WGCMA Floodplain Mapping Program

Floodplain mapping for Fish Creek 2018

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AEP	Annual exceedance probability
AHD	Australian height datum
ARI	Average recurrence interval
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DEM	Digital elevation model
FFA	Flood frequency analysis
FO	Floodway overlay
GDA	Geographic datum of Australia
GIS	Geographic information system (specifically ArcGIS 10.2)
IFD	Intensity-frequency-duration (curve)
LIDAR	Light detection and ranging (specifically, data derived from this process)
LSIO	Land subject to inundation overlay
SES	State Emergency Service
VFD	Victorian Flood Database
WGCMA	West Gippsland Catchment Management Authority

Glossary

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.
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)	The average or expected value of the period between exceedances of a given discharge or event.
Catchment	The area draining to a site.
Discharge	The rate of flow of water measured in terms of volume over time.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event
GDA94	The Geocentric Datum of Australia (GDA) is the new Australian coordinate system, replacing the Australian Geodetic Datum (AGD)
Geographical Information System (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.
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.
Hyetograph	A graph that shows rainfall or rainfall intensity changes over time generally for a particular rainfall event.

Intensity Frequency Duration	The relationship between rainfall intensity (mm/h), frequency (AEP) and duration (usually minutes or hours).
LIDAR	Light Detection and Ranging is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
RORB	A runoff-routing program hydrological modelling program
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Topography	A surface which defines the ground level of a chosen area

1 Introduction

1.1 Purpose

The purpose of conducting floodplain mapping for the Fish Creek catchment is to predict the potential hazards and consequences of a flood event and estimate flood depths, velocity and extent. The information presented in this report has been compiled for use by West Gippsland Catchment Management Authority (WGCMA) for statuary planning, community education/preparedness, flood risk for insurance purposes and emergency management purposes.

1.2 Objective

The objectives of the Fish Creek floodplain mapping project as stated by the WGCMA are as follows:

- Estimate the design flow peaks and hydrographs using RORB for the 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP)
- Develop a TUFLOW hydraulic model(s) and simulate the 1%, 2%, 5%, 10% and 20% AEP flood events
- Generate a map showing the flood extent of an 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP), showing depths, velocity and water surface elevation

1.3 Catchment description

Fish Creek is located in the South Gippsland Region and has a catchment area of approximately 233km^2, feeding directly into the Tarwin River. Fish Creek catchment is in a remote rural area, populated mostly by small towns, the largest of which is Fish Creek, population being 791 in 2011 (Censusdata.abs.gov.au, 2016).

The other features of significance are the mains roads and railway lines that traverse the catchment, these roads are; Waratah road, Meeniyan-Promontory Road and Fish Creek-Foster Road and the Great Southern Rail. These roads and rail line cut through the centre of the catchment (Fish Creek town). The South Gippsland Highway and Foster-Promontory Road lie on the northern and eastern boundaries of the catchment. The only settlements of considerable size are Fish Creek (centre of catchment) and Walkerville (Southernmost tip).

The point of highest elevation is at least 300m AHD in the northern boundaries of the catchment, while the point of lowest elevation is approximately 0m AHD at the western boundary, at the point where Fish creek flows into the Tarwin River.

The current use of the land within the Fish Creek catchment is mainly farming. The agricultural use of this land would have grown over time, causing the removal of native vegetation for agricultural purposes.

Figure 1 is a representation of the Fish Creek catchment hydraulic and hydrologic model extents, as well as the main waterways and infrastructure.

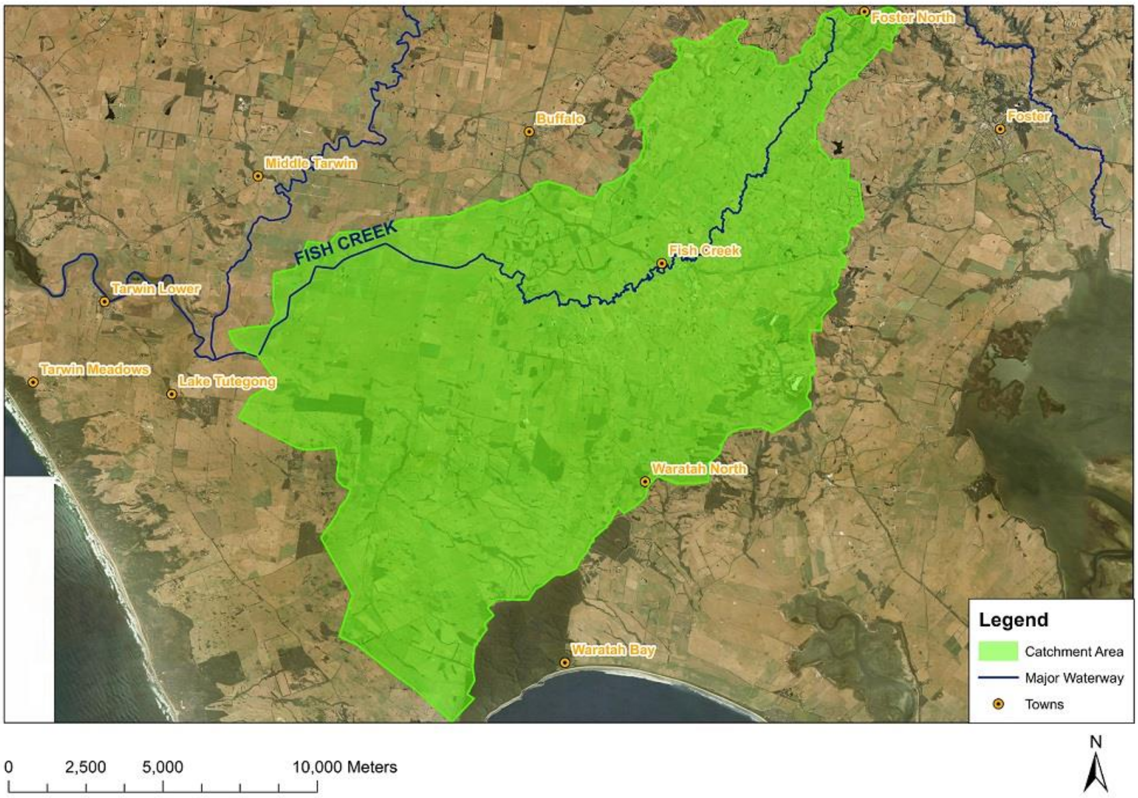

Figure 1 Fish Creek catchment boundaries

1.4 Flood history

The historical data relating to flooding in Fish Creek is vague in regard to the location of flooding. Newspaper articles dating as far back as 1862 state that Fish Creek routinely floods (The Argus, 2016). However, a more recent article by the ABC published in 2013 reports that flood waters has caused damage to Foster-Fish Creek Road. (ABC News, 2013)

1.5 Previous decision-related data

Figure 2 is a graphical representation of the previous flood extent data available to the WGCMA.

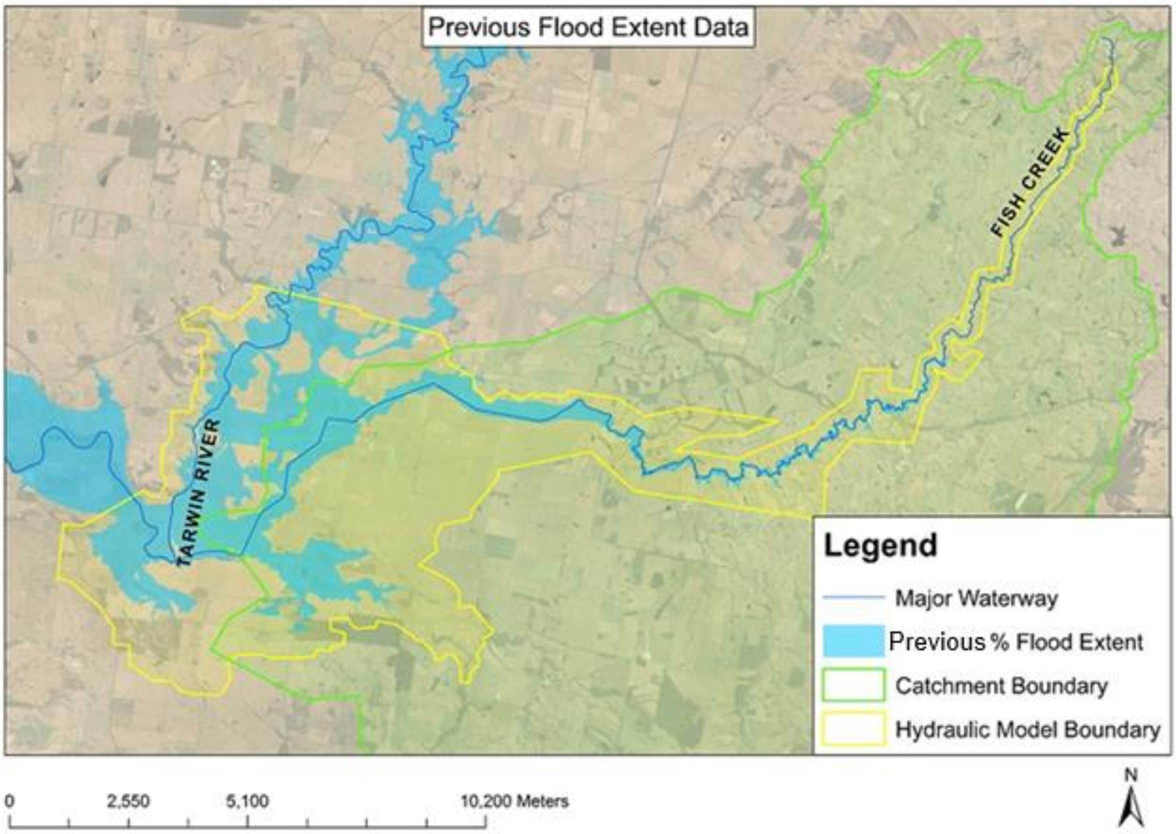

Figure 2 Previous Flood Extent Data

Note: The reliability of the 1% AEP Flood Extent data is considered Low due to the method it was generated

2 Hydrology

2.1 Description of hydrologic modelling approaches adopted

The steps that have been taken to develop a hydrological model for Fish Creek catchment were as follows:

- Perform a desktop study of Fish Creek catchment
- Determine the availability and reliability of any stream gauge and rainfall gauge data
- Perform initial hydrological calculation for the catchment, using the RFFE
- Develop an initial hydrological overview, determining total catchment size and sub-catchments
- Refine the hydrological overview until satisfied it is ready to be input into RORB
- Compile data for RORB, including IFDs, spatial patterns, temporal patterns, losses and routing parameters
- Input data into RORB and run RORB model
- Refine parameters
- Perform final RORB run to obtain flow hydrographs for all inflows required by the hydraulic model.

2.2 Available data

The data available for this study are as follows:

- Aerial photography – 21/1/2010
- Designated Waterway' and Major waterway (ISC reaches)
- Intensity-Frequency-Duration (IFD) tables - (Australian Bureau of Meteorology, 2017)
- LiDAR digital elevation models – Bunurong Coast, reach 27-13 and reach 27-14
- Areal Temporal Patterns – (Geoscience Australia 2016)
- ARF Parameters – (Geoscience Australia 2016)
- Median Preburst Depths and Ratios – (Geoscience Australia 2016)

There was not sufficient gauged streamflow data for Fish Creek to perform flood frequency analysis.

2.3 Streamflow and rainfall gauge review

There was no streamflow data for Fish Creek. There was rainfall data for Fish Creek, the closest gauge to Fish Creek settlement is the Fish Creek gauge (3.6km away from catchment centroid)

2.4 Initial hydrology estimates

The initial hydrological estimates were developed from the methods described below:

Nikolaou and Von't Steen equation

The Nikolaou and Von't Steen equation is a regional equation that uses the catchment area to determine the flow of a 1% AEP flood event. (Grayson et al. 1996 page 108.)

$\boldsymbol{Q_{100} = 4.67 \times A^{0.763}}$ **Equation 1 Regional Estimate**

Where Q_{100} is the 1% AEP flow in m^3/s, and A is the area in km^2

2.4.1 Rational Method

The rational method is a method that can be used to estimate flows for a given AEP, the constant Y relates to the AEP of the runoff coefficient and the rainfall intensity. The main equations for the rational method are Eq. 2.2 Rational Method and Eq. 2.3 Pilgrim McDermott Equation:

$\boldsymbol{Q_Y = 0.278 \times C_Y \times I_{tc,Y} \times A}$ **Equation 2 Rational Method**

$\boldsymbol{t_c = 0.76 \times A^{0.38}}$ **Equation 3 Pilgrim McDermott Equation**

Q_Y is the flow of a Y% AEP flood event, C_Y is the runoff coefficient for a Y% AEP flood event, $I_{tc,Y}$ is the rainfall intensity for a Y% AEP flood event and A is the area of the catchment

2.4.2 Zaman Flow Estimation Method

The Zaman flow estimation method is a series of equations developed by Zaman, Haddad and Rahman, this method determines flow rates for AEPs of 1%, 2% 5%, 10%, 20% and 50%, using the area of the catchment and the rainfall intensity of the same AEP, the equations used in this method are Eq.2.4-9.

