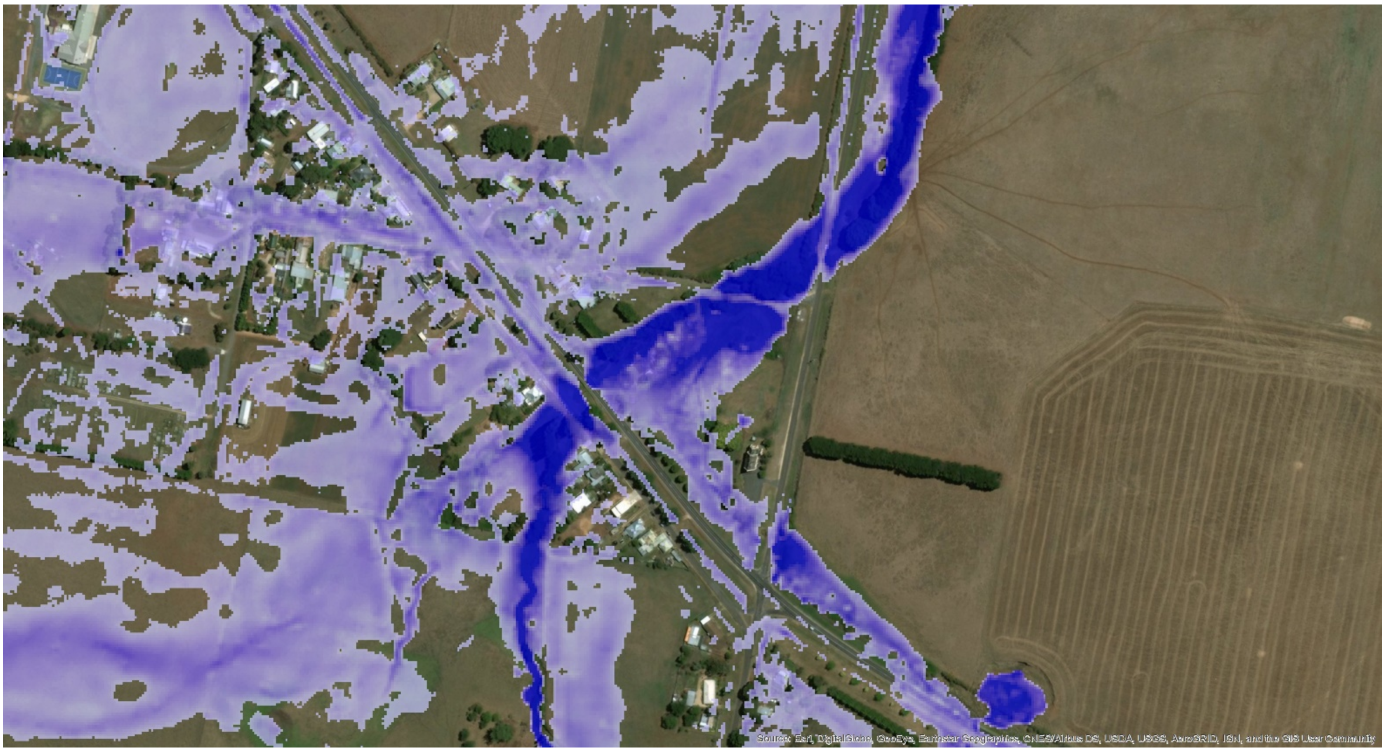

Waubra
Preliminary Flood Study

Report

Prepared For

Pyrenees Shire Council

March 2019

Project Details	Waubra Preliminary Flood Study
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Job Number	18009
Proposal Number	N/A

Document				
Version	Type	Review	Release	Date
1	Draft	N/A	Utilis	24/04/2018
2	Final	Brad Henderson	Utilis	29/03/2019

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1 Introduction

1.1 Study Background

Pyrenees Shire Council (Council) has a number of towns within its Local Government Area that are flood prone, including Waubra. The extent of the flooding and the associated flood risk is largely unknown and this creates difficulties for Council to assess proposed developments with respect to flood issues. As a result, Council is seeking to proceed through the floodplain risk management process (i.e. flood study, floodplain risk management study and plan, plan implementation). However, Council has limited resources and therefore needs to prioritise the towns that have the greatest flood risk.

Council has engaged Utilis and HydroSpatial to undertake a preliminary flood study to determine whether a full flood study is required as well as provide flood risk and flood planning advice for the town.

1.2 Study Objective

The main objectives of the study is to provide an overview of the flood risk within Waubra and determine whether a full flood study, or further improvements to the preliminary flood study are recommended.

1.3 Study Area

Waubra is a small town in the Pyrenees Shire Council on the banks of Mt Greencock Creek. Waubra is primarily residential with limited retail and government services. The main industry in Waubra is sheep grazing and associated support industries and the Waubra Wind Farm.

1.3.1 Physical Description

The study area extends along Mt Greencock Creek through the town to downstream of the Sunraysia Highway. The study area is shown in Figure 1. Mt Greencock Creek flows generally from south to north and is a “gaining” stream through the study area, where it is generally unformed in the upstream area to around 50 m at the downstream end. Mt Greencock Creek splits the town east and west and a number of small tributaries have the potential to further split the town into segments.

The northern end of town has no defined flow paths through the town, however it is likely that some overland flow would come off the upslope hill.

The floodplain is traversed by a number of roads. The Sunraysia highway is the most significant and sits on a raised embankment approximately 500 mm high. A number of other local roads cross the floodplain and are potentially hydraulic controls.

Development within the floodplain is primarily rural residential with relatively low set single storey houses, most properties have other significant infrastructure such as large rural sheds.

There is limited stormwater infrastructure within the town, with no clear stormwater detention or formalised stormwater network. The roads drained using table drains with some culverts crossing the Sunraysia Highway and some other local roads.

