ATTACHMENT D

ALEXANDRA CANAL FLOODPLAIN RISK MANAGEMENT PLAN (DRAFT REPORT)

ATTACHMENT D

Floodplain Risk Management Plan

Alexandra Canal Floodplain Risk Management Study and Plan

W4948

Prepared for
City of Sydney

24 September 2013

CITY OF SYDNEY

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Cardno Shaping the Future

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Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee -

   Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection -

   The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study -

   Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

   Evaluates floodplain management measures for the floodplain in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

   Involves formal adoption by Council of a management plan for the floodplain.

6. Implementation of the Plan –

   Implementation of actions to manage flood risks for existing and new development.

This Alexandra Canal Catchment Floodplain Risk Management Plan is developed from the previous studies, Floodplain Risk Management Study and Flood Study, prepared by Cardno for the City of Sydney Council.

Executive Summary

Cardno were commissioned by the City of Sydney to undertake a Floodplain Risk Management Study and Plan for the Alexandra Canal Catchment. This document forms the Floodplain Risk Management Plan (FRMP), and should be read in conjunction with the Floodplain Risk Management Study (Cardno, 2013a).

This study has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk and make recommendations for options to be adopted as part of this FRMP. The tasks were undertaken alongside community consultations to ensure that community concerns were addressed.

The overall objective of this study is to develop a FRMP that address the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Manual (NSW Government, 2005).

The total catchment area is approximately 1,141ha and includes the suburbs of Alexandria, Rosebery, Erskineville, Beaconsfield, Zetland, Waterloo, Redfern, Newtown, Eveleigh, Surry Hills and Moore Park. It is generally bounded by the Eastern Distributor and Moore Park in the east, Gardeners Road in the south, Sydney Park and Newton in the west and Albion Street in the north-east. The majority of the trunk drainage system is owned by Sydney Water Corporation, while the feeding drainage systems are primarily owned by Council.

The majority of the catchment is fully developed and consists predominantly of medium to high-density housing, commercial and industrial development with some large open spaces.

A draft flood study has been prepared by Cardno (2013b) to define the flood behaviour in the study area, including both mainstream and overland flooding. The flood study determined the flood behaviour for the 100 year ARI, 20 year, 10 year, 5 year, 2 year and 1 year ARI events together with the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels, velocities and flow rates. The study has also defined the Provisional Flood Hazard for flood-affected areas. An assessment of the impact of blockages of culverts and pits was also undertaken for the flood study.

The majority of flooding within the Alexandra Canal catchment is characterised by overland flow. The critical duration is between 1 and 3 hours across the catchment, with the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration "flash" flooding. The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties.

The community consultation undertaken as part of the FRMS built on the consultation undertaken as part of the Flood Study (Cardno, 2013). The purpose of the Flood Study (Cardno, 2013) consultation was to inform the community about the study and gain an understanding of the communities experience with historical flooding in the catchment. The purpose of the more recent consultation undertaken as part of this FRMS was to inform the community about the study, identify community concerns and attitudes, to gather information from the community on potential options for the floodplain and to develop and maintain community confidence in the study results.

The community consultation consisted of:

- A community brochure and survey;
- A press release; and
- Public meetings (to be undertaken during the public exhibition period).

Flooding is likely to cause significant social and economic damages to the communities. A flood damage assessment for the existing catchment and floodplain conditions has been undertaken as part of the current study. The assessment is based on damage curves that relate the depth of flooding on a property, to the potential damage within the property. Average Annual Damage (AAD) is calculated on a probability approach, using the flood damages calculated for each design event. The average annual damage estimated for the Alexandra Canal floodplain under existing conditions is approximately **$13.0 million** (excluding GST).

Under the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and state agency stakeholders, a number of potential options for the management of flooding were identified.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. Various options for flood risk management have been identified and assessed. These options can be broadly defined into three categories of management:

- **Flood modification measures** – Flood modification measures are measures aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment.
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these measures aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

These options were assessed as a part of the FPRMS using a multi-criteria assessment considering economic, environmental and social factors. The draft priority measures were identified in the FPRMS using this method. It is noted that the multi-criteria assessment does not provide an absolute answer, but rather a transparent decision making process. The outcomes of this assessment will likely change following review and input from Council, the community and key stakeholders.

This Plan has taken the prioritised measures from the FPRMS, and developed an implementation plan for Council. An implementation plan is described in Section 5 and recommended measures include:

Non-Structural Measures-

- FM15 Liveable Green Network
- FM23 Increased pit cleaning and maintenance
- EM1 Information Transfer to SES
- EM2 Preparation of District DISPLAN
- EM3 Preparation of Local Flood Plan
- PM3 Opportunities related to Large Scale Future Development
- PM2 Development Controls and Policies
- EM5 Public awareness and education
- PM1 LEP Update
- EM6 Flood warning signs at critical locations
- PM9 Flood Proofing Guidelines
- EM4 Flood Warning System and Temporary Refuge

Structural Measures-

- FM9 Link Road to Alexandra Canal Upgrade – Maddox Street Alignment
- FM6 Additional pipes from Macdonald Street and Coulson Street to Alexandra Canal (alternatively FM21 Detention Basin in Sydney Park – Offset Storage from Macdonald Street)
- FM7 Detention basins in Redfern Park
- FM18 Additional Drainage Network at Harcourt Parade to Gardeners Road
- FM17 Detention basin in Turruwul Park

- FM20 Sheas Creek Channel Flood Walls

Flood modification works at Redfern Park and Turruwul Park are considered on a long-term implementation timeframe to complement recent works at the site.

The next stage of the study is for this draft Floodplain Risk Management Study and Plan to be reviewed by stakeholders and the community during the public exhibition period. It should be noted that the outcomes of the Plan may alter as a result of this process.

Table of Contents

Appendices

Tables

Figures

Glossary

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large. The 1% AEP event is equivalent to the 1 in 100 year Average Recurrence Interval event.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year ARI or 100% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
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 overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard

	flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks;

	able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by Engineers Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.

Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change & Water (now OEH)
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FPRMSP	Floodplain Risk Management Study & Plan
km	kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	metre
m^2	Square metres
m^3	Cubic metres
mAHD	Metres to Australian Height Datum
mm	millimetres
m/s	metres per second
NSW	New South Wales
OSD	On-site Detention
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service
SWC	Sydney Water Corporation

1 Introduction

A Floodplain Risk Management Study (FRMS) and a Floodplain Risk Management Plan (FRMP) for the Alexandra Canal Catchment have been prepared by Cardno on behalf of City of Sydney. The FRMS identifies and examines options for the management of flooding within the Alexandra Canal Catchment. This FRMP takes the recommendations from the FRMS and incorporates them into a plan of implementation. Both the FRMS and the FRMP have been prepared in accordance with the NSW Government *Floodplain Development Manual* (2005).

1.1 Study Context

The Floodplain Management process progresses through 6 stages, in an iterative process:

1. Formation of a Floodplain Management Committee;
2. Data collection;
3. Flood Study;
4. Floodplain Risk Management Study;
5. Floodplain Risk Management Plan; and
6. Implementation of the Floodplain Risk Management Plan.

This report addresses Stage 5.

1.2 Study Objectives

The overall objective of the Floodplain Risk Management Study and Plan is to devise a strategy that addresses the existing, future and continuing issues in the Alexandra Canal catchment in accordance with the NSW Government's Flood Policy, as detailed in the NSW Floodplain Development Manual (NSW Government, 2005).

This Floodplain Risk Management Study and Plan was undertaken in two phases:

- Phase 1 – Floodplain Risk Management Study where management issues are assessed, management options are investigated and recommendations are made, and
- Phase 2 – Floodplain Management Plan detailing how flood prone land within the study area is to be managed.

Specific objectives for Phase 2 included:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change).
- Reduce private and public losses due to flooding.
- Protect and where possible enhance the floodplain environment.
- Be consistent with the objectives of relevant State policies, in particular, the
- Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979.
- Ensure that the draft floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community.
- Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms.

- Ensure that the draft floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans.
- Establish a program for implementation and suggest a mechanism for the funding of the plan which should include priorities, staging, funding, responsibilities, constraints, and monitoring.

2 Existing Flooding Behaviour

2.1 Catchment and Floodplain Description

The Alexandra Canal catchment covers 1,141ha or 43% of Sydney City Council Local Government area, including suburbs of Alexandria, Beaconsfield, Erskineville, Eveleigh, Moore Park, Redfern, Rosebery, Surry Hills, Waterloo and Zetland. Approximately 93% of the total catchment area is within the City of Sydney, with the remaining 7% being shared with the City of Botany Bay, Marrickville and Randwick Councils.

The catchment and study area are shown in **Figure 2-1**.

Drainage systems consisting of open channels, covered channels, in-ground pipes, culverts and pits convey runoff from the catchment to Alexandra Canal which discharges into the Cooks River. The majority of the trunk drainage system is owned by Sydney Water Corporation, with the feeding drainage systems are primarily owned by Council.

The majority of the catchment is fully developed and consists predominantly of medium to high-density housing, commercial and industrial development with some large open spaces that include Moore Park Playing Fields, Moore Park Golf Course, The Australian Golf Course, Sydney Park, Redfern Park, Waterloo Park and Alexandria Park.

Flooding throughout the catchment is a combination of overland flow and mainstream flooding. Mainstream flooding issues tend to occur around Alexandra Canal and the open channels in the study area. Examples of this type of flooding occur at the channel that runs between Alexandra Canal and Bowden Street, the channel near Euston Road and the channel at South Sydney Corporate Park. Elsewhere, flooding is primarily a result of overland flow and the capacity of the stormwater network and overland flowpaths.

One of the interesting features of the catchment is the prevalence of ‘trapped’ low points. These areas, due to topographical and development constraints, result in significant ponding and flooding of properties and roads. In a number of these locations, the only way for water to escape is via the pit and pipe system. Examples of these ponding areas include the Coulson Street sag, Joynton Avenue and the ponding upstream of Erskineville Oval.

