Commercial and industrial damage estimates are more uncertain and larger than residential damages. Commercial and industrial damage estimates can vary significantly depending on:

- Type of business – stock based or not;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself if closed but when access to it becomes available;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to moved and in other instances there may not be sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

Costs to business can occur for a range of reasons, some of which will affect some businesses more than others dependent on the magnitude of flooding and the type of business. Common flood costs to businesses are:

- Removal and storage of stock before a flood if warning is given (not applicable here);
- Loss of production – caused by damaged stock, assets and availability of staff;
- Loss of stock and/or assets;
- Reduced stock through reduced or no supplies;
- Trade loss – by customers not being able to access the business or through business closure;
- Cost of replacing damages or lost stock or assets; and
- Clean-up costs.

No specific guidance is available for assessing flood damages to non-residential properties. Therefore for this Study, commercial and industrial damages were calculated using the methodology for residential properties but with the costs/damages increased to a value which is consistent with commercial/industrial development. For example, the maximum value of internal (contents) damages was increased to $95,625 since the building contents are of higher value whilst loss of rent was set at $1,000 per week to account for the loss of business through having to close for a period. Flooding below floor level uses the same damages curve as the residential properties.

Though the original OEH guidelines for flood damages calculations are not applicable to non-residential properties, they can still be used to create comparable damage figures. The damages value figure should not be taken as an actual likely cost rather it is useful when comparing potential management options and for benefit-cost analysis.

A summary of the commercial/industrial flood damages for the Rushcutters Bay catchment is provided in Table 7. AAD for the surveyed commercial/industrial properties is less than that for residential properties but the number of flood affected properties for the latter is 2 to 3 times more than that of the former. This reflects the higher costs that businesses would incur compared to residential dwellings when flooded above floor level. On a per property basis the AAD is approximately 5.8 times higher when comparing the commercial/industrial properties

against the residential properties.

Table 7: Estimated Commercial and Industrial Flood Damages for Rushcutters Bay Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
PMF	62	43	$ 7,120,500	$ 114,800
0.2%	50	31	$ 4,977,400	$ 99,500
1.0%	45	25	$ 4,039,000	$ 89,800
2.0%	43	22	$ 3,548,400	$ 82,500
5.0%	41	19	$ 3,108,500	$ 75,800
10.0%	33	14	$ 2,333,600	$ 70,700
20.0%	28	12	$ 1,960,000	$ 70,000
50.0%	23	11	$ 1,745,300	$ 75,900
Average Annual Damages (AAD)			**$ 1,528,800**	**$ 24,700**

5.1.3. Climate Change

A damages assessment was carried out for a climate change scenario to estimate the potential increase in flood damages. This scenario entailed combining one of the rainfall increase scenarios (10% increase) with the 2050 sea level rise scenario (+0.4 m) and producing the range of design flood results under these conditions. It should be noted that large uncertainty exists in the estimation of climate change effects on extreme rainfall, and so the scenario is only an example of one possible climate change scenario. For this reason, it should be used as an indication of general sensitivity of the economic damages to changes in rainfall, and not an accurate estimate of what damages will be in the future. Table 8 lists the damages estimate.

Table 8: Estimated Combined Flood Damages Under Climate Change Scenario

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
PMF	201	131	$ 12,744,500	$ 63,400
0.2%	158	57	$ 6,828,200	$ 43,200
1.0%	149	52	$ 6,194,100	$ 41,600
2.0%	143	43	$ 5,238,400	$ 36,600
5.0%	137	41	$ 4,848,300	$ 35,400
10.0%	129	31	$ 3,862,300	$ 29,900
20.0%	126	27	$ 4,012,600	$ 31,800
50.0%	92	14	$ 2,141,100	$ 23,300
Average Annual Damages (AAD)			**$ 2,349,800**	**$ 11,700**

5.2. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss

to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. Within the Rushcutters catchment area, the high hazard areas include Boundary Street and trapped low points with high flood depths, i.e. at Sturt and Taylor Street. However, there will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

6. FLOOD EMERGENCY RESPONSE ARRANGEMENTS

6.1. Flood Emergency Response

The majority of flooding within the Rushcutters Bay catchment is characterised by overland flow, with no mainstream flooding and only a small area of minor tidal influence near the downstream end of the catchment. The critical duration is between 30 minutes and 2 hours across the catchment, with the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration "flash" flooding.

Due to the short interval between the start of the storm and the peak of the flood, there is little in the way of warning that can be provided. Any warning provided would be for immediate safety precautions such as temporary refuge (if available nearby or onsite), raising of items off the ground and accounting for people on site.

The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties. In these situations, evacuation is generally not recommended as the response during a flood event as it is likely to be hurried and uncoordinated, which can expose evacuees to a hazardous situation. As such, the preferred response to flooding in flash flooding catchments is for people to remain within the property, preferably within the upper levels if available. The suitability of the shelter-in-place approach should be considered in consultation with the State Emergency Service (SES) for the preparation of a Local Flood Plan. Assessment of evacuation and emergency response arrangements is given in Sections 9.4.2 and 9.4.4.

It is important that residents are aware of signs that will signal an approaching flood, and are aware of the correct response such that the small time period before the flood arrives may be used as effectively as possible to move people and belongings to a close, safe location.

The nature of the flood problem in the study area does not lend itself to a managed flood response. The issues undermining a planned response are as follows:

- Lack of effective warning time;
- Flood issue is distributed rather than aggregated;
- Difficulty with vehicle movement during an event; and finally
- The flash nature of the flooding. Note that where rainfall exceeds 5 year ARI intensity generally speaking vehicle movement will be limited by visibility.

As such, and given the lack of a specific response plan at this time, it is reasonable to suggest that SES response will be ad hoc and demand based. Arguably then the most critical element of SES response will be flexibility.

The largest impediment to operational flexibility is likely to be vehicle movement. As such in looking at improving flood risk via enhanced flood emergency response the study has focussed on the roads that may be cut in the event of flooding.

Given the relatively low risk nature of most property flooding it is reasonable to assume that flooded roads will be one of the highest risk areas during flooding. As such road locations subject to inundation must be a priority for management.

6.2. Flood Emergency Responses Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for managing flooding in the Rushcutters Bay catchment are discussed as follows.

6.2.1. DISPLAN

The Rushcutters Bay catchment is located within the Sydney East Emergency Management District. Flood emergency management for the study area is organised under the NSW Disaster Plan (2010) (DISPLAN). No district DISPLAN has been prepared for this district.

The DISPLAN details emergency preparedness, response and recovery arrangement for NSW to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies.

The DISPLAN has been prepared to coordinate the emergency management measures necessary at State level when an emergency occurs, and to provide direction at District and Local level.

The plan is consistent with district plans prepared for areas across NSW and covers the following aspects at a state level:

- Roles and strategies for prevention of disasters;
- Planning and preparation measures;
- Control, coordination and communication arrangements;
- Roles and responsibilities of agencies and officers;
- Conduct of response operations; and
- Co-ordination of immediate recovery measures.

