West Gippsland
Catchment Management Authority

WGCMA FLOODPLAIN MAPPING PROGRAM

Floodplain mapping for Upper Traralgon Creek

August 2023

DOCUMENT DETAILS

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GLOSSARY OF TERMS

Annual exceedance probability (AEP)	The probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage.
Australian height datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average recurrence interval (ARI)	A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger.
Australia Rainfall and Runoff (ARR)	ARR is a national guideline for the estimation of design flood characteristics in Australia published by Engineers Australia. ARR aims to provide reliable estimates of flood risk to ensure that development does not occur in high risk areas and that infrastructure is appropriately designed.
Bureau of Meteorology (BOM)	The BOM is Australia's national weather, climate and water agency.
Catchment	The area draining to a site. Relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data, which is used to decide which level of risk should be adopted. An average recurrence interval or exceedance probability is attributed to the estimate.
Digital elevation model (DEM)	A DEM is a matrix of cells (or pixels) organized into rows and columns (or a grid), or a raster, representation of a continuous surface, usually referencing the surface of the earth. Cell-based DEM are the most common digital data of the shape of the earth's surface.
Discharge	The rate of flow of water measured in terms of volume over time.
FLIKE	Flood frequency analysis (FFA), or extreme value analysis, package that calculates the probability of flood events based on historical records.

Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or runoff before entering a watercourse. Results in the inundation of land that is usually dry.
Flood class levels	The terms *Minor*, *Moderate* and *Major* flooding are used in flood warnings to give a general indication of the types of problems expected with a flood.
Flood frequency analysis (FFA)	Procedures that use recorded and related flood data to identify underlying probability model of flood peaks at a particular location in the catchment.
Flood hazard	Potential loss of life, injury or economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolations, rate of rise of floodwaters, duration), topography and emergency management.
Flood risk	The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods.
Floodplain	Area of land which is subject to inundation by floods up to, and including, the largest probable flood event.
Floodway overlay (FO)	The FO is applied by the local government planning scheme to designate areas which convey active flood flows or store floodwater.
FloodZoom	A web-based tool that brings together flood forecasts, flood mapping, real-time river height gauges and property data to provide flood response agencies with improved knowledge of likely flood impacts.
GDA94	The Geocentric Datum of Australia 1994 (GDA94) is Australia's official geodetic datum. The standard map projection associated with GDA94 is the Map Grid of Australia 1994 GDA94 / MGA zone 55.
Geographical Information System (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data. Specifically ArcGIS 10.4.

Hydraulics	The study of water flow in waterways, in particular the evaluation of flow parameters such as water level, extent and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Hyetograph	A graph that shows rainfall or rainfall intensity changes over time.
Intensity Frequency Duration (iFD)	Intensity Frequency Duration, method of determining design rainfalls according to procedures in ARR. This includes total rainfall for a given design storm event and the pre-determined temporal pattern over which this rainfall is distributed.
Light detection and ranging (LiDAR)	Spot land surface heights collected via aerial LiDAR survey. The distance to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
Land subject to inundation overlay (LSIO)	The LSIO is applied by the local government planning scheme to designate areas of mainstream flooding. In general, areas covered by LSIO have a lower flood risk than Floodway overlay (FO) areas.
Peak flow	The maximum discharge occurring during a flood event.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The component of rainfall that runs off into the waterway / drainage network. Also known as rainfall excess.
Topography	A surface which defines the ground level of a chosen area.

TUFLOW	A hydraulic modelling tool used in this study to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement.
Victorian State Emergency Service (VICSES)	VICSES is the control agency during emergency responses to floods, storms, earthquakes and tsunamis in Victoria. A volunteer-based organisation, VICSES provides emergency assistance to the community 24 hours a day, seven days a week.
West Gippsland Catchment Management Authority (WGCMA)	Under the Water Act 1989, catchment management authorities have management powers over regional waterways, floodplains, drainage and environmental water. The WGCMA is responsible for waterway and catchment management across the south-east corner of Victoria.

SECTION A INTRODUCTION

1 PURPOSE

Up until this study, flood information for the areas of Traralgon Creek catchment south of the city of Traralgon was based off solely off a combination of local knowledge, previous real events and the topography of the area. The previous flood information for this area has been deemed by the West Gippsland Catchment Management Authority to be low in reliability and due for a detailed flood study.

Previous flood studies for the Traralgon Creek have focussed on the city of Traralgon itself. The most recent flood study for this area was performed by Water Technology in 2016. This study focused primarily on the urban areas of Traralgon, stopping just under 3 kilometres upstream of the city.

2 OBJECTIVE

This flood study seeks to produce detailed flood mapping along The Traralgon Creek, beginning at the most upstream point of Water Technology's Traralgon Creek Flood Study, finishing approximately 1 kilometre downstream of the township of Koornalla.

This flood study will produce results for;

- Flood Extent
- Flood water depth
- Flood water velocity
- Water surface elevation

These results will cover events 20%, 10%, 5%, 2% and 1%.

The results of this study should transition well into the 2016 Traralgon Study by Water Technology overlapping at the downstream of this study area.

The information presented in this report has been compiled for use by West Gippsland Catchment Management Authority (WGCMA) for statutory planning, community education/preparedness, flood risk for insurance purposes and emergency management purposes.

3 CATCHMENT DESCRIPTION

The Traralgon Creek Catchment is a predominantly rural catchment with an area of approximately 178 square kilometres. The most upstream section of the catchment is near the Grand Ridge Road, which is just north of Balook and the catchment finishes at the inflow of the Traralgon Creek into the Latrobe River (refer to Figure 1 for a map detailing the Traralgon Creek Catchment).

The township layers show that there are 10 townships within this catchment area (Figure 1). These towns have been organised from most populous to least in Table 1. Note that the towns layers show to historic settlements; Le Roy and Valley View which are no longer significantly populated settlements.

Table 1 Localities within Traralgon Creek catchment

Township	Population (2016 Census)	Dwellings (2016 Census)
Traralgon	24,933	11,376
Traralgon South	562	182
Callignee	319	137
Koornalla	98	40
Jeeralang	72	41
Callignee North	50	16
Jumbuk	31	17
Balook	4	10

As mentioned previously, the Traralgon City is the most populous area within the catchment, but will not be included in this study, as it has been recently covered previously in the Traralgon Creek Flood Study performed by Water Technology, (Connell, Inglis, & Tate, 2016).

The two townships that are significant for this study are Traralgon South and Koornalla, with both of these towns potentially impacted by this study.

The channels and tributaries within the southern half of the catchment are all well-defined. This is because the elevation and grade of the terrain are steep in this area. The primary land use of this region of the catchment is tree plantations, this means that not only is this area steep, but it is also very hydraulically rough.

The northern half of the catchment is primarily flat floodplains using primarily for farming.

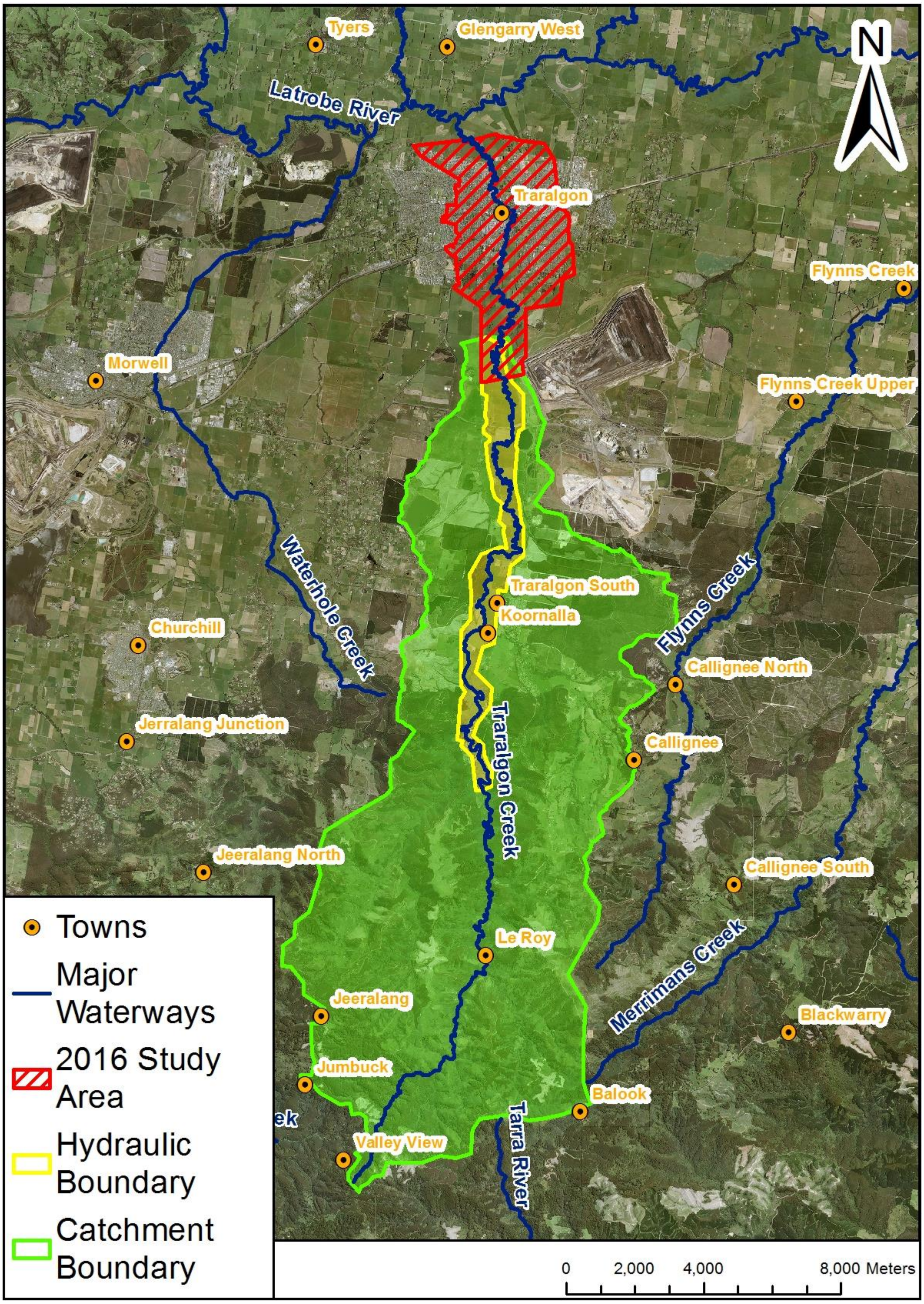


Figure 1 Traralgon Creek Catchment

4 FLOOD HISTORY

The following areal photography was taken during the June 2012 flood event. This flood event has been approximated by the Koornalla (Table 7) and Traralgon South (Table 8) riverine gauges to be close to a 2% AEP flood event. Figure 2 shows the location of the flood photography.

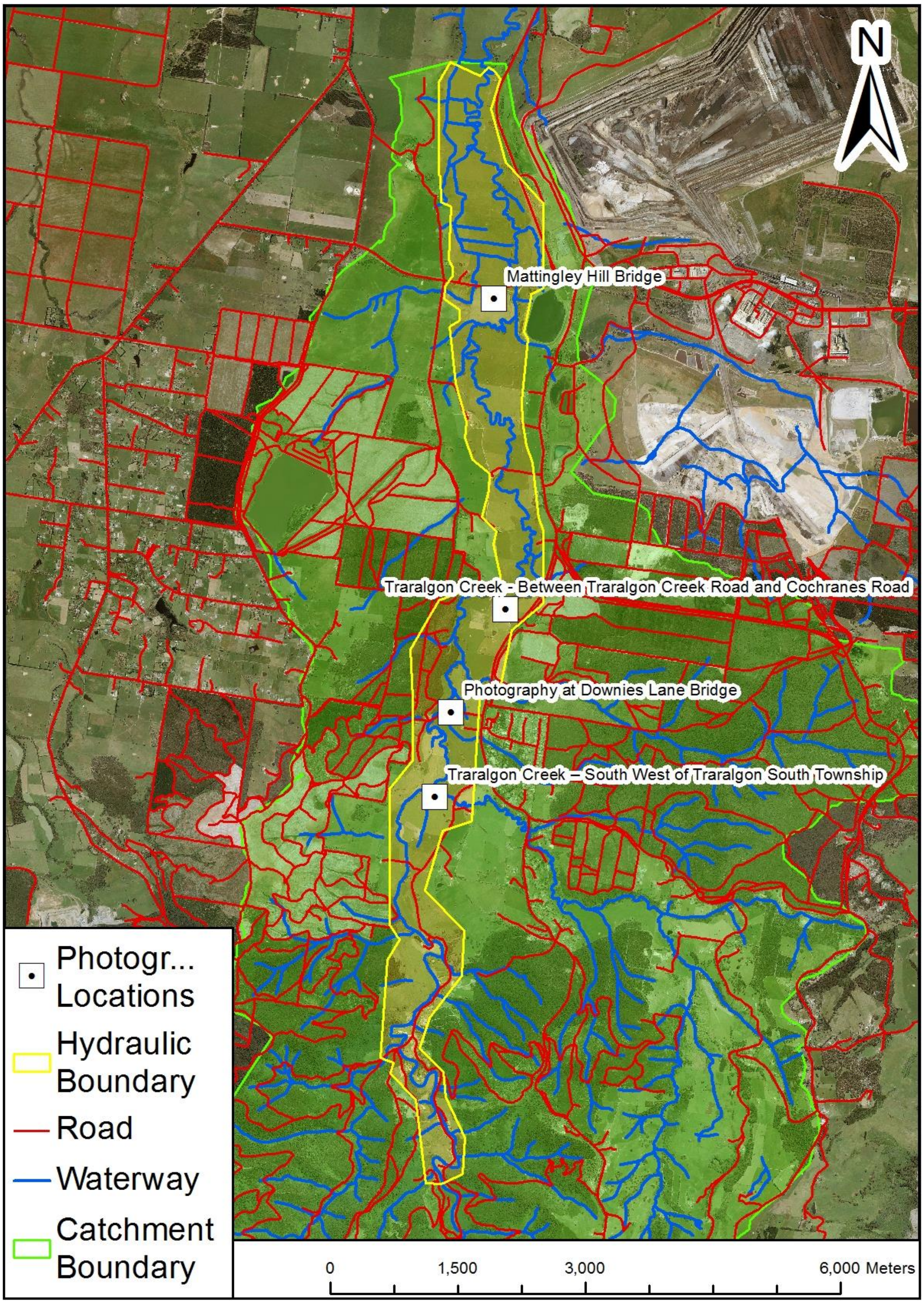


Figure 2 Location of Flood Photography

Figure 3 June 2012 Photography at Mattingley Hill Bridge

Figure 4 June 2012 Photography at Traralgon Creek - Between Traralgon Creek Road and Cochranes Road

Figure 5 June 2012 Photography at Downies Lane Bridge

Figure 6 June 2012 Photography at Traralgon Creek – South West of Traralgon South Township

5 PREVIOUS DECISION-RELATED DATA

Figure 7 shows the previous decision-related flood information for this area. It has been classed by the different reliability ratings. As seen in Figure 7, the reliability for the previous flood information for Upper Traralgon Creek was deemed to be low in reliability.

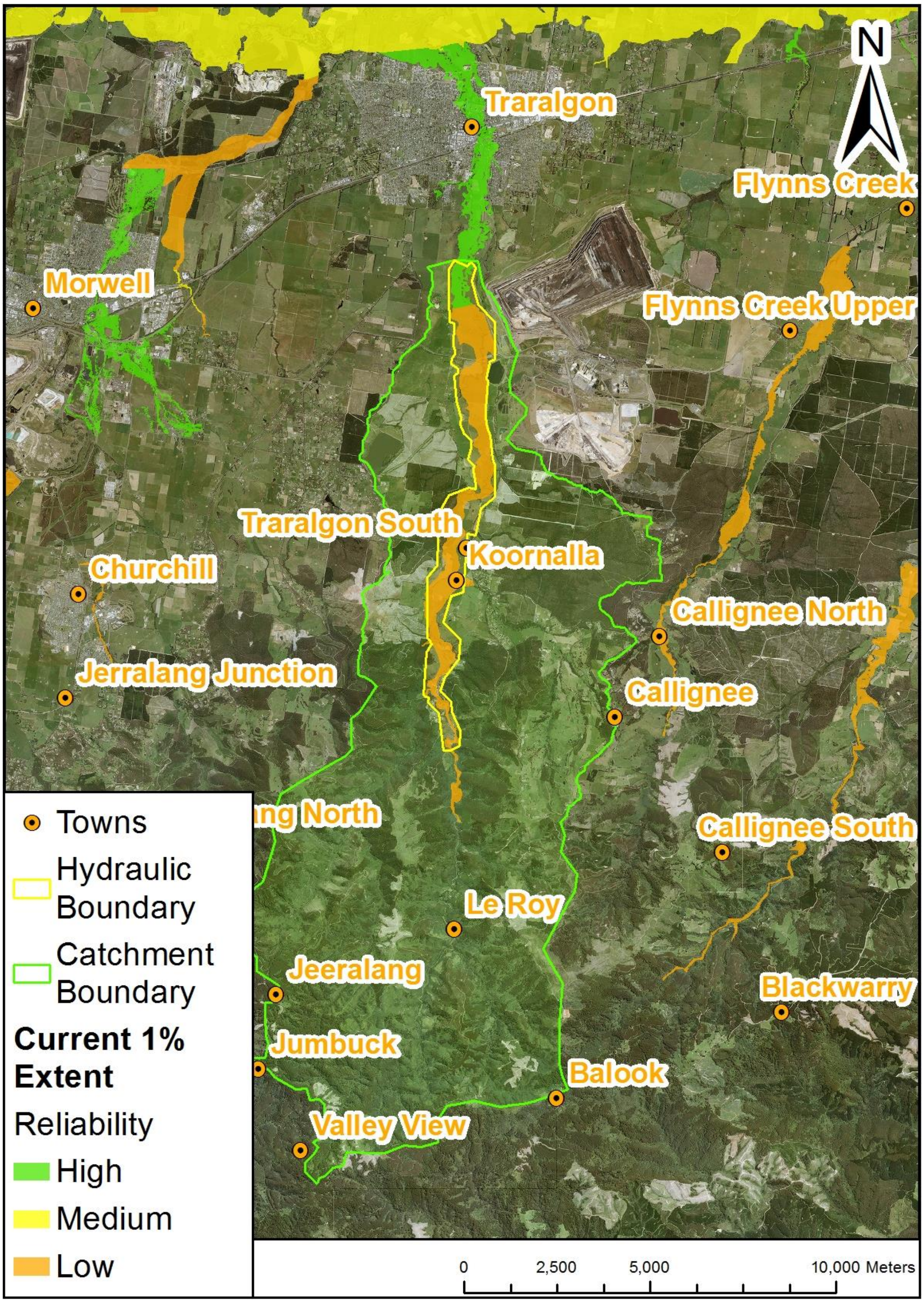


Figure 7 Previous Decision Related Data

SECTION B HYDROLOGY

The hydrology component of this study was used to estimate the amount of flow produced across the catchment during different sized events. These flows were then input into the hydraulic component of the study.

There were three different hydrology approaches that were adopted as part of the hydrology modelling processes, these are;

- A RORB hydrologic model
- Flood frequency analysis of the flow gauges using TUFLOW's FLIKE
- Flood frequency analysis using the ARR's online RFFE Model (Commonwealth of Australia: Engineers Australia, n.d.)