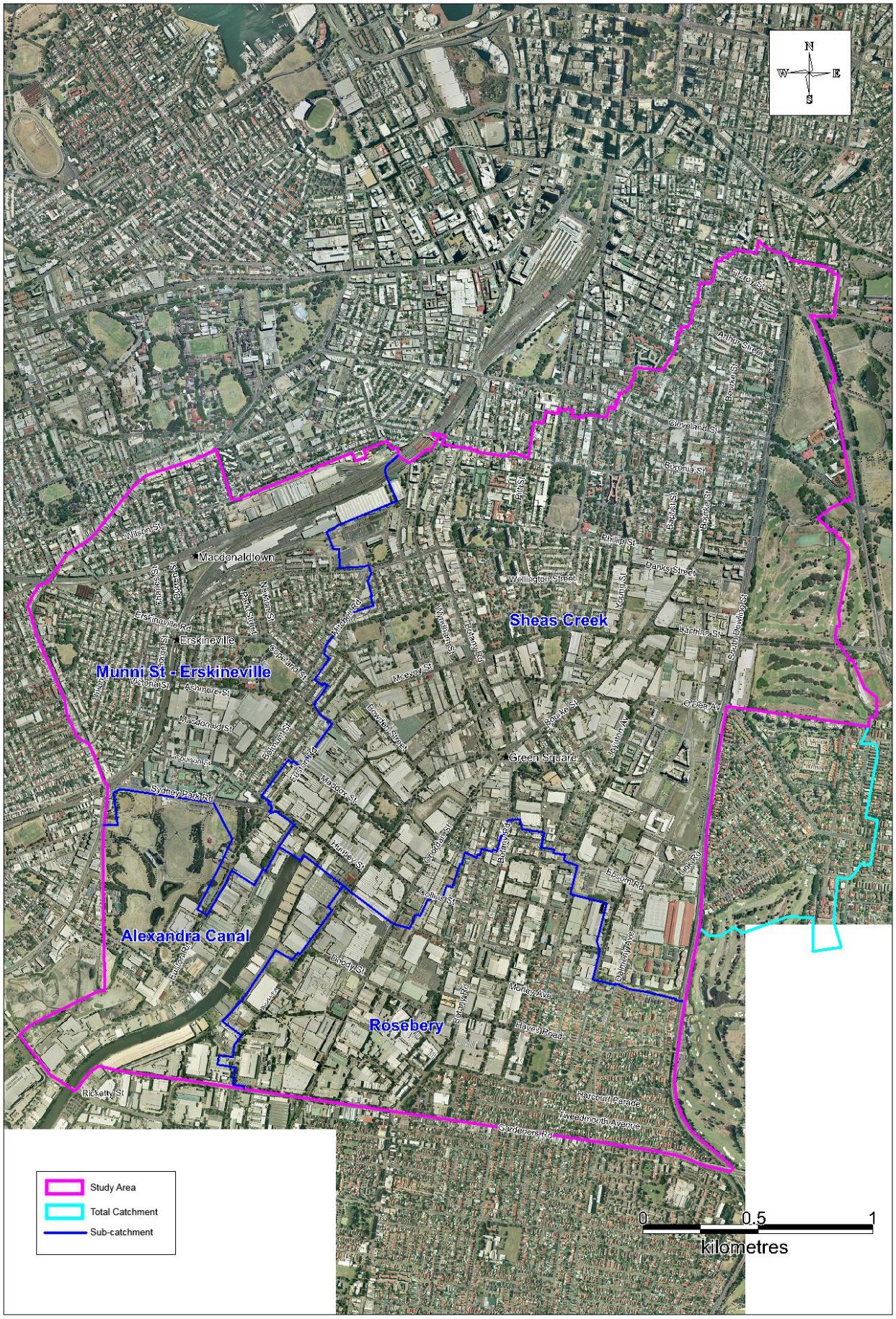


Figure 2-1 Study Area

2.2 Flood Study

A detailed 1D/2D flood model was established as part of the Flood Study (Cardno, 2013b) to describe the flooding behaviour throughout the study area. This model incorporated all pits and pipes from data provided by the City of Sydney and had a 4 metre grid resolution. Hydrological modelling was undertaken through the application of the Direct Rainfall methodology.

The models were calibrated and verified against four historical storms; November 1984, January 1991, April 1998 and February 2001. November 1984 was approximately larger than a 100 year ARI event, while April 1998 was in the order of a 10 year ARI event. The other two events were smaller, with January 1991 roughly a 20 – 50 year ARI event, and February 2001 less than a 1 year ARI event. The calibration events were chosen through a combination of both their magnitude, together with the quantity of flood observations from the storm.

The results of the calibration and verification showed that the model was capable of reproducing the observations from those events, providing confidence in the overall modelling results. The models were further verified against the previous studies that have been undertaken within the catchment.

Using the established models, the study has determined the flood behaviour for the 100 year ARI, 20 year, 10 year, 5 year, 2 year and 1 year ARI events as well as the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels, velocities and flow rates. The study has also defined the Provisional Flood Hazard for flood-affected areas.

Peak flood depths modelled in the Alexandra Canal floodplain are shown in **Figures 2-2 and 2-3** for the 100 year ARI and PMF events respectively. A full presentation and discussion of the existing flood behaviour is provided in the Flood Study (Cardno, 2013b).

The true hazard mapping for the 100 year ARI and PMF events are shown in **Figures 2-4 and 2-5** respectively.

