



Summary Report

Lara Flood Study

City of Greater Geelong

11 February 2020



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CONTENTS

1	INTRODUCTION	4
1.1	Overview	4
1.2	Study Area	4
2	PRELIMINARY/ DATA REVIEW REPORT	7
2.1	Methodology	7
2.2	Summary	7
3	CALIBRATION	8
3.1	Methodology	8
3.2	Summary	8
4	CONSULTATION	9
5	DESIGN MODELLING	10
5.1	Methodology	10
5.2	Design Parameters Adopted	10
5.3	Results	11
5.4	Climate Change	16
5.5	Sensitivity Analysis	16
6	FLOOD MITIGATION	18
6.1	Overview	18
6.2	Existing areas of high flood risk	18
6.3	Prefeasibility Assessment	23
6.4	Mitigation Modelling	24
6.5	Mitigation Discussion	29
6.6	Summary	29
7	FLOOD DAMAGES	31
7.1	Overview	31
7.2	Non – Economic Flood Damages	33
8	MITIGATION BENEFIT-COST ANALYSIS	35
9	FLOOD WARNING	36
9.1	Overview	36
9.2	Riverine Flood Warning	36
9.3	Stormwater Flood Warning	36
9.4	Summary	37
10	FLOOD INTELLIGENCE	38
10.1	Overview	38
10.2	Methodology	38
10.3	Summary	40



11	LAND USE AND PLANNING CONTROLS	41
11.1	Overview	41
11.2	Existing Controls	41
11.3	Identified Risk and Available Controls	44
12	RECOMMENDATIONS	47

LIST OF FIGURES

Figure 1-1	Lara Catchment and Study Area	6
Figure 5-1	Properties with Above Floor Flooding – 1% AEP Riverine Flooding	12
Figure 5-2	Properties with Above Floor Flooding – 1% AEP Stormwater Flooding	13
Figure 5-3	Design Flood Extents for Lara (Combined Riverine and Urban Modelling)	14
Figure 5-4	1% AEP Depth plot (Combined Results)	15
Figure 6-1	1% AEP Water Surface Levels at McClelland Avenue	19
Figure 6-2	Properties Flooded or within 300mm from above Floor Flooding (Urban Flooding)	21
Figure 6-3	Properties Flooded or within 300mm from above floor flooding (Riverine Flooding)	22
Figure 6-4	Location of mitigation options Assessed	23
Figure 6-5	Mitigation Options 1 & 2 Layout	26
Figure 6-6	Mitigation Option 3 - Avalon Diversion Layout	27
Figure 6-7	Mitigation Option 3 - Avalon Diversion Flood Level Difference (1% AEP)	28
Figure 6-8	1% AEP Water Level and Natural Surface	29
Figure 9-1	BoM Rainfall IFD Chart (Lara- Hovells Ck Catchment)	37
Figure 11-1	Existing Flood Related Planning Controls – Study Area	42
Figure 11-2	Existing Flood Related Planning Controls – Lara Township	43
Figure 11-3	Combined Riverine & Stormwater 1% AEP Extent	45
Figure 11-4	Modelled Flood Hazard (ARR2019 Classification)	46

LIST OF TABLES

Table 4-1	Summary of Community Consultation and Key Issues	9
Table 6-1	Mitigation Option Prefeasibility Results	23
Table 6-2	Mitigation Option Cost Estimate	30
Table 7-5	Riverine Existing Conditions Flood Damages	33
Table 8-1	Benefit Cost Analysis	35
Table 10-1	Summary of Above Floor Flooding	38
Table 10-2	Example of Summary of Flood Behaviour for Design Events (50% & 20% AEP)	39



1 INTRODUCTION

This report is one of a series documenting the outcomes of the Lara Flood Study. The Study provides a detailed analysis of the catchments surrounding the township of Lara and the broader Hovells Creek/ Lara catchment and part of the Avalon catchment management units¹. The reporting was broken up into a series of deliverables which are summarised in this report and includes a brief overview of each of the previous reports submitted and the recommendations developed throughout the study.

- R01 - Preliminary Report (Water Technology 2018)
- R02 – Hydrology/Hydraulic Calibration Report (Water Technology 2019)
- R03 – Design Hydrology and Detailed Hydraulic Modelling Report (2020a)
- R04 – Assess and Treat Risk Report (Water Technology 2020b)
- R05 – Flood Warning and Intelligence Report (2020c)
- **R06 - Summary Report (Water Technology 2020d) *This Report***

1.1 Overview

1.1.1 Project Objectives

The study brief prepared by City of Greater Geelong (the City) demonstrated a strong understanding of the area and its floodplain and drainage infrastructure. The objectives of this study are described below.

- 1** - To produce detailed flood mapping for a range of flood modelling scenarios within the study area.
- 2** - To undertake definitive flood investigations for the floodplain reaches within the study area; to pool all the available data and, through rigorous analysis determine robust flood levels, velocities, depths and extents.
- 3** - To build on the previous flood studies undertaken in 2001/02 by the partnership of Corangamite CMA, City of Greater Geelong and a consultant (Floodplain Management Strategy, April 2002) using baseline data and current technology to update flood data, value add for extra flood events, update of land use changes, update flood intelligence for the City of Greater Geelong Flood Emergency Plan, update flood data in the City of Greater Geelong Planning Scheme with a focus on the technical flood information to inform planning and building controls.

1.2 Study Area

The study area consists of two major drainage catchments, Hovells Ck / Lara and part of the Avalon catchment management unit¹, as shown in Figure 1-1. The township of Lara was also a key focus area of the study as it is impacted from riverine flooding from Hovells Creek and stormwater flooding from within the urban area. The Hovells Creek / Lara catchment begins near Mount Anakie and flows in a south easterly direction through farmland and into the urban area of Lara before flowing into Limeburners Bay, an inlet to Corio Bay. There are several large storages including farm dams located throughout the catchment. The Avalon catchment begins just to the south of the Little River township and flows south. There are no named waterways within the catchment, however, is often referred to as Austins Swamp catchment. Farm drains have been constructed to drain wetlands and local storage depressions throughout the catchment. Flow behaviour in the lower end of the catchment is impacted by a former saltworks located between the Princes Freeway and the Avalon Coastal Reserve (Corio Bay).

¹ Stormwater Services Strategy 2020-30, Draft Report. City of Greater Geelong, 2019



The Melbourne-Geelong Railway and Princes Freeway intersect both catchments, crossing Hovells Creek at the lower end of the catchment. The Avalon Road catchment is crossed by the railway line in the mid-upper catchment and the Princes Freeway in the middle of the catchment.

Lara is a residential and commercial town located at the lower end of the Hovells Ck catchment and has a population of just over 16,000². The town has been identified as a growth area for residential, commercial and industrial development. Lara has been subject to flooding from Hovells Creek and stormwater catchments in the past with significant flood events in 1933, 1973, 1983, 1988, 1995, 2005 and 2010. Several flood investigations have been carried out of this area in the past, and flood mitigation work proposed along the Elcho Drain. Further work into the Northern Growth area to the west of the main township has been undertaken recently.

Drainage assets in the town range from roadside open swale drains within wide road reserves, to pit and pipe networks within the urban areas. Hovells Creek and the Elcho Drain make their way through the town. Elcho Drain runs through several man-made lake/retarding basin systems and in parts is channelised and has underground low-flow pipes before outfalling to Hovells Creek.

² Australian Bureau of Statistics, 2016 Census – Lara Population data

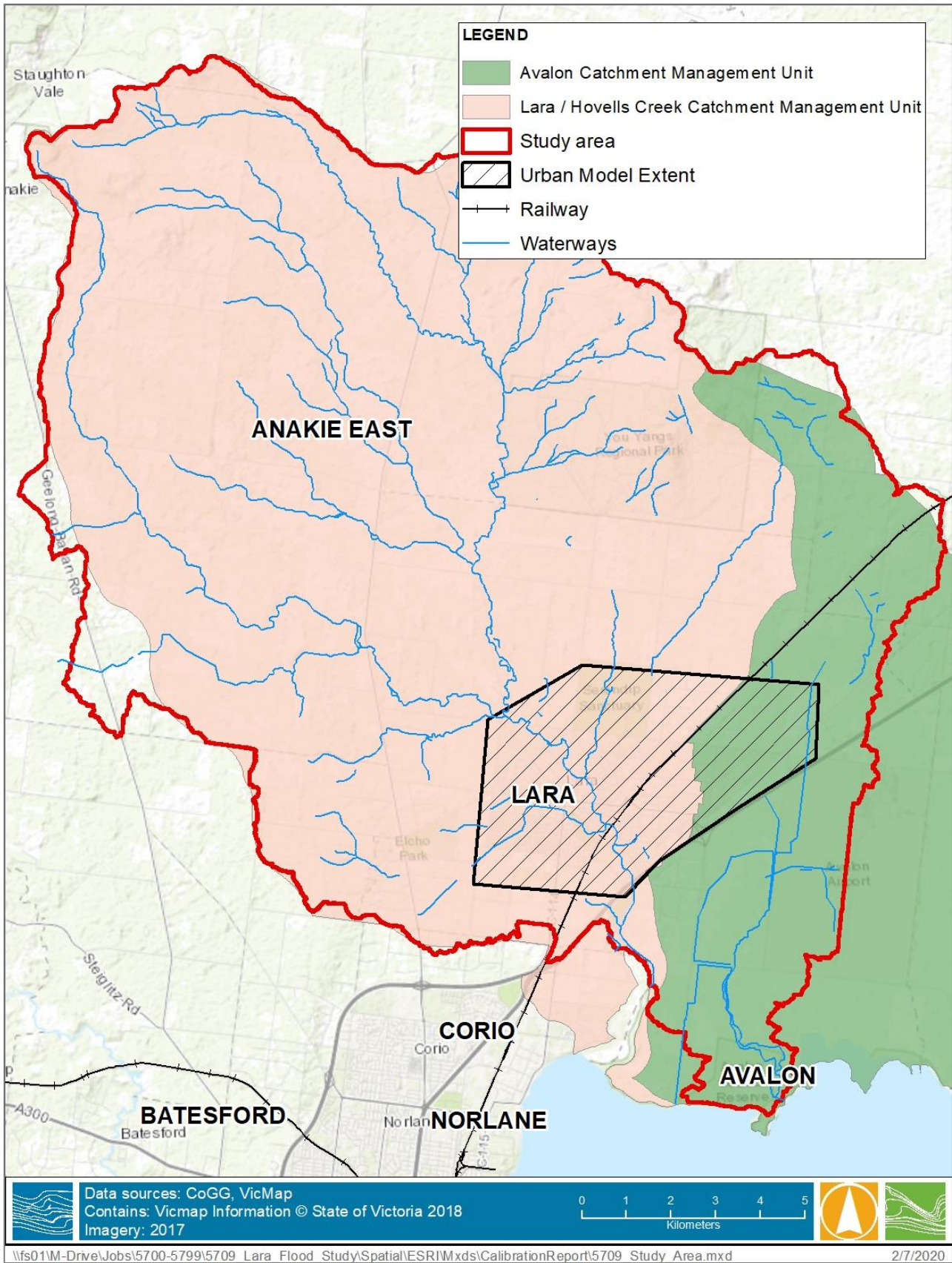


FIGURE 1-1 LARA CATCHMENT AND STUDY AREA

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2 PRELIMINARY/ DATA REVIEW REPORT

The Preliminary/Data Review Report (*R01 - Preliminary Report (Water Technology 2018)*) was completed in August 2018 and provides an overview of the available existing data and methodology which was used to complete the study. The data review detailed previous studies and identified historically inundated areas based on requests for service and with historical flood information. Rainfall and streamflow data were collected and evaluated. A review of the available drainage infrastructure and topography was completed. As a result of the review of available data, floor level survey and trunk drainage CCTV inspections were undertaken.

2.1 Methodology

The study methodology was considered and separated into several separate stages these were as follows:

- Model development - hydrologic and hydraulic models.
- Calibration.
- Design modelling.
- Stormwater Assessment.
- Stakeholder Engagement.
- Online Mapping.

2.2 Summary

The report detailed the thorough data review process undertaken and identified several gaps in the available data with appropriate methods to overcome these issues. The major data gaps included the main stormwater pipe network inverts and major rail and road structure details.

Feature survey was collected across the study area to fill some of these data gaps, as well as to validate the LiDAR used in the study. The existing LiDAR dataset was combined with recently captured photogrammetry of the township.

Cross section survey of Hovells Creek between Station Lake Road and Flinders Avenue was used to provide a suitable cross-sectional representation in the model terrain. It also highlighted erosion and scouring of the channel bed at Station Lake Road.



3 CALIBRATION

The Calibration Report (*R02 – Hydrology/Hydraulic Calibration Report*) discussed the method used to calibrate both the hydrological and hydraulic models.

3.1 Methodology

A joint hydrology/hydraulic calibration approach was adopted for the following reasons:

- There is little available streamflow information for the Hovells Creek catchment, with only a short-term record at Flinders Avenue and Rennie Street streamflow gauges located on Hovells Creek.
- Previous flow estimates of historical flood events were found to have little justification or detail regarding how the estimates were determined.
- The joint calibration approach allowed for the uncertainties in both flow estimation and hydraulic model behaviour to be combined, with both models evaluated against the known flood observations (i.e. flood heights, extents, photos, etc).

Through the calibration phase, storages in the upper catchment and drainage infrastructure throughout the township was incorporated into the model to better estimate runoff (hydrology modelling) and flood behaviour (hydraulic modelling) for the range of modelled flood events. The extensive calibration provided confidence that the models were producing realistic results and ensured the design modelling results were fit for purpose.

The calibration process was able to replicate the recorded streamflow levels for the April 2017 event at Flinders Avenue and Rennie Street, providing limited validation to the appropriateness of the calibration. Despite being a relatively minor event, this is the highest recorded streamflow within the Hovells Creek catchment, with there being no gauged flows available for the older events. The 1988, 1973 and 2005 flood events were also calibrated against the available flood observations and anecdotal evidence.

3.2 Summary

The joint calibration process showed the combination of hydraulic and hydrologic modelling was suitable to replicate a range of flow events from relatively minor in-channel events (April 2017) through to larger, rarer floods such as the December 1988 event. The extensive calibration provides confidence that the models are producing realistic results and ensures that the design modelling results will be fit for purpose.

The calibration and validation process has relied heavily on aerial photography and anecdotal evidence with limited recorded flood information available. The use of aerial imagery, recorded flood marks and previous reporting was used to build a database of flood marks that are recommended to be adopted in the Victorian Flood Data (VFD) Mapping Guidelines. The limited streamflow gauge information was used to ensure the model results for in-channel events and flood behaviour matching with recorded data. The hydrology model parameters adopted (initial loss, continuing loss and k_c) are within reasonable ranges based on the regional parameters documented in Australian Rainfall and Runoff (ARR2019) and the RORB regional approximation equations. The results of the joint calibration validate the parameters adopted in both the RORB and TUFLOW models.

An additional rain-on-grid hydraulic model was developed for the design modelling of urban areas. This ensured that small overland flow paths and local depressions within urban areas are represented. This was not specifically used in the calibration process, however was used to identify inflow locations for the hydraulic model.



4 CONSULTATION

A key element in the Lara Flood Study was the active engagement of community members. Formal and informal engagement was undertaken at the following stages of the study:

- Data Collation Phase – To collect information, photos and anecdotal evidence from previous flood events.
- Calibration Phase – To seek feedback from the community on the modelling of the calibration events.
- Draft Design Modelling – To provide the community an opportunity to view draft study result

Community consultation sessions were held at the Lara RSL with an open drop-in format where hard copy maps and an online mapping portal were on display. A range of flooding and drainage issues were identified during the consultation sessions, with Council staff from planning and engineering, the CCMA, VicSES and the Water Technology project team in attendance. Community attendance was consistent throughout each of the sessions and was supplemented with public notices in the Geelong Independent, Geelong Advertiser and information available on the City’s ‘Have Your Say’ webpage. The web content also hosted a link to the online mapping portal where the community could view the calibration and draft 1% AEP modelling results. A summary of the key issues identified at each stage of the community consultation are shown in Table 4-1.

TABLE 4-1 SUMMARY OF COMMUNITY CONSULTATION AND KEY ISSUES

Engagement	Purpose	Outcome and key issues identified
Data collection phase	To collect information, photos and anecdotal evidence from previous flood events.	Regular Nuisance Flooding occurs in several locations in Lara. Kyema Drive is flooding hot-spot, McClelland Av service Roads Bike path access is cut along Hovells Creek Trail Drainage asset maintenance was highlighted as a key concern form the community
Calibration phase	To seek feedback from the community on the modelling of the calibration events.	Information and photos of the 1988 and 2005 flood events were collected and used in the calibration/ validation. Localised issues were noted, additional site visit was organised to identify culverts not in council database Concerns around the impact of ‘farm dams’ on Creek flows and flood events
Draft design modelling	To provide the community an opportunity to view draft study result	Calibration modelling generally confirmed community anecdotes and recollections Community members concerned with future development

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5 DESIGN MODELLING

The Design Modelling Report (*R03 - Design Hydrology and Detailed Hydraulic*) detailed the model build for both RORB and TUFLOW, the design parameters selected, the scenarios modelled, and sensitivity assessments undertaken.

