Woy Woy Floodplain Risk Management Study

Final Report

Central Coast Council

Report

Dec 2022

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Woy Woy Floodplain Risk Management Study

Final Report

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Executive Summary

The Woy Woy Floodplain Risk Management Study (FRMS) has been prepared for Central Coast Council (Council) in accordance with the New South Wales (NSW) Flood Prone Land Policy and the principles of the Floodplain Development Manual (NSW Government, 2005). The Woy Woy FRMS examines options for managing flood risk across the Woy Woy Peninsula.

This FRMS is to be considered in conjunction with the Woy Woy Floodplain Risk Management Plan (FRMP) and the Woy Woy FRMS Technical Volume, both prepared as separate documents to this FRMS. The FRMP outlines the floodplain management measures recommended to be adopted for implementation along with the implementation strategy associated with those measures. The Woy Woy FRMS Technical Volume details the establishment and calibration of the coupled surface water and groundwater modelling.

Previous studies the Brisbane Water Foreshore Floodplain Risk Management and Plan (Cardno, 2015), Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021) and the Woy Woy Climate Change Adaptation Study (Rhelm, 2021) were considered in the development of this study and plan.

Study Objectives

The overall objective of this study is to improve understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information, and relevant standards and guidelines. The study includes investigations of flood risk management and can continue to be used for this purpose into the future.

This project extended the Woy Woy Peninsula Flood Study completed in 2010, which provided the main technical foundation for developing a robust FRMS and FRMP. As part of this FRMS, modelling was updated from the 2010 Flood Study. The studies provide an increased understanding of the impacts of floods on the existing and future community. The flood models developed as part of this study forms the basis of a flood model to allow testing and investigating practical, feasible and economic management measures to treat existing, future, and residual risk. This FRMS provides the basis for informing the development of the FRMP.

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

- relevant government information systems (flood warning, emergency response, public works planning, etc.)
- 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
- selection of practical, feasible and economic measures for treatment of risk
- development of a floodplain risk management plan
- development of a prioritised implementation strategy.

The outputs of the study will achieve the study objectives 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 climate on flood risk
- emergency response situation and limitations
- effectiveness of current management measures
- options to mitigate flooding impacts

- 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, and informing and educating the community on flood risk and response to floods.

Study Approach

The following approach was undertaken as part of this study:

- Collection and review of available data, including review of relevant flood study reports.
- Site visits by the project team together with Council officers
- Development of a Digital Elevation Model using LiDAR 2013
- Update of the existing flood models using the updated groundwater model (DHI, 2021) and the new LiDAR
- Recalibration of the flood model
- Simulation of design flood events in accordance with the Australian Rainfall Runoff guideline, which had major updates in 2016 and 2019.
- Floor level survey of dwellings for damage assessment
- Consultation with stakeholders and the community
- Review of flood planning policies including flood-related controls in the Local Environmental Plan and Development Control Plan
- Outlining of the consequences of flooding on the community and assessment of flood damages.
- Preparation of information to support decisions on activities in the floodplain including a recommendation for the Flood Planning Areas and Flood Planning Levels and supporting information
- Assessment of a range of flood management options, including Flood Modification, Emergency Response Modification and Property Modification Options.
- Recommendations for the flood management approach.

Key Flood Risk Issues

The study area is impacted by flooding from Brisbane Water as a result of ocean storm surge events and tidal inundation, and catchment flooding as a result of rainfall events. The flood behaviour from these causes can be characterised as follows:

Brisbane Water flooding as a result of ocean storms and tidal inundation

Ocean storm surge events result in the elevation of the Brisbane Water Estuary levels and can lead to flooding of the low-lying areas of the peninsula. During Brisbane Water flooding events, flood levels typically rise and fall over several hours, with inundation occurring for approximately 5 hours in a 1% AEP event. Flood depths can be up to 0.9 m at the peak of the 1% AEP flood event in the areas with the lowest elevations.

The existing flood risks associated with tidal inundation are not as significant in the Woy Woy Peninsula, in comparison to the other mechanisms of flooding. However, in the future, as a result of sea level rise, a large proportion of the low-lying regions of the study area will be subjected to frequent inundation from high tides. For example, in 2100, the lowest areas of

the Woy Woy CBD will experience daily tidal depths of approximately 0.4m and king tide depths of approximately 0.7m. This will compromise the liveability of some portions of the suburbs through flooding of roads, services and private properties.

Local catchment flooding as a result of local rainfall

The Woy Woy Peninsula is subject to two different types of catchment flooding: mainstream and overland flooding. Mainstream flooding is the inundation caused by the overflows from creeks/channels when the flood level in these watercourses rises above the bank level. In the Woy Woy Peninsula, it applies to the watercourses in the Kahibah Creek system and Everglades (Main Drain) catchments. Mainstream flooding can produce peak flood depths adjacent to creeks generally from 0.5m to 1.5m in the 1% AEP flood event.

Flooding from overland flow occurs when catchment runoff concentrates into flow paths along natural or constructed routes such as swales or roadways. Overland flooding in the study area can be generally characterised by shallow 'nuisance' flooding (i.e. generally affecting access and minor property flooding, not posing significant risk to property and life). This is aggravated by high groundwater levels at the low-lying area with a shallow sand layer, typically along the bottom of the escarpment in Everglades catchment where the groundwater mound is observed. Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021) suggests that groundwater flooding (i.e. water starts to emerge on the surface when the water table rises and reaches ground level) can occur after long lasting rainfall around this area. In the 1% AEP flood event, flood depths are generally lower than 0.3m across the study area with a few properties experiencing over-floor flooding. Deeper overland flooding can be observed in localised areas, which include the steeper regions in the upper catchment, the residential areas near the Woy Woy CBD, and at the base of Blackwall Mountain. In these locations, flood depths greater than 0.5m can occur in roads and open spaces.

In the Woy Woy Peninsula, raised groundwater tables can increase the magnitude of both mainstream and overland flow flooding.

Options Assessed

Flood risk is a combination of the likelihood of occurrence of a flood event and the consequences of that event when it occurs. It is the human interaction with a flood that results in a flood risk to the community. This risk will vary with the frequency of exposure to this hazard, the severity of the hazard, and the vulnerability of the community and its supporting infrastructure to the hazard. Understanding this interaction can inform decisions on which treatments to use in managing flood risk.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

- Flood modification measures – options aimed at preventing/avoiding or reducing the likelihood of flood risks through modification of flood behaviour in the catchment.
- Property modification measures – options focused on preventing/avoiding or reducing the consequences of flood risks. Rather than necessarily modify flood behaviour, these options aim to modify existing properties and/or impose controls on property and infrastructure development to modify future properties. Property modification measures, such as effective land use planning and development controls for future properties, are essential for ensuring that future flood damages are appropriately contained, while at the same time allowing ongoing development and use of the floodplain.
- Emergency response modification measures – options focused on reducing the consequences of flood risks, by generally aiming to modify the behaviour of people during a flood event.

A range of possible options were considered and evaluated as part of this FRMS.

Climate Change Adaptation

The suburbs of Woy Woy, Blackwall, Booker Bay and Ettalong are low lying and susceptible to the effects of climate change and the existing threat from flooding in and around the Brisbane Water Estuary. **Figure A** illustrates these locations within the Woy Woy Peninsula. Raising existing ground levels and associated infrastructure was identified in the Brisbane Water Foreshore Floodplain Risk Management Study and Plan (Cardno, 2015) as a potential solution provided there are no long-term detrimental effects as a result of maladaptation. Raising land on a large scale regional basis is not practical given the multiple landholders and existing development. However, by developing a regional adaptation concept masterplan, incremental filling could be achieved, albeit over the longer term on individual or multiple sites through development and urban renewal.

The purpose of the Woy Woy Climate Change Adaptation Study (Rhelm, 2021) was to inform the processes to realise a final adaptation landform. This study defines the conceptual landform designs and drainage masterplan, as well as outlining possible adaptation pathways and significant issues likely to arise during the process of landform raising. The option PM07 - Landform Adaptation within this Woy Woy FRMS and FRMP reflects the recommendations of Rhelm, 2021. Option PM07 involves gradual raising and regrading of the landform to maintain the viability of the at risk suburbs, with actions taken by Council in accordance with Workplan A.

The primary aim of the climate change adaptation study was to undertake a case study that will assist planning for future development in the Woy Woy peninsula and other low lying areas in and around the Brisbane Water Foreshore to adapt to future changes such as climate risks.

The key objectives of the study were:

- Develop a concept landform and drainage study for four areas of inundation located along the foreshore of Woy Woy Peninsula identified in the *Brisbane Water Foreshore Floodplain Risk Management Plan* (Cardno, 2015) as vulnerable areas that require adaptation plans to address existing and future tidal and storm surge events
- Develop adaptation pathways that would assist the implementation of a future landform and drainage master plan that would address priority adaptation *Subset Actions* identified in the *Coastal Councils Climate Change Adaptation Plan* (2010) commissioned by Hunter and Central Coast Regional Environmental Strategy (HCCREMS).
- Undertake this project in line with the NSW Government's initiatives for adapting to climate change and best practice adaptation planning and implementation.

Six adaptation pathways were produced for the project (refer to **Figure B**). These are listed in order of most preferrable (Pathway A) to least (Pathway F). Pathway A requires relatively quick action to be taken this decade to avoid losing liveability of some properties in the Woy Woy study location. Pathway B represents the scenario where initial actions are delayed and an accelerated workplan is required; however, the risk of losing liveability is increased. The other pathways (Pathways C through F) involve planned retreat of some of the lowest-lying and at risk properties. The workplan for Pathway A is summarised in **Table A**.

It should be emphasised that the retreat actions identified in the adaptation pathways only refers to the loss of liveability for the most vulnerable portions of the study areas, and not a signal for the entire study area to begin retreating.

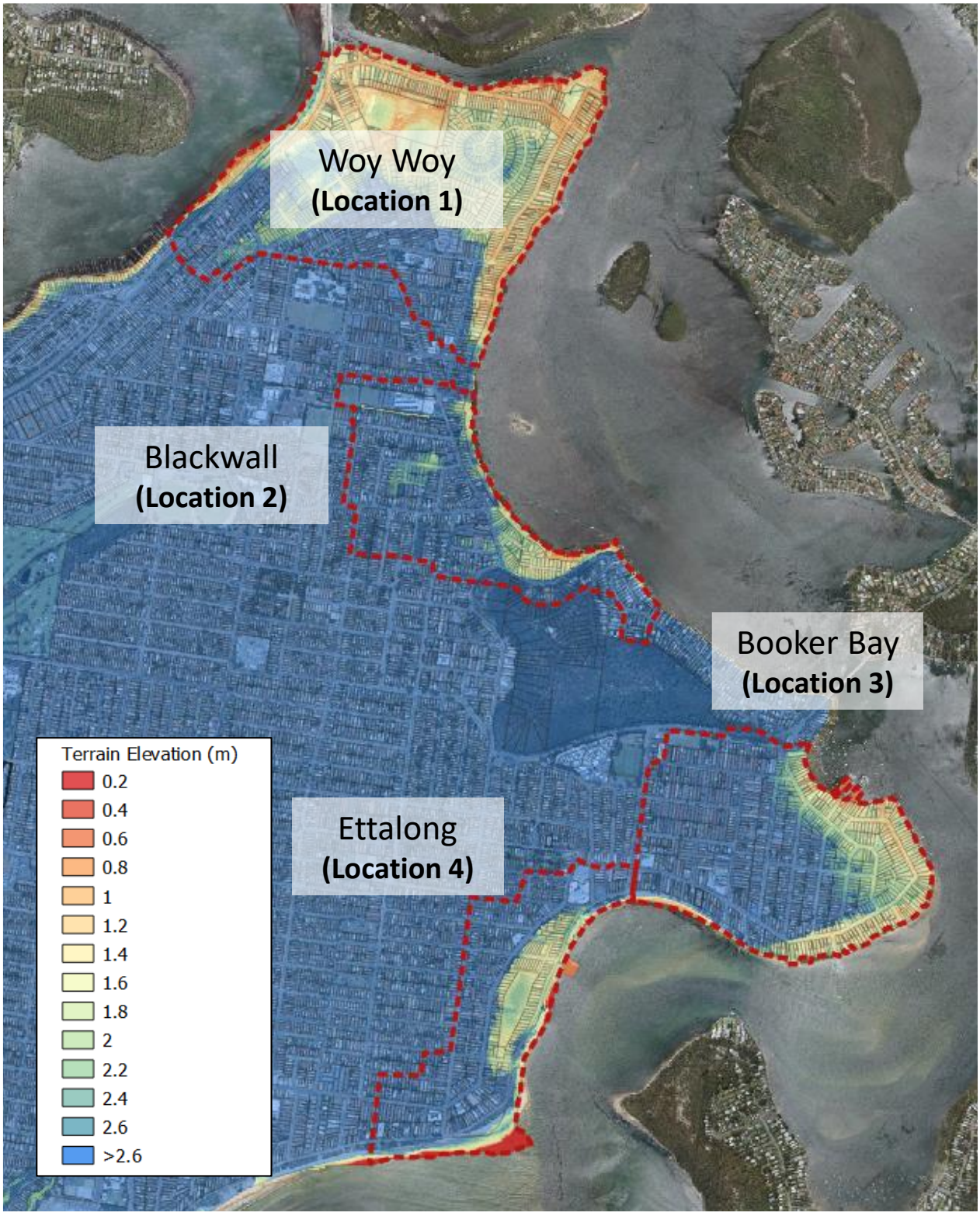


Figure A – Landform Adaptation Locations Overview

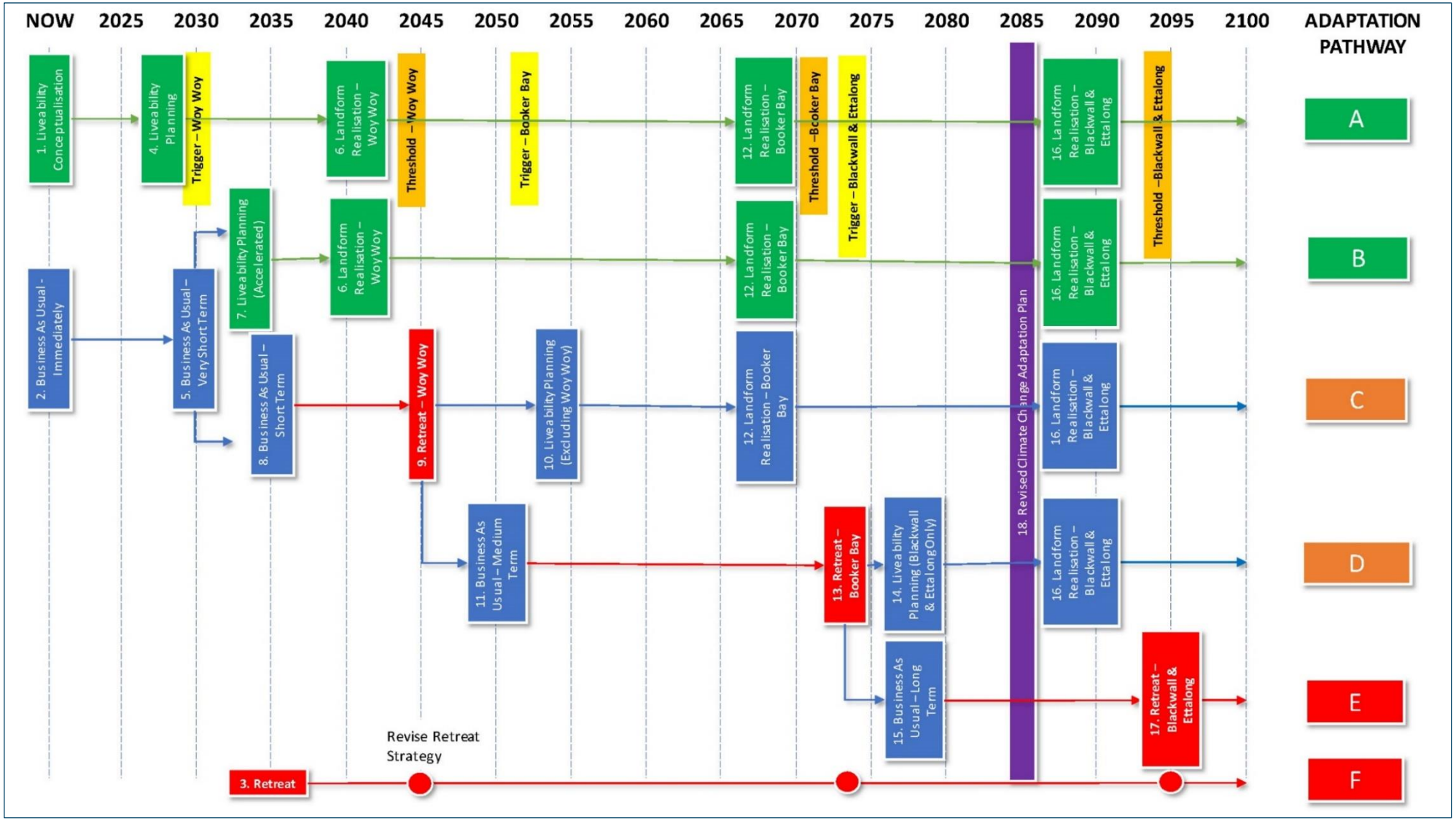


Figure B – Preliminary Adaptation Pathways for Low-Lying Areas in Woy Woy

Table A – Workplan for Adaptation Pathway A

Begin Actions	Option	Actions
Now	Liveability Conceptualisation	• Complete Woy Woy Climate Change Adaptation Case Study • Report Recommendations and Include in Draft Woy Woy FRMSP • Exhibit and Adopt Woy Woy FRMSP • Develop Masterplan and Public Domain Plan • Adopt Sea Level Rise Policy • Adopt Floodplain Risk Management Policy • LEP & DCP Review • Develop Drainage Master Plan - Constructability • Disseminate in Public Domain Results of this Study • Collaborate with Other Coastal Councils to Create a Working Group
2030	Liveability Planning	• Adopt Climate Change Adaptation Plan • Revised Adaptation Pathways • Community Engagement - Triggers and Threshold • Community Education - Adaptation Plan Process • Prepare Climate Adaptation Plan - Place Based • Adopt Masterplan and Public Domain Plan • LEP & DCP Revised to Include Climate Actions • Private Seawalls and Levees Guidelines • Establish Easements • Monitor Sea Level Rise
2040	Landform Realisation - Woy Woy	• Community Education - Filling Process • Property Filling Guidelines • Temporary Private Levees/Seawalls • Raise Landform - Private Land • Raise Landform - Public Land • Raise Landform - Roads • Monitor Sea Level Rise
2070	Landform Realisation – Booker Bay	• Community Education - Filling Process • Property Filling Guidelines • Temporary Private Levees/Seawalls • Raise Landform - Private Land • Raise Landform - Public Land • Raise Landform – Roads • Monitor Sea Level Rise
2085		Undertake Revised Climate Change Adaptation Study
2090	Landform Realisation – Blackwall and Ettalong	• Community Education - Filling Process • Property Filling Guidelines • Temporary Private Levees/Seawalls • Raise Landform - Private Land • Raise Landform - Public Land • Raise Landform – Roads • Monitor Sea Level Rise

Outcomes and Recommendations

This report presents the findings of the Floodplain Risk Management Study for the Woy Woy peninsula, in accordance with the Floodplain Development Manual (NSW Government, 2005). The investigations undertaken as part of this process identified a number of flood risk issues within the floodplain. Based on these issues, a series of floodplain management options were developed and recommended.

The outcomes of the multi-criteria assessment provide a sound basis upon which Council can make decisions about undertaking works, making planning decisions and developing response arrangement to reduce the impact of flooding on property and life. Options were

sub-grouped as part of the multi-criteria assessment as Flood Modification options and Planning options, which incorporate both property modification and emergency response modification options.

The following options are recommended as an outcome of this FRMS:

Table B – Summary of recommended options

Option ID	Description	Multi-Criteria Assessment Ranking	Category
FM03	Infiltration Devices	Flood Modification – 1 Overall – 6	Flood Modification Options
PM01	Land Use and Development Control Planning Recommendations	N/A	Planning (Property Modification and Emergency Response Modification) Options
PM04	Property Flood Risk Education Program	Planning – 6 Overall – 7	
PM05	Property Management Education Programand Compliance	Planning – 7 Overall – 8	
PM06	Reduced Sustainable Level of Major Drainage Service	Planning – 3 Overall – 3	
PM07	Climate Change Landform Adaptation	Planning – 1 Overall – 1	
EM01	SES Review of Evacuation Centre Locations	Planning – 5 Overall – 5	
EM03	SES Review of Flood Warning Systems	Planning – 9 Overall – 14	
EM04	Flood Warning Signs	Planning – 2 Overall – 2	
EM05	Flood Education Programs	Planning – 3 Overall – 3	

As per **Table B**, the highest ranking overall and planning options is the Climate Change Landform Adaptation, the highest ranking flood modification option is the installation of infiltration devices.

The Land Use and Development Control Planning Recommendations were not ranked in comparison to other options. These are the recommended outcomes following review of existing land use and development controls.

1 Glossary of terms

Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded in any given year. Usually expressed as a percentage.
Aquifer	An underground layer of water-bearing permeable rock or unconsolidated material from which water can be extracted.
Australian height datum (AHD)	A common national plane of level corresponding approximately to mean sea level.
Australian Rainfall and Runoff (ARR)	A national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia.
Average recurrence interval (ARI)	The average time period between occurrences equalling or exceeding a given value. ARI is another way of expressing the likelihood of occurrence of a flood event. ARR discourages the use of the terminology ARI which are often seen in previous flood studies, as it leads to confusion with the public for rare events.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	An area where water is collected to a location. This could be by to the natural landscape or by storm drainage network.
Design Rainfall	Design rainfalls are a probabilistic or statistically-based estimate of the likelihood of a specific rainfall depth being recorded at a particular location within a defined duration. It is generally classified by Annual Exceedance Probability (AEP) or Exceedance per Year (EY)
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).
Exceedance Per Year (EY)	Events more frequent than 50% AEP is expressed as X Exceedances per Year (EY) as expressing frequency in AEP is misleading. ARR provides an example “2 EY is equivalent to a design event with a 6 month recurrence interval when there is no seasonality in flood occurrence.”
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, lake or dam and/or 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.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood planning area (FPA)	A flood planning area is the area where flood related development controls may be applied for development. The flood planning area is the area where the topography is below the Flood Planning Level.
Flood planning level (FPL)	Typically, the height used to set floor levels for development of properties in flood prone areas.
Floodplain	Area of land, which is subject to inundation by floods up to, and including the probable maximum flood event, that is, flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines of the NSW Government Floodplain Management Manual 2005. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Flood Hazard	The potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity and loss of flood storage can increase the severity of flood impacts by reducing the natural flood attenuation. Hence it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels.

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
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis, and display of spatially referenced data.
Groundwater	Water that is located beneath the ground surface in soil pore spaces and fractures of lithologic formations.
LiDAR	A surveying method which is widely used to surface topography. It is measuring the reflection with a sensor by targeting with laser light.
Numerical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Probable Maximum Precipitation (PMP)	The theoretical maximum precipitation for a given duration under modern meteorological conditions.
Runoff	The amount of rainfall that ends up as stream flow, also known as rainfall excess.
Topography	A surface which defines the ground level of a chosen area. Ground levels are typically presented in relation to the Australian Height Datum.
Unconfined aquifer	Aquifer with an upper boundary being the water table or phreatic surface.

2 Introduction

The Woy Woy Peninsula is prone to nuisance flooding, especially from long-duration rainfall events. Flooding occurs in the road reserves and in private property, where it remains until it infiltrates or evaporates. Generally, this flooding may remain for a couple of days. However, during very wet periods the groundwater table can rise such that flooding remains for several weeks.

The *Woy Woy Peninsular Flood Study* completed by DHI in 2010 (see Ref. /1/) provided Council with a better understanding of the importance of the interaction of coastal inundation, groundwater conditions and the increasing effects of development on flood behaviour due the changing hydraulics of the existing terrain surface.

In 2019, DHI updated the integrated groundwater (MIKE SHE) model constructed as part of the *Woy Woy Peninsula Flood Study* (DHI, 2010). The purpose of the update was to gain a better understanding of the hydrogeological properties of the Woy Woy Peninsula, including extending the model to include the Kahibah Creek catchment. As part of this study, DHI and Council worked together to investigate potential opportunities for an integrated water management approach to address nuisance flooding in the Everglades case study catchment. Furthermore, conceptual models were developed with key stakeholders to explore the effectiveness of an integrated water management approach to minimise surface flooding within the Everglades Catchment (see Ref. /2/).

Results from the MIKE SHE model informed this Floodplain Risk Management Study and Plan (FRMSP) by providing an understanding of whether groundwater is preventing infiltration (as concluded by the Flood Study) and providing possible flood risk management options for consideration.

A number of mitigation measures were identified by Willing & Partners Consulting Engineers in 1991 as part of the *Kahibah Creek Floodplain Management study* (see Ref. /9/). Since the completion of this study, flood behaviour and risk may have changed. The inclusion of the Kahibah Creek catchment within the scope of this study will enable a more integrated approach to managing flooding on the Woy Woy Peninsula.

The low-lying portions of the study area can also be impacted by inundation from the Brisbane Water Estuary. The coincidence of this coastal inundation and tidal fluctuations adds to the complexity of determining what flood mitigation measures are available to the community.

The *Brisbane Water Foreshore Floodplain Risk Management Plan* (Cardno, 2013) identified that it is impractical to eliminate all existing flood risks around the Brisbane Water foreshore. However, with projected sea level rise it is important that this study addresses any sensitivities that accompany these changes in the Woy Woy study area as well as recommendations of the Brisbane Water Foreshore FRMP.

3 Study Area

The Woy Woy Peninsula (the Peninsula) urban area is bounded by Brisbane Water to the north and east, Broken Bay to the south, and Brisbane Water National Park to the west. The study area is shown in **Figure 3.1**.

The study area including the Kahibah Creek Catchment is approximately 18.5 km2 and is generally a flat sand-plain, where ground levels typically vary between RL 4m to 6m (AHD). The remaining study area backs onto the National Park and Blackwall Mountain and is typically of higher elevation with sandstone outcrops. The majority of the urban area is characterised by predominantly low-medium density residential development.

Typical flooding at Woy Woy peninsula is pluvial and coastal. Pluvial flooding is caused by heavy rainfall not sufficiently draining out of the area and occurs at various locations on the peninsula. Due to its low-lying topography some parts of the peninsula are also at a risk of coastal flooding, generally caused by 'East Coast Lows'. Coastal flooding is addressed in detail by the Brisbane Water Foreshore Flood Study (Cardno, 2013).

The subdivision of the low-lying part of the Peninsula for urban development took place mainly in the early 1900s, based on a rectangular road grid pattern. The subdivision paid little or no regard to the topographic contours characterised by the sand dune ridges and surface flow paths. This resulted in the current typical flood behaviour that rainfall runoff drains to low points in the dune ridge system, which are located on streets and backyards. It had been suggested in a previous study that flooding was not a serious problem at the time where the population was significantly smaller than now as most houses collected roof water for domestic use and had floor levels above the ponded water level (Webb, McKeown & Associates, 1996).

However, ponding deteriorated following the further development of the catchment, including population growth, major reduction of collection of rainwater due to the installation of piped water supply system, increase in paved areas on roads and allotments, upscaling of the dwelling size and filling of natural depressions and swamps. Modifications to the catchment includes a construction of Main Drain which currently collects flow from a large area of the Everglades catchment and serves as the main outlet to Phegans Bay.

Some areas on the Peninsula are not serviced by piped drainage systems or have effective overland flow paths. As a result, runoff that drained to the local sags will pond for an extended duration if these sags are unrelieved.

The local hydrogeology is controlled by a beach ridge system, within an unconfined shallow aquifer. Groundwater flows are evident towards shorelines in the north, east and south fed by the groundwater mound located in the central western region near the Everglades catchment. While soils on the Peninsula are coarse sands, the presence of podsol soils can often impede the transition of water from the surface to the groundwater table, causing surface ponding and waterlogging. Flooding is also affected by a shallow groundwater table in the sand aquifer underlying the peninsula (DHI, 2021).

Surface flow catchments contributing to rainfall-runoff processes are not well-defined except for the Kahibah Creek catchment, due to the peninsula's very flat topography and alteration of flow paths by the development.

Kahibah Creek and its associated tributaries lie in the south-west of the peninsula. The catchment comprises of a steep escarpment to west and relatively flat residential area towards Broken Bay. The Kahibah Creek has five tributaries, former swamps which have been altered in significant manner to accommodate residential developments and the remnant swamps at the foot of the escarpment, which provide storage effects. The Kahibah

Creek joins Ettalong Creek and continues to flow into Broken Bay. The Palmtree Grove Detention Basin is located at one of the tributaries to capture runoff from the upstream catchment.

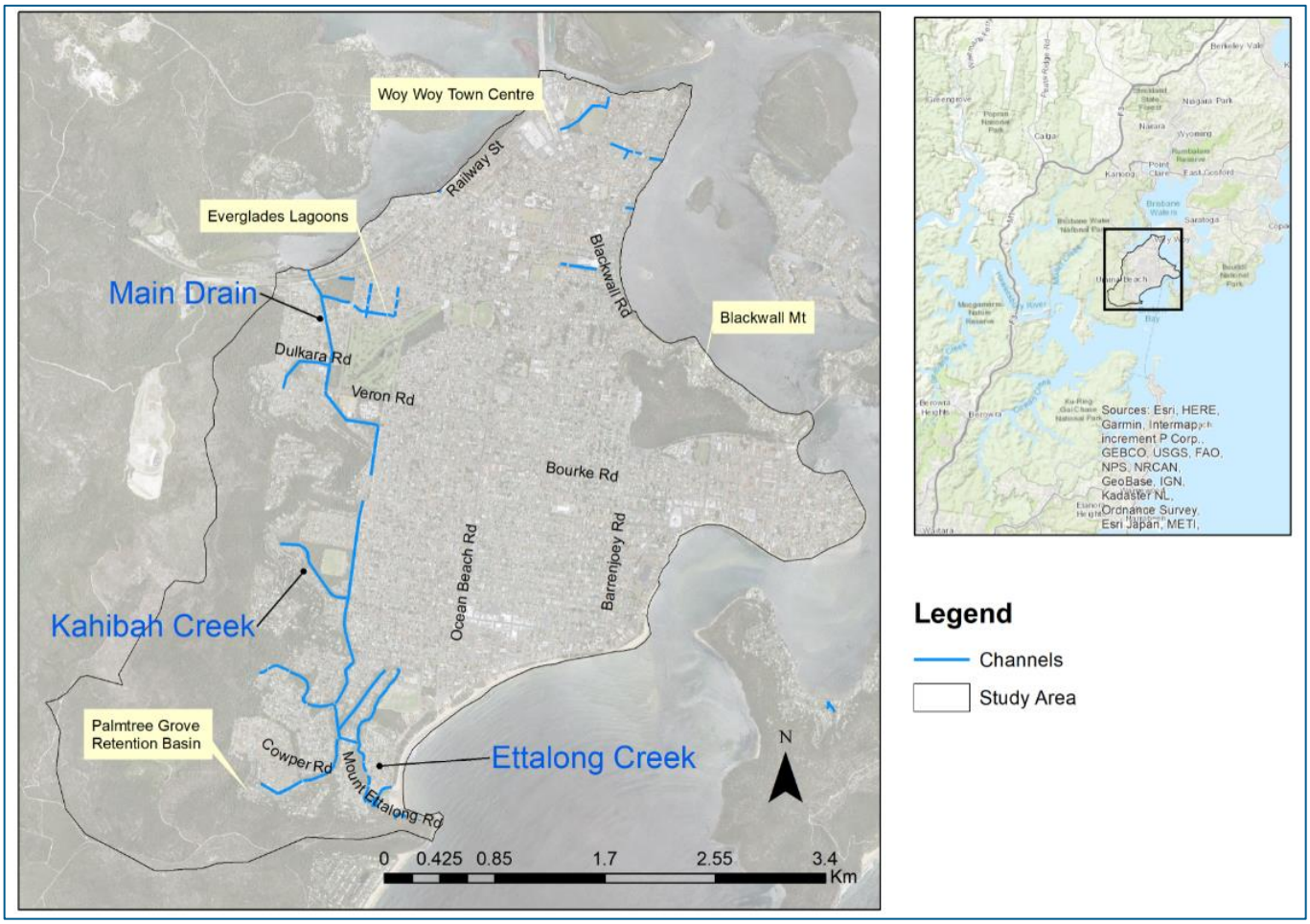


Figure 3.1 Study Area

3.1 Kahibah Creek System

The Kahibah creek system lies south-west of the Woy Woy peninsula. The catchment is approximately 640ha bounded by high ridges to the west and extends to the Broken Bay. A large part of the catchment belongs to the western escarpment, which is a part of the Brisbane Water National Park. A steep catchment to west meets the coastal flat plain where residential area starts with an abrupt change in slope.

The Kahibah system comprises of two major creeks, Ettalong Creek and Kahibah Creek and five drainage arms:

- Australian Avenue arm
- Greenhaven Drive arm
- Iluka Creek
- Ettalong Swamp arm
- Neera Road arm

These channels are shown in **Figure 3.2**.

The Neera Road arm and the Ettalong Swamp arm runs at the southern and northern edges of the residential area which used to be Ettalong Swamp. The swamp used to occupy a large area to south-west of Umina at the foot of the escarpment and provided a storage for flood mitigation. However, the swamp was filled over a number of years and rezoned for subdivision into residential blocks. Residential blocks were developed in the mid-1980s with the approval condition of implementation of drainage works to reduce local flood levels caused by this development (Ref /7/).

Two arms merge downstream of the Cowper Road Extension Bridge to form Ettalong Creek. Ettalong Creek flows through to east and changes direction to north after the Cowper Road Bridge. Ettalong Creek meets Kahibah Creek around McLaurin Road Reserve, flows under the Mt Ettalong Rd Bridge and then turn to south along the NRMA caravan park towards Broken Bay.

The outlet channel is usually disconnected from Broken Bay as shown in the photo (**Figure 3.3)** and connected to the bay only during heavy storm events. Upon the site visit on 25 Sep 2019, a narrow short channel was temporarily dug towards the bay by Council to protect the car park located next to the beach from erosion by the Ettalong Creek. The Council field officer confirmed that digging was not a routine practice. Digging a narrow channel like this at the beach unlikely has a major impact on the flood behaviour of design events as the beach is mostly submerged at the designed sea level.

In the past, Ettalong Creek continued to flow through the northern loop which extends almost up to Calypta Rd, however, a box culvert channel cutting through Mt Ettalong Road was constructed in the 1970s. This box culvert under Mt Ettalong Road was replaced with the bridge in 1993 after a large flood event in 1991.

Currently the northern loop serves as local drainage and only acts as additional storage during high flows or high tides. During the site visit on 25 Sep 2019 around 11:30am, water was observed to flow backwards from the northern loop to the confluence of Kahibah Creek and Ettalong Creek.

Two swamps remain at the base of the escarpment in the catchment: Iluka Lagoon lying near Iluka Road intercepts runoff discharge from the escarpment to west, and Kahibah Swamp located at the upstream end of Greenhaven Drive Arm of Kahibah Creek. Willing & Partners (1991) assessed that the flood retarding effect of the Kahibah Swamp diminished due to filling from development while Iluka Lagoon still provided some temporary storage of water from the escarpment.

The catchment experienced major floods in 1975, 1989, 1990, which became the main motivation for the Kahibah Creek Flood Study and the Kahibah Creek Floodplain Management Plan (Willing &Partners, 1991). During the flood events, several houses along Neera Road and the lower sections of Ettalong Creek were flooded. After these studies in the early 1990s, several management options were implemented. This includes an upgrade of several structures such as Mt Ettalong Rd Bridge, lining and widening of channels and implementation of regular clearing of channels. Plant types that would typically block flow (Typha and Parrot's-feather) were cleared as part of regular maintenance works. No major flooding has occurred in the Kahibah Creek system since the implementation of these management options.

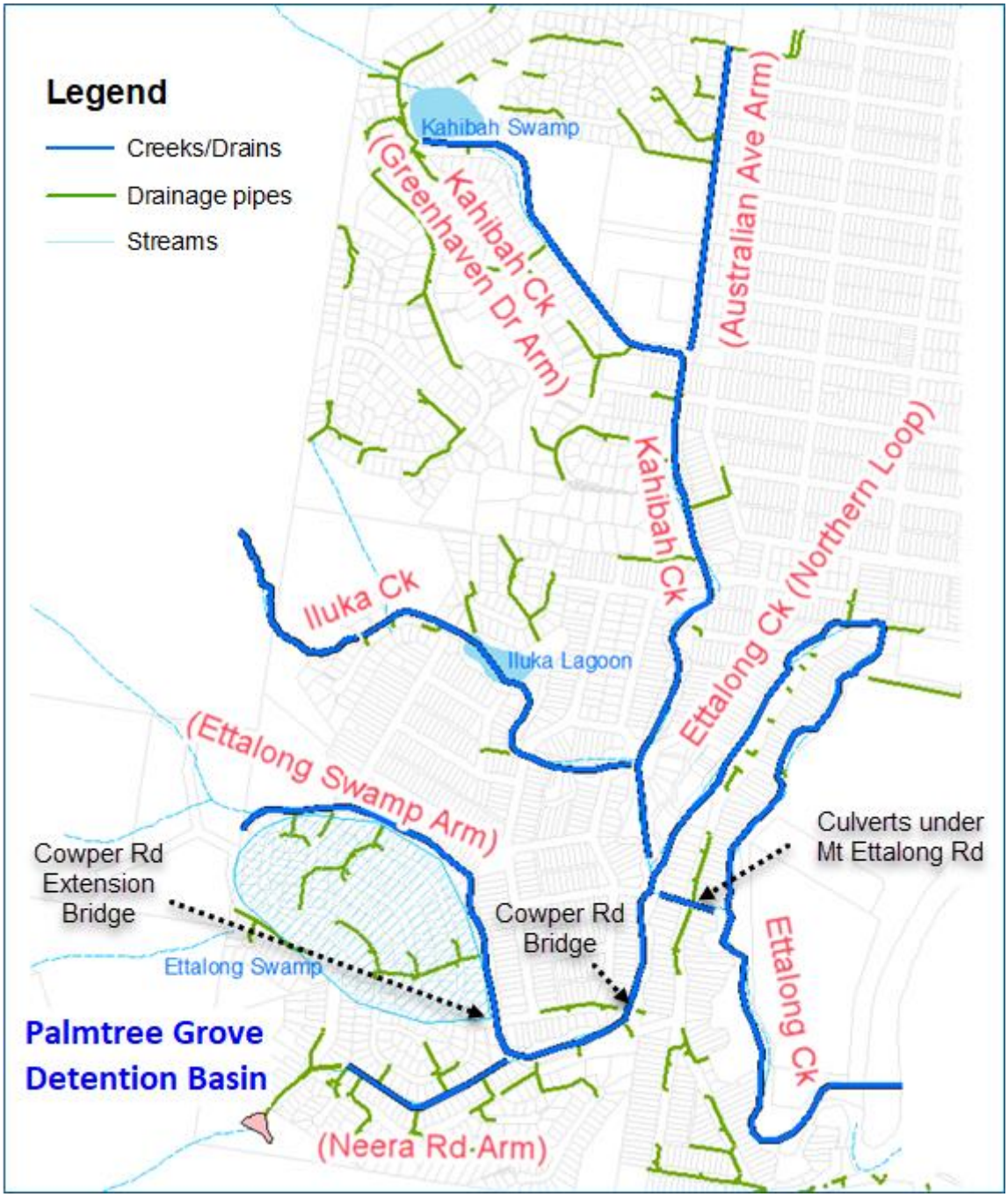


Figure 3.2 Kahibah Creek System

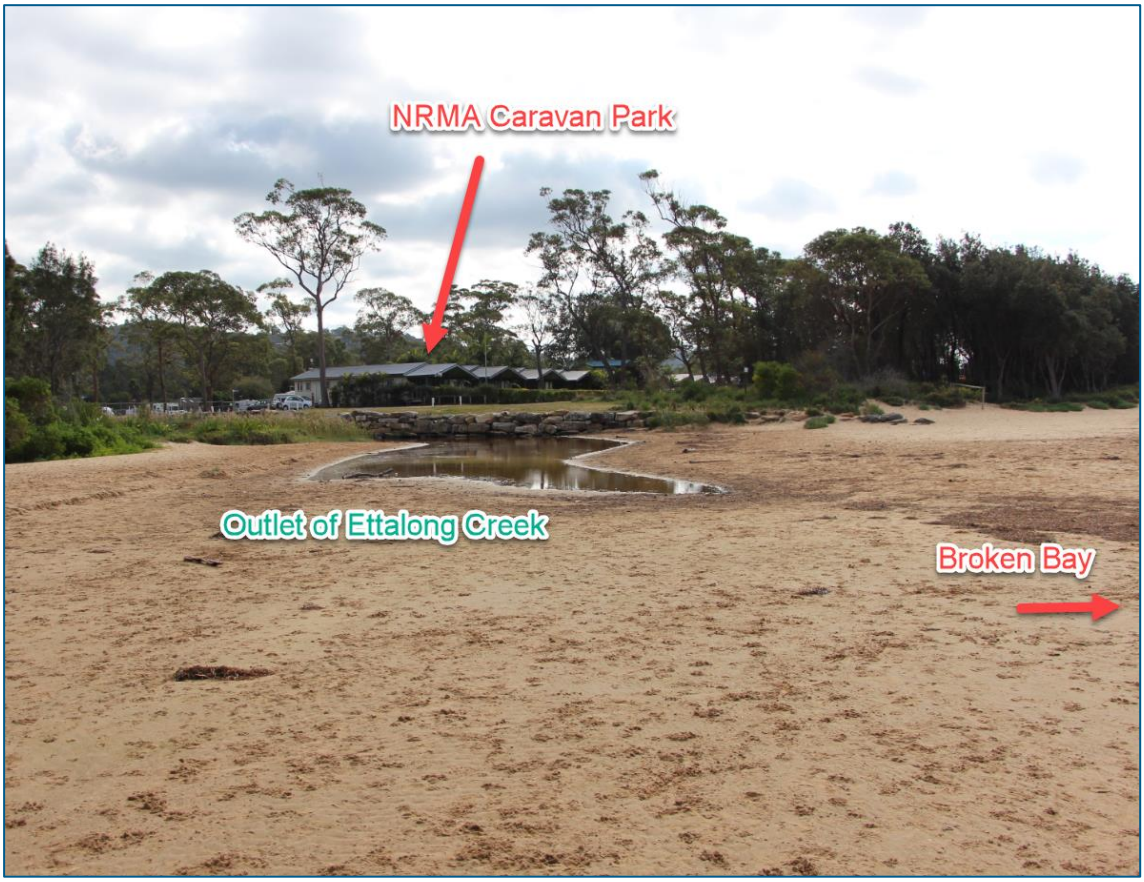


Figure 3.3 A photo of the outlet of Ettalong Creek (taken from the beach looking at the north-west direction on 24 May 2018 11:40 am)

Naming Convention for the Kahibah Creek System

Reports published prior to early 1990s, such as *Kahibah Creek Flood Study* (Willing & Partners, 1991), refer to the major channel of the Kahibah Creek system as Ettymalong Creek. However, the creek started to be called Ettalong Creek around the mid-90s, as it can be seen in *Kahibah Creek Floodplain Management Plan* (Willing & Partners, 1996).

Although no record could be found that the creek was officially renamed from Ettymalong to Ettalong, it was decided to use Ettalong Creek in this study, as the NSW Topographic Map also uses this name.

3.1.1 Palmtree Grove Detention Basin

Palmtree Grove Detention Basin is a small retarding basin located at the top of Palm Tree Grove. It is intended to divert flood flows away from low lying properties in Laurel Place into the two 1500mm diameter pipes running under Palm Tree Grove, which drain into the Neera Road arm of Ettalong Creek. The basin spillway comprises a reinforced grassed overflow path towards Palm Tree Grove.

During the flood event on 6 January 1989, the basin was overtopped at two occasions, at midday and around 5pm. The reported maximum water depth over the crest was in the order of 0.5m. This event resulted in the flooding of residential areas downstream (Willing & Partners, 1989). One of the current two outlet pipes was installed after this event.

GHD undertook the basin breach study in 2013 (GHD, 2013). The study undertook hydrological modelling to estimate design inflow hydrographs to the basin, basin breach

modelling for both piping failure and overtopping failure, and then hydraulic modelling to assess impact of the basin breach on flood levels at downstream. The report concluded that a Flood Consequence Category of 'High C' was assigned to the basin. This is a declared dam under Dams Safety NSW.

3.2 Main Drain

The Main Drain refer to the approximate 1.7km long section of waterway aligned from Ryans Road at the base of the western escarpment north, beneath the railway and into Phegans Bay. It is a combination of natural and constructed waterway.

The current waterway alignment was originally established as a "cut off" drain to discharge flows from the western escarpment and local runoff directly north into Brisbane Water. This was undertaken in an effort to relieve flooding to the east in the Woy Woy Peninsula where original drainage pathways aligned west to east and directed runoff to Brisbane Water north of Blackwall Mountain.

A significantly sized wetland used to occupy the area in roughly what is now the Everglades Golf Course. There are still some remnants of this wetland remaining in the study area, particularly west of Hillview Street as well as within and surrounding the golf course.

3.3 Sand Flats

The Woy Woy sand flats refers to the large, flat, low-lying area east of the escarpment and extending down to Brisbane Water. Apart from Blackwall Mountain, ground levels here do not vary far between approximately 1 and 5 m AHD.

This area is further characterised by the underlying geology predominantly consisting of sandy soils with a high infiltration capacity.

