10 Flood Planning Level Review

10.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has traditionally been based on the 100 Year ARI flood level plus a freeboard. The freeboard is generally set between 0.3m – 0.5m for habitable floor levels of residential properties, and can vary for industrial and commercial properties.

A variety of factors require consideration in determining an appropriate FPL. Of key consideration in the development of an FPL, is the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding;
- Duty of care.

These issues are dealt with collectively in the following sections.

10.2 Likelihood of Flooding

As a guide, **Table 10-1** has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 10-1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100 Year ARI event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 100 Year ARI flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 10-1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70 Years)

Likelihood of Occurrence in Any Year (ARI)	Probably of Experiencing At Least One Event in 70 Years (%)	Probability of Experiencing At Least Two Events in 70 Years (%)
10 Year ARI	99.9	99.3
20 Year ARI	97	86
50 Year ARI	75	41
100 Year ARI	50	16
200 Year ARI	30	5

10.3 Current FPL

Based on the Sydney LEP 2012, Council currently utilises the 100 Year ARI flood level plus a freeboard of 0.5m to define the Flood Planning Level.

It is understood that Council are currently preparing a *Floodplain Management Policy* which will provide further details regarding flood planning levels for various types of development within the floodplain.

10.4 Land Use and Planning

The hydrological regime of the catchment can change as a result of changes to the land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels and flood hazards can be increased.

A potential impact on flooding can arise through the intensification of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. DCP 2012 currently outlined controls relating to the installation of onsite detention to manage increased impervious area. No provisions exist within the current DCP 2012 or LEP 2012 to limit development within floodway or areas or limit filling in storage areas. However, it is understood that the proposed *Floodplain Management Policy* will include provisions relating to these issues. Given the current and proposed planning measures relating to this issue, it is not considered to be a significant issue within the catchment.

10.5 Damage Cost Differential Between Events

Based on an estimated flood damages for a property of $50,000, the incremental difference in Annual Average Damage (AAD) for different recurrence intervals is shown in **Table 10-2**. The table shows the AAD of an example property that experiences over-floor flooding in each design event, and the net present value (NPV) of those damages over 50 years at 7 percent.

Table 10-2 indicates that the largest incremental differences between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 1 and 2 Year ARI events and 2 and 5 Year ARI events. It can be seen that the differences between the larger events are relatively small, suggesting that increasing the FPL beyond the 20 Year ARI level does not significantly alter the savings achieved from a reduction in damages.

Table 10-2 Damage Differential Costs

Event	AAD per Property	Change in AAD	NPV of AAD	Change in NPV
1 Year ARI	$50,000	-	$690,037	-
2 Year ARI	$25,000	$25,000	$345,019	$345,019
5 Year ARI	$10,000	$15,000	$138,007	$207,011
10 Year ARI	$5,000	$5,000	$69,004	$69,004
20 Year ARI	$2,500	$2,500	$34,502	$34,502
100 Year ARI	$500	$2,000	$6,900	$27,601
PMF	$0	$500	$0	$6,900

10.6 Incremental Height Difference Between Events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the incremental height difference between events is shown in **Table 10-3** for selected events. These are average height differences determined based on the flood levels at each of the flood affected properties within the catchment as part of the flood damages analysis.

Table 10-3 Relative Differences Between Design Flood Levels

Event	Average Difference to PMF (m)	Average Difference to 100 Year ARI (m)	Average Difference to 20 Year ARI (m)
100 Year ARI	0.59	-	-
20 Year ARI	0.69	0.10	-
10 Year ARI	0.72	0.13	0.03

Table 10-3 indicates a larger difference in the flood level of the PMF event compared to other events. The adoption of the 100 Year ARI event as the flood planning level is only marginally different from that of the 20 Year ARI (on average 0.1 m higher). Therefore, the adoption of the 100 Year ARI event would provide an increased level of risk reduction over the 20 Year ARI event, without a significant difference in the flood planning level height.

The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 100 Year ARI event (in the order of 0.59 metres) and may therefore potentially present an issue for the setting of flood planning levels in the catchment.

With regards to an appropriate freeboard, the average difference between the PMF and the 100 Year ARI is 0.59 m, indicating that basing the FPL on the 100 Year ARI level, with an appropriate freeboard would result in the protection of some buildings in the PMF event.

10.7 Consequence of Adopting the PMF as a Flood Planning Level

The use of the PMF as a flood planning level provides the greatest level of risk reduction available with regards to planning levels. However, the economic and planning consequences of the adoption of the PMF for these purposes often outweigh the potential benefits.

Analysis of the flood damages (**Table 10-2**) indicates that the choice of the PMF event over the 100 Year ARI event as the FPL would result in limited economic benefits (in annualised terms) to the community.

The difference in average flood levels between the 100 Year ARI and the PMF event (**Table 10-3**) indicate that the use of the PMF as the FPL would result in higher levels (0.59 metres on average), and as a result higher economic costs and inconvenience to the community

The use of the PMF level as the FPL may conflict with other development / building controls in the Council's DCPs.

Given the risk of exposure outlined in **Table 10-1**, it is recommended that emergency response facilities be located outside of the floodplain and any other future planning ensure critical facilities be limited to areas outside of the floodplain. Modifications to existing critical facilities within the floodplain are suggested to have a floor level at the PMF level.

10.8 Environmental and Social Issues

The FPL can result in housing being placed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. This may also cause conflict with other development controls already present within the Council's development assessment process such as those relating to heritage buildings and localities.

10.9 Climate Change

The impacts of climate change on flood behaviour in the catchment were assessed as part of the Flood Study (Cardno, 2013). Models were run for the 100 year ARI 90 minute storm for increased rainfall intensities of 10%, 20%, and 30% with an elevated tailwater level of 2.9m AHD. **Table 10-4** provides a summary of the key impacts of the climate change modelling.

Table 10-4 Climate Change Impacts

Event	Rainfall Intensity Increases		
	10%	20%	30%
Average flood level difference (m)	0.01	0.02	0.03
Median flood level difference (m)	0.00	0.00	0.00
Standard deviation (m)	0.05	0.06	0.08
Maximum flood level difference (m)	0.55	0.70	1.06

The model indicates that areas most sensitive to climate change impacts, and in particular increases in rainfall intensities, are the trapped low points throughout the study area. The increase in rainfall intensities results in a greater volume of runoff arriving at these locations, and an associated increase in peak water level as a result. Other locations that are sensitive are locations like Bowden Street, which is the confluence point for a number of flowpaths. Large increases are also observed along Alexandra Canal, which is directly affected by the backwater from the Cooks River.

10.10 Risk

The selection of an appropriate FPL also depends on the potential risk of different development types. For example, consideration should be given for different FPLs for industrial, commercial and residential properties, which have different implications should overfloor flooding occur.

Critical infrastructure, such as hospitals, fire stations, electricity sub-stations and other critical infrastructure, has wider spread implications should inundation occur. As such, FPLs are typically selected for these types of structures higher than for residential, commercial or industrial properties.

10.11 Culvert Blockage

Stormwater pits can potentially block through a number of factors, including the build-up of leaf litter, parked cars and garbage bins. Blockages to culverts and bridges within the study area can occur by the accumulation of debris washed down from upstream. This debris, from historical observations in other similar catchments, can include vegetation and trees, cars and garbage bins.

Culvert blockages were assessed as part of the Flood Study (Cardno, 2013) for two cases, 100% blockage and 50% blockage. The impact of pit and culvert blockages results in some significant localised increases in peak water levels.

For the 50% blockage, the main areas impacted are Bowden Street, with an approximate 0.7 metre increase, Euston Road, with an approximate 0.35 metre increase and Ralph Street, with an approximate increase of 0.3 metres. These locations are impacted by the culvert blockage together with the lower pit capacities.

The impact of the 100% blockage case results in more widespread impacts. Key areas impacted are the low lying trapped depression locations, such as Coulson Street, areas along Botany Road, the area to the north of Copeland Street and Erskineville Oval and the trapped low points in the vicinity of Danks Street. In these locations, the primary outflow points are via the pit and pipe system. If this system is to become blocked, then there are limited opportunities for outflow of water from these locations.

Whilst it can be seen that the flood levels some areas are sensitive to culvert blockage, the average increase in flood levels as a result of culvert blockage is only 0.02m for the 100% blockage scenario (with a standard deviation of 0.07m). Therefore, it is recommended that the effects of culvert blockages continue to be assessed when undertaking flooding investigations as they can significantly impact some properties. However, with respect to freeboard, the blockage rates have minimal flood level impacts on the majority of properties within the catchment and should not affect the selection of flood planning levels.

10.12 Freeboard Selection

As outlined in **Section 10.1**, a freeboard ranging from 0.3 – 0.5 metres is commonly adopted in determining the FPL. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in the creek / channel vegetation;
- Accuracy of the model inputs (e.g. ground survey, design rainfall inputs for the area);
- Model sensitivity:
  - Local flood behaviour (due to local obstructions);
  - Wave action (e.g. wind induced waves or was from vehicles);
  - Culvert blockage; and
  - Climate change (affecting both rainfall and ocean levels).

The various elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood levels due to small local obstructions not accounted for in the modelling) (+0.1m) (Gillespie, 2005).
- Local wave action (trucks and other vehicles) (allowances of +0.1m are typical).

- Accuracy of ground / aerial survey (+/- 0.15m).
- Climate change impacts on rainfall and sea level rise (+0.03m).
- Sensitivity of the model +/-0.05m.

Based on this analysis, the total sum of the likely variations is in the order of 400mm, excluding climate change. This would suggest that a freeboard allowance of 500mm would be appropriate for the Alexandra Canal Catchment.

When applied to design events less than the PMF, the freeboard may still result in the FPL being higher than the PMF in certain cases.

It should also be noted that flooding within the Alexandra Canal Catchment in many locations could be categorised as overland flow. A shallow overland flowpath may not be significantly impacted with respect to several of the factors listed above thus a freeboard may be adopted only where flood depths are significant. Other municipal councils have adopted a threshold depth of 0.3m for these purposes.

10.13 Flood Planning Level Recommendations

Based on the previous assessments, it is recommended that Council adopt a FPL of 100 Year ARI and a 0.5m freeboard for habitable residential development.

Commercial and industrial properties have often adopted high frequency flood events such as the 20 year ARI event. This is based on the perception of risk. Occupiers of these properties can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots do not generally provide an income to offset the losses. Additionally, inventory, machinery and other assets can be stored above flood levels to lessen the economic loss as a result of a flood event.

