Woy Woy Floodplain Risk Management Plan

Final Draft

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Foreword

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

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

The Central Coast Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or DPE.

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

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

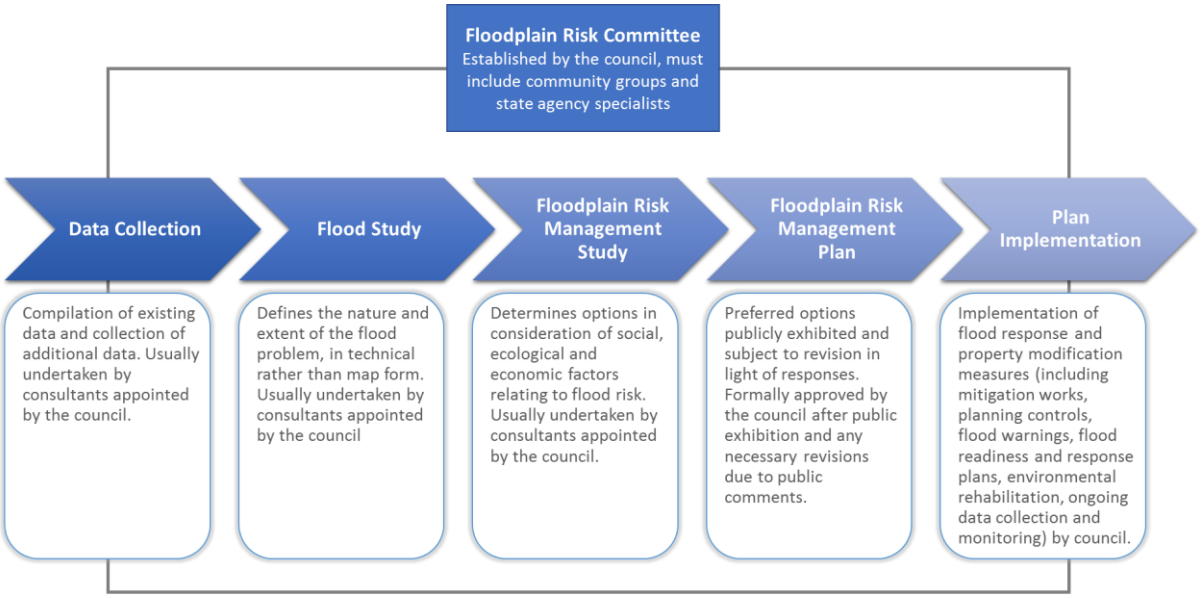

Figure F1 The Floodplain Risk Management Process (source: NSW Government, 2005)

Central Coast Council is responsible for local land use planning in its service area, including in the Woy Woy Peninsula. Through its Catchments to Coast Committee, Council has committed to prepare a comprehensive floodplain risk management plan for the study area in accordance with the NSW Government's *Floodplain Development Manual* (2005). This document relates to the floodplain risk management plan phase of the process.

Executive Summary

Study Overview and Purpose

The Woy Woy Floodplain Risk Management Plan (FRMP) 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).

This FRMP is to be considered in conjunction with the Woy Woy Floodplain Risk Management Study (FRMS), and its associated Technical Volume and Appendices, prepared as a separate document to this FRMP. The FRMS (DHI, 2022), examined options for managing flood risk in the Woy Woy Peninsula. This FRMP outlines the floodplain management measures recommended as an outcome of the assessment undertaken in the FRMS along with the implementation strategy associated with those measures.

In addition to the FRMS, the following associated studies were undertaken on behalf Council for the purposes of preparing this FRMP:

- Woy Woy Climate Change Adaptation Study (Rhelm, 2021b) to identify feasible strategies to adapt the low-lying areas of Woy Woy to the impacts of sea level rise.
- Woy Woy Integrated Water Management Cycle and Case Study Everglades Catchment (DHI, 2021) to define flooding in this catchment utilising an integrated surface water and ground water model, and identify potential solutions to mitigate flooding.

The findings of these studies were also considered in the recommendations presented in this FRMP.

The overall objective of this Floodplain Risk Management Plan is to provide information for the management of flood risk into the future.

This FRMP outlines a range of measures to manage existing, future and residual risk effectively and efficiently. This document also presents a prioritised implementation strategy to guide the implementation of the proposed measures.

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 Peninsula, including the Kahibah Creek Catchment, is generally a flat sand-plain where ground levels typically vary between RL 2m to 6m (AHD). The remaining study area adjoins the National Park and Blackwall Mountain and is of higher elevation with rocky outcrops. The majority of the catchment is characterised by predominantly low-medium density urban development. The study area is approximately 18.5 km^2.

Flood Risk

The study area can be impacted by different mechanisms of flood risk, which can be characterised as follows:

- **Brisbane Water flooding as a result of ocean storms:**
  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 Woy Woy, Blackwall, Booker Bay and Ettalong. During Brisbane Water flooding events, flood levels typically rise and fall over several hours, with inundation occurring for up to 5 hours in a 1% AEP event. Flood depths in lower lying areas can be up to 0.9 m at the peak of the 1% AEP flood event.

- **Local catchment flooding as a result of local rainfall**:
  Catchment flooding occurs as a result of intense rainfall on the catchment, with the greatest modelled flood depths occurring as a result of a shorter duration storm events (typically one to six hours) for most design floods. This type of flooding is typical of the flat sand-plain central area that comprises about 90% of the Woy Woy Peninsula, which is partially mitigated by the infiltration of runoff into the highly permeable sandy soils beneath. However, high groundwater levels can reduce infiltration and sometimes exacerbate flooding in these lower areas. Flooding in the flatter areas is generally low-risk nuisance flooding associated with peak depths in roads and private property up to 0.3 m. High groundwater levels that can exacerbate surface flooding is found west of Ocean Beach Road near Ryans Road. Catchment flooding in areas with steeper gradients, such as the slopes of Blackwall Mountain and along the western escarpment, are associated with and less permeable soils and produce higher velocity runoff. Flooding of roads and private properties in these areas is usually accompanied by relatively greater flooding of roadways and property along drainage pathways and trapped low points with flood depths of up to 0.8 m at the peak of the 1% AEP flood event.
- **Tidal inundation during high tides**:
  The existing flood risk associated with tidal inundation is low in comparison to the other mechanisms of flooding. However, it is expected that in the future, as a result of sea level rise, a large proportion of the study area will be subjected to relatively frequent inundation from high tides.

Consultation

The community engagement strategy undertaken as part of this FRMS and FRMP includes the following components:

- Community newsletter and questionnaire
- Project website
- Publication of media releases
- Community information (drop-in) sessions
- Agency consultation
- Stakeholder meetings
- Public Exhibition.

The community and other stakeholders provided valuable insights about the flooding issues experienced in Woy Woy and how they could be addressed. The potential flood risk management measures identified and assessed as part of the FRMS addressed the reported issues, considering potential impacts, technical constraints, and the current understanding of the local flood behaviour.

A more detailed description of the community consultation strategy adopted in the FRMS and FRMP is provided in **Section 2.4** of this document.

Floodplain Risk Management Study

The Woy Woy Floodplain Risk Management Study (DHI, 2022) provides a comprehensive evaluation of the flood risks in Woy Woy and identified potential options to mitigate these risks.

The key outcomes of the FRMS include:

- Engagement with the local community to gather historical and anecdotal flood information and provide an avenue for direct community involvement in the study.

- Evaluation of flood risk to the community based on the outcomes of a revised and calibrated flood model incorporating the effects of groundwater in the study area. This analysis included flood hazard and emergency response mapping, and economic damages assessments.
- Review of flood planning policy, including flood-related controls covered by the LEP, relevant DCPs, Council policies and plans. The recommendations proposed as an outcome of this review are presented in this FRMP.
- Identification of a range of flood mitigation measures to address existing and future flood risk and evaluation of these measures with the use of a Multi-Criteria Assessment (MCA) approach. The MCA enabled the comparative assessment of all options based on their economic, social, and environmental aspects, as well as on their effectiveness in mitigating flood risk.

This FRMP has drawn from the conclusions of the analysis undertaken in the FRMS and present the recommended measures for managing flood risk at Woy Woy, as well as the strategy to implement these measures.

Climate Change Flood Risk and Planning

A climate change adaptation study was recently undertaken by Council (Rhelm, 2021b), which has informed this Plan; it focused on the technical analysis of a raised landform to provide flood protection against existing and future flood risk.

The proposed concept landform provided for fill to raise properties and infrastructure above defined flood and tidal levels, as well as being designed to improve runoff during rainfall events (current drainage issues are primarily associated with the flat terrain). Drainage and flood protection measures such as easements were also incorporated into the concept designs.

The findings of the climate change adaptation study (Rhelm, 2021b) are presented in **Section 3.**

Recommended Floodplain Risk Management Measures and Implementation Program

The outcomes of the options analysis undertaken in the FRMS form the basis of this FRMP. A detailed description of the recommended floodplain risk management measures is provided in **Section 4.2**.

Table E-1 summarises the recommended measures categorised by mitigation type (Flood Modification, Property Modification, and Emergency Response Modification).

Table E-1 Summary of Recommended Floodplain Risk Management Measures

Mitigation Type	Option ID	Option Name	Implementation Time Frame / Priority
Flood Modification	FM03	Installation of six infiltration devices along low lying streets with a history of ponding and nuisance flooding due to lack of drainage or drainage capacity	< 10 years / Medium
Property Modification	PM01	Land Use and Development Control Planning Recommendations	< 5 years / High
	PM05	Property Education and Compliance	< 5 years / Medium
	PM06	Sustainable Level of Drainage Service	< 10 years / Medium
	PM07	Landform Adaptation	< 10 years / High

Mitigation Type	Option ID	Option Name	Implementation Time Frame / Priority
Emergency Response Modification	EM01	SES Review of Evacuation Centre Locations	< 5 years / Medium
	EM03	SES Review of Flood Warning Systems	< 10 years / Low
	EM04	Flood Warning Signs	< 5 years / Medium
	EM05	Flood Education Programs	< 5 years / Medium

Priorities of each option are categorised as High, Medium and Low in the following manner:

- **High priority:**
  - Require relatively low implementation effort and cost AND achieved a high score in the MCA (overall rank higher than 5).
  - Essential for a future climate change adaptation plan to be implemented before sea level rise triggers are reached.
- **Medium Priority:**
  - Requires significant implementation effort and cost AND achieved a high score in the MCA (rank higher than 5).
  - Achieved a medium score in the MCA (overall rank higher than 10).
- **Low Priority:**
  - Achieved a relatively low score in the MCA (overall rank lower than 10).

To achieve the implementation of relevant management actions, a program of implementation has been developed. The proposed implementation strategy is presented in **Section 4.3**. The proposed program provides information on the estimated costs of each measure, the agency / organization responsible for the action, as well as the priority and time frame for implementation.

Conclusions and Recommendations

This FRMP provides a practical framework and implementation plan for managing existing, future and continuing flood risk within the study area.

Overall, it is considered that existing flood risks to Woy Woy can be managed appropriately through the implementation of development controls, emergency response measures and selected ground works. The effective implementation of development controls will be of key importance in reducing the damages and risk to life associated with flooding into the future through the construction of flood compatible buildings and assets.

This FRMP fulfills its objectives in accordance with the NSW Flood Prone Land Policy (NSW Government, 2001) and the principles of the Floodplain Development Manual (NSW Government, 2005).

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Glossary

Annual exceedance probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m^3/s (or larger) occurring in any one year.
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Attenuation	Weakening in force or intensity.
Catchment	The catchment, at a particular point, is the area of land that drains to that point.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year ARI or 1% AEP flood).
Development	Is defined in Part 4 of the EP&A Act as: - Infill Development: development of vacant blocks of land that are generally surrounded by developed properties. - New Development: development of a completely different nature to that associated with the former land use. - Redevelopment: Rebuilding in an area with similar development.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Awareness	Awareness is an appreciation of the likely effects of flooding and knowledge of the relevant flood warning, response ad evacuation procedures.
Flood Education	Education that seeks to provide information to raise awareness of the flood problem to enable individuals to understand how to manage themselves and their property in a flood event.
Flood hazard	The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as “stage”.
Floodplain	Area of land which is subject to floods up to and including the probable maximum flood.
Floodplain risk management plan	A document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan needs to be developed in accordance with the principles and guidelines contained in the NSW Floodplain Development Manual. The

	plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives.
Flood planning area (FPA)	The area of land below the flood planning level or other flood level defined in the FRMP that is subject to flood related development controls.
Flood planning levels (FPLs)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also consider the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plans. The concept of FPLs supersedes the "standard flood event". As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Hazard	A source of potential harm or a situation with a potential to cause loss.
High high water springs (HHWS)	The highest of all high water observations at the time of spring tide over a period of time (generally 19 years).
Historical flood	A flood that has actually occurred.
Hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems, in particular the evaluation of flow parameters such as water level and velocity.
Mean high water springs (MHWS)	"Every day" tidal inundation caused by high tides. The MHWS tide is the average of all high water observations at the time of spring tide over a period of time (generally 19 years).
Peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood that could conceivably occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian	The interface between land and waterway. Literally means "along the river margins".

Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Topography	The shape of the surface features of land.
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi-2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

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

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
BoM	Bureau of Meteorology
CCC	Central Coast Council
DCP	Development Control Plan
DPE	Department of Planning and Environment (formerly DPIE)
DPIE	Department of Planning, Industry and Environment (now DPE)
IWCM	Integrated Water Cycle Management
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FRMSP	Floodplain Risk Management Study and Plan
ha	hectare
HHWS	High high water springs
km	kilometres
km^2	Square kilometres
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
m	metre
m^2	Square metres
m^3	Cubic metres
m AHD	metres to Australian Height Datum
mm	millimetres
m/s	metres per second
MHWS	Mean high water springs
NSW	New South Wales
PMF	Probable Maximum Flood
SES	State Emergency Service (NSW)

1 Introduction

The Woy Woy Peninsula lies adjacent to the Brisbane Water Estuary within the Central Coast Council Local Government Area (LGA). The catchment is subject to flood inundation associated with both catchment and estuarine flooding.

The Woy Woy Floodplain Risk Management Plan (FRMP) has been prepared for Central Coast Council (Council) and 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 FRMP outlines the floodplain management measures recommended to mitigate flood risk in the Woy Woy Peninsula, along with the implementation strategy associated with those measures.

This FRMP is to be considered in conjunction with a Floodplain Risk Management Study (FRMS), prepared as a separate document to this FRMP. The FRMS provides a detailed assessment of the flood risks in the study area and examines potential options for managing these risks. The FRMS presents the technical analysis which supports the recommendations proposed in this FRMP. The FRMS also includes an upgrade in modelling techniques and methodology from the previous Woy Woy Peninsular Flood Study completed in 2010.

