STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP
WELCOME-DUCK CATCHMENT MODEL CALIBRATION

REPORT

MARCH 2023

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Project Tasmanian Strategic Flood Map Welcome-Duck Catchment Model Calibration	**Project Number** **120038**
Client STATE EMERGENCY SERVICE	**Client's Representative** Chris Irvine
Project Manager Fiona Ling	

Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Draft report for review	Luke Roberts, SES	Sarah Blundy, Fiona Ling, Evmen Wong	Daniel Wood	Mark Babister	FEB 22
1	Revised report	Luke Roberts, SES	Sarah Blundy, Fiona Ling, Evmen Wong	Daniel Wood	Mark Babister	MAR 22
2	Report with minor revisions	Chris Irvine, SES	Sarah Blundy, Fiona Ling, Evmen Wong	Daniel Wood	Mark Babister	MAR 23

Cover image: Flooded Montagu River in far north west Tasmania October 2019. https://www.abc.net.au/news/2019-10-24/flooded-montagu-river-in-far-north-west-tasmania-october-2019-1/11632524?nw=0

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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 Welcome-Duck study area.

2. STUDY AREA

The Welcome-Duck study area is situated in the North-West of Tasmania. The study area includes three larger rivers: Welcome, Montagu and Duck rivers. The study area also includes several smaller watercourses that discharge directly into Bass Strait. The larger rivers rise in the small hills approximately 20-30 km inland from the north coast, and flow generally northwards to discharge into Bass Strait. The hills in the upper catchments are 100 m to 200 m in elevation and the rivers have gentle gradients. Much of the low lying agricultural areas in the Duck River catchment are prone to flooding during the winter months (DPIWE, 2003). The study area includes large areas of plantation forestry and forest reserves and cleared areas used for grazing and agriculture. The Duck Irrigation Scheme operates within the study area. The scheme has a capacity of 5,200 ML. Water is extracted for the scheme from the Duck River and Mill Creek in winter months and is stored within Mill Creek Dam. The scheme commenced in 2019 and supports pasture based enterprises, poppies, potatoes and other fresh vegetables through supply of irrigation water over summer (Tasmanian Irrigation, 2021).

The largest town in the study area is Smithton, located on the coast at the mouth of the Duck River. Smithton has a population of 3,881 people, based on 2016 census. Smaller towns in the study area include Irishtown and Marrawah.

Large floods in the study area include the July 2000 flood event.

The Welcome-Duck study area has an area of 1,800 km^2. The Welcome-Duck study area and the available gauge information are shown in Figure 1 and land use in the study area is shown in Figure 2.

3. AVAILABLE DATA

3.1. Historic Flow Data and Level Data

There are four relevant flow gauges with data available in the Welcome-Duck study area, as shown in Table 1. These gauges are owned by DPIPWE, who supplied timeseries of flows for each site, and ratings and gaugings for some sites. These gauges are still operational. There are other historical gauges in the study area with very short records (one on the upper Montagu River at Togari, one further upstream on the Edith Creek, and one on the Duck at Poilinna Rd) that were not active during the calibration event, so these have not been further investigated.

Table 1: Flow gauges

Gauge attribute	Welcome River at Woolnorth	Montagu River at Stuarts Rd	Duck River u/s Scotchtown Rd	Edith Creek 600m US Duck Confluence
Gauge number	14223-1	14200-1	14214-1	14238-1
Gauge abbreviated name	Welcome River gauge	Montagu River gauge	Duck River gauge	Edith Ck US Duck
Start date	06/04/1981	27/05/1965	23/04/1966	18/06/2008
End date	Current	Current	Current	Current
Latitude	-40.77	-40.78	-40.87	-40.95
Longitude	144.75	144.93	145.11	145.07
High flow rating quality	Fair - good	Fair - Good high flow gaugings out of channel, changes in ratings over time. Rating extended using local hydraulic model.	Fair - Good high flow gaugings out of channel, changes in ratings over time. Rating extended using local hydraulic model.	Not known
Used for calibration	Yes	Yes	Yes	No
Assumed local datum 0m in AHD	N/A	N/A	5.985	N/A
Highest Gauged Level (m local datum)	1.21	4.292	2.876	N/A
Highest recorded stage height (m local datum)	1.74	4.58	3.45	1.26
Highest recorded flow (m^3/s)	22	59	100	4.5
Highest recorded flow date	27/07/2016*	22/07/2000	21/07/2000	06/07/2015

*This is a separate event from the July 2016 calibration supplied for this project in (which was on 12th-15th July)

3.1.1. Calibration Event Data Availability

The major flood event with significant flows across the Welcome-Duck study area occurred July 2000, which was one of the additional calibration events identified (WMAwater 2021d). The largest flow on record at the Welcome River gauge is in July 2016 which is the month of one of the 13 flood events selected by the Bureau as calibration events for this project, however the Bureau event referred to the rainfall event in south and southwestern Tasmanian from about the 12th to the 15th of July and the Welcome River experienced its peak on the 27th of July. The rain provided by the Bureau for this project did not extend until later in the month so this event could not be used for calibration. July 2000 was the largest on record at the Duck River and Montagu River gauges and 5th largest at Welcome River gauge.

Table 2: Summary of the largest events in the Welcome-Duck study area used for model calibration.

Event name	Used for calibration	Event peak flow (m^3/s) (location)
2000_Jul	Yes	53 (Montagu River) 78 (Duck River) 16 (Welcome River)

3.1.2. Rating Curve Quality

The Montagu River at Stuarts Road site is well gauged, including gaugings out of the channel up to 44 m^3/s. There has been a shift in the gaugings and ratings have changed over time (Diagram 1).

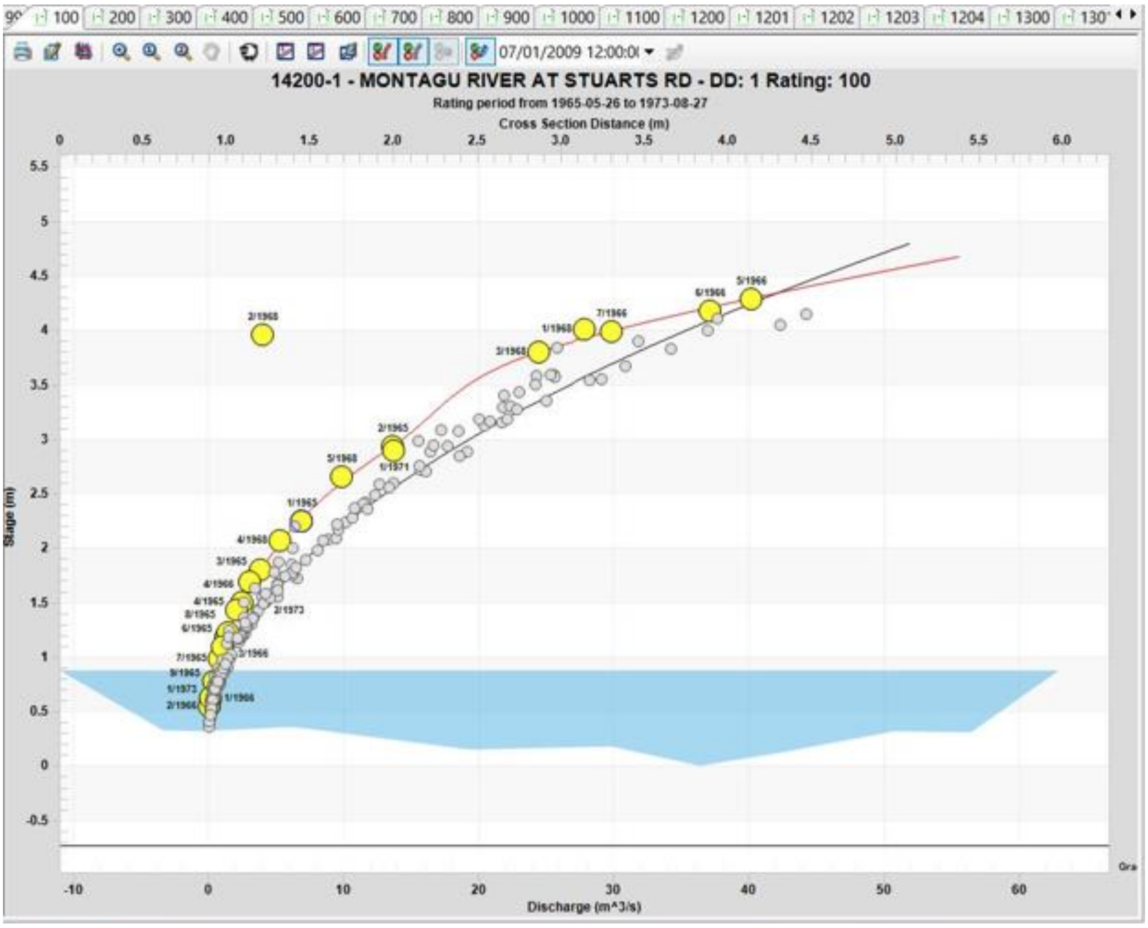

Diagram 1: Montagu River at Stuarts Road gaugings and rating (supplied by DPIPWE)

The rating was changed during the July 2000 event, causing a step-change in flows obtained from DPIPWE data portal (Diagram 2). This can be seen in the sharp drop in flows at the peak of the event. This was not evident in the levels at these gauges Diagram 3. To improve the quality of the high flow rating at this site, a theoretical rating was developed using a local hydraulic model (WMAwater, 2021c, Diagram 5). This rating has been used in calibration.

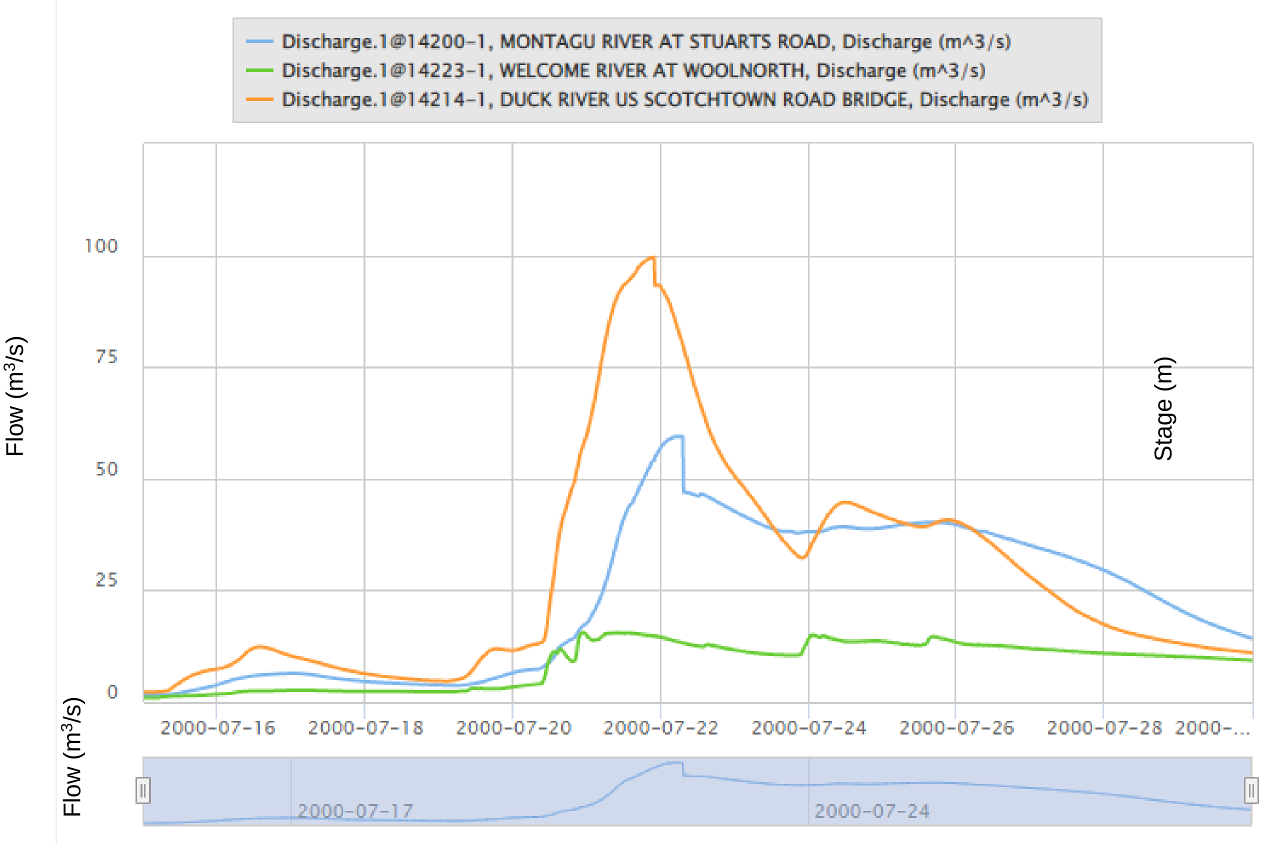

Diagram 2: Flows downloaded from DPIPWE data portal for July 2000 event (Source DPIPWE 2022).

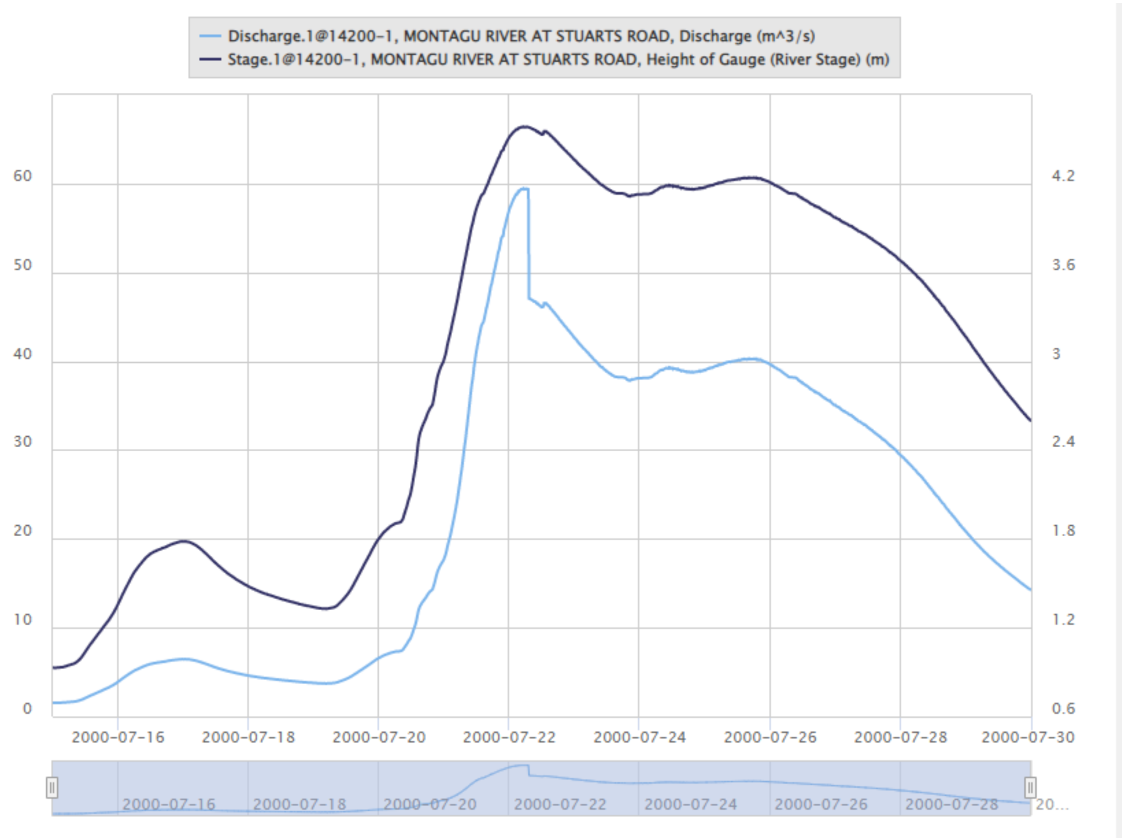

Diagram 3: Montague River stage height and flow showing drop in flow not corresponding to change in stage height (Source DPIPWE 2022).