The RORB hydrology model is the primary hydrologic modelling approach used in this study. This approach will provide the flows for the hydraulic model. The other approaches were used to aid in calibration and verification for developing the design run parameters.

1 CATCHMENT DELNIITATION

The first stage of the flood study was to define the catchment area of Traralgon Creek that will be modelled as part of this study. The process of delimitating the area of the Traralgon Creek catchment was defined using the following sets of data.

1.1 Aerial photography

There are several different datasets for aerial photography available to the WGCMA for this area. These datasets and their corresponding date flown, and resolution have been listed in Table 2. Where possible, the datasets that were the most recent and with the highest resolution were used in preference.

Table 2 Available data - Aerial photography

Dataset Name	Date Flown	Resolution
Gippsland_towns_2014jan10_air_vis_10cm_mga55	January 2014	10cm
Latrobe_2014nov03_air_vis_15cm_mga55	November 2014	15cm
Wellington_2014oct18_air_vis_15cm_mga55	October 2014	15cm
WGCMA-rivers-sth_2010mar13_air_vis_15cm_mga55	March 2010	15cm
Traralgon8221_2010jan09_air_vis_50cm_mga55	January 2010	50cm
Moe8121_2009dec13_air_vis_50cm_mga55	December 2009	50cm

These datasets were used in combination with the elevation data and waterways and catchment mapping layers to digitise the reaches and subareas for this catchment model.

1.2 Elevation data

There were only two different elevation datasets that were used for this study, the details of these can be found in Table 3.

Table 3 Available data - Elevation data

Dataset Name	Date	Resolution	Vertical Accuracy	Horizontal Accuracy
West Gippsland Riparian	September 2011	1m	0.19m at 67% Confidence Interval	0.2m at 78% Confidence Interval
Vicmap Elevation DTM 10m	1974 - 2006	10m	5m	12.5m

As seen in Table 3, the West Gippsland Riparian dataset is significantly more accurate and has a much higher resolution than the VicMap DTM. The limitation of the Riparian dataset is that the Riparian only covers the main Traralgon Creek Branch, whereas the VicMap DTM has complete coverage of the Catchment.

The extents of these two different layers can be seen in Figure 8.

When formulating the subareas for the catchment file, the Vicmap DTM was the primary source of information, due to the Vicmap DTM's complete coverage.

Another component of the West Gippsland Riparian is that the extent of the hydraulic model was limited to the extent of the West Gippsland Riparian. Recommendation from the RORB manual are that there needs to be at least 5 sub-areas upstream of the intersection between a RORB reach and the hydraulic model boundary.

These datasets were used in conjunction with the aerial imagery and waterways and catchment mapping layers to digitize the reaches and subareas for this catchment model.

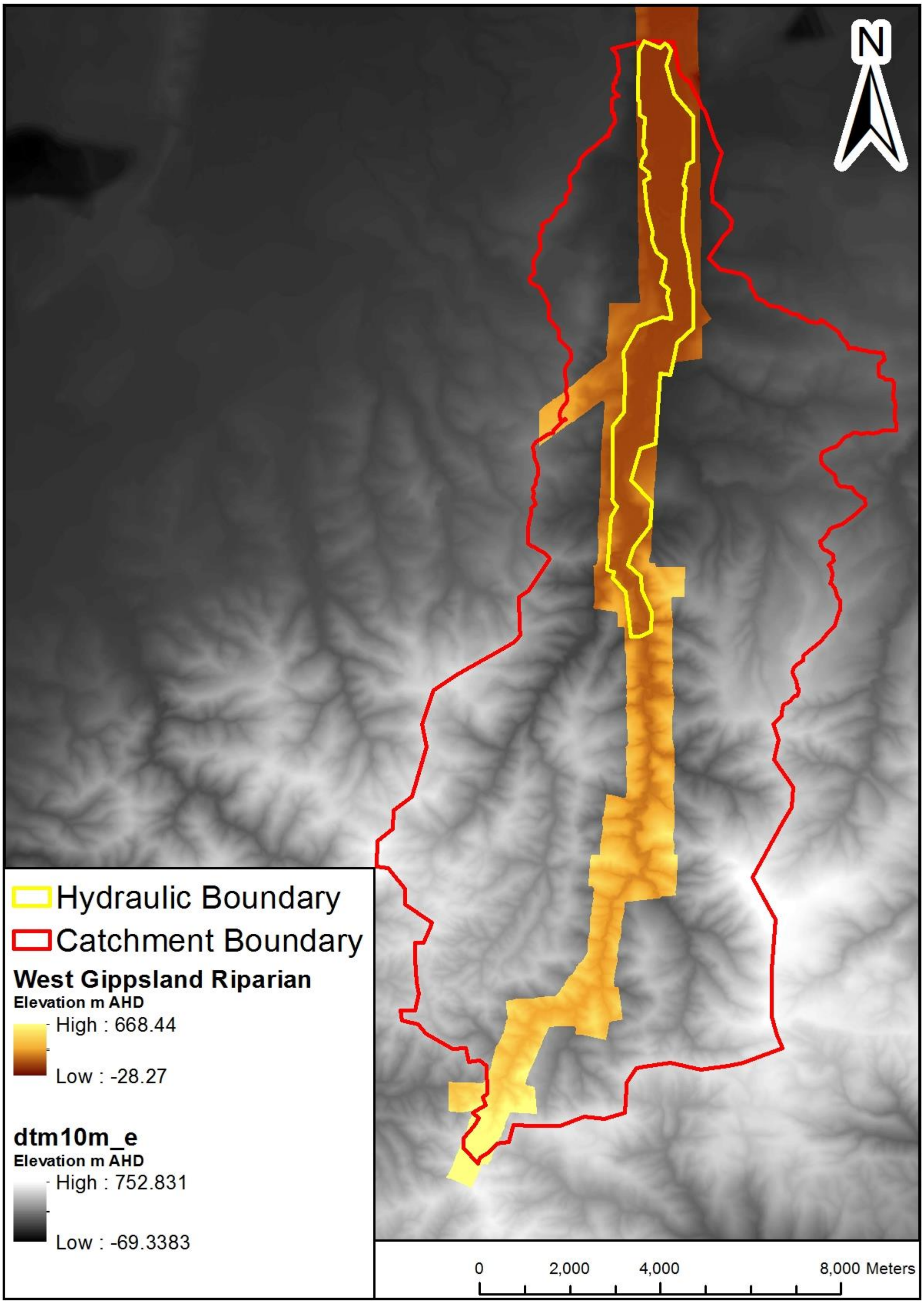


Figure 8 Available Data - Elevation Data

1.3 Catchment area

Figure 9 shows the catchment area defined by this flood study. The catchment area shown does not include the areas of Traralgon Creek covered by the Water Technology study.

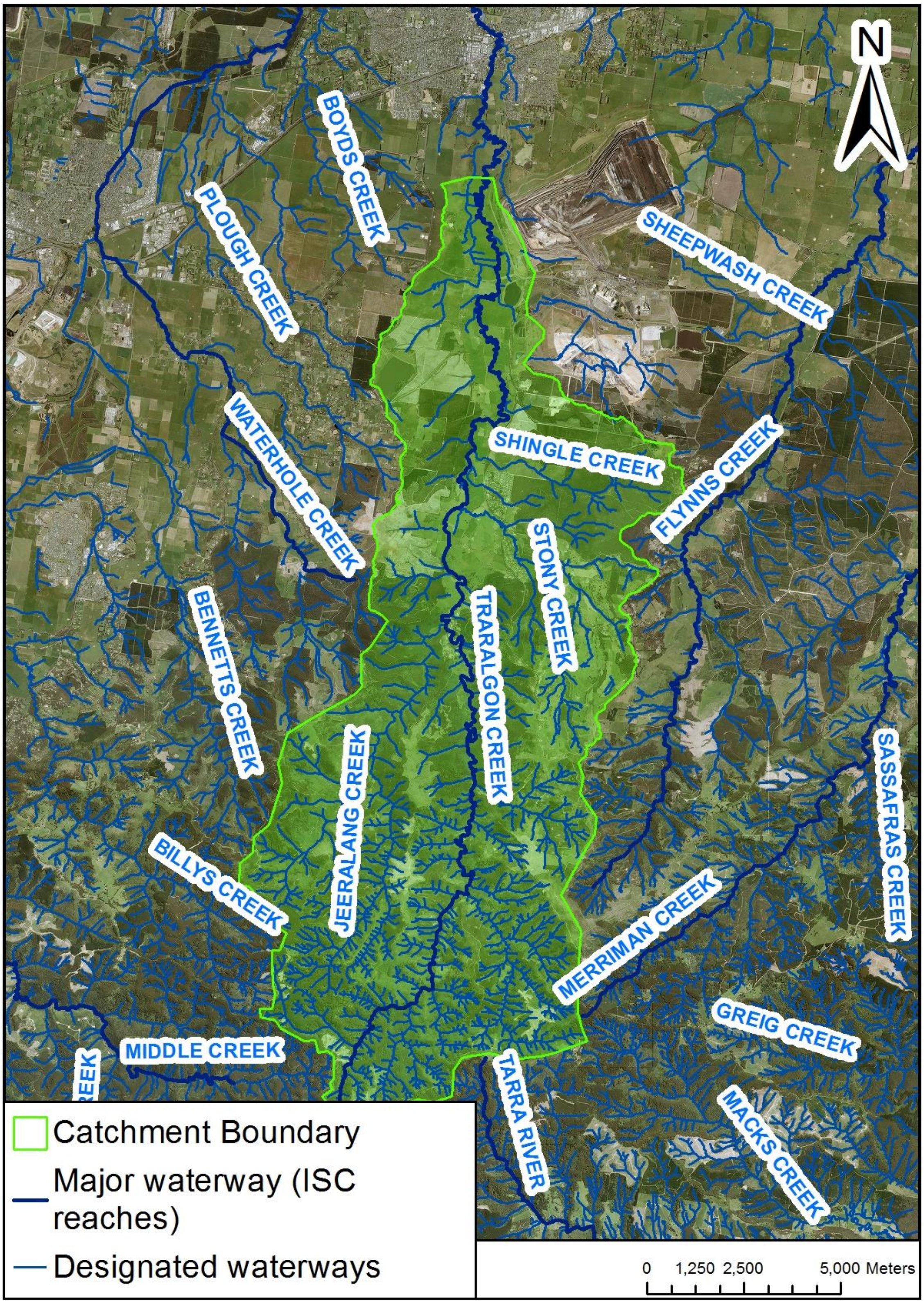


Figure 9 Traralgon Creek Catchment Area

2 FLOW AND RAINFALL GAUGE DATA

As part of the initial desktop analysis an investigation into the availability of the flow and rainfall gauges was performed. The three sources of data that were queried were the Water Measurement Information System (DELWP, 2019), the Bureau of Meteorology Climate Data Online (BOM, 2019) and the Bureau of Meteorology Water Data Online (BOM, 2019). From this investigation, the following results were found;

- There are 2 flow gauges within the boundaries of the hydrology model
- There is another flow gauge on Traralgon Creek, but upstream of the hydrology model boundaries by approximately 4 kilometers
- There are 6 rain gauges within or near the boundaries of the hydrology model
- There are a further 5 rain gauges outside of the hydrology model boundary that had the potential to help inform the hydrology of this catchment

The location, name and type of these gauges have been presented in as a map in Figure 10.

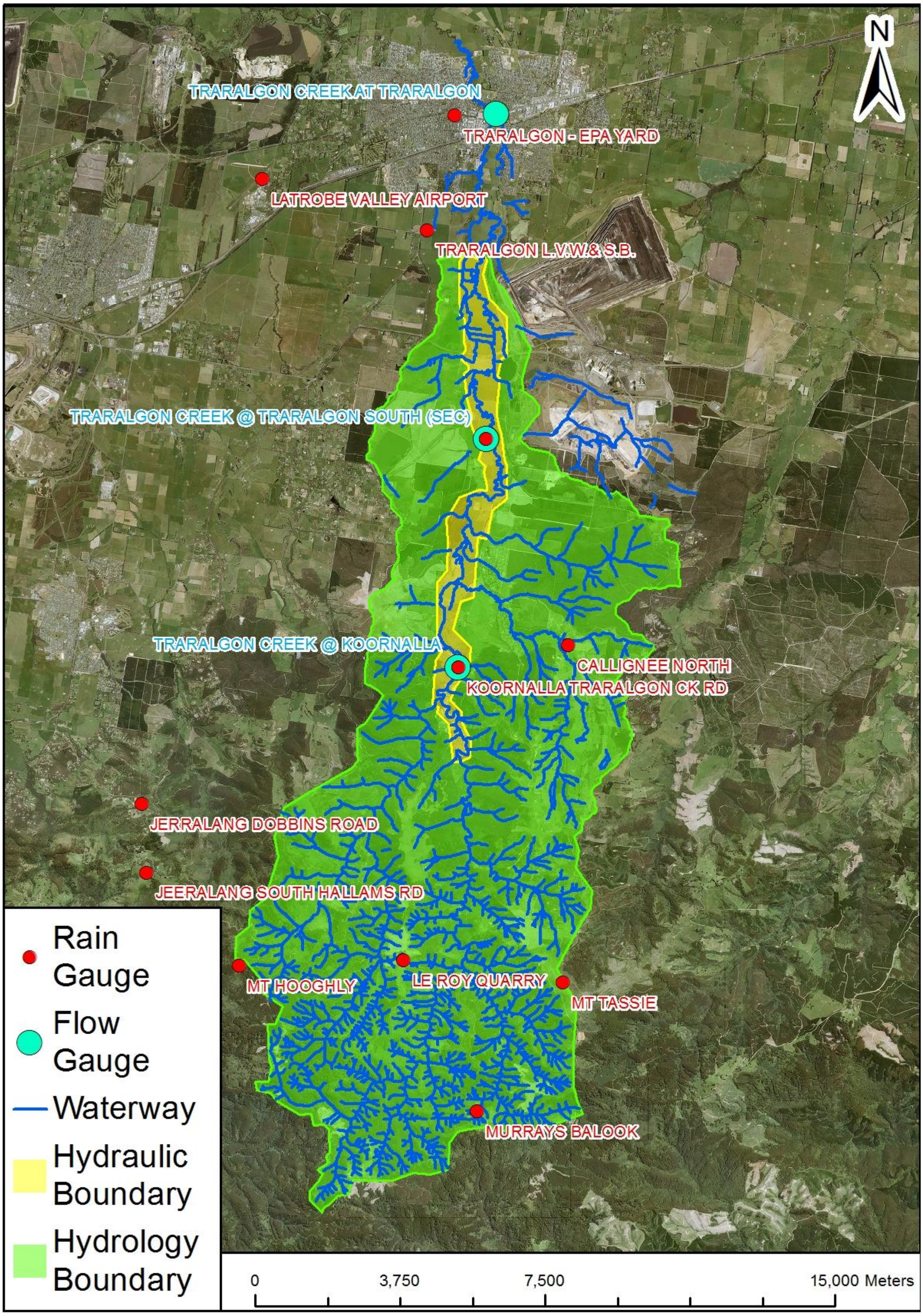


Figure 10 Available Data – Flow and Rainfall Gauge Data

2.1 Flow Gauges

Figure 10 (above) shows the locations of the available riverine gauges within the Traralgon Creek catchment. There are three riverine gauges connected to the Traralgon Creek. Only 2 of these riverine gauges are within the boundaries of this study area.

Table 4 Available Data - Flow Gauge Summary

Site Name	BOM or WMIS?	BOM Station No.	WMIS Site No.	Site commence	Site ceased
TRARALGON CREEK @ TRARALGON	WMIS		226023	13/10/1960	On going
TRARALGON CREEK @ TRARALGON SOUTH (JONES RD)	WMIS		226415	4/06/1974	On going
TRARALGON CREEK @ KOORNALLA	BOTH	085281	226410	(BOM) 31/05/1962 9/07/1953	On going

2.2 Rainfall Gauges

There were two sources for rainfall data used as part of this study, these were the WMIS and the BOM's climate data online. Rainfall data from BOM's climate data online is only available in daily increments which is not suitable for fit run purposes, whereas the WMIS can supply rainfall data with increments as frequent 6-minute intervals. The daily rainfall data was used to help define the rainfall contours to determine the spatial variability of rainfall during an event.

Table 5 Available Data - Rain Gauge Summary

Site/Station Name	BOM or WMIS?	BOM Station No.	WMIS Site No.	Site commence	Site ceased
Rain Gauge at Balook	BOTH	085007	226818	10/06/1999	On going
Rain Gauge at Mt Tassie	WMIS		226814	4/05/1998	On going
Rain Gauge at Mt Hooghly	WMIS		226816	1999	2008
Rain Gauge at Le Roy Quarry	WMIS		226817	30/09/1999	31/10/2009
Traralgon Creek at Koornalla	WMIS		226410	18/12/1995	On going
Rain Gauge at Callignee North	WMIS	085236	226819	25/05/1999	On going
Traralgon Creek at Traralgon South (Jones Rd)	WMIS		226415	(BOM 1956) 5/08/1999	On going
Rain Gauge at Jeeralang South Hallam's Rd	WMIS		226828	6/10/2009	16/11/2011
Rain Gauge (Traralgon Ck) at Traralgon - EPA Yard	BOTH	085009	226815	25/05/1999	On going
Rain Gauge at Jeeralang Dobbins Road (Jeeralang North)	BOTH	85307	226829	(BOM 2009) 29/01/2013	On going
Latrobe Valley Airport	BOM	085280		1984	On going
Rain Gauge at Traralgon L.V.W.& S.B.	BOM	085170		1967	15/01/1999

Most rainfall gauges only began recording data from 1999 onwards. In order to have enough data to get a good representation of the spatial and temporal variation of rainfall during historical events, the range of historical events was restricted to events from 1999 onwards.

3 PREVIOUS STUDIES

Traralgon Creek has been the subject of numerous flood studies, the earliest having been conducted in 1979 by the State Rivers & Water Supply Commission, while the most recent was in 2016 by Water Technology (Tate & Connell, 2016). The advantage of having had these studies performed on this catchment is that the methodology and results of this report can be compared to the previous studies, particularly that of Water Technologies conducted in 2016. A tabulated summary of these studies has been sourced from Water Technology's review of existing hydrology data regarding Traralgon Creek and can be found below in Figure 14.

Table 6 Summary of Previous Studies (Tate & Connell, Traralgon Flood Study - Data Review, 2016)

Year	Study	Type
1979	State Rivers & Water Supply Commission. Report on Flooding from Traralgon Creek (Stage 1)	Flood Study
1979	Gutteridge, Haskins & Davey Pty Ltd. Traralgon Creek Flood Study (Stage 2)	Flood Mitigation Study
1981	Gutteridge, Haskins & Davey Pty Ltd. Traralgon Creek Flood Study (Stage 3)	Management Study
1984	State Rivers & Water Supply Commission. Traralgon Creek Flood Study – Summary Report	Summary Document
1984	Gutteridge, Haskins & Davey Pty Ltd. Report on Flooding Characteristics South of Shakespeare Street	Development Assessment
1984	Rural Water Commission of Victoria. Traralgon Flood Mitigation Proposal – Approved Scheme	Flood Mitigation Design
1995	Department of Conservation and Natural Resources. Documentation and Review of 1993 Victorian Floods Volume 1 & 2	Flood Review
1996	Department of Natural Resources and Environment. Traralgon Flood Mitigation Scheme – Levee Audit Report	Levee Audit
2000	Bureau of Meteorology. Traralgon Creek Flood Forecasting Correlations	Hydrologic Investigation
2000	SKM. Traralgon Creek Floodplain Management Study	Flood study and management plan
2016	Water Technology. Traralgon Flood Study.	Flood Study

4 INITIAL HYDROLOGY ESTIMATES

The following initial hydrology estimates were used in addition to the 2016 study by Water Technology to act as an independent source of information to calibrate and validate the RORB model produced as part of this study.

