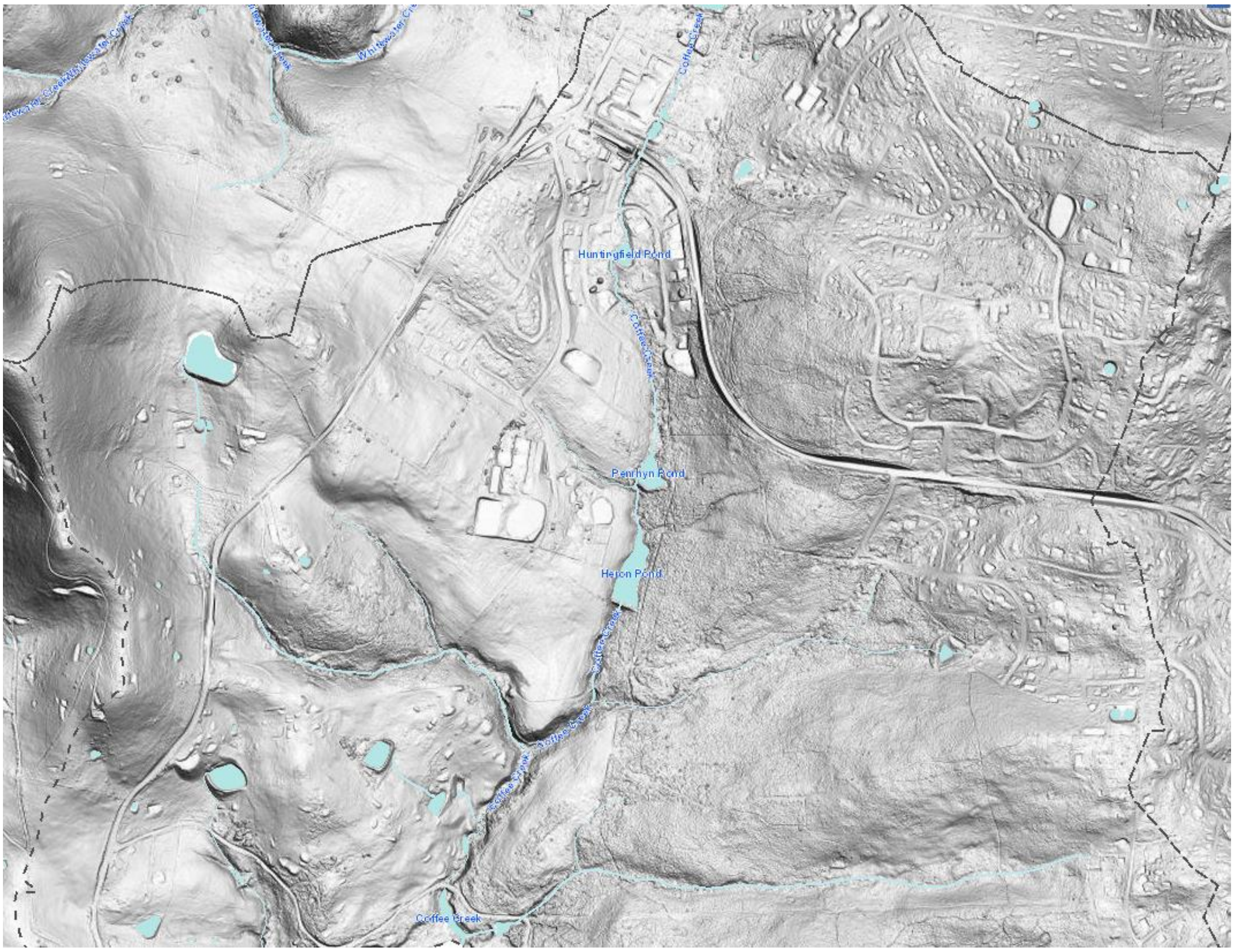
KINGBOROUGH COUNCIL

COFFEE CREEK HYDRAULIC & EROSION ASSESSMENT

FINAL REPORT



SEPTEMBER 2021

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SEPTEMBER 2021

Project Coffee Creek Hydraulic & Erosion Assessment	**Project Number** 120069
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Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Draft Report, Issued to Council for Review		Yuan Li, Mark Colegate			APR 21
1	Final Report - Internal Issue	WMAwater	YL, MC	MC, AA, AW		SEP 21
2	Final Report – For Issue	WMAwater	MC, YL	MC		SEP 21

COFFEE CREEK HYDRAULIC & EROSION ASSESSMENT

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LIST OF ACRONYMS

ADR	Australian Disaster Resilience
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DEM	Digital Elevation Model
DPIPWE	Department of Primary Industries, Parks, Water and Environment
EIA	Effective Impervious Area
ELVIS	ELeVation Information System (data sharing platform)
EY	Exceedances per Year
GIS	Geographic Information System
ICA	Indirectly Connected Area
IFD	Intensity, Frequency and Duration (Rainfall)
IL/CL	Initial Loss / Continues Loss
LiDAR	Airborne Light Detection and Ranging
LIST	Land Information System Tasmania
m AHD	meters above Australian Height Datum
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RPA	Rural Pervious Area
TauDEM	Terrain analysis using Digital Elevation Models
TIN	Triangular Irregular Networks
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends terminology that is not misleading to the public and stakeholders. Therefore, the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example, there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore, the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6-month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
	12			
	6	99.75	1.002	0.17
Very Frequent	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
	0.69	50	2	1.44
	0.5	39.35	2.54	2
Frequent	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
	0.005	0.5	200	199.5
Very Rare	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
	0.0002	0.02	5000	4999.5
Extreme				
			PMP/ PMP Flood	

EXECUTIVE SUMMARY

WMAwater was engaged by Kingborough Council to develop a hydraulic assessment and catchment management plan for Coffee Creek Catchment in Tasmania. The study comprises the development of hydrologic and hydraulic models to define design flood behaviour and establish the flood related risks, including erosion, and future development, for the 5% AEP, 1% AEP and 0.5% AEP design storms and 2050 and 2100 Climate Change scenarios in the Coffee Creek Catchment.

The primary aim of the study is to provide Council with flood intelligence that can be used in the preparation of planning controls for development applications, understanding the flood and erosion risks, developing a catchment management plan using a range of management measures.

The modelling programs used in the study are:

- WBNM (Hydrologic) for the 69 sub-catchments – the model converts rainfall to runoff and the flow hydrographs are input into the TUFLOW model.
- TUFLOW (Hydraulic) for the urban stormwater and natural waterways – The 1D/2D hydraulic model was established to assess the complex overland flow regimes of the catchment to analyse flooding behaviour in the study area.

The models were used to assess design flood behaviour for a range of events including the 5% AEP, 1% AEP and 0.5% AEP events. Comprehensive mapping of the design flood information across the catchment was undertaken, including mapping of peak flood extents, levels, velocities, and depths, as well as hydraulic hazards and hydraulic categories. Sensitivity analysis was conducted in terms of climate change (2050 and 2100 scenarios), surface roughness, drainage and key structure blockage, and future land development. The model results are sensitive to increased rainfall intensity (climate change) and future development, and generally are not sensitive to surface roughness and blockage variations other than for the blockage at the key culverts, e.g., two culverts under Algona Road.

Flood and erosion management measures are summarised for consideration by Council. Structural and non-structural measures have been discussed and preliminarily investigated. Some non-structural measures are recommended with high priority, e.g., development of catchment specific stormwater management and waterway protection strategy in alignment with the Tasmanian Planning Scheme, promoting flood and erosion awareness education, due to their low cost, high feasibility, and reasonable effectiveness. Structural measures are typically expensive. Nevertheless, there are also a couple of structural measures recommended with high priority, including channel and riparian zone revegetation and banks and channel stabilisation (e.g., concrete mats or rock chutes, groynes, and beaching) for High Erosion Risk Locations.

1. INTRODUCTION

Kingborough Council (Council) commissioned WMAwater to conduct a Hydraulic Assessment for Coffee Creek, including the establishment a flood model for existing conditions, flood and erosion mitigation assessment.

The study comprises the development of computational hydrologic and hydraulic models to define design flood behaviour and establish the flood and erosion risk for the 5%, 1% and 0.5% Annual Exceedance Probability (AEP) design storms and, the 2050 and 2100 Climate Change scenarios in the Coffee Creek catchment.

Study outputs will provide Council with flood intelligence that can be used in the preparation of planning controls for development applications, developing flood plain management strategies and understanding the flood risks associated with a range of event probabilities.

Study outputs include maps of flood extent, levels, depth, velocity, hazard, and categories for flood events with a range of Annual Exceedance Probabilities (AEPs), identification and assessment of flood and erosion mitigation options, reports detailing the study methods, investigations and conclusions, hydrologic and hydraulic models, and digital datasets.

The specific tasks undertaken for the study were as follows:

- the collection and collation of existing information relevant to the study which includes the data already held by Council as well as other information, such as development, topographic, GIS and rainfall data
- the preparation of hydrologic and hydraulic models capable of defining the flood behaviour for the study area for a wide range of design flood probabilities
- undertaking sensitivity analysis
- the interpretation and presentation of model results to describe and categorise flood behaviour and hazard for a range of design storm events for the existing catchment conditions
- analysis of hotspots, including the urban development hotspots and erosion prone sections
- on-site investigation of erosion prone locations
- identification and consideration of flood and erosion mitigation opportunities
- investigating and ultimately determining the flood and erosion risk and management plan in the Coffee Creek.

A discussion of terminology and a glossary of other flood-related terms is provided in APPENDIX A.

2. BACKGROUND

2.1. Study Area

Coffee Creek Catchment is approximately 724 hectares and covers areas of Kingston, Huntingfield, Blackmans Bay and the Peter Murrell Conservation Area within Kingborough Municipality (Figure 1). The catchment drains to North West Bay via Coffee Creek. The Coffee Creek alignment is well defined, originating in the residential area of Kingston, and winding through the heavily vegetated Peter Murrell Conservation Area to North West Bay. The watercourse contains of a series of in-stream ponds and detention basins and the creek generally follows a well-defined and incised course during dry weather conditions.

The upper and lower parts of the catchment are distinct in nature. The upper catchment is urbanised with a mix of residential, commercial, and industrial land uses whilst the lower catchment is rural, covered by environmental management land, open space, and recreation. Drainage elements in the catchment include the creek channel, kerbs and gutters, and pits and pipes (mainly in upper urbanised catchment).

Urban growth within the upper Coffee Creek catchment has increased over the last decade. These changes have impacted the catchment characteristics arising from intensive paving of roads, concrete aprons and both extensive industrial and residential developments. These surface disturbance works has resulted in an increased sediment load to the creek and increased peak flow discharge with consequent creek channel erosion and transport of sediment downstream.

Recent increases in the demand for housing and housing affordability in the State has resulted in Housing Tasmania designating Huntingfield as a big growth area. It is expected that urban density will further increase within the Coffee Creek Catchment, putting an emphasis on the importance of having a detailed understanding of flood and erosion risks and stormwater constraints to inform planning decisions moving forward.

2.2. Historical Flooding

In May 2018, the greater Hobart area experienced a greater than 100-year storm event. This event caused widespread damage to Southern Tasmanian catchments including Coffee Creek and its associated instream ponds and detention basins.

Based on the local knowledge and the review of the catchment characteristics, the flood inundation has not been a serious issue. However, the evident sediment transportation and erosion along Coffee Creek has sounded a warning of the problematic health of the natural waterway. Increased urbanisation in the upper catchment is likely responsible for increased demand on the natural waterway through increased quantity and degraded quality of urban catchment stormwater to the creek. Increased flows and sediment transport within Coffee creek has likely resulted in the increased risk of erosion, sediment transport and damages during flood events such as the one seen in May 2018.

2.3. Previous Studies

Kingborough Council has recently undertaken (or engaged a consultant to undertake) several flood studies in catchments adjacent to Coffee Creek Catchment, including:

- Kingborough Council, 2016, Kingston Beach Flood Study (Reference 1)
- Kingborough Council, 2020, Snug River Flood Study (Reference 2)
- Entura, 2020, Adventure Bay Flood Study (Reference 3)
- WMAWater, 2020, Whitewater Creek Flood Study (Reference 4)
- WMAWater, 2020, Kingston CBD Catchment Resilience Program (Reference 5)
- Engeny, 2020, Blackmans Bay Catchment Resilience Program (Reference 6)

The previous studies have mostly been conducted with reference to ARR 2019 processes, exception to the Kingston Beach Flood Study, and provide the most recent estimation of flood characteristics, flood risks and management opportunities within the Kingborough Municipality area. However, there have not been any recent studies undertaken in Coffee Creek Catchment that provide a holistic overview of the hydraulic characteristics. The rapid development taking place within the catchment has been putting an emphasis on the importance of having a detailed understanding of flood risks and stormwater constraints to inform planning decisions moving forward.

3. DATA

3.1. Overview

The first stage in the investigation of flooding matters is to establish the nature, size, and frequency of the problem. On larger river systems there may be stream height and historical records dating back over a considerable period, in some cases over one hundred years. However, in smaller catchments, such as the Coffee Creek Catchment, stream gauges and/or official historical records are generally not available, and there is more uncertainty about the frequency and magnitude of flood problems. Additionally, overland flooding in urban areas, such as the upstream part of Coffee Creek Catchment, is highly dependent on localised changes to development, intensification of development (i.e., increased building sizes and more paved surfaces), and localised drainage features such as kerbs and guttering in roadways. These features are subject to relatively frequent modification and renewal, making it difficult to compare flood behaviour over time.

There are no streamflow gauges or notable historical flood records, e.g., flood marks and photos, available within the Catchment. Although some anecdotal information, e.g., flood questionnaire response from local residents regarding flooding on property during May 2018 event, has been obtained by Council; although no quantitative information could be extracted for locations within the area of interest based on our review of the responses. For this study, most model parameters were adopted from the adjacent Whitewater Creek and Kingston CBD catchments (References 4 and 5), which were calibrated/validated to better quality flood information.

Airborne Light Detection and Ranging (LiDAR) data acquired in 2011 was utilised for catchment delineation and hydraulic modelling. Design data supplied as part of the study were of mixed usability and were used for updating LiDAR-based Digital Elevation Model (DEM) and informing other parameter setups. There were gaps in other datasets, including the Council GIS database where inverts of pits and pipes were only partially available. Such gaps are common for flood studies, since collection of detailed information about drainage networks is expensive and time consuming, and often beyond the resources available to Council. As part of this study, analysis of the available data along with site visits were undertaken to address the limitations of the data in key areas.

The main scope is to investigate stormwater, flooding, and erosion issues along the main watercourse (i.e., Coffee Creek) and the localised drainage issues in the upstream urban area is not the key focus of this study. Therefore, only the underground pipes with diameter/width equal to or over 300 mm were represented in the hydraulic model. It should be recognised that while the information about the drainage system for this study is not perfect, this is often not a critical issue, since the majority of runoff cannot be contained within the formal drainage network, especially for the scope (main watercourse) and events modelled (5%, 1%, and 0.5% AEP events) for this study. Underground drainage networks are typically only designed to cater for the 20% to 5% AEP flow. Therefore, caution must be exercised when applying the broad catchment modelling results at individual properties, particularly for smaller floods or in areas where the pit/pipe drainage network plays a significant role in the flood behaviour.

3.2. Data Sources

Data utilised in the study has been collated from a variety of sources. Data provided by Council and collected from other sources are summarised in Table 1.

3.2.1. Topography

3.2.1.1. LiDAR Data

Mt Wellington LiDAR, covering the catchment and its immediate surroundings, was obtained from ELVIS – Elevation and Depth Foundation Spatial Data. It was indicated that the data were collected in January 2011. These data typically have accuracy in the order of +/- 0.15 m (for 70% of points) in the vertical direction on bare earth. The accuracy of the LiDAR data can be influenced by the presence of open water or vegetation (tree or shrub canopy) at the time of the survey.

The LiDAR-based DEM data, as shown in Figure 2, was used as the primary data set for hydrologic catchment delineation and hydraulic modelling.

The LiDAR was flown in 2011, therefore, it does not accurately reflect catchment morphology under the current state of development. The last ten years have seen an increase in residential development and road infrastructure within the upstream part of Coffee Creek Catchment, resulting in relatively significant changes to catchment hydrology and hydraulics. The aerial imageries shown in Diagram 1 illustrate the land development from 2011 – 2019.

3.2.1.2. Design and Survey

Despite of significant development during the last ten years, there is limited survey and/or design data which can be used to compensate for the lack of representation of current topography by the LiDAR-based DEM.

As summarised in Table 1, Council provided design data for Kingston Green, Algona Rd Subdivision, Coffee Creek Restoration, and Village Pond. However, some of them are .pdf version and some of them are DWG files without usable elevation data. WMAwater reviewed and collated all available design information and only below two elevation datasets were deemed useful and extracted:

- Road strings for Kingston Green Stage C
- 3D TIN for Coffee Creek Restoration Stage 2

Based on the above datasets, DEMs for those developed areas were constructed, as illustrated in Figure 3, and were then used to update LiDAR-based DEM for hydraulic modelling.

Table 1: Summary of Data

Data Type	Data	Source	Collation Comments	Application for The Study
GIS Layers	LIST GIS layers	The LIST	Hydrolines; river sections; municipal boundary; sub-catchments	Used for scoping and preliminary investigation
	Culverts	Kingborough Council	Point layer with no cross-section information available; not covering all key culverts	Jointly used with measurements from site visits for hydraulic model setup with QA and assumptions
	Stormwater Pit	Kingborough Council	Point layer with type information; few with invert level information	Used for hydraulic model setup with QA and assumptions
	Stormwater Pipe	Kingborough Council	Line layer with diameter and limited invert level information; no cross-section type information, e.g., circulate or rectangular	Jointly used with design data for hydraulic model setup with QA, interpolation, and assumptions
	Kerb and Channel	Kingborough Council	The majority part of the road system in the catchment	Gap filled based on aerial imagery; used for hydraulic model setup
	Cadastre	Kingborough Council	Property boundary layer	Used for mapping
	Planning Zones	Kingborough Council	Land use planning zones	Used as ultimate development scenario; amended against aerial imagery for existing scenario; used to define pervious/impervious fractions for hydrological model and roughness for hydraulic model
	Dam registration	DPIPWE	No information for the major Dams within the catchment	Not used
Design Data	Huntingfield development	Kingborough Council	Online Draft Huntingfield Development Plan; still at early planning stage and no design drawings or designed topography available	Used to understand discharge location and confirm Council's planning zones
	Kingston Green	Kingborough Council	Design drawings for Stage 3, C and 3c; elevation data are only availble for road reserve	Road strings for Stage C used to update 2011 LiDAR DEM, other two stages were built before 2011
	Algona Rd subdivision	Kingborough Council	Design drawings with limited elevation data; external reference drawings were not provided	Not used for updating LiDAR DEM
	Coffee Creek Restoration	Kingborough Council	Three design drawings but only one (Stage 2) with elevation data (3d TIN)	Stage 2 3d Tin used to update 2011 LiDAR DEM
	Village Pond	Kingborough	Photos/snapshot of draft design and locality	Used to update the discharge location of the culvert from the

Data Type	Data	Source	Collation Comments	Application for The Study
	Info	Council		Village Pond
	Village South pipes	Kingborough Council	Village South 2*600 pipes locality by hand drawing on aerial imagery	Pipe added and open drain filled in hydraulic model
Flood Information	Downstream boundary conditions	Kingborough Council	Snug Bay Dynamic Tailwater Levels under existing and climate change conditions	Applied similar DS boundary conditions as for Snug River flood study
	2018 Flood Response (Anecdotal)	Kingborough Council	Locations of received responses to a flood questionnaire of May 2018 flooding and extracted textual responses for key locations within the catchment	Data reviewed and no suitable information for model calibration/validation
Documents	Existing documents and reports	Kingborough Council	Climate change report; Flood studies for adjacent catchments; Stormwater Management Plan for Kingston Green; Huntingfield Pond Information	Parameters and climate change index extracted for hydrological and hydraulic model setup
Imagery	Aerial imagery	Kingborough Council	2011 and 2020 aerial imagery	Used for identification of recent development, updating catchment delineation, updating existing land use, mapping, etc.
LiDAR	LiDAR DEM	ELVIS	1m DEM data based on Mt Wellington 2011 LiDAR	Used for hydraulic model setup with amendments based on design and site visit information
Photos and Measurements	Site visits	WMAwater & Council	Photos and Measurements	Used for hydraulic model updating and erosion assessment

Diagram 1: Aerial Imagery (provided by Council) in 2011 and 2020. Green lines indicate the main areas of development between 2011-2020.

3.2.2. Hydraulic Structures

Structures including ponds, bridges, and culverts can have a significant impact on flood behaviour. Therefore, appropriate representation of these structures is essential for the accuracy of the hydraulic model.

There are several ponds along the main watercourse, which however are not registered with DPIPWE and no information was obtained. Site visit photos together with the photos and limited design plans provided by Council were used to cross check the representation of the ponds in LiDAR-based DEM.

There are a number of critical culverts in the catchment, and Council's GIS dataset only documented part of them. The cross-section dimensions of key culverts were measured during site visits and used for hydraulic model setup.

3.2.3. Underground Drainage

GIS information pertaining to the underground drainage system, including pits and pipes, was provided by Council. Pipe diameters are generally provided while only part of the pipes/pits have invert level information available.

3.2.4. Design Rainfall and Losses

The design rainfall intensity-frequency-duration (IFD) data were obtained from Bureau of Meteorology (BOM)'s Design Rainfall Data System (2016).

The median preburst, burst temporal patterns, and rural losses were obtained from the ARR data hub. Table 2 shows rural loss parameters. These values were used for hydrologic modelling, detailed in Sections 4.1.2.2.

Table 2: ARR Losses at Catchment Centroid

Storm Initial Losses (mm)	Storm Continuing Losses (mm)
28.0	3.4

3.2.5. Photos

Photos obtained during the site visits were geographically registered in the MapInfo workspace, as illustrated in Figure 4. Those photos were used to identify key hydraulic features, soil, and vegetation conditions for model setup and erosion assessment.

4. METHODOLOGY

4.1. Model Establishment

4.1.1. Overview

A coupled hydrologic-hydraulic model was developed to address the complex runoff generation and routing processes in the catchment, with the hydrologic model, i.e., the Watershed Bounded Network Model (WBNM), to produce flow hydrographs for each sub-catchment and the hydraulic model, i.e., the TUFLOW model, to characterise the flow propagation throughout the major surface and underground flow paths within the catchment. Figure 5 illustrates the model schematisation of the whole catchment.

The objective of the calibration process is to build a robust hydrologic and hydraulic modelling system that can replicate historical flood behaviour in the catchment being investigated. Typically, in urban areas calibration/validation information is lacking. As mentioned before, there is no streamflow data or historical flood records available within the Catchment. Anecdotal information, i.e., flood questionnaire responses; provided no quantitative information within the area of interest.

For this study, most of the hydrological and hydraulic model parameters detailed below, including losses, fractions (%) of pervious/impervious coverage, hydrological routing, and Manning's *n* values, were adopted from the adjacent Whitewater Creek and Kingston CBD catchments (References 4 and 5), which were calibrated/validated to better quality flood information.

4.1.2. Hydrologic Model

Inflow hydrographs serve as inputs to the hydraulic model. A hydrologic model (simulating rainfall-runoff and runoff routing processes) is generally used to provide these inflows. A range of hydrologic models are available as described in ARR 2019 (Reference 7). These models allow the rainfall depth to vary both spatially and temporarily over the catchment and readily lend themselves to calibration against recorded data.

