Colac Otway Shire Council

Birregurra Flood and Drainage Strategy

Summary Report

3 August 2022

V2013_007-REP-002-2

Job no. and Project Name: V2013_007 Birregurra Flood and Drainage Strategy
Doc Path File: \\online.com\files\ManagementMelbourne\Projects\V2013 Colac Otway Shire\V2013_007 Birregurra Flood Study\07 Deliv\Docs\Report\Revs\Summary Report\V2013_007-REP-002-2-Birregurra Flood Study-Summary Report.docx

Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	15/01/2021	Exhibition Issue	Maria Matamala	Scott Dunn	Maria Matamala	Scott Dunn
1	24/03/2021	Exhibition Issue	Maria Matamala	Scott Dunn	Maria Matamala	Scott Dunn
2	3/08/2022	Client Issue	Maria Matamala	Scott Dunn	Maria Matamala	Scott Dunn
Signatures						

The Colac Otway Shire and Engeny Water Management proudly acknowledges the Gulidjan and Gadubanud peoples of the Eastern Maar Nation as the traditional custodians of the Colac Otway Region.

We pay our respects to their Ancestors and Elders, past, present and emerging. We recognise and respect their unique cultural heritage, beliefs and relationship to their traditional lands, which continue to be important to them today and into the future.

Contents

List of Tables

List of Figures

ABBREVIATIONS AND TERMS

The following abbreviations and terms are used and referenced in the Strategy.

Abbreviation / Term	Explanation
Annual Exceedance Probability (AEP)	Refers to the probability or risk of a rainfall event of a given magnitude (intensity and duration) occurring or being exceeded in any given year. A 90 % AEP event has a high probability of occurring or being exceeded; it would occur quite often and would be a relatively minor rainfall event. A 1 % AEP event has a low probability of occurrence or being exceeded; but is likely to cause extensive damage. A 1 % AEP event has the same probability as a 1 in 100-year ARI.
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. For instance, 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.
Best Practice Environmental Management Guidelines (BPEMG)	Guidelines developed by the Victorian Stormwater Committee and published by the CSIRO in 1999. Guidelines include the required stormwater pollutant removal load and flow attenuation targets.
Birregurra Flood and Drainage Strategy (BFDS)	Detailed within the separate full technical detailed document and summarised within this document.
Development Contribution Plan (DCP)	A DCP is a levy for developments that are proposing to increase the number of dwellings on a site. The contributions collected are used to fund infrastructure required for development and can include shared drainage infrastructure.
Freeboard	A factor of safety above design flood levels typically used in relation to the setting of floor levels or crest heights of flood levees. It is usually expressed as a height above the level of the design flood event.
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 depth and velocity.
Flooding 'Hot Spot'	An area which has a history of repeat flooding highlighted through flood modelling, anecdotal information and / or customer complaints.
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.
Intensity Frequency Duration (IFD)	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.
Light Detection and Ranging (LiDAR)	Airborne surveying technology that provides a regularly spaced grid (one metre horizontal interval in this case) of ground levels. The data allows for the representation of elevations along waterways and other key topographical features across the study area.
Representative Concentration Pathway (RCP)	Greenhouse gas concentration trajectories adopted by the Intergovernmental Panel on Climate Change. These projections consist of four different climate futures relative to temperature and sea level rises possible depending on the volume of greenhouse gases emitted in the years to come.
RORB	Hydrological modelling software used in this study to calculate the runoff generated for rainfall events.
TUFLOW	Hydraulic modelling software used in this study to simulate the flow of flood water through the study area. The model uses numerical equations to describe the water movement.

1 INTRODUCTION

Engeny Water Management (Engeny) in collaboration with specialists in planning schemes and emergency flood warning plans have developed the Birregurra Flood and Drainage Strategy. The study was commissioned by Colac Otway Shire (Council) in partnership with the Project Steering Committee (PSC) which consists of the following stakeholders:

- Corangamite Catchment Management Authority (CCMA);
- Victorian State Emergency Service (VICSES);
- Department of Environment, Land, Water and Planning (DELWP);
- Eastern Maar Aboriginal Corporation; and
- Residents of the Birregurra township.

The study has a number of objectives:

- To improve the understanding of flooding within Birregurra for a range of flood events (minor and major).
- To understand the opportunities available for the installation of a flood warning system in Birregurra.
- To assist with the protection of property and life.
- Inform Planning Scheme Amendments which enable the update of existing flood overlays.
- To improve decision making about development proposals in flood prone areas.
- Inform development advice to ensure new developments consider and do not worsen existing flooding behaviours and risks.
- Inform Council's future growth strategy such as the Birregurra Structure Plan to understand which areas are appropriate for growth.
- Identify structural mitigation measures which could be implemented to reduce existing flood risks.
- Understand Water Sensitive Urban Design (WSUD) measures which could be implemented to ensure future development meets stormwater quality requirements for new development areas.
- Update Council's Flood Emergency Plan and develop flood intelligence outputs to inform emergency response planning.

Whilst the Strategy has a focus on flood management related objectives, it is important to note the importance of waterways in relation to broader ecological, cultural, and aesthetic values. Waterways serve wider ecological functions as habitat and places of biodiversity including for the growling grass frog (*Litoria raniformis*) listed as vulnerable by the *Environment Protection and Biodiversity Conservation Act 1999*. There are areas of cultural sensitivity and significance for Aboriginal people, in addition to places of aesthetic and recreational value. It is important that these values continue to be upheld and enhanced whilst balancing the flood mitigation objectives and outcomes of the strategy.

Several investigations and tasks were undertaken to develop the Birregurra Flood and Drainage Strategy including:

1. Data collation and review.
2. Hydrologic and hydraulic modelling.
3. Peer Review of hydrologic and hydraulic modelling.
4. Flood damages assessment.
5. Structural mitigation works assessment.
6. Stormwater quality assets assessment.
7. Development of planning overlays and schedules.
8. Flood intelligence, warning and planning assessment.
9. Development of Flood Spatial Data Specifications (SDS) outputs.

A series of data sets were collated and reviewed to inform the Birregurra Flood and Drainage Strategy. The data was sourced from several agencies and individuals and consisted of GIS layers and reports in addition to other technical data such as rainfall data, streamflow recordings, historical flood photos, etc. This report provides a summary of the approach and outcomes from each of the subsequent investigations. Engeny's Birregurra Flood and Drainage Strategy Detailed Report (December 2020) should be referenced for further background.

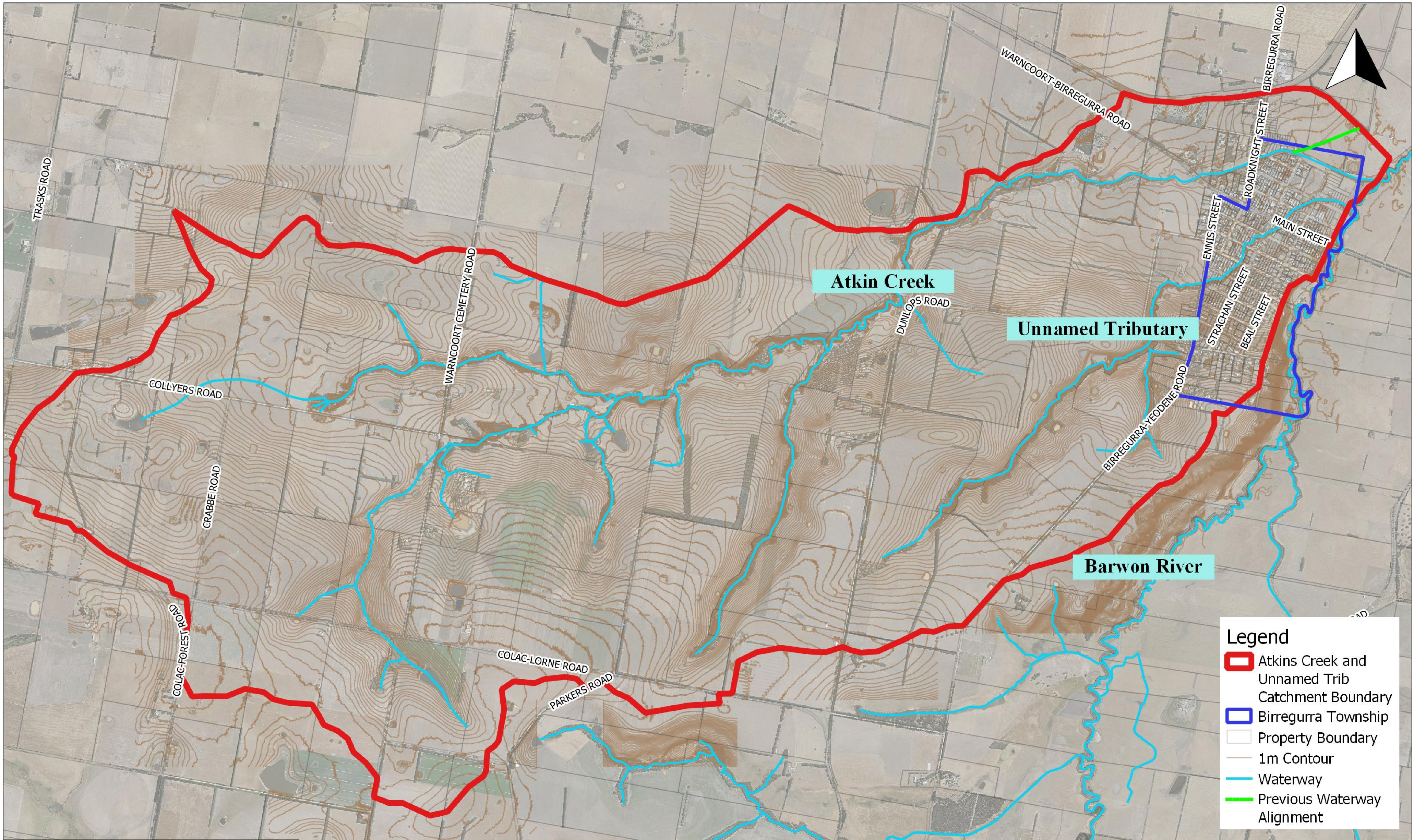
1.1 CATCHMENT DESCRIPTION

The township of Birregurra is located approximately 130 kilometres south-west of Melbourne. Atkin Creek and an Unnamed Tributary of the Barwon River flow through the town. The Unnamed Tributary is unofficially referred to by some locals as Kettles Creek however is referred to herein as the Unnamed Tributary. These waterways have a contributing catchment area of approximately 23 km² and 5.5 km² respectively prior to discharging into the Barwon River which forms the town's eastern boundary.