Historically, in this area development ordinally began along the coastline and in local centres such as the Woy Woy CBD, Booker Bay and Ettalong. As urbanisation increased, roads and residential land use moved westward and, in the process, built over the existing sand dunes. However, the road alignment was established in a more or less grid pattern (north-south and east-west) and not necessarily aligned with the original drainage patterns associated with the sand dunes. What resulted was many trapped low points in the road network with a traditional pit and pipe stormwater drainage system suffering from very flat, and sometimes adverse, gradients trying to discharge runoff to Brisbane Water. Flood behaviour here is characterised by frequent shallow ponding in areas with inadequate drainage which may take days to drain (or evaporate) away.

Exacerbating the flooding problem is the influence of a shallow groundwater table at the bottom of the escarpment where the sand layer is shallow, especially around the Everglades Catchment where the groundwater mound is located. When the groundwater table is high, runoff from rainfall events does not easily infiltrate into the highly permeable soils. Conversely, when groundwater levels are deep below the ground surface, rainfall is readily absorbed into the soil and relatively little runoff is produced. Over time, this positive effect of rainfall easily infiltrating into the sandy soils has diminished with urbanisation and an overall increase in impervious surfaces.

4 Study Approach

4.1 Objectives

The overall objective of this study is to improve understanding of flood behaviour and impacts, and better inform management of flood risk in the study area in consideration of the available information, relevant standards and guidelines. The study includes investigations of flood risk management and can continue to be used for this purpose into the future.

This project involves and extends the *Woy Woy Peninsula Flood Study* completed in 2010 (DHI, 2010), 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. The study provides an increased understanding of the impacts of floods on the existing and future community. It also investigates practical, feasible and economic management measures to treat existing, future and residual risk.

The floodplain risk management study provides a basis for informing the development of the floodplain risk management plan.

The incorporation of the findings from the study of groundwater modelling and integrated management options for the Everglades catchment which was undertaken by DHI (2021) as a vital aspect of the study. This provided the understanding of how groundwater interacts with flooding and informs potential opportunities for flood risk management as part of this study.

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

- Relevant government information systems (flood warning, emergency response, public works planning, etc.);
- 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;
- Selection of practical, feasible and economic measures for treatment of risk;
- Development of a floodplain risk management plan; and
- Development of a prioritised implementation strategy.

The outputs of the study will achieve the study objectives 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 climate on flood risk;
    - emergency response situation and limitations; and
    - effectiveness of current management measures.
- Facilitating information sharing on flood risk across government and with the community.

5 Data Compilation and Literature Review

Most data were provided by Council as part of the *Woy Woy Integrated Water Management and Case Study Everglades Catchment* (DHI, 2021), including:

- Reports of previous studies
- Groundwater records
- LiDAR topographic data (2013)
- Photos of nuisance flooding on the peninsula
- GIS layers
- Old design drawings of cross-sections at Main Drain
- Drainage design plans

The list of previous study reports and GIS layers previously provided by Council are summarised in **Table A.1** and Error! Reference source not found.**,** respectively in **Appendix REF _Ref82102384 \r \h * MERGEFORMAT A**.

Details are provided in the ***Woy Woy Floodplain Risk Management Study – Technical Volume* (DHI, 2022).**

Several site inspections were conducted, mainly focusing on the Kahibah Creek and Everglades catchments, the escarpment above the Everglades catchment and the Woy Woy town centre. These site inspections were attended by senior DHI, Rhelm and/or Council staff and were carried out on the following dates:

- 13/02/2019: Inception Walkover
- 25/09/2019: Structure survey and introduction to the maintenance program by a field officer
- 10/02/2020: Post-rainfall event
- 20/07/2020: Floor level survey scoping

In addition, DHI had undertaken inspections as a part of *Woy Woy Integrated Water Management and Case Study Everglades Catchment" Study* (DHI, 2021) prior to this study.

6 Flood Planning Review

6.1 Purpose

Within the study area, development is largely controlled through the Central Coast Local Environmental Plan 2022 (CCLEP 2022) and the Central Coast Development Control Plan 2022 (CCDCP 2022). 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) such as:

- SEPP Exempt and Complying Development Codes (2008);
- SEPP Educational Establishments and Child Care Facilities (2017);
- SEPP Infrastructure (2007);
- SEPP Housing for Seniors and People with a Disability (2004);
- SEPP Affordable Rental Housing (2009);
- SEPP 21 Caravan Parks;
- SEPP 65 Design Quality of Residential Apartment Development;
- SEPP 33 Hazardous and Offensive Development;
- SEPP 36 - Manufactured Home Estates;
- SEPP Coastal Management (2018);
- Other SEPPs as relevant to land use and/or development type; and
- 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 covered by the LEP, DCP, Council policies and plans has been completed. Recommendations for updates to improve the management of flood risk are provided in **Section 13.2.1**.

The Department of Planning, Industry and Environment finalised the flood-prone land package on 14 July 2021. The package provides advice to councils on considering flooding in land-use planning. The documents and advice included in the package are discussed further in **Section 6.2**. The review of Council's existing flood planning arrangements and recommendations for improved flood risk management have assumed that Council will also be updating the LEP and section 10.7 planning certificates in accordance with the flood-prone land package requirements.

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, 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 this 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 and Environment. 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.

6.2 Flood Prone Land Package

The Department of Planning, Industry and Environment has updated a package of materials relating to the management of flood-prone land. The materials are:

- a new planning circular: Considering flooding in land use planning: guidance and statutory requirements (and revoking the existing planning circular PS 07-003),
- a new guideline: Considering Flooding in Land Use Planning (2021) (and revoking the Guideline on Development Controls on Low Flood Risk Areas),
- an amendment to clause 7A of Schedule 4 to the Environmental Planning and Assessment Regulation 2000. The changes will simplify the notation to advise of flood-related development controls up to the flood planning area (clause 7A(1)) or between the flood planning area and the PMF (clause 7A(2)),
- two standard instrument local environmental plan (LEP) clauses which introduce flood-related development controls (one mandatory, one optional which was eventually deferred by DPE),
- a SEPP amendment to replace councils existing flood planning clause with the new mandatory standard instrument clause, and
- a revised local planning direction regarding flooding issued under section 9.1 of the Environmental Planning and Assessment Act 1979 (the Act).

The revised flood-prone land package allows a more contemporary approach to better manage flood risk beyond the 1% AEP, including building greater resilience to the effects of climate change. The update package addresses the key concerns over the safety of people, the management of potential damage to property and infrastructure, and the management of the cumulative impacts of development, particularly on evacuation capacity.

6.3 Central Coast Local Environmental Plan 2022

The Central Coast Local Environmental Plan 2022 (CCLEP 2022) is a legal document that sets the direction for land use and development in the study area by providing controls and guidelines for development. It determines what can be built, where it can be built and what activities can occur on land.

The CCLEP 2022 was 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).

The Central Coast LEP was gazetted in August 2022 and repealed the following previous planning instruments:

- Gosford Local Environment Plan 2014;
- Wyong Local Environment Plan 2013;and
- Interim Development Order No 146 – Gosford (except Deferred Matters).

6.3.1 Flood Planning Objectives and Controls

The objectives for land at or below the flood planning level are outlined in the compulsory Clause 5.21 of the CCLEP. 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 flood function and behaviour on the land, taking into account projected changes as a result of climate change,
- to avoid adverse or cumulative impacts on flood behaviour and the environment,
- to enable the safe occupation and efficient evacuation of people in the event of a flood.

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 function and behaviour on the land, and
- will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and
- will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and
- incorporates appropriate measures to manage risk to life in the event of a flood, and
- will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.

The above objectives and consent considerations are generally consistent with the compulsory flood clause (see **Section 6.2**).

The CCLEP does not directly define the Flood Planning Level. This provides some flexibility with regards to defining the FPL within the relevant FRMPs. However, the specific wording and intent will be discussed further with Council to better understand how the lack of an FPL definition has impacted implementation of flood related development controls, if at all.

Clause 7.3 of the now repealed Gosford LEP 2014 sets out a second flood related section of the LEP (entitled Floodplain Management) that addresses development controls that are applicable for development within the floodplain (i.e. above the 1% AEP plus 500mm freeboard and up to the Probable Maximum Flood level). This clause is consistent with the intent of the Special Flood Considerations (**Section 10.2**). Clause 7.23 of the CCLEP states that Clause 7.3 of the Gosford LEP remains in effect during a transition period ending on 1 August 2024.

6.3.2 Land Use Zones

The CCLEP defines the land-use zoning for the study area, thereby determining which type of development are allowable through the study area.

The CCLEP 2022 prohibits flood mitigation works in the following zones:

- Zone IN4 Working Waterfront
- Zone SP2 Infrastructure
- C1 National Parks and Nature Reserves

Special permission may need to be sought from Council for any proposed mitigation options to be considered going forward to construction if they lie within any of the aforementioned land-use zones.

6.4 Central Coast Development Control Plan

The Central Coast Development Control Plan 2022 (CCDCP 2022) came into effect with the CCLEP in 2022 and applies to all land zoned under the CCLEP (or in the case of Deferred Matters, Interim Development Order No 146). The purpose of the CCDCP 2022 is to provide Council's requirements for quality development and environmental outcomes within the greater Council LGA.

The sections of the CCDCP 2022 relevant to this FRMS include:

- Clause 2.12 Waterfront Structures;
- Clause 4.2 Peninsula Centres;
- Clause 3.1 Floodplain Management and Water Cycle Management; and
- Clause 3.2 Coastal Hazard Management.

Of particular importance to this FRMS is Clause 3.1 Floodplain Management and Water Cycle Management. This clause applies to all development within the LGA requiring development consent and relates to WSUD and flood mitigation principles. Objectives of this clause include:

- provision of direction and advice to development applicants in order to facilitate WSUD, integrated water cycle management (IWCM) and flood mitigation within the development application process;
- provision of design principles that will assist development to meet the purpose of this chapter of the CCDCP 2022; and
- provide objectives and performance targets for specific water management elements including water conservation, retention / detention, stormwater quality, and flooding caused by local overland flooding, mainstream flooding or storm surge.

This section of the CCDCP 2022 facilitates the application of WSUD, IWCM and flood mitigation through the following principles:

- Maintain and restore natural water balance whilst reducing the cost of providing and maintaining water infrastructure in a sustainable and efficient manner;
- Reduce risk to life and damage to property by restricting and controlling building and other development so that it minimises risks to residents and those involved in rescue operations during floods;
- Reduce nuisance and high level flooding and the cost of providing and maintaining flood mitigation infrastructure whilst improving water quality in streams and groundwater;
- Reduce potable water demand by using stormwater as a resource;
- Protect and enhance natural water systems (creeks, rivers, wetlands, estuaries, lagoons and groundwater systems);
- Protect and enhance the water quality, by improving the quality of stormwater runoff from the urban catchments; and
- Integrate stormwater management systems into the landscape in a manner that provides multiple benefits, including water quality protection, stormwater retention and detention, public open space and recreational and visual amenity.

Clause 3.1 of the CCDCP 2022 also sets out guidance for numerous matters related to development within the floodplain including:

- on-site stormwater detention targets;
- overland drainage management controls;
- reduction of losses from flooding on flood prone property;
- habitable and non-habitable floor levels;
- carpark access levels;

- treatment of subdivisions;
- Floodplain Risk Management Plans;
- fencing;
- filling on land;
- setbacks from watercourses;
- works near stormwater easements; and
- providing access to rural flood prone properties.

The CCDCP 2022 refers to the Flood Planning Area being the land below 1% AEP + 500mm freeboard (Clause 3.1.11.6 of the CCDCP 2022). However, one purpose of a FRMS is to identify a suitable defined flood event (DFE) and 'freeboard' for each floodplain (see **Section 10.1**).

Filling of the land within the Flood Planning Area is generally not permitted by the CCDCP 2022 unless it is allowable as part of an adopted Floodplain Risk Management Plan.

6.5 Central Coast Council Climate Change Policy (2019)

The Central Coast Council Climate Change Policy (The Policy) sets out Council's position relating to climate change with a view to maximising the economic, social and environmental wellbeing of Council and guides the planning and development of the Central Coast Region's resilience to climate change.

Of specific relevance to this FRMS and climate change planning for Woy Woy, are the following strategic principals and commitments made in The Policy:

- Principle 2: Council implement a holistic approach to anticipate and adapt to climate change actions that comprise the time scales such as now and the future as well as the impacts of the complex interactions and interdependencies between the human and the environment systems.
- Principle 3: Council implement an evidence-based decision making to respond, to adapt and build resilience to Climate Change.
- Principle 5: Council implement a proactive approach and ensure continuity to better anticipate and adapt to complex challenges posed by the changing climate.
- Principle 6: Council implement a Place-based approach to enhance Council and community capacity for climate resilience that is context specific, knowledge based and collaborative.
- Commitment D4 - Develop Place Based Climate Change Action Plans in partnership with the community that establishes regional targets for mitigation and prioritises local adaptation planning (e.g. sea level rise, coastal hazards, disaster management).
- Commitment D7 - Incorporate climate change risks in strategic and infrastructure planning for the region to maximise local liveability through informed land use planning, development of planning controls and guidelines that facilitates regional urban growth, transport connectivity and utility services.

6.6 Civil Works Specification - Design Guidelines

The Civil Work Specification - Design Guidelines (CCC, 2018) outlines the requirements for public and private infrastructure in the Central Coast LGA. Specifically, relevant to the FRMS are the requirements for upgrades to the stormwater drainage network. Options assessed as part of this study abide by, as far as practical, the requirements of the Civil Work Specification - Design Guidelines (CCC, 2018).

6.7 Plans of Management

Plans of management categorise land, authorise leases or licenses and determine what development can take place. The key values of the land and its purpose are identified so they can be protected and enhanced.

The following Plans of Management are relevant to the study, particularly where they relate to land where flood mitigation works are proposed or may have an impact:

- Foreshore Parks 1996;
- Gosford Foreshore 2004;
- Gosford City Playground Strategy 2009;
- Ettalong Beach Dune Management Plan 2007; and
- Everglades Lagoon System Precinct 2005.

7 Engagement

7.1 Consultation Strategy

The consultation strategy was developed with assistance from Council, with the aim being to identify stakeholders and provide them with an appropriate degree of input to this study. The approach is in accordance with the IAP2 framework and the requirements of the *NSW Government's Floodplain Development Manual* (2005). Refer to **Appendix M** for complete description of the consultation strategy.

7.2 Agency Consultation

To date, additional agency consultation has been undertaken in the form of attendance at site inspections, progress meetings, inception meetings and options identification by DPIE. Internal Council stakeholders, such as staff from the roads and drainage and planning departments, have been included in progress meetings and during options identification.

DPIE, SES and other agency stakeholders will be engaged with further as part of the public exhibition period.

7.3 Website and Media

A project website has been established for the duration of the project and can be accessed at the following link: www.yourvoiceourcoast.com/woy-woy-floodplain. There is also a link on this page for further study information: www.woywoyfrmsp.com.

The purpose of the website is to provide project information and community updates. Previous studies and community materials are available for download from the website. The website was also used to provide a link to an online survey in February and March 2021 (see **Section 7.4** for further details).

Media releases have been used throughout the study to inform the community of key project updates and opportunities to provide input. A summary of media releases to date are provided in **Table 7.1**, copies of the community brochure and survey are provided in **Appendix B**.

Table 7.1 Media Releases

Date	Purpose
5 February 2021	Inform the community of the project and invite input via the questionnaire (**Section 7.4.2**) and drop in sessions (**Section 7.4.3**).

7.4 Community Newsletter and Survey

7.4.1 Previous Community Input

The previous *Woy Woy Peninsula Flood Study* (DHI, 2010) involved community consultation in the form of a questionnaire mailed to all residents in the study area. Details of this engagement are provided in Section 8 of the report (DHI, 2010).

Key flood risk issues and locations identified from the community input have been considered in the development of floodplain risk management options (**Section 15**).

No flood management strategies were reviewed or proposed as part of the Flood Study (DHI, 2010) consultation.

7.4.2 Community Newsletter and Questionnaire

A one-page community newsletter was distributed in February 2021 to over 8,500 dwellings within the study area. The recipients were identified as residents or owners of properties within the PMF extent. The community newsletter was also available on the project website.

The newsletter included a short questionnaire intended to identify community concerns about flooding and how the community would like flood risk to be managed. Additional questions were aimed at understanding how the community is likely to respond in an event. This will assist SES in their flood planning and also inform Council and SES on the best way to issue flood warnings and other information regarding flooding (e.g. road closures). The questionnaire was also provided online available through Council's Your Voice Our Coast webpage and the project website (**Section 7.3**).

A copy of the community newsletter and questionnaire is provided in **Appendix B**.

From the mail-out and availability of the survey on the website, 389 responses were received, representing a return of 5% of direct distribution. **Table 7.2** summarises the number of responses received for each suburb within and around the study area.

Table 7.2 Number of answers according to suburb

Suburbs	Answers
Woy Woy	88
Umina	43
Umina Beach	111
Ettalong	15
Ettalong Beach	27
Blackwall	19
Booker Bay	13
Other suburbs	15
Unspecified	58

An additional 30 people attended the drop-in sessions to provide face to face input (**Section 7.5**).

In summary, based on the questionnaire responses, it can be concluded that the community in the study area is highly aware that the region is subjected to flooding. However, a significant portion of the respondents suggested they do not believe they could be exposed to high hazard flooding and did not express concern of displacement, major property loss, or risk to life. It can also be observed that the respondents largely attribute the flooding problems in the region to the deficiencies in the drainage systems, particularly poor maintenance, insufficient capacity and lack of kerb and guttering on roads.

Other relevant findings of the questionnaire were:

- Approximately 55% of the responses were provided by people who have resided in or visited the study area for more than 20 years.
- Most of the respondents (67%) consider themselves very aware of flooding in the region and only 9% report they are “not at all aware” of these risks. The remaining 24% marked the option “somewhat aware” of flooding.
- When asked if they have any specific concerns about flooding, 169 respondents were concerned with flooding on roads, 33 were concerned with flooding on properties and 55 were concerned about poor drainage systems. Other significant areas of concern were flooding on public space/other locations (42 responses) and concerns relating to future development/human interference (18 responses). A considerable number of residents reported no concerns about flooding (70 responses).
- According to the questionnaire answers, the residents consider improvements and better maintenance of the drainage systems are the most important measures for better flood management (241 comments in total).
- A total of 29% of the respondents report they will stay in their houses if a major flood occurs. When asked what their reason for staying at home would be, the most common answer was that they were concerned for the security of the property after an evacuation (145 responses). Another common reason, according to the responses, was that they knew their houses could cope with flooding (121 responses).
- A total of 41% of the respondents state they would evacuate in a major flood, 27% say they would evacuate early to an official centre and 14% say they would evacuate elsewhere. According to the responses, the most common reason for an evacuation would be the safety of their household (237 responses).
- 278 respondents (38%) reported that, during a flood event, they look for information on road closures, 195 people (27%) stated they look for evacuation notices and 202 (28%) stated they assess flood characteristics. Most of the respondents would look for information on the radio (27%), on TV (22%) and on websites (18%).
- Out of the flood management objectives listed in the questionnaire, the objectives that received the highest average score (7.56 points) and the lowest average score (3.71 points) were “improving safety of the community during flooding” and “does not cause negative flood impacts to other locations”, respectively.

The questionnaire had 10 questions related to flood behaviour and flood response, 8 questions were multiple choice and 2 required open-ended answers. In order to objectively analyse the information provided on the open-ended questions, the content of each comment was evaluated and classified based on recurring topics. It should be noted that one single comment could be counted in more than one category if it discussed multiple topics.

The answers received for the objective questions are summarised on **Figure 7.1, Figure 7.2** and **Figure 7.3** and the outcomes of the of the open-ended questions analysis can be found on **Figure 7.4**.

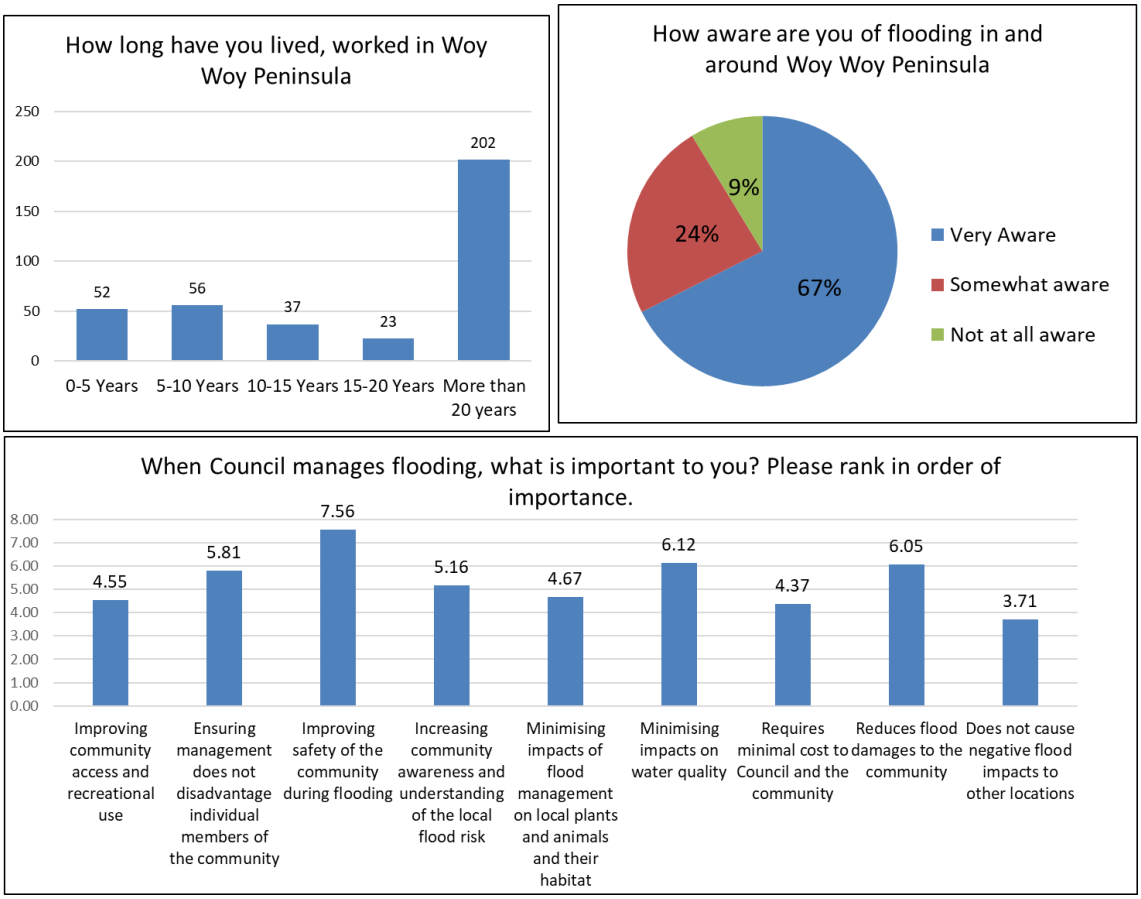


Figure 7.1 Summary of questionnaire responses - multiple choice questions (1 of 3).

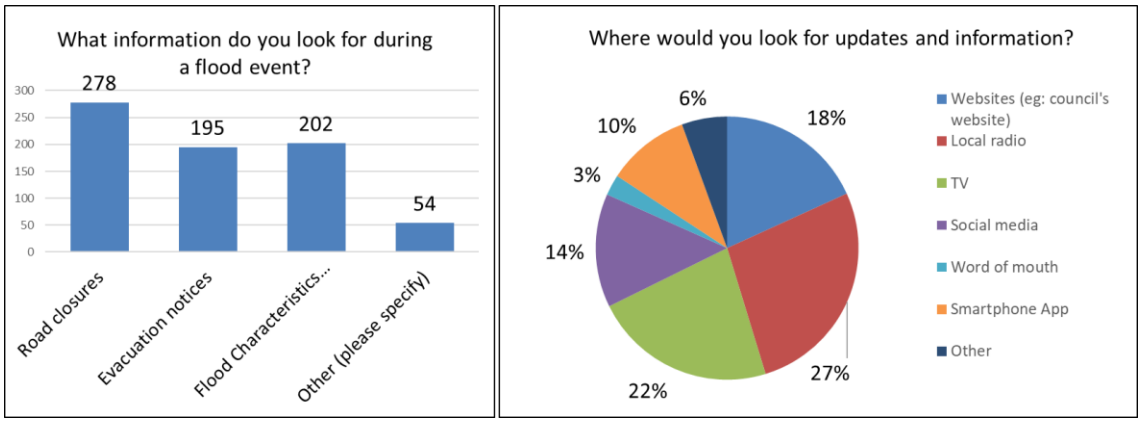
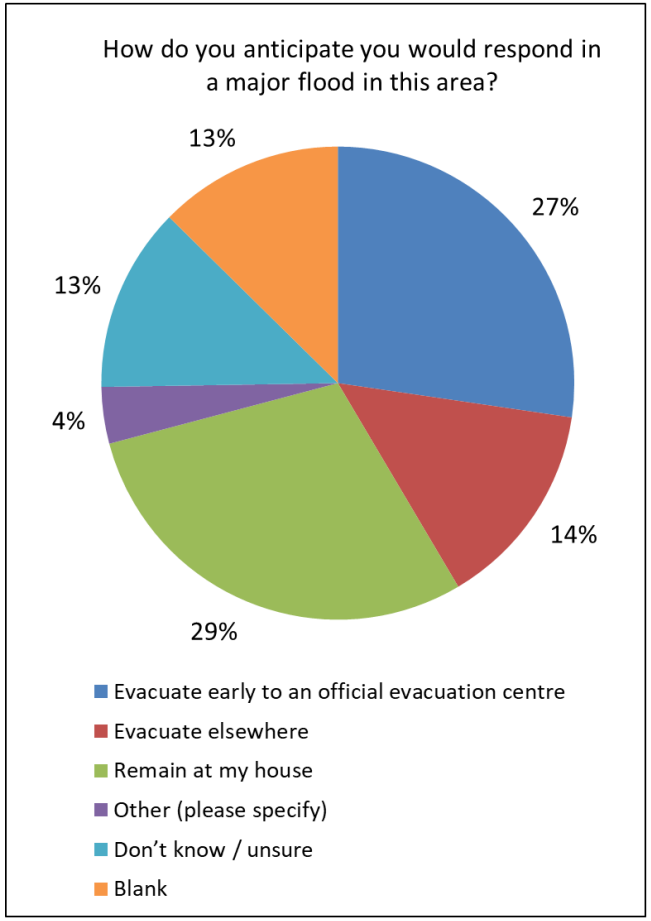
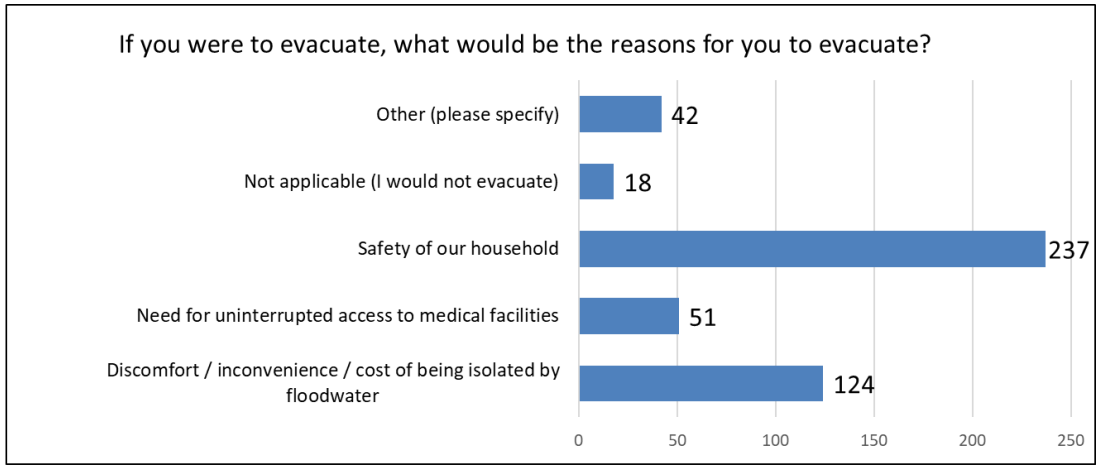


Figure 7.2 Summary of questionnaire responses - multiple choice questions (2 of 3).





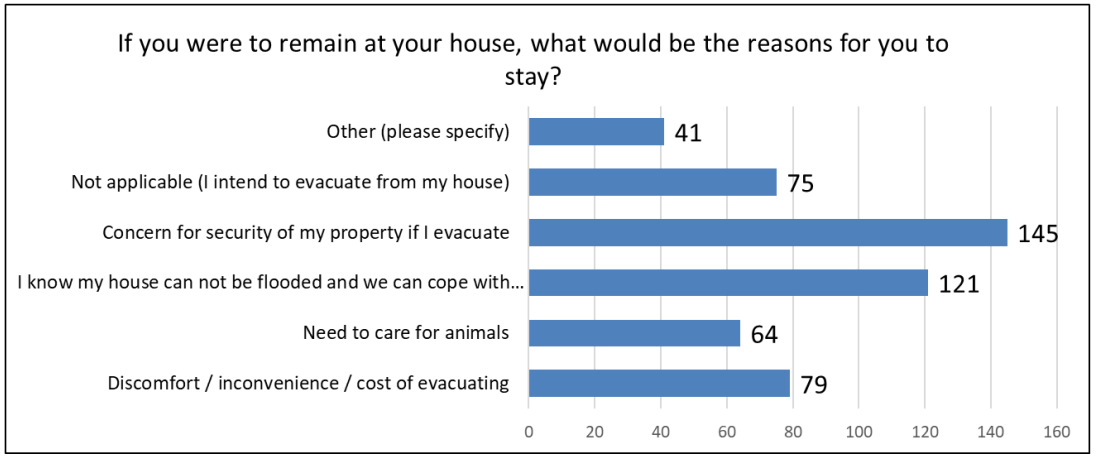


Figure 7.3 Summary of questionnaire responses - multiple choice questions (3 of 3).

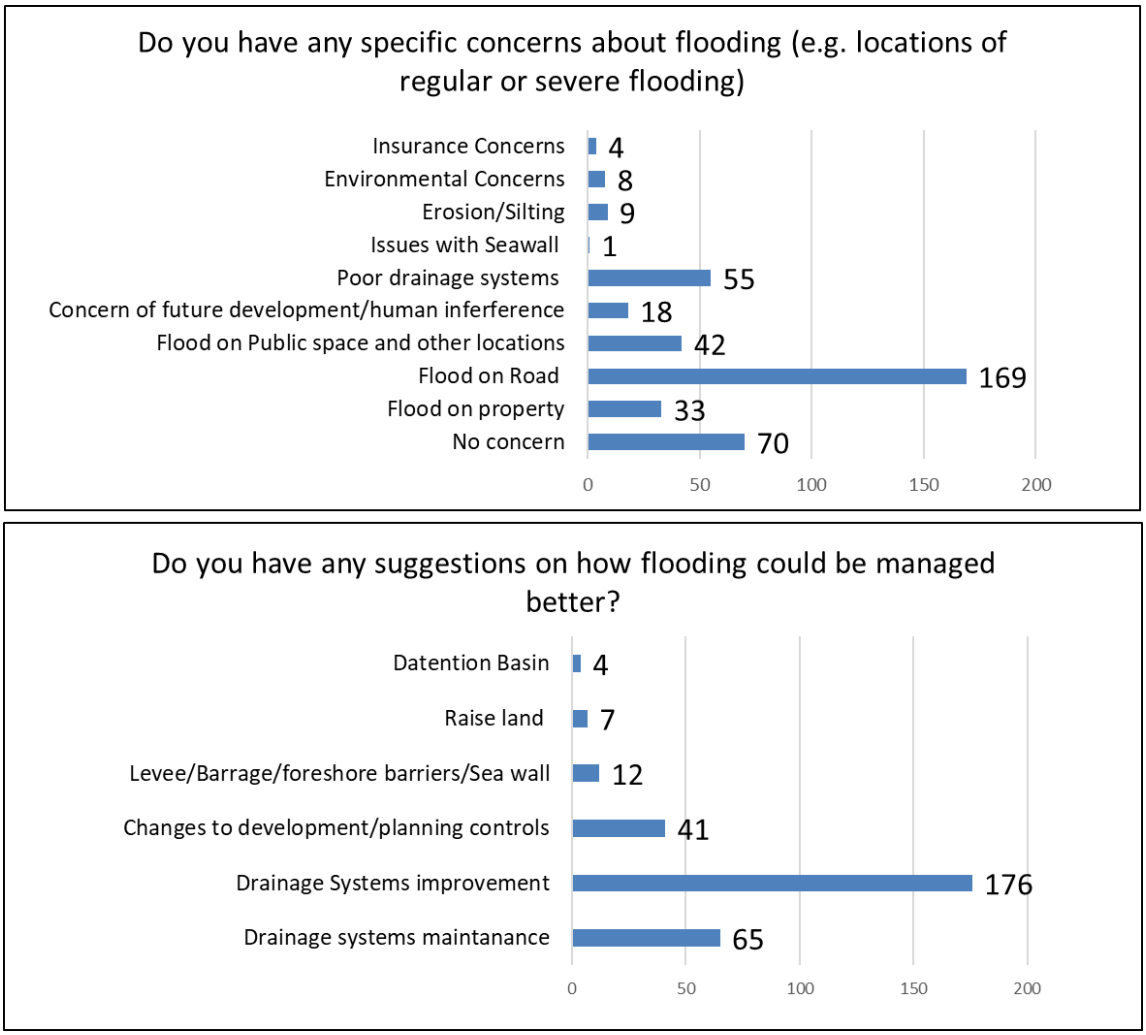


Figure 7.4 Summary of questionnaire responses – Open ended questions.

Note that following the analysis of the above survey response data, 29 additional survey responses were received by mail. It is not anticipated that the information included in these late received responses will significantly alter the outcomes of the above analysis. Although the respondents' contact details were logged to communicate with them the upcoming stages of the FRMSP.

7.4.3 Community Drop-In Information Sessions

One community drop-in information session was held in Woy Woy on 18 February 2021. It was attended by 30 community members.

The general comments provided, and repeated issues raised by community members at the drop-in sessions, are summarised in **Table 7.3** along with the actions arising from them.

Table 7.3 Community Input from Drop In Sessions

Community Input	FRMS Response
Council 'Black Spot' program is preventing development in areas of the Woy Woy Peninsula.	Study will look at the applicability of this program. Refer Section 13.2.1.
Infiltration should be encouraged to accommodate runoff during storm events.	Management options will include looking at increasing infiltration strategies in the study area. Refer Section 13.1.3.3.
Raising of landform is generally acceptable.	Study will include looking at potential landform raising to accommodate future sea level rise.
Multiple locations where runoff ponds on the side of the road and it cannot drain away or takes a long time to drain away.	Study will look at some drainage improvements, but with very flat grades in the majority of the study area and the interaction with groundwater, increased drainage infrastructure may not provide a large benefit. Focus would be to address areas where properties flood as well as roads and open space.
Existing pit and pipe system needs to be better maintained.	Increased maintenance of the existing system is subject to Council's funding availability. Potential flood mitigation options have taken into account the cost of additional maintenance requirements.

7.5 Stakeholder Meetings

Targeted stakeholder meetings will be undertaken as part of the public exhibition of the FRMS.

7.6 Public Exhibition

Following completion of the Draft FRMS, the document will be placed on public exhibition to give members of the public and all relevant stakeholders an opportunity to provide feedback on the Draft FRMS. All submissions received from the public during the public exhibition period will be reviewed.

8 Hydrological/Hydraulic Modelling

Given that the flood behaviour on the peninsula is impacted by both surface water and groundwater processes, a traditional modelling approach of decoupling the groundwater from the surface water component is not suitable. The dynamics between the two components have some unusual or unique mechanism in the hydrological cycle during a rainfall event and can only be captured by an appropriate model. Therefore, the integrated groundwater-surface water modelling tool MIKE SHE was used in this study and coupled to the pipe network modelling tool MIKE URBAN and the river modelling tool MIKE HYDRO:

- The MIKE SHE component calculates local runoff, infiltration and evapotranspiration (ET), as well as groundwater discharge to the surface water and storm water systems. It applies rainfall directly onto the grid.
- The MIKE URBAN model calculates the storm water drainage flow, including potential surcharging to the surface.
- The MIKE HYDRO model calculated flow through the open channels.
- Surface runoff in MIKE SHE discharges to the MIKE URBAN storm water drains and the MIKE HYDRO open channels, while storm water surcharge in MIKE URBAN and open channel flows MIKE HYDRO discharges onto the MIKE SHE topography.
- The combined model framework closes the internal water balance so that all inflows, discharges and internal storage changes are accounted for.

The details of the model setups, calibration and design event results are presented in **the Woy Woy FRMS – Technical Volume (DHI, 2022).**

Figure 8.1 and **Figure 8.2** provide a reference for the flood behaviour in the study area with the 1% AEP event showing significant runoff within the Kahibah Creek and Everglades systems, whereas within the sand flats of the peninsula flooding is generally significant in the low-lying areas and areas without adequate drainage capacity. The areas displaying flooding are also affected by relatively shallow groundwater tables. In the PMF event, flooding is widespread across the study area. The major creeks are flooding in areas surrounding the extents of the original wetlands. Flooding patterns in the sand flats of the peninsula reflect the alignment of the original sand dunes which were historically developed on top of.

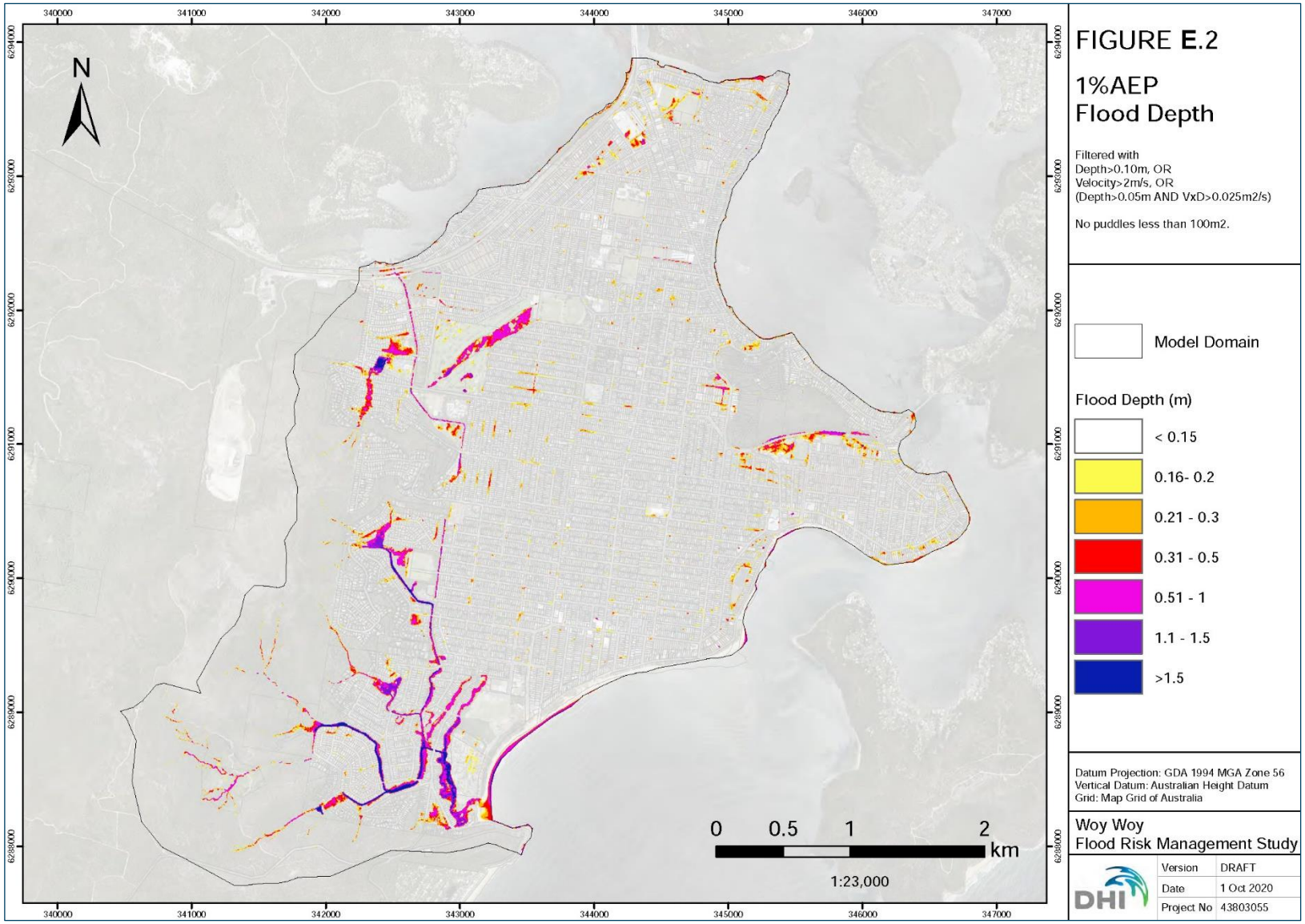


Figure 8.1 Peak 1% AEP Flood Depths

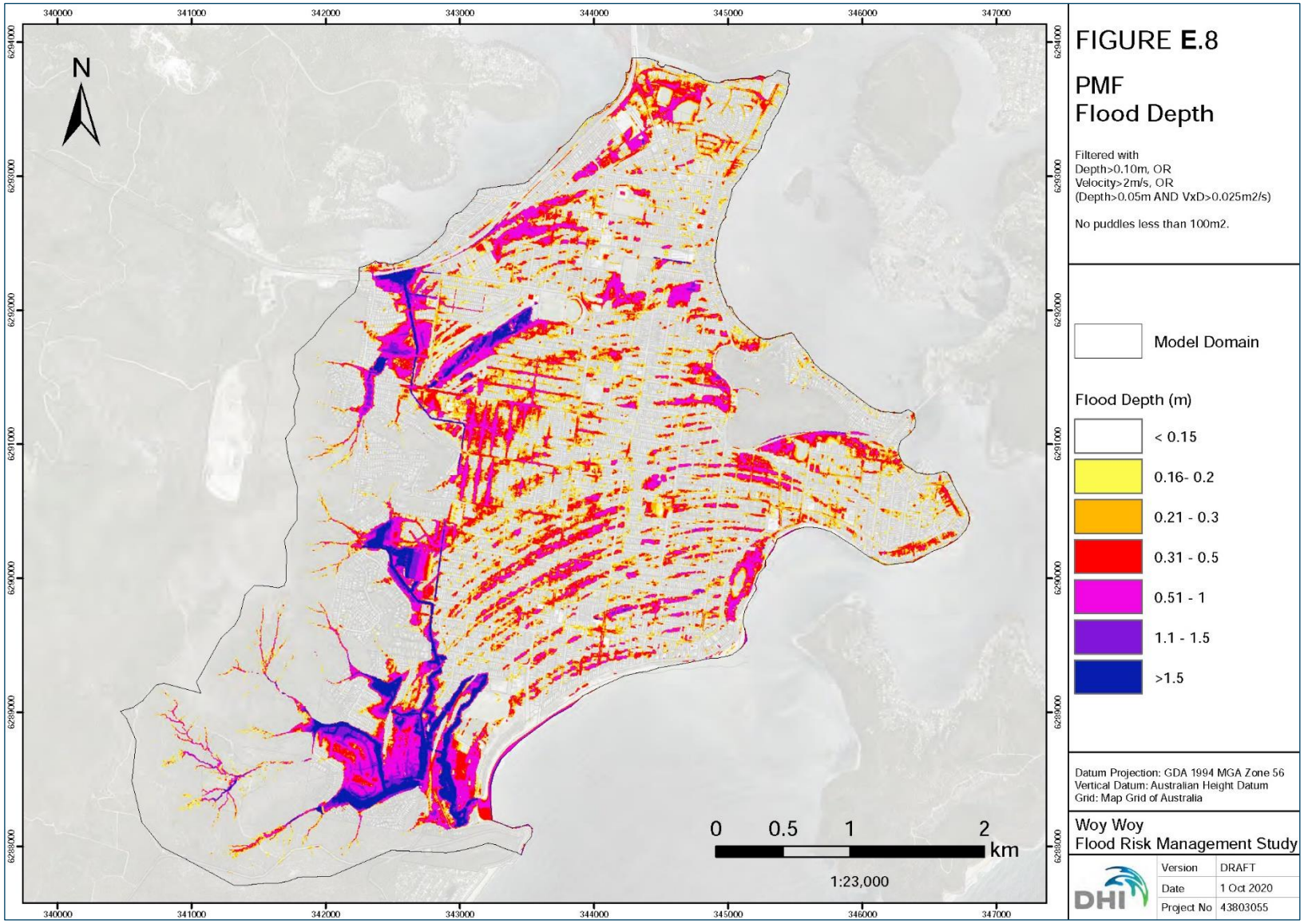


Figure 8.2 Peak PMF Flood Depths

8.1 Climate Change Scenarios

Council has adopted Representative Concentration Pathway Scenarios (RCP) 8.5 as the climate change projection as part of the Central Coast Council Climate Change Policy (2019). RCP8.5 is a scenario with greenhouse gas emissions continuing to rise throughout the 21st century and considered as the worst-case climate change scenario.

Interim Climate Change Factor or the projected rainfall intensity increase are available through ARR Data Hub (arr-software.org).

Council Policy (March 2015) defines the projected medium local sea rise for 2050, 2070, and 2100; 0.20, 0.39 and 0.74m.

Three climate change scenarios were considered for the projected year 2050, 2070 and 2090. **Table 8.1** summarises the climate change scenarios and the projected sea level rise (SLR) in conjunction with rainfall intensity increase (RII) conditions.