4.1 FLIKE Flood Frequency Analysis

FLIKE is a Flood Frequency Analysis tool hosted by BMT. FLIKE was used in this study to perform a flood frequency analysis of the various gauges within the Upper Traralgon Creek catchment.

Sections 0 and 4.1.2 display and discuss the results from these flood frequency analyses. As discussed within these sections, the Traralgon Creek at Koornalla gauge was chosen as the primary source for calibration.

4.1.1 *Traralgon Creek at Koornalla*

The Traralgon Creek at Koornalla gauge has close to 66 years of flood data available and the largest flood event recorded on this gauge is estimated to a 1.05% AEP flood event.

Table 7 Traralgon Creek at Koornalla FFA and Recorded data

AEP	Expected Quantiles	Lower 90%	Upper 90%	Recorded	Year
0.50%	169.16	124.48	275		
1.00%	148.72	112.46	225.6		
1.05%				144.51	1978
2.00%	127.47	98.85	182		
2.80%				111.39	2012
4.55%				97.60	2007
5.00%	98.38	78.31	130.5		
6.29%				81.20	2013
8.05%				79.23	2011
9.79%				75.04	1969
10.00%	75.89	61.13	96.4		
11.53%				73.20	2001
13.28%				64.38	1995
15.04%				64.13	2005
16.78%				63.39	1993
18.52%				59.42	1968
20.00%	53.29	43.05	66.6		
20.28%				58.67	1970
22.03%				53.49	1980
23.75%				43.10	1976
25.51%				42.95	2016
27.25%				42.25	1977
28.99%				39.27	1989
30.77%				37.68	1971
32.47%				35.66	2009
34.25%				34.36	1984
35.97%				30.28	1974
37.74%				30.18	1994
39.53%				29.93	1988
41.32%				29.26	1990
42.92%				29.23	1983
44.84%				25.71	1975
46.51%				25.62	1981
48.31%				22.40	1985
50.00%	23.84	18.65	30.4		
50.00%				22.00	1973

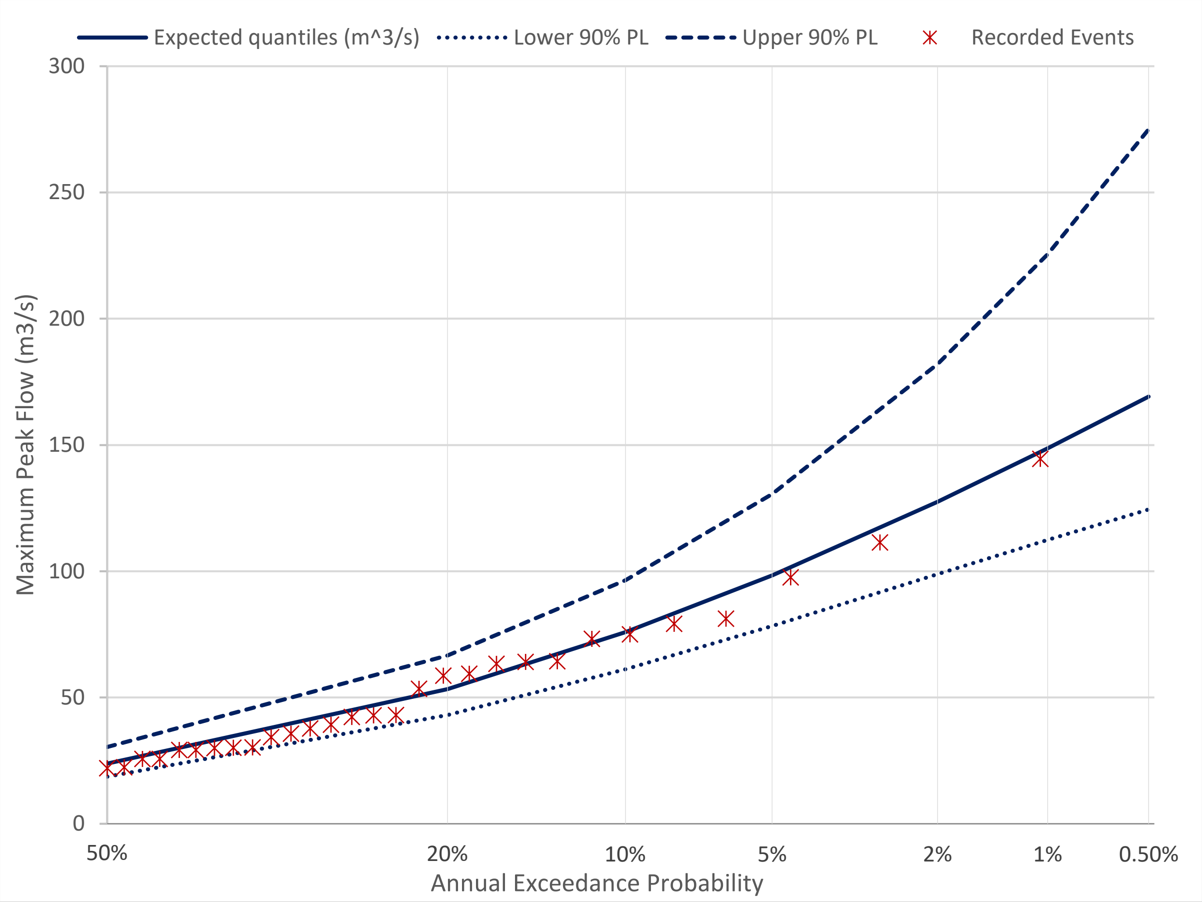


Figure 11 Traralgon Ck at Koornalla Flood Frequency Curve

The Traralgon Creek at Koornalla flood frequency curve shows a strong correlation between the mean flow and the recorded peaks across range of events. The upper and lower probability limits are tight with the mean, even at larger events.

4.1.2 *Traralgon Creek at Traralgon South*

The Traralgon Creek at Traralgon South gauge was established in 1974 and has a more limited range of events. The flood frequency curve does not fit well for larger events, in particular the upper limits for the 1% and 0.5% is 3-4 times the mean. This gauge is not suitable for calibration against.

Table 8 Traralgon Ck at Traralgon South FFA and Recorded data

AEP	Expected Quantiles	Lower 90%	Upper 90%	Recorded	Year
0.50%	516.63	219.88	2017.60		
1.00%	379.30	180.13	1208.00		
1.70%				275.46	2012
2.00%	268.96	140.43	714.70		
4.55%				115.74	2013
5.00%	158.65	92.64	331.10		
7.39%				115.74	2007
10.00%	98.03	60.73	176.70		
10.22%				115.74	2009
13.07%				95.70	2001
15.90%				79.06	1978
18.76%				78.00	2005
20.00%	53.87	34.84	87.50		
21.60%				77.69	2011
24.45%				34.84	1977
27.25%				31.95	2016
30.12%				24.24	1976
33.00%				19.33	1974
35.84%				18.45	2015
38.61%				18.06	1984
41.49%				16.18	1975
44.25%				15.58	1980
47.17%				15.49	1983
50.00%	16.31	10.69	25.20		
50.00%				14.61	1985

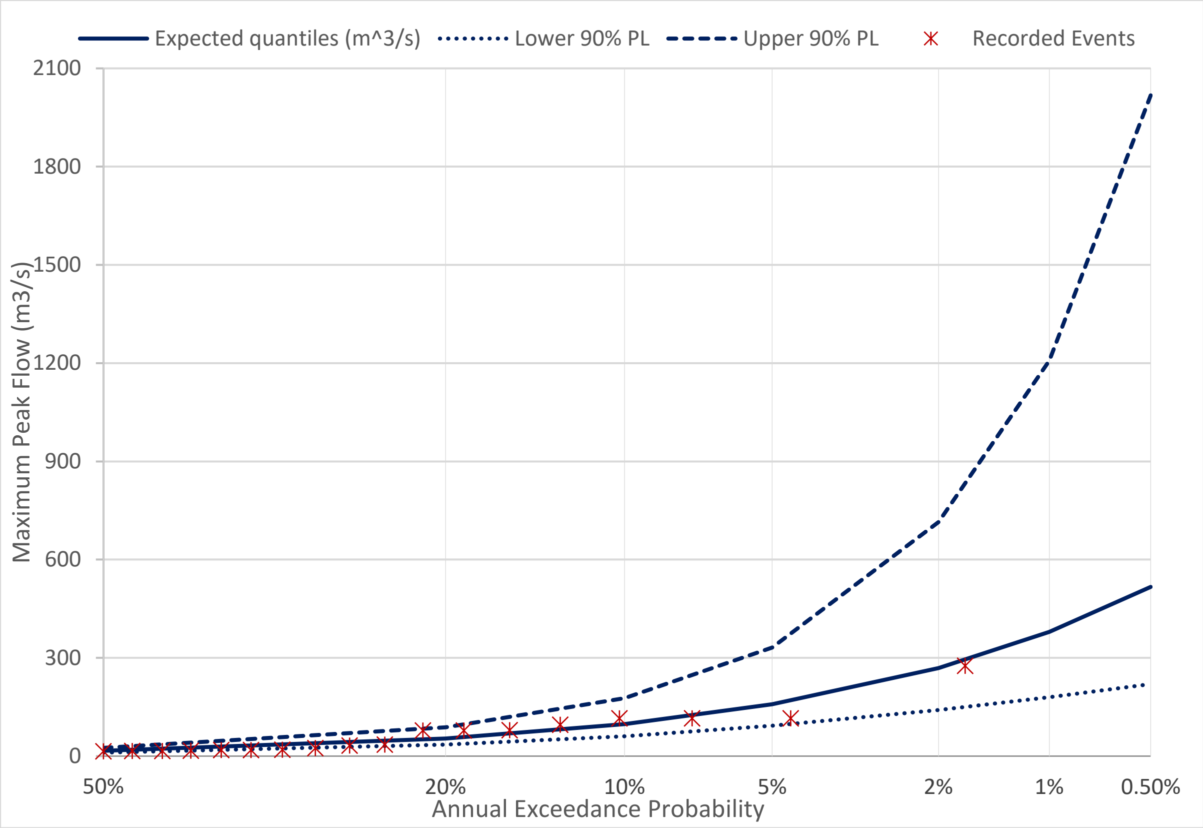


Figure 12 FLIKE analysis of Traralgon Ck at Traralgon South

4.2 Regional Flood Frequency Equation Model

4.2.1 *Traralgon Creek Catchment*

Table 9 Design flows based on flood frequency analysis at Model Outlet

Annual Exceedance Probability	Expected quantiles (m^3/s)	5% Confidence Limits (m^3/s)	95% Confidence Limits (m^3/s)
50%	23.9	11.5	49.5
20%	45.8	23.0	91.3
10%	64.9	32.3	131
5%	86.9	42.3	180
2%	121	56.9	260
1%	151	68.9	335

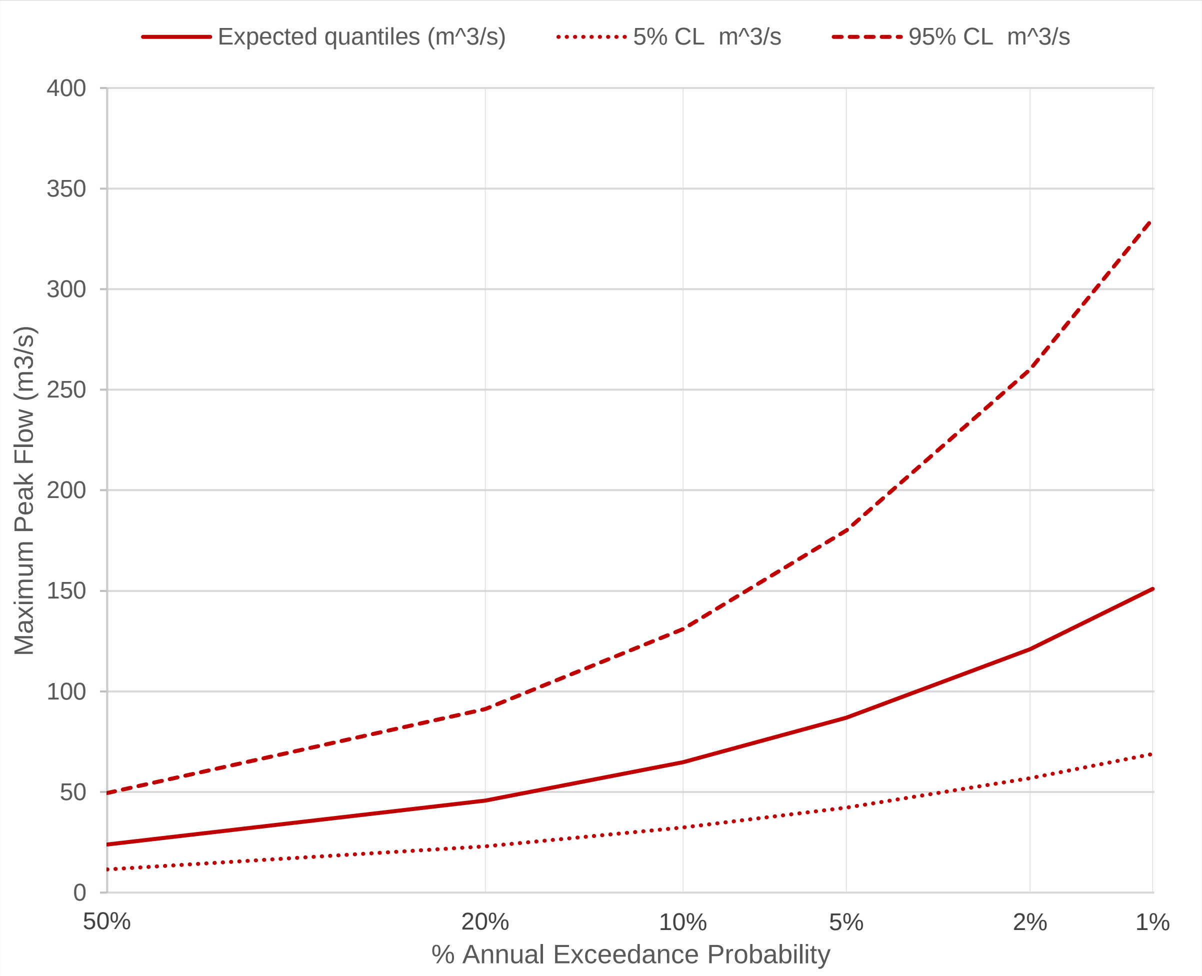


Figure 13 Flood Frequency Curve from ARR's RFFE Model at Model Outlet

4.2.2 *Traralgon Creek Catchment to Koornalla Gauge*

Table 10 Design flows based on flood frequency analysis at Koornalla Gauge

Annual Exceedance Probability (%)	Expected quantiles (m^3/s)	5% CL m^3/s	95% CL m^3/s
50	17.9	8.62	36.9
20	34.2	17.2	67.9
10	48.4	24.1	97.6
5	64.7	31.6	133
2	90.2	42.5	193
1	113	51.4	248

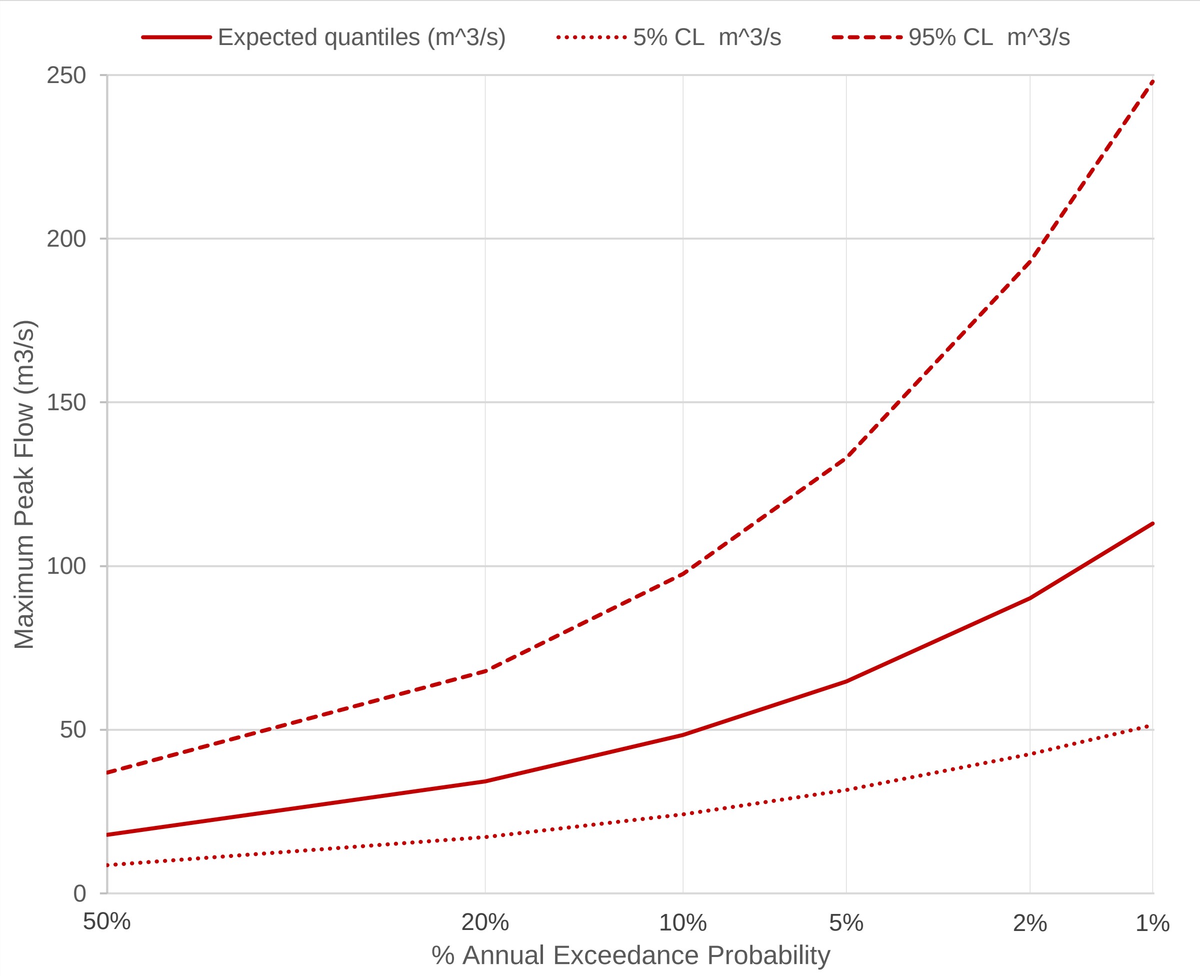


Figure 14 Flood Frequency Curve from ARR's RFFE Model at Koornalla Gauge

4.3 Summary of Initial Hydrology Estimates

The two initial hydrology estimates techniques used were both flood frequency analyses; an analysis of the gauged data using TUFLOW's FLIKE and a flood frequency using various sources around the region using ARR's online RFFE Model. Figure 15 presents the resulting curves from the different techniques alongside the gauges recorded historic flows and their estimated AEP.

