

## MAROUBRA BAY FLOODPLAIN RISK MANAGEMENT STUDY AND DRAFT PLAN





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## MAROUBRA BAY FLOODPLAIN RISK MANAGEMENT STUDY AND DRAFT PLAN

| <b>Project</b><br>Maroubra Bay<br>Floodplain Risk Management Study and<br>Draft Plan |                          | <b>Project Number</b><br>113048                                         |              |
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## ACRONYMS

|            |                                                                          |
|------------|--------------------------------------------------------------------------|
| AAD        | Average Annual Damages                                                   |
| ABCB       | Australian Building Codes Board                                          |
| ABS        | Australian Bureau of Statistics                                          |
| AEP        | Annual Exceedance Probability                                            |
| AHD        | Australian Height Datum                                                  |
| ALS        | Airborne Laser Scanning Survey (LiDAR)                                   |
| AEP        | Annual Exceedance Probability                                            |
| B/C        | Benefit Cost Ratio                                                       |
| BoM        | Bureau of Meteorology                                                    |
| DA         | Development Application                                                  |
| DCP        | Development Control Plan                                                 |
| DSC        | Dam Safety Committee                                                     |
| EMPLAN     | Emergency Management Plan                                                |
| EP&A Act   | Environmental Planning and Assessment Act                                |
| ERP        | Emergency Response Planning                                              |
| EY         | Exceedances per Year                                                     |
| FPA        | Flood Planning Area                                                      |
| FPL        | Flood Planning Level                                                     |
| FMC        | Floodplain Management Committee                                          |
| FRMP       | Floodplain Risk Management Plan                                          |
| FRMS       | Floodplain Risk Management Study                                         |
| IPCC       | Intergovernmental Panel for Climate Change                               |
| LEP        | Local Environment Plan                                                   |
| LFP        | Local Flood Plan                                                         |
| LGA        | Local Government Area                                                    |
| LiDAR      | Light Detection and Ranging (also see ALS)                               |
| mAHD       | Meters above Australian High Datum                                       |
| Mike-Storm | Combined hydrologic and hydraulic computer model                         |
| OEH        | Office of Environment and Heritage                                       |
| OSD        | On-site Detention                                                        |
| PMF        | Probable Maximum Flood                                                   |
| PMP        | Probable Maximum Precipitation                                           |
| SCCG       | Sydney Coastal Councils Group                                            |
| SES        | State Emergency Services                                                 |
| TUFLOW     | A one-dimensional (1D) and two-dimensional (2D) hydraulic computer model |
| WSUD       | Water Sensitive Urban Design                                             |
| 1D / 2D    | One dimensional and two dimensional computer models                      |

## 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 Study**
  - 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 and Development Controls to ensure new development is compatible with the flood hazard.

The Maroubra Bay Floodplain Risk Management Study and Draft Plan (FRMS&P) constitutes the second and third stages of this management process. This study has been prepared by WMAwater on behalf of Randwick City (Council) and provides the basis for the future management of flood prone lands in the Maroubra Bay area of Sydney. To inform this Management Study and Draft Plan, the hydraulic modelling undertaken for the Flood Study was reviewed to ensure that model outputs are fit for purpose as well as taking into account any newly available data since the Flood Study modelling was undertaken.

This report has been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

# PART A Floodplain Risk Management Study

# **1. MAROUBRA BAY FLOODPLAIN RISK MANAGEMENT STUDY AND DRAFT PLAN SUMMARY**

## **1.1. Introduction**

This document comprises the Maroubra Bay Floodplain Risk Management Study and Draft Plan (FRMS&P). Provided within is a description of the flooding problem in the Maroubra Bay area as well as the assessment of a number of floodplain risk management options. This draft report provides an opportunity for Council, Office of Environment and Heritage (OEH) and the Floodplain Management Committee (FMC) to submit feedback prior to being put forward as a draft final document for Public Exhibition.

## **1.2. Objectives of the Floodplain Risk Management Study and Plan**

The objectives of this study are to:

- Develop a draft Floodplain Risk Management Plan that addresses the existing, future and continuing flood problems.
- In doing so, the objectives include:
  - Review of the Flood Study;
  - Preparation of a Floodplain Risk Management Study (FRMS) – investigating flood management options and making recommendations; and
  - Preparation of a draft Floodplain Risk Management Plan (FRMP) – developed from the FRMS detailing how flood prone land within the study area is to be managed.

## **1.3. Desired Outcomes**

The final outcome is a document setting out the flood risk management measures to be implemented which identifies their priority, time for implementation, indicative costs, authority or body responsible for implementation and implementation strategy. This document would be adopted by Council following a period of public exhibition and following feedback from the community, Council can initiate the implementation of any agreed floodplain risk management measures.

## **1.4. Methodology**

Following a thorough engagement process between Council and the Consultant (WMAwater), a detailed methodology has been tailored to achieve the best outcomes from the FRMS&P process for the Maroubra Bay area. The key steps agreed upon can be summarised as follows;

- Compilation and review of available information;
- Review of Flood Study – including revision of hydraulic modelling techniques;
  - Mapping of the design event floods for the 1 EY, 0.5 EY, 0.2 EY, 10% AEP, 5%,

- 2%, 1%, 0.5% and 0.2% AEP events as well as the PMF including;
  - Peak flood levels, depths and velocities;
  - Hydraulic categorisation – floodway, flood storage or flood fringe;
  - Hydraulic hazard categorisation;
- Establish impacts of climate change on flood levels (for the 1% AEP event);
- Assess the flooding issue in Maroubra Bay, including;
  - Identifying key locations for flood management known as flooding hot-spots;
  - Identifying emergency response classifications;
  - Flood damages assessment to identify potential flood damages under current conditions to be compared with costs associated with potential mitigation works; and
- Review of current flood planning controls and emergency management;
- Assessment of risk management options to identify practical options for the study area through options including;
  - Flood modification;
  - Property modification; and
  - Response modification.
- Community consultation through media releases, newsletters, public workshops and the FMC to obtain additional information and seek resident opinions on potential flood management measures proposed; and finally
- The preparation of the draft Floodplain Risk Management Plan.

## 1.5. Summary of Flooding Issues

The Maroubra Bay catchment is urbanised and the piped drainage network generally directs runoff in an easterly direction towards the Pacific Ocean. When the capacity of the piped network is exceeded, flooding occurs through the urbanised areas, down streets and through parks. In addition there are a number of trapped low points throughout the catchment where outflow is via a pipeline or infiltration into the underlying sand. A number of flooding hot-spots have been identified in conjunction with Council and the FMC, and flood modification measures have been explored for each respective area. Response modification measures and property modification measures have also been considered and their respective merits discussed.

## 1.6. Recommendations

This FRMS and draft FRMP identifies a number of management options and strategies to be considered by Council and the FMC. The options considered are detailed in Table 20 and their ranking included for Committee approval in the FRMP.

Discuss highest ranked mitigation option.

## 2. INTRODUCTION

This report prepared by WMAwater on behalf of Randwick City Council comprises the Floodplain Risk Management Study and draft Plan for Maroubra Bay. Recommendations are in accordance with best practice and NSW flood policy as per the Floodplain Development Manual (Reference 1). The NSW Floodplain Management Program places an emphasis on extreme rainfall events and protecting residential dwellings from inundation.

The new draft terminology for referring to flood probability has been used in this study. Details of this can be found in Appendix A.

### 2.1. Study Area Summary

The Maroubra Bay catchment is an urban catchment located in the eastern suburbs of Sydney. The study area is shown in Figure 1 and largely consists of residential developments with some commercial premises. The catchment has an area of approximately 2.4 km<sup>2</sup> and drains the eastern portion of the Maroubra suburb towards the ocean at Maroubra Bay. Major discharge points are located at the northern and southern end of Maroubra Beach.

The steep upper reaches of the Maroubra Bay catchment drain to the flat, low-lying area behind Maroubra Beach which is susceptible to inundation. Waterways within the catchment have been piped with development immediately above or adjacent to the pipes. When the capacity of the piped network is exceeded flooding occurs through urbanised areas, down streets and through parks. In addition, there are a significant number of trapped low points through the catchment where outflow is via at capacity pipes or infiltration into the underlying sand.

Two main trunk drainage lines discharge to the stormwater outlet on Maroubra Beach located in front of the McKeon Street / Marine Parade intersection. The larger trunk line runs along Fitzgerald Avenue from Malabar Road and along Marine Parade up to McKeon Street. This line drains a large proportion of the catchment. A second main trunk line runs along McKeon Street to Marine Parade. A portion of the south Maroubra catchment, approximately 7.6 ha, is drained via a separate pipe network to south of the Arthur Byrne Reserve. Overland flows from this portion of the catchment drain to the main Maroubra Bay catchment via Fitzgerald Avenue.

Much of the western portion of the catchment drains to Coral Sea Park. The park itself is around 5.5 ha in size and is located within a residential area. A small commercial strip is located just east of Coral Sea Park in Lexington Place. The main trunk drainage line from Coral Sea Park runs towards Maroubra Bay along Yorktown Parade before proceeding along Fitzgerald Avenue to the south of Broadarrow Reserve. In large flood events, overland flows tend to follow the road network in this area, generally following an easterly direction to the lower reaches of the catchment. There is a major trapped low point adjacent to the Maroubra Bowling Club greens along Malabar Road.

The catchment is characterised by steep terrain in places and a number of trapped low points

which cannot be easily drained away during rainfall events. Overland flow from the upper reaches and from local sources has been known to inundate significant portions of the lower catchment such as west of Malabar Road, where the terrain is generally less steep. Some areas of the lower catchment in the vicinity of Marine Parade are lower than the remnant dune behind Maroubra Beach, causing water to pond until drained by the pipe network. The main trapped low points within this area are located at the intersection of McKeon Street and Marine Parade and at the intersection of Fenton Avenue and Chapman Avenue. The commercial area along Marine Parade (between McKeon Street and Mons Avenue) is potentially flood prone.

Compared to historical (pre-development) conditions, development within the catchment is likely to have exacerbated flooding as a result of:

- a major increase in the proportion of paved area and consequent reduction in pervious areas, resulting in corresponding increases in runoff (in terms of both peak flows and volumes),
- modification of natural surface drainage system including encroachment of development within flowpaths across the catchment, and
- development within trapped depressions that were once swamps, resulting in flood problems in these areas.

### **2.1.1. Land Use and Heritage**

The study area is within the Randwick City Council LGA and consists of the Maroubra Bay drainage catchment. The majority of the steeper upper reaches of the north and south catchment are established residential uses. The predominant land use within the catchment is residential with commercial development in the vicinity of the beach front. Historically, the catchment has been progressively developed from the early 1900s onwards and was largely urbanised by the 1960s. Much of the study area (Figure 2) comprises residential land zoning or medium and low density residential (R2 and R3) uses. Arthur Byrne Reserve zoned RE1 Public Recreation, makes up for a significant portion of the study area. The main area defined as B1 Neighbourhood Centre is located at the intersection of Mons Avenue and Marine Parade.

There are a number of heritage listed buildings in the area but none are known to be of significance from a flooding perspective. Available vegetation mapping is provided on Figure 1.

### **2.1.2. Social Characteristics**

Understanding the social characteristics of the area can assist in ensuring that the right risk management practices are adopted. The census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population, movement of people into and from the area, all of which provide an understanding of the affected demographics. Information has been extracted from the 2011 census (Reference 2). The study area, consisting of the Maroubra Bay suburb (refer Photograph 1), has a population of 29,594 living in 12,853 private dwellings. The census figures for Maroubra have been adopted as being reflective of the study area and a summary is provided in the following section.

Photograph 1: Map of Maroubra



The data on population movement in recent years is of particular interest. Generally, residents who have lived in an area for an extended period of time will have a better understanding of flooding issues in their area than those who have recently moved to the area. 40% of the population in the Maroubra area have resided there less than 5 year with 48% of the residents born overseas of which 35% were from non-english speaking backgrounds.

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them. Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties. Consequently, those people in rental properties are typically less aware of the flood risks unless they have been there for enough time to have experienced flooding or have been sufficiently informed by their landlords. In the Maroubra Bay area 41% of houses are rented. This figure is typical for the Randwick City area. 33% lived in a separate house, 21% in medium density and 46% in high density accommodation. For NSW the figures are 70% lived in a separate house, 11% in medium density and 19% in high density accommodation.

5% of the population (also average for NSW) consider themselves in need of assistance with

core activities (of which 51% are 75 years or older).

The languages spoken by the population is also worthwhile considering as it can have implications for providing flood information to the public. In the Maroubra Bay area 56% of the population speaks only English, 23% speak English and another language as well and only 4% consider themselves not proficient in English (0.1% did not state). These figures are again typical for the Randwick City area and indicate that lack of English is not a significant issue.

According to the 2011 Census, 18% of the households earned a high income and 24% were low income households, compared with 21% and 16% respectively for Randwick City. These figures may be reflective of the fact that 63% of the population reached Year 12 education at school (or equivalent) and 52% attained a higher qualification. 25% did not obtain a higher qualification (23% did not state). Of interest the % obtaining a Bachelor of Higher degree was 30.7% in Maroubra Bay whereupon the NSW average is only 20%.

94% of the population is employed and 6% unemployed (the same as for NSW).

52% of the population lived in the same house in the 5 year period from 2006 to 2011 with 40% moving (the remainder did not state or were born in this period).

## **2.2. Historical Flood Issues**

The Flood Study (Reference 3) undertook a detailed review of historic floods for the study area including analysis of daily rainfall data. This enabled the identification and placement of past storm events relative to local rainfall patterns including the January 1999 and October 1959 events used to validate the hydraulic modelling. The rainfall analysis also identified February 1956, February 1958, October 1959, March 1975 and August 1986 as large events. While comparatively smaller in magnitude, a number of further historic events are known to have occurred in October 1992, September 1995 and August 1998.

More recently, following heavy rains on the 24<sup>th</sup> of March 2014, evidence of ponding on the corner of Fitzgerald Avenue and Kyogle Street (see Photograph 2) has been reported by local residents.

Photograph 2: Flooding at Fitzgerald Avenue / Kyogle Street Intersection – March 2014



*Source: Provided by Council*

## **2.3. Previous Studies**

A number of flood studies have been undertaken within the catchment area. These studies range from small flood assessments covering limited areas to more complex investigations.

### **2.3.1. Maroubra Bay Flood Study, June 2011**

The Maroubra Bay Flood Study (Reference 3) developed a hydrologic and hydraulic model to determine/quantify flood behaviour in the catchment. While modelling followed best practice at the time, significant improvements in modelling software packages and computational power have been developed in the interim. Consequently, the hydraulic element of the modelling has been converted from MIKE-STORM and SOBEK models to a single TUFLOW model, as part of this current Study. The updated model is discussed further in Section 2.4 while details of flood levels, depths and velocities are shown in Appendix C.

### **2.3.2. Maroubra Bay Assessment of Flood Mitigation Options, July 2010**

The Maroubra Bay Assessment of Flood Mitigation Options (Reference 4) was prepared in response to significant flooding identified in the vicinity of Chapman Avenue, Fenton Avenue and the Maroubra Beach commercial centre. The study used the hydrologic and hydraulic modelling established for the Maroubra Bay Flood Study (Reference 3) to assess a number of flood modification options within the Maroubra Bay catchment. The report recommended a suite of mitigation options costing in the order of \$9 million to address the existing flooding problems

at that location including:

- Lowering of the beach promenade;
- Flood retarding basin in John Shore Park;
- Flood retarding basin in Muraborah Reserve (off Wride Street); and
- Duplication of the drainage network from John Shore Park to the beach outlet.

The report concluded that the proposed works potentially provide significant improvements in terms of flood behaviour and warrant further consideration as part of a Floodplain Risk Management Study for the overall Maroubra Bay catchment.

### **2.3.3. Maroubra Beach Commercial Centre Urban Design Report, August 2011**

Although not specifically related to flooding or flood management, the Maroubra Beach Commercial Centre Urban Design Report (Reference 5) provides master planning and development control provisions for the redevelopment of the Maroubra commercial precinct. The master planning and controls rely on the construction of the works recommended by the Maroubra Bay Assessment of Flood Mitigation Options (Reference 4) in order to facilitate redevelopment of this area.

## **2.4. Flood Study Review and Update**

A key objective of the Maroubra Bay Flood Study (Reference 3) was to produce estimates of design flood behaviour throughout the study catchment. Outcomes facilitate the detailed analysis of potential flood management measures in this current FRMS&P. The Maroubra Bay Flood Study (Reference 3) used the 1D MIKE STORM and 1D/2D SOBEK modelling software packages to simulate hydraulic characteristics of the catchment. Council requested as part of this present study that the hydraulic modelling be redeveloped using the latest TUFLOW 1D/2D hydraulic modelling software.

A summary is provided below and full details of the model revision comprising the initial report and further information on updating flood levels for the full range of design flood events can be found in Appendix B.

The hydrologic component of the modelling for the Maroubra Bay Flood Study (Reference 3) was undertaken using MIKE STORM. Calibration of the MIKE STORM hydrologic model at the time of the Maroubra Bay Flood Study (Reference 3) to historical events provides confidence and no changes were made to the existing hydrologic model. MIKE STORM routed flows were input directly into the TUFLOW hydraulic model.

The Maroubra Bay Flood Study (Reference 3) modelled the drainage network and overland flow paths in the upper portion of the catchment using 1D MIKE STORM software whilst the 1D/2D SOBEK program was used for the lower portions of the catchment. Historical flood data from

1999 and 1959 were used for the model calibration.

To convert the two hydraulic models to one TUFLOW model, data was extracted from the previous models where available. Pits and pipes data were extracted from the SOBEK model as were a number of features in the floodplain. Localised changes to the model schematisation was undertaken to represent changes to the infrastructure on the floodplain. This included the outlet structure at Coral Sea Park retarding basin (constructed circa 2009) and the inlet configuration for the Haig Street trapped low point. Details on the model development are provided in Appendix B.

Results from the TUFLOW modelling are presented in Appendix C and have been used to inform the baseline flood behaviour in this present FRMS study.

## **2.5. Available Data**

The Maroubra Bay Flood Study (Reference 3) provided the majority of data and modelling outputs. ALS survey data was provided by Council and this was used to represent the ground grid used in the TUFLOW model. In addition, a building floor level survey was undertaken by Sydney Surveyors. This survey comprised 641 residential and 56 commercial / other properties (largely public services such as fire station, school, electricity sub-station) with details provided on floor levels and ground level at each property within the 1% AEP flood extent. A number of other properties were identified as vacant or car parks and these details are not provided. The floor level survey was used in identifying potential flood damages for the Maroubra area (see Section 4.4). The database also included details on the number of storeys (to see if residents have a "dry" flood refuge), house size, and floor and wall construction (to see if the house could be raised). For non residential buildings the nature of the business was obtained (to get an idea of the likely magnitude of damages).

## **2.6. Community Consultation**

The FRMS process encourages community participation throughout the process. Community engagement provides information beneficial to the study as well as facilitating the addressing of flood related concerns. Consultation also included interaction with the State Emergency Services (SES) and other interested parties and organisations.

### **2.6.1. Flood Study Community Survey**

As part of the Maroubra Bay Flood Study (Reference 3), a media release community survey was undertaken. Responses received reflected a number of areas within the catchment that have been known to experience overland flooding in the past including:

- A number of trapped low points throughout the catchment – including: Fenton Avenue, Chapman Avenue, Maxwell Avenue, McKeon Street, Marine Parade, French Street and Byrne Crescent;
- Coral Sea Park and some areas of Chester Avenue; and

- Flooding of the car park and surrounding parklands at Arthur Byrne Reserve.

Several respondents provided reports of pit/drain blockages during storms due to rubbish and debris. Evidence of overland flow along the kerb and gutter system being diverted onto property due to the presence of parked cars was also reported.

Of the 35 respondents, one property was identified as having previously flooded above the habitable floor level, six having suffered flooding of the garage and/or non-habitable areas and a further seven had flooding within the property at some time in the past. It is worth noting that the high ratio of flood affected respondents is characteristic of flood surveys where people affected tend to engage in the floodplain management process.

### **2.6.2. Floodplain Management Committee**

A FMC has been formed with the purpose of raising and discussing issues related to the floodplain risk management process. The committee facilitates community input throughout the process from start to finish. The committee includes Councillors, Council engineers and planners, members of the SES, OEH, local residents and other community representatives. During preparation of the draft report, WMAwater held several meetings, including presentations to the committee.

**TO BE UPDATED AFTER COMMUNITY CONSULTATION.**

### **2.6.3. Site Visits**

Several site visits were undertaken by WMAwater and Council staff throughout the duration of the project.

### **2.6.4. Newsletter**

1800 newsletters (Appendix E) were mailed to residents at the start of the FRMS&P project by Council in June 2014. Newsletters informed residents of the Floodplain Management Program and the ongoing work undertaken as part of the FRMS&P including the floor level survey. Residents were provided contact details to raise any concerns or provide comments. Several comments were received following the newsletter including ponding at the corner of Fitzgerald Avenue and Kyogle Street following heavy rain in March 2014.

### **2.6.5. Planned Consultation**

Following endorsement of the draft report by Council and the FMC, the report will be made available for the community during a period of public exhibition. A public workshop will provide the community the opportunity to examine the report and make any comments or suggestions. Formal submissions from the community will be considered by Council and the FMC before finalisation of the FRMS&P.

### 3. FLOOD BEHAVIOUR

The revised hydrological and hydraulic modelling in Appendix B enables the simulation of flooding patterns in Maroubra Bay for a range of design events. Mapping of flood depths, levels and velocities for design events is included in the figures in Appendix C.

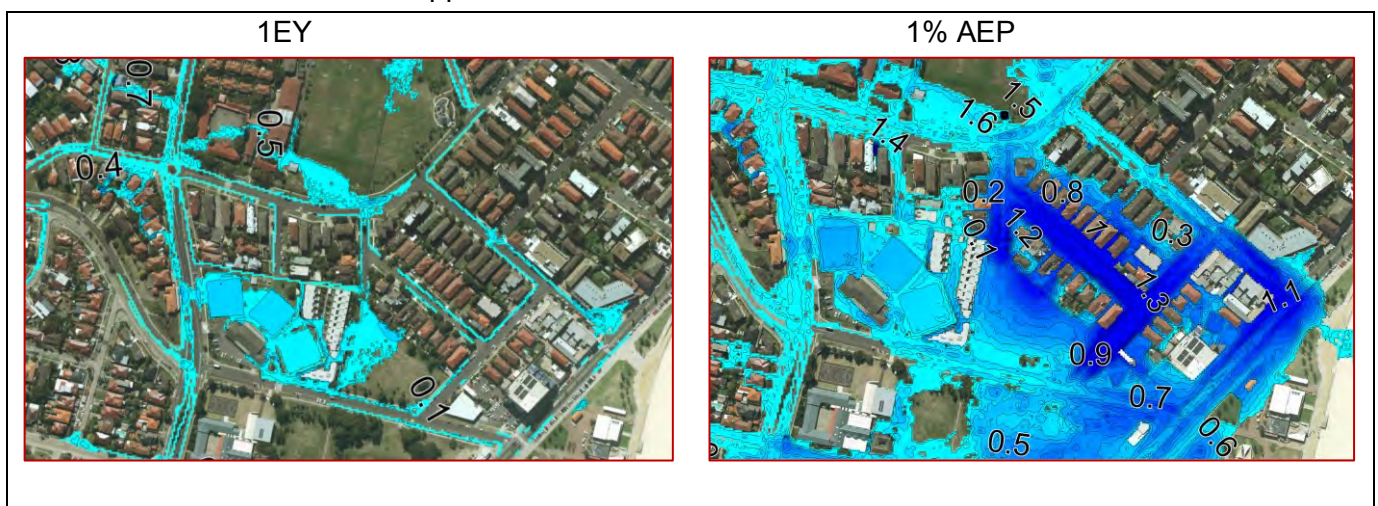
#### 3.1. Flood Mechanisms

Flooding in the study area is characterised by intense rainfall exceeding the capacity of the local drainage infrastructure resulting in overland flow as well as ponding in natural depressions known as trapped low points.

##### 3.1.1. Trapped Low Points

Through a combination of the hydraulic modelling and information provided by the community, a number of trapped low points were identified in the Maroubra Bay Flood Study (Reference 3) and the key ones are shown on Figure 1. These are locations where water cannot drain and begins to pond during heavy rainfall. Being particularly flood prone, these areas are a focus of this FRMS&P. Photograph 3 shows the flood depths and extents in a 1 EY event and a 1% AEP event for the trapped low point at Fenton Avenue / Chapman Avenue.

Photograph 3: Comparison of Peak Depths at Fenton Avenue / Chapman Avenue and Marine Parade / McKeon Street Trapped Low Points



A detailed description of a number of trapped low points is presented in the Flood Study and examples include:

- Fenton Avenue / Chapman Avenue** – located at the downstream end of the Maroubra Bay catchment. This area encompasses residential and commercial development and has experienced significant inundation in January 1999 and October 1959. Areas in the immediate vicinity of Marine Parade, including Fenton Avenue and Chapman Avenue, are lower than the Maroubra Beach berm, causing extensive ponding in these areas.

- **McKeon Street / Marine Parade** – the largest main trunk drainage line within the Maroubra Bay catchment runs along McKeon Street and the stormwater outlet discharges on the beach in front of the McKeon Street / Marine Parade intersection. This area is a known trapped low point suffering previous inundation in the January 1999 event. The area bounded by McKeon Street, Fenton Avenue and Marine Parade is a major retail/commercial centre and contains the Maroubra Seals Club and the Ambulance Station.
- **Byrne Crescent** – located south of Arthur Byrne Reserve and is a known trapped low point.
- **French Street** – located upstream of Marine Parade.
- **Maxwell Avenue** – within the same vicinity as Fenton Avenue and Chapman Avenue.

Modelling undertaken in the Maroubra Bay Flood Study (Reference 3) indicate that for events larger than a 0.2 EY event, the trunk system is surpassed and ponding occurs in Fenton Avenue / Chapman Avenue and McKeon Street / Marine Parade. Overflow from Marine Parade onto Maroubra Beach does not occur until the PMF event. Appendix C provides flood extent and depth mapping.

Figure D1 provides an illustration of the identified hotspots, details of the proposed mitigation measures and resulting benefits are discussed extensively in Section 7, and shown on Figures Figure D2 to Figure D9.

### 3.1.2. Drainage Network Capacity

Once the capacity of the sub-surface drainage system is exceeded, water will surcharge from drains and pits and contribute to overland flows. The hydraulic model enables the assessment of the drainage capacity within the study area and Figure 4 identifies the event at which the capacity of the drainage network shown in Figure 3 is first exceeded. For the majority of the catchment the pipe capacity is 0.2 EY or less.

However it is observed that a number of assets (for example along Malabar Road) do not reach capacity as these assets are constrained by the capacity of downstream pipes. This potential spare capacity has been considered and utilised in the proposed mitigation options.

## 3.2. Design Event Flooding

Peak flood levels for the 1 EY, 0.5 EY, 0.2 EY, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events as well as the PMF are considered. Results are summarised in terms of peak flood levels, depths and velocities and are presented in Appendix C.

- Peak flood depths and level contours are shown in Figure C1 to Figure C10; and
- Peak flood velocities are shown in Figure C11 to Figure C20.

### 3.3. Hydraulic Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to define different areas of the floodplain, namely;

- Floodways;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during flood events and by definition, if blocked would have a significant effect on flood flows, velocities and/or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is usually defined as flood fringe.

There is no quantitative definition of these three categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of an area, hydraulic modelling and previous experiences. A number of approaches, such as that of Howells et al (Reference 6), suggest the use of the product of velocity and depth as well as velocity itself to establish hydraulic categories.

