Greta Floodplain Risk Management Study and Plan

Final Updated Flood Study

Cessnock City Council

RR-02-1703-02

October 2025

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Cover photo: Nelson Street culverts, Greta (Photograph: Rhelm, 2022)

Foreword

The primary objective of the New South Wales (NSW) Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

Through the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) and the NSW State Emergency Service (SES), the NSW Government provides specialist technical assistance to local government on all flooding, flood risk management, flood emergency management and land-use planning matters.

The *Flood Risk Management Manual, the policy and manual for the management of flood liable land* (Department of Planning and Environment, 2023) (the **Manual**) is provided to assist councils to meet their obligations through the preparation and implementation of floodplain risk management plans, through a staged process. **Figure F1**, taken from this manual, documents the process for plan preparation, implementation and review.

The Manual is consistent with Australian Emergency Management Handbook 7: *Managing the floodplain: best practice in flood risk management in Australia* (AEM Handbook 7) (AIDR 2017).

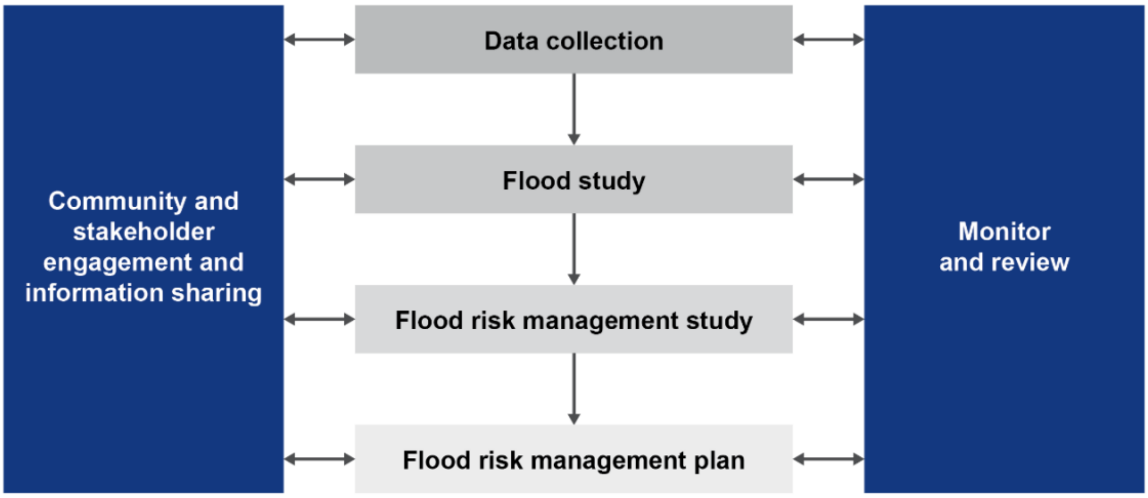


Figure F1. The Floodplain Risk Management Process (DPE, 2023)

Cessnock City Council has committed to prepare a comprehensive flood study for the study area in accordance with the Manual (DPE, 2023). This document relates to the data collection and flood study phase of the process.

Executive Summary

Study Overview and Purpose

The Greta Floodplain Risk Management Study and Plan (FRMSP) is being prepared for Cessnock City Council (Council) to assess and address the flood risks present in the catchment.

The first stage of this FRMSP is an updated Flood Study to document updates to the flood modelling and results from the Greta Flood Study prepared by WMAwater in 2019.

The Greta Flood Study (WMAwater, 2019) defines mainstream flood behaviour across the study area, covering Anvil Creek and its major tributaries. Extension of the flood model developed as part of this study has been completed to cover the Huntlee precinct and a number of high-risk areas identified by Council. Furthermore, there is potential to improve the definition of flood behaviour in nominated high risk areas through the acquisition of additional ground survey data as well as refinements to the hydrologic sub-catchment delineation. Refinements to the WMAwater (2019) flood modelling and subsequent results in modelled flood behaviour are detailed in this updated Flood Study report.

Study Area and Scope

The study area has a total area of approximately 47 km^2 and generally encompasses the entire catchment of Anvil Creek, spanning from the Hunter Expressway Interchange with Lovedale Road down to the confluence with Black Creek.

The overall objective of this study is to improve understanding of flood behaviour and impacts and better inform management of flood risk in the study area. It involves consideration of the local flood history, available flood data, and the development of hydrologic and hydraulic models that are calibrated and verified against historic flood events and extended, where appropriate, to determine the full range of flood behaviour.

Data and Literature Review

A comprehensive data and literature review was undertaken to collate the available data relevant to the study. The review considered the following data and documentation:

- Previous studies and reports relevant to the study area,
- Modelling data for studies undertaken within the study area,
- Survey data,
- Other spatial data, and
- Engineering design and work as executed drawings for development within the study area.

Consultation

Comprehensive engagement was undertaken to inform the community and stakeholders of the FRMSP and updated Flood Study, as well as gather information on their flooding experiences.

Initially, community members were invited to complete an online questionnaire to assist with identification of community attitudes towards flood risk management techniques, both structural and non-structural, as well as understand likely responses of the community during a flood event.

Stakeholders engaged included local community groups, service and utility providers, and state and local government departments.

Further consultation with the community took place during the Public Exhibition of the FRMSP from 13 August to 19 September 2025. The FRMSP was displayed on Council's website with the opportunity for the community to provide feedback via the *Together Cessnock* website (https://together.cessnock.nsw.gov.au/). Community comments were primarily received during the public drop-in session at the Greta Court House on 1 September 2025, from 2:30pm to 6:30pm.

Flood Model Update and Validation

The flood model established as part of the Greta Flood Study (WMAwater, 2019) was provided by Council as a base for establishing an updated flood model.

The hydrologic model was established using the Watershed Bounded Network Model (WBNM) software. In general, only minor changes were made to the WBNM hydrologic model schematisation from the Flood Study (WMAwater, 2019). This primarily consisted of increasing the sub-catchment resolution around urbanised areas and updates to impervious area mapping to account for development in the catchment since the previous model was constructed.

The hydraulic model was established using the TUFLOW software. Key updates to this model included:

- Extending the model to cover additional urban and high-risk areas,
- Modifying the digital elevation model to incorporate design surface information for recent development and ground survey of critical flow paths,
- Updates to the surface roughness delineation to reflect present conditions, and
- Updates to the model 1D network to incorporate additional ground survey, design and GIS data obtained for this study.

In order to confirm that the updated model still sufficiently replicates observed flood behaviour, the model was validated against the April 2015 event used for calibration of the WMAwater (2019) model.

The updated April 2015 model results vary substantially from those from the Flood Study (WMAwater, 2019) which can primarily be attributed to an issue with the original model inflows for calibration and validation events. However, when considering the aggregate of modelled versus observed flood levels, the outcome of the April 2015 calibration/validation is similar to that of the Flood Study (WMAwater, 2019).

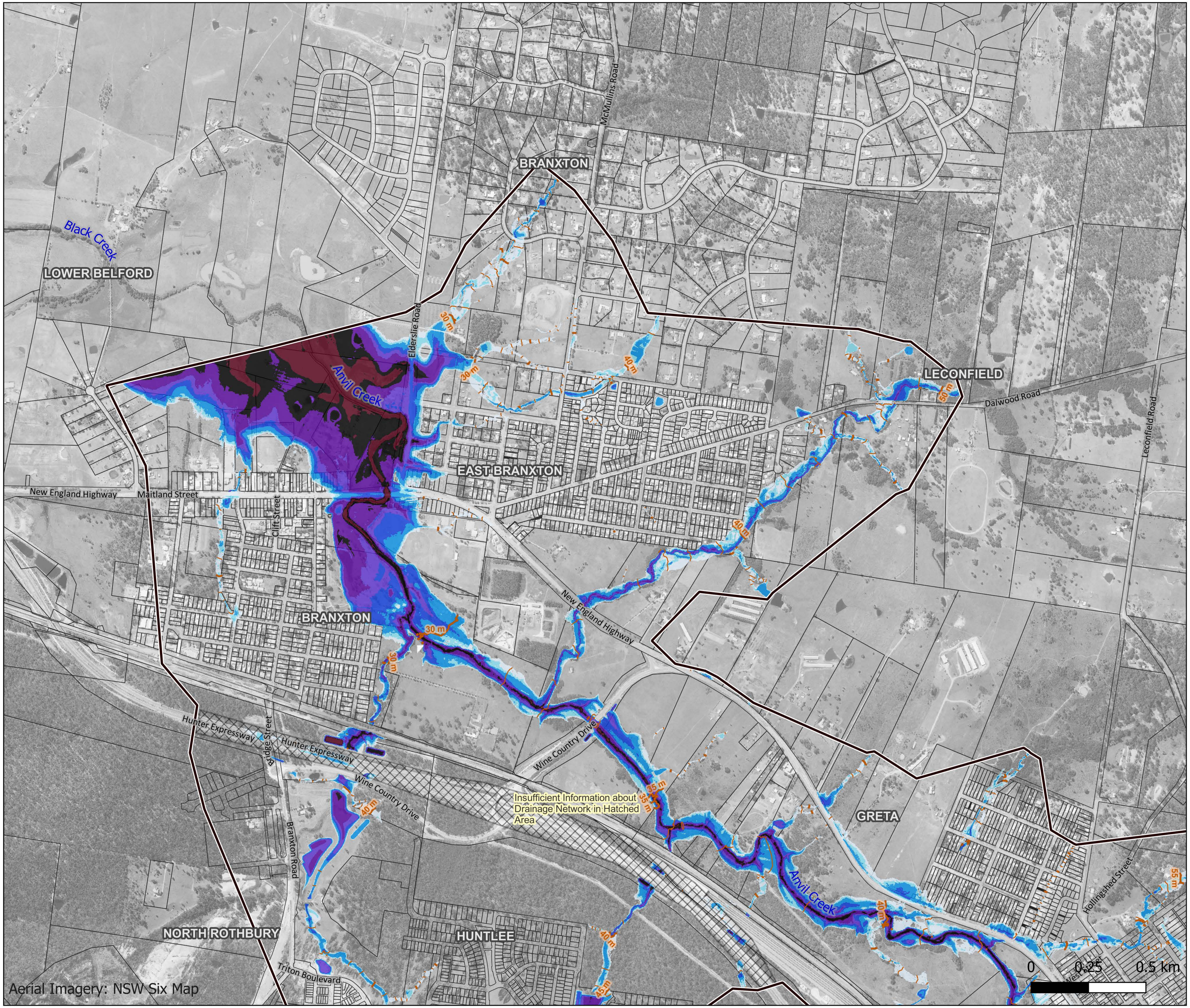
Given the degree of uncertainty in some of the flood observations, rainfall temporal pattern for the catchment and the likelihood of structure blockage to have occurred, the updated model is considered to reasonably replicate historic flood behaviour for the April 2015 event and forms the basis for the analysis of design flood behaviour.

Design Event Modelling

The updated hydrologic and hydraulic models were used to simulate the 1 event per year (EY), 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% annual exceedance probability (AEP) events and the Probable Maximum Flood (PMF) event. Each event was run for the same duration and temporal pattern as the Flood Study (WMAwater, 2019) apart from the 1EY which was not assessed as part of the original study. The peak flood depths and flood levels for the 1% AEP and PMF events, respectively are shown in Maps **RG-02-007** and **RG-02-010** (provided in **Appendix F** of this study and replicated within this executive summary).

The updated 1% AEP results were compared to those from the 2019 Flood Study (WMAwater, 2019) where it was found that the results are generally consistent, with flood level differences along Anvil Creek less than 0.1m along the entire length and less than 0.02m along the majority of the length. As would be anticipated, more pronounced differences are observed immediately downstream of the recently developed Huntlee precinct and around locations where ground survey data was incorporated into the updated model.

The 0.5% AEP and 0.2% AEP events have been used as proxies for the 1% AEP with an allowance for increase in rainfall intensity associated with projected climate change scenarios. Based on the Australian Rainfall and Runoff 2019 – Version 4.2 climate change factors for the subject catchment, the 0.5% AEP is approximately equivalent to the near term (2025) projected increases to rainfall intensity, whilst the 0.2% AEP lies between the Shared Socioeconomic Pathway (SSP) 2 and SSP3 scenarios for the 2090 projection. Climate change impact mapping shows 0.5% AEP increases in the order of 0.1m to 0.2m along major watercourses and generally less than 0.05m around minor watercourses when compared to 1% AEP flood levels. For the 0.2% AEP event, flood level increases are generally in the order of 0.2m to 0.6m along major watercourses and less than 0.2m around minor watercourses. For both events, the impacts at the downstream extent of the study area are far more significant due to the elevated assumed Hunter River tailwater levels compared to the 1% AEP event.



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RG-01-016a

Greta Updated Flood Study

Peak Flood Depth and Elevation 1% AEP Map 1 of 3

Legend

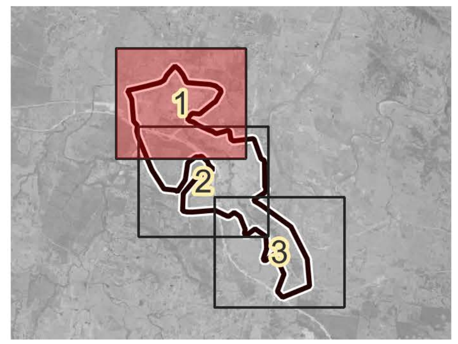
- Hydraulic Model Extent
- Cadastre

Water Level Contours

- 5m
- 1m

Peak Flood Depth (m)

- <= 0.01
- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 4
- \> 4



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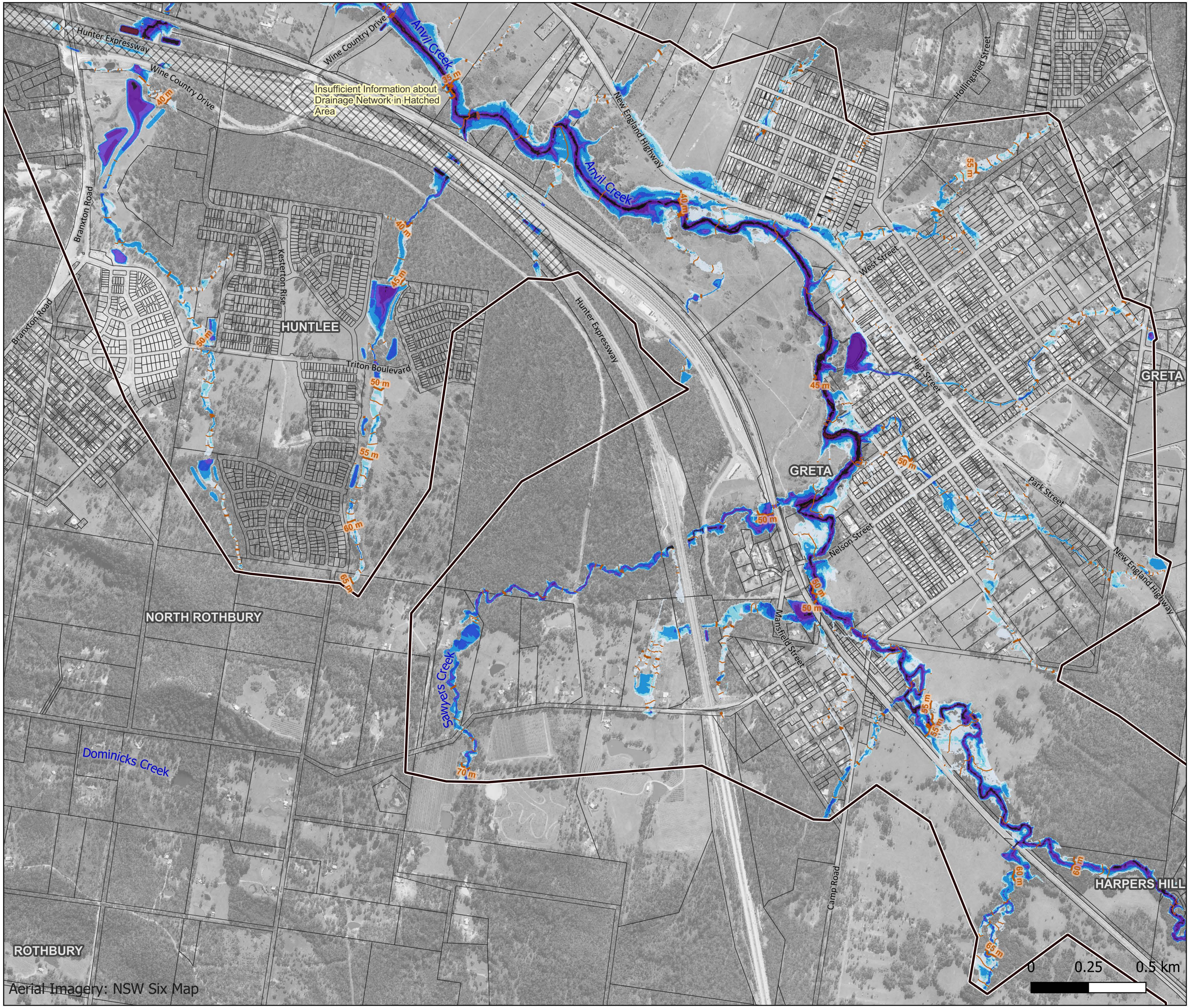

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Greta Updated Flood Study

Peak Flood Depth and Elevation 1% AEP Map 2 of 3

Legend

Hydraulic Model Extent

Cadastre

Water Level Contours

5m

1m

Peak Flood Depth (m)