Typically, a FRMP follows closely behind a flood study for a catchment; however, due to the unique characteristics of the study area and exposure to storm surge it was determined that prior to a FRMP being developed for the Woy Woy community, completion of the Brisbane Water Foreshore Floodplain Risk Management Plan was critical to understanding how the different flood behaviour would have on mitigation measures to ensure that there was no maladaptation. The Brisbane Water Foreshore FRMP was adopted in 2015.

1.1 Report Context

The Woy Woy Peninsula is subject to a complex range of flood risks, including catchment flooding associated with rainfall on the local catchments, flooding from Brisbane Water caused by ocean storm surge and regional rainfall, and inundation of foreshore areas from extreme tides. Some portions of the study area are also affected by mainstream flooding from the Kahibah Creek and Main Drain systems. Additionally, and specific to low-lying areas with highly permeable sandy soils, groundwater levels affect the flooding behaviour seen throughout the study area. High groundwater levels can prevent infiltration into the underlying soils and, if elevated enough, can be a source of flooding for areas with otherwise poor drainage. These flood risks are expected to be aggravated by the effects of climate change.

Several significant flooding and climate change investigations have previously been completed to better understand flood behaviour across the Woy Woy Peninsula.

The Woy Woy Peninsular Flood Study completed by DHI in 2010 provided Council with a better understanding of the flood behaviour in the study area. The Flood Study demonstrated the importance of the interaction of coastal inundation, groundwater conditions and the increasing effects of development on flood characteristics.

The Woy Woy Integrated Water Management and Case Study Everglades Catchment (DHI, 2021) assessed a selection of integrated management options for alleviating flooding in the Everglades catchment. It recommends a series of flood mitigation options as well as a revision to Council's Black Spot Policy. This policy applies to land in the Woy Woy Peninsula where no underground drainage exists and on-site detention is not a satisfactory solution. Council may, in its discretion, refuse any development application

which would have the effect of increasing runoff from the site, until such time as the necessary work can be funded and carried out to relieve the drainage issue, unless the developer undertakes to provide the necessary infrastructure to deal with the existing problem as well as the compounding effect of the development.

As part of the Integrated Water Management Study, the hydraulic model developed in the 2010 Flood Study was updated. The update had the purpose of providing a more accurate and up-to-date representation of the hydrogeological properties of the Woy Woy Peninsula. The model was also extended to include the Kahibah Creek catchment and the overall study area for the Woy Woy FRMS.

Flood impacts due to ocean-driven storm events within the Brisbane Water estuary are detailed in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013) and subsequent Brisbane Water Foreshore Floodplain Risk Management Study and Plan (Cardno, 2015a and 2015b). Regional scale options for managing the flood risk from ocean storm events were considered in the latter study, including options to develop climate change adaptation plans, install flood related signage, review flood warning systems, review evacuation centre locations, and enhance road evacuation routes in the Woy Woy Peninsula.

The Woy Woy Floodplain Risk Management Study (DHI, 2022) provided a comprehensive evaluation of the flood risks in the Woy Woy Peninsula and investigated potential options to mitigate these risks. The FRMS considered the outcomes of all the previous studies referenced above, as well as additional analysis of the local flood behaviour. Community consultation was also undertaken as part of the study, which provided key insights on the local flood issues and potential measures to address them.

This FRMP has drawn from the conclusions of the analysis undertaken in the FRMS and presents the recommended measures for managing flood risk in the Woy Woy Peninsula, as well as the strategy to implement these measures.

Sea level rise is predicted to worsen the impacts of flooding on the study area. In addition, sea level rise is predicted to result in increasingly regular flooding of the low-lying portions of the Woy Woy Peninsula as a result of tidal inundation. The Woy Woy Climate Change Adaptation Study (Rhelm, 2021b) analysed sea level rise adaptation strategies for the suburbs of the Woy Woy Central Business District (CBD), Blackwall, Booker Bay and Ettalong. The scope of the study included the development of several landform options and the assessment of their practical feasibility and performance during tidal and catchment flooding events. As a result, a conceptual optimal landform was proposed for each study area, as well as a phased implementation strategy and adaptation pathway to stage the proposed works. It should be noted that this technical case study and has not been considered by Council yet for implementation.

1.2 Report Objectives

The overall objective of this FRMP is to document and convey the decisions on the management of flood risk into the future. Drawing on the investigations undertaken as part of the FRMS, this FRMP outlines a range of measures to manage existing, future and residual risk effectively and efficiently. This includes a prioritised implementation strategy, describing what measures are proposed and how they will be implemented.

The primary objectives of this FRMP are to:

- Reduce the danger to safety and flood damage (and associated losses) to property and infrastructure.
- Manage the risk to critical infrastructure during and after flood events, to guarantee they will remain serviceable when needed.

- Ensure future development is controlled in a manner compatible with the flood risk and associated danger to personal safety.
- Protect and where possible enhance the floodplain environment.
- Manage the risk to future infrastructure to reduce potential damages.
- Be fully integrated with the local flood plan, catchment management planning, and Council's existing corporate, business and strategic plans and existing and proposed Environmental Planning Instruments. It also needs to meet Council's obligations under the Local Government Act and have the support of the local community.
- Propose measures that are sustainable in social, environmental, cultural and economic terms.
- Establish a program for implementation and a mechanism for funding the management plan, including priorities, staging, funding, responsibilities, constraints and monitoring.
- Develop/update the local flood risk management policy for the study area.
- Consider how to best incorporate findings into Councils' Environmental Planning Instruments, development control plans and policies.

2 Flood Risk

2.1 Study Location and Catchment Description

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 2-1**.

The Peninsula, including the Kahibah Creek Catchment, is generally a flat sand-plain where ground levels typically vary between RL 2m to 6m (AHD). The remaining study area backs onto the National Park and Blackwell Mountain and is typically of higher elevation with rocky outcrops. The majority of the catchment is characterised by predominantly low-medium density urban development. The study area is approximately 18.5 km^2.

Many areas on the Peninsula are not serviced by piped drainage systems, kerb and gutter infrastructure nor do they have effective overland flow paths. As a result, overland flow is prone to gather in local sags in the street network. Where these sags are unrelieved, or the capacity of the stormwater pits is insufficient, stormwater runoff will pond until it reaches a level where it can flow overland through private property or public land, infiltrate or evaporate.

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 high groundwater levels located in the central western region. 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.

Kahibah Creek and its associated tributaries are located at the base of a steep escarpment. It has five tributaries, including former swamps, some of which have been highly modified to form residential subdivisions. Kahibah Creek joins Ettalong Creek and continues to flow into Broken Bay. The catchment is influenced by storage effects of remnant swamps and coincidence of tides at the confluence of the ocean.

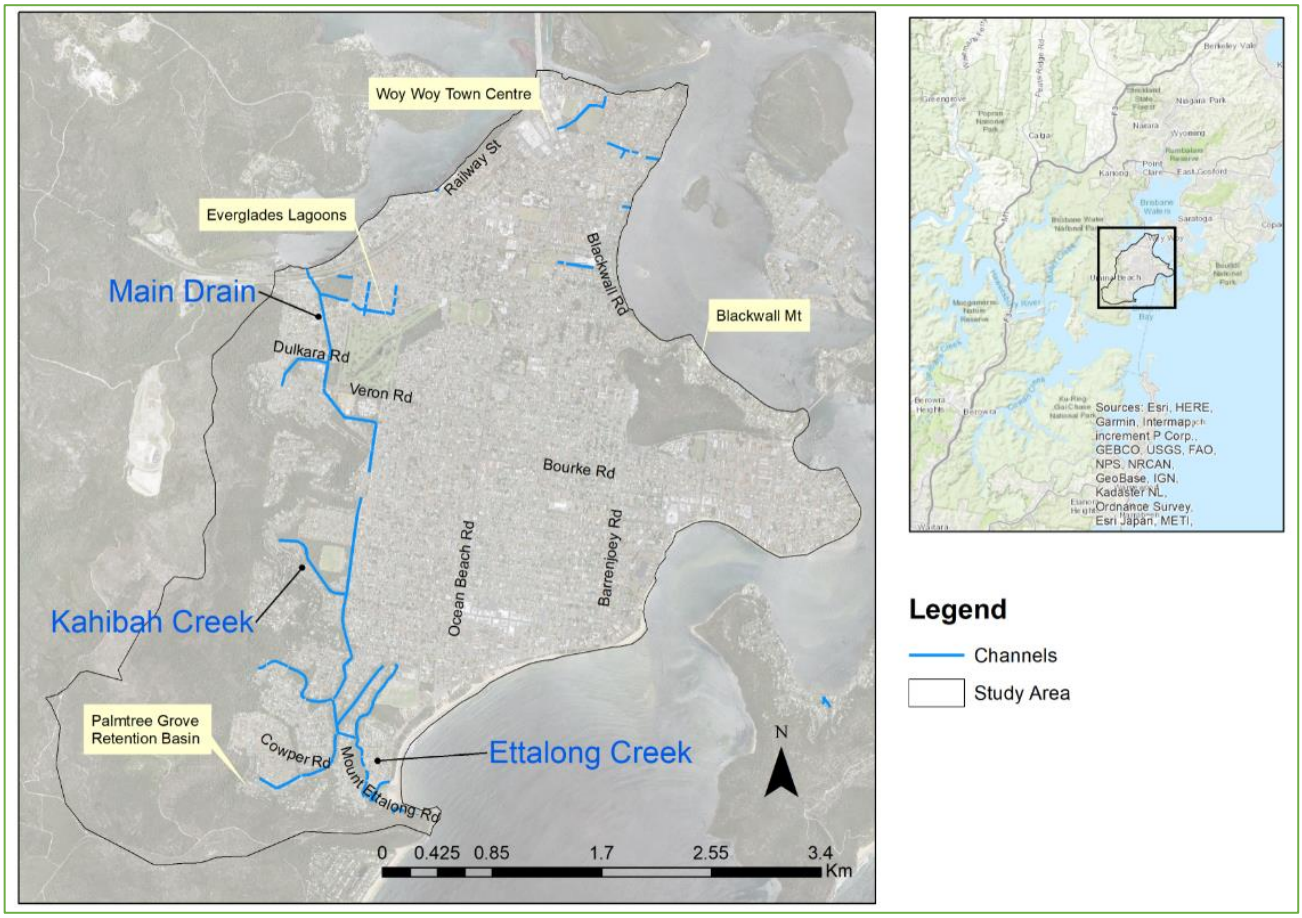

Figure 2-1 Study Area Overview (source: Woy Woy FRMS)

2.2 Flood Behaviour and Flood Risk

Woy Woy can be impacted by three mechanisms of flood risk:

- Brisbane Water flooding as a result of ocean storms;
- local catchment mainstream and overland flow flooding; and
- tidal inundation during high tides.

It is expected that all of these flood risks will be aggravated as an effect of climate change (including changes to rainfall and sea level rise).

Despite the fact that peak flood levels are driven by shorter duration intense rainfall (DHI, 2022), historically, the Woy Woy Peninsula has experienced nuisance flooding from long-duration rainfall events.

Major flood events in the study area were recorded in 1974, 1978, 1984, 1988, 1990, 1992, and 2007 but also included single instances of floods in other years. According to the local community, impacts associated with historical flood events include:

- Flooding of roadways, houses, backyards and non-habitable structures
- 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.

The Kahibah Creek catchment experienced major floods in 1975, 1989, 1990. During the flood events, several houses along Neera Road and the lower sections of Ettalong Creek were flooded. The impacts from these events lead to the implementation several flood management options. No major flooding has occurred in the Kahibah Creek system following the completion of the aforementioned works.

A brief explanation of how the study area is affected by the different sources of flooding and the main flood risks associated with each flooding mechanism is provided in **Sections 2.2.2** and **2.2.3**.

The assumptions behind the sea level rise predictions considered in this study are presented in **Section 2.2.1**.

2.2.1 Sea level Rise

An independent report on projected sea level rise in Brisbane Water was prepared by Doug Lord of Coastal Environment Pty Ltd and by Dr David Wainwright from Whitehead and Associates in 2015.

The independent report recommended RCP (Representative Concentration Pathway) 8.5 as a suitable and defensible basis for sea level rise projection in 2015. The report also identified that research on recent global emissions indicates that we are tracking at the top of the RCP8.5 projection. Within the high emissions scenario (RCP 8.5), there are three possible trajectories (low, medium, high) which encapsulate the range of the modelling. In March 2015, Gosford City Council resolved to adopt sea level rise planning levels based on projections for the RCP8.5 Scenario, utilising the medium sea level rise projection. This projection has been provided from 2015 mean sea level. The adopted sea level rise predictions are summarised in **Table 2-1**.

The Brisbane Water Flood Study (2010) considered the flooding that results from coastal processes, such as significant coastal wave events and storm surge associated with low pressure systems off the East Coast of Australia. Analysis undertaken in the Brisbane Water Flood Study (2010) identified that sea level rise would result in an almost equivalent increase in water levels at Woy Woy when compared to the open coast. Therefore, it has been concluded that the values in **Table 2-1** are applicable across the Woy Woy Peninsula.

Table 2-1 Adopted Projected Sea Level Rise RCP8.5

Year	Sea Level Rise (m)
2015	0.00
2030	0.07
2050	0.20
2070	0.39
2100	0.74

2.2.2 Brisbane Water Flooding and Tidal Flooding

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 Woy Woy Peninsula, which includes the suburbs of the Woy Woy CBD, Blackwall, Booker Bay and Ettalong. High rainfall often, although not always, occurs concurrently with an ocean storm event such as an East Coast Low. This can further exacerbate flood levels in Brisbane Water Estuary, particularly in the upstream reaches. The flood levels at Woy Woy during a Brisbane Water Estuary flood events, are primarily driven by ocean levels (as opposed to inflows to Brisbane Water from rainfall).

Significant areas within the suburbs of the Woy Woy CBD, Blackwall, Booker Bay and Ettalong are susceptible to storm surge and high tides which also cause foreshore inundation, especially with joint occurrence with local rainfall. In the Woy Woy CBD, inland penetration by flood waters and the number of properties affected by flooding is more significant than the other three suburbs due to its extensive low-lying and flat terrain.

During an ocean storm flood levels typically rise and fall over several hours and are accompanied by storm force winds associated with an east coast low pressure system, with inundation occurring for approximately 5 hours in a 1% AEP event. Therefore, it is expected that response times would be relatively long and, provided an effective warning system is in place, that the flood affected residents would be able to safely prepare their properties to shelter in place or evacuate safely, if needed. However, there could be considerable damage to properties and other infrastructure impacting people's ability to shelter in place or evacuate.

