

Rosedale Flood Study – Hydrology & Hydraulics (R02)



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1. INTRODUCTION

Water Technology was commissioned by the West Gippsland CMA to undertake the Rosedale Flood Study. This study included detailed hydrological and hydraulic modelling of Blind Joes Creek, taking into account the adjacent catchments (east of Blind Joes Creek) and stormwater runoff within the Rosedale Township itself. The project produced flood mapping of the Rosedale Township and provided recommendations for flood mitigation works, land use planning and flood warning, and generated flood intelligence for emergency response purposes.

This report details the hydrologic and hydraulic analyses undertaken for the project and is one of a series of reports documenting the outcomes of the Rosedale Flood Study.

- R01 - Data Review Report (Water Technology 2016a)
- **R02 - Hydrology and Hydraulics Report (Water Technology 2016b) – this report**
- R03 - Assess and Treat Risk Report (Water Technology 2016c)
- R04 - Summary Report (Water Technology 2016d)

2. STUDY AREA

Rosedale is a small regional town within the Wellington Shire Council district. It has 1077 permanent residents (ABS, 2006). The township lies between the regional cities of Sale and Traralgon and is 184 km east of Melbourne. With limited employment in the town itself, most residents commute to Sale or Traralgon for work. In recent times, Rosedale has seen an increase in demand for residential land and this has led to investigations into developing land currently zoned as flood prone at the western edge of the township.

The town is located at the downstream end of the Blind Joes Creek catchment, with the creek flowing along the western and northern boundary of the township, before discharging into the Latrobe River east of the main town. In times of significant flooding, the Latrobe River can engage all of the floodplain north of the town, including backing up into the end of the Blind Joes Creek system. The study area and significant watercourses are shown in Figure 2-1.

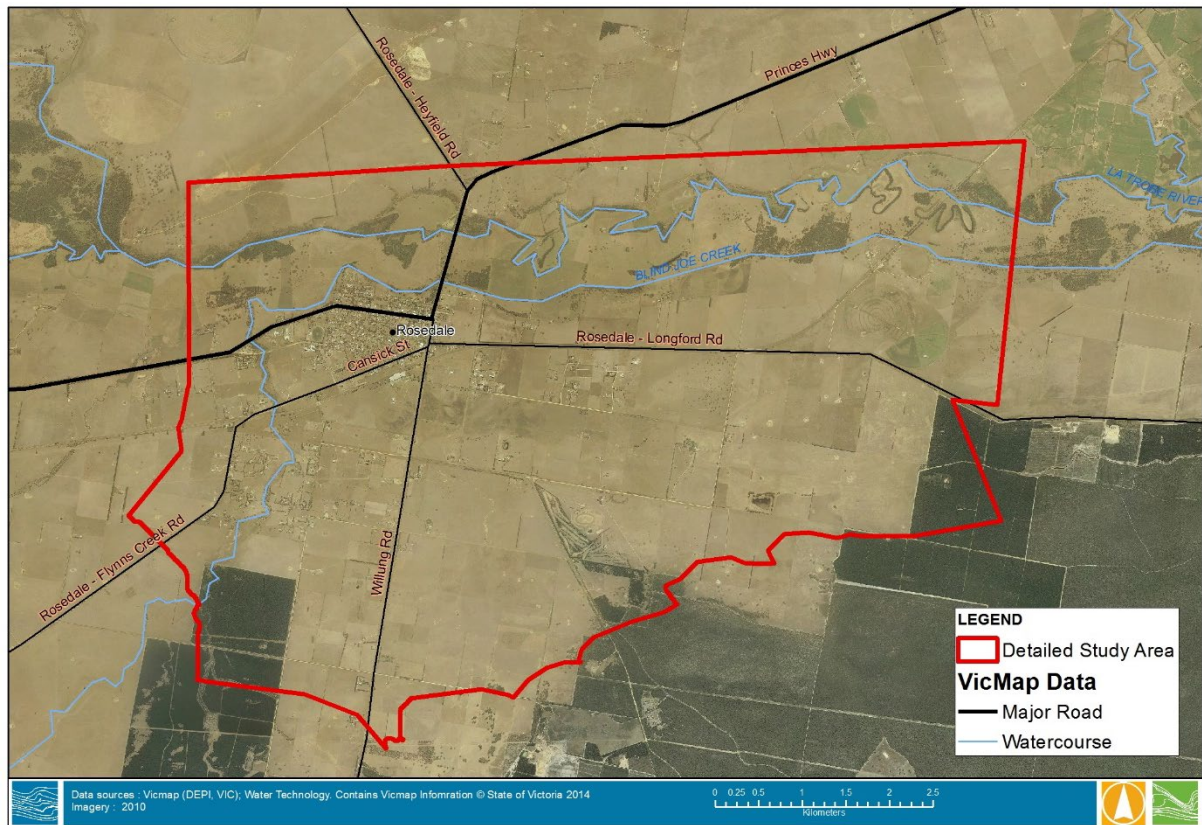


Figure 2-1 Rosedale Study Area

3. HYDROLOGICAL MODEL DEVELOPMENT

3.1 Overview

The hydrological analysis for Rosedale consisted of a review of the hydrological context of the study area followed by hydrologic modelling using RORB. Given the lack of stream flow gauges in the upper catchment and the fact that the Latrobe River flow combines with Blind Joes Creek flow as measured by the Anabranche gauge in Latrobe River in floods greater than 10% AEP, the use of the Latrobe River Anabranche streamflow gauge for a typical model calibration was not possible. The study area was therefore treated as an ungauged catchment, with hydrology and hydraulic modelling being developed in tandem.

Outputs from the hydrology model were input to the hydraulic model, and the resulting extents/timing/peak flows were compared to observed data. Where significant over and/or under estimations occurred in water level and extent in the hydraulic model, the hydrological model parameters were modified/refined. Once a close agreement was achieved in both the anecdotal timing of the peak flow and the modelled water levels and extents within Rosedale, the RORB modelling was considered validated and suitable for design flood estimates.

The lack of data on Blind Joes Creek and its adjacent catchments meant the bulk of the validation work focused on the 1993 event. It was assumed that if a suitable match could be achieved with the 1993 event then the parameters adopted could be applied to other historic events to see if representative flooding could be replicated.

3.1.1 Preliminary TUFLOW rain-on-grid modelling

To inform the LiDAR survey request and the drainage system modelling schematisation, a coarse grid low resolution Rain-on-Grid TUFLOW hydraulic model was constructed of the entire contributing catchment area. This modelling was also used to identify major overland flow paths and to identify the upstream hydraulic modelling boundaries. Nominally the boundary was set to the region where the Strzelecki ranges gives way to the Blind Joes Creek floodplain (change in slope). RORB models of the steeper country (Strzelecki ranges) were then constructed to estimate the external catchment flows impacting the area.

3.2 Catchment Description

The Blind Joes Creek and its adjacent catchments to the east have a combined catchment area of approximately 149 km². Higher up in the catchment the contributing waterways are confined to steep valleys, with the headwaters at an elevation of approximately 240 m AHD. As many as nine defined catchments flow off the Strzelecki ranges towards Rosedale. Further down in the floodplain approximately 3 km south of Rosedale the contributing waterways and floodplain flatten out. Figure 3-1 shows the contributing catchment upstream of Rosedale. Flows from the Strzelecki ranges and along the flatter floodplain country behind the township have been noted by many residents as causing much of the nuisance flooding in recent events in history as opposed to flows from Blind Joes Creek.

Flows move through Rosedale to the Latrobe River floodplain via two locations; at the western edge of the township, via the highway bridge over Blind Joes Creek and at the eastern edge of town with shallow flows moving through the streets before finding their way into the Latrobe River either side of the Princes Highway Bridge. A significant portion of overland flow also continues east sitting behind the Rosedale–Longford Road (and the Railway Line) before flowing north to the Latrobe River near Mullocky Lane.

The township of Rosedale lies on the northern reaches of Blind Joes Creek, immediately upstream of the Latrobe River floodplain. The upper catchment is primarily forested, including plantations, whilst the lower catchment is generally farmland with the exception of the urban areas in and around Rosedale.

There are two streamflow gauges on the Latrobe River floodplain north of the main township. These sites have been very useful in understanding flood levels in the Latrobe River which occur during flooding in Blind Joes Creek (and its adjacent catchments).

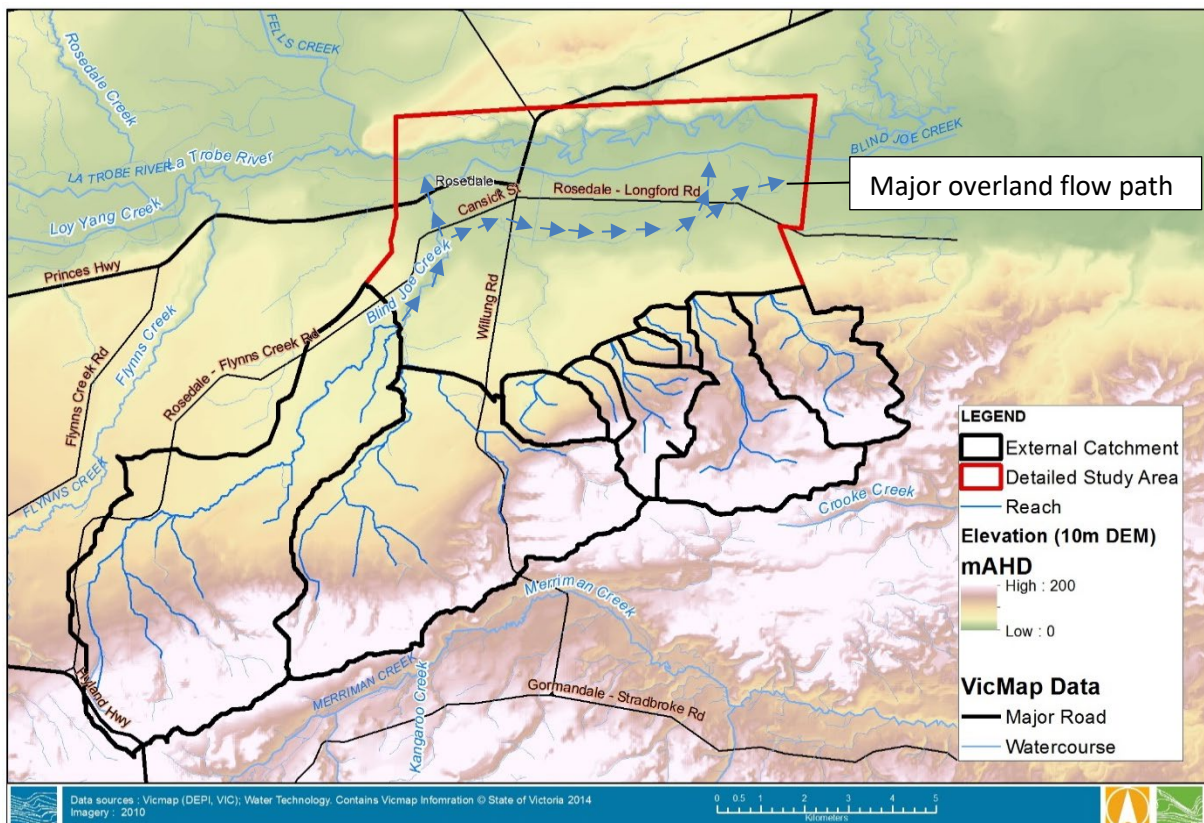


Figure 3-1 Rosedale Contributing Catchments

3.3 Rainfall Data

3.3.1 Official Records – Australian Bureau of Meteorology

The average annual rainfall at Rosedale is approximately 650 mm. A steep rainfall gradient exists over the catchment with average annual rainfall reaching around 1,100 mm in the headwaters.

Numerous daily rainfall sites are in operation around the catchment. Key stations, including current stations and stations operating over the 1993 and 2012 floods, are listed in Table 3-1. Unfortunately, no daily rainfall stations exist within the Blind Joes Creek catchment for both the 1993 and 2012 flood events.

Table 3-1 Daily rainfall stations around Blind Joes Creek catchment

Gauge No.	Location	Distance from township (km)	Year opened	End of Record	Years of Data
85071*	Rosedale	0.7	1878 Sep	2005 Aug	123.9
85126	Nambrok	11.8	1908 Mar	1931 Dec	23.8
85271	Nambrok Murray	14.3	1979 Oct	1980 Mar	0.5
85076	Stradbroke West (Inglenook)	17.5	1891 Aug	1982 Nov	91.1
85022	Denison (Wandocka State School)	17.8	1933 Aug	1993 Nov	55.7
85009	Traralgon Epa	22.4	2000 Dec	2014 Nov	14
85170	Traralgon L.v.w. & S.b.	23.7	1967 Jul	1990 Dec	23.4
85236	Callignee North	26.4	1956 Jan	2014 Aug	57.1
85297	Maffra	26.6	1993 Oct	2012 Dec	19.3
85034	Glenmaggie Weir	26.8	1938 Jan	2014 Nov	76.8
85280	Morwell (Latrobe Valley Airport)	27.3	1984 Jan	2014 Nov	30.9
85083	Tinamba West	27.7	1905 Oct	1950 Jun	44.7
85299	Koornalla Traralgon Ck Rd	28.8	1994 Apr	2014 Sep	20.5
85281	Traralgon Creek at Koornalla	29.0	2000 Dec	2014 Nov	14
85105	Hazelwood North	29.5	1939 Jan	1990 Aug	36.8
85035	Glenmaggie (The Laurels)	29.6	1905 Oct	1957 Dec	51.8
85011	Blackwarry	29.9	1888 Oct	1974 Apr	85.3
85017	Callignee South	30.2	1932 Mar	1985 Nov	53.8

* No data available for September 1993

Pluviograph (sub-daily rainfall) stations around the Blind Joes Creek catchment are listed in Table 3-2. The 1993 event was captured at East Sale Airport, Morwell and Callignee North pluviographs. The 2012 event was captured at all listed stations except East Sale.

Table 3-2 Pluviograph stations around Blind Joes Creek catchment

Gauge No.	Location	Distance from township (km)	Year Opened	End of Record	Years of Data
227239	Stradbroke West	17.5	June 2006	-	9
85236	Callignee North	26.38	1956 Jan	-	57.1
85170	Traralgon L.v.w. & S.b.	23.7	1967 Jul	1990 Dec	23.4
85280	Morwell (Latrobe Valley Airport)	27.34	1984 Jan	2014 Nov	30.9
85072	East Sale Airport	30.87	1943	2011 Sept	71

3.3.2 Other rainfall sources

It was identified in the data review stage of this project that limited rainfall data existed inside the study area for the 1993 and 2012 events. It was also noted that rainfall totals are expected to vary significantly from the upper reaches to the flatter valley country where the township is found. To fill this data gap, community rainfall information was requested for 1993 and 2012 events. Steering committee representative and Coordinator at Rosedale Neighbourhood House, [REDACTED], was instrumental in this process. Daily rainfall totals collected are detailed in Table 3-3 and Table 3-4.

Table 3-3 Community supplied daily rainfall for September 1993

Source	Location	Location (GDA94 MGA 55)	Daily rainfall depth (mm) in September 1993						
			12th	13th	14th	15th	16th	17th	18th
[REDACTED]	[REDACTED]	474,097.4 5,775,757.9	1.5	5.6	3.3	37.6	32.5	1.3	2.0
[REDACTED]	[REDACTED]	482,637.6 5,767,093.6		3.5	15	75	14.5	8.5	

Table 3-4 Community supplied daily rainfall for June 2012

Source	Location	Location (GDA94 MGA 55)	Daily rainfall depth (mm) in June 2012			
			3rd	4th	5th	6th
[REDACTED]	[REDACTED]	481,379.3 5,777,560.7	4.5	5	74	
[REDACTED]	[REDACTED]	482,637.6 5,767,093.6	12	38.5	56.5	
[REDACTED]	[REDACTED]	481,087.9 5,776,925.2		6.5	73	2.5
[REDACTED]	[REDACTED]	473,761.0 5,774,926.0	4.25		71.5	

3.4 Streamflow Data

As many as 18 active gauging stations are found in the Latrobe River catchment upstream of the Rosedale Township. Of most relevance to this study are two sites immediately north of the township (shown in Table 3-5). While both sites are identified as representing Latrobe River flows, this is only true in times of significant flow in the Latrobe River. Under typical conditions, the Latrobe River Anabranh site represents flows from the Blind Joes and Middle Creek catchments as well as the Rosedale township urban runoff.

The recent Latrobe River flood study has shown all of the Latrobe River floodplain north of Rosedale engaged in events $\geq 10\%$ AEP suggesting that using the Latrobe River Anabranh site to represent flooding in Blind Joes Creek would not be appropriate.

A review of flood level information at both sites was undertaken with assistance from Thiess Services. No definitive conclusions were reached regarding at what level the Latrobe River Anabranh site becomes dominated by the Latrobe River. This is because the Latrobe River's primary reach tends to breakout upstream of the township at relatively frequent intervals. Analysis of the gauging station data suggests this occurs when the flood level at Latrobe River at Rosedale (main stream gauging station) level is greater than 3.8 m which is below the current minor flood level at the site. Peak flows from major flood events are shown in Table 3-6.

Table 3-5 Relevant Stream flow gauges in the Rosedale area

Gauge No.	Location	Period	Years	Catchment Area (km ²)
226224	LATROBE RIVER (Blind Joes Creek) @ ROSEDALE (ANABRANCH)	1936-2014	78	4,144
226228	LATROBE RIVER @ ROSEDALE (MAIN STREAM)	1936-2014	78	4,144

The rating curve for both the main stream (Figure 3-3) and the anabranh (Figure 3-2) are shown below. The rating curve for the main stream site is considered reliable up to 4.8 m (17,600 ML/d) and looks to have a very strong history of gaugings across a large range of flows. The current rating curve for the Anabranh station nominates data to be reliable up to 3.5 m (2,720 ML/d), however it is clear that there is considerable scatter in the gauging below this level.



Department of Environment and Primary Industries

HYGPLOT V146 Output 24/05/2014

226224 LATROBE RIVER @ROSEDALE (ANABRANCH)

Gaugings from 25/11/1936 to 22/11/2004

Rating Table 29.00 29.00

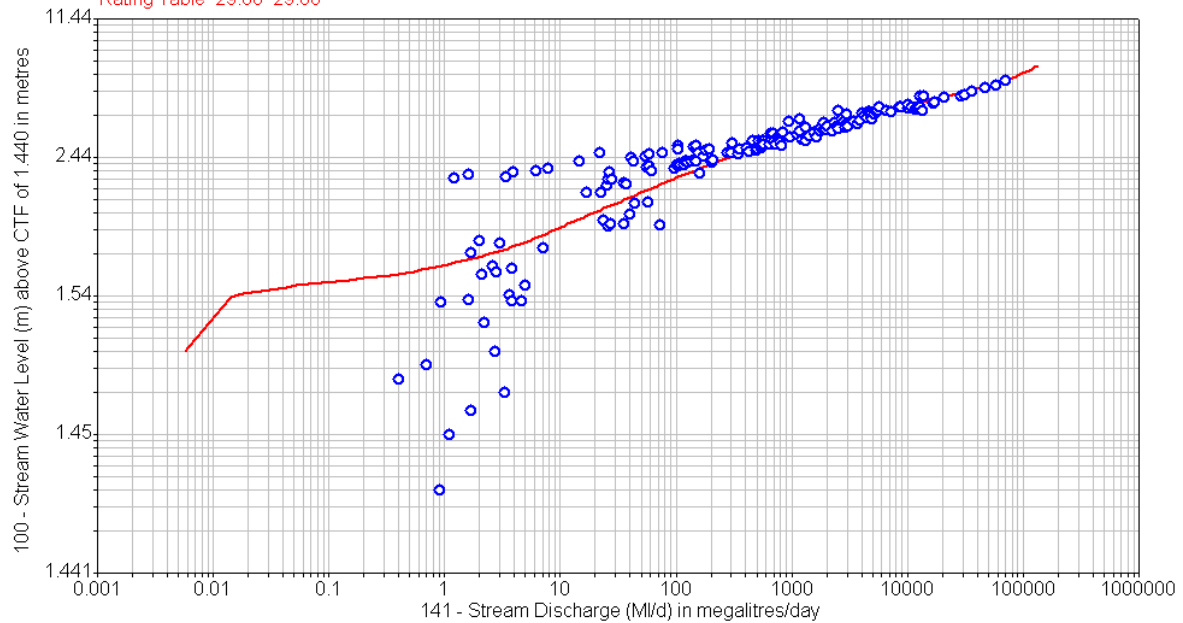


Figure 3-2 Rating Curve for 226224 LATROBE RIVER (Blind Joes Creek) @ ROSEDALE (ANABRANCH)

Department of Environment and Primary Industries

HYGPLOT V146 Output 08/09/2014

226228 LATROBE RIVER @ROSEDALE (MAIN STREAM)

Gaugings from 25/11/1936 to 04/02/2010

Rating Table 41.00 41.00

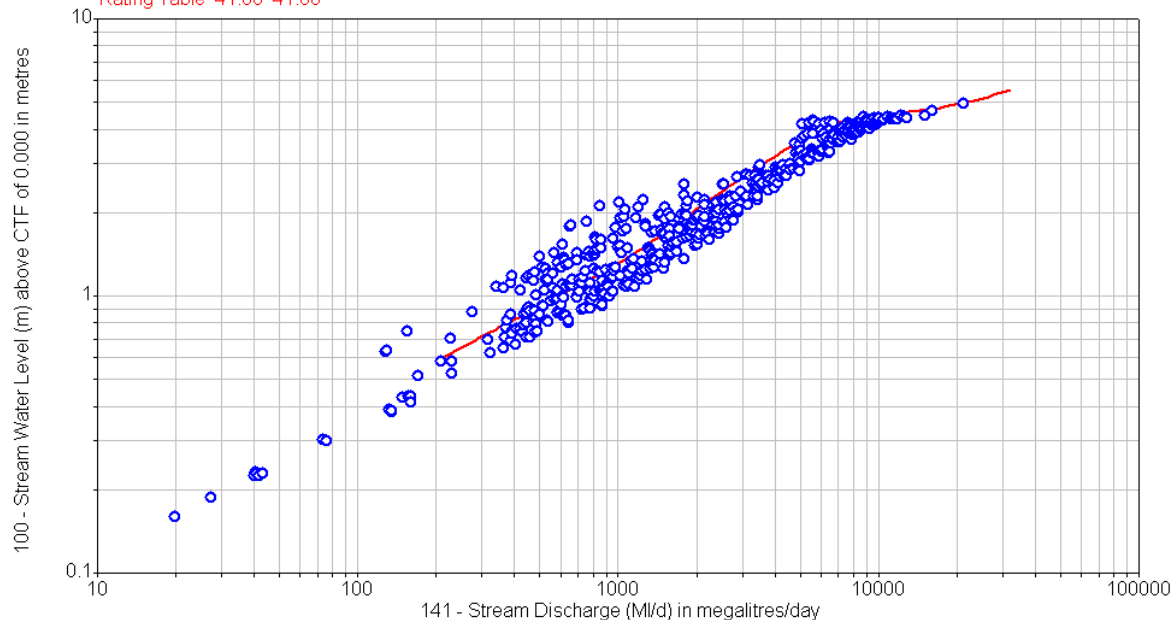


Figure 3-3 Rating Curve for 226228 LATROBE RIVER @ ROSEDALE (MAIN STREAM)

Given a comprehensive investigation into the Latrobe River hydrology was completed in the Latrobe Flood Study and that the focus of this study is not on the Latrobe River, gauging station data on the Latrobe River was not intensively reviewed in this study. Instead assumptions and key findings from the Latrobe Flood Study were reviewed and adopted as boundary conditions. Peak flows were extracted from the available gauging data with the results of this analysis shown in Table 3-6.

Table 3-6 Key event peak flows

Station ID	Station Name	Peak Flow (m ³ /s)					
		June 1952	October 1953	June 1978	September 1993	November 1995	June 2012
226228	<i>Latrobe River @ Rosedale*</i> (Main Stream)	319	353	252	186	160	101
226224	<i>Latrobe River @ Rosedale*</i> (Anabranh)	1,215	1,007	1,012	829	821	353
<i>Combined flow*</i> <i>Latrobe Flood Study 2012</i>		1636	823	1499	1015	980	NA

* Data extracted from the DELWP water portal March 2015 (<http://data.water.vic.gov.au/monitoring.htm>)

+ Cardno hydrology report states their data source as "combined flows from 226228 and 2 26224. Data Warehouse predominantly, in-filled with Red Book data if higher values". It is unclear why this data is not equal to the sum of the data extracted from the DELWP water portal.

3.4.1 Flows for Minor, Moderate and Major events in the Latrobe River

As part of the gauging data and rating curve review, estimated flows for the three flood class events were determined. These flows may be used in the sensitivity analysis during design flood mapping.

Table 3-7 Flood class levels and flows

Station ID	Station Name	Minor		Moderate		Major	
		Level (m)	Flow* (m ³ /s)	Level (m)	Flow* (m ³ /s)	Level (m)	Flow* (m ³ /s)
226228	<i>Latrobe River @ Rosedale</i> (Main Stream)	4.0	68	4.8	204	5.5	363
226228	<i>Latrobe River @ Rosedale</i> (Anabranh)		163		618		1,149

* Data extracted estimated using rating table 41.01

3.5 Latrobe River Flood Study – Hydrology Report

A comprehensive review of the Latrobe River Flood study was undertaken to establish design flow estimates and observed historic flows in the Latrobe River. This review assisted in establishing the likely concurrence of a Blind Joes Creek flood event in relation to a Latrobe River flood event. Flood Frequency Analysis (FFA) undertaken in the Latrobe River Flood study nominated peak flow estimates for 5 historical events and these are shown in Table 3-8. Peak flows nominated for historic events have been included for comparison. Flows in Table 3-8 represent combined flow at both the Latrobe River and the Latrobe River Anabranh gauging stations. These flows were estimated by others as part of the Latrobe Flood study. It is unclear why they slightly differ from the summation of the flows (226228

and 226224) exacted from the DELWP water portal in March 2015 as part of the Rosedale Flood Study (presented in Table 3-6).

Table 3-8 Latrobe Flood Study FFA results and historic peaks from 226228 & 226224 (combined)

Design AEP and Historic Year	Peak Flow (m ³ /s)*	Upper 95% Confidence Limit	Lower 95% Confidence Limit
10%	327	410	269
5%	567	750	448
1953	823		
1995	980		
1993	1015		
2%	1132	1614	845
1978	1499		
1952	1636		
1%	1875	2832	1339
0.5%	3071	4912	2097

* Data reproduced from Latrobe Flood Study - Hydrology report 2012

3.6 Rainfall-Runoff Modelling

To develop historic and design flow estimates for the ungauged Blind Joes Creek and other contributing catchments to the study area, a hydrological rainfall-runoff model was developed using RORB. This section describes the RORB model development and calibration.

3.6.1 RORB Model Development

The ArchHydro tool in ESRI ArcMap was used to determine the initial delineation of catchments, sub-catchments and drainage paths of Blind Joes Creek and adjacent catchments for input to the hydrologic model. This was further supported by the coarse rainfall-on-grid modelling. The catchment was split into 9 independent drainage systems. These catchments were then split into 51 sub-catchments with areas ranging from 0.2 to 6 km². A RORB model was then constructed of the study area using miRORB (MapInfo RORB tools). Key sub-catchment characteristics are shown in Table 3-9. Each of the nine catchments were set up in RORB with interstation areas, this enabled unique RORB modelling parameter to be applied to each catchment. The Blind Joes Creek catchment was used as the reference catchment, with all other catchment parameters scaled using catchment area and average flow distance relationship.

The RORB model was at a resolution adequate to resolve the main drainage paths and sub-catchments, and to provide smooth hydrographs for input to the hydraulic model inflow boundaries. Interstation areas were used for each independent external catchment allowing catchment specific routing parameters to be applied, however this functionality may not necessarily be used as there is no gauged information to inform different parameters across drainage catchments.

The hydrological contribution from the study area downstream of the RORB outlets shown in Figure 3-4 was included via the direct rainfall-on-grid approach in the hydraulic model.

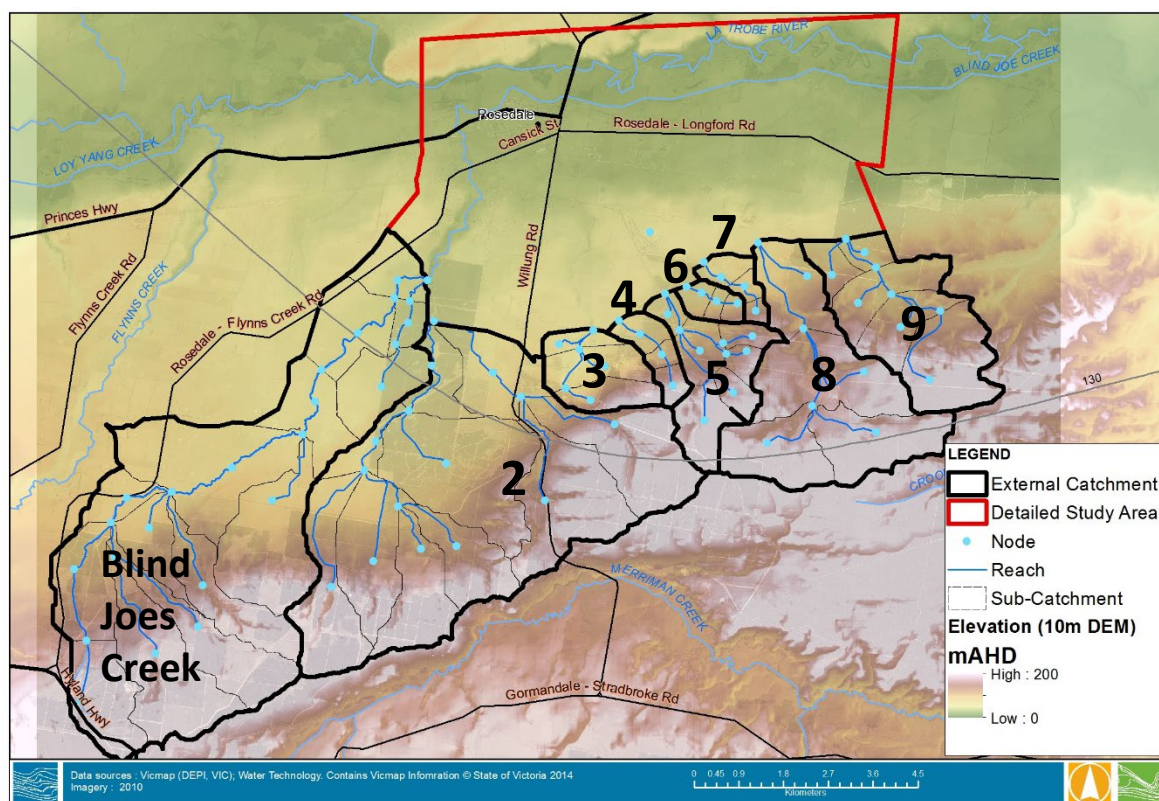


Figure 3-4 RORB model structure

Table 3-9 RORB model sub-catchment details

Catchment Name	Total Area (km ²)	Weighted Average FI	Average flow distance (km)	Sub-catchment in RORB model
Blind Joes Creek	36.68	0.1	9.05	14
Trib 2	31.35	0.1	5.14	10
Trib 3	3.143	0.1	1.41	3
Trib 4	1.369	0.1	1.06	6
Trib 5	4.517	0.1	2.20	3
Trib 6	0.854	0.1	0.64	3
Trib 7	1.037	0.1	0.90	4
Trib 8	11.94	0.1	4.13	5
Trib 9	8.064	0.1	2.87	3

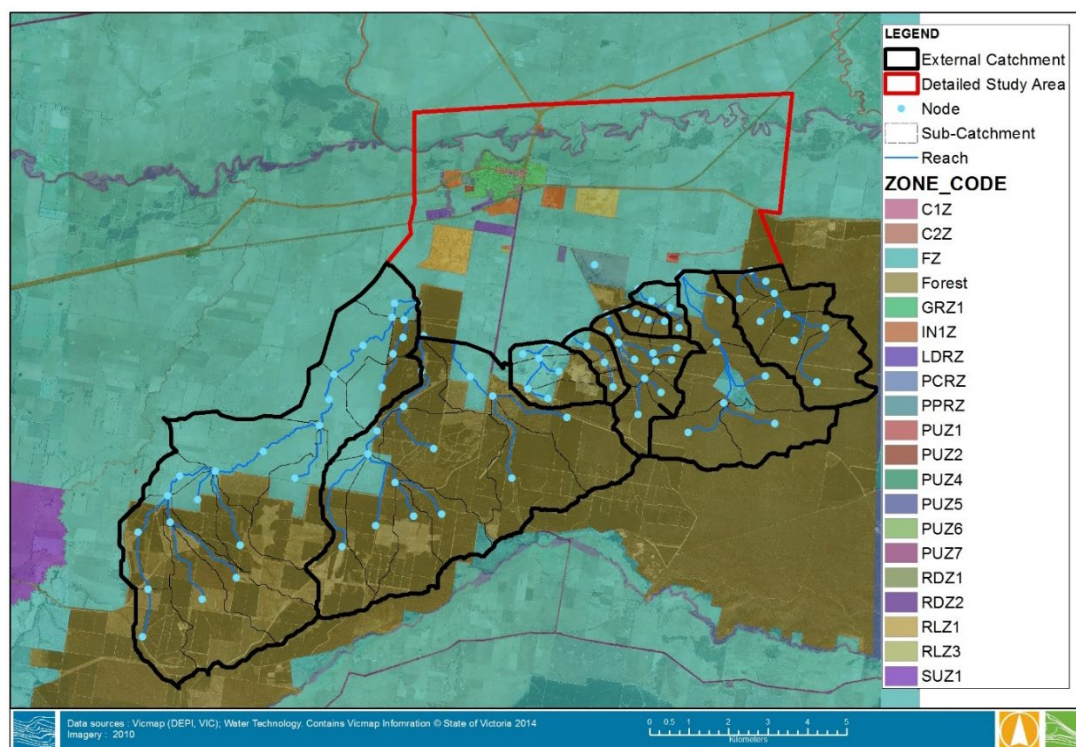
3.6.2 Fraction Impervious

The fraction impervious (FI) was included in the hydrologic model by applying a representative FI for each planning zone, as listed in Table 3-10. The planning zones used for designation of FIs are shown in Figure 3-5. The adopted values representing each planning zone were guided by the Melbourne Water's MUSIC guidelines (2010).