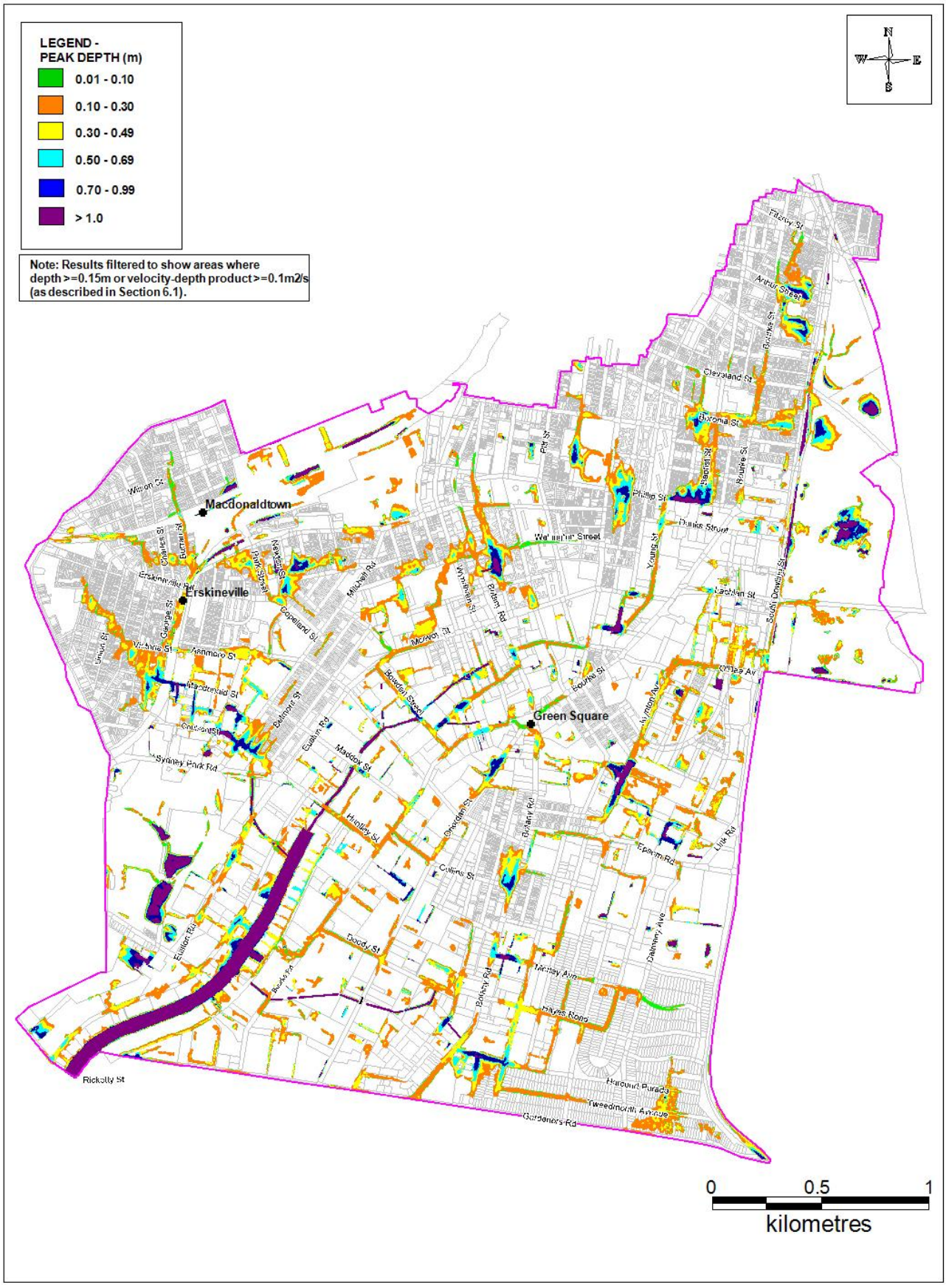


Figure 2-2 100 Year ARI Peak Flood Depths

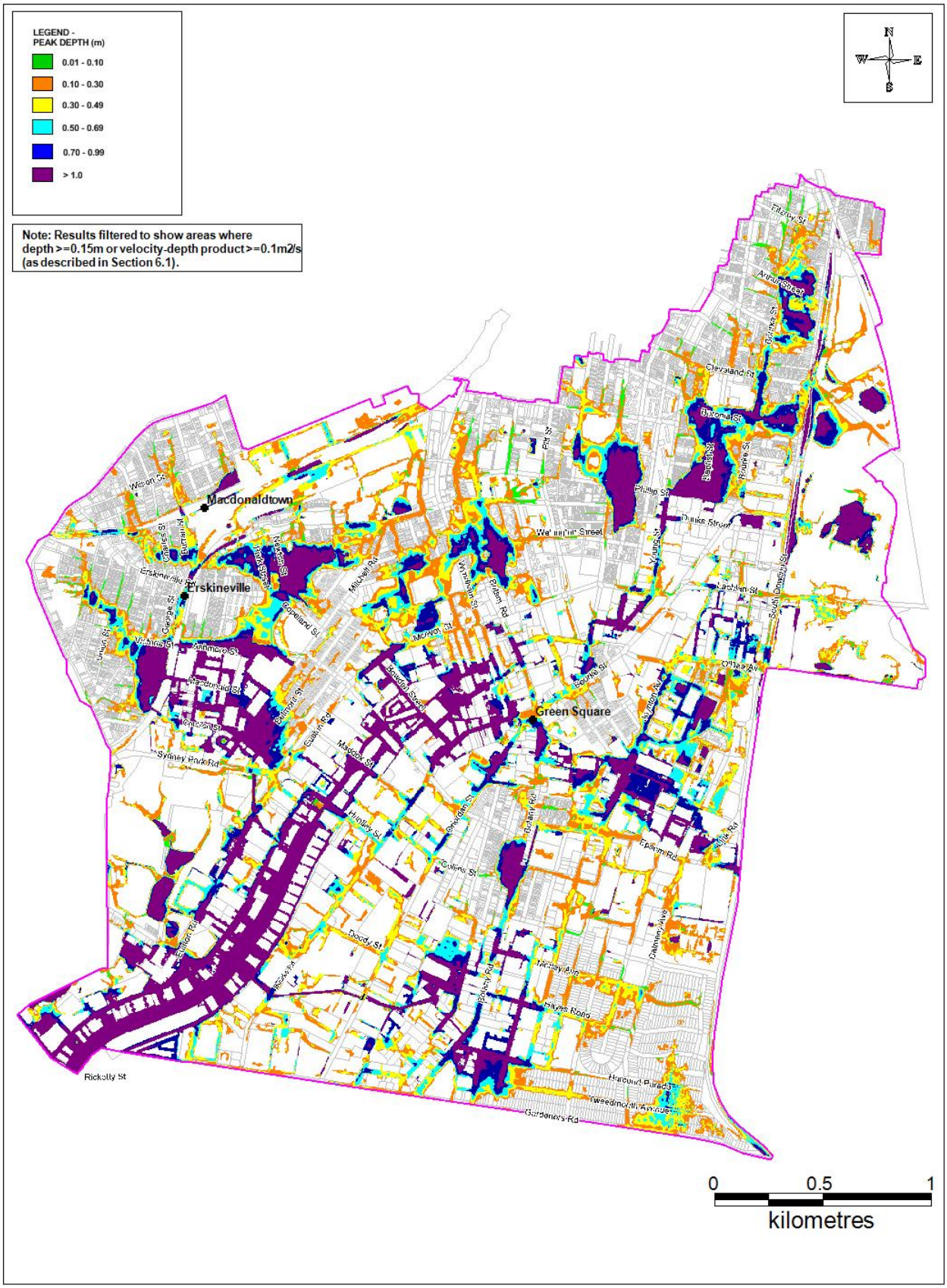


Figure 2-3 PMF Peak Flood Depths

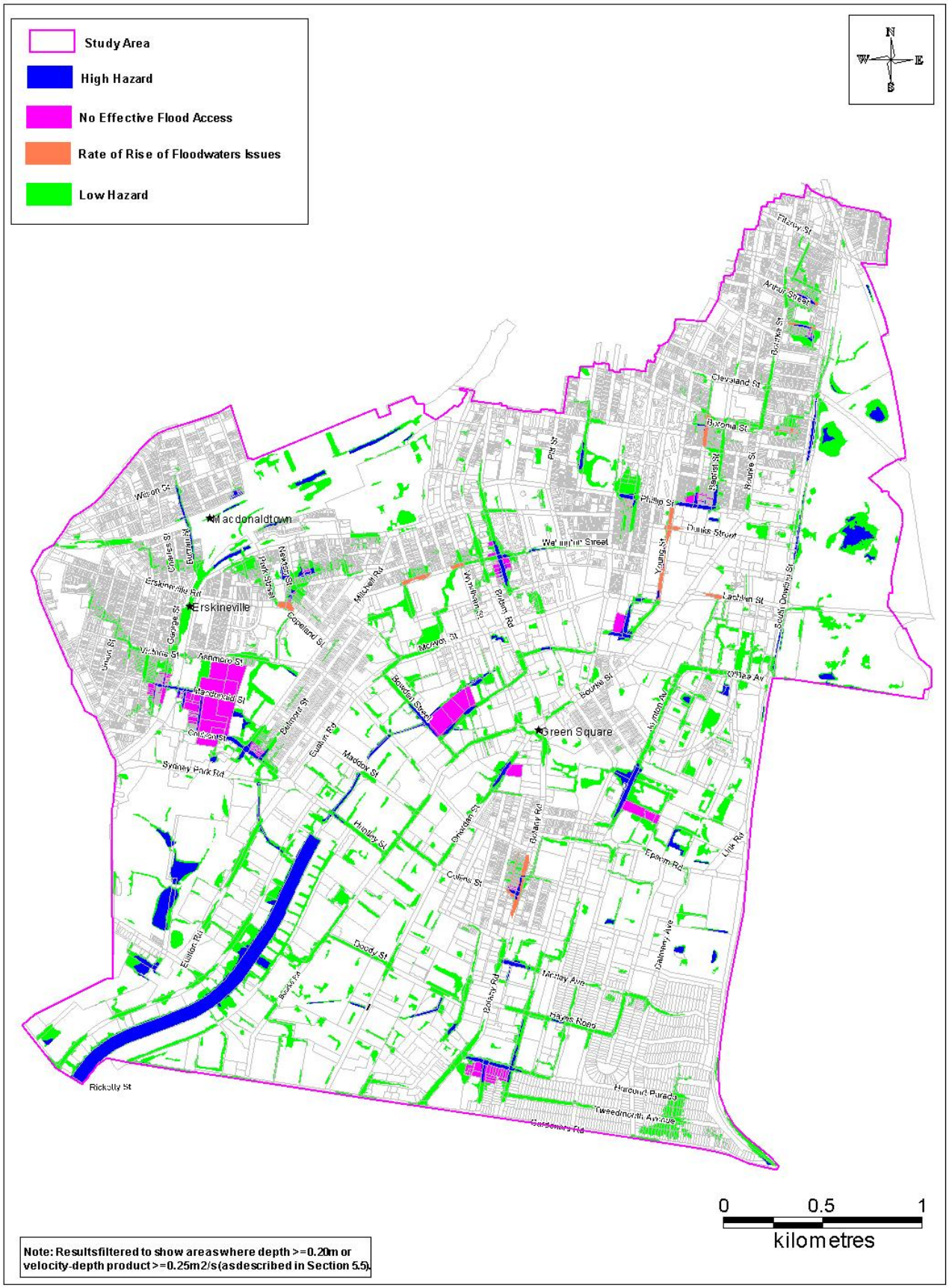


Figure 2-4 100 Year ARI Flood Hazard

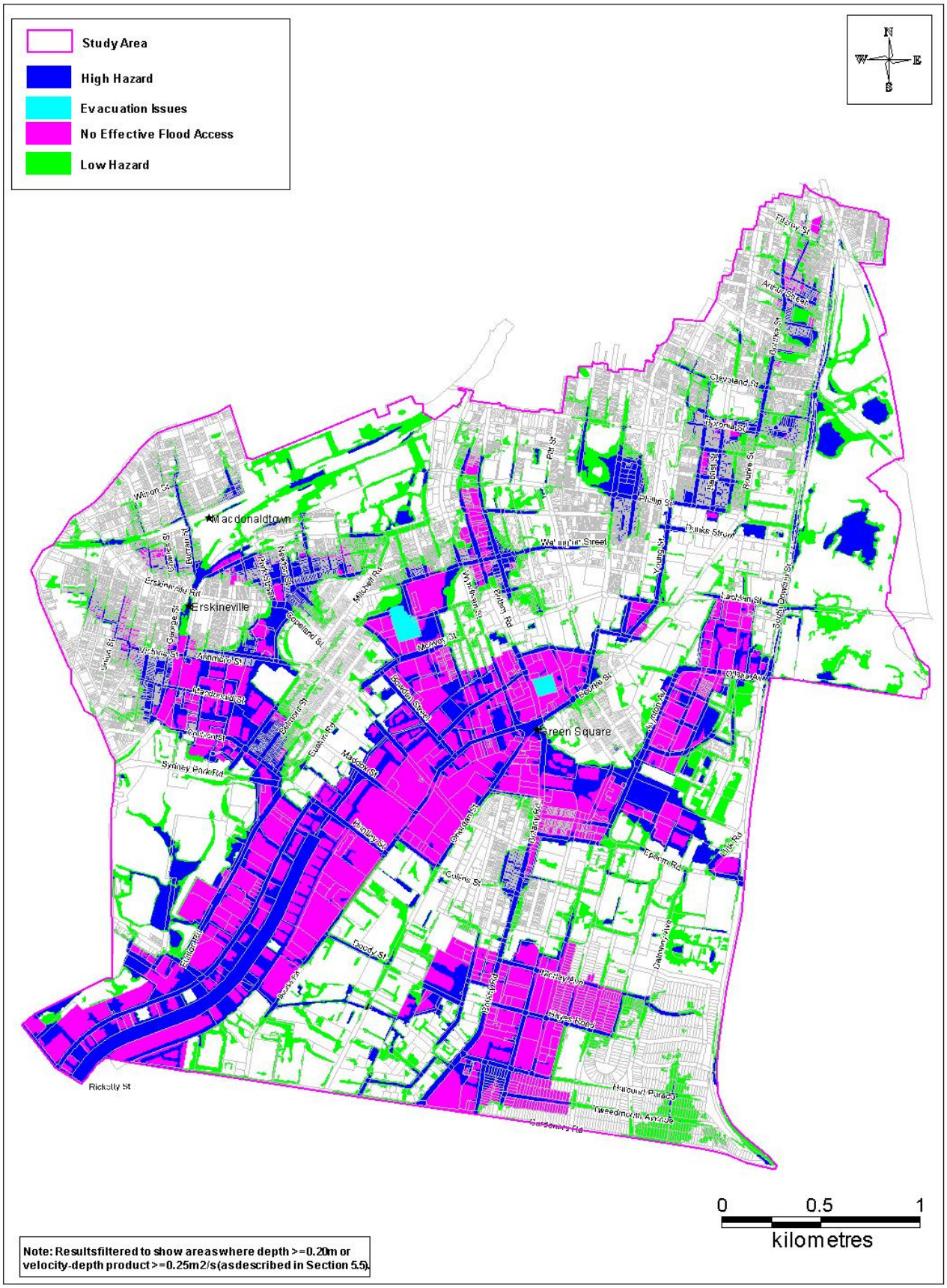


Figure 2-5 PMF Flood Hazard

2.3 Damage Analysis

A flood damage assessment for the existing catchment conditions has been completed and is detailed in the Floodplain Risk Management Study (Cardno, 2013a).

The results from the damage analysis are shown in **Table 2-1**. Based on the analysis described in the Floodplain Risk Management Study, the average annual damage for the Alexandra Canal floodplain under existing conditions is approximately **$13 million** (excluding GST).

Table 2-1 Flood Damage Assessment Summary

Property Type	Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with Overground Flooding	Total Damage ($Nov 2012-Mar 2013) (ex. GST)
PMF					
Residential	1263	0.78	3.26	1345	$91,800,740
Commercial	196	0.71	2.95	207	$97,607,569
Industry	125	0.99	3.16	131	$193,627,407
Total	1584			1683	$383,035,716
100 Year ARI					
Residential	580	0.23	1.51	988	$30,121,637
Commercial	71	0.30	0.96	110	$19,240,425
Industrial	54	0.31	1.58	89	$33,190,832
Total	705			1187	$82,552,895
20 Year ARI					
Residential	271	0.19	0.74	602	$16,236,372
Commercial	42	0.20	0.60	76	$9,928,007
Industrial	35	0.25	0.96	60	$19,491,268
Total	348			738	$45,655,647
10 Year ARI					
Residential	175	0.16	0.55	439	$10,272,581
Commercial	26	0.18	0.43	50	$6,163,448
Industry	29	0.21	0.52	43	$13,817,069
Total	230			532	$30,253,098
5 Year ARI					
Residential	106	0.16	0.39	338	$6,262,566
Commercial	8	0.19	0.29	27	$2,485,745
Industry	16	0.19	0.43	35	$4,889,260
Total	130			400	$13,637,570
2 Year ARI					
Residential	30	0.11	0.29	132	$1,653,255
Commercial	3	0.10	0.24	14	$1,397,261
Industry	6	0.17		15	$856,874
Total	39			161	$3,907,389
1 Year ARI					
Residential	1	0.11	0.19	29	$71,664
Commercial	2	0.13	0.20	8	$1,016,841
Industry	3	0.11		6	$371,364
Total	6			0	$1,459,869

3 Floodplain Risk Management Options

Flood Risk can be categorised as existing, future or residual risk:

- **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding.
- **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built.
- **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 3-1**.

Table 3-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is.

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

- **Flood modification measures** – Flood modification measures are measures aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment.
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these measures aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

Several measures relating to each of these categories were assessed as part of the Floodplain Risk Management Study (Cardno, 2013a) and are summarised in the following sections.

3.2 Flood Modification Measures

Flood modification measures are structural measures aimed at preventing, avoiding or reducing the likelihood of flood risks.

Based on the flood model results, historical information and engineering judgement, possible flood modification measures (i.e. structural measures) for the study area were identified. Flood modification measures for the Alexandra Canal Catchment have been identified based on opportunities for both short term and long term works. Numerous measures were assessed for the Green Square area (within the Sheas Creek subcatchment) as part of the flood assessment for the Green Square Town Centre (GSTC) redevelopment. Measures identified during the GSTC project were used as an initial basis for the subsequent measure configurations assessed for this Study.

In the long term, a drainage strategy has been investigated with an aim to have all drainage infrastructure with a 20 year ARI design capacity (discussed in more detail in **Section 3.2.2**). The key challenge with this strategy is the overall scope of works and the timeframe for this to be undertaken, if it is identified as a preferred solution. Furthermore, due to staging issues, many of the upstream areas of the catchment would be upgraded last.

Therefore, in addition to this overall long term drainage strategy, short to medium term flood modification measures have been identified. These measures could either be used instead of the long term strategy, or be used in the interim until such time as a 20 year ARI drainage strategy can be achieved in that area. A large majority of the short term measures are "independent", and therefore can be undertaken as isolated projects.

3.2.1 Short to Medium Term Flood Modification Measures

Short term flood modification measures have been identified for assessment primarily comprising singular pipe upgrades, detention basins and other localised works. These measures are listed in **Table 3-2**. General locations for Measures FM1 to FM10 are shown in **Figure 3-1** and general locations for other measures are shown in **Figure 3-2**.

