ATTACHMENT F

RUSHCUTTERS BAY CATCHMENT FLOODPLAIN RISK MANAGEMENT STUDY (DRAFT REPORT)

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DRAFT REPORT

DECEMBER 2015

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Project Rushcutters Bay Catchment Floodplain Risk Management Study	**Project Number** 114014
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RUSHCUTTERS BAY CATCHMENT FLOODPLAIN RISK MANAGEMENT STUDY

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FOREWORD

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. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***Implementation of the Plan***
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Draft Rushcutters Bay Catchment Floodplain Risk Management Study and Draft Plan constitute the second and third stages of this management process. This study has been prepared by WMAwater for City of Sydney (Council) under the guidance of Council's floodplain management committee (Committee). This study provides the basis for the future management of those parts of the Rushcutters Bay catchment which are flood liable and within the City of Sydney Local Government Area.

1. INTRODUCTION

1.1. Study Area

The Rushcutters Bay catchment is located in the suburbs of Potts Point, Elizabeth Bay, Kings Cross, Darlinghurst, Paddington and Rushcutters Bay and is shown in Figure 1. The catchment lies within the City of Sydney Local Government Area (LGA) and has been extensively developed for urban usage. It covers an area of approximately 90 hectares and drains to Sydney Water Corporation's (SWC) trunk drainage line, which becomes an open channel near the outlet. Once the pipe drainage capacity has been exceeded, water flows overland along streets and other open space. A number of locations in the area are flood liable, mainly as a result of the area's topography, which includes several unrelieved depressions, as well as a major flow path down the LGA's western boundary. This creates a significant drainage/flooding problem in many areas in the catchment, a detailed description of the study area is provided in Section 2.1.

1.2. The Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 1), the floodplain risk management process is formed of sequential stages:

- Data Collection;
- Flood Study;
- Floodplain Risk Management Study;
- Draft Floodplain Risk Management Plan; and
- Plan Implementation.

The first key stage of the process has been undertaken with the completion of the Data Collection and Draft Rushcutters Bay Catchment Flood Study (Reference 2). Following this, the Draft Floodplain Risk Management Study and Plan (FRMS&P) are undertaken for the catchment in two phases:

Phase I – Draft Floodplain Risk Management Study in which the floodplain management issues confronting the study area are assessed, management options investigated and recommendations made. The objectives of this phase for the Rushcutters Bay catchment include:

- Review the current Draft Rushcutters Bay Catchment Flood Study (2013) and update the hydraulic model to accommodate recent changes in the catchment;
- Extend the hydraulic model to provide design flood information for the adjoining Elizabeth Bay catchment;
- Acquire any additional floor level survey required;
- Review Council's existing environmental planning policies and instruments, identify modifications required to current policies;

- Identify residential flood planning levels;
- Identify and assess works, measures and controls aimed at reducing the impacts and losses caused by flooding and consider their impacts if implemented, taking into account the potential impacts of climate change; and
- Review the local flood plan, examine the present flood warning system, community flood awareness and emergency response measures (involvement with the NSW State Emergency Service).
- Investigate flood mitigation options for flood affected streets and areas as identified in the revised Flood Study.

Phase II – Draft Floodplain Risk Management Plan which is developed from the Floodplain Risk Management Study and details how flood prone land within the study areas is to be managed moving forward. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with flood hazard now and in the future. The Plan consists of prioritised and costed measures for implementation.

1.3. Relevant Studies

A number of previous studies have been undertaken for the Rushcutters Bay catchment. Most of these are summarised in the Flood Study (Reference 2), however, the following sections provide a review of those which are key to this management study.

1.3.1. Rushcutters Bay SWC No. 84 Catchment Management Study

The Rushcutters Bay SWC No. 84 Catchment Management Study, 1991 (Reference 3) was undertaken as an overall investigation of stormwater drainage and water pollution issues in the catchment. The full length of the open channel and piped system controlled by Sydney Water, Woollahra and the City of Sydney Councils was examined.

A large part of the report covered water quality issues not relevant to this Floodplain Risk Management Study. However, the study also included a comprehensive questionnaire survey sent to 8,900 residents, the results of which have been reproduced in the Flood Study (Reference 2) as they are still relevant.

An ILSAX hydrological model and HEC-2 hydraulic model were developed, and based on the results a cost-benefit analysis was undertaken to assess measures to reduce flooding. The main recommendations from the report (relating to stormwater drainage) were to provide new pipe systems. The study found that many of the pipes in the catchment had a 1 in 1 year ARI capacity.

1.3.2. Rushcutters Bay Catchment Draft Flood Study

The draft Flood Study report (Reference 2) was prepared for City of Sydney by WMAwater in 2013, and examined flooding issues for the portion of the Rushcutters Bay catchment within the

City of Sydney LGA.

The study identified a number of trapped low points in the catchment. From this, four hotspots were identified where significant property inundation was likely to occur. The hotspots, all of which are in Darlinghurst, are shown on Figure 2 and are as follows:

1. Taylor Street
2. Boundary Street
3. Barcom Avenue
4. Victoria Street South

The study also considered the potential effects of climate change by modelling rainfall increases of 10%, 20% and 30% on the 1% AEP flood event, as well as two sea level rise scenarios, of 0.4 m and 0.9 m. It was found that each incremental 10% increase in flow generally resulted in 0.03 to 0.05 m increase in peak flood levels at most of the locations analysed. The sea level rise scenarios resulted in negligible impact on flood levels within the catchment, the largest impact being 0.05m at Waratah Street assuming a 0.9 m level increase by 2100.

The key outcomes of the Flood Study which are to be discussed, considered or managed in this Management Study and Plan are:

- The areas identified as being flooding hot spots;
- Establish the "true" hydraulic category and hazard definitions;
- Identify mitigation measures to address the adverse impacts of new developments; and
- Identify risk management measures to reduce flood costs to properties within the catchment by either structural or non-structural measures.

1.3.3. Rushcutters Bay Flood Study Review and Update

The draft Rushcutters Bay Flood Study (Reference 2) was reviewed as part of this Management Study, to incorporate any recent changes to the catchment which had occurred. Three minor updates were made. Firstly, the recently developed complex at 20 Neild Avenue was added to the model. This development regraded footpaths and a garden area within the area. The development has resulted in a reduction in a 1% AEP flood levels of up to 0.72 m on the path between Neild Avenue and McLachlan Avenue and an increase of up to 0.08 m on Neild Avenue. Outside the immediate vicinity of the development site there is minimal impact on the Neild Avenue and Weigall Sportsground.

