Davistown and Empire Bay Floodplain Risk Management Study

Draft

Central Coast Council | Draft | February 2021

Contact Information

Rhelm Pty Ltd
ABN : 55 616 964 517
Level 1, 50 Yeo Street
Neutral Bay NSW 2089
Australia

Lead Author:
Emma Maratea
Emma.maratea@rhelm.com.au

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Further Information

For further information about the copyright in this document, please contact:

Central Coast Council

49 Mann Street, Gosford NSW 2250

ask@centralcoast.nsw.gov.au

+612 4325 8222

Foreword

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

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

The 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 options of the NSW Government or the NSW Department of Planning, Industry and Environment (DPIE).

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).

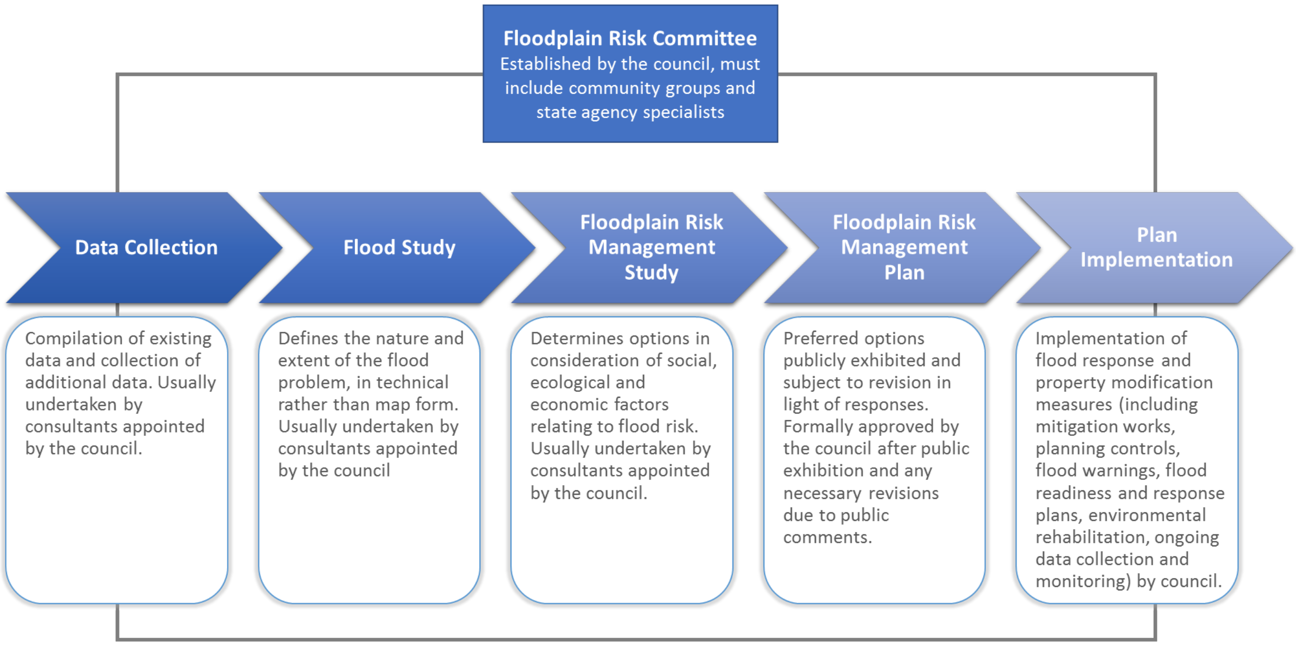


Figure F1 The Floodplain Risk Management Process (source: NSW Government, 2005)

Central Coast Council is responsible for local land use planning in its service area, including in Davistown and Empire Bay catchments and their floodplains. Through its Floodplain Risk Management 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 study phase of the process.

Executive Summary

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

Davistown and Empire Bay catchments are sub-catchments of Brisbane Water, which connects to Broken Bay, and are located in the Central Coast Council local government area. The catchment areas are approximately 190 ha and 554 ha respectively.

This FRMS is to be considered in conjunction with a Floodplain Risk Management Plan (FRMP), prepared as a separate document to this FRMS. The FRMP outlines the floodplain management measures recommended to be adopted for implementation along with the implementation strategy associated with those measures.

In addition to the FRMS, a separate climate change adaptation study was undertaken by Council (Rhelm, 2020) to identify feasible strategies to adapt the low-lying areas of Davistown and Empire Bay to the impacts of sea level rise. The findings of this study were also considered in the assessments undertaken in this FRMS and the recommendations presented in the FRMP.

Study Objectives

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

This project involves and extends the Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010), which are comprehensive technical investigations of flood behaviour that provide the main technical foundation for the development of a robust floodplain risk management plan. The studies provide an increased understanding of the impacts of floods on the existing and future community. The flood models developed as part of the flood studies form the basis of a flood model to allow testing and investigating practical, feasible and economic management measures to treat existing, future, and residual risk. This FRMS provides the basis for informing the development of the FRMP.

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

- relevant government information systems
- government and strategic decision makers on flood risk
- the community and key stakeholders on flood risk
- flood risk management planning for existing and future development
- emergency management planning for existing and future development, and strategic and development scale land-use planning to manage growth in flood risk
- decisions on insurance pricing
- selection of practical, feasible and economic measures for treatment of risk
- development of a floodplain risk management plan
- development of a prioritised implementation strategy.

The outputs of the study will assist this by:

- providing a better understanding of the:
    - variation in flood behaviour, flood function, flood hazard and flood risk in the study area
    - impacts and costs for a range of flood events or risks on the existing and future community
    - impacts of changes in climate on flood risk
    - emergency response situation and limitations
    - effectiveness of current management measures
- facilitating information sharing on flood risk across government and with the community.

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

Study Approach

The following approach was undertaken as part of this study:

- Site inspection of the study area was undertaken by the project team on 6 November 2018.
- Compilation of floor level survey based on previous flood-related studies and some additional floor level survey collected during property surveys in September 2019 as part of this study.
- Review of relevant reports, including six significant previous flood-related studies that encompass the study area.
- Review of existing flood models that encompass the study area. A hydraulic model had been prepared for the catchments as part of the Flood Studies (Cardno Lawson Treloar, 2010). This 1D/2D Sobek model was reviewed for its suitability for use in the current study. The Sobek model was found to be reasonably suitable in most schematisation aspects for use in this study.
- Evaluation of flood risk to the community based on the outcomes of the Flood Studies (2010).
- Consultation with stakeholders and the community on what they identified as key flooding issues and suggested flood management strategies.
- Review of flood planning policy, including flood-related controls covered by the LEP, relevant DCPs, Council policies and plans. Recommendations have been made for updates that could be undertaken to improve the management of flood risk.
- Assessment of a range of flood mitigation strategies, including Flood Modification, Emergency Response Modification and Property Modification Options.
- Providing recommendations for the flood management approach for Davistown and Empire Bay to be included in the Floodplain Risk Management Plan.

Key Flood Risk Issues

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

- **Brisbane Water flooding as a result of ocean storms:**
  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 Davistown and Empire Bay. During Brisbane Water flooding events,

flood levels typically rise and fall over several hours, with inundation occurring for approximately 5 hours in a 1% AEP event. Flood depths can be up to 0.5 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 most significant flooding occurring as a result of a 2 hour duration storm event for most design floods. Flooding of roads and private properties is generally associated with shallow depth (<0.3 m) overland flow. Flood depths increase in trapped low points on the low lying, flat portions of Davistown and Empire Bay.

- **Tidal inundation during high tides**:
  The existing flood risks associated with tidal inundation are not significant in Davistown and Empire Bay, 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. This will compromise the liveability of some portions of the suburbs through flooding of roads, services, and private properties.

It should be noted that the effects of climate change will potentially aggravate the impacts of all three types of flooding in Davistown and Empire Bay. As a result of sea level rise, it is expected that the magnitude and frequency of Brisbane Water flooding and tidal inundation will increase considerably. Additionally, the higher ocean level will compromise drainage conditions and exacerbate the consequences of local catchment flooding. These flood risks have been considered in the Climate Change Adaptation Study (Rhelm, 2020b).

Flood risk associated with catchment flooding has been presented in this report in term of Flood Hazard (**Section 6.1**), Hydraulic Categorisation (**Section 6.2**), and flood impacts on roads (**Section 6.5**). Emergency Response Classification (**Section 6.3**) has been assessed with regards to both catchment flooding and flooding from Brisbane Water.

Flood risk from ocean storm flooding was assessed as part of the Brisbane Water Floodplain Risk Management Study (Cardno, 2015). The outcomes of the 2015 study have been used to inform the assessment of several local floodplain risk management measures as part of this FRMS.

Climate Change Flood Risk and Planning

The suburbs of Davistown & Empire Bay are representative of a number of suburbs in and around Brisbane Water Estuary that are low lying and susceptible to both the existing flood risk and the effects of climate change. The future preparation of an adaptation masterplan for Davistown and Empire Bay is being considered by Council. This masterplan would identify adaption pathways such as development controls, levees and other mitigation measures which could be implemented over time in consultation with the community.

A climate change adaptation study was recently undertaken by Council (Rhelm, 2020) to inform the development of a regional adaptation masterplan and these associated processes. The climate change adaptation study (Rhelm, 2020) 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 proposed 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 and foreshore barriers were also incorporated into the concept designs.

The findings of the climate change adaptation study (Rhelm, 2020) are presented in **Section 7**.

The effects of climate change will potentially aggravate the flood conditions in Davistown and Empire Bay over time and significantly compromise the liveability of some portions of the suburbs through flooding of roads, services, and private properties.

The timely preparation and implementation of a Climate Change Adaptation Masterplan will be crucial to guarantee that the flood mitigation measures are ready for implementation when sea level rise triggers are reached. Therefore, it is recommended that Council proceed with the next stages of the development of a Climate Change Adaptation Masterplan. This will include assessment of the constructability of the proposed adaptation strategy and the implementation planning. The FRMS and FRMP will also provide information to assist in the implementation of the Masterplan.

Additionally, aspects of the infrastructure associated with proposed climate change adaptation (e.g. foreshore barriers and drainage easements) and have been considered and assessed in the FRMS and FRMP as options for managing existing flood risk. It was found that not only are these works critical to the future development of climate change adaptation landforms; they also provide immediate management of flood risk through protection against Brisbane Water flooding and improved drainage. These recommended works included:

- A drainage easement between Myrtle Road and Kendall Road (FM EB5)
- A foreshore barrier at Davistown (FM DT1).

Options Assessed

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

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

- Flood modification measures – options aimed at preventing/avoiding or reducing the likelihood of flood risks through modification of flood behaviour in the catchment
- Property modification measures – options focused on preventing/avoiding or reducing the consequences of flood risks. Rather than necessarily modify flood behaviour, these options aim to modify existing properties (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 range of possible options were considered as part of this FRMS and are discussed in **Section 8**. The proposed measures contemplate catchment and ocean flooding.

Outcomes and Recommendations

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

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

Additionally, this FRMS provides information to assist in the implementation of the future climate change adaptation masterplan, which is an important step in addressing future flood risk in Davistown and Empire Bay.

The options recommended for implementation are described in detail in the FRMP. Table E-1 summarises the recommended measures, according with the type of flood risk they primarily address (catchment flood, storm surge flood and tidal flood). This table also provides information on the recommended timeframe for the implementation of these options. The two timeline horizons are described below:

- 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.

An overview of the recommended measures (where a location is relevant) is presented in **Figure E-1** and **Figure E-2**.

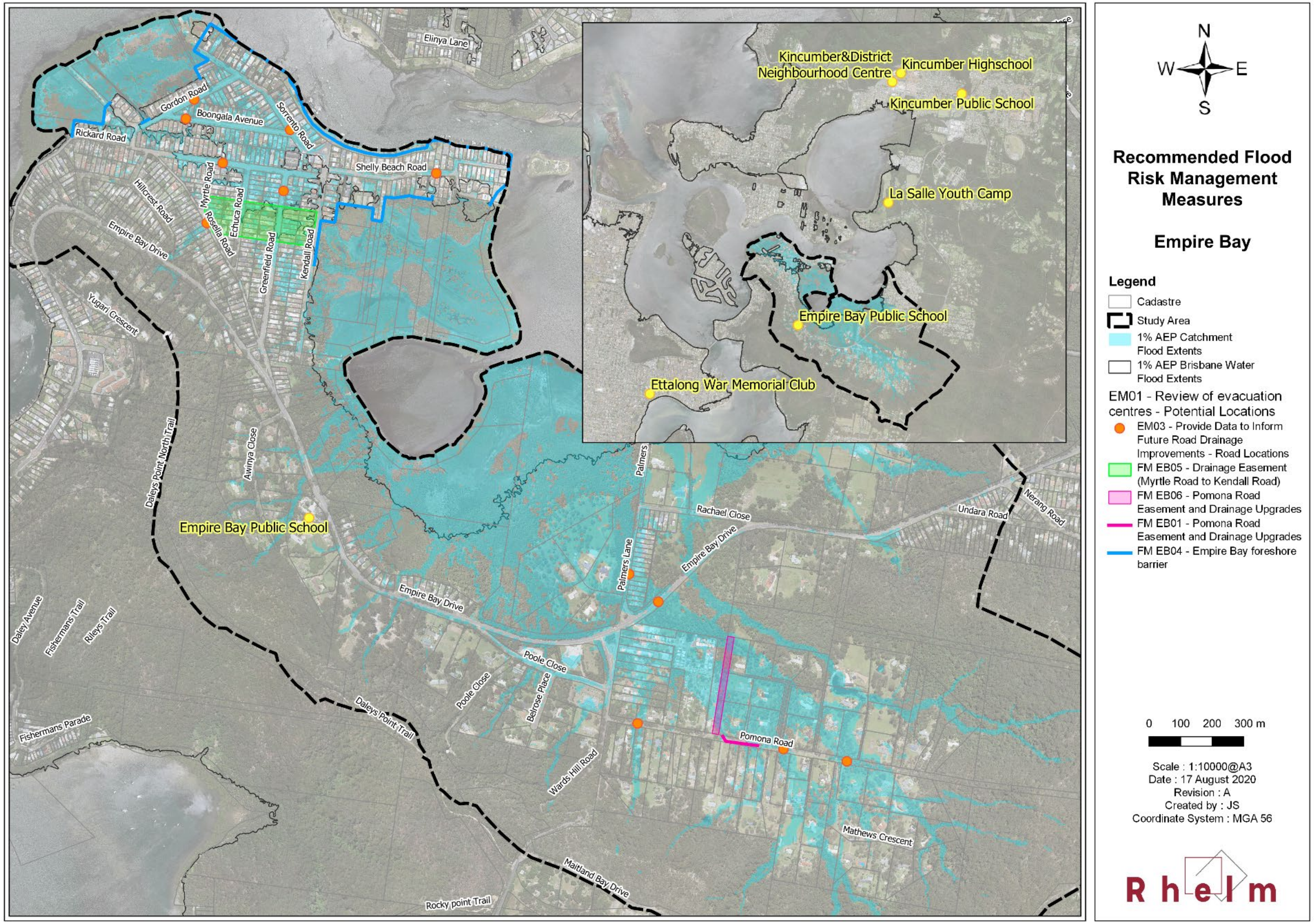
It should be noted that two of the recommended options (FM EB5 and FM DT1) are also elements of the landforms proposed in the Climate Change Adaptation Study (Rhelm, 2020). These options have been selected due to their effectiveness in managing existing flood risk. However, the recommended works will have the added benefit of assisting in the staged implementation of the future Climate Change Adaptation Masterplan.

Table E-1 Summary of Recommended Floodplain Risk Management Measures

Primary Type of flood Risk Addressed	Option ID	Option Name	Implementation Time Frame / Priority
Catchment Flood Risk	FM EB5	Drainage Easement (Myrtle Road to Kendall Road)	Staged / High Priority
	FM EB1 & FM EB6	Pomona Road Easement and Drainage Upgrades	Staged / Low Priority
	PM01	Flood Planning Recommendations	Immediate / High Priority

Primary Type of flood Risk Addressed	Option ID	Option Name	Implementation Time Frame / Priority
	EM03	Provide Data to Inform Future Road Drainage Improvements – Empire Bay Drive and Other Flood Affected Roads	Immediate / Medium Priority
	EM05	Flood Warning Signs (at Empire Bay Drive)	Immediate / Medium Priority
Brisbane Water Flood Risk	FM DT1	Davistown foreshore barrier	Staged / High Priority
	FM EB4	Empire Bay foreshore barrier	Staged / Medium Priority
	EM01	Review of evacuation centres	Immediate / High Priority
	FM EB2	Seawall construction guidelines	Immediate / High Priority
Tidal Flood Risk	CCA-01	Advance to the next stages of the Davistown and Empire Bay Climate Change Adaptation planning process.	Staged / High Priority
	CCA-02	Provide Information to assist in next stages of the Davistown and Empire Bay Climate Change Adaptation planning process.	Immediate / High Priority
Measures Applicable to All mechanisms of Flooding	EM06 & PM04	Flood education programs	Immediate / Medium Priority
	EM04	Flood warning systems.	Immediate / Medium Priority

Figure E-1 Recommended Flood Risk Management Measures - Davistown



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Glossary

Annual exceedance probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m^3/s (or larger) occurring in any one year. (See also average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Attenuation	Weakening in force or intensity.
Average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20 year ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. (See also annual exceedance probability).
Catchment	The catchment, at a particular point, is the area of land that drains to that point.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year ARI or 1% AEP flood).
Development	Is defined in Part 4 of the 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 Control Lot	A property identified as being impacted by flooding (i.e. within the Flood Planning Area) and where residential development controls may apply. These properties are notated through 10.7 planning certificates.
Flood Education	Education that seeks to provide information to raise awareness of the flood problem to enable individuals to understand how to manage themselves and their property in a flood event.
Flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.

Flood hazard	The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
Floodplain	Area of land which is subject to floods up to and including the probable maximum flood.
Floodplain risk management plan	A document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan needs to be developed in accordance with the principles and guidelines contained in the NSW Floodplain Development Manual. The plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives.
Flood planning 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. Properties within the Flood Planning Area are identified as Flood Control Lots.
Flood planning levels (FPLs)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also consider the social, economic, and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plans. The concept of FPLs supersedes the "standard flood event". As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Gauging (tidal and flood)	Measurement of flows and water levels during tides or flood events.
Hazard	A source of potential harm or a situation with a potential to cause loss.
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.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrologic	Pertaining to rainfall-runoff processes in catchments.
Hydrology	The term given to the study of the rainfall-runoff process in catchments, in particular, the evaluation of peak flows and flow volumes. .
Isohyet	Equal rainfall contour.
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).
Minimum floor level	Minimum level to which the floor level should be constructed. Often also referred to as the Flood Planning Level.
Peak flood level, flow, or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
Pluviometer	A rainfall gauge capable of continuously measuring rainfall intensity.
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood that could conceivably occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Probability of Exceedance (PoE)	The probability of exceedance describes the likelihood of a specified flow rate or water level being exceeded in a given year.
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.
Sea level rise	The average long-term global rise of the ocean surface measured from the centre of the earth (or more precisely, from the earth reference ellipsoid), as derived from satellite observations. Relative sea-level rise refers to long-term average sea-level rise relative to the local land level, as derived from coastal tide gauges.
Stage	See flood level.
Stage hydrograph	A graph of water level over time.
Topography	The shape of the surface features of land.
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi-2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

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

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ARR87	The 1987 Edition of Australian Rainfall and Runoff
ARR2019	The 2019 Edition of Australian Rainfall and Runoff
BoM	Bureau of Meteorology
CCC	Central Coast Council
DCP	Development Control Plan
DEM	Digital Elevation Model
DPE	Department of Planning and Environment
DPIE	Department of Planning, Industry and Environment
IFD	Intensity Frequency Duration
IWCM	Integrated Water Cycle Management
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FRMSP	Floodplain Risk Management Study & Plan
ha	hectare
HHWS	High high water springs
km	kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
m	metre
m^2	Square metres
m^3	Cubic metres
m AHD	metres to Australian Height Datum
mm	millimetres

m/s	metres per second
MHWS	Mean high water springs
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW)
PMF	Probable Maximum Flood
PoE	Probability of Exceedance
SES	State Emergency Service (NSW)
WSUD	Water Sensitive Urban Design

1 Introduction

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

This FRMS is to be considered in conjunction with a Floodplain Risk Management Plan (FRMP), prepared as a separate document to this FRMS. The FRMP outlines the floodplain management measures recommended to be adopted for implementation along with the implementation strategy associated with those measures.

1.1 Study Background

Several significant flooding investigations have previously been completed to better understand flood behaviour across the Davistown and Empire Bay catchments. These studies include:

- Davistown Catchment Flood Study (Cardno Lawson Treloar, 2010a)
- Empire Bay Catchment Flood Study (Cardno Lawson Treloar, 2010b)
- Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013)
- Brisbane Water Floodplain Risk Management Study (Cardno, 2015a)
- Brisbane Water Floodplain Risk Management Plan (Cardno, 2015b)
- Davistown and Empire Bay Climate Change Adaptation Study (Rhelm, 2020).

The Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010) determined the flood behaviour within their respective catchments due to local storm runoff from a range of flood events. The studies determined the nature and extent of flooding through the estimation of design flood flows, levels, and velocities.

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 Floodplain Risk Management Study and Plan (Cardno, 2015). Regional scale options for managing the flood risk from ocean storm events were considered in the latter study.

No consideration of local flood risk management options has been undertaken for the Davistown and Empire Bay / Bensville Catchments. This will be the subject of the current Floodplain Risk Management Study and Plan.

1.2 Study Objectives

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

This project involves and extends the Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010), which are comprehensive technical investigations of flood behaviour that provide the main technical foundation for the development of a robust floodplain risk management plan. The studies provide an increased understanding of the impacts of floods on the existing and future community. The flood models developed as part of the flood studies form the basis of a flood model to allow testing and investigating practical, feasible and economic management measures to treat existing, future, and residual risk. This FRMS will provide a basis for informing the development of a FRMP.

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

- relevant government information systems
- government and strategic decision makers on flood risk
- the community and key stakeholders on flood risk
- flood risk management planning for existing and future development
- emergency management planning for existing and future development, and strategic and development scale land-use planning to manage growth in flood risk
- decisions on insurance pricing
- selection of practical, feasible and economic measures for treatment of risk
- development of a floodplain risk management plan
- development of a prioritised implementation strategy.

The outputs of the study will assist this by:

- providing a better understanding of the:
    - variation in flood behaviour, flood function, flood hazard and flood risk in the study area
    - impacts and costs for a range of flood events or risks on the existing and future community
    - impacts of changes in climate on flood risk
    - emergency response situation and limitations
    - effectiveness of current management measures.
- facilitating information sharing on flood risk across government and with the community.

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

The intended end user groups which this study aims to support include:

- high level strategic decision makers
- the local community
- flood risk management professionals
- engineers involved in designing, constructing, and maintaining mitigation works
- emergency management planners
- land-use planners
- hydrologists and meteorologists involved in flood protection and forecasting
- insurers.

Meeting the requirement of the identified end user groups is a key objective of this study.

1.3 Study Location

Davistown and Empire Bay catchments are sub-catchments of Brisbane Water, which connects to Broken Bay, and are located in the Central Coast Council local government area (LGA). The catchment areas are approximately 190 ha and 554 ha respectively. The study area location is shown in **Map G101**.

1.4 Catchment Description

The Davistown catchment consists primarily of the suburb of Davistown, situated to the south of Saratoga. The other boundaries of Davistown are foreshore areas with waterbodies surrounding from the east to the south and to the west, namely The Broadwater, Cockle Bay, Cockle Channel and Lintern Channel. Land-use in the catchment is primarily residential with significant areas of bushland / vegetated areas. A retirement village, RSL club and some commercial buildings are also located in the catchment.

Davistown is relatively flat and stormwater runoff drains discharge to the estuary at multiple locations along the western, southern, and eastern foreshore areas. Pit and piped drainage infrastructure takes the form of many separate branches, each draining to different points on the foreshore. Drainage swales with pipes under driveway crossings are constructed along several streets to convey runoff. The catchment includes two main drainage channels cutting the suburb adjacent to Murna Avenue and behind properties fronting Emora Avenue.

The major drainage channel is located west of Davistown Road draining towards a large open area west of Malinya Crescent, then into Lintern Channel. These areas are tidal. Runoff is also conveyed to depressions that are located within the large vegetated marsh areas.

The Empire Bay catchment consists of the suburb of Empire Bay and the south-western section of Bensville. Cockle Channel and Cockle Bay are the waterbodies situated on the northern side of the catchment. Land-use in the catchment is primarily residential with significant areas of bushland / vegetated areas. The density of residential areas varies from low-density detached houses in the main part of Empire Bay and within Bensville, to larger bushland residential lots between these two areas. Several shops are located within the two main residential areas. Large areas of bushland are located on the higher elevations in the southern part of the catchment and along some areas adjoining the estuary, including Cockle Bay Nature Reserve.

The Empire Bay residential area is relatively flat with an elevation down to approximately 1.0 m AHD at the foreshore and the area around Cockle Bay Nature Reserve is also relatively flat. Pit and piped drainage infrastructure convey stormwater runoff through the main residential areas of Empire Bay and Bensville to the foreshore. Several drainage depressions and natural channels convey runoff from the bushland areas to piped systems crossing Empire Bay Drive.

The catchment area is shown in **Map G102**.

2 Available Data

2.1 Historical Flooding

The flood models developed for the 2010 Flood Studies (Cardno Lawson Treloar) were considered adequate for the purposes of this FRMS (see **Section 2.5.9**) and no major local catchment flooding has occurred since the Flood Studies were completed. As such, it is not the intention of this FRMS to re-calibrate the flood models. However, for completeness, the data provided by Council detailing historical flooding which are relevant to this study are listed in Table 2-1.

Table 2-1 Historical Flooding Data

Data Type	Description	Format	Date	Author
Survey	Historical flood mark coordinates, levels, addresses, photographs	PDF, DWG, 12da, DAT, XLS, JPG	2007	Johnson Partners
Photographs	Photographs of historical flood events	JPG, PDF	Various	Community
Report	Brisbane Water Flood Study - Compendium of Data	PDF	1991	NSW Public Works

The Flood Studies (Cardno Lawson Treloar, 2010) conducted a community questionnaire asking residents to recollect flooding conditions for storms in recent memory.

Many of the respondents gave details on flooding for the June 2007 and a significant number of respondents gave information on the May 1974 event. The June 2007 event approximately corresponded to a 5% AEP event and the May 1974 event approximately corresponded to a 0.5% AEP event. These events affected not only the study area but the wider region, as documented in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013).

Other significant events included: January 1996, February 1992, February 1990, April 1988, October 1985, November 1984, February 1981, January 1978, and March 1977. A majority of the respondents indicated that they were aware of flooding in the area (with only 9% and 25% in Davistown and Empire Bay, respectively, not aware of any flooding), giving the impression that the local residents are cognisant of the flood risks in their community.

The extent of flooding identified by residents ranges from over floor flooding to yard flooding and inundation of local roads and bridges.

During the site inspections undertaken for an associated study in May 2018, a resident supplied photos of a high tide event in December 2018 and localised flooding from heavy rain in March 2018.

Historical flooding in the study area has been primarily driven by water levels in the Brisbane Water estuary. Notwithstanding this, inundation of roads, public open spaces and private property at higher elevations have been caused by runoff along overland flow paths which can be exacerbated by higher water levels in the estuary.

The Brisbane Water Flood Study - Compendium of Data (NSW Public Works, 1991) compiles storm data and presents details of prominent storm events. Sixteen flood events were identified with the May 1974 flood being the largest on record and a June 1931 flood being the second largest on record. Multiple records of flood levels from gauges and resident accounts are contained within the report.

2.2 Site Inspection

A site inspection of the study area was undertaken by Rhlem employees (Emma Maratea and Joel Fraleigh) on 6 November 2018. This inspection was undertaken to review aspects of the stormwater drainage network in the study area and to gain a further appreciation of the local existing development, topography, land usage and property access.

Photos were taken at the locations shown in **Map G103** with noteworthy photos in **Appendix A**.

2.3 Property Survey

A property survey was previously undertaken as part of the Brisbane Water FRMSP (Cardno, 2015). This included all properties within the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013) probable maximum flood (PMF) extent. Survey data for each property included:

- parcel ID
- street name
- street number
- property lot
- property deposited plan
- level of lowest habitable floor level (in m AHD).

Over 4,000 properties were surveyed as part of this study. Of these, 23 are located in Bensville, 868 are located in Davistown and 368 are located in Empire Bay.

The Flood Studies (Cardno Lawson Treloar, 2010) undertook property surveys for some properties which reported flooding as part of the studies' community consultation. These are listed in tabular format and were obtained as part of the model calibration process. Eight surveyed floor levels are given for Davistown and an additional eight are given for Empire Bay.

Based on the Flood Studies (Cardno Lawson Treloar, 2010) results, additional floor level survey was collected in September 2019 as part of this FRMS of 96 properties located within the 1% AEP flood extent.

For a number of properties above the 1% AEP extent but within the PMF extent, no property survey was available. For the purposes of the economic damages assessment (**Section 5.5**), floor level of these properties were estimated to be 0.15m above the ground level based on surrounding property types and floor levels . The ground level was extracted from the LiDAR data.

These properties and the floor level data source associated with each property are shown in **Map G104**.