The catchment generally consists of well-defined flow paths and ridges rising from a level of approximately 198 m Australian Height Datum (AHD) at the top of the Atkin Creek catchment to 106 m AHD at the confluence to the Barwon River over a distance of 10.5 kilometres.

Birregurra has experienced growth and infill development in recent times with a high number of properties reported to be flood affected from the local waterways flowing through the town. During the September 2016 storm event, properties within the new developments along Scouller Street and Anderson Street in particular were affected by significant flooding in addition to other established residential areas within the township.

Figure 1.1 provides an overview of the Birregurra township including the upstream Atkin Creek and Unnamed Tributary catchment areas.



Level 34, T5, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12192, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

Colac Otway SHIRE

600 0 600 m

Scale in metres (1:5000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Birregurra Flood Study

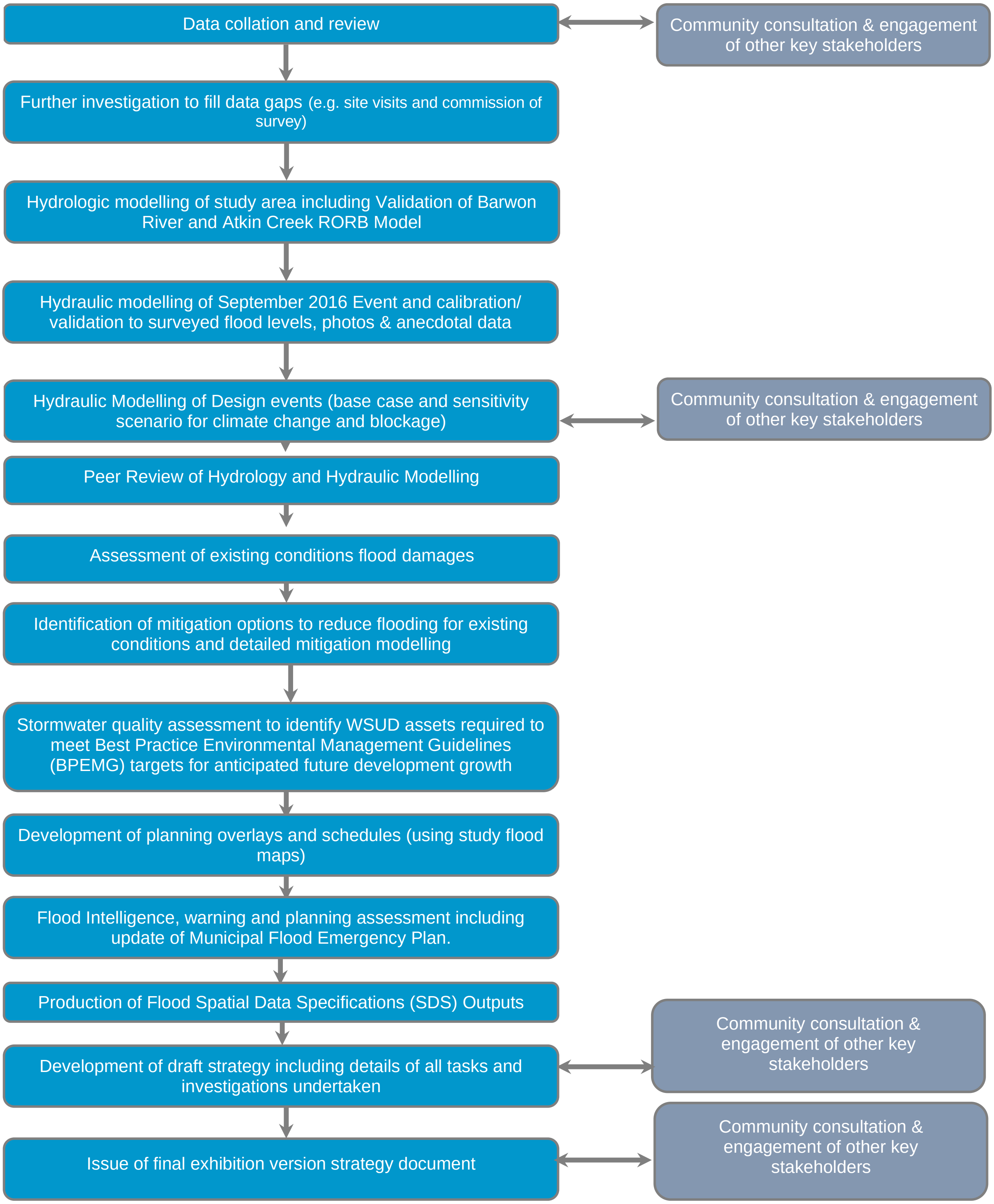
Birregurra Township Catchment Overview

Job Number: V2013_007
Revision: 0
Drawn: AN
Checked: MM
Date: 14/1/2021

1.2 STUDY METHODOLOGY

Figure 1.2 illustrates the key steps undertaken to achieve the objectives of this study.

Figure 1.2: Study Methodology Flow Chart



2 HYDROLOGIC AND HYDRAULIC MODELLING

2.1 OVERVIEW

A key component of the study was the hydrologic and hydraulic modelling.

Hydrologic modelling refers to the study of rainfall and stormwater runoff processes. The RORB[1] modelling produces hydrographs which are graphs representing how fast water is moving across the landscape over the duration of the flood event (flow versus time graphs). Hydraulic modelling in contrast, refers to the study of water flow through the catchment and the associated flow depth and velocity parameters. The hydrologic modelling outputs (i.e. hydrographs) are applied as inputs to the hydraulic TUFLOW[2] model. Put simply, hydrologic modelling determines how much water flows over the course of a flood event, while hydraulic modelling determines where that water will flow, how deep and how fast.

Birregurra has a known history of flooding, predominantly associated with the flows from Atkin Creek and an Unnamed Tributary which enter the township at Warncoort-Birregurra Road and Ennis Street respectively and discharges into the Barwon River. This is typically referred to as riverine flooding. Stormwater flooding is also present within Birregurra and is attributed to the smaller local township catchment only and the insufficient conveyance capacity of underground drainage and roadside swales / channels. The delineation between riverine and stormwater related flooding is highlighted with the difference in critical durations (longer critical durations for larger catchments associated to riverine related flooding in contrast to local township stormwater flooding), velocity vector directions and differences in flood levels.

Hydrologic and hydraulic modelling was undertaken in line with the latest Australian Rainfall and Runoff guidelines (ARR2019) which provides current rainfall data issued from the Federal Government. This allows us to gain a better understanding of flooding conditions for a series of Annual Exceedance Probability (AEP) design events. The AEP design events are commonly referred to as a 1 in 10, or a 1 in 100-year event, for example. Utilising the September 2016 historical flood data, a computer-generated simulation and calibration of the hydrologic and hydraulic models was undertaken to provide confidence in modelling outputs and its accuracy to identify what land is flood prone under certain conditions.

Table 2.1 provides a summary of the events simulated including the sensitivity scenarios analysed. As shown, climate change, blockage and instream vegetation trimming impacts were assessed to understand the given model inputs influence on the resultant flood mapping outputs and whether or not they should be considered further.