Secondly, the inverts of several nodes along the trunk drainage line were re-estimated using updated interpolation techniques (no invert data was available). The amendment caused a localised reduction of 0.32 m in the 1% AEP event flood depth at Victoria Street outside St Vincent's Hospital.

Finally, two small changes to building outlines were made to ensure overland flow paths between buildings were more accurately modelled. The impacts of flood levels around the change were minimal.

1.3.4. Elizabeth Bay Flood Study Extension

A Flood Study has not previously been developed for the Elizabeth Bay catchment, and was included as part of the Flood Study review. The Rushcutters Bay model was extended to include the Elizabeth Bay area. Section 3.1 details the model build and results for Elizabeth Bay.

2. CATCHMENT CHARACTERISTICS

2.1. Study Area

The Rushcutters Bay catchment within the City of Sydney local government area (LGA) includes the suburbs of Potts Point, Elizabeth Bay, Kings Cross, Darlinghurst, Paddington and Rushcutters Bay. Land use is predominantly medium to high-density housing as well as commercial developments. The area includes a number of small parks, the largest of which is Rushcutters Bay Park at the catchment outlet.

The catchment encompasses an area of approximately 92 hectares. The catchment area drains into Sydney Harbour at Rushcutters Bay via the Sydney Water Corporation (SWC) open channel, which generally runs in a north-westerly direction between the Weigall and White City sports complexes. The channel floodplain is largely contained within a series of parks and open spaces. The SWC trunk drainage system is linked to Council's local drainage system consisting of covered channels, in-ground pipes, culverts and kerb inlet pits. The drainage system is shown on Figure 3.

The topography of the catchment is steep. The greatest relief occurs at the top of the catchment along Oxford Street (at elevations of 65 mAHD) which slopes north-east at grades of approximately 5% to 10%. The downstream end of the study area is also the flattest part of the catchment, comprising reclaimed lands within Rushcutters Bay Park, which has a relatively gentle ground gradient of 1%. The Elizabeth Bay catchment is reasonably steep with an overall gradient of approximately 10% with some cliff gradients as well.

A number of locations within the catchment are flood liable, driven by the topography and the drainage capacity. Urbanisation throughout the catchment occurred prior to the installation of road drainage systems in the 1900s and some buildings have been constructed on overland flow paths or in unrelieved sags. Due to these drainage restrictions, topographic depressions can cause localised flooding as excess flows have no opportunity to escape via overland flow paths. Aside from the unrelieved depressions, flow in the catchment accumulates along the western boundary of the LGA, which includes Boundary Street, McLachlan Avenue and Neild Avenue, causing a major high hazard overland flowpath in the roadway and flood liability for some of the lower-lying properties.

Any future development in the area is most likely to be in the form of urban consolidation, with aggregation of individual lots to create high density residential developments. An example of this is the recently completed apartment complexes at 20 Neild Avenue.

2.1.1. Land Use

The land use zones as identified in the Sydney LEP 2012 are shown in Figure 4. The land usage within the study area is predominantly urban residential development, comprising a mixture of pre-1900 terrace buildings (mostly south of William Street) and new high-rise apartment buildings, including several medium- and high-density developments (mostly north of William Street). The non-residential development in the catchment includes several schools, parks (including the Rushcutters Bay Park and Weigall Sportsgrounds), churches and community buildings including St Vincent's Hospital. There are no major industrial developments, and commercial developments are primarily concentrated in the upper catchment areas around Oxford Street and Kings Cross. There are some larger commercial sites such as car dealerships/workshops in the lower part of the catchment near Weigall Sportsgrounds.

The effect of urbanisation on the quantity (and quality) of runoff from the catchment was not previously assessed but has been deemed to have been significant as discussed in the Flood Study (Reference 2). As the catchment is already heavily urbanised any new developments are unlikely to produce further significant increases in peak flows.

2.1.2. Social Characteristics

Understanding the social characteristics of the area can help in ensuring that the floodplain risk management practices adopted are aligned with the communities at risk. For example, 'stable' communities (characterised by a high proportion of homeownership and low frequency of residents moving into or out-of the area) are more like to have a better understanding of the flood risks within the area.

Social characteristic data were obtained from the 2011 census (http://www.abs.gov.au/) for the study area. The census data shows that a significant number of households speak a language other than English at home (18-19%), for example French (2%) and Spanish (1.6%), which should be considered when organising flood awareness education or when issuing evacuation orders. The data also shows that a large number of people moved to the area within the 5-year period prior to the census at around 31% of the residents, and around 46 to 60% of residents are staying in a rented property. This suggests a high frequency of change of residents in the area, which may indicate a need for more frequently occurring flood awareness/community education programmes.

The catchment has a small dwelling size of only 1.59 people, and a high portion of single person dwellings (58.2% compared to the NSW average of 24.2%). This may need to be considered in any evacuation planning as it may indicate a higher than usual number of properties relative to population. There is also a small average number of motor vehicles per dwelling, with 46.7% of households having no motor vehicles (compared to a NSW average of 10.4%), which might need to be considered in any assumptions regarding evacuation routes (i.e. that they should be traversable by foot rather than vehicle as due to the small proportion of vehicle owners in the catchment).

Demographically, the catchment has approximately average portion of greater than 65 year olds (13.6% compared to 14.7% for NSW), but a lower than average portion of under 14 year olds (4.9% compared to 19.2% for the state), which suggests demographics shouldn't have a significant influence on the consideration of mitigation measures.