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 outline 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 East Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the East Metro EM District;
- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies;
- Detail the responsibilities of the District and 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; and
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

6.2.2. Local Flood Plan

A local flood plan has not been prepared for the local area containing the Rushcutters Bay catchment. As such, the New South Wales State Flood Sub-plan (2008) is used to set out the arrangements for the emergency management of flooding.

The State Flood Sub-plan is a sub-plan to the state DISPLAN. The Sub-plan sets out the emergency management aspects of prevention, preparation, response and initial recovery arrangements for flooding and the responsibilities of agencies and organisations with regards to these functions.

There is a requirement for the development and maintenance of a Flood Sub-plan for:

- The State of New South Wales;
- Each SES Region; and
- Each council area with a significant flood problem. In some cases the flood problems of more than one council area may be addressed in a single plan or the problems of a single council area may be addressed in more than one.

Annex B of the Sub-plan lists the Local Flood Sub Plans that exist or are to be prepared in New South Wales and indicates which river, creek and/or lake systems are to be covered in each plan.

The City of Sydney is not listed in Annex B. However, it may be useful for the City of Sydney to prepare a Local Flood Plan in conjunction with the SES to outline the following details:

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

6.2.3. Emergency Service Operators

The emergency response to any flooding of the Rushcutters Bay catchment will be coordinated by the lead combat agency, the SES, from their Local Command Centre located at Erskineville. However, the City of Sydney Security and Emergency Management Centre located at Town Hall is on the notification list for SES flood warning alerts and direct liaison between the SES and the Security and Emergency Management Centre may be conducted via a dedicated radio frequency.

The Manager - Security and Emergency Management may then pass on the flood warnings to any affected Council or Community Building within the Rushcutters Bay catchment.

The Security and Emergency Management Centre will continue to receive regular updates from the SES throughout a flood event.

The relevant flood information from the draft Rushcutters Bay Flood Study (Reference 2) should be transferred to the Security and Emergency Management Centre.

6.2.4. Flood Warning Systems

The critical duration and response times for the catchment limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. However, for areas prone to flash flood within the catchment, the BoM provides general warning services, including:

- Severe Thunderstorm Warnings
- Severe Weather Warnings
- Flood Watches

These services are typically issued for a much larger region, or catchment, that includes the local flash flood site. This information can sometime be used at a local level as discussed below.

6.2.4.1. Flood Warnings Issued by BOM

The Rushcutters Bay catchment is affected by flash flooding (i.e. floods where the warning time is less than 6 hours). As such it is difficult to provide any flood warning in advance of floods. Where possible, the Bureau of Meteorology (BoM) will issue a severe weather / flood warning to the Regional SES headquarters in Bankstown. Where that alert is relevant to the Rushcutters Bay catchment, the SES Regional Command will pass the BoM's warning on to the Local Command based in Erskineville. In some cases, 2-3 days advanced notice may be available (e.g. where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

6.2.4.2. Activation of Local SES Command

SES staff are advised and placed on alert when the SES Local Command has been issued with a flood warning by the BoM. The BoM's flood warning is also forwarded by SMS to the relevant individuals and organisations, including the City of Sydney Security and Emergency Management Centre located at Town Hall.

It is noted that the SES is the designated lead combat agency in an emergency such as a flood event. However, local authorities may wish to act on the advice provided by the SES to minimize the level of risk in the lead up to the flood event. Depending on the amount of lead time provided, Council may undertake any relevant priority works, such as cleaning out storm water pits to reduce the risk of blockage. In addition, Council's Rangers are placed on standby and report any issue directly to the SES (e.g. cars parked in overland flow paths, etc.).

6.3. Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

6.3.1. Access Road Flooding

The catchment area has one arterial road (New South Head Road) and one main road (Oxford Street) that are flood affected, and a number of other roads where traffic will be impeded in a flood event. Both arterial roads connect the CBD to the eastern suburbs and convey a significant volume of vehicle traffic. As shown in Table 9, the depth of inundation on Oxford Street varies from 0.1 m in frequent events to 0.3 m in a 1% AEP event and 0.7 m in the PMF, while New South Head Road has around 0.6 m in frequent events, 0.9 m in a 1% AEP event and 1.5 m in the PMF. Table 9 also lists the depths for other roads in the catchment, while Figure 22 shows their locations.

Table 10 lists the rate of rise in metres per hour for the same locations listed in Table 9, for the 2 hour duration storm. It should be noted that the rate of rise will vary with other event durations,

and therefore the values presented are only to give a general approximation of rate of rise and how it varies in the catchment. Also, the four locations reach their peak depth within one hour of the event occurring, hence the rates of rise are greater than the peak flood depths. Rate of rise is higher for locations in the downstream half of the catchment, with Boundary Street and New South Head Road generally rising around 1 m/hour, for the 2 hour event.

Table 9: Major Road Peak Flood Depths (m) for Various Events

ID	Road Location	2 year ARI	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Oxford Street near Victoria Street	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.7
2	Victoria Street near Oxford Street	0.2	0.3	0.4	0.6	0.8	1.0	1.4	1.8
3	Boundary Street near Neild Avenue	0.5	0.6	0.6	0.7	0.7	0.7	0.8	1.2
4	Craigend Street/New South Head Road near McLachlan Avenue	0.6	0.7	0.7	0.8	0.8	0.9	1.1	1.5

Table 10: Major Road Flooding Rate of Rise (m/hour) for Various Events (2 hour duration event)

ID	Road Location	2 year ARI	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Oxford Street near Victoria Street	0.2	0.2	0.2	0.2	0.2	0.4	0.6	4.4
2	Victoria Street near Oxford Street	0.4	0.5	0.6	0.8	1.0	1.3	1.9	9.5
3	Boundary Street near Neild Avenue	1.0	1.1	1.2	1.2	1.3	1.3	1.4	9.0
4	Craigend Street/New South Head Road near McLachlan Avenue	0.8	1.0	1.0	1.1	1.2	1.3	1.4	7.4

For the 1% AEP flood event, roads cut (as per Figure 22) are shown in Table 11.

Table 11: Major Roads Cut in the 1% AEP Event

Road Location	Description
Oxford Street near Victoria Street	Flood depths are up to 0.3 m and persist for a period of 30 minutes to one hour given the critical storm modelled (2 hour)
Victoria Street near Oxford Street	Flood depths are up to 1.3 m and persist for a period of up to 2 hours given the critical storm modelled (2 hour)
Boundary Street near Neild Avenue	Flood depths are up to 0.7 m and persist for between 15 minutes and 2 hours, depending on the location along the street, for the 2 hour storm.
Craigend Street/New South Head Road near McLachlan Avenue	Flood depths are up to 0.9 m and persist for between 1 and 2 hours given the critical storm modelled (2 hour).

