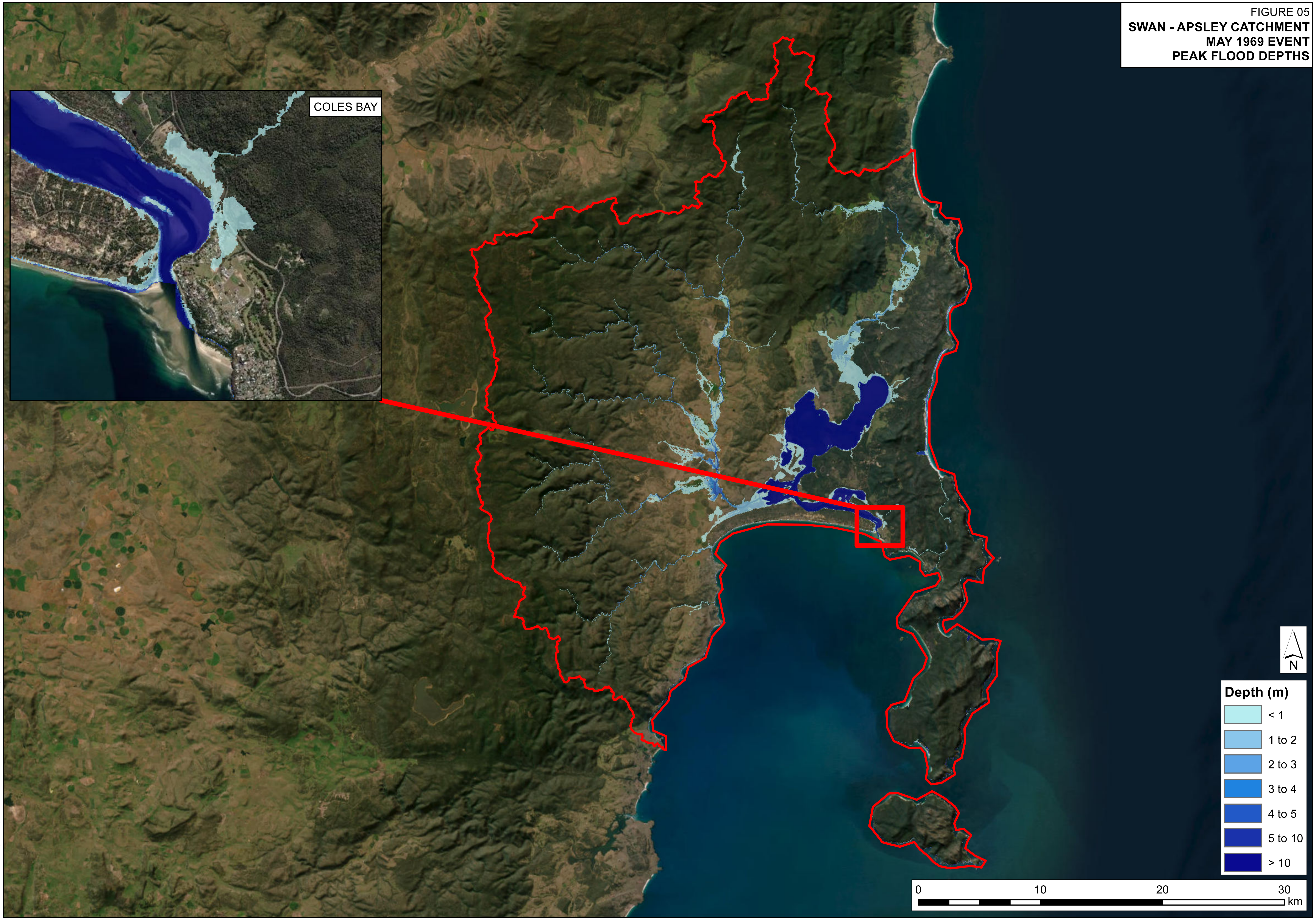
FIGURE 05
SWAN - APSLEY CATCHMENT
MAY 1969 EVENT
PEAK FLOOD DEPTHS
COLES BAY
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
N
0
10
20
30
km
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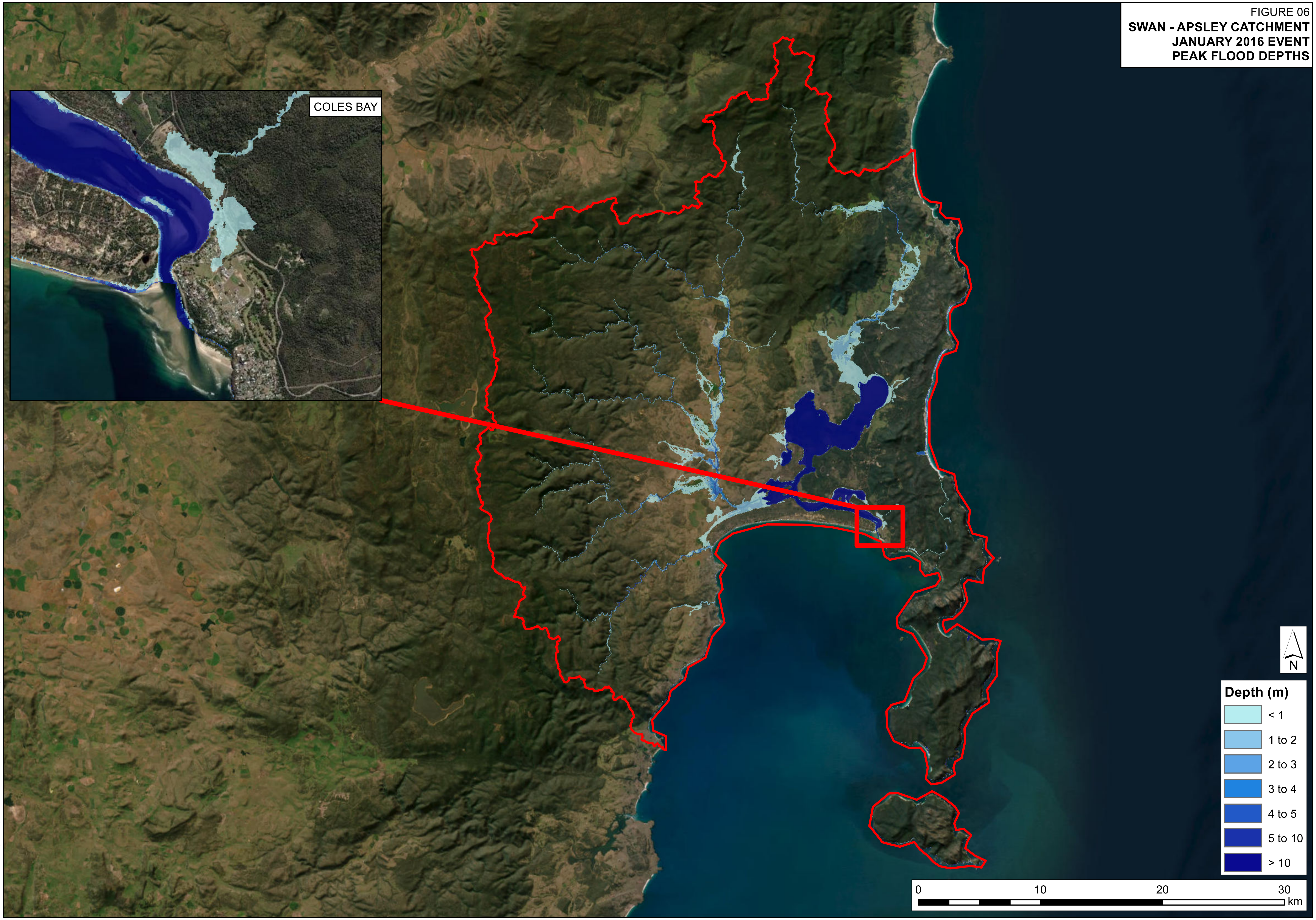