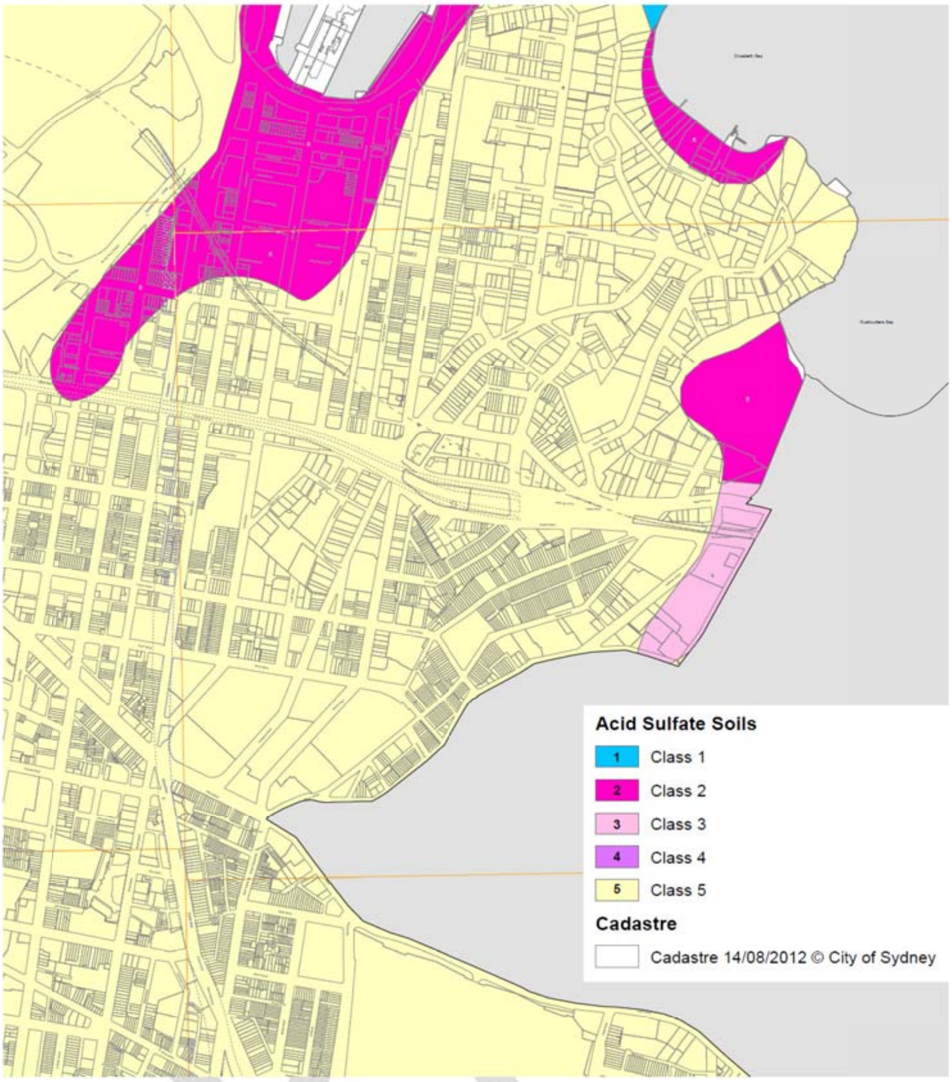
2.1.3. Environmental Features

Rushcutters Bay catchment is developed and urbanised and therefore has limited areas of natural environment, other than some parkland and urban forests. Furthermore, the drainage system has been highly modified and is now completely man-made.

City of Sydney aspires to protect and expand the LGA's urban forest. This includes a list of protected Significant Trees, of which a number of trees in Elizabeth Bay are listed, as well as some sporadically throughout the rest of the catchment. Mitigation measures assessed by this study will consider the value that is placed upon trees in the catchment when there is a potential impact.

Other environmental features of interest in the catchment are;

- The catchment is classified as a general conservation area with a number of conservation buildings identified. No aboriginal heritage sites have been identified in the catchment
- there are no Record of Notices of contaminated land in the catchment area
- The majority of the Rushcutters Bay catchment has an Acid Sulphate Soils classification of 5 (works within 500m adjacent of an area classified 1 -4 and likely to reduced groundwater levels by 1m or more are likely to present an environmental risk) besides a small area adjacent to the bay which is classed as 2 (any works undertaken in this area is likely to present an environmental risk). Maps of the Acid Sulphate Soils classification have been taken from the Sydney LEP (Reference 4) and are presented here.



Sheets ASS_021 and ASS_022 from Sydney LEP 2012

2.1.4. Historical Flood Events

Significant catchment development occurred in the latter part of the 19th century, alongside a major increase in the broader Sydney population between 1860 and 1890. The current catchment population is of the order of 15,000 (Reference 3). Early references clearly identify parts of the lower catchment as low lying and swampy. There was also mention of surface and stormwater problems (flooding and water quality).

The effect of urbanisation on the quantity (and quality) of runoff from the catchment has not been assessed but would have been significant. As the catchment is already heavily urbanised any new developments are unlikely to produce further significant increases in peak flows.

There have been many instances of flooding in the past with 8-9 November 1984, 6 January 1989 and 26 January 1991 being some of the more significant storm events causing extensive flooding throughout the catchment. Over a 20 minute duration, the 1989 event had an approximate ARI of 50 years, while the 1991 event was closer to a 40 year ARI.

2.1.5. Early Catchment Conditions

The drainage features of the catchment reflect the location of the natural watercourse and shoreline that existed prior to urbanisation of the area. That is, the catchment's main trunk drainage line is located along a natural topographic depression, which contained a creek in the 19th century. In the 19th and 20th centuries, the area was developed with increasing density, and this creek was filled in and replaced with subsurface drainage (except for the open channel near the outlet).

Figure 5 shows the area's creeks as they were recorded on 'Woolcott & Clarke's Map of the City of Sydney' (dated 1854), overlaid on the current 5% AEP peak flood depth. The figure shows that the main concentrations of flow are where creeks used to exist in the catchment, including at Taylor Street, Boundary Street and Neild Avenue. It should be noted that the misalignment of the creek with the current overland flowpath at the north end of Boundary Street has likely been caused by small inaccuracies in the original map.

3. EXISTING FLOOD ENVIRONMENT

The existing flood risk for the Rushcutters Bay catchment is defined by the design flood affection in the Flood Study (Reference 2). No similar study had already been undertaken for the Elizabeth Bay catchment, and so was assessed as part of the current study, the details of which are provided in Section 3.1 below.

The design flood information is then used to determine the Hydraulic categories, Hazard classification and the Flood Emergency Response categories (the latter is detailed in 6.4). It also enables the identification of any key flood risk areas or 'hotspots' in the catchment. An overview of the previously undertaken climate change analysis is also given.