There is only an average difference of 0.1m between the 20 year ARI and 100 year ARI event. Considering this relatively small difference between the events and the large number of industrial and commercial properties within the floodplain, it is recommended that the 100 year ARI plus 0.5m be adopted for commercial and industrial properties, as well as residential properties.

Underground car park entrances in addition to vents and openings are also to be set at the 100 year ARI + 0.5m, or PMF, whichever is the higher. These locations are a particularly high risk to life.

For critical infrastructure, such as hospitals, police stations and aged care, the PMF should be adopted as the FPL. It is important that these facilities, which are either difficult to evacuate or are essential during an emergency, remain flood free.

Due to the nature of flooding in the catchment and the large areas affected by shallow overland flow paths, a reduction to the freeboard may be appropriate in some cases. Where the depth of flow from local drainage overland flow paths is less than 0.25m for the 100 year ARI, the FPL could be set at two times the depth of flow with a minimum of 0.3 m above the surrounding surface.

A summary of the proposed flood planning levels for development are shown below in **Table 10-5**. These LGA-wide flood planning level recommendations outlined in the Draft Floodplain Management Policy (**Section 9.4.1**) are consistent with the requirements of the flood behaviour within the Alexandra Canal floodplain.

Table 10-5 Recommended FPLs for Alexandra Canal Catchment

Development		Type of flooding	Flood Planning Level
Residential	Habitable rooms	Inundated by mainstream flooding	100 year flood level + 0.5 m
		Inundated by local drainage flooding	100 year flood level + 0.5 m or Two times the depth of flow with a minimum of 0.3 m above the surrounding surface if the depth of flow in the 100 year flood is less than 0.25 m
		All other	0.3 m above surrounding ground
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Inundated by mainstream or local drainage flooding	100 year flood level
Industrial or Commercial	Business	Inundated by mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 100 year flood level
	Schools and child care facilities	Inundated by mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 100 year flood level
	Residential floors within tourist establishments	Inundated by mainstream or local drainage flooding	100 year floor level + 0.5 m
	Housing for older people or people with disabilities	Inundated by mainstream or local drainage flooding	100 year flood level + 0.5 m or a the PMF, whichever is the higher
	On-site sewer management (sewer mining)	Inundated by mainstream or local drainage flooding	100 year floor level + 0.5 m
	Storage of hazardous substances	Inundated by mainstream or local drainage flooding	100 year flood level + 0.5 m
Below-ground garage or car park (*For this purpose a below-ground garage or car park is where the floor of the car park is more than 1 m below the surrounding natural ground.)*	Single property owner with not more than 2 car spaces.	Inundated by mainstream or local drainage flooding	100 year flood level + 0.5 m
	All other below-ground car parks	Inundated by mainstream or local drainage flooding	100 year flood level + 0.5 m or the PMF (whichever is the higher) See Note 1
	Below-ground car park outside floodplain		0.3 m above the surrounding surface
Above ground car park	All car parks	Inundated by mainstream or local drainage flooding	100 year flood level

Development		Type of flooding	Flood Planning Level
Critical Facilities (include hospitals and ancillary service; communication centres; police, fire and SES stations; major transport facilities, sewerage and electricity plants; any installations containing infrastructure control equipment, any operational centres for use in a flood.)	Floor level		100 year flood level + 0.5m or the PMF (whichever is the higher)
	Access to and from critical facility within development site		100 year flood level

10.14 Flood Planning Maps

Flood planning maps provide a mapping based tool to identify areas relevant to floodplain management. The floodplain is defined by the PMF extent; however, it is common practice to also consider the flood planning level extent for planning purposes. This is usually defined as the extent of the adopted FPL (e.g. 100 year ARI + 0.5m). Development within this extent would need to consider the adopted FPL for setting of floor levels and other flood protection design aspects.

The development of flood planning maps depends on the content of planning instruments. When considering updates to planning instruments, consideration should also be given to developing appropriate flood planning maps to support the planning instruments.

11 Floodplain Risk Management Options

11.1 Managing Flood Risk

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 11-1**.

Table 11-1 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:

- **Flood modification measures –** Flood modification measures are options 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.

11.2 Existing Case

The existing flood behaviour in the Alexandra Canal floodplain is detailed in the Alexandra Canal Flood Study (Cardno, 2013). In order to assess the various management options, it is necessary to define a base case. This base case provides a reference to assess the effectiveness of various flood management options. The existing flood behaviour, as defined in the flood study, will be used for these purposes.

11.3 Flood Modification Measures

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 option 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 11.3.2**). 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.

11.3.1 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 11-2** with reference to the following subsections. Subcatchments in the study area for the measures are shown in **Figure 11-1**. General locations for Measures FM1 to FM10 are shown in **Figure 11-2** and general locations for other measures are shown in **Figure 11-3**. Figures showing the location and general locations of measures as well as modelled results are included in **Appendix D**.

11.3.1.1 Green Square Measures

As part of the Green Square Town Centre flood assessment, a series of flood modification measures were evaluated. The previous reports, Flood Mitigation Options Report – Green Square Town Centre (Cardno and Connell Wagner, 2009) and Flood Mitigation Options Report – Addendum (Cardno, 2012), detailed the assessment of these measures. The “Option 1a” upgrade system to manage runoff through GSTC (Cardno and Connell Wagner, 2009) has been superseded by proposed flood modification works encompassing a more regional perspective. Similarly, the “Mid-term Drainage Response” system (Cardno, 2012) has been superseded by the measures modelled for this Alexandra Canal Catchment Floodplain Risk Management Study (FRMS).

Flood modification works proposed for the Green Square comprise Measure FM9, Link Road to Alexandra Canal Upgrade, which supersedes the other options examined namely FM1, FM2, FM3, FM4, and FM10. These superseded options are further discussed in **Appendix F**.

11.3.1.2 Additional Pipes and Detention Storage at Erskineville Park and Oval (FM5)

Measure FM5 is located within the Munni Street-Erskineville subcatchment to mitigate ponding upstream of Copeland Street around Allen Avenue. It comprises additional pipes along Allen Avenue and Newton Street to divert runoff to Erskineville Park and Oval which both have a detention storage area of 5,000m^3 each. **Figure D1** shows the general layout of the system.

A reduction in flood levels (up to 0.2m) in the areas north of Allen Avenue downstream to Copeland Street, along Fox Avenue and Ashmore Street are shown in **Figure D2** for the 100 year ARI event. **Figure D3** shows modelled reductions in peak water levels compared to existing for the 20 year ARI event.

Potential constraints to the implementation of this option include heritage items and tree removal in the park and approaches to the oval.

Table 11-2 Flood Mitigation Measures

Measure Reference	Description	Detailed in Report Section
FM1	Raising Joynton Avenue and Incorporating Epsom Park Basin	Section 11.3.1.1
FM2	Additional Culvert from Joynton Avenue to Sheas Creek - Bowden Street Alignment	Section 11.3.1.1
FM3	Additional Culvert from Joynton Avenue to Sheas Creek - Maddox Street Alignment	Section 11.3.1.1
FM4	Additional Culvert from Joynton Avenue to Sheas Creek - Maddox Street Alignment excluding Drying Green Storage	Section 11.3.1.1
FM5	Additional Pipes and Detention Storage at Erskineville Park and Oval	Section 11.3.1.2
FM6	Additional Pipes from Macdonald Street and Coulson Street to Alexandra Canal	Section 11.3.1.3
FM7	Detention Basin in Redfern Park	Section 11.3.1.4
FM8	Detention Basin in Alexandria Park	Section 11.3.1.5
FM9	Link Road to Alexandra Canal Upgrade – Maddox Street Alignment	Section 11.3.1.6
FM10	Link Road to Alexandra Canal Upgrade – Sydney Water Easement Alignment	Section 11.3.1.1
FM11	Long Term Strategy for 20 year ARI capacity	Section 11.3.2
FM12	Detention Basin in Moore Park – Offset Storage from Arthur Street and Nobbs Street	Section 11.3.1.7
FM13	Detention Basin in Newtown Public School	Section 11.3.1.8
FM14	Detention Basin near Burren Street	Section 11.3.1.9
FM15	Liveable Green Network	Section 11.3.1.10
FM16	Additional Drainage Capacity in Gardeners Road near Kent Road	Section 11.3.1.11
FM17	Detention Basin in Turruwul Park	Section 11.3.1.12
FM18	Additional Drainage Network at Harcourt Parade to Gardeners Road	Section 11.3.1.13
FM19	Detention Basin in Waterloo Park	Section 11.3.1.14
FM20	Sheas Creek Channel Flood Walls	Section 11.3.1.15
FM21	Detention Basin in Sydney Park – Offset Storage from Macdonald Street	Section 11.3.1.16
FM22	Detention Basin in Young Street	Section 11.3.1.17
FM23	Increased Pit Cleaning and Maintenance	Section 11.3.1.18

