Batemans Bay Urban Creeks Flood Study

Draft Report

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Document Control

Rev	Effective Date	Description of Revision	Prepared by:	Reviewed by:
Stage 1				
0	January 2019	Draft stage report for Council review	Emma Maratea Luke Evans Sean Garber	Rhys Thomson
Stage 2				
0	November 2019	Draft stage report for Council review	Sophie Cant Luke Evans Heath Sommerville	Emma Maratea
1	December 2019	Updated draft stage report for Council review	Luke Evans	Emma Maratea
Stage 3				
0	June 2020	Draft Flood Study for Council Review	Luke Evans	Emma Maratea
Stage 4				
0	October 2020	Public Exhibition Report	Luke Evans	Emma Maratea
1	April 2021	Revision to Public Exhibition report	Luke Evans	Emma Maratea

Prepared For: Eurobodalla Shire Council

Project Name: Batemans Bay Urban Creeks Flood Study

Rhelm Reference: J1114

Document Location: C:\Dropbox (Rhelm)\Jobs\J1114 - Batemans Bay Flood Study\4. Reports\Stage 4 - Public Exhibition\RR-04-1114-01.docx

Client Reference: Stage 4 Report

Foreword

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

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

The *Floodplain Development Manual* (NSW Government, 2005) is provided to assist councils to meet their obligations through the preparation and implementation of floodplain risk management plans, through a staged process. **Figure F1-1**, taken from this manual, documents the process for plan preparation, implementation and review.

The *Floodplain Development Manual* (NSW Government, 2005) is consistent with Australian Emergency Management Handbook 7: *Managing the floodplain: best practice in flood risk management in Australia* (AEM Handbook 7) (AIDR, 2017).

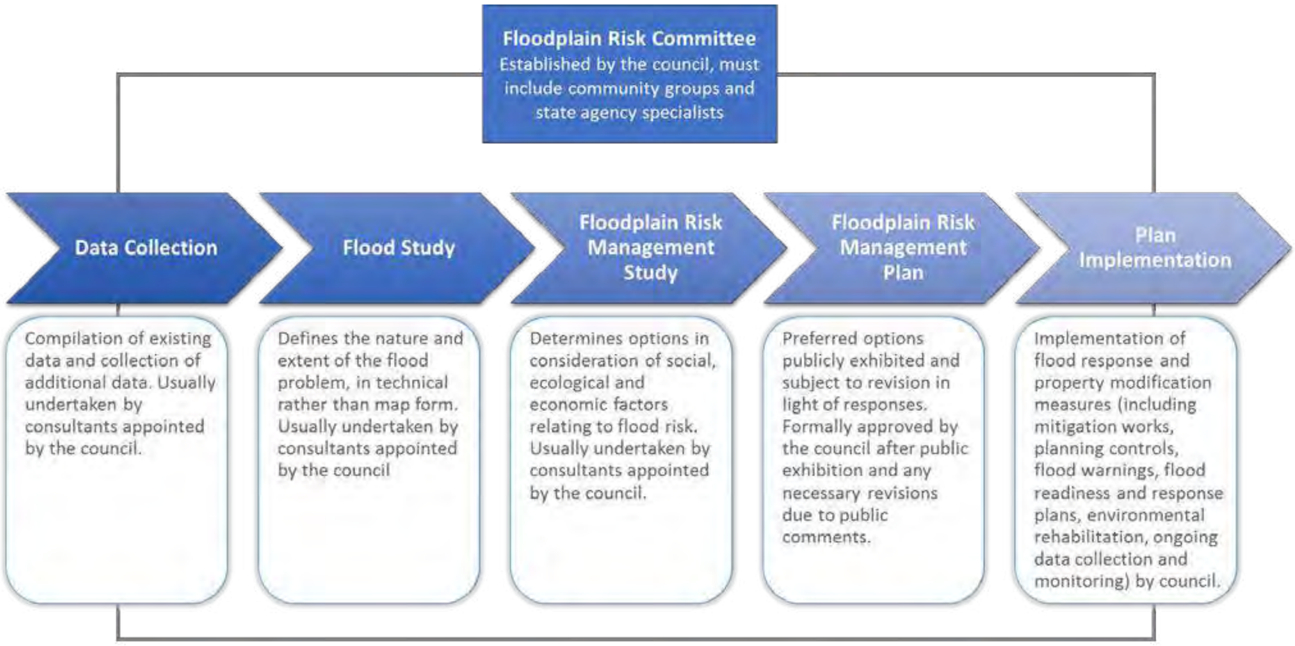

Figure F1-1 The Floodplain Risk Management Process (source: NSW Government, 2005)

Eurobodalla Shire Council is responsible for local land use planning in its service area, including in the Batemans Bay catchment and its floodplain. Through its Coast and Environment Management Advisory Committee, Council has committed to prepare a comprehensive Floodplain Risk Management Plan for the study area in accordance with the NSW Government's *Floodplain Development Manual* (2005). This document relates to the flood study phase of the process.

Executive Summary

The Batemans Bay Urban Creeks Flood Study has been prepared for Eurobodalla Shire Council (Council) to define the existing flood behaviour in the catchment and establish the basis for subsequent floodplain management activities.

Study Area and Scope

The study area covers the catchments of Maloneys Beach, Long Beach, Surfside, Water Gardens, Catalina, Batehaven and Sunshine Bay with a focus on understanding the flood behaviour and risk in these catchments. The study area is shown in Map G101 (provided in Volume 2 of this study, and also replicated within this executive summary).

This project is a flood study, which is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide a better understanding of the full range of flood behaviour and consequences. It involves consideration of the local flood history, available collected flood data, and the development of hydrologic and hydraulic models that are calibrated and verified, where possible, against historic flood events and extended, where appropriate, to determine the full range of flood behaviour.

Engagement

Comprehensive stakeholder engagement was undertaken throughout the development of the flood study. This involved:

- Engaging agency and industry stakeholder to obtain details of historical flooding, survey data and other relevant data sets. Stakeholders will be invited to provide feedback on the draft flood study during public exhibition.
- Community engagement has been undertaken through the mail out of an information brochure and brief survey. A series of community drop in sessions were also held. The purpose of the engagement was to raise awareness of the study and flood risk in the catchment, as well and obtain observations of historical flooding to assist in model calibration. Respondents were contacted for further information by phone and email, as required. The community information sessions were held on:
  - 20 November 2018, Batemans Bay Community Centre
  - 21 November 2018, Narooma Youth Centre

Public exhibition of this draft document will be undertaken to obtain feedback from the community and other stakeholders.

Hydrological and Hydraulic Modelling

Due to the complex nature of flooding across the study area, flood modelling has been undertaken using a combination of hydrological, hydraulic and hydrodynamic models. This allows flooding to be assessed with regards to coastal processes, estuarine dynamics (in particular entrance scour), riverine flooding and overland flow. Hydrological modelling was undertaken for the study area using XP-RAFTS, catchment driven flooding was modelled in TUFLOW and the Joes Creek entrance breakout was modelled in Delft3D.

Historical flood data was limited. A comparison against design flood events and community observations was undertaken to validate the flow behaviour in the models. The assessment indicated a general level of consistency between the modelling and the observations from the community.

The hydrological, hydraulic and hydrodynamic models were analysed for the Probable Maximum Flood (PMF), 0.2% AEP, 0.5% AEP, 1% AEP, 2% AEP, 10% AEP and 20% AEP events. The models were analysed for durations ranging from 60 minutes to 36 hours, using the 10 temporal pattern ensemble approach detailed in ARR2019.

The 1% AEP flood depths and depth of flow over key roads are shown on Maps G801-a to G801-g (provided in Volume 2 of this study, and also replicated within this executive summary).

Flooding within the study area is driven by both lake flooding and catchment flooding. The extent of influence of lake flooding is limited in the smaller events, but flooding driven by elevated lake levels increasingly affect larger regions of the catchments in the 1% AEP and PMF. Catchment driven flooding in the upper catchment regions is typically well contained in events up to the 1% AEP. Road access is lost in some locations in events as small as the 10% AEP.

Hydrological and Hydraulic Model Sensitivity

The sensitivity of the modelling to rainfall losses, lag time and rainfall intensity were undertaken in the hydrological model for the Water Gardens and Batehaven catchments. Overall, the models were very insensitive to changes in lag time, and marginally more sensitive to changes in rainfall intensity than rainfall losses. The smaller Water Gardens catchment was more sensitive to all changes than the larger Batehaven catchment.

While a greater sensitivity was observed for both rainfall losses and rainfall intensity, neither resulted in substantially different peak flows given the scale of the parameter change. A 20% variation in both these parameters typically delivered a 15 – 25% change in peak flows.

The sensitivity of the hydraulic model to inflows, roughness and downstream boundary conditions was assessed for the 1% AEP event.

The results show that the model is reasonably sensitive to flow increases and downstream boundary levels, marginally sensitive to flow decreases, and relatively insensitive to roughness changes.

As a result of a 20% increase in flows, isolated pockets showed increases in the 0.1 – 0.2m range, while typical changes in non-storage driven systems were in the order of 0.05 – 0.1m.

Changes arising from a 20% reduction in flows were more modest, both in size and extent. Reductions were relatively constant across the study area, in the order of 0.1 – 0.15m, and generally focused on areas of storage or local depressions.

The models were relatively sensitive to downstream boundary levels. Increases in the boundary levels resulted in water level increases propagating over 1.5km upstream of the shore in Surfside, Catalina and Batehaven. Impacts in catchments with more controlled entrance conditions such as Maloneys Beach and Long Beach were smaller for both increased and decreased downstream levels. The low-lying areas of Surfside, Catalina and Batehaven were particularly sensitive to water level changes.

The model was relatively insensitive to changes in roughness values. The 20% change in roughness values typically resulted in in changes of less than 0.03m. Larger differences of +/- 0.05m were observed in the Maloneys Beach and Batehaven catchments.

Overall, it was concluded from the results of the sensitivity analysis that the design event flood behaviour produced by the model is robust and reliable.

Climate Change

The impacts of future sea level rises on the study are was assessed in the model for:

- A 0.35m sea level rise, modelled for the 5% AEP and 1% AEP (nominally a 2050 scenario); and
- A 0.72m sea level rise, modelled for the 1% AEP (nominally a 2100 scenario).

In the 5% AEP, the 0.35m sea level rise had a modest impact in most catchment areas. Maloneys Beach, Long Beach and Water Gardens had no impacts arising from a 0.35m sea level rise in the 5% AEP. Impacts of 0.01m were observed in the Surfside in the tributary running adjacent to Mundarra Way. Increases of up to 0.21m where observed across developed areas in Catalina, and smaller increases of up to 0.17m and 0.02m were observed at Batehaven and Sunshine Bay respectively.

The 1% AEP climate change assessment showed that the catchments responded in markedly different manners:

- Maloneys Beach had had increases of up to 0.05m and 0.15m in the 2050 and 2100 scenarios respectively. There were only minimal impacts across developed areas in the 2100 scenario.
- Impacts at Long Beach were restricted to the entrance channel and adjacent properties for both scenarios.
- Within Surfside, impacts extended upstream to the highway for both scenarios. Significantly greater numbers of properties were affected in both scenarios across the low-lying region between the beach and Timbara Cresent and Bayview Street. Increases of up to 0.8m were observed in the 2100 scenario.
- Impacts within the Water Gardens catchment were most significant adjacent to the bay, with levels at the North Street and Clyde Street intersection increasing inline with sea levels, by 0.35m and 0.72m in the 2050 and 2100 scenarios.
- Flood levels along Beach Road and Herarde Street in Catalina increased by 0.32m 0.7m in the 2050 and 2100 scenarios.
- The Big 4 Resort in Batehaven experienced increased levels in both 2050 and 2100 scenarios of up to 0.17m and 0.32m respectively.
- Caseys Holiday Beach Park and Pleasurelea Tourist resort both experienced increased flood levels under both scenarios, with increases of up to 0.35m and 0.25m in the 2100 scenario. The Sunshine Bay Public School as became flood affected in the 2050 scenario.

Conclusion

This report provides an understanding of the flood risk within the study area and provides Council with the tools for planning. This study provides a baseline against which a Floodplain Risk Management Study and Plan can be prepared.

Council's current DCPs (Section 5.5) do not currently contain comprehensive flood related controls for mainstream or overland flow flooding. Although it is also noted that Council does not currently have any specific overland flow studies completed. It is noted that the Draft LSPS makes reference to the introduction of a Council-wide Flood Management Code.

N
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Map G101

Catchment Areas

Legend
Catchment Boundary
Study Areas

500 0 500 1,000 1,500 m

1:35,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : LRE
Coordinate System : MGA 56

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N
W E
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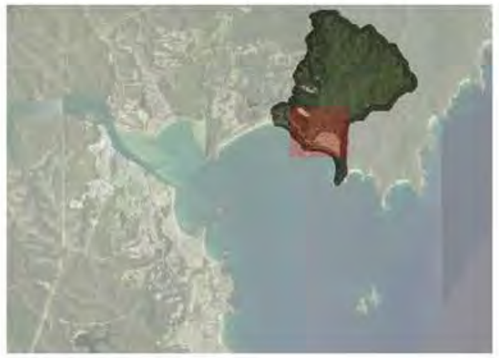
G801-a-2
Maloneys Beach
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4



0 80 160 240 m

1:5000

Size : A3
Date : 15 June 2020
Revision : A
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Coordinate System : MGA 56

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G801-b-2
Long Beach
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

0 80 160 240 m

1:5000

Size : A3
Date : 15 June 2020
Revision : A
Created by : LRE
Coordinate System : MGA 56

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N
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G801-c-2
Surfside
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

0 130 260 390 m

1:8000

Size : A3
Date : 15 June 2020
Revision : A
Created by : LRE
Coordinate System : MGA 56

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N
W E
S

G801-d-2
Water Gardens
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

0 100 200 300 m

1:7500

Size : A3
Date : 15 June 2020
Revision : A
Created by : LRE
Coordinate System : MGA 56

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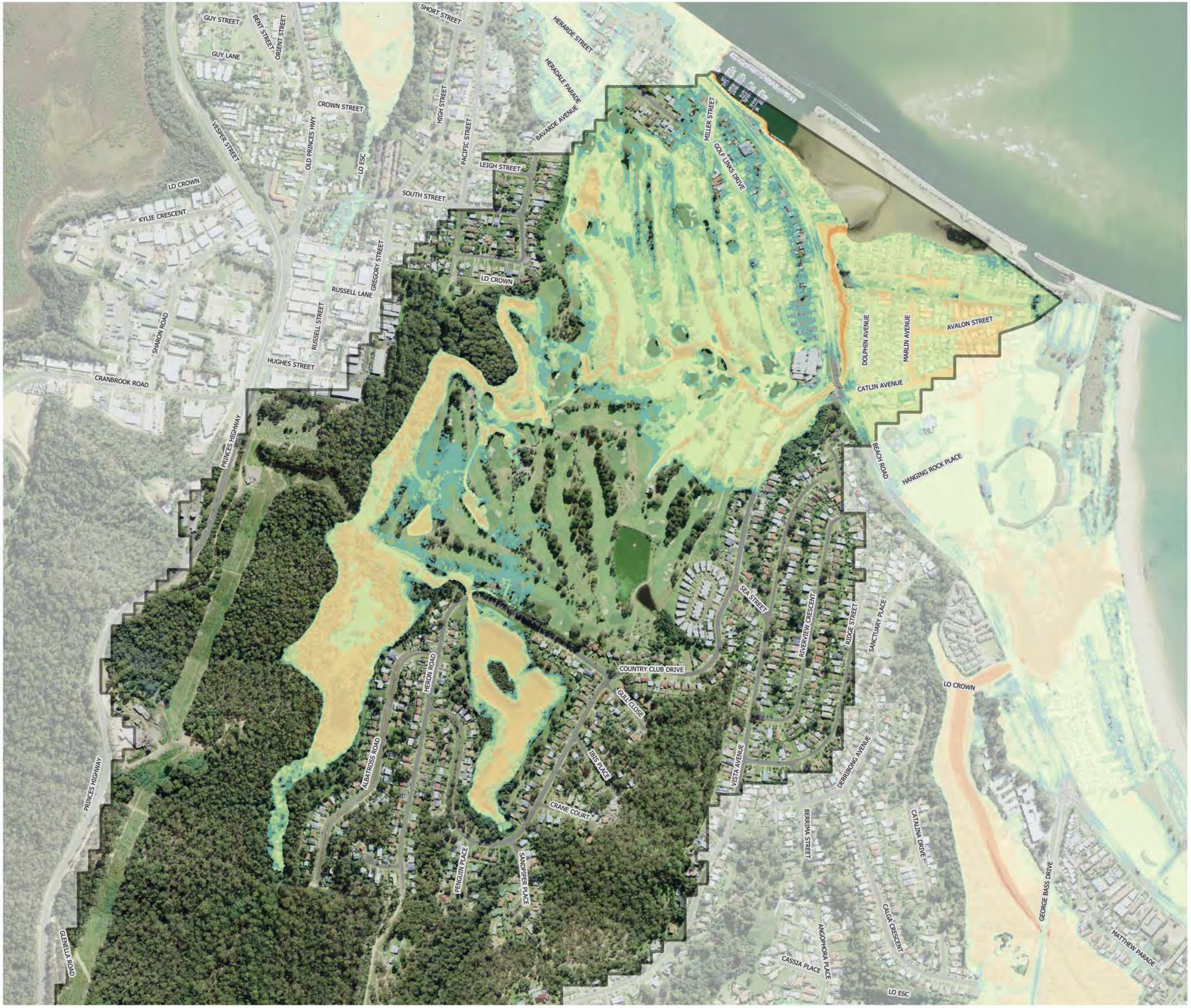

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G801-e-2
Catalina
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

0 130 260 390 m

1:8000

Size : A3
Date : 15 June 2020
Revision : A
Created by : LRE
Coordinate System : MGA 56

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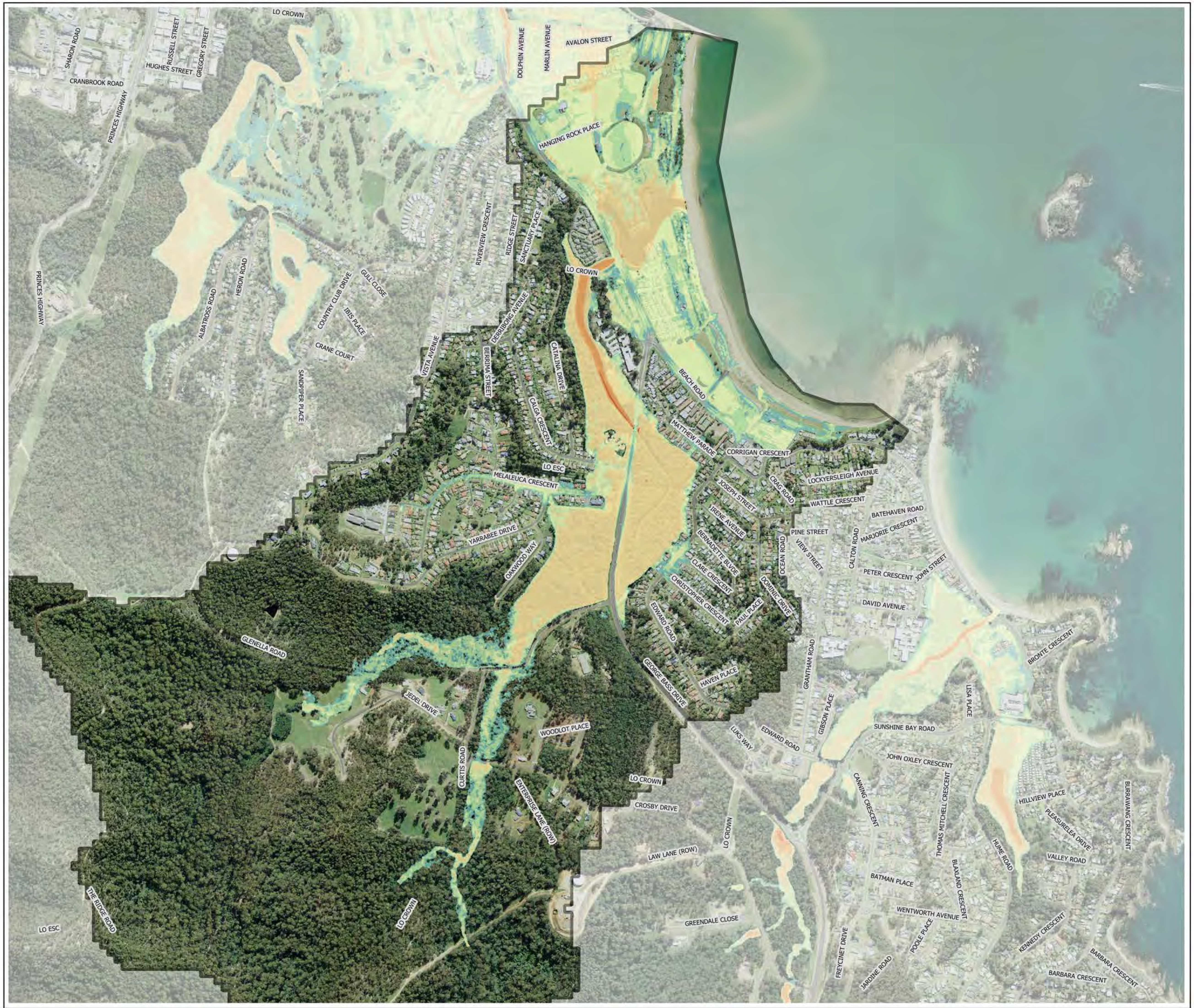

N
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G801-f-2
Batehaven
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

0 200 400 600 m

1:12500

Size : A3
Date : 15 June 2020
Revision : A
Created by : LRE
Coordinate System : MGA 56

Rhelm

N
W E
S

G801-g-2
Sunshine Bay
1% AEP Depth

Legend

Study Areas

Depth (m)

- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

0 160 320 480 m

1:10000

Size : A3
Date : 15 June 2020
Revision : A
Created by : LRE
Coordinate System : MGA 56

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Maps

These are provided as an attachment to this report.

Glossary

Annual exceedance probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m^3/s (or larger) occurring in any one year. (See also average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Attenuation	Weakening in force or intensity.
Average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20 year ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. (See also annual exceedance probability).
Catchment	The catchment, at a particular point, is the area of land that drains to that point.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year ARI or 1% AEP flood).
Development	Is defined in Part 4 of the AP&A Act as: - Infill Development: development of vacant blocks of land that are generally surrounded by developed properties. - New Development: development of a completely different nature to that associated with the former land use. - Redevelopment: Rebuilding in an area with similar development.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Awareness	Awareness is an appreciation of the likely effects of flooding and knowledge of the relevant flood warning, response ad evacuation procedures.
Flood Education	Education that seeks to provide information to raise awareness of the flood problem to enable individuals to understand how to manage themselves and their property in a flood event.
Flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.
Flood hazard	The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.

Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
Floodplain	Area of land which is subject to floods up to and including the probable maximum flood.
Floodplain risk management plan	A document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan needs to be developed in accordance with the principles and guidelines contained in the NSW Floodplain Development Manual. The plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives.
Flood planning levels (FPLs)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also consider the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plans. The concept of FPLs supersedes the "standard flood event". As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Gauging (tidal and flood)	Measurement of flows and water levels during tides or flood events.
Hazard	A source of potential harm or a situation with a potential to cause loss.
Historical flood	A flood that has actually occurred.
Hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems, in particular the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrologic	Pertaining to rainfall-runoff processes in catchments.
Hydrology	The term given to the study of the rainfall-runoff process in catchments, in particular, the evaluation of peak flows and flow volumes. .

Isohyet	Equal rainfall contour.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
Pluviometer	A rainfall gauge capable of continuously measuring rainfall intensity.
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood that could conceivably occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian	The interface between land and waterway. Literally means "along the river margins".
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Stage	See flood level.
Stage hydrograph	A graph of water level over time.
Topography	The shape of the surface features of land.
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi-2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

Terminology in this Glossary has been adapted from the NSW Government Floodplain Development Manual, 2005, where available.

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARF	Areal Reduction Factor
AR&R	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
BVSC	Bega Valley Shire Council
DCP	Development Control Plan
DEM	Digital Elevation Model
DPE	Department of Planning and Environment
DPIE	Department of Planning Industry and Environment
IFD	Intensity Frequency Duration
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FPRMSP	Floodplain Risk Management Study & Plan
ha	hectare
km	kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
m	metre
m^2	Square metres
m^3	Cubic metres
mAHD	metres to Australian Height Datum
mm	millimetres
m/s	metres per second
m^3/s	Cubic metres per second
NSW	New South Wales
PMF	Probable Maximum Flood
SES	State Emergency Service (NSW)

1 Introduction

The Batemans Bay Urban Creeks Flood Study has been prepared for Eurobodalla Shire Council (Council) to define the existing flood behaviour in the catchment and establish the basis for subsequent floodplain management activities.

1.1 Study Location

Batemans Bay is located in the Eurobodalla Shire Council Local Government Area (LGA), which is approximately 280 km south of Sydney via the Princes Highway, and 150 km south-east of Canberra via the Kings Highway on the NSW South Coast.

Batemans Bay is located on a wide embayment with settlements located on the northern and southern shores. The study focuses on seven catchments in the Batemans Bay region, namely:

- Maloneys Beach (Maloneys Lagoon)
- Long Beach (Long Beach Lagoon)
- Surfside (Surfside Creek)
- The Water Gardens
- Catalina (Hanging Rock Creek)
- Batehaven (Joes Creek)
- Sunshine Bay / Caseys Beach (Shortbeach Creek).

The catchment locations are shown in **Map G101**.

1.2 Study Objectives

The overall objective of this study is to improve understanding of flood behaviour and impacts, and better inform management of flood risk in the study area through consideration of available information, and relevant standards and guidelines. The study will also provide a sound technical basis for any further flood risk management investigations in the area.

This project is a flood study, which is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide a better understanding of the full range of flood behaviour and consequences. It involves consideration of the local flood history, available collected flood data, and the development of hydrologic and hydraulic models that are calibrated and verified, where possible, against historic flood events and extended, where appropriate, to determine the full range of flood behaviour.

The overall project provides an understanding of, and information on, flood behaviour and associated risk to inform:

- Relevant government information systems
- Government and strategic decision makers on flood risk
- The community and key stakeholders on flood risk
- Flood risk management planning for existing and future development
- Emergency management planning for existing and future development, and strategic and development scale land-use planning to manage growth in flood risk
- Decisions on insurance pricing (where the information is utilised by insurance companies).

The outputs of this study will assist this by:

- Providing a better understanding of the:
    - Variation in flood behaviour, flood function, flood hazard and flood risk in the study area
    - Impacts and costs for a range of flood events or risks on the existing and future community
    - Impacts of changes in development and climate on flood risk
    - Emergency response situation and limitations
    - Effectiveness of current management measures.
- Facilitating information sharing on flood risk across government and with the community.

The study outputs will also inform decision making for investing in the floodplain; managing flood risk through prevention, preparedness, response and recovery activities; pricing insurance; and informing and educating the community on flood risk and response to floods.

1.3 Study Background and Context

Batemans Bay is the largest urban settlement in the Eurobodalla Shire Council LGA and is home to a significant number of permanent residents, although the population triples in peak holiday periods. This, coupled with a high number of absentee property owners, creates a challenging and complex situation for Council in managing the population during flood events.

Prior flood assessments have been undertaken in the 1980's and 1990's however these primarily focussed on bridge constructions and ocean inundation, with limited catchment flooding data available to assist Council in managing local flood risks.

Anecdotal evidence and community comments have indicated that flooding within the region occurs through a number of mechanisms, namely mainstream and overland flooding from catchment rainfall, ocean inundation, nuisance flooding from ponding behind closed entrances, and in some locations, groundwater inundation. Further information regarding community observations of flooding are provided in **Section 4.4 and 4.5**.

2 Study Area

The catchments are generally characterised by steep upper catchment areas feeding into low lying areas adjacent to the bay. With the exception of Hanging Rock Creek, all the waterways are small ICOLL's (Intermittently Closed and Open Lakes and Lagoons). Flooding can be caused by short duration flooding resulting in 'flash flooding', and longer duration rainfall can also cause flooding issues, particularly if they coincide with certain entrance and tidal conditions.

Development across the study area varies. Some catchment areas such as The Water Gardens and Sunshine Bay have development across the majority of the catchment. Conversely, Maloneys Beach and Long Beach have largely undeveloped catchments, with small townships located along the foreshore.

Maloney Creek Entrance

Long Beach Lagoon Entrance

Surfside Creek Entrance

Hanging Rock Creek Entrance

Joes Creek Entrance

Shortbeach Creek Entrance

2.1 Catchment Description

2.1.1 Maloneys Beach (Maloneys Lagoon)

Maloneys Beach is located on the northern shore of Batemans Bay, and is the eastern-most catchment area included in this study. The catchment is largely undeveloped, with the majority of the catchment being bushland. There is a single developed area in the catchment, Maloneys Beach, located on the water's edge, immediately east of the Maloneys Lagoon outlet. The developed area is relatively small and has a single evacuation route out of the township, Northcove Road, that crosses Maloneys Creek just upstream of the entrance. The entrance is located immediately downstream of the Northcove Road bridge, adjacent to the township.

While the developed area is small, the overall catchment feeding into this area is the largest of the seven catchment areas to be assessed.

The Maloneys Beach catchment area is shown in **Map G201**.

2.1.2 Long Beach (Long Beach Lagoon)

Long Beach is on the northern side of the Bay and lies adjacent to the Maloneys Creek catchment. The catchment is centred on Long Beach Lagoon, with a ring of development around the Lagoon that occurs both along the Bay edge, as well as the ridge around the Lagoon that forms the catchment boundary.

A waterfront road, Sandy Place, runs between Long Beach Lagoon and the Bay. A small channel runs from the south-east corner of the Lagoon, under Sandy Place via a culvert, to discharge into the Bay.

The Long Beach catchment area is shown in **Map G202**.

2.1.3 Surfside (Surfside Creek)

Surfside Creek is on the northern side of the Bay and is located on the northern shore of the Clyde River outlet into Batemans Bay, at the Princes Highway Bridge crossing. The catchment land use is broadly split by the highway, with extensive areas of development in the downstream portions of the catchment, while it remains largely bushland upstream of the highway. The catchment contains the Batemans Bay Primary School, located adjacent to Surfside Creek, downstream of the highway. Surfside Creek discharges into the Bay through a set of piped culverts under Wharf Road. These pipes have a small freeboard to the road level above (approximately 0.4 metres) and were observed to be partially blocked by beach sand at the time of inspection (July 2018). This crossing is likely to be a significant control on the flows out of the catchment.

The Surfside catchment area is shown in **Map G203**.

2.1.4 The Water Gardens

Located on the southern shores of the Bay, immediately south of the Surfside Creek catchment at the outlet of the Clyde River, is The Water Gardens study area. This catchment is fully developed, save for a constructed water body and green space in the centre of the catchment. Residential development dominates most of the catchment, with some commercial / light industrial development occurring in the upper reaches.

The catchment has a wide water frontage, and is a low-lying, placing it at risk of ocean driven flooding, particularly in the eastern portion of the catchment.

A major road, Beach Road, runs adjacent to the water with very little foreshore between the roadway and the water. Most of the waterfront has had rock armouring or similar applied to protect the adjacent road. The catchment drains under Beach Road through a series of culverts into the Bay.

The Water Gardens catchment area is shown in **Map G204**.

2.1.5 Catalina (Hanging Rock Creek)

The Catalina catchment lies adjacent to The Water Gardens to the east. The landuse within the catchment is varied. The downstream region is dominated by the Catalina Country Club Golf Course, with residential development surrounding the golf club. Some residential development has also taken place in the upstream catchment, but much of this region remains undeveloped.

The entrance to this catchment is unique among that other catchment areas, in that it discharges into the Batemans Bay Marina, which is protected from the Bay via a seawall. The entrance appears to be primarily open, discharging into the ocean.

The Catalina catchment area is shown in **Map G205**.

2.1.6 Batehaven (Joes Creek)

Batehaven lies immediately to the east of Catalina, on the southern shores of Batemans Bay and is the second largest of the seven catchment areas. The downstream half is largely residential development, while the upper catchment remains generally vegetated, with some pockets of rural residential lots. Joes Creek runs through the centre of the catchment area. For most of the creek's length there is a reasonable buffer of vegetation between the creek and the development within the catchment. Near the outlet however, Batemans Bay High School and the Big 4 Batemans Bay Caravan Park directly adjoin the creek.

Joes Creek passes under Beach Road some 300m upstream of the entrance. The caravan park lies along this reach of creek between the bridge and the entrance.

The Batehaven catchment area is shown in **Map G206**.

2.1.7 Sunshine Bay / Caseys Beach (Short Beach Creek)

Sunshine Bay / Caseys Beach is the final of the seven catchments to be investigated and lies to the southeast of the Batehaven region. Similar to the adjacent Batehaven catchment, the lower catchment is largely comprised of residential development, while the upper catchment remains vegetated with some pockets of large lot semi-rural residential development. Short Beach Creek runs through the middle of the catchment area. Again, similar to the Batehaven region, there is a reasonable buffer maintained along the creek for much of its length, until near the outlet where St Bernard's Primary School and the Caseys Beach Holiday Park are located immediately adjacent to the creek.

Shortbeach Creek passes under Beach Road immediately upstream of the Bay entrance. The creek is required to break through a small reach of beach before reaching the Bay.

The Sunshine Bay catchment area is shown in **Map G207**.

2.2 Historical Flooding

There is very little information providing details of catchment flood events. Anecdotal information suggests that catchment flooding has occurred across the seven catchments at various times in the past. Catchment flooding has been noted by residents and business owners to cause flooding of roads, footpaths and on occasion private property.

Specific events identified through a review of previous studies (**Section 3.2**) and information provided by the community (**Section 4.4 and 4.5**) identified catchment flooding to have occurred for the events summarised in **Table 2-1**.

Table 2-1 Historical Flood Events

Date	Details	Source
August 1963	Information (including photographs) are provided for the flood event at a range of locations, which was a combination of catchment and coastal flooding.	Batemans Bay Oceanic Inundation Study (NSW Public Works, 1989)
1973	Identified as a 'large event' by the community.	Community drop-in session November 2018.
1974	Identified as a 'large event' by the community.	Community drop-in session November 2018.
1975	Identified as a 'large event' by the community.	Community drop-in session November 2018.

Date	Details	Source
February 1977	Flood observed by a resident in Surfside.	Community drop-in session November 2018.
1990	Overland flow through easement and onto adjacent private property at Avalon Street.	Community Survey (November 2018)
June 1991	Recorded flood levels for event are provided at 4 locations in Long Beach.	Reed Swamp – Long Beach Flood Study (Willing and Partners, 1991)
January 2000	Flooding on roads observed at Caitlin Avenue and Avalon Street.	Community Survey (November 2018)
November 2013	Drains overflowed into vacant lot on Country Club Drive, Catalina, after 2 days of heavy rain.	Community Survey (November 2018)
January 2014	Flooding on roads observed at Caitlin Avenue and Avalon Street. A newspaper article supplied by the community identified the 2014 flooding as a result of a king tide.	Community Survey (November 2018)
August 2015	Drains overflowed into vacant lot on Country Club Drive, Catalina, after 2 days of heavy rain.	Community Survey (November 2018)

3 Review of Available Data

3.1 Site Inspections

Site inspections were undertaken in July 2018 over a period of two days by two Rhelm staff, Council's project manager, and an DPIE representative:

- Thursday July 19th, 2018: Northern catchments including The Waters Gardens, Hanging Rock Creek, Joes Creek, and Short Beach Creek
- Friday July 20th, 2018: Southern catchments including Surfside Creek, Long Beach Lagoon, and Maloneys Lagoon.

The purpose of the site inspections was to gain an appreciation of the catchment and likely flood risks. The site inspections also identified additional survey requirements and assisted with the definition of the hydraulic model extents.

3.2 Previous Studies and Reports

Relevant studies and reports were collated through liaison with Council and DPIE, and consultation with agency and community stakeholders. Additional studies have been sourced through internet searches. A summary of the studies and reports likely to inform this Flood Study are provided in **Table 3-1**.

Table 3-1 Previous Studies and Reports

Document	Relevance to the Study
Batemans Bay Drainage Study (Willing and Partners, 1984)	This drainage study focuses on flood flows from the catchment, including a review of a proposal presented to Council by Coles Pty Ltd to develop the area upstream of the Soldiers Club, the effectiveness of existing infrastructure within the catchment and possible upgrades to allow development. Key findings of 1984 investigation were: • The wetland area was providing a significant detention effect and was reducing existing peak flows from 9.8m^3/s to 4.6m^3/s • Once the catchment was fully developed, peak flows into the wetland would increase to 15.5m^3/s • Recommendations for the management of flows included: o modification to existing pipe work including raising pipes o upgrade the existing 3 x1.2m culvert to remove a step in the culvert o duplication of the 3 x 1.2m culvert o construction of a detention basin. Work undertaken subsequent to the report was the upgrade of the 3x1.2m culvert to remove a step in it and to raise some of the surrounding low-lying drainage around Orient Street.
Batemans Bay Ocean Inundation Study (Lawson and Treloar, 1987)	This report presents the results of an investigation into elevated ocean water levels at the entrance of the Clyde River at Batemans Bay. Design still water levels were estimated for 20, 50 and 100 year ARI events for 17 locations around the Bay.

Document	Relevance to the Study
Batemans Bay Inundation Study (Willing and Partners, 1988)	Willing and Partners used the ocean inundation study carried out by Lawson and Treloar in 1987 and estimated the joint probability 1% AEP level (for ocean and local catchments) to be 2.66m AHD (2.6m from ocean inundation, 0.06m from catchment flooding) for the area. This is the combined effect of a 100 year ARI oceanic flooding with the 1 year ARI flood from the Soldiers Club catchment. Other combined probability combinations were not possible as the ocean inundation study only considered the 1:100 year event.
Joes Creek Flood Study (Willing and Partners, 1989)	This study assesses the flood behaviour of Joes Creek landward of Corrigans Beach. It includes flood levels for 5, 20, 50 and 100 year ARI events at various profiles and cross-sections along Joes Creek. This flooding assessment informs the main road extension and future urban development.
Short Beach Creek Flood Study (Willing and Partners, 1989)	This flood study investigates the adequacy of existing culverts and assesses future urban development. Flood levels and peak flow estimates were provided for the 1 in 5, 1 in 20, 1 in 50, and 1 in 100 AEP flood events at several cross-sections along the creek. Flood levels were calculated using a combination of high tide level of 0.94m AHD and a 100 year ARI still water level of 2.43m AHD. Mitigation options were assessed and compared.
Batemans Bay Oceanic Inundation Study (NSW Public Works, 1989)	This study quantified the extent and severity of ocean inundation in the Batemans Bay CBD and inner Bay. This study reported on still water levels with ARI's of 20, 50 and 100 years at Wharf Road. The still water levels comprised astronomic tide level plus wind and pressure setup and also included the mean water level setup at the shoreline due to waves. This study indicates that for storm events with recurrence intervals in the range of 20 to 100 years, large sections of the foreshore are overtopped by storm still water levels and/or wave run-up. Information (including photographs) are provided for the August 1963 flood event, which was a combination of catchment and coastal flooding.
Reed Swamp – Long Beach Flood Study (Willing and Partners, 1991)	This report studies the flooding of Sandy Place due to Reed Swamp outflows at Long Beach for 5, 20 and 100 year ARI flood events. Flood levels were calculated using a high water summer solstice level of 0.94m AHD, and a 100 year ARI still water level of 2.48m AHD, and were determined for existing and fully developed catchment conditions at several cross sections between Reed Swamp and Batemans Bay. This report investigates culvert options and treatment options for the lagoon outlet. Recorded flood levels for the 1991 event area provided at 4 locations.
Batemans Bay Vulnerability Study (Land and Water Conservation NSW, 1996)	This study defines the impact of present and future coastal hazards on Batemans Bay. Storm bite and beach recession due to different sea level rise by 2050 were described for the beached within Batemans Bay. Wave run-up and still water levels for a 50 year ARI were used for different sea level rise scenarios.
Batemans Bay Vulnerability Study Wave Penetration and Run-up (Lawson and Treloar, 1996)	This study re-assesses wave propagation into Batemans Bay and wave run-up and expands upon the previous work undertaken as part of the PWD Batemans Bay Oceanic Inundation Study (1989).