3.1. Elizabeth Bay Flood Study Extension

Figure 6 the flood affection for the Elizabeth Bay area as determined by the flood study extension. This shows that the area does not have any significant locations of major hazard or flood affectation. The one area of significant depth in the area is a carpark just off the Esplanade at the bottom on the catchment. All floor levels in the catchment are at the second storey and so overfloor inundation is expected to be minimal.

The following sections detail the modelling process used to define the existing flood environment.

3.1.1. Hydrologic Modelling

Sub-Catchments

A hydrological model of the study catchment was established using the DRAINS software package (Reference 7).

Sub-catchment areas were delineated based on LiDAR survey and making the assumptions that:

- properties generally drain to streets or inlet pits; and
- flow in streets is along gutters and uni-directional.

The DRAINS hydrologic runoff-routing model was used to determine hydraulic model inflows for the local sub-catchments within the study area.

Key Model Parameters

Model parameters used in the Elizabeth Bay model were directly taken from either;

- Terrain information (imperviousness percentage etc.) or,
- The Rushcutters Bay DRAINS model.

To provide consistency between the extension and the existing model the same parameters were used. This is a valid assumption as the catchment is immediately adjacent to the existing modelled area.

3.1.2. Hydraulic Modelling

A TUFLOW model (Reference 6) of Elizabeth Bay was developed as part of this study. It was added onto the existing Rushcutters Bay model and the model area was extended.

Terrain Model
A digital terrain model was established using the existing LiDAR dataset. A computational grid cell size of 2 m by 2 m was adopted, as it provided an appropriate balance between providing sufficient detail for roads and overland flow paths, while still resulting in practicable computational run-times. It was also consistent with the grid size used in the Rushcutters Bay model.

Buildings and other structures likely to act as significant flow obstructions were incorporated into the terrain model. These features were identified from the available aerial photography and modelled as impermeable obstructions to the flood flow (i.e. they were removed from the model grid).

The footpath representation in Elizabeth Bay was given in-depth attention particularly on Ithaca Road. The schematisation of the footpath on Ithaca Road is crucial as the street is a flow path and properties on the street may be inundated. Flow paths between buildings on Ithaca Road were also investigated through aerial photos and a site visit.

Boundary Conditions
The tailwater conditions used the in Rushcutters Bay model were adopted for Elizabeth Bay. The details of these can be found in the Rushcutters Bay Flood Study (Reference 2).

Hydraulic Roughness
The adopted roughness values are consistent with the Rushcutters Model and previous experience with modelling similar catchment conditions.

Table 1 - Mannings ‘n’ values

Surface Type	Manning’s “n” value
Very short grass or sparse vegetation	0.035
General overland areas, gardens, roadside verges, low density residential lots etc. (default)	0.045
Medium density vegetation	0.060
Heavy vegetation	0.100
Roads, paved surfaces	0.025
Concrete pipes	0.013

Culvert Type	Manning's "n" value
Concrete pipes	0.013
Clay Pipes	0.025
Brick	0.014
PVC	0.011

Critical Duration
To determine the critical storm duration for various parts of the catchment, modelling of the 1% AEP event was undertaken for a range of design storm durations from 15 minutes to 12 hours. An envelope of the model results was created, and the storm duration producing the maximum flood depth was determined for each grid point within the study area.

The critical duration within the catchment varies. A significant portion of the catchment has a critical duration of 90 minutes, though for a number of locations this increased to 120 minutes. The resulting difference in peak levels however, was less than ±0.01 m. As the critical duration for Rushcutters Bay was 120 minutes and given the trivial difference in levels, it was considered appropriate to adopt the longer duration for Elizabeth Bay also.

Calibration and Validation
It is preferable to test the performance of the hydrological and hydraulic models against observed flood behaviour from past events within the catchment. The assumed model parameters can then be adjusted so that the modelled behaviour best represents the historical patterns of flooding. The process of adjusting model parameters to best reproduce observed flood behaviour is known as model *calibration*. Usually, the models are calibrated to a single flood event for which there is sufficient flood data available (e.g. peak-flood levels, observations regarding flow paths or flood extents etc.). The performance of the calibrated model can then be tested by simulating other historical floods and comparing the ability of the calibrated models to reproduce the observed behaviour. This process is known as model *validation*.

Model calibration and verification is reliant on sufficient amounts of historic flood data being available. The largest flood events known to have occurred within the catchment occurred on 8-9 November 1984, 6 January 1989 and 26 January 1991. For these major events, there is limited flood height data, and only anecdotal or approximate depths were available. However, the data available does not fall within the extension of the Rushcutters Bay model of Elizabeth Bay. Furthermore, there is no stream gauge within the Elizabeth Bay catchment. This meant it was not possible to conduct a thorough calibration of modelled flows to observed data. However, since the Rushcutters Bay model was able to be calibrated for a number of events and locations, the same parameters were used.

3.2. Hydraulic Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to different areas of the floodplain; namely floodway, flood storage or flood fringe. Floodway describes areas of significant discharge during floods, which, if partially blocked, would cause a significant redistribution of flood flow. Flood storage areas are used for temporary storage of floodwaters during a flood, while flood fringe is all other flood prone land.

There is no single definition of these three categories or a prescribed method to delineate the flood prone land into them. Rather, their categorisation is based on knowledge of the study area, hydraulic modelling and previous experiences. Based on analysis of similar catchments, as well as literature review (Reference 9), the Flood Study (Reference 2) defined hydraulic categories as:

Floodway:		Velocity x Depth > 0.25 m^2/s AND Velocity >0.25m/s
	OR	Velocity > 1m/s
Flood Storage:		Land outside the floodway where Depth > 0.2m
Flood Fringe		Land outside the floodway where Depth < 0.2m

The hydraulic categories for the 5% AEP, 1% AEP and PMF events, are shown on Figure 8 to Figure 10. The main overland flow path is along Boundary Street, with the entire street classed as floodway. Other less significant floodways are present on Taylor Street and Barcom Avenue. Taylor Street is also in the area of flood storage on Sturt Street and Sims Street. Victoria Street has a significant area of flood storage just outside of St Vincent's hospital at the intersection of Oxford Street.

3.3. Flood Hazard Classification

Flood hazard is a measure of the overall adverse effects of flooding and the risks they pose. The 2005 NSW Government's Floodplain Development Manual (Reference 1) describes two *provisional flood hazard* categories; High and Low, based on the product of the depth and velocity of floodwaters. These hazard categories do not consider other factors which may influence the flood hazard (Figure L2 of the Floodplain Development Manual); hence they are provisional estimates only with "true" hazard to be defined through the process of the current study. The boundary of the provisional High and Low hazard classification will change according to the magnitude of the flood in question.