The shallow groundwater table in the sand aquifer underlying the peninsula can further aggravate the flooding. Following very wet periods the groundwater table can rise, preventing infiltration of floodwaters and causing some areas to remain flooded for several weeks.

The flood risks associated with flooding from the Brisbane Water in the study areas have been examined as part of the Brisbane Water Foreshore FRMS (Cardno, 2015a). This study considered the combined influence of ocean storms and high inflows due to catchment flooding to obtain the Brisbane Water Estuary flood levels.

This study also examined the influence of the predicted sea level rise in the Brisbane Water Flood levels around the Woy Woy Peninsula as shown in **Table 2-2**. Mapping of these 1% AEP levels for 2015, 2050, 2017 and 2100 are illustrated in **Figure 2-2**, which shows that there is a significant existing flood risk from Brisbane Water, that becomes exacerbated due to sea level rise. The 2015 condition has been used as the 'base case' or 'existing scenario' against which to assess the impacts of future flooding.

Table 2-2 Brisbane Water Flood Level Range Across the Woy Woy Peninsula

Year	Sea Level Rise (m)	1% AEP (m AHD)	5% AEP (m AHD)	20% AEP (m AHD)
2015	-	1.58 – 1.78	1.43 – 1.63	1.29 – 1.51
2030	0.1	1.68 – 1.88	1.53 – 1.73	1.39 – 1.61
2050	0.2	1.78 – 1.98	1.63 – 1.83	1.49 – 1.71
2070	0.4	1.98 – 2.18	1.83 – 2.03	1.69 – 1.91
2100	0.7	2.28 – 2.48	2.13 – 2.33	1.99 – 2.21

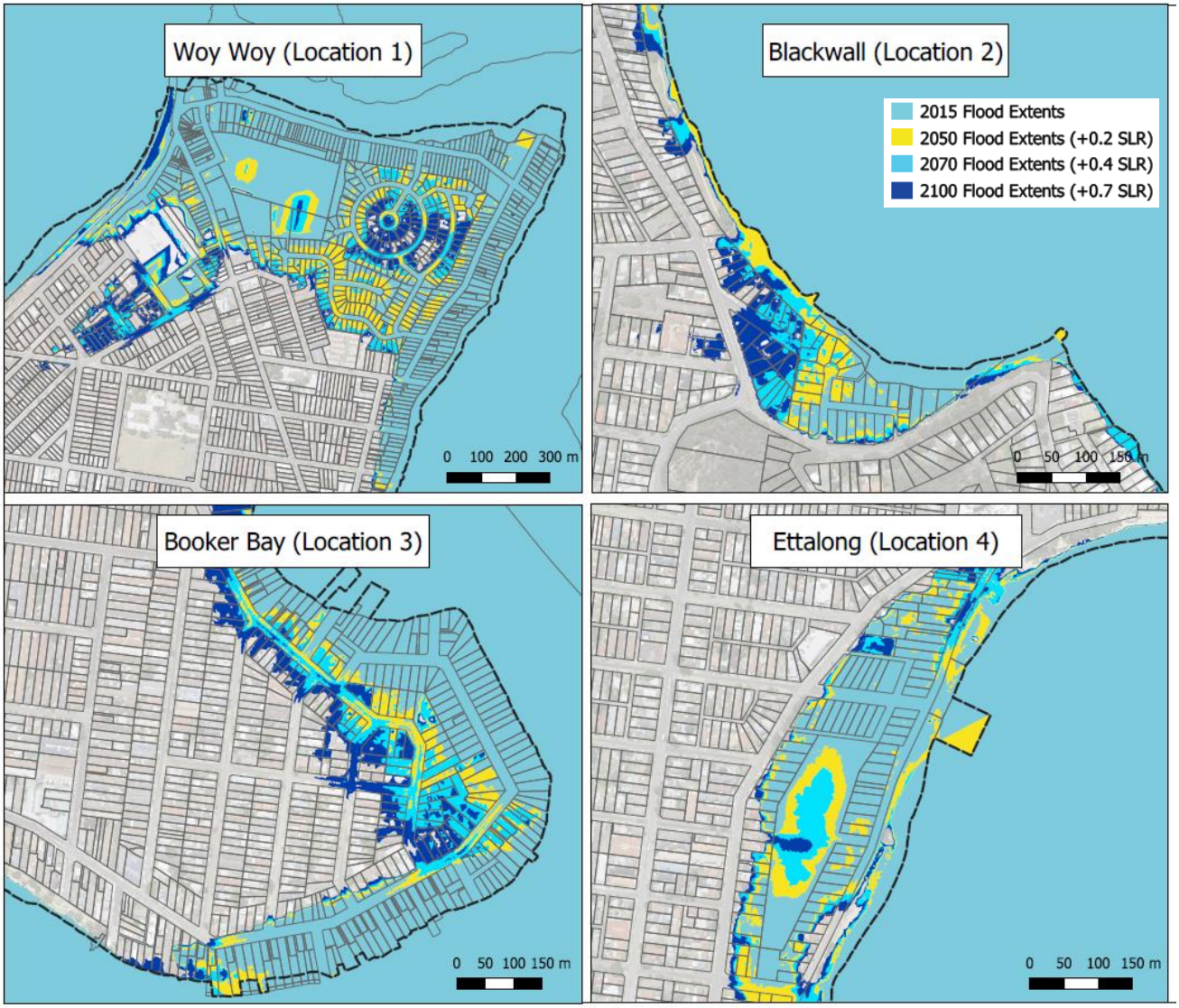

Figure 2-2 Ocean Storm Flooding

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, it is expected that 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. This will compromise the liveability of some portions of the suburbs through flooding of roads, services and private properties.

A discussion paper was included in the Brisbane Water Foreshore Floodplain Risk Management Study (Cardno, 2015a) to identify the impacts of projected sea level rise on tidal inundation. A Delft3D hydrodynamic model was used to investigate the tidal response to climate change and entrance morphology. The potential change in tidal attenuation was investigated for the 0. 39m projected sea level rise scenario.

The modelling indicates that a 0.39m rise in sea levels relates to approximately 0.4m rise in estuarine levels at the study area.

The sea level rise projections outlined were applied to the results of the discussion paper and are summarised in **Table 2-3**. The risk areas associated with the High High Water Spring Solstices (HHWSS) levels are provided in **Figure 2-3**. If we interpolate between the values shown below it can be seen that low lying areas will be extensively affected by "king tides" by 2100. It can be inferred that the impacts of "every day (MHWS)" tides will cause significant road and property flooding in the Woy Woy CBD by approximately 2050. By 2070, the MHWS will further inundate the Woy Woy CBD but also begin to significantly affect the low lying areas of Booker Bay. Finally, by 2100 there will be extensive daily flooding in the Woy Woy CBD and Booker Bay while Ettalong will see significant flooding in the lowest roads and private properties. Only The low-lying area of Blackwall would not see a high risk of tidal flooding this century.

Table 2-3 Sea Level Rise Impacts on Tidal levels

Year	Sea Level Rise (m)	MHWS (mAHD)			HHWSS (mAHD)		
		Woy Woy And Blackwall	Booker Bay	Ettalong	Woy Woy And Blackwall	Booker Bay	Ettalong
2015	0	0.37	0.47	0.52	0.61	0.74	0.80
2030	0.1	0.47	0.57	0.62	0.71	0.84	0.90
2050	0.2	0.57	0.67	0.72	0.81	0.94	1.0
2070	0.4	0.77	0.87	0.92	1.01	1.14	1.2
2100	0.7	1.07	1.17	1.22	1.31	1.44	1.5

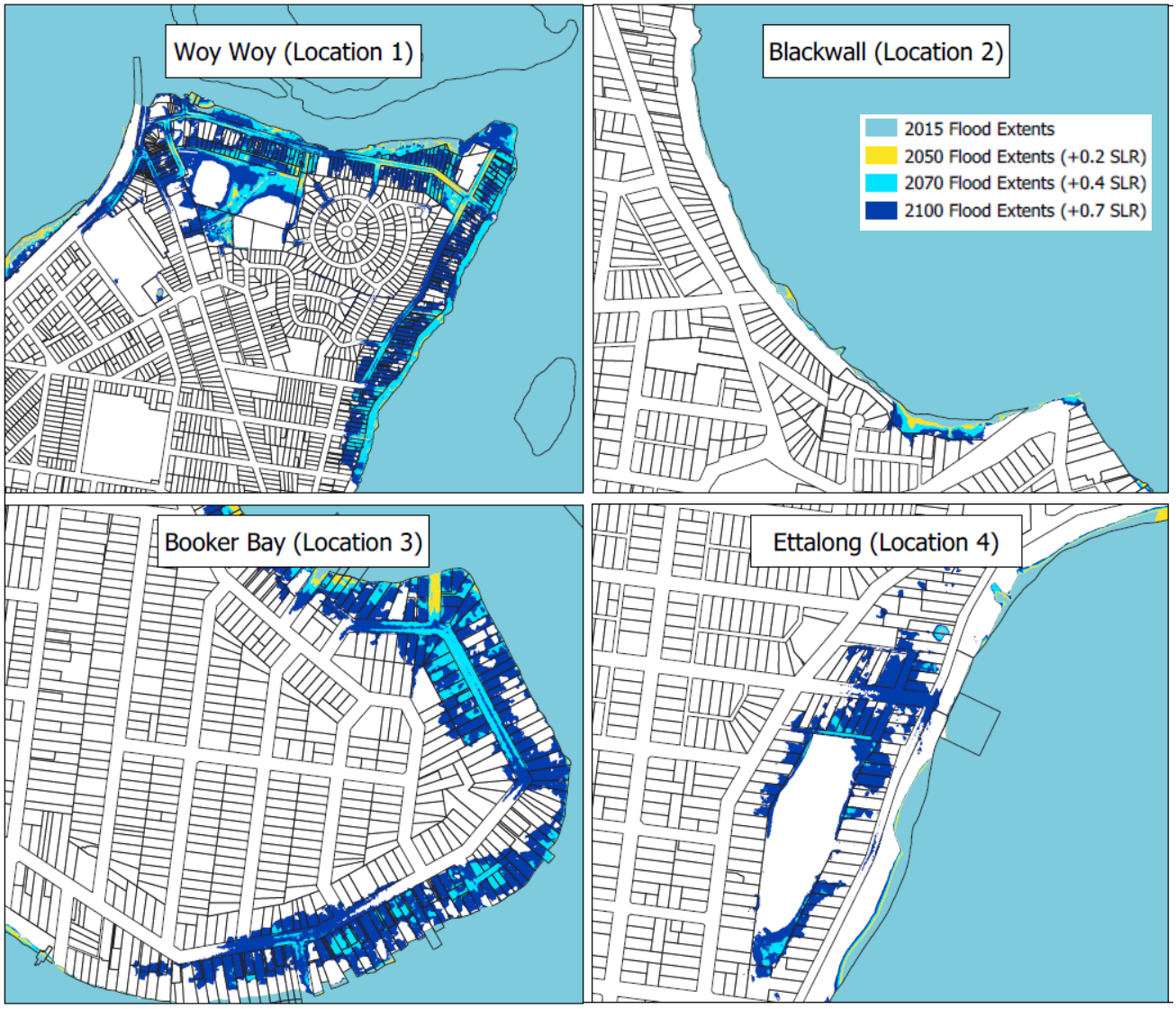

Figure 2-3 HHWSS Tidal Inundation

2.2.3 Local Catchment Flooding

The Woy Woy Peninsula is subjected 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 and Everglades (Main Drain) catchments. Flooding from overland flow occurs when catchment runoff concentrates into flow paths along natural or constructed routes such as swales or roadways. In the Woy Woy Peninsula, raised groundwater tables can increase the magnitude of both mainstream and overland flow flooding.

Overland flood behaviour was initially investigated in the Flood Study (DHI, 2010). This hydraulic model developed in the Flood Study (DHI, 2010) was updated in 2020 to include the most recent catchment information available and incorporate the significant contribution of groundwater on the design flood estimates. The model was also extended to include the entire study area of the Woy Woy FRMS. The detailed results of the revised flood model calibration and design flood behaviour are discussed in the Woy

Woy FRMS (DHI, 2022). This document provides only a summary of the local catchment flood behaviour for the peninsula.

Mainstream flooding mostly impacts properties and roadways adjacent to of Ettalong Creek, Iluka Creek and Kahibah Creek. A number of properties in the upstream section of the Main Drain, near Casuarina Close, are also affected. Flood depths in the significantly impacted areas generally range from 0.5m to 1.5m in the 1% AEP flood event.

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. In the 1% AEP flood event, the flood depths are generally lower than 0.3m across the study area with relatively few properties experience 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 very rare and extreme flood events (i.e. greater than a 1% AEP event), a number of roads in the study area can potentially be impacted by high hazard flooding, compromising evacuation and emergency service access. **Maps G112** and **G114** show the Flood Emergency Response Classifications within the study area for the 1% AEP and PMF, respectively. **Map G115** illustrates the 1% AEP flood and PMF extents of catchment flooding in the study area and highlights the roads that are significantly affected. These roads experience overtopping in the 1% AEP event and/or high hazard (greater than H2 Hazard, as defined in the Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017)) flows in a PMF event.

The number of properties that are subjected to over floor flooding in the analysed catchment flood events is summarised in **Table 2-4**. The economic damages associated with catchment flooding in the study area are discussed in **Section 2.3**.

Table 2-4 Properties subjected to over floor flooding in catchment flooding events

Flood Event	Properties with Over-Floor Flooding	Avg Over-Floor Depth (m)
PMF	2,138	0.23
1% AEP	36	0.25
10% AEP	19	0.25
20% AEP	16	0.12

Floor level survey data was not available for the entire study area, nor is it feasible for Council to obtain these data. To supplement the floor level survey acquired, a general assumption of the height of floor levels above ground levels was made for the remaining properties which experience flooding in all events up to the PMF. This value was assumed to be 300mm based on a combination of site inspections, Google Streetview, and aerial photography. The number of overfloor flooded properties is affected by this assumption on floor levels for properties which have not undergone floor level survey, primarily those flooded in the PMF event. If the assumption of floor levels being 300mm above LiDAR survey ground levels is increased to 500mm, the number of properties modelled as experiencing over floor flood is reduced by one or two in the 1%, 10% and 20% AEP events; however, the number of over floor flooded properties in the PMF is approximately halved.

The effects of catchment flood events can be further aggravated by high water levels in Brisbane Water Estuary, which can compromise the local drainage (e.g. associated with a high tide or an offshore low pressure system).