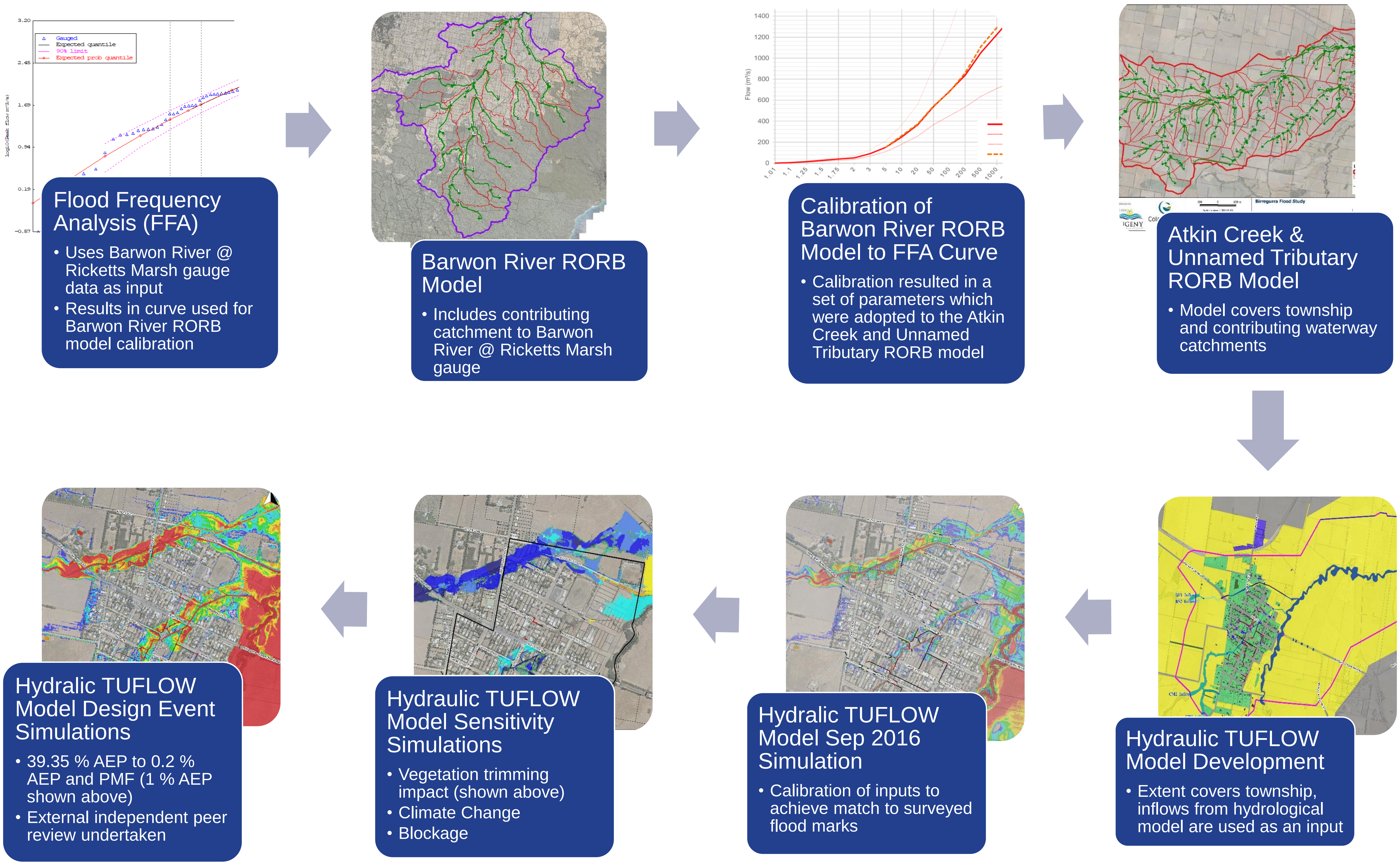
Figure 2.1 provides a summary chart of the hydrologic and hydraulic modelling approach undertaken. Engeny's detailed report can be referenced for further information on the specific modelling parameters and inputs used in Section 3 and Section 4 (pages 26 to 75)

[1] Hydrological modelling software used in this study to calculate the runoff generated for rainfall events
[2] Hydraulic modelling software used in this study to simulate the flow of flood water through the study area. The model uses numerical equations to describe the water movement.

Table 2.1: Hydrological Modelled Scenarios

Storm Event	Existing Conditions	Sensitivity Scenarios		
		Climate Change Conditions	Blockage Impact	Instream Vegetation Trimming
39.35 % AEP or 2-year ARI	x			
18.13 (20) % AEP or 5-year ARI	x			
10 % AEP or 10-year ARI	x	x		
5 % AEP or 20-year ARI	x			
2 % AEP or 50-year ARI	x			
1 % AEP or 100-year ARI	x	x	x	
0.5 % AEP or 200-year ARI	x			
0.2 % AEP or 500-year ARI	x			
Probable Maximum Flood (PMF)	x			
September 2016 validation event	x			x

Figure 2.1: Hydrologic and Hydraulic Modelling Approach



2.2 SEPTEMBER 2016 EVENT

The September 2016 flood event was simulated within the hydraulic TUFLOW model with inputs from the hydrologic RORB model. Modifications to the modelling inputs were made to obtain the calibration of modelled flood levels to the surveyed flood marks displayed in Figure 2.2. Table 4.4 within Engeny's detailed BFDS report can be referenced for the comparison of surveyed to modelled flood level values. The magnitude of this event was estimated to relate to a storm event in the range of a 10 % to 20 % Annual Exceedance Probability (AEP).

Figure 2.2: September 2016 Event Flood Depth Results and Location of Surveyed Flood Marks

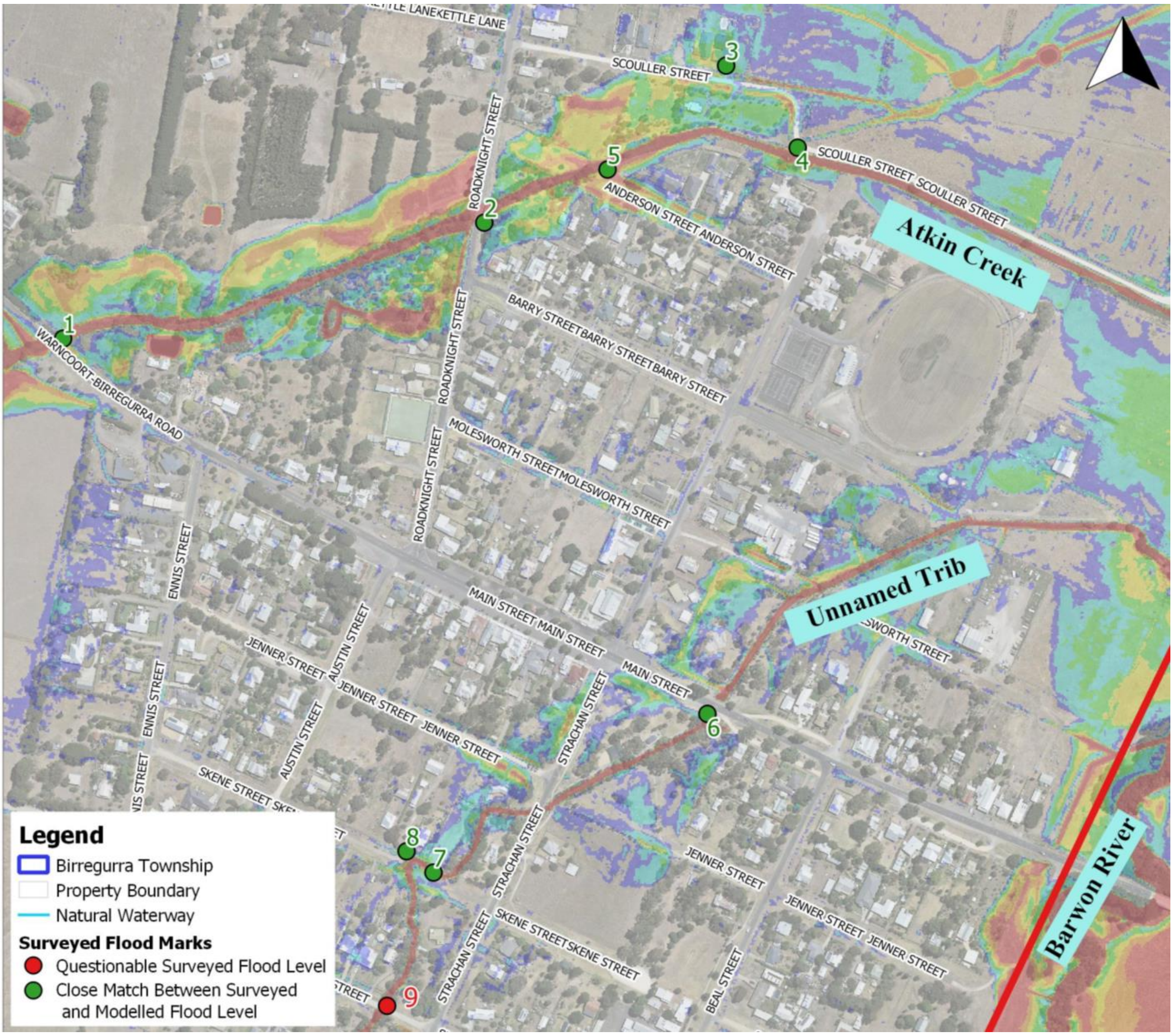
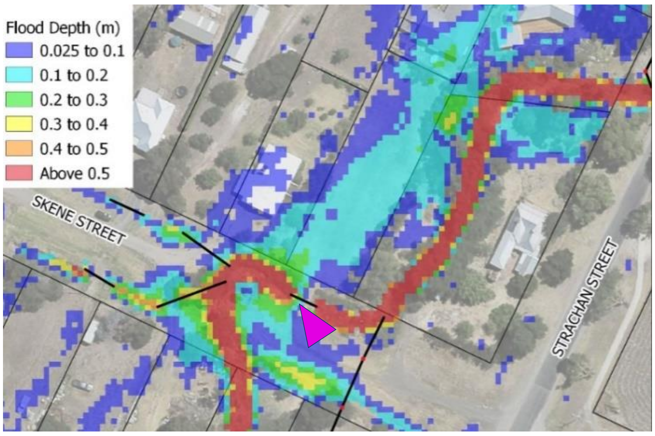


Table 2.2 provides a sample of comparisons between the modelled flood depths and the captured September 2016 event photographs. These comparisons provide further confidence that the hydraulic modelling results are a good match to those reported by residents across the township.