<= 0.01

0.01 - 0.3

0.3 - 0.5

0.5 - 1

1 - 1.5

1.5 - 2

2 - 3

3 - 4

> 4

Job Number: J1703
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Greta Updated Flood Study

Peak Flood Depth and Elevation
1% AEP
Map 3 of 3

Legend

- Hydraulic Model Extent
- Cadastre

Water Level Contours

- 5m
- 1m

Peak Flood Depth (m)

- <= 0.01
- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 4
- > 4

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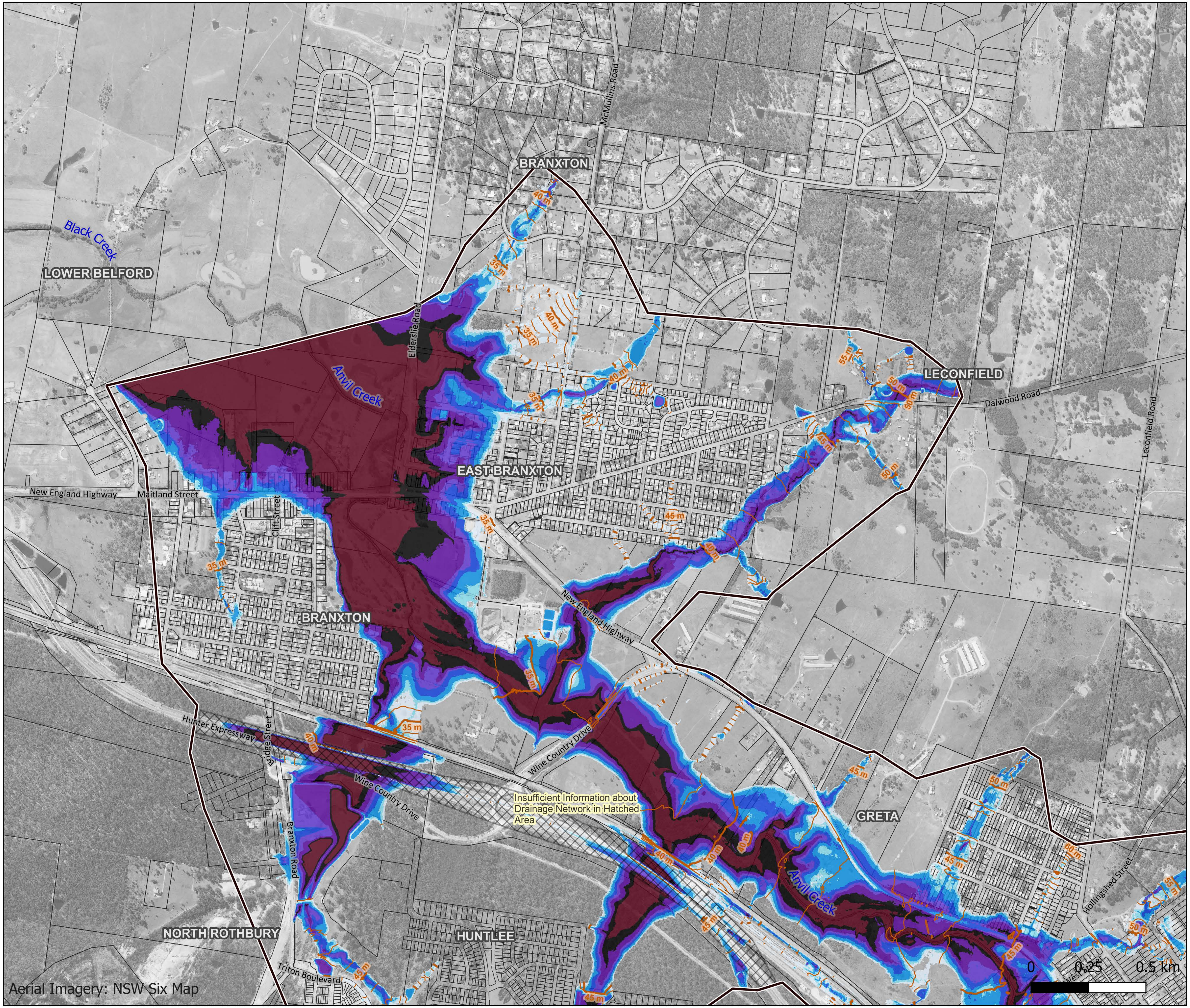

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Greta Updated Flood Study

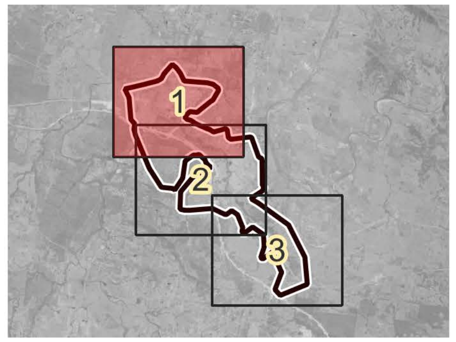
Peak Flood Depth and Elevation PMF Map 1 of 3

Legend

Hydraulic Model Extent
Cadastre

Water Level Contours
5m
1m

Peak Flood Depth (m)
<= 0.01
0.01 - 0.3
0.3 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 3
3 - 4
> 4



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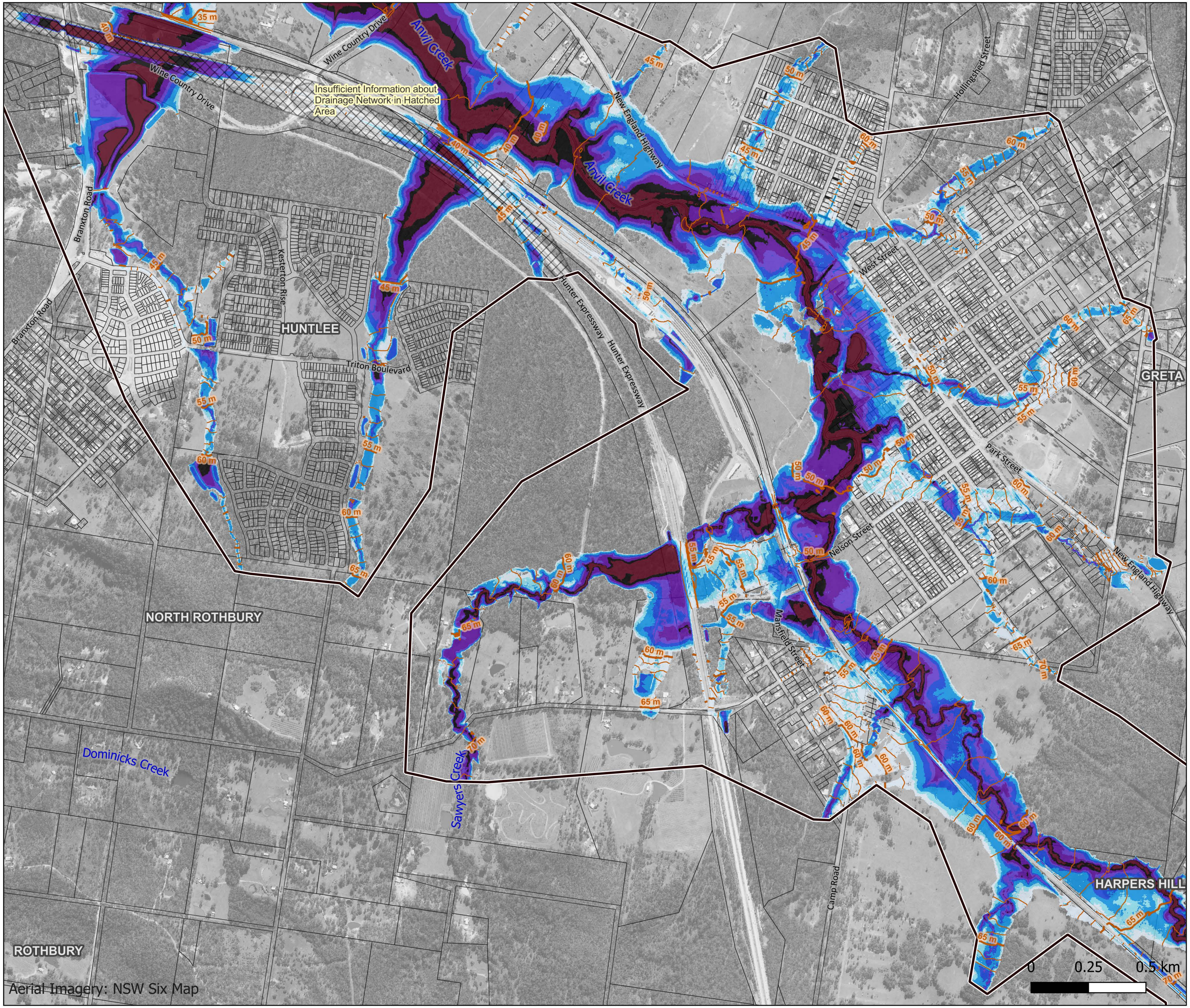

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RG-01-019b

Greta Updated Flood Study

Peak Flood Depth and Elevation PMF Map 2 of 3

Legend

Hydraulic Model Extent

Cadastre

Water Level Contours

5m

1m

Peak Flood Depth (m)

<= 0.01

0.01 - 0.3

0.3 - 0.5

0.5 - 1

1 - 1.5

1.5 - 2

2 - 3

3 - 4

> 4

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Greta Updated Flood Study

Peak Flood Depth and Elevation PMF Map 3 of 3

Legend

- Hydraulic Model Extent
- Cadastre

Water Level Contours

- 5m
- 1m

Peak Flood Depth (m)

- <= 0.01
- 0.01 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- 3 - 4
- > 4

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Glossary

Annual exceedance probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m^3/s (or larger) occurring in any one year (see also average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Catchment	The catchment, at a particular point, is the area of land that drains to that point.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 1% AEP flood).
Development	In accordance with the Environmental Planning and Assessment Act 1979, development is considered to be: the use of land, the subdivision of land, the rection of a building, the carrying out of a work, the demolition of a build or work, or any other act, matter or thing that may be controlled by an environmental planning instrument.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.
Flood hazard	An assessment of how hazardous the physical conditions produced by a flood can be to people, cars, infrastructure and buildings if they were exposed to the flood event, independent of the population at risk. The degree of flood hazard varies with circumstances across the full range of flood events.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as “stage”.
Floodplain	Area of land which is subject to floods up to and including the probable maximum flood.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.

Freeboard	A factor of safety usually expressed as a height above the adopted defined flood event level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Gauging	Measurement of flows and water levels during historic tides or flood events.
Hazard	A source of potential harm or a situation with a potential to cause loss.
Historical flood	A flood that has actually occurred.
Hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems, in particular the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrologic	Pertaining to rainfall-runoff processes in catchments.
Hydrology	The term given to the study of the rainfall-runoff process in catchments, in particular, the evaluation of peak flows and flow volumes. .
Peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs at a specified location during a flood event.
Pluviometer	A rainfall gauge capable of continuously measuring rainfall intensity.
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood that could conceivably occur. Usually as a result of probable maximum precipitation.
Probable maximum precipitation (PMP)	The greatest depth of precipitation (rainfall) for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of year. It is the primary input into the probable maximum flood.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian	The interface between land and waterway. Literally means "along the river margins".
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river, creek or overland flow path.
Topography	The shape and elevation of the surface features of land.
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi-2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

Terminology in this Glossary has been adapted from the Flood Risk Management Manual (DPE, 2023) where available.

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
AEP	Annual Exceedance Probability
ARR	Australian Rainfall and Runoff
ARR2019	Australian Rainfall and Runoff 2019
CSEP	Community and Stakeholder Engagement Plan
DEM	Digital Elevation Model
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DPE	Department of Planning and Environment
EIA	Effective Impervious Area
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FRMSP	Floodplain Risk Management Study and Plan
GIS	Geographic Information System
ha	hectare
IAP2	International Association for Public Participation
IFD	Intensity-Frequency-Duration
km	kilometres
km^2	square kilometres
LGA	Local Government Area
LiDAR	Light Detection and Ranging
m	metre
m^2	square metres
m^3	cubic metres
m AHD	metres to Australian Height Datum
mm	millimetres
m/s	metres per second
NSW	New South Wales
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service (NSW)

1 Introduction

The Greta Floodplain Risk Management Study and Plan (FRMSP) has been prepared for Cessnock City Council (Council) to assess and address the flood risks present in the catchment. The first stage of this FRMSP is this updated Flood Study to document updates to the flood modelling and results from the Greta Flood Study prepared by WMAwater in 2019.

The Greta FRMSP consists of three documents:

- Greta Updated Flood Study,
- Greta Floodplain Risk Management Study, and
- Greta Floodplain Risk Management Plan.

1.1 Study Background

Multiple flood investigations have been undertaken within the study area, both from an individual development and catchment-wide perspective. The most recent Council-commissioned flood study covering the study area is the Greta Flood Study (WMAwater, 2019). This defines mainstream flood behaviour across the study area, covering Anvil Creek and its major tributaries.

Following several significant flood events and community reports of both hazardous and nuisance flooding, Council has identified a number of high-risk areas where improved definition of flood behaviour is desired:

- Mansfield and Bell Streets, Greta
- Station and Hunter Street causeways, Greta
- High Street, Sale Street, Anvil Street, Greta
- 92-94 Maitland Street, Branxton
- Causeways along Tuckers Lane
- Allandale Road Underpass (underneath the railway line).

Extension of the 2019 flood study model is required to cover the Huntlee precinct and a number of the high-risk areas mentioned above. Furthermore, there is potential to improve the definition of flood behaviour in nominated high risk areas through the acquisition of additional ground survey data as well as refinements to the hydrologic sub-catchment delineation. Refinements to the WMAwater (2019) flood modelling and subsequent results in modelled flood behaviour are detailed in this updated Flood Study report.

1.2 Study Objectives

The overall objective of this study is to improve understanding of flood behaviour and impacts and better inform management of flood risk in the study area in consideration of the available information, and relevant standards and guidelines. The information will also assist Council with planning for future development and provide flood intelligence to the NSW State Emergency Services (SES) to enable further emergency management planning for the region.

The floodplain risk management study (FRMS) provides an understanding of the impacts of floods on the existing and future community. Testing and investigation of practical, feasible and economic management measures to mitigate existing, future and residual risk has been undertaken as part of the

FRMS. Recommendations for the implementation and staging of these measures are detailed in the floodplain risk management plan (FRMP).

The recommendations for the implementation and staging of mitigation measures from the FRMS are presented in the FRMP which documents decisions on the management of flood risk into the future for the study area. The FRMP outlines a range of measures to manage existing, future and residual flood risk effectively and efficiently. This includes a prioritised implementation strategy; what measures are proposed and how they will be implemented.

To undertake these assessments (i.e. the FRMS and FRMP), the first step is to update the previous Flood Study. This provides a comprehensive technical investigation of the flood behaviour arising from the updated flood modelling. This analysis provides the main technical foundation for the preparation of the FRMS.

This report details the update of the Flood Study.

2 Study Area

The study area has a total area of approximately 47 km^2 and generally encompasses the entire catchment of Anvil Creek, spanning from the Hunter Expressway Interchange with Lovedale Road down to the confluence with Black Creek. The catchment ranges in elevation from 170 to 20 m AHD.

Major communities in the catchment include Greta, Branxton and East Branxton, and the more recently established community at Huntlee. Based on 2021 Australian Bureau of Statistics (ABS) data, the approximate aggregate population of the study area is 8,000 people with over 3,000 private dwellings. While the Anvil Creek catchment spans the Cessnock, Singleton and Maitland Local Government Areas (LGAs), the majority of area and population falls within the Cessnock LGA.

The largest tributary of Anvil Creek is Redhouse Creek, aligned south and east of East Branxton. Five kilometres downstream of the Anvil Creek and Black Creek confluence is the Hunter River, which can dominate peak flood levels at the downstream end of the Anvil Creek catchment. **Figure 2-1** and **Figure 2-2** provide an overview of the Anvil Creek catchment area and the wider regional waterways.

The largest portion of land use zoning in the catchment is Rural Residential (RU2), located outside of the larger population centres. There are also significant areas of Low Density Residential (R2), General Residential (R1), Large Lot Residential (R5) and Mixed Use (B4). The remaining areas are attributed to commercial, industrial, infrastructure and environmental land uses. **Figure 2-3** illustrates these zones.

Flooding within the study area is characterised by three main flooding mechanisms:

- **Backwater** flooding from the Hunter River. This has been considered in the downstream boundary conditions adopted in the updated flood model; however, the definition of Hunter River flood behavior is not within the scope of this updated Flood Study.
- **Mainstream** flooding around watercourses within the study area. This is the focus of the updated Flood Study.
- **Overland** flooding as runoff is concentrated on its way to the watercourses. The updated flood modelling considers overland flows in the urban areas of Greta and East Branxton.

Often significant flooding occurs when two or more of these sources of flooding coincide within the study area. However, flooding can occur independently via any of the three mechanisms depending on the location and duration of rainfall.

Multiple flood events have been recorded in the study area in recent years, with the most notable examples being the June 2007, June 2011, February-March 2013, November 2013, April 2015 and January 2016 events. The most extreme of these events was the April 2015 event which has been used to validate model results in the updated Flood Study.

