

Rosedale Flood Study – Data Review (R01)



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Water Technology Project Manager	
Report Authors	Watech Modeller
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Cover Photo: Community supplied image from the 1934 Floods. – Main Street of Rosedale (Newsagent)

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15 Business Park Drive
Notting Hill VIC 3168

Telephone (03) 8526 0800

Fax (03) 9558 9365

ACN No. 093 377 283

ABN No. 60 093 377 283

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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 from 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 documents the information and data that were available for use in the Rosedale Flood Study. It also documents the major data gaps and how these gaps were overcome. This report is one of a series of reports documenting the outcomes of the Rosedale Flood Study.

- **R01 - Data Review Report (Water Technology 2016a) – this report**
- R02 - Hydrology and Hydraulics Report (Water Technology 2016b)
- 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 4,683 permanent residents (ABS, 2012). 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 in to 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.

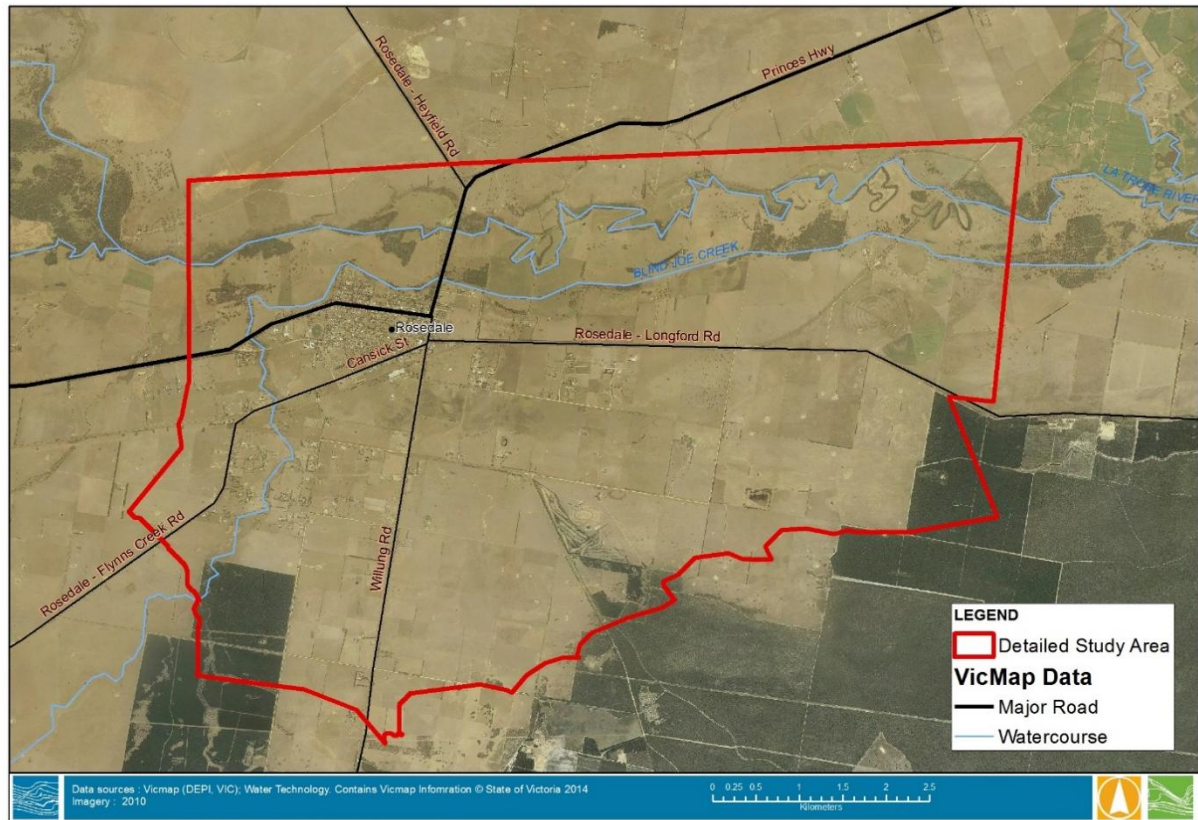


Figure 2-1 Rosedale Study Area

3. FLOOD RELATED STUDIES

Since 1934, several official flood investigations have been undertaken on the Rosedale Township. Several common threads are noted in each study, broadly they fit under the following themes:

- Is flooding in Rosedale driven by the Latrobe River or Blind Joes Creek or a combination of the two?;
- What was the magnitude of the 1934 event (biggest flood in living memory), is it equivalent to a 100 year ARI event?;
- Can the town have an effective flood warning system – what should it focus on?; and,
- Mitigation – can the town be protected with levees, where should they go?

The majority of the major flood studies have been completed by the Victorian Government (under various departmental names) and by [REDACTED]. A historic flood information timeline was compiled using available historical flood studies and associated information provided by stakeholders. Table 3-1 identifies significant events and associated changes in the floodplain and nominates when key studies were completed.

Table 3-1 Historic Flood information timeline

Event	Description	Relevant information
1863	First river levels (unofficial) collected (EJ Crooke)	Data printed in the Gippsland Times 1934 - confirmed 1934 as biggest flood in this period.
December 1934	Largest flood on record (Latrobe River). Anecdotal evidence suggests that the railway crossing (at Glengarry) failed causing backed up water to be released (like a dam break). Railway bridge/embankment failure downstream of Rosedale.	Peak flow estimate (RWC, 1989) 3,500 m ³ /s (150 – 200 year ARI Event) Anecdotal evidence suggests the Latrobe River “backed up” Blind Joes Creek. Flood Level at railway near Willung Road 17.45 m AHD (12 Inches above the railway line)
Post 1934 Floods	Cansick Street Bridge moved Cricket Street Bridge replaced with 5 box culverts (900 x 1,200 mm) Friends & Willung Roads raised by ~300 mm.	
June 1935	Dare report written discussing railway bridge failures in 1934.	Description of bridge failure mechanism and hydrologic implications (flood travel times etc).
1938	New Highway bridge complete	
June 1952	Large flow in Latrobe River (1,874 m ³ /s - ~40 year ARI)	
1952 (date unknown)	Large flow in Blind Joes Creek, limited flooding in Latrobe River. Floodway south of town engaged. Little impact on township.	
October 1953	Large flow in the Latrobe River (1,701 m ³ /s – ~40 year ARI).	

Event	Description	Relevant information
1961	Lake Narracan (Latrobe River – 2,730 ML) & Moondarra Reservoir (Tyers River – 29,700 ML) constructed	
1966-68	Holy Plains drainage scheme constructed. System designed to drain land south and east of the town.	
June 1978	Significant flooding throughout Gippsland. Large flow in the Latrobe River (1,500 m ³ /s - ~ 30 year ARI). Anecdotal evidence suggests the Cansick Street bridge was blocked by debris and the floodway south of town became engaged.	
1983	Residents request a significant maintenance program be undertaken on the Holy Plain drainage system. Council holds community meetings to discuss solutions.	
1984	Blue Rock Dam constructed (Tanjil River - 208,000 ML)	
October 1987	RWC wrote to council nominating the 1934 flood as equivalent to 100 year ARI event (3,500 m ³ /s peak flow in the Latrobe River).	
1989	RWC complete the “Rosedale Flood Study Frequency Analysis” 100 year ARI flow in the Latrobe River is revised down to 3,010 m ³ /s. Flood levels are dropped by ~200 mm.	90 m ³ /s adopted as the 100 year ARI flow in Blind Joes Creek (catchment comparison method with Traralgon Creek).
1992	RWC revise the 100 year ARI flows back to the 1934 flood estimate (3,500 m ³ /s).	
September 1993	Significant rain in the Strzelecki Ranges (up to 300 mm in 24 hours) resulted in major flooding in Blind Joes Creek. Flooding not as significant in the Latrobe River (980 m ³ /s – 20 year ARI).	Shire of Wellington collect flooding images and flood levels (level data possibly not peak heights).
November 1993	 “Rosedale Flood Management Plan (Stage 1)” released to the Shire of Wellington.	1934 Flood > 100 year ARI (150 year ARI); 100 year ARI flow in the Latrobe 2,730 m ³ /s & 90 – 100 m ³ /s in Blind Joes Creek; Flood levels at Rosedale in 1934 were not significantly impacted by the railway embankment failure at Glengarry.
April 1995	Dept. of Conservation & Natural Resources “Rosedale Flood Investigation	1934 Flood represented the 100 year ARI;

Event	Description	Relevant information
	(Stage 1)" released to the Shire of Wellington.	100 year ARI flow in the Latrobe 3,500 m³/s and 100 m³/s in Blind Joes Creek; Blind Joes Creek flows Split at the railway bridge with 40% flowing north and the balance flowing east. HEC2 hydraulic modelling defined a 100 year ARI flood extent, the hydraulic model was calibrated to the 1993 event flood levels, Latrobe TWL sensitivity applied. Mitigation options presented including levees.
June 1995	██████████ "Rosedale Flood Management Plan (Stage 2)" released to the Shire of Wellington.	Dept. of Conservation & Natural Resources 1993 hydrology and Blind Joes Creek flow split adopted. HEC2 model revisited and updated including additional mitigation analysis. Flood level from the Latrobe of 17.6 m AHD (33 year ARI) was determined to be the threshold level at which breakout north of the railway could occur. This happened in 1934. Community consultation undertaken. Community were pro levees.
February 2000	██████████ Report released "Rosedale Flood Management Plan"	The report noted: "Primary mechanism of flooding within in Rosedale township is produced by flood levels in the Latrobe River". Flood Warning system for Blind Joes Creek not justifiable. New alignment of the GHD levee proposed, geotech investigation completed and mitigation costings revisited. Further investigations recommended. Funding application completed on behalf of the Shire of Wellington.
September 2001	██████ report "Rosedale Flood Warning System – Hydrology Report" released to the Shire of Wellington.	Flood frequency revisited, 100 year ARI flow revised down to 2,610 m³/s. New hydrology – URBS model New photogrammetry New hydraulic model (DELFT) Model calibrated to the 1934 and 1993 events

Event	Description	Relevant information
2013	Latrobe Flood Study completed by Cardno. Larger flood study covering Yarragon to Sale. Flooding of the Latrobe and all major tributaries considered (inc. Blind Joes Creek).	New Flood Frequency Analysis, new/revised hydrology (BoM URBS model), new hydraulic model (SOBEK). Latrobe 100 year ARI flow very different to all other historic studies (1,875 m ³ /s), Blind Joes Creek inflows not reported. The coarse grid (40x40m) in the hydraulic modelling resulted in much of the Rosedale Township being shown as flooded in a 100 year ARI event.
2014	New Princes Highway bridge over Blind Joes Creek (highway duplication works).	Water Technology complete waterway investigations for VicRoads. Study includes new hydrology for Blind Joes Creek (RORB Model), limited hydraulic analysis (MIKE FLOOD) focused on Princes Highway bridge.

3.1 The Latrobe Flood Study 2013

WGCMA recently completed the Latrobe River flood study which included updated hydrology and hydraulics. The study generated detailed results throughout the Latrobe River Floodplain including north of Rosedale. This study included inflows from Flynn's, Middle and Blind Joes Creeks but didn't consider the other smaller catchments south of the township.

Due to the grid size applied (40x40m) in the hydraulic modelling of Blind Joes Creek, it is not considered an accurate representation of current flood behaviour. The study did provide a significant amount of information on flood levels on the Latrobe River Floodplain.

This study initially separated the influence of both the Latrobe River and Blind Joes Creek and then later considered the impact of concurrent flooding. Consequently the Water Surface Elevation (WSE) results from the Latrobe Flood Study were reviewed to assess the impact flooding from the Latrobe River in isolation to Blind Joes Creek would have on Rosedale.

This was achieved by determining the WSE data at locations where designated waterways flow into the Latrobe River floodplain. The LiDAR topography was then highlighted at levels equal to or less than that WSE, effectively showing how far the Latrobe River would "backup" into fringing waterways in large flood events. This information was useful in two ways, it helped understand what a flood only from the Latrobe River might look like, and helped drive tailwater estimates and sensitivity ranges for the hydraulic modelling. The results of this analysis are shown in Figure 3-1.

While this analysis was simplistic in nature (often referred to as a "bath tub" analysis), it does provide some interesting information. It suggests that very few homes would be inundated if a large flood occurred only in the Latrobe River, with the worst flood prone areas being Allen Court, Mackay Street (northern end), Queen Street and Mill Lane. At the western edge of the township it suggested that both Blind Joes Creek and the Latrobe River must interact to cause flooding on the land between Cansick Street and the Princes Highway.

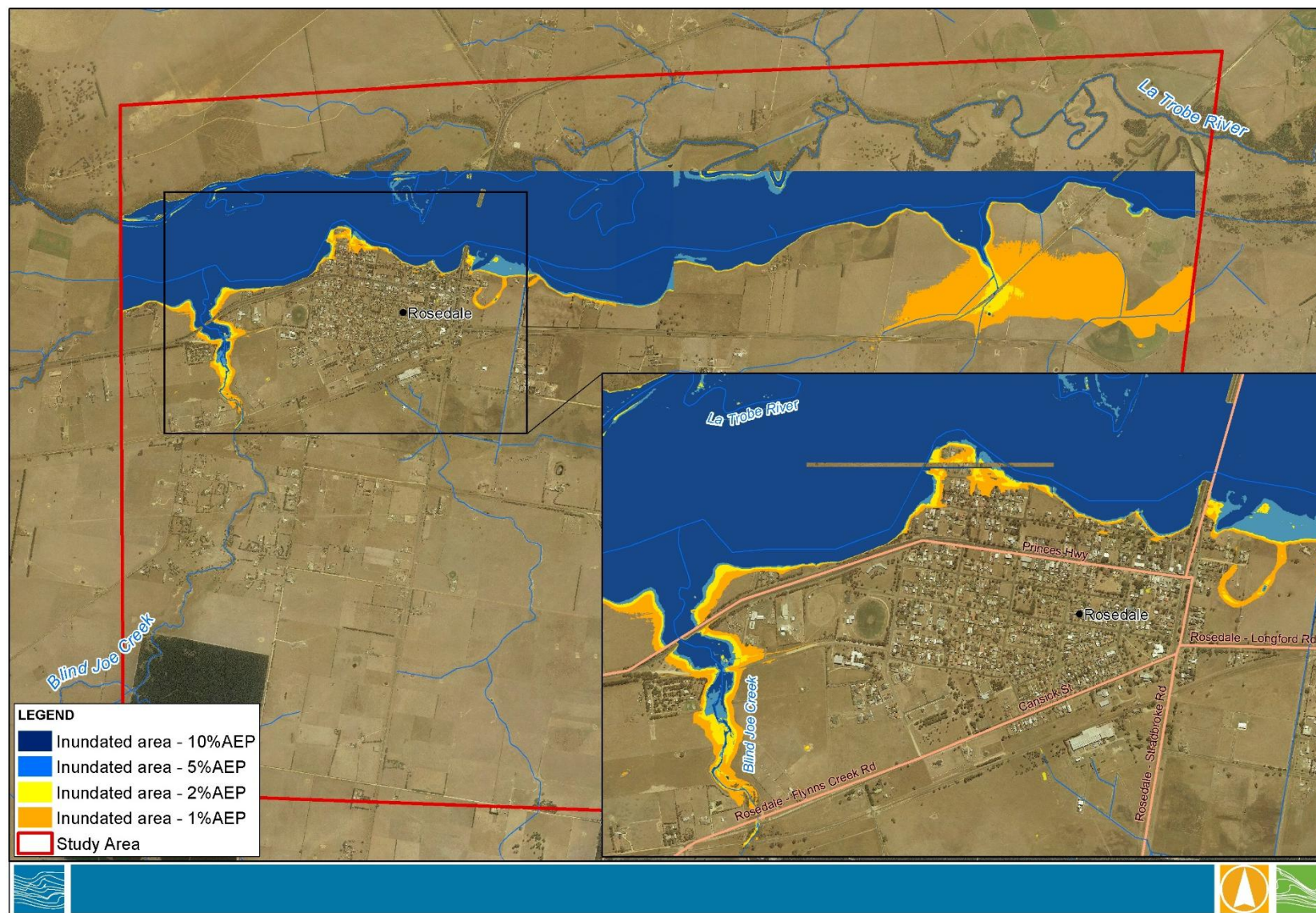


Figure 3-1 Latrobe Flood Study Results – Estimated area inundated by the Latrobe River (excludes Blind Joes Creek flooding)

4. HYDROLOGICAL DATA

4.1 Rainfall Data

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 in and around the catchment. Key stations, including current stations and stations operating over the 1934, 1978 and 1993 floods, are listed in Table 4-1.

Table 4-1 Daily rainfall stations around Blind Joes Creek catchment

Gauge No.	Location	Distance from township	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	Calignee 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	Calignee South	30.2	1932 Mar	1985 Nov	53.8

Pluviograph (sub-daily rainfall) stations in and around the Blind Joes Creek catchment are listed in Table 4-2. The 1993 event was captured at East Sale Airport, Morwell and Calignee North pluviographs. The 1978 events were captured at all listed stations. Key event totals from major flood events are shown in Table 4-3.

Table 4-2 Pluviograph stations around Blind Joes Creek catchment

Gauge No.	Location	Distance from township	Year Opened	End of Record	Years of Data
85236	Calignee North	26.38	1956 Jan	2014 Aug	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	2014 Nov	71

Key event totals from both daily and instantaneous rainfall stations are shown in Table 4-3.

Table 4-3 Rainfall totals for major flood events in Rosedale area

Gauge No.	Location	Event Depth (mm)				
		December 1934	June 1952	October 1953	June 1978	September 1993
85071	Rosedale	131 (3 days)	164 (8 days)	97.5 (2 days)	109 (9 days)	No data
85236	Callignee North		-	-	140 (8 days)	190 (15 days)
85076	Stradbroke West (Inglenook)	119.2 (6 days)-	192 (11 days)	90 (2 days)	178 (10 days)	-
85017	Callignee South	193.3 (3 days)	513 (18 days)^	104.4 (2 days)	324.5 (13 days)*	-
85072	East Sale Airport	-	118.5 (11 days)	82 (2 days)	105.6 (6 days)	174.2 (14 days)

* Including 277mm in two days

^ Including 246.6mm in two days

4.2 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 4-4). While both sites are identified as representing Latrobe River flows, this is only true in times of significant flow in the catchment. Under typical conditions the Latrobe River Anabranche 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 ≥ 10 year ARI suggesting that using the Latrobe River Anabranche 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 Anabranche 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 4-5.

Table 4-4 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 4-2) and the anabranche (Figure 4-1) 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 Anabranche 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.

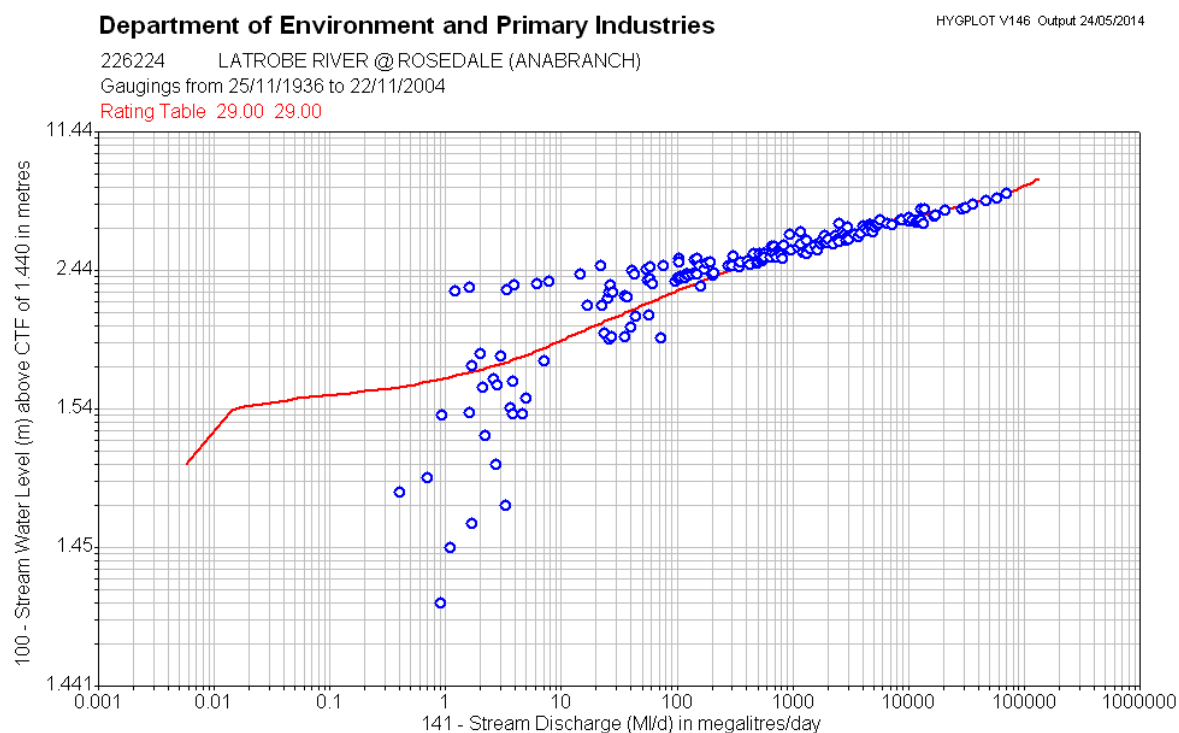


Figure 4-1 Rating Curve for 226224 LATROBE RIVER (Blind Joes Creek) @ ROSEDALE (ANABRANCH)

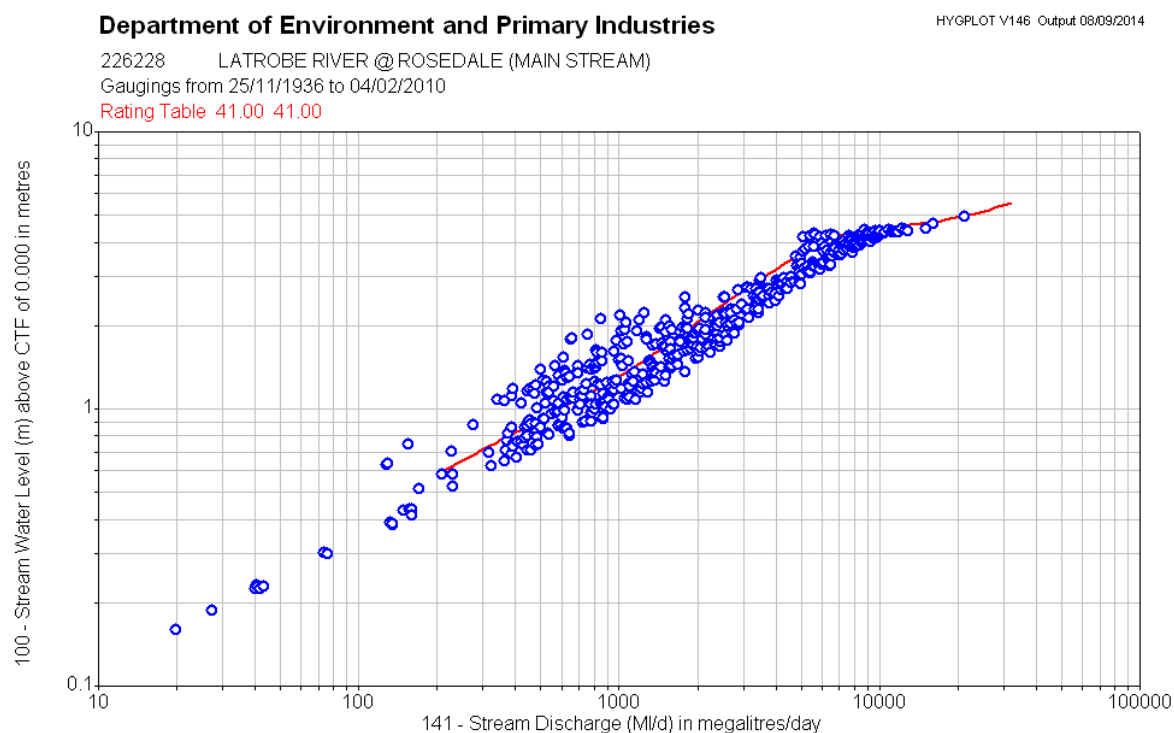


Figure 4-2 Rating Curve for 226228 LATROBE RIVER @ ROSEDALE (MAIN STREAM)

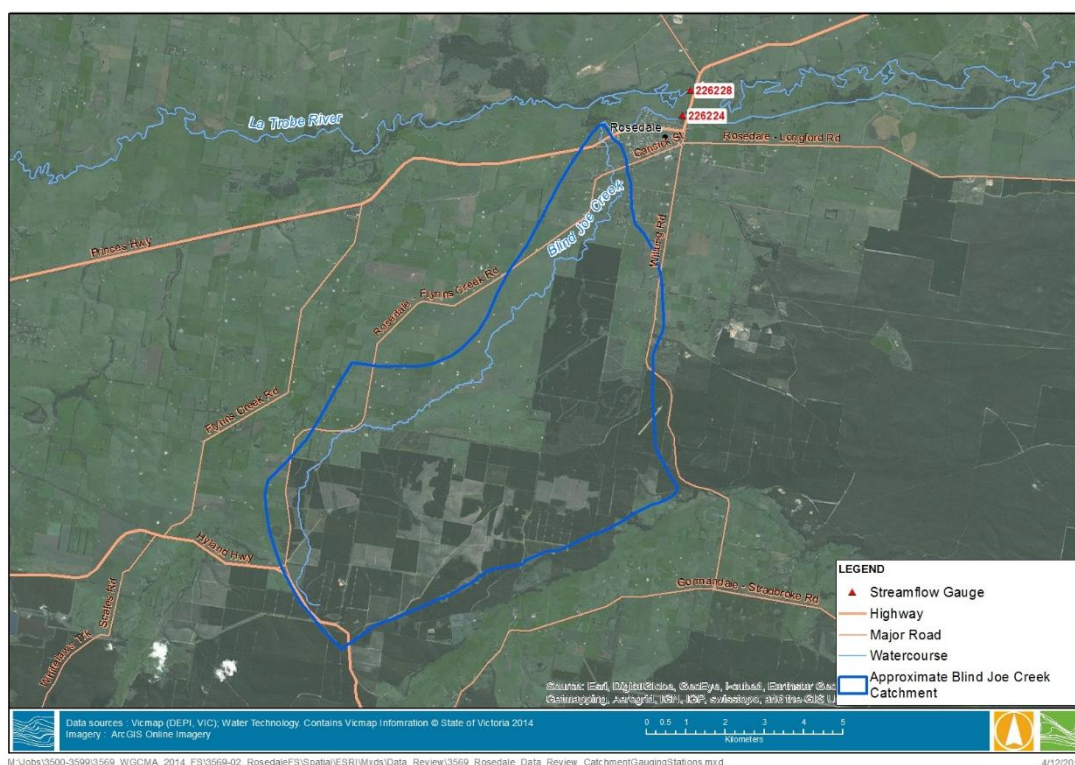


Figure 4-3 Blind Joes Creek Catchment and significant Gauging Stations

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, it was not proposed that gauging station data would be intensively reviewed in this study. Instead assumptions and key findings from the Latrobe Flood Study were reviewed and adopted as boundary conditions.

Table 4-5 Key event peak flows

Station ID	Station Name	Peak Flow (ML/d)			
		June 1952	October 1953	June 1978	September 1993
226228	<i>Latrobe River @ Rosedale (Main Stream)</i>	27,578	30,527	21,787	16,051
226228	<i>Latrobe River @ Rosedale (Anabranh)</i>	104,969	86,985	87,460	71,610

5. FLOOD RECORDS

5.1 Historic Flood Information

Significant historic flood events have been compiled from available sources and are listed in Table 3-1. The largest flood on record (since 1863) was in December 1934, with flows in the Latrobe River estimated to be between a 150 and 200 year ARI event. After this event, two gauging stations were established at Rosedale, with one on the Latrobe River and the other on the Latrobe Anabranch. Review of both rainfall and gauging data have suggested that the next biggest floods on record occurred in the 50's (1952 and 1953), followed by 1978 and 1993.

The most comprehensive historic flood information is available for the 1993 event, including digitised flood extent, surveyed flood levels and numerous flood photographs, collated for Hydrotechnology's report on the 1993 Gippsland floods. Some data is also available for the 1934 and 1978 events.

Historic flood data recorded in the Victorian Flood Database (VFD) is summarised in Figure 5-1, Figure 5-2 and Figure 5-3 below.

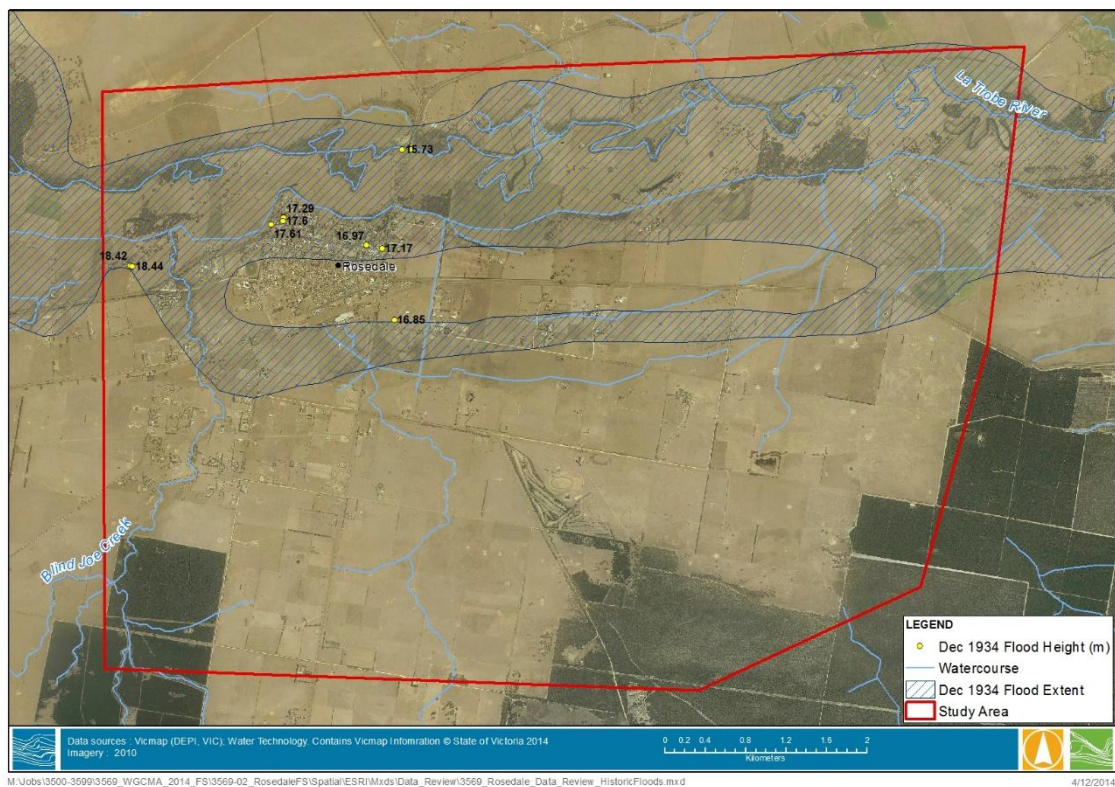


Figure 5-1 December 1934 flood information in VFD

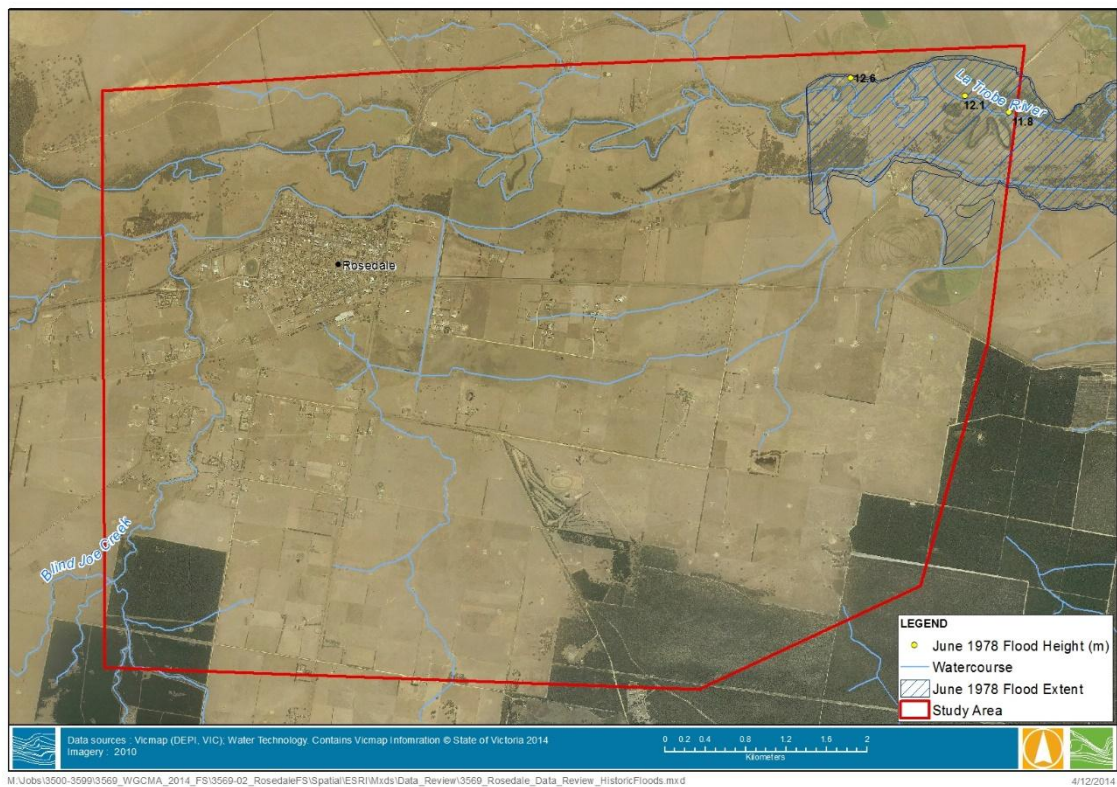


Figure 5-2 June 1978 flood information in VFD

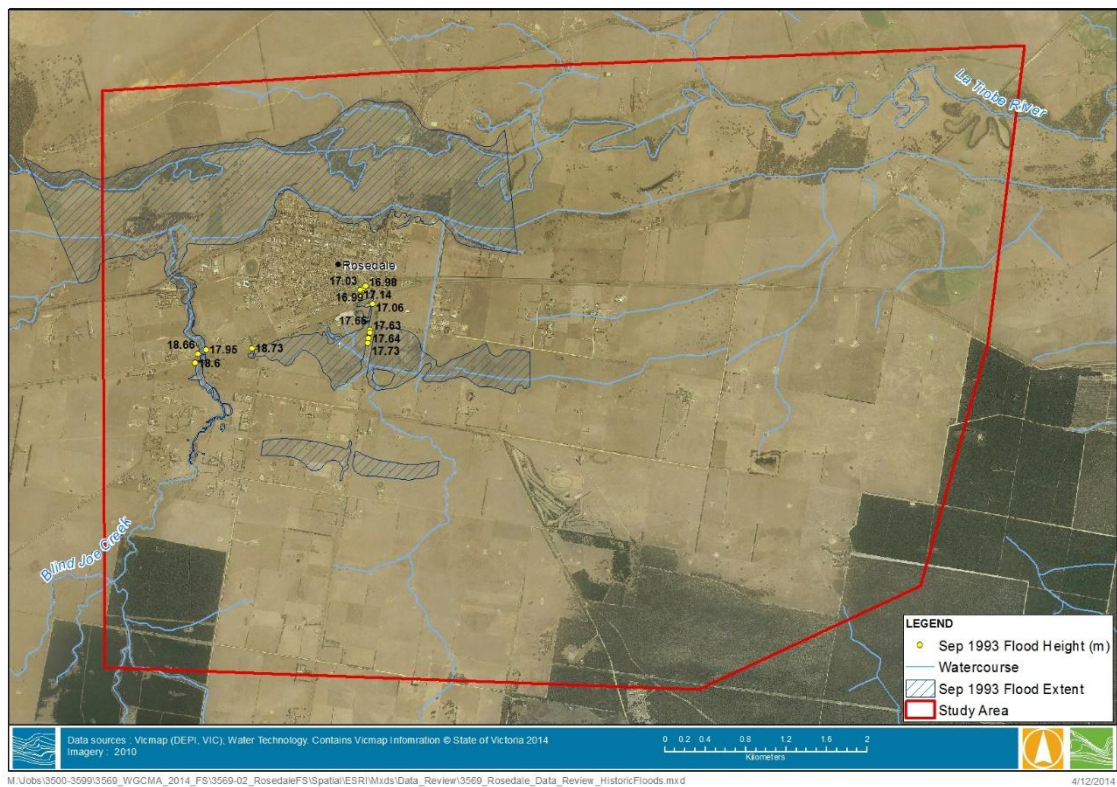


Figure 5-3 September 1993 flood information in VFD

5.2 Imagery

Oblique flood aerial photography was available for the June 1978 event in black and white and colour for 1993, 2011 and 2012. An example is shown in Figure 5-4 below. Aerial photography was also available for the aftermath of the 1993 event (28 September 1993) in the Hydrotechnology (1995) flood review. Table 5-1 gives a summary of flood imagery available by event.

Table 5-1 Historic Flood imagery available

Year	Type of Image			
	Ground based images	Aerial Image (oblique)	Aerial Image (ortho-rectified)	Video footage
December 1934	√ (limited)			
June 1952	√ (limited)			
October 1953	√ (limited)	√		
September 1993	√	√		
July 2011	√	√		√
June 2012	√	√		√



Figure 5-4 September 1993 oblique flood image

6. PHYSICAL FEATURES

6.1 Topographic and Physical Survey

6.1.1 Existing LiDAR Datasets

Initially aerial LiDAR (Light Detection and Ranging) survey was available for the Rosedale area from two difference sources:

- Index of Stream Condition (ISC) Rivers LiDAR
- SRW-90MB LiDAR

Extents of the two datasets are shown in Figure 6-1. A comparison of the two datasets where they overlap (Rivers ISC minus SRW DEM) is shown in Figure 6-2. A slight vertical offset was discernible between the two datasets in flat floodplain areas. In these areas, the River's DEM is around 0.1 m lower than the SRW DEM. Site survey was undertaken to verify the LiDAR datasets and assist in the selection of datasets for modelling. Key metadata for the two datasets is given in Table 6-1.

A coarse (10 x 10 meter resolution) DEM is available from VicMap for the whole Blind Joes Creek catchment for catchment delineation purposes.

Table 6-1 Key metadata for LiDAR datasets

Dataset	Source	Date of Capture	Vertical accuracy (1 sigma)	Resolution
Index of Stream Condition (ISC) Rivers LiDAR	LiDAR	Sep 2007-Sep 2009	0.10 m	1 m
SRW-90MB LiDAR	LiDAR	Feb-Nov 2010	0.20 m	1 m

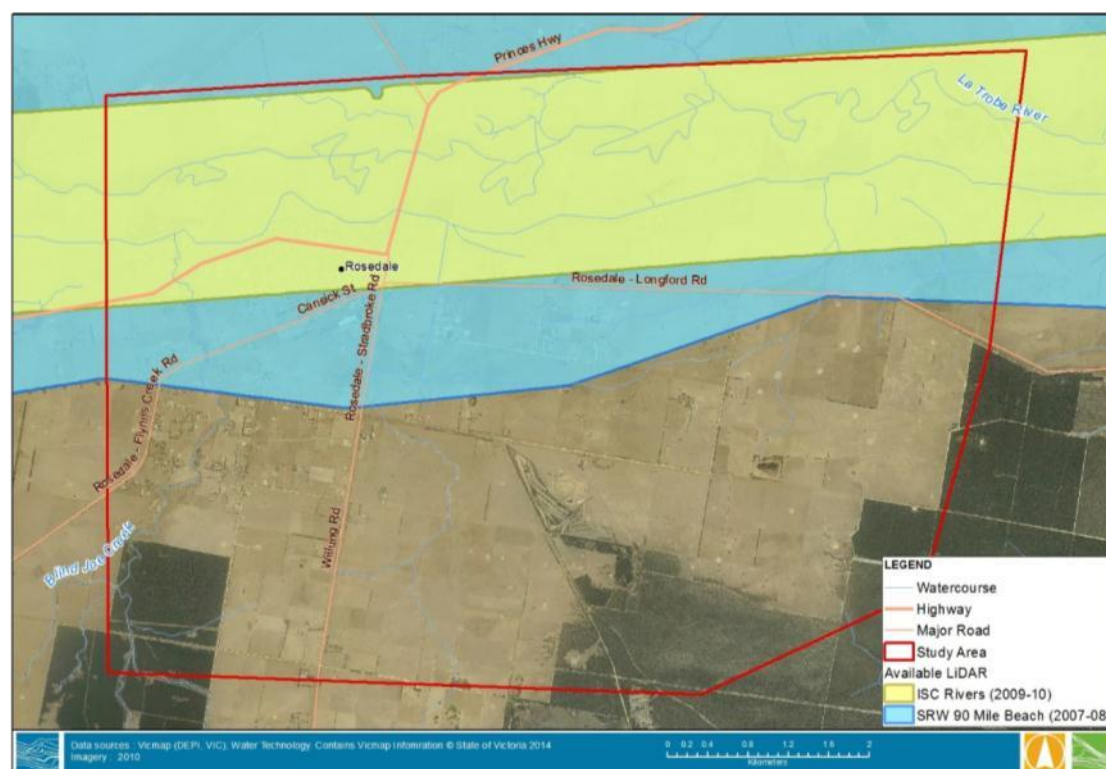


Figure 6-1 Vicmap LiDAR data extents

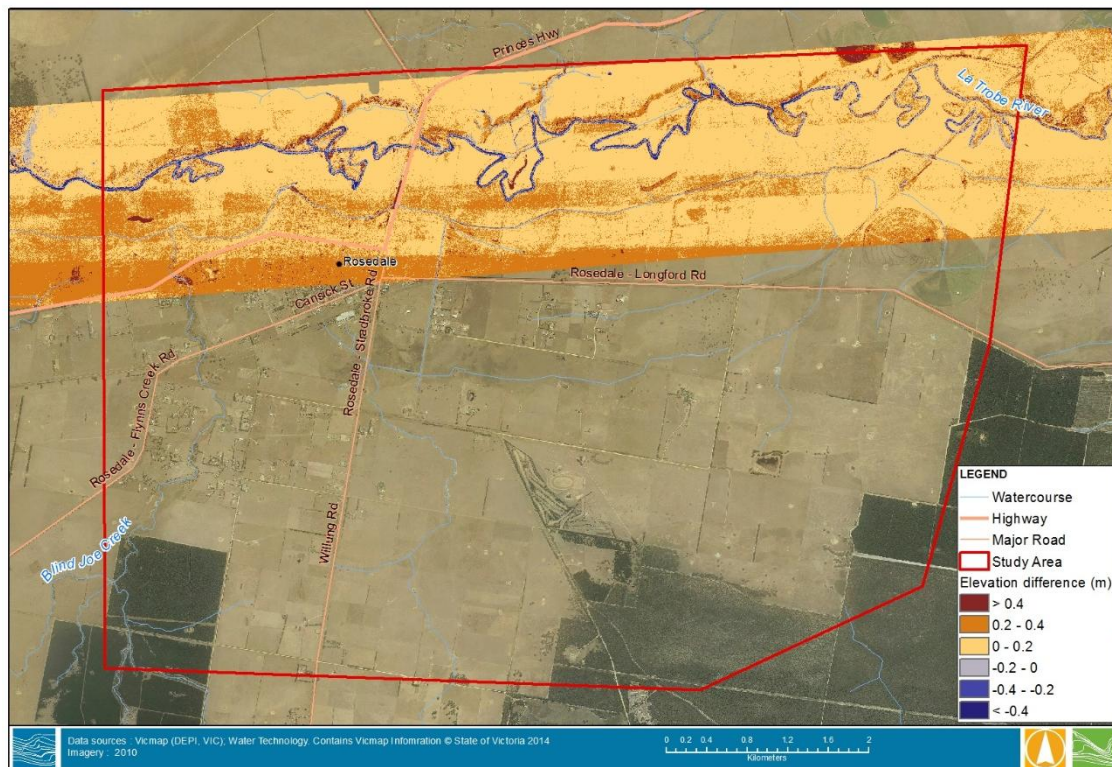


Figure 6-2 LiDAR comparison - Rivers LiDAR DEM minus SRW DEM

LiDAR Validation

The two LiDAR data sets were validated against survey collected by VicRoads as part of the Princes Highway Extension project (PHE). This survey was collected in November 2012 and is assumed to be vertically accurate to 10-20 mm.

The location of the validation survey is shown in Figure 6-3 with the statistical results presented in Table 6-1. The LiDAR validation process showed the data was accurate to its reported tolerance, giving sufficient confidence to use the data in this study.

It is proposed to use the SRW 90MB data as the primary data set in this study. This data was complimented by the new LiDAR captured by the WGCMA for this project (discussed in section 0). Additional validation of the SRW 90MB LiDAR was completed with the new LiDAR captured for this project.

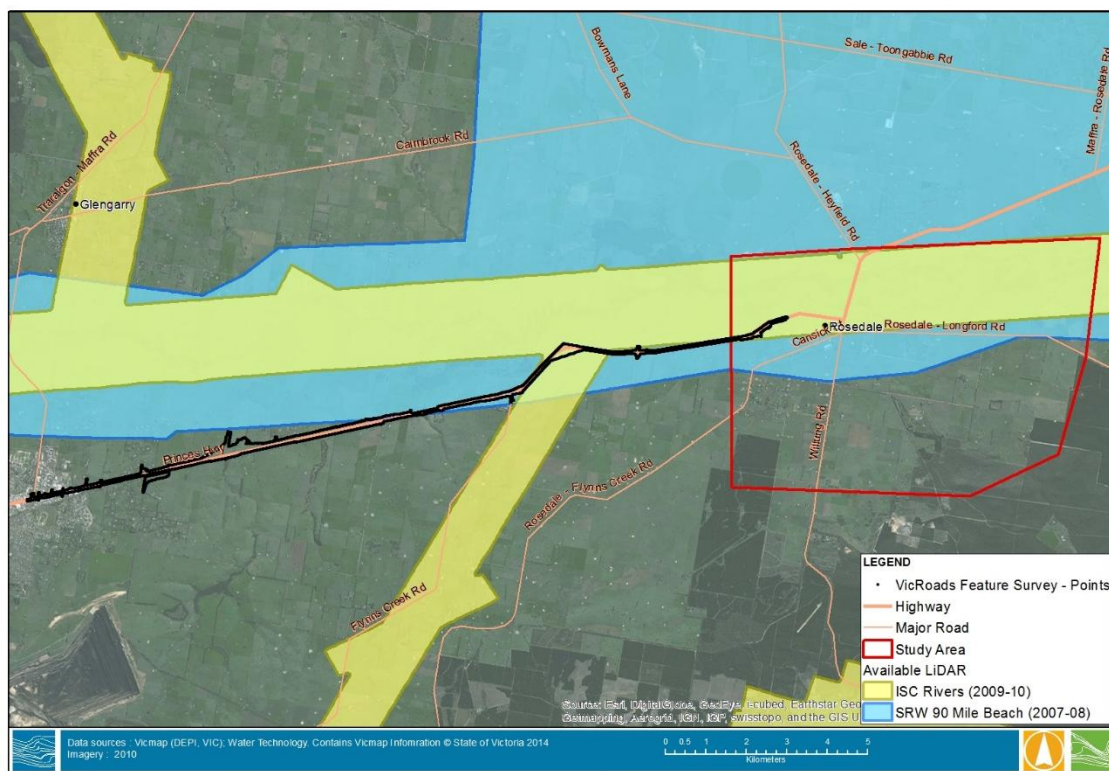


Figure 6-3 LiDAR comparison – VicRoads Survey & LiDAR

Table 6-2 LiDAR Validation results

	Feature survey – Rivers LiDAR (m)	Feature survey – SRW-90MB LiDAR (m)
Minimum	-1.550947	-0.763256
Maximum	0.252527	0.717713
Mean	-0.080881	0.114129
Std. Dev.	0.117919	0.098181

LiDAR Data Request

It was identified in the WGCMA project brief that there was insufficient LiDAR to flood map the southern portion of the study area. To inform what infill LiDAR was required, Water Technology created a preliminary rain-on-grid hydraulic model of the Blind Joes Creek and its adjacent catchments to the east. This modelling was undertaken using the VicMap 10 x 10 m DEM which is only vertically accurate to 5 m. The purpose of this modelling was to identify key inflow points and help understand where flow paths are. Using this information, Water Technology provided a recommended survey area to WGCMA, this area was then further refined by WGCMA. The area adopted for infill survey is shown in Figure 6-4.

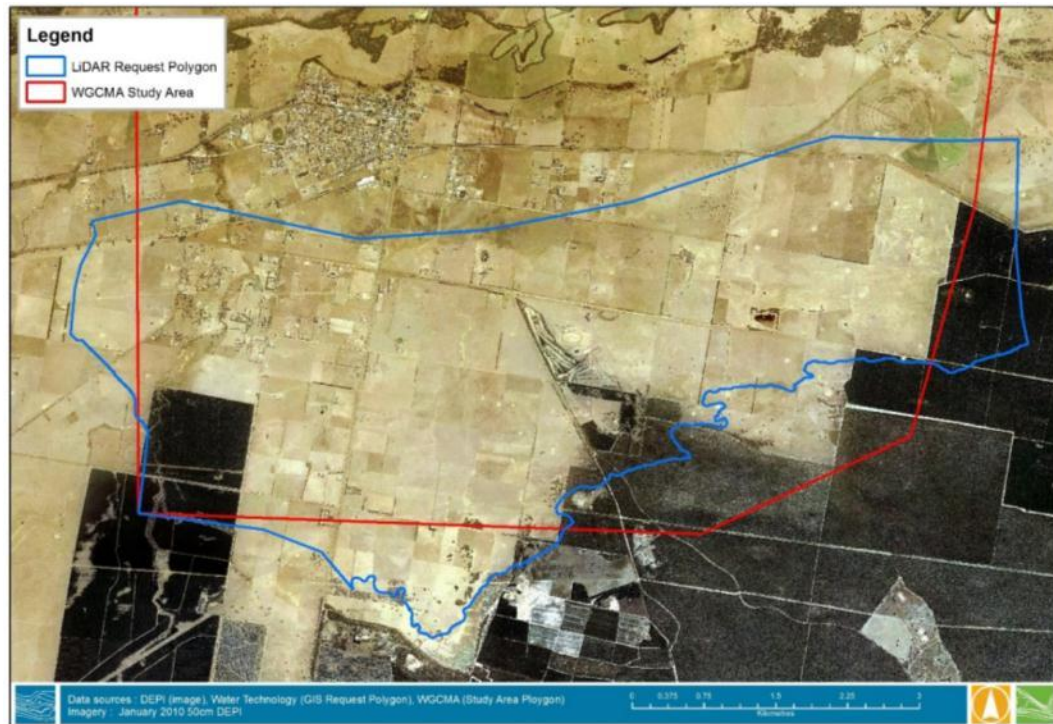


Figure 6-4 LiDAR survey request area

6.1.2 New LiDAR Capture

The new LiDAR was flown in January 2015. The LiDAR was purposely overlapped with the existing SRW 90MB data so comparisons could be made between the two datasets. Compared to each other the two LiDAR data sets showed an acceptable mean error (Table 6-3). Suggesting the new LiDAR data could be used with the old without any modification.

Table 6-3 New LiDAR Validation results

Rosedale LiDAR – SRW-90MB LiDAR	
Minimum	-2.870
Maximum	3.330
Mean	0.069
Std. Dev.	0.103

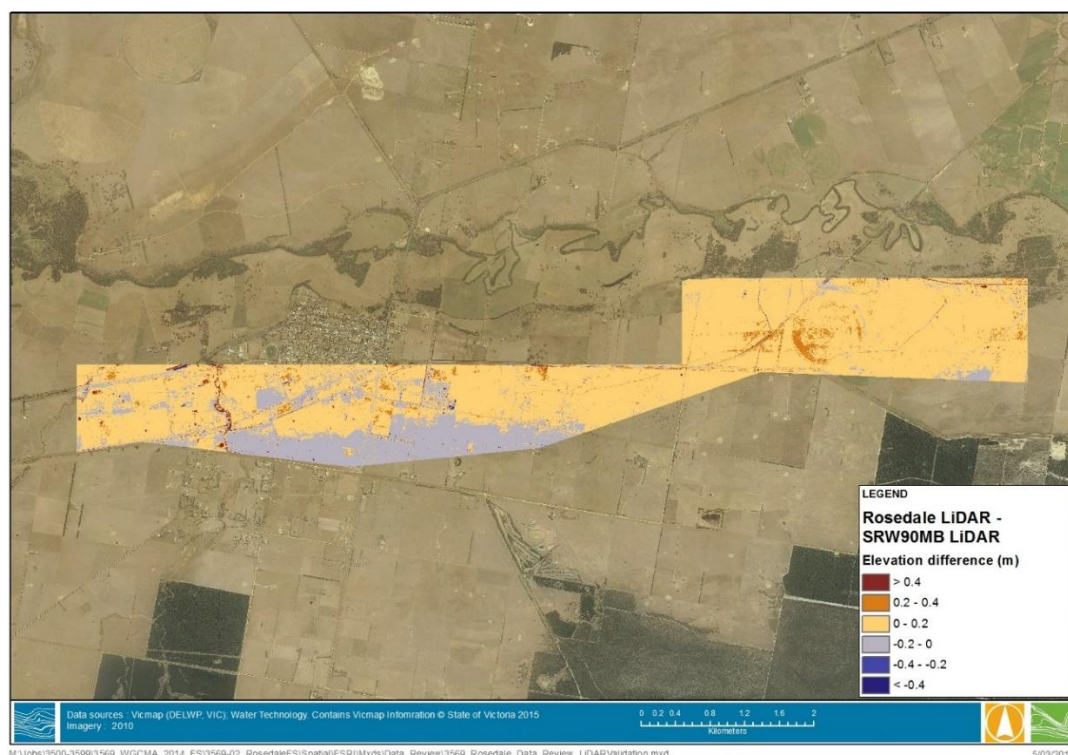


Figure 6-5 LiDAR comparison – New LiDAR 2015 DEM minus SRW DEM

6.1.3 Feature Survey

To further validate both LiDAR datasets they were compared to linear sections captured by Beveridge Williams along generally flat sections of road. One section fell within the new LiDAR area and two sections fell inside the older SRW LiDAR. In each instance the Beveridge Williams survey was higher than the LiDAR data (200mm+). As both LiDAR data sets were generally in agreement with each other it was not proposed to modify them. Further investigation into why the feature survey was generally higher than the LiDAR could be warranted but considered outside the scope of the current project.

Table 6-4 LiDAR Validation against Beveridge Williams feature survey

	Survey - Rosedale LiDAR (one section of road)	Survey - SRW-90MB LiDAR (two sections of road)
Minimum	0.263	0.152
Maximum	0.338	0.309
Mean	0.297	0.226
Std. Dev.	0.019	0.060

6.2 Drainage Information

GIS layers of local pits and pipes were provided by Wellington Shire (Figure 6-6). [REDACTED] from Wellington Shire provided advice on the reliability of the pipe layer and additional/altered pipes. Broadly, the township is drained via three main drainage systems. A fourth system is found on the eastern edge of the township and forms part of the Holy Plains Drainage Scheme. A review of the data showed it is suitable for use in the hydraulic model of the township.



Figure 6-6 Drainage GIS layers (Wellington Shire Council)

7. FLOOD MITIGATION AND WARNING

7.1 Proposed Flood Mitigation Scheme

In the past several investigations into mitigation schemes have been undertaken for the township of Rosedale. To date, no major schemes have been implemented. Favoured mitigation schemes tended to include structural and non-structural measures, with most including levees which achieved one of two outcomes:

- Keeping Blind Joes Creek flowing north to the Latrobe Floodplain; or,
- Allowing Blind Joes Creek breakout flows to move east while protecting flows entering the town with levees.

Different levee options recommended by GHD in 1995 are shown in Figure 7-1. A very similar levee system was recommended by the Department of Conservation and Natural Resources in 1995. Other mitigation measures included in past investigations included:

Structural measures:

- Bridge enlargement at Cansick Street (completed by WSC approximately 5 years ago);
- Road lowering of floodway crossings at Friends and Willung Roads;
- Floodway improvements;
- Blind Joes Creek conveyance improvements; and,
- Retarding basins.

Non Structural measures:

- Land use planning controls;
- Public education and awareness programs; and,
- Flood warning and emergency response plans.