Table 8.1 Climate change scenarios

Scenario	Project Year	Sea level rise	RCP8.5 Interim Climate Change Factor (%)
Climate Change 1 (CC1)	2050	0.20 m	9.0%
Climate Change 2 (CC2)	2070	0.39 m	14.2%
Climate Change 3 (CC3)	2090	0.74 m	19.7%

A flood study typically considers the sea level rise and rainfall intensity change only during a flood event and ignores the impact of these on the antecedent catchment conditions. However, the sea level rise and rainfall intensity increase will likely elevate the average groundwater level in the study area and flooding in a part of the Woy Woy peninsula is sensitive to the antecedent groundwater levels. Therefore, it was decided to test how much the flood extent of a Climate Change scenario is affected by the antecedent catchment conditions.

1. Adopt the *Climate Change 3* scenario (worst projected) and rerun the long-term peninsula groundwater model.
2. Reselect the 80percentile groundwater level of the long-term model with the *Climate Change 3* conditions and use it as the antecedent catchment condition. This corresponded to the groundwater level on 23 March 1984. The initial groundwater level is 0.2-0.7m higher than the one adopted in the Baseline design run.

Figure 8.3 shows the increase of flood depth from Baseline under the *Climate Change 3* scenario with the updated antecedent catchment conditions (*CC3 antecedent conditions*). **Figure 8.4** shows the increase of flood depth from Baseline under *Climate Change 3* scenario, discarding the climate change impact on the antecedent catchment conditions.

A comparison of the two figures highlights that the difference of 0.1-0.2m is primarily found at the bottom of the escarpment and in the Everglades catchment where the groundwater mound is located. These areas are known to have relatively shallow sand

layers and the flooding is affected by the groundwater level. Besides these areas, the antecedent catchment conditions generally do not have a large impact on the flood extent in the 1%AEP design event.

Therefore, Climate Change 1 and 2 scenarios were run disregarding the impact of climate change on the antecedent conditions. These results are summarised in **Appendix F**.

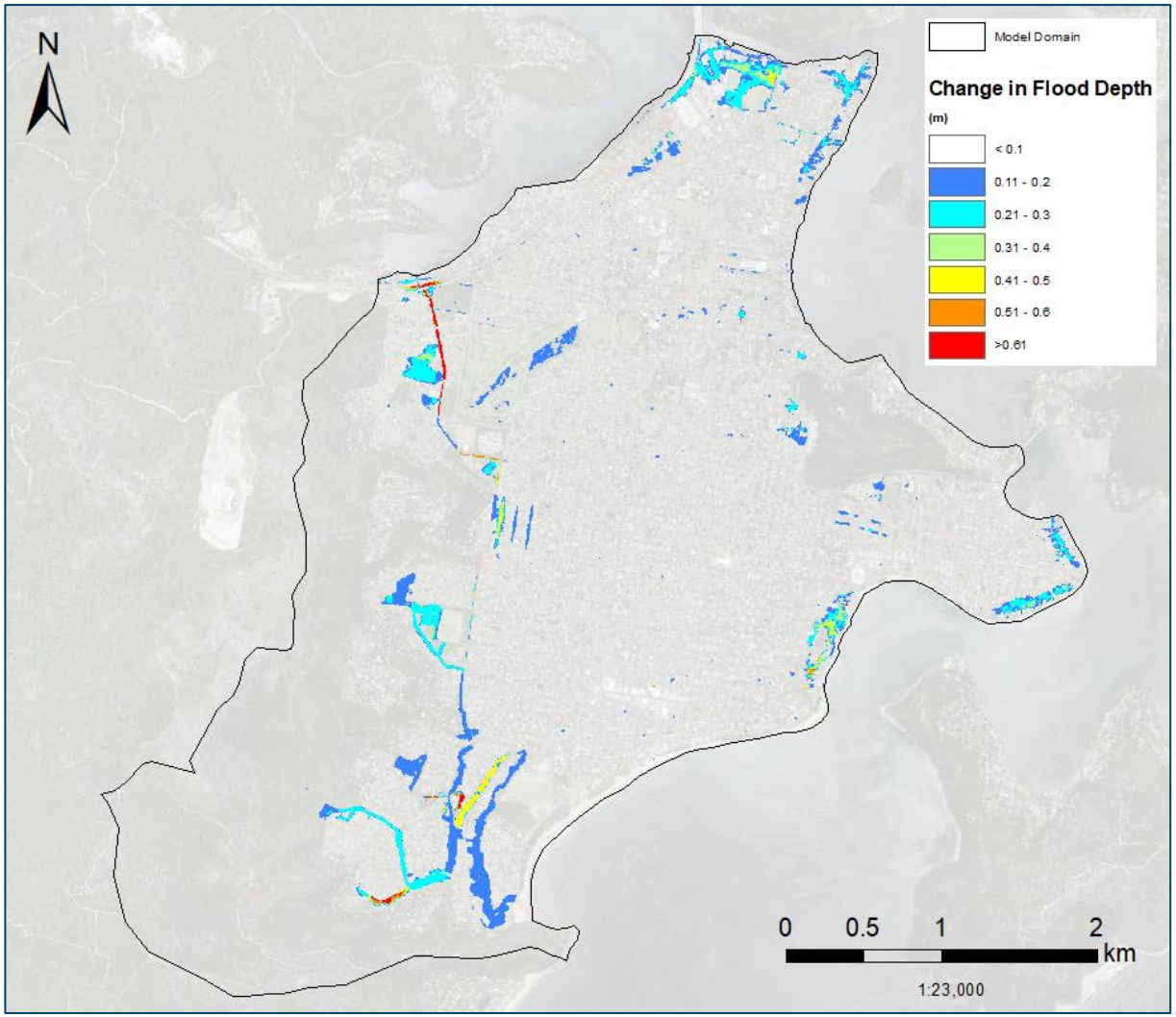


Figure 8.3 Change in flood depth from Baseline (Climate Change 3 with the updated antecedent conditions minus Baseline)

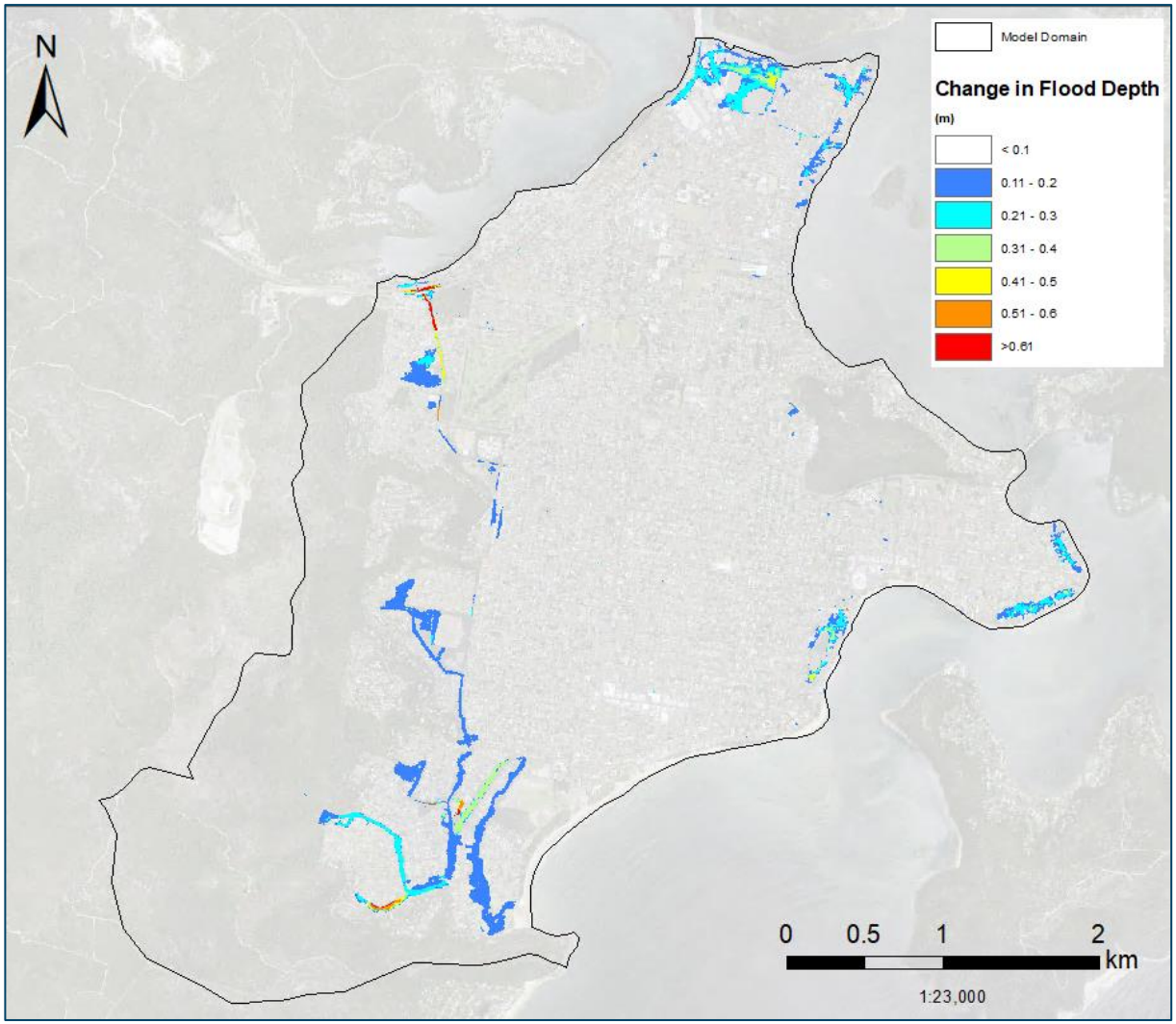


Figure 8.4 Change in flood depth from Baseline (Climate Change 3 minus Baseline)

8.2 Post Processing of Results

Floods can be hazardous to people, property, and infrastructure. However, this flood risk only exists when the community and the built environment interact with hazardous flood behaviour. Floodplain management aims to support management of flood risk by supporting land use planning, emergency management and flood risk management. Understanding flood risk and how it can affect existing and future development is essential to the management of flood risk.

Mapping of design flood extents alone does not provide a full picture of the varying degrees of flood risk across the floodplain. Breaking down the floodplain into varying degrees of flood function (hydraulic categories) or hazard assists in building this picture of flood risk and allows the development of appropriately targeted management measures.

The details of further processing undertaken to inform a range of management are outlined in Sections 8.2.1 to 8.2.3.

Unless specified specifically under 8.2.1 to 8.2.3, the following 2D maps were produced for design events and historical events.

- Maximum water level
- Maximum water depth
- Maximum velocity
- Flood extents

8.2.1 Flood Hazard

Flood hazard is a potential loss of life, injury or economic loss caused by flood events. General flood hazard classification is used for a preliminary assessment of risks. The floodplain is classified for general flood hazard for a strategic floodplain. Flood hazard is assessed as the flood depth-velocity product (D x V) in accordance with the AIDR guideline. The maximum hazard value does not necessarily occur at the peak water level or at the peak velocity.

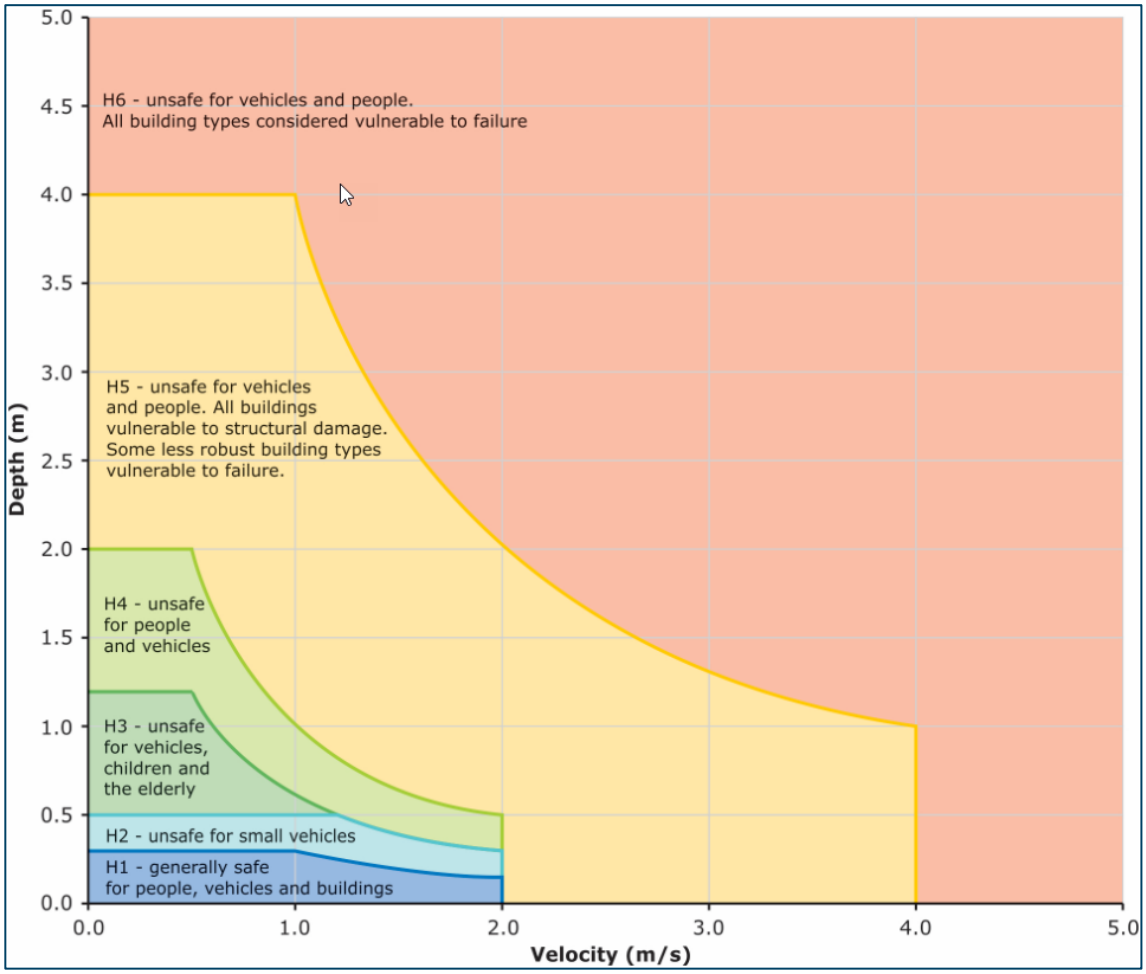


Figure 8.5 Combined Flood Hazard Curves (Smith et al., 2014) (Figure 6.7.9. of ARR 2016)

The time-varying Depth-Velocity product was calculated during the flood event and the maximum is used for Flood Hazard Vulnerability Classification outlined in ARR 2019. This processing was carried out for the 20%, 5%, 0.2% AEPs and PMF. It should be noted that these maps were derived for the critical duration for each AEP.

Flood Hazard maps are provided in **Appendix G**.

8.2.2 Flood Function

Flood function is the flood-related functions of flow conveyance and storage for flood flows. It is a key for development control to identify the areas of the floodplain that are sensitive to changes and impede flow conveyance or flood storage. Maintaining the flood functions of the floodplain is important for flood risk management.

An indicative flood function was determined by identifying areas of the floodplain that will be sensitive to changes that impede flow conveyance or flood storage functions. The following functions are defined in Floodplain Development Manual (NSW, 2005):

- Floodway: those areas of the floodplain where a significant volume of water flows during floods and is often aligned with a natural water course. It relates to areas that, even if only partially blocked, would cause a significant increase in flood levels.
- Flood Storage: those parts of the floodplain and is important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas

may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

- Flood Fringe: the remaining area of flood prone land after the floodway and flood storage have been defined. Development in the flood fringe area would not normally have any significant effect on flood levels or the pattern of flood flows.

There is no definitive method of deriving floodway and flood storage. After several combinations of criteria have been tried with 1% AEP results, the following criteria was used to determine the floodway.

- Velocity is greater than 1m/s OR
- Velocity is greater than 1m/s AND product of velocity and depth product is greater than 0.25 m^2/s.

Criteria for Flood Storage were assessed in conjunction with the outcome of the cumulative impact assessment. The lots which contribute to the increase of flood depth by over 0.1m generally lie in the area where flood depth is greater than 0.3m. Thus, the following criteria was used to define Flood Storage:

- It is not classified as Floodway AND
- Depth is greater than 0.3m.

All areas which are not categorised as Floodway or Flood Storage are set to Flood Fringe.

Flood function maps are provided in **Appendix H**.

8.2.3 Flood Emergency Response Classification of Communities

Flood Emergency Response Classification (FERC) 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 possible 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, 2017).

Flood Emergency Response Classification mapping is a useful tool for emergency services and evacuation planning for a floodplain. For the purposes of this assessment, it was assumed that evacuation centres would be located outside of the study area and on higher ground, well above the modelled flood elevations. Additionally, evacuation to hospitals (or access by ambulance) is expected to be from Woy Woy Public Hospital, Brisbane Waters Private Hospital (both located on Ocean Beach Road), or Gosford Hospital (accessed to the east via Maitland Bay Drive).

AIDR (2017) provides guidance on 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 11.13**.

Table 8.2 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	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

Primary Classification	Description	Secondary Classification	Description	Tertiary Classification	Description
			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.		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.

The 10% AEP, 5% AEP, 1% AEP, 0.5% AEP and PMF events were considered in the FERC mapping. These are presented in Map Series **I110** to **I114** in **Appendix I**. It should be noted that the 'Flood Free' category was not shown on the maps.

The combined effect of coastal and catchment flooding was considered on the emergency response classification. Therefore, the Brisbane Water flood extents, obtained in the flood study from Cardno (2015), were also included in the analysis.

Flooding within the low-lying areas of Woy Woy, Blackwall, Booker Bay and Ettalong, but not affected by Brisbane Water flooding, are assumed to be Flooded with Rising Road Escape Route (FER). Given the nuisance nature of flooding in this area (road flooding in minor events is not extensive or deep enough to prevent cars driving through), most residents are assumed to be able to escape via the existing road network to an emergency evacuation centre or hospital. During the PMF event, while the flooding is comparatively more extensive and deeper, it is assumed the low-lying areas can be categorised as flooded, isolated and elevated (FIE) as most residents would be able to escape flood waters but could only retreat to nearby flood free land and not to an evacuation centre or hospital. Evacuation routes within the study area and regional roads outside of the study are likely to be cut during the PMF.

9 Consequences of Flooding on the Community

To understand the flood risk to a community it is important to understand its impacts on community members and how emergency services can respond in a major flood event. This section assesses the existing impacts to the Woy Woy Peninsula both from historical flood events and modelled design flood events.

9.1 Impacts on the Community and Emergency Response

9.1.1 Community Experience

During the initial community engagement session and from the receipt of community survey responses both online and via mail, the following significant and consistent experiences were highlighted:

- Nuisance flooding within roadways
- Blockage of inlet pits and channels
- Flooding of properties
- Flooding of open spaces

Refer **Section 7.4** for a full summary of community consultation responses.

Acknowledging that those who responded to the community consultation effort do not represent the entirety of flooding experience in the peninsula, information from previous historical events have been provided by Council as evidence of flooding in the past. Previous significant flood events are listed in **Section 5**.

The previous Flood Study (DHI, 2010) also contains a significant amount of information on community experiences. These were primarily from flood events in 1974, 1978, 1984, 1988, 1990, 1992, and 2007 but also included single instances of floods in other years. The recorded comments regarding the magnitude and effects of flooding included:

- Flooding of roadways
- Flooding of yards and non-habitable structures
- Flooding of houses
- Needing watercraft to travel (e.g. canoes, row boats, etc.)
- Loss of possessions (e.g. vehicles)
- Isolation within flooded buildings
- Destruction of roadways following recession of water
- Deposition of sediment and/or rubbish in public and private lands when flood waters recede.

Figures 9.1 and **9.2** are examples of flooding photos received from the community during the previous Flood Study (DHI, 2010).

Previous flooding evidence has also been provided by Council as part of this FRMS showing the results of flooding from an event in March 1956. See **Figure 9.3**.

Although the catchment conditions have been drastically altered since 1956, including the extensive introduction of impervious surfaces, community flooding experiences were still significant in the lower lying areas.

Figure 9.1 Flooding Near the Corner of North Burge Road and Brick Wharf Road, June 2007

Figure 9.2 Flooding Near the Corner of Ross Street and Rowan Road, 1988

Figure 9.3 Flooding Along Winifred Avenue, 1956

9.1.2 Evacuation Routes and Major Roads

Vehicle access the Woy Woy Peninsula generally occur along only three roads:

- Woy Woy Road to the northwest,
- Brisbane Water Drive to the north, and
- Maitland Bay Drive to the east.

These routes provide the community with access to the greater Central Coast region as well as the M1 motorway. If any of these roads become inaccessible, evacuation and access to the peninsula by emergency services will be significantly hindered.

Within the study area, there are also a number of major roadways providing access across the peninsula. However, with the nature of the road network being more or less a gridded system in the lower lying flat areas of the peninsula, the most commonly used roadways are not the only way for vehicular traffic to travel around the study area. **Figure 9.4** below gives an indication of the main thoroughfares across the study area. This is a screen shot from Live Traffic NSW at approximately 5:15pm on Friday 26 March 2021.

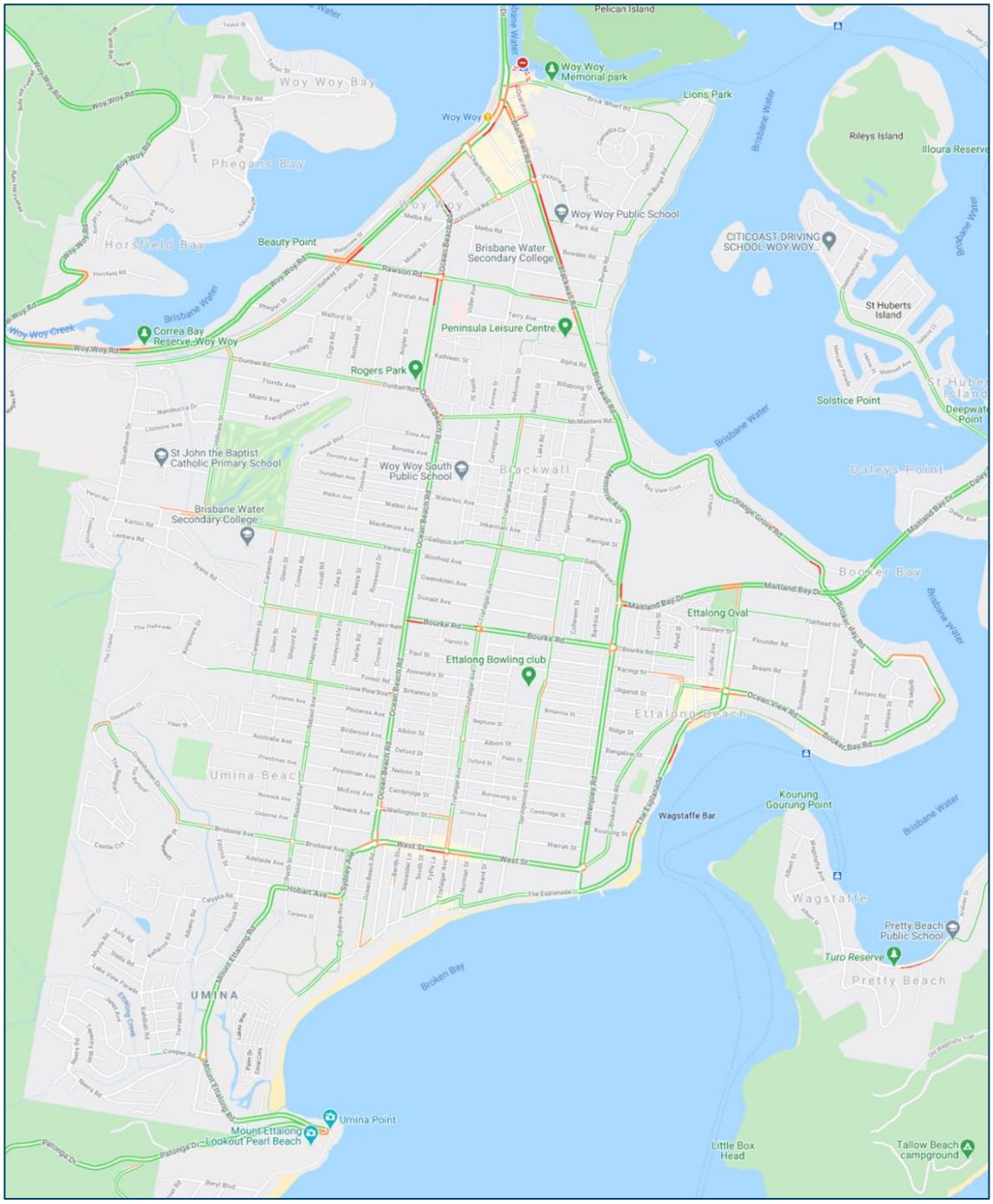


Figure 9.4 Commonly Used Roads in the Woy Woy Peninsula (source: livetraffic.com)

Annecdotal information received from the community in this FRMS as well at the previous Flood Study (DHI, 2010) indicated that many low-lying roadways become inundated and potentially unpassable during signifincat flood events. Flood modelling undertaken as part of this FRMS indicates that design storm events show that a number of roads with typically higher traffic volumes become overtopped in events as frequent as the 20% AEP event. **Figure 9.5** to **Figure 9.10** highlight some of these locations with design event hazard mapping overlaid. The event flood hazard displayed on each figure below represents the modelled event and duration in which flood waters begin to produce significantly widespread unsafe flows overtopping roadways.

Note that any hazard level of H2 or above should be considered as unpassable by small vehicles (i.e. residents) and hazard level of H4 or above would not be passable by larger vehicles (i.e. emergency service vehicles). It is assumed that, ideally, people will not drive through flood waters.

Keeping roadways operational during a flood event is essential for both the ability for residents to be reached by emergency services and so that evacuation can be possible if required.

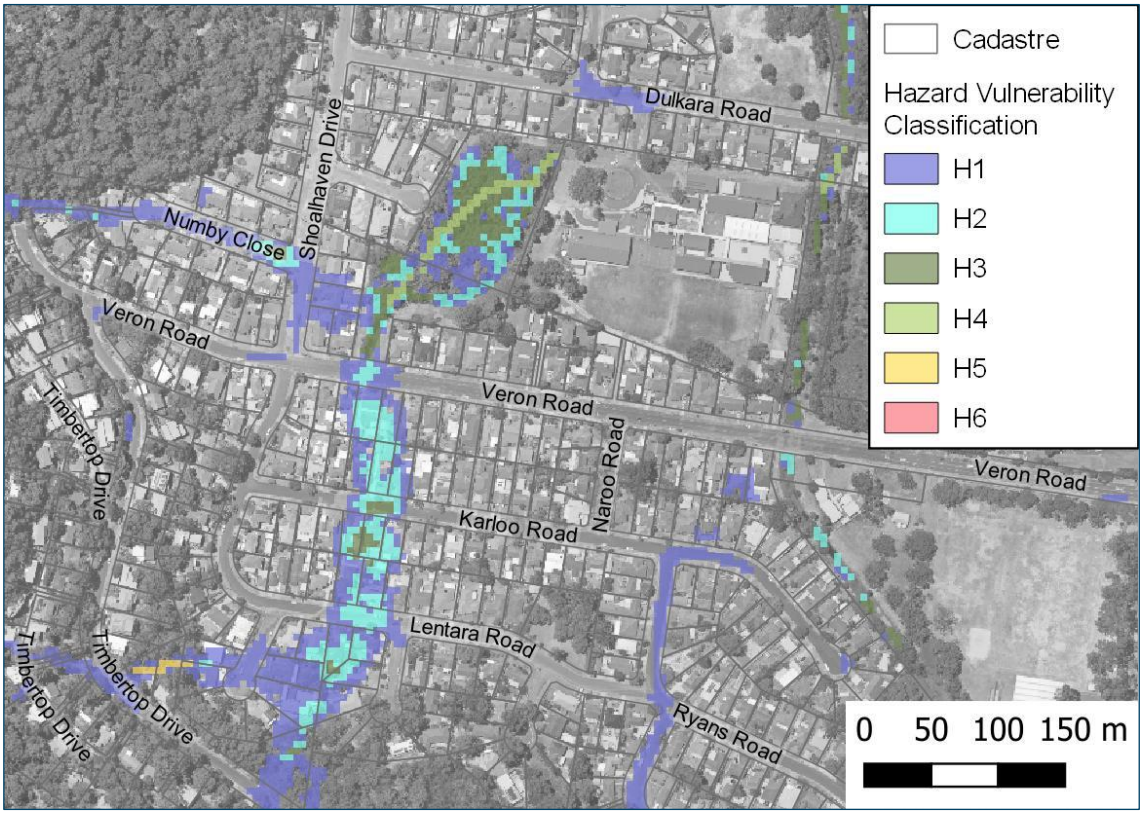


Figure 9.5 Flooding Hazard near Western End of Veron Road - 20% AEP, 1 Hour Event

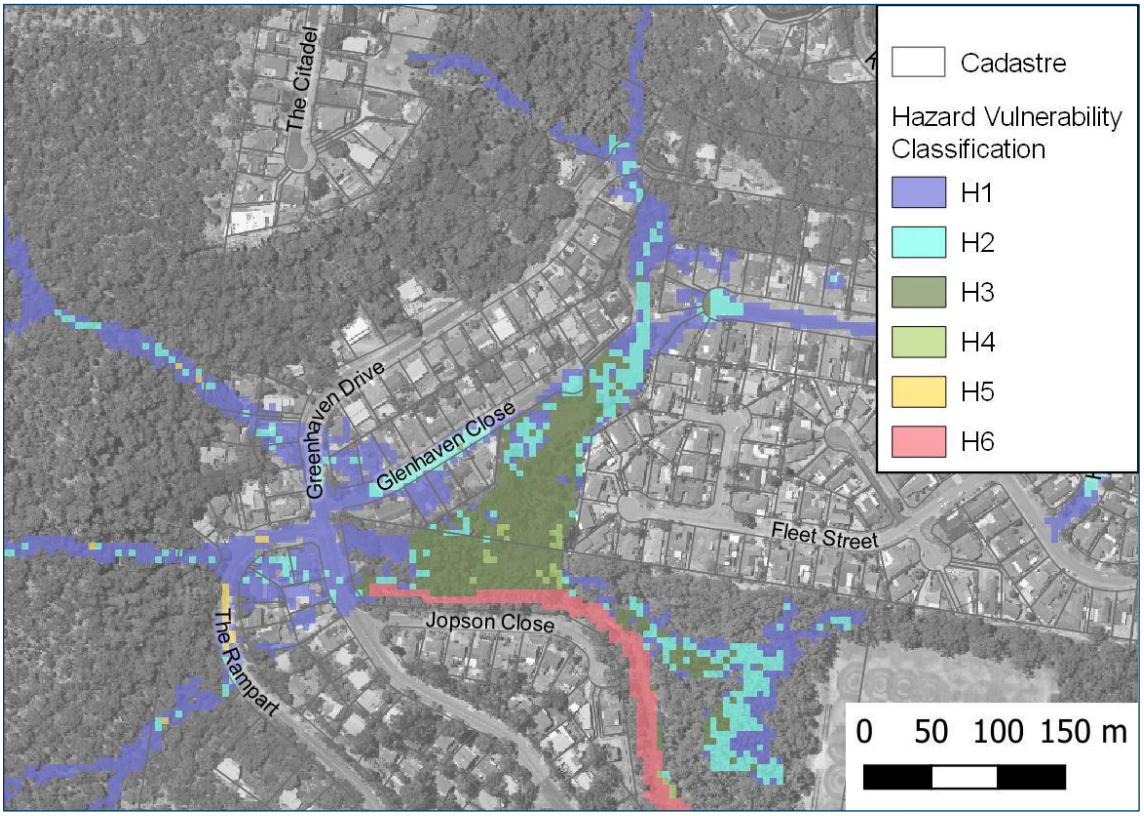


Figure 9.6 Flooding Hazard near Glenhaven Close - 1% AEP, 6 Hour Event

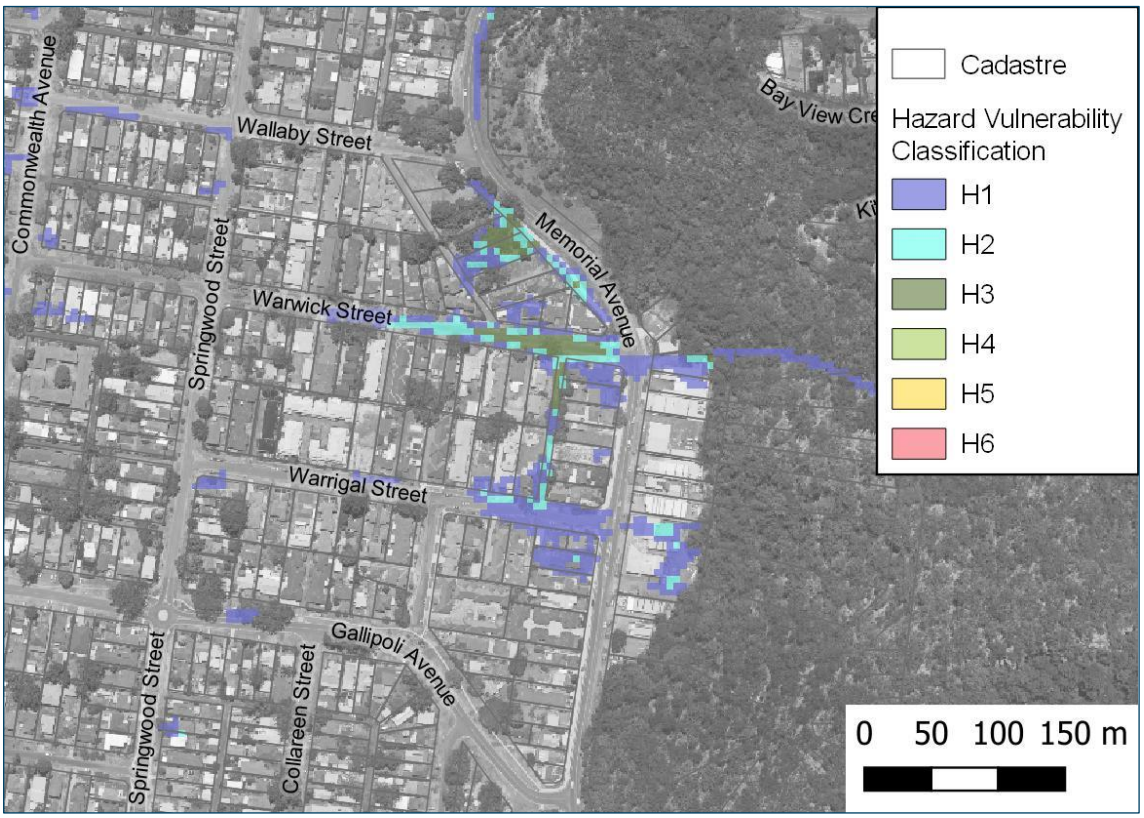


Figure 9.7 Flooding Hazard near Warwick Street - 1% AEP, 6 Hour Event

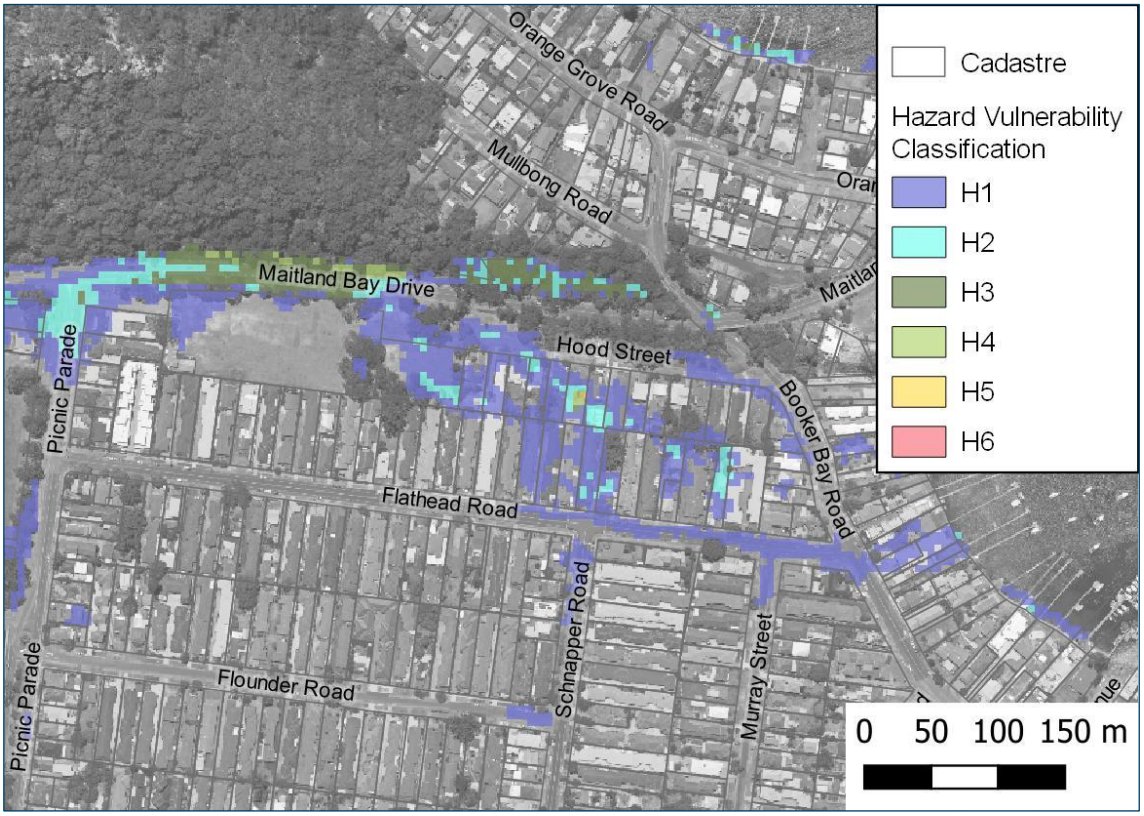


Figure 9.8 Flooding Hazard near Maitland Bay Drive - 1% AEP, 6 Hour Event

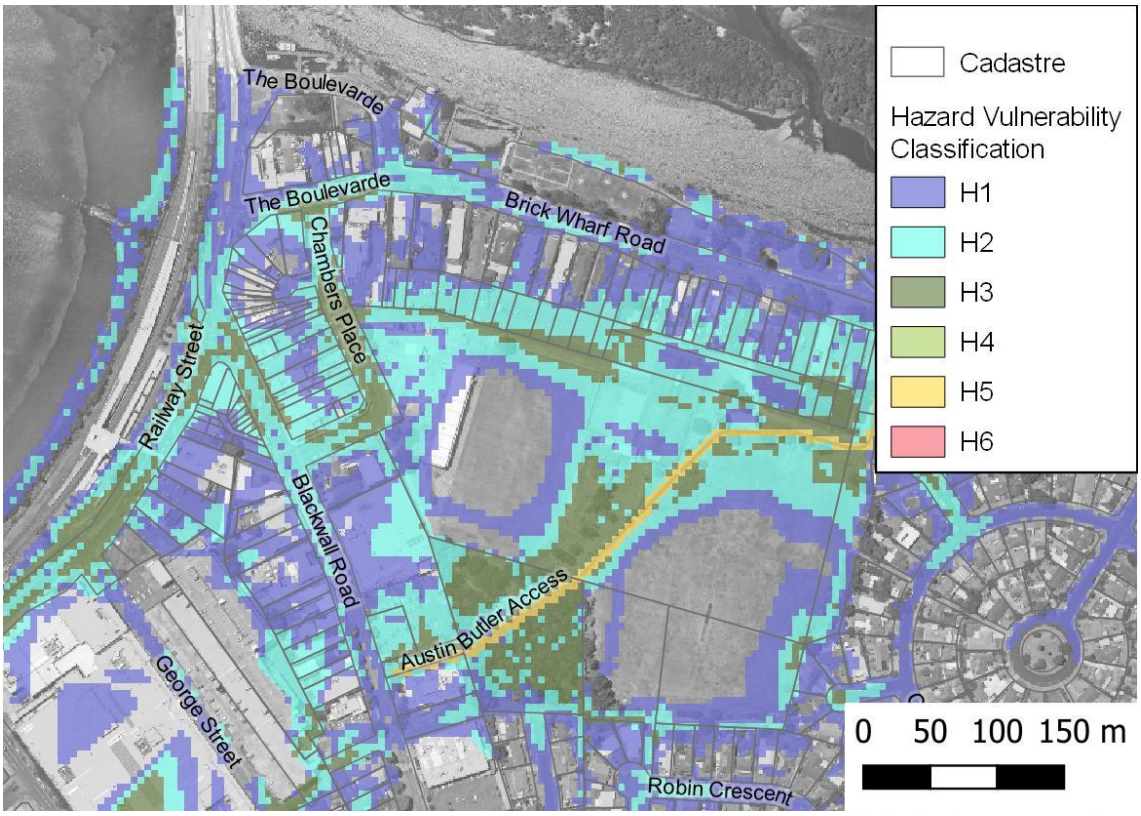


Figure 9.9 Flooding Hazard in Woy Woy CBD – PMF, 2 Hour Event

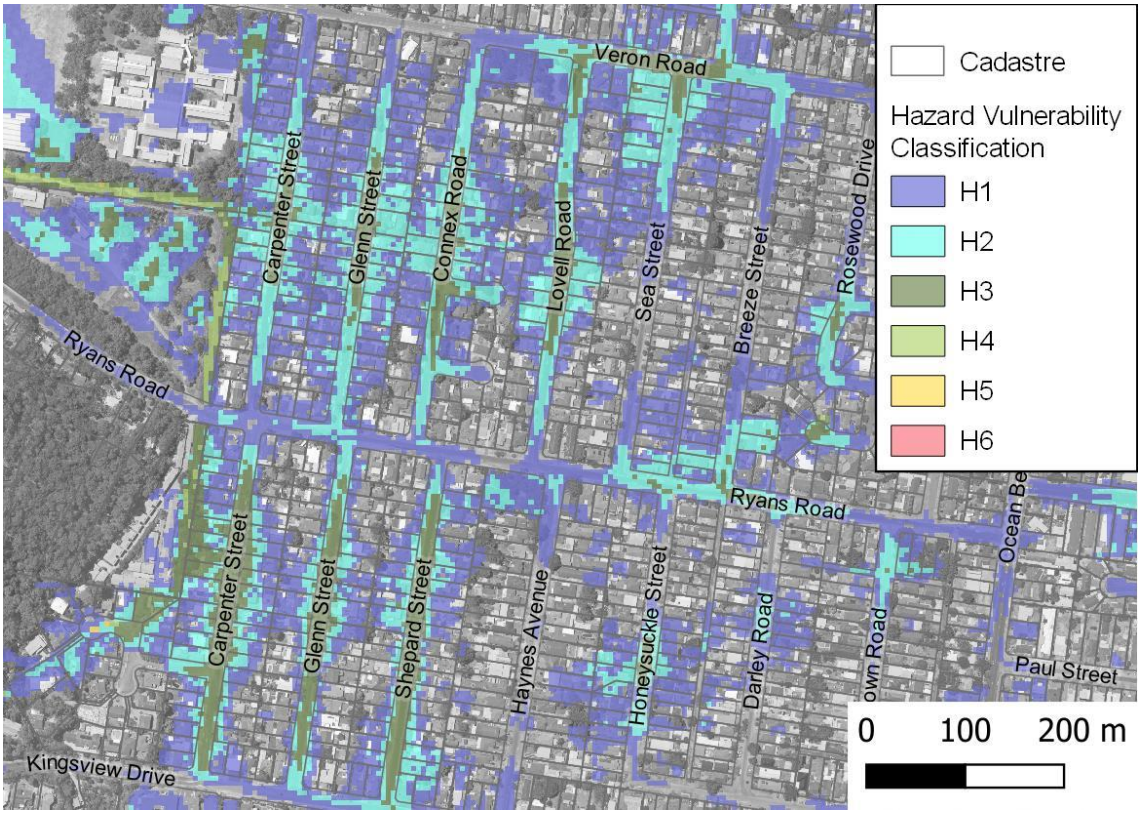


Figure 9.10 Flooding Hazard near Ryans Road – PMF, 2 Hour Event

9.1.3 Services

Each of the three routes listed in the previous section in and out of the peninsula can be used to access the Gosford Hospital (the closest major hospital outside the study area) and the Gosford SES, although this study does not consider any flooding located along the routes to these services beyond the boundaries of the study area. Police Stations (apart from the Woy Woy Police Station) are located in Gosford and Terrigal. **Figure 9.11** shows the location of major emergency services in relation to the study area. Note that as part of the Brisbane Water FRMSP, it was recommended that the Woy Woy Police Station be moved outside of the PMF flood extents (Brisbane Water flooding). Road classifications have been derived from Open Street Maps data.