2.4 Previous Studies and Reports

Six significant studies were reviewed as part of the preparation of this FRMS:

- Davistown Catchment Flood Study (Cardno Lawson Treloar, 2010a)
- Empire Bay Catchment Flood Study (Cardno Lawson Treloar, 2010b)
- Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013)
- Brisbane Water Floodplain Risk Management Study (Cardno, 2015a)
- Brisbane Water Floodplain Risk Management Plan (Cardno, 2015b)
- Davistown and Empire Bay Climate Change Adaptation Study (Rhelm, 2020).

2.4.1 Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010)

2.4.1.1 Scope and Purpose

For the purposes of this FRMS, the 2010 Flood Studies (Cardno Lawson Treloar) are considered as one study given their identical purpose and date of completion; however, it consists of two separate documents:

- Davistown Catchment Flood Study (Cardno Lawson Treloar, 2010a); and
- Empire Bay Catchment Flood Study (Cardno Lawson Treloar, 2010b).

The 2010 Flood Studies (Cardno Lawson Treloar) determine the flood behaviour within their respective catchments due to local storm runoff from numerous flood events. The studies determine the nature and extent of flooding through the estimation of design flood flows, levels, and velocities. They form the basis of this FRMS by providing a detailed description of the existing flood behaviour in the study area.

2.4.1.2 Community Consultation

The flood studies involved community consultation in the form of a questionnaire mailed to all residents in the study area. In Davistown, 144 responses to the questionnaire were received and in Empire Bay 132 responses were received. Without any gauged watercourses in the study area, the details of the questionnaire and subsequent survey of floor levels and estimated high water marks were utilised as calibration data for both the June 2007 (Davistown and Empire Bay models) and April 1988 (Empire Bay model only) events.

The community responses indicated that:

- 64% of respondents were aware of flooding in the Davistown catchment, 28% had some awareness of flooding, and 6% were not aware of flooding in the catchment; and
- 50% of respondents were aware of flooding in the Empire Bay catchment, 25% had some awareness of flooding, and 23% were not aware of flooding in the catchment.

These responses indicate a moderate awareness of flooding. This can mean a higher level of preparedness and subsequent reduction of impacts of flooding. This has been explored further as part of community consultation and options assessed as part of this FRMS.

2.4.1.3 Modelled Events

Modelling was undertaken in the Sobek 1D/2D hydraulic modelling program and utilised rainfall on grid hydrological modelling. Further review of the models provided by Council are in **Section 2.5** of this report.

Design flood estimation was undertaken for the 0.5%, 1%, 2%, 5%, 10%, 20%, 50% AEP, 1EY (formerly referred to as the 100% AEP prior to publication of ARR2019), and PMF events. For the downstream model boundary, the Brisbane Water Estuary 1% probability of exceedance (PoE) level of 0.64 m AHD was used. Note that the PoE is defined in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013) as the estuary water level that one can be 99% confident will not be exceeded during any creek flood event. This should not be confused with the 1% AEP estuary level which is much higher.

Across the entire study area critical storm durations ranged from 15 minutes at higher elevations, to between 90 and 180 minutes for lower elevations and areas with flatter terrain.

For the 1% and 20% AEP, storm durations of 15, 30, 60, 90, 120 and 180 minutes were modelled to obtain peak flood depths and velocities. The PMF considered storm durations of 15, 30, 45, 60 and 90 minutes (GSDM method was used to determine rainfall). All other storm frequencies considered only the 120 minute storm duration. The options modelling to be undertaken in this FRMS will utilise the same events and durations for modelling.

2.4.1.4 Sensitivity Analysis

Sensitivity analysis was carried out by adjustment of the following significant model parameters:

- Downstream boundary conditions - The PoE for the 1% AEP, 2 hour event was modified by +/- 20%
  Result: no significant changes to modelled levels at selected points of measurement (less than 0.01 m)
- Culvert and pipe blockage -Two scenarios were considered: one with all conduits blocked and one with only significant conduits (i.e. those conveying piped discharge from roads and residential areas) blocked which were selected to produce maximum flood depths in developed areas.
  Result: Generally, peak flood depths increased at the reference locations selected from minor increases (e.g. 0.01 m) up to 0.07 m in Davistown and 0.15 m in Empire Bay.
- Model surface roughness - Manning's n values for the 2D model surface were adjusted by +/- 20% (storm event not defined).
  Result: no significant difference in flood depths at reference locations in flat terrain and minor increase in flood depths in steeper terrain where overland flow paths converge.
- Catchment rainfall - The rainfall average intensity for the 1% AEP, 120 minute event was modified by +/- 20%.
  Result: The model showed consistent results across the study area for increased flood depths when rainfall was increased and decreased flood depths when rainfall was decreased.
- Future conditions - The model land use was adjusted for Council specified areas where open space or rural residential lands were changed to low density residential areas. This was for Empire Bay only, as Davistown is already considered to be fully developed. The storm considered was the 1% AEP, 120 minute event.
  Result: In Empire Bay, flood depths increased in some locations up to 0.11 m.

2.4.1.5 Flood Hazard and Hydraulic Categorisation

Flood hazards for the study were defined by the NSW Floodplain Development Manual (NSW Government, 2005) as high or low hazard. This was undertaken for the PMF, 1%, 5%, and 20% AEP events.

Hydraulic categorisation was undertaken to define the floodplain into one of three hydraulic categories: floodway, flood storage and flood fringe. The floodway is defined by assuming the in bank flows are included with additional areas included based on:

- a velocity-depth product of 0.25 m^2/s and velocity greater than 0.25 m/s, or
- a velocity greater than 1.0 m/s.

Flood storage was defined as depths greater than 0.2 m and not contained within the floodway. The flood fringe included all other areas outside of the floodway and flood storage.

Flood hazards have been reassessed in **Section 6.1** of this FRMS using the existing model results and the *Technical Flood Risk Management Guideline: Flood Hazard* (AEMI, 2014).

2.4.1.6 Flood Damages

Annual Average Damages (AAD) were calculated based on spreadsheet analysis and damages curves based on the Department of Energy and Climate Change (DECC). Staged damage curves produced for residential, commercial, and industrial land uses were the same for both Davistown and Empire Bay. The resultant AAD for Davistown and Empire Bay were $548,125 and $45,460, respectively.

The damages analysis was not based on property survey, instead it assumed that all buildings were single story, slab on ground with floor levels 0.3m above a ground level obtained by ALS at the dwelling. The FRMS has revised the damages in **Section 5.5** based on the property survey (**Section 2.3**).

2.4.1.7 Climate Change

Climate change was considered for the flood studies based on guidance from Practical Consideration of Climate Change (DECC, 2007) and the following scenarios were modelled for the 1% AEP, 2 hour storm event:

- 10% increase to rainfall intensities
- 20% increase to rainfall intensities
- 30% increase to rainfall intensities
- 0.2 m rise in estuary level
- 0.2 m rise in estuary level and 30% increase to rainfall intensities
- 0.91 m rise in estuary level
- 0.91 m rise in estuary level and 30% increase to rainfall intensities.

Results indicated that the increased flood depths due to rainfall intensities were minor and generally unchanged with isolated areas increasing by up to 0.05 m. By far the most significant impact from climate change is the rise in sea levels as a significant portion of ground elevations within the study are below the modelled climate change estuary levels.

Since the issue of the 2010 Flood Studies (Cardno Lawson Treloar), the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013) and Brisbane Water FRMSP (Cardno, 2015) have been published with further details on the impacts of climate change in the region.

The ARR data hub suggests that rainfall could increase as a result of climate change by up to 20% by 2090 (RCP8.5). The flood studies (2010) undertook sensitivity testing of the flood behaviour to a 20% increase of the 1% AEP 2 hour storm event rainfall. The analysis resulted in increases in flood levels up to 0.04m. In general, the increased flow 'spread out' rather than increased in depth.

No further climate change modelling for the existing case has been undertaken as part of this FRMS. However, climate change adaptation planning and options modelling was undertaken as part of a separate study (Rhelm, 2020) and the outcomes are summarised in **Section 2.4.4 and 7**.

2.4.2 Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013)

The Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar) was completed in 2013. Prior to this study being undertaken, numerous floodplain management studies for the tributaries of Brisbane Water had been undertaken utilising an FPL in Brisbane Water based on a flood level of 1.95 m AHD. This level was based on the observed levels in Brisbane Water during the 1974 ocean storm event.

The 2013 Flood Study provided more reliable estimates of the 1% AEP flood level throughout Brisbane Water. The study investigated a range of natural mechanisms that impact water level, as well as the effects of man-made structures. The flood study also assessed the locally generated waves across the waterway.

The key results of the Flood Study (2013) in the vicinity of the Davistown and Empire Bay study area are summarised in **Table 2-2**.

Table 2-2 Water Levels at Reporting Location 059 (Cardno Lawson Treloar, 2013)

HHWS[1]	MHWS[2]	1% PoE[3]	1% AEP	5% AEP	20% AEP
0.97 mAHD	0.73 mAHD	0.64 mAHD	1.49 mAHD	1.36 mAHD	1.24 mAHD

[1] High High Water Springs tide (see glossary)
[2] Mean High Water Springs tide (see glossary)
[3] Probability of Exceedance: the level that one can be 99% confident will not be exceeded.

Additional analysis on climate change and its impacts on estuary design flood levels included four case studies where sea level rises of 0.18 m, 0.30 m, 0.55 m, and 0.91 m were considered over a planning period of 100 years.

FPLs were recommended to incorporate the design storm tide level, local wind setup, SLR (0.3 m), and wave run-up height, plus a freeboard.

2.4.3 Brisbane Water Floodplain Risk Management Study and Plan (Cardno, 2015)

Building on the previous Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2013), the FRMS (Cardno, 2015a) object was to:

- derive an appropriate mix of management measures and strategies to effectively manage the full range of flood risk in accordance with Appendix G of the Floodplain Development Manual (NSW Government, 2005), and
- utilise an effective public participation and community consultation program.

A range of strategies to meet those objectives were investigated to address risks to:

- residential areas fronting Brisbane Water
- residential areas above the 100 year ARI level
- drainage reserves/wetlands/marshes
- properties affected by projected sea level rise.

Commentary is provided on the future flood risks associated with sea level rise. Pending further investigation on climate change action plans (CCAPs) (Identified as PM9 in the FRMS) and further review following the release of the 5th Intergovernmental Panel for Climate Change (IPPC), a sea level rise of 0.4 m to 0.9 m was adopted by Gosford City Council for the purposes of the study. An interim FPL was recommended as the 1% AEP design surface water level, plus Council's adopted SLR, plus a freeboard of 0.5 m. It is noted that in 2019 Central Coast Council adopted a revised climate change policy (see **Section 4.4.3**).

From a large list of potential flood risk management options, the FRMS made recommendations for 35 options to be implemented. These options included emergency response modification measures (8 options), property modification measures (13 options) and flood modification measures (14 options). A multicriteria analysis (MCA) was used to evaluate the costs and benefits of each considered management option. Options were generally ranked higher is they addressed current flood risk and / or current flood risk plus future flood risk associated with SLR.

Emergency response options from the Brisbane Water FRMS (Cardno, 2015a) which have been considered for the local study areas as part of this FRMS (**Section 8.3**) include:

- review of evacuation centre locations
- review and enhance road evacuation plans
- review of local emergency plans

- review of flood warning systems
- targeted education programs for flood affected residents
- installation of flood warning signs
- improve evacuation route roadways.

Property modifications options from the Brisbane Water FRMS (Cardno, 2015a) which have been considered for the local study areas as part of this FRMS (**Section 8.2**) include:

- voluntary house purchase program
- voluntary house raising program
- property flood risk education program
- review and update planning measures and development controls
- implement managed retreat.

Flood modifications options from the Brisbane Water FRMS (Cardno, 2015a) that have informed the selection of and provided inputs to local flood modification options as part of this FRMS (**Section 8.1**) include:

- roads raised above the 1% AEP + SLR flood level
- wave energy dissipating foreshore structures / seawalls
- stormwater flood gates / flap valves
- flood protection levees
- regional filling of the floodplain.

Note that some of the options considered as part of the Brisbane Water FRMS (Cardno, 2015a) improve flood risk as part of the entire Brisbane Water study area and would not be considered as part of this FRMS (for example, a storm surge barrier at Half Tide Rocks).

2.4.4 Davistown and Empire Bay Climate Change Adaptation Study (Rhelm, 2020)

The FPL for development within the low-lying areas of Davistown and Empire Bay has an allowance for sea level rise to ensure the building is protected against flood from ocean storms for the life of the structure. However, this does not consider the impacts on the property grounds, streets, and public spaces as a result of elevated tidal levels under sea level rise conditions (i.e. regular inundation). The Adaptation Study considers the feasibility of a landform design that jointly addresses the risk of sea level rise and the current local drainage issues.

The purpose of the Adaptation Study is to inform the development of a regional adaptation masterplan and associated processes. By undertaking a regional adaptation masterplan for Davistown and Empire Bay, adaption pathways can be developed such as development controls, levees and other mitigation measures which could be implemented over time in consultation with the community.

The outcomes of the Adaptation Study provide a series of potential actions and recommendations for Council planning, with some specifically for inclusion in the Davistown and Empire Bay FRMSP (this study). Recommendations that are to be included in the Davistown and Empire Bay FRMSP are:

- include specific works in the FRMSP to assess the existing flood risk management benefits:
    - Davistown levee / foreshore barrier
    - Empire Bay drainage channel / easement.

- include the recommended landform in the FRMSP to assess its ability to address existing and future flood risk. This may assist in application for funding from the NSW Floodplain Management Program for components of the landform (such as raising of public assets, easements).

A more detailed description of how this study has informed climate change floodplain risk management is provided in **Section 7**.

2.5 Previous Modelling

Hydraulic model had been prepared for the catchments as part of the Flood Studies (Cardno Lawson Treloar, 2010). This 1D/2D Sobek model was established and covers the entire study area of this FRMS.

A separate hydrological model was not established, as the Sobek models utilised the rainfall on grid methodology.

This section describes the details of the Sobek model schematisation and provides review of its suitability for use in the current FRMS.

2.5.1 Surface Levels

The report states that aerial laser scanning was received from Gosford City Council; however, no date is mentioned when the data was gathered or the details of data point distances or grid sizes. The DEM produced as part of the Flood Studies (Cardno Lawson Treloar, 2010) utilised a 3 m x 3 m grid in urban areas with a 9 m x 9 m grid in the rural and semi-rural areas between the urban areas of Empire Bay and Bensville.

A comparison of the supplied Flood Studies (Cardno Lawson Treloar, 2010) model DEMs to the LiDAR received from NSW Spatial Services (dated 2013) was undertaken as part of this FRMS. The differences are shown in **Map G105**.

Throughout Davistown, the more recent 2013 LiDAR data is generally at the same elevation with isolated areas where the LiDAR elevation data is greater than 0.3 m different than the DEM. For the lower elevation areas of Empire Bay, the same is true; however, there are greater discrepancies at higher elevations and where tree coverage is dense. The sporadic nature of the comparison in some areas is caused by comparing the 1 m gridded LiDAR data to the 3 m and 9 m DEM data.

Sensitivity analysis of the hydraulic model to the updated LiDAR was undertaken and is described in **Appendix C**.

2.5.2 Stormwater Drainage Network

The Flood Studies (Cardno Lawson Treloar, 2010) models utilised Gosford City Council supplied GIS data to define the stormwater network including pit and pipe information. This was supplemented by the detailed survey provided by Johnson Partners.

Many of the open channels within the Sobek models were represented as 1D elements with typical cross sections also defined in the Johnson Partners detailed survey. Since the completion of the Flood Studies (Cardno Lawson Treloar, 2010) developments in computing power and 2D modelling have made it possible to establish detailed models without the use of extensive 1D open channel networks. Furthermore, the nature of the overland flow paths and open channels in the study do not lend themselves to one cross-section being representative of the entire length of the channel.

The existing pit and pipe network from the Sobek models were duplicated and supplemented where necessary with Council supplied GIS data. Some of the 1D open channels and overland flow paths were represented in the 2D model domain. Refer to **Map G106** for an overview of the Sobek model 1D domain and open channels recommended for inclusion into the revised model 2D domain.

Some of the Council stormwater GIS data supersedes the flood study stormwater drainage network, as infrastructure works have taken place since the flood studies' completion. It has been concluded from a review of the available data that the stormwater data would not necessitate the revision of the flood study model for the purposes of the FRMS.

2.5.3 Rainfall

Investigation of the rainfall data provided with the Sobek model showed that it is consistent with ARR87 design rainfall for the area. Storm frequencies assessed include: 0.5%, 1%, 2%, 5%, 10%, 20%, 50% AEP, 1EY (formerly referred to as the 100% AEP prior to publication of ARR2019), and PMF events.

Given the Gosford DCP refers to ARR87 for design rainfall and any revised model results for this FRMS will require comparison to the supplied Sobek model results, the ARR87 design rainfalls will be maintained. Conversely, the Civil Works Design Specification - Design Guidelines (Central Coast Council, 2018) requires that design methods and data for urban drainage shall be based on ARR2019. Therefore, a sensitivity analysis was undertaken with respect to the revised ARR2019 guidelines for the 1% AEP storm frequency event (see **Appendix C** for details).

2.5.4 Downstream Boundary

The 2010 Flood Studies (Cardno Lawson Treloar) Sobek model utilised the most current version (dated 2009), at the time of writing, of the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar) to identify the downstream boundary. A constant water level of 0.64 m AHD was used along the foreshore of the models. This is equal to the 1% PoE as shown in **Table 2-2**.

This FRMS has used the 1% PoE for the downstream boundary for all option modelling (**Section 8.1.2**).

2.5.5 Infiltration

The supplied model adopts the initial/continuing infiltration loss (IL/CL) model. Infiltration in the Sobek model is incorporated into the design rainfall files applied as rainfall on grid such that rainfall depth is reduced in each rainfall timestep by the total initial or continuing infiltration depth. The adopted loss values are:

- Residential Areas:
    - Initial Loss = 5 mm
    - Continuing Loss = 1 mm/hr
- Bushland Area:
    - Initial Loss = 20 mm
    - Continuing Loss = 2.5 mm/hr

The values adopted are representative of their respective development types; however, there is no distinction between bushland and rural areas, residential areas and business centres and recreation areas, and major roads (e.g. Empire Bay Drive) are not included.

2.5.6 Roughness

Roughness in the model is divided between roughness of 1D model elements and surface roughness in the 2D domain.

In the modelled pipes, culverts and open channels, the roughness values used are shown in **Table 2-3**.

Table 2-3 Sobek Model 1D Roughness Values

Component	Manning's n Value
Pipe	0.018
Culvert	0.025
Open Channel	0.030

Although the Civil Works Design Specification - Design Guidelines (Central Coast Council, 2018) does not directly specify a design Manning's n value for pipe and culvert materials, the values adopted for pipes and culverts appear slightly high. For reference, the Concrete Pipe Association of Australia (CPAA) technical brief A Rational Approach to the Hydraulic Design of Pipe Conduits (CPAA, date unknown) recommends a Manning's n value for reinforced concrete pipes between 0.009 and 0.012.

It was decided in an earlier project meeting (with DPIE and Council) that the Manning's n values would not be revised unless other more significant model changes were also adopted. No other significant model changes were undertaken.

Roughness values adopted in the 2D domain were based on land uses with the following values adopted in **Table 2-4**.

Table 2-4 Sobek Model 2D Roughness Values

Land Use	Manning's n Value
Channel	0.030
Bushland	0.060
Open Space	0.035
Residential (including structures)	0.090
Water Body	0.020
Vegetated Marsh	0.070
Road	0.020
Estuary	0.020

The values adopted are considered reasonable and reflective of their land use types. The spatial variation of the roughness values was based on land zoning, aerial photography, and site inspections.

It is recommended that the 2D surface roughness from the Sobek model be adopted for any future modelling.

2.5.7 Calibration / Validation

The Sobek model was calibrated with pluviograph data from the Manly Hydraulics Laboratory, scaled down to match the rainfall depth recorded at a private rainfall gauge in Davistown. Flood depths for calibration purposes were sourced from community accounts of the April 1988 and June 2007 events.

Calibration results were considered satisfactory.

No separate model validation was undertaken as part of the Flood Studies (Cardno Lawson Treloar, 2010).

A converted Tuflow model has been calibrated to the Sobek model results for the design 1% AEP event (**Section 5.2.1**).

2.5.8 Design Runs

Modelling was undertaken for the 0.5%, 1%, 2%, 5%, 10%, 20%, 50% AEP, 1EY (formerly referred to as the 100% AEP prior to publication of ARR2019), and PMF events as part of the Flood Studies (Cardno Lawson Treloar, 2010).

The 1% AEP, 20% AEP and PMF events modelled a wide range of storm durations, from 15 minutes up to three hours, to determine maximum flood depths and velocity envelopes. Based on these results, the remaining storm frequencies only considered the two hour duration event.

2.5.9 Outcomes of the Hydraulic Model Review

The Sobek model was found to be reasonably suitable in most schematisation aspects for use in this FRMS. A TUFLOW model was created using the Sobek model parameters and inputs with minor updates. The methodology and outcomes of the conversion of Sobek to TUFLOW is discussed in **Appendix C**.

2.6 Survey Information

2.6.1 Aerial Survey

For this study, aerial survey (LiDAR) data was captured during 2011. This data was acquired from the NSW Government spatial services department and is available online via public portals (http://elevation.fsdf.org.au/index.html). This data has been converted into a 1 metre DEM, and the accuracies are provided relative to the DEM rather than the raw LIDAR data and are shown in **Table 2-5**. The accuracies are reported on open hard surfaces (such as roads and ground surfaces).

Council additionally provided LiDAR data in .las format sourced in 2013. This data is assumed to supersede the previous 2011 data.

Table 2-5 Reported Accuracy of 2011 LiDAR Data

LiDAR Date	Format	Data Provider	Vertical Accuracy (m)	Horizontal Accuracy (m)	Confidence Interval
2011	DEM (.asc)	NSW Spatial Services	0.3	0.8	95%
2013	Raw (.las)	Central Coast Council	N/A	N/A	N/A

A comparison between the 2013 LiDAR surface and the DEM provided as part of the Flood Studies (Cardno Lawson Treloar, 2010) is provided in **Section 2.5.1**. The analysis of the impact of the updated LiDAR on flood behaviour is provided in **Appendix C**.

No additional aerial survey data was acquired for the study.

2.6.2 Detailed Survey

A detailed survey was undertaken by Johnson Partners in April 2008 obtaining pertinent information of many of the hydraulic features in study area. Details recorded included seawalls, pit location and dimensions, pipe types and diameters, headwall locations and dimensions, ground levels as part of cross sections and long sections, road centrelines, bridge details, historical flood locations and heights, and retaining walls.

This survey supplemented the GIS data provided by Council to provide more accurate modelling of the stormwater drainage system.

Additional ground survey was undertaken in 2019 as part of this study in the vicinity of Pomona Road to gain a better understanding of the flood behaviour between Pomona Road and Empire Bay Drive.

2.6.3 Historical Flood Marks

Historical flood data was acquired as part of the Flood Studies (Cardno Lawson Treloar, 2010). Flood marks were picked up by the Johnson Partners details survey.

Additional historical flood data is included within the Brisbane Water Flood Study - Compendium of Data (NSW Public Works, 1991). However, this information is associated with storm events and flood from high sea levels rather than runoff from the catchment.

2.7 Rainfall Data

Rainfall data was sourced from the BoM in accordance with ARR87. For the sensitivity analysis on the revised ARR2019 rainfall, the appropriate data was also sourced from the BoM.

2.8 GIS Data

The following information in the form of GIS data sets was provided by Council:

- aerial imagery (WMS)
- cadastral boundaries
- road centrelines
- drainage network dataset
- sewer dataset
- water dataset
- land zoning
- vegetation communities.

3 Consultation

3.1 Consultation Strategy

The consultation strategy outlined in **Table 3-1** describes the approach to consultation adopted for this study. The approach is in accordance with the IAP2 framework and the requirements of the NSW Government's Floodplain Development Manual (2005).

Table 3-1 Consultation Strategy Outline

IAP2 Engagement Strategy Guide	Davistown and Empire Bay FRMSP
Context *The internal and external drivers, pressures and other background information that is of relevance to the consultation strategy, and in particular how these may influence how the community receives and responds to the consultation program.*	The context of the consultation has been defined by the following: • Floodplain Development Manual. • Australian Emergency Management Handbook 7. • Council's policies. • Flood behaviour (e.g. Brisbane Water levels, waterway flooding and overland flow and the coincidence of these). • Past flooding experiences and local, regional, and national media on flooding. • Council's contact with flood impacted residents following previous flood events. • Consultation undertaken as part of the 2010 Flood Studies and 2015 Brisbane Water FRMSP (it is important to build on this rather than just repeat or supersede it). The consultation approach, breadth and outcomes of relevant project will be reviewed prior to finalising the consultation program and materials.
Scope *The scoping statements are based on the project context and articulate why the consultation is being undertaken for this project, what the desired outcomes would be, and what the limitations of the engagement are.*	The scope of the consultation strategy is to engage with stakeholders and the community to better understand the flood risks within the study area, to identify preferred methods of floodplain management and to develop community understanding and ownership of the study outcomes.
Stakeholders *This section provides an overview of the different categories of stakeholders, and their relative level of interest, influence, and impact.* *This process is useful in identifying the level of engagement under the IAP2 Consultation Spectrum that may be suitable for different types of stakeholders.*	A stakeholder matrix has been provided below this strategy. This has informed the selection of appropriate consultation methods.
Purpose *The purpose relates to the purpose of the consultation not the overall project.*	The purpose of the consultation is to: ▪ Inform the community and stakeholders of the study ▪ Gain an understanding of the community and stakeholders' concerns relating to flooding in the study area

IAP2 Engagement Strategy Guide	Davistown and Empire Bay FRMSP
Stakeholders will be linked to each purpose and the goals within each purpose for each stakeholder will be identified.	▪ Seek input from the community on management options ▪ Gather information from the community by participation ▪ Obtain feedback on the Draft Floodplain Risk Management Study ▪ Develop and maintain community confidence and collaboration with the study results.
Methods	Details of the engagement methods are provided in **Section 3.1.2**.

3.1.1 Stakeholder Matrix

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

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

A stakeholder matrix (**Table 3-2**) has been developed to provide an overview of the different categories of stakeholders, and their relative level of interest, influence, and impact on the FRMS. Each stakeholder has been recommended a type of consultation based on the IAP2 consultation spectrum (**Table 3-3**).