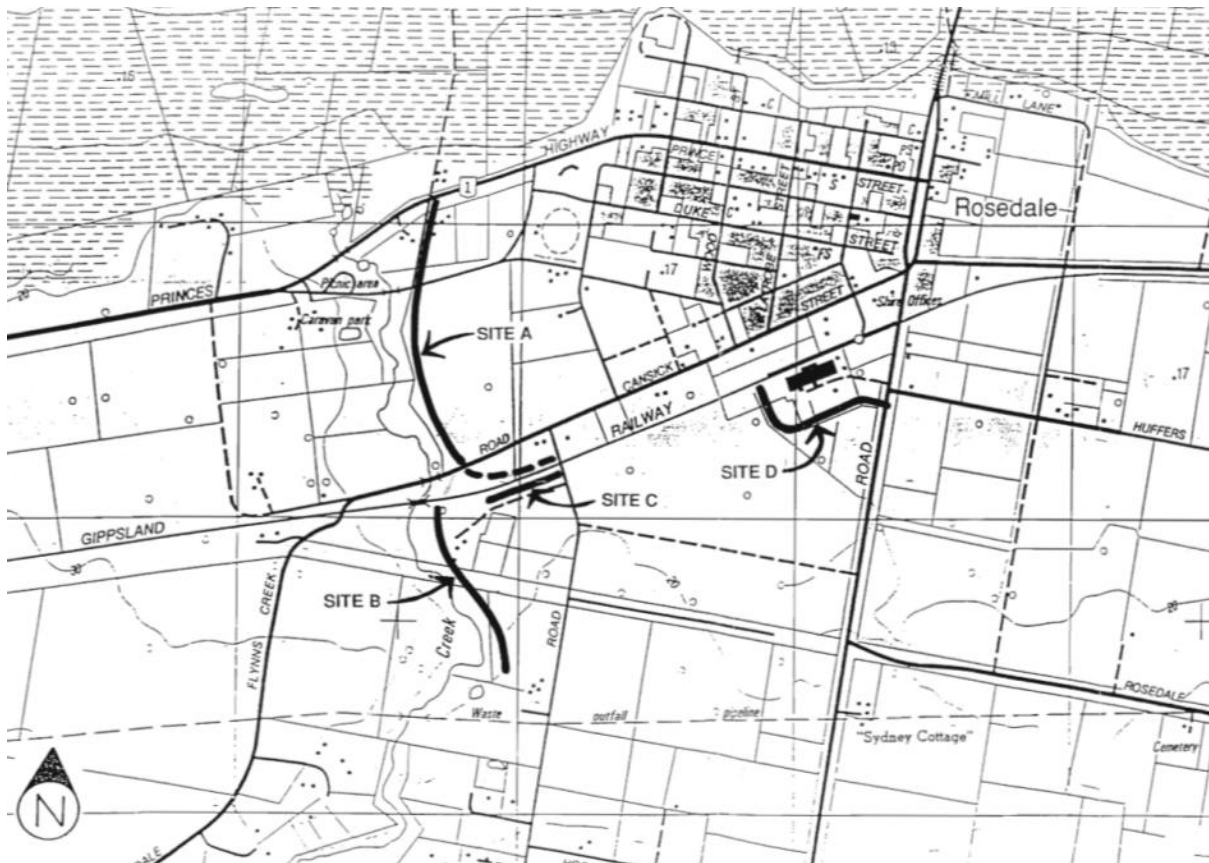


Figure 7-1 Levees recommended in 1995

7.2 Flood Warning Arrangements

The Bureau of Meteorology gauge on the Latrobe River at Rosedale has declared flood heights for minor, moderate and major events. Flood class triggers are set at 4.0 m for minor, 4.8 m for moderate and 5.5 m for Major flood classes. Currently there is no VicSES flood guide for Rosedale. Similarly the Wellington Municipal Flood Emergency Plan (MFEP) discusses adjacent catchments but does not specifically provide flood warning arrangements for Rosedale.

8. SITE INSPECTION

A site inspection was undertaken by representatives from Water Technology, West Gippsland CMA and Wellington Shire Council on 16 October 2014. Key locations visited are shown in Table 8-1.

Table 8-1 Key locations visited by project staff, 16 October 2014

Location/Notes	Photo
Major Waterway Crossings • Princes Highway bridge works currently being completed; ○ WGCMA to provide the "as designed" drawings; ○ RTL/Hyder opted to construct the bridge using the Water Technology recommended waterway area (unlike Flynns Creek); • Cricket Street bridge (Floodway); ○ Lots of reeds on the Floodplain (Phragmites); ○ WGCMA noted local residents have asked for the floodplain between Cricket Street and Flynns Creek Road to be cleaned up, and believe this will reduce flooding. • Flynns Creek Road; ○ Bridge recently replaced (last 5-10 years); ○ Wellington Shire Council did the works; ○ Works included increasing waterway area on the floodplain between the new bridge and the railway bridge; ○ It appears the cut material from these works were left in the floodplain (west bank);	NA

Location/Notes	Photo
Railway bridge (Blind Joes Creek); • Capacity of railway bridge was significantly greater than the Flynns Creek Road bridge; • It appeared the waterway upstream of the railway bridge had been fenced and re-vegetated, possibly by the local Landcare group; • Currently modelling shows the creek breaking out upstream of the railway bridge and flowing east (sitting behind the railway embankment); and, • A number of the railway openings were partially blocked with sediment, potential to increase capacity by excavating out material from under bridge with transition upstream and downstream.	
Old drainage scheme works; Mill Lane (Railway line culvert and channel downstream of Mill Lane); • Significant northerly flowing drain feature; • Rosedale-Longford Road culvert 3.00 x 1.95 m RCP's; • Railway line culvert 3 x 1.5 m RCPs; and • Huffers Road 3x 1.2x1.2 box culverts.	 

Location/Notes	Photo
Eastern Breakout - Rosedale floodway; Friends Road; • Current modelling shows flood water ponding behind Friends Road controlled by a single 0.9 x 0.6 m box culvert; • Current modelling shows breakout flows crossing the railway crossing (with Friends Road) and flowing into the vacant land proposed for R1Z development; and, • Adam Dunn (WGCMA) posed the question could more floodwater flow east, could this protect the land proposed for development. Willung Road; • Overland flow appears shallow and broad; • Willung Road inundated in June 2012, Adam Dunn (WGCMA) was pretty sure this was not from Blind Joes Creek - but more from local runoff; • 3 x 750 mm RCPs convey water under Willung Road; and • Minimal development on the floodplain, tannery or timber mill sits on a fill pad on the northern boundary of the floodplain.	

Location/Notes	Photo
Rosedale-Longford Road (Railway crossing); • Flows from the Rosedale Floodway (and other catchments) connect back to the Latrobe River floodplain near Mullocky Lane - 2 crossings under Rosedale-Longford Road and the railway; and, • Cut off drain observed on Mullocky Lane moving flow back to Rosedale-Longford Road.	

9. MODEL DEVELOPMENT AND SCHEMATISATION

9.1 Hydrologic Modelling Approach

Hydrologic modelling was undertaken to quantify the catchment generated flows in Blind Joes Creek and in adjacent tributaries to the east at the hydraulic model boundaries as well as stormwater inflows within the hydraulic model extent.

9.1.1 Model Build / Development

A RORB hydrological model was developed of the entire Blind Joes Creek catchment to the creek entrance, which includes the hydraulic model extent. ESRI's ArcHydro was used to delineate the catchment, with a minimum of 3 to 5 sub-areas schematised upstream of any required streamflow hydrograph. Print locations were included at all locations where flow is required such as at tributaries, streamflow gauges and model boundaries.

9.1.2 Model Validation

Given the lack of stream flow gauges in the upper catchment and the fact that the Latrobe River connects with the Anabran flow in floods greater than 10% AEP, the use of the Latrobe River Anabran streamflow gauge for a typical model calibration is not possible. The study area was treated as an ungauged catchment, with hydrology and hydraulic modelling being developed in tandem. Output from the hydrology model was input to the hydraulic model, and the resulting extents/timing/peak flows compared to observed data. Where significant over and/or under estimations occur in water level and extent in the hydraulic model, the hydrological model parameters

were 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 hydraulic model parameters were used to fine tune the model results. Model validation in this way is an iterative process. This methodology is summarised in the flow chart shown in Figure 9-1.

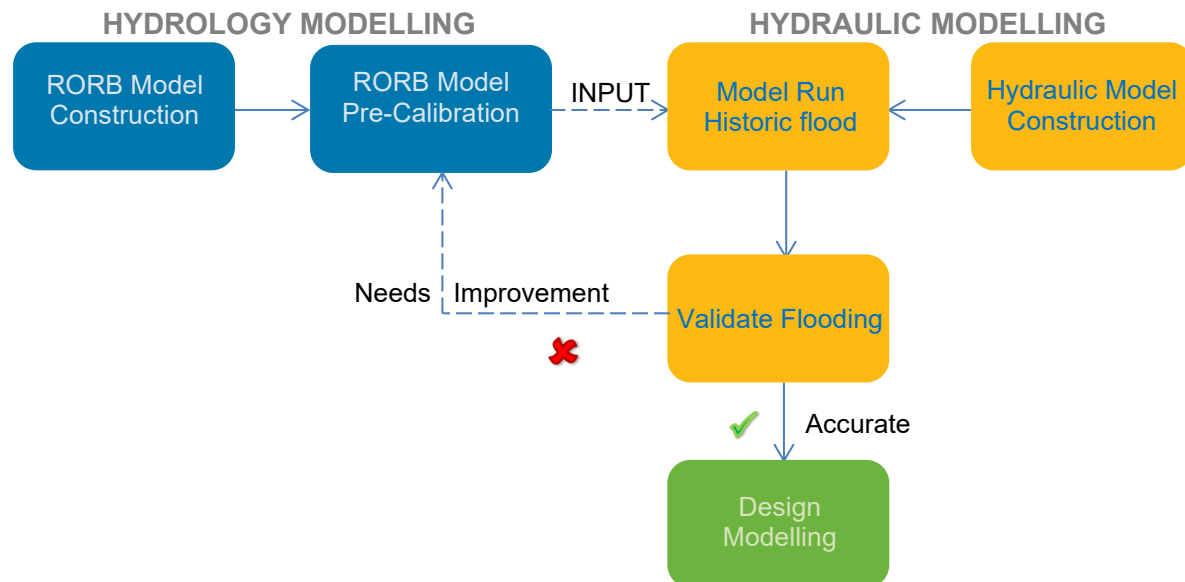


Figure 9-1 Modelling approach flow diagram

The model was validated in this way using 2 historical floods, including the September 1993 flood and June 2012 events.

Local daily rainfall gauges were used to construct a spatial pattern of rainfall for the historic events. Local sub-daily rainfall gauges were used as temporal patterns for the historic storm event. Model parameters kc , m , IL and CL were then developed for each event through prediction methods and validation. A range of methods were adopted for predicting these parameters and provided a starting point for the iterative validation process. Kc values were compared to nearby calibrated RORB models (i.e. Traralgon Creek, previous Blind Joes Creek modelling, Trafalgar modelling, etc.), using a *Dav* scaling technique.

The kc and m were consistent across events with the losses varied to represent different antecedent conditions.

The design events 0.5%, 1%, 2%, 5% and 10% AEP were simulated for a range of storm durations.

9.1.3 Hydrological Design Modelling

It was proposed that the current IFD curves be utilised for design rainfalls. Presently, the revised curves are not recommended to be used in practice until the revised AR&R manual is finalised. The revised IFD curves were used as part of a sensitivity analysis.

RORB model design parameters (kc , m , IL , CL) were determined. The kc and m values adopted for design modelling were the same as that adopted for verification, and were compared to nearby model values as well as values from Australian Rainfall and Runoff and the RORB kc prediction equations.

A number of estimation techniques were tested for design losses, with the flows at Rosedale compared for the various methods:

- Hill *et. al.*;
- Australian Rainfall and Runoff;
- Other models from nearby catchments; and,
- Losses from verification historic events.

Further verification of design flows was undertaken using regional prediction equations and methods such as the Probabilistic Rational Method. However it was noted that the recently released draft version of the updated Australian Rainfall and Runoff – A Guide to Flood Estimation, recommends that the Probabilistic Rational Method is no longer used, and goes on to provide an alternative approach. Both methods were used to provide verification for the RORB design flow estimates.

The design events considered a range of durations with a focus on critical durations for Blind Joes Creek at Rosedale. The catchment critical duration was simulated in the hydraulic model.

The final adopted design model parameters were utilised to produce hydrographs at all hydraulic model boundaries for the 0.5%, 1%, 2%, 5%, and 10%, AEP flood events.

The probable maximum flood (PMF) discharge was estimated using the rapid assessment method developed by Nathan *et. al.* (1994).

The impacts of Climate Change were also be tested by increasing the rainfall intensity by an agreed amount in line with available literature, i.e. an increase of 32% as advised in the report *Climate Change in Australia* (CSIRO, 2007).

The impacts of bushfires were tested by adjusting the fraction impervious of the Blind Joes Creek sub-catchments to reflect an agreed severity of bushfire. In this study Blackham et al (2012) was adopted which nominates values of equivalent percentage impervious for different levels of burn severity, based on BAER (2009).

9.1.4 Stormwater

Stormwater modelling used ARR87 IFD and temporal pattern information for input to the direct rainfall model.

No calibration data is available for stormwater flooding.

Loss values adopted were based on RORB modelling and values adopted in nearby catchments e.g. Warragul and Trafalgar.

9.2 Hydraulic Modelling Approach

9.2.1 Overview

A 1D-2D unsteady state hydraulic model of the study area was developed in TUFLOW. The hydraulic model consisted primarily of a 2D grid model of the township, creeks and floodplains, with hydraulic structures incorporated as dynamically coupled 1D elements.

9.2.2 2D Model Schematisation

The proposed extent of the 2D model area is shown in Figure 9-2. The model is approximately 8 by 6.5 km in size. It is proposed to split the model into two domains to provide adequate resolution within the urban areas whilst maintaining manageable run times. A grid size of 4 x 4 m was adopted for the township, while the Latrobe River floodplain area was modelled at a coarser 12 x 12 m grid resolution. This was similar to the grid resolution combination adopted for Traralgon.

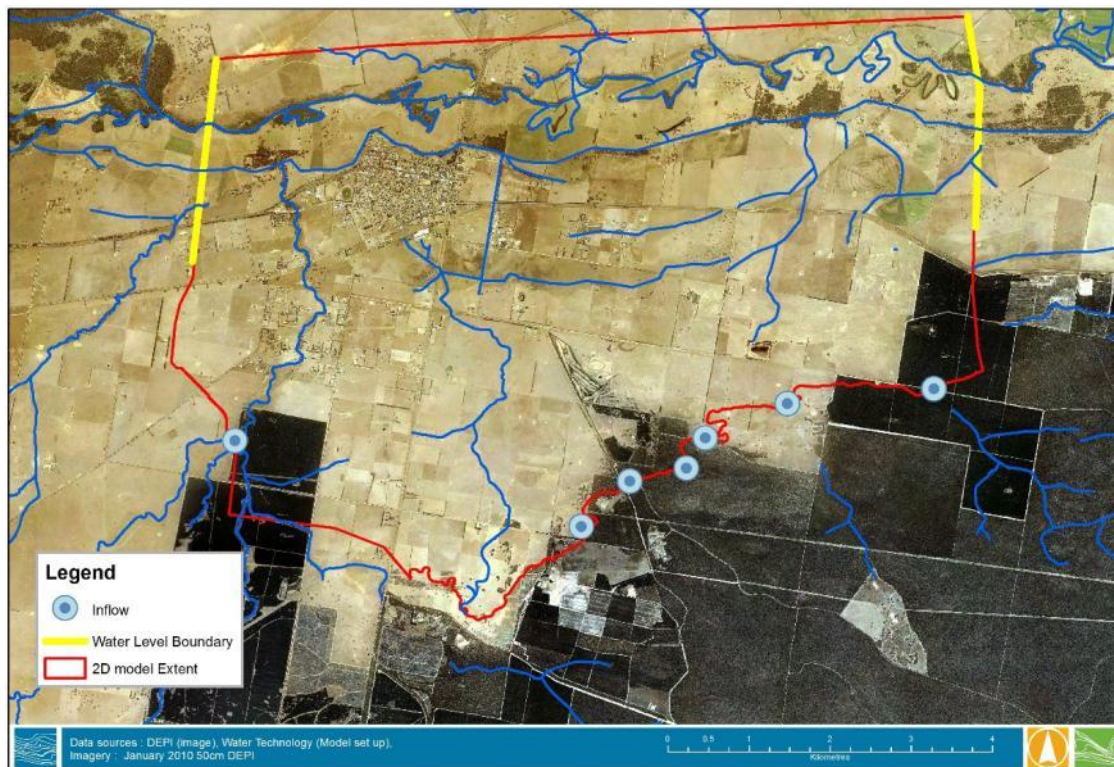


Figure 9-2 2D modelling extent and key features

An inflow hydrograph boundary was applied at the upstream end of Blind Joes Creek, along with all other adjacent catchments to the east. An inflow boundary was applied on the Latrobe River to provide a realistic hydraulic gradient and backwater effect of coincidental flooding.

A water level boundary was applied to the downstream end of the model, on the Latrobe River.

Land cover types were assessed using aerial photography and industry standard roughness values adopted.

9.2.3 1D Model Elements

Bridge, culvert and pipe structures were incorporated in the model as 1D structures. These were coupled to the 2D grid at their upstream and downstream ends. Standard roughness values, inlet and outlet losses were applied based on the material, geometry and inlet condition of the structures.

9.2.4 Stormwater Modelling

Stormwater modelling was undertaken using a direct rainfall on grid approach. For this type of hydraulic modelling the design rainfall estimates are applied directly to the hydraulic model surface. Land planning layers, cadastral and aerial imagery were used to identify unique fraction impervious and loss characteristics for each land parcel in the study area. A representation of Wellington Shire Council's pipe and pit network was included in the model as 1D elements.

9.2.5 Model Validation

The hydraulic model was validated in conjunction with the hydrology model, as discussed in Section 9.1.2. Surveyed water levels, flood photography, gauge readings and anecdotal evidence were used to validate the model for two historic floods.

10. DATA GAPS

Following initial data review the following data gaps were identified.

- LiDAR coverage in the southern portion of the study area.
 - ➔ LiDAR data was captured in January 2015.
- Lack of gauging data in the Blind Joes Creek catchment.
 - ➔ This was resolved by adopting an ungauged catchment methodology. The adopted approach recognises that the major source of uncertainty is in the hydrology estimates. The iterative approach to hydrology and hydraulics results in improved model accuracy as it allows a feedback loop to improve the hydrology prior to final adoption of inflows to the hydraulic model.
- It is understood that no current floor level survey is available for the town.
 - ➔ Floor level survey was collected by the WGCMA in December 2015.

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May 2016

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Cover Photo: Community supplied image from 1934 floods – Main Street of Rosedale (Newsagent).

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15 Business Park Drive
Notting Hill VIC 3168

Telephone (03) 8526 0800

Fax (03) 9558 9365

ACN No. 093 377 283

ABN No. 60 093 377 283

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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.

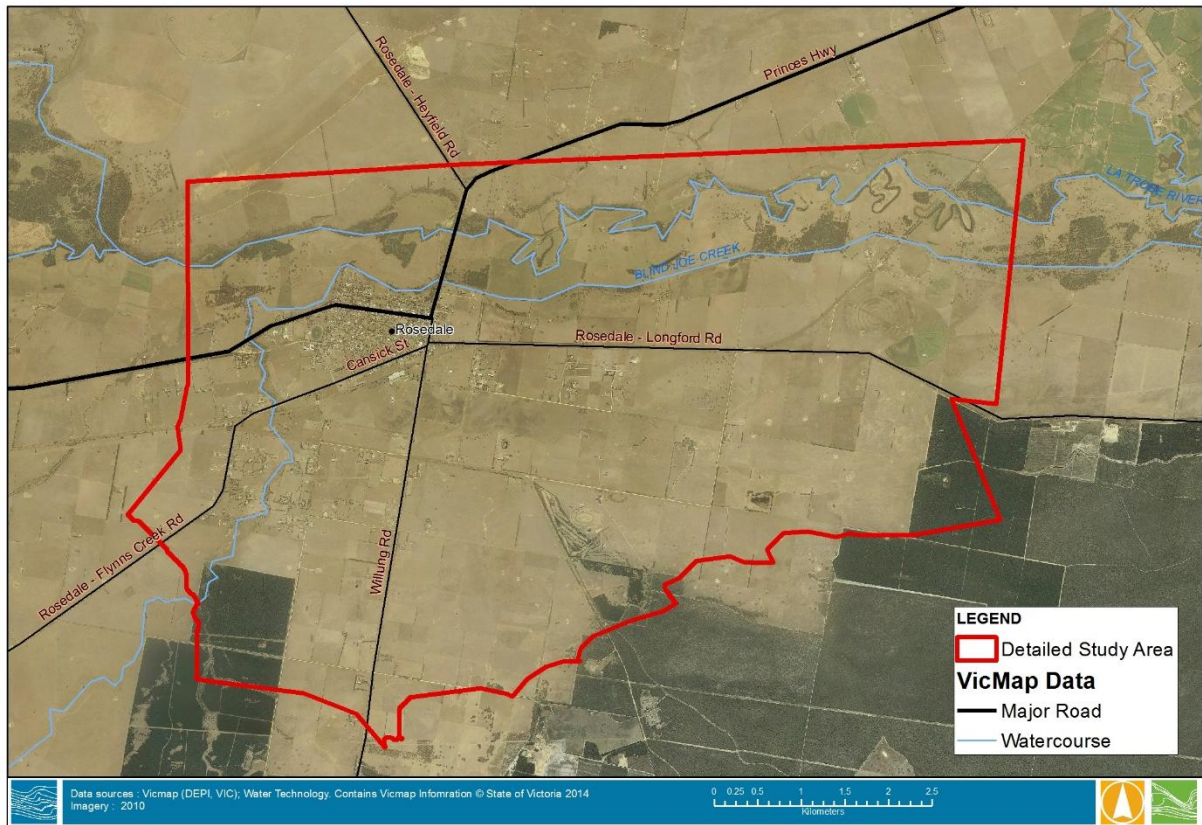


Figure 2-1 Rosedale Study Area

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).

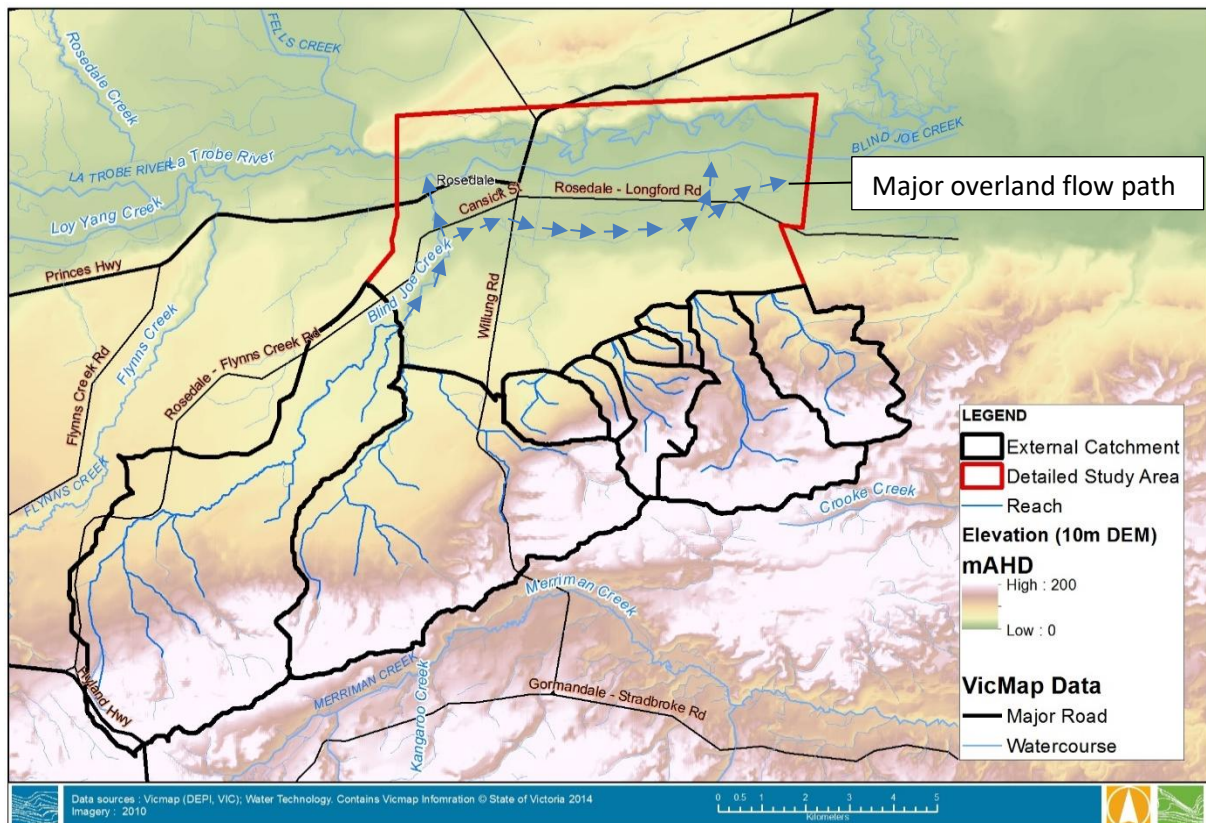


Figure 3-1 Rosedale Contributing Catchments

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

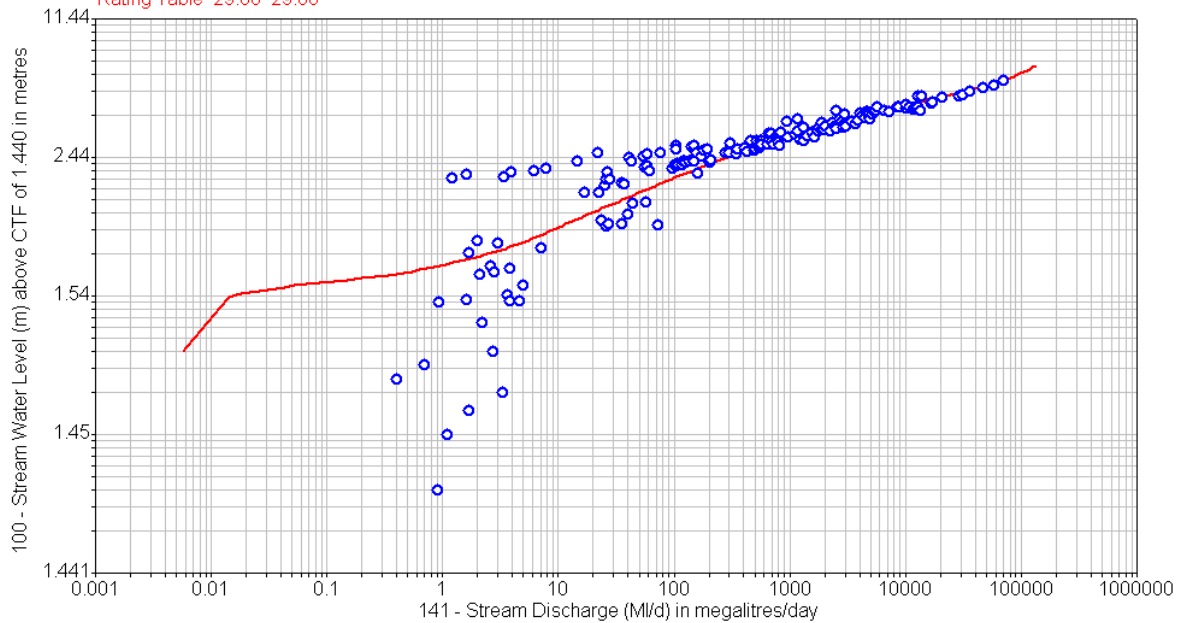


Figure 3-2 Rating Curve for 226224 LATROBE RIVER (Blind Joes Creek) @ ROSEDALE (ANABRANCH)

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

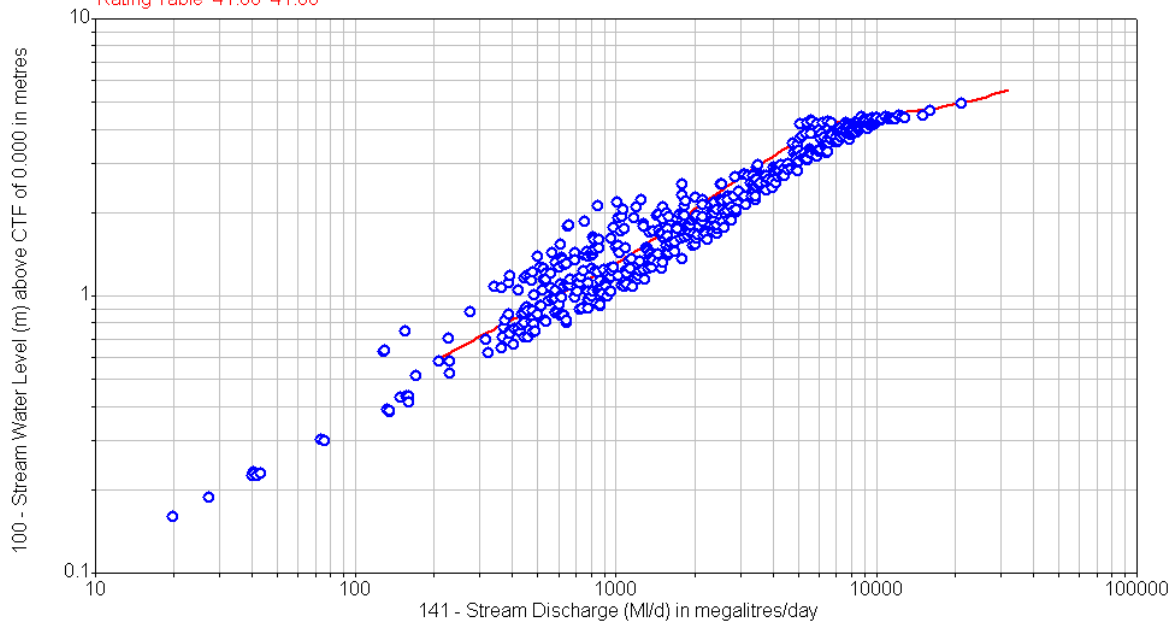


Figure 3-3 Rating Curve for 226228 LATROBE RIVER @ ROSEDALE (MAIN STREAM)

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.

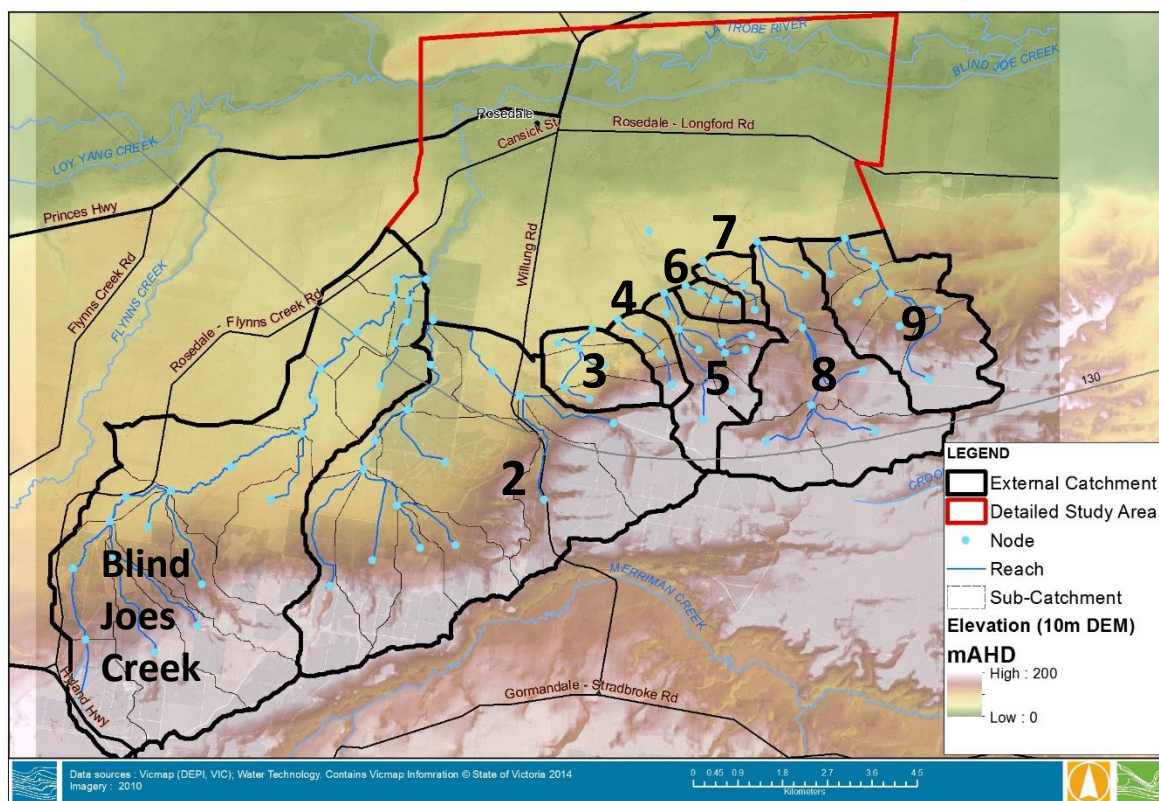


Figure 3-4 RORB model structure

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

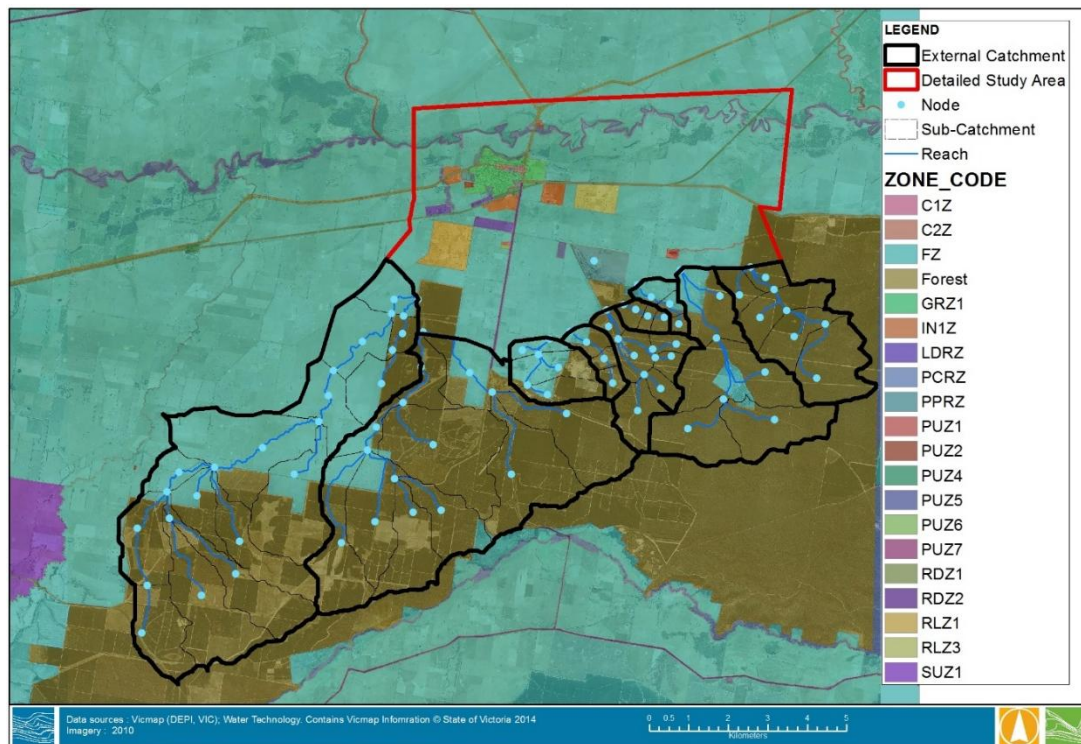
3.6.2 Fraction Impervious

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.

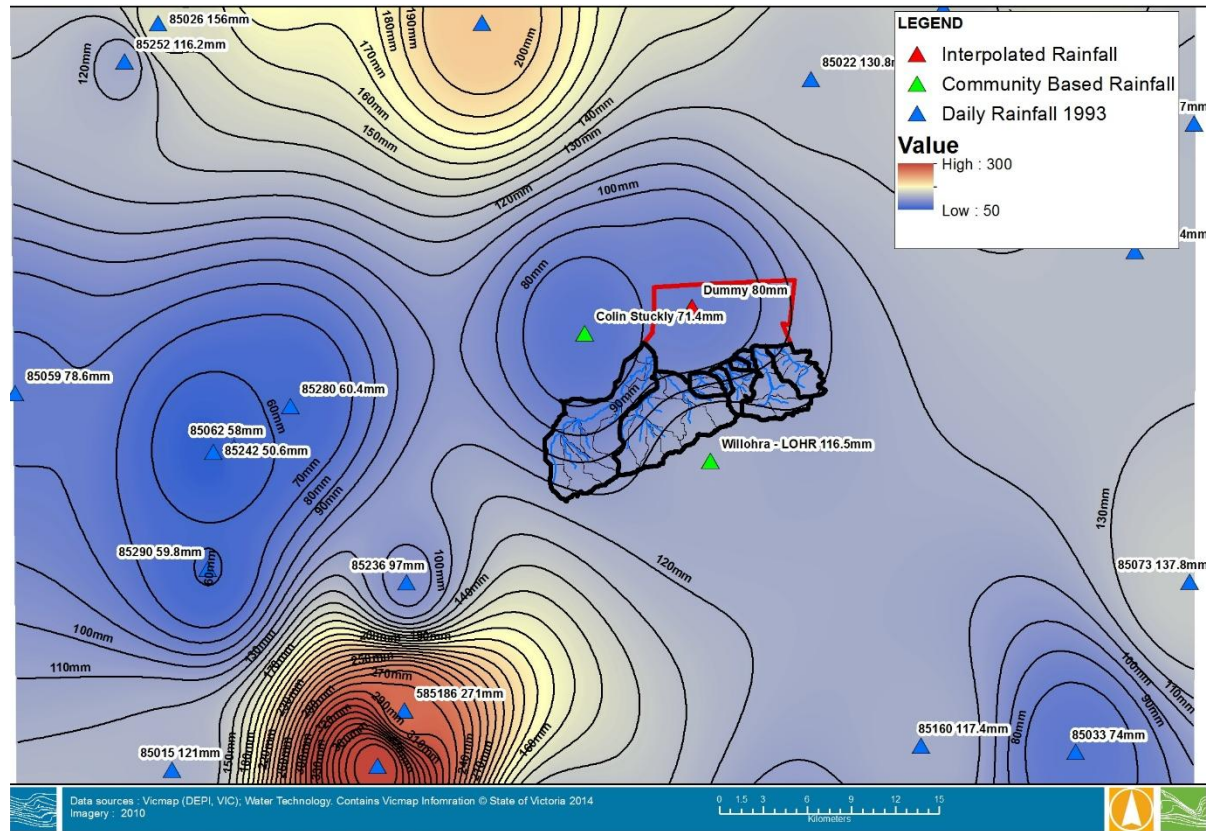


Figure 3-6 Total rainfall across the catchment for the September 1993 calibration event

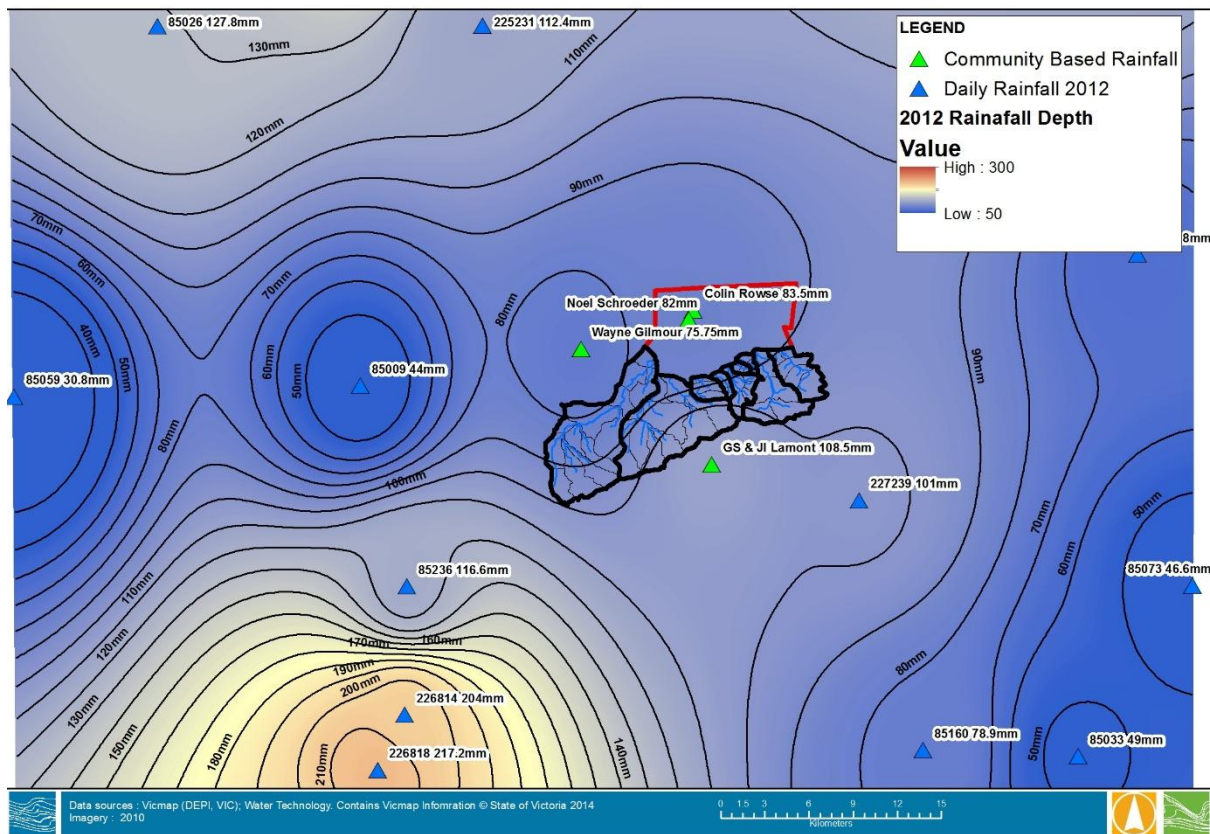


Figure 3-7 Total rainfall across the catchment for the June 2012 calibration event

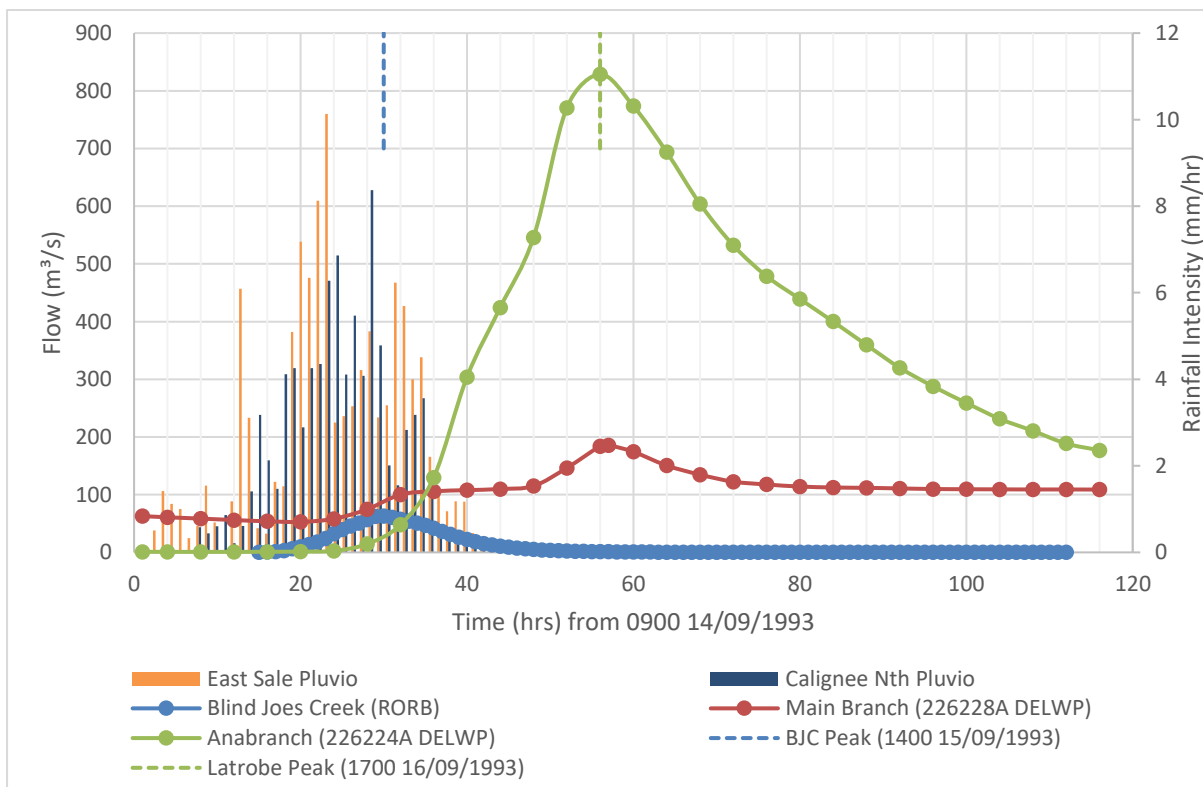


Figure 3-8 Calibration event hyetographs and instantaneous flow hydrographs for the September 1993 calibration event

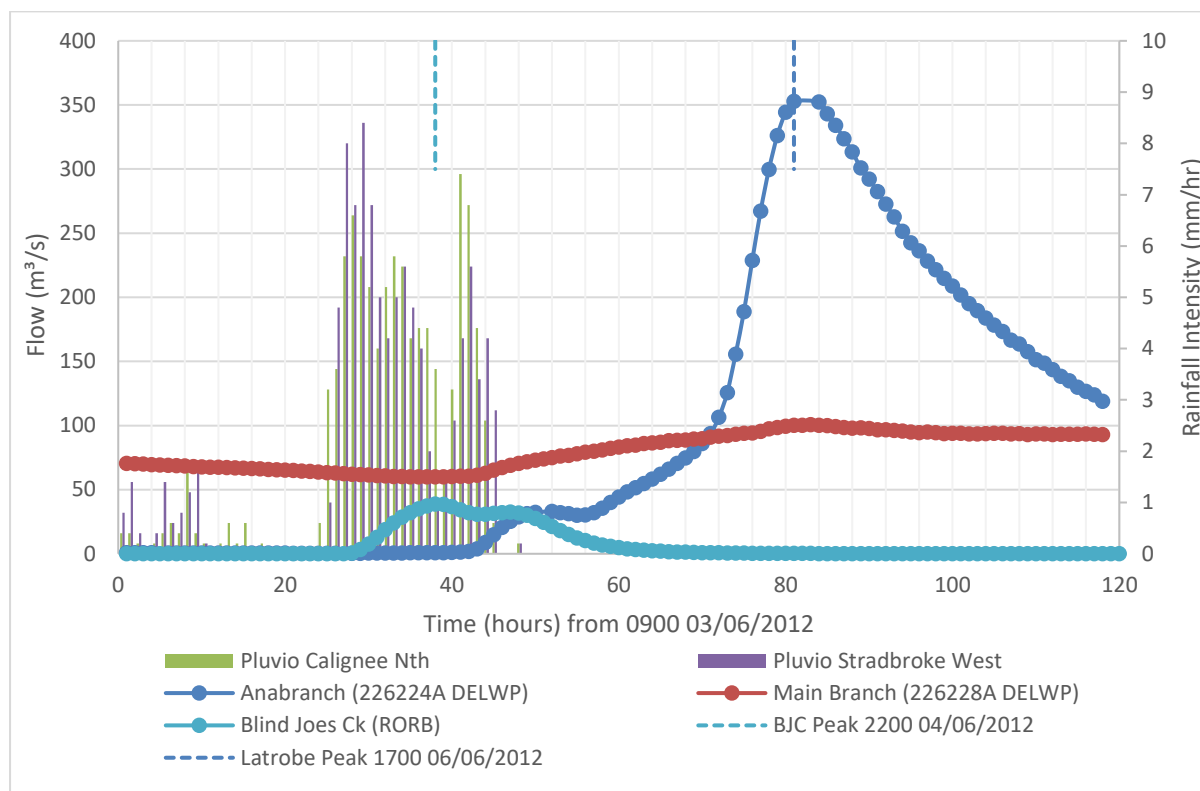


Figure 3-9 Calibration event hyetographs and instantaneous flow hydrographs for the June 2012 calibration event

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.

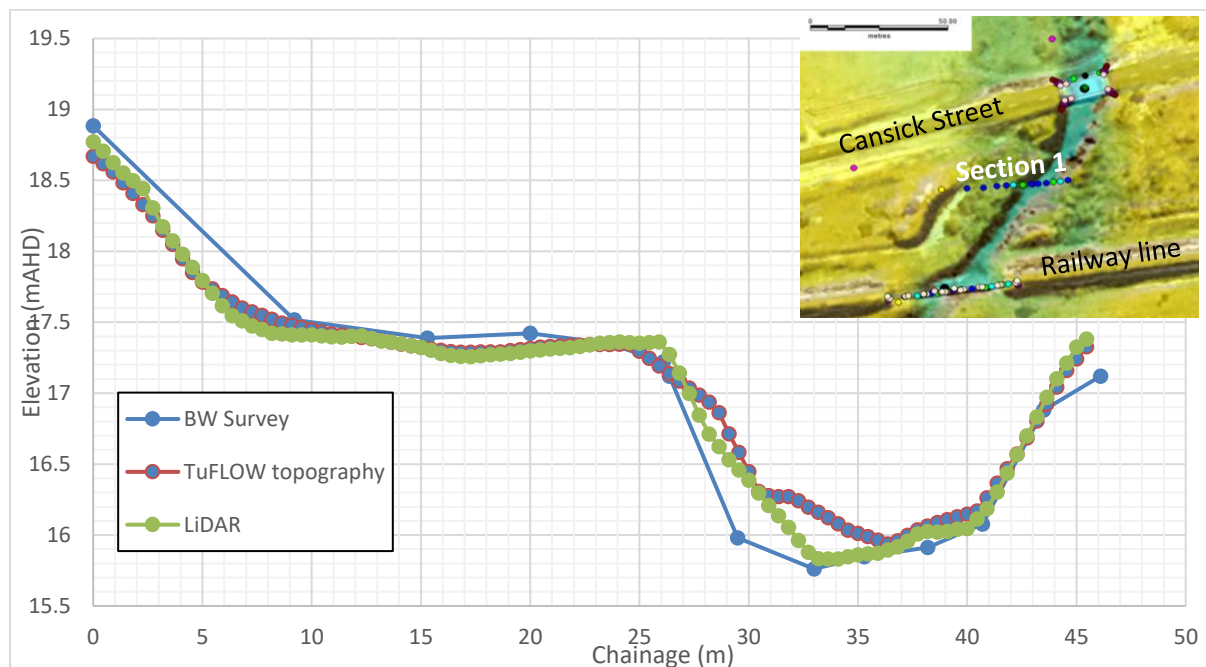


Figure 4-1 Topography checks within Blind Joes creek waterway (between Cansick and the railway line).

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.

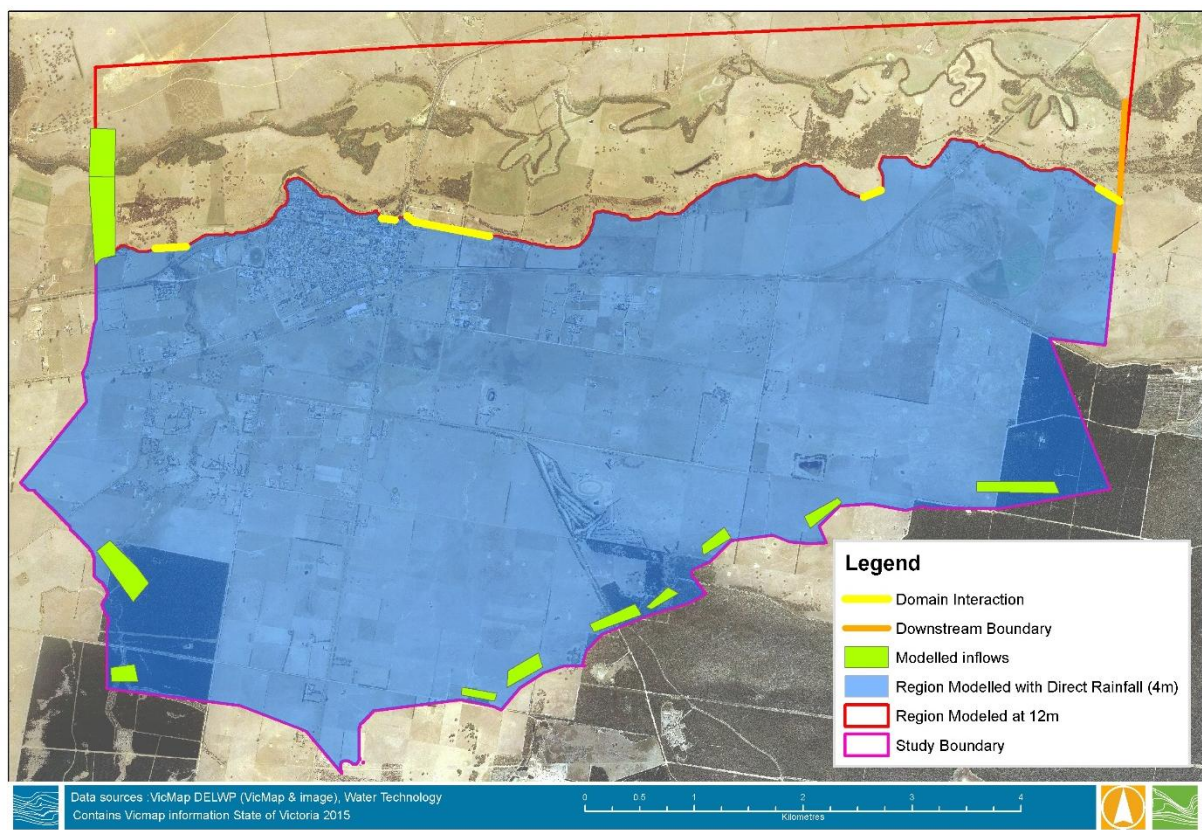


Figure 4-2 2D model extent and boundaries

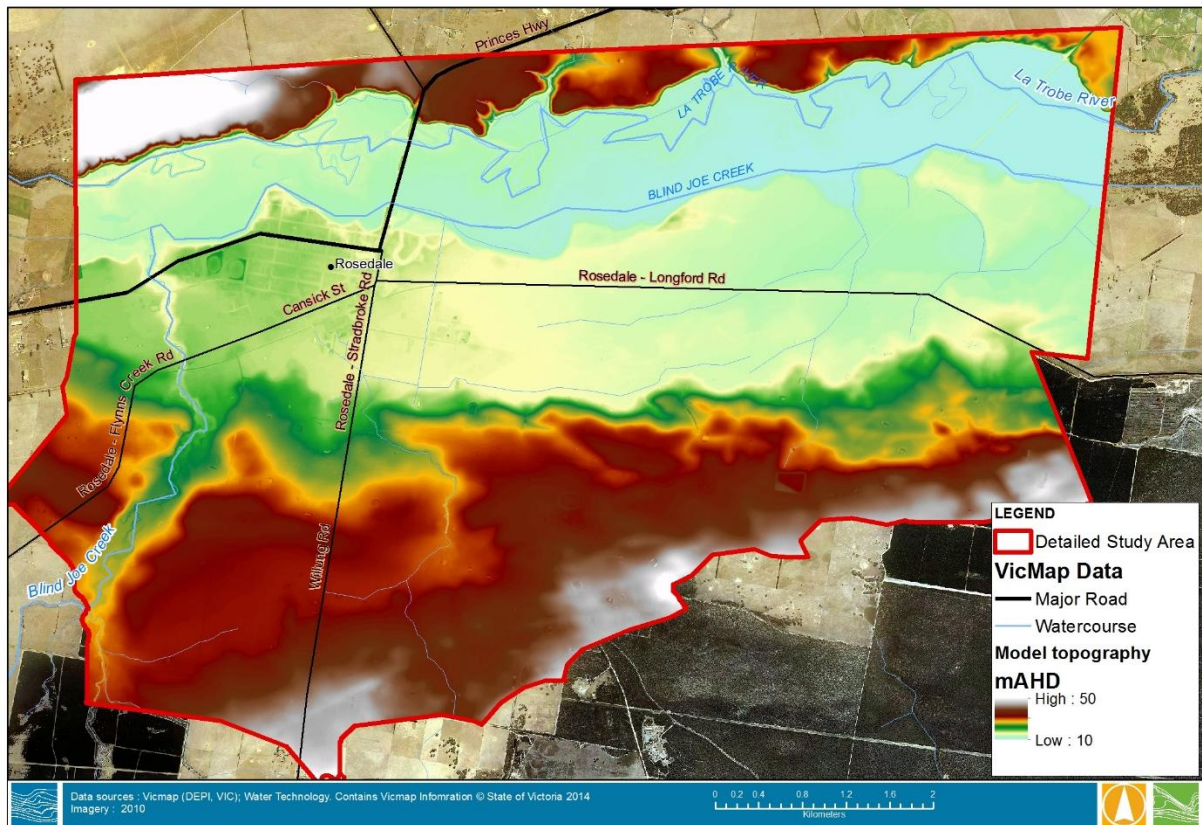


Figure 4-3 Hydraulic model topography

4.1.4 Roughness

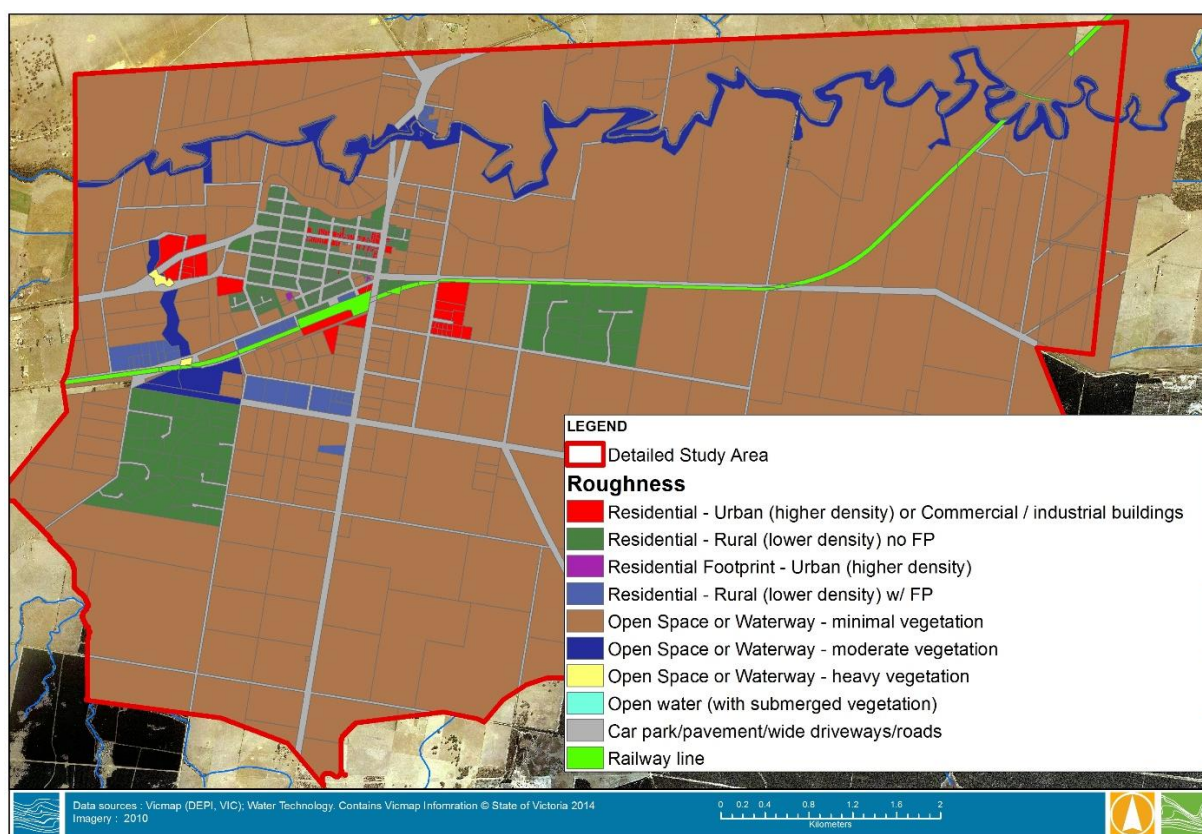
The Manning's 'n' roughness parameter has important effects on flood velocities, depths and extents. Manning's 'n' roughness values were derived from the Wellington Shire Council's planning zone data and refined based on site visits and aerial photography as well as calibration modelling. Roughness values 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.

