PYRENEES SHIRE

Raglan Flood Investigation

Final Report on Flood Warning Assessment

Revision 4
July 2020

Catchment Simulation Solutions

Raglan Flood Investigation

Final Report on Flood Warning and Flood Intelligence Documentation

Client	Client Representative
Pyrenees Shire Council	Renee Robinson

REVISION / REVIEW HISTORY

Revision #	Description	Prepared by	Reviewed by
1	Draft report for Council, CMA & external third-party review	T. Morrison	I. Testoni
2	Update on Version 1 based on discussion with Council and CMA	T. Morrison	N/A
3	Update on Version 2 based on feedback from Council and CMA	T. Morrison	L Davis
4	Final incorporating CMA comment 30/07/2020	T. Morrison	N/A

DISTRIBUTION

Revision	Distribution List	Date Issued	Number of Copies
1	Pyrenees Shire Council	11/06/2020	PDF
2	Pyrenees Shire Council	18/06/2020	PDF
3	Pyrenees Shire Council	20/07/2020	PDF
4	Pyrenees Shire Council	30/07/2020	PDF

Catchment Simulation Solutions

Suite 10.01
70 Phillip Street
Sydney, NSW, 2000

(02) 8355 5500 tim.morrison@csse.com.au

(02) 8355 5505 www.csse.com.au

File Reference: Raglan Flood Investigation - Flood Warning Assessment Final.docx

TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION

1.1 Overview

The Raglan Flood Investigation was commissioned by Pyrenees Shire Council with financial support from the Victorian and Australian Governments as well as technical support from Glenelg Hopkins Catchment Management Authority (GHCMA). The purpose of the Raglan Flood Investigation is to develop information fundamental to provision of effective flood controls, flood response planning and building community resilience to flooding. There are currently no flood related planning controls for Raglan and no high reliability flood information to understand the extent of flood risk.

The following report provides a summary of the flood warning and flood intelligence investigations undertaken as part of the study, in particular it includes:

- Description of flood warning types
- Assessment of flood warning potential at Raglan
- Flood intelligence products, such as flood/no flood tool, flood intelligence card that can be utilised by Council and the SES in flood planning and response

1.2 Catchment Description

The settlement of Raglan is located within the Fiery Creek catchment. Fiery Creek generally flows in a north-south direction and drains a catchment of just under 50 square kilometres to Raglan. The catchment upstream of Raglan comprises rural residential development, cleared grazing land and forested areas. In addition to Fiery Creek, there are a number of smaller unnamed tributaries that drain through Raglan and into Fiery Creek.

Raglan is home to around 230 people living primarily on rural residential lots comprising mostly low set single storey houses (Australian Bureau of Statistics, 2016). Most properties in Raglan also have other significant infrastructure such as large sheds. A public hall is also located within Raglan.

There is limited stormwater infrastructure within the town with no formalised stormwater system. The roadside areas are most commonly drained by roadside ditches which convey runoff to dedicated cross-drainage structures (e.g., culverts).

The floodplain is traversed by a number of significant roads, including Raglan-Elmhurst Road which is the major transportation link between Raglan and Elmhurst. This particular road embankment is typically elevated around 300 mm above the adjoining floodplain elevation and forms a significant hydraulic control. The Western Highway is located about 6 kilometres south of Raglan and forms the major east-west link between Beaufort and Ararat. The Western Highway roadway embankment also serves as a significant hydraulic control, being elevated by more than 3 metres in some parts above the floodplain.

The Fiery Creek channel in the vicinity of Raglan is a natural channel of variable width/depth and condition. The creek width varies from around 6 metres upstream of Raglan to around 20 metres downstream of Raglan. Although much of the creek is well vegetated with good integrity, other sections of the creek show notable erosion. This is particularly evident directly north of Old Beaufort Road.

The study area for the flooding investigation extends along Fiery Creek from Pitchers Lane (located about 3 km upstream of Raglan) down to the Western Highway (located about 6 km downstream of Raglan). It also incorporates each of the major tributaries draining through Raglan and into Fiery Creek.

2 Flood Warning Systems

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. An effective flood warning system requires integration of a number of components (Australian Government, 2009):

- monitoring of rainfall and river flows that may lead to flooding;
- prediction of flood severity and the time of onset of particular levels of flooding;
- interpretation of the prediction to determine the likely flood impacts on the community;
- construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken;
- dissemination of warning messages;
- response to the warnings by the agencies involved and community members; and,
- review of the warning system after flood events.

Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high benefit-cost ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately.

The Bureau of Meteorology issues a number of products that provide warning of floods, including Severe Weather Warnings for torrential rain and/or flash flooding, and Flood Watches that typically provide 24 to 48 hours' notice that flooding is possible based upon current catchment conditions and forecast rainfall.

The opportunity to enhance the flood warning system was considered for each of the phases of the total flood warning system. The Bureau of Meteorology's new Flash Flood Advisory Resource (FLARE) was used as a resource for this analysis. Flash flooding is defined in FLARE as flooding that occurs within 6 hours of the rainfall commencing. In Raglan this is certainly the case, although for Fiery Creek the peak of the flood occurs around 7 - 9 hours, i.e. flooding starts in less than 6 hours, but does not peak till afterwards. For the small overland flow tributaries through the Raglan settlements, these peak within an hour of rainfall occurring for their critical duration.

The FLARE resources include a method of assessing risk and determining the appropriate level of warning system. Risk is a function of Likelihood (how often a significant flood occurs) and the consequence (what are the impacts of the flood).

FLARE does not specifically state what a "significant" flash flood is, however in the case of Raglan there is no above floor flooding in events smaller than the 1% AEP, therefore this event was adopted which leads to a "Likelihood" of Unlikely (Every 50 – 100 years) to Rare (> 100 years).

In terms of consequences, FLARE divides impacts into Social, Environmental and Economic and outlines consequences across four categories; negligible, low, medium and high. Assessment of the consequences has been undertaken from analysis of the flood study results

and the 2012 event, which approached a 1% AEP event. The results are presented in **Table 1**, the highest adopted rating is used for the overall assessment which is "Low".

Table 1 FLARE Consequence Assessment

Assessment Category	Adopted Rating	Consequences for that Rating
Social	Low	Minimal danger to life. Isolated and temporary cases of reduced services within the community Repairable damage to objects of cultural significance Impacts within emotional and psychological capacity of the community
Environment	Low	Isolated cases of environmental damage One off Recovery efforts required
Economic	Low	Disruptions at business level leading to isolated cases of loss of employment Isolated cases of short to mid-term failure of infrastructure and service delivery. Repairs undertaken in 1 week to 1 month Localised inconvenience Isolated repairable damage to residential or commercial properties

Combining the Unlikely likelihood, with a Low consequence. The FLARE methodology assigns a risk rating of "Very Low" for Raglan. **Table 2** outlines the recommended minimum components for a flood warning system for a "very low" risk area. These requirements are largely met with the standard BoM products that are issued and do not list any site-specific requirements.