Hydraulic categorisation has been mapped and is shown on Figure 5. The Maroubra Bay Flood Study (Reference 3) defined hydraulic categories according to the following;

- Flood Fringe (base layer):  
*PMF extent for peak depth greater than 0.15 m.*
- Flood Storage (takes precedence over Flood Fringe when overlapping):  
*1% AEP extent for peak depth greater than 0.15 m.*
- Floodway (takes precedence over Flood Fringe and Flood Storage when overlapping):  
*Extent of 1% AEP peak velocity depth product when greater than 0.3 m<sup>2</sup>/s; or  
Extent of 1% AEP peak velocity when greater than 0.5 m/s.*

Hydraulic categories based on the above criteria are considered provisional and need to be considered in detail to ensure a continuous Floodway through the catchment and ensure that areas are not incorrectly identified as being within Floodway or conversely, areas which may be Floodway are included. Small areas of Flood Fringe and Flood Storage surrounded by Floodway ("islands") were re-categorised as Floodway. Conversely, isolated patches of Floodway less than 30 m<sup>2</sup> were re-categorised as Flood Fringe. A manual cross-check of all re-categorised areas was undertaken and the resultant hydraulic categories are mapped on Figure 5.

The majority of floodway definition in the Maroubra Bay catchment is within the road reserves which act as overland flowpaths conveying flows. Much of the floodway is attributed to the velocity criteria. Nevertheless, properties between Maroubra Road and Wride Street are

affected by flows categorised as floodway and similarly a number of properties between Anzac Parade and Coral Sea Park are within the floodway.

### 3.4. Flood Hazard Classification

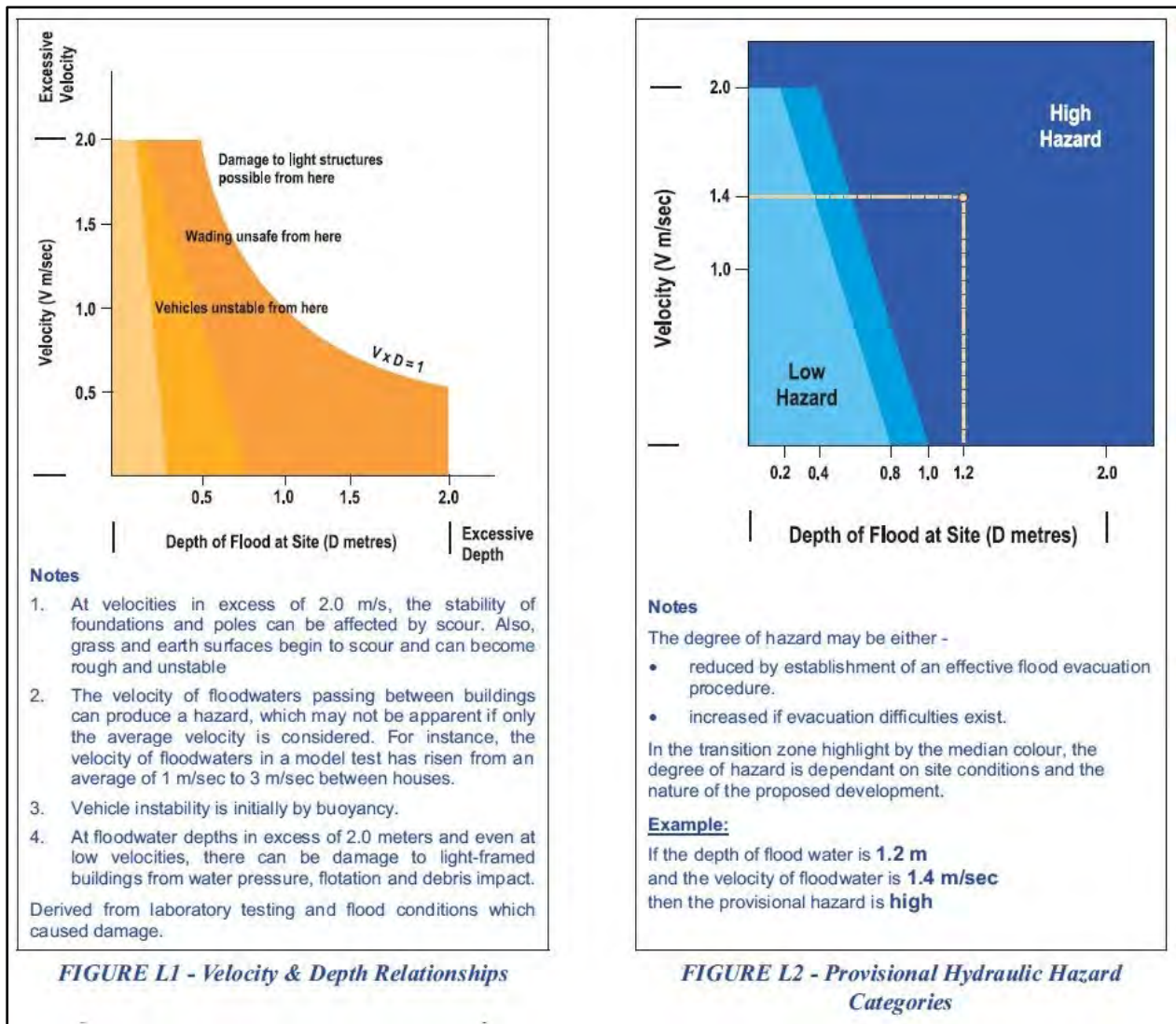
Flood hazard is a quantitative description of the overall adverse effects of flooding and associated risks. The 2005 NSW Government's Floodplain Development Manual (Reference 1) describes two *provisional flood hazard* categories; High and Low, based on the product of the depth and velocity of floodwaters:

**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.*

Provisional hazard categories are only based on depth and velocity (see Diagram 1) and do not take into account any other factors which may influence the flood hazard. True flood hazard takes into account a number of additional flood related criteria, and the provisional hazard is modified accordingly.

Diagram 1: Provisional Flood Hazard Categories



Source: Extracted from the Floodplain Development Manual (Reference 1).

To assess the true flood hazard, a number of other criteria require consideration in addition to provisional (hydraulic) hazard. Table 1 assesses true hazard for the Maroubra area.

Table 1: True Hazard Classification

| Criteria                                                 | Weight <sup>(1)</sup> | Comment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Depth and velocity of floodwaters</b>                 | Medium                | The product of depth and velocity is also termed the provisional hazard (see Diagram 1). These can be influenced by the magnitude of the flood event. At depths of up to 0.3 m, wading should be possible for most mobile adults. This obviously could be more of an issue for children, elderly or disabled people. At velocities over 1 m/s shallow depths may not be a problem, although depths in excess of 1 m would give rise to a high hazard situation.                                                                                                                                                                                                                                   |
| <b>Size of the flood</b>                                 | Medium                | The size or magnitude of the flood can affect depths and velocities. 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. Within the Maroubra Bay study area, flood extents do not scale significantly with event magnitude.                                                                                                                                                                                                                                                                                                                                                        |
| <b>Rate of rise of floodwaters</b>                       | High                  | 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. The faster the onset of flooding the more difficult warning becomes and the quicker evacuation may need to occur. As in many urban situations, the onset of flooding in the Maroubra Bay area can be sudden (in less than one hour) following heavy rainfall.                                                                                                                                                                                                                                                |
| <b>Duration of flooding</b>                              | Low                   | The greater the duration of flooding, the more disruption to the community and potential flood damages. A short period of inundation may allow some materials to dry and recover whereas a long duration may cause damages beyond repair. In terms of direct hazard to people, a longer duration event would give more time for thoughtless behaviour causing risk to life. This is not a significant issue for the Maroubra Bay catchment.                                                                                                                                                                                                                                                       |
| <b>Effective warning and evacuation time</b>             | Medium                | This is dependent on the rate at which waters rise, an effective flood warning system and the awareness and preparedness of the community to act.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Flood awareness and preparedness of the community</b> | High                  | The awareness and preparedness of the community has a high weight in considering flood hazard as a more aware community will be able to better prepare and therefore potentially evacuate before hazards become high. General community awareness / preparedness 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. In areas where flood warning is limited, it is critically important for a community to be flood aware so that an individual can notice the signs of the onset of flooding and prepare for themselves. |
| <b>Effective flood access</b>                            | High                  | The vehicular and pedestrian access routes are all along sealed roads and present no unexpected hazards if the roads have been adequately maintained.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Evacuation problems</b>                               | Low                   | In addition to affected flood access, evacuation problems could also be exacerbated by the time of day during which flooding occurs. The number of people to be evacuated and limited resources of the SES and other rescue services can make evacuation difficult. As there are few significantly flood affected properties in Maroubra, evacuation of streets conducted by the SES is unlikely to occur. Those subject to above floor flooding may choose to locate elsewhere in a flood event.                                                                                                                                                                                                 |
| <b>Type of development</b>                               | Low                   | The type of flood prone development is useful to understand the likely level of occupant awareness and preparedness, mobility of people as well as population                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Criteria                   | Weight <sup>(1)</sup> | Comment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                            |                       | density. Longer term home owners would likely have a better level of flood awareness and preparedness than a guest at a hotel for example. Alternatively, residents from a residential care home are likely to be less mobile than average. In addition, the construction type can affect hazard. Older timber structures are more likely to be susceptible to flood damages.                                                                                                                                        |
| <b>Additional Concerns</b> | Low                   | <p>The impact of debris is unlikely to be a significant factor due to the low flood depths and/or velocities. However, there is always concern over floating debris causing injury to wading pedestrians or structural damages to property. Floating debris, vehicles or other items can increase hazard.</p> <p>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. Sewerage overflows can occur.</p> |

<sup>(1)</sup> Relative weighting in assessing the hazard for Maroubra Bay catchment

The flood hazard for the study area varies by location based on the relative depths, velocities and other factors. Figure 6 and Figure 7 show the true flood hazard for the 1% AEP and PMF events respectively based on the discussions in Table 1. All provisional high hazard areas with inundation depths below 150 mm were re-categorised as low hazard. Furthermore isolated high hazard patches less than 30 m<sup>2</sup> were re-categorised as low hazard. Conversely, small areas of low hazard surrounded by high hazard ("islands") were re-categorised as high hazard. A manual cross-check of all re-categorised areas was also undertaken.

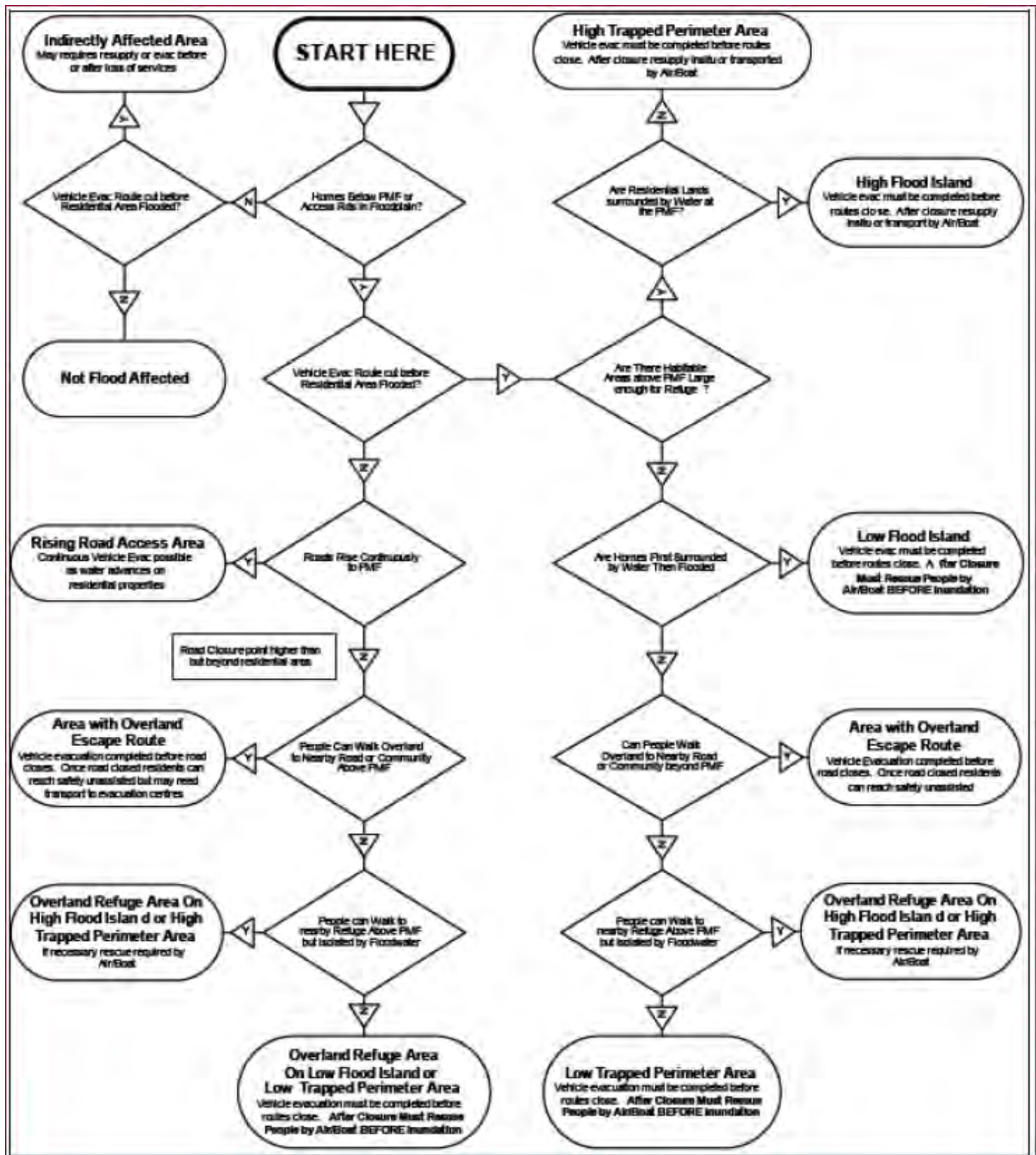
### 3.5. Flood Emergency Response Planning

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH have developed guidelines to classify communities according to the impact that flooding has upon them. These Emergency Response Planning (ERP) classifications (Reference 7) 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. The ERP classification (flow chart shown in Diagram 2) can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 2). They are based on modelling of design event flooding.

Table 2: Emergency Response Planning Classifications of Communities

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

Diagram 2: Preliminary Flow Chart for Emergency Response Classification



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 of the study area have been classified according to the ERP classification and Preliminary flow chart (Diagram 2) above for the 1% AEP and PMF events as shown in Figure 8 and Figure 9 respectively. Note that shallow flood depths below 150 mm were considered to not affect egress.

Most of the upper study area is considered as being indirectly affected or unaffected. Those flood prone areas of Maroubra generally have Rising Road Access or Overland Escape Routes. Low flood islands are concentrated around the downstream section of the catchment around John Shore Park and Broadarrow Reserve. Some properties south-east of Coral Sea Park are also classified as Low Flood Islands. The remaining flood affected areas are all classified as Rising Road Access. For the PMF event, the majority of residential areas downstream of Coral Sea Park are classified as Low Flood Island as well as areas proximate The Causeway and the Haig Street cul-de-sac. The rest of areas are Rising Road Access with the exception of the area between Malabar Road and Curtin Crescent as well as some residences along Kyogle Street which only have Overland Escape Route.

Understanding flood access issues is critical to effective evacuation and flood response planning. Even at shallow depths, fast flowing velocities can occur when flood water overtops a bridge deck or a road for example. Furthermore, once flooding has subsided, if there is significant damage to a road or water crossing then even though it may be no longer flooded, structural damage could make use unsafe. Knowing the likely timing of road closures and depths of flooding on roads can aid flood response planning, and ensure that evacuation occurs in a timely fashion before the depth of flooding hinders the evacuation process or rescue boats and helicopters are required, which may not always be available. This scenario is unlikely in the Maroubra Bay catchment given the short duration of flooding.

### **3.6. Flood Awareness / Preparedness and Flood Warning**

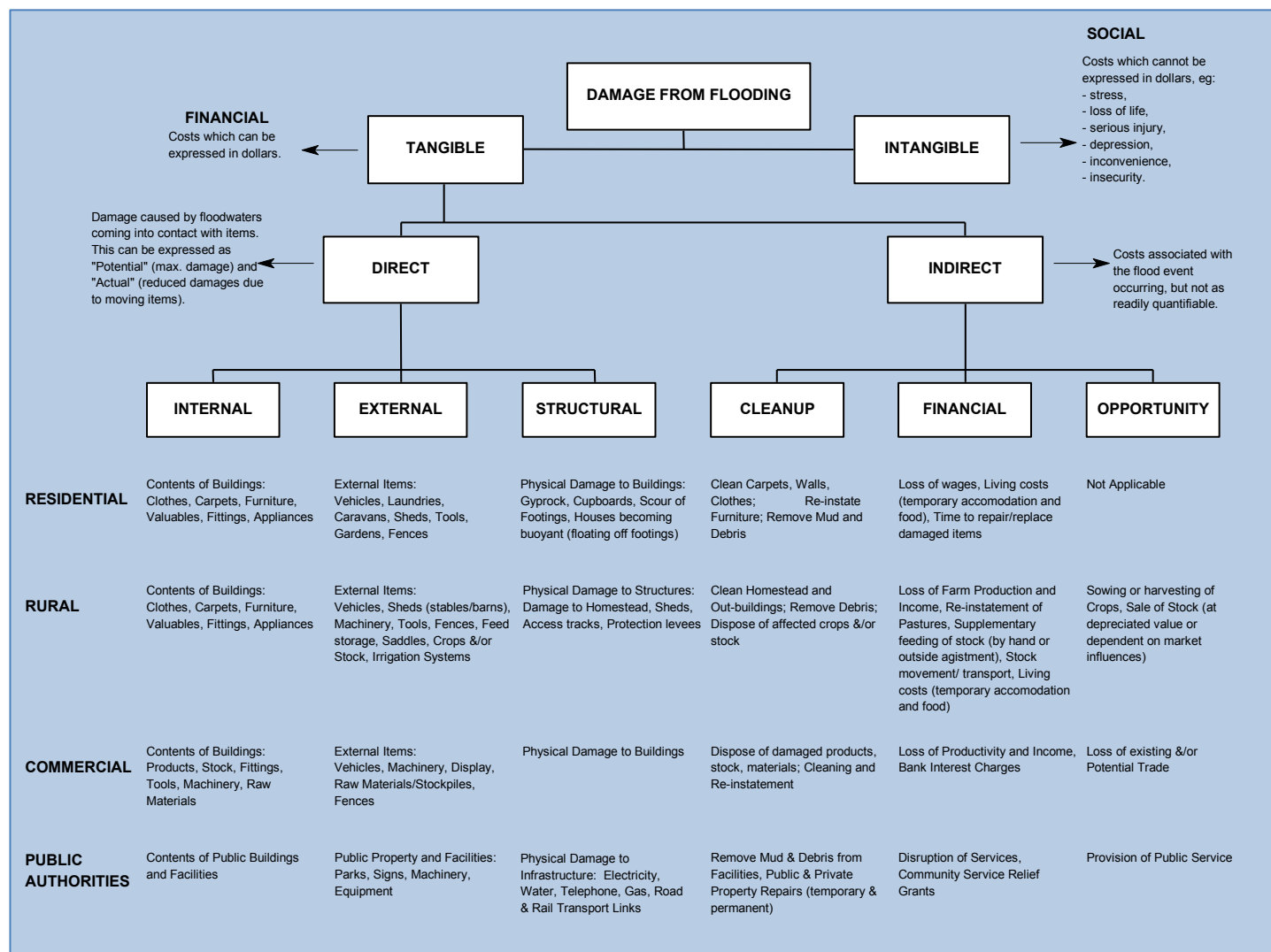
The flood awareness and preparedness of the community and the available flood warning time are important factors in reducing the potential flood damages. Based on the limited community feedback obtained (phone calls, discussions) and past experience in similar urban areas it is likely that the community has a relatively low flood awareness and preparedness. Nonetheless a number of residents have noted ponding in a number of the trapped low spots within the Maroubra Bay area. People are often aware of small high recurrence interval events and associated flooding and flood behaviour and are often unprepared for the impacts of a higher magnitude flood such as the 1% AEP event.

There is no specific flood warning system for the Maroubra Bay area and the nature of flooding often does not allow sufficient time for warning. The relative lack of awareness and preparedness combined with a very short warning time characterises flood risk in urbanised areas. Consequently, as warning times are limited, a strong emphasis should be put on community flood awareness and preparedness as a risk management measure.

## 4. IMPACTS OF FLOODING

Flooding has the potential to impact on a wide range of structures, services and activities and these are summarised in Table 3.

Table 3: Flood Damages Categories (adapted from Reference 1)



### 4.1. Public Infrastructure

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, substations and underground cables; roads and bridges including traffic lights/signs; and costs to employ the emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to councils from flooding typically comprise;

- clean-up costs;

- erosion and siltation;
- removal of fallen trees;
- inundation of Council buildings;
- direct damage to roads, bridges and culverts;
- removal of vehicles washed away;
- assistance to ratepayers;
- increases in insurance premiums;
- closures of streets;
- loss of working life of road pavements; and
- operational costs in the lead up to and during flood events.

The flood damages assessment does not typically include damages to public infrastructure as they can vary significantly.

As re-development occurs measures to mitigate the impacts of flooding can be incorporated into building design encouraged through planning controls, for example flood proofing (see Section 8.4) which can reduce impacts over time. However, these measures cannot necessarily improve the existing situation and other more immediate measures may need consideration for existing public infrastructure.

## 4.2. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents or damage to the structure of the property. Indirect damage costs can be incurred by property occupiers from having to move away from the property while repairs are being made. A damages assessment has been undertaken for the residential properties in Section 4.4 below. Table 4 summarises the number of properties affected for each design event while Figure 10 identifies the design event which first inundates the lowest building floor level on the property.

Table 4: Property Flood Affection

| Event            | Number of Properties Flooded<br>Below Floor Level |            |       | Number of Properties Flooded<br>Above Floor Level |            |       |
|------------------|---------------------------------------------------|------------|-------|---------------------------------------------------|------------|-------|
|                  | Residential                                       | Commercial | TOTAL | Residential                                       | Commercial | TOTAL |
| <b>PMF</b>       | 350                                               | 35         | 385   | 143                                               | 27         | 170   |
| <b>0.2 % AEP</b> | 238                                               | 26         | 264   | 88                                                | 20         | 108   |
| <b>0.5 % AEP</b> | 223                                               | 26         | 249   | 81                                                | 18         | 99    |
| <b>1 % AEP</b>   | 211                                               | 23         | 234   | 74                                                | 15         | 89    |
| <b>2 % AEP</b>   | 186                                               | 20         | 206   | 59                                                | 12         | 71    |
| <b>5 % AEP</b>   | 159                                               | 16         | 175   | 46                                                | 11         | 57    |
| <b>10 % AEP</b>  | 132                                               | 13         | 145   | 28                                                | 5          | 33    |
| <b>0.2 EY</b>    | 111                                               | 10         | 121   | 17                                                | 2          | 19    |
| <b>0.5 EY</b>    | 38                                                | 3          | 41    | 4                                                 | 0          | 4     |

Table 5 provides the maximum and average depth of above floor inundation for both residential

and commercial properties for each design event.

Table 5: Maximum and Average Above Floor Depth of Inundation

| Event            | RESIDENTIAL<br>Depth (m) Above Floor |         | COMMERCIAL<br>Depth (m) Above Floor |         |
|------------------|--------------------------------------|---------|-------------------------------------|---------|
|                  | Maximum                              | Average | Maximum                             | Average |
| <b>PMF</b>       | 4.1                                  | 0.8     | 2.0                                 | 1.2     |
| <b>0.2 % AEP</b> | 4.0                                  | 0.5     | 1.2                                 | 0.6     |
| <b>0.5 % AEP</b> | 1.2                                  | 0.3     | 1.0                                 | 0.5     |
| <b>1 % AEP</b>   | 1.1                                  | 0.3     | 0.9                                 | 0.5     |
| <b>2 % AEP</b>   | 0.9                                  | 0.2     | 0.8                                 | 0.4     |
| <b>5 % AEP</b>   | 0.7                                  | 0.2     | 0.6                                 | 0.3     |
| <b>10 % AEP</b>  | 0.4                                  | 0.1     | 0.1                                 | 0.0     |
| <b>0.2 EY</b>    | 0.2                                  | 0.1     | 0.0                                 | 0.0     |
| <b>0.5 EY</b>    | 0.1                                  | 0.1     | 0.0                                 | 0.0     |

### 4.3. Commercial and Industrial Properties

Of the surveyed floor levels in the Maroubra study area 41 were commercial (6% of the total surveyed buildings) and a further 14 (2%) were other uses such as schools or churches. Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of commercial activity;

- Type of business – stock based or not, costs of damages to goods;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself is closed but when access to it becomes available;
- Ability to move stock or assets before the onset of flooding – constraints such as large machinery and insufficient warning time can lead to significant losses; and
- Ability to transfer business to a temporary location.

Of the non-residential buildings from the survey, 52% were mixed with residential upstairs. A summary of the types of non-residential buildings surveyed is provided in Table 6.

Table 6: Summary of Non Residential Building Types

| Type               | % of Total |
|--------------------|------------|
| <b>Food</b>        | 19%        |
| <b>Service</b>     | 34%        |
| <b>Shop</b>        | 16%        |
| <b>Vehicle</b>     | 2%         |
| <b>Educational</b> | 7%         |
| <b>Medical</b>     | 5%         |
| <b>Vacant</b>      | 5%         |
| <b>Mixed</b>       | 9%         |
| <b>Utility</b>     | 3%         |

A flood damages assessment was undertaken for these non-residential properties and is discussed below. While commercial damages have been considered, it should be noted that the Floodplain Management Program puts emphasis on prioritising protection of existing residential dwellings. Consequently, Councils often apply less stringent flood related development controls to commercial properties making them more liable to flood damages.

Commercial flood damages are more complex in nature and the tangible flood damage to commercial and industrial properties is more difficult to assess. The value of damages to commercial properties is much more varied than for residential properties and damage estimates can vary significantly.

The duration of flooding and flood depths can affect businesses differently. For example shorter duration flooding may allow businesses to re-open to trade again. If the short duration flooding is deep and causes property and stock damage then it may take some time for businesses to re-open. Some businesses are also able to operate temporarily from a different location, often albeit at a reduced capacity, such as the majority of office type businesses. Whether staff are able to get to work or have had flooding issues of their own at home also plays a part in recovery for commercial practices. The type of business also plays a major part in the impacts of flooding. For example a high quality goods electrical store may suffer more damages in terms of loss of stock compared to a stationery store. Where sufficient warning is available, businesses may be able to move stock and assets to higher levels to prevent flood damages. Businesses may also be able to implement contingency plans which allow them to work from another location while their property is inundated. However, depending on the type of commercial or industrial activity this may not always be possible.

Following the Sydney floods of 1986 a survey of damaged properties was undertaken and the result analysed (Reference 8). It was found that the commercial and industrial damages were between 3 and 27 times higher than residential damages. The amount varied considerably depending on the number and type of businesses, size of business, location of properties and extents of development within the floodplain. A number of assumptions were also made in calculating the damages for the Sydney 1986 flood, such as assuming commercial indirect losses to be 55% of direct losses whilst this was only assumed at 15% for residential properties. Where there was a higher ratio of commercial to residential properties flooded (the Georges River catchment for example) the average damage for commercial and industrial properties was three times higher than that for residential properties. After the Nyngan floods of 1990, the average damage to commercial properties was estimated to be approximately 4.4 times higher than the average damage to residential properties (Reference 9). Of damage to commercial properties, indirect financial damages were a major component accounting for 70% of commercial damages. This reflected the long period during which commercial establishments were not trading or trading at reduced levels; a total of ten weeks in many parts. In the Maroubra Bay area, flooding to commercial and industrial properties is likely to be shallow due to the overland flow nature of flooding as opposed to the mainstream nature of the flooding events referred to above.

## 4.4. Flood Damages Assessment

### 4.4.1. Tangible Flood Damages

A flood damages assessment was undertaken for the 641 residential and 56 non-residential properties with floor level data available from the floor level survey. The assessment was undertaken based on the guidelines for residential damages provided by OEH (Reference 10 with details in Appendix F). The standard residential damages curves were used for residential properties and were adjusted to allow for the greater damages non-residential properties are likely to suffer.