$\boldsymbol{\log Q_2 = -3.055 + 1.186 \log A + 2.103 \log I_{tc,2}}$ **Equation 4 Zaman 2yr ARI**

$\boldsymbol{\log Q_5 = = 2.847 + 1.182 \log A + 2.0891 \log I_{tc,5}}$ **Equation 5 Zaman 5yr ARI**

$\boldsymbol{\log Q_{10} = -2.476 + 1.13 \log A + 1.932 \log I_{tc,10}}$ **Equation 6 Zaman 10yr ARI**

$\boldsymbol{\log Q_{20} = -2.766 + 1.173 \log A + 2.108 \log I_{tc,20}}$ **Equation 7 Zaman 20yr ARI**

$\boldsymbol{\log Q_{50} = -2.793 + 1.169 \log A + 2.132 \log I_{tc,50}}$ **Equation 8 Zaman 50yr ARI**

$\boldsymbol{\log Q_{100} = -2.789 + 1.159 \log A + 2.135 \log I_{tc,100}}$ **Equation 9 Zaman 100yr ARI**

The Zaman method is an empirically developed method, using the flow data of catchments for varying region and area, this method was developed back when ARI was the preferred terminology. The region that Fish Creek inhabits is Victoria, which is a region that the Zaman method can be used for as this is one of the regions that catchments were sampled from.

The other parameter is area, Fish Creek catchment has an area of 233km^2, and this area is within the 201-400 km^2 catchment area group, which is the most frequently sampled catchment group, meaning that the Zaman method for Fish Creek will give a relatively accurate fit. (Zaman, Haddad and Rahman, 2013)

2.4.3 Regional Flood Frequency Estimation

Regional Flood Frequency Estimation (RFFE) is an online tool that is used to estimate the flows across AEPs of 50%, 20%, 10%, 5%, 2% and 1%.

2.4.4 Estimation Results

The results of the above methods have been calculated and tabulated in Table 1.

Table 1 Basic Flood Frequency Estimates

Annual Exceedance Probability (AEP)	Nikolaou and von't Steen equation m^3/s	Rational method based on 1987 IFD m^3/s	Rational method based on 2016 IFD m^3/s	AR&R RFFE m^3/s	Zaman et. al. (2013) equations m^3/s
50%		55.57	44.68	42.30	27.62
20%		82.54	72.24	77.30	66.39
10%		102.79	95.35	107.00	105.97
5%		130.14	121.90	140.00	135.52
2%		167.60	159.90	191.00	187.63
1%	299.12	203.71	197.37	235.00	230.98

2.5 RORB hydrologic model

A hydrological model of Fish Creek was developed to generate hydrographs that are to be used in the hydraulic model. The modelling software used is a runoff routing program called RORB. RORB uses parameters such as IFD tables and areal and temporal patterns to determine rainfall, and these initial and continuing losses are subtracted from the rainfall to determine the runoff from an area.

2.5.1 RORB Sub-area and reach delineation

The processes taken in developing the hydrological model of Fish Creek were first to determine the shape and total catchment area from the digital elevation data. Following this the task was to determine the main channel of Fish Creek as well as determining which tributaries are to be included in the hydrologic model. These tributaries were then used to divide up the total catchment into multiple smaller sub-catchments. The areas and location of the centroids of these sub-catchments, as well as the length of the reaches are input into RORB using the RORB graphical editor. (Laurenson et al. 2010)

The hydrological model of Fish Creek (Figure 3) consists of one large catchment spanning the entirety of the catchment area divided into 31 sub-catchments. The RORB model for Fish Creek covers the area east of the Tarwin River. The model outlet is the point at which the Fish Creek flows into the Tarwin River.

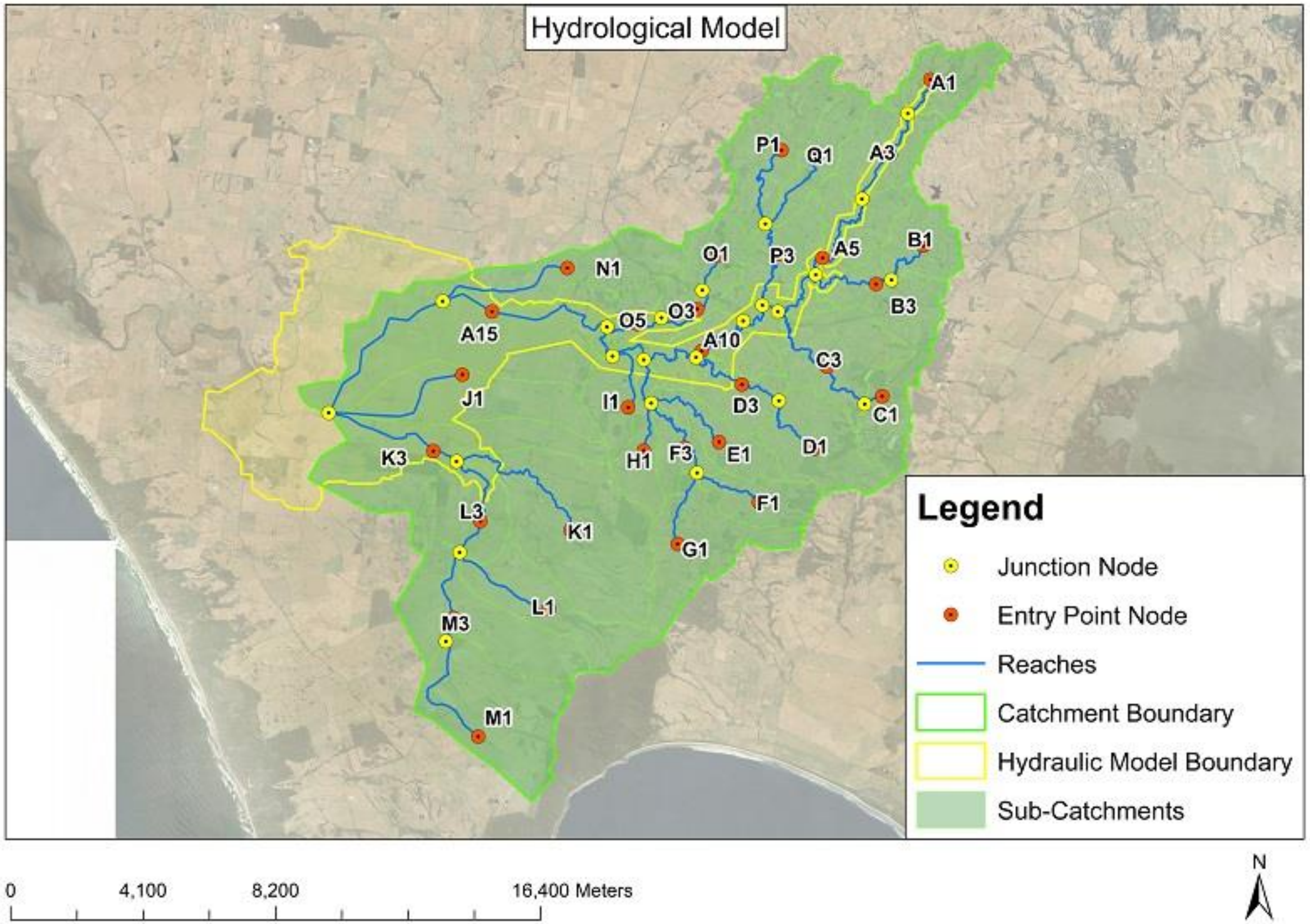

Figure 3 Fish Creek Hydrological Model

2.5.2 Transferring RORB flows to TUFLOW

Hydrographs generated from sub-catchments within RORB are used as inputs to TUFLOW. Depending on location of the sub-catchments, hydrographs are input at the TUFLOW model boundary, or directly onto cells within the model.

2.5.3 Parameters

Many of the parameters required by RORB can be found in a new website called the ARR Datahub 2017 (Accessed 5th of May 2017). By entering the centroid of the catchment, the Datahub provides parameters such as ARF, Storm Losses, Areal Temporal Patterns and Median Pre-Burst Rainfall Depths and Ratios.

2.5.4 Areal Reduction Factor

Areal reduction factors (ARF) consider the effect that size and location have on rainfall within a catchment. The ARF is calculated using the area and centroid of the catchment. As mentioned above, the ARF information was sourced from the ARR Datahub

2.5.5 Storm Losses

The Initial loss/Continuing loss model was used within RORB as recommended in ARR2016.

The storm losses were provided by the ARR Data Hub (Accessed: 16 August 2017 10:19AM). A storm initial loss of **20 mm** and a storm continuing loss of **4.7 mm/hr** were given when the co-ordinates of the Fish Creek catchment were input into the Data Hub, these co-ordinates were 146 Longitude and -38.7 Latitude.

The **burst Initial loss** that is required by RORB is different to the **storm initial loss** that was provided by the ARR Data Hub. The method that was used originally was to calculate the burst initial loss from the storm initial loss parameter of 20 mm by subtracting the pre-burst rainfall from it, this method was recommended by the 2016 ARR (Book 5 Chapter 3.3.2 ARR 2016). However as you can see below in Table 2, the preburst depth varies across each combination of duration and frequency and in Table 3 you can see the initial loss values that are to be input into RORB also varies for each duration and AEP.

Table 2 Median Preburst Depths (Datahub 18/12/2017)

h\AEP(%)	50	20	10	5	2	1
1.0	0.8	0.6	0.5	0.4	0.8	1.1
1.5	3.1	2.3	1.8	1.3	1.4	1.5
2.0	2.5	2.4	2.3	2.3	1.8	1.5
3.0	1.2	1.9	2.4	2.9	2.4	2.1
6.0	0.3	1.7	2.6	3.5	4.9	6.0
12.0	0.3	1.6	2.4	3.3	4.6	5.6
18.0	0.0	0.7	1.2	1.7	1.9	2.1
24.0	0.0	0.1	0.2	0.3	0.6	0.9
36.0	0.0	0.0	0.0	0.0	0.1	0.1
48.0	0.0	0.0	0.0	0.0	0.0	0.0
72.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3 Burst Initial Loss for RORB

min	Hrs	20%	10%	5%	2%	1%
720	**12**	18.4	17.6	16.7	15.4	14.4
1080	**18**	19.3	18.8	18.3	18.1	17.9
1440	**24**	19.9	19.8	19.7	19.4	19.1
2160	**36**	20.0	20.0	20.0	19.9	19.9
2880	**48**	20.0	20.0	20.0	20.0	20.0
4320	**72**	20.0	20.0	20.0	20.0	20.0
5760	**96**	20.0	20.0	20.0	20.0	20.0
7200	**120**	20.0	20.0	20.0	20.0	20.0
8640	**144**	20.0	20.0	20.0	20.0	20.0
10080	**168**	20.0	20.0	20.0	20.0	20.0

This poses a problem, as implementing these values into RORB would require a separate run each time that there is a change in the burst loss in the Table 2. This means that 17 individual simulations would need to be manually performed each run-in order to obtain results for each duration and AEP, dramatically increasing the amount of time taken during the hydrological modelling process.

An alternative to this is to, instead of subtracting the pre-burst rainfall from the storm losses, the pre-burst rainfall was added to the IFD table input into RORB. The resulting IFD is displayed below in Table 4. This process is based from advice given from a HARC forum (Stephens 2017, para.5).

Table 4 IFD Edited to Include Pre-Burst Depths

Duration	Duration in min	50%#	20%*	10%	5%	2%	1%
1 hour	**60**	16.3	21.9	25.9	30.1	36.3	41.1
2 hours	**120**	22.9	30.3	35.6	41.2	48.3	54
3 hours	**180**	25	34.3	41	48	56.3	63.1
6 hours	**360**	31.1	43.2	51.9	60.8	73.8	84.5
12 hours	**720**	39.9	54.3	64.8	75.7	92.4	106.6
18 hours	**1080**	45.7	61.1	72.7	84.8	102.9	119.1
24 hours	**1440**	50.3	66.5	78.8	91.9	112.6	130.9
36 hours	**2160**	57.4	75.7	89.8	105	129.1	151.1
48 hours	**2880**	62.7	82.7	98.3	115	143	166
72 hours	**4320**	70.7	93.1	111	130	161	188
96 hours	**5760**	76.7	101	119	140	172	201
120 hours	**7200**	81.5	106	125	146	179	208
144 hours	**8640**	85.6	111	130	150	182	211
168 hours	**10080**	89.2	114	133	152	182	211

The advantage to this method is that you do not have to make any adjustments to the initial loss, allowing a complete simulation of all durations and AEPs in a single run.

The continuing loss from the Data Hub was used as an initial value for RORB modelling. The continuing loss was then adjusted until the peak flows from the RORB model approximately matched the peaks from obtained from the RFFE.

The routing parameter, kc, was selected based on the regional estimation equations in ARR2016.

The guidelines suggested by the 2016 ARR for the eastern parts of Victoria is that the Vic (MAR>800mm) equation is a suitable equation for working out the Kc of the catchment, MAR being the mean annual rainfall for the catchment (Book 7 Chapter 6 6.2.1.3 ARR 2016). This Equation 10 gives a value of 29.87.

$$\boldsymbol{K_c = 2.57A^{0.45}}$$ **Equation 10 Vic (MAR>800mm)**

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

Critical Duration

After testing all durations across all AEPs it was determined that the duration that resulted in the highest peak flow was 24 hours for 1%, 2% and 5% events and 96 hours for 10% and 20% events.

