City of Canada Bay

Exile Bay Catchment Floodplain Risk Management Study & Plan

Draft Report for Public Exhibition

May 2025

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Draft Report for Public Exhibition

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EXECUTIVE SUMMARY

Introduction

City of Canada Bay (Council) has received financial support from the State Floodplain Management program managed by the NSW Department of Climate Change, Energy, the Environment and Water to undertake a floodplain management investigation for the Exile Bay catchment. GRC Hydro Pty Ltd (GRC Hydro) have been engaged by Council to undertake a floodplain risk management study and develop a draft floodplain risk management plan.

This study comprises a Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Plan (FRMP) which are consistent with the NSW Government's Flood Risk Management Manual (FRMM, 2023).

The objective of this study is to improve the understanding of Exile Bay flood behaviour and flood impacts on the existing and future local community. The study has undertaken testing and investigation of practical, feasible and economic management measures to treat existing, future and residual risk. The FRMS provides a basis for informing the development of a FRMP which will document and convey the decisions on the management of flood risk into the future.

Analysis of Model Results

The computer model results from the Exile Bay Catchment Flood Study (GRC Hydro, 2020) were used to develop important information to better understand and manage flood risk in the catchment. These outputs include definition of flood hazard, flood function, emergency response categories, flood planning levels, flood risk precincts and climate change impacts.

Community Risk Assessment

An assessment of Exile Bay's flood behaviour and community profile was carried out to determine specific areas of flood risk across a range of metrics, including; property flood liability, flood hazard, hydraulic categories and the economic impact of flooding.

Flood consequences for the following were assessed:

- Identification of key flood risk areas / flooding hotpots (Section 6.2);
- Information on flooded roads (Section 6.3);
- Analysis of property flood liability and an assessment of the economic impact of flooding (Section 6.4); and
- Review of critical infrastructure and sensitive land uses (Section 6.5).

The identified flooding hotspots are summarised in Table ES 1.

Table ES 1: Flooding Hotspots and Risk Factors

Hotspot #	Location	Risk Factors
1	Parramatta Road to John Street	Property flooding and road flooding issues
2	Constriction Downstream of Rothwell Park	Property flooding

3	Central Drain upstream of Davidson Avenue	Property flooding and road flooding issues
4	Davidson Avenue	Property flooding, road flooding and evacuation issues
5	Majors Bay Road and Brewer Street Intersection	Property flooding, road flooding and evacuation issues
6	Saltwater Creek	Property flooding issues

A summary of the flood liability of individual lots and buildings within the PMF extent in Exile Bay is presented in Table ES 2.

Table ES 2: Property Flood Affectation

Design Event (AEP)	Residential		Commercial	
	No. of properties flooded above ground	No. of properties flooded above floor	No. of properties flooded above ground	No. of properties flooded above floor
PMF	1,578	409	65	18
0.2%	942	96	41	4
0.5%	883	78	39	4
1%	842	72	35	3
2%	767	55	33	3
5%	706	43	32	2
10%	660	35	30	2
20%	540	20	26	2

Net flood damage estimates that combine residential and non-residential flood damages are presented in Table ES 3 and amount to an average annual cost for flooding of ~$3.1 million per annum.

Table ES 3:Exile Bay Flood Damages

Design Event (AEP)	Flood Damages Total
PMF	$90,181,000
0.2%	$14,545,000
0.5%	$11,517,000
1%	$9,743,000
2%	$7,140,000
5%	$5,211,000
10%	$4,511,000
20%	$3,148,000
Average Annual Damages (AAD)	$3,125,000

The flood liability of various sensitive and critical developments and infrastructure was examined including for medical facilities, aged care, childcare, schools and other critical infrastructure.

Flood Risk Management Measures

Flood risk management measures which aim to reduce, or otherwise, manage flood risk in Exile Bay were assessed. These measures ranged from large-scale civil works, such as the upgrade of trunk drainage systems, to non-works interventions, such as planning controls for new developments. Feasible measures, found to effectively reduce flood risk, have been ranked for implementation in the Floodplain Risk Management Plan (see Section 8).

Floodplain Risk Management measures are categorised in the NSW Floodplain Development Manual (Reference 6) as follows:

- Property Modification Measures (Section 7.1) are those which involve modifying existing properties to manage their flood risk. This includes planning-related measures such as classifying Flood Risk Precincts for Council's DCP. They also include house raising, and in cases of high flood risk, voluntary purchase schemes.
- Response Modification Measures (Section 7.2) are those that improve the ability of people to plan for and react to flood events. They often involve emergency services and can be targeted at different phases of a flood, e.g. preparation, response and recovery.
- Flood Modification Measures (Section 7.3) are those that change the behaviour of the flood itself through works or other measures. These measures often work to reduce the peak flow (for example a berm or drainage upgrade) or improve the drainage of water through flow paths.

Assessment of each of the modification measures for various options has been undertaken.

Draft Flood Risk Management Plan

A Floodplain Risk Management Plan was developed which aims to manage existing and future flood risk for Exile Bay in accordance with theNSW Flood Risk Manage Manual (2023). The Plan aims to achieve the following overarching objectives:

- Reduce the flood hazard and risk to people and property, now and in the future;
- Protect, maintain and where possible enhance the floodplain environment; and
- Ensure floodplain risk management decisions integrate social, economic and environmental considerations.

The flood management measures recommended for implementation are presented in Table ES 4. The measures have been prioritised with high, medium and low classifications along with who is responsible for implementation and cost estimates presented.

Table ES 4: DRAFT Flood Risk Management Plan

Flood Management Measure	Section	Priority	Preliminary Estimates	Responsibility
Property Modification Measure				
Clarify use of Flood Risk Precincts in the DCP	7.1.2	Medium	Council cost estimate	Council
Flood Proofing	7.1.5	Medium	-	Property Owners
Response Modification Measures				
Local Flood Plan	7.2.5	High	SES cost estimate	NSW SES
Flood Modification Measures				
Macnamara Avenue Drainage Upgrade	7.3.3.1	Low	$4.5 million	Council
Davidson Avenue Drainage Upgrade	7.3.3.2	Low	$6.8 million	Council
Clearing of debris along main flowpaths	7.3.3.4	High	Council cost estimate	Council / Property Owners
Coles Street Drainage Upgrade	7.3.3.5	Low	$2.2 million	Council
Queen Elizabeth Park Drainage Upgrade	7.3.3.6	Low	$2.5 million	Council
Shackel Avenue Drainage Upgrade	7.3.3.7	Low	$400,000	Council
Cascading berms in Goddard Park, Queen Elizabeth Park and Rothwell Park	7.3.3.10	Medium	$500,000	Council
Improve conveyance along Davidson Avenue, Majors Bay Road and Brewer Street Intersection	7.3.3.11	High	$500,000	Council
Cascading berms in Central Park	7.3.3.12	Medium	$250,000	Council
Lowering Greenlees Avenue and Greenlees Park	7.3.3.13	Low	$1 million	Council

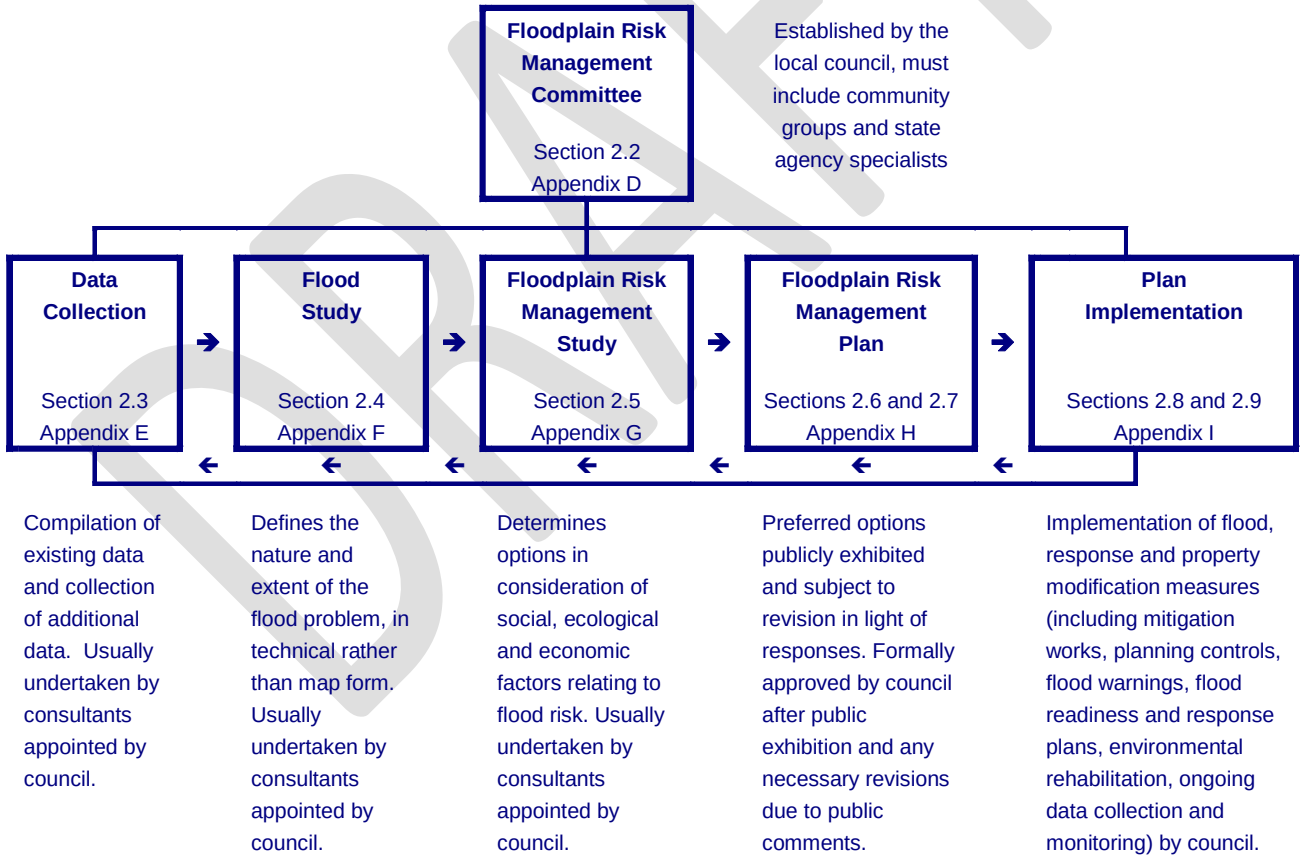
FOREWORD

The New South Wales (NSW) Government's Flood Prone Land Policy aims 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.

Through the NSW Department of Climate Change Energy, Environment and Water (DCCEEW) 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 Flood Risk Management Manual (NSW Government 2023) assists councils to meet their obligations through a five-stage process resulting in the preparation and implementation of floodplain risk management plans. Image 1 presents the process for plan preparation and implementation.

Image 1: The floodplain risk management process in New South Wales (FDM, 2005)



Source: NSW Government (2005)

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1. INTRODUCTION

1.1 Study Overview

This Exile Bay Catchment Floodplain Risk Management Study and Plan (FRMS&P) has been undertaken by GRC Hydro Pty Ltd (GRC Hydro) on behalf of the City of Canada Bay Council (Council), following on from the Exile Bay Flood Study completed in December 2020. The FRMS&P is a continuation of the 2020 Flood Study re-evaluating flood risks in the catchment, informing Council flood planning processes, and providing recommended flood risk mitigation measures in the Floodplain Risk Management Plan.

The Exile Bay catchment covers a 345 hectare area with elevations that range from approximately 33 m AHD to sea level at the Saltwater Creek channel and then discharges into Exile Bay proper. There are approximately 3700 cadastral lots within the catchment. Local heavy rainfall can cause flooding in the area, impacting both homes and commercial premises.

1.2 The Floodplain Risk Management Program

Council has received financial support from the NSW Floodplain Management Program (FMP) managed by the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW)to undertake a flood investigation of the Exile Bay catchment. To meet this objective, GRC Hydro have been engaged by Council to undertake the FRMS&P.

This study composes stages 3 and 4 of the five-stage process outlined in the NSW Government's Flood Risk Management Manual (NSW Government, 2023). These works include:

- Floodplain Risk Management Study (FRMS) – which assesses the impacts of floods on the existing and future community and allows the identification of management measures to manage flood risk; and a
- Floodplain Risk Management Plan (FRMP) – that outlines a range of measures, for future implementation, to manage existing, future and residual flood risk effectively and efficiently.

Following the completion of the FRMP, the final stage of the floodplain management process will involve implementing the findings of the FRMP.

Further details of the floodplain risk management stages are outlined below.

Data Collection (completed as part of the 2020 Flood Study)

The collection and collation of data necessary for the completion of the flood and floodplain risk management studies is a fundamental part of the floodplain management process. It is typically begun at the outset of the study, but generally continues throughout the period of the project as data becomes available, through community involvement. The quality and quantity of available data is key to the success of a flood study and FRMS.

Flood Study (completed as part of the 2020 Flood Study)

A flood study is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to

provide an understanding of flood behaviour and consequences for a range for flood events. Consideration of the local flood history, flood data is used to assist in the development of hydrologic and hydraulic models which are calibrated and verified to improve confidence in model results.

Floodplain Risk Management Study (current study)

A floodplain risk management study increases understanding of the impacts of floods on the existing and future community. It also allows testing and investigating practical, feasible and economic management measures to treat existing, future and residual risk. The floodplain risk management study will provide a basis for informing the development of a floodplain risk management plan.

Floodplain Risk Management Plan (current study)

The floodplain risk management plan outlines a series of prioritised measures to address flood risk. The FRMP is built using the findings of a floodplain risk management study, to outline a range of measures to manage existing, future and residual flood risk effectively and efficiently.

1.3 Objectives

The objective of this FRMS&P is to improve understanding of flood behaviour and impacts within the Exile Bay Catchment, and better inform management of flood risk in the study area in consideration of the available information, relevant standards and guidelines. This study also provides a sound technical basis for any further flood risk management investigation in the area as well as allowing an increased understanding of the impacts of floods on existing and future community. It also allows testing and investigation of practical, feasible and economic management measures to treat existing and future risk so as to achieve a tolerable level of residual risk.

The FRMS provides a basis for informing the development of a FRMP which documents and conveys the decisions on the management of flood risk into the future. The FRMP outlines a range of measures to manage existing and future risk so as to achieve a tolerable level of residual risk effectively and efficiently. The FRMP includes a prioritised implementation strategy, proposed measures as well as how they will be implemented.

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

- Relevant government information systems;
- Government and strategic decision makers on flood risk;
- The community and key stakeholders on flood risk;
- Flood risk management planning for existing and future development;
- Emergency management planning for existing and future development, and strategic and development scale land-use planning to manage growth in flood risk;
- Selection of practical, feasible and economic measures for treatment of risk;
- Development of a floodplain risk management plan and prioritised implementation strategy;
- 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 existing and future community;
    - impacts of changes in development and climate on flood risk;
    - emergency response situation and limitations; and
    - effectiveness of current management measures.
- Facilitating information sharing on flood risk across government and with the community.

The study outputs can 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. Each of these areas has different user groups with varied needs.

1.4 Project End Users

The key end-user groups that this study aims to support are identified in Table 1.

Table 1: Project End Users

Potential end user group	Use for the Project
High-level strategic decision makers	Understanding flooding in the area with regards to flood mitigation, and effect on potential zoning and redevelopment
Community	Better understand flood mechanisms, flooding at property scale, and next steps for Council in managing flood risk
Flood risk management professionals	Use the study's outputs and modelling to conduct site-specific assessments
Engineers involved in designing, constructing and maintaining mitigation works	Use the study's outputs and modelling to design, construct and maintain mitigation works
Emergency management planners	Understand flood risk with regards to road and property flooding, areas of higher risk, and available warning, in preparing response during a flood
Land-use planners (strategic planning and planning controls)	Understanding flooding in the area with regards to effect on potential zoning and redevelopment
Hydrologists and meteorologists involved in flood prediction and forecasting	Use the study's findings with regards to critical duration, rate of rise and duration of flooding
Insurers	May or may not use as insurers generally have their own studies and assessments of flood risk. Some insurers may use study outputs to confirm their flood estimates.
Emergency Services (SES, NSW Police, RFS, NSW Fire and Rescue)	Understand flood risk with regards to road and property flooding, areas of higher risk, and available warning, in preparing response during a flood

2. BACKGROUND

2.1 Study Area

The Exile Bay catchment (the study area) is situated within the suburb of Concord in Sydney's inner west. Concord has a population of 14,551 (2021 census) with a large proportion of this population living within the study area. The Exile Bay catchment is comprised of a 345 hectare area with the upper reaches of the catchment (upstream of Paramatta Road) situated within Burwood Council. Exile Bay is traversed by two key overland flow paths, the Central Drain and Main South Drain[1] (shown in Figure 1). These flowpaths meet near the intersection of Wellbank Street and Ian Parade and form Saltwater Creek. Flow then moves downstream into Exile Bay via a trapezoidal channel, adjacent to the Massey Park Golf Club. Historically, Saltwater Creek extended along the Main South Drain to Crane Street, approximately. The catchment overall is a mixture of relatively steep upper areas and relatively flat downstream areas. The study area and its key features are shown in Figure 1.

The study area is primarily comprised of residential properties with large areas of parks and reserves. As redevelopment and refurbishment of property occurs overtime, an opportunity exists to reduce flood risk for affected properties/residents and for the community more generally by having developers conform to specific flood related development controls.