Table 3-2 Stakeholder Matrix

Stakeholder	Level of Impact	Level of Interest	Level of Influence	Recommended Type of Consultation
Impacted Stakeholders				
Central Coast Council	High	High	High	Involve
Department of Planning, Industry and Environment	High	High	High	Collaborate
Floodplain Management Committee	High	High	High	Collaborate
State Emergency Service	High	High	Moderate	Collaborate
Impacted Infrastructure Service Providers (Ausgrid, Telstra, Jemena Gas, Optus, Ambulance Service)	High	Low	Low	Inform
Technical officers at Council: • Bhusan Acharya, Asset Management Roads • Vanessa McCann, Waterways and Coastal Management • Anumitra Mirti, Environmental Strategies • Scott Irwin, Emergency Protection Natural Assets • David Medcalf, Roads Assets Planning & Design	Moderate	Moderate	Moderate	Involve
Interested Stakeholders				
Roads and Maritime Service	High	High	Low	Inform
WaterNSW	Moderate	Moderate	Low	Inform
Ecosystem managers	Moderate	Low	Moderate	Inform
Aboriginal Land Council Darkinjung	Moderate	Low	Moderate	Inform
Department of Primary Industries	Moderate	Low	Moderate	Inform
Department of Industry	Moderate	Moderate	Low	Inform
Impacted Community Stakeholders				
Flood-affected property owners	High	High	Low	Consult
Flood-affected residents	High	High	Low	Consult
Flood-affected business owners	High	High	Low	Consult
Property owners directly impacted by proposed flood risk management options	Moderate – High (depending on type of option)	Moderate – High (depending on type of option)	Moderate	Involve
Residents and owners of properties not affected by flooding but within the study area (e.g. impacted by flood access)	Moderate	Moderate	Low	Consult
Users of the area (e.g. impacted by flood access)	Moderate	Low	Low	Consult
Interested Community Stakeholders				
Community groups, Empire Bay Progress Association Inc, Davistown Progress Association Incorporated, Bensville Residents Association	Low	Moderate	Low	Consult
Wider community	Low	Low	Low	Consult

Table 3-3 IAP2 Consultation Spectrum

INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
Public Participation Goal	**Public Participation Goal**	**Public Participation Goal**	**Public Participation Goal**	**Public Participation Goal**
To provide the public with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision, including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the Council
Promise	**Promise**	**Promise**	**Promise**	**Promise**
We will keep you informed.	We will keep you informed, listen to, and acknowledge concerns and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
Stakeholders	**Stakeholders**	**Stakeholders**	**Stakeholders**	**Stakeholders**
Impacted Infrastructure Services RMS WaterNSW Department of Industry Ecosystem Managers Local Member (MP)	Impacted Community Stakeholders	Impacted Stakeholders-Internal Business Units Council	Office of Environment & Heritage State Emergency Services Catchments & Coast Committee	Councillors
Engagement Tools	**Engagement Tools**	**Engagement Tools**	**Engagement Tools**	**Engagement Tools**
Media Releases Have your Say Website (including access to online survey) Technical Papers (Study & Plan)	Newsletter & Survey (directly mailed to potentially flood affected residents) Briefings Public Information Sessions (2) Submissions Have your Say Website Stakeholder meetings	Direct email / mail and follow up phone calls, as required	C & C Committee meetings Technical Subcommittee Workshops Briefings Internal	Council Workshops Council Meetings

3.1.2 Engagement Approach and Communication Deliverables

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

Table 3-4 Engagement Methods

Event/Activity	Action / key messages	Target Audience	Engagement level	Responsibility
Brief sent to Communication and Engagement		Internal	N/A	Project Officer
Contact Council's Knowledge Management Officer of Customer Relationships	Currently Sandra Smith – on x8317	Internal	N/A	Project Officer
Inception meeting	• Provide overview of project scope • Identify key issues for the study • Discuss approach to consultation	Internal Business Units Council, SES and OEH	Collaborate and Involve	Project Officer and Consultants
Davistown Progress Association briefing	• Provide brief summary of the project	Progress Association	Inform	Council
Empire Bay Progress Association briefing	• Provide brief summary of the project	Progress Association	Inform	Council
Your Voice Our Coast page – with a link to a more detailed webpage hosted by Rhelm	• 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 project updates throughout project.	Impacted and interested stakeholders.	Inform and consult	Council and Rhelm (Consultant)
Community newsletter and questionnaire	• 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.	Consult	Rhelm (Consultant)
Media release	• Advise of the project and advertise the engagement activities	Residents, property owners, local business owners, and the wider community.	Inform	Rhelm to provide draft content. Council to finalise and release.
Public notice in Express Advocate, Coast Community News and Peninsula News	• Advise of the project and advertise the engagement activities	Residents, property owners, local business owners, and the wider community.	Inform	Communications
Community information sessions	• 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 interactive mapping via WaterRide dongles, laptops, iPad, TVs and connecting cables for ease of representing the study	Residents, property owners, local business owners, and the wider community.	Consult	Engagement, Project Officer and Rhelm

Event/Activity	Action / key messages	Target Audience	Engagement level	Responsibility
Stakeholder meetings	• 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.	Community groups, action groups and other key stakeholders identified	Consult and Involve	Project Officer and Rhelm
Engagement summary	• A one-page summary of the engagement campaign to be uploaded to Your Voice Our Coast	All stakeholders	Inform	Engagement to create and upload summary
Technical Papers Committee Meeting	• Recommendation to Council regarding public exhibition	Catchment and Coasts Committee	Consult	Council and Rhelm (Consultant)
Technical Papers Council Meeting	• Approval for documents to go on public exhibition	Councillors	Consult	Council
Media release	• Advise of the project and advertise the engagement activities	Residents, property owners, local business owners, and the wider community.	Inform	Rhelm to provide draft content. Council to finalise and release.
Public notice in Express Advocate, Coast Community News and Peninsula News	• Advise of the project and advertise the engagement activities	Residents, property owners, local business owners, and the wider community.	Inform	Communications
Public Exhibition – Your Voice Our Coast page	• Invite feedback on draft documents	Residents, property owners, local business owners, the wider community, agency stakeholders and community groups.	Consult	Council and Rhelm (Consultant)
Community information sessions	• Invite feedback on draft documents	All stakeholders	Consult	Council and Rhelm (Consultant)
Stakeholder meetings	• 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.	Community groups, action groups and other key stakeholders identified.	Consult	Council and Rhelm (Consultant)
Engagement summary	• A one-page summary of the engagement campaign to be uploaded to Your Voice Our Coast	All stakeholders	Inform	Engagement to create and upload summary
Finalisation and handover	• Data uploaded to SES Web portal	DPIE, SES		Council and Rhelm (Consultant)

3.2 Agency Consultation

Preliminary agency consultation was undertaken with SES at the community drop in sessions. This focused on the deliverables required from the study to assist SES in effective flood response.

A letter was received from DPIE (Crown Lands) in November 2019 providing some preliminary inputs to the study.

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

3.3 Website and Media

A project website has been established for the duration of the project and can be accessed at the following link: https://www.davistownempirebayfrmsp.com/

The purpose of the website is to provide project information and community updates. Previous studies and community materials are available for download from the website. The website also provided a link to an online survey in October and November 2019 (see **Section 3.4** for further details).

Council provided an additional webpage on their Your Voice Our Coast website (September 2019 – December 2019). This provided an overview of the project, links to the project website and online survey and an interactive map for the community to provide comment on flooding in the area.

Media releases will be used throughout the study to inform the community of key project updates and opportunities to provide input. A summary of media releases to date are provided in **Table 3-5**, copies of the media releases are provided in **Appendix B**.

Table 3-5 Media Releases

Date	Purpose
10 October 2019	Inform the community of the project and invite input via the questionnaire (**Section 3.4.2**) and drop in sessions (**Section 3.5**).
14 October 2019	Interview with Council representative on ABC Central Coast Radio regarding the project and the engagement activities.

3.4 Community Newsletter and Survey

3.4.1 Previous Community Input

The 2010 Flood Studies involved community consultation in the form of a questionnaire mailed to all residents in the study area. Details of this engagement are provided in **Section 2.4.1.2**.

No flood management strategies were reviewed or proposed as part of the 2010 Flood Studies consultation.

3.4.2 Current Newsletter and Questionnaire

A one-page community newsletter was distributed in September and October 2019 to over 2,000 dwellings within the study area. The recipients were identified where they were in the PMF extent. The community newsletter was also available on the project website.

The newsletter also included a short questionnaire intended to identify community concerns about flooding and how they would like flood risk to be managed in their community. Additional questions were aimed at understanding how the community is likely to respond in the event of flooding, this will assist SES in their flood planning and also inform Council and SES on the best way to issue flood warnings and other information regarding flooding (e.g. road closures). The questionnaire was also provided online available through Council's Your Voice Our Coast webpage and the project website (**Section 3.3**).

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

From the distribution and availability of the survey on the website, 160 responses were received, representing a return of 8% of direct distribution. A return rate of 10% is typical for these types of mail-outs. **Table 3-6** summarises the number of responses received for each suburb within and around the study area.

Table 3-6 Number of answers according to suburb

Suburbs	Answers
Davistown	92
Empire Bay	42
Bensville	7
Saratoga	7
Other suburbs	6
Blank	6

An additional 70 people attended the drop-in sessions to provide face to face input (**Section 3.5**). This represents a total return rate of 12%.

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

Other relevant findings of the questionnaire were:

- approximately 56% of the responses were provided by people who have resided/visited the study area for more than 20 years.
- most of the respondents (66%) consider themselves aware of flooding in the region and only 8% report they are "not at all aware" of these risks. The remaining 26% marked the option "Somewhat aware" of flooding.
- when asked if they have any specific concerns about flooding, 43 people answered they have no concerns, 35 people reported they were concerned with flooding on roads and 23 expressed concern of flooding on properties. Additionally, 27 respondents raised issues related to the existing stormwater drainage systems.
- 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 (98 comments in total).
- half 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 knew their houses could cope with flooding (77 answers). Another common reason, according to the responses, is the concern for the security of the property after an evacuation (54 responses).

- a total of 29% of the respondents state they would evacuate in a major flood, 14% say they would evacuate early to an official centre and 15% say they would evacuate elsewhere. According to the responses, the most common reason for an evacuation would be the safety of their household (64 responses).
- 82 respondents (51%) reported that, during a flood event, they look for information on road closures and 41 people (31%) stated they look for evacuation notices. Most of the respondents would look for information on the radio (27%), on TV (20%) and on social media (19%).
- the flood management objectives listed in the questionnaire have similar importance for the community, since each option received a similar average score. The objectives that received the higher score (6.31 points) and the lower score (5.27 points) were “Increasing community awareness and understanding of the local flood risk” and “Ensuring management does not disadvantage individual members of the community”, respectively.

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

The answers received for the objective questions are summarised on **Figure 3-1**, **Figure 3-2** and **Figure 3-3** and the outcomes of the of the open-ended questions analysis can be found on **Figure 3-4**.

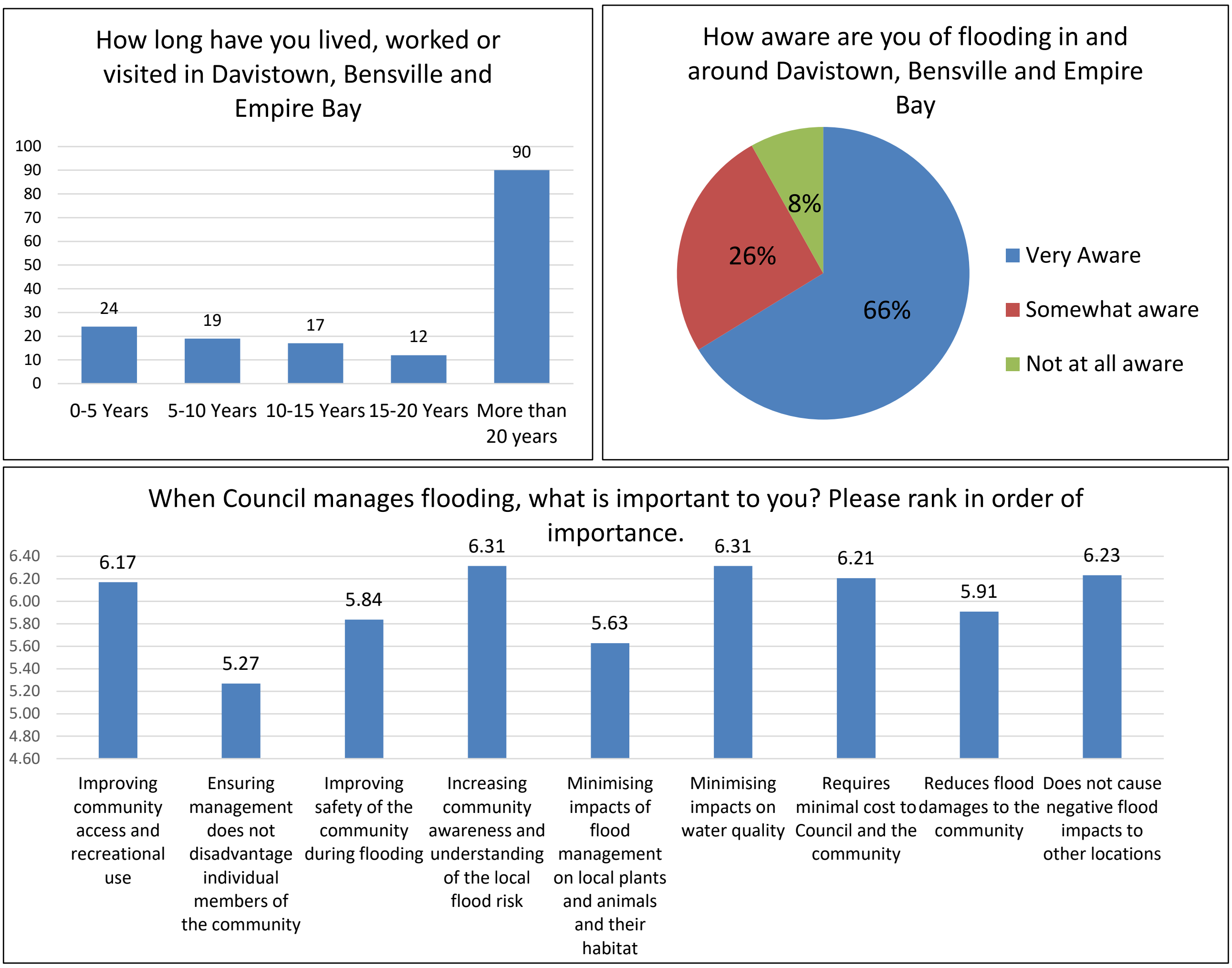


Figure 3-1 Summary of questionnaire responses - multiple choice questions (1 of 3).

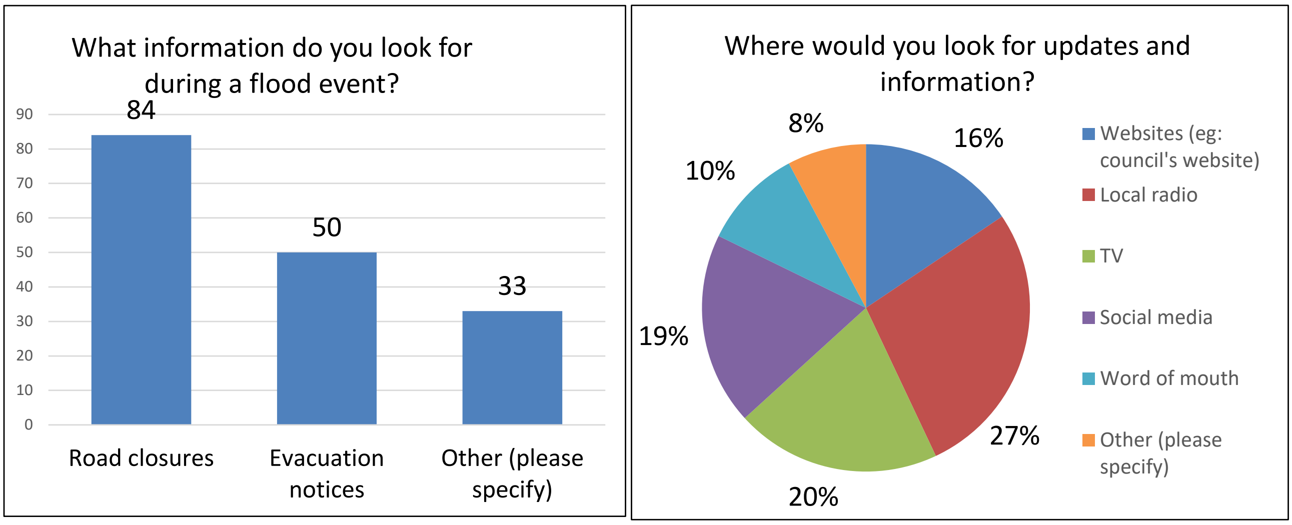
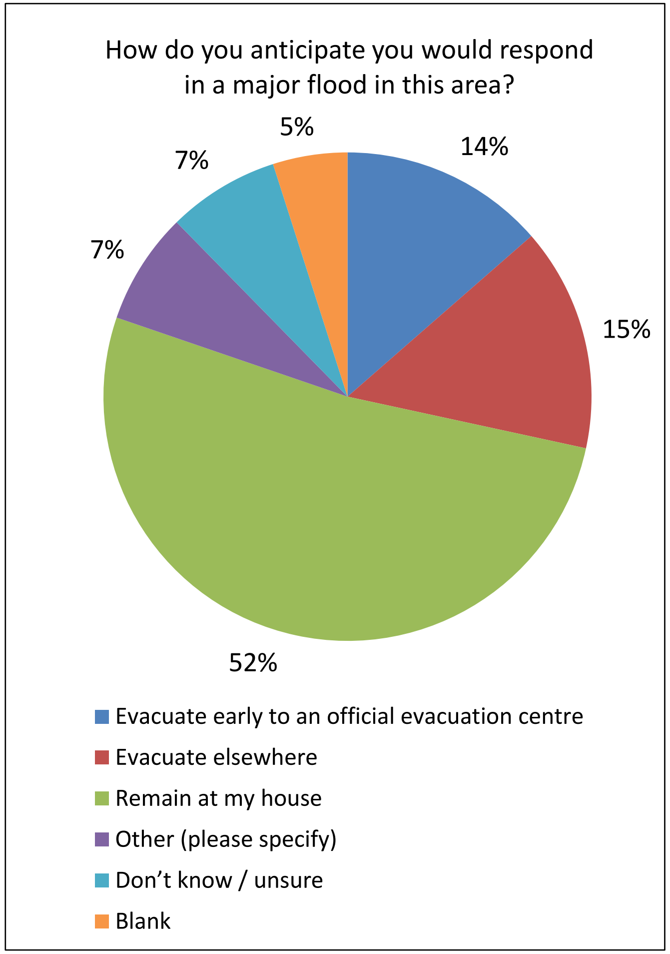
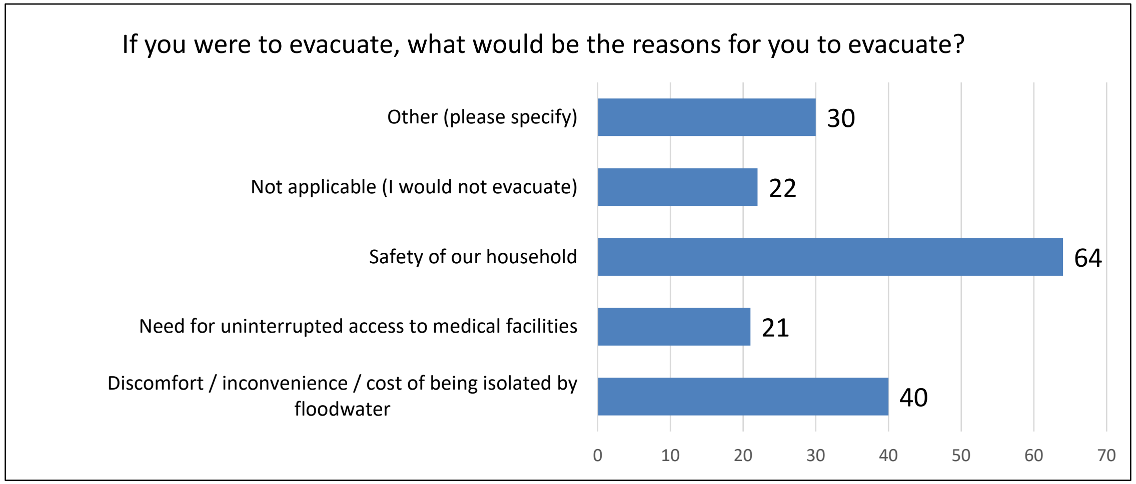


Figure 3-2 Summary of questionnaire responses - multiple choice questions (2 of 3).





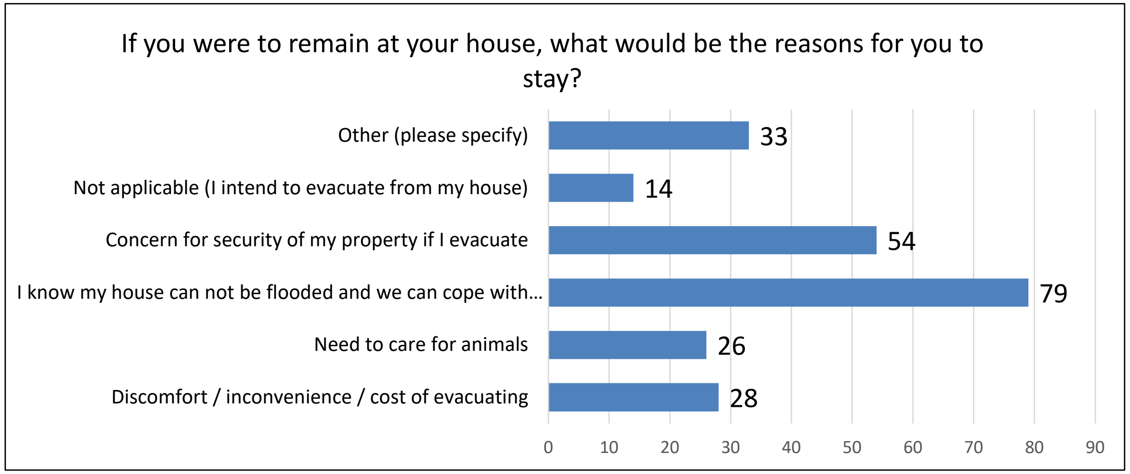
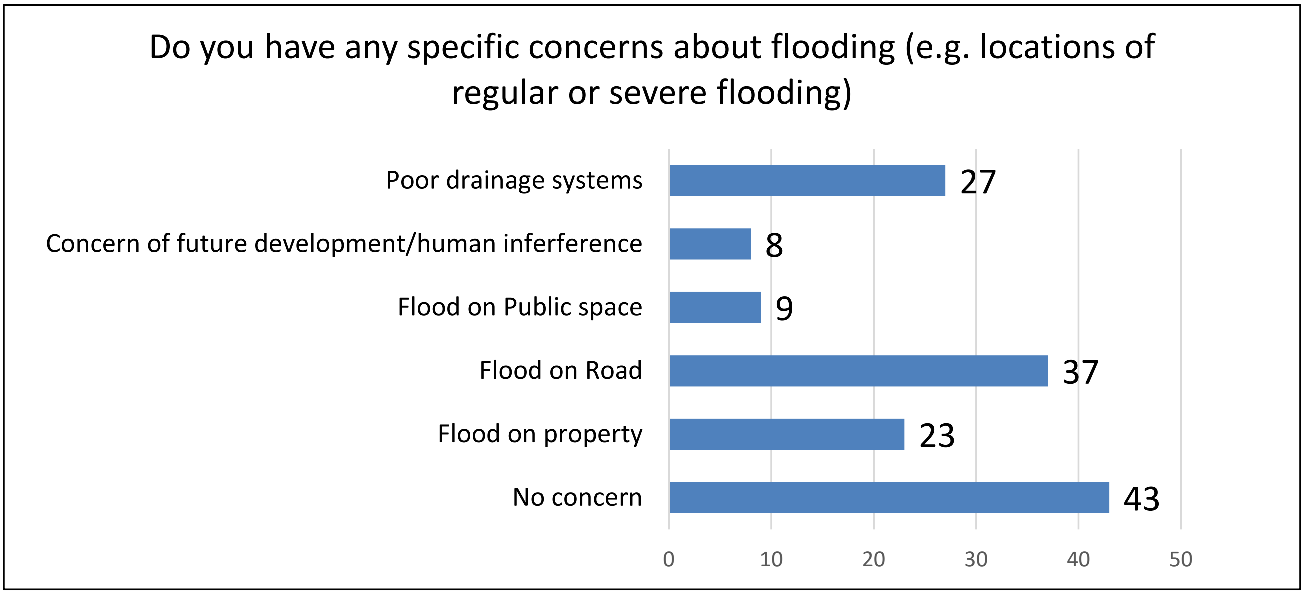


Figure 3-3 Summary of questionnaire responses - multiple choice questions (3 of 3).



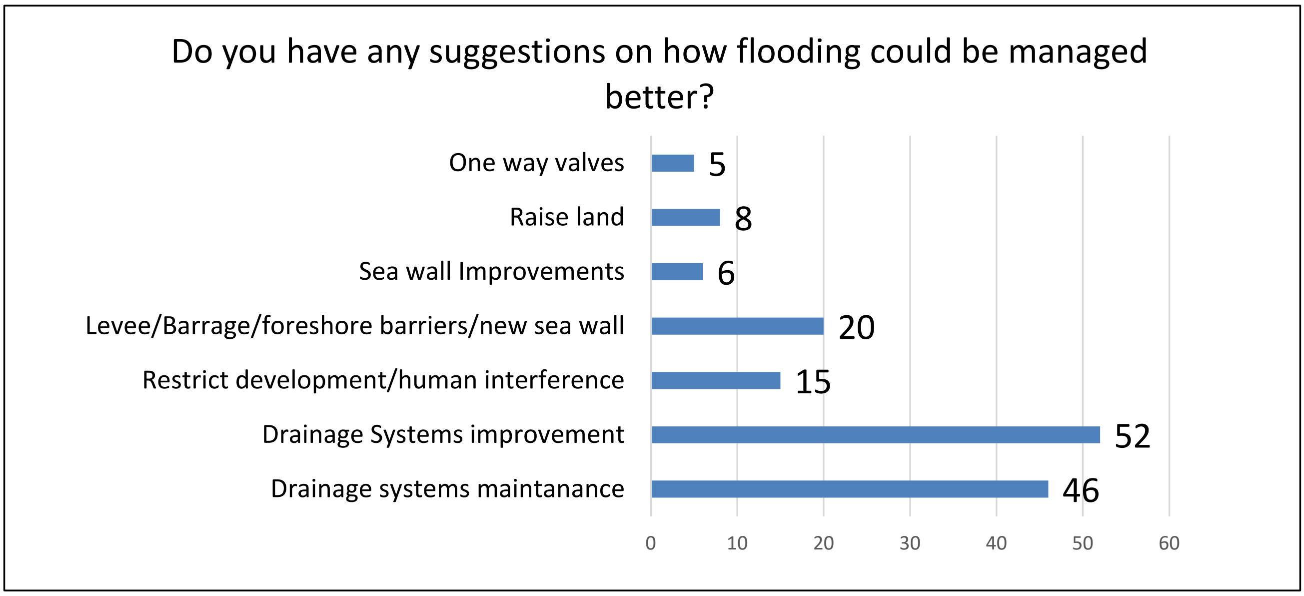


Figure 3-4 Summary of questionnaire responses – Open ended questions.

3.4.3 Community Drop-In Information Sessions

Two community drop-in information sessions were held in Davistown (16th October) and Empire Bay (17th October). They were attended by 43 and 27 community members respectively.

The comments provided and issues raised by community members at the drop-in sessions are summarised in **Table 3-7** along with the actions arising from them.

Table 3-7 Community Input from Drop In Sessions

<table>
<tr><th>Community Input</th><th>FRMS Response</th></tr>
<tr><td>A number of residents from Restella Ave raised issues about an easement between Paringa and the Oval. Concerns were raised on the effects of the strata development on this easement where the land was filled and storage displacement of water. Long term residence spoke of a natural creek with crabs within the easement.</td><td>The open drain along this easement (approximately 3m wide easement) is populated with casuarina and flows appear to be restricted at the box culvert at Paringa Ave (450mm x 300mm).

The preliminary options assessment (Section 8.1.1) considered improving the drainage through this easement.

This easement may also provide for inter allotment drainage for interim filling scenarios considered in the Climate Change Adaptation Strategy. See Section 2.4.4 and 7 for more details on this strategy.</td></tr>
<tr><td>Pine Avenue Park gets flooded as a result of heavy rainfall.</td><td rowspan="2">The preliminary options assessment (Section 8.1.1) considered improvements to road drainage and raising of roads to reduce flooding on roads and adjacent land in this location.</td></tr>
<tr><td>Lilli Pilli Street at the corner of Pine Street gets cut off by flood waters.</td></tr>
<tr><td>Several residents raised the need for curb and guttering across the study area. The following locations were specifically mentioned:
• Pine Avenue, Davistown
• Amy Street, Davistown
• Shelly Beach Road, Empire Bay
• Top end of Rosella Road, Empire Bay</td><td rowspan="2">The preliminary options assessment (Section 8.1.1) considered improvements to road drainage across these locations.</td></tr>
<tr><td>Pine Avenue needs formalised drainage to minimise the ponding of water along the road easement and in the front of private properties. The drainage should direct flow from North of Kincumber crescent northwards into the wetland, and the area south of Kincumber should be directed to the Southern foreshore.</td></tr>
<tr><td>The foreshore area between Amy Street and Alkoomie Close become soggy and limits pedestrian access after rain.</td><td>Any flood management options along the foreshore have considered the need to maintain and improve pedestrian access.</td></tr>
<tr><td>The dog walking park at Pipe Point gets very soggy and wet after rain. And the open drain needs to be cleared out and should be formalised.</td><td>Maintenance issues have been reported to Council’s maintenance staff for consideration.</td></tr>
<tr><td>Many roads in Davistown are in need of repair. The intersection of Pine Street and Kincumber Crescent is dangerous – resident suggested the use of a non-raised roundabout.</td><td>Where flood risk management options can also improve the quality and safety of the road, this would have benefits for the community. This will be used to compare and assess options in this study.

Safety and maintenance issues have been reported to the relevant council officers for consideration.</td></tr>
</table>

Community Input	FRMS Response
If the RSL were to be used as an evacuation centre it would require additional facilities such as an additional generator, and additional showers.	This issue has been considered in the development of Emergency Response Modification Options (**Section 8.2**).
Residents at Alloura Waters have no knowledge of flood response planning at the village.	Access appears to be an issue. This issue has been considered in the development of Emergency Response Modification Options (**Section 8.2**).
Access in or out of Davistown during coastal flooding could be limited by flooding of Davistown Road at Saratoga.	This issue has been considered in the development of Emergency Response Modification Options (**Section 8.2**).
Dredging of the wetland area to the north of Davistown would reduce flooding.	Dredging has been considered as part of the preliminary options assessment (**Section 8.1.1**). However, this approach has not progressed further than initial consideration due to the significant environmental impacts associated with the dredging and the minimal flood benefits likely to be achieved from the works.
Foreshore erosion is occurring along the foreshore easement adjoining the Lenora Avenue properties. The ferry wash is seen to be the most significant cause of this erosion. Sedimentation of the eroded material appears to be accumulating along the channel. It was suggested that the Davistown seawall should extent all the way round the foreshore, including this eroding area.	Foreshore erosion is not a flooding issue. However, this issue has been identified to the relevant council officer. All flood risk management options arising from this FRMS have considered the impacts on foreshore erosion at this location (e.g. a foreshore barrier at this location could look to undertake stabilisation works as well as provided flood protection).
A foreshore barrier (similar to example shown by the project team) was well received by many residents. However, it was noted that the design would need to ensure that local flows would not be “trapped” behind the barrier. The inclusion of a shared pathway in the barrier design was supported.	A detailed assessment of the use of foreshore barriers for flood protection has been undertaken as part of this FRMS (**Section 8.1**).
It was noted that the seawall around Empire Bay is inconsistent in height and condition, especially where it is on private property. This means the seawall will not provide the intended protection against coastal flooding. Another resident noted that some property owners may not be able to afford the cost of seawall maintenance and / or raising.	An option to improve the Empire Bay seawall has be investigated in **Section 8.1**. This included consideration of a merits-based grant process could be implemented to assist with property owners being unable to fund seawall maintenance or upgrades.
Coastal flood impacts on Davistown and Empire Bay could be managed by dredging at half tide rocks and / or constructing a break wall.	This option was investigated as part of the BW FRMSP and was not considered appropriate. No further investigation has been undertaken as part of this current study.
Some Empire Bay residents felt that the wording of the questionnaire was over the top and suggested more serious flooding occurs in the area that is actually	The wording on future correspondence with the community will be reviewed to ensure it does not cause unnecessary stress to the community.