5.1 Methodology

The parameters used in the hydrology model (RORB) and hydraulic model (TUFLOW) for the calibration were used to inform the final parameters adopted in the design modelling. The Lara township and broader urban area is impacted by both stormwater flooding caused by shorter intense storm events within the urban area as well as widespread riverine flooding from the Hovells Creek catchment.

The design mapping produced demonstrates flood behaviour from the two inundation types to inform flood intelligence documentation and planning overlays. The following sections provide an overview of how the modelling outputs were combined to produce final mapping and intelligence outputs.

5.1.1 Riverine Flooding

Riverine flooding across the study area is a result of longer duration storms (6+ hours), with the critical duration being a 12-hour or 18-hour storm event. A hydrology (RORB) model was developed to obtain excess runoff hydrographs that were placed in the hydraulic (TUFLOW) model. This allowed for an assessment of a range of variables within the catchment including antecedent conditions (storage levels within major dams, initial and continuing losses) and the selection of appropriate design storm events (duration and temporal pattern selection).

The hydraulic model (TUFLOW) was built at a 4m grid resolution and utilised the latest available LiDAR and photogrammetry. Over 160 inflow locations were placed across the model to allow the rainfall excess hydrographs developed in RORB to be represented in the model. Available culvert, bridge, pit and pipe information was incorporated into the model and gaps in the drainage network were filled using engineering judgement (ensuring similar cover to nearby pipes and maintaining a consistent downstream gradient etc.).

5.1.2 Urban Stormwater Flooding

Using the calibrated model parameters from the riverine modelling, an urban stormwater model was developed to provide detailed mapping of the township area. While the township area is prone to flooding from short intense storms, both short intense storm events and longer duration events also create inundation issues in the broader urban area due to relatively flat terrain resulting in shallow widespread ponding.

Significant areas of flooding around north east and west Lara were shown to be a result of overland flow from semi-urban areas. A TUFLOW rain-on-grid model at 3 metre grid resolution was used to represent these areas. Available pit and pipe information was incorporated into the model and data gaps in the underground drainage network were filled using engineering judgement (ensuring similar cover to other pipes/downstream gradient etc.).

5.2 Design Parameters Adopted

The recommended design hydrology parameters were highlighted, along with justification for their adoption. A summary of the adopted design parameters for the riverine model are outlined below:

- Significant storages within the model were set at 50% full as initial conditions at the start of the modelling.
- Initial and continuing loss values for rural areas were 15 mm and 1.5 mm/hour respectively.



- The riverine model was simulated for 2-hour, 6-hour, 9-hour, 18-hour and 48-hour event durations to capture the range of critical durations across the study area.
- Temporal Patterns were selected for each event duration based on median peak flow for Hovells Creek at Lara.
- Static tailwater boundaries based on the Highest Astronomical Tide (HAT) were used as the downstream tailwater level. Hydraulic model sensitivity testing demonstrated tailwater levels (from Limeburners Bay) do not extend upstream further than Rennie Street.

Model parameters for the urban modelling included:

- The rain on grid model was simulated for 15-minute, 30-minute, 1-hour, 2-hour, 3-hour and 6-hour duration events to provide a range of critical durations across the study area.
- Initial and continuing losses were applied via the material (land-use) layer of the hydraulic model. Values varied based on the current land use.
- Temporal pattern selection was based on the temporal pattern which gave the 'median' water level the greatest number of times across the urban model area for each 1% AEP duration event.
- Temporal patterns were selected for the remaining AEPs based on the 1% AEP methodology listed above.

5.3 Results

Hydraulic model results were processed to produce a set of GIS layers for the riverine and urban modelling individually as well as a combined set. An example of flood extents for each AEP from the combined results are shown in Figure 5-3. These are examples of different areas within the study area, results of the full study are available and are easily viewed in GIS software. Figure 5-1 and Figure 5-2 show the above floor levels for the urban flood model results and the riverine above floor results. The high-risk areas with above floor flooding are shown by the red dots.

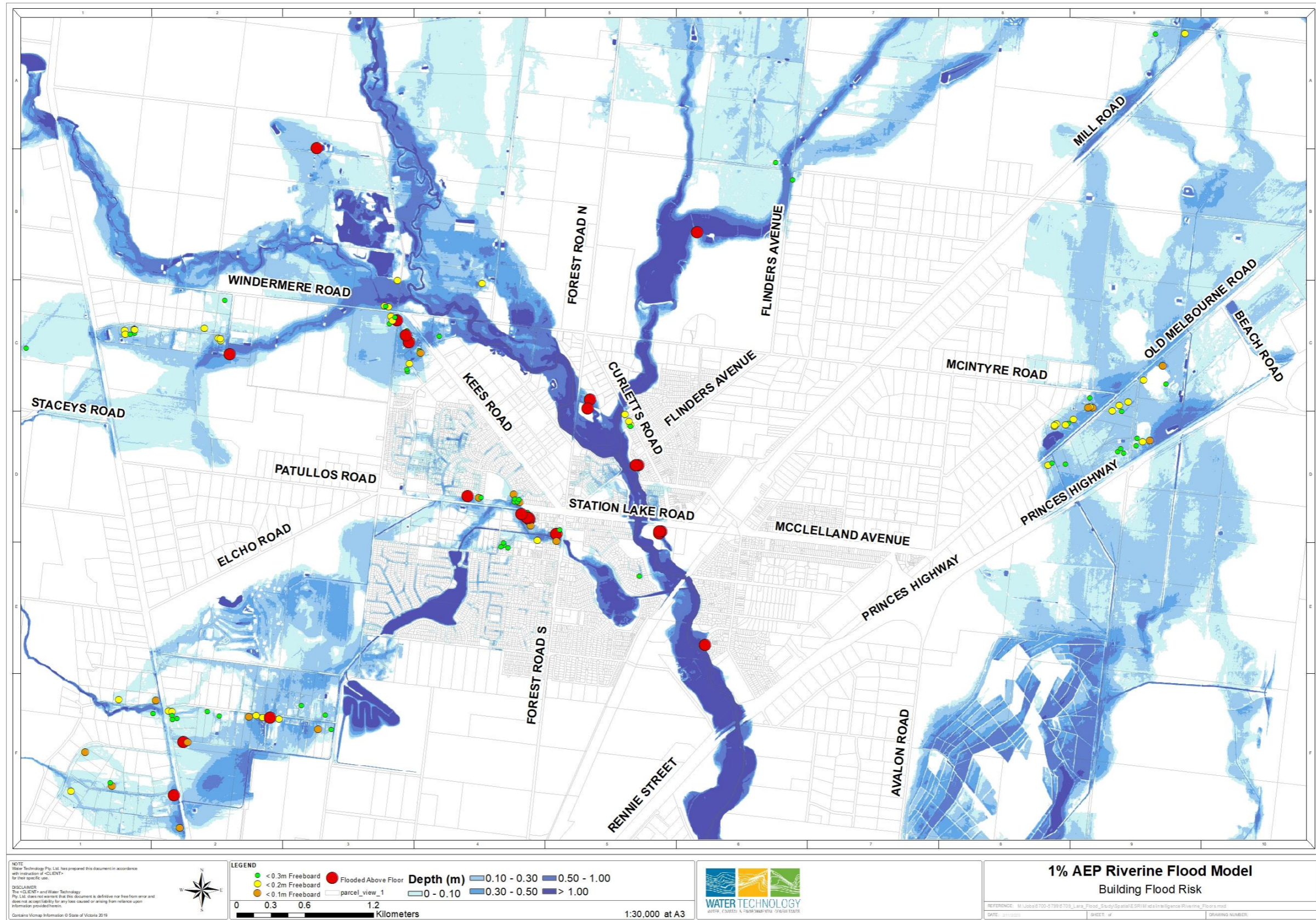


FIGURE 5-1 PROPERTIES WITH ABOVE FLOOR FLOODING – 1% AEP RIVERINE FLOODING

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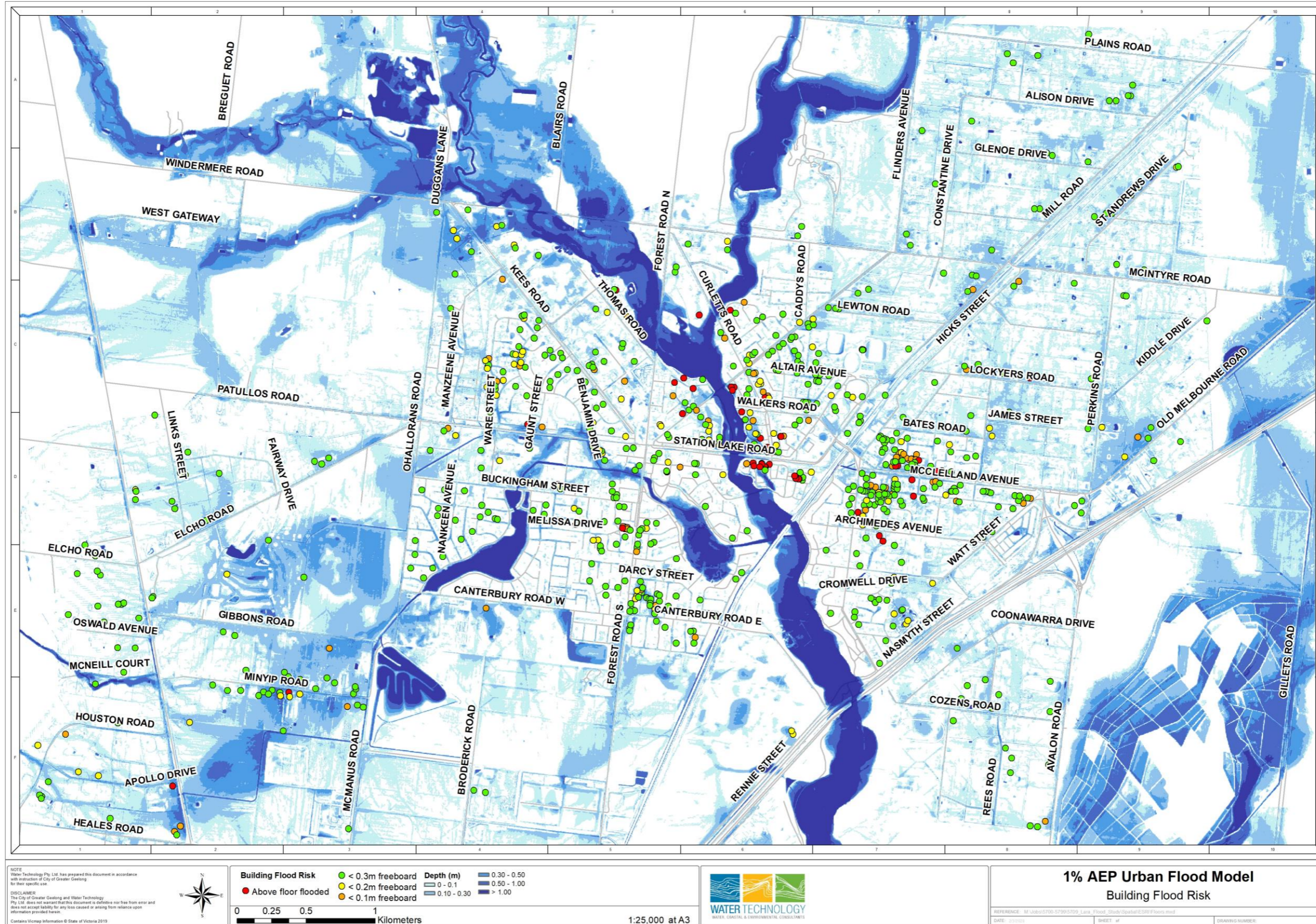


FIGURE 5-2 PROPERTIES WITH ABOVE FLOOR FLOODING – 1% AEP STORMWATER FLOODING

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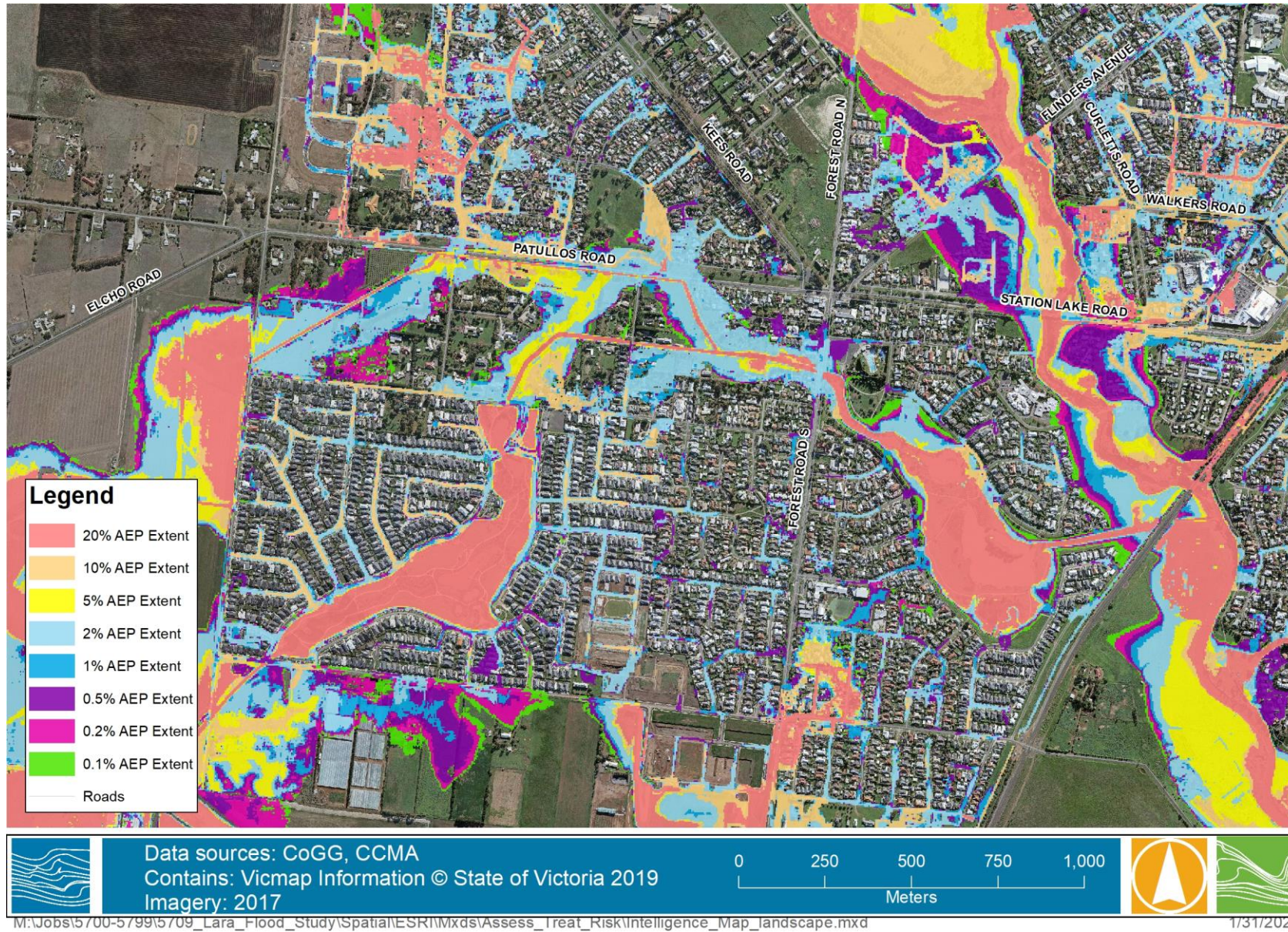


FIGURE 5-3 DESIGN FLOOD EXTENTS FOR LARA (COMBINED RIVERINE AND URBAN MODELLING)



Maps of each design event was produced mapping depth, water surface elevation, velocity and flood hazard. These were produced at a catchment wide scale as well as zoomed in to Lara for easier viewing. Given the size of the study area, the results are more easily viewed using GIS software or via a flood portal. An example of the depth output map (1% AEP) is shown below Figure 5-4.