Areal Pattern (Non-Uniform Spatial Pattern)

The new recommendation from the 2016 ARR is that as a minimum a single non-uniform spatial pattern should be applied to catchments with an area greater than 20 square km (Book 2 Chapter 6.3.2 ARR 2016). To comply with this constraint for each AEP the critical duration was first determined for the catchment. From there the 1% AEP spatial pattern was determined, and this spatial pattern was then applied to all durations and AEPs. Then the non-uniform spatial pattern was tested across a range of durations to confirm that the critical duration was still 24 hours. The spatial pattern used is presented in Table 5 below.

Table 5 Non-Uniform Spatial Pattern

	Area (km2)	Pattern
Sub-area A	4.57	98.41
Sub-area B	6.41	89.73
Sub-area C	5.18	109.99
Sub-area D	6.05	107.82
Sub-area E	9.16	102.03
Sub-area F	4.94	111.44
Sub-area G	8.61	108.54
Sub-area H	9.81	112.16
Sub-area I	4.44	102.03
Sub-area J	4.85	104.93
Sub-area K	7.8	97.69
Sub-area L	4.41	102.03
Sub-area M	6.52	96.24
Sub-area N	4.53	97.69
Sub-area O	9.36	101.31
Sub-area P	3.04	97.69
Sub-area Q	4.53	97.69
Sub-area R	4.02	89.73
Sub-area S	3.98	94.8

Sub-area T	3.42	91.18
Sub-area U	2.84	95.52
Sub-area V	2.85	91.18
Sub-area W	20.86	94.8
Sub-area X	9.1	94.8
Sub-area Y	13.26	91.18
Sub-area Z	11.04	100.59
Sub-area AA	8.17	98.41
Sub-area AB	6.63	95.52
Sub-area AC	18.86	106.37
Sub-area AD	10.16	107.82
Sub-area AE	13.78	98.41

Temporal Pattern

The ARR 2016 recommends that an ensemble of 10 temporal patterns be used for each AEP, therefore a separate simulation was conducted for across combination of AEP and duration (Book 2 Chapter 5.9.2). This process was made simpler by using the ensemble simulation function in RORB.

2.5.6 Sensitivity analysis

The initial parameters run in the RORB model are in Table 6. These parameters were obtained directly from the ARR Data Hub 2016.

Table 6 Parameters Obtained from ARR

Kc	m	IL_{STORM} (mm)	CL (mm/hr)
29.88	0.8	20	4.70

The first RORB model was well below the 5% confidence interval of the RFFE. These parameters needed to be changed to fit within the RFFE's 5% confidence intervals. As a guide to which parameters should be adjusted the Tarwin Lower Flood Study (Table 7) was referred to.

Table 7 Lower Tarwin Flood Study RORB model calibration parameters

Event	K_c value	Tarwin River at Meeniyan			
		Rainfall loss parameters		Peak flow (m^3/s)	
		IL (mm)	CL (mm)	Recorded	Modelled
July 1977	46	30	0.26	254	279
September 1993	46	44	0.37	199	201
August 2001	46	30	0.22	184	193

The model parameters of the Fish Creek catchment needed to be adjusted in a way to increase its peak flow. The parameters that could be adjusted to increase peak flow while still being similar to the Lower Tarwin Flood Study are the continuing losses and the K_c value. The K_c used in the Lower Tarwin Flood Study is different to the equation recommended by the ARR, however without flow gauges there was not enough data to justify changing the K_c from the ARR's guidelines for the Fish Creek catchment. The continuing loss used in the Lower Tarwin Flood Study is lower than what was provided by the data hub, therefor the continuing losses is the parameter that was chosen to be adjusted. The continuing loss was reduced until the peak flows from RORB fell within the 5-95% confidence interval. The final parameters are displayed in Table 8.

Table 8 Final Parameters Used in RORB

Kc	m	IL (mm)	CL (mm/hr)
29.88	0.8	20.0	1.0

2.6 Summary of hydrology results

Storm Parameters

Table 9 RORB Storm Parameters

Parameter	**AEP %**				
	20%	10%	5%	2%	1%
Duration (Critical)	96 Hours	96 Hours	24 Hours	24 Hours	24 Hours
Kc	29.88	29.88	29.88	29.88	29.88
IL	20 mm	20 mm	20 mm	20 mm	20 mm
CL	1 mm/hr	1 mm/hr	1 mm/hr	1 mm/hr	1 mm/hr

Figure 4 displays how the final RORB results compare to the RFFE in terms of flow for each AEP.

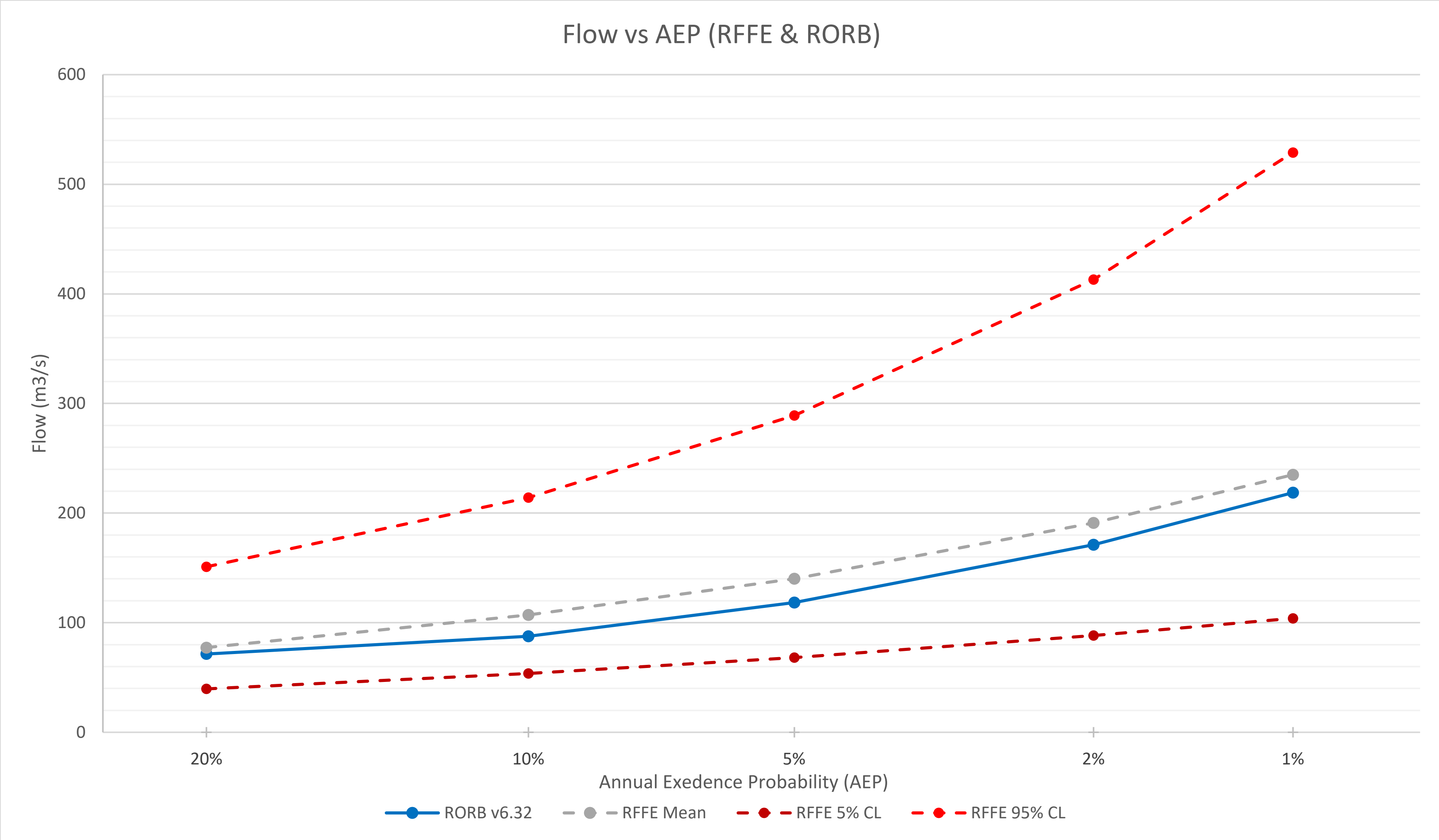

Figure 4 Design run results

Table 10 displays the peak flow and critical duration for each AEP.

Table 10 Design run results

AEP	20%	10%	5%	2%	1%
Critical Duration	12 hours	12 hours	12 hours	12 hours	12 hours
Peak of the hydrograph closest to the mean	71.02	109.7	148.1	211.4	265.3

Figure 5 displays all of the different flow results from RORB, RFFE and the initial hydrologic estimates for each AEP,

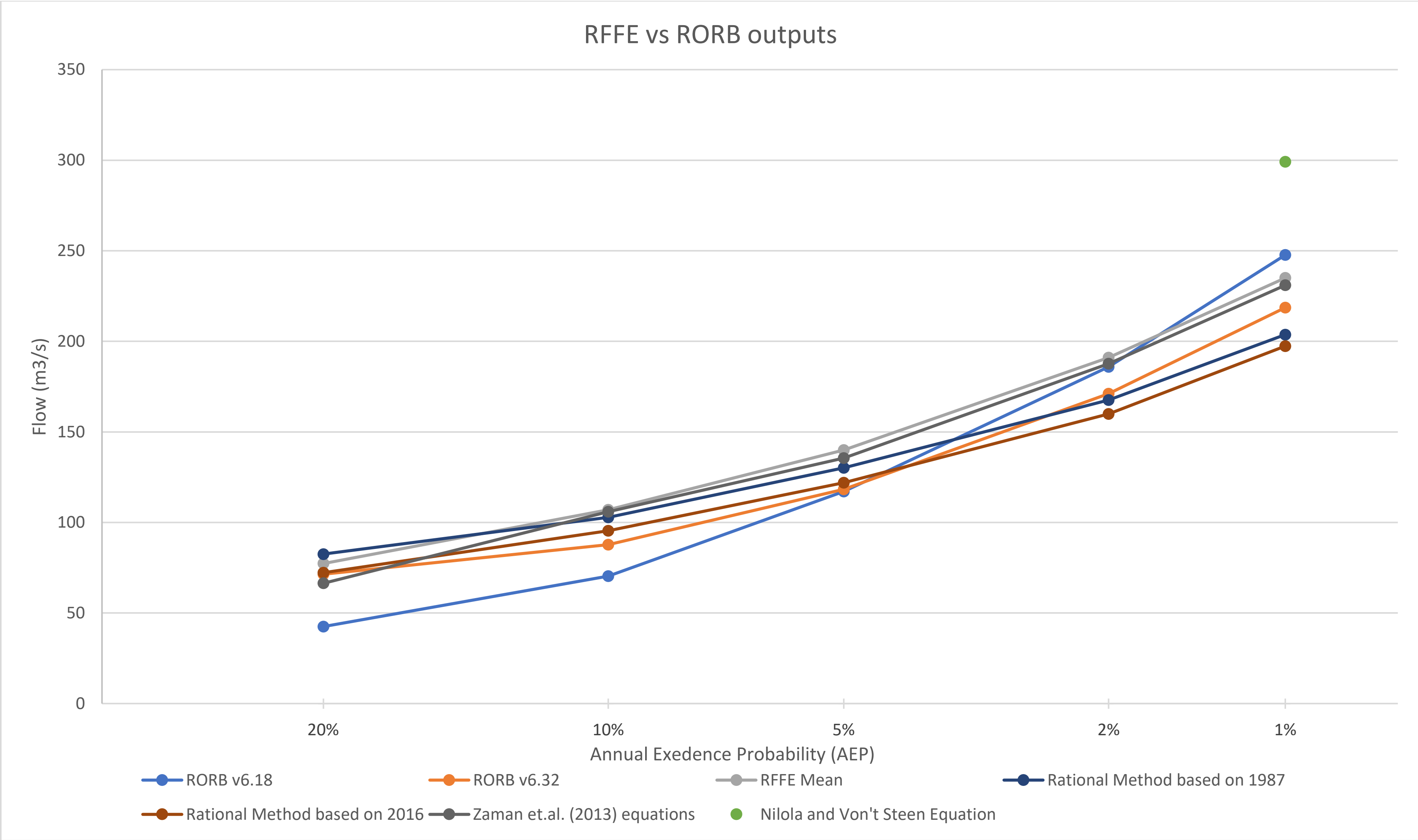

Figure 5 Visual representation between estimates

3 Hydraulics

3.1 Description of hydraulic modelling approach adopted

The hydraulic analysis of Fish Creek was performed through a hydraulic modelling program called TUFLOW. TUFLOW uses the runoff hydrograph data produced by RORB as flow inputs into the hydraulic model. The hydraulic model of Fish Creek is mainly 2D (2-Dimensional), with only a few 1D (1-Dimensional) networks which model the more significant hydraulic structures within the system. The choice to use 2D for this model is due to the new capacity of the modelling computer and the new HPC capacities of TUFLOW. The 2D model components consists of a 5 metre grid DEM representing elevation for Fish Creek.