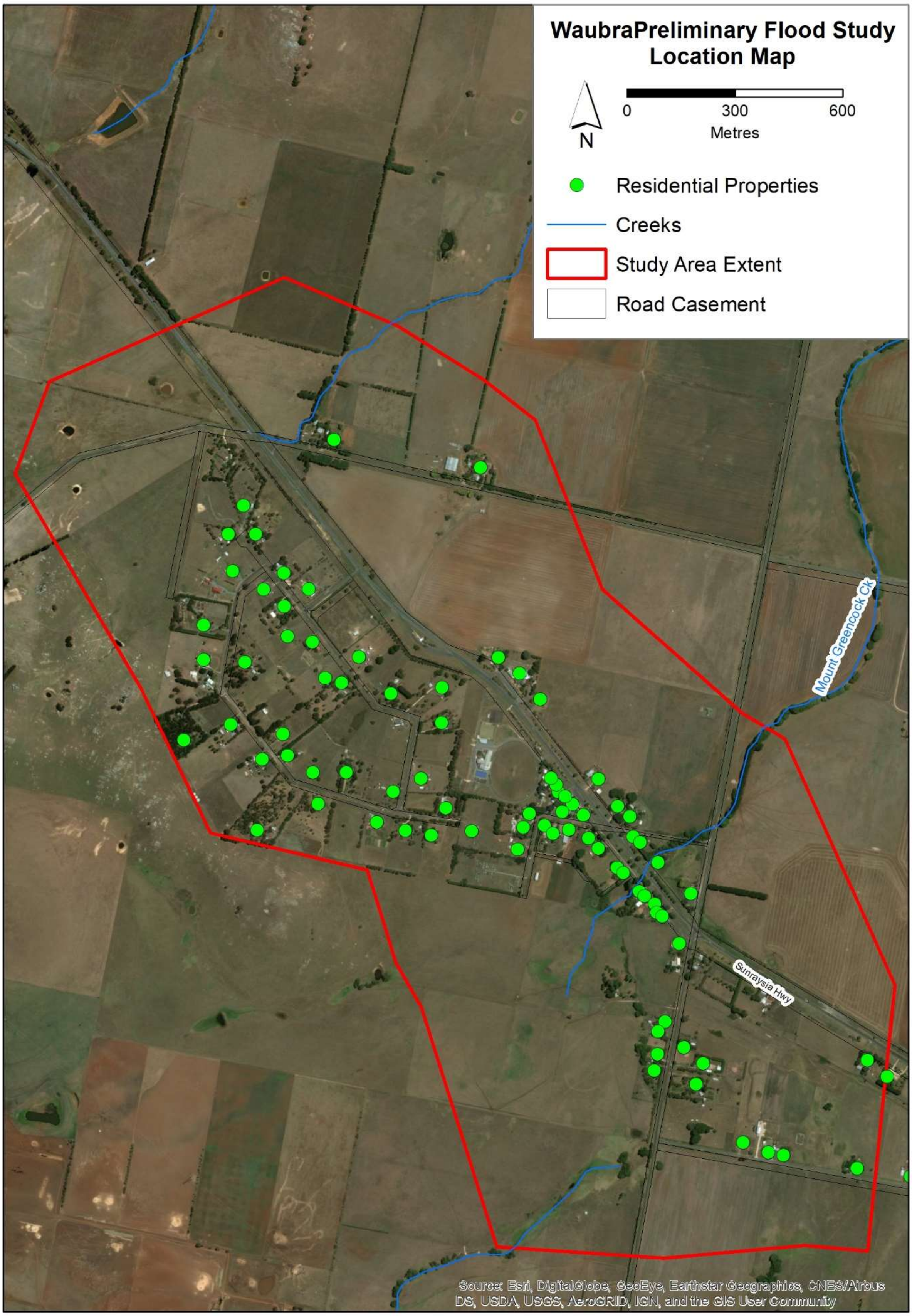

Figure 1 Study Area Location

1.3.2 Study Area Community

Key community statistics have been extracted using the Waubra (SSC) area. At the 2016 census, the Waubra (SSC) covers the study area with some rural additional area. We estimate that approximately 65% of the Waubra (SSC) population is within the study area.

The community statistics provide information on the relative flood risk of the study area with respect to the average across Victoria. Table 1 shows the key statistics that have been extracted and from these it can be inferred that:

- Waubra has a lower population density (people per dwelling). This can present warning and evacuation difficulties. Particularly in single resident houses that may need assistance.
- Waubra has a similar demographic proportion to the rest of Victoria.
- Waubra has a lower proportion of rental properties as the rest of Victoria, who may leave the area or struggle to recover after a flood.
- Waubra has a much smaller proportion of non-English-speaking households who may need assistance interpreting warnings or flood study outputs.
- The average household income in Waubra is significantly lower than the rest of Victoria, indicating potential difficulty to financially recover from flood damage.
- There are a few households without any vehicles that may need assistance to evacuate.

Table 1: Key Community Statistics

Measure	Waubra	Rest of Victoria
Number of People	275	N/A
Average People per Dwelling	2.1	2.8
Percentage Elderly Population (> 65 years of age)	16.3	15.6
Percentage Very Young Population (< 5 years of age)	5.2	6.3
Percentage Young Population (5 - 14 Years of Age)	12.4	12.0
Percentage Rental Properties	12.0	28.7
Percentage Non-English-Speaking Households	3.6	27.8
Median Household Income ($/Week)	1,097	1,419
Number of Households with No Vehicles	7	N/A

1.4 Available Data

The following data was available for the risk assessment:

- LiDAR derived 2 m Digital Elevation Model, provided by Water Technology Pty Ltd.
- Aerial Photography of the site at a 50 cm pixel resolution captured, available as a basemap within ESRI ArcGIS.
- Cadastral Boundaries made available from the Victorian Spatial DataMart.
- Intensity-Frequency-Duration tables for the catchment area using BoM IFD2013, available from the Bureau of Meteorology.
- Recommended Hydrological Modelling parameters (loss values, temporal patterns etc) available through the AR&R 2016 Data Hub (2016_v1).
- Beaufort Flood Study (Water Technology, 2008).
- Shuttle Radar Topography Mission (SRTM) DEM available from Geoscience Australia.

2 Hydrological Modelling

This chapter outlines the hydrological modelling that has been undertaken. The modelling has been undertaken using the RORB Software Package (v 6.31) and in line with the Australian Rainfall and Runoff (AR&R 2016) guidelines.

Modelling has been undertaken of the 1% Annual Exceedance Probability (AEP) design flood, which is typically used to limit flood exposure and damage to development. 1% AEP means that a flood of this magnitude has a 1% chance of occurring in any given year. This means that in some years there may be two or more floods of this magnitude or alternatively, a thousand years could pass before a flood of this magnitude occurs. The 1% AEP is sometimes referred to as the 1 in 100 Year Average Recurrence Interval (ARI) flood, which does not mean that these floods only occur every 100 years.

2.1 Catchment Delineation

The catchment delineation has been undertaken using the hydrologically enforced SRTM DEM, which is a low (30m) resolution DEM covering all of Australia. The spatial location of the catchment is shown in Figure 4. The calculated catchment size is 10 km^2. The majority of which contributes to the Mt Greencock Creek upstream of town, with some smaller inflows contributing to overland flow at the northern end the town. The catchment has been sub-divided into 19 sub-catchments to improve the catchment routing and storage representation.

2.2 Model Development

2.2.1 Design Rainfall Estimation

The design rainfall parameters have been obtained using the AR&R Data Hub (Version 2016_v1) and Bureau of Meteorology using the coordinates of the centroid of the catchment (-37.361 south, 143.633 east).

2.2.2 Loss Parameters

The rainfall loss parameters have been extracted the AR&R (2016) as well as those parameters used in the Beaufort Flood Study (2008). The rainfall loss parameters are provided in Table 2. Both sets of loss parameters have been modelled. However, as the Beaufort Flood Study parameters are based on a calibrated model using a similar hydrological modelling approach we believe these parameters are likely to be more accurate and more appropriate to use than those of the AR&R 2016 Data Hub. Therefore the Beaufort parameters were adopted.

Table 2 Rainfall Loss Parameters

Model Parameter	Data Hub Output	Beaufort Flood Study
Initial Loss (mm)	25	19.75
Continuing Loss (mm/hr)	4.6	1.0

2.2.3 Catchment Parameters

The catchment parameters have been applied using recommended values from the RORB User Manual (v 6.31). The catchment loss parameters are provided in Table 3. These align with the values in the Beaufort Flood Study.