Provisional hazard was established as part of the Flood Study (Reference 2) based on the Floodplain Development Manual criteria (Appendix L of the Floodplain Development Manual). Due to the combination of high flood depths and velocities, many regions of the catchment are affected by high hazard flows. Figure 11 to Figure 18 show the flow hazard classification throughout the catchment for the 50%, 20% 10%, 5%, 2%, 1% and 0.2% AEP and PMF events. It can be seen that during the 50% AEP flood event the Boundary Street-McLachlan Avenue flowpath has high hazard flows, as well as some south of Oxford Street in Sturt Street. These areas have slightly increased high hazard in the 1% AEP, as well as an area in front of St Vincent's Hospital.

To assess the true flood hazard, all adverse effects of flooding have to be considered. This includes the provisional (hydraulic) hazard, threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production including those detailed in Table 2. The classification is a qualitative assessment, which results in two categorisations:

***High Hazard** - an area or situation where there is possible danger to personal safety, evacuation by trucks is difficult and able-bodied adults would have difficulty in wading to safety. There could also be potential for significant structural damage to buildings.*

***Low Hazard** - people and possessions can still be evacuated by trucks if necessary and able-bodied adults would have little difficulty wading to safety.*

Table 2: Hazard Classification

Criteria	Weight [1]	Comment
Size of the Flood	Medium	Relatively low flood hazard is associated with more frequent minor floods while the less frequent major floods are more likely to present a high hazard situation.
Depth & Velocity of Floodwaters	High	The provisional hazard is the product of depths and velocity of flood waters. These can be influenced by the magnitude of the flood event.
Rate of Rise of Floodwaters	Medium	Rate of rise of floodwaters is relative to catchment size, soil type, slope and land use cover. It is also influenced by the spatial and temporal pattern of rainfall during events.
Duration of Flooding	Low	The greater the duration of flooding the more disruption to the community and potential flood damages. Permanent inundation due to sea level rise is of indefinite duration.
Flood Awareness and Readiness of the Community	Medium	General community awareness tends to reduce as the time between flood events lengthens and people become less prepared for the next flood event. Even a flood aware community is unlikely to be wise to the impacts of a larger, less frequent, event.
Effective Warning & Evacuation Time	Medium	This is dependent on rate at which waters rise, an effective flood warning system and the awareness and readiness of the community to act.
Effective Flood Access	Medium	Access is affected by the depths and velocities of flood waters, the distance to higher ground, the number of people using and the capacity of evacuation routes and good communication.
Evacuation Problems	Low	The number of people to be evacuated and limited resources of the SES and other rescue services can make evacuation difficult. Mobility of people, such as the elderly, children or disabled, who are less likely to be able to move through floodwaters and ongoing bad weather conditions is a consideration.
Provision of Services	Low	In a large flood it is likely that services will be cut (sewer and possibly others). There is also the likelihood that the storm may affect power and telephones. Permanent inundation from sea level rise may lead to permanent loss of services.
Additional Concerns	Low	Floating debris, vehicles or other items can increase hazard. Sewerage overflows can occur when river levels are high preventing effective discharge of the sewerage system.

(1) Relative weighting in assessing the hazard for the Rushcutters Bay catchment

Larger flood events in the catchment are associated with increased depths and velocities, however, this is largely accounted for by the provisional hazard criteria being considered over a range of events. Furthermore, the nature of flooding in the catchment results in only small increases in flood levels between design events.

Floodwaters have hazardous depth and velocity in frequent flood events, with overland flow passing down several roads in the catchment. There are associated risks of persons being swept into floodwaters, as well as cars being destabilised in areas with greater depth, such as

Boundary Street and Taylor Street. However, this component does not warrant more attention than others, as the risk posed by high hazard depths and velocities is already well-described by the provisional hydraulic hazard.

The concept of rate of rise of flood waters is more applicable to mainstream flooding scenarios, where a fast rate of rise can leave residents unaware of the flood event, and they can become stranded. However, the rate of rise in this catchment is fast (up to 1-1.5 m/hour in both the 5% and 1% AEP) and flood prone areas will become inundated soon after the rainfall event begins. If evacuation is required in the catchment, the fast rate of rise will likely mean it is undertaken after the peak flood level.

Flood awareness in the community appears to be moderate, with 60% of questionnaire respondents aware of flooding in the catchment (Reference 2) (this is likely to exaggerate the awareness, as aware residents are presumably more likely to respond). Given that only 5% of those surveyed responded, the confidence interval on the estimate is around 15% (i.e. the number of aware respondents is likely between 45 and 75%). The estimate is also complicated by the bias in the respondents, with those residents who are aware of flooding more likely to respond. Although it may be assumed that frequently flood-affected properties are aware of flooding, the high number of renters in the area means this awareness could too be exaggerated. Experience in similar urban catchments indicates residents are generally sceptical of the possibility of large floods and therefore may not ascribe the appropriate level of risk to floodwaters when they are encountered.

Effective warning and evacuation time in the catchment is relatively low, as the flooding is likely to be sudden, with a fast rate of rise. For a resident without additional warning or forecast, flood events will initially resemble more benign (but still heavy) storms, with awareness of the flood coming from direct experience of it. However, effective access, which refers to an exit route that remains trafficable for sufficient time to evacuate people and possessions, is likely to be available to the majority of affected residents, as the flood extents are not wide. The areas where access is an issue are those areas identified as having high hydraulic hazard, shown on Figure 16 for the 1% AEP event. The vehicular and pedestrian access routes are all along sealed roads and present to unexpected hazards if the roads have been adequately maintained.

At depths of 0.3 m wading should be possible for most mobile adults, but could be problematic for children, elderly or disabled people. The majority of flood prone properties in the catchment do have access with flood depths of 0.3 m or less. Areas that do have depths of 0.3 m or more in the 1% AEP include:

- Oxford Street west of South Dowling Street,
- Taylor Street and Sims Street,
- Victoria Street north of Oxford Street,
- Hopewell Street north of Hopewell Lane,
- Comber Street south of Boundary Street,
- Boundary Street,
- McLachlan Avenue,
- Neild Avenue.