While this is the minimum recommended components, the responsible agencies may choose to adopt a more advanced system. For example, if the risk rating were increased to "Low" then the minimum requirements would include additional aspects such as rainfall triggers for action, specific messages and communication methods linked to those triggers which would then lead to more precautionary actions taken by the local community, which could then be enhanced through a simple local public awareness and education program.

Some of these more advanced elements that would be components of a "Low" rated system have been investigated as part of this study.

Table 2 Components of an advanced flash flood warning system

Total Flood Warning System element	Flash Flood Warning System components
Monitoring and Prediction	• Severe weather warnings • Severe thunderstorm warnings • Flood Watches (though not always issued ahead of a low flood risk event) • Access to real-time information from weather radar (where coverage exists).
Interpretation	• Not Required
Message Construction	• Standard Bureau messages for weather warnings and flood watches. • No location specific flash flood warnings issued.
Communication	• Bureau warnings and information available on the web, and broadcast by the media.
Response	• Emergency Services respond to Requests For Assistance. • Typically reactive response to deteriorating conditions. • Some precautionary actions may be taken by the community based on the Bureau warnings.
Review	• Usually limited to the performance of the Bureau's warning services and the response of the Emergency Services to handling Requests for Assistance.

Source: FLARE (Bureau of Meteorology)

3 Flood Warning System Considerations

3.1 Raglan Flood Timing and Behaviour

To get the most out of any flood warning system, users need to understand the behaviour of flooding in the study area. The primary flood mechanism is overbank flooding of Fiery Creek. There is an additional secondary flood mechanism, where overland flow and ill defined tributaries flow through the settlement towards Fiery Creek. These tributaries have a much smaller catchment, therefore respond much quicker to rainfall than Fiery Creek. The critical duration (i.e. the storm that produces the greatest extent of flooding for a given probability) is around 9 – 12 hours for Fiery Creek and 1 – 3 hours for the small tributaries.

In terms of travel time, the average time between peaks between Pitchers Lane (the top of the study area) and Raglan Elmhurst Road, the approximate centre of the settlement, is approximately 30 minutes. Moving upstream, in the 9 hour 1% AEP event, areas that capture approximately 30% of the catchment area peak approximately 2 hours prior to Raglan-Elmhurst Rd.

Flooding across the study is fairly widespread in large events, however given the limited development and fairly shallow nature of flooding outside of the creek, there is limited above floor flooding. In the 1% AEP event, it is estimated that only one property will have above floor flooding, while in the PMF there is four properties with above floor flooding.

In lieu of significant above floor flooding, the main issue in Raglan is the flooding of the road network. In particular the Raglan-Elmhurst Road, which is the main road through and connecting Raglan is flooded for potentially long periods (approximately 12 hours in the 2012 event). Other roads flooded by the tributaries will potentially be flooded prior to the Raglan-Elmhurst Rd and the inundation would typically last for a shorter duration.

Inundated roads pose a risk to life as most of flood rescues and half of all flood deaths occur to people trapped in cars. Recent research by Risk Frontiers (Risk Frontiers, 2017), on the characteristics of crossings where vehicle related flood fatalities occurred, shows that the Raglan-Elmhurst Rd crossing of Fiery Creek has a number of the common characteristics, including; a relatively small catchment size (therefore faster rate of rise) and lack of visible warning signage. These are offset by the side barriers on the road and approaches, where none of the flood fatalities examined by Risk Frontiers occurred where barriers were present.

3.2 Potential Flood Gauge Sites

3.2.1 Water Level Gauges

Gauges are best located upstream of the main area of interest, to provide warning time as the flood travels between the gauge location and the area of interest. Gauges are most often placed on public property, to allow for ease of access for maintenance, and at a stable section of the water course, such as at a bridge or culvert.

Given this, the most appropriate location for any gauging station, moving upstream to downstream would be:

- The E1 Road crossing of Fiery Creek
- Pitchers Lane crossing of Fiery Creek
- Old Beaufort Road bridge abutments
- Raglan Elmhurst Road crossing of Fiery Creek

Placing a gauge is a trade off between the warning time available (the further upstream the better), versus how representative the location is of the flooding behaviour. This can be approximated by comparing the catchment area at the gauge site to the catchment area at the area of interest.

The timing and catchment area values at the selected gauge sites are presented in **Table 3**. The E1 road has a significant lead time, however it only represents a small proportion of the catchment. Pitchers Lane offers a small amount of warning time and represents the majority of the catchment, while Old Beaufort Rd offers minimal warning time but is effectively the whole catchment.

Given the high spatial variability of rainfall, and the lack of detailed information about the distribution of rainfall in the Fiery Creek catchment, using the E1 Road as a site would potentially lead to significant under or over-estimation of the flooding, as flows at this location may not be representative of the overall catchment. At Pitchers Lane, it could be reasonably expected that flow here would be representative of the flooding in Raglan, however the warning time is fairly minimal (not a lot of flood preparation can be effectively undertaken in 30 minutes). Similarly for the Old Beaufort Road.

Table 3 Key statistics for potential gauge sites

Location	Approximate Travel Time to Raglan-Elmhurst Road	Percentage of the catchment area at Raglan-Elmshrst
E1 Road	2 hours	32%
Pitchers Lane	30 minutes	72%
Old Beaufort Road	5 - 10 minutes	Greater than 95%

3.2.2 Rainfall Gauges

There is currently a daily read rainfall gauge within the Fiery Creek study area, however, given the critical duration for the creek is significantly less than this, it is likely that the rain will have fallen and the flood will have occurred between the daily readings. Therefore, for use in flood warning, pluviography gauges are required which record real time rainfall.

The Ben Nevis gauge is located just to the north west of the catchment and has been used in the model calibration for disaggregation of daily data. This was relatively successful, however it is likely that there will be some flood events that are not effectively captured by gauges outside of the catchment.

It is expected that the majority of runoff producing rainfall occurs in the steeper parts that ring the edge of the Fiery Creek catchment, therefore any new gauge would best be placed either in or near to these areas. There is likely no "best" location as rainfall is often highly spatially variable, and experiments have shown that gauges placed only a few hundred metres apart can produce significantly different rainfall depths.