Document	Relevance to the Study
Wharf Road Drainage Report (Eurobodalla Shire Council, 1997)	This report reviews existing stormwater assets located between Wharf Road and Surfside, and provides options for mitigation of minor flooding Flood events were modelled for high tide levels of RL 1.1m and 100 year ARI ocean inundation of RL 2.7m. Design still water and wave run-up heights were the same as those adopted in the Batemans Bay Vulnerability Study (Land and Water Conservation NSW, 1996). These levels were calculated with a sea level rise of 0.20m by 2050.
Batemans Bay Primary School Relocation – Surfside: Stormwater Drainage Study (Eurobodalla Shire Council, 2000)	This report investigates the drainage impact of the proposed primary school relocation. The water surface profiles were calculated using: • 1, 20 and 100 year ARI flows • 0.6, 1.1, 1.5 and 2.3 mAHD tail water levels • Existing and proposed developed roadways • Culverts unblocked, blocked and blocked outlet culvert under Wharf Road with an unblocked northern access road culvert.
Batemans Bay Coastline Hazard Management Plan (Webb, McKeown and Associates, 2006)	This plan identifies mitigation and management options for coastal hazards for the whole of the Batemans Bay coastline. Run-up levels, erosion rates, beach recession rates, inundation level, wave setup, wave height and dune height are provided for each beach.
Eurobodalla Flood Risk Assessment (URS, 2006)	This report assesses strategies for Council to progress with flood studies and risk management for the entire Eurobodalla Shire. The report includes a gap analysis of existing information. The impact of climate change on sea level rise, wind and rainfall is described.
Existing catchment flood behaviour and impact of the proposed building for Batemans Bay Soldiers Club car park – Flood Assessment (Storm Consulting, 2009)	As part of the Development Application and Statement of Environmental Effects, this report provides a brief assessment of groundwater and flooding impacts on the proposed Centrelink development in the Batemans Bay Soldiers Club car park. Hydrological modelling was undertaken using RAFTS. The critical duration was found to be the 120 minute storm. This was consistent with the previous studies undertaken by Willing & Partners. No calibration was undertaken. Verification against the previous Willing & Partners reports was undertaken. Hydraulic modelling was undertaken using HEC-RAS 4.0 using the peak storm duration from the RAFTS model.
Eurobodalla Shire Coastal Hazard Assessment (Water Research Lab UNSW, 2017)	This report forms Stage 2 of Council's Coastal Management Program. The report defines the impact of present and future coastal hazards in Eurobodalla Shire. This information will inform the downstream boundary conditions for the urban creek hydraulic models.
Batemans Bay Estuary Processes Study (WBM Oceanics, 1999)	This study was undertaken in order to develop an understanding of the various estuarine processes of Batemans Bay and their interactions.
Batemans Bay & Clyde River Estuary Management Study (WBM Oceanics, 2004)	The study provides a program of strategic actions to manage the waterways, foreshores and catchments of the estuary.

Document	Relevance to the Study
Batemans Bay Wharf Road Development – Soft Option Coastal Engineering Assessment and Addendum (WMA, 2005)	This report describes a sand transport model and the historical foreshore alignment evolution between 1898 and 1999. The high water mark adopted by Council was chosen from the 1964 most eroded shoreline (100% historical data line). It was assumed that buildings are unlikely to be flooded landward of it. Possible mitigation options were provided as well as wave assessment of erosion, coastal inundation (including setup levels and wave run-up) and sea level rise.
Wharf Road Coastal Hazard Assessment and Hazard Management Plan (BMT WBM, 2009)	This report provides an oceanic inundation level at Wharf Road. The risk of overtopping was detailed, and sedimentation processes assessed. The existing seawall at the corner of Wharf Road was found to be at a high risk of failure due to erosion, overtopping and undersize armour. Some sewer and water supply pipes might also be at risk.
Eurobodalla Shire Coastal Hazards Scoping Study (SMEC, 2010)	This study reviews existing coastal hazard studies for comprehensiveness, adequacy and currency especially in light of Sea Level Rise and climate change. A gap analysis of coastal hazard assessment studies was carried out to identify areas requiring detailed assessment.
Coastal Zone Management Plan for Batemans Bay (Water Research Laboratory, 2012)	This Plan describes proposed actions to be implemented which address priority management issues in the Batemans Bay coastal zone.
Wharf Road North Batemans Bay Coastal Zone Management Plan (Eurobodalla Shire Council, 2017)	This report focusses on Wharf Road, North Batemans Bay, which was identified by the NSW Government as a coastal erosion 'hotspot', requiring the preparation of a CZMP and an Emergency Action Sub-plan. The back beach area at Wharf Road is low lying, and subject to immediate coastal inundation and erosion hazards.

3.3 Local Emergency Management Plans

A variety of relevant emergency planning documents, where available, were also reviewed and considered as part of the study. These documents are listed in **Table 3-2**.

Table 3-2 Local Emergency Management Plans

Document	Relevance to the Study
Eurobodalla Shire Council Local Emergency Management Plan (EMPLAN)	This document will be used to identify what flood information is necessary to support emergency management activities
Eurobodalla Local Disaster Plan (DISPLAN) 2012	This document will be used to identify what flood information is necessary to support emergency management activities
Draft Emergency Action Sub-plan for the Wharf Road Coastal Erosion 'Hot Spot' 2012	This document will be used to identify what flood information is necessary to support emergency management activities

3.4 Survey Information

3.4.1 Aerial Survey

Aerial survey (LiDAR) has been provided by Council for the full catchment of each study area, which includes publicly available LiDAR data that was flown for the east coast of NSW, and is available as a 1m DEM.

Point cloud data is also available for the study area via the Foundation Spatial Data Framework's online portal, ELVIS (Elevation and Depth Foundation Spatial Data), available from http://elevation.fsdf.org.au/. While the 1m DEM is of sufficient resolution for most modelling requirements, the point cloud data can be useful to ensure that terrain features such as retaining walls, or items with sub-metre sizes are appropriately included in the terrain model.

3.4.2 Ground Survey

No existing ground survey was made available at the beginning on the study.

Ground survey has since been collected as part of this study to obtain selected road levels (including at Long Beach) and berm heights (including at Maloneys Beach and Surfside), in addition to culvert and bridge structures within each catchment. The locations of ground survey collected are shown in **Map G303.**

3.4.3 Bathymetric Survey

Creek cross sections have been surveyed at the locations shown in **Map G303**.

Bathymetry data was available from the Australian Ocean Data Network (https://portal.aodn.org.au/) at a 5m resolution.

It is noted that no bathymetry is available for Joes Lagoon and no survey is being undertaken for this purpose. Joes Lagoon will be modelled as a fully hydrodynamic model to represent the berm breakout processes (see **Section 6.4.8**).

3.4.4 Structures

The flood modelling will include all culverts greater than 600mm diameter. In addition, there are several bridges that cross the waterways that will also be included in the model.

The culvert and bridge details have been obtained from a variety of sources:

- Council data (including GIS data and hand drawings of culvert details of Surfside Creek, Princes Highway);
- Survey (**Map G303**).

3.5 Historical Flood Marks

Data on historical flooding was sourced from previous flooding reports and Council data.

Additional descriptions of historical flooding was provided through consultation with the local community. One flood mark was identified for survey. This location represents flooding on private property in Surfside. This finished floor level, as identified in the survey, is set to 2.773m AHD. Further details regarding the consultation is provided in **Section 4**.

3.6 Rainfall Data

There is an extensive network of rainfall gauges (current and discontinued) across the study area, primarily operated by the Bureau of Meteorology (BoM). These stations are shown in **Map G301**. A list of gauges for the area surrounding the catchment is shown in **Table 3-3** and **Table 3-4** together with key information on whether they are pluviometer or daily gauges.

The suitability of these gauges for use in calibrating / validating the identified historical storms is shown in **Table 3-5** and **Table 3-6**. It is noted that the nearest pluviometer gauge is in Araluen, on the western side of the range, and therefore may not be representative of local rainfall patterns.

Further discussion on recorded rainfall data for historical events is presented with the calibration and validation of the models developed for the study in **Section 7.1**.

Table 3-3 BoM Rain Gauges

ID	Station Name	Commenced	Closed	Daily	Pluviometer
069000	Araluen Post Office	1891	31-Dec-1970	Y	Y (1960 – 1970)
069001	Batemans Bay Post Office	1895	29-Dec-1996	Y	N
069004	Benandra State Forest	1936	31-Dec-1959	Y	N
069006	Bettowynd (Condry)	1896	08-Mar-2010	Y	N
069010	Braidwood (Wallace Street)	1887	Open	Y	N
069016	Milton (Sarah Claydon Village)	1876	Open	Y	N
069018	Moruya Heads Pilot Station	1875	Open	Y	N
069020	Murramurrang	1946	31-Dec-1952	Y	N
069023	Nelligen (Thule Road)	1898	Open	Y	N
069031	Ulladulla	1937	31-Dec-1974	Y	N
069033	Moruya (Burra Creek)	2001	Open	Y	N
069035	Bettowynd (Nobbys Hill)	2000	Open	Y	N
069038	Moruya Bowling Club	1886	31-Dec-1966	Y	N
069040	Kioloa Old Post Office	1957	Open	Y	N
069042	Moruya (The Lagoon)	1960	Open	Y	N
069043	Moruya (Deua River Farm)	1971	31-Dec-1971	Y	N
069046	Mongarlowe	1960	31-Dec-1966	Y	N
069048	Upper Deua (Warawitcha)	2001	Open	Y	N
069052	Batemans Bay – Buckenbowra	1943	Open	Y	N
069053	Burrewarra North	1962	31-Dec-1967	Y	N
069092	Nelligen Clyde Road	1967	31-Dec-1971	Y	N
069098	Bevian Park	1968	31-Dec-1973	Y	N
069102	North Araluen	1969	31-Dec-1980	Y	Y (1970 – 1980)
069105	Merricumbene	1970	31-Dec-1979	Y	N
069106	Woodburn State Forest	1925	31-Dec-1980	Y	N
069113	Geju	1974	31-Dec-1974	Y	N
069121	Brooman (Carisbrook)	1979	Open	Y	N
069124	Bawley Point	1913	31-Dec-1920	Y	N
069126	London Foundation	1980	31-Oct-1986	Y	N
069127	Araluen Lower (Araluen Road)	1980	Open	Y	Y (1980 – 2003)
069132	Braidwood Racecourse AWS	1985	Open	Y	N
069134	Batemans Bay (Catalina Country Club)	1991	Open	Y	N
069138	Ulladulla AWS	1989	Open	Y	N
069141	Currowan (Wild Pig Rd)	1993	27-Feb-2006	Y	N
069142	Moruya (Kiora)	1969	Open	Y	N
069145	Moruya (Plumwood)	1993	Open	Y	N
069148	Moruya Airport AWS	1999	Open	Y	N
069150	Braidwood (Mongarlowe (Leweston))	1998	Open	Y	N

Table 3-4 Rain Gauges by Others

ID	Station Name	Commenced	Closed	Daily	Pluviometer
216420D	Lake Conjola D/S (MHL)	TBC	TBC	Y	N
216002	Clyde River at Brooman (WaterNSW)	1960	Open	Y	N

Table 3-5 Operation of BoM Gauge Data for Identified Historical Events

ID	Station Name	Pluvio meter	Historical Events (with observations or recorded water levels)		
			Aug-63	Feb-77	Jun-91
069000	Araluen Post Office	Y	Pluvio and Daily	N	N
069001	Batemans Bay Post Office	N	Daily	Daily	Daily
069004	Benandra State Forest	N	N	N	N
069006	Bettowynd (Condry)	N	Daily	Daily	Daily
069010	Braidwood (Wallace Street)	N	Daily	Daily	Daily
069016	Milton (Sarah Claydon Village)	N	Daily	Daily	Daily
069018	Moruya Heads Pilot Station	N	Daily	Daily	Daily
069020	Murramurrang	N	N	N	N
069023	Nelligen (Thule Road)	N	Daily	Daily	Daily
069031	Ulladulla	N	Daily	N	N
069033	Moruya (Burra Creek)	N	N	Daily	N
069035	Bettowynd (Nobbys Hill)	N	N	Daily	N
069038	Moruya Bowling Club	N	Daily	N	N
069040	Kioloa Old Post Office	N	Daily	Daily	Daily
069042	Moruya (The Lagoon)	N	Daily	Daily	Daily
069043	Moruya (Deua River Farm)	N	N	N	N
069046	Mongarlowe	N	Daily	N	N
069048	Upper Deua (Warawitcha)	N	N	N	N
069052	Batemans Bay – Buckenbowra	N	Daily	Daily	Daily
069053	Burrewarra North	N	Daily	N	N
069092	Nelligen Clyde Road	N	N	N	N
069098	Bevian Park	N	N	N	N
069102	North Araluen	Y	N	Pluvio and Daily	N
069105	Merricumbene	N	N	Daily	N
069106	Woodburn State Forest	N	Daily	Daily	N
069121	Brooman (Carisbrook)	N	N	N	Daily
069124	Bawley Point	N	Daily	Daily	N
069126	London Foundation	N	N	N	N
069127	Araluen Lower (Araluen Road)	Y	N	N	Pluvio and Daily
069132	Braidwood Racecourse AWS	N	N	N	Daily
069134	Batemans Bay (Catalina Country Club)	N	N	N	Daily
069138	Ulladulla AWS	N	N	N	Daily
069141	Currowan (Wild Pig Rd)	N	N	N	N
069142	Moruya (Kiora)	N	N	Daily	Daily
069145	Moruya (Plumwood)	N	N	N	N
069148	Moruya Airport AWS	N	N	N	N
069150	Braidwood (Mongarlowe (Leweston))	N	N	N	N

Table 3-6 Operation of Other Gauges for Identified Historical Events

ID	Station Name	Pluvio meter	Historical Events (with observations or recorded water levels)		
			Aug-63	Feb-77	Jun-91
216420D	Lake Conjola D/S (MHL)	N	TBC	TBC	TBC
216002	Clyde River at Brooman (WaterNSW)	N	Daily	Daily	Daily

3.7 Flow Data

No flow data is available for the waterways within the study area.

3.8 Water Level Data

Water level data is collected by the Manly Hydraulics Laboratory (MHL) at three locations within Batemans Bay and the Clyde River. A list of available data locations is shown in **Table 3-7** together with data coverage. The location of the gauges is shown on **Map G302**. The water level data will allow calibration of the offshore (boundary) water levels through the study area.

The nearest Water NSW Gauge is outside of the study region, on the Shoalhaven River at Warri.

Table 3-7 MHL Water Level Gauges

ID	Location	Type	Data Coverage
216410	Princess Jetty at Batemans Bay	Water Level	Dec 1985 – Ongoing
216450 / BATBOW	Batemans Bay (Offshore)	Water Level and Direction	Sept 2000 – Ongoing
216453	Clyde River at Nelligen	Water Level	Apr 1994 - Ongoing

3.9 GIS Data

Digitally available information such as aerial photography, cadastral boundaries, topography, watercourses, drainage networks, land zoning, vegetation communities and soil landscapes were provided by Council in the form of GIS datasets.

4 Consultation

4.1 Consultation Strategy

The consultation strategy outlined in **Table 4-1** describes the approach to consultation in accordance with the IAP2 framework and the requirements of the NSW Government's Floodplain Development Manual (2005).

Table 4-1 Consultation Strategy Outline

IAP2 Engagement Strategy Guide	Batemans Bay Urban Creek Flood Study
Context ***The internal and external drivers, pressures and other background information that is of relevance to the consultation strategy, and in particular how these may influence how the community receives and responds to the consultation program.***	The context of the consultation will be defined by the following: • Floodplain Development Manual • Australian Emergency Management Handbook 7 • Council's policies • Flood behaviour (e.g. ocean storms, wave direction, riverine flooding and overland flow and the coincidence of these). • Past flooding experiences and local, regional and national media on flooding. • Council's contact with flood impacted residents following previous flood events. • Consultation undertaken as part of previous related studies.
Scope ***The scoping statements are based on the project context and articulate why the consultation is being undertaken for this project, what the desired outcomes would be, and what the limitations of the engagement are.***	The scope of the consultation strategy is to engage with stakeholders and the community to better understand the flood risks within the study area and to develop community understanding and ownership of the study outcomes.
Stakeholders ***This section provides an overview of the different categories of stakeholders, and their relative level of interest, influence and impact.*** ***This process is useful in identifying the level of engagement under the IAP2 Consultation Spectrum that may be suitable for different types of stakeholders.***	A stakeholder matrix has been provided in **Table 4-2**. This will inform the selection of appropriate consultation methods.
Purpose ***The purpose relates to the purpose of the consultation not the overall project.*** ***Stakeholders will be linked to each purpose and the goals within each purpose for each stakeholder will be identified.***	The purpose of the consultation is to: ▪ Inform the community and stakeholders of the study; ▪ Gain an understanding of the community and stakeholders' concerns relating to flooding in the study area; ▪ Obtain historical flood information; ▪ Gather information from the community by participation; ▪ Obtain feedback on the Draft Flood Study; and ▪ Develop and maintain community confidence and collaboration with the study results.
Methods	The methods selection and associated goals is provided in **Table 4-3**.

4.1.1 Stakeholder Matrix

It is important to ensure all those who need to be involved in the floodplain management (i.e. those with responsibility for managing flood risk and those with a vested interest in its management, such as property owners) are kept informed and invited to contribute to the process to establish a common understanding of flood risk and how decisions are made.

Stakeholders may tend to make judgements about risk based solely on their own perceptions. These perceptions can vary due to differences in values, needs, assumptions, concepts, concerns and degrees of knowledge. Stakeholders' views can have a significant impact on the decisions made, so it is important that differences in their perceptions of risk be identified, recorded and addressed.

A stakeholder matrix (**Table 4-2**) was developed at project inception to provide an overview of the different categories of stakeholders, and their relative level of interest, influence and impact on the Flood Study. Each stakeholder has been assigned a recommended type of consultation based on the IAP2 consultation spectrum, conceptualised in **Figure 4-1**.

Figure 4-1 IAP2's Public Participation Spectrum

Table 4-2 Stakeholder Matrix

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Impacted Agency Stakeholders				
Eurobodalla Shire Council	High	High	High	Empower
Office of Environment and Heritage	High	High	High	Empower
Steering Committee	High	High	High	Collaborate
Project Technical Committee	High	High	High	Collaborate
State Emergency Service	High	High	Moderate	Collaborate
Roads and Maritime Service	High	High	Moderate	Involve
Impacted Infrastructure Service Providers (to be confirmed by Council)	High	Moderate	Moderate	Involve
Interested Agency Stakeholders				
Council Engineers	Moderate	Moderate	Moderate	Involve
Council Planners	Moderate	Moderate	Moderate	Involve
Water NSW	Moderate	Moderate	Low	Consult
Manly Hydraulics Laboratory	Moderate	Moderate	Low	Inform
NSW DPI – Crown Lands	Moderate	Moderate	Low	Consult
Bureau of Meteorology	Moderate	Moderate	Low	Inform
Impacted Community Stakeholders				
Flood affected property owners	High	High	Low	Consult
Flood affected residents	High	High	Low	Consult
Flood affected business owners	High	High	Low	Consult

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Residents and owners of properties not affected by flooding but within the study area (e.g. impacted by flood access)	Moderate	Moderate	Low	Consult
Users of the area (e.g. impacted by flood access)	Moderate	Low	Low	Consult
Interested Community Stakeholders				
Community groups (specific groups to be advised by Council)	Low	Moderate	Low	Consult
Wider community	Low	Low	Low	Consult
Impacted Agency Stakeholders				
Eurobodalla Shire Council	High	High	High	Empower
Office of Environment and Heritage	High	High	High	Empower
Steering Committee	High	High	High	Collaborate
Project Technical Committee	High	High	High	Collaborate
State Emergency Service	High	High	Moderate	Collaborate
Roads and Maritime Service	High	High	Moderate	Involve
Impacted Infrastructure Service Providers (to be confirmed by Council)	High	Moderate	Moderate	Involve
Interested Agency Stakeholders				
Council Engineers	Moderate	Moderate	Moderate	Involve
Council Planners	Moderate	Moderate	Moderate	Involve
NSW DPI – Crown Lands	Moderate	Moderate	Low	Inform
Bureau of Meteorology	Moderate	Moderate	Low	Inform
Impacted Community Stakeholders				
Flood affected property owners	High	High	Low	Consult
Flood affected residents	High	High	Low	Consult
Flood affected business owners	High	High	Low	Consult
Residents and owners of properties not affected by flooding but within the study area (e.g. impacted by flood access)	Moderate	Moderate	Low	Consult
Users of the area (e.g. impacted by flood access)	Moderate	Low	Low	Consult
Interested Community Stakeholders				
Community groups (specific groups to be advised by Council)	Low	Moderate	Low	Consult
Wider community	Low	Low	Low	Consult

4.1.2 Engagement Methods Selection

Based on the requirements of the brief, the objectives of the consultation (identified in the consultation strategy outline), the level of consultation identified for each of the stakeholders (in the stakeholder matrix), and discussions with Council engagement methods were selected to achieve the project objectives. A summary of the engagement methods and the key goals of each method are provided in **Table 4-3**.

Table 4-3 Engagement Methods Selection

Method	Stakeholders	Goals	Timing	Details
Media and social media updates.	▪ All stakeholders. ▪ Wider community.	▪ To inform stakeholders of the study. ▪ To increase later engagement with survey and feedback on draft documents. ▪ To capture stakeholders (e.g. visitors and users of the area) not targeted by other consultation methods.	Prior to newsletter and survey release, and drop-in sessions. Prior to and during public exhibition.	Council provided updates to the community on their website, media release for local media, and Council's Facebook Page.
Letter / email of introduction to the study and follow up phone call.	▪ All agency stakeholders. ▪ Community groups.	▪ To inform stakeholders of the study. ▪ To identify any additional relevant documents or data sets to be included in the data analysis and review. ▪ To establish a stakeholder mailing list for ongoing project email updates.	Project inception.	An email of introduction was sent to relevant agency and community stakeholders to inform them of the purpose of the study and how they can provide input. Each email was tailored for the recipient. Follow up was undertaken by email and phone as required.
Project Website	▪ Public	▪ To inform the public of the study. ▪ To provide additional information to interested stakeholders and community. ▪ To provide information of how stakeholders can provide input.	For entire project duration.	Council has provided a webpage on their website providing details of the Flood Study and how the community can be involved.
Newsletter and questionnaire	▪ All flood impacted land owners, business	▪ Inform. ▪ Gain interest and improve likelihood of participation during the public exhibition period.	Project inception	A newsletter and questionnaire was distributed to the residents and property owners within the study area. The newsletter / questionnaire was also made available on Council's project webpage.

Method	Stakeholders	Goals	Timing	Details
	owners and residents. ▪ Wider community	▪ Gather input on flood risk concerns and historical flood data. ▪ To establish a stakeholder mailing list for ongoing project email updates.		
Public Information Session 1	▪ Impacted Community Stakeholders. ▪ Interested Community Stakeholders.	▪ Provide an overview of the study purpose, methodology and aims. ▪ Gather local knowledge including oral history, photographs. ▪ Increase engagement with survey. ▪ Gain interest and improve likelihood of participation during the public exhibition period. ▪ To establish a stakeholder mailing list for ongoing project email updates.	Project inception	The sessions were formatted to allow attendees to drop in at any time during the session and have a one on one chat with the project team. These discussions were facilitated by posters showing each of the catchments (and key features). Attendees were encouraged to mark up the posters with flood observations and points of interest.
Public Exhibition Period	▪ All stakeholders	▪ Provide an opportunity for feedback on the Draft Study.	Following completion of the Draft Study.	The draft FRMS and FRMP will be placed on public exhibition for a minimum period of 4 weeks.
Public Information Session 2	▪ Impacted Community Stakeholders. ▪ Interested Community Stakeholders.	▪ Provide an overview of the study purpose, methodology and outcomes. ▪ Provide location specific information to attendees (via one on one sessions). ▪ Provide an opportunity for feedback on the Draft Study.	Following completion of the Draft Study.	Community information sessions will be undertaken during the public exhibition period to allow the community to discuss the draft study with the project team and provide feedback on the outcomes.

4.2 Agency Consultation

There are many agencies with flood-related interests in the LGA. To best approach these agencies, a letter was sent to key stakeholder agencies to introduce the project and an invitation to be involved in the study. It also included a request for any relevant data or information they may have.

The agencies contacted are listed in **Table 4-4** along with the outcomes of this consultation.

All agency stakeholder will be contacted prior to the public exhibition of the draft Flood Study to request their feedback on the report.

Table 4-4 Agency Consultation

Agency Stakeholder	Outcome of Consultation
Office of Environment and Heritage	Ongoing guidance and input throughout the project
Eurobodalla Shire Council	
Coastal and Flood Management Planner	Council's project manager providing project direction
Surveyors	Council's survey team have provided input on available data and assisted in the collection of additional survey as well as input to the scope for external survey requirements.
Development Assessment Planners	A workshop was undertaken with Council's planners and DA assessors on 23 August 2019. The purpose of the workshop was to gain a better understanding of Council existing flood planning and opportunities for review and improvement. The outcomes of this workshop informed the flood planning review in **Section 5**.
Coast and Environment Management Advisory Committee	No engagement has been undertaken by Rhelm with the Committee.
Roads and Maritime Services	RMS have been contacted both to provide strategic input to the study and provide structure data at Princes Highway.
NSW DPI – Crown Lands	Consultation yet to be undertaken.
State Emergency Service	A range of SES representatives were contacted by Council and Rhelm via email. The unit commander at Batemans Bay responded and advised that most of the Batemans Bay members have a short timeframe as a member and have not seen a flood of significance in Batemans Bay.
NSW Department of Planning and Environment	Consultation yet to be undertaken.
NSW Ambulance Greater Southern Area Health Service	Contacted on two occasions. No responses received to date.
Fire and Rescue NSW	Various members of NSW Fire Service and Rural Fire Service contacted. No response received to date.
NSW Police Force	Contacted on two occasions. No responses received to date.
South East Local Land Services	Contacted on two occasions. No responses received to date.

Agency Stakeholder	Outcome of Consultation
Marine Rescue	Contacted on two occasions. No responses received to date.
Red Cross	Contacted on two occasions. No responses received to date.

4.3 Website and Media

Council utilised the local newspaper, their own website and Facebook profile to provide updates and request input to the study. The media released to date is summarised in **Table 4-5.** Copies of the media releases are provided in **Appendix A**. It should be noted that, in addition to the media releases, residents and property owners likely to be affected by the study were contacted directly by mail on 7-10 November 2018.

Table 4-5 Media Releases

Media	Date	Purpose
Media Release on Council's website	7 November 2018	To inform the community of project inception and scope. Also, to invite community input to the survey and drop-in sessions.
Media statement to local newspaper	7 November 2018	To inform the community of project inception. Also, to invite community input to the survey and drop-in sessions.
Facebook posts	15 November 2018	Inviting attendees to drop-in sessions, requesting flooding photos and providing a link to the online survey.

Council has created a project webpage on their website. This webpage provides background information on the project, relevant links and information on how the community has been and can get involved. The website is updated periodically during the project.

The Facebook post (15/11/2018) generated more than 100 comments, some of the key issues and concerns raised are summarised below.

- A resident of Maloneys Drive from 1992 to 2018 has had no experience of flooding on Maloneys Drive. Some flooding has occurred in the creek at the base of Murramarang which may have entered the back of properties along here.
- Concern that the flood study results will be unrealistic and will exceed actual flood heights.
- Concern that insurance premiums will go up as a result of the flood study.
- Concern that mitigation strategies will not reduce insurance premiums.
- Unclear on the definition of flooding used by Council and insurance companies.
- Concern that there is a 'hidden agenda' to the flood study.
- Concerns that the Facebook post did not provide adequate notice for the drop-in sessions.

4.4 Community Newsletter and Survey

A community newsletter and survey were distributed to property and business owners, as well as residents within the study area. The newsletter and survey were also made available on Council's website, with the survey available to be completed online. A copy of the newsletter and survey is provided in **Appendix A**.

The newsletter provided information on the purpose and scope of the Flood Study and the survey sought information about historical flooding events and other flooding concerns within the community.

The survey was mailed to approximately 650 recipients. A summary was also provided in a media release, informing the community of the Flood Study and advertising that the survey was being undertaken.

From the distribution and availability of the survey on the website, fifteen responses were received, representing a return of only 2.3% of direct distribution. A return rate of 10% is typical for these types of mail-outs. An additional 10 people attended drop-in sessions to provide input face to face (**Section 4.5**). This represents a total return rate of 4%. The low rate of returns may have been due to the fact that very little flooding has occurred within the study area in the last 10 years.

A summary of the responses is provided in **Table 4-6**.

Table 4-6 Community Survey Responses

Question	Responses
How long have you lived, worked or visited in and around Batemans Bay?	Range of responses: 0 to 60 years Average: 27.3 years
Are you aware of flooding in and around Batemans Bay?	Aware: 6 Some Knowledge: 2 Not Aware: 6
Have you seen flooding in and around Batemans Bay?	• Catlin Avenue and Avalon Street, Batemans Bay: flooding on the roads in January 2000 and January 2014. A newspaper article supplied by the community identified the 2014 flooding as a result of a king tide. • Overland flow through easement and onto adjacent private property at Avalon Street in 1990. Water drained away once outlet drain cleared / opened. • Drains overflowed into vacant lot on Country Club Drive, Catalina, after 2 days of heavy rain in November 2013 and August 2015. • Flooding of the road and up to the front step of residential property on Golf Links Drive, Batemans Bay • Backyard flood from flow from Bavarde Avenue, Batemans Bay (35 years ago). Upgrades have since been undertaken and no flooding experienced since then. • Flooding of footpaths and Beach Road near Soldiers Club. • Flooding from waves across the esplanade and up to the shop fronts in Batemans Bay CBD (December 2017) • Myamba Parade, Surfside has experienced very high tides, but the water has never entered the back yard in 30 years. • Flooding of backyards due to inter-allotment drainage along Christopher Crescent properties in Batehaven

4.5 Community Drop-In Information Sessions

Community drop-in sessions were held during the initial stages of the study to gather information from the community about flooding experiences and concerns. The sessions were held at the Batemans Bay Community Centre on Tuesday 20th November between 10am – 2pm, and 3pm – 6pm.

There were approximately 10 attendees across the two sessions. Information was received regarding:

- Road and property flooding on low-lying areas at the downstream end of Hanging Rock Creek catchment is due to the tidal gates on the outlet not opening or a very high tide not allowing the catchment flows to drain away. The flood waters clear quickly after the tidal gates are opened or the tide recedes. In very large events, water has been seen flowing towards Bavard Avenue (rather than the creek at Beach Road). In the early 1970s the four houses at the rear of the club carpark had a foot of water over the floor levels. Large flood events have been experienced in 1963, 1973, 1974, 1975, and 1977.
- Flooding of properties has occurred in Timbara Crescent, Surfside. Flooding is caused by overland flow from uphill properties and poor drainage on Timbara Crescent (no kerb and guttering and very flat). Half of the road floods after significant rain. In February 1977 there was a major flood with water coming up to the front door of some houses. Another large event was experience in June 1987 (some uncertainty regarding the date).
- Floodwaters sometimes overtop Wharf Road, Surfside, but usually just backs up until it flushes out or Council clears the culvert / sand away.
- Flooding issues from overland flow and creek flows at Pleasurelea caravan park.

4.6 Public Exhibition

Following the preparation of the draft Flood Study, the report will be placed on Public Exhibition to allow the community and other stakeholders to review and comment on the report prior to it being finalised and adopted by Council.

4.7 Outcomes of Engagement

4.7.1 Stage 1 Engagement

During Stage 1 of the study, engagement was undertaken with the community vie online surveys and drop-in sessions. In addition, community provided input via comments made on Council's Facebook post and directly onto published media.

The key issues raised and the implications for the study are summarised in **Table 4-7**.

Table 4-7 Key Issues Raised and Community Inputs

Comments from the Community	Response and Implications for Flood Study
A resident of Maloneys Drive from 1992 to 2018 has had no experience of flooding on Maloneys Drive. Some flooding has occurred in the creek at the base of Murramarang which may have entered the back of properties along here.	This information will be used to calibrate / validate the flood study model results.
Concern that the flood study results will be unrealistic and will exceed actual flood heights.	The flood models being developed for the flood study are based on a combination of aerial laser and ground survey, along with best available design

Comments from the Community	Response and Implications for Flood Study
	rainfall datasets and the results are verified against flood observations provided by the community. The flood study will provide a range of flood levels and extents for the study area ranging from more frequent events (e.g. 5 Year ARI) to less frequent events (e.g. 100 Year ARI). Flooding experience by the community may not have been the largest possible event, and may not have even been a particularly rare event. Review of the rainfall data at the time of the flood observation assists in clarifying this.
Concern that insurance premiums will go up as a result of the flood study.	It is Council's understanding that individual insurance companies typically identify Flood Prone Land and assess risk through their own flood studies, analysis and flood mapping exercises, irrespective of whether Council has undertaken a flood study. These calculations are outside Council's control. The information is then used to set policies and premiums. The Insurance Council of Australia (ICA) has advised that if you feel that an insurer has incorrectly assessed the risk of flooding at your property, you can contact the insurer to discuss this. Council can provide flood information relevant to your property to assist you with these discussions.
Concern that mitigation strategies will not reduce insurance premiums.	Flood mapping and property flood notation will be reviewed by Council as an outcome of mitigation strategies that reduce flooding for certain locations. Whether insurance companies consider this information is outside of Council's control (see response above).
Unclear on the definition of flooding used by Council and insurance companies.	Flood is defined by the NSW Government in the *Floodplain Development Manual* (2005) as: • Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and / or local overland flooding associated with major drainage before entering a watercourse, and / or coastal inundation resulting from super-elevated sea levels and / or waves overtopping coastline defences excluding tsunami. Since 2014, all home building, home contents, small business and strata insurance policies have adopted a common definition of "flood": • The covering of normally dry land by water that has escaped or been released from the

Comments from the Community	Response and Implications for Flood Study
	normal confines of any lake, or any river, creek or other natural watercourse, whether or not altered or modified; or any reservoir, canal, or dam.
Concern that there is a 'hidden agenda' to the flood study.	Local councils are responsible for managing flood-prone land in NSW with support from DPIE, which provides specialist technical knowledge. Council is developing a range of floodplain risk management studies that will help them consider the consequences of living on flood prone land. The plans aim to minimise the losses to our community from flooding. Preparing a flood study is the first step in the floodplain risk management process outlined in the NSW Floodplain Development Manual 2005.
Concerns that the Facebook post did not provide adequate notice for the drop-in sessions.	Owners and residents of properties likely to be impacted by flooding associated with the studies were sent a letter on the 7th November notifying them of the drop-in sessions and providing a hard copy of the feedback survey. A media release was also issued on the 7th November. The Facebook post was issued on 15th November as a follow up to the mail-out and media release. The drop-in sessions were held on the 21st November. During the public exhibition period the Facebook post will be released with two weeks notice before the drop-in sessions.
Flood observations noted in online and mailout survey (Table 4-6).	This information will be used to calibrate / validate the flood study model results.
Road and property flooding on low-lying areas at the downstream end of Hanging Rock Creek catchment is due to the tidal gates on the outlet not opening or a very high tide not allowing the catchment flows to drain away. The flood waters clear quickly after the tidal gates are opened or the tide recedes. In very large events, water has been seen flowing towards Bavard Avenue (rather than the creek at Beach Road). In the early 1970s the four houses at the rear of the club carpark had a foot of water over the floor levels. Large flood events have been experienced in 1963, 1973, 1974, 1975, and 1977.	This information will be used to calibrate / validate the flood study model results.
Flooding of properties has occurred in Timbara Crescent, Surfside. Flooding is caused by overland flow from uphill properties and poor drainage on Timbara Crescent (no kerb and guttering and very	This information will be used to calibrate / validate the flood study model results.

Comments from the Community	Response and Implications for Flood Study
flat). Half of the road floods after significant rain. In February 1977 there was a major flood with water coming up to the front door of some houses. Another large event was experience in June 1987 (some uncertainty regarding the date).	
Floodwaters sometimes overtop Wharf Road, Surfside, but usually just backs up until it flushes out or Council clears the culvert / sand away.	This information will be used to calibrate / validate the flood study model results.
Flooding issues from overland flow and creek flows at Pleasurelea caravan park.	This information will be used to calibrate / validate the flood study model results.

5 Flood Planning Review

5.1 Overview of Environmental Planning Instruments

Within the study area, development is largely controlled through the Eurobodalla Local Environment Plan (LEP) 2012 and a series of Development Control Plans (DCP). The LEP is an environmental planning instrument (EPI) which designates land uses and development in the study area, while the DCPs regulate development with specific guidelines and parameters. There are also a number of EPIs and related planning documents that can affect the development of property within the study area. These may be in the form of State Environmental Planning Policies (SEPP) which take precedence over the provisions of the LEP such as:

- SEPP Exempt and Complying Development Codes (2008)
- SEPP Educational Establishments and Child Care Facilities (2017)
- SEPP - Housing for Seniors and People with a Disability (2004)
- SEPP - Affordable Rental Housing (2009)
- SEPP 21 Caravan Parks
- SEPP 36 - Manufactured Home Estates
- SEPP 65—Design Quality of Residential Apartment Development
- SEPP - Primary Production and Rural Development (2019)
- SEPP Coastal Management (2018)
- SEPP Infrastructure (2007)
- SEPP No 33—Hazardous and Offensive Development
- Other SEPPs as relevant to land use and/or development type
- Other Council plans, policies or other publications.

The review of SEPP provisions is relevant insofar as they relate to how they might inter-relate with local provisions are it is generally not possible for a SEPP to be modified as a recommendation of this review.

All relevant planning controls for individual land parcels are summarised in a Section 10.7 certificate (formerly a Section 149 certificate) issued under the Environmental Planning and Assessment Act, 1979.

A review of flood-related controls incorporated within the LEP, relevant DCPs, Council policies and plans has been completed. Recommendations for updates to improve the management of flood risk are provided in **Section 5.8**.

At the time of preparation of this report, the Department of Planning, Industry and Environment released a Draft Floodprone Land Package for comment (over the period May-June 2020). Reference is made here to the documents in this package as they relate directly to potential changes for any revision to existing environmental planning instruments (EPIs) and any new EPIs.

Additionally, at the time of preparation of this report, Eurobodalla Shire Council released their Draft Local Strategic Planning Statement (LSPS, dated 11 May 2020) for comment (over the period May-June 2020). This draft package has been referred to in this review (**Section 5.3**). Reference is also made here to the relevant aspects of the Draft LSPS pertinent to flood risk management (**Section 5.4**).

This review does not specifically deal with matters related to building construction (such as the National Construction Code, which includes the Building Code of Australia (BCA), both of which are updated every three years by the Australian Building Codes Board). However, it is important to note that these types of controls are sometimes called or referenced in planning controls and therefore their content and direction are of relevance. In the regard, how they are applied is directed under the NSW Planning System via numerous mechanisms but primarily via Building System Circulars issued by the Department of Planning, Industry and Environment (DPIE). The most relevant circular is BS 13-004, dated 16 July 2013 entitled *The NSW Planning System and the Building Code of Australia 2013: Construction of Buildings in Flood Hazard Areas*. Importantly the BCA deals with the concept of the 'defined flood event' (DFE) and imposes minimum a construction standard across Australia for specified building classifications 'flood hazard areas' (FHA) up to the DFE. These requirements will be referenced when developing appropriate recommendations for policy and planning approaches within the study area.

5.2 Eurobodalla Local Environment Plan 2012

The Eurobodalla LEP 2012 commenced 20 July 2012. The LEP sets the direction for land use and development in the study area by establishing suitable land uses across the local government area (as 'zones') and defining where development consent is required. It determines what can be built, where it can be built and what uses or activities can occur on land.

The Eurobodalla LEP 2012 (ELEP) is based on a standard format used by all Councils in NSW and can be viewed on the NSW legislation website (www.legislation.nsw.gov.au).