2.2 Exile Bay Flood Mechanisms

Two key flood mechanisms occur in the Exile Bay catchment; overland flow flooding and mainstream flooding.

Overland flow flooding occurs when excess rainfall runoff is generated from impervious surfaces and flows toward a watercourse. This type of flooding is often referred to as overlandflooding or "flash flooding" due to short warning times Typically this type of flooding rises and recedes over a short period of time and the floodwaters are usually relatively shallow and fast moving. Image 2 (page 17) (left hand side) depicts this mechanism.

Overland flow flooding occurs in the study area along the Central Drain and Main South Drain shown in Figure 1. These drains have catchment areas of approximately 134 hectares and 147 hectares respectively. Flooding from overland flow has historically been known to occur at the following locations:

1. Between Paramatta Road and John Street;
2. At the constriction downstream of Rothwell Park;
3. Downstream of Central Park;
4. Near the intersections of Majors Bay Road with Davidson Avenue and Brewer Street; and
5. Low points in Paramatta Road, Gipps Street, Crane Street, Ian Parade, Majors Bay Road and Wellbank Street.

[1] For consistency, this study adopts the foregoing nomenclature from Reference 5

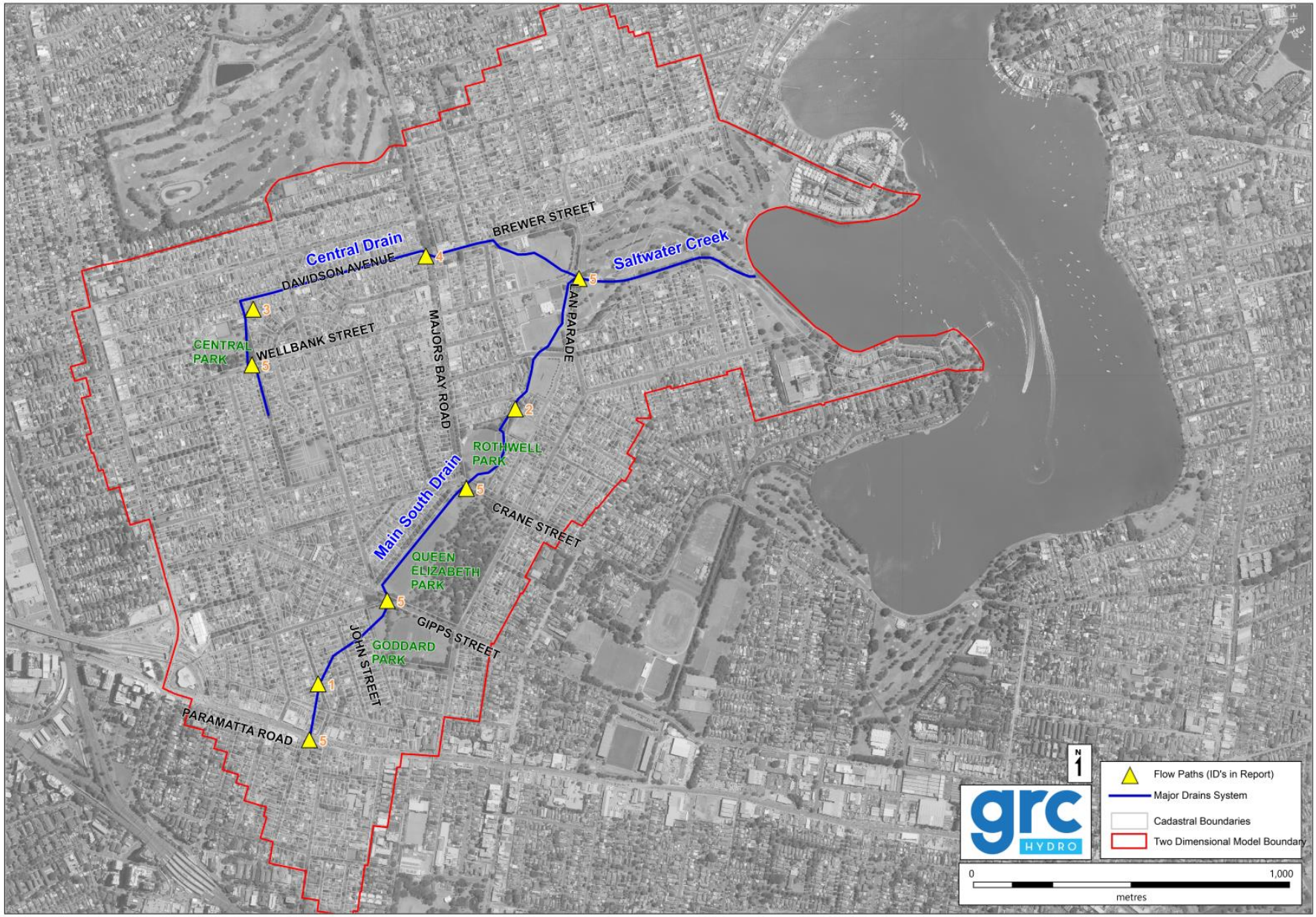
The locations of these flow paths are displayed in Figure 1.

Mainstream flooding occurs from rising water on a defined watercourse causing the watercourse to break its banks, spread over the floodplain and inundate areas that are usually dry. This mechanism typically occurs over a long period of time and generally results in deep, slow moving floodwaters. Image 2 (right hand side) depicts this mechanism.

Mainstream flooding occurs in Exile Bay along the trapezoidal channel known as Saltwater Creek (shown in Figure 1). Historically flooding has occurred along this watercourse from high astronomical tides and was potentially exacerbated between the 1960s and 1990s from the implementation of a weir structure across the channel outlet which was used to retain water for irrigation of the Massey Park Golf Course.

Image 2: Flood Mechanisms affecting Exile Bay

Figure 1: Exile Bay Study Area



2.3 Previous Studies

Several studies related to flooding in the Exile Bay catchment have been undertaken. The most relevant to the current study is the Exile Bay Catchment Flood Study, prepared by GRC Hydro on behalf of Council, with the final report published in December 2020. Other studies include catchment-level studies undertaken by Council, Public Works or consultants on behalf of Council. The following sections summarise the previous studies.

2.3.1 Exile Bay Catchment Flood Study (GRC Hydro, 2020)

The Exile Bay Catchment Flood Study (the Flood Study) was undertaken GRC Hydro on behalf of Council, as park of Council's Floodplain Risk Management Program. As per the NSW FRMM, the flood study covers the first and second stages in the program and prepares Council and the community for the current study, which covers the third and fourth stages of the program.

The Flood Study developed a validated hydrologic/hydraulic modelling system to define flood behaviour for a range of flood magnitudes in the Exile Bay catchment. The flood study used these design flood outputs to:

- Identify properties within the preliminary FPA that may be subject to flood related development controls;
- Analyse key overland flow paths through the catchment and investigate flood mechanism in detail;
- Assess the economics impacts of flooding in the flood damages assessment; and
- Undertake a preliminary mitigation analysis of works identified by Council. This process assessed measures such as removal of potential flow impediments and increasing the capacity of Saltwater Creek for the 10% and 1% AEP events.

2.3.2 Drainage and Catchment-level Studies

Several studies and assessments were undertaken prior to the flood study, for specific drainage or flooding-related issues in and around the Exile Bay catchment. These include a flood study in a neighbouring catchment and reports investigating localised flooding issues within the catchment, work within the Massey Park canal, large historic storms and flood related impacts of the WestConnex development. These studies are summarised in Section 3.2 of the Flood Study and having been used by the flood study in verification of the flood risk ages, do not have a direct bearing on the current study.

2.4 Social Demographics

Exile Bay's social demographics can provide valuable insight into the community flood awareness and identify factors that may impede residents from acting and reacting to a flood. Data from the 2021 Census (Australian Bureau of Statistics) in the suburb Concord has been obtained and assessed below.

Concord has a population of 14,551 residents living in 5,349. 19.7% of the population is aged 65 or older, similar to the NSW average of 17.7%.

Approximately 10% of the respondents to the 2021 Census indicated that they had moved into Concord in the last 12 months and 24% of the respondents had relocated to Concord in the last 5 years. Such information provides insight into the general flood awareness of the community, in particular close to a quarter of the population have moved to the area very recently making them less likely to have knowledge of previous flood events. Given this, additional efforts should be made to build awareness in the community of the potential flood hazards and best preparedness practice.

Community engagement and provision of flood information is a key part of the Floodplain Risk Management Process. As such, the 2021 Census data provides useful information to the languages spoken by Concord's residents. Based on this data, approximately 62% of Census respondents reported that English was the primary language spoken at home. Some other languages spoken at home included Italian, Mandarin, Cantonese and Arabic.

Evacuation, if required, during significant flood events is primarily undertaken by residents in private vehicles, however, consideration needs to be given to those dwellings that do not possess a motor vehicle and as such, alternative means of evacuation need to be provided. The 2021 Census data indicates that only 8.5% of households in Concord do not posses a motor vehicle which was greater the national average of 7.3%.

3. POLICIES, LEGISLATION AND GUIDANCE

3.1 Implemented Guidelines and References

Table 2 presents the guidelines, manuals and technical reference documents used for this study. These documents detail best practice in regard to management of flood risk. They cover both best practice regarding the technical assessment of flood behaviour and flood risk, and, more generally, who has responsibility for managing flood risk and how this management is best achieved.

Table 2: Guidelines and reference documents

Reference	Topic
Australian Emergency Management (AEM) Handbook Series, Managing the floodplain: A guide to best practice in flood risk management in Australia – AEM Handbook 7	Best practice
AEM Handbook 7, Technical flood risk management guideline – Flood Hazard	Flood hazard
AEM Handbook 7, Technical flood risk management guideline – Flood Emergency Response Classification	Emergency response
AEM Handbook 7, Technical flood risk management guideline – Flood risk information to support land-use planning	Land use
AEM Handbook 7, Technical flood risk management guideline – Assessing options and service levels for treating existing risk	Mitigation options and service levels
AEM Handbook 6, National Strategy for Disaster Resilience – community engagement framework	Community engagement
Australian Rainfall & Runoff 2016	Best practice
Section 733 of the Local Government Act, 1993	Flood prone land policy
NSW Government's Flood Risk Management Manual (2023)	Policy and Manual for management of flood liable land
SES requirements from floodplain risk management process	SES requirements
Practical consideration of climate change	Climate change
Coincidence of Coastal Inundation and Catchment Flooding	The chance of flood produced from catchment occurring at the same time as riverine flood

3.2 Summary of Council Planning Policy and Manuals

3.2.1 City of Canada Bay Local Environment Plan

A Local Environmental Plan (LEP) is a statutory document developed to guide planning decisions for local government areas. LEP's are primarily used as a planning tool to aid the future of communities and to direct development in the study area.

In July 2021, the Department of Climate Change, Energy, the Environment and Water (DCCEEW) developed a set of settled model clauses for use in LEPs, with a specific clause for flood affected land. Model provisions relating to flooding were formally incorporated into the Standard Instrument Local Environmental Plan (SI LEP) Order. The first model provision (clause 5.21) is compulsory for inclusion in all council LEPs and effectively relates to development on land within a Flood Planning Area. The second model provision (clause 5.22) is optional and relates to development on land located between the Flood Planning Area and the Probable Maximum Flood.

Both flood related clauses (clause 5.21 and clause 5.22) were incorporated into the City of Canada Bay LEP 2013 (clause 5.21). The current study will be used in the development of a FPA and Flood Risk Precincts for the Exile Bay catchment which will aid the application on these controls (see Section 5.4).

3.2.2 City of Canada Bay Development Control Plan (DCP) 2023

A Development Control Plan (DCP) is a non-statutory document which supports the planning controls in the LEP by providing detailed planning and design guidelines.

The City of Canada Bay DCP was adopted by Council in March 2023. Section B8 – Flooding Control uses a Flood Planning Matrix to outline the relevant Planning and Development Controls within the study area. This approach uses the land use and the level of flood risk at the site to determine the applicable Flood Planning Controls within the Probable Maximum Flood which aligns with the new flood related LEP clauses (clause 5.21 and clause 5.22). The DCP generally contains all the typical DCP components necessary for Council to manage flood risk in the catchment. The outputs from the current study will inform the application and refinement of these controls using the Flood Planning Area (see Section 5.4) and Flood Risk Precincts (see Section 5.4.1).

3.2.3 Section 10.7 Certificates

A Planning Certificate issued under Section 10.7(2) provides information about the zoning and permissible land uses of the property, the relevant state, regional and local planning controls and other property encumbrances such as land contamination, land acquisition, flooding and acid sulphate soils.

Item 9 of Council's 10.7(2) provides information on whether the land is within the flood planning area and/or between the flood planning area and the Probable Maximum Flood. As the present study is finalised and adopted the 10.7(2) wording should be amended identify the flood affectation on the land of interest.

3.3 The Bay Flood Emergency Sub Plan 2021

The Bay Flood Emergency Sub Plan is a subplan of The Bay Local Emergency Management Plan (EMPLAN). This plan was prepared by the Local Emergency Management Committee in accordance with the State Emergency and Rescue Management Ace 1989 (NSW). The plan sets out the emergency management for flooding in the Burwood, Canada Bay and Strathfield Local Government Areas (LGAs).

3.4 State and National Plans and Policies

Management of flood risk in the catchment is also guided by various state-wide and national policies related to floodplain management in Australia. These have been listed below, including their relevance to the current study:

- *Australian Rainfall and Runoff 2019* – This national guideline document is used for the estimation of design flood characteristics in Australia. It sets out hydrological data and procedures to be used for hydrological and hydraulic modelling of flooding in Australia.
- *NSW Environmental Planning and Assessment Act 1979* – Is the overarching state legislation for local legislation. The Act provides the framework for regulating and protecting the environment and controlling development. Pursuant to Section 9.1 of the EP&A Act, councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. It specifies how councils' LEPs manage flooding.
- *NSW Flood Prone Land Policy* - aims to reduce the impact of flooding and flood liability on individual land owners and occupiers of flood prone property and to reduce private and public losses resulting from floods via economically positive methods where possible. The NSW Floodplain Development Manual supports the policy.
- *NSW Government's Flood Risk Management Manual (2023)* – Defines the assessment and management of flood risk in NSW, including flood hazard, flood function, emergency management and other variables. More broadly it sets out the objectives for floodplain development in the state, including descriptions of types of mitigation measures. This manual guides councils in the development and implementation of local floodplain risk management plans to produce robust and effective floodplain risk management outcomes in accordance with the NSW Government's Flood Prone Land Policy.
- *State Environmental Planning Policy (Exempt and Complying Development Codes) (2008)* - are environmental planning tools used to address planning issues within NSW. In a flooding context, the SEPP for Exempt and Complying Development Codes 2008 is key for defining:
    - Exempt developments, where development can occur without the need for development consent; and
    - Complying development, where development must be carried out in accordance with a complying development certificate.

  The policy provides further information on where and development of flood-prone land should occur.

3.5 Previous Studies

Several studies related to flooding in the Exile Bay catchment have been undertaken. The most relevant to the current study is the Exile Bay Catchment Flood Study, prepared by GRC Hydro on behalf of Council, with the final report published in December 2020. Other studies include catchment-level studies undertaken by Council, Public Works or consultants on behalf of Council. The following sections summarise the previous studies.

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- Assess the economics impacts of flooding in the flood damages assessment; and
- Undertake a preliminary mitigation analysis of works identified by Council. This process assessed measures such as removal of potential flow impediments and increasing the capacity of Saltwater Creek for the 10% and 1% AEP events.

3.5.2 Drainage and Catchment-level Studies

Several studies and assessments were undertaken prior to the flood study, for specific drainage or flooding-related issues in and around the Exile Bay catchment. These include a flood study in a neighbouring catchment and reports investigating localised flooding issues within the catchment, work within the Massey Park canal, large historic storms and flood related impacts of the WestConnex development. These studies are summarised in Section 3.2 of the Flood Study and having been used by the flood study in verification of the flood risk ages, do not have a direct bearing on the current study.

4. COMMUNITY CONSULTATION

Community consultation formed an integral part in completing Stages 1 and 2 of the Exile Bay Catchment Flood Study. Following on from this approach, community consultation was undertaken during the Study to inform residents about the current Study, gather further information on flooding as well as potential flood mitigation measures, identify community concerns, and most importantly, develop and maintain community confidence and collaboration in the Study results.

Following the inception of the Study, Council provided information on the floodplain risk management process on their website. A newsletter and online questionnaire was distributed to selected residents in August 2023. Community members who did not receive a newsletter were still able to participate in the questionnaire via Council's website. The results of the survey are documented in the following section.

4.1 Newsletter and Questionnaire

A newsletter and questionnaire was developed for the community in collaboration with Council and presented in Appendix B. The newsletter introduced the study and its objectives and requested feedback via the online questionnaire. Preliminary flood results were used to identify key locations where the targeted newsletter and questionnaire were sent (approximately 1600 properties). Community members who did not receive a questionnaire were still able to participate in the questionnaire via Council's website.

In August 2023, Newsletters were distributed by Council and 80 responses were received from the community. Approximately 23% of respondents indicated that they had experienced flooding in their yard or garage, while 3% of respondents had experienced over floor flooding. These results highlight that there is some awareness of flooding in the study area and the potential for flooding to impact on properties.

Community members were asked whether they had noticed anything that had made flooding in their area worse, with 40% of respondents indicating that they had. These community members provided insight regarding of key areas of concern within the catchment and noted factors exacerbating flooding in their locality such as blocked drains, too few stormwater inlets and development in the area. This input has helped to inform the assessment of Flood Modification Measures in Section 7.

