6 Existing Flood Behaviour

6.1 Model Scenarios

Flood behaviour was modelled in SOBEK for the 20%, 10%, 2%, 1%, 0.5% AEP and PMF design flood events. Model runs were carried out for the rainfall event durations of 15 minutes, 20 minutes, 25 minutes, 30 minutes, 45 minutes, 60 minutes, 90 minutes, 2 hours and 3 hours for all AEP events.

Critical durations for peak flood levels in the study area vary depending on the location and flood characteristics for specific locations. These are listed in **Table 6-1**. Generally, shorter duration events result in higher peak water levels at the upstream and higher elevation areas whilst longer duration events are critical in main flow paths and ponding areas.

Table 6-1 Event Critical Durations

Annual Exceedance Probability	Critical Duration
20% to 0.5% AEP	90 to 120 minutes
PMF	15 to 90 minutes

6.2 Result Maps

Peak water level, depth, and velocity in the study area are determined based on the peak value for each grid cell from all durations modelled in a particular AEP event. As the direct rainfall approach is used, every 2D cell is inundated with some flood depth. A filter is applied to clarify the results and highlight primary flow paths excluding locations of minor localised runoff depths. The flood extents of figures showing design events, sensitivity and scenarios are filtered, such that:

- Depths less than 0.15 m are removed; and
- Ponded areas/island of less than 50 m^2 are removed.

Maps of flood results have been prepared for each of the four modelled zone on individual figures. These are included in **Appendix B**:

- **Figures 1-4**: Flood Peak Inundation Extents (20%, 10%, 2%, 1%, 0.5% AEP and PMF)
- **Figures 5-16**: Peak Flood Water Levels (20% AEP, 1% AEP and PMF)
- **Figures 17-28**: Peak Flood Depths (20% AEP, 1% AEP and PMF)
- **Figures 29-40**: Peak Flood Velocities (20% AEP, 1% AEP and PMF)
- **Figures 41-52**: Hydraulic Categories (20% AEP, 1% AEP and PMF)
- **Figures 53-64**: Provisional Flood Hazard (20% AEP, 1% AEP and PMF)
- **Figures 65-72**: Hazard Vulnerability Classification (1% AEP and PMF)

6.3 Discussion of Results

An analysis of the 20% and 1% AEP results was undertaken and the following significant flood affected areas were identified. Note the below identified locations are not the only areas which are subject to inundation but highlight some areas which are severely impacted. Only regions significantly impacted by the 20% AEP have been highlighted as these locations are most likely to be frequently affected by flood inundation.

6.3.1 Manly

- In the 20% AEP the drainage system in this location has insufficient capacity to cater for the catchment runoff. Due to the presence of a low point in the topography at the corner of Gilbert Street and Eustace Street an area of significant ponding is formed. Depths in excess of 600 mm are

recorded within the roadway in the 20% AEP event. In the 1% AEP event the extent of this flooding increases significantly, affecting properties along West Promenade and resulting in depths in excess of 1000 mm.

- Kangaroo Lane and Pittwater Road north of Raglan Street also have significant flood affectation in the 20% AEP. Similarly this is due to a local depression within the topography which results in an area of ponded floodwater. Depths in excess of 1100 mm are present along Kangaroo Lane in the 20% AEP. In the 1% AEP event, the region of ponded floodwater increases to cover the intersections of Pittwater Road and Raglan Street and Pittwater Road and Sydney Road. This results in a peak flood level of about 5.85 m AHD at this intersection which is a peak depth of 0.6 m on Raglan Street.
- Central Avenue in the 20% AEP suffers from inundation of up to 550 mm. In the 1% AEP the region is further impacted, with depths in excess of 600 mm. Flooding in this region is contributed to by overland flow entering the area from Sydney Road. The flood impacts within this location are due to the drainage system present being inadequately sized to cater for the volume of runoff present in the region. Furthermore, due to downstream boundary conditions, an increase in capacity of the drainage system may not reduce flood impacts.
- Smith Street, located at the bottom of the cliffs behind Kangaroo Street, is impacted by significant ponding in the 20% AEP event (similar to flooding behaviour in Kangaroo Lane). This is due to the underground system having insufficient capacity to drain the region. In the 1% AEP event the area of affectation extends over the corner of Smith Street and Pine Street, resulting in the inundation of multiple properties.
- The corner of North Steyne and Pacific Street suffers from inundation in the 20% AEP when the underground drainage network in the region is exceeded. The water ponds up in the roadway and carpark in this area until there is sufficient capacity in the drainage network to discharge into the ocean. In the 1% AEP event the extent of this flooding increases, resulting in impacts up to the corner of Ceramic Lane and North Steyne.