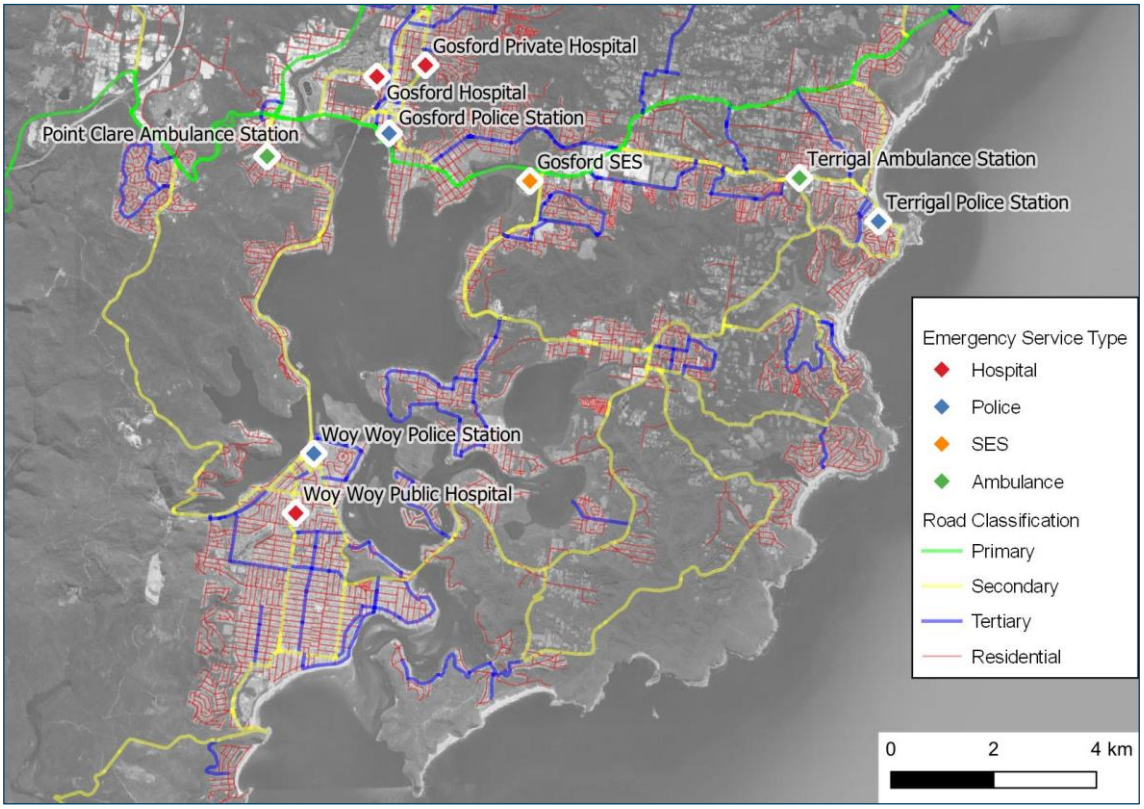


Figure 9.11 Emergency Services Locations in the Region

There were no anecdotal accounts of cutting off of these essential services during historical flood events. However, given the accounts of the depth and extent of flooding experienced by residents documented in the Flood Study (DHI, 2010) and this FRMS, it would be appropriate to assume that there were significant disruptions to access by emergency services.

During design flood events, from the 20% AEP to the 0.5% AEP, flood waters in the lower lying areas of the peninsula do not completely cut off emergency service access to the study area. In some of the steeper sub-catchments draining to Kahibah Creek and the Main Drain, emergency vehicle access can be cut off from flows overtopping roadways, although this would be for a short duration as critical durations in these areas are in the magnitude of hours and not days. The Woy Woy Public Hospital experience significant flooding in the PMF event and emergency vehicles from here would only likely be able to access the immediate surrounds, as a significant number of roads in the study area is subject to hazardous flood conditions. In design storm events, the Woy Woy Police Station may experience difficulties accessing other areas of the peninsula. Its location along Blackwall Road is subject to flooding (up to hazard level H3) in the PMF event.

In the PMF event, flooding across the study area is widespread and significant. It is unlikely that emergency service vehicles from outside and within the peninsula would be able to have flood free access to residential properties.

Refer to Maps I110 to I114 in **Appendix I** for the flood emergency response classification mapping and **Section 8.2.3** for further discussion on emergency response.

9.1.4 Extent of Flooding

There were no recorded fatalities, as a direct result of flooding, in any of the historic flood information received.

The number of houses flooded above floor level is not possible to infer from the April 1988 calibration event, as residential areas have since been redeveloped and the number of habitable dwellings and floor level elevations at the time of the flood event would not be reflected in the information used for the flood damages calculations collected in 2021 (refer **Section 9.2**).

The likely impact of flooding to existing residential and commercial properties for a range of design flood events is provided in **Table 9.1**.

Table 9.1 Degree of Flooding in the Community, Design Events

Flood Event	Total Area Flooded Within Study Area (ha)	Number of Properties Flooded – Yard Only	Number of Properties Flooded – Over Floor
20% AEP	67	57	16
5% AEP	96	103	19
1% AEP	125	205	36
PMF	729	3,133	2,138

9.2 Existing Flood Damages Assessment

9.2.1 Damage Categories

In order to quantify the economic impacts of flooding, a flood damage assessment has been undertaken. A property may suffer economic impacts from flooding through several ways. These are broadly grouped into three categories, as summarised in **Table 9.2**.

Table 9.2 Flood Damages Categories

Type of Flood Damages		Description
Tangible	**Direct**	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc.) Infrastructure
	Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible		Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Damage dealt directly to a property, or its contents (direct damages) are only a component of the total damages accrued during a flood event. Indirect costs, while also tangible, arise as a result of consequences of the flood event, such as clean-up costs, opportunity costs, and other financial impacts.

In addition to tangible damages, there are also a category of damages referred to as intangible damages. Intangible costs relate to social impacts, such as insecurity and depression, that arise as a result of major flood event, or general inconveniences that occur during the post-flood stage. The intangible costs are difficult to calculate in economic terms.

9.2.2 Property Survey

Detailed floor level survey was available for a total of 1,606 properties within the Woy Woy study area. The floor levels of the remaining properties (11,513) were estimated using aerial imagery, Google Street view and site inspections. The ground level was estimated using the LiDAR derived ground surface DEM. Where surveyed floor levels were not available, the damages assessment assumed that the floor level was 0.3 metres higher than the ground level as measured at the approximated dwelling front door location. A total of 13,119 properties were assessed in terms of floodplain damages, with a breakdown of their survey source provided in **Table 9.3**.

Table 9.3 Property Survey in Woy Woy Study Area

Survey Source	Residential Single Storey	Residential Double Storey	Commercial	Total
Woy Woy	138	24	3	165
Brisbane Water	680	256	89	1,025
Kahibah Creek	245	0	2	247
Kahibah	167	0	2	169
'Estimated'	11,300	*N/A*	213	11,513
Total	12,530	280	309	13,119

Due to the large number of properties estimated through aerial imagery and Google Maps, the damages assessment assumed that these properties were single storey. A full list of assumptions and inputs is provided in **Section 9.2.3**.

9.2.3 Damage Assessment: Assumptions and Inputs

The damage assessment undertaken for this study has examined the tangible damages only, using the Excel template (Version 3.00) developed by the Department of Environment and Climate Change (DECC) (now DPIE) in 2007. The spreadsheet is subject to a number of assumptions and inputs, which are detailed in **Table 9.4**. The residential and commercial damage curves applied to the analysis are illustrated in **Figure 9.12**. The sudden 'jump' in the two storey damage curve at a depth of 2.60m indicates that the flooding is starting to impact the upper storey, significantly increasing the damages incurred.

Additionally, it was assumed that there would be zero damage in the 2-year ARI (50% AEP) event.

Table 9.4 List of assumptions and inputs in the damages assessment

Assumption / Input	Value	Justification
Regional cost variation factor	1.02	Obtained from Rawlinsons – Regional Indices. Gosford is 1.02, relative to Sydney (1.00), and is the closest location to Woy Woy

Assumption / Input	Value	Justification
Inflation adjustments	2.02	Based on Average Weekly Earning (AWE): November 2020: $1,711.60 November 2001: $848.70
Post-flood inflation factor	1.50	Large scale impacts in a regional area, with more than 150 properties affected
Typical duration of immersion	6 hours	Assumed
Building damage repair limitation factor	0.85	Short duration
Typical house size	170 m^2	Estimated, based on aerial imagery of a range of representative properties
Contents damage repair limitation factor	0.75	Short duration
Level of flood awareness	Low	Assumed
Effective warning time	0 hours	Assumed
Interpolated Damage Reduction Factor	1.00	Assumed
Likely time and cost in alternate accommodation	6 weeks, $220 per week	Recommended values
Clean-up costs	$4,000	Recommended value, per property
External/Garden damage: Major cost	$5,000 per property	Triggered if depth of inundation above ground level is greater than 0.50 metres
External/Garden damage: Minor cost	$500 per property	Triggered if depth of inundation above ground level is greater than 0.15 metres but less than 0.50 metres
Single Storey Properties	High-Set	All single storey properties within the study area are assumed to be high-set (as opposed to slab on ground). This was based on site inspections throughout the study area and assumptions made which were most representative.
Commercial and Industrial properties	Low value	All commercial and industrial properties within the study area are assumed to be of low value (as opposed to medium or high)

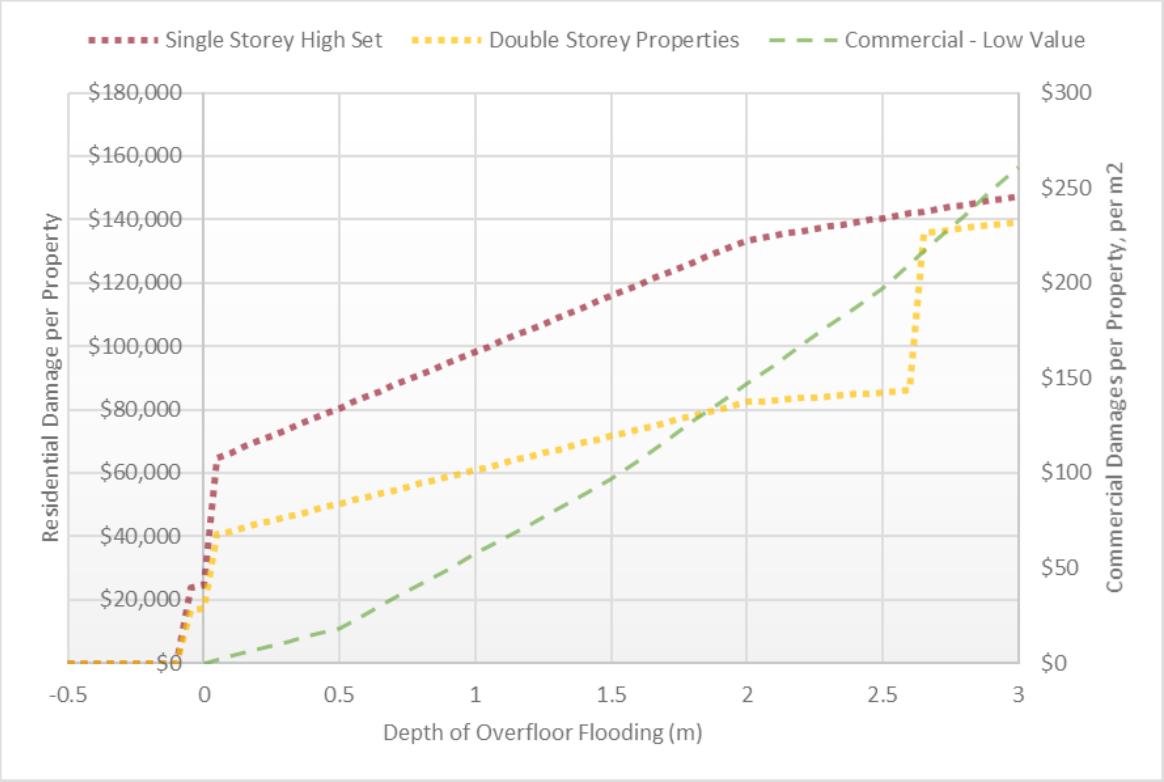


Figure 9.12 Assumed Damage Curves

9.2.4 Damage Assessment: Results

The results from the damage assessment are summarised in **Table 9.5**. The average annual damage (AAD) for the Woy Woy study area under existing conditions is $1,324,615. Over a 50-year assessment period and under a seven per cent discount rate, this is equivalent to a Net Present Value (NPV) of $40.2 million. These damages were calculated based on the tangible damages only.

Table 9.5 Existing Damages Assessment Results

AEP	Properties with Over-Floor Flooding	Max Over-Floor Depth (m)	Average Over-Floor Depth (m)	Total Damages
PMF	2,138	2.07	0.23	$165,207,840
1% AEP	36	1.54	0.25	$2,603,748
10% AEP	19	1.36	0.25	$1,459,712
20% AEP	16	0.32	0.12	$1,152,774

There is widespread flooding observed in the PMF event, relative to the other more frequent events. The number of properties with over floor flooding in this event is multiple levels of magnitude greater, indicating that while the study area is not particularly susceptible to tangible damages in more frequent events, there still exists the possibility for significant extensive damage to occur in extreme flood events.

As there are 2,138 properties in the damages assessment that experience over-floor flooding in the PMF, this equates to an AAD per property of $620.

The removal of garden damages has a negligible impact on the result of the damages assessment, suggesting that the outcome of the damages is not sensitive to this assumption.

As an additional sensitivity test, an assessment was undertaken for the assumption of all buildings using floor levels estimated based on ground LiDAR values. The assumed value of 0.3m above ground level was based on a combination of site inspections, Google Streetview and aerial imagery. **Table 9.6** shows the impact of increasing this value on over floor flooding and total damages.

Table 9.6 Existing Damages Assessment Results – Sensitivity to Estimated Floor Level Heights

		0.3m Above Ground Level	0.4m Above Ground Level	0.5m Above Ground Level	0.6m Above Ground Level
PMF	Properties with Over-Floor Flooding	2,138	1,538	1,127	823
	Total Damages	$165,207,840	$121,392,367	$89,602,079	$67,738,650
1% AEP	Properties with Over-Floor Flooding	36	35	34	34
	Total Damages	$2,603,748	$2,575,765	$2,530,196	$2,463,699
10% AEP	Properties with Over-Floor Flooding	19	19	18	18
	Total Damages	$1,459,712	$1,456,185	$1,391,451	$1,367,448
20% AEP	Properties with Over-Floor Flooding	16	16	15	15
	Total Damages	$1,152,774	$1,086,729	$1,062,274	$1,062,274
Average Annual Damage		$1,324,615	$1,090,814	$918,702	$803,890

The estimated floor level above ground level has a minor impact on the resultant AAD (potentially a 18% to 39% reduction when increased 0.1m to 0.3m, respectively). This reduction is mostly attributed to reduction in damages in the PMF event. In the smaller modelled events, over floor flooding is largely experienced by dwellings which have had their floor levels surveyed, hence the reduction of only one or two properties experiencing a change when the estimated floor level elevation is increased.

In the community survey, only six respondents potentially reported over floor flooding. While there has been no reported 1% AEP rainfall in the study area, the number of properties modelled as having over floor flooding in the 20%, 10% and 1% AEP events is greater than this. While it is possible that additional over floor flooding is slightly more extensive than the results of the community survey indicate, there are other potential reasons for this discrepancy:

- Flood modelling does not allow for smaller micro-scale elements such as bunding or short retaining or diversion walls which may direct flows away from dwellings.
- The nature of using LiDAR for ground level estimation in flood modelling means that actual ground levels are subject to a degree of uncertainty (+/-300mm in vertical accuracy). There is potential for measurement points at some properties to have a modelled LiDAR ground level up to 300mm higher than the real ground level. Subsequently, flood elevations can exceed the surveyed floor level with less depth than required in reality. The chances of this occurring increase with more properties in a study area, and this study area has over 1,600 surveyed floor levels estimated as being flood prone (i.e. within the PMF extents).

- The calibrated flood model is not likely to be perfectly accurate across every property in the study area for design flood events.

10 Information to Support Emergency Management Activities

10.1 Information to Support Emergency Management Activities

Section 9.1.2 identifies key transportation routes in the study area and **Section 9.1.3** identifies emergency service locations which may possibly be used to access the study area.

During a flood event, those who are directly and indirectly impacted from flood waters may need to either evacuate from the area, evacuate to a local evacuation centre, or require assistance from emergency response services. All of these activities rely on the local transportation network to be functional and not impacted by flood waters to the extent that safe passage is not possible.

Evacuation centres are defined as part of the Gosford City Local Flood Plan (SES, 2014) and include the following locations:

- Peninsula Community Centre
- Umina Surf Life Saving Club
- Ettalong Beach War Memorial Club (Ettalong Diggers)
- Everglades Country Club
- Umina Beach Public School

The key transportation links in the study area are shown in **Figure 10.1**, along with emergency services locations and evacuation centre locations. This information, compared to the modelled design flood depths, is used to identify key locations where road overtopping will present a significant flood risk to the community.

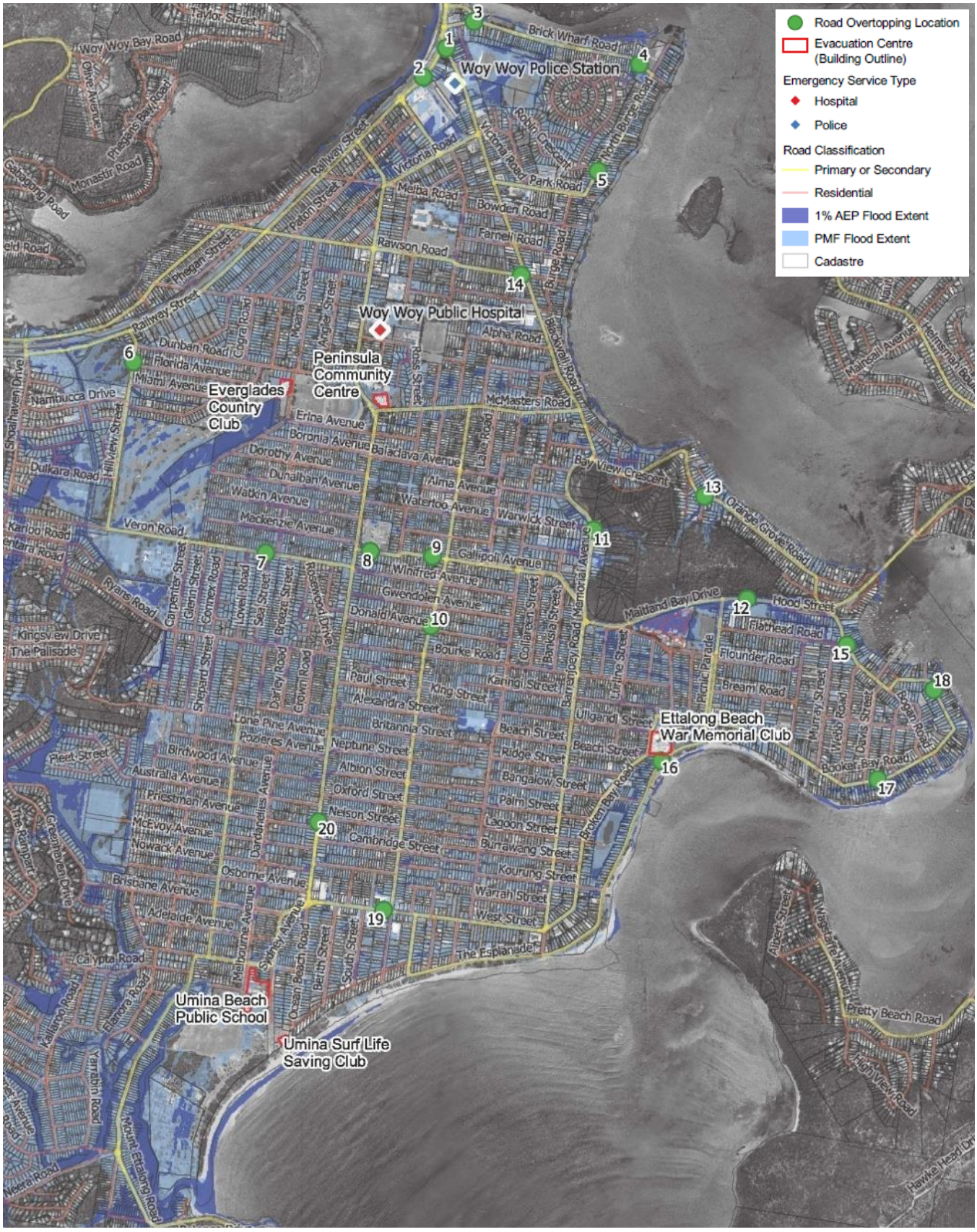


Figure 10.1 Road Overtopping Locations in PMF

Table 10.1 Road Overtopping Location Description

ID	Location Description
1	Blackwall Road, between Oval Avenue and Railway Street
2	Black Wharf Road, intersection with The Boulevarde
3	Railway Street, between Blackwall Road and Charlton Street
4	Brick Wharf Road, west of North Burge Road
5	North Burge Road, intersection with Robin Crescent
6	Hillview Street, intersection with Florida Avenue
7	Veron Road, intersection with Sea Street
8	Gallipoli Avenue, east of Ocean Beach Road
9	Gallipoli Avenue, west of Trafalgar Avenue
10	Trafalgar Avenue, intersection with Donald Avenue
11	Warwick Street, near Memorial Avenue
12	Maitland Bay Drive, east of Picnic Parade
13	Orange Grove Road, intersection with Koonora Avenue
14	Allfield Road, intersection with Blackwall Road
15	Booker Bay Road, intersection with Flathead Road
16	The Esplanade, south of Beach Street
17	Booker Bay Road, west of Petit Street
18	Booker Bay Road, south of Guyra Street
19	West Street, intersection with Trafalgar Avenue
20	Ocean Beach Road, south of Nelson Street

Table 10.2 Road Overtopping Depths

ID	Peak Flood Depth Over Road (m)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
1				0.1	0.2	0.2	0.2	0.6
2			0.1	0.1	0.1	0.1	0.2	0.6

ID	Peak Flood Depth Over Road (m)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
3			0.1	0.1	0.2	0.3	0.3	0.5
4								0.3
5				0.1	0.1	0.1	0.1	0.2
6					0.1	0.1	0.2	0.4
7	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.4
8	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.8
9				0.1	0.1	0.1	0.2	0.4
10	0.1	0.2	0.2	0.3	0.3	0.4	0.4	1.0
11	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.8
12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
13						0.1	0.1	0.3
14				<0.1	<0.1	<0.1	<0.1	0.2
15			0.1	0.2	0.2	0.2	0.2	0.4
16							0.1	0.3
17							0.1	0.4
18					0.2	0.2	0.2	0.5
19							0.1	0.5
20			0.1	0.1	0.1	0.2	0.2	0.4

As previously mentioned, the gridded nature of the road layout in the Woy Woy Peninsula means that there are often multiple ways to access a property. The minor residential streets can provide alternate access but can, in some cases, be more susceptible to greater degrees of flooding.

The development at higher elevations at the western side of the catchment can be cut off during a relatively frequent flood event. For example, if Cowper Road and/or Neera Road overtop near Kahibah Creek, multiple residential properties will not have access to emergency services.

In the low-lying areas of the peninsula, of particular susceptibility to flooding are the roadways in the eastern vicinity of the Everglades catchment (i.e. west of Ocean Beach Road and north of Lone Pine Avenue). Access to this area along Veron Road is generally not advised as it is significantly flood affected.

Access from Brisbane Water Drive in the north of the study area suffers from inundated areas within the Woy Woy CBD. These low-lying areas may not be accessible in events greater than the 2% AEP.

Similarly, access from the east along Maitland Bay Drive Bridge can be difficult with potential for multiple routes around Blackwall Mountain to be cut off during flood events. Although it should be noted in these areas that groundwater assumptions are uncertain and further analysis may be needed to provide more accurate design flood results in this area should Council consider any future improvements to flood risk.

In the PMF event flooding is widespread across the study area. A large majority of roadways suffer from inundation and high hazard vulnerability classifications, significantly restricting the movement of all vehicles.

The duration which roadways become inundated is dependent on the storm events. Design event flood modelling has considered the storm events producing the highest flood depths. Some of which are relatively short duration events such as 1 hour, while others are as long as 72 hours. Inundation is also highly dependent on the coincidence of elevated tidal levels in Brisbane Water for low lying areas around the foreshore. Additionally, higher degrees of blockage in street drainage can cause increased flood depths for flat areas and those with trapped low points and a high degree of impervious surface area.

In general, the five evacuation centres noted in the Gosford City Local Flood Plan (SES, 2014) are flood free during all design storm events, except the PMF. Access to these sites by the road for most of the residents of the peninsula is possible, with only the Ettalong Beach War Memorial Club likely to have restricted access from two roads: Memorial Avenue and The Esplanade.

There are three water supply pump stations in the study area. Two are located in the upper catchment to the west: a booter pump on Timbertop Drive and a pump station on The Rampart. One is located along Ocean Beach Drive at the Council Woy Woy Works Depot. Only the pump station on The Rampart is within the PMF extents. None of the pump stations are inundated in modelled events more frequent than the PMF.

No sewer pump stations were identified in the study area from Council's GIS data.

10.1.1 Land-use Compatibility and Vulnerable Populations

10.1.1.1 Mainstream Flooding

Mainstream flooding within the study area refers to areas which are subject to flooding where significant creeks break their banks and flows begin to inundates adjacent properties. This primarily applies to the watercourses in the Kahibah Creek and Everglades catchments.

Land uses, as defined in the GLEP, surrounding watercourses are generally Low Density Residential, General Residential (one aged care facility), Public and Private Recreation, and Infrastructure including schools.

Some of the current zoning within the study area is not consistent with the modelled flood behaviour. This includes the location of vulnerable populations such as aged/assisted care facilities and schools within the PMF extent. These are located along the Main Drain in the Everglades catchment.

It is acknowledged that some development may have occurred without a full appreciation of the flood risks in the peninsula or based on previous modelling results (or lack thereof). Relocation or removal of these facilities is not recommended. However, it is recommended that all development with vulnerable populations within the PMF extents require a flood emergency response plan

10.1.1.2 Overland Flows

Overland flow flooding in the study area generally applies to all flooding outside of creeks or channels and from elevated tidal conditions. Flooding from overland flow occurs when catchment runoff concentrates into flow paths along natural or constructed routes. It differs from mainstream flooding in that flood waters generally approach from the catchment above and does not rise from a large body of water such as a creek or river. In this FRMS, flooding caused by raised groundwater tables can also be considered as overland flow flooding.

Given it is widespread across the peninsula, all land uses are affected by overland flooding. Most areas in the sand flats of the lower lying section of the Woy Woy Peninsula are not significantly affected by concentrated overland flood flows in events less than the PMF. However, there is a significant degree of nuisance flooding affecting roadways across the study area. Some residential areas near the Woy Woy CBD and at the base of Blackwall Mountain are inundated in events as frequent as the 20% AEP.

More significantly affected by overland flow flooding are the regions of the study area located in the upper catchments of the Main Drain and Kahibah Creek. In these areas, where there is a lack of easements or open spaces to convey runoff, overland flows pass through private properties, affecting existing dwellings.

Simialr to mainstream flooding, some of the current zoning within the study area is not consistent with the modelled flood behaviour. This includes the location of vulnerable populations such as aged/assisted care facilities and schools within the PMF extent.

Of particular vulnerability are the multiple schools affected by overland flow flooding in the PMF event. These include:

- St John the Baptist Primary School, accessed via Dulkara Road. Portions of the site are inundated in events as frequent as the 5% AEP (0.4m deep) and vehicular access at Dulkara Road is compromised in flood events as frequent as the 20% AEP (0.3m deep).
- Umina Beach Public School. Affected by flooding in the PMF event only with only a portion of the site inundated (up to 0.3m deep within building footprints). This is an evacuation centre.
- Ettalong Public School. Affected by flooding in the PMF event (0.2m deep), with adjacent roadways inundated in the 1% AEP event (maximum 0.2m deep at Karingi Street).
- Woy Woy South Public School. Inundated in the PMF event (up to 0.4m deep) but access to an evacuation centre along Ocean Beach Road is maintained.
- Woy Woy Public School. Generally, flood free in the PMF event but access via Park Road and Bowden Road to evacuation centres is compromised for this flood event (up to 0.3m deep flood waters).

In addition to the aforementioned schools, there are multiple child care facilities across the peninsula. In a PMF event it is likely that these locations will be inundated and/or have access to emergency services and evacuation centres compromised.

There are also many aged care and assisted care facilities across the study area which are subject to flooding in the PMF event. Those which are not located adjacent to the Woy Woy Public Hospital or an evacuation centre again are vulnerable to becoming isolated and losing access to emergency services.

Even if the roadways required to evacuate out of the peninsula or to an evacuation centre are above PMF level for these vulnerable populations, considerable warning time would be required to undertake this. A shelter in place strategy would generally not be appropriate given the limited mobility and/or specific medical needs of those occupying primary schools or aged care facilities.

It is recommended that all development with vulnerable populations within the PMF extent require a flood emergency plan.

10.2 Flood Planning Area and Special Flood Considerations

There are two different categories where flood related development controls may be applied/considered. These are:

- Flood Planning Areas (FPAs), and
- Special Flood Considerations (SFCs).

Councils will be required to include the mandatory standard instrument 'flood planning' provision without variation in their LEPs. The new standard clause 5.21 in the GLEP 2014 includes this flood planning provision.

The FPA is the land below Flood Planning Level (FPL). The FPL is a combination of the flood levels from the defined flood event (DFE) and a freeboard selected for flood risk management purposes.

The DFE forms the basis for determining the level of exposure to flooding and associated risks to life and property damage. The Floodplain Development Manual identifies the 1% AEP flood event, or an equivalent historic flood, as an appropriate starting point for determining the DFE for development controls, including for residential development. The manual allows the selection of a rarer DFE to address broad scale flood impacts in consideration of the social, economic, environmental and cultural consequences associated with floods of different probabilities.

The typical freeboard for residential development due to flooding from waterways, such as rivers or creeks, is 0.5m. A lower freeboard or an alternative approach to freeboard may be used where the consequences to people and property of low probability flood events are assessed as minor through the FRM process.

The optional standard instrument SFC provision did not proceed state-wide. However, the existing GLEP 2014 clause 7.3 provides similar outcomes particularly with respect to emergency response and safe occupation of development with vulnerable populations. Council has currently not adopted the optional standard instrument SFC provision.

10.2.1 Freeboard

Figure 10.2 illustrates the traditional way of applying a vertical freeboard. This approach is appropriate for riverine flooding where floodwater propagates from a stream or a lake and is confined by higher grounds. However, the mechanism of overland flooding (surface flood) differs from riverine flooding, and it may result in overly strict development controls in a flat catchment like Woy Woy where multiple flow paths and local depressions exist.

Figure 10.3 and **Figure 10.4** illustrate two situations where the traditional freeboard approach is difficult to manage. Both situations are seen in the Woy Woy peninsula when a freeboard is applied for defining FPA. **Figure 10.3** illustrates the situation where two different FPLs intersect at a floodplain and results in discontinuity in elevations. This leads to a question which FPL is to be applied at the lots located in the middle. **Figure 10.4** illustrates the situation where the topography is flat and the FLP does not encounter a higher ground which generates "infinite" FPA.

For 1% AEP design level plus 500mm of freeboard (**Figure G.1**), spatially interpolated levels from the isolated design flood level plus 500mm were applied as FPL as shown in **Figure 10.5**.

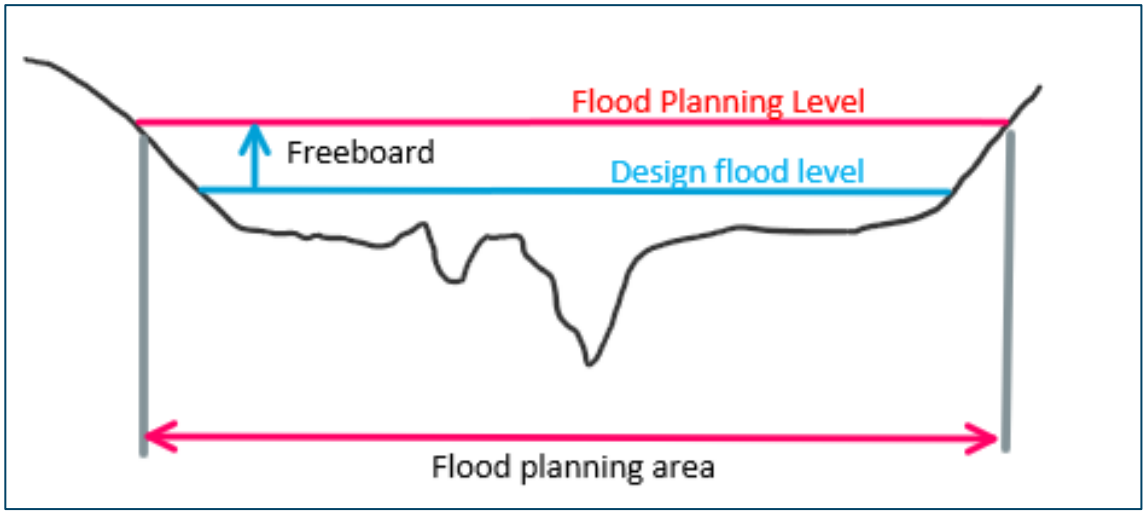


Figure 10.2 Traditional approach of defining Flood Planning Area by vertically raising the design flood level by a freeboard

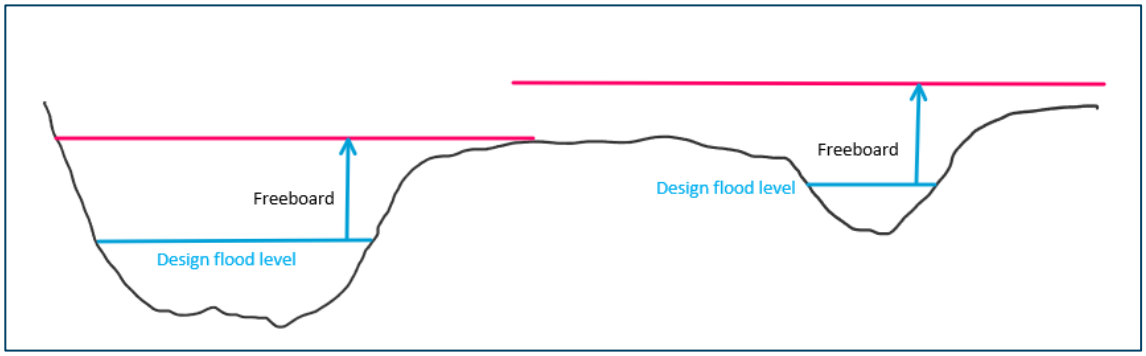


Figure 10.3 Different Flood Planning Level from two separate flood areas

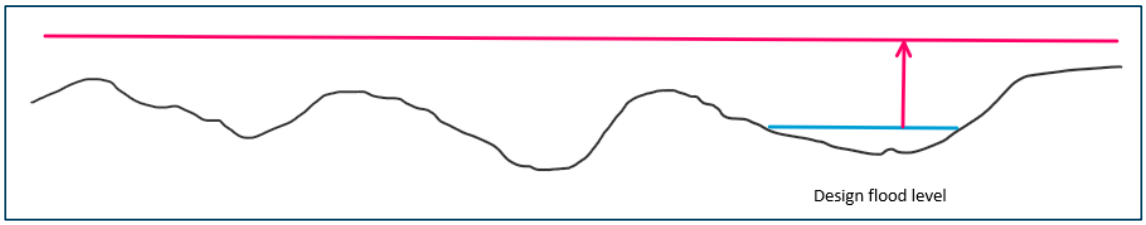


Figure 10.4 Unconfined Flood Planning Level

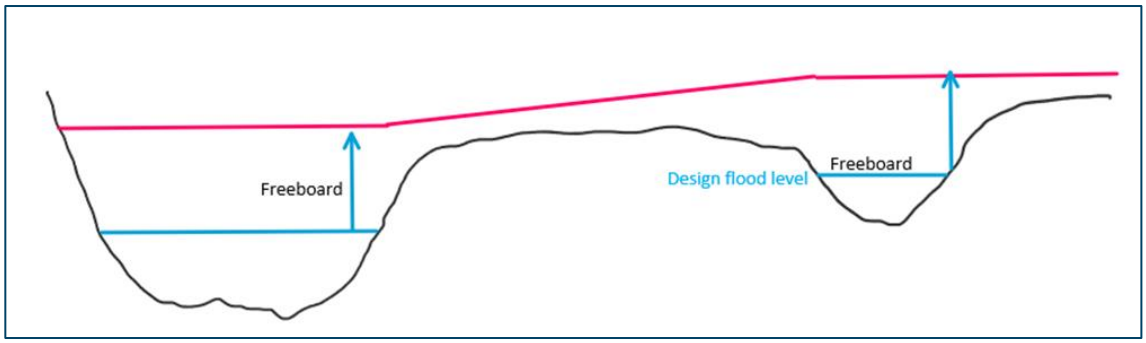


Figure 10.5 Flood Planning Level interpolated from two separate design flood levels

Sensitivity analysis (refer the Woy Woy FRMS – Technical Volume (DHI, 2022)) of model parameters yielded a potential increase to design flood levels of up to +0.5 m in the 1% AEP for sensitivity to antecedent groundwater conditions, surface roughness and blockage assumptions. It would therefore be acceptable to adopt a minimum freeboard for flood planning levels, based on the sensitivity analysis, of 500 mm.

10.2.2 Flood Planning Area Recommendation

A range of DFEs and freeboards were reviewed for their suitability to for the FPA for the Woy Woy Peninsula. The following flood extents were considered for FPAs:

- 1% AEP design event + 500mm of freeboard
- 1% AEP design event + 500mm of freeboard plus sea level rise of 0.2m
- 1% AEP design event + 500mm of freeboard plus sea level rise of 0.39m
- 1% AEP design event + 500mm of freeboard plus sea level rise of 0.74m
- 1% AEP design event + 30% rainfall intensity increase
- 0.5 % AEP design event
- PMF design event.

These flood extents are mapped in **Appendix J**.

Flood extents of 1%AEP, 0.5%AEP and 1%AEP plus 30%rainfall intensity increase are quite limited and the difference in flood level is less than 100mm at the majority of locations in the peninsula as shown in **Figure 10.6** and **Figure 10.7**.

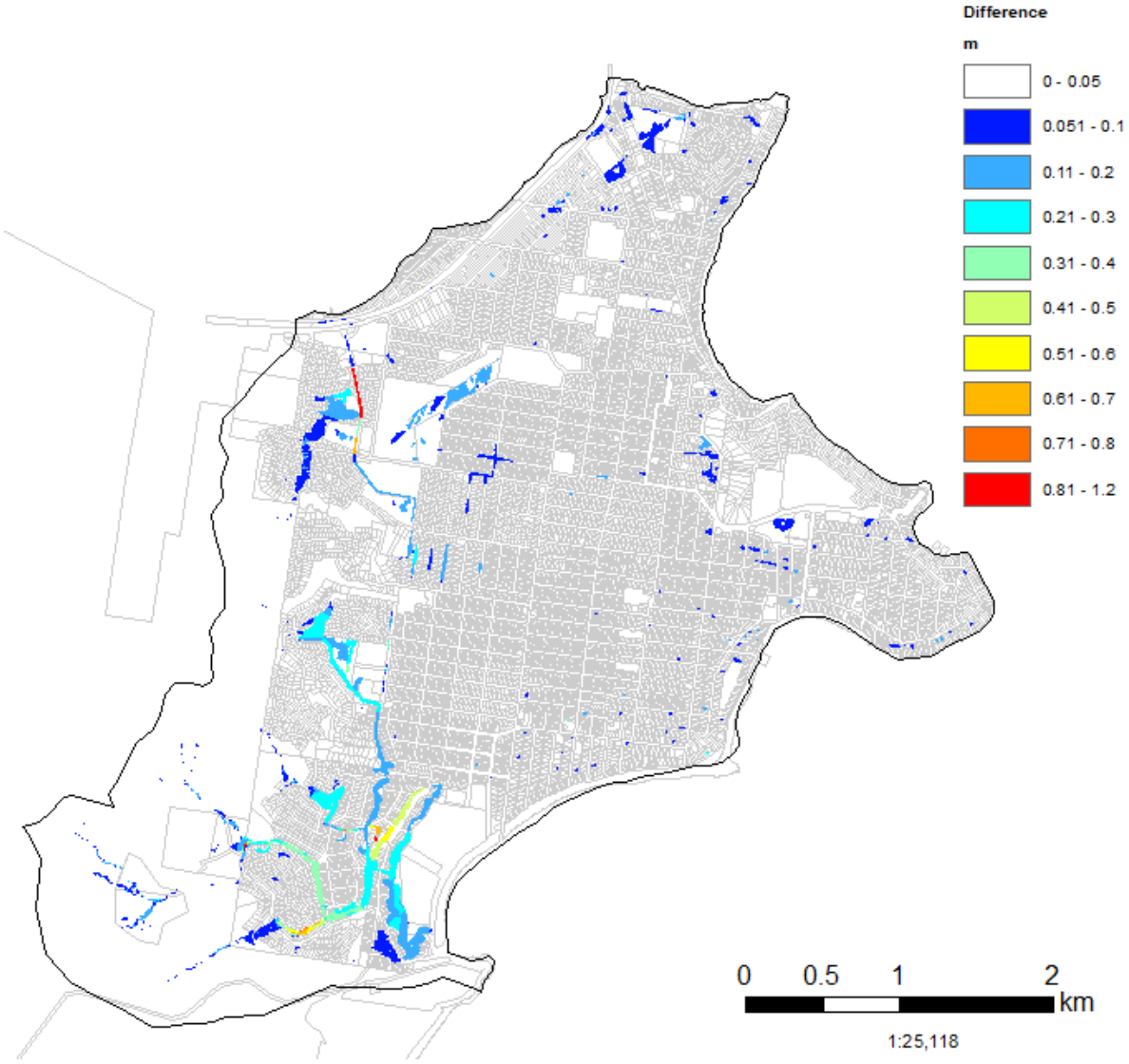


Figure 10.6 Difference in Flood Levels of 1%AEP versus 30% Rainfall Intensity Increase and 1%AEP

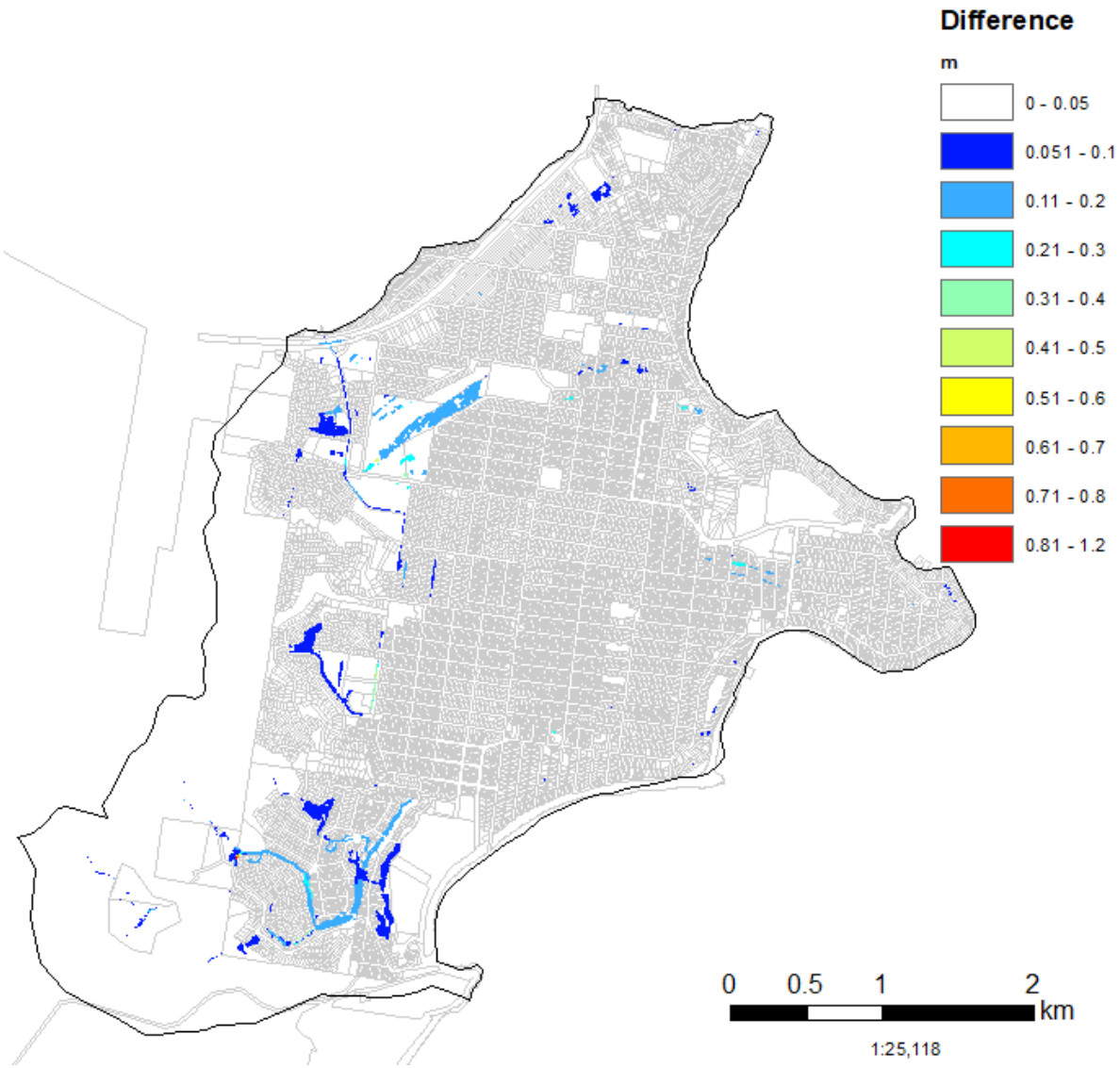


Figure 10.7 Difference in Flood Levels of 0.5%AEP versus 1%AEP

As discussed in 10.2.1, the 1% AEP design level plus 500mm of freeboard covers much larger part of the peninsula due to the flat topography. This is even larger than the PMF extent in the low-lying area of the peninsula. Adopting the 1%AEP design level plus 500mm of freeboard as the flood planning area for the entire peninsula is overestimation of flood risk. At the bottom of the escarpment and within the Kahibah Creek catchment where steeper slopes and underlying soils mean runoff is not as easily infiltrated, the extent of the PMF is greater than the 1% AEP design level plus 500mm of freeboard.

Sea level rise impacts the flood extent largely along the coastline, particularly, in the Woy Woy CBD and Booker Bay. In these areas, the extent of the 1%AEP design level plus 500mm mostly covers the areas affected by the sea level rise.

Figure 10.8 to **Figure 10.13** compare

- the coastal areas affected by the sea level rise,
- the extent of the 1%AEP design level plus 500mm, and

- the flood extent of PMF

The flood planning area recommended is the PMF extent. This allows for coverage over the areas affected by mainstream flooding (e.g. the Kahibah Creek catchment) while still including areas within the sand flats which are significantly flooded in extreme events.