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

3.2 Available data

The available data used for simulating the Fish Creek hydraulics was:

Aerial photography

Most of the aerial photography used was part of the 2009-10 Landcover (mga55) Photography Project.

The three different layers that were used are;

- **wonthaggi8020_2009dec13_air_vis_50cm_mga55.ecw** (Flown 13th of December 2009)
- **foster8120_2010jan21_air_vis_50cm_mga55.ecw** (Flown 21st of January 2010)
- **wgcma_2015dec14_air_vis_10cm_mga55.ecw** (Flown 14th of December 2015)

Another data set was used around the Fish Creek Township. This data set was used where available as it was more current and more detailed than the 2009-10 Landcover.

Terrain data

Figure 6 is a representation of all of the Lidar available for Fish Creek at the time. The amount of terrain data available is quite small compared to the overall catchment, particularly in the southern branches of the catchment.

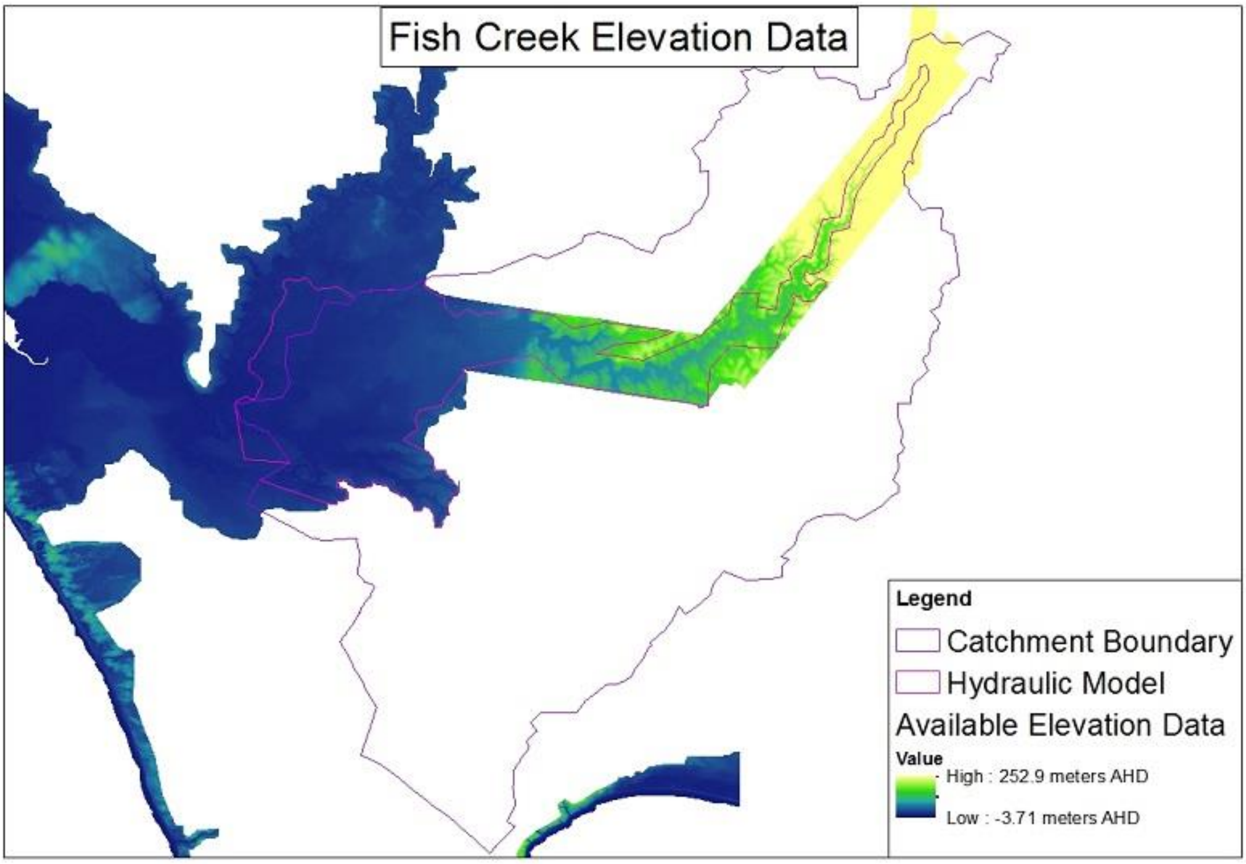

Figure 6 Fish Creek LiDAR extent

The elevation data sets used are as follows:

Table 11 West Gippsland Floodplains

Date Flown	Acquisition Start Date 29 December 2010	Acquisition End Date 10 February 2011
Spatial Accuracy **Horizontal**	Target 0.30m @ 67 % Confidence Intervals (CI)	Actual 0.19m @ 67 % CI
Spatial Accuracy - AHD **Vertical**	Target 0.10m @ 67 % CI	Actual DZ adjustments made according to DSE specifications

Spatial Accuracy - Ellipsoid **Vertical**	Target 0.10m @ 67 % CI	Actual Accuracy 83.8% within 0.10m of Riparian ground data

Fugro Spatial Solutions PTY LTD (2011) West Gippsland Floodplains Metadata Report

Table 12 Victorian Coastal LIDAR Level 3 Classification (East & West Victoria)

Date Flown	23 Oct 2008	09 Feb 2009
Spatial Accuracy **Horizontal**	0.35m *accuracy (RMSE 68% Conf.)*	
Spatial Accuracy - AHD **Vertical**	0.1m *accuracy (RMSE 68% Conf.)*	

Department of Environment, Land, Water, and Planning, (2016), Victorian Coastal LIDAR Level 3 Classification (East & West Victoria)

3.3 Key hydraulic features

Figure 7 shows the hydraulic structures of Fish Creek that were considered significant enough to require representing as 1D structures. These 1D structures were modelled in TUFLOW using a combination of 1d model network and 2D boundary condition features.

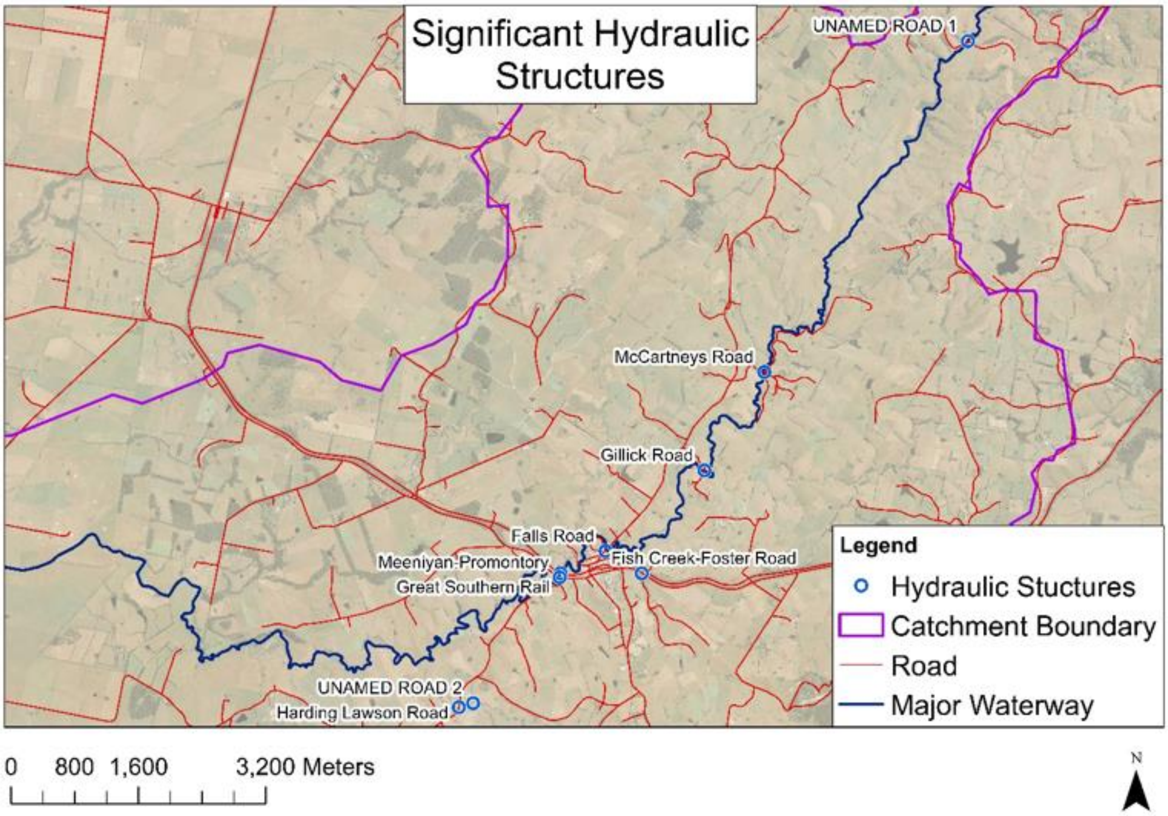

Figure 7 Significant Hydraulic Structures

The most significant of the hydraulic structures are Falls Road Culverts, Meeniyan Promontory Rail-Trail Bridge and Culverts and Meeniyan Promontory Bridge. These structures will be described within the body of the report, however imagery and photos of the other hydraulic structures listed in Figure 7 will be presented in the appendix.

Falls Road Culvert

Figure 8 Imagery of Falls Road Culvert

Figure 9 Photo of Falls Road Culverts (taken during site visit)