Figure 11-1 Study Area Subcatchments

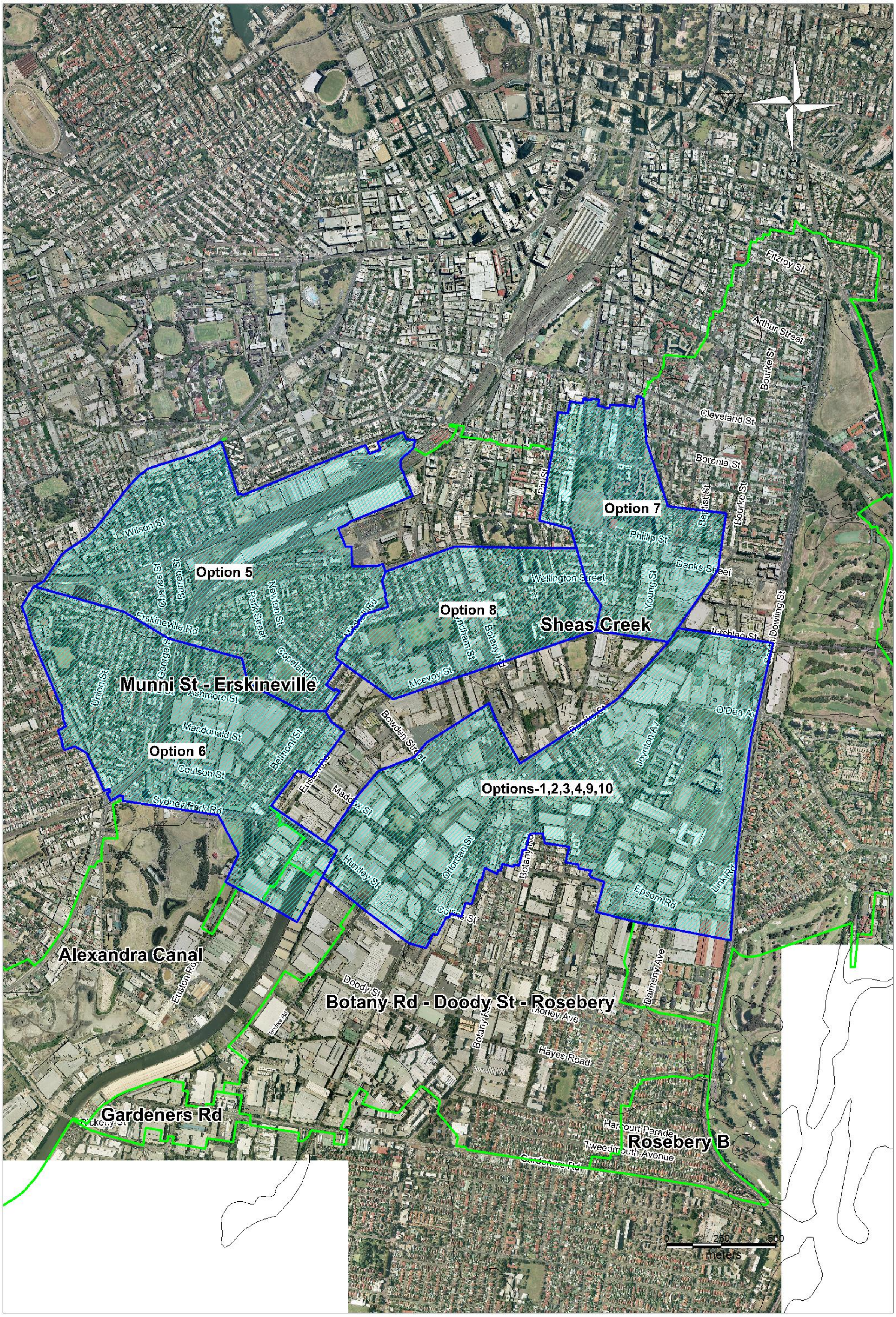


Figure 11-2 Short Term Measures – FM1 to FM10

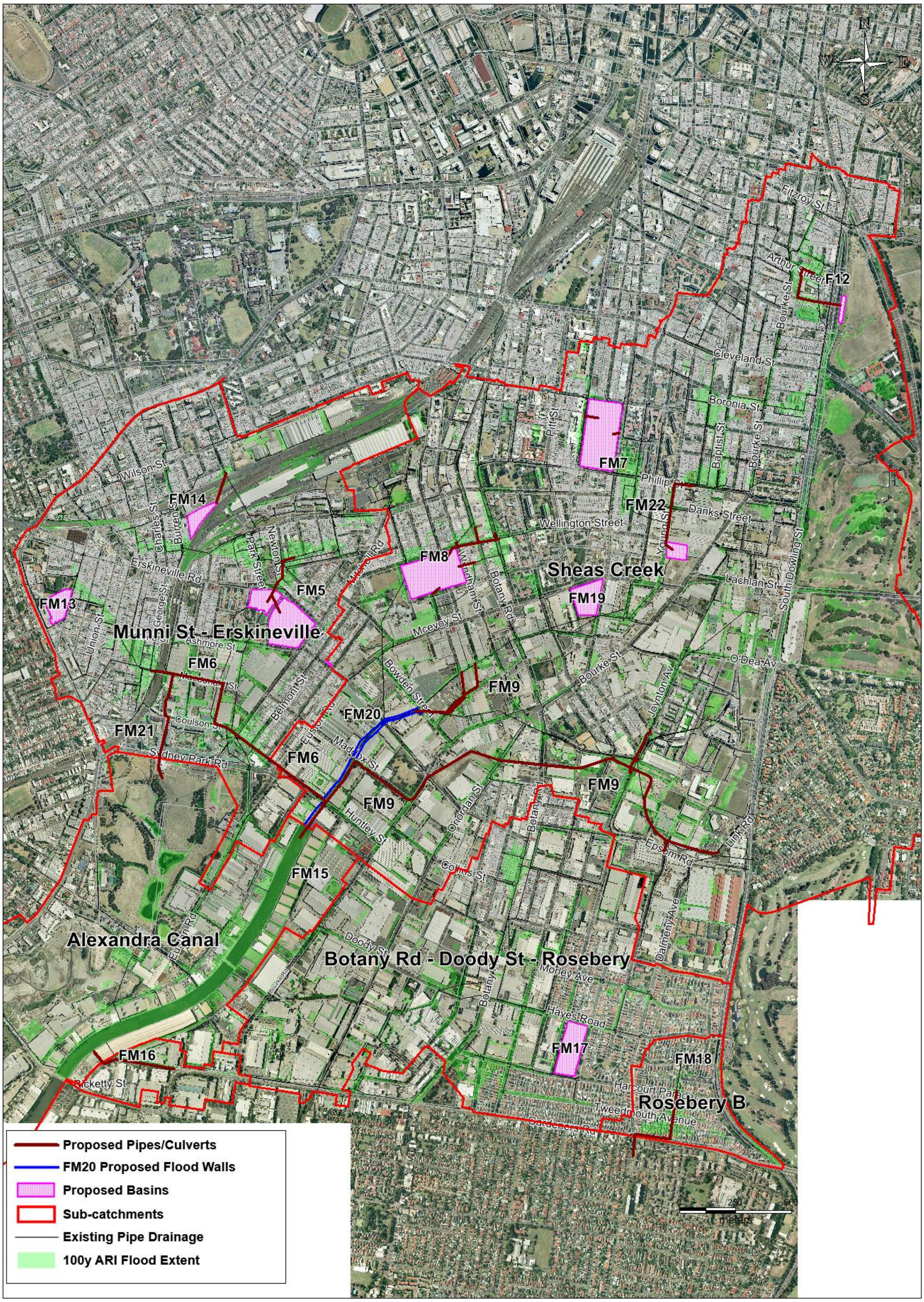


Figure 11-3 Flood Modification Measures (Excluding Long Term Drainage Strategy)

11.3.1.3 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**, 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.

In a 100 year ARI storm event, flood modelling indicates a reduction in flood levels of up to 0.5m at the southern end of Mitchell Road and Belmont Street and along Coulson Street as shown on **Figure D5**. Reductions in flood levels are also noted (0.01 to 0.2m) north of Copeland Street, in the vicinity of Macdonald Street, along Ashmore Street and Euston Road. An increase to flood levels in Alexandra Canal of up to 0.02m occurs due to the additional flow conveyed from upstream. **Figure D6** shows modelled reductions in peak water levels compared to existing for the 20 year ARI event.

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.

11.3.1.4 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**, 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.

Figure D8 shows changes in peak water levels for the 100 year ARI compared to existing based on preliminary modelling. The most significant reduction in flood levels is to the east and south east of Redfern Park (up to 0.2m in the 100 year ARI), primarily benefiting properties along Elizabeth Street, Phillips Street, Beaumont Street and Walker Street. Flood level reductions are also noted to the west of Redfern Park along Chalmers 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.

11.3.1.5 Detention Basin in Alexandria Park (FM8)

Measure FM8 is located within the Sheas Creek subcatchment to mitigate flood inundation around George Street and Cope Street near Wellington Street. Shown in **Figure D9**, it comprises additional 1200mm diameter pipes to drain surface runoff from roads to detention storage in Alexandria Park of 15,000 m^3 capacity.

The primary flood benefits in a 100 year ARI event are shown in **Figure D10** to the north-east of Alexandria Park in Botany Road and Cope Street (up to 0.5m reduction). Flood levels are also reduced in the commercial area between Power Avenue and McEvoy Street and along several streets to the south of the Alexandria Park. **Figure D11** shows modelled reductions in peak water levels compared to existing for the 20 year ARI event.

Potential constraints to the application of this measure include:

- Vegetation removal in Alexandria Park; and
- Potential changes to recreational use of Alexandria Park, depending on the configuration of the basin and if underground storage is adopted.

11.3.1.6 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. Previously examined configurations of the Link Road to Alexandra Canal Upgrade are discussed in **Appendix F**.

The current layout for Measure FM9 was refined by HydroStorm Consulting for Council as shown in **Figure D12**. 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).

In a 100 year ARI event significant reductions in peak water levels are shown in Joynton Avenue (about 1.5m) and Bowden Street (0.4m) as shown in **Figure D13**. An increase to flood levels in Alexandra Canal of up to 0.03m occurs due to the additional flow conveyed from upstream. **Figure D14** shows modelled reductions in peak water levels compared to existing for the 20 year ARI event.

Potential constraints to the application of this measure include:

- Potential increases to downstream flood levels;
- Construction of the system across and along road corridors that may contain significant amounts of services; and
- Impacts due to road closures and traffic disruption during construction of the system.

11.3.1.7 Detention Basin in Moore Park – Offset Storage from Arthur Street and Nobbs Street (FM12)

Measure FM12 is located within the northern part of Sheas Creek subcatchment to mitigate flooding around Arthur Street and Nobbs Street. Shown in **Figure D15**, it comprises additional inlets in Arthur Street and Nobbs Street conveying runoff through a culvert 3.9m wide by 0.6m high to an underground storage in Moore Park with approximate volume of 4,000m^3.

Figure D16 shows in a 100 year ARI event reductions in peak flood level of 0.06m in Phelps Street and 0.13m in Arthur Street. In a 20 year ARI event, peak water levels are reduced by up to 0.2m in Arthur Street but increased by 0.05m in Nobbs Street as shown in **Figure D17**. Additional capacity in the drainage system and underground storage would facilitate additional flood mitigation in the area.

Potential constraints to the application of this measure include:

- Construction of the drainage line across the Eastern Distributor; and
- Significant excavation required within Moore Park for the underground storage.

11.3.1.8 Detention Basin in Newtown Public School (FM13)

Measure FM13 is located within the Munni Street-Erskineville subcatchment to mitigate flooding downstream of Angel Street. Shown in **Figure D18**, it comprises a diversion pipe from the existing Angel Street drainage system into a dual purpose sports field / detention basin on the School.