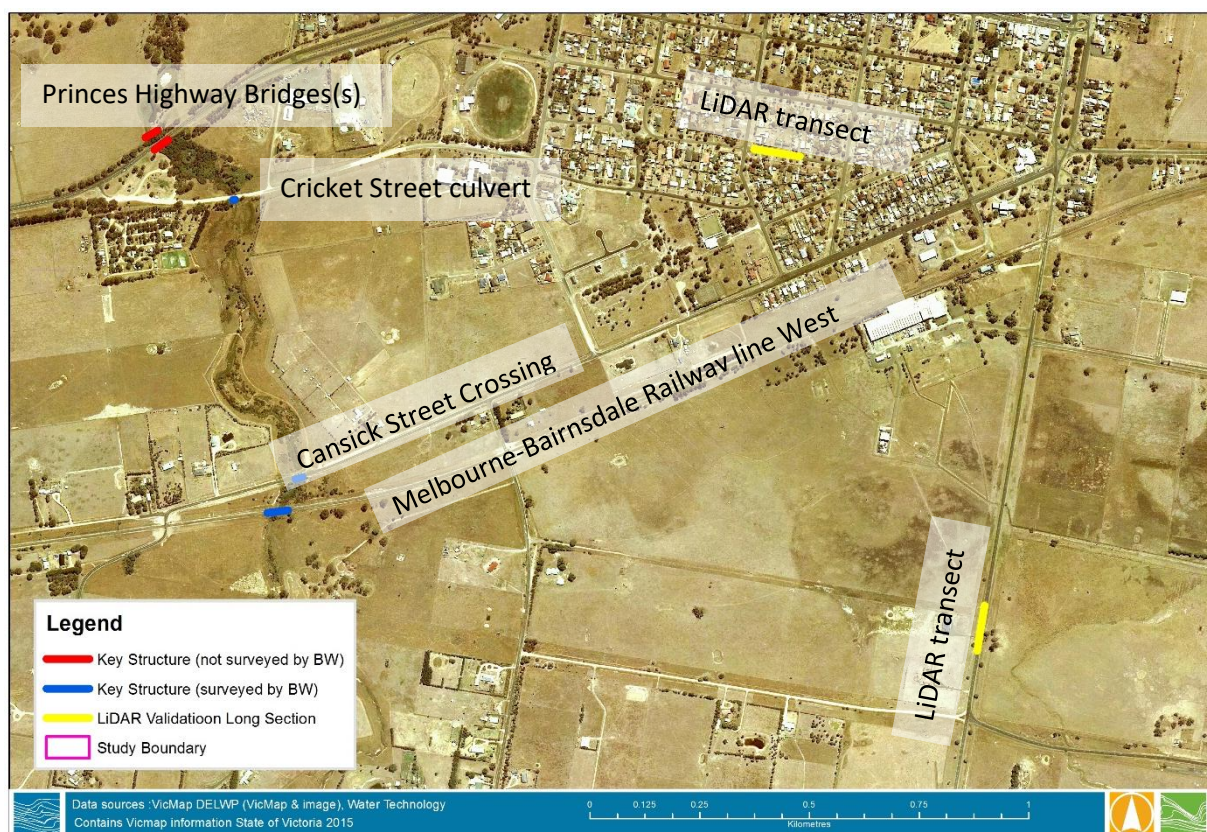


Figure 4-5 Key Hydraulic Structures and Survey Information



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.

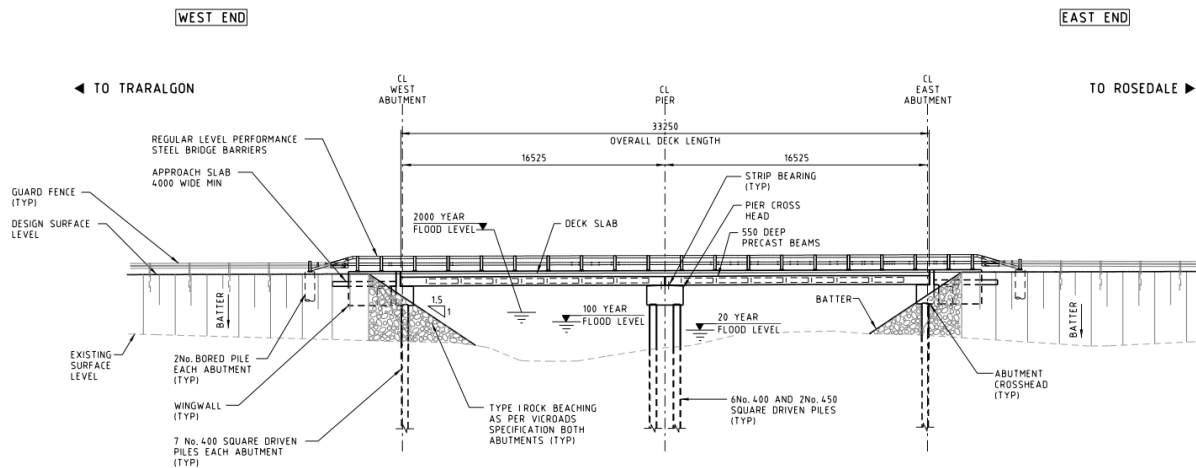


Figure 4-8 Blind Joes Creek – Proposed Princes Highway Bridge - Source: WGCMA

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.

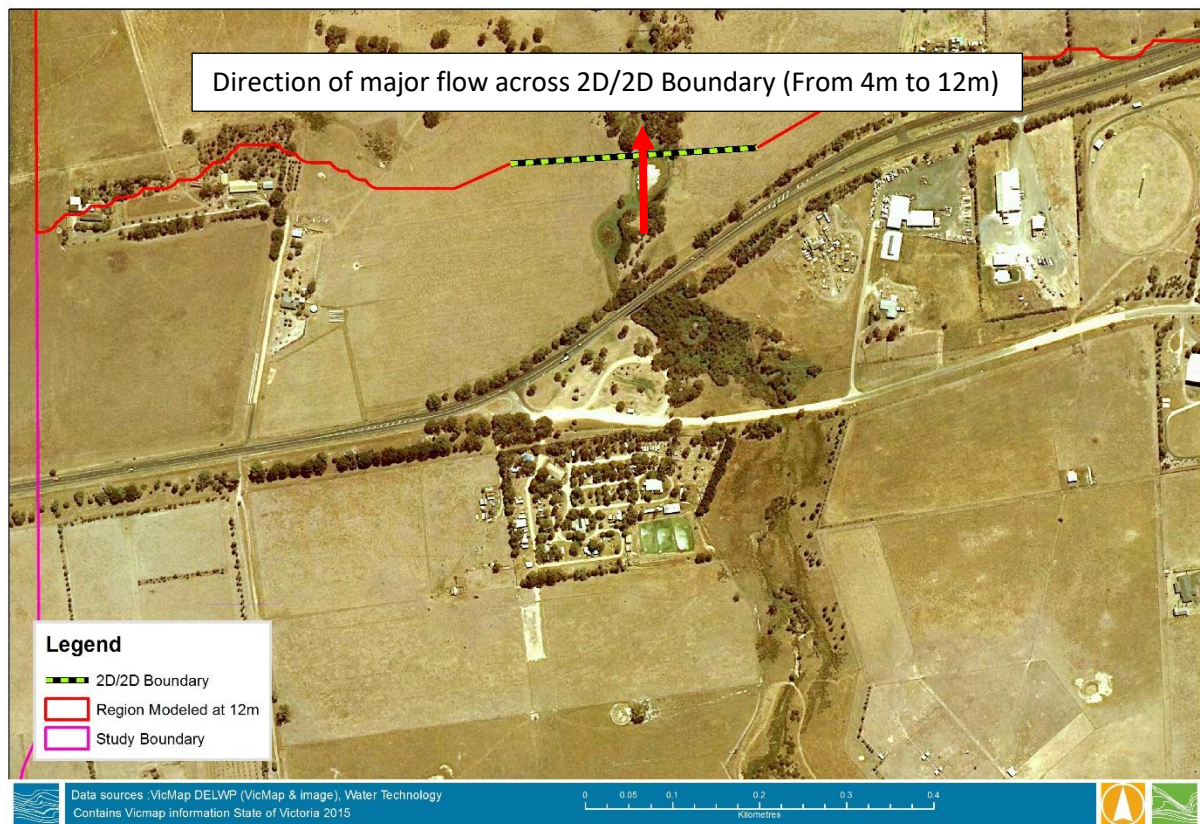


Figure 4-10 Schematisation of the 2D/2D Boundaries within TUFLOW – west

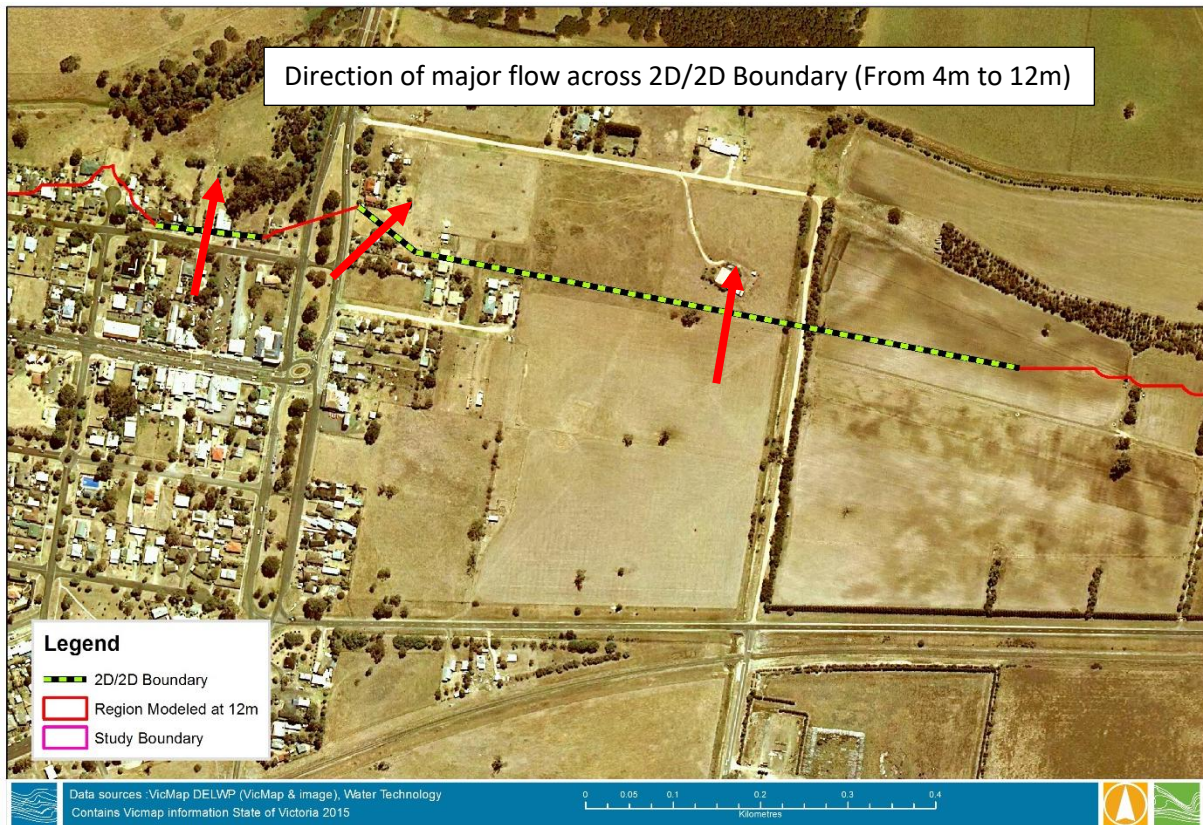


Figure 4-11 Schematisation of the 2D/2D Boundaries within TUFLOW – central

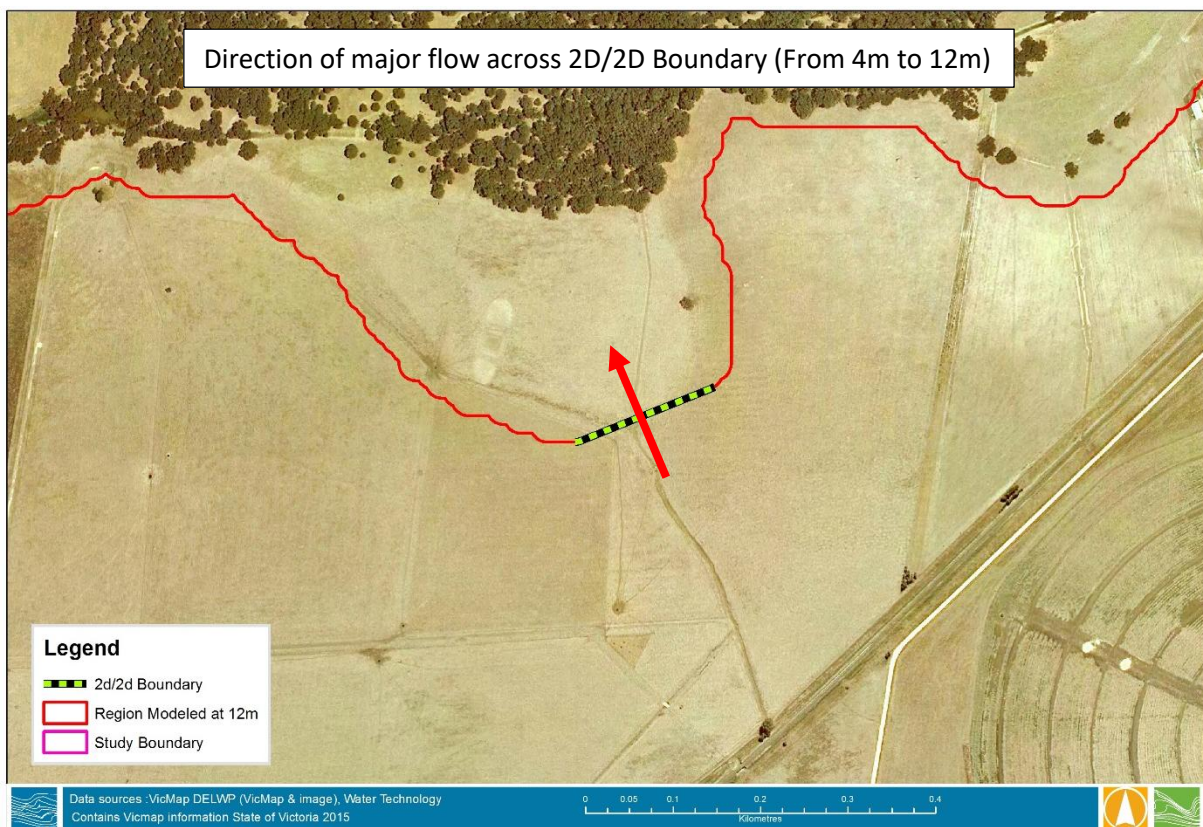


Figure 4-12 Schematisation of the 2D/2D Boundaries within TUFLOW – east

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

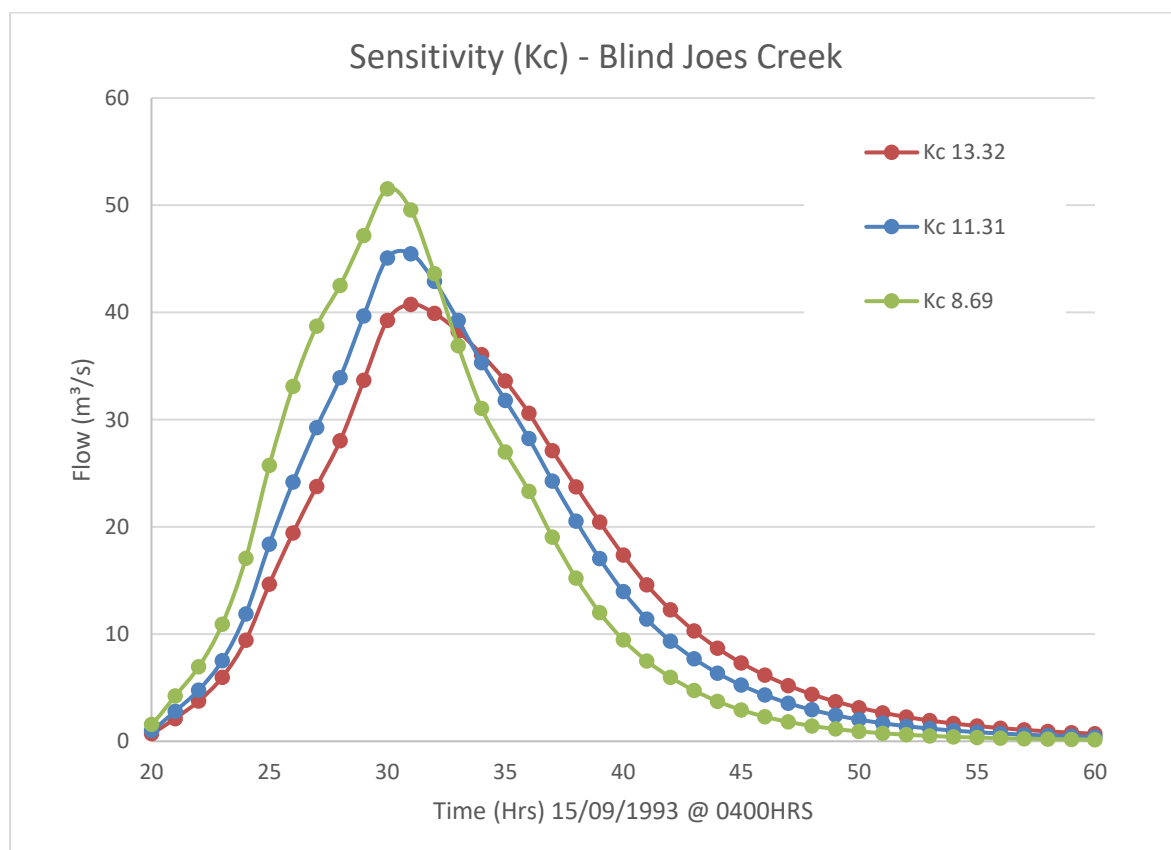


Figure 5-1 Effect on RORB hydrographs for the 1993 event with different Kc values

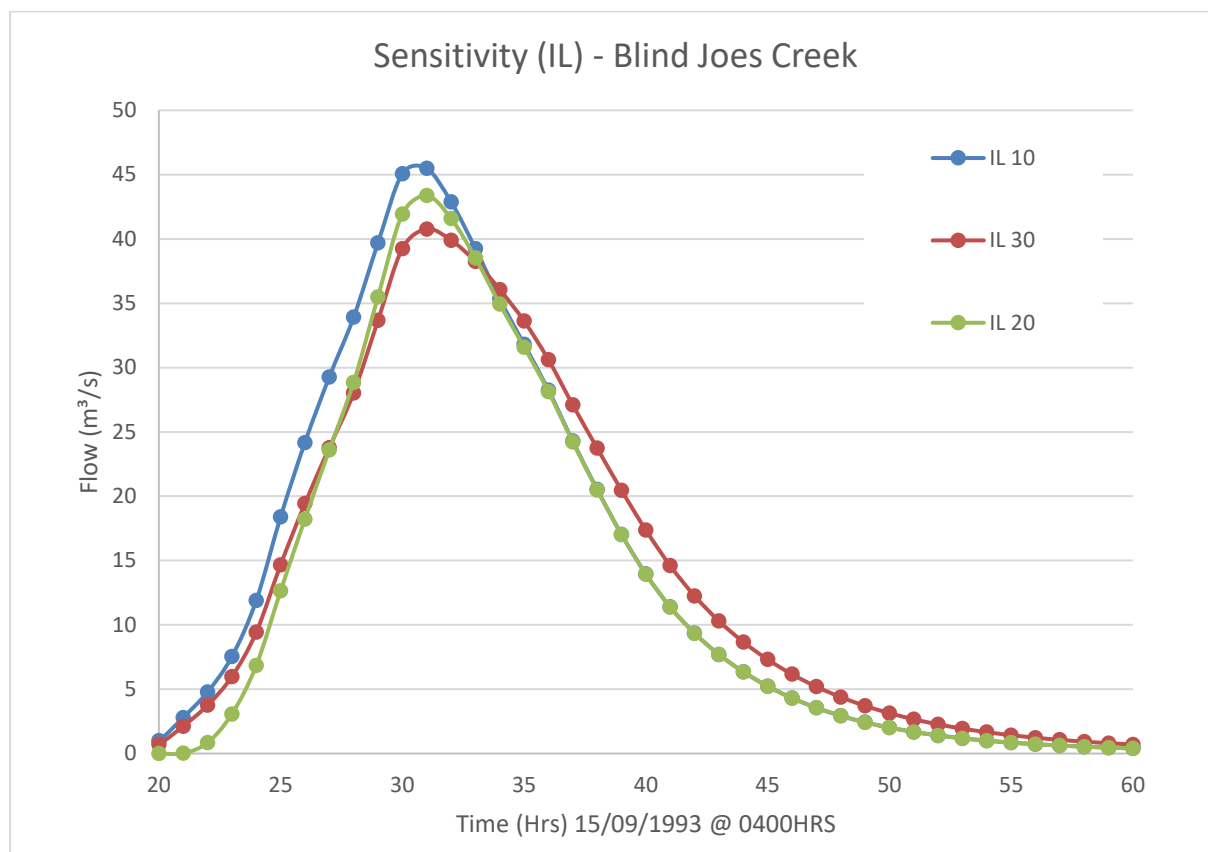


Figure 5-2 Effect on RORB hydrographs for the 1993 event with different IL values

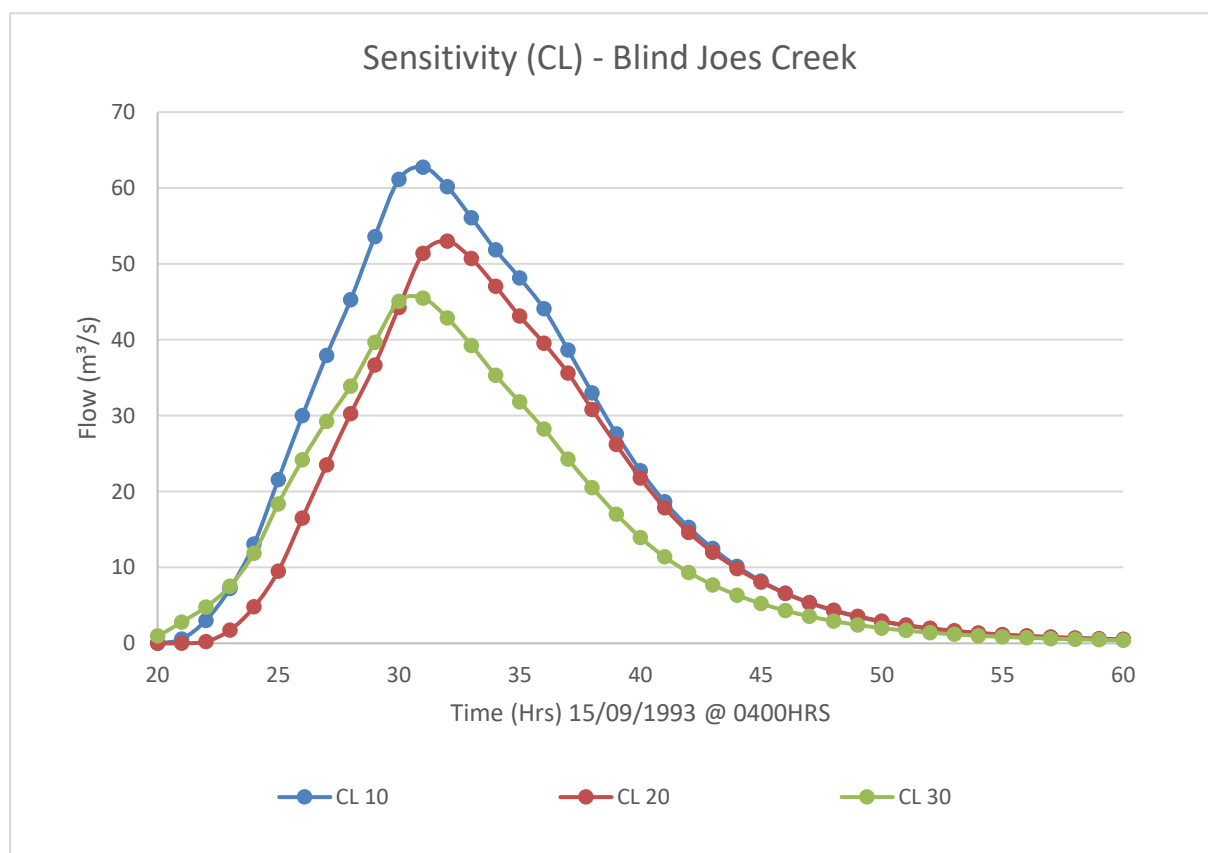


Figure 5-3 Effect on RORB hydrographs for the 1993 event with different CL values

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

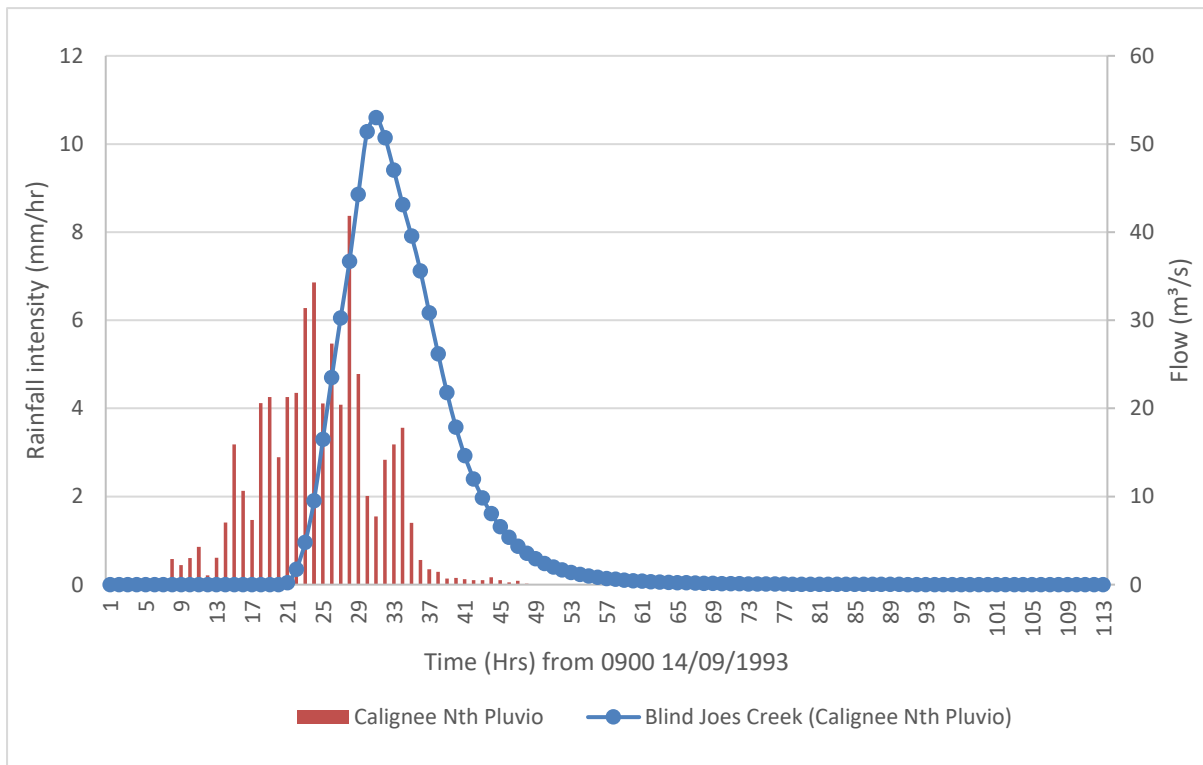


Figure 5-4 September 1993 inflow hydrograph for Blind Joes Creek extracted from the RORB model using the Callignee Nth temporal pattern

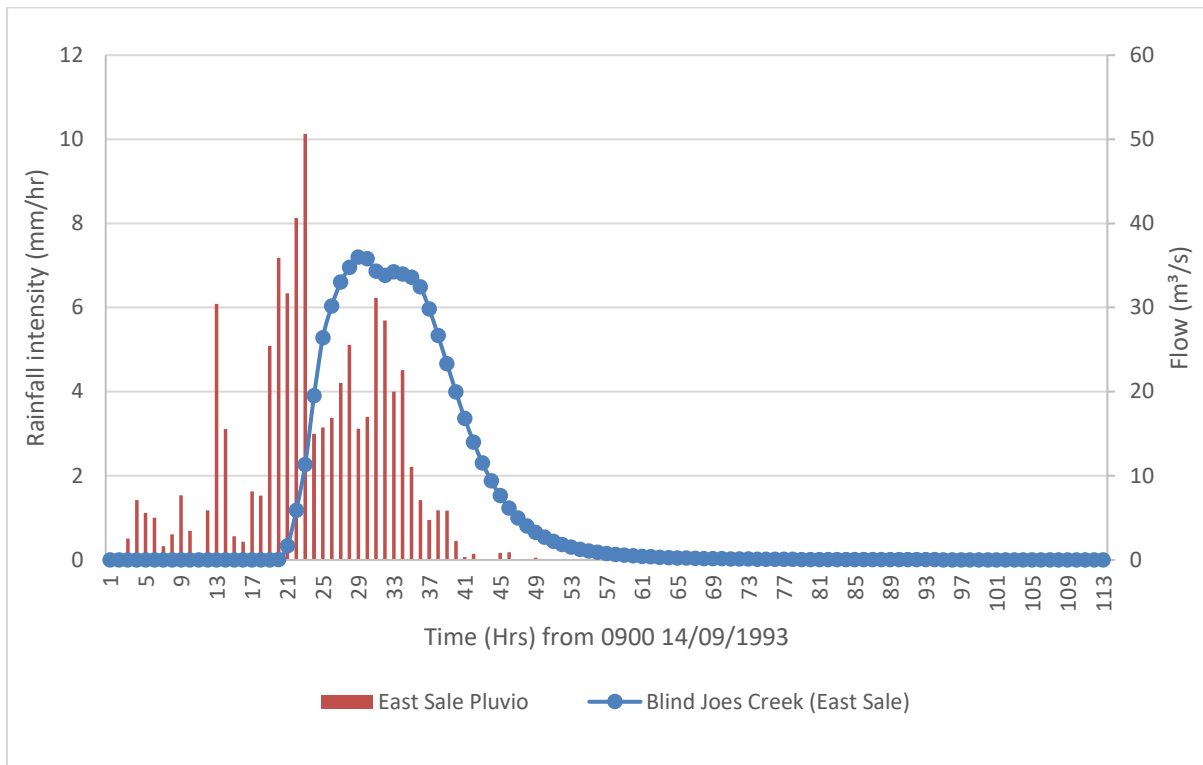


Figure 5-5 September 1993 inflow hydrograph for Blind Joes Creek extracted from the RORB model using East Sale temporal pattern

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.

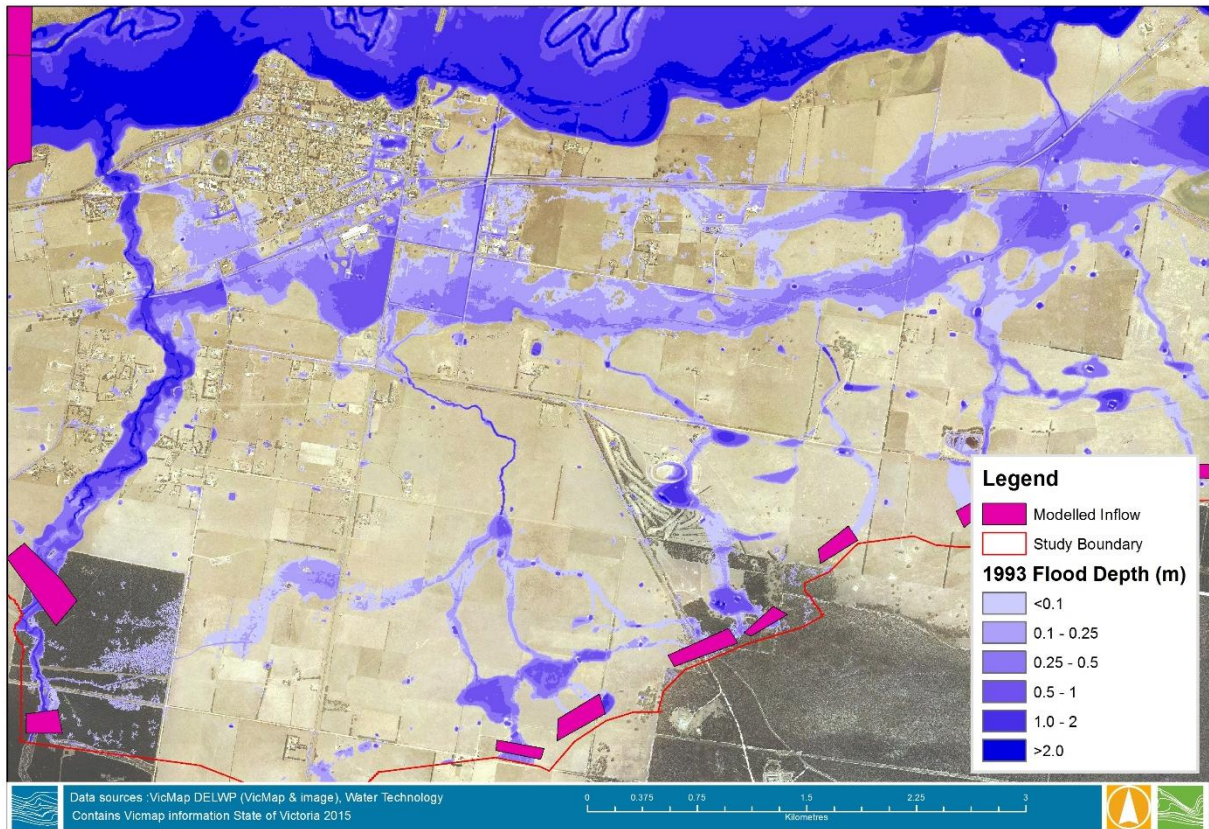


Figure 5-6 September 1993 hydraulic model results using the Callignee North temporal pattern

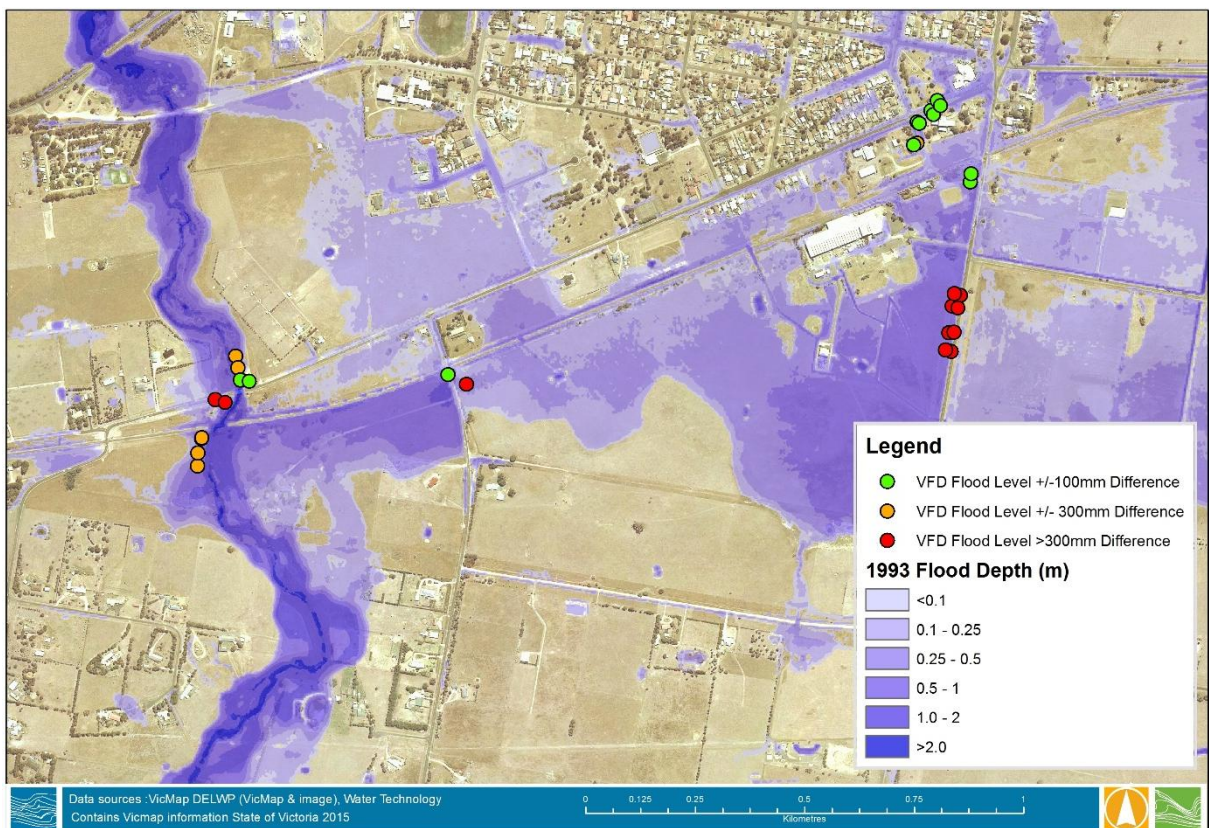


Figure 5-7 September 1993 hydraulic model results compared with observed flood heights – All points

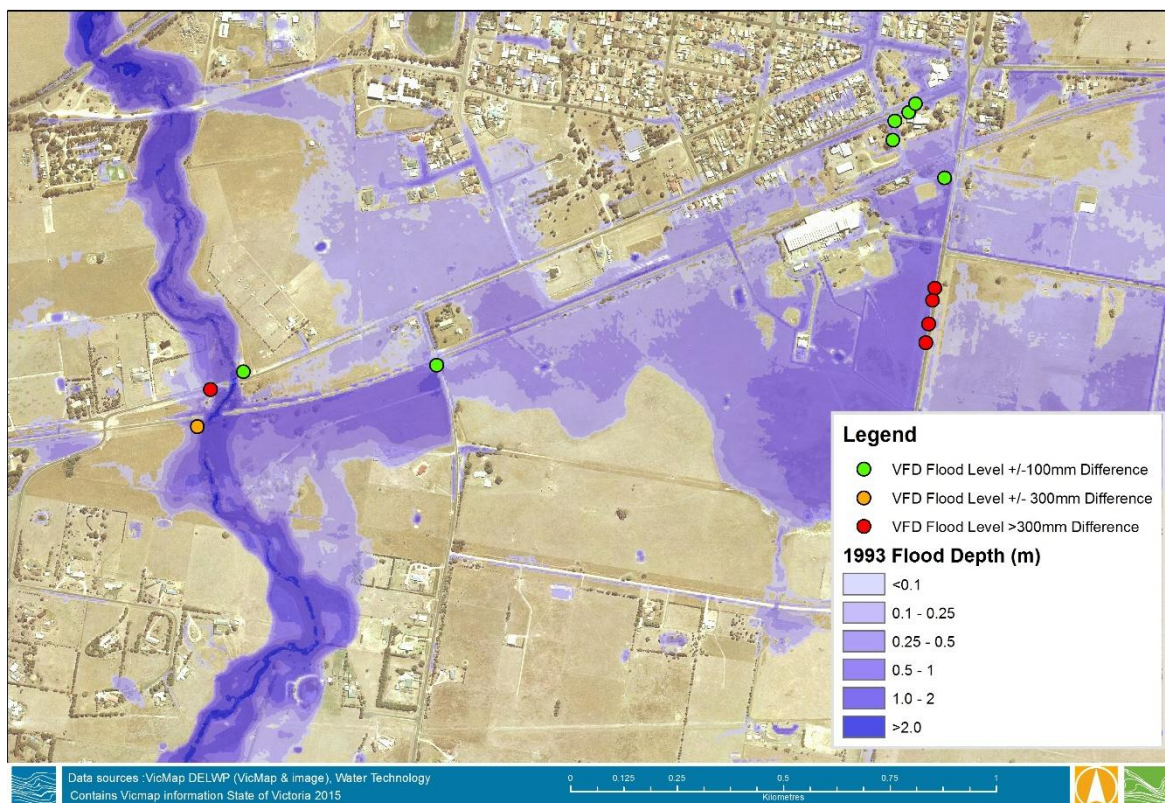


Figure 5-8 September 1993 hydraulic model results compared with observed flood heights – Points nominated as having “detailed contour and flood info”

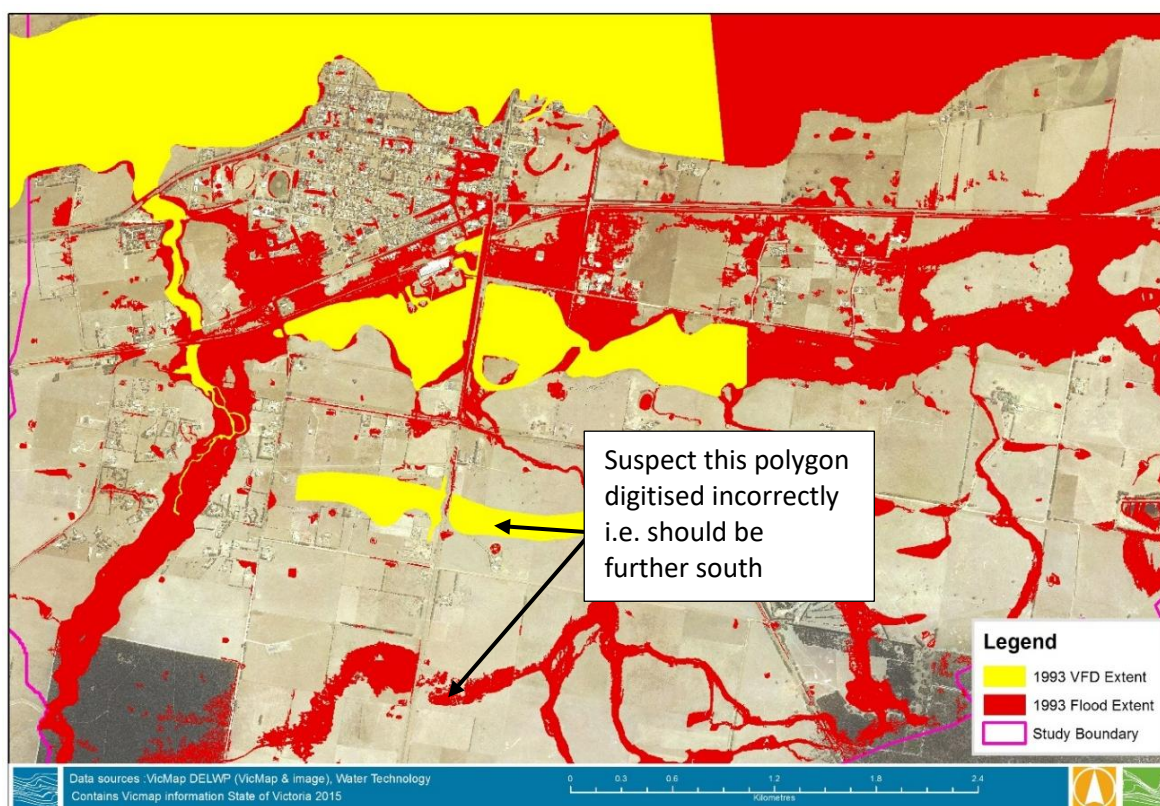


Figure 5-9 September 1993 hydraulic model results compared with VFD flood Extent. Extent base on flood photography from 16th September 1993 (well after the Blind Joes Creek peak flow).

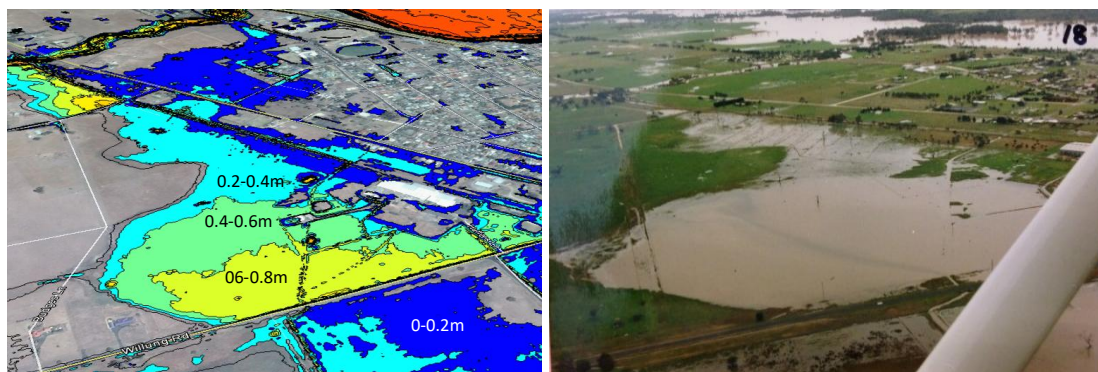


Figure 5-10 September 1993 hydraulic model results (flood depth) compared with oblique aerial photographic record – Willung Road Looking North West

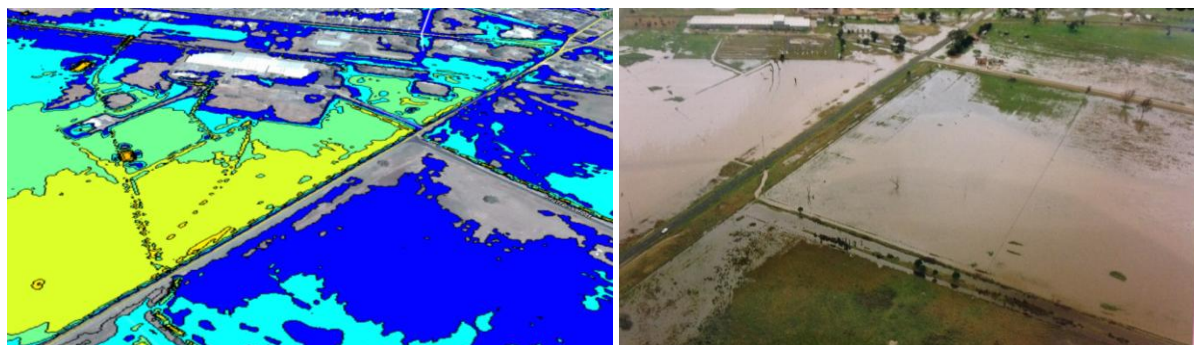


Figure 5-11 September 1993 hydraulic model results compared with oblique aerial photographic record – Willung Road Looking North

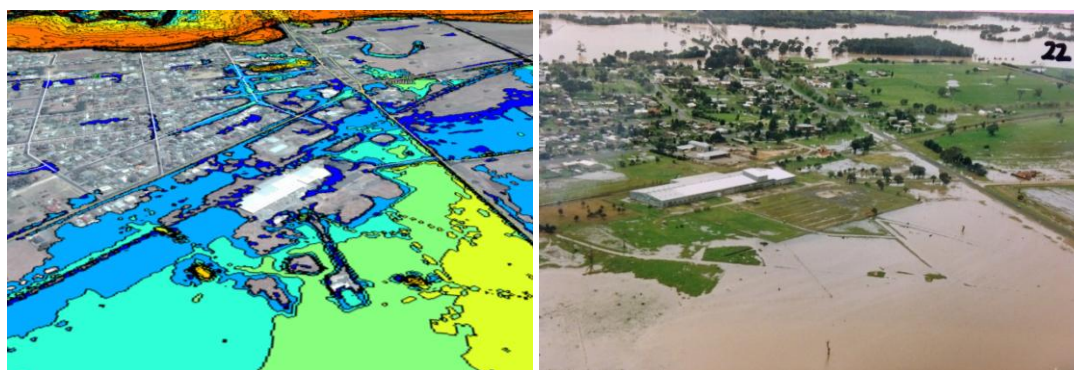


Figure 5-12 September 1993 hydraulic model results compared with oblique aerial photographic record – Willung Road Looking North East

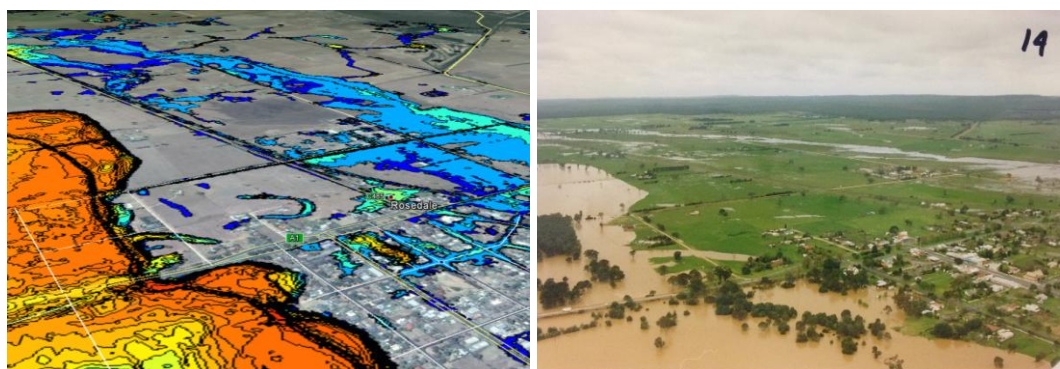


Figure 5-13 September 1993 hydraulic model results compared oblique aerial photographic record Latrobe River

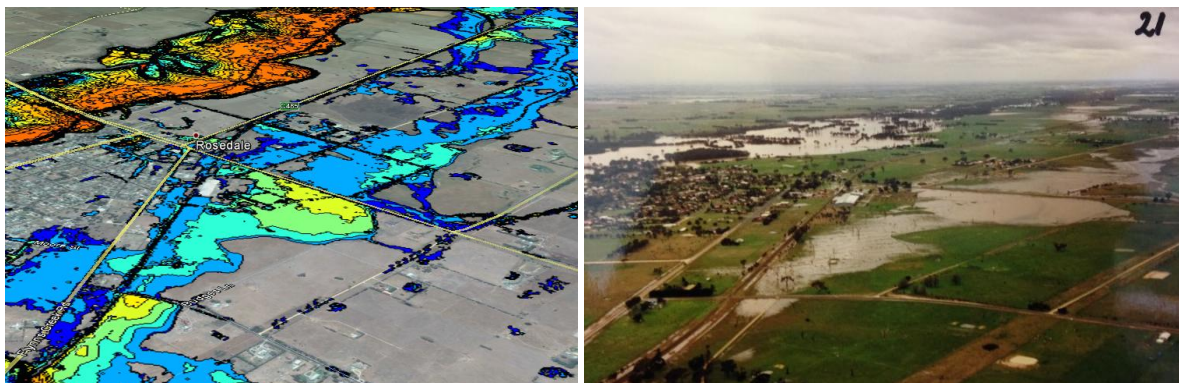


Figure 5-14 September 1993 hydraulic model results compared with oblique aerial photographic record – Friends Road

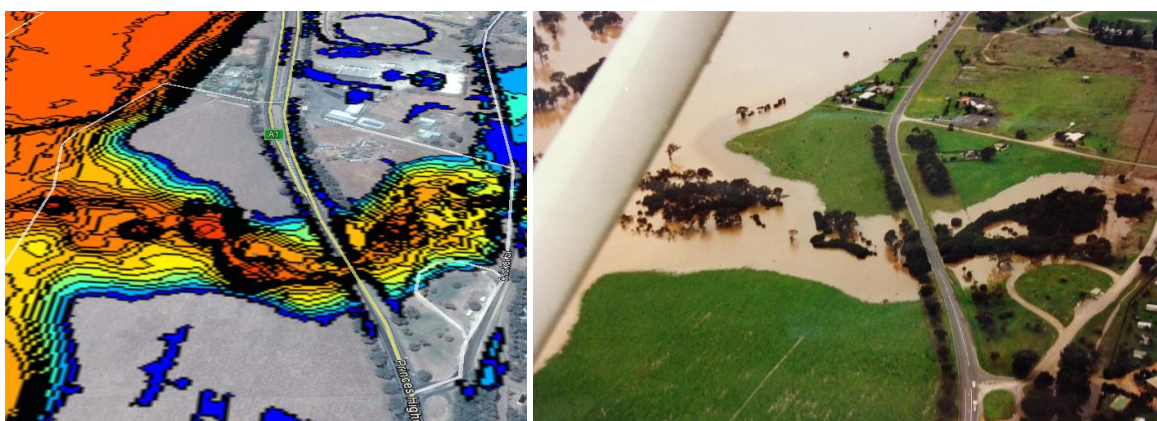


Figure 5-15 September 1993 hydraulic model results compared with oblique aerial photographic record – Princes Highway (west)



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.

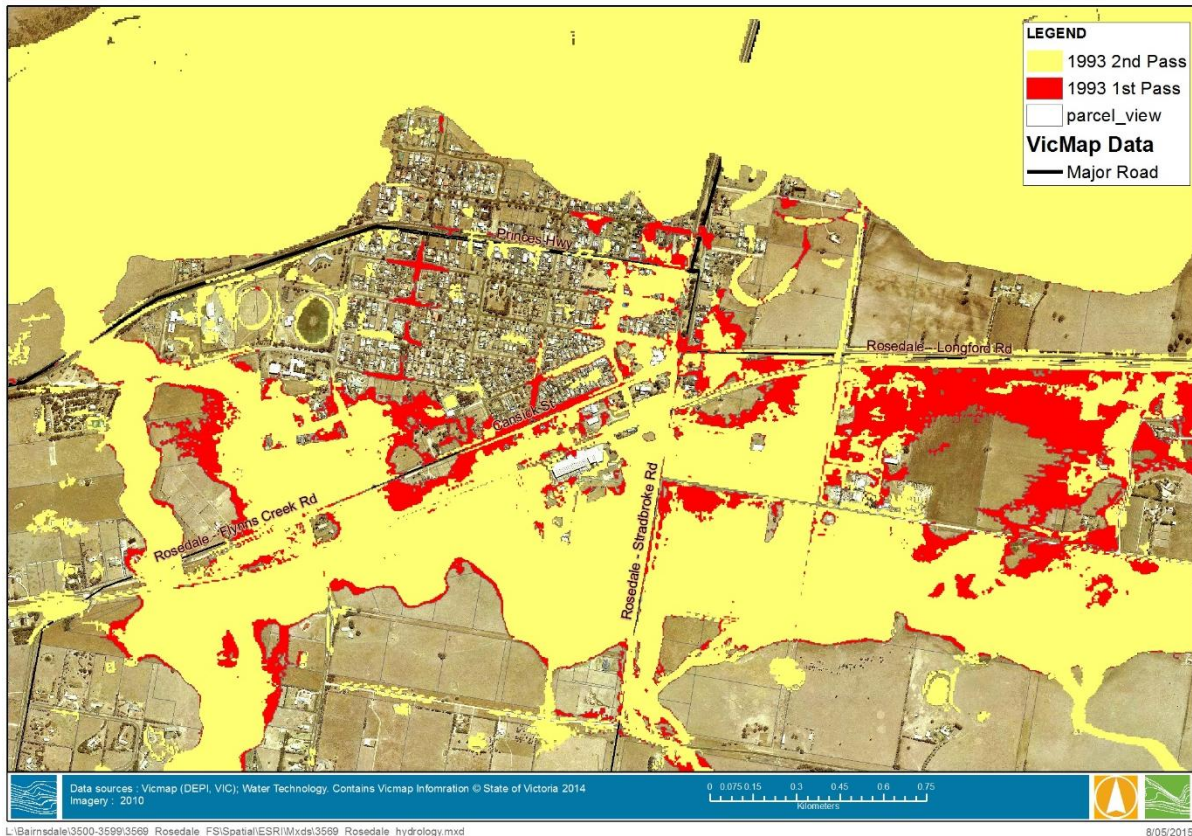


Figure 5-17 Approximate change in flood extent after using community rainfall records

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.