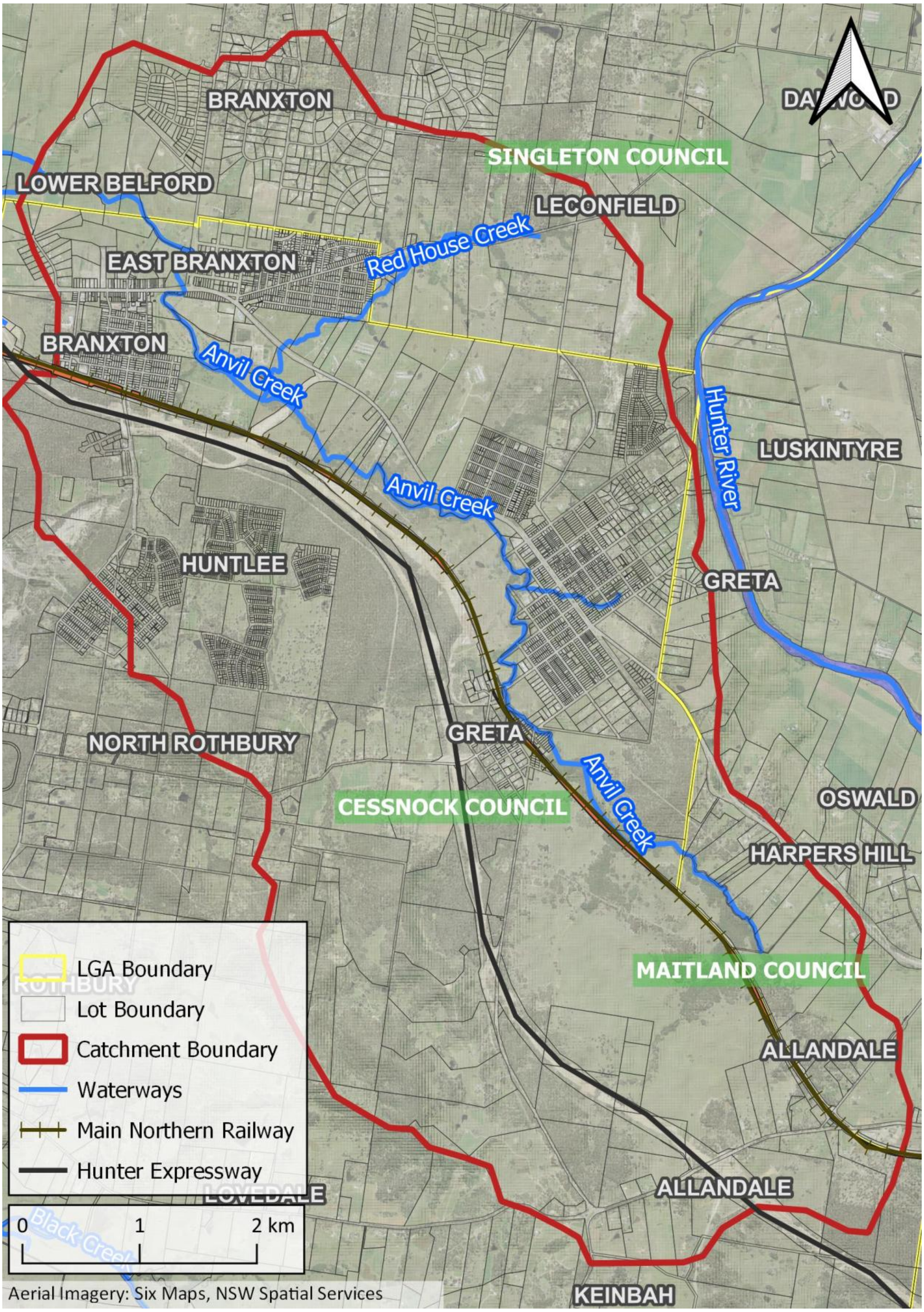

Figure 2-1. Study Area Overview

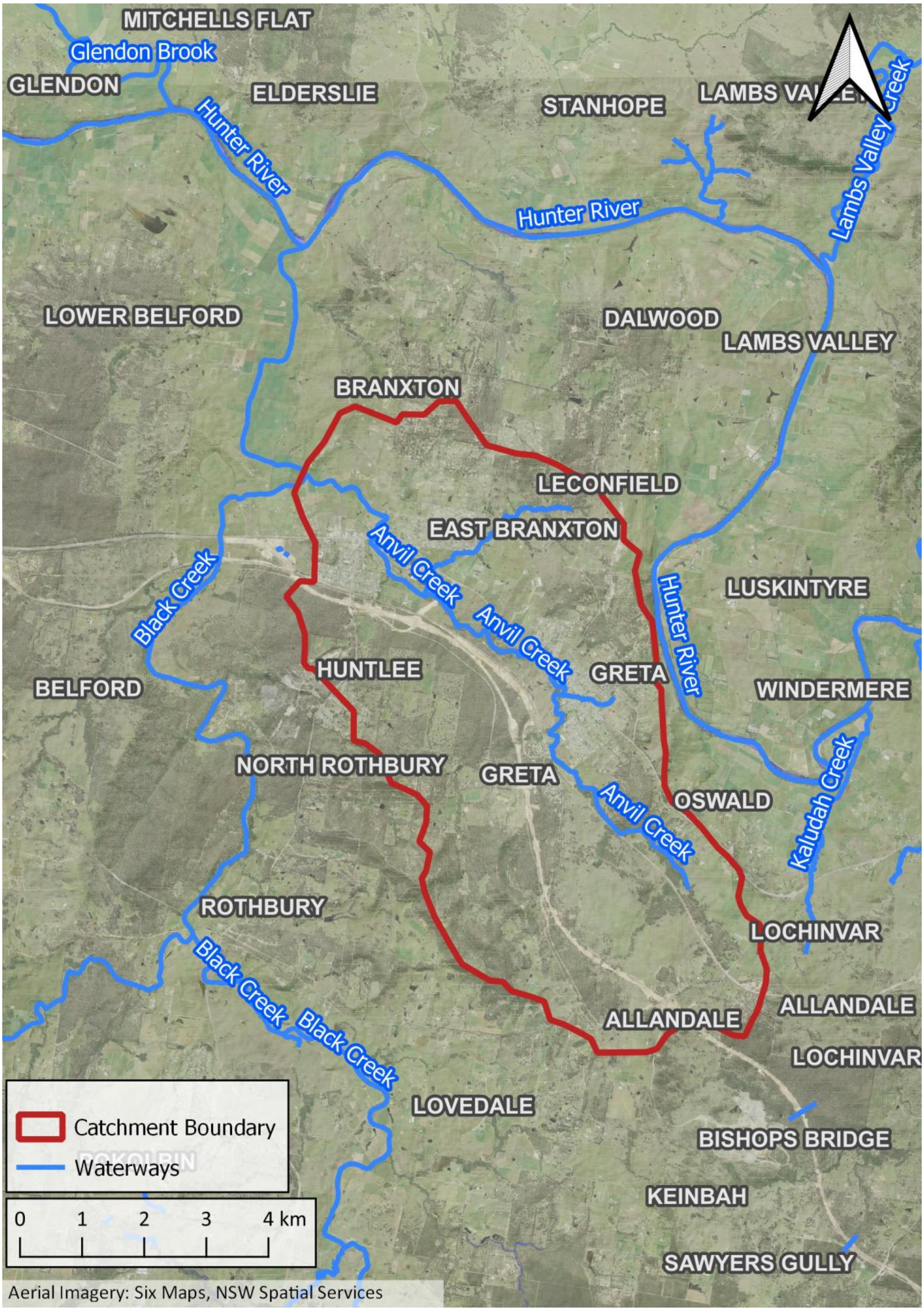

Figure 2-2. Regional Waterways

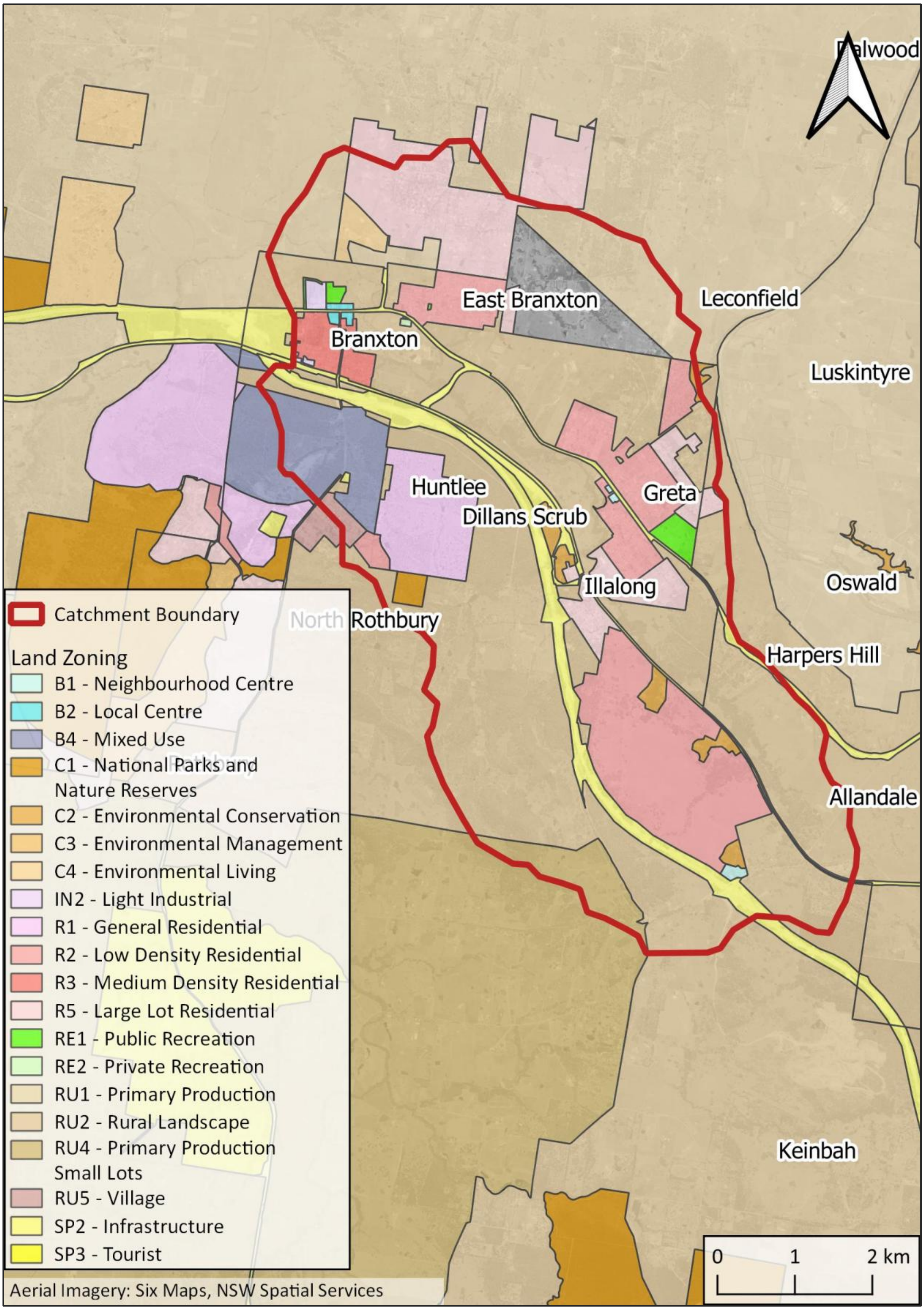

Figure 2-3. Land Use Zoning

3 Review of Available Data

3.1 Site Inspections

Field inspections of the study area were undertaken on 14 November 2022 by two senior Rhelm staff, Council's project manager and a Department of Climate Change, Energy, the Environment and Water (DCCEEW) representative.

The purpose of the site inspection was to gain an appreciation of the catchment features and likely flood risks. The site inspections also identified additional ground survey requirements.

A selection of photographs taken during the site inspection have been included in **Appendix A**.

3.2 Previous Studies and Reports

Several studies have previously been undertaken that are relevant to the preparation of this updated Flood Study and the FRMSP. These studies have been used to inform the understanding of flood behaviour and the assessment of flood management options, including the potential social and environmental impacts of implementing the options.

3.2.1 Greta Flood Study Final Report, 2019

3.2.1.1 Context

Completed by WMAwater in February 2019, this is the key study informing this updated Flood Study and the FRMSP. The Greta Flood Study Final Report, Volumes 1 & 2 (WMAwater, 2019) is referred to as the Flood Study (WMAwater, 2019).

This study area covers the extent of the Anvil Creek catchment, from approximately Allandale in the southeast to the confluence with Black Creek in the northwest; the same study area extents of this FRMSP. Modelled tributaries of Anvil Creek include Red House Creek and several unnamed watercourses. Many of these watercourses run through the urban areas of Greta. Other tributaries west of the Main Northern Railway and Hunter Expressway, including Sawyers Creek and the watercourses originating from North Rothbury and Huntlee, are not included in the hydraulic modelling.

The Flood Study (WMAwater, 2019) established a flood model to define flood behaviour in Anvil Creek and its tributaries for the following design storm events: 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events, as well as the Probable Maximum Flood (PMF) event.

Hydrologic modelling was undertaken using the WBNM software and two-dimensional (2D) hydraulic modelling was undertaken utilising the TUFLOW software.

3.2.1.2 Previous Flood Events

Significant rainfall events were noted as occurring in June 2007, June 2011, February-March 2013, November 2013, April 2015 and January 2016. Intensity-Frequency-Duration (IFD) analysis was undertaken for the June 2007, April 2015 and January 2016 events where it was found that the April 2015 event was the most significant with rainfall intensities exceeding a 1% AEP at several nearby rainfall gauges.

3.2.1.3 Calibration and Validation

One pluviometer gauge is located within the catchment at the Branxton wastewater treatment facility. Other pluviometer gauges are located at least 5 km outside of the catchment, mainly located near Cessnock and Maitland. Temporal patterns from the Maitland 18 WWP and Bolwarra 1A WWPS pluviometers were used for the purpose of model calibration and validation.

No streamflow gauges were available in the study area, and the hydrologic model could not be directly calibrated to historic rainfall events.

The primary data source for historic flood levels utilised in model calibration and validation was gathered during the community consultation process. Flood levels were estimated based on community accounts of their experiences, and these levels were used to calibrate the hydraulic model. The April 2015 event supplied the largest amount of historic flood level data (21 observations) and was selected as the primary calibration event. Additional data (4 observations) were received for the January 2016 and June 2007 flood events and the hydraulic model was validated with these data.

Results of the model calibration and validation were considered to provide a reasonably good match to observed flood marks. For the April 2015 event, modelled flood levels were generally within 0.3 m of observed levels with only two locations where differences were greater than this. The Flood Study (WMAwater, 2019) notes that the modelled peak flood levels were particularly sensitive to the temporal pattern selected for the historic flood events and each event was evaluated using two potentially representative temporal patterns from nearby pluviometer gauges. For the calibration event, an initial loss of 10 mm and a continuing loss of 2 mm/hr were adopted.

3.2.1.4 Design Event Modelling

The calibrated and validated model was then employed to define design storm flood behaviour for mainstream flooding along Anvil creek and its tributaries. Although a number of overland flow paths were included in the modelling and mapping, shallow overland flows were not considered the focus of the study.

The Hunter River design flood levels at Branxton were used as a tailwater condition in the hydraulic model. These levels are originally defined in the *Hunter River Branxton to Green Rocks Flood Study Final Report* (WMAwater, 2010) and were updated as part of the *Hunter River: Review of Branxton Flood Levels* (WMAwater, 2017). A degree of coincidence between flooding in Anvil Creek and flooding in the Hunter River was assumed as outlined in **Table 3-1**.

Table 3-1. Assumed Anvil Creek and Hunter River Flooding Coincidence (2019 Flood Study)

Design Flood	Anvil Creek Catchment Rainfall	Hunter River Flood Event	Hunter River Flood Level (m AHD)
50% AEP	50% AEP	50% AEP	25.1
20% AEP	20% AEP	50% AEP	25.1
10% AEP	10% AEP	50% AEP	25.1
5% AEP	5% AEP	50% AEP	25.1
2% AEP	2% AEP	20% AEP	28.1
1% AEP	1% AEP	10% AEP	29.8
0.5% AEP	0.5% AEP	5% AEP	31.2
0.2% AEP	0.2% AEP	2% AEP	33.1
PMF	Probable Maximum Precipitation (PMP)	2% AEP	33.1

The study includes an analysis of all appropriate factors affecting design storm estimation consistent with Australian Rainfall and Runoff 2016 (ARR2016), being the most up to date version of ARR at the time the Flood Study (WMAwater, 2019) was undertaken. This included analysis of design losses, areal reduction factors, critical durations and temporal patterns.

The critical storm durations for mainstream flooding in the catchment were determined using the WBNM hydrologic model and concluded to be the 360-minute duration event for all storm frequencies, apart from the PMF which displayed a 180-minute critical duration. The 360-minute critical event was compared against other storm durations for a range of storm frequencies to check the impact of selecting different durations depending on the location of interest. Analysis resulted in a peak flood discharge variation ranging between -3% and +9%. It was considered reasonable to assume a critical duration of 360 minutes across the entire catchment for defining design peak flows and flood behaviour.

An initial loss ranging from 8 mm (in the 1% AEP event) to 16 mm (in the 50% AEP event) and continuing loss of 2 mm/hr were adopted. This was consistent with the results of the April 2015 calibration event modelling (10 mm initial loss and 2 mm/hr for continuing loss) and marginally outside reported results from the ARR Data Hub (data.arr-software.org) of a 18 mm initial loss and 2 mm/hr continuing loss.