Potential constraints to the application of this measure include:

- The site is in a location that is relatively high within the catchment thus its effectiveness to manage flows for downstream properties should be evaluated;
- Implementation of a detention basin facility within the School; and
- Vegetation removal.

Flood modelling of this measure has not been undertaken.

11.3.1.9 Detention Basin near Burren Street (FM14)

Measure FM14 is located within the Munni Street-Erskineville subcatchment to mitigate flooding in Holdsworth Street and Burren Street. Shown in **Figure D19** it comprises an additional inlet and pipeline from Holdsworth Street to a detention basin in a property off Burren Street. An inlet and pipeline off Burren Street to the basin may relieve inundation of Burren Street.

Potential constraints to the application of this measure include:

- Construction of a pipeline under the rail corridor; and
- Ownership and availability of the land for the siting of the detention basin.

Flood modelling of this measure has not been undertaken.

11.3.1.10 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** 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.

11.3.1.11 Additional Drainage Capacity in Gardeners Road near Kent Road (FM16)

Measure FM16 is located within the Gardeners Road subcatchment to mitigate flooding on Gardeners Road to the west of Kent Road. Shown in **Figure D21**, it comprises additional inlets and pipeline augmentation from Kent Road to the Canal.

Flood modelling of this measure has not been undertaken.

11.3.1.12 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**, 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 modelling of this measure has not been undertaken.

11.3.1.13 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**, 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.

Flood modelling of this measure has not been undertaken.

11.3.1.14 Detention Basin in Waterloo Park (FM19)

Measure FM19 is located within the Sheas Creek subcatchment to mitigate flooding in the trapped lowpoint at Powell Street and Hunter Street. Shown in **Figure D24**, it comprises augmentation and additional pipe drainage from Powell Street and Pitt Street to detention storage within the adjacent Waterloo Park.

Potential constraints to the application of this measure include:

- The existing elevation of Waterloo Park may not be compatible with this measure; and
- Disturbance to existing vegetation and usage of the Park.

Flood modelling of this measure has not been undertaken.

11.3.1.15 Sheas Creek Channel Flood Walls (FM20)

Measure FM20 is located within the Sheas Creek subcatchment to mitigate flood inundation of properties adjacent to the open channel. Shown in **Figure D25**, 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 measure 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 modification is provided at road crossings of the channel.

Flood modelling of this measure has not been undertaken.

11.3.1.16 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**, 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.

Flood modelling of this measure has not been undertaken.

11.3.1.17 Detention Basin in Young Street (FM22)

Measure FM22 is located within the Sheas Creek subcatchment to mitigate flooding in the vicinity of Phillip Street and Young Street. Shown in **Figure D27**, it comprises provision of detention storage in a vacant block in Young Street (5,000m^3) to offset runoff ponded on nearby roads. An additional 600mm pipe is proposed to convey flow from Phillip Street to the detention basin in Young Street.

Figure D8 shows changes in peak water levels for the 100 year ARI compared to existing based on preliminary modelling. Flood level reductions up to 0.02m occur in Phillip Street and Young Street.

Potential constraints to the application of this measure are the recent development in Danks Street and availability of land in Young Street.

11.3.1.18 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.

11.3.2 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; and
- 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 11-2** as Measure FM11 and shown in **Figure 11-4.**

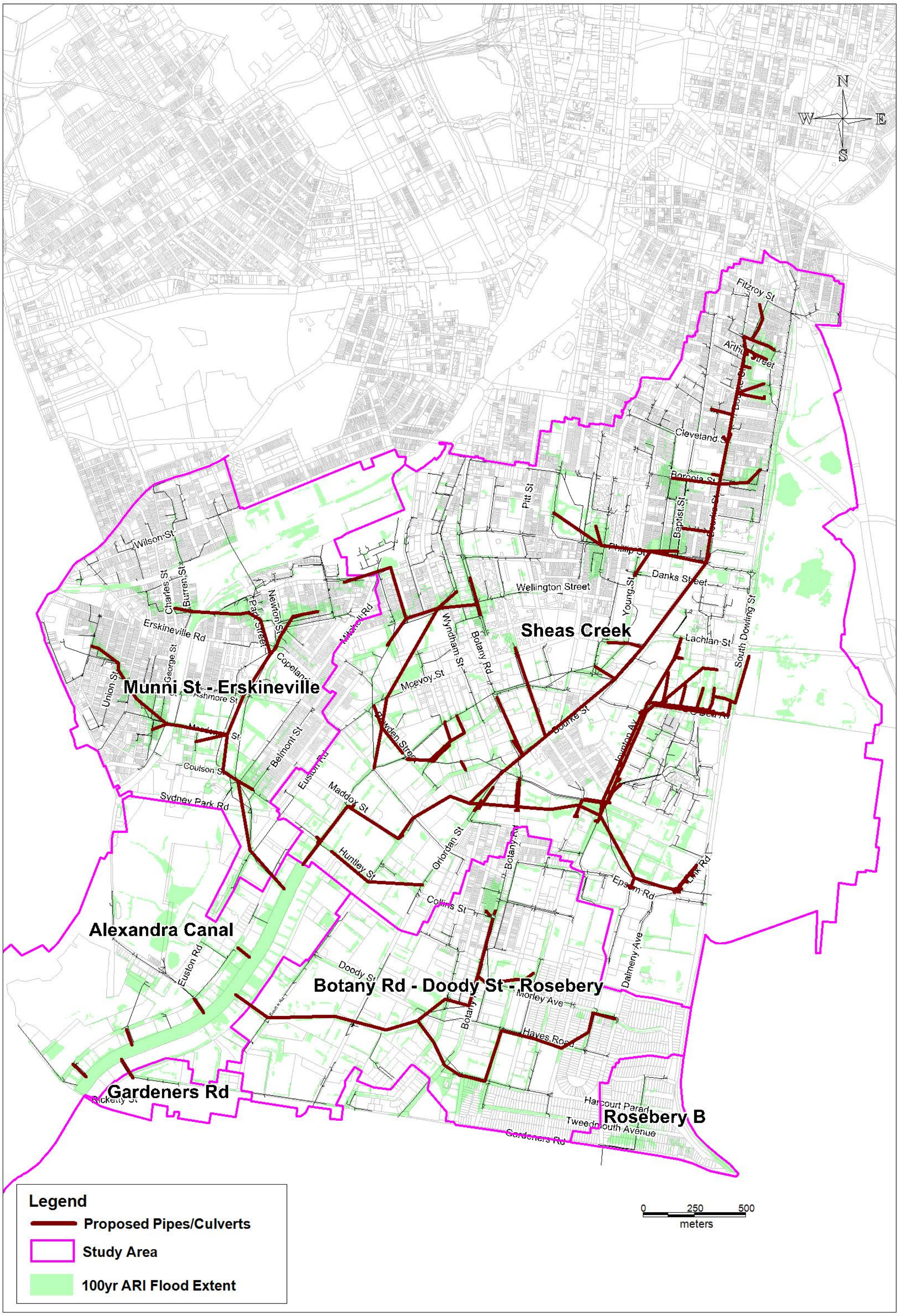


Figure 11-4 Measure FM11 Layout

11.3.2.2 Approach to Assessment

The aim of the assessment was to develop a stormwater drainage infrastructure for the study area that was capable of conveying the 20 year ARI. The key objective of the system was to achieve flood inundation of no more than 170mm of water on the road (or roughly the top of kerb).

The analysis was undertaken in a number of steps:

1. Establish an additional stormwater network throughout the study area in the model;
2. Size the “new” stormwater network in the model to accommodate the 20 year ARI flows, being the additional flows not already conveyed by the existing stormwater system. This is an iterative process, as the downstream pipes are dependent on the upstream pipe solutions;
3. The results of Step 2 above provide guidance on indicative flows and pipe sizes required to achieve a 20 year ARI design capacity. However, they do not take into account constraints to construction like buildings, roads etc. Therefore, they provide a useful benchmark by which to undertake a design of suitable infrastructure;
4. Using the results of Step 2, determine an indicative pipe layout taking into considering constraints based on available information. This concept level strategy generally followed the following principles:
    a. Avoid pipes through residential properties, where easements would be difficult to achieve due to densities of developments and impacts on houses; and
    b. Generally assume a parallel stormwater system is developed, in addition to the existing stormwater system. It is noted that in some cases these two could be combined, with a replacement of the existing stormwater drain with a larger capacity system.
5. Step 4 provides one potential alternative, but it is not the only stormwater layout that is possible. There are likely to be multiple solutions in the different parts of the study area. Some of these are discussed in **Section 11.3.2.3** below.
6. Undertake costings of this proposed layout, to provide Council with an indication of the overall cost. This costing was also broken down into sub-areas, as the works are likely to be staged over a period of time. The next phase of the project will look at optimising these works based on their effectiveness.

11.3.2.3 Strategy Components

The long term flood modification strategy (Measure FM11) involves multiple drainage components across the whole study area. It has been broken into a number of sub-areas. As the works would 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 11-5**.

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 11-3**.

Table 11-3 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 measure 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.