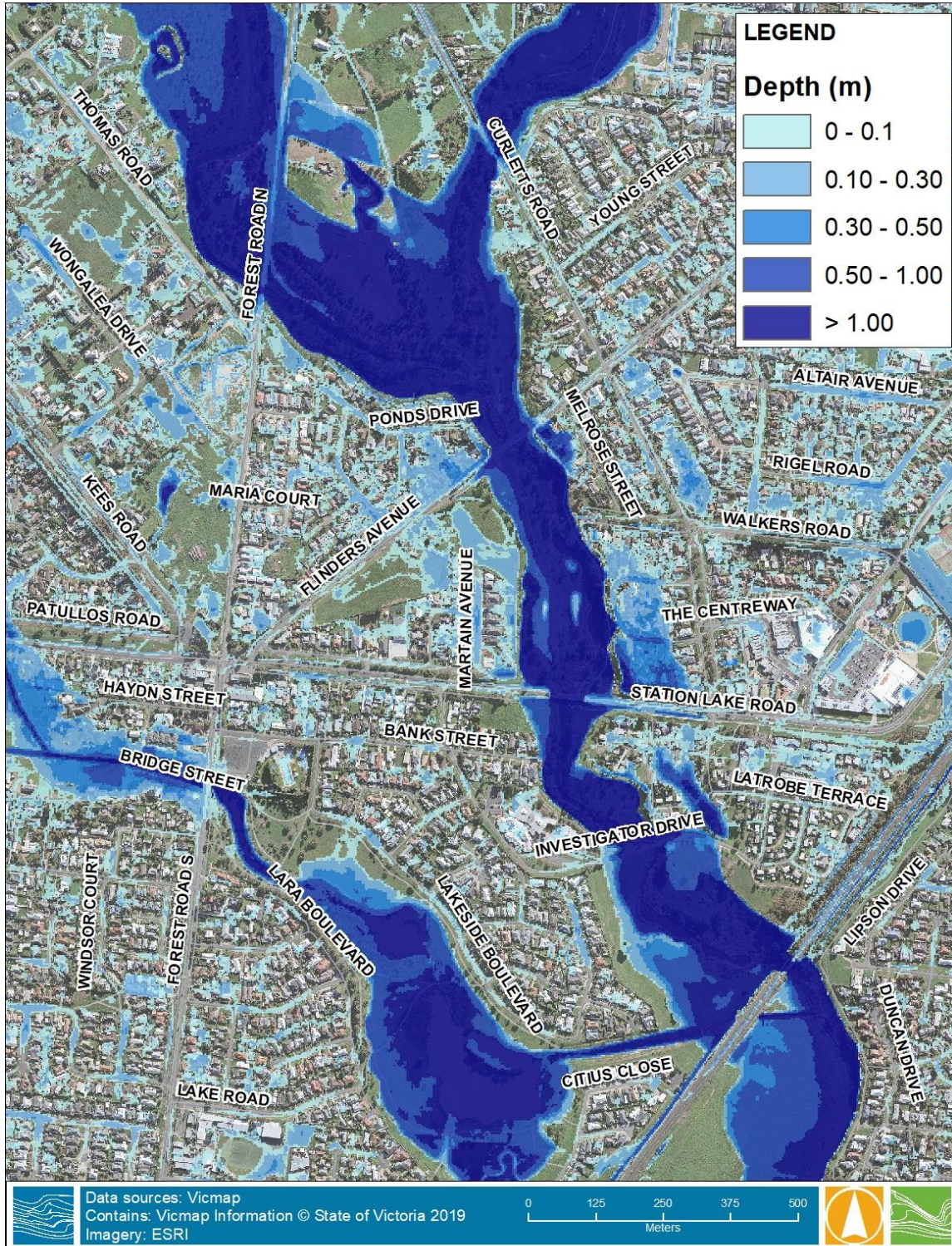


FIGURE 5-4 1% AEP DEPTH PLOT (COMBINED RESULTS)

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5.4 Climate Change

At the time of the scope of the project was defined, climate change was incorporated into the project brief as a sensitivity analysis to understand how sensitive the study area is to proposed changes in climatic conditions. By gaining an understanding of the sensitivity of the catchment to these changes provides an information gathering exercise for decisions and policy regarding future impacts to be considered. Since project inception, more information and guidance on managing climate change risk has been developed by DELWP³. The City currently have a Climate Change Adaption Strategy⁴ which aims to prepare the City and the broader Greater Geelong community for climate change impacts by integrating climate change adaption through its decision-making process.

The climate change sensitivity analysis relating to climate change are summarised in Section 5.5

5.5 Sensitivity Analysis

A range of parameters were selected for sensitivity analysis within the hydraulic model. These are listed below along with a brief summary of the sensitivity analysis undertaken:

- Climate Change
 - **Increased rainfall intensity based on Representative Concentration Pathways (RCP) 4.5 & 8.5 for years 2050 and 2090, undertaken for the 1% AEP 12-hour duration.** The increased rainfall intensity as a result of climate change for the four scenarios modelled was using the IFD data downloaded from Bureau of Meteorology (BoM). The results showed maximum increases in flood levels along Hovells Creek through Lara ranging from 150 mm (RCP 4.5 for year 2050) through to an increase of 500 mm for RCP 8.5 for the year 2090. It should be noted that although the increase in rainfall intensity was modelled, the initial and continuing loss values were maintained as is. While predictions suggest rainfall intensity is likely to increase as a result of climate change, it is also expected that average annual rainfall will decrease⁵ (CSIRO, 2015). Based on this prediction, it is likely that the on average, the broader catchment conditions will be drier and an increase in initial loss and potentially continuing loss would be likely. This would reduce the increase in flood levels in a riverine flooding context, however new major infrastructure along the waterway and within the floodplain should assess the impact of climate change predictions during design. Stormwater flooding in urban areas are more likely to be impacted from predicted increase in extreme events, specifically increased rainfall intensity. Given the antecedent conditions of the impervious areas in Lara are relatively static, increased rainfall intensity is likely to result in an increase in design levels throughout the town.
 - **10% and 1% AEP 12-hour duration with sea level rise for year 2090 (+0.80m tailwater level).** Flood modelling results showed the increases in flood levels were significant within the lower end of the Avalon Road catchment (and likely to cause significant flooding along the Avalon Foreshore Road). It is likely that minimal sea level rise will result in increased frequency and severity of flooding along the foreshore. An increase of 0.80 m along the lower end of Hovells Creek is likely to result in the capacity of the Rennie Street Ford crossing being reduced due to the higher tailwater level. This may reduce the flow rate at which the road is overtopped, increasing the frequency at which the road is closed causing implications on access and egress to the broader road network. Planning to mitigate the implications on access throughout the transport network and its impact is an important consideration and may need to be assessed as part of a broader transport project.

³ DELWP – Managing Climate Change Risk – Guidance for Board Members and Executives of Water Corporations and Catchment Management Authorities

⁴ City of Greater Geelong – Climate Change Adaptation Strategy

⁵ CSIRO – Climate Change in Australia.



- No significant increase in design flood levels is expected upstream of Rennie Street. The Princes Freeway bridge may experience a higher frequency at which the underside of the bridge is inundated, however it is not likely that the frequency of overtopping would increase as a result of the modelled sea level rise.
- **The temporal pattern (9) which produces the highest peak flow (18-hour in the riverine model).** This resulted in a higher flow along Hovells Creek at Lara of around 40 m³/s and increased flood levels through Lara of between 200-300 mm. Temporal patterns are based on the Average Variability Method for estimating the temporal pattern of rainfall in the most intense burst of rainfall within a storm event. This approach is known to result in storm bursts that have higher temporal correlations than exist in real storm events. By selecting the temporal pattern producing the highest peak flow, allows for the most conservative approach to be taken towards producing flood modelling results.
- **Major Storages within the Catchment filled to provide no available storage at the start of the storm event (1% AEP – 6- & 48-Hour Event).** This does not result in an increase in peak flood level (or flow) through Lara in the 48-Hour event, but a faster rise in the rising limb. The 6-Hour event showed with the storage removed, the peak flow increased by 25 m³/s resulting in an increase in flood levels of around 200 mm along Hovells Creek through Lara.
- **Removal of dense vegetation from within the waterway.** To assess the impact of the vegetation within the waterway, the channel roughness (Mannings n value) along Hovells Creek was increased and reduced by 20%. This was found to increase levels varied between 20-50mm (increased for coarser roughness and lowered for smoother roughness). Given there is minimal reduction of flood levels within the waterway and the vegetation plays a significant role in ecology, erosion control and aesthetic value, it is unlikely the removal of vegetation would be viable.
- **100% blockage of key structures along major waterways (1% & 10% AEP 18-hour event)** This showed a significant increase in flood levels along Hovells Creek with isolated increases upto 300 mm. These increases were predominately confined to the floodplain, however and a complete blockage of a major structure is unlikely due to the number of structures and the availability of large debris within the catchment to cause a major blockage.
- **50% blockage of all pit inlets in the urban area (1% & 10% AEP 2-hour event).** Increased flood levels were generally isolated, cul-de-sacs where water ponded up were areas that showed increases.
- **'Ultimate development' scenario assuming no retention of flows to pre-developed conditions (1% & 10% AEP 2-Hour event).** The proposed Elcho Drain upgrade was incorporated into the model and showed a widespread decrease in flood levels downstream of Bacchus Marsh Road (150-300mm) and extended further downstream to the Grand Lakes estate where a decrease of 10-20 mm was observed. Increases appeared in the Elcho Road and Patullos Road area, as expected due to increased run-off from development and no inclusion of flow retardation incorporated. Elsewhere, increases were generally less than 20mm. This suggests that even with higher flow rates (as a result of future development), the Elcho Drain widening provides a positive impact on flood risk.



6 FLOOD MITIGATION

6.1 Overview

The Flood Mitigation Report (*R04 – Assess and Treat Risk*) documented options for treating identified flood risks from coastal, riverine and stormwater flooding. The flood results show that in a 1% AEP event, there are 23 buildings identified to have above floor flooding from the riverine flooding, and 48 buildings identified to have above floor flooding from stormwater flooding. Four of these buildings are at risk of being flooded above floor from both stormwater and riverine flooding. There is also an isolated area of buildings on the Avalon Foreshore Road which have been identified at risk from coastal inundation.

Properties impacted by riverine flooding were generally located either north of Lara or along the Elcho Drain flood extent. The levees provide protection for nearly all properties upto a 1% AEP event, however these properties rely on pumps and flood gates/valves on the stormwater pipes to stop inundation from water backing up into the pipe network.

Properties with above floor flooding from stormwater are scattered across the township with no major clusters of properties flooded above floor identified for the 1% AEP event. There is a significant number of properties throughout the study area which do not have a reasonable level of protection from stormwater flooding (with floor levels less than 300mm above the 1% AEP flood level). These properties are at risk of frequent and nuisance flooding which can result in external property damage. A large portion of these properties are in the eastern side of Lara spreading from Kyema Drive south across McClelland Avenue, to Brunel Close and through to Archimedes Avenue. Flood hazard through these areas is typically low, with slow moving water due to the relatively flat terrain.

A range of mitigation options were identified during the study, with ten options considered at the prefeasibility assessment stage. Each of these options was considered for their benefits and drawbacks at a conceptual level and a decision was made as to whether to take them forward to the detailed modelling stage of the flood study. The initial suggestions were developed from a range of sources, these included Council staff, residents who attended community consultation sessions and Water Technology. Three mitigation options were selected based on the results from the prefeasibility assessment for a detailed assessment which included flood modelling for all AEP's, a flood damages assessment and high-level costing of the mitigation option. The flood modelling results for the three mitigation options selected as part of the detailed assessment do not show a significant reduction in the number of properties flooded above floor.

There are limitations and constraints within the catchment which impact on the current level of protection at a significant number of properties. Both the buildings identified as flooding above floor and those with a low level of protection, that are close to being flooded above floor, have minimal clearance above the surrounding natural surface which increases their sensitivity to localised flood impacts. This reduces the effectiveness of flood level reductions in significant flood events. However, there may be viable mitigation options including improvements to the local drainage network that address nuisance flooding and improves protection during more frequent storm events.

6.2 Existing areas of high flood risk

6.2.1 Riverine Risk

Property damage resulting from riverine flooding within the Hovells Creek catchment is generally confined to the external of buildings for flood events upto a 2% AEP. There are isolated pockets of flooding along Hovells Creek (north of the township), Windemere Road and the Elcho Drain where more significant damage is shown in events larger than a 20% AEP event. Riverine flooding via backwater into local stormwater drains also occurs in events less than a 1% AEP at Melrose Street, Wingara Drive and Walkers Road when flood valves and pumps are not activated behind the levee. However, this is less likely to occur if valves are shut off and



pumps operated. As a result, properties in this area are also at risk of local catchment flooding (stormwater flooding).

In a 1% AEP flood event, there are 27 buildings flooded above floor, including two buildings behind the levee downstream of Flinders Avenue. Eight buildings along the fringe of the floodplain north of Lara are flooded above floor, while eight buildings along the Elcho Drain are also flooded above floor.

6.2.2 Stormwater Risk

The locations of the 44 buildings impacted by above floor flooding from stormwater flooding during a 1% AEP event, are relatively spread out, with the majority of these impacted properties and buildings located behind the Hovells Creek levee and reliant upon the water level in Hovells Creek being low and or the pumps being operational. Other areas impacted by above floor flooding include Kyema Drive, Brunel Close and Archimedes Avenue.

A number of properties have been identified as having frequent and or nuisance flooding and do not have the expected level of protection for buildings located on land subject to flooding (300 mm freeboard above 1% AEP level). These are more easily grouped when compared with the identified building at risk from above floor flooding. A large portion of these buildings in the Hovells Creek floodplain are located behind the existing levees, within Lara East and along Elcho Drain. Figure 6-2 highlights properties that are flooded above floor or close to being flooded above floor in a 1% AEP flood event in the Lara East area.

Model results for the 1% AEP flood event in this area (Figure 6-1) show McClelland Avenue acting as a hydraulic control, resulting in a 200 mm water level drop across the road. This combined with the flat terrain of the area and limited drainage network causes flood water to extend back up from McClelland Avenue into Brownlow Court. The depth of flooding within Kyema Drive is generally less than 300 mm in a 1% AEP flood event, as event magnitude increases, the depth of flooding in Kyema Drive is not likely to get significantly higher due to the weiring of floodwaters over McClelland Avenue. As a result of the flat terrain and relatively low depth of flooding, the mitigation options were unable to yield significant reductions.

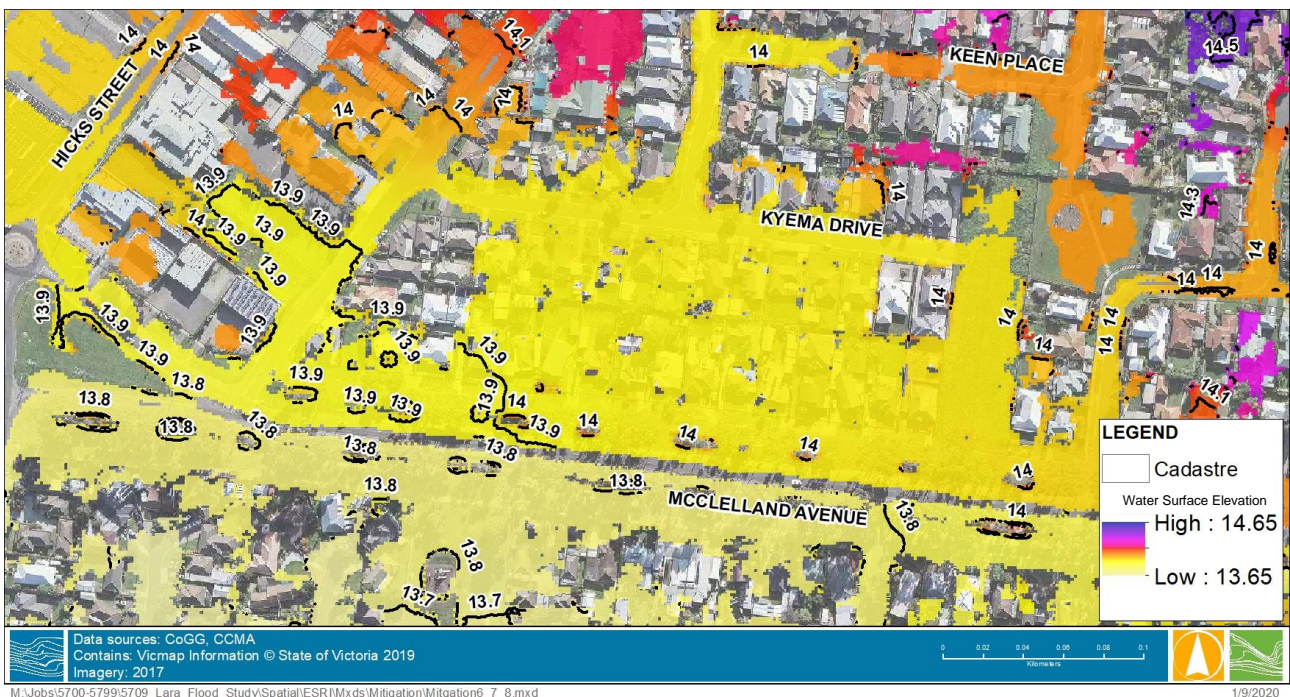


FIGURE 6-1 1% AEP WATER SURFACE LEVELS AT MCCLELLAND AVENUE

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6.2.3 Coastal Inundation Risk

Approximately 30 dwellings located on the Avalon Foreshore Road have been identified to be at risk of becoming isolated during minor storm tide events. The highest astronomical tide level of 1.13 m AHD for Corio Bay indicates a potential flooding risk to these properties. The impact of coastal storm surge combined with a relatively minor catchment storm event is likely to result in a more significant flood impact to these properties. No detailed survey of these building structures was undertaken as part of this assessment. The impact of predicted sea level rise is likely to have a significant impact on these properties. The status of these properties is unknown and were not included in the calculation of flood damages or properties flooded above floor from riverine flooding.