There are a number of other requirements around siting new rainfall gauges, such as being sited twice the height away from the nearest trees. These requirements are documented in the BoM observation specification (2013). Other considerations need to be made to access for maintenance and repair and potential for vandalism. Desktop analysis of the upper catchment shows that appropriate sites would be:

- Richards Campground, although it may be difficult to appropriately site the gauge with surrounding tree cover
- The Cave Hill Creek site, although this is private property and permission and access would need to be negotiated with the landowner

In terms of warning time, it is unlikely that any rain gauge will produce sufficient warning time for the flash flood tributaries through town, however for the Fiery Creek, it is possible that a warning produced by fallen rainfall would provide some time for residents to prepare for flooding. The Flood – No Flood tool presented in Appendix A can be used to relate the fallen rainfall depths over different durations to the design flood extents.

For the modelled 9 hour critical duration 1% AEP, the peak of the flood occurs approximately 9 hours after the onset of rain. Therefore if rainfall is trending along one of the flood lines in the Flood / No Flood tool for several hours, then this could be used to predict flooding with a few hours warning. E.g. if at 5 hours after rainfall onset the depths show a significant flood occurring on the Flood / No Flood tool, then it can be assumed that in 3 – 4 hours that flooding will occur, and residents can be warned.

3.3 Forecast Rainfall

Forecast rainfall is provided by BoM, this would provide additional warning time however it can often be unreliable and lead to false positives (i.e. predicted flooding which does not eventuate) and occasionally false negatives. Forecast rainfall is available on a state wide basis for a range of selected time periods. No specific forecast is provided for the Fiery Creek Catchment.

BoM also produces a range of generic warning products, such as a flood watch, which indicates potential for flooding based on forecast rainfall and has a high degree of uncertainty. A flood warning can then also be issued, typically closer to the rainfall time and therefore more certain. For the Fiery Creek catchment, only a generalised flood warning would be provided with no quantitative data to indicate the size of the flood.

3.4 Community Education

Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

> *'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced'* (Keys, 2002).

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not consisting only of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experiential learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event de-briefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and planning; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain gains that have been made.

The high level of detail available from the Raglan Flood Investigation also makes it possible to prepare customised flood information flyers, fridge magnets etc for individual properties.

These flyers/magnets can be printed by specialist printers using mail merge techniques to provide property level information for all potentially flood liable properties. Alternatively, the flyers/magnets can be generated via a website and individual property owners can print their own. Information that could be potentially included on a customised flyer/magnet may include:

- A river gauge diagram (for the Raglan – Elmhurst Rd) showing the peaks of past floods and information on the gauge level typically coinciding with any cut of the evacuation route for the property.
- The closest evacuation centre, approximate driving distance and even the best route. This could even be presented as a map. However, given that the access from Raglan is likely to be cut in areas beyond the study extent, it is likely that the best action may be to shelter in place (this would need to be confirmed with the SES as part of the MFEP).
- Identification of any special risk factors such as being in an area that may get surrounded by floodwaters or an area at risk of flash flooding, such as the overland flow areas through the settlement that will flood much quicker than the Fiery Creek.

Community education needs to come prior to any flood and needs to be an integral part of any flood warning system. For example, if the residents receive an SMS or door-knock from emergency services, but do not know how to interpret the message, then they may inadvertently put themselves at greater danger.

3.5 Typical System Type and Costing

The following systems are typically used in Australia;

- Total Flood Warning System: This is typically linked to either a database of flood results or a fast real-time model. Forecasts will be quantitative and provide estimates of depth and velocities across the study area.
- BoM Specification Water Gauge: A BoM specification gauge meets the Flood Warning Infrastructure Standard. This will provide current water levels and be published on the BoM website. These can also be easily setup to provide an automated SMS message to those who have opted in.
- BoM Specification Rain Gauge: Similar to the above, although linked to a rain gauge. Any alert would be based on fallen rainfall rather than a water level
- Non-BoM Specification Gauges: Similar to BoM gauges, however these do not meet the specification. These systems are typically significantly cheaper and the main difference is the lack of redundancies in power and communication. E.g. most rely on the 3G network which can often fail during large floods, a BoM specification gauge would have a backup, such as a VHF radio.

- Flashing Warning Sign (linked to a gauge): These need will flash based on a pre-programmed trigger attached to a gauge e.g. when water level reaches a certain height.
- Manual Read Gauge Boards: gauge boards at a location that can be read on site and compared to maps of

The indicative cost for each of these system types is provided in **Table 4.** The amount of detail, and reliability of the system is fairly closely linked to the cost of the system. Note that the BoM has developed it's specification based on their experience in how these gauges operate during a flood, which often presents very harsh conditions for the instrumentation. Non-specification gauges have a significantly higher probability of failure.

Table 4 Indicative cost of commonly used flood warning systems in Australia

Flood Warning Type	Indicative Cost	Source
Total Flood Warning System	$500,000 - $750,000	Published data on the Parramatta NSW and Oakey QLD systems
BoM Specification Water Level Gauge	$50,000	Industry Source
BoM Specification Rain Gauge	$20,000	Industry Source
Non-BoM Specification Water and Rain Gauge	$7,000	Industry Source
Flashing Warning Signs triggered by a water level gauge	$25,000	Industry Source
Manual read gauge boards	$1,000*	Web search

*Assume installed by Council staff

4 Options for Raglan

The FLARE assessment for Raglan suggests that the risk level for Raglan is "very low" which means that the minimum requirements are met with BoM standard products and no local system is required. However, for a relatively low cost, some elements of a "low system" could be further investigated by Council and potentially implemented.

4.1.1 Gauging

- Water Level Gauge: given there is no ideal site that is both representative and provides sufficient travel time, it is not recommended that an automated water level gauge is installed. However, the Raglan-Elmhurst Rd is a common thoroughfare and well known location within the settlement. Manually read gauge boards and perhaps some static flood warning signage would act as both a community education measure and can be easily related to the flood study data.

  Flood depth indicators could be installed at the Raglan – Elmhurst Rd crossing. The depth indicators show the depth of water across the roadway, thereby helping to inform the community about whether the roadway may be safe to cross in a vehicle. However, without any accompanying information to describe the potential dangers associated with crossing flooded roads, the potential success of flood depth indicators can be limited. Furthermore, emergency services advocate not driving through any floodwater regardless of depth as the integrity of the road surface beneath the water cannot be guaranteed. Therefore, there is potential for installation of depth indicators to increase the number of vehicles driving through water which may increase the flood risk.

  Therefore, if this option is pursued it should be supplemented with appropriate signage not to drive through floodwaters and/or other education material

- Rain Gauge: a real time rain gauge (pluviograph) would be useful to provide some advanced warning to emergency responders and Council. These systems can be set up to provide automated alerts through SMS or through online social media platforms based on pre-programmed trigger levels. While three non-specification gauges could be purchased for the price of one specification gauge (and therefore being more representative) there is limited potential locations for gauging sites and there is a high risk of the three gauges failing. Therefore, if the recommendation to install a rain gauge is adopted then it is recommended that a BoM specification gauge is installed.