Table 3 Catchment Parameters

Model Parameter	Value
Kc	2.3

M	0.8

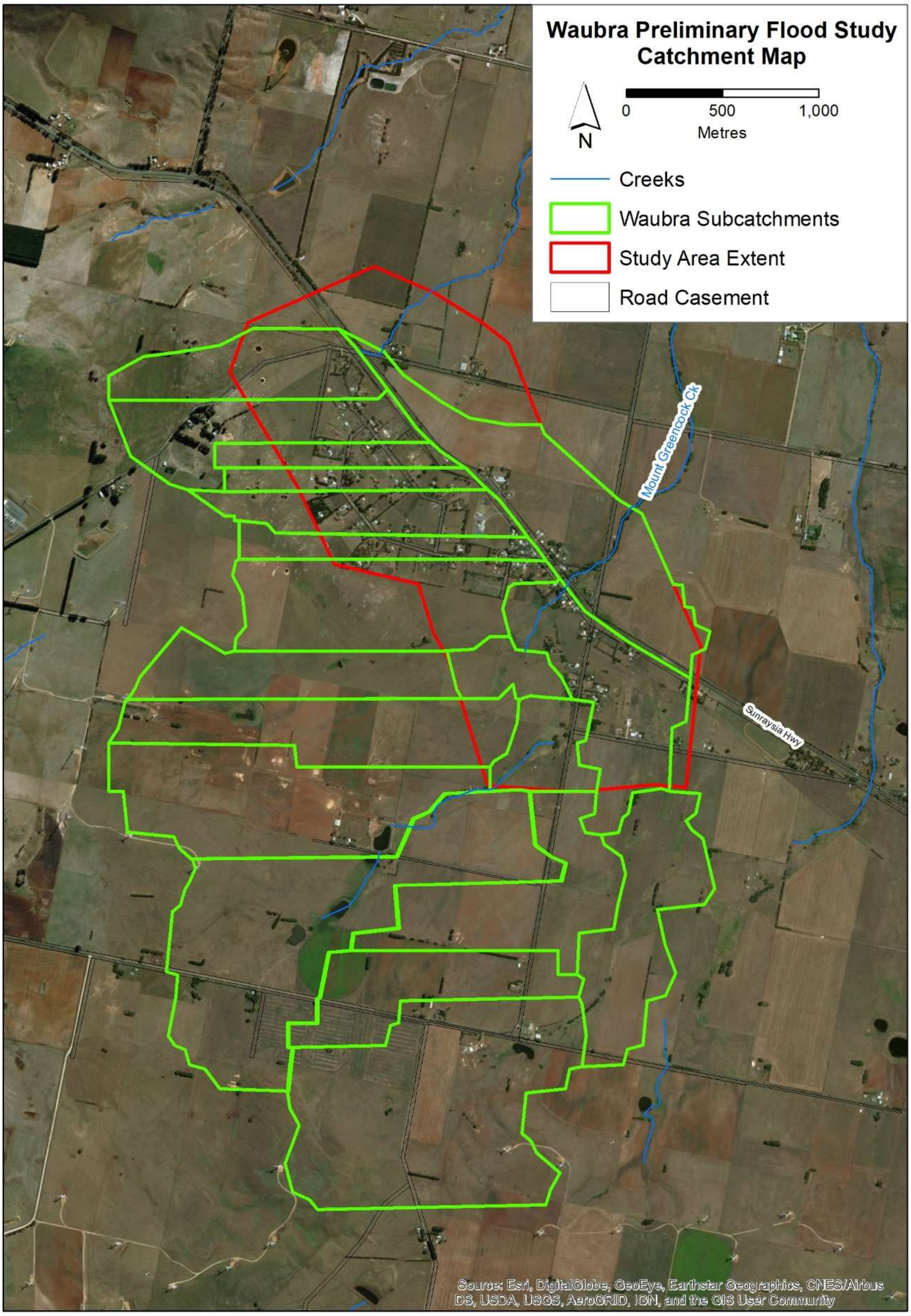

Figure 2 Mt Greencock Ck Catchment Map

2.3 Critical Duration

As per AR&R (2016) recommendations, an ensemble of 10 storms with varying temporal patterns was run through the RORB model with varying storm duration (between 15 minutes and 72 hours).

Figure 3 shows the peak flow comparison for the durations modelled, it can be seen that the 6 hour design storm is more critical than the other durations considered, with a higher mean and median flow than the other durations. The 3 hour duration is fairly similar, and a more detailed analysis may show that the 3 hour storm is more critical in some locations.

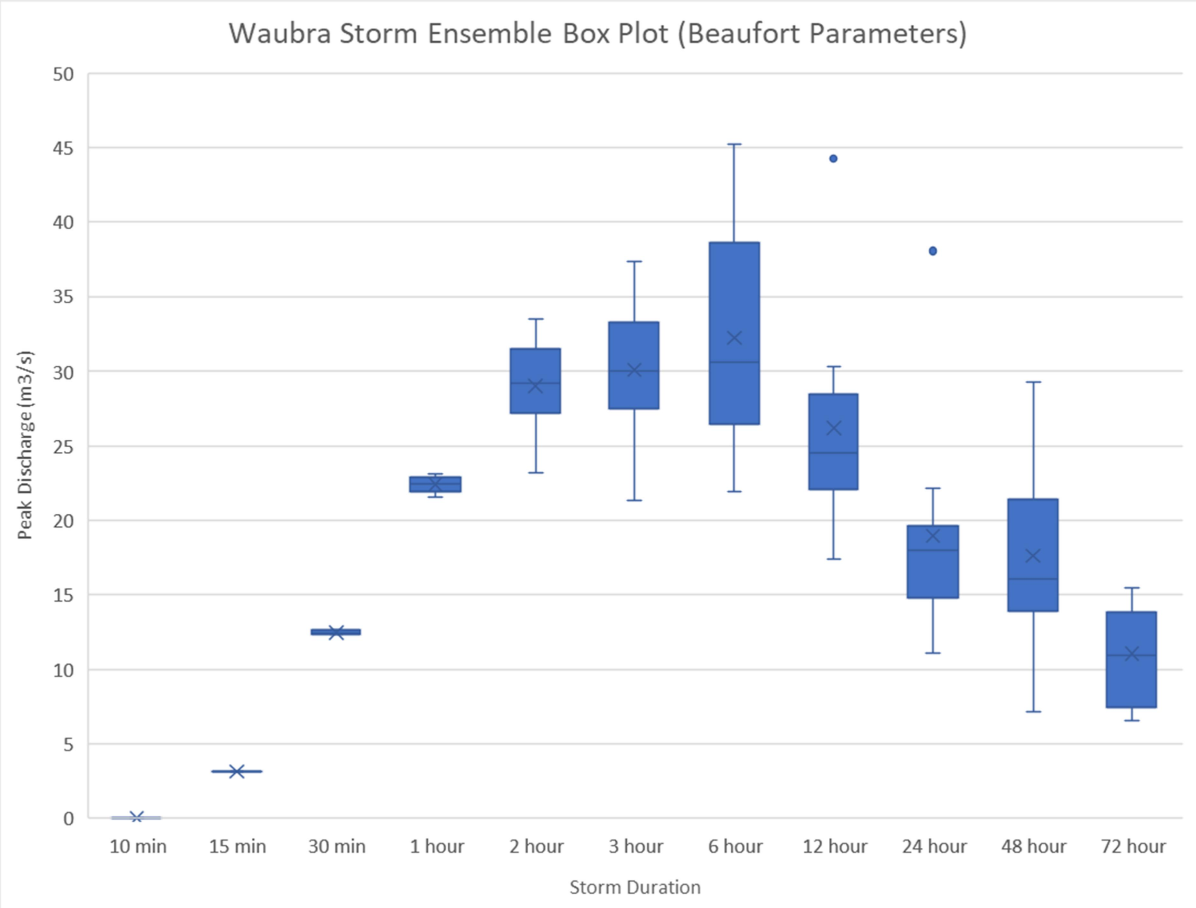

Figure 3 Ensemble Storm Box Plots

2.4 Adopted Design Storm

As recommended in Retallick (2017), the "Median" plus one temporal pattern was used for the critical duration design storm. The temporal pattern selected was ARR2016 Pattern 27, which produced a peak flow of 45.7 m^3/s (combined). The flow hydrographs, which are applied in the hydraulic modelling, is shown in Figure 4.