The Floodplain Risk Management Study assessed the potential impacts to flood behaviour in the study area due to climate change. One climate change scenario was assessed, considering a 0.74m rise in sea levels and 19.7% increase in rainfall. Flood inundation in the Kahibah Creek Catchment and in the low elevation areas of the peninsula were particularly affected by increases in sea level.

The effects of climate change will likely elevate the average groundwater level in the study area. Therefore, an additional climate change scenario was modelled, adopting the same rainfall and sea level increases, but with higher initial groundwater levels. The results for this scenario have shown flood depth increases (ranging from 0.1m to 0.2m) at the bottom of the escarpment and in the Everglades catchment where the highest groundwater levels are located.

2.3 Economic Flood Damages

In order to quantify the economic impacts of flooding, an economic flood damage assessment has been undertaken. This was only undertaken considering catchment flooding. For further detail on the damages resulting from estuarine flooding in Brisbane Water, refer to the Brisbane Water FRMS (Cardno, 2015a).

A property may suffer economic impacts from flooding through several ways. These are broadly grouped into three categories, as summarised in **Table 2-5**.

Table 2-5 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 one 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.

The damage assessment undertaken for this study has examined the tangible damages only. Assessment of the tangible flood damages is based on residential damage curves, which were generated based on the curves prepared by the Department of Natural Resources (now DPE) in 2007. The magnitude of damage attributed to a property is dependent upon its number of storeys and the depth of inundation experienced for all design flood events assessed.

The damages calculated for each of the design events are used to estimate the Annual Average Damages (AAD). The AAD is the typical method that is adopted in economics to annualise damage costs such as those in flooding based on their probabilities. This allows for the conversion of the different flood event damages into a singular annual average that is weighted based on the overall probabilities of events and represents the most likely damage that is likely to be experienced in any given year. The calculation process is described in detail in the Floodplain Development Manual (2005).

The AAD for the Woy Woy Peninsula study area under existing conditions is $1,324,615. Over a 50 year assessment period and under a seven per cent discount rate, this AAD is equivalent to a Net Present Value (NPV) of $18.3 million. This value is an estimate of the total expenses Council is expected to have due to flooding over 50 years, in today's dollar value.

Table 2-6 summarises the flood damages associated with catchment flooding, which includes the effects of overland flooding and mainstream flooding from Kahibah Creek and the Main Drain. As noted in **Section 2.2.3**, the number of affected properties, particularly in the PMF event, is influenced by the assumption of floor level elevations relative to LiDAR surveyed ground levels. The influence of this assumption is not substantial on the estimated AAD value (compared to the number of houses experiencing over floor flooding) given the large number of properties with over floor flooding the in PMF and the relative frequency of this event

Table 2-6 Economic Flood Damages Assessment – Catchment Flooding

Flood Event	Catchment Flooding Damages
PMF	$165,207,840
1% AEP	$2,603,748
10% AEP	$1,459,712
20% AEP	$1,152,774
Average Annual Damages (AAD)	**$1,324,615**

The results of the damage analysis undertaken for Brisbane Water flooding are provided in **Table 2-7**.

Table 2-7 Economic Flood Damages Assessment – Brisbane Water Flooding

Flood Event	Catchment Flooding Damages
PMF	$29,010,750
1% AEP	$9,352,185
10% AEP	$2,093,545
20% AEP	$1,071,234
Average Annual Damages (AAD)	**$853,080**

It should be noted that damages associated with ocean flooding have been originally estimated as part of the Brisbane Water FRMS (Cardno, 2015). However, the costs reported in this study were expressed in 2015 dollars. For this reason, the results reported in **Table 2-7** have been based on the same data, updated to 2019 currency values for use in this study. This update was undertaken as part of the Woy Woy Climate Change Adaptation Study (Rhelm, 2021b).

2.4 Consultation Strategy

Community and stakeholder engagement is an important element of understanding and managing flood risk. It can facilitate:

- understanding of flood behaviour by tapping into community knowledge on historic floods
- informing the community of the flood threat they face and how and when to react to this threat
- developing sustainable floodplain management plans that have broad community support.

The approach undertaken to community and stakeholder engagement as part of this study was in accordance with the IAP2 framework and the requirements of the NSW Government's Floodplain Development Manual (2005).

The consultation strategy outlined in **Table 2-8** summarises the key community engagement activities undertaken as part of this FRMS and FRMP, as well as the other stakeholders involved.

Table 2-8 Engagement Methods

Event/Activity	Purpose	Target Audience	Key outcomes
Community newsletter and questionnaire A one-page community newsletter was distributed in February 2021 to over 8,500 dwellings An online version of the questionnaire was also available through Council's Have Your Say webpage and the project website.	• Provide scope and context of project. • Invite community input on what they see as the key flooding issues and how they would like to see them managed.	Residents, property owners, local business owners, and the wider community.	• A total of 389 residents responded to the questionnaire, representing a return of 5% of direct distribution. • The questionnaire responses provided key insights into the community's perception on flooding and emergency response.
Website and Media A project website was 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. Media releases were used throughout the study to inform the community of key project updates and creating opportunities to provide input.	• Provide project information and community updates. • Invite community input by providing a link to the online survey.	Residents, property owners, local business owners, and the wider community.	• A substantial number of the community questionnaires were responded to online through the website (89 from a total of 389 responses).
Community information (drop-in) session A community drop-in information session was held in Woy Woy on 18 February 2021	• Provide scope and context of project. • Invite community input on what they see as the key flooding issues and how they would like to see them managed. • Provide mapping as a basis for the community to identify areas of concern and validation (or not) of existing modelled flood behaviour.	Residents, property owners, local business owners, and the wider community.	• A total of 30 people attended the community information session. • The attendees provided important information on flood issues experienced in the study areas and potential measures to address them.

Event/Activity	Purpose	Target Audience	Key outcomes
Agency Consultation Agency consultation has been undertaken in the form of attendance at site inspections, progress meetings, inception meetings and options identification by DPE and internal Council stakeholders, such as staff from the roads and drainage and planning departments. DPE, SES and other agency stakeholders will be engaged with further as part of the public exhibition period.	• Identify the deliverables required from the study to assist SES in effective flood response. • Obtain inputs for the study from DPE and Council stakeholders. • Gain further appreciation of the feasibility of preliminary options with respect to funding opportunities.	DPE, Council Stakeholders and SES.	• DPE and Council stakeholders have provided valuable input to the preparation of the Flood Risk Management Study.
Stakeholder meetings Targeted Council stakeholder meetings were undertaken following the identification of the preliminary flood risk management options, to assist in the selection of options for detailed assessment. Targeted stakeholder meetings will be undertaken as part of the public exhibition of this FRMS and FRMP.	• Further identification of flood risks in the study area. • Refinement of mitigation options to best serve the community.	Council stakeholders, community groups, action groups and other key stakeholders identified.	• As part of the stakeholder options workshop meetings, the potential benefits and impacts associated with each of the preliminary options were identified and assessed. The presence of different stakeholders, each with their particular perspective on flood management, resulted in a comprehensive, multidisciplinary assessment. • Better selection of mitigation options that will be financially viable for Council and also have wide community support.
Public Exhibition – Your Voice Our Coast page During the public exhibition period, the Draft documents will be made available on Council's "Your Voice Our Coast page" webpage. This will allow the members of the public and all relevant stakeholders to provide feedback on the draft documents.	• Invite feedback on draft documents	Residents, property owners, local business owners, the wider community, agency stakeholders and community groups.	• This section will be updated following the public exhibition period.
Community information sessions (drop-in and virtual) During the public exhibition period, community drop-in sessions will be held for members of the public to discuss the draft documents and provide feedback.	• Invite feedback on draft documents	All stakeholders	• This section will be updated following the Public Exhibition Period.

2.5 Community Survey and Drop-In Information Sessions

A one-page community newsletter was distributed in February 2021 to over 8,500 dwellings. An online version of the questionnaire was also available through Council's Have Your Say webpage and the project website.

From the distribution and availability of the community survey on the website, 389 responses were received, representing a return of 5% of direct distribution. A return rate of 10% is typical for these types of mail-outs.

An additional 30 people attended drop-in sessions (February 2021) to provide input face to face.

The primary 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 community members that attended the drop-in information session provided valuable insights about the flooding issues experienced in the Woy Woy Peninsula and how they can be addressed. The inputs from the community generally included:

- flooding issues reported at specific roads and public locations.
- need for revision of Council's 'Black Spot' program.
- use of infiltration solutions to accommodate runoff during storm events.
- need for maintenance and improvement of existing drainage infrastructure.
- raising of landform to address sea level rise was, in general, considered acceptable.

The options that were identified and assessed as part of the FRMS attempted to incorporate the community inputs as far as reasonably possible, considering potential impacts, technical constraints, and the current understanding of the local flood behaviour.

2.6 Public Exhibition

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

3 Climate Change Planning

Within the Woy Woy Peninsula, 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. The development of a strategy for climate change adaptation for these suburbs is part of an overall plan for addressing climate change risk for all low-lying areas of the Central Coast LGA.

By undertaking a climate change adaptation Landform and Drainage Masterplan for the Woy Woy Peninsula, adaptation pathways can be developed consisting of development controls and mitigation measures which could be implemented over time in consultation with the community. A climate change adaptation study was recently undertaken by Council (Rhelm, 2021b) for the locations of the Woy Woy CBD, Blackwall, Booker Bay and Ettalong to inform the development of a regional adaptation masterplan and these associated processes.

Figure 3-1 demonstrates how the Floodplain Risk Management Process and the Climate Change Adaptation Planning Process for the Woy Woy Peninsula are integrated (green studies / plans are completed, blue are yet to be undertaken).

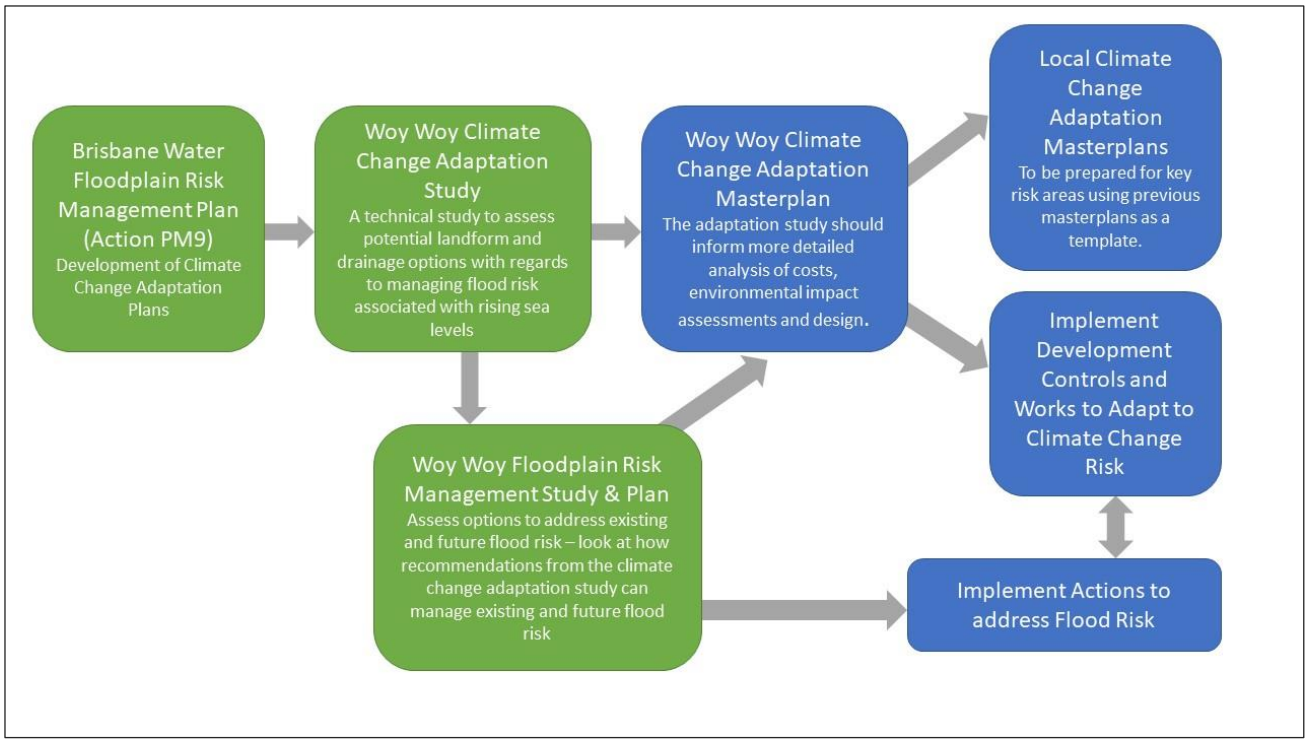

Figure 3-1 Climate Change Adaptation and Floodplain Management for Woy Woy

The Woy Woy Climate Change Adaptation Study (Rhelm, 2021b) focused on the technical analysis of potential landforms and associated measures to provide flood protection against existing and future flood risk associated with both catchment and ocean flooding (both tidal and storm induced).

The adaptation study provides valuable information to assist in the overall climate change adaptation strategy and preparation of a Masterplan. However, this study was of a conceptual nature and further planning is required to allow the adaptation plan to go ahead. This FRMP recommends that Council proceeds with the next stages of the development of a Climate Change Adaptation Landform and Drainage

Masterplan for the Woy Woy Peninsula. The proposed actions to progress the Masterplan are described in detail in **Section 3.4**.

3.1 Approach to Decision Making

Adapting to climate change and rising sea levels is a complex problem, with no single technical solution, and involving multiple interests and stakeholders. The *Decision Support for Coastal Adaptation: The Handbook* (The Handbook) was developed in 2012 to assist the Hunter and Central Coast Regional Environmental Management Strategy (HCCREMS)coastal councils more effectively approach and determine adaptation responses and pathways for vulnerable coastal areas. The Handbook discusses ten key stages in the decision-making process. Although the process is presented as a series of numbered stages, it is recognised that in reality decision-making will often jump backwards and forwards between stages. The stages are summarised in **Figure 3-2**.

The stages focused on in the adaptation study are:

- **Stage 4 Assess hazards and risks:** The existing and future hazards and risks associated with sea level rise have been detailed in previous studies and forms the basis of the adaptation plan.
- **Stage 5 Identify options and pathways:** Various options were explored through review of options outlined in previous studies and plans, and review of climate adaptation in other locations. Through collaboration with stakeholder a preferred approach was identified. Flood behaviour and civil design aspects of the preferred approach were also assessed. Pathways were explored through assessing potential methods of staging of works to manage impacts associated with the works and to identify opportunities for infrastructure works to be undertaken as funding becomes available.
- **Stage 6 Establish Triggers:** A preliminary assessment of triggers was undertaken through the identification of regular inundation of properties and assets. This assessment effectively made assumptions regarding when an area was no longer liveable due to sea level rise. This was assessed over a period of 80 years (2020 to 2100).