Hydrologic modelling was undertaken using WBNM (Reference 8), a widely utilised hydrologic modelling software. The WBNM model includes a relatively simple but well supported method, where the routing behaviour of the catchment is primarily assumed to be correlated with the catchment area.

A hydrologic model for the entire catchment was created and used to calculate internal boundary inflows for the hydraulic model.

4.1.2.1. Sub-catchment delineation

Delineation of sub-areas was carried out by applying a mathematical algorithm called Terrain analysis using Digital Elevation Models (TauDEM, Reference 9) to topographic data sets.

TauDEM is a suite of DEM tools for the extraction and analysis of hydrologic information from topography as represented by a DEM. LiDAR-based DEM was used for TauDEM analysis as there has not been notable development in the upper catchment since 2011. Please refer to Section 3.2.1.1 for a detailed description of the LiDAR-based DEM used here.

TauDEM provides the distinct advantage of applying an objective technique to calculate the stream flow paths and directions, the contributing areas using both single and multiple flow direction methods, as well as to delineate the catchments and sub-catchments draining to each stream segment.

The LiDAR-based DEM, analysed in TauDEM, extended far enough to ensure that the entire contributing catchment area was defined.

The catchment was delineated into 69 sub-catchments with an average sub-catchment size of 10.75 hectares. The sub-catchment delineation is shown in Figure 5.

4.1.2.2. Losses

Methods for modelling the proportion of rainfall that is “lost” to infiltration are outlined in ARR 2019 (Reference 7). The methods are of varying degrees of complexity, with the more complex options only suitable if sufficient data are available. The method most typically used for design flood estimation is to apply an initial loss (IL) and continuing loss (CL) to the rainfall. The initial loss represents the wetting of the catchment prior to runoff starting to occur and the continuing loss represents the ongoing infiltration of water into the saturated soils while rainfall continues.

Rainfall losses from a paved or impervious area are considered to consist of only an initial loss (a sufficient amount to wet the pavement and fill minor surface depressions). Losses from grassed and vegetated areas are comprised of an initial loss and a continuing loss.

The IL / CL obtained from ARR data hub (Section 3.2.4) are for 100% rural pervious areas. Urban area, such as the upper catchment, typically has a mix of pervious and impervious surfaces, and impervious surfaces normally have significant lower IL/CL. Based on ARR 2019 (Reference 7), IL/CL were set for three different surface types, i.e., Rural Pervious Area (RPA), Indirectly Connected Area (ICA), and Effective Impervious Area (EIA), as shown in Table 3.

Table 3: Losses and Assumptions for Three Surface Types

Surface Type	IL (mm)	CL (mm)
Rural Pervious Area	28 (IL_{ARR})	3.4 (CL_{ARR})
Indirectly Connected Area	$0.7 \times IL_{ARR}$	2.5
Effective Impervious Area	1.5	0

It is very difficult to accurately delineate the three types of surfaces for the entire catchment. In this study, a single IL/CL was estimated for each land use zone based on the estimated percentages (%) of the three surface types. The percentages (%) of the three surface types for each land use zone from the Whitewater Creek and Kingston CBD flood model (References 4 and 5) were adopted for this study, as shown in Table 4.

The planning zone GIS layer provided by the Council was firstly stamped by road reserve from the cadastre, and then used to represent the land use under ultimate development conditions. Then it is refined against most recent aerial imagery to represent the land use under existing conditions. The land use zones for losses schematisation under existing and ultimate development conditions are shown in Figure 6 and Figure 7, respectively.

The percentages of the three surface types for each sub-catchment is then calculated based on the areal weighted average of different land use types within the sub-catchment.

Table 4: Estimated Percentage (%) of Three Surface Types for Land Use Zones

Planning Zone	Effective Impervious Area (%)	Indirectly Connected Area (%)	Rural Pervious Area (%)
General Residential	40	50	10
Inner Residential	70	20	10
Low Density Residential	15	55	30
Rural Living	5	10	85
Environmental Living/Forest	0	0	100
Urban Mixed Use	20	40	40
Community Purpose	40	40	20
Recreation	5	20	75
Open Space	0	10	90
Local Business	70	20	10
General Business	70	20	10
Central Business	90	10	0
Commercial	70	20	10
Light Industrial	70	20	10
Rural Resource	0	5	95
Utilities / Road Reserve	60	30	10
Environmental Management	0	0	100

4.1.2.3. Sub-catchment and Stream Routing

WBNM requires a sub-catchment lag parameter and a stream lag factor to be selected which describes the average travel time within and between sub-catchments. The WBNM parameters calibrated for Whitewater Creek Flood Study (Reference 4) were adopted for this study, as summarised in Table 5.

Table 5: Adopted WBNM Routing Parameters

WBNM Parameters	Value
Sub-catchment Lag (C)	1.6
Stream Lag Factor (natural channels)	1.0

4.1.3. Hydraulic Model

Hydraulic modelling was undertaken for the entire catchment (Figure 5) using TUFLOW HPC (build 2018-03-AC-iSP-w64) with Graphics Processing Unit (GPU) solver (Reference 10), a widely utilised 1D and 2D flood simulation software. Hydrographs from the WBNM hydrologic model for each sub-catchment were input as inflow into the TUFLOW model. Hydraulic modelling was carried out on a fixed 2 m grid.

The TUFLOW modelling package includes a finite difference numerical model for the solution of the depth averaged shallow water flow equations in two dimensions. The TUFLOW software is widely used for a range of similar projects. The model is capable of dynamically simulating complex overland flow regimes. It is especially applicable to the hydraulic analysis of flooding in urban areas which is typically characterised by short duration events and a combination of supercritical and subcritical flow behaviour, and interactions between overland flow and the sub-surface drainage network.

In addition to 2D modelling of overland flows, TUFLOW can model drainage elements (pipes) as 1D elements as well as modelling creeks or open channels in 1D if required. The 1D and 2D components of the model can be dynamically linked during the simulation. In TUFLOW the ground topography is represented as a uniformly spaced grid with a ground elevation and a Manning's '*n*' roughness value assigned to each grid cell. The grid cell size is determined as a balance between the model result definition required and the computer run time (which is largely determined by the total number of grid cells, and the number of "wet" cells). A cell size of 2 m by 2 m was found to provide an appropriate balance for this study. The extent of the TUFLOW model is shown in Figure 5.

4.1.3.1. Boundary Conditions

Flow hydrographs from each sub-catchment were used as inflow boundary conditions to the hydraulic model. Two types of inflow boundaries were used, including:

- 2D SA polygons – assign water to the wet pixels or the lowest point if dry;
- 2D SA PITS polygons – assign water to the pixels where inlet pits are.

Similar to the Snug River Flood Study (Reference 2), the mean Snug Bay Tailwater Levels for 5%, 1%, and 0.5% AEP provided by Council were extracted and adopted as downstream boundary conditions. To represent the coincident flooding, the following have been applied:

- the extracted 5% AEP mean tailwater level was used as a static downstream Head vs Time (HT) boundary at catchment outlet for 1% AEP catchment flood modelling;
- the extracted 1% AEP mean tailwater level was used as downstream HT boundary for 5% AEP catchment flood modelling; and
- the extracted 0.5% AEP mean tailwater level was used as downstream HT boundary for 0.5% AEP catchment flood modelling.

Assumptions made for coincident flooding were adopted from the Snug River Flood Study. While the modelled coincident flood characteristics may be sensitive to the adopted tailwater levels, the effect was found to be restricted only in the outlet of Coffee Creek, i.e., downstream of Howden

Rd, which is not the area of interest for this study.

A Head vs Flow (HQ) boundary was applied to the north of the model extent, as there is a sub-catchment (C57) whose surface flow is discharging towards north to Kingston CBD Catchment according to the topography while the underground flow is conveyed towards Coffee Creek through the Stormwater Main along the western side of Redwood Retirement Village.

The locations of the inflow and downstream boundary conditions are shown in Figure 8.

4.1.3.2. Surface Roughness

The hydraulic efficiency of the flow paths within the TUFLOW model is represented in part by the hydraulic roughness or friction factor formulated as Manning's '*n*' values. This factor describes the net influence of bed roughness and incorporates the effects of vegetation and other features which may affect the hydraulic performance of the flow path.

The Manning's '*n*' values were firstly applied according to land use zones as shown in Figure 6 and Figure 7. As a focus of this study is the flooding and erosion assessment along Coffee Creek, additional site inspections were conducted to obtain soil and vegetation conditions along specific sections of the main waterway. The Manning's '*n*' values were then updated specifically for the main waterway according to the aerial imagery and information obtained through site inspections, as shown in Figure 9. The adopted Manning's '*n*' value for each land use zone is summarised in Table 6. The values for land use zones 1 to 17 were adopted from Whitewater Creek Flood Study (Reference 4), whilst the values for the rest of zones (main waterway) were defined based on site inspections and aerial imagery.

4.1.3.3. Hydraulic Structures

<u>Ponds</u>

There are several ponds along the main watercourse, which however are not registered with DPIPWE and no information was obtained. Site visit photos together with the photos and limited design plans provided by Council were used to cross check the representation of the ponds in LiDAR-based DEM.

Initial water level was set to be the same as the invert of spill way for each pond with the assumption that the pond is full before the burst flood event.

<u>Culverts</u>

There are several critical culverts in the catchment, a part of which are documented in Council's GIS dataset. The cross-section dimensions of key culverts were measured during site visits and then defined in hydraulic model. Invert levels of the culverts are typically hard to measure without appropriate survey exercise, therefore, they were set according to the upstream and downstream surface levels interpretated from DEM.

4.1.3.4. Underground Drainage

The underground stormwater drainage network was modelled in TUFLOW as a 1D network dynamically linked to the 2D overland flow domain. The urban drainage system is mainly in upstream area, which is not the focused area of this study. Moreover, only large flood events, i.e., 5%, 1%, and 0.5% AEPs, are within the scope of this study. Therefore, only major pipes (diameter ≥ 300 mm) were modelled. The schematisation of the stormwater network is shown in Figure 10.

Table 6 Manning's '*n*' Coefficient

ID	Land Use Zone	Manning's '*n*' (constant or depth varying)
1	General Residential	0.03, 0.02, 0.1, 0.15
2	Inner Residential	0.03, 0.02, 0.1, 0.15
3	Low Density Residential	0.03, 0.04, 0.1, 0.10
4	Rural Living	0.03, 0.08, 0.1, 0.04
5	Environmental Living/Forest	0.12
6	Urban Mixed Use	0.05
7	Community Purpose	0.045
8	Recreation	0.03, 0.08, 0.1, 0.035
9	Open Space	0.03, 0.06, 0.1, 0.04
10	Local Business	0.03, 0.02, 0.1, 0.15
11	General Business	0.03, 0.02, 0.1, 0.15
12	Central Business	0.03, 0.02, 0.1, 0.20
13	Commercial	0.03, 0.02, 0.1, 0.20
14	Light Industrial	0.03, 0.02, 0.1, 0.15
15	Rural Resource	0.03, 0.08, 0.1, 0.04
16	Utilities / Road Reserve	0.03
17	Environmental Management	0.10
18	Waterway (high density grass/reeds with high density willows/trees)	0.1, 0.08, 0.5, 0.12
19	Waterway (median density grass/reeds with median density willows/trees)	0.1, 0.06, 0.5, 0.09
20	Waterway (median density grass/reeds with low density willows/trees)	0.1, 0.06, 0.5, 0.07
21	Waterway (high density grass/reeds with low density willows/trees)	0.1, 0.08, 0.5, 0.04
22	Pond	0.030

NOTE: For depth varying Manning's '*n*', the values represent – depth1 (m), '*n1*', depth2 (m), '*n2*'. The Manning's *n* was stratified into three layers: 1) *n1* for depth < depth1; 2) interpolation between *n1* and n2 for depth between depth1 and depth2; 3) *n2* for depth > depth2.

Details of the 1D solution scheme for the pit and pipe network are provided in the TUFLOW user manual (Reference 10). For the modelling of inlet pits the "R" pit channel type was utilised, which requires a width and height dimension for the inlet in the vertical plane. The width dimension represents the effective inlet length exposed to the flow, and the vertical dimension reflects the depth of flow where the inlet becomes submerged, and the flow regime transitions from the weir equation to the orifice equation. For lintel inlets, the width was based on the length of the opening which was assumed to be 1.2 m for all inlet pits. As only major pipes were included, inlet pits connected to minor pipes were clustered to connect to major pipe system.

In cases where invert level data were not available, invert levels at the start and end points of the pipe system were estimated based on pipe diameter and minimum depth. Invert levels in the middle of the pipe systems were interpolated by TUFLOW.

4.1.3.5. Road Kerbs and Gutters

LiDAR typically does not have sufficient resolution to adequately define the kerb and gutter system within roadways. The density of the aerial survey points is in the order of one per square metre, and the kerb/gutter feature is generally of a smaller scale than this, so the LiDAR does not pick up a continuous line of low points defining the drainage line along the edge of the kerb.

To deal with this issue, Reference 11 provides the following guidance:

> *"Stamping a preferred flow path into a model grid/mesh (at the location of the physical kerb/gutter system) may produce more realistic model results, particularly with respect to smaller flood events that are of similar magnitude to the design capacity of the kerb and gutter. Stamping of the kerb/gutter alignment begins by digitising the kerb and gutter interval in a GIS environment. This interval is then used to select the model grid/mesh elements that it overlays in such a way that a connected flow path is selected (i.e., element linkage is orthogonal). These selected elements may then be lowered relative to the remaining grid/mesh."*

The road gutter network plays a key role for overland flow conveyance in urbanised area, e.g., the upper catchment. To model the system effectively, the gutters were stamped into the mesh using the method described above.

The majority part of the road kerbs in the catchment were provided in Council's GIS layer. The missing sections, i.e., Redwood Retirement Village and Algona Rd, were digitised to make a complete Kerb and Gutter breakline layer, which was then used to reduce the ground levels along those model cells by 0.1 m, creating a continuous flow path in the model (Figure 11). This was not applied to areas with design breaklines, e.g., Kingston Green Stage C.

For Kingston Green Stage C, road breaklines extracted from the design drawings were modelled in hydraulic model (Figure 11) together with DEM constructed based on design drawing.

4.2. Erosion Assessment

4.2.1. Overview

The erosion assessment is intended to identify if sections of Coffee Creek is actively eroding, identify the severity of the erosion and discuss common management options. The management options provided address existing channel erosion to minimise future erosion problems. Central to this is the erosion classification system, which categorises erosion problems and provides management options for each class category.

Within the Coffee Creek waterway corridor, erosion can be classified as the movement of material via the activity of water. This is a natural process which has over time shaped the alignment and the features of Coffee Creek, seen today. The rate at which this erosion occurs depends on many factors including the water pressure applied and the resistance of the material to which this pressure is applied to.

The influence of construction and development within the Coffee Creek catchment have increased the potential to reduce the resistance of these landscapes to movement or erosion. This has resulted in an acceleration of erosion in many parts of the landscape associated with an increase in stormwater runoff from development areas. Understanding the causes and severity of erosion within Coffee Creek is important to allow Kingborough Council to identify prevention and/or remediation measures that can be implemented to mitigate the erosion.

4.2.2. Causes of Waterway Erosion

Waterway erosion often forms as a result of a disturbance that has led to a change in the groundcover. Groundcover is the key to soil stabilisation. A reduction in groundcover can expose bare soil leading to higher run off volumes and velocity of these flows. For example, development around a waterway can reduce both the protective groundcover and concentrate water flows in certain locations, i.e., urban stormwater discharge locations.

Factors that impact directly on erosion are **ground cover**, erodibility of **soils** and **volume** and **velocity** of flows. The following influences these factors:

4.2.2.1. Rainfall Runoff

Most erosion is caused during storm events with lower Annual Exceedance Probabilities (AEP) rather than during more frequent events or prolonged light showers. The rarer storms produce more surface runoff with higher volumes and flow velocities. Development, as a result, reduces the permeability of catchments which leads to an increase in stormwater runoff and flow characteristics if left unmitigated. The action of rain falling on soil exposed through loss of ground cover, can break up the soil particles making it more susceptible to movement.

4.2.2.2. Base Flows

Base flow is the consistent low-level flows that are generated within a waterway because of the hydrological processes within a catchment. Base flows are typically increased by traditional urbanisation processes – except for catchments where flow harvesting (offtake) and diversion practices might exist. If base flows occur within the waterway channel, they can be beneficial in providing a moisture source for sedges and reeds to stabilise the channel. However, if they occur above the main channel, they can increase the movement of the erosion.

4.2.2.3. Soil Type

Soils that are well structured with high clay content are generally less susceptible to erosion. Soils that are made up predominantly of coarse particles (gravel, sand and silt) and do not have sufficient clay to bind these particles together are more prone to erosion if disturbed and the protective vegetation cover is removed.

Soils that are unstable when wet, such as sodic soils, can erode very quickly when groundcover is reduced, and the topsoil is exposed. These soils often have very low strength when wet and can slump under their own weight when saturated. Vegetation cannot establish naturally on these soils and can remain bare and prone to erosion without intervention.

4.2.2.4. Slope and Topography

Steeper slopes cause the flow velocity of runoff to increase which generates more force to detach and transport soil particles. The length of slope is also important. As the slope gets longer the opportunity for runoff to concentrate increases. Often there is greater erosion on long low slopes than on short steep slopes. The topography of the landscape impacts on the concentration of flows and an assessment of topography can be used to predict the likelihood and location of erosion. Redirection and acceleration of flow around infrastructure, obstructions, debris, or vegetation within the waterway alignment can result in erosion

4.2.2.5. Land Use

Land use practices that reduce ground cover and expose the soil will significantly increase the risk of erosion. Urban development can lead to works within waterways, such as the case within the Coffee Creek alignment. These works can also cause compaction of soil, resulting in less infiltration; the breakdown of soil structure, reducing the cohesion of soil particles and ability to resist erosive forces. As mentioned above, development can increase the frequency and volume of runoff from storm events, consequently adding pressure to drainage lines and increasing the rate of erosion.

4.2.3. Assessment Procedure

Classification of erosion within waterways will enable effective identification and prioritising of appropriate management options. The following four (4) step assessment process will be undertaken to classify erosion within the Coffee Creek waterway –

1. assessment of waterway erosion
2. allocation of Erosion Class Rating
3. identification of suitable options for erosion management
4. prioritisation of management options.

4.2.3.1. Step One: Assessment of Waterway Erosion

Waterway at certain locations (erosion hotspots) will be inspected to determine which components are stable or active. The three components to be considered are the erosion head (the point at which erosive flow begins, point of attack), waterway channel, and sidewalls. If the stability of the components varies along the length of the location reach, it will be delineated into smaller sections so management options can be developed for each section, and/or locations will be assessed only where erosion controls will be implemented.

4.2.3.2. Step Two: Erosion Class Rating

Using the Erosion Classification System, the Locations will be assessed and allocated an erosion class rating (Class 1 to Class 8). An erosion class rating can be determined from assessing the stability of the components of the waterway (head, channel, side walls). The 8-Class System scales from Class 1 being the most active and unstable erosion, to Class 8 being the most inactive and stable erosion.

Locations with erosion Class of 1 to 4 will generally require intervention/remediation works to stabilise the active erosion. Erosion Classes 5 to 8 will be more stable and may require management options to deactivate either the channel erosion, side wall erosion or both components. In some cases, management involves simply maintaining the stability of an area (Class Eight).

The erosion classification system can be visualised in the flow chart shown in Diagram 2.

4.2.3.3. Step Three: Options for Erosion Management

There are a variety of management options for stabilising active erosion within waterways. The options depend on the source of the erosion and how the different components of the waterway are interacting with each other. Table 7 are some suggested management options for each of the Erosion Class Ratings. It is noted that the Options List is designed to provide an indication and description of a sample of potential mitigation opportunities. The suitability and range of options should be considered in a site-specific assessment of the functionality and feasibility of the control measures. Establishment works and timeframes need to be considered when selecting suitable erosion control measures. The intervention works, such as revegetation, can often increase erosion vulnerability by exposing topsoil and removing ground cover during the construction and establishment phase. Temporary works may be required to help facilitate a successful control.