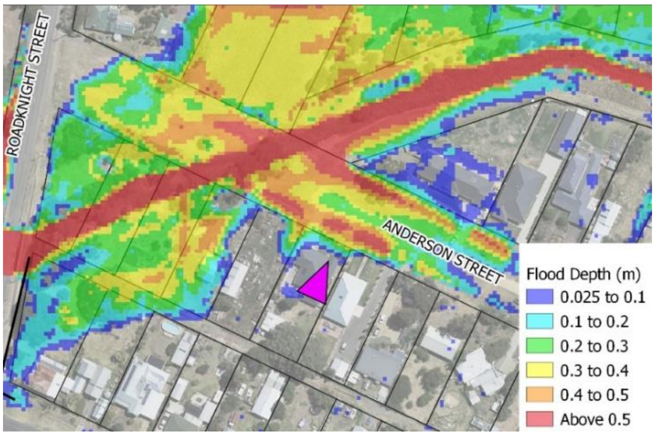
Table 2.2: Comparison of September 2016 Event Photograph to Modelled Flood Extent

Photograph / Anecdotal Evidence | **Modelled Flood Extent**

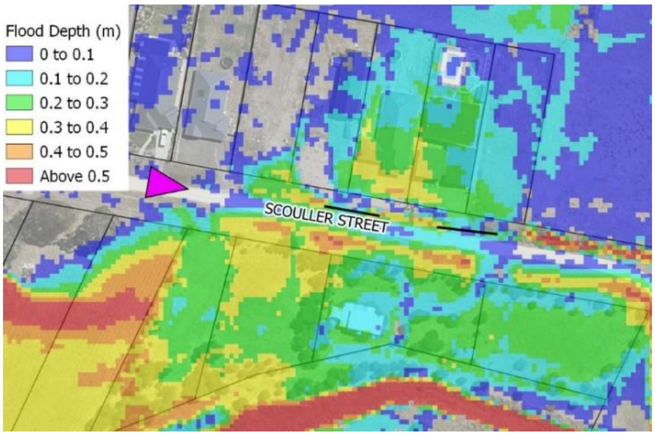
50 Skene Street

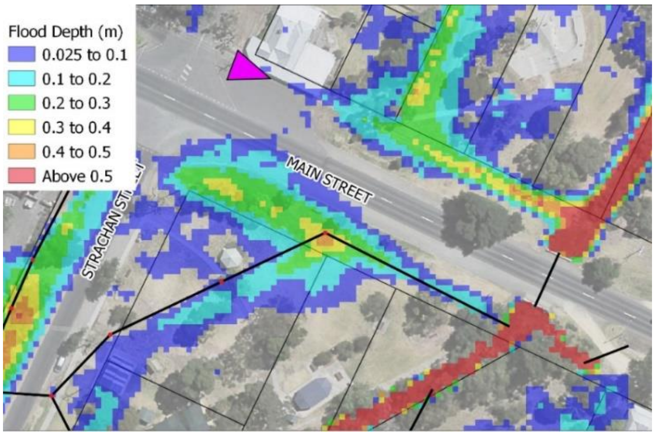


17 Anderson Street



18-24 Scouller Street



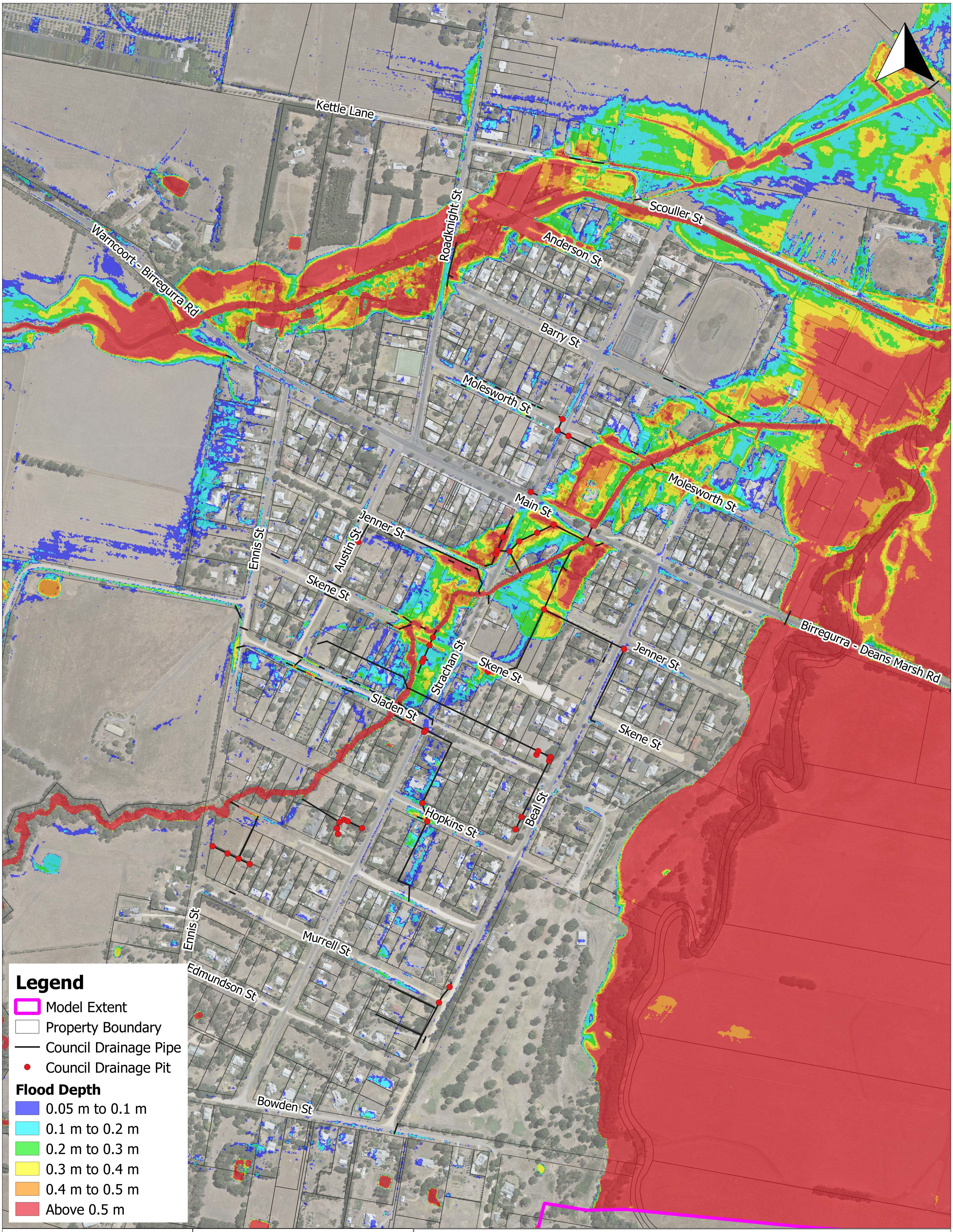
Photograph / Anecdotal Evidence	**Modelled Flood Extent**
Main Street looking east towards Unnamed Tributary	
	

2.3 DESIGN EVENTS

The hydraulic TUFLOW model was also used to simulate the full suite of AEP design events (39.25 %, 20 %, 10 %, 5 %, 2 %, 1 % AEP and Probable Maximum Flood (PMF)).

Figure 2.3 displays the 1 % AEP flood depth layout plan.

Section 2.4, Section 2.5, Section 2.6 below summarises the findings of the sensitivity scenarios assessed. These scenarios seek to highlight the influence and impact of key model inputs (i.e. climate change, instream vegetation trimming, blockage of key culverts/bridges) on the resultant flood mapping results. The results of this modelling have informed whether climate change should be considered during the development of planning overlays and provided justification for the adoption of the base case model inputs associated to instream vegetation trimming and blockage assumptions.



Level 34, T5, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12192, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

Colac Otway SHIRE

110 0 110 m

Scale in metres (1:5500 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Birregurra Flood Study

Flood Depth - 1% AEP

Job Number: V2013_007
Revision: 0
Drawn: AN
Checked: MM
Date: 30/10/2020

2.4 CLIMATE CHANGE IMPACT

Climate Change conditions was assessed for the 1 % and 10 % AEP events. This sensitivity scenario was undertaken to identify the impact to flood depths as a result of an increase in rainfall intensity based on the forecasted year 2100 and representative concentration pathway (RCP) 8.5 percentage of 18.5 %. The following summarises the key findings:

- The 1 % AEP flood depth results (shown within Appendix H of Engeny's detailed BFDS report) displays increases to flood depths, on average, by up to 100 mm in most areas along Atkin Creek and the Unnamed Tributary particularly where the flow path is wider and consists of greater flood storage. In contrast the Unnamed Tributary upstream of Sladen Street is narrow and well incised and as such average flood depth increases of up to 500 mm were noted.
- Although these flood depth increases are evident, the resultant flood extent has not significantly changed when compared to existing / base climate conditions.
- Notable changes to the flood risk were identified particularly for the 1 % AEP. As this event informs the planning overlays, considerations should be taken for land which would be assigned a Land Subject to Inundation Overlay (LSIO) under existing climate conditions but would be assigned a Floodway Overlay if climate change conditions was utilised. This is particularly relevant given the difference in building controls for each overlay i.e. a LSIO would permit a development to proceed with conditions however a FO would not permit the addition of any new developments within. The planning overlays are described in more detail in Section 3 alongside Table 3.2 which provides a comparison of the number of properties covered by each overlay under existing and climate change conditions.

2.5 INSTREAM VEGETATION TRIMMING IMPACT

Thick vegetation, as observed within Atkin Creek and the Unnamed Tributary can often be perceived as having a significant negative impact on the conveyance of flows. To understand this degree of influence, the September 2016 rainfall event was simulated with lower surface roughness values along Atkin Creek and the Unnamed Tributary. This simulation aims to represent a thorough trimming of instream vegetation. The following summarises the key findings:

- Flood depth reductions of up to 100 mm along the waterways with an overall average reduction of 60 mm along Atkin Creek downstream of Warncoort-Birregurra Road.
- As the flood depth difference is not significant, it would not have contributed to a change in the number of dwellings affected by above floor level flooding during the September 2016 flood event. The works would also have a significant ongoing cost and negative environmental impacts.

Section 4.3.9 of Engeny's detailed BFDS report provides further details on the assessment undertaken and presents the resultant flood depth afflux which would be expected with the instream vegetation trimming works.