Following a review of this information revised SES plans might allot responsibility for management of these road closures. Note SES involvement is likely to be required given the presumable limited mobility of Council employees in the event of a severe flood event.

6.4. Flood Emergency Response Classifications

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has

upon them. These Emergency Response Planning (ERP) classifications (Reference 8) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Access Areas; Trapped Perimeter Areas or Indirectly Affected Areas and when used with the SES Requirements Guideline (Reference 8). The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 12).

Table 12: Emergency Response Planning Classifications of Communities

	Response Required		
Classification	**Resupply**	**Rescue/Medivac**	**Evacuation**
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Key considerations for flood emergency response planning in these areas include:

- Cutting of external access isolating an area;
- Key internal roads being cut;
- Transport infrastructure being shut down or unable to operate at maximum efficiency;
- Flooding of any key response infrastructure such as hospitals, evacuation centres, emergency services sites;
- Risk of flooding to key public utilities such as gas, power, sewerage; and
- The extent of the area flooded.

Flood liable areas within the study area have been classified according to the ERP classification above, with the additional criteria of flood depths being greater than 0.1 m. If only the flood extent was used in the Rushcutters catchment, areas surrounded by less than 0.1 m would be classified as flood islands, when in reality, people could move through this water without concern. Therefore, all flood depths of less than 0.1 m were removed from the PMF flood extents prior to classification. The ERP classifications for the study area are shown in Figure 7.

This figure shows that a large proportion of the study area has been classified as high flood island due to the reasonably high depths that would occur in road reserves surrounding properties, prior to inundation of the properties themselves. Adjacent to this are several rising road access areas which allow access out of the flood affected area.

7. POLICIES AND PLANNING

7.1. Legislative and Planning Context

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Under the Policy, the management of flood liable land remains the responsibility of local government. Furthermore, Section 117(2) of the 1979 Environmental Planning and Assessment Act Direction 15 states that Council must ensure development is appropriate in regard to flood risk and that furthermore it does not cause impacts on adjoining property.

Councils have a number of planning tools available to them in order to fulfil this role, including the Local Environment Plan (LEP) and Development Control Plans (DCPs). Detail of the specific planning documents relevant to Rushcutters Bay and Elizabeth Bay are provided below.

7.1.1. NSW Flood Prone Land Policy

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

The NSW Floodplain Development Manual (Reference 1) relates to the development of flood liable land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits based approach to floodplain management. At the strategic level this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk. The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required for each type of floodplain.

7.1.2. Existing Council Policy

With regards to flood risk management, Councils use Local Environment Plans (LEP) and Development Control Plans (DCP) to set policies and development controls. City of Sydney recently adopted the Sydney Local Environmental Plan 2012 and Sydney Development Control Plan 2012 and these are discussed in the following sections in relation to flood risk and management. Council has also prepared an Interim Floodplain Management Policy that will operate until Council completes floodplain risk management plans for its entire LGA and then

integrates these outcomes into planning controls.

Sydney LEP 2012

This planning instrument provides overall objectives, zones and core development standards, including provisions related to "flood planning" applicable to land at or below the flood planning level. Clause 7.15 of the Plan states the following objectives in relation to flood planning:

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

The Clause stipulates that consent will not be granted to development on land to which this Clause applies unless Council is satisfied that the development:

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

Under this Clause, the flood planning level is defined as the level of a 1% AEP flood event plus 0.5 metres freeboard.

Sydney DCP 2012

The purpose of this plan is to supplement the LEP and provide more detailed provisions to guide development. It came into effect on the same day as the LEP and must be read in conjunction with the LEP.

Prescriptive planning controls are provided in Section 3.7 of the document. The objectives of these planning controls are to:

- Ensure an integrated approach to water management across the City through the use of water sensitive urban design principles;
- Encourage sustainable water use practices;
- Assist in the management of stormwater to minimise flooding and reduce the effects of stormwater pollution on receiving waterways;
- Ensure that development manages and mitigates flood risk, and does not exacerbate the potential for flood damage or hazard to existing development and to the public domain; and

- Ensure that development above the flood planning level as defined in the Sydney LEP 2012 will minimise the impact of stormwater and flooding on other developments and the public domain both during and after the event.

Interim Floodplain Management Policy

This interim Policy (Reference 5) was adopted in May 2014 and provides direction with respect to how floodplains are managed within the LGA of the City of Sydney. This Policy has been prepared having regard to the provisions of the NSW Flood Policy and NSW Floodplain Development Manual (Reference 1) and is to be read in conjunction with the provisions of the LEP and DCP.

The Policy outlines Council's responsibilities for managing floodplains and it provides controls to facilitate a consistent, technically sound and best practice approach for the management of flood risk within the LGA. This interim policy will be withdrawn once Council complete Floodplain Risk Management Plans for the entire LGA and then integrate outcomes from these plans into planning controls.

The document provides general requirements for proposed development on flood prone land, Flood Planning Level requirements for different development types and guidelines on flood compatible materials. It makes the following requirements of new development on flood prone land in the area:

- It stipulates the information that is to be provided with a development application relevant to the various controls, for example building layouts and floor plans;
- It gives a criterion that must be satisfied in the case of a development not meeting the relevant Prescriptive Provisions in Sydney DCP 2012. These criteria include the development being compatible with established flood hazard of the land, not impacting flood behaviour so that other properties' affectation is worsened and incorporating appropriate measures to manage risk to life from flood;
- Concession is made to minor additions being made to existing properties, as these additions are acknowledged to not present an unmanageable risk to life. The concession can be given to dwelling additions of up to 40 m^2 and commercial industrial/commercial additions of up to 100 m^2 or 20% of Gross Floor Area. The concession is granted no more than once per development;
- It gives general requirements for development on flood prone land, including design requirements for fencing, minimum floor level, car parking, filling of flood prone land and the impact of climate change;
- It sets flood planning levels to be adhered to by various types of development. For example habitable rooms affected by mainstream flooding are to be at or above the 1% AEP flood level + 0.5 m. Other levels are given for properties affected by local drainage flooding (as per the Policy's definition), industrial/commercial development, car parks and critical facilities; and
- It specifies flood compatible materials for various components of a development, for example use of concrete slab-on-ground monolith construction or suspended reinforced concrete slab for flooring.

7.2. Planning Recommendations

Based on the review of the planning documents presented in the previous sections, the following recommendations have been made:

- There is 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. Also the requirements for a site specific flood study are provided in the Sydney DCP 2012. Though 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;
- Flood related development controls and requirements are provided in the Interim Floodplain Management Policy (Reference 5). 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. Council's current position on climate change requirements should also be informed in the DCP as outlined in the Policy;
- Consideration of emergency response provisions in new development with regards to short duration flooding in the catchment should also be included in the Interim Floodplain Management Policy (Reference 5); and
- 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. 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 Interim Floodplain Management Policy (Reference 5).