5.2.1 Flood Planning Objectives and Controls

The objectives for land at or below the flood planning level (100 Year ARI event plus 0.5m freeboard) are outlined in Clause 6.5 of the ELEP. The objectives of this clause are:

- *to minimise the flood risk to life and property associated with the use of land,*
- *to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,*
- *to avoid significant adverse impacts on flood behaviour and the environment.*

It is stated that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

- *is compatible with the flood hazard of the land, and*
- *is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
- *incorporates appropriate measures to manage risk to life from flood, and*
- *is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
- *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

The above objectives and consent considerations are consistent with the LEP standard template. However, it is noted that the Flood Planning Level (FPL) is specifically defined as the 100 Year ARI plus 0.5m freeboard which is consistent with the Planning System Circular (formerly Section 117 Direction) issued by the NSW Department of Planning, Industry and Environment (Direction PS07-003, dated 31 January 2007).

The LEP provides specific flood related considerations for development approval within the "Moruya Town Centre". While these considerations do not currently apply to the study area, they are relevant in the development of appropriate recommendations for policy and planning approaches within the study area.

The ELEP contains a clause (6.5(4)) that addresses properties that are affected by flooding and coastal processes and states:

Before determining a development application for development on land to which this clause applies, the consent authority must consider the potential to relocate, modify or remove the development if the land is affected by coastal processes, coastal hazards and sea level rise.

In this regard, the LEP Dictionary has the following definition:

- *coastal hazard has the same meaning as in the Coastal Management Act 2016, which is:*

(a) beach erosion,

(b) shoreline recession,

(c) coastal lake or watercourse entrance instability,

(d) coastal inundation,

(e) coastal cliff or slope instability,

(f) tidal inundation,

(g) erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

Coastal processes and sea level rise are undefined in both the ELEP and in the *Coastal Management Act, 2016*.

The Eurobodalla Interim Coastal Hazard Adaptation Code (ESC, 2017) applies to lands within the coastal zone or areas identified by Council as potentially at risk from coastal hazards out to a maximum planning period ending at the 2100 coastal hazard projections identified in the *Eurobodalla Coastal Hazard Assessment* (WRL, 2017 or area mapped within the Code as 'Eurobodalla Investigation Areas' (noting that no maps were incorporated in Appendix A at the time of this review).

The flooding associated with coastal inundation is one element of this study and could potentially be considered as flooding under the definitions of the State Flood Prone Land policy and in accordance with the NSW Floodplain Development Manual (2005) and/or could be considered under the provisions of the Coastal Management Act, 2016.

5.2.2 Flood Mitigation Works

The ELEP 2012 permits flood mitigation works with consent only in areas zoned RU5 Village. This is a relatively limited extent of where works can occur. However, it is noted that the provisions of SEPP (Infrastructure) 2007 allow for Council flood mitigation works without consent in any zone under Clause 50(1) which states:

Development for the purpose of flood mitigation work may be carried out by or on behalf of a public authority without consent on any land.

This includes construction, routine maintenance and environmental management works.

5.2.3 Flood Mapping and Related Amendments

On 8 August 2017, Council endorsed a planning proposal to rezone certain flood prone land from E2 to an appropriate zone and to make related amendments. A Gateway Determination on this planning proposal was issued on 27 November 2017 and it was placed on public exhibition from 8 November 2017 to 2 February 2018.

5.3 Draft Flood Prone Land Package

In May 2020 the Department of Planning, Industry and Environment released a Draft Flood Prone Land Package which contains a series of documents that seek to update the manner in which local planning is conducted for flood prone lands. In summary, the key relevant aspect for strategic planning is the consideration of three types of flood prone areas:

- Flood Planning Area (FPA), which has commonalities with the flood planning level concept in the ELEP and seeks to ensure development is compatible with flood risks within the FPA (noting that there are some circumstances where no development is compatible with flood risks)
- Special Flood Considerations (SFC), which seeks to control certain types of vulnerable and hazardous development within the floodplain in its entirety (i.e. potentially up to the extent of the Probable Maximum Flood)
- Regional Evacuation Consideration Area (RECA), which seeks to ensure lands which are indirectly affected by flood behaviour with respect to being unable to evacuate due to flooding in adjacent areas and becoming isolated.

Whilst only being a draft package, consideration of the potential application of the draft from a strategic planning perspective has been made as part of this study. **Maps G905a – f** show the extent of a potential Flood Planning Area (FPA), **Section 9.1** provide more detail on the selection of the FPA. A Special Flood Consideration (SFC) area is also shown on these maps (which is the extent of the Probable Maximum Flood where it is greater than the 1%AEP plus 0.5 m).

5.4 Draft Local Strategic Planning Statement

The Draft Eurobodalla Local Strategic Planning Statement (LSPS, ESC, 2020) is a strategic document, setting out a 20-year vision for land use planning in the Shire. It outlines how growth and change will be managed to ensure high levels of liveability, prosperity and environmental protection are achieved in Eurobodalla. Once adopted, the LSPS will set the direction for the revision of the ELEP, 2012 and the update of the range of existing development control plans (Section 5.5).

With respect to flooding, the Draft LSPS states that:

- Planning Priority 3 is Consolidate development within town and village centres. In this regard the LSPS states that the region is subject to coastal inundation and erosion, and inland flooding which are threats that are predicted to increase over time. These threats are an ongoing threat to many residents living in the Shire. It is essential that hazards are identified and mitigation measures are put in place to reduce the risk to loss of life or property in the future.
- Planning Priority 4 is Adapt to Natural Hazards. Specifically, Item 4.3 is to adopt the Batemans Bay Urban Creek Flood Study (this study) and Item 4.4 is to Develop a Flood Management Code across Eurobodalla.

5.5 Development Control Plans

5.5.1 Residential Zones DCP

The Residential Zones DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this DCP is to further the aims of the ELEP 2012 and the particular objectives for the R2, R3, R5 and E4 zones as stated in the ELEP 2012.

Section 6.1 of the DCP outlines the Flood, Ocean Influences and Climate Change controls. However, the DCP simply states that "*all development within the area to which the Moruya Valley Floodplain Development Code applies must comply with that Code*". This would suggest that no flood related development controls are applied in R2, R3, R5 and E4 zones elsewhere, including the study area.

Some flooding considerations are included in Section 7.3, which requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding.

5.5.2 Industrial Zones DCP

The Industrial Zones DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this DCP is to further the aims of the Eurobodalla LEP 2012 and the particular objectives of the IN1 General Industrial Zone as stated in the LEP 2012.

Section 4.1 of the DCP outlines the Flood, Ocean Influences and Climate Change controls. However, the DCP simply states that "*all development within the area to which the Moruya Valley Floodplain Development Code applies must comply with that Code*". This would suggest that no flood related development controls are applied to IN1 zone elsewhere, including the study area.

Section 5.1 notes that a Master Plan must be prepared for subdivision of development within any identified Industrial Expansion Area. The Master Plan must consider the protection of the development from flood inundation and the impacts of sea level rise.

Section 7.3 requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding.

5.5.3 Batemans Bay Regional Centre DCP

The Batemans Bay Regional Centre DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this DCP is to further the aims of the Eurobodalla LEP 2012 and the particular objectives for the R3, B4 and B5 zones as stated in the LEP 2012.

Section 7.3 requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding.

No other flood-related controls are specified in the DCP.

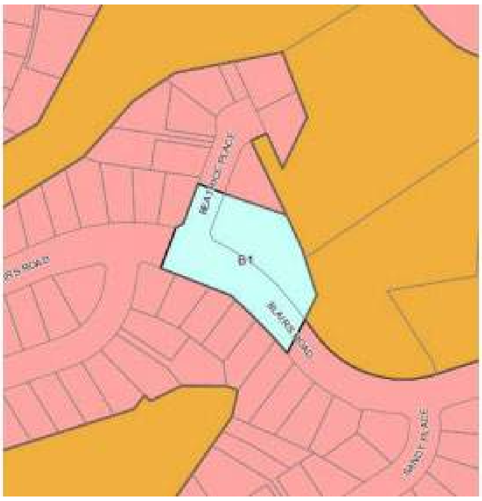
5.5.4 Neighbourhood Centres DCP

The Neighbourhood DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this Plan is to further the aims of the Eurobodalla LEP 2012 and the particular objectives for the B1, B2 and R3 zones as stated in the LEP 2012 and the particular objectives for the Neighbourhood Centres as identified in the *Eurobodalla Settlement Strategy* (**Section 5.6.1**).

The DCP applies to the following neighbourhood centres as shown in the **Figures 5-1** to **5-5**:

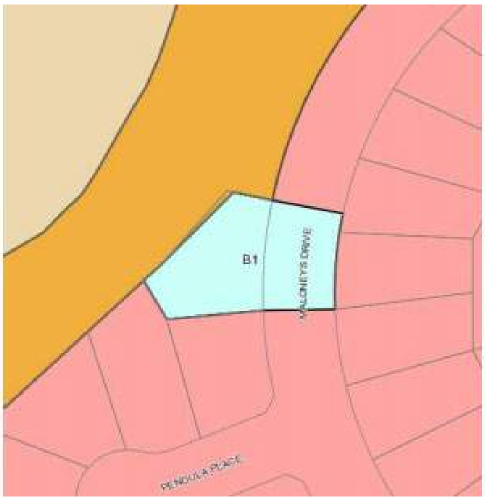
- B1 in Longbeach.
- B1 in Maloney's Beach.
- B1 and R3 in Surfside & North Batemans Bay.
- B2 and R3 in Batehaven.
- B1 and R3 in Sunshine Bay.

Section 7.3 requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding. No other flood related controls are specific in the DCP.



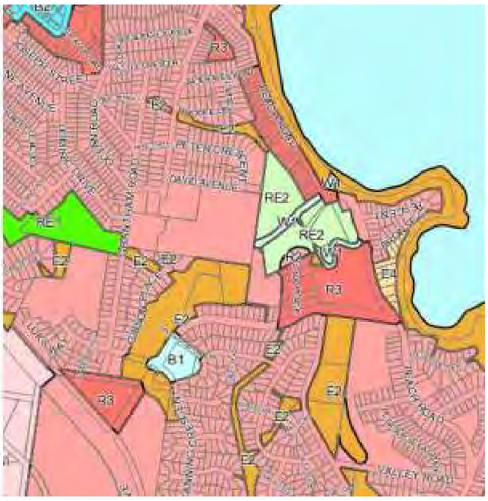
B1 - Longbeach

B1/R3 – Surfside/North Batemans Bay



B1 – Moloney’s Beach

B2/R3 - Batehaven



B1/R3 – Sunshine Bay

Figures 5-1 to 5-5 Maps from Schedule 1 Neighbourhood Centres DCP

5.6 Other Policies, Plans and Codes

5.6.1 Eurobodalla Settlement Strategy 2006 – 2031

The aims of the *Eurobodalla Settlement Strategy 2006 - 2031* are to conserve biodiversity, respect our diverse cultural background, stimulate economic and community development, and provide efficient public services. The strategy reinforces and makes explicit the policy positionings of Council and the NSW Government which in turn are a response to contemporary local and wider community expectations. The Eurobodalla Settlement Strategy is aligned with the South Coast Regional Strategy 2007, prepared by the Department of Planning, Illawarra and South Coast Regional Office.

The Strategy makes reference to the fact that flood inundation has been mapped for most urban areas of the LGA and that restrictions are placed on building and construction on the extent of flooding that may result from a 1 in a 100 year event and, in some cases, from an extreme event. However, this is not supported by the relevant DCPs (**Section 5.5**).

The following actions are proposed in the Strategy:

- Undertake outstanding flood risk studies in areas that are potentially flood prone.
- Implement a management plan for flood liable land incorporating hazard and risk regimes, taking into account the potential effects of climate change, within which appropriate development is identified and restricted.
- Require applicants for new developments in potentially flood affected areas to carry out research to determine the extent of flood risk and potential impact of the development on flood behaviour and to submit this information to Council.

Preparing the Batemans Bay Urban Creeks Flood Study satisfies some of the proposal actions in the Strategy. However, to support the objectives of the Strategy, there needs to be better definition of flood-related controls for development in the floodplain.

5.6.2 South East and Tableland Regional Plan 2036

The *South East and Tableland Regional Plan 2036* (Department of Planning and Environment, 2017) guides the NSW Government's land use planning priorities and decisions over the next 20 years. Direction 16 of the Plan provides actions relating to the protection of the coast and increased resilience to natural hazards, such as flooding. The action relating to catchment flooding include:

- 16.1 – Locate development, including new urban release areas away from areas of flooding hazards and designated waterways to reduce the community's exposure to natural hazards
- 16.2 – Implement the requirements of the NSW Floodplain Development Manual by developing, updating or implementing flood studies and floodplain risk management plans
- 16.4 – Incorporate the best available hazard information in local environmental plans consistent with current flood studies, flood planning levels, modelling, floodplain risk management plans and coastal zone management plans
- 16.6 – Manage risk associated with future urban growth in flood-prone areas as well as risks to existing communities.

5.6.3 Recreation and Open Space Strategy 2018

The *Eurobodalla Recreation and Open Space Strategy* (ESC, 2018) aims to provide the strategic framework for the management, provision and development of recreation and open space in the Eurobodalla LGA. The Strategy focuses on Council owned and/or managed public open space (community land, Crown land under

Council control and road reserves), including community halls and centres. Natural areas, including state-owned bushland reserves, have been considered for their role in providing for nature-based recreation.

The only mention of flooding within the strategy is with reference to the benefits of open space in reducing flood-related problems. This would suggest that the strategy would support the use of open space for the purpose of flood mitigation works as long as the other benefits and uses of open space are maintained.

There are 85 actions recommended in the strategy, none of these relate directly to flood risk management.

5.6.4 Moruya Floodplain Code 2012

The *Moruya Floodplain Code* (2012) is a development code that has been prepared in accordance with the principles of the *NSW Flood Prone Land Policy* and strategies contained in the *Moruya River Floodplain Management Plan (2004)* and the *NSW Floodplain Management Manual (2005)*.

The aim of this Code is to inform the community about Council's requirements in relation to the use and development of land potentially affected by floods.

The Code applies to all flood liable land up to and included the Probable Maximum Flood and some adjacent lands which become isolated during flooding of the Moruya River.

Development requirements are provided for various development types across four hazard categories. The development requirements do not differentiate between mainstream and overland flooding.

5.6.5 Eurobodalla Interim Coastal Hazard Adaptation Code 2017

The Eurobodalla Interim Coastal Hazard Adaptation Code (ESC, 2017) applies to lands within the coastal zone or areas identified by Council as potentially at risk from coastal hazards out to a maximum planning period ending at the 2100 coastal hazard projections identified in the *Eurobodalla Coastal Hazard Assessment* (WRL, 2017 or area mapped within the Code as 'Eurobodalla Investigation Areas' (noting that no maps were incorporated in Appendix A at the time of this review).

The development controls and strategies within this Code relate to coastal hazards and do not provide consideration of catchment flooding. However, the proposed strategies within the Code should be considered when developing floodplain risk management measures in the flood risk management study and plan phase. Further investigation should also be conducted as to how this Code applies in the context of the Coastal Management Act 2016 and the associated Coastal Management SEPP which came into force after the Code (in April 2018).

5.6.6 Eurobodalla Infrastructure Design Standards

This document provides design standards associated with the design of culverts, earthworks, drainage and floor levels. This information will be considered in the preparation of recommended flood related planning controls as an outcome of the FRMSP.

5.6.7 Plans of Management

The following plans of management are within the study area and should be considered when identifying and assessing potential floodplain risk management measures as part of the future Floodplain Risk Management Study and Plan:

- Surfside Beach Foreshore Reserve Plan of Management
- Long Beach Foreshore and Wetlands Reserve Plan of Management
- Hanging Rock Recreational Reserve Plan of Management
- Catalina Reserves and the Hanging Rock Boat Ramp Car Park Reserve Plan of Management.

5.7 Implementation of Flood Planning Provisions and Development Controls – Summary of Current Practice and Desired Outcomes

A meeting was held in August 2019 to discuss Eurobodalla Shire Council's current flood planning processes. The meeting was attended by a range of Council staff across floodplain, planning and development assessment disciplines, as well as DPIE representatives. The key outcomes of the meeting were:

- LEP
  - Council's existing LEP Clause provides a good framework for applying flood related development controls.
  - The LEP Clause has recently been revised and makes reference to Council's adopted Sea Level Rise Policy.
  - Council are seeking direction on whether to include FPA maps within the LEP, the FRMPs or elsewhere. DPIE advised that as long as the FPL is clearly defined in the LEP then the mapping is not necessarily needed to accompany the LEP.
- DCP / Flood Code
  - The LEP Flood Clause (6.5) is not backed up by appropriate details in the DCP or a Code (with the exception of Moruya). Council is seeking guidance on the type of information and requirements within such a Code.
- Council's existing Section 10.7(5) certificates are used to clarify current and future risk; Section 10.7(2) are used to provide information about adopted studies, Public Works Department (PWD) advice from the 1980s, and easements identified by Council's stormwater engineers. A Section 10.7(2) certificate example was provided by Council.
- When development applications (DA's) are received by Council, Council's experience is that there is usually acceptance by the applicant that they have to apply flood related development controls and/or undertake site specific flood investigations, as long as it was already identified on the relevant Section 10.7 Planning Certificate. In some cases, Council identifies potential flood risk for a site that is not currently the subject of an adopted flood study when assessing the development application. The identification of flood-affected sites in this regard is based on the Council engineer's judgement. These are usually related to known overland flow issues or evidence of a low point.
- Development controls relating to overland flow are applied to DAs, however, Council does not have a standard set of controls for this purpose. Council often applies the advice provided by the consultant engaged by the applicant. The selection of an appropriate freeboard for overland flow was discussed, potentially <0.5m when depth of flow is <0.5m.
- Council currently requires flood impact assessments to show "no impact" on neighbouring and downstream properties. There was some discussion about quantifying acceptable impact, this can be discussed further as part of the planning review. If there are recommendations for broadscale filling to address sea level rise, some level of flood impacts may need to be tolerated in the short term (i.e. until neighbouring properties and roads are also filled).
- Both flood hazard and flood function should be considered in flood planning. The draft flood package covers both of these aspects of flooding (Section 5.3).

5.8 Flood Planning Recommendations

The Eurobodalla LEP 2012 currently defines the Flood Planning Level (FPL) as the 100 Year ARI plus 0.5m freeboard. This is shown on **Map Series G901**. At present there is no application of controls for the remainder of the floodplain (up to the extent of the Probable Maximum Flood, which is also shown in on **Map Series G901**). Further discussion on the selection of the Flood Planning Area is provided in **Section 9.1**. It is recommended that the FPA be defined at the 1% AEP plus 0.5m. It is recommended that under the existing ELEP, 2012 and any new LEP that might arise as an outcome of the LSPS process (Section 5.4) be generally retained as the 100 Year ARI plus 0.5 m (also referred to as the 1%AEP plus 0.5 m). It is recommended that any LEP revisions made consider the wording proposed for LEP clauses as per those in the Draft Flood Prone Land Package (Section 5.3). This will address the considerations of flood function and flood hazard.

Council's current DCPs (Section 5.5) do not currently contain comprehensive flood related controls for mainstream or overland flow flooding. Although it is also noted that Council does not currently have any specific overland flow studies completed. It is noted that the Draft LSPS makes reference to the introduction of a Council-wide Flood Management Code. Any such code would need to be consistent with the provisions of the LEP. The code would need to be consistent with the provisions of the Floodplain Development Manual (2005) or any updated Manual.

It is therefore recommended that:

- Council formally adopt this flood study and the associated maps and that all affected lots attract a Section 10.7(2) notation to indicate that flood-related development controls apply. In this regard, all flood-affected lots should become Flood Control Lots to ensure that exempt and complying development provisions under the State Environmental Planning Policy (Exempt and Complying Development Codes) 2008 do not apply to flood-affected lots.
- Council prepare a Flood Management Code to apply to various types of development within the floodplain. This should include:
    - How to determine whether the development is compatible with the flood function and the flood hazard of the land (as defined in the mapping in this study)
    - How to demonstrate the presence or absence of an adverse impact on flood behaviour on other properties or the alteration of flow distributions and velocities to the detriment of other properties or the environment of the floodplain
    - How to determine expectations for evacuation and whether there will be an adverse affect on the safe and efficient evacuation from the land or impact the capacity of existing evacuation routes for the surrounding area,
    - Council's expectations on appropriate measures to manage risk to life from flood,
    - How to determine that a site will not increase the potential for hazardous material to pollute the environment during flood events, and
    - What Flood-compatible building materials are considered acceptable (where some portion of the building is located below the flood planning level or the Probable Maximum Flood for Special Flood Considerations).
    - What Council's expectations are with regard to how climate change risk is addressed.
- Council seek to modify Clause 6.5 of the ELEP 2012 to the adopted clauses in the Standard Instrument when the Draft Flood Prone Land Package is finalised (which would be expected to be later in 2020).
- Council seek to add an additional clause to the ELEP to address Special Flood Considerations (which are not currently considered).

- Council consider whether there are existing land zonings that are incompatible with flood risk in the revision of the LEP and prepare a Planning Proposal for the alteration of the zone to a more flood-compatible zone.

The Moruya Floodplain Code (2012) provides a foundation for the LGA-wide Floodplain Code. However, contemporary flood risk management matters as listed above should be incorporated in the Code to ensure it is relevant for all floodplains across the LGA.

Any requirements contained within the LGA-wide Floodplain Code should be cross checked against the provisions of the National Construction Code (2019) to ensure that there are no gaps or inconsistencies. In some cases, consent conditions may need to be imposed where a specific provision should over-ride any standard provision in the NCC for conditions where a performance solution might be required (e.g. where flood depths are greater than 1.5m, being the limit of the provisions of the NCC, 2019).

6 Flood Modelling

6.1 Flood Modelling Approach

The approach to flood modelling for this project has been to develop site specific modelling approaches for each catchment considering the most appropriate methods of assessing hydrology, 1D / 2D hydraulics, ICOLL entrance behaviour, the influence of coastal processes and the impacts of hydraulic structures.

An integrated modelling system has been developed using TUFLOW as the 1D / 2D hydraulic modelling system for the representation of the hydraulics within the floodplains. The modelling approach for each catchment is provided in **Section 6.4**.

6.2 Hydrological Analysis

The hydrological modelling has been completed using the hydrological model in XP-RAFTS. Each of the catchments have been established as a separate model with the subcatchment delineation based on the supplied LiDAR information. The subcatchment delineation is shown in **Map G601**.

The hydrology has been based on Australian Rainfall and Runoff 2019 (ARR2019) with the parameters extracted from the ARR DataHub shown in **Table 6-1** (extracted 21 February 2020).

Inputs to the model and the data sources for those inputs are summarised in **Table 6-2**.

Table 6-1 ARR DataHub MetaData

Parameter	Value
Latitude	-35.697
Longitude	150.247
Storm Initial Losses (mm)	27
Storm Continuing Losses (mm/h)	6.9
River Region - Division	South East Coast (NSW)
River Region - Number	16
River Region	Clyde River-Jervis Bay
Point Temporal Pattern Code	SSmainland
Point Temporal Pattern Label	Southern Slopes (Vic/NSW)
Areal Temporal Pattern Code	SSmainland
Areal Temporal Pattern Label	Southern Slopes (Vic/NSW)
Version	2016_v2

Table 6-2 Hydrological Model Input Data

Parameter	Data Source
Sub-catchment area and slope	LiDAR data is available for full catchment.
Percentage impervious	Percentage impervious areas are largely a factor of development intensity and can be determined from aerial imagery. High resolution aerial imagery has been provided by Council and will be supplemented by freely available online imagery.
Roughness	Roughness parameters influence how quickly runoff occurs in a sub-catchment. Similar to the percentage impervious, the values have been determined from an examination of aerial imagery and have been largely dependent on land use. Delineation of roughness zones refer to Council's LEP mapping, particularly in areas that are undergoing development or redevelopment.
Runoff routing	Routing refers to the transfer of flows from one sub-catchment to another. This routing can be done in XP-RAFTS through either specifying a lag time between sub-catchments (10 minutes for example) or inputting a typical cross section, roughness and length and allowing XP-RAFTS to compute the lag time based on the flow volume. For this model, the cross section methodology has been adopted, with the sections being extracted from the available terrain and survey data.
Rainfall losses	Under the new methodology set out in ARR2019, rainfall parameters for hydrological modelling are all available from the ARR Data Hub. The parameters relevant to the modelling locations have been downloaded directly from this website. Data have been adopted and used in accordance with the DPIE Floodplain Risk Management Guide (2018).
Rainfall intensities	
Rainfall hyetograph	

6.2.1 Application of ARR2019

The new ARR2019 has a number of changes to the hydrological methods that have been traditionally employed. This includes updated design rainfall intensities, new ensemble storms and other catchment parameters such as losses.

One of the key challenges with the new approaches is the application of ensemble storms, with a number of storms to be run for each duration. This can result in challenges for large direct rainfall models, where it can be difficult to analyse all the temporal patterns due to the run times involved.

Our approach in the current study has been to run the full set of durations and temporal patterns through the XP-RAFTS model to determine the critical duration(s).

The critical duration(s) were then run through the hydraulic model for each of the 10 temporal patterns.

The results were then processed to:

- Extract the median plus one event from the 10 temporal patterns for each duration, and
- Extract the peak median from the set of durations.

6.3 DEM Development

A Digital Elevation Model (DEM) has been developed for input into the hydraulic models. This DEM is based on the survey data collected, including the LiDAR and ground survey. This DEM covers all the individual catchment areas.

One of the important components in the development of hydraulic models is to ensure that key hydraulic controls and features are defined appropriately within the DEM. This includes features such as embankment crest details, road levels where roads overtop etc. These have been incorporated where appropriate through the use of breaklines and other features, using the 12d ground modelling software.

6.4 Hydraulic Analysis

6.4.1 Hydraulic Model Areas

Based on a combination of preliminary 1% AEP rainfall on grid analysis, site inspections and discussions with the community, an 'area of interest' for each catchment has been identified. This represents the hydraulic modelling areas. This also represents the area within which catchment flooding may be significant and locations where flooding may pose risk to property and / or life. The hydraulic model areas are shown in **Map G602.**

6.4.2 Coastal Processes

Council recently completed a comprehensive coastal hazard assessment (WRL, 2017) that included the assessment of coastal water levels, waves, shoreline inundation and coastal erosion. This flood study leverages off the results of that study, specifically the coastal water levels inclusive of wind and wave setup, to define appropriate coastal boundary conditions consistent with guidance in the Floodplain Management Manual (NSW Government, 2005). Timeseries information of coastal water levels has been sourced from the Princess Jetty tide gauge to allow the consideration of tidal phasing with catchment flooding and define the High High Water Solstices Springs (HHWSS) up the reaches of each of the creeks.

6.4.3 Grid Cell Resolution

The urban areas of the study area will require a grid cell resolution fine enough to appropriately define flood risk. Based on site inspections and initial hydraulic model runs, a grid cell of 3 x 3 metres was adopted, which provided a reasonable balance in model run times and representation of flood behaviour.

6.4.4 1D Components

Stormwater infrastructure and culvert crossings within the study area has been included within the 1D portion of the model, with the floodplain defined in the 2D domain. Stormwater drainage, to a minimum pipe diameter of 600mm, has been included where it is available in Council's data sets and from the available survey data. Some smaller pipe reaches were included in order to extend the pipe network to road sag points, or where they provided a localised connection to an inlet pit.

Some regions of the pipe network had missing data for both inverts and pipe sizes. This data was infilled based on the following assumptions:

- 600mm cover of pipes and culverts, unless otherwise suggested by nearby survey.
- Missing pipe sizes were assumed to be the same as the largest of any upstream pipes.
- For a reach of pipes with missing data where sizes increased dramatically between known upstream and downstream sizes, a stepped increase was assumed through the missing reach.

6.4.5 Roughness

Roughness values extents were determined based on land use mapping and aerial photography, with reference made to ARR Project 15. The values adopted are summarised in **Table 6-3** and shown in **Map G603**.

Table 6-3 Adopted Roughness Values

Land Use	Manning's 'n'
Open space	0.035
Neighbourhood Centre (including building footprint)	0.250
Mixed Use (including building footprints)	0.200
Low Density Residential (including building footprints)	0.150
Recreation	0.040
Dense vegetation	0.080
Light vegetation	0.045
Medium Vegetation	0.060
Roads / Carparks	0.020

6.4.6 Buildings

There are several ways that buildings can be incorporated within a hydraulic model.

Buildings were typically incorporated using an increased lot roughness to account for the structures. The exception was the commercial buildings in the Water Gardens catchment.

Buildings within this region were incorporated as null objects, which effectively removes them from the model domain. The flowpaths were identified based on preliminary runs of the PMF event. Buildings were only nulled within the flood extents (refer **Map G602**).

6.4.7 Fences

There are numerous ways to incorporate fences within a 2D hydraulic model. While the techniques can be quite advanced, the reality is that the behaviour of fences in flooding can be quite uncertain and difficult to represent appropriately. Fences have been incorporated in the hydraulic model through a property averaged roughness value.

6.4.8 Downstream Boundary Conditions

Individual downstream water levels were determined for each catchment area, taking into account the offshore water level, wind setup, storm tide and wave set up. A full discussion on the derivation is provided in Appendix B.

Downstream water levels were prepared for the high high water springs solstice tide and the 5% AEP and 1% AEP ocean flood events. The HHWSS was constant at 0.91mAHD for all catchment areas. The derived entrance conditions and boundary levels are summarised below for the 5% AEP and 1% AEP ocean events in **Table 6-4**.

Details on how the ICOLL entrances scour during a flood event were modelled is provided in **Section 6.4.9.**

Table 6-4 Downstream Boundary Conditions

Location	Entrance Berm Height (mAHD)	5% AEP Ocean Level (mAHD)	1% AEP Ocean Level (mAHD)
Maloneys Beach	2.1	2.03	2.13
Long Beach	3.5	2.18	2.31
Surfside	1.5	1.96	2.03
Water Gardens	Permanently open	2.08	2.22
Catalina	Permanently open	2.09	2.21
Batehaven	2.3	1.72	1.82
Sunshine Bay	1.3	1.74	1.83

6.4.9 Modelling of the ICOLL Entrances

In modelling ICOLLs, it is possible to adopt a number of methodologies to represent the entrance, depending on how critical the entrance is to upstream behaviour, and how close development is to the entrance. In increasing order of accuracy, these options include:

- Option 1 - Modelling the entrance as fully closed and fully open in the hydraulic model and taking an envelope of these results. This precludes the need to determine how the entrance scours and is suitable for systems where development is away from the entrance, or the entrance has a minor impact on peak flood levels, regardless of its condition.
- Option 2 - Modelling the failure of the entrance using a terrain varying function or “dam break” style process in the hydraulic model. This approach simulates the scouring of the entrance. The breakout mechanism will be defined based on the geometry of the entrance (i.e. the lateral extent of the entrance), upstream flow regime and the experience of the project team with modelling ICOLL entrance breakout processes. This approach is generally suitable for small ICOLLs, or where development around the entrance is limited
- Option 3 - The most accurate (and resource intensive) method is to construct a hydrodynamic model of the ICOLL entrance, whereby the model determines the progression of the entrance failure based on flow conditions, and the material of the entrance. This level of accuracy may be warranted for large systems where significant development is located close to the entrance, and a detailed understanding of how the entrance behaves in flood events is required. Under this approach, the entrance breakout in TUFLOW will be defined as a “dam break” style process, but with the breakout timing defined based on a Delft3D model of the entrance. A localised Delft3D model of the creek entrance will be established, driven by upstream flows from the hydraulic flood model and by coastal water levels on the downstream boundary. The rate of entrance channel growth (i.e. entrance berm scour) will then be parametrised for input as a dam break in the TUFLOW model.

The approaches adopted for the specific entrances are discussed in **Table 6-5**.

Table 6-5 Modelling Approach

Catchment	Modelling Approach
Maloney's Beach (Maloney's Lagoon)	TUFLOW model covers the downstream catchment, incorporating the township and the entrance. The wider catchment is modelled in the hydrological model, with flow inputs applied at the extents of the hydraulic model. The entrance has been modelled using a dam break approach in TUFLOW (Option 2)
Long Beach Lagoon	TUFLOW model covers the lagoon and immediate foreshore areas. The topography rises steeply from the foreshore areas. The beachfront road and properties also included. The model assumes the lagoon starting level to be equal to the LiDAR level. The entrance has been modelled using a dam break approach in TUFLOW (Option 2)
Surfside Creek	TUFLOW model extends just upstream of Princes Highway on the main waterway but not on tributaries to the south west of the main waterway. The model assumes the lagoon to be full at the start of the storm. The outlet is unlikely to be all that sensitive to the berm due to the small pipes under the road. The entrance has been modelled using a dam break approach in TUFLOW (Option 2).
Water Gardens and Hanging Rock Creek	There are possible cross catchment flows so both Water Gardens and Hanging Rock Creek catchment areas are combined into one TUFLOW model. The model is extended to Princes Highway at the downstream end to better understand flooding in the CBD. Hanging Rock Creek entrance is modelled as an open entrance in TUFLOW (Option 1), this assumes the flood gates are open. Downstream of Water Gardens is controlled by a culvert outlet under the road which has been modelled in TUFLOW (Option 1).
Joes Creek	The entrance and lagoon breakout has been modelled in a dedicated hydrodynamic model. (refer **Section 6.4.9.1**)
Short Beach Creek	Given the short breakout distance required and the flow controls imposed by the bridge immediately upstream, a time varying terrain layer has been adopted to model the opening of this entrance (Option 2).

6.4.9.1 Hydrodynamic Modelling of Joes Lagoon Entrance

Hydrodynamic modelling of the Joes Lagoon entrance was undertaken using a Delft3D model, prepared by Baird.

Catchment inflows at the Beach Road bridge were extracted from the RAFTS model. This location acts as a culvert, channelling discharge into the ICOLL at a single location. The maximum discharge was aligned to the time of high coastal water level, the joint occurrence of which was determined using the guidelines provided by the former Office of Environment and Heritage (OEH, 2015), namely:

- For 5% AEP, 10% AEP and 20% AEP catchment flood events, the HHWSS tide for Batemans Bay was applied
- For 1% AEP and 2% AEP floods, a storm tide of 5% AEP was used
- For flood events 0.2% AEP, 0.5% AEP and PMF (nominally defined as 0.0001% AEP), a storm tide of 1% AEP was applied.

The Delft 3D-Flow model used 2018 LIDAR bathymetry of Joes Creek, and a berm height of 2.3 m AHD. An observation point to obtain the downstream boundary conditions provided in this report was placed in the lagoon landward of the entrance beach berm. The model was run for two days, ensuring maximum flooding levels were captured. Timesteps were set at 0.125s to accurately capture breakout over the berm and model maximum flooding.

The model was run for the full ensemble of storms, as per the ARR2019 guidance.

The levels reported from the Delft3D model were then incorporated in the TUFLOW model as downstream boundary levels.

7 Model Calibration, Validation and Sensitivity

7.1 Model Calibration / Validation

In a typical flood study, a calibration is undertaken by comparing observed flood behaviour, including recorded flood levels where available, against the flood behaviour determined from the flood model. This is done by obtaining or estimating the historical rainfall on the catchment for a particular historical flood event, and then reviewing the flood behaviour in the flood model to determine if it is consistent with observations. This provides greater confidence in the flood model results and assists in understanding the level of potential uncertainty.

In the Batemans Bay catchment areas, as identified in **Section 3.6**, there is a lack of historical pluviometers within the catchments. The nearest pluviometer gauge is located at Moruya Airport, approximately 20 kilometres from the catchment.

In addition to the rainfall data, many of the historical flood observations from the community (**Section 4**) were not specific to a particular date or flood event. In many cases, residents recalled a general period of time (for example, around 15 – 20 years ago), or a general frequency (for example, inundation of a particular area occurs every few years). This makes it difficult to assign a particular flood behaviour that was observed against a particular historical storm event.

Due to these challenges, it was agreed with Council that a full calibration against historical events would not be undertaken. Instead, an indirect validation was undertaken on the modelling. This validation has two key components:

- A review of the historical rainfall intensities – this provides an indication of the frequency and magnitude of historical events within the catchment (**Section 7.1.1**); and,
- A comparison of the modelled design events against the observations by the community (**Section 7.1.2**).

The outcomes of these analyses have been used to refine and confirm the various assumptions made within the model setup. It is noted however, that where ICOLL entrances have an impact on flood levels the historic entrance berm level may not be known.

7.1.1 Rainfall Intensity Assessment

An assessment of rainfall data can provide an indication of the magnitude of the rainfall events that may have been experienced within the catchment. The nearest rainfall gauge to the study area with pluviometer data available is the Moruya Airport gauge (refer to **Section 3.6** and **Map G303** for gauge details and location). This gauge is approximately 20 kilometres from the catchment areas to the south and an analysis of the rainfall may not necessarily represent local rainfall that falls on the catchment due to the variable nature of rainfall patterns in this area.

A common approach when there is no gauge within a catchment is to review surrounding rainfall gauges to understand how a storm event may have moved across the catchment and allow for an interpolation of the likely rainfall that fell on the catchment. Unfortunately, the next nearest pluviometer for the historical events that were identified was over 40 kilometres to the west, at the top of the ranges in Araluen. This makes it difficult to determine any localised movement of the rainfall during the period of a storm event.

An alternative is to use daily rainfall gauges. However, the Batemans Bay catchment areas typically respond to shorter duration rainfall events (i.e. up to 6-hour events). Understanding how these rainfall events move across a catchment is difficult to represent through a daily read rainfall gauge.

To provide an indication of the general magnitude of historical rainfall events that were identified by the community (**Section 4**), an analysis of the Moruya Airport gauge was undertaken. Design rainfalls for ARR2019 IFD data for design events was sourced from the BoM and are summarised on the log plot in **Figure 7-1**. Average rainfalls were determined for each of the historical events for durations ranging from 30 minutes to 6 hours. These historical events are the five largest storms recorded at the pluviostation, and all occurred within the last 20 years.

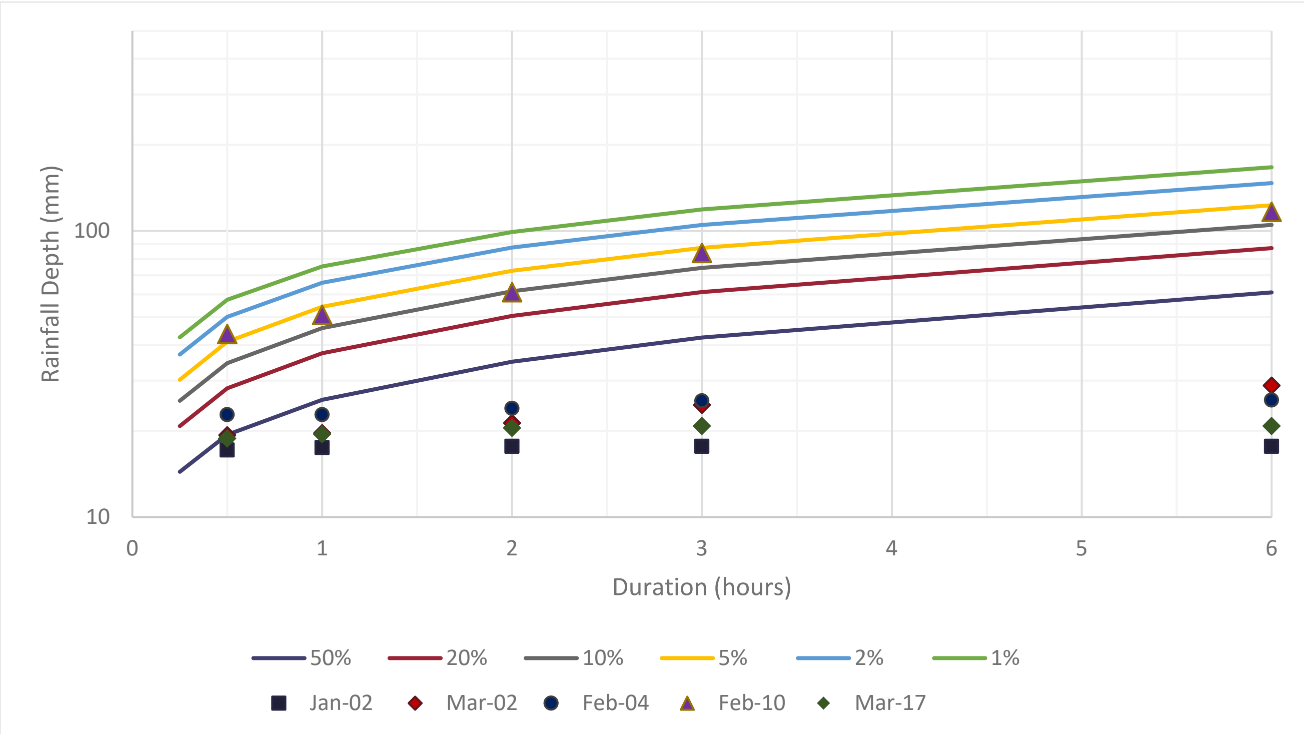


Figure 7-1 **Moruya Airport Gauge Historical Event Intensity Compared to ARR2019 Intensity**

The rainfall assessment showed that all of the events, save the February 2010 event, were very short duration storms, with rainfall being most critical for the 30 minute duration. All the short duration events were relatively small, in the order of a 50% to 20% AEP.