Community Input	FRMS Response
possible. It was noted that in the 1974 event local observations were that flooding was minor. The following was observed: 6 inches of flooding on Shelly Beach Road and a small number of houses had 4 inches of water over the floor. Flooding occurred for only 1 -2 hours.	However, flooding over property floor levels is taken very seriously by Council and may require evacuation of residents. It is noted that the questionnaire was aimed at residents in Empire Bay and Davistown and flooding was more significant in some locations that the observations noted.
It was suggested that Council is intending to use statistics from this questionnaire to make planning laws which will have a major detrimental consequence on future development in the area. In particular the following wording "*What information do you look for during a flood event and where do you currently get updates and information*".	The intention of the questionnaire wording noted was to assist Council and SES in providing future flood updates (e.g. storm warning from BoM, road closures, evacuation notices etc.) to the community in the most effective way.
Establishment of some key easements could improve local drainage and flooding issues.	Drainage easements have been considered in the options assessment.
The concept of incremental filling of private properties over time to allow for climate change adaptation was well received by residents in Davistown and Empire Bay.	Property filling for the purposes of climate change adaptation was assessed in the climate change adaptation strategy (Rhelm, 2020), summarised in **Section 7**.
The construction of a retaining wall and associated works along Empire Bay Drive (at the end of Rosella Road) has diverted local flows through the properties on Rosella Road).	No significant flooding is noted in this location in the flood study. This local drainage issue has been advised to the relevant council officer.
There is an informal low wall along the western boundary of the caravan park at Pamona Road. This wall diverts flood waters to the south and onto adjacent private property.	The impacts of this structure on flood behaviour were assessed, see **Appendix C** for details.
The culvert under Empire Bay Drive (immediately to the west of Palmers Lane) is fully blocked.	Additional modelling was undertake to better understand the impact of this culvert of flood behaviour, the outcomes of this analysis are discussed in **Section 6.5.1.** Improvements to this culvert were also assessed as part of the options analysis in **Section 8.1**.
There are several "gullies" that run along Empire Bay Drive. These should be formalised into piped drainage to assist with drainage, improve safety along the verge and allow for parking near the primary school.	Drainage improvement along Empire Bay Drive were considered as part of the options analysis in **Section 8.1**.
Flood related planning controls are applied inconsistently. An example was given where one property was allowed to fill and another on the same street was not.	A review of the existing planning controls and recommendations for amendments for future flood planning are provided in **Sections 0 and 8.2**.

Community Input	FRMS Response
Impervious fences are often constructed across flow paths without Council consent.	If this is occurring, this issue does not comply with Council's current planning approvals process and has been reported to the relevant Council staff. The community should be informed of the flood planning controls that apply to them and their properties, as well as the consequences of non-compliance. This should be addressed in the Flood Education Program recommended in this FRMS (Section 8.3.6)
Flooding has been observed by residents at Myrtle Road and Greenfield Road in 1985. This aligns with the model results from the Flood Study (2010).	The inclusion of a drainage easement in this location has been included in the options analysis in **Section 8.1**.
There is a culvert near 72 Kendall Road that goes from a 900mm culvert to a 180mm culvert that passes under Kendall Road. This results in backing up of flows on the upstream side of Kendell Road. Nuisance flooding rather than property risk or access issues.	This issue has been referred to Council's assets team for consideration as part of future drainage upgrade works.
After rain the flat section of Echuca Road has ponded water for several days. No drainage to take it away.	The inclusion of a drainage easement in this location has been included in the options analysis in **Section 8.1**.

3.5 Stakeholder Meetings

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

3.6 Public Exhibition

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

4 Flood Planning Review

4.1 Purpose

Within the study area, development is largely controlled through the Gosford Local Environmental Plan 2014 (GLEP 2014) and a series of Development Control Plans (DCP). The LEP is an environmental planning instrument (EPI) which designates land uses and development in the study area, while the DCPs regulate development with specific guidelines and parameters. There are also a number of EPIs and related planning documents that can affect the development of property within the study area. These may be in the form of State Environmental Planning Policies (SEPPs) such as:

- SEPP (Exempt and Complying Development Codes) 2008
- SEPP (Educational Establishments and Child Care Facilities) 2017
- SEPP (Infrastructure) 2007
- SEPP (Housing for Seniors or People with a Disability) 2004
- SEPP No 36 - Manufactured Home Estates
- SEPP (Coastal Management) 2018
- Other SEPPs as relevant to land use and/or development type
- Other Council plans, policies, or other publications.

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

This FRMS provides a review of flood-related controls covered by the LEP, relevant DCPs, Council policies and plans. This FRMS also includes recommendations for updates that could be undertaken to improve the management of flood risk (see **Section 8.2.1**).

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

4.2 Central Coast Council Consolidated LEP and DCP Project

On 12 May 2016, a proclamation to merge the former Gosford City and Wyong Shire Councils and form the Central Coast Council was announced by the Department of Premier and Cabinet. At the same time, the State Government issued Guidance for Merged Councils on Planning Functions. These guidelines recommended Council analyse the differences in the current planning controls, including existing and deemed Environmental Planning Instruments (EPIs) and Development Control Plans (DCPs).

Council has been preparing a draft Central Coast Local Environmental Plan (CCLEP) and draft Central Coast Development Control Plan (CCDCP) in response to these guidelines. Both documents are a consolidation of existing EPIs into one plan.

The consolidation project has not been about introducing new controls. It has been about identifying and applying the most suitable existing controls from existing instruments and plans.

The rezoning of the lands deferred from GLEP 2014 forms part of the Consolidated CCLEP. Until the CCLEP is made, Interim Development Order No. 122 – Gosford (IDO 122) and the Gosford Planning Scheme Ordinance (GPSO) will continue to operate until the CCLEP is adopted.

4.3 Updated Flood Prone Land Package

The Department of Planning, Industry and Environment (DPIE) has been working to update the Flood Prone Land Package which provides advice to councils on considering flooding in land use planning and consists of:

- a proposed amendment to schedule 4, section 7A of the *Environmental Planning and Assessment Regulation 2000*
- a revised planning circular
- a revised local planning direction regarding flooding issued under section 9.1 of the *Environmental Planning and Assessment Act 1979*
- revised Local Environmental Plan flood clauses
- a new guideline: Considering Flooding in Land Use Planning (2020).

The updated Flood Prone Land Package was put on public exhibition from 30 April 2020 till 25 June 2020.

At the time of preparing this Floodplain Risk Management Study, it had not been finalised. However, the review of Councils existing flood planning documents (**Section 4.4**) and recommendations (**Section 8.2.1**) have been undertaken in consideration of the package.

4.4 Existing Documents

4.4.1 Gosford Local Environmental Plan 2014

The Gosford Local Environmental Plan 2014 (GLEP 2014) is a legal document that sets the direction for land use and development in the study area by providing controls and guidelines for development. It determines what can be built, where it can be built and what activities can occur on land.

The GLEP 2014 is based on a standard format used by all Councils in NSW and can be viewed on the NSW legislation website (www.legislation.nsw.gov.au).

The Gosford LEP was gazetted in 2014 and repeals the following previous planning instruments:

- Gosford City Centre Local Environmental Plan 2005
- Gosford City Centre Local Environmental Plan 2007
- Gosford Local Environmental Plan No 22
- Hornsby Planning Scheme Ordinance
- Gosford Planning Scheme Ordinance (except Deferred Matters)
- Interim Development Order No. 122 – Gosford (except Deferred Matters).

Land use planning and development assessment for land which is deferred from the GLEP 2014 (signified on maps as DM, i.e. Deferred Matters) is currently undertaken using the provisions of the GPSO or IDO 122.

Some areas within the study area do fall under Deferred Matters.

4.4.1.1 Flood Planning Objectives and Controls

The objectives for land at or below the flood planning level are outlined in Clause 7.2 of the GLEP 2014. The objectives of this clause are:

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

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

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

The above objectives and consent considerations are generally consistent with the existing LEP standard template and the proposed 'Flood Planning Area' clause in the Flood Prone Land Package (**Section 4.3**). However, some additional objectives and considerations are provided in the proposed 'Flood Planning Area' clause.

The GLEP 2014 does not define the Flood Planning Level (FPL). This provides some flexibility with regards to defining the FPL within the relevant FRMPs.

Clause 7.3 of the GLEP sets out a second flood related section of the LEP (entitled Floodplain Management) that addresses development controls that are applicable for development within the floodplain (i.e. above the 1% AEP plus 500mm freeboard and up to the Probable Maximum Flood level). This clause is consistent with the Planning System Circular (formerly Section 117 Direction) issued by the NSW Department of Planning and Environment (Direction PS07-003, dated 31 January 2007).

This clause is somewhat inconsistent with Clause 7.2, in that the FPL is indirectly defined as the 1% AEP plus 500mm). With this exception, Clause 7.2 is generally consistent with the proposed 'Special Flood Considerations' clause in the Flood Prone Land Package (**Section 4.3**). However, some additional objectives, considerations, and definitions of 'sensitive, vulnerable and critical' uses are provided in the proposed 'Special Flood Considerations' clause.

4.4.1.2 Regional Evacuation Consideration Area

The Flood Prone Land Package (**Section 4.3**) proposes an additional flood planning clause to be included in LEPs. The clause applies to areas that have known evacuation considerations within or outside the floodplain (due to isolation). At this stage, it is understood that it is intended that this clause would only be applied to land within the Hawkesbury Nepean River Floodplain. No clause currently existing within the GLEP 2014 that specifically addresses this issue.

4.4.1.3 Land Use Zones

The Gosford LEP defines the land-use zoning for the study area, thereby determining which type of development are allowable through the study area. The general land zoning for the study area is illustrated in **Figure 4-1**.

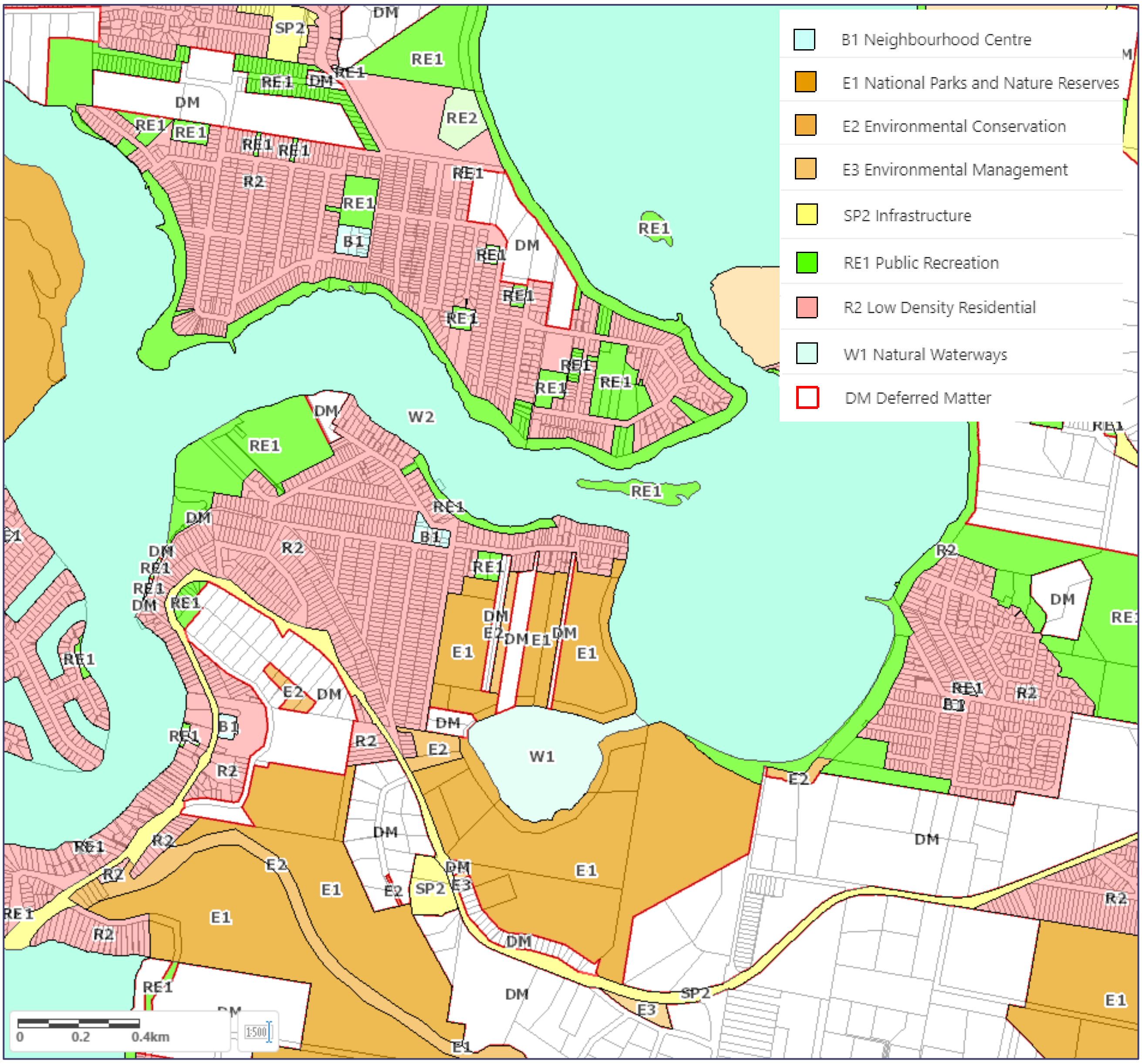


Figure 4-1 Gosford LEP Land Zoning (sourced from environment.nsw.gov.au)

The LEP information is up to date as of 12 October 2018 and can be accessed via www.legislation.nsw.gov.au.

4.4.1.4 Flood Mitigation Works

The GLEP 2014 prohibits flood mitigation works in the following zones:

- Zone B1 Neighbourhood Centre
- Zone B2 Local Centre
- Zone B3 Commercial Core
- Zone B4 Mixed Use

- Zone B5 Business Development
- Zone B6 Enterprise Corridor
- Zone IN1 General Industrial
- Zone IN4 Working Waterfront.

4.4.2 Gosford Development Control Plan

The Gosford DCP came into effect with the Gosford LEP in 2014 and applies to all land zoned under the Gosford Local Environmental Plan (LEP) 2014 (or in the case of Deferred Matters, the Gosford Planning Scheme Ordinance or Interim Development Order No 122). Amendments to the plan have resulted in the most recent updated version of the DCP being June 2018. The purpose of the DCP is to provide Council's requirements for quality development and environmental outcomes within the Gosford area of the greater Council LGA.

The sections of the DCP relevant to this FRMS include:

- Clause 3.16 Water Recreation Structures
- Clause 5.1 Location specific development controls for Bensville
- Clause 6.1 Acid Sulfate Soils
- Clause 6.7 Water Cycle Management.

Of key importance to the FRMS is Clause 6.7 Water Cycle. This clause applies to all development within the LGA requiring development consent and relates to WSUD and flood mitigation principles. Objectives of this clause include:

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

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

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

- Integrate stormwater management systems into the landscape in a manner that provides multiple benefits, including water quality protection, stormwater retention and detention, public open space, and recreational and visual amenity.

Clause 6.7 of the DCP also sets out guidance for numerous matters related to development within the floodplain including:

- on-site stormwater detention targets
- overland drainage management controls
- reduction of losses from flooding on flood prone property
- habitable and non-habitable floor levels
- carpark access levels
- treatment of subdivisions
- Floodplain Risk Management Plans
- fencing
- filling on land
- setbacks from watercourses
- works near stormwater easements
- providing access to rural flood prone properties.

The following issues were identified for further consideration in future updates to Council's DCP:

- The DCP refers to the Flood Planning Area being land below the 1% AEP + 500mm (clause 6.7.7.6.4) rather than being defined for each floodplain within the relevant Floodplain Risk Management Study.
- 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.
- Filling of the land within the Flood Planning Area is not permitted unless:
    - It is allowable as part of an adopted Floodplain Risk Management Plan
    - Or it can be demonstrated (by a skilled flood specialist) that the cumulative effect of filling the area would not raise the flood level by more than 10mm and that the land can be considered 'flood fringe'
    - Unless a Floodplain Risk Management Plan for the catchment has been adopted, which allows filling to occur, filling in flood prone areas is not permitted unless a report from a suitably qualified civil engineer is submitted to Council that certifies that the development will not increase flood affectation elsewhere.
    - Filling of individual sites in isolation, without consideration of the cumulative effects is not permitted. The NSW Government's Floodplain Development Manual states that a case by case decision making approach cannot consider the cumulative impact of flooding behaviour, and associated risks, caused by individual developments. Any proposal to fill a site must be accompanied by an analysis of the effect on flood levels of similar filling of developable sites in the area.

The impact of filling on the flooding has been assessed in **Section 6.6.**

Recommendations associated with the DCP controls are provided in **Section 8.2.1**.

4.4.3 Central Coast Council Climate Change Policy (2019)

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

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

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

4.4.4 Civil Works Specification - Design Guidelines

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

4.4.5 Plans of Management

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

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

- Foreshore Parks 1996
- Gosford Foreshore 2004
- Green and Golden Bell Frogs 2006
- Gosford City Playground Strategy 2009
- Brisbane Water Estuary Management Plan 2010.

4.4.6 Australian Rainfall and Runoff

The ARR87 and ARR2019 guidelines are used to determine hydrologic and hydraulic processes across Australia. These guidelines have been used in the estimation of flood behaviour in various modelled design storm events.

The Davistown and Empire Bay Flood Studies (Cardno Lawson Treloar, 2010) were undertaken utilising the ARR87 guidelines, hence any additional flood modelling needed to be consistent with this version of the guidelines. With the release of the more robust and defensible ARR2019, it was also necessary to consider the impacts of the updated guidelines. Additionally, the Civil Works Specification - Design Guidelines (CCC, 2018) encourages the use of ARR2019 in stormwater drainage designs. A sensitivity analysis (refer to **Section 5.4**) of the impacts of using the updated ARR2019 guidelines has been undertaken (**Appendix C**). Based on the outcomes of the sensitivity analysis, it was agreed by Council and DPIE to undertake modelling for the FRMSP using ARR87.

5 Flood Modelling

5.1 Modelling Approach Overview

Utilising the information reviewed in **Section 2.5**, Rhelm have established an existing conditions 1D/2D model for the analysis of flooding within Davistown and Empire Bay. This model employs rainfall on grid hydrology with the overland flows estimated based on the terrain properties.

The previous model created by Cardno Lawson Treloar utilising the Sobek 1D/2D modelling software was used as a basis for the creation of a new 1D/2D model using the Tuflow software. The hydraulic model inputs for the Sobek model were directly input into the Tuflow model. These include DEM, surface roughness, and initial and continuing losses.

Modifications were made to the 1D network, inclusive of the pit and pipe stormwater system and open drainage channels. These changes were necessitated because of the change in modelling software and for the minimisation of model continuity errors.

No calibration to previous historical flood events was necessary as the Sobek modelling has been accepted by Council as part of the Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010). The purpose of establishing this model is to convert the Sobek model to Tuflow with minimal changes in modelled flood behaviour.

A review of the Flood Studies (2010) model inputs (**Section 2.5**) identified several minor changes that could be undertaken. However, none were considered significant.

5.2 Hydraulic Model

5.2.1 Conversion of Sobek Model to Tuflow

A Sobek 1D/2D model was originally established as part of the Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010). It was calibrated and verified using historical rainfall data. Model setup files and results have been provided to Rhelm by Council. Refer **Section 2.5** for a full review of the model.

As part of this FRMSP, the supplied Sobek model required conversion into a Tuflow model. Converting the model also required the recreation of some model elements in formats which could be input into Tuflow, such as:

- Pit and pipe network
- Rainfall and losses
- Outflow boundary conditions for higher elevations (e.g. not in Cockle Channel)
- Morton Crescent Bridge
- Swales and channels along Murna Road and Emora Avenue in Davistown converted from 1d to 2d elements.

The Sobek flood study model (Cardno Lawson Treloar, 2010) had been split into two separate models: one for Davistown and one for Empire Bay. This separation of model sub-areas remains in the Tuflow model.

Details on rainfall inputs, model DEM, surface roughness, rainfall losses methods, stormwater networks, bridges and boundary condition inputs into the Tuflow model are discussed in detail in **Appendix C**. Detailed model results are also provided in **Appendix C** and summarised in **Section 5.3** below.

5.3 Model Results

The flood model developed for the Flood Studies (Cardno Lawson Treloar, 2010) has effectively been maintained through its conversion to Tuflow. As demonstrated in **Appendix C**, the Tuflow model provides consistent results with the Sobek model. As such, the flood mapping and other results presented in the Flood Studies (Cardno Lawson Treloar, 2010) should be referred to for floodplain management purposes.

The model results have been used in this FRMS to further assess economic flood damages (**Section 2.4.1.6**), flood behaviour and flood risk (**Section 6**), and assess the benefits and impacts of potential floodplain risk management options.

5.4 Sensitivity Analysis

A comprehensive sensitivity analysis was undertaken of the flood models as part of the Flood Studies (Cardno Lawson Treloar, 2010) and as such, no additional sensitivity of model parameters is being undertaken as part of this FRMS.

Sensitivity analysis was undertaken for the application of Australian Rainfall and Runoff hydrological methods, as discussed in detail in **Appendix C**. Since the Davistown and Empire Bay Flood Studies (Cardno Lawson Treloar, 2010) were completed, the Australian Rainfall and Runoff 2019 (ARR2019) has been published. The new ARR2019 has a number of changes to the hydrological methods that have been traditionally employed, including those in the 2010 Flood Studies. This includes updated design rainfall intensities, new ensemble storms and other catchment parameters such as losses.

Comparison of the ARR87 and ARR2019 results found that overall, there were only minor increases in flood depths (up to approximately 30mm) in some areas and a decrease in other areas (up to 50mm). As such, it was agreed by Council and DPIE to continue modelling for the FRMSP using ARR87.

5.5 Flood Damages

In order to quantify the economic impacts of flooding, a flood damage assessment has been undertaken. A property may suffer economic impacts from flooding through several ways. These are broadly grouped into three categories, as summarised in **Table 5-1**.

Table 5-1 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 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. Some of the intangible impacts and benefits have been captured qualitatively through a multi-criteria assessment (**Section 9**).

The damage assessment undertaken for this study has examined the tangible damages only. Assessment of the tangible flood damages is based on a relationship between the depths of flooding on a property and the likely damage within the property.

A detailed discussion of the damages assessment is provided in **Appendix D**.

The results from the damage assessment are summarised in **Table 5-2**.

The average annual damage (AAD) for the Davistown and Empire Bay study area under existing conditions is $1,752,358. The ADD calculation takes into account the total damages associated with each analysed flood event, as well as the likelihood of that flood event occurring. This number provides a representation of the estimated amount of capital that Council would need to set aside every year to address damages caused by flooding (both frequent and rare).

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 $24.1M. 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 5-2 Davistown and Empire Bay – Existing Damages Assessment Results

	Properties with Over-Floor Flooding	Max Over-Floor Depth (m)	Avg Over-Floor Depth (m)	Flood affected properties	Total Damages ($2019)
PMF	274	1.03	0.15	896	$39,436,465
0.5% AEP	45	0.64	0.14	307	$11,300,421
1% AEP	36	0.60	0.13	256	$9,372,400
2% AEP	24	0.56	0.15	221	$7,883,519
5% AEP	20	0.51	0.16	182	$6,427,163
10% AEP	11	0.46	0.19	182	$4,685,971
20% AEP	9	0.42	0.18	182	$3,805,105
				AAD	**$1,752,358**

6 Flood Behaviour and Flood Risk

6.1 Flood Hazard

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

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

The hazard categories mapped are summarised in **Table 6-1** and **Figure 6-1**. These are based on the categories as defined in the AIDR (2017) Guideline.

Flood hazard mapping is provided for the 1% AEP and PMF events in **Map Series G120**. It should be noted that the hazard classification considers only the effects of catchment flooding and, therefore, does not take into consideration ocean flooding from Brisbane Water.

For the 1% AEP flood event Davistown and Empire Bay had a similar pattern of hazard, with hazard categories ranging from H1 to H5. Most of the study area can be classified as H1 and higher hazard can be found on streams and channels, wetland areas and certain roads.

In Davistown, the low-lying portion of the wetlands that surround the urban area can be classified as H2, as well as localised sections of Davis Road, Grevillia Avenue and Emora Avenue. H3 and H4 categories are restricted to the open channels.

In Empire Bay/Bensville the extent of the area classified as H2 is more significant. A considerable portion of the roads situated on the urban centre on the north-west of the study area (between Kendall Road and Rosella road) can be classified as H2. The flooding in some sections of Gordon Road, Boongala Avenue, Rickard Road, Echuca Road and Sorrento Road is associated with more significant hazard and is classified as H3.

The H2 hazard classification also applies to areas in the south-east of Empire Bay, around Pomona Road, and the wetlands to the north of empire bay drive.

Higher hazard (H3 to H5 categories) can be identified on the streams and drainage channels crossing Empire Bay Drive, particularly along the watercourse that flows from the south-west of the study area towards Brisbane Water. These hazard categories can also be observed on the margins of Empire Drive around the intersection with Palmers Lane. Directly west of this intersection, one sections of Empire Bay Drive is classified as H5.

For the PMF event, Davistown is mostly covered by H2 and H3 hazard categories. The H2 category applies to the properties and roads south of Emora Avenue and west of Malynia road, with some areas between Mirren Avenue and Malynia Road being classified as H3. The areas around Grevillia Avenue and Davis Avenue are also covered by H2 hazard, as well as the wetlands on the south-east, north-west, and north-east of the study area.

The wetland areas surrounding the channel on the central portion of the study area are mostly covered by the H3 hazard category. The same level of hazard can be observed in Davistown Memorial Park, in the wetlands west of Pine Avenue and on the following roads: Emora Avenue, Grevillia Avenue, Malynia Road and Henderson Road. Similar to what was observed on the 1% AEP event, in Davistown, higher hazard categories (H4 and H5) are found along the open channels situated in the east and west of the suburb.

In Empire bay, a significant portion of the roads in the north-eastern urban centre can be classified as H3 for the PMF, as well as most of the wetland areas north of Empire Bay Drive. A significant extent of H5 hazard is present around the intersection of Empire Bay Drive with Palmers Lane. This level of hazard also covers a significant part of the area in the south-east, around Pomona Road, affecting roads and properties. Additionally, H6 level hazard can be found on the of the watercourse on the south-east and on some points along Empire Bay Drive.

Table 6-1 Hazard Categories

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

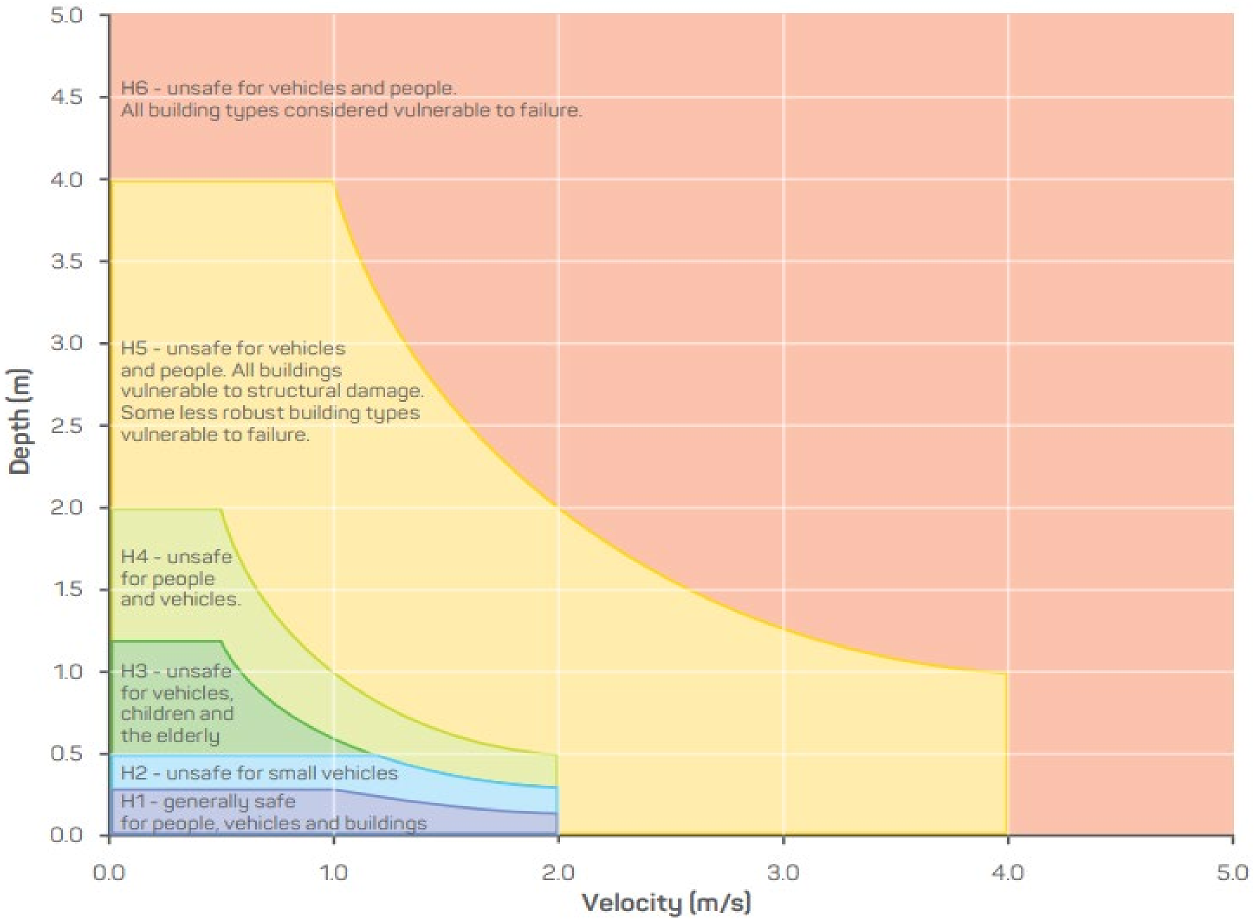


Figure 6-1 Flood Hazard Categories (AIDR, 2017)

6.2 Hydraulic Categorisation (Flood Function)

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

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

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

The Hydraulic Categorisation analysis for the Davistown and Empire Bay catchment areas was undertaken as part of the Flood Studies (Cardno Lawson Treloar, 2010). In the 2010 studies, the Hydraulic Categories were determined for the 1% AEP, 5% AEP, 20% AEP and PMF events. The analysis provided in the flood study was considered sufficient and it was not updated in this report. A summary of the results reported by Cardno Lawson Treloar (2010) is provided below.