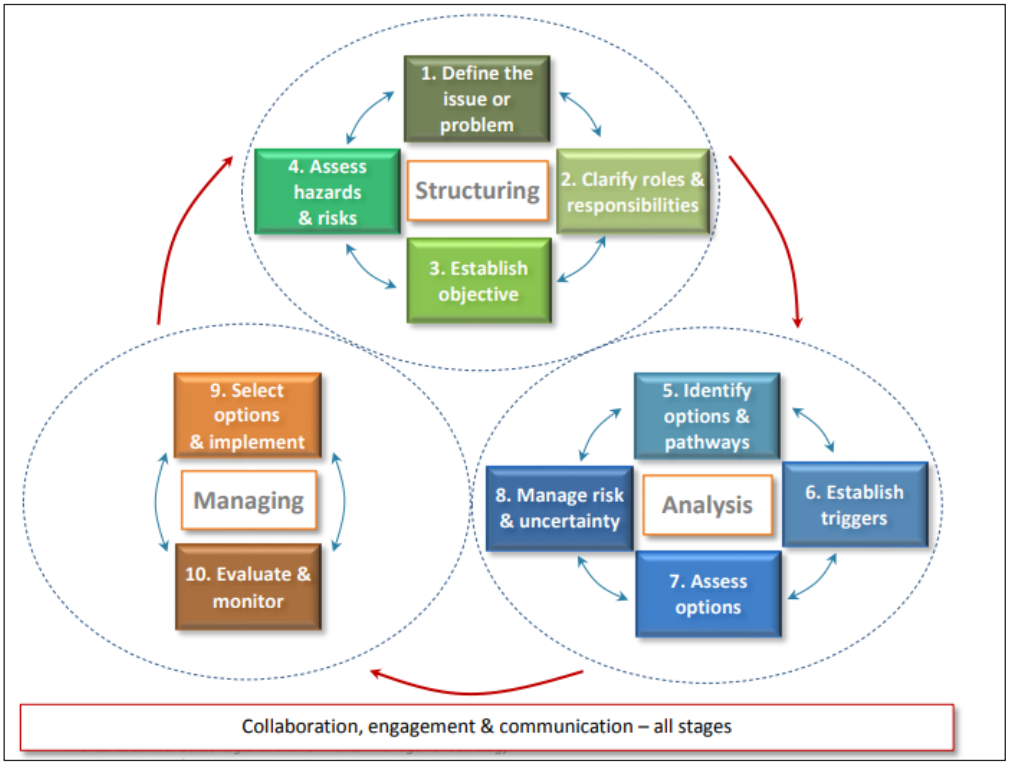

Figure 3-2 Stages in the adaptation decision making process (HCCREMS, 2012)

3.2 Climate Change Adaptation - Concept Designs

3.2.1 Concept Landform and Drainage Plan

The Central Coast DCP 2022 requires all floor levels of residential buildings to be above the Flood Planning Level (FPL). To assist in achieving this level, filling of individual properties is permitted by the Brisbane Water FRMP (Cardno, 2015b) where it does not impact on active flow areas in the stream networks feeding Brisbane Water. Filling operations must include adequate provision for drainage of surface water, erosion and siltation control, and be so placed and graded as to prevent the shedding of surface water direct to adjoining properties.

There is currently very little direction on what level of fill is acceptable and how filling of properties can be undertaken to minimise the long-term impacts on local drainage.

Taking this into consideration, several options for filling of low lying areas of the Woy Woy CBD, Blackwall, Booker Bay and Ettalong have been investigated. Generally, the development of the landform options achieved the following primary objectives:

- Protect the community from ocean and tidal flooding, which will be aggravated from climate change effects. Protection from ocean flood events is achieved for the existing 1% AEP conditions, as well as protection from tidal flooding (i.e. HHWSS) beyond 2100.
- Improve the drainage conditions in the study areas, relative to what would be expected in the 2100 sea level rise scenario. If this is not possible then maintain existing conditions (i.e. do not negatively impact local drainage).
- Consider feasibility of the proposed option, by minimising required land fill depths and by considering other practical implementation aspects at a conceptual level.

The underlying soils across the Woy Woy Peninsula generally have high permeability because of the predominant presence of sand layers. Any filling completed as part of land raising would need to be controlled as to not significantly reduce the capacity of the soil to infiltrate surface water. It is expected that DCP amendments would be necessary to achieve this.

For each of the four study areas considered, opportunities and constraints were assessed to determine a design grading strategy to meet the objectives of the concept design. This involved utilising public lands to accommodate drainage paths and allowing the surrounding private properties to drain to these public lands. Where it was not possible to achieve this through public lands, easements were introduced on private land. It is not advisable to construct underground culverts along these easements – due to the very flat nature of the study areas, any blockage of these culvert would result in widespread flooding of private land and be counterproductive to the design objectives.

The resulting landform designs for the Woy Woy CBD, Blackwall, Booker Bay and Ettalong are shown in **Maps G220** through **G223**.

3.3 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 the Woy Woy CBD, 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, maintenance of liveability).

The higher BCR for the Woy Woy CBD 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.

3.4 Implementation and Adaptation Pathways

The implementation of the proposed landform and drainage plan needs to consider:

- How to fill private land.
- When roads and public land can be filled, i.e. filling of these areas may not be possible until adjoining private land has been filled to avoid drainage issues on remaining low-lying private land.
- Staging of implementation.
- Establishing triggers and thresholds for action with the community at the earliest time frame possible so as to create a monitoring regime to address the rate of change over time.

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 3-3**). These are listed in order of most preferrable (Pathway A) to least preferrable (Pathway F). Pathway A requires relatively quick action to be taken this decade to avoid losing liveability of some properties in the Woy Woy CBD 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 3-1**.

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, 2021b) 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.

Implementing the recommended actions to allow a Woy Woy Climate Change Adaptation Plan to be realised is included as a property modification measure (PM07) in the floodplain risk management options.

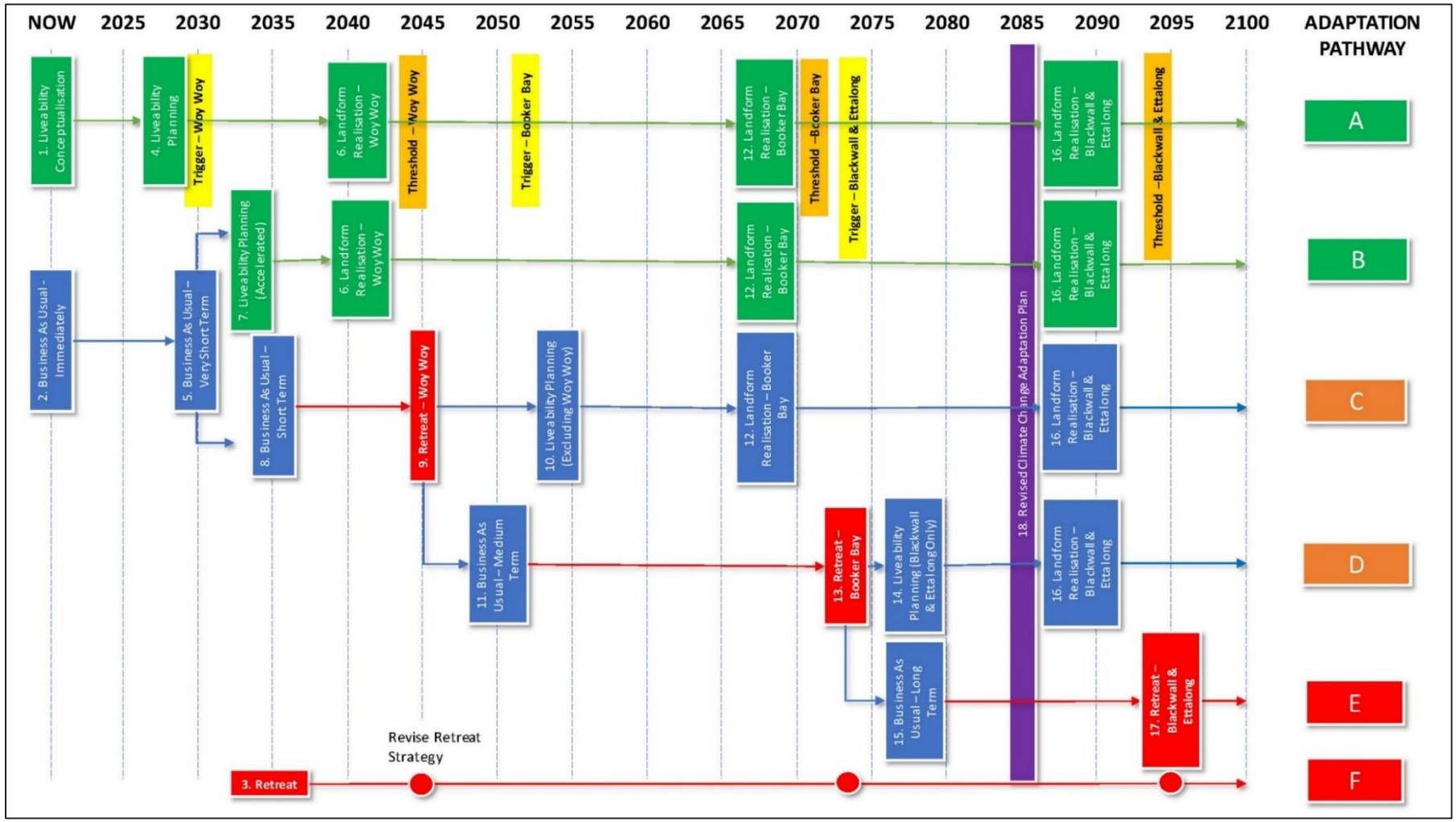

Figure 3-3 Preliminary Adaptation Pathways

Table 3-1 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

4 Floodplain Risk Management

4.1 Floodplain Risk Management Options

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.

As defined in the *Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017), there are three types of flood risk:

- Existing flood risk – the risk associated with current development in the floodplain. Knowing the likelihood and consequences of various scales of floods can assist with decisions on whether to treat this risk and, if so, how.
- Future flood risk – the risk associated with any new development of the floodplain. Knowing the likelihood and consequences of flooding can inform decisions on where not to develop and where and how to develop the floodplain to ensure risks to new development and its occupants are acceptable. This information can feed into strategic land-use planning.
- Residual flood risk – the risk remaining in both existing and future development areas after management measures, such as works and land-use planning and development controls, are implemented. This is the risk from rarer floods like the PMF, which may exceed the management measures. Residual risk can vary significantly within and between floodplains. Emergency management and recovery planning, supported by systems and infrastructure, can assist to reduce residual risk.

The alternate approaches to managing risk are outlined in **Table 4-1**.

Table 4-1 Flood Risk Management Alternatives

Alternative	Examples
Preventing/avoiding risk	Appropriate development within the flood extent (i.e. development commensurate to the flood risk)
Reducing the likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention
Reducing the consequences of risk	Development controls to ensure structures are built to withstand flooding
Transferring risk	Via insurance – may be applicable in some areas depending on insurer
Financing risk	Natural disaster funding
Accepting risk	Accepting the risk of flooding because of having the structure where it is located

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 (e.g. by house raising) 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 comprehensive range of preliminary flood risk management measures for the Woy Woy Peninsula were examined, as part of the Floodplain Risk Management Study (DHI, 2022). The identified measures were a product of an extensive investigation of the flood risks in the study area, which considered:

- Outcomes of previous flood studies undertaken in the study area (referenced in **Section 1.1**).
- Flood hazard and emergency response mapping, and economic damages assessments undertaken as part of the FRMS.
- Inputs obtained through workshops with stakeholders and community engagement activities.

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 and potentially an economic assessment to quantify the reduction in flood damages and benefit-cost ratio.

Options were selected for detailed assessment 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

All identified flood modification, property modification and emergency response modification measures were evaluated through a Multi-Criteria Assessment (MCA) approach, which enabled the comparative assessment of all options based on their economic, social, and environmental aspects. Where appropriate, flood modelling and flood damages analysis were also undertaken as part of the evaluation process and provided key inputs for the MCA.

As an outcome of this assessment, the options identified as being the most advantageous have been recommended as part of this FRMP and are further discussed in **Section 4.2**.

A summary of all the flood risk management options that were assessed for study area is provided in **Appendix A.** This appendix presents a brief description of each option, the flooding issues they aim to address and how the options were identified.

4.2 Recommended Flood Risk Management Measures

Taking into consideration the assessment described in **Section 4.1**, a range of flood risk management measures are recommended as part of this FRMP.

The recommended measures are presented in **Sections 4.2.1** to **4.2.3**. For each floodplain risk management measure, the following general information has been provided:

- Description
- Associated costs (implementation and maintenance)
- Agency responsible for implementation
- Multi-Criteria Assessment rankings

4.2.1 Flood Modification Measures

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. These were also considered in the context for Council's ongoing maintenance budget to discover opportunities for efficiencies in budget allocation.

A range of flood modification measures were assessed which sought to improve either the extent, severity and/or frequency of catchment flooding across the study area. Due to the nature of catchment flooding in the Peninsula (i.e. low lying sand flats with significant influence of groundwater), many of the proposed options did not result in a reduction of flood damages which outweighed the cost of implementation. Those which have been recommended are done so on the basis of improved flood behaviour in public areas and overall reductions of ongoing Council costs.