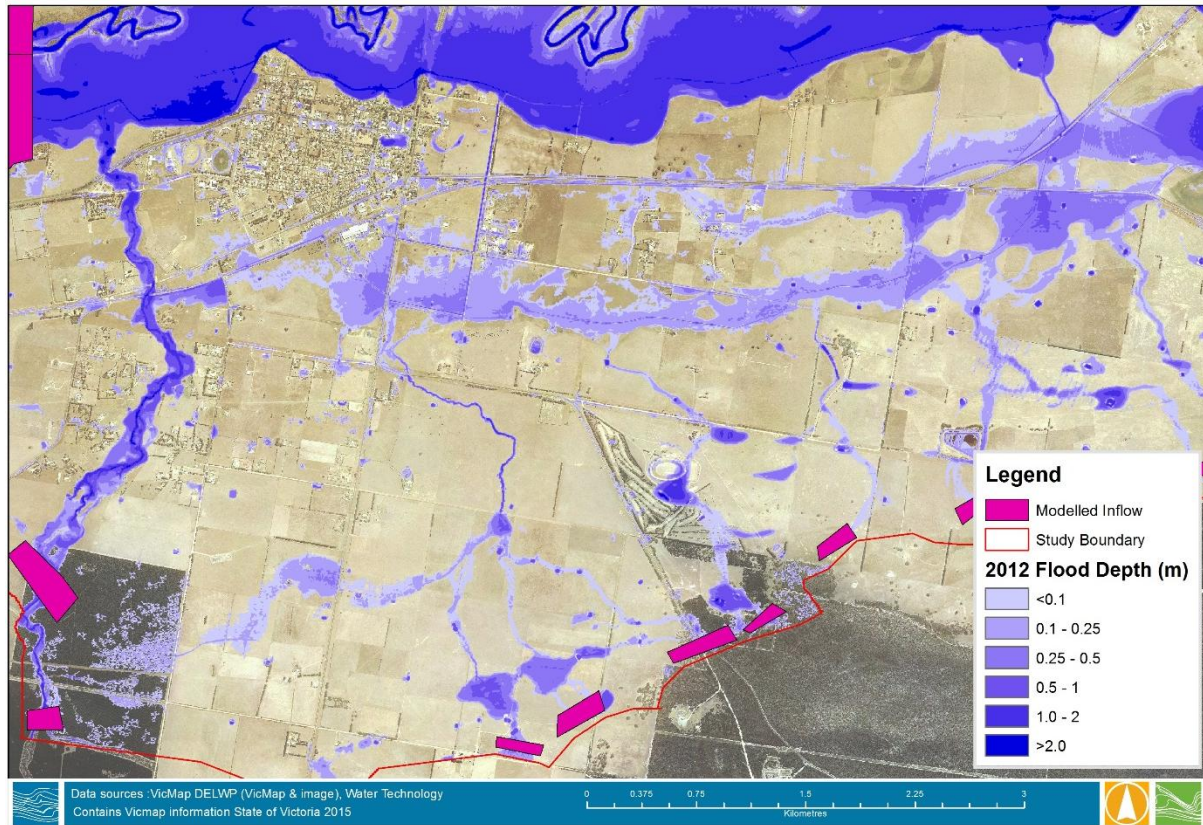


Figure 5-18 June 2012 hydraulic model results using the Stradbroke West temporal pattern

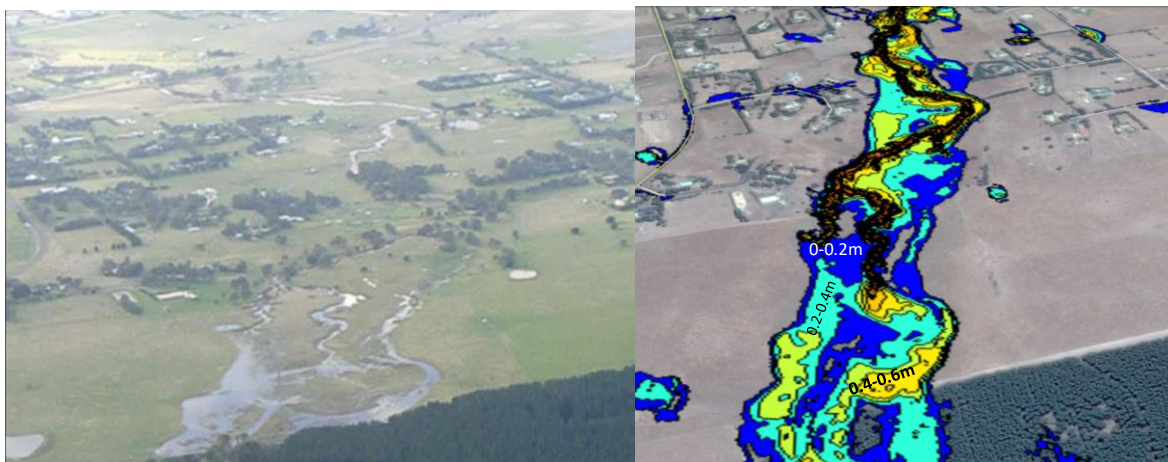


Figure 5-19 June 2012 hydraulic model results compared to video footage from the WGCMA – Rosedale-Flynns Creek Road (South)

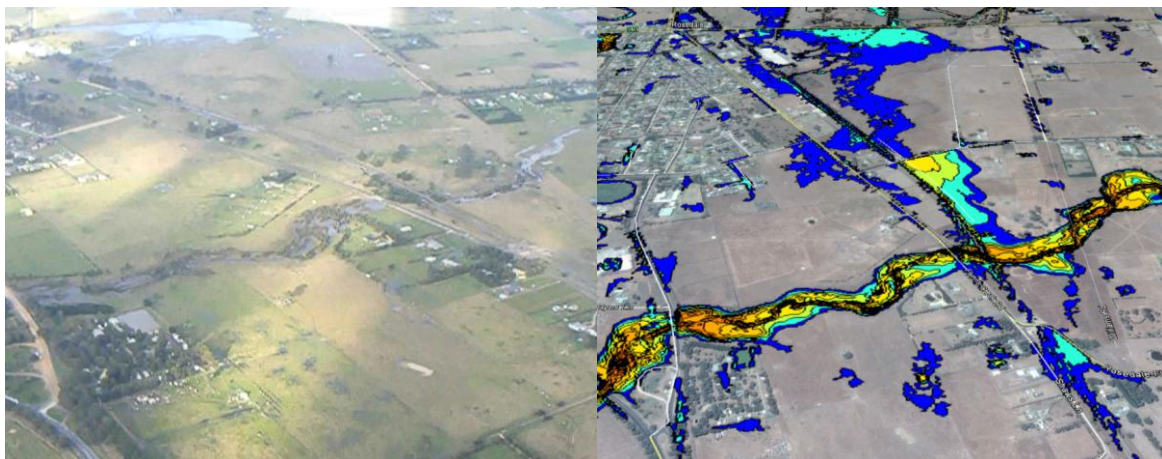


Figure 5-20 June 2012 hydraulic model results compared to video footage from the WGCMA – Rosedale-Flynns Creek Road (North)

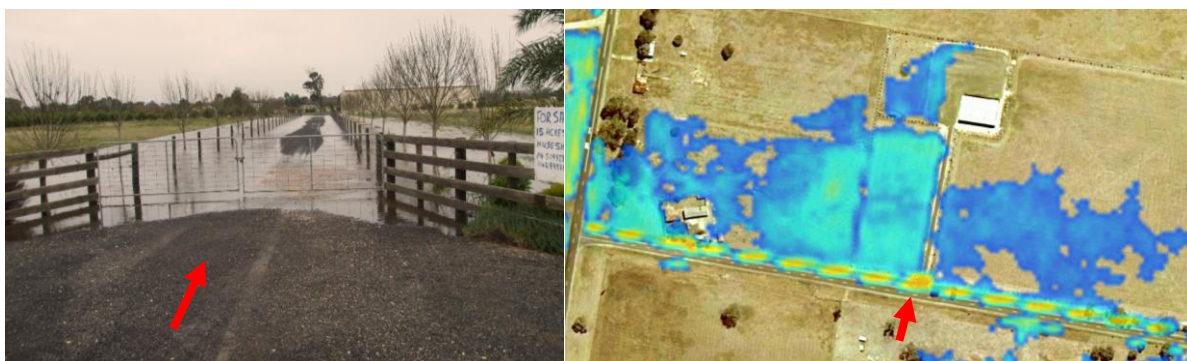


Figure 5-21 June 2012 hydraulic model results compared to photograph from the WSC – Huffers Lane looking north 5th June 2012

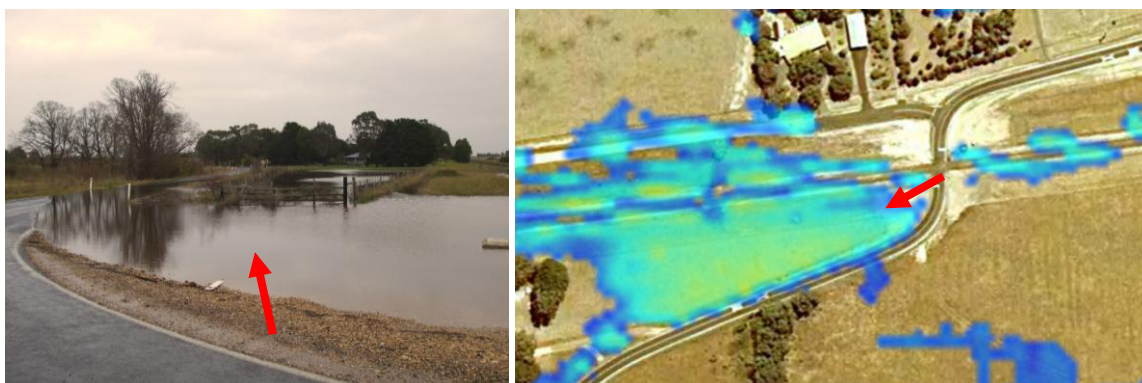


Figure 5-22 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Flynns Creek Road 5th June 2012

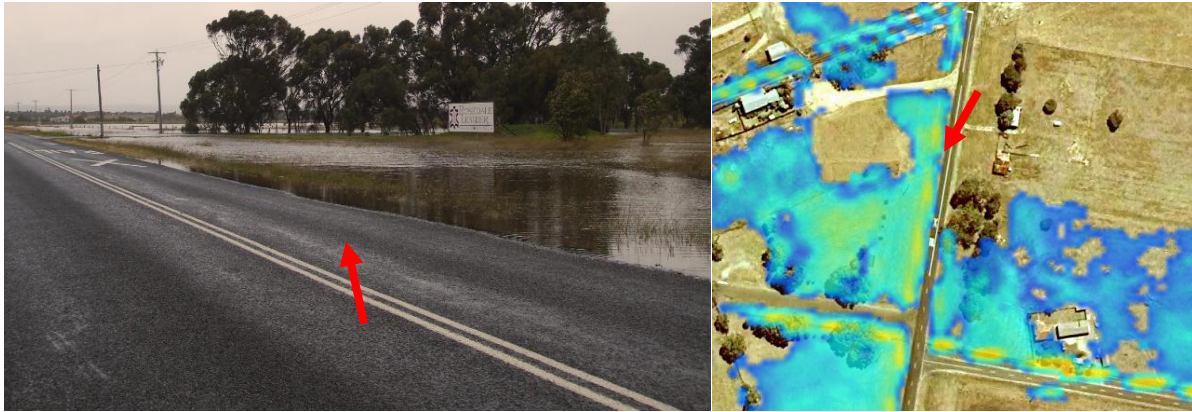


Figure 5-23 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Willung Road 5th June 2012



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

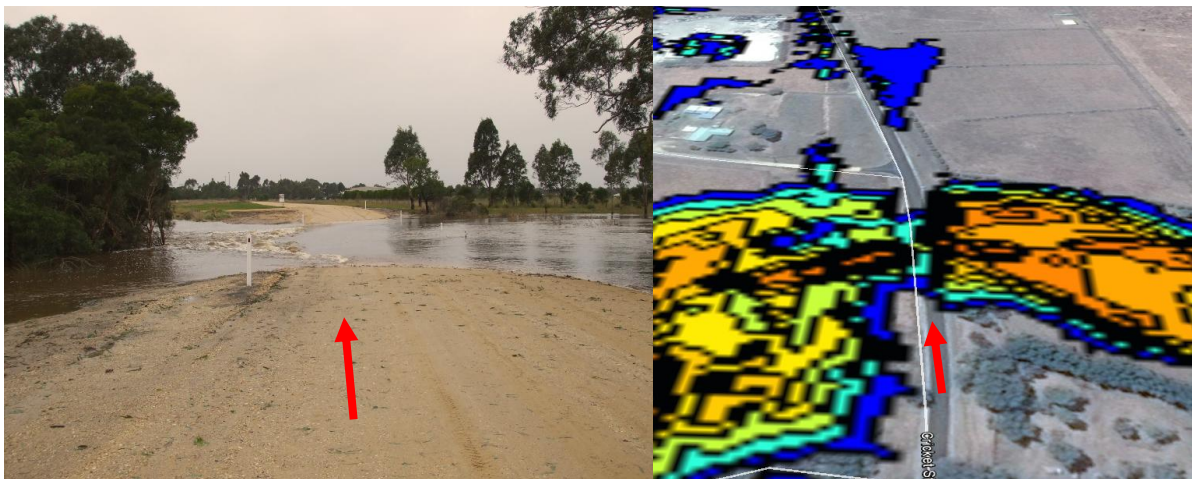


Figure 5-25 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-Cricket Street low level crossing - 5th June 2012

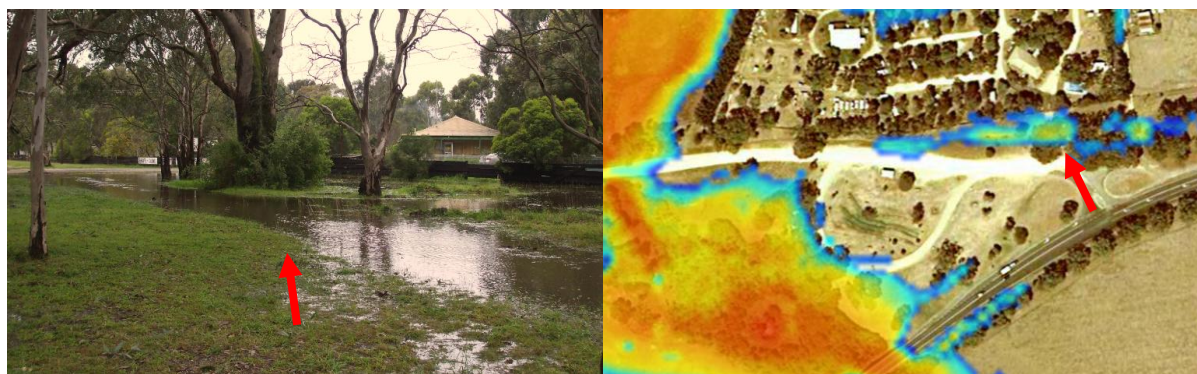


Figure 5-26 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-
Rosedale Caravan Park - 5th June 2012



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

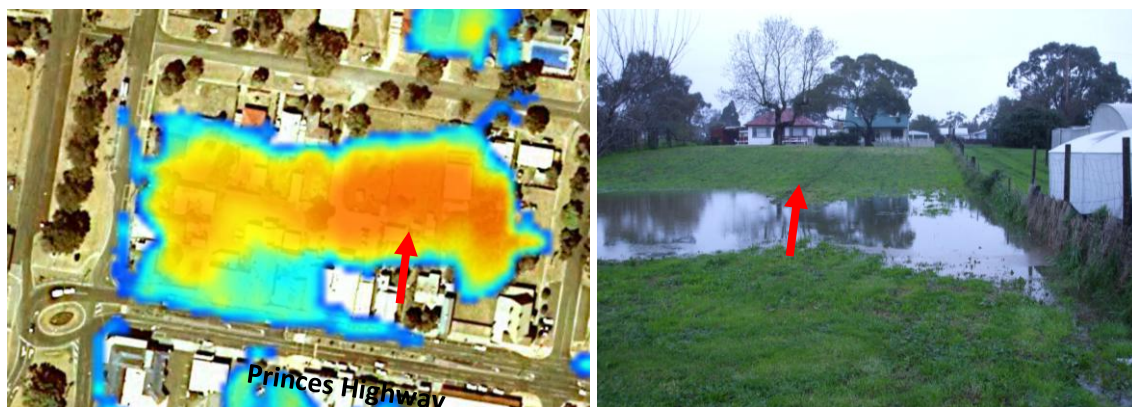


Figure 5-29 June 2012 hydraulic model results compared to photograph from the WSC Rosedale-
Behind Princes Highway - 5th June 2012

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%

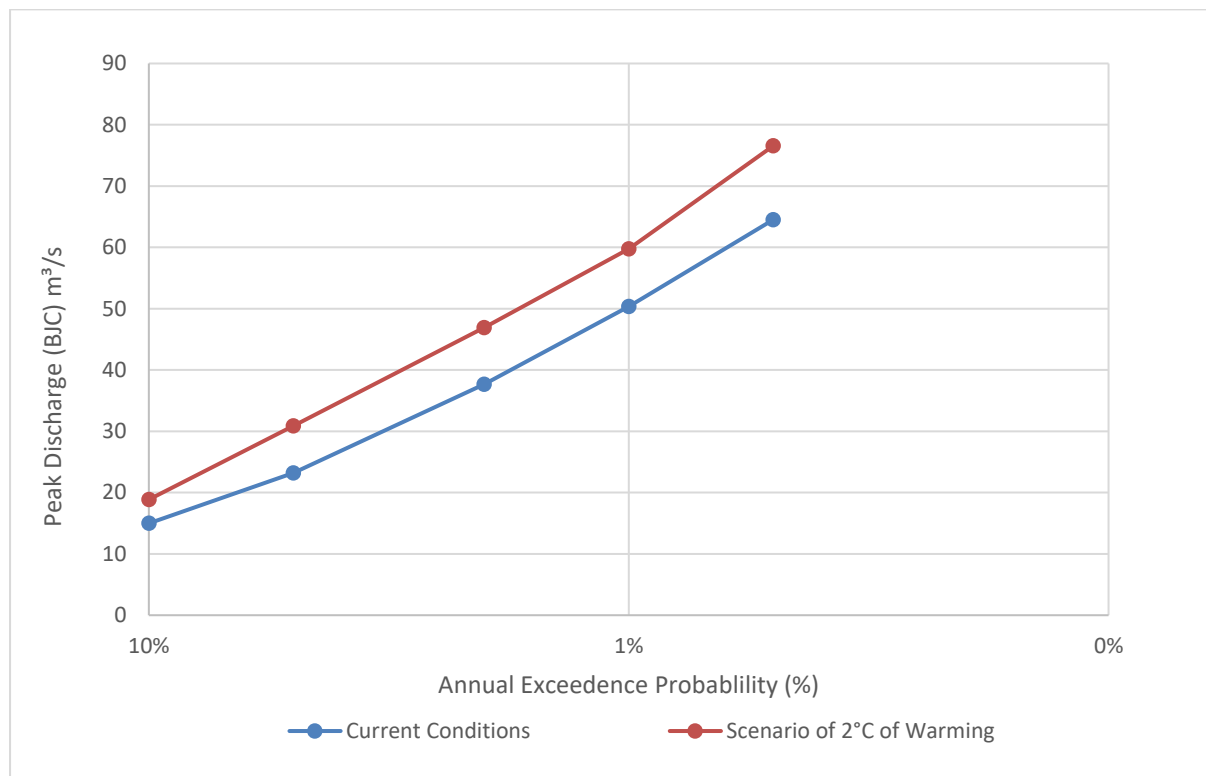


Figure 6-1 Climate change sensitivity comparison for Blind Joes Creek

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).

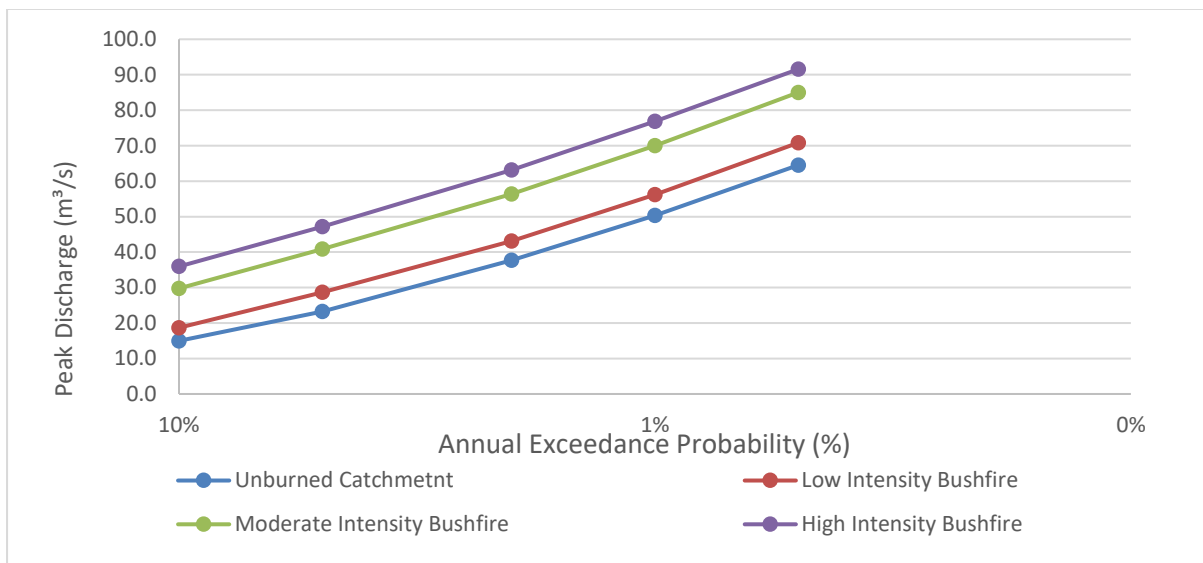
Table 6-8 Equivalent percentage impervious for different levels of burn severity

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.

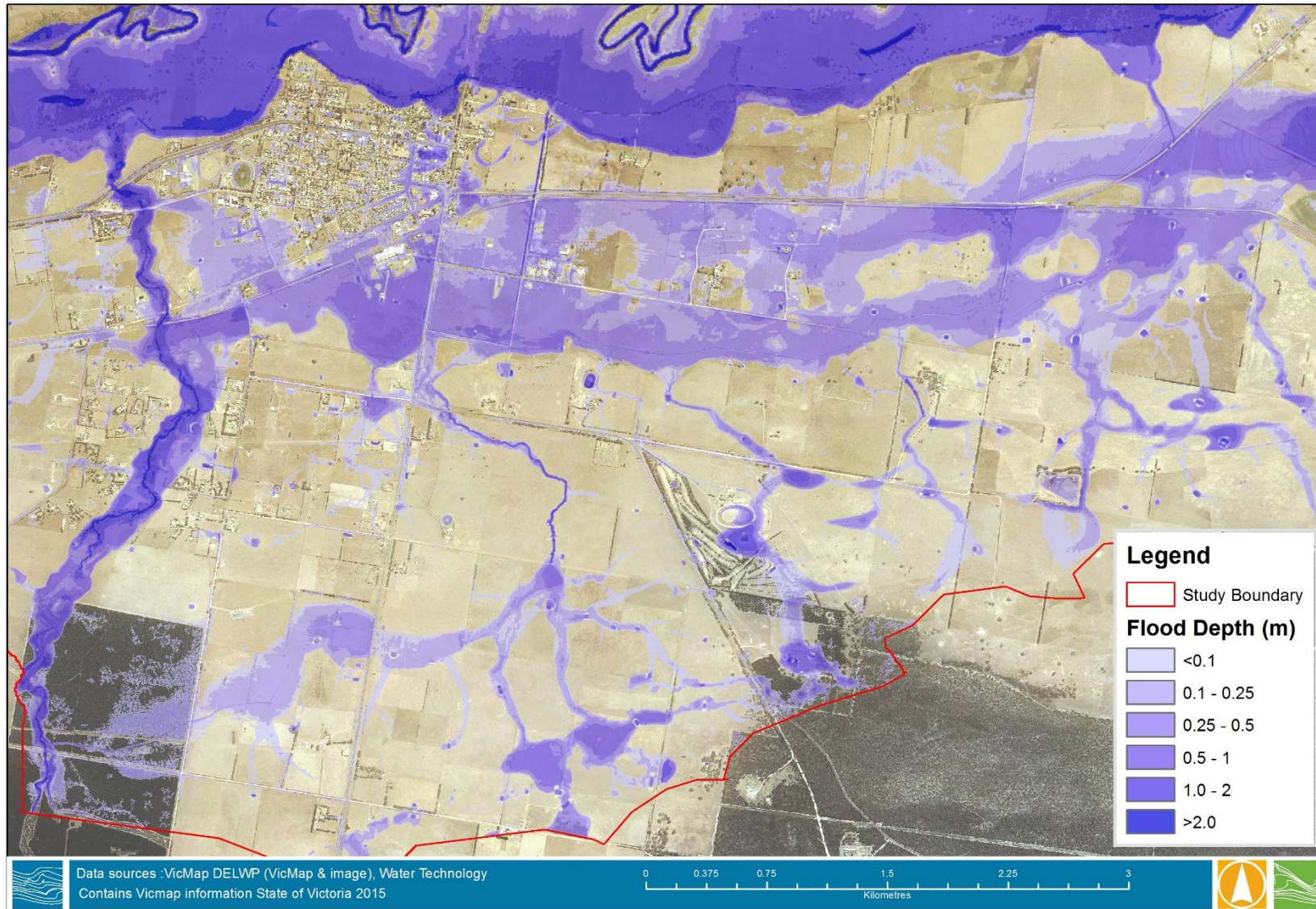


Figure 7-1 1% AEP Blind Joes Creek Flood Depth (10% AEP Latrobe Flow)

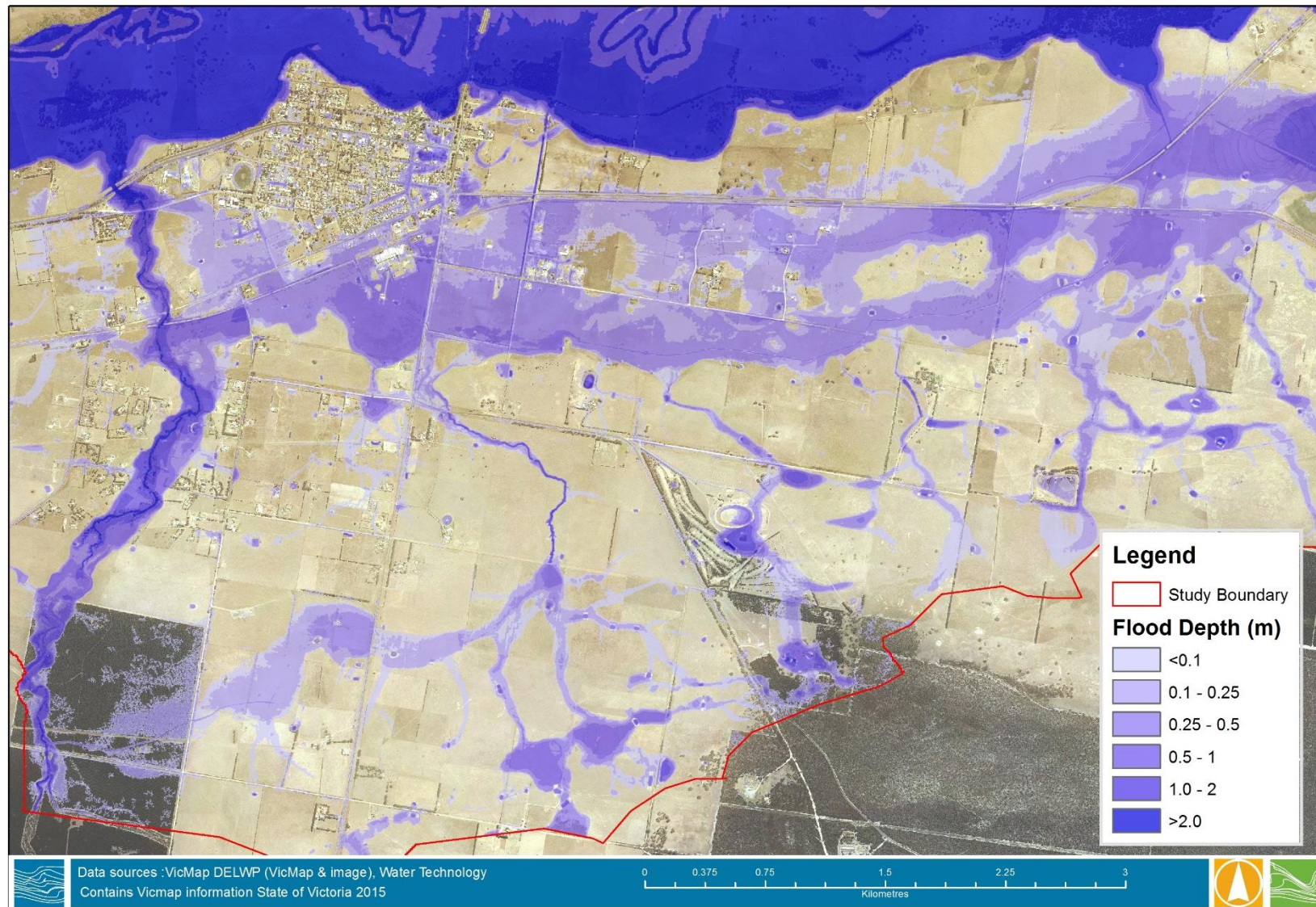


Figure 7-2 1% AEP Flood Depth with 1% AEP Latrobe River flow

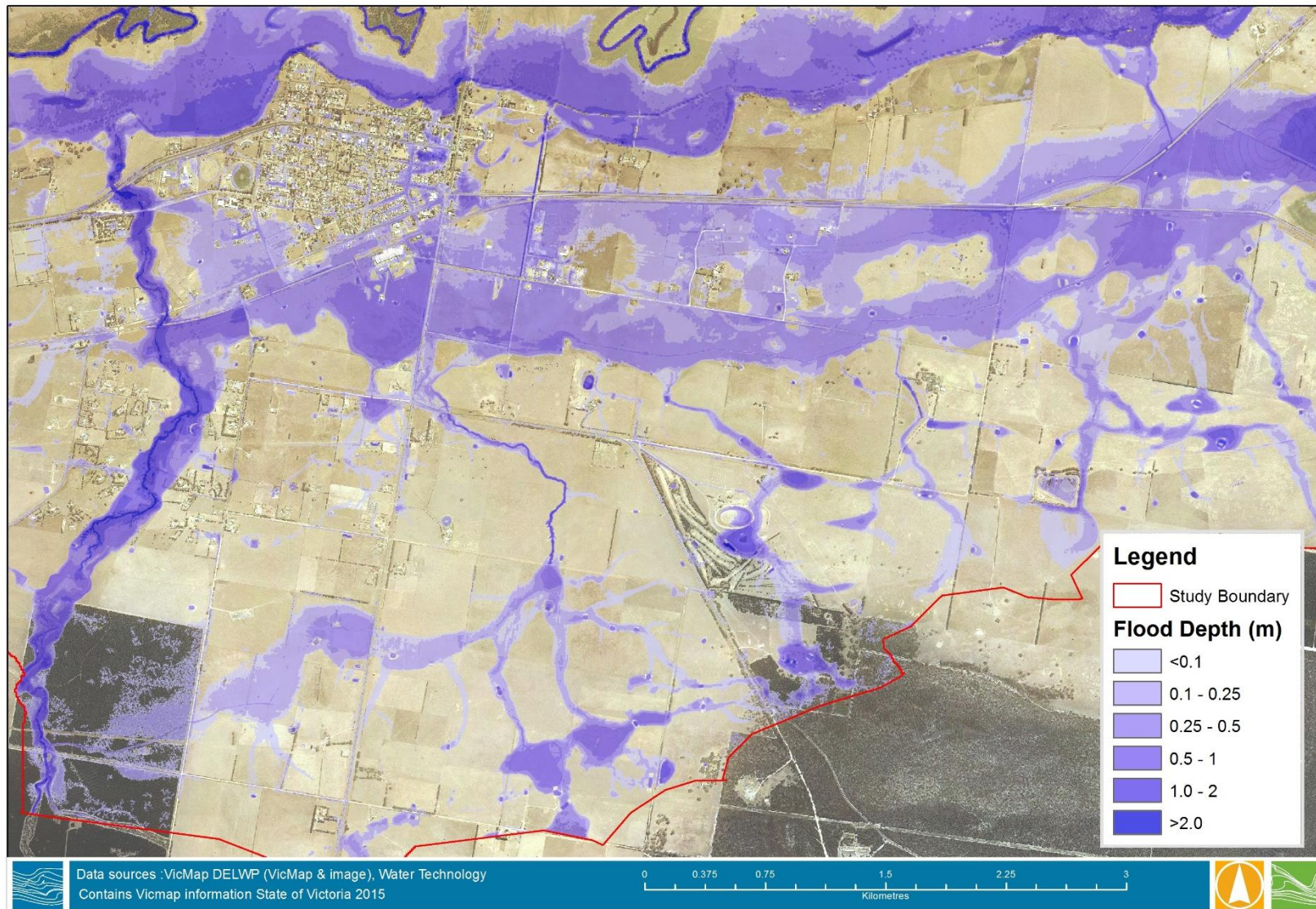


Figure 7-3 1% AEP Flood Depth with low flow Latrobe River conditions

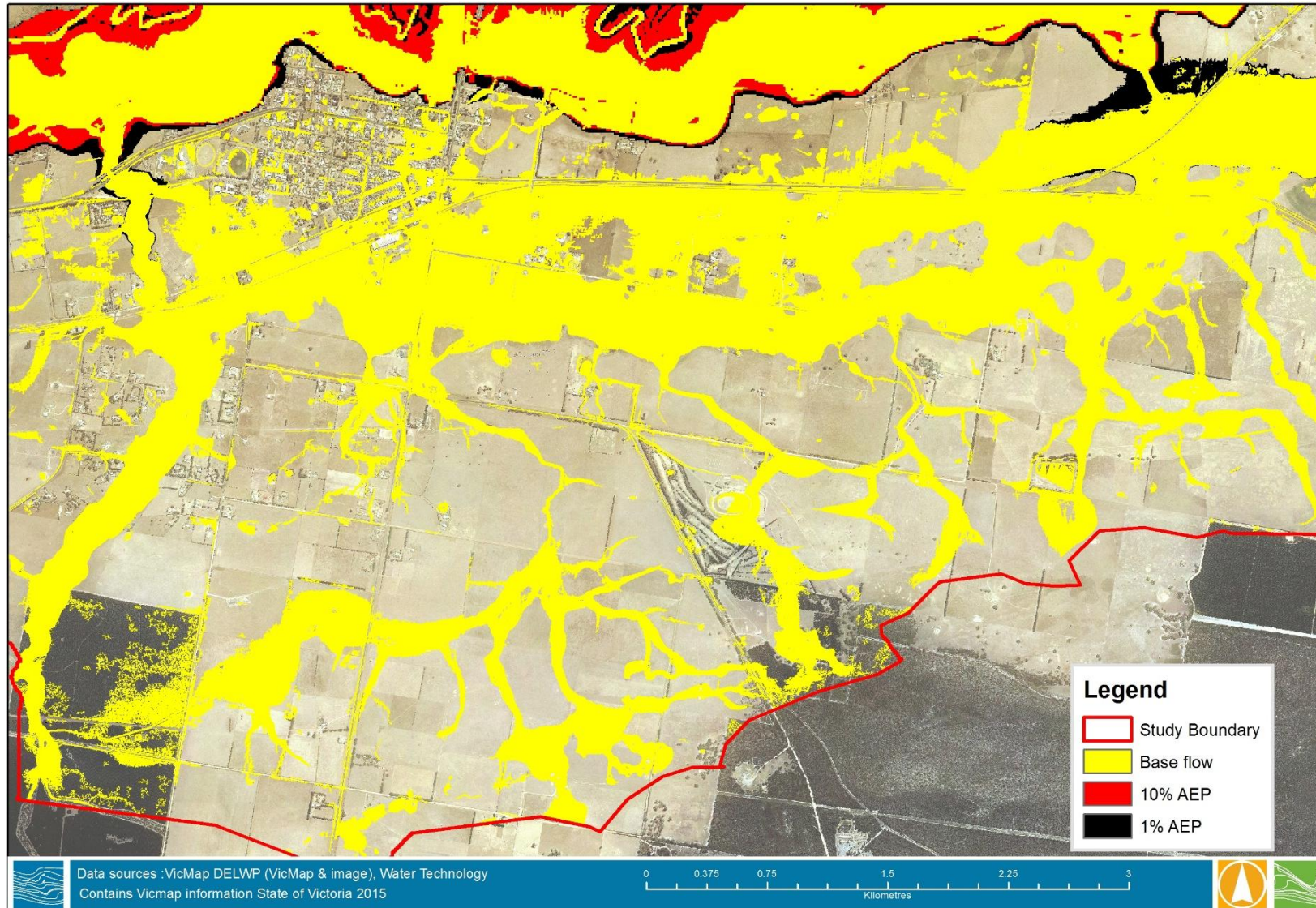


Figure 7-4 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – Study Area

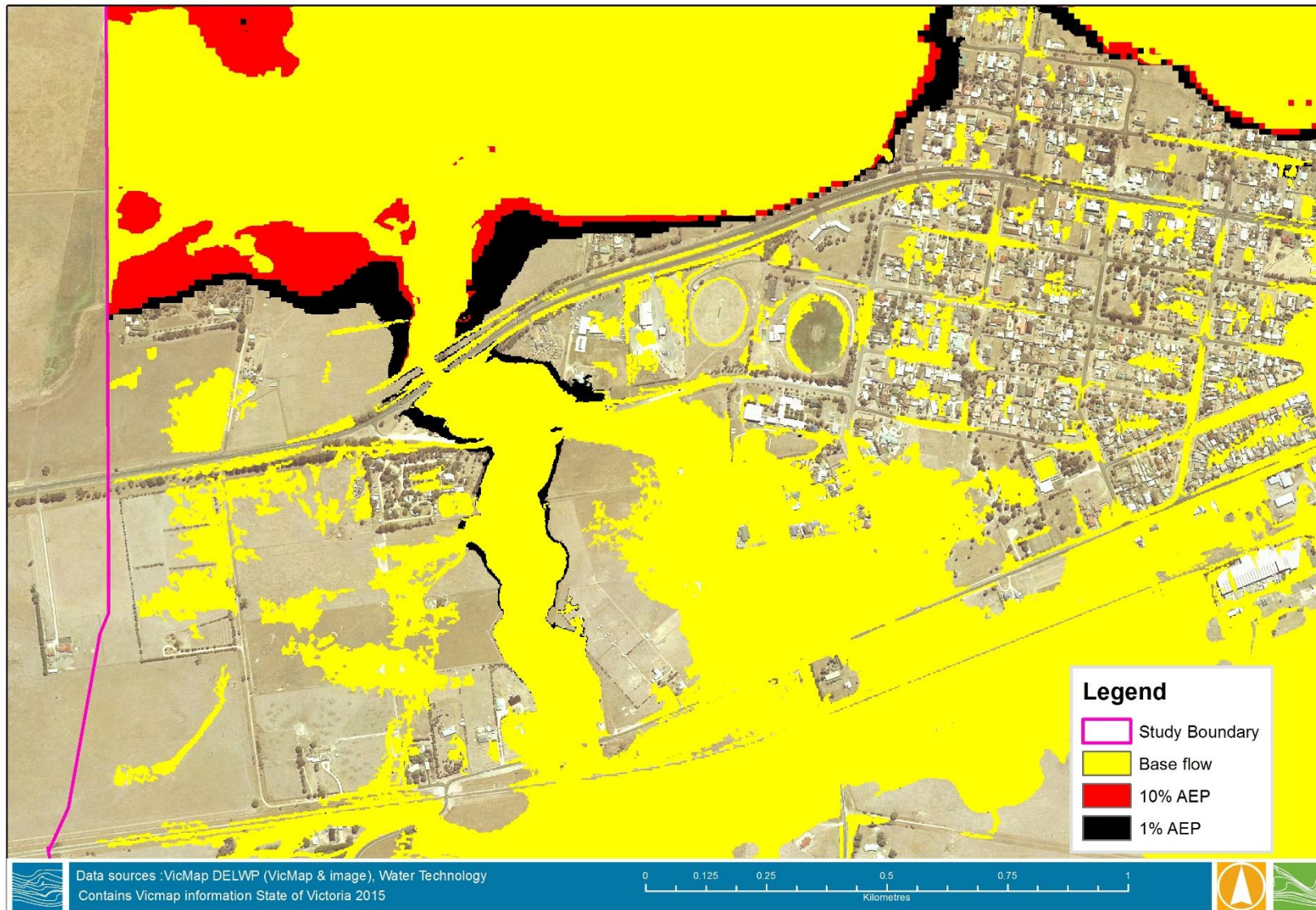


Figure 7-5 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – West

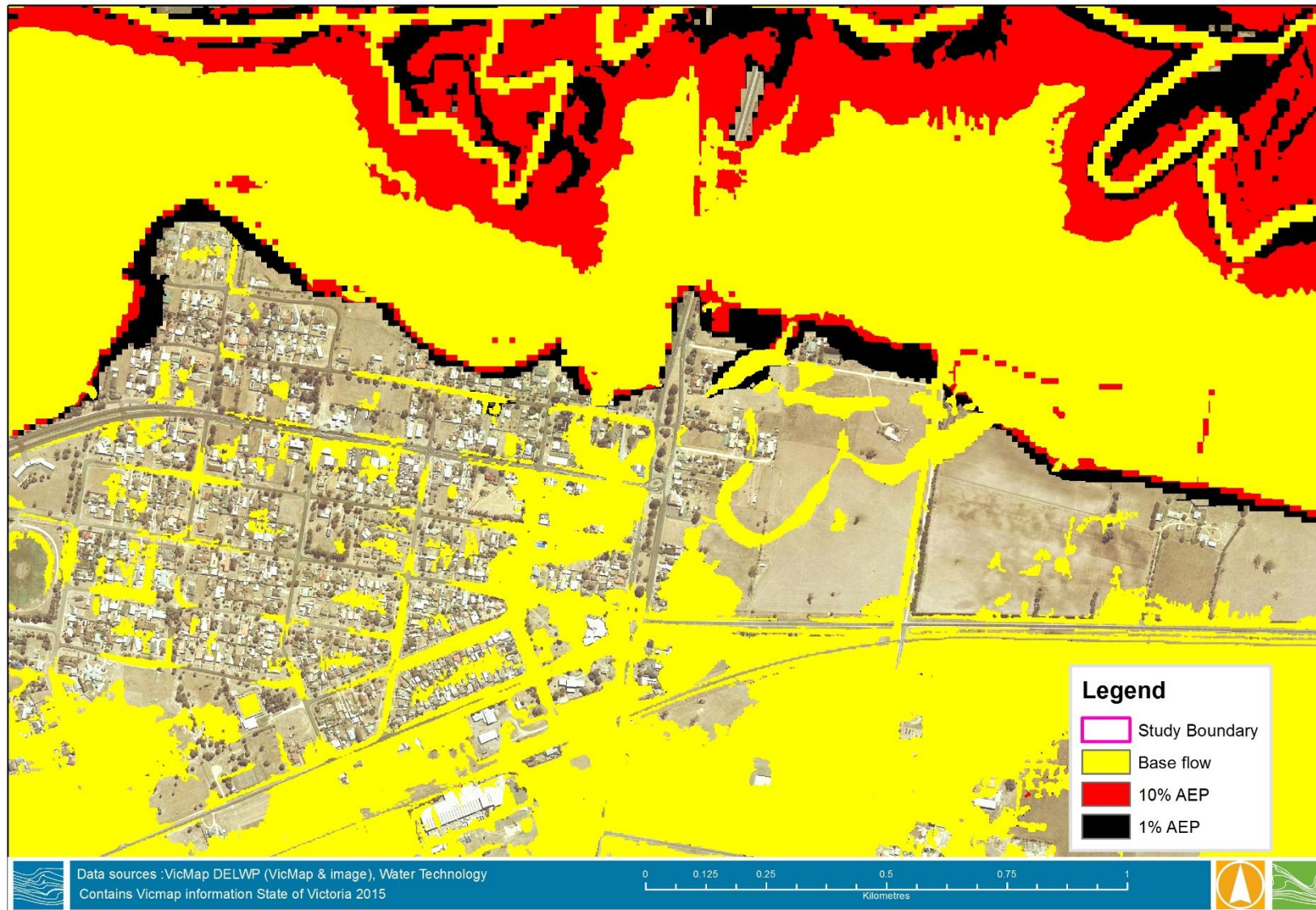


Figure 7-6 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – Central

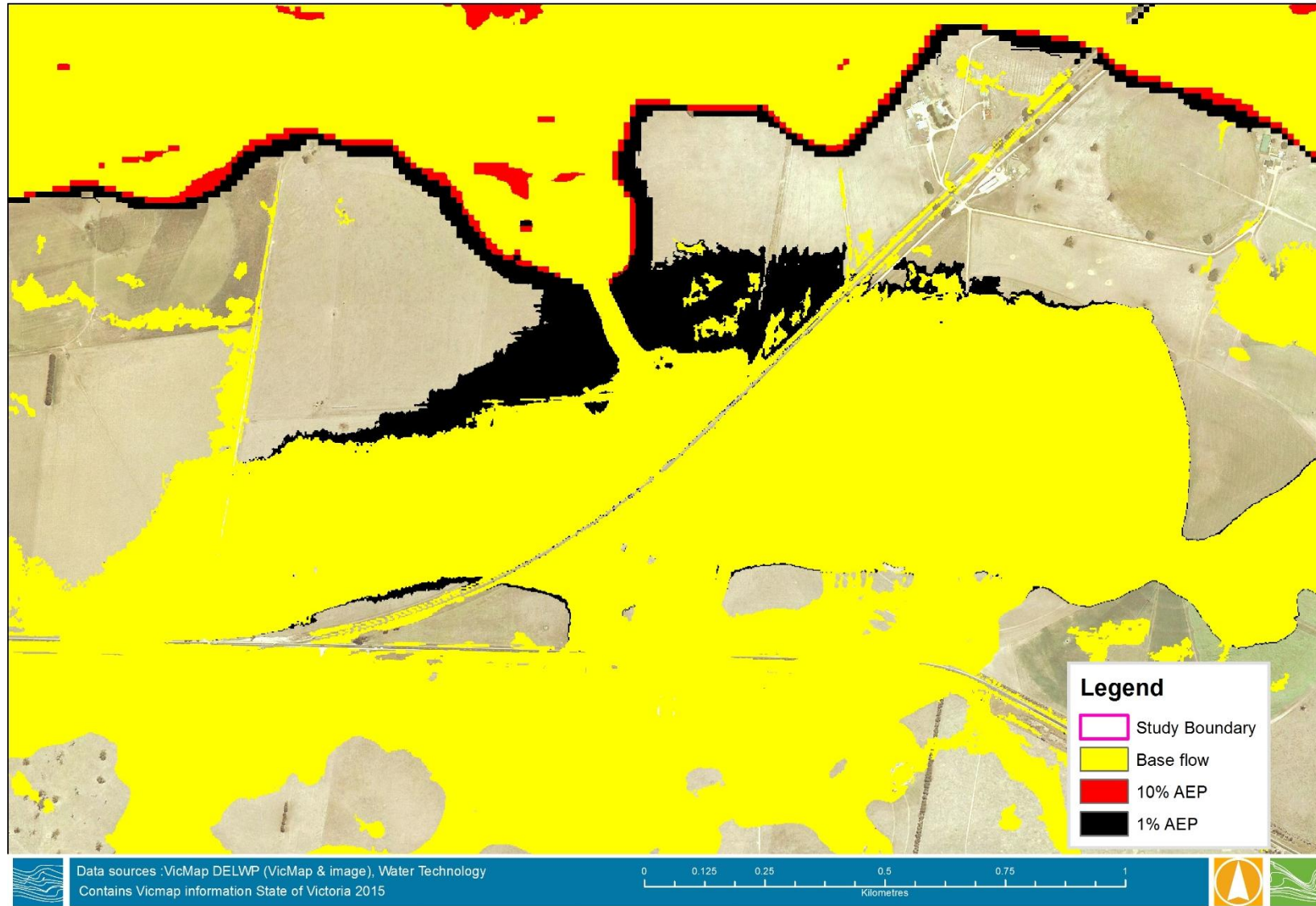


Figure 7-7 1% AEP Latrobe River Tailwater Sensitivity Extent Comparison – East

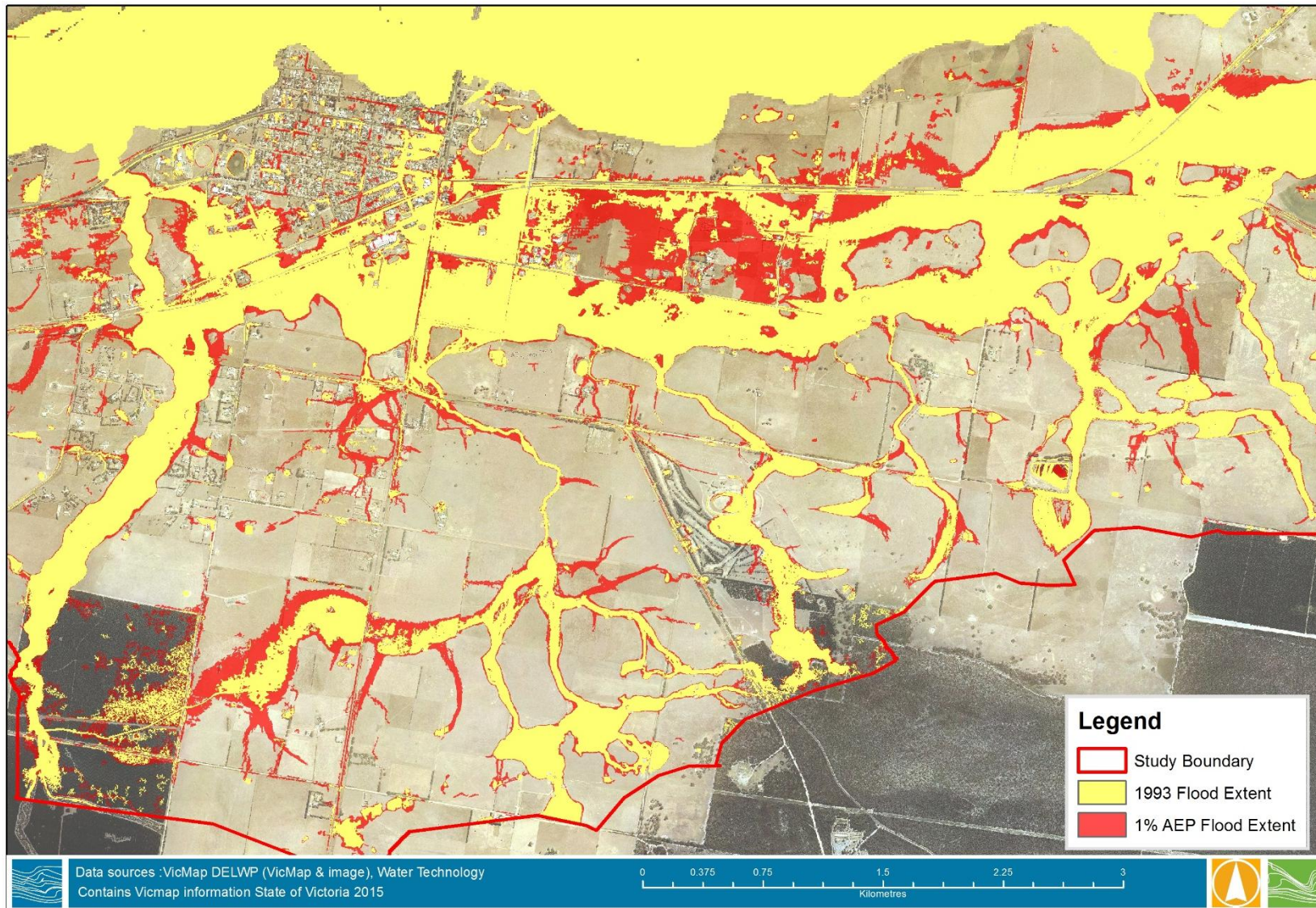


Figure 7-8 1% AEP Flood extent (10% AEP Latrobe River flow) compared with 1993 validation modelling

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 8-2. 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 preferenced 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 8-5), 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 8-6), 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 8-7). 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.