The February 2010 event was a larger event, with more sustained rainfall. The rainfall from the event was in the order of a 5% AEP event, for durations from 30 minutes to 6 hours.

A comparison of the largest rainfall events on record at the Moruya Airport gauge were also compared against the responses from the community collected as part of the mailout and community workshop (**Table 7-1**).

Table 7-1 Comparison of Gauge Record and Community Observations

Event	Approximate AEP	Mentioned by Community in Survey/ Door Knocking
January 2002	50% AEP	No
March 2002	50% AEP	No
February 2004	50% - 20% AEP	No
February 2010	5% AEP	No
March 2017	50% AEP	Yes

While the sizes of the rainfall events at the gauge are generally modest, it is of interest that only one of these events were identified or recollected by residents during the community survey. Conversely, a number of community responses noted a flood event in January 2014, which was not recorded as a significant event at the Moruya Airport gauge. This would suggest that there is variability in the local rainfall patterns particularly for short duration storms and, therefore, the rainfall at the Moruya Airport gauge is not always representative of the rainfall in the catchment and should be considered on a case by case basis in future studies.

7.1.2 Comparison with Community Survey Descriptions

As a part of the community survey and drop in sessions, there was information obtained on general flood behaviour (**Section 4**). This was not always specific to a particular event, or in many cases a general period was recalled. However, it provides useful information on the flood behaviour.

An indirect verification of the modelling was undertaken by comparing the flood behaviour in the model for the 1% AEP event against the observations from the community.

The generalised descriptions of flood behaviour, together with the modelled behaviour, is provided in **Map G701**. The map indicates a general level of consistency between the modelling and the observations from the community.

7.2 Sensitivity Analysis

Sensitivity analysis is a useful tool in understanding the potential variability of model results with different parameter assumptions. The following sensitivity analyses have been undertaken:

- Rainfall losses;
- Lag Time;
- Rainfall Intensity;
- Model roughness;
- Model inflows; and,
- Downstream boundary conditions.

7.2.1 Hydrological Sensitivities

The sensitivity of the modelling to rainfall losses, lag time and rainfall intensity were undertaken in the hydrological model. The testing was done on two catchment areas:

- Water Gardens (a small highly urban catchment)
- Batehaven (a larger catchment with large areas of open space and vegetation)

The results of the sensitivity testing are shown in **Table 7-2**.

Overall, the models were very insensitive to changes in lag time, and marginally more sensitive to changes in rainfall intensity than rainfall losses. The smaller Water Gardens catchment was more sensitive to all changes than the larger Batehaven catchment.

The insensitivity to the lag parameter is likely due to the fact that the models have relatively few subcatchment areas (around 10 to 15) so changes in timing are not given the opportunity to substantially affect outlet flows.

While a greater sensitivity was observed for both rainfall losses and rainfall intensity, neither resulted in substantially different peak flows given the scale of the parameter change. A 20% variation in both these parameters typically delivered a 15 – 25% change in peak flows.

Table 7-2 Hydrological Sensitivity

Parameter	Parameter Change	Peak Flow Rate Change
Water Gardens		
Rainfall Loss	+20%	+25.0%
	-20%	-15.9%
Lag Time	+20%	+10.4%
	-20%	-16.8%
Rainfall Intensity	+20%	+26.0%
	-20%	-25.3%
Batehaven		
Rainfall Loss	+20%	+18.2%
	-20%	-13.0%
Lag Time	+20%	+6.7%
	-20%	-4.9%
Rainfall Intensity	+20%	+23.8%
	-20%	-24.4%

7.2.2 Hydraulic Model Sensitivities

The sensitivity of the hydraulic model to inflows, roughness and downstream boundary conditions was assessed for the 1% AEP event. The results are shown in:

- Map Series G702 for a 20% increase in flows
- Map Series G703 for a 20% decrease in flows
- Map Series G704 for a 20% increase in roughness
- Map Series G705 for a 20% decrease in roughness
- Map Series G706 for a 20% increase in downstream levels
- Map Series G707 for a 20% decrease in downstream levels.

The results show that the model is reasonably sensitive to flow increases and downstream boundary levels, marginally sensitive to flow decreases, and relatively insensitive to roughness changes.

As a result of a 20% increase in flows, increases in peak levels of 0.1 – 0.2 metres occurred in all catchment areas. Those regions with storage driven flood behaviour such as Maloneys Beach, Long Beach and Batehaven showed the most significant increases. While isolated pockets in the other catchments did show increases in the 0.1 – 0.2 metres range, typical changes in these non-storage driven systems were in the order of 0.05 – 0.1 metres.

Changes arising from a 20% reduction in flows were more modest, both in size and extent. Reductions were relatively constant across all catchment areas, in the order of 0.1 – 0.15 metres, and generally focused on areas of storage or local depressions.

The models were relatively sensitive to downstream boundary levels. Increases in the boundary levels resulted in water level increases propagating over 1.5km upstream of the shore in Surfside, Catalina and Batehaven. Impacts in catchments with more controlled entrance conditions such as Maloneys Beach and Long Beach were smaller for both increased and decreased downstream levels. The low lying areas of Surfside, Catalina and Batehaven were particularly sensitive to water level changes.

The model was relatively insensitive to changes in roughness values. The 20% change in roughness values typically resulted in in changes of less than 0.03m. Larger differences of +/- 0.05m were observed in the Maloneys Beach and Batehaven catchment areas.

8 Understanding Flood Behaviour

8.1 Design Flood Behaviour

Peak flood depths (with water level contours) and velocities are provided in **Map Series G801** and **G802** respectively**.** Maps have been prepared for the 10% AEP, 1% AEP and PMF events.

The full set of data for all design events (PMF, 0.2% AEP, 0.5% AEP 1% AEP, 2% AEP, 5% AEP and 10% AEP events) has been provided to Council in a digital format.

Published maps are an envelope of a number of durations. The methodology for prepare the maps involved:

- The determination of the median event for each duration and recurrence interval.
- The determination of the maximum of the median values for each recurrence interval.

The 1% AEP has additional results included in the envelope, as per the guidance in the *Floodplain Risk Management Guide* (OEH, 2015), namely:

- Results from a 5% AEP catchment flood, coupled with a 1% AEP ocean surge which assessed flooding driven by ocean events; and,
- Results from a 1% catchment flood coupled with an Indian Spring Low Water (ISLW) tide to assess peak velocities at the entrances.

Both processed envelopes and raw results for all duration and recurrence interval combinations have been provided electronically to Council.

8.1.1 Maloneys Beach

As a result of the large storage provided by the lake upstream of the township, and the natural restriction at the lake outlet provided by the creek, flooding within the Maloneys Beach catchment is generally well contained within the creek system for events up to and including the 1% AEP.

The exception to this is at the bend in Maloneys Creek immediately upstream of the entrance, where some localised overbank flows commence in the 10% AEP. This results in inundation of properties at the western end of Pendula Place by 0.2m in the 10% AEP and up to 0.7m in the 1% AEP.

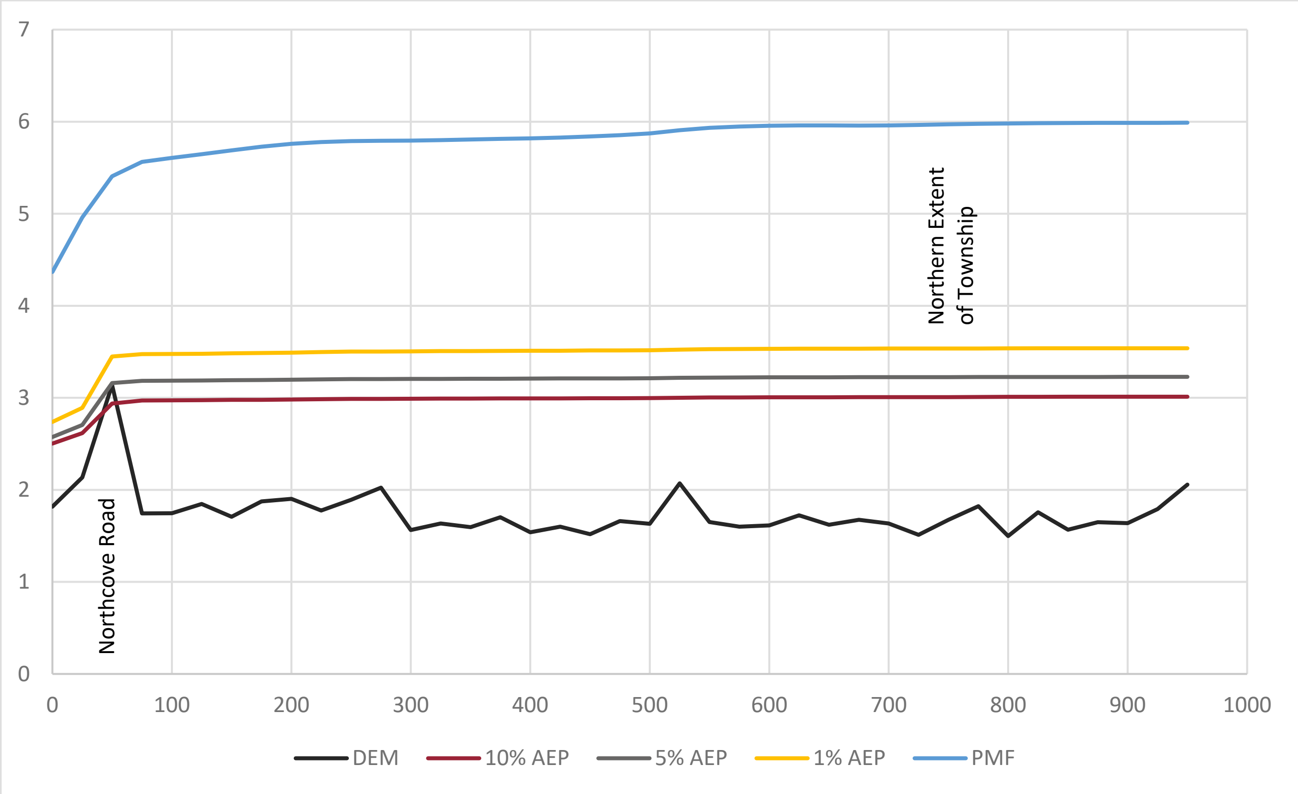
In the 1% AEP event overtopping of 0.6m occurs across Northcove Road at the creek crossing, isolating the township.

In the PMF, flow breaks out of both the lake and the adjacent creek to inundate the entirety of the township. Depth are most significant in the north, adjacent to the lake, with property flooding depths of up to 1.7m occurring in the PMF. Depths of over 1m occur across the majority of the township in the PMF, reducing to 0.2m Belbowie Parade as the terrain rises to the local high point at Maloneys Drive.

Velocities remain low across the catchment for all events. Even in the PMF, creek velocities do not exceed 1m/s. Velocities across the township are less than 0.5m/s in the PMF, although higher velocities of up to 0.8m/s occur within the road reserves.

The exception to this behaviour is the outlet, which sees velocities of 3.1, 2.3 and 4.3 in the 10% AEP, 1% AEP and PMF events, respectively. The velocities in the 10% AEP are higher at the entrance than the 1% AEP as a result of the lower ocean level when the entrance breaks out.

A long-section is shown in **Figure 8-1**.



7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
900
1000
Northcove Road
Northern Extent of Township
DEM
10% AEP
5% AEP
1% AEP
PMF

Long-Section
1% AEP Depth (m)
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4
MALONEYS DRIVE
BOTTLEBRUSH PLACE
BLUE GUM PARADE
TRISTANIA PARADE
WILLOW COURT
EUGENIA PLACE
EXCELSA COURT
PENDULA PLACE
BELBOWRIE PARADE
CEDAR PARADE
NORTHCOVE ROAD

Figure 8-1 Maloneys Beach Long-Section

8.1.2 Long Beach

The flood affectation in Long Beach is minor, due to a combination of the relatively small catchment area, the large lake storage, and the substantial outlet control provided by the small outlet channel. These conditions result in no property flooding in events up to and including the 1% AEP event.

In the PMF event, some property flooding occurs as flow breaks out from the outlet channel at Sandy Place and from the lake directly at the intersection of Blairs Road and Sandy Place. Depths of up to 1.2m occur at properties adjacent to the outlet channel. Depths at the lake breakout are more modest, with property flooding depths of up to 0.5m occurring and 1.1m depths occurring across the intersection.

Velocities of up to 0.8 meters per second occur across properties adjacent to the outlet channel. As the flooding from the lake breakout is driven by lake flooding, and does not flow through to the bay, the velocities for properties affected by this flooding are very low, in the order of 0.1m/s.

A long-section is shown in **Figure 8-2**.

8.1.3 Surfside

The Surfside catchment has a number of locations that act, whether naturally or by design, as detention basins. The Princes Highway creates a large basin on the upstream side where the main channel crosses. Additional water bodies on the eastern and western sides of Batemans Bay Public School provide further storage, with their outlets controlled by small downstream watercourses.

In the 10% AEP event, flows are fully contained within the creek system.

In the 1% AEP, some properties experience flooding along Timbara Crescent due to elevated ocean levels. For the majority of these properties, flooding is confined to the rear of the lots, and does not impact dwellings. Immediately upstream of the Timbara Crescent and Wharf Road intersection, two properties are affected by flood depths of up to 0.5m in the 1% AEP.

Inundation also affects a number of properties on Foam Street, Wallaringa Street and Myamba Parade in the 1% AEP event, most significantly at the western ends around the intersections with Wimbarra Crescent. Local depressions adjacent to The Vista also result in ponding depths of up to 0.5m in the 1% AEP event.

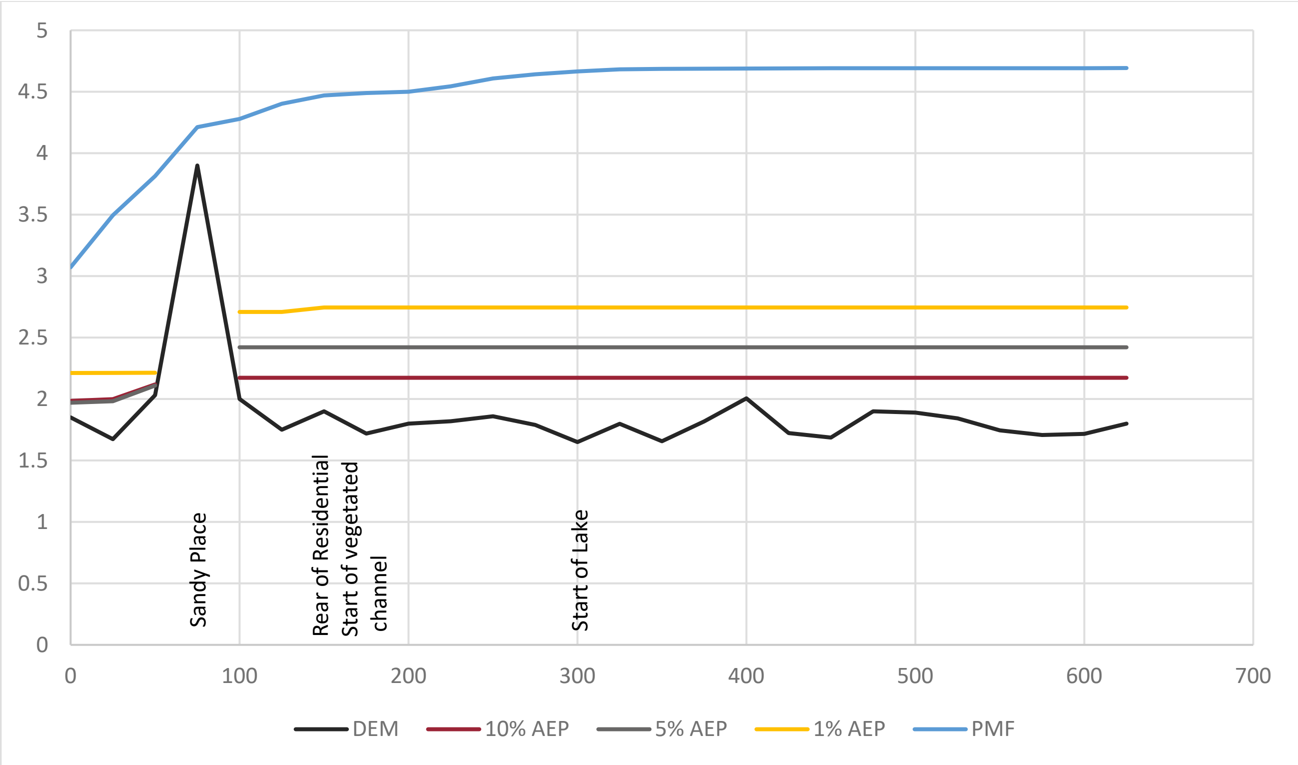
In the PMF event, elevated ocean levels result in widespread flooding across the region bound by Timbara Crescent by depths of up to 0.8m.

Batemans Bay Public School is also flooded by up to 0.3m across some buildings, 0.4m across the sports fields and up to 1.3m across the Mundarra Way access road.

Overtopping of the Princes Highway occurs in two locations in the PMF, with depths of 0.4m.

Velocities in the creek system are modest in the 1% AEP, with peaks up to 0.6 meters per second. These increase to 1.8m/s in the PMF. As residential flooding is largely driven by ocean levels, velocities across these regions remain below 0.5m up to and including the PMF, although higher velocities are observed within the road reserves.

A long-section is shown in **Figure 8-3**.


5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
Sandy Place
Rear of Residential
Start of vegetated channel
Start of Lake
DEM
10% AEP
5% AEP
1% AEP
PMF


Long-Section
1% AEP Depth (m)
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4
SANDY PLACE

Figure 8-2 Long Beach Long-Section

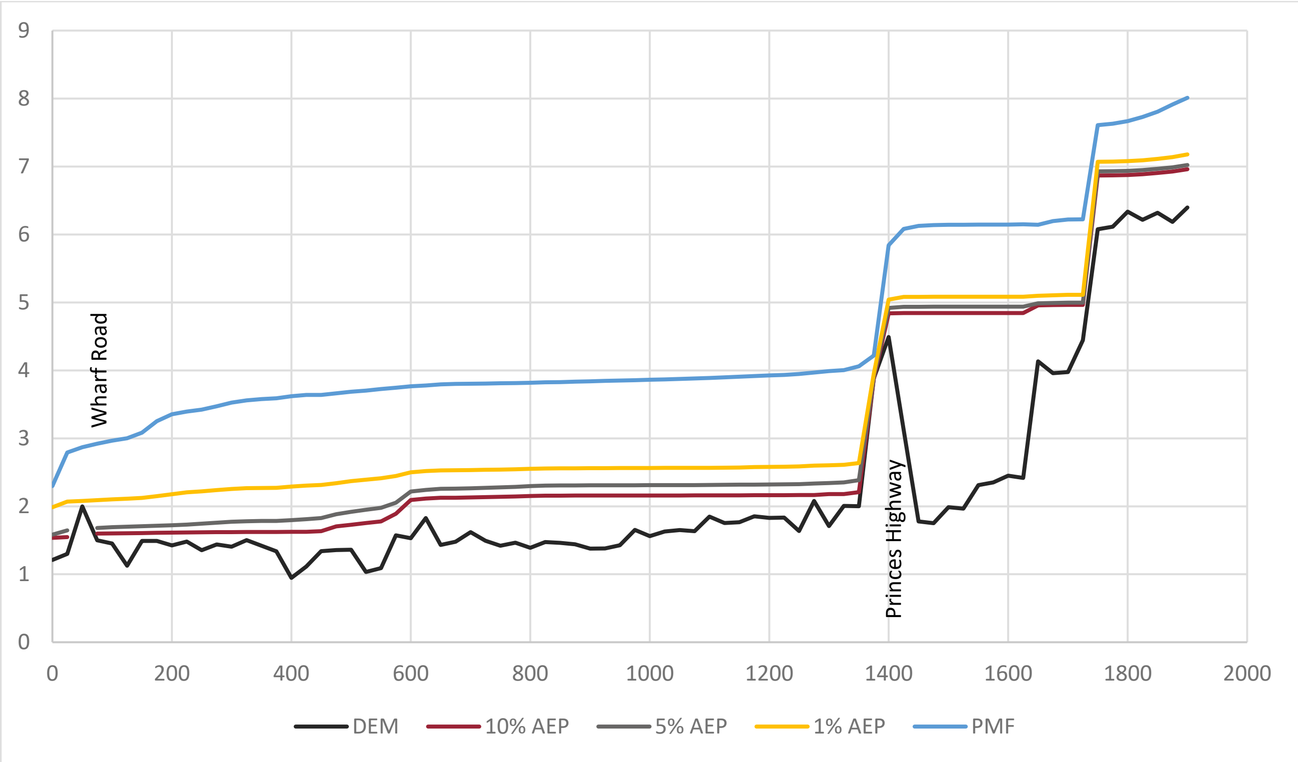


Figure 8-3 Surfside Long-Section

8.1.4 Water Gardens

Unlike the northern catchment areas, property flood affectation commences in more frequent events for the southern subcatchments. Water Gardens experiences property flooding in the 10% AEP, both within the CBD due to catchment flooding, as well as at the low point of Herarde Street and Beach Road. Depths in the CBD reach 0.3m at local low points, due to insufficient capacity in the drainage network. The regions of ponding are generally isolated. The property flooding on Herarde Street is a result of local catchment flows running down Heradale Parade, and then crossing Herarde Street properties and the Argyle Terrace Motor Inn, to discharge into the bay.

In the 1% AEP, flows within the CBD increase with local catchment flows draining out to the bay along the Old Princes Highway and Flora Crescent. The water body within Albert Ryan Park also overtops in the 1% AEP, breaking out through the park and the adjacent Medicare and Centrelink carparks. Flood affectation at the Herarde Street overland flowpath increases significantly in the 1% AEP. Driven by cross catchment flows from the neighbouring Catalina catchment, properties along Herarde Street and Heradale Parade experience depths of up to 0.8m.

The PMF events sees flood depths of up to 1.4m occurring on the Old Princes Highway and 1.2m along Flora Avenue and Beach Road. Flooding driven by elevated ocean levels impacts Clyde Street properties with depths occurring of up to 0.5m. The extent of flooding at the Herarde Street overland flowpath also increases to impact more properties and depths increase to 1.1m.

Velocities are typically low for all events, with velocities of less than 0.5m/s occurring across developed properties in the PMF event. Higher velocities are observed along the road reserves. They are generally less than 1m/s, although increase to 1.2m/s along the Old Princes Highway in the PMF event.

No long-section is shown for Water Gardens due to the highly developed nature of the catchment.

8.1.5 Catalina

The Catalina catchment is dominated by the golf course which covers much of the central region of the catchment, with residential zones located around the course, and between the course and the bay.

Upstream of Beach Road, flood affectation is relatively minor in the 10% AEP event. The golf course experiences widespread, shallow flow across the grounds, but otherwise the upper catchment flows are well contained within the creek corridor. Downstream of Beach Road, however, significant flooding occurs across residential zones located north of Caitlin Avenue (south of Caitlin Avenue is flood affected also but is located in the Batehaven catchment and is discussed below). This flooding arises due to the combined impacts of overbank flow from Hanging Rock Creek, elevated ocean levels, and cross catchment flows from Joes Creek in the Batehaven catchment. Depths of up to 1.2m occur in this region in the 10% AEP event.

In the 1% AEP, flow upstream of the golf course remains well contained. Downstream of the golf course, a wide flowpath inundates much of the region along Golf Links Drive, with depths of up to 0.7m. Flows from the golf course also break out to the north, contributing to the flooding observed along Herarde Street in the Water Gardens catchment (see above). The extent of flooding north of Caitlin Avenue does not increase in the 1% AEP, but the depths increase to up to 1.3m in some locations.

The PMF remains well contained within the upper catchment, although road access along Heron Road is lost. The golf course is fully inundated, as is all the low lying areas north of the golf course. In the PMF, this wide-scale flooding through the downstream region is driven by elevated lake levels. Depths of up to 1.2m and 1.8m occur along Golf Links Drive and Cailtin Avenue respectively.

As a result of the wide, shallow flow behaviour and the elevated lake levels, velocities remain typically low for all events. The 1% AEP event sees only isolated reaches exceed 1.0m/s, with the majority of the flow below 0.5m/s. This behaviour remains consistent in the PMF, save for where Hanging Rock Creeks breaks into the golf course. In the PMF event velocities of up to 2.4m/s were observed in this area.

A long-section is shown in **Figure 8-4**.

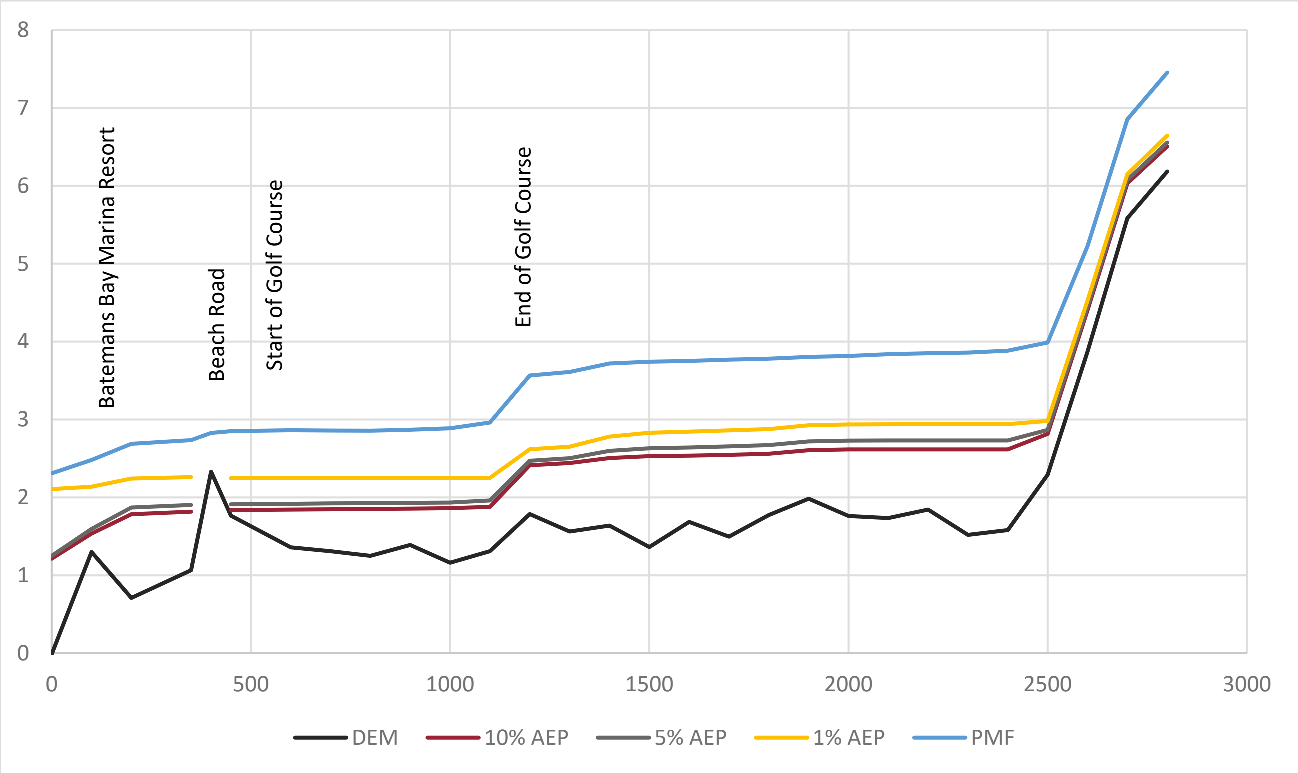


Figure 8-4 Catalina Long-Section

8.1.6 Batehaven

Joes Creek runs through the centre of the Batehaven catchment. In the 10% AEP event, there is no property flooding upstream of Beach Road, however road access is lost along George Bass Drive (0.45m), Calga Crescent (0.34m), Melaleuca Crescent (0.57m) and Glenella Road (0.21m). The region downstream of Beach Road is mostly inundated in the 10% AEP, by depths of 0.4 – 0.7m. This flooding is driven by breakout flow from Joes Creek at the entrance, and affects Clyde View Holiday Park, Big 4 Bay Beach Resort and the Batemans Bay basketball and tennis centre.

In the 1% AEP event, properties along are affected along Edward Avenue by depths of up to 0.78m, and Melaleuca Crescent by up to 0.27m. Downstream of Beach Road, the flood extent remains similar but depths increase from 0.4 – 0.7m to 0.6 – 1.2m.

The PMF event results in significant break out flows from Joes Creek, inundating large numbers of properties along Melaleuca Crescent, Edward Avenue, Clara Crescent, Christopher Crescent, Matthew Parade and Beach Road. Downstream of Beach Road levels increase to 1.2 – 1.4m.

Velocities typically remain low in events up to the 1% AEP, with peaks of less than 1m/s across the catchment, save for the entrance and some road reserves. In the PMF, Joes Creek velocities increase to 2.5m/s in the upper catchment and 1.5 – 2m/s through the downstream reaches. Velocities remain less than 1m/s across residential and commercial areas in the PMF.

A long-section is shown in **Figure 8-5**.

8.1.7 Sunshine Bay

The Sunshine Bay catchment has two tourist parks in the lower reaches of the catchment, Caseys Holiday Park and Pleasurelea Tourist Resort. Both of these sites experience flooding in the 10% AEP event, with depths up to 0.7m in both locations. These depths increase to 1.1m in the 1% AEP and 2.2m in the PMF.

Velocities remain low at these locations for all modelled events, with peaks below 0.5m/s for all modelled events.

With the exception of these two locations, flows are generally well contained in the 10% AEP. There is some overtopping of John Street by up to 0.3m, but otherwise flow is fully contained within the creeks and channels.

In the 1% AEP event, the rear of properties along Beach Road are inundated, and overtopping occurs along Sunshine Road and Edward Road by 0.7m and 0.2m, respectively.

The PMF event results in increased affectation along Beach Road, as well as the inundation of St Bernard's Primary School. In the upstream reaches of the catchment, significant overtopping depths occur across Sunshine Road (2m), Edward Road (1.4m), George Bass Drive (0.9m) and Crosby Drive (0.9m) but no additional property affectation is observed.

Velocities remain low up to and including the 1% AEP for the majority of the catchment, the exceptions being the steeper vegetated reaches upstream of George Bass Drive and the entrance, which see velocities of up to 1.4 and 2.2m/s respectively.

In the PMF, velocities of 0.8 to 1.5m/s are observed through Short Beach Creek, and 4.1m/s at the entrance.

A long-section is shown in **Figure 8-6**.

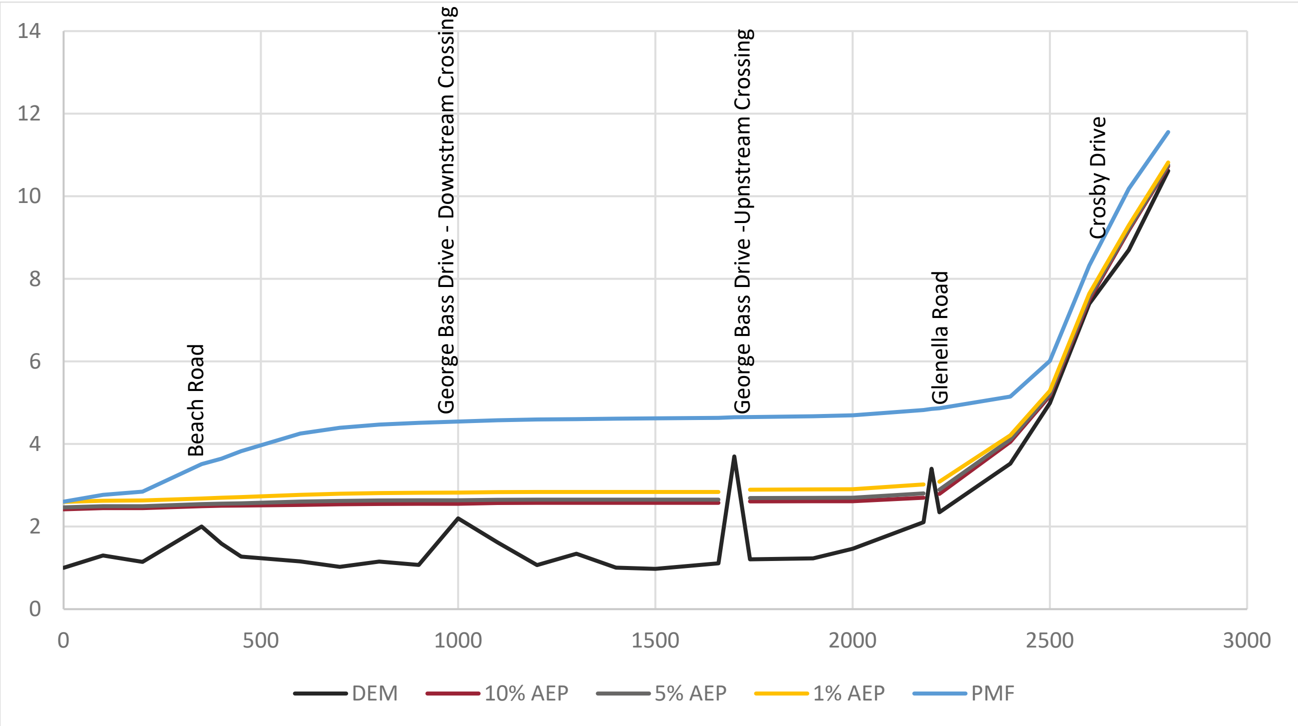


Figure 8-5 Batehaven Long-Section

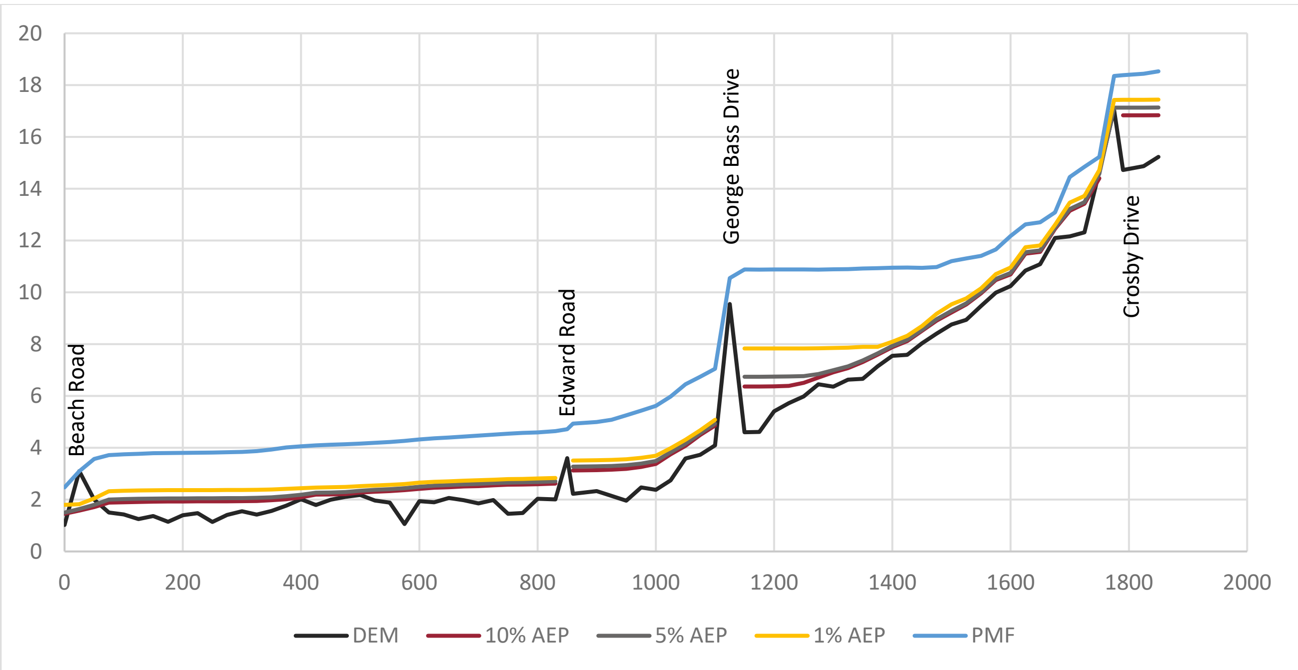


Figure 8-6 Sunshine Bay Long-Section

8.2 Flood Hazard

Flood hazard varies with flood severity (i.e. for the same location, the rarer the flood the more severe the hazard) and location within the floodplain for the same flood event. This also varies with both flood behaviour and in the interactions of the flood with the topography.

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

The hazard categories mapped are summarised in **Table 8-1** and **Figure 8-7**. These are based on the categories as defined in the AIDR (2017) Guideline.

Table 8-1 Hazard Categories

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly

H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure

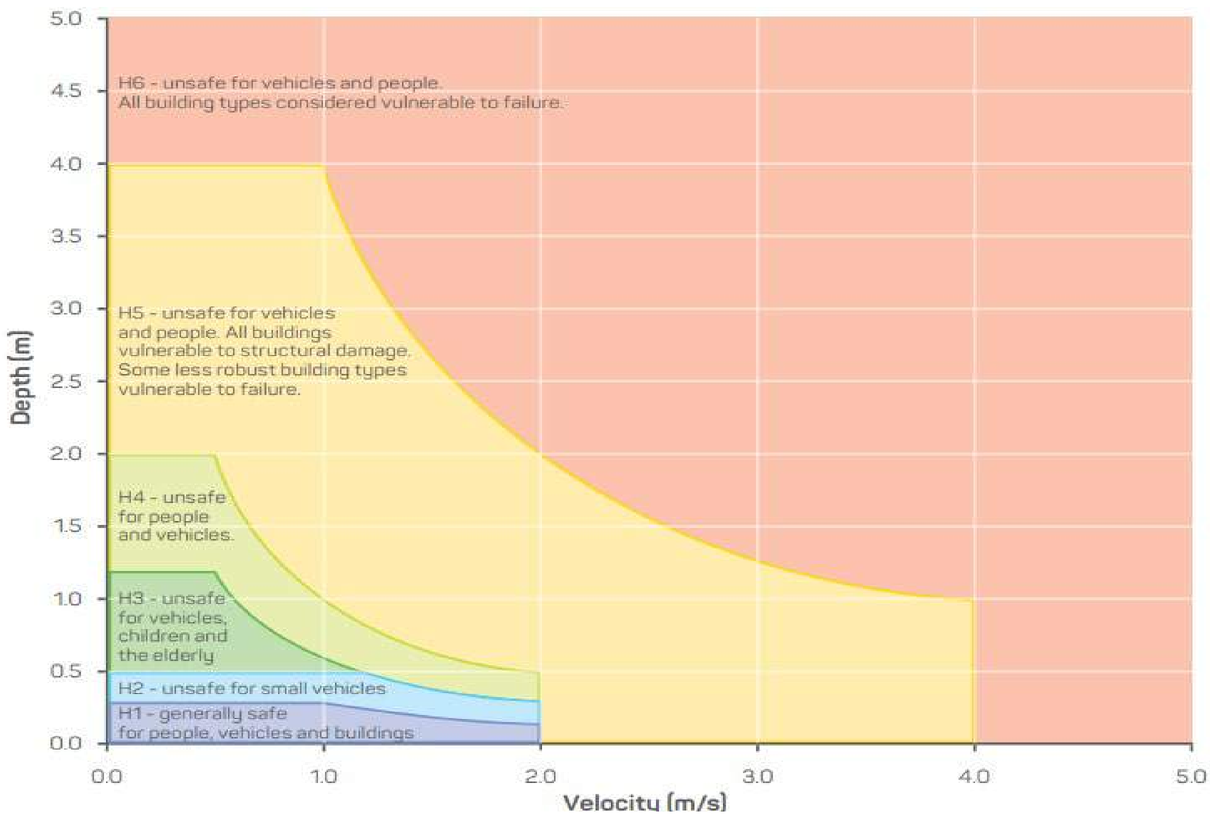


Figure 8-7 Flood Hazard Categories (AIDR, 2017)

Flood hazard mapping is provided for the 1% AEP and PMF events in **Map Series G803**. Hazard data for the full set of design events has been provided electronically to Council.