According to the maps prepared by Cardno Lawson Treloar (2010), in the 1% AEP event, the flood storage classification can be applied to most of the flood affected area in Empire Bay. This includes roads in the urban centre in the north-west and the wetlands surrounding the region. Floodway areas can be identified along drainage channels and properties in the south-east of Empire Bay, around Pomona Road and Empire Bay Drive, as well as along sections of Boongala Avenue, Myrtle Road and Rickard Road.

In Davistown, floodway areas can be found in isolated locations with higher elevation, situated in the northern part of the catchment. Part of the channel adjacent to the culvert at Morton Crescent can also be classified as floodway. Flood storage areas are present in the open space and wetland areas, as well as in parts of a few private properties.

In the PMF event, a significant portion of the roads, properties, and wetland areas in the north-west of Empire Bay are categorised as Flood Storage areas. Floodway areas are found in sections of several roads in this region such as: Gordon Road, Boongala Avenue, Rickard Road, Murrong Road, Myrtle Road, Echuca Road and Greenfield Road. Floodways also occupy most of the flood affected region in the south-east of the suburb, including several roads in Empire Bay and Bensville.

Most of the flood affected area in Davistown can be classified as flood storage in the PMF event. Floodway areas can be identified primarily in the north part of the catchment, along sections of Henderson Road, Broadwater Drive and Davistown Road. In the southern part of the suburb, sections of Magnolia Road and Kyoga Road are also categorised as floodway areas.

6.3 Emergency Response Classification

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

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

AIDR (2014) provides guidance on response classification mapping, which is intended to be undertaken at the community or precinct scale (i.e. not at the lot scale). A summary of the classifications is provided in Table 6-2 Emergency Response Classifications (AIDR, 2014)**Table 6-2**.

The 5% AEP, 1% AEP and PMF flood events were considered in the FERC mapping. These are presented in **Map Series G130**. It should be noted that the 'Flood Free' category was not shown on the maps.

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

In Davistown, for the three considered flood events, most of the low lying community was classified as overland escape route (FEO) or rising road (FER). This is due to the high influence of the ocean flooding to the overall flood behaviour and to the characteristics of the catchment's steeply rising terrain away from the foreshore. The coastal flooding would generally progress from the low-lying areas on the foreshore towards increasingly higher terrain. Since the rate of rise of the ocean water is relatively slow, people will likely be able to escape to flood free areas in advance of the areas becoming flooded, either along roadways or overland. Some isolated elevated areas (FIE) have been identified throughout the floodplain. These typically correspond to properties that have been built in elevated terrain. As expected, the FIE areas are smaller in the larger flood events.

In Empire Bay, isolated submerged (FIS) and isolated elevated (FIE) areas were identified in the urban centre, located in the north-east of the study area. These isolated areas are generally situated around Boongala Avenue and Rickard Road and are a result of the localised low points found on these roads. By the time the flood reaches the properties in these locations, the exit routes are already cut off by the water. Other significant roads in Empire Bay are also affected by the flood, including: Empire Bay Drive, Pomona Road and Palmers Lane. The blockage of these roads results in FIS or FEO areas, depending on the flood event.

Table 6-2 Emergency Response Classifications (AIDR, 2014)

Primary Classification	Description	Secondary Classification	Description	Tertiary Classification	Description
Flooded (F)	The area is flooded in the PMF	Isolated (I)	Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/or impassable terrain as waters rise during a flood event up to and including the PMF. These areas are	Submerged (FIS)	Where all the land in the isolated area will be fully submerged in a PMF after becoming isolated.
				Elevated (FIE)	Where there is a substantial amount of land in isolated

Primary Classification	Description	Secondary Classification	Description	Tertiary Classification	Description
			likely to lose electricity, gas, water, sewerage, and telecommunications during a flood.		areas elevated above the PMF.
		Exit Route (E)	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities (located on flood-free land).	Overland Escape (FEO)	Evacuation from the area relies upon overland escape routes that rise out of the floodplain.
				Rising Road (FER)	Evacuation routes from the area follow roads that rise out of the floodplain.
Not Flooded (N)	The area is not flooded in the PMF			Indirect Consequence (NIC)	Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications, and transport links due to flooding.
				Flood Free (NFA)	Areas that are not flood affected and are not affected by indirect consequences of flooding.

6.4 Flood Planning Area

The Flood Planning Area (FPA) is the area within which development that has the potential to impact flood behaviour or be impacted upon by flooding. Therefore, flood related development controls may apply to development proposed on properties that fall fully or partially within the FPA. All relevant planning controls for individual land parcels are summarised in a Section 10.7 certificate (formerly a Section 149 certificate) issued under the *Environmental Planning and Assessment Act 1979*.

The FPA is usually defined as the area below the Flood Planning Level (FPL). The criteria adopted for the definition of the FPL should take into consideration the singularities of the flood behaviour in the region. The existing FPL applied within the study area is based on:

- the Brisbane Water 1% AEP level + projection of sea level rise + 0.5m freeboard (within the Brisbane Water flood extent); or
- catchment flooding 1% AEP level + 0.5m freeboard (above the Brisbane Water flood extent).

The Brisbane Water FPL was derived as part of the Brisbane Water FRMSP (Cardno, 2015).

A review of the FPL and FPA for catchment flooding has been undertaken as part of this study. Flooding above the Brisbane Water flood extent is primarily overland flow and flooding of small waterways and is generally shallow in depth. Although across NSW the FPA is typically defined as the 1% AEP plus 0.5 m freeboard, this is not always appropriate for this type of flooding. Defining the FPA in this way may result in a FPA extent that is far greater than the PMF extent and may therefore be considered too conservative.

To assess various approaches to the FPA for catchment flooding, the following extents have been compared:

- PMF
- 1% AEP + 0.5m freeboard
- 1% AEP with a 30% increase in rainfall intensity.

The three extents are shown on maps **G140** and **G141**, for Davistown and Empire Bay respectively. It can be seen that the 1% AEP + 0.5m extent extends further than the PMF, therefore including areas outside of the floodplain. The 1% AEP with a 30% increase in rainfall intensity is greater than the 1% extent (1% AEP extent not shown on the map) but still within the PMF. It is recommended that this extent be adopted as the FPA for areas of Davistown and Empire Bay that are affected by catchment flooding as it provides some 'freeboard' above the 1% AEP without being overly conservative.

It should be noted that in keeping with the approach adopted in the Flood Studies (Cardno Lawson Treloar, 2010), a depth filter of 0.1m has been applied to all three extents.

6.5 Flood Impacts on Transport and Infrastructure

The land use in Davistown and Empire Bay is primarily residential. There are a number of transportation routes through the study area, both major arterials (such as Davistown Road and Empire Bay Drive and secondary roads providing access to properties. Understanding when key access routes are overtopped by floodwaters and the duration in which they are flooded is useful, particularly for emergency response planning.

An analysis was undertaken on the maximum depth and duration of overtopping on key access roads within the study area. It should be noted that a roadway was considered to be overtopped when the greatest portion of the analysed section was covered by flood depths higher than 0.1m.

This information is presented on maps **G150** and **G151**, for Davistown and Empire Bay, respectively.

Roads throughout the study areas are cut in events as small as the 20% AEP. In this flood event, significant overtopping depths (greater than 0.3 m) were identified in Empire Bay roads, such as Boongala Avenue, Rickard Road, Greenfield Road, Palmers Lane, and Pomona Road. In Davistown, Emora Avenue, Kincumber Crescent, and two sections of Malynia Road were affected in the 20% AEP, with maximum overtopping depths ranging from 0.1 m to 0.2m, approximately.

In the 1% AEP event, overtopping depths as great as 0.6 m were observed in Empire Bay (Boongala Avenue). Rosella Road is also overtopped in this flood event, for a duration of approximately 30 mins. In Davistown the maximum overtopping depth on key access routes was 0.3m. Overtopping durations were also considerably higher in the 1% AEP scenario, with a few roadway sections in Empire Bay and one in Davistown (Emora Avenue) remaining flooded for more than 4 hours.

The flood impacts on roads in the PMF flood event has been assessed as part of the Emergency Response Modification Options identification process and is discussed in **Sections 8.3.2 and 8.3.3**.

6.5.1 Revised modelling of Empire Bay Drive culvert

During the hydraulic modelling stage of the option assessment process, it was identified that one of the culverts located under Empire Bay Drive was not adequately represented in the existing scenario model. As illustrated by **Figure 6-2**, in the section where the culvert was positioned, there was a gap in the model DEM. Therefore, even though the culvert was included in the model, as a 1d feature, the flows coming from the watercourse upstream where crossing the road through the gap, instead of being transported by the culvert.

Empire Bay Drive is an important regional access road and it important to understand if it is overtopped during a flood event at this location, the existing model does not provide this information sufficiently. As such, an updated version of the existing scenario hydraulic model has been developed. The existing DEM has been modified to represent the existing road levels, which were obtained from the ground survey (**Section 2.6.2**).

The revised modelling identified that, in the section of Empire Bay Drive where the culvert is positioned, road overtopping did not occur in flood events up to the 0.5% AEP event. In the PMF event, flood depths up to 0.28 m were identified on the road surface.

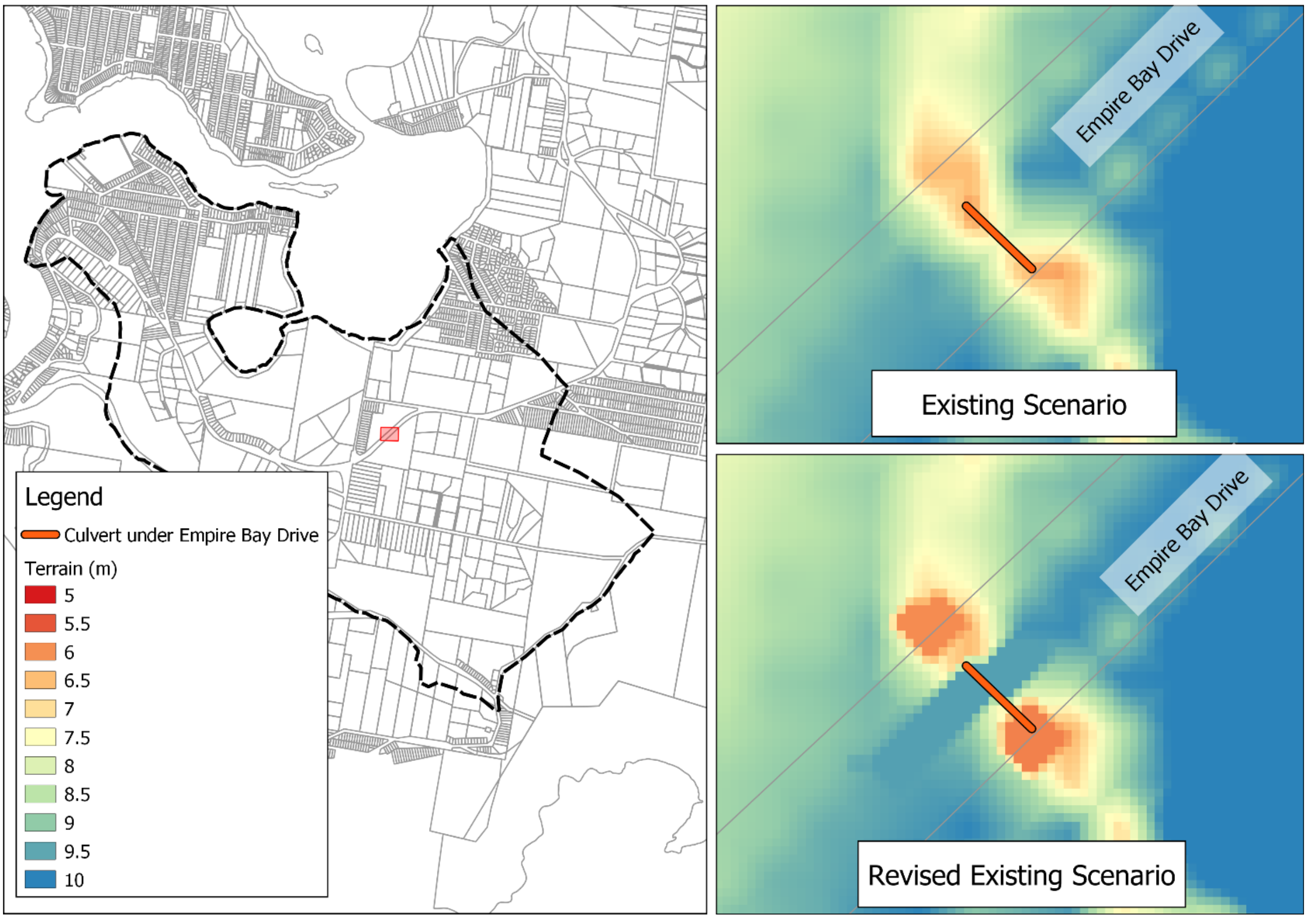


Figure 6-2 Revised Existing Scenario DEM modifications

6.6 Impacts of Filling in the Floodplain

Under current DCP guidelines, new development in Davistown or Empire Bay is required to build to the FPL. This can be achieved by construction of raised housing on piers, filling of the development site, or a combination of both filling and raising floor levels. The DCP only permits filling within the floodplain if it is allowable within a FRMP and only if the cumulative impacts of filling have been considered. The Brisbane Water FRMP allows for filling within the floodplain (which includes the low lying areas of Davistown and Empire Bay), where the fill is not located within the local catchment floodway or flood storage area, and local drainage provisions are provided to mitigate impacts on adjacent properties.

The consequences of filling within a floodplain is primarily changing the existing flood behaviour and negatively impacting private or public land.

In accordance with the Gosford DCP, adverse impacts on other properties within the floodplain may include:

- raising of flood levels, compared to pre-development levels;
- unsustainable social and economic costs to the flood affected community or general community as a consequence of flooding (i.e. damage to public property); and
- cause or increase any potential flood hazard.

For a full list of compliance requirements for development with respect to flooding, refer to Section 6.7.7.6 of the Gosford DCP.

6.6.1 Future Considerations and Cumulative Impact

The impact of climate change and rising sea levels will require the adaptation of land in low lying areas of Davistown and Empire Bay and it is not entirely clear how the process for raising ground levels whilst simultaneously complying with DCP requirements will be achieved. The current adaptation study (refer **Section 7**) details the conceptualisation and refinement of a final landform, as well as an interim strategy for implementing the landform. Given the large overall cost of filling the Brisbane Water floodplain in the low lying areas of Davistown and Empire Bay, it is assumed that the best approach for achieving the landform is to rely on private development to slowly raise ground levels on a lot by lot basis until the landform is realised. However, the process for pragmatically filling to the final landform without adversely impacting neighbouring private properties is not detailed.

It is acknowledged that due to the nature of flooding in this study area, the adverse impacts on other properties are caused by both the loss of storage in the floodplain and the potential rerouting of overland flow paths into previously ‘dry’ land.

6.6.2 Potential Scenarios

To explore the implications of progressively filling in the floodplain and determining the cumulative impacts on flood behaviour, a few scenarios have been selected to be tested against the current DCP guidelines.

Assumptions for this assessment are as follows:

- Only private properties will have their ground levels raised. Raising of roadways will be completed either when all properties fronting the roadway are raised or when rising sea levels require raising the roadway to maintain access.
- The hydraulic categorisation of land within the study is area defined in the Davistown and Empire Bay Flood Studies (Cardno Lawson Treloar, 2010a and 2010b).
- Adverse impact to adjacent properties constitutes the increase of peak flood levels by more than 10mm, in accordance with the DCP.
- Final ground levels for lots will be in accordance with the recommended final landform outlined in the Davistown and Empire Bay Climate Change Adaptation Study (Rhelm, 2020) outlined in **Section 7**.
- Council will not prohibit any new development to raise ground levels, as this would be counter-productive to achieving the long term landform outcome.

The following scenarios have been analysed for the 120 minute, 1% AEP and PMF events in the TUFLOW 2D hydraulic model to determine their cumulative impacts on flood behaviour.

6.6.2.1 Scenario 1 – Filling of Flood Fringe Only

This scenario involves assessing the results of the Davistown and Empire Bay Flood Studies (Cardno Lawson Treloar, 2010a and 2010b) and determining which lots either:

- do not contain any flooded area, or
- only contain areas of ‘flood fringe’.

By definition, in the NSW Floodplain Development Manual (2005), if the flood free areas and flood fringe areas are filled, there should be no change in flood levels within flood storage or floodway areas. These areas are not likely to require extensive assessment or development level flood studies, as per the DCP, to determine if there are adverse impacts to other properties within the floodplain. Or at least there will be less risk associated with raising these lot levels. This scenario assumes that the lots with the least onus on proving that raising of ground levels will be the first to be approved. It represents the initial stages of flood filling to be undertaken.

Mapped results for Davistown and Empire Bay are shown in **Map G160** and **G163**, respectively. These are for the 1% AEP only.

The reality is that raising of lots within the flood free and flood fringe areas does not account for displacement of overland flow paths.

Maximum cumulative impacts on flood depths are approximately +120mm in the 1% AEP and +150mm in the PMF events. This occurred when localised trapped low points were created because of raising of adjacent lots. An example of this is illustrated in **Figure 6-3**.

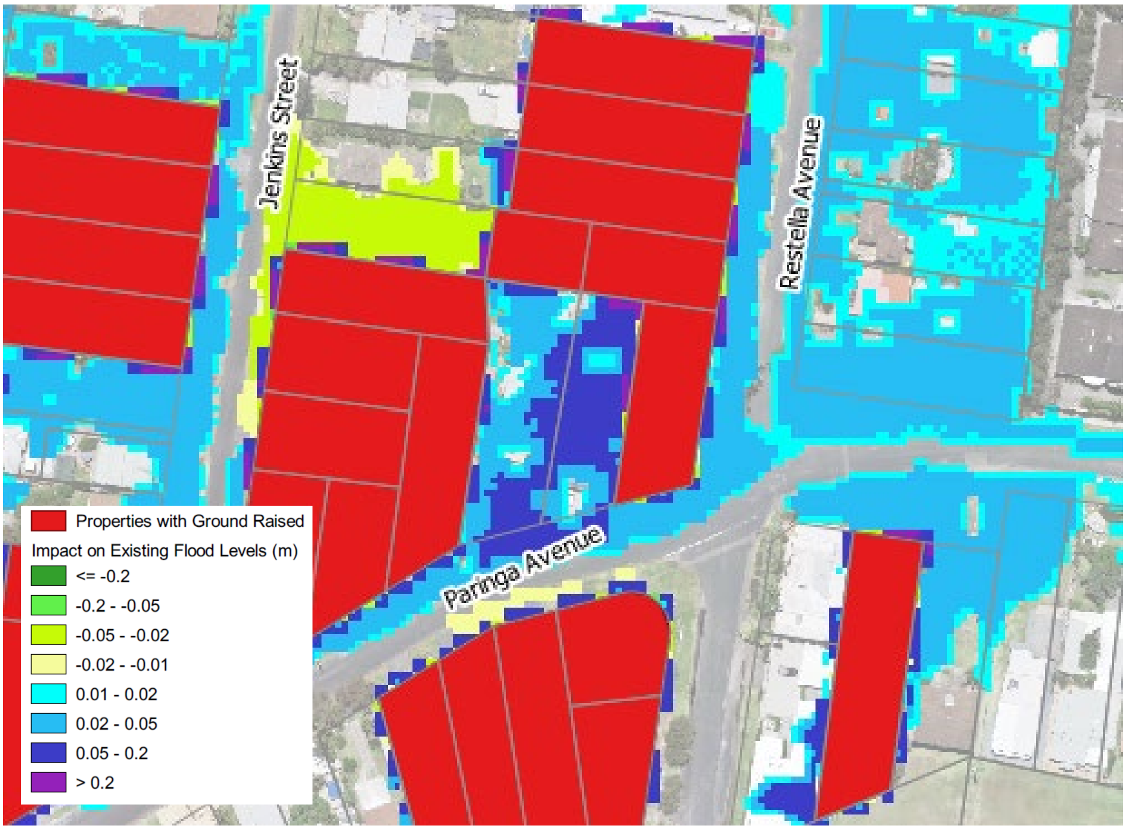


Figure 6-3 Example of Trapped Low Point Created by Filling in Floodplain

6.6.2.2 Scenario 2 – Further Filling in Flood Storage

This scenario assumes that Scenario 1 has been completed and further filling of the floodplain has commenced. The properties selected for ground raising are based on the same principle that lots associated with the least flood risk will be approved first.

Properties defined by the Davistown and Empire Bay Flood Studies (Cardno Lawson Treloar, 2010a and 2010b) as containing areas of flood storage, but not floodway, are filled. Additional properties are assumed to be filled based on the Scenario 1 results where it is not likely that an overland flow path will be obstructed. This scenario represents the situation where a majority of properties in the floodplain have been filled.

Mapped results for Davistown and Empire Bay in this scenario are shown in **Map G161** and **G164**, respectively, for the 1% AEP only.

Similar to Scenario 1, the creation of trapped low points in the resulting topography and displacement of overland flow paths are the main causes for adverse impacts on flood behaviour. Maximum cumulative impacts on flood depths are approximately +130mm in the 1% AEP and +170mm in the PMF events.

6.6.2.3 Scenario 3 –Filling High Risk Areas

While in the previous scenarios, it was assumed that the low flood risk areas would be developed and filled to gradually raise the landform, it is also recognised that this will not be the only influence on the progression of development. Some of the properties with the highest flood risk could conceivably be the first developed.

Even though filling of these properties may cause relatively greater negative impacts to flood behaviour upon adjacent lands, it would be preferable that development may be approved. That is to say, when a property undergoes private development it is in Council's and the wider vulnerable community's best interest to take that opportunity to raise ground levels and become incrementally closer to realising the final climate change adaptation landform. Faster completion of land raising on private properties means that roadways can also be raised earlier and a greater mitigation results achieved, with respect to sea level rise.

This final scenario was devised to determine a 'worst case' scenario for filling in the floodplain where properties are selected to be filled based on the likelihood, they will produce the greatest adverse impacts to neighbouring private properties. This may include filling in defined floodway areas, obstruction of significant overland flow paths, and creation of trapped low points (especially in line with overland flow paths).

Mapped results for Davistown and Empire Bay in this scenario are shown in **Map G162** and **G165**, respectively, for the 1% AEP only.

Maximum cumulative impacts on flood depths are approximately +250mm in the 1% AEP and +400mm in the PMF events.

6.6.2.4 Mitigation of Impacts

The high degree of negative flood impacts potentially resulting from adverse combinations of filling taking place in the floodplain has been broadly modelled in the aforementioned scenarios. However, they do not include any measures to mitigate these impacts.

In order to minimise the impact of filling, the following measures could be used:

- Direct overland flows towards roadways using swales,
- Inter-allotment drainage to drain created trapped low points,
- Temporary easements to allow overland flow paths to maintain their alignment, or
- Partial filling of high flood risk properties (i.e. house pad only).

Note that this list is not exhaustive, and many other potential solutions may become available.

To test the impact of providing inter-allotment drainage to reduce flooding in trapped low points and allow for overland flow paths to be 'piped', some test models were run based on the results in Scenario 3 described previously. These test cases showed that impacts to flood behaviour can be reduced, although not eliminated completely. The best results from the test cases reduced the increases in flood depths, compared to the no mitigation scenario, in the order of 20mm in both the 1% AEP flood and PMF events.

In Empire Bay, there also exists an opportunity to mitigate flood risk for the low lying area by introducing a drainage easement perpendicular to and extending from Myrtle Road to Kendall Road (refer option FM EB5 in **Section 8.1.2.6**). This drainage path will also assist with mitigating the impacts of filling in the floodplain. A sensitivity analysis was run to determine the impacts of constructing this drainage easement prior to raising of ground levels in Empire Bay. Results were generally positive, showing a widespread reduction of the peak increases in flood depth by up to 60mm in the 1% AEP. The effectiveness of this drainage easement on mitigating the impacts of filling in the floodplain increased with proximity to the easement (i.e. its effects cease to influence flooding on the northern extents of Gordon and Sorento Roads).

7 Climate Change Planning

The suburbs of Davistown & Empire Bay are representative of a number of suburbs that are low lying and susceptible to the effects of climate change and the existing threat from flooding in and around Brisbane Water Estuary. The adaptation study is an important step in addressing climate change risk for all low-lying areas of the Central Coast LGA.

By undertaking a regional adaptation masterplan for Davistown and Empire Bay, adaption pathways can be developed such as development controls, levees and other mitigation measures which could be implemented over time in consultation with the community. A climate change adaptation study was undertaken by Council in 2019 (Rhelm) to inform the development of a regional adaptation masterplan and these associated processes.

The climate change adaptation study (Rhelm, 2020) 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).

7.1 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 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 7-1**.

The stages focused on in this adaptation plan 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).

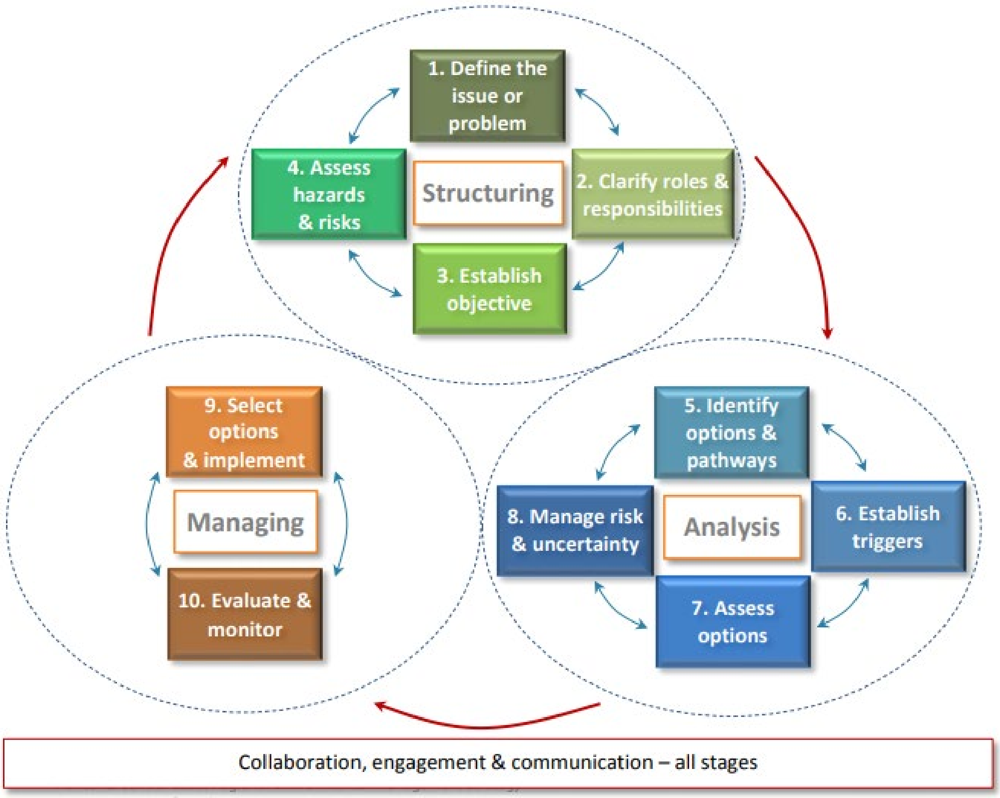


Figure 7-1 Stages in the adaptation decision making process (HCCREMS, 2012)

7.2 Current and Future Risk

Davistown and Empire Bay can be impacted by three mechanisms of flood risk:

- Brisbane Water flooding as a result of ocean storms,
- local catchment flooding as a result of local rainfall, and
- tidal inundation during high tides.