Table 7 shows the potential damages for the range of design events and the resulting Annual Average Damage (AAD). This forms the base case scenario against which potential damages for a number of mitigation measures have been assessed.

Table 7: Potential Flood Damages – Existing Design Event Scenarios

| Event            | Residential       | Non-Residential   | Combined Damages  | Contribution to AAD | % of Residential Contribution to Damages |
|------------------|-------------------|-------------------|-------------------|---------------------|------------------------------------------|
| <b>PMF</b>       | \$ 9,871,700      | \$ 4,612,100      | \$14,483,900      | 3%                  | 68%                                      |
| <b>0.2 % AEP</b> | \$ 5,531,400      | \$ 2,747,800      | \$ 8,279,200      | 3%                  | 67%                                      |
| <b>0.5 % AEP</b> | \$ 4,753,800      | \$ 2,387,700      | \$ 7,141,500      | 4%                  | 67%                                      |
| <b>1 % AEP</b>   | \$ 4,176,400      | \$ 1,756,000      | \$ 5,932,400      | 7%                  | 70%                                      |
| <b>2 % AEP</b>   | \$ 3,237,700      | \$ 1,522,500      | \$ 4,760,200      | 16%                 | 68%                                      |
| <b>5 % AEP</b>   | \$ 2,498,300      | \$ 1,285,200      | \$ 3,783,600      | 17%                 | 66%                                      |
| <b>10 % AEP</b>  | \$ 1,516,000      | \$ 294,500        | \$ 1,810,500      | 18%                 | 84%                                      |
| <b>0.2 EY</b>    | \$ 1,020,100      | \$ 42,900         | \$ 1,062,900      | 24%                 | 96%                                      |
| <b>0.5 EY</b>    | \$ 230,400        | \$ 10,200         | \$ 240,600        | 8%                  | 96%                                      |
| <b>AAD</b>       | <b>\$ 648,500</b> | <b>\$ 150,800</b> | <b>\$ 799,300</b> |                     | 81%                                      |

The small magnitude events such as the 0.5 EY and 0.2 EY events contribute to a large percentage of the AAD (a general rule of thumb is that events up to the 0.2 EY contribute to approximately 30% of the AAD). This is indicative of frequent flash flooding type issues within an urban catchment. However, the FRMS&P process typically places emphasis on the 1% AEP event when considering flood management options. Consequently, it is important for Council to consider smaller events hence the inclusion of smaller events in the benefit / cost calculations for the respective mitigation measures considered.

Although non-residential properties make up about 8% of those included in the floor level survey, non-residential damages account for some 20% of the total AAD. This is attributable to

the higher value of damages incurred by commercial properties relative to residential properties.

#### **4.4.2. Intangible Flood Damages**

Intangible damages are those to which a monetary value cannot be assigned and include additional costs/damages 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. They are dependent on a range of factors such as the size of flood, the individuals affected, community preparedness and sentimental values. 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 affected 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.

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. There will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas. Due to the nature of flooding in the study areas, severe health issues and deaths are unlikely. The most likely intangible damage is stress caused to residents by frequent shallow flooding.

Flooding has occurred many times in the past and thus it is unlikely that it will have any significant impact on heritage or biodiversity within the catchment.

#### **4.5. Implications of Future Climate Change**

The Sydney Coastal Councils Group (SCCG) (Reference 11) considered the vulnerability of Councils in Sydney's coastal areas to climate change. The assessment included extreme heat and health effects, sea-level rise and coastal management, extreme rainfall and stormwater management, bushfire as well as affects on ecosystems and natural resources.

For the Randwick City Council LGA, the study concluded that *“Randwick City Council possesses a high degree of vulnerability to climate change relative to other Councils within the SCCG region. Relatively extensive development conspires with high average rainfall and projected increases in future rainfall extremes to create high vulnerability to extreme rainfall events and*

challenges for stormwater management. Development also limits the resilience of natural ecosystems to climate change. Due to its coastlines and coastal development, vulnerability to sea-level rise and coastal hazards was assessed to be moderate to high, although significant land areas in the LGA are not exposed to coastal hazards. Nevertheless, adaptive capacity in Randwick City Council was judged to be relatively high.”.

As well as considering increases in development in the future, the potential impacts of climate change need to be considered. In terms of increased flood risk it is anticipated that climate change will increase flooding in two ways; increases in sea level and increases to rainfall intensity.

Randwick City Council has adopted the sea level rise predictions of 0.4 m by 2050 and 0.9 m by 2100. The implications of similar such rises in sea level were tested in the hydraulic model (0.55 m and 0.91 m in Reference 3) and increases in the 1% AEP flood extent due to the respective sea level rises indicated no significant changes in peak flows or peak flood levels.

The Maroubra Bay catchment would be likely to see increases in flooding due to projected increases in rainfall intensity. The hydrologic and hydraulic models were used to identify the impact of an increase in rainfall intensity on the peak flood levels for the 1% AEP event. Figure C22, Table 8 and Table 9 illustrates the respective impacts of a 10%, 20% and 30% rainfall increase on the 1% AEP flood extent.

Table 8: Summary of Rainfall Increase Results 1% AEP (at the 21 sites indicated on Figure 1)

| Increase Greater Than (m) | 10% Increase |     | 20% Increase |     | 30% Increase |     |
|---------------------------|--------------|-----|--------------|-----|--------------|-----|
|                           | No           | %   | No           | %   | No           | %   |
| <b>0.05</b>               | 9            | 43% | 11           | 52% | 16           | 76% |
| <b>0.1</b>                | 6            | 29% | 7            | 33% | 9            | 43% |
| <b>0.2</b>                | 0            |     | 5            | 24% | 5            | 24% |
| <b>0.3</b>                |              |     | 0            |     | 5            | 24% |
| <b>0.4</b>                |              |     |              |     | 0            |     |

For example for a 20% rainfall increase 11 of the 21 sites (52%) show an increase of 0.05m or greater in the 1% AEP and 5 (24%) show an increase of 0.2m or greater.

Table 9: Summary of Increase in Affection and Damages for Rainfall Increase (1% AEP)

|              | Buildings Inundated |            |             |            | Land Inundated |            |             |            |             |            |
|--------------|---------------------|------------|-------------|------------|----------------|------------|-------------|------------|-------------|------------|
|              | Commercial          |            | Residential |            | Commercial     |            | Residential |            |             |            |
| Scenario     | No                  | % increase | No          | % increase | No             | % increase | No          | % increase | Damages     | % increase |
| Existing     | 15                  |            | 74          |            | 23             |            | 211         |            | \$5,932,400 |            |
| 10% Increase | 18                  | 20%        | 81          | 9%         | 25             | 9%         | 223         | 6%         | \$7,138,700 | 20%        |
| 20% Increase | 18                  | 20%        | 81          | 9%         | 26             | 13%        | 223         | 6%         | \$7,140,700 | 20%        |
| 30% Increase | 18                  | 20%        | 81          | 9%         | 26             | 13%        | 223         | 6%         | \$7,141,400 | 20%        |

In conclusion sea level rise will have no significant impact on peak flood levels and extents but rainfall increase will increase flood levels throughout the Maroubra Bay catchment.

#### **4.6. Implications of Future Development**

Future development can cause hydrological impacts such as increased runoff due to increased area of impermeable land cover, as well as hydraulic impacts due to diversions of flows by blocking floodways or displacement of water in flood storage areas. Appropriate land zoning, planning and development controls can reduce these impacts. Good planning controls will mean that as areas regenerate they may become more flood compatible as developers are required to consider runoff from sites and impacts on overland flow paths and flood storage areas.

The Maroubra Beach Commercial Centre Urban Design Report (Reference 5) provides master planning and development control provisions for the redevelopment of the Maroubra commercial precinct and relies on the construction of the works investigated and recommended by the Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) in order to facilitate redevelopment of this area. These works include;

- Lowering of the beach promenade;
- Flood retarding basin in John Shore Park;
- Flood retarding basin in Muraborah Reserve; and
- Duplication of the drainage network from John Shore to the beach outlet.

## 5. EXISTING FLOODPLAIN MANAGEMENT

This chapter considers the existing floodplain management within the Maroubra Bay study area in terms of both policy and planning as well as flood response. Structural flood management features are also considered.

### 5.1. Legislative and Planning Management

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, designed to ensure that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. These can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Policies have been discussed below and subsequently reviewed in regard to flood risk management to identify potential improvements.

#### 5.1.1. NSW Government Flood Prone Land Policy

Flooding in NSW is managed in accordance with the NSW Government's Flood Prone Lands Policy. The primary objective of this policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property as well as reduce private and public losses resulting from floods. This is achieved by undertaking studies to quantify flooding risks and potential measures in accordance with the NSW Government's Floodplain Development Manual (Reference 1) and subsequently implementing the recommended measures.

#### 5.1.2. Randwick Local Environmental Plan 2012

A LEP comprises a written Instrument and a range of maps. It is made by Council, in consultation with the community, and approved by the NSW Minister for Planning, under the Environmental Planning and Assessment Act 1979. The Randwick LEP 2012 (Reference 12) covers the whole Randwick City Council LGA, including Maroubra Bay. The Randwick LEP provides the main legal (or statutory) document for planning in Randwick. It controls how land is used (via land use zones) and sets out provisions for how land can be developed. It also contains provisions to conserve Randwick's heritage and protect sensitive land. Clauses 6.3, Flood Planning, and 6.4, Stormwater Management, are particularly relevant to this study.

Clause 6.3 of the Randwick LEP 2012 utilises modelling outputs for flood planning and applies to *“land identified as being within the “Flood Planning Area” on the Flood Planning Map and other land at or below the Flood Planning Level”* (FPL). The FPL is defined as *“the level of a 1:100 ARI (1% AEP) flood event plus 0.5 metre freeboard.”*. The objective of this clause seeks:

- (a) to minimise the flood risk to life and property associated with the use of land,
- (b) to allow development on land that is compatible with the land's flood hazard, taking

- into account projected changes as a result of climate change,*
- *(c) to avoid significant adverse impacts on flood behaviour and the environment.*

*Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:*

- (a) is compatible with the flood hazard of the land, and*
- (b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
- (c) incorporates appropriate measures to manage risk to life from flood, and*
- (d) will not 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*
- (e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

*A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.*

*In this clause: **flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

Clause 6.4 relates to managing stormwater within the Randwick LGA. It applies to all land in residential, business and industrial zones and has the objective to minimise the impacts of urban stormwater on land to which this clause applies and on adjoining properties, native bushland and receiving waters. In order to meet this objective, development will not be granted unless Council is satisfied that the development:

- (a) is designed to maximise the use of water permeable surfaces on the land having regard to the soil characteristics affecting on-site infiltration of water, and*
- (b) includes, if practicable, on-site stormwater retention for use as an alternative supply to mains water, groundwater or river water, and*
- (c) avoids any significant adverse impacts of stormwater runoff on adjoining properties, native bushland and receiving waters, or if that impact cannot be reasonably avoided, minimises and mitigates the impact.*

### **5.1.3. Randwick Comprehensive Development Controls Plan, 2013**

A DCP provides detailed planning and design guidance for new development and supplements the provisions of the LEP. Randwick DCP 2013 (Reference 13) formally commenced in June 2013, replacing all other DCPs and some Council planning policies. General Controls Part B8 refers to water management and includes controls on stormwater management and flooding as well as other water related issues such as groundwater and water quality and has an overall focus on Water Sensitive Urban Design (WSUD) (Section 0).

Part B8, Section 3, of the DCP supports the provisions for stormwater management included in Randwick's LEP 2012. It makes a number of requirements for sediment control from new developments so as to ensure the stormwater runoff is of suitable quality to protect the amenity of receiving watercourses and coastlines. In addition, the DCP stipulates requirements for on-site stormwater detention (OSD) with reference to Council's Private Storm Water Code (see Section 5.1.5). It aims to control the release of private stormwater entering the drainage system to maintain its capacity. Consideration is also given to managing water during the construction phase of development.

For all developments in proximity to public stormwater or inter-allotment drainage<sup>1</sup> and all developments proposing new connections to Council's drainage system, a number of controls are used to ensure stormwater infrastructure is designed to an acceptable standard to prevent adverse impacts of development on the performance and serviceability of the existing drainage systems. Design and installation of drainage infrastructure is to be in accordance with Council's Private Storm Water Code (see Section 5.1.5). Separate approval is required for development proposing to connect private stormwater to the public drainage system and drainage easements may be required for development impacting existing Council stormwater infrastructure or on an inter-allotment drainage line.

Part B8, Section 5, of the DCP supports the provisions of Randwick's LEP with regard to flooding and also provides controls for development consistent with the NSW Government's Flood Prone Land Policy (see Section 5.1.1) and the Floodplain Development Manual (Reference 1). Development controls set out in this part of the DCP apply to:

- *Residential development on land below the 1% Annual Exceedance Probability (AEP) flood plus the required freeboard, and*
- *All other development on land below the Probable Maximum Flood (PMF) plus the required freeboard*

The objectives are to:

- To control development at risk of flooding in accordance with the NSW Government's Floodplain Development Manual.
- To ensure that the economic and social costs which may arise from damage to property due to flooding is minimised and can be reasonably managed by the property owner and general community.
- To reduce the risk to human life and damage to property caused by flooding by controlling development on land impacted by potential floods.
- To ensure that development is appropriately sited and designed according to the site's sensitivity to flood risk.

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<sup>1</sup> Inter-allotment drainage lines carry stormwater from more than one lot across private property before connecting to the public stormwater system.

Controls set in the DCP require development to also comply with any catchment specific controls in an adopted FRMP in addition to the controls set out in the DCP.

The Development controls are sub divided into the following sub-headings, each with their own Objectives and Controls.

- Flood Studies and Plans;
- Flood Effects;
- Floor Levels;
- Building Components;
- Driveway Access and Car Parking;
- Safety and Evacuation;
- Management and Design.

Specific controls relating to finished floor levels are dependent on the type of development and type of flooding and Council requires that a registered surveyor certify that the floor levels are not less than the required level. Minimum required levels are presented in Table 10 below.

Table 10: Floor Levels For Buildings, Randwick Comprehensive DCP

| Scenario                                                                                                      | Floor level                                                                                          |
|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| <b>Habitable Floors - all development (excluding critical facilities)</b>                                     |                                                                                                      |
| Inundated by flooding                                                                                         | 1% AEP + 0.5m freeboard                                                                              |
| Inundated by overland flow path                                                                               | Two times the depth of flow in the 1% AEP flood with a minimum of 0.3m above the surrounding surface |
| <b>Habitable floors - Critical facilities</b>                                                                 |                                                                                                      |
| Inundated by flooding                                                                                         | PMF + 0.5m freeboard                                                                                 |
| Inundated by overland flow path                                                                               | Two times the depth of flow in the PMF with a minimum of 0.3m above the surrounding surface          |
| <b>Non-habitable floors – residential outbuildings (excluding garages) *</b>                                  |                                                                                                      |
| Gross floor area less than or equal to 10 square metres.                                                      | 1% AEP but not less than 0.15m above surrounding ground level                                        |
| Gross floor area greater than 10 square meters.                                                               | The applicable habitable floor level                                                                 |
| <b>Non-habitable floors – Industrial and commercial</b>                                                       |                                                                                                      |
| Located on flooding or overland flow path                                                                     | 1% AEP but not less than 0.15m above surrounding ground level                                        |
| <b>Material storage locations – all development</b>                                                           |                                                                                                      |
| Materials sensitive to flood damage, or which may cause pollution or be potentially hazardous during flooding | 1% AEP + 0.5m freeboard                                                                              |

*Extracted from Randwick Comprehensive DCP 2013 (Reference 13)*

#### **5.1.4. Flooding Advice and Flood Related Development Controls Policy**

Council's Flooding Advice and Flood Related Development Controls Policy (Reference 13) was adopted by Council on the 28<sup>th</sup> of February 2012. The overall objective of this policy is to provide guidance on flooding related matters as the catchments in Randwick's LGA are progressively studied. The Policy is used to establish interim flood related development controls in situations where a Council commissioned Flood Study exists but no Floodplain Risk Management Study and Plan has been adopted by Council. As such, the flood related development controls applied in any DA are as outlined in the Policy, until such time as this FRMS&P is formally adopted by Council. Development controls are applicable to all land below the 1% AEP flood level plus 0.5 m freeboard.

The Policy recognises that certain types of development have a post disaster function or specific evacuation needs during a flood event. Such facilities include schools, hospitals, nursing homes, retirement villages, aged care facilities, SES headquarters, evacuation centres, major utility facilities and emergency response facilities. These types of facilities need to consider safety issues for all floods up to and including the PMF and flood related development controls apply even if land is above the 1% AEP flood level plus 0.5 m, where it is below the PMF.

Flood related development controls are in accordance with the Floodplain Development Manual (Reference 1) and seek to ensure;

- That development causes no adverse impact on flooding, up to and including the 1% AEP flood;
- Safety of people and emergency access for all floods up to and including the PMF;
- Structural soundness and flood compatibility of building materials for all structures below the 1% AEP flood plus 0.5 m freeboard;
- Commercial flood levels and habitable residential floor levels are to be no less than the 1% AEP flood plus 0.5 m freeboard – note that this contradicts the floor level requirements set out in Randwick Comprehensive DCP (see Section 5.1.3); and
- Open car parking spaces or car ports to be no lower than the 5% AEP flood; and
- All other floor levels are to be determined on merit.

The Policy also sets out what flood related information is prescribed under section 149 of the Environmental Planning and Assessment Act 1979 and the Environmental Planning and Assessment Regulation 2000 to be included on the S149(2) certificate and what additional information may be provided on S149(5).

#### **5.1.5. Randwick Council's Private Stormwater Code**

Randwick Council issued the Private Stormwater Code in March 2013 (Reference 14). This Code outlines Council's objectives and requirements for the disposal of private stormwater within the City of Randwick. It is based largely on the methodologies and data provided in Australian Rainfall and Runoff Volume I & II (Reference 15). The objectives of the code are:

- To provide designers, developers, builders and the general public with a guide to Council's requirements for the disposal of private stormwater;
- To prevent damage to both Council and private property and to prevent nuisance and risk to the public, by controlling the disposal of stormwater from private properties;
- To reduce the impact of new development on Council's stormwater system; and
- To direct stormwater back into the ground through infiltration where possible.

Council's OSD policy (applies to all properties except single dwelling houses) ensures that in the critical 5% AEP (20 year ARI) event the lesser of the calculated permissible site discharge or a rate of 25 litres per second is discharged to the kerb and gutter system. For events greater than the 5% AEP (20 year ARI) event an overflow system is to be constructed. New houses are required to provide an infiltration area of at least 5m<sup>2</sup> with overflow to the street.

#### **5.1.6. Randwick City Council Sea Level Rise Considerations**

In October 2009, the NSW Government issued a Sea Level Rise Policy Statement with the best international projection of sea level rise along the NSW coast being an increase of 0.4 m between 1990 and 2050 and an increase of 0.9 m by 2100 based on data from the Intergovernmental Panel on Climate Change (IPCC). However, since then, the NSW Government subsequently issued a statement that Councils are responsible for adopting their own estimates of sea level rise. Randwick Council has adopted the sea level rise benchmarks of 0.4 m increase by 2050 and 0.9 m increase by 2100.

### **5.2. Existing Structural Flood Management Measures**

A number of floodplain management measures have been undertaken over time in order to attempt to relieve localised flooding issues including the use of the Coral Sea Park flood retarding basin. The options investigated in Section 7 aim to supplement these measures so as to reduce the overall impact from flooding in the Maroubra Bay catchment.

Council also undertakes minor stormwater works such as the extension or improvement of stormwater pits and pipes. These works are specific to an area and address local drainage and not catchment wide issues. No major stormwater upgrade works such as trunk drainage amplification works have been undertaken in recent years.

Council also has existing maintenance protocols including annual cleaning of every pit as well as more frequent cleaning of critical pits.

### **5.3. Flood Warning, Evacuation and Response**

Timely flood warning and efficient flood evacuation and response is vital in reducing flood damages. As with all urban catchments in the Sydney basin there is no official Bureau of Meteorology (BoM) warning system for the catchment due to the short time from rain falling until flooding occurs. Severe Weather Warnings and Flood Watches and Warnings are issued by the

BoM. Evacuation warnings and orders are issued by the SES. The SES is the legislated combat agency for floods in NSW and is responsible for the control of flood response operations.

The SES maintains a flood intelligence system based on key flood warning gauges in NSW and develops specific flood emergency plans for LGAs which are subject to flooding. There are no flood gauges within the study area catchment and thus no flood intelligence system based on water levels.

## 6. FLOODPLAIN RISK MANAGEMENT MEASURES

The FRMS aims to identify and assess risk management measures which could be put in place to mitigate flooding risk and reduce flood damages. As well as the hydraulic impacts, flood risk management measures should be assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management measures have been considered to manage existing/future flood risk.

### 6.1. Risk Management Measures Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories.

**Flood modification measures** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, on-site detention, channel improvements, levees or floodways. Pit and pipe improvement and even pumps may also be considered in some cases.

**Property modification measures** modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase.

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

Table 11 provides a summary of typical floodplain risk management measures that can be assessed.

Table 11: Flood Risk Management Measures

| Flood Modification                                                                                                                                                                                                                                                                                                                                   | Property Modification                                                                                                                                                                                                                                | Response Modification                                                                                                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• Flood mitigation and control dams</li> <li>• Retarding basins</li> <li>• Bypass floodways</li> <li>• Channel modifications and improvements</li> <li>• Levees</li> <li>• Flood gates</li> <li>• Pumps</li> <li>• Culvert and drainage structure improvements</li> <li>• Temporary flood defences</li> </ul> | <ul style="list-style-type: none"> <li>• Land use zoning</li> <li>• Voluntary purchase</li> <li>• Flood access</li> <li>• Flood proofing</li> <li>• House raising</li> <li>• Building and development controls</li> <li>• Flood insurance</li> </ul> | <ul style="list-style-type: none"> <li>• Community awareness and preparedness</li> <li>• Flood prediction and warning</li> <li>• Evacuation planning</li> <li>• Evacuation access</li> <li>• Flood plans and recovery plans</li> </ul> |

As taken from The Floodplain Development Manual (Reference 1)

## 6.2. Assessment Methodology and Measures Identified for Consideration

The Maroubra Bay Flood Study (Reference 3) in conjunction with the FMC identified flooding hot-spot areas (see Section 3.1.1 and Reference 4). These hot-spots include;

- Coral Sea Park flood retarding basin and Midway Drive low point;
- Haig Street low point;
- Byrne Crescent;
- corner of Anzac Parade and Wade Street
- corner Fenton Avenue and Chapman Avenue;
- intersection of Fitzgerald Avenue and Chester Avenue;
- White Avenue;
- Curtin Crescent;
- Broome Street.

Several specific management options were noted in the brief for consideration in this FRMS and can be summarised as;

- Provision of a retarding basin within John Shore Park to intercept overland flows from the upper reaches via Maxwell Avenue;
- Provision of a retarding basin within Council land adjacent to Wride Street;
- Upgrade of the trunk drainage system within the lower reaches of the catchment including the system draining from the Fenton Avenue trapped low point and the main stormwater outlet on Maroubra Beach; and
- Lowering the level of the main promenade linking Marine Parade to Maroubra Beach, thereby reducing the level of ponding experienced in the low lying area upstream of the main dune within Marine Parade and McKeon Street.

Two specific management options were noted in the brief for consideration in this FRMS;

- Acquisition or relocation schemes for Fenton Avenue and Chapman Avenue trapped low point; and
- Flood mitigation works for Fenton Avenue and Chapman Avenue trapped low point.

A number of flood modification measures were assessed using the hydraulic model. Additionally, a range of property modification and response modification measures has also been examined and discussed in this report. Often a combined approach is required to achieve success, such as combining flood modification works as well as response measures such as community education.

### **6.3. Relative Merits of Management Measures**

#### **6.3.1. Benefit/Cost Ratio**

To assess the monetary benefits of the management measures, a damages assessment has been undertaken. Damages for the full range of design events were initially calculated to establish the Average Annual Damages (AAD) for existing conditions (refer Section 4.4). However this requires nine design events to be run for each management measures.

Comparison of the AAD for the full range of events against the AAD obtained from the three most representative events (0.5 EY, 20% and 1% AEP) shows a variation of less 15%. On this basis only three events were run in obtaining AAD's for the mitigation measures, saving considerable time. Furthermore, calculation of the benefit of the management measure is based on the incremental advantage and therefore this difference is further negated as the mitigation AAD was compared to the existing AAD obtained from the three events.

Direct comparison of AAD gives an indication of the reduction in damages for any one year. However, to assess the full monetary benefits over the life of the project, including taking into account costs of construction and maintenance, Net Present Value (NPV) calculations are used and the benefit/cost (B/C) ratio established. The B/C approach is used to quantify the economic worth of each measure enabling the ranking against other measures. A B/C ratio is the benefits expressed in monetary terms, i.e. the reduction in AAD over the life of the project, compared to the actual likely cost of achieving those benefits, in other words; construction and maintenance costs. Where the B/C ratio is greater than one the measure is economically feasible, however, where the B/C ratio is less than one, the costs of the measure are higher than the reduction in tangible flood damages and therefore not justifiable from a purely economic basis.

The AAD per annum in today's monetary terms is assumed to apply for each year of the NPV damage calculation and is determined for each year based on a discount rate of 7% as per the recommendation in the Residential Flood Damages FRM Guidelines (Reference 10). Estimation of construction and maintenance cost using the NPV of the AAD assuming a design life of 50 years, enables the calculation of the B/C for each of the measures. Calculations of the

benefits and costs are included in each of the respective mitigation measure sections.

### 6.3.2. Management Measures Matrix

A matrix is used to assess the management measures on other categories to which tangible damages and a B/C ratio cannot be assessed, such as environmental and social implications. The scoring system for a range of criteria is provided in Table 12 and largely relates to the impacts in a 1% AEP event. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions. This matrix is completed for the range of management assessed in the previous sections and presented as Table 20 in the Summary section.

The criteria assigned a value in the management matrix are:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- number of properties benefited by measure;
- technical feasibility (design considerations, construction constraints, long-term performance);
- community acceptance and social impacts;
- economic merits (capital and recurring costs versus reduction in flood damages);
- financial feasibility to fund the measure;
- environmental and ecological benefits;
- impacts on the State Emergency Services;
- political and/or administrative issues;
- long-term performance given the likely impacts of climate change and sea level rise, and
- risk to life.

Table 12: Colour Coded Matrix Scoring System

|                                              | -3                    | -2                     | -1                    | 0         | 1                          | 2                    | 3               |
|----------------------------------------------|-----------------------|------------------------|-----------------------|-----------|----------------------------|----------------------|-----------------|
| <b>Impact on Flood Behaviour</b>             | >100mm increase       | 50 to 100mm increase   | <50mm increase        | no change | <50mm decrease             | 50 to 100mm decrease | >100mm decrease |
| <b>Number of Properties Benefitted</b>       | >5 adversely affected | 2-5 adversely affected | <2 adversely affected | none      | <2                         | 2 to 5               | >5              |
| <b>Technical Feasibility</b>                 | major issues          | moderate issues        | minor issues          | neutral   | moderately straightforward | straight forward     | no issues       |
| <b>Community Acceptance</b>                  | majority against      | most against           | some against          | neutral   | minor                      | most                 | majority        |
| <b>Economic Merits</b>                       | major disbenefit      | moderate disbenefit    | minor disbenefit      | neutral   | low                        | medium               | high            |
| <b>Financial Feasibility</b>                 | major disbenefit      | moderate disbenefit    | minor disbenefit      | neutral   | low                        | medium               | high            |
| <b>Environmental and Ecological Benefits</b> | major disbenefit      | moderate disbenefit    | minor disbenefit      | neutral   | low                        | medium               | high            |
| <b>Impacts on SES</b>                        | major disbenefit      | moderate disbenefit    | minor disbenefit      | neutral   | minor benefit              | moderate benefit     | major benefit   |
| <b>Political/administrative Issues</b>       | major negative        | moderate negative      | minor negative        | neutral   | few                        | very few             | none            |
| <b>Long Term Performance</b>                 | major disbenefit      | moderate disbenefit    | minor disbenefit      | neutral   | positive                   | good                 | excellent       |
| <b>Risk to Life</b>                          | major increase        | moderate increase      | minor increase        | neutral   | minor benefit              | moderate benefit     | major benefit   |

## 7. FLOOD MODIFICATION MEASURES

The purpose of flood modification measures is to change the behaviour of the flood itself through reducing flood levels or velocities and/or excluding water from areas under threat. These measures are characterised by structural works. This section considers management measures that modify flood behaviour on a wider scale, i.e. from a catchment wide perspective. Flood modification measures at the individual property scale are called property modification measures and are included in Section 8.