The Brisbane Water Foreshore Floodplain Risk Management Plan (Cardno, 2015) also provides recommendations for flood planning areas and levels overlapping this study. In instances where these recommendations are inconsistent with this study, the Brisbane Water Foreshore Floodplain Risk Management Plan (Cardno, 2015) recommendations should apply.

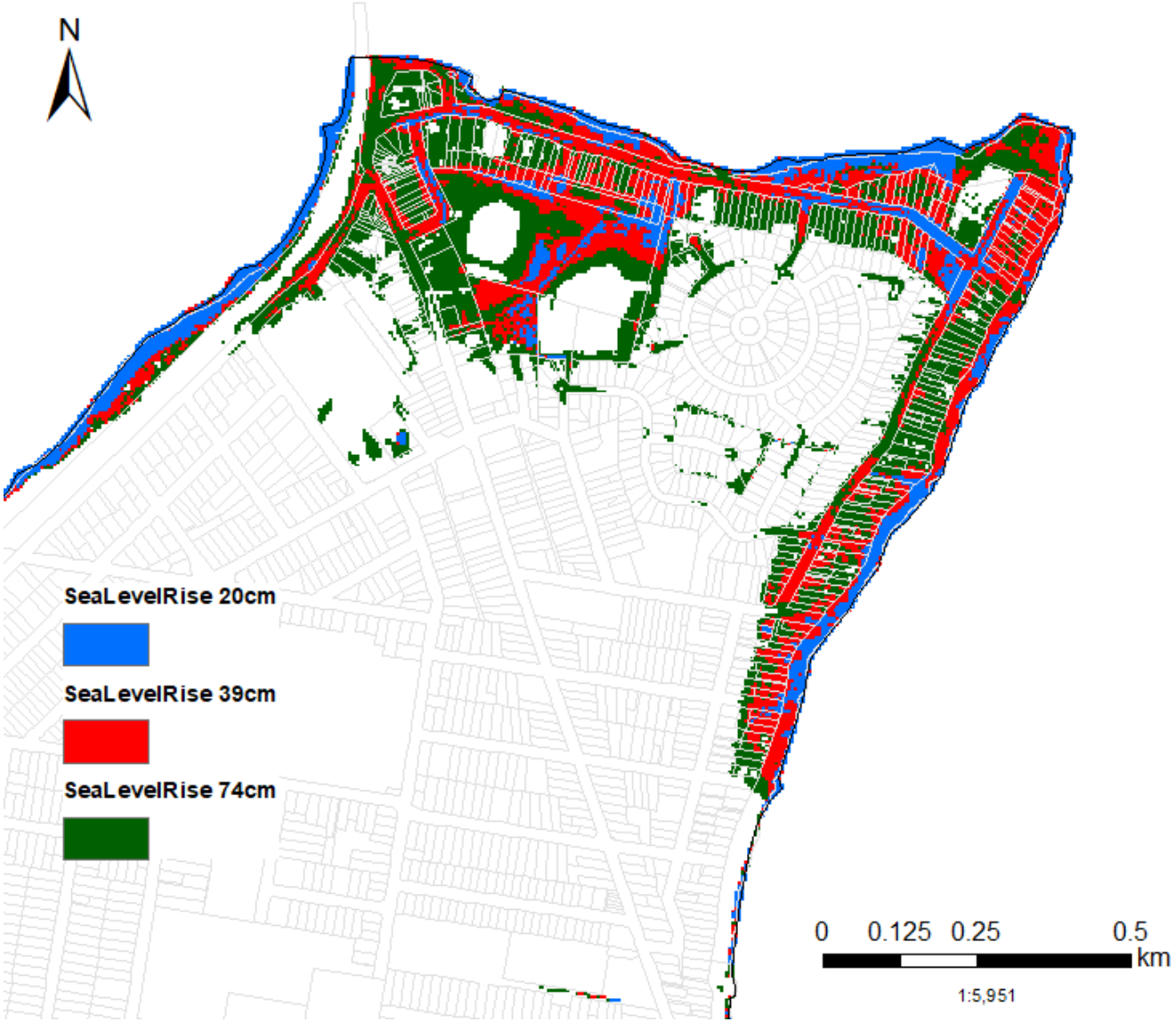


Figure 10.8 The affected areas by the sea level rise of 20cm, 39cm and 74cm in the Woy Woy CBD (No freeboard)

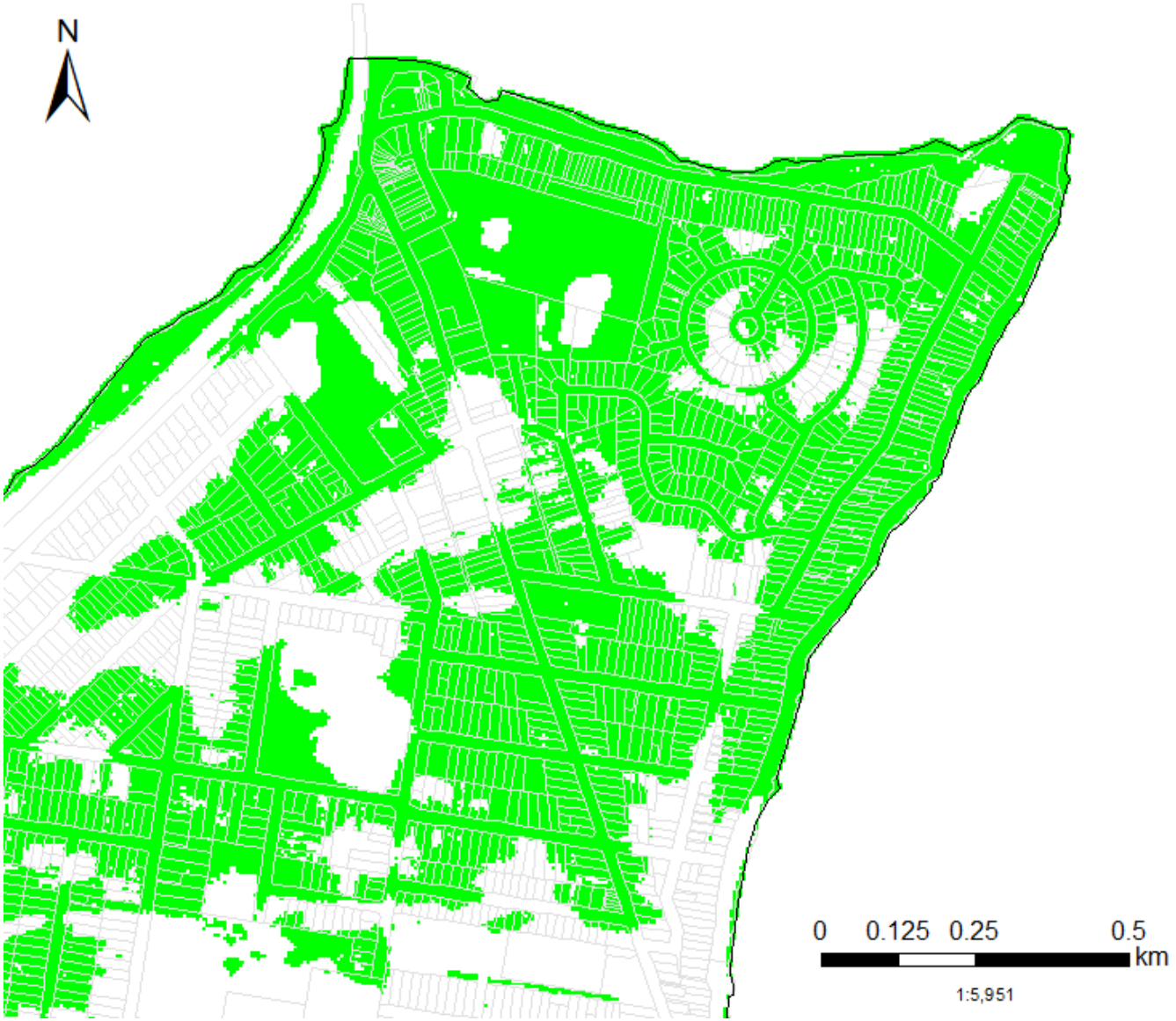


Figure 10.9 Flood extent of 1%AEP design level plus 500mm freeboard in the Woy Woy CBD

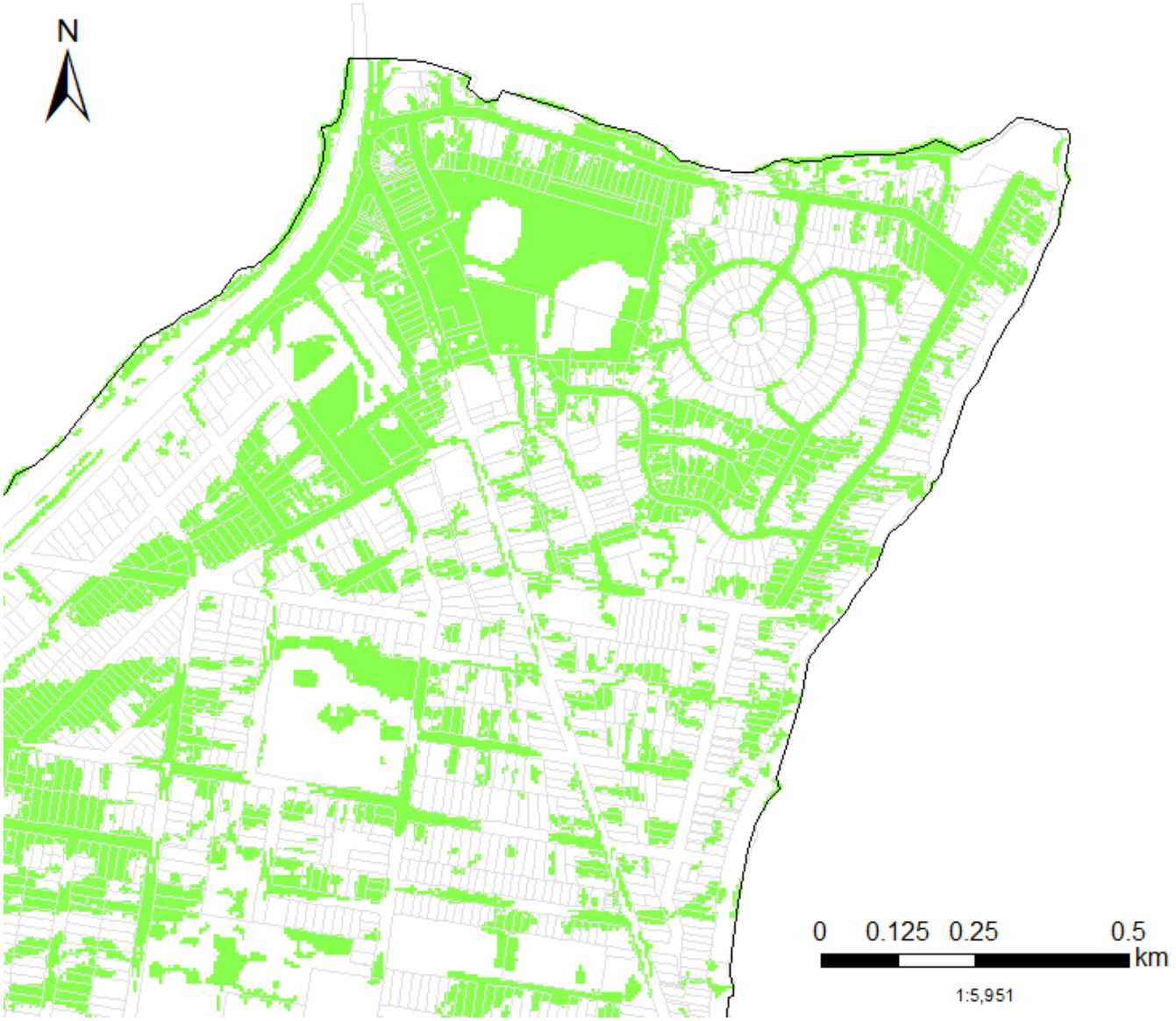


Figure 10.10 Flood extent of PMF in the Woy Woy CBD

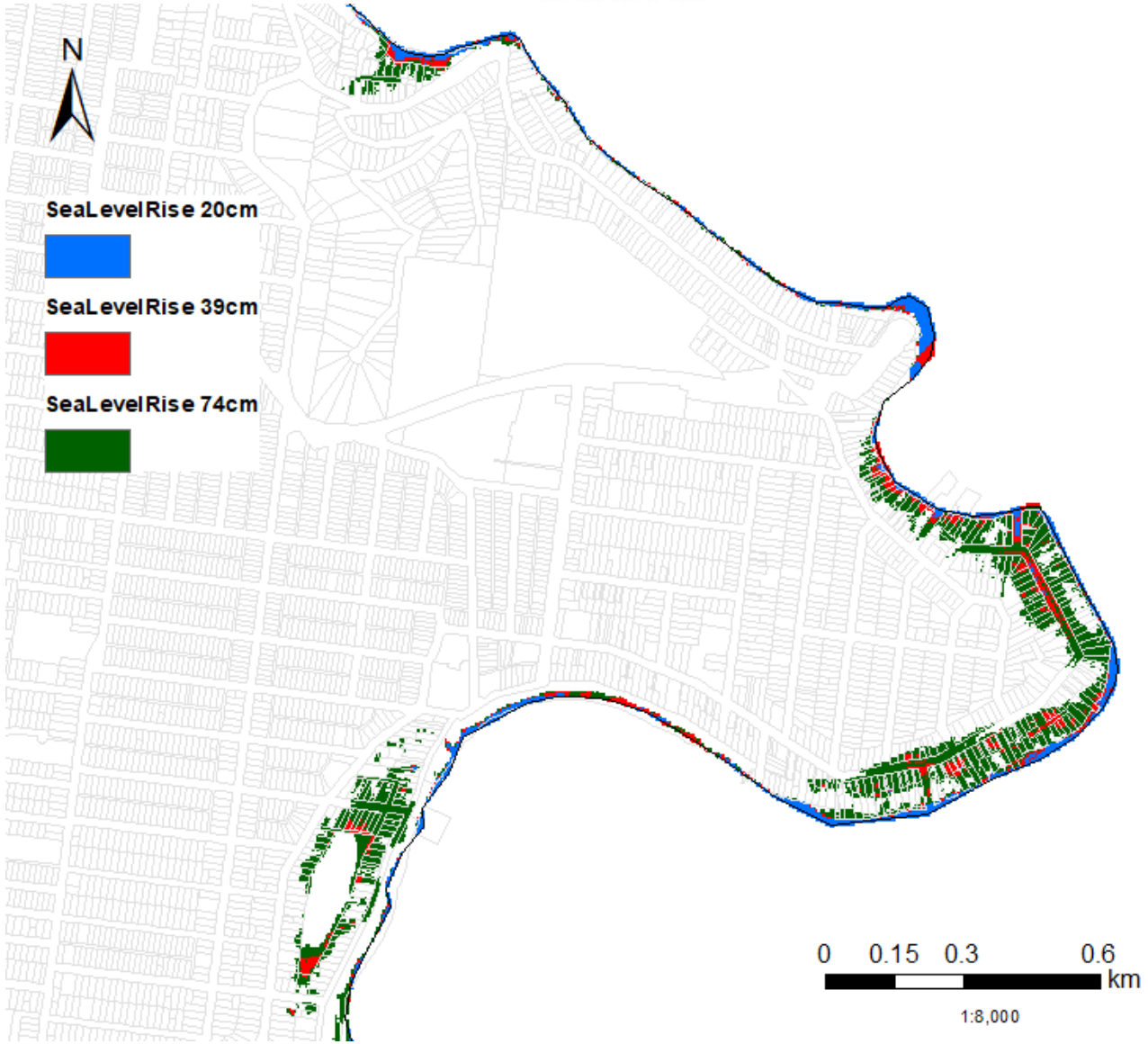


Figure 10.11 The affected areas by the sea level rise of 20cm, 39cm and 74cm in Booker Bay (No freeboard)

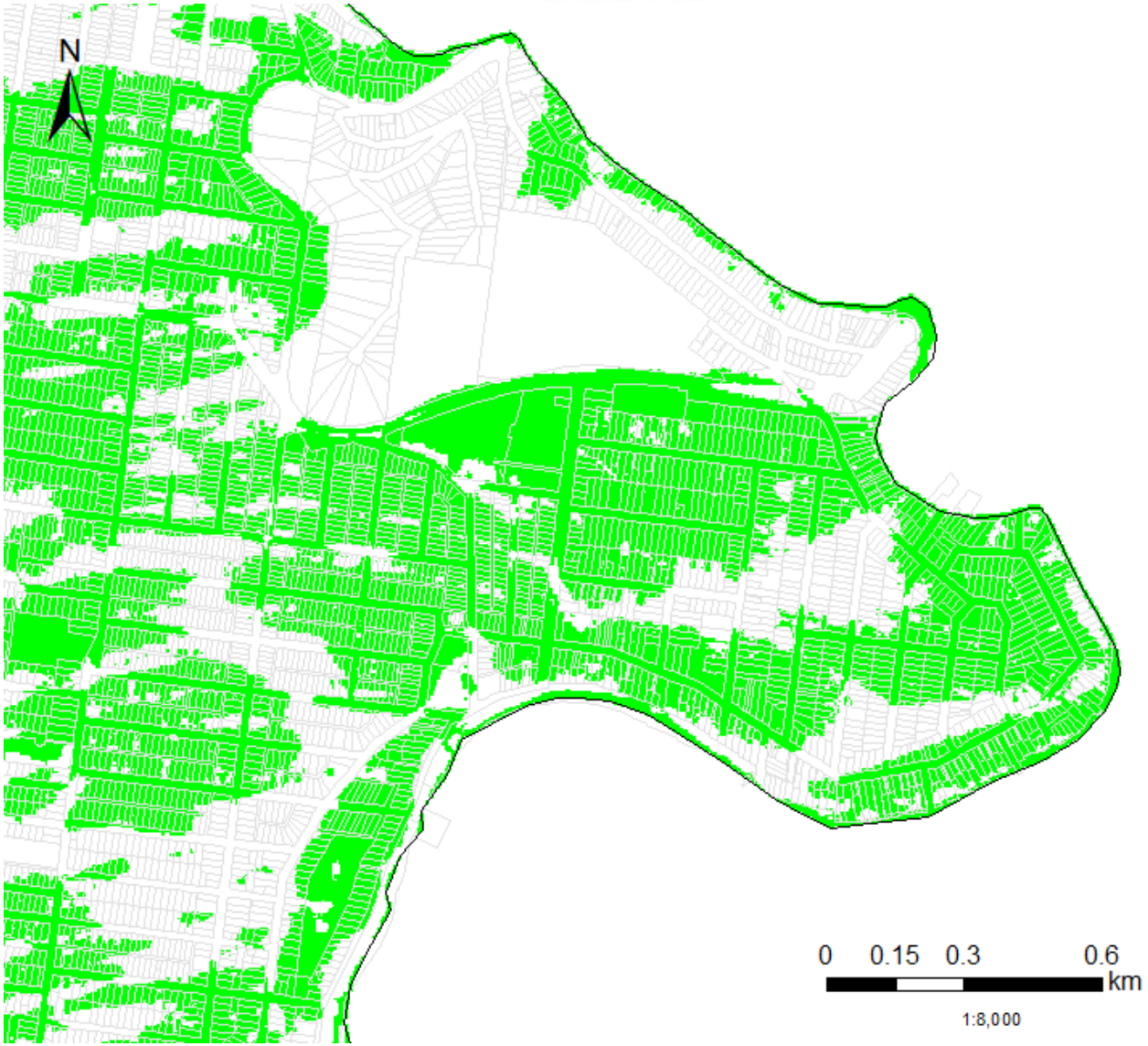


Figure 10.12 Flood extent of 1%AEP design level plus 500mm freeboard in Booker Bay

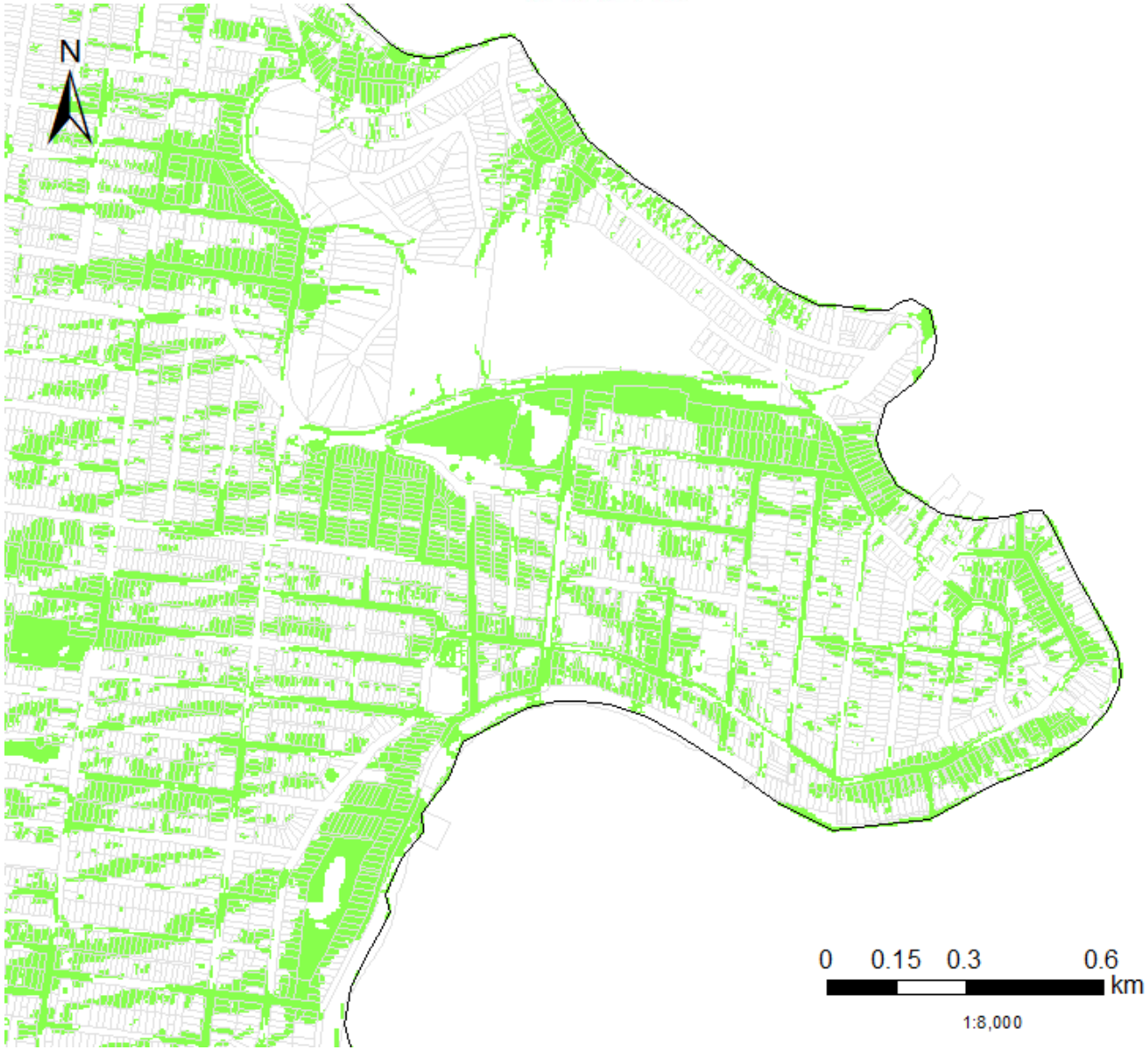


Figure 10.13 Flood extent of PMF in Booker Bay

10.2.3 Flood Planning Levels

Figure 10.14 shows the difference of the PMF and the 1%AEP design levels. In the majority of the catchment, the PMF is up to 500mm higher than the 1% AEP level, whereas the difference is significantly higher than 500mm at the bottom of the escarpment and along the Kahibah Creek catchment which aligns with the discussion in 10.2.2. Adopting the PMF level as the flood planning level may overestimate the risk at these locations.

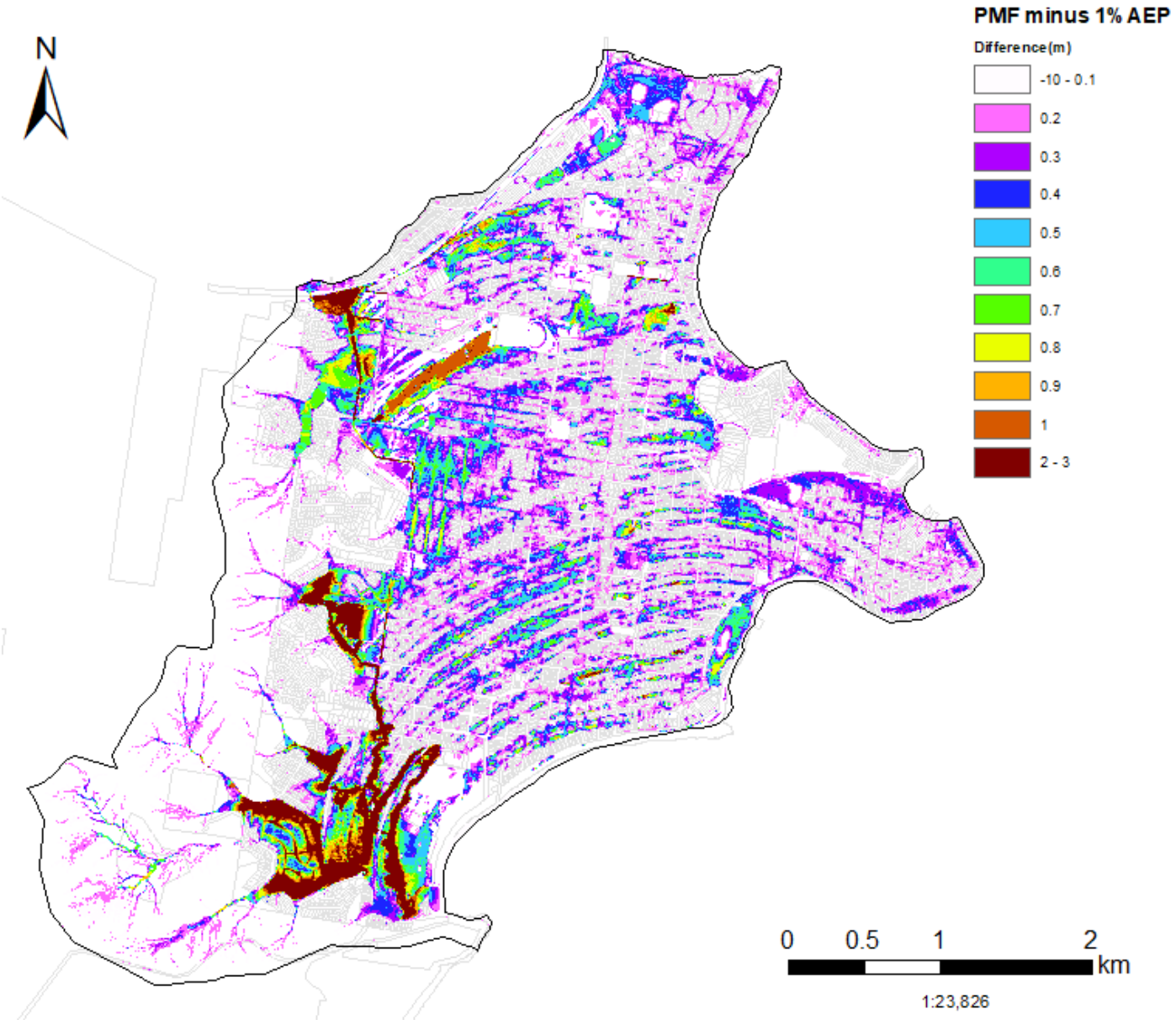


Figure 10.14 Difference between the PMF design level and the 1%AEP design levels

The recommendation for flood planning level is the 1%AEP plus 0.5m freeboard and sea level rise of 0.74m across the study area.

The Brisbane Water Foreshore Floodplain Risk Management Plan (Cardno, 2015) also provides recommendations for flood planning areas and levels overlapping this study. In instances where these recommendations are inconsistent with this study, the recommended level from the Brisbane Water Foreshore Floodplain Risk Management Plan (Cardno, 2015) (1% AEP Design Still Water Level, plus allowance for sea level rise (varies based on type of development), plus 500mm freeboard) should apply.

10.3 Advice on land-use planning considering flooding

A key objective of this study is to provide basic flood information to support land use planning activities. Refer to **Section 6** for a review of Council's current flood planning measures with respect to land use and flooding.

It is acknowledged that flooding within the study area is a combination of mainstream and overland flow flooding, as well as foreshore flooding from Brisbane Water. However, the proposed approach to defining the FPA and FPLs seeks to address the varied flood behaviour.

The existing flood planning approaches are generally considered appropriate for managing the impacts of flooding on and as a result from proposed development in floodplains. However, a range of minor recommendations for updates to Council's flood planning system are provided in **Section 13.2.1** (Option PM01).

10.4 Assessment of cumulative impacts of development

Cumulative impact assessment informs understanding on the broad effects of changing development patterns on flood behaviour. The assessment helps defining flood functions of the floodplain and considers full development within the existing development zonings.

The cumulative impacts on development were assessed by modelling three flood events (5%, 1%, PMF) with 1) the addition of full permissible development in areas outlined by Council, and 2) limitations in the development to maintain flood function.

Figure 10.15 shows the land zoning in Local Environmental Plans (LEPs) available from NSW Planning Portal . It was confirmed by Council that all zones including "Deferred Matter" except national parks will be permissible development areas.

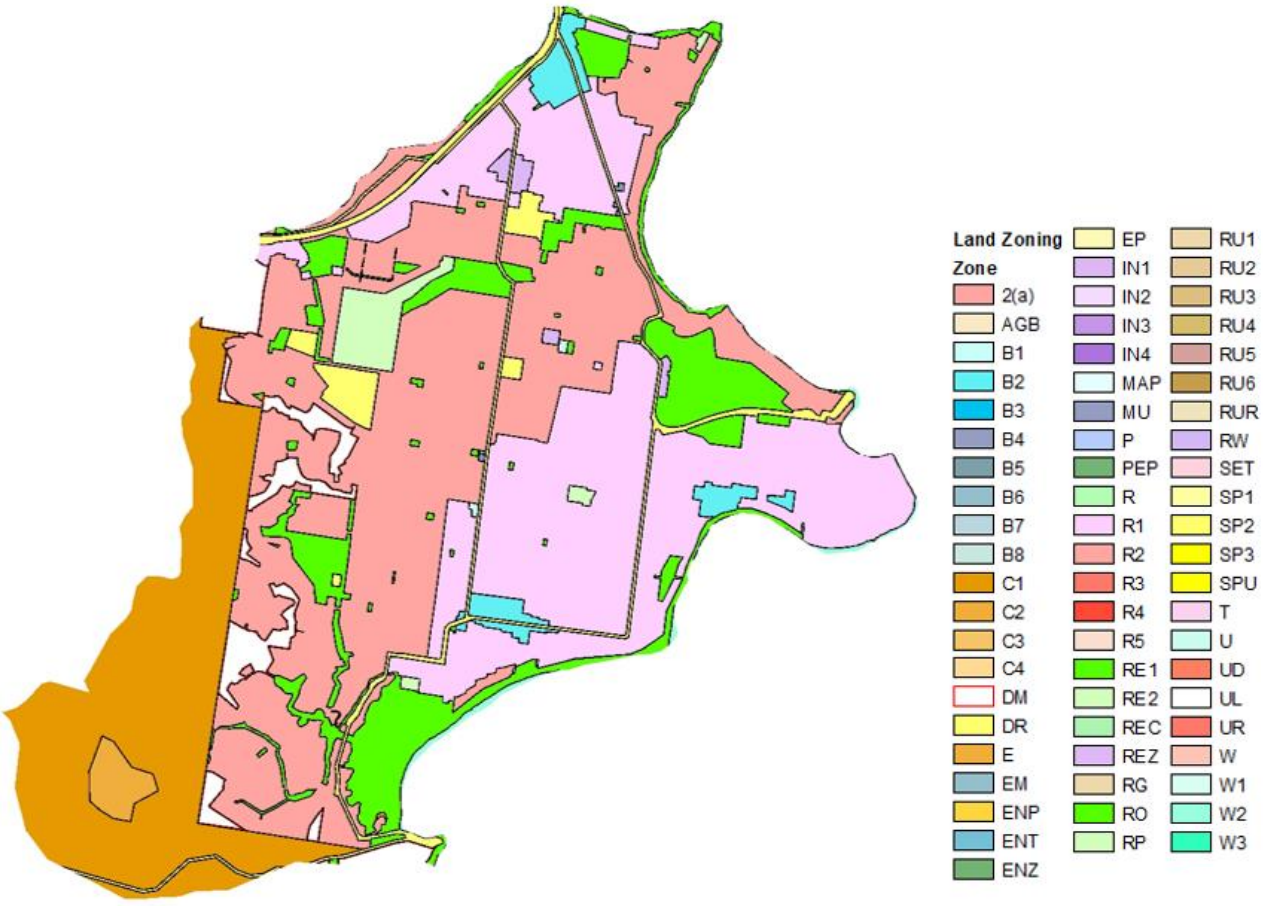


Figure 10.15 Land Zones in Woy Woy peninsula (NSW Planning Portal)

10.4.1 Site filling

Currently a large number of properties in the peninsula are affected by flood related development controls as they are within the Flood Planning Area. However, many of them are located in the low-lying area of the peninsula in an isolated flooding area, where a development on a particular property may not affect the overall flood patterns. After discussion with Council, it was decided to assess the impact of the site filling of the properties located in an isolated flood extent.

The lots located in a flooded area whose extent is less than 1500 m^2 during the 1% AEP event were selected, their topography raised by 0.2m and the ground coverage in the entire lot modified to "paved".

The model was run for the critical duration of the PMF, 1% AEP and 5% AEP events. **Appendix K** shows the difference from the Baseline. While during the PMF the flood depth increased by more than 0.1m in a relatively large area, changes in flood depths are limited to local areas during the 1% AEP and 5% AEP events.

This assessment assumes that sites fill within the current bounds of Council development controls. It does not take into account the potential drainage easement establishments and fill levels defined in the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021). In this study, the lower-lying portions of the study area, which are affected by tidal and ocean flooding taking into account sea level rise up to the year 2100, undergo landform raising to significantly reduce flood risk.

11 Climate Change Planning

Previous studies of Brisbane Water (*Brisbane Water Foreshore Flood Study* (Cardno Lawson Treloar, 2013) and the *Floodplain Risk Management Study and Plan* (Cardno, 2015)) have shown that the low-lying portions of the Woy Woy Peninsula will face difficulty with maintaining normal urban residential area functions under climate change projections for sea level rise.

The suburbs of Woy Woy, Blackwall, Booker Bay and Ettalong are low lying and susceptible to the effects of climate change and the existing threat from flooding in and around Brisbane Water Estuary. **Figure 11.1** illustrates the study locations within the peninsula.

Raising existing ground levels and associated infrastructure was identified in Cardno, 2015 as a potential solution provided there are no long-term detrimental effects as a result of maladaptation. Raising land on a large-scale regional basis is not practical given the multiple landholders and existing development. However, by developing a regional adaptation concept masterplan, incremental filling could be achieved, albeit over the longer term on individual or multiple sites through development and urban renewal.

The *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021) was undertaken to inform the processes to realise a final adaptation landform. The study defined the conceptual landform designs and drainage masterplan, as well as outlining possible adaptation pathways and significant issues likely to arise during the process of landform raising.

11.1 Adaptation Study Objectives

The primary aim of the adaptation study was to undertake a case study that will assist planning for future development in the Woy Woy peninsula and other low lying areas in and around the Brisbane Water Foreshore to adapt to future changes such as climate risks.

The climate change adaptation study focuses on the technical analysis of potential landforms and associated measures to provide flood protection against existing and future flood risk to the year 2100, associated with both catchment and ocean flooding (both tidal and storm induced).

The key objectives of the adaptation study were to:

- Develop a concept landform and drainage study for four areas of inundation located along the foreshore of Woy Woy Peninsula identified in the Brisbane Water Foreshore Floodplain Risk Management Plan (Cardno, 2015) as vulnerable areas that require adaptation plans to address existing and future tidal and storm surge events.
- Develop adaptation pathways that would assist the implementation of a future landform and drainage master plan that would address priority adaptation Subset Actions identified in the Coastal Councils Climate Change Adaptation Plan (2010) commissioned by Hunter and Central Coast Regional Environmental Strategy (HCCREMS). Specifically, actions A4, A5, B6 and B8 shown in *Table ES1 Infrastructure and Assets* (HCCREMS, 2010).
- Undertake the project in line with the NSW Government's initiatives for adapting to climate change and best practice adaptation planning and implementation.

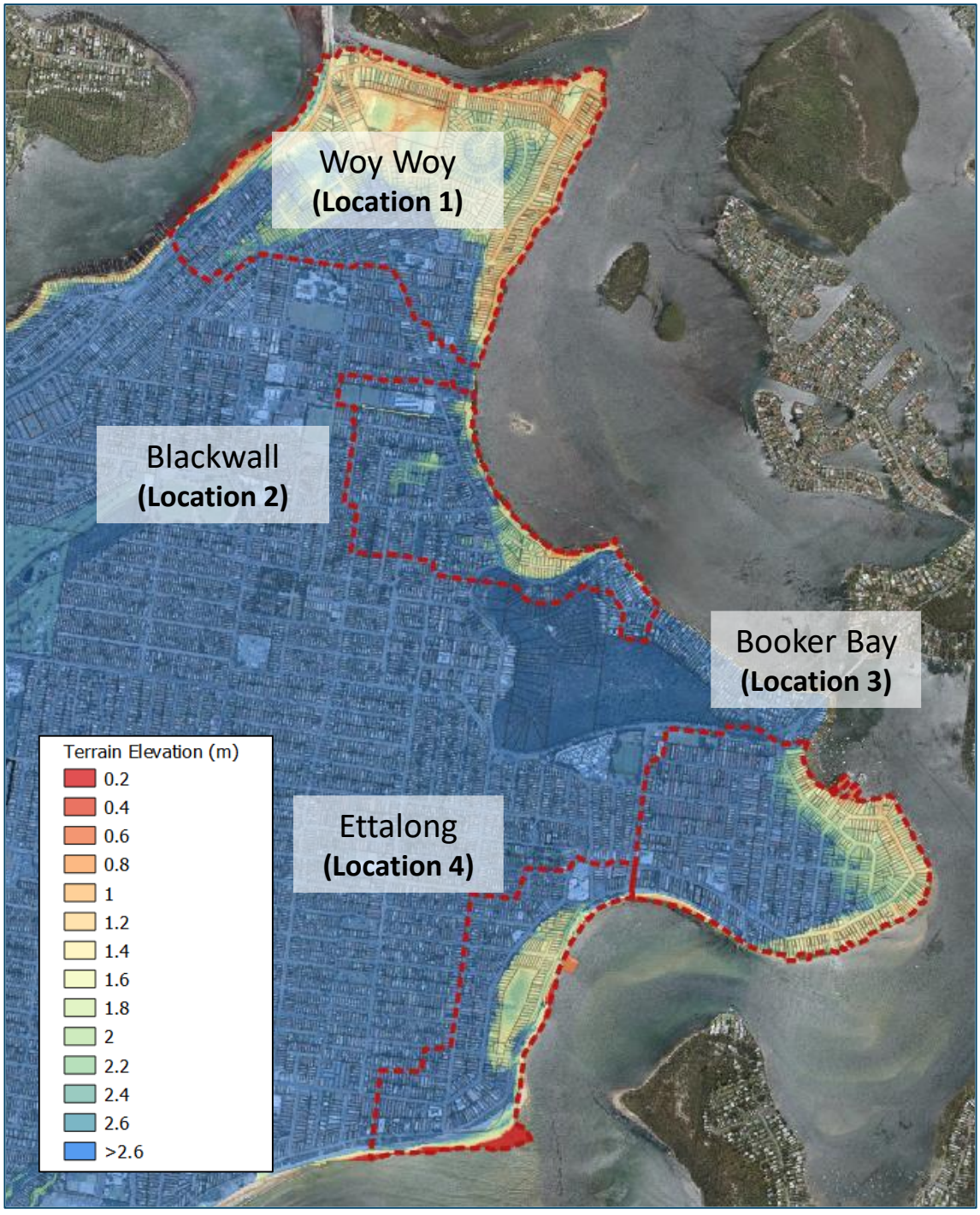


Figure 11.1 Study Area Overview

11.2 Adaptation Decision Making Approach

Adapting to climate change and rising sea levels is a complex problem, with no single technical solution, and involving multiple interests and stakeholders. A Decision Support Framework and Guide (The Handbook) has been developed to assist the HCCREMS coastal councils more effectively approach and determine adaptation responses and pathways for vulnerable coastal areas. The Handbook discusses 10 main stages in the decision-making process. Although the process is presented as a series of numbered stages, it is recognised that, decision-making will often jump backwards and forwards between stages. The stages are summarised in **Figure 11.2**.

The stages focused on in the adaptation study were:

- **Stage 4 Assess hazards and risks:** this was done in previous studies and forms the basis on the adaptation plan.
- **Stage 5 Identify options and pathways:** various options were developed and discussed with stakeholders to identify a preferred approach.
- **Stage 6 Establish Triggers:** As part of the strategic planning to be included in the adaptation plan, a series of triggers were identified to assist future decision making and implementation

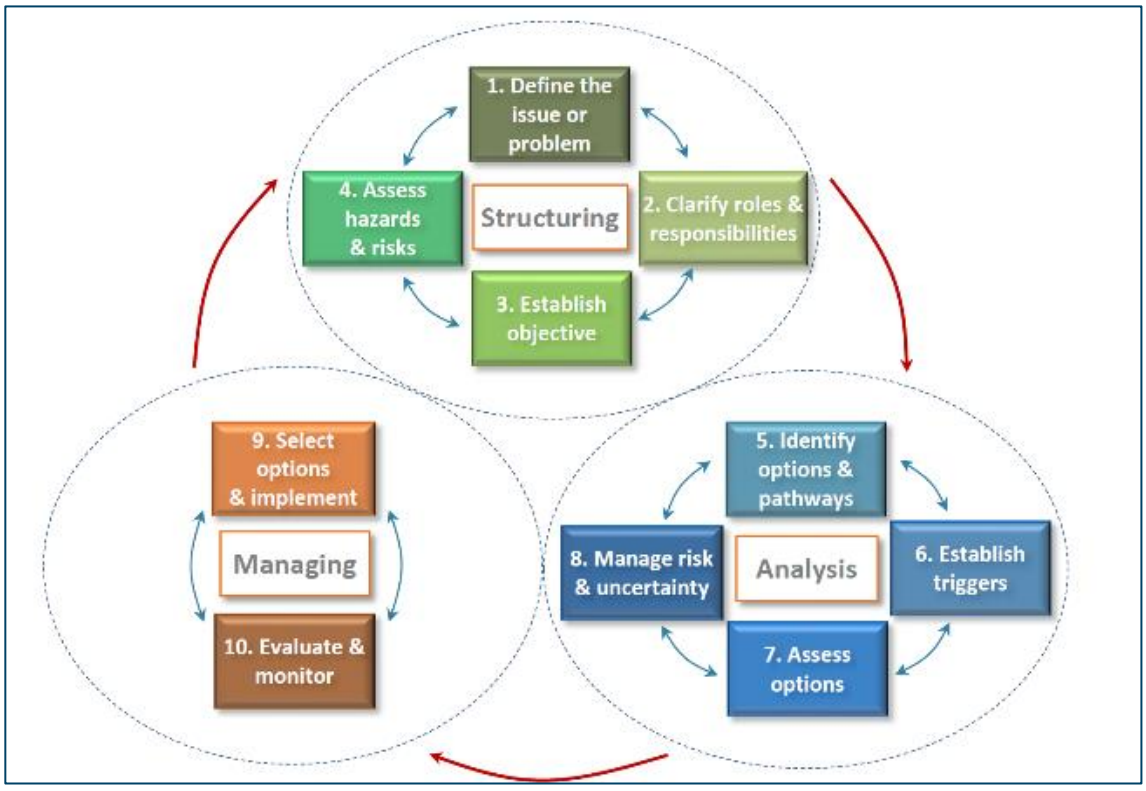


Figure 11.2 Stages in the adaptation decision making process (HCCREMS, 2012)

11.3 Study Approach

The following approach was adopted for the adaptation study:

- Site inspections of the study areas by the project team on 30 January 2020.
- Compilation and review of all previous reports, studies, and available data.
- Definition of the existing flood risk from tides, ocean storms and local catchment runoff.

- Application of guidance from Council's Climate Change Policy (2019) to determine future flood risk from sea level rise up to 2100.
- Provision of a conceptual design for landform adaptation and drainage masterplanning to reduce future flood risk within the study area due to rising sea levels.
- Identification of potential issues associated with incremental lots raising to achieve the final adaptation landform.
- Definition of adaptation pathways based on thresholds for maintaining liveability within the study locations and trigger points for those thresholds associated with sea level rise projections.
- Provision of guidance on adaptive planning measures for Council.

11.4 Existing Flood Risk

The low lying areas of the Woy Woy Peninsula can be impacted by flood risk from Brisbane Water flooding as a result of ocean storms, local catchment flooding as a result of local rainfall and tidal inundation during high tides. All of these flood risks would increase as a result of sea level rise. Sea level rise for the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021) was based on the RCP8.5 projections, consistent with the Brisbane Water Foreshore Floodplain Risk Management Plan (Cardno, 2015). Note that the sea level rise projections were updated following the completion of the *Brisbane Water Foreshore Floodplain Risk Management Plan* (Cardno, 2015), and this Woy Woy FRMS utilises these updated levels were appropriate.