Table 3-10 Fraction Impervious Designation for Planning Zones

Zone Code	Zone Description	Fraction Impervious (FI)
C1Z – C2Z	Commercial (1 – 2) Zone	0.9
FZ	Farming Zone	0.1
FZ	Farming Zone - Forestry*	0.1
IN1Z – IN3Z	Industrial (1 – 3) Zone	0.9
LDRZ	Low Density Residential Zone	0.2
MUZ	Mixed Use Zone	0.7
PCRZ	Public Conservation and Resource Zone	0
PPRZ	Public Park and Recreation Zone	0.1
PUZ1	Public Use Zone - Service and Utility	0.05
PUZ2	Public Use Zone - Education	0.7
PUZ3	Public Use Zone - Health and Community	0.7
PUZ4	Public Use Zone - Transport	0.7
PUZ6	Public Use Zone - Local Government	0.7
GRZ1	General Residential Zone 1	0.45
NRZ1	Neighbourhood Residential Zone	0.45
RGZ1	Residential Growth Zone 1	0.45
RGZ2	Residential Growth Zone 2	0.6
RDZ1	Road Zone - Category 1	0.7
RDZ2	Road Zone - Category 2	0.6
RLZ2, RLZ3, RLZ4, RLZ6	Rural Living Zone	0.2
SUZ1	Special Use Zone 1	0.6

*Farming Zone was split into farming and forestry areas to allow sensitivity to imperviousness caused by bushfire to be tested.

**Figure 3-5 Planning Overlay used for Fraction Impervious**

3.6.3 Validation Events

Two recorded events were used for the validation of the RORB hydrologic model; September 1993 and June 2012. Each of these events was represented with a unique temporal and spatial rainfall pattern generated from local rainfall gauge records. The spatial pattern incorporated both official and community supplied rainfall depth estimates.

Given the lack of any official rainfall records within the Blind Joes Creek catchment, the community rainfall records were very important for understanding rainfall within the catchment. The records clearly showed the official gauges located higher up in the catchment to the north and south received higher rainfall totals than the valley floor. Having a more complete understanding of the rainfall with these community rainfall records has led to improved hydrological estimates for Rosedale.

Figure 3-6 and Figure 3-7 shows the spatial rainfall pattern across the catchment for the two calibration events. Less community supplied rainfall was available for the 1993 event. Spatial distribution rainfall identified in the 2012 event was reviewed against the 1993 data. This analysis identified that, without a point within the Rosedale township, rainfall depths in that area became dominated by the Stradbroke and Willung data (overestimating depth). To rectify this, an interpolated 1993 rainfall depth was included inside the Rosedale Township spatial distribution. The depth applied was consistent with the 2012 relationship between Flynn and Rosedale rainfall depths.

Figure 3-8 and Figure 3-9 show the temporal patterns, Latrobe river gauging station data and RORB model outputs (one catchment only) for the two events. RORB modelling of the catchments to the south of township showed that in 1993 it took 32 hours from the start of the rainfall for Blind Joes Creek to peak. The Latrobe River then peaked 25 hours later. In June 2012 the RORB modelling showed there was 43 hours difference between peaks in Blind Joes Creek and the Latrobe River.

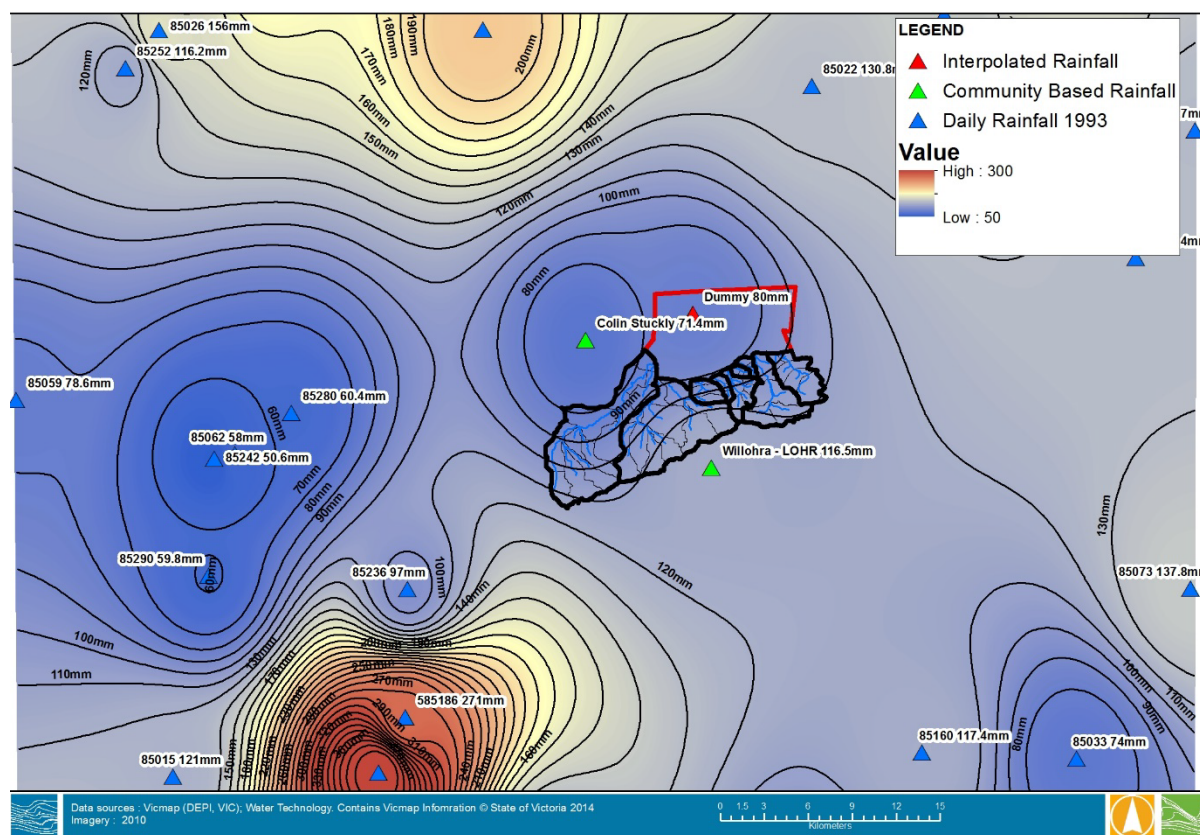


Figure 3-6 Total rainfall across the catchment for the September 1993 calibration event

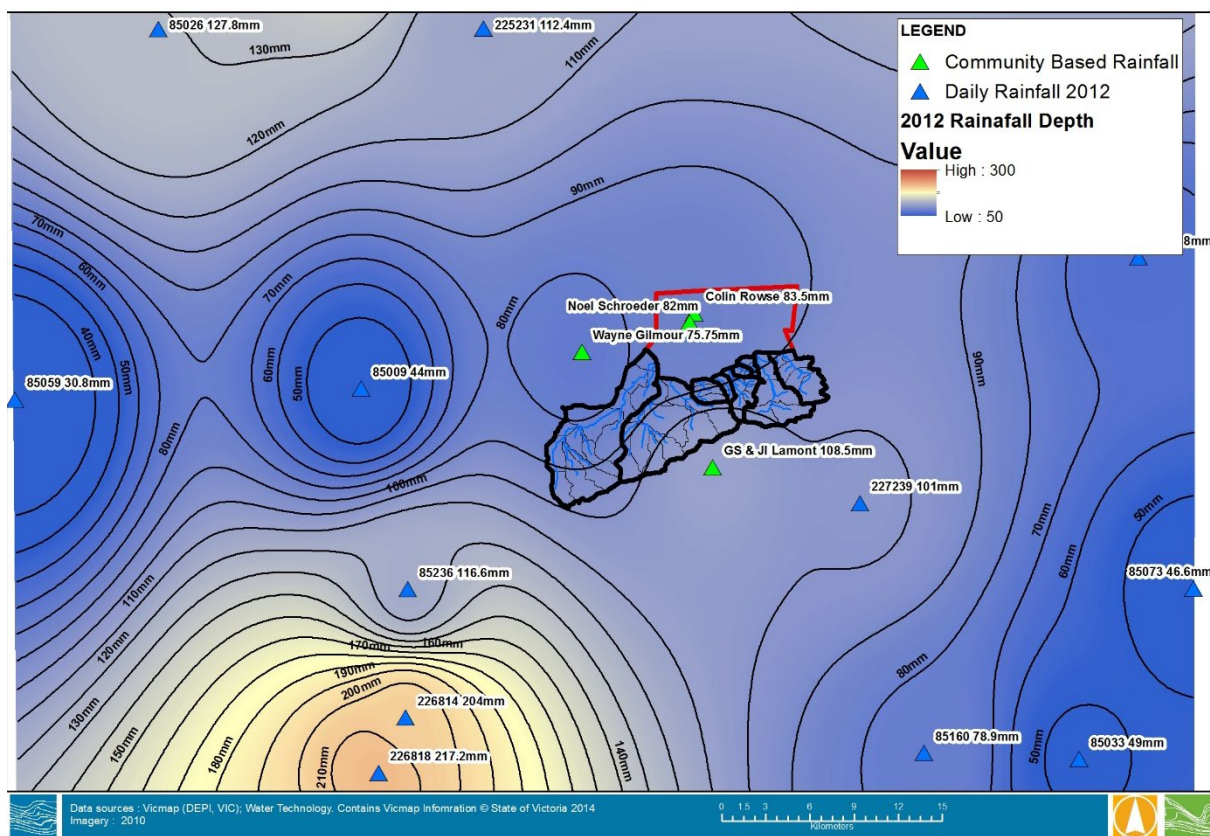


Figure 3-7 Total rainfall across the catchment for the June 2012 calibration event

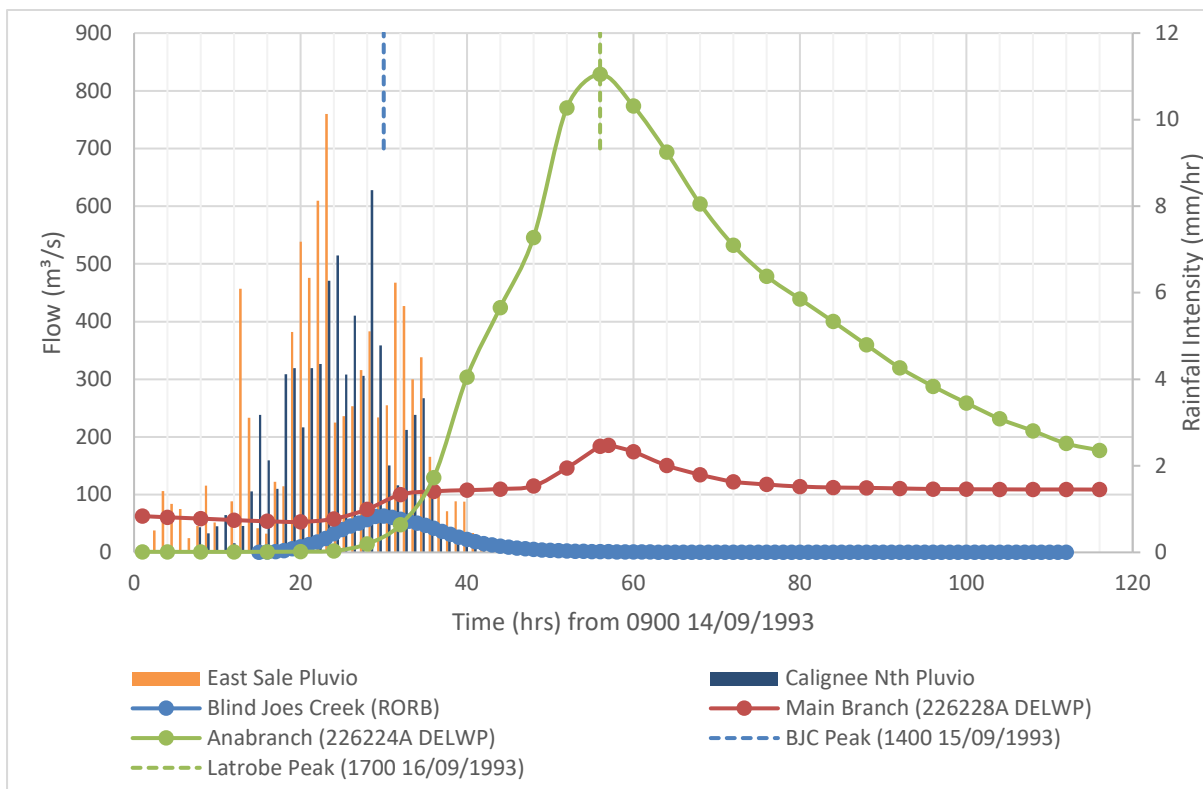


Figure 3-8 Calibration event hyetographs and instantaneous flow hydrographs for the September 1993 calibration event

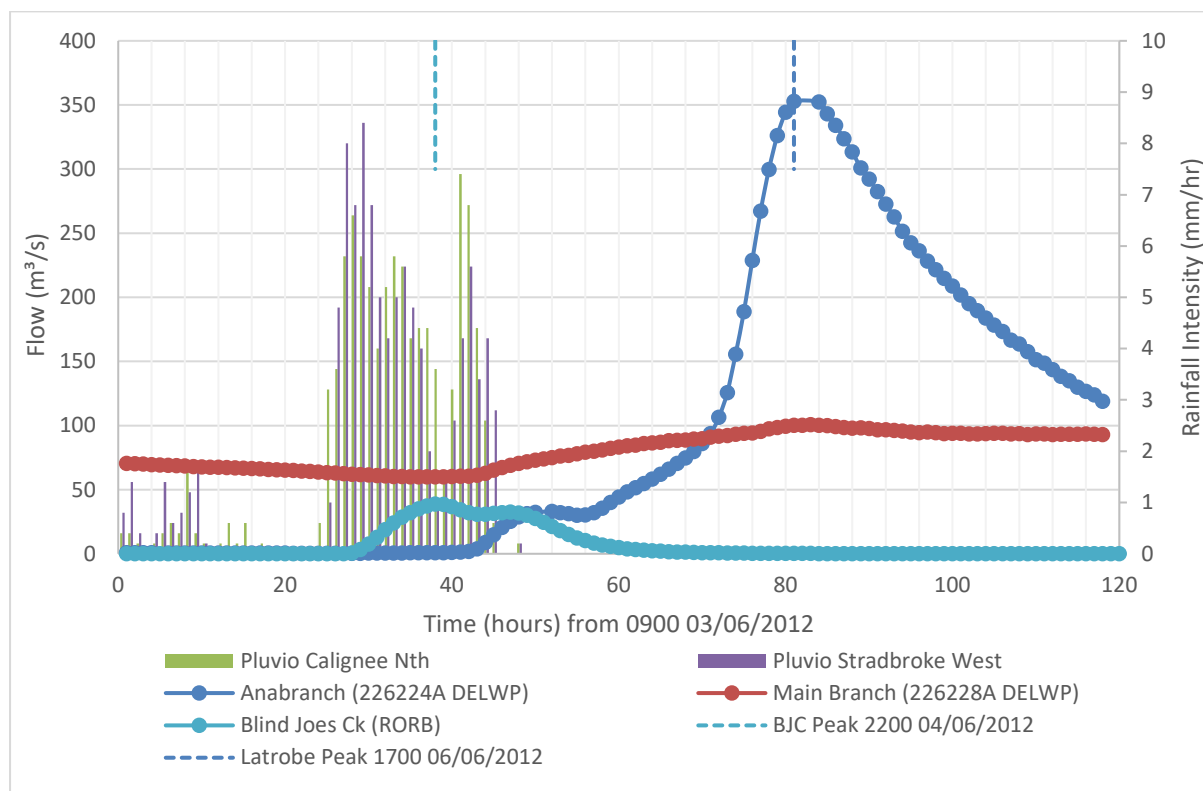


Figure 3-9 Calibration event hyetographs and instantaneous flow hydrographs for the June 2012 calibration event

3.6.4 Possible RORB Parameters

The RORB model was run using the initial loss/continuing loss model. The RORB storage and loss parameters k_c , m , initial loss (IL) and continuing loss (CL) were trialled for the 1993 validation event to establish the study area's sensitivity to these parameters. The routing parameters were set using local knowledge from previous work, regional equations and comparisons to adjacent catchments. Some comparisons to local catchments are shown in Table 3-12. The exponent m was set to 0.8 as per RORB default, with no justification for varying the m parameter.

A number of regional equations for the calculation of k_c are recommended in ARR87 and the RORB manual, and these were used to guide the initial selection of this parameter (Table 3-11).

Table 3-11 Regional equations for the calculation of k_c

Source	Blind Joes Creek	Trib 2	Trib 9	Trib 3	Trib 4	Trib 5	Trib 6	Trib 7	Trib 8
Default RORB	13.32	12.32	6.25	3.90	2.57	4.68	2.03	2.24	7.60
Vic MAR>800 mm - Eq 3.21 ARR (BkV)	13.00	12.11	6.57	4.30	2.96	5.07	2.39	2.61	7.84
Victoria data (Pearse et al, 2002)	11.31	6.43	3.59	1.76	1.33	2.75	0.80	1.13	5.16
Aust wide Dyer (1994) (Pearse et al 2002)	10.32	5.86	3.27	1.61	1.21	2.51	0.73	1.03	4.71
Aust wide Yu (1989) (Pearse et al 2002)	8.69	4.93	2.76	1.35	1.02	2.11	0.61	0.86	3.96

Table 3-12 Initial Loss, Continuing Loss - Comparisons from others studies

Catchment	Event	Model	IL (mm)	CL (mm/hr)	Distance from Rosedale (km)	Study
Latrobe River @ Rosedale	1993	URBS	20	5	0	Latrobe Flood Study (2013)
Traralgon Creek @ Traralgon Sth		RORB	30	2	6	Traralgon Flood Study (2015)
Merriman's Creek @ Prospect Rd		RORB	70	2.3	40	Seaspray Flood Study (2015)
Traralgon Creek @ Traralgon Sth	2012	RORB	20	3	6	Traralgon Flood Study (2015)
Merriman's Creek @ Prospect Rd		RORB	50	3.8	40	Seaspray Flood Study (2015)
Latrobe River @ Rosedale	Design	URBS	20	1 - 6.8	0	Latrobe Flood Study (2013)
Traralgon Creek @ Traralgon Sth		RORB	35	3.3	6	Traralgon Flood Study (2015)
Merriman's Creek @ Prospect Rd		RORB	50	3.8	40	Seaspray Flood Study (2015)

3.7 RORB Validation approach

As discussed, there are no streamflow gauges on either Blind Joes Creek or the smaller catchments to the east. As a result, the predicted flows from the RORB model were input into the hydraulic model and verified against observed flood levels and extents during the September 1993 flood event. In addition, the June 2012 event was modelled and compared to video footage (WGCMA) and flood images provided by Wellington Shire Council.

The RORB model was run using a range of kc model parameters and loss values (initial and continuing loss) to understand the sensitivity of predicted peak flow and volume to these model parameters. Based on the results, a selection of the RORB model results were run in the hydraulic model to understand the sensitivity of peak water level and extent to the estimated flows. This was completed for both the September 1993 event and June 2012 events. As there was greater information available for the September 1993 event, it was used as the primary event for validation of model parameters, with the June 2012 event used for comparison and to provide additional verification.

The process was iterative, and model parameters were modified to match the modelled water levels and extents to observations during the September 1993 and June 2012 events. Further information regarding the hydraulic model build is included in Section 4. The combined hydrologic and hydraulic model verification is further discussed in Section 5, with design hydrology in Section 6.

4. HYDRAULIC MODEL DEVELOPMENT AND SCHEMATISATION

4.1 Hydraulic Modelling

4.1.1 Overview

A combined 1D-2D hydraulic model was constructed, consisting of:

- A one dimensional (1D) hydraulic model of key hydraulic structures and the Rosedale township's pit and pipe network; and
- A two dimensional hydraulic model of Blind Joes Creek, the smaller catchments to the east which flow from the Holey Plain area as well as the broader floodplain including the Latrobe River.

The hydraulic modelling package TUFLOW was selected. TUFLOW is a tool for floodplain modelling that combines the dynamic coupling of the one-dimensional and two-dimensional system elements in the one modelling platform. Through coupling of these two systems it is possible to represent both river and floodplain processes. Figure 4-2 provides an overview of the model schematisation.

4.1.2 Grid Extent and Resolution

The hydraulic modelling for the Rosedale Flood Study aimed to include both flooding from Blind Joes Creek and the contributing catchments to the east, as well as flooding from the Latrobe River itself. A multi domain model utilising a 4 m grid resolution for Rosedale and the surrounding land, combined with a 12 m grid resolution for the large Latrobe River floodplain was used. The Latrobe River floodplain was modelled using a larger grid size as the level of detail required for the Latrobe River was less and the waterway features are wider and are able to be resolved in a coarser grid.

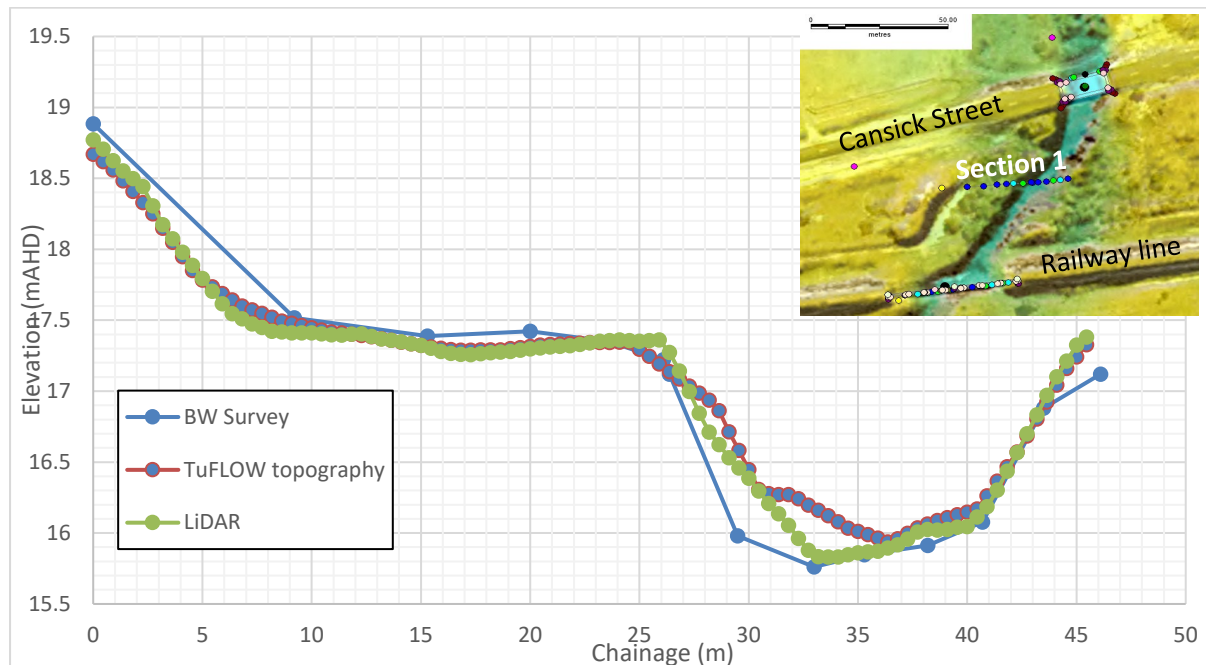


Figure 4-1 Topography checks within Blind Joes creek waterway (between Cansick and the railway line).

The 4m grid model topography was checked against the 1m LiDAR (SRW 1m 90MB dataset) and survey by Beveridge Williams at 3 locations (an example of these checks is shown in Figure 4-1). Analysis of bank full volume showed that increasing the cell size from 1m to 4m resulted in about 10% loss in

channel volume and allowed the main channel to be represented by at least 4-5 cells in the main Blind Joes Creek reach (south of the railway line). In each case, it was concluded that waterway conveyance would be adequately resolved in the hydraulic model using a 4m grid size.

This multi-domain approach allows faster model run times by reducing the number of grid cells inundated and the associated computational points. In total, the model extent is around 50 km², with 35.6 km² modelled at a 4 m grid resolution and 14.4 km² modelled at the 12 m floodplain resolution.

There has been conjecture in the past regarding the flood impact of the smaller catchments to the east and the behaviour of the breakout flows from Blind Joes Creek to the south of the Rosedale-Longford Road. To resolve this, the model was extended beyond that suggested in the original study brief, minimising the assumptions required to build the model.

4.1.3 Topography

The hydraulic model extent begins approximately 5 km south of Rosedale. The southern model boundary broadly matches the change in grade from the Strzelecki ranges to the Blind Joes Creek floodplain. Local waterways draining the Strzelecki ranges to the east of Blind Joes Creek are channelized but these conditions quickly give way to broadsheet flow across the floodplain where flow direction changes from north to east before connecting to the Latrobe River floodplain. Blind Joes Creek and its adjacent catchments to the east outfall at two independent locations. One being the main Blind Joes Creek channel, immediately west of the main township at an elevation of around 15 m AHD and the other found approximately 5 km east of the township close to where the Rosedale-Longford road crosses the railway line at an elevation of around 12 m AHD. Other smaller connections between the Blind Joes Creek catchment and the Latrobe River floodplain exist but are predominately associated with man-made drainage features. Figure 4-3 shows the elevation of the topography within the hydraulic model extent.

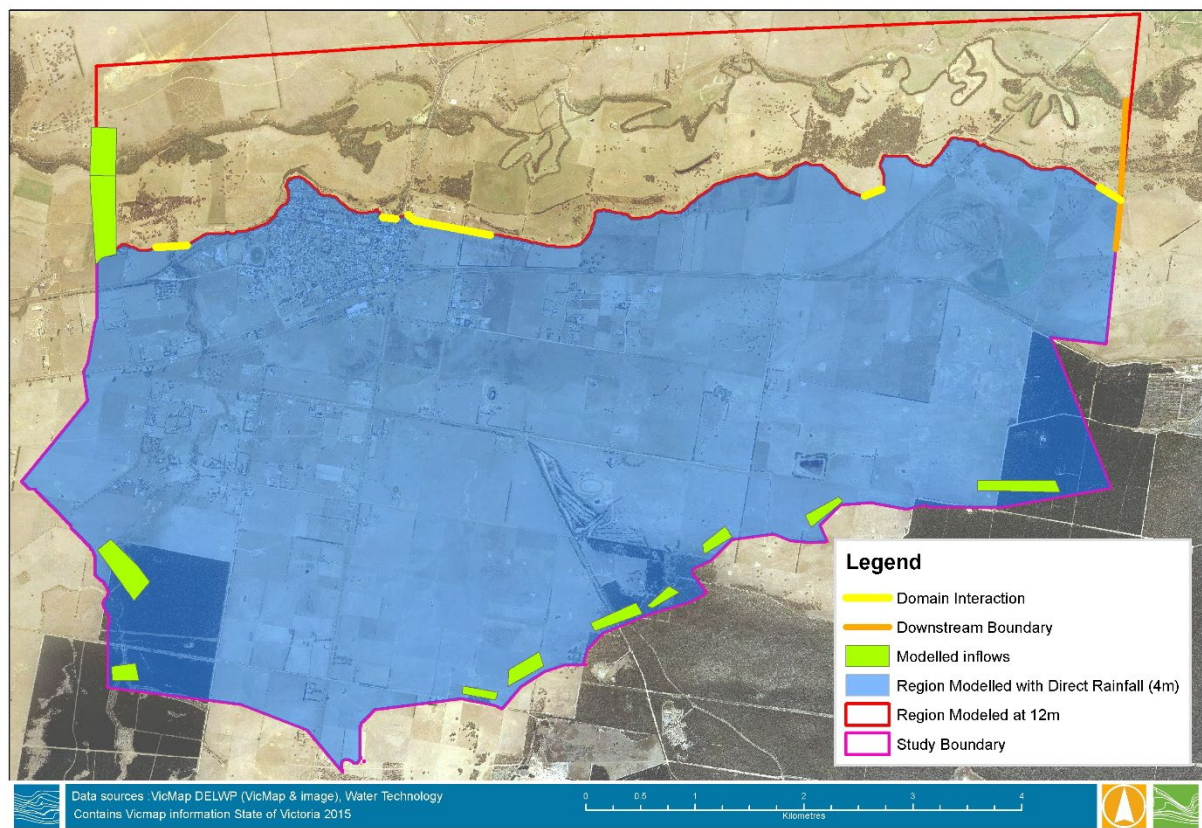


Figure 4-2 2D model extent and boundaries

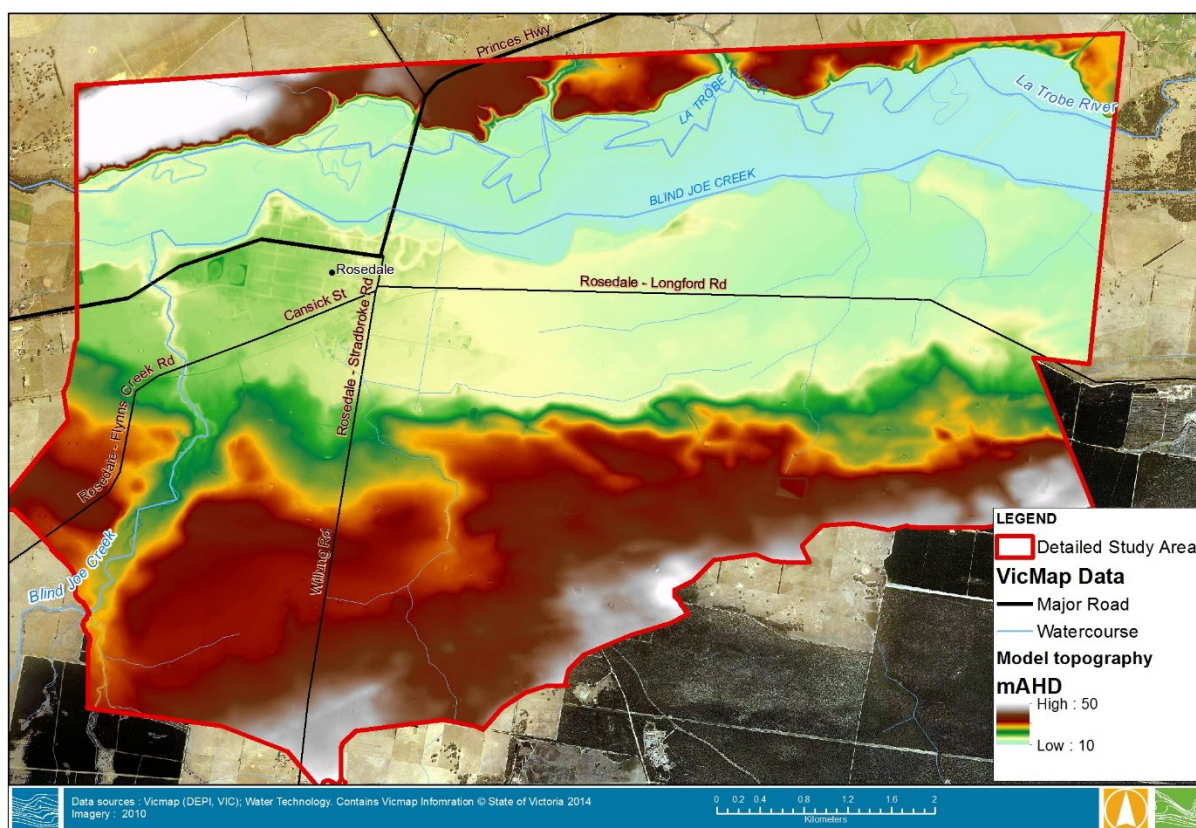


Figure 4-3 Hydraulic model topography

4.1.4 Roughness

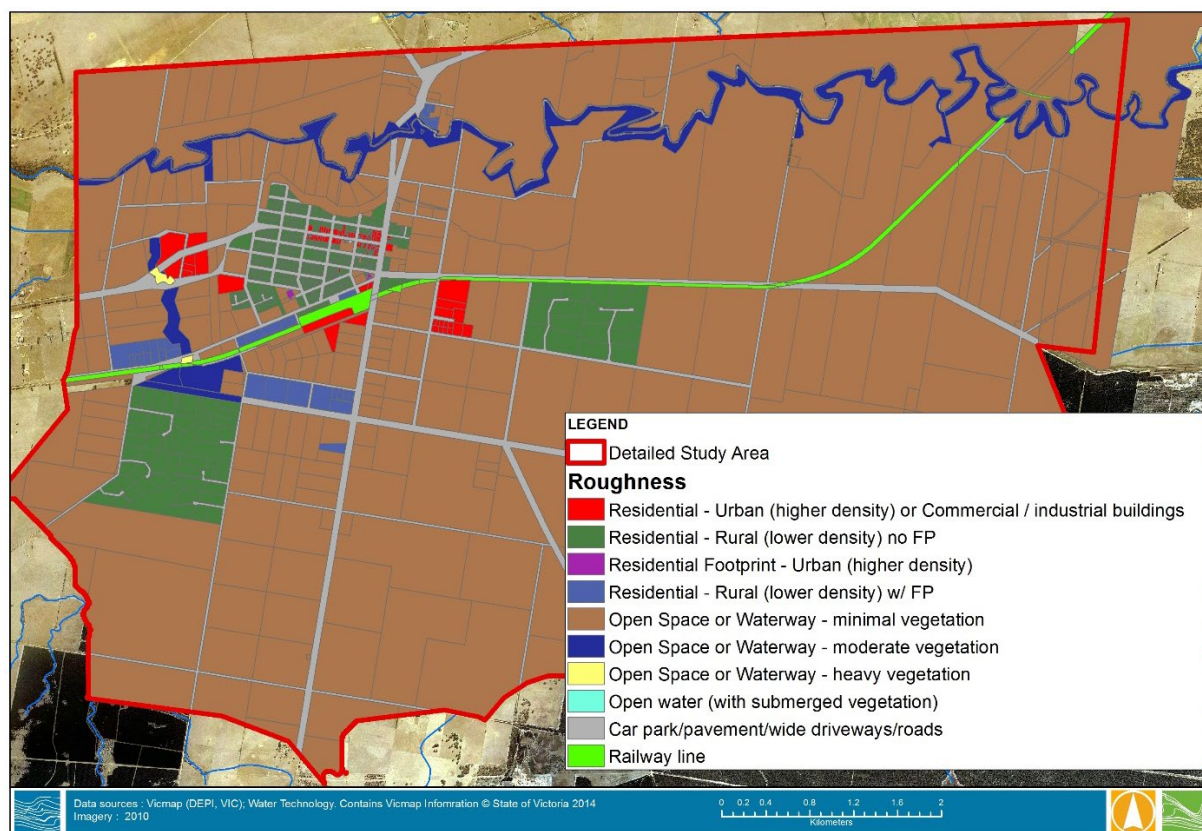
The Manning's 'n' roughness parameter has important effects on flood velocities, depths and extents. Manning's 'n' roughness values were derived from the Wellington Shire Council's planning zone data and refined based on site visits and aerial photography as well as calibration modelling. Roughness values were initially assigned based on the guidelines provided by the Melbourne Water Flood Mapping Technical Specifications (Melbourne Water, 2010a).