  A key consideration for any gauge system is the requirement for on-going maintenance, this is often completed annually and would include checking the calibration of the system and battery and other component replacement. Period checks between annual

maintenance can be completed following rainfall by comparing the gauge depth to other nearby gauges. Gauge providers typically also offer maintenance contracts.

The next steps in this process would be for Council to further investigate a rain gauge by discussing with appropriate providers.

4.1.2 Community Education

Pyrenees Shire Council is completing the Upper Avoca Creek, Upper Mt Emu Creek and Raglan Flood Investigations concurrently. It has also completed the Beaufort Flood Study and preliminary flood investigations for Lexton and Waubra. It now has significant information covering the major flood affected centres in the shire that can be used to develop integrated, ongoing flood community education programme that covers all these areas.

5 Flood Warning Conclusions

A flood warning system has been investigated for Raglan using the FLARE methodology provided by the BoM. The outcome is that the risk for Raglan is considered “very low” and the minimum requirements are the standard BoM products with no requirement for a local system.

Despite this, for relatively low cost, elements of a more advanced system can be implemented for a relatively low cost, particularly;

- Gauge boards at the Raglan Elmhurst Road which can be linked to the Flood Intelligence Card provided in Appendix A
- A rain gauge is further investigated by holding discussions with service providers, this can provide automated warnings based on fallen rainfall and appropriate trigger levels
- Council develop and implement a shire wide community flood education program that includes specifically tailored information and events for Raglan. This could be developed and implemented in partnership with the SES.

These measures would decrease the risk to life for the residents of Raglan as well as educate the community as to the risks of flooding.

6 Flood Intelligence Documentation

A range of flood intelligence documentation has been prepared as part of this study to assist Council and other stakeholders, such as the VIC SES prepare for and respond to flooding. The documentation is provided in **Appendix A**, and a brief description in the following sections.

6.1 Flood Intelligence Card

A flood intelligence card (FIC) has been prepared for the Raglan – Elmhurst Road crossing of Fiery Creek as this is the recommended location for any potential future gauge.

Flood intelligence cards (FIC) essentially outline the flood impacts expected for a range of different water levels at a gauging site. These impacts are expressed in terms of access (i.e. when roads are inundated and cut) and residential flooding. Other key features such as the bridge deck level are also added to make the reported flood levels relatable to easily observable features.

Currently there is no gauge at Raglan and therefore the FIC is not useful unless gauge boards are installed and related to the FIC by reducing the depth to AHD. The bridge level could be used as a rudimentary datum in the meantime.

For access, the roads have been broken down into the depth of inundation across the road, particularly;

- High hazard flood waters
- Greater than 0.3 m depth, which is unlikely to be trafficable to most vehicles and should not be encouraged by any vehicles
- 0.1 to 0.3 metres depth, which is potentially trafficable to most vehicles but should not be encouraged
- Less than 0.1 m, which is likely to be trafficable to most vehicles, but should not be encouraged

6.2 Flood / No Flood Tool

A Flood / No Flood tool has been developed for Raglan using the Intensity-Frequency-Duration curves. This tool can be used to relate the fallen rainfall to potential flood impacts by looking up the depth of rainfall that has occurred over the time that has occurred since rainfall has begun.

This method is fairly approximate and will be conservative in all durations except for the critical duration. For example, while 130 mm over 30 hours and 45 mm over 1 hour are both 1% AEP rainfalls, these are both likely to produce smaller flood extents than the critical duration for Fiery Creek (around 9 – 12 hours).

In some instances where the appears to be a storm burst within a longer duration of rainfall, then the time since the storm burst has occurred also needs to be measured. For example, rain may be falling at a non-flood intensity for 12 hours, but then a much more intense storm may occur within that period of rain for a few hours. The time from rainfall beginning for that storm should be read from when the intensity increases, not including the initial 12 hours, while the overall duration of rainfall should also be continuously checked.

6.3 Above floor flooding for Residential Properties

A map has been produced showing the locations of residential properties that have above floor flooding, with each property colour coded based on the design flood event their floor levels first become inundated. During emergency management and evacuation planning, this information can be used to identify the priority properties for evacuation. During a flood event, this information can be related to the Flood / No Flood tool to determine the potential for above floor flooding. The information presented in this figure should also be communicated to the owners of each of the properties as part of the community flood education campaigns.

6.4 Road Inundation Timing and Duration

There are a number of roadways within the Raglan study area which may be required for evacuation or emergency services access during floods. It is important to understand the impacts of flooding on these roads so that appropriate emergency response planning can occur.

An assessment of the location where roadways are first predicted to be overtopped was completed as part of this study as well as the duration that they are overtopped for each event. The roadway overtopping locations are shown as yellow dots in **Appendix A** for the 10% and 1% AEPs as well as the PMF. The time indicated is in hours since the rainfall has begun.

It must be noted that where a culvert goes under a roadway, the peak floodwater depth and level figure indicates the water that is travelling through the culvert under the roadway, not the water that is travelling across the road crest exclusively. Those locations where the roadway does become inundated and is overtopped are included in **Appendix A.**

.

Appendix A – Flood Intelligence Products

Flood Intelligence Card for Raglan – Elmhurst Road

This flood intelligence card has been prepared for the Raglan – Elmhurst Road crossing of the Fiery Creek. Levels have been provided in AHD, if flood markers are to be installed for the crossing then a relationship between the flood mark height and AHD will need to be established and the Flood Intelligence Card updated, for example 3 m depth on the gauge may be equivalent to 373 m AHD.

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts
50.8mm in 12 hours	20%AEP	372.30 mAHD	Following road is **potentially cut to traffic** by floodwater (0.3m to 0.5m): •**Pitchers Lane** – at the Fiery Creek crossing Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m) •**Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd •**Lucardies Road** – at the Fiery Creek crossing Following roads are **subject to minor inundation** due to floodwater (less than 0.1m) •**Stars Road** – 1km north of junction with Western Highway •**Raglan-Elmhurst Road** – 250m east of junction with Dundas Street
60mm in 12 hours	10%AEP	372.54 mAHD	Following road is **potentially cut to traffic** by floodwater (0.3m to 0.5m): •**Pitchers Lane** – at the Fiery Creek crossing Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m) •**Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd •**Lucardies Road** – at the Fiery Creek crossing Following roads are **subject to minor inundation** due to floodwater (less than 0.1m) • **Stars Road** – 1km north of junction with Western Highway • **Raglan-Elmhurst Road** – 250m east of junction with Dundas Street • **Vaughan Street** – Just north of intersection with Raglan – Elmhurst Rd