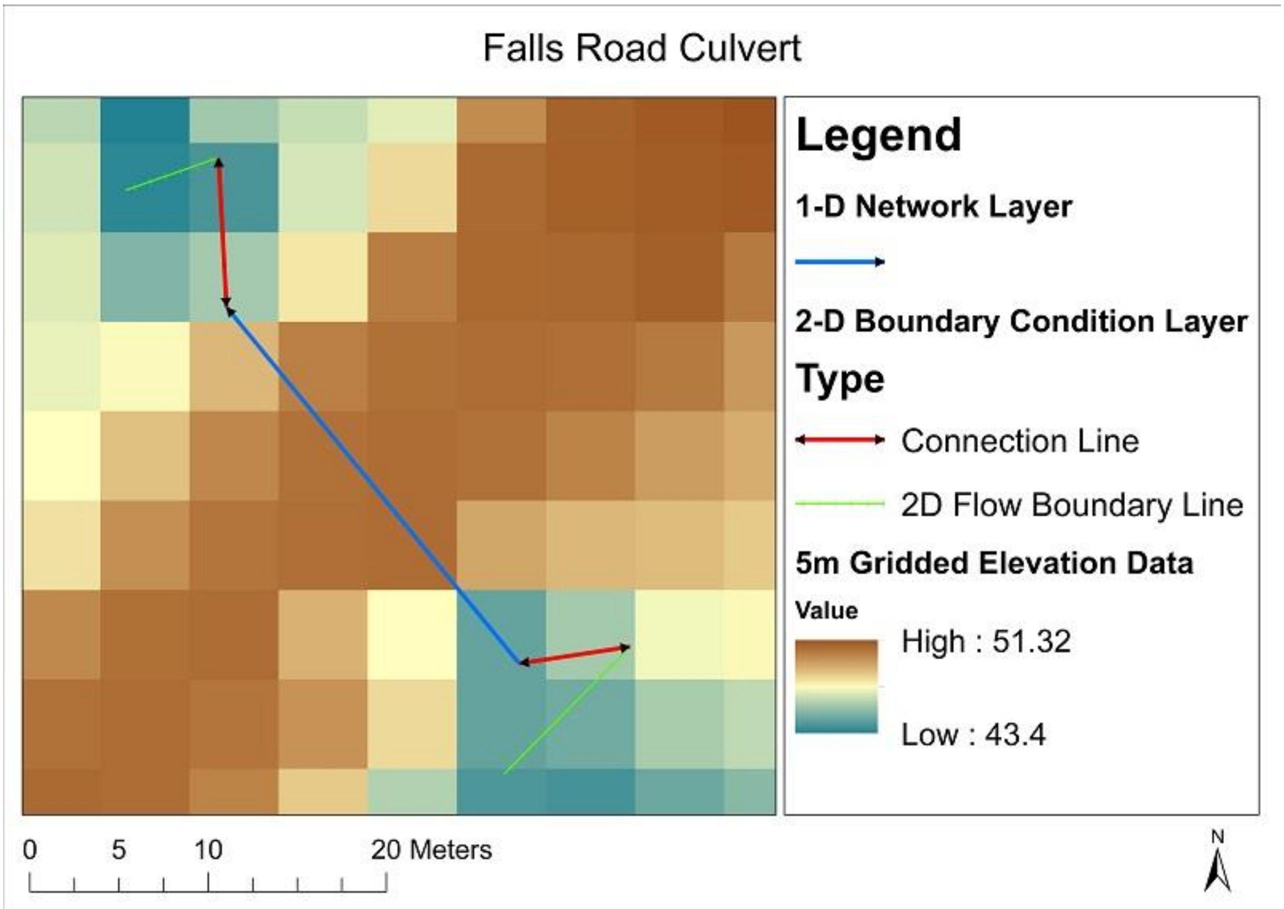

Figure 10 Falls Road Culvert Input Method

Meeniyan-Promontory Rail-Trail Bridge and Culverts

Figure 11 Imagery of Meeniyan-Promontory Rail-Trail Bridge and Culverts

Figure 12 Meeniyan-Promontory Rail-Trail Culverts

Figure 13 Meeniyan Promontory Rail-Trail Bridge

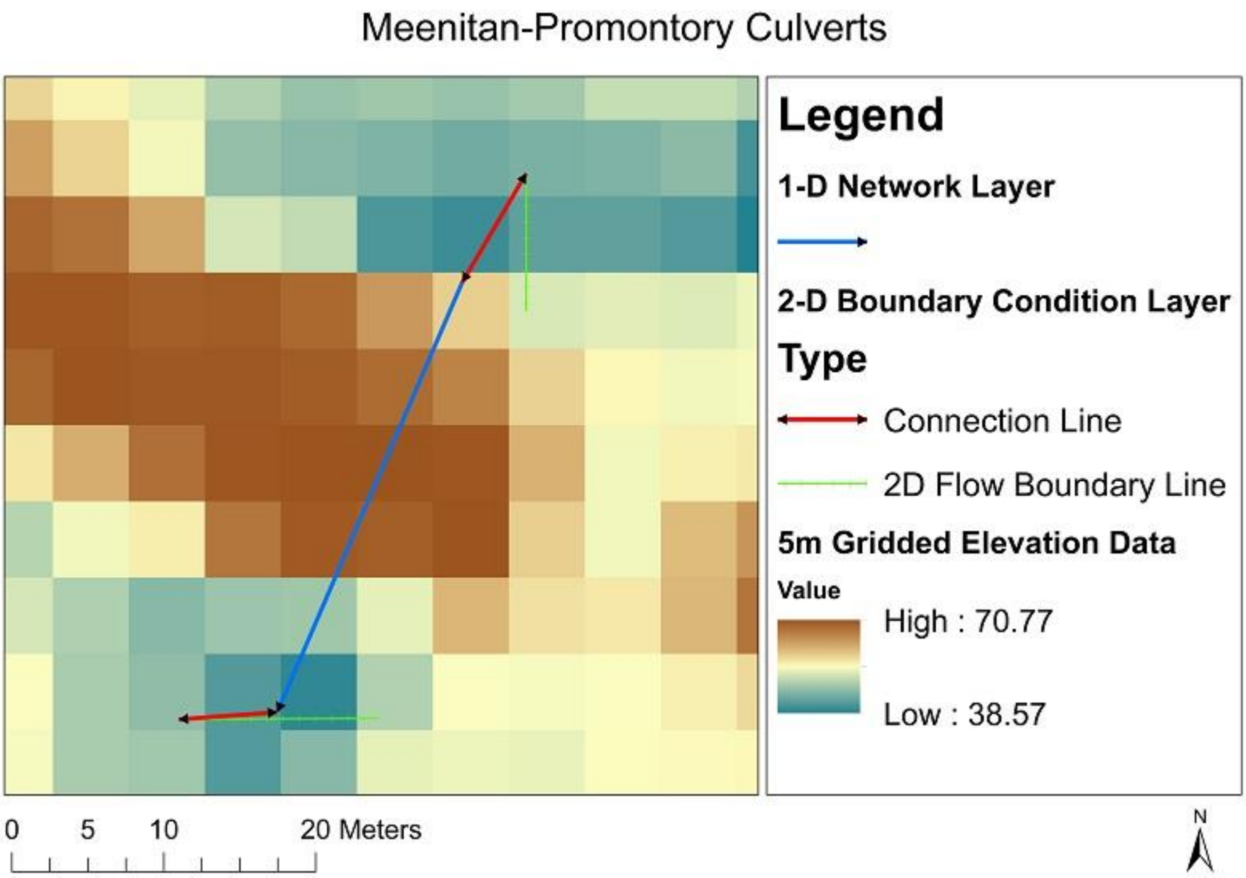

Figure 14 Meeniyan-Promontory Culverts Input Method

Meeniyan Promontory Bridge

Figure 15 Imagery of Meeniyan Promontory Bridge

Figure 16 Meeniyan Promontory Bridge Side View

Figure 17 Meeniyan Promontory Under-Deck View

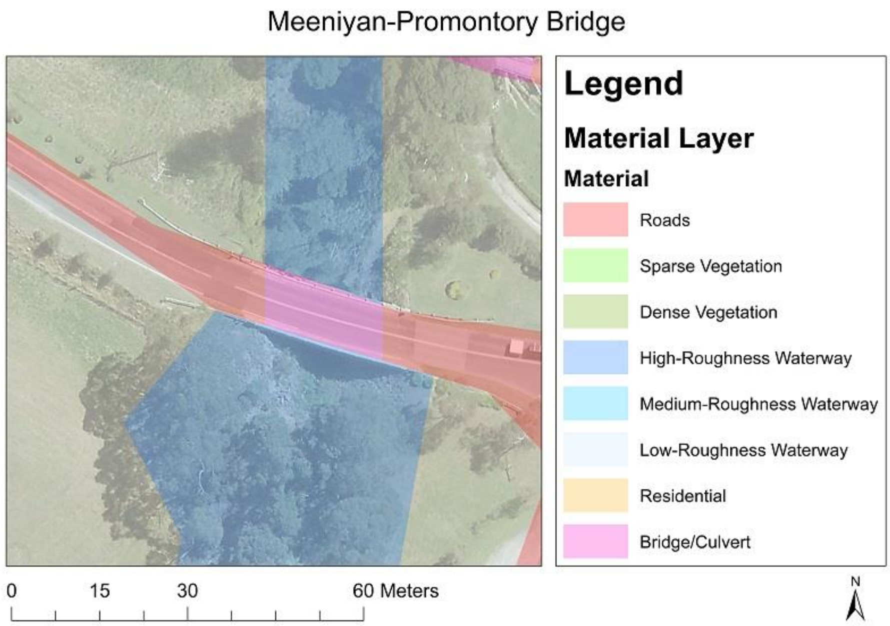

Figure 18 Meeniyan-Promontory Bridge Input Method

3.4 Model extent

The initial model extent used as much of the available LIDAR as possible. In the upper reaches of the catchment the LIDAR available is quite limited. The initial model extent for the southern boundary was also dictated by the LIDAR available there, a large portion of the channels that feed into the southern boundary did not have any available lidar.

Once an initial flood extent was produced a new model boundary was developed. The hydraulic boundary was narrowed to reduce the amount of dry cells in the simulation. The hydraulic boundary was buffered to be approximately 50m away from the extent produced during the initial run. Figure 19 shows the boundary of the hydraulic model.

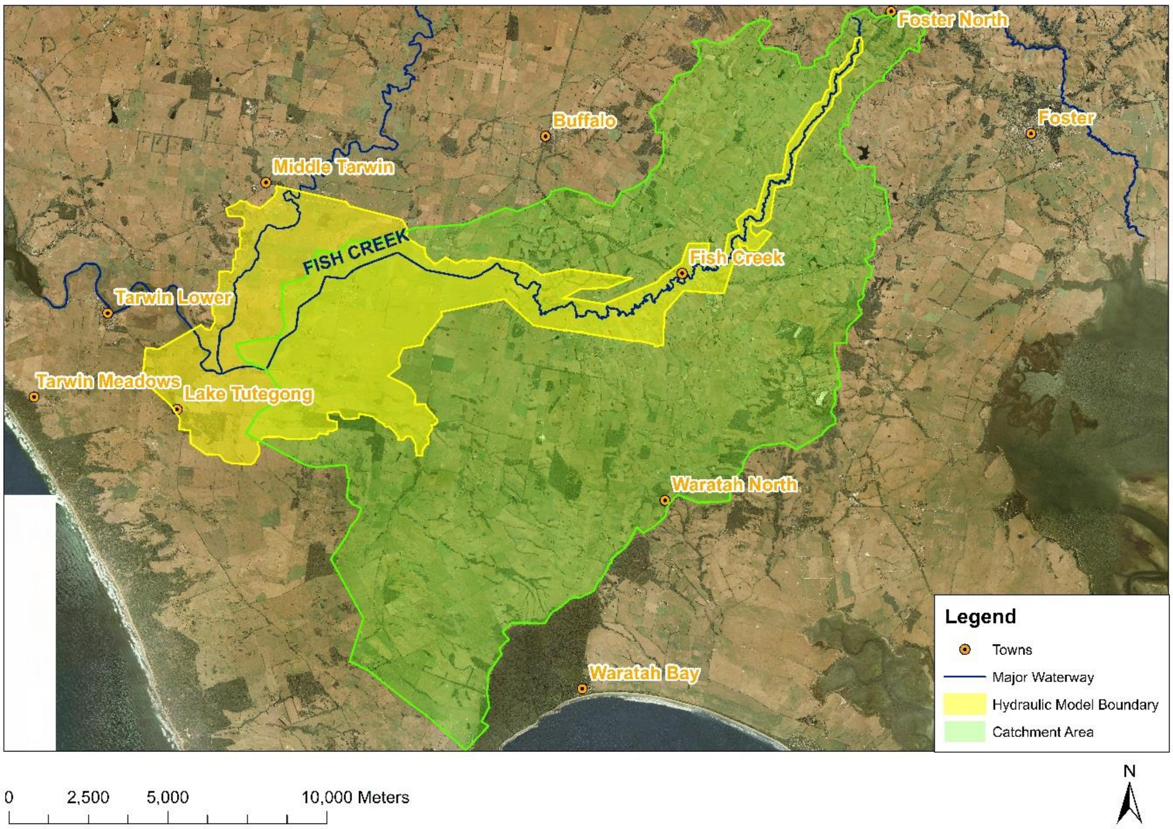

Figure 19 Hydraulic Model Boundary

3.5 Input data

3.5.1 Gridded Elevation Data

The topography of the model is based primarily off a 5 metre grid that was sampled from the 1 metre Lidar set. The main manipulation of the data is a result of resampling the 1m data set to a 5m grid. This conversion was necessary as increasing grid size drastically increases the speed of the model. Figure 20 shows the gridded elevation data that was used for this model.

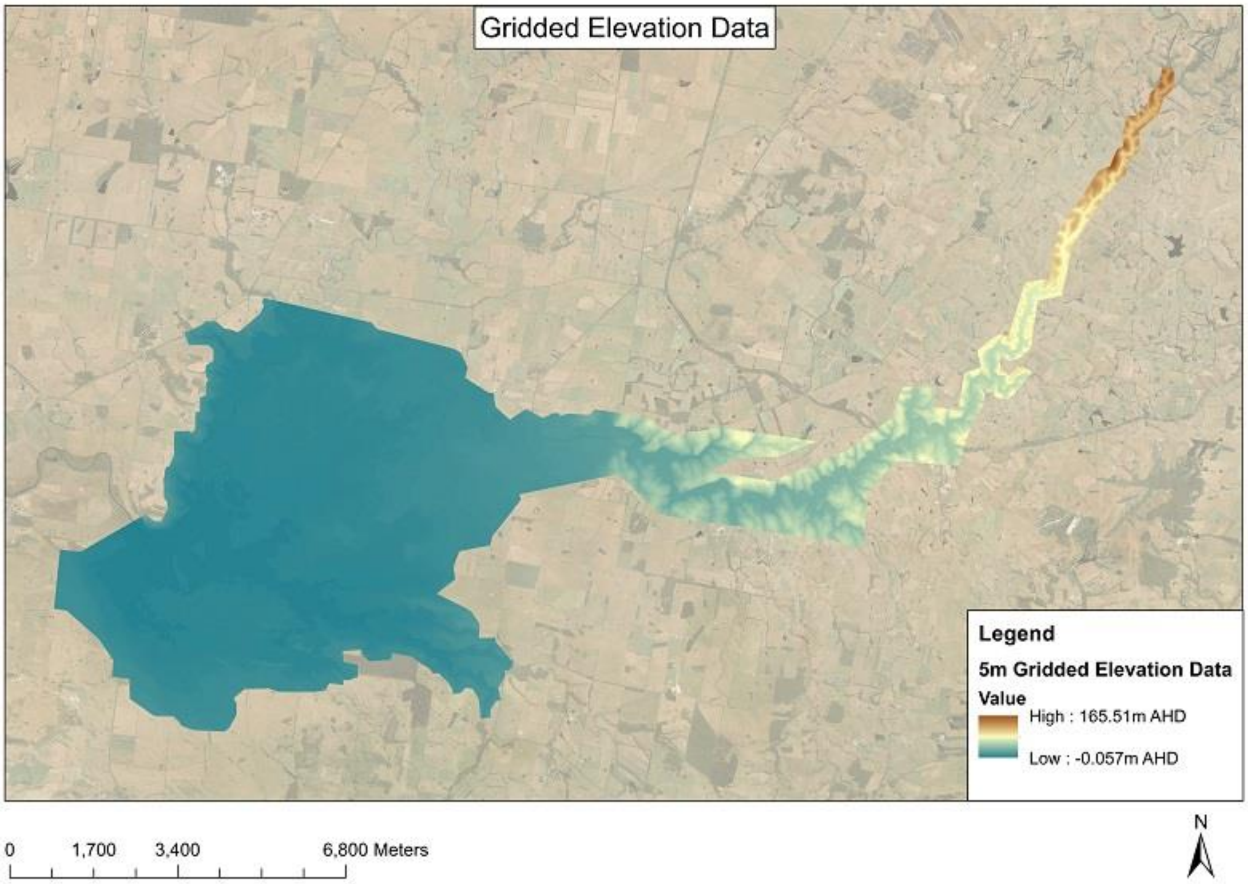

Figure 20 5x5 meter gridded elevation data

In order to make the model more representative of the waterway system, the topography of key areas have been manually adjusted to make the model more representative of reality and to help the model run. The changes include smoothening out the creek bed, adjusting the terrain to remove bridges and fixing errors in data. All topography adjustments were performed in TUFLOW using z shape features. Figure 21 shows the locations of these features.