Table 11.1 outlines the sea level rise projections as they apply to a range of ocean storm events and tidal events. Ettalong, with its closer proximity to the ocean, is subject to the highest end of the range and Woy Woy being furthest inland has the lower limit applied. **Figure 11.3** and **Figure 11.4** show the extent of flooding during the 1% AEP ocean storm event and representative tidal event.

Table 11.1 Brisbane Water Estuary Level for Representative Tidal and Ocean Events

Year	Sea Level Rise (m)	Tidal 1% PoE[1] (mAHD)	Ocean Storm 1% AEP[2] (mAHD)
2015	0	0.68 – 0.93	1.58 – 1.78
2030	0.1	0.78 – 1.03	1.68 – 1.88
2050	0.2	0.88 – 1.03	1.78 – 1.98
2070	0.4	1.08 – 1.33	1.98 – 2.18
2100	0.7	1.38 – 1.63	2.28 – 2.48

1 Probability of Exceedance. The 1% PoE is defined as the level which is exceeded, on a time basis, for 1% of time recorded in the estuary water level gauge.

2 Annual Exceedance Probability. The 1% AEP is defined at the estuary level produced by an ocean storm surge event which has a 1% chance of occurring at least once in the next 12 months.

Investigation into the existing flood risk for the low-lying areas of the Woy Woy Peninsula and the flood levels with respect to the existing ground level provided a reasonable technical objective for landform adaptation: protection of private and public land for existing ocean storms in the 1% AEP event and for the 1% PoE tidal events considering sea level rise up to 2100.

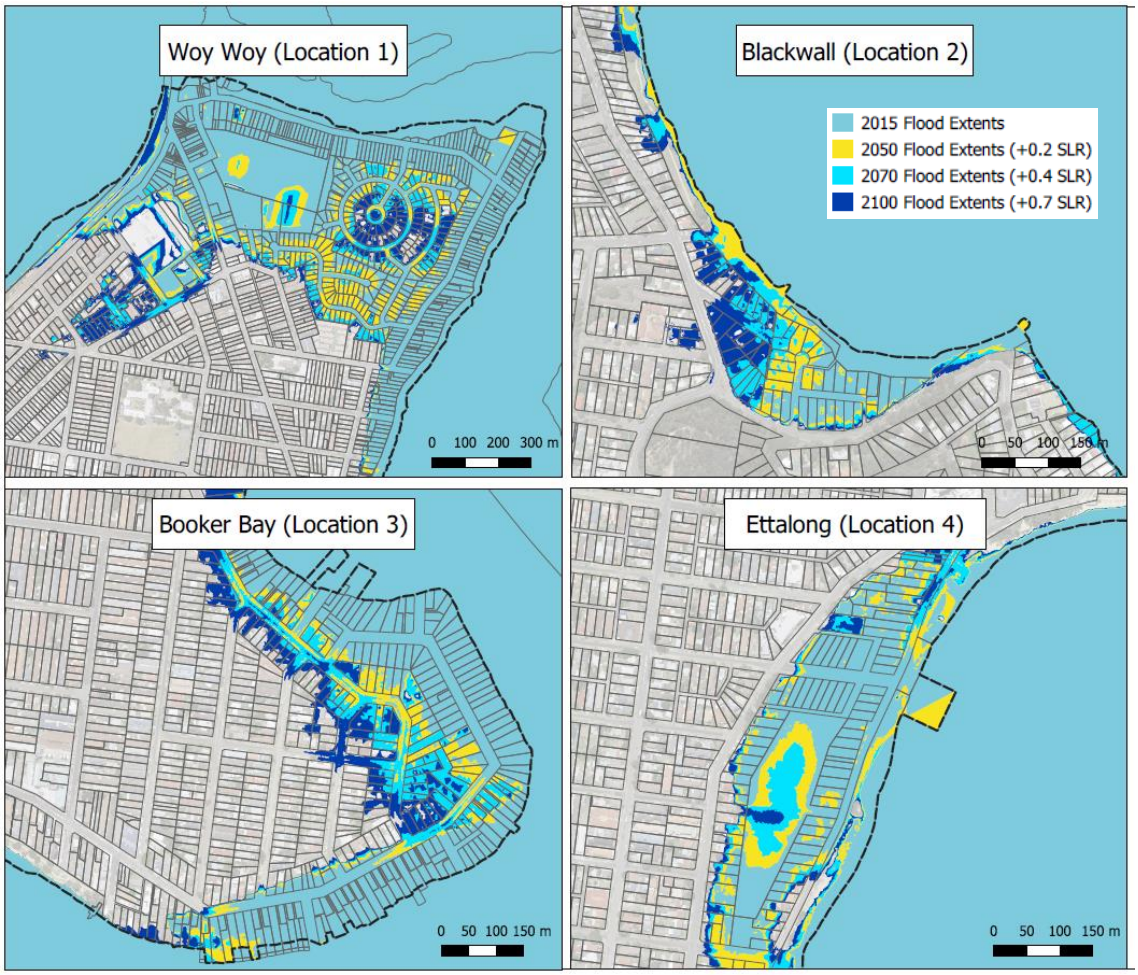


Figure 11.3 Sea Level Rise Impact on 1% AEP Ocean Storm Flood Extents

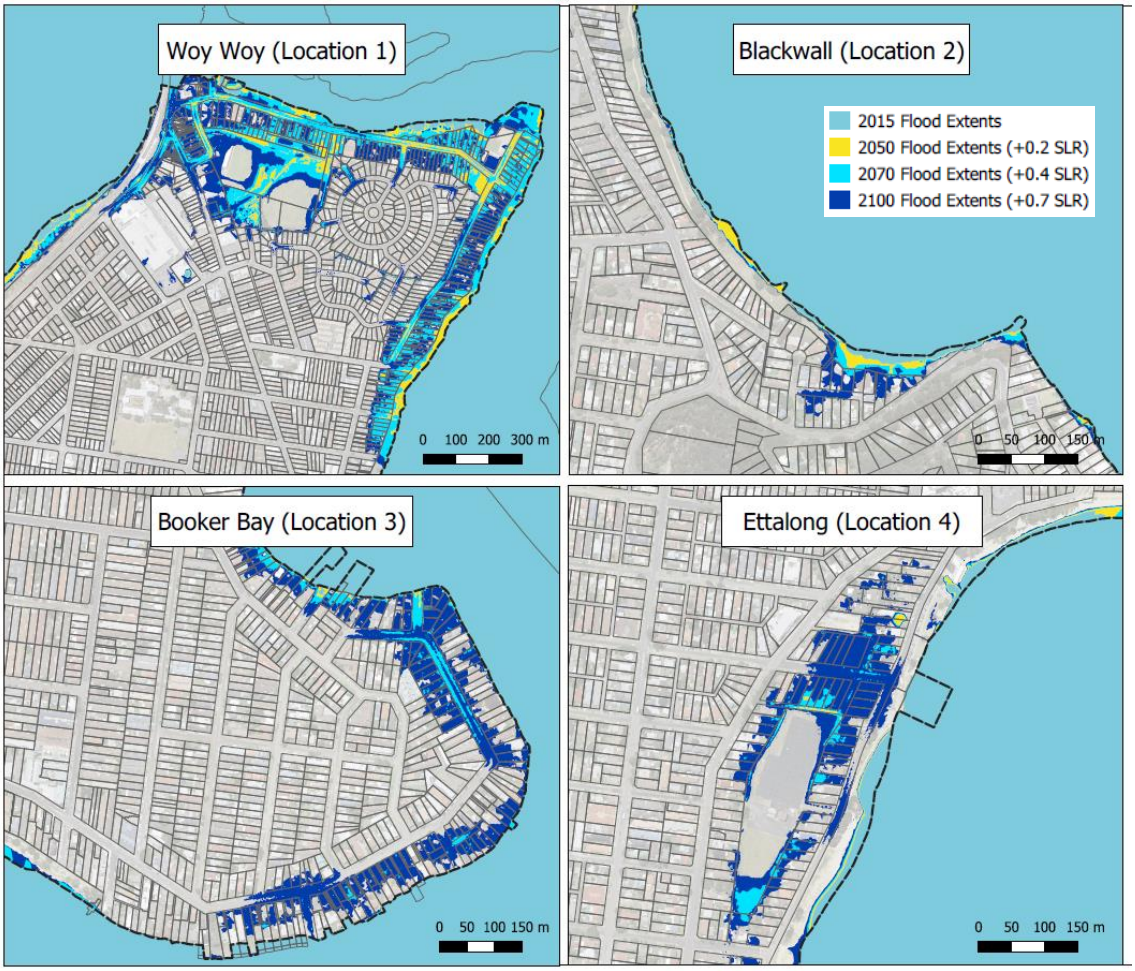


Figure 11.4 Sea Level Rise Impact on Tidal Extents

11.5 Landform Outcomes

The adaptation landform design was developed iteratively to achieve an outcome where:

- Flood risk for the 1% PoE tidal level (for sea level rise top 2100) and the 1% AEP ocean storm (existing conditions) are eliminated.
- Flood risk from local catchment runoff is significantly reduced.
- Fill levels for private properties are minimised, generally around 0.5 m, with a maximum of approximately 1.5 m in isolated instances.

To achieve these outcomes, the adaptation landforms made use of existing open spaces and laneways which could be converted into drainage paths, as well as the introduction of new drainage easements. This allows the stormwater drainage network to run a shorter distance (i.e. not all the way to the foreshore), requiring less rise from the outlet and less fill for the surrounding land. The easements and open space drainage paths will eventually become tidal due to sea level rise and could take on multiple forms, such as culverts, open channels, riparian areas, or combination of these.

Refer to the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021) for full details on the landform design. Further refinement of the landform and drainage masterplan will be required as

the strategy progresses to eliminate isolated instances where flood depths have increased on private property.

Figure 11.5 to **Figure 11.8** show the conceptual landform for each location in the study area.

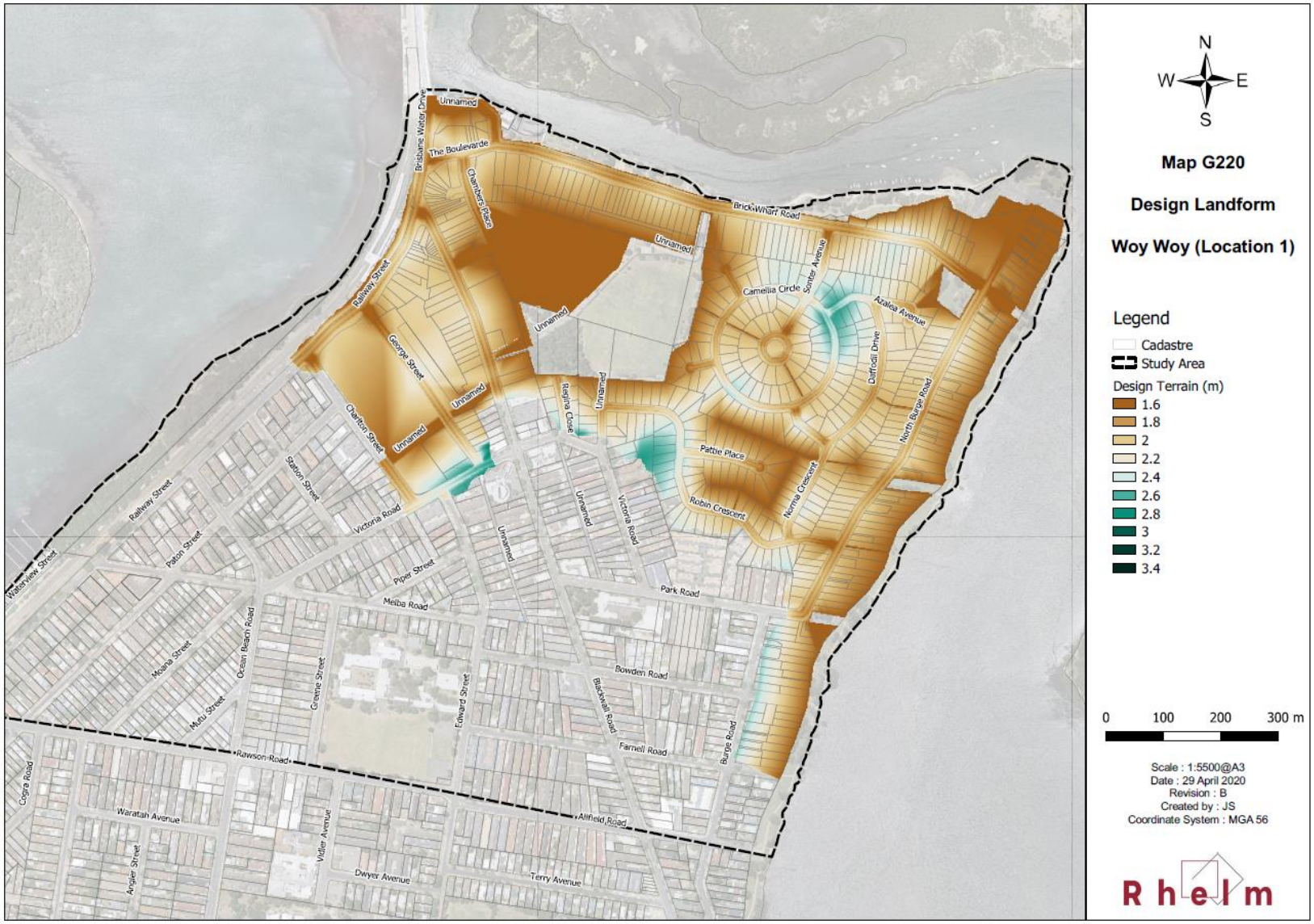


Figure 11.5 Design Landform – Woy Woy

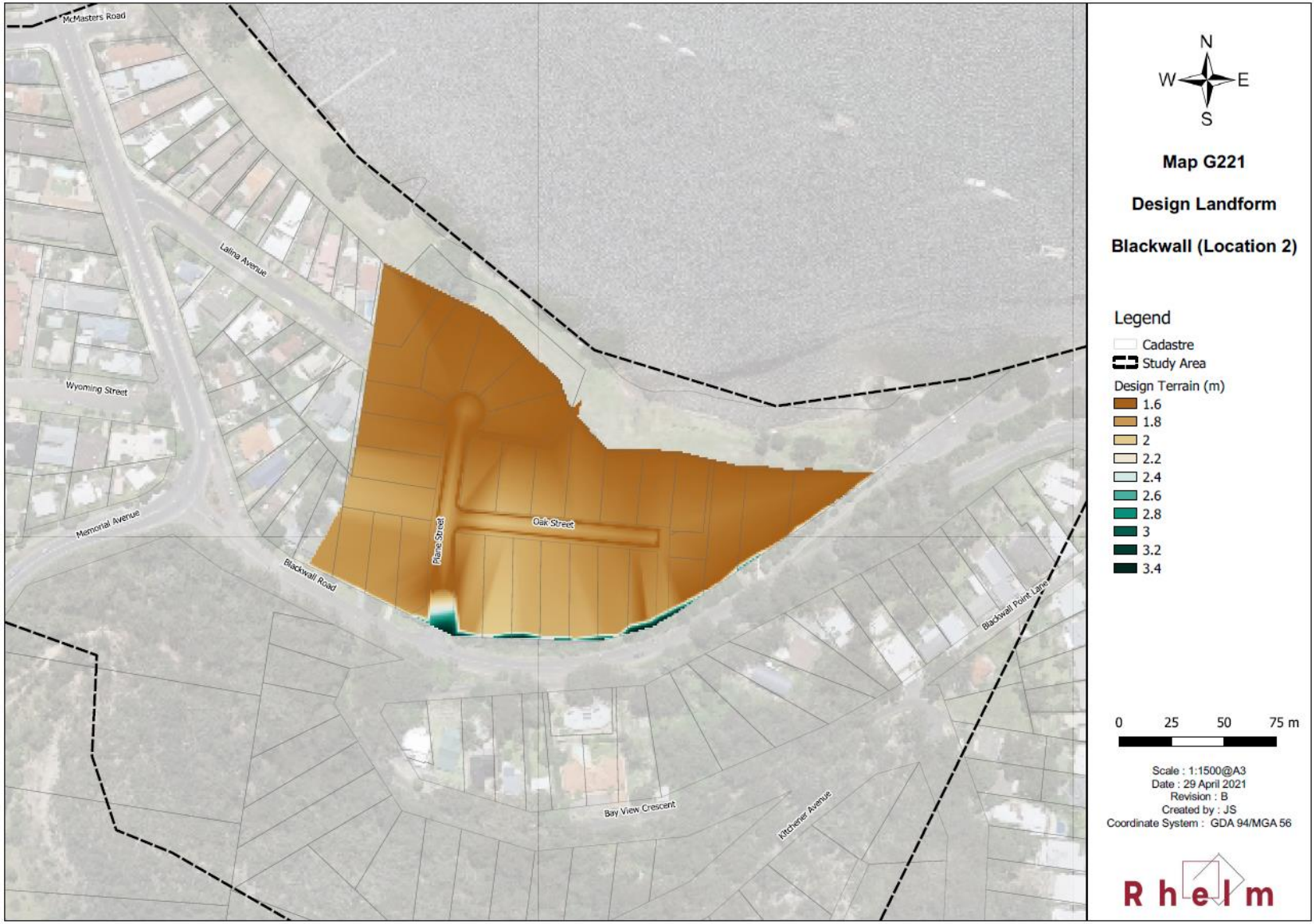


Figure 11.6 Design Landform – Blackwall

Figure 11.7 Design Landform – Booker Bay

Figure 11.8 Design Landform – Ettalong

11.6 Adaptation Pathways

Following development of the landforms and identification of issues associated with progressing the adaptation strategy from concept to realisation, a series of adaptation pathways were generated with the guidance outlined in the Decision Support for Coastal Adaptation: The Handbook (HCCREMS, 2012). The pathways include a conceptual breakdown of the options and actions associated with realising the proposed landforms over the next century.

Six adaptation pathways were produced for the project (refer to **Figure 11.9**). These are listed in order of most preferrable (Pathway A) to least (Pathway F). Pathway A requires relatively quick action to be taken this decade to avoid losing liveability of some properties in the Woy Woy study location. Pathway B represents the scenario where initial actions are delayed and an accelerated workplan is required; however, the risk of losing liveability is increased. The other pathways (Pathways C through F) involve planned retreat of some of the lowest-lying and at risk properties, which is the likely consequence of not taking action to implement the workplan for Pathway A or B. The workplan for Pathway A is summarised in **Table 11.2**.

Although Pathways E and F have the same outcome – retreat of all low lying areas – Pathway E represents the situation where inaction occurs at all sea level rise triggers and retreat strategies are hastily required for each individual area. Pathway F represents the outcome where the early decision to retreat from all areas is taken well in advance of triggers, allowing for an overarching retreat plan to be created and updated as each threshold is reached.

It should be emphasised that the retreat actions identified in the adaptation pathways only refers to the loss of liveability for the most vulnerable portions of the study areas, and not a signal for the entire area to begin retreating. But these demonstrate the likely consequences of not taking steps to plan for the necessary landform adjustments in Pathways A or B

The adaptation pathways assessed in the adaptation study only reflect the consequences to the year 2100. A revised climate change adaptation study would need to be completed prior to this end date to ensure the liveability, with respect to sea level rise, of the Woy Woy Peninsula into next century.

The recommendation of the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021) is to implement Adaptation Pathway A. Similar results are achieved in Pathway B, but with additional risk of loss of liveability from additional time constraints. This FRMS considers the implementation of Adaptation Pathway A as a property modification option to be evaluated (refer **Section 13.2**).

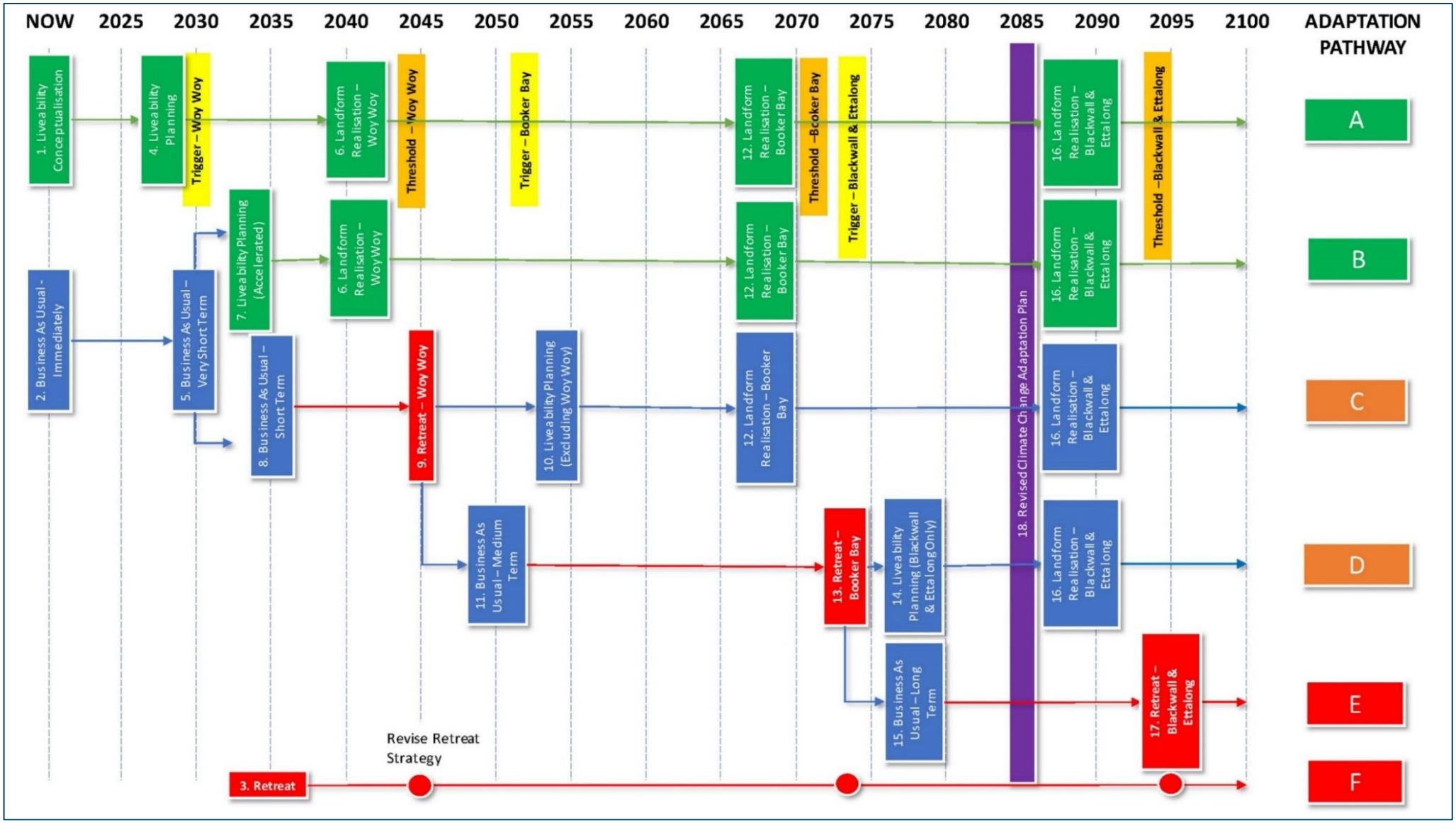


Figure 11.9 Preliminary Adaptation Pathways

Table 11.2 Workplan - Adaptation Pathway A

Begin Actions	Option	Actions
Now	Liveability Conceptualisation	• Complete Woy Woy Climate Change Adaptation Case Study • Report Recommendations and Include in Draft Woy Woy FRMSP • Exhibit and Adopt Woy Woy FRMSP • Develop Masterplan and Public Domain Plan • Adopt Sea Level Rise Policy • Adopt Floodplain Risk Management Policy • LEP & DCP Review • Develop Drainage Master Plan - Constructability • Disseminate in Public Domain Results of this Study • Collaborate with Other Coastal Councils to Create a Working Group
2030	Liveability Planning	• Adopt Climate Change Adaptation Plan • Revised Adaptation Pathways • Community Engagement - Triggers and Threshold • Community Education - Adaptation Plan Process • Prepare Climate Adaptation Plan - Place Based • Adopt Masterplan and Public Domain Plan • LEP & DCP Revised to Include Climate Actions • Private Seawalls and Levees Guidelines • Establish Easements • Monitor Sea Level Rise
2040	Landform Realisation - Woy Woy	• Community Education - Filling Process • Property Filling Guidelines • Temporary Private Levees/Seawalls • Raise Landform - Private Land • Raise Landform - Public Land • Raise Landform - Roads • Monitor Sea Level Rise
2070	Landform Realisation – Booker Bay	• Community Education - Filling Process • Property Filling Guidelines • Temporary Private Levees/Seawalls • Raise Landform - Private Land • Raise Landform - Public Land • Raise Landform – Roads • Monitor Sea Level Rise
2085		• Undertake Revised Climate Change Adaptation Study

Begin Actions	Option	Actions
2090	Landform Realisation – Blackwall and Ettalong	• Community Education - Filling Process • Property Filling Guidelines • Temporary Private Levees/Seawalls • Raise Landform - Private Land • Raise Landform - Public Land • Raise Landform – Roads • Monitor Sea Level Rise

11.7 Economic Analysis

An economic assessment was undertaken by comparing the costs and benefits of two scenarios: the Base Case (or do minimum) and the concept masterplan scenarios. It is important that these scenarios or alternatives were clearly defined to ensure a robust analysis.

A benefit-cost ratio (BCR) was determined by comparing the concept masterplan scenarios against the base case, for each study location. A BCR greater than 1 result in an economic outcome that exceeds the cost of implementing the works, a BCR between zero and one produces less economic benefits than the cost of implementing the works but still has an economic benefit, and a BCR less than zero has a negative economic outcome. For Woy Woy, the concept masterplan had a BCR of 0.8. For Blackwall, Ettalong and Booker Bay, the estimated BCR was 0.4, 0.7 and 0.2, respectively. However, the incorporation of unquantified benefits may change this outcome (e.g. recreational value, environmental value, public infrastructure).

The higher BCR for Woy Woy reflected the fact that this area is subject to tidal and ocean storm inundation in the relatively immediate future.

The economic analysis for all locations assumed that works would start immediately. The lower short term risk at Blackwall, Ettalong and Booker Bay, would suggest that initiating landform works could commence at a later date (as per the adaptation pathways presented). The delay in works, and therefore delay in expenditure, would likely improve the outcome of the economic analysis for these locations.

12 Integrated Water Management

The Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021) assessed a range of integrated water management options that have been considered for their suitability to also manage flood risk in the Case Study Everglades catchment.

DHI (2021) found that a typical flood mechanism for the Case Study Everglades catchment was as follows:

- Surface water runoff flows along streets and the remaining patterns of the sand dunes to local depressions.
- Low permeability of the ground surface was introduced by residential developments such as pavement and compacting of surface soil. This results in much higher runoff.
- Water that flowed into the local depression is trapped due to lack of a stormwater drainage or low permeability.
- The Everglades catchment lies above the groundwater mound and after a sequence of small events or a large event, the groundwater level reaches the ground surface of low-lying spots which causes prolonged nuisance flooding.

Table 12.1 summarises the potential management options. Some of these management options were further assessed for nuisance flooding at the Everglades catchment in the Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021) and brief outcomes are also summarised in the table. It should be noted that the Everglades catchment has its own flood characteristics, and the effectiveness of options is not always appliable to other parts of the peninsula or to a larger flood event.

Table 12.1 Potential Management Options from the Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021)

Management Option	Description	Assessment for nuisance flooding in the Everglades Catchment (DHI, 2021)
Construct new stormwater systems in areas experiencing nuisance drainage problems	This is a traditional measure to cope with flooding. Installing stormwater systems proposed in the previous drainage studies was too costly. Soakaway pits in some areas where runoff pools in impermeable areas is another option. Or larger infiltration devices in areas where groundwater levels are significantly lower than the surface level.	Installation of the new stormwater inlets and drainage pipes at MacKenzie Ave improved local flooding on the street.
Increase the existing stormwater system capacities	This option considers increasing the capacity of the piped system downstream of areas which are connected to the system but still suffer from significant ponding in larger events and/or nuisance ponding in frequent events. It should be carefully evaluated if ponding is due to the capacity limit at the downstream pipe system or not.	As above, the installation of a parallel drainage pipe to the existing one at MacKenzie improved local flooding on the street.

Redirect Surface Flow to follow the groundwater gradient	Due to residential developments on the Woy Woy peninsula, the surface water flow direction in some areas has been altered from its natural flow direction. This is particularly apparent in the drainage catchment flowing into Main Drain which now runs to the north, rather than making its way across the Everglades to the east. This option is to connect stormwater runoff to drains following the natural flow paths by also taking the groundwater flow gradient, which is substantial, into account. There may also be opportunity to introduce new overland flow paths or channels that flow following the groundwater gradient. This could possibly need to be in concert with possible future up-zoning and redevelopment of existing properties, as new green zones and easements would need to be established.	A small improvement was seen in flood depth. However, a careful consideration should be given to feasibility of the option as the invert levels of the actual stormwater network was unknown.
Utilise potential storages in existing parks and drainage asset free roads	This option proposes to introduce underground detention storage in existing parks or drainage asset free roads. The idea is to add underground storage by installing a detention storage with infiltration capacity or other types of storage cells underneath roads and traffic intersections, which can be then connected to the existing stormwater system. It is furthermore proposed to add swales to road reserves by making the road pavements narrower. This will increase the infiltration areas along the roads as well as add further drainage capacity and will retain water prior to draining into the low point. This option could be effective typically on low points on streets where water gets trapped. The current study does not look at the following points which are required for further consideration of the feasibility of the option: • Water quality issues, e.g. contaminated groundwater • Duration of construction • Allocation of utilities • Minimum road width and impact on speed limit • Reduction of parking areas • Local groundwater levels impact practicability • Any additional maintenance required to avoid reduction in infiltration capacity over time from siltation.	A detention storage at Connex Park was considered. A small reductions in flood depths were simulated in the surrounding area. Inclusion of swales within road reserves alleviated flooding across the site.

Increase storage capacities at existing allotments	Typical dwellings have very little pervious areas due to granny flats/ houses and concrete pavements. Currently all rainfall falling on impervious areas are converted to surface runoff to local depressions. This option includes the installation of infiltration pads/pits, on-site tanks or slotted pipes at the allotments, hence creating additional storage capacities. By capturing and storing rainfall at each allotment, flush runoff from the residential areas can potentially be reduced and delayed. Consequently, this can add spare capacities to the existing drainage system and impose less stress of water quality at downstream drainage sections. Furthermore, this potentially helps reduce water supplies. Precaution must be paid not to undermine footings of buildings and to keep the storage above the groundwater table.	Minor reductions in flooding impacts were observed in several locations. This was particularly evident during longer duration events and secondary peak water levels, when allotment scale runoff may dominate flood contributions. The mitigation of peak flood levels was limited. While this option was not considered effective in reducing flood risk it could potentially be useful when considering demonstration of a 'satisfactory solution' in the context of Development in areas identified as Drainage "Black Spots."
Reduce groundwater table prior to a rain event (pumping)	This option is to pump groundwater prior to a heavy rainfall event to lower the groundwater table and increase spare infiltration capacity. There are 12 production bores available for water supply purpose. In addition, 6 test bores for monitoring purpose and 7 production bores for a recreation purpose. The following needs to be considered to examine the feasibility of the option: • Pumping can potentially be very expensive • Pumping can potentially take a very long time and effectiveness of the option is reduced if pumping does not start early enough; increasing frequency of pumping should be discussed • Impacts on groundwater-dependent ecosystems (GDEs), namely Paperbark Swamp Forest and Umina Coastal Sandplain Woodland in the Woy Woy catchment (Conacher, 2005). • Pumping activities may potentially be beneficial towards water supply • Potential risk of subsidence of ground levels on private properties • Opportunity to add more pumps at strategic locations	Strategic reduction of groundwater would be ineffective if pumping is undertaken for only short periods of time (e.g. 1 month) prior to a typical flood season. However, a permanent reduction in the groundwater table through constant 4 ML/d pumping for portable water uses can improve flooding significantly at Shepard Street, Glenn Street and Carpenter Street where the high groundwater table contributes to flooding.

Reduce groundwater table prior to a rain event (subsoil drain)	The above option can be extended to installation of subsoil drains in public areas where groundwater levels are high. These would then connect into the existing stormwater system to lower groundwater levels when it is not raining, thereby creating additional infiltration capacity when rainfall does occur. Areas where this option is feasible can be limited.	
Rezone and redevelopment	This option proposes potential up-zoning and redevelopment of some flood affected areas to become more flood resilient. The redevelopment should incorporate green structures that will increase infiltration and storage capacity. Green structures can include wetlands, lagoons, park avenues, flood corridors, etc. At the same time, the number of dwellings would be increased in the redevelopment area. This would achieve a medium density development area, allowing a higher total number of residents, while increasing the total infiltration areas. This aligns well with the Council's policy to increase population density on the peninsula. In addition, the Development Control Plan could be changed to encourage or make it mandatory for future higher density development to infiltrate a portion of rainfall on their site. For instance, not only reducing peak discharge off site to pre-development levels but also requiring runoff volumes to match pre-development levels. The current study did not consider the following points which are required for further consideration of the feasibility of the option: • the number of dwellings and types of green structures that will be most efficient, • matters around the purchasing of land for rezoning by the State Government.	The streets with low-lying spots located above the groundwater mound experience flooding caused as a result of the high groundwater table. Up-zoning and redevelopment allow these low-lying areas to function as naturally ponded areas.

Where possible, the recommendations of the Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021) have been further considered for flood risk management options in this FRMS.

13 Flood Risk Management Options

As outlined in this study, a number of properties, roads and assets on the Woy Woy peninsula are estimated to be subject to flooding. This section outlines options to manage the flood risk.

Managing flood risk are typically categorised into three ways:

- **Flood Modification Options**: Flood modification options aim to modify the existing flood behaviour to reduce flood levels, velocities or flood extents and consequently reduce damages to properties. Typical examples are implementation of a flood mitigating structures such as dams or levees, and modifications to the floodway such as deepening or realigning of flowpaths.
- **Property Modification Options**: This refers to modifications to existing properties such as land filling or house raising to reduce potential flood damages as well as modifications to the planning measures such as zoning or development controls to manage future flood risk.
- **Emergency Response Modification Options**: This aims to modify the response of the community to a flood to manage a residual flood risk which cannot be completely eliminated by the above two measures. This includes flood warning and emergency evacuation plans.

13.1 Flood Modification Options

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from areas under threat. Flood modification measures, such as levees, are a common and proven means of reducing damages to existing properties under threat from flooding. However, they are usually costly and have the greatest potential of the range of flood management option to affect the ecology and social values of the floodplain.

A preliminary assessment range of potential flood modification options (**Section 13.1.1**) identified several feasible options for further detailed assessment (**Section 13.1.3**).

13.1.1 Identification and preliminary assessment of management options

Flood behaviour was defined in the *Woy Woy Peninsula Flood Study* (DHI, 2010) and further refined as part of this FRMS. In addition, community engagement between February and March 2021 (**Section 7**) identified community concerns about flooding and several recommendations on potential flood mitigation works. Based on the flood risk data and the community input, a range of preliminary flood modification options were identified.

Table 13.1 provides a summary of all the potential flood modification options that were identified for the Woy Woy Peninsula and considered for more detailed assessment (see **Section 13.1.3** for the detailed assessment of options).

Refer to **Figure L120** in **Appendix L** for the location of each option within the study area.

Table 13.1 Identified preliminary management options

Preliminary Option ID	Description
P-FM01	Increase a drainage capacity between Blackwall Road to Charlton Street and creation of an open channel along Oval Avenue and Chambers Place in Woy Woy CBD. In addition, inlets to the drainage network upstream from Charlton Street to approximately Melba Road is upgraded to increase inlet capacities. This option would also form part of the Woy Woy CBD adaptation landform (refer **Section 11**)
P-FM02A	The purpose of this option is to direct flood waters into public spaces (e.g. roads and open space) and away from private properties. Elements of this option include: Increase drainage capacity at Dulkala Road to Karingal Close. Basin in public open space between Dulkara Road and Karingal Close (to increase storage capacity in this area) and/or direct more runoff into adjacent main drain. Increase flood storage in bushland/wetland west of St John The Baptist Primary School. Increase pipe diameters and number of inlet pits where runoff is collected.
P-FM02B	The purpose of this option is to direct flood waters into public spaces (e.g. roads and open space) and away from private properties. Elements of this option include: Increase drainage capacity in network from Timbertops Drive down to Veron Road, and Numby Close. Increase pipe diameters and number of inlet pits where runoff is collected. Regrading of localised sections of roadway including bunding to maximise flow into underground drainage system.
P-FM02C	Basin upstream of Timbertops Drive to reduce peak flows downstream.
P-FM03	Increase infiltration on public lands through the further use of infiltration devices within the drainage system. Possible use of porous pipes, soakaway pits, infiltration trenches, porous paving, or proprietary modular storage/infiltration systems. Not location specific in the preliminary options assessment.
P-FM04	Additional drainage capacity in flat areas from Watkin Avenue south to Shepard Street to reduce the frequency and severity of flooding in the vicinity.
P-FM05	The purpose of this option is to direct flood waters into public spaces (e.g. roads and open space) and away from private properties. Elements of this option include: Increase drainage capacity in network along The Rampart, Greenhaven Drive, Australia Avenue, and Glenhaven Close. Increase pipe diameters and/or number of inlet pits where runoff is collected. Regrading of localised sections of roadway including bunding to maximise flow into underground drainage system and away from properties.
P-FM06	Assessment of the viability of maintenance works along Kahibah, Ettalong and Iluka Creek banks to reduce vegetation load.
P-FM07	Widening of Kahibah, Ettalong and Iluka Creeks
P-FM08	Assessment of the existing Palmtree Grove detention basin. This could involve one of the following revised basin modifications:

Preliminary Option ID	Description
	Increase capacity of the basin; Decreasing the basin capacity and provide mitigation measures; Combination of raising embankment, excavating storage capacity, and/or increasing outlet pipe capacity; or Remove the basin completely.
P-FM09	The purpose of this option is to direct flood waters into public spaces (e.g. roads and open space) and away from private properties. Elements of this option include: • Increase drainage capacity in network along McManus Close, Wilks Avenue and Calypta Road. • Increase pipe diameters and/or number of inlet pits where runoff is collected. • Regrading of localised sections of roadway including bunding to maximise flow into underground drainage system and away from properties.
P-FM10	Drainage improvements at Neera Road and Mountain Ash Way, inclusive of local regrading of roadway and easement downstream to channel.
P-FM11A	Drainage improvement work along the side of Maitland Bay Drive and road regrading
P-FM11B	Alteration of the drainage system to alleviate flooding in private properties. This will include: • Additional pipes and inlet pits. • Local regrading of roadways including introduction of roadside swales and better definition of low points for collection of runoff. • Potential to utilise public open space for runoff storage (Ettalong Oval, Kitchener Park). • Possibility for utilisation of infiltration devices.
P-FM12	Alteration of the drainage system to alleviate flooding in private properties. This will include: • Increased drainage capacity at Egdecliff Road and Sylvania Road. • Possibility for utilisation of infiltration devices.
P-FM13	Increased drainage capacity on the east side of Blackwall Mountain from Warrigal Street to Warwick Street, including: • Additional pipes and inlet pits. • Possibility for utilisation of infiltration devices.
P-FM14	Continuous bore water pumping to reduce groundwater table. Not location specific.
P-FM16	Rainwater tanks and infiltration requirements in DCP for new developments

13.1.2 Options Refinement

Through consultation with stakeholders, the preliminary list of options was interrogated to determine their constraints and opportunities, and their likely overall benefit for the community. Ten options were brought forward for detailed assessment. This includes modelling using the calibrated flood model to determine the flood risk impacts of each, an economic assessment and a multi-criteria assessment.

Options were selected qualitatively based on multiple criteria, such as:

- Likely community acceptance
- Feasibility of funding
- Constructability
- Likely impacts on future maintenance
- Recommendations from other studies
- Environmental impacts

Table 13.2 summarises the refined options. Some options were split for consideration as separate options while others were combined to form new options. A new ID was assigned to each option taken forward to detailed assessment.

Table 13.2 Options for detailed assessment

Preliminary Option ID	Detailed Assessment	Notes	Detailed Option ID
P-FM01	Yes		FM01
P-FM02A	Yes	Combined with P-FM02B	FM02
P-FM02B	Yes	Combined with P-FM02A	
P-FM02C	No		
P-FM03	Yes		FM03
P-FM04	Yes		FM04
P-FM05	Yes		FM05
P-FM06	Yes	Separated into 06A (review current maintenance work) and 06B (additional maintenance)	FM06A
			FM06B
P-FM07	No		
P-FM08	Yes		FM08
P-FM09	Yes		FM09
P-FM10	Yes		FM10
P-FM11A	No		
P-FM11B	No		
P-FM12	No		
P-FM13	No		
P-FM14	No		
P-FM16	No		

13.1.3 Detailed Assessment of Flood Modifications Options

The final list of 10 preferred options were then modelled for the 20% AEP and 1% AEP design events to determine their impacts on flood levels both in private and public

property. If these runs show an improvement to flooding likely to be reflected in damage reduction for private properties, the 10% AEP and PMF were also run as part of a more detailed assessment of options.

The detailed assessment of these options generally involved:

- Flood modelling;
- Economic analysis; and
- Multi-Criteria Assessment (MCA).

Initial modelling for each flood management option was conducted for the 1% AEP and 10% AEP event to better understand the quantitative effects these mitigation works will have on the surrounding private properties. If the initial modelling showed that design flood behaviour was not significantly reduced enough to result in a reduction in economic flood damages, it would not provide value to further model these options for the remainder of the design flood events. That is, it would be fair to assume that the benefit cost ratio of these options would be close to zero. This does not mean that the option would not be considered for non-economic reasons, as it still undergoes further assessment in the multi-criteria assessment.

Out of the ten flood management options proposed for the Woy Woy study area, seven were assessed for economic damages as initial modelling indicated minimal flood benefits for the option.

The outcomes of this economic analysis are detailed in the sections below, including a comparison with the existing scenario (i.e. Base Case) damages (**Section 9.2**). **Appendix N** details the inputs behind the damages calculation, such as the capital cost and annual maintenance cost associated with each option.

Flood modelling results of each option are mapped in **Appendix L.**

13.1.3.1 FM01 Woy Woy CBD

FM01 considers mitigation of flooding around Woy Woy CBD which is low-lying area close to the coastline. Modifications illustrated in **Figure 13.1** include:

- Install a new open channel along Oval Ave and connect it to the existing open channel running through the oval.
- Increase the pipe capacity between Charlton Ave and Blackwall Rd
- Improve inlets and add new inlets

This option aligns with the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021). The proposed future adaptation landform for the Woy Woy CBD involves the establishment of a drainage easement stretching from the existing channel bordering the Woy Woy Oval to Charlton Street. This easement will allow for the surrounding raised landform to efficiently drain incorporating minimum allowable road gradients.

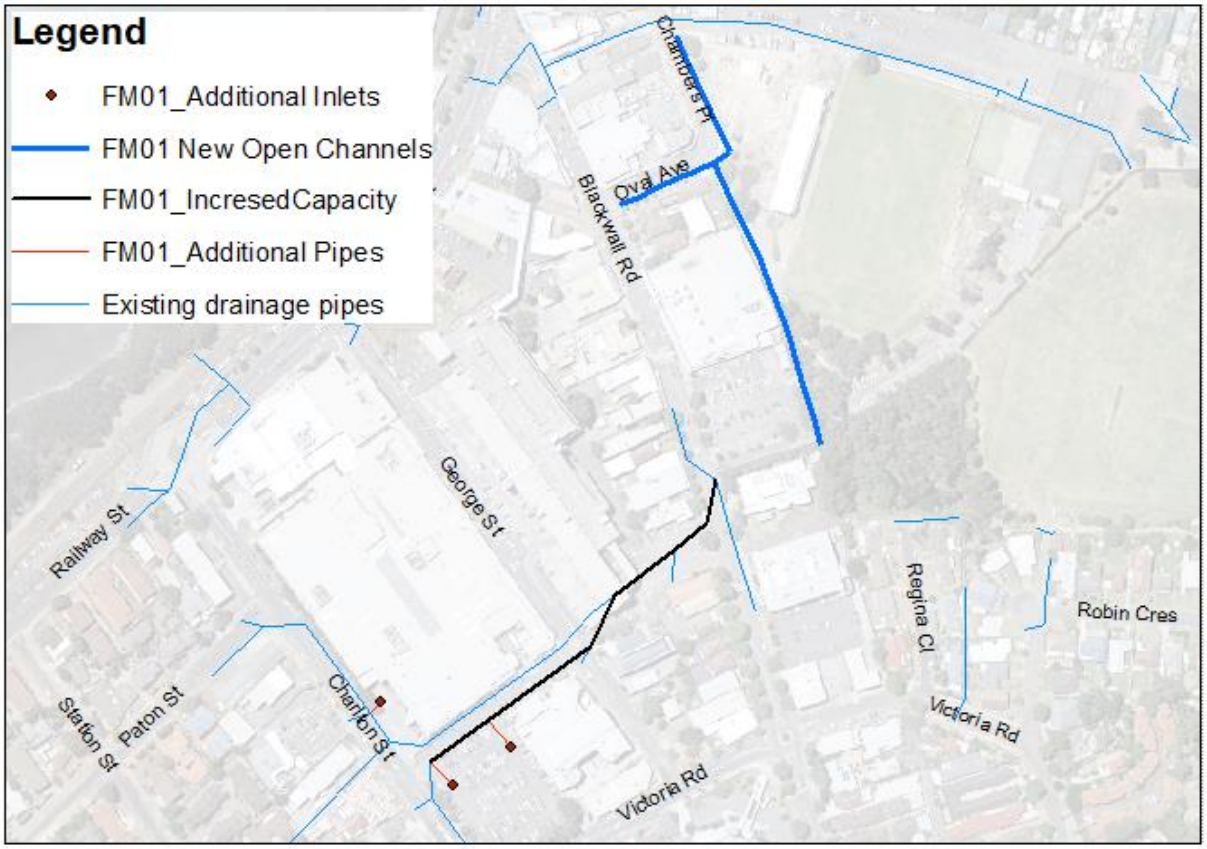


Figure 13.1 Modifications in FM01

Although portions of this option lie within a land-use zone (B2 Local Centre) where, under the current LEP, flood mitigation measures are not allowed, this does conflict with Council's climate change policy and the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021). This contradiction will need to be considered if the mitigation works are implemented.