The questionnaire provided a range of potential mitigation measures to manage flood risk and asked community members to select their preferred measures. A large majority of respondents indicated that they would prefer an upgrade of stormwater drains to increase their capacity to handle flood events. Given this, stormwater upgrades has been a key focus area for the subsequent analysis of Floodplain Risk Management Measures (see Section 7). Other popular measures included an improvement of overland flow paths to increase their capacity and imposing greater flood-related development controls and increase strategic flood planning. Consideration of these community preferences has been taken into account when deriving and assessment potential flood management measures.

4.2 Public Exhibition

Additional community consultation will be undertaken during the public exhibition of the draft Floodplain Risk Management Study and Plan.

5. ANALYSIS OF FLOOD MODEL RESULTS

5.1 Flood Hazard

Flood hazard is defined as a source of potential harm or a situation with the potential to result in loss (Reference 2). It is initially calculated based on the depth and velocity of floodwaters. Flood Hazard is calculated in accordance with the Australian Emergency Management Handbook 7 Guideline (Reference 1) and ARR2019. This considers the threat to people of various ages (children, adults) and to the community interacting with floodwaters (pedestrians, vehicles and those within buildings). Chart 1 and Table 3 present the relationship between the velocity and depth of floodwaters and the corresponding classification.

Chart 1: Flood Hazard Curves (Australian Emergency Management Handbook 7)

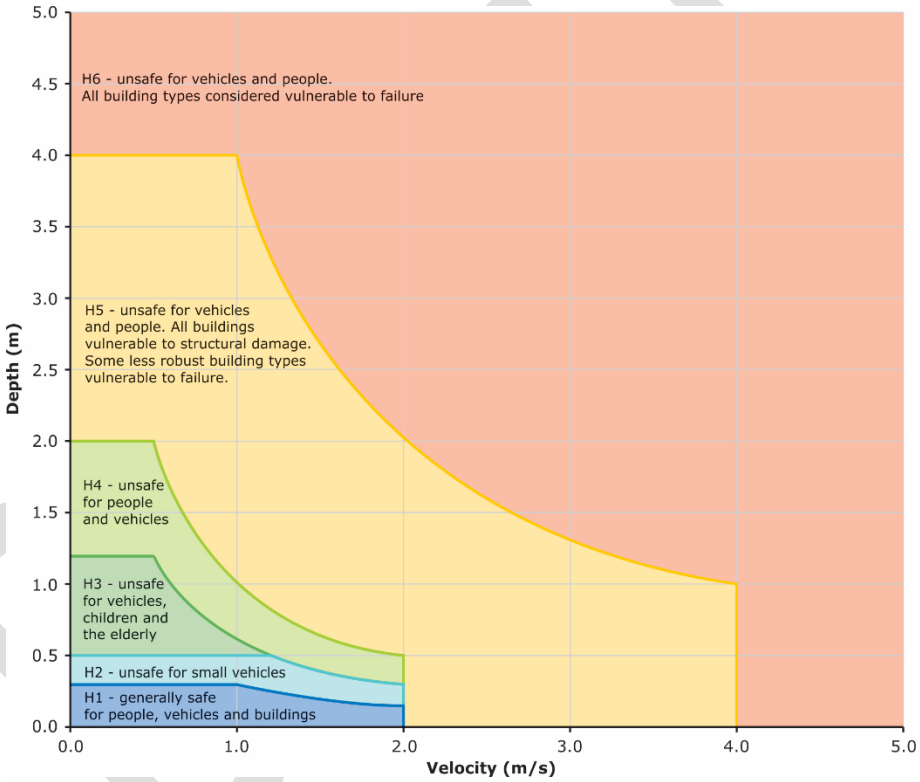

Table 3: Flood Hazard – Vulnerability Thresholds

Hazard Classification	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 buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Figure 2 to Figure 5 present the flood hazard classifications for the 5% AEP, 1 % AEP, 0.2% AEP and PMF events respectively. Across all design flood events, the majority of the study area has been classified as H1 hazard indicating that flooding in these areas is generally safe for the community. As the flood event increases in magnitude, so too does the flood hazard classifications along the Central Drain and the Main South Drain.

In the 1% AEP event, the majority of the Main South Drain is either a H2 or H3 hazard classification indicating that flooding along this waterway is unsafe for vehicles, children and the elderly. On the Main South Drain there is a small area of H4 to H5 at the constriction downstream of Rothwell Park (Hotspot 2, see Section 6.2.2) indicating that flooding is unsafe for all vehicles and people. Similarly, along the Central Drain, the hazard classification in the 1% AEP event is typically H2 or H3 with areas of H4 or H5 along on Davidson Avenue as it approaches Majors Bay Road and along Brewer Street. These high hazard classifications (H4 to H5) are primarily located along roadways rather than within properties in the 1% AEP event. As such, it is recommended that traffic and pedestrian management measures are implemented to ensure those in the hazardous areas are safe i.e. cars and pedestrians are not entering hazardous floodwaters. These measures have been considered further in Section 7.

In the 5% AEP event, a number of key roadways in the catchment are affected by H2 hazard. These include, John Street, Gipps Street, Crane Street, Greenlees Avenue, Davidson Avenue, Majors Bay Road, Brewer Street and Spring Street. Further, Ian Parade and Wellbank Street are both affected by H3 hazard in the 5% AEP making it unsafe for vehicles and people during this event.

5.2 Flood Function

Flood Function (also known as Hydraulic Categories) refers to the classification of floodwaters into three categories; Floodways, flood storage and flood fringe. These categories help to describe the nature of flooding across the floodplain and aid planning when assessing developable areas. According to the NSW Government's Flood Function these three categories can be defined as:

- Floodways – are generally areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels. ;
- Flood Storage – which are areas outside of floodways, are generally areas that store a significant proportion of volume of water and where flood behaviour is sensitive to changes that impact on the storage of water during a flood..
- Flood Fringe –are area with in the extent of flooding for the event but which are outside floodways and flood storage areas. Flood fringe areas are not sensitive to change in either flow conveyance or storage. .

There is no prescribed methodology for deriving each category and as such categorisation is typically determined based on experience and knowledge of the study area.

For the current study, the flood function classifications have been undertaken in accordance with the findings of Howells et al, 2003 (Reference 4), who defined these categories based on the depth and velocity of flood waters. For the technical calculation of these classifications in Exile Bay the following is proposed:

- Floodway – areas where:
  - the velocity-depth product > 0.25 m^2/s and peak velocity >0.25 m/s
    or
  - velocity > 1 m/s
- Flood Storage - areas outside the Flow Conveyance where depths exceed 0.5 m
- Flood Fringe – areas outside of Flow Conveyance where depths are less than 0.5 m

Figure 6 to Figure 9 present the Flood Function for the 5% AEP, 1% AEP, 0.2% AEP and PMF events respectively.

In the 1% AEP event, the flow conveyance in Exile Bay occurs primarily along key flow paths such as the Central Drain, Main South Drain and Saltwater Creek. Flow conveyance also occurs along key overland flow paths through private properties. Development in these areas is likely to significantly alter the distribution of flow and increase flood levels nearby.

Flood Storage areas are predominantly found along the downstream areas at Edwards Park, Greenlees Park and in Massey Park Golf Course. Filling of flood storage areas may cause flood level impacts in downstream neighbouring areas.

The remainder of flood affected areas in the catchment are classified as Flood Fringe. Development in areas of Flood Fringe are unlikely to significantly alter flood behaviour.

5.3 Emergency Response Classifications

Flood Emergency Response pertains to a set of classifications that advise how a community is affected by flooding and informs the decision-making process during a flood event. These classifications consider the full range of flood behaviour up to the PMF event. Factors such as isolation, evacuation routes, effective warning times, the rate of rise of floodwaters and the duration of isolation are considered when determining the classification.

In the current study, Flood Emergency Response classifications have been undertaken in accordance with the Australian Emergency Management Handbook 7 (Reference 1) and are detailed in Table 4.

Table 4: Flood Emergency Response Classifications (Reference 1)

Primary Classification	Secondary Classification	Tertiary Classification
Flooded (F) The area is flooded in the PMF	Isolated (I) Isolated from community evacuation facilities by floodwater and/or impossible terrain as waters rise during events up to the PMF. Likely to lose services during a flood.	Submerged (FIS) Where all land in isolate area will be fully submerged in PMF after becoming isolated.
		Elevated (FIE) Where there is a substantial amount of land in isolated areas elevated above the PMF.
	Exit Route (E) Areas that are not isolated in the PMF and have an exit	Overland Escape (FEO) Evacuation from the area relies upon overland escape routes that rise out of the floodplain

	route to community evacuation facilities.	Rising Road (FER) Evacuation routes from the area follow roads that rise out of the floodplain.
Not Flooded	Indirect Consequence (NIC) Areas that are not flooded but may lose services.	
	Flood Free Areas that are not flood affected or indirectly affected by flooding.	

Emergency response classifications typically pertain to areas impeded by mainstream flooding where there are significant warning times allowing for preventative action to be taken. In areas predominantly affected by overland and flash flooding, such as Exile Bay, preventative action cannot be undertaken due to a lack of flood warning time (effectively zero). In the event of flooding, generally, residents are safest indoors and should avoid walking or driving in flood waters. Therefore, in Exile Bay, emergency response classifications will be most useful for agencies, such as the SES, as a response to the aftermath of a flood.

Figure 10 presents the emergency response classifications for Exile Bay. Much of the catchment was found to be Flood Free, Indirect Consequence or Flooded with a Rising Road Exit Route (see Table 4). Along the Main South Drain and the Central Drain there are large areas of Flooded, Isolated and Submerged (FIS) or areas with an Overland Escape Exit Route (FEO).

In areas of FEO, road access would not be possible for the duration of the flood event however access can be achieved overland (i.e. on foot). Due to the short duration of these events (for much of the catchment – peak duration will be measured in minutes), residents in these areas would generally be safest waiting for floodwaters to recede before exiting their properties.

In areas of FIS, road access would be cut prior to properties being inundated by floodwaters. The flooding Hotspots assessed in Section 6.2 are located within areas classified as FIS.

Flood Emergency Response classifications are derived for the PMF flood event only. Due to the flash flood nature of the catchment the event magnitude is unknown at the time of the event. If those responding to a flood used Emergency Response classifications derived for a smaller event than that which is occurring, these classifications may be incorrect. A key example of this is the classification of Flooded, Isolated, Elevated (FIE) and Flooded, Isolated, Submerged (FIS). The classifications derived for a smaller event may define areas as FIE meaning that they lose flood access however they are not inundated. In larger events however, these FIE areas may become inundated meaning that their classification changes to FIS and as such their affectation is more severe. Thus, given the flash flood nature of the catchment and the unknown event magnitude, it is precautionary to only use the PMF emergency response classifications.

5.4 Flood Planning Area

The Flood Planning Area (FPA) defines properties that are subject to flood related development controls. The FPA is a key planning tool for managing and mitigating flood risk in an LGA.

The process of deriving the FPA varies greatly depending on the dominant flood mechanism in a study area. The Floodplain Development Manual (Reference 6) recommends the generation of the FPA using the 1% AEP flood level plus 0.5 m freeboard level. This methodology is suitable for mainstream flooding however in Exile Bay if this approach is used to define the FPA, homes with no level of flood affectation will be subject to flood related development controls. Since such an outcome is untenable, a different approach is utilised for deriving the FPA in areas of overland flow. Where the two flood mechanisms exist, such as in the study area, FPA's generated by both methods will be enveloped.

For areas affected by overland flow, analysis of the flood affection of each cadastral lot can be undertaken to derive the FPA. This approach has been adopted in numerous studies within the Sydney Metropolitan area.

The following methodology has been used to select cadastral lots within the preliminary Exile Bay FPA:

- Mainstream Flooding: The 1% AEP peak flood level within Saltwater Creek, Edwards Park and Greenlees Park plus 0.5 m freeboard, then extending the level perpendicular to the direction of flow.
- Overland Flow Flooding: Cadastral lots where 10% or greater of the cadastral lot is affected by 1% AEP peak flood depths of greater than 0.15 m.

Using the aforementioned criteria, a set of properties were identified using the 1% AEP design flood results and their flood affectation was verified during a ground truthing exercise carried out during the Flood Study. Following the site visit, further understanding was gained regarding the different flood mechanisms that can affect individual properties within the study area. This process identified 274 properties for inclusion in the Section 10.7 certificate and these residents were notified and consulted with during public exhibition of the Flood Study. These properties were also included in the Flood Planning Maps in Council's DCP.

The properties which form the current FPA are shown in Figure 11.

5.4.1 Flood Risk Precincts

Since the completion of the Flood Study, new flood related LEP clauses (clause 5.21 and clause 5.22) and state government ministerial directions have shifted the focus of the application of flood related development controls from the 1% AEP extent to a wider range of events. Given this, Council's DCP (see Section 3.2.2), adopted in March 2023, has introduced a Flood Planning Matrix approach to outline relevant Planning and Development controls using the land use and level of flood risk at a site. The DCP outlines Flood Risk Precincts to define flood affected areas as Low, Medium and High Risk using the 1% AEP and PMF flood outputs. The DCP defines these precincts as follows:

High Flood Risk Precinct: An area of land that under 1% AEP conditions is either subject to high hydraulic hazard or present significant evacuation difficulties.

Medium Flood Risk Precinct: An area of land that under 1% AEP conditions is not subject to high hydraulic hazard and presents less than significant evacuation difficulties.

Low Flood Risk Precinct: An area of land above the 100 year flood and includes all area up to and including the 'Probable Maximum Flood (PMF)'.

Council may consider expanding the FPA to include all areas in the PMF extent to align with the DCP's Flood Planning Matrix (see Section 7.1.2). Should this approach be adopted, it is expected that a very small number of properties within the Flow Conveyance would be classified as a High Flood Risk Precinct, properties within the 1% AEP would receive a Medium classification and remaining lots within the PMF extent would be categorised as a Low Flood Risk Precinct.

5.5 Climate Change

The impact of climate change on flood producing rainfall and resultant flooding has been assessed. The assessment used the IPCC (Intergovernmental Panel on Climate Change) greenhouse gas concentration scenarios to estimate the effect of climate change on rare rainfall events. There are four IPCC greenhouse gas concentration projections named Representative Concentration Pathways (RCPs) 2.6, 4.5, 6.0 and 8.5, with the RCP 2.6 being the most optimistic and 8.5 the least optimistic. The ARR2019 methodology recommends the use of RCP 4.5 and 8.5 scenarios, and their projected increase in precipitation intensity were obtained from the ARR Data Hub and shown in Table 5 for the 2090 planning horizon.

Table 5: Climate Change Factors – Percentage Increase in Rainfall Intensity in 2090

Year	RCP 4.5	RCP 8.5
2090	+9.1%	+18.6%

The IPCC recommendations indicate, under a relatively low emissions scenario (RCP 4.5), that rainfall intensity is expected to increase by 9.1% in the Exile Bay catchment by 2090. The significance of this percentage is measured by comparing it to the range of design flood events. The results of this assessment are shown in Table 6, which lists the total rainfall depth for the 1%, 0.5% and 0.2% AEP events (for the 1% AEP critical duration) and then compares those events with the increased rainfall caused by two emissions scenarios – RCP 4.5 and RCP 8.5.

Table 6: Comparison between Design Rainfall and Projected Climate Change Rainfall Depths

AEP	Duration (mins)	Total Rainfall Depth (mm) IFD	2090 RCP 4.5 +9.1%	2090 RCP 8.5 +18.6%
1%	60	64.2	70.0	76.1
	180	94.8	103.4	112.4
0.5%	60	70.2	76.6	83.3
	180	103	112.4	122.2
0.2%	60	79.6	86.8	94.4
	180	117	127.6	138.8

The table shows that the 1% AEP flood event will increase to a magnitude close to the present day 0.5% AEP event under the 2090 RCP 4.5 scenario (corresponding depths shown in red in Table 6).

Under the 2090 RCP 8.5 scenario, the 1% AEP storm event will be equivalent to a present-day event between 0.5% and 0.2% AEP (shown in red and green in Table 6). Accordingly, these rarer design events have been used as proxies for the assessment of climate change sensitivity with flood impact maps comparing the 1% AEP event to the 0.5% AEP and 0.2% AEP events presented in Figure 12 and Figure 13.

The results show that increases in flood level associated with climate change is likely to be less than 0.15 m for along the central drain and the main south drain under both emissions scenarios. For the RCP 8.5 emissions scenario, increase in flood level of typically less than 0.2 m are noted at the constraint between Rothwell Park and Jessie Stewart Reserve.

5.5.1 Sea Level Rise

Guidance on predicted sea level rise was released by the NSW Government in 2009, again in 2010 and then, in 2012, the NSW State Government retracted this advice. Since that time, sea level rise has been determined by individual local government areas.

In the absence of sea level rise advice, a 2100 level of 0.9 m has been adopted and tested for the current study in accordance with the "NSW Sea Level Rise Policy Statement" (October 2009). The application of these levels in the Exile Bay hydraulic model are summarised in Table 7.

Table 7: Adopted 2100 Sea Level Rise Tailwater Conditions

Design Event (AEP)	2100 Sea Level Rise Tailwater Level (m AHD)
1% Envelope	1% Harbour Level + 0.9 m 1.435 m AHD + 0.9 m = 2.335 m AHD
	5% Harbour Level + 0.9 m 1.375 m AHD + 0.9 m = 2.275 m AHD
0.5%	1% Harbour Level + 0.9 m 1.435 m AHD + 0.9 m = 2.335 m AHD
0.2%	1% Harbour Level + 0.9 m 1.435 m AHD + 0.9 m = 2.335 m AHD
PMF	1% Harbour Level + 0.9 m 1.435 m AHD + 0.9 m = 2.335 m AHD

Changes to peak flood levels from the sea level rise scenario are presented in Table 8. As expected, peak, flood levels in upstream areas were found to be generally unaffected by a change in sea level however significant increases of up to 0.86 m were found in downstream areas such as Massey Park Golf Club and along Saltwater Creek.