For the 2D domain, TUFLOW '2d_mat' files were produced based on land use zones, with further refinement through the use of high-resolution aerial photographs and findings from the site visits. The Manning's 'n' values were specified in the .tmf TUFLOW model file. The final layout of Manning's 'n' is shown in Figure 4-4.

Manning's 'n' roughness coefficients used in the model were adopted from Melbourne Water Guidelines as a starting point and adjusted during calibration of the model. The final values used are listed below in Table 4-1. For the 1D domain, roughness values were applied directly to the TUFLOW '1d_nwk' file to represent the material roughness of culverts, pits and pipes.

Table 4-1 Land Use Manning's 'n' Roughness values

Material	Manning's n Roughness
Residential - Urban (higher density) (lot modelled with one roughness value)	0.350
Commercial / industrial buildings	0.350
Residential - Rural (lot modelled with one roughness value)	0.150
Residential Building Footprint - Urban (higher density)	0.400
Residential - Rural (lower density) (building footprint modelled separately)	0.050
Open Space or Waterway - minimal vegetation	0.040
Open Space or Waterway - moderate vegetation	0.060
Open Space or Waterway - heavy vegetation	0.090
Open water (with submerged vegetation)	0.020
Car park/pavement/wide driveways/roads	0.020
Railway Line	0.200

**Figure 4-4 Hydraulic model roughness**

4.2 Key Hydraulic Structures

There are several key hydraulic structures within the study area, with some located on Blind Joes Creek and others associated with the Blind Joes Creek Floodway. These hydraulic structures play an important role in flood events ranging from small, frequent events through to large, rarer flood events. Several of these structures within and around the town include; the Melbourne-Bairnsdale Railway line West (a crossing over Blind Joes Creek); Cansick Street Bridge; Princes Highway crossings (one old and one newly constructed); Friends Road, Willung road and the Cricket Street culvert crossings (floodway).

These structures were assessed during a site visit on October 16 2014 and compared against existing information provided by Wellington Shire Council. Survey was commissioned of important hydraulic structures and two transects for LiDAR validation, as is shown in Figure 4-5.

The major hydraulic structures surveyed included the Melbourne-Bairnsdale Railway line West (a crossing over Blind Joes Creek); Cansick Street Bridge (new structure); and the Cricket Street culvert crossing (floodway).

Many other smaller (minor) structures are found throughout the study area. In most cases, the structure details for these features were provided by Wellington Shire council. Where no details were available, features (crossings) were visited by Water Technology and manually measured.

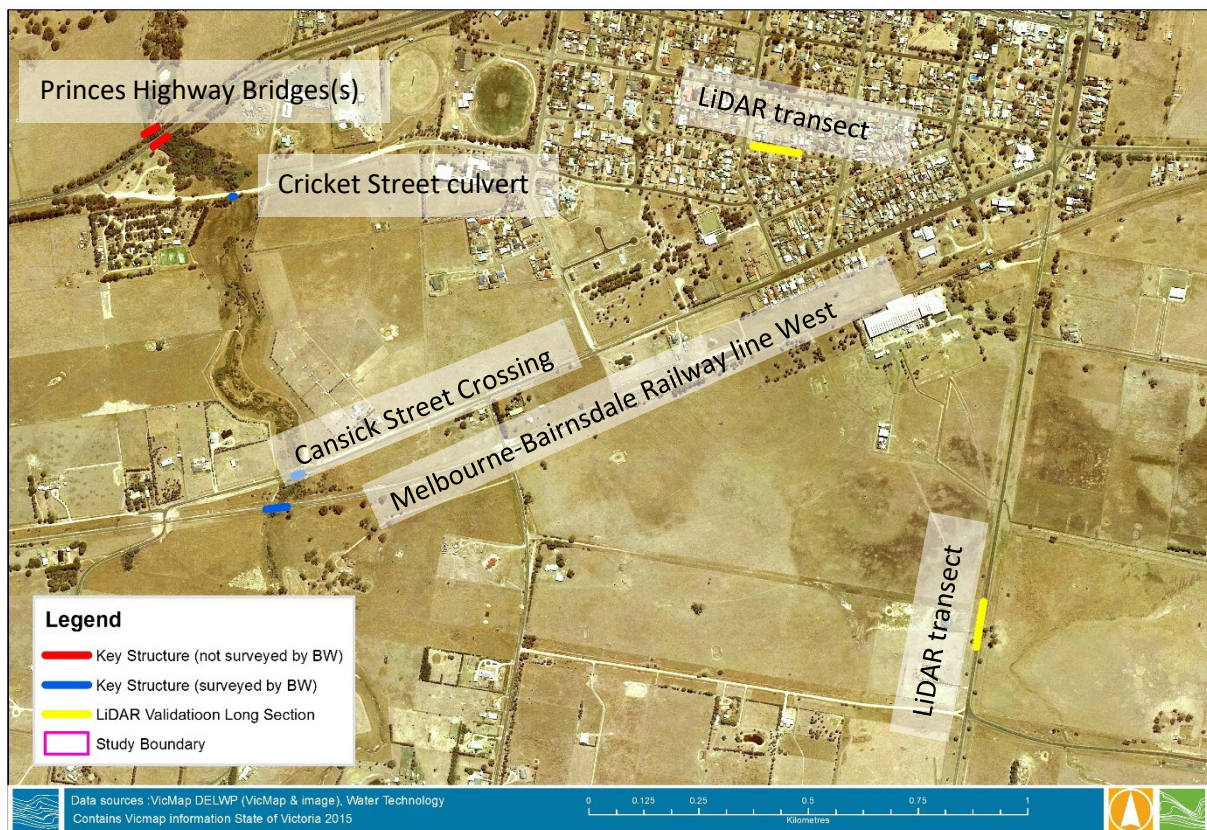


Figure 4-5 Key Hydraulic Structures and Survey Information



Figure 4-6 Blind Joes Creek – Railway Crossings (West LHS & East RHS)

4.2.1 Additional Structures / Changes inside the study area

In two instances, major changes have occurred with the structures found in the catchment now to that found in the system during 1993 and 2012. After the 1993 flood, but prior to 2012 (suspected to be in 2008), significant works were completed on the Cansick Street (Flynn's Creek Road) bridge over Blind Joes Creek. These works included replacing the existing bridge and increasing waterway capacity upstream of the new bridge. No details were available of the old bridge or the land form prior to the works being completed. Water Technology worked with Wellington Shire council to establish the likely conditions at this time. The new bridge feature (surveyed by Beveridge Williams) is included in the 2012 and design flood modelling. Figure 4-7 (a screen shot from google maps) shows the two structures, the downstream (lower feature) was removed when the new bridge became operational.



Figure 4-7 Blind Joes Creek – Cansick Street Bridge(s) – April 2008 - Source: Google Maps

The other major land form and structure change in the study area is the recent construction of the dual carriageway of the Princes highway at the western edge of the township. These works are currently (mid 2015) under construction and include a new (second) crossing over Blind Joes Creek. The new bridge is located downstream (north) of the current bridge. As the project is currently being completed, no 'as-constructed' plans of the works were available for this study. Bridge design drawings supplied by the WGCMA (Figure 4-8) were combined with other proposed site drawings from VicRoads to establish the likely bridge and new carriageway conditions.

The dual carriageway and bridge works were applied in the design flood modelling but not in the 1993 or 2012 flood modelling.

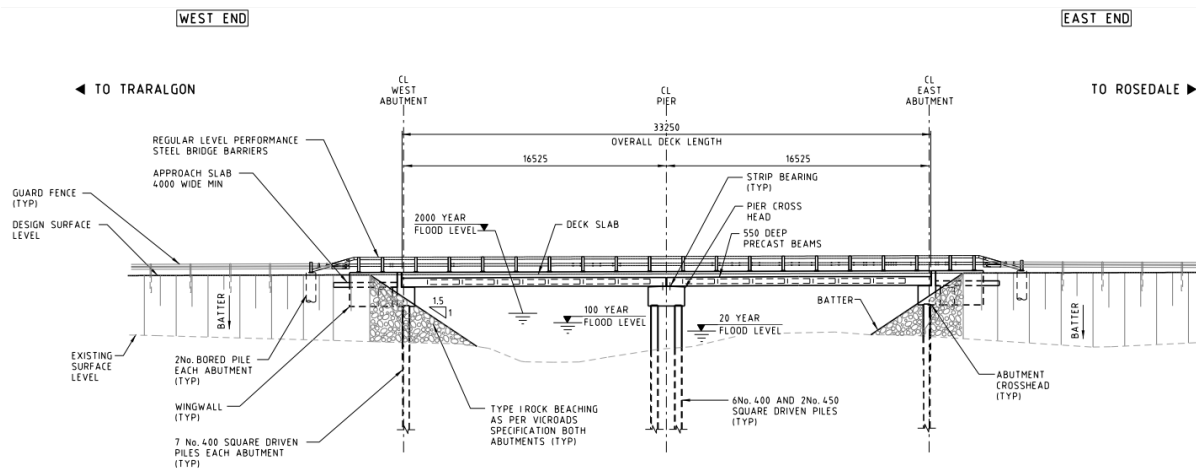


Figure 4-8 Blind Joes Creek – Proposed Princes Highway Bridge - Source: WGCMA

4.3 Pit and Pipe Network

Wellington Shire Council drainage assets were provided in GIS format. The quality of the drainage asset data varied from high quality detail including pipe and pit size, location and invert, while other areas lacked sufficient data for use in the hydraulic model. Where the accuracy of the locations and attributes is unknown, Wellington Shire Council [REDACTED] advised that errors in the data are common. A thorough review of the drainage network identified areas of data which were suitable for use within the hydraulic modelling. In areas where the dimensions of the pipes were missing, a pipe diameter was assumed based on available information upstream and downstream. For pipe and pit inverts, the available information on pit depths was used in combination with the LiDAR surface at the pit location, and an assumed minimum cover. These changes were noted within a MapInfo table database. The drainage information assessed for the hydraulic model is shown in Figure 4-9.

Following a data review, modification of the drainage dataset was undertaken to fill the missing gaps and further checks were undertaken to ensure the pit and pipe network placed into the model was functioning as expected. Much of this involved engineering judgement to schematise the drainage network slope throughout the catchment to ensure water is running downhill towards the outfall, as it was designed to do. This information was provided back to Wellington Shire Council in the final deliverables to help provide additional information in their database.



Figure 4-9 Rosedale Flood Study Drainage Network Information

4.3.1 Pit Configuration

Pits along the 1D pipe section were connected to the 2D grid using the TUFLOW “SXL” option for the ‘1d_nwk pit Conn_2D’ attribute. This option automatically lowered the 2D cells connected to the pits by 0.1 m, specified in the ‘1d_nwk’ file, to allow surface water to enter the pits and pipes more easily.

Pit types were determined from the information provided by Wellington Shire Council. Appropriate model pit types were used to model the side entry pits, grated pits and headwalls to allow water to enter and exit the pipe network as required. Where pit type information was not provided, a weir type pit was used.

The model’s weir and rectangular type pits were uniformly assigned a width of 1 m, based on the average pit size (900 x 600 mm) in the catchment. This provides a slight overestimation of the pit inlet capacity (for the average pit size) resulting in the pipe characteristics being the principal limiting factor to water entering the 1D Network. Allowing the pipe to be the limiting factor is a routine approach in urban flood studies.

4.4 Boundary Conditions

4.4.1 Inflow Boundaries from RORB

Flow hydrographs from nine print locations in the RORB hydrologic model were extracted to provide inflow boundaries to the hydraulic model, these inflows represent the external catchments to the south of town (from the Strzelecki ranges). Further detail of flow estimates is provided in following sections.

4.4.2 Inflow Boundaries - Latrobe River

The major inflow into the model representing the Latrobe River was located approximately 4 km upstream of Rosedale. Validation model runs used flows from gauge records. Design modelling used Flood Frequency Flow estimates (modelled as steady state flows) from the Latrobe River flood study (Cardno, 2013) to represent the concurrent flows.

4.4.3 Direct (Rain-on-Grid) Rainfall

As the flooding mechanisms within the southern part of the study area were somewhat unresolved within any previous studies, it was decided to undertake rain-on-grid modelling over the flatter country to the south of the township. Rain-on-grid modelling was not conducted on the Latrobe River floodplain.

Validation Rainfall

Temporal and spatial rainfall patterns applied in the RORB modelling were used to create Hyetographs for the rain-on-Grid study area. Rainfall depths on the valley floor (inside the Rain-on-Grid study area) were broadly uniform and therefore not scaled spatially (see Figure 3-6 and Figure 3-7). Run-off coefficients were based on estimated AEP of the rainfall events using the Bureau of Meteorology's IFD (1987) generator software. The 1993 and 2012 event depths and event durations estimated the ARI's at between 20-10% events (based on rainfall on the valley floor, supplied by the community).

Design Rainfall / IFD Parameters

IFD parameters (1987 Method) were determined at the centroid of the catchment using the Bureau of Meteorology IFD Program and were consistent with those applied in the RORB modelling. AusIFD Software used IFD parameters to generate hyetographs for each required ARI Event and duration. These were then converted to an appropriate format for the TUFLOW hydraulic model input.

Fraction Impervious

The Fraction Impervious (FI) values across the rain-on-grid study area were determined using the Wellington Shire Council planning zones and current Melbourne Water guidelines. The land use zones were checked against aerial imagery to ensure that the applied FI values were appropriate.

Validation modelling Losses

As discussed, the validation modelling used rainfall patterns with consistent spatial distribution and temporal patterns to that applied to the RORB modelling. Initial loss estimates (consistent with the RORB modelling) were manually subtracted from the hyetographs.

Design modelling Losses

Rainfall losses were incorporated in the modelling in two forms, initial loss (IL) and Runoff Coefficient (RoC), values adopted are shown in Table 6-2. Rainfall Runoff coefficients were set in accordance with Melbourne Water guidelines (MWC, 2010b). The IL values are consistent with that used for other flood mapping projects in similar catchments. The runoff coefficient refers specifically to the rate at which runoff is generated from the pervious areas within the catchment, not to be mistaken for the commonly used runoff coefficient (C) within the Rational Method which refers to pervious and impervious areas.

Table 4-2 Direct Rainfall runoff coefficients and loss

Event	Runoff Coefficient	Initial Loss
1993	0.25	30
2012	0.25	20
10% AEP	0.35	15
5% AEP	0.45	15
2% AEP	0.55	15
1% AEP	0.6	15
0.5% AEP	0.65	15

4.5 Tail water Boundary

The downstream boundary of the model, located 7 km downstream of the Princes Highway Bridge on the Latrobe River, utilised a static (fixed) Height/Time (HT) type boundary to allow the flow out of the model. Water level data was estimated for the 1993 and 2012 flood events from initial runs of the hydraulic model which matched observed flood levels and the two gauging stations upstream of the boundary. The design model runs used static water level boundary based on results of previous modelling of the Latrobe River (Cardno, 2013). Sensitivity analysis of the downstream boundary level was undertaken.

Table 4-3 Tail water Levels applied in validation modelling

Event	Level (mAHD)	Source
1993	10.3	Estimated upon review of initial modelling runs
2013	9.4	Estimated upon review of initial modelling runs

4.6 Multi-domain Boundary

When defining the 2D/2D boundary locations, it is best to try and set boundaries perpendicular to the flow direction. Initially, the TUFLOW model was run with large cell size in a single domain. A review of these results help decide the locations of the 2D/2D boundaries. In most instances, the 2D/2D boundaries were located on the fluvial terrace (high land immediately before it gave away to the Latrobe River Floodplain), however the Blind Joes Creek northern flow path 2D/2D boundary was set up as it is spreads out onto the Latrobe River floodplain.

Several locations where the two domains interacted were identified. Main flow direction along these boundaries are shown in Figure 4-10, Figure 4-11 and Figure 4-12.

Minor urban overland flows were let out of the high resolution (4m) domain using HQ boundaries.

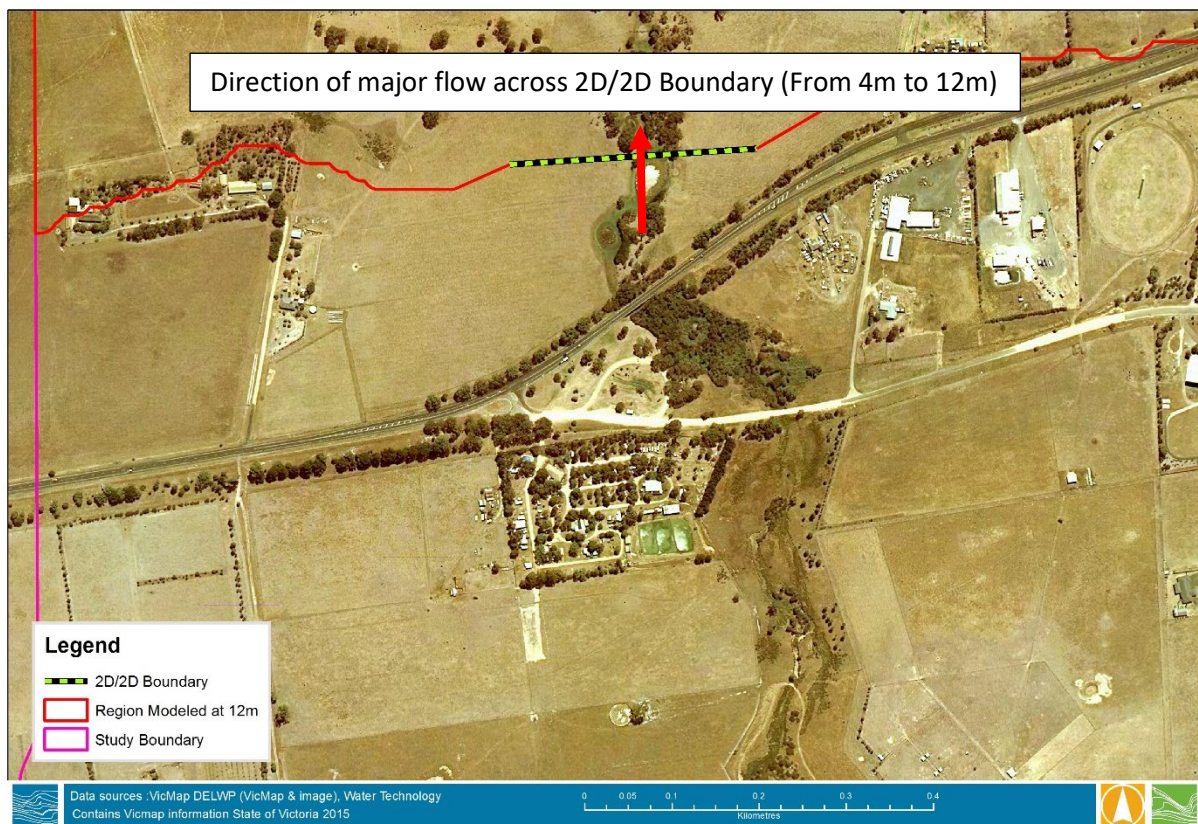


Figure 4-10 Schematisation of the 2D/2D Boundaries within TUFLOW – west

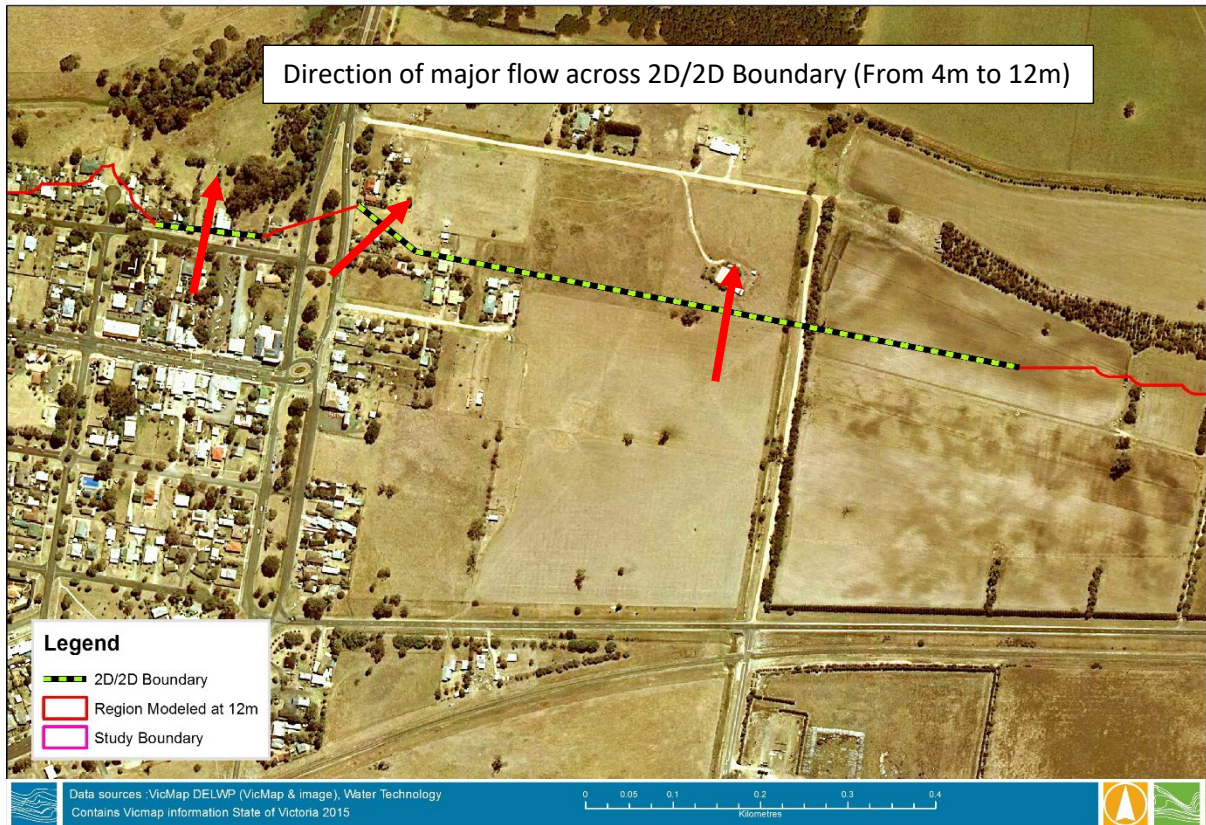


Figure 4-11 Schematisation of the 2D/2D Boundaries within TUFLOW – central

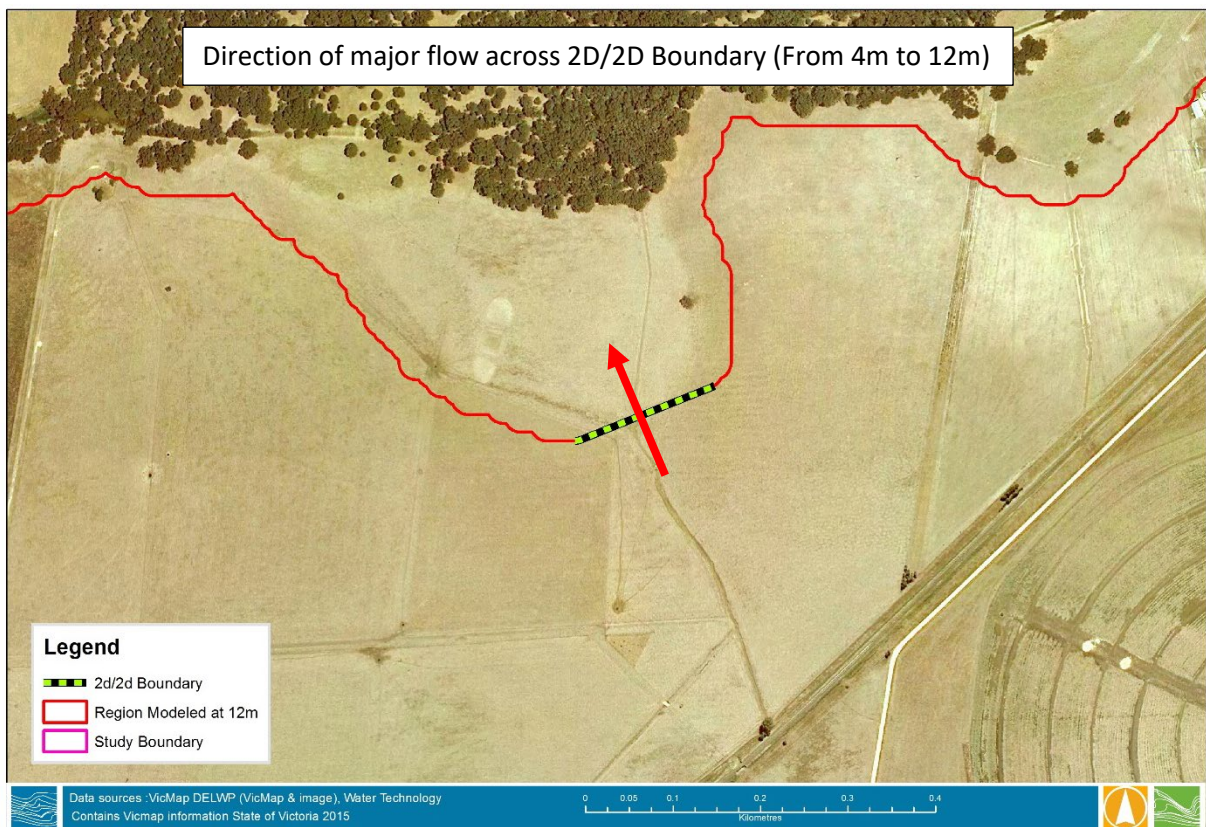


Figure 4-12 Schematisation of the 2D/2D Boundaries within TUFLOW – east

4.7 Model Results Post Processing

Filtering of Results

Rain-on-Grid hydraulic models produce flood model results at every active cell within the model. While ultimately this represents what happens, these results are often filtered to remove inactive shallow ponding. For this study, TUFLOW model results were filtered according to the following criteria, in accordance with Melbourne Water requirements:

- Minimum Depth Threshold – any flooded cells with depths less than 0.02 m were removed; and
- Velocity * Depth Criteria – The results were filtered to remove any cells where both the depth is less than 0.1 m and the $V \cdot D$ is less than 0.008.

All cells considered as flooded after the application of the above filters (1 and 2) are then combined into a flood extent that connects neighbouring cells. Any disconnected flooded areas that are less than 400 m² are then removed.

5. HYDROLOGIC & HYDRAULIC MODEL VALIDATION

5.1 September 1993

5.1.1 Antecedent conditions

The September 1993 event spans 14th – 19th September. In the week prior to the September 1993 flood event, the catchment received around 35 to 40 mm of rain. The catchment was therefore wet prior to the significant rainfall burst which occurred on the 14th and 15th of September.

5.1.2 Verification Method

Various RORB model runs were completed to determine the final k_c and initial and continuing loss. The parameters trialled were selected based on regional estimates or empirical equations. Table 5-1 summarises the range and combination of k_c and initial and continuing loss values run in the hydraulic model. An 'm' value of 0.8 was used throughout the model calibration.

Model results from several simulations were routed through the hydraulic model based on the range of RORB model predictions. The runs were completed to develop an understanding of how the catchment responds to changes in each parameter.

Table 5-1 Trialled RORB loss values and method of determination

II (mm)	CI (mm/hr)	Kc value	Method of k_c and loss determination
10, 20 & 30	1, 2 & 3	13.32	Highest Kc Value (Default RORB)
10, 20 & 30	1, 2 & 3	11.31	Mid-range Kc Value (Victoria data (Pearse et al, 2002))
10, 20 & 30	1, 2 & 3	8.69	Highest Kc Value (Aust wide Yu (1989) (Pearse et al 2002)

The results of these RORB scenarios were tested in the hydraulic model and the flood levels, depths and extents compared to available observations.