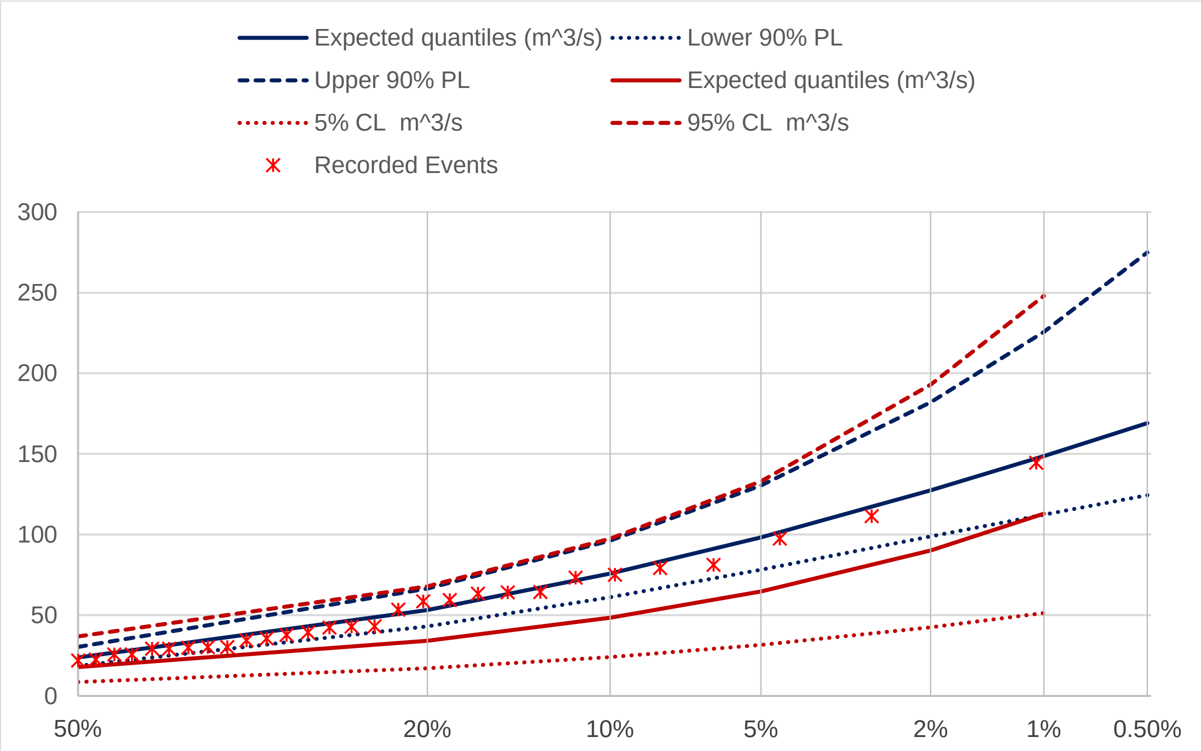


Figure 15 Comparison between FLIKE and RFFE at the Traralgon Creek at Koornalla

5 RORB HYDROLOGIC MODEL

RORB is the standard hydrology model used by the West Gippsland Catchment Management Authority (WGCMA). It is an interactive runoff and streamflow routing program (Laurenson, Mein, & Nathan, 2010) and has traditionally been used by the WGCMA to calculate streamflow hydrographs at location within a stream from rainfall events. These hydrographs are usually input into a hydraulic model (e.g. TUFLOW) to represent the rainfall occurring within the catchment during a specific AEP event.

5.1 Sub-area and reach delineation

The catchment file for RORB was set up using HARC's ArcRORB tool. The sub-areas and reaches were defined from the elevation data sets.

The sub areas were delineated in a way to ensure that all print nodes intended to be used to generate hydrographs for TUFLOW had at least 5 subareas upstream of any nodes that results are required (Laurenson, Mein, & Nathan, 2010).

The catchment was split into two different interstations. These interstations allow the user to define separate routing parameters (Kc) to each interstation area. Areas upstream of the Traralgon Creek at Koornalla gauge were defined as one interstation area and the areas downstream of the gauge were defined as another. The choice of inputting an interstation area above the Koornalla gauge allowed the upstream sections of the catchment to be calibrated to the Koornalla gauge and the downstream sections to the outlet. This allowed for more representative parameters for the areas that the interstation was covering.

The VicMap DTM was once again the primary elevation dataset used to delineate the sub-areas and reaches.

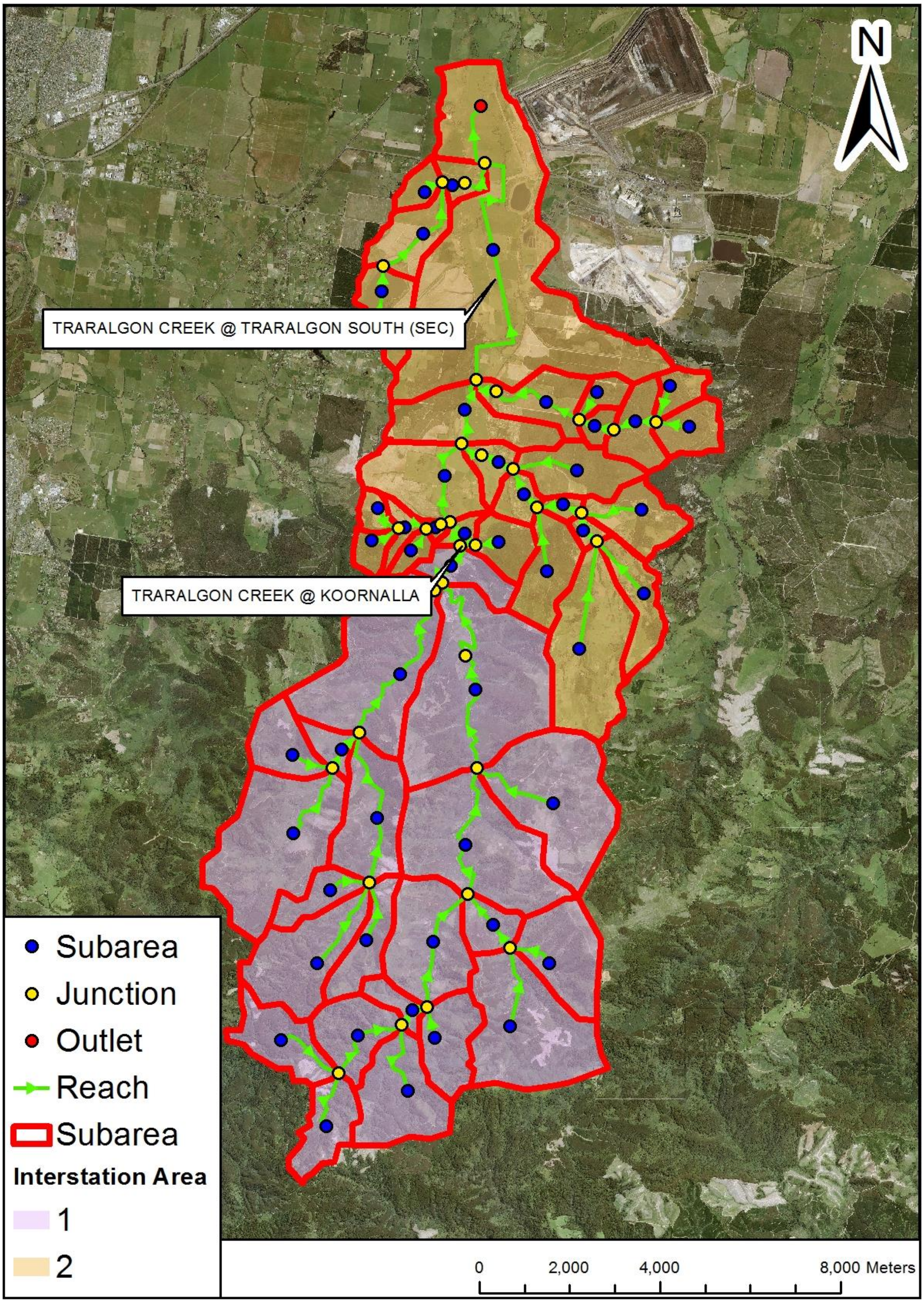


Figure 16 RORB Hydrology Model

5.2 Initial Parameters

5.2.1 *Storm loss parameters*

The initial parameters that were used were based off values given from the Australian Rainfall & Runoff's Data Hub (Ball, et al., 2016). The catchment data from coordinates of 146.53 longitude and -38.35 latitude were inputted into the Data Hub (location shown in Figure 17) on the 20th of February 2018.

The Data Hub prescribed a Storm Initial Loss of **21.0** millimeters and a Storm Continuing Loss of **4.2** millimeters.

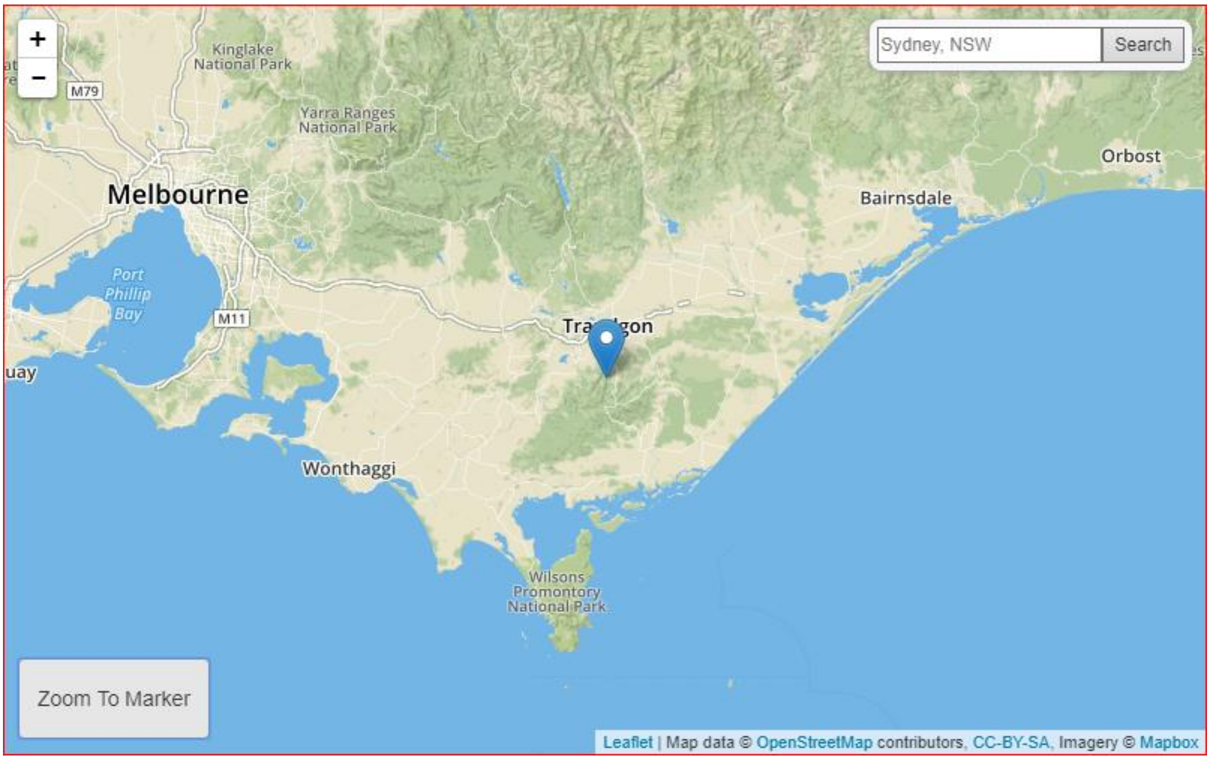


Figure 17 Map from the ARR Datahub showing catchment centroid

5.2.2 *Kc*

Kc is a flow routing parameter used by RORB that effects the way that the water moves through the catchment model.

The initial estimates for kc, were based on the regional estimation equations in ARR2016.

The guidelines suggested by the 2016 ARR for the eastern parts of Victoria is that the Vic (MAR>800mm) equation is a suitable equation for working out the Kc of the catchment, MAR being the mean annual rainfall for the catchment (Book 7 Chapter 6 6.2.1.3 ARR 2016).

Recommendations from HARC developer David Steph ______ is that the Pearse equation is more suitable for this application as it takes into consideration the average distance from sub-area centroid to outlet in its calculations.

In addition to the calculations used, Water Technology's RORB hydrology model also serves as a suitable comparison for Kc, as the Koornalla interstation area is quite similar to the ones used in this study.

Table 11 shows the resulting Kc values from different techniques.

Table 11 Kc Initial Estimates

Equation	To Koornalla	To Outlet
RORB	20.21	17.32
Vic (MAR>800mm)	18.92	16.46
Pearse eta al, 2002	11.90	12.83
Traralgon Creek 2016 Study	13	N/A

5.2.3 *m*

The industry standard for the non-linearity parameter (m) is 0.8 (Book 7 Chapter 6.2 ARR 2016). There was not adequate data provided to indicate that the m value should be adjusted from this industry standard, therefore the value for m used for RORB was 0.8.

5.3 Calibration

The calibration stage was used to obtain the Kc parameter for the catchment. In theory, the Kc parameter should not change between events, allowing the catchment to be calibrated to an event to obtain a Kc parameter which should be suitable for the required design events.

After reviewing the available riverine and rainfall data, it was decided that the June 2012 flood event should be the chosen event for calibration against.

This event has been rated approximately a 2% flood event by FLIKE's flood frequency analysis of the gauged information available in section 4.1.

5.3.1 *Input Data*

The main data that was used for the calibration stage was the Traralgon Creek catchment file, the initial parameters defined in 5.2 and the historic rainfall and flow data recorded during the event.

5.3.1.1 Rainfall and riverine data

Figure 18 displays the available hyetographs and hydrographs for the June 2012 flood event.

The historical hyetographs were used to define the shape of the hyetograph for each of the subareas within the hydrology model. This was defined using by weighting the distance and recorded total rainfall depths of each gauge to define which hyetograph the sub-areas should use. In addition, the total rainfall that each subarea receives was defined by using isohyetal lines, once again using the location of the gauge and the total recorded rainfall for a given event.

These rainfall parameters helped define the amount of rainfall encountered by each individual subarea.

The gauges that were used for the June 2012 calibration and the total rainfall recorded during the event are displayed in Table 12.

Table 12 June 2012 Rainfall Gauges and Total Depths

Site/Station Name	Total Rainfall Depth (mm)
Rain Gauge at Balook	213.8
Rain Gauge at Mt Tassie	223.8
Traralgon Creek at Koornalla	137.0
Rain Gauge at Callignee North	99.4
Traralgon Creek at Traralgon South (Jones Rd)	62.4

The recorded rainfall depths from these gauges were began just over 36 hours before the rising limb of the Traralgon Creek at Koornalla riverine gauge began.

Two hydrographs were input into RORB during the June 2012 calibration. These were the Traralgon Creek at Koornalla riverine gauge and a hydrograph that was extracted from Water Technology's 2016 Traralgon Creek study used by Water Technology to calibrate their TUFLOW model. The location of this hydrograph was at the most upstream section of their model, which is the same location as the outlet of this flood study's RORB outlet.

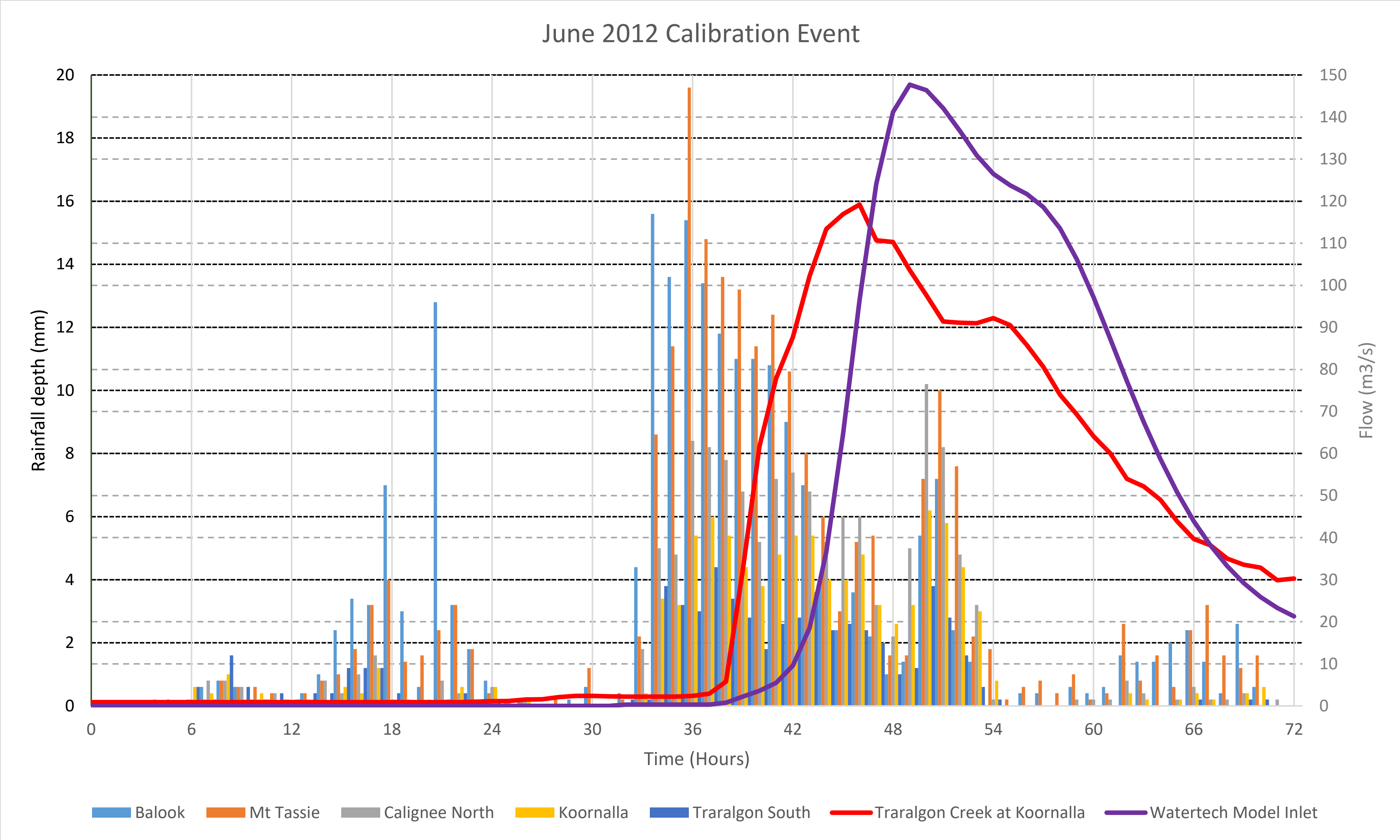


Figure 18 Calibration Rainfall and Flow Input Data

5.3.2 *Results*

Table 13 shows the parameters obtained from the calibration process across the two interstation areas of this model.

The primary parameter of interest is the Kc. As mentioned before. this is because the Kc parameter should still be relevant for other design events.

The initial loss and continuing loss parameters served as an initial estimate and comparison point. However, these parameters will likely change with the scale of the event.

The following Figure 19 and Figure 20 show the final calibration hydrographs produced from RORB compared to the Koornalla Gauge and the extracted hydrograph from Water Technology's study.