The details of the recommended actions included the following, with additional details provided in the tables below:

- Infiltration Devices

<table>
<tr><th colspan="3">Infiltration Devices</th></tr>
<tr><td>Flood Management Type: Flood Modification Option
(ID: FM03)</td><td colspan="2">Responsibility: Council</td></tr>
<tr><td rowspan="2">MCA Ranking: Flood Modification – 1
Overall – 6</td><td rowspan="2">Associated Costs:</td><td>Initial Cost: $25,000 per device, six (6) devices</td></tr>
<tr><td>Recurrent Cost: $1,250 per device</td></tr>
<tr><td colspan="3">Overview:
This option considered installation of six (6) infiltration devices along low lying streets with a history of ponding and nuisance flooding due to lack of drainage or drainage capacity. A number of infiltration devices were tested in six locations of the Woy Woy Peninsula and showed improvements to local drainage issues, albeit a majority in public areas such as roadways and with minor positive impacts in private property.
The locations in Albion Street, Nelson Street and Gross Avenue were selected because they are situated in an area where the sand layer is relatively deep and the depth to the phreatic surface is large. In contrast, the locations in Watkin Avenue, Makenzie Avenue and Veron Road were positioned in areas relatively shallow groundwater. Therefore, for these locations the device considered was a large infiltration pad.
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 is under stress and potentially at further risk by anthropogenic influences.
Initial costs for each device will depend on the selection of which proprietary product is selected to be installed. Recurrent annual costs are assumed to be 5% of initial costs.</td></tr>
<tr><td colspan="3">Flooding issue addressed:
The installation of the infiltration devices has the purpose of improving local drainage and minimizing excessive ponding of rainfall runoff and nuisance flooding.
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 and nuisance flooding.</td></tr>
<tr><td>Expected Mitigation Outcomes:
The flood modelling undertaken for this measure indicates a significant reduction in flood depths around proposed installation locations. However, improvement in flooding was restricted to the vicinity of the infiltration devices.
Therefore, it is expected that this option will only address local flooding in the streets where the proposed infiltration devices are located.</td><td colspan="2">Considerations:
• Further feasibility study is required to determine best possible locations for implementation.
• Maintenance of these devices is required for effective operation. This is likely to require periodic inspection and removal of sedimentation to ensure ongoing effective operation without significant reduction in infiltration capacity.
• Device manufacturers will provide maintenance schemes.
• Upstream filtration of inflows to the system will</td></tr>
</table>

Infiltration Devices	
	aid in device efficiency and reduce overall maintenance costs. • Consideration of impacts to groundwater quality and treatment process for drinking water sourced from bores in the peninsula.

4.2.2 Property Modification Measures

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.

The land use planning and building controls recommended for updates are summarised below.

- Land Use and Development Control Planning Recommendations
- Property Management Education Program
- Reduced Level of Major Drainage Service
- Climate Change Landform Adaptation

<table>
<tr><th colspan="4">Land Use and Development Control Planning Recommendations</th></tr>
<tr><td colspan="2" rowspan="2">Flood Management Type: Planning Modification (ID: PM01)</td><td colspan="2">Responsibility: Council</td></tr>
<tr><td rowspan="2">Associated Costs:</td><td>Initial Cost: Council rates</td></tr>
<tr><td colspan="2">MCA Ranking: N/A</td><td>Recurrent Cost: -</td></tr>
<tr><td colspan="4">Overview:
Council’s existing land use planning controls were reviewed in the FRMS. This includes both the existing LEP and DCP covering the study area (i.e. the Central Coast Local Environment Plan (CCLEP) 2022 and the Central Coast Development Control Plan (CCDCP) 2022). 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.
Council may wish to consider each of the items listed below individually for implementation.</td></tr>
<tr><th colspan="4">Planning Recommendations</th></tr>
<tr><th colspan="2">Issue</th><th colspan="2">Recommendation</th></tr>
<tr><td>1</td><td>The FRMS investigated the appropriate definition of the Flood Planning Area and the Flood Planning Level.</td><td colspan="2">It is recommended that the Flood Planning Area (FPA) within the Woy Woy Peninsula is defined as PMF extent.
This should be superseded in the Brisbane Water floodplain by the FPLs in the Brisbane Water FRMS, and the higher of the two will apply.
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, 2015b).</td></tr>
</table>

Land Use and Development Control Planning Recommendations		
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 in the CCLEP 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 and Flood Planning Level are provided in this FRMS.	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) 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 FRMP.
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. This may also take into consideration emergency access issues and the provision of an emergency flood plan for the relevant developments.

Land Use and Development Control Planning Recommendations		
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 perviousness 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.

<table>
<tr><th colspan="3">Property Education and Compliance</th></tr>
<tr><td colspan="2">Flood Management Type: Property Modification Option (ID: PM05)</td><td>Responsibility: Council</td></tr>
<tr><td colspan="2" rowspan="2">MCA Ranking: Planning Modification – 6
Overall – 7</td><td rowspan="2">Associated Costs*:</td><td>Initial Cost: - $80,000</td></tr>
<tr><td>Recurrent Cost: - 5,000</td></tr>
<tr><td colspan="3">Overview:
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 and therefore often neglect to consider flood impacts.
In addition, stockpiling of materials including soil, construction or demolition materials, and garden waste within the floodplain 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 achieve a significant flood risk reduction with buy-in from the community.</td></tr>
<tr><td colspan="3">Flooding issue addressed:
Flooding along Kahibah Creek and encroachment of development into the floodplain in this location.</td></tr>
<tr><td colspan="2">Expected Mitigation Outcomes:
Overall reduction in flood levels for those properties which border along the Creek. This will be an initiative involving significant community action and stewardship of the Kahibah Creek riparian areas.</td><td colspan="2">Considerations:
• Development of Council policy and methodology for enforcing compliance and resources for monitoring.
• Monitoring will be required to ensure that the desired effect is being achieved.</td></tr>
</table>

<table>
<tr><th colspan="3">Sustainable Level of Drainage Service</th></tr>
<tr><td colspan="2">Flood Management Type: Property Modification Option (ID: PM06)</td><td>Responsibility: Council</td></tr>
<tr><td colspan="2" rowspan="2">MCA Ranking: Planning Modification – 3
Overall – 3</td><td rowspan="2">Associated Costs*:</td><td>Initial Cost: - $20,000</td></tr>
<tr><td>Recurrent Cost: -</td></tr>
<tr><td colspan="3">Overview:
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 drainage works 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, often 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) requires that the major system 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 to be addressed, the impacts of flooding do not justify 1% AEP 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 back 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 be reduced as residents of the peninsula have repeatedly highlighted issues with nuisance flooding.
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 improvement to the current 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 FM03, requiring effective infiltration devices (and maintenance plans) to be incorporated within the stormwater drainage system as an alternative to providing drainage to Brisbane Water.</td></tr>
<tr><td colspan="3">Flooding issue addressed:
Prohibitive construction costs of public stormwater infrastructure works.</td></tr>
</table>

Sustainable Level of Drainage Service	
Expected Mitigation Outcomes: The initial costs to construct major stormwater system works will be reduced allowing a greater extent of works to be constructed, and the eventual raising of the entire Peninsula's stormwater system capacity Increased feasibility of new stormwater infrastructure works will reduce the duration of inundation for nuisance flooding throughout the Peninsula, particularly where trapped low points exist in roadways not serviced by the existing drainage network.	**Considerations:** • This option should be implemented for works only occurring within the lower lying sand flats of the Woy Woy Peninsula where high runoff infiltration rates give rise to minimal difference in very rare and frequent flood extents. • Hydraulic assessments should be undertaken for each individual stormwater upgrade project to ensure existing flood behaviour is not negatively impacted. • Further study is required to determine a revised level of major stormwater service, with respect to design flood events.

<table>
<tr><th colspan="3">Climate Change Landform Adaptation</th></tr>
<tr><td colspan="2">Flood Management Type: Property Modification Option (ID: PM07)</td><td>Responsibility: Council/DPE/private development</td></tr>
<tr><td colspan="2">MCA Ranking: Planning Modification – 1
Overall – 1</td><td>Associated Costs*:</td><td>Initial Cost: Net Present Value $2.0M to $49.6M
Recurrent Cost: $0</td></tr>
<tr><td colspan="3">Overview:
The Woy Woy Climate Change Adaptation Study (Rhelm, 2021b) provided valuable information to assist adaptation planning for low-lying areas of the Woy Woy Peninsula. The study was carried out for four locations within the Woy Woy FRMSP study area: the Woy Woy CBD, Blackwall, Booker Bay and Ettalong.

This option recommends the adoption of the outcome of the Woy Woy Climate Change Adaptation Study (Rhelm, 2021b), which is the implementation workplan associated with Adaptation Pathway A (Figure 3-3). 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 and tidal flooding and improve catchment flooding.

In the low-lying areas of the study area, where filling is required for adaptation to rising sea levels, restrictions should be softened with respect to ‘adverse flooding impacts’ of filling being greater than 10mm. Hydraulic impact modelling in the Davistown and Empire Bay FRMS (Rhelm, 2021a) was undertaken, that has been used as a guide for the Woy Woy Peninsula. The modelling identified that the maximum cumulative impact on peak flood depths on private properties could be:
• + 150mm in the 1% AEP, and
• + 200mm in the PMF.
Given that it is the cumulative impact causing these peak flood depth impacts, and not a single lot being raised, Council could consider an approach where developers are required to contribute (based on per square metre area of their lot) to a drainage fund. The capital accumulated in this fund shall be used for lot-scale drainage works to mitigate the interim impacts of cumulative filling in the floodplain. The mechanism for releasing these funds should be further considered by Council based on the progress and pattern of filling realised in the future.

The conceptual landforms proposed in the Woy Woy Climate Change Adaptation Study (Rhelm, 2021b) need to be further refined for implementation. This will include:
• Detailed feasibility analysis
• Community consultation and engagement to resolve any issues associated with proposed easements
• Development of detailed design drawing and plans
• Detailed design of drainage components associated with the landforms
• Detailed staging plans to manage the impacts of filling and raising infrastructure on adjoining properties.</td></tr>
<tr><td colspan="3">Flooding issue addressed:
This option involves a long-term strategy for landform and drainage improvements in low-lying areas of the Woy Woy Peninsula to prevent frequent inundation from high tides under future sea level rise conditions and provides protection from current 1% AEP ocean storm events.</td></tr>
</table>

Climate Change Landform Adaptation	
Expected Mitigation Outcomes: It is expected that the implementation of this option will achieve increased protection for the community from ocean and tidal flooding, which will be aggravated from climate change effects. Additionally, the modified landforms will generally improve the drainage conditions in almost all areas within the larger study area, relative to what would be expected in a 2100 sea level rise scenario. Further concept design refinements during the masterplanning stage will ensure all areas will experience this improved drainage condition.	**Considerations:** • Relatively urgent action is required to consider Adaptation Pathways A or B. • Individual raising of property ground levels are likely to conflict with existing DCP requirements to not adversely affect flood behaviour on neighbouring properties. • Voluntary house raising is not compatible with the landform proposed in the climate change adaptation strategy. Considering the context of the climate change adaptation study, it is preferable that properties fill and redevelop, rather than raise existing structures and maintain existing ground levels.

4.2.3 Emergency Response Modification Measures

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. 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.

The following emergency response modification options are recommended for the Woy Woy Peninsula study area.

- Review of Evacuation Centre Locations
- Flood Warning Signage
- Flood Warning Systems
- Flood Education Programs.

In addition to the options discussed below, it is noted that floor level survey has been collected as part of the Brisbane Water Foreshore FRMS (Cardno, 2015a), Kahibah flood studies (Willing & Partners, 1991), and the Woy Woy FRMS (DHI, 2022). This information will greatly assist SES in responding to flood events.

<table>
<tr><th colspan="3">SES Review of Evacuation Centre Locations</th></tr>
<tr><td colspan="2">Flood Management Type: Emergency Response Modification (ID: EM01)</td><td>Responsibility: Council / SES</td></tr>
<tr><td colspan="2" rowspan="2">MCA Ranking: Planning Modification – 5
Overall – 5</td><td rowspan="2">Associated Costs:</td><td>Initial Cost: $10,000</td></tr>
<tr><td>Recurrent Cost: -</td></tr>
<tr><td colspan="3">Overview:
Flood-free locations that can function as evacuation centres for Woy Woy have been identified below. These are locations that are accessible during significant flood events by most of the community. The list below includes venues identified in the Brisbane Water FRMS (Cardno, 2015a) and in the Gosford Local Flood Plan:
• Peninsula Community Centre Green Point Community Centre
• Umina Surf Life Saving Club Saratoga Community Hall
• Ettalong Beach War Memorial Club (Ettalong Diggers)
• Everglades Country Club
• Umina Beach Public School
• Umina Beach PCYC.
The location of the identified venues is shown in Map G115 in the FRMS. These venues have been</td></tr>
</table>

SES Review of Evacuation Centre Locations	
identified exclusively from a flood access perspective. Council and the SES should review the venues including the facilities, indoor area available and flood free access to the sites and liaise with the owners and / or managers of the venues to identify appropriate evacuation centres. During the PMF event, areas of Umina Beach become flooded, isolated and submerged (refer **Map G114** in the FRMS). 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 and also accessible. 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.	
Flooding issue addressed: Evacuation Centres would play a fundamental role in the Emergency Response to a major ocean flooding event in the study areas. In this type of flooding event, dislocating towards an evacuation centre could be the appropriate response option for many residents in the Woy Woy Peninsula. The relatively slow rate of rise and fall of the floodwaters 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.	
Expected Mitigation Outcomes: As an outcome of these recommendations, designated evacuation centres will be defined for the Woy Woy Peninsula. Therefore, flood affected residents will have the option to seek shelter in these locations, during and immediately after a major flood event. This would likely be associated with Brisbane Water flooding but could also provide refuge for residents if their properties sustain damage from catchment flooding or other storm impacts such as wind.	**Considerations:** In the Woy Woy Peninsula, evacuation might not be the recommended response during a flood event, depending on the mechanism of flooding. During catchment flooding events, there is typically little response time available and, for some locations, staying at home might be the safest course of action. It is fundamental that residents are aware of the how to respond to the different mechanisms of flooding their local area is subjected to. The Flood Education Measures proposed in this FRMP (**EM05**) should address this issue.

<table>
<tr><th colspan="3">SES Review of Flood Warning Systems</th></tr>
<tr><td colspan="2">Flood Management Type: Emergency Response Modification (ID: EM03)</td><td>Responsibility: Council</td></tr>
<tr><td colspan="2" rowspan="2">MCA Ranking: Planning Modification – 9
Overall – 14</td><td rowspan="2">Associated Costs:</td><td>Initial Cost: $50,000</td></tr>
<tr><td>Recurrent Cost: $10,000 p/ year</td></tr>
<tr><td colspan="3">Overview:
While there currently are flood warning systems in place by Council. The following is an extensive list of actions to support flood warnings, and there may be some overlap with what is currently in place.
The NSW Bureau of Meteorology (BOM) is the organisation 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, Council and the SES play an important role in distributing these warning to the local community.
Currently there is no consolidated system in place for delivering these warnings and for informing the community of the recommended course of action.
<u>Ocean Flooding -</u> The Brisbane Water Floodplain Management Study (Cardno, 2015a) provides a series of recommendations for the review of flood warning systems in the Brisbane Water foreshore (EM4). The measures listed below would be applicable to Woy Woy Peninsula and are also proposed in this FRMSP.
• 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 the 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.
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.
<u>Catchment Flooding</u> - 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.
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</td></tr>
</table>

<table>
<tr><th colspan="2">SES Review of Flood Warning Systems</th></tr>
<tr><td colspan="2">

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

Alerts could be sent by:

e-mail
SMS
recorded message to a landline.