Table 3-2 Flood Modification Measures Assessed in the FRMS

Measure Reference	Description	Comments
FM1	Raising Joynton Avenue and Incorporating Epsom Park Basin	Green Square measure. Superseded by FM9.
FM2	Additional Culvert from Joynton Avenue to Sheas Creek - Bowden Street Alignment	Green Square measure. Superseded by FM9.
FM3	Additional Culvert from Joynton Avenue to Sheas Creek - Maddox Street Alignment	Green Square measure. Superseded by FM9.
FM4	Additional Culvert from Joynton Avenue to Sheas Creek - Maddox Street Alignment excluding Drying Green Storage	Green Square measure. Superseded by FM9.
FM5	Additional Pipes and Detention Storage at Erskineville Park and Oval	
FM6	Additional Pipes from Macdonald Street and Coulson Street to Alexandra Canal	Provides a possible alternative to components of FM11.
FM7	Detention Basin in Redfern Park	
FM8	Detention Basin in Alexandria Park	
FM9	Link Road to Alexandra Canal Upgrade – Maddox Street Alignment	Green Square measure.
FM10	Link Road to Alexandra Canal Upgrade – Sydney Water Easement Alignment	Green Square measure. Superseded by FM9.
FM11	Long Term Strategy for 20 year ARI capacity	
FM12	Detention Basin in Moore Park – Offset Storage from Arthur Street and Nobbs Street	
FM13	Detention Basin in Newtown Public School	
FM14	Detention Basin near Burren Street	
FM15	Liveable Green Network	Provides a possible alternative to components of FM11.
FM16	Additional Drainage Capacity in Gardeners Road near Kent Road	
FM17	Detention Basin in Turruwul Park	
FM18	Additional Drainage Network at Harcourt Parade to Gardeners Road	
FM19	Detention Basin in Waterloo Park	

Measure Reference	Description	Comments
FM20	Sheas Creek Channel Flood Walls	Provides a possible alternative to components of FM11.
FM21	Detention Basin in Sydney Park – Offset Storage from Macdonald Street	
FM22	Detention Basin in Young Street	
FM23	Increased Pit Cleaning and Maintenance	

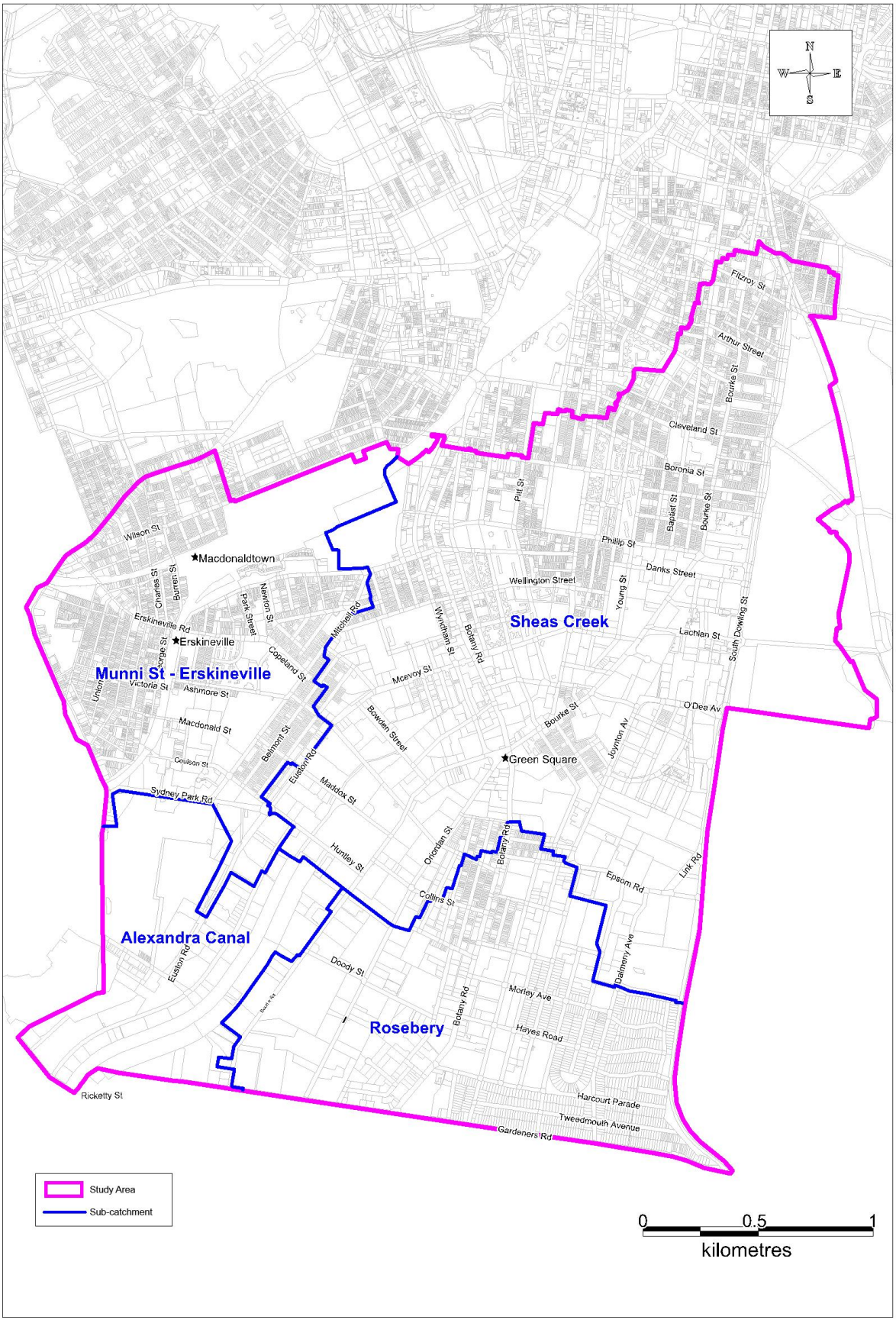


Figure 3-1 Short Term Measures – FM1 to FM10

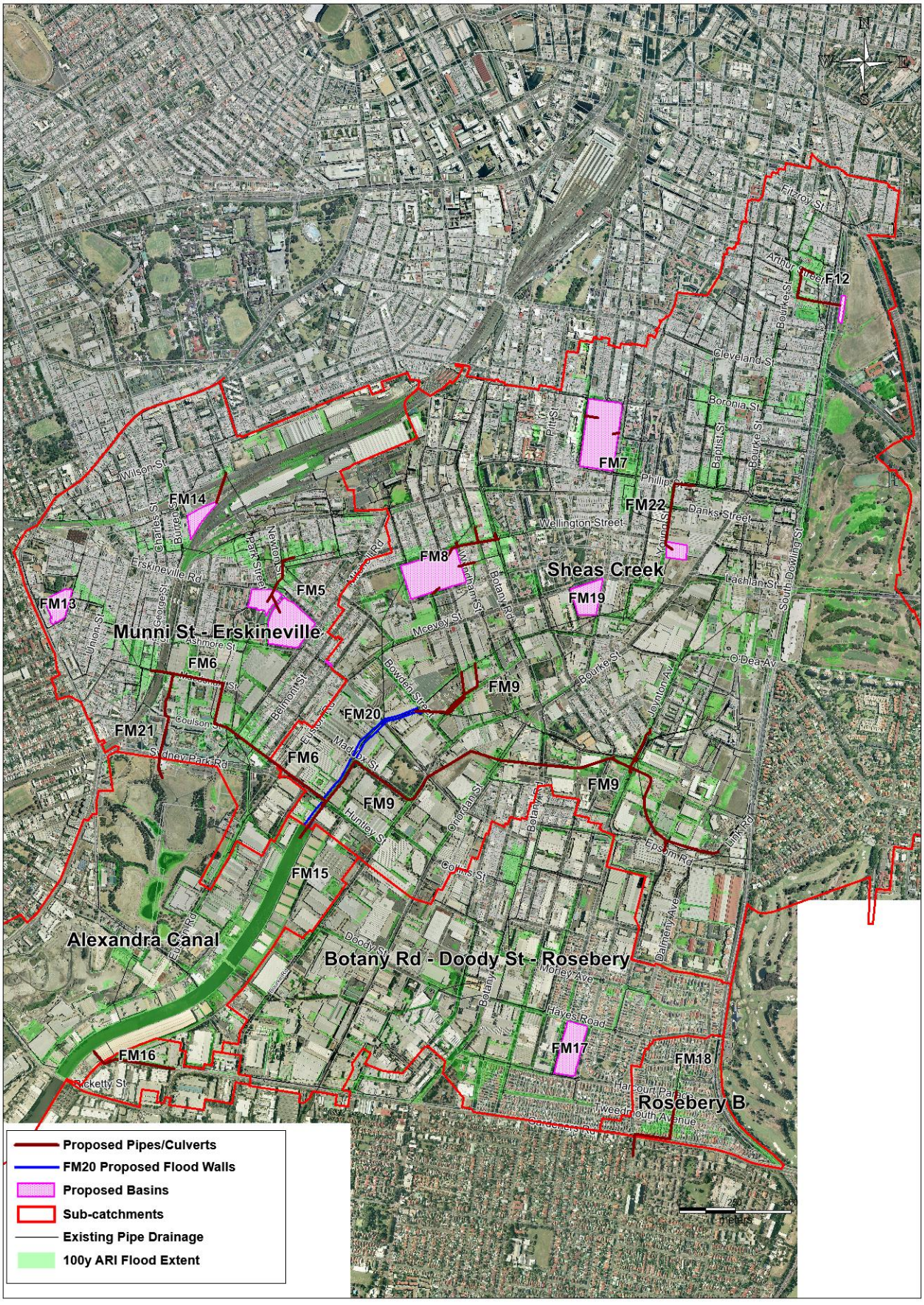


Figure 3-2 Flood Mitigation Measures (Excluding Long Term Drainage Strategy)

3.2.2 Long Term Flood Modification Measures

A long term strategy has been developed for the Alexandra Canal Catchment in order to achieve the following outcomes:

- A 20 year ARI design capacity of the drainage system.
- Parity across the floodplain with regards to delivery of infrastructure and floodplain management.

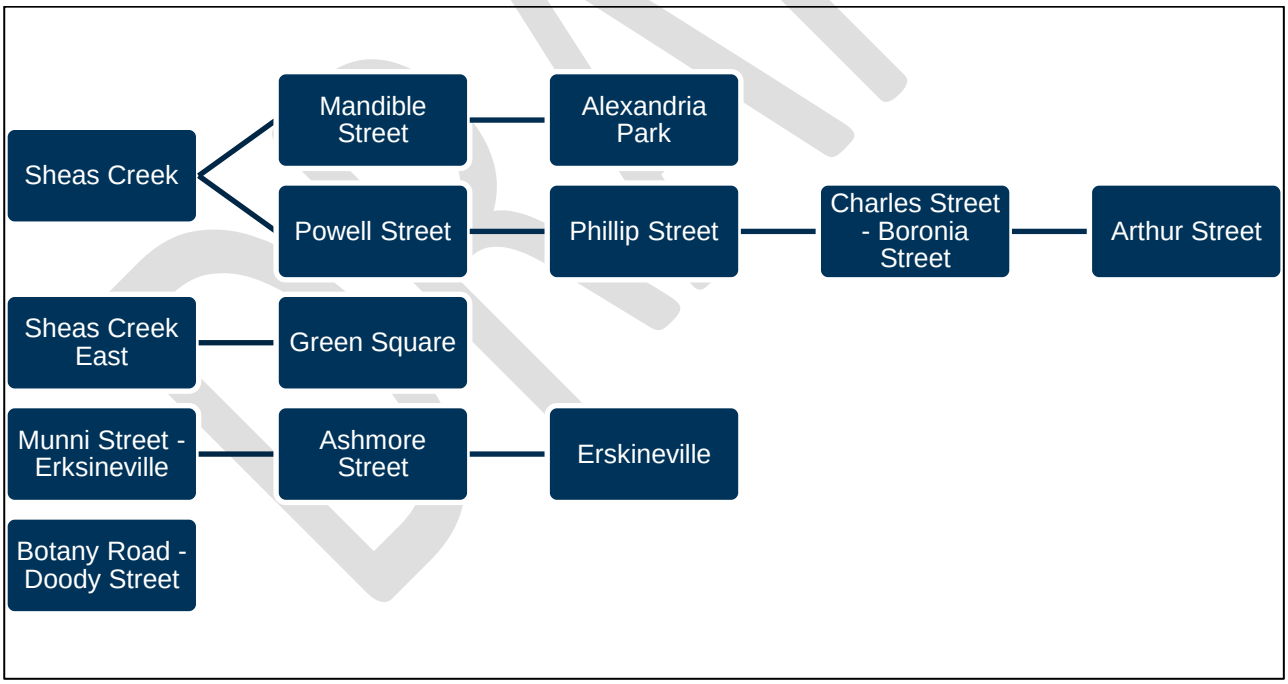
The potential of these measures is to provide a long term strategy and guidance for the City of Sydney in upgrading their stormwater infrastructure. It is listed in **Table 3-2** as Measure FM11 and shown in **Figure 3-4.**

The long term flood modification strategy involves multiple drainage components across the whole study area. It has been broken into a number of sub-areas. As the works would not be undertaken over a long time period, for the purposes of this study it was important to understand the cost differential between different parts of the study area, and to potentially assist in prioritising works in these different areas. The sub-areas are shown in **Figure 3-3**.