2.6 BLOCKAGE IMPACT

Potential for blockage in a 1 % AEP design event was estimated using the approach detailed in the Australian Rainfall and Runoff guidelines (ARR 2019). A blockage percentage of 15 % was applied to large bridge structures and 50 % to culvert structures along the Atkin Creek and Unnamed Tributary waterways. The following summarises the key findings:

- Resultant changes to flood depth are generally within + / - 100 mm with the exception of the blockage to the culvert structure at Main Street (referred to as location 3) where flood depths are predicted to increase by up to 150 mm at the intersection of Main Street and Strachan Street in addition to upstream of the culvert structure.
- The differences do not however result in an increase to the 1 % AEP flood extent.
- The flood risk changes at this location were also assessed and no significant changes were noted except for the Council owned reserve upstream of Main Street.

Section 4.3.8 of Engeny's detailed BFDS report provides further details on the assessment undertaken and presents the resultant flood depth afflux and changes in flood hazard when blockage is assumed.

3 PLANNING OVERLAYS AND CONTROLS

Planning controls are one of the most cost-effective non-structural mitigation means of reducing the community's flood risk by:

- Encouraging people to, where possible, avoid development on flood-prone land.
- Minimising the potential impacts on existing flood-prone developments by raising floor levels of proposed habitable buildings and ensuring the development does not increase the risk of flooding on other properties. This is because the suite of flooding overlays clearly identifies through maps in planning schemes what land is flood prone. They also provide guidance in relation to the level of flood risk and whether development may be acceptable under certain conditions.

Proposed flood control overlay maps were prepared using the 1 % AEP flood depth, water surface elevation, velocity and hazard outputs. The planning overlay controls available as part of the Victorian Planning Provisions and their purpose is summarised in Table 3.1 and include:

- Special Building Overlay (SBO)
- Land Subject to Inundation Overlay (LSIO)
- Floodway Overlay (FO).

Table 3.1: Summary of Planning Overlay Objectives

SBO	LSIO	FO
To identify land in urban areas liable to inundation by overland flows from the urban drainage system as determined by, or in consultation with, the floodplain management authority.	To identify land in a flood storage or flood fringe area affected by the 1 in 100 year flood or any other area determined by the floodplain management authority.	To identify waterways, major flood paths, drainage depressions and high hazard areas which have the greatest risk and frequency of being affected by flooding.
To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and will not cause any significant rise in flood level or flow velocity.	To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and will not cause any significant rise in flood level or flow velocity.	To ensure that any development maintains the free passage and temporary storage of floodwater, minimises flood damage and is compatible with flood hazard, local drainage conditions and the minimisation of soil erosion, sedimentation and silting.
To protect water quality in accordance with the provisions of relevant State Environment Protection Policies, particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria).	To reflect any declaration under Division 4 of Part 10 of the Water Act, 1989 where a declaration has been made.	To reflect any declarations under Division 4 of Part 10 of the Water Act, 1989 if a declaration has been made.
	To protect water quality in accordance with the provisions of relevant State Environment Protection Policies, particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria).	To protect water quality and waterways as natural resources in accordance with the provisions of relevant State Environment Protection Policies, and particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria).
	To ensure that development maintains or improves river and wetland health, waterway protection and flood plain health.	To ensure that development maintains or improves river and wetland health, waterway protection and flood plain health.

In summary, the FO is where the flood hazard is considered unsafe and most development is generally not supported. The LSIO is where the flood hazard is within safe parameters and development is generally supported subject to conditions such as raising the floor level of buildings. This is also the case for the SBO.

Using the latest technical guidelines and best available data, these overlays have highlighted that the existing overlays and flood planning controls in the Colac Otway Planning Scheme for Birregurra do not sufficiently identify flood prone land. As such the updated overlays are intended to replace the existing overlays within the township. Draft amendments to the Colac Otway Planning Scheme to implement revised flooding controls have been prepared and will form the basis of a planning scheme amendment subject to Council's consideration.

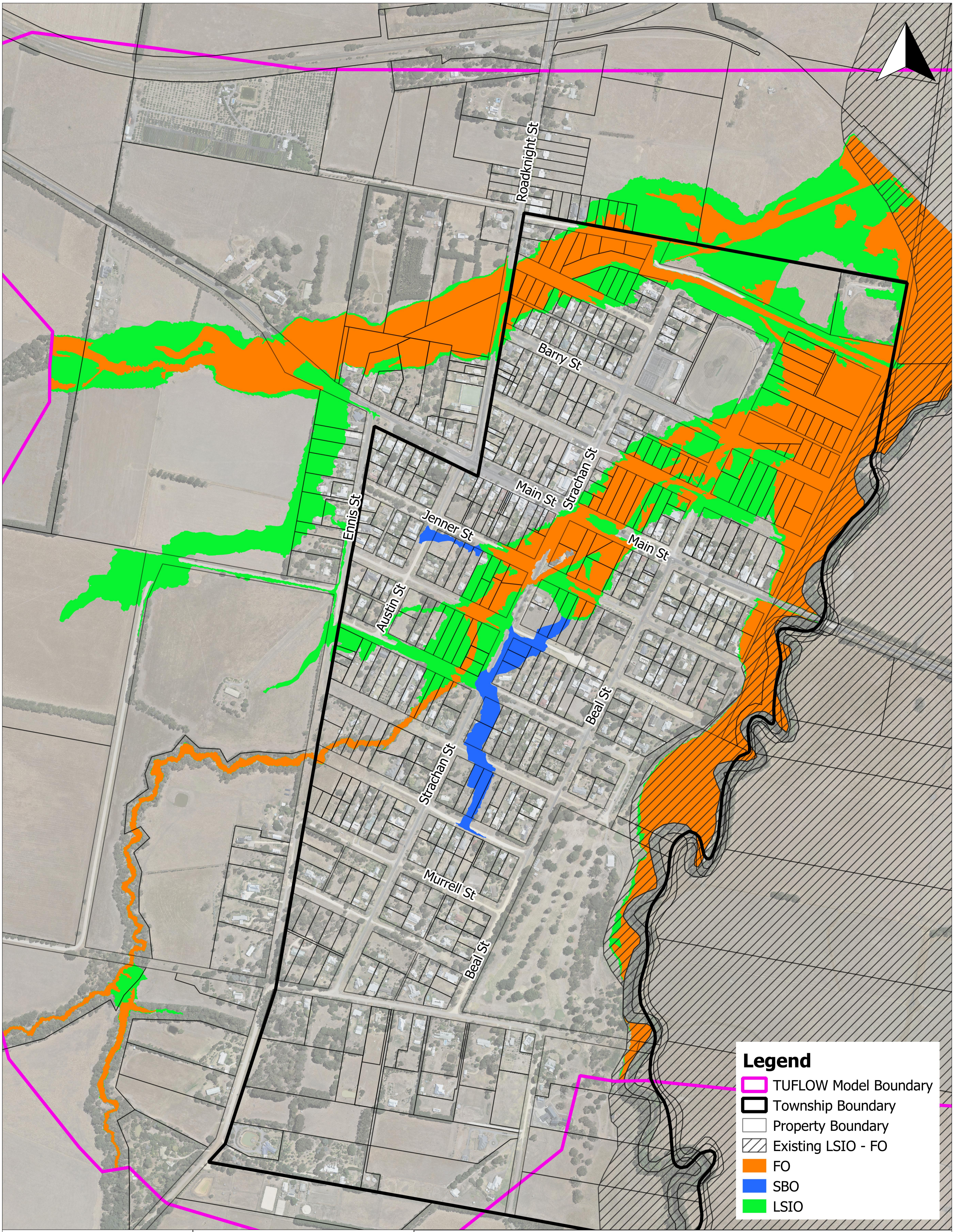
An assessment of how the overlays would differ if climate change was considered, was also undertaken. This identified that the key difference would be the delineation of the FO extent and the subsequent increase to the number of properties covered by both the LSIO and FO extents. Table 3.2 provides a comparison of the number of properties covered by each of the proposed overlays when current and future climate change conditions are considered. Given these differences were not considered significant and to maintain consistency with current State Government policy on riverine flooding and the recently produced Colac township overlays, the final Birregurra overlays will be based on current climate conditions.

The table below also highlights the number of properties captured by the existing overlays and how this insufficiently captures all properties affected by flooding due to the now outdated but previously best available data and modelling approaches.

Table 3.2: Summary of property counts captured by existing and proposed planning overlays

Overlay	Existing Overlays	Proposed Overlays based on current climate conditions	Proposed Overlays based on climate change conditions
SBO only	-	12	12
LSIO only	45	35	20
FO only	-	9	4
LSIO & FO	-	60	84
SBO, LSIO & FO	-	1	1
Total	**45**	**117**	**121**

Figure 3.1 and Figure 3.2 displays the proposed overlays for Birregurra with current and future climate change conditions respectively.