6.3.2 Balgowlah and Balgowlah Heights

- A prominent flow path is present between New Street and Lower Beach Street. This flow path travels primarily through properties until it reaches North Harbour Reserve where it then discharges into Jilling Cove. This flow path is present due to the underground drainage network having insufficient capacity to cater for the 20% AEP event. This flowpath affects several properties but in the majority of cases it is through the back of properties and does not affect many buildings. In the 1% AEP event the flow path width increases resulting in more properties being affected.
- Another flow path is present which begins near the corner of Glenside and Ernest Street. This flow path travels primarily through properties, also passing through Nanbaree Reserve. The flow path then continues through properties until it discharges into Jilling Cove. This flow path is present due to the underground drainage network having insufficient capacity to cater for the 20% AEP event. This flow path affects several properties with many buildings identified as potentially impacted.

6.3.3 Clontarf

- At the corner of Monash Crescent and Holmes Avenue there is a significant area of ponding in the 20% AEP event. This is due to the drainage network in the region being under capacity as well as the properties at the corner being lower than the roadway. As a result of these issues when runoff can no longer enter the drainage system, the properties to the north of Monash Crescent become inundated. Depths up to 650 mm are present in the 20% AEP, with this increasing to 950 mm in the 1% AEP event.

6.4 Hydraulic Categories

As per The Floodplain Development Manual (NSW Government, 2005), hydraulic category mapping has been produced for the categories:

- Floodways;

- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods that are often, but not always, aligned with naturally defined channels. They are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Flood Storages are parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. Flood Fringe is the remaining area of flood-prone land after floodway and flood storage areas have been defined.

Hydraulic categories were determined using an in-house developed program which utilises model results from velocity and depth in addition to post processing to ensure categories are contiguous. Hydraulic category mapping figures are shown in **Appendix B**.

6.5 Provisional Hazard

6.5.1 General

Flood hazard can be defined as the risk to life and limb caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These factors are:

- Size of the flood
- Depth and velocity of floodwaters
- Effective warning time
- Flood awareness
- Rate of rise of floodwaters
- Duration of flooding
- Evacuation problems
- Access.

Hazard categorisation based on all the above factors is part of establishing a Floodplain Risk Management Plan. The scope of the present study calls for determination of provisional flood hazards only. The provisional flood hazard is generally considered in conjunction with the above listed factors as part of the Floodplain Risk Management Study to provide a comprehensive analysis of the flood hazard.

6.5.2 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations.

Historically, the criteria for these relationships have been taken from the NSW Floodplain Development Manual (Appendix L; NSW Government, 2005). The Manual defines two major categories for provisional hazard – high and low. A High Hazard refers to flood conditions that pose a possible danger to personal safety, evacuation by trucks would be difficult, able-bodied adults would have difficulty wading to safety, and there is a potential for significant structural damage to buildings. A Low Hazard refers to flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks and able-bodied adults would have little difficulty wading to safety. The Transition Zone the degree of hazard is dependent on the site conditions and the nature of the proposed development. The FDM hazard relationship is shown in **Figure 6.1**. **Figures 53 to 64** in **Appendix B** show the provisional flood hazard for the 20% AEP, 1% AEP, and PMF) event.

Recently, a new method of hazard categorisation has been developed by the revised Australian Rainfall and Runoff (AR&R) guideline (2016) (Book 6: Flood Hydraulics, Section 7.2.7). The classification is still based on depth and velocity, but utilises six categories based on the stability of children, adults, the elderly and vehicles in floodwaters:

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

The AR&R hazard curves are shown in **Figure 6.2**. **Figures 65 to 72** in **Appendix B** show the hazard categorisation for the 1% AEP and PMF events based on the AR&R classification.