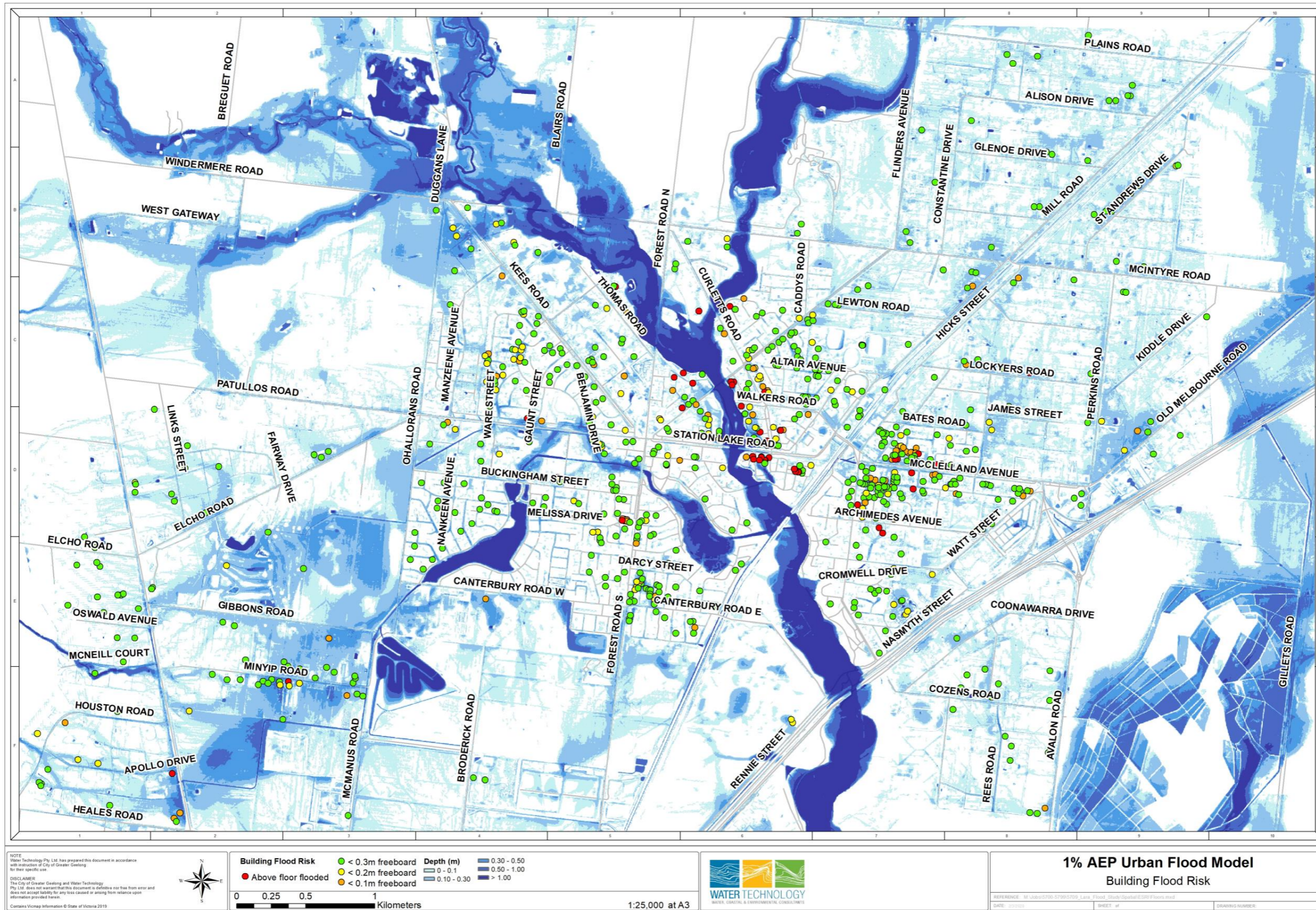


FIGURE 6-2 PROPERTIES FLOODED OR WITHIN 300MM FROM ABOVE FLOOR FLOODING (URBAN FLOODING)

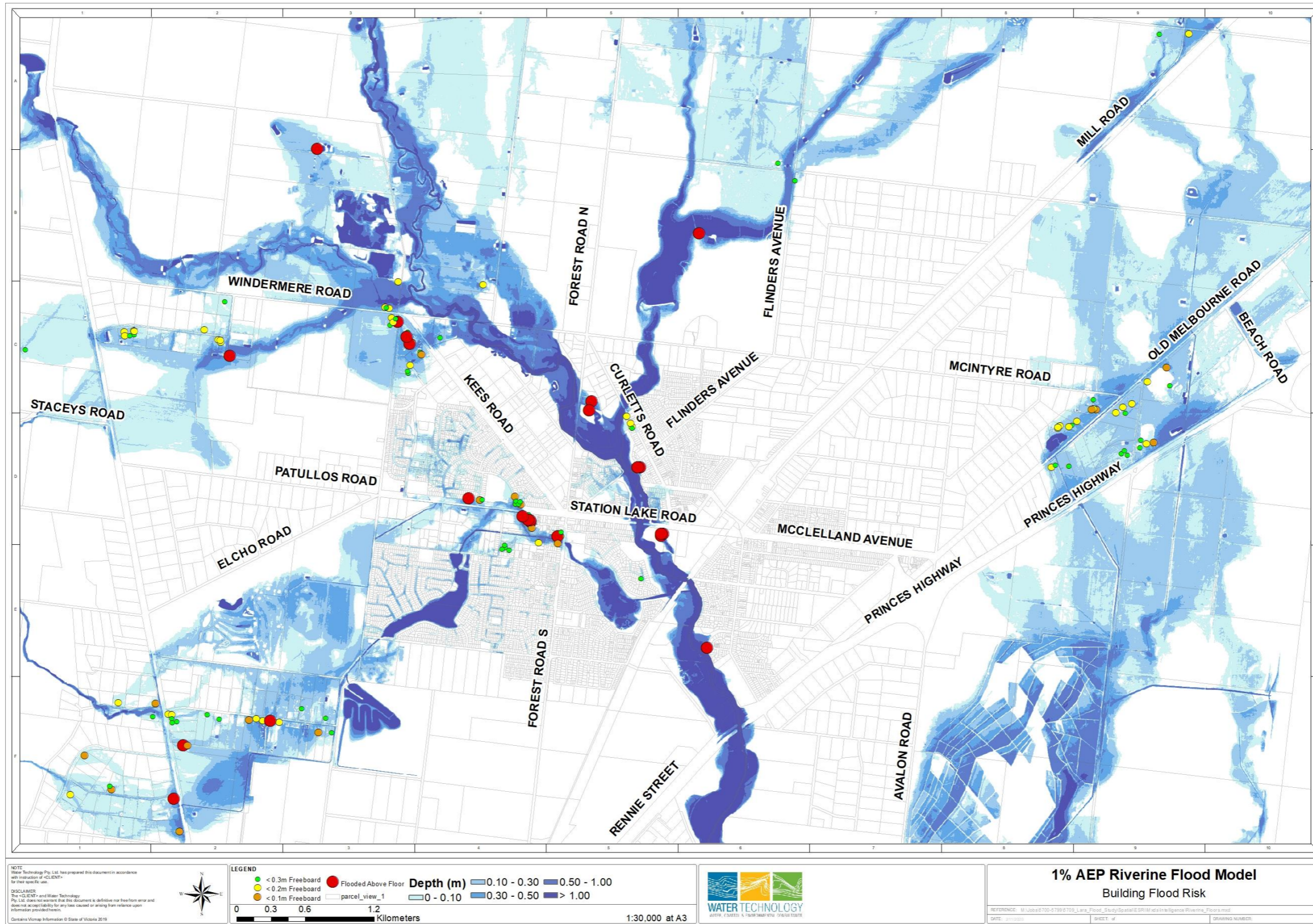


FIGURE 6-3 PROPERTIES FLOODED OR WITHIN 300MM FROM ABOVE FLOOR FLOODING (RIVERINE FLOODING)

6.3 Prefeasibility Assessment

Prefeasibility mitigation assessment and preliminary testing identified 10 potential mitigation options across the study area. Each of the 10 options were assessed against a range of criteria, including their potential to reduce flood damage, cost and feasibility of construction and potential environmental impact. This weighted assessment is an approach developed by Water Technology and has been used across numerous flood studies to compare mitigation options prior to detailed modelling in order to determine which options may be most suitable.

Table 6-1 detailed the results of the prefeasibility assessment, reviews and the scores of each mitigation option against the four criteria. The table also presents the calculated total score for each option by summing the weighted criterion. Reduction in flood damage is the most heavily weighted criteria as this is considered to be the most important objective for all flood mitigation. Details of each option are outline in *R04 Assess and Treat Risk Report*.



FIGURE 6-4 LOCATION OF MITIGATION OPTIONS ASSESSED

TABLE 6-1 MITIGATION OPTION PREFEASIBILITY RESULTS

Mitigation option	Damage Reduction	Cost	Feasibility/ Constructability	Environmental Impact	Score
Lipson Drive pipe and open drain	6	1	2	2	11
Lipson Drive + regrading Kyema Drive to RB (gravity fed outlet)	8	1	1.5	2	12.5
Lipson Drive + regrading Kyema Drive to RB (pumped outlet)	10	1	1.5	2	14.5
Rennie Street Ford Crossing Upgrade	2	2	2.5	1.5	8
Increase pipe size along Rennie Street	6	1	2	1.5	10.5

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Mitigation option	Damage Reduction	Cost	Feasibility/ Constructability	Environmental Impact	Score
Levee Failure at St Laurence at single failure location at peak water level	-	-	-	-	-
Divert Kyema Drive Upstream Catchment East to Avalon Catchment	8	2	1.5	1.5	13
Station Lake Road Upgrade	4	1	4	1.5	10.5
Removal of vegetation within Creek	4	5	2	0.5	10.5
Raised houses in Kyema Drive	6	1	1.5	2	10.5

6.4 Mitigation Modelling

6.4.1 Overview

The three options selected for detailed modelling and costing are listed below:

- Option 1 – Installation of new Lipson Drive pipe and open drain.
- Option 2 - Installation of new Lipson Drive pipe and open drain + regrading Kyema Drive to the City owned land + retarding basin + pumped outlet to open drain west of Rennie Street.
- Option 3 - Divert overland flow upstream of Kyema Drive toward Avalon Road Catchment via a new detention basin.

6.4.2 Option 1 - Lipson Drive Pipe and Open Drain

A new pipe alignment beneath a proposed open drain between Lipson Drive and the railway reserve was assessed to improve the drainage of flood water from McClelland Avenue, (east of Rennie St) into Hovells Creek. An upgrade of the culvert at Rennie Street to convey flows from McClelland Avenue to the open drain behind the Lara RSL was also included in this option. The option was initially developed following the Lara North-East Flood Study in 2002.

The existing pipe network along with the additional open drain, pipes and pits that were added to this scenario are displayed in Figure 6-5. The materials, construction, design and associated traffic management and administration costs for this mitigation option are summarised in Section 6.5.

Flood modelling results showed only minor reductions in flood levels and were concentrated to the residential areas south of McClelland Avenue. Only a single building was reduced from above floor to below floor flooding in the 1% AEP event.

6.4.3 Option 2 - Lipson Drive Drain and Kyema Drive Regrading

In addition to the Lipson Drive Pipe and Open Drain (Option 1), a regrade of Kyema Drive (road reserve) east of Brownlow Court towards existing vacant land owned by the City was modelled. It is proposed that this would house a small retarding basin with a pumped outlet, with connection pipes draining to the open drain situated to the west of Rennie Street. The option is displayed in Figure 6-5.

The pump was modelled using a pump control, with a capacity of 0.3 m³/s. The pump was controlled using a water level trigger, turning on when the level reached 13.05 m AHD and turning off when the level drops below 12.50 m AHD. The pump was essential to the design of this mitigation option as a result of the flat terrain limiting the capacity of existing pipes and the potential to construct new gravity fed pipes, which is not practical

in this area. The option aimed to alleviate the pressure on the existing and new drainage infrastructure south of Kyema Drive which is exceeded from local runoff falling directly within the immediate vicinity of Kyema Drive, McClelland Avenue and further south at Smeaton Close, Rennie Street, Lipson Drive and Archimedes Avenue.

Flood modelling results showed a similar reduction in flood levels when compared with the previous mitigation option, with again, only one building changing from above to below floor flooring. There is a slightly wider spread of flood level reductions along Brunel Close and through McAdam Court; however, the reductions are still limited to less than 50 mm through the residential areas.

Further investigation into an alternative pumped option (involving additional pumps at the western end of Kyema Drive) and potentially larger pumps to remove floodwater from within Kyema Drive may provide additional benefits to those identified from the current modelling. There are several risks associated with the reliance on a pump-based mitigation system that need to be considered. These include the need for a reliable power source (and back up source), ongoing operation and maintenance costs and perceived sense of protection within the community.

6.4.4 Option 3 - Divert Lara North East Flows towards the Avalon Catchment

Mitigation Option 3 included an open channel diversion drain. The option diverted overland flow and runoff from north-east Lara towards the Avalon Catchment. Under existing conditions, this water flows south towards Kyema Drive and McClelland Avenue, and adds to existing water ponding behind McClelland Avenue. This option involved using roadside drainage and a proposed drainage easement through private property to capture and convey flows east to reduce the flood risk around Kyema Drive and McClelland Avenue.

It should be noted that purchase and or compensation for land is not a preferred action and consultation with the private property owner of the land identified for this mitigation option would be required for this to be considered. The location of the 8-m wide open drains added to the model is shown in Figure 6-6. The open drain would outfall to a proposed retarding basin at Old Melbourne Road before discharging via an existing culvert set at Princes Freeway into the Avalon Road catchment. The option offers a potential drainage alternative for any further growth in north-east Lara. Currently, most of the area upstream (north) of Bates Road is low-density residential properties. There currently appears to be a lack of formal drainage infrastructure within this area, with anecdotal evidence suggesting water often pools on the flat terrain following relatively minor storm events. Any future growth of this area would likely require a formalised drainage scheme to accommodate increased runoff frequency associated with any development.

This option had the largest and most widespread reduction in flood levels, with reductions around Kyema Drive and minor reductions south of McClelland Avenue, while also provided a reduction in levels and extents between Lockyers Road and McClelland Avenue. Further refinement of this option to remove the isolated areas of increased flood levels north of Bates Road would be required. There would also need to be provision for work to incorporate the open drains and the allocation of a suitable area for a retarding basin. An additional culvert crossing at the Princes Freeway was not investigated as part of this project but may be required into the future.