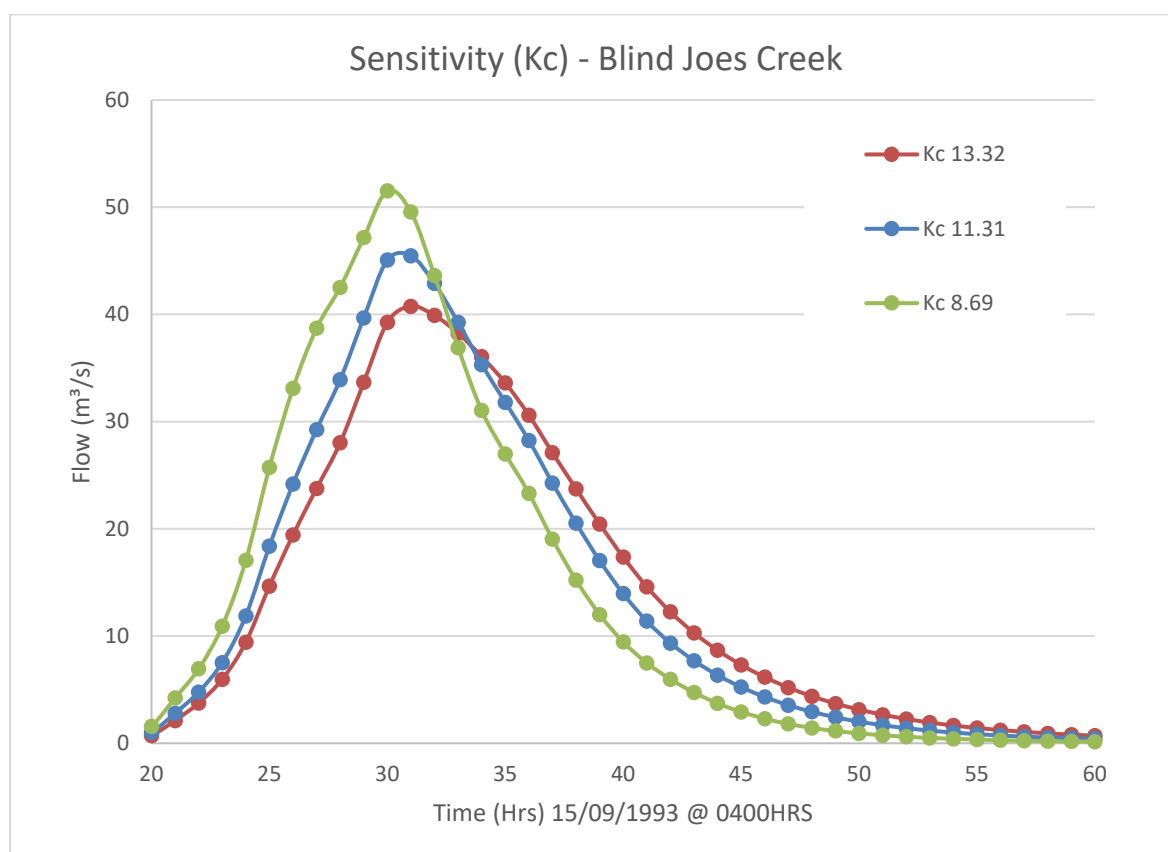
5.1.3 Parameter Sensitivity

Prior to running the hydraulic model, parameter sensitivity analysis was completed to understand each parameter's influence on timing, peak flow and flood volumes. Figure 5-1, Figure 5-2 and Figure 5-3 show the resultant hydrographs (for the 1993 event) as each of the parameters was incrementally adjusted, Table 5-2 gives a summary of the findings.

Table 5-2 Effect on RORB hydrograph for the 1993 event by changing each parameter

Parameter*	Value	Effect on Peak flow	Effect on Peak time (from 4am - 15 th September 1993)
Kc (IL 20 CL 3)	13.32	40.8m ³ /s (base case)	31 hours (base case)
	11.31	Increase of 4.7m ³ /s	Same peak time
	8.69	Increase of 10.8m ³ /s	Peaked 1 hour earlier
Initial Loss (IL) (Kc 11.31 & CL 3)	10mm	46.1m ³ /s (base case)	No change
	20mm	Decrease of 0.6m ³ /s	No change
	30mm	Decrease of 2.7m ³ /s	No change
Continuing Loss (CL) (Kc 11.31 & IL 20)	1mm/hr	62.8 m ³ /s (base case)	No change
	2mm/hr	Decrease of 9.8m ³ /s	No change
	3mm/hr	Decrease of 17.3m ³ /s	No change

* Callignee North temporal pattern used for parameter sensitivity testing

**Figure 5-1 Effect on RORB hydrographs for the 1993 event with different Kc values**

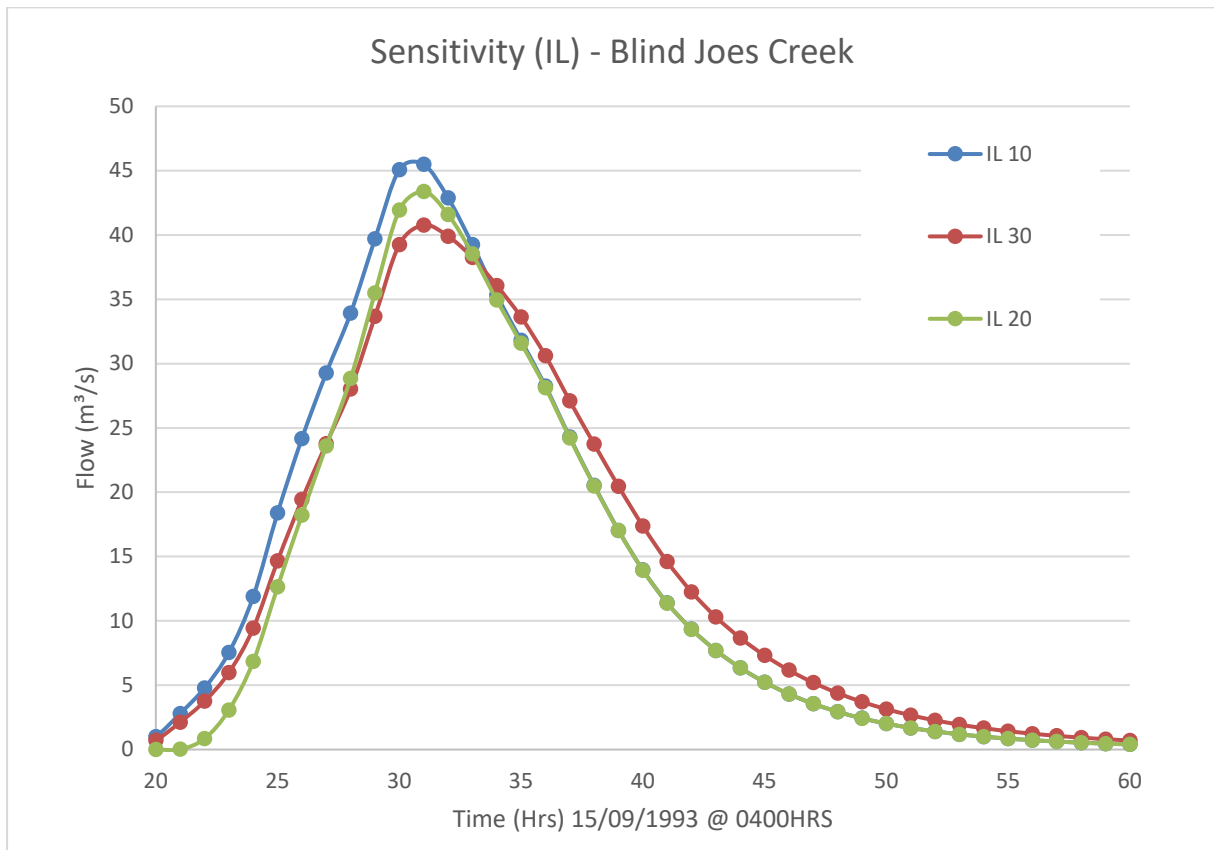


Figure 5-2 Effect on RORB hydrographs for the 1993 event with different IL values

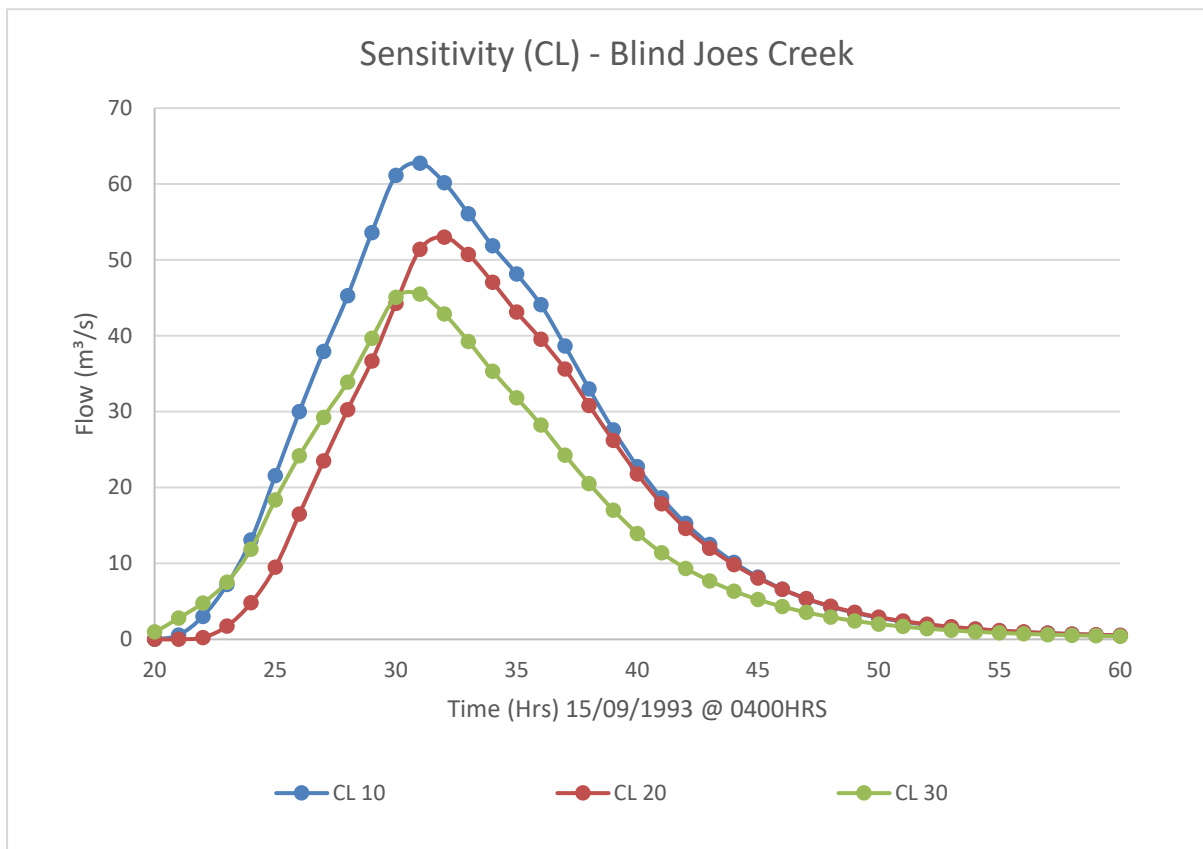


Figure 5-3 Effect on RORB hydrographs for the 1993 event with different CL values

Another check conducted was to test the effect of the pluvio record used to represent the local rainfall pattern during the 1993 event. The stations East Sale (85072) and Callignee North (85236) had quite different event totals and temporal patterns. These conditions impacted on event peak flow estimates, time to peak and hydrograph shapes significantly. The RORB model hydrographs and temporal patterns are shown in Figure 5-4 and Figure 5-5. Table 5-3 summarises the findings of this analysis.

Table 5-3 Effect on RORB hydrograph by changing temporal pattern

Temporal Pattern	General Shape	Effect on Peak flow	Effect on Peak time
East Sale	Flat (double) peak, longer duration,	36 m ³ /s (base case)	31 hours (base case) from 4am on the 15 th September
Callignee North	More peaky, flashy, higher peak flow, shorter duration	Increase of 17 m ³ /s	Peaks two hours earlier

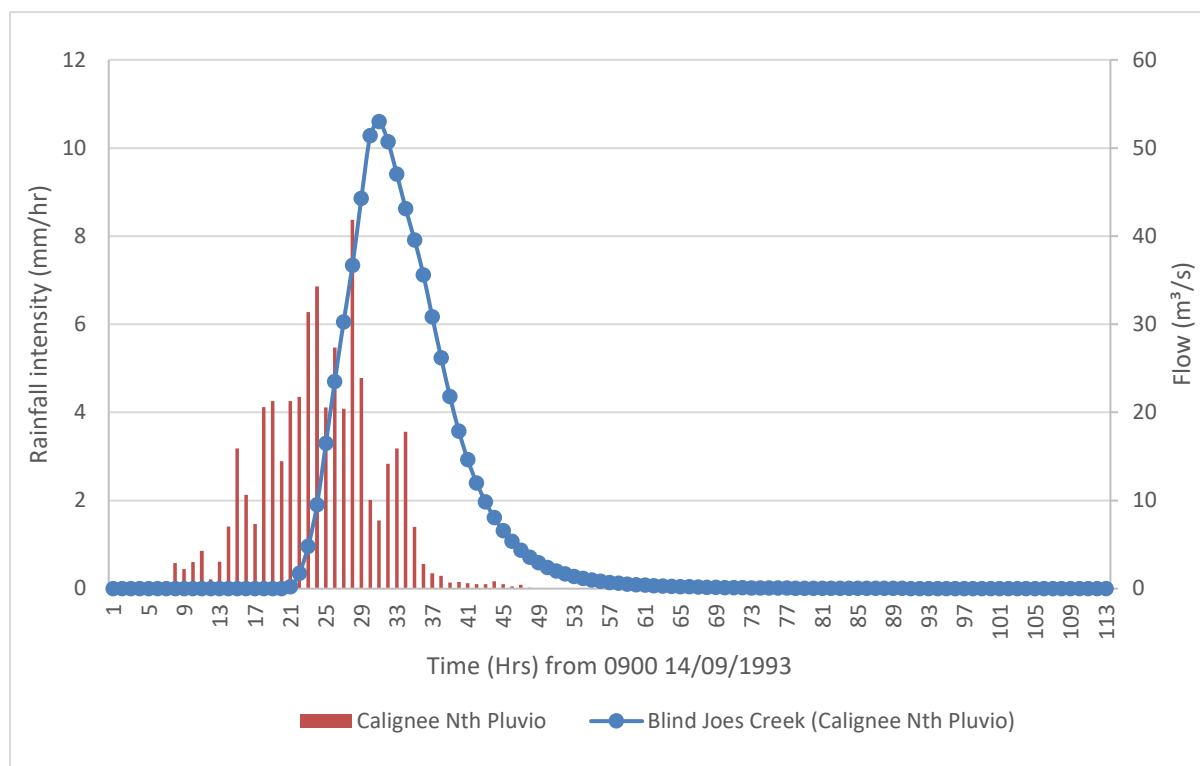


Figure 5-4 September 1993 inflow hydrograph for Blind Joes Creek extracted from the RORB model using the Callignee Nth temporal pattern

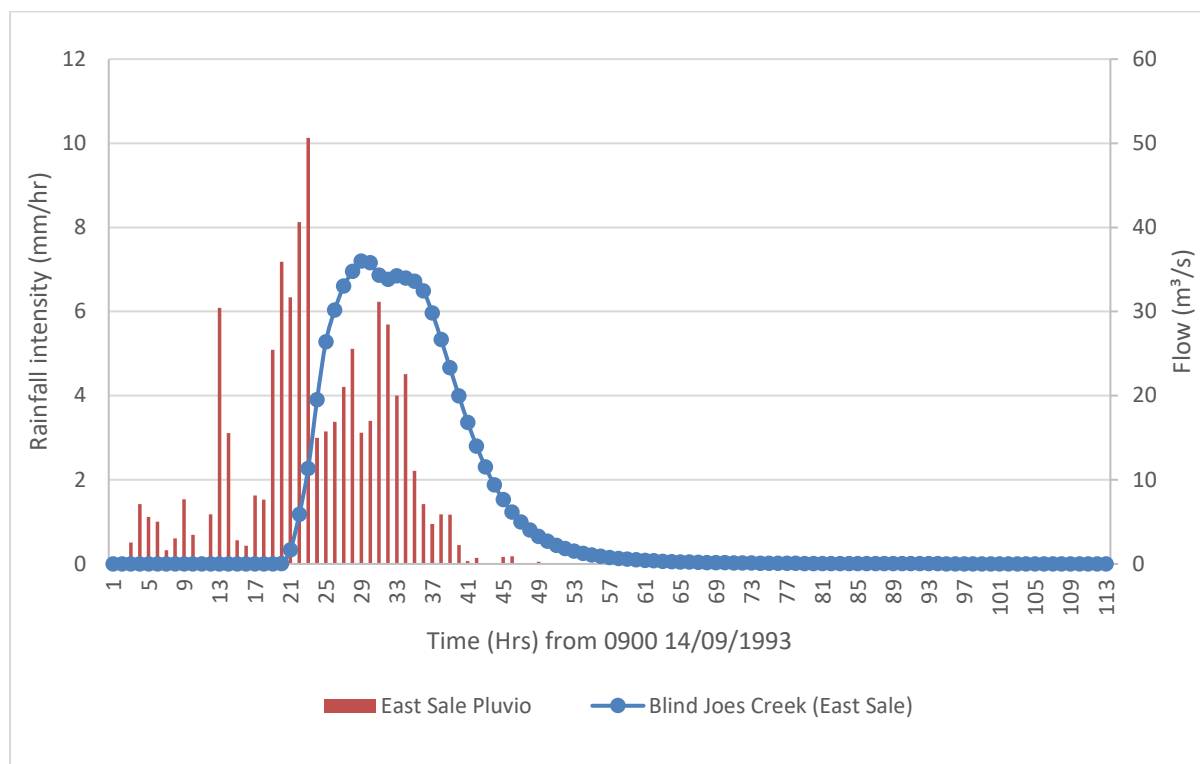


Figure 5-5 September 1993 inflow hydrograph for Blind Joes Creek extracted from the RORB model using East Sale temporal pattern

5.1.4 RORB Parameters and associated results

Table 5-4 below shows the k_c value, initial loss and continuing loss which showed the most accurate hydraulic model estimations of VFD water levels and other data used to validate the flood modelling results. These results used the Callignee north temporal pattern. They also showed peak flow timing consistent with that described by residents in the first and second community consultation sessions. The parameters and peak flows shown in Table 5-4 correspond with the hydraulic model inflow hydrographs shown below in Figure 5-4.

Table 5-4 RORB Validation Parameters – September 1993

Catchment	k_c	m	IL (mm)	CL (mm/hr)	Peak Flow (m ³ /s)
Blind Joes Creek	11.31	0.8	30	2	31
Trib 2	6.43	0.8	30	2	39
Trib 3	1.76	0.8	30	2	5
Trib 4	1.33	0.8	30	2	2
Trib 5	2.75	0.8	30	2	6
Trib 6	0.8	0.8	30	2	1
Trib 7	1.13	0.8	30	2	2
Trib 8	5.16	0.8	30	2	16
Trib 9	3.59	0.8	30	2	11

Various flow regimes associated with different RORB model parameter estimates were routed through the hydraulic model to allow for a comparison to be made to flood heights surveyed during the September 1993 event. In addition to this, flood extents were compared to a series of oblique images captured from a flight on the 16th of September 1993. The time of the flight is unknown but it is assumed to be at least 18-24 hours after the peak in Blind Joes Creek, and slightly before the peak in the Latrobe River based on an analysis of the imagery and the Latrobe River gauges.

This process was iterative and ultimately determined that the parameters shown in Table 5-4 gave the best representation of the available validation data. Using the final adopted combination of parameters, the model results were checked against 30 surveyed heights across the model area. Twelve of the survey heights matched within 0.10 m, a further seven are within 0.3m of the surveyed flood marks. This is considered to be within the level of accuracy deemed appropriate for the study. It is noted that each of the 1993 flood levels were given an estimate of accuracy (e.g. “detailed contour” or “reasonable contour”). Considering only the flood levels deemed to be of higher quality 8 of the 13 heights were within 200 mm.

Figure 5-6 shows the modelled flood depth results, while Figure 5-7 and Figure 5-8 show how well the model is predicting water levels at the surveyed flood height locations. Figure 5-9 shows the flood extent compared with the VFD flood extent. It is noted that the VFD flood extent is digitised from aerial photography assumed to be at least 18-24 hours after the peak in Blind Joes Creek, and slightly before the peak in the Latrobe River. There are significant doubts over the accuracy of the VFD 1993 extent. Figure 5-10 to Figure 5-16 also show the maximum modelled extent of inundation directly compared with aerial photographs taken during the flood event on the 16 September 1993.

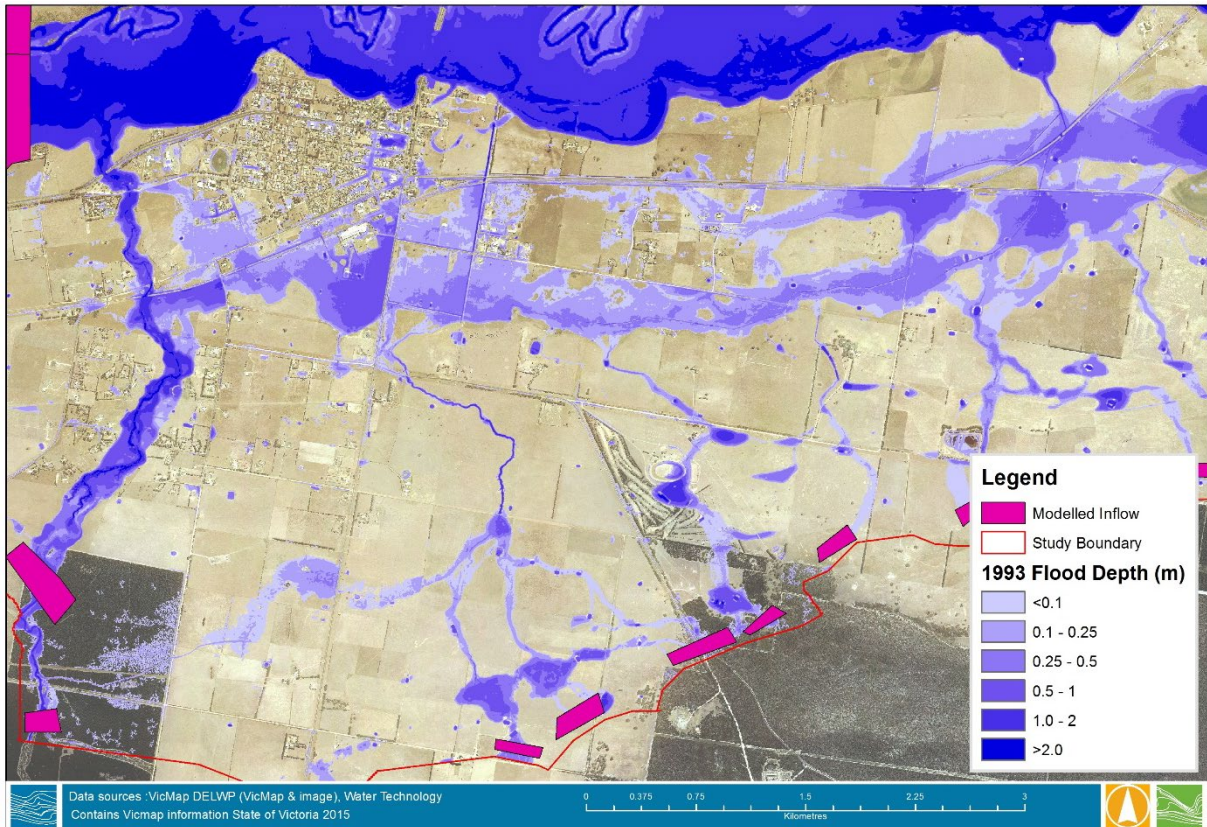


Figure 5-6 September 1993 hydraulic model results using the Callignee North temporal pattern

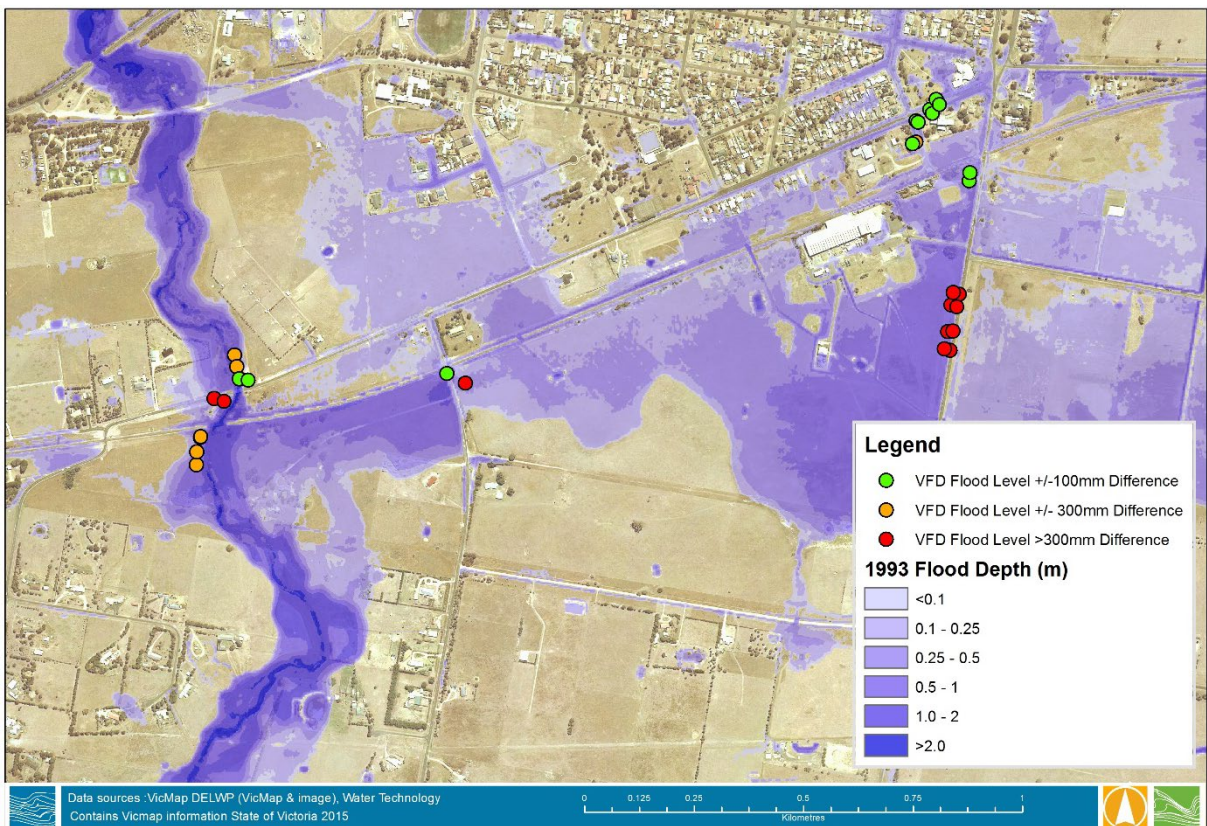


Figure 5-7 September 1993 hydraulic model results compared with observed flood heights – All points

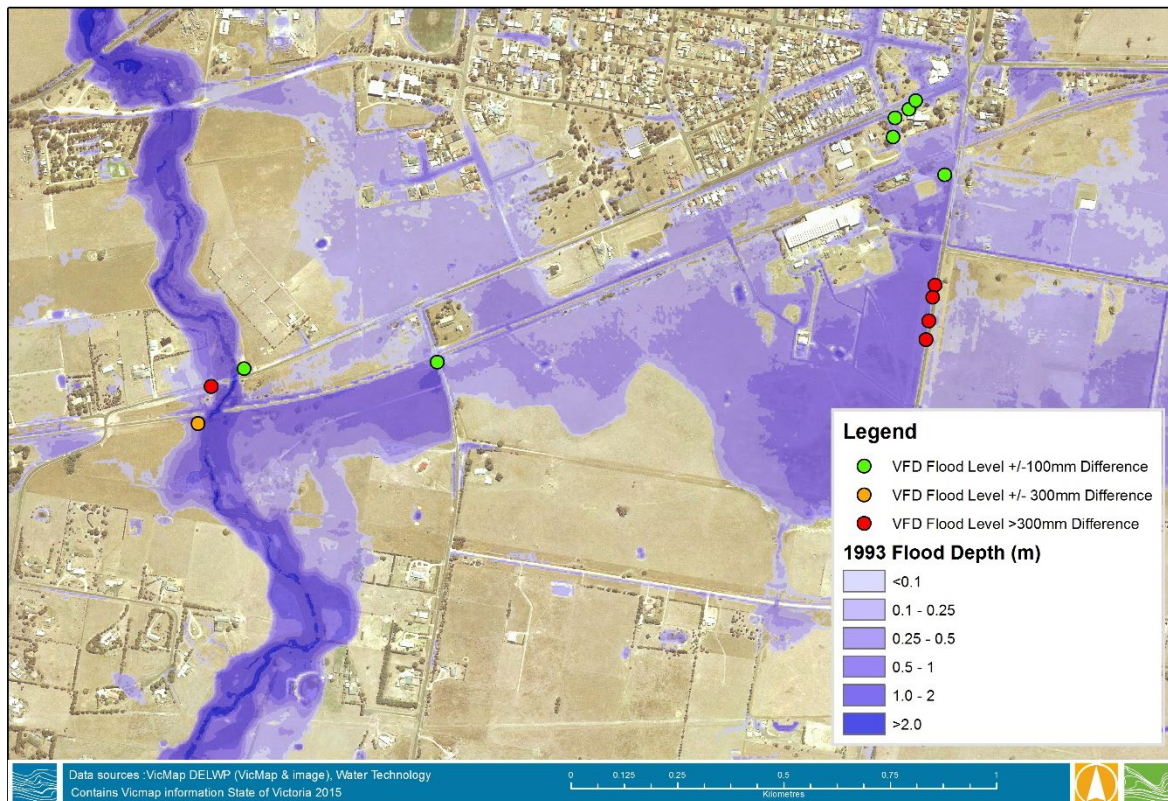


Figure 5-8 September 1993 hydraulic model results compared with observed flood heights – Points nominated as having “detailed contour and flood info”

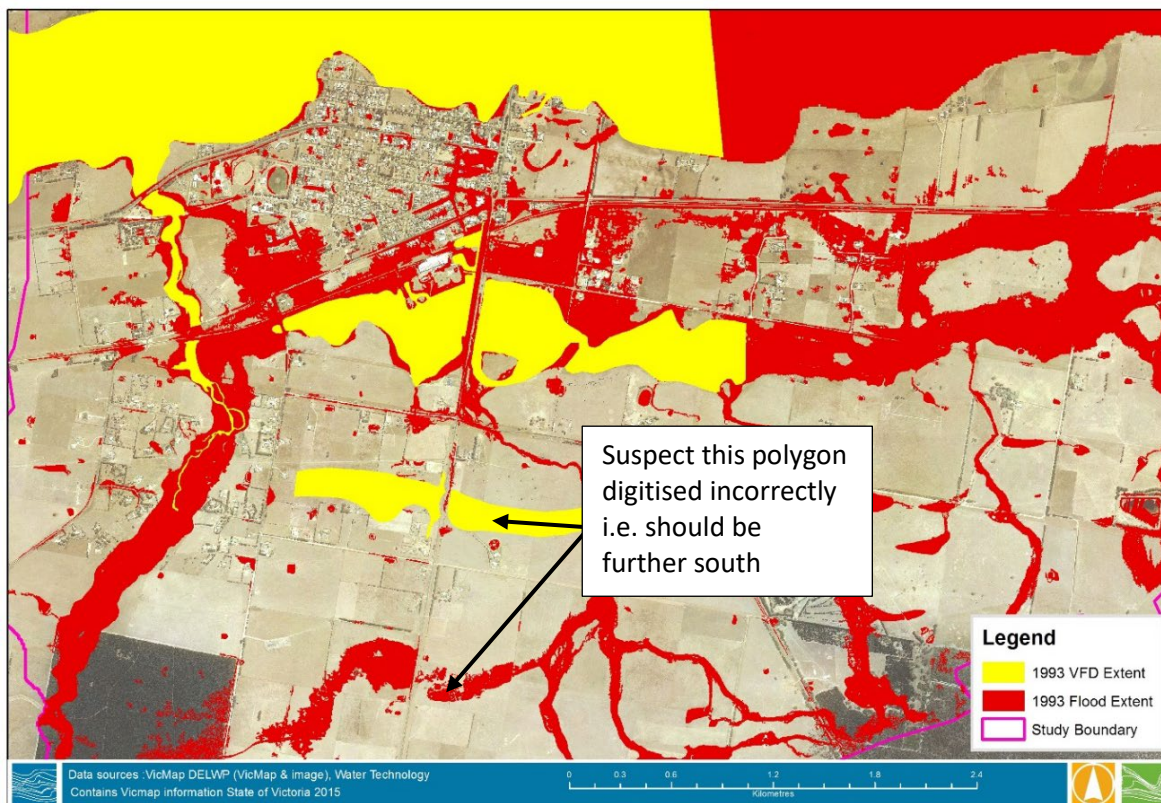


Figure 5-9 September 1993 hydraulic model results compared with VFD flood Extent. Extent base on flood photography from 16th September 1993 (well after the Blind Joes Creek peak flow).