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Appendix A

APPENDIX A. AVALIABLE DATA

A.1. Sub-catchment data

FIGURE A1

HYDROLOGICAL SOIL GROUP MAPPING

DOMINANT SUBCATCHMENT SOIL INFILTRATION RATE

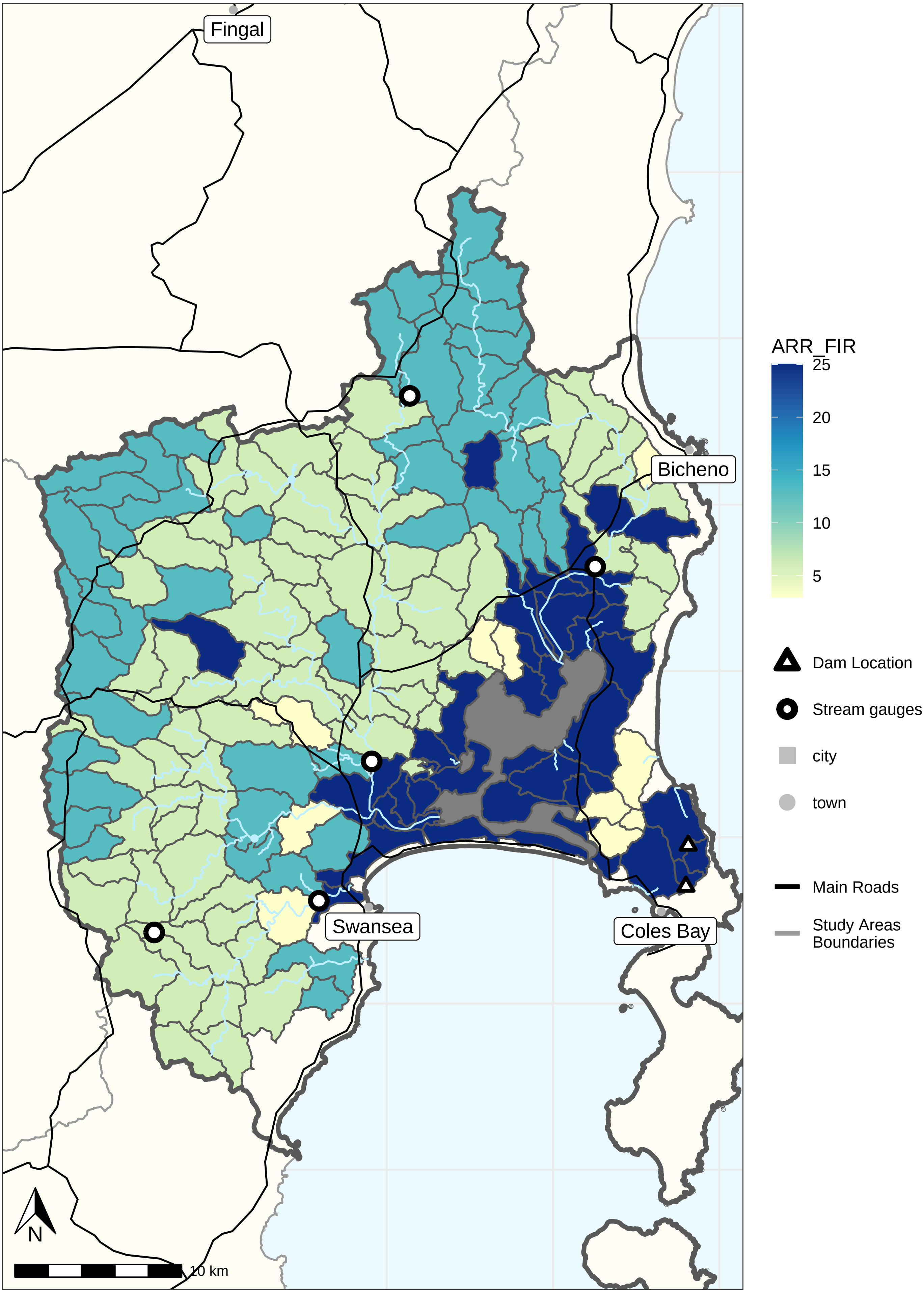

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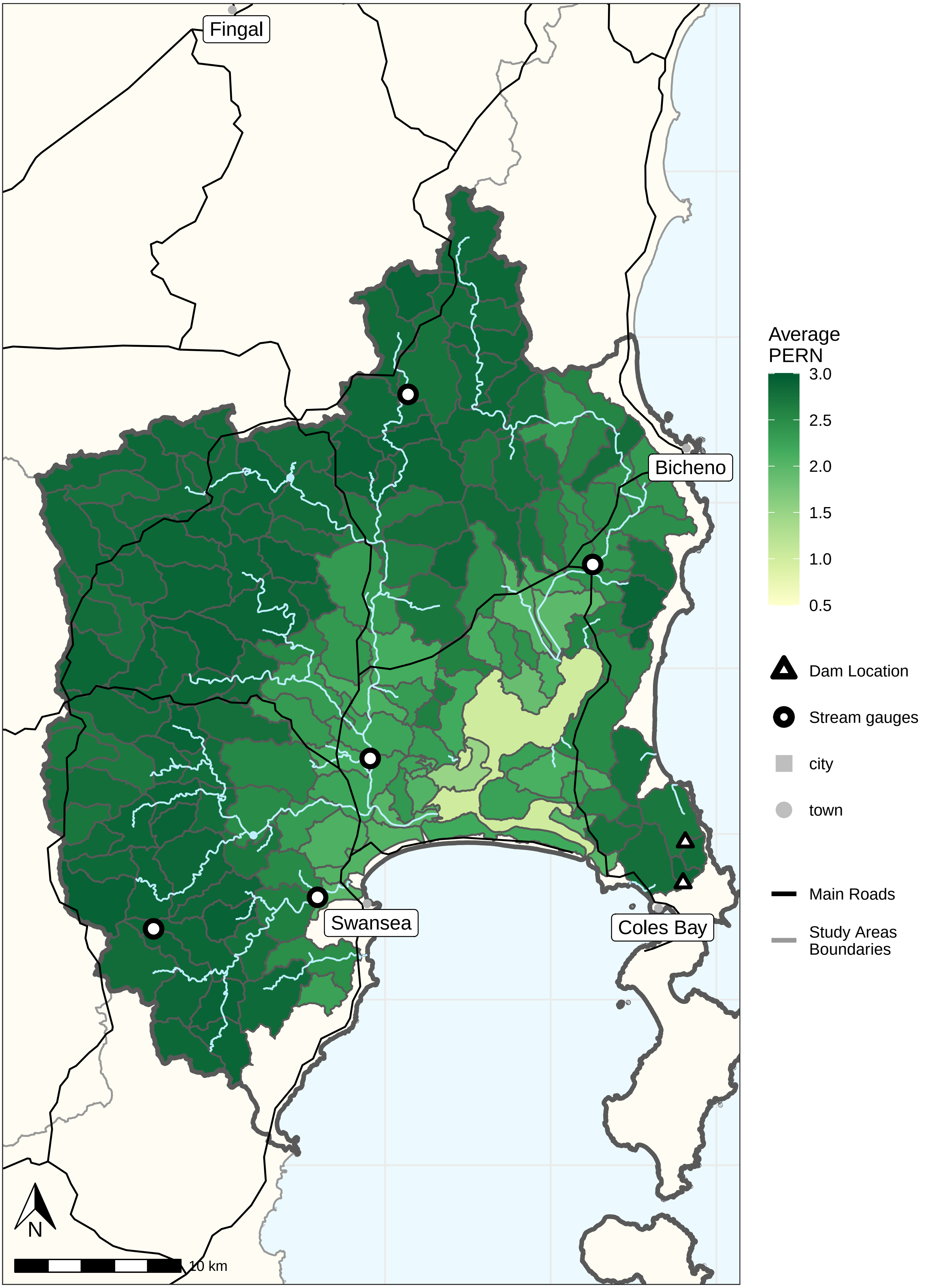
FIGURE A2
SWAN−APSLEY STUDY AREA
SUBCATCHMENT AVERAGE PERN