Additionally, these alerts could be also broadcasted in local radio channels and provide to local community groups to distribute to their members.
</td></tr>
<tr><td colspan="2">Flooding issue addressed:
Flood warnings and alerts have the potential to reduce the flood risks associated with both catchment and ocean driven flooding. Although the ability to better predict elevated ocean levels, and the longer warning time means that flood warnings associated Brisbane Water flooding are likely to have more benefits.</td></tr>
<tr><td>Expected Mitigation Outcomes:
Increasing the community's readiness for a flood event will reduce flood risk to property and life by allowing them time to take actions such as:

Moving possessions within their home or business to higher levels
Moving parked cars to safe locations
Ensuring flow paths are not blocked by debris, or other moveable items
Evacuating, if appropriate
Checking on neighbours.
</td><td>Considerations:

The effectiveness of flood warnings and alerts will be increased through a concurrent flood education program.
The wording of the issued flood warnings would be critical to increase responsiveness, without creating unnecessary alarm.
Based on the responses from the community survey (Section 2.5) Most of the respondents would look for updates or information on radio (27%), on TV (22%), on Council's website (18%) and on social media (14%). Therefore, it is recommended that these avenues be targeted when releasing information related to weather and flood warnings.
Warning could also be sent using SMS messages and e-mails. However, this approach needs to be considered with caution, as a few false alarms could deteriorate the community's trust in the system and negatively affect future emergency responses. The ability to forecast and predict catchment flooding is limited, and as such this method of flood warning would likely have limitations.
The flood warning system recommendations in this FRMP are aligned to short term propositions outlined in the Southern Central Coast Storm and Flood Forecasting Study (MHL, 2017).
The flood forecasting study also outlines long-term recommendations applicable to the Woy Woy Peninsula. 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.
</td></tr>
</table>

<table>
<tr><th colspan="3">Flood Warning Signage</th></tr>
<tr><td colspan="2">Flood Management Type: Emergency Response Modification (ID: EM04)</td><td>Responsibility: Council</td></tr>
<tr><td colspan="2" rowspan="2">MCA Ranking: Planning Modification – 2
Overall – 2</td><td rowspan="2">Associated Costs:</td><td>Initial Cost: $5,000 per sign</td></tr>
<tr><td>Recurrent Cost: -</td></tr>
<tr><td colspan="3">Overview:
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 high flood depths (>0.3 m) in the 20% AEP flood event (catchment flooding) were identified. This resulted in nineteen (19) locations where flooding signs could improve flood risk outcomes. If the criteria were changed so that flood depth markers were placed where flood hazard in the 1% AEP is greater than H2, the locations this would apply to would reduce to five (5) of the more significantly affected roadways.
Refer to Section 13.3.4 of the FRMS for further details on signage locations.
Signage should 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. In these locations, the waves produced by passing cars can make the difference between yard flooding and over floor flooding. This can also be incorporated into a flood education program (EM05).</td></tr>
<tr><td colspan="3">Flooding issue addressed:
Driving through floodwater can be extremely dangerous. Often people drive through floodwaters because it is unclear how deep the flooding is. Depth markers or warning signs can assist in deterring drivers from entering flood waters. Ideally, roads are closed when flooding occurs, but this is not always feasible as flooding can occur quickly and across numerous locations at once.</td></tr>
<tr><td colspan="2">Expected Mitigation Outcomes:
Reducing drivers entering floodwaters and therefore reducing accidents, damage to property and risk to life.</td><td colspan="2">Considerations:
• This location is a wide flat area, which is primarily affected by shallow flooding. The location of the depth markers or flood warning signs should consider this.
• It is encouraged to use flood depths markers along existing evacuation routes.
• 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.</td></tr>
</table>

<table>
<tr><th colspan="3">Flood Education Programs</th></tr>
<tr><td colspan="2">Flood Management Type: Emergency Response Modification (ID: EM05)</td><td>Responsibility: Council / SES</td></tr>
<tr><td colspan="2" rowspan="2">MCA Ranking: Planning Modification – 3
Overall – 3</td><td rowspan="2">Associated Costs:</td><td>Initial Cost: $10,000</td></tr>
<tr><td>Recurrent Cost: $4,500 p/ year</td></tr>
<tr><td colspan="3">Overview:
Community awareness and behaviour is an important aspect of reducing flood risk within a catchment. If a community is aware of how flood risks develop within their local area, and the correct ways in which to respond, risk to life can be substantially reduced.
Council’s Flood Education Strategy is outlined in a working document, which summarises flood education objectives, measures, and resources. However, it is recommended that this document be periodically reviewed and updated to reflect Council’s existing practices and any new information.
It is recommended that the existing Flood Education Strategy is reviewed and updated as an outcome of this FRMP. 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.
• 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 older people 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 flood emergency response categorisation figures (Maps G110 to G114 in the Woy Woy FRMS (DHI, 2022)).
• 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</td></tr>
</table>

Flood Education Programs

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.

It is proposed that Flood Risk Education Program is also include elements of how private property affects flooding, and this be undertaken to advise the local community about the risk and effects of flooding.

This could include measures such as:

- Ensure that spatial risk information is readily available to members of the public
- Include brochures titled "What does my Planning Certificate mean?" with all property planning certificates when received by property purchasers.

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.

This option includes elements of the original Option PM04 (including recurrent costs) from the FRMS and had been consolidated with EM05 for overall harmonisation of Council's wider flood education programs.

Flooding issue addressed:

Woy Woy can be affected by both catchment flooding and foreshore inundation due to ocean storm events. The response time available associated with both mechanisms of flooding is substantially different, which impacts the recommended actions that should be taken by the community during ocean flood and catchment flood events. Therefore, it is important that public education progress address the two different types of flooding and what would be the adequate response for each. It should be noted that ocean flooding events can occur concurrently or separately from catchment flooding.

Expected Mitigation Outcomes:

If the members of the community understand their role in the overall floodplain management strategy for the study area, they are able to respond quickly and effectively to an emergency.

A flood ready community are more likely to take actions to protect life and property such as:

- Moving possessions within their home or business to higher levels
- Moving parked cars to safe locations
- Ensuring flow paths are not blocked by debris, or other moveable items
- Evacuating, if appropriate
- Checking on neighbours
- Enable community members to make better decisions regarding the flood risk to their properties and the impacts of any development pursued in the floodplain.

Considerations:

- The involvement of NSW SES members in community engagement and educations programs has been successful in engagement activities undertaken by Council and across NSW. SES members could be invited to participate in face to face education activities at community events, pop up stalls, or even door knocking of key locations.
- Another aspect that needs to be considered is that the terminology used in the flood awareness program is accessible and that it effectively communicates the level of flood risk.
- Another aspect that needs to be considered is that the terminology used is accessible and that it effectively communicates the level of flood risk for private properties.
- This Option should be built into Council's LGA wide flood education program.

4.3 Implementation Program

The actions listed in **Table 4-2** are recommended for implementation as an outcome of the NSW Government Floodplain Risk Management Process. In order to achieve the implementation of relevant management actions, a program of implementation has been development.

Table 4-2 provides the following information relevant to the implantation of the management actions:

- An estimate of capital and recurrent costs for each action (this may, in some cases, include existing staff and funding).
- The agency or organisation likely to be responsible for the action.
- The timeline for implementation (immediate or staged) and priority for implementation (high, medium or low).

The following provides further detail on the implementation timelines:

- **Immediate** – this indicates actions that could be implemented in the short term (less than 5 years) if funding and resourcing permits. Feasibility of the action is generally high and additional investigations or further development of the management strategy would be minimal;
- **Staged** – this indicates actions that could be undertaken in the short to medium term (up to 10 years). However, additional investigations, feasibility studies or further development of the management strategy are likely to be required. Where appropriate, interim policy and planning measures could be employed in the intervening time.

The following provides further detail on the priorities:

- **High priority:**
  - Require relatively low implementation effort and cost AND achieved a high score in the MCA (overall rank higher than 5).
  - Essential for a future climate change adaptation plan to be implemented.
- **Medium Priority:**
  - Requires significant implementation effort and cost AND achieved a high score in the MCA (rank higher than 5).
  - Achieved a medium score in the MCA (overall rank higher than 10).
- **Low:**
  - Achieved a relatively low score in the MCA (overall rank lower than 10).

Table 4-2 Implementation Action List

Option ID	Recommended Action	Indicative Costs		Potential Funding Sources/ Responsibilities	Implementation Time Frame	Priority	Performance Measures
		Capital Cost	Recurrent Cost				
FM03	Infiltration Devices	$25,000 per device	$1,250 per device	Council	Immediate	Medium	Reduced depth, extent and duration of nuisance flooding in flat, low-lying areas. Construction of infiltration devices with effective life span by ensuring routine maintenance.
PM01	Land Use and Development Control Planning Recommendations	-	-	Council	Immediate	High	Land use and development control planning documents updated.
PM05	Property Education and Compliance	$80,000	$5,000	Council	Immediate	Medium	Circulation of information within the community about the effects of encroaching into the riparian corridors with approved or exempt structures. Reduction of number of structures in the riparian corridors and subsequent reduction in flood levels.
PM06	Sustainable Level of Drainage Service	$20,000	-	Council	Staged	Medium	Update of Council development control planning documents and engineering specifications.
PM07	Landform Adaptation	$2.0M to $49.6M Net Present Value	-	Council/DPE/private development	Staged	High	Undertaken further feasibility studies, including detailed design and staging plan for works (filling, drainage and infrastructure raising). Confirm Sea Level Rise triggers and thresholds. Update Council's Policy and Planning Controls to enable to implementation of adaptation drainage and landform works.

Option ID	Recommended	Indicative Costs		Potential Funding	Implementation	Priority	Performance Measures
EM01	SES Review of Evacuation Centre Locations	$10,000	-	Council / SES	Immediate	Medium	Produce a flood emergency response plan for residents west of Ettalong and Iluka Creeks. List of evacuation centres suitable for flood emergency evacuation is prepared and added to SES protocols. Identification of evacuation centres in need of upgrades.
EM03	SES Review of Flood Warning Systems	$50,000	$10,000	Council	Staged	Low	Documented review of flood warning systems is completed. Actions outlined in EM03, and Southern Central Coast Storm and Flood Forecasting Study (MHL, 2017) completed.
EM04	Flood Warning Signs	$5,000 each		Council	Immediate	High	Installation of roadside signage, where deemed necessary.
EM05	Flood Education Programs	$10,000	$4,500	Council	Immediate	Medium	Flood education program is prepared. Program is implemented (each component may have specific performance metrics).

5 Conclusions

This FRMP provides a practical framework and implementation plan for managing existing, future and continuing flood risk within the study area.

Overall, it is considered that existing catchment flooding risks to the Woy Woy Peninsula can be managed appropriately through the implementation of development controls, property modification measures, emergency response measures and selected on ground works. The effective implementation of development controls will be of key importance in reducing the damages and risk to life associated with flooding through the construction of flood compatible buildings and assets.

More significant flood mitigation works will be necessary for mitigating risks from Brisbane Water Estuary flooding and for addressing future issues associated with sea level rise. More significant planning work are required in the immediate term to implement Adaptation Pathway A and its associated work plan outlined in the Woy Woy Climate Change Adaptation Study (Rhelm, 2021b). Without action being taken, there is significant risk to the lowest lying areas of the Woy Woy Peninsula becoming unliveable.

In order to achieve the implementation of relevant management actions, a program of implementation has been developed. The actions listed in **Section 4** are recommended for implementation.

The steps in progressing the floodplain risk management process from this point onwards are:

- Council will consider adopting the final Plan and submit applications for funding assistance to relevant State and Commonwealth agencies, as appropriate and within Council's available resources;
- The flood management actions will be prioritised for funding through the Integrated Planning and Reporting Process; and
- As funds become available from DPE, the Commonwealth, other state government agencies and/or from Council's own resources, recommended management actions will be implemented in accordance with the established priorities.

This FRMP fulfils its objectives accordance with the New South Wales (NSW) Flood Prone Land Policy (NSW Government, 2001) and the principles of the Floodplain Development Manual (NSW Government, 2005).

6 References

NSW Government (2005) Floodplain Development Manual

DECC (2007) Practical Consideration of Climate Change

Cardno Lawson Treloar (2013) *Brisbane Water Foreshore Flood Study*, Prepared for Gosford City Council

Gosford City Council (2014) Gosford Local Environmental Plan 2014

Cardno (2015a) *Brisbane Water Floodplain Risk Management Study*, Prepared for Gosford City Council

Cardno (2015b) *Brisbane Water Floodplain Risk Management Plan*, Prepared for Gosford City Council

Central Coast Council (2015) Flood Education Strategy - Working Document (2011-2015)

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

Central Coast Council (2018) Civil Work Specification - Design Guidelines

DHI (2021) Woy Woy Integrated Water Management and Case Study Everglades Catchment, Prepared for Central Coast Council

Rhelm (2021a) Davistown and Empire Bay Floodplain Risk Management Study, Prepared for Central Coast Council

Rhelm (2021b) Woy Woy Climate Change Adaptation Study, Prepared for Central Coast Council

Central Coast Council (2022a) Central Coast Local Environmental Plan 2022

Central Coast Council (2022b) Central Coast Development Control Plan 2022

DHI (2022) Draft Woy Woy Floodplain Risk Management Study, Prepared for Central Coast Council

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Maps

N

W E

S

Figure G112

Flood Emergency Response Classification

1% AEP

Legend

Cadastre

Emergency Response Category

- Flooded, Isolated, Submerged
- Flooded, Isolated, Elevated
- Flooded, Escape Overland
- Flooded, Escape Rising Road

1% AEP Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.2
- > 1.2

0 0.5 1 km

Scale : 1:20000@A3
Date : 22 March 2022
Revision : B
Created by : JRF
Coordinate System : MGA 56

Throughout the flatter area in the eastern side of the Woy Woy peninsula (generally bound by Hillview Street, Carpenter Street, and Hobart Avenue) flooding consists of isolated pockets mainly occurring on roadways. Maximum flood depths are in the order of 300-400mm and the affected properties all have rising road access within 50m.