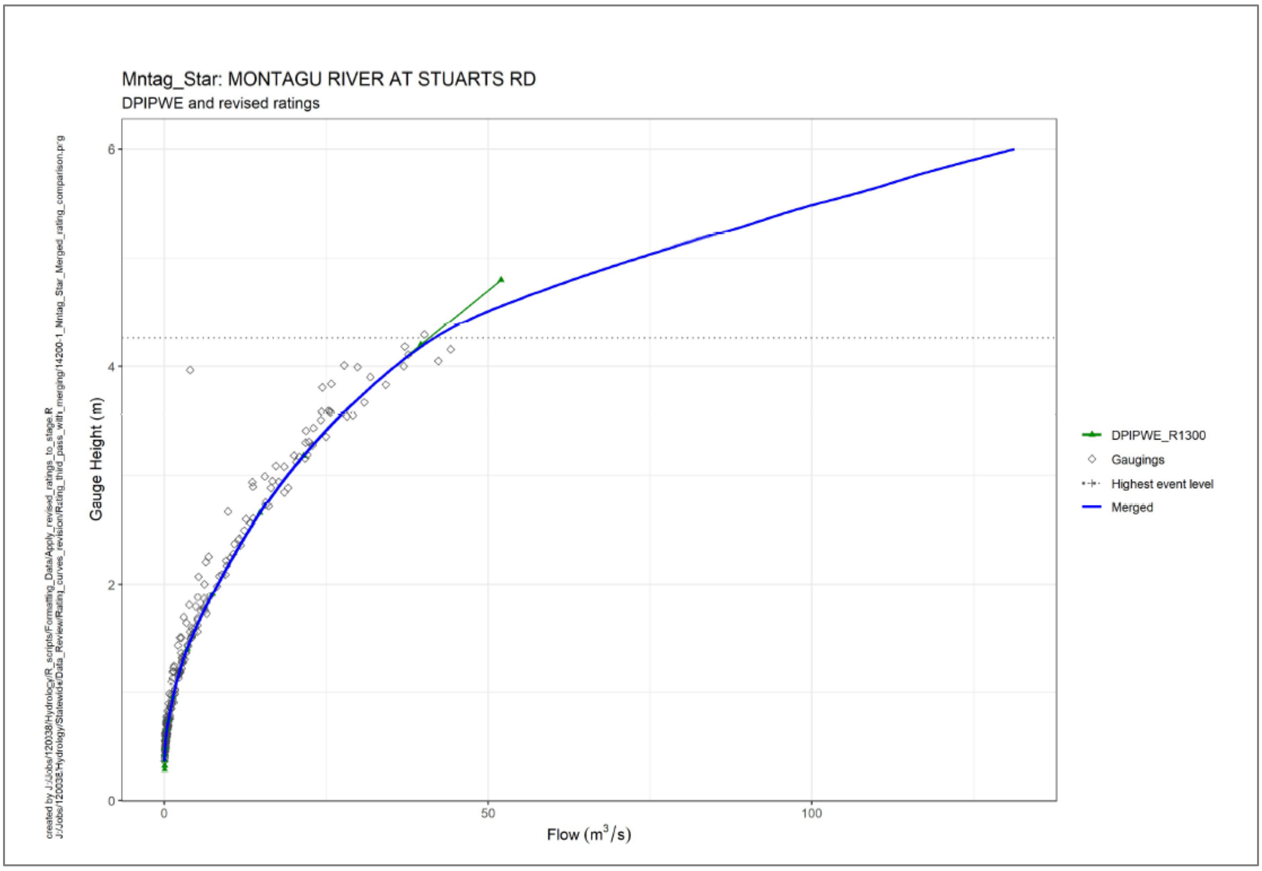

Diagram 4: Montagu River at Stuarts Road revised rating (from WMAwater 2021c)

The Duck River u/s Scotchtown Road gauge has some older high flow gaugings. There have been a range of ratings at the site, and there is a large range in the ratings in the higher flow range (Diagram 5).

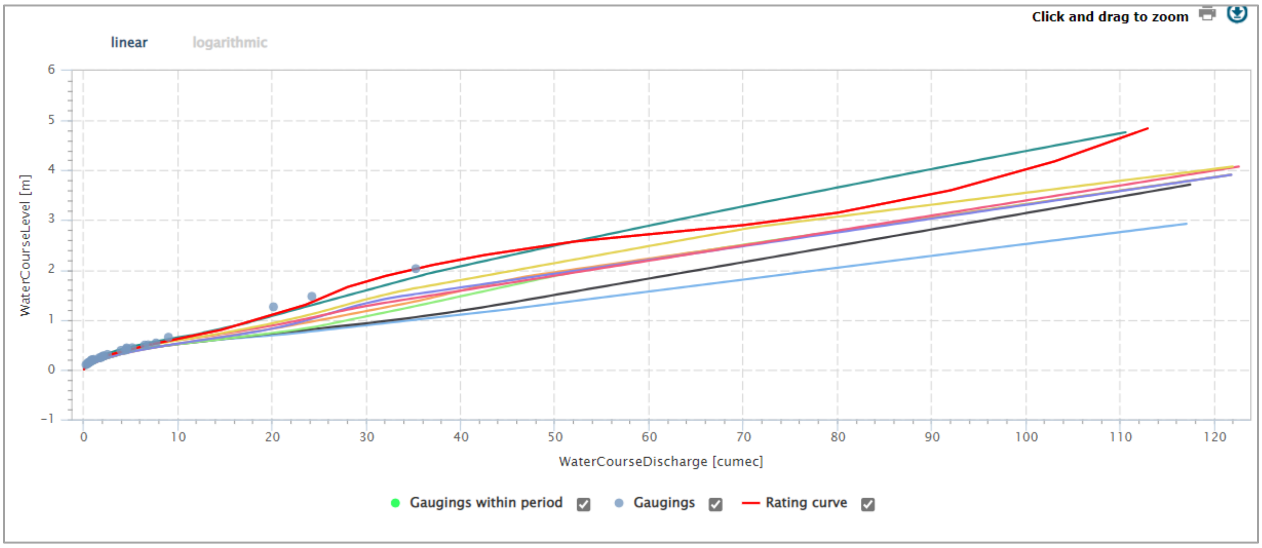

Diagram 5: Duck River u/s Scotchtown Road ratings, current rating shown in red (screenshot from Bureau of Meteorology, 2021)

The rating at this site was also changed midway through the July 2000 event (Diagram 3). To improve the quality of the high flow rating at this site, a theoretical rating was developed using a local hydraulic model (WMAwater, 2021c, Diagram 6). This rating has been used in calibration.

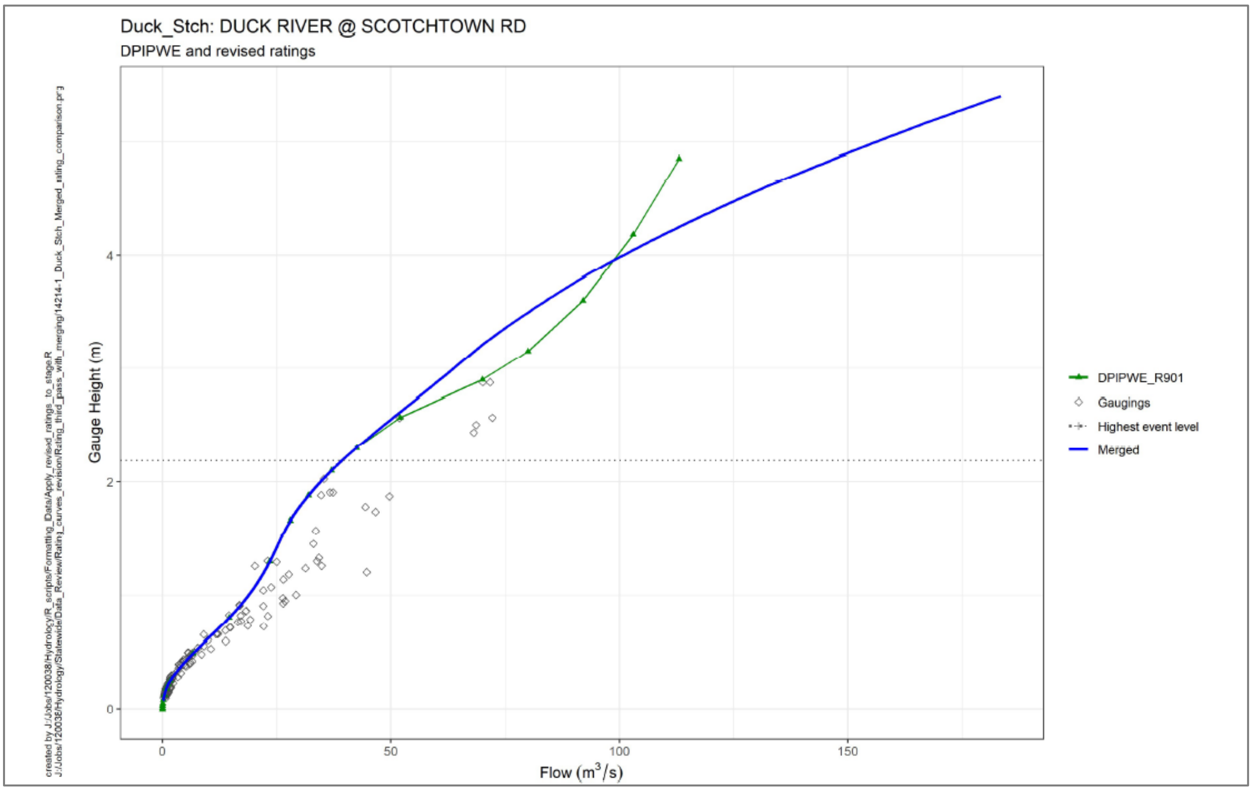

Diagram 6: Duck River at Scotchtown Road revised rating (from WMAwater 2021c).

The Welcome River at Woolnorth gauge has been well gauged historically, including a gauging at approximately 12 m^3/s in 1981. The highest gauging since 1991 is approximately 7 m^3/s. Historic rating curves are reasonably consistent in the higher flow range (Diagram 7).

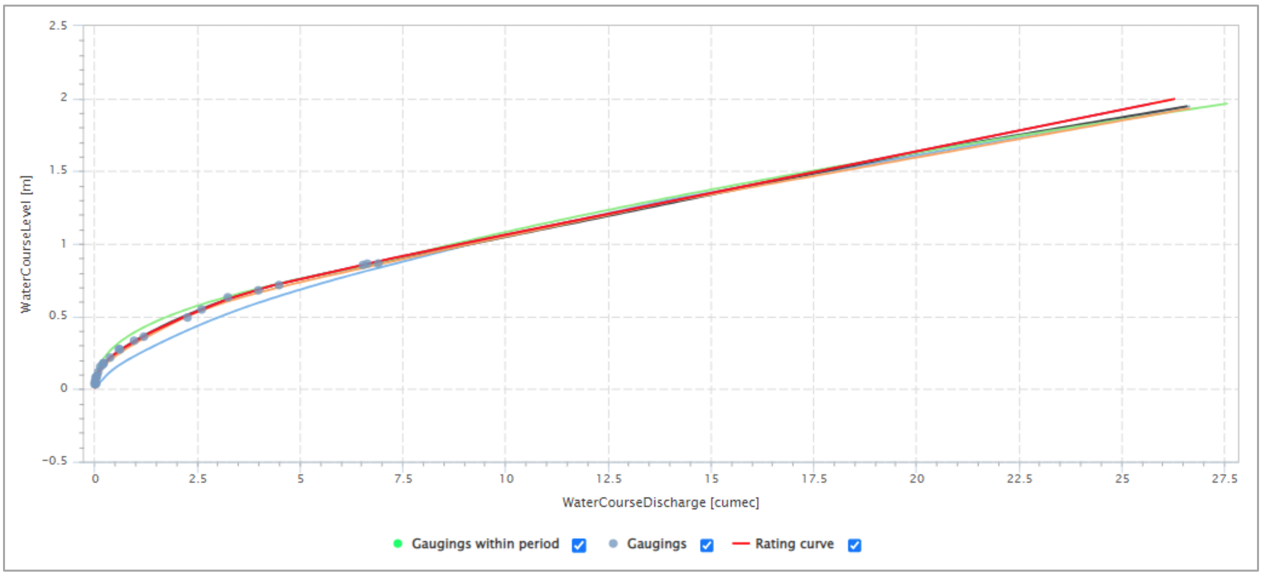

Diagram 7: Welcome River at Woolnorth ratings, current rating shown in red (screenshot from Bureau of Meteorology, 2021)

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 the 13 events were not significant events in the Welcome Duck study area (WMAwater, 2020). An additional calibration event was identified for this catchment, in July 2000 (WMAwater, 2021d).

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 are two sub-daily rain gauges within the Welcome-Duck study area with data available during the July 2000 event, and twelve daily gauges. The daily gauges are well spread over the study area, while the sub-daily rain gauges are in the lower catchments in the study area (Diagram 8). The gauges in and around the Welcome-Duck study area are shown in Figure 1.

Table 3: Available Rainfall Information

	July 2000
Number of Sub-daily Stations Available within the study area	2
Number of daily Stations Available within the study area	12
Number of sub-daily surrounding gauges ~15km	1
Number of daily surrounding gauges ~15km	3
Rainfall Totals	70-140 mm
Approx duration of rainfall event (hours)	72

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

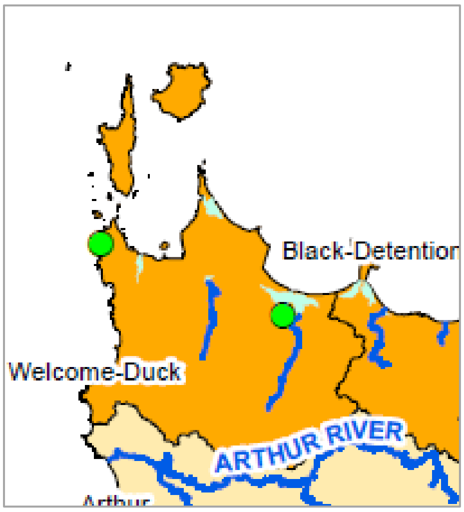

Diagram 8: Sub-daily rainfall gauges, July 2000 (from WMAwater, 2021d).