Table 13 Parameters from calibration

Interstation area above:	Kc	m	Initial loss (mm)	Cont. loss (mm/hr)
Koornalla Gauge	18.92	0.8	30	2.5
Model Outlet	10	0.8	30	2.5

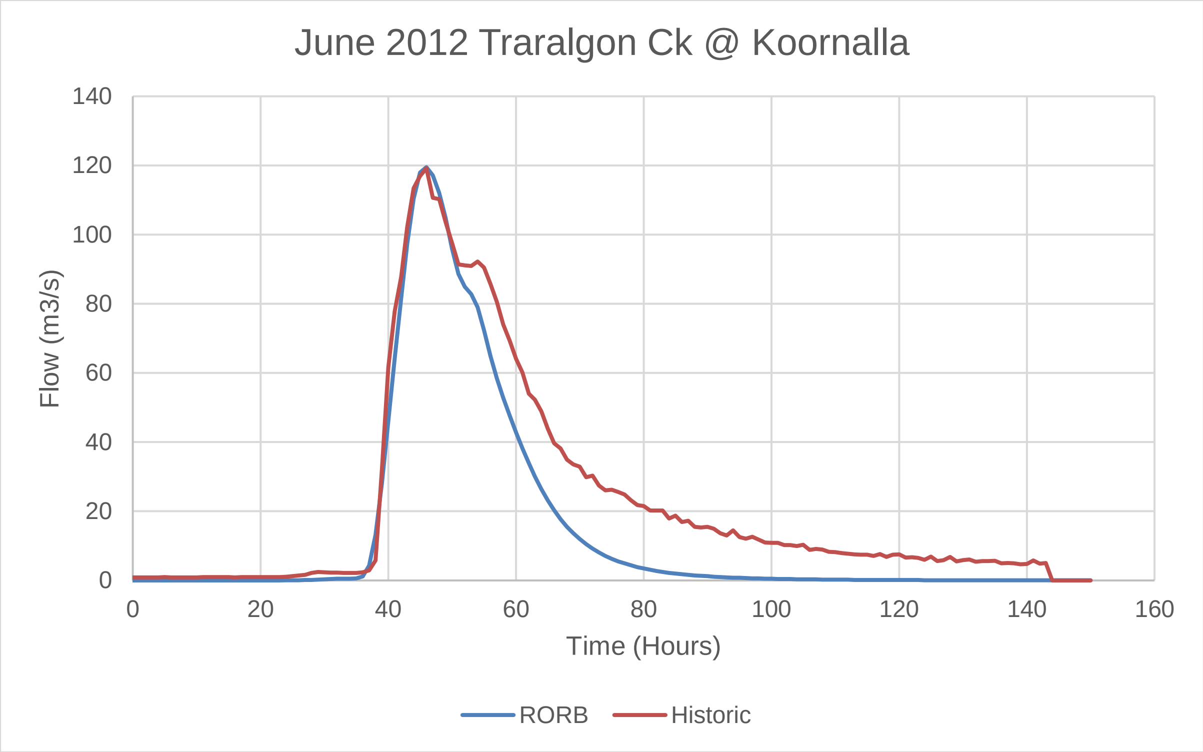


Figure 19 Final calibration hydrograph at Koornalla gauge

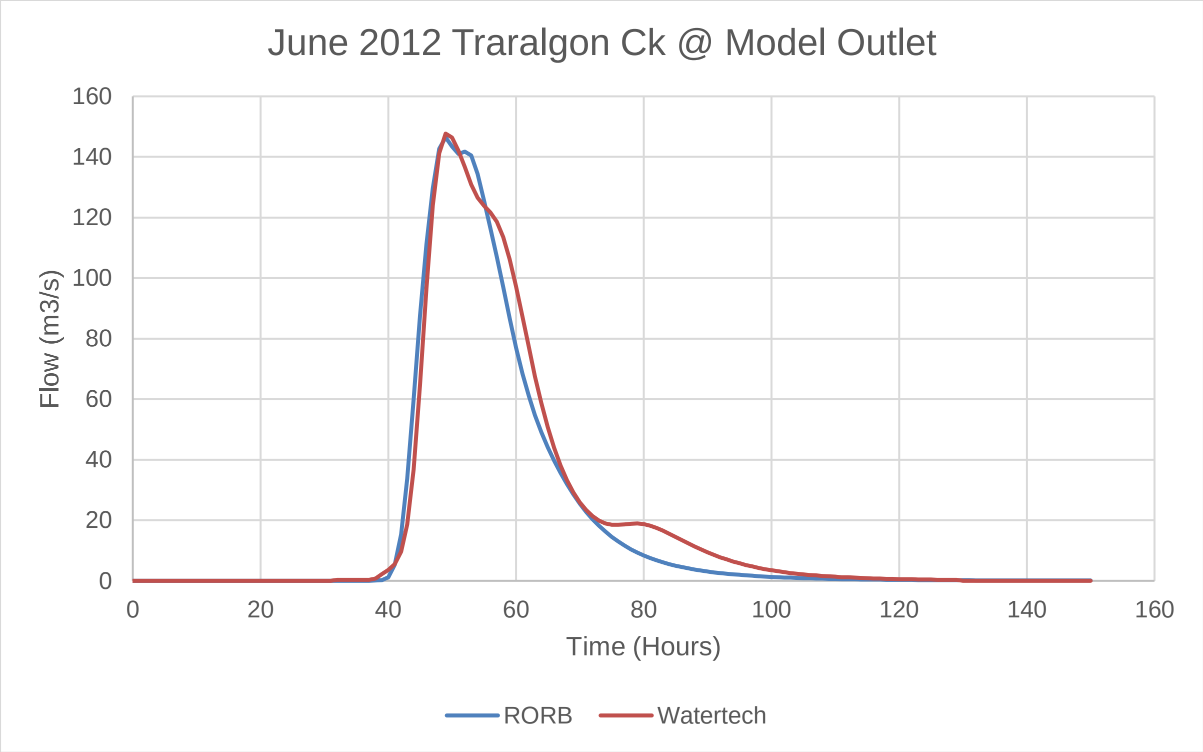


Figure 20 Final calibration hydrograph at model outlet

5.4 Verification

Verification is the process of comparing the flood frequency curve produced by RORB against a flood frequency analysis produced either by FLIKE or ARR's online RFFE Model. Rather than using a user generated storm file like in the calibration stage, the verification stage uses storms generated by RORB controlled by parameters.

RORB's Monte Carlo simulation type was used for the verification process. This follows the ARR's recommendation for reducing any bias of estimated flood probabilities (Nathan & Ling, 2016). In a Monte Carlo simulation, influential modelling parameters are stochastically varied across each run. For Traralgon Creek, 10,000 individual runs are performed during each simulation.

Rather than outputting a series of hydrographs, the Monte Carlo simulation outputs just the peak flows of each of the 10,000 individual runs along with the parameters used to create them, forming a flood frequency curve.

The Traralgon Creek Catchment was verified at two locations; against an FFA of the Koornalla gauge Figure 22 and the RFFE results at the outlet of the model Figure 23. The resulting parameters from the verification stage can be seen in Table 15.

During the verification phase, only the initial loss and continuing loss parameters were adjusted.

In addition to adjusting parameters, the verification phase also defines the initial loss, critical duration and temporal pattern number that will be used in the design runs.

5.4.1 *Input Data*

The following sections present the alternative data that is used during the verification and design run stages of the RORB hydrology modelling.

The data here varies significantly from the calibration stage because the calibration stage attempts to fit the RORB calculated hydrograph to a historical hydrograph using the historically measured rainfall for that event. Whereas verification generates a storm from a series of data and parameters and generates a series of hydrographs ranging in size and shape, comparing an FFA of these results to an FFA from either gauged or another estimation source.

5.4.1.1 Intensity Frequency Duration tables

The Intensity Frequency Duration (IFD) tables were by RORB used to define the total amount of rainfall depth expected during an event of a certain size and duration.

The IFD table that was used as part of this study has been displayed in Table 14. The left column relates to the total duration of the rainfall event, the top row is the size or AEP % of the rainfall event and the remaining numbers are the depth of rainfall expected for a rainfall event of a given duration and event.

Table 14 Traralgon Creek Catchment IFD Chart

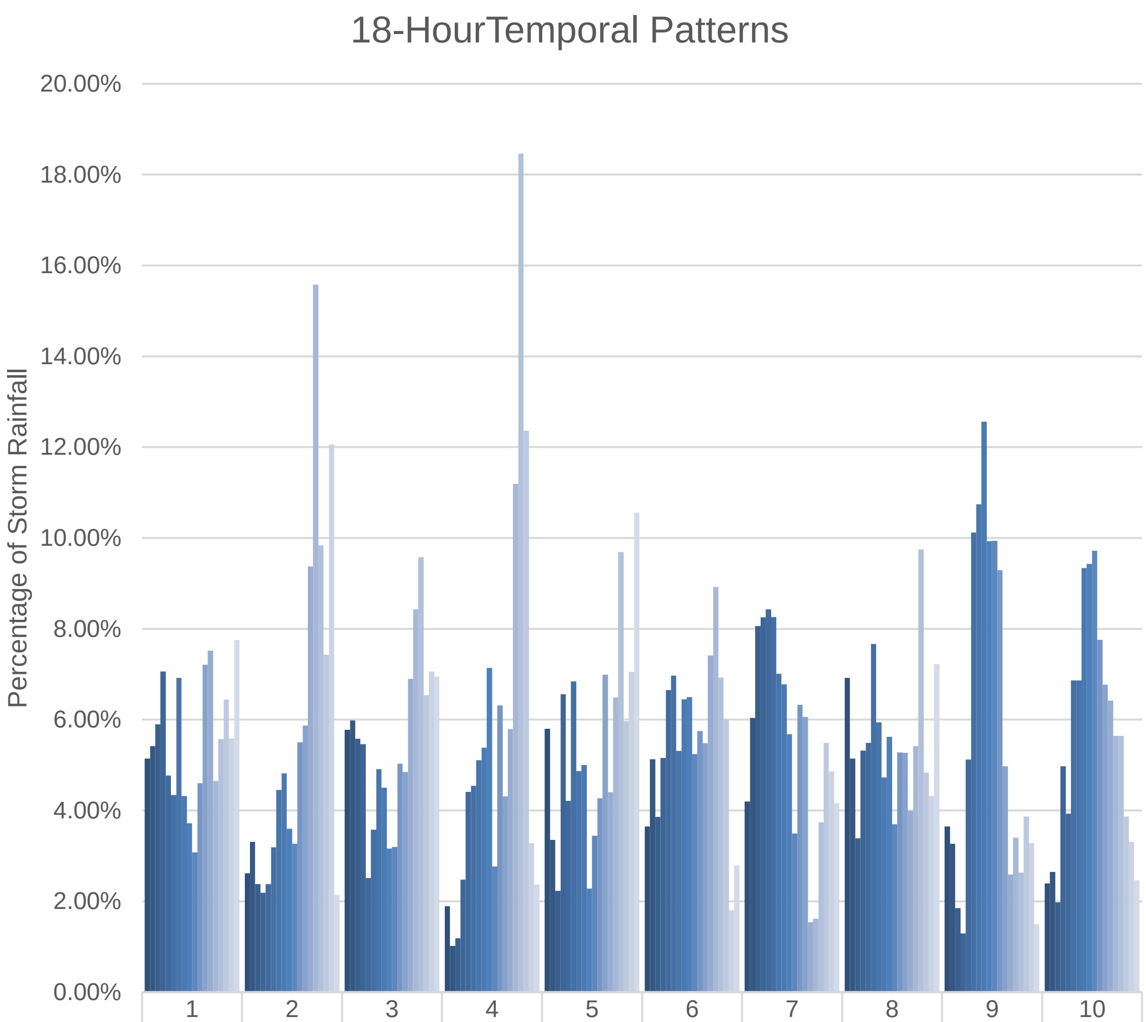
	50%#	20%*	10%	5%	2%	1%	0.50%
12 hour	46.1	64.1	77.5	91.8	112	129	147.1
18 hour	54.4	75.4	91.3	108	132	153	174.4
24 hour	60.9	84.4	102	121	148	171	193
36 hour	70.8	98.1	119	141	172	199	227
48 hour	78.1	108	131	155	190	219	252
72 hour	88.1	121	147	174	212	244	280
96 hour	94.6	130	156	184	224	258	295
120 hour	99.1	135	162	190	231	265	302
144 hour	102	138	165	193	234	268	306
168 hour	105	140	166	193	235	268	307

5.4.1.2 Temporal Patterns

A temporal pattern is a unit hyetograph which is used by RORB to temporally vary the rainfall input into a hydrology model.

The temporal pattern was used to multiply each percentage increment in the temporal pattern by the total storm intensity specified by the IFD table across the duration of the storm, giving a hyetograph.

The 2016 ARR guidelines recommends that at a minimum 10 temporal patterns are ran through a hydrology model and the most suitable of the 10 be selected for use within the design runs. The set 10 temporal patterns have been supplied by the ARR via the ARR datahub (Babister, Trim, & Retallick, 2017).



	1	2	3	4	5	6	7	8	9	10
1	5.14%	2.62%	5.78%	1.89%	5.80%	3.65%	4.20%	6.92%	3.65%	2.39%
2	5.42%	3.31%	5.98%	1.02%	3.35%	5.13%	6.04%	5.14%	3.27%	2.65%
3	5.90%	2.38%	5.58%	1.19%	2.23%	3.86%	8.06%	3.39%	1.85%	1.98%
4	7.06%	2.19%	5.46%	2.48%	6.56%	5.16%	8.25%	5.32%	1.29%	4.97%
5	4.77%	2.38%	2.51%	4.41%	4.21%	6.65%	8.43%	5.49%	5.12%	3.93%
6	4.34%	3.19%	3.58%	4.54%	6.84%	6.97%	8.26%	7.67%	10.12%	6.86%
7	6.92%	4.45%	4.91%	5.11%	4.87%	5.31%	7.01%	5.94%	10.74%	6.86%
8	4.32%	4.82%	4.50%	5.38%	5.00%	6.45%	6.78%	4.73%	12.56%	9.34%
9	3.72%	3.60%	3.16%	7.14%	2.28%	6.50%	5.68%	5.62%	9.93%	9.43%
10	3.08%	3.27%	3.20%	2.77%	3.44%	5.24%	3.49%	3.70%	9.94%	9.72%
11	4.60%	5.50%	5.03%	6.31%	4.27%	5.75%	6.33%	5.28%	9.29%	7.76%
12	7.21%	5.87%	4.85%	4.31%	6.99%	5.48%	6.06%	5.27%	4.97%	6.77%
13	7.52%	9.37%	6.90%	5.79%	4.40%	7.41%	1.54%	3.99%	2.59%	6.42%
14	4.65%	15.58%	8.43%	11.19%	6.49%	8.92%	1.62%	5.42%	3.40%	5.64%
15	5.57%	9.84%	9.58%	18.46%	9.69%	6.93%	3.74%	9.75%	2.63%	5.64%
16	6.44%	7.43%	6.54%	12.36%	5.97%	6.00%	5.49%	4.83%	3.87%	3.87%
17	5.59%	12.06%	7.06%	3.28%	7.05%	1.80%	4.86%	4.32%	3.28%	3.31%
18	7.75%	2.14%	6.95%	2.37%	10.56%	2.79%	4.16%	7.22%	1.50%	2.46%

5.4.1.3 Spatial Patterns

The spatial variation for the hydrologic aspect of the hydrology modelling process was taken into consideration through the use of a spatial pattern. This spatial pattern adjusts the amount of rainfall experienced within each catchment by applying a certain coefficient of the overall model's rainfall to each individual sub-catchment. The value of this coefficient is determined by comparing the rainfall intensities specified by the Bureau of Meteorology for each sub-catchment's centroid. Each combination of storm duration and AEP have a different spatial pattern, however in general the overall spatial distribution between events remained similar. Figure 21 shows spatial pattern for a 1% rainfall event of a storm with the critical duration.

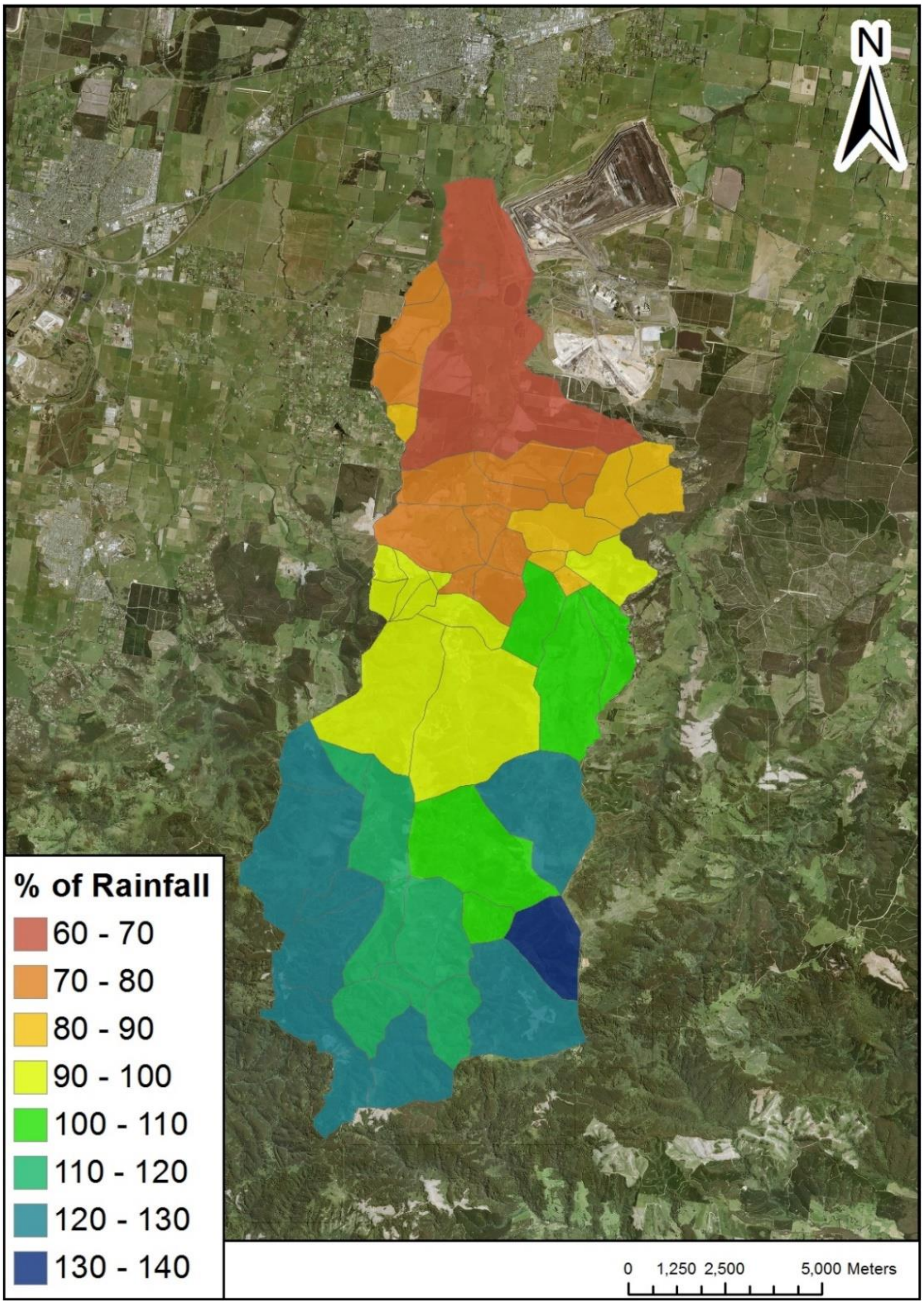


Figure 21 Spatial Pattern for a 1%, 18-hour storm event

5.4.1.4 Areal Reduction Factors

The Areal Reduction Factor (ARF) is another parameter that comes from the Data Hub. The ARF value that was used was based off the area of the entire catchment to the outlet. Well into the hydraulic modelling phase, advice from Hydrology and Risk Consulting (HARC) was delivered around the ARF factor. This advice was that the ARF should be calculated based off stream length and catchment areas to each print node, rather than the outlet (Stephens, 2019). In order to have each printed hydrograph feature a correct ARF, a new model would need to be ran for each print node that would require a different ARF value.