As a result of the generally low velocities present through the study area, hazard levels are typically driven more by depth than by velocity.

Hazard behaviour was largely similar through much of the study area. Creeks and channels remained relatively well contained in the 1% AEP, with hazard classes of H3 and H4. Hazard in the creeks increased to H5 and occasionally H6 in the PMF event.

Residential flooding was typically classed as H1 or H2 in the 1% AEP, increasing to H3 or H4 in the PMF, largely as a result of higher ocean levels increasing flood depth.

Exceptions to this typical behaviour were observed at some locations:

- Low lying residential regions of the Water Gardens, Catalina, Batehaven and Sunshine Bay experienced H3 and occasionally H4 flood hazard in the 1% AEP.

- These hazard classifications remained largely consistent in the PMF, albeit with an increase of H4 affectation. However, the Pleasurelea Tourist Resort in Sunshine Bay experienced a marked increase in hazard in the PMF, with regions of the site classed as H5.

No H6 hazard was observed across residential areas in any of the modelled flood events.

8.3 Flood Function

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

The hydraulic categories (also known as flood function), as defined in the Floodplain Development Manual (2005), are:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

It is noted that there is no "one size fits all approach" to hydraulic category / flood function definition. Thomas & Golaszewski (2012) investigated a number of different approaches in some case study catchments. However, it was emphasised in this paper to test the underlying assumptions through methods such as "encroachment", testing the impact of reducing or increasing the floodway.

An initial categorisation (based on Thomas & Golaszewski, 2012) was undertaken based on the criteria below:

- Floodway – VelocityxDepth Product is greater than $0.5m^2/s$;
- Flood Storage – VelocityxDepth product is less than $0.5m^2/s$ and depth is greater than 0.5m; and
- Flood Fringe – areas in the flood extent outside of the above criteria.

Manual adjustments were then undertaken to ensure the continuity of floodways, and to remove isolated regions of storage within floodways and fringe within storage that occurred as a result of the automated process.

An encroachment test was then undertaken to assess the suitability of this categorisation. The model was run with:

- All flood fringe areas removed from the model extent; and,
- All storage areas revised to have a roughness of 1.

All floodway zones remained as per the design events.

These changes were made to determine if:

- Fringe areas are appropriately zoned and are not serving any conveyance or storge function during flood events;
- Storage zones are appropriately zoned, and not serving any conveyance function during flood events; and,
- Floodway zones are capable of conveying the active flow through the system.

The results indicated that peak levels changed by less than 0.1m across the study area as a result of these changes, indicating that the classifications are appropriate.

The flood function mapping is provided for the PMF and the 1% AEP events in **Map Series G804**.

In the 1% AEP, floodways are confined within the creeks and channels. Property affectation in the 1% AEP is typically classed as flood fringe, although in the low lying regions of the Water Gardens, Catalina and Batehaven catchments, some property flooding is classed as flood storage.

In the PMF event, the floodway extent increases substantially. While it is still typically contained within the overbank areas of the creeks and channels, some road flow becomes classed as floodway in the PMF. Some properties in the lower reaches of Batehaven and Sunshine Bay also fall within floodways in the PMF event, namely:

- Corrigans Cove Retreat in Batehaven;
- Matthew Parade, Batehaven;
- Caseys Beach Holiday Park; and,
- Sunshine Bay Public School.

8.4 Critical Durations

The critical durations for the PMF, 1% AEP and 10% AEP events are shown in **Map Series G807**.

A similar pattern is observed in all events, with shorter duration, higher intensity events dominating in the upper catchment regions, and longer duration, higher volume events dominating in the lower catchment regions.

The PMF event ha critical durations of 90 minutes and 120 minutes across the majority of developed regions within the study area, with the 60-minute event being critical for the steeper, upper reaches of the catchments. The exception to this was Maloneys Beach, which had peak levels occurring in the 180-minute event across both the creek and the township.

In the 1% AEP event, the 180-minute was the dominant event, governing flooding across the majority of the developed areas. The 60-minute event was critical for much of the road flooding within he Water Gardens catchment, as well as the upper reaches of Joes Creek and Short Beach Creek. Long Beach Lagoon experienced peak flood levels in the 120-minute event.

The 10% AEP was largely governed by the 120-minute event upstream and the 270-minute downstream. Notable exceptions were that the 90-minute event was critical at the downstream reach of the Surfside catchment, and the 120-minute event was critical for the full length of Short Beach Creek.

8.5 Tidal Inundation Extents

An assessment on tidal inundation was undertaken for the existing scenario and a 0.35m sea level rise scenario. The assessment was undertaken using the TUFLOW model, with the downstream boundary revised to a tidal time series based on the high high water solstice spring (HHWSS) tide. The series is shown in **Figure 8-8** and has a peak tidal level of 0.91mAHD and 1.26mAHD for existing and the sea level rise respectively.

The model was run assuming that all entrances were fully open. All the closed entrance levels would prohibit tidal inundation in both existing and sea level rise scenarios.

The tidal inundation extents for both scenarios are shown in **Map G808**.

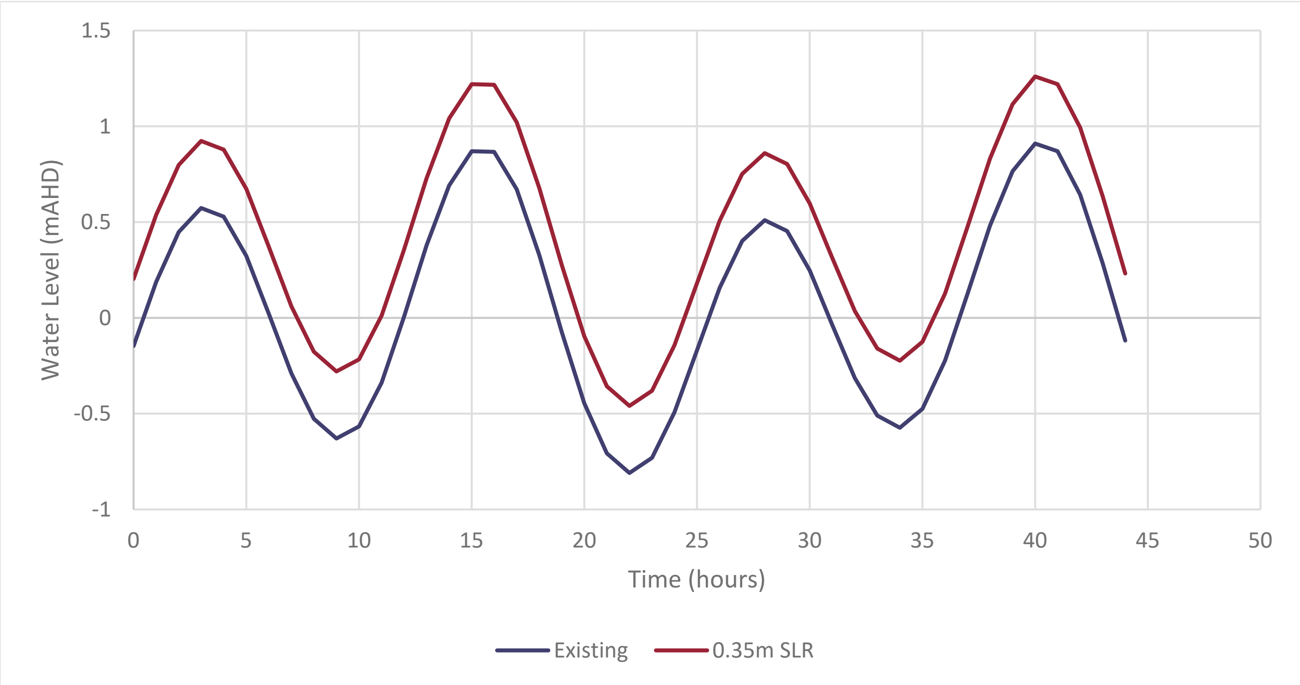


Figure 8-8 Tidal Inundation Downstream Boundary

The results show that 2050 sea levels have a relatively modest impact on tidal extents across the study area, with the 2100 levels exhibiting a greater impact, with the severity varying markedly between catchments. Increased high tide levels had no impact on developed regions in any catchment area in the 2050 scenario. However, some development was affected in the 2100 scenario.

At Maloneys Beach, the existing HHWSS tide did not progress past the Northcove Road crossing. With 2050 SLR, the tidal extent reached 1km upstream, and remained fully contained by the creek banks. The 2100 SLR tidal extent reached the model boundary, and also spread east around the top of the township. No development was impacted in either scenario at Maloneys Beach

The Long Beach catchment results showed that tidal impacts did not progress beyond the foreshore in either the existing scenario nor the climate change scenarios.

At Surfside the tidal impacts were restricted to the foreshore in the existing scenario. With 2050 SLR, tidal impacts extended 250m upstream of Wharf Road, and remained fully contained within the creek banks. The 2100 tidal extents progressed further upstream, extending approximately 600m upstream of Wharf Road. The 2100 tide breaks out of the existing channel immediately upstream of Wharf Road, inundating the rear of some properties along Timbara Crescent.

The Watergardens foreshore remained above the peak tidal level for the 2050 scenario. In the 2100 scenario, the tide was observed to flood the low point of Beach Road at Herarde Street. The tidal extent in this region affected a number of properties.

There was very little difference between the existing and 2050 tidal extents in the Catalina catchment, with both scenarios having tidal limits that finished immediately downstream of Beach Road. In the 2100 scenario, while there was only a minor increase in the tidal extent upstream, there was a significant lateral expansion to the east, due to a breakout near the Batemans Bay Marina Resort. This expanded tidal area affected a large number of properties to the east of Hanging Rock Creek.

Differences between the existing and 2050 scenarios were most pronounced along Joes Creek in the Batehaven catchment. The existing tidal extent is fully contained within the creek, and extends to immediately downstream of George Bass Drive. The 2050 SLR rise scenario however extended beyond George Bass Drive by 230m, and also resulted in water breaking out of the creek channel. It is noted that this breakout remained fully within the adjacent vegetated space, and did not impact any developed areas. The 2100 scenario results in further lateral expansion of the tidal region, but remains fully contained within the adjacent vegetated space upstream of Beach Road. Downstream of Beach Road, the 2100 scenario affects property within both the Big 4 Batemans Bay Beach Resort on the south bank of the creek, and Birdland Animal Park on the northern side.

Within the Sunshine Bay catchment, there was very little difference between the existing and 2050 scenarios, although the 2050 SLR tidal extents did begin to progress up two tributaries by a small amount (20 – 30m). In the 2100 scenario, there was a significant extension of the tidal area along minor flowpaths feeding into the creek, immediately upstream of Beach Road. Properties adjacent to the creek on both the north and south banks experienced property flooding in the 2100 scenario, although dwellings remained unaffected.

8.6 Climate Change Impacts

The impacts of future sea level rises on the study are was assessed in the model for:

- A 0.35m sea level rise, modelled for the 5% AEP and 1% AEP (nominally a 2050 scenario); and
- A 0.72m sea level rise, modelled for the 1% AEP (nominally a 2100 scenario).

For each event, the downstream boundary was increased by the nominated amount. The entrance berms were also assumed to increase inline with sea levels. All other model parameters remained as per the design runs.

The results for the 0.35m sea level rise are shown in **Map Series G805** and for the 0.72m sea level rise in **Map Series G806**.

In the 5% AEP, the 0.35m sea level rise had a modest impact in most catchment areas. Maloneys Beach, Long Beach and Water Gardens had no impacts arising from a 0.35m sea level rise in the 5% AEP. Impacts of 0.01m were observed in Surfside in the tributary running adjacent to Mundarra Way.

Flooding within the Catalina catchment showed flood level increases at Herarde Street of up to 0.07m, at Beach Street of up to 0.21m and at Golf Links Road of up to 0.12m. Impacts affected across the golf course, with increases of 0.12m, but did not extend further upstream.

Within the Joes Creek catchment, flood levels increased across the Big 4 Resort by 0.17m, and across the low point of Edward Street by 0.08m. Impacts extended to Glenella Road, but did not affect additional properties.

The impacts at Sunshine Bay were restricted to within approximately 350m of the entrance. Increases of 0.02m were observed across both Caseys Holiday Beach Park and Sunshine Bay Public School.

For the 1% AEP event, the 0.35m sea level rise had varied impacts across the study area.

Peak levels increased by a consistent 0.05m throughout the Maloneys Beach catchment. Increased levels did not impact any development and remained fully contained within the vegetated areas adjacent to the creek.

The Long Beach catchment showed negligible impacts from the 0.35m sea level rise, as a result of the relatively steep grade in the entrance channel. The observed impacts were fully contained within the entrance channel, and did not impact adjacent properties.

Impacts within the Surfside catchment extended as far upstream as the highway in the 1% AEP. While much of the increase was contained upstream, the downstream reaches, particularly the residential area between the beach and Timbara Cresent and Bayview Street, saw level increases of 0.27m and a significant expansion in flood affectation.

The North Street and Clyde Street intersection in the Watergardens catchment experienced flood level increases of 0.35m, and Beach Road (within the Water Gardens catchment) increases of 0.16m. Upstream of Museum Place, impacts were well contained and did not further impacts roads or properties.

Within the Catalina catchment, the low-lying areas around Herarde Street and Beach Road experienced a 0.32m increase. Increases of 0.24m were observed along Golf Links Road and the golf course. While impacts extended upstream beyond the golf course, they did not impact any further developed areas.

The Big 4 Resort in Batehaven was affected by increases of 0.17m due to increased sea levels. Impacts from sea level rise extended upstream as far as Glenella Road, but additional impacts on development were only observed at the low point on Edward Road, where levels increased by 0.1m.

Within the Sunshine Bay catchment, the 0.35m sea level rise resulted in increases across Caseys Holiday Beach Park and Pleasurelea Tourist Resort of 0.15m and 0.1m respectively. Levels also increased at Sunshine Bay Public School by up to 0.14m, and additional areas of the school became flood affected. Impacts extended up Short Beach Creek as far as Sturt Place, but were fully contained within the vegetated overbank areas.

Similar to the 0.35m sea level rise impacts, the impacts in the 1% AEP of the 0.72m sea level rise varied substantially across the various catchments.

In the Maloneys Beach catchment, peak levels increased by a generally consistent 0.15m due to the restriction at the outlet stabilising upstream levels. Residential properties remained flood free, however, the intersection of Maloneys Drive and Blue Gum Parade was inundated by 0.15m depths.

At Long Beach, as a result of the relatively steep grade of the outlet channel, sea level rise impacts were confined to the channel downstream of the lake, and did not influence lake levels at all. The increased sea levels did result in some additional flooding of low-lying properties adjacent to the outlet, due to coastal inundation.

Impacts at Surfside extended as far upstream as the highway, and resulted in a significantly larger flood extent downstream. The school buildings remained flood free, however their grounds became inundated. A significant number of additional properties became flood affected between the beach and Timbara Cresent and Bayview Street, due to ocean flooding. A large number of these properties experienced flood depths in excess of 0.5m, and up to 0.8m in some locations.

Within the Water Gardens catchment, increases of 0.7m occurred at the intersection of North Street and Clyde Street, adjacent to the bay, and increases of 0.5m were observed along Beach Road and Flora Crescent. Due to the rising terrain within the catchment, increases did not extend beyond South Street, just beyond the central parklands.

Flood levels along Beach Road and Herarde Street in Catalina increased by 0.7m, further exacerbating flooding across these low-lying areas. Properties along Golf Links Road experienced increases of up to 0.6m. While increases extended a significant distance upstream, they were all contained within the golf course and vegetated areas, and did not impact properties upstream.

Within Batehaven, levels across the Big 4 Resort increased by 0.32m. Impacts extended upstream as far as Glenella Road, however, impacts were modest, and largely restricted to properties along the creek side of Edward Avenue who experienced increases of 0.2m to 0.3m.

The impacts along the main reach of Short Beach Creek were fully contained within the creek reserve. The eastern tributary however saw impacts of 0.35m across Caseys Holiday Beach Park and the inundation of Sunshine Bay Public School by up to 0.2m of water. Increases of 0.25m also occurred across Pleasurelea Tourist Resort.

9 Understanding Flood Risk

9.1 Flood Planning Area

9.1.1 Flood Planning Area

In May 2020 the Department of Planning, Industry and Environment released a Draft Flood Prone Land Package which contains a series of documents that seek to update the manner in which local planning is conducted for flood prone lands. In summary, the key relevant aspect for strategic planning is the consideration of three types of flood prone areas:

- Flood Planning Area (FPA), which has commonalities with the flood planning level concept in the ELEP and seeks to ensure development is compatible with flood risks within the FPA (noting that there are some circumstances where no development is compatible with flood risks)
- Special Flood Considerations (SFC), which seeks to control certain types of vulnerable and hazardous development within the floodplain in its entirety (i.e. potentially up to the extent of the Probable Maximum Flood)
- Regional Evacuation Consideration Area (RECA), which seeks to ensure lands which are indirectly affected by flood behaviour with respect to being unable to evacuate due to flooding in adjacent areas and becoming isolated.

Mapping has been undertaken for the existing scenario, a 0.35m sea level rise scenario and a 0.72m sea level rise scenario, with the FPL set at the relevant 1% AEP flood level plus 0.5m.

The results of the analysis are provided in **Map Series G901**.

Flood risk precincts, incorporating the additional aspects of the Draft Flood Prone Land Package, are mapped in **Map G905**.

It is useful to note that the extent of the flood planning level mapping is generally similar to the extent of the Probable Maximum Flood, which is not uncommon for small coastal creeks where the catchments are not extensive and the variance in plan extent of flooding is not great between rare and extreme events.

9.2 Emergency Response Classification

Flood Emergency Response Classification aims to categorise the floodplain based upon differences in isolation due to the potential for entrapment of an area by floodwaters, potentially in combination with impassable terrain. It also considers the potential ramifications for an isolated area based upon its potential to be completely submerged in the probable maximum flood (PMF) or a similar extreme flood (AIDR, 2014).

Flood Emergency Response Classification mapping is a useful tool for emergency services and evacuation planning for a floodplain.

AIDR (2017) provides guidance on emergency response classification mapping, which is intended to be undertaken at the community or precinct scale (i.e. not at the lot scale). A summary of the classifications is provided in **Table 9-1**. These are presented in **Map Series G902**. It is noted that the Flood Free category was not shown on the map, and that ocean flooding has been removed, as emergency classification is not applicable to these regions.

Table 9-1 Emergency Response Classifications (AIDR, 2017)

Primary Classification	Description	Secondary Classification	Description	Tertiary Classification	Description
Flooded (F)	The area is flooded in the PMF	Isolated (I)	Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/or impassable terrain as waters rise during a flood event up to and including the PMF. These areas are likely to lose electricity, gas, water, sewerage and telecommunications during a flood.	Submerged (FIS)	Where all the land in the isolated area will be fully submerged in a PMF after becoming isolated.
				Elevated (FIE)	Where there is a substantial amount of land in isolated areas elevated above the PMF.
		Exit Route (E)	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities (located on flood-free land).	Overland Escape (FEO)	Evacuation from the area relies upon overland escape routes that rise out of the floodplain.
				Rising Road (FER)	Evacuation routes from the area follow roads that rise out of the floodplain.
Not Flooded (N)	The area is not flooded in the PMF			Indirect Consequence (NIC)	Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications, and transport links due to flooding.
				Flood Free (NFA)	Areas that are not flood affected and are not affected by indirect consequences of flooding.

Across most study area, communities were typically classified as overland escape route (FEO) or rising road (FER). This is largely due to the nature of flooding, where flow emanates from a single waterway or rising ocean levels.

Some locations however had more significant response ratings:

- The entire Maloneys Creek community is classed as an elevated flood island (FIE) in the 1% AEP and a submerged flood island in the PMF, due to the only access road being cut in advance of property flooding in both events.
- Some rural lots in the upper Surfside catchment area are classed as elevated flood islands (FIE) for both events. They remain flood free in the PMF but access is lost in both 1% AEP and PMF events.
- A region at the boundary of the Catalina and Batehaven catchments, covering parts of Golf Links Drive and Beach Road is classed as an elevated flood island (FIE) in the 1% AEP and a submerged flood island (FIS) in the PMF.
- In the PMF event, large regions across the Water Gardens, Catalina, Batehaven and Sunshine Bay catchments are classed as elevated flood islands (FIE), as road access to these regions is lost.

9.3 Flood Impacts on Transport

There are a number of transportation routes through the study area, both major arterials (such as the Princes Highway and secondary roads providing access between the catchment areas. Understanding when these routes are overtopped by floodwaters and the duration in which they are flooded is useful, particularly for emergency response planning.

An analysis was undertaken on overtopping in the design events, with a road considered overtopped when flood depths exceeded 0.15m.

This information is presented in **Map Series G903**.

Roads throughout the study area are cut in events as small as the 20% AEP, including multiple locations along Beach Road in the southern catchment areas, multiple locations in the CBD within the Water Gardens catchment, and the Princes Highway in the Surfside catchment. Affectation increased in larger events, resulting in multiple isolated regions in both the 1% AEP and the PMF (see FERC mapping above).

The merits of increasing flood immunity of roads in the study area and regional access during a flood event should be investigated as part of the Floodplain Risk Management Study.

9.4 Flood Impacts on Infrastructure

The study area contains several developments that either accommodate or service higher risk groups, such as the elderly, children or tourists (who are less likely to be aware of local flood conditions. A number of these locations are flood affected, to varying degrees.

The location of these sites is shown in **Map Series G904**. Note that no sites are found in Maloneys Beach or Long Beach, so these plots are not included in the Map Series. A summary of flood depths at these locations are summarised in **Table 9-2**.

Only a single health or aged care site, The Manor Retirement Village and Aged Care home, was impacted by flooding, and that only in the PMF, by flood depths of up to 0.71m. The site is located on Beach Road, immediately adjacent to Joes Creek, and is inundated in the PMF as a result of elevated ocean levels.

Both the Batemans Bay Hospital and the Catholic Healthcare Maranatha Lodge remained flood free in the PMF.

A number of large scale accommodation sites, such as motor inns and caravan parks, are located within the study area. The caravan parks in particular are vulnerable to flooding, with inundation commencing in the 20% AEP event. Significant depths occur across these sites in the 1% AEP, ranging from 0.5m to 1m, save for Corigans Cove Resort which is only impacted in the PMF.

All education facilities within the study area remain flood free in the 1% AEP, but are inundated in the PMF. Sunshine Bay Public School is the most affected, with depths of up to 1.23m occurring in the PMF. The Batemans Bay library is inundated by 0.76m in the 20% AEP, increasing to 1.36m in the PMF.

The Fire and Rescue NSW property in the Water Gardens catchment is inundated in the 1% AEP by 0.49m and the PMF by 0.91m.

The Batemans Bay SES property is located just south of the Water Gardens catchment boundary. While it is located on a rise that suggests it remains largely flood free, it is noted that access to the north along the Old Princes Highway is lost. As such, the unit will not be able to service the northern catchments during a flood event. The southern catchments will still be accessible, albeit via a long detour south.

Table 9-2 Infrastructure Flooding

Location	Peak Flood Depth (m)				
	20% AEP	5% AEP	10% AEP	1% AEP	PMF
Health and Aged Care					
Batemans Bay Hospital	-	-	-	-	-
Catholic Healthcare Maranatha Lodge	-	-	-	-	-
The Manor Retirement Village and Aged Care	-	-	-	-	0.71
Accommodation					
Argyle Terrace Motor Inn	-	-	-	0.59	0.88
Big 4 Batemans Bay Beach Resort	0.32	0.42	0.38	0.55	0.96
Caseys Beach Holiday Park	0.23	0.57	0.45	0.90	2.31
Clyde View Holiday Park	-	0.34	0.30	0.48	0.95
Coachhouse Marina Resort	0.25	0.29	0.28	0.50	0.80
Corrigans Cove Resort	-	-	-	-	0.29
Pleasurelea Tourist Resort	0.33	0.62	0.51	0.98	2.30
Community					
Batemans Bay Library	0.76	0.88	0.85	1.03	1.36
Batemans Bay Public School	-	-	-	-	0.24
Catalina Country Club	-	-	-	-	0.51
SDN Batemans Bay Primary School	-	-	-	-	1.15
St Bernards Primary School	-	-	-	-	0.80
Sunshine Bay Public School	-	-	-	-	1.23
Emergency Response					
Fire and Rescue NSW Batemans Bay	-	-	-	0.49	0.91

10 Conclusions and Recommendations

The Batemans Bay Urban Creeks Flood Study has been prepared for Eurobodalla Shire Council to define the existing flood behaviour across these areas, and to establish the basis for subsequent floodplain management activities.

This project is a flood study, which is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide a better understanding of the full range of flood behaviour and consequences. It involves consideration of the local flood history, available collected flood data, and the development of hydrologic and hydraulic models that are calibrated and verified, where possible, against historic flood events and extended, where appropriate, to determine the full range of flood behaviour.

Hydrological modelling was undertaken using XP-RAFTS. Hydraulic modelling was undertaken through a combination of TUFLOW and Delft3D for catchment and ocean flooding, respectively.

Validation was undertaken across the region through a comparison of historical community observations with design flood behaviour.

The hydrological and hydraulic models were analysed for the Probable Maximum Flood (PMF), 0.2%, 0.5%, 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP) events. The models were analysed for storm durations from 60 minutes to 24 hours. Details and descriptions of the flood behaviour associated with these events has been provided.

In order to provide Council with an indication of future flood behaviour arising from climate change in the future, two climate change scenarios were modelled incorporating a 0.35m and 0.72m sea level rise.

From the results developed, planning and emergency response data has been prepared for use by Council and emergency services, including:

- Hazard mapping;
- Flood emergency response classification; and,
- Identification of road and crossing inundation and duration.

The assessment undertaken provides a thorough understanding of the existing flood behaviour and floodplain risks present in the study area.

Council’s current DCPs (Section 5.5) do not currently contain comprehensive flood related controls for mainstream or overland flow flooding. Although it is also noted that Council does not currently have any specific overland flow studies completed. It is noted that the Draft LSPS makes reference to the introduction of a Council-wide Flood Management Code. Any such code would need to be consistent with the provisions of the LEP. The code would need to be consistent with the provisions of the Floodplain Development Manual (2005) or any updated Manual.

11 References

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MAPS

N
W E
S

Map G101

Catchment Areas

Legend
Catchment Boundary
Study Areas

500 0 500 1,000 1,500 m

1:35,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : LRE
Coordinate System : MGA 56

Rhelm

N
W
E
S

Map G201

Maloneys Creek (Maloneys Lagoon)

Legend
Catchment Boundary
Key Locations

250 0 250 500 750 m

1:20,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm

N W E S

Map G202

Long Beach (Long Beach Lagoon)

Legend

Catchment Boundary

Key Locations

100 0 100 200 300 400 m

1:10,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm

N
W E
S

Map G203

Surfside (Surfside Creek)

Legend

Catchment Boundary

Key Locations

100 0 100 200 300 400 m

1:10,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm

N
W E
S

Map G204

The Water Gardens

Legend

Catchment Boundary

Key Locations

100 0 100 200 300 m

1:8,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm

Map G205

Catalina (Hanging Rock Creek)

Legend

Catchment Boundary

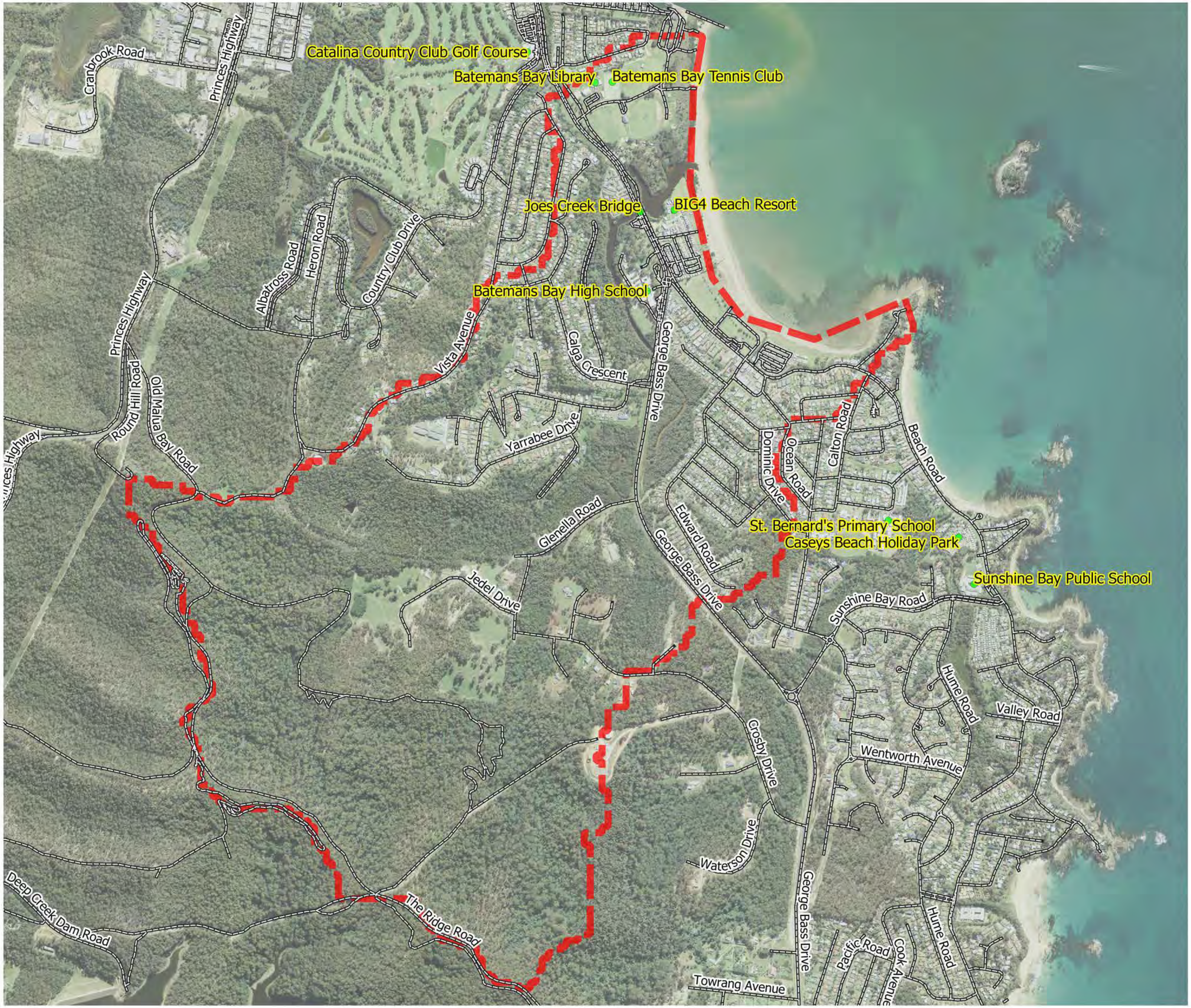
Key Locations

100 0 100 200 300 400 m

1:10,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm



N
W E
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Map G206

Batehaven (Joes Creek)

Legend

Catchment Boundary

Key Locations

200 0 200 400 600 m

1:15,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm

N
W E
S

Map G207

Sunshine Bay / Caseys Beach

(Short Beach Creek)

Legend

Catchment Boundary

Key Locations

200 0 200 400 600 m

1:15,000

Size : A3
Date : 18 January 2019
Revision : A
Created by : AXS
Coordinate System : MGA 56

Rhelm

N
W E
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Map G302

Rainfall Gauges

Legend

Catchment Boundaries

Rain gauges - MHL

Rain gauges - water NSW

Rain gauges - BoM

Daily

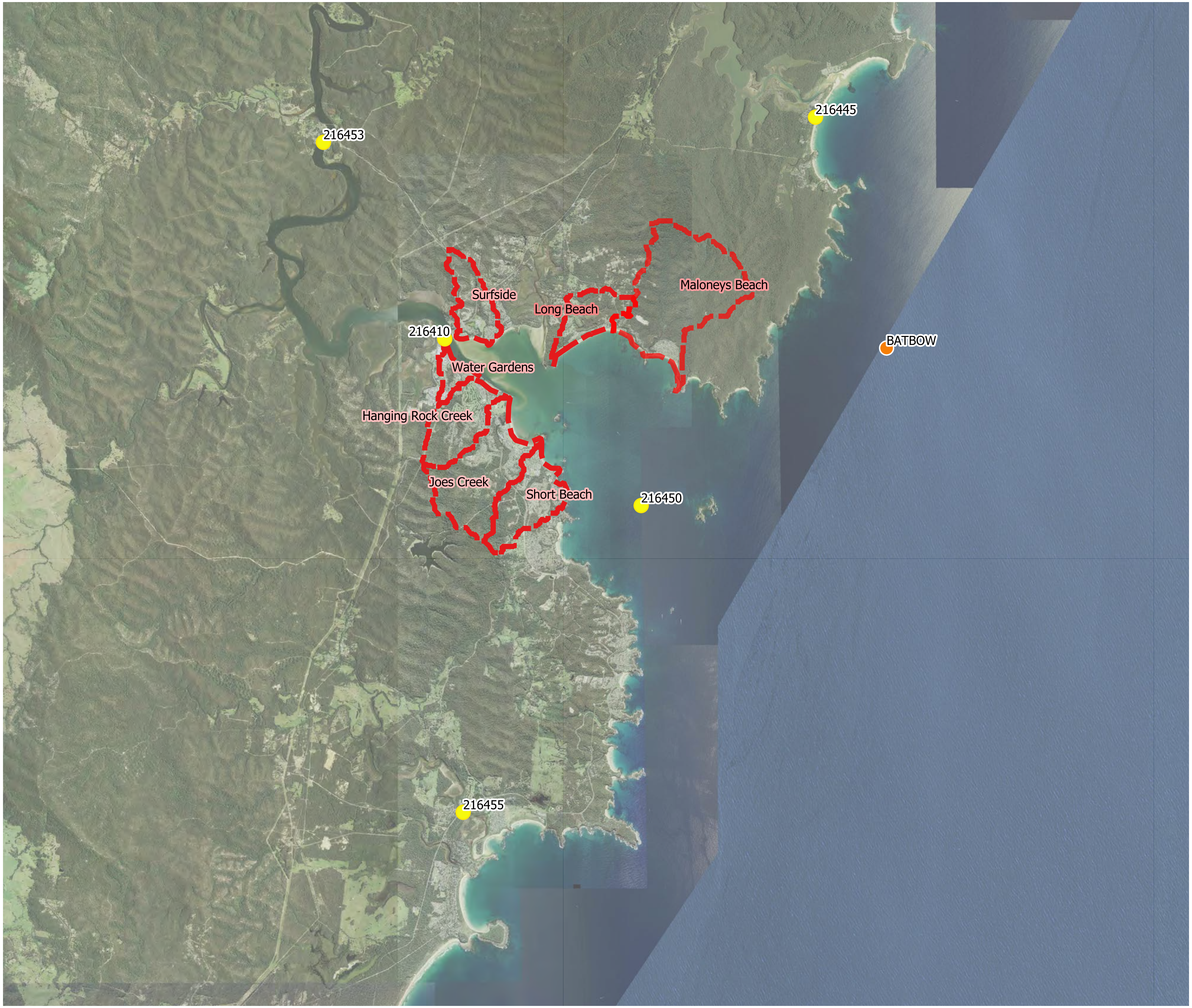
Pluvio

5000 0 5000 10000 m

1:200000

Size : A3
Date : 18 January 2019
Revision : A
Created by : LRE
Coordinate System : MGA 56

Rhelm



N
W E
S

Map G302

MHL Gauges

Legend
Catchment Boundary
MHL Gauges
Water Level
Wave Direction

1200 0 1200 2400 3600 m

1:100000

Size : A3
Date : 18 January 2019
Revision : A
Created by : LRE
Coordinate System : MGA 56

Rhelm

N
W
E
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Map G303

Survey Obtained

Legend

Catchments

Survey Obtained

0 500 1000 1500 m

1:50000

Date : 14 November 2019
Revision : A
Created by : SLC
Coordinate System : Map Grid of Australia 94

Rhelm
engineering | environmental | economics | engagement

N
W
E
S

Map G601

TUFLOW Model

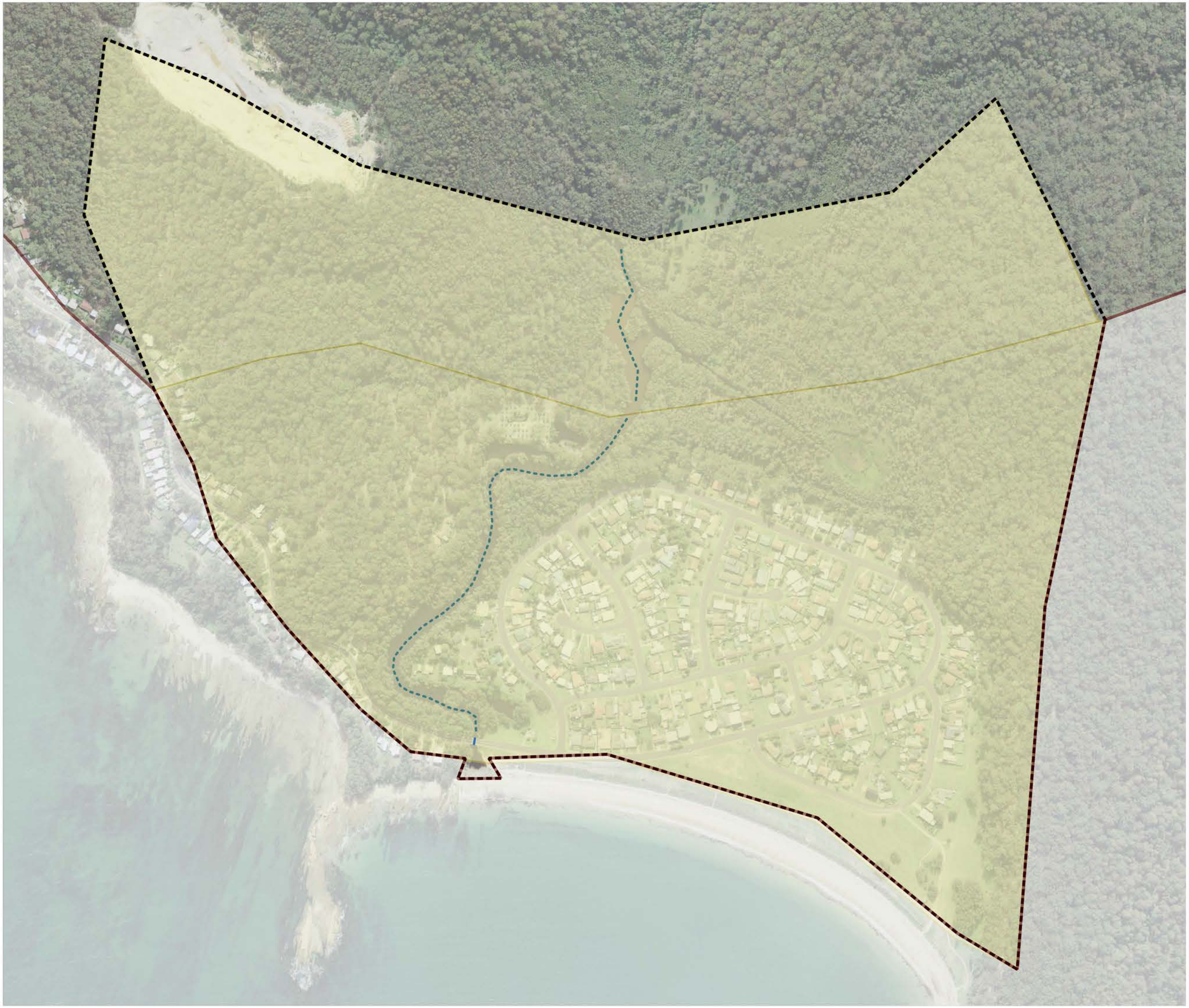
Legend

Tuflow Model Extents

1 0 1 2 km

Scale : 1:30000@A3
Date : 29 January 2019
Revision : 0
Created by : ERM
Coordinate System : MGA 56