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 surface for the selected calibration event is shown in Figure 3.

3.3. Dam Information

There is one significant dam that was explicitly modelled in the Welcome-Duck study area, operated by Taswater. Details are shown in Table 4 (from DPIPWE, 2009).

Table 4: Dam information

Name	Storage Volume (ML)	Storage Elevation at FSL	Crest Length (m)	Spillway Width (m)
Mikany Dam	2741	35.4	400	16

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 used at two of the four operational gauges in the study area, with the SES state-wide 10 m DEM used at the remaining gauges (Welcome River and Montagu River). 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 is shown in Diagram 9.

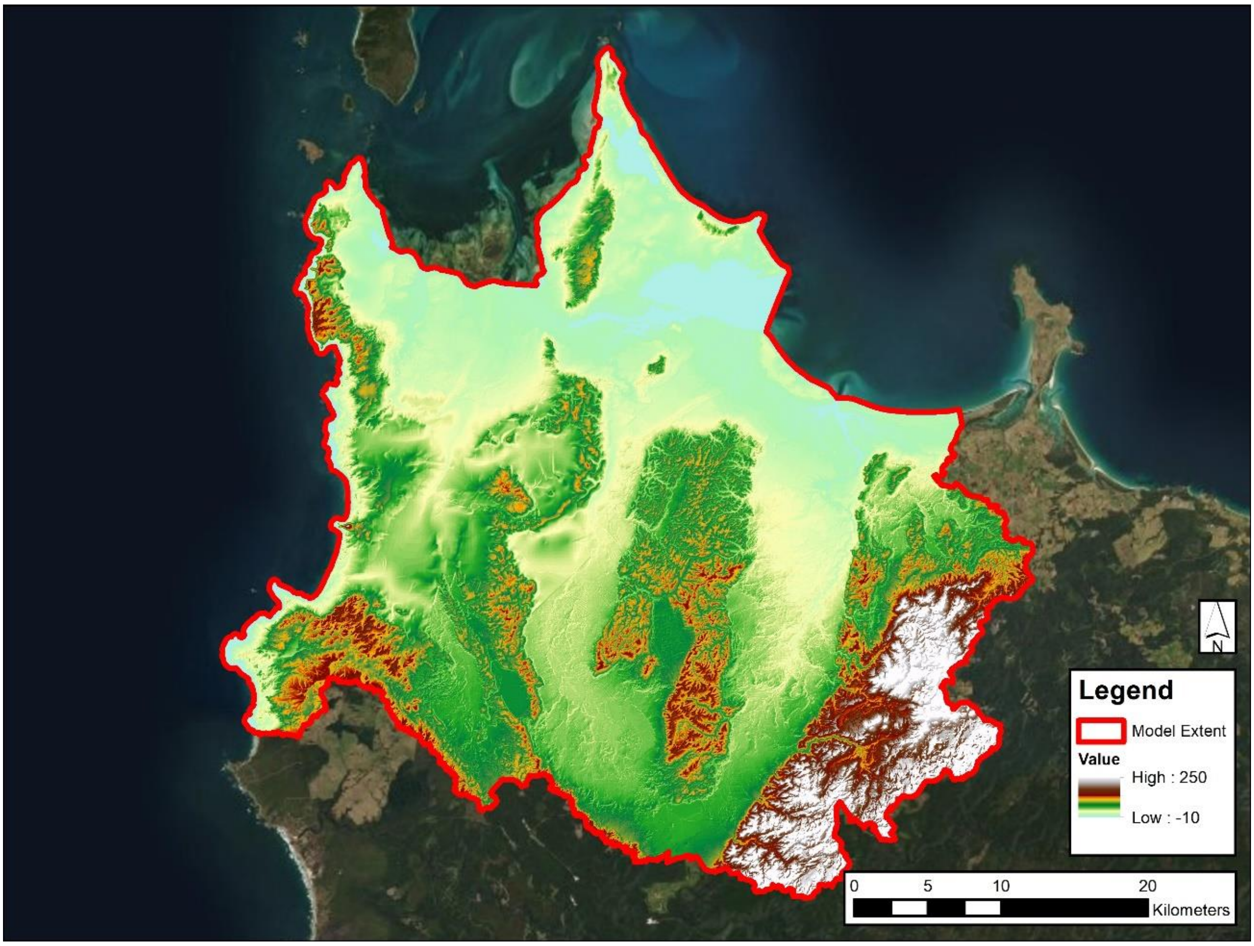

Diagram 9: DEM of the Welcome-Duck study area

The SES state-wide 10 m DEM consists of a 'Default DTM' that is state-wide and a 'LiDAR DTM' that covers the areas where LiDAR data was available at the time, as shown in Diagram 10.

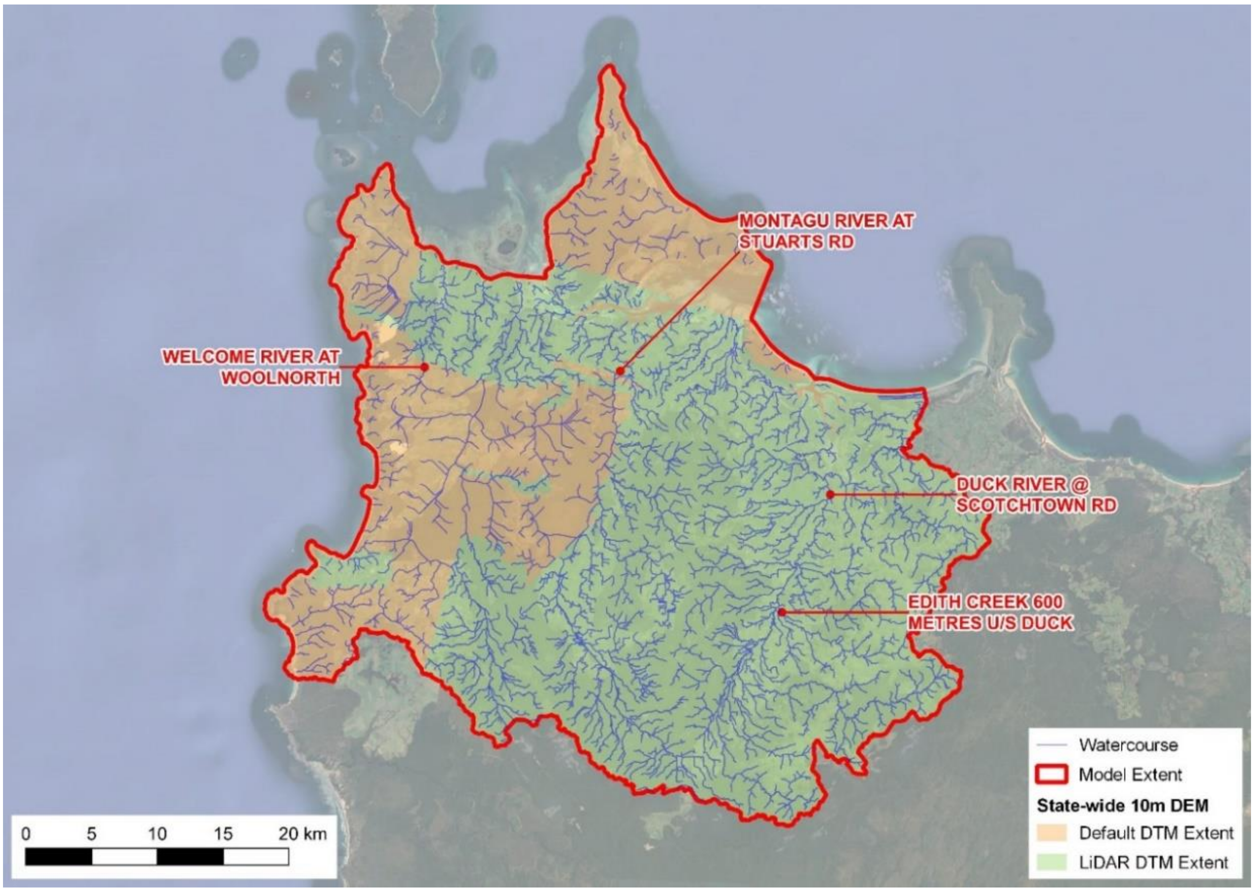

Diagram 10: ‘Default DTM’ extents for the Welcome-Duck study area

The majority of the DEM along Welcome River is covered by the poor quality ‘Default DTM’ and it was found that the modelled flow paths do not match the actual flow paths. The southern portion of catchment is diverting to the west rather than following the path of the Welcome River north. This means over 40% of the catchment area is incorrectly discharging into Ann Bay in the Southern Ocean instead of into Boullanger Bay in Bass Strait (Diagram 11). Additionally, the majority of flows to the east of the gauge are diverted directly north into the Harcus River rather than following the Welcome River west, this results in almost no flows reaching the Welcome River gauge as shown in Diagram 11. There are river improvement works in the area that are not well represented in the DEM.

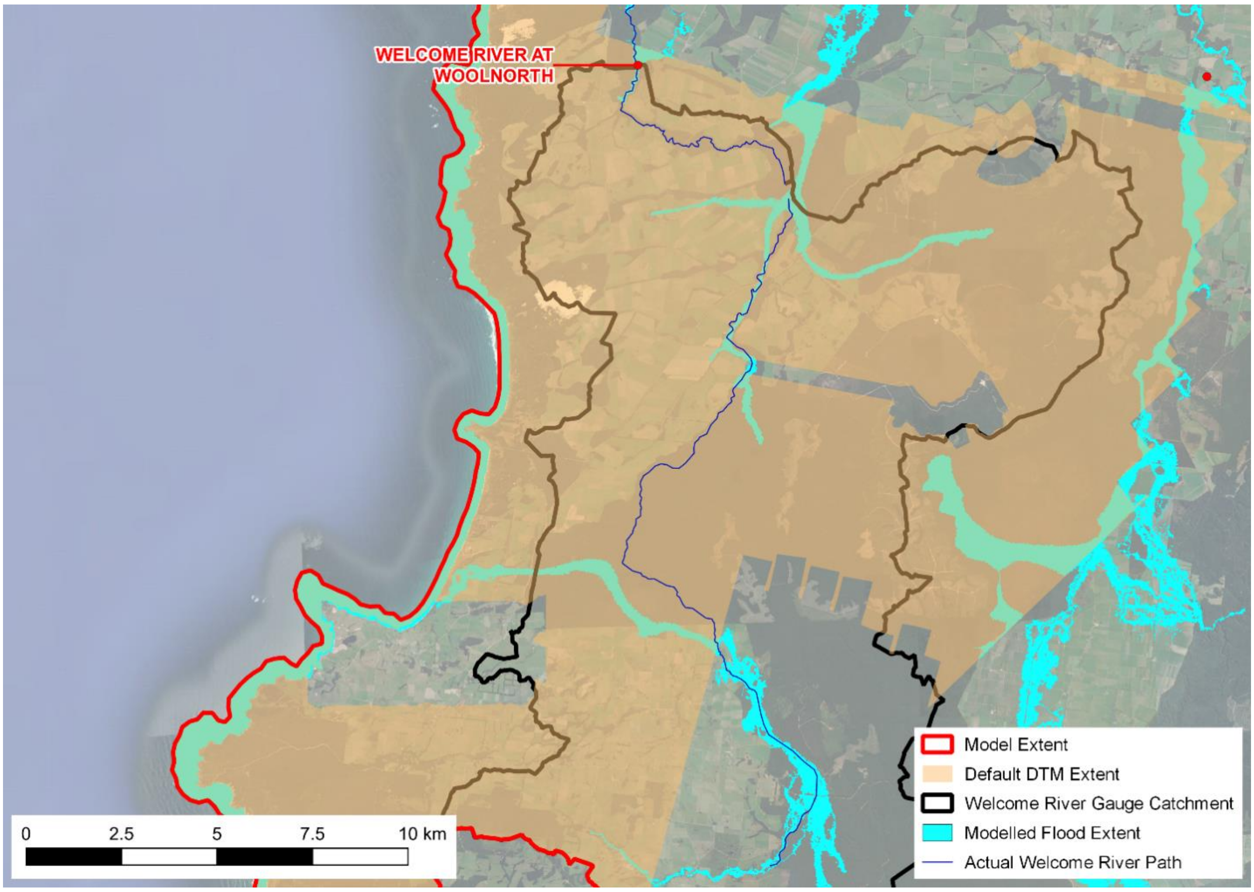

Diagram 11: Welcome River catchment modelled flood extent

A review of the DEM along Montagu River found that the 10 km reach upstream of the Montagu River gauge abruptly transitions from the 'LiDAR DTM' to the poor quality 'Default DTM' at several locations. This is expected to impact the routing of the hydrodynamic model. In addition, the area just upstream of the gauge is covered by the 'Default DTM' and the modelled flow paths do not match the actual flow paths. This results in no flows reaching the gauge (as the flows are diverted to the east), as shown in Diagram 12.