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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 other cases, the following shading is used to highlight relevant statements:

- For observed flow ratings description, Swan River at The Grange and Apsley River upstream Coles Bay Rd are shown in orange shading for the 2016 event and blue shading for the 1969 event.
- Meredith River at Swansea and Swan River upstream Hardings Falls are 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	Rating extrapolated with	Rating shows	Rating shows	Rating shows

	no consideration for shape of cross section	no consideration for shape of cross section	consideration to shape of cross section	consideration to shape of cross section	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:

- Apsley River upstream Coles Bay Rd and Meredith River at Swansea are shown in orange shading
- Swan River at The Grange is shown in blue.

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. Green shading is used to highlight relevant statements.

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

EXTERNAL HYDROLOGY MODEL TO ICM HYDRAULIC MODEL COMPARISON CHARTS

Figure C 1 Event Hydrographs

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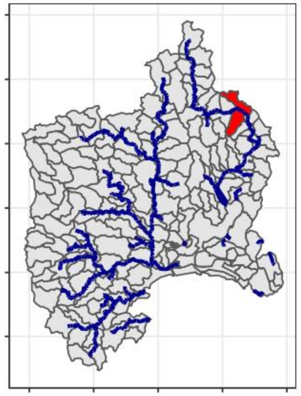
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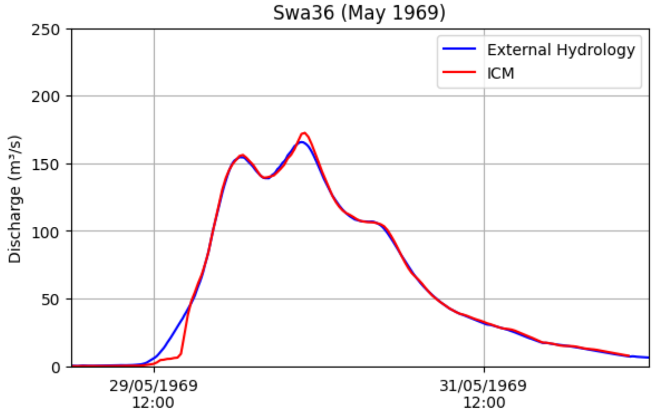

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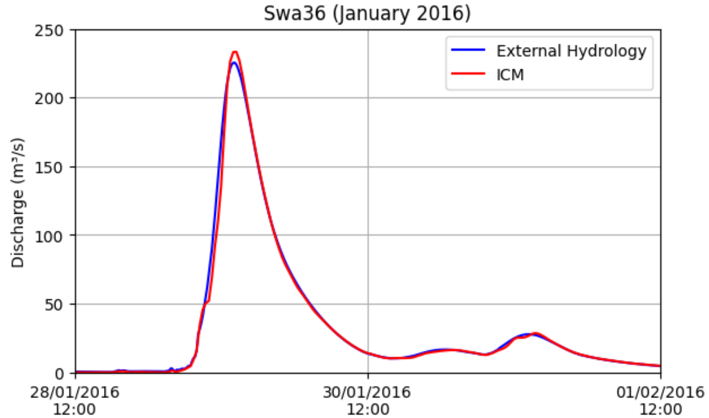

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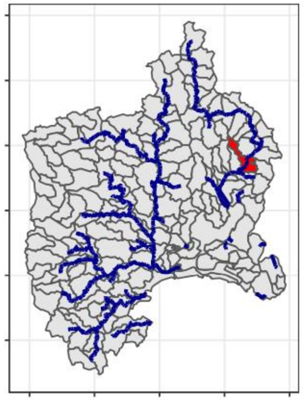
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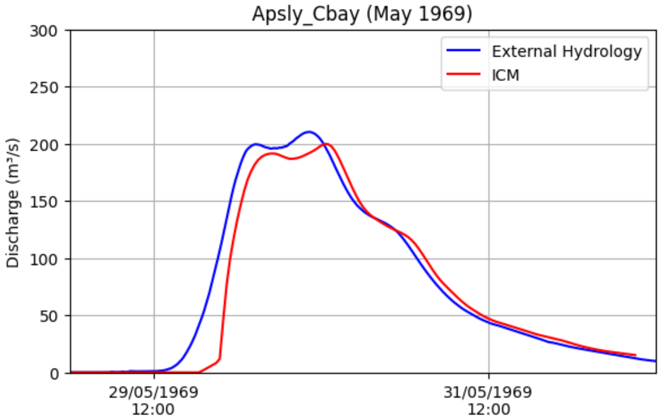