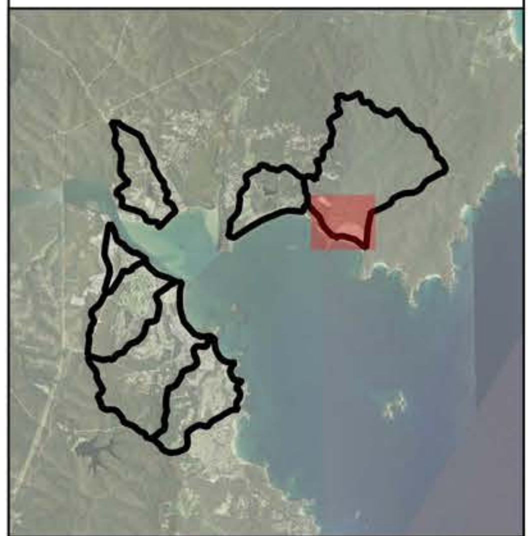
Rhelm



G602-a-1
Maloneys Beach Tuflow Model

Catchment Area
Tuflow Model Area
Included Pipes
Excluded Pipes
Bridges
SA Polygons
SA Streamlines

Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)



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Date : 10 September 2019
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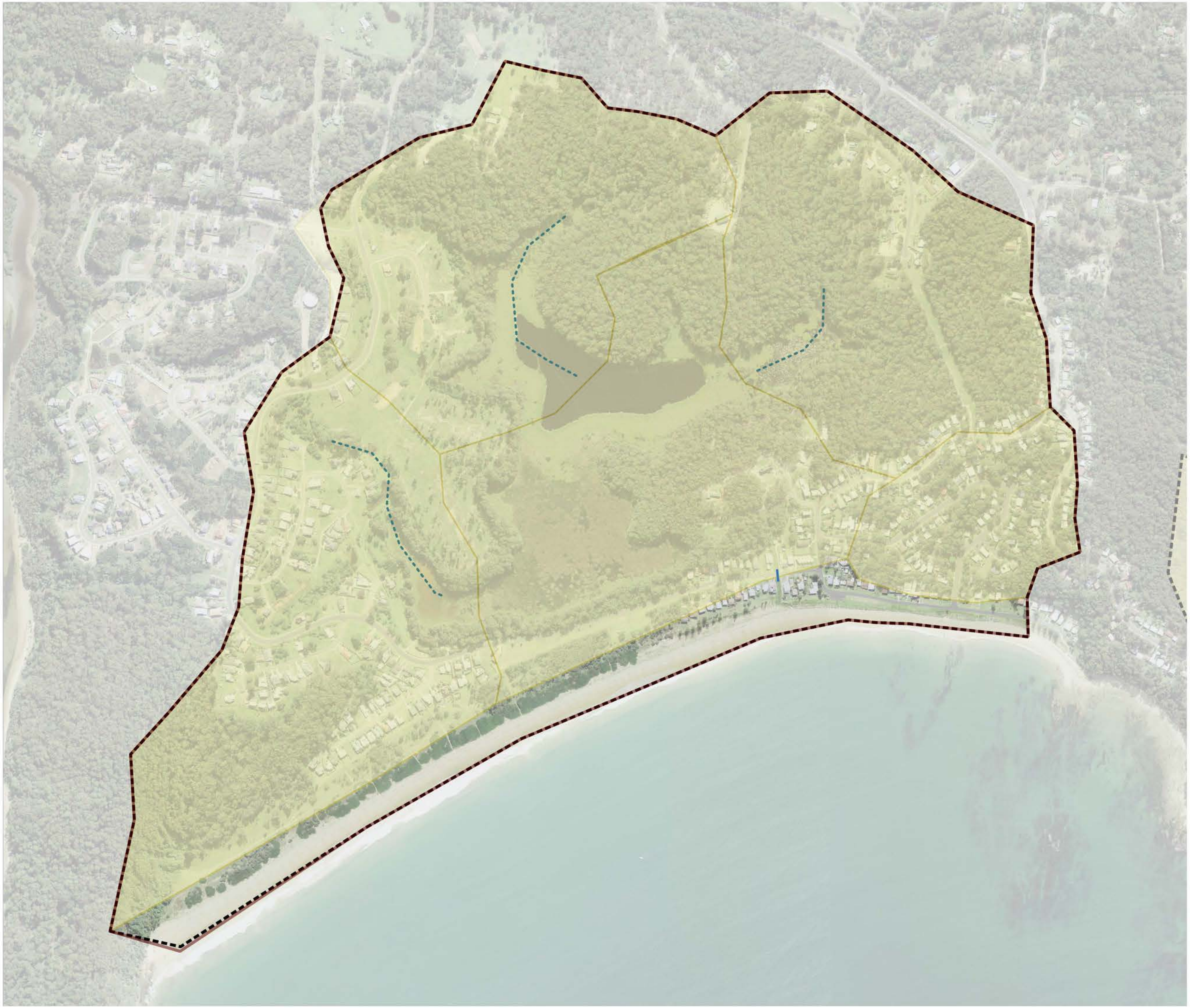
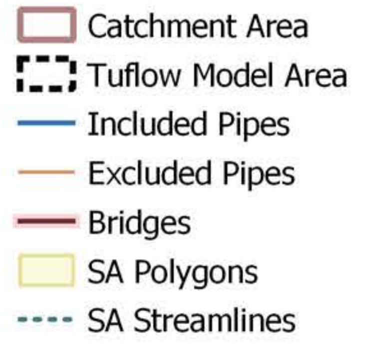
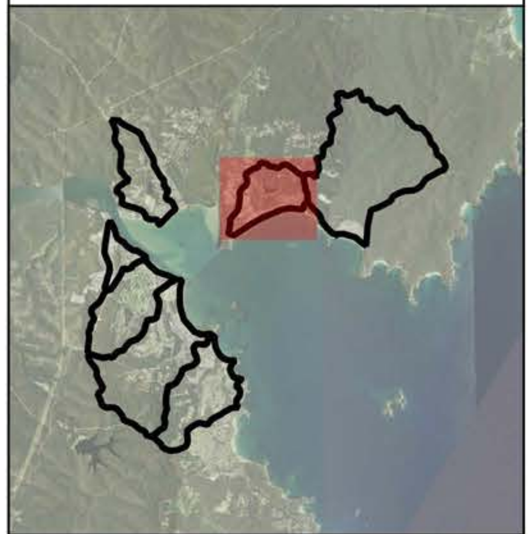
Rhelm

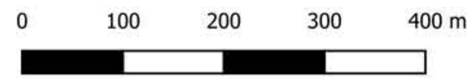


G602-b-1
Long Beach
Tuflow Model



Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)





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Revision : A
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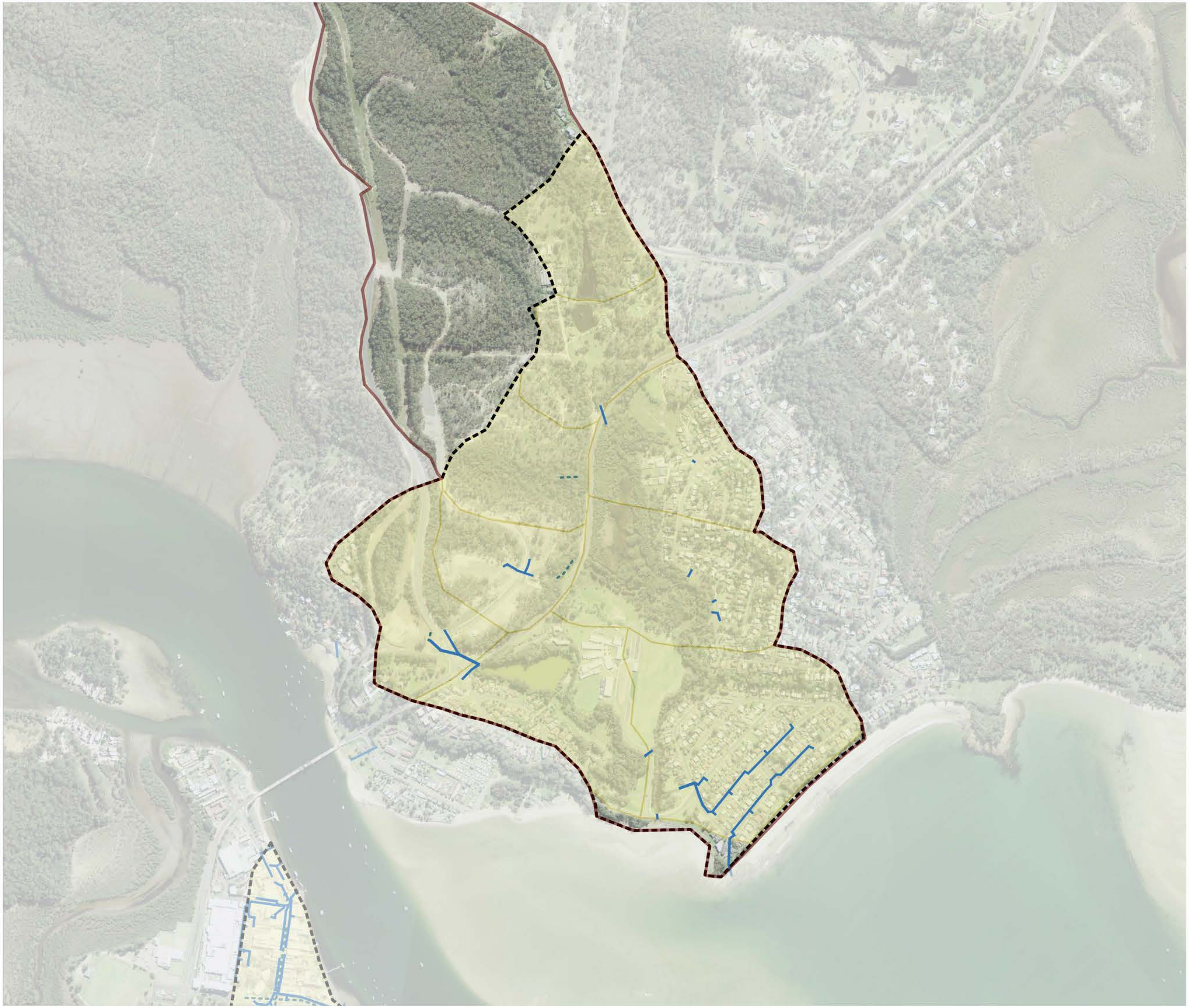
Coordinate System : MGA94 Zone 56

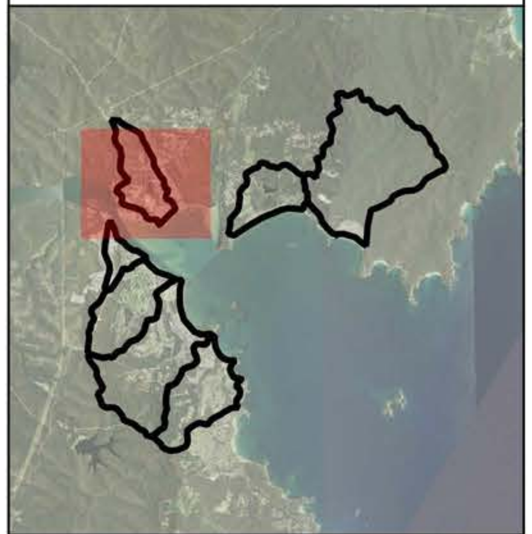
Rhelm

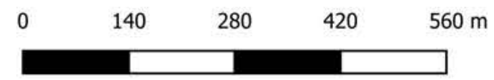


G602-c-1 Surfside Tuflow Model

Catchment Area
Tuflow Model Area
Included Pipes
Excluded Pipes
Bridges
SA Polygons
SA Streamlines

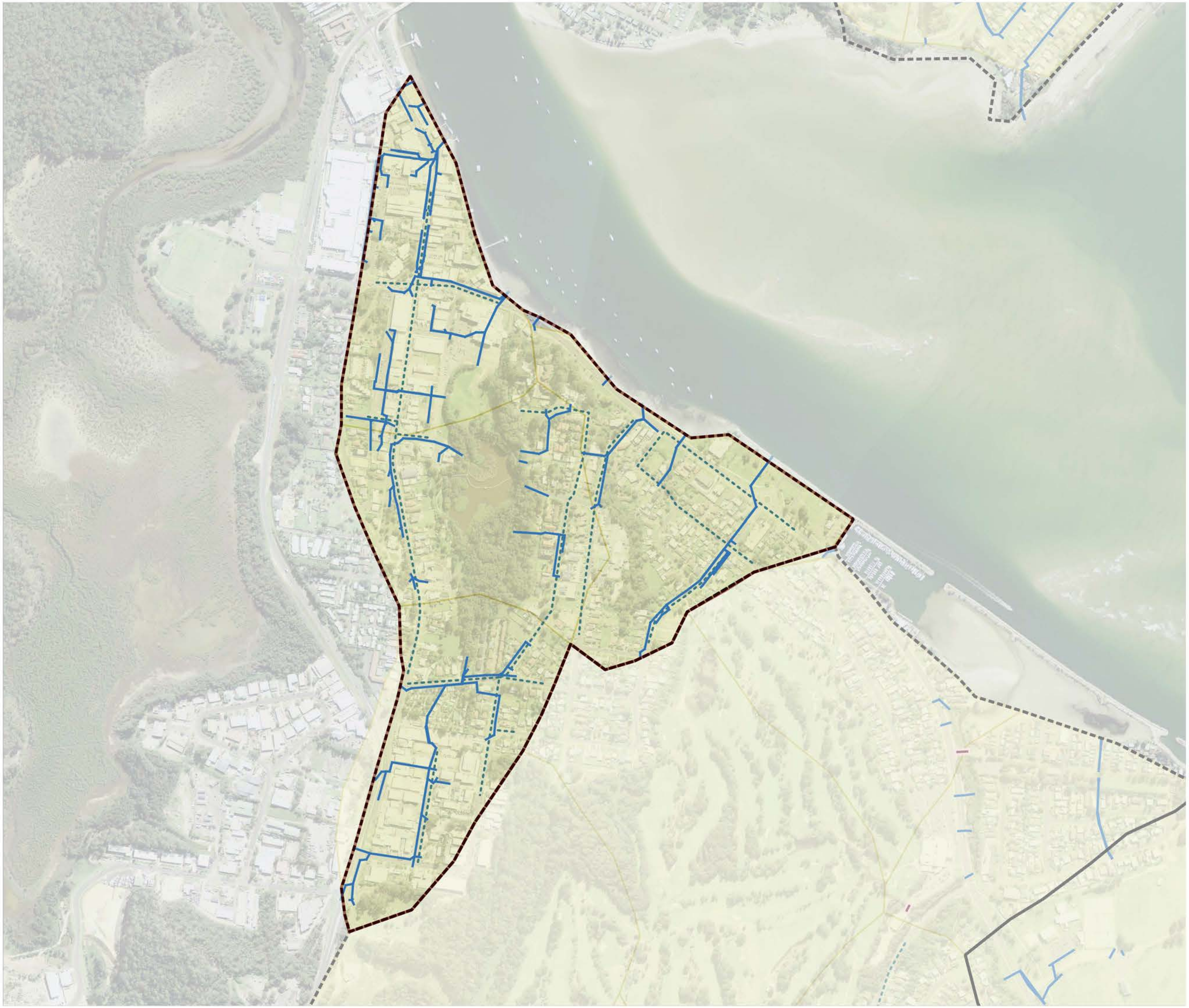
Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)





Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

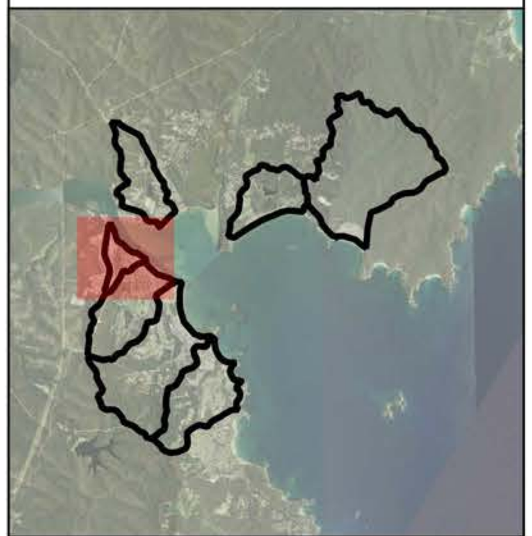
Rhelm

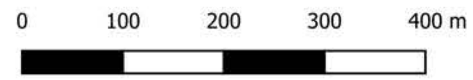


G602-d-1
Water Gardens
Tuflow Model

- Catchment Area
- Tuflow Model Area
- Included Pipes
- Excluded Pipes
- Bridges
- SA Polygons
- SA Streamlines

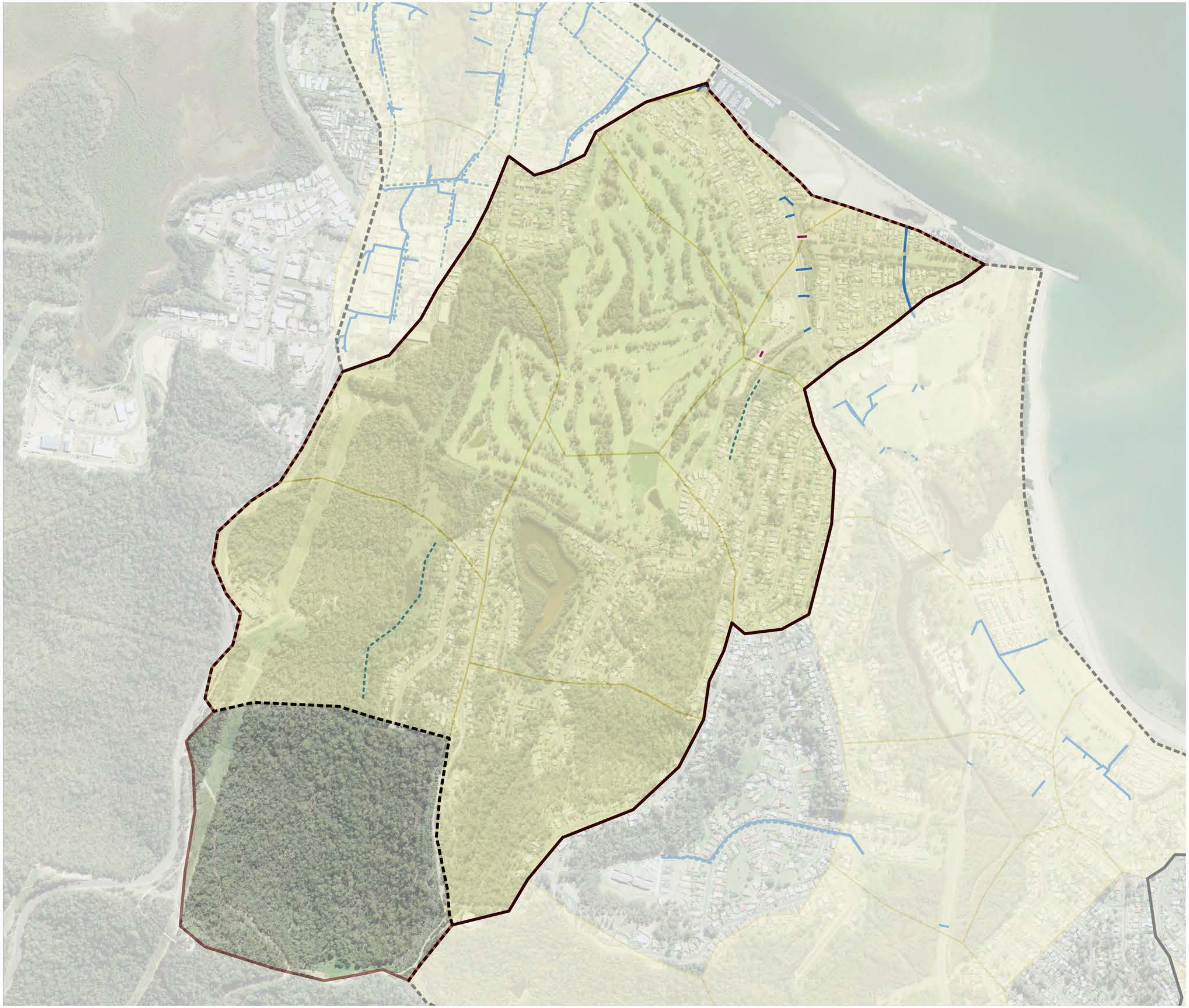
Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)





Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

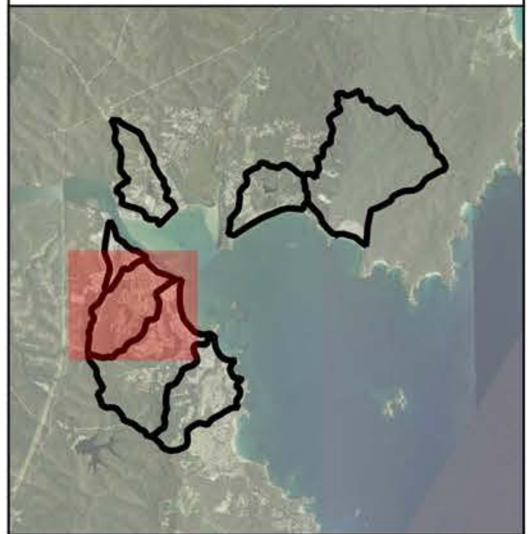
Rhelm



G602-e-1
Catalina
Tuflow Model

- Catchment Area
- Tuflow Model Area
- Included Pipes
- Excluded Pipes
- Bridges
- SA Polygons
- SA Streamlines

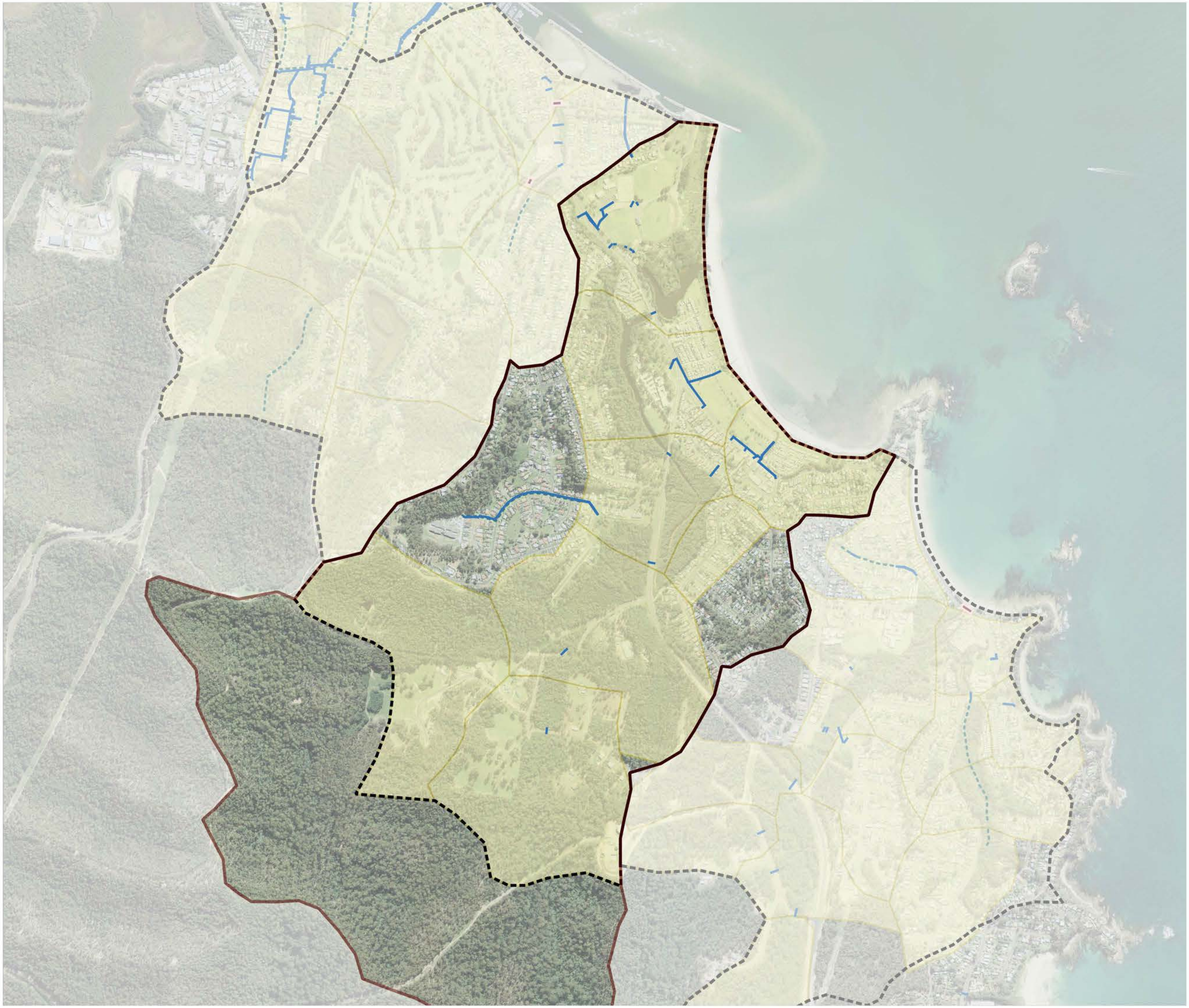
Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)



0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

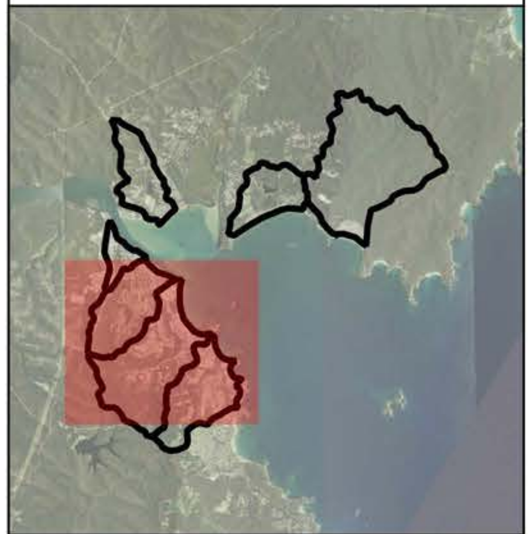
Rhelm



G602-f-1
Batehaven
Tuflow Model

Catchment Area
Tuflow Model Area
Included Pipes
Excluded Pipes
Bridges
SA Polygons
SA Streamlines

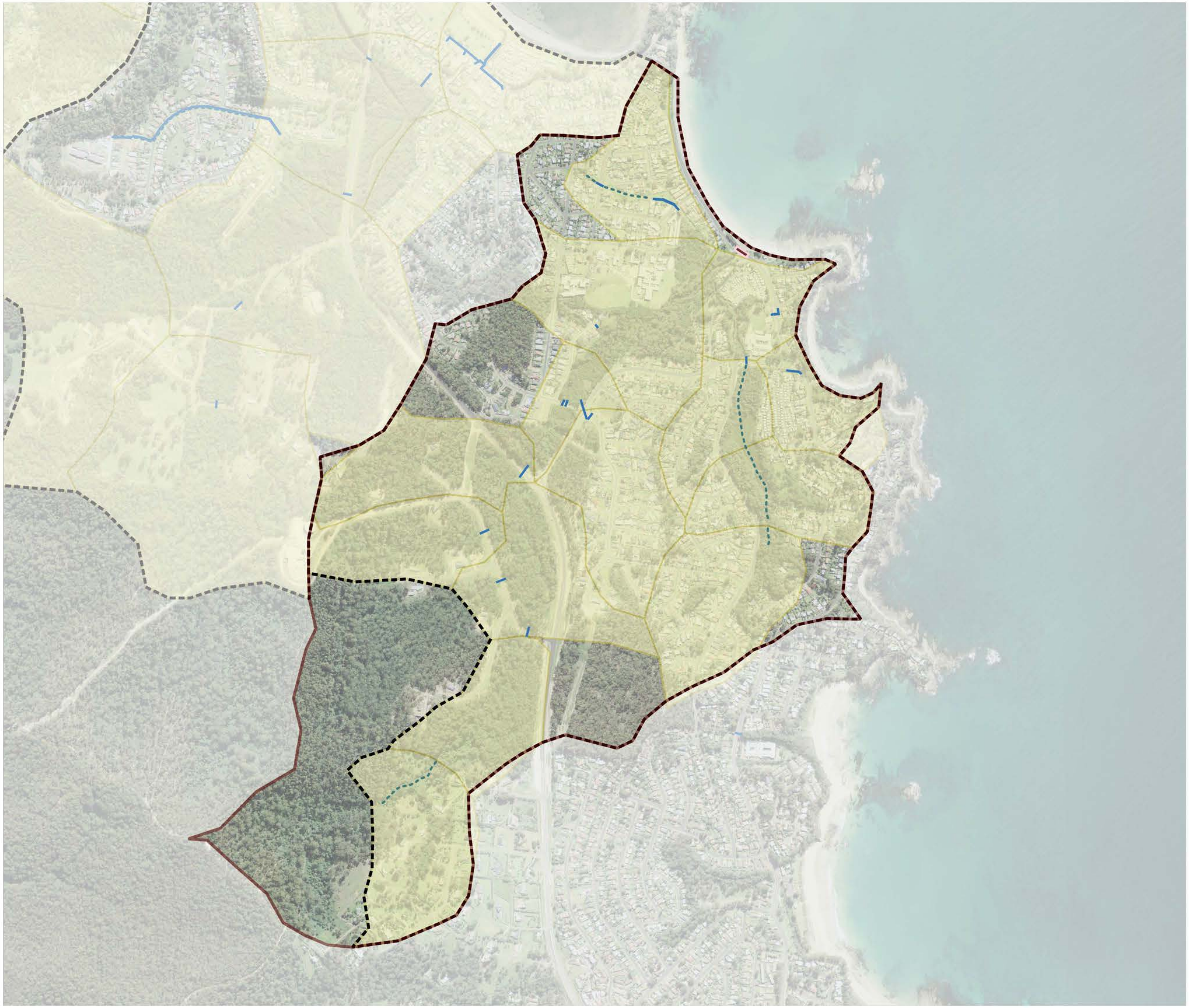
Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)



0 200 400 600 800 m

Scale : 1:15000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

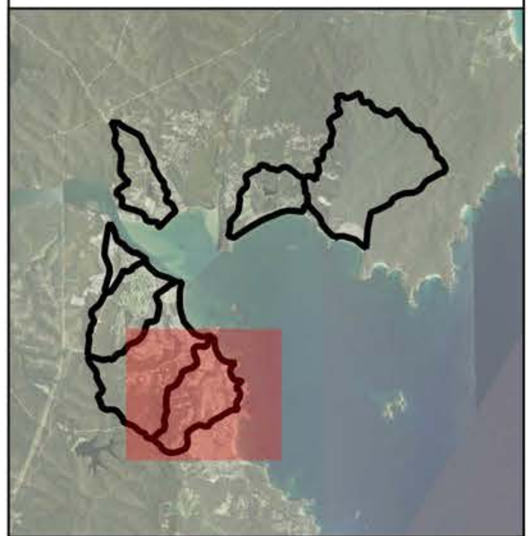
Rhelm



G602-g-1
Sunshine Bay
Tuflow Model

- Catchment Area
- Tuflow Model Area
- Included Pipes
- Excluded Pipes
- Bridges
- SA Polygons
- SA Streamlines

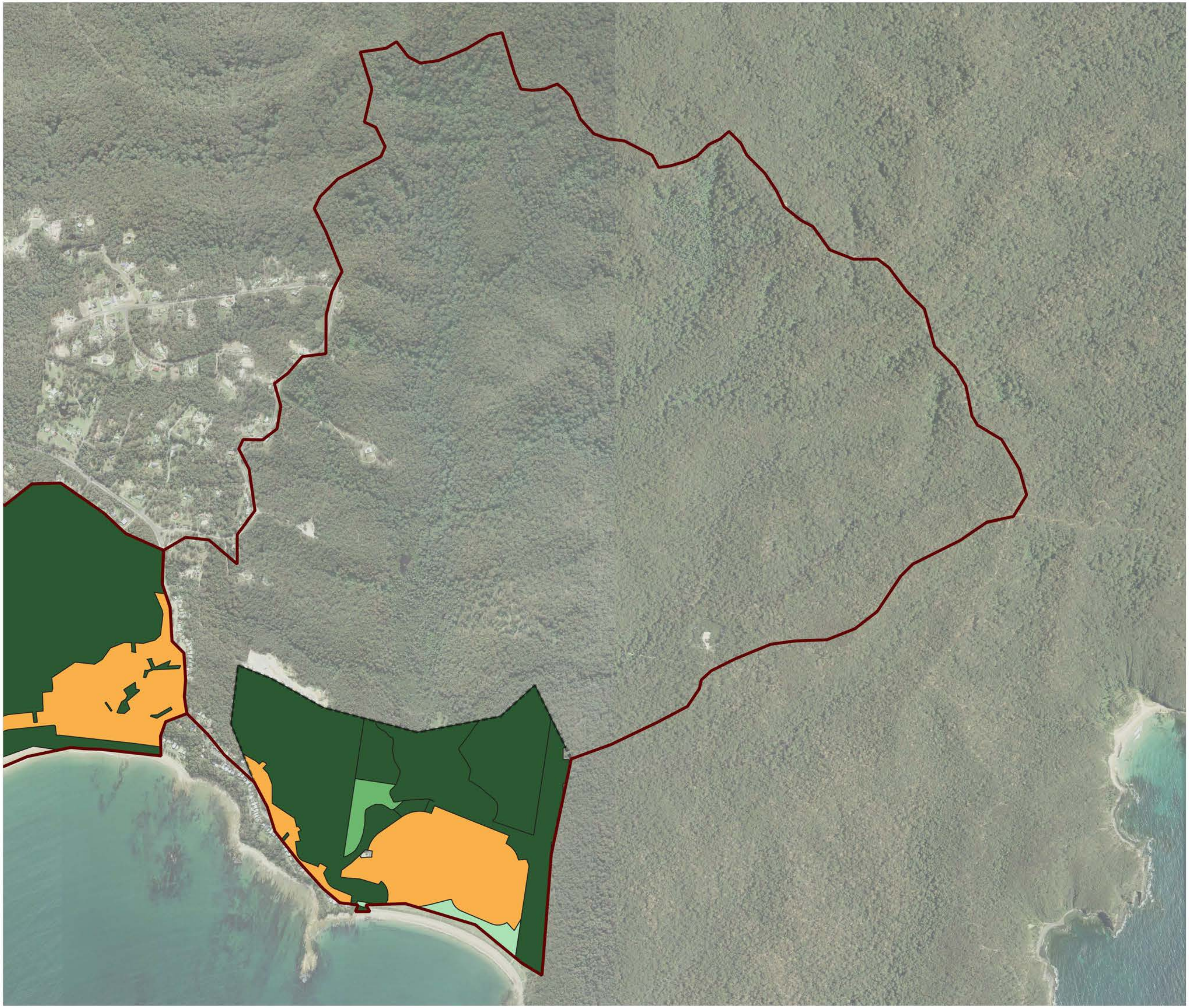
Note: Pipes have been included if:
- They have a size > 600mm
- They connect pipes >600mm
- They play a critical role in flood behaviour (ie: mionr drainage in Water Gardens)



0 170 340 510 680 m

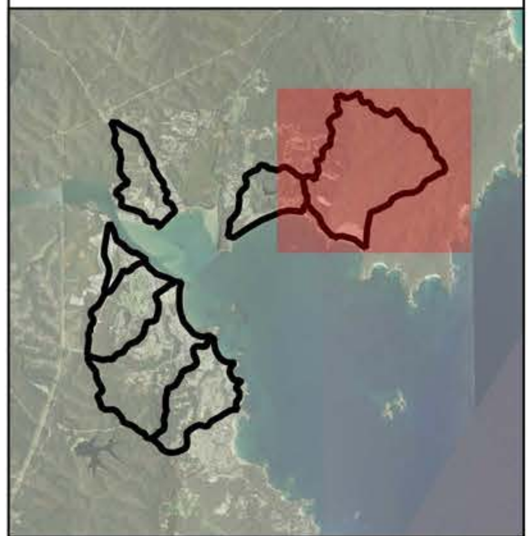
Scale : 1:12000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm



G603-a-1
Maloneys Beach
Tuflow Roughness

Catchment Area
Tuflow Model Area
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks

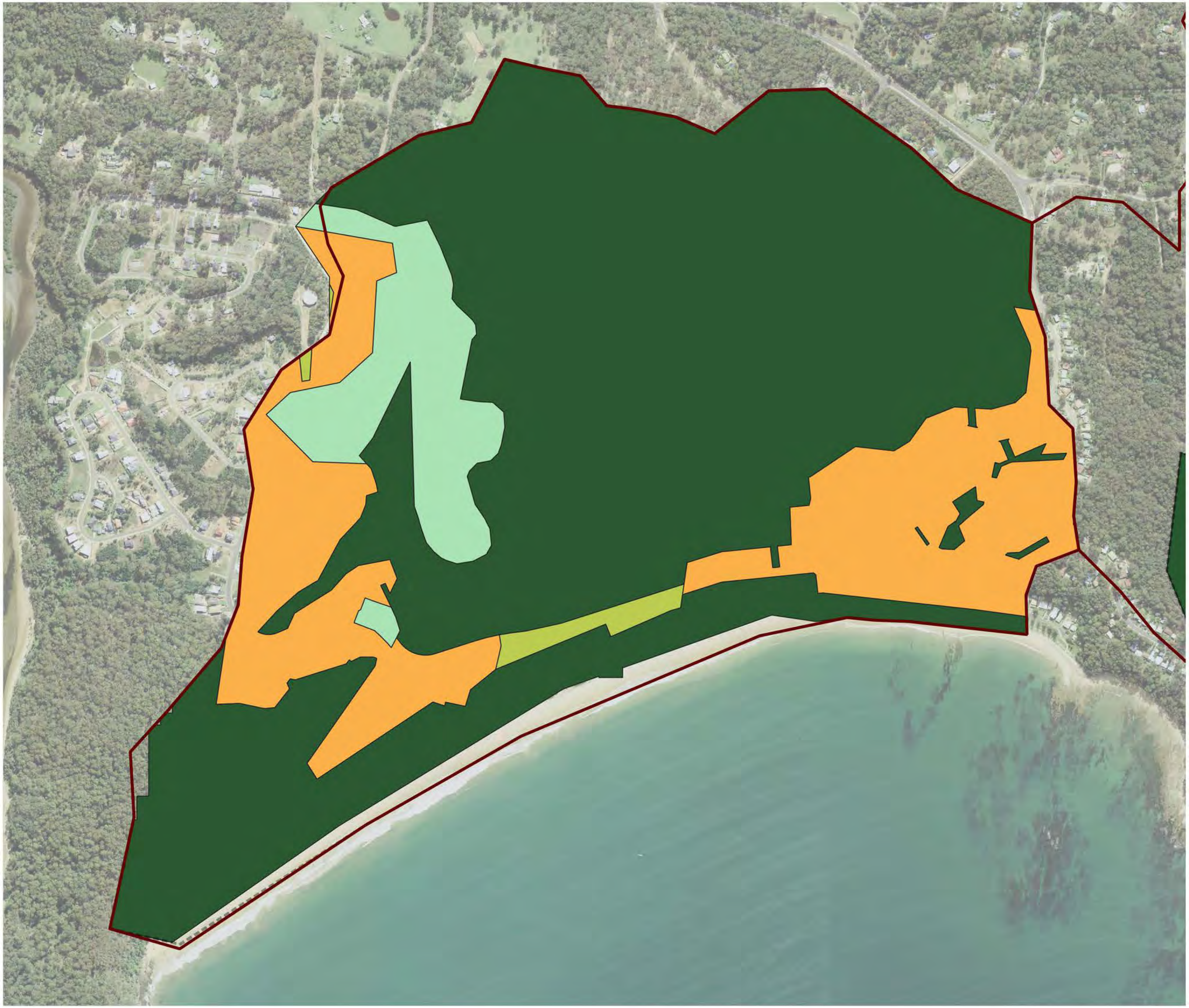


0 200 400 600 800 m

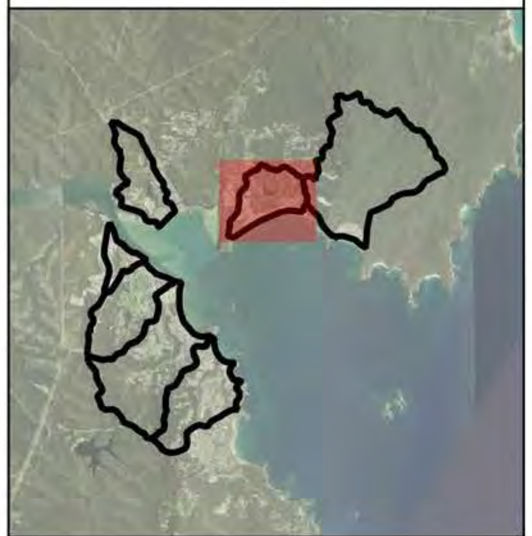
Scale : 1:15000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