Table 8: Sea Level Rise Sensitivity

ID	Location	Change in Design Flood level with 2100 sea level rise (0.9 m)			
		1% AEP	0.5% AEP	0.2% AEP	PMF
1	Low Point on Davidson Ave, near Flavelle St	0.00	0.00	0.00	0.00
2	Intersection of Davidson Ave & Majors Bay Rd	0.01	0.01	0.00	0.00
3	Low Point on Spring St, near Brewer St	0.04	0.04	0.04	0.02
4	Low Point on Curtin Pl	0.01	0.01	0.01	0.00
5	Low Point on Wellbank St, near Central Park	0.01	0.01	0.01	0.00
6	Low Point on Creewood St	0.00	0.00	0.00	0.00
7	Low Point on Kentwell Ave	0.00	0.00	0.00	0.00
8	Low Point on Parramatta Rd	0.00	0.00	0.00	0.00
9	Low Point on Ada St	0.00	0.00	0.00	0.00
10	Low Point on Coles St	0.00	0.00	0.00	0.00
11	Low Point on Melbourne St	0.00	0.00	0.00	0.00
12	Low Point on John St, near Goddard Park	0.00	0.00	0.00	0.00
13	Low Point on Gipps St, downstream of Goddard Park	0.00	0.00	0.00	0.00
14	Intersection of Crane St & Majors Bay Rd	0.00	0.00	0.00	0.00
15	Eastern edge of Rothwell Park	0.00	0.00	0.00	0.00
16	Downstream of the Rothwell Park	0.01	0.01	0.01	0.00
17	Low Point on Jones St	0.03	0.03	0.02	0.00
18	Western edge of Jessie Stewart Reserve	0.05	0.04	0.04	0.02
19	Low Point on Greenlees Ave	0.05	0.04	0.04	0.02
20	Low Point on Ian Parade	0.05	0.04	0.03	0.02
21	Intersection of Wellbank St & Ian Parade	0.06	0.04	0.03	0.03
22	Low Point on Brewer St, close to Edwards Park	0.01	0.01	0.01	0.02
23	Low Point on Smythes St	0.01	0.01	0.01	0.00
24	Low Point on Anderson Rd	0.00	0.00	0.00	0.00
25	Upstream of the first Saltwater Creek Crossing	0.27	0.27	0.22	0.03
26	Upstream of the second Saltwater Creek Crossing	0.73	0.73	0.67	0.06
27	Upstream of the Saltwater Creek Crossing closest to Exile Bay	0.81	0.86	0.85	0.86
28	Low Point on Cabarita Rd, near Massey Park Golf Club	0.00	0.00	0.00	0.00
29	Low Point on Massey Park Golf Course	0.26	0.26	0.22	0.03
30	Low Point on Broughton St	0.00	0.00	0.00	0.00
31	Downstream of Central Park	0.00	0.00	0.00	0.00

6.COMMUNITY FLOOD RISK ASSESSMENT

6.1 Overview

An assessment of Exile Bay's flood behaviour and community profile has been carried out to determine specific areas of flood risk across a range of metrics, including; property flood liability, flood hazard, hydraulic categories and the economic impact of flooding.

The Flood Study results have been utilised in the following sections to examine areas of risk associated with flooding in the Exile Bay catchment. The following sections describe the consequences of flooding in the study area and include:

- Identification of key flood risk areas and the development of flooding hotpots (Section 6.2);
- Information on flood roads (Section 6.3);
- Assessment of the economic impact of flooding in Exile Bay (Section 6.4) and
- Review of critical infrastructure and sensitive land uses (Section 6.5).

The findings from this analysis have aided the selection and assessment flood risk management measures in Section 7.

6.2 Flooding Hotspots

Hotspots refer to areas that are particularly flood affected and/or affected by hazardous flooding. These areas have been identified over the course of the floodplain risk management process via consultation with Council and the community and analysis of flood modelling results. The following sections will discuss the flood mechanisms affecting the selected hotspots.

Please note that all figures for the Hotspot Analysis are presented at the end of the report.

6.2.1 Hotspot 1: Parramatta Road to John Street

Hotspot 1 denotes the natural overland flow path at the upstream reach of the Main South Drain. Hotspot 1 traverses properties between Parramatta Road and John Street. Figure 14 presents the 5% AEP, 1% AEP and PMF design flood results at Hotspot 1 and the peak flow results at various locations along the flow path.

Flow originates in the upper Exile Bay catchment areas (in Burwood Council LGA) and flows in a northerly direction toward Parramatta Road where it enters the Canada Bay LGA. The catchment area upstream of Parramatta Road is approximately 22 hectares. In the 1% AEP event, approximately 5.5 m^3/s (4.3 m^3/s overland flow and 1.2 m^3/s of pipe flow) crosses Parramatta Road at the low point downstream of Phillip Street, Strathfield. Flood waters then enter Coles Street where 6.6 m^3/s (4.7 m^3/s of overland flow and 1.9 m^3/s of pipe flow) flows toward the low point in the road before traversing properties along Coles Street and Melbourne Street. In the 1% AEP event, 10 m^3/s (7.2 m^3/s of overland flow and 2.8 m^3/s of pipe flow) moves through properties on Melbourne Street toward John Street.

The capacity of the trunk drainage system, between Ada Street and Gipps Street is reached in the 1 EY event and as such additional flow is conveyed overland. Increasing the capacity of the trunk

drainage system would provide some benefit however the application of this measure has limited feasibility as the current pipe network lies beneath private property. This has been investigated in Section 7.3.3.5.

6.2.2 Hotspot 2: Constriction downstream of Rothwell Park

Hotspot 2 represents a flow constriction along the Main South Drain downstream of Rothwell Park. At this constriction, overland flow moves along the low point between the Council Depot in the east and behind properties on Jones Street in the west. Figure 15 present the 5% AEP, 1% AEP and PMF design flood results at Hotspot 2 and the peak flow results at various locations along the flow path.

The Main South Drain at Hotspot 2 has an upstream catchment area of approximately 115 hectares. In the 1% AEP event, 19.6 m^3/s (10.1 m^3/s of overland flow and 9.5 m^3/s of pipe flow) flows through the constriction and properties nearby are inundated by depths of up to 0.7 m. Although Hotspot 2 is traversed by several large stormwater assets, these assets are full in the 1EY event.

GRC Hydro have previously undertaken numerous studies which have investigated modifications to the mounding of the Council depot site to the increase conveyance capacity along this flow path.. Furthermore, Section 7.3.3.3, 7.3.3.6 and 7.3.3.8 have looked at drainage modifications in this location to mitigate the more frequent flood events. Other topographic modifications such a lowering roadway and implementing embankments in this area were investigated Section 7.3.3.10 and 7.3.3.13.

6.2.3 Hotspot 3: Central Drain upstream of Davidson Avenue

Hotspot 3 pertains to the upper reaches of the Central Drain where several overland flow paths meet at Wellbank Street, upstream of Central Park. Figure 16 present the 5% AEP, 1% AEP and PMF design flood results at Hotspot 3 and the peak flow results at various locations along the flow path.

Overland flow paths from the 34 hectare catchment, upstream of Wellbank Street, combine before flowing through Central Park and Curtin Place and moving toward Davidson Avenue (see Section 6.2.4). These overland flow paths and their respective peak 1% AEP flows are listed below:

- Overland flow path from Station Street and Cross Street – 4.1 m^3/s (2.8 m^3/s of overland flow and 1.3 m^3/s of pipe flow);
- Overland flow path from Macnamara Avenue – 4.9 m^3/s (4.4 m^3/s of overland flow and 0.5 m^3/s of pipe flow);
- Overland flow path from Castlereagh Street – 1.4 m^3/s of overland flow; and
- Minor overland flow path from the catchment east of Wellbank Street – 0.8 m^3/s (0.7 m^3/s of overland flow and 0.1 m^3/s of pipe flow).

As flow moves downstream, through Central Park, 8.8 m^3/s approaches Davidson Avenue (6.3 m^3/s of overland flow and 2.5 m^3/s of pipe flow) in the 1% AEP event. Approximately 4.3 m^3/s of the overland flow from Central Park, deviates and inundates Curtin Place to the east where floodwaters store in the cul-de-sac. Flow from Curtin Place and Central Park then traverses properties on Davidson Avenue and moving in an easterly direction (see Section 6.2.4).

Despite there being several large trunk drainage assets along Hotspot 3, the capacity of this system is typically reached in the 1EY event. Section 7.3.3.1 and 7.3.3.12 have examined drainage and topographic modifications, respectively, in this location to alleviate flooding at this location.

6.2.4 Hotspot 4: Davidson Avenue

Hotpot 4 is a continuation of the Central Drain from Hotspot 3 (see Section 6.2.3) and denotes the natural overland flow path that moves along Davidson Avenue toward Majors Bay Road. Figure 17 present the 5% AEP, 1% AEP and PMF design flood results at Hotspot 4 and the peak flow results at various locations along the flow path.

At Favelle Street, overland flow paths from the north, south and west, with a total catchment area of 64 hectares, meet at Davidson Avenue and continue to flow in an easterly direction. From the north of Favelle Street, 1.2 m^3/s in the 1% AEP event (1.1 m^3/s of overland flow and 0.1 m^3/s of pipe flow) approach Davidson Avenue. To the south, 1.5 m^3/s (1.2 m^3/s of overland flow and 0.3 m^3/s of pipe flow) approach Davidson Avenue in the 1% AEP event. Upstream of Favelle Street (west), 12.5 m^3/s (9.7 m^3/s of overland flow and 2.8 m^3/s of pipe flow) flow along Davidson Avenue. Downstream of Favelle Street, 14.5 m^3/s (12.1 m^3/s of overland flow and 2.4 m^3/s of pipe flow) flows along Davidson Avenue in the 1% AEP event.

As floodwaters on Davidson Avenue approach Majors Bay Road, flood depths increase to up to 0.85 m in the 1% AEP event as the flow path crosses Majors Bay Road to Brewer Street (see Hotspot 5, Section 6.2.5)

Hotspot 4 is a key thoroughfare for flood waters along the Central Drain and as such, it has been a key location for the investigation of Floodplain Risk Management Measures. Section 7.3.3.2 investigates drainage enhancements along this roadway.

6.2.5 Hotspot 5: Majors Bay Road and Brewer Street intersection

Hotspot 5 is located downstream of Hotspot 4 (see Section 6.2.4), along the Central Drain, at the intersection of Majors Bay Road and Brewer Street. Figure 18 present the 5% AEP, 1% AEP and PMF design flood results at Hotspot 4 and the peak flow results at various locations along the flow path.

At the Majors Bay Road intersection, the Davidson Avenue flow path (Hotspot 4, see Section 6.2.4) meets flow from the north and south of Majors Bay Road and then flows along Brewer Street. In the 1% AEP event, 15.7 m^3/s (13.4 m^3/s of overland flow and 2.3 m^3/s of pipe flow) enters the Hotspot 5 intersection from Davidson Avenue. This flow is met by 1.0 m^3/s (0.7 m^3/s of overland flow and 0.3 m^3/s of pipe flow) from the north of Majors Bay Road and 2.2 m^3/s (1.7 m^3/s of overland flow and 0.5 m^3/s of pipe flow) from the south. On Brewer Street, 19.2 m^3/s (14.2 m^3/s of overland flow and 5.0 m^3/s of pipe flow) continues downstream.

Similar to Hotspot 4 (see Section 6.2.4), Hotspot 5 is a key thoroughfare for floodwaters on the Central Drain and as such, given the large upstream catchment area, flooding is unlikely to be eliminated. The current study has assessed ways in which these floodwaters could be better managed to improve flooding in the vicinity. The current study has considered reconfiguring the vegetated and median strip at this intersection and regrading the roadway to allow for efficient flow to Brewer Street (see Section 7.3.3.11).

6.2.6 Hotspot 6: Saltwater Creek

Hotspot 6 denotes Saltwater Creek, downstream of Ian Parade, which acts as the key drain to the catchment outlet at Exile Bay. The Saltwater Creek channel flows through the Massey Park Golf

Course and is adjacent to properties on the southern side. Figure 19 present the 5% AEP, 1% AEP and PMF design flood results at Hotspot 4 and the peak flow results at various locations along the flow path.

In the 1% AEP event, 25.3 m^3/s flows along Saltwater Creek toward Exile Bay. The capacity of Saltwater Creek is reached in the 1 EY event albeit for a very brief period. In the 10% AEP event, flooding from the overtopped creek begins to encroach on nearby properties to the south which becomes progressively worse as flood magnitude increases. The Flood Study investigated several mitigation strategies outlined by Council to mitigate flooding in this area. Council has since undertaken steps toward upgrading the Saltwater Creek Channel.

6.3 Road Inundation

Hazardous flooding of roads occurs when there is enough flow to knock over pedestrians or transport cars off the road due to buoyancy and frictional instability. In Australia, vehicles attempting to cross flooded roads is the largest causes of injury and fatality during a flood. The ability of flow to move or completely float a car is often underestimated, with as little as 0.3 m (30 cm) depth enough to move a small car, even at low flow speeds (this corresponds to H2 hazard). Given these figures, an analysis of key flooding hotspots and evacuation routes has been undertaken.

Table 9 presents the flood hazard at key hotspots and roadways throughout the study area and shown in Figure 3.

Table 9: Inundation of hotspots and roads in Exile Bay

ID	Location	Peak Flood Hazards per design event						
		1EY	20% AEP	10% AEP	5% AEP	1% AEP	0.2% AEP	PMF
1	Davidson Ave intersection with Flavelle St	H2	H2	H2	H2	H3	H4	H5
2	Davidson Ave intersection with Majors Bay Rd	H2	H2	H3	H3	H3	H3	H4
3	Spring Street near Brewer Street	H2	H3	H3	H3	H3	H3	H5
4	Curtin Pl near Churchill Cres	H2	H3	H3	H3	H3	H3	H5
5	Wellbank St intersection with Castlereagh St	H1	H1	H1	H1	H2	H2	H4
6	Creewood St near Patterson St	H1	H1	H1	H1	H2	H2	H3
7	Kentwell Ave near Cross St	H1	H1	H2	H2	H2	H2	H4
8	Parramatta Rd intersection with Philip St	H2	H2	H2	H2	H2	H3	H3
9	Ada St near Coles St	H1	H2	H2	H2	H2	H2	H3
10	Coles St near Ada St	H1	H1	H2	H2	H2	H2	H4
11	Melbourne St near Alexandra St	H1	H1	H2	H2	H2	H3	H4
12	John St near Alexandra St	H2	H2	H2	H2	H3	H3	H4
13	Gipps St near Flavelle St	H2	H2	H2	H2	H3	H3	H5
14	Intersection of Major Bay Rd and Crane St	H2	H2	H2	H2	H3	H4	H5
15*	East of Rothwell Park near Beaconsfield Ave	H2	H3	H3	H3	H4	H4	H5
16*	North of Rothwell Park near Beaconsfield Lane	H4	H5	H5	H5	H5	H5	H5
17	Jones St near Rhonda Place	H1	H2	H2	H2	H3	H3	H5

18*	Greenlees Ave- near Gallipoli St	H3	H3	H3	H3	H3	H4	H5
19	South-west of Greenlees Park on Greenlees Ave	H1	H2	H2	H2	H3	H3	H5
20	Ian Parade near Freeman Place	H2	H3	H3	H3	H3	H3	H5
21	Intersection of Wellbank St and Ian Parade	H2	H3	H3	H3	H3	H3	H5
22	Pamela Pl near Spring St	H3	H3	H3	H3	H3	H3	H5
23	Symthes St near Noble St	H1	H1	H1	H1	H2	H2	H5
24	Anderson Rd near Symthes St	H1	H2	H2	H2	H2	H2	H3
28	Cabarita Rd near Bayview Street	H1	H1	H1	H1	H2	H2	H4
30	Broughton St near Richards Pl	H1	H2	H2	H2	H2	H2	H3
31*	North of Scout Hall Central Park	H1	H1	H1	H1	H1	H1	H5

*Note these points are not located on a road, rather on a reserve or parkland

The information presented in Table 9 indicates that roadways in key hotspot areas present safety risks to cars and pedestrians in events as frequent as the 1EY.

6.4 Flood Damages Assessment

6.4.1 Overview

A flood damages assessment is used to quantitively assess the impacts of flooding on the community (Reference 2). Generally, a flood damages assessment aggregates the following:

- Direct costs to individual properties such as structural damages or damage to contents;
- Indirect costs to individual properties such as clean-up, disposal or loss of income; and
- Cost of damage to infrastructure.

The assessment is based on design flood results and information on properties' floor levels, flood hazard and ground levels. Based on the flood liability of each development, a monetary value is applied to each property based on the level of property damage over a range of design flood events. The flood damages assessment is not of sufficient accuracy to determine the exact potential cost of damage at the individual property level. However it gives a fairly accurate catchment-wide estimate that can be compared to other catchments, which use the same assumptions, and also can be used to quantitatively assess any mitigation options that reduce property damage.