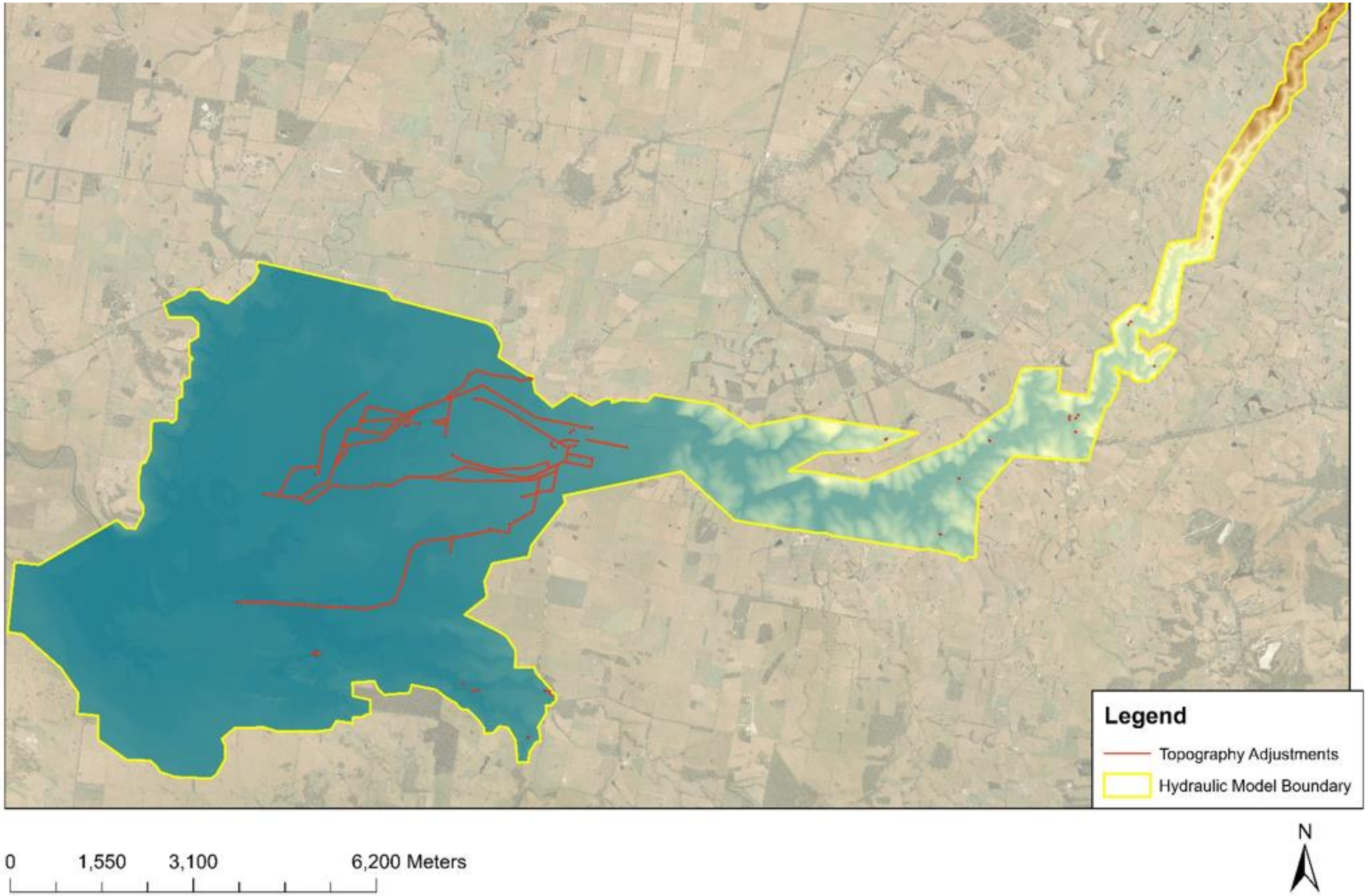

Figure 21 Topography Adjustments

3.5.2 Flow Data

Figure 22 shows the locations where the flows from the hydrology model were input into the hydraulic model as hydrographs. The inflow points are labelled the same way as they were labelled in RORB.

The inflow labelled “Upper_Tarwin” is a steady flow that represents the flow that would come from the section of the Tarwin River located above the Fish Creek model. The flow used was derived from the RFFE as a constant peak flow. A 10% AEP flow from the Upper Tarwin Reaches has been used for a 1% AEP Fish Creek flood event, for smaller flood events the following equation was used to calculate the flow from the Tarwin. X represents the AEP% of the Fish Creek storm event, i.e. 2%, 5%, 10%, 20%.

$$X\ \%\ Tarwin\ River\ Flow = \frac{1\%\ Fish\ Creek\ Flow\ (RORB)}{X\ \%\ Fish\ Creek\ Flow\ (RORB)} \times\ 10\%\ Upper\ Tarwin\ Flow\ (RFFE)$$

Equation 11 Equation Used to Calculate Upper Tarwin Flows

The other inflows into the hydraulic model hydrographs are sourced from RORB. The hydrographs were filtered to remove flows less 0.5 m^3/s. It was seen as an acceptable flow to filter to as flows lower than this were found to have little effect on flooding yet still required TUFLOW computation.

Figure 23 plots hydrographs for all hydraulic model inflow locations for the 1% AEP event. The hydrograph data for other events can be viewed in the appendix in tabular form.

Figure 22 Inflow Locations

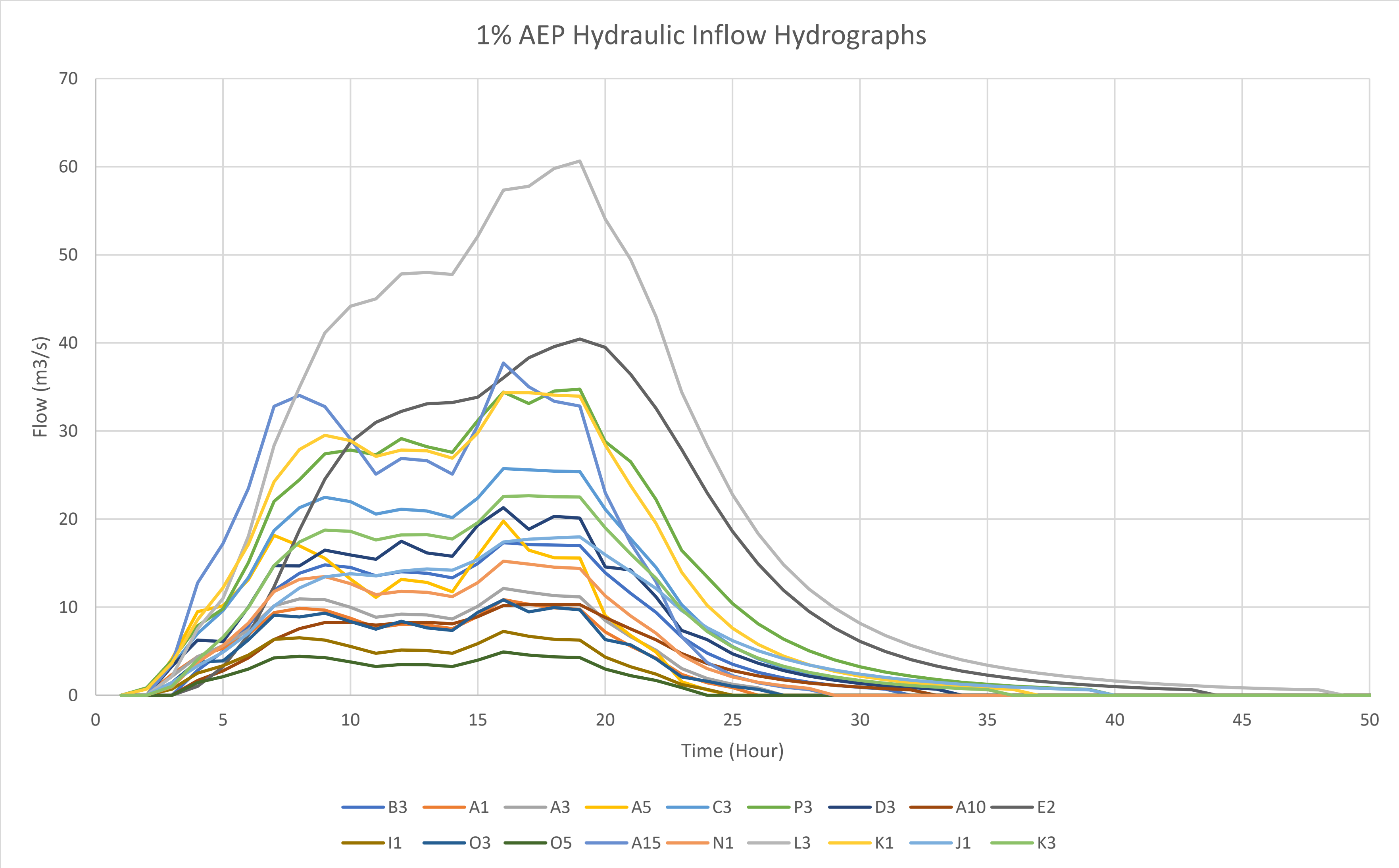

Figure 23 1% AEP Hydraulic Inflow Hydrographs

3.6 Assumptions, Parameters and Settings

3.6.1 Assumption

- The steady state flow condition adopted for the Tarwin catchment upstream of Fish Creek was based of the 10% AEP flood flow calculated from the RFFE. The assumption is that during a 1% AEP storm condition in Fish Creek, the Tarwin River would be experiencing a 10% AEP storm event.
- A detailed inspection of the lidar sets was performed to check for any faults such as vegetation, bridges or other structures being incorrectly displayed in the lidar. The assumptions are that from this process;
    - the resulting lidar is free of defects, and
    - the waterway has not been artificially smoothened
- When representing the larger bridges in the hydraulic model, the bridges were tested to see if the water passing underneath the bridge would be impacted by the deck of the bridge. This was done by using the elevation of the run-ups of the bridge to estimate the elevation of the deck of the bridge. If the water surface elevation of the bridge was at least a meter below the estimated elevation of the bridge then the bridge was removed from the lidar and the Manning's roughness coefficient was increased to represent any obstacles, blockages or bridge abutments.
- It was assumed that aside from any areas of thick vegetation or roads, that the roughness of the floodplain was a uniform 0.03.
- As the hydraulic model outlet was located in the Tarwin River channel it was assumed that the flows from the Tarwin River would dominate the behaviour at the model boundary and that a hydraulic gradient of 0.001 was suitable for the Tarwin River flows.

3.6.2 Parameters

Roughness coefficients

The materials shapefile was mapped from the available imagery. The model extent was divided into 8 different roughness zones. The Bridge/Culvert roughness material was used to model some of the less significant hydraulic structures. The materials and their respective Manning's Coefficient are displayed below in Table 13.

Table 13 Material & Manning's Coefficient

Material	Manning's Coefficient
Farmland	0.03
Roads	0.02
Sparse Vegetation	0.035
Dense Vegetation	0.06
High Roughness Waterway	0.035
Medium Roughness Waterway	0.03
Low Roughness Waterway	0.025
Residential	0.08
Bridge/Culvert	0.1

Figure 2**4** displays the material layer shapefile for the hydraulic model. The Farmland was not drawn in the material layer shapefile, in the TUFLOW geometery control file the model enitre model was initially set to material 1, the farmland material. Then the material shapefile was read over the top, replacing parts the farmland with their designated roughness.