As noted above, the strategy provides an indication of the pipe sizes and the capacity required throughout the system. There are numerous potential alternatives that could also be achieved, through different alignment of pipes or different configurations. Some of these larger deviations and differences that might be possible are discussed in **Table 3-3**.

In order to achieve the best outcomes from the long term flood modification strategy both in the short term and the long term, works should be undertaken at the downstream end of the catchment working towards the upstream end of the catchment where possible. This is required such that there is sufficient capacity in the downstream end of the network for upstream upgrades to be connected into.

A general overview of the staging of the areas for the upgrades is provided below.



Various short to medium term measures may be required for the upper catchment areas, where works are unlikely to commence for a long period of time.

Preliminary modelling of the measure shows a significant reduction in the extent of ponding depths greater than 0.17m in a 20 year ARI event. In a 100 year ARI event the reductions in peak water levels across the catchment are more extensive than for a 20 year ARI event.

Table 3-3 Alternatives in the Long Term Drainage Strategy

Area	Sub-Area	Comments	Alternatives
Sheas Creek Catchment	Sheas Creek Channel	The current strategy includes a culvert/ pipe that runs parallel to Sheas Creek Channel. There are a few alternatives to this, which are related to the short to medium term measures.	FM15 – include the Liveable Green Network option to increase the capacity of the channel and hence reduce the need for a parallel culvert.
			FM20 – provide flood walls along the channel to increase the capacity of the channel and reduce the need for a parallel pipe or culvert.
			Connect the pipe into the proposed Sydney Water pipe which is part of the Green Square Town Centre works. This may require additional capacity in this pipeline. There are also challenges in connecting across to this area in some instances due to existing stormwater lines.
Munni Street – Erskineville	Connection from Coulson Street to Alexandra Canal	The current alignment of the strategy has the alignment of the pipe connecting Coulson Street to Alexandra Canal via Euston Road and Sydney Park. However, there are a number of constraints along this route.	Alternative is similar to FM6 – pipeline to be located along Huntley Street.

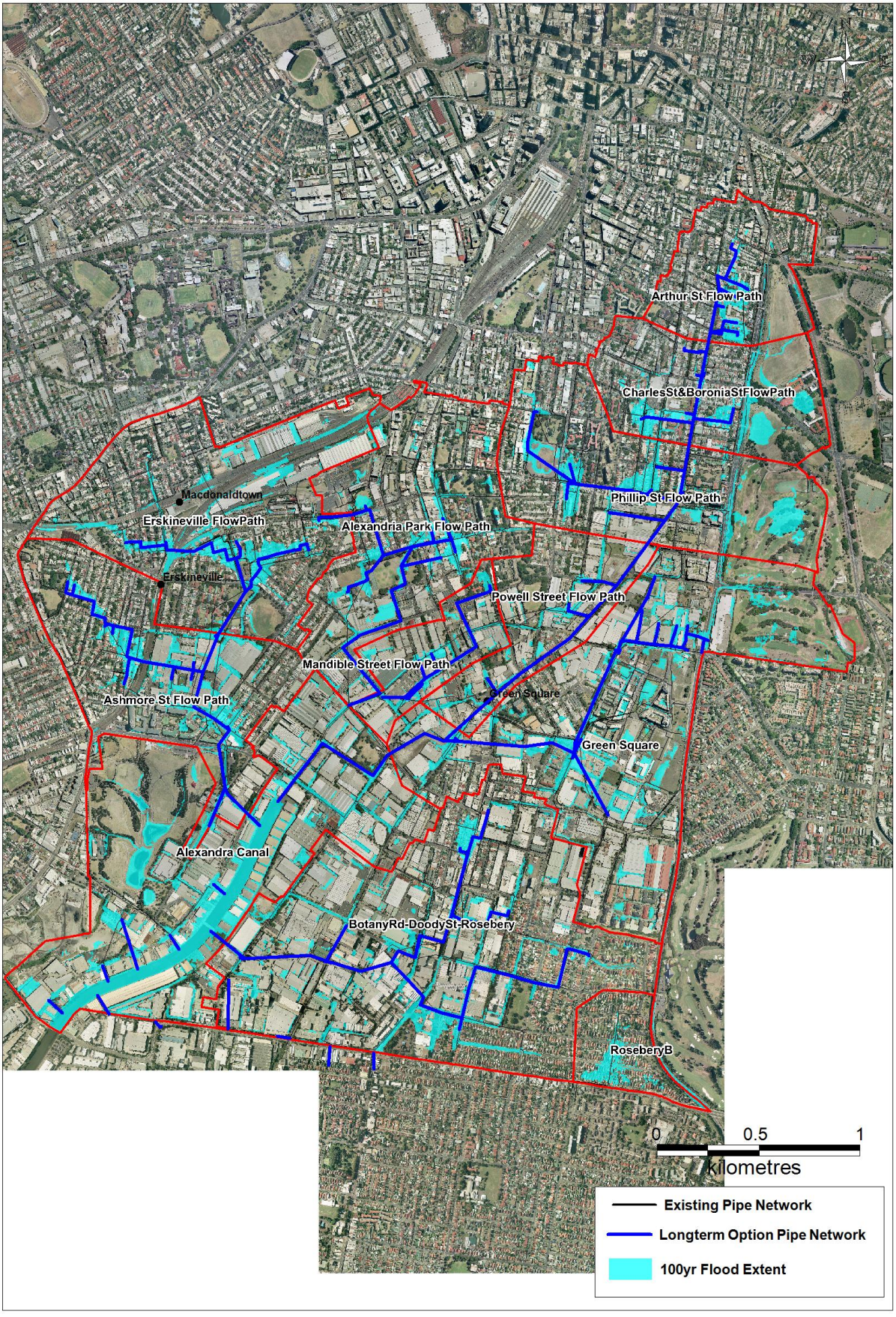


Figure 3-3 Sub-Areas for Measure FM11

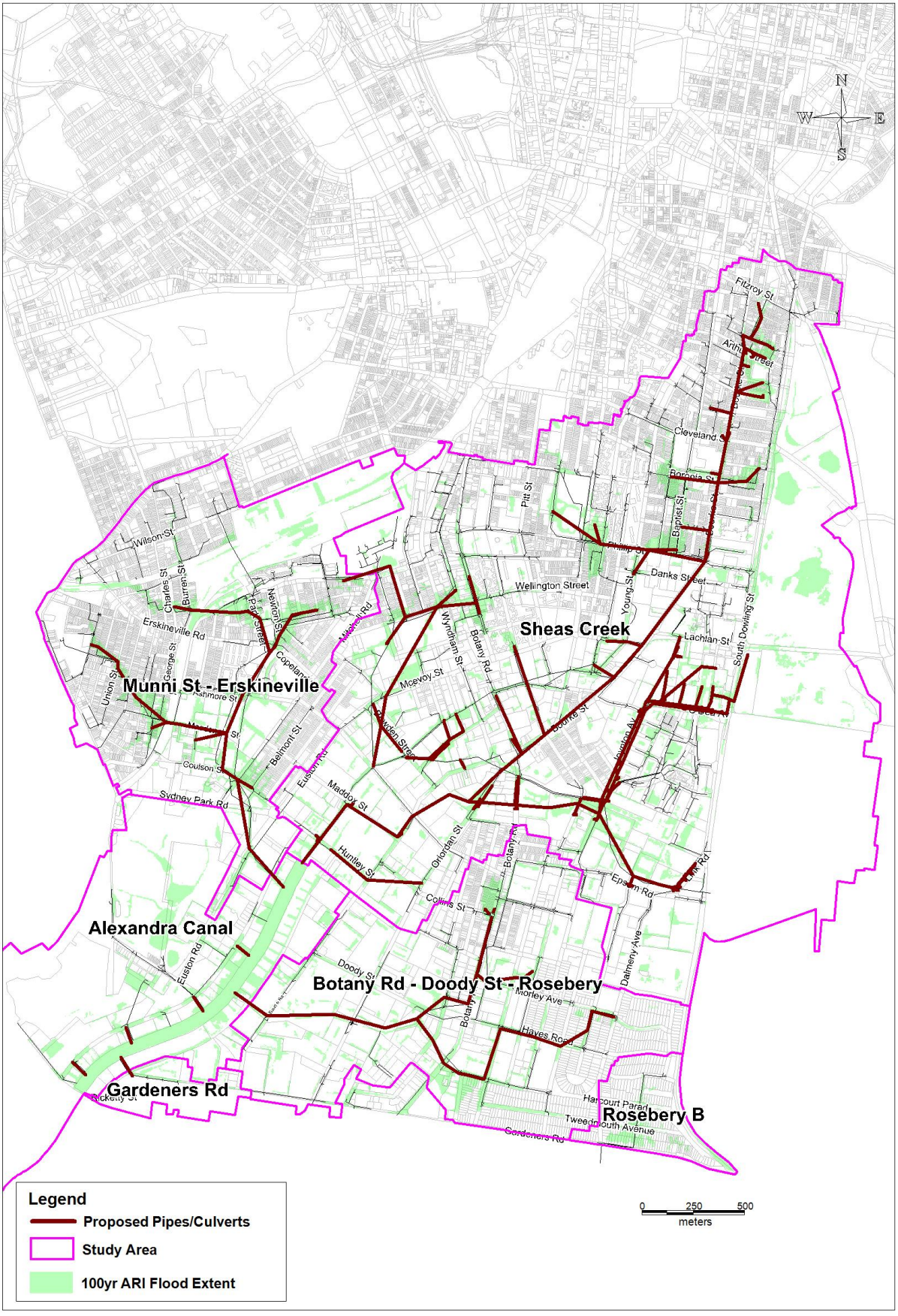


Figure 3-4 Measure FM11 Layout

3.3 Property Modification Measures

A number of property modification measures were identified for consideration in the Alexandra Canal floodplain. Detailed descriptions of these measures are provided in the FRMS (Cardno, 2013a) and are summarised below in **Table 3-4**.

Table 3-4 Property Modification Measures Assessed in the FRMS

Measure Reference	Description	Comments
PM1	LEP and DCP Update	
PM2	Floodplain Management Policy	
PM3	Opportunities Related to Large Scale Future Development	
PM4	House Raising	
PM5	House Rebuilding	
PM6	Voluntary Purchase	There are no residential properties with flooding in the 5 year ARI event, which result in property damages even in the PMF greater than $800,000. Therefore no properties have been identified for voluntary purchase.
PM7	Land Swap	As no properties were identified for voluntary purchase, this measure is also not recommended.
PM8	Council Redevelopment	As no properties were identified for voluntary purchase, this measure is also not recommended.
PM9	Flood Proofing	

3.4 Emergency Response Modification Measures

A number of emergency response measures were identified for consideration in the Alexandra Canal floodplain. Detailed descriptions of these measures are provided in the FRMS (Cardno, 2013a) and are summarised below in **Table 3-4**.

Table 3-5 Property Modification Measures Assessed in the FRMS

Measure Reference	Description
EM1	Information transfer to the SES
EM2	Preparation of a District DISPLAN
EM3	Preparation of a Local Flood Plan
EM4	Flood warning system and temporary flood refuge
EM5	Public awareness and education
EM6	Flood warning signs at critical locations

3.5 Data Collection Strategies

This would involve the preparation of a flood data collection form and the use of this form following a flood event. This would allow for more information to be gathered concerning the nature of flooding within the catchment, building on the knowledge from the Flood Study.