The current study uses the recently updated NSW government Flood Damages spreadsheet. A total of 2146 properties were included in the analysis including, 2058 residential properties and 88 non residential sites. Figure 20 and Figure 21 present the first event to inundate each property over ground level (above 0.1 m) and floor level, respectively.

6.4.2 Floor Level Estimation

Floor level estimation was completed for all properties within the Flood Planning Area (FPA) (see Section 5.4). This process was undertaken by estimating the height between the ground level and the lowest habitable floor level. The ground level for each property was determined using LiDAR data. The floor level was determined by adding the LiDAR ground level to the estimated height from ground to floor level.

The height from ground level and to the lowest habitable floor level was estimated, where possible, via Google StreetView for each property within the FPA. Nearby physical features were used to aid the estimation of the ground to floor height, such as the number of bricks to the floor level or the height of a nearby garbage bin. A site visit was undertaken to verify existing floor level estimates and obtain ground to floor estimates for properties that were unable to be seen from Google StreetView. During this process, additional information pertaining to each property was recorded such as the type of house construction and the number of storeys.

For the properties outside of the FPA but within the PMF extent, the ground to floor level was estimated based on the average ground to floor level difference derived for the properties within the FPA.

6.4.3 Residential Flood Damages

Residential flood damages have been estimated in accordance with 'Disaster Cost Benefit Analysis Framework' (NSW Treasury, 2023) and Flood Risk Management Measures: Flood Risk Management Guide (DPE, 2023) which uses the revised 'DT01' flood damages tool. Applied parameters used in this analysis are presented in Table 10.

Table 10: Residential flood damages inputs

	Input Value
Inflation adjustment CPI level	132.7 (Q1, 2024)
Nexis Data Region	Canada Bay LGA
Regional Uplift Factor	1.00 (default)
Infrastructure Damages Uplift	10% of resd. Damage
Emergency Management Uplift	0% (default)
Damage Downscale (Townhouse or Units)	30% (default)
Road repair cost	$5.65
Relocation Cost	$0 (default)
House size	220 m^2 (default)
Average contents per m2	$550
Residential clean-up cost	$4,500
Estimated cost per fatality	$5,300,000
Speed of onset category	3 (rate of rise less than one hour)
Primary Nature of Area	Detached residential dwellings
Effective Warning Time	0 hours

Residential Flood Damage estimates provide a monetary value of flood damages for each property for a range of design flood events. A key outcome of this assessment is the Average Annual Damage (AAD). The AAD is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period. The AAD is primarily used during a Floodplain Risk Management Study and Plan (FRMS&P) to compare the relative economic merits of various proposed flood mitigation measures.

A residential AAD of $2,664,000 was calculated for the Exile Bay catchment. Table 11 presents the AAD and total Residential Flood Damages per design event. Relatively small events have around $3-4 million damage while rare events have around $8-10 million damage, due to the significant amount

of overland flow moving through the catchments. The majority of the AAD is from relatively common events.

Table 11: Residential Flood Damages

Design Event (AEP)	No. of properties flooded above ground	No. of properties flooded above floor	Total Damages	Contribution to AAD total
PMF	1,578	409	$78,330,000	$91,000
0.2%	942	96	$12,737,000	$34,000
0.5%	883	78	$10,076,000	$46,000
1%	842	72	$8,515,000	$74,000
2%	767	55	$6,267,000	$162,000
5%	706	43	$4,536,000	$211,000
10%	660	35	$3,899,000	$330,000
20%	540	20	$2,711,000	$1,715,000
			Average Annual Damages (AAD)	$2,664,000

6.4.4 Non-Residential Flood Damages

The calculation of tangible non-residential flood damages on a large scale can be highly varied. Non-residential flood damages are dependent on factors such as:

- The nature of business undertaken at the property. For example, a business which has a quick turnaround of produce (or limited stock), such as a florist, is likely to suffer a smaller economic loss due to flooding than a business with highly valuable stock and a slower turnaround time, such as an electronics store.
- The floor space of a non-residential property can be related to the amount of stock stored on site and therefore the amount of stock vulnerable to flooding.
- The duration of inundation of a non-residential property and extent of damages can directly affect the length of time that the business may be closed.
- The level of flood awareness/preparedness such as the amount of flood warning and ability to move vulnerable stock can affect the level of flood damage experienced.

The study area is largely residential with only 6 properties in the flooded area identified as non-residential.

Table 12 presents the AAD and the total Non-residential Flood Damages per design event.

Table 12: Non-Residential Flood Damages

Design Event (AEP)	No. of properties flooded above floor	Total Damages	Contribution to AAD total
PMF	18	$4,011,000	$5,000
0.2%	4	$535,000	$1,000
0.5%	4	$434,000	$2,000
1%	3	$377,000	$3,000
2%	3	$247,000	$7,000
5%	2	$222,000	$11,000
10%	2	$222,000	$19,000
20%	2	$167,000	$111,000

Average Annual Damages (AAD)	$160,000

6.4.5 Combined Flood Damages

Net flood damage estimates that combine residential and non-residential flood damages are presented in Table 13. The total damages estimates include infrastructure uplift, estimated as 10% of the residential damages cost.

Table 13: Combined Flood Damages

Design Event (AEP)	Properties Flooded Above Floor	Flood Damages Total
PMF	427	$90,181,000
0.2%	100	$14,545,000
0.5%	82	$11,517,000
1%	75	$9,743,000
2%	58	$7,140,000
5%	45	$5,211,000
10%	37	$4,511,000
20%	22	$3,148,000
Average Annual Damages (AAD)		$3,125,000

6.5 Risk to Sensitive Land Uses and Critical Infrastructure

Critical infrastructure is located throughout the area and if inundated during a flood, may significantly impact the functioning of the local area. The following section describes the flood liability of various critical infrastructure. The section also describes the exposure of facilities particularly sensitive to inundation, including childcare, schools and aged care.

6.5.1 Medical Facilities

Medical Facilities often house vulnerable persons who may require additional resources, warning time and assistance, flooding occurs. In Exile Bay, there are no critical medical facilities such as hospitals or ambulance stations however there are a number of facilities providing medical service during business hours. These facilities have been detailed in Table 14..

Table 14: Flood affectation at medical facilities

Medical Facility	Location	First Flooded at Ground Level	Hazard on Lot and Access Route
Concord Medical Centre	114 Majors Bay Road	Not Flooded	Access issues with H5 on Majors Bay Road in PMF
Majors Bay Medical Centre	77 Majors Bay Road	Not Flooded	Access issues with H5 on Majors Bay Road in PMF
Wellbank Street Medical Practice	28 Wellbank Street	Not Flooded	Not Flooded
Concord Family Doctors	19 Brewer Street	PMF	Up to H4 in PMF on the lot On access route, H2 in 1% AEP (up to H5 in PMF)

Majors Bay Family Dental	148 Majors Bay Road	PMF	Up to H5 in PMF on the lot. Access issues from Majors Bay Road and Davidson Road in the south. Clear access from the north.
Concord Dental Care	126 Majors Bay Road	Not Flooded	Access issues from Majors Bay Road to the north. Clear access from the south.
Concord Dental Practice	103 Majors Bay Road	Not Flooded	Access issues from Majors Bay Road to the north. Clear access from the south
Cabarita Dental	15 Cabarita Road	Not Flooded	Some access issues in extreme events with H5 on roadway in 1% AEP and H6 in the PMF event.
Distinct Dental Centre	219-221 Concord Road	Not Flooded	Not Flooded
Better Teeth Dental Care	177A Concord Road	Not Flooded	Not Flooded

6.5.2 Aged and Vulnerable Care

Aged and special care facilities often house vulnerable persons who may require additional resources, warning time and assistance, if flooding occurs. The unplanned/abrupt evacuation of aged care facilities is associated with increased mortality rates in vulnerable people.

It is important that the three aged care facilities in the Exile Bay catchment have effective flood plans for extreme flood events.

Table 15 presents the flood affection of these aged care facilities. One of these facilities is isolated from access in the PMF event.

Table 15: Flood affectation at aged care facilities

Aged Care Facility	Location	First Flooded at Ground Level	Hazard on Lot and Access Route
Right at Home Sydney	103 Majors Bay Road	Not Flooded	Access issues at the Majors Bay Road and Brewer Street intersection however access is possible to the south up to the 0.2% AEP. Access not possible in the PMF.
Redleaf Manor Aged Care	16 Flavelle Street	PMF	Access is available up to the PMF via the western end of Patterson Street. Access via Flavelle Street is possible up to the PMF event.

St Mary's Villa Residential Aged Care	56 Burton Street	Not Flooded	Not Flooded

6.5.3 Schools and Childcare Centres

Table 16 and Table 17 present the flood affectation of early learning facilities and educational facilities in the Exile Bay catchment. Typically, these locations are not flooded or only experience flooding during extreme events. Of note are Amanda's Family Day Care and Wellbank Children's Centre which experience flooding on the lot in the 1% AEP event and are subject to access issues in extreme events, as does Concord Kindergarten.

Table 16: Flood affectation at Exile Bay catchment early learning facilities

Early Learning Facility	Location	First Flooded at Ground Level	Hazard on Lot and Access Route
St Mary Early Learning Centre Concord	40 Brays Road	Not Flooded	H1 on surrounding roads in PMF
Cabarita-Mortlake Kindy	Cnr Willam & Denison Streets	Not Flooded	H1 on surrounding road in PMF and1% AEP
Concord Kindergarten	19A Bent Street	PMF	H2 in 1% AEP H5 in PMF Access issues with flooding on Brewer St up to H2 in 1% AEP and H6 in PMF
Amanda's Family Day Care	1 Davidson Ave	1% AEP	Significant flooding and access issues. H5 in the 1% AEP on Davidson Avenue
Wellbank Children's Centre/Concord Occasional Childcare Service	60 Flavelle Street	1% AEP	H3 on southern part of lot. Up to H4 in PMF on Churchill Crescent
Cubby College	81/83 Correys Ave	Not Flooded	Not Flooded
Integricare North Strathfield Early Learning Centre/Kids at Weldon	132 Davidson Ave	Not Flooded	Not Flooded

Table 17: Flood affection at Exile Bay catchment educational facilities

Educational Facility	Location	First Flooded at Ground Level	Hazard on Lot and Access Route
Strathfield North Public School	251 Concord Road	Not Flooded	Not Flooded
St Mary's Catholic Primary School	60 Burton Street	Not Flooded	Not Flooded

6.5.4 Risk to Critical Infrastructure

Flood damage to public infrastructure can have a significant contribution to the total cost of a flood event as well as disturbing the day-to-day operations of the local community. Table 18 presents the flood affectation of Concord Fire Station in the Exile Bay catchment.

Ausgrid were contacted to obtain the location of any electrical substations within the study area to undertake an analysis of the flood liability of these structures. Due to confidentiality concerns and issues with putting this information in the public domain, however, GRC Hydro did not obtain these locations (if any).

Table 18: Flood affectation to critical public infrastructure

Critical Infrastructure	Location	First Flooded at Ground Level	Hazard on Lot and Access Route
Concord Fire Station Fire and Rescue NSW	153 Concord Road	Not Flooded	Not Flooded

7. FLOODPLAIN RISK MANAGEMENT MEASURES

Assessment of flood risk management measures is a key objective of the current study which aims to reduce, or otherwise, manage the flood risk in Exile Bay. These measures can vary from large-scale civil works, such as the construction of levee, to non-works interventions, such as planning controls for new developments. The current study has undertaken a detailed assessment of management measures and their relative cost/benefit. Feasible measures, found to effectively reduce flood risk, have been ranked for implementation in the Floodplain Risk Management Plan (see Section 8).

Floodplain Risk Management measures are categorised in the NSW FRMM as follows:

- Property Modification Measures (Section 7.1) are those which involve modifying existing properties to manage their flood risk. This includes planning-related measures such as minimum floor levels and zoning based on the locality's flood risk. They also include house raising, and in cases of high flood risk, voluntary purchase schemes.
- Response Modification Measures (Section 7.2) are those that improve the ability of people to plan for and react to flood events. They often involve emergency services and can be targeted at different phases of a flood, e.g. preparation, response and recovery.
- Flood Modification Measures (Section 7.3) are those that change the behaviour of the flood itself through works or other measures. These measures often work to exclude flow from an area (for example a levee bank) or to reduce the peak flow (for example a detention basin).

Table 19 briefly describes typical mitigation measures in each of these categories.

Table 19: Description of Modification Measures (according to (Reference 6))

	Measure	Description
Property Modification Measures	Land Use Planning	Strategic assessment of flood risk to guide consent authorities to manage and reduce exposure to flood risk for future development areas.
	Zoning	Application of land use controls for flood prone areas of future development without also unjustifiably restricting development in these areas.
	Development Controls	Where development is acceptable, development controls are used to manage flood risk.
	Voluntary Purchase	In residential areas of high hazard on the floodplain posing a risk to life, the purchase of properties can their removal/demolition can be undertaken.
	Voluntary House Raising	In residential areas, exposed to frequent over floor flooding from low hazard and localised flow, this can be avoided by voluntary house raising.
	Flood Proofing of Buildings	Flood proofing pertains to the design and construction of buildings using materials that are flood compatible as to minimise flood damage to the building and its contents.
	Flood Access	In areas where isolation occurs during a flood event for long periods of time, planning measures need to be considered for access during these times.

Response Modification Measures	Flood Education, Flood Information Leaflets & Community Readiness	Flood education pertains to informing the community of the flood risk to ensure general community awareness and flood readiness.
	Flood Prediction and Warning	Flood prediction and warning can be implemented on catchments with large times of concentration to allow time to ready to the community.
	Local Flood Plans	Local flood plans can be used to identify significantly flood affected areas and outline various measures to be undertaken before, during and after a flood.
	Recovery Planning	Plans for recovery planning can be developed to ensure that Council and other authorities have addressed the community's needs and provided the needed services.
Flood Modification Measures	Flood Mitigation Dams	Flood mitigation dams can be used to reduce downstream discharges. This relies on the dam having capacity to store flood waters prior to a flood.
	Retarding Basins	Retarding basins pertain to small dams to provide flood storage on overland flowpaths or small tributaries.
	Levees	Levees and embankments can be used to protect existing developed areas by excluding flood waters.
	Bypass Floodways	Bypass floodways can be used to redirect floodwaters away from flood existing developed areas to reduce flood levels along a channel.
	Channel Modifications	Channel modifications refer to modifying a channel either by widening, deepening, realigning or clearing the waterway to allow for more efficient channel flow.
	Floodgates	Floodgates can be used to control and exclude flow along a small creeks or waterways.

The following sections provide detailed assessment of these measures and their relative cost/benefit.

7.1 Property Modification Measures

7.1.1 Background

Property Modification (PM) measures are those that modify existing properties, or future development in the area, to manage the area's flood risk. These measures tend to be either interventions for specific properties with high flood risk, such as house raising or voluntary purchase (few suitable examples in the study area), or broader policy changes that gradually reduce flood risk as development occurs (more applicable to this study area). While such measures do not change the flood behaviour itself, over time they can remove dwellings and other buildings from hazardous flood areas and ensure the remaining flood-prone areas are well-equipped to deal with flooding. Such measures are particularly suited to areas where flood modification measures (works) are either not feasible or prohibitively expensive. In most cases property modification measures are implemented via Council policies, which can be used to stipulate where and how development can occur within the floodplain.

The measures outlined in the following sections are proposed to be included in the Floodplain Risk Management Plan.

7.1.2 Clarify Use of Flood Risk Precincts in the DCP

In keeping with the new LEP clauses (clause 5.21 and clause 5.22) and state government ministerial directions, Council's updated DCP, adopted in March 2023, has included a Flood Planning Matrix approach to the implementation of flood related development controls within the PMF extent. This matrix uses Flood Risk Precincts (see Section 5.4.1) and the land use to provide relevant controls at a site. Council may consider expanding the FPA, or using another planning overlay, to show that all properties in the PMF extent have flood planning controls that apply to them, in accordance with these DCP controls. That is, all properties in the 'Low Flood Risk' and many properties in the 'Medium Flood Risk' area outside the FPA. If this is pursued then community consultation is recommended through the public exhibition and clear guidance on what the FPA denotes.

Recommendation: The continued use of Flood Risk Precincts in the DCP is recommended in the Floodplain Risk Management Plan. It is recommended that the set of properties to which the controls apply should be updated or otherwise clarified. Community consultation through this process is recommended with clear guidance on what the FPA denotes.

7.1.3 Voluntary Purchase

In a situation where it is impractical or uneconomical to mitigate high hazard flooding from properties, it may be necessary to acquire the affected properties and undertake demolition to remove them from the floodplain. Where dwellings lie in flow conveyance, voluntary purchase (VP) may be the best way to manage flood risk. This would remove residents from the high-risk areas and restore the hydraulic capacity of the floodplain. The purchase of such properties should be at an equitable price and only where voluntarily offered. Generally, voluntary purchase has minimal impacts on the environment though this scheme can have significant economic and social costs.

Recommendation: This option is supported in the Floodplain Risk Management Plan. VP is a sensitive issue and so the recommendation herein is for further work to be done in this regard to identify suitable properties based on VP criteria and then to assess the feasibility of VP for identified properties and make specific recommendations to Council.

7.1.4 Voluntary Floor Raising

This measure can be undertaken to raise habitable floor levels and eliminate above floor flooding for affected properties. It is suitable mainly for timber or non-brick single storey buildings and for properties generally located in low hazard areas. The building structure must be able to withstand loadings from floodwaters and debris. Even though the raised building provides safe refuge to residents during a flood event, the risk to life remains present should residents choose to exit the building or a medical emergency occurring during the flood event. For properties located in high hazard areas, rare floods could still cause inundation of the building should the floor levels not be sufficiently raised.