Results of all design storm events are provided in both tabular and map formats.

3.2.1.5 Planning Analysis

The 2019 study provides preliminary mapping for the following to assist in planning and flood emergency management:

- Provisional hydraulic categorisation,
- Provisional flood hazard categorisation in accordance with both the NSW Floodplain Development Manual (NSW Government, 2005) and Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017),
- Emergency response planning classification, and
- Flood planning area.

The above listed mapping was prepared for all design storm events between the 5% AEP and the PMF. The exception to this is the flood planning area, which was based on 1% AEP water levels with the addition of 500mm freeboard.

An assessment of roadway inundation was included, showing the peak flood flows and depths overtopping roadways at important locations throughout the study area.

3.2.1.6 Sensitivity Analysis

Sensitivity was undertaken for the model input parameters to determine their impacts on modelled flood behaviour. **Table 3-2** summarises the model parameters adjusted, which storm event was considered in the analysis, and the resulting impacts on flood behaviour.

Table 3-2. Flood Study (WMAwater, 2019) Sensitivity Analysis Summary

Model Parameter	Adjustment	Event Assessed	Impact to Flood Behaviour
Rainfall intensity accounting for future climate change	+10% +20% +30%	1% AEP	+10%: increased flow up to 16%, increased flood levels up to 0.15 m +20%: increased flow up to 29%, increased flood levels up to 0.30 m +30%: increased flow up to 44%, increased flood levels up to 0.30 m
Rainfall losses	Decrease continuing loss to 0 mm/hr Increase initial loss to 30 mm	April 2015 calibration event	Continuing loss 0 mm/hr: increased flood levels up to 0.1 m Initial loss 30 mm: decreased flood levels up to 1.0 m (storage areas) and 0.5 m (Anvil Creek)
2D hydraulic model surface roughness Manning's 'n'	+20% -20%	1% AEP	+20%: increased flood levels up to 0.25 m -20%: decreased flood levels up to 0.25 m
Bridge / culvert blockage	No blockage High blockage (approximately double design blockage)	1% AEP	No blockage: decrease in flood levels up to 0.3 m High blockage: increase in flood levels up to 0.5 m
Downstream boundary condition	Increase downstream flood conditions	June 2007 event: shift Hunter River flood peak to coincide with the Anvil Creek flood peak April 2015 event: increase Hunter River level to 28.14 mAHD (20% AEP)	June 2007 event: flood levels increased more than 1.0 m extending to New England Highway at Branxton. April 2015 event: flood levels increased more than 1.0 m extending to New England Highway at Branxton.
Catchment lag	WBNM 'C' parameter + 20% WBNM 'C' parameter - 20%	1% AEP	+20%: decreased flow up to 13%, decreased flood levels up to 0.1 m -20%: increased flow up to 19%, increased flood levels up to 0.1 m

The sensitivity assessment also includes the impacts each parameter has on modelled peak flood levels at key road overtopping locations.

3.2.2 Hunter River Branxton to Green Rocks Flood Study Final Report, 2010

This flood study was completed by WMAwater in September 2010 and superseded the previous flood study for the same reach of the Hunter River issued in 1998.

This study involved defining the flood behaviour and extent of the Hunter River from approximately the confluence with Glendon Brook downstream to the confluence with Barties Creek. Models were calibrated to historical flood data from 1955, 1971, 1977 and 2007. Accuracy of the modelled and observed flood levels ranged from +/- 0.3 m at gauge locations to +/-0.5 m at other surveyed flood observations marks.

This study adopted the 36-hour duration events as critical for tributaries discharging into the Hunter River, including Anvil Creek although it first discharges into Black Creek approximately 4 km south of the Hunter River. The joint probability of Hunter River design events and tributary design events was sensitivity tested with respect to timing, storm duration and flood magnitude.

The major outcome of this study utilised in this FRMSP is the design flood levels in the Hunter River near the downstream extent of Anvil Creek to inform the source of flooding for this portion of the study area.

3.2.3 Hunter River: Review of Branxton Flood Levels, 2013

The *Hunter River: Review of Branxton Flood Levels* (WMAwater, 2013) study involved a review of the flood modelling from the Hunter River: Branxton to Green Rocks Flood Study (WMAwater, 2010) due to discrepancies identified between flood levels reported in this study and the more localised Black Creek Crossing at Branxton – Flood Study (Lyall and Associates, 2004). Based on this review, the modelling was updated with a revised 1% AEP flood level at Branxton of 33.5 m AHD. This updated 1% AEP level at Branxton was used in the downstream boundary conditions adopted in the Greta Flood Study (WMAwater, 2019).

It should be noted that no updated flood levels for the remainder of design storm events were provided as part of this study. As such, there is increased uncertainty regarding the adopted Hunter River flood levels for events outside of the 1% AEP. This only impacts the downstream portion of the study area and is not expected to influence the outcomes of the FRMSP.

3.3 Previous Modelling

3.3.1 Greta Flood Study

As part of the Flood Study (WMAwater, 2019), a WBNM hydrologic model and TUFLOW hydraulic model were developed to define flood behaviour in the study area. A review of the models developed is provided below.

3.3.1.1 Hydrological Model

The details of the hydrological model schematisation and summarised and discussed in **Table 3-3**.

Table 3-3. 2019 Flood Study WBNM Setup Parameters

Data	Comment
Catchment Delineation	The 45.6 km^2 catchment area was broken down into 140 sub-catchments. Sub-catchment areas range from 2.0 – 183.9 ha, with an average area of 32.5 ha. The sub-catchment delineation appears reasonable, with sub-catchments generally of a similar and compact shape. A finer sub-catchment delineation has been adopted over the urban areas. This has been further refined as part of the current study to enable additional hydraulic model inflows and better definition of flood behaviour in urban and high-risk areas.

<table>
<tr><th>Data</th><th>Comment</th></tr>
<tr><td>Lag Parameters</td><td>The Catchment Lag Parameter ‘C’ influences the rate of runoff response from sub-catchments in WBNM. Similarly, the Stream Lag Factor influences the delay of hydrographs through stream routing links. The following parameters have been adopted in the model:
• Pervious Area ‘C’: 1.7
• Impervious Area ‘C’: 0.1
• Stream Lag Factor: 1
The above parameters are consistent with typical values for similar catchments and natural channel types which are prevalent across the study area.</td></tr>
<tr><td>Impervious Area</td><td>The impervious area was calculated individually for each sub-catchment. WMAwater (2019) indicates this was achieved by measuring the area of Manning’s ‘n’ roughness layers (from the hydraulic model) within each sub-catchment and assigning a percentage Effective Impervious Area (EIA) to each roughness categorisation.
Impervious areas were found to be appropriate for the land use within the sub-catchments.
Modifications to impervious area assumptions have been made as part of this updated Flood Study for areas subject to significant land use change since the original Flood Study (WMAwater, 2019), most notably around the Huntlee development precincts.</td></tr>
<tr><td>Rainfall</td><td>For design events, ARR2016 intensity-frequency-duration (IFD) data and temporal patterns were adopted in the model. No change was made to this IFD data or temporal patterns with the ARR2019 update.
Gridded rainfall was applied to account for considerable spatial variability in design rainfall intensity across the subject catchment.
Areal reduction factors (ARFs) were calculated for the 45.6 km^2 catchment in accordance with ARR2016 guidance. Similar to the IFDs and temporal patterns, no change has been made to the ARR2016 ARF equations with the ARR2019 update.</td></tr>
<tr><td>Losses</td><td>Rainfall losses were applied through an initial and continuing loss method. A burst initial loss was applied by subtracting median pre-burst depths (which vary with AEP and duration) from storm initial losses in accordance with ARR2016 procedures.
Similar to rainfall, the model accounts for spatial variability in loss rates across the sub-catchments. The values adopted at the catchment centroid for the critical duration (360 minute) event were:
• Impervious Areas: 0 mm IL / 0 mm/hr CL
• Pervious Areas: 8 mm (1% AEP) – 16 mm (50% AEP) IL / 2 mm/hr CL
The loss values across the model sub-catchments are generally similar to those adopted for the model calibration event.
A small initial loss (typically 1 mm) is usually applied to impervious surfaces; however, adopting nil initial loss for these surfaces is more conservative and is not expected to have a significant impact on modelled flows.
It should be noted that the model does not adopt the ARR2019 methodology of differentiating between pervious and indirectly connected area losses in urban portions of the catchment. This is not considered a significant issue for the subject catchment as the adopted pervious loss values are typical of indirectly connected surfaces in urban areas.</td></tr>
</table>

An issue was identified with the calibration/validation WBNM models involving a mismatch between the sub-catchment naming and the assigned parameters. As a result, incorrect inflows are being applied across the hydraulic model for each calibration and validation event. The correct sub-catchment parameters were assigned for the design event models.

Overall, the Flood Study (WMAwater, 2019) hydrological model utilises appropriate parameters and methodologies based on ARR2016 guidelines. No major revisions to the underlying model assumptions were considered necessary, with the exception of addressing the abovementioned issue with the calibration/validation WBNM inputs for the purpose of validating the updated model.

Refinement to the sub-catchment delineation has been undertaken for urban and high-risk areas to improve the definition of flood behaviour in these areas. Impervious area assumptions have also been revised for areas subject to significant land use change since the development of the Flood Study (WMAwater, 2019) hydrological model.

3.3.1.2 Hydraulic Model

The details of the hydraulic model schematisation and summarised and discussed in **Table 3-4**.

Table 3-4. 2019 Flood Study TUFLOW Model Setup Parameters

Data	Comment
Digital Elevation Model	The Flood Study (WMAwater, 2019) indicates that the Digital Elevation Model (DEM) is based upon LiDAR data collected in 2012. The resolution of this data adopted in the model is 1 m. A 2 m grid cell resolution was adopted across the 15.9 km^2 model area. This resolution is considered sufficient to define the topography of key overland flow paths across the study area. Given the resolution of the model is already high, there is unlikely to be substantial benefit in using recently developed TUFLOW heavily parallelised compute (HPC) features such as sub-grid sampling (SGS) or Quadtree to improve the terrain representation. Although the LiDAR and grid resolution is generally appropriate, there is benefit in supplementing the LiDAR data with ground survey in constrained overland flow paths through high-risk areas to better define flood behaviour.
Inflows	Inflow hydrographs were taken directly from the WBNM model and applied either along the perimeter of the hydraulic model domain or inside the hydraulic model domain at sub-catchment outlets. Inflow locations have been updated as part of the current study to suit the revised sub-catchment delineation in urban and high-risk areas.
Downstream Boundary	A static water level boundary was adopted at the downstream extent of the model using Hunter River flood levels from the *Hunter River: Review of Branxton Flood Levels* (WMAwater, 2017). Given the degree of coincident flooding that would likely occur between the Anvil Creek and Hunter River systems, design events for Anvil Creek were assumed to coincide with a less severe Hunter River event. This approach for defining flood levels in the downstream portion of the model is considered appropriate.

Data	Comment
Roughness	Roughness values were determined based on aerial photography and the hydraulic model calibration. Values adopted were: • Default 0.040 • Light Vegetation 0.040 • Thick Vegetation 0.070 • Waterways (light veg) 0.050 • Waterways (thick veg) 0.100 • Pavement 0.020 • Urban 0.100 • Wetland 0.050 • Railway 0.040 • Lakes 0.100 • Concrete Channel 0.014 • Pipes/Culverts 0.012 These values are generally considered reasonable. However, the roughness of 0.100 attributed to lakes is significantly higher than the typical range of values for this surface type. Roughness delineation has been reviewed and revised as part of this update as necessary to reflect present conditions.
Buildings and Obstructions	The influence of buildings and obstructions (such as fences) in urban areas of the model was accounted for by adopting a higher lot-averaged roughness of 0.100. This approach is considered reasonable.
Drainage Features	The main drainage channel through Greta (a tributary of Anvil Creek) has been modelled as a 1D element. This likely provides a better representation of this drainage feature than if it were modelled in 2D given it is predominantly a narrow, concrete-lined channel with steep side slopes. The remainder of channels/overland flow paths in the study area have been represented in the 2D domain. Culvert crossings and trunk stormwater networks have also been modelled in the 1D domain. It is understood that details of these features have been based on work as executed (WAE) drawings, site measurements and estimates using LiDAR and aerial photography. In the updated modelling, the 1D network has been extended to include larger stormwater networks (with pipe diameters greater than 600mm) in critical areas and new cross drainage structures associated with the Huntlee development. This required the acquisition of stormwater survey data in a number of areas to infill data gaps and confirm the dimensions of key structures.
Bridges	Bridges located between a series of 1D channels were modelled as 1D structures with an overflow weir in TUFLOW. For the remainder of the model (in the 2D domain), bridges have been represented using 2D layered flow constrictions. Avoiding the transition from 1D to 2D and vice versa is the best practice approach for preserving momentum through these structures.

Data	Comment
Blockage	The following structure blockage values were applied for each design event based on the bridge/culvert opening width: • Opening Width < 0.9m 50% • 0.9m <= Opening width <= 1.5m 25% • Opening Width > 1.5m 10% ARR2019 guidance recommends blockage factors that vary based on the event AEP in relation to structure opening widths. Adopting ARR2019 AEP blockages would result in similar, if not slightly less conservative, blockage factors for events ranging from the 5% AEP up to and including the 0.5% AEP and as such, the Flood Study (WMAwater, 2019) blockages are considered appropriate for use in the updated Flood Study. Changes due to blockage factors in more extreme events would not be expected to significantly impact results because of the higher proportion of flow being conveyed overland in these events. It should be noted that no blockage factors were being applied to 1D bridge structures as TUFLOW does not currently allow the direct application of blockage to these structure types. This has been amended in the updated modelling by applying an equivalent bridge skew factor.
Stability	The Flood Study (WMAwater, 2019) model was run for the 1% AEP and PMF events. The model was found to run stably in the 1% AEP event; however, some stability issues were identified in the 1D channel element traversing Greta in the PMF event. This 1D channel has been stabilised in the updated modelling.

The TUFLOW model developed for the Flood Study (WMAwater, 2019) was found to be generally suitable for its use in the Floodplain Risk Management Study. Minor updates to the model were required (as noted in **Table 3-4**) to reflect current site conditions, improve the definition of flood behaviour in critical areas and to address some minor issues identified in the model review.

3.3.2 Huntlee Modelling

The north-western portion of the catchment contains the Huntlee urban release area. This area is traversed by two tributaries of Anvil Creek that are subject to altered flood behaviour because of the development. It is important that design information for these areas be included in the updated model. The civil engineering design for these areas is being undertaken by Northrop who have provided the following information to Council to assist with the FRMSP:

- 3D design surfaces for the development area surrounding both tributaries. These have been incorporated into the updated TUFLOW model DEM as part of the current study.
- Hydraulic structure details for cross drainage culverts and detention basin outlets. These features have been included as 1D elements in the updated TUFLOW model as part of the current study.
- Peak flood depth, elevation, velocity, hazard and hydraulic category files for the individual site flood models established for the developments.

3.4 Survey

3.4.1 Aerial Survey

Light Detection and Ranging (LiDAR) data was collected for this study area between approximately October 2011 and May 2012 by NSW Spatial Services. These data are freely available on the ELVIS - Elevation and Depth - Foundation Spatial Data website (elevation.fsdf.org.au). **Table 3-5** summarises the metadata for this data set.

Table 3-5. LiDAR Metadata Summary

Parameter	2011 / 2012 LiDAR Data Set
Source	NSW Spatial Services
Formats	DEM, Point Cloud
Resolution	1 m (DEM) 1.6 points/m^2 (Point Cloud)
Vertical Accuracy	0.30 m (at 95% confidence interval)
Horizontal Accuracy	0.80 m (at 95% confidence interval)

The Flood Study (WMAwater, 2019) notes that LiDAR ground survey data collected in 2012 was provided by Land and Property Information (LPI) NSW.

Additional LiDAR data were provided by Council. This data has a resolution of 5 m and was not utilised in the updated flood model due to the lower resolution than was used in the Flood Study (WMAwater, 2019).

3.4.2 Ground Survey

The Flood Study (WMAwater, 2019) notes that no detailed ground or creek cross-section survey was obtained as part of that study.

As part of this updated Flood Study, a ground survey of targeted areas was undertaken in October 2023 by Marshall Scott Surveyors. The acquisition of survey data was intended to refine the hydraulic model, particularly in areas adjacent to existing residential properties. More accurate geometric data were also gathered for the following elements:

- Hydraulic structures (bridges and culverts),
- Stormwater pits and pipes, and
- Creek and overland flow path cross sections.

Photographs of surveyed hydraulic structures have been included in **Appendix B**.

3.4.3 Bathymetric Survey

No bathymetric survey is available for this updated Flood Study, nor was any been utilised in the establishment of the Flood Study (WMAwater, 2019).

Based on a site inspection and review of the LiDAR data used in the WMAwater (2019) TUFLOW model, the capacity of waterways within the study area do not appear to be impacted by the presence of standing water. As such, no bathymetric survey is proposed for this FRMSP.

3.4.4 Floor Level Survey

This information is used in the FRMSP to estimate flood damages to properties (buildings and yard damages) in design flood events, providing a sound economic analysis of the benefits for any proposed flood modification measures.