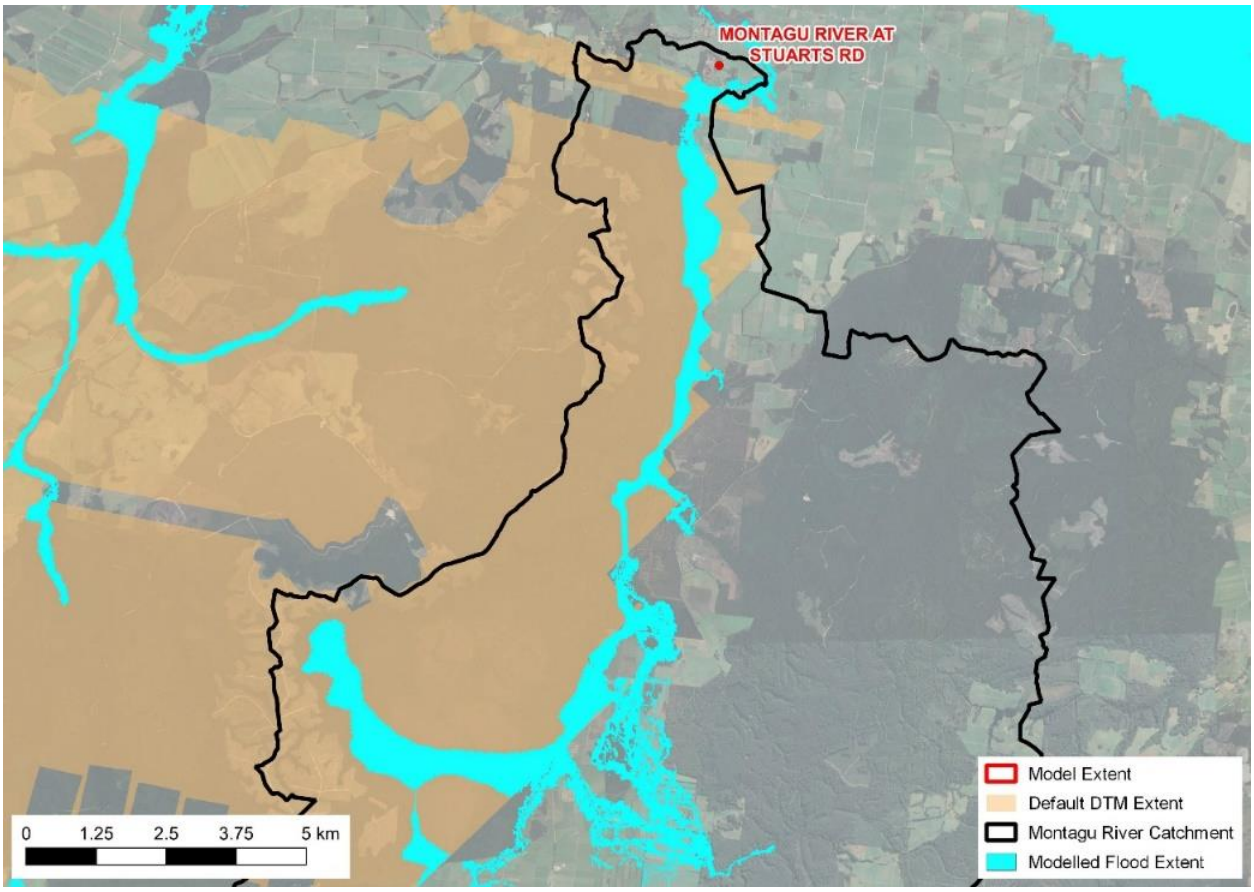

Diagram 12: Montagu River catchment modelled flood extent

A review of the DEM along Duck River found that a breach was incorrectly applied to the river channel between the quarry in Smithton and the Duck River bridge, resulting in erroneous levels along the river channel in the order of -20 mAHD. This is not expected to impact the calibration of the hydrodynamic model as all calibration points are upstream of the area, however, should be addressed in design given the proximity to the population centres, should improved bathymetry data be available.

The poor quality DEM in parts of this study area means that it was not possible to undertake a credible calibration at the Welcome River and Montagu River gauges and that mapped flood extents do not reflect the true flow paths.

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). 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.

During the calibration process, modifications were made to the roughness at the gauge supported by aerial imagery which identified that the area at and downstream of the gauge is constantly full of water. To represent this, the channel roughness at the gauge was decreased from the default of 0.05 to 0.02.

The resulting roughness layer is shown in Diagram 13.

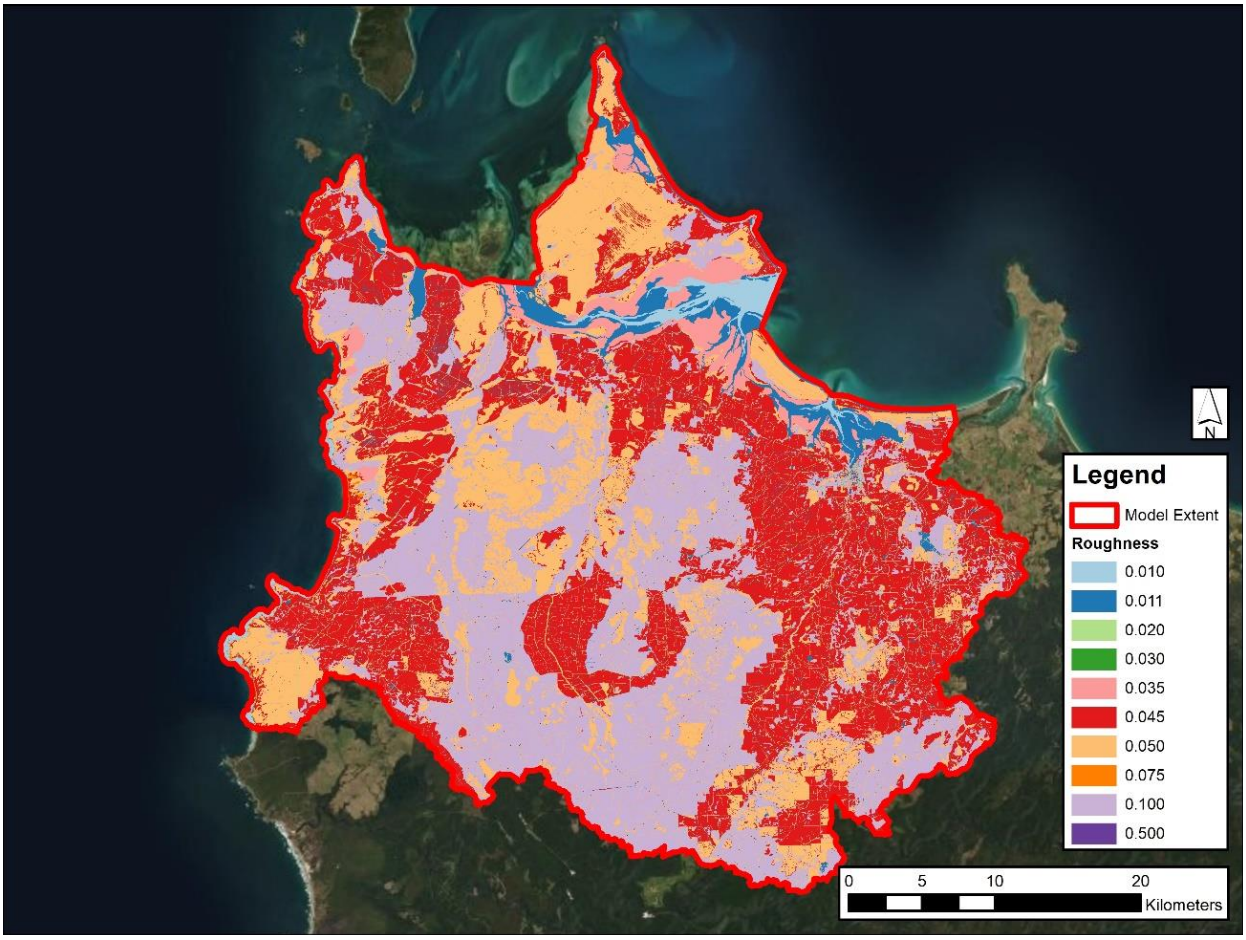

Diagram 13: Roughness layer for the Welcome-Duck study area

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 m^2 and a minimum of 400 m^2
- Stream mesh zones – set as an independent mesh zone with a maximum mesh size of 400 m^2 and a minimum of 100 m^2
- Upper stream mesh zones – streamlines of strahlar order 2-5 and strahlar 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 m^2 and a minimum of 100 m^2. 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 m^2 and a minimum of 25 m^2

The resulting mesh zones are shown in Diagram 14.

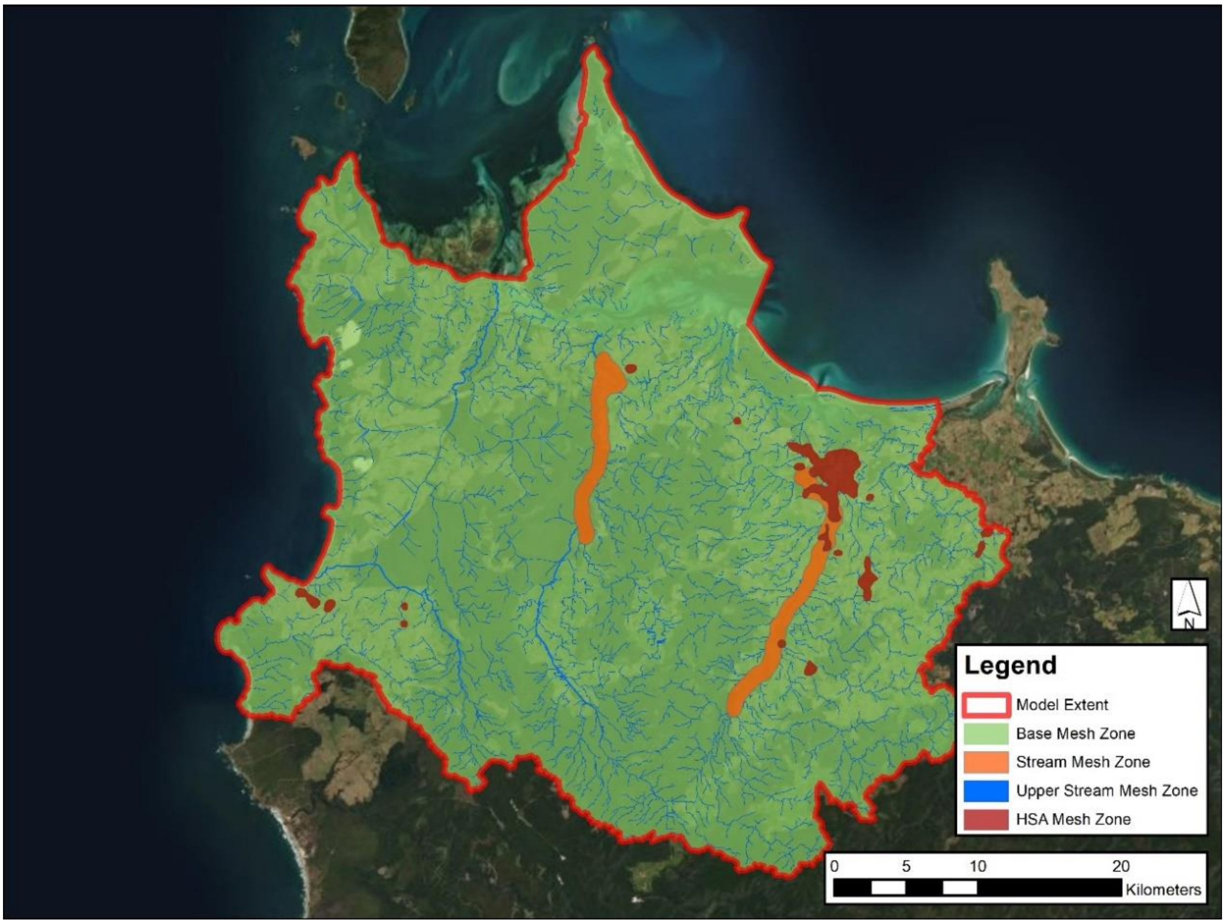

Diagram 14: Mesh zones for the Welcome-Duck study area

5.4. Structures

Within the study area, four significant bridges were identified from the SES state-wide bridge database and these were modelled in the hydrodynamic model in the 2D domain using linear 2D bridge structures. Further discussion on this process is provided in the Hydrodynamic Modelling Methods Report (WMAwater, 2021b).

The bridges modelled included:

- Trowutta Road at Duck River (near Upper Scotchtown Road)
- Kubanks Road at Duck River
- Bass Highway at Duck River
- Duck River Bridge, Smithton

Within the study area, one significant culvert was identified and was modelled in the hydrodynamic model in the 1D domain (linked to the 2D domain). As detailed drawings were not available, the dimensions and inverts of the culvert was estimated from aerial imagery and the DEM.

The details of the culvert are as follows:

- Bass Highway at Deep Creek – assumed to be a 3/2700x2700 RCBC

The locations of the modelled structures are shown in Diagram 15.

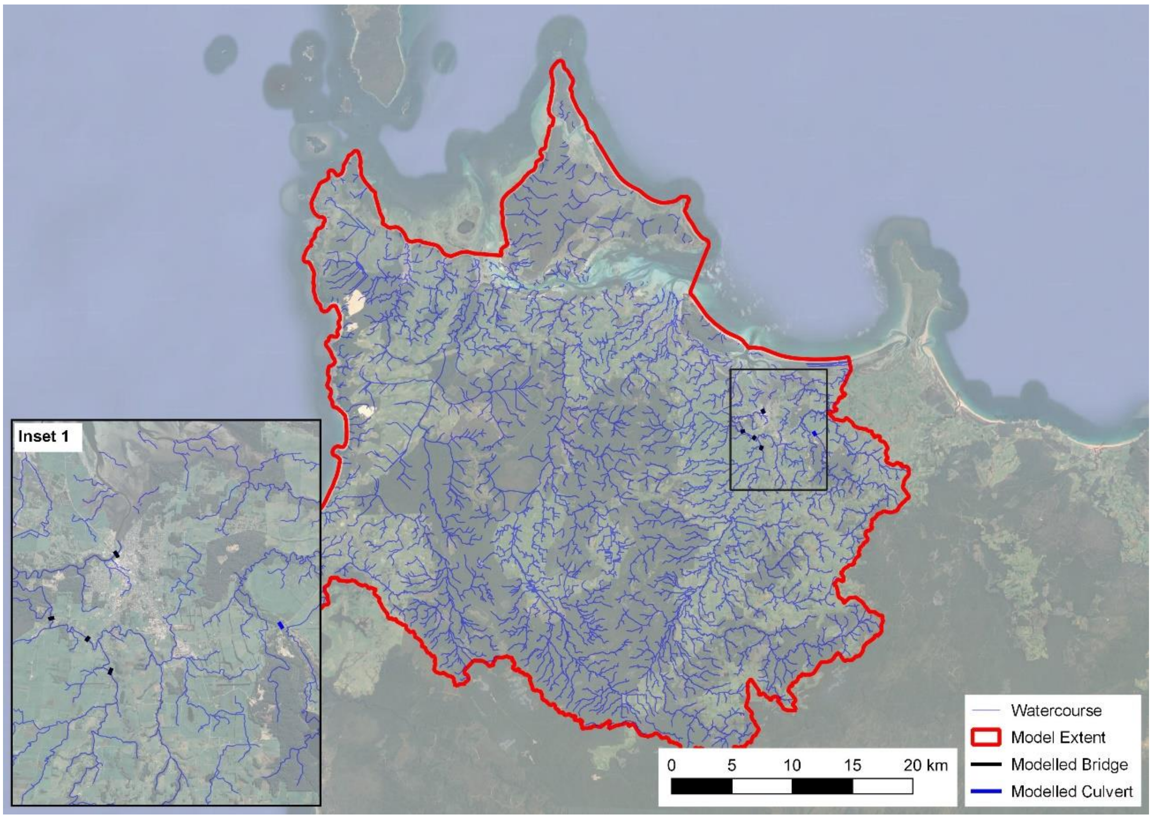

Diagram 15: Modelled structures in the Welcome-Duck study area

5.5. Dams

Mikany Dam was modelled in the hydrodynamic model in the 2D domain, assuming initial conditions at the full supply level of the dam. As detailed drawings were not available for this study, the dimensions of the spillway were estimated from available photography and the spillway was modelled assuming a broad-crested weir.

5.6. Downstream Boundaries

Downstream boundaries were applied at the base of the model to provide the interaction with the tidal zone. Given the proximity of the Welcome-Duck study area to the Burnie Tide Gauge, real tide data was extracted for this study area for the July 2000 calibration event. This data was extracted at 60-minute time increments from the Bureau of Meteorology Australian Baseline Sea Level Monitoring Project Portal and was imported into the hydrodynamic model as a time varying boundary condition.