Recommendation: The option is not considered in the Floodplain Risk Management Plan as most properties within the study area are of slab-on-ground construction and the shallow nature of overland flow flooding means comparatively cost-effective measures such as flood proofing are available.

7.1.5 Flood Proofing

Flood proofing can be undertaken to seal all building entry points such as doors and windows from floodwaters. Both temporary and permanent flood proofing methods are available with the temporary ones being sandbags, portable flood barriers, whilst permanent ones being flood gates, sealing of gaps between brick works and electrical wiring insulation. This measure is generally less expensive compared to other property modification measures and causes less disruption. The effective deployment of temporary flood proofing measures would rely on the experience and knowledge of the user as well as sufficient warning time before the onset of flooding. As the study area experiences mainly flash flooding, this is generally not possible.

Recommendation: Permanent flood proofing measures are considered as an option in the Floodplain Risk Management Plan.

7.1.6 Property Modifications

Modifications can be made to flood-affected properties either to manage overland flows through the property or strengthening the building to provide shelter and reduce flood risk to the residents. For the former, this can be in the form of adjustment to walls and fences within the property or provision of an easement to maintain continuity of overland flow paths. This, however, may have knock on effects on neighbouring properties which may prompt adjustment on neighbouring properties as well. In terms of building strengthening, this is undertaken to provide a structurally stable refuge for residents. Both measures, nevertheless, cannot be mandated by Council nor can Council or the State Government provide funding for these modifications. As such, any decision to employ these measures would be up to the individual property owners.

Recommendation: The option is not considered in the Floodplain Risk Management Plan as the benefits are generally localised and as such implementation of the scheme is problematic.

7.1.7 Assessment of On-Site Detention Requirements

On-Site Detention (OSD) is a means of stormwater management whereby runoff is temporarily stored and slowly released to offset potential downstream flooding impacts from increasing paved surfaces within a catchment. During the community consultation process (see Section 4), residents expressed concern regarding increases in rainfall runoff due to new developments, inadequate installation of OSD and pumping of basement carparks increasing runoff. Given this, a brief examination of Council's OSD requirements in the DCP was undertaken and found to be detailed and prescriptive. Thorough review could be undertaken by a qualified stormwater engineer to ensure these requirements are adequate.

Recommendation: No action required from a flooding standpoint as Council's DCP provides detailed OSD requirements for stormwater engineers to adhere to.

7.2 Response Modification Measures

7.2.1 Background

Owing to the flash flood nature of flooding within the LGA, Response Modification (RM) measures have limited use in flood risk management for this study area. Simply put, flooding happens

irregularly, and without any effective warning. For most if not all impacted properties the idea that a response can be planned and implemented is not realistic. The exception may be for road crossings throughout the study area impacted by overland flow, buildings in lower catchment areas frequented by the public that are subject to high levels of flood hazard and basements (e.g. car parks) that have persistent and hazardous flooding problems.

7.2.2 Flood Prediction and Warning

BOM provides flood forecasting and warning services suited mainly for mainstream riverine flooding rather than flash flooding which is more common in the Exile Bay catchment. The services may be of some benefit in alerting residents of potential flooding though there is not adequate time to develop reliable flood warnings or to disseminate same. The BOM services include:

- Weather forecast – which may indicate the likelihood of heavy rain with often more than 24 hours' notice;
- Flood Watch – will typically provide +24 hours' notice of potential flooding;
- Severe Weather Warning – typically issued when heavy rain and/or flash flooding are forecast; and
- Severe Thunderstorm Warning – generally provide between 0.5 to 2 hours' notice of impending severe storms.

Recommendation: The difficulty in predicting flash flooding and lack of warning time available for the catchment means that the provision of an effective flood warning service is not possible, hence this option is not considered in the Floodplain Risk Management Plan.

7.2.3 Education and Flood Awareness

The community readiness in responding to a flood event is correlated to awareness of flood occurrence and issues within their neighbourhood. The responses from the community consultation undertaken during the current study (see Section 4) and during the flood study indicate that there is some awareness of flooding from overland flow in the catchment and within individual properties. In the absence of a recent significant rainfall event within the catchment, community awareness of flooding typically declines. Further with a quarter of the population relocating to the area within the last five years (see Section 2.4), flood awareness within the study area is likely to be quite low This is usually addressed by implementing a community awareness programme.

Given the lack of frequency of flooding, its transitory nature and the overall lack of consequence associated with it for the community in the study area (whilst acknowledging there will be private losses), keeping flooding at the forefront of community awareness is unrealistic and perhaps also unwarranted given the level of flood risk in the catchment.

Recommendation: Community education and raising flood awareness among the residents are deemed unrealistic and unwarranted, hence this option is not considered in the Floodplain Risk Management Plan.

7.2.4 Flood Signage

For areas with flood liability issues especially road crossings, specific actions such as the installation of flood signage may prove of use in reminding people of existing flood issues and how best to respond to them. On flood-prone roads and locations, a warning sign and a depth marker is often used to warn vehicles and pedestrians of dangerous flooding. They are used particularly in regional areas where a creek may completely submerge a section of road when the cross-drainage is exceeded. Recent research has found that while such signage is important given the high number of fatalities due to vehicles crossing flooded roads, signage is often ineffective at persuading motorists to turn around, especially if it is static signage that does not change the warning when a flood is occurring.

In Exile Bay there are a number of flood-affected roads where vehicles are likely to enter hazardous floodwaters during a flood (see Table 9, Section 6.3). Overall, upgraded cross-drainage and general awareness is recommended for such locations, over warning signage. Signage in the study area would have to be static, as there is not robust advance warning of flooding occurring in the area, and as such vehicles are likely to ignore the signage as in virtually all instances it will be perceived as warning against a non-existent risk. In addition, the primary risk that signage would be aimed at, which is risk to life, is largely not present in Exile Bay and is more applicable to larger creeks and rivers in other areas of Sydney and NSW.

Recommendation: Proposal for the installation of flood signage at the appropriate locations is not included in the Floodplain Risk Management Plan.

7.2.5 Local Flood Plan

As discussed in Section 3.3, The Bay Flood Emergency Sub Plan sets out the emergency response arrangements for Exile Bay catchment. The plan identified the NSW SES as the primary agency responsible for dealing with emergencies related to storm and flash flooding. The characteristics of the study area's flood behaviour, however, do not lend themselves to a managed flood response as there is lack of effective warning time and flooding would be distributed across the LGA. Hence, the SES response would be ad-hoc or demand based.

No local Flood Plan is currently available for Exile Bay and the development of such a plan in conjunction with the SES to complement the Local Emergency Management Plan (EMPLAN) would be useful. The Plan should include the following as a minimum:

- Purposes and authority of the plan;
- Responsibilities of the SES Local Controller, other officers, agencies and local organisations;
- Description of the local catchment flood behaviour, hotspots of flooding and its consequences (as per Section 6.2);
- List of key emergency egress routes and their trafficability during a flood event (as per Section 6.3);
- List of vulnerable facilities and sensitive infrastructure (as per Section 6.5); and
- List of suitable evacuation centres which are flood free and accessible by road.

Recommendation: Preparation of a local Flood Plan to complement the EMPLAN is considered in the Floodplain Risk Management Plan. The Plan will include description of the responsibilities of SES and other local agencies as well as provide details of flood-related arrangements.

7.2.6 Requirement for Site Specific Flood Emergency Plans

This measure involves requiring a Flood Emergency Plan to form part of a development application for any lot in a high hazard area. The Plan will ensure that development in these areas includes planning for evacuation if required (including access routes) and other preparation (e.g. responsibilities of individuals or building management and warning systems).

Such a plan should only be required as a risk mitigation measure where the lot has significant areas of high hazard (e.g. H3 to H6 flow) or evacuation constraints (e.g. not flooded but isolated).

Recommendation: No further action required as the flood related planning controls in Council's DCP includes a requirement for a site-specific Flood Emergency Plan.

7.3 Flood Modification Measures

7.3.1 Background

Flood Modification (FM) measures were developed based on assessment of the flood risk and flooding hotspots, with support for measures also coming via consultation with Council and the community. As the catchment is highly urbanised and fully developed, suitable measures are limited to costly and disruptive drainage upgrades or repurposing of park lands for flood storage or attenuation of overland flows.

The following sections present the findings from the detailed assessment of agreed flood modification measures. A 'Longlist' of flood modification measures was developed with Council and in consideration of community input obtained from questionnaire responses (Section 4). These measures are discussed in the following section. The 'Longlist' of options was then refined to produce a 'Shortlist' of options based on discussions with Council.

7.3.2 Flood Modification Measures – Longlist

A staged process was used to select measures that warranted detailed assessment. This involved developing a longlist of measures, and then further assessing those that were most likely to be effective, with input from Council and the Floodplain Management Committee.

The longlist of measures has been summarised in

Table 20, with the location of each option presented in Figure 22.

Table 20: Flood Modification Measures Longlist

Code	Description	Preliminary Assessment Outcome
FM01	Macnamara Avenue Drainage Upgrade	Selected for further assessment.
FM02	Davidson Avenue Drainage Upgrade	Selected for further assessment.

Code	Description	Preliminary Assessment Outcome
FM03	Beaconsfield Lane Drainage Upgrade	Selected for further assessment.
FM04	Clearing of debris along main flowpaths	Selected for further assessment.
FM05	Damaged drain at corner of Flavelle Street and Wordsworth Avenue due to tree roots	Council to review and address any issues. Not selected for further assessment
FM06	Coles Street Drainage Upgrade	Selected for further assessment.
FM07	Queen Elizabeth Park Drainage Upgrade	Selected for further assessment.
FM08	Shackel Avenue Drainage Upgrade	Selected for further assessment.
FM09	Catchment wide Drainage Upgrade	Selected for further assessment.
FM10	Upgrade of Saltwater Creek Channel and Sea Wall	Not selected for further assessment. Council is investigating this separately.
FM11	Formalise overland flowpath between Central Park and Davidson Avenue	Selected for further assessment
FM12	Investigated lot re-grading at 23-25 Macnamara Avenue	Not selected for further assessment. Being investigated separately
FM13	Additional flood storage in lower catchment including golf course	Not selected for further assessment. This was subject to several detailed assessments between 2020 and 2022. It found that changes to the area are unlikely to provide any benefit, short of completely regrading large sections of the golf course.
FM14	Cascading berms in Queen Elizabeth Park, Goddard Park and Rothwell Park	Selected for further assessment.
FM15	Improve conveyance around Council depot site	Not selected for further assessment. This was subject to detailed assessment in 2022. It found that removal of this mounding led to increased flood impacts on neighbouring properties.
FM16	Improve conveyance along Davidson Avenue, Majors Bay Road and Brewer Street intersection	Selected for further assessment.
FM17	Cascading berms in Central Park	Selected for further assessment.
FM18	Lowering of Brewer Street near Pamela Place	Selected for further assessment.
FM19	Lowering Greenlees Avenue and Greenlees Park	Selected for further assessment.

7.3.3 Flood Modification Measures – Shortlist

Options identified for further consideration and analysis are presented in the following sections.

7.3.3.1 Macnamara Avenue Drainage Upgrade (Option FM01)

Option Overview

Option FM01 aimed to reduce flooding along Macnamara Avenue and the surrounds. This location was identified as Hotspot 3 (see Section 6.2.3) and feedback from the community consultation suggested increasing the stormwater capacity may help to alleviate inundation in frequent events.

This mitigation measure involved doubling the pipe capacity along Macnamara Avenue and extending to Davison Avenue, as well as increasing the pit capacity and adding pits on the western side of Macnamara Avenue to capture additional overland flow.

Impact on Flood Liability

Figure 23 presents the 20% AEP and 1% AEP event flood level impacts for the implementation of Option FM01. In both the 20% and 1% AEP events, peak flood level reductions of up to 0.08 m occur between the northern end of Macnamara Avenue through to Davidson Avenue. Notably, however, was that these reductions in flood levels were fairly localised and only provide benefit to a few properties relative to the large scale of the proposed works. Pipe flow in the 20% AEP event along Macnamara Avenue increased from 0.3 m^3/s in the existing case to 0.65 m^3/s.

Option FM01 was simulated for a range of flood events with the results presented in Table 21 below. The table shows that the option provides from benefit with several properties no longer flooded over floor level in the 20%, 10% and 5% AEP events and a reduction of $143,000 in Average Annual Damages.

Table 21: Economic Impacts of Option FM01

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0[2]	0[2]	+$3,000[1]
0.2%	1	0	$187,000
0.5%	0	1	$153,000
1%	0	1	$118,000
2%	3	0	$272,000
5%	1	4	$318,000
10%	1	4	$138,000
20%	10	2	$146,000
		Average Annual Damages Reduction	$143,000

[1]These numbers represent an increase with the implementation of Option FM01

[2]Note, pipes are modelled fully blocked in the PMF event

Cost Estimate

A preliminary cost estimate for Option FM01 estimated that this measure would cost $4.5 million. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $143,000
- NPV of reduction: $2,098,000
- Cost estimate of option: $4,461,000
- Benefit-Cost Ratio: 0.47

The benefit-cost ratio is 0.47, which means the cost of Option FM01 outweighs the economic benefit and as such, this measure cannot be justified on economic grounds alone.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

This measure was assessed after residents raised it in the Community questionnaire (see Section 4). It is likely that the general community may be less accepting once the economic impacts are understood.

Recommendation: Option FM01 is recommended as a long term measure in the Floodplain Risk management Plan due to the reductions in peak flood levels achieved along the trunk alignment.

7.3.3.2 Davidson Avenue Drainage Upgrade (Option FM02)

Option Overview

Option FM02 worked to address the flood liability along Davidson Avenue (Hotspot 4, see Section 6.2.4) by implementing large-scale stormwater upgrades along Davidson Avenue at Flavelle Street and extending to Saltwater Creek. This measure aimed to reduce nuisance flooding on the roadway in frequent flood events and property inundation in the locality in rare flood events.

This mitigation measure involved doubling the pipe capacity along Davidson Avenue and extending to Saltwater Creek, as well as increasing the pit capacity to capture additional overland flow.

Impact on Flood Liability

Figure 24 presents the 20% AEP and 1% AEP event flood level impacts for the implementation of Option FM02. In the 20% AEP event, peak flood levels reductions typically in the order of 0.05 m to 0.01 m occur along Davidson Avenue from Central Park extending down to Edwards Park. Peak flood level increases, largely less than 0.03 m, occur in Saltwater Creek and Massey Park Golf Course. In the 1% AEP event, peak flood level reductions were found to be more significant and widespread as flood water is able to move downstream more efficiently. Peak flood level reductions of up to 0.04 m along Davidson Avenue occur in the 1% AEP event with a 2.4 m^3/s increase in pipe flow (87% increase).

Table 22 presents the changes in pipe flow and overland flow along Davidson Avenue, downstream of Flavelle Street. Of note is the decrease in overland flow that occurs in Davidson Avenue due to the increased pipe capacity.

Table 22: Comparison of flows on Davidson Avenue with Option FM02

		20% AEP	1% AEP
Existing Case	Pipe Flow (m^3/s)	2.4	2.4
	Overland Flow (m^3/s)	3.9	12.1
	Total Flow	6.3	14.5
Option FM02	Pipe Flow (m^3/s)	4.8	4.8
	Overland Flow (m^3/s)	1.5	9.9
	Total Flow	6.3	14.7

Option FM02 was simulated for a range of flood events with the results presented in Table 23 below. The table shows that this measure provides from benefit for floods in the 20% to 0.2% AEP range, with a $321,000 reduction in damages.

Table 23: Economic Impacts of Option FM02

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0[2]	0[2]	+$3,000[1]
0.2%	5	5	$681,000
0.5%	5	1	$504,000
1%	4	3	$376,000
2%	14	3	$536,000
5%	12	7	$421,000
10%	19	3	$339,000
20%	19	6	$433,000
		Average Annual Damages Reduction	$321,000

[1]These numbers represent an increase with the implementation of Option FM02

[2]Note, pipes are modelled fully blocked in the PMF event

Cost Estimate

A preliminary cost estimate for Option FM02 estimated that this measure would cost $6.8 million. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $321,000
- NPV of reduction: $4,705,000

- Cost estimate of option: $6,791,000
- Benefit-Cost Ratio: 0.69

The benefit-cost ratio is 0.69, which means the cost of Option FM02 outweighs the economic benefit and as such, this measure cannot be justified on economic grounds alone.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

This measure was assessed after residents raised it in the Community questionnaire (see Section 4). Given the widespread benefit and minimal negative impact, it is likely that the general community would be supportive of this measure. Support may decline once the economic impact is understood along with the disruption caused to residents during the construction phase.

Recommendation: Option FM02 is recommended as a long term measure in the Floodplain Risk management Plan due to the reductions in peak flood levels achieved along Davidson Avenue, Brewer Street and Edwards Park.

7.3.3.3 Beaconsfield Lane Drainage Upgrade (Option FM03)

Option Overview

Feedback from the Community Consultation indicated that overland flow from Beaconsfield Lane, at the northern end of Rothwell Park was causing inundation of the roadway and residents yards. As such, Option FM03 investigated doubling the drainage capacity and increasing the pit capacity along this laneway.

Impact on Flood Liability

Figure 25 presents the 20% and 1% AEP peak flood level impacts of the implementation of this measure. Of note, is the negligible change to peak flood levels in both flood magnitudes. This is likely because the stormwater system downstream is full and, as such, the additional drainage capacity cannot be optimised.