At a depth of 0.3 m, larger vehicles can easily travel through water and aid evacuation. Nevertheless, for areas within the catchment without effective flood access, evacuation is generally not recommended considering the short duration of flooding experienced as residents are more likely to put themselves in harm's way by evacuating. This is further discussed in Section 9.4.2.

The impact of debris is unlikely to be a significant factor due to the low flood depths and/or velocities for large parts of the catchment. It would impact the time of inundation as waters would take longer to recede, however as the duration of the flooding is generally short across the catchment this is not considered significant.

Figure 19 shows the length of inundation taken at each of the drainage pit inlets in the 1% AEP, 1 hour event. This shows that the duration of flooding is typically less than 1 hour except in the known trapped depressions (such as on McLachlan Avenue, Nelid Street, Boundary Road, Oxford Street etc) where it may take a few hours to drain, assuming the piped network is operating efficiently (i.e. without blockages).

3.4. Hotspots

Hotspots in the area are defined as those locations where there is a known flood issue. They are identified by considering accounts of previous floods, and by examining the flood behaviour as defined by the Flood Study (Reference 2). The latter involves identifying areas of high hazard flow where flooding of property occurs, and through consideration of subsurface drainage capacity.

The Flood Study (Reference 2) informally identified several such hotspots. Additional flood level survey undertaken as part of the current study expanded the assessment of property flooding, but did not result in the identification of any additional hotspots. The current study also undertook some further assessment of the hotspots through more detailed analysis of the model in conjunction with the flood damages assessment. The refined hotspots are as follows:

3.4.1. Boundary Street

Boundary Street constitutes the main overland flowpath in the middle section of the Rushcutters Bay catchment, and as such, it conveys a significant overland flow in all flood events. The existing feeder pipes reach capacity in the 50% AEP event and as such excess discharge flows overland for events larger than this. Trunk drainage exists along Boundary Street and extends to the outlet at Rushcutters Bay. Along Boundary Street, there is between 0.2 m and 0.7 m of depth in the 10% AEP event and up to 0.9 m in the 1% AEP event.
Figure 24 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The high velocities that occur in the hotspot result in significant areas of high hydraulic hazard across the range of design events. In a 50% AEP event, Boundary Street and McLaclan Avenue have high hazard in the gutters, while in the 1% AEP event the high hazard area covers the majority of Boundary Street, McLachlan Avenue and parts of Neild Avenue. The area has a long duration of flooding relative to the rest of the catchment, but can still be expected to drain within 2 hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning.

The hotspot has significant property inundation and cuts off vehicle and pedestrian thoroughfares. 13 properties are inundated above floor level in the 50% AEP event, while there are 22 properties inundated in the 1% AEP event. There is significant risk of damage of property in the area with many properties directly at or below street level. There is also a risk of damage to cars within these garages, as they may be lower than the street level and so detain a significant volume of water.

3.4.2. Taylor Street

The area consists of three trapped low points on Taylor, Sims and Sturt Street. Piped drainage is relied on to transmit flow from the area, as the topography slopes up from the area (towards both Oxford Street, South Dowling Street and Flinders Street), creating an unrelieved depression. Sturt Street has a depth of up to 1.65 m in the 10% AEP event; while the 1% AEP event has depths of up to 1.69 m. Figure 29 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The large depths of inundation that occur in the hotspot result in significant areas of high hydraulic hazard across the range of design events. In a 50% AEP event, Sturt Street and the elbow of Sims Street has high hazard ponding, while in the 1% AEP event the high hazard area covers the east part of the Sturt Street, some spots on Taylor Street and the elbow and yards in Sims Street. Sims Street and Sturt Street have a long duration of flooding relative to the rest of the catchment, but can still be expected to drain within a few hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning. In the same event, Taylor Street has a shorter duration of flooding of less than 30 minutes.

The hotspot has significant property inundation but does affect any vehicle or pedestrian thoroughfares. Two properties are inundated above floor level in the 50% AEP event, while there are 22 properties inundated in the 1% AEP event. There is significant risk of damage of property in the area with many houses directly on street level. Vehicles are also at risk of damage by street parking in the area and high flood depths.

3.4.3. Victoria Street South

Similar to Taylor Street, the area is a flood storage area. Piped drainage is relied on to transmit flow from the area, as the topography slopes up from the area (towards both Oxford Street and along Victoria Street to the north), creating an unrelieved depression. Victoria Street has a depth of 0.44 m in the 10% AEP event, while in the 1% AEP depths reach up the 1.1 m directly outside St Vincent's Hospital Clinic. Figure 34 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The large depths of inundation that occur in the hotspot result in areas of high hydraulic hazard from the 2% AEP event to rarer events. In a 50% AEP event, Victoria Street only has low hazard ponding, while in the 1% AEP event the high hazard area extends across the road in the lowest part of Victoria Street. Victoria Street has a long duration of flooding relative to the rest of the catchment, but can still be expected to drain within 2 hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning.

The hotspot has no property inundation but does cut off a vehicle and pedestrian thoroughfare. The area poses risk to both vehicles and pedestrians in frequent events such at the 50% AEP event and a significant risk in larger events. It is also a potential risk to the Hospital's function, as there is a main entrance in the area. Although the hotspot does not occur at the emergency response entrance, it is still considered a significant issue as it impedes access to the hospital facilities.

3.4.4. Barcom Avenue

The area of interest is at the intersection of Barcom Avenue and Liverpool Street. The flood study (Reference 2) indicated that a number of houses would be inundated in the 50% AEP flood event even though depths on the road are not significant (less than 0.3 m). Through the community consultation it was made apparent that the assessment of over floor inundation in the 50% AEP event was overstated. The method for tagging properties as inundated was updated (Section 5.1) and the properties are no longer classified as flooded (in any event, up to and including the PMF). No further assessment of the area as a hotspot was made.

Mitigation measures for the hotspots are discussed in Section 9.3.

3.5. Impact of Climate Change

The impact of climate change on flood behaviour has been assessed as part of the Flood Study (Reference 2) through a sensitivity analysis of rainfall increase and sea level rise due to climate change. The assessment followed the NSW State Government guidelines, which require testing of rainfall increases of 10, 20 and 30%, and sea level rise of 0.4 and 0.9 m by the years 2050 and 2100 respectively. Table 3 gives the results of the analysis.