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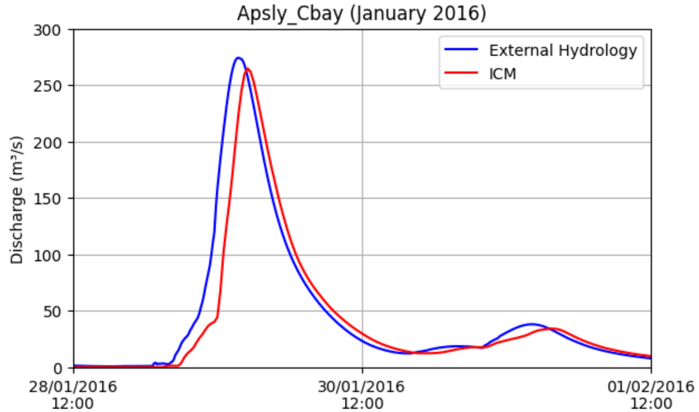

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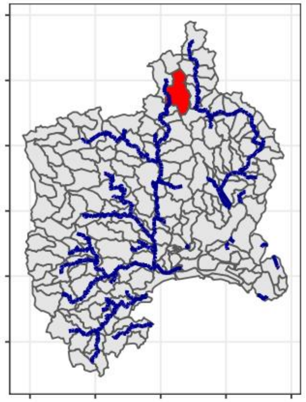
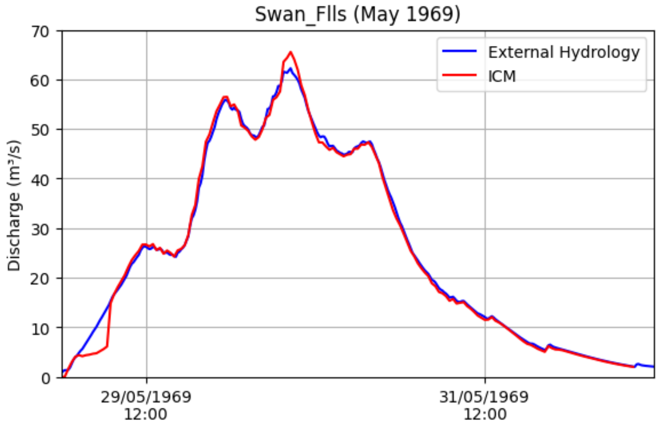
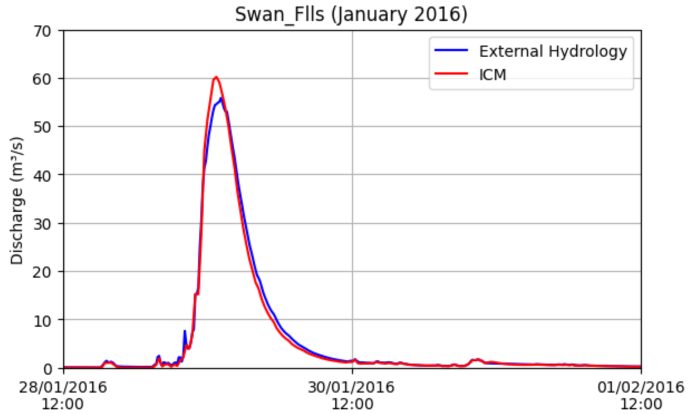
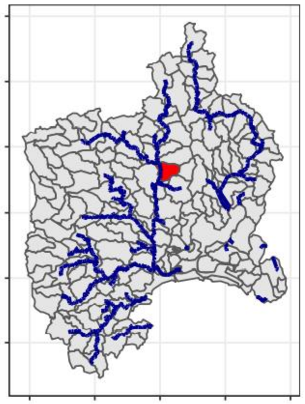
Swa64

