8 DESIGN FLOOD RESULTS

A range of design flood conditions were modelled, the results of which are presented and discussed below. The simulated design events included the 20% AEP, 5% AEP, 2% AEP, 1% AEP and 0.2% AEP for both catchment derived and ocean derived flooding. The PMF flood event has also been modelled.

The impact of future climate change on flooding in Woolgoolga was also considered for both catchment derived and ocean derived flood events, focussing on the 1% AEP flood event.

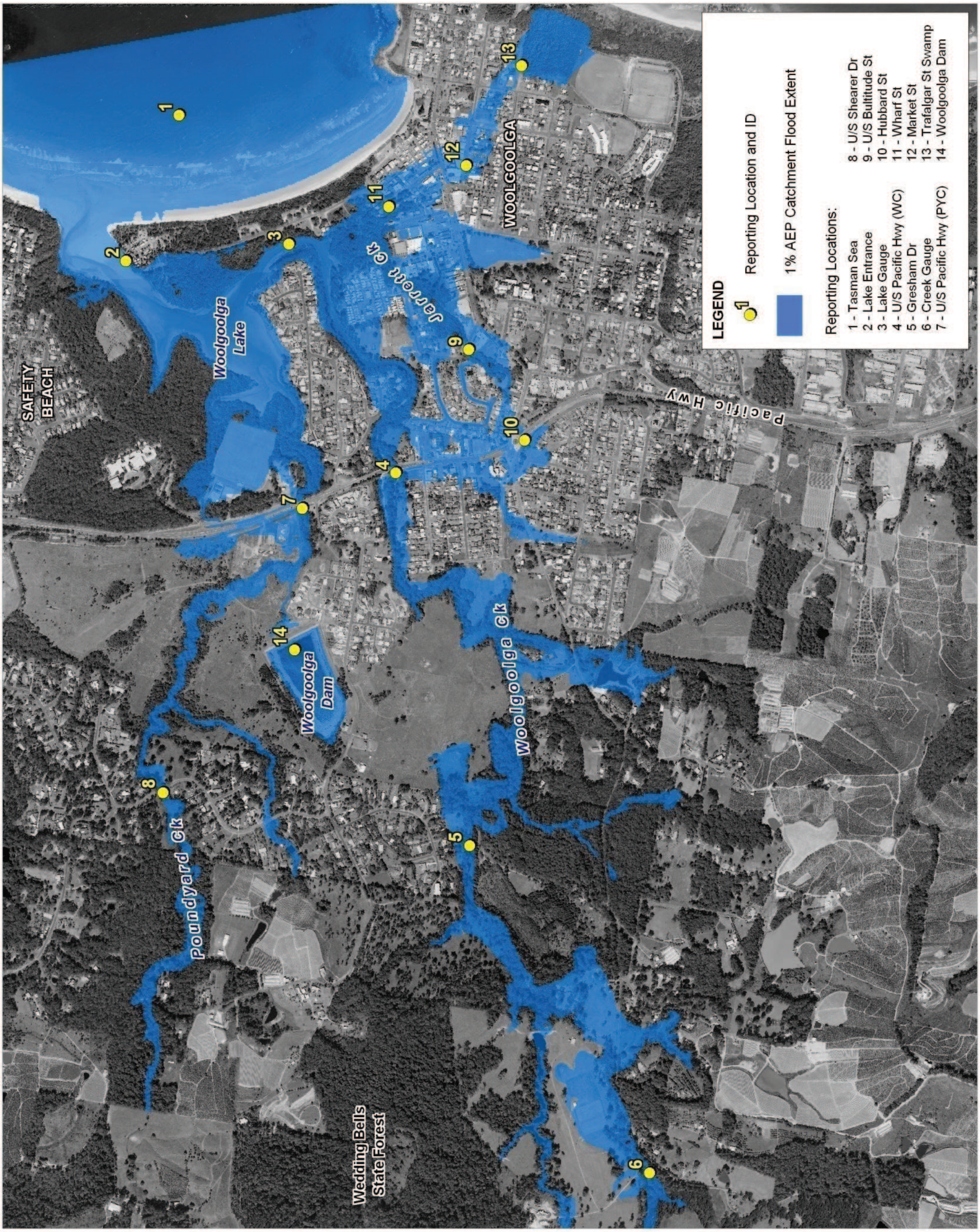
8.1 Peak Flood Conditions

8.1.1 Catchment Derived Flood Events

Predicted flood levels at selected locations (as presented in Figure 8-1) are shown in Table 8-1 for the full range of catchment derived flood events considered. Longitudinal profiles showing predicted flood levels along Woolgoolga Creek are shown in Figure 8-2.

Table 8-1 Modelled Peak Flood Levels (m AHD) for Catchment Derived Flood Events

ID	Location	Flood Event Frequency					
		20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Tasman Sea	0.6	0.6	0.6	0.6	0.6	2.7
2	Lake Entrance	2.4	2.5	2.6	2.6	2.7	3.2
3	Lake Gauge	2.5	2.6	2.7	2.8	2.9	4.4
4	U/S Pacific Hwy (WC)	3.7	4.2	4.4	4.5	5.0	7.6
5	Gresham Dr	12.3	12.6	12.7	12.8	13.1	14.6
6	Creek Gauge	20.1	20.7	21.0	21.1	21.5	23.2
7	U/S Pacific Hwy (PYC)	3.5	3.8	4.1	4.3	4.8	6.7
8	U/S Shearer Dr	17.1	17.7	18.2	18.5	18.7	19.7
9	U/S Bultitude St	3.2	3.2	3.3	3.3	3.4	5.3
10	Hubbard St	6.2	6.3	6.4	6.5	6.6	7.0
11	Wharf St	2.6	2.7	2.8	2.9	3.2	4.9
12	Market St	3.4	3.5	3.5	3.6	3.7	4.9
13	Trafalgar St Swamp	5.0	5.3	5.3	5.4	5.5	5.8
14	Woolgoolga Dam	18.3	18.5	18.6	18.7	18.9	19.0



Title:
Water Level Reporting Locations

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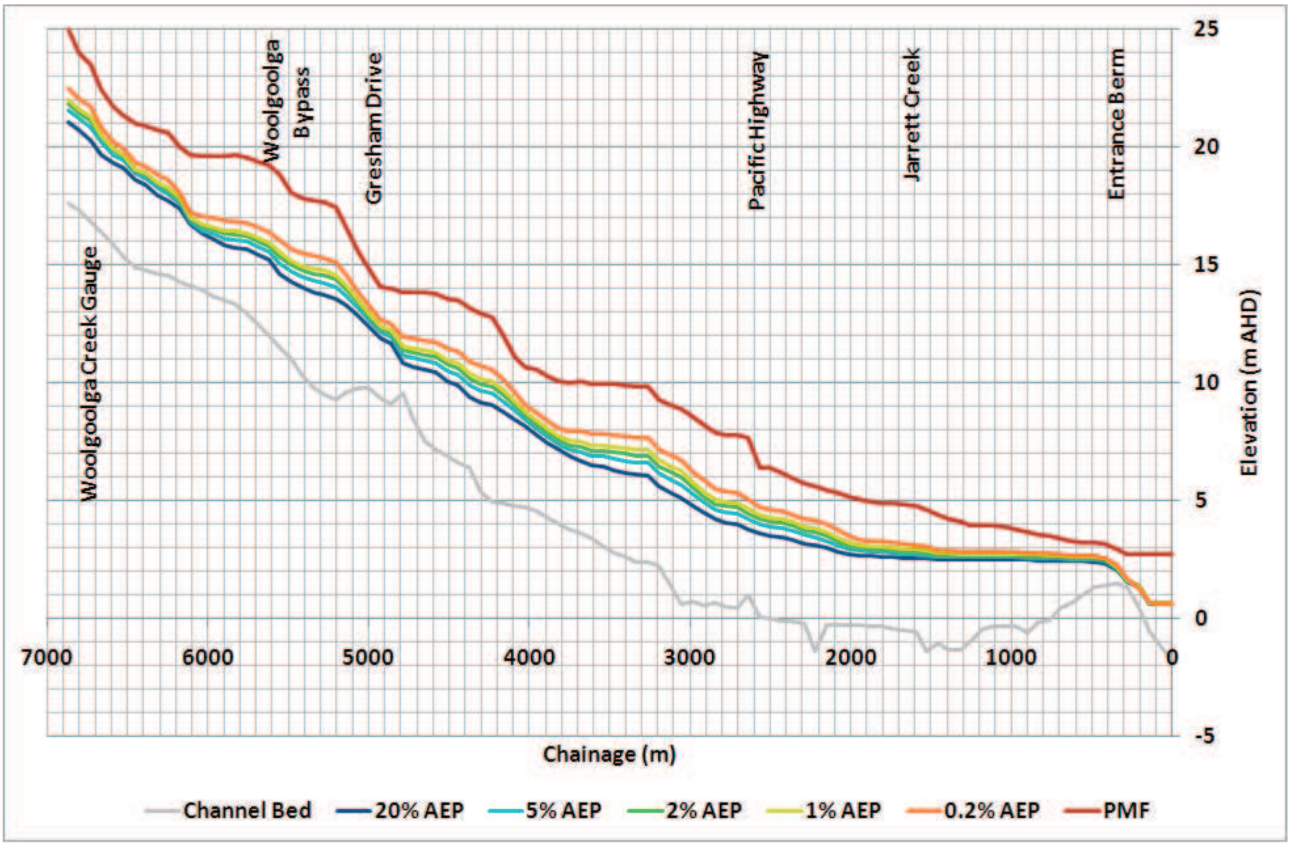

Figure 8-2 Woolgoolga Creek Catchment Event Peak Flood Level Profiles

8.1.2 Ocean Derived Flood Events

Predicted flood levels at selected locations (as presented in Figure 8-1) are shown in Table 8-2 for the full range of ocean derived flood events considered. Longitudinal profiles showing predicted flood levels along Woolgoolga Creek are shown in Figure 8-3.

It can be seen that the limit of ocean derived flooding on Woolgoolga Creek extends some 500m or so beyond the Pacific Highway.

8.1.3 Coincident Flood Events

The coincident flood events, which considered both catchment and ocean flooding occurring at the same time provide a more conservative approach and have been adopted for design purposes. The design flood results are presented in a flood mapping series in Appendix A. For the simulated design events including the 20% AEP, 5% AEP, 2% AEP, 1% AEP and PMF events, a map of peak flood level, depth and velocity is presented covering the modelled area.

Predicted flood levels at selected locations (as presented in Figure 8-1) are shown in Table 8-3 for the full range of coincident flood events considered. Longitudinal profiles showing predicted flood levels along Woolgoolga Creek are shown in Figure 8-4.

It can be seen through comparison of Table 8-3 with Table 8-1 that the coincident design flood events are similar to the catchment derived flood events. For locations around Woolgoolga Lake the coincident events provide around a 0.1m to 0.2m increase in peak flood levels. The catchment derived flooding is the dominant flood mechanism for Woolgoolga.

Table 8-2 Modelled Peak Flood Levels (m AHD) for Ocean Derived Flood Events

ID	Location	Flood Event Frequency				
		20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
1	Tasman Sea	1.9	2.1	2.3	2.4	2.7
2	Lake Entrance	1.9	2.1	2.3	2.4	2.7
3	Lake Gauge	1.9	2.1	2.3	2.4	2.7
4	U/S Pacific Hwy (WC)	1.9	2.1	2.3	2.4	2.7
5	Gresham Dr	N/A	N/A	N/A	N/A	N/A
6	Creek Gauge	N/A	N/A	N/A	N/A	N/A
7	U/S Pacific Hwy (PYC)	1.9	2.1	2.3	2.4	2.7
8	U/S Shearer Dr	N/A	N/A	N/A	N/A	N/A
9	U/S Bultitude St	1.9	2.1	2.3	2.4	2.7
10	Hubbard St	N/A	N/A	N/A	N/A	N/A
11	Wharf St	N/A	2.1	2.3	2.4	2.7
12	Market St	N/A	N/A	N/A	N/A	N/A
13	Trafalgar St Swamp	N/A	N/A	N/A	N/A	N/A
14	Woolgoolga Dam	N/A	N/A	N/A	N/A	N/A