Level 34, T5, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12192, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

Colac Otway SHIRE

150 0 150 m

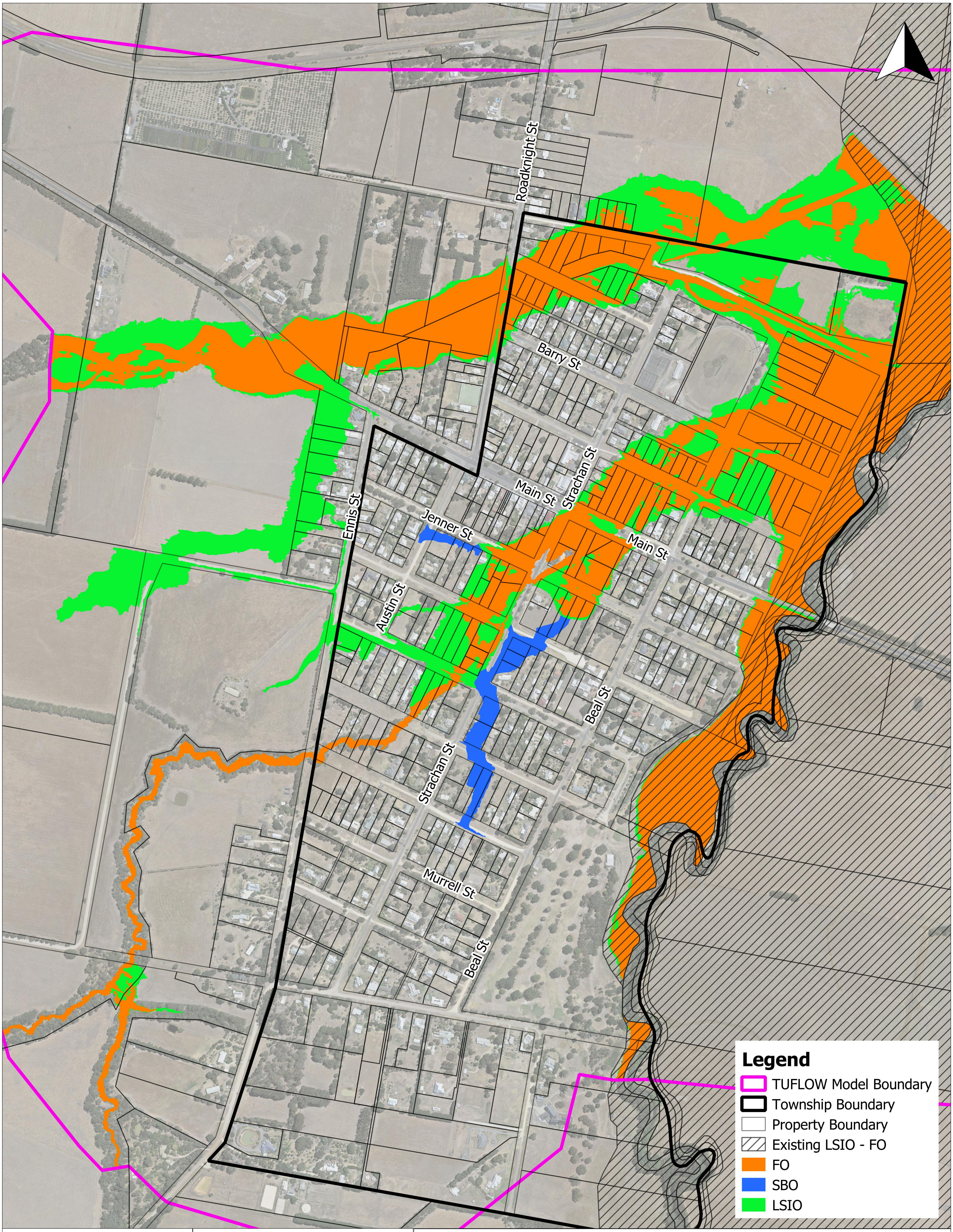
Scale in metres (1:6800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Birregurra Flood Study

Birregurra Draft Planning Overlays

Job Number: 2013_007
Revision: 1
Drawn: AN
Checked: MM & SD
Date: 30/11/2020



Level 34, T5, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12192, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

Colac Otway SHIRE

Scale in metres (1:6800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Birregurra Flood Study

Birregurra Draft Planning Overlays
Climate Change Scenario

Job Number: 2013_007
Revision: 1
Drawn: AN
Checked: MM & SD
Date: 30/11/2020

4 FLOOD DAMAGES

The Average Annual Damages (AAD) assessment estimates the average probable tangible flood damages expected in a year for residential, commercial and industrial property land use types, as well as major, minor and unsealed roadways. The AAD was calculated using Melbourne Water's 2020 AAD spreadsheet which utilises the flood mapping results from a range of storm events including the 20 %, 10 %, 5 %, 2 %, and 1 % AEP.

A flood damages assessment for existing flooding conditions is useful in understanding whether the cost of structural mitigation works is justified. Section 5 presents the mitigation assessment undertaken and also provides a comparison of the mitigation work's resultant AAD value to that presented in this section for base case existing conditions.

The assessment considers the properties and dwellings which intersect the proposed flooding overlays based on the 1 % AEP flood mapping results. The proposed flooding overlays are shown in Section 3. Table 4.1 provides a summary of the number of properties affected and dwellings affected by above floor level flooding in addition to the associated total flood damages. Based on these results, the flood related damages in Birregurra can be considered high.

Table 4.1: Summary of Flood Damages

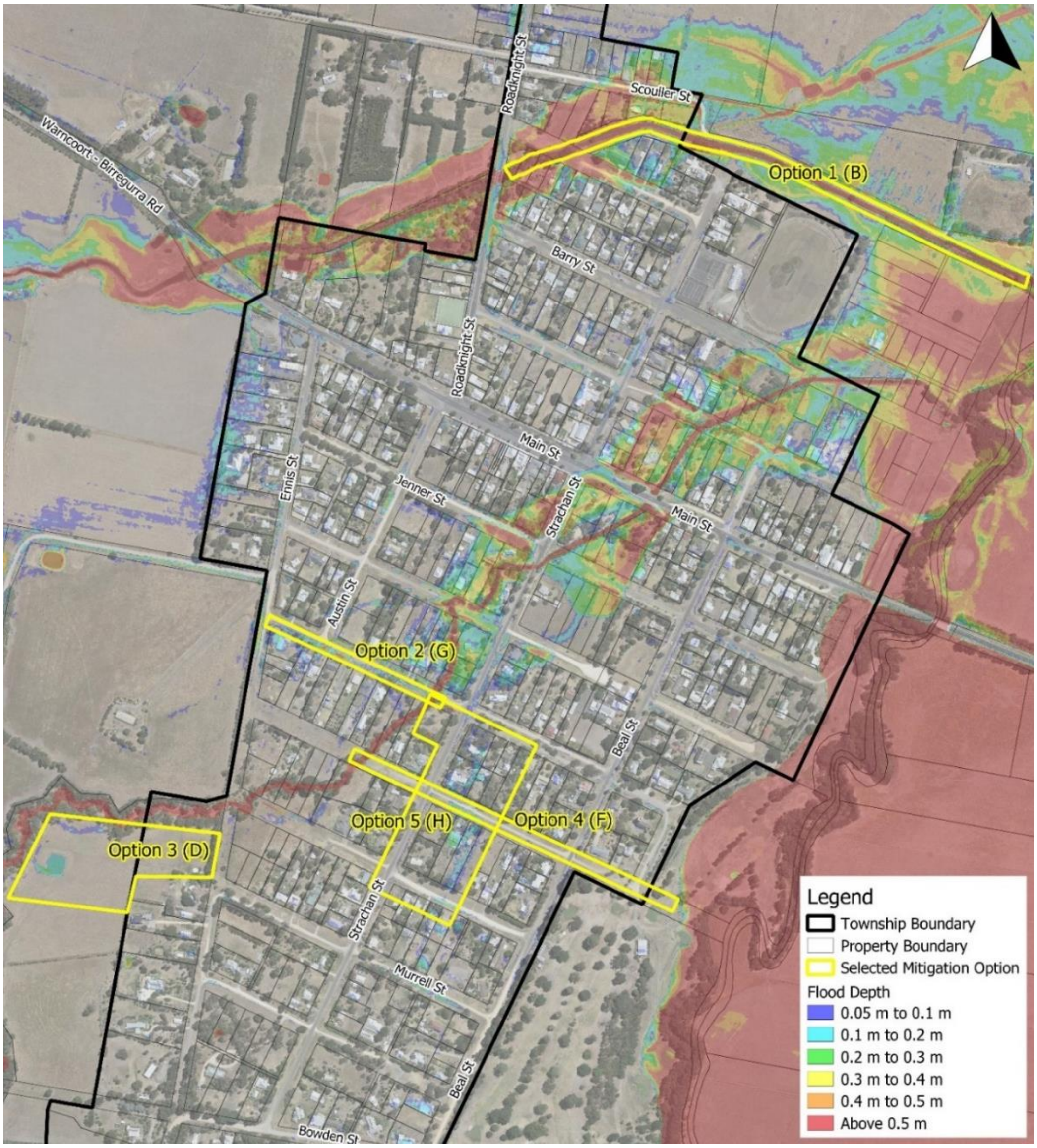
AEP	Number of Dwellings with above floor flood damage	Number of Properties affected by flood waters	Total Damages (S)
20 %	5	14	$1,316,613
10 %	7	27	$2,543,329
5 %	9	34	$3,662,597
2 %	23	44	$5,664,210
1 %	26	47	$6,576,244
		AAD	**$746,741 / year**

5 STRUCTURAL FLOOD MITIGATION

To reduce both flood risk and flood damages, structural flood mitigation measures were conceptually identified and assessed. These works differ from non-structural mitigation works such as the planning overlays and controls summarised in Section 3 and the flood emergency warning assessment summarised in Section 6. Structural mitigation works typically consist of engineered solutions which are constructed to improve the conveyance of overland stormwater flows or provide flood water storage (e.g. pipe upgrades / diversions, new retarding basin, etc.).

Following discussions with Council and the wider Project Steering Committee (PSC), five (5) structural mitigation works were assessed within the hydraulic TUFLOW model for the 20 % to 1 % AEP storm events. The locations of the five (5) mitigation works assessed are displayed in Figure 5.1. It is important to note that these options are conceptual only and subject to further investigations which may identify some if not all options are unfeasible.