Missing data was found between 21 July 2000 to 11 August 2000 (which includes the peak of the July 2000 calibration event) and was inferred from the last recorded high and low tide. It is noted that the selection of the tailwater condition is not expected to impact the calibration of the hydrodynamic model as all calibration points are upstream of the tidal zone. Diagram 16 shows the tide data that was used for the July 2000 event.

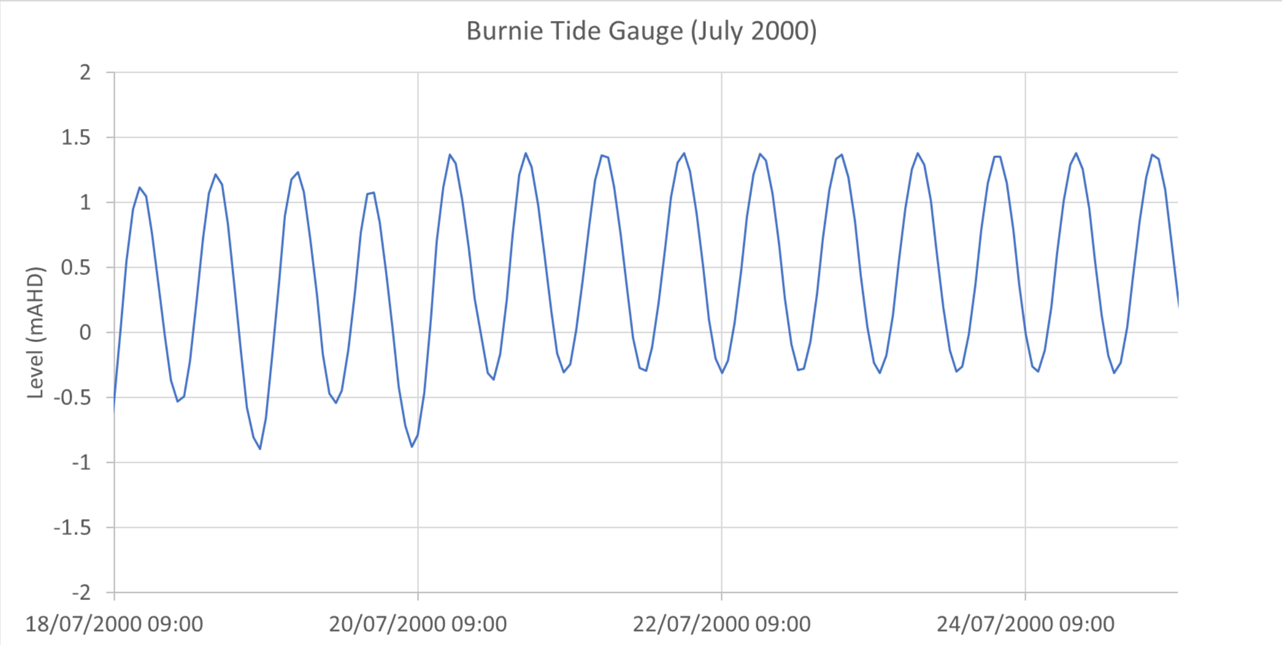

Diagram 16: Burnie Tide Gauge (July 2000)

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 17. 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.

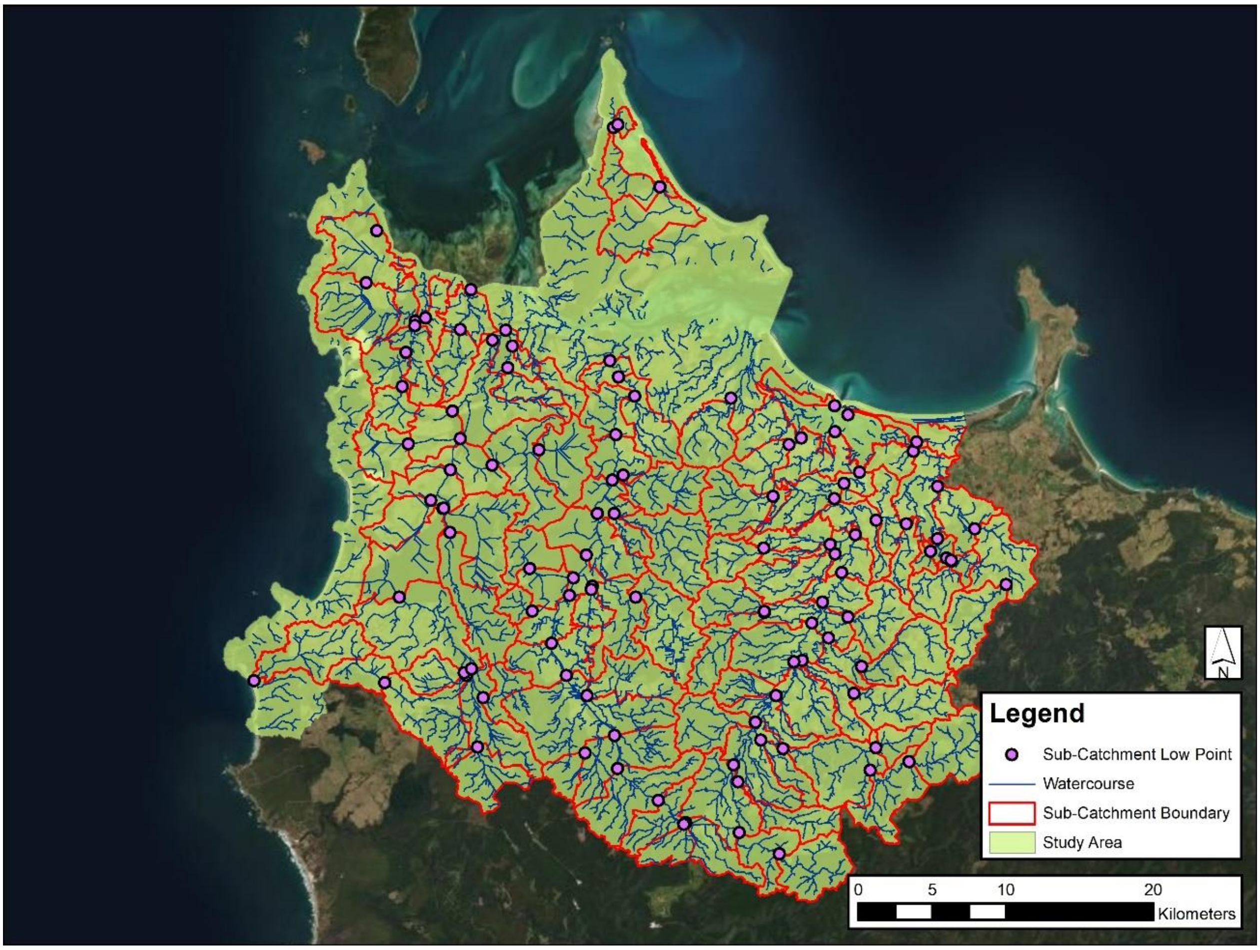

Diagram 17: RAFTS sub-catchment model setup for the Welcome-Duck study area

6. CALIBRATION RESULTS

Calibration to Welcome River and Montagu River gauges was not able to be undertaken in the ICM model due to the DEM issues presented in Section 5.1. The hydrodynamic model has been calibrated to Duck River gauge. Calibration to the other gauges could be undertaken in ICM when improved topographic information is available. Initial calibration of the routing parameter and losses was undertaken at all gauge sites in the external hydrologic model.

6.1. Sub-catchment Routing and Loss Parameters

The ICM model was run with the routing and loss parameters derived from the external hydrologic model and the calibration process was undertaken for the July 2000 calibration event. A spatially varying sub-catchment routing parameter was not found to be necessary to achieve a reasonable calibration to Duck River, and a single sub-catchment routing parameter was used (RAF of 2).

A RAF of 2 was assumed based on initial model runs which indicated that the routing within the sub-catchment component of the model was faster than the recorded catchment responses. Noting the presence of several large waterfalls and other significant grade variations in the catchment, it is likely the average slope of a number of catchments is over estimated, resulting in a need to offset this with a larger RAF.

A comparison of the selected RAF of 2 and a RAF of 1 at Duck River is shown in Diagram 18.

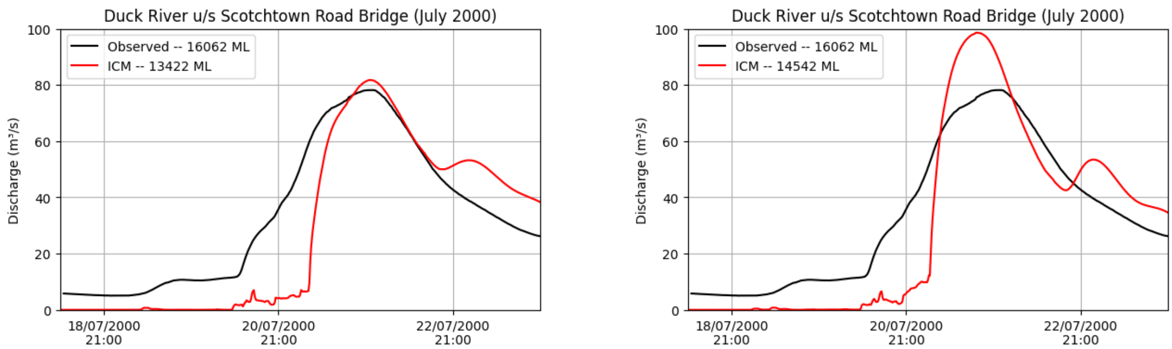

Diagram 18: Flow comparison at Duck River at Sctochtown Road (left: RAF 2, right: RAF 1)

Upon completion of the calibration process, the external hydrologic model and the hydrodynamic model were compared to ensure that the modelled flows are comparable. This is shown in Appendix C.

Differences in the external hydrologic model and the hydrodynamic model were noted in the upper reaches of Montagu River (e.g. WDk93 shown in Appendix C). It is noted that the upper reaches of Montagu River are not affected by the DEM issues presented in Section 5.1.

Review of the hydrodynamic model shows flows across the agricultural fields between WDk89 and WDk93 and the ponding of water at the Bass Highway, as shown in Diagram 19. Minor modifications were made to the hydrodynamic model to improve the local accuracy of the model, however, were not able to reconcile the differences to the external hydrologic model. These modifications included adjusting the mesh zones of the model (to ensure that the main channel was covered by a high-resolution mesh) and carving out a channel in the 2D domain across the Bass Highway structure (to ensure the main river channel was not blocked).

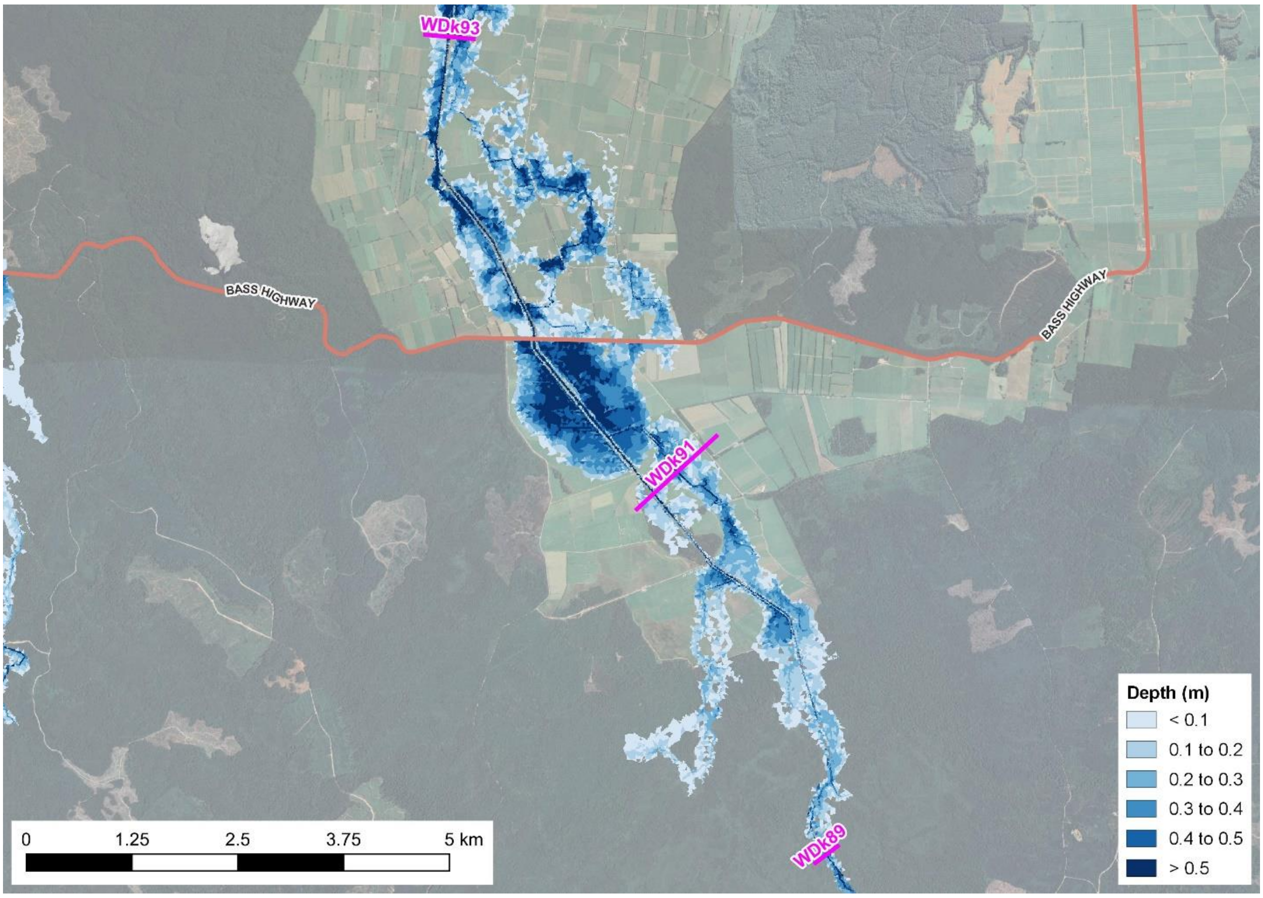

Diagram 19: Modelled peak flood depth in the upper reaches of Montagu River

It is recommended that the channel routing in the external hydrologic model is revisited when the hydrodynamic model can be calibrated to the Montagu River gauge.

6.2. Initial Conditions

Prefilling of the ICM model was not found to be necessary to achieve a reasonable calibration to the Duck River gauge. On occasion it is necessary to prefill hydraulic models to manage the loss of flood volume due to local depression storage. This scenario however may result in filling of floodplain storage and as such should only be considered where necessary. To ensure there was no incidental filling of floodplain storage in this model it has been run without prefilling.

6.3. Gauge Results

Historic event information was available for the July 2000 event at the Duck River gauge and is presented herein. Mapping of the peak flood depths from the hydrodynamic model for the July 2000 calibration event is shown in Figure 4, as discussed in Section 5.1, this includes modelled flows in the Welcome and Montague River which do not align with the known paths of these rivers.