8. FLOOD PLANNING

8.1. Flood Planning Level (FPL)

The FPL is the height at which new building floor levels should be built. Due to the mixture of residential and commercial development in the Rushcutters Bay catchment, a variety of FPLs may be applicable depending on where in the catchment development is being considered and also based on the type of development being proposed.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. The Floodplain Development Manual (Reference 1) 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.

8.1.1. Likelihood of Flooding

As a guide, Table 13 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 13 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 (1% AEP) 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 1% AEP 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 (0.5% AEP) 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 13: Likelihood of given design events occurring in a period of 70 years

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

8.1.2. 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. The Sydney 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. Provisions to these issues, however, have been included in the Interim Floodplain Management Policy (Reference 5).

8.1.3. Freeboard Selection

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 flowpath 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 waves from vehicles);
    - Blockage of drainage network; 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) (+0.1 m);
- Local wave action (trucks and other vehicles) (allowance of +0.1 m is typical);
- Climate change impacts on rainfall (0.01 m to 0.21 m, mean 0.06 m, as per Rushcutters Bay Flood Study (2013))
- Climate change impacts on sea level rise (negligible impact, as per Rushcutters Bay Flood Study (2013)); and
- Sensitivity of the model +/-0.05 m.

Based on this analysis, the total sum of the likely variations is between 250 mm and 500 mm, depending on climate change, which has a varying effect across the catchment. Based on this range, the freeboard recommended in the Interim Floodplain Management Policy (Reference 5) is suitable for the catchment. The policy specifies a freeboard of 500 mm, except for in areas with local drainage flooding. In the policy, local drainage flooding refers to where there the 1% AEP depth is less than 0.25 m and the area is not in, or influenced by, a trapped low point. In these areas, the flood planning level is two times the depth of flow with a minimum of 0.3 m. Given the difference in flood depth between the 1% AEP and the PMF in the catchment, this freeboard is suitable for local drainage flooding.

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.

8.1.4. Current FPL as Adopted by Council

FPL requirements have been outlined by Council in their Interim Floodplain Management Policy (Reference 5). This policy was tested each time a development application was received. The policy provides further details regarding flood planning levels for various types of development within the floodplain and these are outlined in Table 14.

Table 14: Adopted Flood Planning Levels in CoS Interim Floodplain Management Policy (Reference 5)

Development		Type of flooding	Flood Planning Level
Residential	Habitable rooms	Mainstream flooding	1% AEP flood level + 0.5 m
		Local drainage flooding	1% AEP 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 1% AEP flood is less than 0.25 m
		Outside floodplain	0.3 m above surrounding ground
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Mainstream or local drainage flooding	1% AEP flood level

Industrial or Commercial	Business	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 1% AEP flood level
	Schools and child care facilities	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 1% AEP flood level + 0.5m
	Residential floors within tourist establishments	Mainstream or local drainage flooding	1% AEP floor level + 0.5 m
	Housing for older people or people with disabilities	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or a the PMF, whichever is the higher
	On-site sewer management (sewer mining)	Mainstream or local drainage flooding	1% AEP floor level
	Retail Floor Levels	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP flood. The proposal must demonstrate a reasonable balance between flood protection and urban design outcomes for street level activation.
Below-ground garage/ car park	Single property owner with not more than 2 car spaces.	Mainstream or local drainage flooding	1% AEP floor level + 0.5 m
	All other below-ground car parks	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or the PMF (whichever is the higher)
	Below-ground car park outside floodplain	Outside floodplain	0.3 m above the surrounding surface
Above ground car park	Car parks	Mainstream or local drainage flooding	1% AEP flood level
	Open car parks	Mainstream or local drainage	5% AEP flood level
Critical Facilities	Floor level	Mainstream or local drainage flooding	1% AEP flood level + 0.5m or the PMF (whichever is higher)
	Access to and from critical facility within development site	Mainstream or local drainage flooding	1% AEP flood level

In the policy, Council also provided clarity in the definition of local drainage flooding as opposed to mainstream flooding as follows:

1. Local drainage flooding occurs where:
   - The maximum cross sectional depth of flooding in the local overland flow path through and upstream of the site is less than 0.25 m for the 1% AEP flood; and
   - The development is at least 0.5 m above the 1% AEP flood level at the nearest downstream trapped low point; and

- The development does not adjoin the nearest upstream trapped low point; and
- Blockage of an upstream trapped low point is unlikely to increase the depth of flow past the property to greater than 0.25 m in the 1% AEP flood.

2. Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.
3. A property is considered to be outside the floodplain where it is above the mainstream and local drainage flood planning levels including freeboard.

The establishment of the flood planning levels in conjunction with the publication of the Interim Floodplain Management Policy is a positive step forward for Council in setting development controls for new developments within the Rushcutters Bay catchment. Nevertheless, it could be helpful to provide several case studies to illustrate how these levels could be applied to individual developments to assist in development applications.

9. FLOODPLAIN RISK MANAGEMENT MEASURES

9.1. General

The NSW Government's Floodplain Development Manual (2005) separates floodplain management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins and levees.

Property modification measures modify land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (zoning) or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the cost of the works. Generally, the ratio only expresses the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health, etc.).

The potential environmental or social impacts of any proposed flood mitigation measure are of great concern to society and these cannot be evaluated using the classic B/C approach. For this reason, a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. The public consultation program has ensured that identifiable social and environmental factors were considered in the decision making process of the Rushcutters Bay catchment.

A summary of the measures considered for the catchment and at the specific hotspot locations is provided in Table 15 and discussed in the following sections.

Table 15: Flood Affected Areas and Investigated Management Options

Hotspot	Flooding issues	Investigated Measures	Measures Reference
Boundary Street	Frequent inundation with moderate depth and velocity, flooding of major roads, many properties flooded above floor	Trunk Drainage Upgrade from Boundary Street to either New South Head Road or to Weigall Sportsground	FM-RB01, FM-RB02

Taylor Street	Frequent inundation with moderate depth and velocity, several properties flooded above floor.	Drainage Upgrade from Sims Street, Taylor Street, Sturt Street, South Dowling Street to either Oxford Street or to Weigall Sportsground	FM-RB03, FM-RB04
Victoria Street South	Localised inundation with moderate depth, flooding of major roads.	Drainage Upgrade – 170 m of 1.5 m diameter pipe	FM-RB05
Catchment-wide General flood risk, inundation of major roads		Variable Message Display on Major Roads	RM-RB01
		Evacuation Planning	RM-RB02
		Public Information and Raising Flood Awareness	RM-RB03
		Local Flood Plan and DISPLAN	RM-RB04
		Flood Planning Levels	PM-RB01
		Flood Proofing of Affected Properties	PM-RB02
		Voluntary Purchase	PM-RB03
		Development Control Planning	PM-RB04

9.2. Measures Not Considered Further

During the early phase of this study a review of all possible floodplain management measures and their application in the Rushcutters Bay catchment was undertaken. The measures not taken forward for further consideration, and the reasons for their exclusion, are summarised in the following sections.