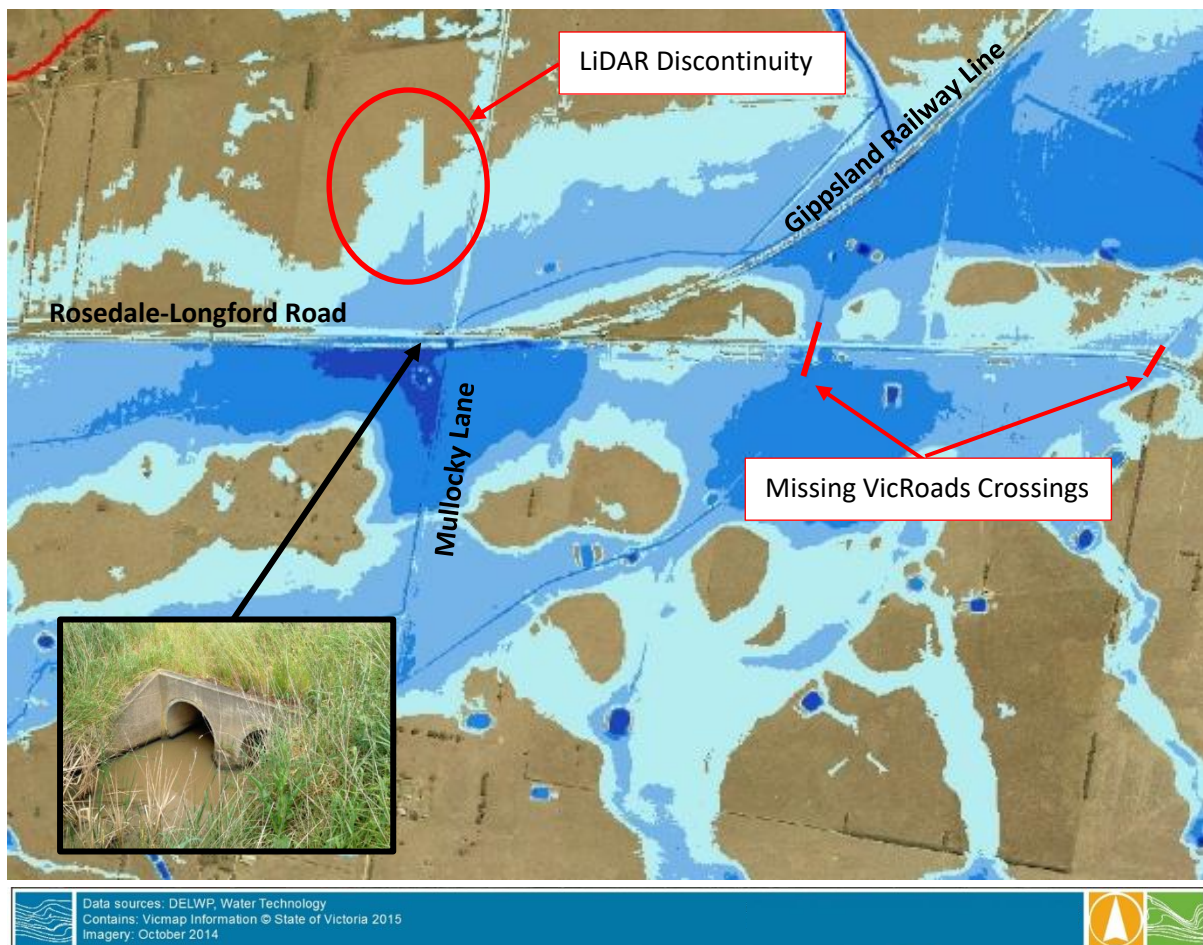


Figure 8-1 Minor problems identified with design mapping

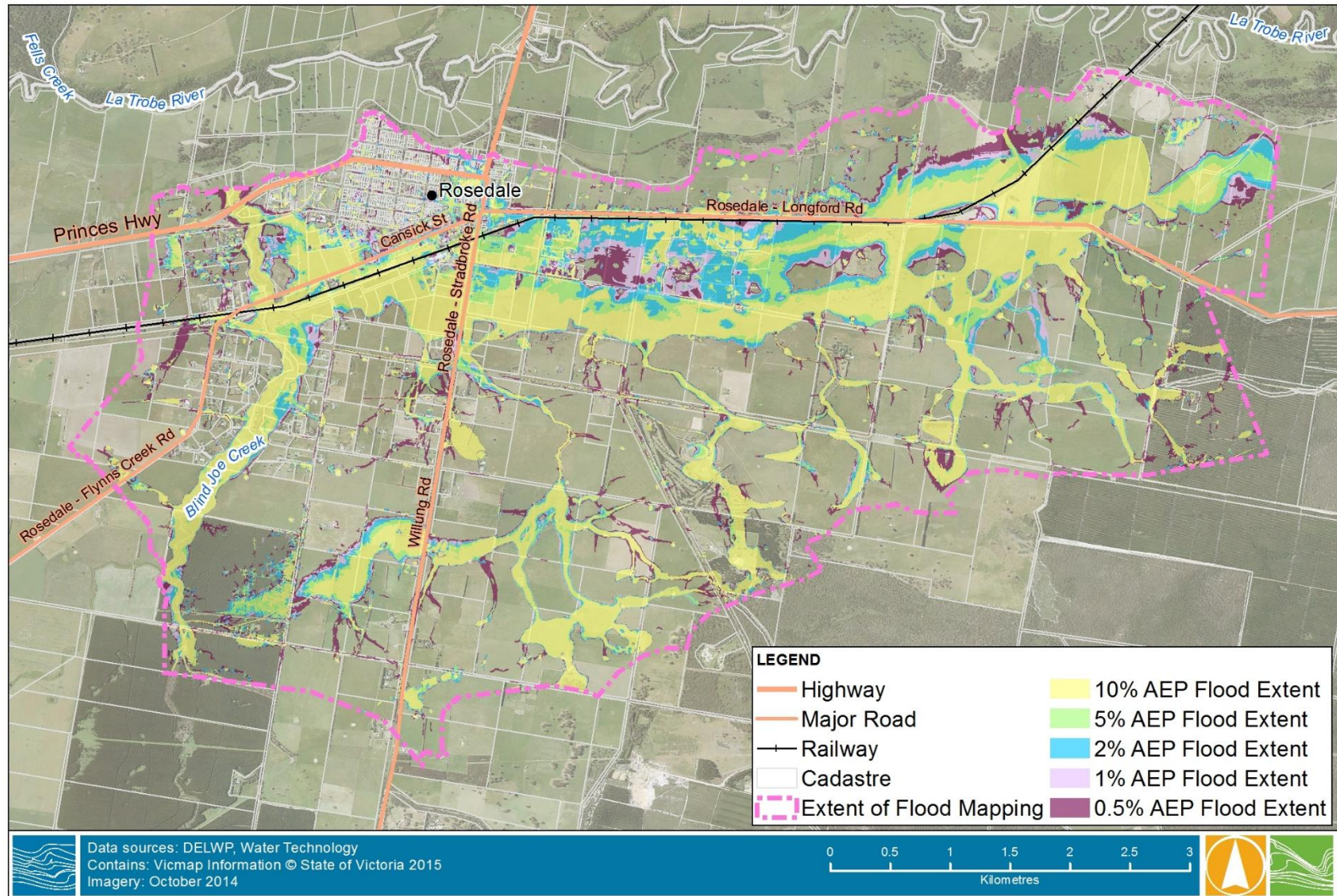


Figure 8-2 Design modelling results - 0.5%, 1%, 2%, 5% and 10% AEP flood extents

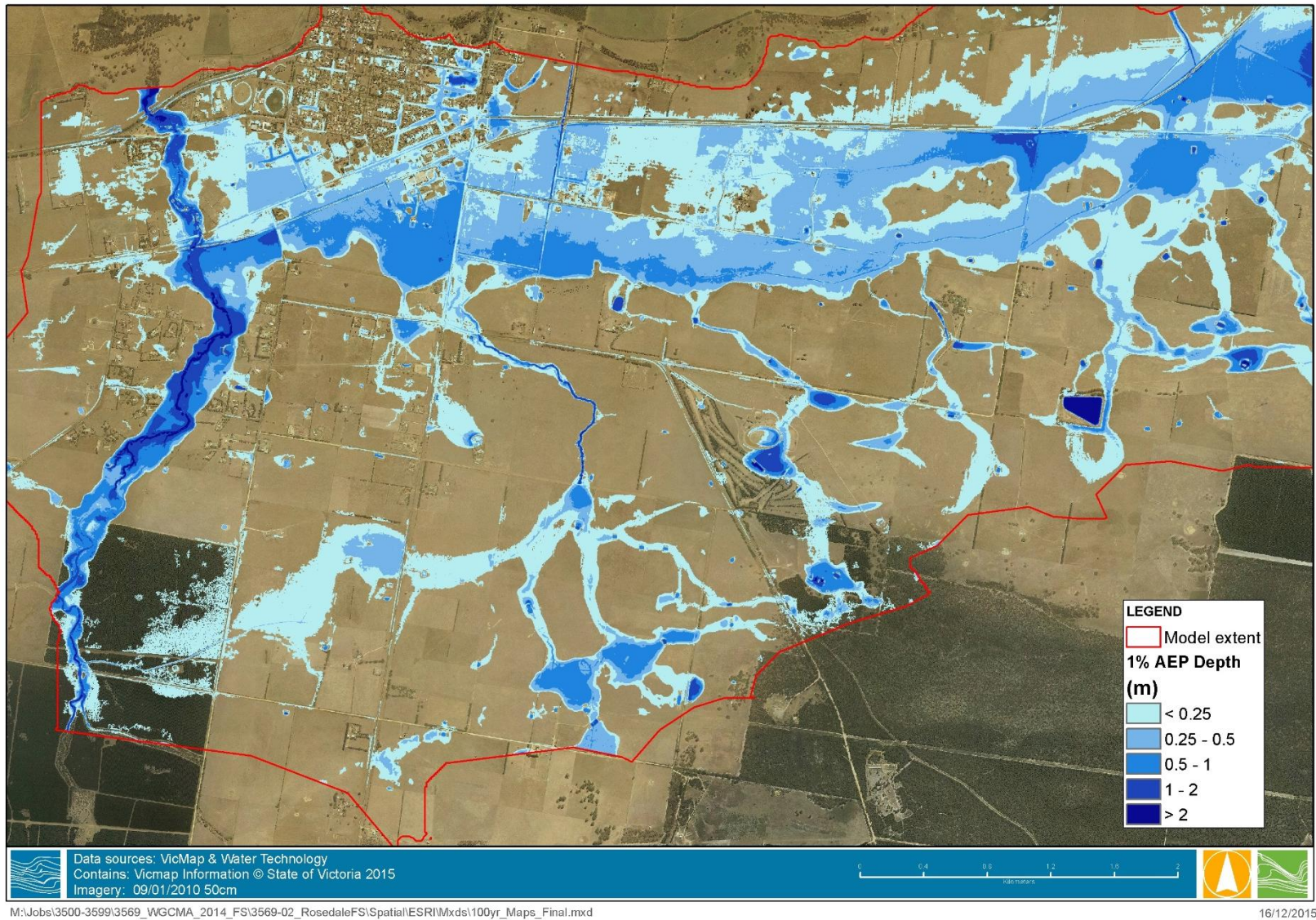


Figure 8-3 Design modelling results 1% AEP flood depth

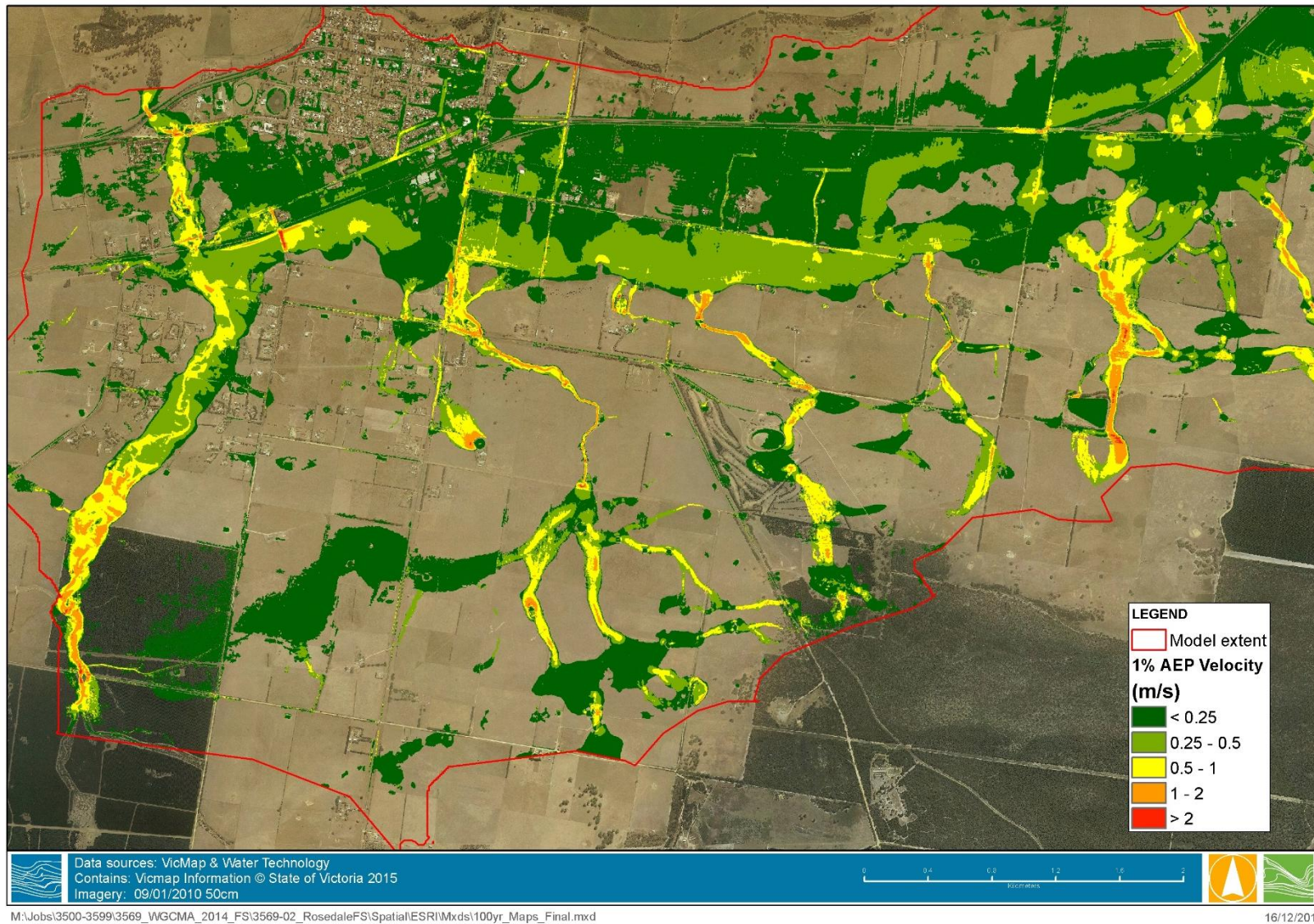


Figure 8-4 Design modelling results 1% AEP flood velocity

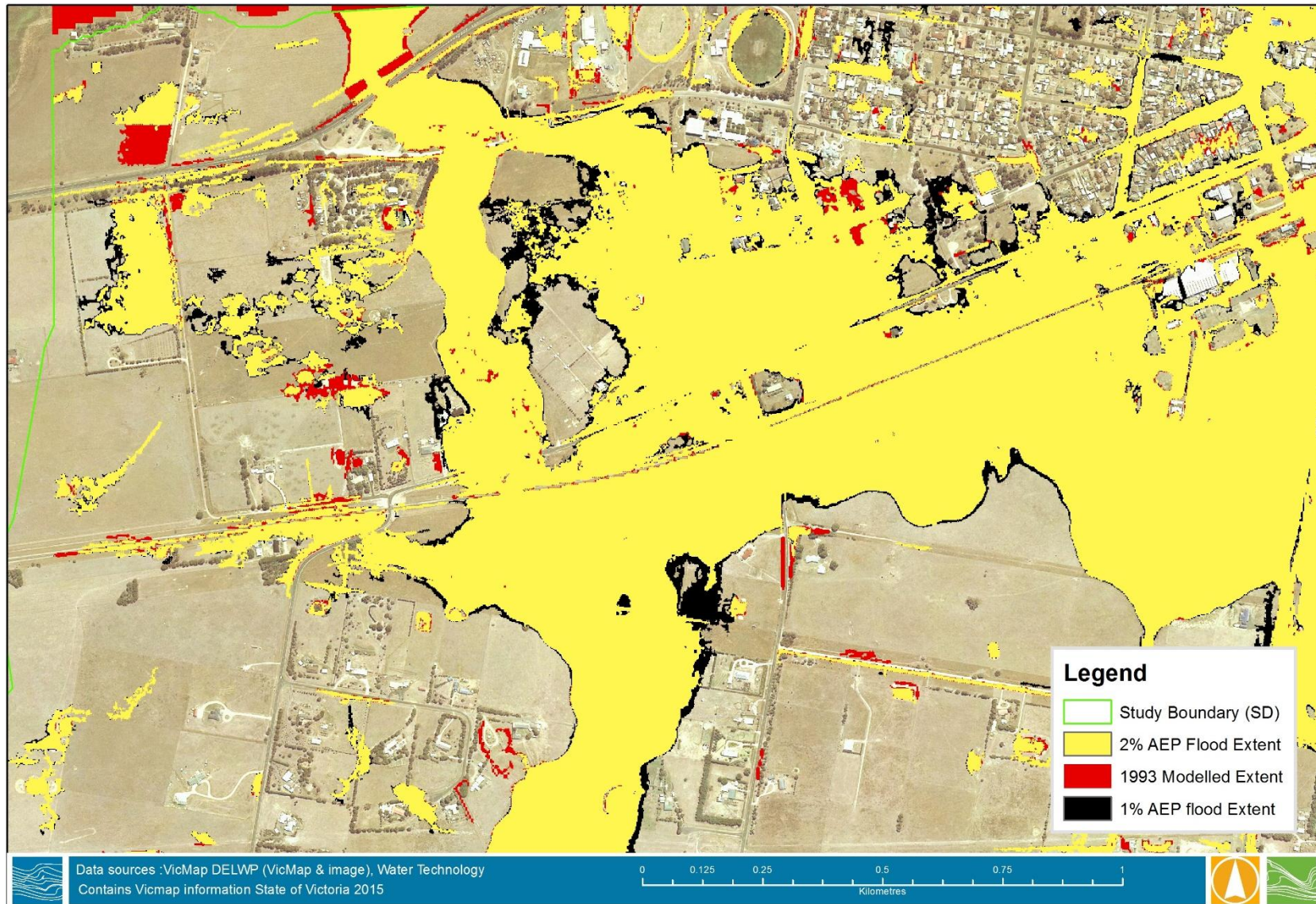


Figure 8-5 Design modelling results compared with 1993 flood

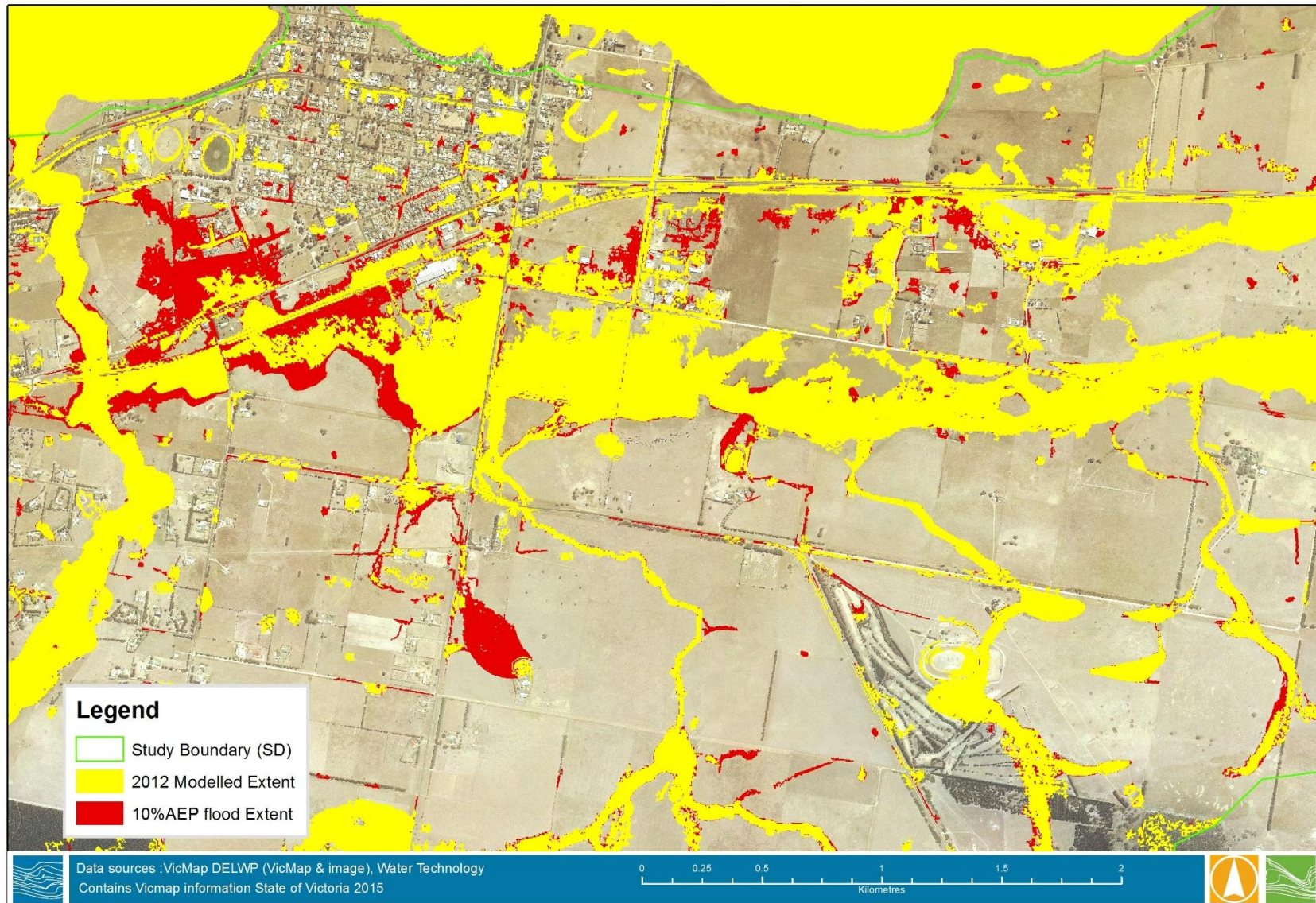


Figure 8-6 Design modelling results compared with 2012 flood

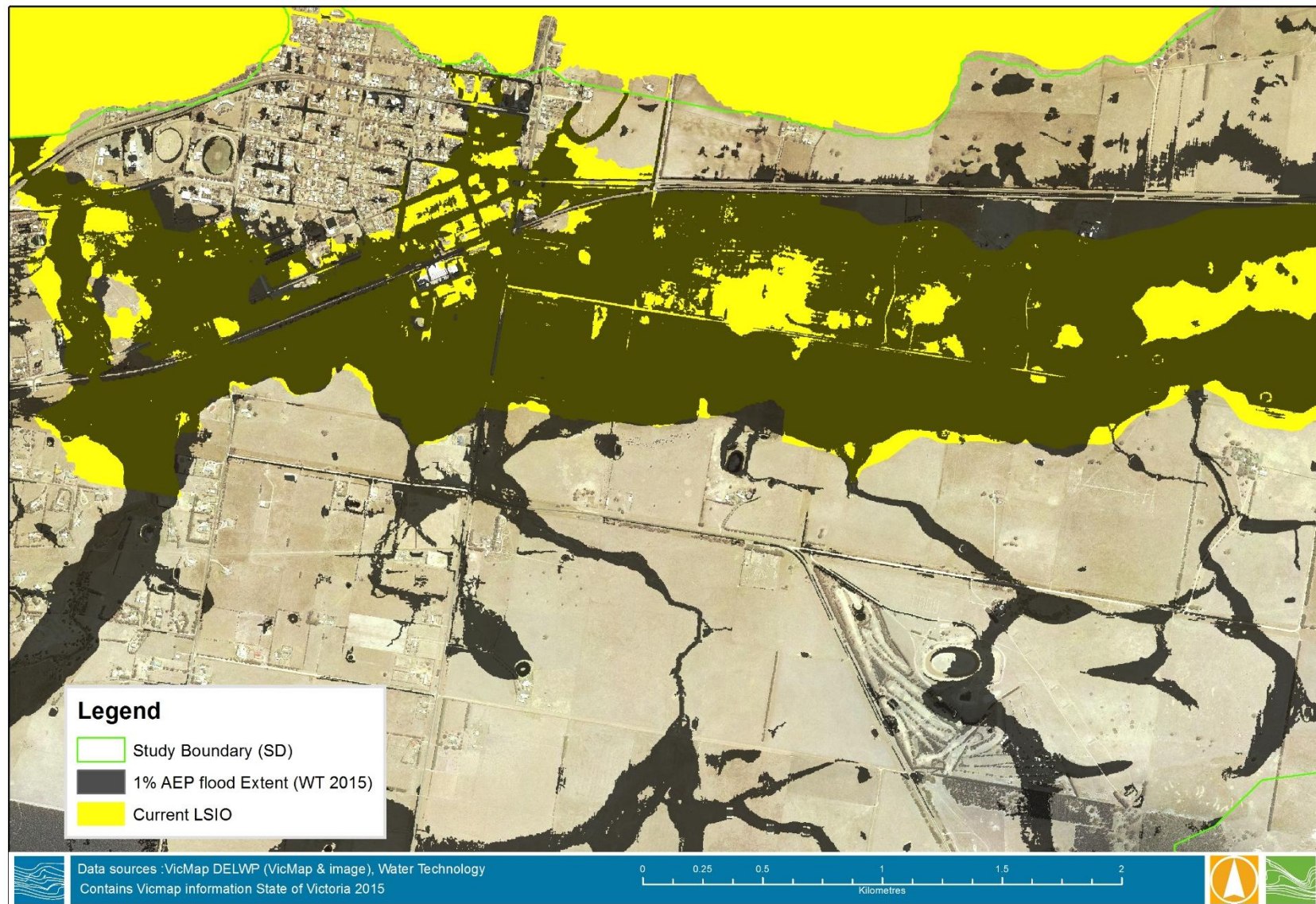


Figure 8-7 1% AEP Design modelling extent compared with the current LSIO

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

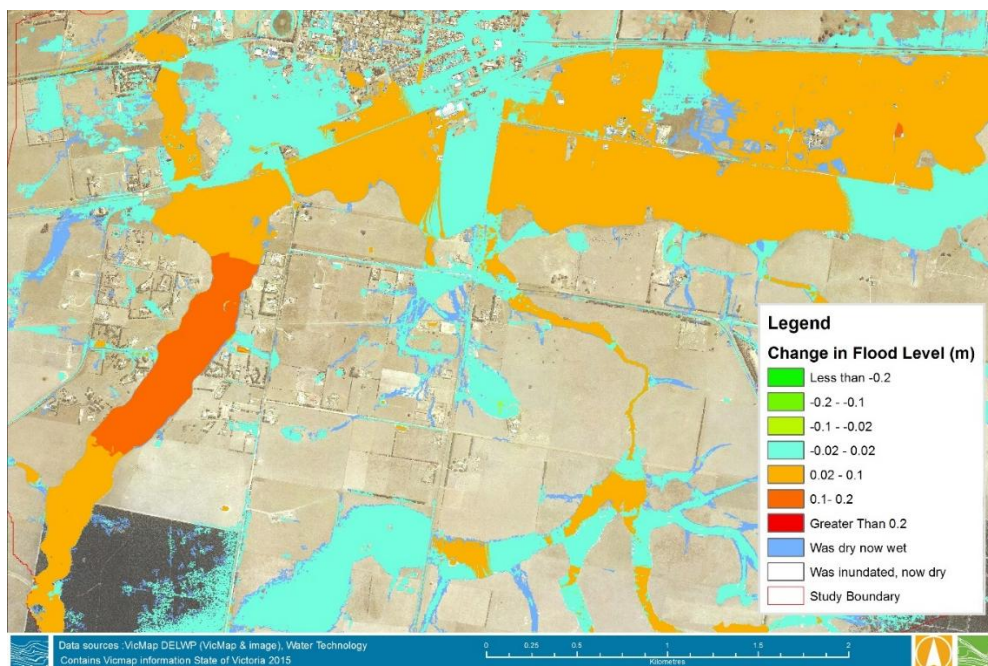


Figure 9-1 1% AEP Flood level difference plot with 20% increase in Manning's roughness

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.

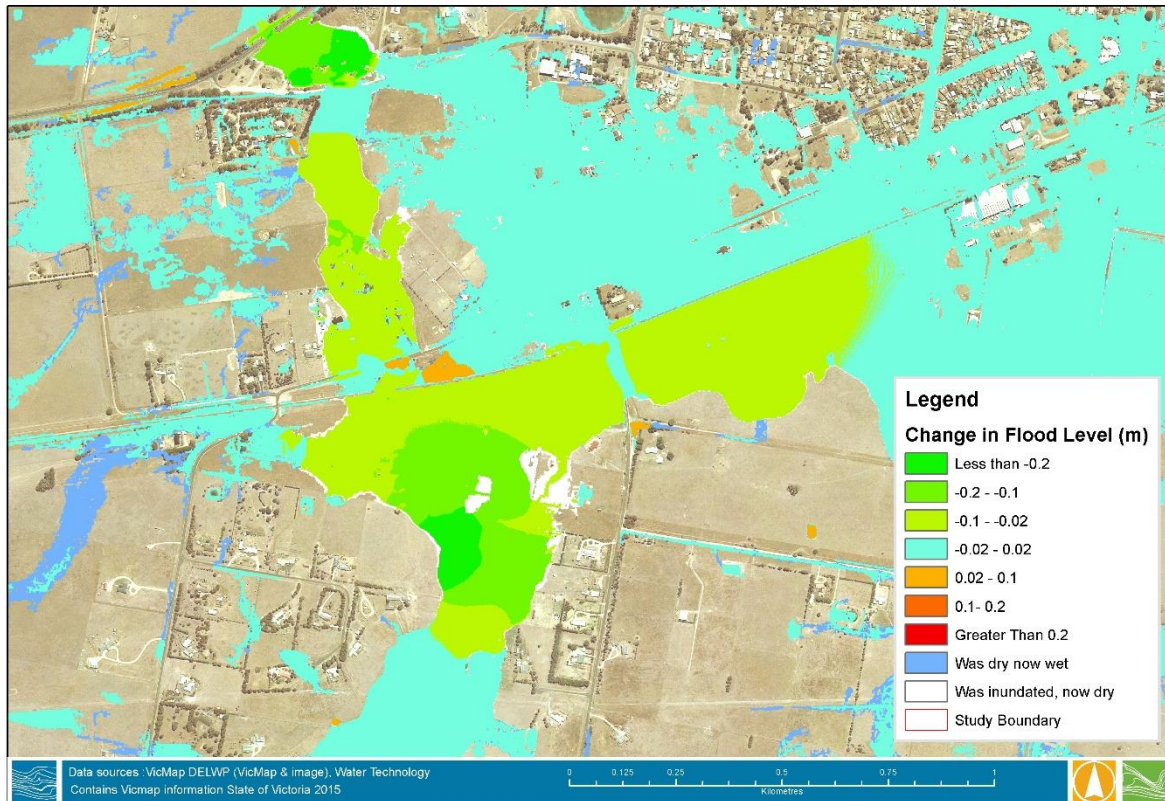


Figure 9-3 1% AEP Flood level difference plot with reduced Manning's roughness inside Blind Joes Creek waterway.

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

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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

Rosedale Flood Study – Assess & Treat Risk (R03)



May 2016

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Cover Photo: Community supplied image from 1934 floods – Main Street of Rosedale (Newsagent)

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15 Business Park Drive
Notting Hill VIC 3168

Telephone (03) 8526 0800

Fax (03) 9558 9365

ACN No. 093 377 283

ABN No. 60 093 377 283

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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 existing flood risk within the Rosedale area and a number of potential options to treat and reduce the flood risk. The Wellington Shire Municipal Flood Emergency Plan (MFEP) was also updated at the same time as this report was written. Much of the information in this report is also contained within the MFEP. This report 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)
- **R03 - Assess and Treat Risk Report (Water Technology 2016c) – this report**
- 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.

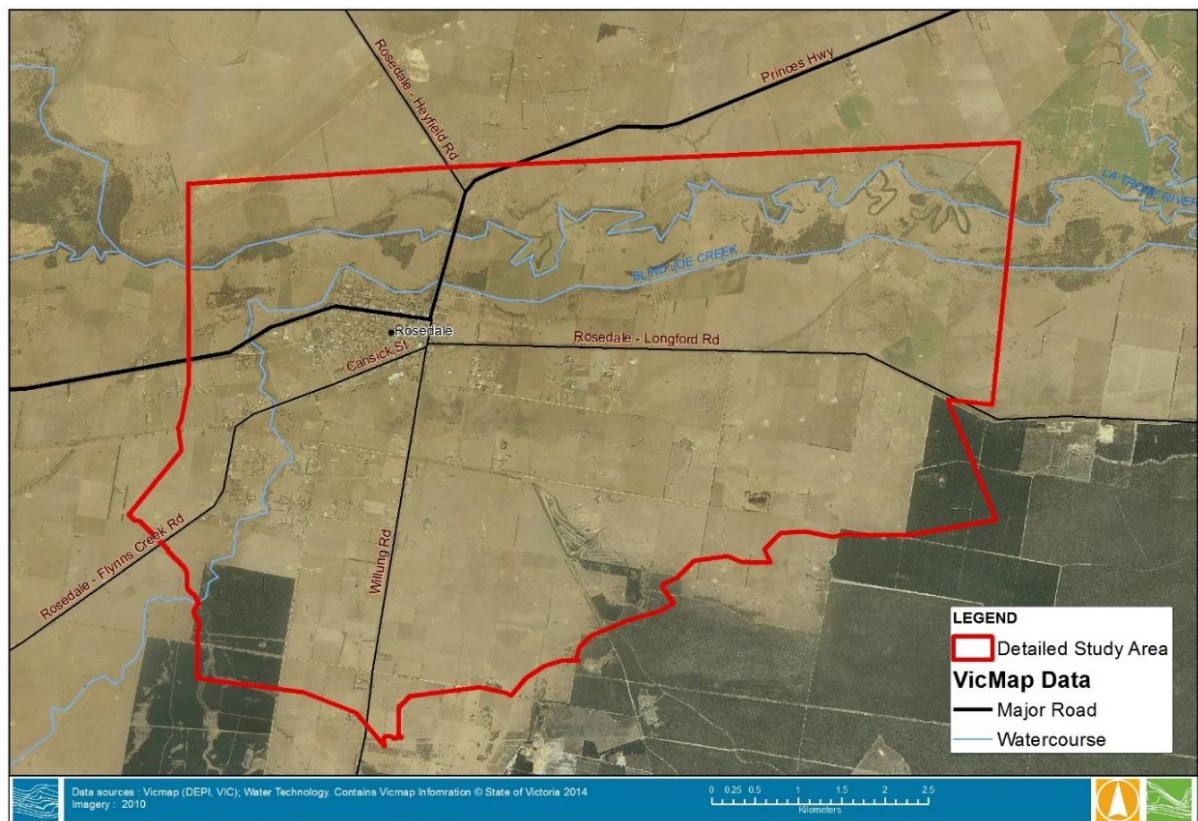


Figure 2-1 Rosedale Study Area

3. FLOOD INTELLIGENCE

Flooding in and around Rosedale can occur via three independent mechanisms:

- Flooding from the Latrobe River. Latrobe River has a large upstream catchment area approximately 4,150 km² so can generate larger flows and take longer to reach Rosedale after rainfall occurs.
- Flooding from the smaller catchments south of the township including Blind Joes Creek. Relatively small catchment area of approximately 150 km², generates less flow than the Latrobe River and will arrive quicker than Latrobe River flows after intense rainfall.
- Localised flooding within the town itself from high intensity short duration rainfall generating stormwater flooding.

Flooding from each of these mechanisms can occur independently or often at the same time. As the main portion of town sits above the Latrobe River floodplain, direct flooding from the Latrobe River is relatively limited with the Latrobe River Flood Study (Cardno 2013) showing only Mackay, King and Queen Streets seeing direct inundation from the Latrobe River and only in very rare events (1% and 2% AEP floods). Similarly, stormwater flooding can cause significant localised nuisance flooding but is unlikely to cause inundation above floor levels or isolation for extended periods (road closures). The major driver of significant flooding in Rosedale is the smaller catchments found to the south of the township including Blind Joes Creek. Whilst flooding from these catchments doesn't inundate a lot of dwellings above floor, inundation is widespread and can cause isolation.

3.1 Latrobe River Flooding

Currently declared flood class levels are set for the Latrobe River at Rosedale gauging station and are shown in Table 3-1

Table 3-1 Latrobe River Flood Class Levels (226228 Rosedale - Main Stream) SOURCE: Australian Bureau of Meteorology

Flood Class Level	Gauge Height (m)	Water Surface Level (m AHD)
Minor	4.0	13.7
Moderate	4.8	14.5
Major	5.5	15.2

A desktop analysis of the Latrobe River Flood Study (Cardno 2013) results (Table 3-2) versus the existing declared flood class levels suggests that even at major flood heights the township (if flooding only occurred in the Latrobe River) would largely be un-impacted. Major impacts (flood damages) could still be expected on the agricultural land which fringes the floodplain.

Table 3-2 Latrobe River Stream Flow Gauge and Design Flood Levels SOURCE: Latrobe River Flood Study (2013)

Flood Event	Gauge Height (m)*	Water Surface Level (m AHD)
10% AEP	4.288	13.988
5% AEP	4.614	14.314
2% AEP	5.121	14.821
1% AEP	5.714	15.414

* Estimated using Water Surface elevation data provide by the WGCMA and a gauge zero estimate of 9.7 m AHD

Analysis of the water surface elevation data from the Latrobe River Flood Study, removing any flooding direct from Blind Joes Creek, has shown that the main township of Rosedale is not significantly impacted by direct flooding from only the Latrobe River. Only Mackay, King and Queen Streets receive direct inundation from the Latrobe River and only in very rare events (1% and 2% AEP floods). Figure 3-1 shows a simplified analysis of what peak flood levels might look like if flooding only occurred in the Latrobe River.

A major conclusion of this study is that significant rainfall and flooding must also occur in the Blind Joes Creek catchment (and the smaller catchments to the south-east) for significant flooding to impact the greater Rosedale area.

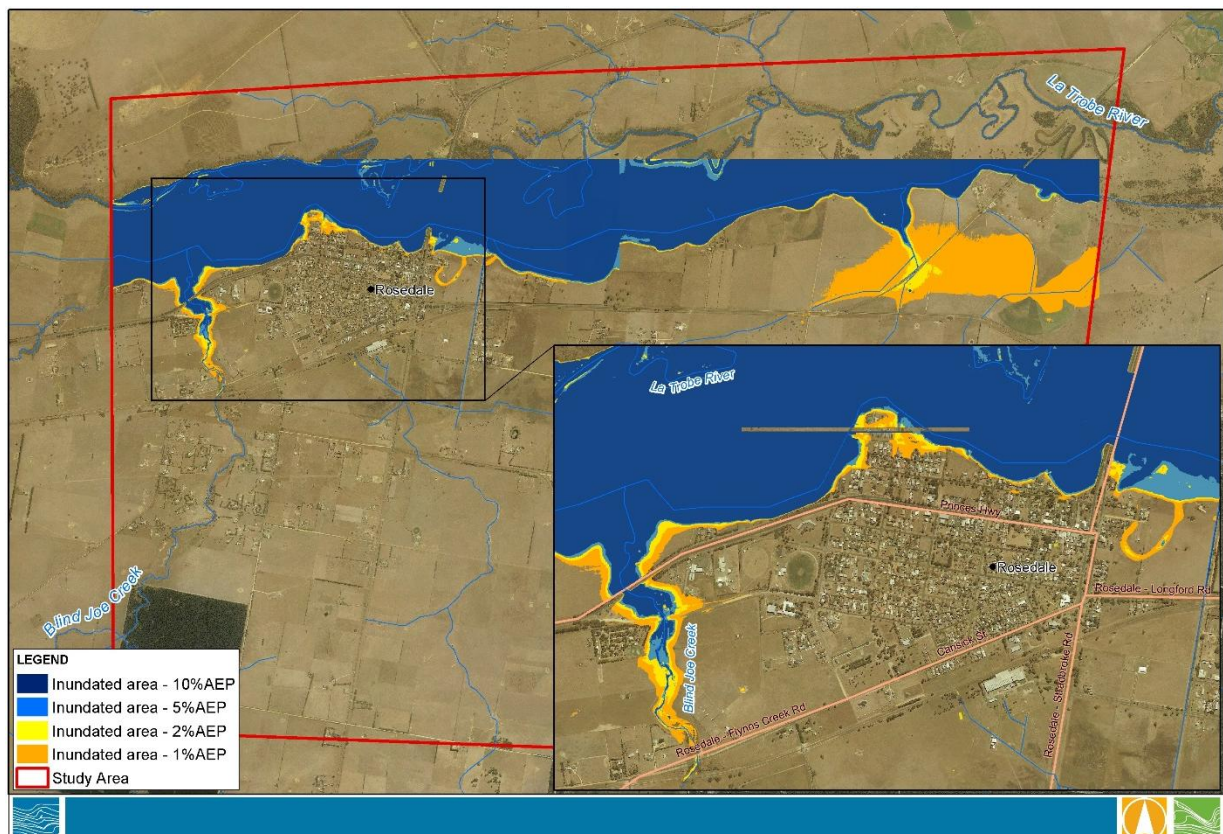


Figure 3-1 Latrobe Flood Study Results – Estimated area inundated by the Latrobe River (excludes Blind Joes Creek flooding)

3.2 Blind Joes Creek and localised Flooding

This study has shown that rainfall in the ranges south of Rosedale is a major driver of flooding in the town. For example, for the Blind Joes Creek floodway south of the township to be engaged, flood water from the Blind Joes Creek catchment must break its banks south of the railway line and flow east. This phenomenon cannot occur with only Latrobe River flooding. Once flood water breaks out of Blind Joes Creek south of the railway line, it tends to combine with the other adjacent catchment flows from the ranges south of town and inundates the low land south of the railway line and Huffers Lane. Some of this flood water can make its way into the township via flow paths over the railway line at Friends Road, two culvert crossings between Friends Road and the Tannery and at Willung Road. Some flood water also leaves the Blind Joes Creek and moves up an open drain on the north side of the railway eventually flowing over Cansick Street and inundating some of the residential land on the western boundary of the township.

Figure 3-2 below provides flood mapping for a number of selected design flood events. This shows the general increase in flood impacts with larger magnitude flood events. Table 3-3 below provides a description of the general flood behaviour of various flood events and the consequences for Rosedale. For a given flood height, the consequences likely to be experienced include all the consequences described for the smaller events in the above rows of the table. The table should therefore be read from top down.

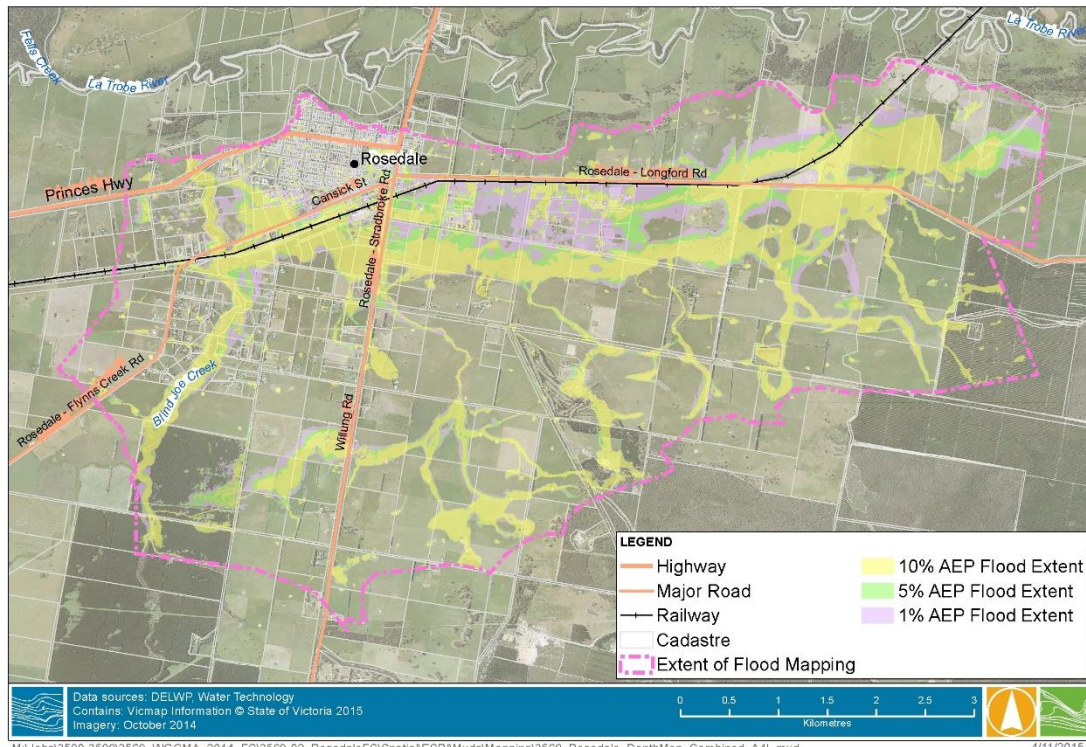


Figure 3-2 Rosedale Flood Extents for Selected Design Flood Events

3.2.1 Impact of stormwater (localised) flooding in Rosedale

Flood modelling of Rosedale in this study has considered impacts of the Latrobe River, catchments to the south of the township and also localised flooding within the township (stormwater flooding). Figure 3-3 shows the effect of including the catchment flows from lower land immediately north of the ranges. It shows that the major impacts inside the township tend to be driven by the catchment flows from the ranges but that there are many places within the township itself which are only impacted by stormwater.

Fortunately, most of the observed stormwater impacts in the township are confined to the local road network and natural low points but do not tend to impact homes or major infrastructure.

For the remainder of this report, flood impacts of localised stormwater flooding and flooding from the ranges south of the township will be considered together.

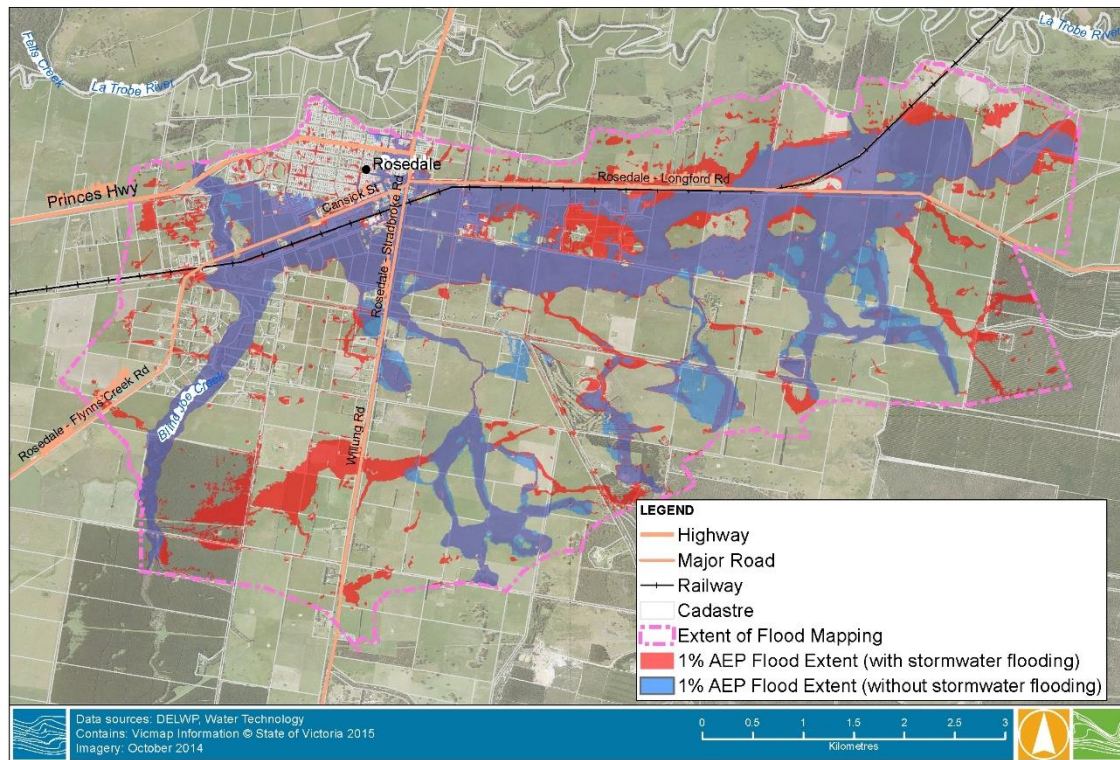


Figure 3-3 Impact of localised rainfall (valley floor) on overall flood extents (1% AEP event)

When using Table 3-3 to identify particular consequences for a given flood event, the reader should read all rows of consequences above the selected magnitude design event.

Table 3-3 Design flood events and associated flooding areas

AEP Design Event	Flood Consequences
10% AEP	Blind Joes Creek floodway engaged, ponding behind Friends, Rosedale-Longford and Willung Roads. Moore Street, McLeod Street, Cricket Street and Cansick Streets cut by flood water. Localised ponding (stormwater impacts) in the low lying land between Princes highway and Albert Street. Residential Buildings Flooded Above Floor 0 Commercial Buildings Flooded Above Floor 0 Properties Flooded Below Floor 177
5% AEP	Blind Joes Creek floodway flows enter the township via Friends and Willung Road. Ponding behind Wilung road, Friends and Rosedale-Longford roads over a 1 m deep in sections. Newer sections of the western edge of the town between Cansick and Cricket Street are inundated from breakout flows from Blind Joes Creek. Larger portions of land on the township fringes inundated such as land between Cansick street and the railway line (east of Blind Joes creek), and Huffers and Mill Lane area. Ponding in the low lying land between Princes highway and Albert Street is now more significant with one residential lot flooded above floor level. Residential Buildings Flooded Above Floor 1 Commercial Buildings Flooded Above Floor 1 (depth less than 10 mm) Properties Flooded Below Floor 212
2% AEP	Most of the Blind Joes Creek Floodway is deeper than 0.5 m. Residents in some of the newer streets (e.g. Macleod Street) west of the main township may be isolated by floodwater. Flooding east of Willung Road is more significant with deeper flooding observed in the industrial estate east of Mill Lane. Mill Lane itself would likely be cut with flood water. Deep flooding (>0.5 m) is observed on the low density residential land north of Huffers Lane. Flooding in the CBD is much more significant with some streets inundated up to 0.5 m deep. The riverine and stormwater flooding combine likely cutting the Princes highway between Willung Road and Latrobe Street. The car park north of the Princes Highway is inundated with flood water making it to Queen Street. Ponding in the low lying land between Princes Highway and Albert Street is significant with one residential lot and 5 commercial lots flooded above floor level. Residential Buildings Flooded Above Floor 1 Commercial Buildings Flooded Above Floor 5 Properties Flooded Below Floor 219
1% AEP	Generally flood extents between the 1% AEP and 2% AEP are not significantly different but flood depths tend to be significantly deeper. A large portion of the Blind Joes Creek floodway is now deeper than 1 m. Ponding at the intersection of Willung and Rosedale-Longford Roads is deep (up to a 1 m). Most homes east of Willung Road and south of the Rosedale-Longford Road would lose access to the main township (for several hours) during this flood. Much of the low density residential land north of Huffers Lane is between 250 mm and 500 mm deep.

	Residential Buildings Flooded Above Floor 2 Commercial Buildings Flooded Above Floor 7 Properties Flooded Below Floor 234
0.5% AEP	The flood extent is similar to the 2% and 1% AEP events, but flood depths throughout the township are now hazardous at many locations. The majority of the land on the western fringe of the main township (east of Blind Joes Creek) is inundated. Residential land north of Cansick Street and west of Willung Road and east of Hood Street is significantly impacted by riverine flooding. Additional flooding is observed north of the Princes Highway in Queen Street. People living east of Willung Road would expect to be isolated from the Rosedale township for extended periods during this event. Residential Buildings Flooded Above Floor 7 Commercial Buildings Flooded Above Floor 8 Properties Flooded Below Floor 239

3.3 Flood Risk

Flood Risk is the product of the likelihood of a certain event and the consequence of that event occurring. To assess the flood risk within Rosedale, the hydraulic modelling outputs (depth, velocity and flood hazard mapping) can be used to identify both the likelihood of the event happening (in terms of annual exceedance probability) and the consequence of such an event happening. Depth maps are useful in showing the areas impacted by the flooding, while the velocity and flood hazard mapping provides more detail for the areas which pose a higher consequence. Flood hazard is based on criteria including depth, velocity and depth x velocity and is explained further below. The high and low flood hazard areas for the 1% AEP flood event is shown in Figure 3-4.

When considering the emergency response for Rosedale during a flood event, it is important to consider the areas that are flooded first within the township, not just areas of high consequence (high hazard). Areas first flooded are often areas that have a higher likelihood of occurring and will occur at lower flow rates. A plot of the flood hazard categories for a 10% AEP flood event is shown in Figure 3-5. This plot highlights that for a 10% AEP flood event, the majority of the high hazard areas are located within the Blind Joes Creek channel. Some areas of high depth built up behind roads are observed south of the township, with some high depths along Moore Street, Widdowson, McLeod and Chown Courts.

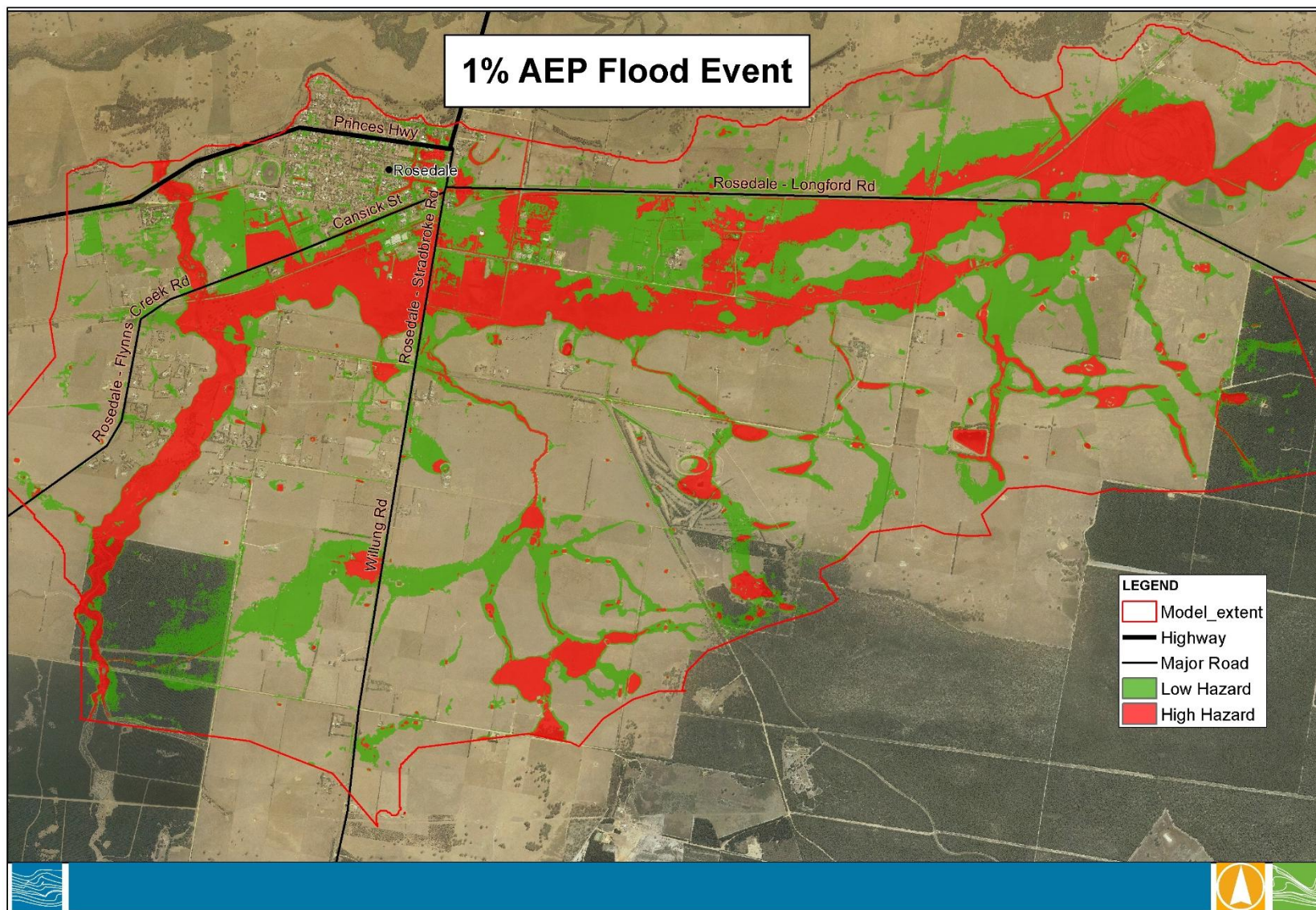


Figure 3-4 Flood Hazard for 1% AEP Flood Event

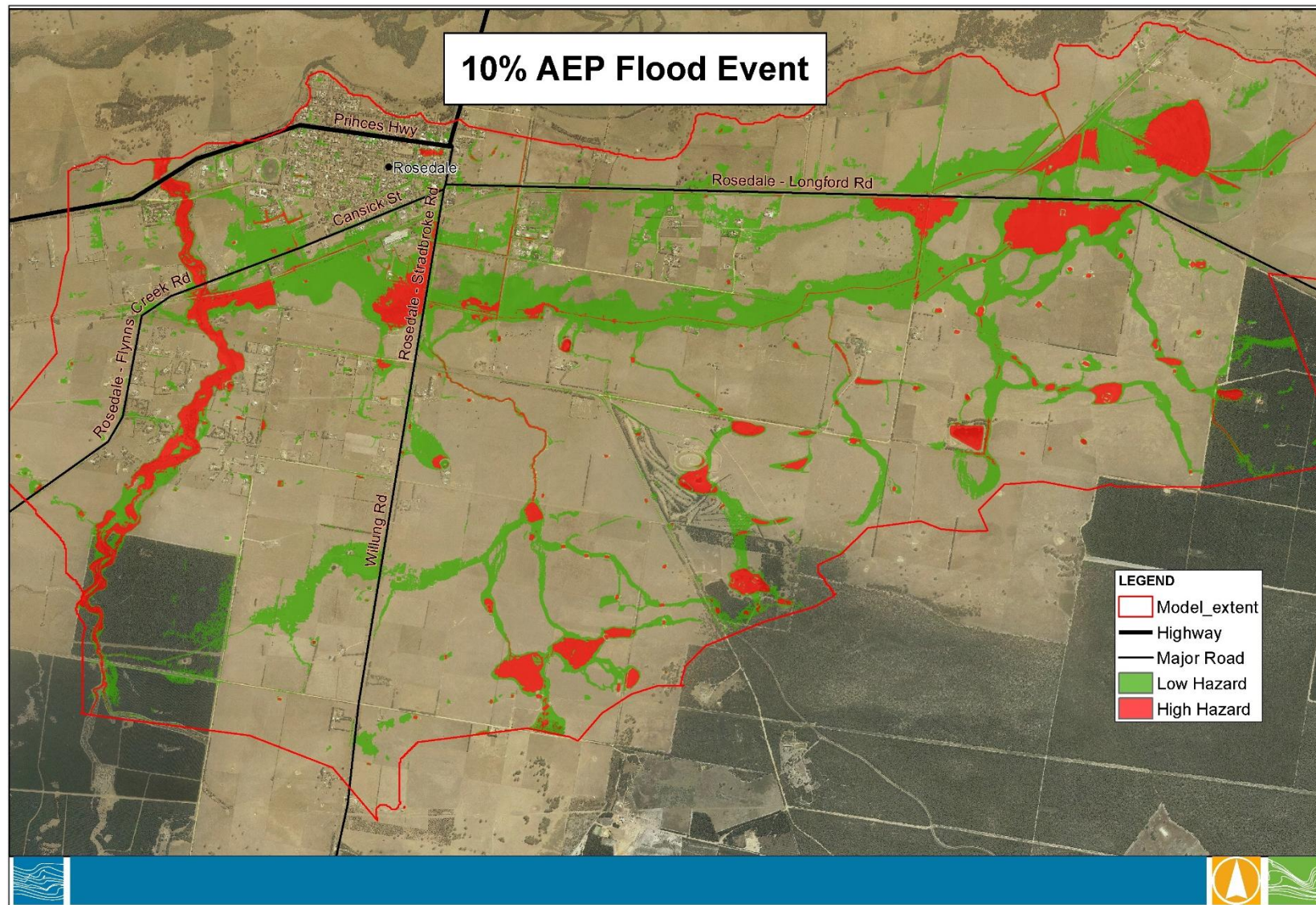


Figure 3-5 Flood Hazard for 10% AEP Flood Event

3.4 Flood Warning

As previously discussed, it has been identified that one of the main drivers for significant flooding in Rosedale is from intense rainfall in the ranges south of the township. Due to Rosedale's proximity to these ranges, the onset of flooding can potentially occur quite soon after heavy rainfall. The hydrological modelling showed that for the catchments south of the township a 12 hour storm duration is generally the critical duration for a range of design storms. The onset of flooding can occur before the peak of the flood, so this means that the available flood warning time is potentially less than 12 hours after the start of the storm event.