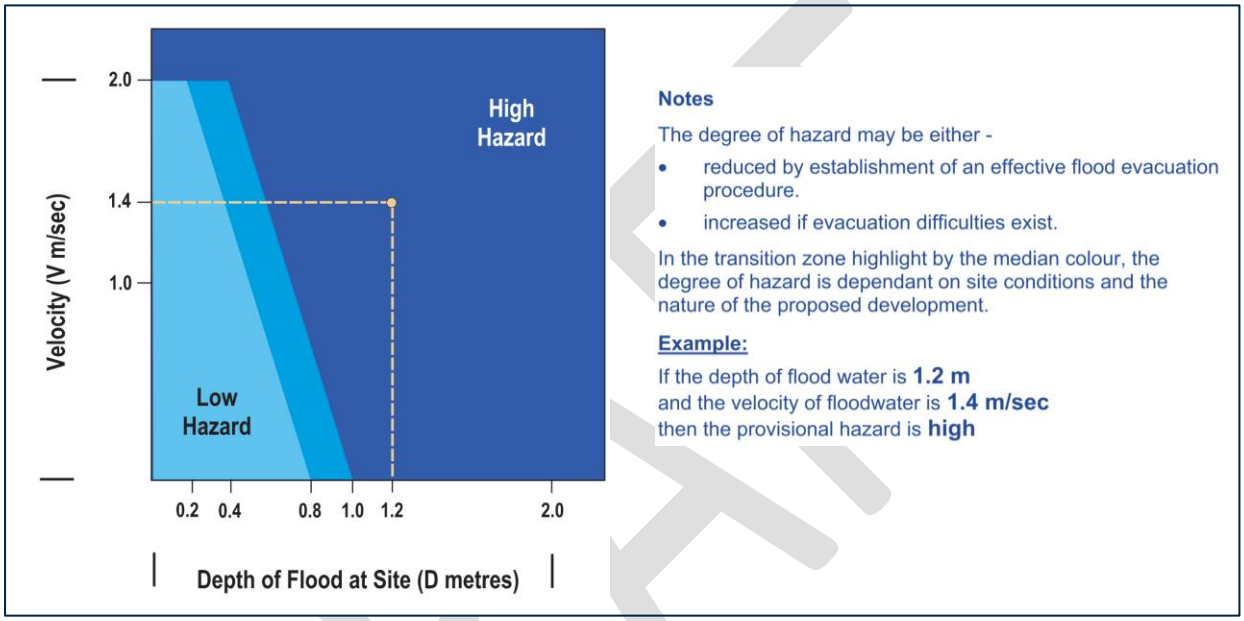

Figure 6-1 Provisional Hazard Categories from Appendix L of the Floodplain Development Manual

High provisional hazard is shown at several independent areas in the study area for the 20% AEP storm event. Streets with occurrences of high provisional hazard in the 20% AEP event include Kangaroo Lane, Jackson Street, and New Street.

In the 1% AEP design event, areas with a high hazard classification (of H3 to H6, which describe unsafe conditions for vehicles and people) occur along the main flow paths to the channels and in trapped low points on roads. Roads with this high hazard classification include: Smith Street, Manly; Kangaroo Lane, Manly; Gilbert Street, Manly; Ashburner Street, Manly; College Street, Manly; Bower Lane, Manly; Central Avenue, Manly; Raglan Street, Manly; Pittwater Road, Manly; North Steyne, Manly; Woodland Street, Balgowlah; Condamine Street, Balgowlah; New Street East, Balgowlah; Valley Road, Balgowlah Heights; Sandy Bay Road, Clontarf; Castle Circuit, Seaforth; and Bligh Crescent, Seaforth. Properties may also be inundated with high hazard classification on Smith Street, Manly; Kangaroo Lane, Manly; Gilbert Street, Manly; Ashburner Street, Manly; Woodland Street, Balgowlah; and Valley Road, Balgowlah Heights.