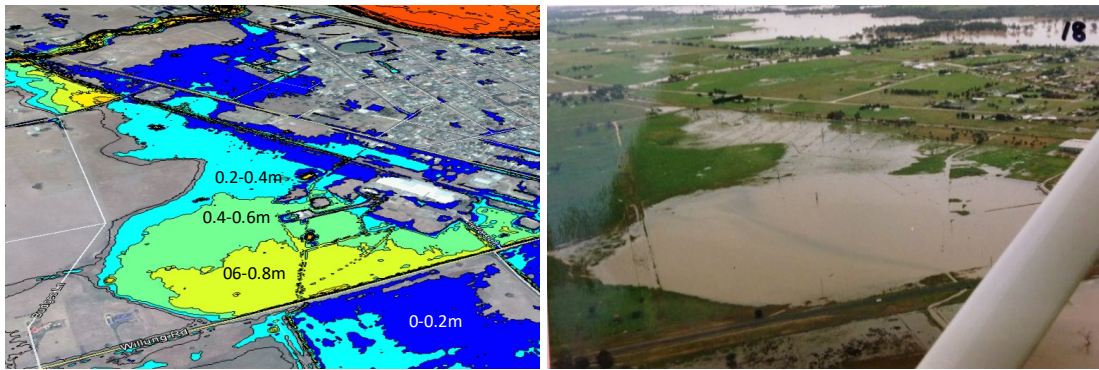


Figure 5-10 September 1993 hydraulic model results (flood depth) compared with oblique aerial photographic record – Willung Road Looking North West

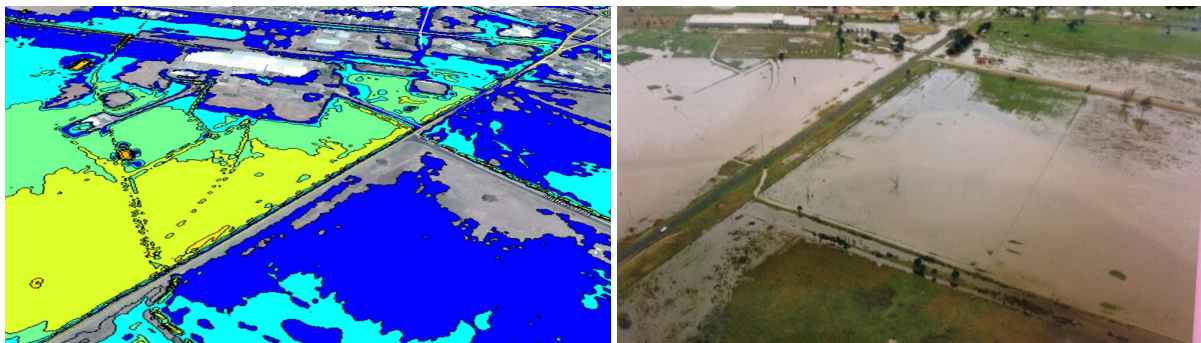


Figure 5-11 September 1993 hydraulic model results compared with oblique aerial photographic record – Willung Road Looking North

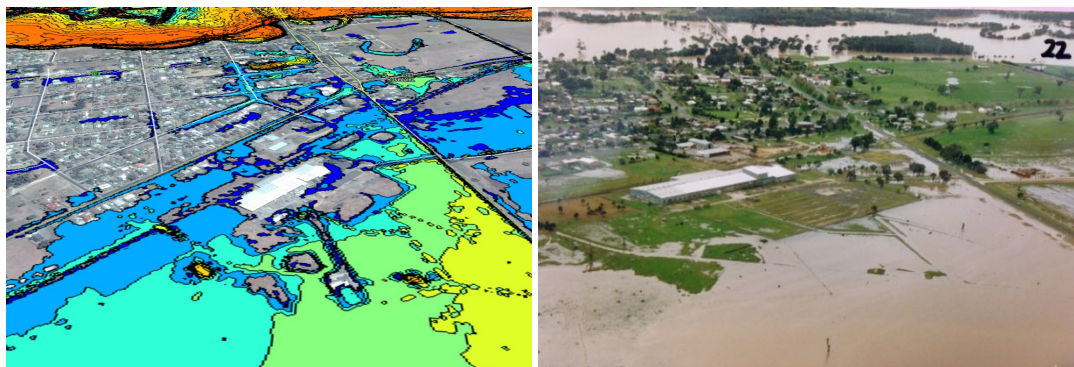


Figure 5-12 September 1993 hydraulic model results compared with oblique aerial photographic record – Willung Road Looking North East

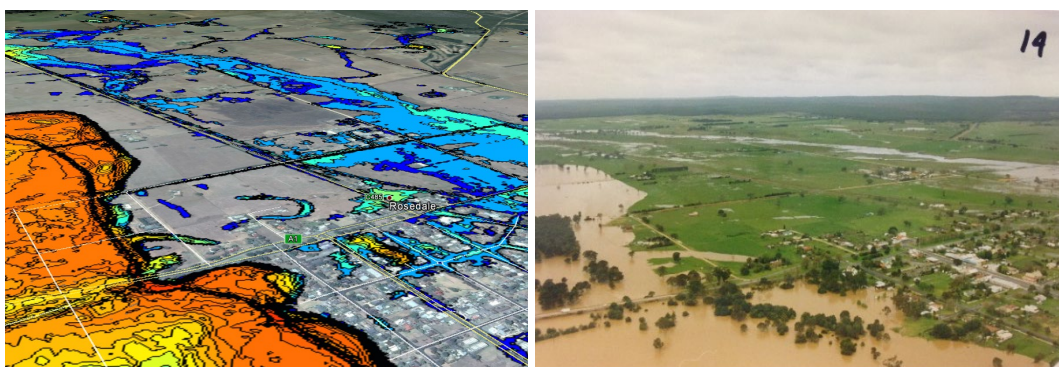


Figure 5-13 September 1993 hydraulic model results compared oblique aerial photographic record Latrobe River

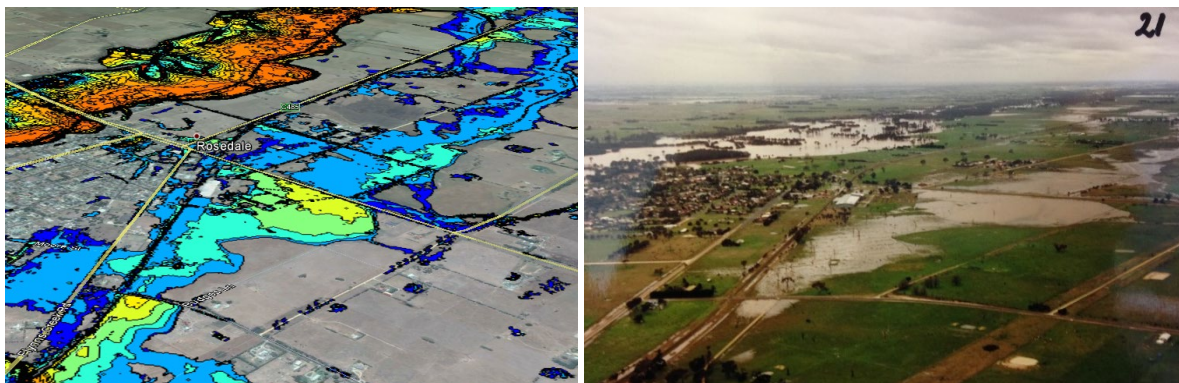


Figure 5-14 September 1993 hydraulic model results compared with oblique aerial photographic record – Friends Road

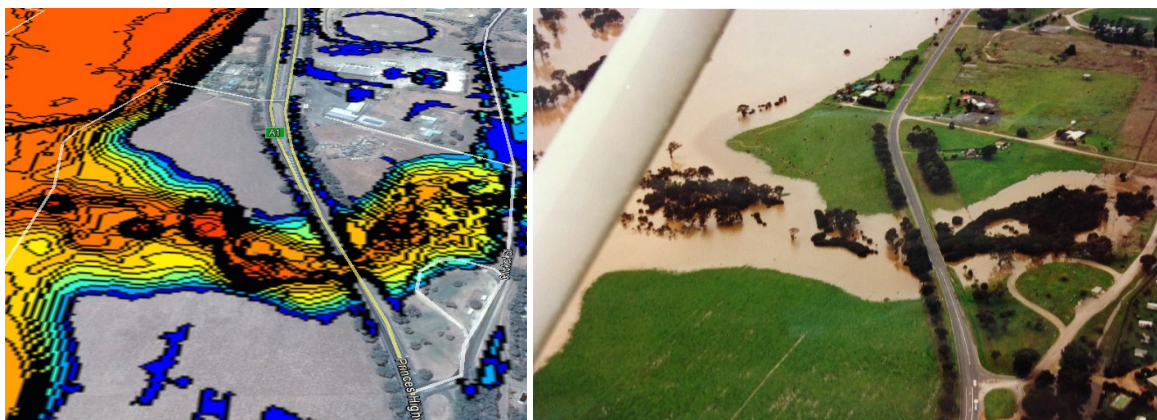


Figure 5-15 September 1993 hydraulic model results compared with oblique aerial photographic record – Princes Highway (west)



Figure 5-16 September 1993 hydraulic model results compared with oblique aerial photographic record – Willung Road south of town

5.1.5 Event timeline

Using all data collected and produced in this study for the 1993 event the following timeline was developed:

Time	Cumulative event hours	Item	Source
Antecedent conditions Week prior to the 14 th September 1993	0	35-40 mm of rainfall Flows in the Latrobe River typical for that time of year ~60 m ³ /s	BoM (data review)
11:00AM 14/09/1993	3	Rain began to fall at East Sale	BoM (data review)
3:00PM 14/09/1993	7	Rain began to fall at Callignee North	BoM (data review)
6:00PM 14/09/1993	10	Flow observed backing up to the downstream boundary of the Princes Highway Bridge	TuFLOW Modelling
4:00AM 15/09/1993	20	Ponding began to be observed at Willung Road (Blind Joes Creek Floodway)	TuFLOW Modelling
7:00AM 15/09/1993	23	Maximum rainfall intensity recorded at East Sale	BoM (data review)
8:00AM 15/09/1993	24	Maximum rainfall intensity recorded at Callignee Nth	BoM (data review)
9:00AM 15/09/1993	25	37.6mm of rain recorded in previous 24 hrs at Flynn & 75mm recorded at Willung	Community supplied rainfall
11:00 15/09/1993	27	Break out observed at upstream of the western railway crossing	TuFLOW modelling
2:00PM 15/19/1993	30	Flows weir over the railway line and Friends Road and flow north and east	TuFLOW modelling
4:00PM 15/09/1993	32	Peak flow observed in Blind Joes Creek	RORB Modelling
5:00PM 15/09/1993	33	Flow from Blind Joes Creek Floodway sitting behind Willung Road starts to move toward the north towards the township	TuFLOW modelling
9:00AM 15/09/1993	49	Significant rainfall ceases	BoM (data review)
5:00PM 15/09/1993	57	Peak flow observed in the Latrobe River	DELWP gauging data (Data Review)

5.1.6 Feedback from online mapping portal

On the 7th of April 2015 Water Technology launched an interactive ArcGIS online web portal presenting the 1993 (and 2012) preliminary flood modelling results and available flood levels. These results were based on hydrology produced using only the official Bureau of Meteorology rainfall data. This web based service gave anyone with access to the internet the ability to view the flood study validation results. The service included a feedback mechanism giving users the opportunity to leave comments and “mark up” the results with points, polylines and polygons. Four comments were left on the site.

Three suggested that the mapping was over estimating flood depths in both events, while the fourth suggested some of the urban mapping was accurate.

As a result of this feedback mechanism and the community consultation process, additional rainfall data was requested from the community. It became apparent that the official gauges located on higher elevation to the north and south of our study catchment were all recording higher rainfall estimates than the community rainfall records located lower in the Latrobe River valley. These community rainfall records are most likely more representative of the rainfall that actually occurred in our study catchment. Hydrologic and hydraulic modelling using the additional community rainfall record resulted in a reduction in extent and depth of flooding throughout the study area.

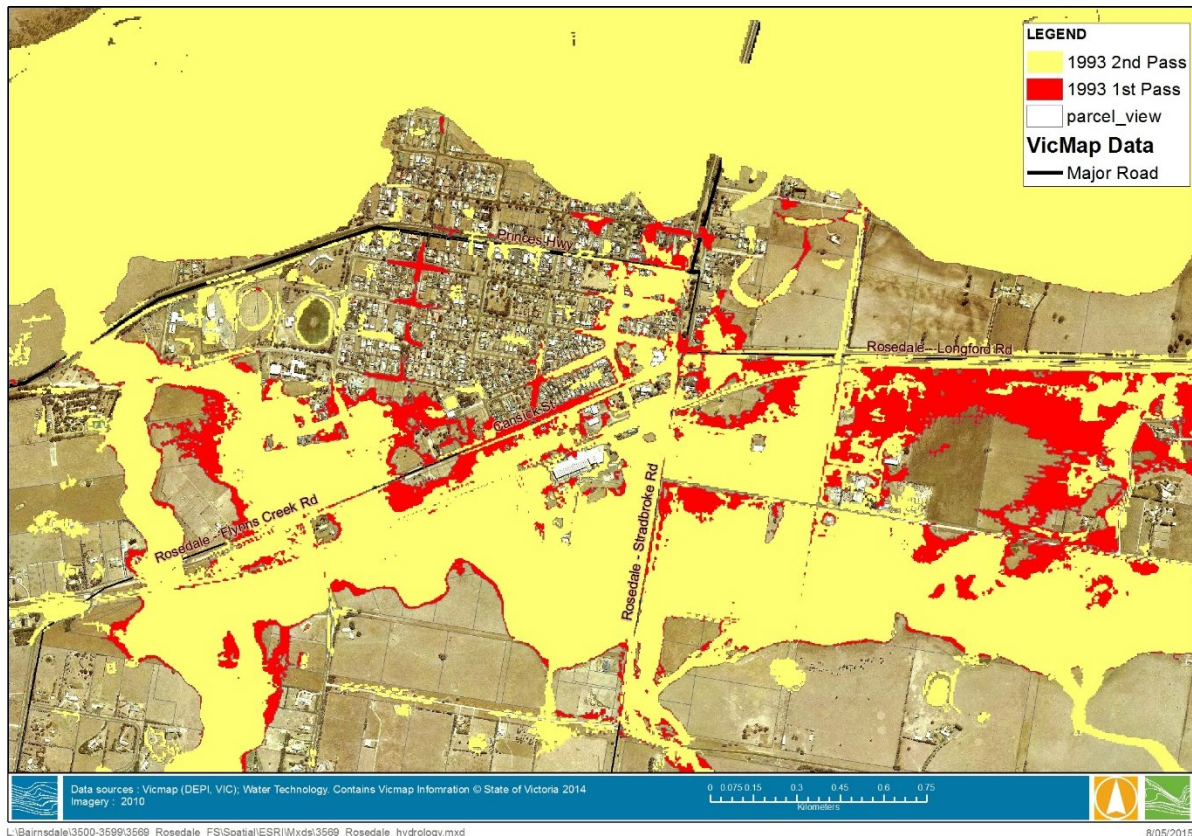


Figure 5-17 Approximate change in flood extent after using community rainfall records

5.1.7 Results Discussion

Considering the limited amount of meteorological data available within the catchment and the limited amount and quality of observations to validate this flood modelling, the results are considered to be representative of the 1993 historic event. Some of the challenges faced in the validation process included:

- Available flood marks are concentrated at two locations;
- The flood marks have been noted in a past report to potentially include error;
- Changes have occurred in the floodplain specifically at the Cansick Street Bridge. Limited data is available on the system prior to these changes;
- A lot of weight has been put on a series of aerial images collected on the 16 September 1993. Unfortunately this was some time (18-24 hours) after our RORB modelling suggested Blind Joes Creek peaked. Some of the flood marks suggest that areas were inundated that are not shown in the aerial images; and

- Much effort has been put in trying to represent flooding at the Friends Road Railway crossing. At this location, our modelling shows water flowing over the railway to the north. Wellington Shire Council believes that this did not happen in 1993. However the flood model is reproducing a flood level at this location 100 mm lower than the observed level, which would indicate that this would have happened assuming the current railway level is the same as in 1993.

Due to these challenges, every effort was made to source additional information to improve our verification of the 1993 event, including discussions with Council regarding historic physical floodplain conditions, community rainfall estimates and observations, etc. After receiving feedback indicating our model was overestimating flood levels in the 1993 event, we revised our hydrology estimates using improved information, leading to better flood estimates within Rosedale.

5.2 June 2012

5.2.1 Antecedent conditions

The June 2012 event spans 3rd – 6th June. Prior to June 2012, approximately 40-70mm of rain fell in the catchment on the 24-26th May, with very little additional rainfall recorded up to the event.

5.2.2 Verification Method

No flood levels or extents were available for the June 2012 event. It was included in the study as it was much more recent event than 1993 and did have some photographic validation data available and anecdotal community observations. No justification could be found to modify the RORB modelling parameters (kc and m) from the 1993 modelling so they were kept consistent. Initial and continuing losses were modified based on values adopted in the Traralgon and Seaspray studies for the June 2012 event.

An additional pluviographic record was available for the June 2012 event. These records came from the Merrimans Creek at Stradbroke West gauging station, found ~14km South East of the centre of the study area on the other side of the Strzelecki Range. Located significantly closer to the study area than both the Callignee North and the East Sale gauges it was decided that this temporal pattern would be the best dataset to use for this modelling scenario.

5.2.3 RORB Parameters and associated results

Table 5-5 documents the RORB modelling parameters adopted in the hydraulic modelling.

Table 5-5 RORB Validation Parameters – June 2012

Sub-Catchment	kc	IL (mm)	CL (mm/hr)	Peak flow (m ³ /s)
Blind Joes Creek	11.31	20	3	12
Trib 2	6.43	20	3	21
Trib 3	1.76	20	3	3
Trib 4	1.33	20	3	2
Trib 5	2.75	20	3	3
Trib 6	0.8	20	3	1
Trib 7	1.13	20	3	1
Trib 8	5.16	20	3	8
Trib 9	3.59	20	3	6

5.2.4 Hydraulic model Results

As the June 2102 event was deemed less significant than September 1993, the hydraulic model was run with a larger cell size to decrease model run times. The results presented in Figure 5-18 were run with a 6 m grid size. Model results (depths and extents) were compared to video footage captured on 6th of June 2012 at about 2:00PM (Figure 5-19 and Figure 5-20). It is noted that this was approximately 22 hours after the peak flow occurred in the Latrobe and 39 hours after the peak in the Blind Joes Creek (estimated using the RORB model). Figure 5-21 to Figure 5-29 compare the results to photos captured by Wellington Shire Council.

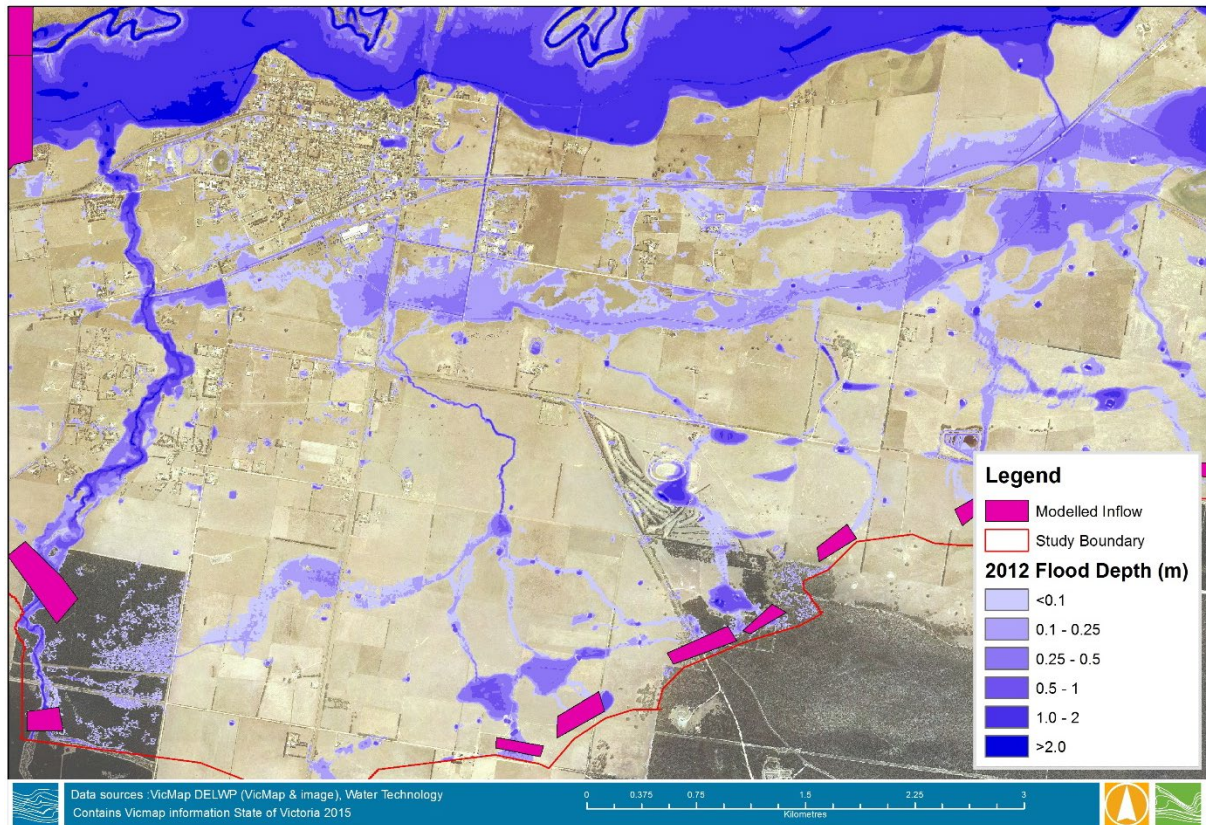


Figure 5-18 June 2012 hydraulic model results using the Stradbroke West temporal pattern

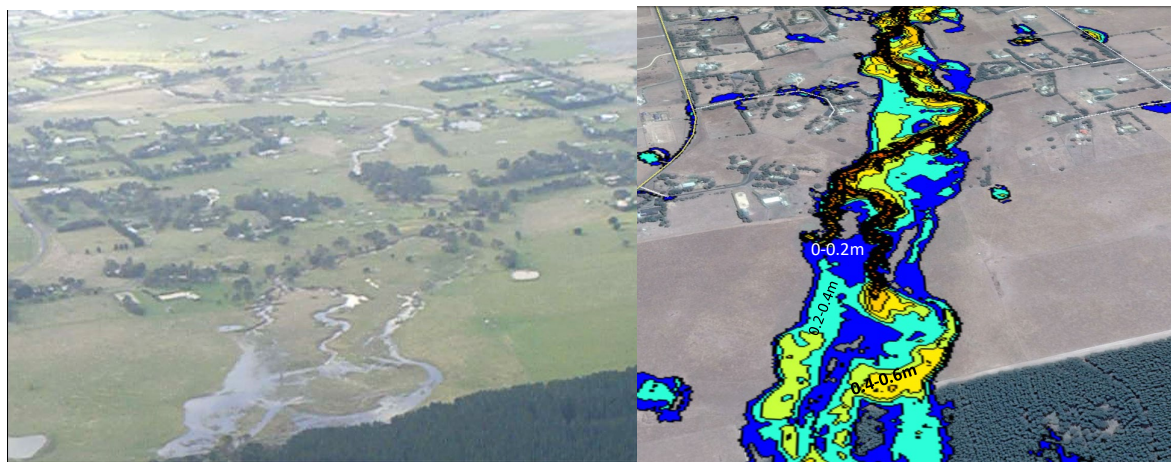


Figure 5-19 June 2012 hydraulic model results compared to video footage from the WGCMA – Rosedale-Flynns Creek Road (South)

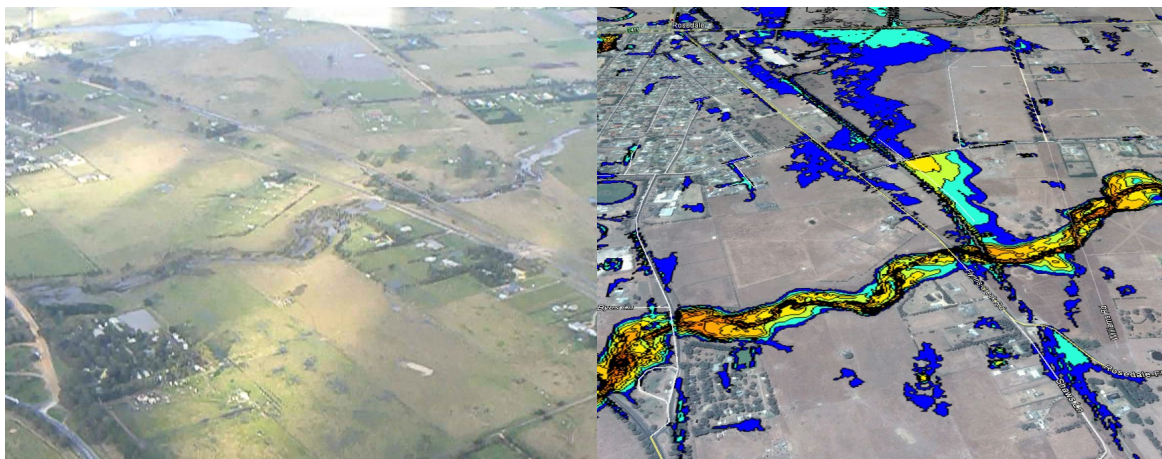


Figure 5-20 June 2012 hydraulic model results compared to video footage from the WGCMA – Rosedale-Flynns Creek Road (North)

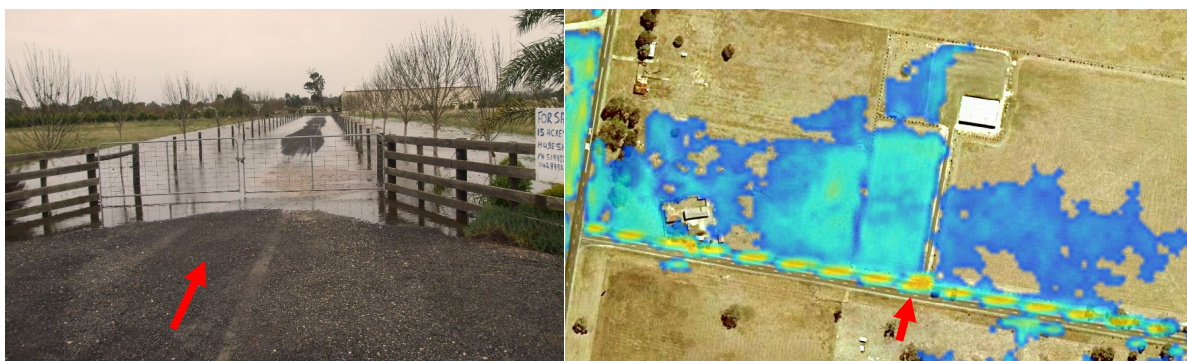


Figure 5-21 June 2012 hydraulic model results compared to photograph from the WSC – Huffers Lane looking north 5th June 2012

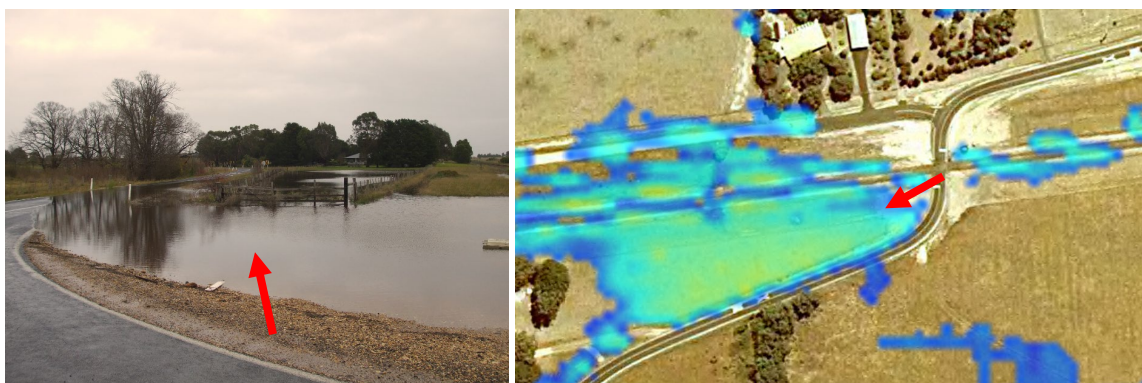


Figure 5-22 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Flynns Creek Road 5th June 2012

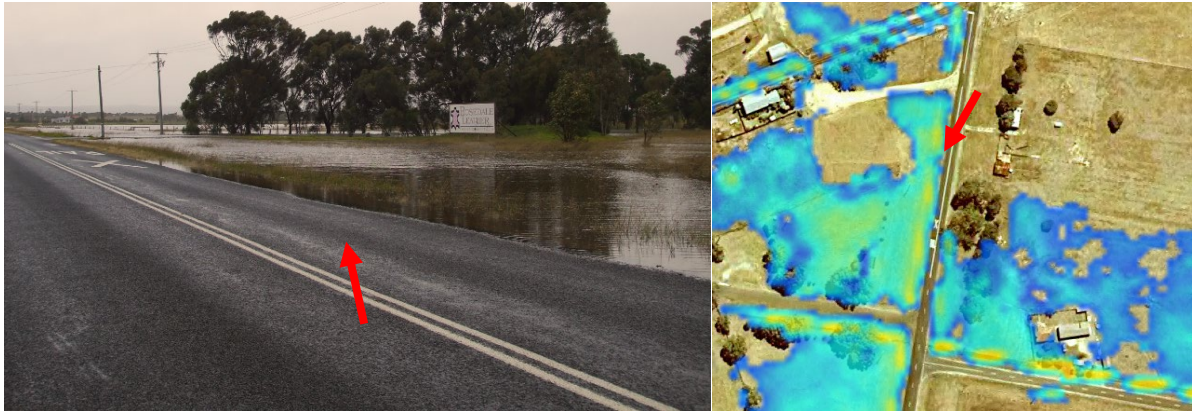


Figure 5-23 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Willung Road 5th June 2012



Figure 5-24 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Cansick Street Bridge - 5th June 2012

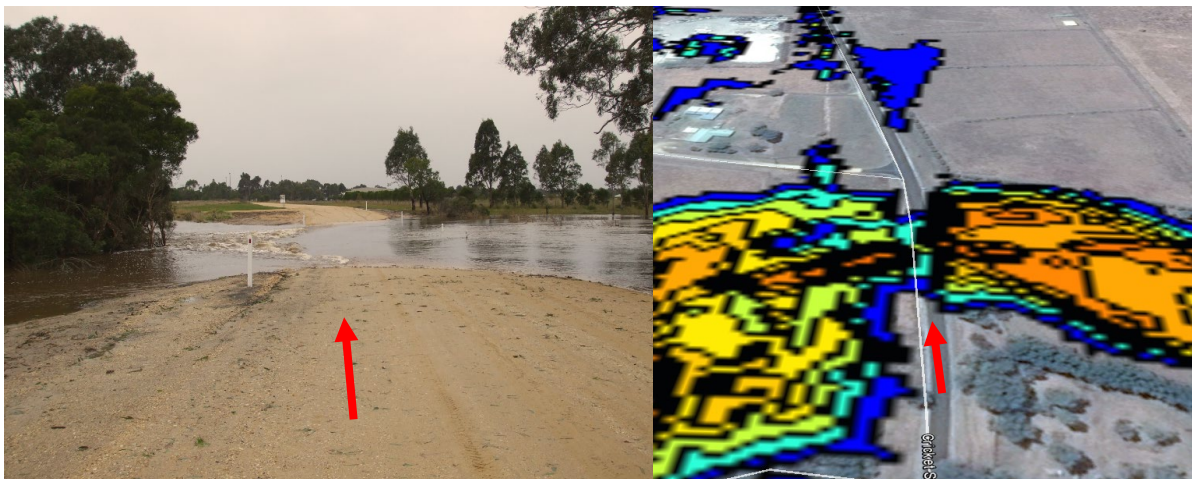


Figure 5-25 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Cricket Street low level crossing - 5th June 2012

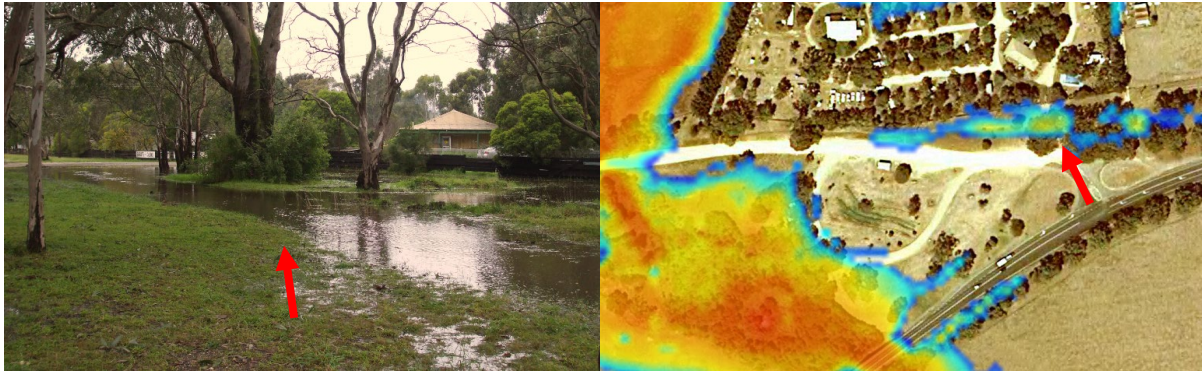


Figure 5-26 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Caravan Park - 5th June 2012



Figure 5-27 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Corner of Huffers Lane and Willung Road - 5th June 2012



Figure 5-28 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Mill Lane - 5th June 2012

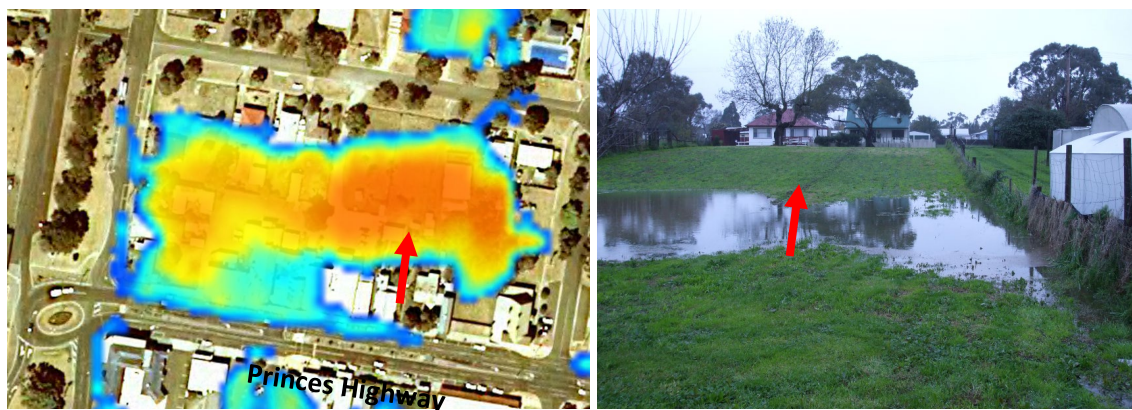


Figure 5-29 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-
Behind Princes Highway - 5th June 2012

5.2.5 Results Discussion

In the absence of other data, it is believed that the 2012 validation modelling produced a reasonable representation of flooding during that event. This fact also added confidence to the 1993 modelling as the 2012 validation was heavily influenced by the key findings of the 1993 RORB validation flows.