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts
69.4mm in 12 hours	5%AEP	373.06 mAHD	Following road is subject to floodwater **hazardous to traffic and pedestrian movement** (greater than 0.5m): • **Lucardies Road** – at the Fiery Creek crossing Following roads are **potentially cut to traffic** by floodwater (0.3m to 0.5m): • **Pitchers Lane** – at the Fiery Creek crossing • **Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m) • **Raglan-Elmhurst Road** - 250m east of junction with Dundas Street • **Vaughan Street** – just north of intersection with Raglan-Elmhurst Road • **Stars Road** – 1km north of junction with Western Highway Following roads are **subject to minor inundation** due to floodwater (less than 0.1m) • **Raglan-Mount Cole Road** – just west of junction with Raglan-Elmhurst Road • **Drews Lane** – multiple locations between junctions with Old Beaufort Road and Raglan-Elmhurst Road
		373.40 mAHD	Bottom of the Raglan-Elmhurst bridge at the Fiery Creek crossing
82.8mm in 12 hours	2%AEP	373.80 mAHD	Fiery Creek has broken its banks and overtopped Old Beaufort Rd. Most properties within the confines of Old Beaufort Rd, Raglan-Elmhurst Road and Fiery Creek subject to some below floor flooding. Secondary floodpath created at the over topping of Raglan-Elmhurst Road between Drews Lane and the Fiery Creek bridge crossing. Following roads are subject to floodwater **hazardous to traffic and pedestrian movement** (greater than 0.5m): • **Pitchers Lane** – at the Fiery Creek crossing

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts

			• **Lucardies Road** – at the Fiery Creek crossing
			
			Following roads are **potentially cut to traffic** by floodwater (0.3m to 0.5m):
			• **Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd
			• **Vaughan Street** – just north of intersection with Raglan-Elmhurst Road
			• **Stars Road** – 1km north of junction with Western Highway
			• **Drews Lane** – multiple locations between junctions with Old Beaufort Road and Raglan-Elmhurst Road
			• **Old Beaufort Rd**
			  ○ From Fiery Creek to junction with Drews Lane
			  ○ The remainder subject to floodwater of 0.1m to 0.3m
			
			Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m)
			• **Raglan-Elmhurst Road**
			  ○ 250m east of junction with Dundas Street
			  ○ Between junction with Drews Lane and Fiery Creek bridge crossing
			• **Raglan-Mount Cole Road** – just west of junction with Raglan-Elmhurst Road
			• **Intersection of Drews Lane and Lucardies Road**
			
			Following roads are **subject to minor inundation** due to floodwater (less than 0.1m)
			• **Tip Road** – between junctions with Raglan-Elmhurst Rd and Drews Lane
			• **Intersection of Panthers Road and Lucardies Road**

93.6mm in 12 hours	1%AEP	374.02 mAHD	**Above floor flooding** at: • 15 Tip Rd Following roads are subject to floodwater **hazardous to traffic and pedestrian movement** (greater than 0.5m):

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts
			• **Pitchers Lane** – at the Fiery Creek crossing • **Lucardies Road** – at the Fiery Creek crossing Following roads are **potentially cut to traffic** by floodwater (0.3m to 0.5m): • **Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd • **Vaughan Street** – just north of intersection with Raglan-Elmhurst Road • **Stars Road** – 1km north of junction with Western Highway • **Drews Lane** o multiple locations between junctions with Old Beaufort Road and Raglan-Elmhurst Road o Remainder of Drews Lane subject to inundation less than 0.1m • **Old Beaufort Rd** o From Fiery Creek to junction with Drews Lane o The remainder subject to floodwater of 0.1m to 0.3m • **Raglan-Elmhurst Road** o 250m east of junction with Dundas Street o Between junction with Drews Lane and Fiery Creek bridge crossing Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m) • **Raglan-Mount Cole Road** – just west of junction with Raglan-Elmhurst Road • **Intersection of Drews Lane and Lucardies Road** • **Tip Road** – between junctions with Raglan-Elmhurst Rd and Drews Lane Following roads are **subject to minor inundation** due to floodwater (less than 0.1m) • **Intersection of Panthers Road and Lucardies Road** • **Eurambeen-Raglan Road**
107mm in 12 hours	0.5%AEP	374.17 mAHD	**Above floor flooding** at:

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts

			• 15 Tip Rd
			• 24 Old Beaufort Rd
			
			Following roads are subject to floodwater **hazardous to traffic and pedestrian movement** (greater than 0.5m):
			• **Pitchers Lane** – at the Fiery Creek crossing
			• **Lucardies Road** – at the Fiery Creek crossing
			
			Following roads are **potentially cut to traffic** by floodwater (0.3m to 0.5m):
			• **Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd
			• **Vaughan Street** – just north of intersection with Raglan-Elmhurst Road
			• **Stars Road** – 1km north of junction with Western Highway
			• **Drews Lane**
			  ○ multiple locations between junctions with Old Beaufort Road and Raglan-Elmhurst Road
			  ○ Remainder of Drews Lane subject to inundation less than 0.3m
			• **Old Beaufort Rd**
			  ○ From Fiery Creek to junction with Drews Lane
			  ○ The remainder subject to floodwater of 0.1m to 0.3m
			• **Raglan-Elmhurst Road**
			  ○ 250m east of junction with Dundas Street
			  ○ Between junction with Drews Lane and Fiery Creek bridge crossing
			
			Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m)
			• **Raglan-Mount Cole Road** – just west of junction with Raglan-Elmhurst Road
			• **Intersection of Drews Lane and Lucardies Road**
			• **Tip Road** – between junctions with Raglan-Elmhurst Rd and Drews Lane
			• **Welshes Lane** – between junctions with Drews Lane and Panthers Road

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts
			Following roads are **subject to minor inundation** due to floodwater (less than 0.1m) • **Intersection of Panthers Road and Lucardies Road** • **Eurambeen-Raglan Road**