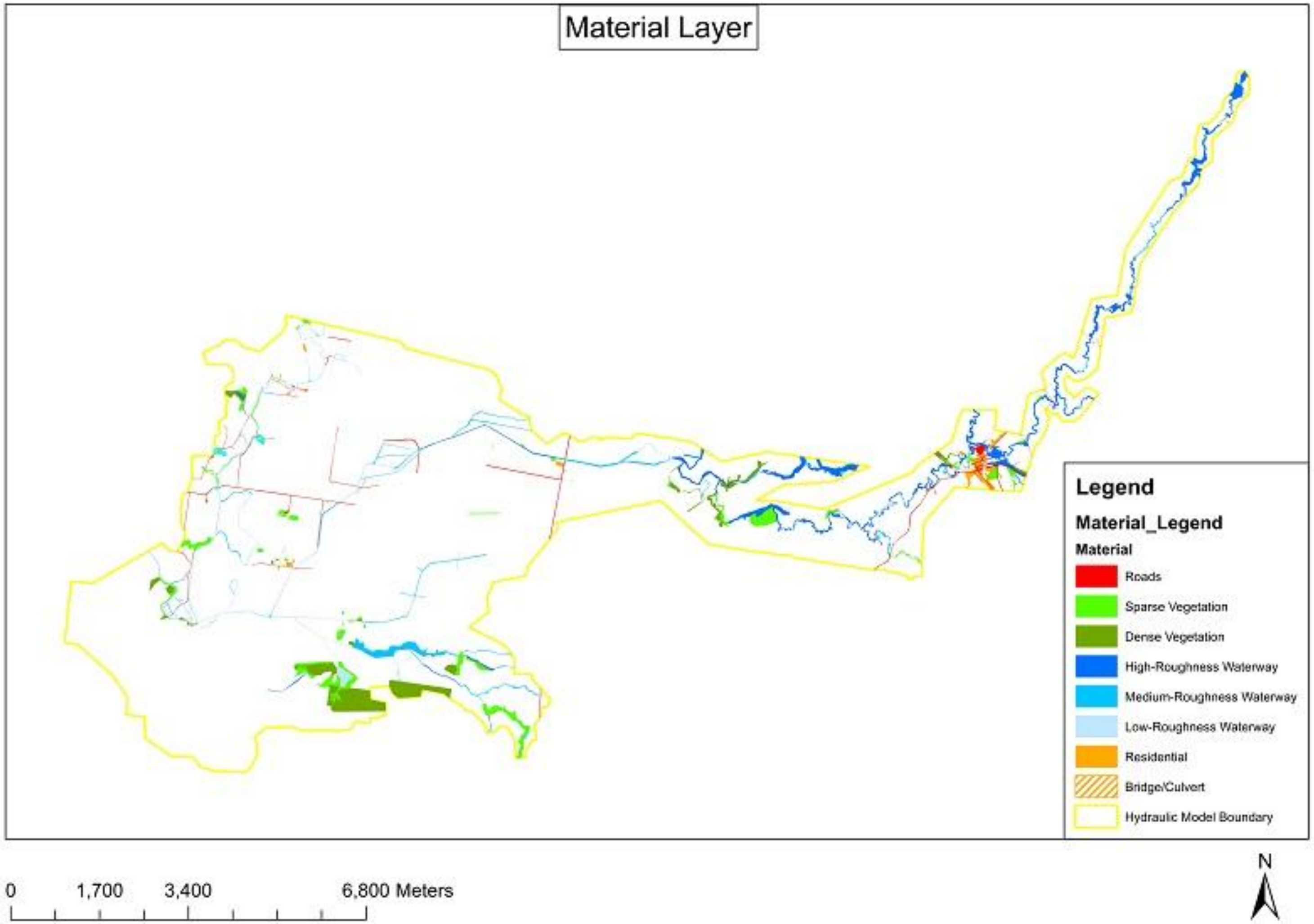

Figure 24 Material Layer for Fish Creek (Upstream Section)

Boundary Conditions

Figure 25 displays the location of the boundaries of this model.

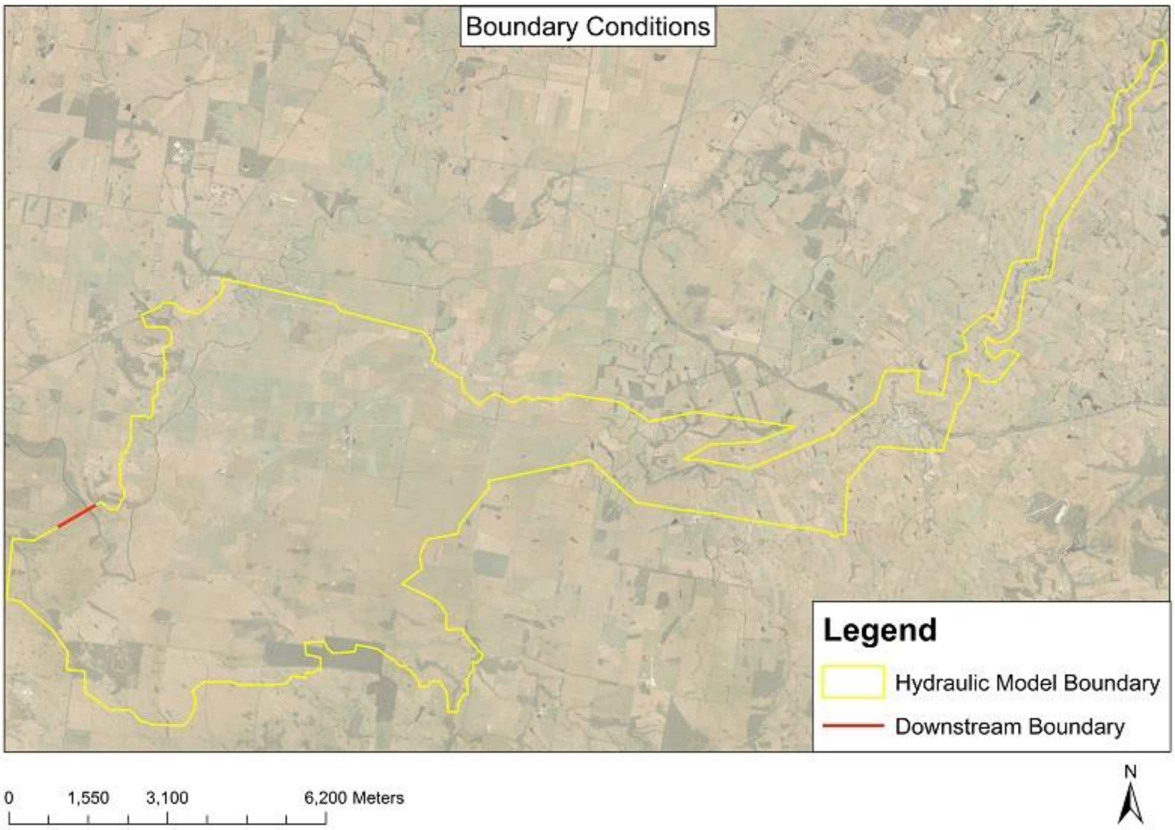

Figure 25 Location of Model Boundaries

The boundary condition of the model outlet is an automatically generated stage-discharge boundary with a hydraulic slope of 0.001. This is a suitable slope for this model as the water coming in from the Upper Tarwin reaches tend to dominate the boundary conditions of this model.

3.6.3 Settings

The geographic co-ordinate system of the model was set to GDA_1994_MGA_Zone_55 (Geocentric Datum of Australia, 1994, Map Grid of Australia, Zone 55)

The hardware used by Tuflow was set to use the Graphical Processing Unit (GPU) rather than the Central Processing Unit (CPU). Using the GPU allowed the hydraulic to be run on a finer grid size in a practical period of time.

The solution scheme used was Heavily Parallelised Computations (HPC).

The model was set to output as an XMDF (eXtensible Model Data Format) every 2 hours and an ASCII (American Standard Code for Information Interchange) when maximums occurred.

Due to the capacities of the HPC solver an adaptive time step was used for this model. Using an adaptive timestep increases the stability of the model.

The orientation of the model was set so that the X and Y plane of the model was equivalent to eastings and northings.

The grid size used is 5 meters by 5 meters raster in ASCII format, it was derived initially from the Lidar and was edited in TUFLOW to smooth channels, remove bridges, clear vegetation and fix any further errors in the Lidar.

3.7 Sensitivity analysis

The hydraulic model was tested to see how sensitive it was to certain parameters. The parameters that were tested are as follows;

The Manning's roughness coefficient within the material csv. The Manning's coefficient was adjusted by ±20%.

The effectiveness of hydraulic structures within the model. This was tested by adjusting the Manning's roughness values given to the hydraulic structures by ±20%, and where 1-Dimensional culverts were used, the cross section of these culverts were adjusted by ±20%.

The hydraulic slope of the downstream HQ boundary, which was adjusted from slope a of 0.001 to slopes of 0.01 and 0.1.

The changes to the parameters listed above have had little effect on the hydraulic results. The effect being changes in maximum velocity by less than ±0.3 m/s, maximum depth by less than ±0.1 meters and maximum water surface elevations by less than ±0.1 meters. These effects are slight when compared to the effect that the results from the hydrologic model have on the hydraulics in terms of hydrograph shape and peak flows and the uncertainty involved when producing these hydrographs.

3.8 Results

Figure 26 displays the maximum depth plot for 1% AEP event. A complete display of flood extent, water velocity, depth and water surface elevation across AEPs of 20%, 10%, 5%, 2% and 1% is available for viewing in appendices E through to H.

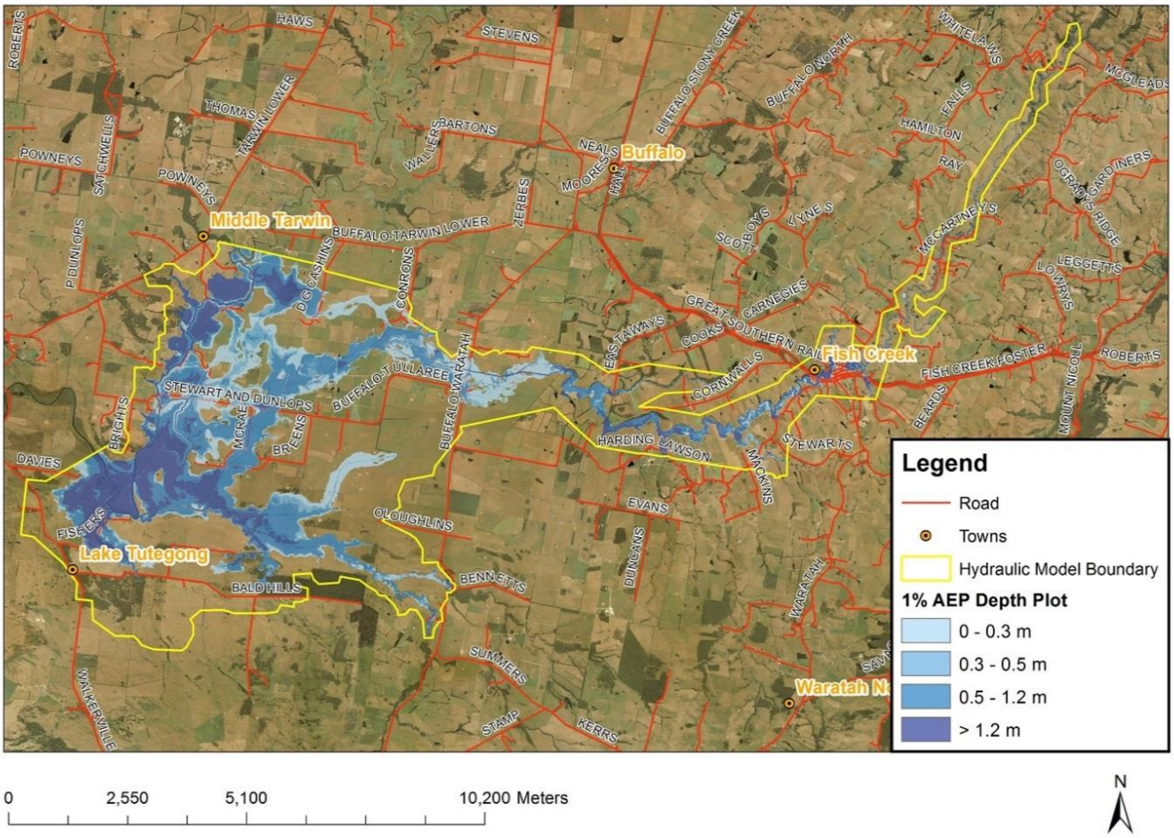

Figure 26 1% AEP Depth Plot

3.9 Flood Intelligence

Tables 14 through to 18 list the roads that are flooded during each AEP event.

Figures 27 & 28 display which houses within the Fish Creek township will be directly affected by flooding during a 1% and 2% flood event.