4 Findings of the Floodplain Risk Management Study

The measures identified in the Floodplain Risk Management Study were assessed using a multi-criteria matrix, which incorporated a benefit / cost analysis for the structural measures which can be quantitatively assessed. The multi-criteria matrix, detailed in Section 13 of Cardno 2013a, utilises a triple bottom line approach to assess the measures on their economic, environmental and social suitability. The structural and non-structural (primarily planning related) measures have been assessed separately to ensure consistency in the application of the matrix criteria. The matrix is attached in **Appendix A**.

The Plan consists of a mixture of:

- Flood modification measures,
- Property modification measures, and
- Emergency modification measures.

The flood management options recommended in the plan are outlined in further detail below. The implementation strategy associated with the options is discussed in the **Section 5**.

4.1 Flood Modification Measures Recommended for Implementation

Measures recommended based on the multi-criteria matrix assessment are listed below and are further detailed in Cardno, 2013a.

4.1.1 Link Road to Alexandra Canal Upgrade (FM9)

Measure FM9 is located within the Sheas Creek subcatchment and was developed based on the proposal of Sydney Water and Council to upgrade the trunk drainage facilities in this area. The system formed the basis for an application to fund its construction under the Housing Assistance Fund.

The current layout for Measure FM9 was refined by HydroStorm Consulting for Council as shown in Figure D12 (of Cardno, 2013a). It includes an additional culvert 5.5m wide by 1.8m high from Joynton Avenue to a 6.0m wide by 1.8m high culvert at Alexandra Canal. This scheme is identified as the “Option A” trunk drainage upgrade recommended in the Green Square Catchment Floodplain Risk Management Plan (WMA Water, 2013).

4.1.2 Additional Pipes from Macdonald Street and Coulson Street to Alexandra Canal (FM6)

Measure FM6 is located within the Munni Street-Erskineville subcatchment to mitigate flood inundation of the Ashmore Street Precinct including Macdonald Street and Coulson Street. Shown in Figure D4 (of Cardno, 2013a), it comprises an additional 1800mm diameter pipe from Macdonald Street to Coulson Street (south east corner of the Ashmore Street Estate). Twin 1800mm diameter pipes are proposed to run from the south east corner of the Ashmore Street Estate to Alexandra Canal via Huntley Street.

Future extension of the system upstream of the railway line could be considered to mitigate flooding to the west. Potential constraints for this measure include potential increases to downstream flood levels and pipe crossings of major roads with associated costs due to services and traffic management requirements.

It is noted that if the ability to connect this pipeline to Alexandra Canal is not feasible, then Measure FM21 should be considered as an alternative (although it is not as effective as FM6).

4.1.3 Detention Basin in Sydney Park – Offset Storage from Macdonald Street (FM21)

Measure FM21 is located in the Munni Street-Erskineville subcatchment to mitigate flood inundation in Macdonald Street and benefit streets downstream. Shown in Figure D26 (of Cardno, 2013a), it comprises inlets in Macdonald Street conveying runoff through about 500m of pipeline to detention storage in Sydney Park.

A potential constraint to the application of this measure is the elevation of Sydney Park with respect to Macdonald Street and impacts to Sydney Park from the storage basin.

4.1.4 Detention Basin in Redfern Park (FM7)

Measure FM7 is located within the Sheas Creek subcatchment to mitigate flooding in the vicinity of Redfern Park in Chalmers Street and Elizabeth Street. Shown in Figure D7 (of Cardno, 2013a), it comprises provision of detention storage in Redfern Park (10,000m^3) with inlets and pipelines to convey surface runoff and relieve existing drainage systems in Chalmers Street and Elizabeth Street.

Potential constraints to the application of this measure include:

- The relative elevation of Redfern Park to the lowpoints; and
- Potential impacts to Redfern Park, depending on the configuration of the adopted works.

Flood modification works at Redfern Park are considered on a long-term implementation timeframe to complement recent works at the site.

4.1.5 Additional Drainage Network at Harcourt Parade to Gardeners Road (FM18)

Measure FM18 is location within the Rosebery B subcatchment to mitigate flooding in Harcourt Parade, Tweedmouth Avenue and Gardeners Road (to the east of Dalmeny Avenue). Shown in Figure D23 (of Cardno, 2013a), it comprises additional inlet and pipeline capacity to convey runoff from the lowpoints on these roads. Council has constructed permeable pipes in this vicinity to relieve flood inundation making use of the high infiltration soil profile.

A potential constraint to the application of this measure is the capacity of the downstream drainage network within City of Botany Bay LGA to accommodate additional flow considering potential increases to downstream flood levels. Therefore, this measure may be undertaken in the longer term.

4.1.6 Detention Basin in Turruwul Park (FM17)

Measure FM17 is located within the Botany Road - Rosebery subcatchment to mitigate flooding in the street downstream of the Park (located at Hayes Road and Primrose Avenue. Shown in Figure D22 (of Cardno, 2013a), it comprises diversion of flows from Hayes Road to a detention basin within Turruwul Park.

Potential constraints to the application of this measure include:

- Disturbance to existing vegetation and usage of the Park; and
- Effectiveness to mitigate flooding downstream as it is limited to one of the flowpaths in the catchment.

Flood modification works at Turruwul Park are considered on a long-term implementation timeframe to complement recent works at the site.

4.1.7 Sheas Creek Channel Flood Walls (FM20)

Option FM20 is located within the Sheas Creek subcatchment to mitigate flood inundation of properties adjacent to the open channel. Shown in Figure D25 (of Cardno, 2013a), it comprises raised walls (about 1.2m high) along the existing banks of the open channel from Bowden Street to Alexandra Canal (about 700m in length).

Potential constraints to the application of this option include:

- Increased inundation both downstream and to properties behind the flood walls;
- Impacts to internal drainage of properties behind the flood walls; and
- No additional protection or mitigation is provided at road crossings of the channel.

4.2 Property Modification Measures Recommended for Implementation

4.2.1 Liveable Green Network (FM15)

Measure FM15 is located within the Alexandra Canal subcatchment to mitigate flooding around the Sheas Creek Channel by creating additional open area adjacent to the channel which serves as a pedestrian and cycleway link. This concept by City of Sydney Council is primarily focussed on social and environmental improvements but would also have benefits for flood mitigation. Shown in Figure D20 (of Cardno, 2013a) it

comprises widening of the channel corridor from Bourke Road and Wyndham Street to along Alexandra Canal creating additional flowpath width and may include additional culverts within the expanded corridor. Council's Liveable Green Network proposal also includes revision of the nearby street layout to improve access and connections to the new pedestrian link.

Potential constraints to the application of this measure include:

- Significant areas of land required adjacent to the channel would have to be acquired or dedicated within future development; and
- Likely to be a longer term measure as redevelopment occurs along its alignment.

This measure has been assessed with regards to the planning consideration required to enable the implementation of the Liveable Green Network. Therefore flood modelling of this measure has not been undertaken for this Study.

4.2.2 Increased Pit Cleaning and Maintenance (FM23)

Measure FM23 comprises two components across the whole Alexandra Canal catchment:

- Increased stormwater pit cleaning and system maintenance; and
- Refined schedule that targets potential flooding problem areas.

A sensitivity analysis for potential blockage to the drainage system was undertaken for the Flood Study. This analysis showed increases in flood levels primarily around the identified trapped lowpoints and primary overland flowpaths. A refined maintenance and cleaning schedule can be developed based on the flood model results which identify higher risk areas susceptible to increased inundation if blockage occurs.

4.2.3 PM3 – Opportunities Related to Large Scale Future Development

There may be opportunities to incorporate flood management measures into new developments as a condition of consent, Section 94 contribution offsets or government-related funding. Works of this nature may involve:

- Detention storage;
- Drainage capacity upgrades;
- Use of open space along drainage easements to achieve multiple objectives of recreational, environmental and flood benefits.

There are a number of areas within the Alexandra Canal catchment that are progressively being developed over time. Many of these re-development areas are quite large. Four key large precincts which have been identified by Council for redevelopment are included in Figure 11-6 (of Cardno, 2013a).

The nature of the flood controls implemented will be dependent on the location of the development, the flooding behaviour and the type of development. However, allowance and / or requirements for these works could be identified through amendments to the Sydney DCP 2012 or the Floodplain Management Policy.

4.2.4 PM2 – Floodplain Management Policy

Council is currently preparing a Floodplain Management Policy. The purpose of the policy is to ensure the flood related objectives of the Sydney LEP 2012 are met and to provide specific development principals, controls and guidance not available in the LEPs or DCPs.

The current draft version of the policy includes provisions for the following:

- Development application requirements and inclusions;
- Performance criteria;
- Allowances for concessional development;
- Specific controls relating to residential and industrial / commercial development, fencing, car parking, filling, on-site sewer management and storage hazardous substances.

- Flood planning levels (FPLs) are provided for various development types and components.
- Details regarding flood compatible materials.

In addition to the provisions listed above, it is recommended that the Policy include details regarding:

- Impacts of climate change on flooding and how this should be considered in development and planning.
- Consideration of the flood planning levels recommended in **Section 9.1**.

Guidelines for on-site detention (OSD) are provided in *Stormwater Drainage Connection Information* (City of Sydney, 2006). The policy requires all development sites in the LGA greater than 250 m^2 and less than 1000 m^2 to incorporate OSD to reduce the 100 year ARI post-development site run-off to the 5 year ARI site run off. Council may wish to consider using the outcomes of the Alexandra Canal Flood Study (Cardno, 2013) to develop OSD requirements specific to the catchment requirements.

4.2.5 PM1 – LEP and DCP Update

Local environmental plans are prepared by councils to guide planning decisions for local government areas. Through zoning and development controls, they allow councils to supervise the ways in which land is used.

A development control plan is a non-legal document that supports the LEP with more detailed planning and design guidelines. The key document for flood related controls in the City of Sydney LGA is Sydney Development Control Plan 2012.

The review of the relevant LEPs and DCP in Section 9 (of Cardno, 2013a) identified the following:

- Whilst the Sydney LEP 2012 is the primary state planning document relating to the catchment the South Sydney LEP 114, South Sydney LEP 1998 and the SEPP Major Development 2005 are also relevant to specific areas or development types in the catchment. These other documents contain more detailed consideration of flood management than the Sydney LEP 2012. Council may wish to consider updating the Sydney LEP 2012 to be consistent with the flood related clauses in these other documents.
- There was a lack of consistency between the Sydney LEP 2012 and the Sydney DCP 2012. It is recommended that either the LEP or the DCP or both are updated to ensure accurate cross referencing between the two documents.
- The requirements for a site specific flood study are provided in the Sydney DCP 2012. However, the DCP notes that the Sydney LEP 2012 outlines when a site specific flood study is required. The LEP does not contain this information. Either the LEP or the DCP or both should be updated to ensure this information is provided.
- The Sydney DCP 2012 outlines the objective of the DCP with regards to flooding and the requirements for a site specific flood study. However, no specific flood related development controls are provided. It is understood that Council is currently preparing a Floodplain Management Policy, which will include more detailed controls and requirements for flood planning. Reference to this policy should be included in the DCP or the key controls outlined in the Policy could also be included in the DCP (in particular the flood planning levels for various development types).
- The flood management provisions in the Sydney DCP 2012 do not provide consideration of the impacts of climate change on flooding and how that should be responded to in development. The DCP should be updated to identify Council's current position on climate change and floodplain management. Alternatively, this information could be included in the Floodplain Management Policy.

4.2.6 PM9 – Prepare Flood Proofing Guidelines

Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property, and thus the damage caused by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding.

These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating, to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of proofing measures include:

- All structural elements below the flood planning level shall be constructed from flood compatible materials.
- All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the 1% AEP flood event. If the structure is to be relied upon for shelter-in-place evacuation then structural integrity must be ensured up to the level of the PMF.
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the flood planning level.

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties.

These measures should be carried out according to a pre-arranged plan. These measures may include:

- Raising belongings by stacking them on shelves or taking them to a second storey of the building.
- Secure objects that are likely to float and cause damage.
- Re-locate waste containers, chemical and poisons well above floor level.
- Install any available flood proofing devices, such as temporary levees and emergency water sealing of openings.