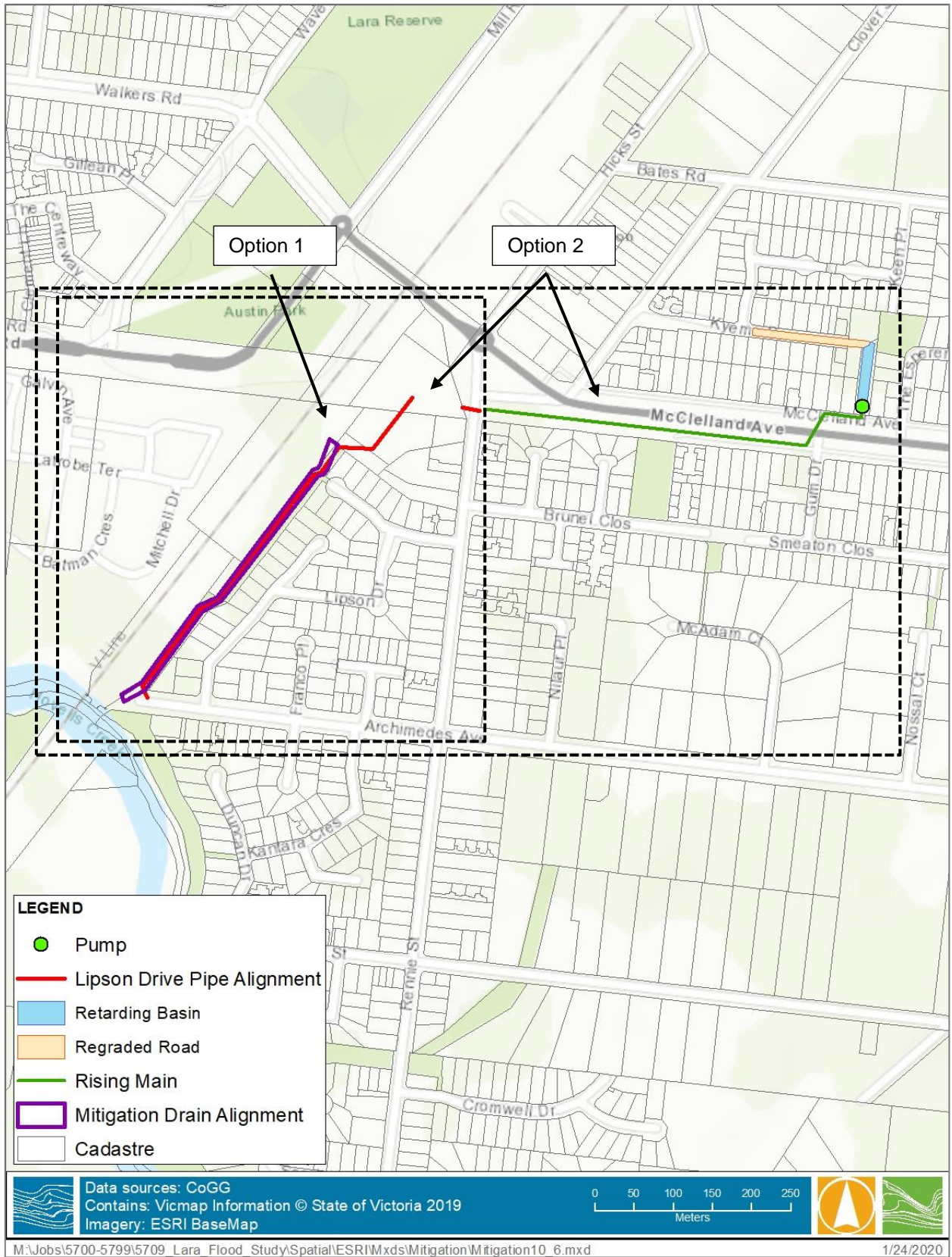


FIGURE 6-5 MITIGATION OPTIONS 1 & 2 LAYOUT

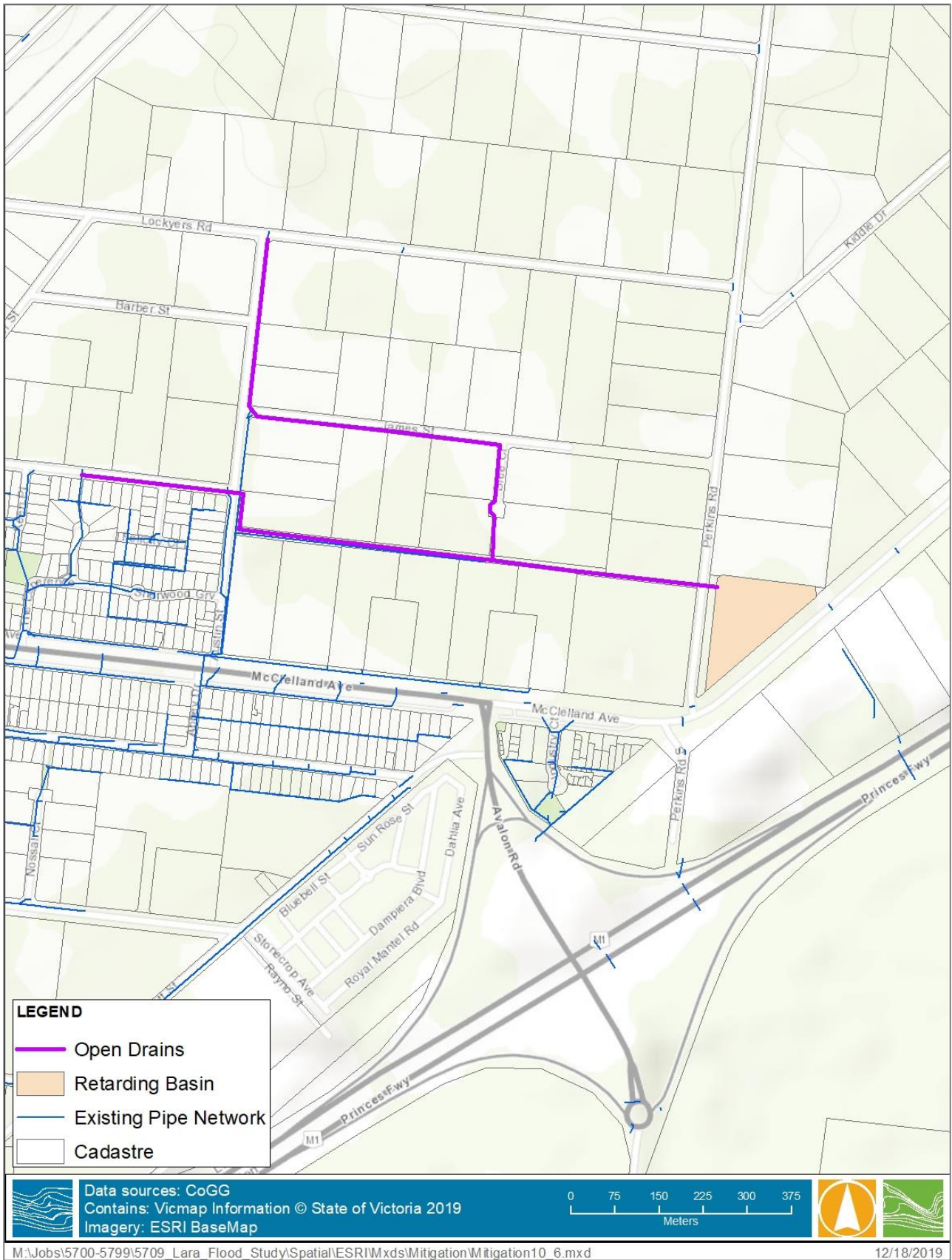
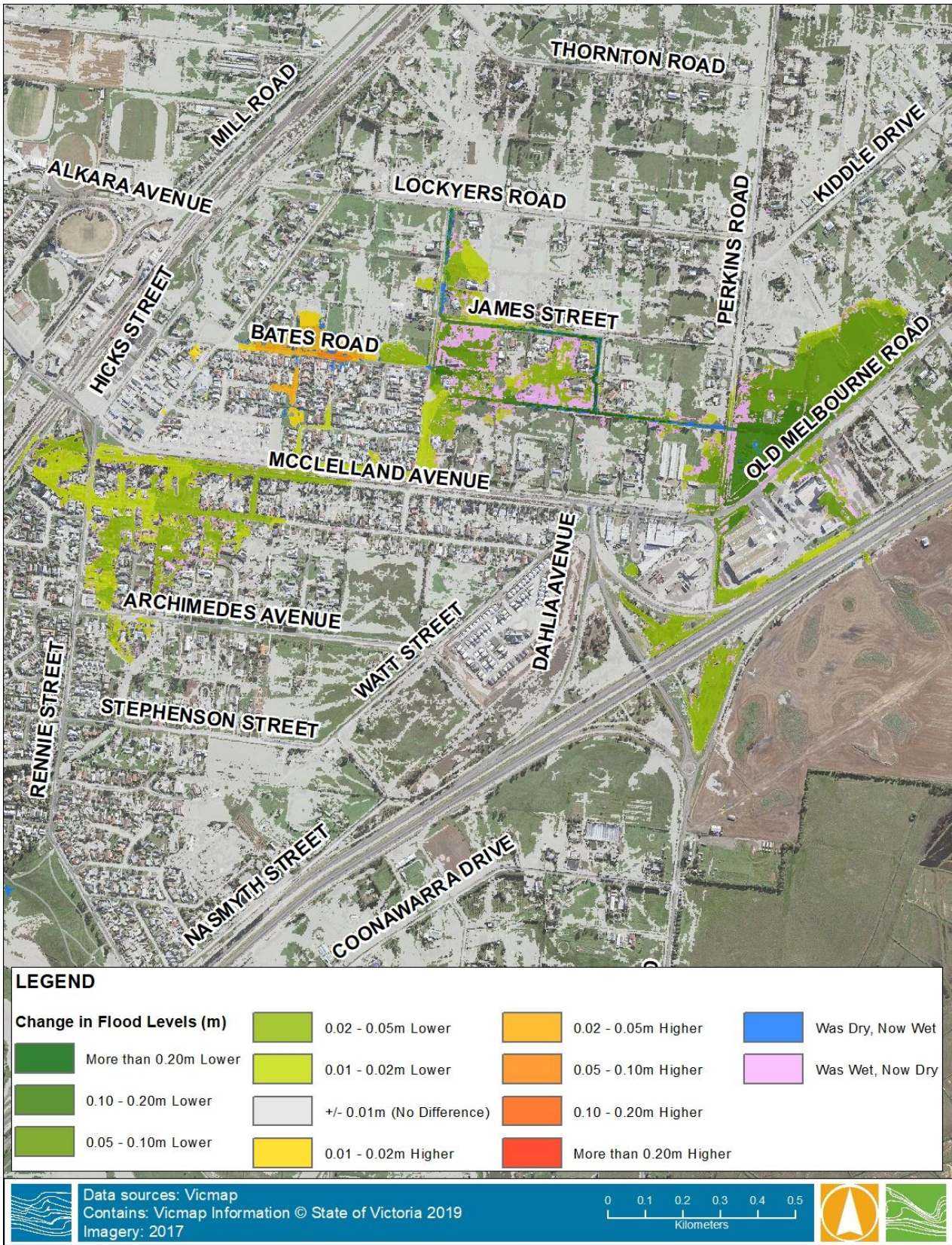


FIGURE 6-6 MITIGATION OPTION 3 - AVALON DIVERSION LAYOUT



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FIGURE 6-7 MITIGATION OPTION 3 - AVALON DIVERSION FLOOD LEVEL DIFFERENCE (1% AEP)

6.5 Mitigation Discussion

When assessing the current model results and topography of Kyema Drive, it appears McClelland Avenue is acting as the main hydraulic control, with flood water backing up behind the road crest. A long section showing the existing topography and the 1% AEP water level from Brownlow Court, Kyema Drive, McClelland Avenue through to Brunel Close is provided (Figure 6-8) as described Section 6.2. This highlights the flat terrain and hydraulic control that McClelland Avenue has on flood behaviour. Whilst lowering the crest level of McClelland Avenue might seem to be an obvious solution, it is likely to result in increased flooding risk to the downstream catchment and would likely increase the flood risk on McClelland Avenue itself, such that it would be unlikely to meet road safety limits.

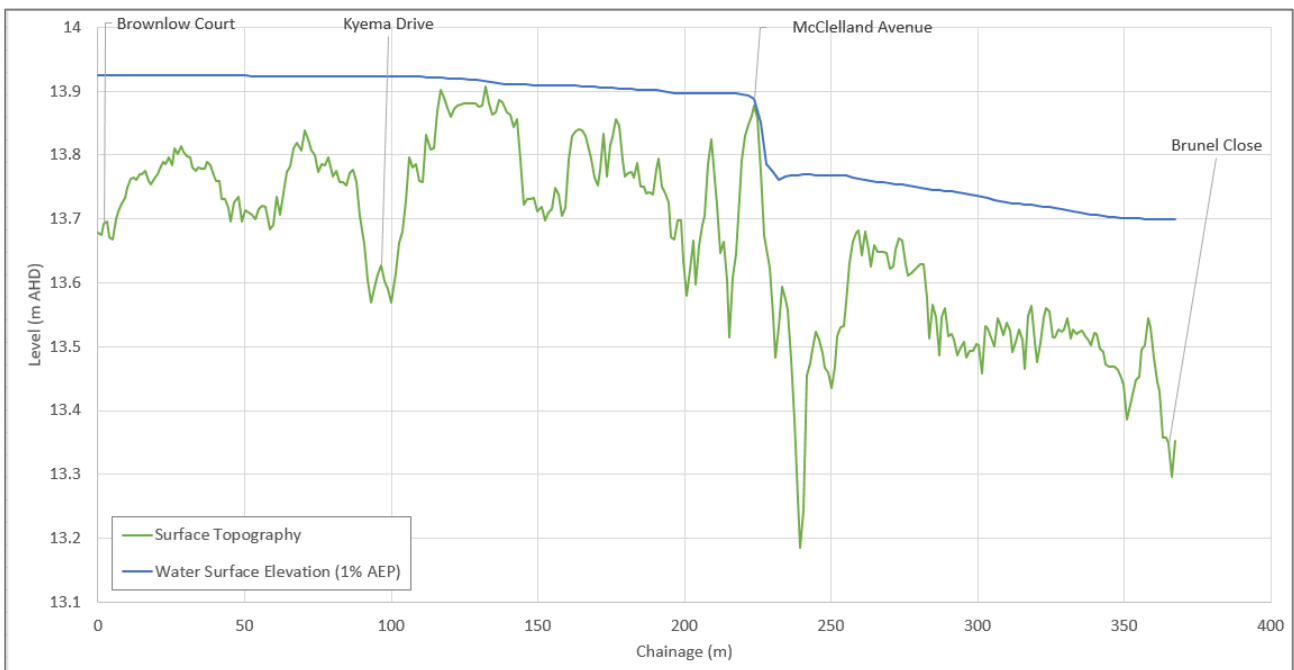


FIGURE 6-8 1% AEP WATER LEVEL AND NATURAL SURFACE

6.6 Summary

Each of the mitigation options tested showed a reduction in 1% AEP flood levels south of McClelland Avenue. The focus of the mitigation scenarios tested was to reduce flooding in the broader McClelland Avenue area including Kyema Drive. Outlined below are some key points of the findings.

- Option 3 (Avalon Diversion) was the only option that showed a reduction north of McClelland Avenue. Despite this, there was still only a minor reduction in flood levels (less than 1 cm) in a 1% AEP Flood event.
- There is no significant or noticeable reduction in the 1% AEP flood levels upstream of McClelland Avenue, likely due to the flat design pipe grade.
- Further investigation into an alternative pumped option (involving additional pumps at the western end of Kyema Drive) and potentially larger pumps to remove floodwater from within Kyema Drive may provide additional benefits to those identified from the current modelling.
- Sensitivity of pipe blockage within the main pipe alignment along Clover Street which drains the western end of Kyema Drive was found to result in a larger reduction in flood levels compared to both mitigation options focused on Kyema Drive. The design slope of the existing pipe is less than 0.2%, which makes the pipe susceptible to blockage from sediment deposition. Pipe blockage of up to 50% due to

sedimentation was found during CCTV of the alignment during the flood study. As a result, a 50% blockage was applied to the 900 mm drainage pipe along Clover Street for all design modelling.

Maintenance within the area has typically been reactive, responding to drainage blockages only once a storm event has occurred. Flood modelling has highlighted the sensitivity to reduced effectiveness of the drainage network for several areas in Lara. A more pro-active maintenance schedule for critical drainage assets (large or flat pipes) may be a viable option to reduce the frequency of nuisance flooding and risk of failure. This is one of the recommendations of the study. This would likely involve the identification of pipes with a low grade, existing blockages within pipes (as part of an on-going CCTV program), reporting of blockages and cleaning of debris/blockages from pipes.

A summary of the cost associated with the design and construction of each mitigation option is summarised in Table 6-2. The mitigation works were costed based on several key references:

- Costing spreadsheet originally developed by Melbourne Water that has been adapted by Water Technology of the course of several flood mitigation projects to provide a more accurate cost for works and materials in regional areas.
- Rawlinsons Australian Construction Handbook Rates (Rawlinson, 2011)
- The United Kingdom Environmental Agency Temporary and Demountable Flood Protection Guide (EA UK, 2011)
- Comparison to cost estimates for similar mitigation works for other flood studies undertaken by Water Technology

TABLE 6-2 MITIGATION OPTION COST ESTIMATE

	Option 1- Lipson Drive Pipe and Drain	Option 2- Lipson Drive Pipe and Drain + Pumped Outlet from RB	Option 3 – Avalon Road Diversion Drain
Construction	\$ 661,875	\$ 960,000	\$ 1,030,000
Engineering (15%)	\$ 100,000	\$ 144,000	\$ 154,000
Admin (9%)	\$ 60,000	\$ 88,000	\$ 90,000
Contingency (30%)	\$ 200,000	\$ 288,000	\$ 300,000
Total	\$1,021,875	\$1,480,000	\$1,574,000
Annual Maintenance /Operating	\$ 500	\$ 2,000	\$ 1,000

7 FLOOD DAMAGES

7.1 Overview

An existing conditions flood damage assessment will be undertaken for the study area in two facets. The flood assessment determined the monetary flood damages for design floods (50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and 0.1% AEP events) for the riverine and urban stormwater flooding separately. The flood damage assessment will also be undertaken for the three mitigation options assessed in detailed modelling and be used in the cost-benefit-analysis.