Council nominated 16 flood modification measures to be assessed as shown in Table 13 and on Figure D1. The outcomes are provided in the relevant sections and a summary of the modelling results is provided in Table 14 and Table 15 and in Appendix D.

Table 13: Council Nominated Flood Modification Measures

| Report Section | OPTION                                                                                     | COMMENT                                                                                                                                               |
|----------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7.5.1          | <b>Option A – Lowering of main promenade</b>                                               | Lower the crest and widen the current crest width of the main promenade at Maroubra Beach.                                                            |
| 7.1.2          | <b>Option B – Flood retarding basin in Muraborah Reserve (Wride Street)</b>                | Refine layout of this basin.                                                                                                                          |
| 7.1.3          | <b>Option C – Flood Retarding Basin in John Shore Park</b>                                 | Re-grade Maxwell Avenue to direct overland flow to John Shore Park. Earthworks within John Shore Park will be required to provide detention capacity. |
| 7.2.1          | <b>Option D – Duplication of drainage network from John Shore Park to the beach outlet</b> | Upgrade the existing trunk system that drains the Fenton Avenue low point.                                                                            |
| 7.1.4          | <b>Option E – Coral Sea Park retarding basin performance improvement</b>                   | Lower Coral Sea Park to increase detention capacity.                                                                                                  |
| 7.2.2          | <b>Option F – Midway Drive trapped low point</b>                                           | Upgrade Midway Drive drainage network.                                                                                                                |
| 7.2.3          | <b>Option G – Haig Street low point</b>                                                    | Upgrade drainage from Galvin Street to the beach outlet – Haig Street.                                                                                |
| 7.2.4          | <b>Option H – Byrne Crescent low point</b>                                                 | Manage overland flow through private property                                                                                                         |
| 7.2.5          | <b>Option I – 134-140 Marine Parade</b>                                                    | Upgrade drainage at 134-140 Marine Parade.                                                                                                            |
| 7.2.3          | <b>Option J – Maroubra Road/Flower Street intersection</b>                                 | Upgrade drainage from Galvin Street to the beach outlet – intersection of Maroubra Road and Flower Street.                                            |
| 7.2.6          | <b>Option K – Fitzgerald Avenue/Chester Avenue intersection</b>                            | Drainage upgrade proximate Coral Sea Park – Fitzgerald Avenue and Chester Avenue.                                                                     |
| 7.2.6          | <b>Option L – 1008 Anzac Parade</b>                                                        | Drainage upgrade proximate Coral Sea Park – Anzac Parade.                                                                                             |
| 7.2.6          | <b>Option M – 25 Astoria Circuit</b>                                                       | Drainage upgrade proximate Coral Sea Park – 25 Astoria Circuit.                                                                                       |
| 7.2.7          | <b>Option N – White Avenue (between Bennet Place and Farthing Place)</b>                   | Drainage upgrade to White Avenue – White Avenue (between Bennet Place and Farthing Place).                                                            |
| 7.2.8          | <b>Option O – Tyrwhitt Street near Malabar Road</b>                                        | Doubling the pipe capacity produces only a very small reduction in flood level in large events.                                                       |
| 7.2.9          | <b>Option P – Curtin Crescent</b>                                                          | Drainage upgrade at Curtin Crescent – between South Maroubra Village Green to Broome Street.                                                          |

Table 14: Summary of Council Nominated Option Results

| Option     | Event  | Max Decrease in Flood Level (refer notes) | Location              | Max Increase in Flood Level (refer notes) | Location                  | OUTCOMES                                                                                                                                                                                                                                        |
|------------|--------|-------------------------------------------|-----------------------|-------------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A</b>   | 0.5 EY | 0.00                                      |                       | 0.00                                      |                           | Provides a significant benefit with no adverse flood impacts for the 5% AEP and larger events. Will require further investigation to determine if possible impacts on foreshore.                                                                |
|            | 0.2 EY | 0.00                                      |                       | 0.00                                      |                           |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.42                                     | 35_MCKEON STREET      | 0.02                                      | 126-128_MONS AVENUE       |                                                                                                                                                                                                                                                 |
| <b>B</b>   | 0.5 EY | 0.00                                      |                       | 0.00                                      |                           | Not justifiable purely from an economic standpoint                                                                                                                                                                                              |
|            | 0.2 EY | -0.07                                     | 6_FENTON AVENUE       | 0.19                                      | 8_MAXWELL AVENUE          |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.13                                     | 7_MCKEON STREET       | 0.02                                      | 126-128_MONS AVENUE       |                                                                                                                                                                                                                                                 |
| <b>C</b>   | 0.5 EY | -0.31                                     | 15_FENTON AVENUE      | 0.00                                      |                           | Provides reasonable reduction in flood level for range of flood events. The main drawback is the potential increase in risk to life with creation of a basin in an urban area.                                                                  |
|            | 0.2 EY | -0.42                                     | 27_CHAPMAN AVENUE     | 0.19                                      | 8_MAXWELL AVENUE          |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.15                                     | 194_MARINE PARADE     | 0.04                                      | 44_WRIDE STREET           |                                                                                                                                                                                                                                                 |
| <b>D</b>   | 0.5 EY | -0.13                                     | 27_CHAPMAN AVENUE     | 0.00                                      |                           | Will provide a significant benefit but expensive and difficult to undertake as requires secondary outlet to Maroubra Beach. As a long term objective any additional pipes to the ocean would reduce flood levels in Marine Parade and upstream. |
|            | 0.2 EY | -0.13                                     | 11A_CHAPMAN AVENUE    | 0.19                                      | 8_MAXWELL AVENUE          |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.11                                     | 17_MCKEON STREET      | 0.04                                      | 44_WRIDE STREET           |                                                                                                                                                                                                                                                 |
| <b>E</b>   | 0.5 EY | not modelled                              |                       |                                           |                           | Provides no significant benefit as existing basin is sufficiently large.                                                                                                                                                                        |
|            | 0.2 EY | not modelled                              |                       |                                           |                           |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.05                                     | 1014_ANZAC PARADE     | 0.02                                      | 126-128_MONS AVENUE       |                                                                                                                                                                                                                                                 |
| <b>F</b>   | 0.5 EY | 0.00                                      |                       | 0.00                                      |                           | The high cost and very low benefit / cost ratio make this measure unviable.                                                                                                                                                                     |
|            | 0.2 EY | 0.00                                      | 45_MCKEON STREET      | 0.01                                      | 255_FITZGERALD AVENUE     |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.14                                     | 37_MIDWAY DRIVE       | 0.03                                      | 106-108_FITZGERALD AVENUE |                                                                                                                                                                                                                                                 |
| <b>GJ</b>  | 0.5 EY | -0.45                                     | 15_FENTON AVENUE      | 0.03                                      | 117_HAIG STREET           | The high cost and very low benefit / cost ratio make this measure unviable even though there are significant reductions in flood levels for the range of design events.                                                                         |
|            | 0.2 EY | -0.36                                     | 20_CHAPMAN AVENUE     | 0.08                                      | 117_HAIG STREET           |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.44                                     | 35_MCKEON STREET      | 0.18                                      | 335_MAROUBRA ROAD         |                                                                                                                                                                                                                                                 |
| <b>H</b>   | 0.5 EY | not modelled                              |                       |                                           |                           | Investigation of mitigation measures provided in Appendix G.                                                                                                                                                                                    |
|            | 0.2 EY | not modelled                              |                       |                                           |                           |                                                                                                                                                                                                                                                 |
|            | 1% AEP | not modelled                              |                       |                                           |                           |                                                                                                                                                                                                                                                 |
| <b>I</b>   | 0.5 EY | 0.00                                      |                       | 0.03                                      | 126_MARINE PARADE         | Provides minimal reduction in flood levels and a low benefit / cost ratio.                                                                                                                                                                      |
|            | 0.2 EY | -0.08                                     | 122-124_MARINE PARADE | 0.06                                      | 126_MARINE PARADE         |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.22                                     | 136-138_MARINE PARADE | 0.22                                      | 126_MARINE PARADE         |                                                                                                                                                                                                                                                 |
| <b>LMK</b> | 0.5 EY | -0.04                                     | 18_CHESTER AVENUE     | 0.00                                      |                           | Small reductions in flood level combined with high costs provide a small benefit / cost ratio.                                                                                                                                                  |
|            | 0.2 EY | -0.11                                     | 25_ASTORIA CIRCUIT    | 0.00                                      | 5_CHAPMAN AVENUE          |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.18                                     | 25_ASTORIA CIRCUIT    | 0.05                                      | 399_MAROUBRA ROAD         |                                                                                                                                                                                                                                                 |
| <b>N</b>   | 0.5 EY | 0.00                                      | 30_WHITE AVENUE       | 0.00                                      |                           | Low benefit / cost ratio. This option may result in increased flood levels to the system outside of the study area.                                                                                                                             |
|            | 0.2 EY | -0.17                                     | 30_WHITE AVENUE       | 0.00                                      | 111_DUNCAN STREET         |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.21                                     | 30_WHITE AVENUE       | 0.01                                      | 44_WRIDE STREET           |                                                                                                                                                                                                                                                 |
| <b>O</b>   | 0.5 EY | not modelled                              |                       |                                           |                           | Minimal reduction in flood level makes this option unviable.                                                                                                                                                                                    |
|            | 0.2 EY | not modelled                              |                       |                                           |                           |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.05                                     | 1014_ANZAC PARADE     | 0.20                                      | 589_MALABAR ROAD          |                                                                                                                                                                                                                                                 |
| <b>P</b>   | 0.5 EY | 0.00                                      |                       | 0.06                                      | 496-504_MALABAR ROAD      | Provides minimal reduction in flood levels and a low benefit / cost ratio.                                                                                                                                                                      |
|            | 0.2 EY | 0.00                                      | 40_THE CAUSEWAY       | 0.00                                      | 31-33_MCKEON STREET       |                                                                                                                                                                                                                                                 |
|            | 1% AEP | -0.46                                     | 38-40_CURTIN CRESCENT | 0.25                                      | 1R_BERNIE KELLY DRIVE     |                                                                                                                                                                                                                                                 |

**Note:** The maximum increase and decrease in flood level were taken at each property in the floor level database. However greater changes in level may occur elsewhere, such as on roads.

Table 15: Change in Number of Above Floor Inundated Buildings for Council Nominated Options

| Combined    | A   | B  | C  | D  | E | F  | GJ  | H | I | LMK | N | O | P  |
|-------------|-----|----|----|----|---|----|-----|---|---|-----|---|---|----|
| 1% AEP      | -11 | -1 | -7 | -4 | 0 | -2 | -19 |   | 0 | -2  | 0 | 0 | -2 |
| 0.2 EY      | 0   | 0  | -1 | 0  |   | 0  | -1  |   | 0 | 0   | 0 |   | 0  |
| 0.5 EY      | 0   | 0  | 0  | 0  |   | 0  | -1  |   | 0 | 0   | 0 |   | 0  |
| Residential |     |    |    |    |   |    |     |   |   |     |   |   |    |
| 1% AEP      | -11 | -1 | -7 | -4 | 0 | -2 | -19 |   | 0 | -2  | 0 | 0 | -2 |
| 0.2 EY      | 0   | 0  | -1 | 0  |   | 0  | -1  |   | 0 | 0   | 0 |   | 0  |
| 0.5 EY      | 0   | 0  | 0  | 0  |   | 0  | -1  |   | 0 | 0   | 0 |   | 0  |
| Commercial  |     |    |    |    |   |    |     |   |   |     |   |   |    |
| 1% AEP      | 0   | 0  | 0  | 0  | 0 | 0  | 0   |   | 0 | 0   | 0 | 0 | 0  |
| 0.2 EY      | 0   | 0  | 0  | 0  |   | 0  | 0   |   | 0 | 0   | 0 |   | 0  |
| 0.5 EY      | 0   | 0  | 0  | 0  |   | 0  | 0   |   | 0 | 0   | 0 |   | 0  |

0

## 7.1. Retarding Basins

### DESCRIPTION

Retarding basins work by storing runoff and releasing it over time subsequent to the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate existing flood problems.

### DISCUSSION

These systems are easy to implement when new development is proposed as Council can place the responsibility on the developer to provide appropriate drainage systems. This is usually implemented through development controls requiring that runoff rates from new developments be not greater than existing rates. While the 1% AEP event is typically used as the design event, flows also need to be restricted back to the pre-development rates (or less) for smaller events. Council's Stormwater Code (refer Section 5.1.5) requires that all new development, other than single dwelling houses must comply with a maximum discharge up to the 5% AEP (20 year ARI) event.

Hydraulic structures can be used to restrict the discharges rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin. When designing flood retarding basins, the performance of the basin should be assessed for a full range of storm durations including longer duration events to confirm concept design prior to detailed design.

Within the catchment, retarding basins can be used as part of the overall catchment drainage. However, in urban areas such as the Maroubra Bay study area, there is little space for new basins to be included. In some instances basins can be designed to utilise existing parks and sports fields as considered in this floodplain risk management for the Maroubra Bay study area.

It should be noted that large retarding basins can be a safety hazard. Consequently,

appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, particularly large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities located downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder.

Whilst retarding basins appear to be a fairly simple and effective means of controlling runoff and water quality in urban catchments there are a number of potential issues that need to be resolved. These are summarised in Table 16 below.

Table 16: Considerations For Retarding Basins

| ISSUE                                             | COMMENT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Size:</b>                                      | In order to be effective at reducing peak flows and benefiting water quality the basin area must cover a reasonably high percentage of the upstream catchment. The larger the basin, the more effective it will be. The outlet controls are also important in the design of the basin and generally comprise a low flow culvert and a weir which overtops in a large event.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Cost:</b>                                      | Whilst construction costs of the basin and wall in a rural or urban environment will be high, additional costs are associated with any alterations to services (gas, electricity, telephone, water, sewerage, roads, etc.) that are within or in close proximity to the proposed basin. There will also be some ongoing maintenance cost. Some sites in urban areas, which at first glance may appear suitable, are unviable due to the deposition of inappropriate fill material in the past (ex rubbish site, buried asbestos or other forms of waste).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Benefit:</b>                                   | Whilst any basin will provide some peak flow reduction and water quality benefit this must be balanced against the cost, and whether there are more cost effective methods. For example, it is generally acknowledged that public education and awareness and point source reduction provides the greatest benefit from a water quality perspective. The benefit for peak flow reduction is subject to the size of the basin and the outlet works. These are not easily defined at a concept stage, as detailed survey and design is required. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or significant hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives. The use of a basin for dual purposes (water quality and peak flow reduction) generally means that a compromise of the benefits for each purpose has to be reached. This is because the water quality purpose is best achieved by containing all the frequent inflows. For flood mitigation purposes, these flows are generally not contained to allow the volume in the basin to be “empty” at the time of the peak inflow. |
| <b>Loss of Land Use and Availability of Land:</b> | In a rural or some urban areas the loss of land for basin construction is acceptable. However in a relatively dense rural and urban catchment, where areas of open space are very valuable, the loss of previously useable land is significant. Basins can have multi-uses, such as being used as sports fields when dry, but this can be difficult to achieve.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Environmental</b>                              | In both rural and urban areas there is likely to be a high environmental impact with                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

| ISSUE          | COMMENT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Impact:</b> | removal of vegetation and construction of an embankment wall. In relatively densely developed urban catchment such as Maroubra Bay the lack of a potential basin site obviously restricts the use of this mitigation measure. The most preferred sites are within golf courses or any sports ground where many of the above issues can be negated. Examples in Sydney are in Fox Hills (Prospect) and Muirfield (North Rocks) golf courses or in a soccer field at Bateau Bay.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Safety:</b> | This is one of the most important factors to be considered when constructing a basin with a downstream urban area. Council will be changing an open space area with a low hazard potential during rainfall events to an area with a greater hazard. Apart from the risk of wall failure and consequently a sudden rush of floodwaters, there is the risk that people may drown or be swept into the basin. This can be negated by using fencing but this then precludes the use of the basin for other purposes. Generally basins deeper than say 1.2 m are unacceptable as a person cannot wade out of them. Some basins can be designed to have shallow and gradual depths closer to the edges but this means less potential storage volume over the same land area. The benefit of a reduction in hazard downstream must be balanced with the potential increase in hazard at the basin site. Constructing a basin places a significant potential liability on Council should it cause harm to persons in flood (or even non-flood) times. Signs can be placed advising of the hazard, however in a legal environment it is difficult to argue that this removes Council's responsibilities. Also children, older residents and non-English speaking background residents may not understand the signs. |

## ASSESSMENT

The hydraulic benefit from a retarding basin is a function of the storage within the basin, the height of the basin wall and the dimensions of the outlet structures. A number of basin options were considered for retrofitting into the existing drainage network of Maroubra Bay and improving existing detention capacity.

### 7.1.1. Existing Basins in the Catchment

There is only one purpose designed retarding basins within the catchment (Coral Sea Park - refer Section 7.1.4) but all the other areas of large public open space (John Shore Park, Arthur Byrne Park, Maroubra Bay Primary School and Broadarrow Reserve) will act as areas where floodwaters will pond.

The proposed revision to Australian Rainfall and Runoff (Reference 15) will require a more sophisticated design flood approach which will involve the use of several design rainfall temporal patterns rather than the single temporal pattern approach adopted currently.

### 7.1.2. Option B – Muraborah Reserve (Wride Street) Retarding Basin

Located upstream of Maxwell Avenue on Council parkland (Photograph 4), this basin is designed to capture a combination of flow from the trunk drainage system in addition to overland flow from contributing catchments draining to the upper reaches of Wride Street.

The Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) undertook an initial assessment of this option. The basin was sized to provide 4,500m<sup>3</sup> of storage and is

intended to be drained by the current 1.05 m diameter pipe trunk system outlet at this location which has a capacity sufficient for the 0.5 EY event. In larger events excess flows will be captured within the basin. Based on a peak basin depth of 1.2 m in the 1% AEP event, this corresponds to a surface area of 3,750m<sup>2</sup>. The Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) identified that, given the available land, there is scope to refine the layout of this basin to capture water for smaller events by restricting the basin outlet to a smaller size and further consideration of this approach may be needed to reduce the loading on the proposed basin within John Shore Park downstream.

Additional works will be required upstream of the basin within Wride Street to capture and direct overland flow from upstream catchments. The layout of these works has not been specifically examined for this study as they will be subject to the adopted layout of the basin. It is envisaged that these aspects will be reviewed as part of future detailed design.

The proposed drainage layout and impacts from the proposed Option B relative to existing conditions for the 1% AEP event are shown in Figure D2.

The peak flood depth for the 0.2 EY is 0.25 m near the eastern side of the basin and increased to 0.35 m for the 1% AEP event. The ground level of the eastern basin was lowered to 9 mAHD to test the hydraulic benefit. In this scenario, the peak flood depth has been reduced by 0.13 m for 1% AEP near the corner of Wride Street and Duncan Street. Only 1 property was no longer inundated above the floor level in the 1% AEP.

Option B reduces the AAD by \$0.015 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.22 million. From the preliminary analysis undertaken estimate costs for Option B are \$0.35 million. This results in a B/C ratio of 0.63 indicating that this mitigation option is not justifiable purely from an economic standpoint.

Photograph 4: Muraborah Reserve (Wride Street)



### 7.1.3. Option C – John Shore Park Retarding Basin

John Shore Park is a low-lying area in the vicinity of Fenton Avenue and Chapman Avenue and is subject to flooding as a result of the capacity of the local sub-surface drainage system being exceeded and overland flows entering the area from the upper reaches of the catchment via Maxwell Avenue. The Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) considered a retarding basin in John Shore Park (Photograph 5) and showed this could have benefit to flooding in the 1% AEP design event.

The main aim of the proposed retarding basin within John Shore Park is to intercept and detain the overland flow component entering Chapman Avenue from Maxwell Avenue. Extensive re-grading of Maxwell Avenue will be required to ensure that overland flow is directed through to the north-western end of John Shore Park, rather than entering Chapman Avenue as occurs under current conditions. Earthworks and regrading within the park itself will be required to provide the detention capacity, particularly as much of the existing park surface is above the general level of Chapman Avenue and Maxwell Avenue.

The proposed basin layout assessed in the Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) assumed a typical basin invert of approximately 3.7 mAHD. By comparison, the general ground level within the existing John Shore Park varies from 5.3 mAHD to 6.1 mAHD roughly rising from north to south.

Photograph 5: John Shore Park



The creation of a retarding basin in an urban area requiring over 1.5m depth of excavation introduces significant social and economic issues that are broadly outlined in Table 16. The key concerns are:

- re-grading of Maxwell Avenue to ensure all runoff enters the park;
- approximately 5,000m<sup>3</sup> of excavation and disposal of fill. At an indicative cost of \$100/m<sup>3</sup> this equates to \$500,000;

- creating a frequently inundated "park" in an urban area will require fencing which will limit access to the park;
- the frequency of inundation will restrict the use of the park;
- the use of the park as a quickly filling retarding basin will introduce a significant "risk to life" issue into the area, particularly for children who may be playing in the park or who venture into the park as it fills for "adventure".

To provide full hydraulic advantage from construction of a basin would require a new pipeline to Maroubra Bay to carry the 1 EY peak flow (or similar). Linking a new outlet from the basin into the existing stormwater system would provide only limited benefit as the existing downstream pipe system is largely already at capacity. There are a wide range of possible excavation and outlet scenarios.

Runoff enters John Shore Park in events as small as the 0.5 EY (typical depth of 0.2 m) and has depths up to 1 m in the 1% AEP. The hydraulic benefit of construction of a basin with no additional outlet but with the ground level reduced to 4 mAHD lowers flood levels by up to 0.3 m in the 0.5 EY, 0.4 m in the 0.5 EY and 0.15 m in the 1% AEP. In the 1% AEP 7 properties are no longer inundated above floor level.

The proposed drainage layout and impacts from the proposed Option C relative to existing conditions for the 1% AEP event are shown in Figure D3.

Option C reduces the AAD by \$0.1 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$1.5 million. From the preliminary analysis undertaken estimate costs for Option C are \$1.0 million. This results in a B/C ratio of 1.5 indicating that this mitigation option is justifiable from an economic standpoint.

#### **7.1.4. Option E – Coral Sea Park Retarding Basin**

Coral Sea Park has a total area of approximately 5 hectares (Photograph 6) and has been formed into a retarding basin with an earthen embankment (approximately 1.5m in height) on the eastern side and continued part way along Midway Drive. It is occupied by four full sized football fields in winter and a cricket pitch in summer. The outlet (formed in approximately 2009 - refer Photograph 6) is three grates (900mm wide and a total length of 4000 mm) located near the Collier Place cul-de-sac. This outlet connects to the 2400 mm by 1600 mm box culvert running from west to east beneath the park which ultimately connects to the pipe system in Yorktown Parade.

Option E investigates enhancement of the Coral Sea Park retarding basin. Lowering of Coral Sea Park to 14 mAHD was considered in order to increase the detention volume capacity of the basin. However as the existing crest level of the basin and resulting storage is sufficient to largely contain the 1% AEP event lowering the ground level has negligible impact and for this reason the option was not considered further due to the high cost to excavate, regrade and returf the fields. In addition there is the commonly held engineering view that increasing the

depth further (above 1.2m) will significantly increase the risk to life as able bodied people will become unable to wade out if "trapped" in the basin during an event.

One potential risk with this basin is the blockage of the three grates at the outlet with leaves and other movable debris. This is a common issue with all these types of structures and there is no type of structure which can be classified as 100% certain to not block at all.

The earthen embankment on the eastern boundary is vegetated (Photograph 6) and immediately downstream are houses. With all basins there is a risk of embankment failure (possibly increased with vegetation on the embankment) and a "wall of water" entering downstream properties with a significant risk to life.

In conclusion no works are proposed but Council should undertake a safety inspection of the basin in accordance with current advice from the NSW Dams Safety Committee and their June 2010 DSC3E - Retarding Basins guideline.

Photograph 6: Coral Sea Park



### 7.1.5. SUMMARY

For new developments, requirements for inclusion of retention basins or similar drainage features, and the restriction of flow to pre-development rates can be adequately enforced through planning controls. Restricting flows to pre-development rates is a good method for ensuring no increased flood risk downstream of new development.

One retarding basin (Coral Sea Park) already exists in the catchment and there are no records of issues in past floods. Increasing the capacity of the basin through excavation could not be

justified. Regular maintenance and monitoring (after floods) of the outlet structure should be undertaken as with the rest of the drainage network infrastructure. A safety audit of the outlet and embankment should be undertaken.

Preliminary investigation of a possible basin at John Shore Park indicates that it may be economically viable.

### RECOMMENDATIONS

The following measures are recommended:

- ▶ Council should ensure stormwater runoff is appropriately considered, commensurate to the size and scale of development, in all development applications.
- ▶ Development controls should be used to ensure that for large developments retention basins, or other appropriate water retention methods, will be used.
- ▶ Development controls should be used to ensure that runoff from new developments is equal to or less than the pre-development rate for all design events up to and including the 1% AEP event.
- ▶ A safety audit should be undertaken for the Coral Sea Park retarding basin and continued monitoring of the outlet structures.
- ▶ Further investigation into construction of a basin at John Shore Park should be undertaken.

The following are not recommended for improving the flooding situation:

- ▶ **OPTION E** - Detention volume capacity of Coral Sea Park is sufficient and does not require enhancing.

## 7.2. Drainage Network Modifications

### DESCRIPTION

Modification of the existing drainage network can be made to increase the capacity of the system by installing larger/additional pits and pipes, creating diversions or enhancing flow routes. Additionally, network modification can assist in the drainage of low trapped points to reduce ponding. It is worth mentioning that while enhancing assets can mitigate flood risk, regular maintenance of the drainage network to ensure that it is operating with maximum efficiency is required to reduce risk of blockage or failure. The maintenance of existing infrastructure is considered in Section 7.3.

### DISCUSSION

Section 3.1.2 and Figure 4 indicates that the majority of the drainage infrastructure is of low capacity. This is typical of all Sydney urban drainage systems. Furthermore, a number of low trapped points exist (see Section 3.1.1) where natural topographic depressions and poor drainage results in the ponding of runoff. For such areas, the only way to reduce an existing problem is to reduce the surface water reaching the area or provide additional below ground drainage to drain trapped low points.

In an urban environment such as Maroubra Bay, most flood modification floodplain risk management measures will involve modification of the existing drainage network. The drainage

network is made up of a number of features including open channels, pipes, box culverts and detention basins. Often in an urbanised area with an established drainage infrastructure, a number of measures have to be taken to improve drainage. The difficulty is that the upgrade of the underground system in one area upstream facilitates more conveyance of water downstream with the potential to exacerbate flood levels there. A combined management approach requires assessment of impacts of flood improvement measures in one area onto other areas within the catchment to assess if further improvements are necessary to mitigate resulting effects.

Utilising the Maroubra Bay Flood Study (Reference 3) and through discussions with Council and the FMC, a number of areas that could benefit from upgrading of the existing drainage network have been identified. Measures considered in this assessment consist of either increasing pipe sizes or improving inlet efficiency.

Detailed costing of the drainage upgrades investigated was undertaken. Items considered included:

- General construction costs (site establishment, geotechnical survey, etc.);
- Demolition and clearing costs;
- Excavation and earthworks;
- Installation of drainage assets;
- Backfilling;
- Footpath and road surfaces relaying; and
- Traffic management costs.