Figure 5.1: Location of Selected Mitigation Options (1 % AEP Flood Depth)



Where relevant, the flood mitigation benefits were assessed with the calculation of the AADs and the expected reduction in damages when compared to existing conditions. Other factors such as the estimated capital costs were considered in addition to the social impacts / benefits, environmental impacts / benefits and construction / feasibility risks. This analysis is summarised in Table 5.1 below. As noted, further investigations which consider areas of cultural and heritage significance and flora and fauna impacts would be required to gain a better understanding of the feasibility of the works prior to implementation.

Table 5.1: Multi-Criteria Assessment for Selected Mitigation Options

ID	Description	AAD Reduction	Estimated Capital Cost	Social impacts / benefits, Environmental impacts / benefits, Construction / feasibility risks
1	Atkin Creek Waterway Widening	$169,908	$1,282,000[3]	• Medium disruption to public open spaces as works are maintained within Council owned land or road reserve. Some disruption to Scouller Street likely. • Benefits several properties currently subject to above floor level flooding in all storm events between 20 % to 1 % AEP • Likely impact to areas of cultural heritage significance – Cultural Heritage Management Plan (CHMP) would be required • Disruption to existing environmental values provided by vegetation within Atkin Creek requiring substantial erosion control and revegetation treatments • Habitat disturbance and likely impact to vulnerable species within waterway. • A flora and fauna impact assessment would need to be conducted prior to any works to understand feasibility • Widening works do not include the deepening of the existing Atkin Creek invert and as such clashes with existing underground services is reduced. • No additional land acquisition required • Increase to flood depths identified however afflux area is contained to the Barwon River floodplain where no existing dwellings are present. • Geological assessment required to understand feasibility and impacts
2	Drainage Upgrades along Sladen Street	N/A	N/A	• Option not assessed in detail as the flood mitigation benefits were limited by the Unnamed Tributary's peak flood level. • For small to moderate flood events, where the mitigation works would be less inhibited by the downstream peak flood level, the flooding impacts to properties north of Sladen Street were less critical.
3	Unnamed Tributary Retarding Basin Upstream (RB) Ennis Street	$144,308	$6,569,000	• Disruption limited to farmland and driveway upgrade at 48 Skene Street • Likely impact to areas of cultural heritage significance – Cultural Heritage Management Plan would be required • Opportunity to incorporate wetland / stormwater harvesting system within base of RB • A flora and fauna impact assessment would be required • Land acquisition required • Geological assessment required to understand feasibility and impacts
4	Hopkins Street Pipe Diversion	$114,554	$3,624,000	• Disruption to use of Hopkins Street and access to properties • Potential impact to areas of cultural heritage significance – CHMP would be required • Removal of vegetation required within the Unnamed Tributary offtake location in addition to Barwon River outlet. • Likely habitat disturbance with vegetation removal • A flora and fauna impact assessment would be required • Due to depth of pipe, likely to require construction via boring technique for a section of the 1500 mm diameter pipe • Potential maintenance burden associated with pipe offtake and weir pit arrangement within the Unnamed Tributary to ensure low flow bypass functions as intended.
5	Drainage Upgrade Between Prime & Sladen Street	$17,949	$1,380,000	• Disruption to use of Prime Street and along Strachan Street • Potential impact to areas of cultural heritage significance – CHMP would be required

[3] Estimated capital cost has used standard typical rates for channel works. They are indicative only and subject to further investigation with consideration of the specific site's characteristics and constraints.

6 FLOOD WARNING ASSESSMENT

Improved emergency flood warning management also provides a non-structural means for reducing the flood risk to the Birregurra community. A flood warning or alerting system does not currently exist for Birregurra. Essential building blocks (elements) of a Total Flood Warning System (TFWS) have, however, been delivered as part of this study via a series of flood modelling outputs. This has included the delivery of flood inundation mapping, an updated Municipal Flood Emergency Plan (MFEP), an indicative flood guidance tool and other outputs also suitable for inclusion in a local flood guide such a property inundation tables and associated flood intelligence information. This information is aimed at developing an approach to flood warning that will enable individuals including Council, CMA and Vic SES to make informed decisions about risk and what they need to do. The emphasis has been "what would work best for Birregurra" with due regard for flood risk, available flood warning and response times, available rain and creek level data, and the funding and other responsibilities associated with implementing and maintaining elements of a (flash) flood warning system.

The existing effective flood warning time has been estimated to be around 3 to 5 hours for Atkin Creek and the Unnamed Tributary under severe flood conditions. With the use of the developed indicative flood guidance tool (provided within Engeny's detailed BFDS report as Figure 9.4) and flood intelligence and mapping outputs, it is estimated that this effective flood warning time could be extended by at least 3 hours. It is likely that even with this effective warning time, the emergency services driven flood response actions within Birregurra in the lead up to flooding would be limited. Local residents however, armed with the indicative flood tool and with access to rain data from the gauge at Ricketts Marsh and an overall improved awareness of the flood risk offer substantial opportunity for improved community preparedness.

A feasibility assessment was undertaken into how this effective flood warning time could be further extended through improved alerting and warning systems. The identified options range from making better use of existing rainfall monitoring resources (i.e. no / low cost options) through to the investment in improved rain and / or river monitoring in conjunction with automated messaging requiring a greater level of investment but also providing more reliable and substantive outcomes. The following summarises these options:

- Minimum investment achievable in the near term which:
  - Involves adopting and making best use of the immediate deliverables from this investigation (i.e. making the indicative flood tool, flood intelligence and flood mapping available to both the emergency agencies and the Birregurra community.
  - Involves making better use of rainfall data that will (hopefully) soon be available in near real-time from BoM).
  - Achieves increased flood awareness and provides the opportunity for residents to recognise imminent flooding and initiate appropriate response actions.
- Moderate investment achievable in the mid-term which:
  - Involves installing a telemetered rain gauge in the mid reaches of the Atkin Creek catchment close to the shared boundary with the Unnamed Tributary
  - Achieves additional confidence in the expected flood severity along with an increase in the time available for damage reducing actions by the town's residents.
- Significant investment achievable in the longer term which:
  - Involves installing additional and more sophisticated instrumentation to monitor rainfall and creek levels on the upstream side of the Warncoort-Birregurra Road Bridge and upstream side of Ennis Street (displayed as Locations 1 and 2 within Figure 6.1).
  - Involves adopting the associated automated messaging systems to alert emergency services and individuals to the exceedance of trigger values.
  - Achieves further increased confidence in the expected severity of a developing flood, along with an increase in effective flood warning time resulting in additional time available to undertake damage reducing measures.

Figure 6.1: Suggested Gauge Locations

7 STORMWATER TREATMENT ASSESSMENT

In addition to the management of flood risks within Birregurra, consideration of the opportunities available to manage stormwater quality were also assessed. This was particularly relevant given the township's expected future growth informed by the Birregurra Structure Plan (2013) and the additional pollutant loads generated through increased impervious areas from new developments.

Current policy requires new developments to achieve the Best Practice Environmental Management Guidelines (BPEMG) pollutant removal targets. This consists of the following requirements:

- 80 % reduction of Total Suspended Solids (TSS).
- 45 % reduction of Total Phosphorus (TP).
- 45 % reduction of Total Nitrogen (TN).
- 70 % reduction of Gross Pollutants (GP).
- Retention of flows to pre-development 1.5 year Average Recurrence interval (ARI) pre-development.

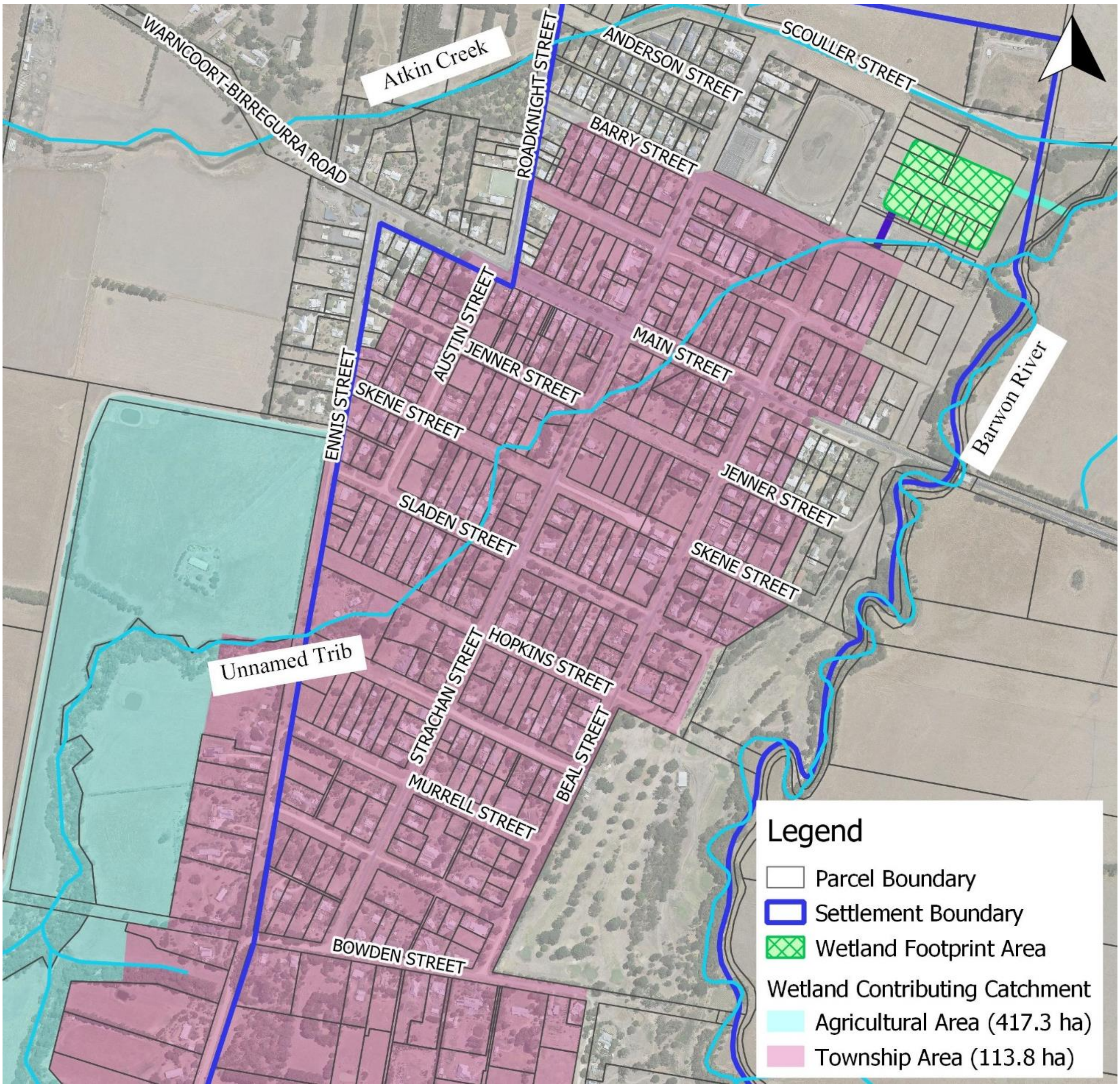
As such, a range of Water Sensitive Urban Design (WSUD) options were investigated and sized in order to achieve these BPEMG targets for the predicted increase in impervious area. The benefits of other works such as incorporating lot scale rainwater tanks and the benefits of sealing the township's roads were also investigated. It is important to note that the options assessed are for Council's consideration and subject to further investigations which may deem some options not feasible.