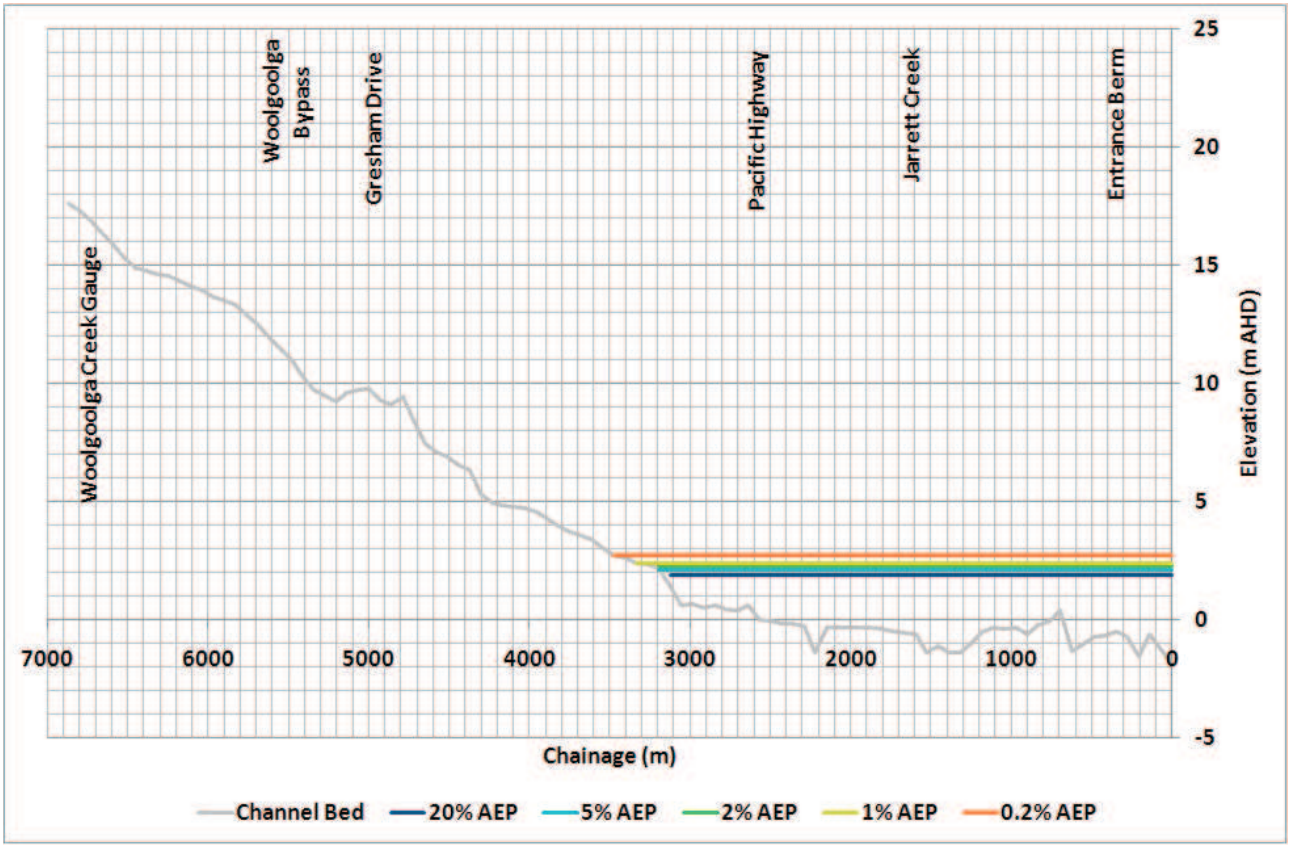

Figure 8-3 Woolgoolga Creek Ocean Event Peak Flood Level Profiles

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Table 8-3 Modelled Peak Flood Levels (m AHD) for Design Coincident Flood Events

ID	Location	Flood Event Frequency					
		20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Tasman Sea	1.9	1.9	1.9	2.1	2.4	2.7
2	Lake Entrance	2.5	2.6	2.7	2.7	2.9	3.2
3	Lake Gauge	2.6	2.7	2.8	2.9	3.1	4.4
4	U/S Pacific Hwy (WC)	3.7	4.2	4.4	4.6	5.0	7.6
5	Gresham Dr	12.3	12.6	12.7	12.8	13.1	14.6
6	Creek Gauge	20.1	20.7	21.0	21.1	21.5	23.2
7	U/S Pacific Hwy (PYC)	3.5	3.8	4.1	4.3	4.8	6.7
8	U/S Shearer Dr	17.1	17.7	18.2	18.5	18.7	19.7
9	U/S Bultitude St	3.2	3.2	3.3	3.3	3.4	5.3
10	Hubbard St	6.2	6.3	6.4	6.5	6.6	7.0
11	Wharf St	2.6	2.8	2.9	3.1	3.4	4.9
12	Market St	3.4	3.5	3.5	3.6	3.7	4.9
13	Trafalgar St Swamp	5.0	5.3	5.3	5.4	5.5	5.8
14	Woolgoolga Dam	18.3	18.5	18.6	18.7	18.9	19.0

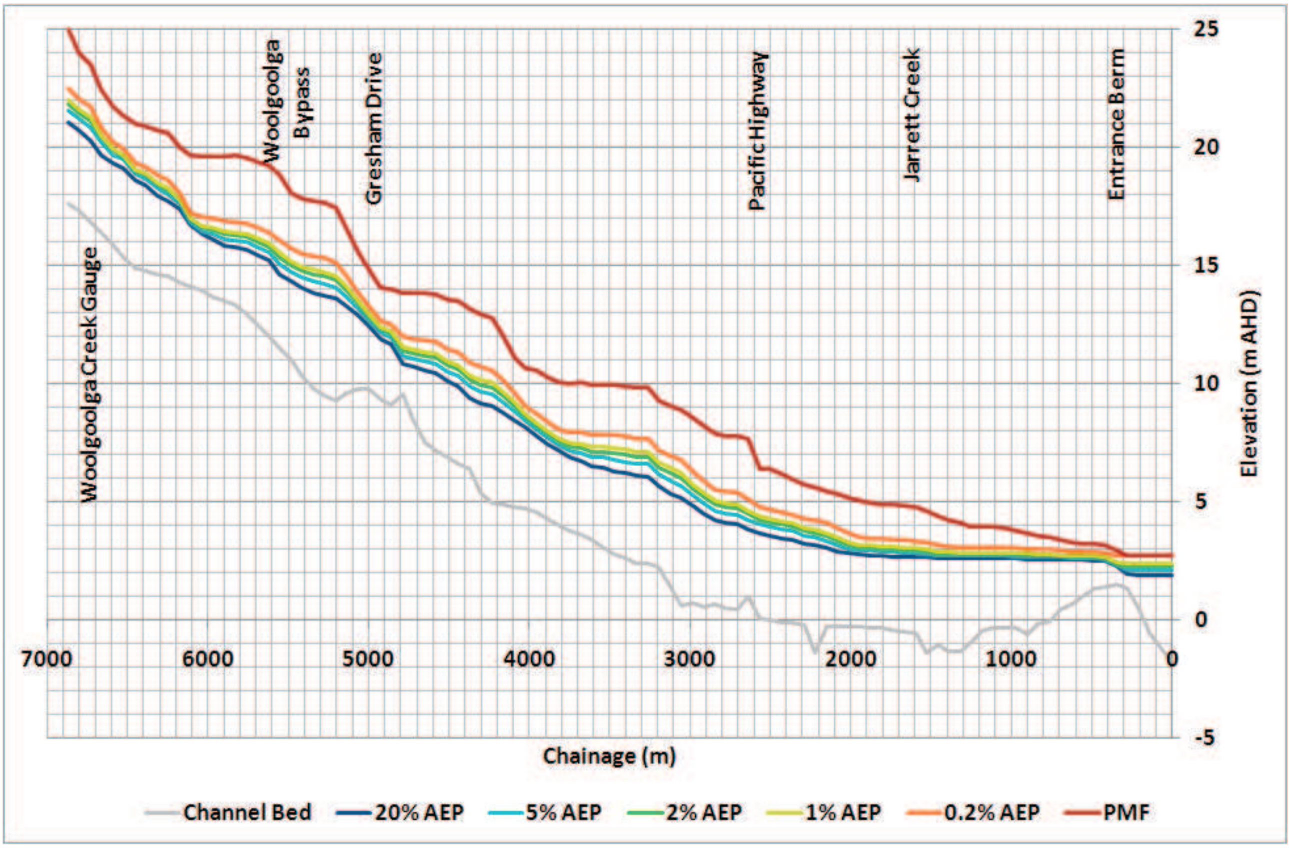

Figure 8-4 Woolgoolga Creek Coincident Event Peak Flood Level Profiles

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Figure 8-5 shows the design flood inundation extents for the 20% AEP, 1% AEP and PMF events. The flood extents for the 20% AEP event and 1% AEP event are broadly similar, albeit with some additional flood flow paths becoming active, particularly in Woolgoolga between the Pacific Highway and Jarrett Creek. The inundation extents for the PMF event show a much increased area at risk to flooding, especially in the following locations:

- The area to the west of the Pacific Highway including Nash Street, Dalgety Street, Knox Street and Moore Street;
- The area between the Pacific Highway and Jarrett Creek including Turon Parade;
- The area between Woolgoolga Creek and Woolgoolga Lake including Melaleuca Avenue, Pandanus Place and Clear Place; and
- The area around the Woolgoolga beachfront including the Woolgoolga Beach Caravan Park.

For events up to the 1% AEP magnitude the flooding within the catchment is largely restricted to undeveloped floodplain areas. There appears to be no significant flooding to properties located on Poundyard Creek or Woolgoolga Creek upstream of the Pacific Highway. The flood risk to developed areas is primarily located in the Woolgoolga Creek – Jarrett Creek confluence area and the surrounding floodplain, particularly Newman Street, Boundary Street, Ganderton Street and Wharf Street.

In addition to the flood risk from main stream sources there are also a number of locations at risk from local catchment runoff and overland flows, including Clarence Street, Turon Parade, Market Street and Trafalgar Street.

Peak in channel flood velocities are typically around 1.5m/s to 2.5m/s, being lower in the floodplain areas. Flood velocities on the developed floodplain areas are typically less than 0.5m/s, but may be locally high around control structures and on roadways.

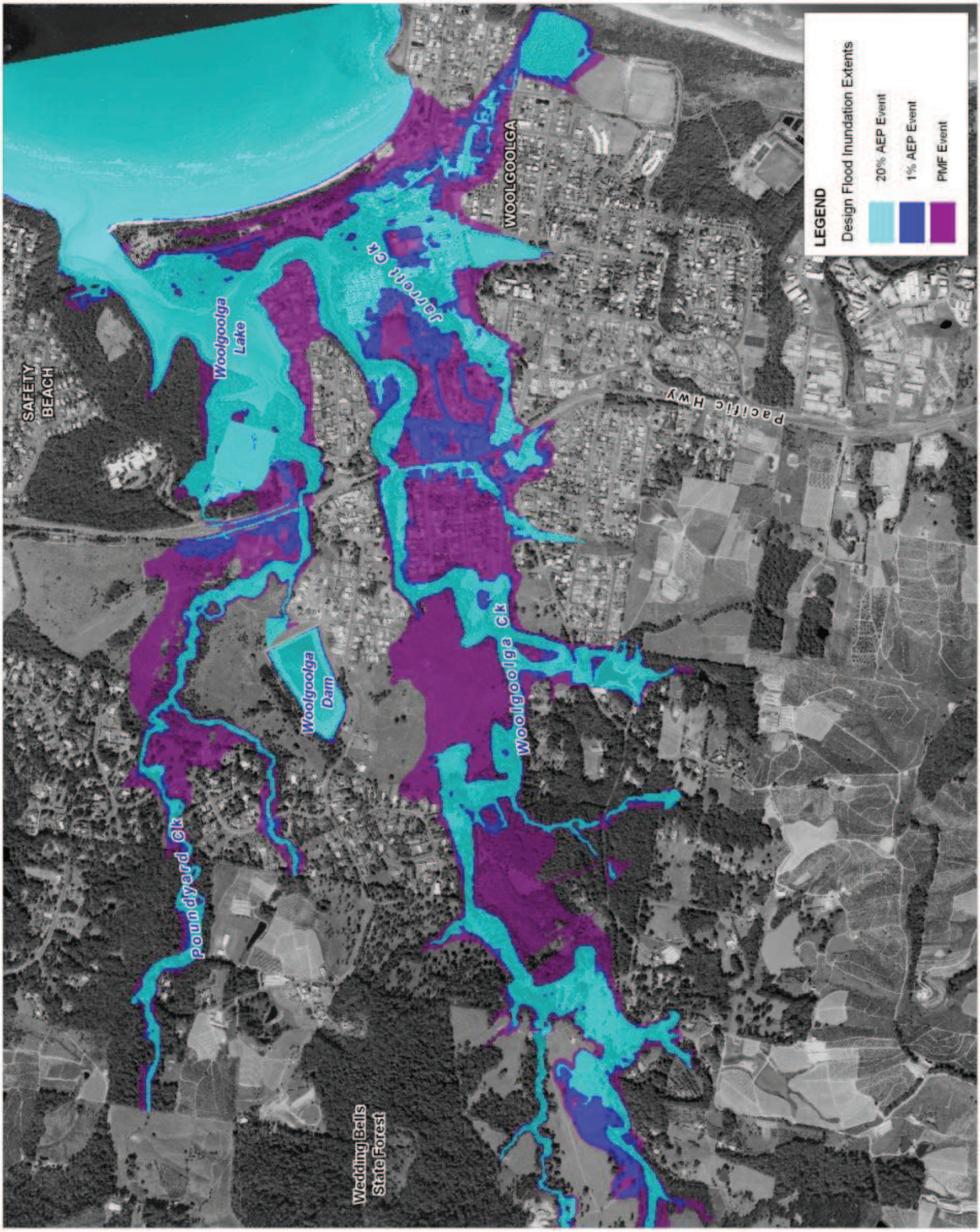
8.1.4 Sensitivity of Design Results to Adopted Conditions

The adopted design conditions are for the coincident occurrence of both catchment and ocean events, with the catchment flows in Woolgoolga Lake occurring at the same time as the peak tide and surge conditions in the ocean. A relatively high berm level of 1.5m AHD has also been adopted. Although these conditions are reasonable for future planning considerations, they do provide results which are somewhat conservative. This is most noticeable in the model results for the 20% AEP event, which shows inundation of areas which may not have experienced flooding at this frequency.