9.2.1. Flood Modification - Dams and Retarding Basins

Flood mitigation dams and their smaller urban counterparts termed retarding basins have frequently been used in NSW to reduce peak flows downstream. However, dams are rarely used as a flood mitigation measure for existing development on account of the:

- high cost of construction,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low B/C ratio,
- lack of suitable sites as a considerable volume of water needs to be impounded by the dam in order to provide a significant reduction in flood level downstream.

This measure was not considered further for the above reasons.

9.2.2. Flood Modification - Levees, Flood Gates and Pumps

Levees are built to exclude previously inundated areas of the floodplain from the river up to a certain design events, and are commonly used on large river systems (e.g. Hunter and Macleay Rivers), but can also be found on small creek systems in urban areas.

Flood gates allow local waters to be drained from the leveed area when the external level is low, but when the river is elevated, the gates prevents floodwaters from entering.

Pumps are also generally associated with levee designs. They are installed to remove local floodwaters from behind levees when flood gates are closed or there are no flood gates.

These measures were not considered further due to the absence of a defined channel / riverway in the catchment area (except for the open channel at the outlet, which does not have associated flooding issues).

9.2.3. Response Modification – Catchment Wide Flood Warning

During a major flood it may be necessary for some residents to evacuate their homes. Whilst not all will have their house floors inundated, it is possible that their power, water and sewerage systems could be affected. The amount of evacuation time depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

The effectiveness of a flood warning systems depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators,
- the flood awareness of the community responding to a warning.

At a present there is no flood warning system in place for the Rushcutters Bay catchment area. This is a result of the heavily modified drainage network as well as the short time from the start of the rainfall to the flood peak (around 1 hour for the critical storm duration) which would not allow sufficient time for evacuation to occur prior to the flood event. This option was not considered further for these reasons, although site specific warnings are discussed further in Section 9.4.1.

9.2.4. Property modification - House raising

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. However, it has limited application as is not suitable for all building types. It is also more common in areas where there is a greater depth of inundation then that in the Rushcutters Bay catchment.

House raising is suitable for most non-brick, single storey buildings on piers and is particularly relevant to those houses situated in low hazard areas of the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor, and consequently reduces the flood damages.

Due to the nature of development and the heavily urbanised city catchment, it is considered highly unlikely that any of the flood affected buildings would be suitable for house raising. As such, this measure has not been considered further.

9.3. Site Specific Management Options

Site specific management options involve works aimed at managing the flood risk in a particular part of the catchment. Modifying the flood behaviour at a particular location involves either detaining runoff or improving the drainage capacity. The catchment has limited open space and therefore little opportunity for even a small retarding basin. Given this constraint, upgrading the drainage capacity has been focussed upon.

Measures to increase the capacity or efficiency of the existing piped drainage network include upgrading pipe capacity; re-profiling the pipe network; removing fixed blockages or impediments to flow and improved maintenance. This measure was assessed in detail for a number of flood affected areas within the catchment. An overview of the flood affected areas and proposed mitigation options are provided in Table 16 and shown in Figure 23. These options are discussed in detail in Sections 9.3.1 to 9.3.5.

Table 16: Flood Affected Areas and Proposed Mitigation Options

Suburb	Flood Affected Streets/Areas	Proposed Mitigation Options	Ref
Darlinghurst	Boundary Street and McLachlan Avenue property inundation	Boundary Street trunk drainage upgrade from before the intersection of McLachlan Avenue, down Neild Avenue	FM - RB01
Darlinghurst	Boundary Street and McLachlan Avenue property inundation	Boundary Street trunk drainage upgrade from before the intersection of McLachlan Avenue, down part of Neild Avenue, outlet into Weigall Sportsground	FM - RB02
Darlinghurst	Taylor, Sturt and Sims Street trapped low points	Trunk drainage upgrade on Sims, Taylor, Sturt Streets, up to Oxford Street	FM - RB03
Darlinghurst	Taylor, Sturt and Sims Street trapped low points	Trunk drainage upgrade on Sims, Taylor, Sturt Streets, down Boundary Street up to Weigall Sportsground	FM - RB04
Darlinghurst	Victoria Street near Oxford Street trapped low point outside St Vincent's Hospital	Pipe and drainage upgrades along Victoria Street	FM - RB05

9.3.1. Trunk Drainage Upgrade – Boundary Street (FM - RB01)

Option Description

Option FM – RB01 describes a trunk drainage upgrade along Boundary Street and Neild Avenue with the goal of mitigating property and road inundation in the 10% AEP event. The 10% AEP event is used as this ties in with City of Sydney's goal to reduce flood hazard on major roads for the 10% AEP event.

The proposed works are extensive and include the following elements:

- Upgrade of the pit and feeder pipe capacity to ensure that the upgraded trunk elements are full in the 10% AEP event;
- A new, additional trunk drainage pipe on Boundary Street ranging from 1.2 m diameter to a 1.5 m x 0.6 m box culvert
- Upgrade of the Neild Avenue pipe with one 1.5 m x 0.6 m box culvert until Craigend Street, and then a 1.8 m x 1.2 m box culvert up to the open channel.
- Higher capacity feeder pipes on McLachlan Avenue in order to increase conveyance to the trunk drainage on that road.

These drainage elements are in addition to what currently exists in the location, which would remain in place and is shown on Figure 24. Figure 25 shows the new drainage elements.

Modelled Impacts

The proposed works achieve a significant reduction in flood level and hazard along the area of upgrade. The impact of the proposed works on the 10% AEP flood level and over floor flood liability is shown on Figure 25, while Figure 26 shows the change in hazard in the same event. The reduction in flood level is around 0.3 m on Boundary Street and McLachlan Avenue, and 0.02 m on Neild Avenue. The band of high hazard along the flowpath has been reduced to low hazard in a 10% AEP event, except for parts of the kerb/gutter on McLachlan Avenue which would remain high hazard. The upgrade produces significant relief of overfloor flooding, with eleven properties no longer flooded in the 50% AEP event, and eight properties in the 10% AEP, as shown on Figure 25. The option does not produce any adverse impacts downstream of the upgrade.

Evaluation

The proposed upgrade produces significant benefit for the affected streets, relieving the area of high hazard flooding; however, it requires large-scale pit and pipe upgrades. At present, there is significant relief on either side of the flowpath, with grades of up to 10%, that concentrates runoff onto Boundary Street and McLachlan Avenue, causing high hazard flow on the road and footpaths. The upgraded trunk system would convey this flow and mitigate the existing overland flowpath. The upgrade is in the downstream half of the catchment and does not increase flood levels downstream. The new drainage has a cross-sectional area of up to 2.2 m^2, which would require significant capital outlay and may be technically difficult to design. The option has both large-scale benefits and costs, which are further evaluated in Section 9.3.6.