Table 7.1 provides a summary of the stormwater quality management options assessed and the corresponding outcomes.

Table 7.1: Assessed Stormwater Quality Management Options

Stormwater Quality Management Options	Description	Outcome
Centralised Wetland (displayed on Figure 7.1)	• Wetland treatment Area = 9,000 m² • Total Wetland footprint = 22,500 m² • Contributing catchment consists of approximately 114 ha of township area and 417 ha of upstream agricultural area entering the Unnamed Tributary. • Located within Barwon River floodplain where residential development is constrained and limited	• Meets BPEMG pollutant reduction targets • Opportunity to also receive low flows from the Atkin Creek catchment which may result in further stormwater quality benefits. • Opportunity to integrate a stormwater harvesting system which could provide an alternative water source for the irrigation of the oval located on the west.
Street-scale Bioretention Assets	• 17 bioretention assets with a treatment area of 100 m² each. • Treating contributing catchment area of approximately 24 ha.	• Meets BPEMG pollutant reduction targets • Increased reliance on ongoing maintenance to ensure each asset's treatment effectiveness.
Lot-scale Rainwater Tanks	• 3 KL rainwater tank assumed with the development of each undeveloped lot. • Would service the lot's toilet flushing demand. • Capital and ongoing maintenance cost of each rainwater tank would be the property owner's responsibility.	• These works alone, would not achieve the BPEMG pollutant reduction targets but would reduce the mean annual pollutant loads being discharged to the receiving waters, thus assisting with the pollutant reduction targets. • By incorporating rainwater tanks, an opportunity to reduce the treatment area requirements of the wetland / bioretention assets could be possible.
Sealing of Roads Works	• Works which involve formalising all road networks within the township and incorporating paved kerb and channels.	• These works alone, would not achieve the BPEMG pollutant reduction targets but would substantially reduce the Total Suspended Solids generated with minor decreases to the nutrient loads.

Figure 7.1: Wetland Footprint and Contributing Catchment Area



8 CONCLUSIONS

The investigations undertaken as part of this study highlight the following key outcomes:

- Several dwellings within the 1 % AEP design event flood extent (approximately 78) of which 26 dwellings are affected by above floor level flooding.
- The key flooding hotspots are associated with:
  - Atkin Creek downstream of Roadknight Street due to the existing channel's limited capacity.
  - Unnamed Tributary downstream of Sladen Street due to the existing waterway's limited capacity.
  - Council's existing underground drainage capacity between Prime to Sladen Street and along Sladen Street from Ennis Street.
- The September 2016 flood event modelling and the resultant close match between the surveyed and modelled flood levels provide confidence in the selected model parameters.
- The mitigation assessment undertaken identified 4 key structural mitigation works which could be implemented to reduce flooding impacts to dwellings, subject to securing an appropriate funding source. The high-level multicriteria assessment considering both tangible (capital cost and average annual damage reduction) in addition to intangible factors (such as environmental and social impacts and constructability and risks) were assessed.
  - Detailed assessments have not been considered including in relation to flora and fauna (biodiversity), cultural heritage values, or geotechnical matters. These will need to be examined before any mitigation option is pursued in addition to approval processes.
- The stormwater quality assessment identified the wetland footprint area which would be required to ensure the predicted future development / increase in impervious area meet the BPEMG targets. Although further investigations would be required to confirm its feasibility, the asset could be funded through developer contributions. The assessment also highlighted the benefits of rainwater tanks and sealing roads within Birregurra and the practicality of implementing bioretention assets to meet the targets.
- The strategy highlighted the importance of updating the existing overlays with the extents delineated and implementation of planning scheme amendments that include schedules for the developed FO, LSIO and SBO with the relevant planning controls.
- The flood warning assessment identified the effective food warning time relevant to Birregurra in addition to highlighting the essential building blocks of a Total Flood Warning System (TFWS) which have been delivered via the outputs of this study including:
  - Updated flood inundation and related mapping.
  - An updated Municipal Flood Emergency Plan (MFEP) with Birregurra-centric flood consequence information.
  - An indicative flood guidance tool.
  - Information suitable for inclusion in a Local Flood Guide (LFG).
- As part of the flood warning assessment a feasibility assessment was also undertaken into how the effective flood warning time could be further extended through improved alerting and warning systems. The identified options range from making better use of existing rainfall monitoring resources (i.e. minimum investment achievable in the near term) through to the improved rain and / or river monitoring with automated messaging (i.e. moderate to significant investment achievable in the mid to longer term).
- Flood intelligence data was extracted from the study deliverables and collated into the updated Municipal Flood Emergency Plan template. This separate working document has been delivered to Council and VicSES directly and aims to provide guidance on the approximate relationship between food magnitude and flood consequences so that appropriate actions can be taken.

9 RECOMMENDATIONS

Following the completion of these investigations, the following recommendations are provided:

1. Colac Otway Shire Council:
   a) Seek internal endorsement of the flood study and undertake public exhibition to ensure the Birregurra community has the opportunity to comment and provide feedback.
   b) Update the planning scheme to incorporate the findings of this study.
   c) Consider the outcomes of the high level multicriteria assessment and findings of additional investigations and consider options which may progress to further feasibility assessments, subject to funding requirements.
   d) Reference the provided flood modelling outputs, in particular the flood level information, to provide advice on recommended minimum floor levels for new developments for which Council is the responsible authority.
   e) Review the Municipal Flood Emergency Plan with input from VICSES and adopt revised document.
2. Corangamite CMA:
   a) Seek internal endorsement of the flood study and use mapping outputs to manage floodplain risk and inform development advice to ensure risks are minimised.
   b) Reference the provided flood modelling outputs, in particular the flood level information, to provide advice on recommended minimum floor levels for new developments for which CCMA is the responsible authority.
   c) Add the produced Flood Spatial Data Specification (SDS) outputs and other relevant mapping outputs to FloodZoom.
3. Victorian State Emergency Services:
   a) Continue to engage with the community to increase their awareness of flood related risks.
   b) Review and discuss the updated MFEP.

10 QUALIFICATIONS

a) In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) The strategy is based on best available information at the time and is subject to an exhibition period which may include minor updates.

c) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

d) During the exhibition period, Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

   Once the document has been adopted and included in the planning scheme it can no longer be amended and a new version would need to be issue

e) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g) This Report does not provide legal advice.

11 REFERENCES

Australian Emergency Management Institute (AEMI) (1995): *Flood Warning: An Australian Guide*.

Australian Institute for Disaster Resilience (AIDR) (2009): *Manual 21: Flood Warning*.

Bureau of Meteorology (1996): *Bureau of Meteorology Policy on the Provision of the Flash Flood Warning Service.* May 1996.

Bureau of Meteorology (2020): *Service Level Specification for Flood Forecasting and Warning Services for Victoria – Version 3.2.* August 2020.

Commonwealth Scientific and Industrial Research (CSIRO) (1999): *Urban Stormwater Guidelines: Best Practive Environmental Management Guidelines*

Corangamite Catchment Management Authority (CCMA) (2017): *Corangamite Regional Floodplain Management Strategy, 2017-2027*.

Department of Environment Land Water & Planning (2016): *Victorian Floodplain Management Strategy*. April 2016.

Michael Cawood & Associates for the Victorian Flood Warning Consultative Committee (VFWCC) (2005): *Flood Warning Service Development Plan for Victoria: Review of Flood Warning System Development Priorities within Victoria*. October 2005.

United Nations (UN) (1997): *Guiding Principles for Effective Early Warning*. Prepared by the Convenors of the International Expert Groups on Early Warning of the Secretariat of the International Decade for Natural Disaster Reduction, IDNDR Early Warning Programme, October 1997, Geneva, Switzerland.

Victorian Flood Warning Consultative Committee (VFWCC) (2001): *Arrangements for Flood Warning Services in Victoria*. February 2001.

ENGENY
WATER MANAGEMENT

engeny.com.au

P: 03 9888 6978
Level 34, Tenancy 5, 360 Elizabeth Street, Melbourne VIC 3000 | PO Box 12192 Melbourne VIC 8006