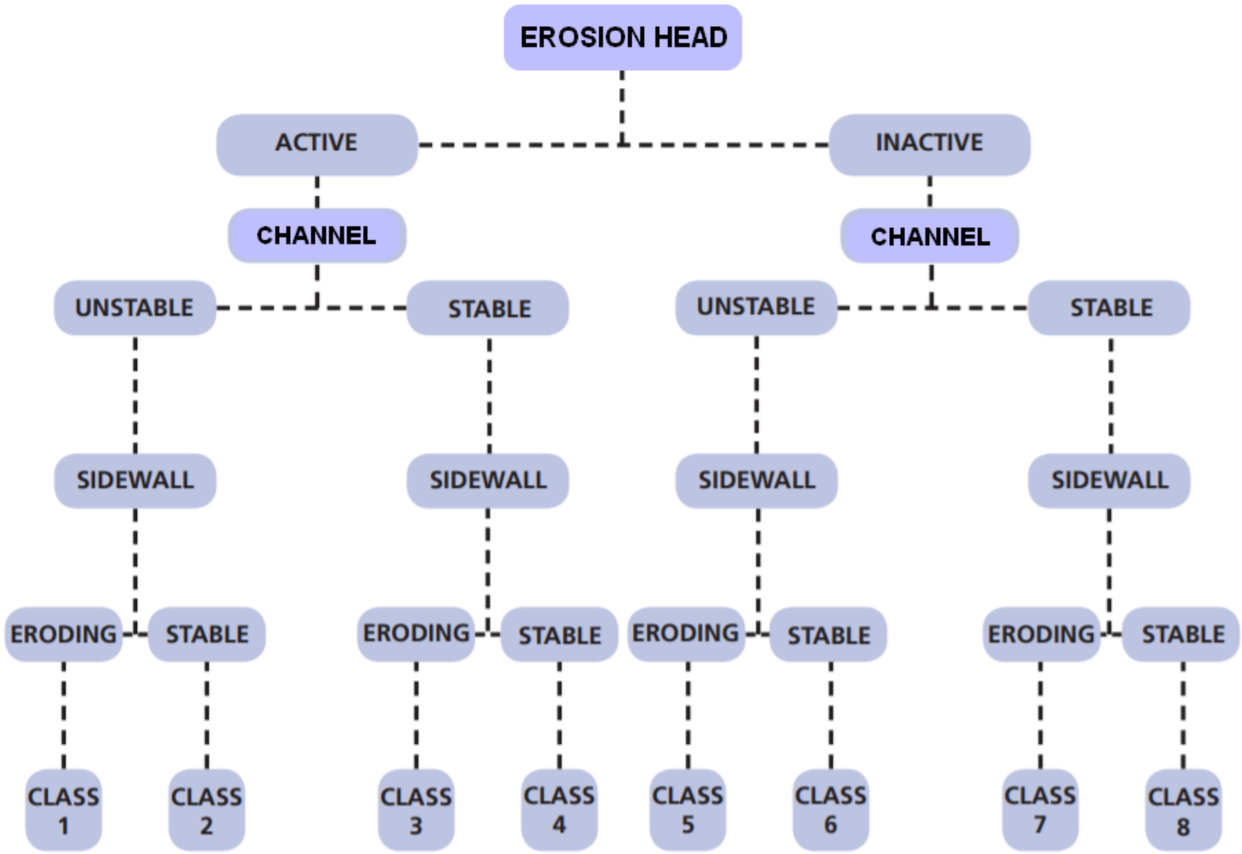

Diagram 2: Erosion Classification System

Table 7: Options for Erosion Management

Erosion Class Rating	Management Options
Class 1	1. **Head**: Stabilisation of erosion head through application of complex earthworks, and control structures. These can include – Rock Chutes, Rock Groynes, Rock Beaching, Flow Control Structures (refer Options Description) 2. **Channel**: if the erosion head has been stabilised it is likely that the channel will become stable also. Regeneration can occur naturally, or revegetation can be undertaken to speed up this process if desired. If the channel continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the waterway via underground lateral movement) or diversion flows created by structures, vegetation, or debris. Install bed stabilisation structures (such as a V-notch weir or rock ramp/concrete mats) within the channel. Revegetate channel corridor (may include riparian zone) with appropriate flora species. 3. **Sidewalls**: if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks or stabilised using bank stabilisation measures. If urban development is causing the erosion, then stormwater management systems to control erosive flows is a more appropriate option. Appropriate intervention should allow these areas to stabilise over time through natural processes.
Class 2	1. **Head**: Stabilisation of erosion head through application of complex

Erosion Class Rating	Management Options
	earthworks, and control structures. These can include – Rock Chutes, Rock Groynes, Rock Beaching, Flow Control Structures (refer Options Description) 2. **Channel**: if the erosion head has been stabilised it is likely that the channel will become stable also. Regeneration can occur naturally, or revegetation can be undertaken to speed up this process if desired. If the channel continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the waterway via underground lateral movement) or diversion flows created by structures, vegetation, or debris. Install bed stabilisation structures (such as a V-notch weir or rock ramp/concrete mats) within the channel. Revegetate channel corridor (may include riparian zone) with appropriate flora species.
Class 3	1. **Head**: Stabilisation of erosion head through application of complex earthworks, and control structures. These can include – Rock Chutes, Rock Groynes, Rock Beaching, Flow Control Structures (refer Options Description) 2. **Sidewalls**: if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks or stabilised using bank stabilisation measures. If urban development is causing the erosion, then stormwater management systems to control erosive flows is a more appropriate option. Appropriate intervention should allow these areas to stabilise over time through natural processes.
Class 4	1. **Head**: Stabilisation of erosion head through application of complex earthworks, and control structures. These can include – Rock Chutes, Rock Groynes, Rock Beaching, Flow Control Structures (refer Options Description)
Class 5	1. **Channel**: if the erosion head has been stabilised it is likely that the channel will become stable also. Regeneration can occur naturally, or revegetation can be undertaken to speed up this process if desired. If the channel continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the waterway via underground lateral movement) or diversion flows created by structures, vegetation, or debris. Install bed stabilisation structures (such as a V-notch weir or rock ramp/concrete mats) within the channel. Revegetate channel corridor (may include riparian zone) with appropriate flora species. 2. **Sidewalls**: if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks or stabilised using bank stabilisation measures. If urban development is causing the erosion, then stormwater management systems to control erosive flows is a more appropriate option. Appropriate intervention should allow these areas to stabilise over time through natural processes.
Class 6	1. **Channel**: if the erosion head has been stabilised it is likely that the channel will become stable also. Regeneration can occur naturally, or revegetation can be undertaken to speed up this process if desired. If the channel continues to erode after the head has been stabilised, the source of this erosion can be lateral flow (water moving into the waterway via underground lateral movement) or diversion flows created

Erosion Class Rating	Management Options
	by structures, vegetation, or debris. Install bed stabilisation structures (such as a V-notch weir or rock ramp/concrete mats) within the channel. Revegetate channel corridor (may include riparian zone) with appropriate flora species.
Class 7	1. **Sidewalls**: if the side wall erosion is caused by run-on water, this will need to be diverted using diversion banks or stabilised using bank stabilisation measures. If urban development is causing the erosion, then stormwater management systems to control erosive flows is a more appropriate option. Appropriate intervention should allow these areas to stabilise over time through natural processes.
Class 8	1. Manage ground cover, development practices and stormwater flows to maintain soil stability

Options Description

- **Rock Chutes** are also known as rock riffles and rock ramps. They generally involve the excavation of the bed and banks of a stream and the placement of quarried rock on the bed or banks on a slope steeper than the natural stream to create a graded weir. Rock chutes are largely constructed to control the gradient of stream beds.
- **Rock Groynes** are largely impermeable deflectors placed into stream systems to prevent bank erosion, create deposition, and alter the local plan form of the stream. Rock groynes provide some erosion protection and result in a small-scale deposition.
- **Rock Beaching** involves the placement of quarried rock (rip rap) on stream banks. The rock is founded on the bed of the stream and generally extends up the portion of the bank threatened by erosion. This technique provides localised protection only and does not address system wide processes.
- It is noted that the installation of rock beaching and/or rock groynes can generate erosion through the scouring process when not properly sized or installed. The use of flexible **Concrete Erosion Mats** (https://www.concretemats.com.au/concrete-mat/) can be a suitable alternative. **Geofabric** or Geotextile meshing can provide a cheap, cost-effective method of stabilising erosion and promoting vegetative growth, however, suitability will be determined by flow characteristics (i.e., regime, velocity, etc) and erosion severity.
- **Flow Control Structures** include detention basins, weirs, diversion walls, etc. Structures that can mitigate the flow characteristics of the stormwater contributing the point of erosion.
    - **Flumes** are used where it is necessary to convey water to a lower level over a short distance. They are designed in such a way to dissipate the erosive energy generated by dropping the water in this fashion, for example into the stable channel floor.
- **Bank Battering** involves the modification of the stream bank to provide a stable surface which aids the establishment of vegetation. Bank battering can be used to accelerate the rate of recovery from past channel erosion, or to increase the safety of a steep bank in an urban environment.
- **Bed Stability** or grade stabilisation is generally implemented to halt an ongoing erosion process, increasing stream stability and stream health in the vicinity of the erosion, as well as helping to protect upstream assets from erosion and reducing downstream sediment supply and deposition.

4.2.3.4. Step Four: Prioritisation of Management Options

Based on defined Class, based on future development and land use change, etc., the management options can be prioritised.

The actual erosion assessment for Coffee Creek (Steps 1-3) is presented in Section 7.1. The prioritisation of erosion management options (Step 4) was conducted systematically with other stormwater and flood related management options, which is presented in Section 8, to form a catchment management plan for Coffee Creek.

5. DESIGN EVENT MODELLING

5.1. Temporal Patterns and Durations Selection

Temporal patterns are a hydrologic tool that describe how rainfall falls over time and are often used in hydrograph estimation. Advice in ARR 1987, was to adopt a single burst temporal pattern for each rainfall event duration. However, ARR 2019 (Reference 7) discusses the potential inaccuracies with adopting a single temporal pattern and recommends an approach where an ensemble of temporal patterns is investigated.

An ensemble of 10 temporal patterns is applicable across AEP ranges for durations ranging from 10 mins to 7 days. However, assessment of all durations and patterns in the hydraulic model is inefficient in terms of run time and data storage, especially when multiple iterations and scenarios were conducted for this study and there will be possible future applications by Council. Therefore, critical temporal patterns and durations were selected based on an initial modelling experiment.

For each duration, the temporal pattern producing the flood level closest to the mean of all patterns at a given location is typically deemed as being the representative pattern at that location. The duration producing the highest flood level at the given location is deemed as being the critical duration at that location.

To determine the critical storm duration(s) and select representative temporal pattern(s) for various parts of the catchment, modelling of the 1% AEP event was undertaken for a range of design storm durations from 15 minutes to 6 hours, with the consideration of the catchment size and previous experience.

Each duration utilised ten temporal patterns from ARR 2019 (Reference 7). The following process was undertaken in order to determine the critical duration(s) and representative pattern(s):

1. Run hydrologic and hydraulic models of 10 temporal patterns for each duration for the 1% AEP event. The hydraulic model was run with a 3 m × 3m grid size for this purpose to reduce the run time.
2. Determine the mean peak level from the 10 model runs at all hydraulic grids within the catchment from each duration modelled.
3. Select the critical duration(s), producing the maximum mean peak level for representative areas, Coffee Creek Catchment in this case.
4. For each critical duration, select a single temporal pattern that produces the closest peak level to the mean peak level in representative areas.
5. Examine the representativeness of selected critical durations and temporal patterns outside the representative areas, to ensure that they produce peak flows close enough to the maximum mean peak level, e.g., within ± 0.1m, over most of the catchment.

It was found that the 4.5-hour duration was critical for Coffee Creek for the 1% AEP event. Temporal pattern #6777 (ARR 2019 pattern numbers) was selected. The patterns and durations selected for 1% AEP were extended to 5% and 0.5% AEP events modelling.

5.2. Design Results

The results from this study are presented in APPENDIX B as:

- Peak flood extent and levels in Figure B1 to Figure B4
- Peak flood velocities in Figure B5 to Figure B7
- Peak flood depths in Figure B8 to Figure B10
- Hydraulic hazard in Figure B11 to Figure B13
- Hydraulic categories in Figure B14 to Figure B16

The results were provided in digital format compatible with Council's Geographic Information Systems. The digital data should be used in preference to the figures in this report as they provide more detail. Please note that all flood maps and tables below are presented for flood depth ≥ 0.05 m. Areas with flood depth ≤ 0.05 m are treated as non-inundated area.

5.2.1. Summary of Results

A number of reporting locations were digitalised to obtain flood levels, depths, velocities, and flows from TUFLOW, which were provided in csv files together with the model and other result files. Table 8 and Table 9 summarise results at sample locations (as shown in Figure 12). These locations coincide with the sample locations used for the sensitivity analysis discussed in Section 6.

Table 8: Peak Flood Levels, Depth, and Velocity at Key Locations (depth ≥ 0.05 m)

ID	Levels (m AHD)			Depth (m)			Velocity (m/s)		
	5% AEP	1% AEP	0.5% AEP	5% AEP	1% AEP	0.5% AEP	5% AEP	1% AEP	0.5% AEP
RL1	63.30	63.57	63.70	1.30	1.57	1.70	0.05	0.06	0.06
RL2	60.58	60.92	61.10	1.05	1.39	1.56	1.65	1.64	1.63
RL3	57.70	57.80	57.84	1.15	1.24	1.28	0.63	0.74	0.78
RL4	50.51	50.65	50.72	1.39	1.54	1.60	0.89	1.03	1.05
RL5	55.83	55.87	55.89	1.51	1.56	1.57	0.06	0.04	0.04
RL6	40.97	41.03	41.05	0.78	0.84	0.86	0.06	0.10	0.11
RL7	34.84	35.03	35.09	0.76	0.94	1.01	1.14	1.32	1.37
RL8	32.96	33.03	33.06	1.10	1.17	1.20	0.33	0.41	0.41
RL9	25.05	25.32	25.41	1.51	1.77	1.86	1.17	1.34	1.40
RL10	38.16	38.22	38.24	0.60	0.65	0.68	0.30	0.33	0.36
RL11	28.54	28.67	28.72	1.03	1.16	1.21	0.40	0.51	0.63
RL12	12.11	12.38	12.47	0.61	0.87	0.97	1.00	1.19	1.26
RL13	15.37	15.63	15.73	2.07	2.33	2.43	1.23	1.53	1.67
RL14	9.69	10.08	10.21	1.26	1.65	1.78	0.74	0.90	0.95
RL15	5.33	5.53	5.60	4.06	4.27	4.34	0.17	0.27	0.31
RL16	67.83	67.85	67.86	0.17	0.19	0.20	0.37	0.58	0.59
RL17	65.12	65.15	65.16	0.31	0.34	0.35	0.19	0.23	0.25
RL18	64.37	64.40	64.41	0.26	0.29	0.30	0.37	0.39	0.42
RL19	62.91	62.96	62.98	0.91	0.96	0.98	0.08	0.09	0.10
RL20	65.65	66.37	66.76	1.26	1.98	2.36	0.09	0.08	0.08

ID	Levels (m AHD)			Depth (m)			Velocity (m/s)		
	5% AEP	1% AEP	0.5% AEP	5% AEP	1% AEP	0.5% AEP	5% AEP	1% AEP	0.5% AEP
RL21	76.11	76.15	76.17	0.53	0.58	0.59	0.31	0.36	0.39
RL22	44.22	44.38	44.44	1.42	1.58	1.64	0.70	0.82	0.87
RL23	75.25	75.26	75.27	0.06	0.08	0.08	0.75	0.84	0.89
RL24	22.95	23.11	23.16	2.34	2.49	2.55	0.65	0.61	0.60
RL25	30.64	30.75	30.78	0.93	1.04	1.08	0.55	0.67	0.72
RL26	18.73	18.85	18.91	1.19	1.31	1.37	0.86	1.27	1.38
RL27	6.21	6.46	6.55	2.19	2.44	2.53	0.70	0.90	0.95
RL28	52.65	52.66	52.67	0.06	0.07	0.07	0.84	0.97	0.99

Table 9: Peak Flows (m^3/s) at Key Cross-sections

ID	Description	5% AEP	1% AEP	0.5% AEP
XS33	Redwood Retirement Village West	0.38	0.53	0.63
XS14	Redwood Retirement Village South	2.97	4.29	4.94
XS28	Kingston Green D/S	0.22	0.35	0.41
XS13	Coffee Creek @ Algona Rd U/S	2.89	3.91	4.43
XS12	Coffee Creek @ Algona Rd D/S	5.11	6.77	7.57
XS11	Coffee Creek @ Hunfingfield Pond D/S	5.58	7.51	8.43
XS10	Tributary from Urban Area East of Algona Rd	0.50	0.67	0.75
XS09	Tributary from Huntingfield North	2.62	3.91	4.62
XS08	Coffee Creek @ Penrhyn Pond D/S	8.63	13.25	15.29
XS05	Coffee Creek @ Heron Pond D/S	8.99	14.28	16.56
XS17	Tributary from Peter Murrel Conservation	4.29	6.34	7.19
XS04	Tributary from Huntingfield New Development	4.02	6.49	7.72
XS02	Coffee Creek @ Howden Rd U/S	17.55	29.85	34.81

5.2.2. Hydraulic Hazard

Hazard classification plays an important role in informing floodplain risk management in an area. Provisional hazard categories have been determined for the Coffee Creek catchment in accordance with the Australian Disaster Resilience Handbook Collection (Reference 12).

In recent years, there have been a number of developments in the classification of hazards. Research has been undertaken to assess the hazard to people, vehicles and buildings based on flood depth, velocity and velocity depth product. The Australian Disaster Resilience Handbook Collection deals with floods in Handbook 7 (Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia). The supporting guideline 7-3 (Reference 12) contains information relating to the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 3.

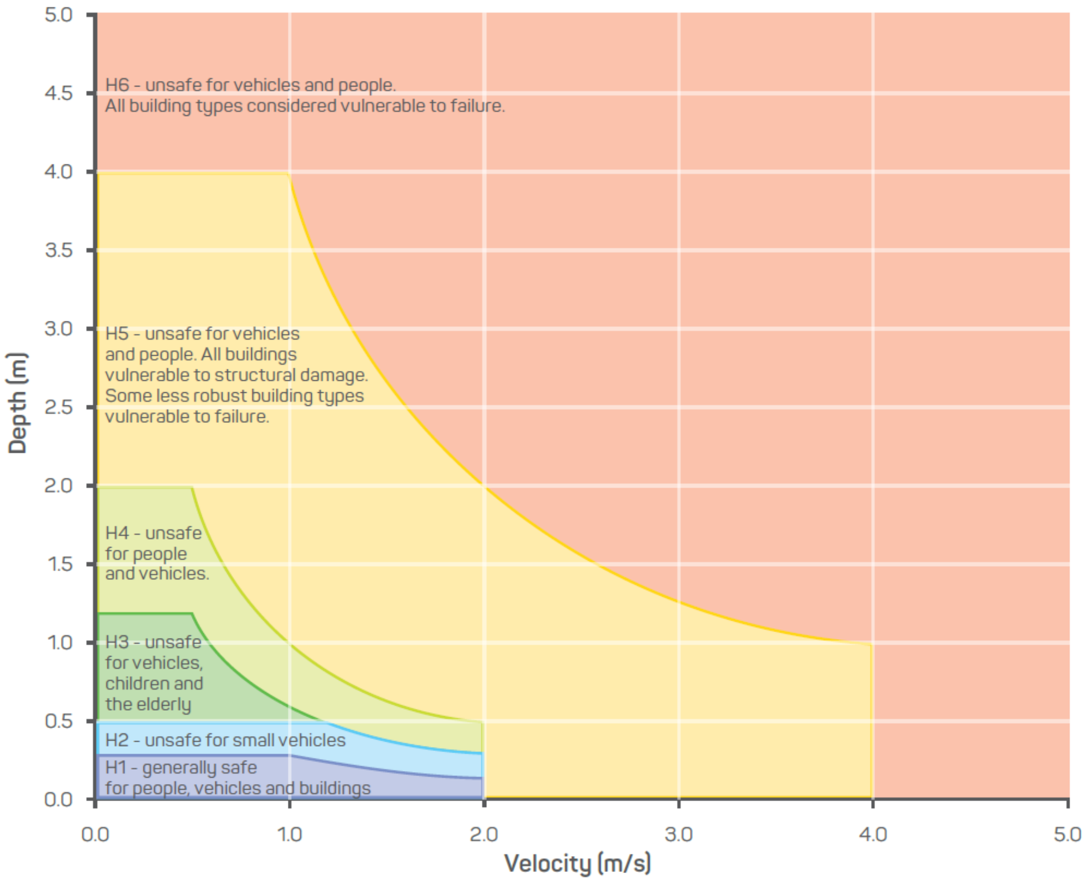

Diagram 3: General Flood Hazard Vulnerability Curves (ADR)

This classification provides a more detailed distinction and practical application of hazard categories, identifying the following 6 classes of hazard:

- H1 – No constraints, generally safe for vehicles, people and buildings;
- H2 – Unsafe for small vehicles;
- H3 – Unsafe for all vehicles, children and the elderly;
- H4 – Unsafe for all people and all vehicles;
- H5 – Unsafe for all people and all vehicles. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure. Buildings require special engineering design and construction; and
- H6 – Unsafe for all people and all vehicles. All building types considered vulnerable to failure.

The hazard maps created using the Australian Disaster Resilience (ADR) classification are presented in Figure B11 to Figure B13 for the 5% AEP, 1% AEP, and 0.5% AEP events.

5.2.3. Hydraulic Categorisation

Floodplains can be classified into the following hydraulic categories depending on the flood function:

- Floodways
- Flood Storage and
- Flood Fringe.

There is no quantitative definition of these three categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of an area and flood behaviour, hydraulic modelling, and previous experience in categorising flood function. A few approaches are available, such as the method defined by Howells *et al* (Reference 13).

For this study, hydraulic categories were defined by the following criteria, which has been tested and is considered to be a reasonable representation of the flood function of this catchment.

- Floodway is defined as areas where:
  - the peak value of velocity multiplied by depth (V x D) > 0.25 m^2/s, **AND** peak velocity > 0.25 m/s, **OR**
  - peak velocity > 1.0 m/s **AND** peak depth > 0.1 m.

The remainder of the floodplain is either Flood Storage or Flood Fringe,

- Flood Storage comprises areas outside the floodway where peak depth > 0.2 m, and
- Flood Fringe comprises areas outside the Floodway where peak depth ≤ 0.2 m.

Figure B14 to Figure B16 show the provisional hydraulic categorisations for the Coffee Creek catchment for the 5% AEP, 1% AEP, and 0.5% AEP events.

6. SENSITIVITY ANALYSIS

6.1. Overview

A number of sensitivity analyses were undertaken for 1% AEP events to establish the variation in design flood levels and flow that may occur if different parameter assumptions were made. These sensitivity scenarios are summarised in Table 10.

Table 10: Overview of Sensitivity Analyses

Scenario	Description
Climate Change	Sensitivity to rainfall and sea level increase due to Climate Change assessed for: • Year 2050 scenario with 8.4% IFD and 0.3m sea level increase; • Year 2100 scenario with 15.6% IFD and 1.0m sea level increase.
Roughness	Sensitivity to hydraulic roughness assessed for: • Manning's '*n*' decreased by 20%; • Manning's '*n*' increased by 20%.
Blockage	Sensitivity to blockage assessed for: • 50% blockage of bridge and culverts; • 50% blockage of all inlet pits; • 50% blockage of bridge and culverts, and all inlet pits.
Future Development	Sensitivity to future scenarios assessed for: • Ultimate developed scenario

6.2. Climate Change

Adopted from Council's recent climate report (Reference 14), rainfall intensities were set to increase 8.4% and 15.6% by Year 2050 and Year 2100, respectively when compared to the 1990 estimates. Adopted from Snug River Flood Study (Reference 2), sea levels were set to increase 0.3 m and 1.0 m by Year 2050 and Year 2100, respectively. Flood depth and velocity mapping are presented in Figure C1 to Figure C4. The climate change sensitivity results at sample locations are shown in Table 11.

The increase in rainfall results in an increase in peak flood levels at all locations analysed, and an increase of peak flood velocity at the majority of those locations.

Modelling indicates that increases in rainfall intensity would result in notable increase in flood levels where flood are detained, e.g., upstream of major culverts (Reporting Locations 1, 2, 20) and notable increase in flood velocities along downstream waterways (Reporting Locations 11, 13, 26). Both flood level and velocity in major ponds are not sensitive to climate change as they are typically full before flooding.

Table 11: Results of Climate Change Analysis for 1% AEP (depth ≥ 0.05 m)

ID	Flood Level (m AHD)			Difference (m)		Flood Velocity (m/s)			Difference (m/s)	
	Existing	Y2050	Y2100	Y2050	Y2100	Existing	Y2050	Y2100	Y2050	Y2100
RL1	63.57	63.66	63.73	0.09	0.16	0.06	0.06	0.06	0.00	0.00
RL2	60.92	61.03	61.13	0.11	0.20	1.64	1.64	1.63	0.00	-0.01
RL3	57.80	57.82	57.84	0.02	0.05	0.74	0.76	0.79	0.03	0.06
RL4	50.65	50.70	50.72	0.04	0.07	1.03	1.05	1.05	0.02	0.02
RL5	55.87	55.88	55.89	0.01	0.02	0.04	0.04	0.04	0.00	0.00
RL6	41.03	41.04	41.06	0.01	0.03	0.10	0.11	0.12	0.01	0.02
RL7	35.03	35.07	35.11	0.04	0.08	1.32	1.35	1.38	0.04	0.07
RL8	33.03	33.05	33.07	0.02	0.03	0.41	0.42	0.42	0.00	0.01
RL9	25.32	25.38	25.43	0.06	0.11	1.34	1.37	1.41	0.03	0.08
RL10	38.22	38.23	38.25	0.01	0.03	0.33	0.35	0.37	0.02	0.03
RL11	28.67	28.70	28.73	0.03	0.06	0.51	0.58	0.68	0.06	0.16
RL12	12.38	12.44	12.49	0.06	0.12	1.19	1.23	1.27	0.04	0.07
RL13	15.63	15.70	15.75	0.06	0.11	1.53	1.62	1.68	0.09	0.15
RL14	10.08	10.17	10.24	0.09	0.16	0.90	0.93	0.96	0.04	0.07
RL15	5.53	5.58	5.62	0.05	0.08	0.27	0.30	0.32	0.02	0.05
RL16	67.85	67.86	67.86	0.01	0.01	0.58	0.53	0.53	-0.05	-0.05
RL17	65.15	65.16	65.16	0.01	0.02	0.23	0.24	0.26	0.01	0.03
RL18	64.40	64.41	64.41	0.01	0.02	0.39	0.41	0.42	0.01	0.03
RL19	62.96	62.98	62.99	0.01	0.02	0.09	0.09	0.10	0.00	0.01
RL20	66.37	66.60	66.84	0.23	0.47	0.08	0.08	0.08	0.00	0.00
RL21	76.15	76.16	76.17	0.01	0.02	0.36	0.38	0.39	0.01	0.03
RL22	44.38	44.42	44.45	0.04	0.08	0.82	0.85	0.88	0.03	0.06
RL23	75.26	75.27	75.27	0.00	0.01	0.84	0.87	0.90	0.03	0.07
RL24	23.11	23.14	23.18	0.04	0.07	0.61	0.60	0.60	-0.01	-0.01
RL25	30.75	30.77	30.79	0.02	0.04	0.67	0.70	0.72	0.03	0.05
RL26	18.85	18.89	18.92	0.04	0.07	1.27	1.33	1.39	0.07	0.12
RL27	6.46	6.52	6.57	0.06	0.11	0.90	0.93	0.96	0.03	0.07
RL28	52.66	52.67	52.67	0.00	0.01	0.97	0.99	0.99	0.02	0.02

6.3. Roughness Variations

Flood depth and velocity mapping for roughness variations are presented in Figure C5 to Figure C8. The results at sample locations are shown in Table 12.