Hydraulic modelling of historical floods and potential future flood (design events) has added some useful information on flood travel times. This information is based on the design event assumptions and it must be noted that every storm and flood is different, so actual timing may differ depending on the characteristics of the storm and the catchment conditions at the time of the event.

Table 3-4 Travel Time between beginning of Rainfall and Flood Peaks

Event	Time from beginning of the intense* rainfall to peak level observed at Railway Bridge south of Rosedale
2012	13 hrs
1993	12 hrs
Design Modelling (Future Floods)	6 -8 hrs

* Assumed to be approximately >5mm/h for consecutive hours

Table 3-4 above shows the difference in two of the historic events compared to the design floods. The historic events had a less intense longer duration storm than the critical duration design storms for design flood mapping. This highlights the large differences that can be experienced across a range of storm events, which may lead to different observed flood behaviour during an event.

The major challenge in managing flood warning in Rosedale is the complete lack of localised information to base a warning off. Currently there is no stream flow gauging or government operated rain gauges with the catchment south of the township.

Table 3-5 Rainfall Totals and Design Flood Magnitude

Event	Rainfall (mm)		
	Strzelecki Ranges	Valley Floor (Rosedale)	Duration
June 2012	~105-95	~80	48 hours with majority of rain over a 20 hour period
September 1993	~115-105	~80-90	48 hours with majority of rain over a 16 hour period
10% AEP	55		12 hours
5% AEP	65		12 hours
2% AEP	80		12 hours

1% AEP	91	12 hours
0.5% AEP	104	12 hours

Table 3-5 above presents the historic rainfall totals that were recorded for 1993 and 2012 flood events in the ranges and more locally across the valley floor. For the design events, only a single rainfall total is provided, which was uniform across the catchment, a reasonable assumption given the catchment is quite small.

A review of official rain gauges closest to Rosedale located high on the Strezlecki Ranges (e.g. Callignee South, Balook, Stradbroke West and others) has shown that rainfall totals can be very different to rainfall recorded lower on the valley floor, particularly as an east coast low moves into the region. A review of rainfall data provided from the community has shown that event totals in the local catchment in 1993 and 2012 were up to 150 mm less than recorded in some of the gauges higher up on the ranges.

There is currently no flood warning service provided by the Bureau of Meteorology for the Blind Joes Creek catchment, and given the short available warning time the Bureau would most likely classify this as flash flooding so would not be covered under the traditional flood warning service. The Flood Warning Arrangements for Victoria (VFWCC, 2001) report outlines the following principles for flash flood warning services: The Bureau of Meteorology has a responsibility to provide predictions of weather conditions likely to lead to flash flooding (e.g. thunderstorms). Local Government has prime responsibility for flash flood warning extending from system establishment and operation through to the provision of predictions of stream levels if required. The Bureau of Meteorology will provide specialist technical assistance and advice to Local Government to assist in system establishment and in relation to flood prediction techniques. This means that any flood warning system considered for Rosedale would be the responsibility of Wellington Shire Council, with the Bureau of Meteorology providing assistance in the development of the system and the supply of software, as well as the supply of severe weather warnings and flood watches. It is understood that the State Government through DELWP can assist in funding the setup of flood warning systems but the cost to maintain and operate the systems is the Council's responsibility.

Considering these points, it is recommended that Wellington Shire Council investigate and document the feasibility of a flash flood warning service. Wellington Shire Council can seek assistance in this investigation from the Bureau of Meteorology and the West Gippsland CMA.

While it is not within the scope of this project to develop a comprehensive flash flood warning system for the township, it has been considered at a high level. To better manage and understand flood warning in Rosedale, it is recommended that two rain gauges with telemetry are established, one within the township of Rosedale and the other towards the top of the Blind Joes Creek catchment. These gauges would provide the information required for a flash flood warning system, coupled with a gauge at a location upstream of the railway line. Whilst it would be excellent if a telemetered water level gauge could be installed, a manually read gauge board is considered sufficient if a community observer relationship is developed to monitor this gauge during an event.

With access to this information via the internet and radio during times of predicted flooding, emergency management authorities and the general public would be better placed to understand the likely impact of future floods and have some lead time to prepare for and respond to a flood when it arrives. While no two floods are the same, predictions such as "this flood is expected to be bigger than 1993" can be very useful to people who are directly impacted and those that are tasked with managing such emergencies.

Figure 3-6 is a flash flooding early warning tool developed by Water Technology for Rosedale. If instantaneous rainfall records were available inside the catchment, they could be cross referenced

with the table to estimate the likely magnitude of the event, this estimate could then be cross referenced with the design map outputs to get an estimate of likely flooding. If a gauge board is established in town, the gauge board level can be tied to this chart and the flood mapping. When using the below chart it is advised to base the estimate on the rainfall total and duration around the peak of the rainfall. If a very short burst is observed over the first two hours this may not lead to the expected flooding because not enough rainfall volume has fallen yet and a lot of that may be lost to the catchment. It is advised to reassess the rainfall totals numerous times during an event which may lead to a revision in the estimated flood magnitude.

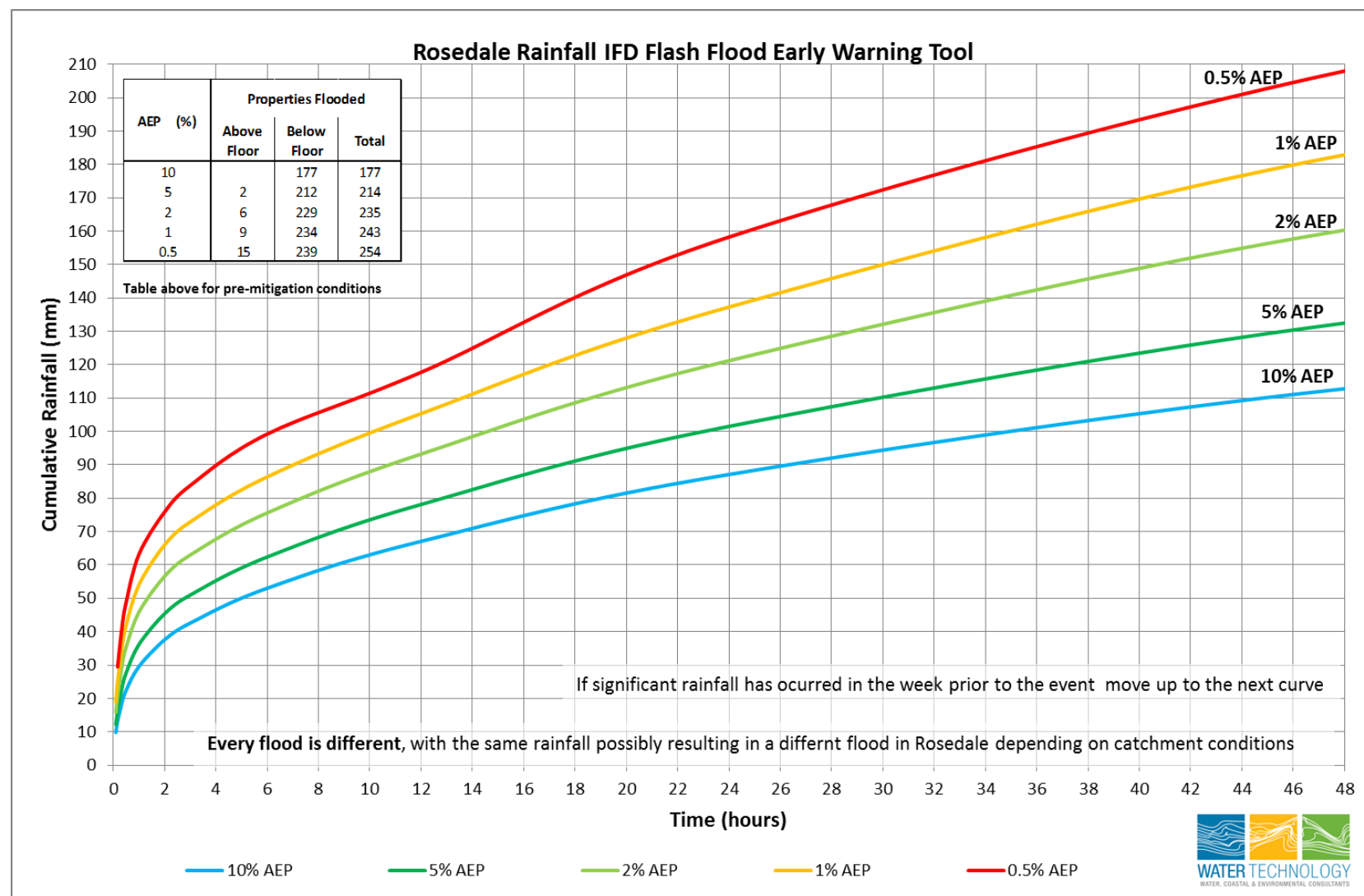


Figure 3-6 Flash Flooding Early Warning Tool

3.5 Land Use Planning

The Victoria Planning Provisions (VPPs) contain a number of controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

Section 6(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or likely to be hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Planning and Community Development's (DPCD) Practice Note on Applying Flood Controls in Planning Schemes.

Planning Schemes can be viewed online at <http://services.land.vic.gov.au/maps/pmo.jsp>. It is recommended that the planning scheme for Rosedale be amended to reflect the flood risk identified by this project. Edwin Irvine of Planning and Environmental Design undertook a detailed review of the Wellington planning scheme in relation to flood risk at Rosedale and made a number of recommendations contained in a separate standalone document. These recommendations are summarised in the Summary Report (R04).

The method used to delineate the proposed FO is broadly based on the new Australian Rainfall and Runoff Project 10 'Appropriate Safety Criteria for People'. Criterion for delineating the Floodway Overlay considers both vehicle and people safety, and are as follows, based on the 1% AEP flood:

- Depth > 0.3 m
- Velocity > 1.5 m/s
- Depth x velocity > 0.3 m²/s.

The WGCMA Board have approved Floodplain Development Guidelines which adopt a depth threshold of 0.3 metres for safety requirements, and as such the FO has been defined using the above criteria.

The LSIO includes the area outside of FO and bounded by the 1% AEP flood extent. Small disconnected puddles such as farm dams and stormwater flooding were removed from the overlays. Figure 3- shows the proposed FO and LSIO maps based on the criteria adopted by the West Gippsland CMA.

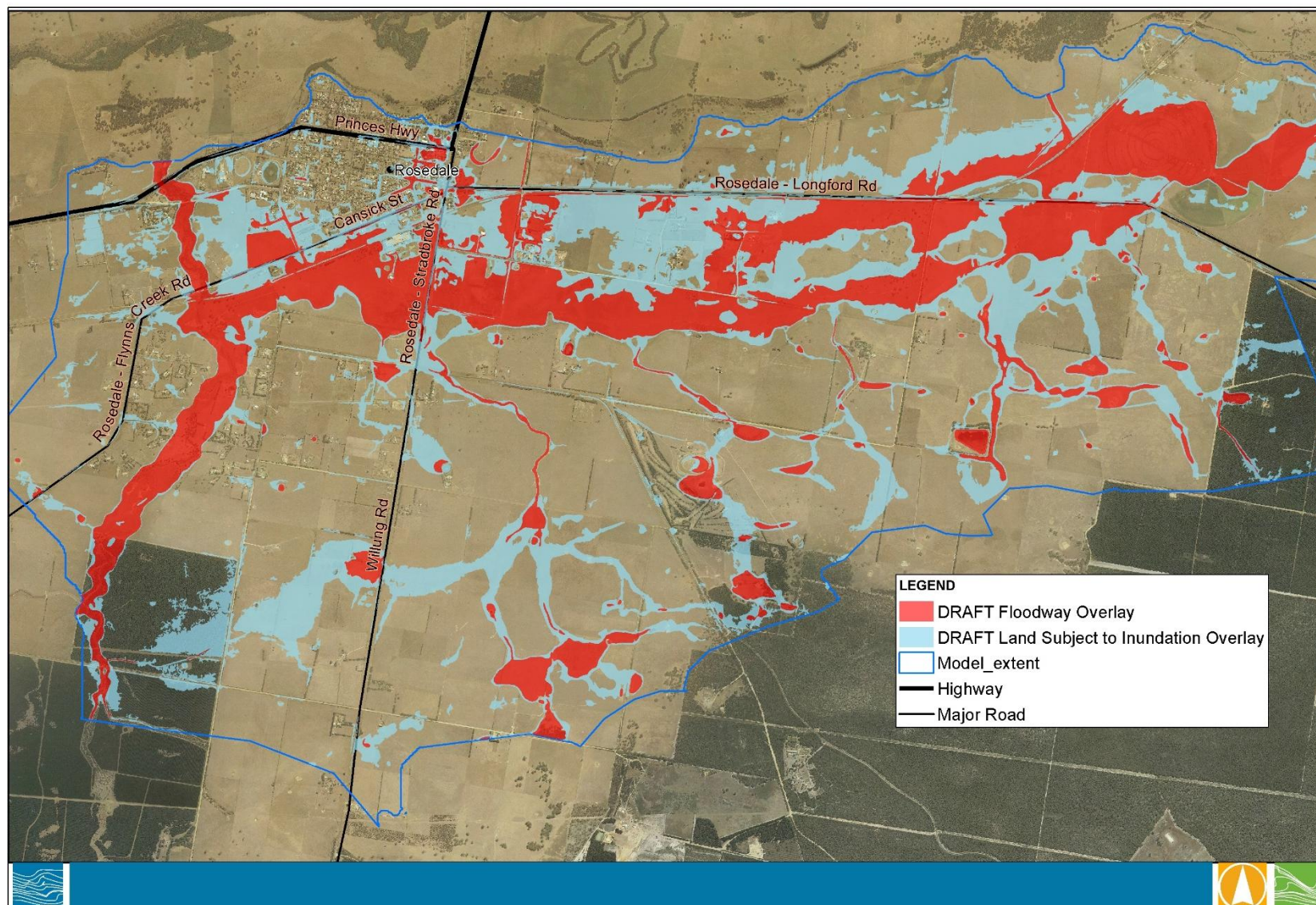


Figure 3-7 Draft LSIO and FO Map for Existing Conditions

4. FLOOD MITIGATION

This section provides an overview of the mitigation options considered to reduce the flood risk and flood damages in Rosedale. The aim of structural mitigation works is to reduce the flood risk in Rosedale and protect, where feasible, vulnerable buildings and infrastructure. Protection from a 1% AEP event is typical, and has been adopted for this study.

Possible mitigation options, detailed in Table 4-1, were derived from suggestions from community members in the community consultation sessions, discussion with the Steering Committee and inspection of the flood modelling results by Water Technology.

Table 4-1 Potential mitigation options initially considered

Option No.	Detail	Assumed Pros/cons
1a	More flow to the East Increase capacity of Friends & Willung Road crossings to increase flow to the east. Formalise a floodway to encourage the land to more effectively drain the land.	Culvert works pretty simple. Floodway works impact a large amount of land. Option would likely flood proof all of the land north of the railway line. This option would force more flood water east potentially impacting landowners within the Blind Joes Creek Floodway. These impacts would need to be addressed in the floodway design
2	More Flow to the North Increase flow north through the main Blind Joes Creek Waterway by opening up the Railway bridge and creating levees on each bank between the railway line and the Princes Highway.	Bridge works very expensive. All land currently zoned for residential, commercial and industrial land use would be protected from riverine flooding.
3	Floodway Cansick to Cricket St Create a drainage reserve between Cansick and Cricket streets. Works would likely include creating a channel and a levee on the eastern extent of the works.	Drainage reserve could be used for open space and WSUD if the land north of Cansick street was developed. Connection back to BJC would need to be considered carefully i.e. don't want to create erosion issues etc.
4	Blind Joes Creek Retarding Basin Construct a retarding basin on the Blind Joes Creek south of the township.	Only capture flows from a proportion of the contributing catchment. Land is available. Basin would need to be quite large triggering maintenance and risk management considerations. Flood timing i.e. concurrence with Latrobe flows could be an issue
5	Blind Joes Creek Diversion Construct a diversion on the BJC south of the town. The diversion would likely need to be combined with some floodway works to connect the additional flow back to the BJC's floodplain.	Could result in winners and losers. Only capture flows from a proportion of the contributing catchment. Land available but ownership an unknown.
6	Longford-Rosedale Road Culverts Longford-Rosedale Road creates a barrier stopping flow getting back to the Latrobe. Adding additional culverts along the road may help drain the BJC floodway.	Could result in winners and losers. Easy to trial in the hydraulic model. No obvious locations come to mind looking at the LiDAR.

4.1 Structural Mitigation Option Prefeasibility Assessment

Each mitigation option was assessed against a number of criteria: potential reduction in flood damage, cost of construction, feasibility of construction, and environmental impact. The score for each criterion was based on a ranking system of 1 to 5, with 1 being the worst score and 5 the best. Each criteria score was then weighted according to the weighting shown in Table 4-2. The reduction in flood damage was the most heavily weighted criteria as this is really the main objective for all flood mitigation. Table 4-3 reviews and scores each mitigation option against the four criteria and calculates a total score for each option. The options with the higher scores indicate the more appropriate mitigation solutions for Rosedale. While these options were reviewed and scored individually it is important to consider a combination of options when developing a flood mitigation scheme.

Using the prefeasibility assessment above, the 6 identified mitigation options are listed in order of total weighted score as seen in Table 4-3.

Table 4-2 Ranking score for mitigation criteria

Score	Reduction in Flood Damages	Cost (\$)	Feasibility/Constructability	Environmental Impact
Weighting	2	1	0.5	0.5
5	Major reduction in flood damage	Less than \$ 50,000	Excellent (Ease of construction and/or highly feasible option)	None
4	Moderate reduction in flood damage	\$ 50,000 – \$ 100,000	Good	Minor
3	Minor reduction in flood damage	\$ 100,000 – \$ 500,000	Average	Some
2	No reduction in flood damage	\$ 500,000 – \$ 1,000,000	Below Average	Major
1	Increase in flood damage	Greater than \$ 1,000,000	Poor (No access to site and/or highly unfeasible option)	Extreme

Table 4-3 Mitigation option prefeasibility results

No.	Mitigation Option	Criteria				Score
		Damage Reduction	Cost	Feasibility/Constructability	Environmental Impact	
1	<i>More flow to the East</i>	5	2	4	4	16
2	<i>More flow to the North</i>	5	1	3	3	14
5	<i>Blind Joes Creek RB</i>	4	2	3	3	13
3	<i>Floodway Cansick to Cricket St</i>	3	3	3	4	12.5
4	<i>Blind Joes Creek Diversion</i>	4	3	1	2	12.5
6	<i>Longford-Rosedale Culverts</i>	2	4	5	4	10.5

4.2 Structural Mitigation Options Modelled

Preliminary modelling was undertaken to analyse the potential for proposed mitigation options. Two scenarios were modelled, these are listed below and covered in more detail in subsequent sections.

- **More flow to the North:** Increasing the conveyance in the Blind Joes Creek waterway through to the Latrobe River via increasing capacity of the railway bridge and confining riverine flooding to the main waterway using levee banks.
- **More flow to the East:** Allowing the flow which breaks out of Blind Joes Creek south of the railway line to continue to flow east around the back of the main township with reduced constrictions. This would require increasing the capacity of some road crossing and some levees to prevent water flowing into the township.

In modelling these options, the approach was to start with extreme changes to determine if the proposed options could achieve a positive outcome, and then to refine (and downscale) the options accordingly. Given the model run times of the rain-on-grid model (3-4 days) all mitigation work was undertaken using only the direct riverine flows (flows from the ranges south of town). Final mitigation runs were undertaken using the combined riverine and rain-on-grid model. This led to some areas now showing localised ponding from local rainfall. It assumed this could easily be rectified when the concepts are taken to a functional design stage through drainage works.

The mitigation works were costed based on a number of key references:

- Melbourne Water's standard rates for earthworks and pipe/headwall construction costs;
- Rawlinsons Australian Construction Handbook Rates (Rawlinsons, 2011);
- The United Kingdom Environmental Agency Temporary and Demountable Flood Protection Guide (EA UK, 2011);
- Costs of other similar projects (e.g. bridge replacements) within the Wellington Shire Council;
- VicRoads cost estimate for the Traralgon By-pass retarding basin option (part of the Traralgon Flood Study 2016);
- Comparison to cost estimates for similar mitigation works for other flood studies undertaken by Water Technology

4.2.1 More Flow to the North Option

This mitigation option was originally proposed in 1995 by both Department of Conservation & Natural Resources and Gutteridge Haskins & Davey (GHD) in independent flood studies. At this time they were not investigated in any detail with flood modelling.

For this mitigation option, we have focused on what was required to get the majority of Blind Joes Creek flows to connect to the Latrobe River floodplain via the primary channel at the western edge of the township. To achieve this, the following works were required.

- Increase the railway bridge opening from 48 m to 112 m wide. This would require earthworks on the railway embankment and the floodplain upstream and downstream of the railway.
- Increase the size of the Cansick Street bridge from 20m to 40m wide. This would require works on the waterway and floodplain upstream and downstream of Cansick Street bridge.
- Construct levees on the left bank (886 m long) and right bank (1,095 m long) of Blind Joes Creek running from the railway bridge through to the Princes Highway. This would include an allowance for 600 mm freeboard. The average height of the levees was around 1.1 m. On the western side levee, the highest location was 2.4 m, it is noted that if the levee was moved slightly west at this location the levee height could be significantly reduced (by over a meter).
- Raise a section of Friends Road (200 m long) by approximately 0.6 m (average depth).
- Raise a section of the Railway line (300 m long) by approximately 0.5 m (average depth).

- Modification to the two new Princes Highway bridges was not included in this mitigation package. It is noted that all existing freeboard in the new Princes Highway bridge designs would likely be lost under this mitigation option. If freeboard was required to be retained, then replacing both structures be required. This is obviously a high cost solution.

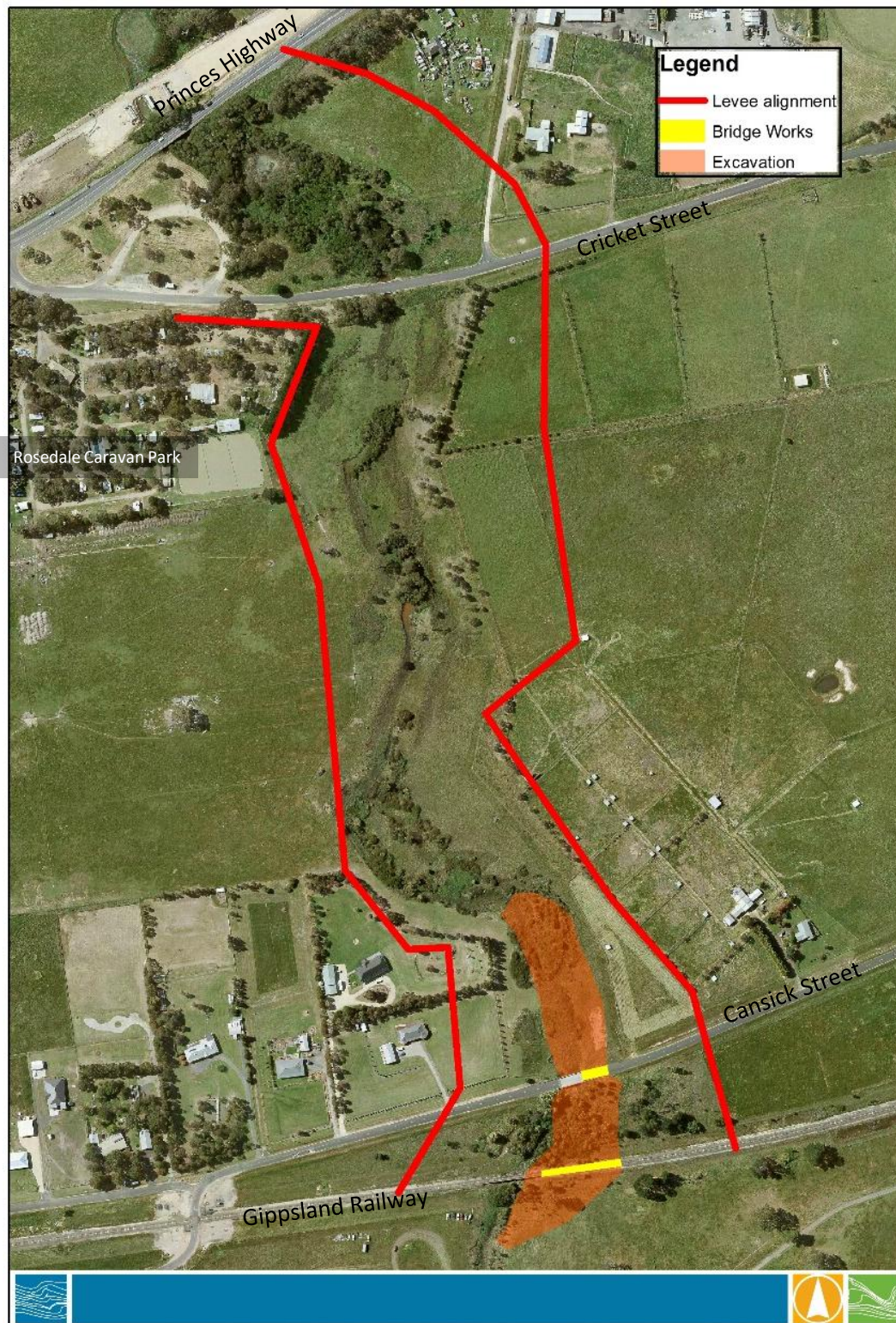


Figure 4-1 Proposed Works – More Flow to the North Option

Results

Increasing the amount of flood water flowing north along the Blind Joes Creek channel significantly reduced ponding on the western side of the township. With these works in place, a large amount of land once heavily inundated (over 500 mm deep) now only receives local stormwater runoff with flood depths reduced by over 400 mm in places (Moore Street, McLeod Court and Chown Court).

Moving east, the impact of the mitigation option was reduced. Willung Road was still over topped in this scenario, allowing some riverine flows to move into the township (albeit a lot less than in existing conditions). East of Willung Road, the Blind Joes Creek floodway peak water levels were typically reduced by around 200 mm. Generally, flood level increases were only observed behind the levee banks, however localised spots e.g. south of the caravan park also showed increases. This was a result of local runoff no longer being able to enter Blind Joes Creek. It is envisaged that this localised ponding could be managed with a pipe solution, possibly with a one-way pipe arrangement or a pumping solution.

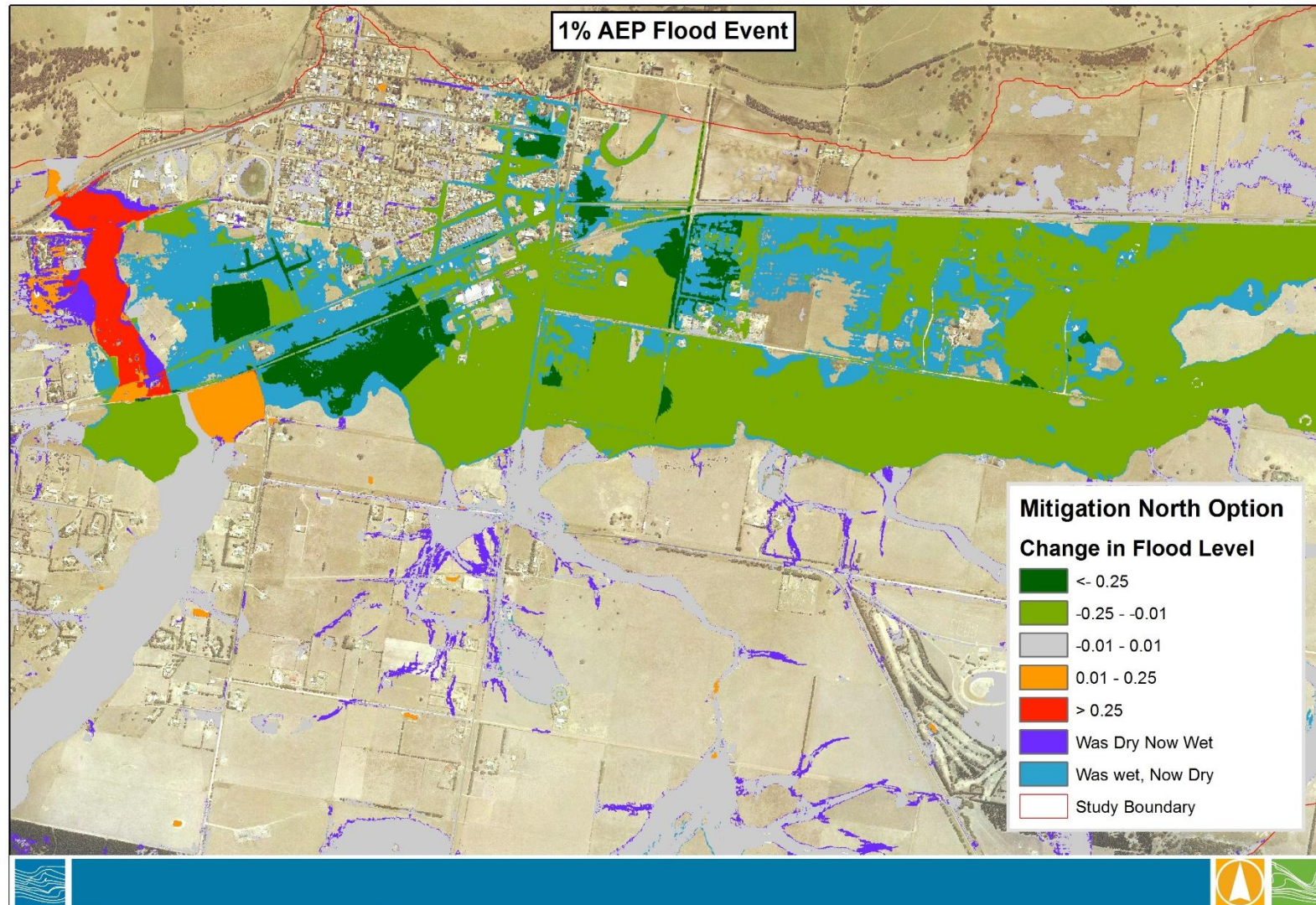


Figure 4-2 More Flow to the North Option - 1% AEP Water Level Difference Plot

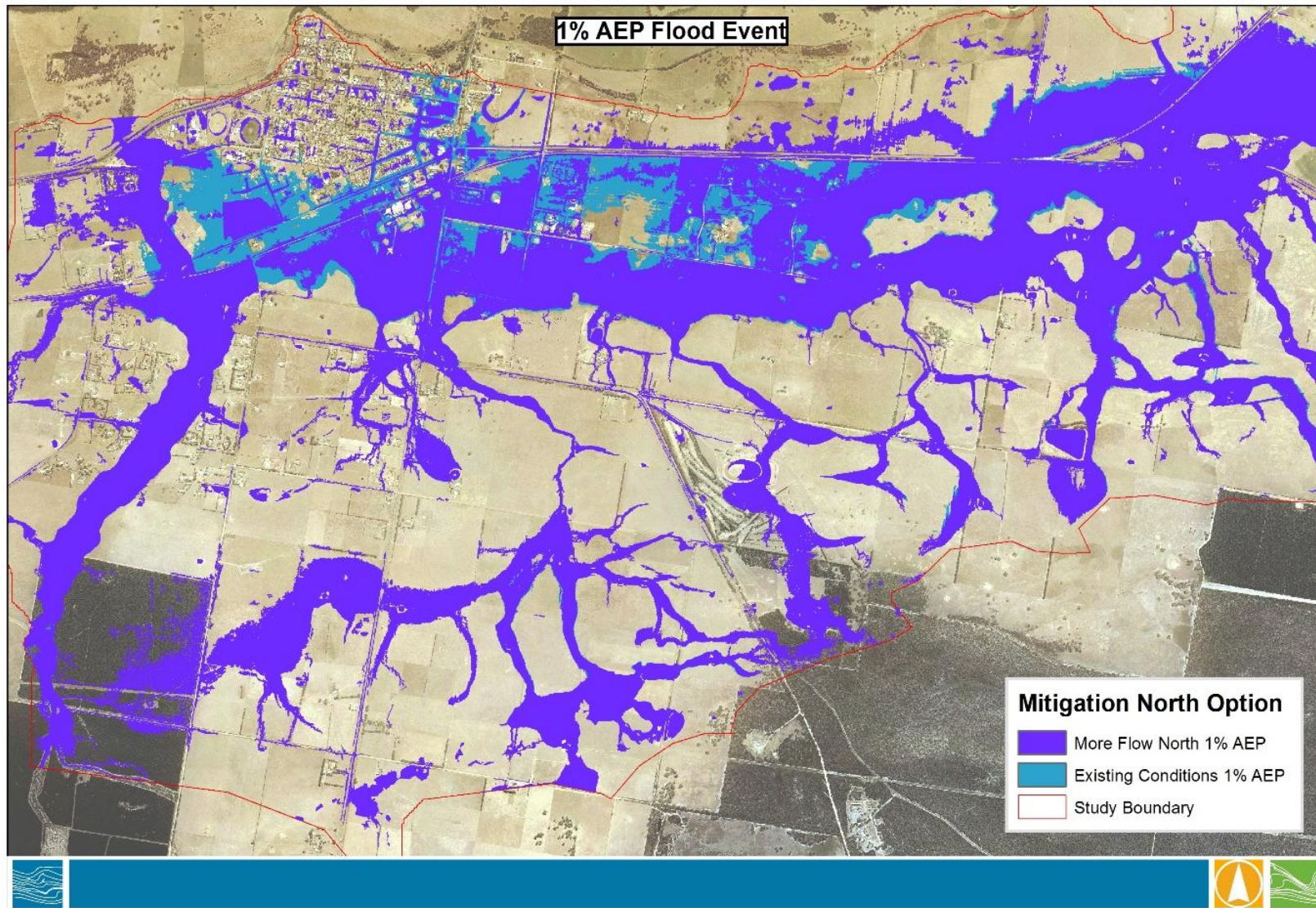


Figure 4-3 More Flow to the North Option - 1% AEP Flood Extent Comparison

Table 4-4 More Flow to the North Costs

Component	Quantity	Cost
Railway Bridge Works	112 m widening	\$ 5,330,000
Excavation work within the waterway	22,841 m ³	\$ 1,890,000
Cansick Street Bridge Works	40 m widening	\$ 1,670,000
Levee Work	5,809 m ³	\$ 420,000
Raise Friends Road	200 m length	\$ 270,000
Raise Railway Line	300 m length	\$ 680,000
Total Costs		\$ 10,990,000

Cost associated with the More Flow to the North option are shown in Table 4-4. Railway bridge costs were scaled from the Traralgon by-pass bridge estimate by VicRoads. It would be recommended that VicTrack be engaged to confirm if this preliminary estimate was accurate. The other works in the package are assumed to be accurately costed.

4.2.2 More Flow to the East Option

This option to move more flood water east along the existing floodway has also been discussed in previous flood studies. This mitigation option involved more modest works and avoided major bridge works where possible. It does still require road works to increase the capacity of crossings, but they are on smaller Council roads. Ultimately the following works were found to significantly reduce flood impacts in Rosedale Township.

- Block off a small open drain between the railway line and Cansick Street on the right bank of Blind Joes Creek. In large floods, this open drain allows flood water to move up Cansick Street and into the residential area of the township.
- Remove the culvert crossing and lower Friends road to create a floodway allowing significantly more flow to break out and flow east down the Blind Joes Creek floodway.
- Provide temporary blockage solutions for two VicTrack culvert crossings between Friends road and Willung Road.
- Create a small levee around the Tannery from the railway line on the west connecting to Willung road on the east.
- Remove the culvert crossing and lower a section of Willung Road to create a floodway allowing significantly more flow to flow east down the Blind Joes Creek floodway.
 - It is noted that this option would potentially isolate residents south of the Blind Joes Creek floodway for a period of time during a flood event (consistent with what happens now). A solution to reduce this risk maybe to raise Willung road and create a large low level bridge structure. In the interest of finding a cost effective option this concept was not costed as part of the initial mitigation solution.
- Create a levee along Huffers Lane to stop flood water entering the land zoned low density residential north of Huffers Lane.
- Minor earth works in the Blind Joes Creek floodway to accommodate the additional overland flow moving east.
- Increase the culvert capacity under Rosedale-Stradbroke Road.

It is noted that a low bridge solution for Willung Road may be favourable to a floodway. This option could be investigated if this mitigation solution was taken to the next design phase.

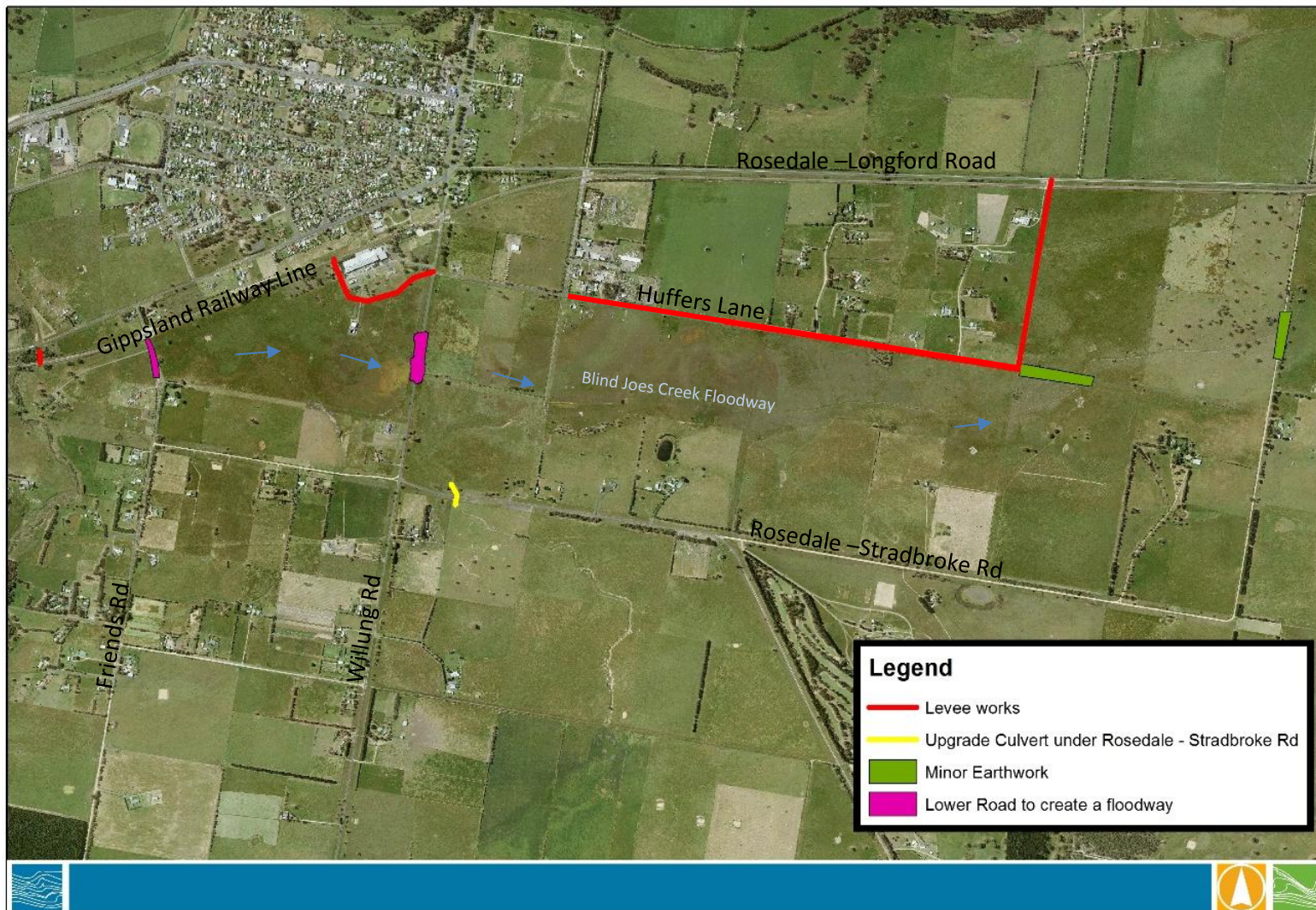


Figure 4-4 Proposed Works – More Flow to the East Option

Results

Increasing the amount of flood water flowing east along the Blind Joes Creek floodway significantly reduced ponding on the western side of the township. With these works in place, a large amount of land once heavily inundated (over 500 mm deep) now only receives local stormwater runoff with flood depths reduced by over 400 mm in places (Moore Street, McLeod Court and Chown Court). The riverine flood impact has been removed from the protected area north of the floodway, with the only impact now from stormwater.

Moving east, the impact of the mitigation option was continued with much of the land east of Willung Road and North of Huffers Lane now only suffering the impacts of stormwater flooding. The major breakout which once allowed flood water from Blind Joes Creek to move north at Willung Road into town over the railway line was now removed. Localised stormwater issues are noted behind the Huffers Lane levee. These are isolated to two locations and could likely be managed with local stormwater infrastructure (not the focus of this study).

With significantly more water allowed to flow east, flood levels within the Blind Joes Creek floodway have increased. East of Willung Road these increases tend to be less than 150 mm. Flood extents are not dramatically increased by the mitigation works. The roads and farm land along the Blind Joes Creek floodway are regularly inundated under current conditions. The proposed option doesn't change the frequency of inundation, it just removes some of the obstructions at the upstream end of the floodway. It therefore lowers levels upstream of these obstructions close to town and allows more flow to move east. It is likely that road users and farmers along the floodway would not notice any significant change, however these people would need to be consulted with as part of the process. Land owners directly affected would need to be identified and have a negotiated outcome between them and the WGCMA. If the change in flooding was not accepted, then a design response would be required (e.g. deepening of the floodway to remove afflux) this would add additional costs to the mitigation option.

It is also assumed that, with the flow restrictions of Friends and Willung Road removed, agricultural land west of these road crossings in the Blind Joes Creek floodway would drain more efficiently, reducing the time the land is unusable after a flood event. These works could form part of a formal drainage scheme, providing dual benefit of flood mitigation and rural drainage. Cost associated with package two are shown in Table 4-5.

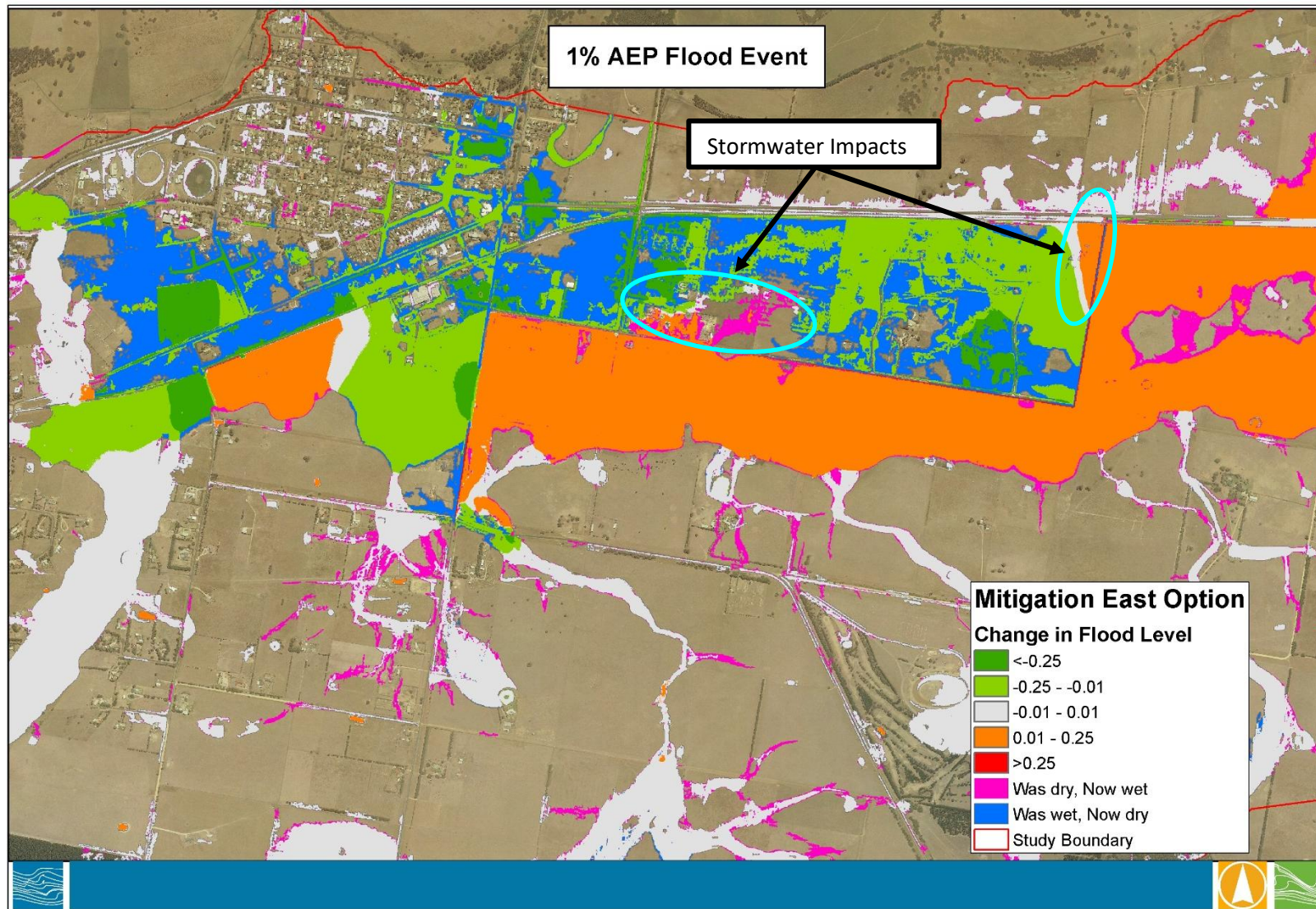


Figure 4-5 More flow East Option - 1% AEP Difference Plot

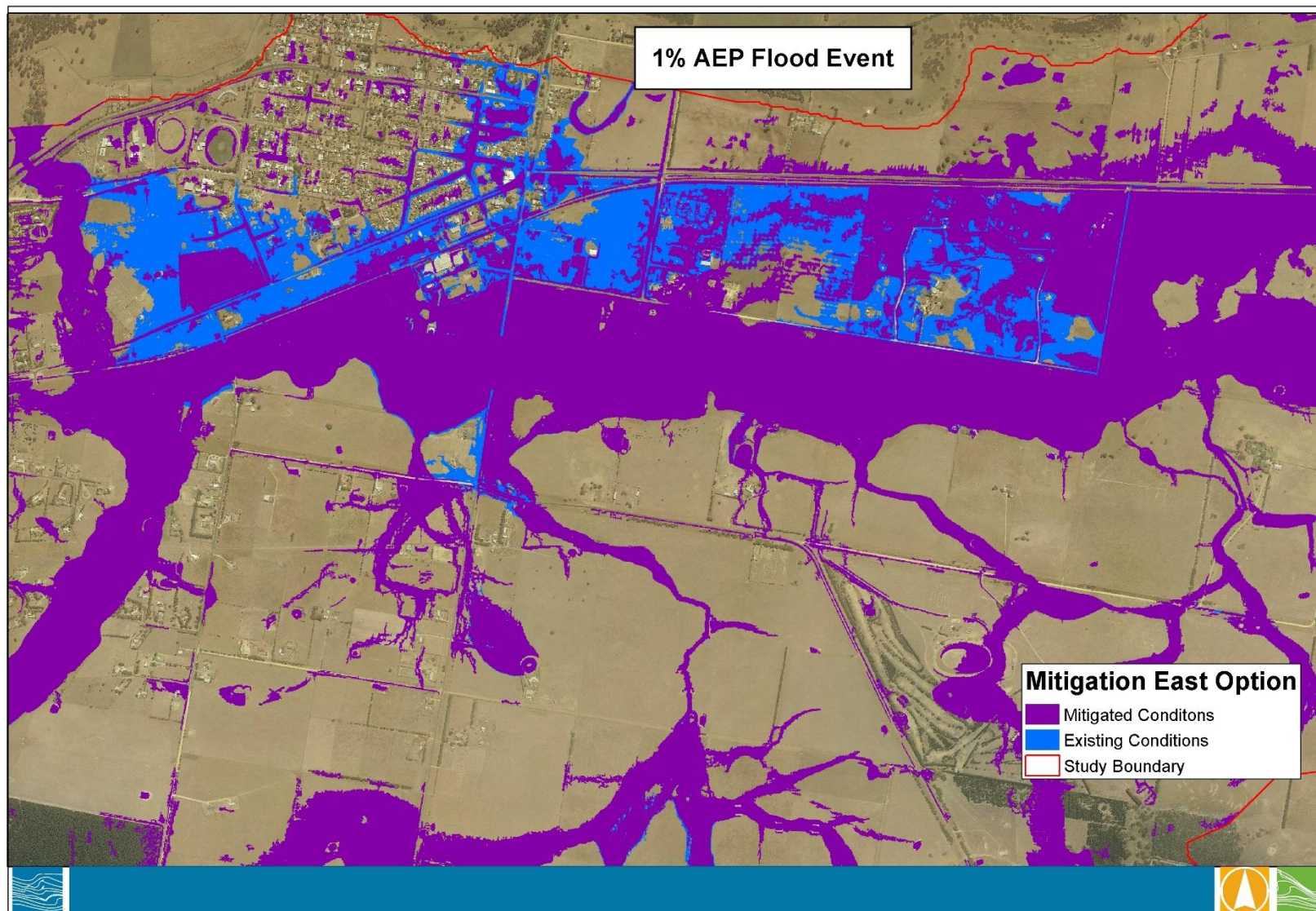


Figure 4-6 More flow East Option - 1% AEP Flood Extent Comparison.

Table 4-5 More Flow to the East Costs

Component	Quantity	Cost
Embankment between Railway & Cansick St	50m	\$ 8,000
Culvert works (VicTrack Land)		\$ 11,000
Levee around the Tannery	112 m	\$ 57,000
Lower Friends Road	220m	\$ 550,000
Culvert Works Rosedale –Stradbroke Rd		\$ 80,000
Huffers Lane Levee	2700m	\$ 280,000
Lower Willung Road	555m	\$792,000
Earth works within the Floodway	8000 m ³	\$233,000
Total Cost		\$ 2,011,000

Costs associated with the More Flow to the East option are shown in Table 4-5. Avoiding major crossings or bridge works on VicRoads and VicTrack land has significantly reduced the more flow east option costs when compared to the more flow north option. One trade-off for this is the observed flood level increases on privately owned land within the Blind Joes Creek floodway. Additional costs to manage localised stormwater impacts have not been costed as part of this project.

5. FLOOD DAMAGES

5.1 Overview

A flood damages assessment was undertaken for the study area under existing conditions. The flood assessment determined the monetary flood damages for design floods (20%, 10%, 5%, 2%, 1% and 0.5% AEP events). The flood damage assessment was also undertaken for the final mitigation package.

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD, more recent damage curves from the NSW Office of Environment and Heritage and other relevant flood damage literature. The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated. Note that rural agricultural damages have not been included in this study as the focus for mitigation is on the township. Details of all properties inundated within the study area are provided in Appendix A.

5.2 Existing Conditions

A flood damages assessment was undertaken on existing conditions and is shown in Table 5-1. The 1% AEP damage calculated was **\$ \$1,431,000** with 2 residential properties flooded above floor and 7 commercial properties also flooded above floor. The average annual damage (AAD), a measure of the flood damage, per year over an extended period was estimated for existing conditions to be **\$ 76,000**. The AAD is an estimate of the cost of flooding to the community that includes both public and privately owned assets.

Table 5-1 Existing Conditions Flood Damages Summary

EXISTING CONDITIONS					
ARI (years) AEP	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1
Residential Buildings Flooded Above Floor	7	2	1	1	0
Commercial Buildings Flooded Above Floor	8	7	5	1	0
Properties Flooded Below Floor	239	234	229	212	177
Total Properties Flooded	254	243	235	214	177
Direct Potential External Damage Cost	\$975,000	\$834,710	\$692,023	\$406,527	\$171,178
Direct Potential Residential Damage Cost	\$329,788	\$102,545	\$69,906	\$65,330	\$0
Direct Potential Commercial Damage Cost	\$323,104	\$263,366	\$215,941	\$7,695	\$0
Total Direct Potential Damage Cost	\$1,627,892	\$1,200,621	\$977,870	\$479,552	\$171,178
Total Actual Damage Cost (0.8*Potential)	\$1,302,314	\$960,497	\$782,296	\$383,642	\$136,942
Infrastructure Damage Cost	\$571,352	\$470,626	\$407,191	\$314,058	\$201,785
Indirect Clean Up Cost					
Indirect Residential Relocation Cost					
Indirect Emergency Response Cost					
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0
Total Cost	\$1,873,666	\$1,431,123	\$1,189,487	\$697,699	\$338,728

5.3 More Flow to the North

Flood damages were costed for the more flow to the north option. This option aims to reduce flooding north of the railway line and Huffers Lane. The results (Table 5-2) showed that the number of residential properties flooded in a 1% AEP event remains at 2, however all commercial properties were protected from flooding above floor level in the 1% AEP event. This reduced the flood damage estimate for a 1% AEP flood event to **\$735,000**. The AAD was also reduced to **\$41,000**.

Table 5-2 Mitigation Flood Damages Summary for More Flow to the North

ARI (years) AEP	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1
Residential Buildings Flooded Above Floor	2	2	1	0	0
Commercial Buildings Flooded Above Floor	4	0	0	0	0
Properties Flooded Below Floor	213	198	178	168	143
Total Properties Flooded	219	200	179	168	143
Direct Potential External Damage Cost	\$492,724	\$362,442	\$252,626	\$208,110	\$142,861
Direct Potential Residential Damage Cost	\$114,036	\$99,572	\$27,689	\$0	\$0
Direct Potential Commercial Damage Cost	\$127,986	\$0	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$734,746	\$462,014	\$280,315	\$208,110	\$142,861
Total Actual Damage Cost (0.8*Potential)	\$587,797	\$369,611	\$224,252	\$166,488	\$114,289
Infrastructure Damage Cost	\$444,361	\$365,376	\$305,512	\$224,765	\$142,179
Indirect Clean Up Cost					
Indirect Residential Relocation Cost					
Indirect Emergency Response Cost					
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0
Total Cost	\$1,032,158	\$734,988	\$529,764	\$391,253	\$256,468

5.4 More Flow to the East

Flood damages were costed for the more flow to the east option. Similar to the other mitigation option it aims to reduce flooding north of the railway line and Huffers Lane. The results (Table 5-3) showed that the number of residential properties flooded in a 1% AEP event remains at 2, however all commercial properties were protected from flooding above floor level in the 1% AEP event. One of the residential properties inundated in this scenario is from localised rainfall. This reduced the flood damage estimate for a 1% AEP flood event to **\$703,000**. The AAD was also reduced to **\$42,000**.

Table 5-3 Mitigation Flood Damages Summary for More Flow to the East

ARI (years) AEP	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1
Residential Buildings Flooded Above Floor	3	2	1	0	0
Commercial Buildings Flooded Above Floor	2	0	0	0	0
Properties Flooded Below Floor	216	197	182	169	145
Total Properties Flooded	221	199	183	169	145
Direct Potential External Damage Cost	\$498,387	\$329,375	\$252,733	\$215,589	\$154,358
Direct Potential Residential Damage Cost	\$172,157	\$77,615	\$27,689	\$0	\$0
Direct Potential Commercial Damage Cost	\$70,442	\$0	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$740,986	\$406,990	\$280,422	\$215,589	\$154,358
Total Actual Damage Cost (0.8*Potential)	\$592,789	\$325,592	\$224,338	\$172,471	\$123,486
Infrastructure Damage Cost	\$447,532	\$377,192	\$325,632	\$236,948	\$150,395
Indirect Clean Up Cost					
Indirect Residential Relocation Cost					
Indirect Emergency Response Cost					
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0
Total Cost	\$1,040,321	\$702,784	\$549,969	\$409,419	\$273,881

6. BENEFIT COST ANALYSIS

A Benefit Cost Analysis was undertaken for both mitigation options modelled (results shown in Table 6-1). This analysis showed clearly that both options have limited financial benefit when considering existing flooding conditions. This is because the existing flood damages are quite low through Rosedale compared to the cost of the considered mitigation options. The analysis didn't consider the potential economic benefit of releasing flood prone land for development. To better understand these conditions, a detailed benefit cost analysis would need to be undertaken by an economist.

The Benefit Cost Analysis showed that if the more flow to the north option was implemented it would actually cause a net annual liability (cost) of around \$117,000. More flow east showed better results but not at a level which would likely attract State and Federal funding. This option may be further considered if development north of the railway line and Huffers Lane is required into the future to enable growth within Rosedale.