Table 14 List of Roads Flooded During a 20% AEP Flood Event

AEP%	Road Name
20%	Bald Hills Rd
	Brown and Johnsons Rd
	Buffalo - Waratah Rd
	D G Cashins Rd
	Eastaways Rd
	Fish Creek - Foster Rd
	Fish Creek Quarry Rd
	Fishers Rd
	Great Southern Rail Trl
	Harding Lawson Rd
	McCartneys Rd
	McRae Rd
	Stewart And Dunlops Rd
	Synan Rd

Table 15 List of Roads Flooded During a 10% AEP Flood Event

AEP%	Road Name
10%	Bald Hills Rd
	Breens Rd
	Brown And Johnsons Rd
	Buffalo - Tullaree Rd
	Buffalo - Waratah Rd
	D G Cashins Rd
	Eastaways Rd
	Falls Rd
	Fish Creek - Foster Rd
	Fish Creek Quarry Rd
	Fishers Rd
	Foster Rd
	Great Southern Rail Trl
	Harding Lawson Rd
	Keanes Rd
	Larkin Rd
	Lorimer St
	McCartneys Rd
	McRae Rd
	Meeniyan - Promontory Rd
	Stewart And Dunlops Rd
	Synan Rd

Table 16 List of Roads Flooded During a 5% AEP Flood Event

AEP%	Road Name
5%	Bald Hills Rd
	Brown and Johnsons Rd
	Buffalo - Tullaree Rd
	Buffalo - Waratah Rd
	D G Cashins Rd
	Eastaways Rd
	Fish Creek - Foster Rd
	Fish Creek Quarry Rd
	Fishers Rd
	Great Southern Rail Trl
	Harding Lawson Rd
	Keanes Rd
	McCartneys Rd
	McRae Rd
	Stewart And Dunlops Rd
	Synan Rd

Table 17 List of Roads Flooded During a 2% AEP Flood Event

AEP%	Road Name
2%	Bald Hills Rd
	Breens Rd
	Brown and Johnsons Rd
	Buffalo - Tullaree Rd
	Buffalo - Waratah Rd
	D G Cashins Rd
	Eastaways Rd
	Falls Rd
	Fish Creek - Foster Rd
	Fish Creek Quarry Rd
	Fishers Rd
	Great Southern Rail Trl
	Harding Lawson Rd
	Keanes Rd
	McCartneys Rd
	McRae Rd
	Meeniyan - Promontory Rd
	Stewart And Dunlops Rd
	Synan Rd

Table 18 List of Roads Flooded During a 1% AEP Flood Event

AEP%	Road Name
1%	Bald Hills Rd
	Breens Rd
	Brown and Johnsons Rd
	Buffalo - Tullaree Rd
	Buffalo - Waratah Rd
	D G Cashins Rd
	Eastaways Rd
	Falls Rd
	Fish Creek - Foster Rd
	Fish Creek Quarry Rd
	Fishers Rd
	Foster Rd
	Great Southern Rail Trl
	Harding Lawson Rd
	Keanes Rd
	Larkin Rd
	Lorimer St
	McCartneys Rd
	McRae Rd
	Meeniyan - Promontory Rd
	Stewart And Dunlops Rd
	Synan Rd

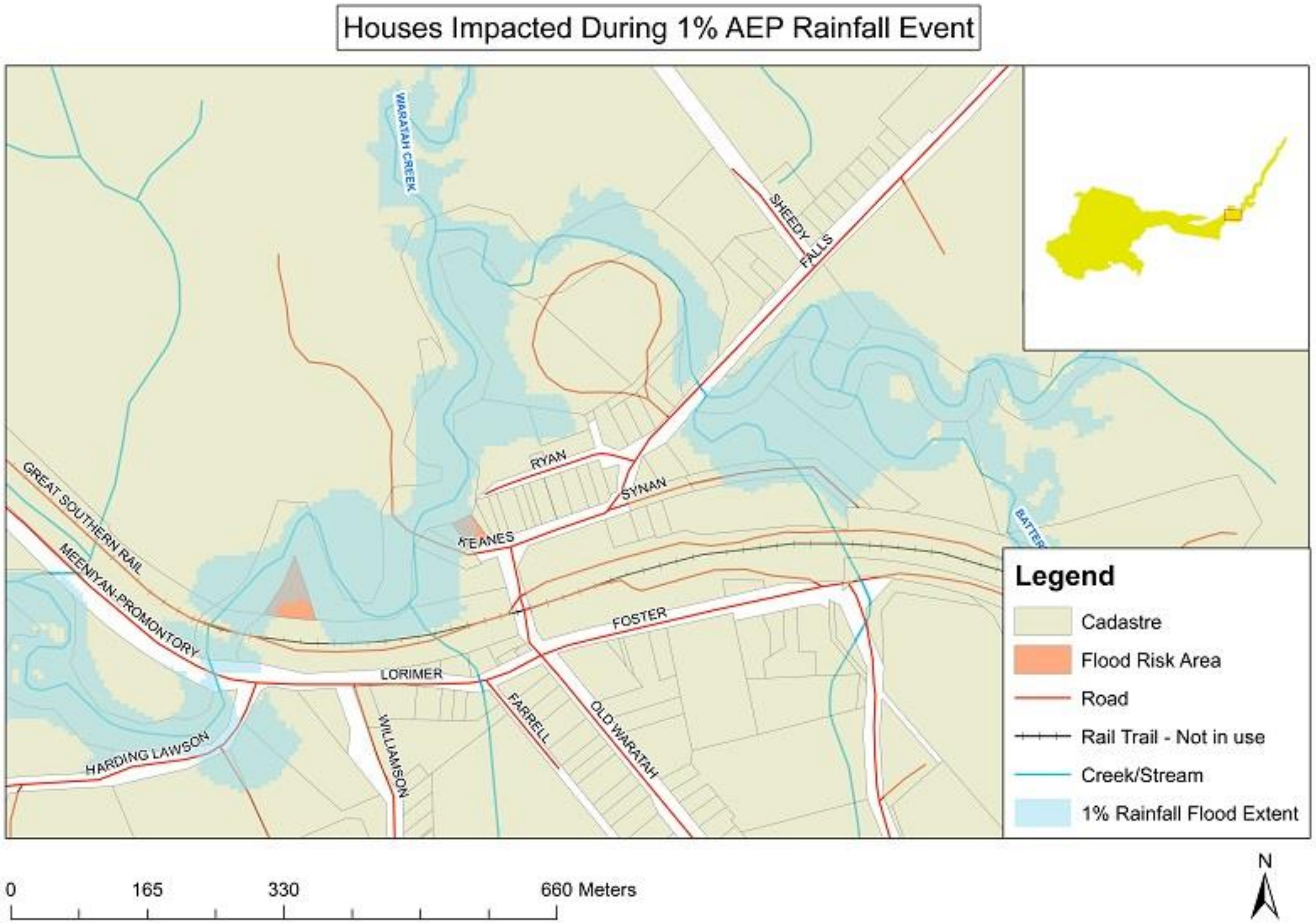

Figure 27 Houses Impacted During a 1% AEP Rainfall Event

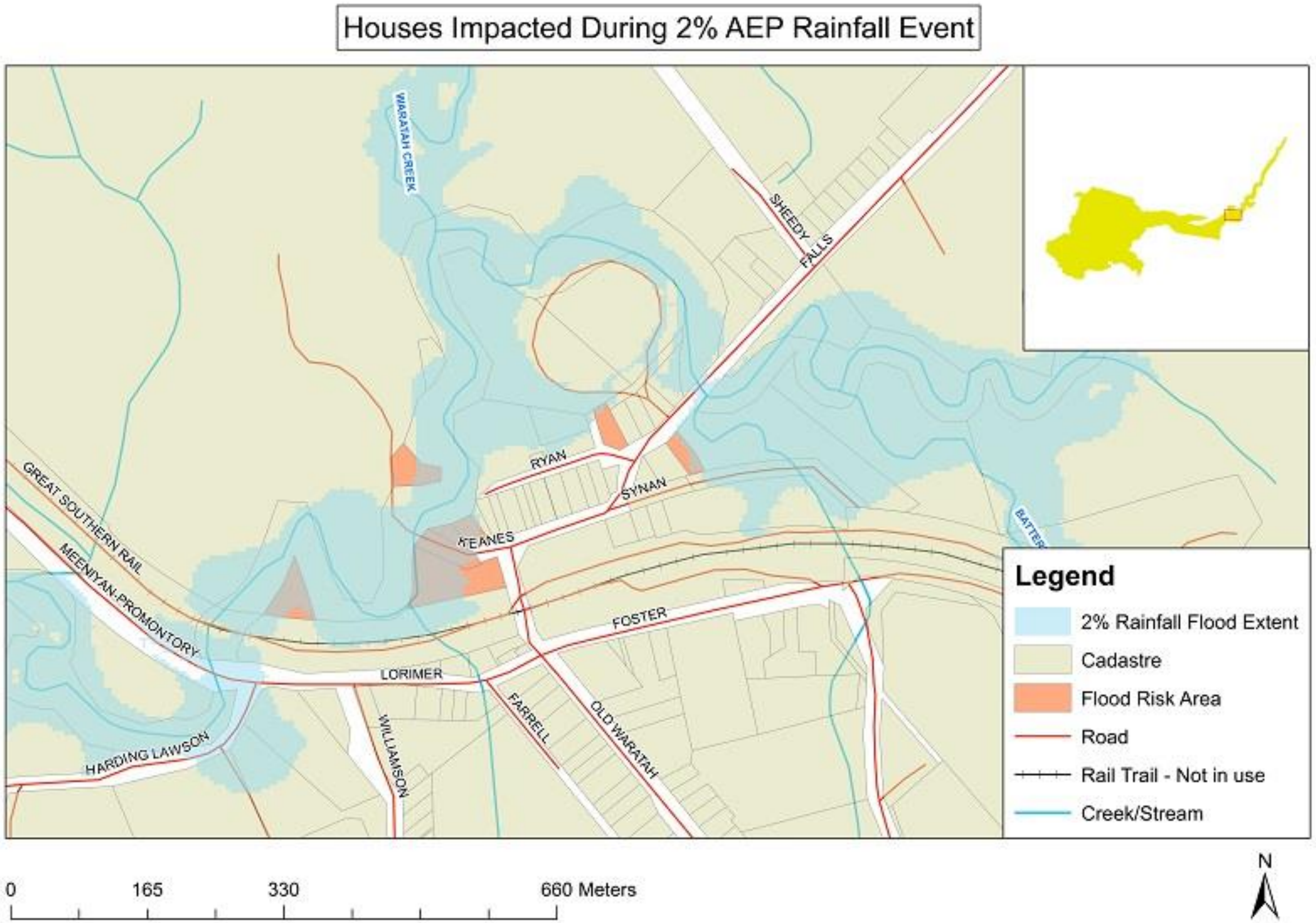

Figure 28 Houses Impacted During a 2% Rainfall Event

4 Conclusion

Figure 37 compares the new modelled 1% flood extent against the flood extent that was previously used by the WGCMA for flood decisions. As you can see in Figure 37, there are many sections that have been designated as flooding by the hydraulic model that were missed in the previous decision related extent. As mentioned back in section 1.5, the method that the previous 1% extent was produced is deemed to be unreliable, the modelled extent is seen as much more accurate and will likely replace the old extent in the WGCMA's 1% extent layer.

In addition to this, the previous flood information for the Fish Creek area gave only the extent of the flood. The new modelled data provides the depth, velocity and water surface elevation as well as an extent, making it much more useful during emergency management situations.

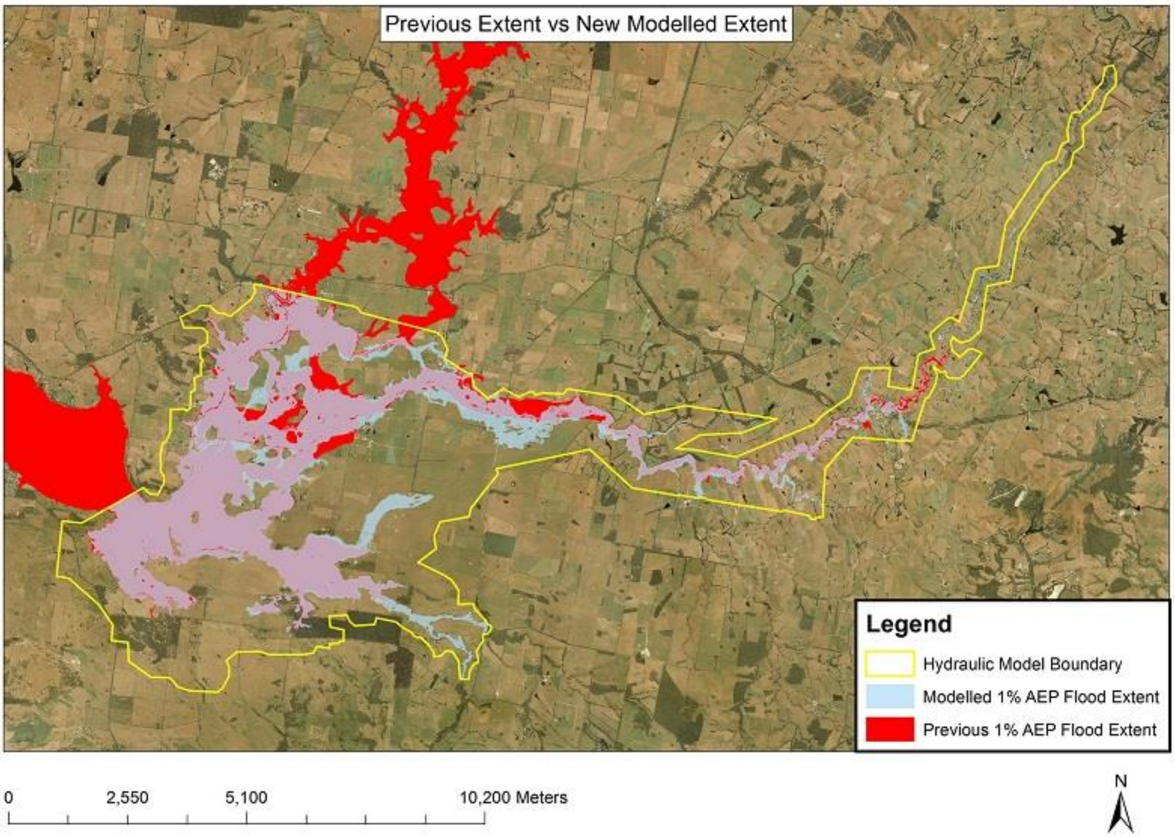

Figure 29 Comparison Between Previous 1% Flood Extent and New Modelled Data

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