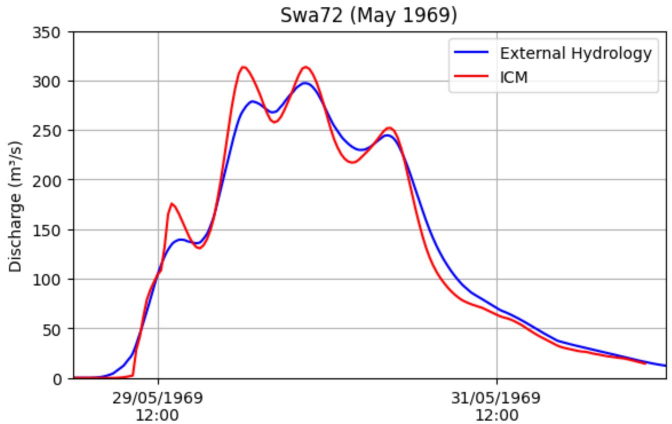


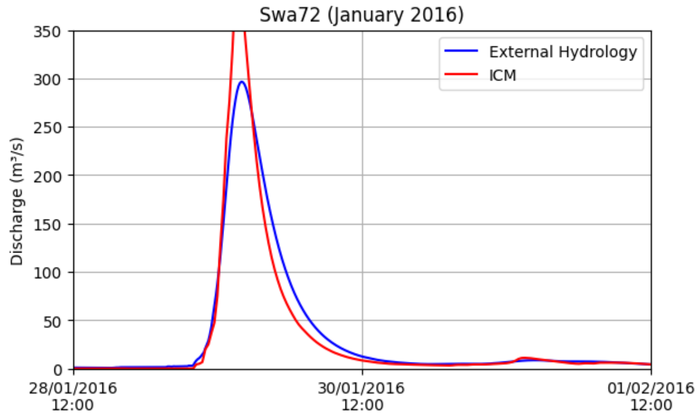

Swan_Flls (May 1969)
External Hydrology
ICM
Discharge (m³/s)
29/05/1969 12:00
31/05/1969 12:00


Swan_Flls (January 2016)
External Hydrology
ICM
Discharge (m³/s)
28/01/2016 12:00
30/01/2016 12:00
01/02/2016 12:00

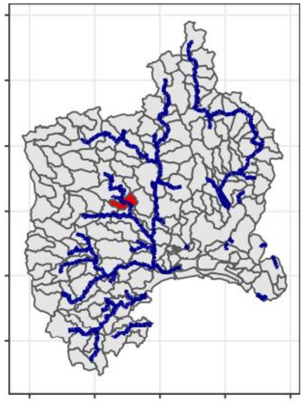
Swa72

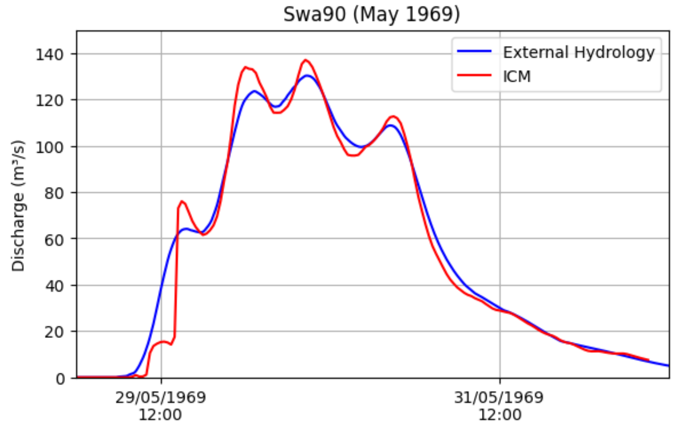


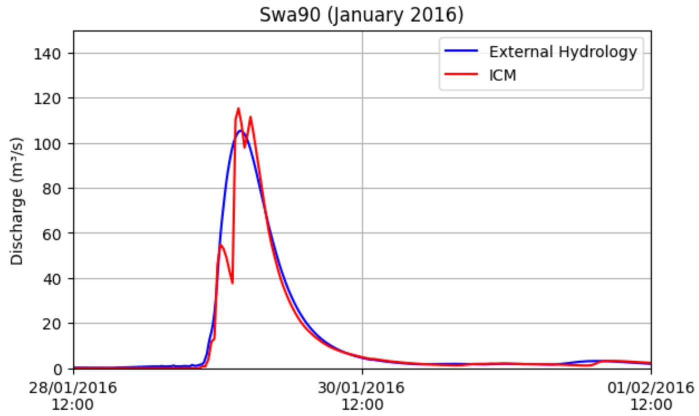

Swa72 (May 1969)
External Hydrology
ICM
Discharge (m³/s)
29/05/1969 12:00
31/05/1969 12:00


Swa72 (January 2016)
External Hydrology
ICM
Discharge (m³/s)
28/01/2016 12:00
30/01/2016 12:00
01/02/2016 12:00