5.4.2 *Results*

The following Figure 22 and Figure 23 present the final comparison between the flood frequency curves (FFC) produced from RORB via Monte Carlo and flood frequency curves produced either from an FFA of the gauge or ARR's RFFE model.

As seen in Figure 22 the FFC from RORB fits well within the upper and lower probability limits (PL) associated with the data from the Koornalla Gauge. RORB begins to stray from the gauges mean for the 1% and 0.5% but is still well within the upper and lower 90% probability limits.

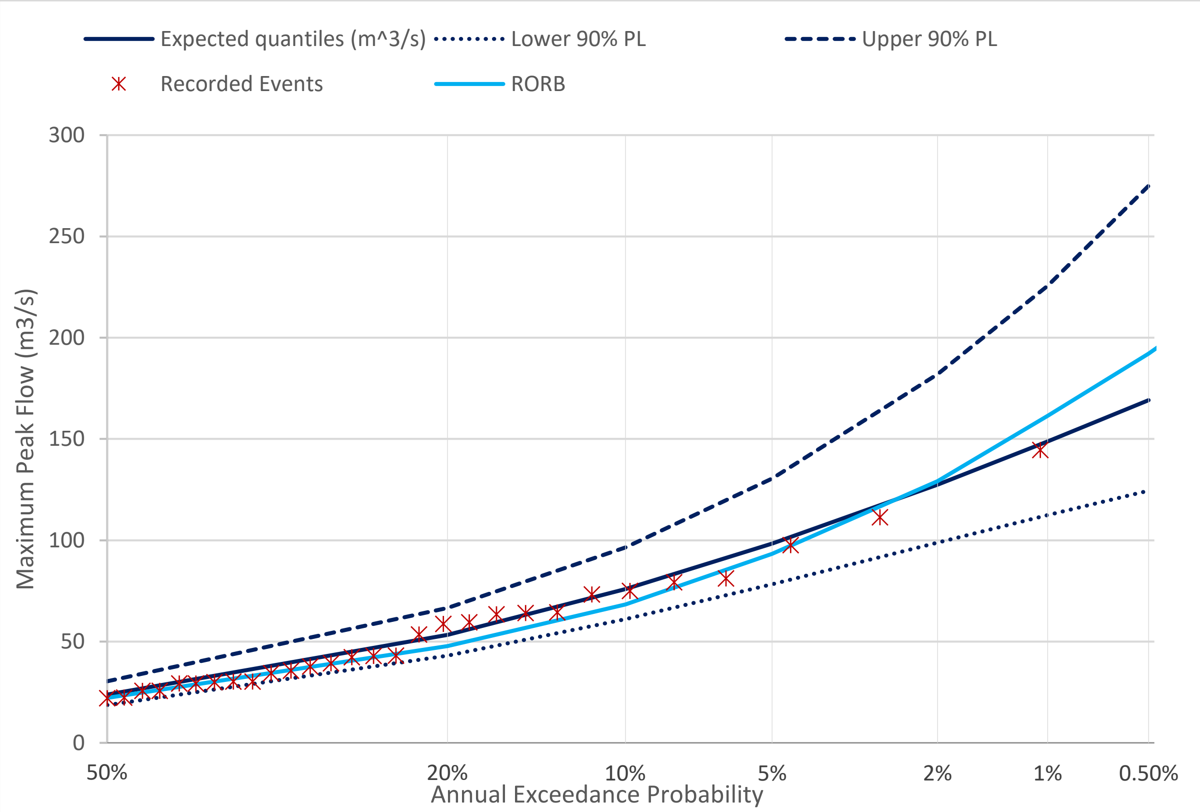


Figure 22 Flood Frequency Curve from Verification at the Koornalla Gauge

Figure 23 shows a strong match between the RORB FFC and the ARR's RFFE Model, with the mean of the RFFE overlapping RORB for a majority of design event sizes.

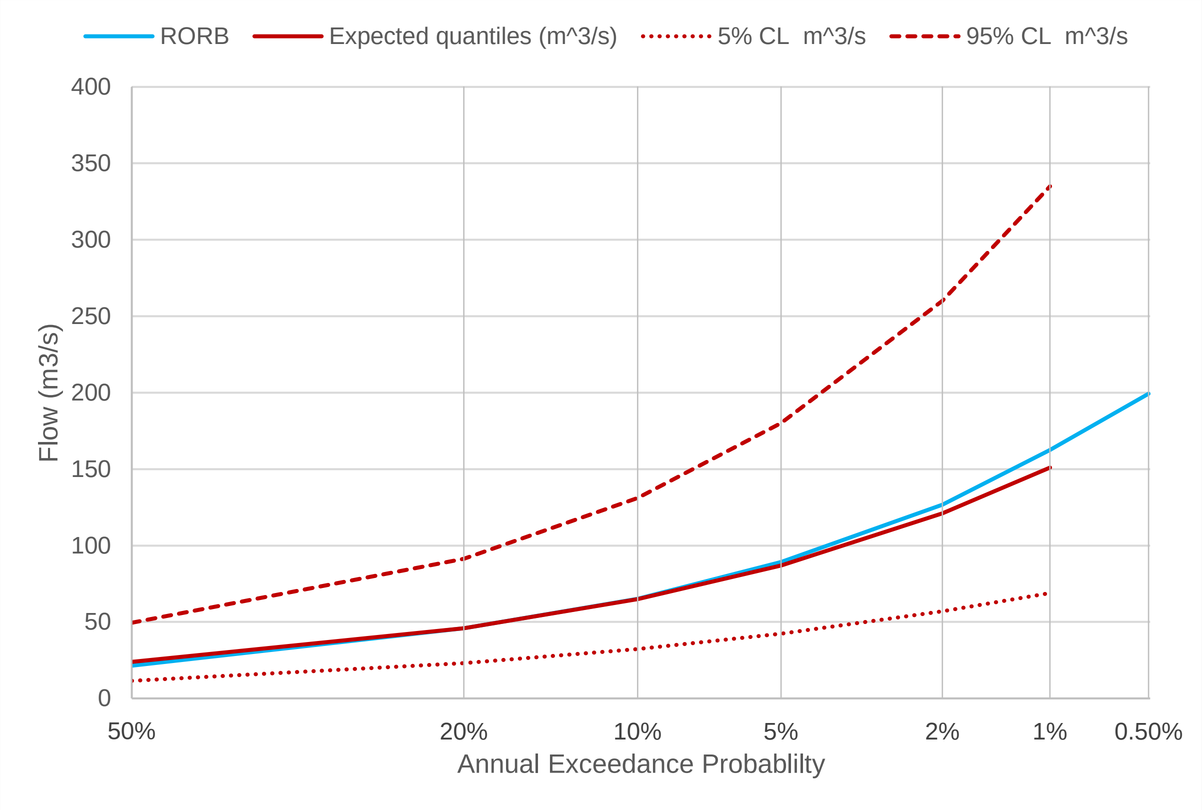


Figure 23 Flood Frequency Curve from Verification at the Model Outlet

The parameters obtained from the verification process have been listed in Table 15. The new initial and continuing losses differ from the calibration stage.

Table 15 Parameters from Verification

Interstation area above	Kc	m	Unfactored Initial Loss (mm)	Continuing Loss (mm/hr)
Koornalla Gauge	18.92	0.8	20	1.25
Catchment outlet	10	0.8	40	1.0

Table 16 Parameters Obtained for Design Events

AEP	1%	2%	5%	10%	20%
ARI	103.7	51.9	20.3	9.8	4.7
Depth	143.9	124.6	101.9	85.6	69.8
Temporal Pattern No.	6	6	1	3	7
Initial Loss Factor	1.00	0.82	0.54	0.98	0.28

5.5 Design run

The purpose of the design run stage is to produce hydrographs at key location throughout the catchment, (shown further in the report in Figure 32). The design run stage uses the same input data as the validation stage. However, rather than running a Monte Carlo suite of varying parameters, the Design run stage only runs a singular ____ for each AEP. These ___ are described in Table 16.

5.5.1 *Results*

The following graphs Figure 24 through to Figure 28 present the results produced from the Design Run stage. These graphs show each hydrograph that was calculated at each of the print node locations, as well as the rainfall hyetograph shape that was used across the catchment.