Table 6-1 Mitigation Impacts and Cost - Benefit

	More Flow North	More Flow East
Average Annual Damage	\$41,000.	\$42,000
Annual Maintenance Cost*	\$152,000	\$28,000
Annual Cost Saving	-\$117,000	\$6000
Net Present Value (6%)	-\$1,642,000	\$81,000
Capital Cost of Mitigation	\$10,989,000	\$2,011,000
Benefit – Cost Ratio	-0.15	0.04

* Annual maintenance costs estimated at ~3% of the capital works cost

Mitigation costings for these options are considered conservative however given the results of the benefit cost analysis, it is unlikely that more accurate costing would render either option viable. Mitigation options analysed in this study considered large scale works to flood proof the whole township. It is envisaged that smaller more modest works could be implemented to flood proof smaller areas within the town. This analysis does not consider a number of indirect and non-economic benefits discussed in section 6.1.

6.1 Non-Economic Flood Damages

The previous discussion relating to flood damages has concentrated on monetary damages, that is, damages that are easily quantified. In addition to those damages, it is widely recognised that individuals and communities also suffer significant non-monetary damage, i.e. emotional distress, health issues, etc. There has been extensive research undertaken and documented in the scientific literature relating to the individuals and communities response to natural disasters. A recent publication entitled *“Understanding floods: Questions and Answers”* by the Queensland Floods Science Engineering and Technology Panel, when discussing the large social consequences floods have on individuals and communities states:

Floods can also traumatise victims and their families for long periods of time. The loss of loved ones has deep impacts, especially on children. Displacement from one's home, loss of property and disruption to business and social affairs can cause continuing stress. For some people the psychological impacts can be long lasting.

The *“Disaster Loss Assessment Guidelines”* (EMA, 2002) make the following key points:

- *Intangibles are often found to be more important than tangible losses.*
- *Most research shows that people value the intangible losses from a flooded home—principally loss of memorabilia, stress and resultant ill-health—as at least as great as their tangible dollar losses.*
- *There are no agreed methods for valuing these losses.*

There is no doubt that the intangible non-monetary flood related damage in Rosedale is high. The benefit-cost analysis presented earlier in this report has not considered this cost. Nor has the additional benefits gained from land that could be developed if the mitigation options were adopted been considered. Anecdotal stories reveal that a number of properties in this area have had trouble getting home insurance as a result of the current LSIO planning layer, the same residences are concerned that this may also devalue their homes. The cost benefit analysis also has not taken into account the possibility for land currently zoned within the flood overlay or land subject to inundation which may have the flood risk significantly reduced as a result of the mitigation options discussed. Any decisions made that are based on the benefit-cost ratios need to understand that the true cost of floods in Rosedale is far higher than the economic damages alone. This would have the effect of increasing the benefit cost ratio, improving the argument for approving a mitigation scheme at Rosedale.

7. CONCLUSION AND RECOMMENDATIONS

The hydraulic modelling undertaken for the Rosedale flood study has allowed for locations within Rosedale that pose a high flood risk to be identified. The modelling has also identified potential mitigation options to reduce flood risk, with demonstrated benefits in terms of reducing the frequency and magnitude of flooding. The mitigation options identified along with the updated planning information aim to treat the existing risk within the Rosedale Township.

Further detailed assessment of the More Flow to the East mitigation option would be required to proceed to the next stage of implementation. It could be that this option can be carried out into the future in cooperation between Wellington Shire Council, West Gippsland CMA and potential land developers. Based on the current analysis, it is considered unlikely that the mitigation option would be able to attract full government funding to cover the construction costs. It may be possible to cover the costs through developer contributions into the future if the land protected is to be developed.

Smaller scale mitigation options that are complementary to other council projects might be more viable from a cost benefit perspective (e.g. Huffers Lane works), similarly works which unlock flood prone land for development and match current township scale strategies for growth may also warrant further investigation (e.g. west of the township).

The proposed planning scheme amendments require Wellington Shire Council to run a planning scheme amendment process in consultation with affected landholders.

A key theme through the project and through the steering committee and community meetings was the fact that there is very limited data for residents and authorities to use to undertake flood warning and emergency management within the Rosedale area. Given this and the catchment's relatively short response time (8-12hrs), it is recommended that 2 instantaneous rain gauges with telemetry services be investigated for installation in the Blind Joes Creek catchment, one inside the Rosedale Township and one in the upper catchment of Blind Joes Creek.

Data from these stations could be combined with flood risk analysis in this study to create a flash flood warning system for the town. As the town is prone to flash flooding, the responsibility for management of any early warning system becomes the responsibility of Wellington Shire Council. It is expected that the Bureau of Meteorology and DELWP would provide assistance in the development of the system and the supply of software, as well as the supply of severe weather warnings and flood watches.

Considering these points, it is recommended that Wellington Shire Council investigate and document the feasibility of a flash flood warning service. Wellington Shire Council can seek assistance in this investigation from the Bureau of Meteorology, the West Gippsland CMA and DELWP.

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APPENDIX A – PROPERTIES & ROADS INUNDATED

Easting	Northing	Floor Level	Ground Level	Building Type	Address	0.5% AEP Depth Above Floor	1% AEP Depth Above Floor	2% AEP Depth Above Floor	5% AEP Depth Above Floor	10% AEP Depth Above Floor
481058.2	5776811	17.508	17.506	COM	47 CANSICK ST	-0.221	-0.256	-0.279	-0.307	-0.312
481384.5	5777335	17.564	17.225	COM	29 PRINCE ST	-0.506	-0.506	-0.506	-0.506	-0.508
481340.3	5777344	17.312	17.172	COM	37-39 PRINCE ST	-0.352	-0.374	-0.386	-0.387	-0.387
481519.8	5777314	17.063	16.993	COM	1 PRINCE ST	-0.118	-0.134	-0.154	-0.313	-0.514
481368.3	5777387	17.121	17.021	COM	34B PRINCE ST	-0.264	-0.274	-0.279	-0.279	-0.28
481373.9	5777386	17.13	17.078	COM	34A PRINCE ST	-0.237	-0.241	-0.242	-0.243	-0.232
481385.2	5777384	17.155	17	COM	30-32 PRINCE ST	-0.227	-0.228	-0.23	-0.23	-0.224
480977	5777402	17.729	17.761	COM	89 PRINCE ST	-0.158	-0.159	-0.159	-0.16	-0.158
481409.4	5777380	16.944	16.891	COM	26-28 PRINCE ST	-0.162	-0.209	-0.245	-0.365	-0.352
481340.4	5777391	17.161	17.055	COM	40 PRINCE ST	-0.308	-0.312	-0.312	-0.312	-0.311
481486.5	5777367	16.824	16.799	COM	12 PRINCE ST	0.034	-0.019	-0.065	-0.241	-0.24
481346	5777390	17.15	17.046	COM	38B PRINCE ST	-0.254	-0.255	-0.254	-0.255	-0.254
481351.5	5777389	17.152	17.046	COM	38A PRINCE ST	-0.246	-0.246	-0.246	-0.247	-0.238
481444.6	5777327	16.866	16.893	COM	17-19 PRINCE ST	0.078	0.063	0.042	-0.116	-0.335
481516	5777298	17.078	17.031	COM	26 LYONS ST	-0.129	-0.146	-0.168	-0.328	-0.435
481400.5	5777334	17.642	17.105	COM	25-27 PRINCE ST	-0.541	-0.542	-0.542	-0.543	-0.545
481436.2	5777376	16.896	16.911	COM	22 PRINCE ST	-0.073	-0.124	-0.169	-0.393	-0.393
481423.5	5777330	17.079	17.013	COM	21-23 PRINCE ST	-0.135	-0.15	-0.171	-0.29	-0.296
480883.9	5777425	17.801	17.755	COM	95-99 PRINCE ST	-0.275	-0.283	-0.286	-0.291	-0.298

481420.3	5777378	16.958	16.918	COM	24 PRINCE ST	-0.158	-0.209	-0.254	-0.491	-0.505
481372.4	5777339	17.202	17.134	COM	31 PRINCE ST	-0.246	-0.267	-0.29	-0.331	-0.332
481477.7	5777321	16.807	16.764	COM	11 PRINCE ST	0.136	0.122	0.101	-0.057	-0.361
481007.5	5777402	17.7	17.666	COM	87 PRINCE ST	-0.172	-0.178	-0.182	-0.188	-0.195
481485.3	5777320	16.743	16.696	COM	9 PRINCE ST	0.201	0.186	0.165	0.007	-0.431
481464.1	5777323	16.819	16.826	COM	15 PRINCE ST	0.124	0.109	0.089	-0.069	-0.322
481472.6	5777322	16.825	16.746	COM	13 PRINCE ST	0.118	0.104	0.083	-0.075	-0.341
481360.6	5777392	17.142	17.079	COM	36 PRINCE ST	-0.215	-0.188	-0.189	-0.189	-0.22
481021.4	5777400	17.658	17.624	COM	85 PRINCE ST	-0.13	-0.136	-0.14	-0.146	-0.153
480983.6	5777591	17.768	17.666	COM	50 QUEEN ST	-0.38	-0.38	-0.381	-0.381	-0.381
482025.8	5776621	16.462	16.432	COM	145 MILL LANE	0.143	0.07	-0.012	-0.107	-0.159
481028.4	5775492	21.543	21.22	COM	164 WILLUNG RD	-0.471	-0.471	-0.471	-0.472	-0.48
481012.6	5775486	21.583	21.506	COM	164 WILLUNG RD	-0.304	-0.305	-0.305	-0.305	-0.302
482074.3	5776711	16.457	16.433	COM	133 MILL LANE	0.128	0.052	-0.039	-0.162	-0.181
481796	5776735	16.999	16.958	COM	29 HUFFERS LANE	-0.372	-0.385	-0.385	-0.385	-0.383
480121	5777025	18.571	18.496	COM	CRICKET ST	-0.579	-0.586	-0.59	-0.593	-0.593
480173.6	5777035	18.672	18.658	COM	CRICKET ST	-0.338	-0.338	-0.339	-0.339	-0.324
480147.2	5776991	18.507	18.419	COM	CRICKET ST	-0.306	-0.306	-0.306	-0.306	-0.305
479886.5	5777228	18.74	18.662	COM	2194 PRINCES HWY	-0.404	-0.404	-0.405	-0.405	-0.408
479780.8	5777182	18.701	18.672	COM	2188 PRINCES HWY	-0.258	-0.261	-0.265	-0.27	-0.275
479358.9	5776898	18.268	17.824	COM	73-97 CRICKET ST	-0.546	-0.546	-0.546	-0.546	-0.507
481388.1	5776946	17.218	17.209	COM	5-13 CANSICK ST	-0.151	-0.152	-0.152	-0.152	-0.166

481209.9	5777019	17.438	16.772	RES	1 DAWSON ST	-0.421	-0.458	-0.485	-0.532	-0.522
481214.9	5776926	18.032	17.399	RES	26 CANSICK ST	-0.875	-0.92	-0.968	-0.996	-0.991
481190.6	5776912	18.021	17.27	RES	30 CANSICK ST	-0.85	-0.897	-0.939	-0.959	-0.959
481178.4	5776902	17.959	17.329	RES	32 CANSICK ST	-0.776	-0.824	-0.873	-0.978	-1.018
481027.1	5776801	17.962	17.419	RES	51 CANSICK ST	-0.64	-0.671	-0.697	-0.735	-0.794
480907.1	5776940	18.328	17.576	RES	28 DAWSON ST	-0.81	-0.811	-0.811	-0.812	-0.813
481162	5776901	18.041	17.389	RES	34 CANSICK ST	-0.847	-0.895	-0.945	-0.982	-0.978
481138.3	5776892	17.944	17.282	RES	38 CANSICK ST	-0.731	-0.78	-0.831	-0.891	-0.893
481076.7	5776862	18.004	17.247	RES	46 CANSICK ST	-0.762	-0.808	-0.855	-0.954	-0.96
481230.5	5776928	17.948	17.213	RES	24 CANSICK ST	-0.799	-0.845	-0.897	-0.92	-0.924
481052.2	5776855	18.077	17.254	RES	48 CANSICK ST	-0.814	-0.86	-0.903	-0.97	-0.97
480949.6	5776956	18.062	17.285	RES	22 DAWSON ST	-0.63	-0.633	-0.635	-0.637	-0.631
481142.1	5776990	17.506	16.786	RES	11 DAWSON ST	-0.474	-0.479	-0.481	-0.481	-0.479
481104	5776878	18.108	17.291	RES	42 CANSICK ST	-0.878	-0.925	-0.97	-1.001	-1.003
481121.5	5776882	17.989	17.319	RES	40 CANSICK ST	-0.765	-0.814	-0.862	-0.976	-0.975
481032.3	5776908	18.094	17.411	RES	7 LATROBE ST	-0.87	-0.873	-0.873	-0.873	-0.873
481097.9	5776968	17.495	16.595	RES	17 DAWSON ST	-0.354	-0.355	-0.356	-0.357	-0.357
481157.7	5776997	17.448	16.74	RES	9 DAWSON ST	-0.41	-0.426	-0.443	-0.464	-0.44
481009.6	5776795	17.609	17.441	RES	53 CANSICK ST	-0.261	-0.295	-0.323	-0.364	-0.405
481251.6	5776938	17.993	17.255	RES	22 CANSICK ST	-0.875	-0.914	-0.959	-0.995	-0.983
481039.8	5776808	17.992	17.41	RES	49 CANSICK ST	-0.689	-0.722	-0.746	-0.779	-0.87
481116.8	5776979	17.43	16.705	RES	15 DAWSON ST	-0.366	-0.367	-0.368	-0.369	-0.371

481146.5	5776895	18.066	17.323	RES	36 CANSICK ST	-0.858	-0.908	-0.959	-0.992	-0.976
481170.9	5777002	17.437	16.742	RES	7 DAWSON ST	-0.418	-0.45	-0.491	-0.538	-0.576
481209.1	5776921	18.017	17.142	RES	28 CANSICK ST	-0.853	-0.903	-0.948	-0.985	-0.992
481125.6	5776983	17.407	16.822	RES	13 DAWSON ST	-0.375	-0.406	-0.407	-0.407	-0.407
481045.1	5776950	18.057	17.377	RES	25 DAWSON ST	-0.85	-0.863	-0.873	-0.873	-0.872
481060.6	5776958	18.057	17.339	RES	23 DAWSON ST	-0.94	-0.963	-0.979	-0.981	-0.982
481126.6	5777028	17.384	17.007	RES	10 DAWSON ST	-0.366	-0.396	-0.404	-0.41	-0.415
481089.2	5776874	18.155	17.425	RES	44 CANSICK ST	-0.918	-0.965	-1.011	-1.058	-1.061
481181.9	5777004	17.369	16.775	RES	5 DAWSON ST	-0.354	-0.393	-0.427	-0.463	-0.474
481201.6	5777012	17.452	16.781	RES	3 DAWSON ST	-0.442	-0.478	-0.517	-0.606	-0.612
481288	5776956	17.599	17.269	RES	2 HOOD ST	-0.548	-0.578	-0.59	-0.59	-0.589
480922.4	5776943	18.208	17.474	RES	26 DAWSON ST	-0.741	-0.741	-0.742	-0.742	-0.734
481072.3	5776961	17.468	16.781	RES	21 DAWSON ST	-0.368	-0.382	-0.388	-0.389	-0.384
481084.5	5776965	17.524	16.617	RES	19 DAWSON ST	-0.433	-0.448	-0.449	-0.45	-0.453
480937.7	5776949	18.188	17.351	RES	24 DAWSON ST	-0.789	-0.788	-0.789	-0.79	-0.795
480872.3	5776738	17.668	17.446	RES	69 CANSICK ST	-0.146	-0.205	-0.262	-0.347	-0.456
480892	5776742	18.289	17.472	RES	67 CANSICK ST	-0.776	-0.822	-0.877	-0.973	-1.037
481404.3	5777202	17.839	16.896	RES	9 ALBERT ST	-0.87	-0.895	-0.92	-1.042	-1.264
481169.5	5777242	17.608	17.445	RES	31 ALBERT ST	-0.436	-0.438	-0.439	-0.441	-0.444
481420.8	5777112	17.474	17.334	RES	4-6 DUKE ST	-0.446	-0.446	-0.447	-0.447	-0.448
481444	5777112	17.305	17.201	RES	4-6 DUKE ST	-0.319	-0.345	-0.375	-0.397	-0.398
481414.2	5777134	17.535	17.407	RES	4-6 DUKE ST	-0.386	-0.387	-0.388	-0.389	-0.388

481439.6	5777140	17.651	17.534	RES	4-6 DUKE ST	-0.45	-0.451	-0.451	-0.452	-0.441
481451.2	5777130	17.499	17.414	RES	4-6 DUKE ST	-0.351	-0.351	-0.352	-0.352	-0.322
481302.3	5777160	17.87	17.116	RES	21 HOOD ST	-0.886	-0.914	-0.944	-1.041	-1.085
480819.3	5776760	17.678	17.556	RES	66 CANSICK ST	-0.132	-0.194	-0.254	-0.294	-0.293
481373.9	5777206	17.568	16.597	RES	13 ALBERT ST	-0.599	-0.624	-0.649	-0.771	-1.1
480935.7	5776809	17.963	17.535	RES	56 CANSICK ST	-0.497	-0.55	-0.597	-0.611	-0.612
481321.2	5777124	17.933	17.141	RES	14 DUKE ST	-0.944	-0.972	-1.003	-1.087	-1.1
480903.6	5776794	18.365	17.469	RES	60 CANSICK ST	-0.871	-0.928	-0.983	-1.062	-1.072
480903.4	5776752	17.643	17.444	RES	65 CANSICK ST	-0.143	-0.201	-0.256	-0.343	-0.449
480918.3	5776756	17.988	17.419	RES	63 CANSICK ST	-0.494	-0.55	-0.604	-0.689	-0.726
481218	5777144	17.574	17.086	RES	20 DUKE ST	-0.585	-0.614	-0.646	-0.744	-0.753
480779.4	5776702	17.855	17.733	RES	79 CANSICK ST	-0.294	-0.358	-0.418	-0.507	-0.546
481538.6	5776940	17.796	17.387	RES	3 LYONS ST	-0.652	-0.653	-0.653	-0.654	-0.654
481347.3	5777120	17.377	17.294	RES	12 DUKE ST	-0.388	-0.398	-0.398	-0.398	-0.393
481348.5	5777146	17.811	17.316	RES	12 DUKE ST	-0.797	-0.798	-0.799	-0.802	-0.803
481259.8	5777137	17.237	16.987	RES	18 DUKE ST	-0.248	-0.277	-0.308	-0.416	-0.574
481453.3	5777236	17.309	17.151	RES	8 ALBERT ST	-0.344	-0.367	-0.392	-0.489	-0.489
481264.9	5777160	17.549	16.809	RES	14 HOOD ST	-0.563	-0.591	-0.622	-0.732	-0.937
480854.6	5776728	17.556	17.438	RES	71 CANSICK ST	-0.024	-0.084	-0.143	-0.228	-0.332
480837.1	5776722	17.58	17.431	RES	73 CANSICK ST	-0.036	-0.098	-0.158	-0.245	-0.369
480636.8	5776628	18.593	17.905	RES	89 CANSICK ST	-0.884	-0.929	-0.936	-0.936	-0.937
481543.6	5776965	17.594	17.388	RES	5-7 LYONS ST	-0.62	-0.625	-0.625	-0.625	-0.65

480937.4	5776765	17.706	17.455	RES	61 CANSICK ST	-0.227	-0.281	-0.333	-0.415	-0.498
481402.2	5777073	17.367	16.986	RES	7 DUKE ST	-0.379	-0.407	-0.437	-0.53	-0.675
481116.2	5777164	17.765	17.456	RES	30 DUKE ST	-0.557	-0.561	-0.563	-0.563	-0.571
480704.6	5776661	18.266	17.598	RES	85 CANSICK ST	-0.648	-0.709	-0.768	-0.844	-0.854
481543.2	5777019	17.559	17.046	RES	9 LYONS ST	-0.671	-0.704	-0.757	-0.834	-0.885
481266	5777180	17.232	17.073	RES	16 HOOD ST	-0.248	-0.276	-0.307	-0.418	-0.513
481267.1	5777229	17.422	17.292	RES	21 ALBERT ST	-0.417	-0.435	-0.436	-0.437	-0.471
481372.5	5777120	17.494	17.166	RES	10 DUKE ST	-0.506	-0.534	-0.564	-0.607	-0.604
481474	5777237	17.138	17.1	RES	6 ALBERT ST	-0.177	-0.199	-0.223	-0.37	-0.401
481341.3	5777252	17.287	17.109	RES	18 ALBERT ST	-0.32	-0.344	-0.369	-0.472	-0.478
481388.3	5777118	17.653	17.147	RES	8 DUKE ST	-0.665	-0.693	-0.723	-0.808	-0.829
481474.5	5777102	17.376	17.108	RES	12 LYONS ST	-0.403	-0.426	-0.452	-0.51	-0.568
480522	5776583	18.22	17.909	RES	109 CANSICK ST	-0.399	-0.451	-0.498	-0.564	-0.647
481422.3	5777204	17.538	16.906	RES	7 ALBERT ST	-0.569	-0.594	-0.619	-0.741	-0.958
480921.1	5776800	17.886	17.613	RES	58 CANSICK ST	-0.409	-0.461	-0.507	-0.507	-0.512
480974.1	5776826	18.48	17.557	RES	52 CANSICK ST	-1.111	-1.141	-1.17	-1.184	-1.174
481396.8	5777206	17.519	16.882	RES	11 ALBERT ST	-0.55	-0.575	-0.6	-0.723	-0.967
481304.1	5777128	17.461	17.065	RES	16 DUKE ST	-0.47	-0.5	-0.532	-0.633	-0.647
481323.3	5777254	17.402	17.073	RES	20 ALBERT ST	-0.429	-0.455	-0.481	-0.542	-0.59
481137.2	5777287	17.886	17.578	RES	36 ALBERT ST	-0.57	-0.575	-0.579	-0.581	-0.584
481267.7	5777189	17.48	16.981	RES	18 HOOD ST	-0.498	-0.526	-0.555	-0.668	-0.76
480953.1	5776771	17.57	17.359	RES	59 CANSICK ST	-0.109	-0.161	-0.209	-0.286	-0.438

481526	5776916	17.374	17.262	RES	1 LYONS ST	-0.354	-0.364	-0.373	-0.384	-0.389
481432.9	5777245	17.673	17.275	RES	10 ALBERT ST	-0.7	-0.715	-0.716	-0.717	-0.714
481465.5	5777059	17.337	17.072	RES	10 LYONS ST	-0.357	-0.38	-0.407	-0.456	-0.532
481507.8	5777285	16.427	16.145	RES	24 LYONS ST	0.523	0.505	0.483	0.323	-0.393
480481.3	5776995	18.569	18.027	RES	28 GEORGE ST	-0.752	-0.752	-0.753	-0.753	-0.752
480769.9	5777010	18.694	18.07	RES	18 WOOD ST	-0.886	-0.889	-0.89	-0.891	-0.892
480443.6	5776963	18.316	18.138	RES	31 GEORGE ST	-0.501	-0.502	-0.502	-0.503	-0.503
481591.4	5777210	17.61	17.64	RES	23 LYONS ST	-0.395	-0.395	-0.396	-0.396	-0.403
481567.2	5777133	17.525	16.802	RES	15 LYONS ST	-0.684	-0.724	-0.789	-0.844	-0.853
481391.4	5777379	17.259	16.985	RES	30-32 PRINCE ST	-0.418	-0.426	-0.431	-0.437	-0.407
480634.5	5776970	18.598	18.135	RES	16 GEORGE ST	-0.704	-0.709	-0.713	-0.714	-0.729
481763.5	5777018	17.084	16.942	RES	50 ROSEDALE- LONGFORD RD	-0.275	-0.302	-0.347	-0.533	-0.554
480444.8	5777004	18.384	18.114	RES	32 GEORGE ST	-0.63	-0.634	-0.641	-0.653	-0.667
481568.3	5777118	17	17.136	RES	13 LYONS ST	-0.159	-0.199	-0.264	-0.368	-0.373
480468.5	5776960	18.247	18.164	RES	29 GEORGE ST	-0.442	-0.442	-0.442	-0.442	-0.441
481559.7	5777097	17.74	17.138	RES	11 LYONS ST	-0.851	-0.867	-0.893	-0.906	-0.909
481607.1	5777157	17.529	16.814	RES	19 LYONS ST	-0.689	-0.728	-0.793	-1.031	-1.004
481577	5777163	17.704	17.268	RES	19 LYONS ST	-0.756	-0.757	-0.758	-0.759	-0.759
480399.2	5777146	19.073	18.11	RES	5 AYRES CT	-1.268	-1.272	-1.274	-1.275	-1.284
480466.8	5777002	18.543	18.069	RES	30 GEORGE ST	-0.799	-0.804	-0.805	-0.805	-0.825
480614.1	5776973	18.598	18.114	RES	18 GEORGE ST	-0.707	-0.708	-0.708	-0.709	-0.696
480527.6	5776998	18.304	17.978	RES	24-26 GEORGE ST	-0.535	-0.536	-0.537	-0.538	-0.52

481742.2	5777006	17.462	16.773	RES	44 ROSEDALE- LONGFORD RD	-0.624	-0.653	-0.703	-0.913	-0.93
481572.3	5777151	17.238	17.255	RES	17 LYONS ST	-0.393	-0.404	-0.406	-0.407	-0.409
481581.9	5777180	17.618	17.566	RES	21 LYONS ST	-0.468	-0.468	-0.469	-0.469	-0.469
481584.8	5777013	17.313	16.903	RES	30 ROSEDALE- LONGFORD RD	-0.437	-0.468	-0.522	-0.624	-0.639
481189.8	5777509	16.627	16.298	RES	29 QUEEN ST	-0.332	-0.596	-0.596	-0.599	-0.612
481229.5	5777539	17.158	16.556	RES	28 QUEEN ST	-0.864	-0.974	-0.974	-0.974	-0.969
480462.6	5777270	18.267	18.06	RES	86 DUKE ST	-0.389	-0.387	-0.39	-0.388	-0.382
481382.5	5777461	17.525	16.784	RES	31-33 HOOD ST	-0.854	-0.884	-0.91	-1	-1.02
480344.9	5776789	18.086	17.914	RES	22 MOORE ST	-0.224	-0.264	-0.304	-0.356	-0.389
480316.9	5776872	18.235	18.104	RES	30 MOORE ST	-0.37	-0.399	-0.428	-0.434	-0.434
480489	5777263	18.152	18.075	RES	84 DUKE ST	-0.435	-0.44	-0.443	-0.446	-0.451
480465.3	5776826	18.211	18.111	RES	5 ROSEMONT AVE	-0.35	-0.389	-0.43	-0.479	-0.479
480249.6	5776813	18.581	17.918	RES	6 MCLEOD CT	-0.724	-0.763	-0.804	-0.856	-0.908
480443.9	5777359	18.184	18.054	RES	97 ALBERT ST	-0.388	-0.394	-0.399	-0.402	-0.406
480437.3	5777335	18.259	18.19	RES	97 ALBERT ST	-0.46	-0.466	-0.472	-0.476	-0.481
481396.6	5777472	17.352	16.705	RES	13 QUEEN ST	-0.81	-0.828	-0.85	-0.925	-0.926
481232.5	5777499	17.057	15.975	RES	25 QUEEN ST	-0.762	-1.177	-1.19	-1.195	-1.2
480309.5	5776887	18.129	18.09	RES	32 MOORE ST	-0.268	-0.307	-0.336	-0.342	-0.338
480371.2	5776838	18.243	18.102	RES	31 MOORE ST	-0.381	-0.412	-0.426	-0.434	-0.403
480364.5	5776856	18.2	18.064	RES	33 MOORE ST	-0.338	-0.378	-0.419	-0.431	-0.427
480195.9	5776763	18.228	18.065	RES	13 MCLEOD CT	-0.363	-0.389	-0.413	-0.445	-0.421

480318.2	5776839	18.329	17.979	RES	28 MOORE ST	-0.468	-0.508	-0.549	-0.602	-0.64
480518.8	5777466	18.038	17.895	RES	129 PRINCE ST	-0.366	-0.368	-0.371	-0.376	-0.382
480490.4	5777402	18.688	17.985	RES	90 ALBERT ST	-0.965	-0.965	-0.965	-0.965	-0.954
480328.9	5776813	18.336	17.925	RES	24 MOORE ST	-0.475	-0.51	-0.546	-0.592	-0.609
480459.8	5777359	18.286	18.112	RES	95 ALBERT ST	-0.499	-0.499	-0.5	-0.5	-0.5
480244.3	5776868	18.301	18.069	RES	5 WIDDOWSON CT	-0.435	-0.439	-0.453	-0.455	-0.455
480455.1	5776846	18.262	18.128	RES	3 CHOWN CT	-0.386	-0.403	-0.403	-0.403	-0.371
480283.1	5776828	18.362	18.25	RES	4 MCLEOD CT	-0.451	-0.458	-0.46	-0.46	-0.457
480459.8	5777460	18.519	17.838	RES	131-133 PRINCE ST	-0.793	-0.793	-0.794	-0.794	-0.794
480444.5	5776867	18.273	18.041	RES	5 CHOWN CT	-0.408	-0.422	-0.423	-0.423	-0.422
480353	5776769	18.381	17.963	RES	20 MOORE ST	-0.518	-0.558	-0.599	-0.644	-0.644
480380	5776816	18.205	18.114	RES	29 MOORE ST	-0.343	-0.383	-0.424	-0.476	-0.487
480457.4	5776886	18.267	18.142	RES	6 CHOWN CT	-0.389	-0.406	-0.41	-0.41	-0.413
480474.4	5776880	18.338	18.044	RES	8 CHOWN CT	-0.454	-0.476	-0.488	-0.495	-0.488
481205.2	5777546	16.535	16.371	RES	30 QUEEN ST	-0.439	-0.525	-0.525	-0.525	-9999.99
480540.1	5777459	18.32	17.904	RES	127 PRINCE ST	-0.627	-0.627	-0.629	-0.629	-0.619
480211	5776805	18.223	18.083	RES	2 WIDDOWSON CT	-0.366	-0.405	-0.44	-0.478	-0.503
480204.4	5776878	18.199	18.041	RES	10 WIDDOWSON CT	-0.337	-0.368	-0.402	-0.435	-0.455
480223.2	5776767	18.193	17.951	RES	11 MCLEOD CT	-0.335	-0.375	-0.415	-0.455	-0.457
481245.5	5777494	17.215	16.325	RES	23 QUEEN ST	-0.92	-1.191	-1.184	-1.184	-1.194
480241.3	5776774	18.185	18.172	RES	9 MCLEOD CT	-0.326	-0.363	-0.39	-0.417	-0.411
480199.1	5776866	18.208	18.029	RES	8 WIDDOWSON CT	-0.352	-0.391	-0.431	-0.467	-0.469

480585.4	5777309	18.19	18.069	RES	17 MACKAY ST	-0.614	-0.613	-0.613	-0.614	-0.627
480211	5776826	18.226	17.879	RES	4-6 WIDDOWSON CT	-0.369	-0.409	-0.449	-0.502	-0.551
479505.1	5772309	49.766	49.412	RES	FRIENDS RD	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
481906.2	5773088	40.846	40.695	RES	472 FAIRLEYS RD	-0.306	-0.306	-0.306	-0.307	-0.304
482052.2	5776570	17.192	16.842	RES	61 HUFFERS LANE	-0.586	-0.586	-0.586	-0.586	-0.579
482035	5777589	14.898	14.354	RES	41 MILL LANE	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
482040.1	5777454	17.145	16.606	RES	38 MILL LANE	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
482061.4	5776638	16.536	16.483	RES	FAWKES RD	0.058	-0.016	-0.102	-0.234	-0.258
481522.7	5776629	17.283	16.625	RES	9 HUFFERS LANE	-0.428	-0.446	-0.47	-0.52	-0.634
481892.2	5777620	15.494	15.168	RES	45 MILL LANE	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
482213.4	5776681	16.652	16.522	RES	LOT 14 FAWKES RD	-0.096	-0.167	-0.252	-0.355	-0.337
480077.8	5774913	35.034	34.776	RES	5 BELLE VIEW CT	-0.282	-0.288	-0.296	-0.313	-0.35
482031.2	5776485	17.611	16.76	RES	58 HUFFERS LANE	-0.964	-1.001	-1.012	-1.018	-1.019
483638.6	5776701	15.226	15.104	RES	45 KYLE ST	-0.134	-0.3	-0.383	-0.385	-0.38
479895	5776111	19.259	18.888	RES	18 FRIENDS RD	0.005	-0.098	-0.218	-0.404	-0.567
481224.5	5775850	19.611	19.516	RES	124 WILLUNG RD	-0.38	-0.381	-0.381	-0.381	-0.379
483154.7	5776489	16.497	16.027	RES	171 HUFFERS LANE	-0.718	-0.729	-0.729	-0.73	-0.707
482433.2	5775729	26.128	25.982	RES	105 ROSEDALE- STRADBROKE RD	-0.202	-0.205	-0.207	-0.209	-0.222
479421.6	5776258	19.665	19.554	RES	105 SHAWS LANE	-0.25	-0.25	-0.25	-0.25	-0.218
479624.5	5776394	18.59	18.434	RES	206 ROSEDALE- FLYNNS CREEK RD	-0.391	-0.408	-0.426	-0.461	-0.476
483659.4	5776535	15.528	15.353	RES	24 KYLE ST	-0.39	-0.497	-0.51	-0.51	-0.523

483674.8	5776397	15.233	15.227	RES	12 KYLE ST	0.032	-0.035	-0.162	-0.3	-0.309
480234.1	5776108	19.69	19.63	RES	34 FRIENDS RD	-0.037	-0.038	-0.038	-0.039	-0.037
483200.5	5776602	15.804	15.713	RES	24 MERRIMAN ST	-0.174	-0.284	-0.334	-0.334	-0.334
483851.1	5776823	15.193	14.881	RES	61 KYLE ST	-0.244	-0.386	-0.485	-0.485	-0.49
483874.8	5776844	14.85	14.779	RES	61 KYLE ST	0.058	-0.089	-0.217	-0.239	-0.244
479365.4	5776287	19.666	19.408	RES	99 SHAWS LANE	-0.442	-0.449	-0.451	-0.455	-0.458
483161.2	5776773	15.906	15.555	RES	48 MERRIMAN ST	-0.283	-0.41	-0.548	-0.557	-0.558
481266.6	5775974	19.468	18.539	RES	112 WILLUNG RD	-0.921	-0.966	-0.992	-0.999	-1.021
480844.2	5774385	32.929	32.545	RES	276 WILLUNG RD	-0.71	-0.72	-0.734	-0.743	-0.74
483567.3	5776779	14.996	14.83	RES	46 KYLE ST	0.14	-0.027	-0.193	-0.276	-0.291
483151	5776860	15.74	15.596	RES	47 MERRIMAN ST	-0.106	-0.222	-0.276	-0.358	-0.378
482972	5776669	16	15.747	RES	35 MERRIMAN ST	-0.243	-0.377	-0.461	-0.47	-0.452
479962.9	5776421	18.628	18.087	RES	166 ROSEDALE- FLYNNS CREEK RD	-0.604	-0.636	-0.667	-0.703	-0.74
480701.7	5772735	49.723	49.182	RES	440 WILLUNG RD	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
480855.1	5772556	51.161	50.326	RES	451 WILLUNG RD	-9999.99	-9999.99	-9999.99	-9999.99	-9999.99
482930.9	5776455	16.307	16.212	RES	149 HUFFERS LANE	-0.284	-0.335	-0.344	-0.344	-0.341
479481.3	5776329	19.197	18.751	RES	212 ROSEDALE- FLYNNS CREEK RD	-0.636	-0.636	-0.636	-0.636	-0.63
483191.9	5776843	16.616	15.396	RES	59 MERRIMAN ST	-1.037	-1.158	-1.219	-1.272	-1.305
479566	5776324	19.004	18.87	RES	208 ROSEDALE- FLYNNS CREEK RD	-0.457	-0.458	-0.458	-0.46	-0.456
480196.9	5776459	18.525	18.159	RES	2 FRIENDS RD	-0.501	-0.51	-0.52	-0.535	-0.544

480279.8	5776462	18.699	18.585	RES	133 ROSEDALE- FLYNNIS CREEK RD	-0.514	-0.514	-0.515	-0.515	-0.533
479337.9	5776262	20.197	19.777	RES	97 SHAWS LANE	-0.62	-0.62	-0.62	-0.621	-0.622
479492.3	5775335	24.288	24.164	RES	29 ASHTON CT	0.049	0.016	-0.011	-0.04	-0.067
479329.6	5775870	25.38	25.19	RES	9 BOYD CT	-0.551	-0.556	-0.561	-0.568	-0.582
479247.9	5776121	21.309	20.716	RES	236 ROSEDALE- FLYNNIS CREEK RD	-0.827	-0.829	-0.833	-0.834	-0.841
479492.2	5775581	28.631	28.013	RES	60 BOYD CT	-0.713	-0.714	-0.714	-0.714	-0.725
479649.4	5776342	18.417	18.154	RES	196 ROSEDALE- FLYNNIS CREEK RD	-0.144	-0.178	-0.214	-0.277	-0.365
479636	5776339	18.387	18.335	RES	196 ROSEDALE- FLYNNIS CREEK RD	-0.097	-0.131	-0.169	-0.229	-0.278
479744.7	5777062	18.05	17.449	RES	BYES LANE	-0.707	-0.768	-0.769	-0.769	-0.775
480098.8	5776748	18.236	18.131	RES	15 MCLEOD CT	-0.355	-0.372	-0.387	-0.4	-0.399
480412.2	5777432	18.526	18.033	RES	96-98 ALBERT ST	-0.722	-0.724	-0.724	-0.725	-0.726
480514.4	5776814	18.117	17.951	RES	14 ROWLEY CL	-0.257	-0.296	-0.335	-0.357	-0.345
480441.8	5776788	18.181	17.961	RES	6 ROWLEY CL	-0.319	-0.358	-0.396	-0.446	-0.479
480422.5	5776778	18.013	17.852	RES	4 ROWLEY CL	-0.151	-0.19	-0.231	-0.283	-0.336
483595.7	5776453	15.408	15.335	RES	17 KYLE ST	-0.144	-0.212	-0.288	-0.356	-0.343
480536.4	5776825	18.276	18.092	RES	16 ROWLEY CL	-0.408	-0.421	-0.432	-0.448	-0.439
480500	5776836	18.187	17.936	RES	9 ROWLEY CL	-0.326	-0.366	-0.407	-0.457	-0.479
480475.7	5776802	18.15	17.947	RES	10 ROWLEY CL	-0.289	-0.328	-0.369	-0.421	-0.468
480495	5776811	18.088	17.892	RES	12 ROWLEY CL	-0.227	-0.266	-0.307	-0.36	-0.412
483672.2	5776774	15.447	14.712	RES	47 KYLE ST	-0.374	-0.537	-0.663	-0.687	-0.697

480519.6	5776846	18.176	18.018	RES	11 ROWLEY CL	-0.316	-0.355	-0.395	-0.411	-0.39
480557	5776828	18.278	18.061	RES	18 ROWLEY CL	-0.418	-0.425	-0.429	-0.43	-0.428
480343.5	5776978	18.498	18.388	RES	39-45 GEORGE ST	-0.416	-0.417	-0.417	-0.42	-0.423
483440.8	5776348	15.52	15.365	RES	203 HUFFERS LANE	-0.01	-0.1	-0.246	-0.401	-0.406
480573.4	5776844	18.205	18	RES	20 ROWLEY CL	-0.347	-0.347	-0.347	-0.348	-0.347
483717	5776698	15.279	14.574	RES	48 KYLE ST	-0.229	-0.392	-0.544	-0.768	-0.791
480401.2	5776771	18.177	18.066	RES	2 ROWLEY CL	-0.315	-0.355	-0.384	-0.444	-0.468
480456.6	5776796	18.162	18.039	RES	8 ROWLEY CL	-0.301	-0.34	-0.38	-0.433	-0.485
480556.3	5776860	18.26	18.109	RES	15 ROWLEY CL	-0.384	-0.409	-0.418	-0.422	-0.42
480541.6	5776861	18.215	17.994	RES	13 ROWLEY CL	-0.352	-0.373	-0.389	-0.392	-0.395
481209.9	5777019	17.438	16.772	RES	1 DAWSON ST	-0.421	-0.458	-0.485	-0.532	-0.522

AEP Design Event	Flood Consequences		
	Red text denotes a road not inundated in the previous AEP event		
10% AEP	Street	Length (m)	Peak depth (m)
	MERRIMAN STREET	140.3	0.2
	HOOD STREET	181.9	0.2
	MILL LANE	110.4	0.2
	MCPHERSONS LANE	156.1	0.2
	WALTON STREET	69.9	0.2
	LATROBE STREET	168.9	0.2
	FARRELL LANE	374.6	0.2
	WILLUNG ROAD	208.6	0.2
	WILLIAMS ROAD	131.1	0.2
	FRIENDS ROAD	361.7	0.2
	HOOPERS ROAD	389.1	0.2
	DAWSON STREET	212.3	0.2
	GEORGE STREET	190.3	0.2
	DUKE STREET	244.8	0.3
	ASHTON COURT	138.5	0.3
	CANSICK STREET	98.6	0.3
	BUDGES LANE	227.3	0.3
	HUFFERS LANE	389.3	0.3
	ROSEDALE-STRADBROKE ROAD	505.0	0.4
	KYLE STREET	161.5	0.4
	AYRES COURT	123.5	0.4
	CRICKET STREET	153.7	0.4
	MOORE STREET	442.8	0.5
	MULLOCKY LANE	1003.6	0.5
	ROWLEY CLOSE	175.5	0.5
	MCLEOD COURT	180.5	0.7
	WIDDOWSON COURT	87.2	0.8
	FARLEYS ROAD	329.0	1.4
	ROSEDALE-FLYNN'S CREEK ROAD	617.9	1.5
	PRINCES HIGHWAY	324.2	1.7
	Residential Buildings Flooded Above Floor		0
	Commercial Buildings Flooded Above Floor		0
	Properties Flooded Below Floor		177
5% AEP	Street	Length (m)	Peak Depth (m)
	ALBERT STREET	419.0	0.3
	ASHTON COURT	144.5	0.3
	AYRES COURT	129.7	0.4
	BUDGES LANE	399.2	0.6
	BYES LANE	32.6	0.3
	CANSICK STREET	530.3	0.4
	CHOWN COURT	55.4	0.5
	CRICKET STREET	225.1	0.5

	DAWSON STREET	314.5	0.4
	DUKE STREET	343.5	0.5
	FARLEYS ROAD	430.4	1.6
	FARRELL LANE	426.1	0.2
	FRIENDS ROAD	529.9	0.2
	GEORGE STREET	220.6	0.3
	HOOD STREET	412.3	0.4
	HOOPERS ROAD	426.7	0.2
	HUFFERS LANE	633.1	0.4
	KYLE STREET	216.3	0.4
	LATROBE STREET	271.6	0.2
	MCLEOD COURT	180.5	0.8
	MCPHERSONS LANE	195.3	0.2
	MOORE STREET	478.5	0.5
	MULLOCKY LANE	1033.2	0.8
	PRINCES HIGHWAY	334.9	1.8
	ROSEDALE-FLYNN'S CREEK ROAD	930.6	1.6
	ROSEDALE-STRADBROKE ROAD	742.9	0.3
	ROWLEY CLOSE	191.5	0.6
	WALTON STREET	87.1	0.2
	WIDDOWSON COURT	87.2	0.8
	WILLIAMS ROAD	272.6	0.2
	WILLUNG ROAD	1252.0	0.3
	Residential Buildings Flooded Above Floor	1	
	Commercial Buildings Flooded Above Floor	1	
	Properties Flooded Below Floor	212	
2% AEP	Street	Length (m)	Peak Depth (m)
	ALBERT STREET	506.1	0.5
	ASHTON COURT	157.8	0.3
	AYRES COURT	134.5	0.5
	BUDGES LANE	419.8	0.7
	CANSICK STREET	857.3	0.4
	CHOWN COURT	55.4	0.5
	CRICKET STREET	337.5	0.6
	DAWSON STREET	347.5	0.5
	DUKE STREET	382.4	0.6
	EVERGREEN ROAD	556.5	0.2
	FARLEYS ROAD	516.2	1.7
	FARRELL LANE	432.4	0.3
	FAWKES ROAD	177.3	0.3
	FRIENDS ROAD	597.1	0.3
	GEORGE STREET	220.4	0.3
	HOOD STREET	488.6	0.5
	HOOPERS ROAD	426.6	0.2
	HUFFERS LANE	1023.1	0.6
	KYLE STREET	676.3	0.6

	LATROBE STREET	403.2	0.3
	MCLEOD COURT	180.5	0.8
	MCPHERSONS LANE	222.0	0.3
	MILL LANE	354.0	0.4
	MOORE STREET	514.2	0.6
	MULLOCKY LANE	1064.8	1.0
	PRINCES HIGHWAY	407.6	1.9
	QUEEN STREET	413.1	0.2
	ROSEDALE-FLYNN'S CREEK ROAD	1148.6	1.7
	ROSEDALE-LONGFORD ROAD	911.0	0.2
	ROSEDALE-STRADBROKE ROAD	803.4	0.4
	ROWLEY CLOSE	193.6	0.6
	WALTON STREET	99.6	0.3
	WIDDOWSON COURT	87.2	0.9
	WILLIAMS ROAD	365.9	0.3
	WILLUNG ROAD	1349.3	0.3
	WOOD STREET	172.0	0.2
	Residential Buildings Flooded Above Floor	1	
	Commercial Buildings Flooded Above Floor	5	
	Properties Flooded Below Floor	219	
1% AEP	Street	Length (m)	Peak Depth (m)
	ALBERT STREET	531.6	0.5
	ASHTON COURT	165.4	0.3
	AYRES COURT	136.5	0.5
	BUDGES LANE	437.8	0.8
	BYES LANE	63.2	0.6
	CANSICK STREET	937.9	0.5
	CHOWN COURT	55.4	0.6
	CRICKET STREET	442.8	0.7
	DAWSON STREET	351.6	0.6
	DUKE STREET	458.7	0.6
	EVERGREEN ROAD	577.6	0.2
	FARLEYS ROAD	593.0	1.8
	FARRELL LANE	430.2	0.3
	FAWKES ROAD	177.3	0.4
	FRIENDS ROAD	619.6	0.3
	GEORGE STREET	224.9	0.3
	HOOD STREET	520.0	0.5
	HOOPERS ROAD	435.5	0.2
	HUFFERS LANE	1123.5	0.6
	KYLE STREET	781.5	0.7
	LATROBE STREET	411.5	0.3
	MACKAY STREET	146.0	0.2
	MCLEOD COURT	180.5	0.9
	MCPHERSONS LANE	259.3	0.3

	MERRIMAN STREET	580.3	0.3
	MILL LANE	409.4	0.5
	MOORE STREET	535.0	0.6
	MULLOCKY LANE	1079.1	1.1
	PRINCES HIGHWAY	430.7	2.0
	QUEEN STREET	454.5	0.3
	ROSEDALE-FLYNN'S CREEK ROAD	1198.3	1.8
	ROSEDALE-LONGFORD ROAD	1320.4	0.2
	ROSEDALE-STRADBROKE ROAD	808.0	0.4
	ROWLEY CLOSE	193.6	0.7
	WALTON STREET	102.5	0.3
	WIDDOWSON COURT	87.2	0.9
	WILLIAMS ROAD	369.2	0.3
	WILLUNG ROAD	1384.0	0.4
	WOOD STREET	216.1	0.3
	Residential Buildings Flooded Above Floor	2	
	Commercial Buildings Flooded Above Floor	7	
	Properties Flooded Below Floor	234	
0.5% AEP	Street	Length (m)	Peak Depth (m)
	ALBERT STREET	638.4	0.5
	ASHTON COURT	221.1	0.3
	AYRES COURT	139.4	0.5
	BUDGES LANE	541.9	0.8
	BYES LANE	115.0	1.3
	CANSICK STREET	972.4	0.5
	CHOWN COURT	55.4	0.6
	CRICKET STREET	646.6	1.2
	DAWSON STREET	436.6	0.6
	DUCK COURT	86.8	0.3
	DUKE STREET	615.6	0.6
	EVERGREEN ROAD	765.7	0.2
	FARLEYS ROAD	1052.1	1.9
	FARRELL LANE	796.3	0.3
	FAWKES ROAD	177.3	0.5
	FRIENDS ROAD	909.8	0.3
	GEORGE STREET	315.8	0.3
	HOOD STREET	591.5	0.5
	HOOPERS ROAD	505.0	0.2
	HUFFERS LANE	1288.9	0.6
	KYLE STREET	789.1	0.9
	LATROBE STREET	525.9	0.4
	MACKAY STREET	317.1	0.2
	MCLEOD COURT	180.5	0.9
	MCPHERSONS LANE	425.9	0.4
	MERRIMAN STREET	584.5	0.4
	MILL LANE	497.6	0.6

MOORE STREET	551.7	0.7
MULLOCKY LANE	1323.7	1.1
PRINCES HIGHWAY	503.4	3.2
QUEEN STREET	707.2	0.7
ROSEDALE-FLYNN'S CREEK ROAD	1371.3	1.9
ROSEDALE-LONGFORD ROAD	1508.4	0.3
ROSEDALE-STRADBROKE ROAD	1365.2	0.4
ROWLEY CLOSE	193.6	0.7
WALTON STREET	169.6	0.4
WIDDOWSON COURT	87.2	0.9
WILLIAMS ROAD	406.1	0.3
WILLUNG ROAD	1675.6	0.4
WOOD STREET	272.9	0.3
Residential Buildings Flooded Above Floor	7	
Commercial Buildings Flooded Above Floor	8	
Properties Flooded Below Floor	239	

Rosedale Flood Study – Summary Report



May 2016

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Cover Photo: Community supplied image from 1934 floods – Main Street of Rosedale (Newsagent).

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- (West Gippsland CMA)
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- I (Rosedale Neighbourhood House -Community Representative)
- (Community Representative)

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GLOSSARY OF TERMS

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.

Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.

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1. INTRODUCTION

1.1 Overview

Following the recent Latrobe River flood study, it was identified that a flood intelligence gap existed in Rosedale and Water Technology was subsequently 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.

The following Summary Report (R04), provides a summary of three detailed standalone reports produced earlier in the project. This report acts as an executive summary of the entire study. A description of each of the staged reports is included below.

R01 - Rosedale Flood Study – Data Review (Water Technology 2016a)

Review of flood related information for the study area, a review of available topographic and structure data (bridges and culvert information), and verification of topographic data. The report also provided a proposed outline of the hydrologic analysis and hydraulic modelling methodology.

R02 - Rosedale Flood Study – Hydrology & Hydraulics (Water Technology 2016b)

Hydrologic modelling and analysis report, summarising results of RORB modelling, estimation of design event, and probable maximum flood hydrographs. Hydraulic modelling report providing details of hydraulic model construction and calibration, sensitivity tests, and results of design event simulations.

R03 - Rosedale Flood Study – Assess and Treat Risk (Water Technology 2016c)

Includes mitigation prefeasibility and modelling, flood intelligence, flood warning and planning control review.

R04 - Traralgon Flood Study – Summary Report (Water Technology 2016d)

This report which provides a summary of the three reports described above.

These four reports detail the approaches adopted, the findings and the recommendations of the Rosedale Flood Study. The four reports are supported by a number of standalone PDF flood maps and digital deliverables.

1.2 Study Catchment and Floodplain

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 1-1 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 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 back 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.

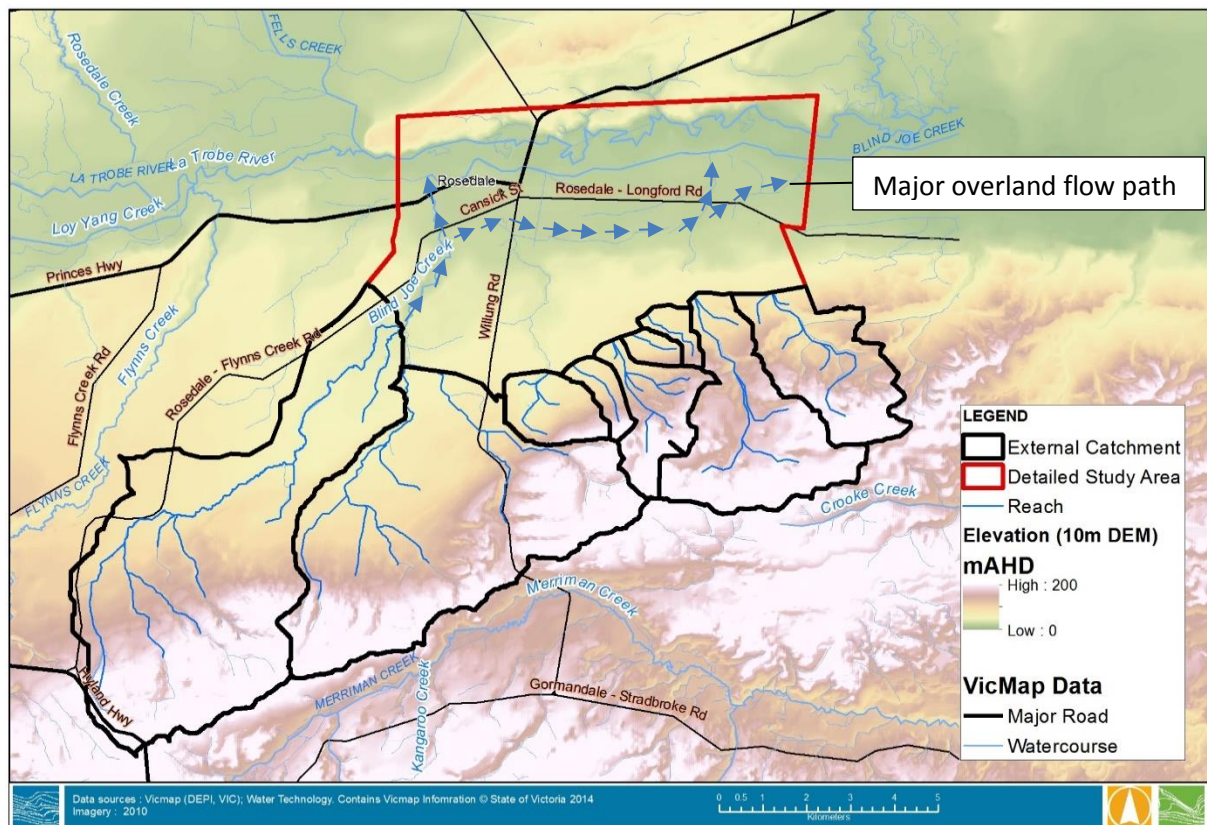


Figure 1-1 Rosedale Contributing Catchments

2. DATA REVIEW

Shortly after the project inception meeting, a detailed review was undertaken of all available flood related information as well as topographic data, structure information, and hydrological data. Details of this review are provided in the Data Review (R01), while a short overview is provided below.

2.1 Flood Related Studies

Rosedale has been the subject of numerous flood related studies and associated mitigation works on the Blind Joes Creek and Latrobe River from the 1930s. Table 2-1 summarises the available reports that were reviewed as well as significant changes within the study area over time.