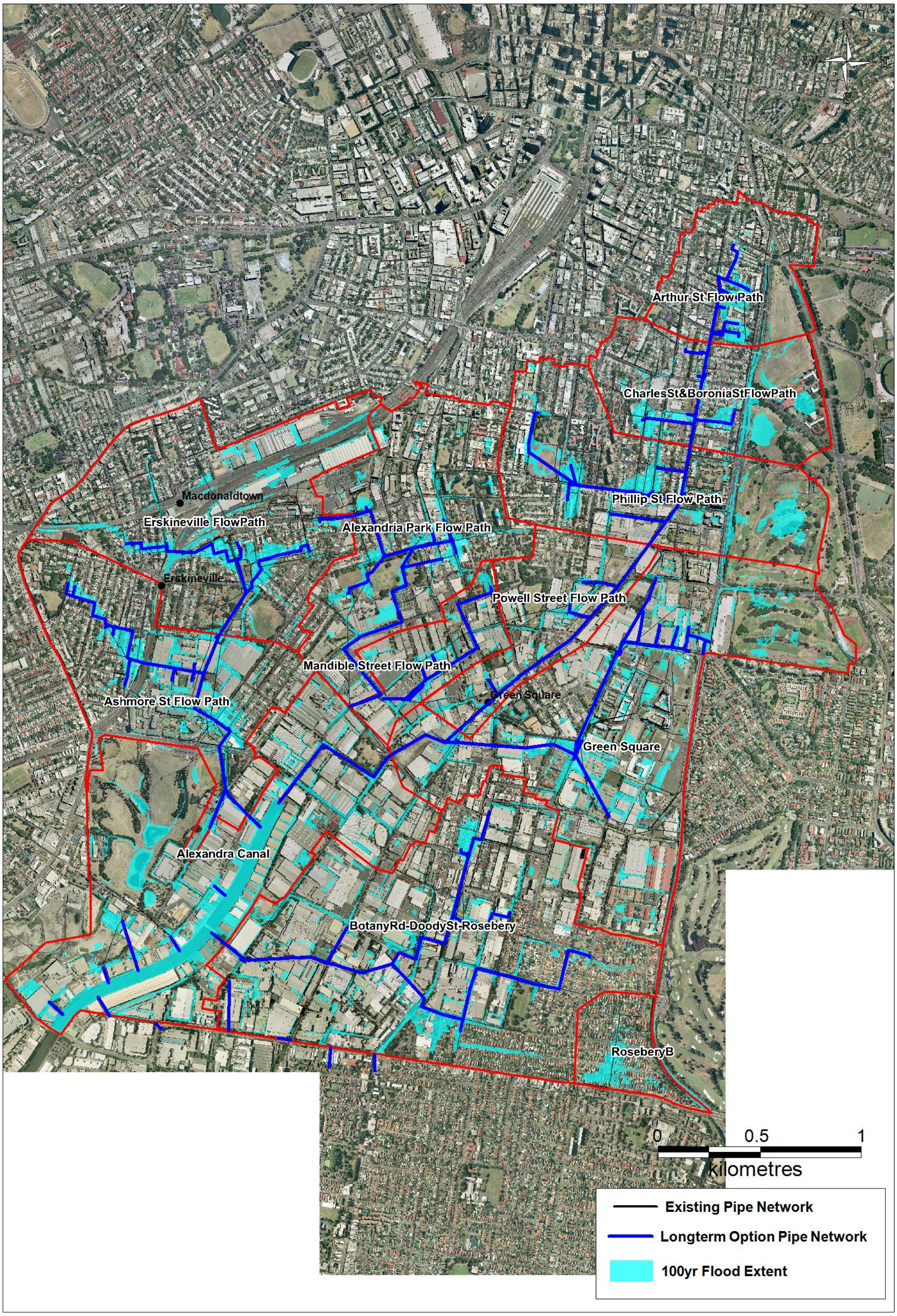
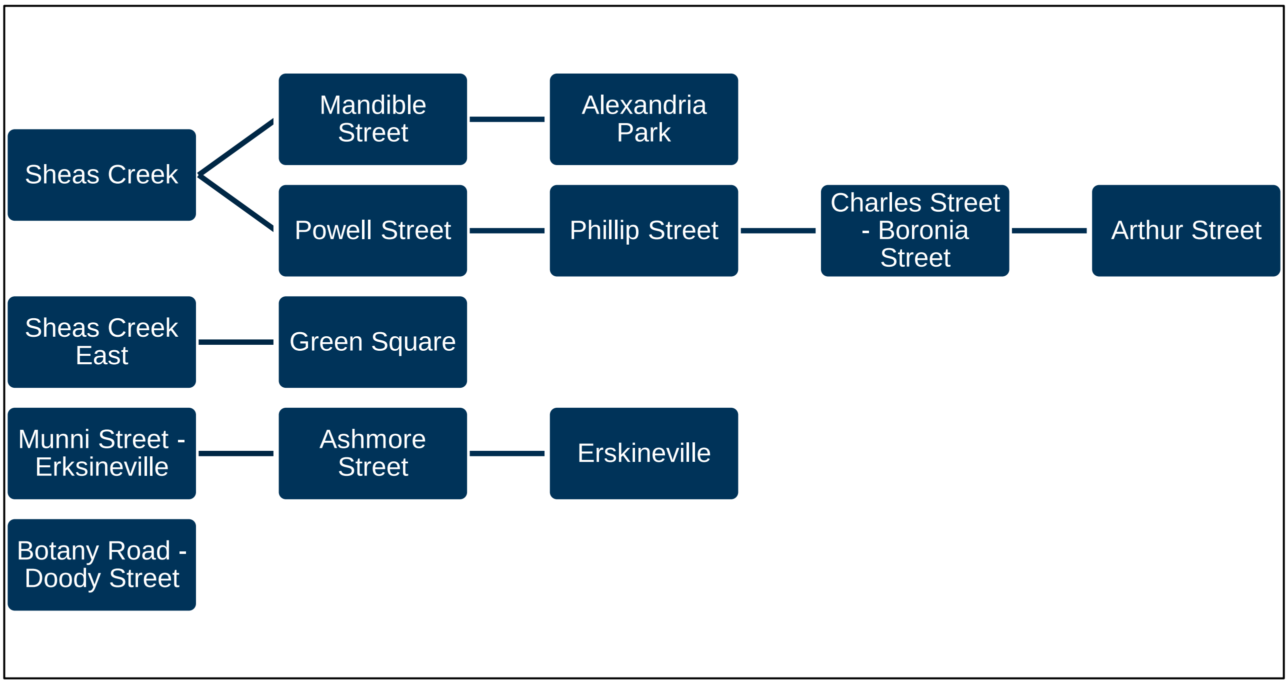


Figure 11-5 Sub-Areas for Measure FM11

11.3.2.4 Implementation and Staging

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.

11.3.2.5 Measure FM11 Model Results

Preliminary modelling of the long term flood modification strategy (Measure FM11) shows a significant reduction in the extent of ponding depths greater than 0.17m in a 20 year ARI event as shown in **Figure D28** (in **Appendix D**). **Figure D29** shows the reductions distributed across the catchment in a 20 year ARI event. In a 100 year ARI event the reductions in peak water levels across the catchment (shown in **Figure D30**) are more extensive than for a 20 year ARI event. The removal of the upstream ponding areas results in an increase in flood levels in Alexandra Canal, by up to 0.3m at the Sheas Creek outlet and by 0.05m at Ricketty Street in a 100 year ARI event. Flood level increases in Alexandra Canal are further discussed in **Section 11.8**.

11.3.3 Environmental Considerations

According to State Environmental Planning Policy (SEPP) (Infrastructure) 2007, flood mitigation works “may be carried out by or on behalf of a public authority without consent on any land”. These works include construction, routine maintenance and environmental management works which applies to most of the flood modification measures in **Table 11-2**.

Although consent is not required, most flood modification measures will require further environmental assessment.

The determining authority, in this case City of Sydney, is required to “examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors (REF).

When carrying out flood modification works, Council will be required to take out further permits, licenses and approvals such as:

- Flood modification works which emit into a water body will need an Environment Protection Licence complying with the Protection of the Environment Operations Act (POEO) 1997,
- Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the Fisheries Management Act 1999,
- A license to harm threatened species, population or ecological community or damage habitat under the Fisheries Management Act 1999.

Heritage is a key environmental consideration in the catchment and it is important to consider the implication of any proposed flood management works on heritage items or the constraints that may apply due to the presence of heritage items. 31 heritage items are found within or surround the catchment which have been listed by the Heritage Council under the NSW Heritage Act. A further 825 items were found within or surrounding the catchment area which have been listed by local council and state government agencies.

Part 5, Clause 5.10 of the Sydney LEP 2011 outlines the provisions which must be followed in relation to heritage items in the LGA.

11.4 Property Modification Measures

A number of property modification measures were identified for consideration in the Alexandra Canal floodplain. These are:

- LEP and DCP Update (PM1)
- Floodplain Management Policy (PM2)
- Opportunities Related to Large Scale Future Development (PM3)
- House Raising (PM4)
- House Rebuilding (PM5)
- Voluntary Purchase (PM6)
- Land Swap (PM7)
- Council Redevelopment (PM8)
- Flood Proofing (PM9)

These measures are discussed in more detail below.

11.4.1 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** 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.

11.4.2 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.

11.4.3 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; and
- 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**.

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.

11.4.4 PM4 – House Raising

House raising is a possible measure to reduce the incidence of over floor flooding in properties. However, whilst house raising can reduce the occurrence of over floor flooding, there are issues related to the practise, including:

- Difficulties in raising some houses, such as slab on ground buildings. In some slab on ground situations it may be possible to install a false floor, although this is limited by the ceiling heights.
- The potential for damage to items on a property other than the raised dwelling are not reduced – such as gardens, sheds, garages, etc.
- Unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists – i.e. there will still be a residual risk.
- Evacuation may be required during a flood event for a medical emergency or similar, even if no overfloor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounds a property.
- The need to ensure the new footings or piers can withstand flood-related forces.
- Potential conflict with height restrictions imposed for a specific zone or locality within the local government area.

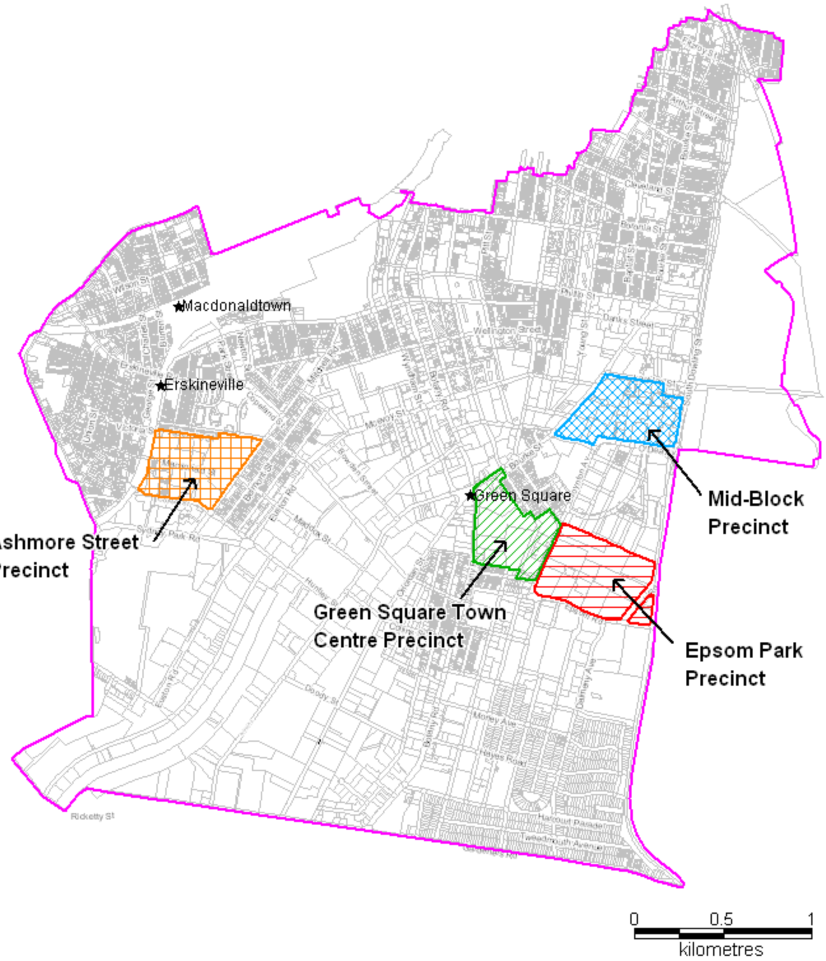


Figure 11-6 Large Scale Re-Development Areas

For a single storey property, the flooding damage that occurs for over-floor flooding of around 0 to 0.5m of depth is around $50,000. **Table 11-4** provides the approximate Annual Average Damage (excluding overground only damage) for over-floor flooding commencing in different AEP events for individual residential properties. It assumes that over-floor flooding damage is constant at $50,000 for each over-floor event. This effectively provides a typical AAD for an individual property, and can be used as a guide of the damages incurred.