7.1.1 Urban Damages

A summary of the existing conditions flood damage assessment of the urban flooding is shown in Table 7-1.

Table 7-1 Existing Conditions Flood Damages – Urban Modelling

EXISTING CONDITIONS										
ARI (years) AEP	1000yr 0.001	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2	2yr 0.5	
Residential Buildings Flooded Above Floor	81	65	51	44	35	27	20	13	5	
Commercial Buildings Flooded Above Floor	3	3	2	2	0	0	0	0	0	
Properties Flooded Below Floor	4494	4341	4101	3924	3691	3339	3122	2857	2498	
Total Properties Flooded	4578	4409	4154	3970	3726	3366	3142	2870	2503	
Direct Potential External Damage Cost	\$6,239,039	\$5,468,696	\$4,477,807	\$3,842,924	\$3,150,914	\$2,609,064	\$2,143,878	\$1,534,711	\$971,156	
Direct Potential Residential Damage Cost	\$3,937,103	\$3,176,321	\$2,478,477	\$2,117,676	\$1,686,730	\$1,252,450	\$956,293	\$657,100	\$272,026	
Direct Potential Commercial Damage Cost	\$6,665	\$4,816	\$2,244	\$1,018	\$0	\$0	\$0	\$0	\$0	
Total Direct Potential Damage Cost	\$10,182,807	\$8,649,833	\$6,958,528	\$5,961,618	\$4,837,644	\$3,861,514	\$3,100,171	\$2,191,811	\$1,243,182	
Total Actual Damage Cost (0.8*Potential)	\$8,146,246	\$6,919,866	\$5,566,822	\$4,769,294	\$3,870,115	\$3,089,211	\$2,480,137	\$1,753,449	\$994,546	
Infrastructure Damage Cost	\$2,124,348	\$1,936,828	\$1,687,417	\$1,497,980	\$1,273,082	\$1,037,100	\$831,149	\$572,422	\$359,025	
Indirect Clean Up Cost										
Indirect Residential Relocation Cost										
Indirect Emergency Response Cost										
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Total Cost	\$10,270,593	\$8,856,695	\$7,254,240	\$6,267,274	\$5,143,198	\$4,126,311	\$3,311,286	\$2,325,871	\$1,353,571	
Average Annual Damage (AAD)	\$1,283,343									

A summary of the flood damage assessment of the urban flooding for Mitigation Option 1 is shown in Table 7-2

Table 7-2 Mitigation Option 1 Flood Damages – Urban Modelling

MITIGATION SCENARIO 1										
ARI (years) AEP	1000yr 0.001	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2	2yr 0.5	
Residential Buildings Flooded Above Floor	79	65	51	43	35	27	20	13	5	
Commercial Buildings Flooded Above Floor	3	3	2	2	0	0	0	0	0	
Properties Flooded Below Floor	4494	4338	4097	3921	3688	3338	3120	2856	2499	
Total Properties Flooded	4576	4406	4150	3966	3723	3365	3140	2869	2504	
Direct Potential External Damage Cost	\$6,215,578	\$5,436,308	\$4,443,481	\$3,812,630	\$3,136,211	\$2,610,230	\$2,145,177	\$1,534,405	\$971,077	
Direct Potential Residential Damage Cost	\$3,870,544	\$3,166,868	\$2,456,656	\$2,077,255	\$1,681,319	\$1,252,440	\$956,333	\$657,104	\$272,027	
Direct Potential Commercial Damage Cost	\$6,664	\$4,815	\$2,244	\$1,017	\$0	\$0	\$0	\$0	\$0	
Total Direct Potential Damage Cost	\$10,092,786	\$8,607,991	\$6,902,381	\$5,890,902	\$4,817,530	\$3,862,670	\$3,101,510	\$2,191,509	\$1,243,104	
Total Actual Damage Cost (0.8*Potential)	\$8,074,229	\$6,886,393	\$5,521,905	\$4,712,722	\$3,854,024	\$3,090,136	\$2,481,208	\$1,753,207	\$994,483	
Infrastructure Damage Cost	\$2,122,787	\$1,934,500	\$1,685,722	\$1,496,442	\$1,271,978	\$1,036,977	\$832,480	\$572,643	\$359,168	
Indirect Clean Up Cost										
Indirect Residential Relocation Cost										
Indirect Emergency Response Cost										
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Total Cost	\$10,197,016	\$8,820,893	\$7,207,627	\$6,209,164	\$5,126,002	\$4,127,113	\$3,313,688	\$2,325,850	\$1,353,651	
Average Annual Damage (AAD)	\$1,282,488									

A summary of the flood damage assessment of the urban flooding for Mitigation Option 2 is shown in Table 7-3

Table 7-3 Mitigation Option 2 Flood Damages – Urban Modelling

MITIGATION SCENARIO 2										
ARI (years) AEP	1000yr 0.001	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2	2yr 0.5	
Residential Buildings Flooded Above Floor	77	64	49	43	34	27	20	13	5	
Commercial Buildings Flooded Above Floor	3	3	2	2	0	0	0	0	0	
Properties Flooded Below Floor	4492	4336	4098	3921	3669	3333	3120	2855	2498	
Total Properties Flooded	4572	4403	4149	3966	3703	3360	3140	2868	2503	
Direct Potential External Damage Cost	\$6,175,996	\$5,393,504	\$4,416,676	\$3,805,787	\$3,092,620	\$2,603,001	\$2,140,274	\$1,531,935	\$969,204	
Direct Potential Residential Damage Cost	\$3,788,460	\$3,114,850	\$2,372,979	\$2,075,239	\$1,627,100	\$1,252,544	\$956,259	\$657,021	\$271,941	
Direct Potential Commercial Damage Cost	\$6,665	\$4,814	\$2,242	\$1,017	\$0	\$0	\$0	\$0	\$0	
Total Direct Potential Damage Cost	\$9,971,121	\$8,513,168	\$6,791,897	\$5,882,043	\$4,719,720	\$3,855,545	\$3,096,533	\$2,188,956	\$1,241,145	
Total Actual Damage Cost (0.8*Potential)	\$7,976,897	\$6,810,534	\$5,433,518	\$4,705,634	\$3,775,776	\$3,084,436	\$2,477,226	\$1,751,165	\$992,916	
Infrastructure Damage Cost	\$2,120,473	\$1,931,216	\$1,681,132	\$1,495,253	\$1,266,392	\$1,034,091	\$827,181	\$573,219	\$360,522	
Indirect Clean Up Cost										
Indirect Residential Relocation Cost										
Indirect Emergency Response Cost										
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Total Cost	\$10,097,369	\$8,741,751	\$7,114,649	\$6,200,888	\$5,042,168	\$4,118,527	\$3,304,407	\$2,324,384	\$1,353,438	
Average Annual Damage (AAD)	\$1,278,805									

A summary of the flood damage assessment of the urban flooding for Mitigation Option 3 is shown in Table 7-4

Table 7-4 Mitigation Option 3 Flood Damages – Urban Modelling

MITIGATION SCENARIO 3										
ARI (years) AEP	1000yr 0.001	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2	2yr 0.5	
Residential Buildings Flooded Above Floor	81	64	49	42	33	26	20	13	5	
Commercial Buildings Flooded Above Floor	3	3	2	2	0	0	0	0	0	
Properties Flooded Below Floor	4481	4327	4085	3907	3648	3321	3106	2843	2483	
Total Properties Flooded	4565	4394	4136	3951	3681	3347	3126	2856	2488	
Direct Potential External Damage Cost	\$6,155,385	\$5,354,101	\$4,366,614	\$3,746,100	\$3,032,462	\$2,566,678	\$2,111,874	\$1,515,508	\$965,119	
Direct Potential Residential Damage Cost	\$3,934,535	\$3,114,208	\$2,364,469	\$2,028,353	\$1,580,335	\$1,219,638	\$956,093	\$657,108	\$272,024	
Direct Potential Commercial Damage Cost	\$6,665	\$4,815	\$2,244	\$1,017	\$0	\$0	\$0	\$0	\$0	
Total Direct Potential Damage Cost	\$10,096,585	\$8,473,124	\$6,733,327	\$5,775,470	\$4,612,797	\$3,786,316	\$3,067,967	\$2,172,616	\$1,237,143	
Total Actual Damage Cost (0.8*Potential)	\$8,077,268	\$6,778,499	\$5,386,662	\$4,620,376	\$3,690,238	\$3,029,053	\$2,454,374	\$1,738,093	\$989,714	
Infrastructure Damage Cost	\$2,112,818	\$1,925,952	\$1,678,478	\$1,493,579	\$1,259,059	\$1,025,618	\$814,446	\$561,885	\$359,688	
Indirect Clean Up Cost										
Indirect Residential Relocation Cost										
Indirect Emergency Response Cost										
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Total Cost	\$10,190,086	\$8,704,451	\$7,065,139	\$6,113,955	\$4,949,297	\$4,054,671	\$3,268,819	\$2,299,978	\$1,349,403	
Average Annual Damage (AAD)	\$1,265,359									

7.1.2 Riverine Damages

A summary of the existing conditions flood damage assessment of the riverine flooding is shown in Table 7-5.

TABLE 7-5 RIVERINE EXISTING CONDITIONS FLOOD DAMAGES

EXISTING CONDITIONS										
ARI (years) AEP	1000yr 0.001	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2	2yr 0.5	
Residential Buildings Flooded Above Floor	215	185	104	27	16	6	4	4	1	
Commercial Buildings Flooded Above Floor	0	0	0	0	0	0	0	0	0	
Properties Flooded Below Floor	993	930	893	858	791	702	596	443	350	
Total Properties Flooded	1208	1115	997	885	807	708	600	447	351	
Direct Potential External Damage Cost	\$3,417,995	\$3,244,718	\$3,028,565	\$2,676,502	\$2,313,125	\$1,834,593	\$1,556,679	\$1,185,963	\$737,238	
Direct Potential Residential Damage Cost	\$16,266,296	\$12,954,033	\$6,492,763	\$1,856,217	\$895,348	\$664,538	\$505,263	\$422,258	\$194,989	
Direct Potential Commercial Damage Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Total Direct Potential Damage Cost	\$19,684,291	\$16,198,751	\$9,521,328	\$4,532,719	\$3,208,473	\$2,499,131	\$2,061,942	\$1,608,221	\$932,227	
Total Actual Damage Cost (0.8*Potential)	\$15,747,433	\$12,959,001	\$7,617,062	\$3,626,175	\$2,566,778	\$1,999,305	\$1,649,554	\$1,286,577	\$745,782	
Infrastructure Damage Cost	\$2,588,684	\$2,454,467	\$2,263,551	\$2,001,316	\$1,669,464	\$1,422,940	\$1,199,276	\$902,751	\$624,715	
Indirect Clean Up Cost										
Indirect Residential Relocation Cost										
Indirect Emergency Response Cost										
Total Indirect Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
Total Cost	\$18,336,117	\$15,413,467	\$9,880,614	\$5,627,491	\$4,236,242	\$3,422,245	\$2,848,830	\$2,189,328	\$1,370,497	
Average Annual Damage (AAD)	\$1,200,441									

7.2 Non – Economic Flood Damages

Assessment of non-monetary flood related damage in Lara and the broader study area is high as observed from the study. This covers damage such as emotional distress and health issues. The benefit-cost analysis (see Section 8) has not considered this cost, which is standard practice for this level of assessment. There has been extensive research undertaken and documented in the scientific literature relating to the individual and community response to natural disasters. The reason for this being is that there are no agreed methods for valuing these costs, despite intangible losses often being found to be more important than tangible losses.

The additional benefits gained for houses throughout Lara that would be protected in events up to 1% AEP design flood level have also not been calculated in this assessment. Anecdotal stories reveal that several

residents in the Kyema Drive area perceive their property value reduced as a result of frequent flooding occurring in the previous decades. Any decisions made that are based on the benefit-cost ratios need to understand that the true cost of floods in Lara is far higher than the economic damages alone, and that there is uncertainty over calculating their worth. This would have the effect of increasing the benefit cost ratio, improving the argument for approving a mitigation option within Lara.

8 MITIGATION BENEFIT-COST ANALYSIS

A benefit cost analysis was undertaken to assess the economic viability of the three mitigation options that were modelled and costed. Indicative benefit-cost ratios were based on the construction cost estimates and average annual damages. For the analysis, a net present value model was used, applying a 6% discount rate over a 30-year project life. A 30% contingency cost has been added along with engineering and administration costs. An annual maintenance cost including mowing, weed control and electricity costs (Mitigation Option 2) was also included.

The mitigation works were costed (Table 6-2) based on key references including but not limited to:

- Melbourne Water’s standard rates for earthworks and pipe/headwall construction costs.
- Rawlinsons Australian Construction Handbook Rates
- Comparison to cost estimates for similar mitigation works for other flood studies

Based on the minimal reduction in flood levels for each of the mitigation options showing only minor reductions in the number of properties flooded above floor, it was not anticipated that benefit-cost analysis would provide a high benefit-cost ratio. The comparison of the benefit-cost ratio does allow for each of the three mitigation options to be assessed alongside each other. A summary of the Benefit-Cost Ratio for the three mitigation options is shown in Table 8-1.

TABLE 8-1 BENEFIT COST ANALYSIS

	Option 1- Lipson Drive Pipe and Drain	Option 2- Lipson Drive Pipe and Drain + Pumped Outlet from RB	Option 3 – Avalon Road Diversion Drain
Average Annual Damage	\$ 1,282,488	\$ 1,278,804	\$ 1,265,359
Annual Maintenance Cost	\$ 500	\$ 2,000	\$ 1,000
Annual Cost Saving	\$ 354	\$ 2,538	\$ 16,983
Net Present Value (6%)	\$ 4,987	\$ 35,693	\$ 238,829
Capital Cost of Mitigation	\$ 1,021,875	\$ 1,478,400	\$1,540,000
Benefit-Cost Ratio	0.005	0.02	0.16

9 FLOOD WARNING

The Flood Warning Assessment Report (*R05 – The Flood Warning and Intelligence Report*) documented the existing flood warning system for the study and potential improvements.

9.1 Overview

Flood warning systems are necessary to ensure the safety of the public and enhance readiness in the event of a flood. An effective flood warning system will provide communities with time to protect themselves and if time permits, their property. A review of the available data (rainfall, streamflow and intelligence data) for the study areas was undertaken before several recommendations for potential flood warning information was also provided.

9.2 Riverine Flood Warning

Historically the onset of riverine flooding in Lara can potentially happen quite soon after heavy rainfall. The onset of riverine flooding (rise in stream levels) can occur some 6-8 hours after heavy rainfall. When considering the processes of detection, forecasting, interpretation and messaging, the flood warning time is likely to be shorter than 6 hours under typical storm events. The impacts of local stormwater are likely to occur in a much shorter time frame than riverine flooding.

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

In the event of severe weather conditions for Lara and the broader catchment that may lead to flooding, the BoM may issue a Severe Weather Warning, Severe Thunderstorm Warning or a Flood Watch for the broader Barwon Moorabool and Leigh area. This is intended to inform the community when heavy or severe rainfall that may lead to flooding or flash flooding in town could occur. This typically relates to stormwater flooding, however warnings for storm durations greater than 6 hours may lead to riverine flooding.

BoM does not issue river height predictions for the Hovells Creek in Lara streamflow gauge. Warnings issued by BoM may provide information about when flooding is possible in the town, but the warning is not specific, and does not include the expected height of the river peak for riverine flooding.

The installation of a new flood warning system on Rennie Street at Hovells Creek was completed in 2018 as part of a broader Hovells Creek Flood Warning system. This system entails flashing lights which are activated when water reaches the road level. The system was installed to improve driver safety at Hovells Creek, where drivers are known to drive through flood water. The system still relies upon flood gates being manually closed by Council staff to close the road. In the event of flood waters reaching the underside the Princes Freeway support beam, VicRoads officers are notified via an automatic SMS alert as part of the flood warning system.

9.3 Stormwater Flood Warning

As identified above, the BoM may issue a Severe Weather Warning or Severe Thunderstorm Warning for Lara. This is intended to inform the community when heavy or severe rainfall that may lead to flooding or flash flooding in town could occur. This is likely to impact on the township and broader urban areas.

9.4 Summary

It is recommended that the City investigate and document the feasibility of a flash flood warning service for Lara. While it was not the scope of this project to develop a comprehensive flash flood warning system for the township, it has been considered at a high level. To better manage and understand flood warning in Lara it is recommended the three rainfall gauges with telemetry within Hovells Creek catchment along with the Avalon automatic weather station (BoM managed gauge) be investigated for their use in a flash flood warning system. Alternatively, calibrated radar rainfall and weather model forecasts could be used to develop a flash flood warning system. This along with hydrological models and rating curves developed during the Lara Flood Study (2020), could provide the information required for a flash flood warning system.