Figure 4 Adopted Design Storm Flow Hydrographs

2.5 Comparison to Regional Methods

Comparison has been made between the critical duration flows and alternative techniques, including:

- The same RORB model with the AR&R 2016 rainfall parameters.
- The same RORB model using the AR&R 1987 rainfall intensities and temporal patterns.
- The Regional Flood Frequency Estimation (RFFE) model, developed as part of AR&R 2016.
- The Probabilistic Rational Method, developed as part of AR&R87 and is replaced by the RFFE.

Table 4 shows the different estimation techniques and resulting peak flow in the 1% AEP event. There a range of results between each of the different calculation techniques. The RFFE has a significantly lower estimated flow than all other methods. Previous modelling in similar rural catchments show that RFFE is often inaccurate and therefore shouldn't be applied. Also, given that the AR&R2016 techniques are designed to replace the AR&R1987 techniques, it is recommended that the RORB model with Beaufort parameters remains as the adopted flow.

Table 4 Comparison of Flow Estimates

Estimation Technique	1% AEP Flow (m^3/s)
RORB (Beaufort Parameters)	45.7
RORB (AR&R 2016 Parameters)	41.2
RORB (AR&R 1987 with Beaufort Parameters)	55.9
RFFE (AR&R 2016)*	32.4
Probabilistic Rational Method (AR&R 1987)	16.3

3 Hydraulic Modelling

The model for this study has been developed using the HEC-RAS v5.03 software. HEC-RAS is widely used both internationally and in Australia for similar projects.

HEC-RAS differs from traditional two-dimensional software in that rather than simply averaging the elevation within a computational cell, it calculates a storage vs elevation relationship from the terrain (DEM) as well as cross-sectional relationships along the face of each cell. The practical effect of this is that HEC-RAS can accurately represent features that are smaller than the grid size (e.g. a flow path that is 5 m wide in a 10 m resolution grid).

Recent benchmarking tests undertaken by HEC (the software developer) shows that its' two-dimensional flow solver is on par with other similar modelling software (TuFlow, MIKE Flood, ISIS etc) in terms of accuracy (US Army Corps of Engineers, 2016).

3.1 Model Schematisation

The model has been setup using a ten-metre resolution grid representing the catchment.

The model timestep is 1 minute timestep with up to 500 time slices (allowing for a minimum timestep of less than 0.001 minutes). Time slices effectively reduce the time step to ensure stability and maintain the mass balance.

Figure 5 shows the model schematic, boundaries and proposed development.

3.2 Model Roughness

Roughness, or Mannings 'n', has been applied variably across the model domain based on the land use observed in the aerial photo. Values are based Table 10-1 of Institute of Engineers Australia (2012).

Table 5 Roughness Values

Land Use	Roughness (Manning's n)
Roads	0.03
Buildings	0.5
Channel	0.04
Land	0.05

3.3 Model Structures

In-channel structures such as bridges and culverts have been represented roughly using in field measurements and reducing this to AHD using LiDAR. Floodplain structures such as elevated roads and levees are represented by breaklines which force the cell boundaries on to the crest of the structure.

3.4 Model Boundaries

3.4.1 Initial Conditions

The model has been set with a "dry" initial condition.

3.4.2 Inflows

The main inflow has been applied at the upstream end of the study area on Mt Greencock Ck, which has been split into the creek and two small tributaries. Smaller additional inflows from overland flow catchments have been applied at the northern end of the town. The flow rates that have been applied are shown in Figure 4Figure 4.

3.4.3 Outflows

There is a two model outflows located at the north east end of the model domain. The outflows have been applied using the “Normal Depth” boundary formulation in HEC-RAS which uses Mannings equation to derive a stage-discharge curve based on the assigned slope, which has been applied as 1% for these boundaries.

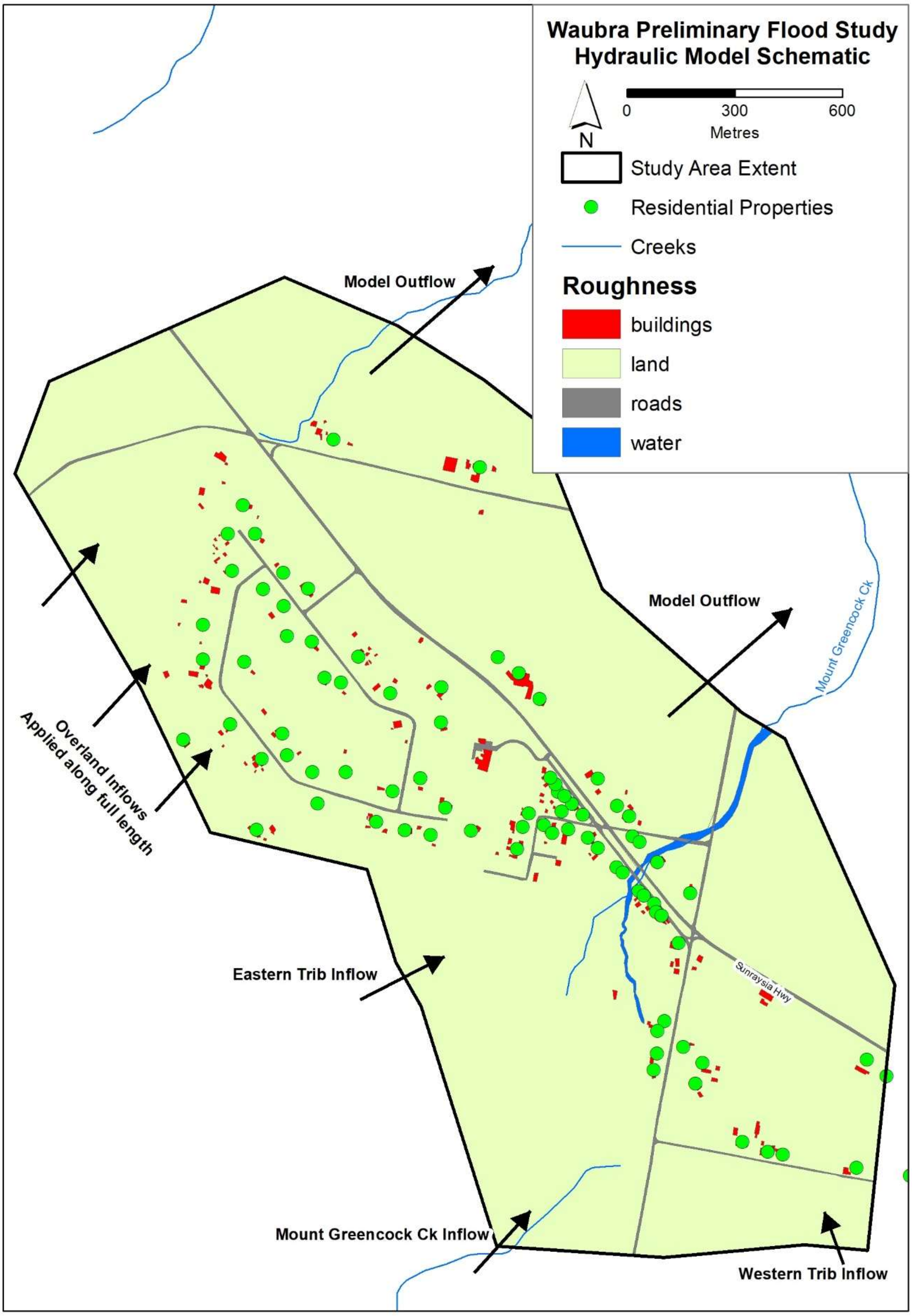

Figure 5 Hydraulic Model Schematic

4 Results

4.1 Model Calibration

No model calibration data was found by either Council or during the community consultation. However, anecdotal evidence suggests that the property on the right bank of Mt Greencock Ck just downstream of the Sunraysia Hwy has been flooded several times in the past. This is supported by the model which shows it significantly inundated during the 1% AEP flood.