The SES business Flash Flood Tool Kit (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures. It is recommended that this tool kit is distributed to the flood affected businesses within the Alexandra Canal floodplain.

4.3 Emergency Response Measures Recommended for Implementation

4.3.1 EM 1 – Information Transfer to SES

The findings of the Flood Study and the Flood Risk Management Study and Plan provide a useful data source for the State Emergency Service. This should specifically include the transfer of information to the City of Sydney Security and Emergency Management Centre located at Town Hall.

4.3.2 EM 2 – Prepare a District DISPLAN

The DISPLAN states that:

“Each District and Local Emergency Management Committee is to develop and maintain its own District / Local Disaster Plan, with appropriate Supporting Plans and Sub Plans, as required by Functional Area Coordinators and Combat Agency Controllers at the appropriate level. Supporting plans are to be the exception at local level and their development must be approved by District Functional Area Coordinators.”

It is recommended that a DISPLAN be prepared for the *Sydney East Emergency Management District* to outlines emergency response arrangement specific to the district. In particular the purpose of a District DISPLAN is to:

- Identify responsibilities at a District and Local level in regards to the prevention, preparation, response and recovery for each type of emergency situation likely to affect the district.
- Detail arrangements for coordinating resource support during emergency operations at both a District and Local level.
- Outline the tasks to be performed in the event of an emergency at a District and Local level.
- Specifies the responsibilities of the South West Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the South West Metro EM District.

- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies.
- Detail the responsibilities of the District & Local Emergency Management Committees within the District
- Detail agreed Agency and Functional Area roles and responsibilities in preparation for, response to and recovery from, emergencies.
- Outline the control, coordination and liaison arrangements at District and Local levels
- Detail arrangements for the acquisition and coordination of resources.
- Detail public warning systems and responsibility for implementation.
- Detail public information arrangements and public education responsibilities.
- Specifies arrangements for reporting before, during and after an operation.
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

Further details regarding the existing DISPLAN and the purpose and function of a DISPLAN are provided in Section 8 (of Cardno 2013a).

4.3.3 EM 3 – Prepare a Local Flood Plan

It is recommended that the City of Sydney to prepare a local flood plan in conjunction with the SES to outline the following details:

- Evacuation centres in close proximity to the floodplain which allow flood free access to the centres and are flood free sites.
- Inclusion of a description of local flooding conditions.
- Identification of potentially flood affected vulnerable facilities.
- Identification of key access road subject to flooding.

Further details of evacuation centres, access road flooding and recommended inclusions for the flood plan are provided in Section 8 (of Cardno 2013a).

4.3.4 EM 5 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

Flood awareness campaigns should be an ongoing process and requires the continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area.

For effective flood emergency planning, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be undertaken to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment.

It is recommended that the following awareness campaigns be considered for the floodplain. These should be prepared together with the SES, as they have a responsibility for community awareness under the DISPLAN.

- Preparation of a FloodSafe brochure. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information. Once prepared, the FloodSafe brochure can then be uploaded to the Council and SES websites in a suitable format, where it would be made

available under the flood information sections of the website. The brochures could also be made available at Council offices and community halls.

- Development of a Schools Package from existing material developed by the SES and distribution to schools accordingly. Education is not only useful in educating the students, but can be useful in dissemination of information to the wider community.
- A regular (annual) meeting of local community groups to arrange flood awareness programs on a regular basis.
- Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.

4.3.5 EM 6 – Flood Warning Signs at Critical Locations

A number of public places in the catchment experience high hazard flooding in the 1% AEP event. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths.

It is recommended that depth gauges be installed at road crossings which are subject to inundation in frequent events.

4.3.6 EM 4 – Flood Warning System and Short-Term Refuges

The critical duration and response times for the Alexandra Canal floodplain limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

There may be some opportunity to connect in with the City of Sydney Emergency Response Centre. This may provide some limited warning, as well as a more coordinated response to a flood event.

A number of open, public areas are located within the Alexandra Canal Catchment. The provision of temporary refuges which can be accessed in a few minutes, even a small warning time may provide the public with sufficient time to seek refuge. The provision of rapid flood warnings within the Alexandra Canal Catchment may be delivered through an automated process that triggers a warning (e.g. with the installation of water level sensors placed in trapped depression areas). The warning itself can be delivered through the use of suitably located electronic information boards at key locations.

Another option is to have a public address system, which can relay a recorded message. The system could be similar to what the City of Sydney has already installed to manage emergencies in the busy streets of the City. An example of this system can be found near the main entrance of the Council building at Town Hall Square, where the public address speakers are installed on a traffic light pole.

5 Implementation Program

5.1 Floodplain Risk Management Measures

The implementation program essentially forms the action list for this Plan.

The benefit of following this sequence is that gradual improvement of the floodplain occurs, as the funds become available for implementation of these measures.

Further steps in the floodplain management process from this point forwards are:

1. Floodplain Management Committee to consider and adopt recommendations of this Plan
2. Council to consider the Floodplain Management Committee's recommendations
3. Council to adopt the Plan and submit an application for funding assistance to OEH and other agencies as appropriate
4. As funds become available from OEH, other state government agencies and / or Council's own resources, implement the measures in accordance with the established priorities.

This plan should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding and reviews of Council planning policies. In any event, a review every five years is warranted to ensure the ongoing relevance of the Plan.

The measures selected for the plan are based on the ranking of the multi-criteria analysis and are summarised in **Table 5-1** and **Table 5-2**. Recommended structural measures are shown on **Figure 5-1**. For the existing catchment plan, the measures selected represent a capital outlay of approximately $110 million (exclusive of GST). Of this total, $208,000 would be for non-structural (primarily policy related) measures.

It is noted that a specific timeframe for the Plan has not been explicitly identified. Experience with these types of Plans has identified that the works are undertaken when and as funding becomes available, as well as when various opportunities might arise specifically for an option. In general:

- Non-structural measures can generally be implemented in the short term (1 to 3 years), as they are relatively low in capital expenditure and general revolve around policy and information.
- Structural measures can generally be implemented in the medium term (1 to 10 years), and will be implemented as funding and opportunities arise (such as land availability).

5.2 Long Term Strategy

As identified in 3.2.2, a long term strategy has been developed for the Alexandra Canal Catchment in order to achieve the following outcomes:

- A 20 Year ARI design capacity of the drainage system.
- Parity across the floodplain with regards to delivery of infrastructure and floodplain management.

This long term strategy will take many years to complete, and will generally extend well beyond the timeframe of this plan (5 to 10 years). Therefore, it has not been explicitly included in the plan. However, it is recommended that all future drainage upgrades within the catchment consider a 20 year drainage capacity, to ensure that progressively the entire system may be upgraded in the future and to prevent "lock-out" of some opportunities as they arise.

As identified in Cardno (2013a), no optimisation was undertaken on the 20 year ARI drainage strategy. However, it is recommended that Council develop a long term strategic plan that will assist in the implementation of this strategy.

It is noted that FM 6, FM 9 and FM 20 all provide initial downstream connections for an overall long term 20 year drainage strategy, and therefore provide a good initial commencement of this process.

Table 5-1 Non-Structural Floodplain Risk Management Measures Recommended for Implementation

Measure Reference	Description	Estimated Capital Cost (excl. GST)	Estimated Annual Recurring Cost (excl. GST)	Potential Funding Sources	Responsibility
FM15	Liveable Green Network	$15,000	$0	Council/ Developer	Council
FM23	Increased pit cleaning and maintenance	$10,000	$10,000	Council	Council
EM1	Information Transfer to SES	$3,000	$0	SES	SES
EM2	Preparation of District DISPLAN	$5,000	$0	SES	Council/ SES
EM3	Preparation of Local Flood Plan	$5,000	$0	SES	Council/ SES
PM3	Opportunities related to Large Scale Future Development	$5,000	$1,000	Council/ Developer	Council
PM2	Development Controls and Policies	$15,000	$0	Council	Council
EM5	Public awareness and education	$20,000	$2,000	Council/ SES	Council/ SES
PM1	LEP Update	$5,000	$0	Council	Council
EM6	Flood warning signs at critical locations	$20,000	$0	Council/ SES/ State Government	Council/ SES
PM9	Flood Proofing Guidelines	$15,000	$0	Council/ SES	Council/ SES
EM4	Flood Warning System and Temporary Refuge	$50,000	$2,000	Council/ SES/ State Government	Council/ SES
Total		**$208,000**	**$55,000**		

Table 5-2 Structural Floodplain Risk Management Measures Recommended for Implementation

Measure Reference	Description	Estimated Capital Cost (excl. GST)	Estimated Annual Recurring Cost (excl. GST)	Potential Funding Sources	Responsibilities
FM9	Link Road to Alexandra Canal Upgrade – Maddox Street Alignment	$80,540,000	$35,000	Council, Sydney Water, State Government	Council/ Sydney Water
FM6*	Additional pipes from Macdonald Street and Coulson Street to Alexandra Canal	$22,880,000	$16,000	Council, Sydney Water, State Government	Council/ Sydney Water
FM18	Additional Drainage Network at Harcourt Parade to Gardeners Road	$2,710,000	$5,000	Council	Council
FM20**	Sheas Creek Channel Flood Walls	$3,220,000	$7,000	Council, Sydney Water, State Government	Council/ Sydney Water
Total		**$109,350,000**	**$63,000**		

**FM21 (Detention Basin in Sydney Park – Offset Storage from Macdonald Street) to be undertaken as an alternative to FM6, if FM6 connection to Alexandra Canal not feasible.*

***Note that this is an interim measure while the Liveable Green Network (FM15) is implemented. However, depending on redevelopment, the Liveable Green Network make take many years to be fully complete.*

Note that flood modification works at Redfern Park (FM7) and Turruwul Park (FM17) are considered on a long-term implementation timeframe to complement recent works at the site.