Table 2-1 Historic Flood information timeline

Event	Description	Relevant information
1863	First river levels (unofficial) collected (EJ Crooke)	Data printed in the Gippsland Times 1934 - confirmed 1934 as biggest flood in this period.
December 1934	Largest flood on record (Latrobe River). Anecdotal evidence suggests that the railway crossing (at Glengarry) failed causing backed up water to be released (like a dam break). Railway bridge/embankment failure downstream of Rosedale.	Peak flow estimate (RWC, 1989) 3,500 m ³ /s (150 – 200 year ARI Event) Anecdotal evidence suggests the Latrobe River “backed up” Blind Joes Creek. Flood Level at railway near Willung Road 17.45 m AHD (12 Inches above the railway line)
Post 1934 Floods	Cansick Street Bridge moved Cricket Street Bridge replaced with 5 box culverts (900 x 1,200 mm) Friends & Willung Roads raised by ~300 mm.	
June 1935	Dare report written discussing railway bridge failures in 1934.	Description of bridge failure mechanism and hydrologic implications (flood travel times etc).
1938	New Highway bridge complete	
June 1952	Large flow in Latrobe River (1,874 m ³ /s - ~40 year ARI)	
1952 (date unknown)	Large flow in Blind Joes Creek, limited flooding in Latrobe River. Floodway south of town engaged. Little impact on township.	
October 1953	Large flow in the Latrobe River (1,701 m ³ /s – ~40 year ARI).	
1961	Lake Narracan (Latrobe River – 2,730 ML) & Moondarra Reservoir (Tyers River – 29,700 ML) constructed	

Event	Description	Relevant information
1966-68	Holy Plains drainage scheme constructed. System designed to drain land south and east of the town.	
June 1978	Significant flooding throughout Gippsland. Large flow in the Latrobe River (1,500 m ³ /s - ~ 30 year ARI). Anecdotal evidence suggests the Cansick Street bridge was blocked by debris and the floodway south of town became engaged.	
1983	Residents request a significant maintenance program be undertaken on the Holy Plain drainage system. Council holds community meetings to discuss solutions.	
1984	Blue Rock Dam constructed (Tanjil River - 208,000 ML)	
October 1987	RWC wrote to council nominating the 1934 flood as equivalent to 100 year ARI event (3,500 m ³ /s peak flow in the Latrobe River).	
1989	RWC complete the "Rosedale Flood Study Frequency Analysis" 100 year ARI flow in the Latrobe River is revised down to 3,010 m ³ /s. Flood levels are dropped by ~200 mm.	90 m ³ /s adopted as the 100 year ARI flow in Blind Joes Creek (catchment comparison method with Traralgon Creek).
1992	RWC revise the 100 year ARI flows back to the 1934 flood estimate (3,500 m ³ /s).	
September 1993	Significant rain in the Strzelecki Ranges (up to 300 mm in 24 hours) resulted in major flooding in Blind Joes Creek. Flooding not as significant in the Latrobe River (980 m ³ /s – 20 year ARI).	Shire of Wellington collect flooding images and flood levels (level data possibly not peak heights).
November 1993	Gutteridge Haskins & Davey (GHD) "Rosedale Flood Management Plan (Stage 1)" released to the Shire of Wellington.	1934 Flood > 100 year ARI (150 year ARI); 100 year ARI flow in the Latrobe 2,730 m ³ /s & 90 – 100 m ³ /s in Blind Joes Creek; Flood levels at Rosedale in 1934 were not significantly impacted by the railway embankment failure at Glengarry.
April 1995	Dept. of Conservation & Natural Resources "Rosedale Flood Investigation (Stage 1)" released to the Shire of Wellington.	1934 Flood represented the 100 year ARI; 100 year ARI flow in the Latrobe 3,500 m ³ /s and 100 m ³ /s in Blind Joes Creek;

Event	Description	Relevant information
		Blind Joes Creek flows Split at the railway bridge with 40% flowing north and the balance flowing east. HEC2 hydraulic modelling defined a 100 year ARI flood extent, the hydraulic model was calibrated to the 1993 event flood levels, Latrobe TWL sensitivity applied. Mitigation options presented including levees.
June 1995	Gutteridge Haskins & Davey (GHD) "Rosedale Flood Management Plan (Stage 2)" released to the Shire of Wellington.	Dept. of Conservation & Natural Resources 1993 hydrology and Blind Joes Creek flow split adopted. HEC2 model revisited and updated including additional mitigation analysis. Flood level from the Latrobe of 17.6 m AHD (33 year ARI) was determined to be the threshold level at which breakout north of the railway could occur. This happened in 1934. Community consultation undertaken. Community were pro levees.
February 2000	Shepherd Round Consultants Report released "Rosedale Flood Management Plan"	The report noted: "Primary mechanism of flooding within in Rosedale township is produced by flood levels in the Latrobe River". Flood Warning system for Blind Joes Creek not justifiable. New alignment of the GHD levee proposed, geotech investigation completed and mitigation costings revisited. Further investigations recommended. Funding application completed on behalf of the Shire of Wellington.
September 2001	GHD report "Rosedale Flood Warning System – Hydrology Report" released to the Shire of Wellington.	Flood frequency revisited, 100 year ARI flow revised down to 2,610 m³/s. New hydrology – URBS model New photogrammetry New hydraulic model (DELFT) Model calibrated to the 1934 and 1993 events
2013	Latrobe Flood Study completed by Cardno. Larger flood study covering Yarragon to Sale. Flooding of the Latrobe	New Flood Frequency Analysis, new/revised hydrology (BoM URBS model), new hydraulic model (SOBEK). Latrobe 100 year ARI flow very different

Event	Description	Relevant information
	and all major tributaries considered (inc. Blind Joes Creek).	to all other historic studies (1,875 m ³ /s), Blind Joes Creek inflows not reported. The coarse grid (~40 x40m) in the hydraulic modelling resulted in much of the Rosedale Township being shown as flooded in a 100 year ARI event.
2014	New Princes Highway bridge over Blind Joes Creek (highway duplication works).	Water Technology complete waterway investigations for VicRoads. Study includes new hydrology for Blind Joes Creek (RORB Model), limited hydraulic analysis (MIKE FLOOD) focused on Princes Highway bridge.

2.2 The Latrobe Flood Study 2013

WGCMA recently completed the Latrobe River Flood Study (Cardno, 2013), which included updated hydrology and hydraulics for the river. The study generated detailed results throughout the Latrobe River Floodplain including north of Rosedale. This study included inflows from Flynn's, Middle and Blind Joes Creeks but didn't consider the other smaller catchments south of the township.

Due to the grid size applied (40x40m) in the hydraulic modelling of Blind Joes Creek, it is not considered an accurate representation of current flood behaviour. The study did provide a significant amount of information on flood levels on the Latrobe River Floodplain.

Using the Latrobe River flood study results, Water Technology was able to demonstrate how far the Latrobe River can "back up" into the town during different events. The results of this analysis are shown in Figure 2-1. It suggests that very few homes would be inundated if a large flood occurred only in the Latrobe River, with the worst flood prone areas being Allen Court, Mackay Street (northern end), Queen Street and Mill Lane. At the western edge of the township, it suggested that both Blind Joes Creek and the Latrobe River must interact to cause flooding on the land between Cansick Street and the Princes Highway.

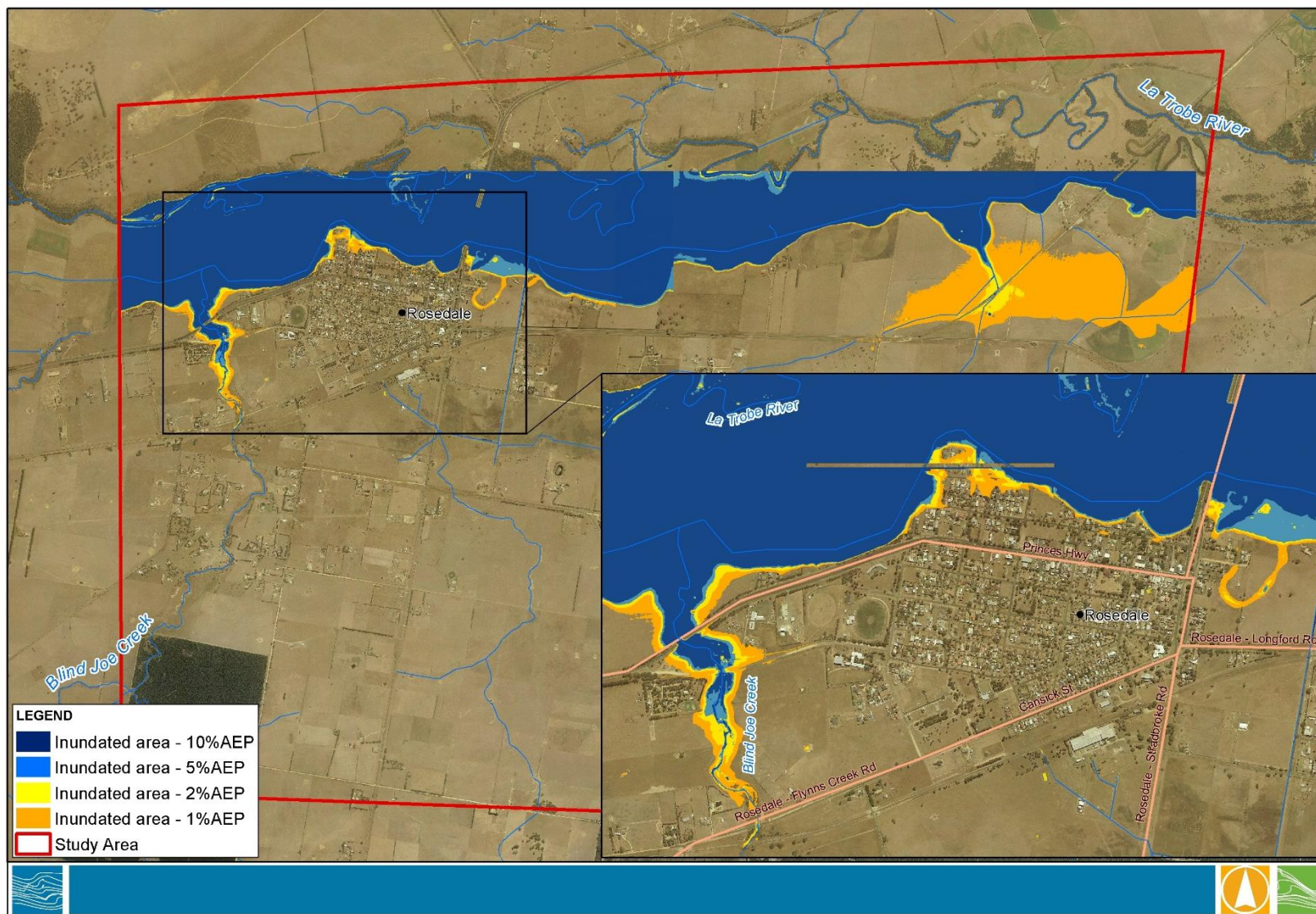


Figure 2-1 Latrobe Flood Study Results – Estimated area inundated by the Latrobe River (excludes Blind Joes Creek flooding)

2.3 Historic Flood Information

Significant historic flood events have been compiled from available sources and are listed in Table 2-1. The largest flood on record (since 1863) was in December 1934, with flows in the Latrobe River estimated to be close to a 0.5% AEP event. After this event, two gauging stations were established at Rosedale, with one on the Latrobe River and the other on the Latrobe Anabranche. Review of both rainfall and gauging data have suggested that the next biggest floods on record occurred in the 50's (1952 and 1953), followed by 1978 and 1993.

The most comprehensive historic flood information is available for the 1993 event, including digitised flood extent, surveyed flood levels and numerous flood photographs, collated for Hydrotechnology's report on the 1993 Gippsland floods. Some data was also available for the 1934 and 1978 events.

2.4 Topographic Data

2.4.1 Available Datasets

Initially, two Aerial LiDAR (Light Detection and Ranging) survey datasets were available for use in this study (listed below); however, between them they did not cover the entire area of interest.

- Index of Stream Condition (ISC) Rivers LiDAR
- SRW-90MB LiDAR

Additional LiDAR data was captured as part of the project to fill the gap. Upon review of the available LiDAR it was decided to use the SRW-90MB LiDAR and the "new LiDAR" in the hydraulic model build. Additional field survey including several transects, river cross sections and culverts was carried out to verify the LiDAR data, provide an estimate of channel capacity and fill data gaps of important hydraulic structures.

2.4.2 Data Verification

The two LiDAR datasets that were used for the construction of the hydraulic model were compared against the field survey data and each other. The survey data included several cross sections of the creek and two transects located at Willung Road and Dawson Street.

Compared to each other the two LiDAR data set were generally very accurate, with a mean difference of 0.069 m. Compared to the transect survey sections, the survey was higher than the LiDAR data (200 mm+). As both LiDAR data sets were generally in agreement with each other it was not proposed to modify them.

2.4.3 DEM Development

As mentioned previously, the SRW-90MB LiDAR and "new LiDAR" were combined and used to generate the digital elevation model for the hydraulic model. Initially, the Latrobe River was modelled at a 12 m grid resolution while the Rosedale Township was modelled with a 4 m grid resolution.

For the validation modelling of 1993 and 2012 events, the SRW-90MB LiDAR (2008) was used in preference (sat on top) over the "new LiDAR", however this arrangement was reversed in the design modelling as the new LiDAR better reflected current conditions.

2.5 Structure Information

There are several key hydraulic structures within the Rosedale Township located on Blind Joes Creek. 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 township include; the Melbourne-Bairnsdale Railway line; Cansick Street and Princes Highway. Information on these structures was obtained through the Wellington Shire Council, West Gippsland CMA as well as

a site visit on October 16, 2014. Bridge piers, deck heights and culvert dimensions were sourced and added to the hydraulic model.

2.5.1 Pit and Pipe Network

The Rosedale stormwater drainage network was incorporated in the 1D/2D hydraulic model using pipe and pit information provided by the Wellington Shire Council. A significant data gap was identified in the pit and pipe network, therefore considerable engineering judgement was applied to the drainage network. The changes made to the existing database ensure the pit and pipe network functioned within the hydraulic model and were noted in the GIS database.

2.6 Hydrological Data

2.6.1 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 region. Key stations, including current stations and stations operating over the 1993 and 2012 floods, are listed in Table 2-2. Unfortunately, no daily rainfall stations exist within the Blind Joes Creek catchment for both the 1993 and 2012 flood events.

Table 2-2 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 2-3. 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 2-3 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

2.6.2 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 the 1993 and 2012 events. Steering committee representative and Coordinator at Rosedale Neighbourhood House, _____ was instrumental in this process. Daily rainfall totals collected are detailed in Table 2-4 and Table 2-5.

Community rainfall records were cross checked (where possible) and combined with the official BoM records to provide a more accurate spatial spread of rainfall event depths throughout the study area. The rainfall depth information (combining community and BoM records) was then used in the hydrologic model (RORB) to estimate runoff from the ranges south of the township. Hydraulic modelling outputs using the community and BoM rainfall information was then compared to observed flood information. This approach is common in catchments where limited data is available.

Table 2-4 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
	1580 Princes Highway Flynn Vic 3844	474,097.4 5,775,757.9	1.5	5.6	3.3	37.6	32.5	1.3	2.0
	8140 Willung Rd Willung Vic 3847	482,637.6 5,767,093.6		3.5	15	75	14.5	8.5	

Table 2-5 Community supplied daily rainfall for June 2012

Source	Location	Location (GDA94 MGA 55)	Daily rainfall depth (mm) in June 2012			
			3rd	4th	5th	6th
	18 Queen Street Rosedale	481,379.3 5,777,560.7	4.5	5	74	
	8140 Willung Rd Willung Vic 3847	482,637.6 5,767,093.6	12	38.5	56.5	
	1/33 Dawson Street, Rosedale	481,087.9 5,776,925.2		6.5	73	2.5
	Princes Highway Flynn Vic 3844	473,761.0 5,774,926.0	4.25		71.5	

2.6.3 Streamflow Data

Gauge Locations

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 2-6). 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 Anabranche site represents flows from the Blind Joes and Middle Creek catchments as well as the Rosedale township urban runoff.

Table 2-6 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

Given a comprehensive investigation into the Latrobe River hydrology was completed in the Latrobe River Flood Study and that the focus of this study was 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 River 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 2-7.

Table 2-7 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	Latrobe River @ Rosedale* (Main Stream)	319	353	252	186	160	101
226224	Latrobe River @ Rosedale* (Anabranche)	1,215	1,007	1,012	829	821	353
Combined flow* Latrobe Flood Study 2012		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.

2.6.4 Latrobe River Flood Study – Design Flow estimates

Table 2-8 represent combined flow at both the Latrobe River and the Latrobe River Anabranche gauging stations. These flows were estimated during the Latrobe River Flood Study. This information was used to represent concurrent flooding in the Latrobe River when significant rainfall occurred in the ranges south of the Rosedale Township.

Table 2-8 Latrobe River 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. PROJECT CONSULTATION

3.1 Overview

An important element of the flood mapping study was the active engagement of residents in the study area. This engagement was developed over the course of the study through community consultation sessions and meetings with a Steering Committee. The aims of the community consultation were as follows:

- To raise awareness of the study and to identify key community concerns; and
- To provide information to the community and seek their feedback/input regarding the study outcomes including the existing flood behaviour and proposed flood mapping extents.

3.2 Steering Committee

The flood mapping study was led by a Steering Committee consisting of representatives from West Gippsland Catchment Management Authority (WGCMA), Wellington Shire Council (WSC), Department of Environment Land Water and Planning (DELWP), Victorian State Emergency Service (VicSES), Ventia (the current Gippsland Regional Water Monitoring Partnership contractor) and community members from Rosedale.

The Steering Committee met on three occasions at key points throughout the study, to review study progress, provide comments regarding results, and manage the development of the study.

3.3 Community Consultation

The main aim of the community engagement process was to provide information regarding the development of the study and to seek feedback, both verbally and through the use of online methods. All community meetings were supported by media releases to local papers and meeting notices.

The public consultation process was coordinated by West Gippsland CMA. The following community meetings were held as part of the consultation process:

- Initial community meeting, 25 November 2014 at the Rosedale Community Hub – The first public meeting was held to outline the objectives of the study to the community and to receive any flood information the community may be able to provide;
- Second community meeting, 30st March, 2015 at the same venue – This meeting presented the results of the flood modelling. Community feedback was sought on the flood modelling results.
- Final Community meeting 16th of September 2015 at the same venue – This meeting discussed potential future flooding and mitigation options to manage flood risk into the future.

The community provided knowledge of a range of previous floods. Most data was anecdotal (personal accounts opposed to photos or physical flood marks or locations of direct impact) and related to the 1993 and 2012 flood. Never the less this information was useful in validating the 1993 and 2012 events. In the first meeting we were lucky enough to have a 94 year old resident attend who lived in Rosedale during the 1934 flood (the largest in living memory). Listening to his accounts of this event were both interesting and informative.

An ArcGIS online portal presenting the flood mapping was published allowing for public comment. 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 combining the BoM records with the additional community rainfall record resulted in a reduction in extent and depth of flooding throughout the study area for the historic calibration events, this led to a better estimate of the observed flood marks and other data such as oblique flood images. Note that these community rainfall estimates do not influence the design rainfall estimates used to produce the design flood mapping.

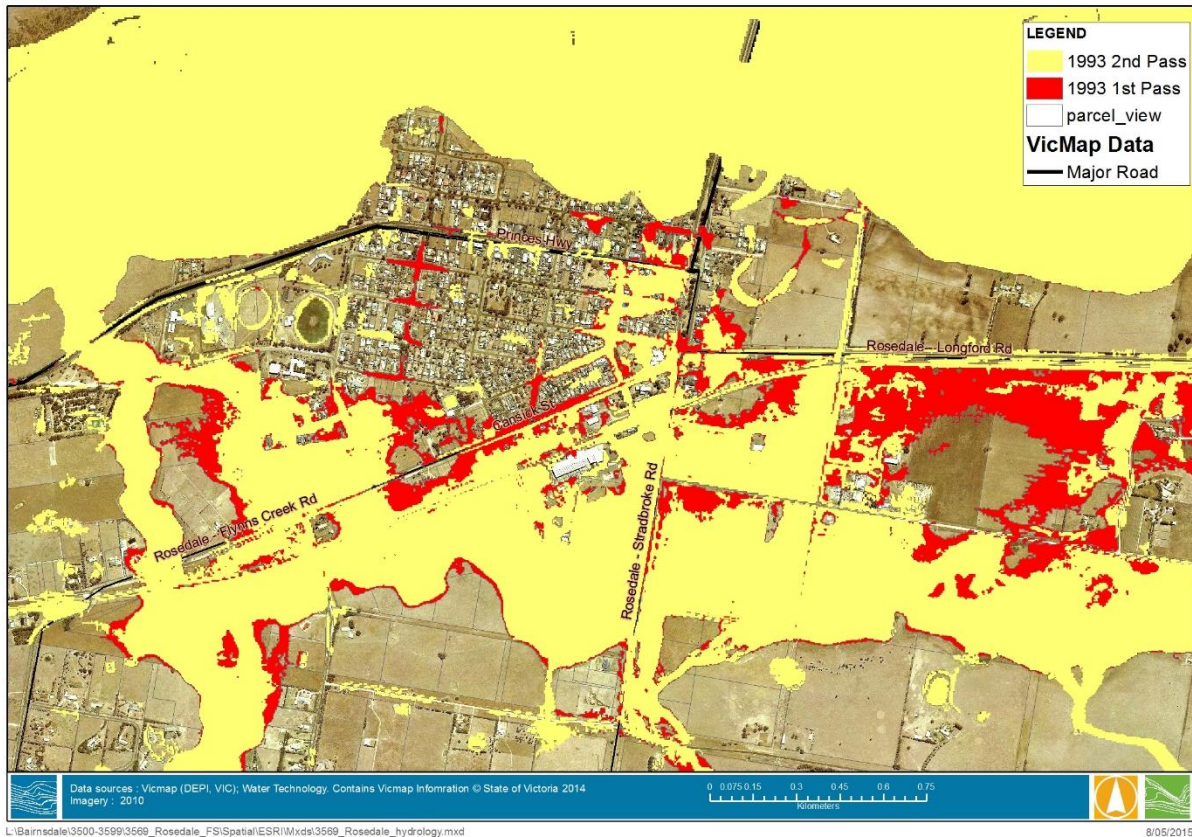


Figure 3-1 Approximate change in flood extent after using community rainfall records

4. FLOOD BEHAVIOUR

4.1 Overview

Flooding in and around Rosedale can occur via three independent mechanisms:

- Flooding from the Latrobe River. Latrobe River has a large upstream catchment area approximately 4,150 km² so can generate larger flows and take longer to reach Rosedale after rainfall occurs.
- Flooding from the smaller catchments south of the township including Blind Joes Creek. Relatively small catchment area of approximately 150 km², generates less flow than the Latrobe River and will arrive quicker than Latrobe River flows after intense rainfall.
- Localised flooding within the town itself from high intensity short duration rainfall generating stormwater flooding.

Flooding from each of these mechanisms can occur independently or often at the same time. As the main portion of town sits above the Latrobe River floodplain direct flooding from the Latrobe River is relatively limited with the Latrobe River Flood Study (Cardno 2013) showing only Mackay, King and Queen Streets seeing direct inundation from the Latrobe River and only in very rare events (1% and 2% AEP floods). Similarly stormwater flooding can cause significant localised nuisance flooding but is unlikely to cause inundation above floor levels or isolation for extended periods (road closures). The major driver of significant flooding in Rosedale is the smaller catchments found to the south of the township including Blind Joes Creek. Whilst flooding from these catchments doesn't inundate a lot of dwellings above floor, inundation is widespread and can cause isolation.

The flood behaviour associated with catchment flooding mechanisms has been assessed using a range of industry standard approaches and tools:

- Hydrological analysis – this involves the analysis of the magnitude of previous flood events in the catchment, the development of a rainfall-runoff model for the entire catchment, and the prediction of the likelihood of future flood events of a given magnitude.
- Hydraulic analysis – the physical understanding of how a given flood event may behave as the flood flows break out of Blind Joes Creek and flow from the various minor waterways and overland flow paths south of town. A hydraulic model was used to predict the extent of flooding, flood depths and flow velocities for a range of possible future flood events.

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 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 discrepancies 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.

The different flood mechanisms and the results of the hydrologic and hydraulic analysis for the study area are discussed in detail in the following sections.

4.2 Hydrology

Detailed information on the hydrology can be found in the Hydrology & Hydraulics Report (R02).

4.2.1 Streamflow Gauging

The data review report identified that current existing gauging data inside the study area was only useful for identifying flows within the Latrobe River. This information was used to inform boundary conditions within the hydraulic model.

4.2.2 Hydrologic Modelling

A hydrological model of the catchment was developed for the purpose of extracting design flows to be used as boundary conditions in the Rosedale hydraulic model. The rainfall-runoff program, RORB (Version 6) was used for this study.

RORB is a non-linear rainfall runoff and streamflow routing model which is used for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Specified losses are then deducted, and the excess routed through the reach network. The RORB model setup is shown in Figure 4-1.

The catchment was split into 9 independent drainage systems (Figure 4-1). These catchments were then split into 51 sub-catchments with areas ranging from 0.2 to 6 km². 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 hydrological contribution from the study area downstream of the RORB outlets shown in Figure 4-1 was included via the direct rainfall-on-grid approach in the hydraulic model.

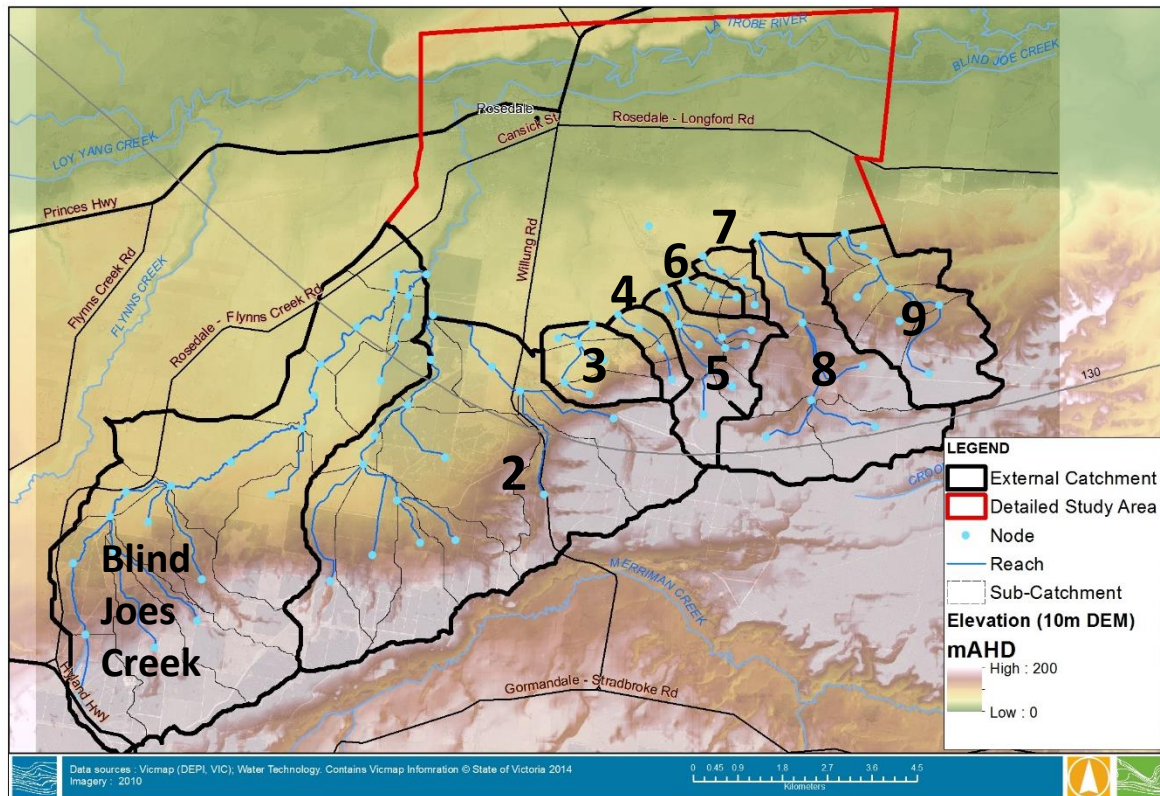


Figure 4-1 RORB Model Structure

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 Bureau of Meteorology and community supplied rainfall depth estimates.

Given the lack of any Bureau of Meteorology 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 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 4-2 and Figure 4-3 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.

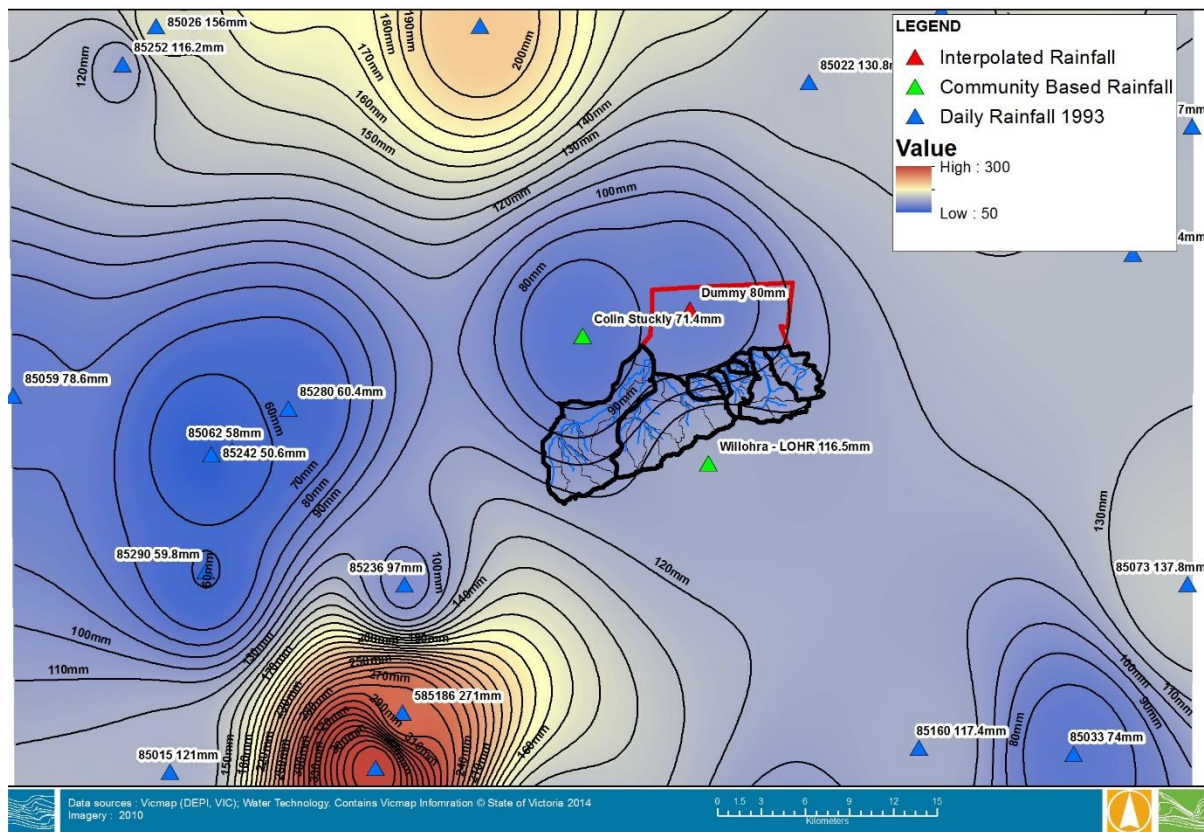


Figure 4-2 Total rainfall across the catchment for the September 1993 calibration event

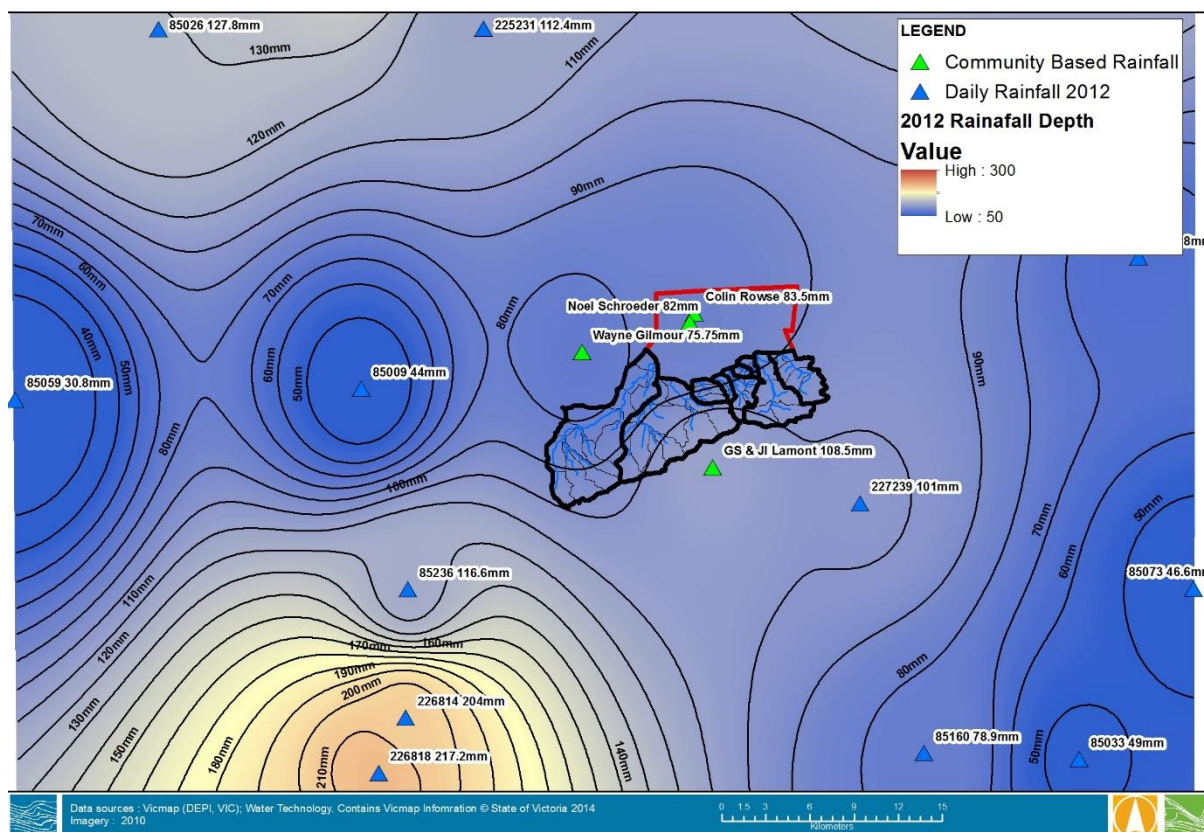


Figure 4-3 Total rainfall across the catchment for the June 2012 calibration event

RORB modelling parameters were initially estimated using Regional equations. Losses were informed by recent studies in adjacent catchments.

As there were no streamflow gauges on either Blind Joes Creek or the smaller catchments to the east, 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 September 1993 event and June 2012 events.

4.3 Hydraulic Modelling

This section discusses the application of the hydraulic model to simulate flood behaviour (extents, depth, velocities) for a range of flood magnitudes.

The hydrologic analysis previously discussed, provided flood inflow hydrographs for the hydraulic model. The hydraulic model was then used as a tool to validate the hydrology against the limited available data (flood marks and photography).

A detailed description of the hydraulic model setup, validation, sensitivity tests and design event simulation is provided in the Hydrology & Hydraulic Report (R02). This section summarises the general model development and key outcomes from the hydraulic modelling investigation.

Initially a multi domain model using 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 adopted. 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.

This setup was used in the validation modelling and initial design modelling. With the validation modelling complete and approved, sensitivity to initial flood levels in the Latrobe River was undertaken, this analysis showed that with higher levels in the Latrobe changes in peak flood levels and extents within the town were largely unchanged. At the conclusion of this process it was agreed to modify the flood model to a single domain covering only the Rosedale Township and its surrounds. In this modelling the Latrobe River levels were represented with a static water level consistent with a smaller flood occurring concurrently with the localised flooding.

The modelling process involved the following stages:

- Model setup and calibration to the two calibration events (1993 and 2012).
- Validation and sensitivity tests (boundary conditions and materials roughness).
- Design flood simulations (events from 10% AEP through to 0.5% AEP).

The calibration, validation, and sensitivity assessments are an iterative investigative process and all outcomes from these stages inform the final design flood simulations.

4.4 Hydrologic & Hydraulic Model Validation

Various RORB model runs were completed to determine the final kc and initial and continuing loss. The parameters trialled were selected based on regional estimates or empirical equations

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

Using the final adopted combination of hydrology modelling 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.

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 were considered to be representative of the 1993 historic event.

2012 modelling results (depths and extents) were compared to video footage captured from the air on 6th of June 2012 at about 2:00PM and a series of land based photo's collected by Wellington Shire council. Both the community and steering group found these comparisons useful and suggested the modelling was accurate.

Using key learnings from the 1993 and 2012 validation, modelling was used to generate design flows in the RORB model. Table 4-1 documents the peak flows applied at the southern boundary of the hydraulic model (refer to Figure 4-1) representing catchment flows from Blind Joes Creek and its adjacent catchments to the east. These flows were then combined in the hydraulic model with "direct rainfall" within the study area to determine the design flooding conditions for the various AEP events considered.

Table 4-1 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

4.4.1 Understanding Flood Behaviour

This study has shown that rainfall in the ranges south of the Rosedale is a major driver of flooding in the town. For example, for the Blind Joes Creek floodway south of the township to be engaged flood water from the Blind Joes Creek catchment must break its banks south of the railway line and flow east. This phenomenon cannot occur with only Latrobe River flooding. Once flood water breaks out south of the railway line it tends to combine with the other adjacent catchment flows from the ranges south of town and begins to inundate the low land south of the township. Some of this flood water can make its way into the township via flow paths over the railway line at Friends Road, two culvert crossings between Friends Road and the Tannery and at Willung Road. Some flood water also leaves the Blind Joes Creek and moves up an open drain on the north side of the railway eventually flowing

over Cansick Street and inundating some of the residential land on the western boundary of the township.

Table 4-2 below gives an overview of at what design flood level certain areas are likely to begin to experience flooding. The table has been set out to be read from the top down to include all flood consequences identified at lower design flows.

When using Table 4-2 to identify particular consequences for a given flood event, the reader should read all rows of consequences above the selected magnitude design event.

Table 4-2 Design flood events and associated flooding areas

AEP Design Event	Flood Consequences
10% AEP	Blind Joes Creek floodway engaged, ponding behind Friends, Rosedale-Longford and Willung Roads. Moore Street, McLeod Street, Cricket Street and Cansick Streets cut by flood water. Localised ponding (stormwater impacts) in the low lying land between Princes highway and Albert Street. Residential Buildings Flooded Above Floor 0 Commercial Buildings Flooded Above Floor 0 Properties Flooded Below Floor 177
5% AEP	Blind Joes Creek floodway flows enter the township via Friends and Willung Road. Ponding behind Willung road, Friends and Rosedale-Longford roads over a 1 m deep in sections. Newer sections of the western edge of the town between Cansick and Cricket Street are inundated from breakout flows from Blind Joes Creek. Larger portions of land on the township fringes inundated such as land between Cansick street and the railway line (east of Blind Joes creek), and Huffers and Mill Lane area. Ponding in the low lying land between Princes highway and Albert Street is now more significant with one residential lot flooded above floor level. Residential Buildings Flooded Above Floor 1 Commercial Buildings Flooded Above Floor 1 (depth less than 10 mm) Properties Flooded Below Floor 212
2% AEP	Most of the Blind Joes Creek Floodway is deeper than 0.5 m. Residents in some of the newer streets (e.g. Macleod Street) west of the main township may be isolated by floodwater. Flooding east of Willung Road is more significant with deeper flooding observed in the industrial estate east of Mill Lane. Mill Lane itself would likely be cut with flood water. Deep flooding (>0.5 m) is observed on the low density residential land north of Huffers Lane. Flooding in the CBD is much more significant with some streets inundated up to 0.5 m deep. The riverine and stormwater flooding combine likely cutting the Princes highway between Willung Road and Latrobe Street. The car park north of the Princes Highway is inundated with flood water making it to Queen Street. Ponding in the low lying land between Princes Highway and Albert Street is significant with one residential lot and 5 commercial lots flooded above floor level. Residential Buildings Flooded Above Floor 1 Commercial Buildings Flooded Above Floor 5 Properties Flooded Below Floor 219

1% AEP	Generally flood extents between the 1% AEP and 2% AEP are not significantly different but flood depths tend to be significantly deeper. A large portion of the Blind Joes Creek floodway is now deeper than 1 m. Ponding at the intersection of Willung and Rosedale-Longford Roads is deep (up to a 1 m). Most homes east of Willung Road and south of the Rosedale-Longford Road would lose access to the main township (for several hours) during this flood. Much of the low density residential land north of Huffers Lane is between 250 mm and 500 mm deep. Residential Buildings Flooded Above Floor 2 Commercial Buildings Flooded Above Floor 7 Properties Flooded Below Floor 234
0.5% AEP	The flood extent is similar to the 2% and 1% AEP events, but flood depths throughout the township are now hazardous at many locations. The majority of the land on the western fringe of the main township (east of Blind Joes Creek) is inundated. Residential land north of Cansick Street and west of Willung Road and east of Hood Street is significantly impacted by riverine flooding. Additional flooding is observed north of the Princes Highway in Queen Street. People living east of Willung Road would expect to be isolated from the Rosedale township for extended periods during this event. Residential Buildings Flooded Above Floor 7 Commercial Buildings Flooded Above Floor 8 Properties Flooded Below Floor 239

4.4.2 Flood Damages

A flood damages assessment was undertaken for the study area under existing conditions. The flood damages assessment determined the monetary flood damages for design floods (20%, 10%, 5%, 2%, 1% and 0.5% AEP events). The flood damage assessment was also undertaken for the final mitigation package.

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD, more recent damage curves from the NSW Office of Environment and Heritage, and other relevant flood damage literature. The model results for all mapped flood events were processed to calculate the numbers and locations of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were. In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated.

Under existing conditions, the 1% AEP damage was calculated at \$ 1.4M with 2 residential properties flooded above floor and 7 commercial properties also flooded above floor. The average annual damage (AAD), a measure of the average flood damage, per year over an extended period was estimated for existing conditions to be **\$ 76,000**. The AAD is an estimate of the average annual cost of flooding to the community that includes both public and privately owned assets.

5. ASSESS AND TREAT RISK

5.1 Flood Mitigation

A report detailing the flood risk and options to treat the flood risk within Rosedale was produced following design mapping (R03). Six mitigation concepts were presented to the steering committee at a meeting held in September 2015. Feedback from the steering committee was that two of the options were favourable and these were presented to the community at the September meeting. At the same meeting the community were offered the opportunity to add additional options for consideration. No new ideas were mentioned. The two options listed below were the most favoured.

1. Increasing the conveyance in the Blind Joes Creek Waterway through to Latrobe River via increasing capacity of the railway bridge and confining riverine flooding to the main waterway using levee banks (More Flow to the North option); and
2. Allowing the flow that breaks out of bank from Blind Joes Creek south of the railway line to continue to flow east around the back of the main township unimpeded (More Flow to the East option).

A prefeasibility assessment was carried out on the original 6 options. This analysis showed the same two options favoured by the steering group were the most viable and were consequently chosen to be investigated further including hydraulic modelling and costing. Flood damage assessments and a benefit-cost analysis were also carried out for the two mitigation options, with the results shown below in Table 5-1.

The Benefit Cost Analysis showed that if the more flow to the north option was implemented it would actually cause a net annual liability (cost) of around \$117,000 per year. More flow east showed better results but not at a level which would likely attract State and Federal funding. This option may be further considered if development north of the railway line and Huffers Lane is required into the future to enable growth within Rosedale.

Table 5-1 Mitigation Impacts and Cost - Benefit

	More Flow North	More Flow East
Average Annual Damage	\$41,000.	\$42,000
Annual Maintenance Cost	\$152,000	\$28,000
Annual Cost Saving	-\$117,000	\$6000
Net Present Value (6%)	-\$1,642,000	\$81,000
Capital Cost of Mitigation	\$10,989,000	\$2,011,000
Benefit – Cost Ratio	-0.15	0.04

5.2 Planning Controls

An assessment of the existing planning controls for Rosedale was undertaken resulting in a document outlining a number of recommended planning scheme amendments which could be implemented to further treat flood risk within Rosedale. Further planning outputs for the project include a Floodway Overlay and a Land Subject to Inundation Overlay produced in the Treat and Assess Risk Report (R03).

The report also recommends the WGCMA and Latrobe City Council undertake a planning scheme amendment process to incorporate new LSIO and FO mapping into the Latrobe Planning Scheme as soon as possible.

6. FLOOD BEHAVIOUR AND INTELLIGENCE OUTPUTS

6.1 Overview

The flood behaviour and intelligence outputs developed as part of the Rosedale Flood Study are described in this section.

6.2 Model Result Outputs

The model result data including grids and extents have been provided in specified Victorian Flood Database (VFD) format for each flood event. The following result components were generated:

- Flood level, flood depth, flood velocity and flood hazard grids
- Flood elevation contours
- Flood extent data
- Hydrographs at key locations
- Long-section of river water levels

Grids and shapefiles (ESRI/VFD format), and Data tables (Excel csv/xlsx format) were provided on a Study USB on completion of the study.

6.2.1 Data Sets

The following datasets were provided as shown in Figure 6-1.

Grids

Gridded datasets of model results were provided for the following:

- Design events (10%, 5%, 2%, 1%, 0.5%AEP and PMF events) – maximum depth, hazard, velocity and water surface elevation.
- Calibration events (1993, 2012, and 2013 events) – maximum depth and water surface elevation.
- Model Topography

The hydraulic analysis provides a regular grid of flood elevations across the hydraulic model study area. The flood extent was defined by converting the 3 m grid flood elevations grid to an extent polygon. The extent was smoothed to remove the sharp edges of the grid cells for cartographic / presentation purposes.

Flood depths were classified for mapping using the following classifications:

- 0 m to 0.25 m
- 0.25 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- Greater than 2.00 m

Vector Data

ERSI shapefiles in VFD format were provided for the following:

- Peak flood extents
- Peak flood elevation contours
- Mapping limits
- Recommended Flood Overlay & Land Subject to Inundation Overlay

Data Tables

Data tables in excel CSV format were provided for the following:

- A list of all properties impacted by the design flood events detailing property location, address and maximum depth of flooding at each property.
- Flood damages for all design events under existing conditions as well as the two mitigation options modelled (1 and 0.5% AEP events). This allowed for the average annual damages to be assessed.

6.2.2 Maps

The flood response inundation maps have been produced for the following design flood events:

- 10%, 5%, 2%, 1% and 0.5% AEP events – maximum depth.

Each map includes:

- Flood extent,
- Flood level contour at 1m intervals,
- Depth of inundation,
- Identification of essential services,
- Major Road/street names
- Cadastral base

Copies of the maps were provided as PDFs, and in Appendix A of the Hydraulics Report (R02). A mapping limits layer was provided in the vector data. An example maximum depth plot for the 1% AEP flood event is shown in Figure 6-1.

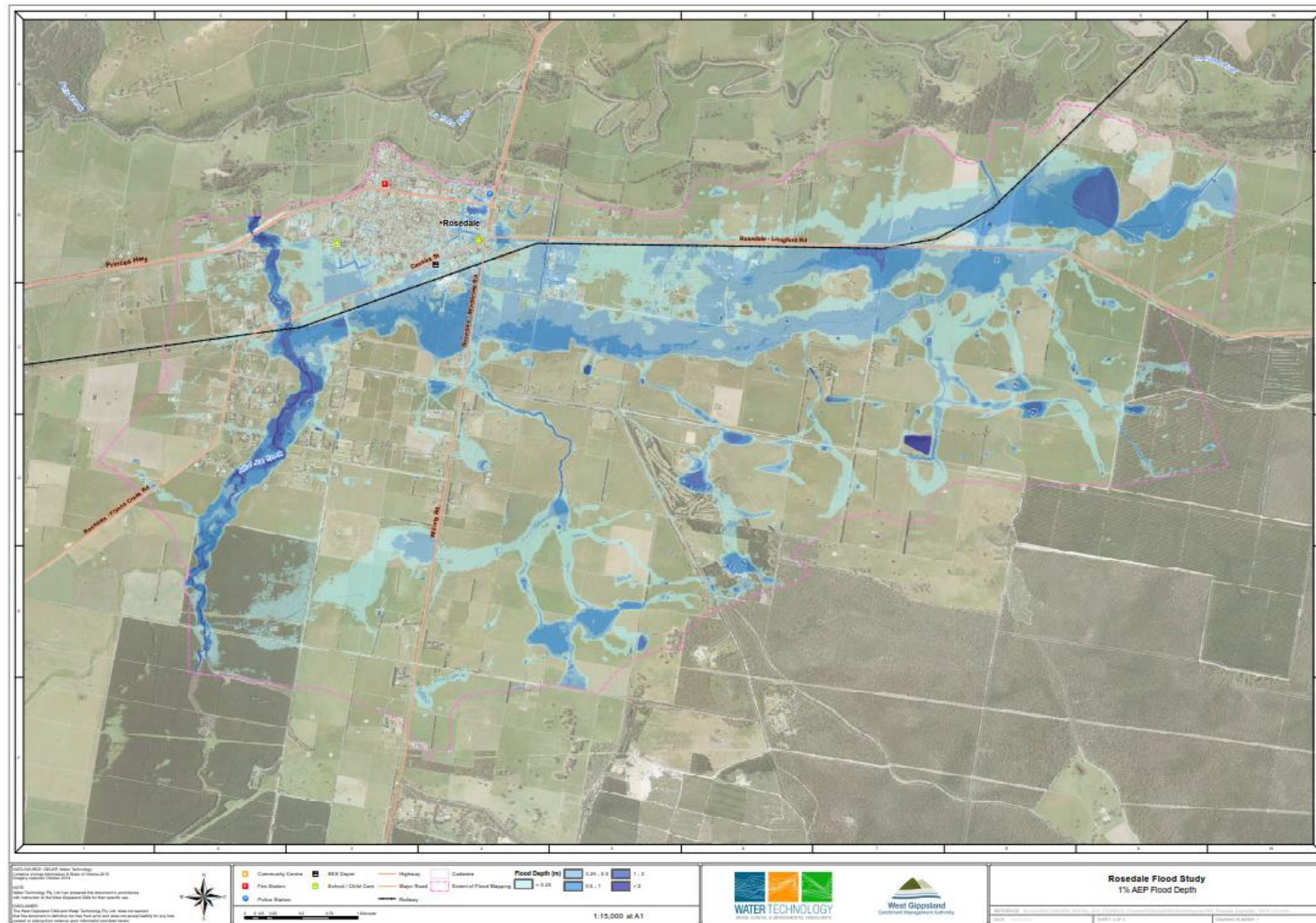


Figure 6-1 1% AEP Maximum Flood Depth Map

6.3 Flood Warning

As previously discussed, it has been identified that one of the main drivers for significant flooding in Rosedale is from intense rainfall in the ranges south of the township. Due to Rosedale's proximity to these ranges, the onset of flooding can potentially happen quite soon after heavy rainfall. The hydrological modelling showed that a 12 hour storm duration is generally the critical duration for a range of design storms. The onset of flooding can occur before the peak of the flood, so this means that the available flood warning time is significantly less than 12 hours after the start of the storm event, once the processes of detection, forecasting, interpretation and messaging are completed.

The major challenge in managing flood warning in Rosedale is the complete lack of localised information to base a warning from. Currently there is no stream flow gauging or government operated rain gauges with the catchment south of the township.

There is currently no flood warning service provided by the Bureau of Meteorology for the Blind Joes Creek catchment, and given the short available warning time the Bureau would most likely classify this as flash flooding so would not be covered under the traditional flood warning service. The Bureau of Meteorology has a responsibility to provide predictions of weather conditions likely to lead to flash flooding (e.g. thunderstorms), while Local Government has prime responsibility for flash flood warning extending from system establishment and operation through to the provision of predictions of stream levels if required.

It is recommended that Wellington Shire Council investigate and document the feasibility of a flash flood warning service for Rosedale. While it was not within the scope of this project to develop a comprehensive flash flood warning system for the township, it has been considered at a high level. To better manage and understand flood warning in Rosedale, it was recommended that two rain gauges with telemetry be established. One within the township of Rosedale and the other towards the top of the Blind Joes Creek catchment.

This information could be combined with a simple tool such as that shown in Figure 6-2 to help emergency management authorities and the general public better predict the magnitude of an event based on rainfall alone. Using the estimate of the AEP, the reference design flood maps could be used to estimate flood risk and consequences.

6.4 Study Deliverables

The study deliverables provide a comprehensive set of data that support the study outcomes. The deliverables were supplied on a study USB and consisted of background data and outputs as listed below:

- Digital copies of study reports in PDF format.
- Digital copies of the maps (PDF format)
- GIS datasets for the model results (ArcGIS VFD format and Excel csv format)
- Digital elevation models

There is a readme.txt file on the USB that describes the directory structure of the data contained on the USB.

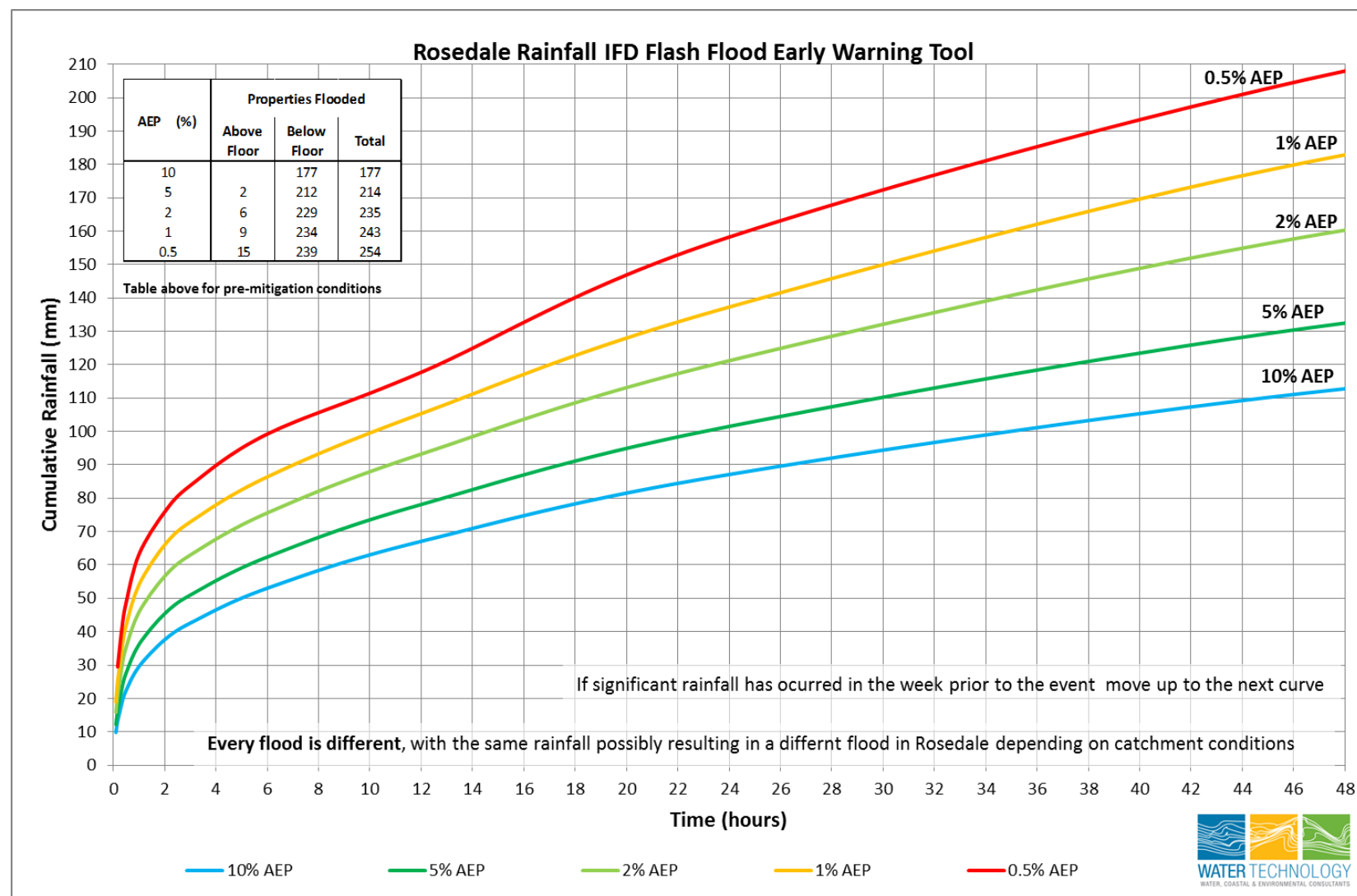


Figure 6-2 Flash Flooding Early Warning Tool

7. SUMMARY OF THE INVESTIGATION

7.1 Overview

The hydraulic modelling undertaken for the Rosedale flood study identified locations within Rosedale and its surrounds which are subject to high flood risk. The modelling has also identified potential mitigation options to reduce flood risk, reducing the frequency and magnitude of flooding. The mitigation options identified along with the updated planning information aim to treat the existing risk.

7.2 Key Outcomes

In undertaking this study, a number of important aspects of flood risk relevant to the Rosedale area (Blind Joes Creek catchment and other smaller local catchments) were determined. These are summarised as follows.

Local Hydrology – A thorough investigation into the hydrology of Blind Joes Creek and adjacent catchments to the east was undertaken using the best data available. This work provided estimates of design flows and hydrographs for a range of AEP events. The effective warning time for the catchment is limited, with travel times from the upstream catchment relatively short.

Hydraulic Characteristics – While the Latrobe River can impact the Rosedale area, these effects are relatively minor. Major flood impacts within the town tend to be driven by local catchment rainfall and runoff from Blind Joes Creek and the other minor catchments to the east of Blind Joes Creek. Overland flow paths from these minor catchments impacting Rosedale were mapped for the first time in this study.

Assess and Treat Risk - Using the hydraulic modelling results, several mitigation options were investigated, costed and modelled to assess the impact on flooding. A flood damages assessment was completed on the existing flood conditions as well as the proposed mitigation options. This allowed for a cost-benefit analysis to be undertaken for the mitigation options. Proposed flood related planning scheme mapping was produced, and flood warning recommendations made.

7.3 Conclusions & Recommendations

Based on the study process and outcomes, the following conclusions and recommendations are made.

- Parts of Rosedale are susceptible to out of bank flooding within the Blind Joes Creek floodplain. Private properties are inundated (above floor level) at flows greater than 5% AEP.
- The lack of local rainfall data was identified as a major knowledge gap limiting any future flood warnings. The installation of multiple instantaneous rain gauges (with telemetry), would be useful to local resident and emergency management authorities. It is suggested that, subject to further investigation of capital and ongoing costs, rainfall gauges be installed in Rosedale and in the Blind Joes Creek upper catchment.
- Some practical mitigation options exist for the township. Implementing these would need to be considered against the observed impacts on current and potential future land use.
 - Overall the mitigation options assessed within this study have a positive impact on reducing flood risk within Rosedale.
 - The benefit cost analysis (based on current conditions) suggest both options are not viable from an economic perspective alone.
 - It is recommended that Wellington Shire Council and West Gippsland CMA discuss the potential for joint funding of additional mitigation analysis which considers other external factors such as potential future land use.

- A review of the existing planning scheme was undertaken, with suggested LSIO and FO planning maps produced. It is recommended that Wellington Shire Council implement a planning scheme amendment reflecting the current mapping as soon as possible.
- The Municipal Flood Emergency Plan (MFEP) was updated with flood intelligence from this study. This should be utilised during future floods. It is recommended that the current format of the MFEP be revised. It is different to other MFEPs across the State. The flood intelligence section of the Assess and Treat Risk Report (R03), would provide a valuable resource during a flood emergency.

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