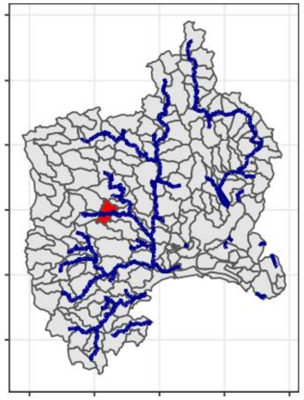
Swa90

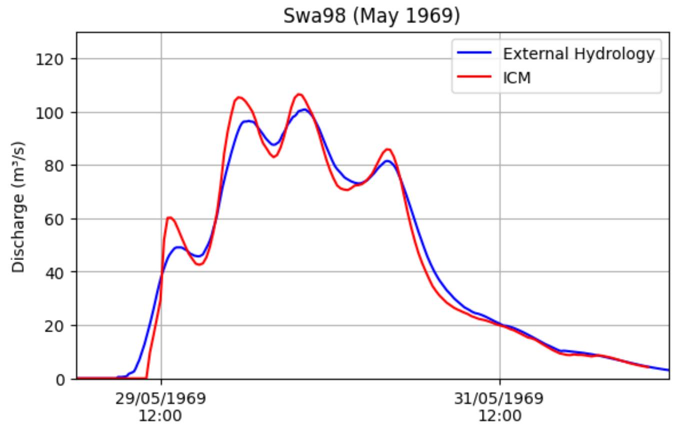


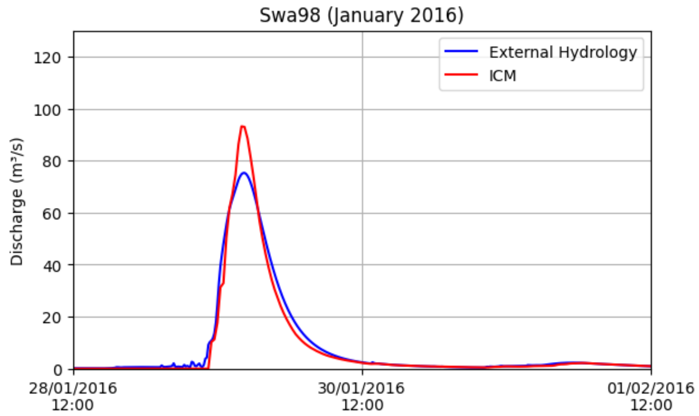

Swa90 (May 1969)
External Hydrology
ICM
Discharge (m³/s)
0
20
40
60
80
100
120
140
29/05/1969 12:00
31/05/1969 12:00


Swa90 (January 2016)
External Hydrology
ICM
Discharge (m³/s)
0
20
40
60
80
100
120
140
28/01/2016 12:00
30/01/2016 12:00
01/02/2016 12:00

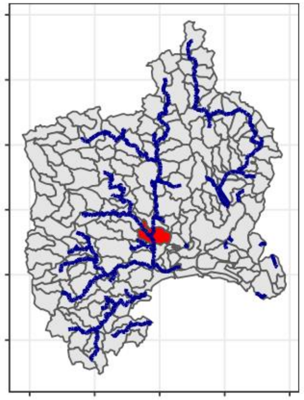
Swa98

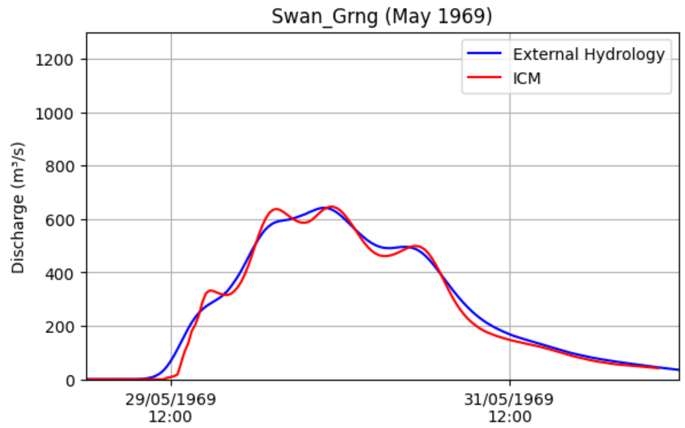


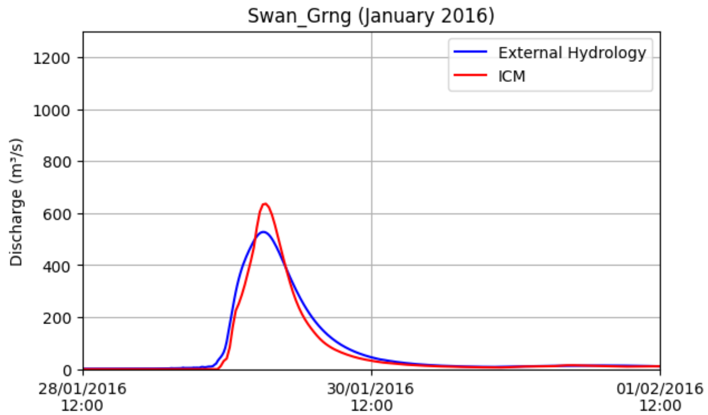

Swa98 (May 1969)
External Hydrology
ICM
Discharge (m³/s)
0
20
40
60
80
100
120
29/05/1969 12:00
31/05/1969 12:00


Swa98 (January 2016)
External Hydrology
ICM
Discharge (m³/s)
0
20
40
60
80
100
120
28/01/2016 12:00
30/01/2016 12:00
01/02/2016 12:00