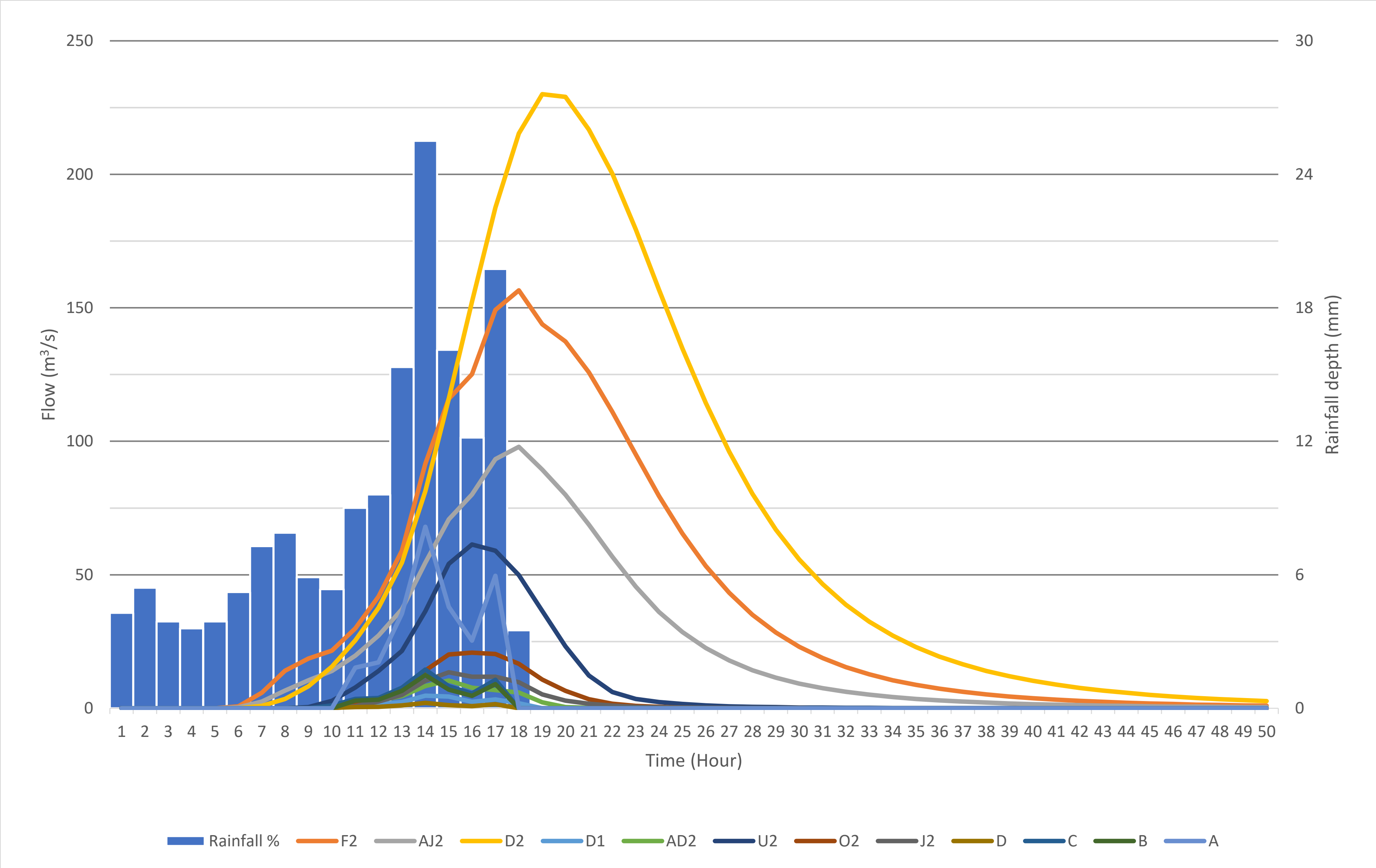


Figure 24 1% AEP Design Flood Results

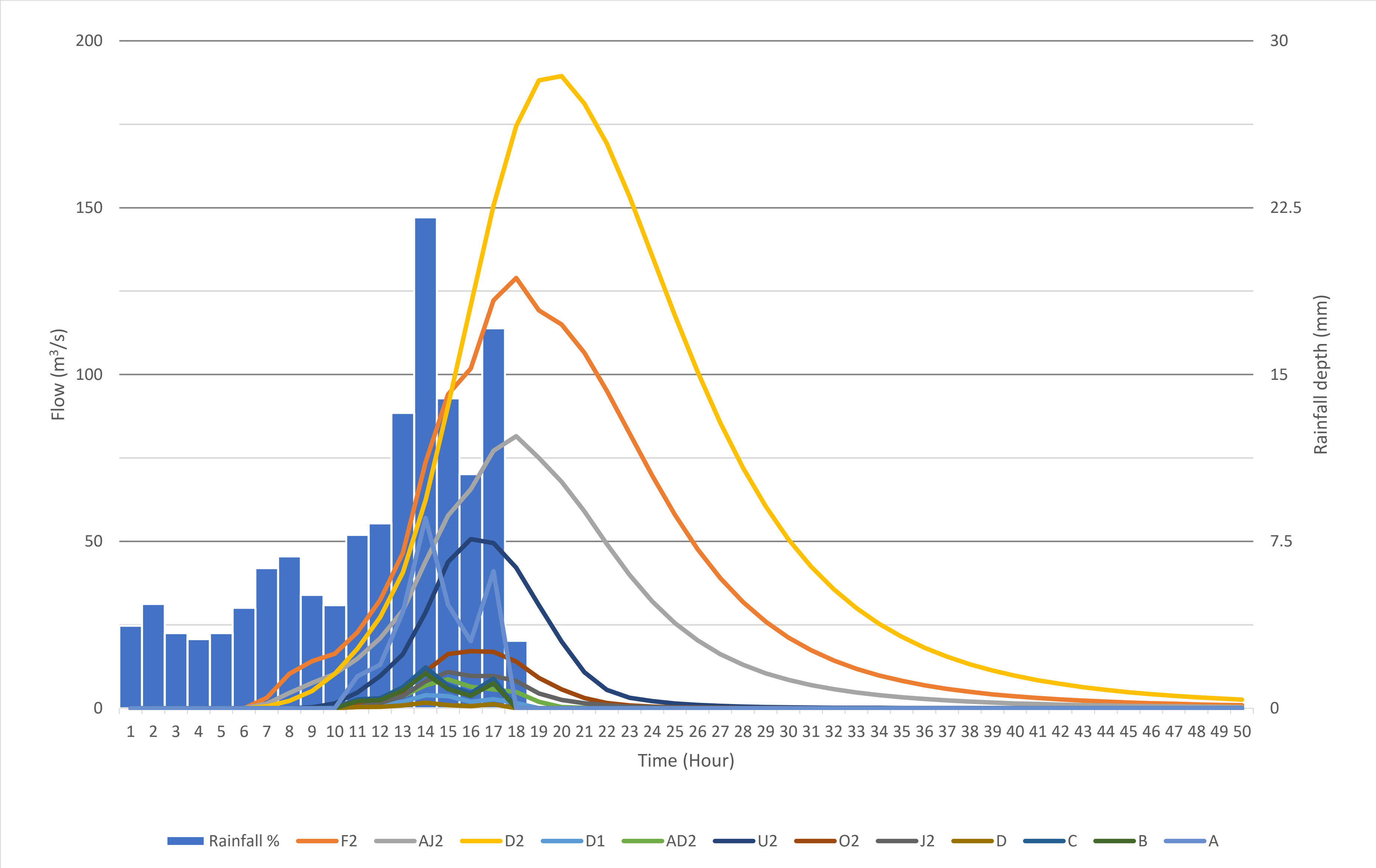


Figure 25 2% AEP Design Flood Results

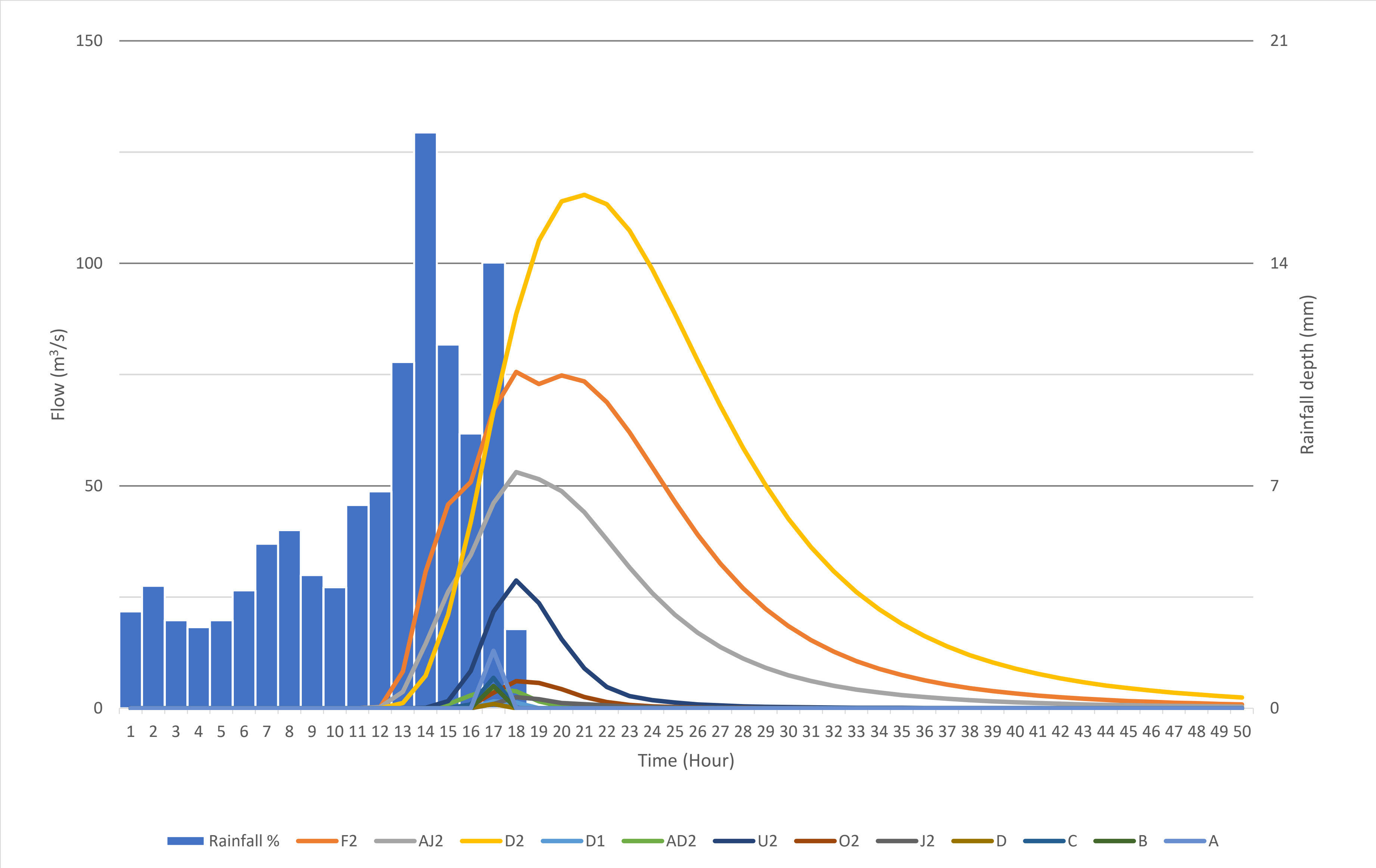


Figure 26 5% AEP Design Flood Results

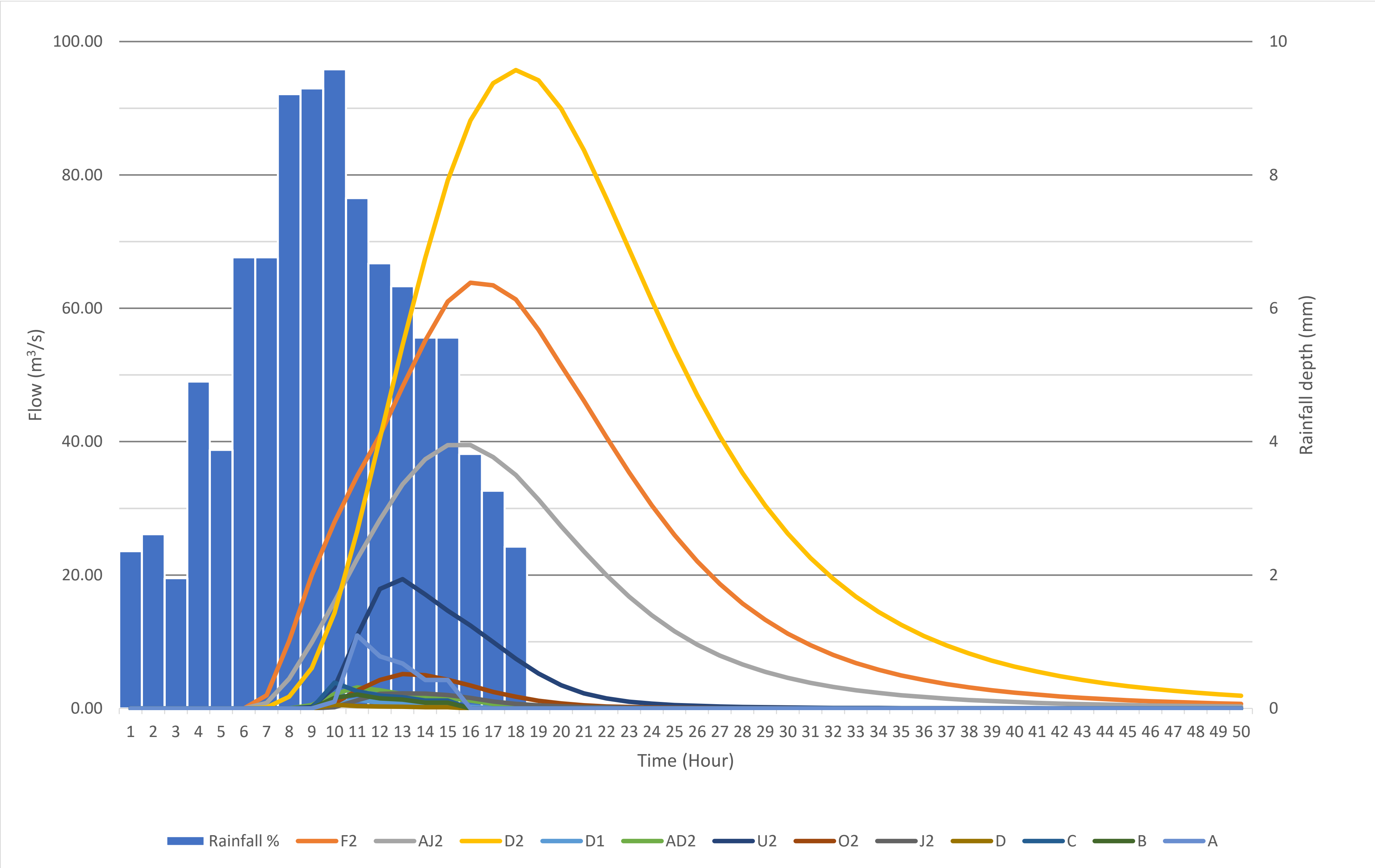


Figure 27 10% AEP Design Flood Results

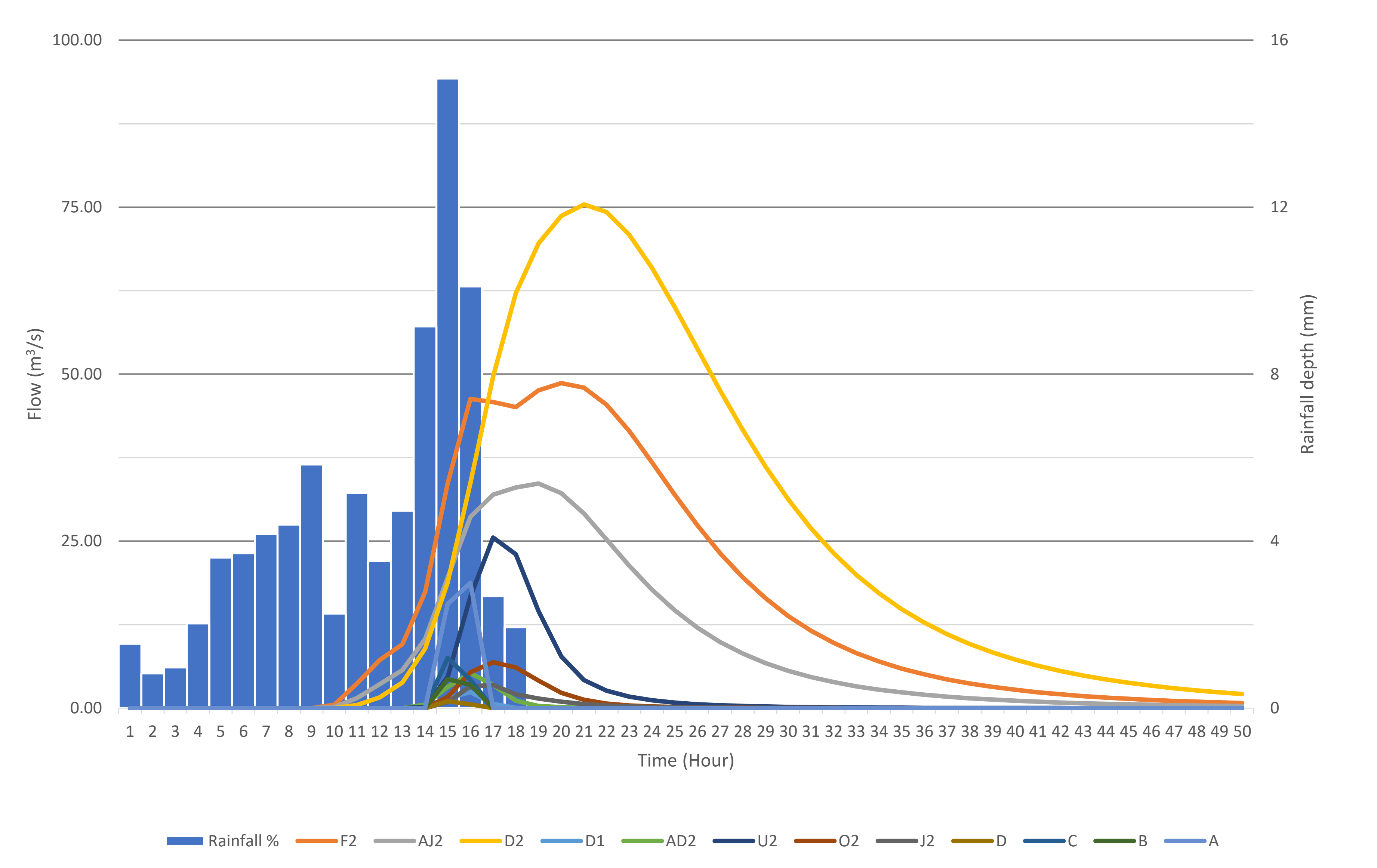


Figure 28 20% AEP Design Flood Results

5.6 Assumptions

5.6.1 *Validation stage using the Monte Carlo*

Much like when performing a flood frequency analysis of gauged results, RORB's Monte Carlo analysis only looks at the peak flow of each of the hydrographs produced during a simulated storm to calculate the storms AEP. The issue with this approach is that it does not take into account the overall shape of the hydrograph and _(give priority?)___ to hydrographs that are more peaked.

In addition to this, analysis during the validation really should be conducted at a larger number of print locations rather than just at the outlet or gauge locations in order to find a design storm that causes the desired AEP across locations across the entirety of the catchment.

5.6.2 *Delineation of the catchment*

In order to meet recommendations around the size of subareas and the 5 subareas above a print location. A number of potential flow paths were not included in the RORB model. While these missed flow paths are unlikely to significantly affect the flooding of the Traralgon Creek, some localised inundation may have been missed.

SECTION C HYDRAULICS

1 DESCRIPTION OF HYDRAULIC MODELLING APPROACH ADOPTED

The hydraulic analysis of Traralgon Creek was performed through a hydraulic modelling program called TUFLOW. TUFLOW uses the hydrographs produced by RORB as flow inputs into the hydraulic model. The hydraulic model of Traralgon Creek is primarily 2D (2-Dimensional), with only a few 1D (1-Dimensional) networks which model the more significant hydraulic structures within the system. The choice to use 2D for this model was made as generally it is quicker and more advantages to set up a 2D model than a 1D/2D hybrid. The 2D model components consists of a 2 metre grid DEM representing elevation for Traralgon Creek.

Aerial photography was used to identify any hydraulic features of significance within the model extent and model these features either as hydraulic structures such as culverts, or simply as areas of increased roughness. The aerial photography was also used to check LiDAR data for any inaccuracies or errors.

2 AVAILABLE DATA

2.1 Aerial photography

The aerial photography was used primarily to define the different materials within the floodplain and to identify hydraulic structure that needed further investigation.

In addition, the aerial imagery helped identify defects within the lidar datasets, as it was able to confirm whether the presence of dense vegetation, fences or other features had possible been picked up.

2.2 Elevation data

For this component of the study the primary criteria is the accuracy and resolution of the elevation dataset. The coverage of the elevation was less of a concern, as the hydraulic extent needed to be reduced to aid in run time.

In light of the above criteria, the West Gippsland Riparian Lidar Dataset was the most suitable of the two elevation datasets. As described previously, this dataset was chosen as it was the most resolute and accurate dataset available to the WGCMA.

2.3 VicMap data

2.3.1 *Roads*

Information around the location of roads was primarily from the Road Network – Vicmap Transport layer. The roads layer was used to define the location of where road material roughness should be applied.

2.3.2 *Land-zoning*

The Vicmap Planning layers were used to determine the land usage of each of the lots and was used in conjunction with the available areal imagery to delineate the material layer across the catchment. While the Vicmap Planning layer was a good start, due to the majority of the catchments land zone being FZ, the imagery and lidar datasets where still required for much of the roughness defining process.

3 KEY HYDRAULIC FEATURES

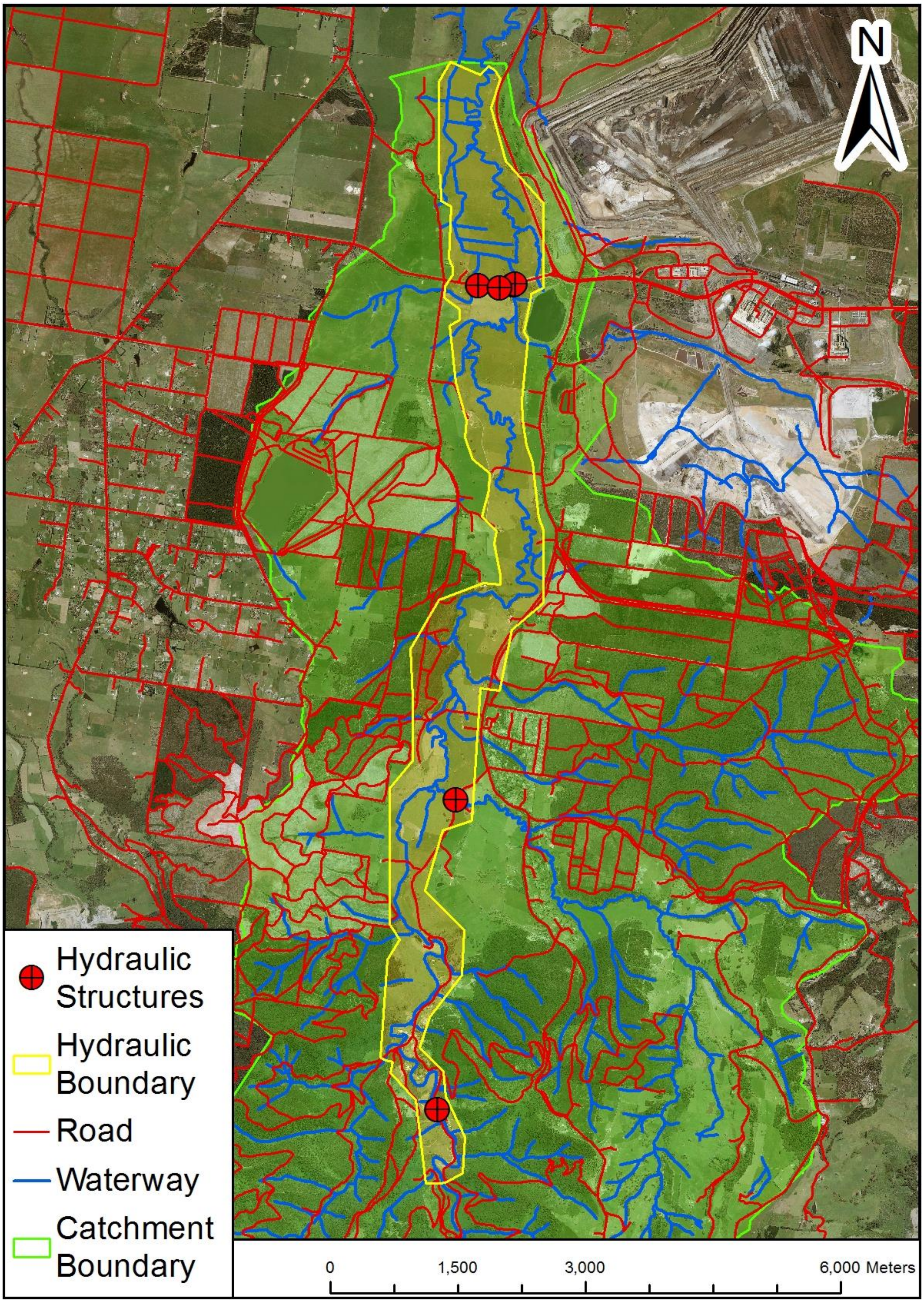


Figure 29 Location of Modelled Hydraulic Structures

4 CATCHMENT EXTENT HYDRAULIC MODEL

4.1 Model extent

Figure 30 displays the extent of the boundary of the hydraulic model. The extent of the boundary was defined this way due to the following criteria.

4.1.1 *Available Elevation Data*

The feature that had the most influence on the hydraulic extent was the available lidar for this area. As discussed previously, the Vicmap DTM is not of a suitable resolution to be used for hydraulic modelling at this scale. The only elevation data that was used for the hydraulic modelling was the West Gippsland Riparian Lidar Dataset. The Riparian dataset captured only the main branch of the Traralgon Creek Catchment. Stony Creek and Jeeralang creek are some of the more significant creeks within that catchment that were unfortunately outside of the areas captured by the Riparian dataset.

4.1.2 *Grid Resolution*

Grid resolution is another typical constraint when defining the amount of area able to be modelled. The grid resolution needs to be fine enough to be able to adequately represent the significant waterways, while also having a model simulation time that can be ran within a reasonable timeframe.

Recommendation from TUFLOW is that in order to adequately represent the waterway, the grid resolution must be fine enough to allow at least 3-4 cells to fit across the waterway. The resolution of the elevation grid input into TUFLOW was 2 metres. Towards the upstream sections of the catchment the stream width varies between 4-8 metres, which is on the edge of the acceptable levels.

4.1.3 *Significant Areas*

The hydraulic model needed to make sure that it was far south enough to capture the Traralgon Creek campsite south of Koornalla.

4.1.4 *Flood data*

After taking the above criteria into consideration, and performing some initial runs, the extent of the hydraulic model was refined further to remove section of the model that had not received any flooding. This was done to further reduce the run time of the model.

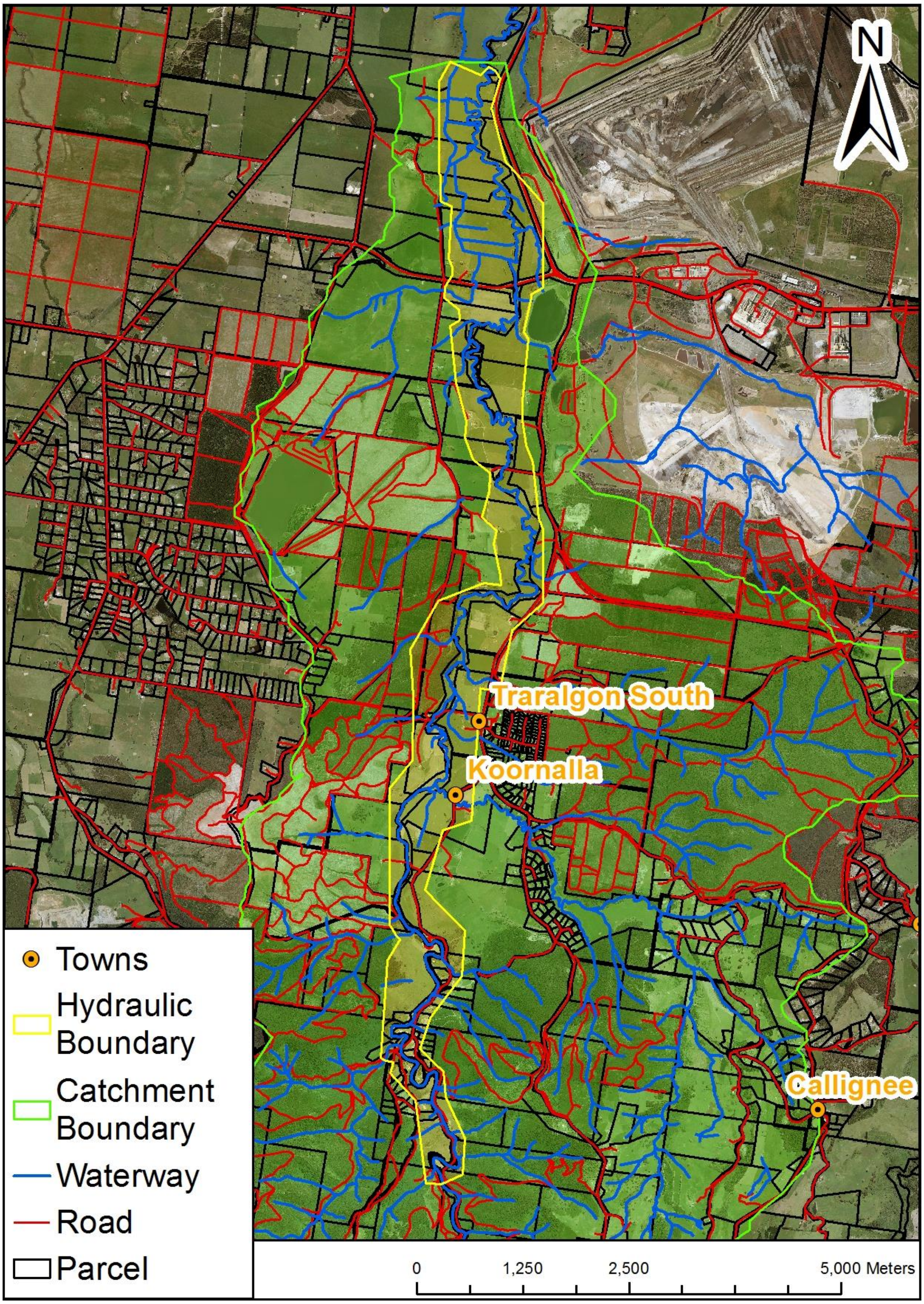


Figure 30 Hydraulic Model Extent

4.2 Input data

4.2.1 *Gridded elevation data*

Almost all the topography data input into TUFLOW was done using a Digital Elevation Model (DEM). As mentioned above, the DEM input into TUFLOW had a 2-metre resolution. The DEM was generated by resampling the West Gippsland Riparian Lidar Dataset from a 1-metre resolution to a 2-metre resolution. The resampling was performed using ArcMaps resample tool with the “CUBIC” resampling technique. The resulting DEM can be seen in Figure 31.