Recommendation: Option FM03 is not recommended as a measure in the Floodplain Risk management Plan due to the negligible changes to peak flood levels and likely costly construction.

7.3.3.4 Clearing of debris along main flowpaths (Option FM04)

Debris management may provide limited localised benefits for flood affectation. Widespread removal of stormwater debris or vegetation is not feasible or cost effective, and will result in significant detrimental impacts to the riparian corridor. Feedback from the community consultation indicated that debris along flow paths and blockage of stormwater pits was exacerbating flooding. A level of blockage of stormwater pits is expected during significant rainfall events however excessive

blockage can be problematic. As such, a debris management program can be implemented after significant rainfall events to ensure that flow paths and stormwater drains are optimised. Key flow paths and stormwater pits susceptible to blockage can be identified and prioritised for maintenance.

Council is however known to maintain these assets to a high standard and even if perfectly maintained, the inadequate capacity of such assets (by design) to address all floods, means that maintenance is not the solution it is sometimes perceived to be by the community.

Recommendation: Council is recommended to better document and communicate their current debris management program that aims to remove vegetation and debris along key flowpaths and large inlet pits after significant rainfall events.

7.3.3.5 Coles Street Drainage Upgrade (Option FM06)

Option Overview

Option FM06 aimed to ease the level of flood inundation experienced between Ada Street and John Street in the upper catchment (Hotspot 1, see Section 6.2.1) by implementing a secondary stormwater system. This approach sought to collect additional overland flow from the topographic low points on Coles Street and Melbourne Street via a new stormwater system. This system followed the street alignment to Alexandra Street and John Street where it connected back into the existing stormwater network. This measure was suggested during the flood study and flooding issues in the area were raised during the Community Consultation.

Impact on Flood Liability

Figure 26 presents the 20% and 1% AEP peak flood level impacts for the implementation of the Coles Street Drainage Upgrade. In the 20% AEP event peak flood level decreases of up to 0.04 m and typically in the order of 0.02 m occur between Coles Street and John Street. In the 1% AEP event reductions of 0.01 m occur in the vicinity. The secondary stormwater system takes approximately 0.5 m^3/s from Coles Street and Melbourne Street in the 20% AEP event and 0.6 m^3/s in the 1% AEP event.

Option FM06 was simulated for a range of flood events with results presented in Table 25 below. An Annual Average Damages reduction of $66,000 is achieved with the implementation of Option FM06 with two properties no longer flooded over floor level in the 20% AEP event.

Table 24: Economic Impacts of Option FM06

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0[2]	0[2]	+$3,000[1]
0.2%	0	0	$47,000
0.5%	0	0	$68,000
1%	1	0	$129,000
2%	2	0	$6,000
5%	2	1	$92,000
10%	1	-1[1]	$66,000
20%	0	2	$113,000
		Average Annual Damages Reduction	$66,000

[1]These numbers represent an increase with the implementation of Option FM06
[2]Note, pipes are modelled fully blocked in the PMF event

Cost Estimate

A preliminary cost estimate for Option FM06 estimated that this measure would cost $2.2 million. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $66,000
- NPV of reduction: $971,000
- Cost estimate of option: $2,252,000
- Benefit-Cost Ratio: 0.43

The benefit-cost ratio is 0.43, which means the cost of Option FM06 outweighs the economic benefit and as such, this measure cannot be justified on economic grounds alone.

Constraints

To obtain the grade required to implement Option FM06, the stormwater system will need to be very deep below the road surface (up to 4 metres below ground at points). This depth of this system will pose significant construction and maintenance constraints.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

This measure was assessed after residents raised it in the Community questionnaire (see Section 4). It is likely that the general community would be supportive of this measure, given the benefit to residents in the vicinity. The economic cost of construction and disruption caused by the construction may affect the community acceptance of the upgrade.

Recommendation: Option FM06 is recommended as a long term measure in the Floodplain Risk management Plan due to the reductions in peak flood levels achieved along Coles Street, Melbourne Street and John Street.

7.3.3.6 Queen Elizabeth Park Drainage Upgrade (Option FM07)

Option Overview

During the Community Consultation (see Section 4) residents noted that flooding had occurred along Queen Elizabeth Park and the adjacent roadways to the north causing traffic issues. Given this, analysis was undertaken whereby the pipe capacity along Queen Elizabeth Park was doubled through to Rothwell Park as well as increasing the pit capacity through this area to capture additional overland flow.

Impact on Flood Liability

Figure 27 presents the 20% and 1% AEP peak flood level impacts for the implementation of the Queen Elizabeth Park Drainage Upgrade. In the 20% AEP event peak flood levels reductions predominantly occur along Rothwell Park and extend to Jesse Stewart Reserve. Reductions of up to 0.06 m occur at the properties adjacent to Rothwell Park. In the 1% AEP event, peak flood level reductions are less widespread with decreases of up to 0.03 m at the properties adjacent to Rothwell Park.

Option FM07 was simulated for a range of flood events with results presented in Table 26 below. This table shows modest reductions in damages for events between the 10% AEP and the 0.2% AEP with an Average Annual Damages reduction of $37,000.

Table 25: Economic Impacts of Option FM07

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0	0	+$3,000[1]
0.2%	0	0	$6,000
0.5%	2	0	$1,000
1%	1	0	$6,000
2%	1	0	$18,000
5%	1	0	$1,000
10%	0	0	$3,000
20%	0	0	$0
		Average Annual Damages Reduction	$37,000

[1]These numbers represent an increase with the implementation of Option FM07

Cost Estimate

A preliminary cost estimate for Option FM07 estimated that this measure would cost $2.5 million. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $37,000
- NPV of reduction: $549,000
- Cost estimate of option: $2,453,000
- Benefit-Cost Ratio: 0.22

The benefit-cost ratio is 0.22, which means the cost of Option FM07 far outweighs the economic benefit and as such, this measure cannot be justified on economic grounds alone.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

This measure was assessed after residents raised it in the Community questionnaire (see Section 4). Given the benefit and minimal negative impact, it is likely that the general community would be supportive of this measure. Support may decline once the economic impact is understood along with the disruption to traffic, pedestrians and park users during the construction phase.

Recommendation: Option FM07 is recommended as a long term measure in the Floodplain Risk management Plan due to the reductions in peak flood levels achieved along Rothwell Park.

7.3.3.7 Shackel Avenue Drainage Upgrade (Option FM08)

Option Overview

Option FM08 aimed to capture overland flow from the eastern end of Shackel Avenue by extending the existing stormwater network at Cormiston Avenue. Flooding issues in this area was reported by respondents to the community questionnaire (see Section 4). The nature of flooding at this location is typically widespread, shallow flow and as such, very large pits (in the order of 10 m wide) were required on either side of the roadway to capture the dispersed flow on the roadway.

Impact on Flood Liability

Peak flood level impacts for the 20% and 1% AEP events are shown in Figure 28. In the 20% AEP event, the proposed stormwater extension captures 0.27 m^3/s of flow which results in a flood level

decrease of up to 0.04 m at downstream properties on Cormiston Avenue and Majors Bay Road. In the 1% AEP, 0.33m^3/s is captured in the proposed stormwater network and peak flood level reductions of up to 0.02 m occur at the downstream properties.

This measure was simulated for a range of flood events with results presented Table 26 below. The table generally shows that Option FM08 is beneficial across all flood events with a modest reduction in Annual Average Damages of $19,000.

Table 26: Economic Impacts of Option FM08

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0[2]	0[2]	$0
0.2%	1	0	$4,000
0.5%	1	0	+$1,000[1]
1%	0	0	$139,000
2%	3	1	$24,000
5%	2	2	$45,000
10%	3	2	$45,000
20%	4	0	$14,000
		Average Annual Damages Reduction	$19,000

[1]These numbers represent an increase with the implementation of Option FM08
[2]Note, pipes are modelled fully blocked in the PMF event

Cost Estimate

A preliminary cost estimate for Option FM08 estimated that this measure would cost $391,000. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $19,000
- NPV of reduction: $277,000
- Cost estimate of option: $391,000
- Benefit-Cost Ratio: 0.71

The benefit-cost ratio is 0.71, which means the cost of Option FM08 outweighs the economic benefit and as such, on economic grounds, this measure cannot be justified.

Constraints

A key constraint pertaining to the design and implementation of Option FM08 is the shallow, dispersed and relatively high velocity (~1m/s in the 20% AEP) of flood water moving along Shackel Avenue. To capture flow of this nature, large pits are required leading to considerable economic and logistical impacts.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

This measure was assessed after residents raised it in the Community questionnaire (see Section 4). Since, Option FM08 has a benefit to properties along Cormiston Avenue and Majors Bay Road and minimal negative impact, it is likely that the general community would be supportive of this measure. Support may decline once the economic impact is understood along with the disruption to traffic, residents and pedestrians during the construction phase.

Recommendation: Option FM08 is recommended as a long term measure in the Floodplain Risk management Plan due to the reductions in peak flood levels achieved along Cormiston Avenue and Majors Bay Road.

7.3.3.8 Catchment Wide Trunk Drainage Upgrade (Option FM09)

Option Overview

An investigation was undertaken to determine the flood impact of a catchment wide trunk drainage upgrade. This strategy (Option FM09) involved tripling the existing trunk drainage capacity along the Central Drain and the Main South Drain (see Figure 1) and increasing the pit capacity along these drainage lines. While this upgrade would involve significant cost and disruption to the catchment, the impact of such extreme scenarios can inform future decisions and expectations pertaining to flood mitigation.

Impact on Flood Liability

Figure 29 presents the 20% AEP and 1% AEP peak flood level impact of Option FM09 where the capacity of the trunk drainage lines were tripled. Along Davidson Avenue, peak flood levels are typically decreased by approximately 0.05 m and up to 0.25 m in the 20% AEP event. In the 1% AEP event, peak flood level reductions along Davidson Avenue were generally around 0.05 m and up to 0.07 m. In Edwards Park and Greenlees Park, peak flood levels are reduced by 0.19 m and 0.12 m respectively in the 20% AEP event and 0.17 m and 0.21 m respectively in the 1% AEP event. Peak flood level increases of less than 0.1 m occur on Massey Park Golf Course, along Saltwater Creek and at properties adjacent to the creek channel.

Table 27 presents the change in peak flows in the 20% and 1% AEP events along the Central Drain and the Main South Drain. Of note is the significant reduction in peak flows with an average overland flow decrease of 76% in the 20% AEP event and 48% in the 1% AEP event at the reported locations.

Table 27: Comparison of overland flows along main drainage lines with Option FM09

	Location	Flow (m^3/s)			
		20% AEP		1% AEP	
		Existing Case	Option FM09	Existing Case	Option FM09
Central Drain	Upstream of Trafalgar Parade	3.9	0.8	12.1	7.8
	Brewer Street Downstream of Majors Bay Road	3.9	1.7	14.2	8.8
	Edwards Park	3.4	0.6	11.7	7.6
Main South Drain	Melbourne Street	1.4	0.4	7.2	4.7
	Queen Elizabeth Park	3.7	0.7	13.3	7.6
	Downstream of Rothwell Park	2.3	0.1	11.4	4.0
	Greenlees Park	1.6	0.5	10.1	1.7
Average Percentage Change		-76%		-48%	

This option would benefit road access since the depth of inundation of key routes would be reduced. Several flood affected properties would also benefit from the reduction in flood levels. If this option is adopted, further refinements can be made to the alignment of the proposed trunk upgrade and pit locations.

Table 28 presents the economic impacts of Option FM09 for a range of flood events. With the implementation of this measure, many properties are no longer flooded above floor level and ground level across the range of flood events and the Annual Average Damages is reduced by $700,000.

Table 28: Economic Impacts of Option FM09

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0[2]	0[2]	+$3,000[1]
0.2%	15	14	$2,081,000
0.5%	20	7	$1,854,000
1%	28	9	$1,605,000
2%	35	14	$1,625,000
5%	33	14	$1,286,000
10%	30	11	$1,111,000
20%	25	10	$866,000
Average Annual Damages Reduction			$700,000

[1]These numbers represent an increase with the implementation of Option FM09

[2]Note, pipes are modelled fully blocked in the PMF event

Cost Estimate

A preliminary cost estimate for Option FM09 estimated that this measure would cost over $650 million. Further cost estimate details area presented in Appendix C. This cost estimate is indicative

only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $700,000
- NPV of reduction: $10,245,000
- Cost estimate of option: $655,000,000
- Benefit-Cost Ratio: 0.02

The benefit-cost ratio is 0.02, which means the cost of Option FM09 is fifty times more than its expected benefit, and it cannot be justified on economic grounds.

Constraints

While there are significant benefits associated with the implementation of Option FM09, this The option has technical and administrative constraints that would need to be addressed in the planning stages. Key constraints of implementing Option FM09 include:

- Cost of construction;
- Mitigating peak flood level increases at properties in downstream areas;
- Disruption caused by construction to residents, pedestrians and traffic; and
- Design and construction of sections of drainage in urbanised areas would likely encounter significant issues relating to the high density of underground utilities in the area.

Social and Environmental Impacts

An environmental impact assessment would likely be required while scoping these proposed works given the significant upgrades over a large area.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

Implementation of Option FM09 is likely to be met with mixed support from the community. It is expected that given the large economic cost and disruption to the community of such a measure, the general community would not support Option FM09's implementation.

Recommendation: Option FM09 is not recommended as a strategy in the Floodplain Risk management Plan due to various feasibility constraints.

7.3.3.9 Formalised overland flow path between Central Park and Davidson Avenue (Option FM11)

Option Overview

In the upper reaches of the Central Drain, several overland flow paths meet upstream of Central Park and move through neighbouring properties on Curtin Place and Davidson Avenue before flowing onto the roadway. This flood mechanism, known as Hotspot 3 (see Section 6.2.3), causes inundation for residents in the vicinity and as such the Flood Study suggested collecting overland flow in Central Park and channelling the flow through a pedestrian footpath to Davidson Avenue. A 0.3 m berm along the eastern boundary of Central Park was used to collect overland flow and the pedestrian footpath was lowered by 0.06 m on average to convey floodwaters to Davidson Avenue.

Impact on Flood Liability

Peak flood level impacts for the 20% and 1% AEP events are shown in Figure 30 for the implementation of Option FM11. In the 20% AEP event, peak flood levels are decreased at properties in Curtin Place and Davidson Avenue by up to 0.02 m and there are increases at two properties upstream of up to 0.06 m. Similarly in the 1% AEP event, downstream properties experience flood level decreases of up to 0.02 m and properties upstream have flood level increases of up to 0.07 m.

Summary and Recommendations

The current study has investigated a similar mitigation measure recommended by Council in Option FM17 (see Section 7.3.3.12) whereby a series of cascading berms in Central Park capture overland flow. Option FM17 was found to have favourable peak flood level impacts compared to Option FM11. Given this, Option FM11 has not been recommended for inclusion in the Floodplain Risk Management Plan.

Recommendation: Option FM11 is not recommended as a strategy in the Floodplain Risk Management Plan as a similar measure has favourable peak flood level impacts.

7.3.3.10 Cascading berms in Goddard Park, Queen Elizabeth Park and Rothwell Park (Option FM14)

Option Overview

Option FM14 implemented a series of berms of varying heights in Goddard Park, Queen Elizabeth Park and Rothwell Park to attenuate flood flows and decrease peak flood levels along the Main South Drain. This measure was suggested by Council and aimed to use public land to address flooding issues over a large area with minimal disruption to the community.

This measure implemented eight berms (0.5 m to 0.7 m high) perpendicular to the flow direction in the parklands and three smaller berms (0.2 m high) to protect neighbouring properties (see Figure 31). This assessment has not incorporated a freeboard to the height these embankments however freeboard would be required during the design and construction of these structures.

Impact on Flood Liability

Figure 31 presents the 20% AEP and 1% AEP peak flood level impacts associated with the implementation of Option FM14. In the 20% AEP event, peak level decreases extend to the Exile Bay outlet. Typically these decreases are less than 0.05 m , with larger reductions of up to 0.10 m at the construction downstream of Rothwell Park (Hotspot 2, see Section 6.2.2). There are some peak flood level increases at properties adjacent to the berms (up to 0.1 m) which would require further assessment during the design stages for the berms. Peak flood level decreases in the 1% AEP event extend to the downstream outlet however they are less significant (typically less than 0.02 m decrease). This is to be expected as the berms are overtopped with the greater volume of runoff in rare events.

The option was simulated for a range of flood events with the results presented in Table 29 below. The table shows that the measure provides a benefit to overfloor flooring for a number of properties for a range of flood events leading to a reduction in Annual Average Damages of $102,000.

Table 29: Economic Impacts of Option FM14

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0	+2[1]	+$377,000[1]
0.2%	0	1	$104,000
0.5%	0	0	$1,000
1%	+1[1]	1	$15,000
2%	+1[1]	0	$59,000
5%	2	1	$191,000
10%	1	1	$127,000
20%	1	1	$105,000
		Average Annual Damages Reduction	$102,000

[1]These numbers represent an increase with the implementation of Option FM14

Cost Estimate

A preliminary cost estimate for Option FM14 estimated that this measure would cost $500,000. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $102,000
- NPV of reduction: $990,000
- Cost estimate of option: $500,000
- Benefit-Cost Ratio: 1.98

The benefit-cost ratio is 1.98, which means the economic benefit of Option FM14 outweighs the cost by two times and as such, on economic grounds, this measure is justified for further investigation.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

Provided that flood impacts on affected residents are properly assessed and mitigated during the design phase and the proposed berms do not affect the utility of the parks, it is likely that the general community would be supportive of this measure given the benefits.