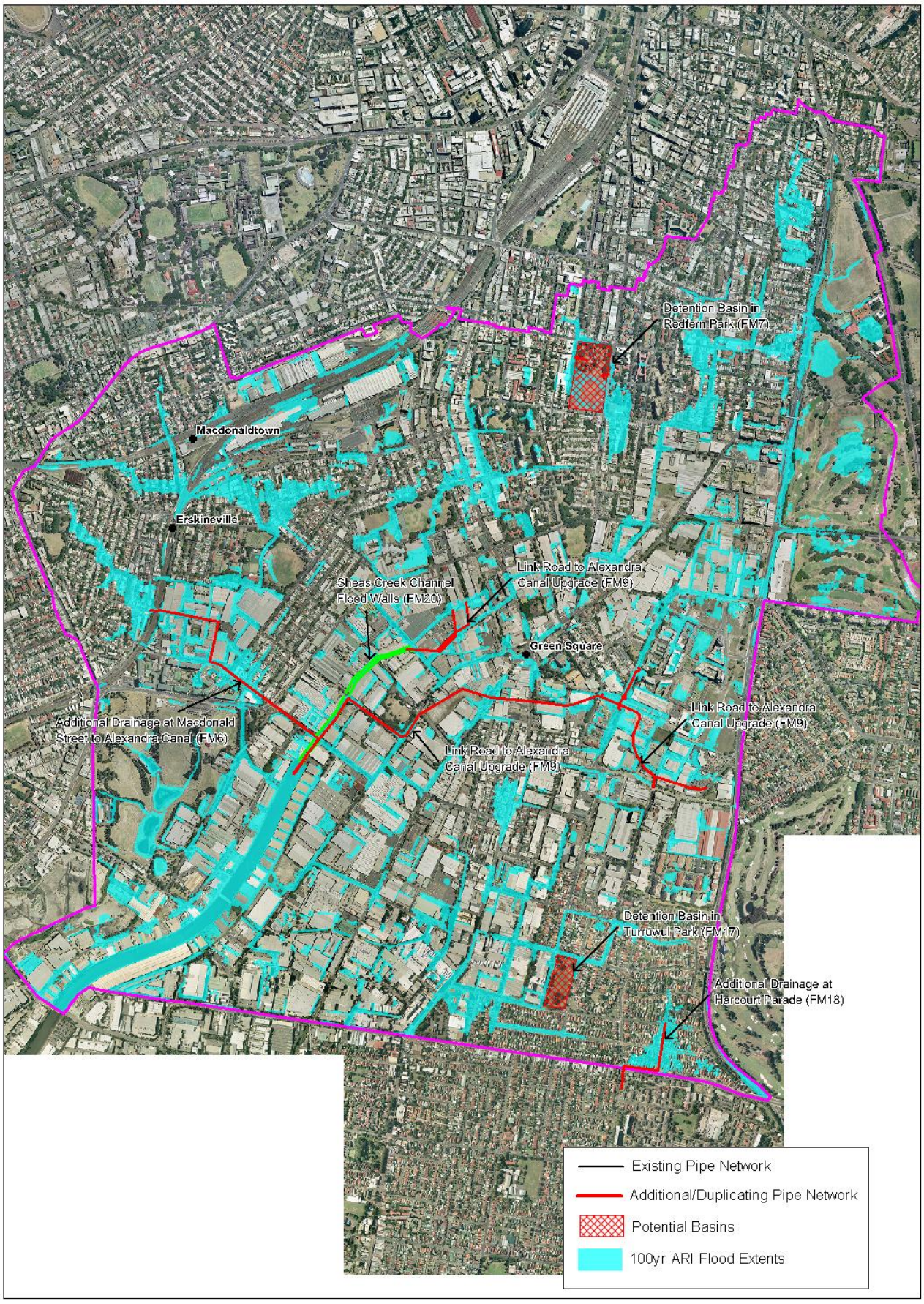


Figure 5-1 Recommended Structural Measures

5.3 Key Stakeholders

As a part of the implementation of the Plan and the detailed design phase of some of the measures, liaison should be undertaken with key stakeholders. These stakeholders should include, but are not limited to:

- Private residents: In particular, those affected by proposed works.
- Community groups.
- Sydney Water: Particularly with regard to any impacts on their assets within the catchment.
- State Rail Authority / Rail Corp.
- Roads and Maritime Services (RMS).
- State Emergency Services (SES): Particularly with regards to the emergency management measures. Generally, the SES should also be kept informed of changes to the flood behaviour resulting from any of the implemented measures.
- Office of Environment and Heritage (OEH): As it is likely that funding would be sourced from OEH for a number of the measures, they should be consulted as a part of the design process.

6 Conclusions

This report presents the findings of the Floodplain Risk Management Plan for the Alexandra Canal catchment. The investigations and consultations undertaken as part of the Floodplain Risk Management Study identified a number of issues for the floodplain. Based on these issues, a series of floodplain management measures were developed, and have been recommended in this Floodplain Risk Management Plan.

The assessment of management options provided in the Floodplain Risk Management Study facilitates the identification of the most beneficial measures (in terms of hydraulics, economics, environmental and social issues).

7 Qualifications

This report has been prepared by Cardno for City of Sydney and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe data provided by Council.

Study results should not be used for purposes other than those for which they were prepared.

8 References

Cardno (2013a) *Draft Alexandra Canal Floodplain Risk Management Study*, Prepared for City of Sydney.

Cardno (2013b) *Draft Alexandra Canal Flood Study*, Prepared for City of Sydney.

Alexandra Canal Floodplain Risk Management Study and Plan

APPENDIX A
MULIT-CRITERIA MATRIX

Cardno
Shaping the Future

Appendix A – Multi-Criteria Matrix

Measure Details										Category	Economic								Social						Environmental							
										Weighting	49.6%								30.7%						27.5%							
										Criteria	BCR	Reduction in Risk to Property	Essential Infrastructure	Future Development	Capital Cost	Operating Cost	Constructability	Implementation Timeframe	Reduction in Risk to Life	Reduction in Social Disruption	Compatibility with Council Policies & Plans	Community & Stakeholder Support	Urban Design	Governance	Compatibility with Water Quality Objectives	Groundwater	Heritage	Compatibility with Alternative Water Schemes	Flora / Fauna Impact	Contaminated Land & ASS		
Measure ID	Measure Description	Capital Cost (excl. GST)	Operating Cost (excl. GST)	AAD (excl. GST)	Change in AAD	Capital Cost - Rounded (excl. GST)	Operating Cost - Rounded (excl. GST)	AAD - Rounded (excl. GST)	BCR	Weighting	84.0%	73.5%	72.6%	62.9%	59.1%	56.4%	53.7%	48.5%	94.6%	65.6%	61.5%	55.0%	51.0%	47.1%	61.5%	59.1%	55.0%	55.0%	53.7%	51.0%	Score	Overall Rank
Structural Options																																
FM9	Link Road to Alexandra Canal Upgrade – Maddox Street Alignment	$80,533,163	$34,200	$12,815,163	-$142,761	$80,540,000	$35,000	$12,815,000	0.0		-4	1	4	4	-4	-1	-4	-4	3	4	4	4	0	4	2	0	0	0	0	-3	7.49	13
FM6	Additional pipes from Macdonald Street and Coulson Street to Alexandra Canal	$22,870,920	$15,400	$12,507,150	-$450,774	$22,880,000	$16,000	$12,507,000	0.2		-4	2	3	3	-4	1	-3	-3	2	3	4	4	0	4	2	0	0	0	0	-4	6.91	14
FM7	Detention basins in Redfern Park.	$7,222,256	$1,800	NC	NC	$7,230,000	$2,000	NC	0.3		-3	2	2	2	-3	4	-3	-2	2	2	2	1	-2	2	3	0	0	0	-1	0	5.78	17
FM21	Detention Basin in Sydney Park – Offset Storage from Macdonald Street	$4,813,125	$5,000	NC		$4,820,000	$5,000	NC	NC		-3	1	2	3	-2	4	-3	-3	2	3	1	2	-1	2	3	0	0	0	-2	-3	4.81	18
FM18	Additional Drainage Network at Harcourt Parade to Gardeners Road	$2,702,025	$4,800	NC		$2,710,000	$5,000	NC	NC		-2	1	1	1	-1	4	-4	-4	1	1	2	4	0	1	2	0	0	0	0	0	4.72	19
FM17	Detention basin in Turruwul Park	$4,562,145	$10,000	NC		$4,570,000	$10,000	NC	NC		-2	1	1	1	-2	3	-3	-2	2	2	0	1	-2	1	3	0	0	0	0	0	3.39	20
FM20	Sheas Creek Channel Flood Walls	$3,213,525	$6,900	NC		$3,220,000	$7,000	NC	NC		-2	2	0	2	-1	3	-3	-3	2	3	1	2	-2	1	0	0	0	0	0	-3	2.58	21
FM14	Detention basin near Burren Street	$3,133,294	$10,000	NC		$3,140,000	$10,000	NC	NC		-3	1	2	2	-1	3	-3	-2	2	2	0	2	-2	-1	3	0	0	0	0	-3	2.57	22
FM19	Detention basin in Waterloo Park	$4,053,863	$10,000	NC		$4,060,000	$10,000	NC	NC		-2	1	1	1	-2	3	-3	-2	2	1	1	1	-2	0	3	0	0	0	-1	0	2.34	23
FM8	Detention basin in Alexandria Park	$8,084,764	$25,300	$12,741,453	-$216,471	$8,090,000	$26,000	$12,741,000	0.3		-3	1	2	2	-3	-1	-3	-2	2	3	2	1	-2	2	3	0	0	0	-1	-2	1.86	24
FM22	Detention basin in Young Street	$2,500,000	$5,000	NC		$2,500,000	$5,000	NC	NC		-4	1	1	1	-1	4	-1	-1	1	1	0	0	-1	0	3	0	0	0	-1	0	1.77	25
FM16	Additional drainage capacity in Gardeners Road near Kent Road	$2,633,775	$4,000	NC		$2,640,000	$4,000	NC	NC		-4	1	1	1	-1	4	-4	-2	1	1	0	1	0	1	2	0	0	0	0	0	1.13	26
FM13	Detention basin in Newtown Public School	$2,756,550	$10,000	NC		$2,760,000	$10,000	NC	NC		-4	1	2	2	-1	3	-3	-1	2	1	0	-2	-3	-1	3	0	0	0	0	0	0.38	27
FM5	Additional pipes and detention storage at Erskineville Park and Oval	$7,202,483	$13,500	$12,930,956	-$26,969	$7,210,000	$14,000	$12,931,000	0.0		-4	1	1	1	-3	2	-3	-2	1	2	2	4	-1	2	2	0	0	0	-1	-4	0.28	28
FM12	Detention basin in Moore Park – Offset Storage from Arthur Street and Nobbs Street	$13,451,715	$14,500	$12,458,451	-$499,473	$13,460,000	$15,000	$12,458,000	0.5		-3	2	1	1	-4	2	-4	-2	1	1	2	0	-2	2	3	0	-3	0	-1	-1	-2.14	29
Non-Structural Options																																
FM15	Liveable Green Network	$15,000	$0	NC		$15,000	$0	NC	NC		1	1	4	4	4	4	-2	-4	3	4	4	3	3	4	4	1	0	0	-1	-2	23.08	1
EM1	Information Transfer to SES	$3,000	$0			$3,000	$0				0	0	0	0	4	4	4	4	4	2	4	3	0	4	0	0	0	0	0	0	19.79	2
FM23	Increased pit cleaning and maintenance	$10,000	$10,000			$10,000	$10,000				1	1	1	0	4	3	4	4	1	1	3	4	0	2	4	0	0	0	0	0	19.49	3
EM2	Preparation of District DISPLAN	$5,000	$500			$5,000	$0				0	0	0	0	4	4	3	4	4	2	4	3	0	4	0	0	0	0	0	0	19.26	4
EM3	Preparation of Local Flood Plan	$5,000	$500			$5,000	$0				0	0	0	0	4	4	3	4	4	2	4	3	0	4	0	0	0	0	0	0	19.26	4
PM3	Opportunities related to Large Scale Future Development	$5,000	$1,000			$5,000	$1,000				1	3	1	0	4	4	3	4	2	0	2	3	3	2	0	0	0	0	0	0	19.18	6
PM2	Floodplain Management Policy	$15,000	$0			$15,000	$0				1	3	0	0	4	4	3	4	2	0	4	3	0	3	0	0	0	0	0	0	18.63	7
EM5	Public awareness and education	$20,000	$5,000			$20,000	$2,000				0	0	0	0	4	4	2	4	4	2	4	2	0	4	0	0	0	0	0	0	18.17	8
PM1	LEP Update	$5,000	$0			$5,000	$0				0	2	0	0	4	4	2	4	2	0	4	3	0	3	0	0	0	0	0	0	16.51	9
EM6	Flood warning signs at critical locations	$20,000	$1,000			$20,000	$0				0	0	0	0	4	4	3	3	3	1	2	3	0	2	0	0	0	0	0	0	15.00	10
PM9	Flood Proofing Guidelines	$15,000	$1,000			$15,000	$0				0	1	0	0	4	4	4	4	0	0	2	3	0	4	0	0	0	0	0	0	14.20	11
EM4	Flood Warning System and Temporary Refuge	$20,000	$2,000			$50,000	$2,000				0	0	0	0	4	4	2	4	3	1	1	3	0	1	0	0	0	0	0	0	13.86	12
PM5	House Rebuilding	$4,600,000	$0	$12,222,924	-$735,000	$4,600,000	$0				0	3	0	0	-2	4	2	0	1	0	2	0	0	1	0	0	-1	0	0	0	6.45	15
PM4	House Raising	$4,600,000	$0	$12,222,924	-$735,000	$4,600,000	$0				0	3	0	0	-2	4	1	0	1	0	2	0	0	2	0	0	-1	0	0	0	6.38	16
PM6	Voluntary Purchase	$4,800,000	$0	$7,316,500																												
PM7	Land Swap	$3,000,000	$0	$7,316,500																												
PM8	Council Redevelopment	$3,000,000	$0	$7,316,500																												