All of these flood risks will increase as a result of sea level rise.

The flood risks in Davistown and Empire Bay have been discussed briefly below with regards to existing risks (based on existing studies) and the likely increase in those risks as a result of sea level rise, based on the RCP8.5 projections (**Section 7.2.1**).

7.2.1 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 RCP8.5 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, former Gosford City Council resolved to adopt sea level rise planning levels based on projections for the Representative Concentration Pathway Scenario RCP8.5, 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 7-1**.

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 Davistown and Empire Bay when compared to the open coast. Therefore, the values in **Table 7-1** are applicable at Davistown and Empire Bay.

Table 7-1 Projected Sea Level Rise RCP8.5

Year	Sea Level Rise (m)
2015	0
2030	0.1
2050	0.2
2070	0.4
2100	0.7

7.2.2 Brisbane Water (Ocean Storm) Flooding

Major historical coastal flood events for the Brisbane Water foreshore floodplain include the severe ocean storm of 1974 and the more recent, but less severe, event in 2007.

There are significant low-lying areas within Davistown and Empire Bay susceptible to flooding from Brisbane Water even in more frequent events. Existing high tides in this area can cause foreshore inundation, especially with joint occurrence with local rainfall. In Davistown, inland penetration by flood waters and number of properties affected by flooding is more significant than Empire Bay due to the very flat terrain.

Flood levels at Davistown and Empire Bay are shown in **Table 7-2** and include the sea level rise values shown in **Table 7-1**. The mapping of these 1% AEP levels for 2015, 2050 and 2100 are shown in **Figure 7-2**. The 2015 condition has been used as the 'base case' or 'existing scenario' against which to assess the impacts of future flooding.

Table 7-2 Brisbane Water Flood Levels (Flood Study Reporting Location 059)

Year	Sea Level Rise (m)	1%PoE (m AHD)	1% AEP (m AHD)	5% AEP (m AHD)	20% AEP (m AHD)
2015	0	0.64	1.5	1.4	1.2
2030	0.1	0.74	1.6	1.5	1.3
2050	0.2	0.84	1.7	1.6	1.4
2070	0.4	1.04	1.9	1.8	1.6
2100	0.7	1.34	2.2	2.1	1.9

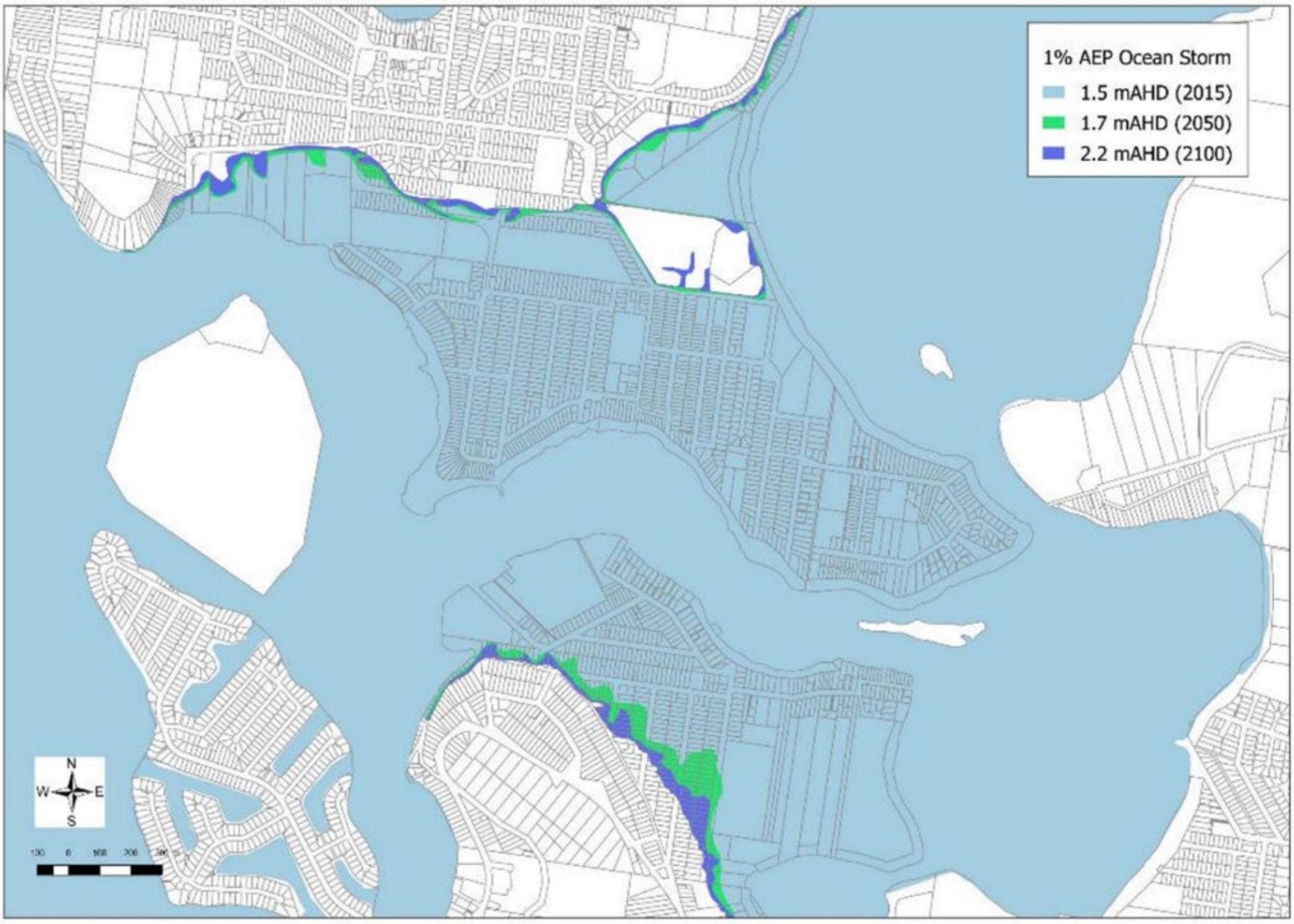


Figure 7-2 Ocean Storm Flooding

7.2.3 Local Catchment Flooding

The Davistown and Empire Bay Catchment Flood Studies (Cardno Lawson Treloar, 2010a and 2010b) assessed the potential impacts to flood behaviour in the catchments due to climate change for estuary level rises of 0.2m and 0.91m. These values were selected based on the recommendations of the 'Practical Consideration of Climate Change' (DECC, 2007).

Flood inundation in the low elevation areas of the catchment were particularly affected by increases in sea level which influences the levels in Brisbane Water estuary.

Climate change also has the potential to impact rainfall. The flood studies (2010) identified that a 20% increase of the 1% AEP event rainfall resulted in increases in flood levels up to 0.04m. In general, the increased flow 'spread out' rather than increased in depth.

7.2.4 Tidal Inundation

A discussion paper was included in the *Brisbane Water Foreshore Floodplain Risk Management Study* (Cardno, 2015) 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 0.4m projected sea level rise scenario.

The modelling indicates that a 0.4m rise in sea levels relates to close to 0.4m rise in estuarine levels at Davistown and Empire Bay.

The tidal events selected for mapping represent:

- High High Water Spring Solstices (HHWSS) – Rare high tides occurring approximately twice a year, during the June and December solstices (“king tides”); and
- 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).

The sea level rise projections outlined in **Section 7.2.1** were applied to the results of the discussion paper and are summarised in **Table 7-3**. The risk areas associated with the HHWS levels is provided in **Figure 7-3**. If we interpolate between the values shown below it can be seen that the majority of the study area will be affected by “king tides” tides by 2085. And it can be inferred that the impacts of “every day (MHWS)” tides will cause significant road and property flooding by approximately 2070.

Table 7-3 Sea Level Rise Impacts on Tidal levels

Year	Sea Level Rise (m)	MHWS (m AHD)	HHWSS (m AHD)
2015	0	0.33	0.56
2030	0.07	0.4	0.96
2050	0.2	0.53	1.09
2070	0.39	0.72	1.28
2100	0.74	1.07	1.63

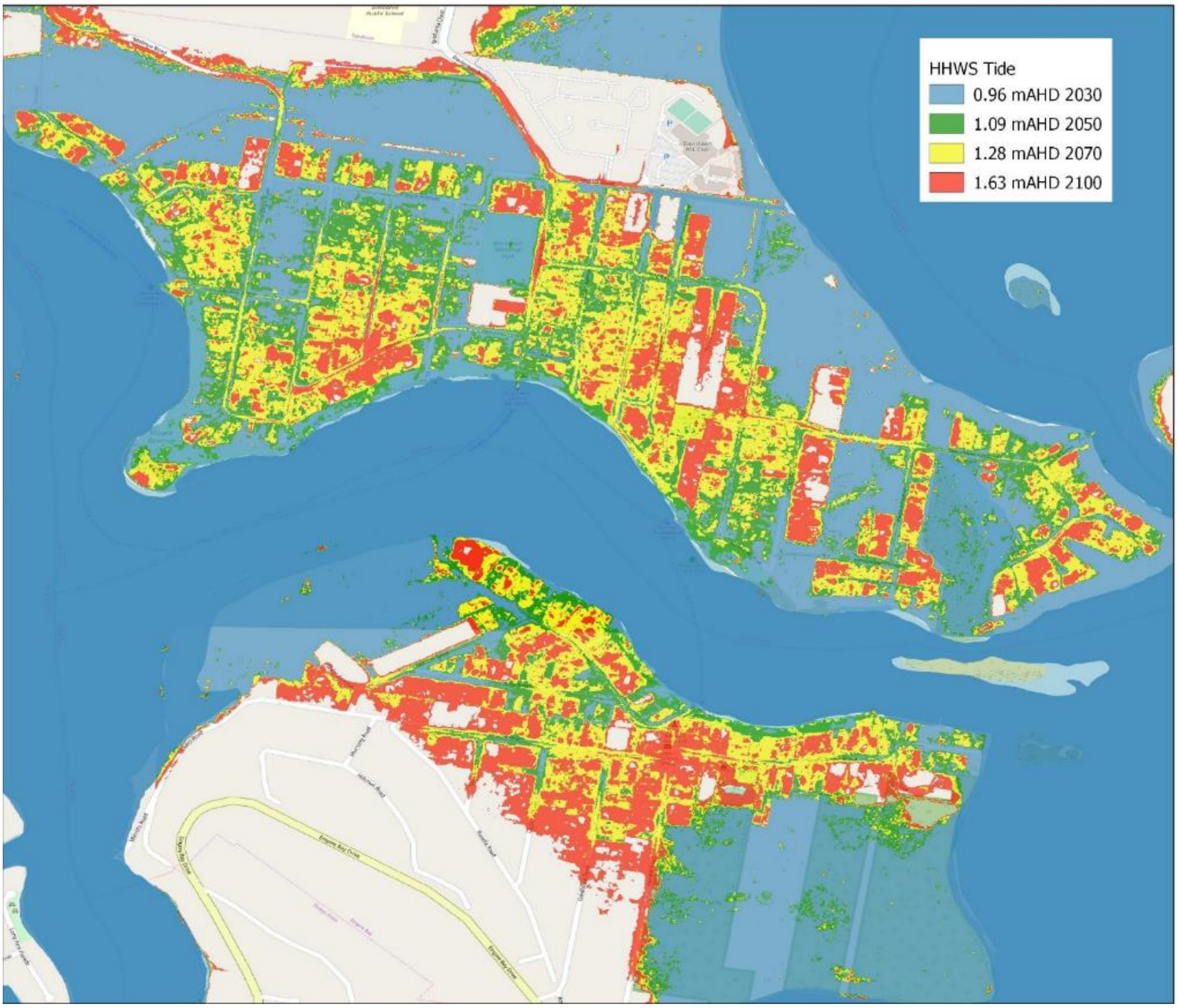


Figure 7-3 HHWS Tidal Inundation

7.3 Climate Change Adaptation - Concept Designs

7.3.1 Concept Landform and Drainage Plan

The Gosford DCP 2013 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 FRMP (2015) 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 directly to adjoining properties.

The flood planning level for Davistown and Empire Bay varies slightly depending on location but is approximately 2.2 m AHD. There is currently very little direction in Council's DCP with regards to filling properties in the floodplain, the fill level, and how filling of properties can be undertaken to minimise the long-term impacts on local drainage.

The *Brisbane Water Floodplain Risk Management Study* (2015) assessed options to address flood risk that included broadscale filling of Davistown and Empire Bay (Option FM9). However, it was found that master planning, consultation, and effective staging, were required to establish whether filling would be feasible on a regional scale. Further the *Floodplain Risk Management Study* suggested that planning controls could consider longer term management strategies such as incremental filling. The *Floodplain Risk Management Study* noted that the potential change in flood hazard (i.e. from low to high hazard) as a result of climate change would need to be considered in any filling strategy (i.e. partial filling of the areas could result in flood island surrounded by high hazard flooding in the future).

The initial step in investigating fill options was to identify an appropriate level of protection. Based on the information presented in **Section 7.2**, it was determined that a minimum level of 1.5m AHD provides reasonable protection for existing and future risks, namely because;

- The existing 1% AEP flood level is approximately 1.5m AHD,
- This provides protection from king tides (HHWS) until approximately 2090, and
- This provides protection from 1% PoE past 2100.

It should be noted that floor levels would generally be set higher than the ground level affording a greater level of protection than the fill levels proposed, e.g. the Flood Planning Level of flood affected properties under current conditions would be around 2.2 m AHD.

The landforms for both Davistown and Empire Bay adopted a minimum grade along roads of 0.3%, which is less than the preferred 0.5%, but within acceptable range for drainage and an increase in the grade of the existing landform in most locations.

Landform features such as drainage easements were incorporated into the concept design to minimise the depth of fill as much as possible, and the manage impacts on flood behaviour on private property.

7.3.1.1 Davistown

A landform concept design was developed for Davistown that provided a minimum level of protection of 1.5mAHD. The minimum levels were primarily location along the foreshore, wetland perimeters, and within Davistown Reserve. The concept design provides an undulating landform providing improved drainage across the suburb.

Davistown Memorial Park's incorporates a 0.3% grade towards the proposed swale. This will assist in reducing minor ponding as a result of rainfall events and the park remaining usable for longer as sea levels rise.

A conceptual pit and pipe system was included to provide drainage in low points along the roadways to achieve the desired drainage outcomes. The proposed pits are located within the roadside swales and are assumed to be grated inlet pits with a 1.2 x 1.2 m opening. During detailed design, the inlet sizes may vary depending on approaching flows in the swales, or potentially be changed to a letterbox style inlet pit as is currently used in Empire Bay.

Design of typical roadside swale sections for longitudinal drainage was provided as part of the concept design. This includes various sizes of swales and some piped drainage to eliminate significant flooding of the roadways during minor local catchment rainfall events.

The proposed landform is shown on **Map G230**.

To achieve the ultimate landform design presented by any of the filling options above, the majority of roads cannot be filled until all adjoining properties have also been filled to allow for access and avoid drainage issues (i.e. if the street is higher than the property, the property will not be able to drain to the street. Depending on Council's approach to policy and planning around property filling, it is likely that in the short term, at least, properties will be filled as Development Applications are lodged for property redevelopment and therefore the staging will be subject to progressive urban renewal.

Although there will likely be trigger points with regards to sea level rise that may expediate property owners need or desire to fill, the reality is that impacts associated with king tides and ocean storm events are likely to increase to a level that causes access issues and property damage before the final landform is achieved.

In Empire Bay, this is likely to be less of an issue due to the smaller number of properties and the fact that 'key locations' could be targeted by Council for voluntary or compulsory acquisition to allow for landform completion.

In Davistown an interim measure may be required if property filling does not progress sufficiently in time to provide adequate protection from sea level rise. A foreshore barrier has been identified as a potential option for this purpose.

The preliminary concept design of the foreshore barrier is shown in **Map G231**. The concept includes:

- Achieving a barrier for the majority of Davistown at 1.5m AHD
- Retrofitting existing drainage pipes which discharge from behind the barrier to Brisbane Water with non-return valves or flap gates
- Integrating a foreshore cycle / pathway along the existing foreshore reserve
- Integrating with ground levels already at or above 1.5m AHD to reduce the length of constructed barrier
- Incorporating 'walls' in locations that do not allow for a battered slope
- Utilising the barrier to protect wetlands from the impacts of sea level rise (i.e. restricting flows through the barrier to replicate existing tidal flows into the future).

Once the final landform is complete, the foreshore barrier would no longer be higher than the adjoining ground levels.

7.3.1.2 Empire Bay

A landform concept design was developed for Empire Bay that provided a minimum level of protection of 1.5mAHD. The minimum levels were primarily location along the foreshore, wetland perimeters, and within a proposed drainage reserve (further details on this are below). The concept design provides an undulating landform providing improved drainage across the suburb.

The concept landform design proposes the introduction of a drainage reserve between, and aligned perpendicular to, Myrtle Road and Kendall Road to allow for drainage improvements both immediately and into the future.

It is proposed to raise Rickard Road to create a ridge in the landform where runoff is split between flowing south to the proposed channel and north to the existing drainage points to Brisbane Water.

A conceptual pit and pipe system was included to provide drainage in low points along the roadways to achieve the desired drainage outcomes. The proposed pits are located within the roadside swales and are assumed to be grated inlet pits with a 1.2 x 1.2 m opening. During detailed design, the inlet sizes may vary depending on approaching flows in the swales, or potentially be changed to a letterbox style inlet pit as is currently used in this area. The location of the drainage infrastructure would also be confirmed during the detailed design stage.

Design of typical roadside swale sections for longitudinal drainage was provided as part of the concept design. This includes various sizes of swales and some piped drainage to eliminate significant flooding of the roadways during minor local catchment rainfall events.

The proposed landform is shown on **Map G232**.

The most significant change to the landform of Empire Bay is the introduction of a drainage reserve crossing all of Echuca Road, Greenfield Road and Kendall Road. The total length is approximately 360 m and a set of three 3.7m wide x 0.6m high reinforced concrete box culverts are proposed beneath the aforementioned roadways. The proposed channel is essentially a rectangular section with an invert at 0.9 m AHD for the purposes of modelling; however, the final form is flexible and may range from a swale set in public open space, a buried culvert, or a full width channel. This is largely dependent on Council's and the community's preference and what can hydraulically convey the flows east to Brisbane Water. Whichever form the channel eventually takes, a degree of property acquisition will be necessary to create the drainage easement.

This feature was introduced to 'cut off' the high energy flows approaching from the steep slopes to the south. In previous landform design iterations, these high flows resulted in runoff not being able to be contained to the roadways in the 1% AEP without the introduction of large lengths of cost prohibitive culverts which may also be susceptible to blockage.

In addition to the ability to convey runoff to the receiving waters, the channel is also able to lower the surrounding road and property fill depths because it relies on hydraulic head and not gradient to discharge water to the east.

It should be noted from a staging point of view; it would be essential to construct the proposed channel / drainage easement prior to raising of the adjacent properties and roadways.

7.3.2 Drainage

For Davistown and Empire Bay, the proposed landform improves the existing drainage conditions within the study areas. Refer to the attached set of drawings for a contoured plan of the Davistown and Empire Bay landforms and sections showing typical street drainage.

In Davistown, trapped low points are removed and roads are raised to provide positive drainage gradients along roadways. The regrading of lots above the roadways will also eliminate the potential for isolated ponding areas within private properties.

The drainage outcomes for both study areas achieve:

- Flood free private properties in all events equal to or less than the 1% AEP,
- A minor drainage system to convey runoff in roadside swales and drains in all event equal to or less than the 20% AEP, and
- Swales have been designed to keep the velocity-depth product below 0.3m/s.

Potential flooding issues were identified from the increasing of flood depths on properties adjacent to those which have raised ground levels. This will need to be investigated further as part of detailed design, and as part of individual DA submissions.

Further investigation into the outlet arrangement for existing drainage which crosses the flood barrier has been undertaken as part of the options analysis for this FRMS.

7.4 Economic Analysis

An economic assessment was undertaken on the proposed landform and drainage plan for Empire Bay and Davistown to understand the overall economic viability of implementing it.

An economic assessment is undertaken by comparing one alternative against another. It is important that these scenarios or alternatives are clearly defined to ensure a robust analysis. Three scenarios have been adopted for this assessment:

1. **Base Case** – this represents the 'Do-Minimum' scenario and represents the base case against which the masterplan options are considered.
2. **Masterplan Scenario** – this scenario incorporates the masterplan (landform and drainage plan), without the proposed levee around Davistown.
3. **Masterplan with the Levee Scenario** – this scenario incorporates the masterplan plus the levee. It is noted that the levee only benefits Davistown, and therefore there is no change to Empire Bay in this scenario, when compared to Scenario 2.

The economic assessment was undertaken by comparing the masterplan scenarios against the base case, for both Davistown and Empire Bay using a discount rate of 7 percent. These results are summarised in **Table 7-4**.

For Davistown, the masterplan with no levee has a BCR of 1.5, with the present value of benefits exceeding the costs. This suggests that the masterplan is economically viable.

The incorporation of the levee provides a significant improvement for Davistown, with the BCR increasing to 1.7. This is a result of the significant reduction in flood damages both now and moving forward throughout the assessment period, which compensates for the increase cost of the levee relative to the masterplan scenario with no levee. It is also noted that the scenario with the levee provides additional benefits, such as flexibility in timing of filling and development of the masterplan levels, which is not incorporated in this analysis.

Empire Bay has a BCR of 0.9, suggesting that it is marginally unviable based on the assumptions in this report. However, the incorporation of some of the unquantified benefits may change this outcome.

It is also important to note, the ground levels of the properties as a whole in Empire Bay are higher than those in Davistown. However, there are still a number of low-lying areas. The economic outcome may improve if the masterplan were focused to more of the low-lying properties. However, further testing would be required to confirm this.

Table 7-4 Summary of Economic Results[1]

Davistown				Empire Bay	
Masterplan - no levee		Masterplan - with levee		Masterplan	
NPV	BCR	NPV	BCR	NPV	BCR
$4.95M	1.5	$13.27M	1.7	$-0.41M	0.9

The results suggest that the masterplan is economically viable for Davistown, with a BCR of 1.5 without the levee, and 1.7 with the levee. Empire Bay has a lower BCR of 0.9, which suggests that it is marginal unviable. However, there are a number of unquantified benefits that may change this outcome.

[1] BCR – Benefit Cost Ratio, NPV – Net Present Value

7.5 Implementation Approach

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. Triggers and thresholds enable the understanding of how much time is available to implement adaptation. Knowing this in advance of the trigger being reached is critical; the point that the business as usual approach has not been successful, and the hazard is unacceptable to the community as it will be impractical or uneconomically to maintain essential infrastructure.

It was proposed that the landform and drainage plan be implemented through the following approach:

- Preparation of a detailed Masterplan that develops a detailed design of the proposed landform and also provides property filling design guidelines and other specifications.
- Update of *Gosford Council DCP 2013* (or the Draft Central Coast DCP) to require filling of properties in accordance with this climate change adaptation plan. This would be enforced as part of any significant development application within the study area. This would incrementally raise private property to the final landform levels, allowing Council to then raise roads and other infrastructure.
- Council to look for opportunities to raise roads. This would likely be done as part of road maintenance programs. However, there may also be opportunities to raise key access roads through the state government floodplain risk management process to improve existing emergency response access during Brisbane Water flood events. The FRMP provides details on locations where existing flooding is an issue at the locations identified for road raising in the interim scenario for the climate change adaptation landform.
- Council to implement the foreshore barrier / access path as soon as practical. This would likely be as funds become available. Funds could be secured through the NSW Government Floodplain Management Grants as a result of the findings of the FRMP.
- Implementation of selected aspects of the landform and drainage plan that address existing flood risk. The FRMP recommends the implementation of:
    - A drainage easement between Myrtle Road and Kendall Road (FM EB5)
    - A foreshore barrier at Davistown (FM DT1)
- Raising of infrastructure, including roads as completion of adjoining property filling allows.

8 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 8-1**.

Table 8-1 Flood Risk Management Alternatives

Alternative	Examples
Preventing/avoiding risk	Appropriate development within the flood extent
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

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 (structural) – options aimed at preventing/avoiding or reducing the likelihood of flood risks through modification of flood behaviour in the catchment
- Property modification measures (structural/non-structural) – 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 (structural/non-structural) – options focused on reducing the consequences of flood risks, by generally aiming to modify the behaviour of people during a flood event.

A floodplain risk management plan needs to consider all three types of management measures and adopt and integrated and effective mix, which is appropriate to the specific circumstances of the flood prone community.

A range of possible options were considered as part of this FRMS and are discussed in the following sections. The proposed measures contemplate catchment and ocean flooding, since the two study areas are subjected to both.

8.1 Flood Modification Options

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

A preliminary assessment range of potential flood modification options (**Section 8.1.1**) identified several feasible options for further detailed assessment (**Section 8.1.2**).

8.1.1 Preliminary Identification of Options

Flood behaviour was defined in the Flood Studies (2010), and further assessed as part of this FRMS (**Section 6** of this document. In addition, community engagement in October 2019 (**Section 3**) identified community concerns about flooding and several recommendations on potential flood mitigation works. Based on the flood risk data and the community input, a range of preliminary flood modification options were identified. Based on the likely merits and feasibility of the options, six of these options were selected for detailed assessment (including hydraulic modelling, and or economic damages calculations). **Table 8-2** and

Table 8-3 provide a summary of all the potential Flood Modification options that were identified for Davistown and Empire Bay, respectively. The summary provides details of each flood modification option, the flooding issues that each option aims to address, how the option was identified, and how it was considered for detailed assessment or not. The location of all options is provided on **Maps G202 and G203**.

Table 8-2 Preliminary Flood Modification Options for Davistown

Option ID	Description	Primary Flood Issue addressed	*Source of option*	*Consideration for Detailed Assessment*
DT1	Foreshore barrier around Davistown (excluding properties where it is not likely to be economically viable to include them in the barrier design). Levee Elevation would be the 1% AEP Brisbane Water flood level.	Flooding caused by ocean storm surges and tides, which should be aggravated by the effects of Climate Change.	A foreshore levee was considered in the Brisbane Water FRMS (2015); however, insufficient local flood data was available to properly assess it. Community engagement identified support for further assessment of a levee option.	A foreshore barrier has the potential to protect a large number of properties. Catchment flood modelling (as opposed to storm surge flooding) can be used to assess the potential impacts of the barrier on drainage and local flooding. While the damages analysis undertaken for Brisbane Water (2015) can be used to assess the financial viability of a foreshore barrier. In addition, a foreshore barrier could provide interim protection against sea level rise as discussed in **Section 7**. This option was selected for inclusion in the detailed options assessment.
DT2	Foreshore barrier around Davistown, including all properties regardless of feasibility. Levee Elevation would be the 1% AEP Brisbane Water flood level.	Flooding caused by ocean storm surges and tides, which should be aggravated by the effects of Climate Change.	As for DT1	This option was selected for inclusion in the detailed options assessment to provide a comparison against DT1 and to identify if it is economically viable to protect a larger number of properties could be protected from flooding.
DT3	Foreshore barrier around Davistown. Same extent as Option DT2, but with elevation corresponding to the 5% AEP Brisbane Water flood level to reduce the potential aesthetic impacts and cost of the barrier.	Flooding caused by ocean storm surges and tides, which should be aggravated by the effects of Climate Change.	As for DT1	Providing a levee at the 5% AEP level is not significantly lower than the 1% AEP level. As such, the aesthetic and cost impacts would not differ significantly from the 1% AEP foreshore barrier. However, the likelihood of it being overtopped would be higher. The presence of the barrier could reduce the flood preparedness of the community and may increase the impacts of flooding when it is overtopped. This option was not selected for detailed assessment.
DT4	Road drainage improvements. Approach would go beyond standard kerb and guttering, with possible letterbox inlet pit arrangement similar to the works recently completed on Greenfield Road, Empire Bay.	Excessive ponding caused by flat grades in Davistown	Key issue identified by the community in the Flood Study (2010) and October 2019 engagement.	This is a key issue for the community and should be assessed further by Council. However, this option only deals with local drainage not rare event flooding. As such, it has not been selected for detailed assessment as part of this FRMS.

Option ID	Description	Primary Flood Issue addressed	*Source of option*	*Consideration for Detailed Assessment*
DT5	Improve drainage through the drainage easement between Paringa Avenue and Davistown Memorial Park.	A number of residents from Restella Ave raised issues about the easement were raised on the effects of the strata development on this easement where the land was filled and storage displacement of water.	Identified by local residents at the community drop-in session in October 2019.	Drainage through this easement is an inter-allotment drainage issues, not an issue related to rare event flooding. This option has not been selected for detailed assessment. However, there are opportunities to utilise this easement as part of any long term property filling strategy to adapt to sea level rise (**Section 7**).
DT6	Wetland dredging to improve existing drainage system capacity.	It is the perception of some residents that the drainage system becomes 'backed up' due to flows being unable to drain out of the wetland into Brisbane Water efficiently.	Identified by local residents at the community drop-in session in October 2019.	The flood modelling undertaken as part of the Flood Study (2010) did not indicate that improving flow conveyance through the wetland would improve drainage within Davistown. In addition, the environmental impacts of dredging within the wetland would be significant. This option has not been selected for detailed assessment.
DT7	Climate change adaptation proposed landform and drainage system.	Flooding caused by ocean storm surges and tides, which would be aggravated by the effects of Climate Change.	Property filling was identified by residents during the Brisbane Water FRMS (2015) as an approach they supported to manage the impacts of flooding and climate change. Further, retreating from the area as a result of sea level rise is not supported by the community.	Climate change adaptation for Davistown has been explored through the implementation of property filling and asset raising. The proposed outcomes are a design landform that not only provides protection against sea level rise, but also improves location drainage issue by providing grade along roadways and drainage easements. Details of the assessment undertaken are provided in **Section 7**.