5.3 Adopted Historic Verification Event RORB Parameters

The final validated model parameters for each historic event are summarised in Table 5-6.

Table 5-6 RORB Validation Parameters

Event	k _c	m	IL (mm)	CL (mm/hr)
Blind Joes Creek				
1993	11.31	0.8	30	2
2012			20	3
Trib 2				
1993	6.43	0.8	30	2
2012			20	3
Trib 3				
1993	1.76	0.8	30	2
2012			20	3
Trib 4				
1993	1.33	0.8	30	2
2012			20	3
Trib 5				
1993	2.75	0.8	30	2
2012			20	3
Trib 6				
1993	0.8	0.8	30	2
2012			20	3
Trib 7				
1993	1.13	0.8	30	2
2012			20	3
Trib 8				
1993	5.16	0.8	30	2
2012			20	3
Trib 9				
1993	3.59	0.8	30	2
2012			20	3

6. DESIGN HYDROLOGY

6.1.1 Design Rainfall Estimates

Design rainfalls were calculated for the 10%, 5%, 2%, 1% and 0.5% AEP events using the Intensity-Frequency-Duration analysis from AR&R (1987). The IFD parameters were obtained from the Bureau of Meteorology's IFD program website (www.bom.gov.au/water/designRainfalls/ifd) for the catchment centroid (Table 6-1).

Table 6-1 IFD parameters

2yr (50% AEP) 1hr rainfall intensity (mm/hr)	17.94
2yr (50% AEP) 12hr rainfall intensity (mm/hr)	3.47
2yr (50% AEP) 72hr rainfall intensity (mm/hr)	0.93
50yr (2% AEP) 1hr rainfall intensity (mm/hr)	42.16
50yr (2% AEP) 12hr rainfall intensity (mm/hr)	6.98
50yr (2% AEP) 72hr rainfall intensity (mm/hr)	2.2
Skew	0.35
F2	4.23
F50	15.2

Comparisons were made with the new IFDs developed for Project 1 of the Australian Rainfall and Runoff Revision Project (Engineers Australia, 2014). On average the new IFD approach had rainfall depths around 2% higher than ARR87, with some AEP/duration values up to 8% higher. For the 1% AEP event the new IFD rainfall depths were within 1% of the old rainfall estimates for short durations up to 0.5hrs, beyond 0.5hrs the percentage difference was greater, up to 17% for the 72hr event. The 1987 IFD parameters were adopted to be consistent with existing methods for areal reduction factors, design losses and hydrologic parameter estimates, which were developed with the older IFD information. At the time of finalising the report it was understood that the Bureau of Meteorology was revising the new IFD and that it would be available for use later in 2016.. Rainfall depths were applied uniformly across the catchment.

Areal reduction factors from Siriwardena and Weinmann (1996) were applied to the point design rainfall estimates. These areal reduction factors are recommended for use in Victoria instead of the original AR&R values (Hill et al. 1998). These have now been recommended for adoption in the ARR Project 2 Stage 2 report (Engineers Australia, 2012).

6.1.2 RORB Design Loss Estimates

Design losses were estimated by the design loss prediction equations developed by Hill et al (1998) and (Hill et al. 2014). The losses recommended in ARR87 consistently overestimated peak flows. The Hill et al (1998) losses, in combination with the new areal reduction factors from Siriwardena and Weinmann (1996), produced peaks that were more consistent with the results of validation modelling.

The initial loss using the earlier Hill et al (1998) method is calculated by first calculating the storm initial loss using Equation 1, then the burst initial loss (Equation 2). The burst initial loss varies with storm duration and accounts for the embedded nature of AR&R design rainfalls (Hill et al 1998). The continuing loss is estimated using Equation 3.

Storm initial loss:

$$IL_s = -25.8BFI + 33.8 \quad (1)$$

Burst initial loss:

$$IL_b = IL_s \left\{ 1 - \frac{1}{1 + 142 \frac{\sqrt{\text{duration}}}{MAR}} \right\} \quad (2)$$

Continuing loss:

$$CL = 7.97BFI + 0.00659PET - 6.00 \quad (3)$$

The ARR Project 6 Stage 3 report (Hill et al. 2014) contains new recommended initial and continuing loss equations, as shown below. No recommendation has been made for the conversion of storm initial loss to burst initial loss.

Storm initial loss:

$$IL_s = 16.7 + 0.141P_{24h}^{2\%} - 0.291MedianAPI \quad (4)$$

Continuing loss:

$$CL = 3.0 \text{ mm/hr} \quad (5)$$

The values of the input parameters to the previous equations are as follows:

- Median API 34 mm
- BFI 0.34
- PET 1,008 mm
- MAR 820 mm
- $P_{24h}^{2\%}$ 112 mm

The design loss estimates produced by both methods are given in Table 6-2. The design initial losses tended to be lower than those used in the RORB verification events, while the continuing losses tend to be similar. The Project 6 losses (Hill et al. 2014) are only slightly smaller than the ARR87 losses (Hill et al. 1996).

Table 6-2 Design loss parameter estimates

Source	IL _s (mm)	IL _b (mm)	CL (mm/hr)
Hill et al (1998)	25	9-15 (for 9-72 hour events)	3.4
Project 6 Stage 3 Report (Hill et al. 2014)	23	-	3

6.2 RORB Design Flows and Hydrographs

The routing and loss parameters summarised in Table 6-3 were adopted for design modelling. Higher range initial loss estimates were adopted after consideration of the validation process and adopted parameters in adjacent catchments (e.g. the Traralgon creek). The sensitivity analysis on IL presented earlier in this report gave confidence that the peak flows and volumes estimated by RORB were not overly sensitive to IL. The CL was shown to have a significant impact on peak flow and volume, and the fact that the design CL adopted is similar to the verification events provides additional confidence in the parameters adopted.

Critical durations are shown in Table 6-4 and ranged between 9 and 12 hours for the catchments analysed. The smaller catchments tended to have 9 hour critical durations. Being that larger catchments had critical durations of 12 hours, this duration is being recommended for design model runs.

Table 6-3 Recommended design parameters

Blind Joes Creek	k_c							m	IL (mm)	CL (mm/hr)
	Trib 2	Trib 3	Trib 4	Trib 5	Trib 6	Trib 7	Trib 9			
11.31	6.43	1.76	1.33	2.75	0.8	1.13	3.59	0.8	30	3

Table 6-4 Critical Duration for design peak flows for Blind Joes Creek and its adjacent catchments to the east

AEP	Blind Joes Creek (hrs)	Trib 2 (hrs)	Trib 3 (hrs)	Trib 4 (hrs)	Trib 5 (hrs)	Trib 6 (hrs)	Trib 7 (hrs)	Trib 8 (hrs)	Trib 9 (hrs)
10%	12	12	9	9	12	9	9	12	9
5%	12	12	9	9	9	9	9	12	9
2%	12	12	9	9	9	9	9	9	12
1%	12	12	9	9	9	9	9	12	9
0.5%	12	9	9	9	9	9	9	9	9

Table 6-5 Maximum design peak flows for Blind Joes Creek and its adjacent catchments to the east

AEP	Blind Joes Creek (m ³ /s)	Trib 2 (m ³ /s)	Trib 3 (m ³ /s)	Trib 4 (m ³ /s)	Trib 5 (m ³ /s)	Trib 6 (m ³ /s)	Trib 7 (m ³ /s)	Trib 8 (m ³ /s)	Trib 9 (m ³ /s)
10%	14	21	4	2	4	2	2	8	6
5%	23	33	7	3	7	3	3	13	11
2%	38	51	11	4	11	4	4	20	17
1%	50	65	13	6	14	5	5	26	22
0.5%	65	83	16	7	18	5	6	33	28

6.3 RORB Design Flow Checks

Peak flows from RORB were checked against current empirical peak flow estimates. These checks are shown in Table 6-6. Results for only 1 of the 9 catchments modelled are shown in Table 6-6 however the relationship was consistent across all of the catchments. 1% AEP flows from RORB adopted in this study are at the higher end of the peak flow estimates but are also backed by a robust validation process. Considering these factors, the design flows adopted are deemed accurate and suitable for use in the design hydraulic modelling.

Table 6-6 Design peak flows checks for Blind Joes Creek catchment

Design AEP and Historic Year	RORB Peak Flow (m ³ /s)	Rational Estimate (AR&R 87)	Regional FF Estimation Model (AR&R 4 th Ed).	VicRoads Drainage Manual	Hydrological Recipes: Rural Estimate (1996)
June 2012	12				
10%	15		26		
5%	23		31		
September 1993	31				
2%	38		39		
1%	50	32	46	39	73
0.5%	65		NA		

6.4 External Catchment Sensitivity Analysis

6.4.1 Climate Change

The impacts of climate change were tested by increasing the rainfall intensity by 5% per degree of warming, in line with latest guidance from Australian Rainfall and Runoff (Engineers Australia 2014). A scenario of 2°C of warming (i.e. 10% increase in rainfall intensity) was adopted for this sensitivity test. This is consistent with 'Climate Change in Australia Projections' (CSIRO, 2015) report which suggest for an intermediate climate scenario, a temperature increase of between 1.1°C to 2.0°C is likely for the Southern Slopes of Australia, which includes the Blind Joes Creek and its adjacent catchments to the east.

The 10% increase in rainfall intensity was applied to the burst rainfall depth in the RORB storm files for each of the design events for the critical duration. The results of the climate change sensitivity test are summarised in Table 6-7 and shown in Figure 6-1. The increase in flows from a 10% increase in rainfall intensity are more evident in the more frequent events, with a 25-33% increase in flow in the 10%-2% AEP design events compared to a 19% increase in flow in the 1% and 0.5% AEP design event. The proportional increases in flows are larger than the proportional increases in rainfall intensities due to the rainfall losses assumed in the design scenarios.

Table 6-7 Comparison of peak flows for increases in rainfall intensity due to climate change

AEP	Current Conditions		Scenario of 2°C of Warming		Increase in Flow (%)
	Burst Rainfall Depth (mm)	RORB Design Flow (m ³ /s)	Burst Rainfall Depth (mm)	RORB Design Flow (m ³ /s)	
10%	55.0	14	60.5	19	26%
5%	65.2	23	71.7	31	33%
2%	79.6	38	87.5	47	25%
1%	90.3	50	99.3	60	19%
0.50%	103.9	65	114.3	77	19%

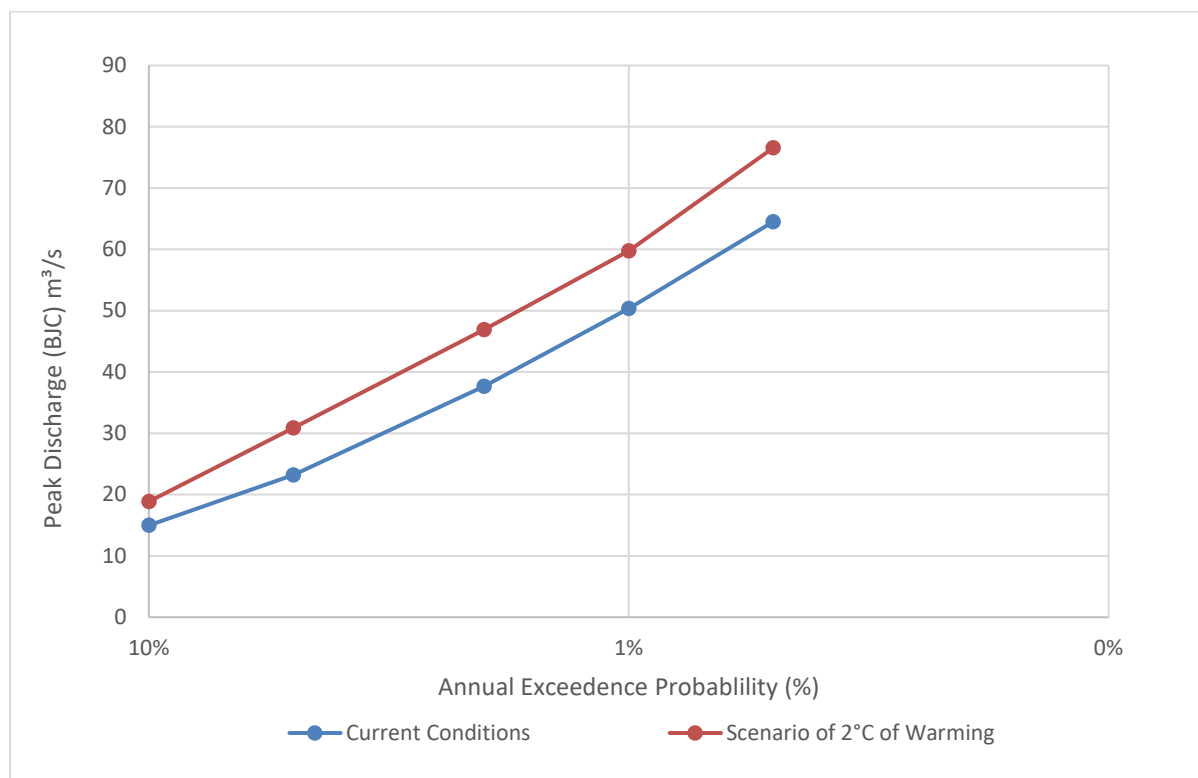


Figure 6-1 Climate change sensitivity comparison for Blind Joes Creek

6.4.2 Bushfire

The impacts of bushfires were tested by adjusting the catchment fraction imperviousness of Blind Joes Creek (and its adjacent catchments to the east) to reflect an agreed severity of bushfire. For example, Blackham et al (2012) provides values of equivalent percentage impervious for different levels of burn severity, based on BAER (2009) (Table 6-8).

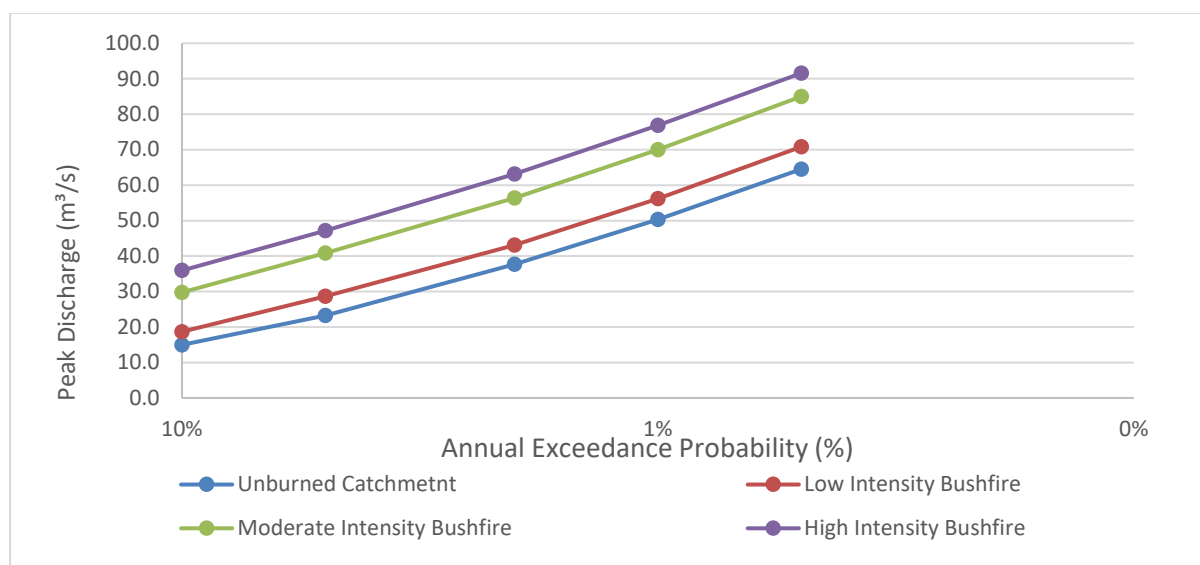
Table 6-8 Equivalent percentage impervious for different levels of burn severity

Burn severity	Equivalent percentage impervious
Unburned	0.1
Low	0.3
Moderate	0.7
High	0.9

The impervious fraction for all Farming Zone (Forestry) and Public Conservation and Resource Zone areas across the catchment were increased to 0.3, 0.7 and 0.9 to represent a low, moderate and high severity burn across the catchment. The resulting fraction impervious for each of the sub-catchments in the RORB model were then recalculated for each scenario and input into the RORB model and run for the range of design events. As expected, the increase to fraction impervious had a significant impact on flows generated from the catchment.

Table 6-9 Comparison of peak flows for increases impervious fraction due to bushfire

AEP	Unburned Catchment (m ³ /s)	Low Intensity Bushfire (m ³ /s)	Moderate Intensity Bushfire (m ³ /s)	High Intensity Bushfire (m ³ /s)
10%	15	19	30	36
5%	23	29	41	47
2%	38	43	56	63
1%	50	56	70	77
0.5%	65	71	85	92

**Figure 6-2 Bushfire sensitivity comparison for Blind Joes creek (1 of the 9 catchments modelled).**

6.5 PMF Estimation

A PMF Estimate for Blind Joes Creek and its adjacent catchments to the east were prepared using the Quick Method of Nathan et al. (1994). This method applies a set of empirical equations to compute a triangular PMF hydrograph. The equations are:

$$Q_p = 129.1 A^{0.616}$$

$$V = 497.7 A^{0.984}$$

$$T_p = 0.0001062 A^{-1.057} V^{1.446}$$

$$T_r = V / (1.8 Q_p)$$

Where:

Q_p is peak flow (m³/s)

A is catchment area (km²)

V is hydrograph volume (ML)

T_p is time to peak of hydrograph (h)

And T_r is base length of hydrograph (h)

The equations are applicable to southeast Australian catchments from 1 to 10,000 km² that do not have large lakes or storages. The resulting PMF peak flow, volume, time to peak and hydrograph length are shown in Table 6-10.

Table 6-10 PMF Peak Flow Estimates for Blind Joes Creek and its adjacent catchments to the east

Catchment Name	Total Area (km ²)	Qp (m ³ /s)	V (ML)	Tp (h)	Tr (h)
Blind Joes Creek Flow	36.68	1,187	17,233	3.1	8.1
Trib 2	31.35	1,078	14,766	3.0	7.6
Trib 3	3.14	261	1,536	1.3	3.3
Trib 4	1.37	157	678	0.9	2.4
Trib 5	4.52	327	2,195	1.5	3.7
Trib 6	0.85	117	426	0.8	2.0
Trib 7	1.04	132	516	0.9	2.2
Trib 8	11.94	595	2,195	2.1	5.3
Trib 9	8.06	467	3,882	1.8	4.6

7. MULTI - DOMAIN DESIGN FLOOD MODELLING

Ultimately, it was concluded that a single domain model would be sufficient to accurately represent flooding in Rosedale. The following sections describe the sensitivity testing undertaken using the multi-domain model to establish the floodplain's sensitivity to initial condition in the Latrobe River (tailwater condition). This approach was discussed with West Gippsland CMA and the Steering Committee and was approved for adoption in all design modelling.

7.1 Latrobe River Sensitivity Analysis

Sensitivity analysis for the Rosedale flood model was undertaken to assess the impact of the Latrobe River tailwater. To assess the impact of the Latrobe River on flood levels in Blind Joes Creek, the 1% AEP flow event for Blind Joes Creek (and its adjacent catchments to the east) were modelled with three flow conditions on the Latrobe River. Two of these conditions were obtained from the Latrobe River Flood Study (Cardno, 2013), and the third used low flow conditions in the Latrobe River.

The initial model used the 10% AEP water level and flow rate (run as a steady state flow) in the Latrobe River in conjunction with the 1% AEP conditions in the Blind Joes Creek (and its adjacent catchments to the east), flood depth from this run are shown in Figure 7-1. The second model used the 1% AEP Blind Joes Creek (and its adjacent catchments to the east) event flows with the 1% AEP Latrobe River water level and flow rate, Figure 7-4. The Third model used the 1% AEP Blind Joes Creek (and its adjacent catchments to the east) event flows with winter low flow conditions in the Latrobe River (below minor flood class) water level and flow rate. Tailwater conditions for each model run are detailed in the Table 7-1.

Table 7-1 Tailwater Levels applied in design sensitivity analysis

BJC Flow Condition (AEP)	Direct Rainfall Condition (AEP)	Latrobe Floodplain Tailwater Condition (AEP)	Latrobe Floodplain Tailwater Level (mAHD)	Source used to estimate tailwater condition
1%	1%	10%	10.2	Latrobe Flood Study Results
1%	1%	1%	11.5	Latrobe Flood Study Results
1%	1%	Low flow	8.5*	Estimated upon review of initial modelling runs

* Tailwater only applied to main channel, overland flow from Blind Joes Creek let out of the model using a HQ boundary.

The results of the sensitivity analysis provide answers regarding the unknown impact of Latrobe River levels on flooding in Blind Joes Creek. Feedback from the community consultations and steering committee members has suggested that the concurrence of flood events between the Latrobe River and Blind Joes creek can have a large impact on flooding conditions at the western edge of the township. However this analysis suggests major impacts from the Blind Joes Creek are relatively independent from flooding in the Latrobe River, with only localised changes observed when the 1% AEP event in Blind Joes Creek is modelled with 1% or 10% AEP Latrobe River downstream conditions. Similarly, no discernible differences were identified in flooding from Blind Joes Creek between the scenarios with 10% AEP flow and base flow conditions in the Latrobe River. Differences in flood extents from the three sensitivity runs are shown in Figure 7-4 to Figure 7-7.

A comparison with the 1% AEP flood mapping (using 10%AEP Latrobe River flows) and the 1993 event is shown in Figure 7-8. The difference between the two events is most noticeable east of the township with flooding inside the township having reasonably similar extents between the two scenarios.

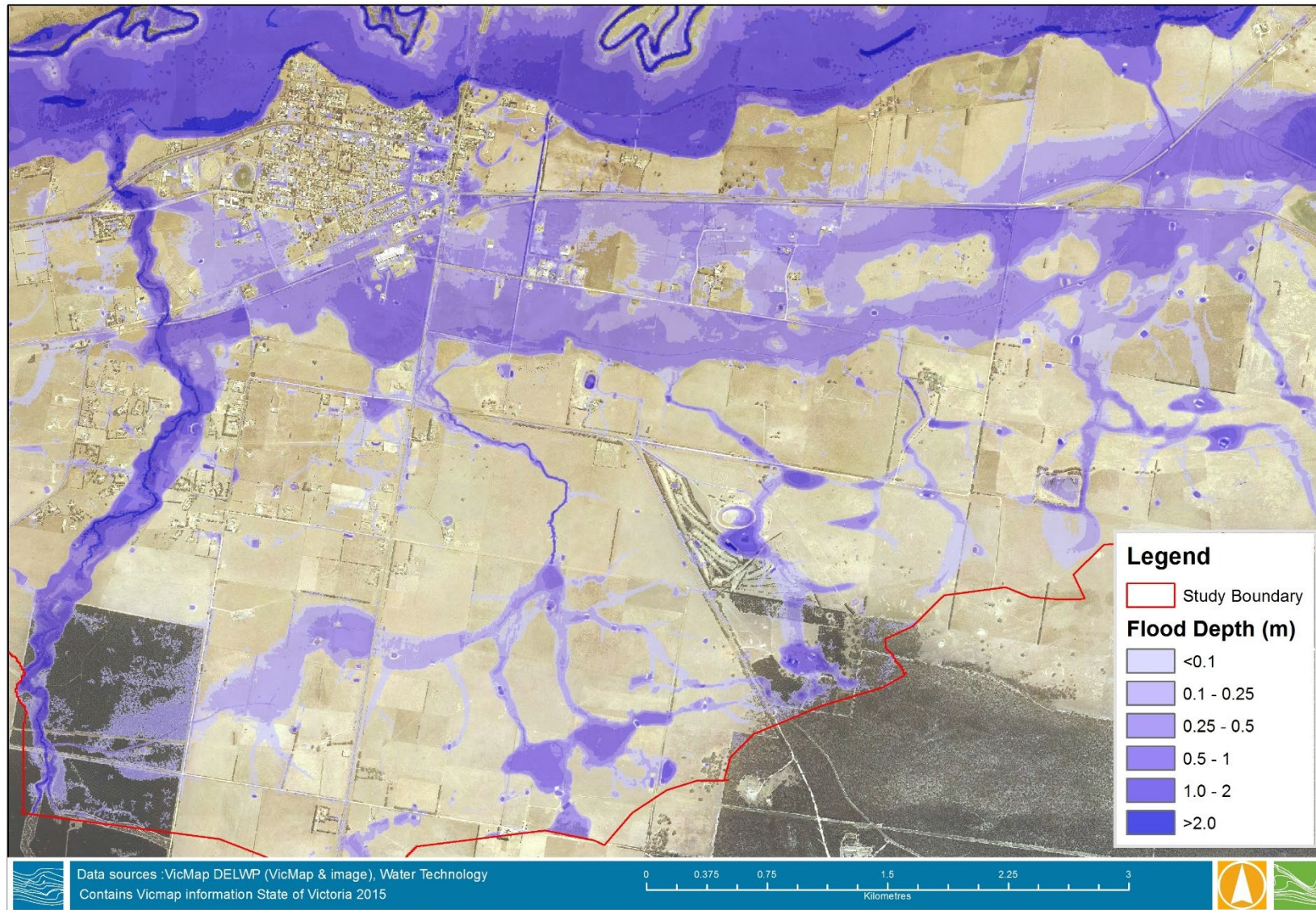


Figure 7-1 1% AEP Blind Joes Creek Flood Depth (10% AEP Latrobe Flow)