Recommendation: Option FM14 is recommended as a measure for inclusion in the Floodplain Risk management Plan due to the reductions in peak flood levels particularly in frequent flood events.

7.3.3.11 Improve Conveyance along Davidson Avenue, Majors Bay Road and Brewer Street intersection (Option FM16)

Option Overview

The Flood Study noted that the kerbs, guttering and median strips at the intersection of Davidson Avenue, Majors Bay Road and Brewer Street were impeding the efficient movement of overland flow through the vicinity and exacerbating the flood affectation of Hotspot 5 (see Section 6.2.5). Furthermore, residents have noted that the slightly raised footpath at the Davidson Avenue and Majors Bay Road intersection causes floodwaters to pool and backwater to residential properties. Given this, Option FM16 aimed to reduce flood affectation by smoothing the topography through the intersection by works such as removal of low-lying bushes, lowering gutter heights and median strips.

Impact on Flood Liability

In the 20% AEP event, peak flood level decreases of up to 0.23 m occur on Majors Bay Road (see Figure 32) with a decrease of up to 0.1 7 m at properties in the vicinity. There are some increases to peak flood levels at the corner of Majors Bay Road and Brewer Street which would require further mitigation assessment during design stages. In the 1% AEP event, peak flood levels are reduced by up to 0.25 m at the corner of Davidson Avenue and Majors Bay Road (see Figure 32), as flow can move through the intersection more easily.

Option FM16 was simulated for the full range of flood events with results presented in Table 30 below. The table shows that this measure provides modest benefit across all flood events, excluding the PMF event where the flood damages increase slightly (0.01% increase relative to the total PMF damages). One property which was previously flooded above floor level in the 20% event is instead flooded above floor in the 10% AEP event.

Table 30: Economic Impacts of Option FM16

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0	0	+$13,000[1]
0.2%	0	1	$72,000
0.5%	2	1	$48,000
1%	+1[1]	1	$49,000
2%	0	0	$50,000
5%	0	0	$55,000
10%	1	+1[1]	$60,000
20%	0	1	$76,000
		Average Annual Damages Reduction	$53,000

[1]This number represents an increase with the implementation of Option FM16

Cost Estimate

A preliminary cost estimate for Option FM16 estimated that this measure would cost $505,000. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $53,000
- NPV of reduction: $780,000
- Cost estimate of option: $505,000
- Benefit-Cost Ratio: 1.58

The benefit-cost ratio is 1.58, which means the economic benefit of Option FM16 outweighs the cost and as such, on economic grounds, this measure is justified for further investigation.

Constraints

The safety of frequent ponding behind berms would need to be considered as well as embankment failure during flood events.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

Provided that flood impacts on affected residents are properly assessed and mitigated during the design phase, it is likely that the general community would be very supportive of this measure given the benefits.

Recommendation: Option FM16 is recommended as a measure for inclusion in the Floodplain Risk management Plan due to the reductions in peak flood levels particularly in frequent flood events.

7.3.3.12 Cascading berms in Central Park (Option FM17)

Option Overview

Option FM17 worked to reduce the flood affectation in the Davidson Avenue area (Hotspot 4, see Section 6.2.4) by implementing a series of berms of varying heights in Central Park to attenuate flood flows. This measure was suggested by Council and aimed to use public land to address flooding issues with minimal disruption to the community.

This measure implemented five berms (0.6 m high) perpendicular to the flow direction in the park framed by two berms parallel to flow (up to 1.3 m high, 0.5 m on average) to capture and retain flood waters (see Figure 33). This assessment has not incorporated a freeboard to the height these embankments however freeboard would be required during the design and construction of these structures.

Impact on Flood Liability

In the 20% AEP event, peak flood levels are reduced by up to 0.06 m along Davidson Avenue and Curtin Place with the implementation of Option FM17 (see Figure 33). Within the berms, peak flood levels are increased up 0.5 m. Further, peak flood level increases occur in the vicinity of Central Park with up to 0.06 m at properties which would require further mitigation assessment during design stages.

Peak flood level reductions of up to 0.12 m and typically 0.01 m occur in the 1% AEP event along Davidson Avenue and Curtin Place with the implementation of Option FM17 (see Figure 33). Peak flood levels increase to the height of the berms (0.6 m) and by up to 0.05 m at properties in the vicinity. These flood level increases are relatively minor and would require further mitigation if the design would progress.

This measure was modelled for a range of flood events with results presented in Table 31 below. The table shows that Option FM17 has significant benefit across the full range of flood events with 4 properties no longer experiencing above-floor flooding in the 1% AEP event and a corresponding reduction of around $441,000 in flood damages expected. A reduction in AAD of $343,000 is expected with the implementation of this measure.

Table 31: Economic Impacts of Option FM17

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0	1	$541,000
0.2%	4	2	$365,000
0.5%	6	1	$570,000
1%	3	4	$441,000
2%	10	5	$550,000
5%	9	5	$399,000
10%	12	2	$265,000
20%	15	6	$423,000
		Average Annual Damages Reduction	$343,000

Cost Estimate

A preliminary cost estimate for Option FM17 estimated that this measure would cost $250,000. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $343,000
- NPV of reduction: $5,018,000
- Cost estimate of option: $250,000
- Benefit-Cost Ratio: 20.07

The benefit-cost ratio is 20.07, which means the economic benefit of Option FM17 outweigh the cost by 20 times and as such, on economic grounds, this measure is justified for further investigation.

Constraints

The safety of frequent ponding behind berms would need to be considered as well as embankment failure during flood events.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

Provided that flood impacts on affected residents are properly assessed and mitigated during the design phase and the proposed berms do not affect the utility of the park, it is likely that the general community would be supportive of this measure given the benefits.

Recommendation: Option FM17 is recommended as a measure for inclusion in the Floodplain Risk management Plan due to the reductions in peak flood levels particularly in frequent flood events.

7.3.3.13 Lowering Greenlees Avenue and Greenlees Park (FM19)

Option Overview

Inundation along the Main South Drain in the vicinity of Jessie Stewart Reserve (Hotspot 2, see Section 6.2.2) is exacerbated by several factors. Consultation with the community indicated that the slightly elevated level of the Greenlees Avenue roadway and Greenlees Park was causing floodwater to pond and worsen flooding for nearby residential properties. Given this, Option FM19 investigated lowering the level of the roadway and Greenlees Park by 0.1 m on average over a 0.6 hectare area and implementing a 0.6 m high embankment along the western side of Jesse Stewart Reserve to protect neighbouring properties from inundation (Figure 34 presents this configuration).

Impact on Flood Liability

Figure 34 presents the peak flood level impact in the 20% and 1% AEP events. In the 20% AEP event, peak flood levels are reduced by 0.02 m at neighbouring properties and up to 0.09 m in Greenlees Park. Peak flood levels downstream are increased by up to 0.04 m within Greenlees Park and on Ian Parade. Flood levels are reduced by up to 0.03 m in the 1% AEP event with notably no peak flood level increases downstream.

The option was simulated for a range of flood events with results presented in Table 32 below. The table show that that Option FM19 provides minor benefits to the depth of flooding at individual properties as indicated by the reduction in event damage. Of note is the increase in event damages in the 0.5% AEP event which is due to decreases in affectation in the more common flood events. A reduction in AAD of $8,000 is expected with the implementation of this option.

Table 32: Economic Impacts of Option FM19

Design Event (AEP)	Number of Properties No Longer Flooded Over Ground	Number of Properties No Longer Flooded Over Floor	Reduction in Event Damages
PMF	0	0	$6,000
0.2%	0	0	$4,000
0.5%	0	0	+$12,000[1]
1%	0	0	$18,000
2%	0	0	$28,000
5%	0	0	$66,000
10%	1	0	$56,000
20%	0	0	$6,000
		Average Annual Damages Reduction	$8,000

[1]This number represents an increase with the implementation of Option FM19

Cost Estimate

A preliminary cost estimate for Option FM19 estimated that this measure would cost $970,000. Further cost estimate details area presented in Appendix C. This cost estimate is indicative only and should not be relied on for reasons other than the purposes of this preliminary feasibility assessment.

Benefit / Cost Ratio Analysis

This option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 30 year design life and 5% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $8,000
- NPV of reduction: $116,000
- Cost estimate of option: $970,000
- Benefit-Cost Ratio: 0.12

The benefit-cost ratio is 0.12, which means the cost of Option FM19 is over eight times more than its expected benefit, and it cannot be justified on economic grounds alone.

Social and Environmental Impacts

The proposed works are not expected to have significant adverse environmental impacts.

The reduction in risk to life provides intangible benefits including reduced disruption, social stresses, trauma and impacts on emergency personnel and health care facilities.

Community Acceptance

This measure was assessed after residents noted the flood liability of the area. Given the benefit and minimal negative impact, it is likely that the general community would be supportive of this measure. Support may slightly decline once the residents consider the disruption to traffic, pedestrians and park users during the construction phase.

Recommendation: Option FM19 is recommended as a long term measure in the Floodplain Risk management Plan due to the reductions in peak flood levels achieved in Jesse Stewart Reserve.

7.3.3.14 Lowering of Brewer Street near Pamela Place (FM18)

As an additional option to the shortlisted measures, the lowering of Brewer Street near Pamela Place was assessed. At the intersection, there is a gutter of around 2.3 mAHD on the north side of Brewer Street, a road crest of 2.63 mAHD on Brewer Street, and then lower levels to the south, into the park. The sag in Brewer Street and the higher road crest create a topographic low point where flooding has been observed. The area receives significant flow from the west which then discharges into the park. The option consists of lowering the road crest to 2.4 mAHD over a ~7 m width. The option was tested for the 20% AEP and 1% AEP. In the latter there was no significant change to flood levels as the park backwaters into the sag point. In the 20% AEP, there was 0.05 m reduction in flood level. While not insignificant, there is still around 0.4 m depth of runoff and the flooding issue would remain largely unchanged. The results indicate that the road crest is slightly exacerbating flooding but is not the dominant cause of flooding at the location. Measures that address the overland flow rates, i.e. FM02, have a similar reduction in flooding at the site. It is also noted that lowering the road would slightly increase road flooding at the location, and in certain floods, may lead to more flooding from the park.

Recommendation: Option FM18 is not recommended in the Floodplain Risk management Plan due to the minimal reduction in flood levels.

7.3.4 Multi-Criteria Assessment

The assessment of various flood modification measures is presented in Table 33. The measures are evaluated against various criteria and are scored in order to compare their relative advantages and disadvantages.

This evaluation enables options to be prioritised and is a useful tool for decision-makers and other stakeholders. It should be noted that scoring and ranking is only used for an indicative comparison and is not intended to act as a final verdict on the options. Also note that the scoring and ranking may be updated following the public exhibition period, especially in regard to community acceptance.

The results of the analysis are presented in Table 33. Each criteria corresponds to a column and has been scored between -3 (lowest score) and 3 (highest score).

Table 33: Multi-criteria Assessment

Ref.	Mitigation Measure	Impact on road flooding	Impact on property flooding	Impact on risk to life	Technical Feasibility	Community Acceptance	Economic Value	Environmental Impact	Total Score	Rank
FM01	Macnamara Avenue Drainage Upgrade	1	1	1	-1	1	-2	-1	0	8
FM02	Davidson Avenue Drainage Upgrade (benefit extends to Brewer Street)	1	2	1	-1	1	-2	-1	1	5
FM04	Clearing of debris along main flowpaths	1	1	1	-1	2	0	1	5	2
FM06	Coles Street Drainage Upgrade	1	1	1	-3	1	-2	-1	-2	9
FM07	Queen Elizabeth Park Drainage Upgrade	1	1	1	-1	1	-3	-1	-1	10
FM08	Shackel Avenue Drainage Upgrade	1	1	1	-1	1	-2	-1	0	8
FM14	Cascading berms in Goddard Park, Queen Elizabeth and Rothwell Park	1	1	-1	-1	1	2	-1	2	4
FM16	Improve Conveyance along Davidson Avenue, Majors Bay Road and Brewer Street Intersection	1	1	1	1	3	2	-1	8	1
FM17	Cascading Berms in Central Park	2	2	-2	-1	1	3	-1	4	3
FM18	Lowering of Brewer Street near Pamela Place	-1	1	0	1	1	-1	0	1	5
FM19	Lowering Greenlees Avenue and Greenlees Park	1	1	1	1	1	-3	-1	1	5

The total score is highest for Option FM16 which has benefits across the range of criteria excluding environmental factors as this measure will require clearing of low-lying vegetation. The lowest scoring measure was found to be Option FM09 which provides significant benefits to flood affection however is extremely expensive to implement, technically not feasible and will have significant environmental impacts.

8. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

8.1 Plan Objectives

The objective of a Floodplain Risk Management Plan is to manage existing and future flood risk the Exile Bay Catchment with the NSW FRMM (2023).

The Plan aims to achieve the following overarching objectives:

- Reduce the flood hazard and risk to people and property, now and in the future;
- Protect, maintain and where possible enhance the floodplain environment; and
- Ensure floodplain risk management decisions integrate social, economic and environmental considerations.

8.2 Recommended Flood Management Measures

The flood management measures recommended for implementation are presented in Table 34. The measures have been prioritised with high, medium and low classifications as defined below:

- High – can be undertaken in the short term (<12 month) with minimal cost and/or have the potential to provide significant reductions in flood risk;
- Medium – can be undertaken in the medium term (1 to 5 years), require input from other studies or investigations, provide reductions in flood risk but could be expensive;
- Low – measures that are unlikely to be feasible to implement in the next 5 years or that are likely subject to significant financial constraints.

Responsibility for implementation and cost estimates are also presented, along with the relevant section of this report which provides details of each option.

Table 34: DRAFT Flood Risk Management Plan

Flood Management Measure	Section	Priority	Preliminary Estimates	Responsibility
Property Modification Measure				
Clarify use of Flood Risk Precincts in the DCP	7.1.2	Medium	Council cost estimate	Council
Voluntary Purchase	7.1.3	Medium	Council cost estimate	Council
Flood Proofing	7.1.5	Medium	-	Property Owners
Response Modification Measures				
Local Flood Plan	7.2.5	High	SES cost estimate	NSW SES
Flood Modification Measures				
FM01 - Macnamara Avenue Drainage Upgrade	7.3.3.1	Low	$4.5 million	Council
FM02 - Davidson Avenue Drainage Upgrade	7.3.3.2	Low	$6.8 million	Council
FM04 - Clearing of debris along main flowpaths	7.3.3.4	High	Council cost estimate	Council / Property Owners
FM06 - Coles Street Drainage Upgrade	7.3.3.5	Low	$2.2 million	Council
FM07 - Queen Elizabeth Park Drainage Upgrade	7.3.3.6	Low	$2.5 million	Council
FM08 - Shackel Avenue Drainage Upgrade	7.3.3.7	Low	$400,000	Council
FM14 - Cascading berms in Goddard Park, Queen Elizabeth Park and Rothwell Park	7.3.3.10	Medium	$500,000	Council
FM16 - Improve conveyance along Davidson Avenue, Majors Bay Road and Brewer Street Intersection	7.3.3.11	High	$500,000	Council
FM17 - Cascading berms in Central Park	7.3.3.12	Medium	$250,000	Council
FM19 - Lowering Greenlees Avenue and Greenlees Park	7.3.3.13	Low	$1 million	Council

REFERENCES

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3. City of Canada Bay, *Development Control Plan*, City of Canada Bay, August 2023

4. Howells L, McLuckie D, Collings G, Lawson N, *Defining the Floodway – Can one Size Fit All?*, Lawson and Treloar, 2003.

5. Municipality of Concord, *Stormwater Drainage capacity assessment within the Municipality of Concord*, E. S. Rowe & Ennie, July 1973

6. Department of Planning and Environment - NSW Government, *Flood Risk Management Manual*, June 2023

7. Department of Planning and Environment – NSW Government, *Flood Risk Management Manual*, Department of Planning and Environment, February 2022.

8. Australian Construction Handbook, 2023, Rawlinsons Publishing.

FIGURES

APPENDIX A

Glossary of Key Terminology (Reference 6)

annual exceedance probability (AEP)	the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. Eg, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m3/s or larger events occurring in any one year (see ARI). (see Table 35, Appendix A)
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
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 flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
catchment	the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	the council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify a Minister or public authority (other than a council), or the Director General of DIPNR, as having the function to determine an application.
development	is defined in Part 4 of the EP&A Act infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development new development: refers to development of a completely different nature to that associated with the former land use. Eg, the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. redevelopment: refers to rebuilding in an area. Eg, as urban areas age, it may become necessary to demolish and reconstruct buildings on a

	relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
disaster plan (DISPLAN)	a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m3/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).
effective warning time	the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage (refer Section C6) before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	the remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	is synonymous with flood prone land (ie) land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).

flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
flood planning area	the area of land below the FPL and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
flood planning levels (FPLs)	are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
flood readiness	Readiness is an ability to react within the effective warning time.
flood risk	potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below: existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town

	protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. (See Section K5). Freeboard is included in the flood planning level.
habitable room	in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding	inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flowpaths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.
minor, moderate and major flooding	both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

	major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	measures that modify either the flood, the property or the response to flooding.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood	the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
probable maximum precipitation	the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	a statistical measure of the expected chance of flooding (see AEP).
risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	a plan prepared by a registered surveyor.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.

Table 35: ARR 2016 Preferred Terminology (Reference 2)

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

APPENDIX B

Community Consultation Newsletter and Questionnaire

Council report on Public Exhibition

APPENDIX C

Preliminary Cost Estimations