Table 11-4 also demonstrates that properties with over-floor flooding in less frequent events are not exposed to flood damages as frequently, and hence the annualised damage for that property is not as significant.

Table 11-5 shows the reduction in AAD from different house raising scenarios. In order for the scheme to be equitable, the house raising should only occur by raising floor levels up to the next ARI flood level. If it were to occur for a higher level, then it is arguable that the properties experiencing over-floor flooding in the next ARI event would be disadvantaged. In order to overcome this equity issue, it may be possible to apply a sliding scale subsidy which applies to all properties which are affected by over-floor flooding in events more frequent than the 100 year ARI event.

There are a significant number of properties that experience over-floor flooding in the more frequent events. The comparison of benefits and costs provided in **Table 11-5** identifies economic benefits in undertaking house raising for properties experiencing over-floor flooding in events equal to and less than the 5 year ARI.

The Office of Environment and Heritage has prepared guidelines for house raising schemes that details the objectives, eligibility criteria, funding and implementation procedure.

Table 11-4 Estimates of AAD and NPV for Over-Floor Flooding Scenarios

Event in which over-floor flooding commences	Number of Properties with over-floor flooding	AAD per property	NPV (50yrs) per property
1 Year ARI	6	$50,000	$690,037
2 Year ARI	39	$25,000	$345,019
5 Year ARI	130	$10,000	$138,007
10 Year ARI	230	$5,000	$69,004
20 Year ARI	348	$2,500	$34,502
100 Year ARI	705	$500	$6,900
PMF	1584	$0	$0

Table 11-5 Reduction in AAD Resulting from House Raising Scenarios

Scenario	No. of Properties	Reduction in AAD (per property)	Overall Reduction in AAD	NPV Reduction	Estimated Cost of Raising
1 to 2 Year ARI	6	$25,000	$150,000	$2,070,112	$480,000
2 to 5 Year ARI	39	$15,000	$585,000	$8,073,437	$3,120,000
5 to 10 Year ARI	130	$5,000	$650,000	$8,970,485	$10,400,000
10 to 20 Year ARI	230	$2,500	$575,000	$7,935,429	$18,400,000
20 to 100 Year ARI	348	$2,000	$696,000	$9,605,319	$27,840,000
100 Year ARI to PMF	705	$500	$352,500	$4,864,763	$56,400,000

11.4.5 PM5 – House Rebuilding

Under a re-building scheme, the property owner would have the option of utilising the subsidy for house raising described above for re-construction instead. In a number of cases, the ability to raise properties can be difficult and therefore rebuilding may be the only option. The advantage of this measure is that the new structure can also be built in a flood compatible way (such as including a second storey for flood refuge).

One of the issues associated with this measure is that there is still a significant cost for the property owner to redevelop their land. In addition, this provides an inequitable situation for those properties that are subject to the subsidy and those that are not. It can have the effect of skewing the property development market, where those properties subject to the subsidy are made more attractive for development than those properties that are not.

11.4.6 PM6 – Voluntary Purchase

An alternative to the construction of flood modification measures and for properties where house raising is not possible is the use of voluntary purchase of existing properties. This measure would free both residents and emergency service personnel from the hazard of future floods. This can be achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be rezoned to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard.

However, this measure should be considered after other, more practical measures have been investigated and exhausted.

The recommended criteria to determine properties that are eligible for voluntary purchase are:

- Located in the high hazard zone for the 1% AEP flood event, and
- Occurrence of above floor flooding in the 20% AEP flood event, and
- Economic value of damages for a particular property is comparable to the property market value (approximately $800,000 for a dwelling).

The Office of Environment and Heritage has prepared guidelines for voluntary purchase schemes that details the objectives, eligibility criteria, funding and implementation procedure.

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.

11.4.7 PM7 – Land Swap

An alternative to specific voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land in a non-flood prone area, such as an existing park, for the flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land rezoned to open space.

This may potentially be a constraint within the City of Sydney as alternative sites would need to be found that are Council owned, of sufficient size, currently un-used, and which are not flood affected.

As no properties were identified for voluntary purchase or suitable land available this measure is also not recommended.

11.4.8 PM8 – Council Redevelopment

This measure also provides an alternative to the voluntary purchase scheme. While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and re-sell them with a break-even objective.

As no properties were identified for voluntary purchase, this measure is also not recommended.

11.4.9 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. It is primarily suited to industrial or commercial properties.

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.

11.5 Emergency Response Modification Measures

A number of emergency response modification measures are suitable for consideration within the Alexandra Canal floodplain. These are:

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

These measures are discussed in more detail below.

11.5.1 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.

11.5.2 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**.

11.5.3 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 are flood free sites with flood free access.
- 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**.

11.5.4 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.

11.5.5 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.

11.5.6 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.

11.6 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.

11.7 Green Square – West Kensington

As noted in Section 3.1.2, the Green Square West Kensington Floodplain Risk Management Study and Plan identified a number of measures for floodplain management. Some of these measures are within the study area for this report.

The Green Square West Kensington Studies identified a number of high priority measures for implementation, and these have been included in the table below. Generally, these align with measures assessed in this report

Table 11-6 Green Square West Kensington High Priority Measures

Measure	Included in this Study (Y/N)	Comments or Reference in this Study
Maintain Flood and Drainage Database	N	Council has recently completed collected of pit and pipe data across the entire LGA. Maintaining of this database would be worthwhile, to prevent additional costs in the future. However, it is considered that this is more of an asset management issue, and therefore has not been included in this report. This can be added following review of the draft of this report if required.
Public Information and Raising Flood Awareness	Y	EM4
Planning Instruments & Development Control Planning	Y	P1, P2 & P3
Flood Planning Levels	Y	P1
Section 149 Notations	Y	P1. This should be undertaken in conjunction with an update in the LEP.
Management of Blockage	Y	FM23
Detention Basins	Y	The report specifically refers to the potential for detention basins in the Green Square and neighbouring areas. No specific sites have been identified, although general locations are discussed. In the current study, detention basins have been included based on the current designs for this area and feedback from Council
Option A pipe upgrade	Y	FM9
Mid-Block Precinct	N	There are some drainage augmentation measures that have been identified in the report for the mid-block precinct. These would generally be undertaken as a part of a larger redevelopment. This type of individual private redevelopment has generally not been included in this study, save for the guidance of the 20 year drainage strategy.

11.8 Additional Inflows to Alexandra Canal

A number of the measures identified above result in additional inflows into Alexandra Canal. The 20 year drainage strategy (FM11), outlined above, results in the largest increase in flows in the Canal, with flood levels increasing by up to 0.3m.

Additional flood management measures, such as increases to levee banks, may be considered at detailed design stage of catchment improvement works to offset potential water level increases in the Canal.

12 Economic Assessment of Options

It is possible to quantitatively assess the economic benefits of some of the measures, namely those that were hydraulically modelled, and those with known benefits. For those measures, a benefit-cost ratio can be calculated as discussed in the following sections.

12.1 Preliminary Costing of Options

Detailed cost estimates have been prepared for those measures which allow for an economic assessment. A summary of these estimated capital costs (exclusive of GST) are provided in **Table 12-1**. Further details are provided in **Appendix E**.

For other measures, broad cost estimates were made for the purpose of comparison in the multi-criteria assessments. These are detailed in **Section 13**.

Prior to a measure proceeding, it is recommended that in addition to detailed analysis and design of the measure, that these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

Table 12-1 Costs of Quantitatively Assessed Measures

Measure ID	Measure	Capital Cost (excl. GST)	Ongoing (Annual) Costs (excl. GST)
FM5	Additional pipes and detention storage at Erskineville Park and Oval	$7,210,000	$13,500
FM6	Additional pipes from Macdonald Street and Coulson Street to Alexandra Canal	$22,880,000	$15,500
FM8	Detention basin in Alexandria Park	$8,090,000	$25,500
FM9	Link Road to Alexandra Canal Upgrade – Maddox Street Alignment	$80,540,000	$34,500
FM11	Long term strategy for 20 year ARI capacity	$600,000,000	$339,000
FM12	Detention basin in Moore Park – Offset Storage from Arthur Street and Nobbs Street	$13,460,000	$14,500

12.1.2 Long Term Measure (FM11)

Preliminary cost estimates have been prepared for the overall long term drainage strategy. They have been broken down into the different sub-areas and are shown in **Figure 12-1**.

The preliminary cost estimated for the strategy is in the order of $600 - $700 million.