Table 3: Results of Climate Change Analysis - 1% AEP Event Depths (m)

ID	Location	100 Year ARI Peak Flood Depth (m)	Rainfall Increase 10%	Rainfall Increase 20%	Rainfall Increase 30%	Sea Level Rise 2050	Sea Level Rise 2100
			Difference with 1% AEP Base Case (m)				
1	Sims Street	1.1	0.01	0.03	0.06	-	-
2	Oxford Street (West)	1.0	0.10	0.16	0.21	-	-
3	Victoria Street	1.8	-	-	0.03	-	-
4	Taylor Street	0.9	0.02	0.04	0.05	-	-
5	Sturt Street	0.5	0.03	0.08	0.11	-	-
6	Victoria St adjacent St Vincents Hospital	1.7	0.02	0.05	0.07	-	-

7	Boundary Street	1.3	0.06	0.11	0.15	-	-
8	McLachlan Ave	0.6	0.03	0.06	0.09	-	-
9	Neild Ave and New South Head Rd	0.8	0.03	0.05	0.08	-	-
10	Kellett Place	0.3	0.02	0.04	0.05	-	-
11	Waratah Street	0.8	0.03	0.05	0.07	-	-
12	Sims Street	0.5	0.02	0.04	0.06	-	-

The table shows that 1% AEP peak flood depths across the catchment will increase by around 0.05 m in a 10% rainfall increase, while a 30% rainfall increase will correspond to depth increases of around 0.1 m. The most sensitive areas are on Oxford Street, Sturt Street and Boundary Street. The analysis also found that a rise in sea level has no impact in the majority of the catchment. This is due to the catchment's steep topography which means a higher sea level only impacts the very downstream end of the catchment, where the open channel passes into the bay.

4. STAKEHOLDER CONSULTATION

4.1. Community Consultation

One of the central objectives of the FRMS process is to actively liaise with the community throughout the process, keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. The consultation programme consists of:

- Distribution of brochure and questionnaire survey;
- Media release;
- The Floodplain Risk Management Committee;
- City of Sydney's website; and
- Public meetings.

4.1.1. Previous Consultation

As part of the Flood Studies (Reference 2), community questionnaire surveys were undertaken during October-November 2012 to gather historical data for model calibration. 792 surveys were distributed to residents within the Rushcutters catchment. 36 responses were received, which equates to a return rate of 5%. Unfortunately few flood levels or depths were provided although the reported flood observations were able to be used as a means of model verification. It was found that there was not one historic event in particular that the residents within the study area identified as being significant, although June 2007 was identified as an event of notoriety. Approximately 75% of respondents are aware of flooding or have some knowledge of flooding in the study area. Further, almost half of the respondents reported flooding on roads, which serve as formalised overland flow paths in this catchment as the sub-surface drainage system is overwhelmed by the runoff volume associated with more extreme events.

4.1.2. Consultation as Part of This Study

Further community questionnaire survey work was undertaken during June-July 2014 to inform residents of the next stage of the floodplain management process as well as to gather flood information and community's preferred options for managing flood risks within the catchment. 826 copies of the newsletters and questionnaires were printed and delivered to the owners of properties likely to be aware of flooding issues. In total 45 responses were received constituting a 5% return rate and the results are as shown in Figure 20. The newsletter and questionnaire is shown in Appendix B.

36% of the respondents experienced some form of flooding within the catchment and 4 respondents reported floodwaters entering their houses or businesses. Many residents expressed concern in regards to the maintenance of the drainage assets within the study area whereby leaves and debris have not been sufficiently cleared from the entry points resulting in local nuisance flooding and exacerbation of existing flood problems.

Among the preferred management options for managing flood risks within the catchment: defined flow paths, pit/pipe upgrades, education of the community and retarding basins were the most popular. The least desired options were levees and improved culverts.

4.1.3. Community Information Session

Two community information sessions were held. These were:

- July 25th at the Paddington Markets – WMAwater and City of Sydney staff manned a booth and discussed flooding issues in the catchment with interested members of the public. Several community members engaged with the material and made flooding specific observations; and
- August 1st at Kings Cross Organic Flood Markets – WMAwater and City of Sydney staff manned a booth and again discussed flooding issues with interested members of the public.

4.2. Floodplain Committee Meetings

The Floodplain Management Committee (FMC) oversees and assists with the floodplain risk management process being carried out within the Council LGA. The committee is comprised of representatives from various stakeholder groups and includes local Councillors, emergency services (SES), Sydney Water Corporation and community representatives. Progress on the current study has been presented to the committee at 3 month intervals, at which point questions or feedback from the various representatives were taken.

4.3. Internal Stakeholders Workshop

Workshops with internal stakeholders were held to gather feedback on the management measures being assessed for the study. The workshops, which were held in December 2014, consisted of presentation of the various measures, including their cost and impact on flooding and property affectation. Attendees included representatives from City of Sydney, OEH, SES and Sydney Water, and each provided input on the feasibility and suitability of the measures, as well as possible variations to the measures presented.

4.4. Public Exhibition

4.4.1. Summary of Submissions

The draft report has been exhibited. No responses have been received in regard to the report exhibited.

4.4.2. Discussion

The exhibition of the draft document occurred at the same time as the exhibition of draft documents for the Centennial Park and Woolloomooloo Catchments. Of these only the latter received a significant number of detailed submissions from those impacted by flooding. This likely relates to the fact that at least two significant events have occurred in the Woolloomooloo Catchment during 2015 alone.