Overall peak flood level results were shown to be relatively insensitive to 20% variations in the roughness parameter. Varying the roughness parameter by 20% typically resulted in a peak flood height difference within ± 0.1 m. However, the roughness variation has a notable impact on peak flood velocity, i.e., the water generally flows slower when the surface is rougher.

Table 12: Results of Roughness Sensitivity Analysis for 1% AEP (depth ≥ 0.05 m)

ID	Flood Level (m AHD)			Difference (m)		Flood Velocity (m/s)			Difference (m/s)	
	Existing	- 20%	+ 20%	- 20%	+ 20%	Existing	- 20%	+ 20%	- 20%	+ 20%
RL1	63.57	63.54	63.59	-0.03	0.02	0.06	0.07	0.05	0.01	0.00
RL2	60.92	60.97	60.89	0.05	-0.04	1.64	1.80	1.48	0.16	-0.16
RL3	57.80	57.77	57.82	-0.03	0.03	0.74	0.79	0.68	0.05	-0.05
RL4	50.65	50.60	50.70	-0.06	0.05	1.03	1.10	0.92	0.07	-0.11
RL5	55.87	55.87	55.87	0.00	0.00	0.04	0.03	0.07	-0.01	0.02
RL6	41.03	41.02	41.04	-0.01	0.01	0.10	0.10	0.09	0.01	0.00
RL7	35.03	34.98	35.07	-0.04	0.04	1.32	1.45	1.20	0.14	-0.12
RL8	33.03	33.02	33.05	-0.01	0.01	0.41	0.49	0.36	0.07	-0.05
RL9	25.32	25.27	25.37	-0.06	0.05	1.34	1.44	1.23	0.10	-0.11
RL10	38.22	38.21	38.23	-0.01	0.01	0.33	0.37	0.30	0.04	-0.03
RL11	28.67	28.64	28.70	-0.03	0.03	0.51	0.55	0.49	0.04	-0.03
RL12	12.38	12.28	12.46	-0.10	0.08	1.19	1.40	1.05	0.21	-0.15
RL13	15.63	15.55	15.71	-0.08	0.08	1.53	1.75	1.41	0.22	-0.12
RL14	10.08	9.97	10.17	-0.10	0.10	0.90	1.02	0.80	0.12	-0.09
RL15	5.53	5.53	5.55	-0.01	0.01	0.27	0.29	0.26	0.02	-0.01
RL16	67.85	67.85	67.85	0.00	0.00	0.58	0.53	0.49	-0.05	-0.09
RL17	65.15	65.14	65.16	-0.01	0.01	0.23	0.25	0.21	0.02	-0.02
RL18	64.40	64.39	64.40	0.00	0.00	0.39	0.44	0.36	0.04	-0.04
RL19	62.96	62.93	63.00	-0.04	0.03	0.09	0.10	0.09	0.01	-0.01
RL20	66.37	66.42	66.32	0.05	-0.05	0.08	0.10	0.07	0.02	-0.01
RL21	76.15	76.14	76.16	-0.01	0.01	0.36	0.36	0.36	-0.01	0.00
RL22	44.38	44.34	44.42	-0.04	0.05	0.82	0.90	0.75	0.07	-0.07
RL23	75.26	75.26	75.27	0.00	0.00	0.84	0.94	0.75	0.11	-0.09
RL24	23.11	23.09	23.13	-0.02	0.02	0.61	0.69	0.55	0.08	-0.07
RL25	30.75	30.71	30.78	-0.04	0.03	0.67	0.73	0.61	0.07	-0.06
RL26	18.85	18.82	18.88	-0.03	0.03	1.27	1.32	1.14	0.05	-0.13
RL27	6.46	6.40	6.52	-0.06	0.06	0.90	0.94	0.85	0.04	-0.05
RL28	52.66	52.66	52.67	-0.01	0.01	0.97	1.14	0.82	0.18	-0.15

6.4. Blockage Variations

There are multiple factors to be considered in assessing the potential for blockage of drainage systems, e.g., the type and size of the structure, the type of mobility of debris causing blockage, and catchment land use. In this study, 50% blockage was applied to major culverts for open channels, inlet pits for underground drainage, or both. Flood depth and velocity mapping for blockage variations is presented in Figure C9 to Figure C14. The results at key locations are shown in Table 13 and Table 14 for the Flood Level and Velocity, respectively.

Peak flood levels at most locations were found to be relatively insensitive to blockage, with a few notable exceptions. The flood levels upstream of major culverts, e.g., Reporting Locations 1, 2, 20, are generally very sensitive to the blockage of culverts.

Table 13: Flood Level of Blockage Sensitivity Analysis for 1% AEP (depth ≥ 0.05 m)

ID	Flood Level (m AHD)				Difference (m)		
	Existing	50% Block Culverts	50% Block Pits	50% block Culverts & Pits	50% Block Culverts	50% Block Pits	50% block Culverts & Pits
RL1	63.57	63.86	63.59	63.89	0.29	0.02	0.32
RL2	60.92	61.68	60.90	61.62	0.76	-0.03	0.70
RL3	57.80	57.76	57.79	57.75	-0.04	0.00	-0.05
RL4	50.65	50.55	50.65	50.55	-0.10	0.00	-0.10
RL5	55.87	55.85	55.87	55.85	-0.03	0.00	-0.03
RL6	41.03	41.00	41.03	41.00	-0.03	0.00	-0.03
RL7	35.03	35.01	35.02	35.00	-0.02	-0.01	-0.03
RL8	33.03	33.02	33.03	33.02	-0.01	0.00	-0.01
RL9	25.32	25.29	25.31	25.27	-0.04	-0.02	-0.05
RL10	38.22	38.22	38.22	38.22	0.00	0.00	0.00
RL11	28.67	28.67	28.67	28.67	0.00	0.00	0.00
RL12	12.38	12.36	12.37	12.35	-0.01	-0.01	-0.02
RL13	15.63	15.61	15.62	15.60	-0.02	-0.01	-0.04
RL14	10.08	10.06	10.06	10.04	-0.02	-0.01	-0.04
RL15	5.53	5.63	5.53	5.62	0.09	-0.01	0.09
RL16	67.85	67.85	67.84	67.84	0.00	-0.01	-0.01
RL17	65.15	65.15	65.15	65.15	0.00	0.01	0.01
RL18	64.40	64.40	64.40	64.40	0.00	0.00	0.00
RL19	62.96	62.87	62.97	62.87	-0.09	0.00	-0.09
RL20	66.37	67.41	66.72	67.74	1.04	0.35	1.37
RL21	76.15	76.15	76.15	76.15	0.00	0.00	0.00
RL22	44.38	44.28	44.38	44.28	-0.10	0.00	-0.10
RL23	75.26	75.26	75.27	75.27	0.00	0.01	0.01
RL24	23.11	23.12	23.10	23.11	0.01	-0.01	0.00
RL25	30.75	30.75	30.73	30.73	0.00	-0.02	-0.02
RL26	18.85	18.85	18.85	18.85	0.00	0.00	0.00
RL27	6.46	6.45	6.45	6.44	-0.01	-0.01	-0.02
RL28	52.66	52.66	52.66	52.66	0.00	0.00	0.00

Table 14: Flood Velocity of Blockage Sensitivity Analysis for 1% AEP (depth ≥ 0.05 m)

ID	Flood Velocity (m/s)				Difference (m/s)		
	Existing	50% Block Culverts	50% Block Pits	50% block Culverts & Pits	50% Block Culverts	50% Block Pits	50% block Culverts & Pits
RL1	0.06	0.05	0.06	0.05	-0.01	0.00	-0.01
RL2	1.64	1.71	1.62	1.71	0.07	-0.03	0.07
RL3	0.74	0.64	0.73	0.64	-0.09	0.00	-0.09
RL4	1.03	0.95	1.03	0.95	-0.09	-0.01	-0.09
RL5	0.04	0.04	0.04	0.04	0.00	0.00	0.00
RL6	0.10	0.07	0.10	0.07	-0.03	0.00	-0.03

ID	Flood Velocity (m/s)				Difference (m/s)		
	Existing	50% Block Culverts	50% Block Pits	50% block Culverts & Pits	50% Block Culverts	50% Block Pits	50% block Culverts & Pits
RL7	1.32	1.29	1.31	1.28	-0.02	-0.01	-0.03
RL8	0.41	0.41	0.41	0.41	0.00	-0.01	-0.01
RL9	1.34	1.31	1.32	1.30	-0.03	-0.02	-0.03
RL10	0.33	0.33	0.33	0.33	0.00	0.00	0.00
RL11	0.51	0.51	0.51	0.51	0.00	0.00	0.00
RL12	1.19	1.18	1.19	1.18	-0.01	-0.01	-0.02
RL13	1.53	1.52	1.52	1.52	-0.01	-0.01	-0.02
RL14	0.90	0.89	0.89	0.88	-0.01	-0.01	-0.01
RL15	0.27	0.25	0.27	0.25	-0.02	0.00	-0.02
RL16	0.58	0.51	0.50	0.44	-0.07	-0.08	-0.14
RL17	0.23	0.23	0.24	0.24	0.00	0.01	0.01
RL18	0.39	0.39	0.40	0.40	0.00	0.01	0.01
RL19	0.09	0.06	0.09	0.06	-0.03	0.00	-0.03
RL20	0.08	0.04	0.08	0.04	-0.04	0.00	-0.04
RL21	0.36	0.36	0.36	0.36	0.00	0.00	0.00
RL22	0.82	0.75	0.82	0.75	-0.07	0.00	-0.07
RL23	0.84	0.84	0.93	0.93	0.00	0.09	0.09
RL24	0.61	0.60	0.61	0.60	-0.01	0.00	-0.01
RL25	0.67	0.67	0.65	0.65	0.00	-0.02	-0.02
RL26	1.27	1.27	1.27	1.27	0.00	0.00	0.00
RL27	0.90	0.89	0.89	0.88	-0.01	0.00	-0.02
RL28	0.97	0.97	0.97	0.97	0.00	0.00	0.00

6.5. Ultimate Development

Both peak flood level and velocity were found to be only sensitive to development at locations where development would take place. It is shown that flood velocity varies within the developed area, due to the change of roughness, while the flood level experiences a minor increase, typically, in the waterway sections to which the developed area is contributing (e.g., Reporting Locations 1, 2, 10, 26), refer Table 15. The peak flood depths and flow velocities for the modelled Ultimate Development Scenario can be seen in Figure C15 and Figure C16, respectively.

Table 15: Results of Development Sensitivity Analysis for 1% AEP (depth ≥ 0.05 m)

ID	Flood Level (m AHD)		Difference (m)	Flood Velocity (m/s)		Difference (m/s)
	Existing	Ultimate Development		Existing	Ultimate Development	
RL1	63.57	63.61	0.04	0.06	0.10	0.04
RL2	60.92	60.94	0.02	1.64	1.58	-0.07
RL3	57.80	57.80	0.00	0.74	0.74	0.01
RL4	50.65	50.66	0.01	1.03	1.04	0.01

ID	Flood Level (m AHD)		Difference (m)	Flood Velocity (m/s)		Difference (m/s)
	Existing	Ultimate Development		Existing	Ultimate Development	
RL5	55.87	55.87	0.00	0.04	0.04	0.00
RL6	41.03	41.03	0.00	0.10	0.10	0.00
RL7	35.03	35.04	0.01	1.32	1.32	0.01
RL8	33.03	33.04	0.01	0.41	0.44	0.03
RL9	25.32	25.34	0.02	1.34	1.34	0.00
RL10	38.22	38.25	0.03	0.33	0.43	0.09
RL11	28.67	28.68	0.01	0.51	0.68	0.17
RL12	12.38	12.38	0.01	1.19	1.20	0.00
RL13	15.63	15.64	0.01	1.53	1.54	0.01
RL14	10.08	10.09	0.01	0.90	0.90	0.00
RL15	5.53	5.54	0.00	0.27	0.27	0.00
RL16	67.85	67.84	-0.01	0.58	0.40	-0.18
RL17	65.15	65.14	-0.01	0.23	0.25	0.02
RL18	64.40	64.39	0.00	0.39	0.46	0.06
RL19	62.96	62.97	0.01	0.09	0.09	0.00
RL20	66.37	66.37	0.00	0.08	0.08	0.00
RL21	76.15	76.15	0.00	0.36	0.36	0.00
RL22	44.38	44.38	0.01	0.82	0.83	0.01
RL23	75.26	75.25	-0.01	0.84	1.04	0.20
RL24	23.11	23.12	0.01	0.61	0.60	-0.01
RL25	30.75	30.75	0.00	0.67	0.67	0.00
RL26	18.85	18.87	0.02	1.27	1.40	0.13
RL27	6.46	6.47	0.01	0.90	0.86	-0.04
RL28	52.66	52.67	0.00	0.97	1.00	0.03

7. RISK AND MANAGEMENT OPTION ASSESSMENT

Some of the key areas where flooding is problematic, sometimes referred to as "hotspots", requires detailed assessment of flood-related risks and potential management options. The existing condition flood hazard mapping indicates that flood inundation is not a key risk as there is no residential or commercial properties which are obviously subject to high level flood hazard. However, based on the local knowledge, the health of the natural waterway and its vulnerability to erosion and sedimentation risks are alarming issues. Related to the erosion risks, the increasing house demand and on-going land development is putting increased pressure on stormwater drainage systems and waterway health.

With the consideration of the issues faced by Council and local Community, the risk and management option assessment were carried out in accordance with below categories:

- Erosion Assessment
- Future Development Assessment

7.1. Erosion Assessment

The indicator adopted in this study for erosion potential is the velocity and volumetric flow rates of flood water within the Creek alignment. Review of flood velocity mapping of the Coffee Creek waterway has highlighted seven (7) locations where the velocities exceed 2.0 m/s during 1% AEP flood event. These locations were flagged for the erosion assessment. An additional three (3) locations were identified as being subject to development flows from areas of the catchment with a high impervious surface characteristic which results in high volumetric runoff, although part of those locations have maximum velocities lower than 2.0 m/s. The high velocity (1-7) and high flow (8-10) assessment locations (erosion hotspots) can be seen in Figure 13.

To inform the erosion risk assessment, additional site inspections were conducted on 11th and 16th of February 2021 for the ten (10) locations. Photos were geo-registered in MapInfo together with photos taken during the initial site visit (Figure 4). The site inspection notes for each location, including selected photos, are attached in APPENDIX F.

7.1.1. Risk Assessment

The erosion risk assessment for each of the 10 locations was conducted in accordance with the methodology described in Section 4.2, using the site inspection notes and regional geology soil maps. The detailed erosion risks assessment, including the cause of erosion and erosion class rating, is attached in APPENDIX G. The erosion classification is summarised in Table 16.

7.1.2. Erosion Management Measures

Based on the cause of erosion and class rating, the 10 locations can be grouped into four categories. As listed in Section 4.2.3.3, there are a number of measures for erosion management. Those measures have been screened and the recommended management measures are summarised for each of the four erosion categories, as shown in Table 17.

7.1.2.1. High Risk and Actively Eroding Locations

Locations 2b, 8, and 10 have active head, unstable channel, and eroding sidewalls (Class 1), and thus been identified as Category 1 – High risk and actively eroding locations. Erosion management should be considered for erosion head, channel, and sidewalls, as suggested in Table 7.

Table 16: Erosion Classification

Location	Sub-Location	Head	Channel	Sidewalls	Class
1	-	Inactive	Stable	Stable	8
2	2a	Inactive	Unstable	Eroding	5
	2b	Active	Unstable	Eroding	**1**
	2c	Inactive	Unstable	Eroding	5
3	-	Inactive	Stable	Eroding	7
4	-	Inactive	Stable	Stable	8
5	-	Inactive	Stable	Stable	8
6	-	Inactive	Stable	Eroding	7
7	-	Inactive	Unstable	Eroding	5
8	-	Active	Unstable	Eroding	**1**
9	-	Inactive	Stable	Stable	8
10	-	Active	Unstable	Eroding	**1**

Table 17: Erosion Risk Groups and Management Measures

ID	Location	Erosion Class	Erosion Category	Measures
1	2b, 8, 10	1	High risk and actively eroding	• Stabilisation of banks (erosion head) • Bed stabilisation • Channel and riparian zone revegetation
2	2a, 2c, 7	5	Median risk of erosion	• Channel and riparian zone revegetation • Bed stabilisation
3	1, 3, 4, 5, 6	7, 8	Low risk but high potential to future development	• Stormwater management and waterway protection plan • Other prevention measures
4	9	8	Low risk of erosion	N/A

As detailed in the site inspection notes and photos (APPENDIX F) and assessment tables (APPENDIX G), those locations generally have exposed and unvegetated topsoil, or topsoil and vegetation have been affected by recent works, e.g., land development or pond spillway. There is no or not enough erosion management measures in place.

It is recommended to implement stabilisation measures for banks (erosion head) and channel bed, such as rock chutes, rock groynes, rock beaching, or concrete mats, which have already been partially implemented at some other locations, e.g., see photos for Locations 2a and 3a (APPENDIX F). It is also important to gradually increase vegetation cover along the channel and riparian zone, which were degraded during construction works. Vegetation, especially natural vegetation typically has a deep and strong root system preventing erosion and sedimentation movement, and it is environmental and ecological friendly.

7.1.2.2. Median Risk Locations

Locations 2a, 2c, and 7 have inactive head, but unstable channel and eroding sidewalls (Class 5), and thus been identified as Category 2 – Median risk locations. Erosion management should be considered for channel and sidewalls, as suggested in Table 7.

Locations 2a and 7 are immediate downstream of hydraulic structures, e.g., pond spillway or culvert, and the soil exposure and vegetation deterioration are notable. There have been certain measures at Location 2a, i.e., concrete/stone invert with bluestone cage gabions, which might have been helpful for this location to avoid an active erosion head. There are still additional measures can be implemented.

For those locations, the most effective and environment friendly measure may be revegetation of channel and riparian zone. Besides, it is also recommended to implement stabilisation measures for channel bed, such as V-notch weir or rock ramp/concrete mats.

7.1.2.3. High Potential to Future Development Locations

Locations 1, 3, 4, 5, and 6 have low risk of erosion (Classes 7 or 8); however, they are directly adjacent to or receiving stormwater from the proposed Huntingfield Development. Therefore, they have been identified as Category 3 – Low risk but high potential to future development locations. The impact of the future development on the current erosion potential and flow regimes should be considered with any new development application within the Coffee Creek catchment. The impact of developments such as Huntingfield can result in an increase in runoff characteristics, i.e., volumes and velocities; of anywhere between 40%-90% above existing conditions, depending on the intensity of urbanisation. Examples of runoff control considerations are detailed below.

Stormwater Management and Waterway Protection

The most important measure for those locations is prevention measure, e.g., implementation of sustainable development practices by developing stormwater management and waterway protection strategy/policy to guide future development.

Urban development is a common issue for floodplain management, which affects not only erosion and sedimentation transportation processes, but also flooding and waterway health. Therefore, future development assessment and the management measure, has been independently assessed in detail in Section 7.2.

Flow Control Ponds / Detention Basins

Another measure could be flow control structures, such as ponds or detention basins. Such measures have the potential to reduce flow rate and velocity for a section of a waterway, instead of just a small spot of erosion head or channel. However, as there have already been several ponds along the upstream and middle section of Coffee Creek, including Huntingfield Pond, Penrhyn Pond, and Heron Pond, there is limited space to accommodate additional ponds / detention basins.

To assess the performance and potential of flow control ponds / detention basins, six (6) management scenarios, i.e., two ponds and their combination and two detention basins and their combination, were modelled, including:

- Option A: Flow Control Pond 1
- Option B: Flow Control Pond 2
- Option A+B: Cascade Flow Control Ponds 1 and 2
- Option C: Flow Control Detention Basin 1
- Option D: Flow Control Detention Basin 2
- Option C+D: Cascade Flow Control Detention Basins 1 and 2

The two ponds / detention basins were located along Erosion Location 6, as highlighted in Figure 14. The two ponds were represented by adding a bund (2d zsh) with 4-metre-wide spillway at each location, while the two detention basins were represented by adding a low-flow outlet pipe to each of the two bunds. The key configurations of the ponds / detention basins in TUFLOW are summarised in Table 18.

Table 18: Modelled Configurations of Flow Control Ponds / Detention Basins

	Bund Top (m AHD)	Spillway Invert (m AHD)	Low Flow Pipe		Initial Water Level (m AHD)
			Invert (m AHD)	Diameter (mm)	
Pond 1	13.5	12.5	-	-	12.5
Detention Basin 1			8	450	-
Pond 2	8	7	-	-	7
Detention Basin 2			4	225	-

The flood impact maps, showing changes of flood height and velocity resulted from the flow control ponds / detention basins, are illustrated in Figure D1 to Figure D36. It is shown that the proposed ponds / detention basins can significantly reduce the peak flow velocity within the pond / basin area during 5%, 1%, and 0.5% AEP events, which has the capability to remediate existing erosion risk and prevent potentially increased erosion risk due to future development. However, increase of flow velocity is also observed for the spots immediate downstream of the spillways, which is a disadvantage of flow control ponds / detention basins. Therefore, additional erosion mitigation works, such as rock beaching or concrete mats, downstream of the spillways are required. Similar measures have already been done to remediate erosion downstream of the Heron Pond spillway (Location 2a), as shown in the site photos (APPENDIX F). There is no significant difference in terms of the effectiveness between using ponds (without low flow pipe) and detention basins (with low flow pipe).

Despite of the effectiveness of this type of measures, their disadvantages are also obvious. Beside the challenge downstream of the spillway, these measures can be very costly and typically have a bigger impact on the natural environment and ecology. A high-level cost estimation (APPENDIX E) shows that it can cost approximately $191,184 and/or $116,013 for the construction of Pond 1 and/or Pond 2, or approximately $214.284 and/or $130,797 for Detention Basin 1 and/or 2 with low flow pipes.