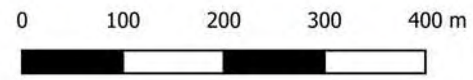
Rhelm

G603-b-1
Long Beach
Tuflow Roughness



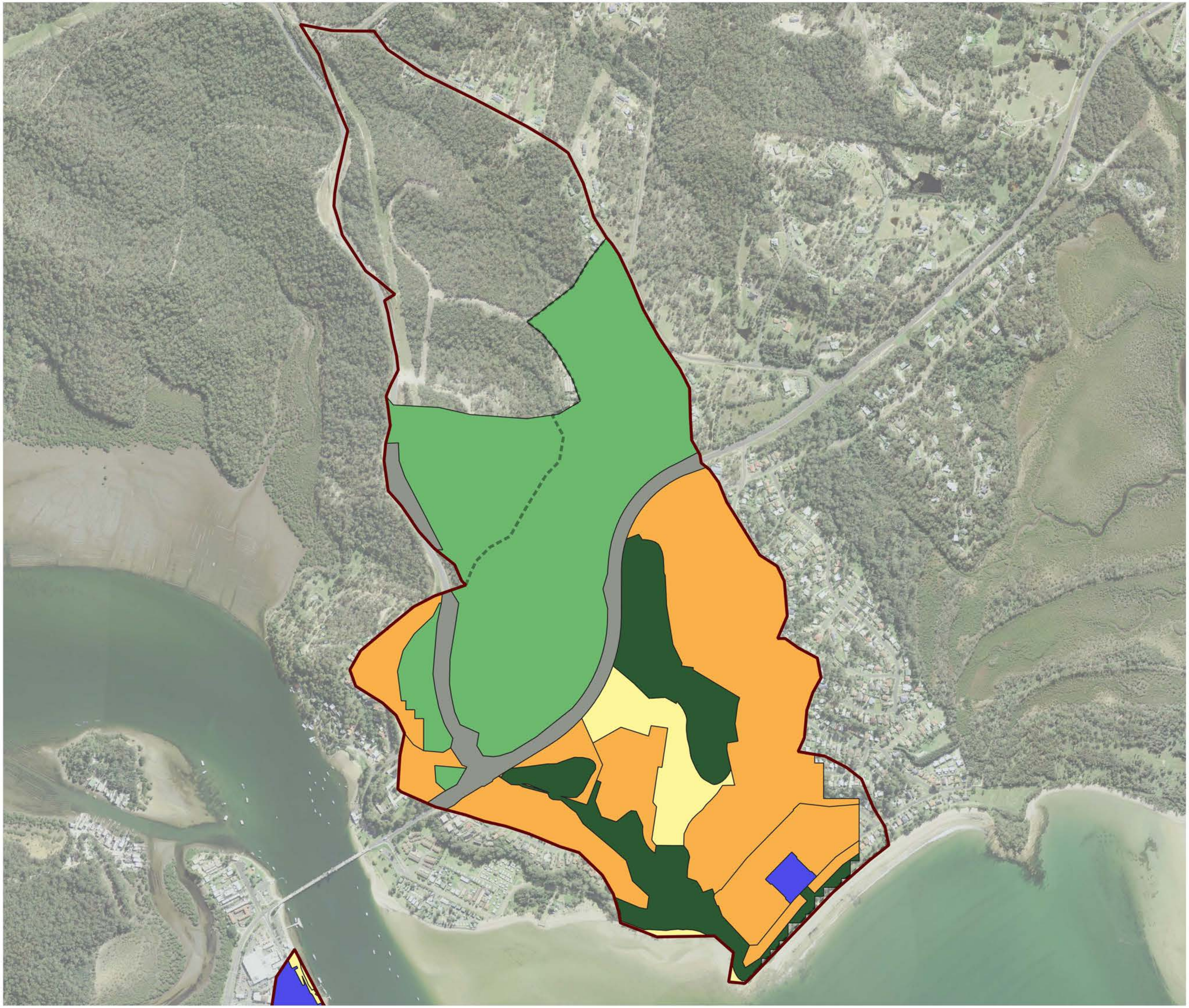
Catchment Area
Tuflow Model Area
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks





Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

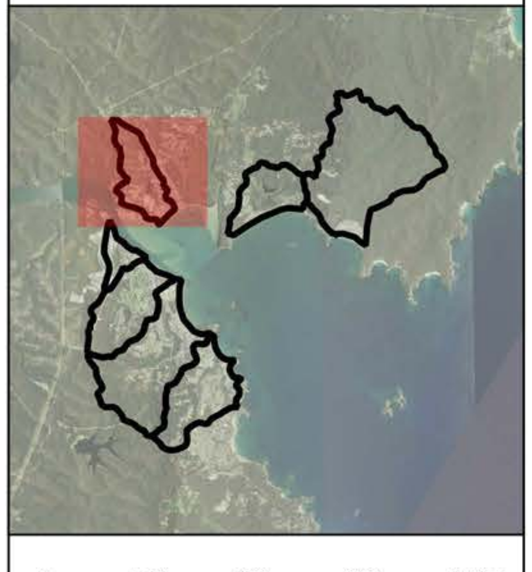
Rhelm



G603-c-1
Surfside
Tuflow Roughness

Catchment Area
Tuflow Model Area

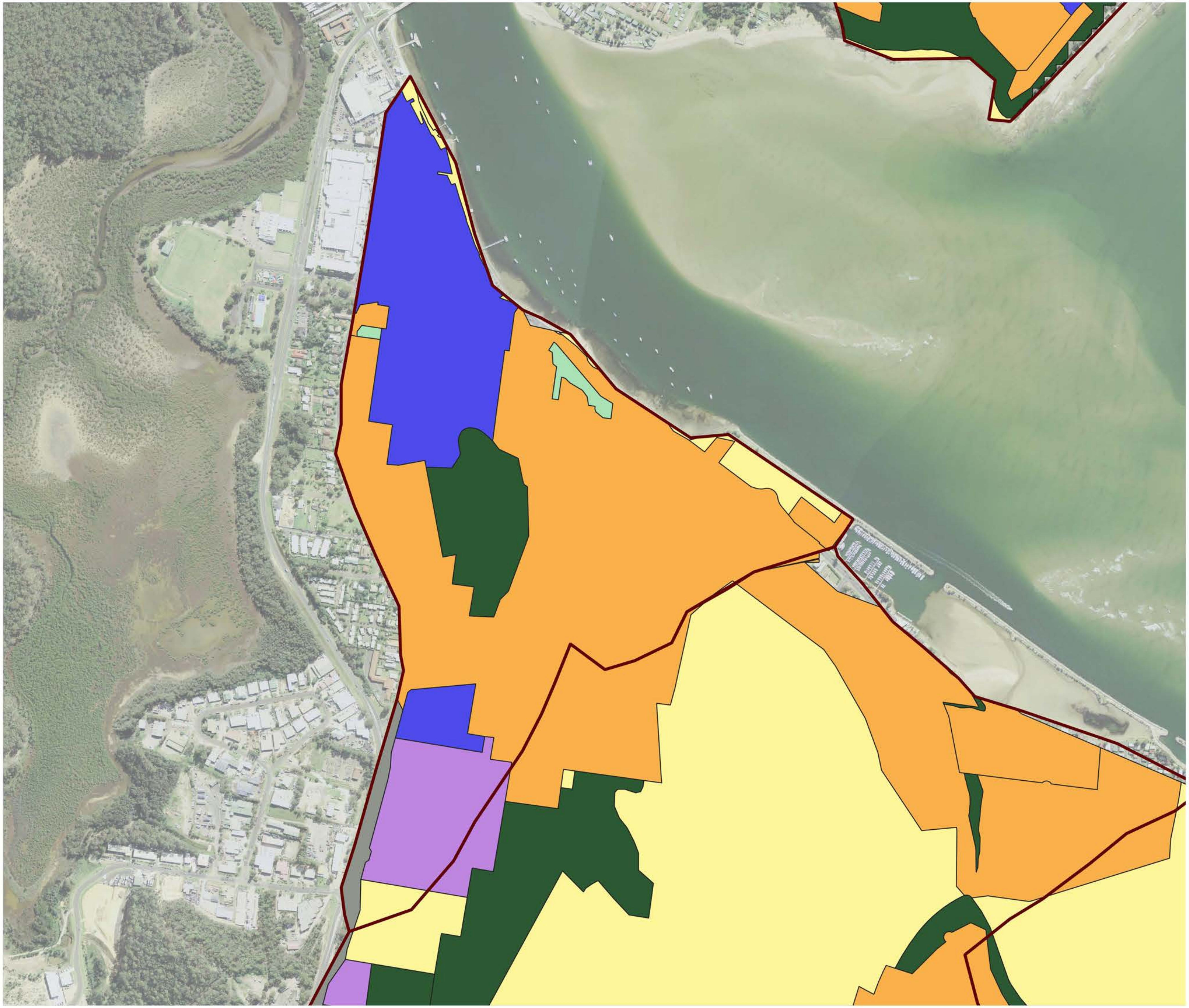
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks



0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

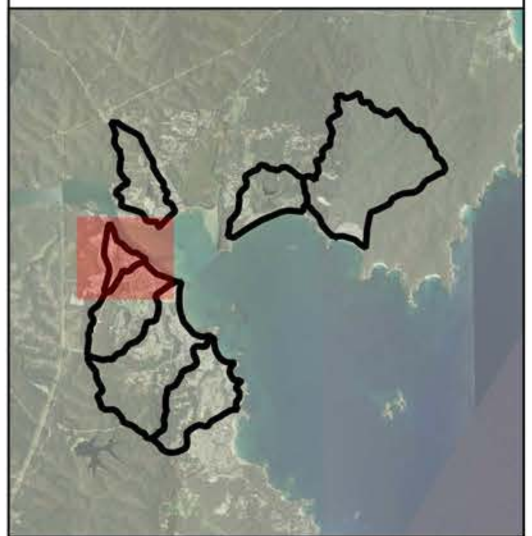
Rhelm



G603-d-1 Water Gardens Tuflow Roughness

Catchment Area
Tuflow Model Area

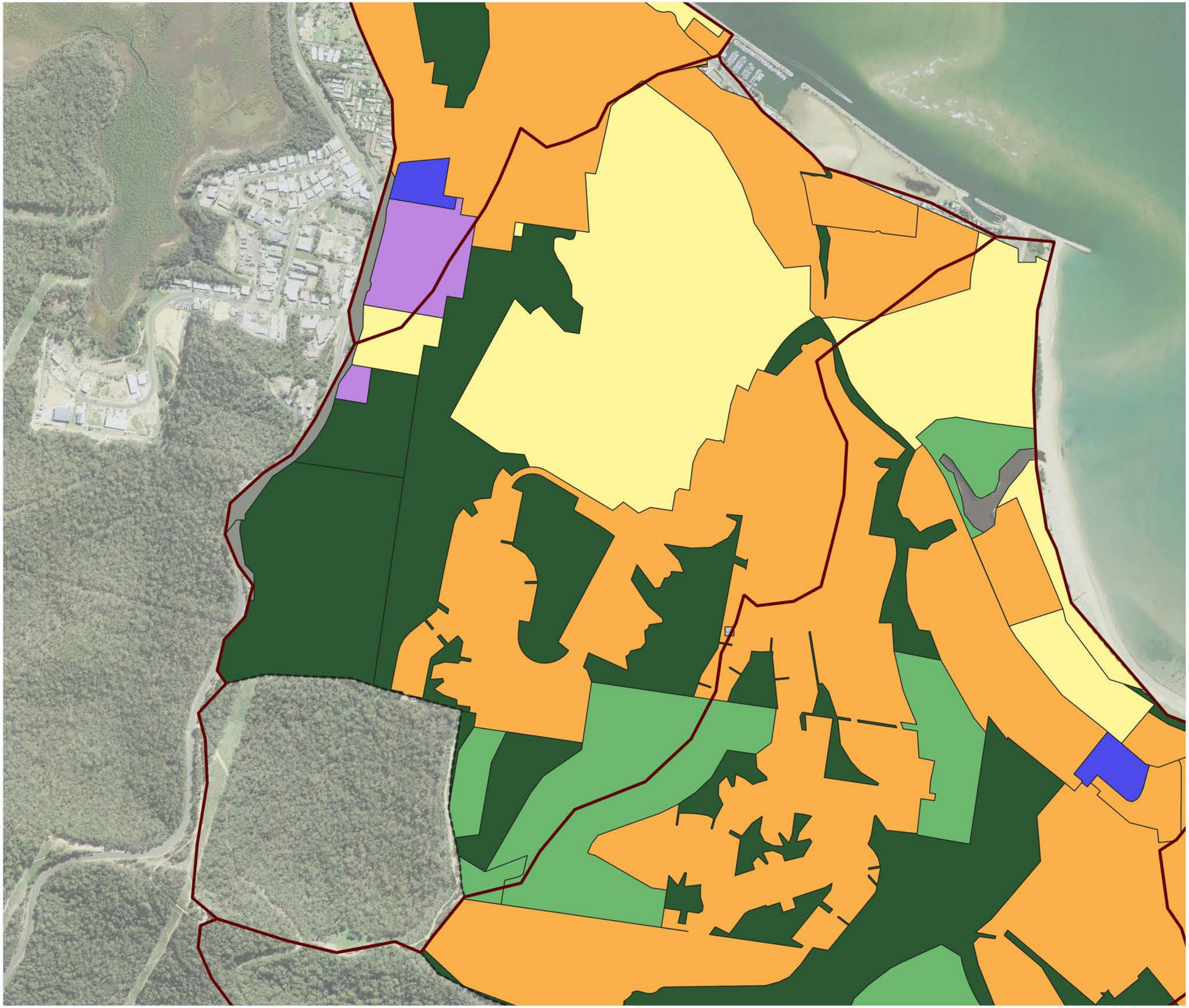
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks



0 100 200 300 400 m

Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

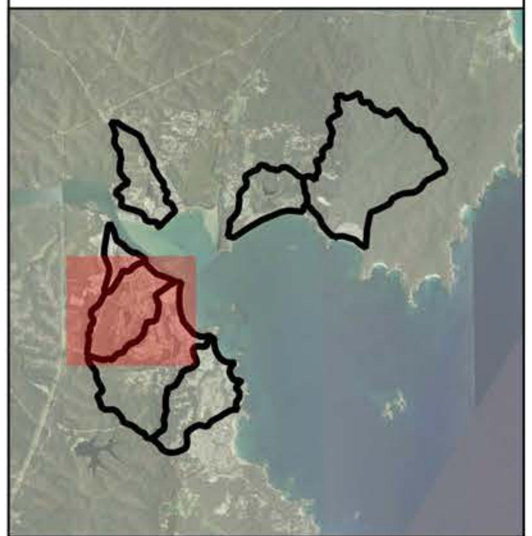
Rhelm



G603-e-1
Catalina
Tuflow Roughness

Catchment Area
Tuflow Model Area

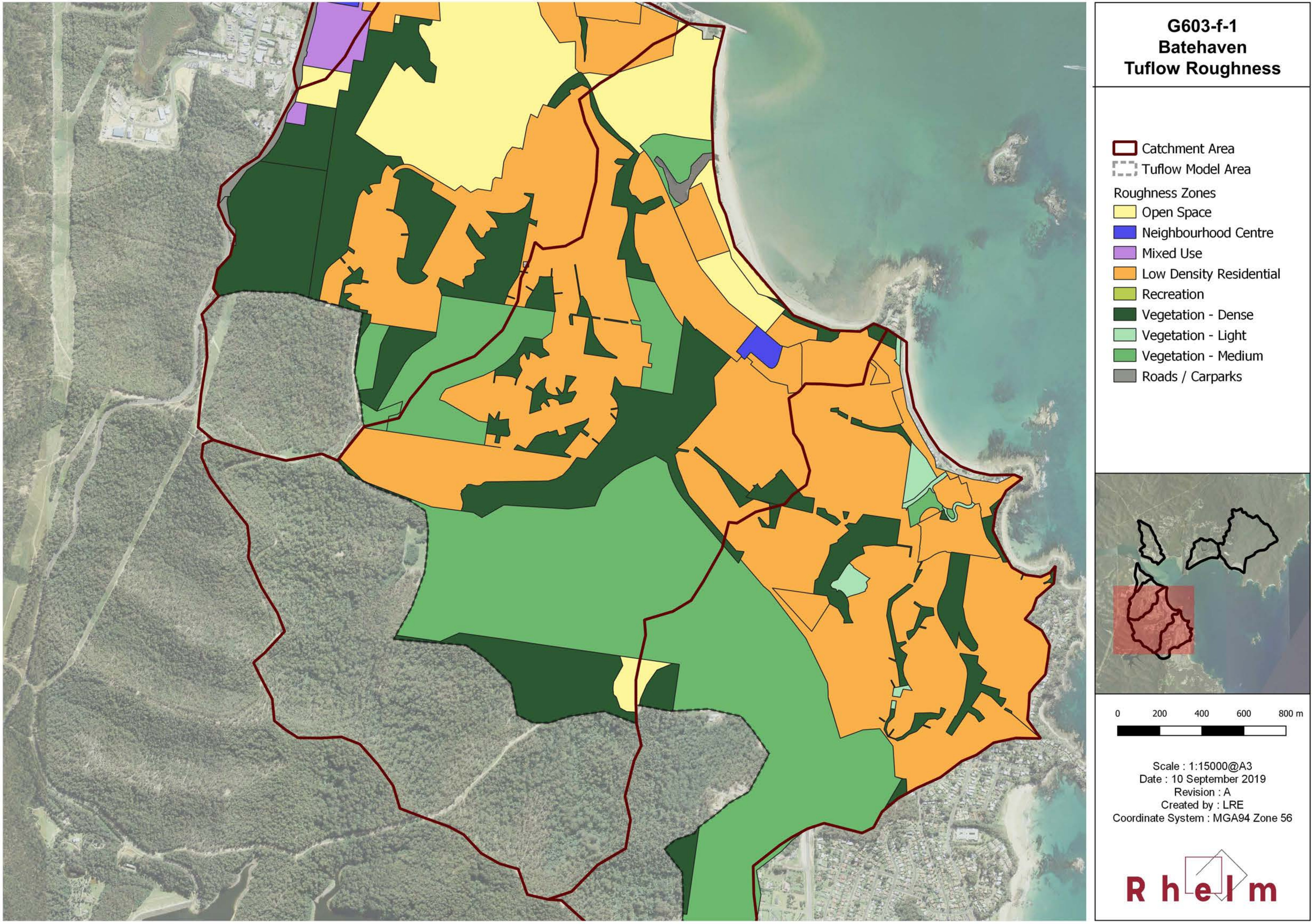
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks



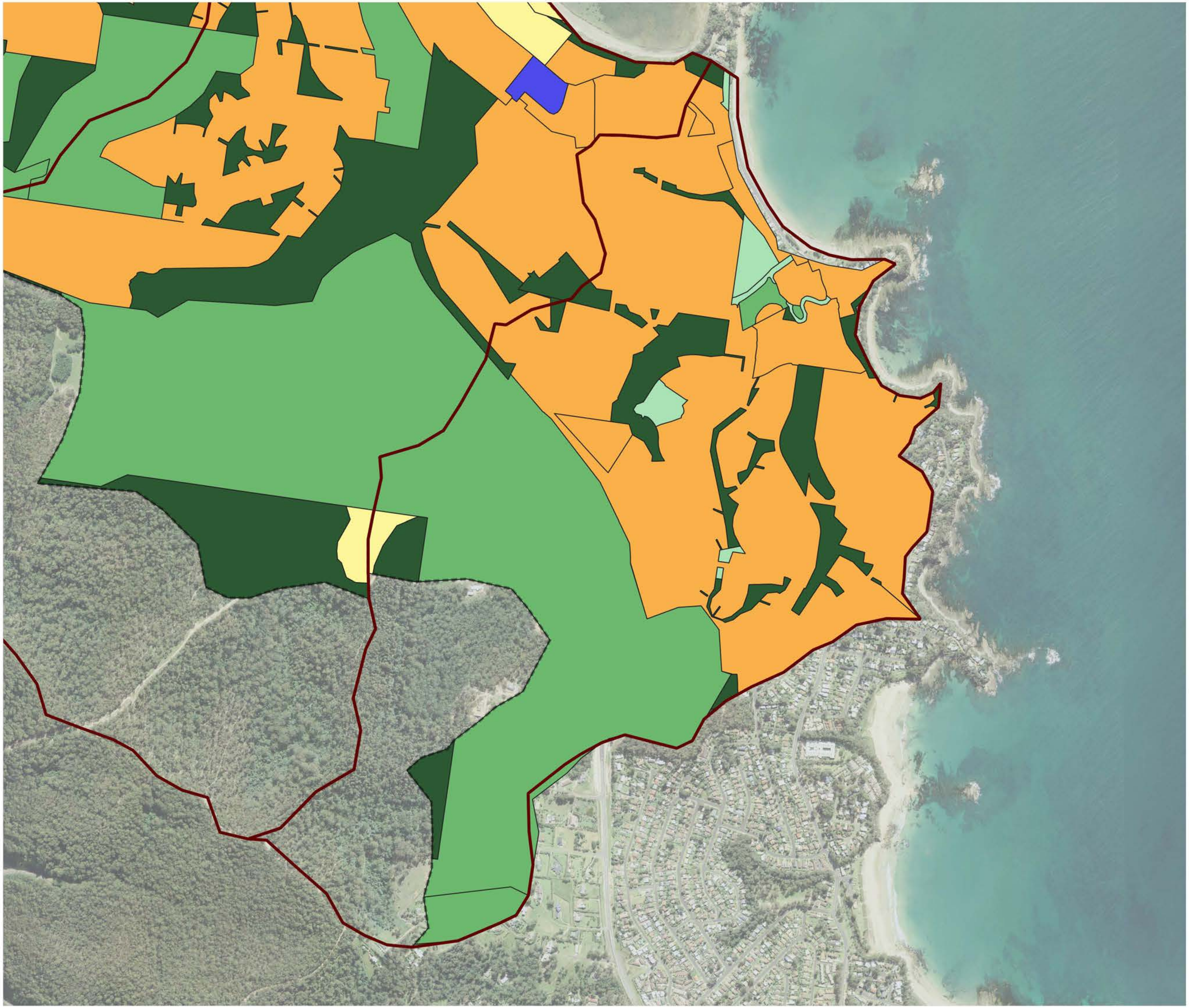
0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm

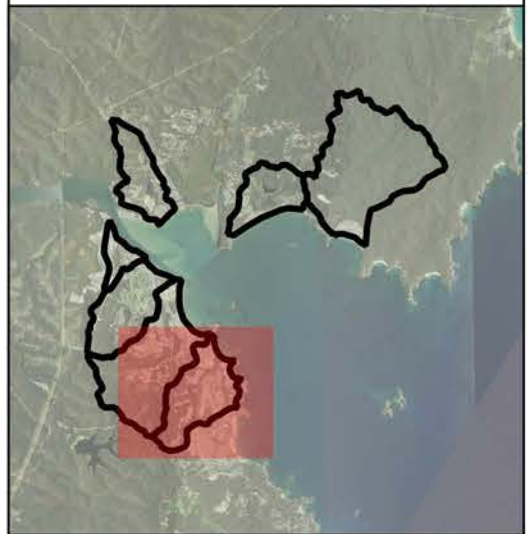


G603-f-1
Batehaven
Tuflow Roughness
Catchment Area
Tuflow Model Area
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks
0
200
400
600
800 m
Scale : 1:15000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56
Rhelm



G603-g-1
Sunshine Bay
Tuflow Roughness

Catchment Area
Tuflow Model Area
Roughness Zones
Open Space
Neighbourhood Centre
Mixed Use
Low Density Residential
Recreation
Vegetation - Dense
Vegetation - Light
Vegetation - Medium
Roads / Carparks



0 170 340 510 680 m

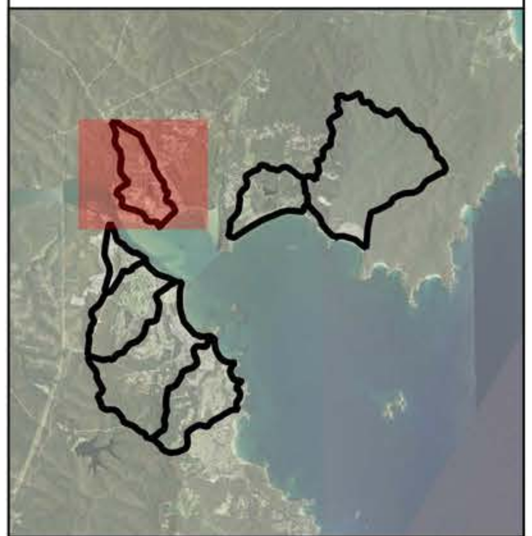
Scale : 1:12000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm

G701-c-1
Surfside
Community Responses

Catchment Area
Community Responses

1% AEP Depth
- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4



0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm

G701-d-1
Water Gardens
Community Responses

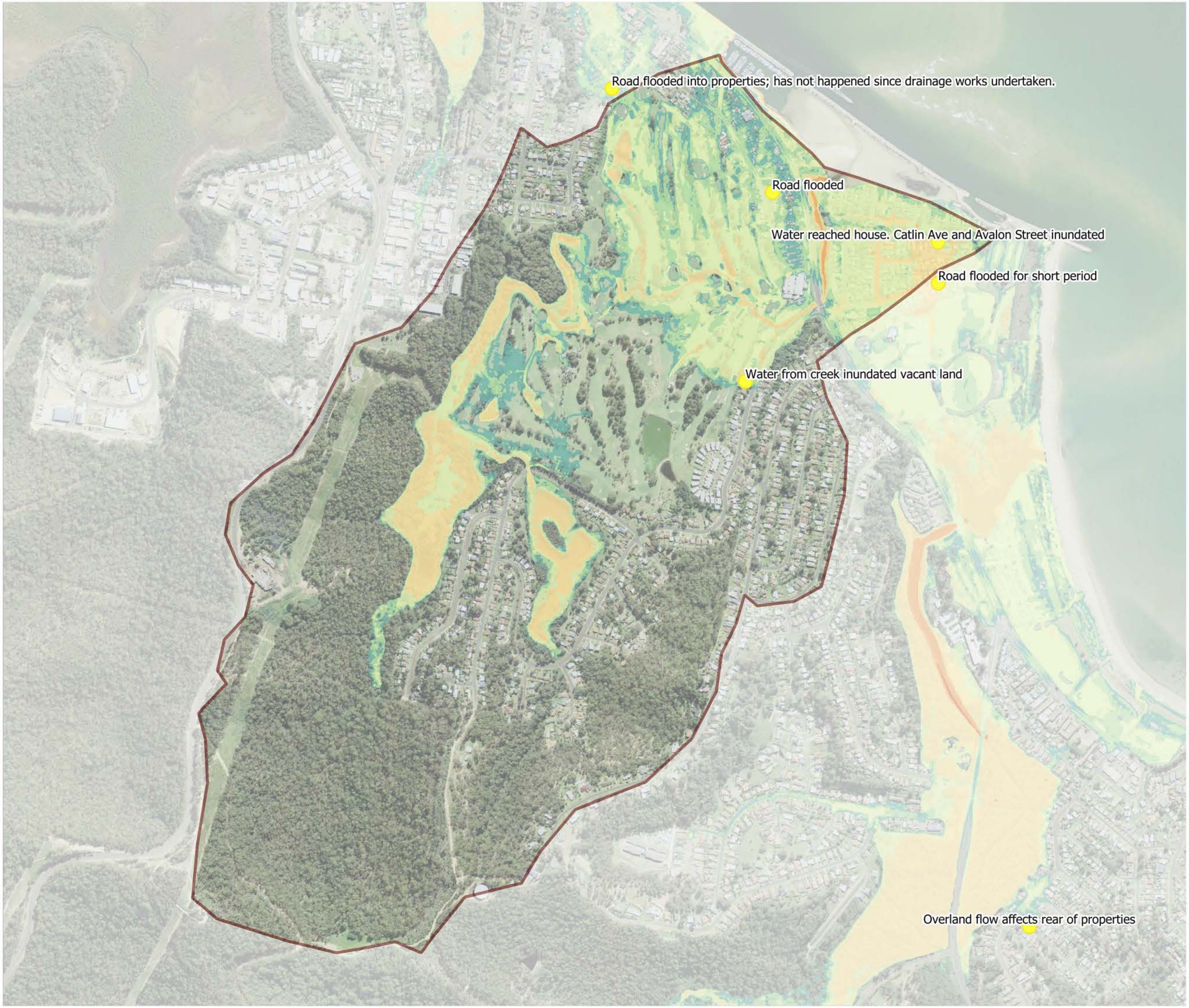
Catchment Area
Community Responses
1% AEP Depth
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4

0 100 200 300 400 m

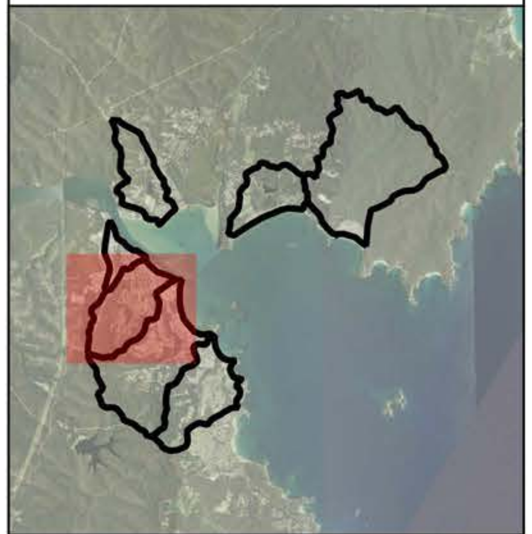
Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm

G701-e-1
Catalina
Community Responses



Catchment Area
Community Responses
1% AEP Depth
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4

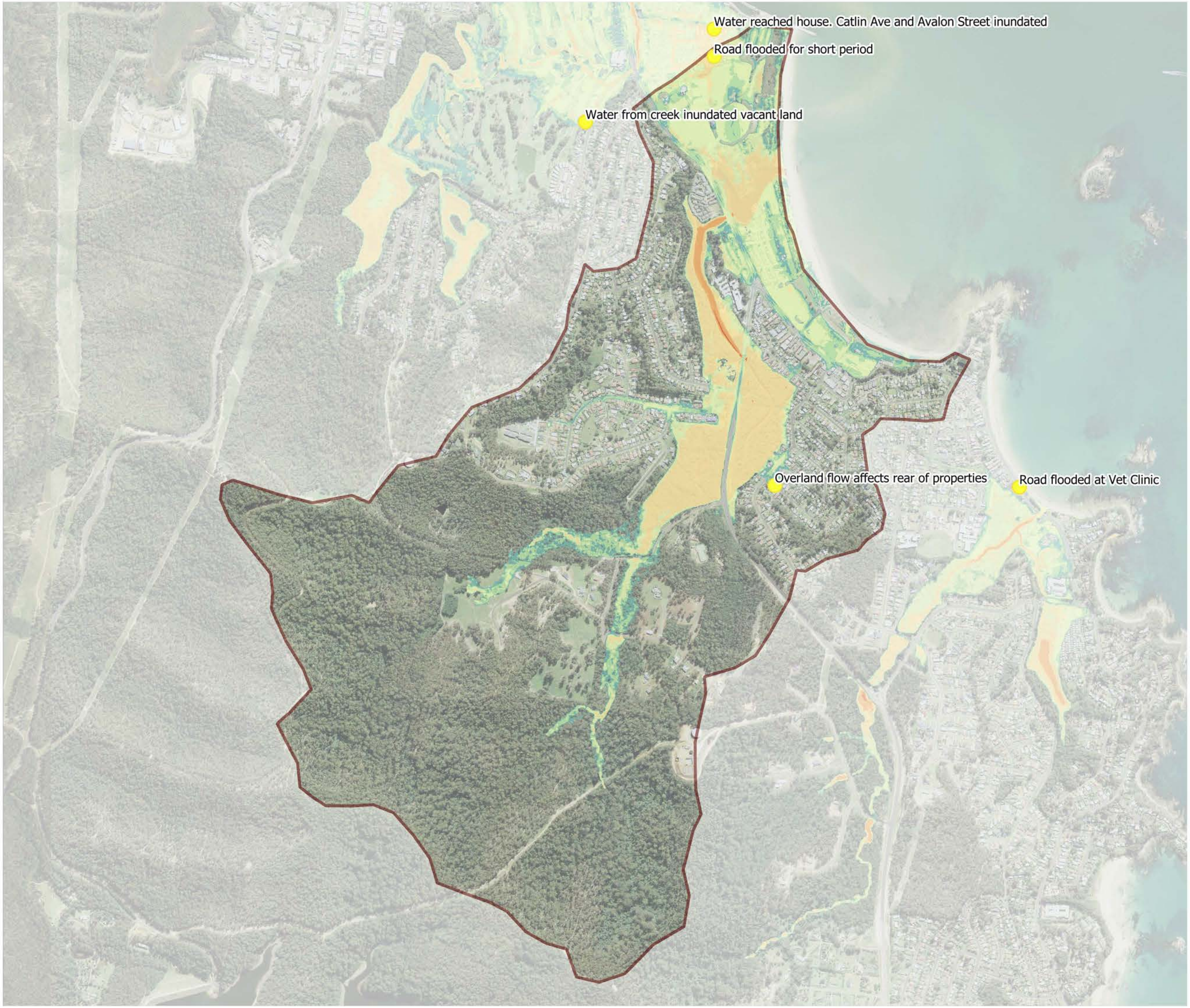


0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm

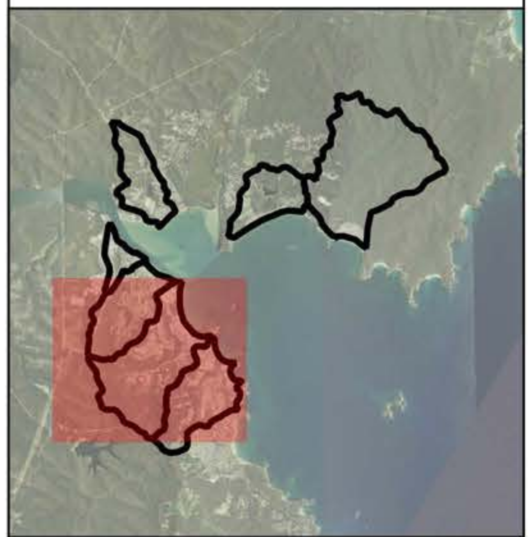
G701-f-1
Batehaven
Community Responses



Catchment Area
Community Responses

1% AEP Depth

- 0 - 0.15
- 0.15 - 0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- >4

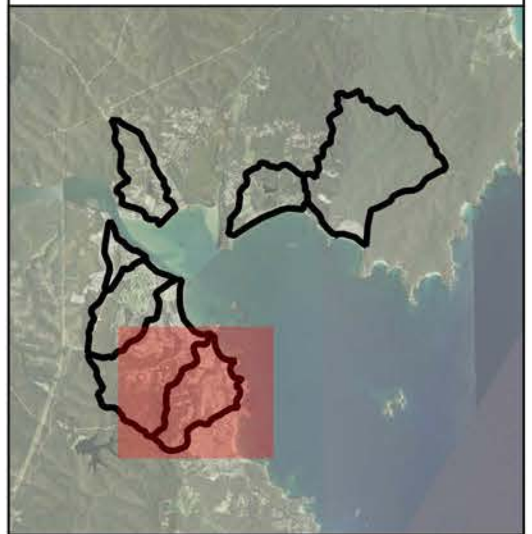


0 200 400 600 800 m

Scale : 1:15000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

G701-g-1
Sunshine Bay
Community Responses

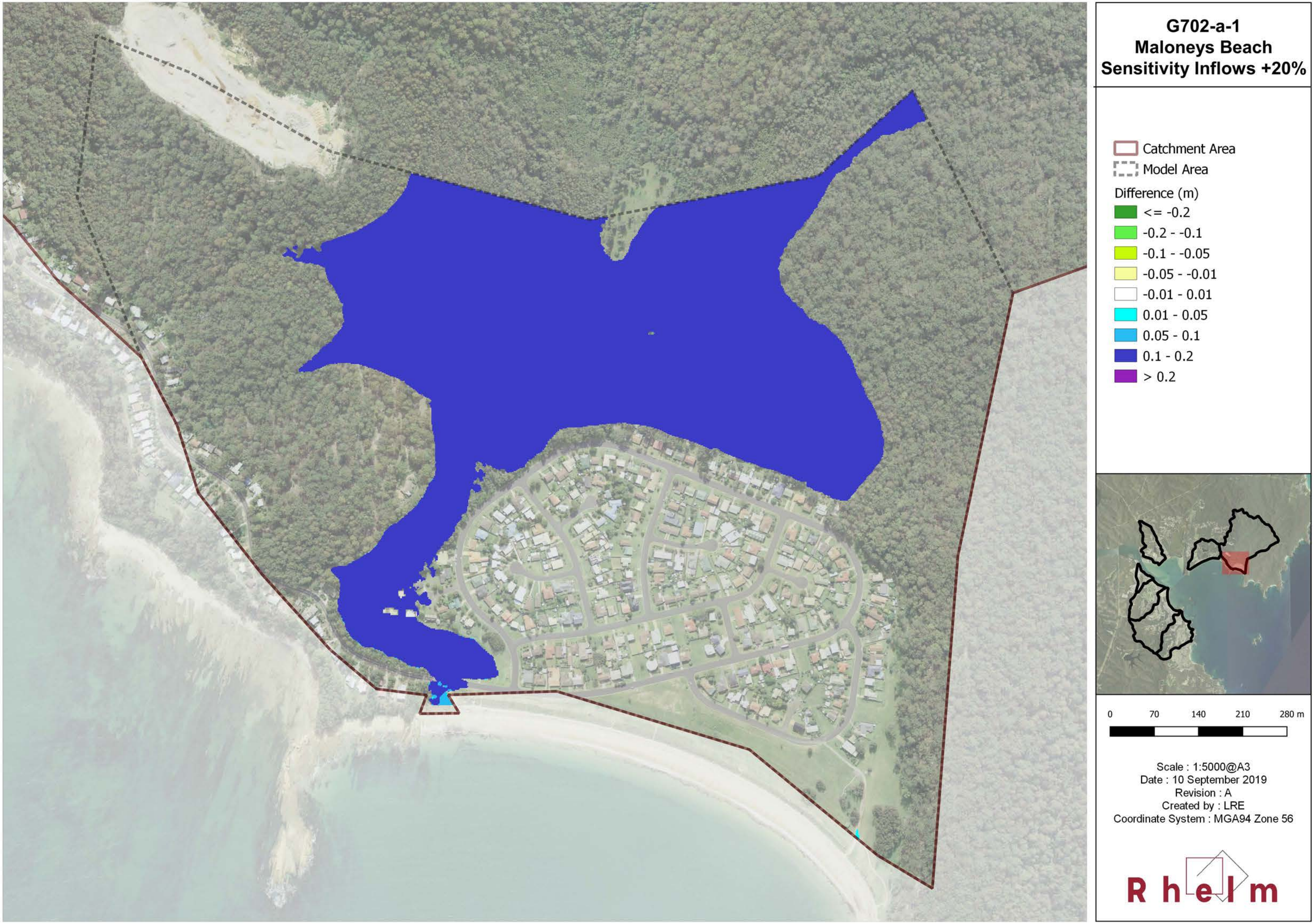
Catchment Area
Community Responses
1% AEP Depth
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4