5. ECONOMIC IMPACT OF FLOODING

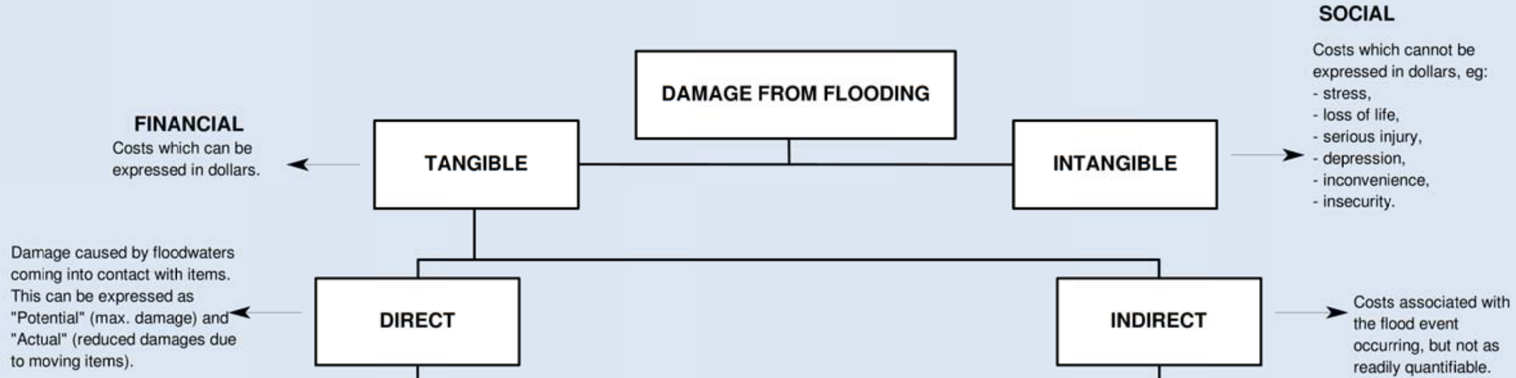
The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also a non-subjective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris, sedimentation; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Table 4.

The assessment of flood damages not only looks at potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding as shown on Figure 21.

Table 4: Flood Damages Categories (including damage and losses from permanent inundation)



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

5.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 4). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Flood damages estimates are also useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development a floor level survey was undertaken. As part of this floor level survey work an indicative ground level was recorded for use in the damages assessment. This was used in conjunction with modelled flood level information to calculate damages. Damage calculations were carried out for all properties within the 1% AEP flood extent, and floor level survey was undertaken for these properties. It should be noted that by including only those properties in the 1% AEP extent, properties that are inundated in rarer events have not been accounted for. Therefore damage calculations for the PMF event are likely to be underestimated.

The floor level survey used as part of this study is given in Appendix E.

A flood damages assessment was undertaken as part of the Flood Study (Reference 2) for existing development in accordance with current OEH guidelines (Reference 10) and the Floodplain Development Manual (Reference 1). As additional properties floor levels were surveyed as part of this study (and old flood models revised), the estimated flood damages were revised. The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

Rushcutters Bay has a small catchment size (92 hectares) that limits the volume of runoff that occurs in a rainfall event. This limited volume, combined with the relatively short duration of the flood event (typically a few hours), means there is limited opportunity for floodwaters to enter premises. This is especially true of basement flats - flats where the entry is below the level of the footpath. For example, a basement flat may have a floor level two metres below the design flood level, but will not experience two metres of depth throughout the dwelling, due to the limited runoff volume. To account for this, the maximum depth of inundation in the damages calculation for each property is 0.5 m.

Similarly, the damages calculation was augmented so as to avoid designating these basement flats as being flooded over floor in frequent flood events. This change was made after detailed assessment of the properties in question, as well residents' experiences via the questionnaire, suggested that these basement flats were typically not flooded in frequent flood events (e.g. a 1 in 2 year ARI event). The damages calculation was augmented by not designating properties as flooded overfloor when the depth on the footpath is less than 0.15 m. This is not to say that a depth of 0.15 m cannot inundate a low-lying property. Rather, that without this threshold, the flood affectation is overestimated.

Damages were calculated for residential and commercial\industrial properties separately and the process and results are described in the following sections. The combined results are provided as Table 5. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements damages can be under estimated.

Table 5: Estimated Combined 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	200	119	$ 11,558,600	$ 57,800
0.2%	156	55	$ 6,640,100	$ 42,600
1%	145	45	$ 5,434,200	$ 37,500
2%	137	41	$ 4,861,800	$ 35,500
5%	131	35	$ 4,248,900	$ 32,400
10%	117	23	$ 3,155,500	$ 27,000
20%	110	17	$ 2,570,300	$ 23,400
50%	92	14	$ 2,141,100	$ 23,300
Average Annual Damages (AAD)			**$ 1,967,900**	**$ 9,800**

Section 9.3.6 presents results of the damages assessment undertaken for the proposed mitigation options which were compared against the existing scenario so that the feasibility of the proposed mitigation options can be determined.

5.1.1. Residential Properties

The flood damages assessment for residential development was undertaken in accordance with OEH guidelines (Reference 10). For residential properties, external damages (damages caused by flooding below the floor level) were set at $6,700 and additional costs for clean-up as $4,000. For additional accommodation costs or loss of rent a value of $220 per week was allowed assuming that the property would have to be unoccupied for up to three weeks. Internal (contents) damages were allocated a maximum value of $33,750 occurring at a depth of 0.5 m above the building floor level (and linearly proportioned between the depths of 0 to 0.5 m). Structural damages vary on whether the property is slab/low set or high set. For the purpose of this study, any property with a floor level of 0.5 m or more above ground level was assumed to be high set. For two storey properties, damages (apart from external damages) are reduced by a factor of 70% where only the ground floor is flooded as it is assumed some contents will be on the upper floor and unaffected and that structural damage costs will be less. In some instances external damage may occur even where the property is not inundated above floor level and therefore tangible damages include external damages which may occur with or without house floor inundation.

A summary of the residential flood damages for the Rushcutters Bay catchment is provided in Table 6. Overall, for residential properties in the catchment there is little difference in the average tangible damages per property for all the design events analysis up to the 1% AEP event. This is reflective of the relatively small differences in flood levels between the design flood events. Average damage per property increases at events larger than the 1% AEP when more properties become flooded above floor level. Note that the terminology used refers to a property or lot being the land within the ownership boundary. Flooding of a property does not necessarily mean flooding above floor level of a building on that property/lot.

Table 6: Estimated Residential 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	138	76	$ 4,438,100	$ 32,200
0.2%	106	24	$ 1,662,700	$ 15,700
1.0%	100	20	$ 1,395,200	$ 14,000
2.0%	94	19	$ 1,313,300	$ 14,000
5.0%	90	16	$ 1,140,400	$ 12,700
10.0%	84	9	$ 821,900	$ 9,800
20.0%	82	5	$ 610,300	$ 7,400
50.0%	69	3	$ 395,700	$ 5,700
Average Annual Damages (AAD)			**$ 439,200**	**$ 3,200**

5.1.2. Commercial and Industrial Properties

The tangible flood damage to commercial and industrial properties is more difficult to assess.