Two floor level surveys were provided by Council for this FRMSP:

- Flood Level Survey for 8 June 2007 Storm Event, Cessnock LGA (Carman Surveyors, 2008). This survey includes flood survey data following the significant storm event across the Hunter region. Flood marks were surveyed for all locations. In some instances, floor levels were also surveyed where flooding affected residential dwellings. This survey contains flood survey information in Branxton, Branxton East and Greta.
- Cessnock Floor Level Survey Appendix B – Building Details, Volume 1: Northern Region (Carman Surveyors, 2011). Data provided in this survey includes full building information for a range of properties within Cessnock, as well as some in Nulkaba. It does not cover the study area of the Greta FRMSP.

While these data sets provide useful information with respect to historic flooding, particularly for the survey of the 2007 storm event flood levels, there is little data for existing floor level information within the study area of this updated Flood Study.

A floor level survey of 96 properties was undertaken in October 2023 by Marshall Scott Surveyors to provide a higher accuracy estimate of flood damages. This survey was based on dwellings identified as likely being subject to over floor flooding in the 1% AEP event using the results of the flood extents from the Flood Study (WMAwater, 2019).

3.5 Other Spatial Data

The following spatial data has been provided by Council to assist in the completion of this updated Flood Study:

- **Existing Culverts**. The data provided identifies the location of culverts within the study area located in the public roadway corridor. There are a mix of public and privately owned assets. These data only contain the location of the culverts and not all hydraulic characteristics are provided; only culverts internal dimensions are given. These data were utilised to identify any significant culverts not included in the Flood Study (WMAwater, 2019) hydraulic model to refine flood behaviour in areas of significant flood risk.
- **Existing Stormwater Pits and Pipes**. The data received includes information on these stormwater assets such as pit internal dimensions, inlet types and sizes, pipe sizes and general condition of the asset. These data have been used be used, where appropriate, to supplement the hydraulic flood model data in locations subject to significant flood risk.
- **Hunter Water Concrete Channels**. This data shows the extent of Hunter Water owned and operated concrete channels in the region. However, the extent of the data provided is constrained to the Cessnock urban area and not within the extents of this updated Flood Study.
- **Ground Contours**. These data include contour lines at varying intervals (10 m and 2 m). These data do not have any discernible use for this study as the LiDAR data available provides greater accuracy and resolution for determining ground levels.

- **Planning Data**. This includes multiple spatial layers utilised for planning purposes. Data received relevant to this study, and spanning the study area, include:
  - Flood data (PMF, 1% AEP, Flood Planning Area, flood category, hazard) for the following studies:
    - Greta Flood Study Final Report (WMAwater, 2019), and
    - Hunter River Branxton to Green Rocks Flood Study Final Report (WMAwater, 2010).
  - Land zoning, including areas applicable to clauses of the Cessnock LEP 2011,
  - Biodiversity mapping,
  - Aboriginal Land Council mapping,
  - Resilience and hazards SEPP mapping,
  - Huntlee lot types,
  - Local development contributions,
  - Planning proposal locations (as at the time of issue),
  - Mine subsidence mapping, and
  - Native Vegetation Act mapping.

3.6 Design and Work as Executed Drawings

Design and work as executed drawings were provided for relevant developments and civil works within in the study area. These include:

- Devonrise Estate (Devon Street, Greta) work as executed drawings,
- Whitburn Estate (Whitburn Street, Greta) Stage 2 work as executed drawings, and
- Whitburn Estate (Whitburn Street, Greta) Stages 3 and 4 civil engineering design drawings.

Where appropriate, ground surface and drainage information contained in these drawing sets were incorporated into the updated flood model.

4 Consultation

4.1 Background

The Community and Stakeholder Engagement Plan (CSEP) for the updated Flood Study and FRMSP were developed in consultation with Council. Refer to **Appendix C** for details of this plan.

The consultation for both the Anvil Creek (Greta) and Black Creek Nulkaba to Branxton (Stage 2) catchments was held concurrently, considering the proximity of the catchments to each other, and the potentially affected stakeholders and community members. The engagement approach was also informed by the guidance in the Flood Risk Management Manual (DPE, 2023).

Preparation of the Greta updated Flood Study and FRMSP consists of two instances of public consultation where the local community is invited to provide feedback and suggestions and share their experiences of flooding. The first instance being aimed at informing the community of the studies and gathering flood information. This occurred over the period of July and August 2023.

The second instance of direct community engagement was during the Public Exhibition of the updated Flood Study and FRMSP between 13 August and 19 September 2025. The studies were displayed on Council's website with the opportunity to provide feedback via the *Together Cessnock* website (https://together.cessnock.nsw.gov.au/). In addition, a public drop-in session occurred at the Greta Court House on 1 September 2035, from 2:30pm to 6:30pm.

4.1.1 Previous Engagement

Earlier community engagement conducted to inform the development of the Greta Flood Study (WMAwater, 2019) identified residents who had experienced problems with flooding. Thirty-two (32) respondents had reported their properties being affected by flooding in the past. Of those who reported flooding, 10 properties were flooded above floor level, of which six provided a flood mark. A further six flood marks were collected during secondary site visits to community member's households in April 2015. Further flood marks were discovered during a data collection exercise in April 2015.

Overall, it is considered that the Greta community is likely to support flood mitigation measures given the relatively recent history of flooding. There is generally a high awareness of flood risk in the study area and a willingness by residents to take action to reduce their flood risk exposure. In assessing current community sentiment consideration for nuisance flooding and/or isolation issues that have been reported to Council at several rural and residential locations within the catchment including:

- Mansfield and Bell Streets, Greta
- Station and Hunter Street, Greta causeways
- High Street, Sale Street, Anvil Street, Greta
- Maitland Street, Branxton
- Causeways along Tuckers Lane
- Allandale Road Underpass (under railway line)
- The Huntlee Commercial Precinct.

4.2 Purpose and Objectives

The purpose of the Community Engagement Program was to:

- Inform the community regarding the flood risk context and potential flood modification options.

- Seek input from the community and incorporate their local flooding knowledge to inform the updated Flood Study and the FRMSP.

The community engagement objectives were to:

- Work with the community to identify flood risk, develop appropriate flood mitigation works, and the appropriate methods to educate the community on how to prepare for a flood event.
- Inform the local community of the scope of the updated Flood Study and FRMSP.
- Establish a common understanding of flood risk and how decisions are made by inviting key stakeholders to contribute to the development of the FRMSP.

4.2.1 Stakeholder Matrix

A Stakeholder Matrix was developed within the CSEP following the project inception, this matrix included an assessment of the key stakeholders and their level of interest, influence, and impact on the development of the update Flood Study and FRMSP. This stakeholder analysis also included the suitable level of consultation identified for each stakeholder based on the International Association for Public Participation (IAP2) consultation spectrum. The level of engagement with each stakeholder was also refined in consultation with Council and the DCCEEW.

4.3 Engagement Methods

A variety of communication and engagement methods were used to encourage community involvement and participation in the consultation process. The communication and engagement methods and the details of each method used are outlined below in **Table 4-1.**

Table 4-1. Communication and Engagement Methods

Method	Details
Communication Methods	
Brochure	Printed copies of the brochure were placed in public buildings including local libraries, and at Council's admin office.
Posters	56 posters were displayed in the Greta & Black Creek Study area in local takeaway shops, retail outlets, restaurants, pharmacies, shopping centres, and in community halls and on notice boards.
Electronic Newsletter	An electronic newsletter was sent out when the questionnaire was sent out on 19 July 2023 and 20 September 2023.
Cessnock Council Website	The Together Cessnock webpage was updated on 13 June 2023 to include: • Overview of the Project, • Maps of both the Greta and Black Creek study areas (including waterways), • Online questionnaires, • Frequently Asked Questions (FAQs), and • Details on how to seek more information. During the Public Exhibition period, in August and September 2025, the website was further updated to • Display the draft updated Flood Study and FRMSP, and • Enable feedback to be provided by the community online.

Method	Details
Media Releases	A Media Release titled *The Floodplain Risk Management Study & Plan for Greta and Black Creek* was published on 7 July 2023. Media articles were included both in print and online in the Cessnock Advertiser on 14 July 2023 and in Branxton Greta Vineyard News for their July Edition.
Social Media	Social media posts were featured on Council's Facebook page on 12 July 2023 encouraging the community to provide their input on the FRMSPs, and a reminder to submit their input and complete the questionnaire was posted ahead of the closure of the initial consultation period. A post was featured on Council's Facebook page on 9 August 2023 to inform the community of an extension in the time that the questionnaire would remain open. The post encouraged and reminded the community to contribute their thoughts ahead of the closure of the initial consultation period.
Community and Stakeholder Engagement Methods	
Email to key stakeholders	Stakeholder letters were sent to the following key stakeholders on 10 July 2023 ahead of the public release of the questionnaire on Council's website to encourage their feedback: • Hunter Water • Mindaribba Local Aboriginal Land Council (LALC) • Around Hermitage Association • SES • DCCEEW • Cessnock Council staff.
Questionnaire	17 online completed responses to the questionnaire were received during the initial consultation period from 31 August 2023 to 30 September 2023 when the questionnaire was open for feedback. A summary of the feedback received via the questionnaire is detailed in **Section 4.5.** During the Public Exhibition period, the draft studies were downloaded a total of 40 times. No online surveys were received.
Public Exhibition	The Draft Updated Flood Study, FRMS and FRMP was placed on Public Exhibition between 13 August and 19 September 2025 to allow the public to provide comment. The public drop in session occurred at the Greta Court House on 1 September 2035, from 2:30pm to 6:30pm. Seven community members registered their attendance at the session where they discussed the draft studies with Council, DCCEEW and Rhelm.

4.4 Stakeholder Engagement

Key stakeholders identified in the CSEP were invited for further consultation to raise their awareness of the updated Flood Study and FRMSP and to seek preliminary input.

Responses were received from the following stakeholders:

- Huntlee Development,
- SES,
- Around Hermitage Association,
- Mindaribba LALC, and
- Hunter Water Corporation.

4.5 Online Questionnaire Feedback

During the initial public consultation period (July to August 2023), 17 questionnaire responses were received to the online questionnaire which is considered a low response rate relative to the population. A copy of the questionnaire is included in **Appendix D.** Most respondents to the Greta FRMSP questionnaire were from Greta (postcode 2334) – 76%, then equally from Cessnock (postcode 2325)-12% and Branxton (postcode 2335) -12%.

The questionnaire was promoted through numerous communication channels including Council's website, Media Release, E-newsletter, social media posts, brochures, posters in the local area, and a surveyor letter sent to affected property owners during the floor level survey. A summary of the feedback received via the questionnaire is included below.

Figure 4-1 illustrates the spread of respondents based on their length of time spent in the study area.

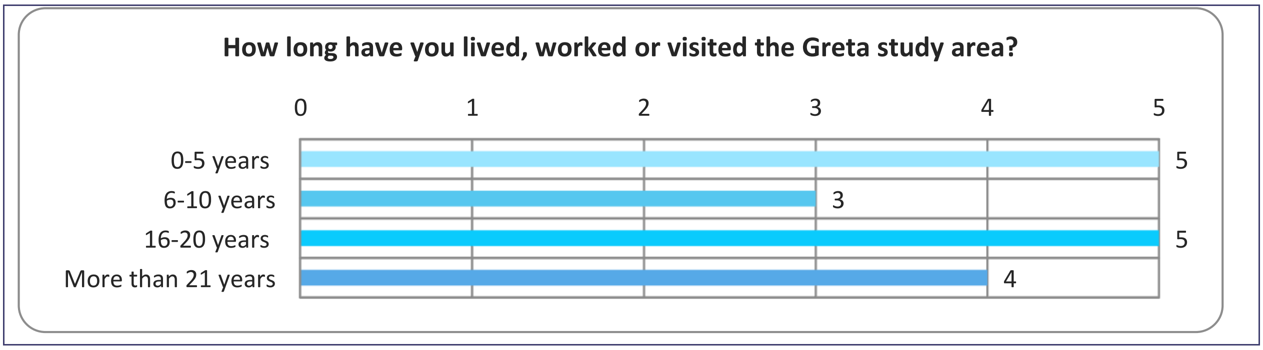

Figure 4-1. Questionnaire Results - Length of Time in Study Area

Figure 4-2 shows responses to a number of questions aimed to understand how residents behave during a flood risk scenario. Most respondents are likely to remain in their homes during a flood event and given the nature of flooding in Anvil Creek and local overland flow paths (i.e. inundation duration likely to be a few hours instead of a few days) this is a reasonable response. Results also tend to skew towards respondents utilising internet-based sources for information about potential flooding.

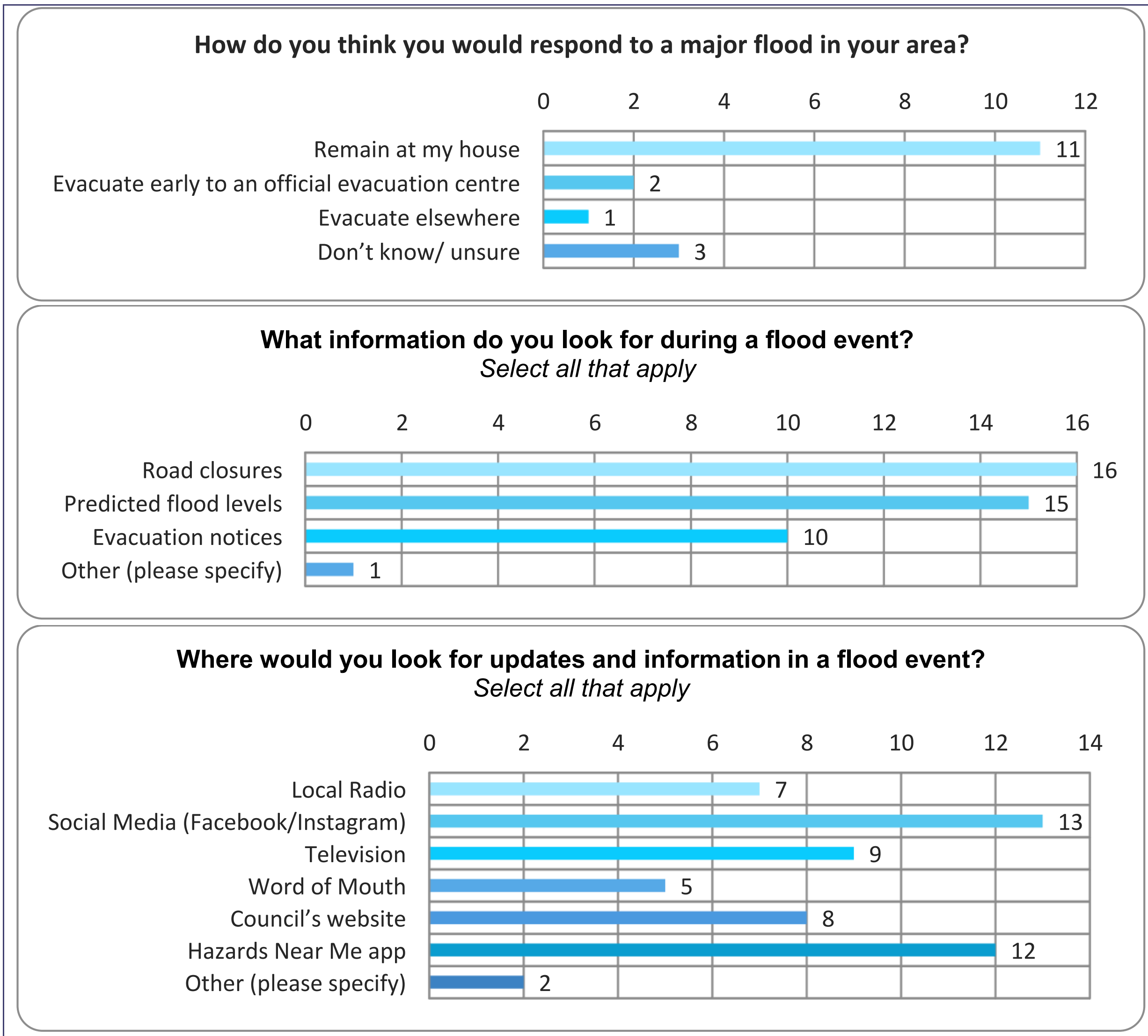

Figure 4-2. Questionnaire Results – Behaviour in Response to Flood Risk

Figure 4-3 and **Figure 4-4** summarise community attitudes towards common flood risk management options. While this may not be pertinent information for the updated Flood Study, the FRMSP recommendations are influenced by the support of community members in the study area. In general, support was displayed for all the flood risk mitigation measures suggested in the questionnaire. The greatest support (i.e. ten or more respondents 'strongly support') was shown for development controls, emergency response plans and flood warning signs; all non-structural flood risk mitigation options.