Table 8-3 **Preliminary Flood Modification Options for Empire Bay**

Option ID	Description	Primary Flood Issue addressed	*Source of Option*	*Consideration for Detailed Assessment*
EB1	Pomona Road culvert and drainage upgrades. Increase the capacity if the drainage network to reduce flooding of Pomona Road.	Flooding along Pomona Road, which is an important evacuation route	Residents at the October 2019 Drop-In sessions identified flooding along Pomona Road to be of concern with regards to accessing their properties during a flood event.	Flooding on Pomona Road in a 1% AEP event is not considered high hazard (H4 – H6). As such this option has not been selected for detailed assessment. However, it is recommended that the flood depths and velocities provided by the Flood Study (2010) be utilised by Council when routine maintenance and upgrades are occurring along this roadway. There may be opportunities to raise road levels or increase culvert capacities at locations identified to be flooded as part of these routine works.
EB2	Private seawall maintenance and/or upgrade in existing guidelines	Seawalls along private properties provide protection against flooding from storm surge and extreme tides. However, no clear guidance exists for the local area to assist landowners in maintaining or upgrading seawalls to contribute to this flood protection.	Brisbane Water FRMP (2015)	The Floodplain Risk Management Plan will provide recommendations for design aspects to be included in Council's seawall guidelines that will contribute to flood protection.
EB3	Private seawall maintenance and/or upgrade in construction	Seawalls along private properties provide protection against flooding from storm surge and extreme tides. However, seawalls on private properties are set at various levels and are in various conditions reducing their effectiveness	Brisbane Water FRMP (2015)	No detailed assessment (flood modelling of damages analysis) has been undertaken for this option. However, the results of Option EM5 have been used to inform the assessment of this option within the multi-criteria assessment (**Section 9**).
EB4	Foreshore barrier around Empire Bay. Levee Elevation at the 1% AEP Brisbane Water flood level.	Flooding caused by ocean storm surges and tides, which should be aggravated by the effects of Climate Change.	A foreshore levee was considered in the Brisbane Water FRMS (2015); however, insufficient local flood data was available to properly assess it. Community engagement identified support for further assessment of a levee option.	A foreshore barrier has the potential to protect a large number of properties. Catchment flood modelling (as opposed to storm surge flooding) can be used to assess the potential impacts of the barrier on drainage and local flooding. While the damages analysis undertaken for Brisbane Water (2015) can be used to assess the financial viability of a foreshore barrier. In addition, a foreshore barrier could provide interim protection against sea level rise as discussed in **Section 7**. This option was selected for inclusion in the detailed options assessment.

Option ID	Description	Primary Flood Issue addressed	*Source of Option*	*Consideration for Detailed Assessment*
EB5	Drainage channel and easement from Myrtle Road to Kendall Road	Excessive ponding in Empire Bay (private properties and roads).	Collaboration between Council, DPIE and Rhelm.	A significant amount of water flows from the upper catchment areas (Empire Bay Drive and Rosella Road) into Myrtle, Echuca, and Greenfield Roads. There is a sudden flattening of grade contributing to excessive ponding of water within these streets and adjacent properties. The proposed easement and drainage infrastructure could reduce flooding in this area. In addition, the easement provides an integral component of future climate change adaptation for the whole suburb (**Section 7**). This option was selected for inclusion in the detailed options assessment.
EB6	Pomona Road Easement and drainage upgrades	Flooding in properties along Pomona Road and section of Empire Bay Drive	Pomona Road Structure analysis (Appendix C)	**The Pomona Road Structure analysis (Appendix C) identified that the presence of an unapproved 'wall' significant impacts on local flood behaviour. This option investigates opportunities to modify flow behaviour in a similar manner to further reduce flood risk.** This option was selected for inclusion in the detailed options assessment.
EB7	Swale along Empire Bay Drive to divert flows into the adjacent creek.	Flooding of Empire Bay Drive, which is an important evacuation route, and flooding through Palmers Lane properties.	Analysis of Flood Study (2010) results and liaison between Rhelm, Council and DPIE.	Flooding of properties in Palmers Lane was identified by the community as a flooding concern. In addition, Empire Bay Drive provide regional access and evacuation during flood events and should be flood free, if possible. This option was selected for inclusion in the detailed options assessment
EB8	Climate change adaptation proposed landform and drainage system.	Flooding caused by ocean storm surges and tides, which would be aggravated by the effects of Climate Change.	Property filling was identified by residents during the Brisbane Water FRMS (2015) as an approach they supported to manage the impacts of flooding and climate change. Further, retreating from the area as a result of sea level rise is not supported by the community.	Climate change adaptation for Davistown has been explored through the implementation of property filling and asset raising. The proposed outcomes are a design landform that not only provides protection against sea level rise, but also improves location drainage issue by providing grade along roadways and drainage easements. Details of the assessment undertaken are provided in **Section 7**.

8.1.2 Detailed Options Assessment

From the options listed on Table 8-2 and on Table 8-3**,** 6 options were selected to be analysed in detail, 2 for Davistown and 4 for Empire Bay. The detailed assessment of these options involved:

- Flood modelling; and
- Economic analysis.

The outcomes of the detailed assessment are outlined in the sections below.

8.1.2.1 FM DT1 Foreshore barrier around Davistown (excluding properties on the peninsula east of Magnolia Ave and the southern side of Morton Crescent)

Description

Flooding as a result of storm surge events contribute the most significant types of flooding for the majority of Davistown. This type of flooding is expected to increase in severity and frequency as a result of climate change.

In this context, this option proposes the construction of a foreshore barrier around Davistown, which would offer protection against ocean flooding from the Brisbane Water. The barrier crest would be set at 1.5m AHD, which corresponds to the existing 1% AEP Brisbane Water flood level and the 1% PoE in 2100.

The foreshore barrier would be comprised of various components, utilising the existing topography and infrastructure, where possible:

- Shared pathway along foreshore reserve areas
- Existing ground levels, where these already exceed 1.5mAHD
- Roadways
- Retaining walls along private property boundaries.

The foreshore barrier design has been developed to balance the cost of the structure against flood protection, while also minimising disturbance on natural ecosystems. For this reason, the foreshore barrier has not been proposed to extend around the most eastern portion of Davistown. There are relatively fewer properties per metre length of the foreshore barrier, and the large areas of tidal wetlands, as such extending the foreshore barrier to protect these additional properties, would result in several cost and feasibility challenges. However, the merits of the extended foreshore barrier have been investigated as part of Option FM DT2.

Map G210 illustrates the levee prosed in option FM DT1.

The foreshore barrier in this option has been further designed and evaluated to the one proposed in the Davistown and Empire Bay Climate Change Adaptation Study (Rhelm, 2020), outlined in **Section 7**. In the Climate Change Adaptation Study, the foreshore barrier would be included as part of an interim scenario, providing additional flood protection while the landform adaptation plan is implemented.

In addition to providing protection from Brisbane Water flooding, up to a 1% AEP event, the foreshore barrier would also provide protection from tidal inundation for predicted sea level rise until 2100, while requiring low maintenance costs.

Levees were investigated for Davistown as part of the Brisbane Water FRMS (2015), the FRMS identified that levees are susceptible to breaches potentially endangering property and life. The FRMS (2015) was particularly concerned that a levee could impact on catchment flooding. However, the regional nature of the study did not allow for detailed analysis of this issue. This particular issue has been explored further in this current study through the hydraulic modelling outlined below and the preliminary consideration of design features such as one way valves on stormwater outlets.

Modelling Results

To assess how the foreshore barrier would affect local drainage conditions hydraulic modelling was undertaken for the 1% AEP catchment flood event.

The hydraulic modelling for this option had the primary purpose of indicating the impact the foreshore barrier would have on the catchment flooding behaviour. The economic analysis for this option took into consideration the effects of foreshore inundation from the Brisbane Water and, therefore, was based on the results of the Brisbane Water FRMS (Cardno, 2015). For this reason, only the 1% AEP event the was considered in the catchment flood modelling, as opposed to the full range of event frequencies.

The hydraulic model developed for this option was mostly equivalent to the existing conditions model described in **Section 5.1**. The model was run with 1% AEP rainfall conditions, with a 1% PoE downstream boundary condition: i.e. this represents an elevated water level in Brisbane Water but not an extreme ocean storm condition. This is consistent with the approach adopted in the Flood Study (2010) and allows comparison of flood depths behind the barrier to understand the potential impacts of the barrier on local flooding and assess whether drainage solutions could solve these issues. This modelling scenario differed from the Flood Study model in that the DEM was modified to include the foreshore barrier proposed in this option.

The model was initially run with no stormwater outlets designed into the foreshore barrier. The results from this modelling were used to identify locations that would require stormwater outlets with one way valves installed. The model was then re-run to test the suitability of preliminary drainage design in mitigating the impacts of the foreshore barrier on local flooding.

Map G210 illustrates the outcomes of the modelling undertaken for option FM DT1, by showing how the implementation of this option would alter the local flooding characteristics (i.e. the impact on 1% AEP flood depths when compared to existing conditions).

The results show that the foreshore barrier would have a relatively small impact on local flooding, provided that one-way drainage pipes are installed in the locations where trapped low points are created by construction of the barrier.

A minor increase in flood depths was identified in some properties on the eastern side of Magnolia Avenue and on the northern side of Pine Avenue. The flooding issues in these locations could be addressed by the implementation of drainage infrastructure beneath the levee. However, in this analysis, the possibility of installing drainage pipes in private land was not considered. This could be included in future detailed design of the foreshore barrier and may possibly result in a decrease in the number of outlets or the size of the outlets required on public land.

It should be noted that, even with the implementation of the levee, significant flood risk would still exist for events greater than 1% AEP. Therefore, flood related development controls would still apply to properties behind the levee. Additionally, community engagement measures should be put in place to guarantee that the levee will not compromise flood preparedness in the community, by generating complacency.

Economic Assessment

The proposed foreshore barrier aims to reduce the impact of flooding from Brisbane Water and the model results show that it has negligible impact on local catchment flooding, as such the economic damages provided in **Section 5.5** are not applicable in assessing the reduction in economic damages. The economic damages developed for the climate change adaptation assessment (**Section 7**), were utilised for this assessment.

The foreshore barrier would reduce flood damages for private properties behind the barrier up to and including 1% AEP storm surge flooding. Damages for events greater than this were assumed to remain the same. The outcomes of the economic assessment are summarised in terms of costs and benefits in **Table 8-4**. Further discussion on the how the economic assessment of options was undertaken is provided in **Appendix D**.

The economic assessment found that the levee returned a significant benefit to the community (reduction in AAD) and when compared to the cost, provided more economic benefits than costs (BCR>1).

Table 8-4 FM DT1 Economic Assessment

Capital Cost	Average annual maintenance cost	Reduction in AAD	Benefit Cost Ratio
$12,343,100	$5,000	$1,489,811	1.77

8.1.2.2 FM DT2 Foreshore barrier around Davistown (including all properties)

Description

This option proposes the construction of a foreshore barrier around Davistown similar to option FM DT1. However, in this option, the levee proposed in option FM DT1 would be extended to protect all properties in this study area, including the properties on the peninsula east of Magnolia Ave and the southern side of Morton Crescent. Extending the foreshore barrier in this way provides flood protection to additional properties, however, also provides the following challenges:

- Significant increase in construction costs
- Limited space to implement the barrier along the additional Morton Crescent properties
- Significant increase in the length of retaining walls required along private properties east of Magnolia Avenue
- Potential environmental impacts of works being undertaken around tidal wetlands.

The proposed foreshore barrier is shown on **Map G211**.

Modelling Results

The impacts of the foreshore barrier on local catchment flooding were assessed in the same way as for FM DT1.

The modelling results for this option are presented in **Map G211**.

The model results suggest that the implementation of the foreshore barrier would result in increased flood levels in several properties along Kincumber Crescent. In option FM DT1, ponding in private properties was also observed, however, the number of residencies affected was considerably smaller. As discussed in **Section 8.1.2.1**, this issue could be address by the implementation of additional drainage infrastructure. However, in this analysis, interventions in private land were not explored as an option.

Therefore, for this option it is important to consider whether the benefit of protecting those additional properties in Davistown from ocean flooding would outweigh the increased implementation costs and potential drainage issues. This is discussed further below.

Economic Assessment

The proposed foreshore barrier aims to reduce the impact of flooding from Brisbane Water and the model results show that it has negligible impact on local catchment flooding, as such the economic damages provided in **Section 5.5** are not applicable in assessing the reduction in economic damages. The economic damages developed for the climate change adaptation assessment (**Section 7**), were utilised for this assessment.

The foreshore barrier would reduce flood damages for private properties behind the barrier up to and including 1% AEP storm surge flooding. Damages for events greater than this were assumed to remain the same. The outcomes of the economic assessment are summarised in terms of costs and benefits in **Table 8-5**. Further discussion on the how the economic assessment of options was undertaken is provided in **Appendix D**.

The economic assessment found that the levee returned a significant benefit to the community (reduction in AAD) and when compared to the cost, provided more economic benefits than costs (BCR>1).

Table 8-5 FM DT2 Economic Assessment

Capital Cost	Average annual maintenance cost	Reduction in AAD	Benefit Cost Ratio
$19,454,050	$8,000	$2,080,107	1.57

8.1.2.3 FM EB6 Pomona Road easement and drainage upgrades

Description

The flows from the higher terrain on the south-east portion of the Empire Bay catchment impacts a large area extending from the properties on the eastern end of Pomona Road to the wetlands to the north-east of Palmers Lane. The flooding affects key infrastructure such as Empire Bay Drive, which is an important evacuation route, and vulnerable areas such as the caravan park in Pomona Road.

The sensitivity modelling undertaken to assess the impact of a small 'wall' north of Pomona Road (**Appendix C**) identified that a considerable volume of flow can be diverted to the north, reducing the flooding of the caravan park and adjacent properties. This option seeks to provide for and optimise this flow diversion through the use of an existing drainage easement on the north side of Pomona Road. This 20m wide Council easement would be utilised to provide an open grassed channel (or similar landscaped easement to reflect a 'natural' creek design), which would be connected to the natural watercourse to the north of Pomona Road. The easement would be designed to direct the runoff coming from the South-East of Pomona Road to the watercourse and, subsequently to the culvert under Empire Bay Drive. This option also comprises upgrades in the capacity of the culverts under Pomona Road, with the purpose of maximizing the volume of runoff that is directed to the swale.

Based on preliminary modelling results, it was observed that the swale would be more effective if retaining walls (approximately 0.5 m high) were positioned in two sections of the channel, where the existing terrain elevations were particularly low. These retaining walls could be executed as grassed embankments or 'natural looking' rock walls, which would not negatively impact the existing landscape.

The feasibility of this option may be limited by the fact that Council would need to negotiate the use of private land at the northern end of the easement. The costs associated with this land use have not been considered in the costing of this option.

Modelling Results

Hydraulic modelling was undertaken for the PMF, 0.5% AEP, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 20% AEP flood events.

To understand the impact of this option on flow behaviour at Empire Bay Drive, the revised culvert modelling (**Section 6.5.1**) have been used as the 'existing case' against which to compare this option. A comparison between the results obtained for this option and existing conditions was undertaken for the 1% AEP, 20% AEP and PMF and is presented in **Maps G212 to G214**. These maps also provide a schematic representation of the swale considered in the model. It should be noted that the dimensions adopted for this structure are preliminary and only supposed to provide guidance for future design stages. These dimensions were selected based on what was considered feasible and cost-effective.

The results for this option suggest that, in all the evaluated scenarios, the flood depths and extents to the west of the proposed swale would be significantly reduced. A decrease in flood depths was also observed in the properties along Palmers Lane and a section of Empire Bay Drive. In the 1% AEP flood event, the reduction in flood depths ranged from 0.1 m to 0.3 m in the area directly downstream of the channel. Generally, the same depth differences were observed in the 20% AEP event, however, the reduction in the flood extents was more noticeable in this event (i.e. more areas became flood free than in the 1% AEP). According to the results, in the 20% AEP flood event, the implementation of the swale would prevent the overtopping of sections of Empire Bay Drive and Palmers Lane.

It should be noted that redirecting the flow to the culvert under Empire Bay Drive lead to a minor increase in flood depths in the properties located downstream of this structure. Flooding was also increased in the properties in the corner of Allawa Close with Palmers Lane and the rural properties and wetlands north of Allawa Close. In the PMF, the increase in flood depths was lower than 0.1 m around properties. In the 20% AEP event, flood depths of up to 0.15m were identified in two properties in Allawa close and one property in Palmers lane. In the 1% AEP event, increases of up to 0.18 m were observed in several properties in Allawa Close.

Council's DCP requires development to have an impact on flooding of less than 0.01m. It is expected that the minor increases in flood depths noted in the modelling could be mitigated through more detailed consideration of the swale design.

Economic Assessment

The proposed option aims to reduce the impact of catchment flooding, as such the economic damages provided in **Section 5.5** were used in assessing the reduction in economic damages.

The outcomes of the economic assessment are summarised in terms of costs and benefits in **Table 8-6**. Further discussion on the how the economic assessment of options was undertaken is provided in **Appendix D**.

The economic assessment found that the levee returned a moderate benefit to the community (reduction in AAD) and when compared to the cost, provided more economic benefits than costs (BCR>1).

Table 8-6 FM EB6 Economic Assessment

Capital Cost	Average annual maintenance cost	Reduction in AAD	Benefit Cost Ratio
$737,100	$2,000	$90,793	1.75

8.1.2.4 FM EB7 Empire Bay Drive Easement

Description

Flooding of properties in Palmers Lane was identified by the community as a flooding concern. Immediately upstream of Palmers Lane, Empire Bay Drive is flooded in events equal to and greater than the 20% AEP flood event. Empire Bay Drive provide regional access and evacuation during flood events and should be flood free, if possible.

In this context, this option comprises the implementation of a drainage swale along Empire Bay Drive (within the existing road easement). The swale aims to direct the runoff coming from the south-east of the catchment from this location, towards the creek and culvert passing under Empire Bay Drive. The option aims to minimise the magnitude and frequency of the overtopping in this section of Empire Bay Drive and the associated flow through the downstream properties on Palmers Lane.

Consideration was also given to increasing the culvert capacity under Empire Bay Drive. However, as discussed below, the swale was not effective enough to substantially increase the volume of flow take by the culvert.

Modelling Results

Hydraulic modelling was undertaken for the PMF, 0.5% AEP, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 20% AEP flood events.

To understand the impact of this option on flow behaviour at Empire Bay Drive, the revised culvert modelling (**Section 6.5.1**) have been used as the 'existing case' against which to compare this option. A comparison between the results obtained for this option and existing conditions was undertaken for the 1% AEP, 20% AEP and PMF and is presented in **Maps G215 to G217**. These maps also provide a schematic representation of the proposed swale. It should be noted that the dimensions adopted for this structure are preliminary and only supposed to provide guidance for future design stages. These dimensions were selected based on what was considered feasible and cost-effective.

The results show that the swale would not effectively mitigate the flooding issues around Empire Bay Drive. Although flood depths were reduced slightly near the road, the magnitude of the reduction was relatively low, with depth differences around 0.05 m in the 20% AEP event and around 0.02 m in the 1% AEP event.

The outcomes of this analysis suggest that the capacity of the swale was not sufficient to adequately transport the volume of runoff that flows into Empire Bay Drive. It is noted that increasing the dimensions of the swale would not be feasible or cost-effective, given the constraints imposed by the existing terrain and the current occupation of the area.

Economic Assessment

The proposed option aims to reduce the impact of catchment flooding, as such the economic damages provided in **Section 5.5** were used in assessing the reduction in economic damages.

Although the modelling of this option included increasing the capacity of the culvert under Empire Bay Drive, the modelling showed that this was not required. As such the capital costs of this option have not included the construction of the culvert enhancement.

The outcomes of the economic assessment are summarised in terms of costs and benefits in **Table 8-7**. Further discussion on the how the economic assessment of options was undertaken is provided in **Appendix D**.

The economic assessment found that the easement returned a very minor benefit to the community (reduction in AAD) and when compared to the cost, it was found that the economic benefit was more than the cost of implementing the option (i.e. BCR less than 1, but greater than 0).

Table 8-7 FM EB7 Economic Assessment

Capital Cost	Average annual maintenance cost	Reduction in AAD	Benefit Cost Ratio
$310,940	$1,000	$10,172	0.46

8.1.2.5 FM EB4 Foreshore barrier around Empire Bay

Description

This option consists of a foreshore barrier around Empire Bay similar to the one proposed for Davistown in Options FM DT1 and FM DT2 (**Sections 8.1.2.1 and 8.1.2.2**). This barrier would protect the low lying portions of Empire Bay against ocean flooding (up to the 1% AEP Brisbane Water flooding) and contribute to protection of this area under sea level rise conditions.

The design consideration, benefits and potential issues associated with the implementation of a foreshore barrier have already been described in **Section 8.1.2.1**. The primary difference between this foreshore barrier, and the Davistown foreshore barrier options is that the Climate Change Adaptation Study (**Section 7**) did not include a foreshore barrier for Empire Bay.

Modelling Results

Similar to Options FM DT1 and FM DT2, hydraulic modelling was undertaken for this option to assess how the foreshore barrier would impact the local drainage conditions in the 1% AEP catchment flood event and where stormwater outlets (with one way valves) should be located. The modelling results are presented in **Map G218.**

As discussed in **Section 8.1.2.1**, as Option FM EB4 primarily addresses ocean flooding, the economic analysis for this option was undertaken considering the results from the Brisbane Water FRMSP. Therefore, the catchment flood modelling for this option had only the purpose of showing the potential impacts the foreshore barrier would have on catchment flooding depths and, for this reason, was not undertaken for the full range of flood frequencies.

According to the results obtained for this option, the implementation of the foreshore barrier would lead to increased ponding of runoff in a number of private properties upstream of the barrier. The affected properties include houses along Sorrento Road, Shelly Beach Road, Rickard Road and Kendall Road.

As discussed in **Sections 8.1.2.1 and 8.1.2.2**, in order to mitigate the flooding in these areas it would be necessary to install drainage infrastructure in private land, which was not included in the design for the purposes of this FRMS assessment. However, the volume of ponding and flows at these locations would suggest that more detailed design of the drainage infrastructure associated with the foreshore barrier would be able to address these issues.

Economic Assessment

The proposed foreshore barrier aims to reduce the impact of flooding from Brisbane Water and the model results show that it has negligible impact on local catchment flooding, as such the economic damages provided in **Section 5.5** are not applicable in assessing the reduction in economic damages. The economic damages developed for the climate change adaptation assessment (**Section 7**), were utilised for this assessment.

The foreshore barrier would reduce flood damages for private properties behind the barrier up to and including 1% AEP storm surge flooding. Damages for events greater than this were assumed to remain the same. The outcomes of the economic assessment are summarised in terms of costs and benefits in **Table 8-12**. Further discussion on the how the economic assessment of options was undertaken is provided in **Appendix D**.

The economic assessment found that the levee returned a significant benefit to the community (reduction in AAD) and when compared to the cost, provided more economic benefits than costs (BCR>1).

Table 8-8 FM EB4 Economic Assessment

Capital Cost	Average annual maintenance cost	Reduction in AAD	Benefit Cost Ratio
$4,553,588	$3,000	$1,468,566	4.72

8.1.2.6 FM EB5 Drainage easement from Myrtle Road to Kendall Road

Description

A significant amount of water flows from the upper catchment areas (Empire Bay Drive and Rosella Road) into Myrtle, Echuca, and Greenfield Roads. There is a sudden flattening of grade contributing to excessive ponding of water within these streets and adjacent properties.

This option proposes a drainage easement including a grassed swale or natural channel to direct the flows coming from the south of Empire Bay Drive to the wetlands on the eastern side of the study area. As illustrated by **Map G219**, this easement would be situated between Myrtle Road and the wetlands to the east, covering the area that is currently occupied by residential lots. The easement could convey flows via a channel, overland flow (with minor flows in underground pipes), or a large underground culvert. The composition of the easement design will determine if, and how many property purchases would be required. This could be directed by outcomes of community engagement. If the easement were to be a full property (or even two) wide, this would provide a significant green corridor for the community, which could incorporate shared pathways, parkland, landscaping, as well as a 'natural channel'. Alternatively, if voluntary purchase of properties is not palatable to the community, the flow diversion could be incorporate in an underground culvert with a narrow drainage easement over the top. However, this would not achieve any public open space and may limit the volume of flow that can be diverted into the easement.

The channel would cross Echuca Road, Greenfield Road and Kendall Road, through culverts positioned under these roads.

It is expected that the implementation of this option will minimise the ponding experienced in the adjacent flat area, reducing the flood impact in the properties, and improving flood access along Kendall, Greenfield, and Echuca Roads.

The easement proposed in this option has also been included in the final landform developed as part of the Climate Change Adaptation Study (Rhelm, 2020), described in **Section 7**. Therefore, another benefit associated with this option is that it is compatible with the future climate change adaptation for Empire Bay.

Model Results

Hydraulic modelling for this option was undertaken for the full range of design flood events (PMF, 0.5% AEP, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 20% AEP flood events). The results for the 1% AEP, 20% AEP and PMF are presented in **Maps G219 to G221**, which provide a comparison between the flooding in the option FM EB5 scenario and the existing conditions. These maps also provide a schematic representation of the easement / channel included in the model.

It should be noted that the channel was represented in the model as a continuous structure extending from Myrtle Road to the wetlands in the eastern side of the study area. Therefore, the culverts which would need to be placed under Echuca Road, Greenfield Road and Kendall Road were not considered in the model. It is assumed that these structures will be appropriately sized in future design stages.

The results show that the implementation of the drainage channel would not substantially reduce the flood depths in the urban centre of Empire Bay, however, small reductions in flood depth are widespread; reaching as far north of the easement as Sorrento Road and Gordon Road. In the 1% AEP event, the most considerable decrease in flood depths was in Greenfield Road (up to 0.05 m difference). The 1% AEP flood extents are also reduced (i.e. some areas become flood free), particularly in the properties around Greenfield Road.

In the 20% AEP flood event, the difference in flood depths is less significant and more concentrated in the roads directly north of the channel (Myrtle Road, Echuca Road and Greenfield Road). However, in this event, the difference in the flood extents is more substantial, with two properties in Myrtle Road and five properties in Greenfield Road becoming flood free as result of the easement implementation.

Economic Assessment

The proposed option aims to reduce the impact of catchment flooding, as such the economic damages provided in **Section 5.5** were used in assessing the reduction in economic damages.

The outcomes of the economic assessment are summarised in terms of costs and benefits in **Table 8-9**. Further discussion on the how the economic assessment of options was undertaken is provided in **Appendix D**.

The economic assessment found that the easement returned a very minor benefit to the community (reduction in AAD) and when compared to the cost, it was found that the economic benefit was more than the cost of implementing the option (i.e. BCR less than 1, but greater than 0).

Table 8-9 FM EB5 Economic Assessment

Capital Cost	Average annual maintenance cost	Reduction in AAD	Benefit Cost Ratio
$6,481,400	$4,000	$169,931	0.43

This easement is a critical feature of the implementation of a landform to allow for adaptation to sea level rise. It is noted that the overall adaptation of the landform in Davistown has a benefits cost ratio of 1.7 (**Section 7.4**).

8.2 Property Modification Options

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

8.2.1 PM01 Land Use Planning Recommendations

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

Council's existing land use planning controls are reviewed in **Section 4.4**. As an outcome of this review a series of recommendations have been made to assist Council in achieving best practice flood planning in the Davistown and Empire Bay catchments and across the LGA (**Table 8-10**).