4.2 Flood Behaviour

4.2.1 Flood Extent

The flood extent of the 1% AEP is shown in Figure 6. It can be seen that the flooding upstream of the Sunraysia Highway is spread across the tributaries to Mt Greencock Ck and minor flooding to the north from overland flow paths.

As the creek approaches the Sunraysia Highway there is a more widespread flooding that has the potential to inundate several residential properties along the local streets.

In addition to the adopted 1% AEP design flood, the same flood using the AR&R 2016 rainfall loss parameters has also been modelled, as well as a sensitivity check by increasing the inflows by 20%. The floods extents have been layered such that the smaller flood is on top of the larger flood (i.e. the area inundated by the 20% increased flow includes the area of the design storm and the AR&R 2016 parameter runs.

It can be seen that by using the AR&R 2016 loss parameters, the flood extent is fairly similar, however as discussed these are likely to be less accurate than the adopted Beaufort Flood Study parameters in terms of depth and velocity. Without calibration it is difficult to determine the correct rainfall loss parameters.

The 20% increase in flow from the adopted design storm shows minimal increase in the flood extent. This suggests that the flood extent does not change between flows of a magnitude of the AR&R parameters (67 m^3/s) and flows 20% greater than the Beaufort Parameters (125 m^3/s).

4.2.2 Flood Depth

1% AEP Flood depths are shown in Figure 7. The figure shows that in general flood depths are greatest along Mt Greencock Ck. In the outer floodplain depths are generally lower than 0.3 m and flooding does not exceed this in the northern end of the town (except for in table drains).

4.2.3 Flood Velocity

Similarly to depth, the highest velocities are generally in the floodway around Mt Greencock Ck. Significant velocities (> 1 m/s) are also in some the tributaries and overland flowpaths. Most floodplain areas exceed 0.5 m/s.

4.2.4 Flood Hazard (Hydraulic)

Hydraulic Flood Hazard (the product of depth and velocity) and it shown in Figure 9. The majority of the floodplain has relatively has a low hazard (< 0.2 m^2/s) with only areas within creeks presenting a higher hazard (generally less than 0.4 m^2/s.

Hydraulic hazard is a good indicator of where the most dangerous floodwaters are located as it highlights areas that are either fast flowing or deep or a combination of the two. The high hazard along the main channels would be largely obvious to most people and there are no locations where there is significant overland flow that is high hazard.

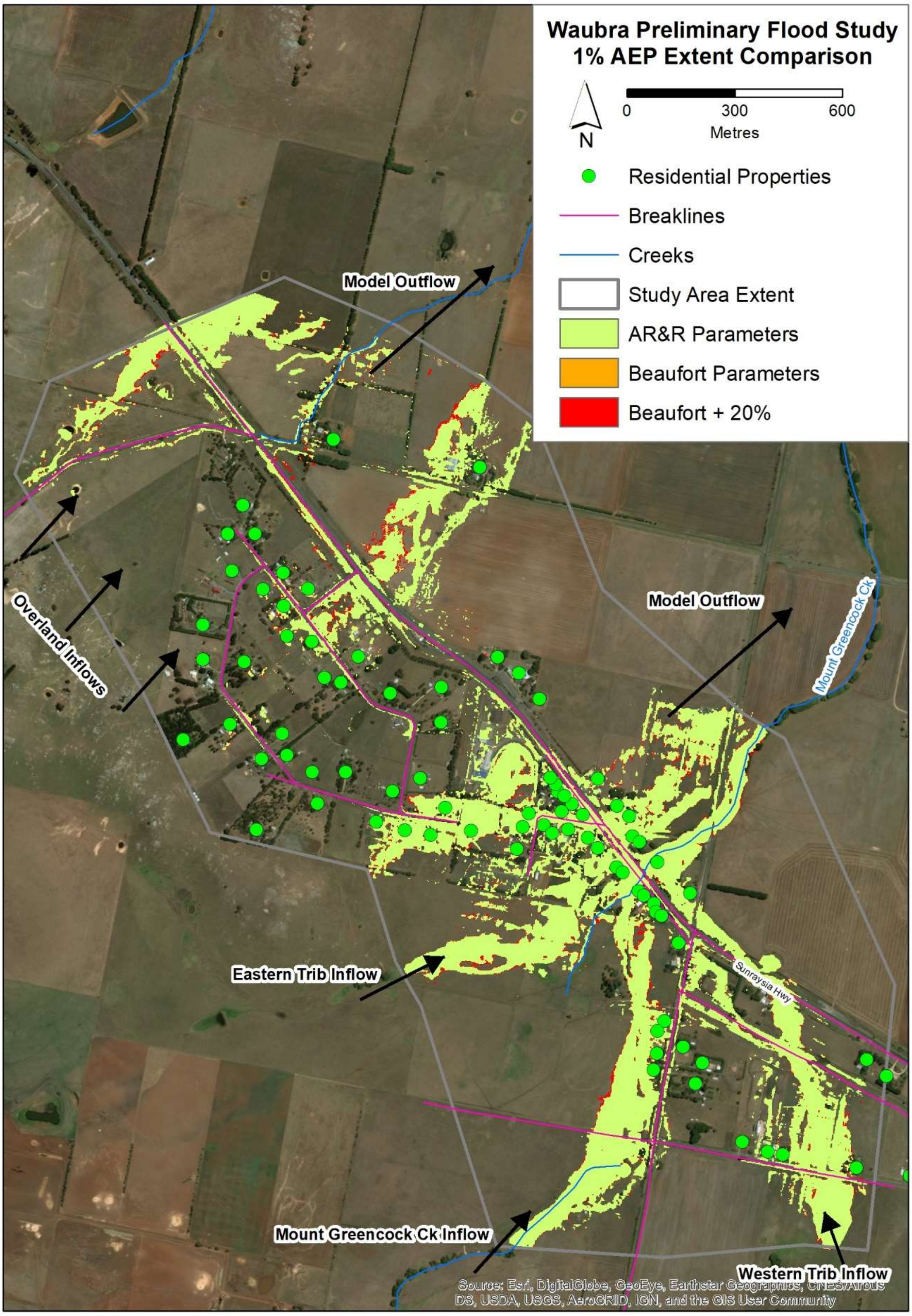

Figure 6 1% AEP Extent Comparison (AR&R 2016 vs Beaufort Parameters)