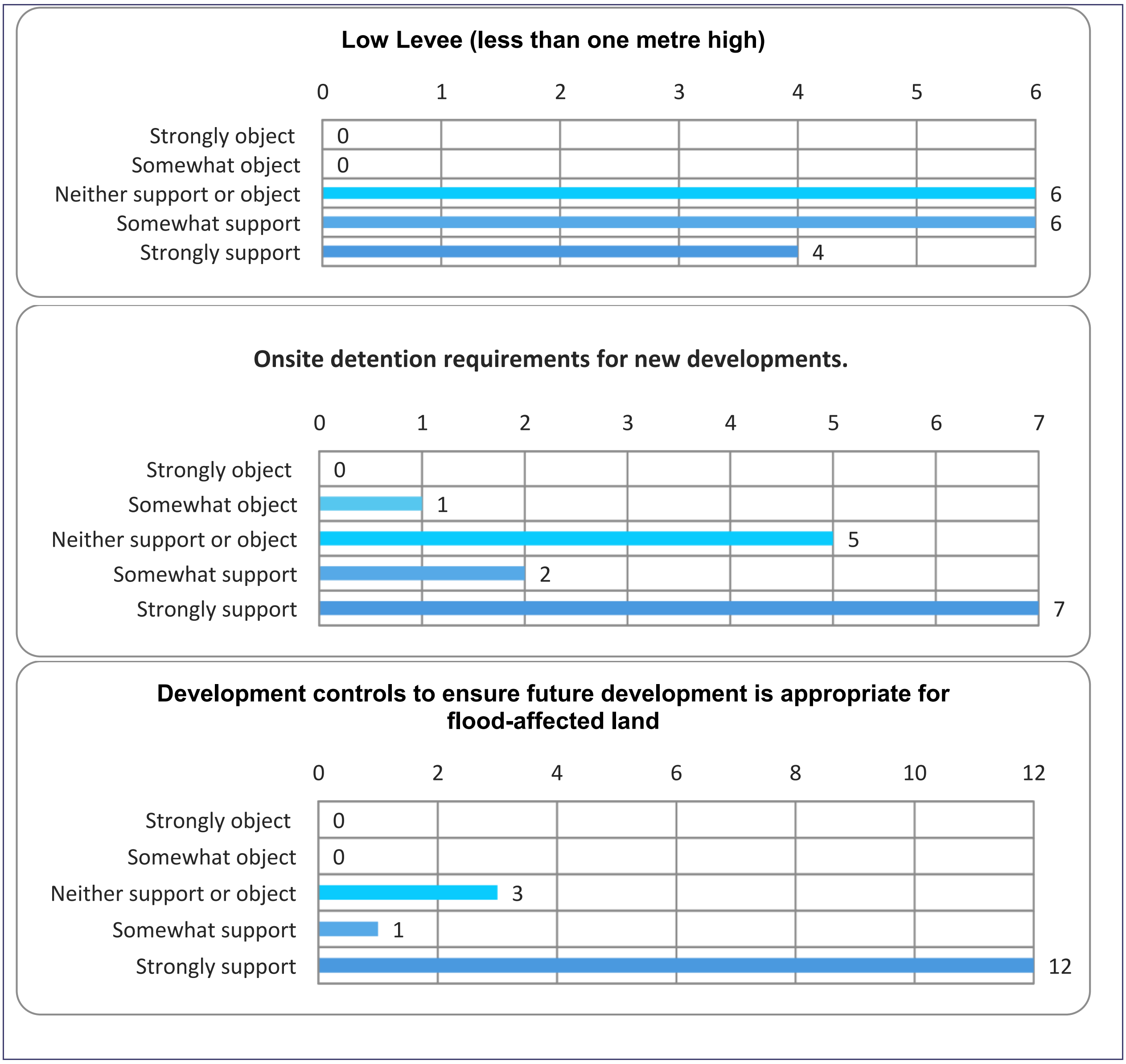

Figure 4-3. Questionnaire Results – Respondent Attitude Towards Flood Mitigation Options (1 of 2)

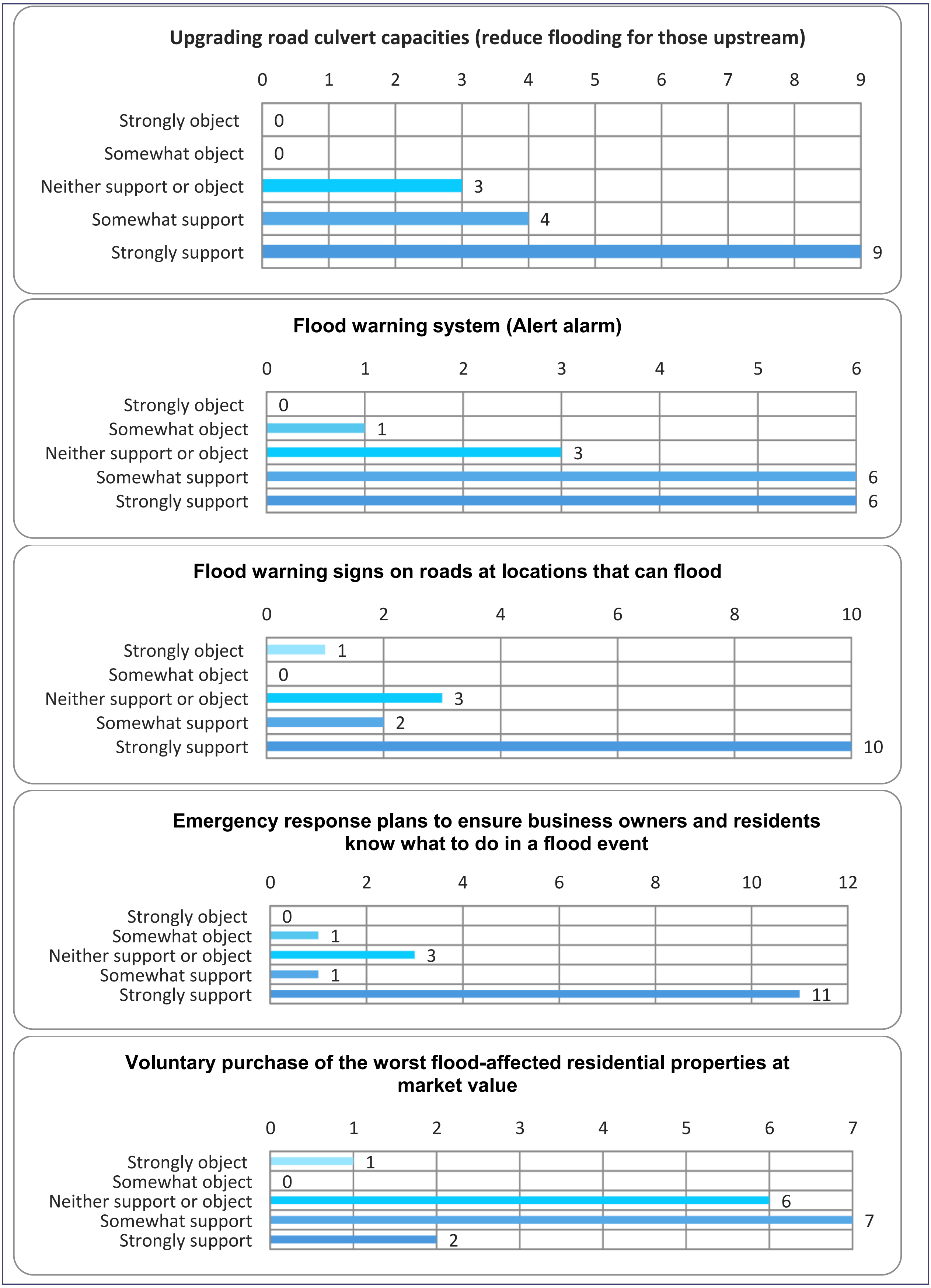

Figure 4-4. Questionnaire Results – Respondent Attitude Towards Flood Mitigation Options (2 of 2)

4.6 Public Exhibition Outcomes

During the Public Exhibition period, Council's *Together Cessnock* webpage was updated to allow the community to submit feedback online. A total of 49 participants were considered to be 'informed' by the study. This included downloading the exhibited documents, frequently asked questions, or visited the 'key dates' page. 84 participants were considered to be 'aware' of the study, defined by the number of times the webpage was visited. No participants were considered 'engaged' with the study (e.g. leaving feedback, filling surveys, asking questions, etc.).

Further details on the Public Exhibition period and the issues raised are found in the FRMS.

5 Flood Model Update

5.1 Hydrologic Model Updates

In general, only minor changes were made to the WBNM hydrologic model from the Flood Study (WMAwater, 2019). This primarily consisted of increasing the sub-catchment resolution around urbanised areas and updates to impervious area mapping to account for development in the catchment since the previous model was constructed.

More substantial changes to the hydrologic model were made in the area representing the north-western tributaries of Anvil Creek to reflect the recent catchment changes associated with the Huntlee development. Sub-catchment delineation across these tributaries was largely based on development design information (refer **Section 3.3.2**). The urban areas within the Huntlee development generally have a higher dwelling density compared to the broader catchment and as such, a higher EIA assumption of 60% (compared to 30% for the remainder of the catchment) was applied to the urban lots.

All other aspects of the WBNM model, including loss assumptions, design rainfalls and temporal patterns remained as per the Flood Study (WMAwater, 2019) model. The previous impervious area assumptions for the recently constructed Wyndham Rydge subdivision, to the north-east of Greta, were retained with the updated modelling. This was considered appropriate given that hydraulic model inflows are applied downstream of this area and on-site detention would be provided to reduce post-development flows to pre-development levels for events up to and including the 1% AEP. It is not expected that minor flow increases in rarer events would have a significant impact on downstream design flood levels.

Updated sub-catchment mapping is shown in **Figure 5-1**. Details of each sub-catchment are provided in **Appendix E**.

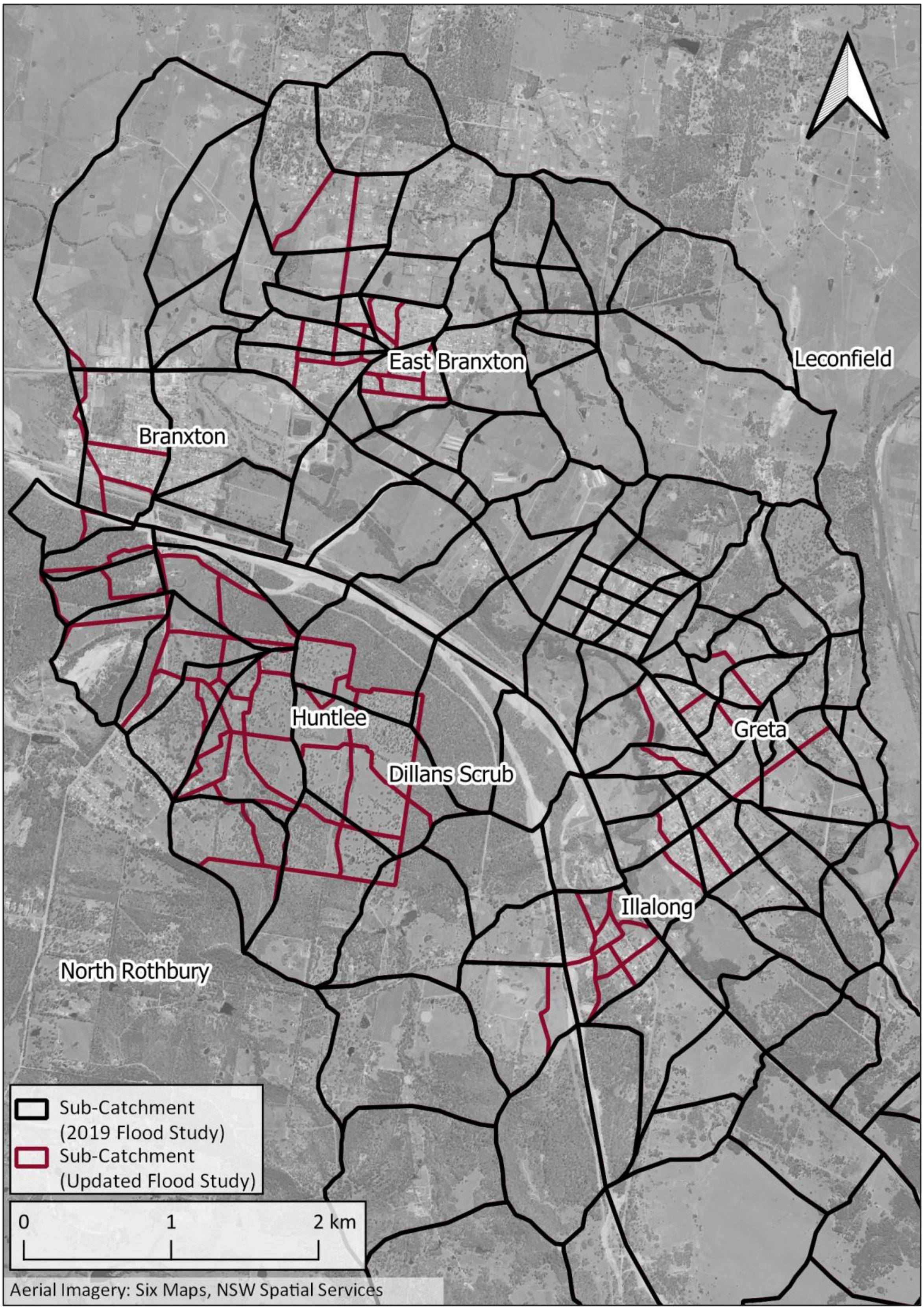

Figure 5-1. Updated Sub-Catchments

5.2 Hydraulic Model Updates

The TUFLOW model developed as part of the Flood Study (WMAwater, 2019) was extended and updated to provide improved definition of flood behaviour in areas identified by Council as having known flood risk. The details of the hydraulic model developed for the current study are provided in the following sections.

An overview of the key model changes is presented spatially in **Figure 5-2**.

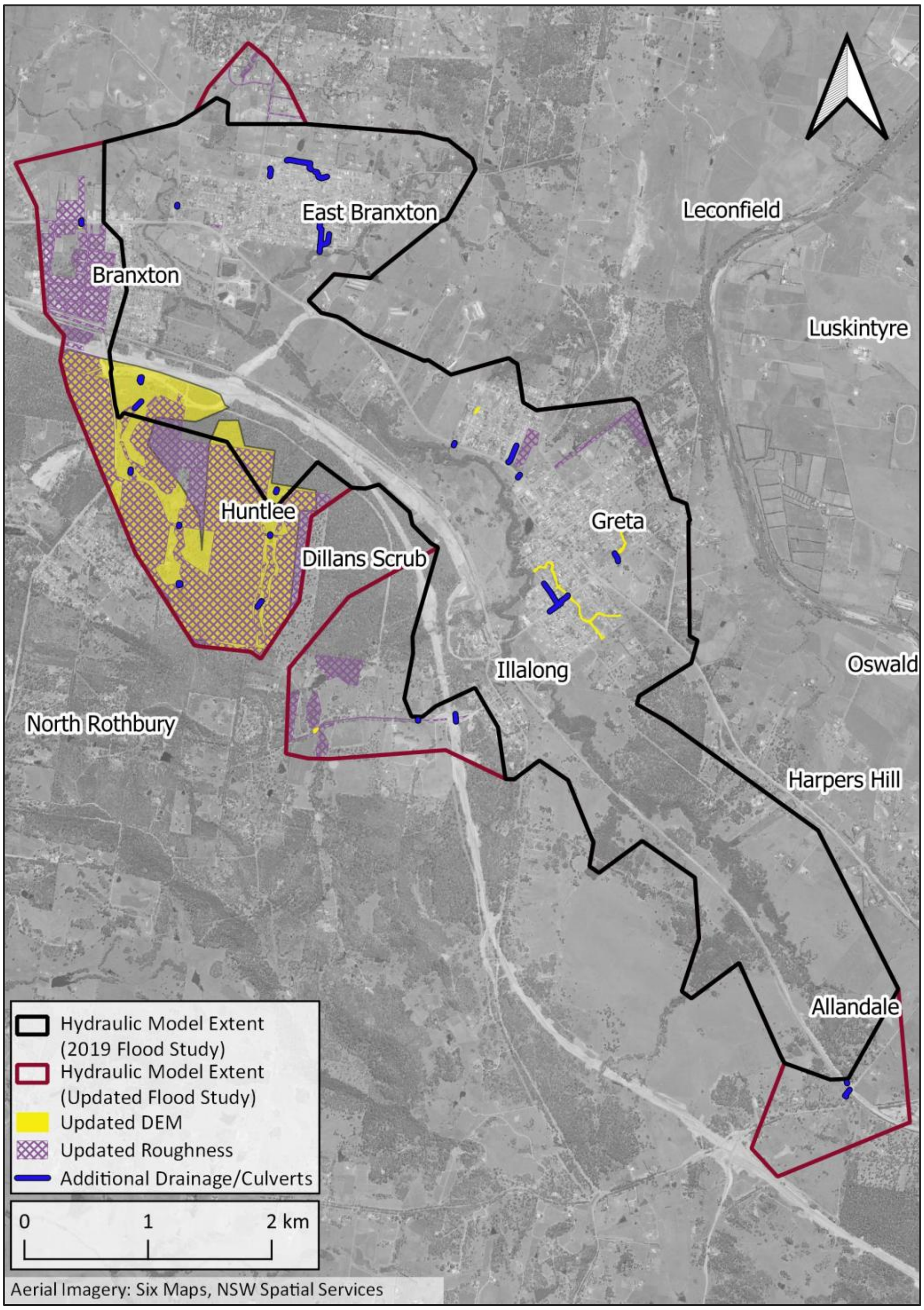

Figure 5-2. Hydraulic Model Updates

5.2.1 Model Extent

The hydraulic model domain was extended to cover:

- The Huntlee development,
- Northern and western Branxton/East Branxton,
- The Allandale Road underpass, and
- Additional tributaries of Anvil Creek that intersect Tuckers Lane.

The updated TUFLOW model extent is shown in **Figure 5-3**.