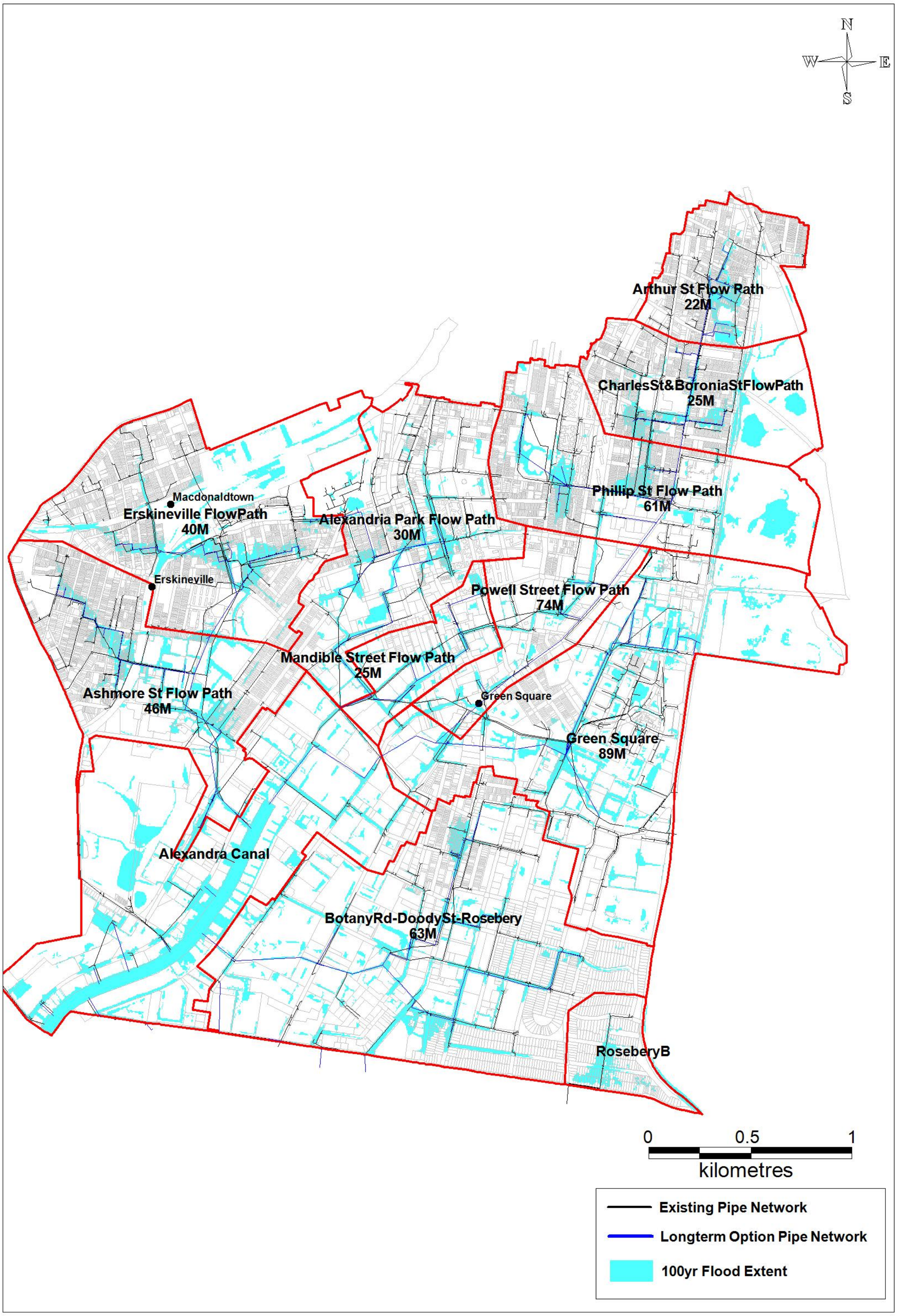


Figure 12-1 Measure FM11 Preliminary Cost Estimates per Sub-Area

12.2 Average Annual Damage Assessment of Measures

The total damage costs were evaluated for each of the measures assessed by hydraulic modelling (quantitative assessment). The average annual damage (AAD) calculated for each measure is shown comparatively against the existing case ($12,957,924 excluding GST) in **Table 12-2**.

Table 12-2 Average Annual Damage for Quantitatively Assessment Measures

Measure ID	Measure	Resultant AAD of Measure (ex. GST)	Reduction in AAD due to Measure (ex GST)
FM5	Additional pipes and detention storage at Erskineville Park and Oval	$12,930,956	$26,969
FM6	Additional pipes from Macdonald Street and Coulson Street to Alexandra Canal	$12,507,150	$450,774
FM8	Detention basin in Alexandria Park	$12,741,453	$216,471
FM9	Link Road to Alexandra Canal Upgrade – Maddox Street Alignment	$12,815,163	$142,761
FM11	Long term strategy for 20 year ARI capacity	$4,727,307	$8,230,618
FM12	Detention basin in Moore Park – Offset Storage from Arthur Street and Nobbs Street	$12,458,451	$499,473

The results in Table 12-2 show that FM11, which represents the 20 year ARI drainage strategy, has the largest reduction in AAD. FM5, by comparison, has the smallest reduction in AAD.

The AAD may be reduced to various degrees for different measures. This reduction then needs to be offset against the capital and recurrent costs of the measure. This is investigated through the calculation of a benefit cost ratio.

12.3 Benefit Cost Ratio of Measures

The economic evaluation of each modelled measure was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the measure.

The existing condition (or the ‘do nothing’ option) was used as the base case to compare the performance of modelled measures. Inputs for the assessment include those data derived from the floor levels and property survey along with damage curves for other similar areas. The 1 year, 2 year, 5 year, 10 year, 20 year, 100 year ARI and PMF events were considered for this evaluation. The preliminary costs of each measure were used to undertake a benefit-cost analysis of each measure on a purely economic basis.

Table 12-3 summarises the overall economics for each measure that was able to be economically assessed. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C).

The benefit-cost ratio provides an insight into how the damage savings from a measure, relate to its cost of construction and maintenance:

- Where the benefit-cost is greater than 1 the economic benefits are greater than the cost of implementing the measure.
- Where the benefit-cost is less than 1 but greater than 0, there is still an economic benefit from implementing the measure but the cost of implementing the measure is greater than the economic benefit.

- Where the benefit-cost is equal to zero, there is no economic benefit from implementing the measure.
- Where the benefit-cost is less than zero, there is a negative economic impact of implementing the measure.

Table 12-3 Summary of Economic Assessment of Management Measure

Measure ID	AAD (ex. GST)	Reduction in AAD due to Measure (ex. GST)	NPW of AAD Reduction	Estimate of Capital Cost (ex. GST)	Estimate of Maintenance Cost (ex. GST)	NPW of Measure	B/C Ratio	Rank
FM5	$12,930,956	$26,969	$372,186	$7,210,000	$13,500	$8,109,110	0.05	5
FM6	$12,507,150	$450,774	$6,221,020	$22,880,000	$15,400	$25,370,631	0.25	3
FM8	$12,741,453	$216,471	$2,987,460	$8,090,000	$25,300	$9,242,459	0.32	2
FM9	$12,815,163	$142,761	$1,970,209	$80,540,000	$34,200	$89,058,486	0.02	6
FM11	$4,727,307	$8,230,618	$113,588,665	$600,000,000	$338,100	$666,974,332	0.17	4
FM12	$12,458,451	$499,473	$6,893,098	$13,460,000	$14,500	$14,997,011	0.46	1

* NPW = Net Present Worth calculated over 50 years at 7 percent.

The benefit cost analysis suggests that all measures considered have a BCR of less than 1. This is not unusual in this type of analysis. Importantly, the economic analysis in this situation has only incorporated changes to economic damages of properties, and does not consider social factors, risk to life and environmental factors. These types of benefits are difficult to quantify in dollar terms. If they could be included, then the BCR would increase. The MCA, discussed in Section 13, attempts to incorporate some of these non-quantified benefits into the decision making process.

From the results above, the detention basin in Alexandria Park (FM8) has the highest benefit cost ratio, suggesting that this has the largest reduction in economic damages relative to the cost.

12.3.2 Economic Assessment of Desktop Assessed Measures

Where a desktop assessment was utilised for measures (as opposed to hydraulic modelling), a detailed economic analysis was not undertaken. Instead, a judgement on the likely economic benefits of the measures was made. This is described in **Section 13**.

13 Multi-Criteria Matrix Assessment

A multi-criteria matrix assessment approach has been adopted for the comparative assessment of all measures identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach uses a subjective scoring system to assess the merits of various measures. The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives “transparent” (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute “right” answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine measures and, if necessary, debate the relative scoring assigned.

Each measure is given a score according to how well the measure meets specific considerations. A framework for scoring has been developed for each criterion as shown in **Table 13-2**.

13.1 Scoring System

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

A workshop with stakeholders was undertaken to determine appropriate criteria and relative weightings for each criteria and assessment categories (economic, social and environmental). During the workshops, participants were asked to identify criteria, and then score these criteria from 1 to 5 (1 being lowest importance, 5 being highest importance). **Table 13-1** shows the average scores from the two workshops that were undertaken. Note that there will also be an opportunity to update these scores following input from stakeholders and the community during the exhibition of the draft report.

Weightings for each of the criteria were based on the scoring system that was adopted. The scores were scaled to a weighting for each criteria on the following basis:

- A score of 1 is equivalent to 10% weighting
- A score of 5 is equivalent to 100% weighting
- Scores in between these values are on a linear slide scale

The weightings of each of the scores are provided in **Table 13-1.** These weightings have been utilised in the MCA to determine the relative importance of each of the criteria.

The weightings also provide some insight into the inferred importance of each of the overall categories of Economic, Social and Environmental. These overall category weightings are provided in **Table 13-1.**

Table 13-1 Criteria for Matrix Assessment

Category	Effective Category Weighting	Criteria	Average Scores - Workshops	Weightings
Economic	49.6%	Benefit Cost Ratio	4.3	84%
		Reduction in Risk to Property	3.8	73%
		Essential Infrastructure	3.8	73%
		Future Development	3.4	63%
		Capital Cost	3.2	59%
		Operating Costs	3.1	56%
		Constructability	2.9	54%
		Implementation Timeframe	2.7	48%
Social	30.7%	Reduction in Risk to Life	4.8	95%
		Reduction in Social Disruption	3.5	66%
		Compatibility with Council Policies & Plans	3.3	62%
		Community & Stakeholder Support	3.0	55%
		Urban Design	2.8	51%
		Governance	2.7	47%
Environment	27.5%	Compatibility with Water Quality Objectives	3.3	62%
		Groundwater	3.2	59%
		Heritage	3.0	55%
		Compatibility with Water Reuse Schemes	3.0	55%
		Fauna/Flora Impact - including street trees	2.9	54%
		Contaminated Land & Acid Sulfate Soils	2.8	51%

The scoring system is shown in **Table 13-2** for the above criteria.

Each measure is assigned a score for each criterion. The score for each category (i.e. economic, environment and social) is determined by the score for each criterion, factored by a weighting as shown in **Table 13-1**.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the measure on flooding as well as its affordability. Measures that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score is calculated to identify those measures with the greatest potential for implementation. A summary of the MCA is provided in **Appendix G**.