Capital costs as well as yearly maintenance costs converted to net present value are summed together and used in the calculation of the B/C ratio for each of the options below.

### **7.2.1. Option D – Fenton Avenue (John Shore Park to Beach Outlet) Trunk Drainage**

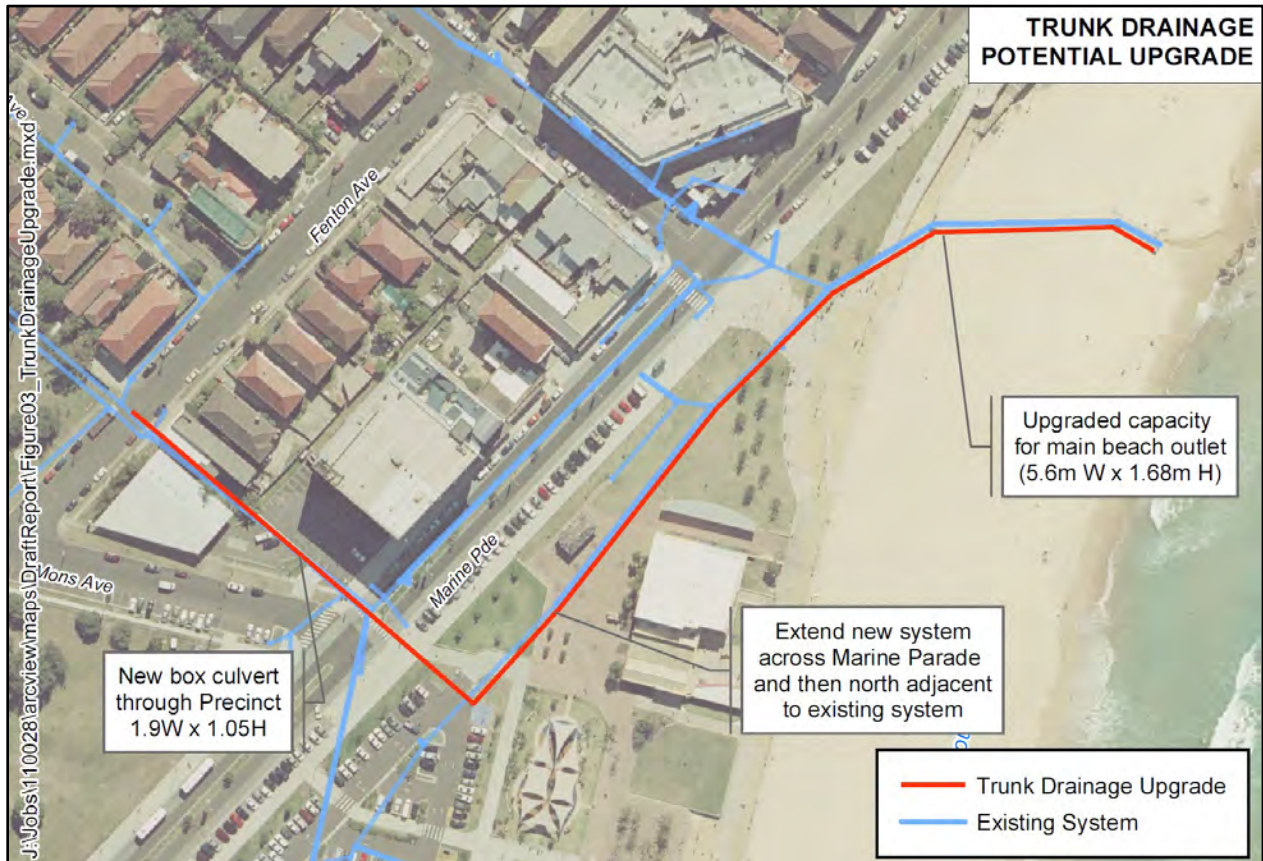
Given the potential re-development of the commercial precinct area (see Section 2.3.3), there is an opportunity to upgrade the existing trunk system that currently drains the Fenton Avenue low point. This option was considered in the Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) through which an upgrade concept was identified following consultation with Council engineers. The proposed drainage layout and peak flood level impacts from Option D relative to existing conditions for the 1% AEP event are presented in Figure D10.

The main components of the trunk system upgrade assessed included:

- replacement of the existing trunk system through the development site to a larger box culvert (1.9 m x 1.05 m from Fenton Avenue to Marine Parade);
- extending this new system across Marine Parade then northwards following a similar alignment to the existing trunk line in this area; and
- provision of corresponding capacity to the main stormwater outlet along Maroubra Beach (5.6 m x 1.68 m).

Details of the existing and upgraded trunk drainage system are provided in Diagram 3. The Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) did not look at the trunk drainage upgrade in isolation, instead it assessed the upgrade in conjunction with a retarding basin at Wride Street and a second retarding basin at John Shore Park as well as lowering of the main promenade at Maroubra Beach.

Diagram 3: Potential Trunk Drainage Upgrade



Extracted from Figure 3 of Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4)

Whilst upgrades of pipe systems in other areas were initially assessed, further consideration of this option was not considered appropriate given the significant costs (estimated at over \$3 million) and disruption associated with retro-fitting existing systems in established areas. However as a long term objective any additional pipes to the ocean would reduce flood levels in Marine Parade and upstream.

This is the only option that will provide significant reductions in flood levels for the Fenton Avenue and adjoining areas. However the two main constraints with this measures are:

- High cost. The cost will vary depending upon the extent and magnitude of the works but it will be of the order of \$2+ million. This amount of funding will generally not be available through normal flood mitigation funding by the State or Federal Governments.
- Constructing a duplicate ocean outlet across Maroubra Beach will introduce many aesthetic, social and environmental issues. These will need to be addressed through a detailed community consultation program prior to advancing this option.

Option D reduces the AAD by approximately \$0.05 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.7 million. Assuming a preliminary estimated capital cost for Option D of \$2.14 million this results in a B/C ratio of 0.33 indicating that the mitigation option is not justifiable from an economic standpoint alone. It should be noted that the actual cost may be significantly higher, further reducing the B/C ratio.

### **7.2.2. Option F – Upgrade to Midway Drive Drainage Network**

This option considered two additional 1.2 m diameter pipes at Midway Drive and adding another 1.2 m diameter pipe from Midway Drive to the drainage junction near Collier Place. The proposed drainage layout and impacts from the proposed Option F relative to existing conditions for the 1% AEP event are shown in Figure D4.

Option F is located in the low trapped point in the Midway Drive where water ponds in events as low as the 0.5 EY. Existing peak flood depth of 0.8 m in 1% AEP are reduced by 0.14 m in Midway Drive with the implementation of Option F. Two properties are no longer flood affected and one property which was affected above floor level is no longer inundated.

Option F reduces the AAD by \$5,000. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.07 million. From the detailed analysis undertaken estimate costs for Option F are \$1.75 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.04 indicating that this mitigation option is not justifiable from an economic standpoint alone.

### **7.2.3. Option G&J – Upgrade Drainage from Galvin Street to Beach Outlet**

This option considered upgrading the drainage from Galvin Street to the beach outlet. The proposed option will mitigate the flood risk in two hotspots namely, G and J. Limiting the drainage upgrade to near the hotspots will have little benefit, since the pipe capacity is significantly constrained by small downstream pipes. Therefore, a worthwhile assessment requires upgrading of the entire reach of drainage. Option G&J considers increasing the existing pipe size to 1.2 m from Galvin Street to Fitzgerald Avenue. After Fitzgerald Avenue, the entire drainage system is duplicated. The proposed drainage layout and peak flood level impacts from Option G&J relative to existing conditions for the 1% AEP event are presented in Figure D5.

Hotspot G has a trapped low point in Haig Street where water ponds in events as small as the 0.5 EY and depths of 0.9 m are observed in the 0.2 EY. Hotspot G has a peak flood depth of 2 m in the 1% AEP and Option G&J increases this peak flood level by 0.08m near 117 Haig Street in the 0.2 EY and 0.03m in the 0.5 EY. Haig Street properties are shown to benefit from reductions in peak flood level of up to 0.2 m in 1% AEP as a result of Option G&J.

Hotspot J is located in the intersection of Maroubra Road and Flower Street. Runoff starts ponding in events as low as the 0.2 EY where depths of 0.3 m are observed. Hotspot J has a peak flood depth of 0.4 m in 1% AEP. For the 1% AEP, the peak flood level is reduced by 0.16 m along Flower Street near the intersection and a 0.12 m reduction is achieved on Maroubra Road near the intersection through Option G&J. Option G&J has decreased the peak flood level in various downstream locations near Chapman Avenue and Mckeen Street.

Option G&J reduces the AAD by approximate \$0.16 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$2.47 million. From the detailed analysis undertaken estimate costs for Option G&J are \$13.27 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.19 indicating that the mitigation option is not justifiable from an economic standpoint alone.

#### **7.2.4. Option H – Byrne Crescent Low Point**

No. 11 Byrne Crescent (Photograph 7 - though front yard has been modified since 2014) is subject to above floor inundation on a frequent basis (possibly as much as three times a year from discussions with the resident). A site visit was undertaken in September 2014 during which WMAwater spoke with local residents. The resident has sand bags ready to divert flow and opens doors to allow the free flow of water through the house. This causes significant disruption, inconvenience and some internal house and yard damages. The front door of the house is at ground level and runoff which overtops the kerb will largely flow directly to the front door.

A detailed assessment of possible mitigation measures was undertaken and this is provided as Appendix G.

Photograph 7: No. 11 Byrne Crescent (circa 2015 - changed since 2014 assessment)



### 7.2.5. Option I – Drainage Upgrade at 134 – 140 Marine Parade

Option I considered increasing the outlet pipe capacity from 0.6 m to 0.9 m near 134-140 Marine Parade. The proposed drainage layout and peak flood level impacts from Option I relative to existing conditions for the 1% AEP event are shown in Figure D6.

Hotspot I is located in the local trapped low point near 134-140 Marine Parade. This hotspot is subjected to flood depths of 0.2 m in the 0.2 EY increasing to 0.3 m in the 1% AEP. Option I reduces peak flood levels by 0.19 m near the trapped low point. Conversely, an increase of 0.22 m is also observed in the vicinity of the hotspot.

Option I reduces the AAD by about \$1,500. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.02 million. From the detailed analysis undertaken estimate costs for Option I are \$0.06 million which results in a B/C ratio of 0.36.

### 7.2.6. Option LMK – Drainage Upgrade Proximate Coral Sea Park

This proposed option will mitigate the flood risk in three hotspots, namely L, M and K. In order to alleviate the flood issue in the hotspot L and M, four new pipes from Anzac Parade to the discharge area in Coral Sea Park are proposed (note: the assessment would lead to similar results with any number of pipe arrangement as long as the pipe area is of equivalent capacity). In hotspot K, two additional 0.9 m diameter pipes from Fitzgerald Avenue to Coral Sea Park are introduced. The proposed drainage layout and peak flood level impacts from Option LMK

relative to existing conditions for the 1% AEP event are presented in Figure D7.

Hotspot L is located at the intersection of Anzac Parade and Wade Street. This area is subjected to a peak flood depth of 0.2 m in the 10% AEP increasing to 0.3 m in the 1% AEP event. Reductions in the order of 0.19 m are observed at the intersection when Option LMK is compared against existing conditions for the 1% AEP event.

Hotspot M is located near 25 Astoria Circuit. This area experiences flood depths of 0.2 m in the 0.2 EY and 0.4 m in 1% AEP events respectively. Option LMK reduces peak flood level in the 1% AEP event by 0.18 m.

Hotspot K is located in the intersection of Fitzgerald Avenue and Chester Avenue where water ponds in events as low as the 0.5 EY. Peak flood depths of 0.4 m are observed for the 1% AEP event and these decrease by approximately 0.1 m when Option LMK is introduced.

Option LMK reduces the AAD by \$ 10,500. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.15 million. From the detailed analysis undertaken estimate costs for Option LMK are \$3.37 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.05 indicating that the mitigation option is not economically viable.

### **7.2.7. Option N – Drainage Upgrade to White Avenue**

This option considers the upgrade to the drainage system along White Avenue (between Bennett Place and Farthing Place). A low capacity pipe, which traverses a property adjacent to the hotspot, connects to a drainage network separate to the study area. The proposed option involves increasing the size of this pipe from 0.6 m to 0.9 m diameter. The proposed drainage layout and peak flood level impacts from Option N relative to existing conditions for the 1% AEP event are shown in Figure D8.

Hotspot N is located on White Avenue (between Bennett Place and Farthing Place). The hotspot is currently exposed to a peak flood depth of 0.3 m in 0.2 EY. Peak flood depths of 0.5 m on White Avenue for the 1% AEP are reduced by up to 0.21 m for the option providing significant benefit to dwellings and reducing below floor flood affectation at up to five properties.

Option N reduces the AAD by \$4,000. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.06 million. From the detailed analysis undertaken estimate costs for Option N are \$0.20 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.29. It is worth noting that this option may result in increased flood levels to the system outside of the study area.

### **7.2.8. Option O – Drainage Upgrade Tyrwhitt Street near Malabar Road**

Peak flood water ponds up to 0.25 m in the 1% AEP in the Tyrwhitt Street near Malabar Road.

The existing pipes along Tyrwhitt Street are small ones with a diameter of 0.375 m. The pipes are very inefficient in carrying the overland flow, as all of them are at capacity in the 0.5 EY. An option of doubling those pipes was modelled. Nevertheless, the doubled pipes have little impact even in the 1% AEP; the maximum decrease in peak flood depth being less than 0.05m. The reason is that the efficiency of the pipes is significantly constrained by the downstream pipes. Due to the very small benefit in larger events this option was ruled out for further investigation from a floodplain management perspective (i.e. reducing flood damages). However larger pipes would obviously reduce the incidence of nuisance flooding in smaller more frequent events.

Upgrading the pit and pipe network in this area should be considered as part of Council's Drainage Capital Works program.

### **7.2.9. Option P – Drainage Upgrade at Curtin Crescent**

Option P considers upgrading the drainage system in Curtin Crescent (between South Maroubra Village Green to Broome Street). The flooded area is close to Arthur Byrne Reserve and the option considers discharging floodwaters into the reserve which would act as a retarding basin. The option aims to duplicate the drainage system along Curtin Crescent and a new pipe from Curtin Crescent to Arthur Byrne Reserve is added to convey floodwaters. The proposed drainage layout and peak flood level impacts from Option P relative to existing conditions for the 1% AEP event are presented in Figure D9.

Hotspot P is located in Curtin Crescent (between South Maroubra Village Green to Broome Street). This area is a low trapped point and experiences a peak flood depth of 0.2 m in the 0.2 EY event and 0.7 m in the 1% AEP event. The option results in decreases to peak flood levels of 0.46 m for the 1% AEP event.

Option P reduces the AAD by approximately \$ 10,000. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$0.15 million. From the detailed analysis undertaken estimate costs for Option P are \$3.75 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 0.04 indicating that the mitigation option is not justifiable from an economic standpoint with flood levels increasing by 0.25 m in the vicinity of a property located in Arthur Byrne Reserve.

### **7.2.10. Summary of Council Nominated Pipe Upgrade Options**

By increasing drainage capacity larger volumes of surface water can be drained away more quickly. Enhancing the capacity of trunk drainage systems will achieve a degree of flood relief for properties exposed to flooding on a regular basis. Several drainage upgrade options have been considered and modelled. Some are shown to be beneficial, although for others the reduction in peak flood levels is not significant enough to warrant implementation of the option. Flood damages assessment and B/C ratios shows that most options have a B/C of less than one. Therefore it is difficult to make recommendation for these options as they are not economically feasible. Table 17 summarises the variation in peak flood levels and economic

benefits relative to costs of the above drainage network modifications.

Table 17: Summary of Drainage Network Modifications

| Option     | Hotspot | 1% AEP Depth-Base Case (m) | Decrease in 1% AEP Flood Level (m) | Increase in 1% AEP Flood Level (m) | Benefit (reduction in damages) | Cost         | B/C Ratio |
|------------|---------|----------------------------|------------------------------------|------------------------------------|--------------------------------|--------------|-----------|
| <b>D</b>   | D       | 1.4                        | -0.11                              | 0.04                               | \$700,000                      | \$2,150,000  | 0.33      |
| <b>F</b>   | F       | 0.8                        | -0.14                              | 0.03                               | \$70,000                       | \$1,750,000  | 0.04      |
| <b>GJ</b>  | J       | 0.4                        | -0.16                              | 0.18                               | \$2,470,000                    | \$13,270,000 | 0.19      |
|            | G       | 2.0                        | -0.23                              | 0.18                               |                                |              |           |
| <b>I</b>   | I       | 0.3                        | -0.22                              | 0.22                               | \$20,000                       | \$60,000     | 0.36      |
| <b>LMK</b> | L       | 0.3                        | -0.19                              | 0.05                               | \$150,000                      | \$3,370,000  | 0.05      |
|            | M       | 0.4                        | -0.18                              | 0.05                               |                                |              |           |
|            | K       | 0.4                        | 0.02                               | 0.05                               |                                |              |           |
| <b>N</b>   | N       | 0.5                        | -0.21                              | 0.01                               | \$60,000                       | \$200,000    | 0.29      |
| <b>P</b>   | P       | 0.7                        | -0.46                              | 0.25                               | \$150,000                      | \$3,750,000  | 0.04      |

**Note:** The change in flood level is the peak at the hotspot and is not necessarily the peak at a property as quoted in Table 14.

## RECOMMENDATIONS

- From a purely economic standpoint no options are viable.
- Option O - Upgrading the pit and pipe network in this area should be considered as part of Council's Drainage Capital Works program.

## 7.3. Drainage Network Maintenance

### DESCRIPTION

Regular maintenance of the drainage network is important. It ensures that assets are operating with maximum efficiency and reduces but not eliminates the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network. As indicated in Section 5.2 Council has a regular maintenance program.

### DISCUSSION

As part of the Maroubra Bay Flood Study (Reference 3 and Appendix B), sensitivity of blockage of the sub surface drainage system was tested in the hydraulic model. Full blockage of the sub surface drainage system only caused nominal increases in peak flood levels for the 1% AEP event due to the fact that for larger events, the majority of flow is conveyed overland (roads etc.) rather than via the limited sub surface drainage system. However, in smaller more frequently occurring events such as the 20% AEP event, blockage is likely to have a larger impact on peak flood levels and therefore it is important for Council to undertake clearance of the sub surface drainage system.

A review of maintenance protocols or policies would ensure that drainage assets are effectively managed and regularly maintained such that they will perform at their optimum as required.

## SUMMARY

Regular maintenance can reduce risk of blockage of structures during flood events and ensure that flood waters are drained efficiently. It would be beneficial for Council to review their maintenance protocols and ensure a record of all drainage infrastructure within the LGA as well as the authority, organisation or body responsible for its maintenance.

## RECOMMENDATIONS

The following measures are recommended:

- ▶ Review and identification of policies for general maintenance of pipes, drains and channels and determination of protocols for ownership maintenance and development / upgrade of infrastructure.
- ▶ Review the database of all drainage infrastructure and its owner and authority responsible for its maintenance.

## 7.4. Open Channel Modifications and Maintenance

### DESCRIPTION

Channel modification includes a range of measures from straightening, concrete lining, removal of structures, dredging and vegetation clearing. In some instances 'naturalising' the channel upstream can reduce peak levels downstream by slowing flows and making better use of flood storage, however this measure would increase flood levels upstream.

### DISCUSSION

There are no open channels in the catchment. There is therefore minimal opportunity to create or alter overland flow drainage system. There are significant social and environmental issues with construction of this measure. Extending or creating easements into private property will not be supported by the adjoining residents and would affect their land value.

## SUMMARY

Open channel modification measures cannot be reasonably undertaken.

The following is not recommended for improving the flooding situation:

- ▶ Open channel modifications

## 7.5. Modifying Ground Levels

### DESCRIPTION

Localised high or low points in the topography can cause the built up or ponding of runoff. By modifying ground levels in these areas the flow of runoff can be aided, thereby preventing ponding. In urban areas it is often difficult to implement such measures although they can be undertaken in areas of open space and are often done so in conjunction with other management measures, such as retarding basins.

## DISCUSSION

Assessment of the hydraulic model shows that a number of low trapped points exist where natural topographic depressions results in the ponding of runoff. For such areas where reducing the surface water reaching the area is not feasible, modification in the local ground levels can be used to drain trapped low points.

## ASSESSMENT

Modification of local ground levels is a viable measure but generally there are a number of additional issues that need to be considered. The most significant of these is the possible lowering of the main promenade at Marine Parade (Section 7.5.1).

### 7.5.1. Option A – Lowering of Main Promenade, Maroubra Beach

The area in the vicinity of Marine Parade / McKeon Street is lower than the remnant dune behind Maroubra Beach (Photograph 8). This causes flood water to pond until drained by the pipe network via the exposed pipe on the beach (Photograph 8). In large flood events, floodwaters cannot flow overland out of this area until the ponding level in Marine Parade / McKeon Street exceeds the crest level of the main promenade across Maroubra Beach (approximately 6.2mAHD) at which point the crest overtops. The main promenade therefore has a significant effect on peak flood levels in this portion of the catchment.

If the crest of the main promenade was lowered, flood levels in this area would be lowered by a significant amount especially for events including and greater than the 5% AEP event. For more the more frequent and smaller events this option would provide minimal benefit as the peak flood depth is only 0.25 m in the 0.5 EY event but increases to 1.5 m in the 1% AEP event at the low point in Fenton Avenue.

Option A assumed the crest of the promenade was lowered and also widened to 40 m (this compares to a current width of around 15 m). This configuration was adopted following a review of current road and footpath levels along Marine Parade in this location and consultation with Council. The flood mitigation scenario assessed in the Maroubra Bay Assessment of Flood Mitigation Options Report (Reference 4) was also run with the main promenade lowered to a level of 5.4 mAHD.

Photograph 8: View from McKeon Street across Marine Parade and exposed Pipe on Beach



This mitigation option reduced the peak flood level by 0.2 metres in Fenton Avenue and 0.42 m in McKeon Street in the 1% AEP event. Eleven properties were no longer flooded above floor level in the 1 % AEP event.

Option A reduces the AAD by approximately \$0.07 million. Assuming a life cycle of 50 years and an interest rate of 7%, the net present value of the reduction in damages is \$1.04 million. From the detailed analysis undertaken estimate costs for Option A are \$1.3 million consisting of a capital and yearly maintenance costs. This results in a B/C ratio of 1.04 indicating that the mitigation option is justifiable from an economic standpoint.

The main issue with this measure that would need to be addressed is whether there are adverse impacts or consequences on the foreshore (erosion or influx from wave runup). Wave runup could reach 4 to 5m AHD depending upon the nature of the beach and the magnitude of the ocean event. A more rigorous analysis is required to more fully investigate this issue.

## SUMMARY

Lowering the level of the main promenade does provide a significant reduction in flood levels for events including and greater than the 5% AEP event. For smaller events there is no reduction in flood level until the level of the lowered promenade is below the peak flood level for the event. This measure has no adverse flooding impacts and from a flood community perspective is likely to be well supported. Further investigation of possible adverse impacts or consequences on the foreshore would need to be undertaken.

## RECOMMENDATION

The following measure is recommended:

- Further investigation and community consultation regarding widening and lowering of the level of the concrete promenade opposite McKeon Street.

## 7.6. Review of Levees

### DESCRIPTION

Levees are raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a defined design height. Levees usually take the form of earth embankments but can also be constructed concrete walls where there is limited space or other constraints (Photograph 9). Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

Photograph 9: Example of Levees a) Earth Embankment b) Concrete Wall



### DISCUSSION

Whilst there are some levees in urban areas in Sydney they are very difficult to retro fit to solve an existing flood problem. The main issues are loss of visual and access amenity, the need to obtain an easement, maintenance and resolution of local drainage issues. While major levees are not suitable for the Maroubra Bay catchment, localised levees or bunding can be applied around individual properties. This is considered as minor property adjustments in Section 8.5.

## SUMMARY

The following is not suggested for improving the flooding situation:

► **Large levee systems** – are not applicable for the Maroubra Bay catchment.

## 7.7. On-Site Stormwater Detention (OSD)

### DESCRIPTION

Retarding basins are typically used on large developments and as communal temporary floodplain storage. However, other means of on-site stormwater detention can be used for the same purpose on smaller individual lots. OSD does not necessarily mean surface water must be attenuated in a basin; on the smaller scale storage areas can include flooding above ground to shallow depths, such as parking areas, or garden features. Storage can also be provided in underground systems. Randwick City Council has a comprehensive OSD policy as do the majority of other Sydney councils. In some LGAs more discretion is allowed in the application of the policy depending upon the local circumstances.

### DISCUSSION

Many councils have adopted OSD policies to require that runoff from new developments are restricted to the pre-development rates. As with retarding basins, peak flow rates need to be restricted for a range of design events, not just to the 1% AEP event (as is the case at Randwick).

OSD can be beneficial in areas where overland flow is the main source of flooding. Generally, OSD is not effective in areas of the floodplain which are subject to mainstream flooding although the benefits of one individual OSD system may be minor relative to the overall scale of flooding, the encouragement or requirement for OSD on all new development will manage the cumulative impacts of increased runoff over time.

Maintenance of OSD is important to ensure it continues to function as intended. As OSD infrastructure tends to be on private property and falls under the responsibility of the property owner to maintain, there is a risk of lack of maintenance. Therefore Council should maintain a register of all OSD features within the LGA and undertake regular inspections to ensure they maintain full function over time. This notation of OSD features on a development could be provided on S149 (5) certificates to prospective owners.

OSD as a means of reducing existing flood levels is not viable because of the amount of storage that would be required. At best OSD can ensure that new development will not increase peak flows.

Whilst it is recognised that some form of OSD is required to reduce peak flood flows from new development, Council should take into account the limited developable area in the Maroubra Bay catchment and therefore measures other than detention basins may be more effective. Consequently, where appropriate, OSD should be enforced by Council, however, some flexibility should be allowed where future developments can demonstrate alternative, potentially more

effective, compensatory measures. These would need to be agreed upon by Council.

## SUMMARY

Where it is appropriate, providing OSD on new developments should be encouraged and can have beneficial effects in preventing exacerbation of urban flooding in the future as a result of intensification of development. However, a pragmatic approach should be taken as OSD is not applicable to all sites and alternative drainage solutions may provide greater benefits. To aid development applicants Council should provide advice on appropriate OSD and the long term maintenance requirements.

## RECOMMENDATIONS

The following measures are recommended:

- ▶ Review and ensure the OSD policy is in accordance with best practice.
- ▶ Council to develop a register of all OSD features within the LGA and undertake regular inspections.
- ▶ Notation of OSD requirements and existing features on S149 (5) certificates.
- ▶ Council should ensure stormwater runoff is appropriately considered, commensurate to the size and scale of development, in all development applications.
- ▶ Council should consider how the maintenance and inspection of OSD systems can be improved upon.

## 7.8. Catchment Treatment and Water Sensitive Urban Design (WSUD)

### DESCRIPTION

Catchment treatment is similar to OSD in that it modifies the runoff characteristics of the catchment to reduce flows and improve water quality. For an urban catchment, this involves the use of Water Sensitive Urban Design (WSUD). Appropriately designed WSUD seeks to minimise the impacts of development on the natural water cycle through technologies to reduce potable water consumption, reduce pollution from stormwater ending up in local waterways and increasing runoff. It does this through the use of rainwater tanks, gross pollutant traps (GPTs), OSD and on-site water reuse, landscaped swales and infiltration systems. These measures can reduce the volumes and peak flow of storm water runoff in relatively small, frequent events, typically up to the 20% AEP events but they have less effect in larger, less frequent events.

### DISCUSSION

By increasing the permeable surface area such schemes can reduce runoff and may be suitable in mitigating areas of localised flooding. By enforcing simple policies such as standard treatment within public space, such as kerbside catchment treatment, and limiting the imperviousness of proposed developments, unless accompanied by offset works, Council can reduce flood volumes and hence reduce flooding. Requirements can also be made of new larger scale developments that some form of WSUD is included. However, the effects of small scale catchment treatment and WSUD features in terms of their reduction in flood levels are impossible to accurately quantify through hydraulic modelling and depend on a range of factors such as permeability of soil, antecedent conditions, intensity of rainfall, size of the garden etc.