There are a number of conditions which impact the peak flood levels in Woolgoolga Lake and the surrounding floodplain, including:

- The entrance berm geometry;
- The coincidence of catchment derived and ocean derived flood events; and
- The inclusion of wave setup in the ocean water level boundary.

The entrance berm geometry has the most significant impact on the modelled flood levels in Woolgoolga Lake and the surrounding floodplain. A catchment derived flood event occurring when the entrance is closed will provide a much higher flood level in the lake than a similar one occurring



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Design Flood Inundation Extents

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Filepath : K:\N2245_Woolgoolga_Flood_Study\MapInfo\Workspaces\DRG_012_120503_Flood_Extents.WOR with an open entrance. As discussed in Section 2.1.1, Council initiates a mechanical entrance breakout when the water level in the lake reaches 1.8m AHD, in order to help alleviate flooding. The last such breakout was initiated in 2007.

When considering flooding from the ocean, the small storage capacity of the lake means that the ocean derived flood events are largely insensitive to the entrance conditions. The sensitivity of flood levels to entrance conditions is discussed further in Section 8.6.1.

The coincidence of catchment derived and ocean derived flood events can be conservative as the joint probability of the events coinciding can be less likely than the probability of the design event being represented. The inclusion of wave setup for coincident flood events is also uncertain as large flows passing through the lake entrance can result in the wave setup being reduced from the typical design level of 15% of the offshore significant wave height. The sensitivity of flood levels to the adopted ocean boundary conditions is discussed further in Section 8.6.2.

To better understand the impact of the adopted design conditions on the peak flood levels a number of simulations were undertaken with various combinations of entrance berm geometry and ocean boundary conditions. The minimum conditions which could be reasonably adopted for design purposes were then compared to the adopted design flood conditions to determine the level of sensitivity. The minimum standard conditions comprised:

- A design catchment flow condition with an open entrance and a neap tide; and
- A design ocean flood condition with a 1.5m berm height and no catchment flows.

This assessment was conducted for both the 5% AEP and 1% AEP events.

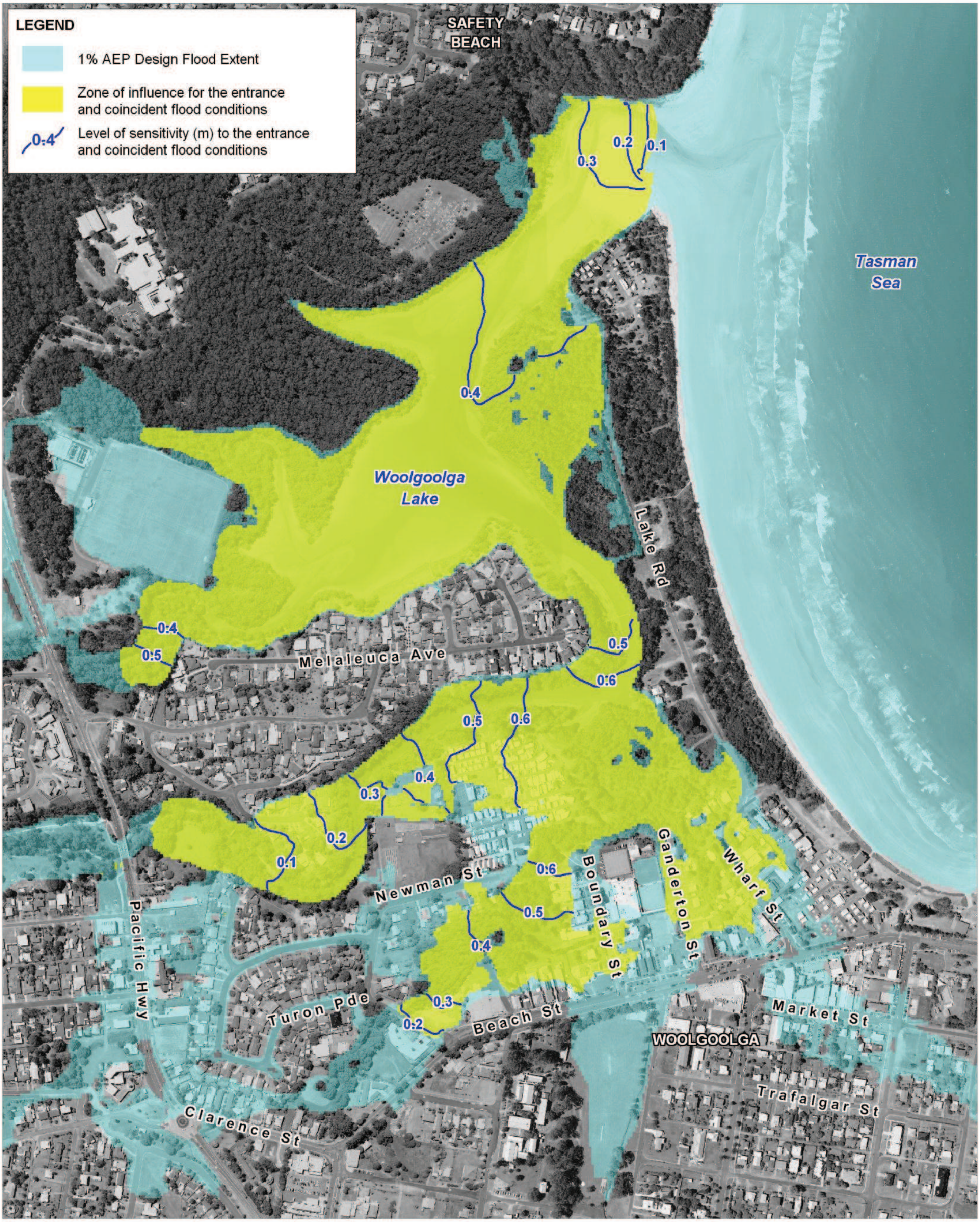
Figure 8-6 shows the results of this comparison between the adopted design conditions and the minimum conditions at the 1% AEP event. It can be seen that the area which is most sensitive to the adopted design conditions is the area around the Woolgoolga Creek – Jarrett Creek confluence, where over a 0.6m difference in modelled peak flood levels is experienced. Within Woolgoolga Lake the difference is closer to 0.4m. The level of sensitivity observed for the 5% AEP event was of a similar order to that of the 1% AEP event.

The limit of influence that the adopted design conditions have occurs at around the Pacific Highway on both Woolgoolga Creek and Poundyard Creek and at Bultitude Street on Jarrett Creek. The zone of influence extends almost to Beach Street in the town centre. It is important to understand these sensitivities when considering floodplain management activities within Woolgoolga.

8.2 Flood Flows

8.2.1 Flood Frequency Analysis

The Woolgoolga Creek stream gauge has been in operation since 1960 and as such offered sufficient data to undertake a flood frequency analysis at the site. Annual maxima water levels were extracted from the available data for the years 1960 to 1983 and were supplied by MHL for the years 1990 to 2012. There is a six year data gap in the intervening period. The hydraulic model was used to derive a rating curve at the gauging site, from which the recorded flood levels were converted to flows. The modelled rating curve is presented in Figure 8-7, alongside the existing gauge site rating curve and the available spot gauging flow records.



Title:

Sensitivity of Design Peak Flood Levels to the Entrance and Coincident Conditions

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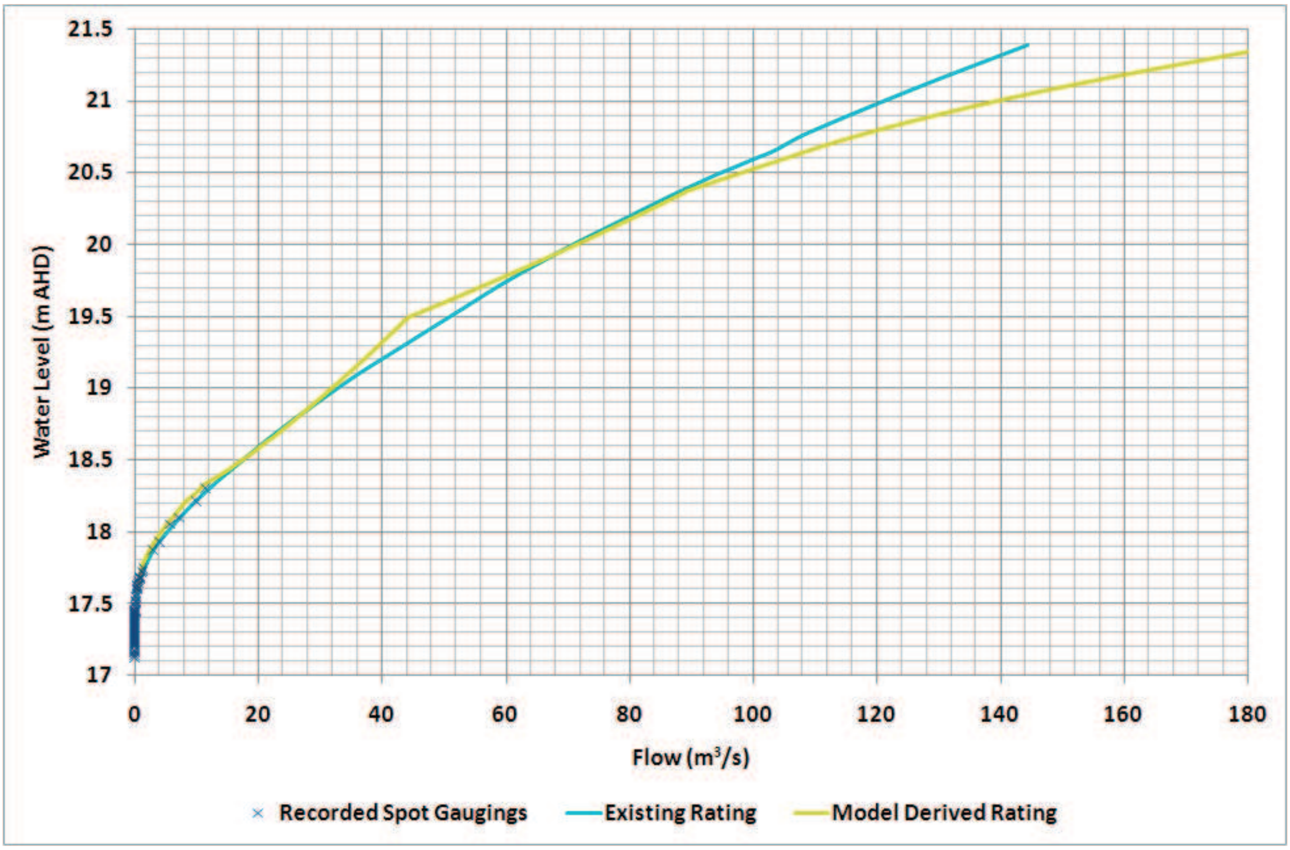

Figure 8-7 Rating Curves for the Woolgoolga Creek Gauge

It can be seen that there is a close match between the two rating curves until around 90m^3/s when the two curves begin to deviate. This is to be expected, as rating curve extensions are not often accurate without the aid of hydraulic modelling. The largest recorded flow gauging is less than 12m^3/s.

The available annual maxima flow series was filtered to remove outliers, resulting in a total of 45 years on which the analysis was based. Both a Log Pearson III distribution and a Gumbel distribution were fitted to the data and are presented alongside the observed annual maxima in Figure 8-8. There is a significant difference between the two distributions. The Gumbel distribution is preferred in this instance, as it provides a better fit to the observed data in the 20% AEP to 5% AEP flood event range.

Peak flood flows at the Woolgoolga Creek gauge derived from the Gumbel distribution are presented in Table 8-4. The peak flood flows from the modelled design events and the recent calibration events are also provided for comparison.

The modelled peak flood flows are similar to those derived through the flood frequency analysis, supporting the adoption of a 0mm initial loss value, as discussed in Section 7.3.3. The only event where the modelled peak flood flow differs significantly to that of the flood frequency analysis is the 20% AEP event. It may be that events of this magnitude often occur with drier antecedent catchment conditions, whereas larger magnitude rainfall burst events typically occur in longer periods of wet weather, when the catchment is saturated at the onset of the event. At the Woolgoolga Creek gauge the January 2012 event was of a 5% AEP order of magnitude, whereas June 2011 represents a 2% AEP magnitude event.