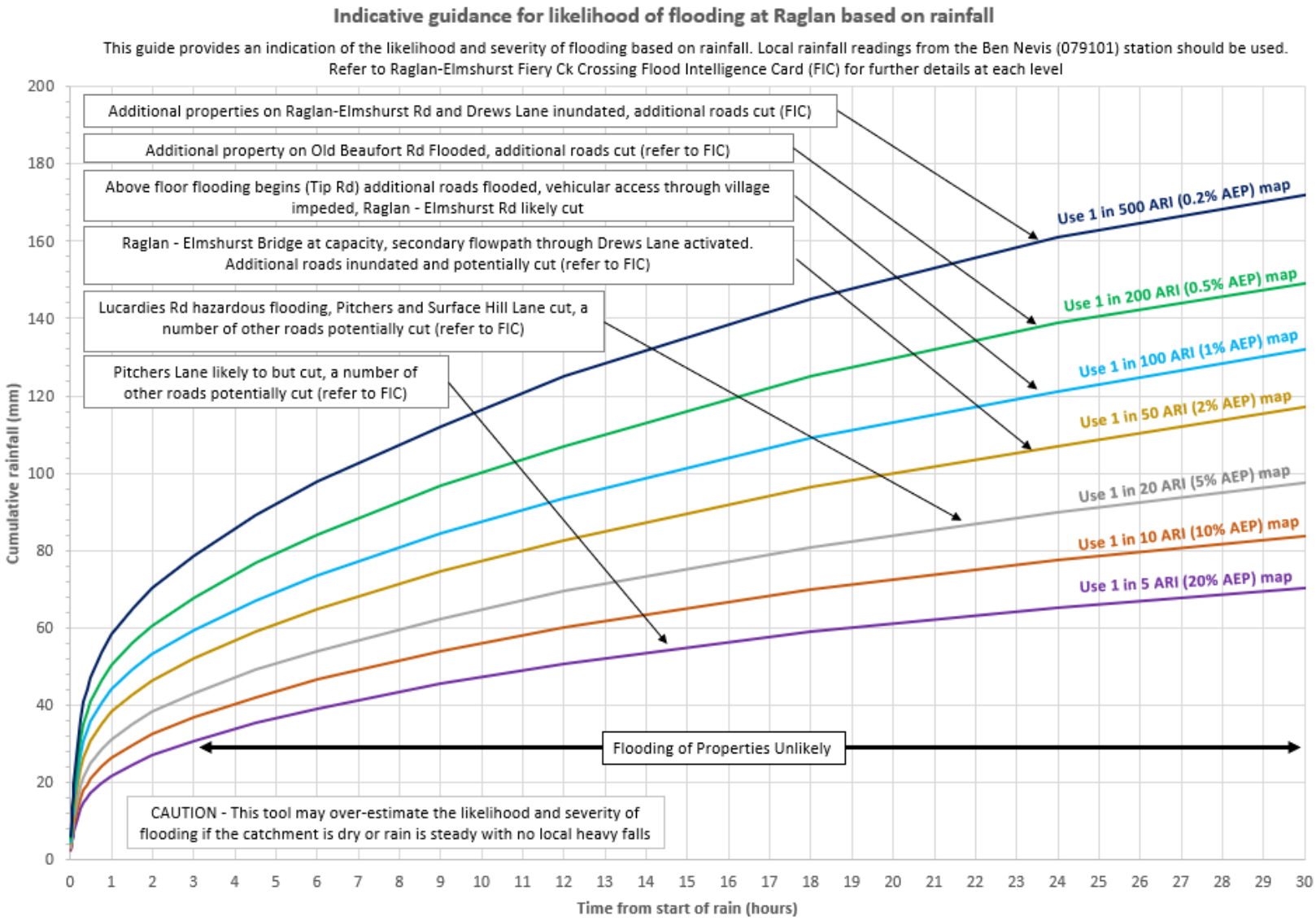
125mm in 12 hours	0.2%AEP	374.30 mAHD	**Above floor flooding** at:
			• 15 Tip Rd
			• 24 Old Beaufort Rd
			• 224 Raglan Elmhurst Rd
			• 189 Drews Lane
			
			Following roads are subject to floodwater **hazardous to traffic and pedestrian movement** (greater than 0.5m):
			• **Pitchers Lane** – at the Fiery Creek crossing
			• **Lucardies Road** – at the Fiery Creek crossing
			• **Drews Lane**
			  ○ multiple locations between junctions with Old Beaufort Road and Raglan-Elmhurst Road
			  ○ Remainder of Drews Lane subject to inundation less than 0.5m
			• **Old Beaufort Rd**
			  ○ From Fiery Creek to junction with Drews Lane
			  ○ The remainder subject to floodwater of 0.1m to 0.3m
			• **Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd
			• **Stars Road** – 1km north of junction with Western Highway
			
			Following roads are **potentially cut to traffic** by floodwater (0.3m to 0.5m):
			• **Vaughan Street** – just north of intersection with Raglan-Elmhurst Road
			• **Raglan-Elmhurst Road**

Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts
			○ 250m east of junction with Dundas Street ○ Between junction with Drews Lane and Fiery Creek bridge crossing • **Tip Road** – between junctions with Raglan-Elmhurst Rd and Drews Lane Following roads are **inundated but potentially still trafficable** (0.1m to 0.3m) • **Raglan-Mount Cole Road** – just west of junction with Raglan-Elmhurst Road • **Intersection of Drews Lane and Lucardies Road** • **Welshes Lane** – between junctions with Drews Lane and Panthers Road • **Intersection of Panthers Road and Lucardies Road** • **Eurambeen-Raglan Road**
380mm in 3 hours	PMF event	374.45 mAHD	**Above floor flooding** at: • 15 Tip Rd • 4 Tip Rd • 224 Raglan Elmhurst Rd • 14 Raglan Elmhurst Rd • 238 Raglan Elmhurst Rd • 4 Old Beaufort Rd • 24 Old Beaufort Rd • 48 Old Beaufort Rd • 72 Old Beaufort Rd • 56 Balls Rd • 154 Drews Lane • 166 Drews Lane • 55 Drews Lane • 174 Drews Lane • 189 Drews Lane
			• 86 Drews Lane