The resampling was necessary as to reduce the run time to a practical duration. The cell size still satisfies the recommendations from TUFLOW that the resolution should be fine enough to be able to fit 3 cells across the width of the river at the point of interest.

The digital elevation grid was altered using TUFLOW’s zsh shapes and commands. The bridges had been removed from the Riparian dataset as part of its post processing and the zsh commands raised the elevation around the bridges to the equivalent height of the bridge deck.

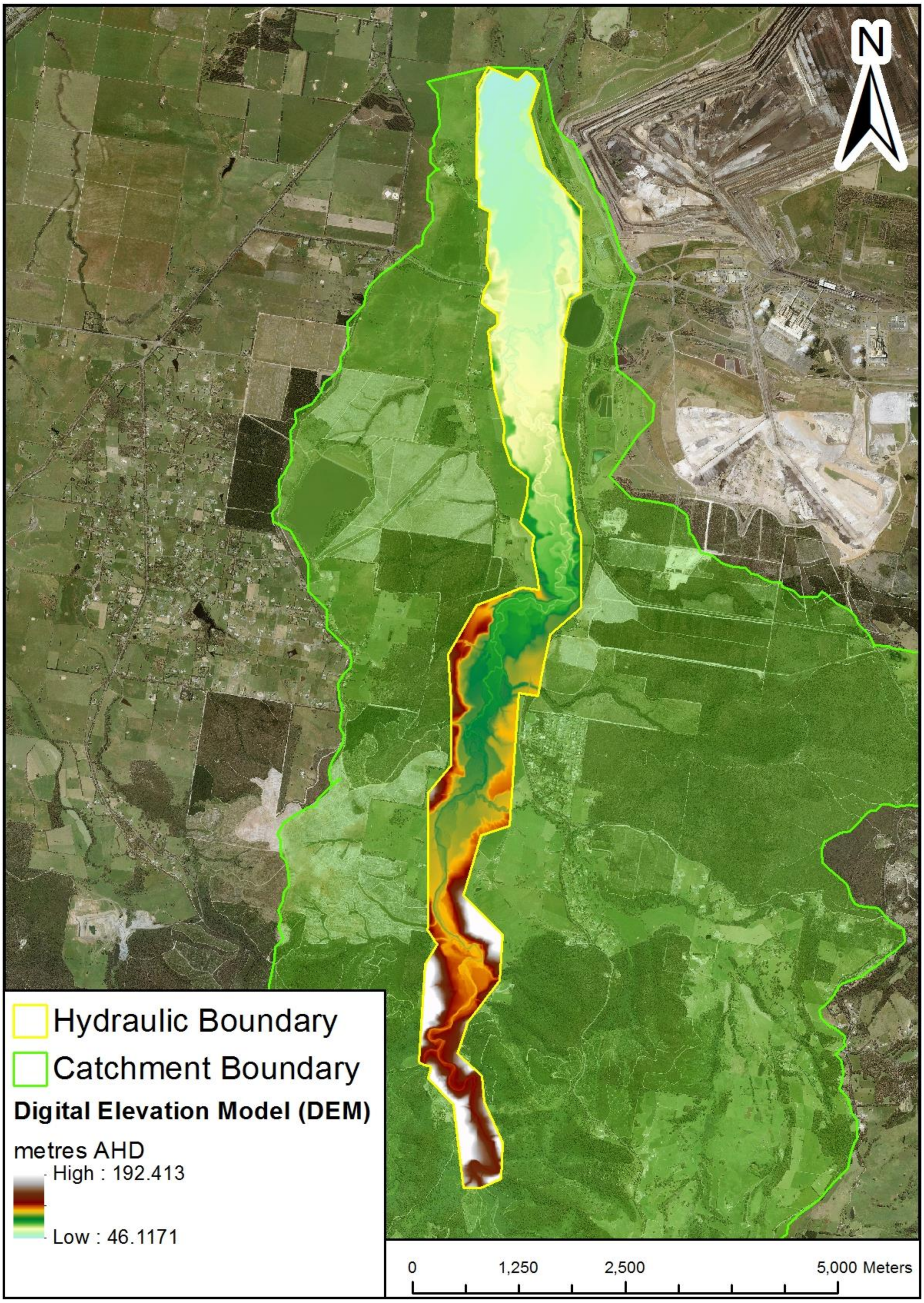


Figure 31 Hydraulics - Elevation Data

4.2.2 *Flow data*

As mentioned previously in this report, the flow hydrographs generated from RORB were input into the hydraulic model. The flow data was input into TUFLOW using either a 2D boundary condition line (2d_bc_L) or a 2D source area polygon (2D_SA_R), these shape files referenced flow vs time plots from external csv directed by the boundary condition data base (bc_dbase).

2D_bc_Ls and 2D_SA_Rs were used based on whether or not the source of flow originated from inside or outside of the hydraulic boundary area. Figure 32 describes the locations of inflow into the hydraulic model.

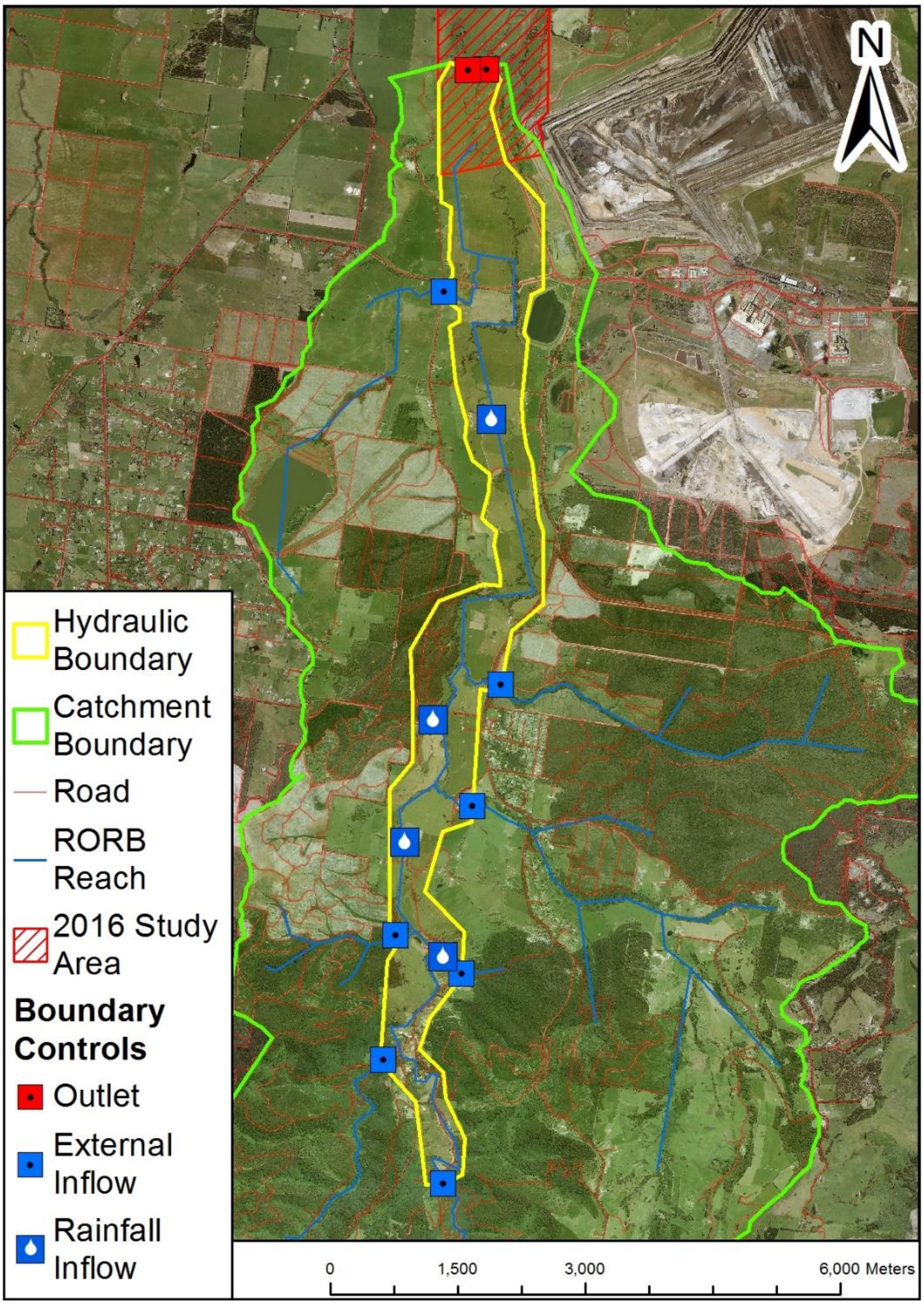


Figure 32 Location of model inflows and outflows

4.2.3 *Materials*

The material layers and tables were used to define the Manning's roughness coefficients across the hydraulic model. The Manning's coefficients were varied spatially through the use of material shape files (shown in Figure 33). The model was divided up into 8 different material types, Table 17 displays the different material types and values used.

The digitisation of these material types was done primarily using the areal imagery, with the land use layers helping define residential and road materials.

Table 17 Material Parameters

Material ID	Manning's n	Description
1	0.03	Veg – Low
2	0.04	Veg – Med
3	0.05	Veg – High
4	0.045	Floodplain – Low
5	0.04	Floodplain – Med
6	0.035	Floodplain – High
7	0.035	Residential – Low
8	0.01	Road

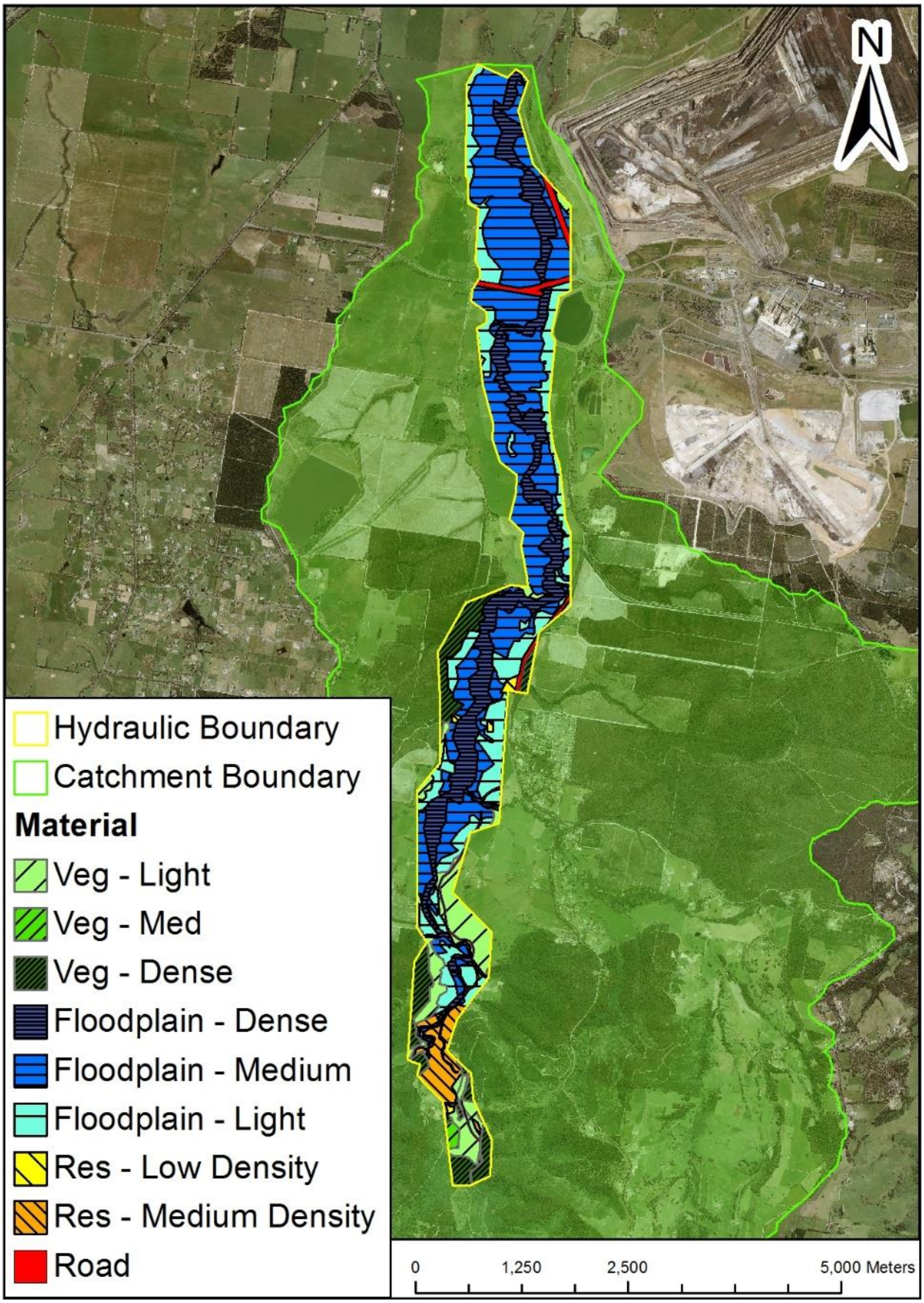


Figure 33 Material Layer

4.3 Assumptions

4.3.1 *Loss model*

Losses were modelled during the hydrology modelling stage, not within the hydraulic model. This means that all water that enters the hydraulic model will either exit the model through the outlet or remain in the model until the simulation finishes. This can cause water to remain trapped in small depressions in the model, potentially acting as an unintentional additional loss that was not accounted for during the hydrology modelling phase. However, the volume of water "lost" as a result of this is likely to be negligible.

4.3.2 *Waterway delineation*

As mentioned previously, the assumptions made during the delineating of waterways as part of the hydrology phase has caused some minor flow paths into the main Traralgon Creek channel to be _____. While this may result in some localised inundation around the edges of the model being missed, omitting these flow paths are unlikely to have a significant effect on the overall flood behaviour of the Traralgon Creek.

4.3.3 *Flow application*

The applications of flow are defined in **Error! Reference source not found.**. Of particular c oncern is the internal flow sources which use Source Area polygons (2d_SA) to define the location of runoff when the centroid of a subarea falls within the boundaries of the hydraulic model.

In reality, runoff would be spread out across the subarea, taking fine flow paths into the Traralgon Creek channel. Whereas the application of the flow using a SA polygon was restricted to often a 16 square metre area, typically directly within the main channel of the Traralgon Creek. This approach has the potential to of both sped up the runoff ____ by a SA polygon's time of concentration and missed possible flow paths. However, as shown by the hydrographs in SECTION B 5.5.1, the amount of runoff produced by subareas with centroids within the hydraulic boundaries tend to be insignificant.

4.3.4 *Roughness model*

The roughness model used by the study applies a singular Manning's value to a particular material type. It is likely that the roughness of the catchment material would change due to factors like; the depth flood waters, vegetation being flattened during larger events, and growth or removal of vegetation.

Additionally, the accuracy of the definition of material type is dependent largely on how the catchment has changed since the capture of the imagery datasets.

- Hydrology aspect
- Downstream boundary slope
- 1-D structures
- Grid resolution

4.4 Parameters and settings

TUFLOWs HPC simulation mode uses an adaptive timestep.

The grid size that was adopted for this model is 2x2 metres. This grid size allowed the model to finish its simulation in approximately 4 hours, while still being fine enough to represent the main channel with at least 3 cells in the upper most areas of the study.

The domain was rotated 3.8^0 East from North to minimize the number of required cells.

4.5 Sensitivity analysis

Present this section as a descriptive paragraph or as dot points with a brief introductory paragraph of what the section will include.

- Boundary conditions
- Flows adopted
- Roughness coefficients

4.6 Results

Include a description of results and selected water surface elevation, depth and velocity plots (e.g. 1% AEP maps)

SECTION D CONCLUSION AND RECOMMENDATIONS

1 CONCLUSION

Relationship of results to previous decision-related information

Impact of flooding on populated areas

2 RECOMMENDATIONS

Limitations / areas for improvement in the modelling conducted

SECTION E REFERENCES

Australian Bureau of Statistics. (2016). *2016 Census Quickstats*. Retrieved March 8, 2018, from http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SSC22556

Babister, M., Trim, A., & Retallick, M. (2017, 4 11). Retrieved from The Australian Rainfall & Runoff Datahub: http://data.arr-software.org

Ball, J., Babister, M., Nathan, R., Weeks, W., Weinmann, E., Retallick, M., . . . (Editors). (2016). *Australian Rainfall and Runoff: A Guide to Flood Estimation.* Commonwealth of Australia: Engineers Australia. Retrieved 2018, from http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

BOM. (2019). *Climate Data Online*. Retrieved from http://www.bom.gov.au/climate/data/

BOM. (2019). *Water Data Online*. Retrieved from http://www.bom.gov.au/waterdata/

Commonwealth of Australia: Engineers Australia. (n.d.). *Regional Flood Frequncy Equation Model: About the Technique*. Retrieved March 26, 2018, from https://rffe.arr-software.org/about.html

Connell, R., Inglis, L., & Tate, B. (2016). *Traralgon Flood Study - Hydraulics.* Water Technology.

DELWP. (2016). *Victorian Floodplain Management Strategy.* Victoria: The State of Victoria Department of Environment, Land, Water and Planning.

DELWP. (2019). Retrieved from Water Measurement Information System: http://data.water.vic.gov.au

Laurenson, E. M., Mein, R. G., & Nathan, R. J. (2010). *RORB Version 6 Runoff Routing Program User Manual.* Monash University and Hydrology and Risk Consulting.

Nathan, R., & Ling, F. (2016). Cathment Simulation. In *Australian Rainfall and Runoff - A Guide to Flood Estimation.* Commonwealth of Australia: Engineers Australia.

Tate, B., & Connell, R. (2016). *Traralgon Flood Study - Data Review.* Melbourne: Water Technology.

WGCMA. (2013, February). Flood Guidelines: Guideines for development in flood prone areas. Victoria: West Gippsland Catchment Management Authority.