Table 8-4 Peak Flood Flows at the Woolgoolga Creek Gauge

Flood Event Magnitude	Peak Flood Flow (m^3/s)	
	Flood Frequency Analysis	Modelled
20% AEP	62	80
5% AEP	107	113
Jan 2012	*111*	*106*
Jun2011	*134*	*134*
2% AEP	135	131
1% AEP	157	150
0.2% AEP	206	198

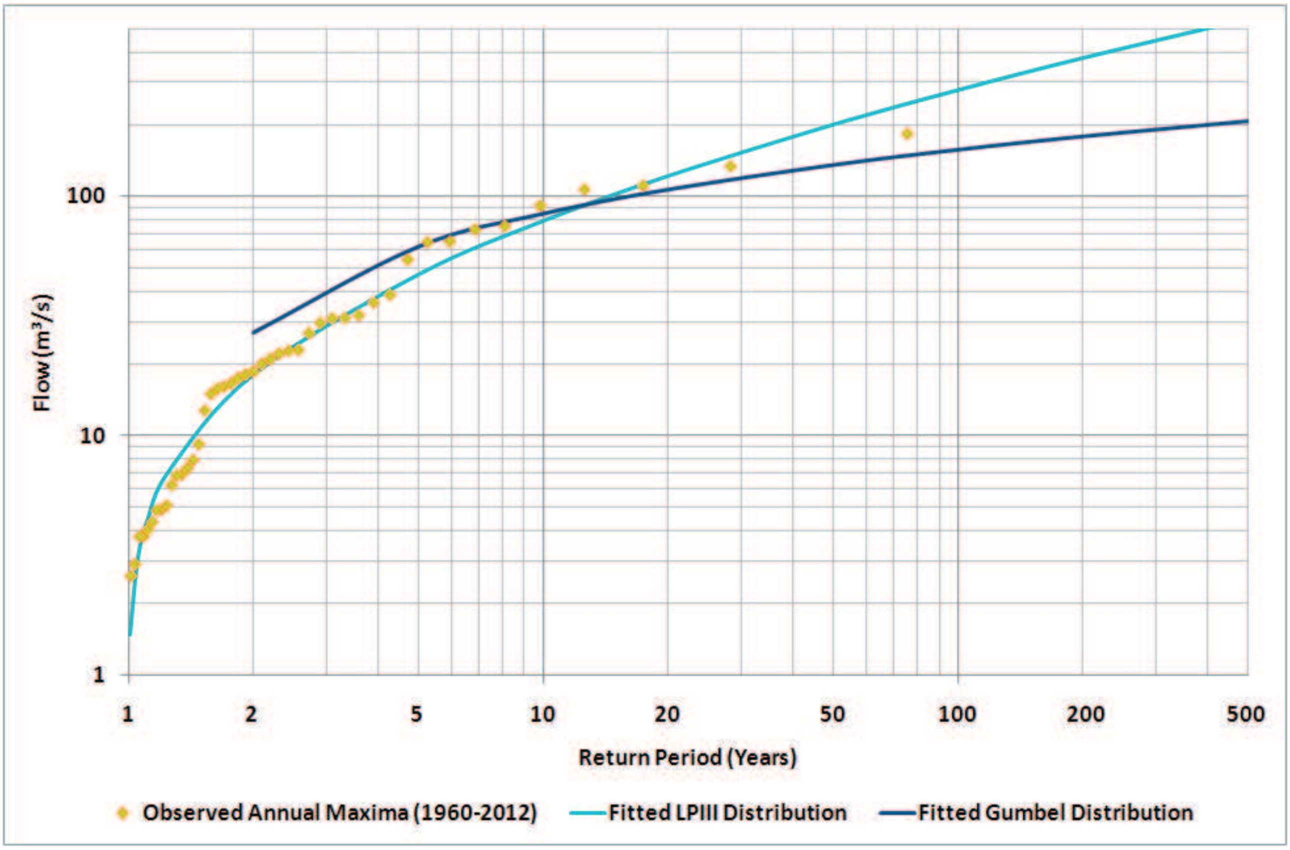

Figure 8-8 Flood Frequency Analysis at the Woolgoolga Creek Gauge

8.2.2 Flood Hydrographs

Predicted peak flood flows at selected locations (as presented in Figure 8-1) are shown in Table 8-5 for the full range of catchment derived flood events considered. Peak flood flows for the PMF event have not been included, as the substantial increase in floodplain area for this event makes reporting flows at many of the selected locations inappropriate. The modelled peak flood flow at the Woolgoolga Creek gauge for the PMF event is around 680m^3/s. The corresponding peak flow at the lake entrance is around 1,070m^3/s.

The flood flow hydrographs for the modelled events at the Woolgoolga Creek gauge are presented in Figure 8-9 and at the Woolgoolga Lake gauge in Figure 8-10. The hydrographs at the creek gauge are taken from the 2-hour duration storm, as this is the critical event at that location. They peak at around 2.5 hours after the onset of the storm. The hydrographs at the lake gauge are taken from the 6-hour duration storm. The time to peak at this location is some 4.5 hours after the onset of the storm.

Table 8-5 Modelled Peak Flood Flows for Catchment Derived Flood Events

ID	Location	Flood Event Frequency				
		20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
2	Lake Entrance	145	196	226	254	320
3	Lake Gauge	113	157	183	207	264
4	U/S Pacific Hwy (WC)	103	144	168	191	248
6	Creek Gauge	77	109	131	150	198
7	U/S Pacific Hwy (PYC)	26	38	46	53	71
9	U/S Bultitude St	4	6	8	10	12

The flood hydrographs at each of the six locations reported in Table 8-5 are presented in Figure 8-11 for the 1% AEP event. The hydrographs that have been presented are for the critical storm duration at each location. For the Woolgoolga Creek gauge and the locations on Poundyard Creek and Jarrett Creek this is the 2-hour storm event. For the remaining locations on Woolgoolga Creek and Woolgoolga Lake this is the 6-hour duration.