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W E
S

Figure G114

Flood Emergency Response Classification

PMF

Legend

Cadastre

Emergency Response Category

- Flooded, Isolated, Submerged
- Flooded, Isolated, Elevated
- Flooded, Escape Overland
- Flooded, Escape Rising Road

PMF Flood Depth (m)

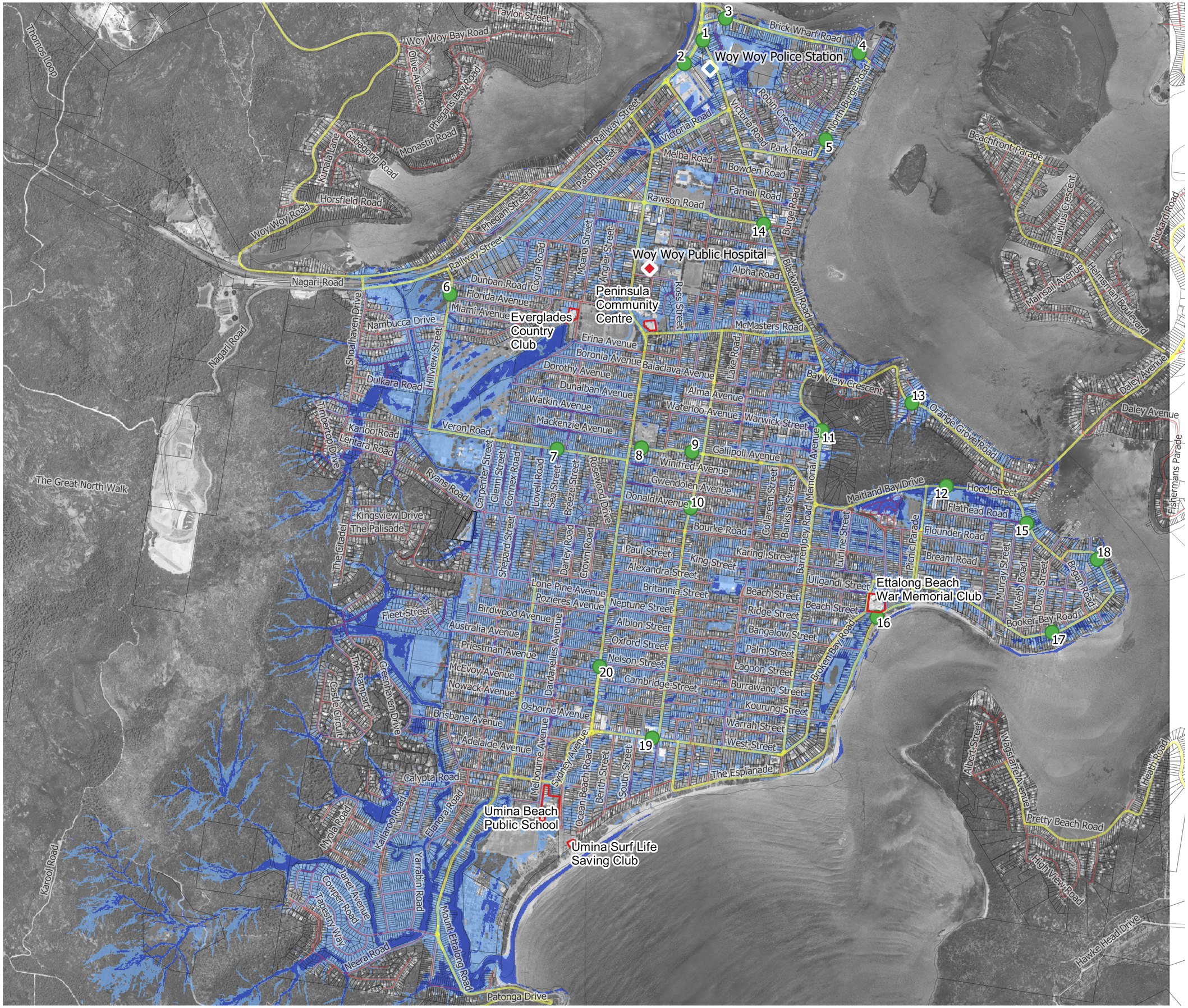
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.2
- > 1.2

0 0.5 1 km

Scale : 1:20000@A3
Date : 9 November 2020
Revision : A
Created by : JRF
Coordinate System : MGA 56

Rhelm

In the flatter areas in the eastern side of the Woy Woy peninsula categorised at Flooded, Isolated, Elevated, flooding is extensive and many areas become isolated while others have rising road access but it is unlikely that emergency services will be able to access these areas from the Woy Woy Hospital or Gosford Hospital.



N

W E

S

Figure G115

Roadway Overtopping Locations

- Road Overtopping Location
- Evacuation Centre (Building Outline)

Emergency Service Type

- Hospital
- Police

Road Classification

- Primary or Secondary
- Residential
- 1% AEP Flood Extent
- PMF Flood Extent
- Cadastre

0 500 1000

Scale : 1:20,000@A3
Date : 7 April 2021
Revision : A
Created by : JRF
Coordinate System : MGA 56

Rhelm

Appendix A

Floodplain Risk Management Options Identified in the FRMS

Option ID	Option Description	Brief description	Primary Flood Issue addressed	Source of option	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	MCA Rank - Overall	MCA Rank – Flood or Planning Modifications	Recommendation of FRMP
Flood Modifications											
FM01	Woy Woy CBD drainage upgrades	Establishment of a drainage easement stretching from the existing channel bordering the Woy Woy Oval to Charlton Street.	Catchment flooding within the Woy Woy CBD where roadway ponding frequently occurs.	The Woy Woy Climate Change Adaptation Study's concept landform for the Woy Woy CBD involves establishing a drainage pathway which surrounding properties and roads can grade down to using minimum gradients.	$1,708,840	$500	$176	0.00	18	8	Not recommended The advantages of implementing this drainage upgrade in the short term (as opposed to implementing as part of a climate change adaptation plan) are marginal with respect to reduction in flood levels for the immediate surrounds.
FM02	Dulkara Road to Karringal Close drainage upgrades	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.	Catchment flooding producing overland flows through private property.	Discussions with DHI, Rhelm, Council and DPE	$653,100	$500	$14,457	0.32	19	9	Not recommended The benefits of the improved drainage capacity do not outweigh the costs for its implementation.
FM03	Infiltration Devices	Installation of infiltration devices along streets with significant ponding.	Catchment flooding near roadways across the Woy Woy Peninsula where groundwater levels are relatively deep below the surface.	Woy Woy Integrated Water Management and Case Study Everglades Catchment	$144,200	$6,000	-	-	6	1	**Recommended** Although there is minimal reduction in peak flood level in private property, the advantages of reducing ponding extents and durations along roadways is the main outcome of this option. Additionally, this will reduce dependency on traditional pit and pipe drainage systems. The six nominated locations may be adjusted as needed.
FM04	Groundwater pumping and Everglades drainage update work	Bore water pumps were originally installed to augment the council water supply. This option considered the strategic long-term pumping at the existing production bores to reduce groundwater levels and increase infiltration capacity.	Catchment flooding across the Woy Woy Peninsula which is exacerbated by shallow groundwater levels.	Woy Woy Integrated Water Management and Case Study Everglades Catchment	$-	$4,000	-	-	11	3	Not recommended Constant pumping of groundwater did not have a significant impact on design flood levels.
FM05	Greenhaven Drive drainage upgrades	Increasing the capacity of the drainage along The Rampart, Greenhaven Drive, Australia Avenue, and Glenhaven Close and direct runoff away from private properties.	Catchment flooding producing overland flows through private property.	Discussions with DHI, Rhelm, Council and DPE	$163,520	$-	$15,247	1.38	10	2	Further consideration Although this option produced a BCR greater than 1, the option did not rank highly in the MCA.

Option ID	Option Description	Brief description	Primary Flood Issue addressed	Source of option	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	MCA Rank - Overall	MCA Rank – Flood or Planning Modifications	Recommendation of FRMP
FM06A	Kahibah Creek system maintenance	Cease routine maintenance within the riparian areas of the Kahibah Creek system and redirect funding.		Discussions with DHI, Rhelm, Council and DPE	$-	$320,000	$803	0.00	20	10	Recommended The annual cost savings is significant enough to warrant further consideration of this option for implementation. However, other actions will need to be taken to mitigate the increases in peak flood levels in the riparian area, such as a program for removal of structures recommended in Option PM05.
FM06B	Increase Kahibah Creek system maintenance	Increase routine maintenance within the riparian areas of the Kahibah Creek system, and potentially line the downstream extents to increase hydraulic capacity.	Mainstream flooding along Kahibah Creek	Discussions with DHI, Rhelm, Council and DPE	$300,000	$200,000	N/A	N/A	15	6	Not recommended Capital and recurrent costs are too high given the minimal reduction in flood levels along the lower portions of Kahibah Creek.
FM08	Palmtree Grove detention basin reduced capacity	Basin storage is reduced so that it might no longer be a 'declared' dam and annual maintenance expenditure can be reduced. To minimize the flood risk impact, alternative mitigation measures are proposed.		Discussions with DHI, Rhelm, Council and DPE	$295,400	-$30,000	-$2,822	3.54	12	4	Further Consideration Although there would potentially be significant cost savings for annual maintenance of the basin, this is conditioned that the basin be de-declared by Dams Safety NSW. Furthermore, the proposed basin arrangement will need to be refined, as the increase in peak flood levels on the eastern side of Palmtree Grove in more frequent storm events will need to be mitigated. BCR for this option was 3.54.
FM09	Wilks Avenue and McManus Close drainage upgrades	Increasing the capacity of the drainage along Wilks Avenue and McManus Close and direct runoff away from private properties.	Catchment flooding producing overland flows through private property.	Discussions with DHI, Rhelm, Council and DPE	$95,830	$-	$-	-	16	7	Not recommended The proposed upgrades did not have a significant positive effect on flood behaviour in private properties.
FM10	Neera Road drainage upgrades	Increasing drainage capacity near the intersection of Neera Road and Mountain Ash Way. Excavation of channel leading to the north.	Catchment flooding producing overland flows through private property.	Discussions with DHI, Rhelm, Council and DPE	$138,880	$-	$-	-	12	4	Not recommended The benefits of the improved drainage capacity do not outweigh the costs for its implementation.

Option ID	Option Description	Brief description	Primary Flood Issue addressed	Source of option	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	MCA Rank - Overall	MCA Rank – Flood or Planning Modifications	Recommendation of FRMP
Planning Modifications											
PM01	Land Use and Development Control Planning Recommendations	Council's existing land use and development planning controls were reviewed as part of this study. 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.	Catchment flooding across the Woy Woy Peninsula	Standard option to be assessed as part of the NSW Floodplain Risk Management Process	$ -	$-	N/A	N/A	N/A		**Recommended**
PM03	Voluntary House Raising	Under the NSW Floodplain Management Program, DPE provides funding to assist home owners raise the floor level of their house to reduce the damages and trauma caused by flood water inundating their house.	Properties subjected to high flood risk from Catchment flooding in the Woy Woy Peninsula	Standard option to be assessed as part of the NSW Floodplain Risk Management Process	$100,000 per house	$-	$10-20K per house	< 0.1	9	8	Not recommended There is a prohibitively significant capital cost required from Council. This may not be able to be supplemented by DPE funding assistance.
PM04	Property Flood Risk Education Program	A strategic, balanced and socially sensitive education program to advise the local community and prospective property purchasers about the risk and effects of catchment and coastal flooding.	It cannot be assumed that all residents are sufficiently aware of the flood risk they are subjected to and of how respond in a flood emergency.	Brisbane Water FRMP	$-	$2,000	N/A	N/A	7	6	Recommended
PM05	Property Management Education Program	Establish a program to educate residents about how to mitigate flooding through their own property management. This would be beneficial to the surrounding properties but can also reduce flood risk for the individual resident who manages their own property	Mainstream flooding along Kahibah Creek	Discussions with DHI, Rhelm, Council and DPE	$80,000	$5,000	N/A	N/A	8	7	Recommended

Option ID	Option Description	Brief description	Primary Flood Issue addressed	Source of option	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	MCA Rank - Overall	MCA Rank – Flood or Planning Modifications	Recommendation of FRMP
PM06	Reduced 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 drainage works in this area may be possible without increasing flood risk.		Discussions with DHI, Rhelm, Council and DPE	$20,000	-	N/A	N/A	3	3	Recommended
PM07	Landform Adaptation	Implementation of Adaptation Pathway A and associated work plan to incrementally raise the landform of low-lying areas of the Woy Woy Peninsula	flooding of low-lying areas up to the existing 1% AEP ocean event and 'king tides' up to 2100 accounting for sea level rise. Also improves catchment flooding by allowing steeper road gradients for drainage.	Woy Woy Climate Change Adaptation Study	$2.0M to $49.6M	-	> $100K	0.2 to 0.8	1	1	Recommended
EM01	SES Review of Evacuation Centre Locations	Identification of Flood-free locations that could function as evacuation centres for the Woy Woy Peninsula.	Some areas in the upper reaches of Kahibah Creek do not have an evacuation centre or plan, and they are cut off from access during extreme flood events.	Brisbane Water FRMS	$10,000	-	N/A	N/A	5	5	Recommended
EM02	Access Improvements During Flooding	Significant to moderate extents of road raising and associated cross drainage works for flood affected roads that are part of key access routes across the peninsula.	Flooding across many of the key access routes in the Woy Woy Peninsula during very rare and extreme events.	Brisbane Water FRMS	" $1.6M - 1% AEP $12.2M - PMF "				17	10	Not Recommended There are significant costs involved in road raising, particularly up to the PMF level, without significant access improvements considering the catchment flood risk during the 1% AEP and PMF events. If, in Council's future works plan, any of the listed roads in this option require reconstruction or resurfacing, at this time the road could be considered for raising.

Option ID	Option Description	Brief description	Primary Flood Issue addressed	Source of option	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	MCA Rank - Overall	MCA Rank – Flood or Planning Modifications	Recommendation of FRMP
EM03	SES Review of Flood Warning Systems	Implementation of a flood warning system, through which Council and the SES can effectively disseminate warnings issued by BOM.	Currently there is not an official system in place to warn the community of potential flood events.	Brisbane Water FRMS	$50,000	$10,000	N/A	N/A	14	9	Recommended
EM04	Flood Warning Signage	Positioning of flood warning signs and depth markers in roads that are subjected to frequent flooding, to inform drivers, prevent potential accidents, and reduce the wave action creating by vehicles spreading into properties and houses.	Catchment flooding in road sections.	Discussions with DHI, Rhelm, Council and DPE	$5,000	$1,000	NA	NA	2	2	Recommended
EM05	Flood Education Programs	Education program to promote flood awareness in the community	It cannot be assumed that all residents are sufficiently aware of the flood risk their properties are subjected to and of how respond in a flood emergency.	Woy Woy FRMS	$10,000	$2,500	NA	NA	3	3	Recommended
PM02	Voluntary House Purchase	Not considered									

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