9.3.2. Trunk Drainage Upgrade – Boundary Street to Weigall Sportsground (FM - RB02)

Option Description

Option FM – RB02 describes a trunk drainage upgrade along Boundary Street with the goal of mitigating property and road inundation in the 10% AEP event. It is largely similar to FM – RB01, with an outlet of the new trunk system into Weigall Sportsground, instead of along Neild Avenue. Having an outlet onto the sportsground removes the need to upgrade the trunk drainage along Neild Avenue, which is a large portion of the previous option's cost. As with FM – RB01, the

10% AEP event is used as this ties in with City of Sydney's goal to reduce flood hazard on major roads for the 10% AEP event.

The proposed works are extensive and include the following elements:

- Upgrade of the pit and feeder pipe capacity to ensure that the upgraded trunk elements are full in the 10% AEP event;
- A new, additional trunk drainage pipe on Boundary Street ranging from 1.2 m diameter to a 1.8 m x 1.5 m box culvert, which has an outlet in Weigall Sportsground.
- Higher capacity feeder pipes on McLachlan Avenue in order to increase conveyance to the trunk drainage on that road.

These drainage elements are in addition to what currently exists in the location, which would remain in place and is shown on Figure 24. Figure 27 shows the new drainage elements.

Modelled Impacts

The proposed works achieve a significant reduction in flood level and hazard along the area of upgrade, having largely the same effect as FM-RB01. The impact of the proposed works on the 10% AEP flood level and over floor flood liability is shown on Figure 27, while Figure 28 shows the change in hazard in the same event. As with FM-RB01, the reduction in flood level is around 0.3 m on Boundary Street and McLachlan Avenue, and 0.02 m on Neild Avenue. The band of high hazard along the flowpath has been reduced to low hazard in a 10% AEP event, except for parts of the kerb/gutter on McLachlan Avenue which would remain high hazard. The upgrade produces significant relief of overfloor flooding, with eleven properties no longer flooded in the 50% AEP event, and nine properties in the 10% AEP, as shown on Figure 27. Downstream impacts occur in Weigall Sportsground, with an area of approximately 1 hectare having an increase of around 0.01 m in the 10% AEP event. This is considered manageable, given that the area already has around 0.1 m depth, but will require further consultation with Sydney Grammar School.

Evaluation

The proposed upgrade produces significant benefit for the affected streets, relieving the area of high hazard flooding; however, it requires large-scale pit and pipe upgrades. As described for FM-RB01, the area becomes a hazardous flowpath in a flood event, and this can be mitigated by upgraded drainage. In relation to FM-RB01, it achieves a slightly better reduction in flood level, and requires fewer new drains to be constructed. These advantages are slightly offset by the adverse impact it causes in Weigall Sportsground. The upgraded drainage has a cross-sectional area of up to 2.7 m^2, which would require significant capital outlay and may be technically difficult to design. The option has both large-scale benefits and costs, which are further evaluated in Section 9.3.6.

9.3.3. Trunk Drainage Upgrade – Taylor, Sims and Sturt Street (FM – RB03)

Option Description

Option FM – RB03 describes a trunk drainage upgrade of the system in Taylor Street, Sims Street and Sturt Street, aimed at relieving the trapped depressions in the area. The option consists of upgraded pipes on each of the streets, which combine to drain towards Barcom

Avenue and Boundary Street. The proposed works are extensive and include the following elements:

- Upgrade of pit and feeder pipe capacity to ensure that the upgraded trunk elements are at capacity in the 5% AEP event;
- New, additional drainage pipes of 0.9 m diameter along Sims Street and Taylor Street;
- A new, additional drainage pipe of 1.2 m diameter on part of Sturt Street;
- A new, additional drainage pipe of 0.6 m diameter on South Dowling Street; and
- New, additional drainage elements crossing Oxford Street, consisting of one 1.2 m diameter pipe and one 1.8 m x 1.2 m box culvert.

These drainage elements are in addition to what currently exists in the location, which would remain in place and is shown on Figure 29. Figure 30 shows the new drainage elements.

Modelled Impacts

The upgrade achieves a significant reduction in the peak flood level at each of the depressions in the hotspot; however, it also has a wide-scale adverse impact downstream of Oxford Street. Figure 30 shows the location of the upgrade and its impact on the 5% AEP peak flood level, while Figure 31 shows the change in hazard in the same event. The reduction in peak flood level is up to 1.5 m on Sturt Street, 0.4 m on Taylor Street and 0.7 m on Sims Street. The area of shallow inundation on Oxford Street is no longer flooded. The low section of Sturt Street is no longer high hazard in a 5% AEP event, and the small areas of high hazard on Taylor Street and Sims Street have been removed. The upgrade also alleviates the property flooding issue, with 15 properties no longer flooded overfloor in a 5% AEP event. The adverse downstream impact consists of a 0.04 m increase in peak flood level for most of the length of Boundary Street.

Evaluation

The upgrade greatly assists the existing flood issue in the area; however, it also produces adverse downstream impact and would require large-scale pipe upgrades. The benefit to the area is comprised of the reduction in high hazard ponding on the three low points on Sturt Street, Taylor Street and Sims Street respectively, and the benefit to the property flooding issue in the area – both via the reduced peak flood level. However, relieving the current flood storage in the area directs flow downstream, resulting in a wide-scale downstream impact. Under the floodplain management program, mitigation works must not adversely impact flooding in a developed area, and any upgrade will therefore require additional mitigation works to manage the downstream impact. Furthermore, the upgrade requires drainage of up to 2.4 m^2, which would require significant capital outlay and may be technically difficult to design.

9.3.4. Trunk Drainage Upgrade – Taylor Street to Boundary Street (FM - RB04)

Option Description

Option FM-RB04 describes a trunk drainage upgrade from the Taylor Street hotspot, along Boundary Street, up to a new outlet at Weigall Sportsground. It combines the upgraded sections from FM-RB02 and FM-RB03 as well as slightly upgrading the section in between those two options on Boundary Street. Both the 5% AEP and 10% AEP design events were used for the option as follows:

- For the Taylor Street area (i.e. drainage upgraded in FM-RB03), the drainage was sized to convey a 5% AEP event,
- For the lower Boundary Street area (i.e. drainage upgraded in FM-RB02), the drainage was sized to convey a 10% AEP event,
- For the section on Boundary Street in between the two areas, the drainage was sized so that the additional discharge from the Taylor Street area had no adverse impact in the 5% AEP event.

The option was assessed as it was found that more localised stormwater upgrades for the Taylor Street area produced an adverse impact downstream (see Section 9.3.3), and so were not viable without increased drainage capacity along Boundary Street.