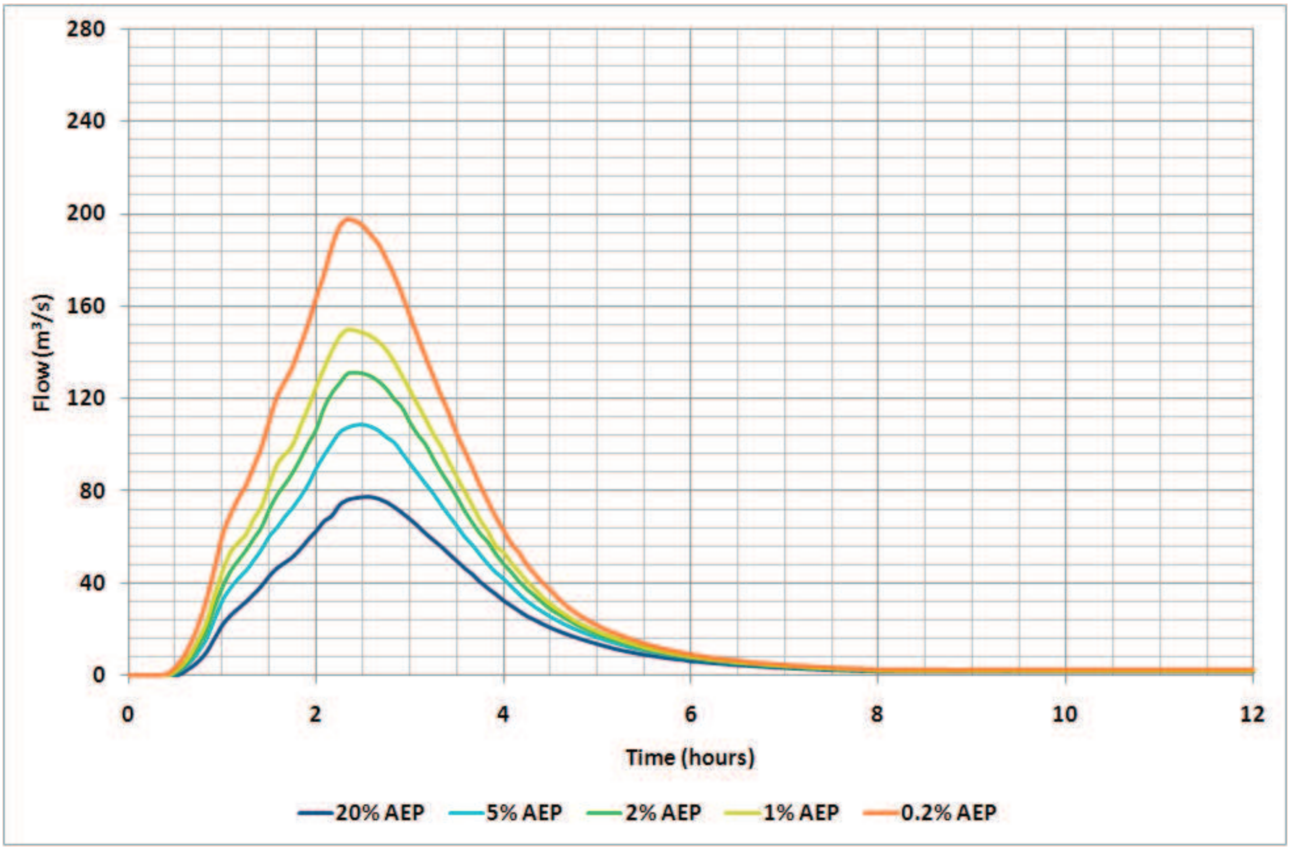

Figure 8-9 Modelled 2-hour Duration Event Hydrographs at Woolgoolga Creek Gauge

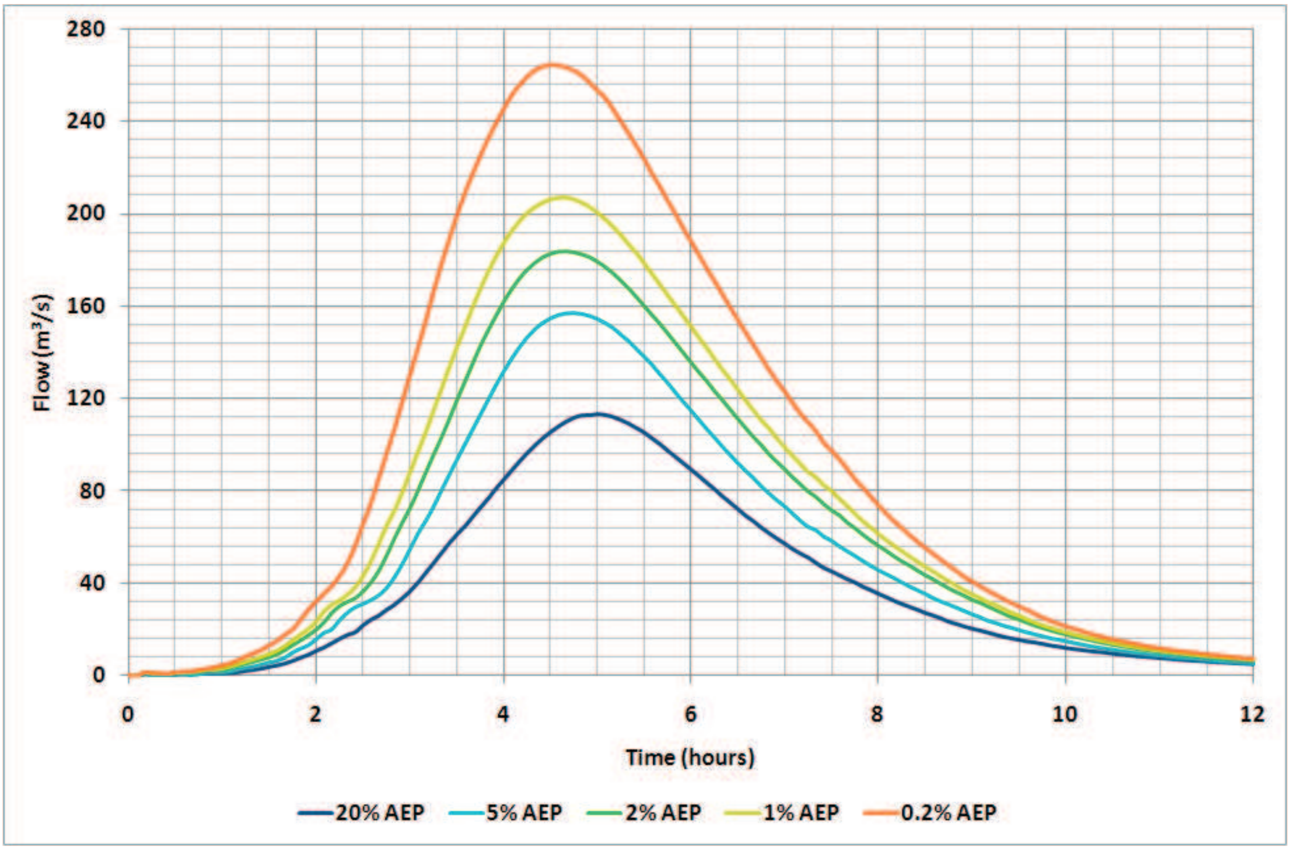

Figure 8-10 Modelled 6-hour Duration Event Hydrographs at Woolgoolga Lake Gauge

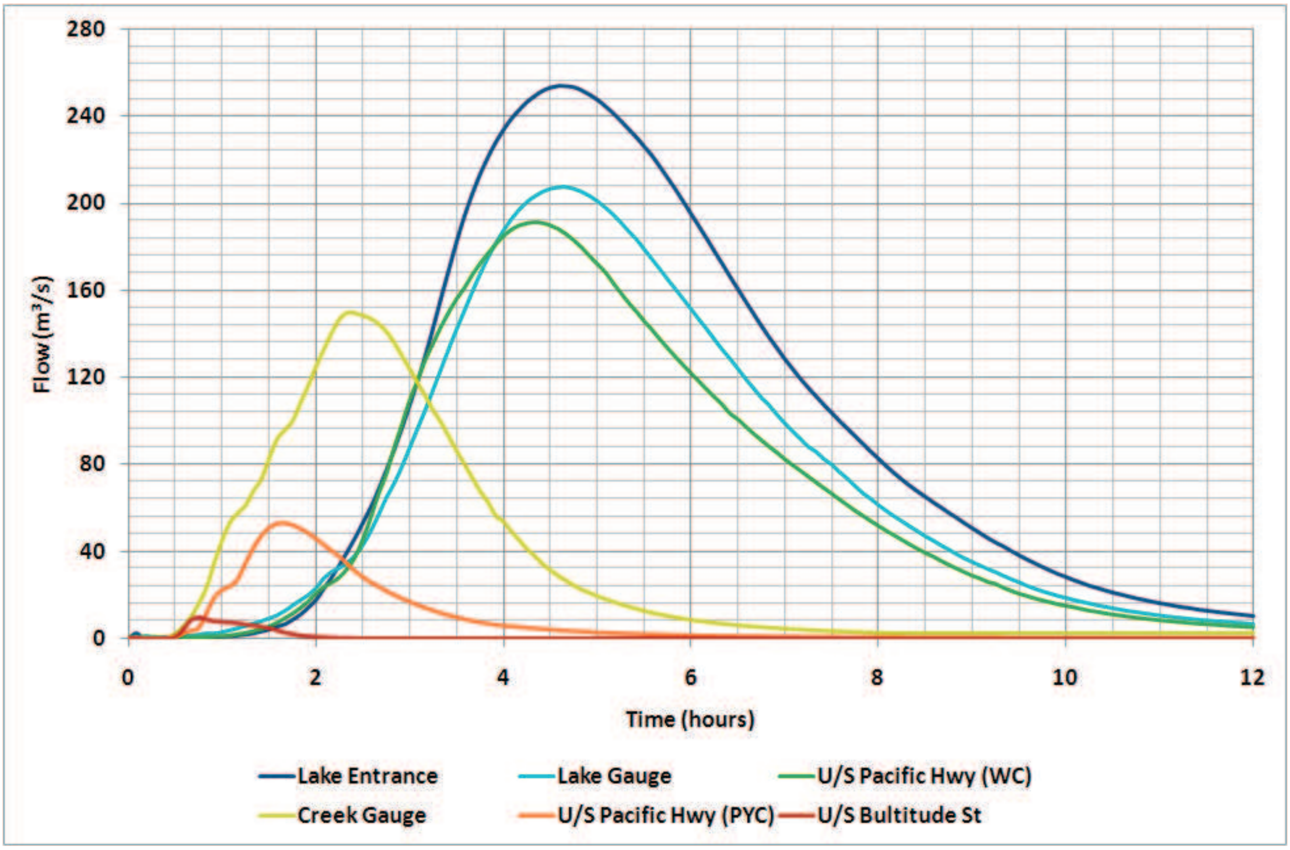

Figure 8-11 Modelled 1% AEP Event Hydrographs at Selected Locations

8.3 Climate Change

The potential impacts of future climate change were considered for the 1% AEP design event. The most significant impact for Woolgoolga Lake will be from the impact of the predicted increase in berm height, which is in line with the 0.4m and 0.9m sea level rise for the 2050 and 2100 planning horizons. This impact can be observed in Table 8-6 at the Lake Entrance and Lake Gauge where similar increases in peak flood level can be observed. These impacts also extend into the low-lying floodplain areas including at Bultitude Street and Wharf Street. For areas further upstream the 10% increase in rainfall intensities gives typical peak flood level increases of between 0.1m to 0.2m.

The flood levels in Table 8-6 are from the locations presented in Figure 8-1. Longitudinal profiles showing climate change impacts along Woolgoolga Creek are shown in Figure 8–12.

8.4 Hydraulic Categorisation

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (NSW Government, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- **Floodway -** Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage -** Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- **Flood Fringe -** Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant affect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define flood impact categories across the study catchment. The approach that was adopted derived a preliminary floodway extent from the velocity * depth product (sometimes referred to as unit discharge). The floodway extent was then locally adjusted where appropriate. The peak flood depth was used to define flood storage areas. The adopted hydraulic categorisation is defined in Table 8-7.

Preliminary hydraulic category mapping is included in Appendix A. It is also noted that mapping associated with the flood hydraulic categories may be amended in the future, at a local or property scale, subject to appropriate analysis that demonstrates no additional impacts (e.g. if it is to change from floodway to flood storage).

Table 8-6 Modelled Peak Flood Levels (m AHD) for Climate Change Scenarios

ID	Location	Flood Event Scenario		
		Existing 1% AEP	2050 1% AEP	2100 1% AEP
1	Tasman Sea	2.4	2.9	3.6
2	Lake Entrance	2.7	3.1	3.6
3	Lake Gauge	2.9	3.2	3.7
4	U/S Pacific Hwy (WC)	4.6	4.8	4.9
5	Gresham Dr	12.8	13.0	13.0
6	Creek Gauge	21.1	21.3	21.3
7	U/S Pacific Hwy (PYC)	4.3	4.5	4.6
8	U/S Shearer Dr	18.5	18.6	18.6
9	U/S Bultitude St	3.3	3.4	3.8
10	Hubbard St	6.5	6.5	6.5
11	Wharf St	3.1	3.4	3.8
12	Market St	3.6	3.6	3.8

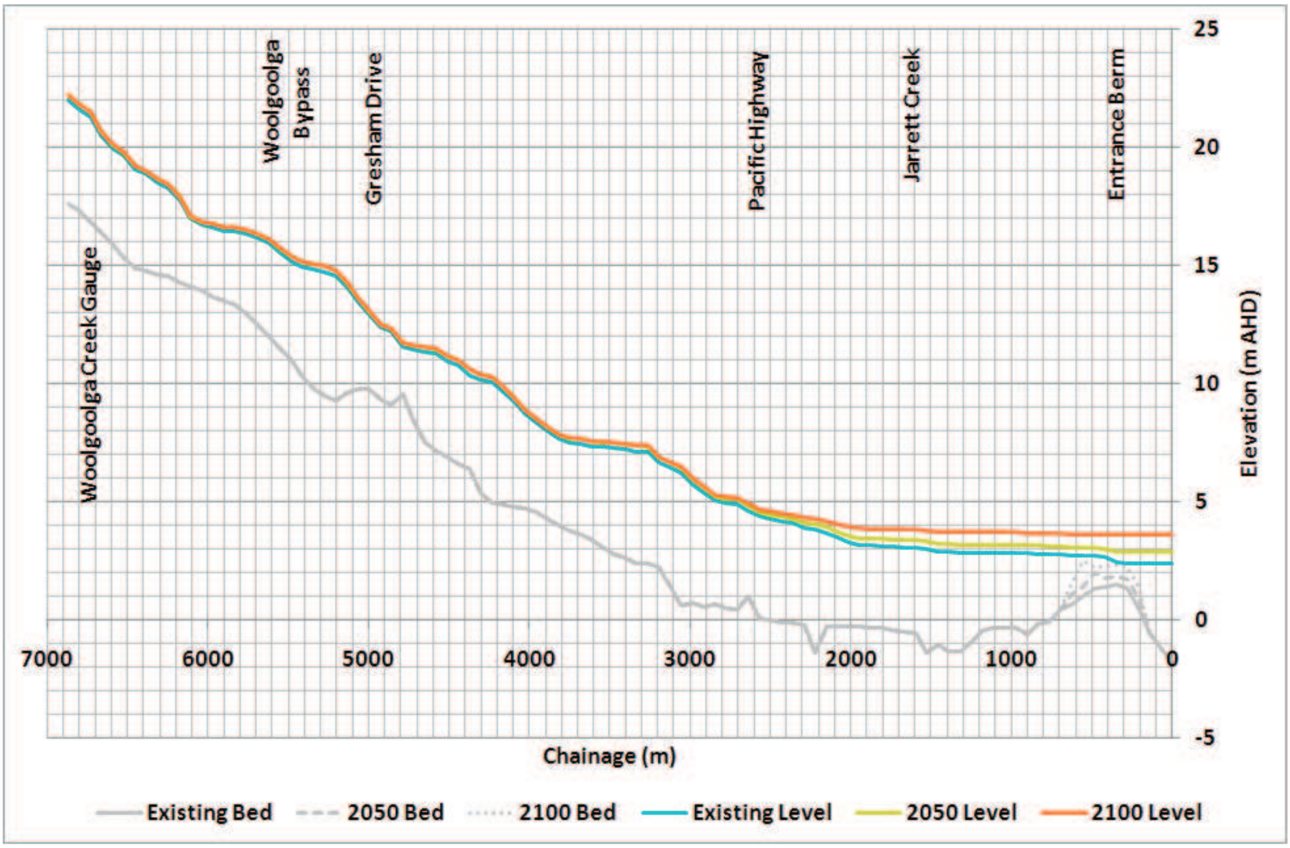

Figure 8-12 Woolgoolga Creek Climate Change Scenario Peak Flood Level Profiles

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Table 8-7 Hydraulic Categories

Floodway	Velocity * Depth > 0.3 at the 1% AEP event	Areas and flowpaths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	Velocity * Depth < 0.3 and Depth > 0.5 metres at the 1% AEP event	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Flood extent of the PMF event	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

8.5 Provisional Hazard

The NSW Government's Floodplain Development Manual (2005) defines flood hazard categories as follows:

- **High hazard** – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- **Low hazard** – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities have no major threat.

Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005) are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 8-13.

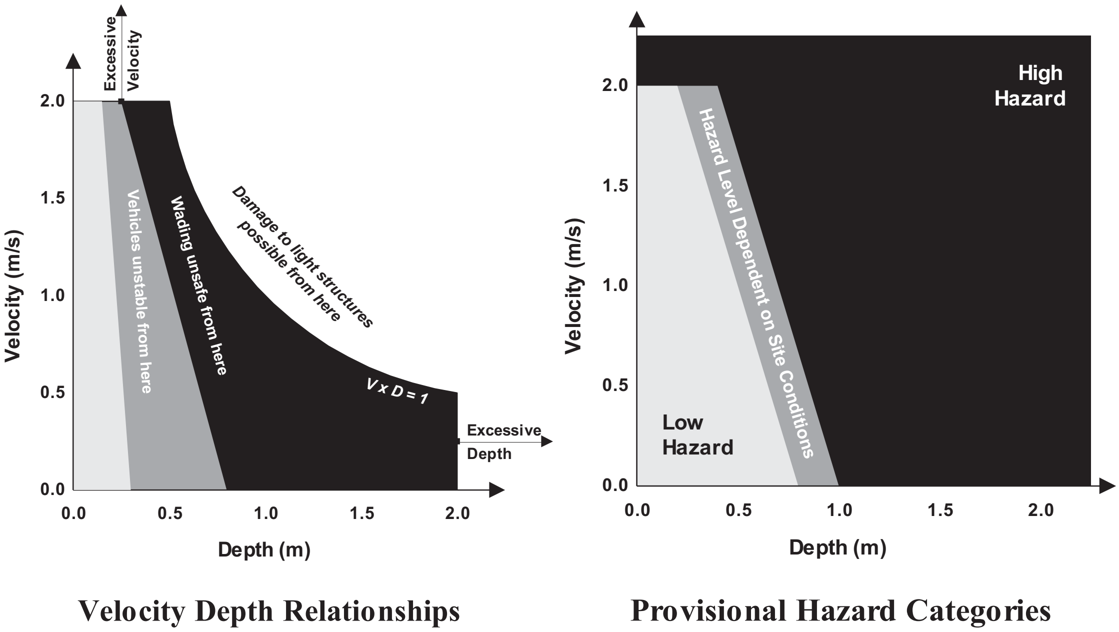


Figure 8-13 Provisional Flood Hazard Categorisation

The provisional hydraulic hazard is included in the mapping series provided in Appendix A.

8.6 Sensitivity Tests

8.6.1 Entrance Conditions

As discussed in Section 8.1.4 the adopted entrance conditions have a significant impact on design flood levels, particularly in Woolgoolga Lake and the surrounding floodplain areas. The design flood conditions adopted a 1.5m berm height. For the 5% AEP and 1% AEP events the impact of adopting a 1m berm height and an open entrance condition were assessed. Figure 8-14 and Figure 8-15 show the results of this assessment for the 5% AEP event and the 1% AEP event respectively. The berm profiles are those at the onset of the event. The geomorphologic model scours the berm during the flood event, opening the lake entrance. The peak flood level results of each event show a similar level of impact, which is greatest within Woolgoolga Lake, reduced at the Jarrett Creek confluence and negligible upstream of the Pacific Highway.