WSUD features can have significant water quality benefits by allowing settlement of sediments carried by the runoff. Vegetated areas also act as a filter to water, removing various particulates.

The use of WSUD in the Maroubra Bay catchment is unlikely to have wide scale benefits in reducing peak flood levels in large flood events, however during smaller flood events, and from localised intense rainfall events, there will be localised flood management benefits as well as water quality benefits.

The use of WSUD is encouraged through Council's DCP (see Section 5.1.3).

### **SUMMARY**

As a general concept, catchment treatment techniques and WSUD should be encouraged. Examples include: limiting on-site imperviousness for developments and controls on land use. Water quality and other environmental controls should also be encouraged as these approaches provide significant benefits to local drainage and overland surface water flooding.

### **RECOMMENDATIONS**

The following measures are recommended:

- ▶ Encourage the use of WSUD features in all developments. This can be implemented through planning controls.

## 8. PROPERTY MODIFICATION MEASURES

Property modification measures refer to modifications to existing structures and/or development controls on property and community infrastructure for future development. Flood modification measures which apply at the individual property scale have also been included in this section.

### 8.1. National Construction Code

New performance requirements for buildings in flood hazard areas were introduced in the National Construction Code (NCC) in 2013 with *The Australian Building Codes Boards Construction of Buildings in Flood Hazard Areas* and the accompanying Handbook (Reference 16 and Reference 17). This Standard contains requirements to ensure new buildings and structures, located in flood hazard areas do not collapse during a flood when subjected to flood actions and includes consideration of appropriate construction, use of appropriate materials, electrical, plumbing and drainage installation as well as setting floor levels. It applies to residential buildings (Classes 1, 2, 3 and 4) and health care buildings (Classes 9a and 9c). The Standard is not intended to override any land use planning controls imposed by Council or the appropriate authority.

### 8.2. House Raising

#### DESCRIPTION

House raising is a means to eliminate or significantly reduce flooding of habitable floors by raising the habitable floor level of the dwelling above a given flood level. An existing house is simply raised above the ground and supported by piers; usually brick or steel and sometimes a non-habitable room, such as a garage, can be created beneath.

#### DISCUSSION

The main benefit of house raising is in eliminating or reducing frequency of above floor flooding and consequently reducing flood damages. Floor levels are usually raised above a chosen design flood level, for example the 1% AEP flood level, dependent on a number of factors such as the ability to raise the house and building height requirements. The occurrence of a flood larger than the design flood may mean that above floor flooding still occurs. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency. House raising is not recommended in areas of high hazard or in floodways where other measures such as voluntary purchase would be considered preferable to remove the population from high hazard areas.

The type of construction of a house can make raising an unfeasible option and house raising is not suitable for all building types, being more suitable for non-brick single storey buildings. Raising a brick property can be structurally difficult and also incur significantly higher costs than a timber property. For timber properties house raising can be in the order of \$ 80,000 when

taking into account the full project costs including cost of raising, design costs, fees and relating plumbing and electrics.

A number of properties along Chapman Avenue and Fenton Avenue have been assessed for potential house raising. Very few are suitable as the majority are of brick construction or 2 storey or their age makes them unviable.

Within the rest of the Maroubra Bay catchment area peak flood depths at houses are generally fairly low and over floor flooding is minimal, even in the larger design events. Other simple property modification measures such as temporary defences, sandbagging etc. would be a more cost effective option.

For new developments, floor level requirements (see Section 5.1.4) will negate the need for future raising of properties.

## SUMMARY

House raising is not considered to be the most cost effective measure in the Maroubra Bay study area and no individual houses have been identified for raising. Owners can be offered house raising funding, however it is very unlikely that this will be taken up considering the value of the land and the age of the building.

If owners wish to protect their own building from inundation flood proofing is more appropriate and cost effective for flooding at shallow depths where the construction is brick. Most of the flood affected buildings are of brick construction and therefore impractical to raise.

The following is not suggested for improving the flooding situation:

► **House Raising** – No individual buildings have been identified as suitable for house raising.

## 8.3. Voluntary Purchase

### DESCRIPTION

Voluntary purchase involves the acquisition of flood affected properties, in particular those subject to high hazard flows and/or located within defined floodways. Once purchased, the residence is demolished to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain; the temporary floodplain storage volume and waterway area.

### DISCUSSION

Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high hazard flooding to an existing property and it is more appropriate to cease occupation to meet the risk management objectives. It is often a measure that is used as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Management Program (Reference 18) as long as a number of complying criteria are met. Voluntary purchase areas are not classified under any specific land

use in the Standard Instrument LEP. However, Council can consider creating Voluntary Purchase Zones through their DCP or requiring that voluntary purchase zones apply to all flood prone areas also identified as being high hazard floodway.

Although measures such as flood proofing or raising could reduce flood damages for these properties during smaller events, the high flood hazard means that conditions are unsafe for people and they would still need to be evacuated before the onset of flooding. Voluntary purchase of the properties would allow the areas to be given over to public open space and more importantly, would be the only way of reducing flood risk and hazard for those residents by encouraging them to move to a less flood hazardous area. The purchased properties should be demolished and the land rezoned as appropriate use such as Environmental Conservation or similar in the LEP so that no development may take place. The land can also be defined as floodway in Council's DCP.

Estimating the value of property at \$1,700,000 (median house price from realestate.com.au for Maroubra in March 2016) and given the high density of housing in the Maroubra Bay area, voluntary purchase is unlikely to be feasible. Furthermore the inclusion of purchase fees, legal costs and demolition costs means that the economic viability of the option is highly improbable.

## SUMMARY

Voluntary purchase is not considered to be the most cost effective option for the type of flooding occurring in the Maroubra Bay area and no houses have been identified for voluntary purchase. Flood proofing, discussed in Section 8.4, is more appropriate and cost effective for flooding at shallow depths.

The following is not suggested for improving the flooding situation:

► **Voluntary Purchase** – No properties have been identified as suitable for voluntary purchase.

## 8.4. Flood Proofing of Buildings

### DESCRIPTION

Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times by the choice of materials which are resistant to flood water and facilitate draining and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

As an alternative to retrofitting permanent flood proofing measures to existing properties, temporary flood barrier methods can also be achieved by the use of sandbags in conjunction with plastic sheeting or private flood barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding (Photograph 10).

For existing residential and non residential buildings the use of temporary flood barrier methods to reduce flood damages is supported. However, due to the very infrequent nature of flooding it

is likely that a flood will occur and for some reason the barrier will not be installed. Thus this method should not be relied upon unless there is some rigorous installation approach undertaken. For example, the barrier shown in Photograph 10 is installed every night at lock up time on the commercial premises. It is unlikely that relying on some form of flood warning before installation will ensure success.

Photograph 10: Flood Barrier at Front Door of Residential Property



## DISCUSSION

Retro fitting permanent flood proofing measures can be difficult and permanent flood proofing is best achieved during construction. Temporary flood proofing can be achieved during flooding although relies on someone to implement flood barriers or similar and therefore effective flood warning times and the time of flooding can affect their efficiency.

Fitting non-return valves on plumbing can be useful to prevent back up of sewerage systems. During a flood events, sandbagging in bathrooms and toilets is beneficial, as although water may be prevented from entering the dwelling through doors and windows, backing up through the plumbing could still occur.

Temporary flood barrier measures such as sandbagging and floodgates can be a cheaper option than retrofitting to existing properties and can be useful in areas where there is frequent shallow flooding. This form of flood proofing has occurred in the catchment but the full extent is unknown. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and decrease foulness of floodwaters, thus aiding the clean-up process. Temporary barrier methods are better used when flooding is of short duration otherwise people may become stranded in their homes. Alternatively they can be used to make a property more flood resistant before evacuation. For these measures to be successful, sufficient warning time needs to be given so that defence measures can be deployed. There is little warning time in Maroubra Bay catchment area due to the nature of overland flow flooding, and although the use of temporary measures should not be discouraged they should not be

relied on as a solution to flood problems at individual properties.

Whilst it is a requirement of the NSW Government's Floodplain Development Manual (Reference 1) that new residential properties have their floor levels above the 1% AEP event plus a suitable freeboard, commercial properties are not subject to such requirements unless stipulated by Council. New commercial buildings can be required to be flood proofed to a nominated level when constructed, which would include consideration of suitable materials, electrical and other services installation and efficient sealing of any possible entrances for water. Council would make these requirements through the DCP and various planning controls. Council's current Flood Policy (see Section 5.1.4) requires that finished floor levels for commercial development is no less than the 1% AEP flood plus 0.5 m freeboard. No comment is made with regard to industrial development. This is considered reasonable, however, for new commercial development raised floor levels can cause issues with access for customers or goods supply. Some councils allow for commercial / industrial development to have lower floor levels subject to flood proofing measures to the FPL. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing to be used, and for temporary flood gate options to also be included in building design for low person risk, non-habitable developments.

## SUMMARY

Flood proofing is a good solution to reducing flood risk to commercial and industrial properties and should be encouraged for all new developments of this type, particularly if floors are allowed to be lower than the FPL. Consideration of appropriate construction materials is still needed for those residential developments where floor levels will be raised above the 1% AEP flood level but the structure can still become inundated below the floor level.

Temporary flood proofing techniques may be deployed for existing buildings that are inundated, although lack of warning time may limit their efficiency and they should be considered as a secondary option to more permanent measures being implemented.

## RECOMMENDATIONS

The following measure is recommended:

- Include requirements for flood proofing, wet or dry as appropriate, in development controls. This approach should be the minimum flood related requirement for non-habitable buildings such as commercial or industrial developments where existing or proposed floor levels are below the FPL.

## 8.5. Minor Property Adjustments

### DESCRIPTION

In overland flow areas, minor property adjustments can be made to manage overland flow passing through private property. Such adjustments can include low level bunding (small levees) or drainage channels around individual properties, amendments to fences or construction of fences which act as deflector levees, modifying gardens and ground levels etc. all of which can affect the local continuity of overland flow paths.

## DISCUSSION

Property adjustments can be used to manage overland flows through private property and minimise impacts on dwellings by helping to divert local overland flows away from dwellings and access points. However, if not designed well, adjustments on one property may impact on adjoining properties, or require modifications on neighbouring properties to be effective.

Therefore any works in flood prone areas which could modify the localised flood behaviour should be shown to have no significant impact on adjoining properties and be subject to approval from Council.

This approach has been suggested at Byrne Crescent (Appendix G).

## SUMMARY

Minor property adjustments can have localised benefits however they should be assessed for their impact on neighbouring properties. At properties within a floodway or subject to above floor flooding, minor property adjustments may not always be sufficient and other management measures may need consideration, such as pipe upgrades.

## 8.6. Drainage Easements

### DESCRIPTION

Drainage easements are set distances, usually measured from the centreline of a watercourse, drainage channel or pipe, to which development is restricted. For above ground structures drainage easements provide an area for water to spill when the capacity of the channel may be exceeded without immediately affecting properties. Easements also ensure that pipes and channels can be accessed for maintenance. Easements can also be applied where overland flow paths have been identified and Council requires them to be maintained (i.e not built over).

### DISCUSSION

There can be some social issues related with introducing easements onto a property. People can feel part of their property is no longer developable and believe this can reduce property values. In reality the easements are still allowed to be used as open space areas and can be retained under the ownership of the resident. It can be difficult for Council to enforce easement controls particularly on existing properties. Council could consider purchasing the land within the easement area however, there can be high costs involved with this and in addition, if the easement separates a property into two it is unlikely that the property owners would be co-operative. Community consultation will be key in establishing easements and controls.

### SUMMARY

Drainage easements are a means of ensuring existing flow paths are maintained in perpetuity. The creation of additional overland flow easements through private property would further assist in this regard. The main and overwhelming drawback of this proposal is that private property owners would be very unlikely to permit an easement over their land as it will affect their

property value.

## **8.7. Protecting Key Infrastructure**

### **DESCRIPTION**

It is important to protect key infrastructure from flooding which could cause failure of systems such as electricity, telecommunication or sewerage supply. Protection can be by relocation to areas outside of the PMF flood extents, or where this is not possible, ensuring that the operation will not be flood affected through incorporation of minor property modifications or flood proofing.

### **DISCUSSION**

For future development, Council's current policy for flood prone land (see Section 5.1.4) recognises that some development types are more vulnerable to flooding than others. The Policy recognises that certain types of development have a post disaster function or specific evacuation needs during a flood event, such as schools, hospitals, nursing homes, retirement villages, aged care facilities, SES headquarters, evacuation centres, major utility facilities and emergency response facilities. These types of facilities need to consider safety issues for all floods up to and including the PMF and flood related development controls apply even if land is above the 1% AEP flood level plus 0.5 m, where it is below the PMF. This is considered to be a suitable policy.

### **SUMMARY**

Council's flood policy requires higher floor level and protection for more vulnerable developments which are needed to function during flooding. This is considered to be an appropriate development control as there are large flood free areas within the catchment in which this more vulnerable type of development could be located. Consideration may want to be given to all utility facilities (sewerage and electricity).

## **8.8. Flood Insurance**

### **DESCRIPTION**

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments.

### **DISCUSSION**

It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance as well as how insurance companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.

**SUMMARY**

Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this Maroubra Bay Flood Study and Risk Management Study and Plan. This planning must include consideration of the future risk from climate change.

## 9. RESPONSE MODIFICATION MEASURES

Flood response measures encompass various means of modifying the response of the population to the flood threat.

### 9.1. Flood Emergency Management

#### DESCRIPTION

Planning for emergency response can reduce losses due to flooding. Emergency response for flooding is detailed in the Local Flood Plan (LFP). LFPs are subordinate plans of the Emergency Management Plan (EMPLAN) which describes emergencies and the responsible combat and support agencies. The SES is the lead combat agency for flooding in NSW and responsible for coordinating evacuation in a flood event. The LFP is prepared and used by the NSW SES and describes the risk to the community, outlines roles and responsibilities for the SES plus supporting agencies and describes how the SES will manage flood events.

#### DISCUSSION

The LFP usually sets out responsibilities of various response agencies, details how evacuation should occur, those access points which may become impassable, and locations for emergency evacuation centres. The preparation of a LFP aids to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, location of resources and roles and responsibilities. It is the role of the SES to develop a LFP for vulnerable communities and, at present, the NSW SES have no specific LFP for the Maroubra Bay catchment area.

From the assessment undertaken in this FRMS it is identified that there are few properties which would benefit from evacuation (see Section 3.5) in a major flood. As there are so few flood prone houses in the Maroubra Bay catchment it is unlikely that the SES will call for evacuation of many properties. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings such as the BoM's weather warnings, and may be assisted by local residents. Should evacuation be necessary the Local SES unit will usually coordinate. The Randwick SES unit covers the Maroubra Bay catchment area.

Council can, in conjunction with the NSW SES, prepare Local FloodSafe Guides which can be made available to the public in community centres and online. The FloodSafe Guides inform the public of how to prepare for and act during a flood or severe weather event. Information is available to the public on the SES's StormSafe.com.au and FloodSafe.com.au websites.

Although flood warning is limited and the number of properties requiring evacuation is also small, a local disaster plan or LFP should be continually updated to include the latest information on design flood levels and details on roads, properties, and other facilities which would be flood affected. The LFP is based on data from hydraulic modelling and should be updated to include hazard mapping and emergency response classifications (see Section 3.5) for a range of design events. The hydraulic modelling for the Maroubra Bay catchment, as per Appendix C of this

FRMS&P, should be used.

## SUMMARY

Despite the reduced flood warning time available, planning for response during a flood event can still be highly beneficial. Council should ensure there is appropriate disaster planning for the Maroubra Bay catchment area either in the form of Council's own local disaster plan for an NSW SES prepared LFP. This should also take into account those properties not directly flood affected but which may have had access cut and become flood islands. This plan should be regularly kept up to date and should include feedback from recent flood events and the recommendations of this FRMS&P once adopted.

## RECOMMENDATIONS

The following measures are recommended:

- Council should prepare local disaster plan using information provided in this FRMS and from the NSW SES.

AND/OR

- The SES should prepare a Local Flood Plan for the Maroubra Bay catchment.

## 9.2. Flood Warning and Evacuation

### DESCRIPTION

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Severe weather warnings and thunderstorm warnings are provided by the BoM and are issued when severe weather or thunderstorms are expected. The warning may also note the hazards associated with the storm including damaging wind gusts, large hail and flash flooding. The BoM will also, for some areas, issue a flood watch covering a particular river basin or catchment. This can be upgraded to a flood warning when flooding is expected to occur or is happening.

Evacuation warnings are issued by the SES and advise that people should prepare for the instance that an Evacuation Order may be issued. Evacuation Orders require that all people evacuate the area and may be issued through door knock, radio, automated telephone and/or other forms of media (SMS etc.). Once the risk has subsided an All Clear is issued.

### DISCUSSION

Flood warning can significantly reduce damages and risk to life and studies have shown that flood warning systems generally have a high B/C ratio if sufficient warning time is provided. Adequate warning can give residents time to move goods and cars above the reach of floodwaters, raise house contents onto tables and worktops and evacuate from the area. However, flood warning time in the Maroubra Bay catchment is low due to the nature of the overland flow flooding which can occur very quickly, within 2 hours.

The success of any flood warning system and the evacuation process in reducing flood losses and damages depends on;

- *Flood Awareness*: How aware is the community of the flood threat? Has it been adequately informed and educated?
- *Flood Preparedness*: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?
- *Flood Evacuation*: How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

Due to the fast onset of overland flooding that characterises the Maroubra Bay catchment, residents would be likely to have noticed rising flood waters before evacuation warnings are issued. To aid the SES emergency response, residents can be made aware through community awareness and preparedness schemes how to act on BoM weather warnings prior to SES evacuation orders. Many Councils prepare a Local FloodSafe brochure in collaboration with the SES to advise residents in this regard.

## SUMMARY

Due to the nature of flooding in the study area, flood warnings are limited in effectiveness. It should be noted that there are few areas where a full scale evacuation would be necessary during most flood events. Severe weather warnings should be used as a caution to potential onset of flooding. These are available through BoM and could also be made available on Council's website.

## RECOMMENDATIONS

The following measures are recommended:

- ▶ Severe Weather Warnings and Thunderstorm Warnings should be provided on Council's website and in local media.
- ▶ Council can produce a Local FloodSafe brochure in collaboration with the SES.

## 9.3. Flood Access

### DESCRIPTION

Evacuation can be improved by ensuring adequate evacuation routes and appropriate warning as to when the routes will become impassable. For example, roads could be raised or low spots eliminated to ensure routes are not blocked. In addition, emergency services could be exposed to lower hazards in carrying out their duties.

### DISCUSSION

Due to the nature of flooding in the Maroubra Bay catchment, local change to ground levels such as raising roads could have significant implications in terms of flooding for local properties. Consequently, major raising of road levels is not advised.

Instead other measures should be investigated such as improving drainage to reduce flood

levels (see Section 7). The hydraulic modelling undertaken for assessment of potential flood management options has shown that this would be a more appropriate solution.

## SUMMARY

Raising existing roads within the Maroubra Bay catchment should be done with caution and an assessment of appropriate compensatory drainage should be made.

The following is not suggested for improving the flooding situation:

- **Road Raising** – in particular those roads perpendicular to flow could exacerbate local flood levels.

## 9.4. Community Awareness and Preparedness Program

### DESCRIPTION

Public information and the level of public awareness and preparedness is key in reducing flood damages and losses. A more aware and prepared community is likely to be more prepared and will suffer less losses and damage than an unprepared community. Raising community awareness and preparedness can be achieved through a number of means such as leafleting, local posters, media releases, Council and SES attendance at community events.

### DISCUSSION

The level of flood awareness and preparedness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including frequency and impact of previous floods, history of residence, and whether an effective community awareness and preparedness program has been implemented. Generally community awareness and preparedness will decline as the time since the last flood increases and a difficulty with flood awareness and preparedness campaigns is often convincing residents that major floods will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. Community awareness and preparedness can be raised as a result of community flood or climate change awareness programs. A community with high flood awareness and preparedness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation.

Following a flood event it is important to collect available information but to also let the community know that Council is aware of the problems and are managing it. On-going post flood data collection by Council in conjunction with the SES should occur after every flood event to enable improved understanding of the flooding situation and ensure data is always the most recent to allow better decision making for flood management.

It is generally considered that the benefits of community awareness and preparedness far outweigh the costs. Costs can be low if awareness media is issued with regular Council media such as newsletters or local community leaflets. As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness and preparedness is maintained through implementation of a suitable

flood awareness and preparedness program that would include FloodSafe brochures as well as advice provided on Council's and SES's websites

Table 18 provides examples of possible further methods to raise community flood awareness that may be developed and supported by Council.

Table 18: Community Flood Awareness and Preparedness Methods

| Method                                                  | Comment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Letter/pamphlet from Council</b>                     | Sending with information already being sent to residents, such as rate notices, would reduce costs. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of on-going implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.                                                                                                            |
| <b>Council website</b>                                  | Council's website already provides good information on the flood management within their LGA. Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required. |
| <b>Community Working Groups</b>                         | Council should initiate a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council. The current FMC includes representatives from Council, OEH, and local residents (see Section 2.6.2).                                                                                                                                                                                                                                                |
| <b>School project or local historical society</b>       | This provides a means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.                                                                                                                                                                                                                                                                         |
| <b>Historical flood markers and flood depth markers</b> | Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.                                                                                                                                                         |
| <b>Articles in local newspapers</b>                     | On-going articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.                                                                                                                                                                                                                                                                                 |
| <b>Collection of data from future floods</b>            | Collection of data (including photographs and recorded flood levels) assists in reinforcing to the residents that Council is aware of the problem. Collected data can also be used to update hydrologic and hydraulic model calibration and ensures that the design flood levels are as accurate as possible.                                                                                                                                                                                          |
| <b>Types of information available</b>                   | A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the S149 certificate during the purchase process. Council has a policy on providing flooding advice (see Section 5.1.4). Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be                     |

| Method                                                                                  | Comment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                         | provided to all visitors who may rent for a period. Some Councils have conducted briefing sessions with real estate agents and conveyancers.                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Establishment of a flood effects database and post flood data collection program</b> | A database would provide information on a number of issues such as which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event and updated with input from the community.                                                                                                                                                                                                                                                                |
| <b>Flood preparedness program</b>                                                       | Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The NSW SES would take a lead role in this.                                                                                                                                                                                      |
| <b>Develop approaches to foster community ownership of the problem</b>                  | Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as blockage of drains or such like. This process can be linked to water quality or other water related issues. The specific approach can only be developed in consultation with the community. |

## SUMMARY

Although this flood risk management process had raised community awareness and preparedness through its community consultation program, continuingly ensuring community awareness and preparedness of flood risks is important in reducing overall damages and losses. Therefore Council should undertake a regular community awareness program to ensure that there is continuous flood awareness and preparedness.

The specific flood awareness and preparedness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

## RECOMMENDATIONS

The following measure is recommended:

- Undertake regular community awareness and preparedness campaigns. Set Council policy to ensure a new campaign is undertaken on a regular basis, for example every two years.

## 10. PLANNING AND DEVELOPMENT CONTROL MEASURES

### 10.1. Land Use Zoning

#### DESCRIPTION

Defining appropriate land uses in flood prone areas can prevent inappropriate development from occurring and thus reduce flood risk. Land uses zones are governed by the LEP. To make any significant changes to land use zones within the LEP a planning proposal usually has to be submitted to the Department of Planning and Infrastructure and subject to some public consultation.

#### DISCUSSION

The current land uses for the Maroubra Bay area are presented in Figure 2. The developed nature of the catchment means that significant land use changes are unlikely. Nevertheless it is worth ensuring that flood affected area that are currently recreational are not rezoned as residential and similarly that low residential areas are not rezoned as medium/high density residential.

#### SUMMARY

Appropriate land use planning can assist in reducing future flood risk and ensuring development in flooded areas is flood compatible.

#### RECOMMENDATIONS

The following measure is recommended:

- Reconsider the planned revisions to the LEP land use zones to reduce future areas of residential development from the floodplain.

### 10.2. Flood Planning Area and Property Tagging

The Flood Planning Area (FPA) is an area to which flood planning controls are applied and a FPA map is a required outcome of the FRMS&P. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. As suggested by the Floodplain Development Manual (Reference 1), the FPA is typically based on the flood extent formed by the 1% AEP mainstream flooding event plus freeboard (0.5 m). Therefore planning controls may be applied to development which is not necessarily within the 1% AEP flood extent but is in the FPA. The purpose of extending the FPA past the 1% AEP flood extents is to allow for any future increases in flood extents due to climate change as well as an allowance for differences between flood behaviour during events due to wave action or other effects.

The LEP permits a Flood Planning Area map to be included as a layer imposed across all land zones.

## DISCUSSION

While the 1% AEP + 0.5 m criteria is appropriate for areas of mainstream flooding (rivers and other watercourses), it is not always appropriate for areas subject to flooding from overland flows. Much of the study area is overland flooding for which depths are characteristically lower than mainstream flooding and do not tend to scale much for rarer events.

In light of this, and through discussions with Council, the following approach has been adopted for defining the FPA (and property tagging) in areas subject to overland flow:

- All flood depths less than 0.15 m are discounted as "rainfall drainage" - it is considered too unsubstantial to be called flooding, given the relatively shallow depth.
- All the study area has been described as "major overland flow" and not "mainstream" flooding. As flood liability is due to major overland flows and not mainstream flooding, only those lots which are impacted by substantial floodwaters (for example more than 10% of the lot) are selected for inclusion in the FPA.

The above process is undertaken by comparing Council's cadastre with the peak flood levels, depths and extents of the 1% AEP design event.

To ensure that the cadastral lots tagged by this method are reasonable a ground truthing exercise was undertaken. Engineers from WMAwater spent several days in the Maroubra Bay area reviewing the computer generated outputs and manually making amendments where necessary. For example, where all lots on one street were identified as flood prone except one, a review was undertaken on that property, looking at the hydraulic model outputs, ALS and survey data and on site to assess if it should be included.

The final FPA and tagged cadastral lots has been submitted to Council in a separate report.

## SUMMARY

Defining the FPA is crucial as the FPA is a key concept referred to in Council's LEP. It is important to define a FPA to efficiently apply flood related development controls to only the relevant areas of the Maroubra Bay catchment area. The 1% AEP flood level plus 0.5 m freeboard is not considered appropriate for the Maroubra Bay area as flooding is mainly overland flows. Instead an alternative method has been developed and properties tagged as flood prone have been verified through on site inspection.

## RECOMMENDATIONS

The following measure is recommended:

- Flood Tagging of properties based on 10% of the lot flooded to depths more than 150 mm criteria in the 1% AEP. A separate report has been issued to Council.

## 10.3. Flood Planning Levels

### DESCRIPTION

The *Construction of Buildings in Flood Hazard Areas Standard* (Reference 16) states that,

unless otherwise specified by the appropriate authority (e.g Council), the finished floor level of all habitable rooms must be above the Flood Hazard Level<sup>2</sup> and the finished floor level of enclosed non-habitable rooms must be no more than 1 m below the Defined Flood Level<sup>3</sup>.

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual, 2005 (Reference 1) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.

The Floodplain Development Manual (Reference 1) states that in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard, typically 0.5 m. According to the Floodplain Development Manual (Reference 1) the purpose of the freeboard is to provide reasonable certainty, that the reduced flood risk exposure provided by selection of a particular flood, as the basis of a FPL, is actually provided given the following factors;

- Uncertainties in estimates of flood levels;
- Differences in water level because of local factors;
- Climate change (rainfall intensity increase);
- Increases due to wave action; and
- The cumulative effect of subsequent infill development on existing zoned land.

Typically the FPL is used to define the minimum level at which habitable floor levels should be constructed but can also be used to define requirements for flood proofing and site access.