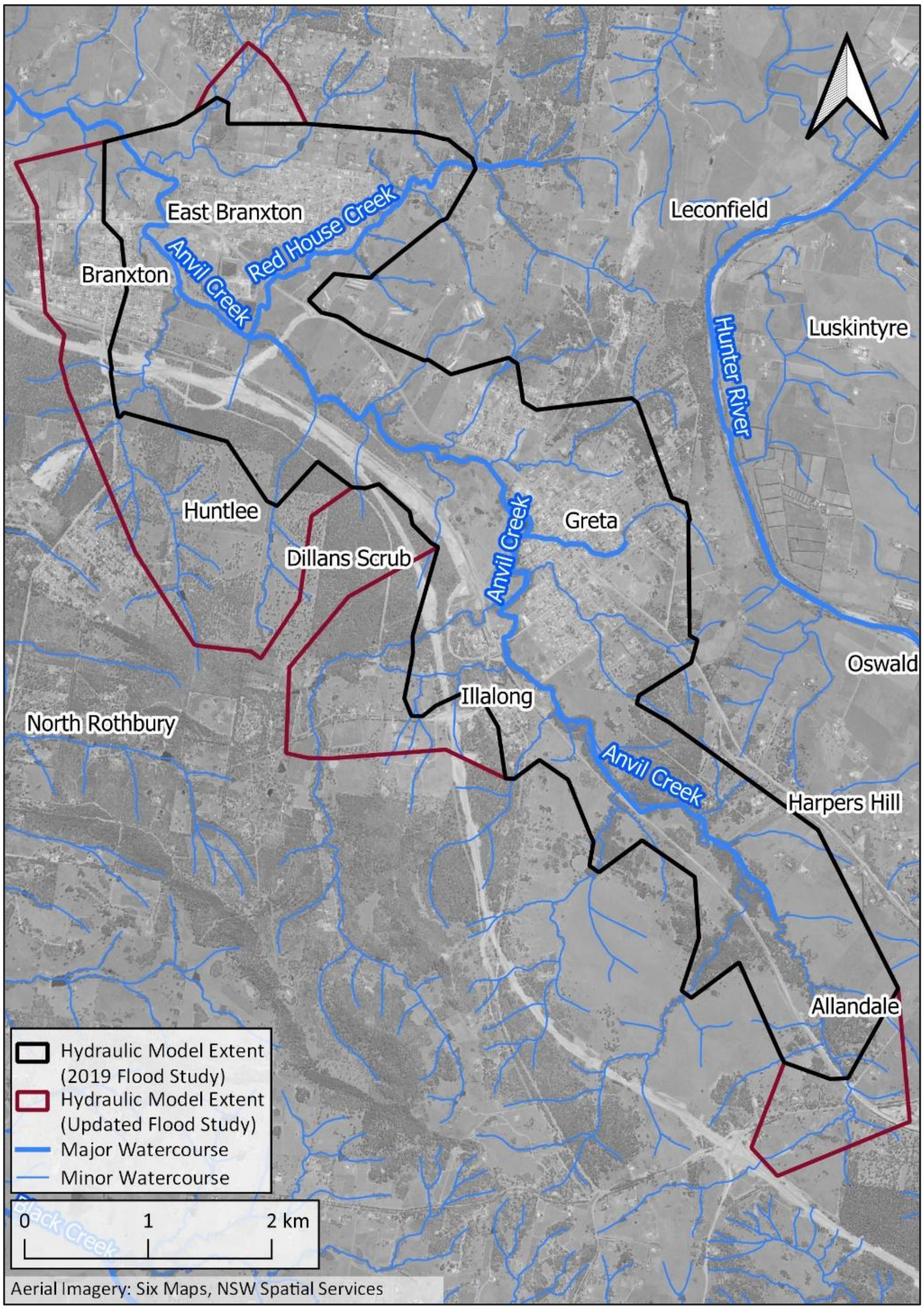

Figure 5-3. Hydraulic Model Extent

5.2.2 Digital Elevation Model

The DEM was updated to include cross section survey data (**Section 3.4.2**) for a number of key flow paths, a design surface DEM (**Section 3.3.2**) covering the two Anvil Creek tributaries within the Huntlee precinct and work as executed information for the Whitburn Estate watercourse (**Section 3.6**).

The updated model DEM is shown in **Figure 5-4**.

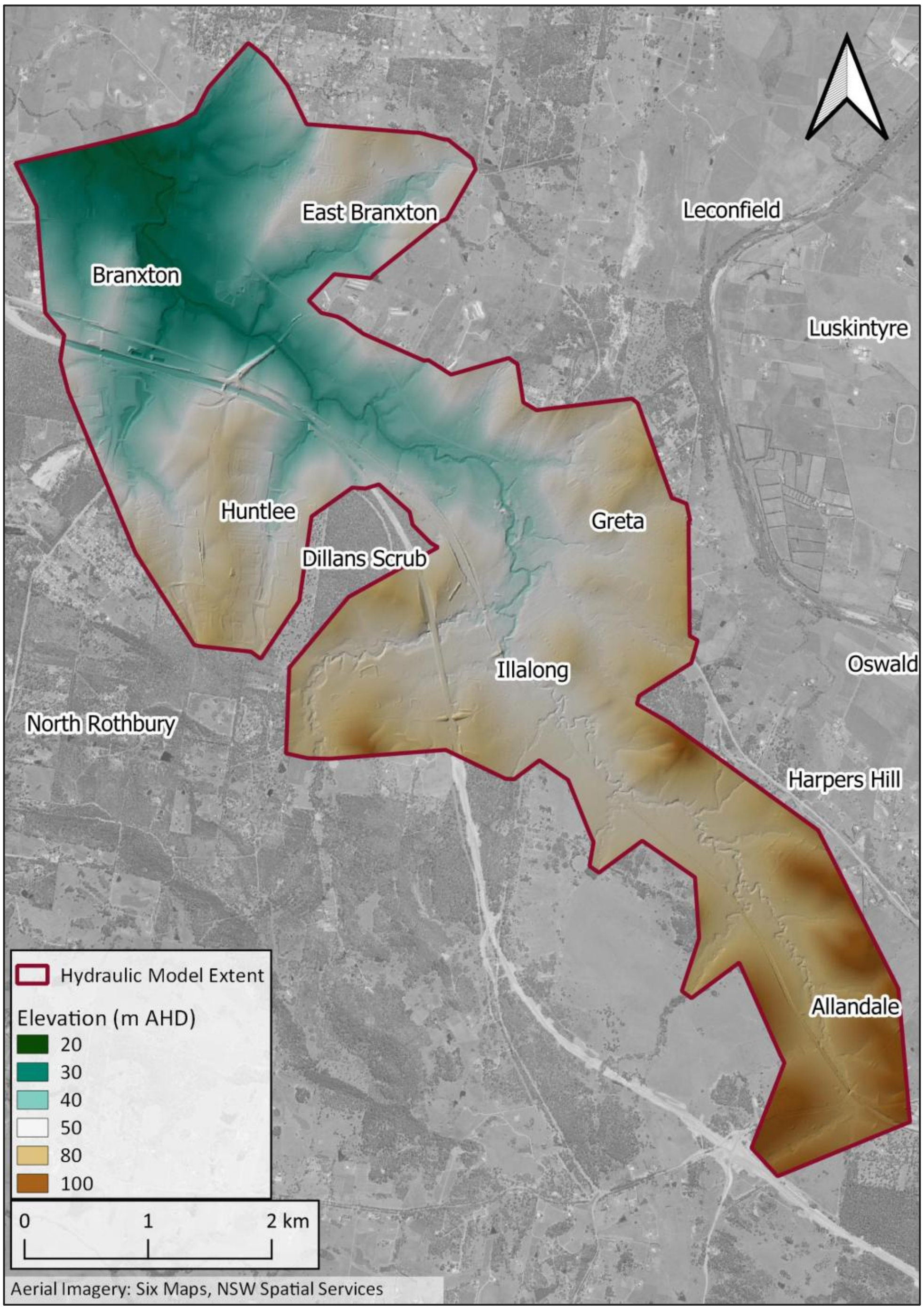

Figure 5-4. 2D Hydraulic Model DEM

5.2.3 Surface Roughness

The surface roughness delineation was updated for areas where development has occurred since the construction of the Flood Study (WMAwater, 2019) model, and where the TUFLOW model has been extended. The corresponding roughness values for each surface type were kept consistent with the 2019 Flood Study, with the exception of farm dams/permanent waterbodies where the roughness value was changed from 0.1 to a more typical value of 0.03.

The delineated roughness zones are shown in **Figure 5-5**.

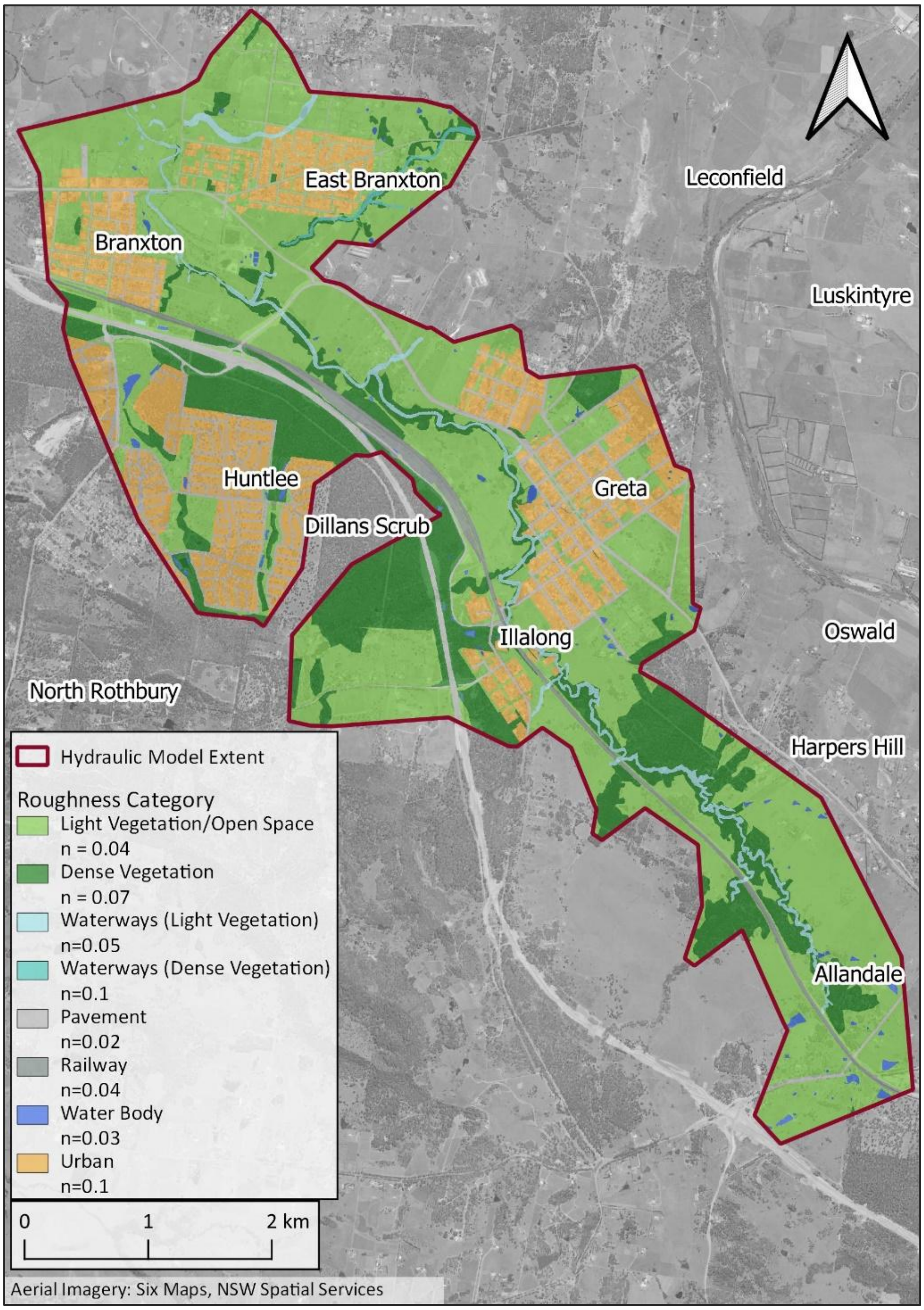

Figure 5-5. Surface Roughness Categories

5.2.4 Culverts and Drainage

One dimensional culvert and drainage features were updated based on ground survey (**Section 3.4.2**) and engineering drawings (**Section 3.6**) for key cross drainage structures and trunk drainage lines. Additional trunk drainage lines in the urban areas of Greta and Branxton were included in the model using Council's GIS stormwater data (**Section 3.5**). The additional stormwater network data included in the model has been limited to drainage lines with pipes greater than 600mm in diameter.

The model excludes longitudinal drainage networks within the Hunter Expressway corridor due to a lack of information on these features in the WMAwater (2019) model or provided GIS drainage information. However, key transverse drainage elements have been included as they tend to have a greater impact on flood behaviour. The areas where flood levels and inundation durations may be overestimated due to the lack of longitudinal drainage representation have been highlighted in the attached flood mapping (**Appendix F**).

Within the Huntlee precinct, cross drainage and basin outlet structures were incorporated into the model based on design information provided by Northrop (**Section 3.3.2**). For this area, inflows were applied to basins and riparian corridors consistent with the precinct-specific flood modelling and as such, stormwater drainage networks were not included in the updated TUFLOW model.

Structure blockage and energy loss assumptions remained as per the Flood Study (WMAwater, 2019) model.

The 1D elements incorporated into the model are shown in **Figure 5-6**.

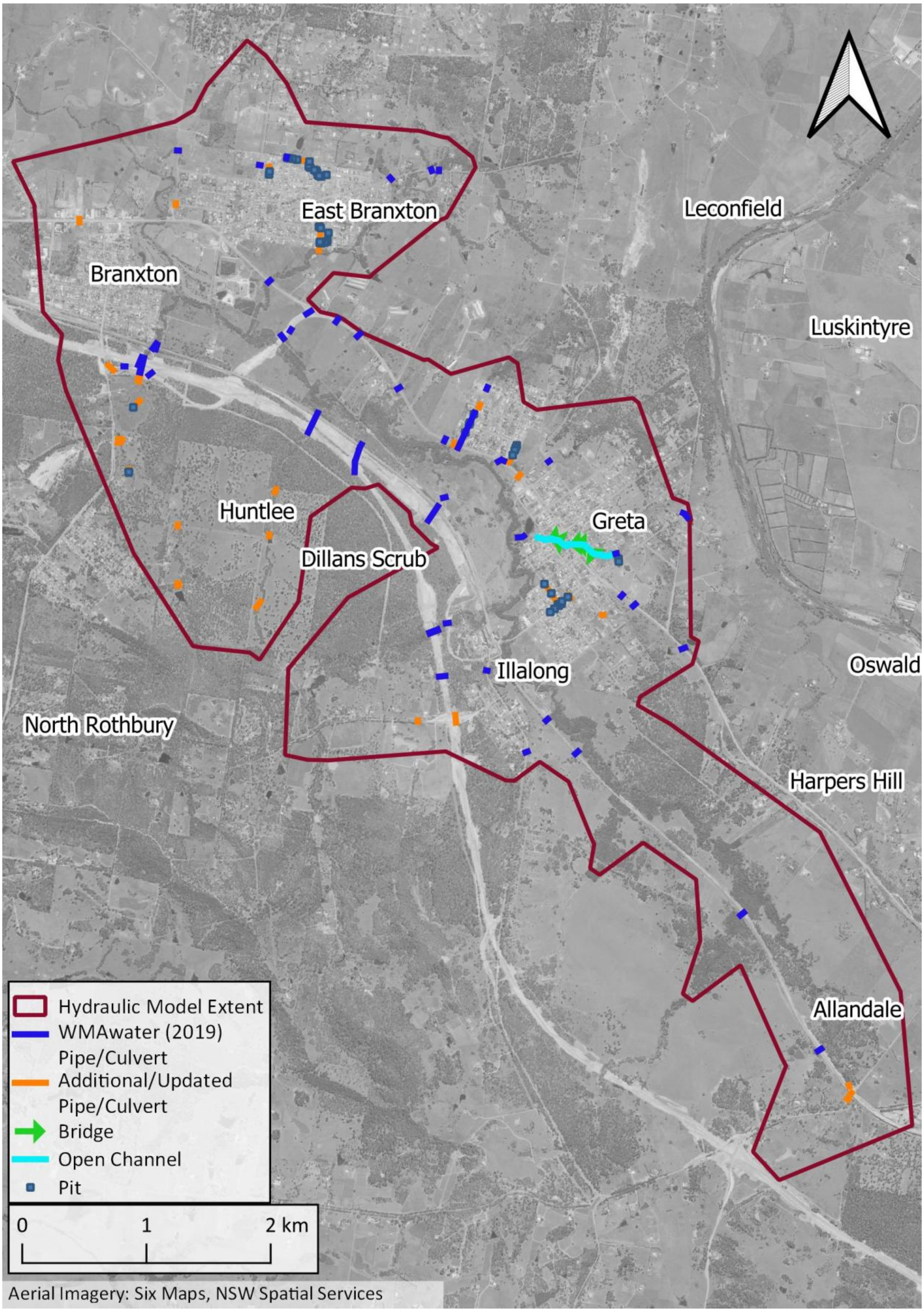

Figure 5-6. Location of TUFLOW 1D Elements

6 Model Validation

To confirm that the updated model still sufficiently replicates observed flood behaviour, the updated model was validated against the April 2015 event used for calibration of the WMAwater 2019 model.