It should be noted that the above costing was based on high-level conceptual design and estimated volume fill requirement for pond/basin wall construction. Diagram 4 illustrated an indicative sketch of the proposed wall(bund) of the pond/basin used for construction volume calculation and cost estimation. The wall was assumed to be 3 m wide on top with 1:2 (V:H) batters on the upstream and downstream sides of the wall. The length of the top was the same as the width of the Creek at the wall top level as summarised in Table 18. The cross-section of the Creek extracted from LiDAR DEM at each pond/basin was used to define the profile of the pond/basin.

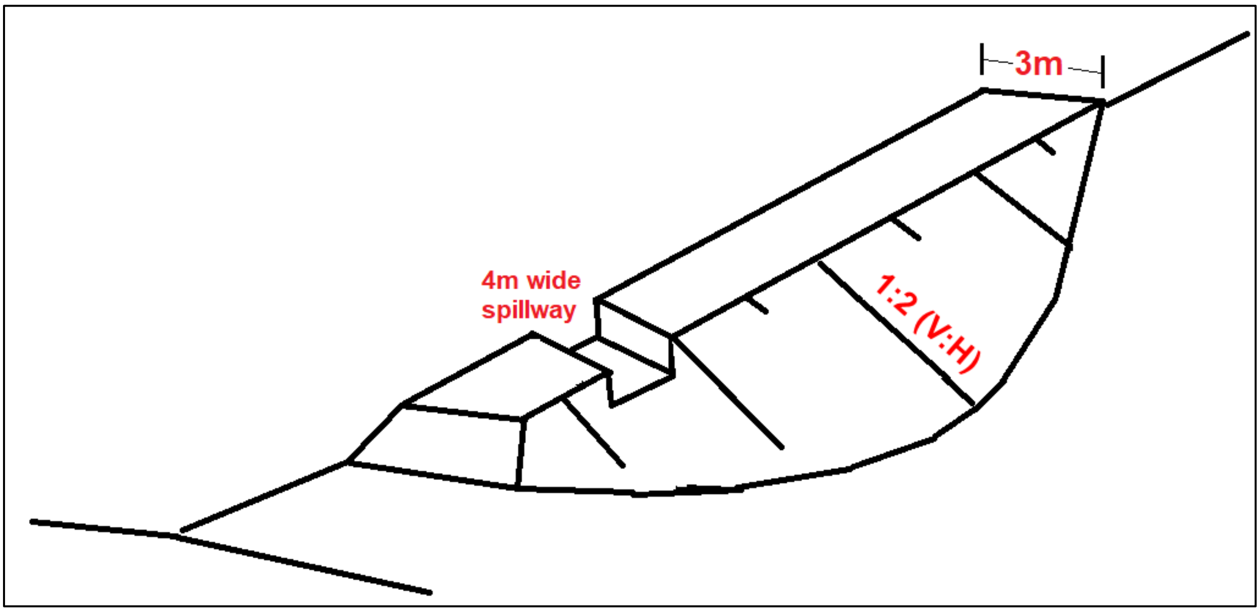

Diagram 4: Indicative Sketch of the Pond/Bain Wall.

7.1.2.4. Low Risk Locations

Location 9 has been identified as low risk locations and it is unlikely to be affected by future development. Therefore, no additional erosion management measures are required at this stage, which however can be reassessed when the circumstance changes.

7.2. Future Development Assessment

As noted, increased urbanisation in the upper catchment is likely responsible for increased demand on the natural waterway through increased quantity and degraded quality of urban stormwater to the creek. It is expected that urban density will further increase within the Coffee Creek Catchment, which is likely to put higher threats on the health of the waterway. The potential risk from future development is assessed in this section.

The potential future development based on Kingston Interim Planning Scheme (KIPS) 2015 has mainly been planned in two areas, including 1) the inner residential (Kingston Green) and commercial development north of Algona Road and 2) Huntingfield general and inner residential development, as highlighted in Figure 15. The following risk and mitigation option assessment is based on the proposed development in KIPS 2015. It should be noted that the recent proposed zoning changes under new Tasmanian Planning Scheme (TPS) indicates that there is limited development potential near Kingston Green north of Algona Road. Nevertheless, the “future development” modelled in this study, including the future development area highlighted in the mapping, represents an “worst case” developed scenario.

7.2.1. Risk Assessment

Without appropriate management, the impacts of future development on flooding and erosion risks are from several perspectives:

- Impact on vegetation and soil structure
- Impact on stormwater quantity
- Impact on stormwater quality
- Temporal impact during construction

7.2.1.1. Vegetation and Soil structure

Urban development leads to change of land use, e.g., from permeable forest / grassland / pasture to urban impermeable surfaces. This typically means 1) reduction of vegetation coverage rate and 2) change of soil structure.

The less vegetation coverage and compaction of soil in developed area will result in reduced infiltration and increased stormwater volume, which is further discussed in Section 7.2.1.2. The reduction of vegetation and permeable surface also means less capacity to treat and filter the increased pollutant/contamination generated from the development. That will degrade stormwater quality, which is further discussed in Section 7.2.1.3.

Another key risk from land use change is that urban development can lead to works within waterways. These works can cause compaction of soil, breakdown of soil structure, reducing the cohesion of soil particles and ability to resist erosive forces. An example is the recent development within the Coffee Creek alignment between Algona Road and Penrhyn Pond, accounting for the erosion happening at Erosion hotspot Locations 8 and 10 as discussed in Section 7.1.

7.2.1.2. Stormwater Quantity

As mentioned above, development can increase the frequency, volume, and velocity of runoff from storm events, consequently adding pressure to drainage lines and increasing the rate of flood inundation and waterway erosion.

Ultimate development scenario was modelled as a sensitivity analysis (Section 6.5). The flood impact maps for 1% AEP events, showing changes of flood height and velocity caused by the future development, are illustrated in Figure D37 and Figure D41. Based on the impact mapping, the future development can result in change of flood behaviour in three main areas, i.e., Hotspots 1, 2, and 3 highlighted in Figure D37. The flood impacts in those three hotspots are illustrated in zoomed-in maps from Figure D38 to Figure D40 and Figure D42 to Figure D44.

The peak flow rates across key cross-sections and culverts within each development impacted Hotspot are extracted and summarised in Table 19. The locations of those cross-sections and culverts are highlighted in Figure D38 to Figure D40.

Hotspot 1

Hotspot 1 is the area around the two water ponds, namely North and South Ponds connected through a culvert between, on the east of Australian Antarctic Division and north of Algona Road (Figure D38). This hotspot receives stormwater from the potential inner residential (Kingston Green) and commercial development to the northeast.

Table 19: Peak Flows (m^3/s) across Key Culverts and Cross-sections.

Hot-spot	Culvert / Cross-section	AEP 5%			AEP 1%			AEP 0.5%		
		Existing	Ultimate Developed	Difference	Existing	Ultimate Developed	Difference	Existing	Ultimate Developed	Difference
1	Pond Culvert	1.72	1.82	0.10	2.18	2.24	0.06	2.39	2.43	0.05
	Algona Rd Culvert	4.73	4.88	0.15	6.30	6.39	0.09	7.06	7.15	0.09
	XS12	5.11	5.24	0.13	6.77	6.89	0.12	7.57	7.70	0.13
2	XS09	2.62	2.92	0.31	3.91	4.20	0.29	4.62	4.95	0.33
	XS08	8.63	9.05	0.41	13.25	13.88	0.64	15.29	15.75	0.47
	XS05	8.99	9.46	0.47	14.28	14.71	0.43	16.56	16.99	0.43
3	XS20	0.57	0.81	0.24	0.87	1.11	0.24	1.02	1.27	0.25
	XS22	3.40	3.51	0.11	5.76	5.91	0.15	6.80	6.94	0.14
	XS26	14.38	15.13	0.76	23.07	23.41	0.35	26.79	27.22	0.43
	XS04	4.02	4.08	0.06	6.49	6.76	0.27	7.72	7.98	0.27
	XS03	17.45	18.42	0.97	29.01	29.42	0.41	34.00	34.39	0.39

The future development was represented through the change of impervious fractions and roughness in the model, as detailed in Methodology (Sections 4.1.2.2 and 4.1.3.2). However, as there is no actual design plan for future development, the modelled flow path for the development scenario was the same as the existing conditions scenario, which is not a realistic reflection of the flow conveyance through the developed site. Therefore, the modelled change of flood behaviour through the developed area is hatched (Figure D38) and should not be interpretated as a true representation of the ultimate development scenario. Any future development should have appropriate design of underground and surface drainage system to convey stormwater through the developed site.

As indicated in Figure D38, the increased runoff volume caused by the potential development can be accumulated in the North Pond, and result in flood level increase of approximately 40 mm in the North Pond during 1% AEP flood events. As shown in Table 19, the increase of hydraulic head in the North Pond will lead to increased flow rates through the connection culvert and the culvert across Algona Road, as well as the cross-section (XS12) further downstream (highlighted in Figure D38). However, the increases of flow rates are not significant and there is no notable impact downstream of Algona Road in terms of flood height (Figure D38) and velocity (Figure D42). This is because the North Pond can provide storage to detain the stormwater generated from the development and thus reduce the impact downstream.

Hotspot 2

Hotspot 2 includes the tributary section flowing from west (Nautilus Grove) towards Penrhyn Pond and the Coffee Creek section downstream of Penrhyn Pond (Figure D39). The flow in the tributary has stormwater contribution from the northern part of Huntingfield development.

The potential development can result in an increase of flow rate from the tributary, i.e., 0.29 to 0.33 m^3/s increase of peak flow across XS09. This will lead to increased flood level in the tributary and the impact on flood level can be propagated to the Coffee Creek downstream of Heron Pond (Figure D39). The change in velocity map (Figure D43) indicates that part of the downstream section of the tributary before joining Coffee Creek can suffer from 0 to 1 m/s velocity increase during 1% AEP event after development.

The increased flood volume and velocity can deteriorate the erosion issues in the waterway.

Hotspot 3

Hotspot 3 includes the tributary flowing from northwest joining Coffee Creek downstream of Sandflats Fire Trail, as well as the section of the Coffee Creek upstream and downstream of the confluence (Figure D40).

The upstream section of the tributary is affected by the western part of Huntingfield development, with 0.24 to 0.25 m^3/s peak flow increase across XS20 and over 50 mm flow level increase along the section (Figure D40). The middle section of the tributary does not have a significant increase of flood level as the contribution from Huntingfield development joins with a flow path from the west. The downstream section of the tributary is likely to experience noticeable flood level increase due to the stormwater flowing from the southeast part of Huntingfield development.

Coffee Creek upstream of the tributary confluence is impacted by the stormwater from the southeast part of Huntingfield development, with 0.35 to 0.76 m^3/s increase of flow rates across XS26, which is amplified after joining with the tributary, with 0.39 to 0.91 m^3/s increase of flow rates across XS03. However, as this section of Coffee Creek is wider than upstream, there is limited locations with noticeable flood level increase (Figure D40).

The tributary and the section of Coffee Creek have been identified as Class 7 or 8 in terms of risk to erosion, i.e., lower risks, due to the dense vegetation cover on sidewalls and waterway channel (Section 7.1). However, the potential development in Huntingfield can degrade the waterway if no appropriate stormwater management is in place, which will make the waterway more vulnerable to the change of flow volume and velocity.

7.2.1.3. Stormwater Quality

The pollutants and/or contaminations can be increased due to the increased human activities in developed area. Moreover, the reduction of vegetation and permeable surface due to urban development can reduce the capacity of the land to treat and filter the pollutant/contamination. Therefore, without appropriate stormwater management, the future development, especially the significant development such as Huntingfield, can result in significant degradation of stormwater quality and impact the health of the receiving natural waterway.

7.2.1.4. Temporary Impact during Construction

The vulnerability of the developable land to erosion risks is the highest during construction, as typically the vegetation is removed while the buildings, paved surfaces, and urban reserves/gardens are yet to be constructed/planted. This will leave significant portion of loose soil uncovered during construction, in addition to the erosible construction materials, e.g., cement. Diagram 5 shows the aerial image of Kingston Green Stage C during construction as an example.

A flood event, especially a rare event, is likely to have a higher risk to cause erosion if happening during construction than before and after.

Diagram 5: Exemplary Erosion Risk during Construction. The aerial imagery shows the Kingston Green Stage C during construction.

7.2.1. Mitigation Measures

As discussed above, future development will result in removal of natural vegetation, increases in impervious surfaces, and an increase in runoff volumes and contaminant loads. The impact of increased flows and removal of riparian vegetation along the bed and banks of the Coffee Creek waterway can increase the risk of erosion. The erosive processes often result in increased turbidity, smothering in-stream vegetation and ultimately increasing sediment loads in North West Bay.

Increased erosion also undermines remnant indigenous vegetation within the Coffee Creek corridor and threatens assets and infrastructure. The best approach is to reduce the impact of urbanisation with *in-situ* measures as part of the developments stormwater management strategy, incorporating Water Sensitive Urban Design (WSUD). Although, where necessary direct intervention may be required. Implementation of stormwater management and waterway protection strategies should be integral in the planning process for new development applications through development, it will be effective to develop a stormwater management and waterway protection strategy, which should expand upon Clause 6.11.2(g) of the Tasmanian Planning Scheme (TPS).

7.2.1.1. Review of Kingborough Interim Planning Scheme

The Interim Planning Scheme has requirements on stormwater management (E7.0 Stormwater Management Code) and natural waterway protection (E11.0 Waterway and Coastal Protection Code). The stormwater quality and quantity targets defined in the Interim Planning Scheme are listed in Table 20.

Table 20: Acceptable Stormwater Quality and Quantity Targets (Table E7.1 of Interim Planning Scheme)

80% reduction in the average annual load of total suspended solids (TSS) based on typical urban stormwater TSS concentrations.
45% reduction in the average annual load of total phosphorus (TP) based on typical urban stormwater TP concentrations.
45% reduction in the average annual load of total nitrogen (TN) based on typical urban stormwater TN concentrations.
Stormwater quantity requirements must always comply with requirements of the local authority including catchment-specific standards. All stormwater flow management estimates should be prepared according to methodologies described in Australian Rainfall and Runoff (Engineering Australia 2004) or through catchment modelling completed by a suitably qualified person.

The Waterway and Coastal Protection Code specifies that building and subdivision works near or within Waterway and Coastal Protection Areas should not have an unnecessary or unacceptable impact on natural values (Sections E11.7 and E11.8). The Waterway Protection Areas are defined in accordance with the waterway class as shown in Table 21.

Table 21: Spatial Extent of Waterway Protection Areas (Extracted from Table E11.1 of Interim Planning Scheme)

Class	Watercourse, Wetland, other Waterbody	Width
1	Watercourses named on the 1:100,000 topographical series maps, lakes, artificial water storages (other than farm dams), and the high water mark of tidal waters.	40 m
2	Watercourses from the point where their catchment exceeds 100 ha.	30 m
3	Watercourses carrying running water for most of the year between the points where their catchment is from 50 ha to 100 ha.	20 m
4	All other watercourses carrying water for part or all of the year for most years.	10 m

Limitations

Although the Interim Planning Scheme has set requirements for stormwater and waterway protection, there are limitations in those requirements:

- The TSS, TP, and TN reduction targets defined above are consistent with the Urban Stormwater Best Practice Environmental Management Guidelines (Reference 16), however, there is no target defined for gross pollutant (GP).
- The requirements for stormwater quantity are very general, referring to the out-dated version of Australian Rainfall and Runoff.
- The waterway protection guidelines are general for all waterways, which may not account for the catchment-specific requirements. For example, Coffee Creek is relatively vulnerable to erosion risks, and the erosion information provided by this project can be used to guide the waterway health protection strategy development.
- The effectiveness of the implementation of the stormwater and waterway protection codes can vary from each development. For example, Coffee Creek is classified as Class 2, which has 30m protection area on each side. Nevertheless, there are several buildings which are very close to the waterway, e.g., less than 10 m from the waterway, for the waterway section through Huntingfield, as illustrated in Diagram 6 and Diagram 7. It is also believed that the development in this area has led to increased stormwater rate and velocity which was not well managed through the development.

It is noted that the new Tasmanian Planning Scheme (TPS) is about to be introduced in Kingborough, potentially later this year. Work is underway to develop a state-wide stormwater policy to sit under the new planning scheme. This will provide clearer guidance and requirements for stormwater management in new developments. The TPS will replace the Kingborough Interim Planning Scheme (KIPS) 2015, to better guide the stormwater management and future development.

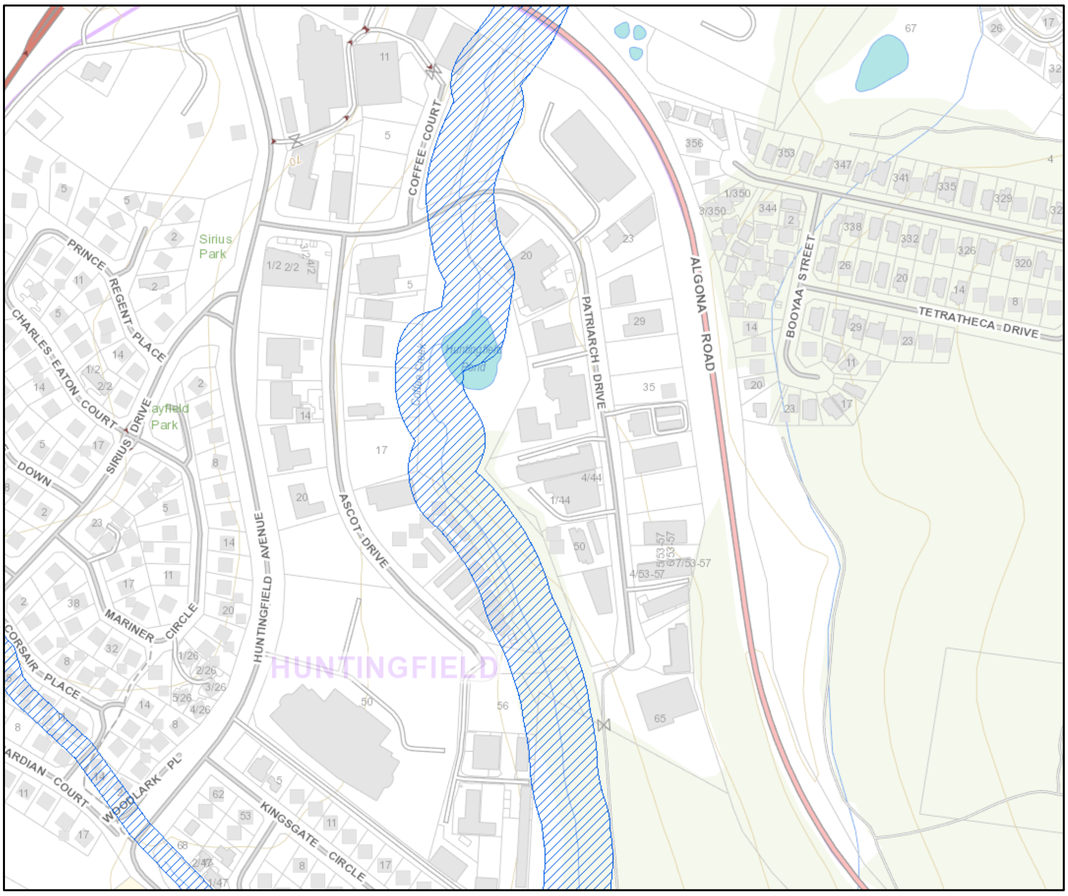

Diagram 6: Waterway Protection Area for Coffee Creek Section through Huntingfield.

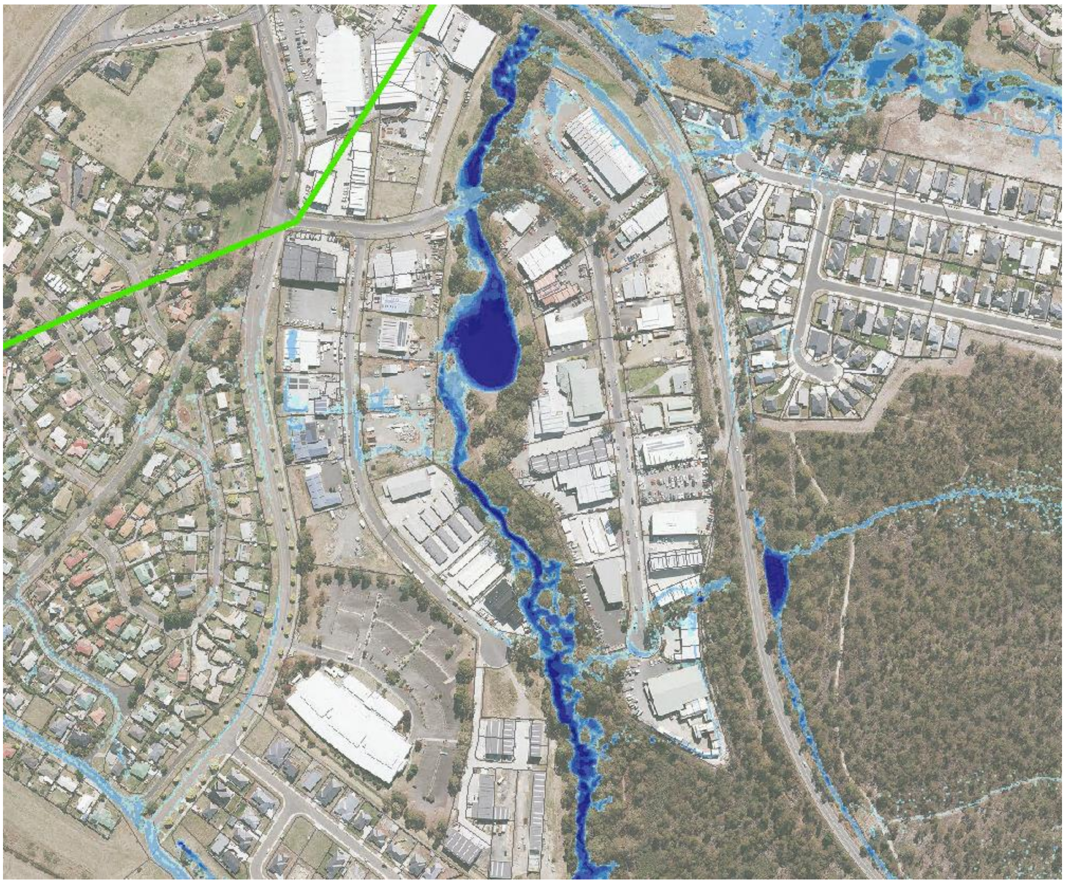

Diagram 7: 1% AEP Flood Extent (depth ≥ 50mm) for Coffee Creek Section through Huntingfield.

7.2.1.2. Stormwater Management and Waterway Protection Strategy

It is recommended to develop a stormwater management and waterway protection strategy specific for Coffee Creek Catchment. The strategy should be developed based on the information identified in this report and other recent studies for Coffee Creek and be enforced in line with the updated Planning Scheme. The following requirements are suggested to be included:

- Stormwater quality should achieve targets for TSS, TP, TN, and GP based on current industry best practice guidelines, e.g., the CSIRO guidelines (Reference 16).
- Stormwater quantity should achieve "no-worsening" target, i.e., the post-development discharge should not cause negative impact on neighbour and downstream properties and environment in terms discharge rate and flow velocity.
- The development should ensure a certain ratio of vegetation coverage and where possible to maximise the use of native vegetation.
- Specific requirements for the waterway protection area along Coffee Creek and its tributary should be itemised, including the prevention of development within the protection area, protection of native vegetation, erosion control measures for any work within protection area or new discharge locations.
- Specific requirements for the temporary erosion and sedimentation control measures for sites during construction, e.g., temporary mat/cover and temporary sedimentation pond.