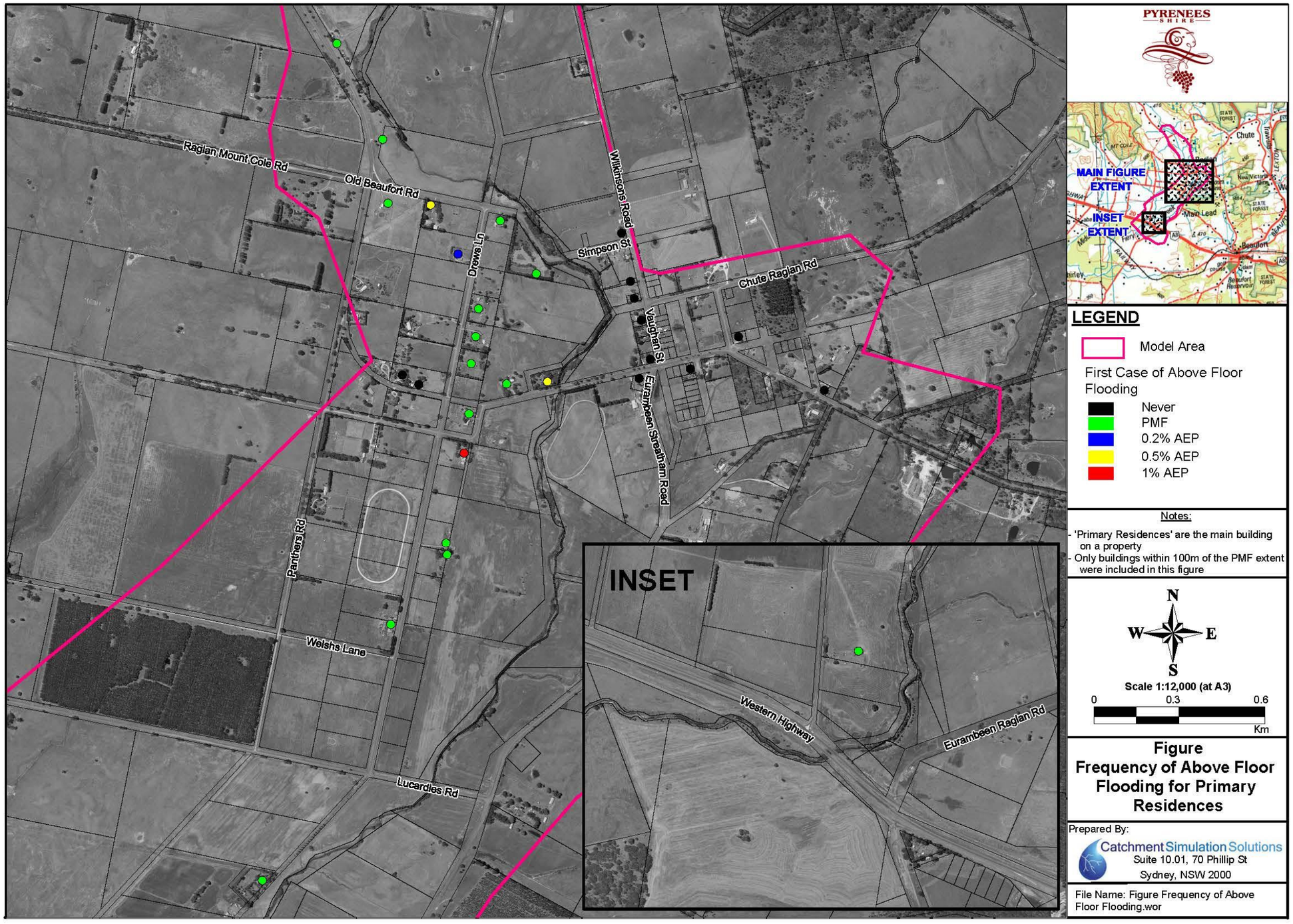
Observed Rainfall	AEP of Flood	River Height (mAHD)	Consequence/Impacts

			Following roads are subject to floodwater **hazardous to traffic and pedestrian movement** (greater than 0.5m):
			• **Pitchers Lane** – at the Fiery Creek crossing
			• **Lucardies Road** – all
			• **Drews Lane -** all
			• **Old Beaufort Rd -** all
			• **Surface Hill Lane** – 250m east of junction with Eurambeen-Streatham Rd
			• **Stars Road** – 1km north of junction with Western Highway
			• **Raglan-Elmhurst Road**
			  ○ Between junction with Drews Lane and junction with Vaughan Street
			  ○ Inundated east from junction with Vaughan Street and junction with Amphitheatre Road between 0.3m and 0.5m
			  ○ Inundated at junction with Old Beaufort Rd between 0.3m and 0.5m
			  ○ Inundated 650m south of junction with Pitchers Lane by 0.1m to 0.3m
			• **Tip Road** – between junctions with Raglan-Elmhurst Rd and Drews Lane
			• **Welshes Lane** – between junctions with Drews Lane and Panthers Road
			• **Raglan-Mount Cole Road** – just west of junction with Raglan-Elmhurst Road
			• **Western Highway**
			
			Following roads are **potentially cut to traffic** by floodwater (0.3m to 0.5m):
			• **Vaughan Street** – just north of intersection with Raglan-Elmhurst Road