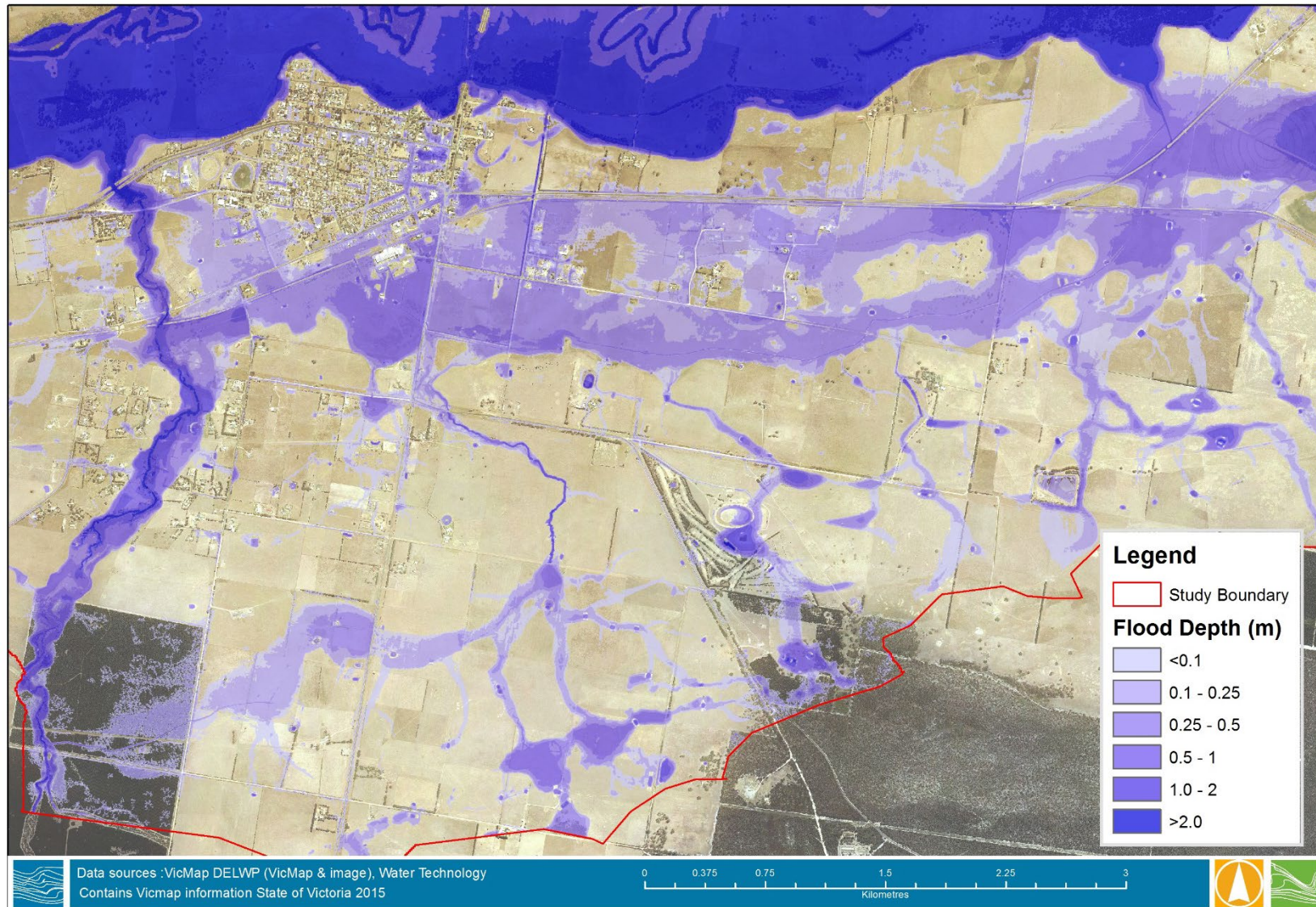


Figure 7-2 1% AEP Flood Depth with 1% AEP Latrobe River flow

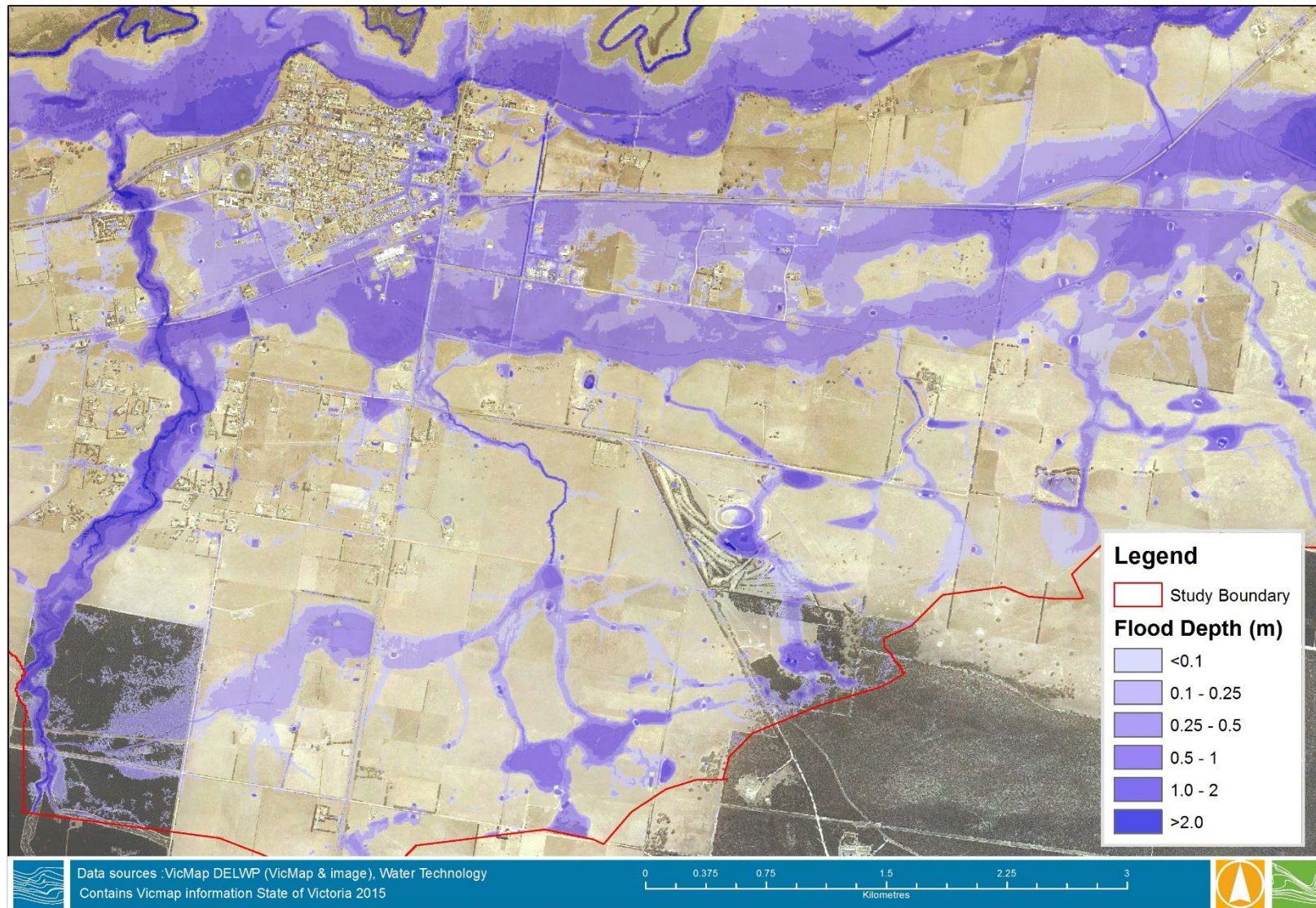


Figure 7-3 1% AEP Flood Depth with low flow Latrobe River conditions

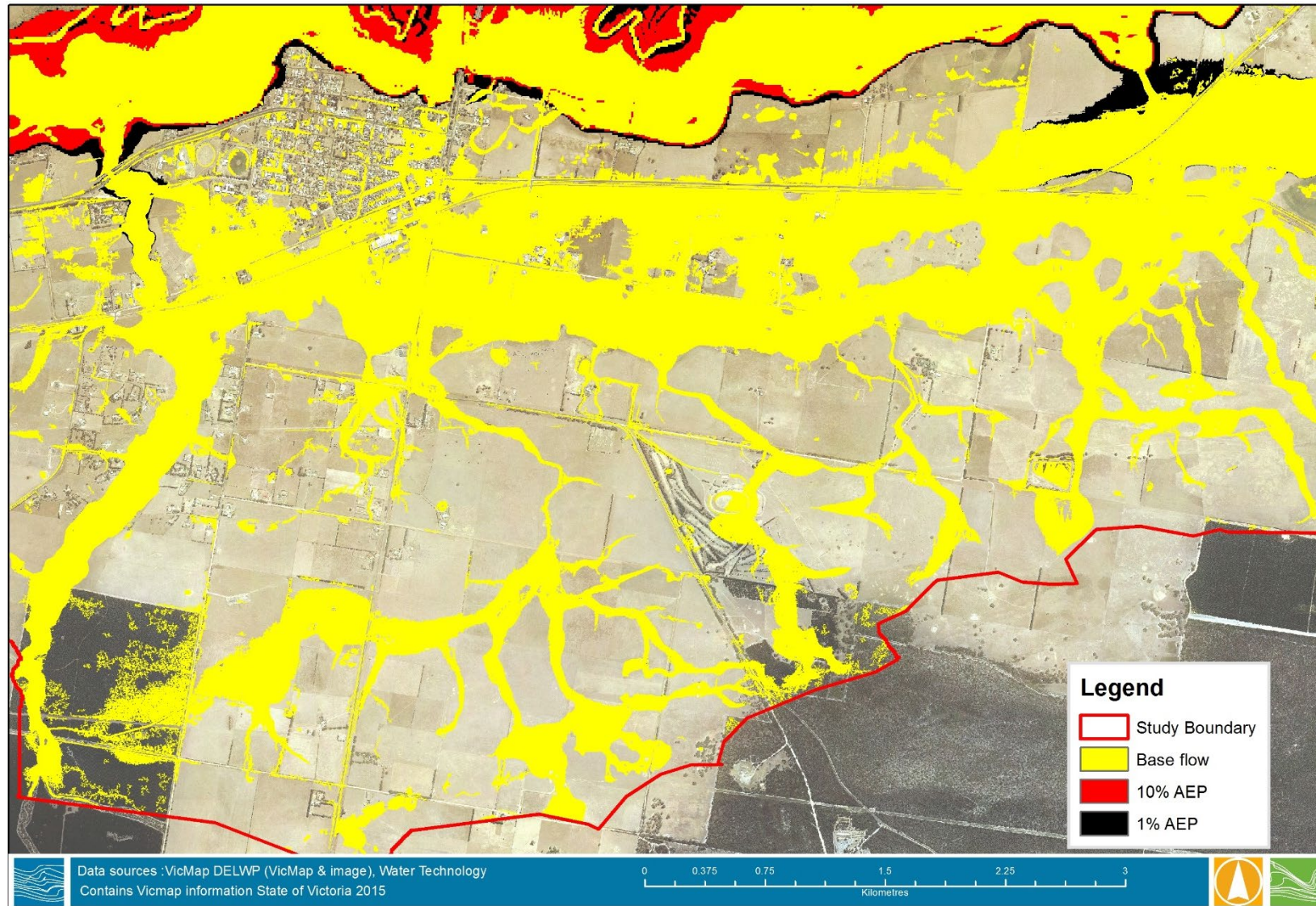


Figure 7-4 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – Study Area

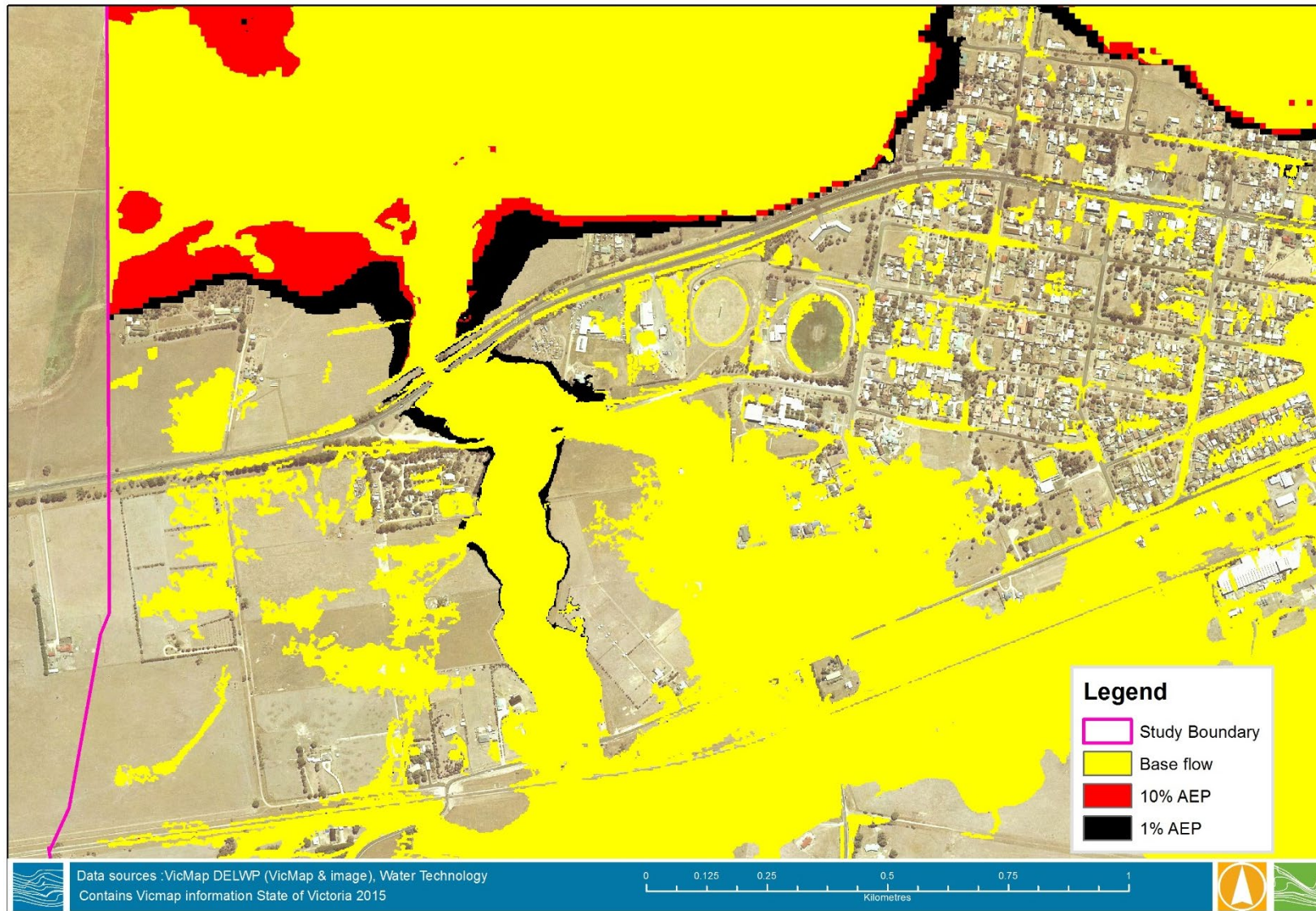


Figure 7-5 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – West

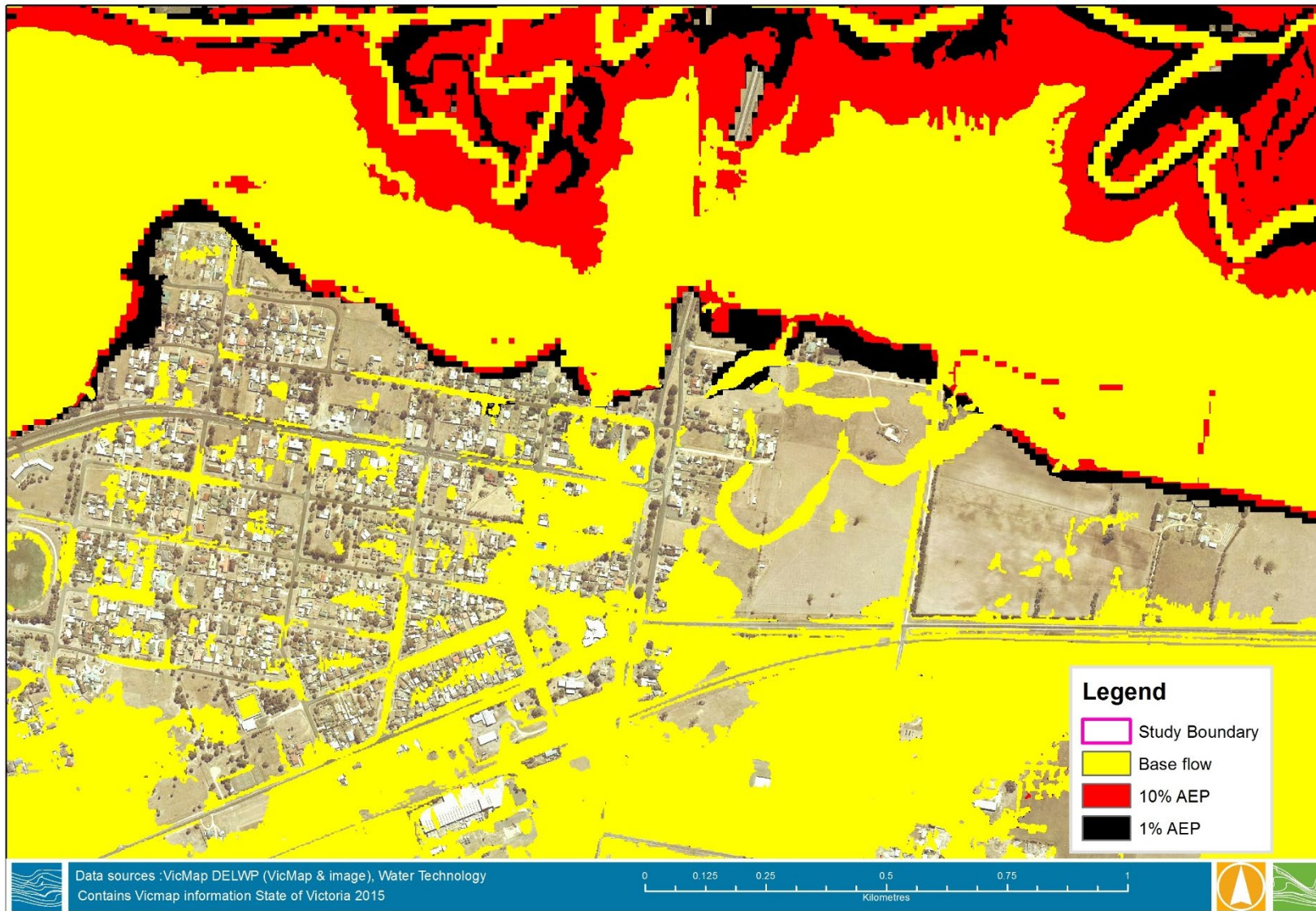


Figure 7-6 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – Central

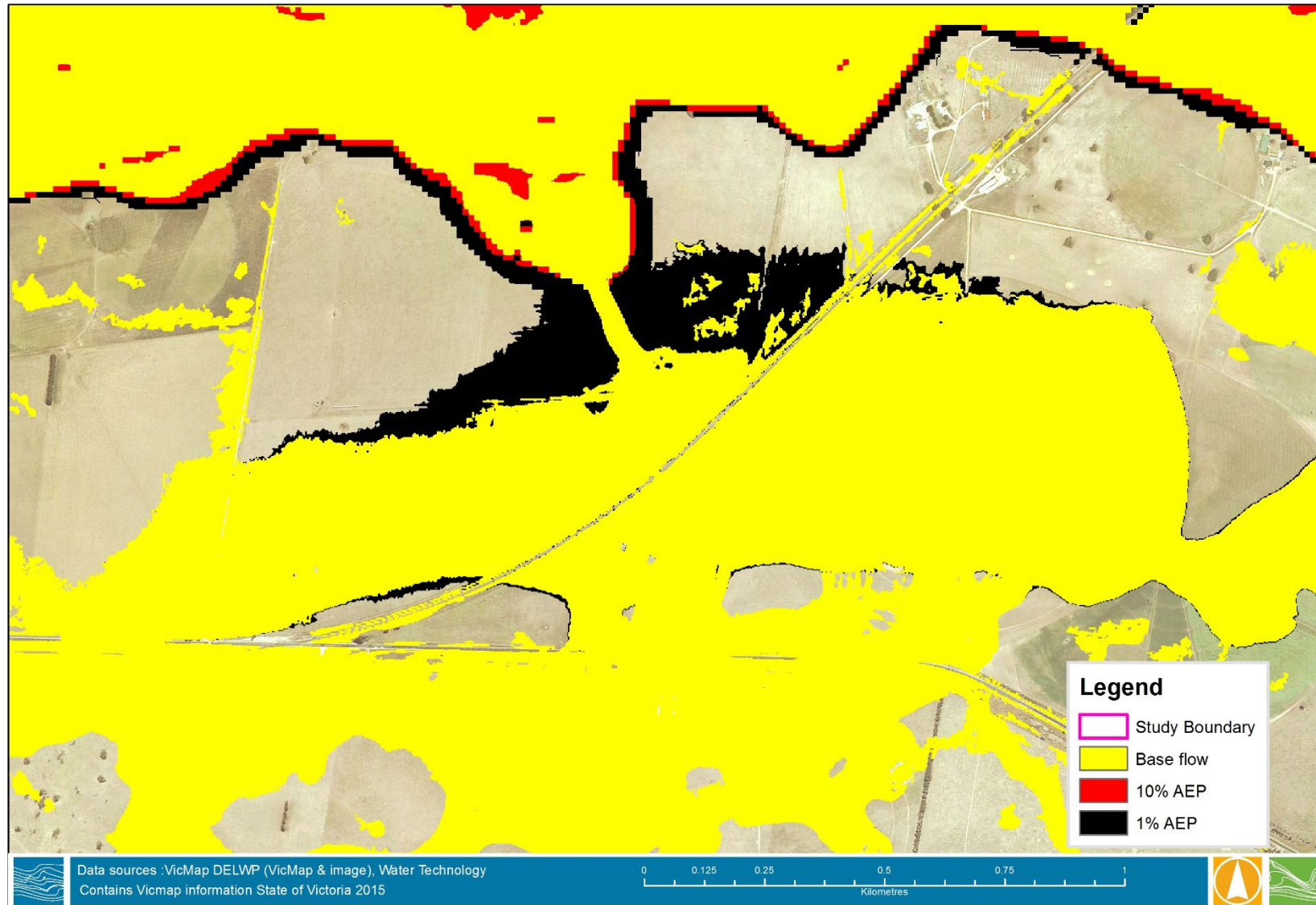


Figure 7-7 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – East

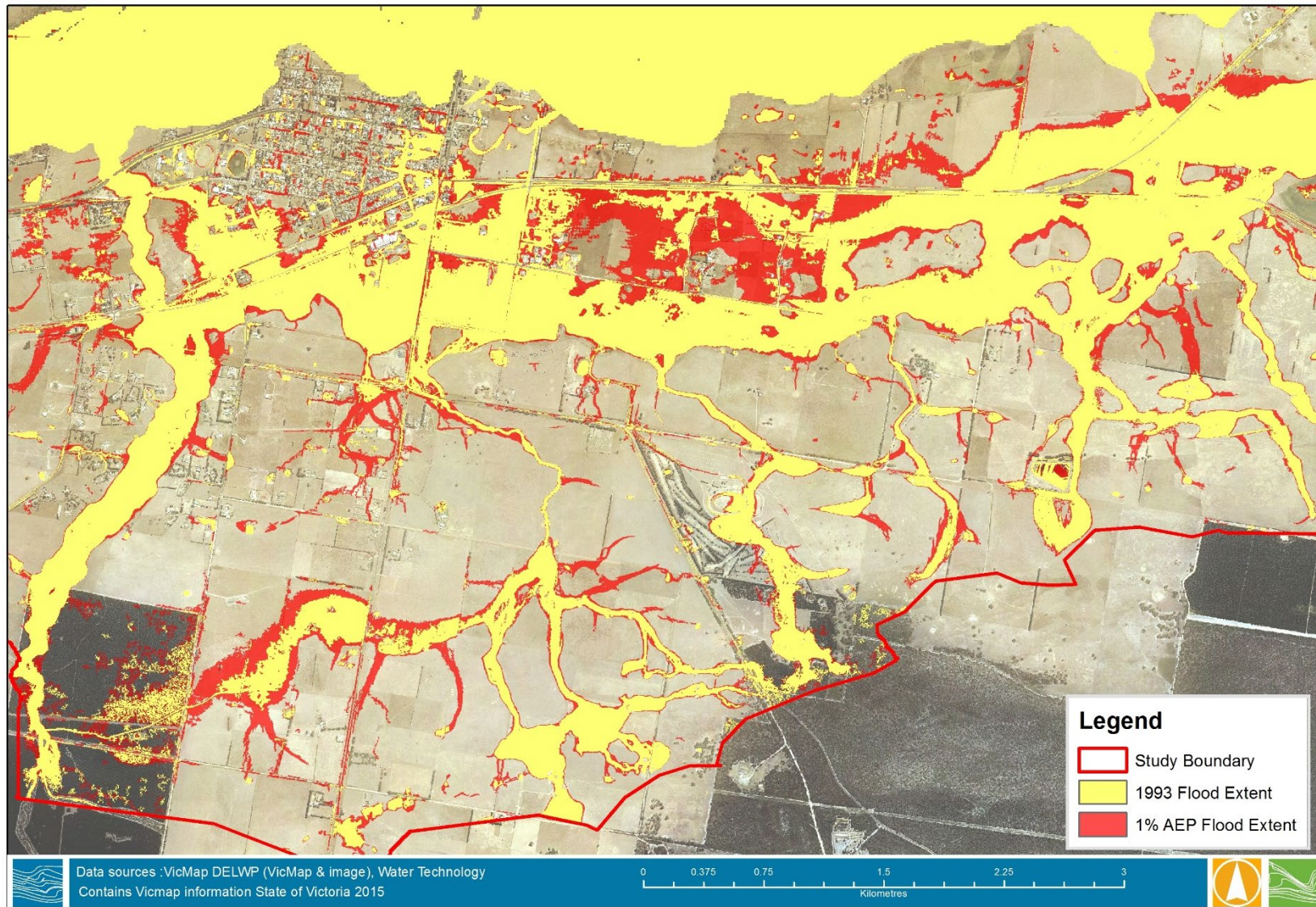


Figure 7-8 1% AEP Flood extent (10% AEP Latrobe River flow) compared with 1993 validation modelling

8. SINGLE DOMAIN DESIGN HYDRAULIC MODELLING

Section 7.1 demonstrated that flooding from a 1% AEP Blind Joes Creek and local catchment event is not particularly sensitive to Latrobe River tailwater conditions. After consideration and discussion with West Gippsland CMA, it was decided that the hydraulic model would be trimmed back to a single domain model of Blind Joes Creek, the local catchment and the Rosedale township. The Latrobe River was removed and an appropriate Latrobe River tailwater condition was applied (extracted from the original model which included the Latrobe River). The high resolution (4m) domain discussed in section 4.6 was retained with Latrobe River boundary conditions represented with static Height / Time (HT) boundaries (these values are shown in Table 8-1). The remainder of the model had Height / Flow (HQ) boundaries set to their localised slope conditions. This allowed less significant overland flow to be removed from the model.

Table 8-1 Tailwater Levels applied in design modelling

Blind Joes Creek Flow (AEP)	Direct Rainfall (AEP)	Latrobe River Tailwater (AEP)	Western Boundary Latrobe Floodplain Tailwater Level (m AHD)	Eastern Boundary Latrobe Floodplain Tailwater Level (m AHD)
10%	10%	10%	15.415	11.7
5%	5%	10%	15.415	11.7
2%	2%	10%	15.415	11.7
1%	1%	10%	15.415	11.7
0.5%	0.5%	1%	16.892	13.062
PMP	No direct Rainfall Applied	1%	16.892	13.062

The single domain hydraulic model was run for all the design events included in the project scope using the boundary conditions described in Table 8-1. The resultant flood extents by event are shown in Figure 8-1. The analysis showed that between Blind Joes Creek and Willung Road, the flood extents don't change much between the design events. This is due to the broad flat nature of the floodplain to the south of Rosedale, with out of bank flooding inundating the majority of the floodplain to shallow depths even in 10% AEP events. East of Willung Road, the larger events do extend out and inundate significant additional land.

Design flood mapping was also compared to historic flooding to better help understand the magnitude of these past events. It should be noted that LiDAR from 2008 was used in preference to that captured in 2014 in the validation modelling (1993 and 2012), while the design modelling preferred the newer 2014 data, more representative of today's conditions. The change in underlying LiDAR does result in slight changes in the model results, particularly in relation to the direct rain-on-grid results.

The 1993 flood extent fell between the 1% and 2% AEP events (shown in Figure 8-4), with the 1993 modelled water levels generally closer to the 2% AEP results. The 2012 validation results showed an extent less than a 10% AEP event (as shown in Figure 8-5), which was consistent with the hydrologic analysis estimates of the event magnitude.

Finally, the 1% AEP design modelling results were compared to the current LSIO (Figure 8-6). This showed that the two studies (GHD 2002 and Water Technology 2015) captured similar overland flow paths throughout the study area. Generally, the results from the current study showed less land inundated than that determined in 2002 (by GHD). Flood extents determined in this study extended much further south making use of the LiDAR captured as part of this project.

Two items were identified which could be rectified if the project was revisited; however, they are both well outside the key area of focus (Rosedale township) and are therefore not considered critical to fix. These items are shown in Figure 8-1.

A small discontinuity (~100mm) between the new (2015) and old (2008) LiDAR data sets was observed immediately north of the Gippsland Railways crossing over Rosedale Longford Road. This consistent slight rising of the land between the topographic datasets has resulted in the shallow overland flow backing up in an unnatural manner. The recommended LSIO shape has been smoothed to marry the results at the boundary together.

Two minor crossings are not included under Longford Rosedale Road. Based on the crossing size and conditions immediately north of the intersection of Mullocky and Longford Rosedale Road (shown below) it is not expected that these missing features have significant capacity.