The system could be kept simple, similar to that shown in Figure 9-1 to help emergency management authorities and the general public better predict the magnitude of an event based on rainfall alone. With the estimated rainfall storm AEP used to select flood maps to predict likely flood impacts. The system could also be slightly more complex and could use a combination of rainfall gauges and radar rainfall, along with the hydrological models run in forecast mode, generating automated alerts. This is all possible using available technology.

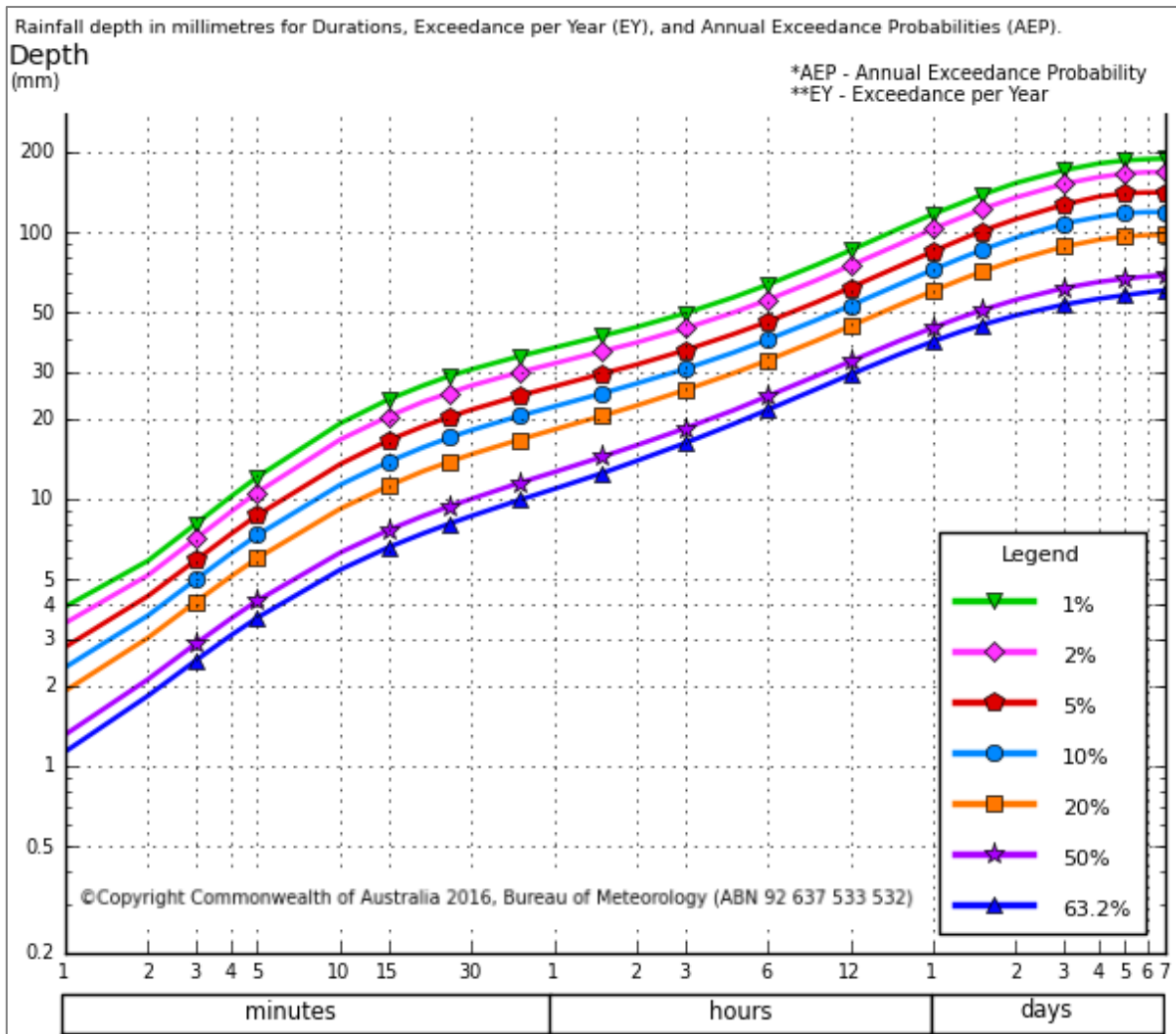


FIGURE 9-1 BOM RAINFALL IFD CHART (LARA- HOVELLS CK CATCHMENT)

10 FLOOD INTELLIGENCE

The Flood Intelligence Report (*R05– Flood Warning Intelligence Report*) provides a detailed description of the flood behaviour in the study area and the impact flooding has on people and assets throughout the catchment.

10.1 Overview

During significant rainfall events, the catchment to the northwest and north of Lara begins to contribute runoff which accumulates and flows towards Lara, the Princes Freeway and eventually Corio Bay. While there is significant flow along Hovells Creek, there is also accumulation of shallow flows across agricultural properties. In order to appropriately plan for flood response activities. Intelligence information collected from the study will be used to update the Municipal Emergency Management Plan, the VicSES Lara Local Flood-Guide, and general information which can be utilised by agencies for flood warning and response purposes. It can also be used to be distributed to the public for education purposes including building community resilience.

10.2 Methodology

Above floor flooding was provided as a separate spreadsheet and where possible has been based on floor level survey. It should be noted the above floor flooding impacts described do not consider individual flood protection measures such as local flood walls or levees which protect individual homes (sandbagging, flood gates, sealed fencing). For this reason, such measures cannot be assumed to be in place and operating effectively under design conditions.

Flooding from urban stormwater runoff impacts different parts of the town compared to riverine flooding. Impacts from both forms of flooding is summarised in Table 10-1. Above floor flooding increases significantly above the 1% AEP flood event from riverine flooding as levees become overtopped.

A set of summary tables and maps were developed to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences across different regions of the study area. An example of this (Table 10-2), if the reader is wishing to understand the consequences of a 20% AEP event, then the flood characteristics should be read for the 50% and 20% AEP events in succession.

TABLE 10-1 SUMMARY OF ABOVE FLOOR FLOODING

Design Event (AEP)	Properties Flooded Above Floor	
	Riverine	Stormwater
50%	1	5
20%	4	13
10%	4	20
5%	6	27
2%	16	35
1%	27	44
0.5%	104	51
0.2%	185	65
0.1%	215	81

TABLE 10-2 EXAMPLE OF SUMMARY OF FLOOD BEHAVIOUR FOR DESIGN EVENTS (50% & 20% AEP)

Flood Event	Characteristics – Flood Behaviour	Key Roadways Inundated
<p>50% AEP ~1,400 ML/d 7.06 m Gauge Height at Flinders Avenue 2.58 m Gauge Height at Rennie Avenue</p>	<p>Floodwaters begin to accumulate across the upper Hovells Creek floodplain. Flooding of the Elcho Drain begins to inundate private property. Elcho Golf Course flooded. Stream level rises along Hovells Creek Widespread ponding across flat areas.</p>	<ul style="list-style-type: none"> ■ Windermere Road Overtopped. ■ Flinders Avenue Overtopped. ■ Rennie Street Floodway Overtopped. ■ Duggans Lane overtopped.
<p>20% AEP ~4,000 ML/d 7.90 m Gauge Height at Flinders Avenue 3.00 m Gauge Height at Rennie Avenue</p>	<p>Upper Hovells Creek Floodplain Overland flows impact farmland west of the HM Prison Barwon, north of Windermere Road and west of Blairs Road</p> <p>Hovells Creek floodplain & Lara West: Widespread flooding north to the town having impacts on farmlands. Overland flows at West Gateway impact on several properties. Two houses are flooded above floor at Station Lake Road.</p> <p>Lara West, Elcho Park & Elcho Drain: Widespread floodwaters along waterways impact farmlands and properties. Elcho Park has widespread flooding across the golf course.</p> <p>Hovells Creek through Lara: Flooding is confined to a narrow floodplain along Hovells Creek on most of the study area.</p> <p>Lara East: Land between Lockyers Road and McClelland Avenue is partially overtopped.</p> <p>Avalon Road Catchment (Mill Road to Princes Freeway): The floodwater flows across farmland from upstream until Old Melbourne Road. Floodwater breaks out of waterways and spread across farmlands south of Princes Freeway</p>	<ul style="list-style-type: none"> ■ Peak School Road overtopped (depth <0.2m). ■ Peak School Road at Duggans Lane bridge (depth >1m). ■ Windermere Road cut at Blairs Road (depth >1.5m). ■ Windermere Road overtopped east of Forest Rd North (depth <0.1m). ■ O'Hallorans Rd overtopped near Windermere Rd (depth <0.3m). ■ Kees Road overtopped near Windermere Rd (depth <0.1m). ■ Forest Rd North overtopped north of Peak School Rd (depth <0.2m). ■ Forest Road South overtopped near Canterbury Rd (depth <0.1m). ■ Flinders Avenue overtopped near Plains Road (depth >0.3m). ■ Flinders Avenue overtopped for 50m east of Hovells Creek (depth < 0.1m). ■ Flinders Avenue cut at Hovells Creek (depth > 0.5m). ■ Mill Road inundated south to Peak School Road (depth < 0.5m). ■ Rennie Street cut at Hovells Creek (depth > 0.5m). ■ Old Melbourne Road overtopped near McIntyre Rd (depth < 0.1m).

R06_V05_Project_Summary_Report.docx

10.3 Summary

The flood intelligence report was compiled using existing resources combined with the hydrological and hydraulic flood modelling undertaken as part of this project. The report aimed to provide a standalone document to provide information on flood behaviour, design flood extents and potential consequences related to water levels at the existing streamflow gauges on Hovells Creek. Flood warning is limited due to the relatively short warning time prior to riverine flooding from Hovells Creek occurring in Lara following heavy rainfall in the Hovells Creek catchment. Stormwater flood warning is also limited and is currently issued as a Severe Weather Warning or Severe Thunderstorm Warning by BoM. The report was also developed in a manner that will allow for inputs into an update of the MFEP and the Lara Flood Guide in conjunction with the VicSES.

The Flood Intelligence component of the study should not only inform staff and volunteers involved in emergency management, but to also raise awareness to the broader community of flood risk within the study area. To enable information from this study to be shared, it is recommended that the City undertake the following:

- Review the information within the Flood Warning and Intelligence Report to undertake an update of the MFEP
- Flood mapping outputs and information from the study be considered for a planning scheme amendment to update current planning controls.

Consider the flood information to inform any designation of flood prone land.

- Use the available flood mapping to develop the online Lara Flood Report portal to improve flood preparedness and awareness within the community. (An example of the portal can be found here: www.floodreport.com.au). It is noted that this has been funded as part of this project.

General information and resources providing information on the Hovells Creek and Avalon Road/Austin Swamp Catchments can be found at:

- Lara Local Guide – VicSES
 - <https://www.ses.vic.gov.au/documents/112015/135106/Lara+Local+Flood+Guide-pdf/7e6d23d2-3733-4467-9fae-f0063cb131a3>
- City of Greater Geelong Municipal Flood Emergency Plan
- Victorian State Emergency Service - Flood Safe (General Information)
 - <https://www.ses.vic.gov.au/get-ready/floodsafe>
- City of Greater Geelong – Emergency Information
 - <https://www.geelongaustralia.com.au/em/floods/article/item/8cb670e83e30ce8.aspx>

11 LAND USE AND PLANNING CONTROLS

11.1 Overview

The CCMA and the City have a responsibility to assess and if possible, treat flood risk. In some cases, flood risk is unable to be reduced or eliminated by structural means. In Lara the result of the flood investigation indicates a widely spread flooding risk which is difficult and costly to manage with typical structural mitigation measures. Where residual risk remains, planning and building controls provide an important role in ensuring that development within areas known to be at risk is appropriately managed and measures are taken to ensure potential damage and loss of life mitigated.

The Victoria Planning Provisions (VPPs) provide guidance for the use and development of land that is affected by inundation from floodwaters by way of several planning zones and overlay controls. These available controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

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

Guidance for applying flood controls to Planning Schemes is available from the Department of Planning and Community Development's (DPCD) Practice Note on Applying Flood Controls in Planning Schemes. The objective of the State Planning Policy Framework⁶ for Floodplain Management is to assist in the protection of:

- Life, property and community infrastructure from flood hazard.
- The natural flood-carrying capacity of rivers, streams and floodways.
- The flood storage function of floodplains and waterways.
- Floodplain areas of environmental significance or of importance to river health.

11.2 Existing Controls

An assessment of the existing planning controls for Lara, along with the broader Hovells Creek and Avalon catchments was undertaken by Water Technology and Planning and Environmental Design.

The current controls include both planning scheme zones and overlays, along with building controls. Within the study area planning overlays including the Floodway Overlay (FO), Land Subject to Inundation Overlay (LSIO) and Special Building Overlay (SBO) have been applied. There are also several areas within the study area where Urban Floodway Zone (UFZ) applies.

The current zones and overlays within the Lara area do not cover the extent of the known flood risk. As shown in Figure 11-1 and Figure 11-2 the designated flood prone layer (Building Regulations) covers a broader area than that of the existing planning controls.

The current planning and building controls as they apply within the study area are shown in Figure 11-1 and Figure 11-2.

⁶ Victorian Floodplain Management Strategy (2016) , accessed from: https://www.water.vic.gov.au/_data/assets/pdf_file/0021/53715/Victorian-Floodplain-Management-Strategy-Part-1-to-5.pdf