The impact of adopting a 1.5m berm over a 1m berm is around a 0.4m increase in flood level within Woolgoolga Lake and a 0.3m increase at the Jarrett Creek confluence. The impact of adopting a 1.5m berm over an open entrance condition is around a 1.0m increase in flood level within Woolgoolga Lake and a 0.6m increase at the Jarrett Creek confluence.

8.6.2 Sea Level Boundary

As discussed in Section 8.1.4 there is a certain level of uncertainty with adopting coincident catchment and ocean flood conditions and the inclusion of wave setup for these coincident flood events. A sensitivity test was therefore undertaken for the 5% AEP and 1% AEP design events to assess the impact of the adopted sea level boundary for the catchment derived flood events, which are the dominant flood mechanism for Woolgoolga. The sensitivity tests have been undertaken adopting a 1m berm height as the 1.5m berm conditions would tend to mask the true impacts of the boundary conditions, being the dominant control of flood levels in the lake.

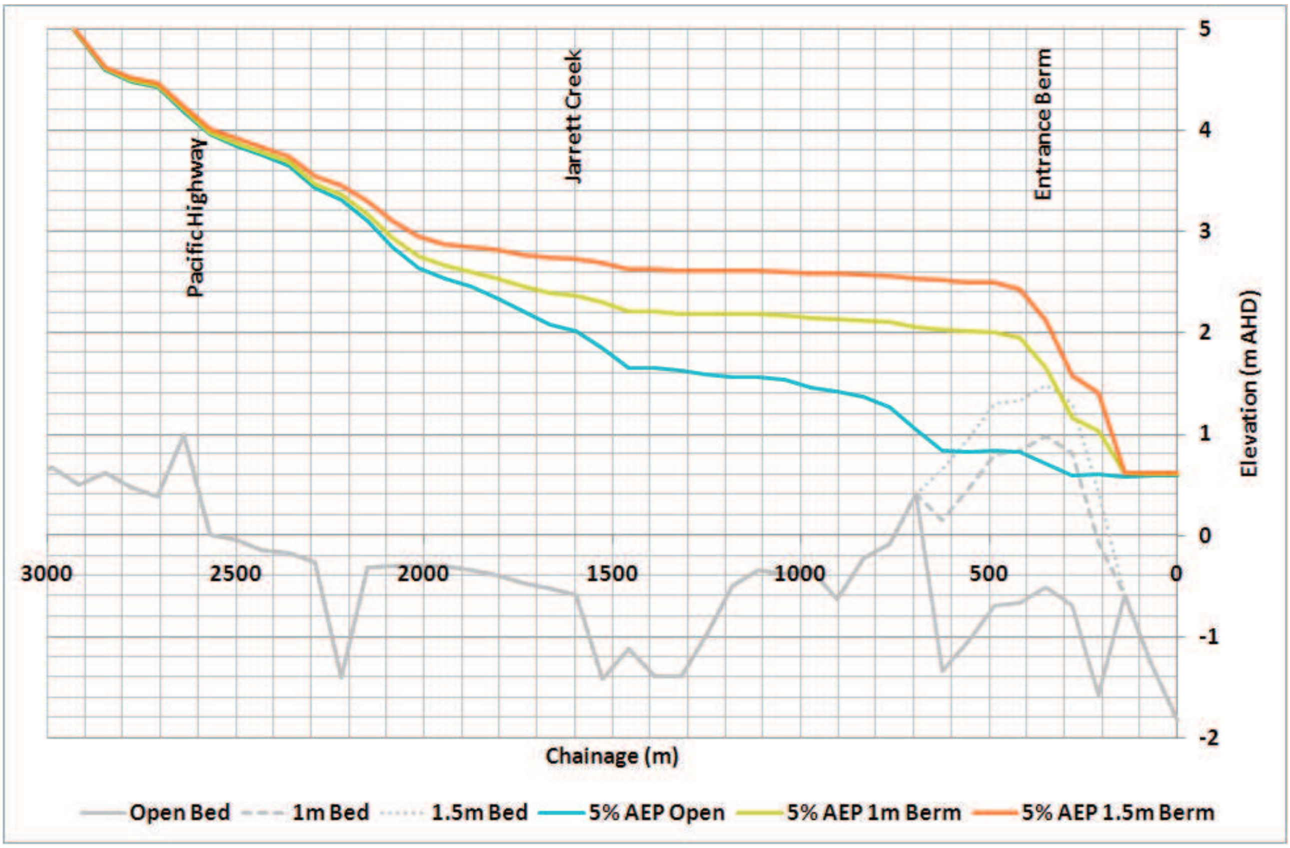


Figure 8-14 Sensitivity of the 5% AEP Peak Flood Levels to the Lake Entrance Conditions

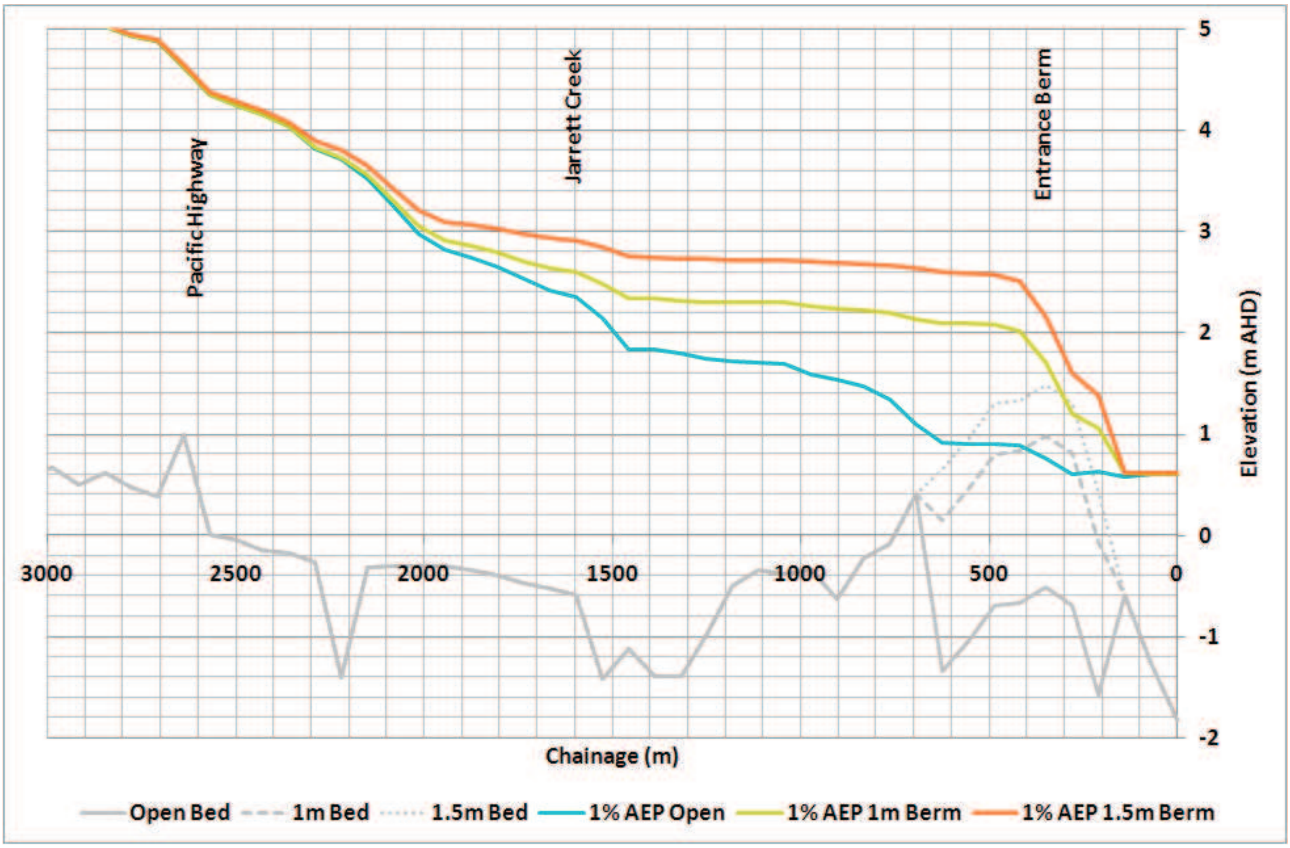


Figure 8-15 Sensitivity of the 1% AEP Peak Flood Levels to the Lake Entrance Conditions

The design flood conditions adopted a 20% AEP ocean boundary for the 5% AEP catchment event and a 5% AEP ocean boundary for the 1% AEP catchment event. The design ocean levels included the full wave setup component. The inclusion of wave setup for coincident flood events is uncertain as large flows passing through the lake entrance can result in the wave setup being reduced. Therefore, the 5% AEP and 1% AEP design events were tested with a coincident 20% AEP and 5% AEP ocean boundary with the wave setup component removed, i.e. the design still water level.

To assess the impact of the coincident catchment and ocean flood conditions the 5% AEP and 1% AEP catchment events were also undertaken with the normal neap tide as the downstream boundary. Figure 8-16 and Figure 8-17 show the results of the sea level boundary sensitivity assessment for the 5% AEP event and the 1% AEP event respectively.

The impacts are much less than for the adopted entrance conditions sensitivity discussed in Section 8.6.1. However, for this boundary condition assessment, the impacts are more pronounced for the 1% AEP event than at the 5% AEP event. The adoption of a coincident ocean boundary with the wave setup component removed reduces peak flood levels in Woolgoolga Lake by around 0.1m for the 5% AEP event and by around 0.2m for the 1% AEP event. The removal of a coincident ocean flood condition further reduces the peak flood level by around 0.1m for both events. The limit of influence of the adopted sea level boundary conditions extend beyond the Jarrett Creek confluence but not as far upstream as the Pacific Highway.

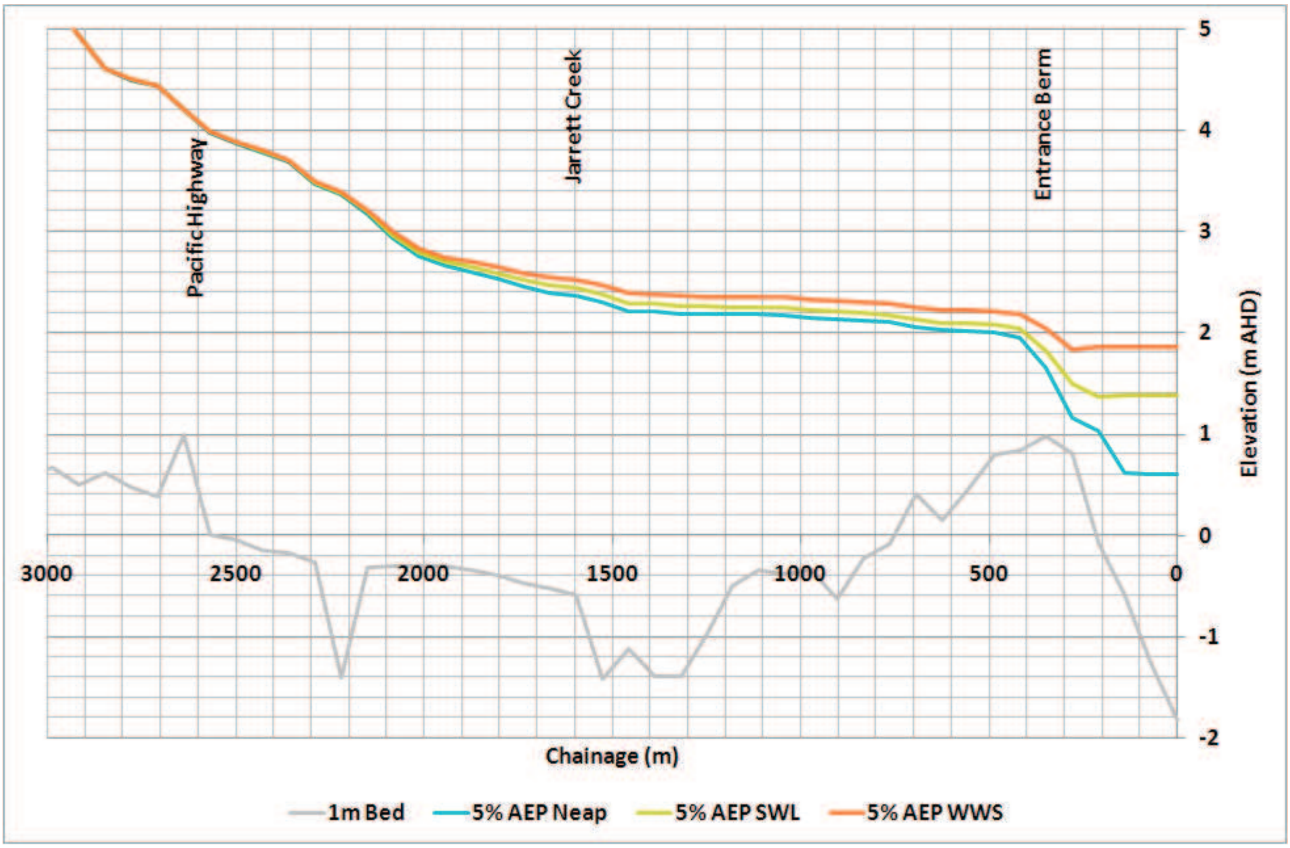


Figure 8-16 Sensitivity of the 5% AEP Peak Flood Levels to the Sea Level Boundary