6.3.1. Duck River u/s Scotchtown Road

The modelled peak flow and level for the July 2000 event at the Duck River gauge shows a good match to the recorded peak flow and level (Table 5). The modelled hydrograph and water level response also shows a good match to the timing and shape of the recorded flows and levels, as shown in Diagram 21 and Diagram 22.

A gauge zero of 5.785 mAHD was provided for this gauge from the DPIPWE database. This was adjusted to 5.985 mAHD to better align with the DEM of the hydrodynamic model and align the two rating curves at the location.

While the model appears to respond reasonably well, it is noted that a review of the base DEM at the gauge indicated elevated levels along the river channel. As shown in Diagram 20, it appears that the base DEM has captured the water level in the river channel (set by the weir control for the gauge), instead of the bathymetry of the river channel. No other sources of data were available as part of the project to otherwise inform the bathymetry of the river channel.

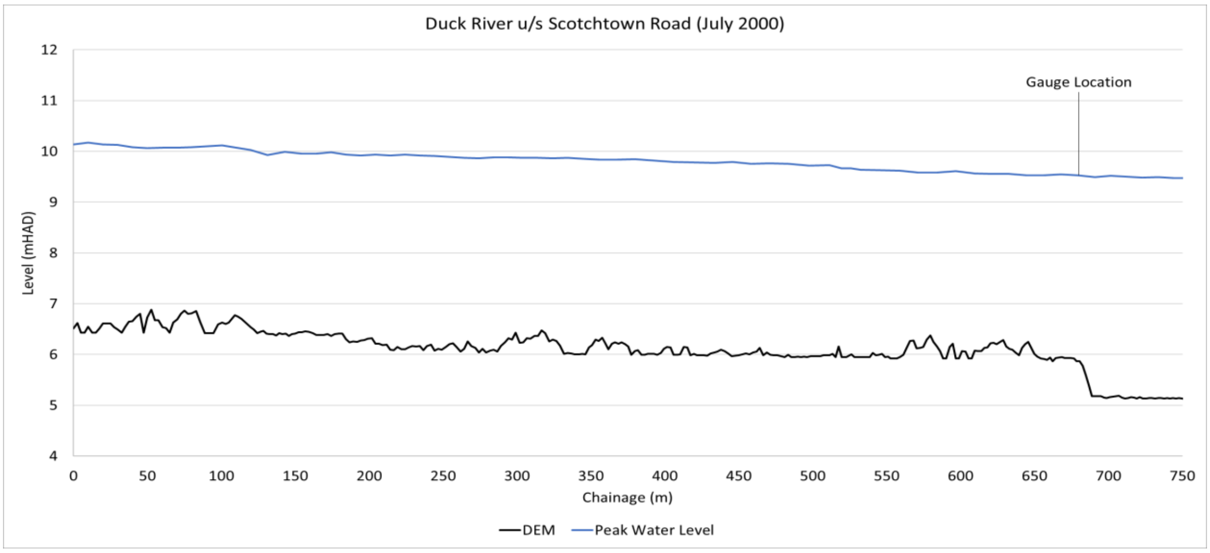

Diagram 20: Profile of the base DEM at Duck River u/s Scotchtown Road

Given the good match to the recorded levels with the current model calibration and the lack of data to otherwise inform the bathymetry of the river channel, no modifications were made to the base DEM. It is recommended that the current model calibration is revisited when improved bathymetry data is available, to ensure that it is appropriate with a revised representation of the river channel and weir control for the gauge.

A comparison of the gauge rating curve and the modelled rating curve is shown in Appendix D. The lack of definition of channel bathymetry impact the modelled rating at lower flows.

Table 5: Calibrated parameters and results at Duck River u/s Scotchtown Road

Statistic	July 2000
IL (mm)	74
Average CL (mm/h)	0
RAF	2
Modelled Peak (m^3/s)	82
Observed Peak (m^3/s)	78
Peak % difference	+5%
Modelled Volume (ML)	13,422
Observed Volume (ML)	16,062
Volume % difference	-16%
Modelled peak (mAHD)	9.52
Observed peak (mAHD)	9.43
Peak difference (m)	+0.09m

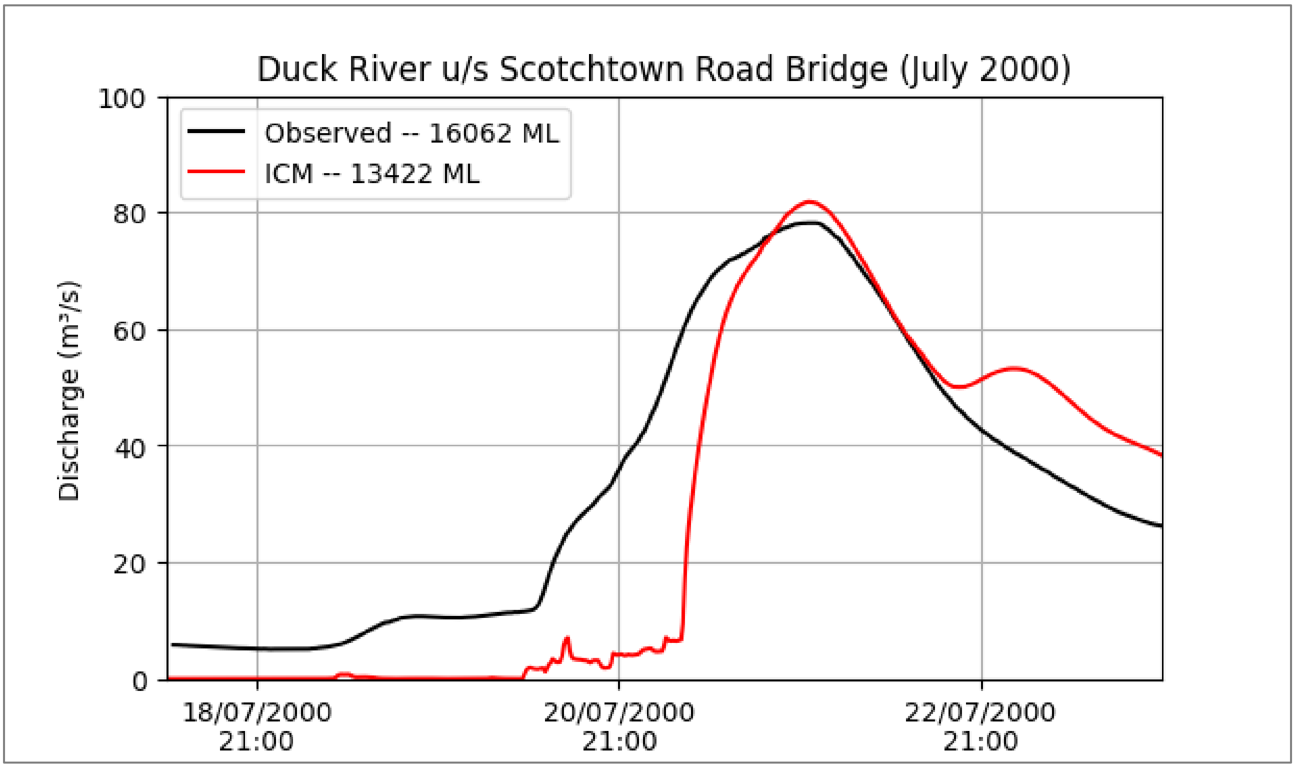

Diagram 21: July 2000 flow comparison at Duck River u/s Scotchtown Road

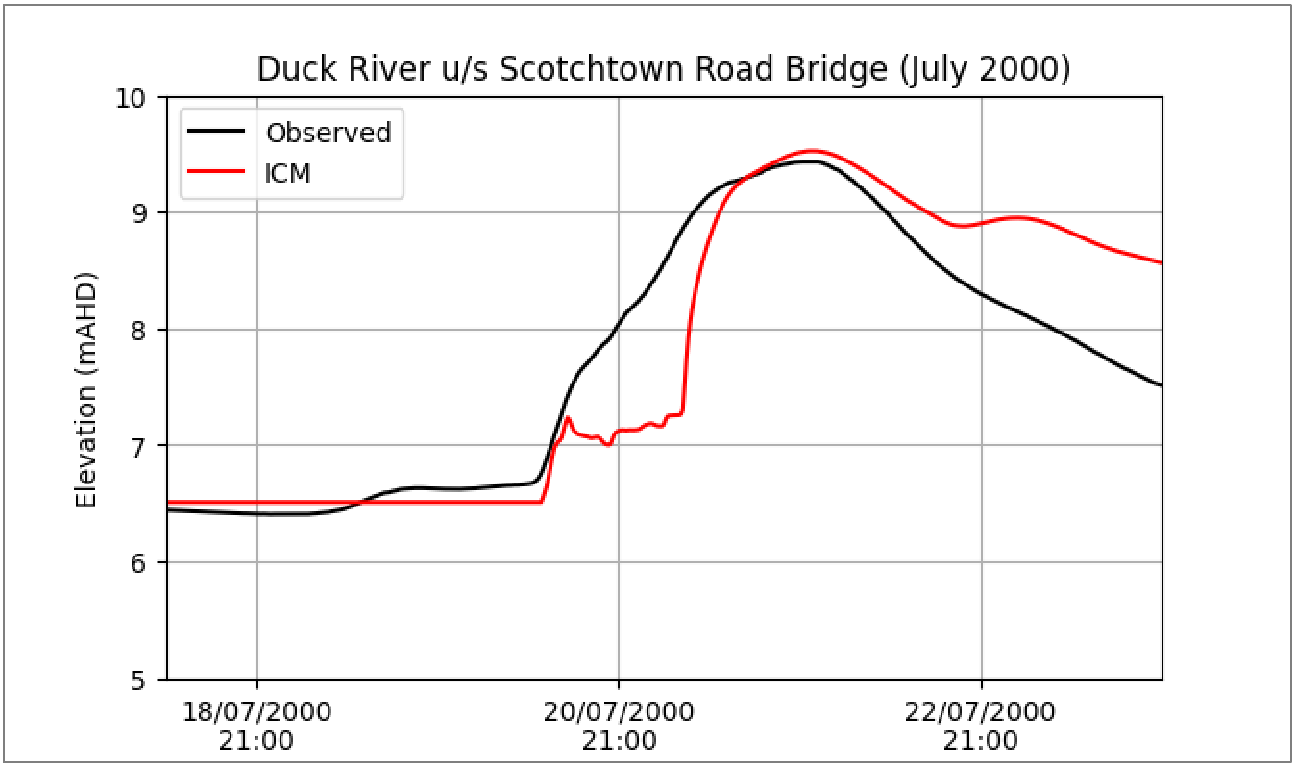

Diagram 22: July 2000 water level comparison at Duck River u/s Scotchtown Road

6.4. Identified Issues

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

- The hydrodynamic model was not able to be calibrated to Welcome River and Montagu River gauges due to the DEM issues presented in Section 5.1 and mapped flow paths do not follow the actual watercourses. If high resolution topographic information is obtained in the future, these areas should be reviewed in detail to ensure appropriate flow and level replication is achieved.
- Due to the limited number of events and locations available for calibration, it is considered that while the model appears to respond appropriately, there is insufficient information to provide a high level of confidence in the model calibration. The model is considered to be valid for Duck River based on the available information, however, future detailed analysis should attempt the calibration of other events and locations to improve the confidence in the model calibration.
- If available, the representation of the significant structures across the Bass Highway should be updated with as constructed or surveyed data instead of the estimated parameters that are currently used.
- If available, the representation of the rivers and channels that that are frequently submerged (such as the river channel upstream and downstream of the weir at the Duck River gauge) should be updated with improved bathymetry data.

7. UNCERTAINTY ASESSMENT

Significant flows were not recorded in the catchment area for any of the 13 flood events selected by the Bureau as calibration events for this project. An additional event was used for calibration, in July 2000.

Flow data was available at three gauges for the calibration events, and these were used for calibration of the external hydrologic model. The ICM model was calibrated to the Duck River u/s Scotchtown Road gauge. The ICM model could not be calibrated at gauges on the Welcome River and Montagu River due to issues in the DEM. Large areas of the DEM in this study area are covered by the poor quality ‘Default DTM’ and it was found that the modelled flow paths do not match the actual flow paths.

Due to the limited number of events and locations available for calibration, it is considered that while the model appears to respond appropriately, there is insufficient information to provide a high level of confidence in the model calibration. The model is considered to be valid based on the available information, however, future detailed analysis should attempt the calibration of other events and locations to improve the confidence in the model calibration.

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

The uncertainty assessment for the modelling is shown in Table 6 and Appendix B.

Table 6: Uncertainty assessment for Welcome Duck study area model

Category	Quality statement
Hydrology – rainfall input quality	The quality of the rainfall data is generally good. There are two sub-daily raingauges operating in the lower region of the study area for the calibration event and a good spread of daily gauges within the study area. There is some uncertainty in event temporal patterns in the upper catchment, given the lack of sub-daily raingauges in this area.
Hydrology – observed flows	The rating for the Duck River gauge used in calibration is considered to be good based on use of a theoretical rating developed using a local hydraulic model, which was used in calibration.
Hydrology – calibration events	The July 2000 event was the largest on record at the Duck River and Montagu River gauges. Only one event was used for calibration in this catchment. None of the events identified by the Bureau of Meteorology for use in this study were significant in this catchment.
Hydrology – calibration results	The hydrology calibration was considered to provide an excellent match to peak flows at the Duck River gauge and a very good match to observed volume and hydrograph shape.
DTM definition	Large areas of the DEM in this study area are covered by the poor quality ‘Default DTM’ and it was found that the modelled flow paths do not match the actual flow paths. The DEM is considered to be poor for this study area.

Category	Quality statement
DTM waterways	No bathymetric data was available and waterway definition was based on the LiDAR to water surface or the default DEM. Waterway definitely was considered to be poor.
Hydrodynamic – calibration results, peak levels	Modelled peaks were considered to be excellent match to the observed peak at the Duck River gauge, with the modelled peak within 0.1 m of observed.
Hydrodynamic – calibration results, flood extents	No flood extents were available in this study area
Hydrodynamic – calibration results, flood depths	No flood depths were available in this study area

8. REFERENCES

Babister, M., Trim, A., Testoni, I. & Retallick, M (2016): The Australian Rainfall & Runoff Datahub 37th Hydrology and Water Resources Symposium Queenstown NZ, 2016 available at http://data.arr-software.org/

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (2019): Editors Australian Rainfall and Runoff: A Guide to Flood Estimation Commonwealth of Australia, Australia, 2019

Bureau of Meteorology (2019): 2016 Rainfall IFD Data System. Bureau of Meteorology, Victoria, Australia URL: http://www.bom.gov.au/water/designRainfalls/revised-ifd/

Bureau of Meteorology (2020): Rainfall Map Information. Bureau of Meteorology, Victoria, Australia URL: http://www.bom.gov.au/climate/austmaps/about-rain-maps.shtml

Bureau of Meteorology (2021): Water Data Online. http://www.bom.gov.au/waterdata/

DPIWE (2003): State of Rivers Report for the Duck River Catchment, Water Assessment and Planning Branch, DPIWE, Report WAP 03/08, December 2003.