7.3. Other Risk Management Measures

There is a plethora of stormwater and erosion mitigation measures that can be applied in general practice to mitigate the impact of stormwater runoff. However, considering the major challenges in Coffee Creek Catchment, e.g., the increasing land development, erosion and sedimentation transportation, and waterway health issues, some flood management measures are deemed to be less effective and urgent and are NOT evaluated in detailed in this study, such as:

- Flood protection structures, such as levees
- Wet and dry proofing
- Flood Emergency Management
- Flood warning and forecasting systems
- Flood action plan
- Disaster recovery plans
- Improved flood access and notifications

In addition to the measures proposed for the erosion mitigation, and future development control, there are other non-structural measures can be benefit, including:

- Flood planning and control overlays
- Creek and drainage maintenance program
- Flood and erosion risk awareness program

7.3.1. Flood Planning and Control Overlays

The purpose of flood planning and control overlays is to minimise the effects of overland flows and flooding on new buildings and to ensure new developments don't adversely affect existing properties. Flood related overlays provide information on drainage issues that can be addressed at the beginning of the development proposal and/or design process.

Although riverine inundation of properties is not a key existing issue in Coffee Creek Catchment, implementation of a set of flood overlays will be an important measure to minimise the flood related risks and damages on future development, considering the intensive on-going development happening in the catchment.

Flood overlays can be determined based on flood modelling results. For instance, the hydraulic hazard and hydraulic categorisation mapping (Figure B12 and Figure B15) can be used to define flood overlays. Alternatively, flood overlays can be categorised as land that is subject to flooding from –

- urban drainage systems (i.e., Special Building Overlays)
    - control measure: set appropriate design conditions to address flood risk, i.e., floor levels
- waterways and open drainage systems, flood depth <1 metre (i.e., Land Subject to Inundation Overlays)
    - control measure: Development works must consider a range of flood impacts and design criteria
- waterways and open drainage systems actively conveying flood flows, depths >1 metre

(i.e., Floodway Overlay)
   - control measure: Development not encouraged
- major urban overland flow path (i.e., Urban Floodway Zone)
   - control measure: Development is typically prohibited in these areas.

7.3.2. Creek and Drainage Maintenance Program

Maintenance of the drainage network is important to ensure it is operating efficiently and to reduce the risk of blockage or failure. It is also helpful to reduce the erosion risk and keep the health of the natural waterway which are affected by human activities.

The following guidelines are proposed to develop a maintenance program for Coffee Creek Catchment:

- ensure that as far as possible, significant amounts of debris (natural and manmade) are regularly removed from the drainage system and particularly at major culvert and bridge crossings, and the spillway of the ponds;
- ensure man-made debris will not enter the creek and drainage system. This may include inspecting the creek system to ensure potential debris providing locations are identified and controlled;
- following each flood, undertake a survey of the creek system and contact residents to establish where significant erosion, sedimentation, and blockages have occurred;
- conduct regular inspection and assessment of the erosion prone waterway sections to update the erosion database;
- remind residents to take photos and to advise Council of any erosion and debris build up in the creek and pond spillways. This can be done online or by contacting Council, and will ensure that reported issues can be addressed;
- develop an educational community action program to improve the community's understanding of the impacts of sending gross and other pollutants into the natural waterway system. This can be done through community consultation processes;

7.3.3. Flood and Erosion Risk Awareness Program

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program, but it is generally considered that the benefits far outweigh the costs.

For Coffee Creek Catchment community, it is important to raise the awareness of not only the risk of flooding but also the risk and harmfulness of erosion on the health of the waterway and natural environment. The knowledge should be conveyed through educational and consulting programs that the erosion and sedimentation process can cause significant issue to the waterways like Coffee Creek which have a series of online ponds. The erosion and sedimentation processes can not only impact the environment and ecological system but also increase the risk of pond failure and/or spillway blockage which eventually increase the risk of flooding.

The specific flood awareness measures that are implemented will need to be developed by

Council considering the views of the local community, funding considerations and other awareness programs within the Council area. The details of the exact measures would need to be developed in consultation with affected communities.

8. CATCHMENT MANAGEMENT PLAN

8.1. Risk Management Measures

A catchment management plan requires development of a set of flood and erosion risk management measures, that may be put in place to avoid the realisation of the risks. The management measures include structural (e.g., detention basins, gabions) and non-structural (e.g., land-use planning, early warning systems) solutions.

A number of possible flood and erosion risk management measures were discussed and/or evaluated in this study from erosion, future development, and flooding perspectives (Section 7), including:

- Stabilisation of banks (erosion head) and channel bed for High Erosion Risk Locations
- Revegetation of channel bed and riparian zone for High Erosion Risk Locations
- Stabilisation of channel bed for Median Erosion Risk Locations
- Revegetation of channel bed and riparian zone for Median Erosion Risk Locations
- Flow Control Pond(s) / Detention Basin(s) for Erosion Prevention from Future Development
- Definition of suitable stormwater management and waterway protection policy is in place and supported within the forthcoming Tasmanian Planning Scheme
- Development of stormwater management and waterway protection strategy for Coffee Creek
- Flood planning and control overlays
- Creek and drainage maintenance program
- Flood and erosion risk awareness program

Those measures are evaluated and prioritised through a multi-criteria assessment detailed below.

8.2. Multi-criteria Assessment

Various methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option, enabling ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows) of the project over its life. It is a standard method using the time value of money to compare the reduction in flood damages (benefit) with the capital and ongoing cost of the works. Generally, the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood and erosion mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason, a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. A multi-variate decision matrix was used for the Coffee Creek Catchment, allowing B/C estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

The criteria assigned a value in the management matrix are:

- impact on flood and erosion behaviour (reduction in flow rate, velocity, and erosion risks) over the range of flood events
- number of properties benefited by measure
- technical feasibility (design considerations, construction constraints, long-term performance)
- likely community acceptance and social impacts
- economic merits (capital and recurring costs versus reduction in flood and erosion damages)
- financial feasibility to fund the measure
- environmental and ecological benefits
- impacts on the State Emergency Services
- political and/or administrative issues
- long-term performance given the likely impacts of climate change
- risk to life.

The colour coded scoring system for the above criteria is provided in Table 22 and largely relates to the impacts in a 1% AEP event. Table 23 indicates the score assigned to each measure, however these may be adjusted in the light of local conditions and future community consultations.

8.3. Catchment Management Program for Coffee Creek

The recommendations on proposed measures are described in Table 24 according to the ranking in Table 23. However, a high rank in Table 23 may not necessarily be a high priority measure for implementation as, for example, funds may not be available and it will depend upon the ease of implementation (agreement between agencies, responsibility etc.).

Key points for each measure based on the assessment in Section 7 are summarised in Table 25 according to the ranking.

Table 22: Colour Coded Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	depth>100mm or velocity>0.5 m/s increase	depth 50 to 100mm or velocity 0.2 to 0.5 m/s increase	depth<50mm and velocity<0.2 m/s increase	no change	depth<50mm and velocity<0.2 m/s decrease	depth 50 to 100mm or velocity 0.2 to 0.5 m/s decrease	depth>100mm or velocity>0.5 m/s decrease
Number of Properties Benefitted	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight forward	straight forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

Table 23: Matrix of Management Measures Investigated in Study (sorted by rank)

Option	Section in Study	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental / Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	Total Score	Rank (Total)
Reviewing and updating Planning Scheme	7.2.2.1			3	2	1	3	3		1	2	1	16	1
Flood and erosion risk awareness program	7.3.3			3	2	1	2	2	1	2	1	1	15	2
Stormwater management and waterway protection strategy	7.2.2.2 / 7.1.2.3			3	2	1	2	3		1	2	1	15	2
Channel and riparian zone revegetation for High Erosion Risk	7.1.2.1	1		1	2	3	1	3		1	2	1	15	2
Flood planning and control overlays	7.3.1			3	2		3			1	1	1	11	5
Banks and channel Stabilisation for High Erosion Risk	7.1.2.1			1	2	2	1	1		1	2	1	11	5
Channel and riparian zone revegetation for Median Erosion Risk	7.1.2.2	1		1	2	2	1	2			2		11	5
Creek and drainage maintenance program	7.3.2	1		2	3		1	2		1	-2		8	9
Channel Stabilisation for Median Erosion Risk	7.1.2.2			1	2	1	1				2		7	11
Pond(s) / Detention Basin(s) for Erosion Control	7.1.2.3	3		-1	1	2	-2	2		-1	3	-1	6	12

Table 24: Recommended Management Measures in Plan

Option	Section in Study	Priority	Responsibility	Costing	Timeframe	Rank (Total)
Reviewing and updating Planning Scheme	7.2.2.1	High	Council	Low	Short	1
Flood and erosion risk awareness program	7.3.3	High	Council / SES	Medium	Medium	2
Stormwater management and waterway protection strategy	7.2.2.2 / 7.1.2.3	High	Council	Medium	Short	2
Channel and riparian zone revegetation for High Erosion Risk	7.1.2.1	High	Council	Low	Medium	2
Flood planning and control overlays	7.3.1	Medium	Council	Low	Short	5
Banks and channel Stabilisation for High Erosion Risk	7.1.2.1	High	Council	Medium	Short	5
Channel and riparian zone revegetation for Median Erosion Risk	7.1.2.2	Medium	Council	Low	Medium	5
Creek and drainage maintenance program	7.3.2	Medium	Council	Medium	Long	9
Channel Stabilisation for Median Erosion Risk	7.1.2.2	Low	Council	Medium	Short	11
Pond(s) / Detention Basin(s) for Erosion Control	7.1.2.3	Low	Council	High	Medium	12

Table 25: Key Points of Recommended Management Measures for Coffee Creek

MEASURE	PURPOSE	COMMENT	RECOMMENDATION
Non-Structural Measures:			
Reviewing and updating Tasmanian Planning Scheme (Section 7.2.2.1)	Enhance the sections / codes regarding stormwater and waterway protection to better guide future development.	• A cheap and effective method which can be completed in a short period. • Updated codes provide legal basis for the development and enforcement catchment-specific stormwater management and waterway protection strategy for Coffee Creek Catchment.	• Low cost and medium timeframe with high benefit. • Suggest implementing directly with high priority.
Stormwater management and waterway protection strategy (Sections 7.2.2.2 / 7.1.2.3)	A strategy targeting at specific challenges in the Catchment to guide future development	• A cheap and effective method which can be completed in a short to median period. • To be developed based on the information identified in this and other recent studies for Coffee Creek and enforced in line with the updated Planning Scheme. • Details on stormwater quality and quantity, waterway protection, and temporary control during construction should be included.	• Median cost and short timeframe with high benefit. • Suggest implementing after updating Planning Scheme with high priority.
Flood planning and control overlays (Section 7.3.1)	Define the boundaries of the flood planning area and implementing	• Flood overlays need to be developed for planning purpose. Hydraulic hazard, hydraulic categorisation, or specific overlays can be used/developed.	• An effective way with low cost and short timeframe which can help to avoid damage for future development, although flood

MEASURE	PURPOSE	COMMENT	RECOMMENDATION
	flood related planning controls.	• It is recommended that planning policy is reviewed and updated revised in accordance with the flood behaviour data modelled from this study.	inundation is not a key issue in Coffee Creek Catchment. • Suggest implementing with median priority.
Flood and erosion risk awareness program (Section 7.3.3)	Educate people to protect the natural environment and waterways, to prepare for floods, and to minimise risks and damages.	• A cheap and effective method but requires continued effort. • It is important that a high level of awareness of the flood and erosion risks is maintained. • Community education and consultation are suggested.	• Median cost and medium timeframe with high benefit. • Suggest implementing an on-going program including regular educational sessions to maintain high level of awareness of flooding and erosion risks with high priority.
Creek and drainage maintenance program (Section 7.3.2)	To ensure drainage is operating efficiently and to reduce the risk of erosion, blockage, or failure.	• Maintenance is costly and requires ongoing investment. • Regular and post-flooding inspection and assessment of erosion and blockage for ponds and waterway are recommended. • Engaging community through educational program can be effective.	• Reasonable benefit but requiring ongoing (long-term) investment. • Public education, erosion assessment updating, vegetation and debris maintenance are suggested with median priority if funding is available.
Structural Measures:			
Pond(s) / Detention Basin(s) for erosion control (Section 7.1.2.3)	Flow control ponds / detention basins to remediate existing erosion risks and prevent potentially increasing erosion due to future development.	• Two ponds and the combination and two detention basins and the combination were modelled and assessed. • Additional measures are needed for the spillway and the immediate downstream. • The reduction of flow velocity can be significant, but there are also disadvantages, e.g., high cost, disruption of the naturel waterway.	• High cost and median timeframe with notable benefit but also impacts on the waterway. • Suggest being further assessed if funding is available with low priority.
Channel and riparian zone revegetation for High Erosion Risk Locations (Section 7.1.2.1)	Increase the vegetation cover along the channel and riparian zone to remediate erosion at High Erosion Risk Locations (2b, 8, 10)	• Restore vegetation cover, preferably native vegetation. • Useful to stabilize the soil, reduce the flow velocity, so as to remediate the active erosion issue at those locations. • Environmental and ecological friendly.	• Low cost and median timeframe with high benefit. • Suggest implementing directly with high priority.
Banks and channel Stabilisation for High Erosion Risk Locations	Structural measures to remediate erosion at High Erosion Risk Locations (2b, 8, 10)	• Potential measures include rock chutes, rock groynes, rock beaching, or concrete mats. • Useful to stabilize erosion head and channel bed, so as to remediate the active erosion issue at those locations.	• Median cost and short timeframe with high benefit. • Suggest implementing following functionality assessment with high priority.

MEASURE	PURPOSE	COMMENT	RECOMMENDATION
(Section 7.1.2.1)			
Channel and riparian zone revegetation for Median Erosion Risk Locations (Section 7.1.2.2)	Increase the vegetation cover along the channel and riparian zone to remediate erosion at Median Erosion Risk Locations (2b, 8, 10)	• Restore vegetation cover, preferably native vegetation. • Useful to stabilize the soil, reduce the flow velocity. • Environmental and ecological friendly. • Less urgent than the measures for the High Erosion Risk Locations.	• Low cost and median timeframe with reasonable benefit. • Suggest implementing median priority.
Banks and channel Stabilisation for Median Erosion Risk Locations (Section 7.1.2.2)	Structural measures to remediate erosion at Median Erosion Risk Locations (2b, 8, 10)	• Potential measures include V-notch weir or rock ramp/concrete mats. • Useful to stabilize channel bed. • Less urgent than the measures for the High Erosion Risk Locations.	• Median cost and short timeframe with some benefit. • Suggest functionality assessment with low priority.

9. CONCLUSIONS

Hydrologic and hydraulic models have been established in this study to improve the understanding of the stormwater, flood, and erosion issues and investigate potential solutions.

Flood mapping, including peak flood extents, levels, depths, velocities, as well as hydraulic hazards and hydraulic categories, was produced for 5%, 1% and 0.5% AEP design events, which provides flood intelligence and behaviour information for Council to adopt for planning purposes. Sensitivity analysis was conducted for key factors, including rainfall intensity and sea level changes due to climate change (Years 2050 and 2100), roughness variations, blockage variations, and future land development, to inform considerations required for catchment management and future planning. Site investigations were conducted for erosion prone locations to obtain first-hand erosion status.

Modelling results and information obtained from site inspections were used to assess flood related issues across the catchment, including:

- Erosion risks and remediation/prevention measures
- Future development and management measures

Potential structural and non-structural stormwater, erosion, and future development management measures were proposed, evaluated, and then prioritised through a multi-criteria assessment. The assessment and scores of the proposed measures are summarised in Table 23. The prioritisation and further recommendations of each measure are presented in Table 24 and Table 25, respectively, which forms the Catchment Management Plan for Coffee Creek.

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Figures

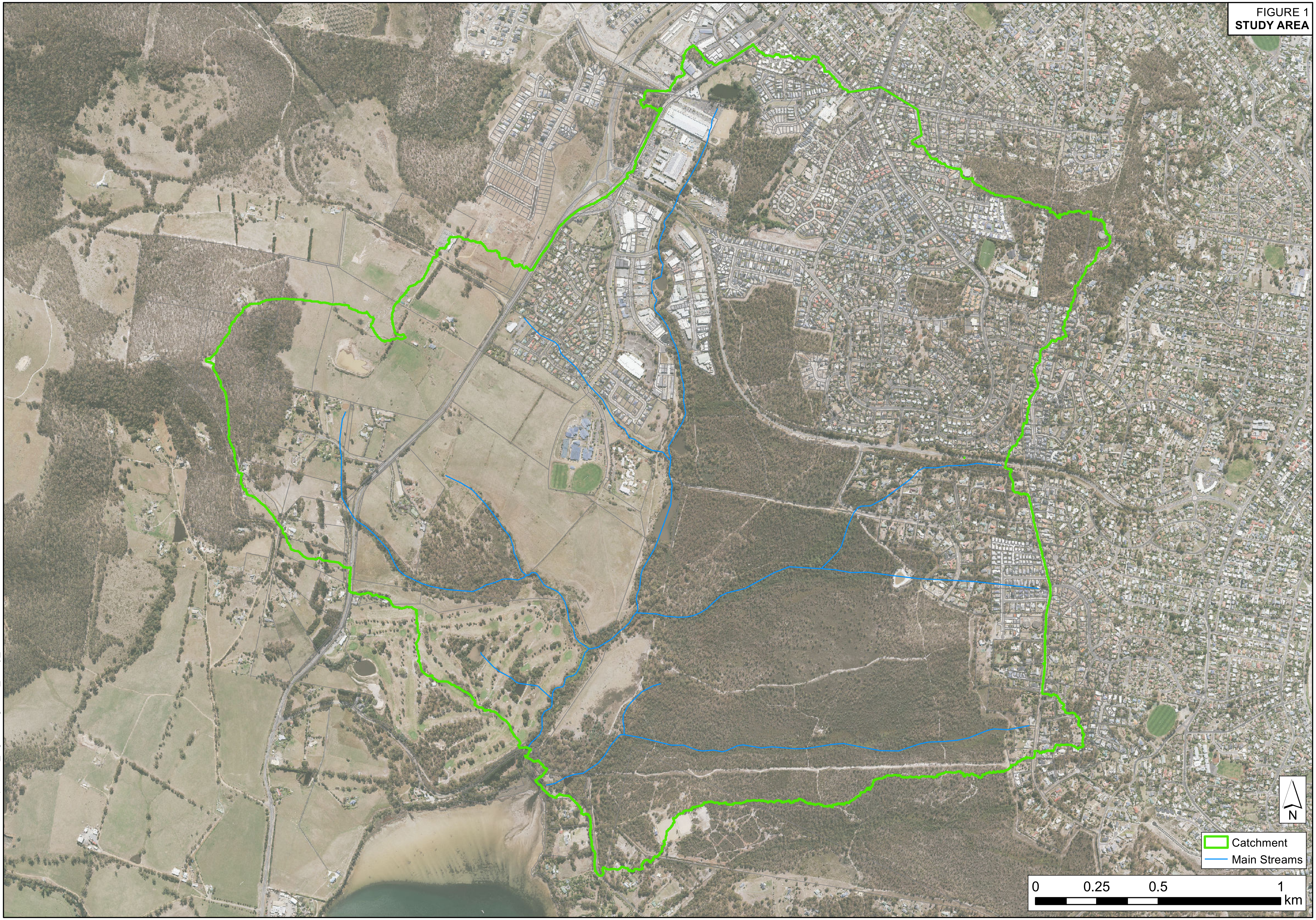

FIGURE 1
STUDY AREA

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FIGURE 2
DIGITAL ELEVATION MODEL (2011 LIDAR)