Flood Reduction

Reduction of peak flood depths (100-200mm reduction) was seen at the Plaza (shopping mall) in the 1%, 10%, and 20% AEP events. A minor reduction was seen in the PMF event which was limited to less than 100mm.

Economic Assessment

The cost of implementing Option FM01 is compared against the reduction in AAD to provide a benefit cost ratio (see Table below). Since the BCR is less than one, the economic analysis has concluded that this is not a viable option from an economic viewpoint. The reduction in AAD for this option is low enough to be considered zero as that is within the bounds of variability of the damages assessment.

Table 13.3 FM01: Economic Assessment

Option	Capital Cost	Recurrent Cost (Annual)	Reduction in AAD	Benefit Cost Ratio
FM01	$1,708,840	$500	$176	0.00

13.1.3.2 FM02 Dulkala Road to Karingal Close

This option considers increase of drainage capacity at Dulkala Road to Karingal Close including the utilization of the public space north of Dulkala Road and west of St John the

Baptist Catholic Primary School. Modifications include increase of the drainage pipe sizes and gradient changes to Karloo Road and Lentara Road to reduce flow entering to properties.

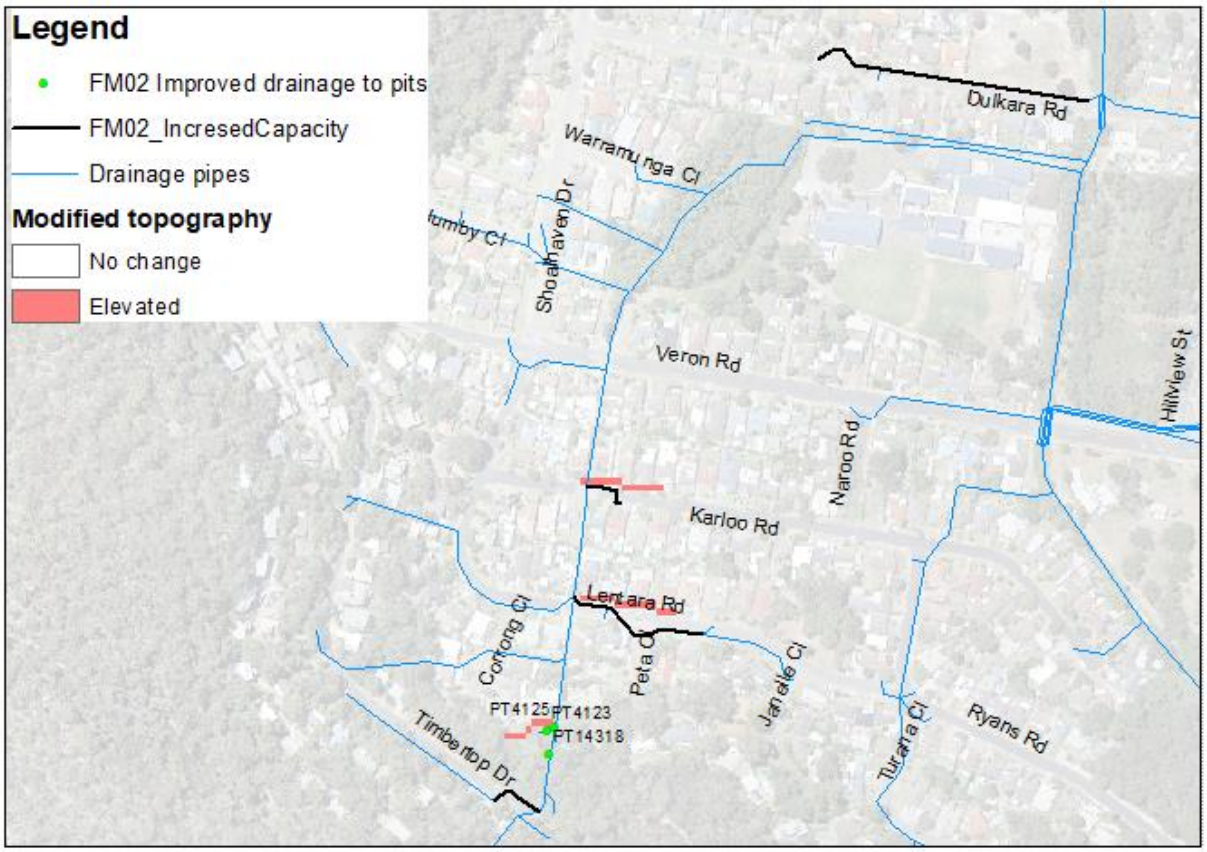


Figure 13.2 Modifications in FM02

Flood Reduction

While the street gradient change retains more water on the streets, reduction in flooding is marginal at the downstream properties except for the 1%AEP event where a small reduction less than 100mm is seen at the north of Dulkara Road. This can be explained that the simulated flood in this area is largely caused by a high groundwater table due to the assumption of a thin sand layer along the foot of the escarpment. Diverting surface water has a marginal impact on flood depth.

Increases in flooding within private properties and roadways (up to 200mm) will require further mitigation if this option is recommended for implementation.

Economic Assessment

The cost of implementing Option FM02 is compared against the reduction in AAD to provide a benefit cost ratio (see Table below). Since the BCR is less than one, the this may not be a preferred option from an economic viewpoint.

Table 13.4 FM02: Economic Assessment

Option	Capital Cost	Recurrent Cost (Annual)	Reduction in AAD	Benefit Cost Ratio
FM02	$653,100	$500	$14,457	0.32

13.1.3.3 FM03 Infiltration Devices

This option considered installation of infiltration devices along streets with ponding. Six infiltration devices were tested in several locations of the Woy Woy peninsula previously and showed improvements to local drainage issues, while the maintenance of devices has been a challenge.

Figure 13.3 and **Figure 13.4** show the nominated locations for the infiltration devices. Grey colors show flooding at Baseline. **Figure 13.3** shows the area where the sand layer is relatively deep and the depth to the phreatic surface is large. In contrast, the locations in **Figure 13.4** are selected at areas relatively shallow groundwater. A device was modelled as a large infiltration pad.

The results show local improvements in flooding, but the extent is limited to the street where the device was installed. This option can be utilized as a solution for local drainage issues.

The selection of individual locations for implementation of infiltration devices would need to be subject to a detailed feasibility study prior to design and construction. This feasibility study should also consider any negative impacts to groundwater quality or the water treatment process for Council's groundwater extraction systems for drinking water during periods of drought. A neutral or beneficial impact on groundwater quality in the aquifer would be required to be demonstrated. Any action that involves increasing infiltration into the groundwater supply and bypassing the natural sand filtration needs to be approached with caution. The Woy Woy aquifer is an important resource that is sensitive to any pollutants/contaminants that are introduced. This region is heavily urbanised and groundwater quality may be under stress and potentially at further risk by anthropogenic influences.

A detailed maintenance routine will be required to ensure the ongoing performance of any installed infiltration devices. This is likely to include relatively frequent inspection and/or removal of sediment buildup (in accordance with the system manufacturer's specifications) to ensure ongoing operation of the devices.

Figure 13.3 FM03 nominated locations for infiltration devices in the area with relatively deep sand layer

Figure 13.4 FM03 nominated locations for infiltration devices in the area with relatively shallow sand layer

Flood reduction

The results show local improvements in flooding, but the extent is limited to the street where the device was installed. This option can be utilized as a solution for local drainage issues or reduction of time of inundation for nuisance flooding in roadways.

Economic Assessment

With a minimal change in impacts to property, it was not considered necessary to determine the benefits and cost for this option. The eventual BCR would be close to zero. The main benefits released from this option would be intangible benefits from reduced ponding durations.

13.1.3.4 FM04 Groundwater pumping and Everglades drainage update work

DHI (2020) concluded that strategic lowering of the groundwater level can improve flooding impacts in areas where the groundwater mound is located.

Following the Millennium drought, prior to the construction of the Mardi-Mangrove Link in 2012, Council installed a series of production bores and the Woy Woy Bore Water Treatment Plant as emergency supply for portable water during a drought. The production bores were designed to operate to extract groundwater as required to supplement the surface water supply. So far, they have not been utilised besides testing extractions and to ensure they are still able to function.

The Central Coast Water Security Plan (CCWSP) identifies actions to maximise the efficient use of existing supply sources (including Woy Woy Ground Water) to improve resilience to population growth and climate change into the future. This may include significant changes to existing trigger levels to utilise the Woy Woy Ground Water scheme and greater utilisation of those assets.

The objective of the option is to reduce nuisance flooding in smaller design events. This option considered the strategic long-term pumping at the existing production bores. In addition, this option also included the planned and recently completed drainage improvement works in the Everglades catchment:

- Mackenzie Avenue duplication pipes work (Completed in 2020)
- Everglades Catchments Drainage Upgrade Stage5 work

Mackenzie Avenue duplication pipes work extended the drainage network on Mackenzie Avenue to the intersection with Onslow Avenue by adding a parallel slotted pipe. Everglades Catchments Drainage Upgrade Stage5 work is primarily cleaning and rehabilitation works of the existing network improvements to the inlets.

The strategic pumping was implemented in the model by replacing the antecedent catchment conditions.

As described in the Woy Woy FRMS Technical Volume (2022), the antecedent catchment condition for Baseline was selected as the 80-percentile groundwater level extracted from the 100-year long groundwater simulation. To assess the impact of the strategic long-term pumping, the 100-year long groundwater simulation with the 4ML/d continuous pumping was run and the corresponding groundwater level was extracted.

Figure 13.5 compares the selected antecedent groundwater levels of BASELINE and FM04 under the strategic pumping. Differences in groundwater levels between pumping and no-pumping scenarios vary greatly across different locations of the peninsula but are generally large in the centre of the peninsula (up to 0.6m difference), while the foreshore area's levels are bounded by the sea level condition.

Flood Reduction

Results of the 1% AEP and 20% AEP show improvements in flood depths at the golf course, the Kahibah creek and at properties around Dulkara Rd. On the other hand, it did not lead to significant reductions at the properties in other areas. Refer to **Figures L.149** and **L.150** in **Appendix L**.

Improvements are seen in the area where the sand layer is estimated to be shallow, mainly at the bottom of the escarpment. In these areas, the groundwater table is likely to hit the ground surface and water starts to emerge during a flood event. A direct impact on the groundwater table is seen in this area.

No significant improvements were seen at properties around Ryans Rd or Veron Rd in the Everglades catchment where the groundwater mound is located. Flood depth reductions are seen near MacKenzie Ave but this is mainly caused by the aforementioned drainage upgrade works, not by the groundwater pumping. This contradicts the outcome of Option4 in the IWM study (DHI, 2020) which showed some improvements in flooding in the Everglades catchment which lies above the groundwater mound.

There are differences between this study and the DHI (2020) study such as:

- The DHI (2020) study modelled flooding only in the Everglades catchment while this study covers the entire peninsula.
- The DHI (2020) study modelled a historical flood event while this study considers design events.

The likely reason for the differences between the two studies is a combination of difference in the antecedent groundwater levels and the rainfall intensity. **Table 13.5** compares the antecedent groundwater levels between the two studies at the locations WW21 and WW43. WW21 is next to the intersection of Connex Road and Veron Road and WW 43 is near the intersection of Shepard Street and Ryans Road in the Everglades catchment. While the magnitude of the drop of the groundwater level due to the pumping is similar, the antecedent groundwater levels used in this study are approximately 0.3m lower than the ones used in DHI (2020). The historical rainfall event used for the assessment in DHI (2020) is the flood event in 1990. However, this was a relatively long duration event over 48hours, while option FM04 has been assessed for the critical durations of the 1%AEP and the 20%AEP which are relatively shorter durations (6hrs and 1hr, respectively) with high rainfall intensities.

When the antecedent groundwater table is relatively high to start with, there is less infiltration capacity. With a high rainfall intensity, the underground storage quickly fills up and the difference is unlikely to be seen at the peak.

- The strategic pumping improves flooding at the bottom of the escarpment. However, a caution should be paid to further consider this option, as information about the groundwater data are limited at these location and seepage from the groundwater from the escarpment should be further assessed.
- The impact of the strategic pumping could vary depending on the dryness of the antecedent catchment condition and the rainfall intensity at the Everglades catchment. Potentially it could improve flooding at more frequent but long duration events.
- It is unlikely that the improvement will be seen in other parts of the Woy Woy peninsula where a deep sand layer exists or where groundwater levels are bounded by the sea level.

The 10% AEP and PMF were not further assessed as similar outcomes (i.e. limited improvements, no significant reductions in flood damages) are expected under these antecedent catchment conditions.

Table 13.5 Comparison of the antecedent groundwater levels used in this study and the IWM project at WW21 and WW43.

	WW21		WW43	
	BASELINE (mAHD)	Scenario (mAHD)	BASELINE (mAHD)	Scenario (mAHD)
This study	2.85	2.65	3.57	3.0
IWM (DHI, 2021)	2.55	2.35	3.28	2.82

Economic Assessment

The capital cost of implementing Option FM04 is assumed to be zero, as the infrastructure is already in place. An assumed operational cost would be approximately $4,000 per annum, or a similar magnitude.

This option was not further assessed for flood damages or BCR.

BASELINE Antecedent groundwater level

FM04 Antecedent groundwater level

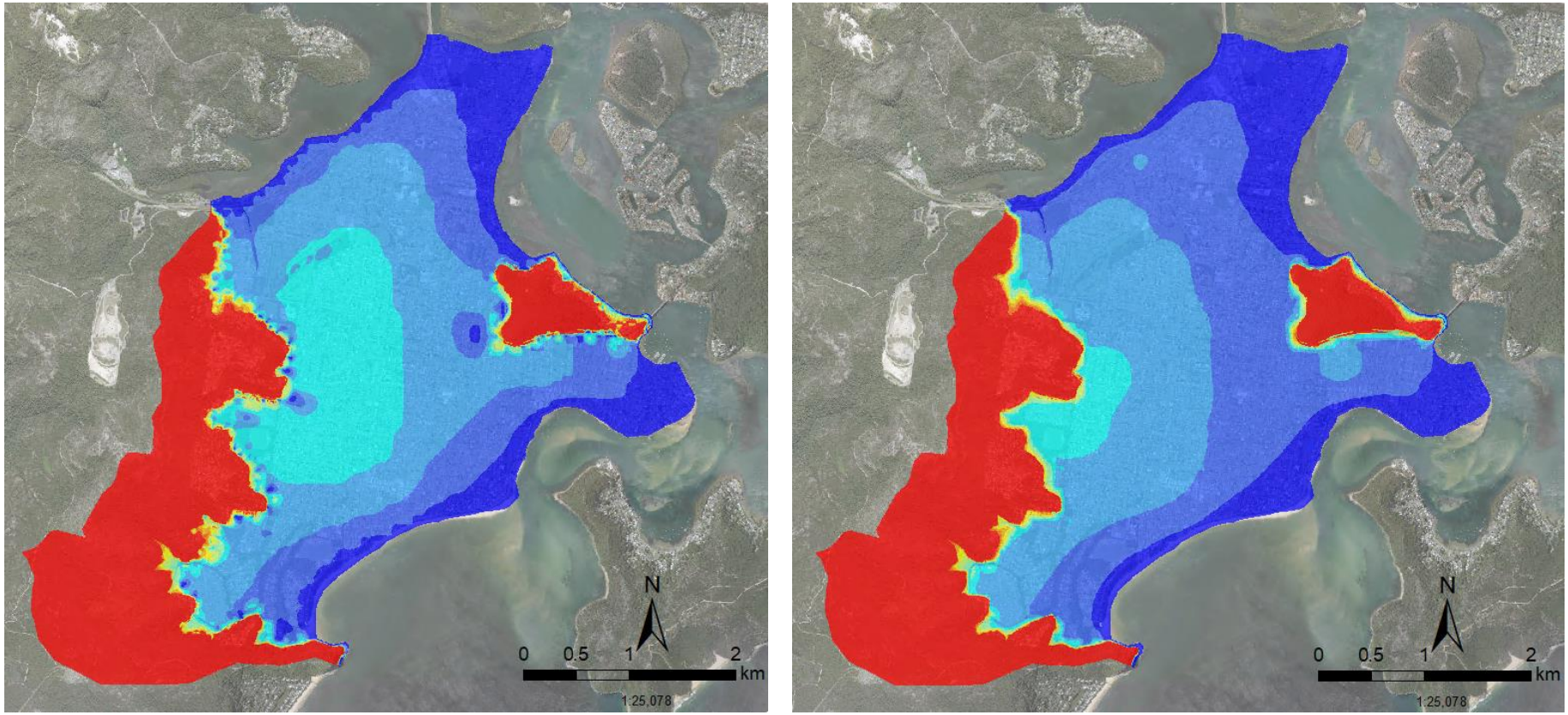


Figure 13.5 Comparison of the antecedent catchment conditions in BASELINE (left) and FM04 (right)

13.1.3.5 FM05 Greenhaven Drive

This option considers increasing the capacity of the drainage along The Rampart, Greenhaven Drive, Australia Avenue, and Glenhaven Close and directing more runoff to the drainage system. This is inclusive of raised kerb levels or bunding on the downstream side for sections of The Rampart, and Greehaven Drive, but also the effective redirection of flows at the eastern end of Greenhaven Drive (increase capacity of drainage pathway) and western end of Australia Avenue (improved headwall entry) to reduce flooding depths on private property. **Figure 13.6** summarises the proposed changes.

Further refinement of the option will be required to determine the exact extent and feasibility of roadworks with respect to bunding and increased capacity of the roadway cross sections.

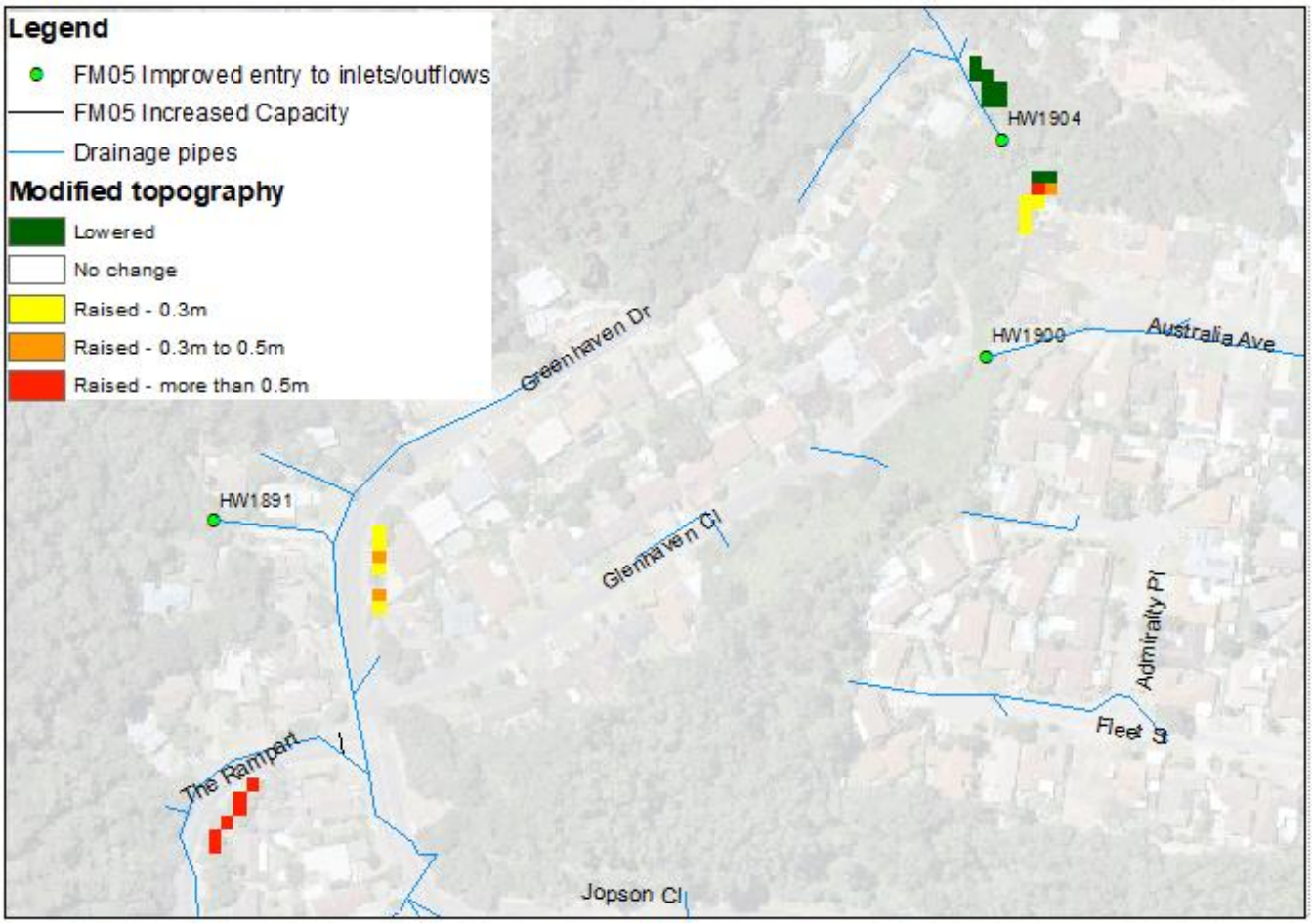


Figure 13.6 Modifications in FM05

Flood Reduction

Flooding at residential blocks along The Rampart, Greenhaven Drive and Australian Ave was reduced by up to 0.3m and more runoff was retained on streets.

The are some very minor increases in flood depths on portions of some properties. This could be mitigated during further refinement of the concept design.

Economic Assessment

The cost of implementing Option FM05 is compared against the reduction in AAD to provide a benefit cost ratio (see Table below). Since the BCR is greater than one, the economic analysis has concluded that this is a viable option from an economic viewpoint.

Table 13.6 FM05: Economic Assessment

Option	Capital Cost	Recurrent Cost (Annual)	Reduction in AAD	Benefit Cost Ratio
FM05	$163,520	$0	$15,247	1.38

13.1.3.6 FM06A Kahibah Creek system maintenance work

Council has been undertaking a routine vegetation maintenance program at the Kahibah Creek system established following the *Kahibah Creek Floodplain Management Plan* (Willing & Partners, 1996) as well as development controls along the drainage reserves along the channels.

This option reassesses the feasibility of the ongoing maintenance regime. The Baseline model was modified to increase surface roughness along the creek riparian area, representing a scenario prior to the implementation of a routine maintenance program. It did not consider any reduction in conveyance caused by an increase in sediment deposition associated with greater vegetation loads. This option determines the economic viability of the maintenance program by comparing the flood risk benefits it produces against the cost of its implementation.

Flood Reduction/Increase

As shown in the flood level difference maps, design flood levels increase in the scenario where the maintenance program was not implemented compared to the current conditions. Flood depths at properties along the channel increase a maximum of approximately 300m in the 20%, 10% and 1% AEP events. This is mostly limited to in bank and riparian areas. Only the 10% AEP displayed an increase in properties experiencing over-floor flooding (one property). Aerial imagery and site inspections established that at many of these properties, dwellings are located at higher ground and outside of the 1% AEP flood extent in most cases.

Impacts to public infrastructure as an outcome of implementation of this option potentially include the sewer pump station (ID: OB04) in events equal to and greater than the 10% AEP. Mitigation works for this could include a small flood wall to maintain the frequency of inundation experienced in existing conditions.

Economic Assessment

The approximate annual maintenance cost associated with this program are $320,000. The benefits associated with reductions in flood levels at properties are a decrease in AAD by $803. The resultant BCR is zero. This confirms that the vegetation maintenance regime currently in place is unviable from an economic perspective.

Table 13.7 FM06A: Economic Assessment

Option	Recurrent Costs (Annual)	Decrease in AAD	Benefit Cost Ratio
FM06A	$320,000	$803	0.00

Other potential methods for increasing the viability of vegetation management along the corridor could be to only reduce large woody growth which is the main driver for increased roughness in the riparian areas, implementation of a community-based effort to manage vegetation along the riparian corridors.

13.1.3.7 FM06B Further improvement of the Kahibah Creek system maintenance work

Following on from FM06A, this option considered the impact of more regular clearance of vegetation load and removal of urban debris, and potential lining of the lower channels. This has been implemented by reducing the roughness coefficient in the model.

Flood Reduction/Increase

As seen in the results (refer to Figures **L.159** and **L.160** in **Appendix L**), the positive impact is only found at the part of the upstream channels in the 1% AEP and 20% AEP. Therefore, further investigation of this option did not proceed.

Economic Assessment

The capital cost of implementing Option FM06B was estimated at approximately $300,000 for a combination of initial significant clearance of vegetation and potential construction of lined sections of the creek. An assumed increase in operational cost would be approximately $200,000 per annum, or a similar magnitude.

This option was not further assessed for flood damages or BCR.

13.1.3.8 FM08 Palmtree Grove Detention Basin Capacity Reduction

Palmtree Grove Detention Basin detailed in **Section 3.1.1** stores runoff from the upper catchment originating on the escarpment. The basin is registered as a declared dam by Dams Safety NSW and requires ongoing maintenance costs for Council. If it is no longer a declared dam the annual maintenance expenditure can reduce. This option considers the impact on flood risk if the basin storage is reduced in size. This also comes with a reduction of risk to the community downstream, as the effects of hazardous flow in a dam breach scenario would be less. To minimize the negative flood impact this option has due to a large overtopping of the embankment, alternative mitigation measures are proposed.

Palmtree Grove Detention Basin has a high side wall (>10mAHD) which prevents floodwater from flowing directly to the residential blocks to the east of the basin. The spillway is located at the south-western end of Palmtree Grove and the level is approximately 9.6 mAHD. Overtopped water flows down towards Palmtree Grove but the street does not function as a flow path to the Neera Road Arm since the street has a gradient towards south-east as shown in **Figure 13.7**. Runoff is expected to immediately flow to the properties on the south-eastern side of the street.

The basin is served with two outlets located under the crest which connects to two 1500mm parallel pipes running under Palmtree Grove and exiting at the easement towards the Neera Road Arm. These pipe inverts are located at 6.24mAHD at the outlet of the basin. The minimum level to which the crest can be lowered without modifications to the existing outlet pipes would be approximately 8mAHD.

The following modifications were considered:

- The crest level will be lowered from 9.6mAHD to 8mAHD
- The side wall will be maintained.
- The gradient of Palmtree Grove would be modified, and small bunding is introduced along the southern side of the street to retain more flow on the street.
- Downstream easement is to be deepened, allowing greater flow directly into the downstream channel.

This option would require further refinement to determine the optimal height for the embankment by balancing flood risk downstream for operational rainfall events and dam break rainfall events. Additionally, the feasibility of the proposed regrading of Palmtree Grove and introduction of bunding will need to be further considered to ensure appropriate driveway gradients can be maintained.

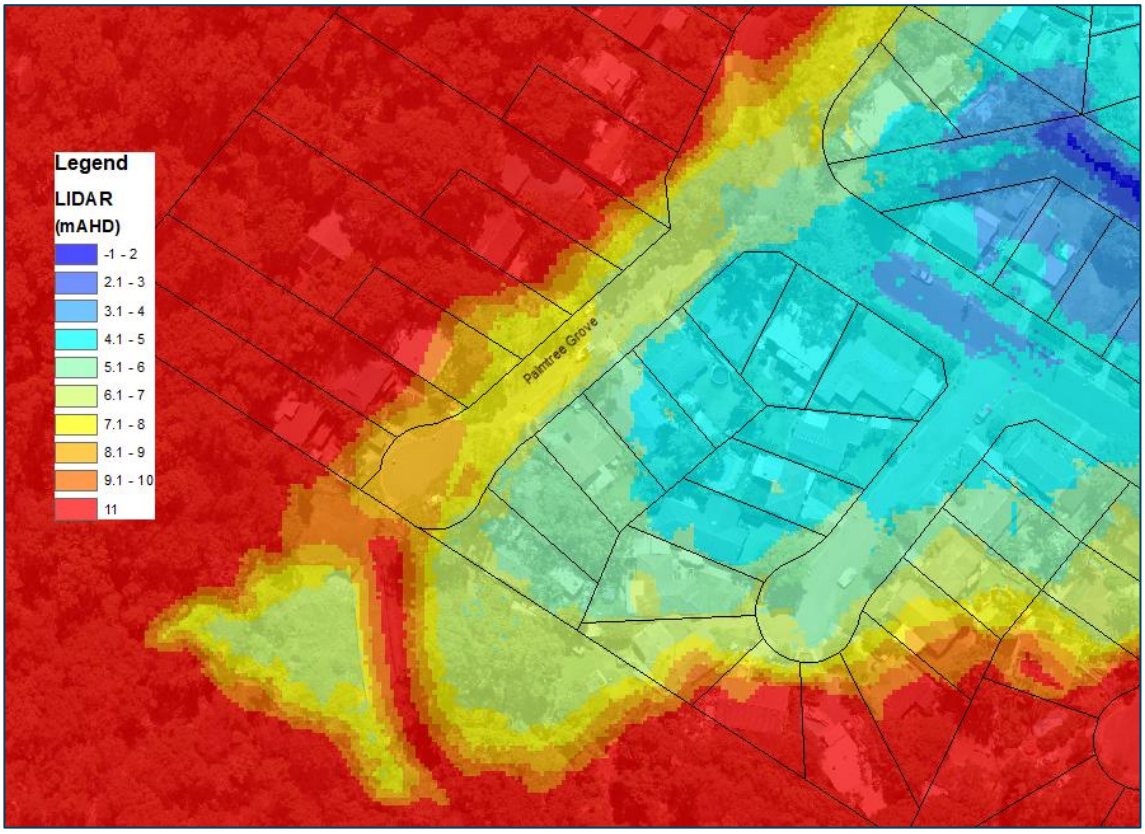


Figure 13.7 Topography around Palmtree Grove

Figure 13.8 Modifications in FM08

Flood Reduction/Increase

For this option, as modelled, flood depth becomes higher due to lowering of the crest level and the mitigation by modification of the gradient of Palmtree Grove is seen in PMF, 1%AEP and 10%AEP. However, it does not mitigate flooding in the more frequent event (20%AEP). (Refer to **Figures L.161** to **L.164** in **Appendix L**).

Results indicate that this option could potentially be feasible but would require further investigation to refine the proposed:

- embankment and outlet arrangement,
- road drainage capacity on Palmtree Grove, and
- downstream mitigation works.

Economic Assessment

The cost of implementing Option FM08 is compared against the reduction in AAD to provide a benefit cost ratio (see Table below).

Implementation of this option may result in the dam being taken off the list of declared dams in NSW, and ongoing inspection and maintenance costs being significantly reduced. This economic assessment has made the assumption that maintenance costs have been reduced (assumed annual savings of $30,000) by the basin being taken off the list of declared dams. However, to confirm this outcome, analysis including a new dam consequence category study is required and submission to Dams Safety NSW for review.

With a proposed embankment lowered and a reduced basin peak capacity, the flood risk to life and property due to dam break would be significantly reduced. That is, when an embankment breach occurs, a lesser volume of water will flow towards the houses immediately downstream. This economic analysis does not quantify the benefits associated with reduced flood risk in a dam

break event. If this option is taken forward for further consideration, it is recommended this be further explored to determine its viability.

Table 13.8 FM08: Economic Assessment

Option	Capital Cost	Recurrent Savings (Annual)	Increase in AAD	Benefit Cost Ratio
FM08	$295,400	$30,000	$2,822	3.54

Although the BCR would indicate that this is a viable option, the increase in flooding within private properties during more frequent rainfall events (e.g. the 20% AEP) and resultant increase in AAD would need to be addressed. Further refinement of the conceptual design may mitigate this increase in flood risk and the option could be considered viable.

13.1.3.9 FM09 Wilks Avenue and McManus Close

This option considers increasing the capacity of the drainage around Wilks Avenue and McManus Close and navigating more ponding water to the drainage system. **Figure 13.9** summarises the proposed changes.

Flood Reduction

Despite water being more retained on the streets, this option did not significantly reduce inundation levels at all properties and some properties were subject to higher design flood depths (Refer to **Figures L.165** and **L.166** in **Appendix L**). Further modelling with the 10% AEP and PMF, as well as detailed economic assessment, was not undertaken.

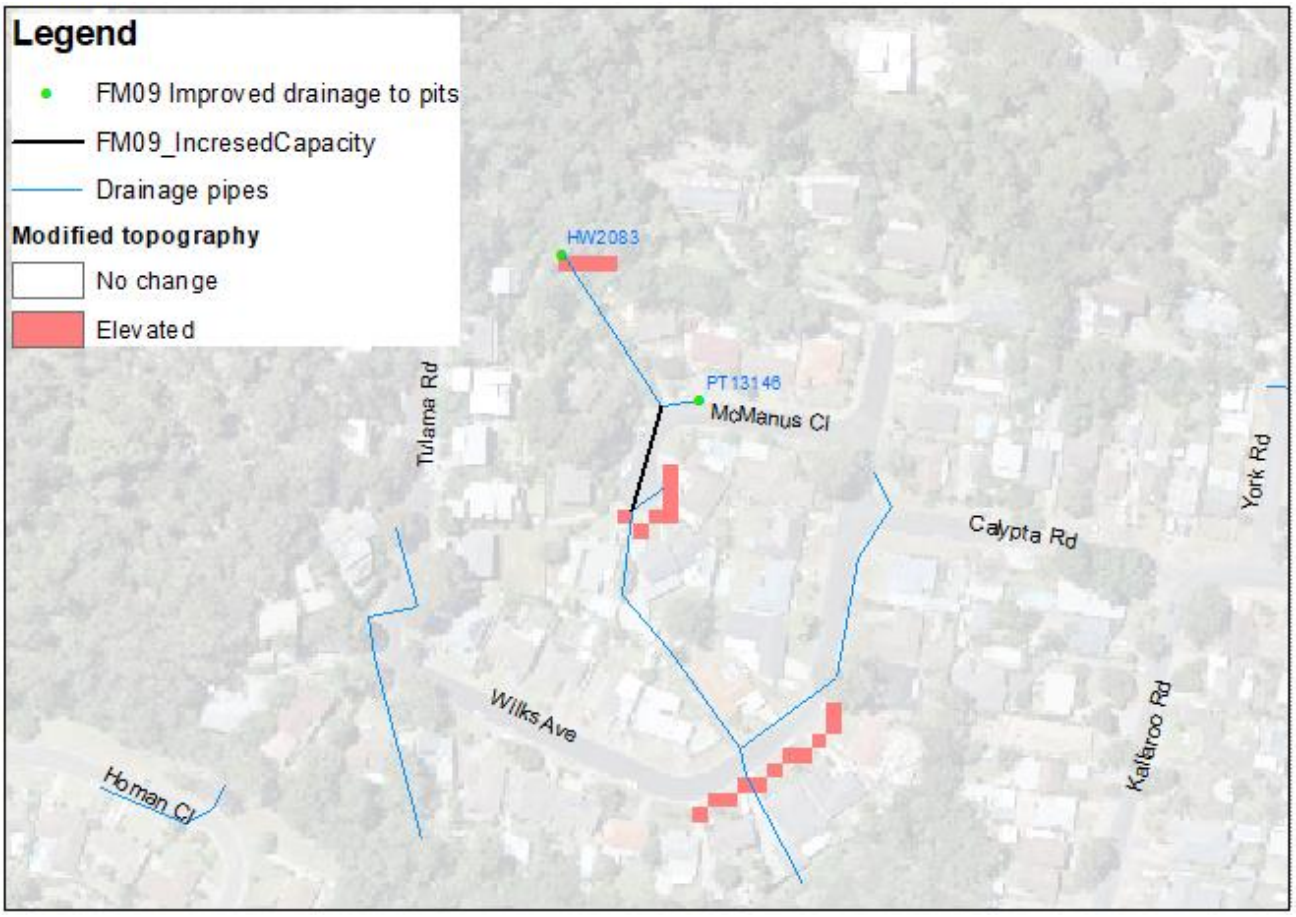


Figure 13.9 Modifications in FM09

Economic Assessment

The capital cost of implementing Option FM06B was estimated at approximately $96,320 with no increase in annual maintenance costs.

This option was not further assessed for flood damages or BCR.

13.1.3.10 FM10 Neera Road

This option considers increasing the capacity of the drainage at Neera Road and navigating more ponding water to the drainage system. **Figure 13.10** summarizes the adopted changes, including lowering of the easement and bunding at the corner of the property and the easement.

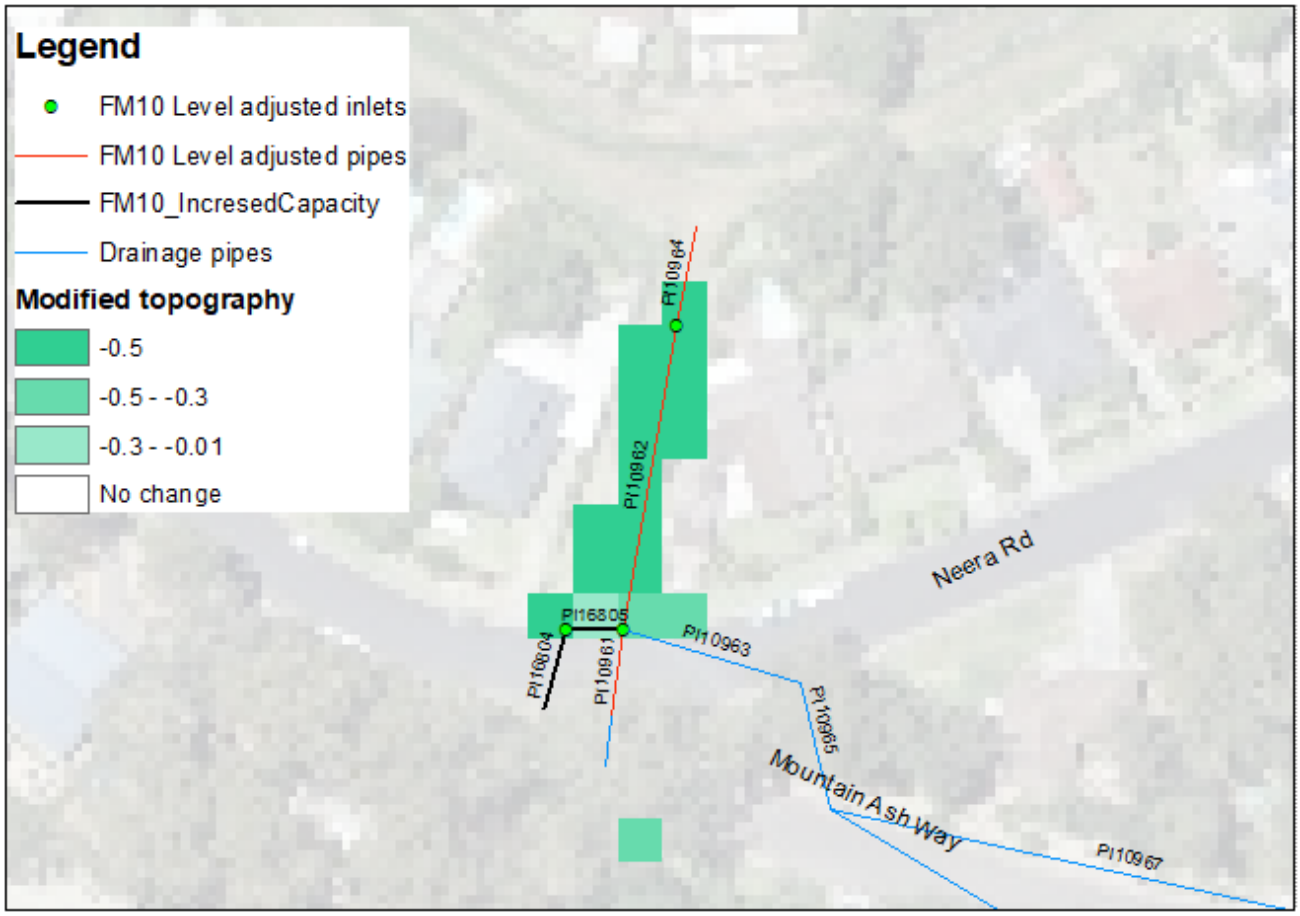


Figure 13.10 Modifications in FM10

Flood Reduction

This option reduces flooding at two or three properties along Neera Road, up to 200mm in the 1%, 10% and 20% AEP events.

Economic Assessment

The reduction in flood risk for this option is limited to only a few properties. Furthermore, the reduction in AAD is minimal and given the uncertainties in the economic modelling this could be interpreted as having a likely BCR very close to zero.

This option is not considered any further for implementation.

13.1.4 Options Damages Economic Assessment: Summary

The economic assessment considers the comparative costs and benefits of the proposed floodplain management options against the existing scenario (base case). The economic merit of the options was determined by comparing the present value (PV) of the change in AAD (compared with the base case) less the change in capital and maintenance costs.

Table 13.9 summarises the results of the economic assessment of floodplain damages for the options where significant reduction in flood depths on private properties were observed or where there are significant capital costs or changes to ongoing maintenance costs.

This was taken across a 50-year assessment period. A positive NPV and BCR greater than one support a claim for the program to be considered as economically feasible.

Table 13.9 Economic Summary of Floodplain Management Options

Option	Capital Cost	Recurrent Cost (Annual)	Reduction in AAD	Benefit Cost Ratio	Outcome
FM01	$1,708,840	$500	$176	0.00	Not recommended for further consideration – no immediate benefit to flood damages
FM02	$653,100	$500	$14,457	0.32	Not recommended for further consideration – BCR less than 1
FM03	Approx $25K per device	Approx $1,250 per device	-	-	Recommended to reduce flooding duration and extent within roadways
FM04	-	$4,000	-	-	Not recommended – no benefit to flood damages
FM05	$163,520	$0	$15,247	1.38	Further consideration required to determine feasibility
FM06A	$0	$320,000	$803	0.00	Recommended with further feasibility study needed to mitigate increased flood levels
FM06B	$300,000	$200,000	-	-	Not recommended – option not likely viable given significant investment required
FM08	$295,400	-$30,000[1]	-$2,822[2]	3.54	Further consideration required – concept design can be further refined for potential greater benefit
FM09	$95,830	$0	-	-	Not recommended – no benefit to flood damages

[1] Negative value indicates an annual cost savings

[2] Negative value indicates an increase in AAD

FM10	$138,880	$0	-	-	Not recommended – benefit to flood damages limited and confined to two properties

13.2 Property Modification Options

Property modification measures refer to modifications to existing development and / or development controls on property and community infrastructure for future development. These are aimed at steering inappropriate development away from areas with a high potential for damage and ensuring that potential damage to development likely to be affected by flooding is limited to acceptable levels by means of measures such as minimum floor levels, and flood proofing requirements.

13.2.1 PM01 Land Use and Development Control Planning Recommendations

Land use and development control planning limits and controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately. Effective consideration of future development involves strategic assessment of flood risk to future development areas to guide councils in wisely and rationally controlling development to reduce the risk of exposure of new development to an acceptable level.

Council's existing land use and development planning controls are reviewed in **Section 6**. As an outcome of this review a series of recommendations have been made to assist Council in achieving best practice flood planning in the Woy Woy Peninsula and across the LGA.

Table 13.10 Flood Planning Recommendations

	Issue	Recommendation
1	The FRMS investigated the appropriate definition of the Flood Planning Area and the Flood Planning Level.	It is recommended that the Flood Planning Area (FPA) within the Woy Woy Peninsula is defined as PMF extent. It is recommended that the Flood Planning Level (FPL) within the Woy Woy Peninsula is defined as: • The 1% AEP plus 0.5m freeboard with sea level rise of 0.74m across the study area. • In the low-lying areas along the coastline, adopt the flood planning level provided by the *Brisbane Water Foreshore Floodplain Risk Management Plan* (Cardno, 2015).
2	Existing flood planning does not consider Flood Planning Constraint Categories (Australian Disaster Resilience Guideline 7-5 Flood Information to Support Land-use Planning, AIDR 2017).	These categories can assist Council in making planning decisions in the floodplain. Council may want to consider referencing FPCC in future updates to the DCP.
3	Clause 7.23 of the CCELP 2022 indirectly defines the Flood Planning Level to be 1% AEP plus 500mm. This planning level may not be appropriate for all floodplains. Discussion on selection of an appropriate Flood Planning Area	It is recommended that the Council provide scope within their LEP to allow for the Flood Planning Level (FPL) and the Flood Planning Area (FPA)

	and Flood Planning Level are provided in this FRMS.	to be defined for each floodplain within the relevant Floodplain Risk Management Plan. Further, it is recommended that the wording in the LEP allows for the FPA to be defined as other than the land below the FPL. As this is not consistent with the recommendations in this FRMS.
4	The CCDCP 2022 refers to the Flood Planning Area being land below the 1% AEP + 500mm (clause 3.1.11.6 of the CCDCP 2022) rather than being defined for each floodplain within the relevant Floodplain Risk Management Plan.	Update the definition of the FPA and FPL in the DCP to be consistent with Item 1 in this table.
5	Floor levels for Group homes, seniors housing, and emergency facilities are set at the PMF. However, there may be situations where the PMF is lower than the FPL.	Sensitive, vulnerable, or critical use developments that require floor levels to be set at the PMF should be updated to include all sensitive, vulnerable, or critical uses defined in the Flood Prone Land Package. The DCP should be updated to have special controls for sensitive, vulnerable, or critical uses such that there should be consideration that the FPL be set at a level up to the PMF level of the 1% AEP level plus 500mm freeboard (whichever is higher). This may also take into consideration emergency access issues and the provision of an emergency flood plan for the relevant developments.
6	Section 3.1.12 of the CCDCP 2022 discusses proposed development within areas of the Woy Woy Peninsula designated as drainage “black spots” where the necessary public funding to overcome the drainage problem is unlikely to become available. Development within these areas is subject to the current requirement that they “Provide the drainage works required to overcome the problem of any increased flow or problems caused by the increased flow as a result of the development proposal…”	Given the origin of the creation of these “black spots” was based on now outdated rainfall-runoff methodologies and modelling techniques, it is recommended that Council consider removal of the ongoing implementation of Section 3.1.12 of the CCDCP 2022.
7	Ongoing development in the Peninsula has led to significant increases in impervious area. The source of this has been the increase in redevelopment of housing with larger dwelling footprints, and construction of additional dwellings (e.g. granny flats) on existing properties. These include both approved and non-approved structures. The increase in impervious area has reduced the overall infiltration capacity of the Peninsula.	Consideration should be given for changes in land use zoning to enable significant increases in pervious surfaces and rainfall infiltration across the peninsula. This should also include revisions to the DCP requirements for development. This re-zoning strategy can also be implemented in areas where flood hazard cannot be reduced with traditional mitigation measures, by allowing more flood compatible development such as requiring open spaces which also convey flood water in rare storm events.