DPIPWE (2009): Dam Permit Locations – The List Map. https://www.thelist.tas.gov.au/app/content/data/geo-meta-data-record?detailRecordUID=94cdc4f5-07f6-4ac7-9db1-0c21d3715e32

DPIPWE (2019): Hydrologic Soil Groups of Tasmania (Unpublished). Department of Primary Industries and Water, Hobart, Tasmania. Created March 2019

DPIPWE (2022): Tasmania Water Information Web Portal. Department of Primary Industries and Water, Hobart, Tasmania.

Tasmanian Irrigation (2021): Active Schemes List – Scheme Snapshots. https://www.tasmanianirrigation.com.au/active-schemes-map

WMAwater (2020): Tasmanian Strategic Flood Map Data Review, September 2020. Report for State Emergency Service, Tasmania.

WMAwater (2021a): Tasmanian Strategic Flood Map Hydrology Methods Report, August 2021. Report for State Emergency Service, Tasmania.

WMAwater (2021b): Tasmanian Strategic Flood Map Hydrodynamic Model Methods Report, August 2021. Report for State Emergency Service, Tasmania.

WMAwater (2021c): Tasmanian Strategic Flood Map, Flow Gauge Rating Revision, Draft, May 2021.

WMAwater (2021d): Tasmanian Strategic Flood Map, Additional Calibration Event Rainfalls Report, November 20201. Report for State Emergency Service, Tasmania.

Figures

FIGURE 01
WELCOME-DUCK STUDY AREA

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FIGURE 02
WELCOME-DUCK STUDY AREA LAND USE

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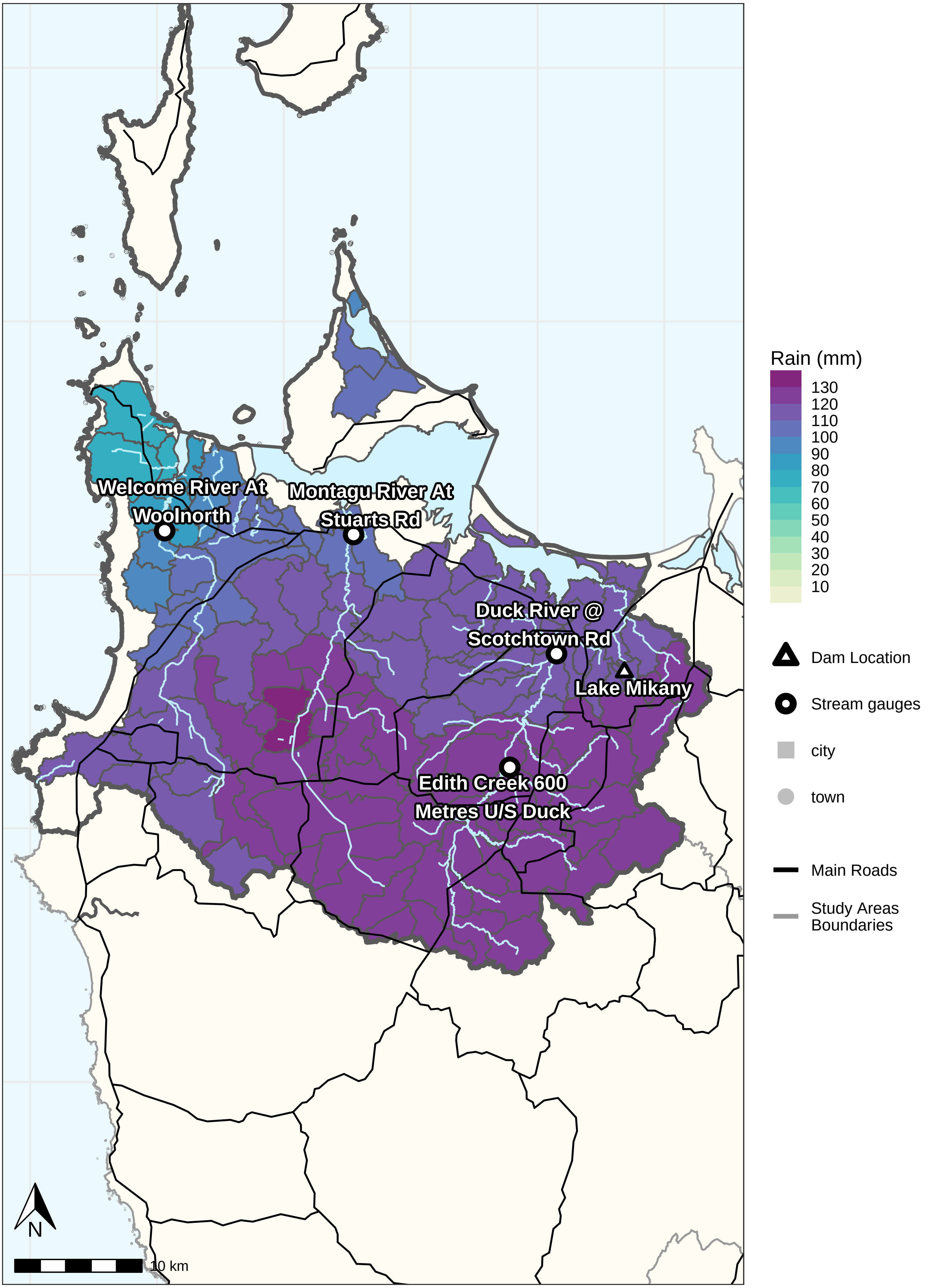
FIGURE 03
WELCOME−DUCK STUDY AREA
RAINFALL 2000_JUL



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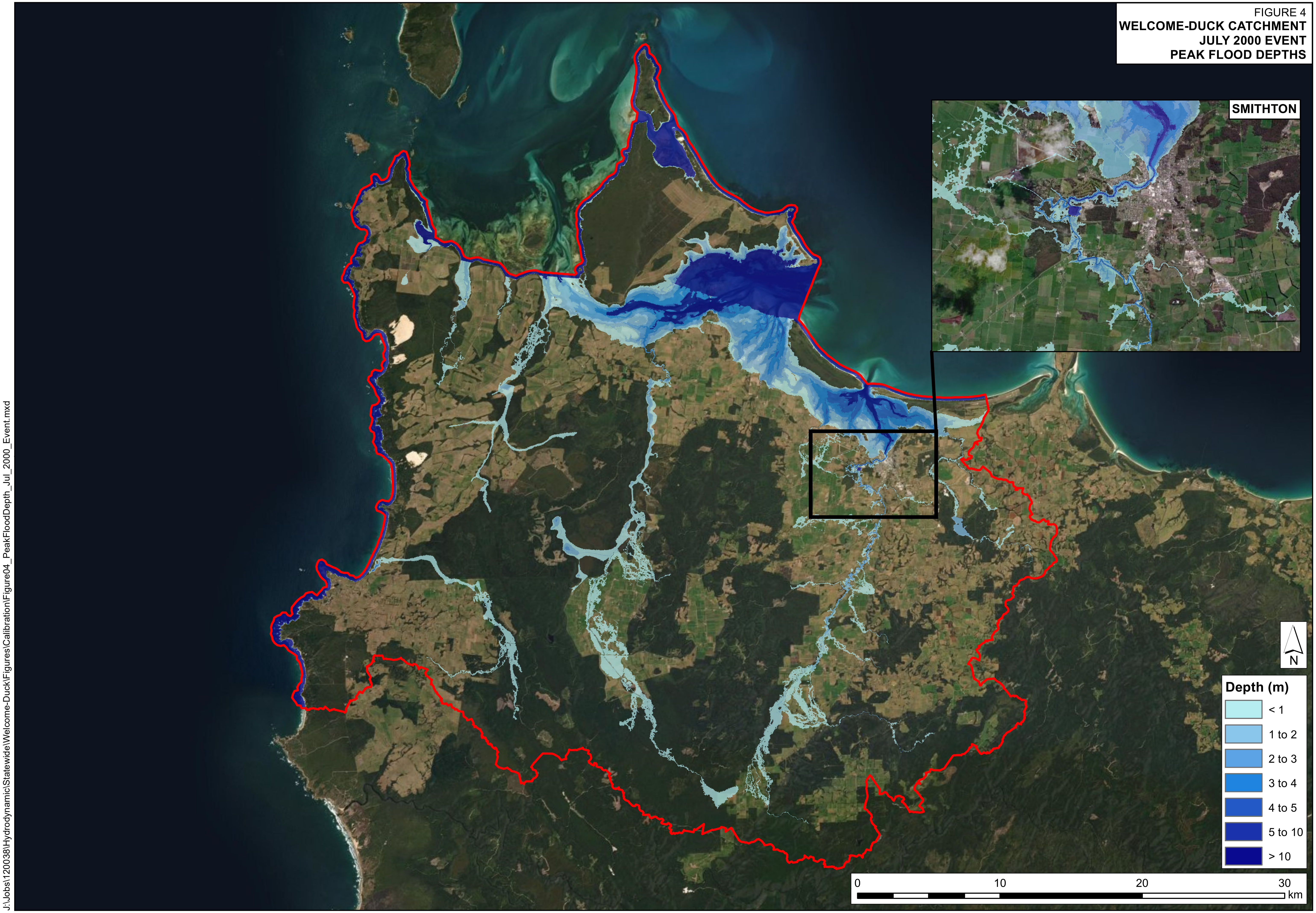


FIGURE 4
WELCOME-DUCK CATCHMENT
JULY 2000 EVENT
PEAK FLOOD DEPTHS
SMITHTON
N
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
30
km
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Calibration\Figure04_PeakFloodDepth_Jul_2000_Event.mxd