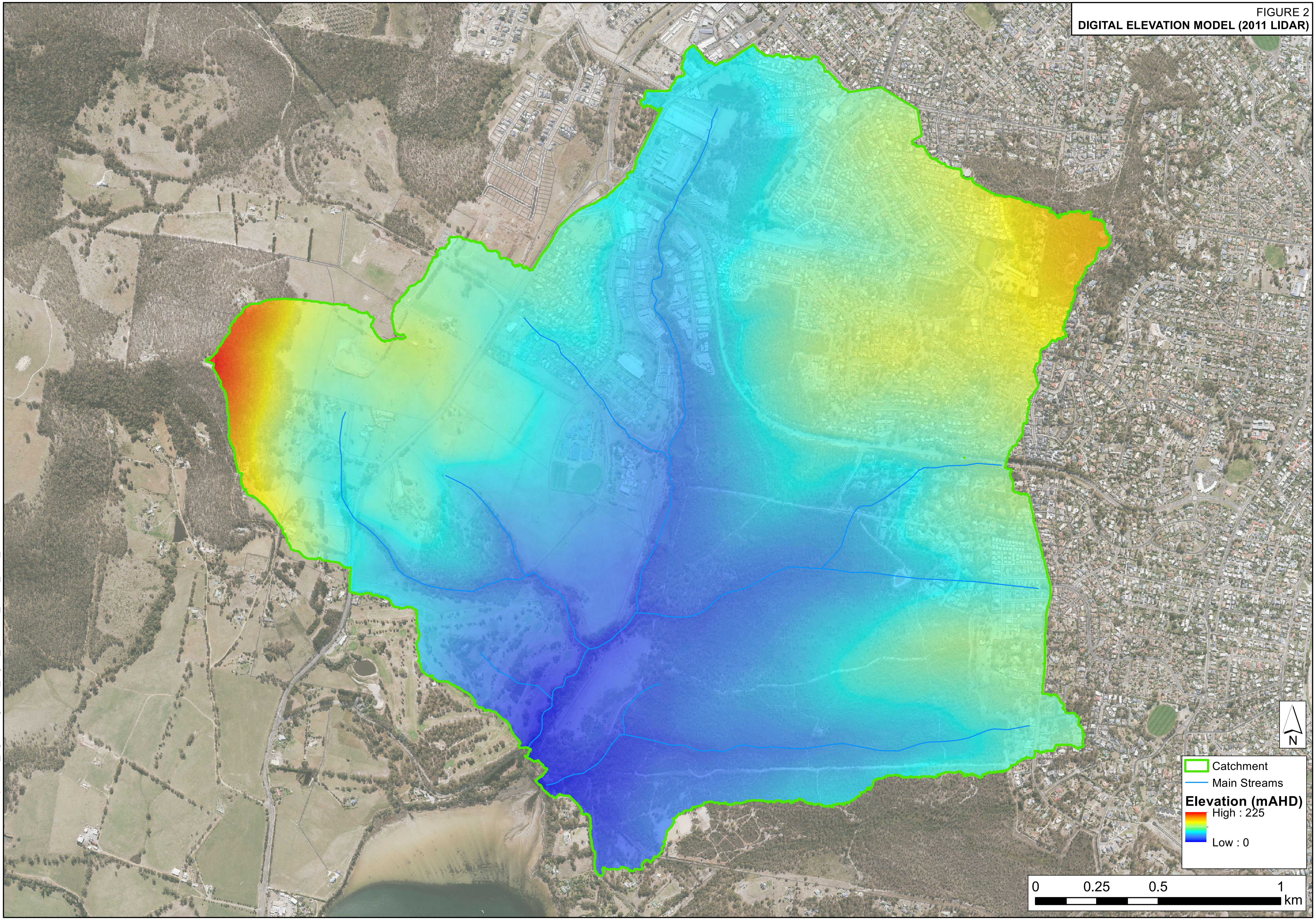

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FIGURE 3
DIGITAL ELEVATION MODEL (OTHER DESIGN)
Catchment
Main Streams
Elevation (mAHD)
High : 80
Low : 40
N
0
50
100
200
m
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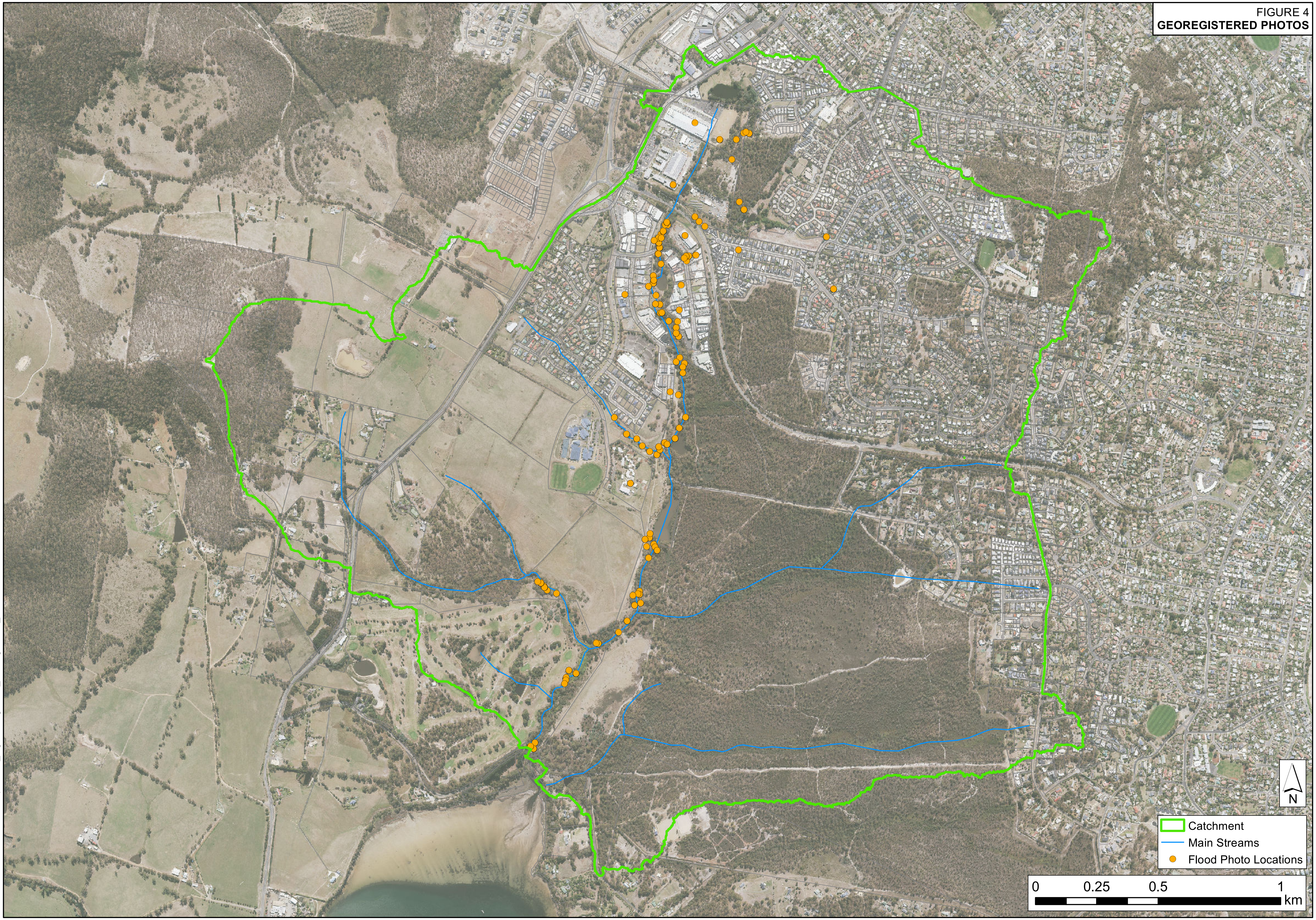

FIGURE 4
GEOREGISTERED PHOTOS

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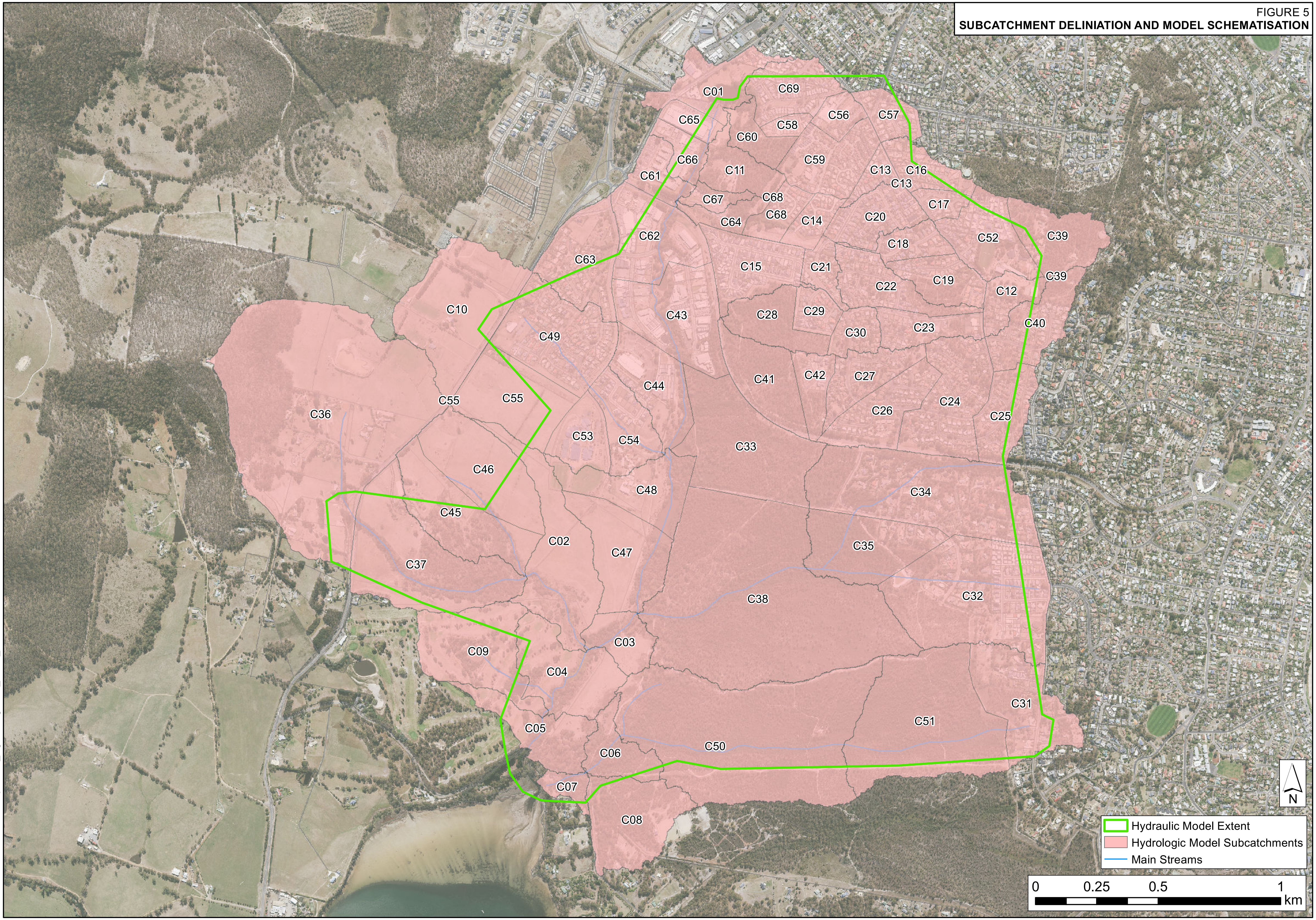
FIGURE 5
SUBCATCHMENT DELINIATION AND MODEL SCHEMATISATION



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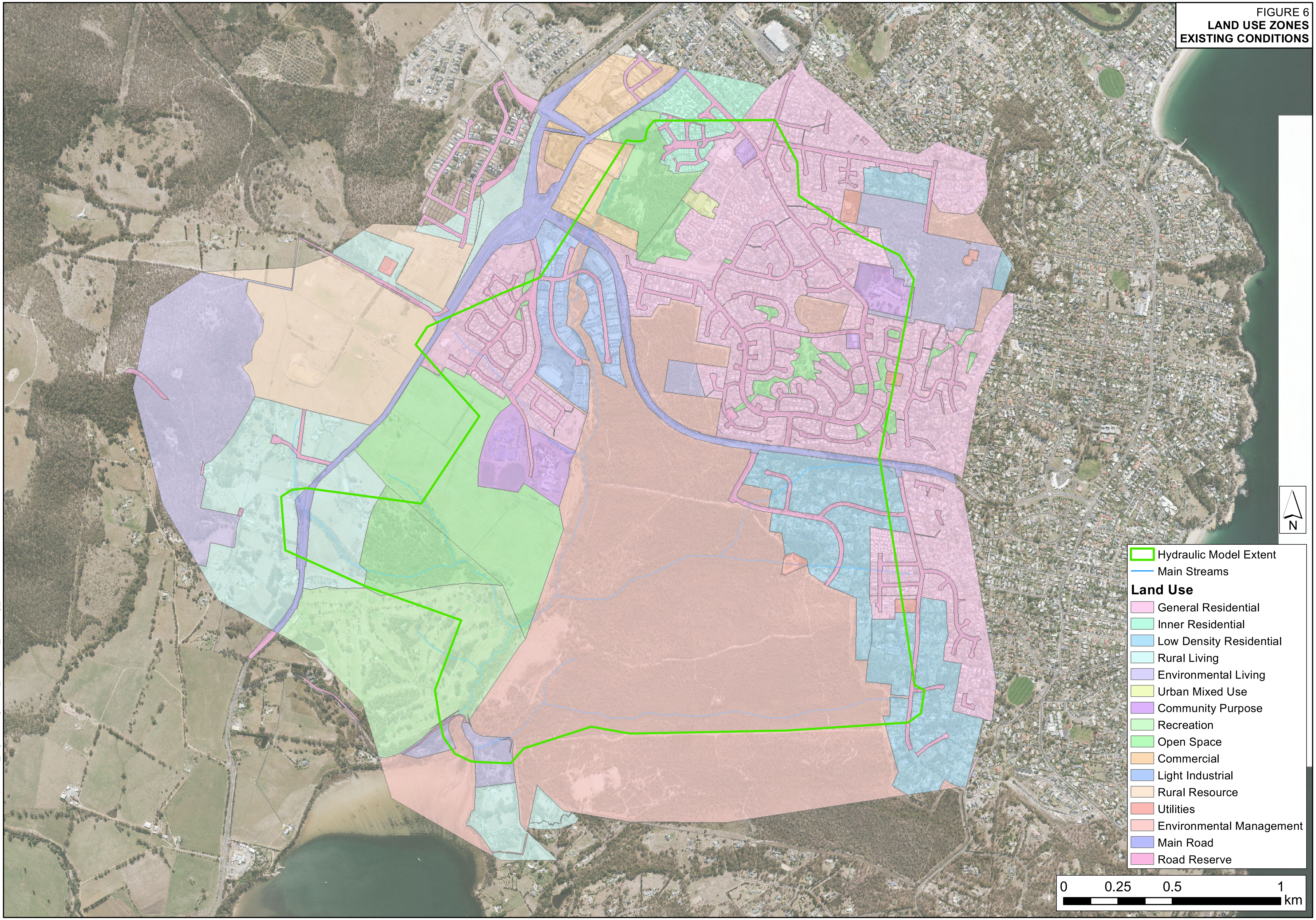

FIGURE 6
LAND USE ZONES
EXISTING CONDITIONS

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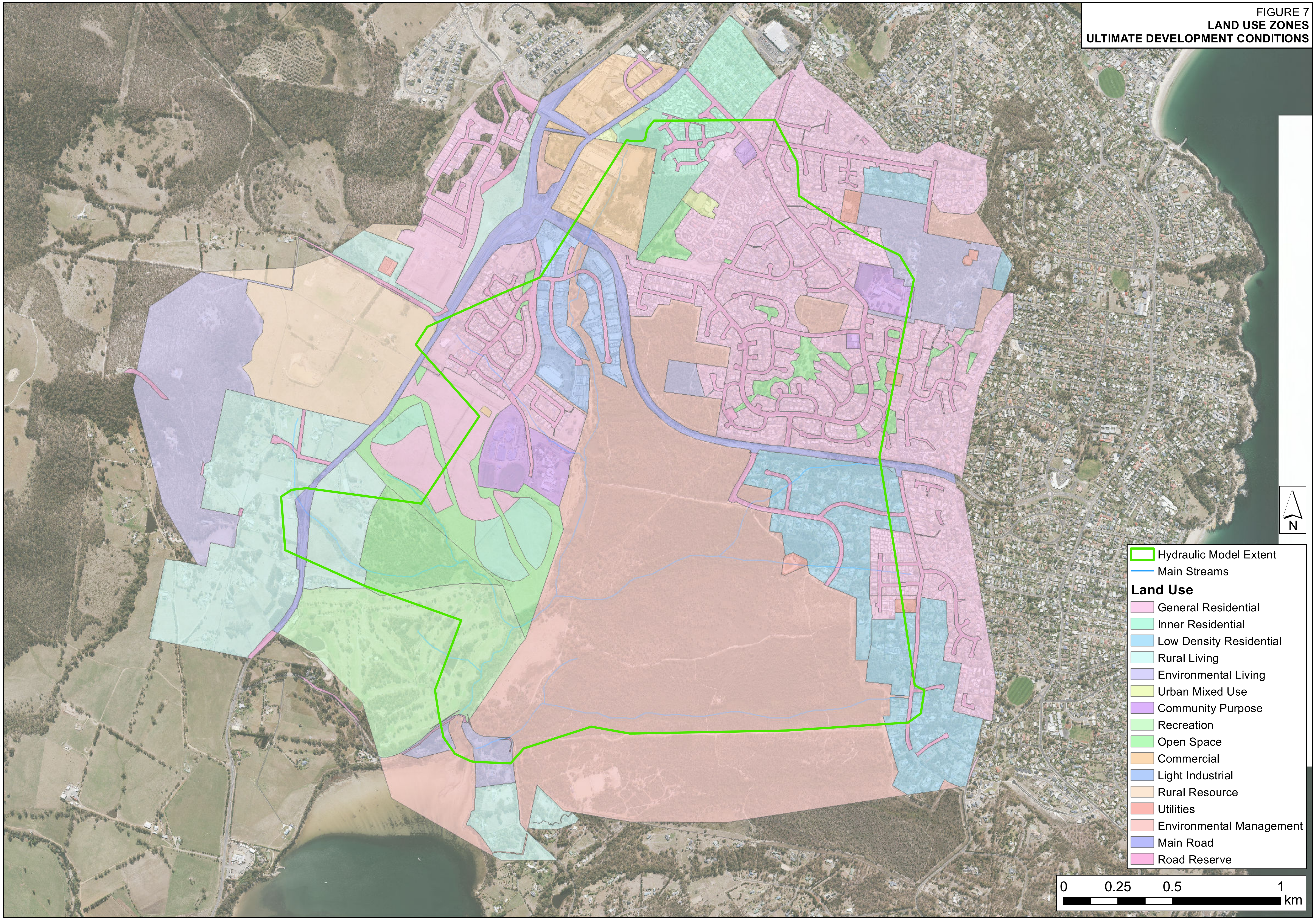

FIGURE 7
LAND USE ZONES
ULTIMATE DEVELOPMENT CONDITIONS

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FIGURE 8
HYDRAULIC MODEL - BOUNDARY CONDITIONS

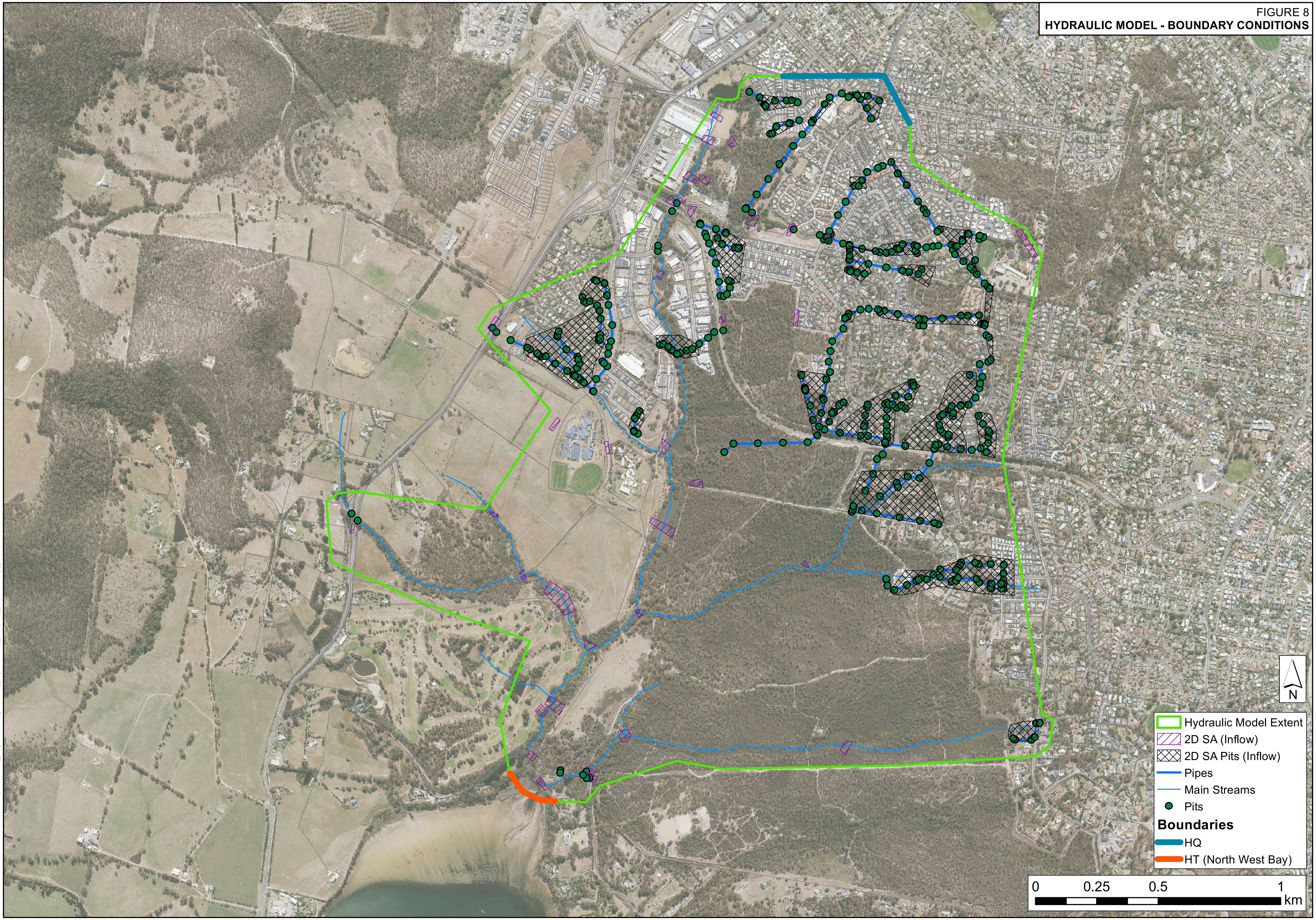

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FIGURE 9
HYDRAULIC MODEL - SURFACE ROUGHNESS FOR MAIN WATERWAY

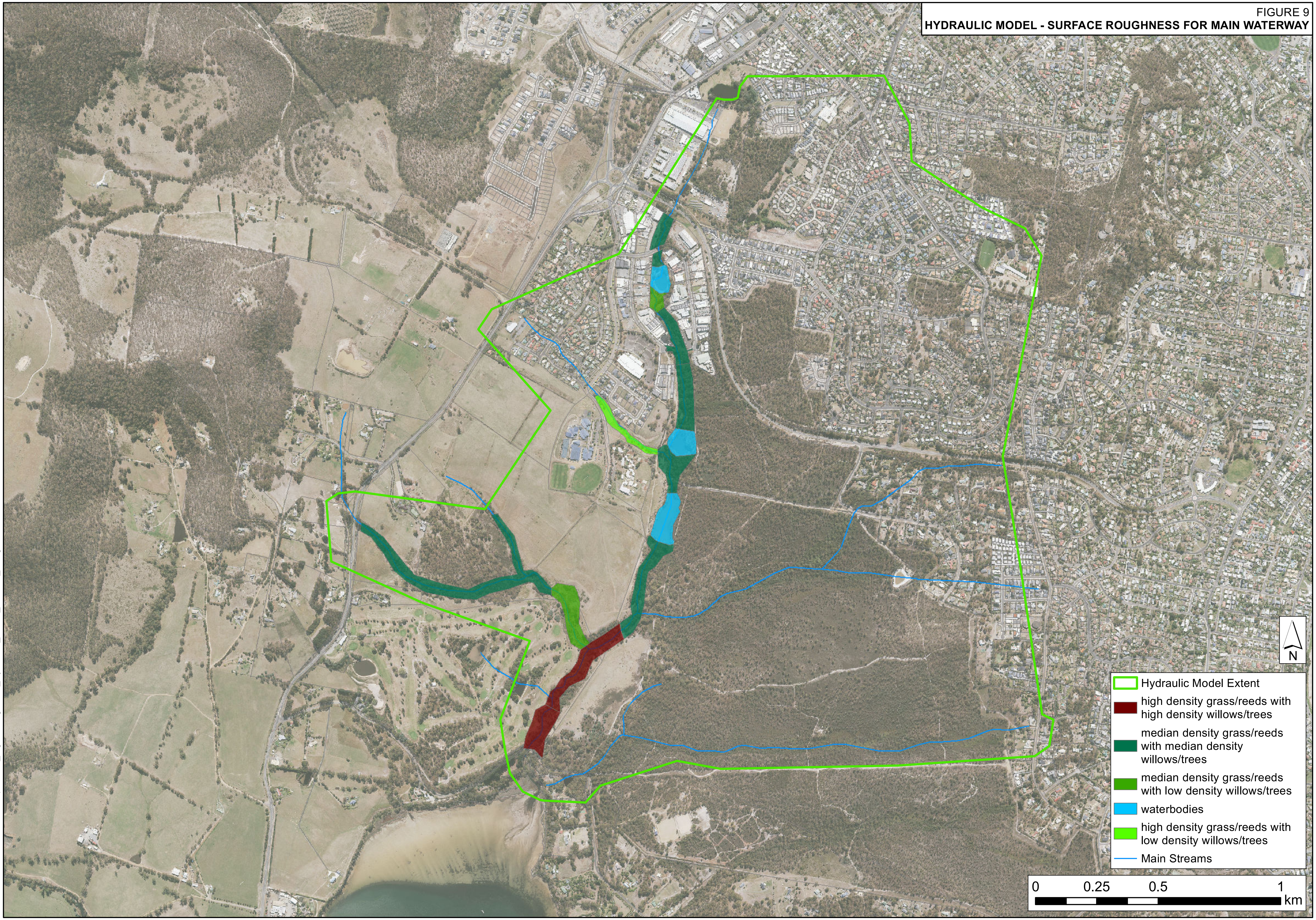

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FIGURE 10
HYDRAULIC MODEL - DRAINAGE