The proposed works are extensive and include the following elements:

- Upgrade of pit and feeder pipe capacity to ensure that the upgraded trunk elements are at capacity in the 5% AEP event at the Taylor Street hotspot and 10% AEP at the Boundary Street hotspot;
- New, additional drainage pipes of 0.9 m diameter along Sims Street and Taylor Street;
- A new, additional drainage pipe of 1.2 m diameter on part of Sturt Street;
- A new, additional drainage pipe of 0.6 m diameter on South Dowling Street; and
- New, additional drainage elements crossing Oxford Street, consisting of one 1.2 m diameter pipe and one 1.8 m x 1.2 m box culvert.
- A new, additional drainage pipe of 1.5 m diameter along Boundary Street up until the intersection of Liverpool Road
- New, additional drainage elements along the lower section of Boundary Street, ranging from 1.2 m diameter to 1.8 m x 1.5 m area, and having an outlet into Weigall Sportsground.

These drainage elements are in addition to what currently exists in the location, which would remain in place and is shown on Figure 24 and Figure 29. Figure 32 shows the new drainage elements.

Modelled Impacts

The upgrade achieves a significant reduction in the peak flood level in both the Taylor Street and Boundary Street hotspots, while having minimal effect on the upper section of Boundary Street. Figure 32 shows the location of the upgrade and its impact on the 10% AEP peak flood level, while Figure 33 shows the change in hazard in the same event. Table 17 lists the impact at several locations in the two design events used. As can be seen, the impacts in the two design events are largely similar, with the largest reduction in the Taylor Street area where several depressions are relieved.

Table 17: Reduction in Peak Flood Level under FM-RB04

Location	10% AEP reduction	5% AEP reduction
Taylor Street	0.3 m	0.4 m
Sims Street	0.6 m	0.7 m
Sturt Street	1.5 m	1.6 m
Boundary Street near Liverpool Street	0 m	0 m
Boundary Street near McLachlan Avenue	0.2 m	0.2 m
McLachlan Avenue	0.2 m	0.2 m
Neild Avenue	0.02 m	0.02 m

The reduction in peak flood level also corresponds to reduced areas of high hazard. The Boundary Street hotspot has the majority of its high hazard removed in the 10% AEP event, while the small areas of existing high hazard on Taylor Street and Sims Street have been removed. The upgrade also alleviates the property flooding issue, with 21 properties no longer flooded overfloor in a 5% AEP event.

Evaluation

The upgrade alleviates the majority of the area's flood risk; however, it requires large-scale pipe upgrades in several areas. The benefit to the area is virtually a combination of the benefit provided by FM-RB02 and FM-RB03; there is reduced flooding in the Taylor Street area which reduces overfloor inundation and high hazard ponding, and the overland flow on Boundary Street becomes largely contained by the trunk system, which reduces property inundation and high hazard flows in that area. These benefits are the most widespread of the structural options assessed; however, this option also requires the largest stormwater drainage upgrades. The new drainage elements have a combined length of 1700 m, compared to between 500 and 750 m for the previous three options. As with the other options, the new drainage elements are generally large, with a cross-sectional area of up to 2.7 m^2. This would require significant capital outlay and may be technically difficult to design. The option has both large-scale benefits and costs, which are further evaluated in Section 9.3.6.

9.3.5. Trunk Drainage Upgrade – Victoria Street South (FM - RB05)

Option Description

Option FM – RB05 describes a trunk drainage upgrade connecting the trunk drainage at the southern end of Victoria Street to the branch further north on Victoria Street (see Figure 35). The proposed pipe upgrade includes approximately 120 m of new pipe and 30 m of upgraded existing pipe. The proposed works include the following elements:

- Upgrade of the pit and feeder pipe capacity to ensure that the upgraded trunk elements are at capacity in the 5% AEP event;
- Upgrade of 30 m of pipe on Victoria Street to one 1.5 m diameter pipe; and
- Addition of 120 m of one 1.5 m diameter pipe on Victoria Street.

Modelled Impacts

The upgrade resolves the flooding issue on Victoria Street for events up to the 5% AEP event, while also producing a localised downstream impact on the same street. Figure 35 shows the location of the upgrade and its impact on the 5% AEP peak flood level, while Figure 36 shows the change in hazard in the same event. The impact is up to 0.5 m at the hotspot, which reduces

the flooding to either shallow ponding or no longer flooded. The depth of ponding that is currently high hazard in a 1% AEP event is reduced to low hazard. The impacts downstream, which are caused by conveying the runoff downstream, are up to a 100 mm in a localised area. The downstream impact does not extend as far as the entrance to the hospital's underground carpark.

Evaluation

The option largely resolves the flooding issue that currently exists in front of the hospital and the size of the upgrade is modest, relative to other measures assessed. At present, the ponding does not inundate the hospital in the 1% AEP event, and so the issue is largely with the ponding hindering access to the hospital. It should be noted that the ponding does not prevent access to the emergency section of the hospital, but rather is an entrance to the private hospital. When flooding does occur, the private hospital can still be accessed from other points on Victoria Street. If temporarily closing the affected entrance does not have a large impact on the hospital, it may be that a response measure, such as warning signage at the hotspot, is more feasible.

9.3.6. Economic Assessment of Site Specific Options

The cost effectiveness of the site specific management options in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. A costing was estimated for each option and this was compared, where appropriate, to the option's reduction in AAD. Where no significant benefit to AAD was found, the option's cost effectiveness was assessed qualitatively.

Costing

Detailed cost estimates have been prepared for each option and these are summarised in Table 18, with detailed costing in Appendix C. It is important to note that these are estimates and should be revised prior to the detailed design phase of the options to obtain a more accurate costing. For the first four options, the large capacity of the upgrade's pipes meant that the width of the upgrade was comparable to the width of the available area (i.e. roadway and footpaths). Such a large upgrade would incur additional costs due to the re-location of existing services, and this has been accounted for by a higher contingency multiplier in the costing estimates.

Table 18: Costings of Management Options

Option	Capital	Maintenance per year
FM-RB01 Boundary Street trunk drainage upgrade from before the intersection of McLachlan Avenue, down Neild Avenue	$ 7,515,000	$ 7,500
FM-RB02 Boundary Street trunk drainage upgrade from before the intersection of McLachlan Avenue, down part of Neild Avenue, outlet into Weigall Sportsground	$ 5,578,100	$ 5,300
FM-RB03 Trunk drainage upgrade on Sims, Taylor, Sturt Streets, up to Oxford Street	$ 5,711,800	$ 7,200
FM-RB04 Trunk drainage upgrade on Sims, Taylor, Sturt Streets, down Boundary Street up to Weigall Sportsground	$ 15,987,900	$ 17,100
FM-RB05 Pipe and drainage upgrades along Victoria Street	$ 1,178,200	$ 11,700

Table 18 shows that the drainage capacity upgrade Option FM – RB04 is the most costly, as it

involves the longest section of trunk drainage being upgraded, followed by the more localised upgrades, all of which require significantly large works. It should be noted that although FM-RB01 and FM-RB02 both entail upgrades on Boundary Street, FM-RB02 is around 25% cheaper due to the shorter section being upgraded (RB02 does not continue along Neild Avenue).