13.2.2 PM02 Voluntary House Purchase

Voluntary house purchase (VP) is a flood risk management tool, used in high hazard residential areas when there are no other feasible options for protecting an existing community from severe flooding, such as building levees, diverting flood flows, or improving evacuation access.

The main aim of VP is to permanently remove at risk people from high flood hazard areas (areas with high flood depths and velocities) by purchasing their properties. The dwelling is then removed (for relocation, if suitable) or demolished and the property is back zoned to a more flood compatible land use, such as recreational park.

Removal of buildings from flow paths may also reduce flood impacts on other areas and potentially provide more land to carry out flood mitigation works such as flow diversions or levees.

The NSW State Government, through DPIE provides grants to councils under the Floodplain Management Program for eligible properties in defined VP schemes. Assessing the viability of a VP scheme or an individual property for VP is part of a collective assessment of floodplain risk management options for the community when an FRMP is developed. The FRMP should have considered:

- flood hazard classification and associated risk to life
- hydraulic classification in relation to location in a floodway
- the benefits of floodway clearance to the flood-affected areas
- economic, social, and environmental costs and benefits
- viability of the scope and scale of the scheme and how the scheme will be prioritised generally on the basis of degree of flood hazard exposure
- identification of each affected property and the buildings on them
- the support of the affected community for VP as determined through consultation with affected owners
- an implementation plan for the scheme.

Properties being considered for VP should be located:

- within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them.
- within a floodway where the removal of the house may be part of a floodway clearance program aimed to reduce the significant impacts caused by the existing development on flood behaviour elsewhere in the floodplain and enable the floodway to more effectively perform its flow conveyance function.
- within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected.

There are no residential dwellings located in 1% AEP high hazard flood locations (H4 – H6) within the study area.

13.2.3 PM03 Voluntary House Raising

Under the NSW Floodplain Management Program, DPIE provides funding to assist homeowners raise the floor level of their house to reduce the damages and trauma caused by flood water inundating their house.

Homeowners can only access this funding through a Voluntary House Raising (VHR) Scheme coordinated by Local Councils.

Assessing the viability of a VHR scheme or an individual property for VP is part of a collective assessment of floodplain risk management options for the community when an FRMP is developed. The FRMP should consider:

- the full range of flood events and their associated impacts
- the hydraulic function of the area, as VHR is generally excluded in floodways
- the area's flood hazard classification, as VHR is generally limited to low hazard areas
- the effectiveness as an ongoing maintenance requirement of complementary measures to address risk to life, such as those based around supporting self-evacuation in response to directions from the State Emergency Service (SES)
- the identification of individual houses' suitability for raising
- cost-effectiveness of the scheme (benefit–cost ratio) measured across the full range of floods with VHR aiming to generate positive financial returns from reduced damage relative to costs
- the viability of the scope and scale of the scheme and how the scheme will be prioritised (considering flood hazard exposure)
- the support of the affected community for VHR as determined through consultation with affected owners
- an implementation plan for the scheme.

A voluntary house raising program was assessed for properties affected by flooding from Brisbane Water as part of the *Brisbane Water FRMS* (Cardno, 2015). The viability of a voluntary house raising program was assessed for properties impacted by catchment flooding as part of this FRMS. It is noted that numerous properties are affected by both catchment and Brisbane Water flooding. Only the catchment flooding was considered in this option.

An economic analysis was undertaken to assess the economic viability of house raising in this catchment. This assessment considered the number of houses flooded for each modelled design events and compared the costs and benefits of raising the floor level for those properties. This assessment assumes that there is no significant difference in cost between, for example, raising a floor level above the 10% AEP and the 20% AEP given the minimal difference in flood levels between the two events. The assumed capital cost of raising one house is $100,000 and this would take place in the first year of the 50 year assessment period.

Table 13.11 summarises the results of this assessment.

Table 13.11 PM02 Economic Assessment

Design Event	Number of houses with over floor flooding	Net Present Value of Damages	Benefit Cost Ratio
1% AEP	36	$69,806	0.02
10% AEP	19	$54,355	0.03
20% AEP	16	$48,057	0.03

Council might want to consider the individual property benefits if applying for state government funding and prioritising the houses involved. Only properties eligible for voluntary house raising under current DPIE guidelines should be raised. Refer to https://www.environment.nsw.gov.au/resources/water/coasts/20130056fmpvolraising.pdf

It should be noted that those properties which would be subjected to raising of ground levels from the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021) should not be encouraged to raise only their floor levels.

From an economic standpoint, it is not economically viable to raise houses in this study area.

13.2.4 PM04 Property Flood Risk Education Program

It is important to educate the members of the community on how to respond during a flood emergency to mitigate the risk of potential injuries and loss of lives. However, it is also valuable to provide education in terms of protection of property.

It is crucial that property owners and potential buyers are able to access flood risk information properties are subjected to and to make informed decisions about how they manage these risks.

The Brisbane Water Flood Risk Management Study and Plan proposes, as a property modification option (PM4), the conduct of a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchasers about the risk and effects of coastal flooding.

According to the *Brisbane Water FRMS* (Cardno, 2015), the Property Flood Risk Education Program could include measures such as:

- Ensure that spatial risk information is readily available to members of the public
- Provide flood risk brochures at real-estate agencies
- Include brochures titled “What does my Planning Certificate mean?” with all property planning certificates when received by property purchasers

Since the Woy Woy Peninsula is also subjected to catchment flooding, the flood risk associated with this type of flooding should also be incorporated in the Property Flood Risk Education Program.

This option should be considered in conjunction with other flood education programs in the FRMP, such as those recommended in **Section 13.3.5 (EM05)**.

13.2.5 PM05 Property Education and Compliance

Property owners and residents living adjacent to significant channels and creek (such as the Main Drain and Kahibah Creek) can significantly affect flood behaviour with the types of structures constructed within the floodplain. Depending on the location of the structure (i.e. in the floodway or flood storage), these structures can either remove flood storage or deflect flood waters and increase surrounding flood levels. In addition to the primary property dwelling, this may include structural features such as:

- Sheds,
- Fencing,
- Animal enclosures and shelters, or
- Additional dwellings such as granny flats.

These structures may or may not be approved structures within the context of the current DCP guidelines. In addition, some structures are exempt under the *Exempt and Complying Development Codes SEPP (2008)*, as such they do not need to be approved by Council or private certifier.

In addition, stockpiling of materials including soil, construction or demolition materials, and garden waste can also affect flood behaviour by not only providing an impediment to flood waters but when washed away, they can be a source of debris causing blockage at downstream culverts.

A program to educate residents about how to mitigate flooding through their own property management would not only be beneficial to the surrounding properties but can also reduce flood risk for the individual resident who takes action to manage their own property. This might include conveying an understanding of where existing overland flow paths are located and the issues associated with blocking these paths with landscape works, sheds, stockpiling and other small works that are “exempt” from development restrictions.

Council does not currently have an LGA wide encroachment policy to manage illegal structures in the floodplain. Any encroachment policy will require further consideration of the methodology for enforcing compliance orders and resources for ongoing monitoring and management.

A program to manage encroachment into the floodplain / riparian corridor could also be implemented in concert with community education programs. This would enable Council to progressively reduce the impacts of flow obstructions along channels and subsequently achieve a significant flood risk reduction with buy-in from the community.

13.2.6 PM06 Sustainable Level of Drainage Service

Given the very flat nature of the topography of the Woy Woy Peninsula, combined with the significant groundwater contribution to flooding, a reduced level of service for proposed Council stormwater infrastructure in this area may be possible without increasing flood risk.

New stormwater infrastructure requires significant capital investment because of the flat gradients across the Peninsula, possibly requiring the design of multiple large pipes and culverts to convey the 1% AEP flow from the catchment down to Brisbane Water. This problem will be exacerbated by sea level rise in the future, further reducing stormwater drainage capacities especially near the foreshore.

The *Central Coast Council Civil Works Specification - Design Guideline* (2020) currently requires that the major system stormwater drainage including overland flow paths and trunk drainage be sized for the 1% AEP design storm event, and the minor system (pits and pipes) be sized to convey between the 5% and 20% AEP design storm event, depending on the type of land use.

Flood modelling as part of this study indicates that even with existing infrastructure the consequences of 1% AEP flooding are generally not significant, with respect to developed land on the sand flats of the Peninsula. While residents have highlighted concerns regarding nuisance flooding, the impacts of flooding do not justify 1% AEP capacity trunk drainage systems and similar results may be achieved by having less capacity in the major stormwater system. However, ongoing maintenance will need to be undertaken to ensure services are not reduced to unacceptable levels (e.g. full blockage of pipes and culverts).

A financially sustainable approach to stormwater asset management will be required into the future. Requiring all major stormwater systems to convey peak 1% AEP flows is likely to not be achieved given the initial costs associated with construction. Ideally, a future level of major stormwater system service will enable the entire system to be upgraded in a financially sustainable manner.

It is not recommended that the minor system requirements be reduced as residents of the peninsula have repeatedly highlighted issues with nuisance flooding. However, by reducing the capacity requirements of the major drainage system public works can be more easily funded.

This option recommends that within the Woy Woy Peninsula sand flats only, the requirements of the *Central Coast Council Civil Works Specification - Design Guideline* (2020) be relaxed to provide an alternative level of service. The desired outcome is that areas which are difficult or prohibitively expensive to provide the 1% AEP major drainage systems for (such as existing trapped low points in the public road network) can then be drained with undersized infrastructure. This provides an overall improvement to the duration of inundation experienced by residents. Further studies will be required to define what level of service is acceptable by the community and feasible for Council to construct.

It may be possible in to combine this option with opportunities for infiltration devices (refer Option FM03), with effective and maintenance plans to be incorporated within the stormwater drainage system as an alternative to providing drainage directly to Brisbane Water.

13.2.7 PM07 Landform Adaptation

This option is the recommended outcome of the *Woy Woy Climate Change Adaptation Study* (Rhelm, 2021): implementation of the workplan associated with Adaptation Pathway A. Alternatively, Pathway B would also provide the same flood risk outcomes but comes with added risk that some low-lying lands may not be able to be raised in a timely manner to avoid loss of livability.

Raising of the landform incrementally on private property through development controls and on public lands through Council funded works provides the most cost-effective solution to protect low-lying areas from coastal flooding and improve catchment flooding.

The study was carried out for four locations within the Woy Woy FRMSP study area: Woy Woy CBD, Blackwall, Booker Bay and Ettalong. **Table 13.12** provides the resulting BCR values associated with realizing the adaptation landform for each location.

Table 13.12 Adaptation Landforms Benefit Cost Ratio Summary

Location	BCR
Woy Woy CBD	0.8
Blackwall	0.4
Booker Bay	0.7
Ettalong	0.2

Refer to **Section 11** for summary description of the process and outcomes of this option.

This option recommends that the outcomes and recommendations from the adaptation study be adopted by Council as a strategy for adapting to future sea level rise in low-lying areas of the Woy Woy Peninsula.

13.3 Emergency Response Modification Options

Emergency response modification measures aim to reduce the consequences of flood risks by:

- Increasing the effective warning time, such as via the use of flood warning systems
- Planning the evacuation of an area so that it proceeds smoothly during a flood event
- Preparing for a flood event (e.g. stockpiling sand and sandbags for future deployment)
- Enabling recovery following a flood event.

These types of measures are typically incorporated into the local flood plan, and education of the community on the contents of the plan is very important. As noted within the Floodplain Development Manual (NSW Government, 2005) these measures effectively modify the response of the community at risk to better cope with a flood event.

Of all the floodplain risk management options available for consideration, it is only emergency management modifications (which includes community planning) that addresses the residual flood risk after all the flood and property modification options have been implemented. Emergency management and education measures are an effective ongoing flood risk management tool (NSW Government, 2005).

13.3.1 EM01 SES Review of Evacuation Centre Locations

Evacuation centres play an important role in the Emergency Response to a major ocean flooding event in the study areas. In this type of flooding event, if shelter-in-place is not possible, residents in Woy Woy might need to travel to an evacuation centre. The relatively slow rate of rise and fall of the floodwaters during an ocean storm event would give people enough time to evacuate safely, however it would also result in properties remaining flooded for a longer period, until floodwaters recede.

In catchment flooding events, the flood depths in properties and roads rise rapidly after the start of the rainfall event, allowing for little response time. Therefore, evacuation in this scenario would be a less viable option and would not be recommended for some locations. However, immediately after the event, the evacuation centres could be required for residents who had their properties significantly damaged.

Evacuation centres identified in the Gosford Local Flood Plan are identified in **Section 10.1**. These, along with other evacuation centres identified in the Brisbane Water Floodplain Risk Management Study are shown below in **Table 13.13**.

Table 13.13 Evacuation Centre Locations

Potential Evacuation Centre	Address	Source
Peninsula Community Centre	93 McMasters Rd, Woy Woy	Gosford Local Flood Plan
Umina Surf Life Saving Club	509 Ocean Beach Rd, Umina Beach	Gosford Local Flood Plan
Ettalong Beach War Memorial Club (Ettalong Diggers)	52 The Esplanade, Ettalong Beach NSW	Gosford Local Flood Plan
Everglades Country Club	Dunban Rd, Woy Woy NSW	Gosford Local Flood Plan
Umina Beach Public School	Sydney Ave, Umina Beach	Gosford Local Flood Plan
Umina Beach PCYC	101 Osborne Ave, Umina Beach	Brisbane Water FRMS

During the PMF event, areas of Umina Beach become flooded, isolated and submerged (refer **Figure I114** in **Appendix I**). In particular, the area west of Ettalong Creek and Iluka Creek become submerged and no access to an evacuation centre is possible because Mt Ettalong Road is inaccessible. Land use in this area is residential without any large-scale building to serve as an evacuation centre. Residents will be left with little choice but to evacuate to other flood free homes.

It is recommended that an evacuation centre be established in this area. There are no current public open spaces outside of the PMF extents. Land may need to be purchased or rezoned (e.g. bushland converted to open space) to provide space for a future evacuation centre. Ideally, this location would also serve multiple purposes, such as a community facility, during dry periods.

Alternatively, if it is not possible to establish an evacuation centre, a Flood Emergency Response Plan should be established specifically local to this area. This may provide instructions on which houses provide shelter (i.e. the extent of non-flood prone homes) in the event of an extreme rainfall event.

13.3.2 EM02 Access Improvements During Flooding

Improved access during a flood event can be achieved by range of different measures, which comprise vehicular access via public roads, pedestrian access to flood refuge areas and regional access to key emergency facilities, including hospitals, ambulance services and evacuation centres.

The *Brisbane Water FRMS* (Cardno, 2015) identified roads for raising based on the impacts of storm surge flooding. This FRMS has reviewed flooding of key access roads associated with catchment flooding and provided recommendations associated with improving the flood immunity of these locations. This option does not necessarily include the roadways recommended for raising as part of the *Brisbane Water FRMS* (Cardno, 2015) and should be considered in additional to the *Brisbane Water FRMS* (Cardno, 2015) recommendations.

The information contained in this option should be used to inform Council decisions on asset upgrades and road maintenance. Detailed assessments prior to undertaking works would quantify the flood behaviour across the assets and allow for design of appropriate upgrades, this may involve road raising, drainage improvement or a combination of both.

Flooding across the study area in the PMF event is extensive and upgrading all roads and cross drainage to have flood free access is not feasible. Instead, a focus on the primary or secondary classified roads (refer **Figure 10.1**) is more realistic. The table below summarises the key access routes that are subjected to high hazard (larger than H2) in the PMF and 1% AEP flood events, based on the flood hazard analysis discussed in **Section 8.2.1**. The 1% AEP flood event displays significantly less flooding across the same road sections, with only two roads modelled as having hazard classifications above H2. This table also identifies the length of the affected sections, as well as the suggested measures to be taken for each section.

Table 13.14 Identification of Key Access Routes Requiring Modification

Road Name	Section	Approximate Extent of Section in PMF Event (and 1% AEP where indicated)	Maximum Hazard Classification in the PMF event	Maximum Hazard Classification in the 1% AEP event
Mt Ettalong Road	From: Etta Road To: North of Etta Road	60 m	H3	
Booker Bay Road	From: Davis Street To: Telopea Street	110 m	H3	
Booker Bay Road	From: Guyra Street To: Mareela Avenue	150 m	H3	
The Esplanade	From: Beach Street To: Kourung Street	300 m	H3	
West Street	From: Fyffe Lane To: Trafalgar Avenue	50 m	H3	
Maitland Bay Drive	From: Picnic Parade To: Booker Bay Road	250 m – PMF 170 m – 1% AEP	H3	H3
Warwick Street	From: Memorial Avenue To: Springwood Street	180 m – PMF 100 m – 1% AEP	H3	H3

Road Name	Section	Approximate Extent of Section in PMF Event (and 1% AEP where indicated)	Maximum Hazard Classification in the PMF event	Maximum Hazard Classification in the 1% AEP event
Veron Road	From: Lovell Road To: Onslow Avenue	190 m	H3	
Gallipoli Avenue	From: Wentworth Avenue S To: Trafalgar Avenue	170 m	H3	
Railway Street	From: Shoalhaven Drive To: Hillview Street	400 m	H5	
Railway Street	From: Walford Street To: Rawson Road	180 m	H3	
Railway Street	From: Charlton Street To: Blackwall Road	300 m	H3	
Blackwall Road	From: Railway Street To: Oval Avenue	100 m	H3	
Brick Wharf Road	From: North Burge Road To: Sonter Avenue	170 m	H3	
Brick Wharf Road	From: Brisbane Water Drive To: Oval Avenue	80 m	H3	

Special consideration needs to be given to road raising designs in the Woy Woy Peninsula. Due to the flat terrain, raising the roads might direct the runoff into private properties, worsening the flood conditions at these locations.

This is by no means an extensive list and considering that during the PMF event flooding is experienced extensively throughout the Woy Woy Peninsula, should be used as a starting point for Council to prioritise road upgrades in concert with existing forward planning of capital works.

Other roads which could be used as evacuation routes, although only considered residential roads, which are subject to flood hazards on the PMF over H2 are: Cowper Road, western extent of Veron Road, Calypta Road, Greenhaven Drive, western extent of Brisbane Avenue, or Springwood Street.

The estimated capital costs involved in raising evacuation routes to the PMF level and 1% AEP flood level are $12.2 million and $1.6 million, respectively. This significant capital cost associated with raising roadways to the PMF level may make it unfeasible. Raising roadways to the 1% AEP level is suggested as this option's preferred action.

This option was split into two sub-options:

- EM02A – Roads raised to 1% AEP level
- EM02B – Roads raised to PMF level

13.3.3 EM03 SES Review of Flood Warning System

Previous Studies providing recommendations for flood warning systems covering this area include:

- Brisbane Water Floodplain Management Plan (Cardno, 2015), and
- Southern Central Coast Storm and Flood Forecasting Study (MHL, 2017).

The Brisbane Water Floodplain Management Plan (Cardno, 2015) provides the following recommendations for the review of flood warning systems in the Brisbane Water foreshore (EM4).

- Ensure that warnings for storm-surge flooding are appropriately distributed (in addition to warnings for catchment flooding) by acknowledging the similarities and differences between the two flooding types.
- Liaise with Council operators and TfNSW so that light-emitting diode (LED) variable messaging signage (VMS) (both permanent and demountable) can be utilised to provide flood warnings.
- Integrate the results of the Brisbane Water FRMS into NSW SES flood planning (e.g. sharing of GIS data for use by NSW SES).
- Develop/review alternative routes and detours and distribute plans as appropriate.
- Undertake periodic liaison (between BoM, NSW SES and Council) to ensure consistency.

These measures would be applicable to Woy Woy and are also proposed in this FRMS.

The flood warning system recommendations in this FRMS are aligned to short term propositions outlined in the Southern Central Coast Storm and Flood Forecasting Study (MHL, 2017). The following short-term recommendations are applicable to Woy Woy:

- Council continues the yearly maintenance of the existing network as part of the “Business As Usual” that costs approximately $55,000-$70,000 per year.
- Review and update of historical flood studies with two-dimensional hydraulic modelling.
- Full operational review of flood infrastructure assets with key stakeholders.
- Update Council flood education strategy and promote SES FloodSafe program
- SES to update the Gosford Local Flood Plan (SES, 2014)
- Promote “Floods Near Me” education.

The flood forecasting study also outlines long-term recommendations applicable to Woy Woy. The proposed measures include the implementation of an Early Warning Network Alert and Flood Forecasting System (EWNAFFS), the development of a web based EWNAFFS portal and the development of a “Floods Near Me” application specific to the Central Coast. This FRMS recommends that these measures are included in Council’s long-term strategy. The flood forecasting study did not include medium-term recommendations relevant to Woy Woy.

In catchment flood events, the flood depths rise rapidly after the start of the rainfall event, allowing for a relatively short response time. For this type of flooding event, an early severe weather alert system would likely be a better option.

In concert with the implementation of the EWNAFFS, Council could also develop an early warning alert database of members, to provide severe weather alerts to registered residents and business owners. Council could deliver alerts to the residents based on weather warning provided by BoM and other sources. These alerts could also include a consideration of the ocean level conditions and how they could interact with the catchment flooding.

The alerts could cover events, such as:

- hail and severe thunderstorms
- destructive winds and cyclones

- floods from a number of different sources including king tide, storm surge and tsunamis.

The wording of these alerts would be critical to ensure unnecessary alarm is not caused, but responsiveness is increased.

Another valuable source of real-time flooding information for Woy Woy is the “Floods Near Me” application, which is a mobile device app that is currently being developed by Manly Hydraulics Laboratory (MHL). The app provides information on current flooding events across NSW, by integrating data sourced from BoM, SES, Transport NSW, and local councils.

Based on the responses of the community questionnaire, the “Floods Near Me” app is not widely used by the community. This might be due to a lack of knowledge on how to use the app or how to interpret the information provided by it. Therefore, it is recommended that guidance on how to effectively use “Floods Near Me” app is included in the flood education program for Woy Woy (**Section 13.3.5**). This app would only be effective for ocean storm events as there are no local catchment gauges in the study area.

The NSW Bureau of Meteorology (BOM) is responsible for issuing warnings when potential flood emergencies are imminent. In New South Wales, these warnings are carried out by the New South Wales and Australian Capital Territory Flood Warning Centre, which is a specialised organization within the BOM. In Woy Woy, the Council, and the SES play an important role in distributing these warning to the local community.

The dissemination of the information received from BoM is integral to the community’s emergency response for catchment and ocean flooding events. The primary objective of this option is to guarantee that the warnings are effectively delivered and that they will trigger the appropriate response from the community.

In order to increase the effectiveness of distributing any extreme weather of flood watch warnings to the community, they should be made available in as many means of communication as possible. Potential suggestions include (and may already be utilised):

- Council’s website and social media pages
- SES website and social media pages
- local radio and TV channels
- community centres and public schools, through printed posters or fliers.

It should be noted, that based on the responses from the community survey (**Section 7.4**), most of the respondents would look for updates or information on radio (27%), on TV (22%), on social media (14%) and Council’s website (18%). Therefore, it is recommended that these avenues be targeted when releasing information related to weather and flood warnings. Note that currently, the SES sends out warnings via SMS and email.

13.3.4 EM04 Flood Signage

Flood warning signs and depth markers could be positioned in roads that are subjected to frequent flooding, to inform drivers and prevent potential accidents.

In order to assess the locations where it would be relevant to position these signs/markers, the roads which were subjected to flood depths greater than 0.3 m in the 20% AEP flood event (catchment flooding) were identified. These nineteen locations are:

- Brick Wharf Road
- Oval Avenue
- George Street
- Warwick Street
- Onslow Avenue

- Mackenzie Avenue
- Dulkara Road
- Shoalhaven Drive
- Veron Road
- Lentara Road
- Karloo Road
- Numby Close
- Connex Road
- Shepard Street
- Casuarina Close
- Heritage Close
- Glenhaven Close
- Neera Road
- Edgecliff Road

If the criteria were changed so that flood depth markers were placed where flood hazard in the 1% AEP is greater than H2, the five locations where this would apply to are:

- Neera Road
- Karloo Road
- Numby Close
- Dulkara Road
- Warwick Street

It is not safe to drive through flood waters in general. These locations have been identified based on their hazard and therefore flood risk.

However, the use of depth markers in most of the locations identified above might not necessarily be the best approach. The main reason is that some of these are residential roads, with relatively small traffic flow and low speed limits. In addition, home-owners adjacent to depth markers may object to the placement of these for fear that they may impact future property purchase, by creating the perception that their properties are flood affected. For these roads, the installation of a flood warning or infographic sign may be more appropriate, identifying that the road may generally be subject to flooding during extreme rainfall events, rather than targeting a specific location on a road. This information could be supported through public education programs relating to driving through flood waters.

Furthermore, signage could also be implemented to discourage cars from driving through flood waters in streets. The wash from passing cars was identified by several residents at the drop in sessions as a major issue for impacting houses along these streets. This can also be incorporated into a flood education program (refer **Section 13.3.5**).

Where the initial list (depths greater than 0.3 m in the 20% AEP event) intersects with locations noted in **Table 13.14**, flood depth markers should be used as these are important evacuation routes. Most notably, this includes Veron Road and Brick Wharf Road.

It is recommended that flood markers or signage be placed, at minimum, where hazard classifications of 1% AEP flood flows across roads are greater than H2 are located. However, consideration should be given to additional markers placed where flood depths on roads during the 20% AEP event are greater than 0.3 m. Homeowners should be consulted prior to placement of flood depth markers in front of their properties.

The overall recommendation of this option is:

- At minimum, have depth markers or signage where flood hazard in the 1% AEP is greater than H2
- Depth markers should be located along evacuation routes

- Flood warning signs should be located along on secondary roads

13.3.5 EM05 Flood Education Programs

It cannot be assumed that all residents within the study area are sufficiently aware of the flood risk they are subjected to and how to respond to a major flood event. For this reason, flood Education Programs are essential to promote continuous flood awareness in the community and to guarantee people understand their role in the overall floodplain management strategy for the study area and are able to respond quickly and effectively to an emergency. During a major flood event it is unlikely that emergency response services, such as the SES will have time and resources to assist all flood-affected residents. Therefore, the community's readiness and preparedness have a substantial impact in preventing loss of life and damages to properties.

The Woy Woy Peninsula can be affected by both catchment flooding and foreshore inundation due to ocean storm events. In the study area, during catchment flood events, flood depths increase quickly allowing for little response time. Foreshore inundation, on the other hand, is usually characterised by a slow rate of rise and fall of flood waters, which means the community would potentially have time to evacuate safely and potentially prepare their property (i.e. move vehicles to higher ground and possessions to higher levels in their house), however, properties would remain flood affected for a longer period of time. It should be noted that ocean flooding events can occur concurrently or separately from catchment flooding. Therefore, it is important that public education progress address the two different types of flooding and what would be the adequate response for each.

The availability of reliable flood warnings for areas impacted by catchment flooding is limited. For this reason, in order to get the most benefit out of the warnings that are available, residents in the floodplain need to have an adequate understanding of the potential effect flooding would have on their property and the access routes in their local area. People will also need to know how to react to a flood situation and be able to assess when it is safe and necessary to evacuate and what would be the best way to do it.

It is also important to ensure residents understand the difference between smaller more frequent floods and rarer larger events and how they respond in each situation. In addition, residents need to understand how to respond to catchment flooding verses flooding from Brisbane Water.

According to responses from the resident survey, most residents (91%) report to be "aware" or "somewhat aware" of flooding in the region.

When asked how they would react in a major flood event 42% of the residents responded they would remain at their houses or they didn't know or are unsure of what they would do. Around 23% responded they would stay because they believe their house could cope with flooding. Therefore, even though the survey suggests a high level of awareness, it is important to question whether the residents fully understand how they would be impacted by a larger, rarer flood which exceeds the frequent flooding they are accustomed to dealing with.

A key aspect on any flood awareness program within Woy Woy is clear explanation of the different flood risks associated with catchment and Brisbane Water flooding and how responses to these types of floods may vary, e.g. staying at home may be viable (and safer) during a catchment event, but in some locations may not be safe during a large ocean surge storm event, where over floor flooding or several hours of isolation may not be tolerable or safe.

Council's Flood Education Strategy is outlined in a working document, which summarises flood education objectives, measures, and resources. However, it is understood that this document has not been updated recently and does not reflect Council's existing practices.

Taking into consideration what has been discussed in this section, it is recommended that the existing Flood Education Strategy is reviewed and updated. The updated strategy should contemplate the following awareness campaigns for the floodplain. These should be prepared together with the SES, as they have joint responsibility for community awareness under the DISPLAN.

- Preparation of a FloodSafe brochure relevant to the study area by the SES, for both residential and business premises. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information. Once prepared, the FloodSafe brochure can then be uploaded to the Council and SES websites in a suitable format, where it would be made available under the flood information sections of the website. The brochures could also be made available at Council offices and community halls. The brochure should address both catchment flooding and foreshore inundation, or separate brochures be prepared.
- Targeted awareness programs for specific groups of residents, such as residents in retirement villages (e.g. HammondCare Woy Woy, Bluewave Living, etc.), or residents that may be cut off from transport routes and isolated. Examples of the areas that could be potentially isolated include the properties west of Mount Ettalong Road. Other potentially isolated areas are identified in the FERC figures (I110 to I114).
- Development of a Schools Package from existing material developed by the SES and distribution to schools accordingly. Education is not only useful in educating the students but can also be useful in dissemination of information to the wider community.
- A regular (annual) meeting of local community groups to arrange flood awareness programs on a regular basis. Engaging with long term residents who have memories of past flood events can be useful to share this knowledge with other residents at these events.
- Flood awareness information, including the FloodSafe brochure and relevant warnings should be regularly distributed at community events and gatherings. Information should also be provided on existing flood planning controls and their benefits to the wider community, as well as consequences of non-compliance.
- Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.
- Prepare educational materials of the flood planning controls that apply to them and their properties, as well as the consequences of non- compliance.

One of the primary challenges in flood emergency planning is maintaining flood awareness during extended periods when major flooding does not occur. Therefore, a continuous awareness program needs to be undertaken to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to take into consideration the changing circumstances of flood behaviour and new development. An effective flood awareness program requires ongoing commitment.

Therefore, it is recommended that Council's team includes a dedicated person (or group of people) responsible for guaranteeing the effective and consistent implementation of the Flood Education Strategy. The dedicated officer would coordinate the flood education program across the entire LGA, overseeing the implementation of awareness campaigns and the development of educational material, as well as collecting constant feedback from the community.

The involvement of the SES in the flood education program in Woy Woy should be reinforced. The outcomes of the engagement process suggest the SES participation would positively impact the community's perception of the program and consequently lead to more effective results.

Another aspect that needs to be reinforced is that the flood language used in the flood awareness program is accessible and that it effectively communicates the level of flood risk. Therefore, it is important to consider how to better express technical terminology, such as flood frequency and magnitude, so that the information will be absorbed by the community.

This option should be considered in conjunction with other property risk education programs in the FRMP, such as those recommended in **Section 13.2.4**.

This option should be built into existing LGA wide flood education programs and not just apply to the study area of this FRMS.

14 Multi-Criteria Assessment

A Multi-Criteria Assessment (MCA) approach has been developed by Council's technical working group for the comparative assessment of all floodplain management options identified within the study area using a similar approach to that recommended in the Floodplain Development Manual (NSW Government, 2005). This approach uses a subjective scoring system to assess the merits of various options. This assists Council in identifying the flood mitigation options that provide the most benefits for the community, by comparing all options across the entire study area against each other based on factors including, but not limited to, the reduction in flood risk and economic flood damages.

The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index, as well as making the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute "right" answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned. Therefore, the MCA provides opportunities for the direct participation of stakeholders in the analysis.

Each option is given a score according to how well the option meets specific considerations. A framework for scoring has been developed for each criterion.

14.1 Scoring System

A scoring system was devised to subjectively rank each measure for a range of criteria considering the background information on the nature of the catchment and floodplain. The scoring is based on a triple bottom line approach incorporating economic, social, and environmental criterion.

Each of the criteria has been given a preliminary weighting from 1 to 5 to reflect its importance with regards to floodplain management. This weighting has been based on the project team's understanding of flood risk in the local area, existing Council policies, community input, and other available data. The responses to the community engagement survey and found in **Section 7.4**. The weighting aims to retain the focus of the options on managing flood risk, while still considering other values in the study area. The weightings will be reviewed with regards to submissions received from the public during the public exhibition period.

The categories and criteria adopted are:

- Economic
  - Reduction in flood damages
  - Capital cost of option
  - Operating and maintenance costs of option
  - Implementation complexity
  - Ability to stage works
  - Availability of financial assistance
- Social
  - Increased community flood awareness
  - Reduction in risk to like
  - Emergency access and traffic disruption
  - Compatible with Council's Plans and Policies
  - Likely community support

- Environmental
  - Flora / fauna impacts
  - Visual impacts
  - Recreational space
  - Water quality

Each criterion has been allocated a preliminary weighting based on the flood behaviour, outcomes of previous community engagement and other similar studies. These weightings will be reviewed with regards to submissions received from the public during the public exhibition period.

The details of each criteria, the scoring system applied, and the relevant weightings are provided below in **Table 14.1.**

Weighting for all environment criteria combined is 5. It is assumed that all options identified would need to mitigate against any environmental impacts. The focus of the options are on assessing flood risk and therefore the criteria have focused on their relevant benefit in providing a reduction in that flood risk. If an option considered has a significant environmental impact which cannot be mitigated, then the option is considered not viable and shouldn't proceed.

The most important criteria are the reductions in flood damages, capital cost, risk to life, and ongoing costs. These are given a weighting of 5.

Table 14.1 MCA Criteria Descriptions and Weighting

Category	Criteria	Criteria Description	Criteria Weighting	Metric	-3	-2	-1	0	1	2	3
Economic	Reduction in Flood Damages	Where an economic assessment has been undertaken for an option, this would be an explicit value. Where no economic assessment has been undertaken, this should be an estimate based on catchment damages and flood behaviour. An increase in annual average damages which cannot be mitigated would exclude the option from being recommended overall.	5	Change in Annual Average Damage	> $500,000	$50,000 to $500,000	< $50,000	No change	> -$50,000	-$50,000 to -$500,000	< -$500,000
	Capital Cost	Cost of constructing or implementing the option.	5	Capital cost of option	> $500,000	$50,000 to $500,000	< $50,000	Existing infrastructure or council policy continued	N/A	N/A	N/A
	Operating and Maintenance Costs	Annual costs associated with operation and / or maintenance of the option. This is assumed to be in addition to existing maintenance programs undertaken by Council.	5	Annual operating cost of option	> $50,000	$5,000 to $50,000	< $5,000	No cost in addition to council's existing maintenance program	< -$5,000	$-5,000 to -$50,000	> -$50,000
	Implementation Complexity	Consideration of constraints related to implementing the option (e.g. traffic impacts, works located on private property, etc).	2	Implementation or construction timeframe and challenges	Implementation timeframe > 1 year with major constraints, challenges and uncertainties which may render the option unfeasible	Implementation timeframe > 1 year with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes slightly	N/A	Implementation timeframe < 6 months with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe < 6 months with constraints, challenges and uncertainties which may increase costs or timeframes slightly	Implementation timeframe < 6 months with no constraints or challenges / No construction requirements (e.g. planning related option)

Category	Criteria	Criteria Description	Criteria Weighting	Metric	-3	-2	-1	0	1	2	3
	Staging of Works	If works can be staged this may increase the viability of the option, by spreading out costs.	2	Ability to stage proposed works	N/A	Works cannot be staged, very high capital cost	Works cannot be staged, high capital cost	Works cannot be staged, low capital costs	Some minor components of the works may be staged	Significant components of the works can be staged	N/A
	Availability of Financial Assistance	Can funding be sought from higher levels of government, grant programs or developers?	4	Availability of funding streams	N/A	N/A	No external funding available	N/A	Some external funding is available	A significant amount of contribution could be sought	A majority of contribution could be sought
Social	Increased Community Flood Awareness	Increased flood awareness often results in a community preparing and responding to flooding better. This can result in both a reduction in property damages, social disruption and risk to life.	2	Level of likely increased awareness	N/A	N/A	N/A	No increased awareness of flooding and appropriate response	N/A	Increased awareness likely to protect property	Increased awareness likely to protect life
	Reduction in Risk to Life and Property	Reduction in risk to life and social impacts can be achieved by reducing the number of properties being flooded, or through other means such as reducing flood depths on roads, informing the community of flooding (e.g. flood depth markers).	5	Change in number of properties with over floor flooding in 1% AEP event	Increase: > 10 properties	Increase: 5 to 10 properties	Increase: 1 to 5 properties	No change	Reduction: 1 to 5 properties	Reduction: 5 to 10 properties	Reduction: > 10 properties
	Emergency Access and Traffic Disruption	Reducing flooding of access routes, or providing alternative access during flooding.	4	Flood depth and duration changes for critical transport routes in 100 Year ARI event	Key access roads become flooded that were previously flood free	Significant increase in local or main road flooding	Minor increase in local or main road flooding	No change	Minor decrease in local or main road flooding	Significant decrease in local or main road flooding	All roads flood free in vicinity of option
	Compatible with Council's Plans and Policies	Are the works permissible within the landuse zone, and in accordance with the DCP	2	Level of compatibility	Conflicts directly with objectives of several plans and policies	Some conflicts with several objectives or direct conflicts with one or few objectives	Minor conflicts with one or very few objectives	Not relevant to objectives	Minor support for one or very few objectives	Some support for several objectives or achieving one or few objectives	Achieving objectives of several plans and policies
	Likely Community Support	Likely community support to be estimated based on previous community engagement, and public exhibition of draft FRMS.	3	Level of agreement	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	No responses	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions

Category	Criteria	Criteria Description	Criteria Weighting	Metric	-3	-2	-1	0	1	2	3
Environmental	Flora/Fauna, Visual, Recreational Space, and Water Quality Impacts	Impacts on flora and fauna based on Council's vegetation GIS data and the presence of vegetation noted during site inspections. Impact on the visual amenity of the area. Impact on the quality, total area, and accessibility of open spaces. Impact on measurable water quality such as sedimentation, pollutants, oxygen levels, etc.	5	Estimated qualitative impact on environmental assets	Significant or catastrophic impact on environment. Complete loss or deterioration of assets. Option would not be viable because environmental impacts cannot be mitigated.	Likely impact on environment. Minor reduction or some deterioration of assets. Can be mitigated.	Isolated impact on environment. Likely to recover over medium term. Can be mitigated	No impacts or neutral outcome	Minor improvement in environment, with isolated improvements in quality/quantity of assets.	Moderate improvement in environment, with multiple instances of improvements in quality/quantity of assets.	Significant lasting improvement in environment, with widespread improvements in quality/quantity of assets.

14.2 Outcomes

The results of the MCA, including the score for each criterion assigned to each option and the calculated total score, is shown in its entirety in **Appendix O**. An MCA rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are shown in both **Table 14.2** and **Appendix O**.

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring shown in **Appendix O** is not "absolute" and the proposed scoring and weighting should be reviewed carefully as part of the process of finalising the overall Floodplain Risk Management Plan.

Table 14.2 Multi-Criteria Outcomes

Option ID	Option Description	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	Score	Rank		
FM01	Woy Woy CBD drainage upgrades	$1,708,840	$ 500	$ 176	0.00	-14.0	18	8	Flood Modification Measures Rank
FM02	Dulkara Road to Karringal Close drainage upgrades	$653,100	$ 500	$ 14,457	0.32	-15.0	19	9	
FM03	Infiltration Devices	$25,000 each	$ 1,250 each	N/A	N/A	11.0	6	1	
FM04	Groundwater pumping and Everglades drainage update work	$ -	$ 4,000	N/A	N/A	-1.0	11	3	
FM05	Greenhaven Drive drainage upgrades	$163,520	$ -	$ 15,247	1.38	0.0	10	2	
FM06A	Review Kahibah Creek system maintenance	$ -	$ 320,000	$ 803	0	2.0	20	10	
FM06B	Increase Kahibah Creek system maintenance	$ 300,000	$ 200,000	N/A	N/A	-9.0	15	6	
FM08	Palmtree Grove detention basin reduced capacity	$295,400	-$ 30,000	-$ 2,822	3.54	-3.0	12	4	
FM09	Wilks Avenue and McManus Close drainage upgrades	$ 80,920	$ -	N/A	N/A	-10.0	16	7	
FM10	Neera Road drainage upgrades	$ 138,800	$ -	N/A	N/A	-3.0	12	4	
PM03	Voluntary House Raising	$100,000 per house	$ -	$10K - $20K per house	< 0.1	3.0	9	8	Planning Measures Rank
PM04	Property Flood Risk Education Program	$ -	$ 2,000	N/A	N/A	5.0	7	6	
PM05	Property Education and Compliance	$ 80,000	$ 5,000	N/A	N/A	4.0	8	7	
PM06	Sustainable Level of Drainage Service	$ 20,000	N/A	N/A	N/A	13.0	3	3	
PM07	Landform Adaptation	$2.0M to $49.6M	$ -	$1,000 to $10,000 per property	0.2 to 0.8	53.0	1	1	
EM01	SES Review of Evacuation Centre Locations	$ 10,000	$ -	N/A	N/A	12.0	5	5	
EM02A	Access Improvements During Flooding to 1% AEP	$1,610,000	$ -	N/A	N/A	-13.0	18	10	
EM02B	Access Improvements During Flooding to PMF	$12,225,500							
EM03	SES Review of Flood Warning Systems	$50,000	$10,000	NA	NA	-5.0	15	9	

EM04	Flood Warning Signs	$5,000 each	$ -	NA	NA	19.0	2	2	
EM05	Flood Education Programs	$10,000	$2,500	NA	NA	13.0	3	3	
PM02	Voluntary House Purchase	No properties qualify for a Voluntary House Purchase Program							

15 Conclusion remarks and recommendations

This report presents the findings of the Floodplain Risk Management Study stage of the Flood Risk Management Process for the Woy Woy peninsula, in accordance with the *Floodplain Development Manual* (NSW Government, 2005). The investigations undertaken as part of this process identified a number of issues within the floodplain. Based on these issues, a series of floodplain management options were developed and recommended.

The outcomes of the multi-criteria assessment provide a sound basis upon which Council can make decisions about undertaking works, making planning decisions and developing response arrangement to reduce the impact of flooding on property and life.

The implementation strategy associated with the outcomes of this study may not necessarily approach the options from “highest ranking to lowest ranking” but will also need to incorporate various other considerations such as existing works programs, availability of funding and other opportunities to combine floodplain works with other activities.

The options identified as having significant flood risk reductions that also do not have adverse social or environmental impacts will be incorporated into the Floodplain Risk Management Plan as proposed management actions. This document will provide a realistic strategy to manage flood risk and will outline the process of implementation for recommended management actions within the floodplain.

The table below summarises the recommended options.

Table 15.1 Recommended Options

Option ID	Description	Multi-Criteria Assessment Ranking	Notes
FM03	Infiltration Devices	Flood Modification – 1 Overall – 6	
PM01	Land Use and Development Control Planning Recommendations	N/A	
PM04	Property Flood Risk Education Program	Planning – 6 Overall – 7	To be combined with EM05 as part of the FRMP.
PM05	Property Education and Compliance	Planning – 7 Overall – 8	
PM06	Sustainable Level of Drainage Service	Planning – 3 Overall – 3	Combined with FM03 where possible
PM07	Landform Adaptation	Planning – 1 Overall – 1	

Option ID	Description	Multi-Criteria Assessment Ranking	Notes
EM01	SES Review of Evacuation Centre Locations	Planning – 5 Overall – 5	
EM03	SES Review of Flood Warning Systems	Planning – 9 Overall – 14	
EM04	Flood Warning Signs	Planning – 2 Overall – 2	
EM05	Flood Education Programs	Planning – 3 Overall – 3	To be combined with PM04 as part of the FRMP.

Other options evaluated which may be further considered if Council deems it necessary include:

- FM05 Greenhaven Drive – The resulting BCR of 1.3 suggests that this option may have further merit. This was not recommended as it received an overall ranking of 11 and would take significant capital cost to implement.
- FM08 Palmtree Grove Detention Basin Reduced Capacity – The option results in minor increases in rainfall event flood risk to downstream properties in the 20% AEP. While undesirable, refinement of the basin design may eliminate this or other mitigation measures may be implemented. The benefits of a reduced flood risk from a dam break scenario have not been considered in this option, but should be considered if further assessment is undertaken. The resultant BCR for this option was 3.54 and its overall rank was 13.

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/25/ Kellogg Brown & Root (2005) Everglades Lagoon System Precinct, Plan of Management

/26/ Manly Hydraulics Laboratory (2017) Southern Central Coast Storm and Flood Forecasting Study