## DISCUSSION

In determining a suitable FPL, the FMC and Council must balance the cost to the community by restricting development in flood prone areas with the benefits of the reduction in damages, frequency and danger to life caused by flooding. The FPL can be varied depending on the use, and the vulnerability of the building/development to flooding. For example, residential development could be considered more vulnerable whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Developments more vulnerable to flooding such as critical facilities including hospitals, schools, electricity sub-stations, senior's housing etc., should consider rarer events than the 1% AEP when determining their FPL or be situated outside of the floodplain where possible. For the less vulnerable commercial and industrial developments, flood proofing a building can be considered where raising floor levels is not an option or is not feasible, but should not be allowed for residential developments or other vulnerable uses.

Council's current floor level requirements in the Comprehensive DCP (Reference 13) are

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<sup>2</sup> The Standard defines the Flood Hazard Level (FHL) as "*the flood level to be used to determine the height of floors in a building and represent the defined flood level (DFL) plus the freeboard*".

<sup>3</sup> The DFL is defined in the Standard as "*the flood level associated with the defined flood event*". Therefore the FHL is effectively the same as the FPL.

provided in Table 19.

Table 19: Current Floor Level Requirements (taken from Reference 13)

| Scenario                                                                                                      | Floor level                                                                                          |
|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| <b>Habitable Floors - all development (excluding critical facilities)</b>                                     |                                                                                                      |
| Inundated by flooding                                                                                         | 1% AEP + 0.5m freeboard                                                                              |
| Inundated by overland flow path                                                                               | Two times the depth of flow in the 1% AEP flood with a minimum of 0.3m above the surrounding surface |
| <b>Habitable floors - Critical facilities</b>                                                                 |                                                                                                      |
| Inundated by flooding                                                                                         | PMF + 0.5m freeboard                                                                                 |
| Inundated by overland flow path                                                                               | Two times the depth of flow in the PMF with a minimum of 0.3m above the surrounding surface          |
| <b>Non-habitable floors – residential outbuildings (excluding garages) *</b>                                  |                                                                                                      |
| Gross floor area less than or equal to 10 square metres.                                                      | 1% AEP but not less than 0.15m above surrounding ground level                                        |
| Gross floor area greater than 10 square meters.                                                               | The applicable habitable floor level                                                                 |
| <b>Non-habitable floors – Industrial and commercial</b>                                                       |                                                                                                      |
| Located on flooding or overland flow path                                                                     | 1% AEP but not less than 0.15m above surrounding ground level                                        |
| <b>Material storage locations – all development</b>                                                           |                                                                                                      |
| Materials sensitive to flood damage, or which may cause pollution or be potentially hazardous during flooding | 1% AEP + 0.5m freeboard                                                                              |

Table 19 requires that critical facilities have floor levels above the PMF flood level plus freeboard. Seeing as the PMF is the largest flood that can conceivably occur, adding such a freeboard can be considered an unnecessary restriction to development. Where possible such critical facilities should be located outside of both the FPA and the PMF extents (whichever is greater). Where this is not possible, floors and access should be raised above the greater of the PMF or the 1% AEP plus 0.5 m level.

For non-habitable commercial and industrial uses floor levels could be subject to a lower level conditional to flood proofing to the FPL. As well as suitable materials and construction, this includes locating unsealed electrical circuits at least above the designated FPL for the area to reduce risk of electrocution (see Section 8.4).

It is appropriate to use a reduced freeboard for areas subject to overland flow flooding rather than mainstream flooding as depths tend to be shallower. However, rather than identify a

variable freeboard dependent on depths as the current DCP does, a fixed freeboard is recommended. For areas of overland flow a reduced freeboard of 0.3 m may be appropriate. A single freeboard with reference to a flood level has benefit over a variable freeboard based on depth as it is less subjective to define. In all locations subject to flooding a minimum height of floor level above ground is also recommended if lower than the 1% AEP flood level plus freeboard.

## SUMMARY

The FPL is the 1% AEP flood level plus a given freeboard (either 0.5m or the depth of inundation for overland flow areas). It should be used to set finished floor levels requirements for residential development. Less vulnerable uses such as commercial developments could be subject to lower floor level requirements but it is recommended that they should be subject to flood proofing to the FPL where floor levels are lower.

Anthropomorphic induced climate changes have the potential to increase design rainfall intensities and consequently design flood levels and the associated flood related planning controls. This issue has been examined and quantified in Section 4.5. At this time (2016) the potential rainfall increase has not been incorporated into Council's flood related planning controls for the following reasons:

- there is insufficient firm advice from expert authorities (CSIRO, BoM, Institute of Engineers etc) regarding the likely rainfall increase;
- Council has adopted a freeboard of 0.5m for residential floors which is considered conservative for the largely shallow depth overland flow flooding in the catchment (it can be argued that the freeboard should not exceed the depth of inundation in the design event). Freeboard includes some allowance for climate change;
- this study has quantified a range of design rainfall intensity increases (Section 4.5) and for approximately of the 21 locations considered (Table 8) the increase in depth of inundation for a 10% rainfall increase is 0.1m or less and thus equates to less than 50% of the freeboard allowance.

## RECOMMENDATIONS

The following measures are recommended:

- ▶ Make consistent requirements for floor levels between Council's DCP and the Flood Policy.
- ▶ Continually monitor best practice advice regarding anthropomorphic induced rainfall increases. At a minimum every 2 years Council should provide a statement outlining the status of the best practice advice and whether Council's adopted design rainfall, flood levels and associated flood related planning controls should be adjusted as a result.
- ▶ The Flood Planning Level (FPL) is adopted as:
  - ▶ Areas subject to overland flow flooding: 1 % AEP flood level plus the depth of inundation as freeboard;
  - ▶ Areas subject to mainstream flooding: 1% AEP flood level plus 0.5 m freeboard.
- ▶ Variable requirements for floor levels dependent on type of flooding and development use (Recommendations are given in Table 19).
- ▶ For commercial or industrial developments where finished floor levels are not set at the FPL

(1% AEP plus freeboard), flood proofing measures will be required to the FPL.

- ▶ Most vulnerable developments such as hospitals, schools, services including power supplies should be encouraged to be located outside of the PMF or FPA extents or at the very least have floors and/or essential machinery above the FPL or PMF level, whichever is higher.

## 10.4. Modification to S149 Certificates

### DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. A certificate issued under Section 149(2) provides information about the zoning of the property, the relevant state, regional and local planning controls and other property affectations such as land contamination and road widening. A certificate issued under Sections 149(2) and 149(5) provides both the information available in a Section 149(2) certificate and additional information such as advice from other authorities, subdivision history and easements where Council has information available. While the certificate will state all the relevant planning instruments that apply to the property, it does not provide specific development standards or terms of the instruments.

Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. Under Part 2, it is compulsory for Council to advise if they are aware of flood risk or of any other known risks such as bush fire, land slip etc., while Part 5 provides additional details and may not be made known to the purchaser unless it is specifically requested.

### DISCUSSION

Council's Flooding Advice and Flood Related Development Controls Policy (see Section 5.1.4) provides details on the provision of flood information on both S149(2) and S149(5) certificates.

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined). It should be noted that the Section 149 certificate only relates to the subject land and not any specific building on the property.

The information provided under Part 2 of the certificate is determined by legislation, under the Environmental Planning and Assessment Act 1979, as amended, and the Environmental Assessment and Planning Regulation, 2000, and unless specifically included by the Council provides no indication of the extent of flood inundation. Under Part 5, which provides further details, there is scope for providing this additional type of information. There can be a general perception from the public that insurance companies, lending authorities or other organisations

may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information onto Part 5 to show the percentage of the property inundated as well as floor levels and other flood related information. In addition the hazard category could be provided and also advice regarding climate change increases in flood level. It is recommended that Council provide information under Part 5 where possible.

The following flood risk information should be included in Part(2) of the S149 certificate:

- Whether or not the property is in a FPA;
- Any development control due to siting of the property in the FPA;
- Responsibility for maintenance and compliance for OSD features; and
- Highlight any drainage easements through the property and controls that apply.

Some Councils include detailed flooding information in Part(5) of the S149 certificate as standard practice. This ensures that residents are fully made aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in Part(5) could include:

- Flood levels / depths at the property;
- Percentage of property flood affected;
- The likelihood of flooding;
- Floor levels (from Council's floor level survey if available); and
- Potential flood hazard.

## SUMMARY

Data from the hydraulic modelling used in this FRMS&P should be incorporated into Council's S149 certificates. As Council information for S149 Certificates is currently obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site. As a result of this FRMS&P a database of flood prone properties has been prepared in a GIS format, linked to Council's own cadastre dataset.

## RECOMMENDATIONS

The following measures are recommended:

- Update and re-issue S149 certificates based in this FRMS&P.
- Allow residents to request flooding information for their property through Council's website.

## 11. ACKNOWLEDGMENTS

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- The Maroubra Bay Catchment Flood Management Committee;
- Residents of the Maroubra Bay catchment area;
- Randwick City Council;
- State Emergency Services;
- NSW Office of Environment and Heritage.

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# **PART B Draft Floodplain Risk Management Plan**

## 1. RISK MANAGEMENT MEASURES CONSIDERED

A matrix of possible management measures was prepared and evaluated in the Flood Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures including flood mitigation dams and voluntary purchase of all flood liable buildings which are clearly not viable.

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 benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows) of the project over its life. It is a standard method for using the time value of money to compare the reduction in flood damages (benefit) with the capital and on going cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical 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. A multi-variate decision matrix was developed for the study area, allowing benefit/cost estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

The full range of measures was evaluated in Sections 6 to 10 and the outcomes are summarised in Table 20. Table 12 details the matrix scoring system and Table 14 provides a summary of results for the drainage upgrade options.

Community opinion on the full range of options has been canvassed during the public exhibition period in Section 2.6.5, however, it should be noted that these outcomes may change in the future and/or as an outcome of further more detailed investigation subsequent to this project.

**TABLE 20: DRAFT MAROUBRA BAY FLOODPLAIN RISK MANAGEMENT PLAN**

The flood mitigation and management measures set out below for the Maroubra Bay Floodplain Risk Management Plan are assessed according to the criteria described in Table 12. These measures have been identified through the floodplain risk management process in accordance with the NSW Government Flood Prone Land Policy and the Floodplain Development Manual (2005). THIS PLAN COMPRISES THE DRAFT PLAN ONLY AND IS TO BE FINALISED FOLLOWING A PERIOD OF PUBLIC CONSULTATION, APPROVAL FROM COUNCIL AND THE FLOODPLAIN RISK MANAGEMENT COMMITTEE.

|                    | Report Ref    | OPTION                                                                                     | COMMENT                                                                                                                                               | B/C Ratio | Impact on Flood Behaviour                                   | Number of Properties Benefitted | Technical Feasibility | Community Acceptance | Economic Merits | Financial Feasibility | Environmental/ Ecological Benefits | Impact on SES | Political / Admin Issues | Long Term Performance | Risk to Life | TOTAL | RANK |
|--------------------|---------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-------------------------------------------------------------|---------------------------------|-----------------------|----------------------|-----------------|-----------------------|------------------------------------|---------------|--------------------------|-----------------------|--------------|-------|------|
| Flood Modification | Section 7.5.1 | <b>Option A – Lowering of Main Promenade</b>                                               | Lower the crest and widen the current crest width of the main promenade at Maroubra Beach.                                                            | 1.0       | 3                                                           | 3                               | 1                     | 2                    | 3               | 1                     | -1                                 | 0             | -1                       | 2                     | 1            | 14    | 5    |
|                    | Section 7.1.2 | <b>Option B – Flood Retarding Basin in Muraborah Reserve (Wride Street)</b>                | Refine layout of this basin.                                                                                                                          | 0.6       | 1                                                           | 1                               | -1                    | 0                    | 2               | 1                     | 0                                  | 0             | -1                       | 2                     | -1           | 4     | 16   |
|                    | Section 7.1.3 | <b>Option C – Flood Retarding Basin in John Shore Park</b>                                 | Re-grade Maxwell Avenue to direct overland flow to John Shore Park. Earthworks within John Shore Park will be required to provide detention capacity. | 1.5       | 3                                                           | 3                               | -1                    | 0                    | 3               | 1                     | 0                                  | 0             | -1                       | 2                     | -1           | 9     | 9    |
|                    | Section 7.2.1 | <b>Option D – Duplication of drainage network from John Shore Park to the Beach Outlet</b> | Upgrade the existing trunk system that drains the Fenton Avenue low point.                                                                            | 0.3       | 3                                                           | 3                               | -3                    | 3                    | -2              | -2                    | -1                                 | 1             | 0                        | 3                     | 2            | 7     | 12   |
|                    | Section 7.1.4 | <b>Option E – Coral Sea Park Retarding Basin Performance Improvement</b>                   | Lower Coral Sea Park.                                                                                                                                 | n/a       | <b>No works proposed except undertake safety inspection</b> |                                 |                       |                      |                 |                       |                                    |               |                          |                       |              | n/a   | n/a  |
|                    | Section 7.2.2 | <b>Option F – Midway Drive Trapped Low Point</b>                                           | Upgrade Midway Drive Drainage Network.                                                                                                                | 0.0       | 1                                                           | 1                               | 1                     | -1                   | -3              | -2                    | 0                                  | 0             | 0                        | 3                     | 0            | 0     | 18   |
|                    | Section 7.2.3 | <b>Option G &amp; J – Haig Street Low Point &amp; Maroubra Road/Flower Street to Beach</b> | Upgrade drainage from Galvin Street to the beach outlet – Haig Street.                                                                                | 0.2       | 3                                                           | 2                               | 1                     | 1                    | -2              | -3                    | 0                                  | 0             | 0                        | 3                     | 0            | 5     | 14   |
|                    | Section 7.2.4 | <b>Option H – Byrne Crescent Low Point</b>                                                 | No works proposed                                                                                                                                     | n/a       | <b>No works proposed</b>                                    |                                 |                       |                      |                 |                       |                                    |               |                          |                       |              | n/a   | n/a  |
|                    | Section 7.2.5 | <b>Option I – 134-140 Marine Parade</b>                                                    | Upgrade drainage at 134-140 Marine Parade.                                                                                                            | 0.4       | 1                                                           | 1                               | 1                     | 1                    | 1               | 0                     | 0                                  | 0             | 0                        | 1                     | 0            | 6     | 13   |
|                    | Section 7.2.6 | <b>Option LMK – Fitzgerald Avenue/Chester Avenue Intersection</b>                          | Drainage Upgrade proximate Coral Sea Park – Fitzgerald Avenue and Chester Avenue.                                                                     | 0.1       | 1                                                           | 1                               | 1                     | 1                    | 1               | -1                    | 0                                  | 0             | 0                        | 1                     | 0            | 5     | 14   |
|                    | Section 7.2.7 | <b>Option N – White Avenue (between Bennet Place and Farthing Place)</b>                   | Drainage Upgrade to White Avenue – White Avenue (between Bennet Place and Farthing Place).                                                            | 0.3       | 2                                                           | 1                               | 2                     | 2                    | 2               | 1                     | 0                                  | 0             | 0                        | 1                     | 0            | 11    | 7    |
|                    | Section 7.2.8 | <b>Option O – Tyrwhitt Street</b>                                                          | Drainage Upgrade                                                                                                                                      | unknown   | 0                                                           | 0                               | 0                     | -1                   | -2              | -1                    | 0                                  | 0             | 0                        | 1                     | 0            | -3    | 19   |
|                    | Section 7.2.9 | <b>Option P – Curtin Crescent</b>                                                          | Drainage Upgrade at Curtin Crescent – between South Maroubra Village Green to Broome Street.                                                          | 0.0       | 1                                                           | 1                               | 1                     | -1                   | -1              | -1                    | 0                                  | 0             | 0                        | 1                     | 0            | 1     | 17   |

|                       | Report Ref   | OPTION                                                               | COMMENT                                                                                                      | B/C Ratio | Impact on Flood Behaviour | Number of Properties Benefitted | Technical Feasibility | Community Acceptance | Economic Merits | Financial Feasibility | Environmental\ Ecological Benefits | Impact on SES | Political / Admin Issues | Long Term Performance | Risk to Life | TOTAL | RANK |
|-----------------------|--------------|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------|---------------------------|---------------------------------|-----------------------|----------------------|-----------------|-----------------------|------------------------------------|---------------|--------------------------|-----------------------|--------------|-------|------|
|                       | Section 7.7  | <b>On Site Detention</b>                                             | Mitigate effects of urbanisation                                                                             |           | 0                         | 0                               | 3                     | 1                    | 0               | 3                     | 1                                  | 0             | 0                        | 0                     | 0            | 8     | 11   |
| Property Modification | Section 8.4  | <b>Flood Proofing</b>                                                | Most adequate for garages and non-residential buildings                                                      |           | 3                         | 1                               | 2                     | 1                    | 3               | 3                     | 0                                  | 0             | 0                        | 1                     | 0            | 14    | 5    |
|                       | Section 10.3 | <b>Flood Planning Levels</b>                                         | Ensures flood problem is not exacerbated                                                                     |           | 0                         | 3                               | 3                     | 2                    | 2               | 3                     | 0                                  | 0             | 0                        | 3                     | 0            | 16    | 3    |
|                       | Section 10   | <b>Development Control Planning</b>                                  | Ensures negative impact is not imposed on public/private property from new development                       |           | 0                         | 3                               | 3                     | 1                    | 3               | 3                     | 0                                  | 0             | 0                        | 3                     | 0            | 16    | 3    |
|                       | Section 8.8  | <b>Flood Insurance</b>                                               | Does not reduce flood damages but transforms the random sequence of losses into a regular series of payments |           | 0                         | 2                               | 2                     | 0                    | 0               | 3                     | 0                                  | 0             | -1                       | 3                     | 0            | 9     | 9    |
| Response Modification | Section 9.2  | <b>Evacuation Planning</b>                                           | Ensures maximum possible warning time is available to minimise damage and enable safe evacuation             |           | 0                         | 3                               | 1                     | 3                    | 2               | 3                     | 0                                  | 3             | 0                        | 3                     | 1            | 19    | 2    |
|                       | Section 9.4  | <b>Public Information and Flood Awareness / Preparedness Raising</b> | Council and SES to provide information to residents.                                                         |           | 0                         | 3                               | 3                     | 2                    | 3               | 3                     | 0                                  | 3             | 0                        | 2                     | 1            | 20    | 1    |
| Others                | Section 7.3  | <b>Management of Blockage</b>                                        | Minimising of pit, drains and channel blockage                                                               |           | 1                         | 2                               | -1                    | 3                    | 0               | 3                     | 1                                  | 0             | 2                        | 0                     | 0            | 11    | 7    |

## 2. FLOOD RISK MANAGEMENT MEASURES IN PLAN

The Maroubra Bay Floodplain Risk Management Plan summarises the outcomes from the Management Study as a series of measures which will assist in reducing flooding for existing and future developments. The mix of measures has been developed following consideration of the ranking developed in the management options matrix in the study (Table 20) as well as discussions with the Floodplain Management Committee and as a result of community consultation.

The recommended measures are described below (according to the ranking in Table 20). The priority rating (High, Medium, Low) is based upon a qualitative assessment of the rankings in Table 20 and the ease of implementation (availability of funds, responsibility). The measures in the plan have been separated into Structural and non Structural measures.

Further detail and insight into each measure is provided in the relevant section of the Maroubra Bay Floodplain Risk Management Study.

The provision of benefit/cost ratios (i.e the benefit in terms of reduction in flood damages compared to the cost of the works) cannot be adequately provided for all floodplain management measures because the benefit is often the reduction in intangible damages (risk to life, injury etc.) which cannot be assigned a monetary value.

### 2.1. Non Structural Measures in the Plan

#### **HIGH Priority**

1. **(Rank 1) Public Information and Flood Awareness Raising.**
  - **Cost:** low will depend on approach
  - **Responsibility:** Council, SES
  - **Timeframe:** ongoing
2. **(Rank 2) Improve Evacuation Planning.**
  - **Cost:** low will depend upon approach
  - **Responsibility:** SES
  - **Timeframe:** ongoing
3. **(Rank 3=) Enforce Flood Planning levels.**
  - **Cost:** low
  - **Responsibility:** Council
  - **Timeframe:** ongoing
4. **(Rank 3=) Ensure Appropriate Development Control Planning Including Consideration of Anthropomorphic Climate Change Induced Rainfall Increase and safety inspection of Coral Sea Park basin to meet DSC requirements.**

- **Cost:** low
- **Responsibility:** Council
- **Timeframe:** ongoing

### **LOW Priority**

**5. (Rank 5=) Flood Proofing.**

- **Cost:** will depend upon approach, to be paid by property owner
- **Responsibility:** Property owner
- **Timeframe:** ongoing

**6. (Rank 7=) Management of Blockage.**

- **Cost:** moderate depends on approach
- **Responsibility:** Council and in places Sydney Water
- **Timeframe:** by the year 2017

**7. (Rank 9=) Have Flood Insurance.**

- **Cost:** low will depend on approach
- **Responsibility:** Residents - owner and renter
- **Timeframe:** ongoing

**8. (Rank 11) Enforce On Site Detention policy.**

- **Cost:** low construction costs by property owner
- **Responsibility:** Council, property owner
- **Timeframe:** ongoing

## **2.2. Structural Measures in the Plan**

### **HIGH Priority**

**1. (Rank 5=) Option A – Further Investigation of Lowering of Main Promenade.**

- **Cost:** \$1 million
- **Responsibility:** Council
- **Timeframe:** 2018 onwards

**2. (Rank 7=) Option N – Further Investigation of drainage upgrade at White Avenue (between Bennet Place and Farthing Place).**

- **Cost:** \$200,000
- **Responsibility:** Council
- **Timeframe:** 2020

**3. (Rank 9=) Option C – Further Investigation of Flood Retarding Basin in John Shore Park.**

- **Cost:** \$1 million
- **Responsibility:** Council

- **Timeframe:** 2018

#### **LOW Priority**

4. **(Rank 12) Option D – Further Investigation of Duplication of drainage network from John Shore Park to the Beach Outlet.**
  - **Cost:** \$3 to \$9 million
  - **Responsibility:** Council
  - **Timeframe:** 2020
  
5. **(Rank 16) Option B – Further Investigation of Flood Retarding Basin in Muraborah Reserve (Wride Street).**
  - **Cost:** \$350,000
  - **Responsibility:** Council
  - **Timeframe:** 2018

The following options were not considered viable enough (based on ranking) to be included in the Plan.

| <b>Measure</b>                                                              | <b>Comment</b>                                                                               |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Option E – Coral Sea Park Retarding Basin Performance Improvement           | Lower Coral Sea Park to increase detention capacity.                                         |
| Option F – Midway Drive Trapped Low Point                                   | Upgrade Midway Drive drainage network.                                                       |
| Option G & J – Haig Street Low Point & Maroubra Road/Flower Street to Beach | Upgrade drainage from Galvin Street to the beach outlet – Haig Street.                       |
| Option H – Byrne Crescent Low Point                                         | No works proposed                                                                            |
| Option I – 134-140 Marine Parade                                            | Upgrade drainage at 134-140 Marine Parade.                                                   |
| Option LMK – Fitzgerald Avenue/Chester Avenue Intersection                  | Drainage Upgrade proximate Coral Sea Park – Fitzgerald Avenue and Chester Avenue.            |
| Option O – Tyrwhitt Street                                                  | Drainage Upgrade                                                                             |
| Option P – Curtin Crescent                                                  | Drainage Upgrade at Curtin Crescent – between South Maroubra Village Green to Broome Street. |



FIGURE 1  
STUDY AREA



FIGURE 2  
LOCAL ENVIRONMENTAL PLAN ZONES  
LEP 2012

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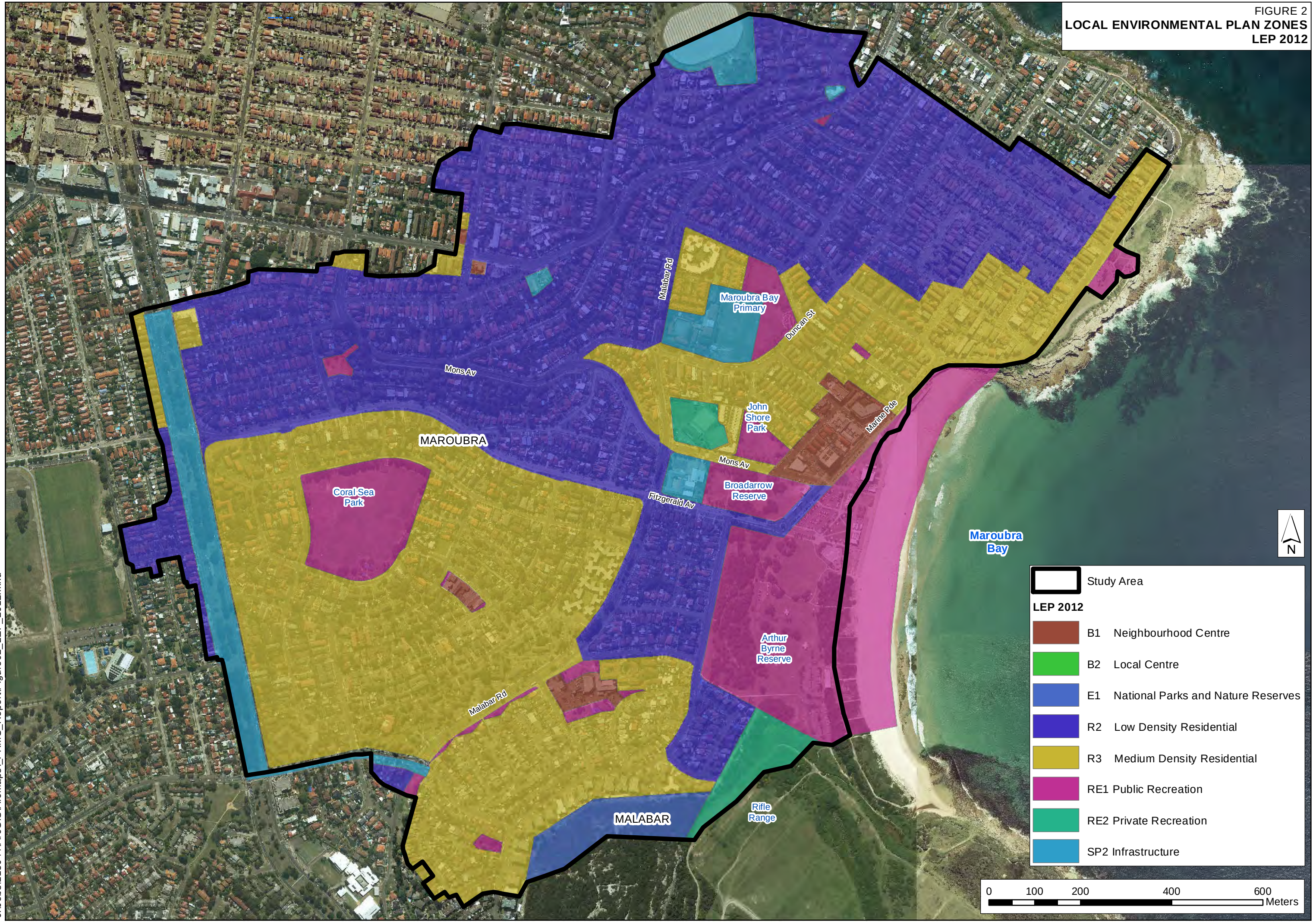


FIGURE 3  
EXISTING DRAINAGE ASSETS

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FIGURE 4  
EXISTING DRAINAGE CAPACITY