Damage Assessment of Options

The total damage costs were evaluated for four of the options and compared against the existing base case, as shown in Table 19. FM – RB05 has minimal effect on overfloor flooding and so has not been assessed. The assessment for the remaining four options was carried out in accordance with OEH guidelines utilising data obtained from the flood level survey and height-damage curves that relate the depth of water above the floor with tangible damages. The damages were evaluated for a range of design events from the 2 year ARI up to the PMF.

Table 19: Average Annual Damage Reduction of Management Options

Option	AAD	Reduction in AAD due to Option
FM-RB01 Boundary Street trunk drainage upgrade from before the intersection of McLachlan Avenue, down Neild Avenue	$1,155,800	$867,500
FM-RB02 Boundary Street trunk drainage upgrade from before the intersection of McLachlan Avenue, down part of Neild Avenue, outlet into Weigall Sportsground	$1,165,200	$858,100
FM-RB03 Trunk drainage upgrade on Sims, Taylor, Sturt Streets, up to Oxford Street	$1,799,100	$224,200
FM-RB04 Trunk drainage upgrade on Sims, Taylor, Sturt Streets, down Boundary Street up to Weigall Sportsground	$1,009,500	$1,013,800
FM-RB05 Pipe and drainage upgrades along Victoria Street	ND	ND

* ND – Not determined

The results show that the Boundary Street drainage upgrades have the greatest reduction in AAD, with the first two options achieving around $900,000 reduction in AAD, and the combined option (FM-RB04) giving just over $1 million reduction. The Taylor Street upgrade also produces a large reduction ($224,200), while FM-RB05 was not assessed as it has minimal effect on property inundation. Given that the AAD in the catchment under existing conditions is $2,123,800, the four options assessed all achieve a significant reduction in the cost of flooding.

Benefit Cost Ratio of Options

Following estimation of the option's cost and AAD, the benefit/cost ratio (B/C) of four of the options was calculated. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the cost of the works and is used to compare the economic worth of a set of works to others in the area. Table 20 lists the reduction in AAD due to the options, and compares this to the works' capital and maintenance costs to produce a B/C. The B/C of both options was between 0.7 and 2.2, with values above 1 indicating that the economic benefit of the option is greater than its cost. The damages estimation under the options is given in detail in Appendix D.

Table 20: Benefit/Cost Ratio for Management Options

Options	Benefit			Cost Estimate			
	AAD	Reduction in AAD	NPW of AAD Reduction*	Capital	Maintenance (Annual)	NPW of Costs*	B/C Ratio
FM- RB01	$1,155,800	$867,500	$ 12,809,390	$ 7,515,000	$ 7,500	$ 7,626,100	1.7
FM- RB02	$1,165,200	$858,100	$ 12,671,228	$ 5,578,100	$ 5,300	$ 5,656,900	2.2
FM- RB03	$1,799,100	$224,200	$ 3,310,779	$ 5,711,800	$ 7,200	$ 5,817,800	0.6
FM- RB04	$1,009,500	$1,013,800	$ 14,970,817	$ 15,987,900	$ 17,100	$ 16,239,900	0.9
FM- RB05	ND	ND	ND	$ 1,178,200	$ 11,700	1,351,100	ND

* NPW: Net present worth calculated over 50 years at 7%, ND – Not determined

The first two options presented in Table 20 have a B/C of greater than 1, indicating they are economically feasible. FM-RB01 has a B/C of 1.7, which reflects the large economic benefit the option has ($867,500 per year in today's dollars) relative to its total cost ($7.6 million). FM-RB02 has a similar benefit to the area but a cheaper construction cost, which gives it a higher B/C of 2.2. Such B/C values are not common in urban areas, where the flood risk is typically difficult to mitigate with structural works and the cost of such works is high. The B/C values demonstrate that the existing flood issue on Boundary Street has a large associated cost, and that the cost of works is comparable to the benefit they will achieve.

The analysis does not consider social factors, environmental factors and risk to life which cannot be quantified in monetary terms but would have been a net contributor to the benefits that could be gained from these management options.

9.3.7. Other Site Specific Management Options Considered

Each hotspot had a range of management options that were assessed to manage the flood risk in the area. Of these options, those that were determined to have the greatest benefit, or were the most technically or economically feasible, were assessed in detail. For the Rushcutters Bay catchment, these are the previously described options, FM – RB01 to FM – RB05. Other options were assessed in the hotspots that were discarded, and these are presented in Table 21. The table also lists why the option was not considered further. For example, re-instating a flowpath from Sims Street to Taylor Street relieved the issue on Sims Street but adversely impacted the peak depth at Taylor Street.

Table 21: Other Site Specific Management Options Considered

Hotspot	Option	Reason Discarded
Boundary Street	Establish a retarding basin at Weigall Sport ground (adjacent to Neild Avenue).	Basin would be downstream of flooding hotspots and therefore have limited benefit.
Boundary Street	Re-grade parts of trunk drain on Boundary Street.	Found to have negligible effect
Taylor Street	Remove house on Sims Street to relieve trapped depression via a new overland flowpath.	New flowpath has some benefit on Sims Street; however, has significant adverse impact on Taylor Street where flow is directed.
Victoria Street	Regrading Victoria Street near St Vincents Hospital.	Large-scale regrading would be required, not feasible given hospital location.
Victoria Street	Upgrade pipe system on Oxford Street to reduce inflow into Victoria Street.	Oxford Street drainage is already full in frequent events, would require very wide-scale upgrade, Victoria Street pipe more feasible.

9.4. Catchment Wide Management Options

9.4.1. Response Modification – Variable Message Display (RM-RB01)

DESCRIPTION

Although a catchment wide flood warning system has been excluded as described in Section 9.2.3, there may be an opportunity to develop localised warning and notifications to alert the community during a flood to areas that are flooded or will be in the near future. Variable message displays on main roads in the area would be able to warn drivers not to enter floodwaters. William Street and Craigend Street, which are at the downstream end of McLachlan Avenue, are the main affected roads in the area, as well as Oxford Street and Victoria Street outside St Vincent's Hospital. The displays would likely be operated by Roads and Maritime Services (RMS).

DISCUSSION

Variable Message Displays on major roads, such as William Street, would reduce the flood risk associated with vehicles entering floodwaters and becoming stranded. Oxford Street near Taylor Street has up to 0.4 m in the 10% AEP event and is therefore capable of disabling a vehicle that drives through the ponding. The nature of urban areas means vehicles or pedestrians may underestimate flood hazard, and unknowingly try to cross the floodwaters. For example, in October 2014, a small flood inundated part of Parramatta Road in Summer Hill, and people became stranded in their cars and required SES assistance. The written warnings would aim to avoid this scenario by communicating the risk to people in the area and suggesting an alternative route.

EVALUATION

The measure is inexpensive relative to other options and it has the ability to manage the risk associated with people and vehicles entering floodwaters. However, people do not always heed flood warnings. Consideration should also be given to possible diversion routes and how traffic in a flood can be managed.