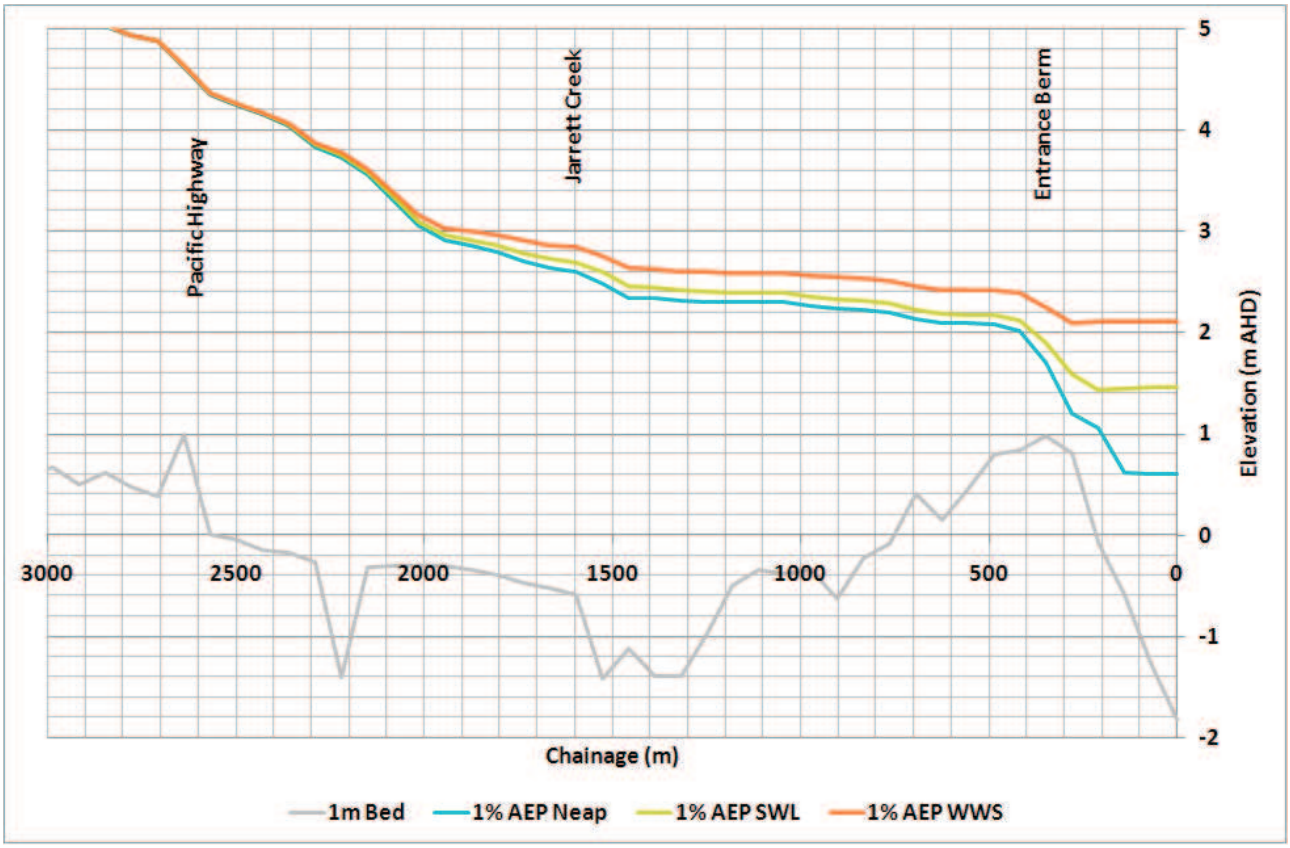


Figure 8-17 Sensitivity of the 1% AEP Peak Flood Levels to the Sea Level Boundary

8.6.3 Increased Rainfall Intensity

For the climate change scenarios discussed in Section 8.3 a 10% increase in design rainfall intensities was adopted. Guidelines for consideration of increased rainfall for climate change recommend that values as high as a 30% increase be tested. The 1% AEP climate change scenario for 2050 was also tested with a 20% and a 30% increase in design rainfall intensity. Figure 8-18 shows the results of this assessment. A 20% increase in design rainfall intensity provides a typical peak flood level increase of between 0.1m and 0.2m above that of the adopted 10% increase. A 30% increase in design rainfall intensity provides a typical peak flood level increase of between 0.2m and 0.4m above that of the adopted 10% increase.

8.6.4 Structure and Pipe Blockage

The assessment of the impact of structure blockages on peak flood levels is a key consideration for floodplain management. The design flood conditions assumed that all hydraulic structures and stormwater pipes were free from blockage. For the blockage sensitivity test the 1% AEP design event was simulated adopting a 25% blockage for structures with openings larger than 6m and a 100% blockage for all other structures and stormwater pipes. Figure 8-19 shows the increase in peak flood inundation extents resulting from the blockage of structures. The peak flood levels at the identified locations are presented in Table 8-8.

The impact of structure blockages is typically localised and does not have a significant impact on the overall flood behaviour. The location at which the blockage of structures has the most significant impact, both in terms of flood level and flood extent, is the Woolgoolga town centre around Market

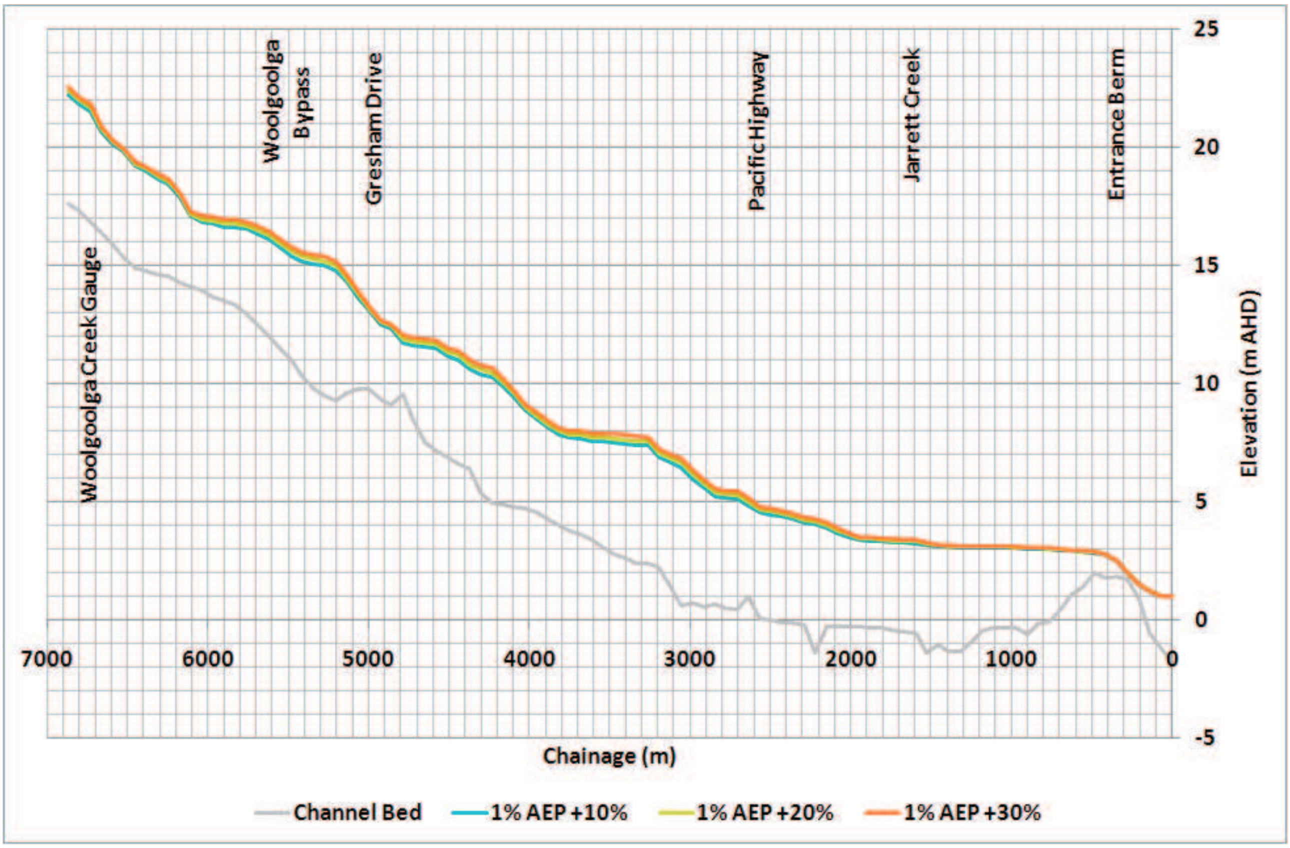
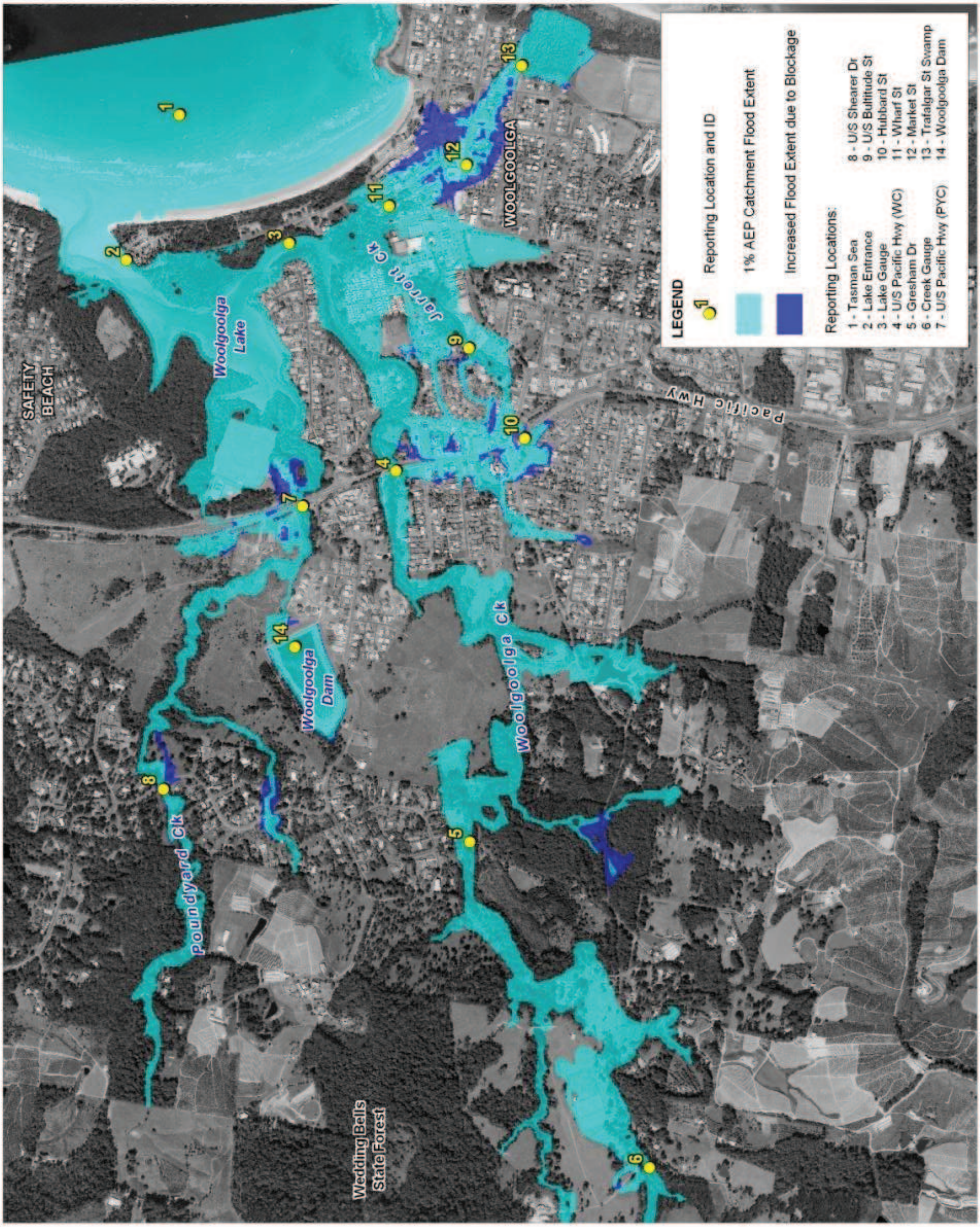


Figure 8-18 Sensitivity of Peak Flood Levels to Increased Rainfall Intensity

Table 8-8 Modelled Peak Flood Levels (m AHD) for the Blockage Scenario

ID	Location	Peak Flood Level (m AHD)		Impact (m)
		1% AEP	Blockage	
1	Tasman Sea	0.6	0.6	0.0
2	Lake Entrance	2.6	2.6	0.0
3	Lake Gauge	2.8	2.8	0.0
4	U/S Pacific Hwy (WC)	4.5	4.6	0.1
5	Gresham Dr	12.8	12.8	0.0
6	Creek Gauge	21.1	21.1	0.0
7	U/S Pacific Hwy (PYC)	4.3	4.6	0.3
8	U/S Shearer Dr	18.5	19.0	0.5
9	U/S Bultitude St	3.3	3.4	0.1
10	Hubbard St	6.5	6.7	0.2
11	Wharf St	2.9	2.9	0.0
12	Market St	3.6	4.2	0.6
13	Trafalgar St Swamp	5.4	5.4	0.0
14	Woolgoolga Dam	18.7	18.9	0.2



Title:

Impacts of Structure and Pipe Blockages

Figure: **8-19**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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Street and Beach Street. Here the flood levels increase by around 0.6m and the flood inundation is substantially more extensive. Under normal circumstances much of the contributing catchment to this area is drained through the stormwater pipes along Queen Street, discharging into the Tasman Sea at Woolgoolga Beach. However, when the stormwater pipes are blocked the flood water instead flows overland to Jarrett Creek, significantly increasing the flood risk to the local area.