Appendix A

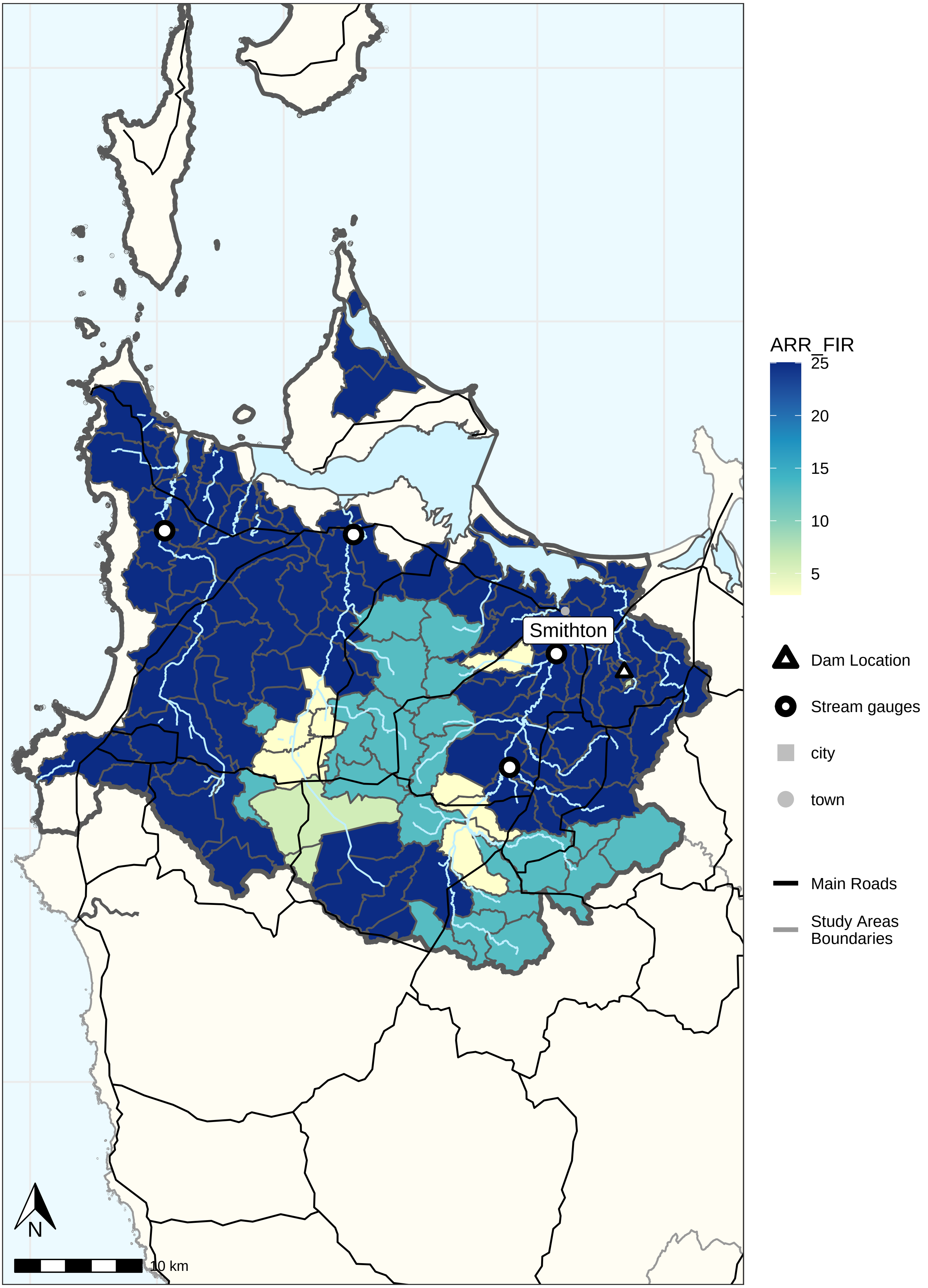
APPENDIX A. AVALIABLE DATA

A.1. Sub catchment data

FIGURE A1

HYDROLOGICAL SOIL GROUP MAPPING

DOMINANT SUBCATCHMENT SOIL INFILTRATION RATE



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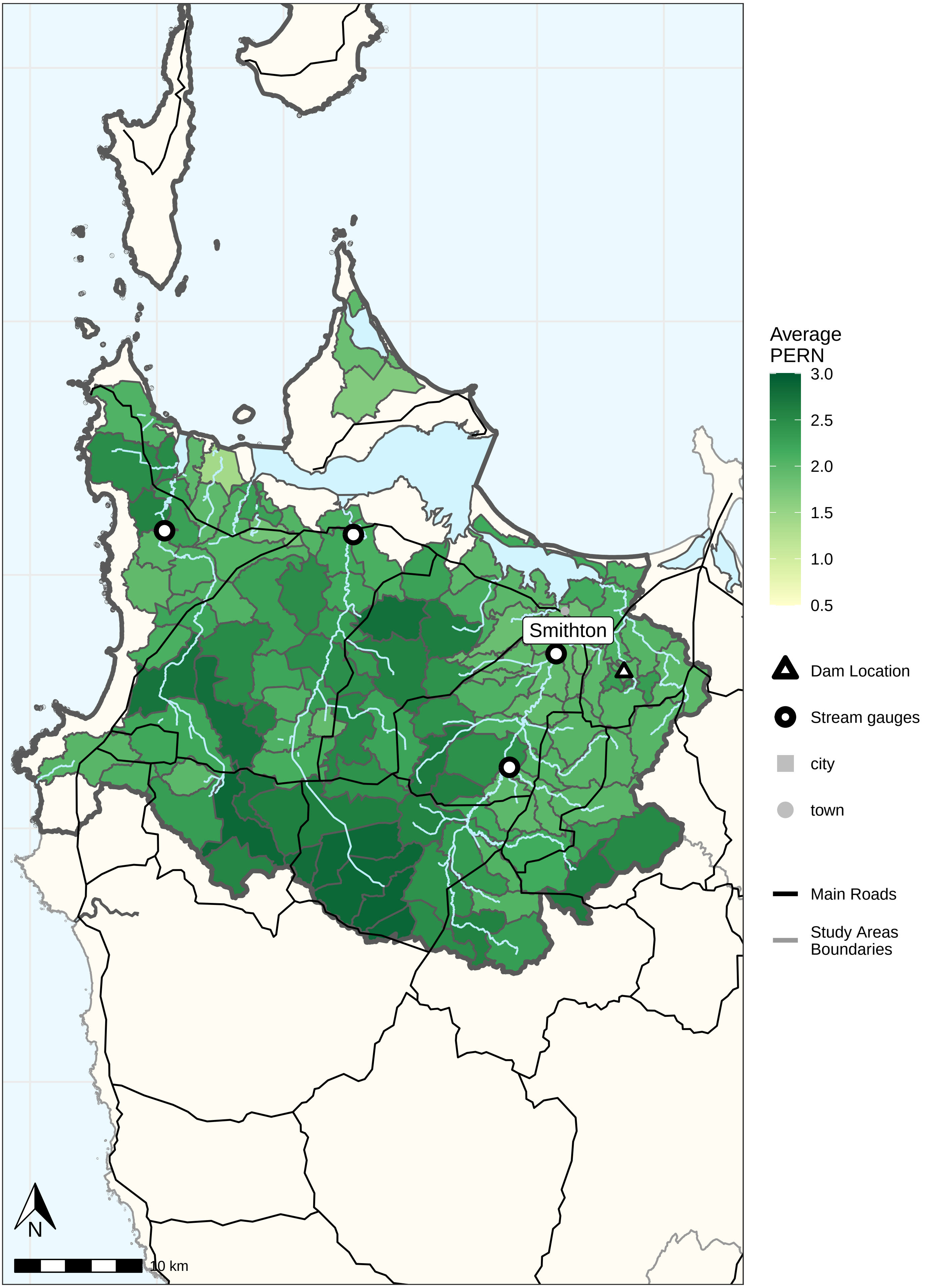
J:/Jobs/120038/Hydrology/Statewide/Calibration/Welcome−Duck/Subcatchment_rainfalls/Figure_A1_Welcome−Duck_SoilTypesReport.pdf

FIGURE A2
WELCOME−DUCK 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.

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. Green shading is used to highlight relevant statements:

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 relevant statements highlighted 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 AND ICM HYDRODYNAMIC MODEL COMPARISON

Figure C 1: Event hydrographs

<table>
<tr><th>Catchment</th><th>July 2000</th></tr>
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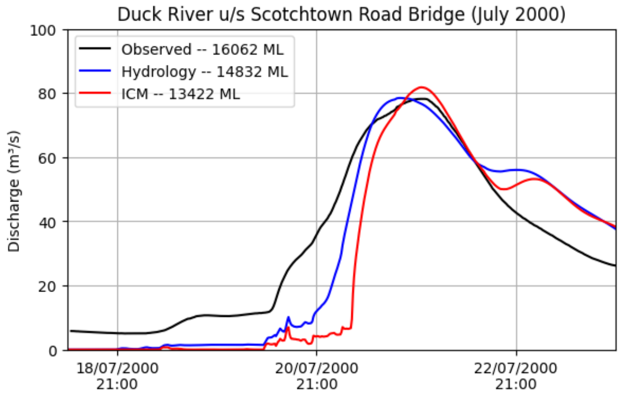

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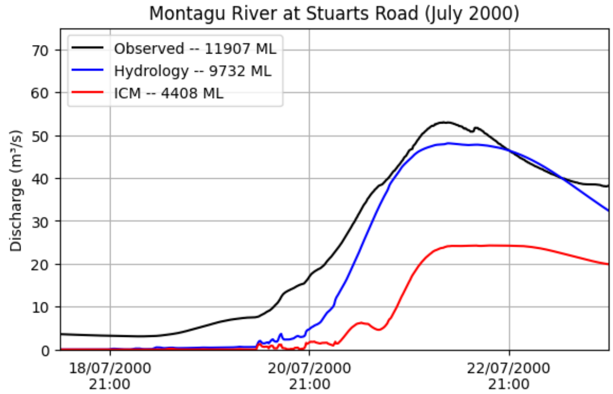

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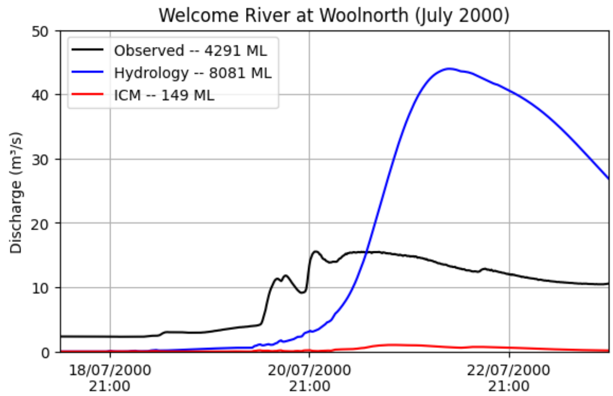

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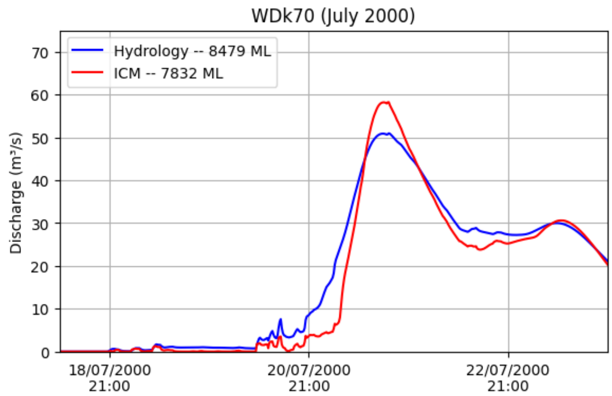

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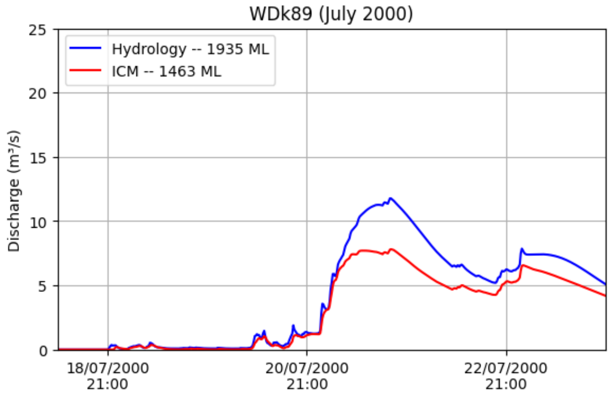
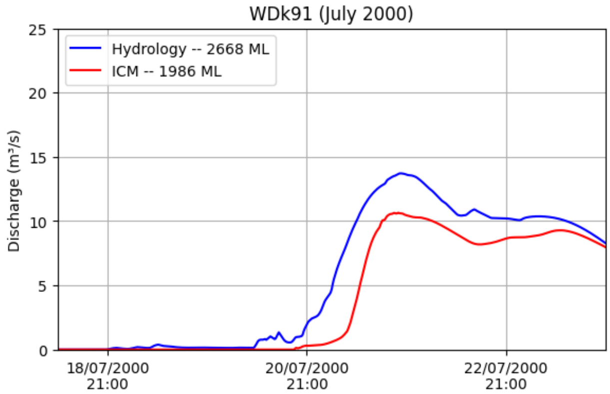
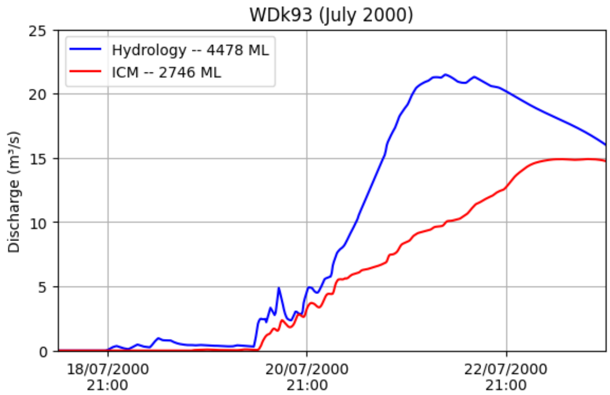
wdk89


WDk89 (July 2000)
Hydrology -- 1935 ML
ICM -- 1463 ML
Discharge (m³/s)
18/07/2000 21:00
20/07/2000 21:00
22/07/2000 21:00

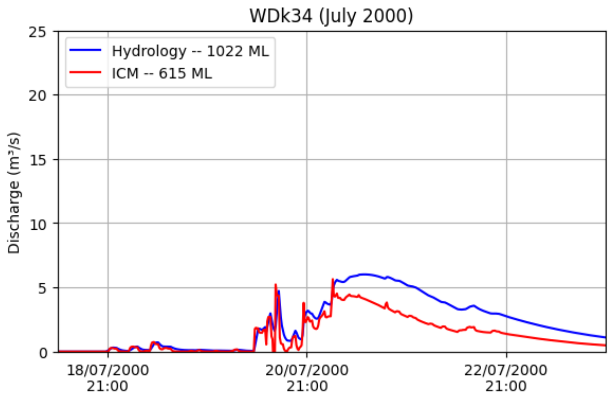

wdk91


WDk91 (July 2000)
Hydrology -- 2668 ML
ICM -- 1986 ML
Discharge (m³/s)
18/07/2000 21:00
20/07/2000 21:00
22/07/2000 21:00

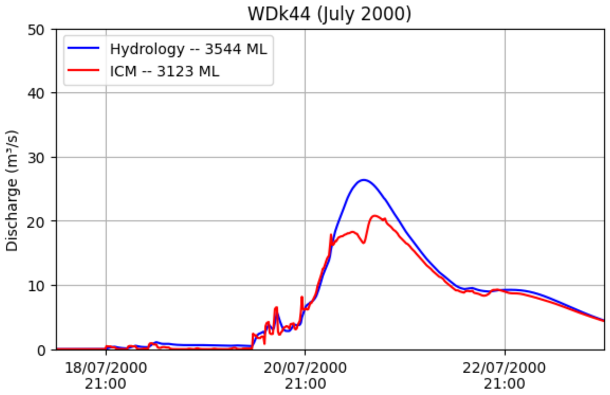

wdk93


WDk93 (July 2000)
Hydrology -- 4478 ML
ICM -- 2746 ML
Discharge (m³/s)
18/07/2000 21:00
20/07/2000 21:00
22/07/2000 21:00


wdk34


WDk34 (July 2000)
Hydrology -- 1022 ML
ICM -- 615 ML
Discharge (m³/s)
18/07/2000 21:00
20/07/2000 21:00
22/07/2000 21:00


wdk44


WDk44 (July 2000)
Hydrology -- 3544 ML
ICM -- 3123 ML
Discharge (m³/s)
0
10
20
30
40
50
18/07/2000 21:00
20/07/2000 21:00
22/07/2000 21:00

Appendix D

APPENDIX D. RATING CURVE COMPARISON

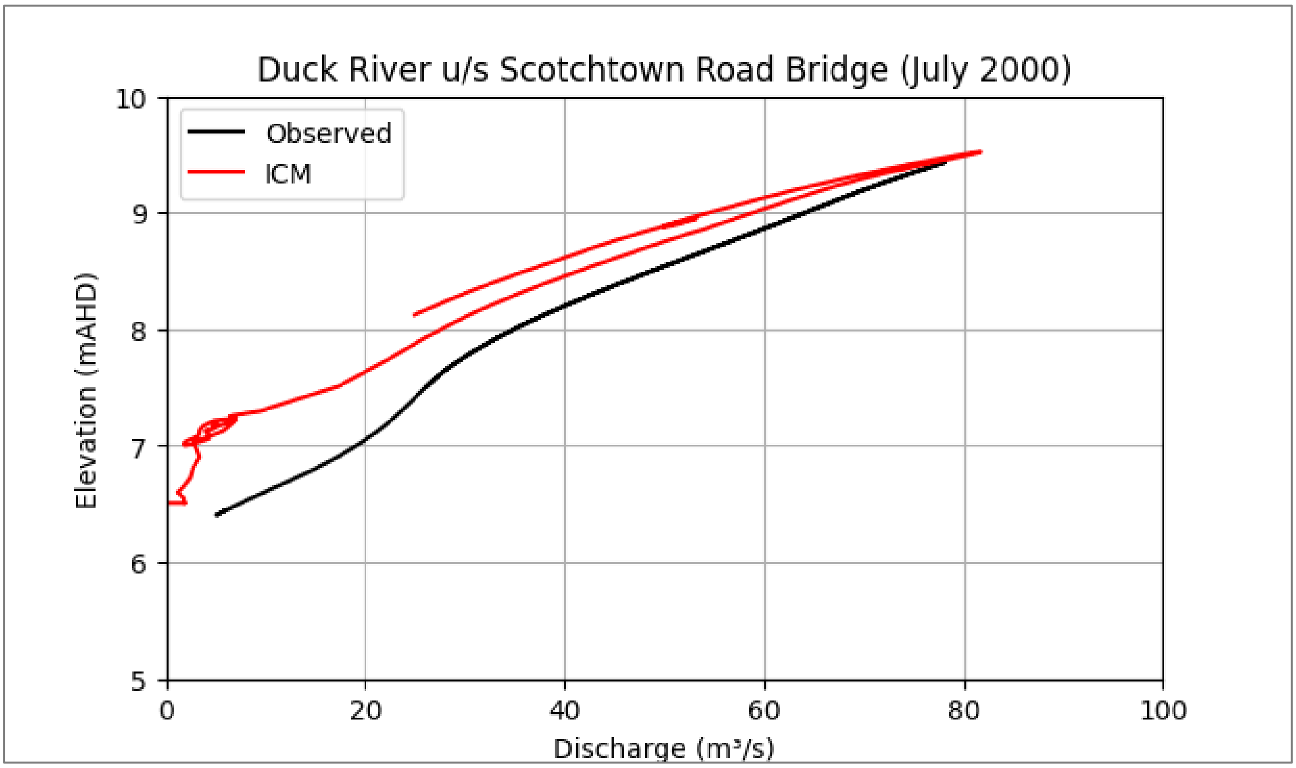


Figure D 1: Rating comparison - Duck River u/s Scotchtown Road Bridge, July 2000 event