0 170 340 510 680 m

Scale : 1:12000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

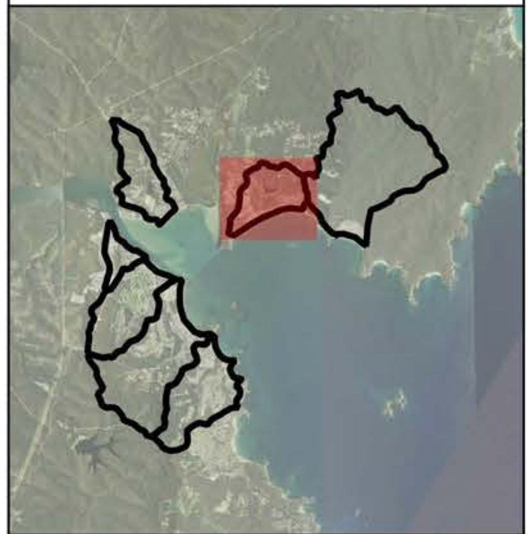
Rhelm



G702-a-1
Maloneys Beach
Sensitivity Inflows +20%
Catchment Area
Model Area
Difference (m)
<= -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
0
70
140
210
280 m
Scale : 1:5000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56
Rhelm

G702-b-1
Long Beach
Sensitivity Inflows +20%

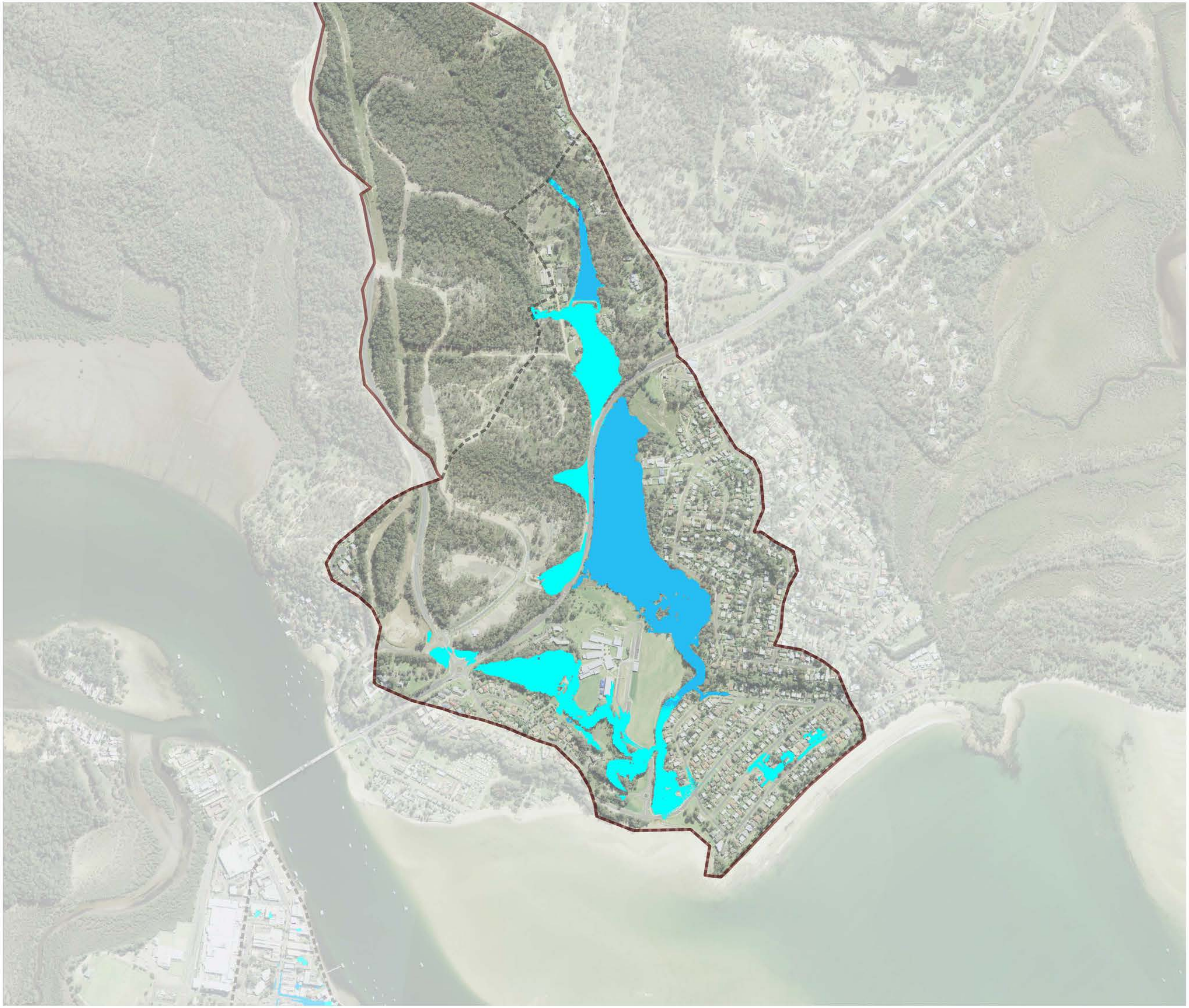
Catchment Area
Model Area
Difference (m)
<= -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2



0 100 200 300 400 m

Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

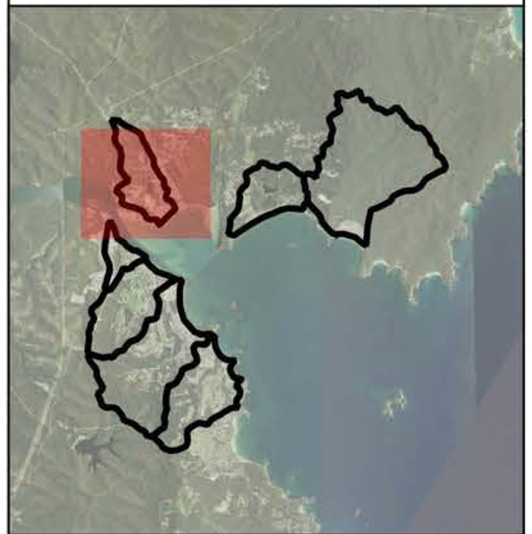
Rhelm



G702-c-1
Surfside
Sensitivity Inflows +20%

Catchment Area
Model Area

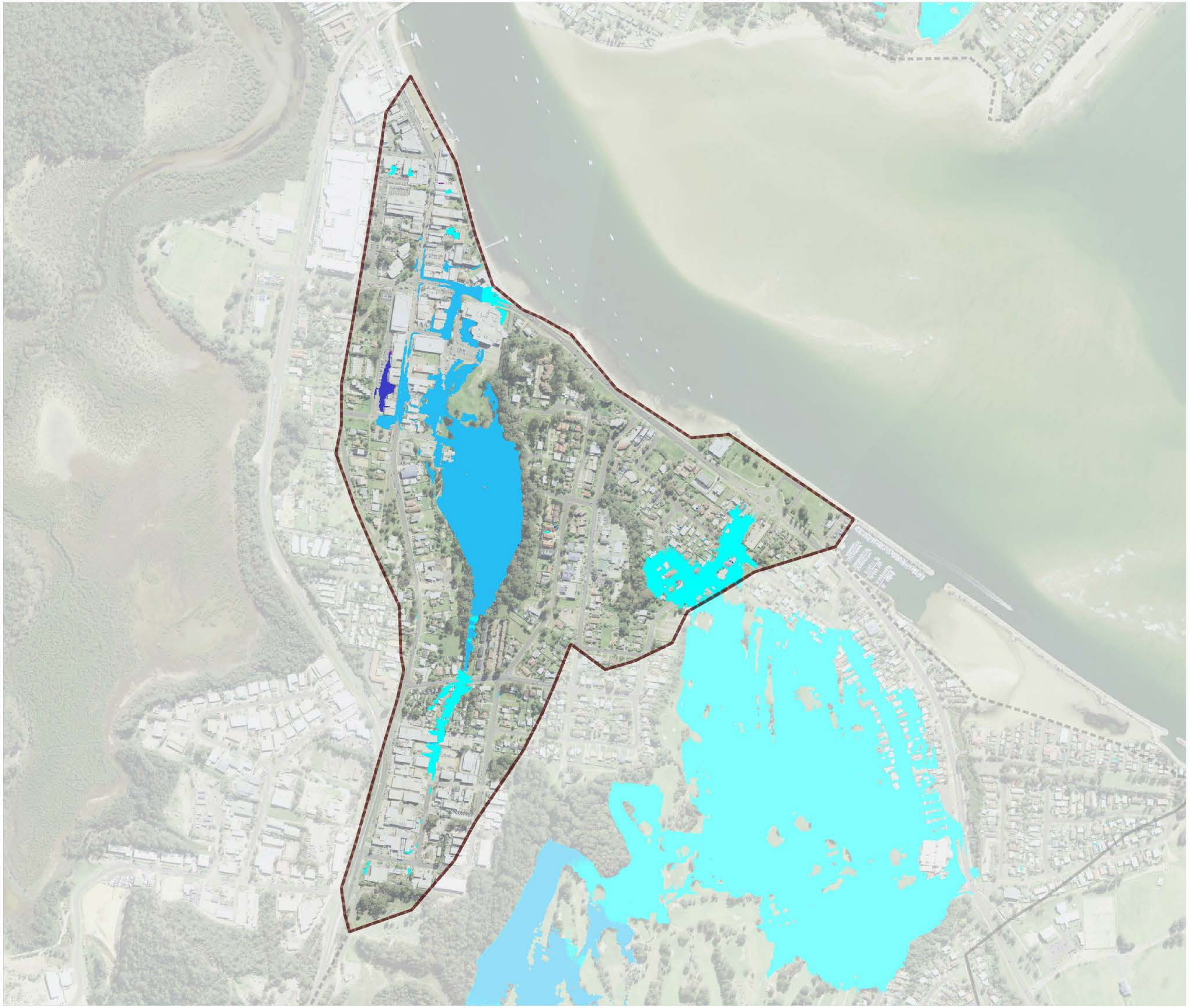
Difference (m)
- <= -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2



0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm



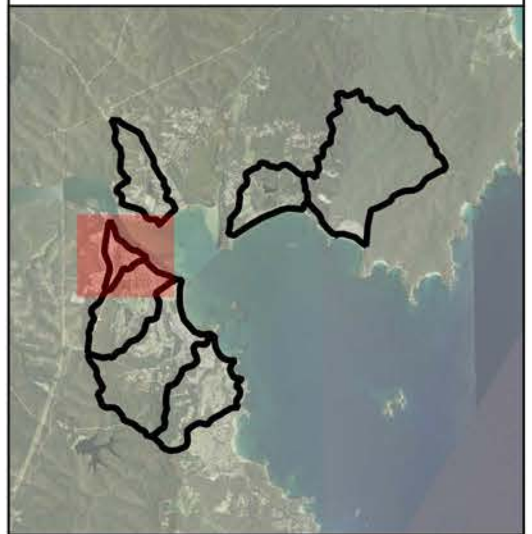
G702-d-1
Water Gardens
Sensitivity Inflows +20%

Catchment Area

Model Area

Difference (m)

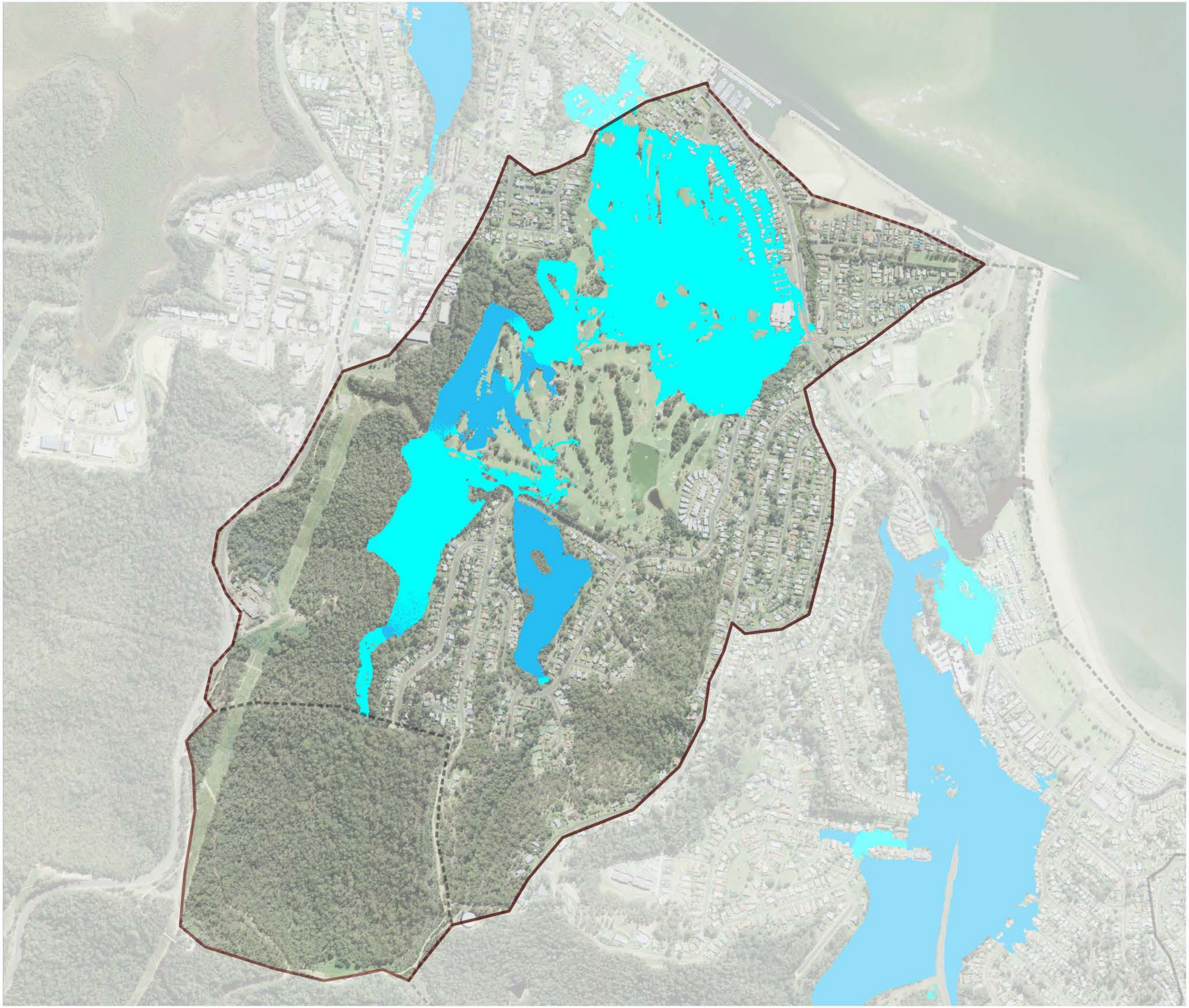
- <= -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2



0 100 200 300 400 m

Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

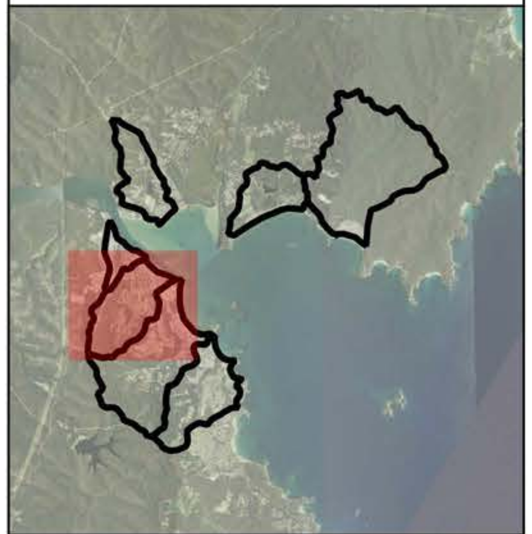
Rhelm



G702-e-1
Catalina
Sensitivity Inflows +20%

Catchment Area
Model Area

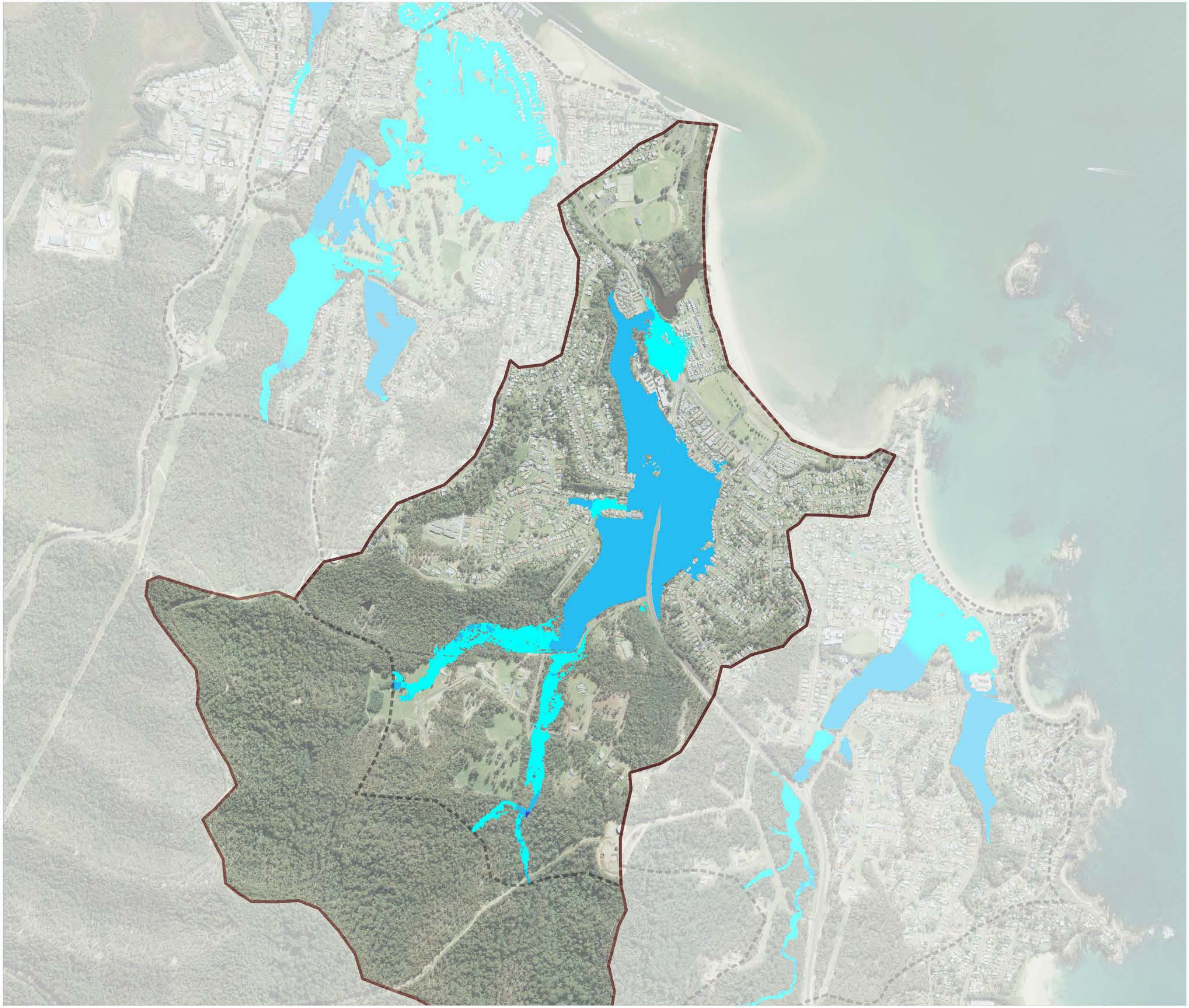
Difference (m)
- <= -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2



0 140 280 420 560 m

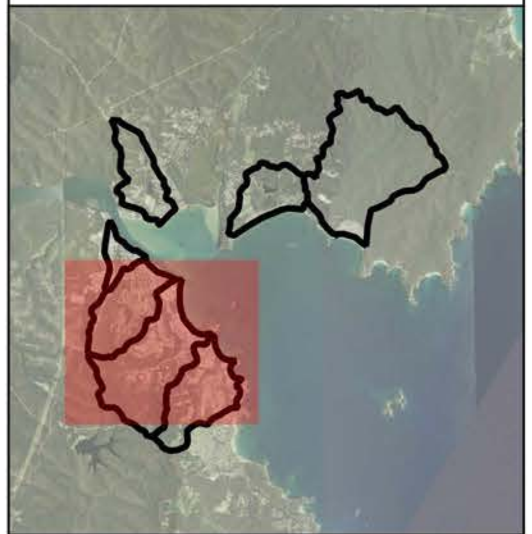
Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm



G702-f-1
Batehaven
Sensitivity Inflows +20%

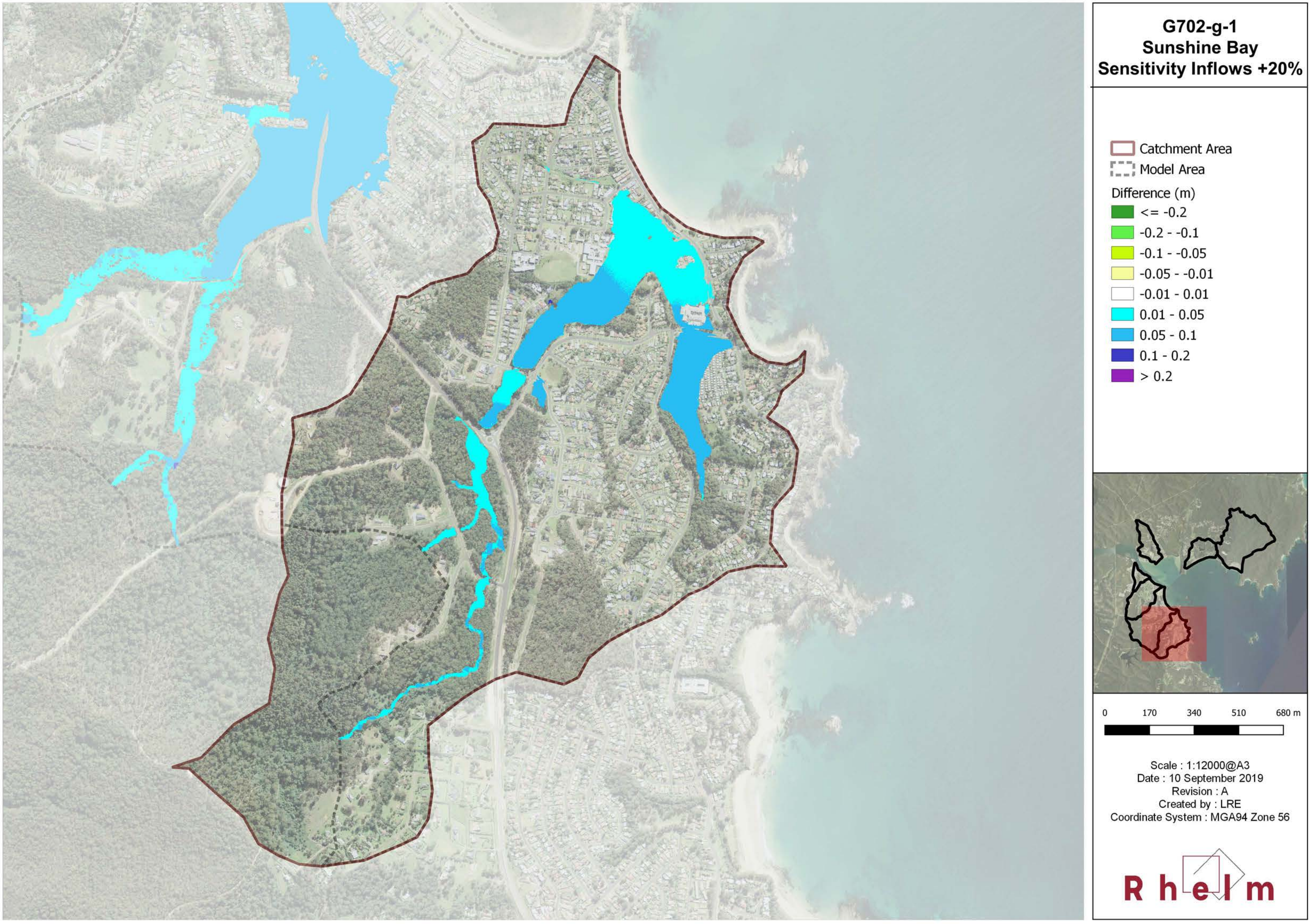
Catchment Area
Model Area
Difference (m)
<= -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2



0 200 400 600 800 m

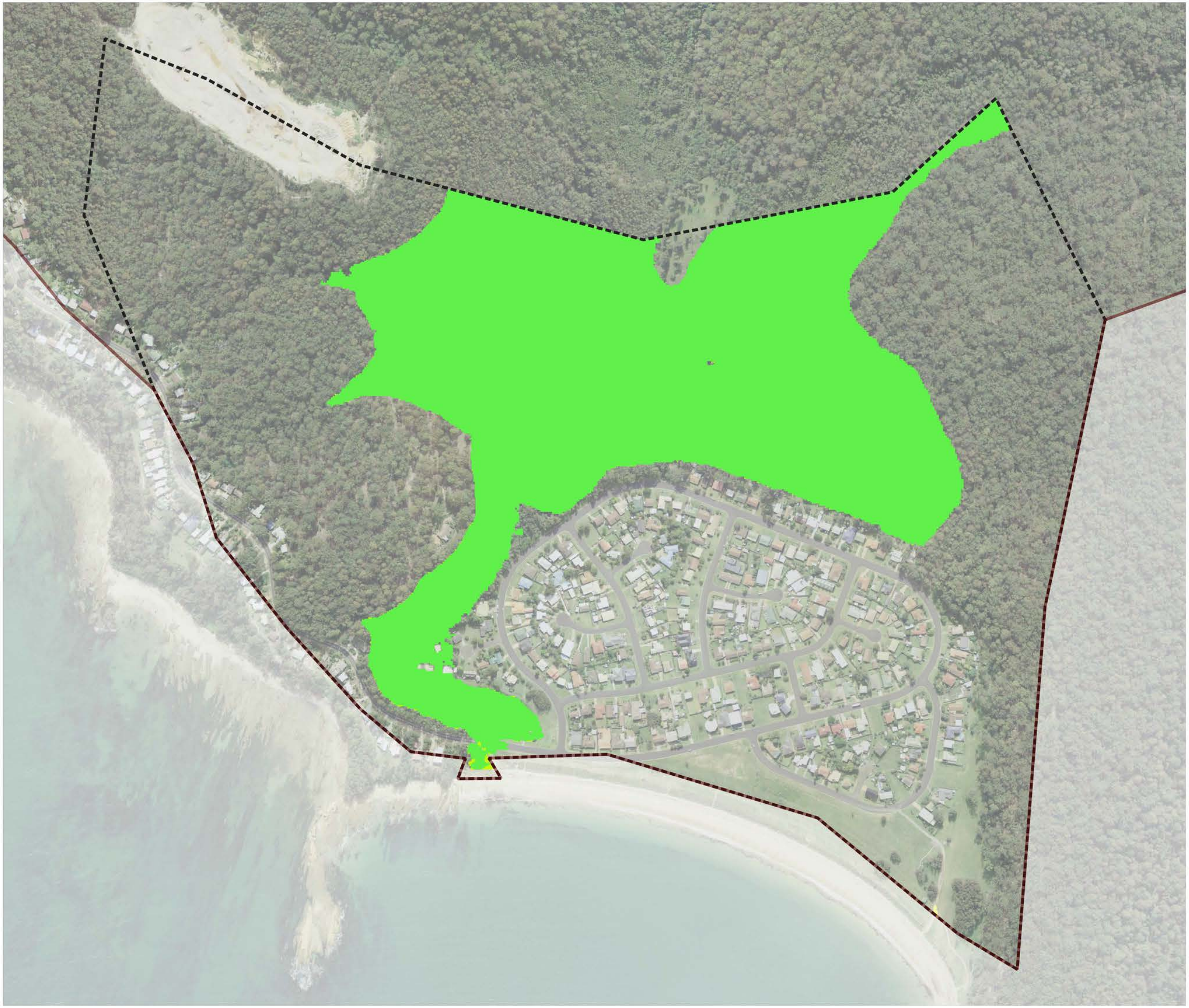
Scale : 1:15000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm



G702-g-1
Sunshine Bay
Sensitivity Inflows +20%
Catchment Area
Model Area
Difference (m)
<= -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2
0
170
340
510
680 m
Scale : 1:12000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56
Rhelm

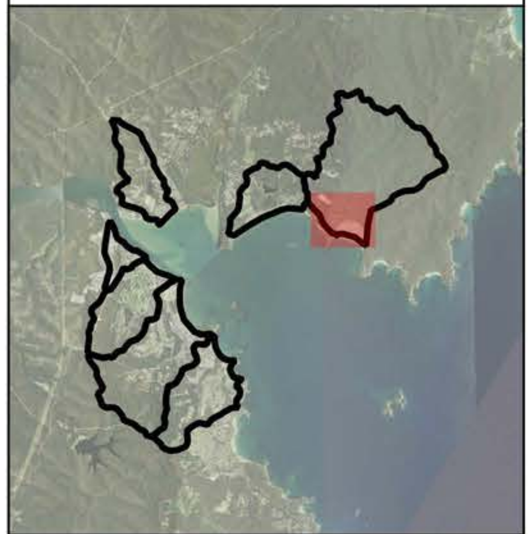
G703-a-1
Maloneys Beach
Sensitivity Inflows -20%



Catchment Area
Model Area

Difference (m)

- <= -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2



0 70 140 210 280 m

Scale : 1:5000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

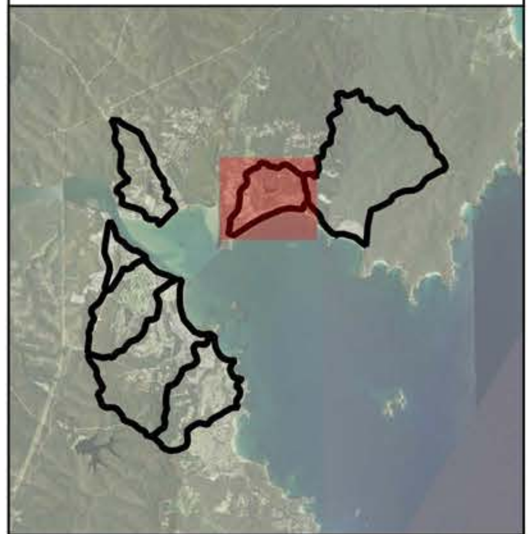
Rhelm

G703-b-1
Long Beach
Sensitivity Inflows -20%

Catchment Area
Model Area

Difference (m)

- <= -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2



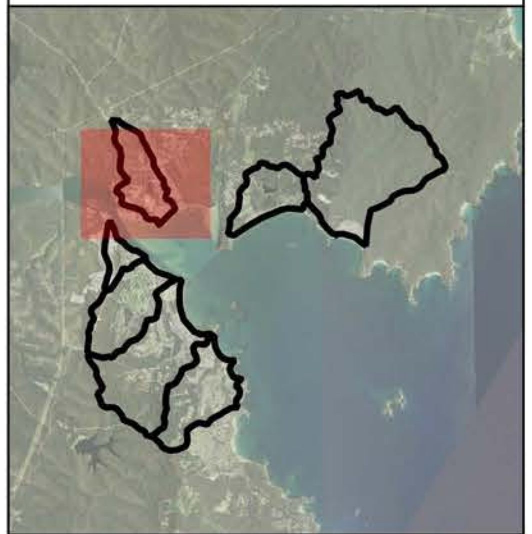
0 100 200 300 400 m

Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm

G703-c-1
Surfside
Sensitivity Inflows -20%

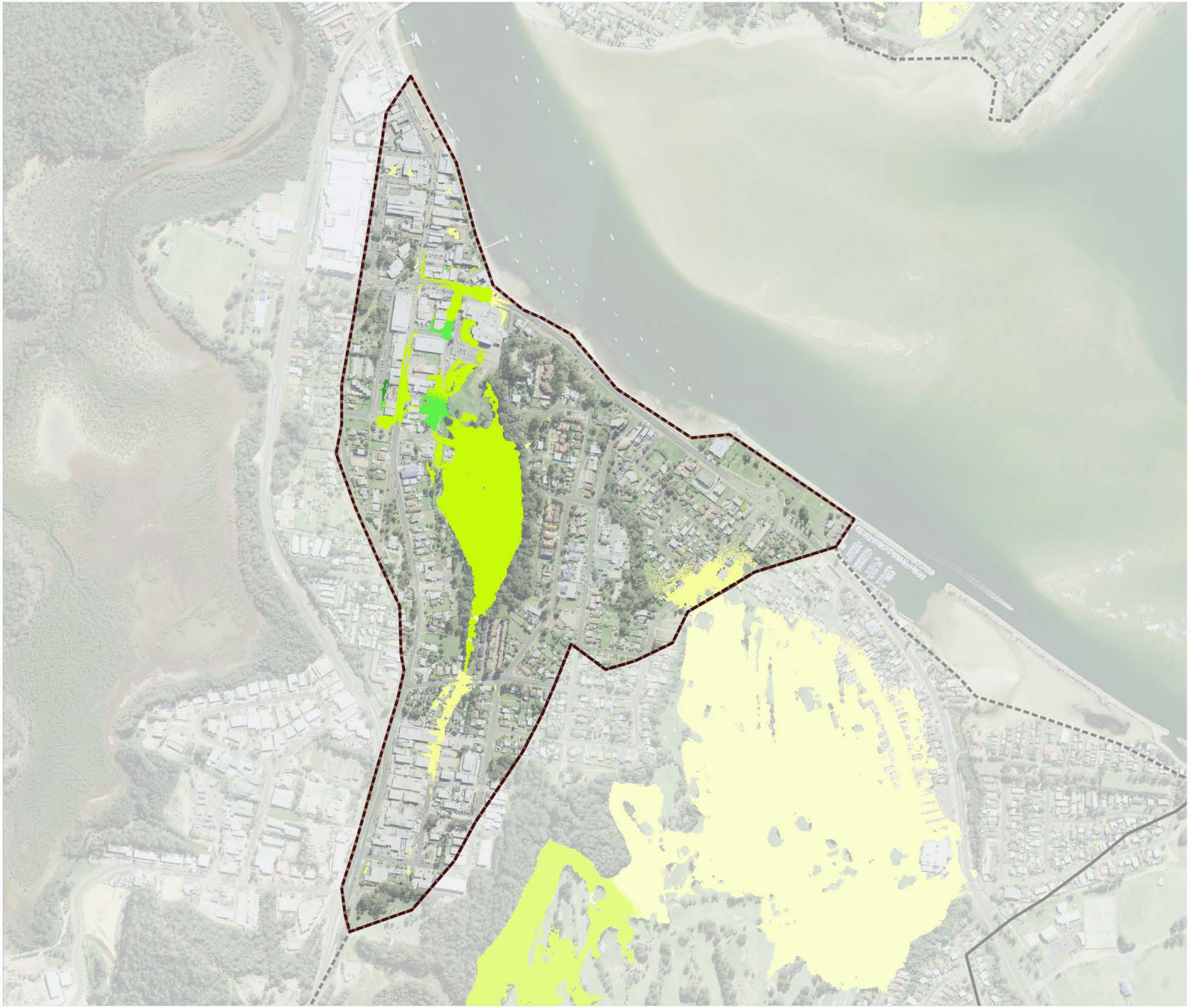
Catchment Area
Model Area
Difference (m)
<= -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2



0 140 280 420 560 m

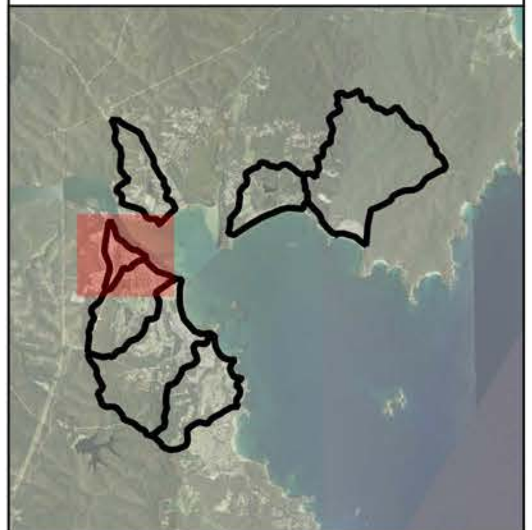
Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

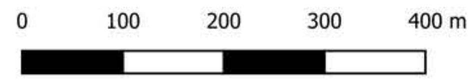
Rhelm



G703-d-1
Water Gardens
Sensitivity Inflows -20%

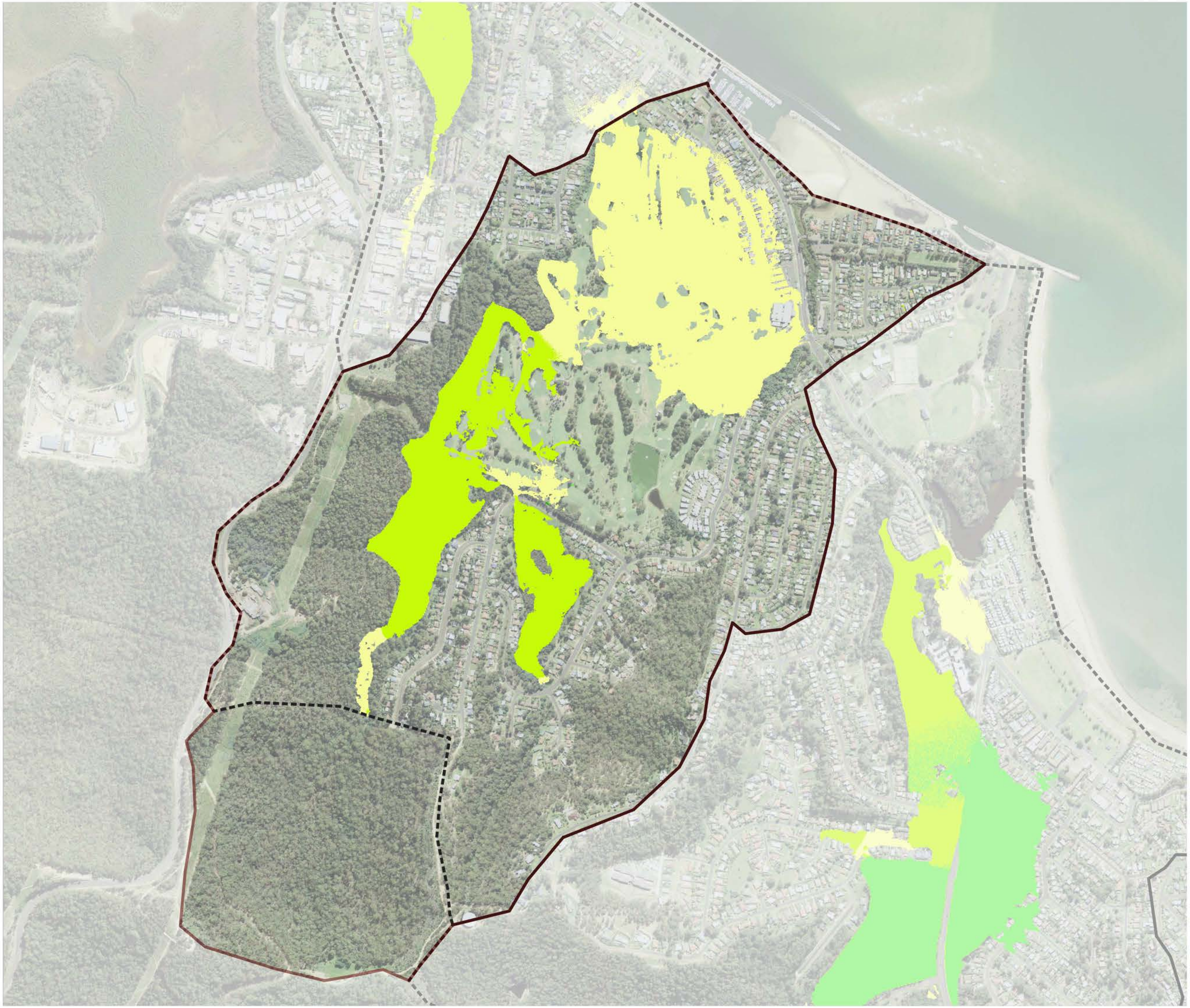
Catchment Area
Model Area
Difference (m)
<= -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.1
0.1 - 0.2
> 0.2





Scale : 1:7500@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm



G703-e-1
Catalina
Sensitivity Inflows -20%

Catchment Area
Model Area

Difference (m)
- <= -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2

0 140 280 420 560 m

Scale : 1:10000@A3
Date : 10 September 2019
Revision : A
Created by : LRE
Coordinate System : MGA94 Zone 56

Rhelm