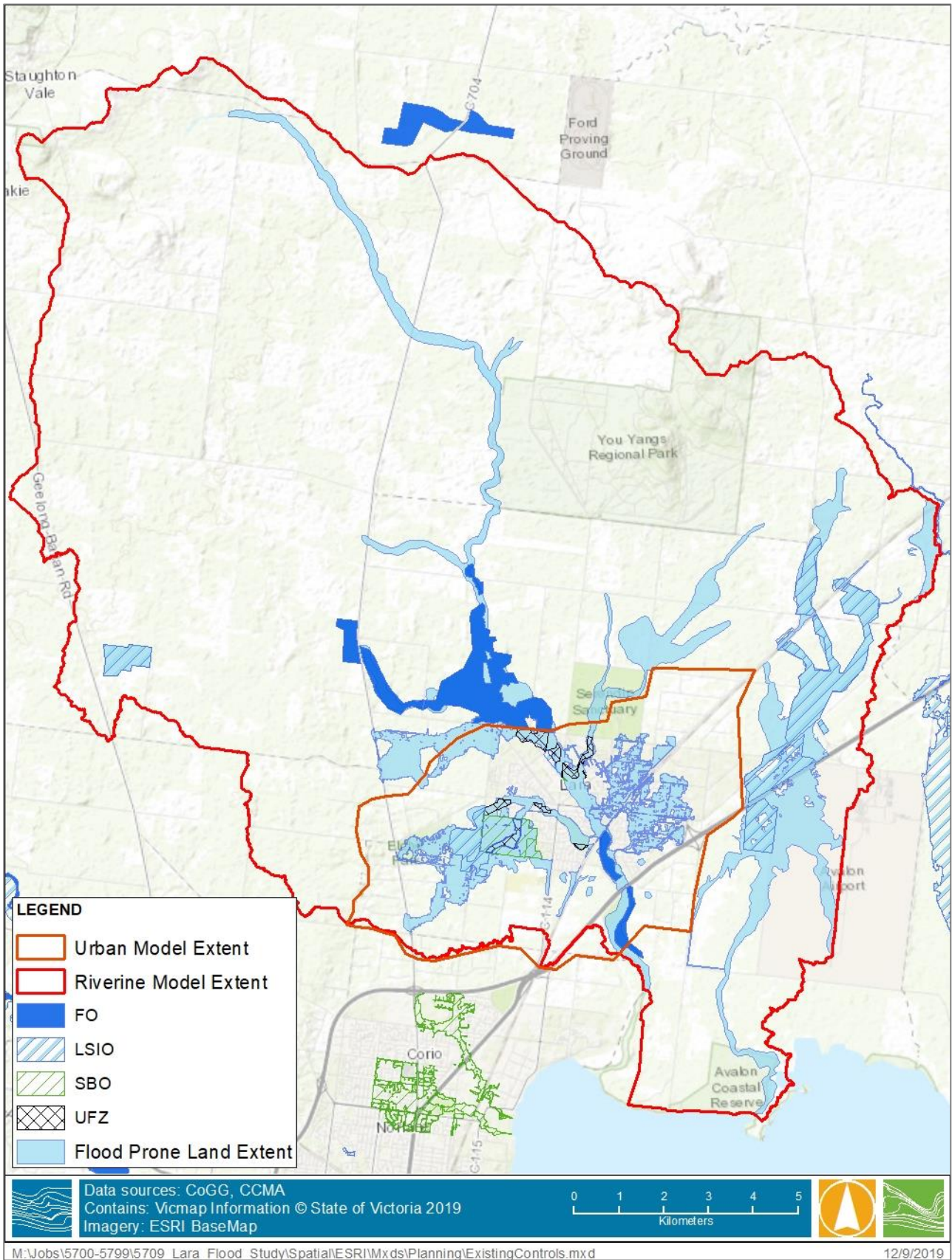


FIGURE 11-1 EXISTING FLOOD RELATED PLANNING CONTROLS – STUDY AREA

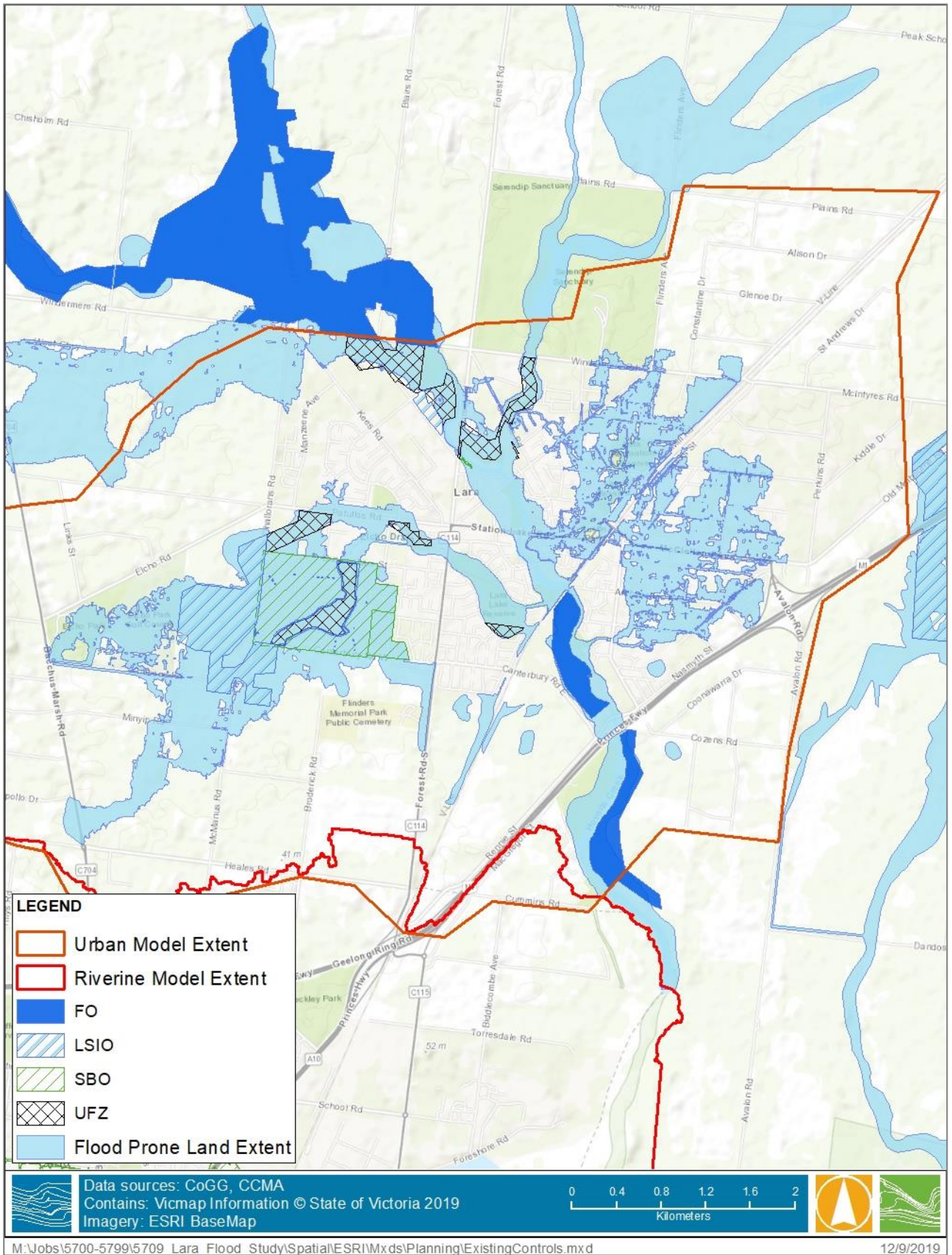


FIGURE 11-2 EXISTING FLOOD RELATED PLANNING CONTROLS – LARA TOWNSHIP

11.3 Identified Risk and Available Controls

The State Planning Policy framework floodplain management policy currently recognise the 1% AEP flood event as the design flood event by which planning and building controls should apply. There are a number of available land use and development controls which enable authorities to regulate development so that the likelihood and consequences of flooding to community safety and property are considered and where possible minimised.

In assessing how controls should be applied within Lara Study Area, consideration must be given to both the extent of the 1% AEP flood event as produced by the study result and the nature of the flood risk. Each of the available flood provisions (VPP) provides differing degrees of flexibility for the development of flood affected land which directly relates to the identified flood risk. Available controls include:

- **Land Subject to Inundation Overlay (LSIO)** – defines the floodplain fringe and lower hazard areas within the 1% AEP flood extent

Purpose: Land Subject to Inundation Overlays are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known as floodplains. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths and velocities are typically lower.

- **Floodway Overlay (FO)**– defines the high hazard portion of the floodplain

Purpose: Floodway Overlays apply to land that's identified as carrying active flood flows associated with waterways, natural flow paths and drains.⁷ The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.

- **Special Building Overlay (SBO)** – defines flooding within the urban environment from overland flow results from stormwater

*Purpose: The Special Building Overlay (SBO) identifies land in **urban areas** liable to inundation by overland flows that exceed the capacity of the drainage system. The purpose of the SBO is to ensure that future developments allow the free passage of floodwaters, minimise flood damage, are compatible with flood hazard and local drainage conditions, and will not cause a significant rise in flood level or flow velocity.⁸*

- **Urban Floodway Zone (UFZ)** – defines flooding high hazard areas and major flow paths within the urban areas

Purpose: To identify waterways, major flood paths, drainage depressions and high hazard areas within urban areas which have the greatest risk and frequency of being affected by flooding.

It is recommended that the planning scheme and building controls for Lara and the broader study area be updated to reflect the flood risk identified by this project. Selection of the most appropriate planning controls must consider both the nature of the flood risk (riverine or urban stormwater) and the flood hazard in accordance with Australian Rainfall and Runoff safety limits⁹. For the purposes of this assessment, hazard category H1 has been considered to be safe with hazard categories H2-H6 being acknowledged as being unsafe. The delineation between the urban and riverine 1% AEP flood extent is shown in Figure 11-3. The extent of the safe and unsafe flood hazard during the 1% AEP flood event is shown Figure 11-4. A comprehensive assessment of land use and planning controls is addressed in the Flood Warning and Mitigation Report (R04 - Flood Warning and Mitigation Report).

⁷ Corangamite Catchment Management Authority knowledge base website.
http://www.ccmaknowledgebase.vic.gov.au/flood/cb_pages/floodplain_management.php

⁸ City of Greater Geelong Planning Website:
<https://www.geelongaustralia.com.au/sbo/article/item/8d4024c6c179322.aspx>

⁹ Australian Rainfall and Runoff, www.arr.org.au

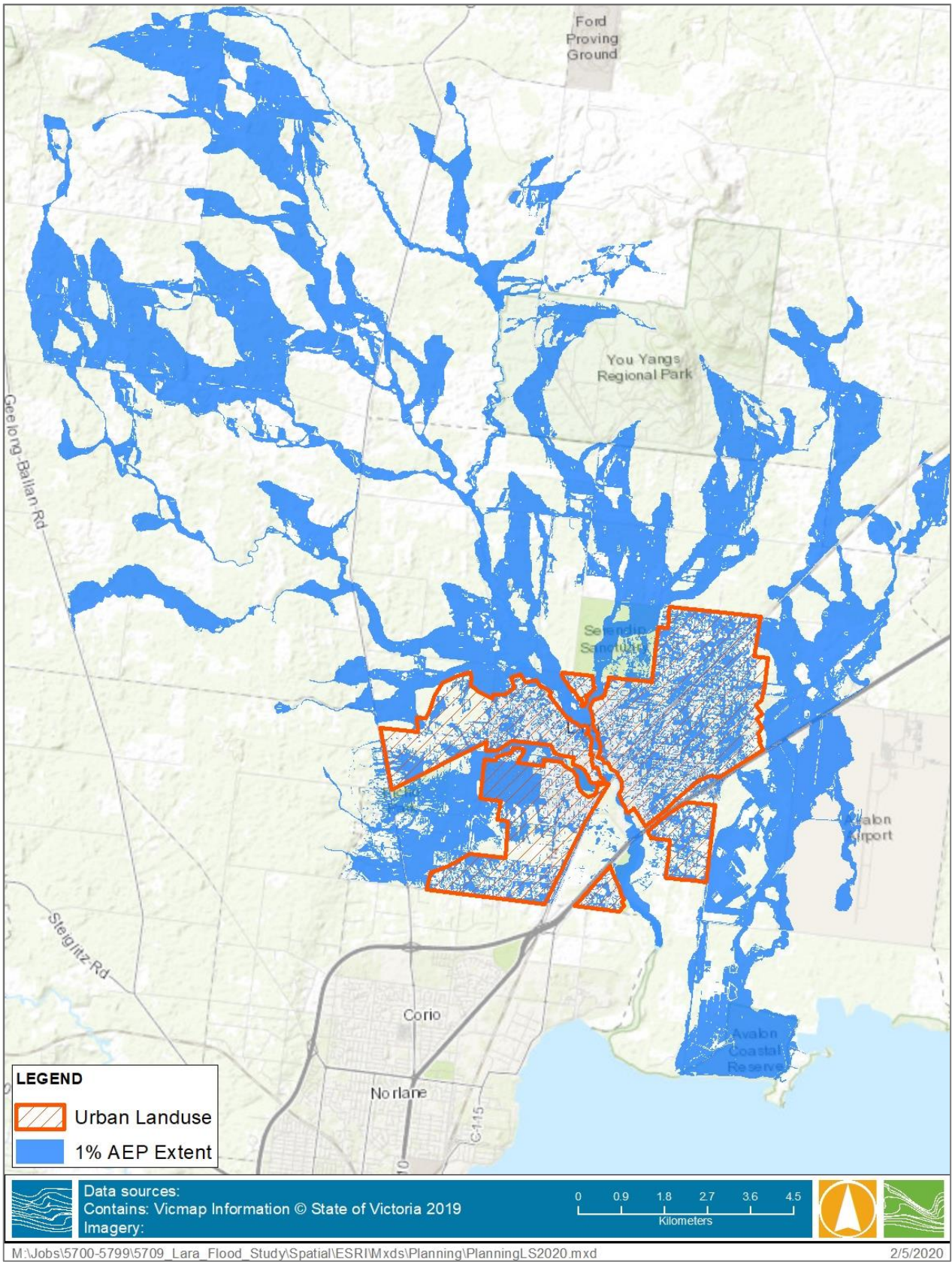


FIGURE 11-3 COMBINED RIVERINE & STORMWATER 1% AEP EXTENT

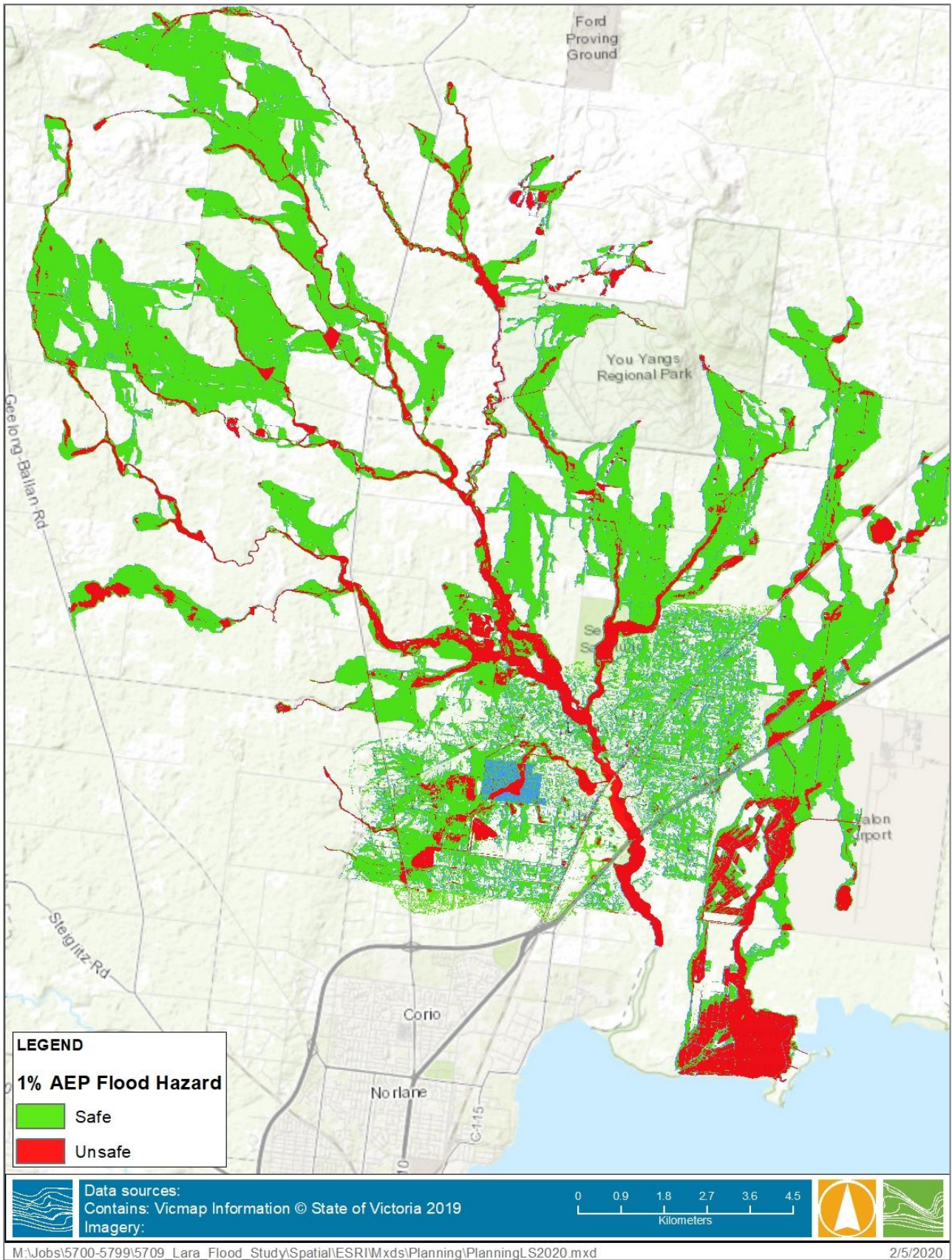


FIGURE 11-4 MODELLED FLOOD HAZARD (ARR2019 CLASSIFICATION)

12 RECOMMENDATIONS

Recommendations from the Lara Flood Study have been separated into the agencies responsible for their fulfilment, these are as follows:

■ **City of Greater Geelong**

- Endorse the flood study with the aim of adopting the flood study recommendations.
- Undertake a planning scheme amendment to update the flood related planning overlays to introduce new SBO, LSIO and FO mapping along with UFZ into the planning scheme.
- Consider the designation of flood prone land as provisioned under the Building Act
- Continue to include Climate Change as a consideration in understanding and assessing flood risk.
- Liaise with DELWP regarding measures to respond to emerging risks arising from increased extreme weather events. It is noted that the City currently has a Climate Change Adaption Strategy which seeks to respond to current climate science and policy.
- Discuss with the Bureau of Meteorology and CCMA for the consideration of the:
 - Potential Flash Flood Warning system for Lara.
 - Review of existing water level boards along road networks impacted.
- Review the information within the Flood Warning and Intelligence Report to undertake an update of the MFEP.
- Use the available flood mapping to develop the online Lara Flood Report portal. It is noted that this has been funded as part of this project.
- Undertake a review of the current response, maintenance and operations documentation with Council staff.
- Ensure adequate maintenance of pumps/training is carried out on regular basis.
- Develop maintenance schedule for large pipes and pipes with low design grade.
- Assess funding options to pursue a mitigation option discussed in this report.

■ **Corangamite Catchment Management Authority**

- Endorse the flood study and use the flood mapping data to inform floodplain risk management decisions.
- Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
- Assess the need to develop Flood Warning System for Hovells Creek at Lara based on the information contained within the Flood Warning and Intelligence Report.

■ **Victoria State Emergency Service** with assistance from Corangamite CMA and the City:

- Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
- Update Local Flood Guide once new template is developed.
- Assist the City in updating the MFEP.
- Review the updated MFEP (when available) and discuss with the City the changes proposed by Water Technology prior to adopting the revised document.

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