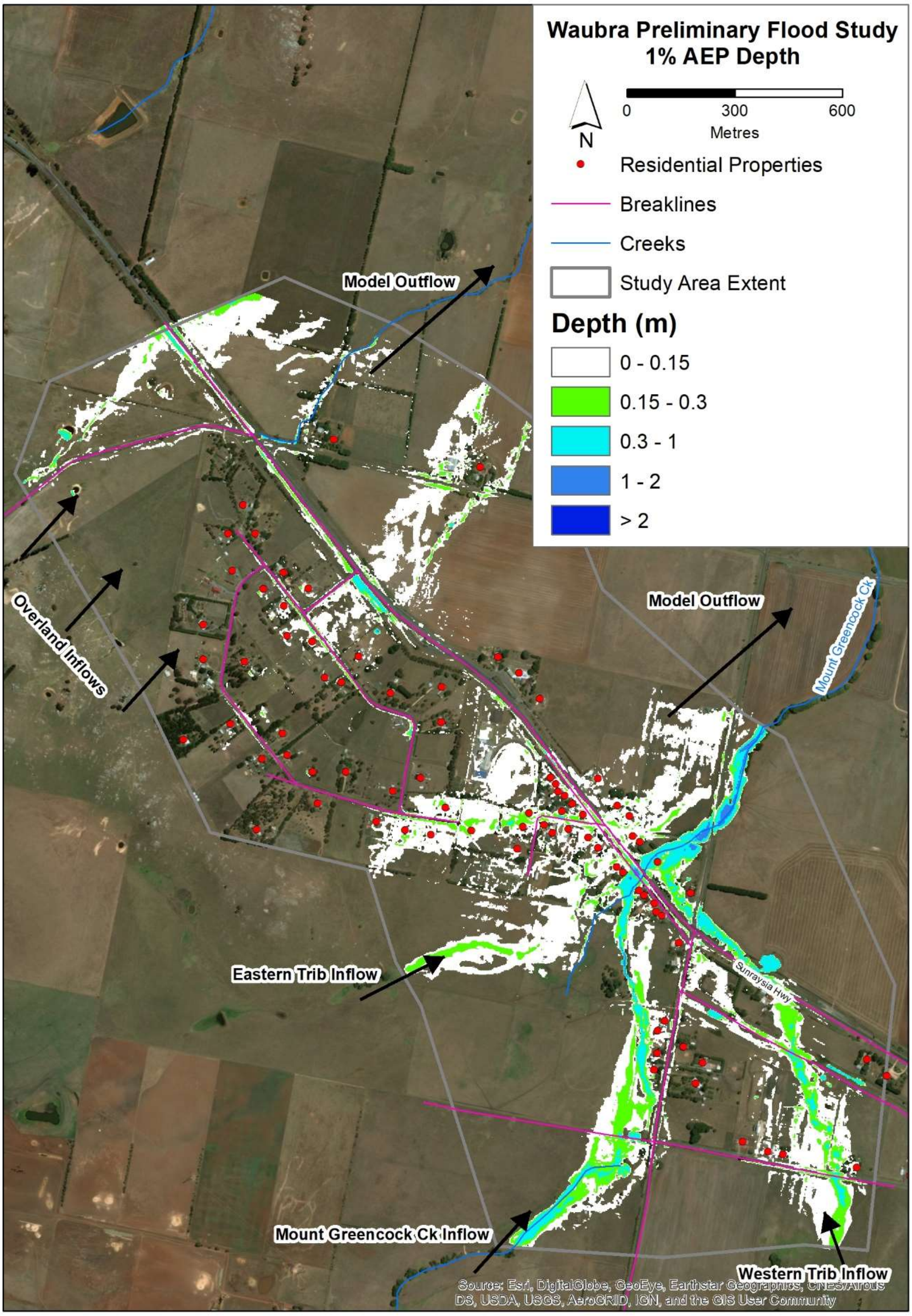

Figure 7 1% AEP Peak Depth

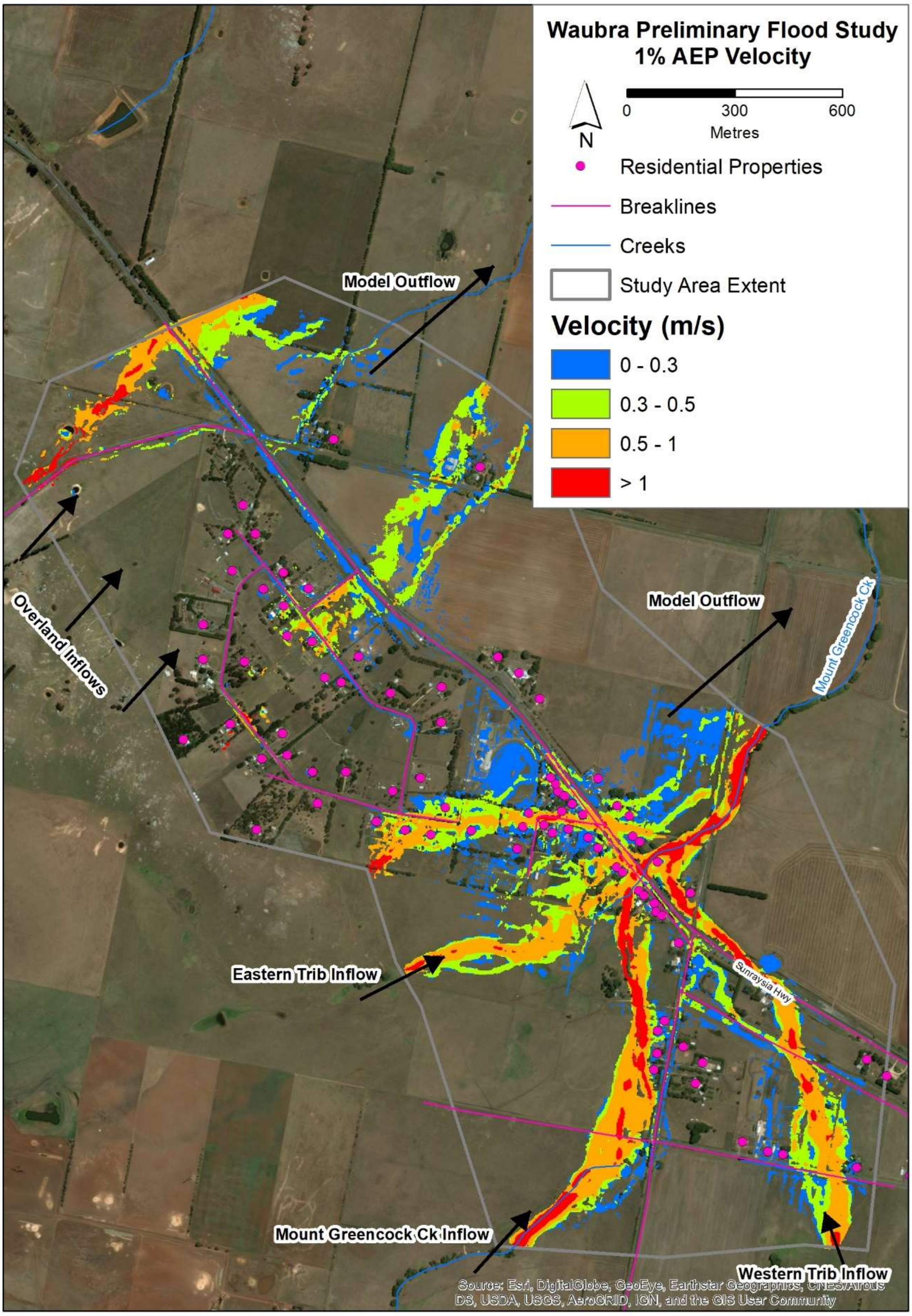

Figure 8 1% AEP Peak Velocity

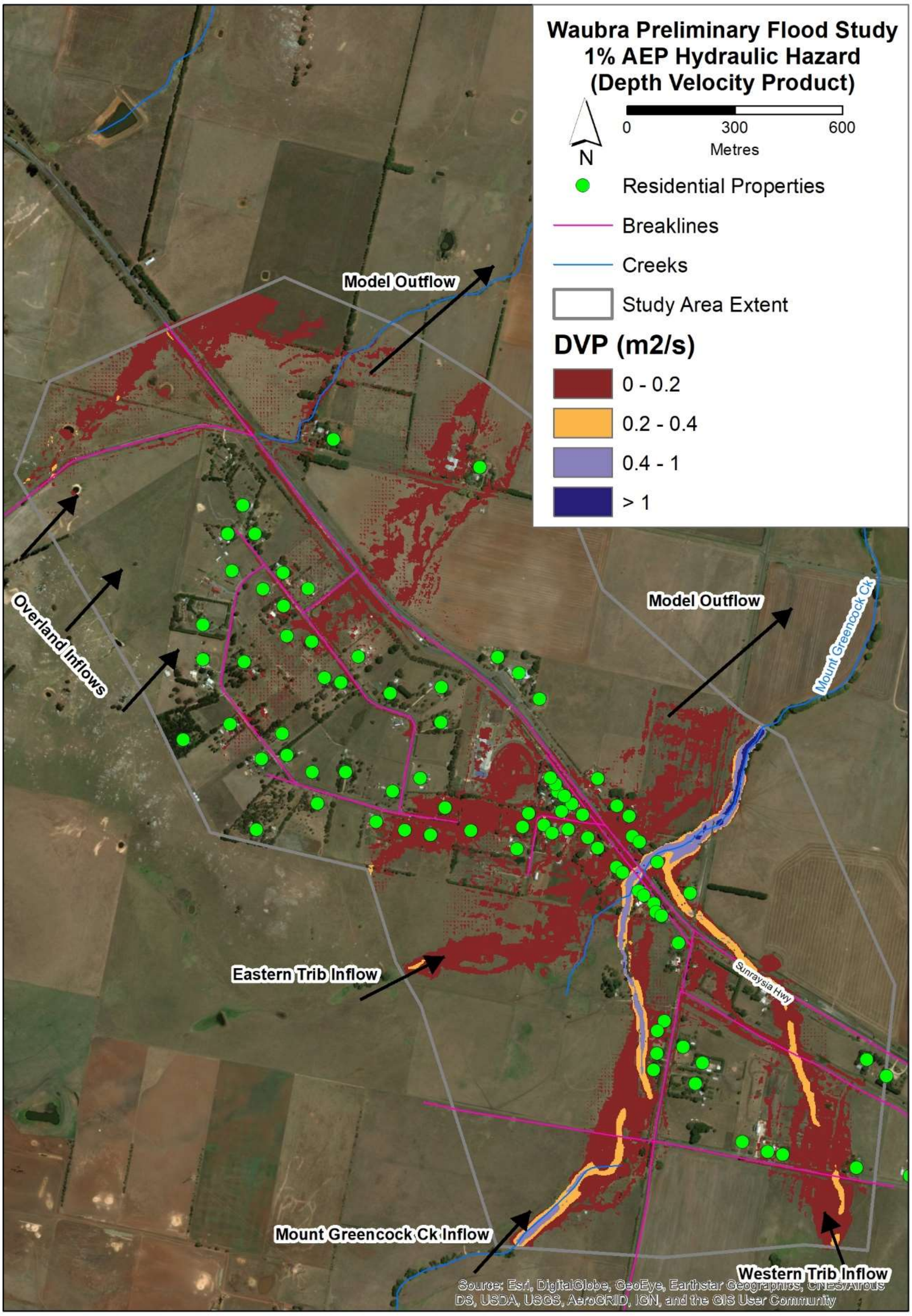

Figure 9 1% AEP Hydraulic Hazard

4.3 Flood Risk

4.3.1 Flood Risk to Life

The flood risk to life can be calculated from the Population at Risk (PAR). The PAR is estimated by taking the number of flood affected buildings and multiplying it by the average dwelling density (see Table 1). This is often calculated from the PMF, however in this case only the 1% AEP flood is available.

Table 6 shows the number of properties within the study area and the number of flood affected properties. It can be seen that using the Beaufort rainfall parameters significantly increases the PAR from around 105 people with the AR&R rainfall parameters to 111 people (properties with above ground flooding). As discussed in Section 0, the Beaufort parameters are likely to be more accurate. The higher risk PAR are generally located along closer to Mt Greencock Ck and the Sunraysia Hwy.

If flow is increased by 20% on top of the Beaufort Parameters run, then there is no corresponding increase in the PAR and no discernible increase in the severity of flooding (i.e. move from above ground flooding to potential above floor flooding or move from potential to a higher likelihood of above floor flooding). However, depths in properties that are likely to flood will increase. The population at risk is shown spatially in Figure 10.

The PAR can also include people that may not be flood affected on their property but are potentially cut off from their homes or work places. The Sunraysia Highway, which would be the main access to the town appears to be cut during the flood.

Given the size of the catchment and lack of gauging information, it is unlikely that any flood warning would be available and emergency services would need to mobilise prior to rainfall occurring.

Table 6 Flood Affected Residences

Residential Properties	Number of Properties (Beaufort Parameters)	Number of Properties (AR&R 2016 Parameters)	Number of Properties (Beaufort Parameters plus 20% flow)
Total Number of Residential Properties in Study Area	84	84	84
Properties with Above Ground Flooding	53	50	53
Properties with Potential Above Floor Flooding	33	30	33
Properties with Higher Likelihood of Above Floor Flooding (Depth => 0.3)	1	1	1

4.3.2 Commercial Flood Risk

In addition to the potential for residential properties to be inundated, the study areas have a significant number of sheds that would either be used for residential storage or commercial purposes (primarily agricultural). Inundation of these sheds would cause some financial loss.