As mentioned in **Section 3.3.1**, an error was found in the calibration and validation WBNM models from the Flood Study (WMAwater, 2019) which was amended for the updated validation model. All other model assumptions for the April 2015 event remained as per the WMAwater (2019). It should be noted that the WMAwater (2019) model did not adopt any structure blockage for the April 2015 event which would be expected to result in the under-prediction of flood levels at several locations.

The updated model was run using the Maitland 18 WWP pluviometer temporal pattern which was noted as being the most consistent with other nearby gauges (WMAwater, 2019). A comparison of observed and modelled flood levels at the 21 observation points used in the Flood Study (WMAwater, 2019) shown in **Table 6-1**. Mapped results for the April 2015 validation event using the updated model are included in map **RG-01-001**.

Table 6-1. April 2015 Observed and Modelled Flood Level Comparison

Location	Observed Flood Level (m AHD)	WMAwater (2019) Model Flood Level Difference (m)	Updated Model Flood Level Difference (m)
3 Branxton Street Greta	54.14	0	-0.1
30 Hunter Street Greta	50.80	0.1	-0.2
1 Sale Street Greta	57.05	-0.3	0.2
6 The Barracks Close Greta	51.00	0.7	-0.5
76 Sale Street Greta	47.75	-0.3	-0.3
9 Hunter Street Greta	48.20	0.1	0.1
21 Hunter Street Greta	50.15	-0.2	-0.5
17C Evans Street Greta	58.70	0.1	Not Flooded
1 Wyndham Street Greta	47.45	0.1	-0.3
11 Hunter Street Greta	49.60	0.3	-0.3
20 Anvil Street Greta	56.21	0.1	0
51 York Street Greta	49.40	0	0
78 Sale Street Greta	47.70	-0.3	-0.4
19 Mansfield Street Greta	58.35	-0.3	0
43 Sale Street Greta	51.10	0	-0.2
5 Katerina Close Greta	55.8	-0.1	Not Flooded
6-8 Dalwood Street Greta	54.26	0	Not Flooded
67 High Street Greta	48.70	0	-0.2
100 Hillview Street East Branxton	38.40	-0.5	-0.1
1 Durham Road East Branxton	41.05	Not Flooded	Not Flooded
7 Preston Close East Branxton	42.83	Not Flooded	-0.2

As shown in **Table 6-1**, the updated April 2015 model results are improved at six locations when compared to flood observations, and further from observed values at ten locations. When considering the aggregate of modelled vs observed flood levels, the outcome of the April 2015 calibration/validation is similar to that of the Flood Study (WMAwater, 2019), with a general tendency to slightly underpredict flood levels when using the rainfall temporal pattern from the Maitland 18 WWP gauge. Discrepancies between the updated April 2015 results and those from the Flood Study (WMAwater, 2019) can be primarily attributed to amending the model inflow error.

The results of the WMAwater (2019) calibration modelling indicate that flood levels at observation points are sensitive to the rainfall temporal pattern adopted in the WBNM model. The flood levels produced from the Bolwarra 1A WWPS gauge are generally higher than those from the Maitland 18 WWP gauge, with an overprediction of flood levels at a number of locations where the Maitland 18 WWP gauge underpredicts levels. It is possible that the characteristics of the rainfall temporal pattern over the Anvil Creek catchment during the April 2015 were somewhere in between those recorded at the two aforementioned gauges, which would produce modelled flood levels closer to observed values.

Structure blockage would also have an impact on flood levels in the calibration events. Results of the WMAwater (2019) sensitivity testing indicate that adopting nil structure blockage per the assumptions of the calibration/validation modelling reduced flood levels by up to 0.3m when compared to results with the adopted design blockages. This could also account for some of the underprediction of flood levels in the April 2015 event.

Given the degree of uncertainty in a number of the flood observations, the historical rainfall temporal pattern for the catchment and the likelihood of structure blockage, the updated model is considered to reasonably replicate historic flood behaviour for the April 2015 event.

7 Design Event Modelling

The updated hydrologic and hydraulic models were used to simulate the 1 Event per Year (EY), 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% AEP events and the PMF event. Each event was run for the same duration and temporal pattern as the Flood Study (WMAwater, 2019) with the exception of the 1EY which was not assessed as part of the original study.

For the 1EY event, the 6-hour duration, temporal pattern 05 storm was selected as the representative critical duration, median temporal pattern event for the study area using the results of the WBNM hydrologic model. The 50% AEP Hunter River downstream boundary conditions were conservatively assumed for this event.

7.1 Flood Study (WMAwater, 2019) Comparison

For the 1% AEP event, results from the updated modelling were compared with those from the Flood Study (WMAwater, 2019) with difference mapping provided in map **RG-01-002**.

In general, the results of the updated modelling are consistent with the Flood Study (WMAwater, 2019). Differences along Anvil Creek are less than 0.1 m along the entire length and less than 0.02 m along the majority on Anvil Creek. Flood level differences in the southern portion of Anvil Creek can be attributed to the extension of the hydraulic model.

A general reduction in flood levels is observed at the locations where ground survey data was incorporated into the model due to the surveyed levels being lower than LiDAR in confined flow paths and differences in structure dimensions compared to the WMAwater (2019) model. This is most pronounced immediately upstream of Nelson Street where the surveyed culvert dimensions were significantly larger than those adopted in the WMAwater (2019) TUFLOW model, resulting in a decrease in flood levels by up to 1m.

There are also general decreases in flood levels where additional stormwater pit and pipe networks have been added to the model. A notable example of this is Whitburn Estate where flood levels are reduced by up to 0.3 m to the east of Devon Street.

Increases in flood levels of up to 0.3 m are observed immediately downstream of the Huntlee development. These increases can largely be attributed to the altered hydrology associated with the development.

7.2 Flood Depth and Velocity

Peak depth and velocity maps have been prepared for each modelled event. In order to remove areas of shallow, low hazard overland flow and smaller isolated ponding areas, flooded areas that did not meet the following filtering criteria were excluded from the mapping:

- Depth < 0.10 m, or
- Depth < 0.05 m and velocity x depth < 0.025 m^2/s, or
- Velocity < 2.0 m/s, and
- Isolated ponding extents < 100 m^2.

Peak flood depths and elevations are shown in maps **RG-01-010** to **RG-01-019**. Peak velocities are shown in maps **RG-01-020** to **RG-01-029**.

It should be noted that the 1EY flood levels are slightly higher (up to 0.07 m) than the 50% AEP levels in the middle portion of Anvil Creek due to the selection of a single, representative critical duration and median temporal pattern for these events. Despite the 50% AEP event having a higher design rainfall depth than the 1EY (45mm compared to 40mm for the 6-hour duration), this can occur due to the different timing of hydrograph peaks associated with the different representative temporal patterns. As expected, 1EY flood levels are lower than 50% AEP levels across the remainder of the study area (including all urban areas).

7.3 Flood Hazard

Flood hazard is a combination of depth and velocity at a single point within a floodplain. It varies depending on localised flood behaviour across different sized flood events.

It is important to understand the varying degree of hazard and the drivers for the hazard, as these may require different management approaches. Characterising flood hazard informs emergency and flood risk management for existing communities, and strategic planning for future areas of development.

The criteria and descriptions for hazard categories mapped in this study are summarised in **Table 7-1** and **Figure 7-1**. These are based on the categories defined in the AIDR (2017) guideline.

Flood hazard mapping is provided in maps **RG-01-030** to **RG-01-033**.

Table 7-1. Flood Hazard Category Description

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

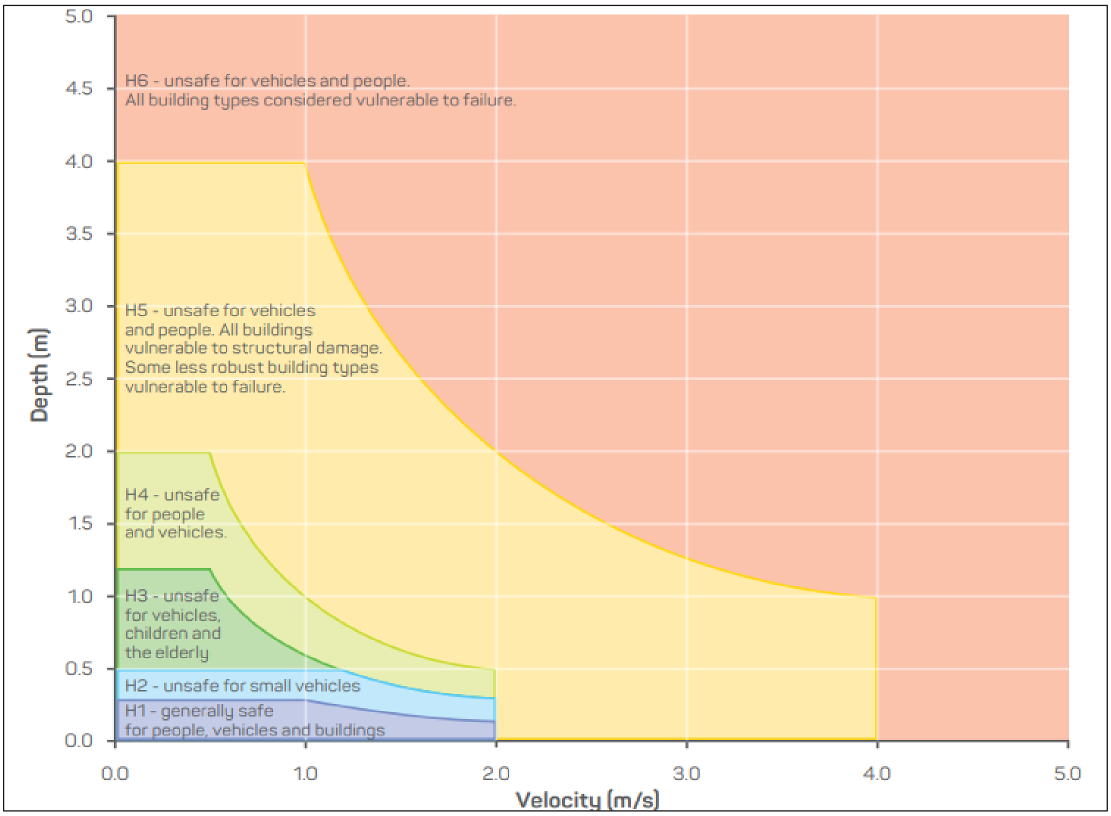

Figure 7-1. Flood Hazard Categories (AIDR, 2017)

7.4 Flood Function

Identifying the flood functions of the floodplain is a key objective of best practice in flood risk management in Australia, because it is essential to understanding flood behaviour. The flood function across the floodplain will vary with the magnitude of an event. An area which may be dry in small floods may be part of the flood fringe or flood storage in larger events and may become an active flow conveyance area in an extreme event. In general, flood function is examined in the defined flood event (DFE), so it can be accommodated as part of floodplain development, and in the PMF so changes in function relative to the DFE can be considered in flood risk management.

The flood function categories, as defined in the Flood Risk Management Manual (DPE, 2023), are:

- **Floodway** - Generally areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels.
- **Flood Storage** - Areas outside of the floodway and are generally areas that store a significant proportion of the volume of water and where flood behaviour is sensitive to changes that impact on the storage of water during a flood.
- **Flood Fringe** - Areas within the extent of flooding for the event but are outside floodway and flood storage areas. They therefore do not play a significant role in flood storage or conveyance. Flood fringe areas are not sensitive to changes in either flow conveyance or storage.

Flood function mapping was undertaken using the same criteria as the Flood Study (WMAwater, 2019), namely:

- Floodway
    - Peak velocity x depth product is greater than 0.25 m^2/s AND peak velocity is greater than 0.25 m/s, OR
    - Peak velocity is greater than 0.6 m/s AND peak depth is greater than 0.3 m, OR
    - Areas within 10 m of creek and tributary centrelines.
- Flood Storage – remaining areas where depth is greater than 0.5m, and
- Flood Fringe – areas in the flood extent outside of the above criteria.

Flood function classifications were manually refined at select locations to ensure the continuity of floodways. Floodways were also manually refined in the downstream portion of the study area where elevated Hunter River boundary conditions in rarer events resulted in a smaller floodway extent than more frequent events where velocities are higher (due to lower boundary conditions). For these areas, the maximum extent from more frequent AEPs was used to define the floodway.

Flood function mapping is provided in maps **RG-01-040** to **RG-01-043**.

7.5 Climate Change Impacts

Estimation of climate change impacts are important due to the potential for rainfall intensities and flood levels to increase across the study area in a future climate change scenario. Climate change will also impact sea level rise, but this is not considered for the Anvil Creek catchment.

When the modelling for this updated Flood Study was undertaken, the latest guidance regarding climate change sensitivity analysis for the purpose of flood assessments was the interim guidance outlined in Book 1, Chapter 6 of ARR2019 (Version 4.1). The interim guidance recommended a 5% increase in design rainfall per °C of projected warming, with site-specific IFD factors available on the ARR DataHub (for different Representative Concentration Pathway [RCP] projections). In August 2024, the ARR2019 guidance regarding design rainfalls and the application of climate change was revised, as detailed in the updated Book 1, Chapter 6 of ARR2019 (Version 4.2). The updated guidance includes near and long-term climate change rainfall and loss scaling factors for a range of different Shared Socioeconomic Pathway (SSP) global temperature projections.

The 0.5% AEP and 0.2% AEP events have been used as proxies for the 1% AEP with an allowance for increase in rainfall intensity associated with projected climate change scenarios. For the subject catchment, these events approximately correspond with the 11% increase in rainfall intensity (0.5% AEP) and 30% increase in rainfall intensity (0.2% AEP) assessed as part of the Flood Study (WMAwater, 2019). For the purposes of this study the proxy events have been adopted; however, the updated ARR2019 climate change guidance should be further considered by Council for future flood modelling and major infrastructure design.

A summary of the percentage increase of rainfall intensities for each climate change scenario is shown in **Table 7-2.** This compares the 1% AEP, 6-hour ARR2019 IFD rainfall intensity of 20.8 mm/hr. The 0.5% AEP underestimates even the SSP1 scenario 2050 projection and is more likely to represent the near term (2025) projected increases to rainfall intensity, whilst the 0.2% AEP lies between the SSP2 and SSP3 scenario 2090 projection.

Table 7-2. Climate Change Scenario Comparison – Increase in ARR2019 1% AEP, 6-hour Rainfall Intensity

Scenario	2025	2050	2090
Proxy ARR2019 Event			
0.5%	-	11%	-
0.2%	-	-	30%
Updated Climate Change Scenarios			
SSP1-2.6	12%	15%	16%
SSP2-4.5	12%	18%	26%
SSP3-7.0	12%	19%	38%
SSP5-8.5	13%	23%	49%

Climate change impact mapping is provided in maps **RG-01-050** and **RG-01-051.**

Consistent with the results of the 10% rainfall increase assessment from the Flood Study (WMAwater, 2019), the updated climate change impact mapping shows 0.5% AEP increases in the order of 0.1 m to 0.2 m along major watercourses and generally less than 0.05 m around minor watercourses when compared to 1% AEP flood levels. Similarly, the increases in 0.2% AEP flood levels are similar in magnitude to those from the 30% rainfall increase assessment from the Flood Study (WMAwater, 2019). Flood level increases in this event are generally in the order of 0.2 m to 0.6 m along major watercourses and less than 0.2 m around minor watercourses.

For both events, the impacts at the downstream extent of the study area are far more significant due to the elevated Hunter River tailwater levels in the coincident events assumed for the 0.5% AEP and 0.2% AEP events compared to the 1% AEP event (refer **Table 3-1**). Hunter River flows at Oakhampton provided in the *Hunter River Branxton to Green Rocks Flood Study Final Report* (WMAwater, 2010) suggest that the 5% AEP and 2% AEP flows are higher than those that would be expected for the Hunter River event assumed to coincide with the 1% AEP local catchment event under climate change conditions, namely the 10% AEP with appropriate climate change allowances. In the absence of 10% AEP with climate change levels for the Hunter River event, these coincident tailwater assumptions provide a conservative representation of potential impacts of climate change in the northern portion of the study area.

8 Conclusions and Recommendations

This updated Flood Study has been prepared for Cessnock City Council and has been undertaken in accordance with the Flood Risk Management Manual (DPE, 2023). The flood model developed as part of the Greta Flood Study (WMAwater, 2019) has been updated to extend into a number of areas not included in the previous hydraulic model and improve the definition of flood behaviour in Council-nominated high-risk areas.

The results of the updated study are used as a basis for the assessment of existing flood risk and the identification of mitigation measures in the FRMS. It is recommended that this updated Flood Study should be read in conjunction with the associated Greta FRMS and FRMP.

9 References

ARR2019 [Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)], 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia.

Australian Institute for Disaster Resilience [AIDR] (2017). *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*, Handbook 7.

Ian H Marshall & Associates (1985). *Greta Drainage Study – including Red House Creek at East Branxton*, May 1985.

NSW Department of Planning and Environment (2023). *Flood Risk Management Manual, the policy and manual for the management of flood liable land,* ISBN 978-1-923076-17-4, June 2023.

WMAwater (2019). *Greta Flood Study Final Report*, Prepared for Cessnock City Council, February 2019, Revision 3.

WMAwater (2010). *Hunter River Branxton to Green Rocks Flood Study Final Report*, Prepared for Maitland City Council.

WMAwater (2013). *Hunter River Review of Branxton Flood Levels Final Report*, Prepared for Cessnock City Council.

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