In a PMF design event, all flow paths are inundated to a greater severity and the hazard classification often increases by one level on the H1-6 scale. Major roads affected by a high hazard classification include Manly Road, Seaforth (near the Spit Bridge) and Sydney Road, Manly (near the CBD).

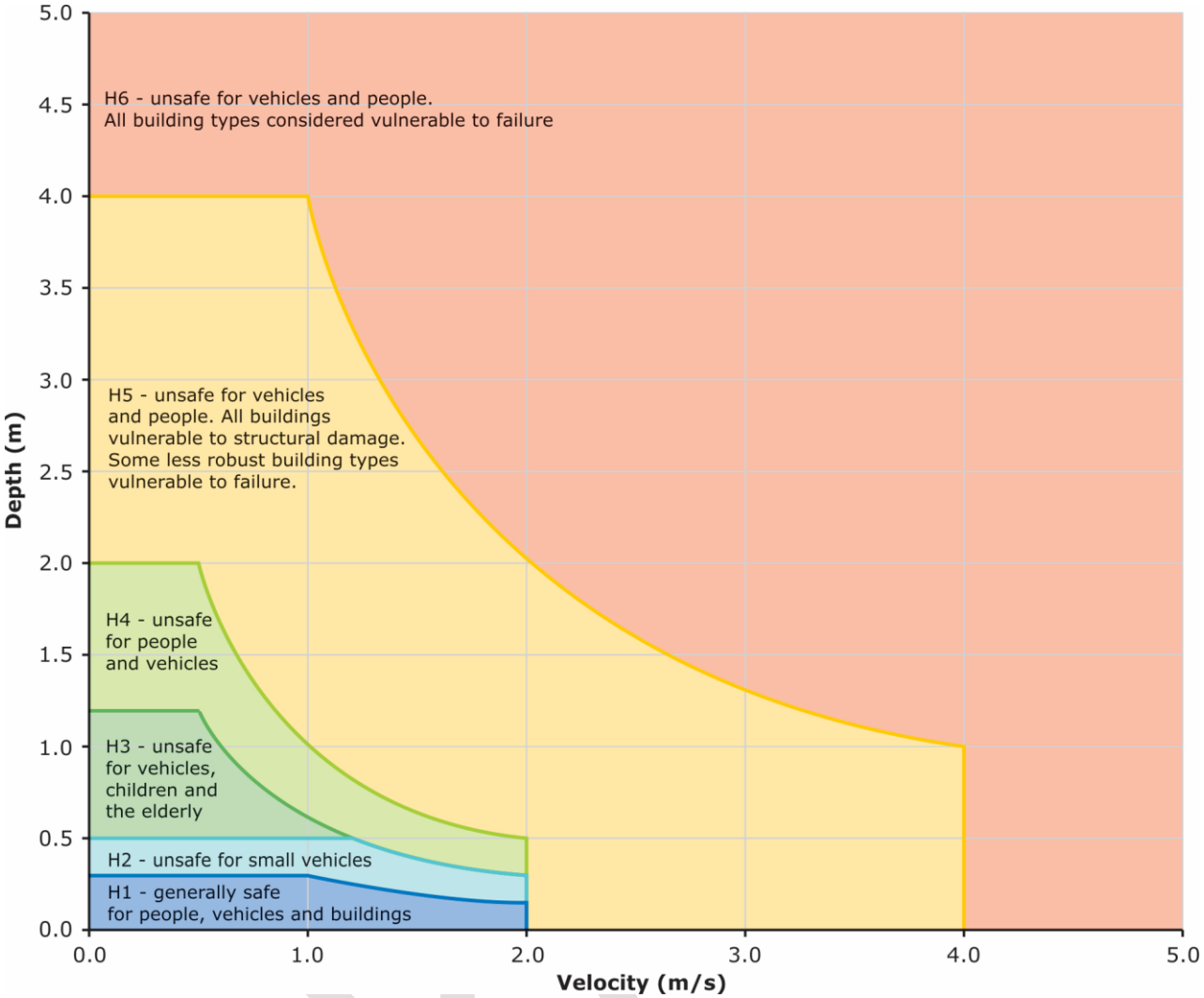

Figure 6-2 Provisional Hazard Categories from AR&R