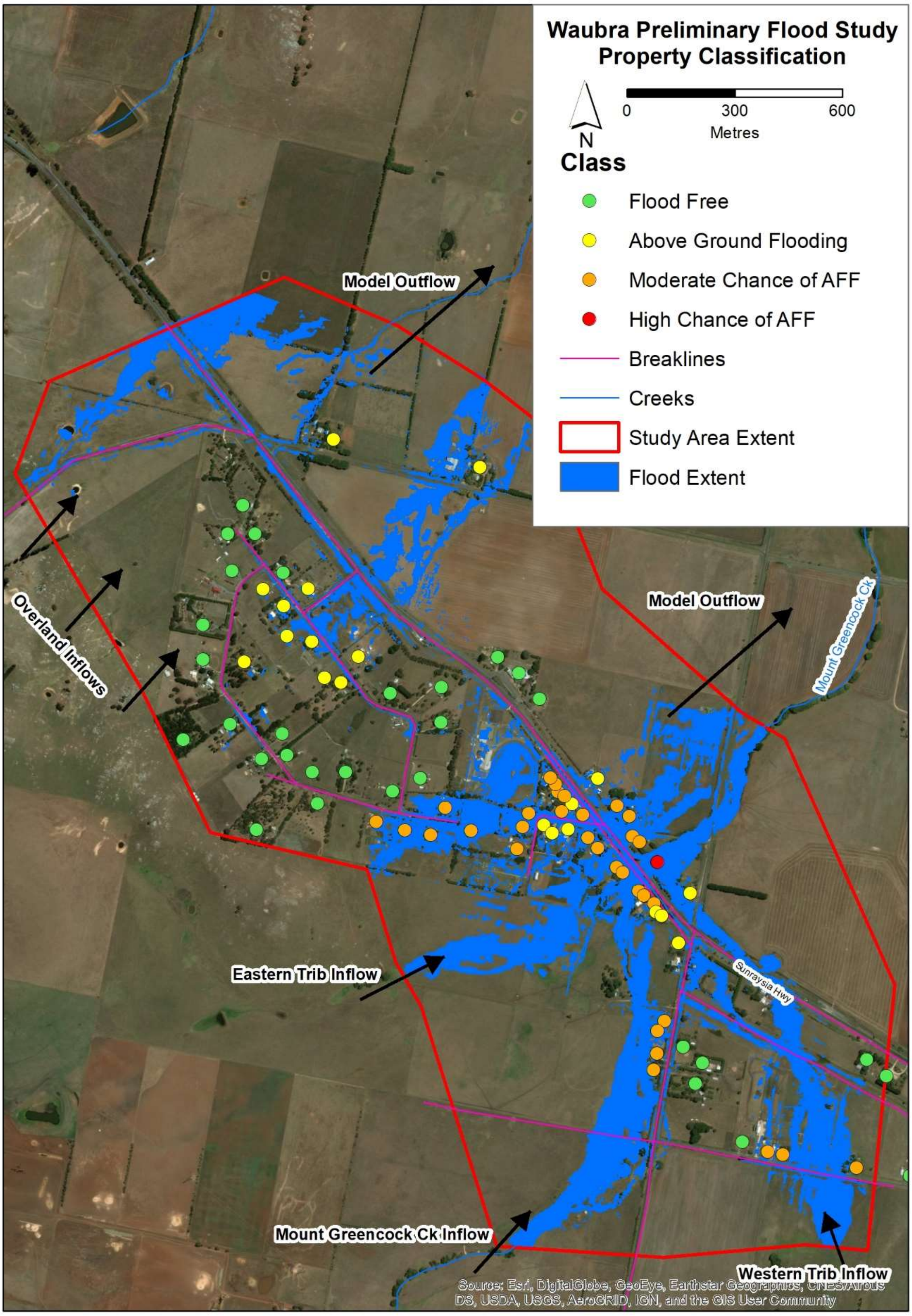

Figure 10 Waubra Population at Risk

4.4 Flood Planning

Floodway mapping has been undertaken in accordance with *Applying the Flood Provisions in Planning Scheme – Planning – Practice Note 12* (Victorian Department of Environment, Land Water and Planning, 2015). The floodway maps are shown in Figure 11.

The figure shows the extent of the Floodway Overlay (FO) which is defined as areas of high depth and velocity and is generally used to delineate land that should not be developed. The Land Subject to Inundation Overlay (LSIO) is also shown, which is the extent of the 1% AEP (defined flood event) and would be used to limit development to appropriate uses. Both proposed overlays are based on modelling outputs and further delineation to suit planning scheme mapping for any future amendment, is required.

Also shown on Figure 11 is the cadastral lots that are potentially subject to flooding (i.e. intersect with the LSIO). Given the uncertainty associated with the flood modelling, it is not recommended that planning controls such as a declared flood levels be placed on these lots, rather these lots should be tagged as potentially requiring a site specific hydraulic assessment if proposed development intersects the LSIO.

4.5 Shallow Depths

In areas where flood depths are less than 0.15 m due to overland flow, many floodplain management authorities choose to treat this as stormwater rather than riverine flooding, and do not consider this as part the floodplain management scope.

As shown in Figure 7, this would apply to a large area, particularly around the “Waubra Heights” estate where the vast majority of the flooding is less than 0.15 m.

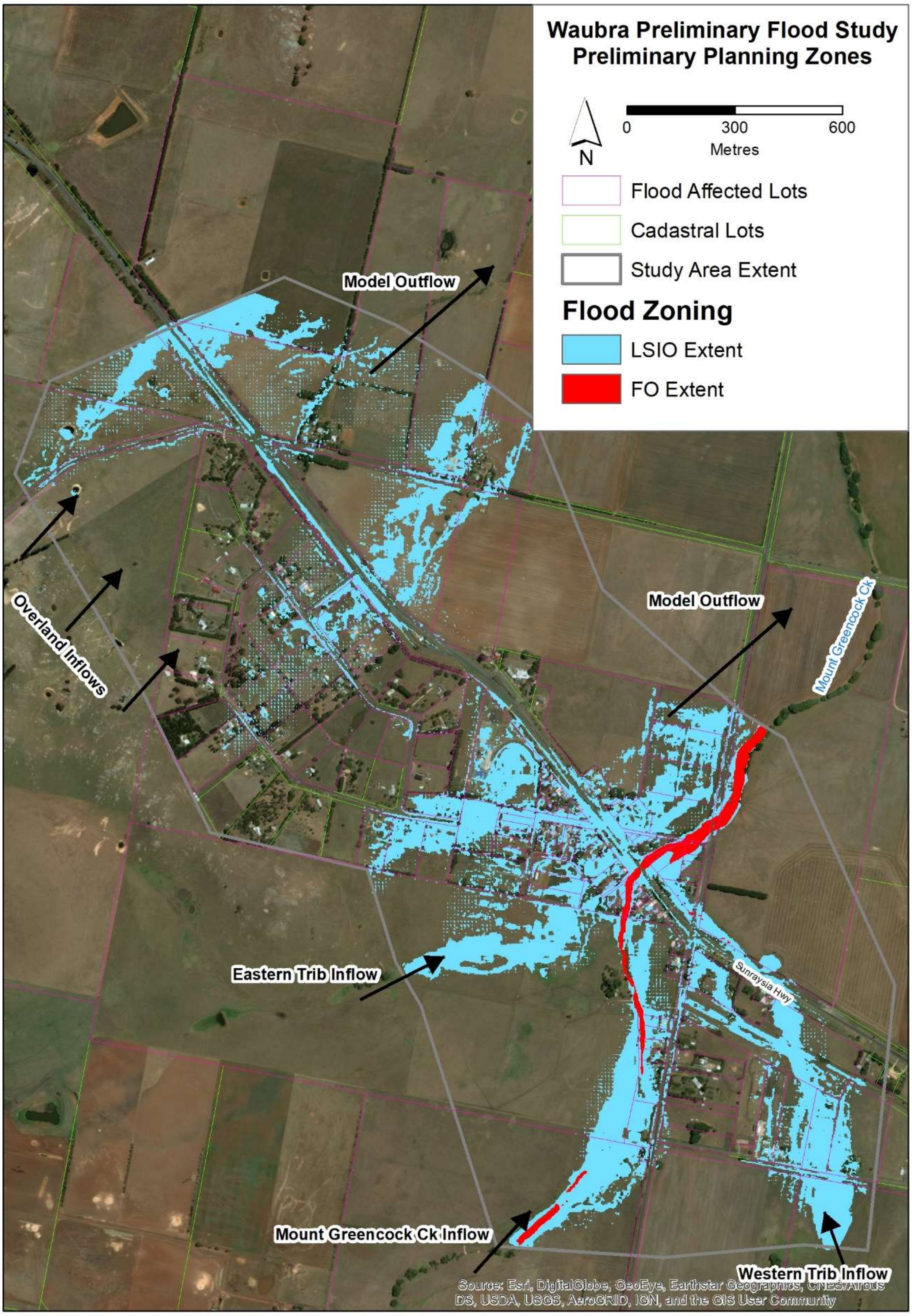

Figure 11 Preliminary Planning Overlays

5 Summary

A hydrologic and hydraulic model has been setup to provide a preliminary estimate of the flood impacts within Waubra. The results show while flooding is widespread, it is relatively shallow outside of Mt Greencock Ck and mostly below 0.15 m in Waubra Heights.

Based on the results, there is a relatively low risk to property, with around 33 properties with a reasonable chance of above floor flooding in the 1% AEP however only 1 of these properties has a high likelihood of above floor flooding. In our view the flood impact does not warrant a full flood study.

There appears to be limited scope for flood mitigation works within the town, although flood detention basins upstream of the town could potentially reduce flooding risk for a small number of properties. Further assessment would be required to quantify this.

6 References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

Institute of Engineers Australia, 2012, Australian Rainfall and Runoff Revision Project 15 – Two Dimensional Modelling in Urban and Rural Floodplains.