Table 8-10 Flood Planning Recommendations

	Issue	Recommendation
1	The FRMS investigated the appropriate definition of the Flood Planning Area and the Flood Planning Level.	It is recommended that the Flood Planning Area (FPA) within the Davistown and Empire Bay Catchments is defined as **1% AEP extent including 30% increase in rainfall**. The FPA is shown on **Maps G312 and G313.** • It is recommended that the Flood Planning Level (FPL) within the Davistown and Empire Bay Catchments is defined a **1% AEP level + 500mm freeboard**. This would be applied only where this level is higher than the Brisbane Water FPL.
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*).	The Flood Planning Constrain Categories (FPCC) have been mapped using the outputs of the Flood Studies (2010) and FRMS (2020a) in **Maps G314 and G315**. 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 7.2 in the GLEP 2014 defines the Flood Planning Area as the area below the Flood Planning Level. No further definition of the Flood Planning Level is provided in this clause. This provides some scope for the Flood Planning Level to be defined for each floodplain within the relevant Floodplain Risk Management Plan.	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

	However, Clause 7.3 in the GLEP 2014 indirectly defines the Flood Planning Level to be 1% AEP plus 500mm. This planning level may not be appropriate for all floodplains, especially where flooding is dominated by shallow overland flow, such as Davistown and Empire Bay. Discussion on selection of an appropriate Flood Planning Area and Flood Planning Level are provided in the FRMS).	defined as other than the land below the FPL. As this is not consistent with the recommendations in this FRMP.
4	The Department of Planning, Industry and Environment (DPIE) has been working to update the Flood Prone Land Package which provides advice to councils on considering flooding in land use planning.	Council's future revision of the LEP, DCP and Planning Certificates should consider the outcomes of the Flood Prone Land Package once it is finalised.
		It is recommended that the Council provide scope within their DCP 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 DCP 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.
5	The DCP refers to the Flood Planning Area being land below the 1% AEP + 500mm (clause 6.7.7.6.4) rather than being defined for each floodplain within the relevant Floodplain Risk Management Plan.	It is recommended that the Flood Planning Area (FPA) within the Davistown and Empire Bay Catchments is defined as **1% AEP extent including 30% increase in rainfall**. The FPA is shown on **Maps G312 and G313.** It is recommended that the Flood Planning Level (FPL) within the Davistown and Empire Bay Catchments is defined a **1% AEP level + 500mm freeboard**. This would be applied only where this level is higher than the Brisbane Water FPL.
6	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.
		Floor levels for sensitive, vulnerable, or critical uses should be set at the higher of the PMF and FPL. The FPL is higher than the PMF in almost all locations within the study area (for catchment flooding).
7	The flood related planning controls applicable in Davistown and Empire Bay, can be confusing due to the range flood risks present. Compiling all relevant controls into a simple format, would assist developer and property owners comply with the required controls.	A draft Floodplain Risk Planning Matrix template has been provided in the FRMP. This would need to be completed and adopted following completion of the FRMP.

8.2.2 PM02 Voluntary House Purchase

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

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

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

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

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

Properties being considered for VP should be located:

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

There are no residential dwellings located in 1% AEP high hazard flood locations (H4 – H6) within the study area. However, several properties would need to be purchased as part of the implementation of the drainage diversion and easement between Myrtle Road and Kendall Road (**Section 8.1.2.6**). The acquisition of these properties has been considered in the preliminary costing of this option.

8.2.3 PM03 Voluntary House Raising

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

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

Assessing the viability of a VHR scheme or an individual property for VP is part of a collective assessment of floodplain risk management options for the community when an FRMP (such as this document) is developed. The FRMP should have considered:

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

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

It should be noted that only properties which have pier floor construction were considered as viable options for house raising. Therefore, "Slab on Ground" properties were not included in the analysis. The floor construction information for each property was obtained based on the property survey, discussed in **Section 2.3**.

An economic analysis was undertaken to assess the economic viability of house raising and to identify which properties might be appropriate. It was concluded that, considering a $100,000 capital cost, raising a property would only be economically advantageous if the associated reduction in the average annual damage was higher than $6,772.

Based on this conclusion, it was found that It would be economically advantageous to raise five properties in total, all located in Empire Bay. The addresses for each of these properties have been provided to Council.

The overall benefit and benefit cost ratio associated with raising all five properties, as part of the voluntary house raising program, is show in **Table 8-11**.

It should be noted that the economic assessment for this option considered the overall benefits of raising the five houses as part of a program. However, when each property is analysed individually, the associated benefit cost ratios vary depending on the property (between 1 and 2).

Council might want to consider the individual property benefits if applying for state government funding and prioritising the houses involved.

Table 8-11 PM02 Economic Assessment

Initial Cost	Recurrent Cost	Reduction in AAD	Benefit Cost Ratio
$500,000	0	$46,794.47	1.38

8.2.4 PM04 Property Flood Risk Education Program

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

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

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

According to the Brisbane Water FRMS, the Property Flood Risk Education Program could include measures such as:

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

Since Davistown and Empire Bay are also subjected to catchment flooding, the flood risk associated with this type of flooding should also be incorporated in the Property Flood Risk Education Program.

8.3 Emergency Response Modification Options

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

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

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

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

8.3.1 EM01 Review of Evacuation Centre Locations

Evacuation Centres would play an important role in the Emergency Response to a major ocean flooding event in the study areas. In this type of flooding event, if shelter-in-place is not possible, residents in Davistown and Empire Bay might need to travel to an Evacuation Centre. 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.

Flood-free locations that could function as evacuation centres for Davistown and Empire Bay have been identified in **Table 8-12**. This table comprises the venues identified in the Brisbane Water FRMS (Cardno, 2015) and in the Gosford Local Flood Plan, as well as additional locations identified as part of this Floodplain Management Study.

Table 8-12 Potential evacuation centre locations

Study Area	Potential Evacuation Centre Venue	Address	Source
Davistown	Kincumber and District Neighbourhood centre	20-22 Kincumber St, Kincumber NSW 2251	Brisbane Water FRMS
	Green Point Community Centre	96 Koolang Rd, Green Point NSW 2251	Gosford Local Flood Plan
	Brisbania Public School	High St, Saratoga NSW 2551	Additional potential venue identified as part of this FRMS
	Saratoga Community Hall	15 Kyeema Ave, Saratoga NSW 2251	Additional potential venue identified as part of this FRMS
	Davistown RSL Club	19 Murna Rd, Davistown NSW 2251	Additional potential venue identified as part of this FRMS
Davistown/ Empire Bay	Kincumber High School	Bungoona Rd, Kincumber NSW 2251	Additional potential venue identified as part of this FRMS
	Kincumber Public school	Avoca Dr, Kincumber NSW 2251	Additional potential venue identified as part of this FRMS
Empire Bay	La Salle Youth Camp	38 Mackillop Rd, Kincumber South NSW 2251	Brisbane Water FRMS
	Ettalong War Memorial Club	51-52 The Esplanade, Ettalong Beach NSW 2257	Brisbane Water FRMS
	Empire Bay Public School	232 Empire Bay Dr, Empire Bay NSW 2257	Additional potential venue identified as part of this FRMS

The location of the identified venues is shown in **Map G222**. These venues have been 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.

8.3.2 EM02 Access Improvements During Flooding

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

The Brisbane Water FRMS (2015) identified roads for raising based on the impacts of storm surge flooding. This FRMS has reviewed flooding of key access roads associated with catchment flooding and provided recommendations associated with improving the flood immunity of these locations. It should be noted that the flood modelling (Cardno, 2010) is of a regional nature and as such can only provide indicative flood depths at these locations. The information contained in this option should be used to inform Council decisions on asset upgrades and road maintenance. Detailed assessments prior to undertaking works would quantify the flood behaviour across the assets and allow for design of appropriate upgrades, this may involve road raising, drainage improvement or a combination of both.

Table 8-13 summarises the key access routes that are subjected to high hazard (larger than H2) in the PMF flood event, based on the flood hazard analysis discussed in **Section 6.1** and provided in maps provided in **maps G121** and **G123**. This table also identifies the length of the affected sections, as well as the suggested measures to be taken for each section.

It should be noted that **Table 8-13** also include all the roads that were identified as being overtopped in maps **G150 and G151**, discussed in **Section 6.5.**

Table 8-13 Modification measures for key access routes

Study Area	Road name	Road Section	Approximate Extent of Section	Maximum Hazard Classification in the PMF event	Proposed management measures
Davistown	Malinya Road	Between numbers 106 and 64, Malinya Road	380 m	H3	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
	Malinya Road (North-west)	Between numbers 151 and 135, Malinya Road	100 m	H2	
	Paringa Avenue	Between Restella Avenue and Davistown Road	160 m	H2	
	Davistown Road	Between numbers 45 and 54, Davistown Road	170 m	H2	

Study Area	Road name	Road Section	Approximate Extent of Section	Maximum Hazard Classification in the PMF event	Proposed management measures
	Lilli Pilli Street	Between Davistown Road and Pine Avenue	410 m	H2	
	Kincumber Crescent	In the intersection with Alkoomie Close	50 m	H2	
	Emora Avenue	From Malinya Road to Davistown Road (Entire Road Section)	-	H3	The entire section of the road is affected by high hazard flooding in the PMF event. It is suggested that this road is not considered as a viable evacuation route. An alternative evacuation route exists through Paringa Avenue (to the south). Residents should be informed not to utilise this road during flooding.
Empire Bay	Gordon Road	Between Sorrento Road and Boongala Avenue	260 m	H3	Possible combination of road modifications (total or partial raising), flood awareness education program informing residents for the risk and notification to the SES that this area needs to be a priority in flood emergencies.
	Boongala Avenue	Entire Section	400 m	H3	
	Sorrento Road	Between numbers 2 and 22, Sorrento Road	160 m	H3	
	Rickard Road	Between numbers 19 and 57, Rickard Road	280 m	H4	
	Greenfield Road	Between numbers 1 and 41, Greenfield Road	320 m	H3	
	Empire Bay Drive[1]	Between Poole Close and Rachel Close	700 m	H5	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
	Pomona Road	Between numbers 22 and 72, Pomona Road	610 m	H5	
	Pomona Road (West)	Between numbers 6 and 10, Pomona Road	60 m	H5	

Study Area	Road name	Road Section	Approximate Extent of Section	Maximum Hazard Classification in the PMF event	Proposed management measures
	Palmers Lane	Between Allawa Close and Empire Bay Drive	350 m	H5	
	Rosella Road	Between numbers 32 and 38, Rosella Road	50 m	H5	
	Shelly Beach Road	Between numbers 27 and 37, Shelly Beach Road	80m	H2	

[1]Measures to improve flood immunity in Empire Bay Drive are further discussed in **Section 8.3.3.**

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

From the locations listed in **Table 8-13,** Empire Bay Drive and Davistown Road should be considered priority, as these roads are the main access route to Empire Bay and Davistown, respectively, and are subjected to significant hazard. Measures to improve flood immunity in Empire Bay Drive are further discussed in **Section 8.3.3.**

The area situated north of Rickard Road and south of Gordon Road and Sorento Road, in Empire Bay also requires special attention from a flood access perspective. This area is classified as flooded, isolated and submerged, according to the FERC classification analysis, discussed in Section 6.3. Raising the roads that give access to this area might not be possible, since it could result in floodwater being directed into private properties. Therefore, it is important that SES is informed that that is a critical location and that the residents are flood aware know how to respond in an emergency situation.

An alternative to road raising is proposed by the Brisbane Water Floodplain Risk Management Study (Cardno, 2015). This study recommended the following road evacuation enhancement measure (EM8):

- Develop/review alternative routes and detours in accordance with the results of the FRMS
- Distribute alternative route plans to relevant organisations and authorities (e.g. Council, NSW SES, Police) as appropriate. Electronic data transfer is desirable (e.g. GIS data)
- Integrate the results of this FRMS into future road planning undertaken by the TfNSW.

Therefore, it is recommended the road evacuation enhancement measures proposed by the Brisbane Water FRMS are adopted in conjunction with the measures outlined in **Table 8-13** and taking into consideration the joint effect of catchment flooding and ocean inundation.

8.3.3 EM03 Improve Empire Bay Drive Flood Immunity

Empire Bay Drive is a key access route to Empire Bay. Therefore, it is important to guarantee the serviceability of this road during a flooding event.

Based on the results of the Flood Study (2010), a number of sections of Empire Bay Drive are subjected to high hazard (higher than H2), as shown on **Map G123**. These sections are illustrated in **Map G223**.

Table 8-14 summarises the sections identified on **Map G223**, as well as the overtopping depths in each section for the 20% AEP, 1% AEP and PMF flood events.

Table 8-14 Sections of Empire Bay Drive subjected to High hazard

Section of Empire Bay Drive	Flood Depth (m)		
	PMF	1% AEP	20% AEP
Section 01	0.30	<0.1	<0.1
Section 02	0.30	<0.1	<0.1
Section 03	0.25	<0.1	<0.1
Section 04	0.20	<0.1	<0.1
Section 05	0.38	0.10	<0.1
Section 06	0.30	0.10	<0.1
Section 07	0.65	0.30	0.20
Section 08	0.30	<0.1	<0.1
Section 09	0.20	<0.1	<0.1

Most of these locations correspond with a culvert crossing Empire Bay Drive or are located immediately next to a crossing (Sections 1, 2, 3, 5 and 8). Drainage investigations should be undertaken to confirm the capacity of these culverts and upgrades should be considered utilising the design flows from the Flood Study (2010).

The section of Empire Bay Drive immediately east of Palmers Lane (Section 07) is the section that is most critically affected. This section is overtopped in events greater than a 20% AEP event, resulting in flood depths on the road of approximately 0.2m. In the PMF, flood depths in this section as high as 0.65 m were identified in this section. Detailed drainage investigations should be undertaken at this location to identify if culverts could be provided to carry flow under the road, rather than overtopping.

8.3.4 EM04 Flood Warning Systems

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

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

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

- Ensure that warnings for storm-surge flooding are appropriately distributed (in addition to warnings for catchment flooding) by acknowledging the similarities and differences between the two flooding types.
- Liaise with Council operators and TfNSW so that light-emitting diode (LED) variable messaging signage (VMS) (both permanent and demountable) can be utilised to provide flood warnings.

- Integrate the results of the Brisbane Water FRMS into NSW SES flood planning (e.g. sharing of GIS data for use by NSW SES).
- Develop/review alternative routes and detours and distribute plans as appropriate.
- Undertake periodic liaison (between BoM, NSW SES and Council) to ensure consistency.

These measures would be applicable to Davistown and Empire Bay and are also proposed in this FRMS.

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

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

It should be noted, that based on the responses from the community survey (**Section 3.4.2**) Most of the respondents would look for updates or information on radio (27%), on TV (20%) and on social media (19%). Therefore, it is recommended that these avenues be targeted when releasing information related to weather and flood warnings.

Another possibility would be sending these warnings 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.

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
- 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 provided to local community groups to distribute to their members. As explained previously in this section, the wording of these alerts would be critical to ensure unnecessary alarm is not caused, but responsiveness is increased.

Another valuable source of real-time flooding information for Davistown and Empire Bay is the "Floods Near Me" application, which is a mobile device app that is currently being developed by MHL. The app provides information on current flooding events across NSW, by integrating data sourced from BoM, SES, Transport NSW, and local councils.

Based on the responses of the community questionnaire, the "Floods Near Me" app is not widely used by the community. This might be due to a lack of knowledge on how to use the app or how to interpret the information provided by it. Therefore, it is recommended that guidance on how to effectively use "Floods Near Me" app is included in the flood education program for Davistown and Empire Bay (**Section 8.3.6**)

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

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

It should be noted that the flood forecasting study also outlines long-term recommendations applicable to Davistown and Empire Bay. 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 Davistown and Empire Bay.

8.3.5 EM05 Flood Warning Signs

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 (>0.3m) in the 20% AEP flood event (catchment and ocean Flooding) were identified. These locations are summarised in **Table 8-15**. It should be noted that the 0.3 m depth was adopted as a reference because that is the maximum still water depth that allows for the safe passage of small vehicles, according to the hazard classification describes in **Section 6.1** .

Table 8-15 Roads Subjected to Frequent Flooding

Study Area	Road Subjected to Frequent Flooding	Type of Flooding
Davistown	Malinya Road	Ocean Flooding
	Emora Avenue	Ocean Flooding
	Restella Avenue	Ocean Flooding
	Magnolia Road	Ocean Flooding
Empire Bay	Shelly Beach Road	Ocean Flooding
	Boongala Avenue	Ocean Flooding/ Catchment Flooding

Study Area	Road Subjected to Frequent Flooding	Type of Flooding
	Gordon Road	Ocean Flooding/ Catchment Flooding
	Sorrento Road	Ocean Flooding/ Catchment Flooding
	Rickard Road	Catchment Flooding
	Greenfield Road	Catchment Flooding
	Empire Bay Drive (Section between Palmers Lane and Rachel Close)	Catchment Flooding
	Pomona Road	Catchment Flooding
	Palmers Lane	Catchment Flooding

It should also be noted that flooding issues in Boongala Avenue and Greenfield Road have been reported by the community through the questionnaire sent as part of the engagement process. Flooding in Boongala Avenue was mentioned by around 11 residents and around 4 reported flooding in Greenfield Road.

However, it should be noted that the use of depth markers in most of the locations identified in **Table 8-15**, might not necessarily be the best approach. The main reason is that these are residential roads, with relatively small traffic flow and low speed limits. In addition, home-owners adjacent to depth markers may object to the placement of these for fear that they may impact future property purchase, by creating the perception that their properties are flood affected.

For these roads, the installation of a larger flood warning or infographic sign may be more appropriate, identifying that the road may generally be subject to flooding during extreme rainfall events, rather than targeting a specific location on a road. This information could be supported through public education programs relating to driving through flood waters.

The only road where the installation of a depth marker would be recommended is Empire Bay Drive since this road in an important access road to and from Empire Bay. In the PMF event, the section where the recommended marker would be installed is overtopped for approximately 5 hours, with a maximum flood depth of 0.6 m. This section is also upstream of a culvert, which could potentially become blocked and further increase the flood depth on the road surface.

8.3.6 EM06 Flood Education Programs

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

Davistown and Empire Bay can be affected by both catchment flooding and foreshore inundation due to ocean storm events. In the study areas, during catchment flood events, flood depths increase allowing for little response time. Foreshore inundation, on the other hand, is usually characterised by a slow rate of rise and fall of flood waters, which means the community would potentially have time to evacuate safely, however, properties would remain flood affected for a longer period of time. It should be noted that ocean flooding events can occur concurrently or separately from catchment flooding. Therefore, it is important that public education progress address the two different types of flooding and what would be the adequate response for each.

As discussed in **Section 8.3.3**, the availability of reliable flood warnings for areas impacted by catchment flooding is limited. For this reason, in order to get the most benefit out of the warnings that are available, residents in the floodplain need to have an adequate understanding of the potential effect flooding would have on their property the access routes in their local area. People will also need to know how to react to a flood situation and be able to assess when it is safe and necessary to evacuate and what would be the best way to do it.

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

According to the local residents, the most significant flood events that occurred recently in the study area were June 2007 and May 1974 event. The June 2007 event approximately corresponded to a 5% AEP event and the May 1974 event approximately corresponded to a 0.5% AEP event. However, both events were derived by elevated water levels in Brisbane Water, not rainfall.

According to responses from the resident survey, most residents (92%) report to be “aware” or “somewhat aware” of flooding in the region.

When asked how they would react I a major flood event 50% of the residents responded they would remain at their houses, and around 30% responded they would stay because they believe their house could cope with flooding. Therefore, even though the survey suggests a high level of awareness, it is important to question whether the residents fully understand how they would be impacted by a larger, rarer, flood which exceeds the frequent flooding they are accustomed to dealing with.

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

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

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

- Preparation of a FloodSafe brochure relevant to the study area by the SES, for both residential and business premises. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information. Once prepared, the FloodSafe brochure can then be uploaded to the Council and SES websites in a suitable format, where it would be made available under the flood information sections of the website. The brochures could also be made available at Council offices and community halls. The brochure should address both catchment flooding and foreshore inundation, or separate brochures be prepared.

- Targeted awareness programs for specific groups of residents, such as older people in retirement villages (e.g. Alloura Waters), or residents that may be cut off from transport routes and isolated. Examples of the areas that could be potentially isolated include the properties between Sorrento Road and Rickard Road and north of Pomona road (Empire Bay). Other potentially isolated areas are identified in the FERC maps (**G130** to **G135**).
- 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 the consequences of non-compliance.
- Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.
- Prepare educational materials of the flood planning controls that apply to them and their properties, as well as the consequences of non- compliance.

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

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

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

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

9 Multi-Criteria Assessment

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

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

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

9.1 Scoring System

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

Each of the criteria has been given a preliminary weighting to reflect its importance with regards to floodplain management. This weighting has been based on the project team's understanding of flood risk in the local area and existing Council policies and other available data. The responses to the community engagement survey (**Section 3.4**). The weighting aim to retain the focus of the options on managing flood risk, while still considering other values in the study area. The weightings will be reviewed with regards to submissions received from the public during the public exhibition period.

The categories and criteria adopted are:

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

- Acid sulfate soils
- Visual impacts
- Recreational space

Each category is given a weighting based on its relative importance (compared to the other categories), which is then factored by the number of criteria within each category (i.e. so categories with more criteria do not influence the final score than those with less criteria).

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

The details of each criteria, the scoring system applied, and the relevant weightings are provided in **Appendix E**. An example of how the MCA score is calculated is provided below.

Category	Economic					Social					Environmental				
Category Weighting	*0.2*					*0.20*					*0.13*				
	Reduction in Flood Damages	Capital Cost	Operating and Maintenance Costs	Implementation Complexity	Staging of Works	Increased Community Flood Awareness	Reduction in Risk to Life	Emergency Access and Traffic Disruption	Compatible with Council's Plans and Policies	Likely Community Support	Flora / Fauna Impacts	Acid Sulfate Soils	Visual Impacts	Recreational Space	Score
Criteria Weighting	*5*	*2.5*	*2.5*	*3*	*3*	*5*	*5*	*4*	*3*	*3*	*3*	*3*	*3*	*3*	
Drainage easement (Myrtle to Kendall Rd)	**2**	**-3**	**-1**	**-3**	**1**	**0**	**2**	**2**	**2**	**2**	**2**	**-2**	**2**	**3**	**6.8**

The score for each category equals the sum of each criteria score multiplied by its weighting (shown in brackets):

- **Economic** score: 2(5) + -3(2.5) + -1(2.5) + -3(3) + 1(3) = -6
- **Social** score: 0(5) + 2(5) + 2(4) + 2(3) + 2(3) = 30
- **Environmental** score: 2(3) + -2(3) + 2(3) + 3(3) = 15

The categories are weighting is shown below (and in **Appendix E**). These effectively represent the fact that the focus of the study is to evaluate how effectively the proposed options can manage flood risk to life and property, while still considering the environmental impacts and benefits. However, the number of criteria within each category can impact the total score for that category. Therefore, the Category weightings are normalised against each other based on how many criteria it contains (i.e. weighting divided by the number of criteria). The normalised weightings are shown in brackets.

- **Economic** weighting = 1 [0.2]
- **Social** weighting = 1 [0.2]
- **Environmental** weighting = 0.5 [0.13]

The overall score for the option then calculated: -6(0.2) + 30(0.2) + 15(0.13) = 6.8

9.2 Outcomes

The results of the MCA, including the score for each criterion assigned to each option and the calculated total score, is shown in its entirety in **Appendix E**. An MCA rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are shown in both **Table 9-1** and **Appendix E**.

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

Table 9-1 Multi-Criteria Outcomes

Option ID	Option Description	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	Score	Rank	Considerations
FM DT1	Davistown Foreshore Barrier	$ 12,343,000	$ 5,000	$ 1,490,000	1.77	7.90	1	This option is one aspect of a range of measures aimed to provide long term climate change adaptation for Davistown. The benefits provided in this assessment, only consider the protection from ocean storm flooding under existing sea level conditions.
FM DT2	Davistown Foreshore Barrier (all properties protected)	$ 19,454,000	$ 8,000	$ 2,080,000	1.57	6.80	2	This option provides a high BCR and a high score overall. However, the BCR is slightly lower that DT1 (due to the higher cost of implementation), and the score slightly lower also because of the high level of complexity involved in constructing the barrier around the eastern portion of Davistown.
FM DT3	Davistown foreshore barrier (5%AEP Crest)	$ 13,341,000	$ 5,000	NA	NA	3.10	11	This option scores lower than DT1 and DT2 due to the lower level of flood protection provided.
FM DT4	Road drainage improvements	$ 2,072,000	$ 3,000	NA	NA	1.80	16	This options scores fairly low in this assessment as it does not address large flood events. However, drainage improvements would reduce flooding of roads in minor events.
FM DT5	Drainage easement (Davistown Memorial Park to Paringa Ave)	This option addresses an inter-allotment drainage issue for private property owners to address and has not been assessed further in this FRMS						
FM DT6	Wetland dredging	The environmental impacts inhibit any further assessment of this option						
FM EB1	Pomona Road drainage upgrades	$ 371,000	$ 5,000	NA	NA	3.03	13	Pomona Road is the only access route for the properties located along it. As such, providing flood free access is important. Flooding of Pomona Road was not shown to be significant, however, where Council can find opportunities to improve cross drainage structures, the flood data from the Flood Study (2010) and the details provided in this option should be used to inform the design and location of these structures.

Option ID	Option Description	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	Score	Rank	Considerations
FM EB2	Seawall construction guidelines	$ 10,000	$ -	NA	NA	3.10	12	The Floodplain Risk Management Plan should consider recommendations for design aspects to be included in Council's seawall guidelines that will contribute to flood protection. This should include the appropriate crest level to achieve flood protection from storm surge events. This may be combined with Planning Recommendations (PM01).
FM EB3	Maintenance and upgrade of private seawalls	$ 435,000	$ 5,000	NA	NA	0.43	20	Raising of seawalls is a critical component of FM EB4, however, flood protection cannot be achieved by raising seawalls alone. The remainder of the foreshore barrier needs to be constructed before the flood protection is achieved.
FM EB4	Empire Bay foreshore barrier	$ 4,554,000	$ 3,000	$ 1,469,000	4.72	6.33	5	This option provides a very high BCR but does not score as highly as the Davistown Foreshore Barriers as the Davistown options protect more properties and have the added benefit of reducing risk to life considerably through reduction in over floor flooding. This option could have complexities associated with the large number of private properties along which the barrier would need to be implemented. This affected the overall score from the MCA, which is still high but lower than the Davistown Foreshore Barriers.
FM EB5	Drainage easement (Myrtle to Kendall Rd)	$ 6,481,000	$ 4,000	$ 170,000	0.43	6.68	3	This option only provides moderate flood benefits to private properties, but also provide reduced flooding on roads. The overall score of this option is increased due to the option providing open space, recreational corridors, and additional vegetation. The assessment of this option has been undertaken assuming 6 properties are purchased and rezoned to open space. If the number of properties purchased increased, or the drainage diversion was undertaken through an unground culvert with no properties purchased, this would impact the economic analysis.

Option ID	Option Description	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	Score	Rank	Considerations
FM EB6	Pomona Road easement and drainage upgrades	$ 737,000	$ 2,000	$ 91,000	1.75	1.35	18	This option only has moderate flood benefits, but the moderate costs result in a BCR > 1. Complexities may exist with this option regarding the use of the existing easement through private property, and the acquisition of an additional easement to the north to allow the swale to connect into the existing waterway.
FM EB7	Empire Bay Drive easement	$ 310,000	$ 1,000	$ 10,000	0.46	1.43	17	This option provides very small flood benefits, and does not provide additional benefits to environment, transport, or the like. Flood of Empire Bay at this location should instead be addressed through drainage design (EM03).
PM1	Land Use Planning Recommendations	$ -	$ -	NA	NA	6.40	4	Several recommendations have been made for Council to consider as part of their DCP and LEP updates.
PM2	Voluntary House Purchase	No properties qualify for a Voluntary House Purchase Program						
PM3	Voluntary House Raising	$ 500,000	$ -	$ 47,000	1.38	3.40	10	The economic assessment for this option considered the overall benefits of raising the five houses as part of a program. However, when each property is analysed individually, the associated benefit cost ratios vary depending on the property (between 1 and 2). Council might want to consider the individual property benefits if applying for state government funding and prioritising the houses involved.
PM4	Property Flood Risk Education Program	$ 100,000	$ 5,000	NA	NA	5.10	6	Could be combined with planning for the Flood Education Programs, however, materials and target audiences may differ slightly.
EM1	Review of evacuation centre locations	$ -	$ -	NA	NA	3.60	8	This information should be provided to SES to assist them with flood planning.
EM2	Road raising	$ 13,545,000	$ -	NA	NA	0.98	19	The flood modelling (Cardno, 2010) is of a regional nature and as such can only provide indicative flood depths at these locations. The information contained in this option should be used to inform Council decisions on asset upgrades and road maintenance. Detailed assessments prior to undertaking works would quantify the flood

Option ID	Option Description	Capital Cost	Recurrent Cost	Reduction in AAD	BCR	Score	Rank	Considerations
								behaviour across the assets and allow for design of appropriate upgrades, this may involve road raising, drainage improvement or a combination of both.
EM3	Drainage upgrades on Empire Bay Drive	$ 180,000	$ -	NA	NA	2.83	14	Most of these locations identified in this option correspond with a culvert crossing Empire Bay Drive or are located immediately next to a crossing. Drainage investigations should be undertaken to confirm the capacity of these culverts and upgrades should be considered utilising the design flows from the Flood Study (2010).
EM4	Flood warning systems	$ 50,000	$ 5,000	NA	NA	3.60	8	Community engagement provided an insight into how and where people obtain information related to flood warnings and response. This information should be used to collaborate with SES to improve the dissemination of flood warnings to the community.
EM5	Flood warning signage	$ 100,000	$ -	NA	NA	2.00	15	Flood depth markers are likely not appropriate at all locations where roads can flood. However, road flooding is widespread during catchment and Brisbane Water flooding. General signage relating to the possibility of roads flooding and information to drivers could be installed at key locations.
EM6	Flood Education Programs	$ 100,000	$ 5,000	NA	NA	4.50	7	Could be combined with planning for the Property Flood Risk Education Programs, however, materials and target audiences may differ slightly.

10 Outcomes and Recommendations

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

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

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

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

11 References

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Rhelm Pty Ltd
ABN 55 616 964 517
ACN 616 964 517

Head Office
Level 1, 50 Yeo Street
Neutral Bay NSW 2089
contact@rhelm.com.au
+61 2 9098 6998
www.rhelm.com.au