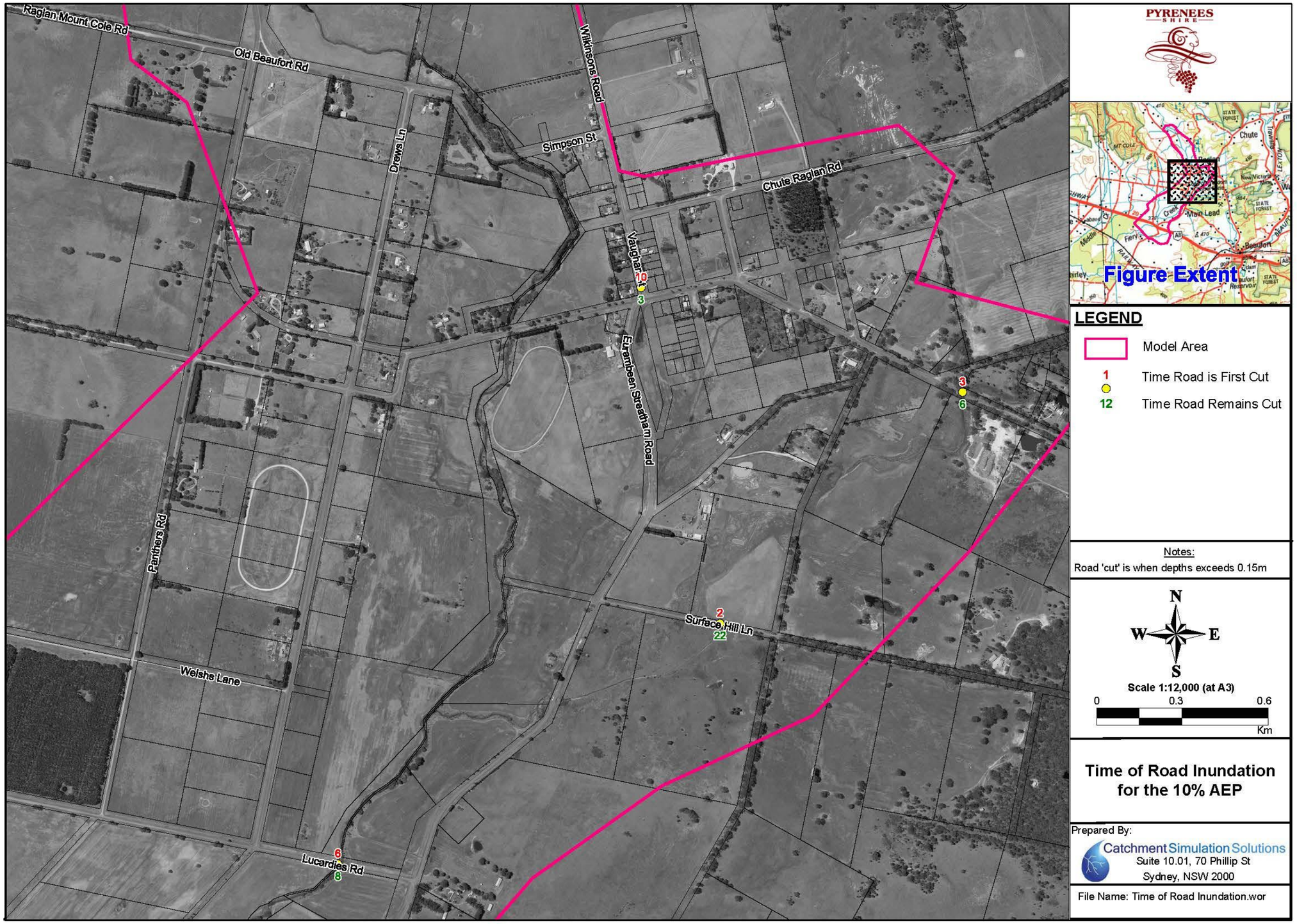
Raglan Flood / No Flood Tool



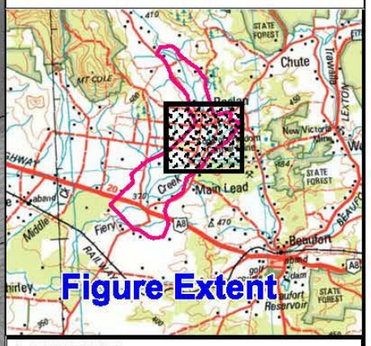
Above floor flooding for Residential Properties



Road Inundation Timing and Durations – Time is in hours since rainfall has begun



PYRENEES SHIRE



LEGEND

- Model Area
- 1 — Time Road is First Cut
- 12 — Time Road Remains Cut

Notes:
Road 'cut' is when depths exceeds 0.15m

N
W E
S

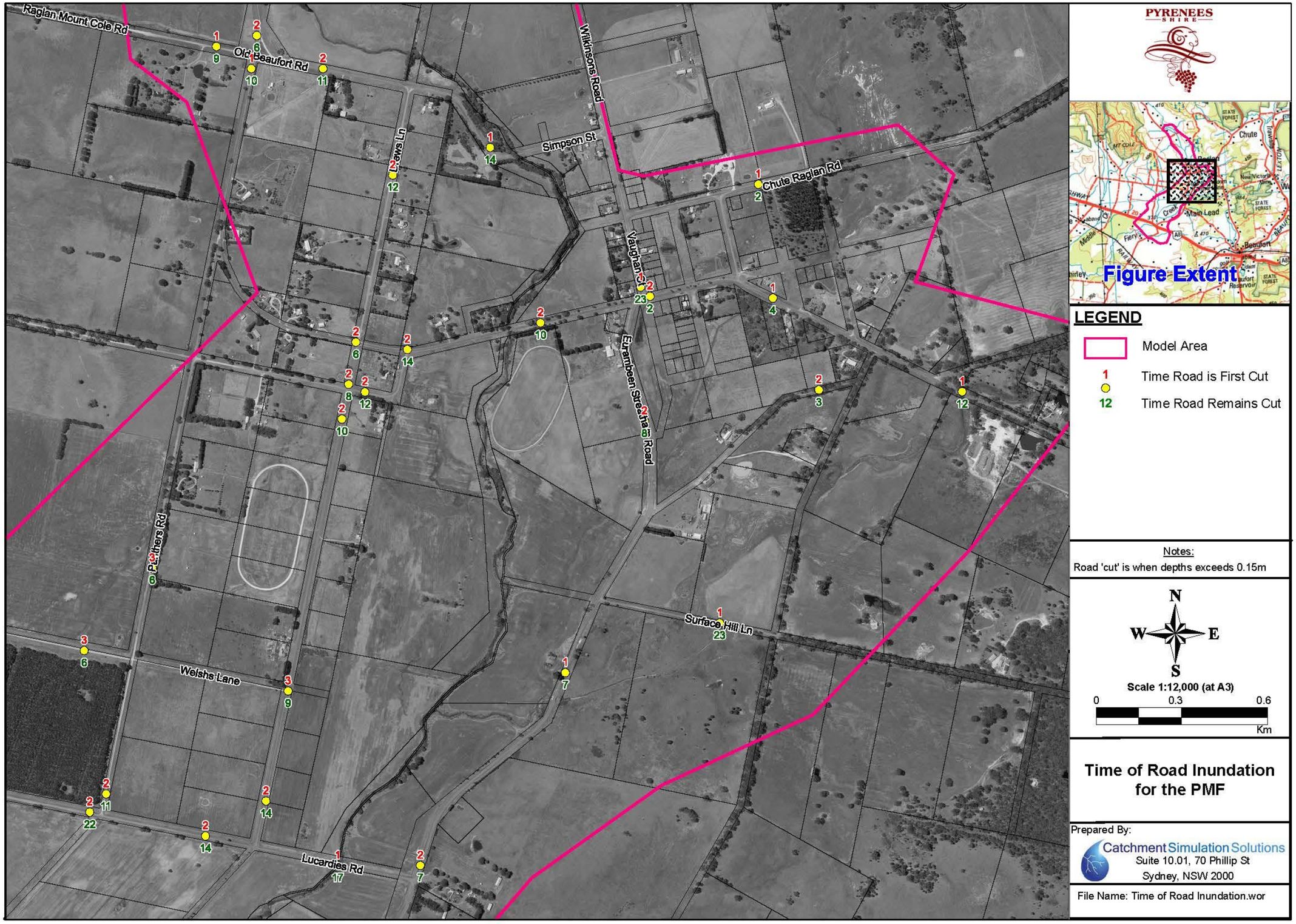
Scale 1:12,000 (at A3)

0 0.3 0.6
Km

Time of Road Inundation for the 1% AEP

Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name: Time of Road Inundation.wor


Raglan Mount Cole Rd
Old Beaufort Rd
Wilkinsons Road
Simpson St
Chute Raglan Rd
Vaughan St
Eurambeen Streatham Road
Surface Hill Ln
Brothers Rd
Welshs Lane
Lucardies Rd
PYRENEES SHIRE
Figure Extent
LEGEND
Model Area
Time Road is First Cut
Time Road Remains Cut
Notes:
Road 'cut' is when depths exceeds 0.15m
N
W
E
S
Scale 1:12,000 (at A3)
0
0.3
0.6
Km
Time of Road Inundation for the PMF
Prepared By:
Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000
File Name: Time of Road Inundation.wor