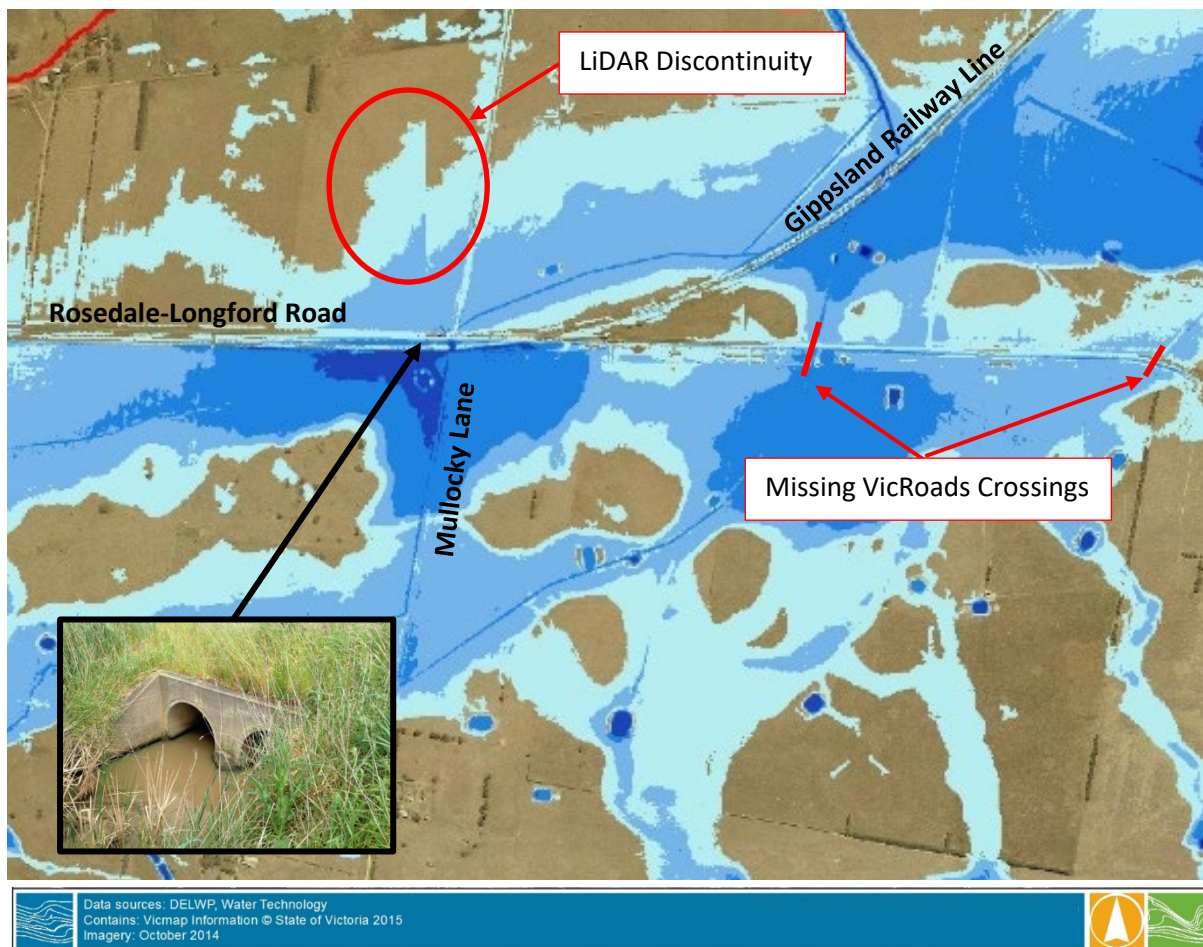


Figure 8-1 Minor problems identified with design mapping

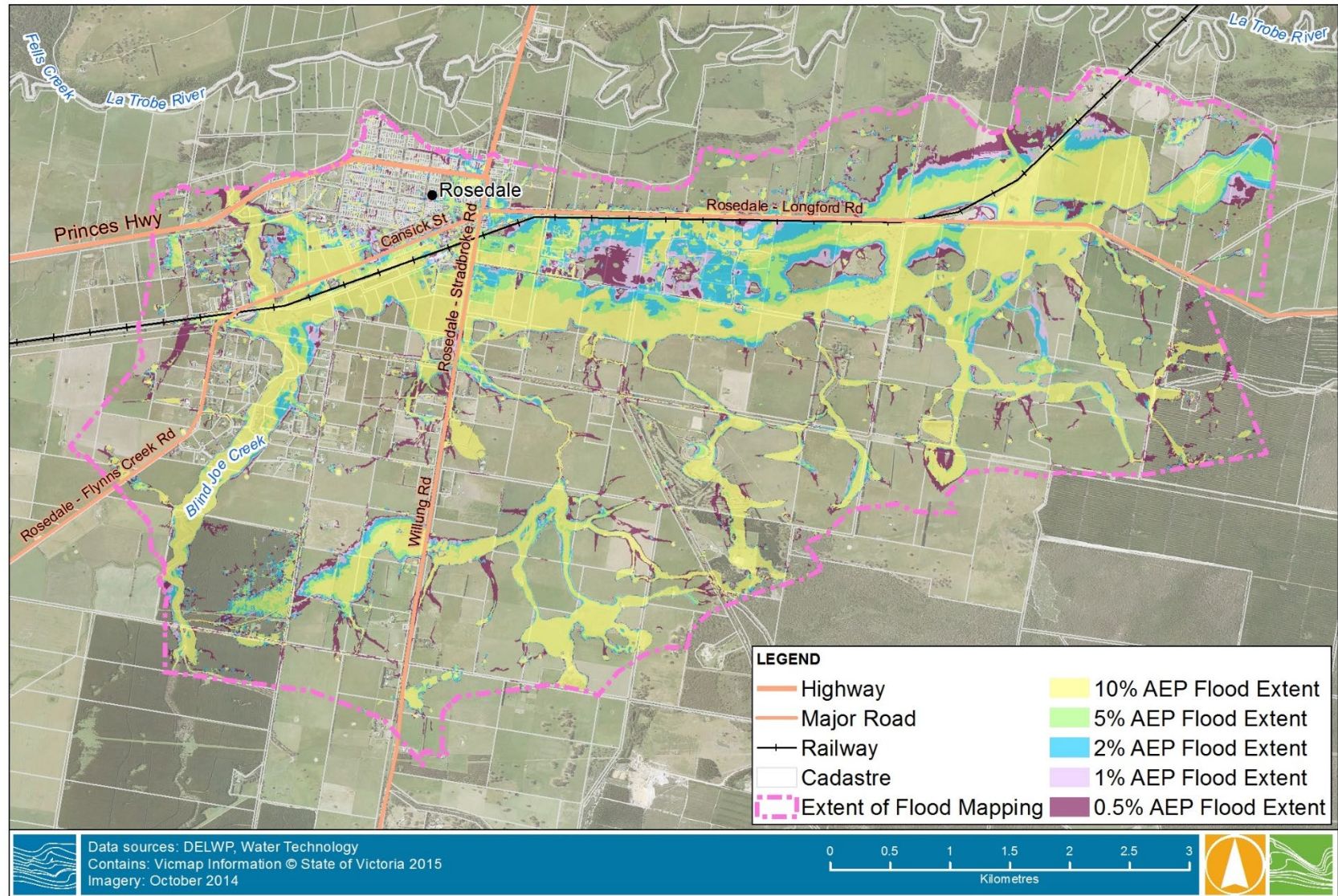


Figure 8-2 Design modelling results - 0.5%, 1%, 2%, 5% and 10% AEP flood extents

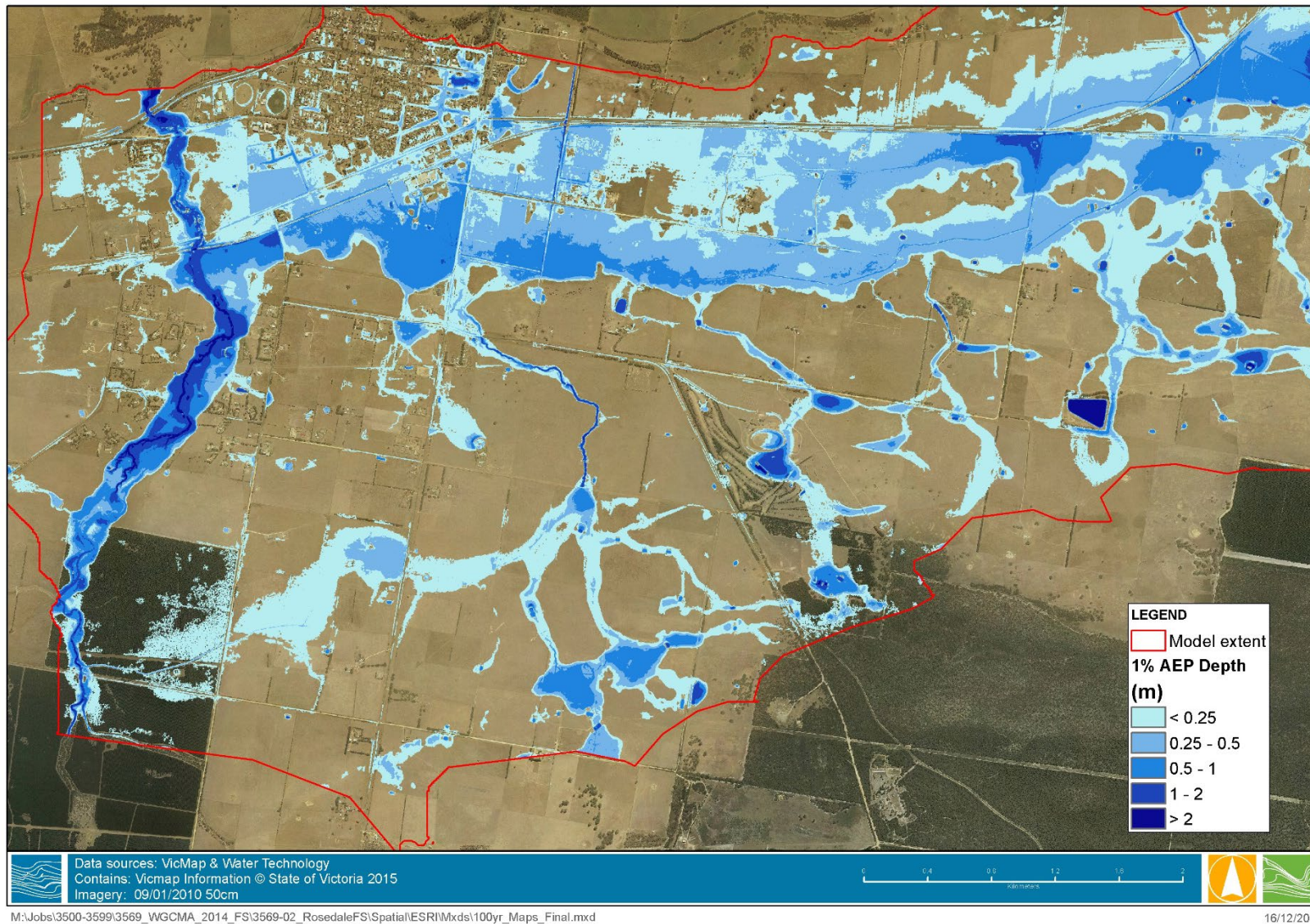


Figure 8-3 Design modelling results 1% AEP flood depth

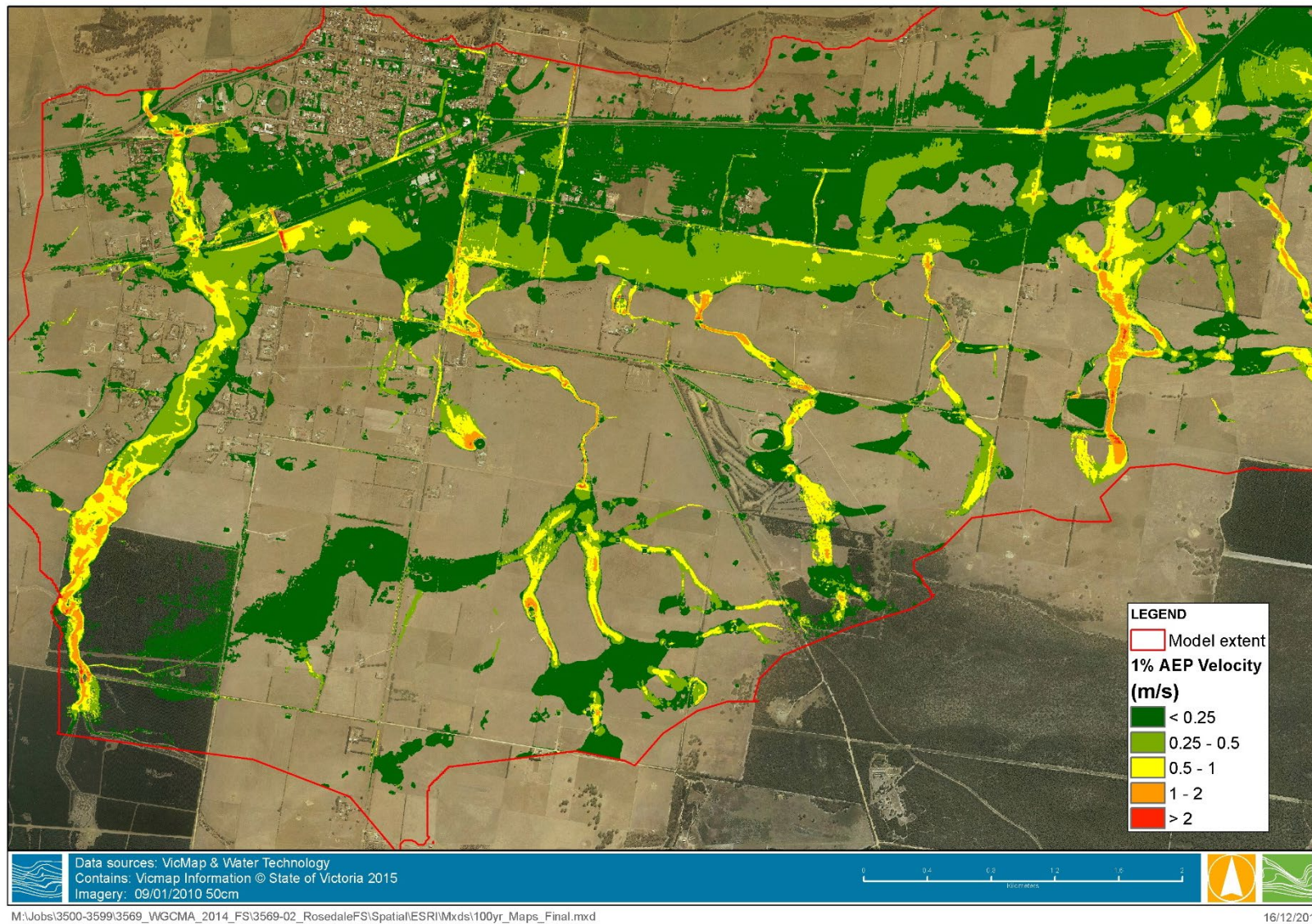


Figure 8-4 Design modelling results 1% AEP flood velocity

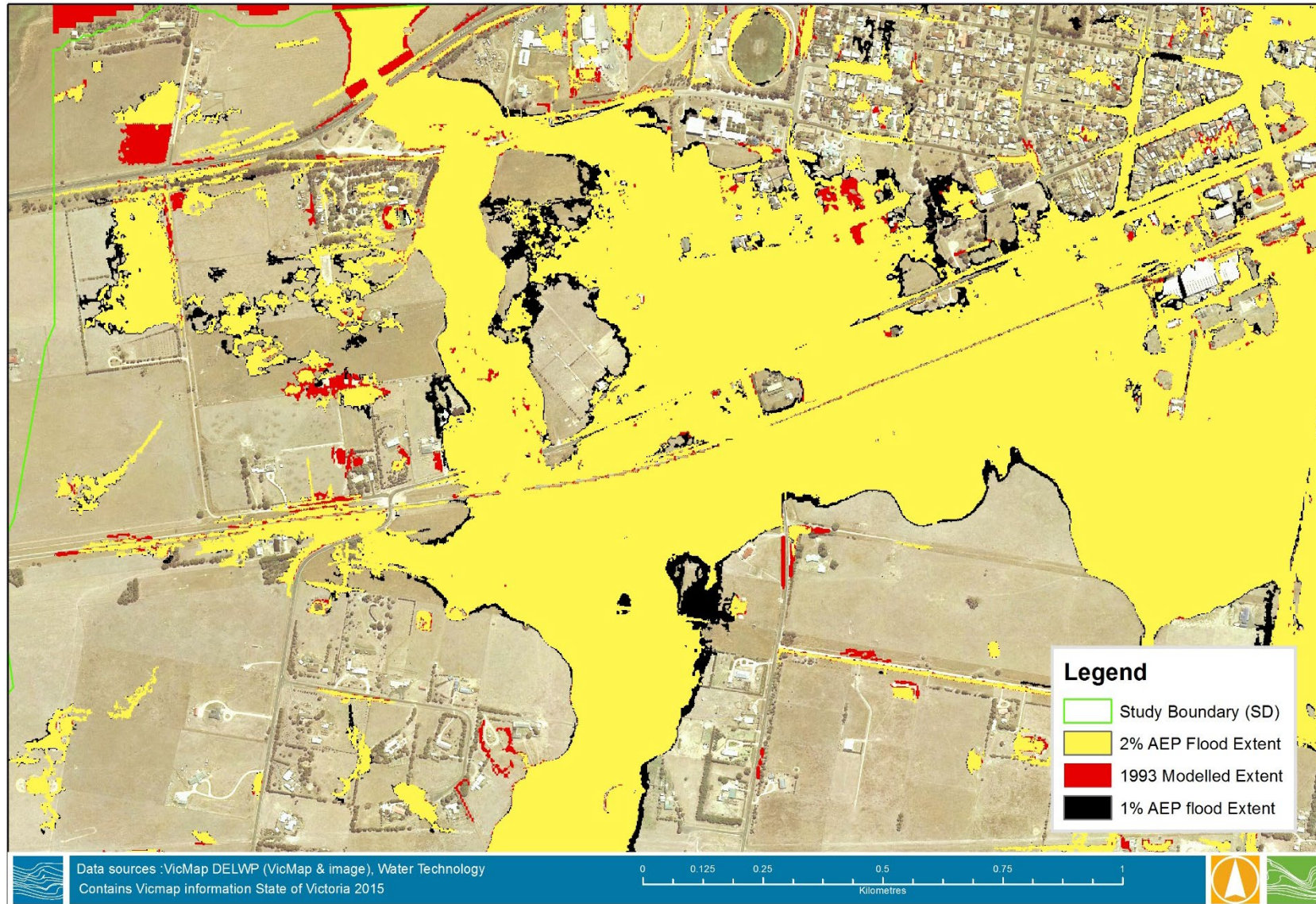


Figure 8-5 Design modelling results compared with 1993 flood

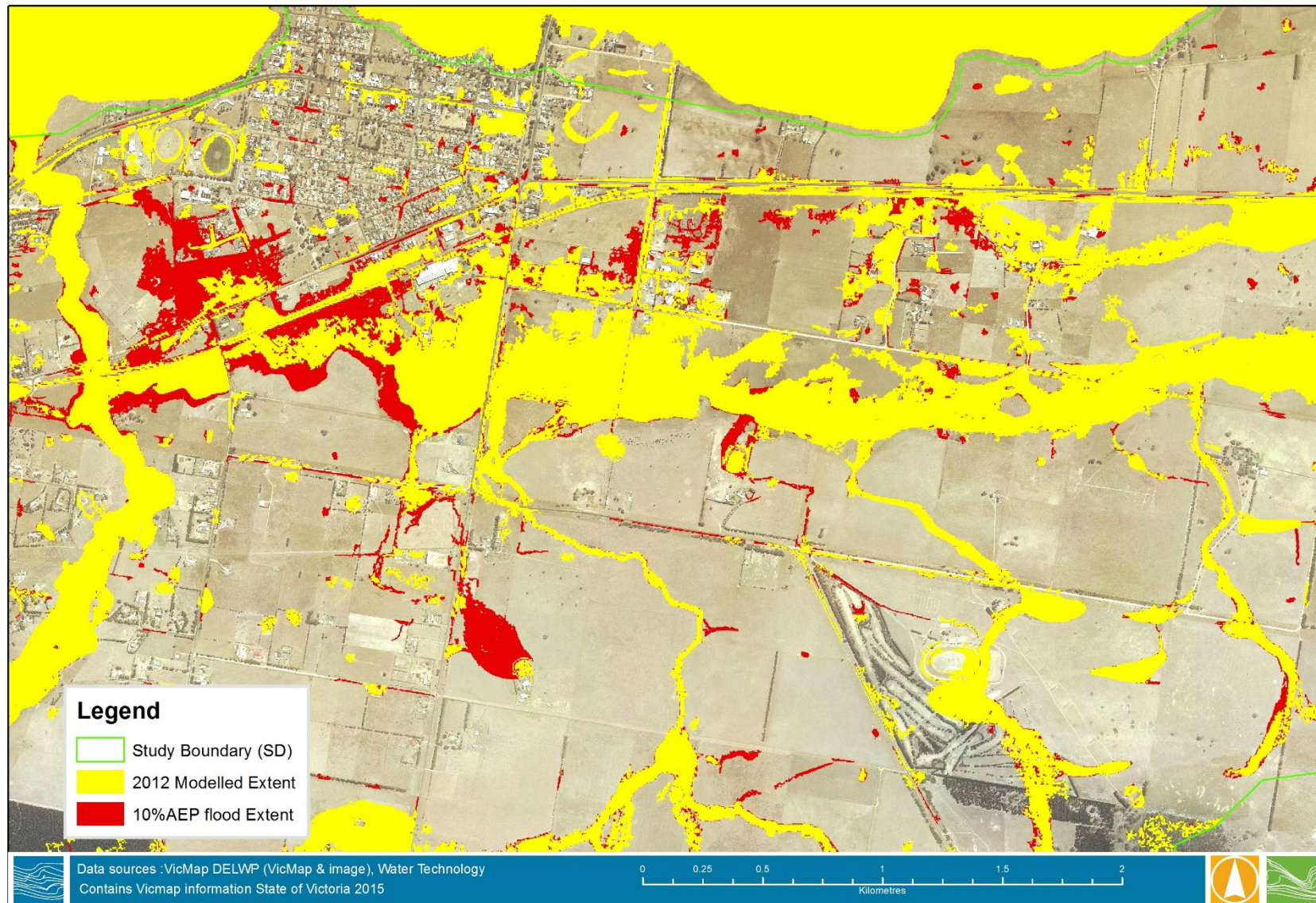


Figure 8-6 Design modelling results compared with 2012 flood

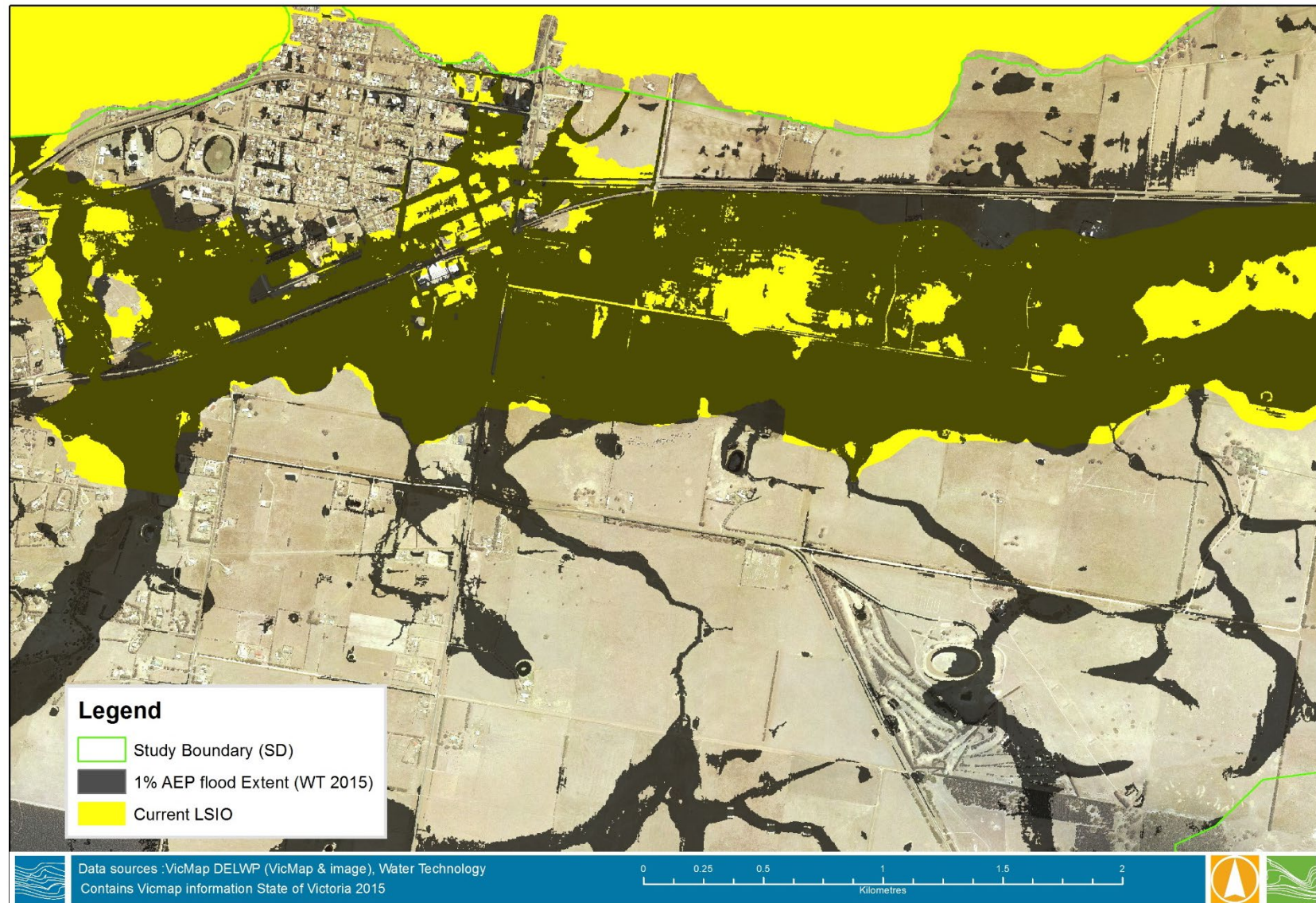


Figure 8-7 1% AEP Design modelling extent compared with the current LSIO

9. SENSITIVITY TESTING

9.1 Roughness Sensitivity – Total study area

Sensitivity analysis for the single domain model was undertaken to assess the impact of Manning's n roughness. To assess the sensitivity of roughness within the modelling, Manning's n values were increased by 20% as shown in Table 9-1.

In comparison to the existing roughness values used, there was a relatively small increase in water levels. As shown in Figure 9-1, increases were generally up to or less than 100 mm along Blind Joes Creek and the floodway. Within the defined floodway of Blind Joes Creek between Williams Road and the pine plantation south of the township, a larger 0.19m increase was observed. The result was likely attributable to the higher roughness applied on the flood fringes (low density residential vs farming zone modelled as open space) Throughout much of the township and behind some road embankments where the velocities are very low, the change in roughness has resulted in a very minor increase in water levels. This test gives confidence that the model is not overly sensitive to the chosen Manning's ' n ' values.

Table 9-1 Manning's n roughness values to assess roughness sensitivity

Material	Original Manning's n Roughness	Tested Manning's n Roughness
Residential - Urban (higher density) (lot modelled with one roughness value)	0.35	0.42
Commercial / industrial buildings	0.35	0.42
Residential - Rural (lot modelled with one roughness value)	0.15	0.18
Residential Building Footprint - Urban (higher density)	0.4	0.48
Residential - Rural (lower density) (building footprint modelled separately)	0.05	0.06
Open Space or Waterway - minimal vegetation	0.04	0.048
Open Space or Waterway - moderate vegetation	0.06	0.072
Open Space or Waterway - heavy vegetation	0.09	0.108
Open water (with submerged vegetation)	0.02	0.024
Car park/pavement/wide driveways/roads	0.02	0.024
Railway Line	0.2	0.24

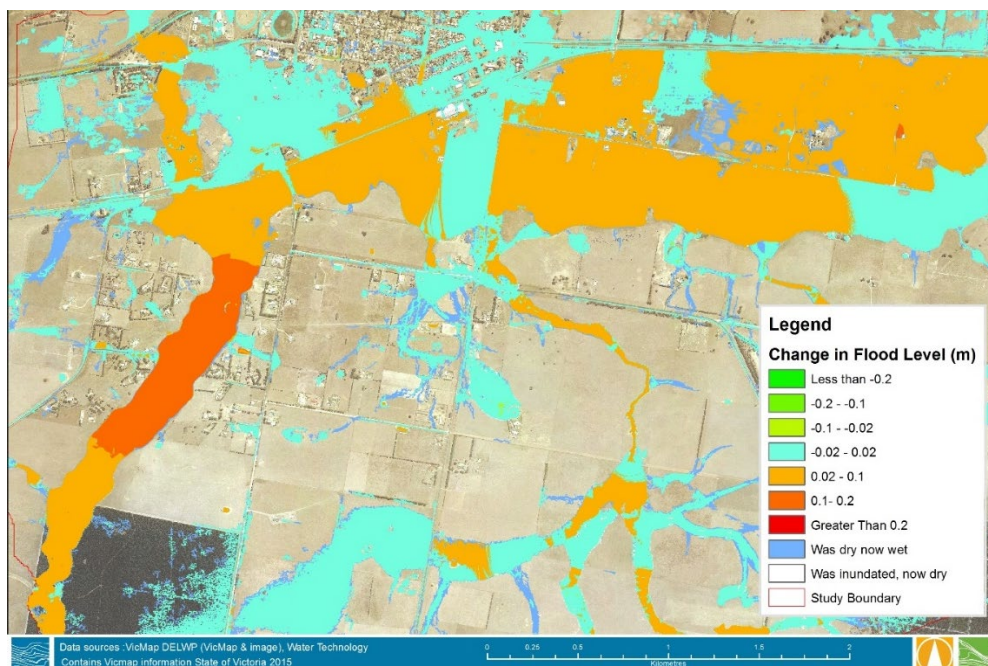


Figure 9-1 1% AEP Flood level difference plot with 20% increase in Manning's roughness

9.2 Roughness Sensitivity – Blind Joes Creek Waterway

Based on the observations from multiple site visits and community feedback, the section of Blind Joes Creek from the railway through to the Latrobe River was modelled using a reasonably high roughness values representing moderate, and in places, high density vegetation within the waterway.

Consistently in the community meetings throughout the project, the comment was raised that “if the waterways were better maintained (i.e. vegetation removed) flooding would be much less”. To test this theory, manning’s roughness values within the waterway were adjusted to represent Open Space or Waterway with minimal vegetation (manning’s n of 0.040). Figure 9-2 represents the roughness conditions applied in the design modelling (LHS) and the roughness sensitivity modelling (RHS).

Results of this analysis showed some changes in flood levels throughout the Blind Joes Creek waterway (see Figure 9-3), however not at a sufficient level to be considered as a potential mitigation solution.

Off stream changes in flood levels were also observed either side of Friends Road almost to the Tannery, this region showed reductions in flood levels less than or equal 100 mm. Changes in flood level inside the area of interest (the railway line to the confluence with the Latrobe River) were generally less than 100 mm, with a region of greater change observed immediately downstream of Cricket Street on the right bank. Flood extents east and north of the railway are largely unchanged under the reduced waterway roughness scenario suggesting the overall effect is generally localised.

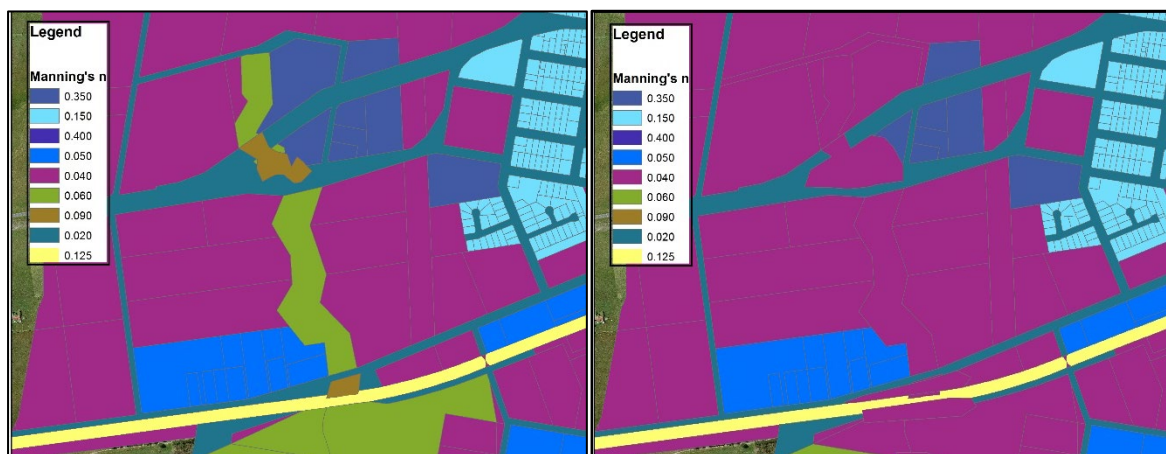


Figure 9-2 Manning’s roughness applied inside the Blind Joes Creek LHS design modelling RHS roughness tested.

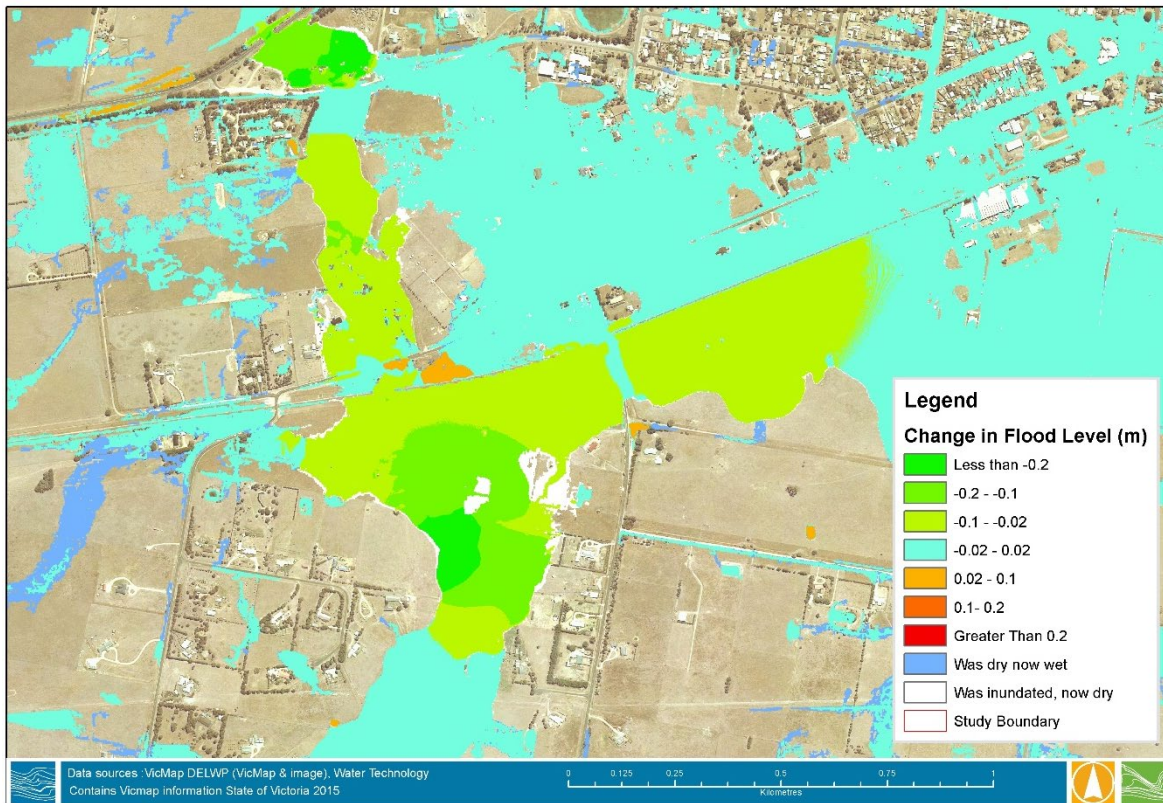


Figure 9-3 1% AEP Flood level difference plot with reduced Manning's roughness inside Blind Joes Creek waterway.

9.3 Climate Change

After completing the design hydraulic modelling, the sensitivity of the modelling to climate change (2°C of warming scenario), was reviewed. Applying a 5% increase in rainfall intensity per degree of warming results in much higher flows generated in all design events. Comparing the flows from existing conditions to that of the climate change conditions showed that under climate change conditions the magnitude of each AEP event generally could be moved up to the next standard design event. For instance, the existing 10% AEP event magnitude is increased to that of the 5% AEP event under the climate change scenario. Table 9-2 describes the relationship observed.

Table 9-2 Comparison of peak flows for increases in rainfall intensity due to climate change

Current Conditions	Scenario of 2°C of Warming Corresponding Reference Design Mapping Output
10% AEP	~5% AEP
5% AEP	In between 2% AEP and 5% AEP
2% AEP	~1% AEP
1% AEP	In between 1% AEP and 0.5% AEP
0.5% AEP	Greater than 0.5% AEP

9.4 Bush Fire

After completing the design hydraulic modelling, the hydrology sensitivity to bush fire (3 burn intensity scenarios) was investigated. The bush fire risk is strongest in the upper catchment forested areas, so the change in hydrology is skewed toward changes in the flows generated from the upper catchments. The sensitivity analysis showed:

- Under a low intensity burn, the same design AEP mapping is applicable;
- Moderate intensity burn, the flow magnitude tended to step up one standard event i.e. a 1% AEP became approximately equal to the current 0.5% AEP event; and
- High intensity burn caused the flows to increase by two standard events i.e. a 10% AEP event under intense burn conditions would produce flooding approximately equal to that seen in the 2% AEP mapping.

Further detail of this analysis is shown below in Table 9-3

Table 9-3 Comparison of peak flows for increases in rainfall intensity due to Bush Fire

Current Conditions	Corresponding Reference Design Mapping Output		
	Low Intensity Bushfire (m ³ /s)	Moderate Intensity Bushfire (m ³ /s)	High Intensity Bushfire (m ³ /s)
10% AEP	10% AEP	5% AEP	2% AEP
5% AEP	5% AEP	2% AEP	1% AEP
2% AEP	2% AEP	1% AEP	0.5% AEP
1% AEP	1% AEP	0.5% AEP	>0.5% AEP
0.5% AEP	0.5% AEP	> 0.5% AEP	>0.5% AEP

10. REFERENCES

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APPENDIX A – DESIGN FLOOD EVENT MAPS

Figure A - 1 Maximum Flood Depth 20% AEP Flood Depth

Figure A - 2 Maximum Flood Depth 10% AEP Flood Depth

Figure A - 3 Maximum Flood Depth 5% AEP Flood Depth

Figure A - 4 Maximum Flood Depth 2% AEP Flood Depth

Figure A - 5 Maximum Flood Depth 1% AEP Flood Depth

Figure A - 6 Maximum Flood Depth 0.5% AEP Flood Depth