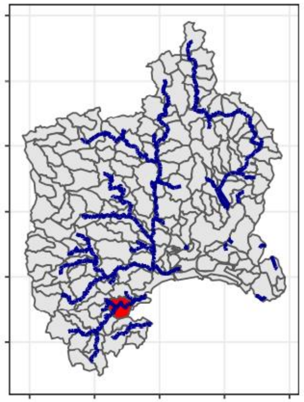
Swa100

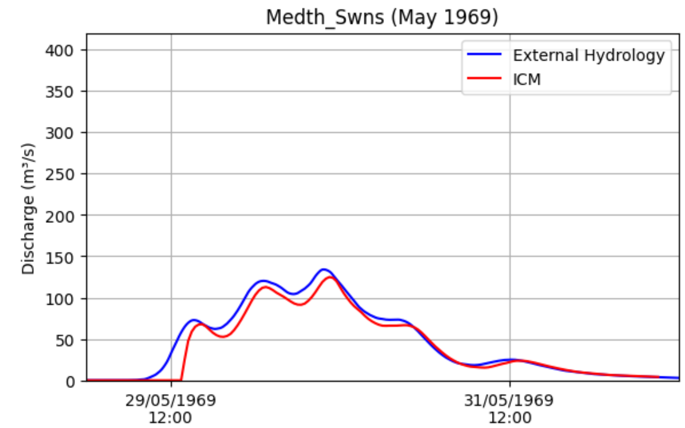


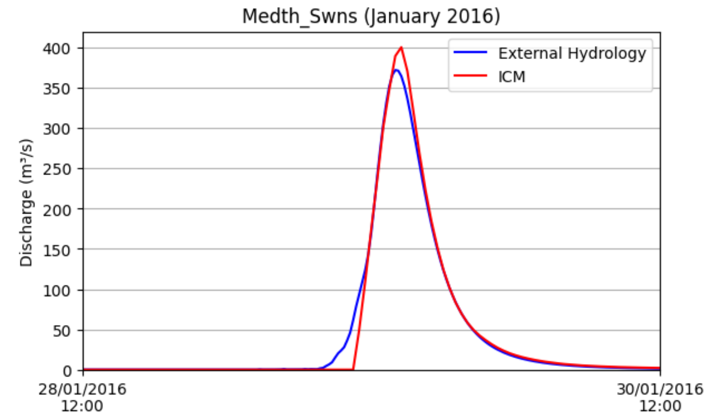


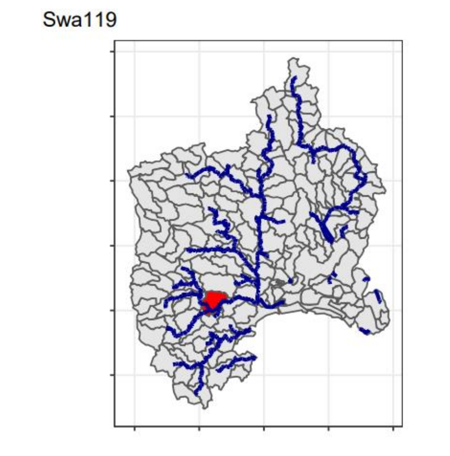


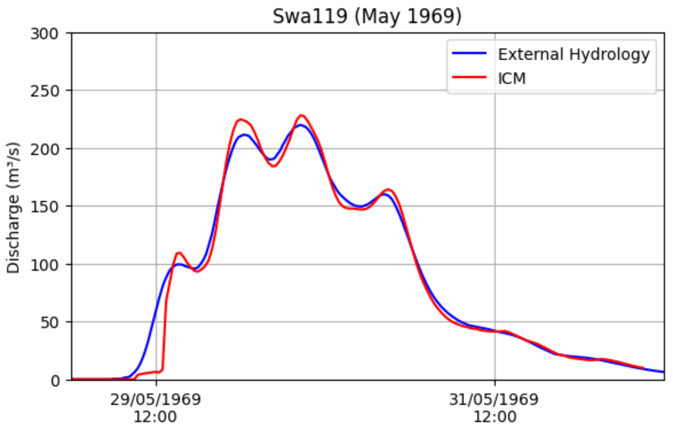
Swa153

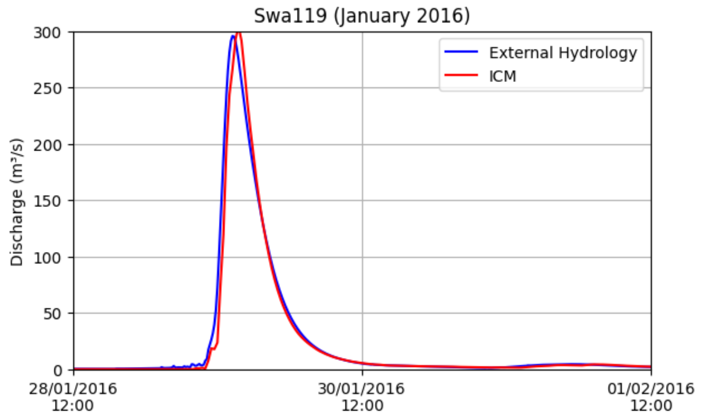







Swa119


Swa119 (May 1969)
External Hydrology
ICM
Discharge (m³/s)
0
50
100
150
200
250
300
29/05/1969
12:00
31/05/1969
12:00


Swa119 (January 2016)
External Hydrology
ICM
Discharge (m³/s)
0
50
100
150
200
250
300
28/01/2016
12:00
30/01/2016
12:00
01/02/2016
12:00