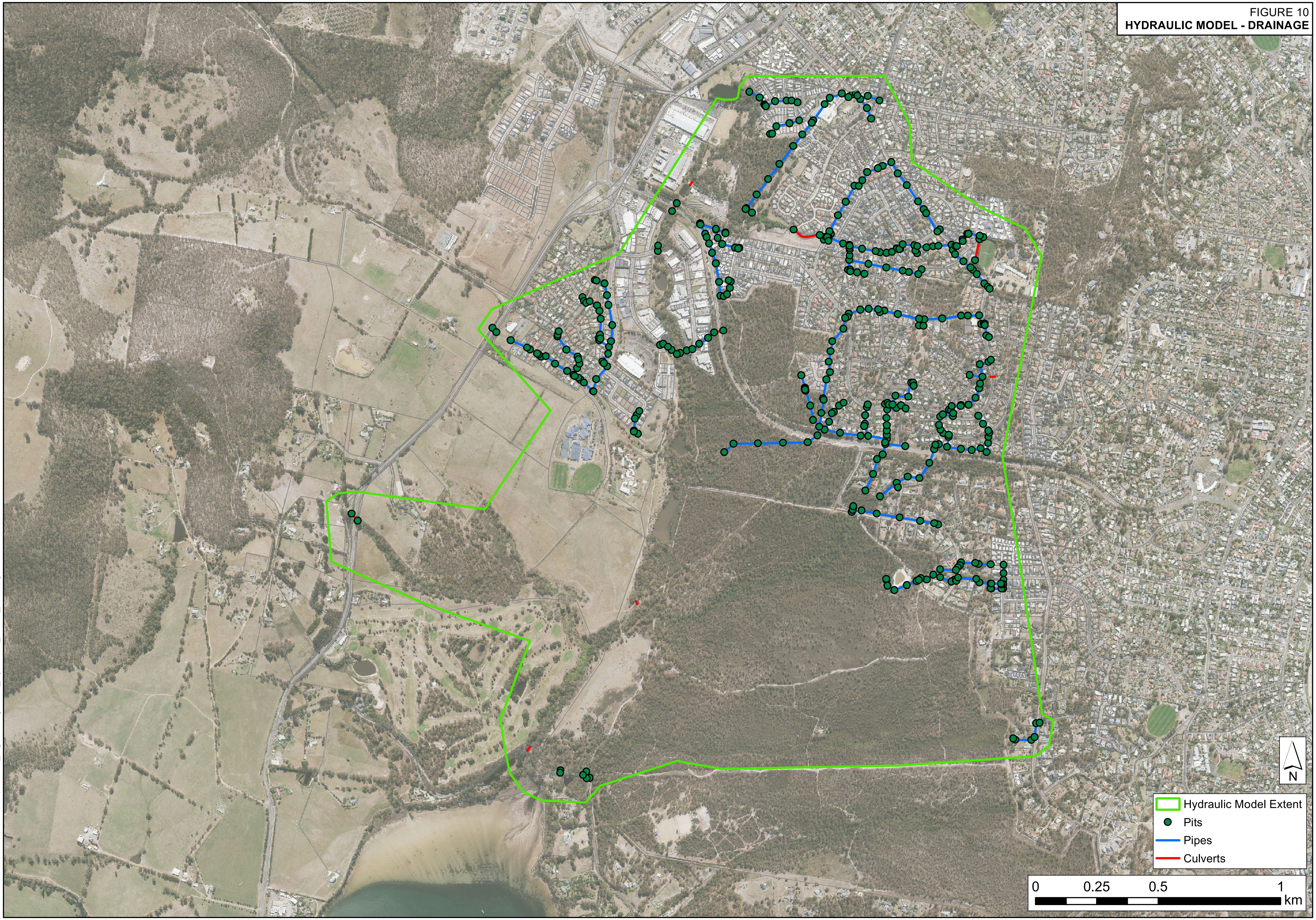

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FIGURE 11
HYDRAULIC MODEL - ROAD KERBS AND GUTTERS

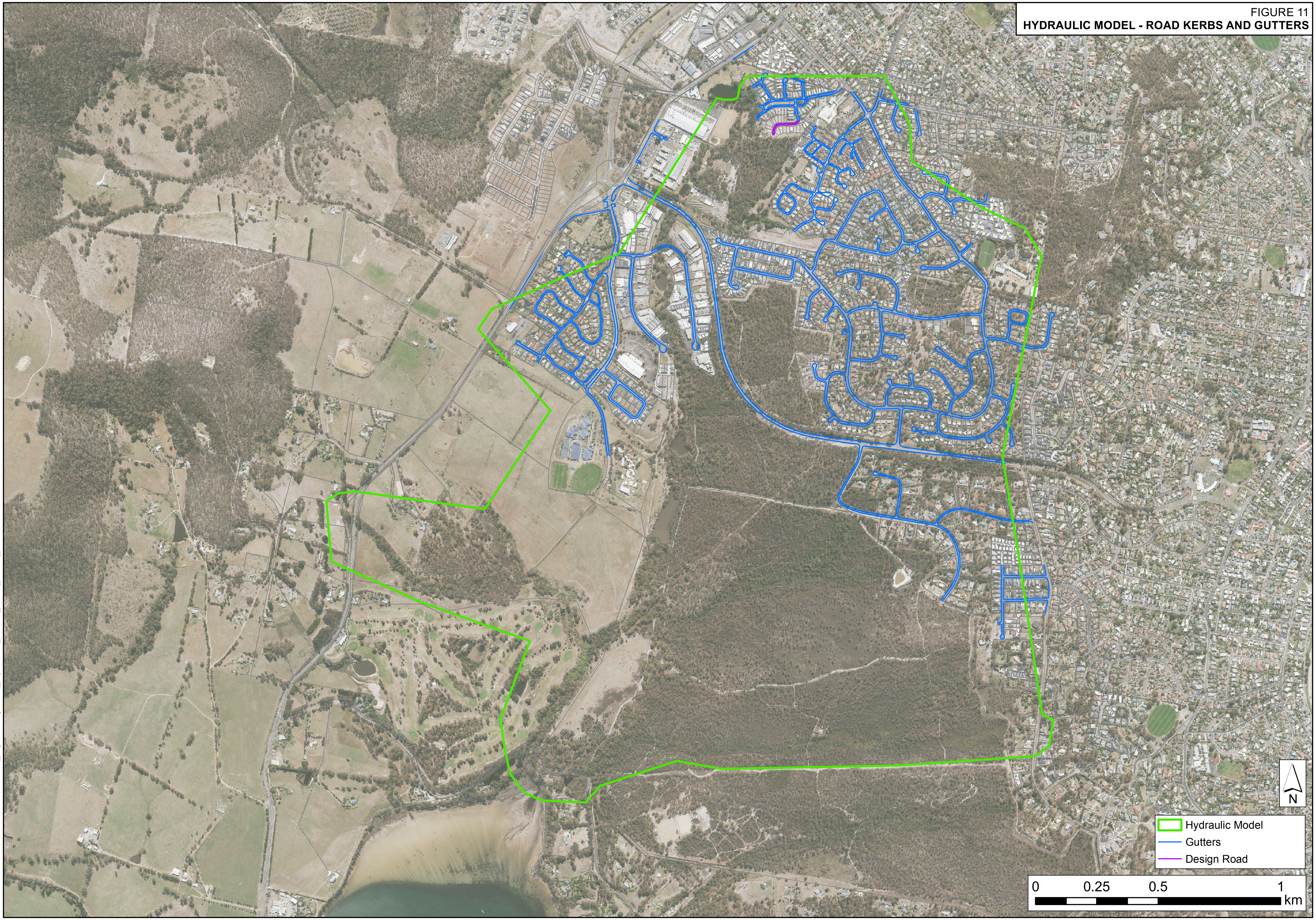

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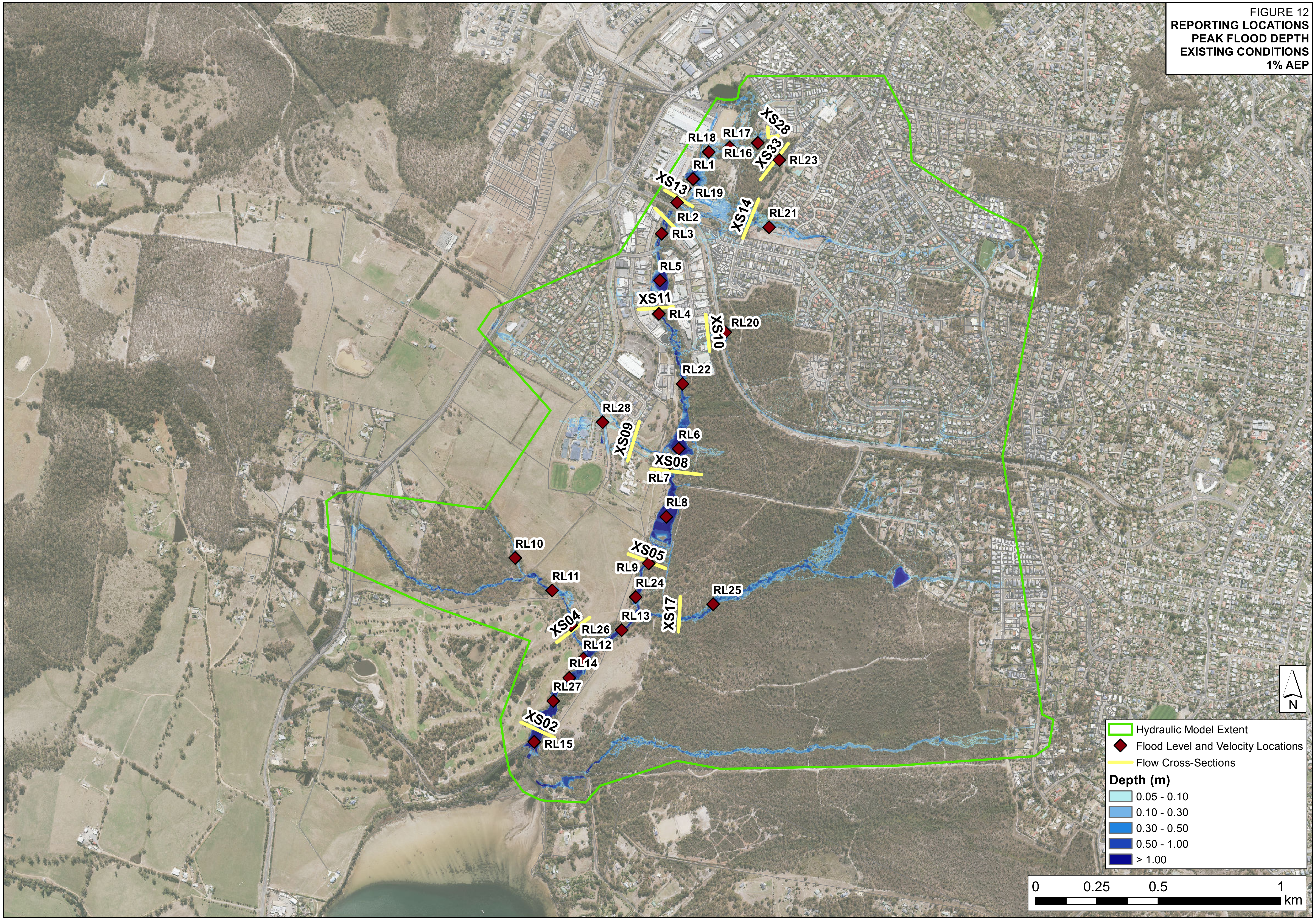
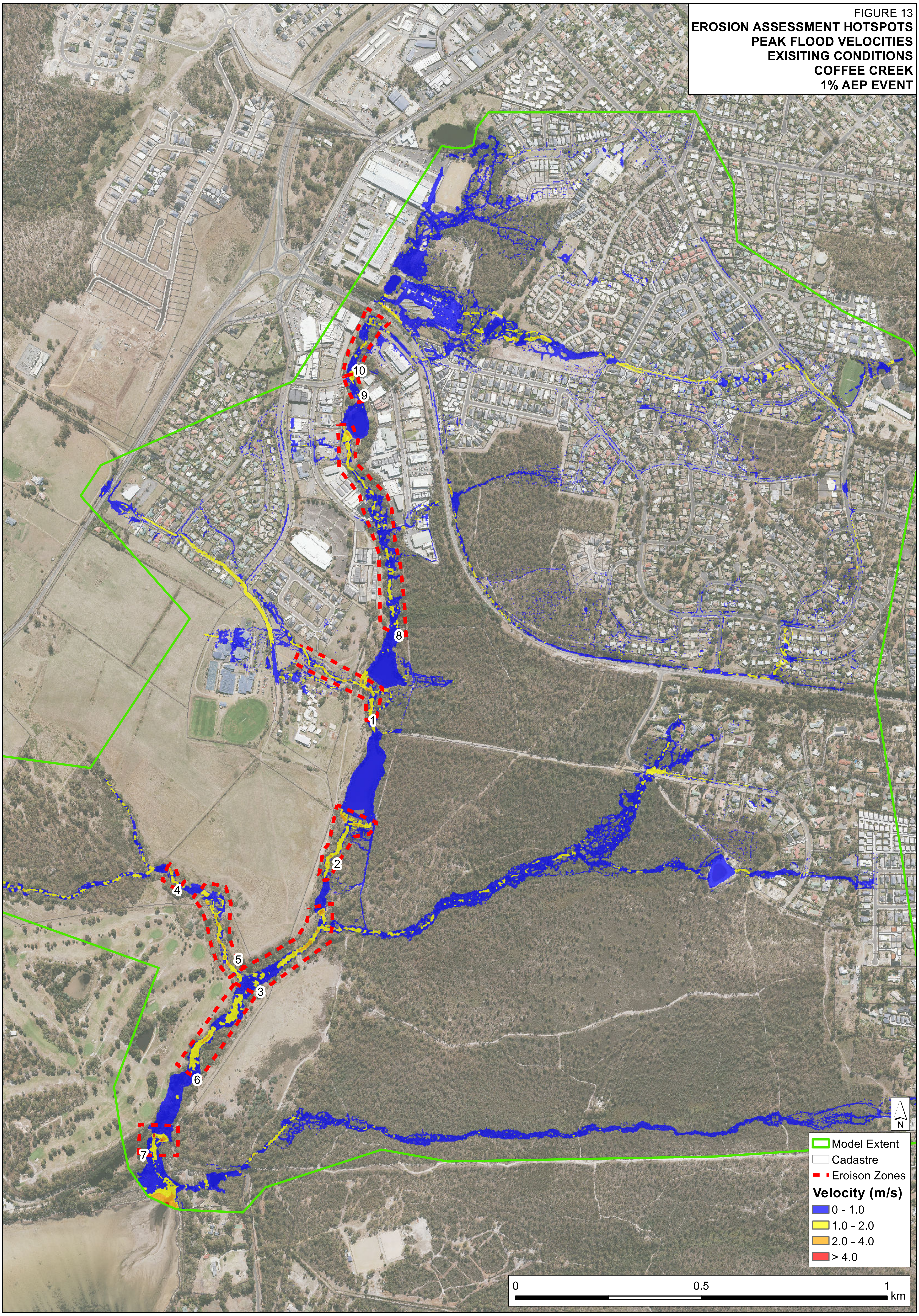
FIGURE 12
REPORTING LOCATIONS
PEAK FLOOD DEPTH
EXISTING CONDITIONS
1% AEP





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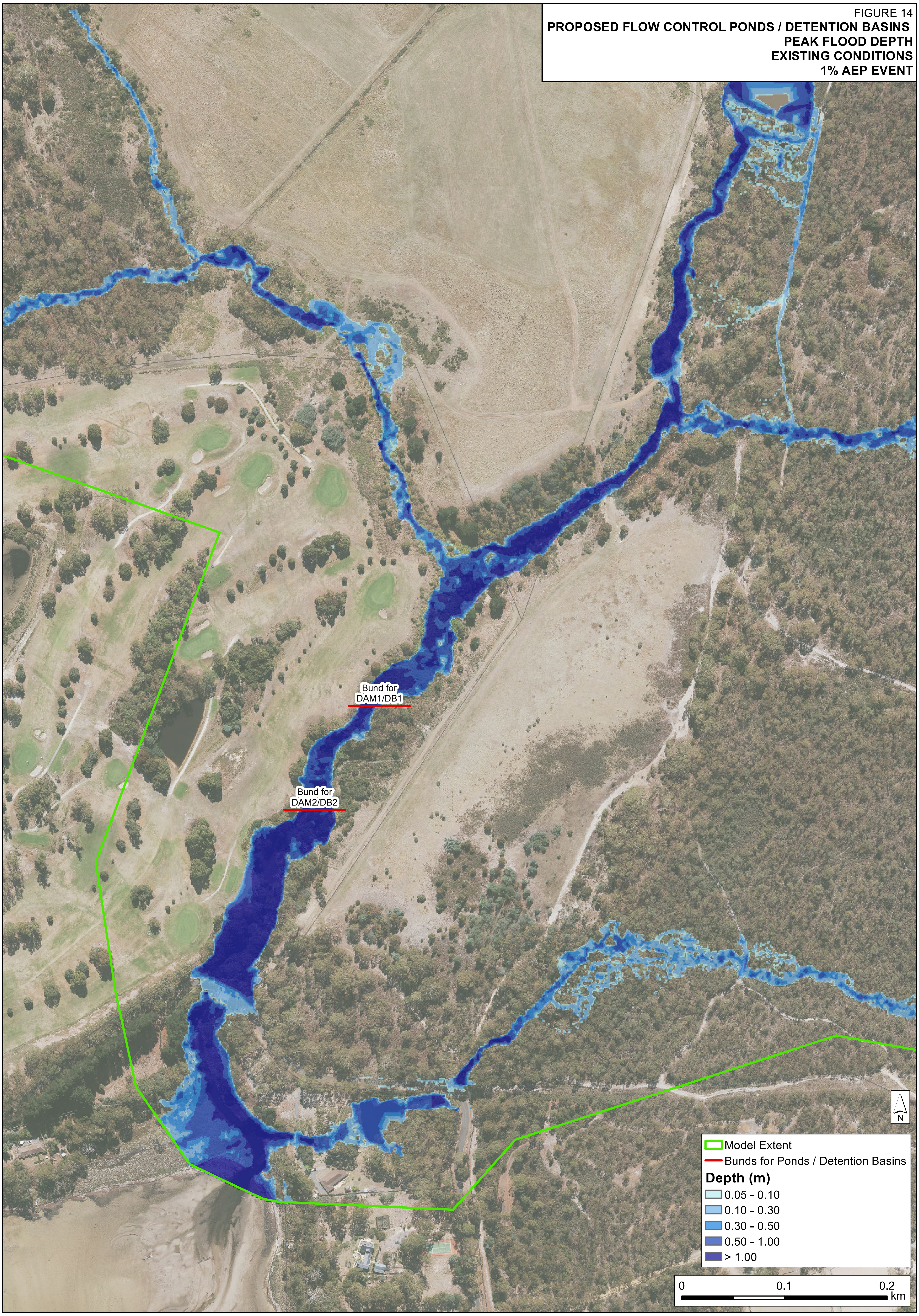
FIGURE 14
PROPOSED FLOW CONTROL PONDS / DETENTION BASINS
PEAK FLOOD DEPTH
EXISTING CONDITIONS
1% AEP EVENT
Bund for
DAM1/DB1
Bund for
DAM2/DB2
N
Model Extent
Bunds for Ponds / Detention Basins
Depth (m)
0.05 - 0.10
0.10 - 0.30
0.30 - 0.50
0.50 - 1.00
> 1.00
0
0.1
0.2
km
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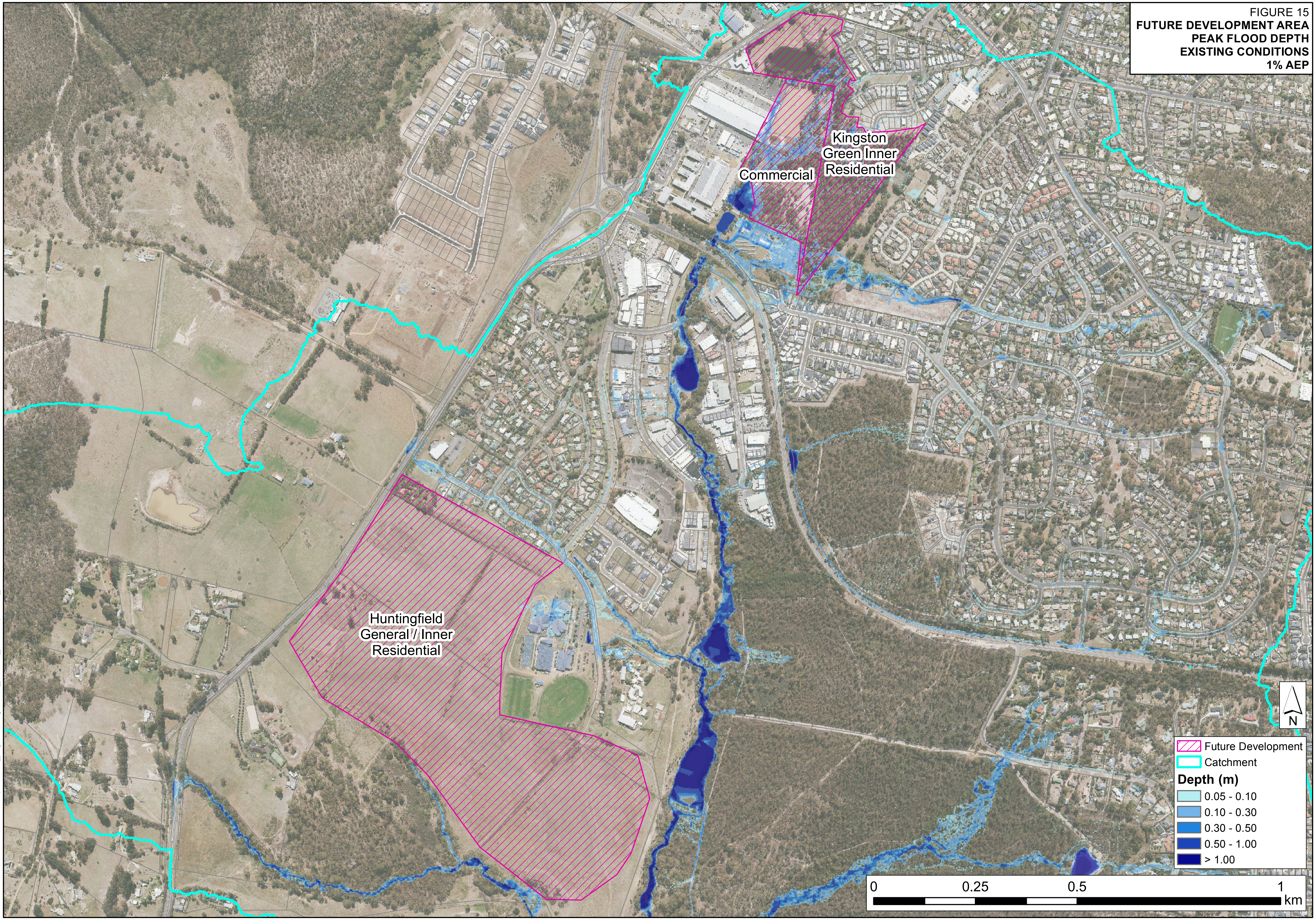

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Appendix A