The other location where a large increase in flood level is reported is at Shearer Drive, where a 0.5m impact is modelled. However, in this location the extent of the impact is limited to the immediate area upstream of the Shearer Drive culverts.

8.6.5 Channel and Floodplain Roughness

The sensitivity of modelled peak flood levels to the adopted manning's 'n' roughness values were tested for the 1% AEP catchment event. Figure 8-20 shows the results of this assessment. The impact of increasing the adopted manning's 'n' values typically raises peak flood levels by 0.2m to 0.3m. Reducing the adopted manning's 'n' values typically lowers peak flood levels by 0.2m to 0.3m.

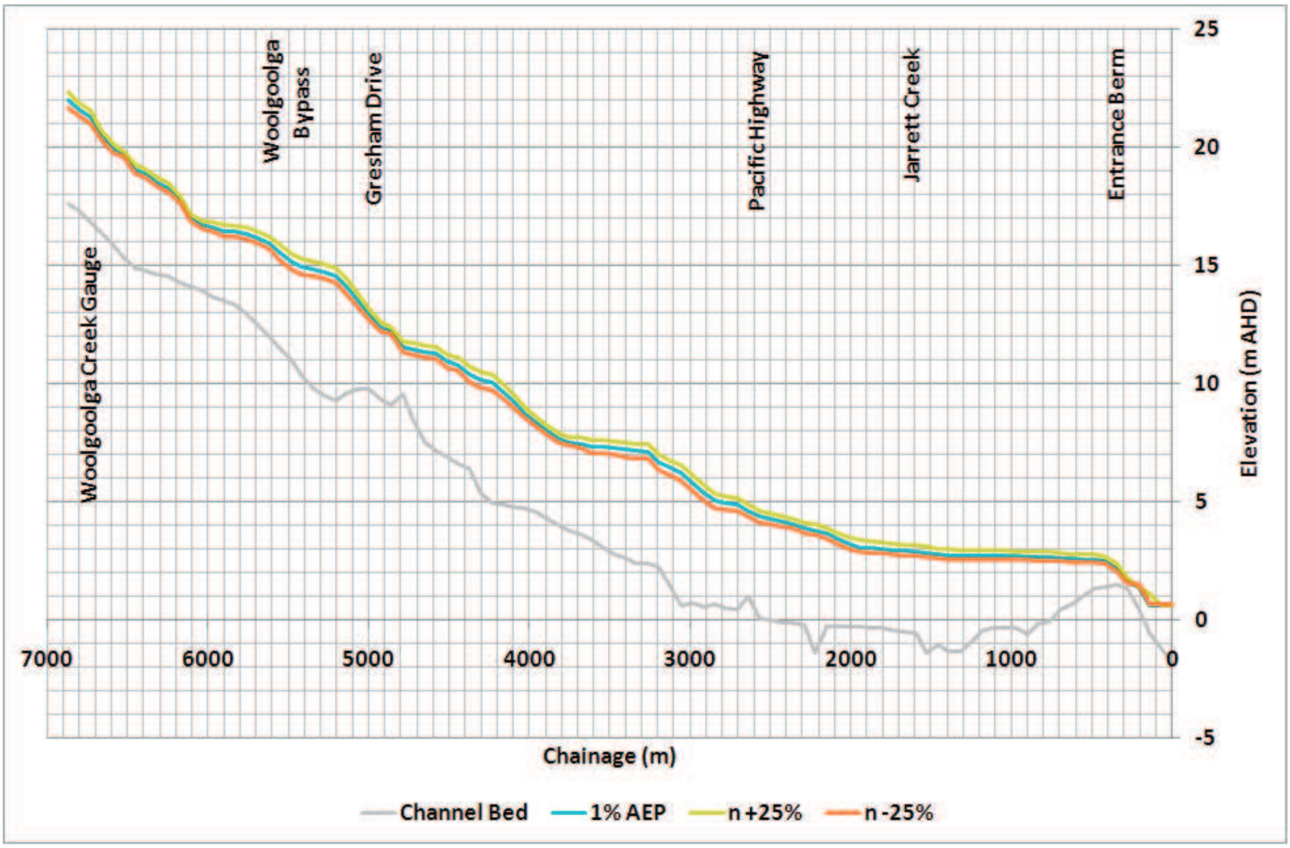

Figure 8-20 Sensitivity of Peak Flood Levels to Changes in Roughness

8.6.6 Entrance Berm Grain Size

One of the most significant parameters associated with the dynamic entrance breakout modelling, aside from the berm geometry, is the adopted entrance berm grain size. The median grain size adopted for the model design scenarios was 0.25mm, which is representative of a fine to medium sand. The impact of the berm grain size was assessed for the 1% AEP catchment event by adopting both a 0.125mm and 0.5mm median grain size, representing a very fine to fine sand and a medium to coarse sand respectively.

Figure 8-21 shows the results of this assessment. It can be seen that increasing the berm grain size raises the peak flood level in Woolgoolga Lake by less than 0.1m. Reducing the berm grain size has a negligible impact on the modelled peak flood levels. The sensitivity of the modelled peak flood levels to parameters of the morphological modelling is much less than the impact of the adopted design entrance conditions.

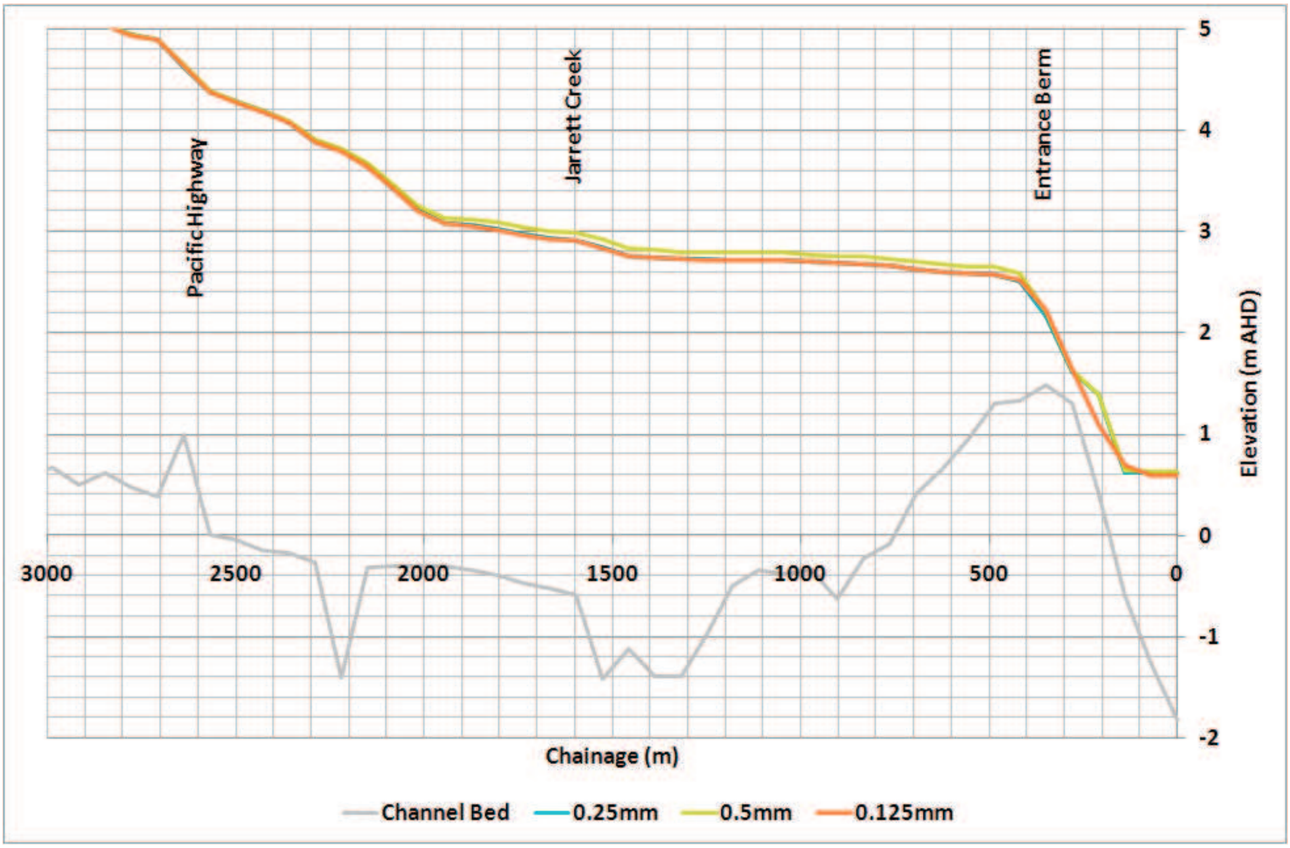

Figure 8-21 Sensitivity of Peak Flood Levels to Changes in Grain Size

8.7 Model Uncertainties and Limitations

There are a number of inherent uncertainties and limitations with the modelling of environmental phenomena such as flooding. Some of the key considerations include:

- The dynamic nature of the Lake Woolgoolga entrance berm has a significant impact on flood levels within Woolgoolga Lake and the surrounding floodplain areas. The resultant flooding from catchment runoff of a given magnitude will vary depending on the entrance conditions at the onset of the event;
- The modelled flood behaviour is driven by the model geometry, derived primarily form the LiDAR dataset and channel cross section survey. Local topographic features that have not been captured by these datasets may have a local influence on flood behaviour and differ to that which has been modelled;

- The modelled stormwater drainage network provides an appropriate capacity to assess the likely overland flood flows. However, the local pit capture has not been explicitly modelled and the assumption is that all upstream runoff is being diverted into the stormwater network;
- The land cover conditions in the catchment will change through time and changes in vegetation within the channel and on the floodplain may impact on the local flood conditions.

8.8 Key Locations for Future Consideration

Through the catchment modelling process undertaken for this study, three locations have been identified that should be considered from a future floodplain risk management perspective. These include:

- The low-lying floodplain areas around the Woolgoolga Creek – Jarrett Creek confluence where both the most significant existing flood risk and potential increased flood risk due to climate change occurs;
- The area around Turon Parade and Clarence Street where a significant overland flow path occurs upstream of the open channel of Jarrett Creek; and
- The area around Market Street and Beach Street where flood levels are particularly sensitive to the blockage of the stormwater drainage network.

9 CONCLUSIONS

The objective of the study was to undertake a detailed flood study of the Woolgoolga Lake catchment and establish models as necessary for design flood level prediction.

In completing the flood study, the following activities were undertaken:

- Collation of historical and recent flood information for the study area;
- Development of a computer models to simulate hydrology and flood behaviour in the catchment;
- Calibration of the developed models using the available flood data, primarily relating to the June 2011 and January 2012 events;
- Prediction of design flood conditions in the catchment and production of design flood mapping series.

Through the undertaking of the flood study it has been found that much of the catchment has no significant flood risk. The flood risk to developed areas is primarily located in the Woolgoolga Creek – Jarrett Creek confluence area and the surrounding floodplain, particularly Newman Street, Boundary Street, Ganderton Street and Wharf Street.

In addition to the flood risk from main stream sources there are also a number of locations at risk from local catchment runoff and overland flows, including Clarence Street, Turon Parade, Market Street and Trafalgar Street.

Low-lying floodplain areas around Woolgoolga Lake were found to be particularly sensitive to both the adopted design flood conditions (primarily the lake entrance conditions) and to future increased flood risk as a result of climate change. The sensitivity of flood levels in these areas should be taken into consideration from a floodplain risk management perspective.

The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain risk management process. The key locations to consider during this process have been identified as:

- The low-lying floodplain areas around the Woolgoolga Creek – Jarrett Creek confluence where both the most significant existing flood risk and potential increased flood risk due to climate change occurs;
- The area around Turon Parade and Clarence Street where a significant overland flow path occurs upstream of the open channel of Jarrett Creek; and
- The area around Market Street and Beach Street where flood levels are particularly sensitive to the blockage of the stormwater drainage network.

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