It is noted that both structural and non-structural measures have been considered separately. Generally, it is difficult to directly compare these types of measures. Furthermore, funding sources and implementation timeframes for the two different types of measures are typically different. Therefore, they have been considered separately and ranked as such.

Table 13-2 Criteria Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Metric	Score -4	-3	-2	-1	0	1	2	3	4
Economic	49.6%	Benefit Cost Ratio	84%	BCR	0 to 0.25	0.25 to 0.5	0.5 to 0.75	0.75 to 0.9	0.9 to 1.1	1.1 to 1.25	1.25 to 1.5	1.5 to 1.75	>1.75
		Reduction in Risk to Property[1]	73%	Change in Annual Average Damage (AAD)	>+$1 million	+$500,000 to +$750,000	+$250,000 to +$500,000	$0 to +$250,000	0	-$250,000 to $0	-$500,000 to -$250,000	-$750,000 to -$500,000	< -$1 million
		Essential Infrastructure	73%	For flood affected rail and road areas. Metric = Total area of flood reduction x average water level reduction in this area for the 100 year ARI (ha.m)	Increase road and rail flooding of 0.75 - 1.00	Increase road and rail flooding of 0.50 - 0.75	Increase road and rail flooding of 0.20 - 0.50	Increase road and rail flooding of 0 - 0.25	No Change	Decrease road and rail flooding of 0 - 0.25	Decrease road and rail flooding of 0.25 - 0.50	Decrease road and rail flooding of 0.50 - 0.75	Decrease road and rail flooding of 0.75 – 1.00
		Future Development	63%	For flood affected future development areas. Metric = Total area of flood reduction x average water level reduction in this area for the 100 year ARI (ha.m)	Decrease in future development potential of 1.5 - 2	Decrease in future development potential of 1 – 1.5	Decrease in future development potential of 0.5 - 1	Decrease in future development potential of 0 – 0.5	No Change	Increase in future development potential 0 – 0.5	Increase in future development potential 0.5 - 1	Increase in future development potential 1 – 1.5	Increase in future development potential 1.5 - 2
		Capital Cost	59%	Capital cost of measure	>$10 million	$6 million – $10 million	$4 million – $6 million	$2 million – $4 million	$1 million – $2 million	$500,000 – $1 million	$100,000 – $500,000	$50,000 – $100,000	$0 – $50,000
		Operating Costs	56%	Operating cost of measure	>$100,000 per year	$75000 – $100,000 per year	$50,000 – $75,000 per year	$25,000 – $50,000 per year	$20,000 – $25,000 per year	$15,000 – $20,000 per year	$15,000 – $10,000 per year	$5,000 – $10,000 per year	$0 – $5,000 per year
		Constructability	54%	Difficulty in construction / implementation of measure. Including difficulties in construction, number of constraints, engineering challenges and uncertainties	Very low constructability with major constraints, challenges and uncertainties which may render the measure unfeasible	Very low constructability with some significant constraint, challenges and uncertainties which may increase costs or timeframes significantly	Low constructability with some significant constraints and challenges which may increase costs or timeframes significantly	Low constructability with some significant constraints and challenges which may increase costs or timeframes slightly	NA	Medium constructability with some likely constraints during construction and inception (but able to be overcome)	Medium constructability with some likely constraints at inception (but able to be overcome)	Very easy to construct / implement with only minor likely constraints	Very easy to construct / implement with no known constraints
		Implementation Timeframe	48%	Construction timeframe and impacts on transport and surrounding services	Long-term construction timeframe (>1 year) with significant impacts on transport and surrounding services during construction	Long-term construction timeframe (>1 year) with minor impacts on transport and surrounding services during construction	Medium-term construction timeframe (6 months – 1 year) with significant impacts on transport and surrounding services during construction	Medium-term construction timeframe (6 months – 1 year) with minor impacts on transport and surrounding services during construction	Medium to long-term construction timeframe (>6 months) with minimal impacts on traffic and surrounding services	Short-term construction timeframe (<6 months) with minimal impacts on services and traffic on major roads.	Short-term construction timeframe (<6 months) with minimal impacts on services and traffic on minor roads.	Short-term construction timeframe (<6 months) with no impacts on traffic and surrounding services	Planning related measure
Social	30.7%	Reduction in Risk to Life	95%	FM Measures: Change in 100 year ARI high hazard area Other Measures: Subjective impacts	>9% increase in 100 Year ARI High Hazard extent OR Likely localised increase in risk to life	6-10% increase in 100 Year ARI High Hazard extent OR Likely localised increase in risk to life	3-6% increase in 100 Year ARI High Hazard extent OR Possible widespread increase in risk to life	1-3% increase in 100 Year ARI High Hazard extent OR Possible localised increase in risk to life	No change to 100 Year ARI Hazard OR No change in risk to life	1-3% decrease in 100 Year ARI High Hazard extent OR Possible localised decrease in risk to life	3-6% decrease in 100 Year ARI High Hazard extent OR Possible widespread decrease in risk to life	6-10% decrease in 100 Year ARI High Hazard extent OR Likely localised decrease in risk to life	>9% decrease in 100 Year ARI High Hazard extent OR Likely widespread decrease in risk to life
		Reduction in Social Disruption	66%	Changes in social disruption	Major, widespread increase in social disruption	Slight, widespread increase in social disruption	Major, localised increase in social disruption	Slight, localised increase in social disruption	No change to social disruption	Slight, localised decrease in social disruption	Major, localised decrease in social disruption	Slight, widespread decrease in social disruption	Major, widespread decrease in social disruption
		Compatibility with Council Policies & Plans	62%	Level of compatibility	Very Strong disagreement	Strong disagreement	Moderate Disagreement	Minor Disagreement	Neutral/No response	Minor Support	Moderate Support	Strong support	Very Strong support

Category	Category Weighting	Criteria	Criteria Weighting	Metric	Score -4	-3	-2	-1	0	1	2	3	4
		Community & Stakeholder Support	55%	Level of agreement	Majority strong disagreement, no positive responses	Majority strong disagreement, isolated positive responses	Majority disagreement, no positive responses	Majority disagreement, isolated positive responses	Neutral or limited responses provided	Majority support, isolated negative responses	Majority support, no negative responses	Majority very strong support, isolated negative responses	Majority very strong support, no negative responses
		Urban Design[2]	51%	Urban design considerations	Major conflicts with catchment wide urban design considerations already in place or planned for the catchment	Minor conflicts with catchment wide urban design considerations already in place or planned for the catchment	Major conflicts with localised urban design considerations already in place or planned for the catchment	Minor conflicts with localised urban design considerations already in place or planned for the catchment	No urban design considerations incorporated	Some urban design considerations could be incorporated in measure	Some urban design considerations have been incorporated in measure	Significant urban design considerations could be incorporated in measure	Significant urban design considerations have been incorporated in measure
		Governance	47%	Level of support by government agencies and Council	Majority strong disagreement, no positive responses	Majority strong disagreement, isolated positive responses	Majority disagreement, no positive responses	Majority disagreement, isolated positive responses	Neutral or limited responses provided	Majority support, isolated negative responses	Majority support, no negative responses	Majority very strong support, isolated negative responses	Majority very strong support, no negative responses
Environment	27.5%	Compatibility with Water Quality Objectives[3]	62%	Compatibility with objectives	Very Strong disagreement	Strong disagreement	Moderate Disagreement	Minor Disagreement	Neutral/No response	Minor Support	Moderate Support	Strong support	Very Strong support
		Groundwater	59%	Impact on groundwater	Very high potential to negatively impact groundwater quality and/or flow	High potential to negatively impact groundwater quality and/or flow	Moderate potential to negatively impact groundwater quality and/or flow	Slight potential to negatively impact groundwater quality and/or flow	No impact	Slight potential to positively impact groundwater quality and/or flow	Moderate potential to positively impact groundwater quality and/or flow	High potential to positively impact groundwater quality and/or flow	Very high potential to positively impact groundwater quality and/or flow
		Heritage	55%	Impacts to heritage items, including consideration of heritage items as identified in Appendix C.	Destruction of State or National heritage Item	Likely impact on State or National heritage Item	Likely impact on local heritage item[5]	Possible impact on local heritage item[5]	No impact	Possible minor benefit	Likely minor benefit	Possible considerable benefit	Likely considerable benefit
		Compatibility with Alternative Water Schemes[4]	55%	Compatibility with alternative water schemes	Very Strong disagreement	Strong disagreement	Moderate Disagreement	Minor Disagreement	Neutral/No response	Minor Support	Moderate Support	Strong support	Very Strong support
		Fauna/Flora Impact - Including Street Trees	54%	Impacts to flora/ fauna	Likely impacts on threatened species	Likely broad-scale vegetation / habitat impacts	Likely isolated vegetation / habitat impacts	Possible isolated vegetation / habitat impacts	No impact	Possible isolated vegetation / habitat benefits	Likely isolated vegetation / habitat benefits	Likely broad-scale vegetation / habitat benefits	Broad-scale vegetation / habitat benefits and benefits for threatened species
		Contaminated Land & Acid Sulfate Soils	51%	Works within PASS or contaminated land.	Significant excavation within areas identified as PASS or Contaminated Land	Minor excavation within areas identified as PASS or Contaminated Land	Significant surface works within areas identified as PASS or Contaminated Land	Minor surface works within areas identified as PASS or Contaminated Land	No impact	NA[6]	NA[6]	NA[6]	NA[6]

[1] Values of likely AAD reduction assumed where calculations were not able to be undertaken.

[2] Urban design considerations include elements such as underground basins, open space and road upgrades.

[3] DCP 2012 Objectives (for sites greater than 1,000m^2):

a) reduce the baseline annual pollutant load for litter and vegetation larger than 5mm by 90%;

b) reduce the baseline annual pollutant load for total suspended solids by 85%;

c) reduce the baseline annual pollutant load for total phosphorous by 65%; and

d) reduce the baseline annual pollutant load for total nitrogen by 45%.

[4] Compatibility with Decentralised Water Master Plan 2012–2030.

[5] Local heritage items have not been specifically identified as part of this study. The Sydney Local Environment Plan (LEP) 2011 also lists 559 heritage items of significance that are found within or around the catchment under Schedule 5 of the LEP.

[6] For the purposes of this assessment the rehabilitation of ASS or Contaminated Sites has not been considered.