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FIGURE 5  
HYDRAULIC CATEGORISATION  
1% AEP AND PMF EVENT

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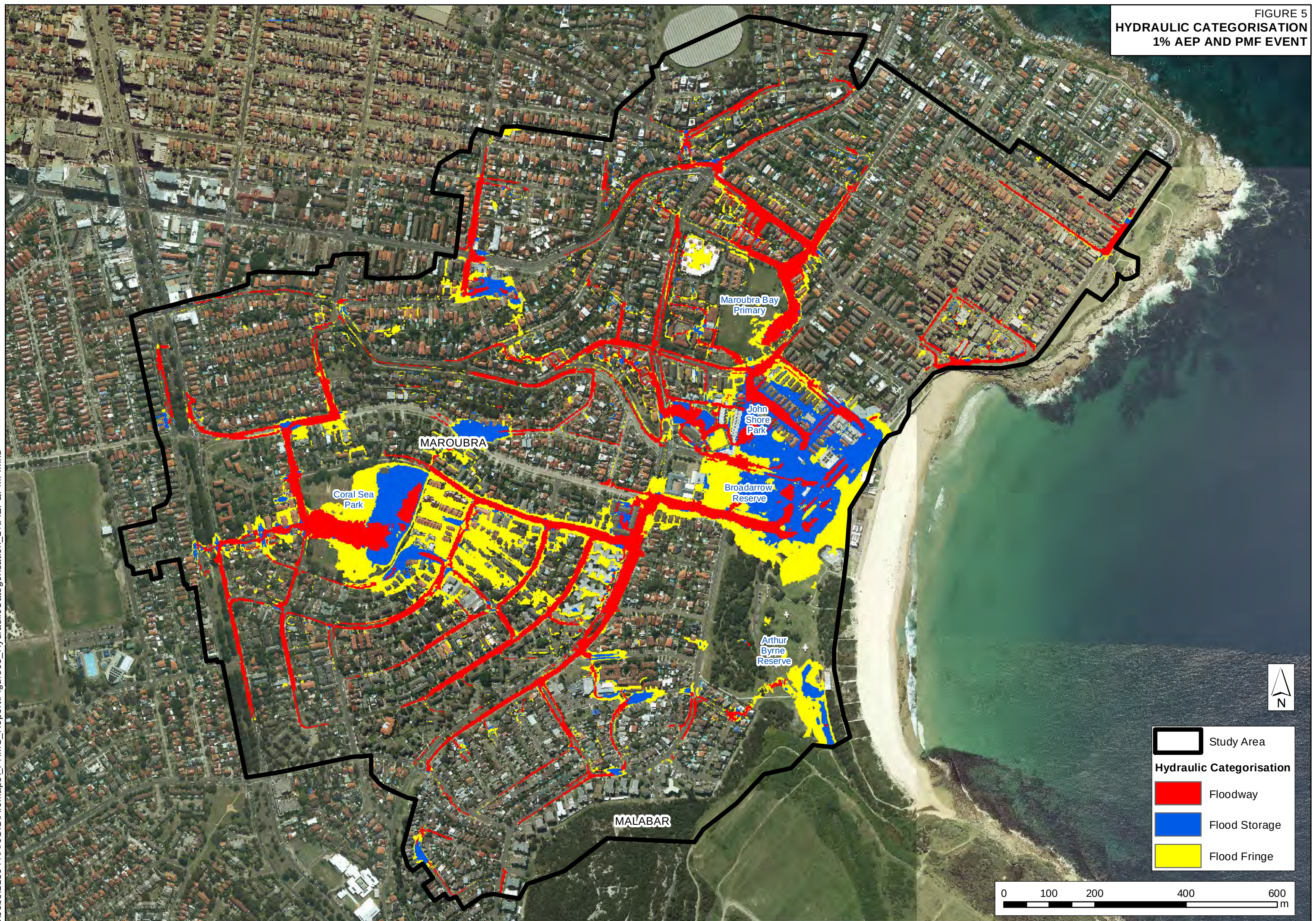


FIGURE 6  
TRUE FLOOD HAZARD CLASSIFICATION  
1% AEP EVENT

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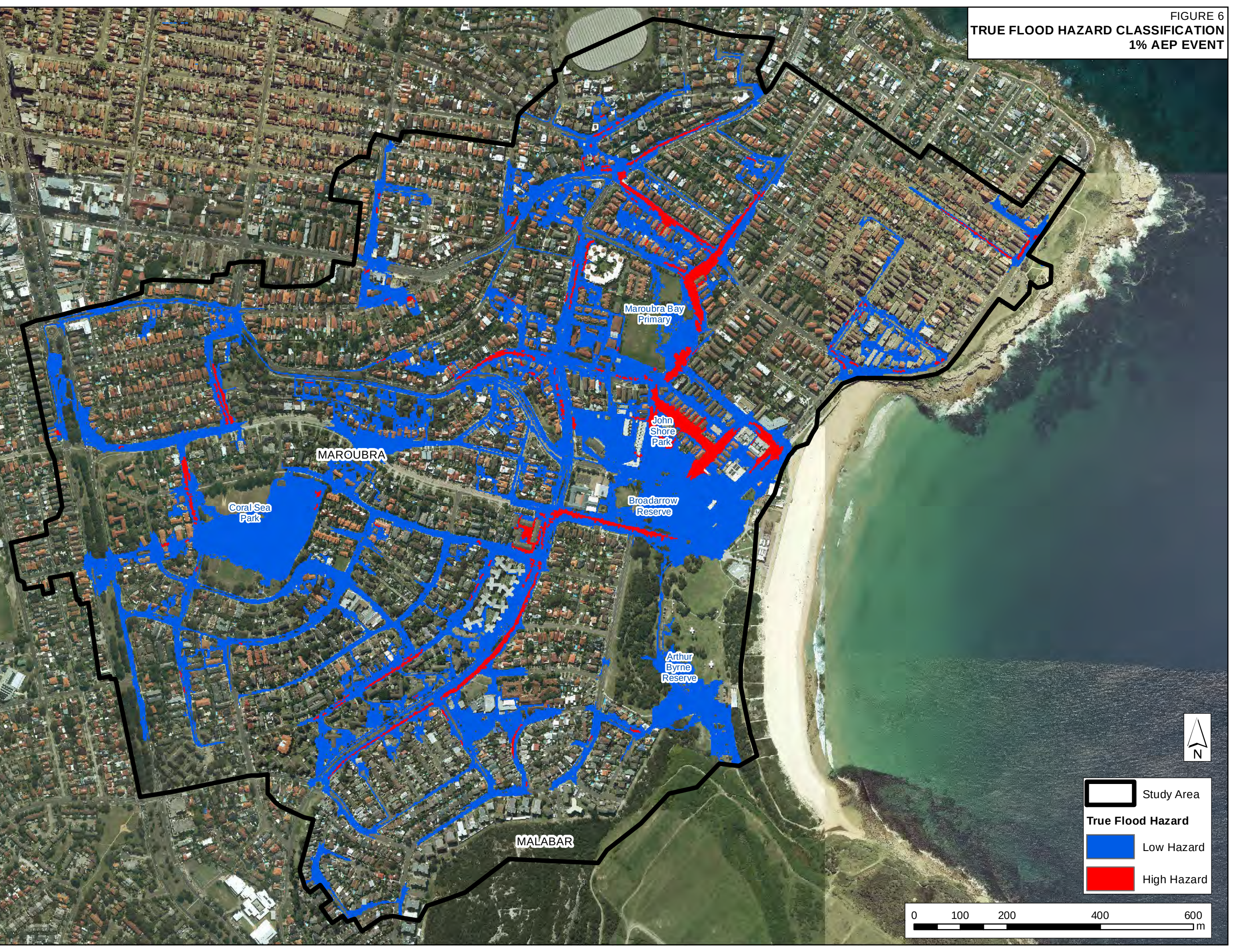


FIGURE 7  
TRUE FLOOD HAZARD CLASSIFICATION  
PMF EVENT

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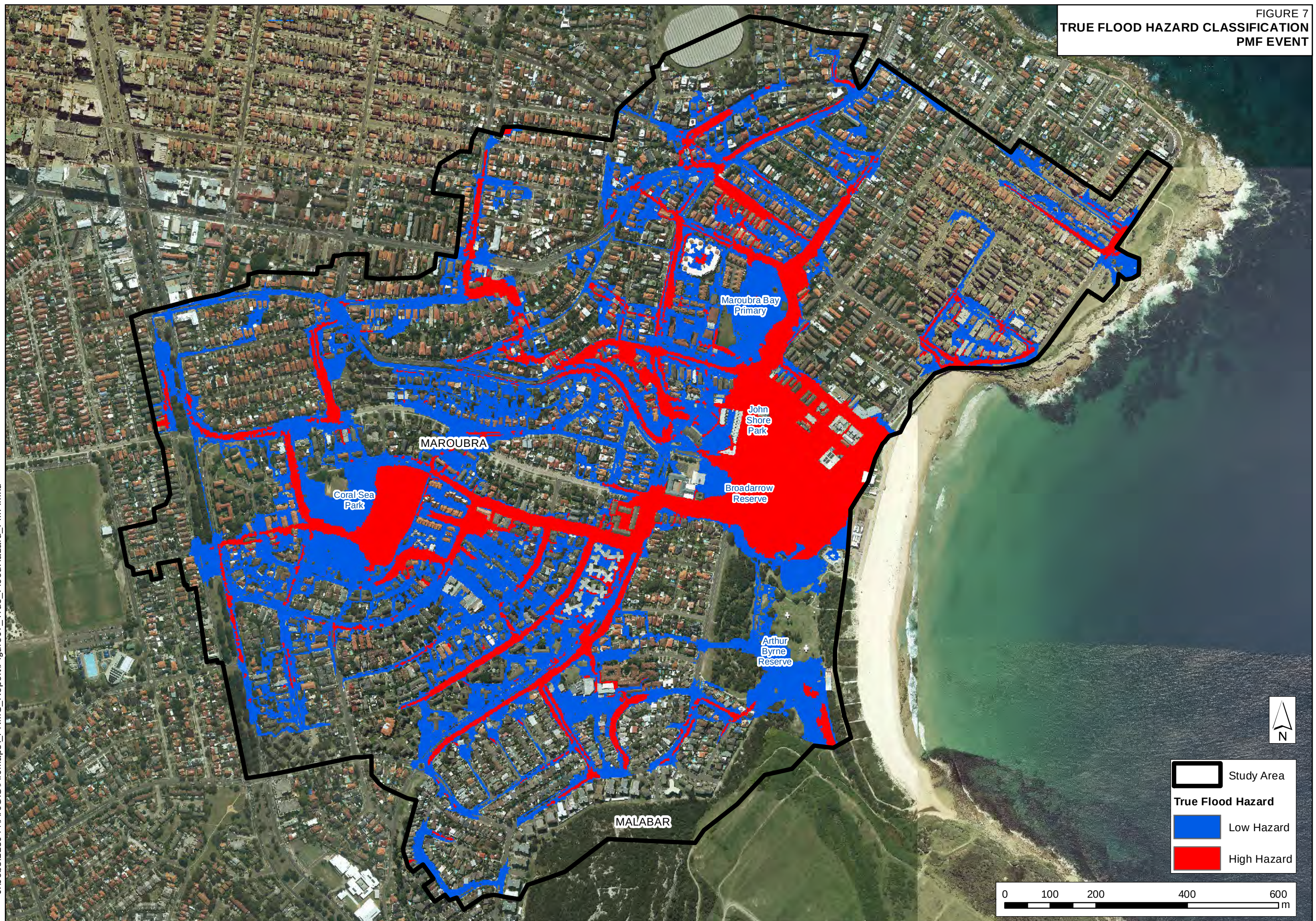


FIGURE 8  
FLOOD EMERGENCY RESPONSE CLASSIFICATION  
1% AEP EVENT

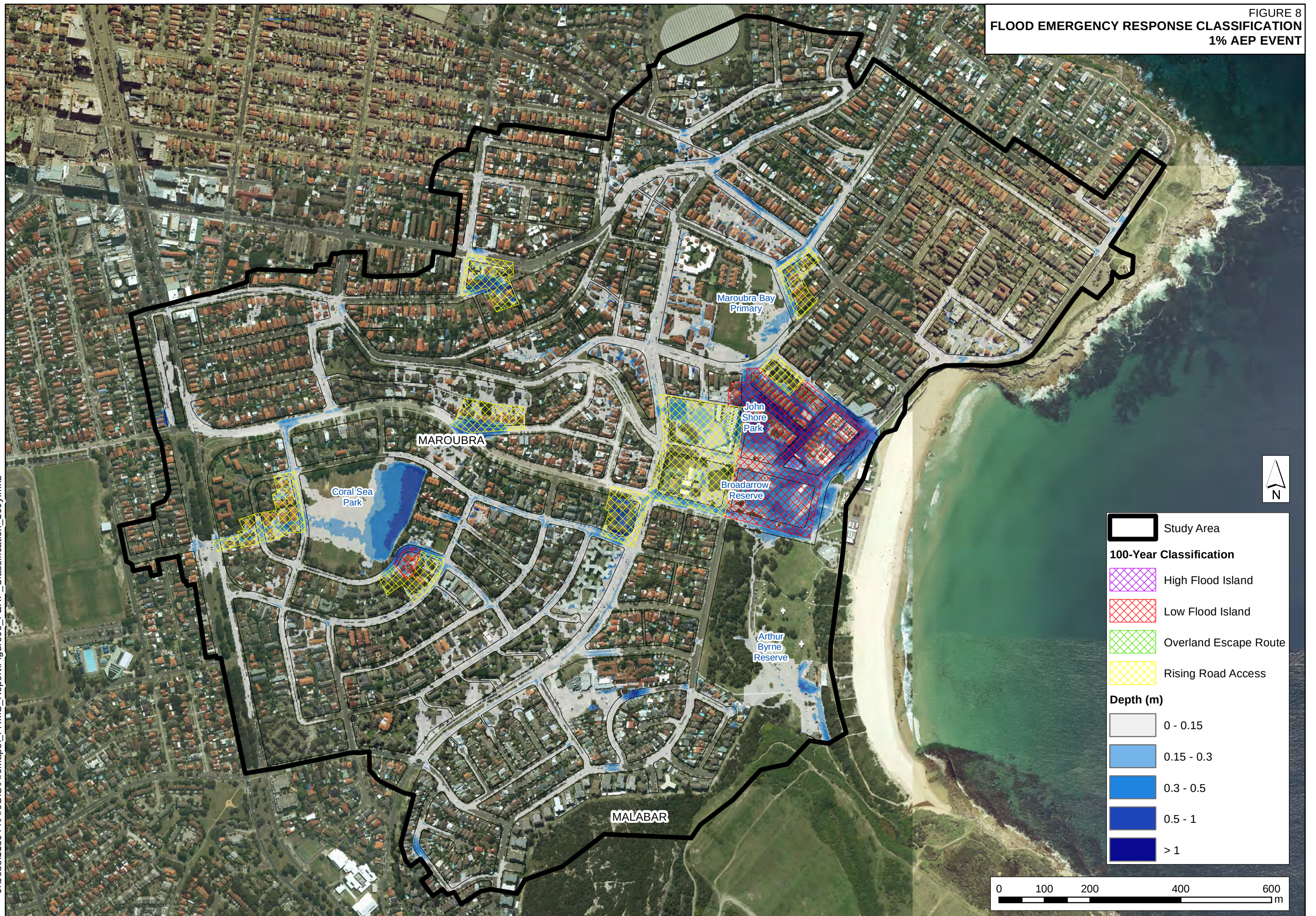
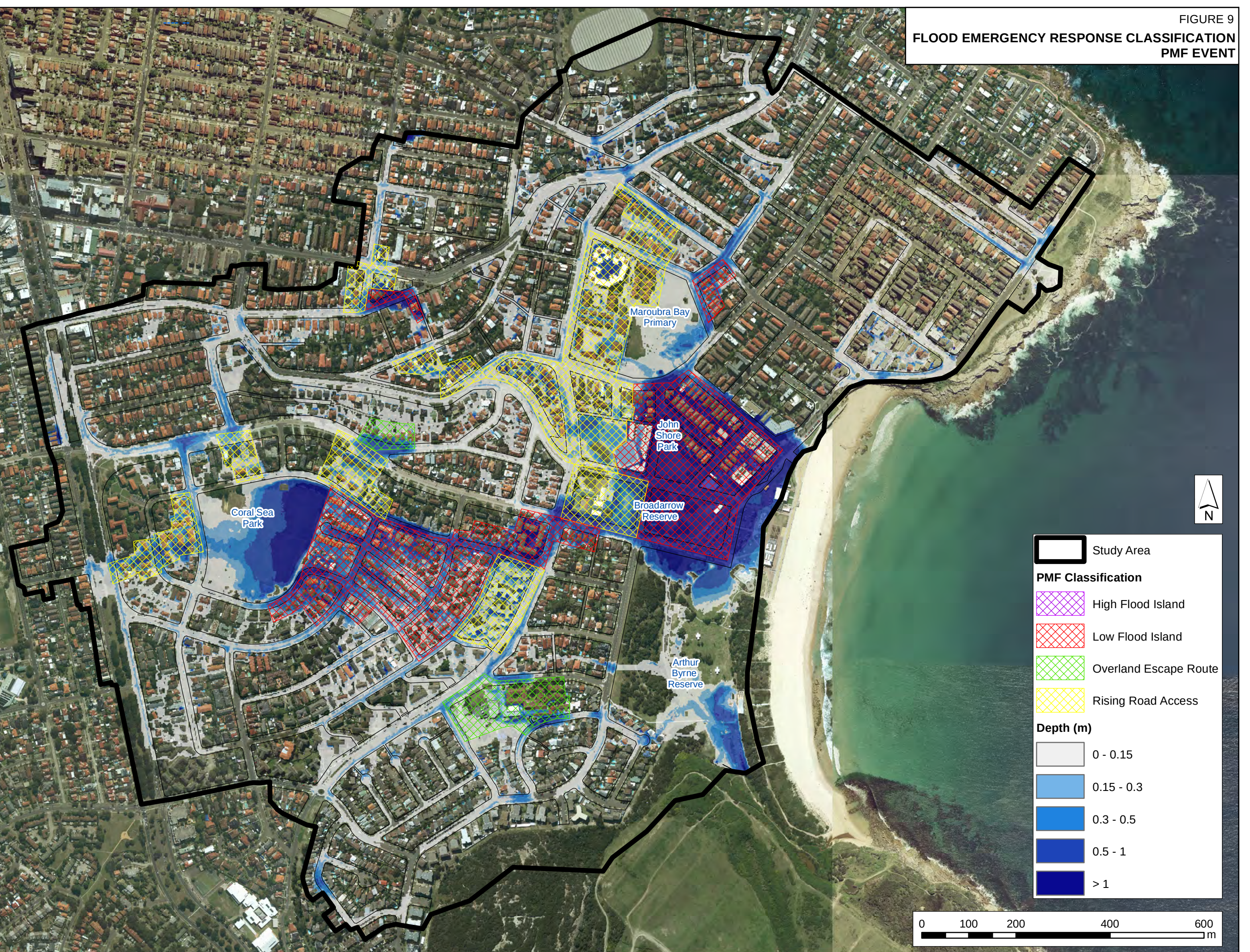
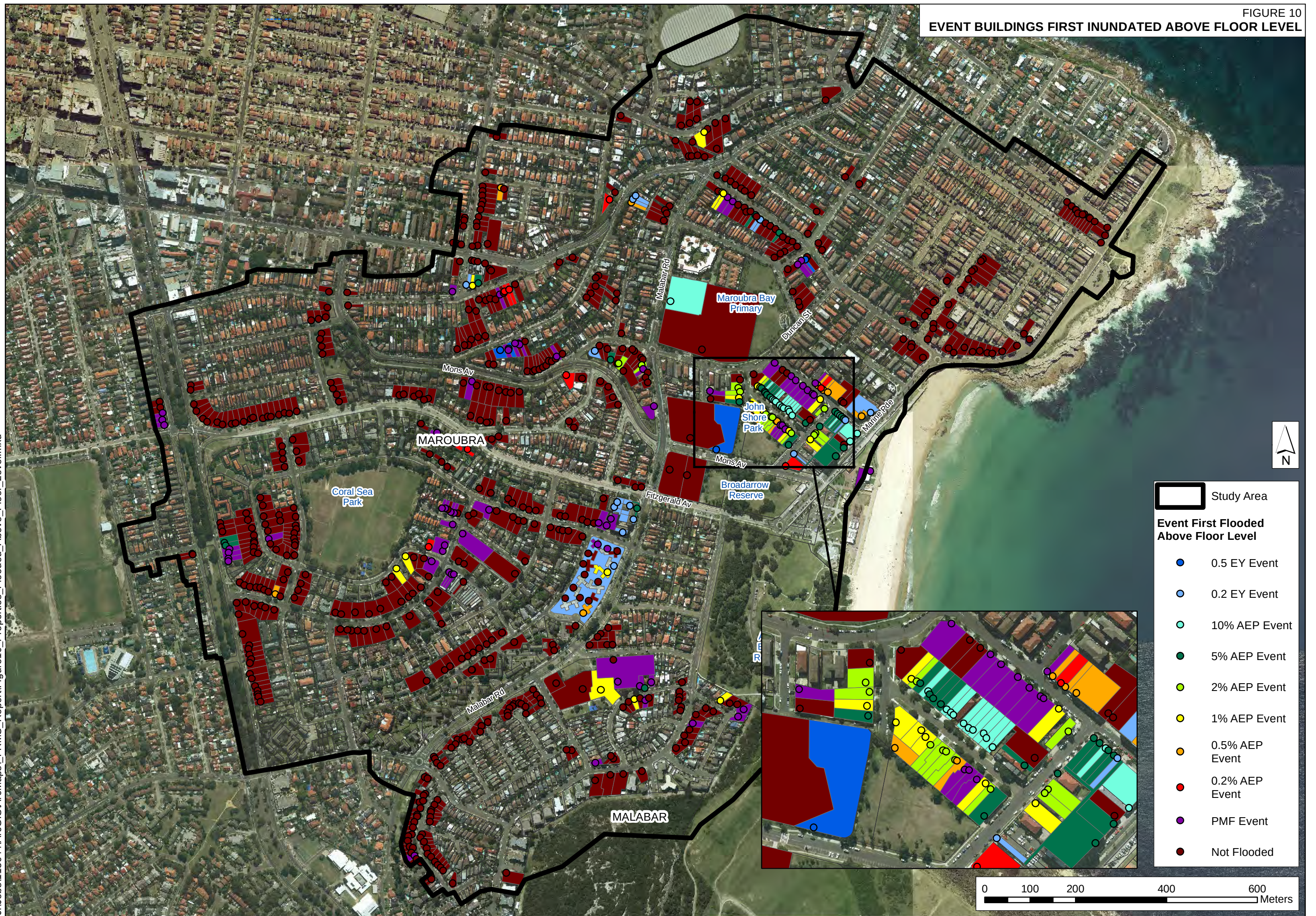


FIGURE 9  
FLOOD EMERGENCY RESPONSE CLASSIFICATION  
PMF EVENT



EVENT BUILDINGS FIRST INUNDATED ABOVE FLOOR LEVEL

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## APPENDIX A TERMINOLOGY AND GLOSSARY

### A1 Probability Terminology

Engineers Australia as part of the team developing the updated Australian Rainfall and Runoff (AR&R) have produced a set of draft guidelines for appropriate terminology when referring to the probability of floods. In the past, Annual Exceedance Probability (AEP) has generally been used for those events with greater than 10% probability of occurring in any one year, and Annual Recurrence Interval (ARI) used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, Exceedances per year (EY).

AEP is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence Interval, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

The Probable Maximum Flood (PMF) is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the Engineers Australia AR&R draft terminology guidelines and uses % AEP for all events greater than the 10% AEP and EY for all events smaller and more frequent than this.

*A copy of the draft terminology is available at: <http://www.arr.org.au/arr-guideline/draft-chapters/>*

## A2 Glossary

*Taken from the Floodplain Development Manual (April 2005 edition)*

|                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>acid sulfate soils</b>                  | Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Annual Exceedance Probability (AEP)</b> | The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m <sup>3</sup> /s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m <sup>3</sup> /s or larger event occurring in any one year (see ARI).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Australian Height Datum (AHD)</b>       | A common national surface level datum approximately corresponding to mean sea level.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Average Annual Damage (AAD)</b>         | Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Average Recurrence Interval (ARI)</b>   | The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>caravan and moveable home parks</b>     | Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>catchment</b>                           | The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>consent authority</b>                   | The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>development</b>                         | <p>Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&amp;A Act).</p> <p><b>infill development:</b> refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.</p> <p><b>new development:</b> refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.</p> <p><b>redevelopment:</b> refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.</p> |
| <b>disaster plan (DISPLAN)</b>             | A step by step sequence of previously agreed roles, responsibilities, functions,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

|                                                   |                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   | actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.                                                                                                                         |
| <b>discharge</b>                                  | The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m <sup>3</sup> /s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).                                                                              |
| <b>ecologically sustainable development (ESD)</b> | Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.   |
| <b>effective warning time</b>                     | The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.                                                      |
| <b>emergency management</b>                       | A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.                                                                                                                                                                             |
| <b>flash flooding</b>                             | Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.                                                                                                                                                                             |
| <b>flood</b>                                      | Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami. |
| <b>flood awareness</b>                            | Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.                                                                                                                                                                                                         |
| <b>flood education</b>                            | Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.                                                                                           |
| <b>flood fringe areas</b>                         | The remaining area of flood prone land after floodway and flood storage areas have been defined.                                                                                                                                                                                                                                                                |
| <b>flood liable land</b>                          | Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).                                                                                        |
| <b>flood mitigation standard</b>                  | The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.                                                                                                                                                                             |
| <b>floodplain</b>                                 | Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.                                                                                                                                                                                                                          |
| <b>floodplain risk management options</b>         | The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.                                                                                                                                           |
| <b>floodplain risk management plan</b>            | A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed                                                                                                                          |

|                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                     | to achieve defined objectives.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>flood plan (local)</b>           | A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>flood planning area</b>          | The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the “flood liable land” concept in the 1986 Manual.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Flood Planning Levels (FPLs)</b> | FPL’s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the “standard flood event” in the 1986 manual.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>flood proofing</b>               | A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>flood prone land</b>             | Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>flood readiness</b>              | Flood readiness is an ability to react within the effective warning time.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>flood risk</b>                   | <p>Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.</p> <p><b>existing flood risk:</b> the risk a community is exposed to as a result of its location on the floodplain.</p> <p><b>future flood risk:</b> the risk a community may be exposed to as a result of new development on the floodplain.</p> <p><b>continuing flood risk:</b> the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.</p> |
| <b>flood storage areas</b>          | Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>floodway areas</b>               | Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>freeboard</b>                    | Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>habitable room</b>               | <p><b>in a residential situation:</b> a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.</p> <p><b>in an industrial or commercial situation:</b> an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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| <b>hazard</b>                             | A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>hydraulics</b>                         | Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>hydrograph</b>                         | A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>hydrology</b>                          | Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>local overland flooding</b>            | Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>local drainage</b>                     | Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>mainstream flooding</b>                | Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>major drainage</b>                     | <p>Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:</p> <ul style="list-style-type: none"> <li>• the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or</li> <li>• water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or</li> <li>• major overland flow paths through developed areas outside of defined drainage reserves; and/or</li> <li>• the potential to affect a number of buildings along the major flow path.</li> </ul> |
| <b>mathematical/computer models</b>       | The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>merit approach</b>                     | <p>The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.</p> <p>The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.</p>                                                                                                                                 |
| <b>minor, moderate and major flooding</b> | <p>Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:</p> <p><b>minor flooding:</b> causes inconvenience such as closing of minor roads and the</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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|                                             | <p>submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.</p> <p><b>moderate flooding:</b> low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.</p> <p><b>major flooding:</b> appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.</p>                                                                                                                                                                                   |
| <b>modification measures</b>                | Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>peak discharge</b>                       | The maximum discharge occurring during a flood event.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Probable Maximum Flood (PMF)</b>         | The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study. |
| <b>Probable Maximum Precipitation (PMP)</b> | The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.                                                                                                                                                                                                                                                                                                                                                                             |
| <b>probability</b>                          | A statistical measure of the expected chance of flooding (see AEP).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>risk</b>                                 | Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>runoff</b>                               | The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>stage</b>                                | Equivalent to “water level”. Both are measured with reference to a specified datum.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>stage hydrograph</b>                     | A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>survey plan</b>                          | A plan prepared by a registered surveyor.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>water surface profile</b>                | A graph showing the flood stage at any given location along a watercourse at a particular time.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>wind fetch</b>                           | The horizontal distance in the direction of wind over which wind waves are generated.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |