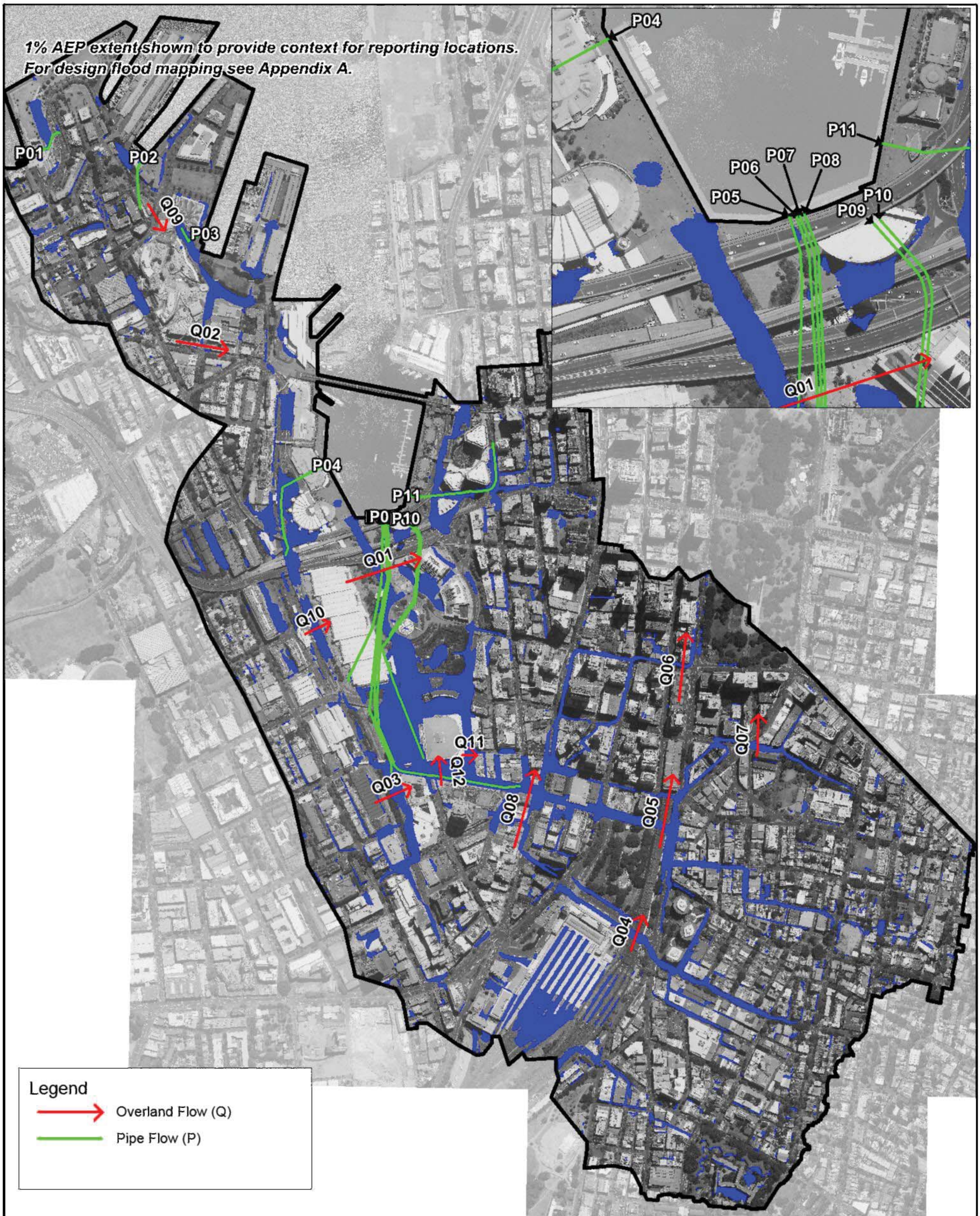

Title:

Darling Harbour Result Locations
Flow Recording - Overland and Pipe Flow

Figure: 7-2

Rev: -

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.

0 375 750m
Approx. Scale

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7.1 Peak Flood Conditions

7.1.1 Flooding Behaviour

7.1.1.1 Overview

Section 2.1 provides a general overview of the layout of the drainage network infrastructure and major flow paths. The trunk drainage network across the study area is comprised of predominantly pipe reaches. Overland flow routes are generally confined to the road network which is typical of urban environments, but even more pronounced in the Darling Harbour catchment.

The Darling Harbour catchment has two distinct catchments areas with the Western Distributor being the divide. Flows underneath the Western Distributor arrive from the Surry Hills area to the south-east. North of the Western Distributor, flood waters have very small catchment areas and flow quickly to Cockle Bay/Sydney Harbour by the shortest distance.

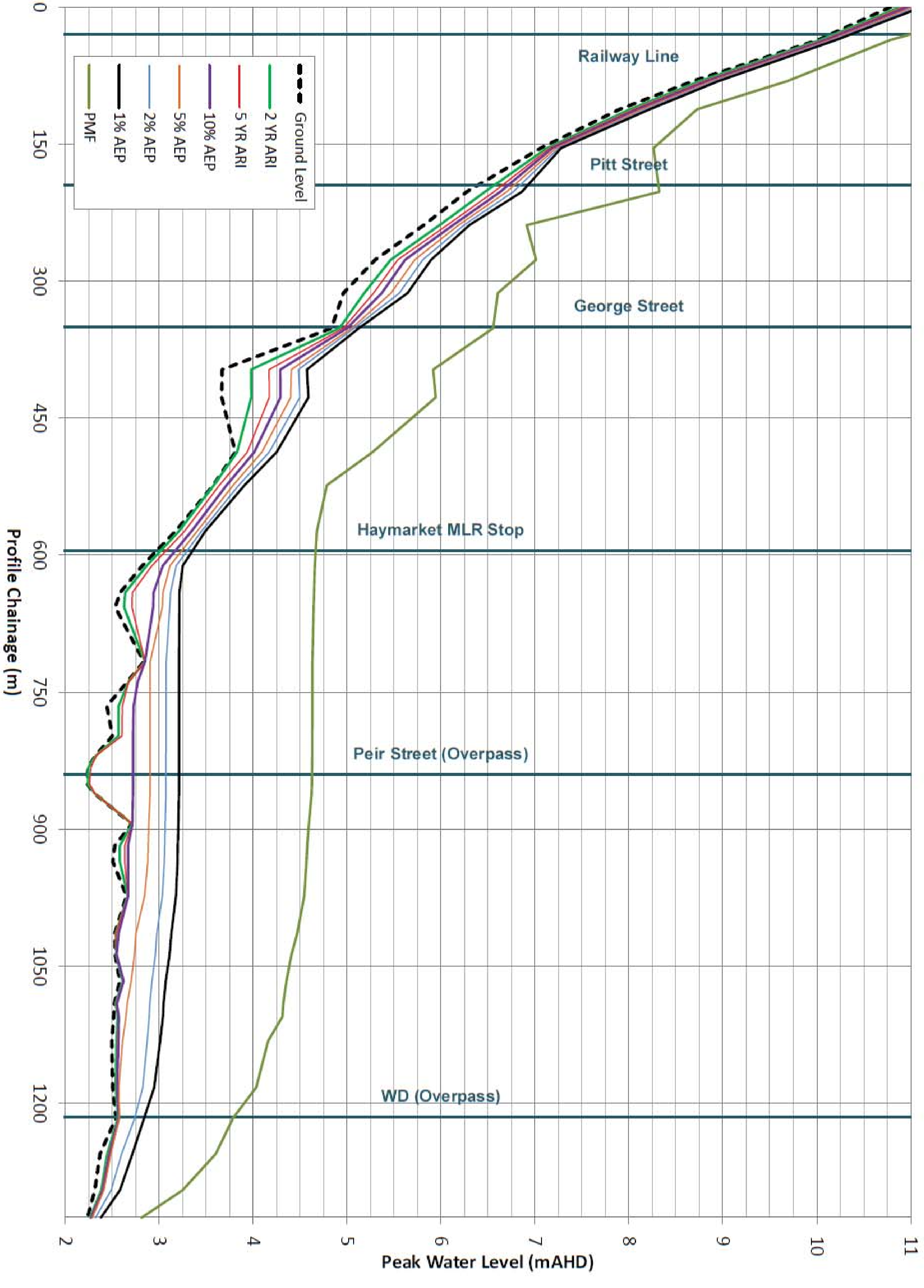
High in the catchment upstream of the Western Distributor (south east Surry Hills area), steep streets quickly convey flows downstream to the Darling Harbour area. Figure 7-4 shows the peak flood level profile at Foveaux Street for all modelled design events and demonstrates the limited flood level sensitivity to the event exceedance probability. A noted exception to the limited sensitivity in upper catchment reaches is at Commonwealth Street. Commonwealth Street has a trapped low point which was identified in the community consultation stage of the study. Figure 7-5 shows the peak flood level profile for the Commonwealth Street trapped low point for all modelled design events. Figure 7-5 shows the limited flood level sensitivity to event recurrence interval in Ann Street which feeds the trapped low point and Reservoir Street which drains overflow. The flood level in the trapped low point however increases by 0.9m from the 2 year ARI event to the 1% AEP event and is further sensitive to pit blockage assumptions.

Downstream of Elizabeth Street (and the railway line), the catchment slope starts to reduce. Sub-surface conduits become very important in relieving flood waters. Overland flow at Q01 (see Figure 7-2) first initiates in the 5% AEP (20 year ARI) event. For events more frequent than the 2% AEP event, pipes P05, P06, P07, P08, P09 and P10 drained catchment flows. For the 5% AEP event, these 6 pipes convey a peak flow of $43m^3/s$. In the 1% AEP event, overland flow at Q01 is $5.3m^3/s$, representing 10% of the flow from the catchment at this location.

North of the Western Distributor, flooding in the catchment is from localised catchments with small upstream catchment areas. These catchments may drain to trapped low points such as Pyrmont Road (point H06) where piped infrastructure is critical in relieving flooding.

Peak flood behaviour for design modelling is best interpreted by reviewing the extensive series of design flood mapping figures presented in Appendix A.

FIGURE 7-3
DARLING HARBOUR PROFILE - DESIGN EENT RESULTS



FOVEAUX STREET PROFILE - DESIGN EENT RESULTS

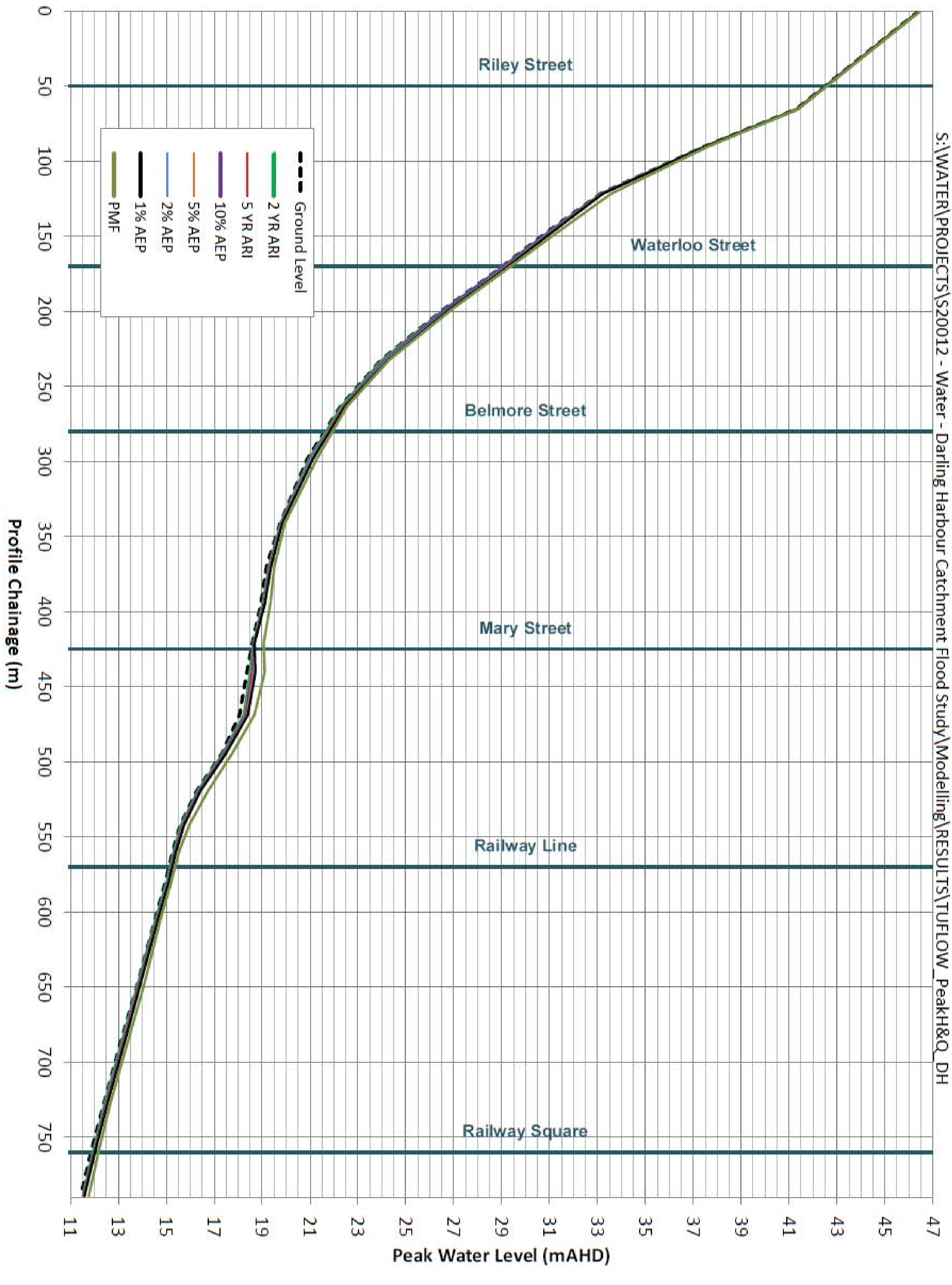
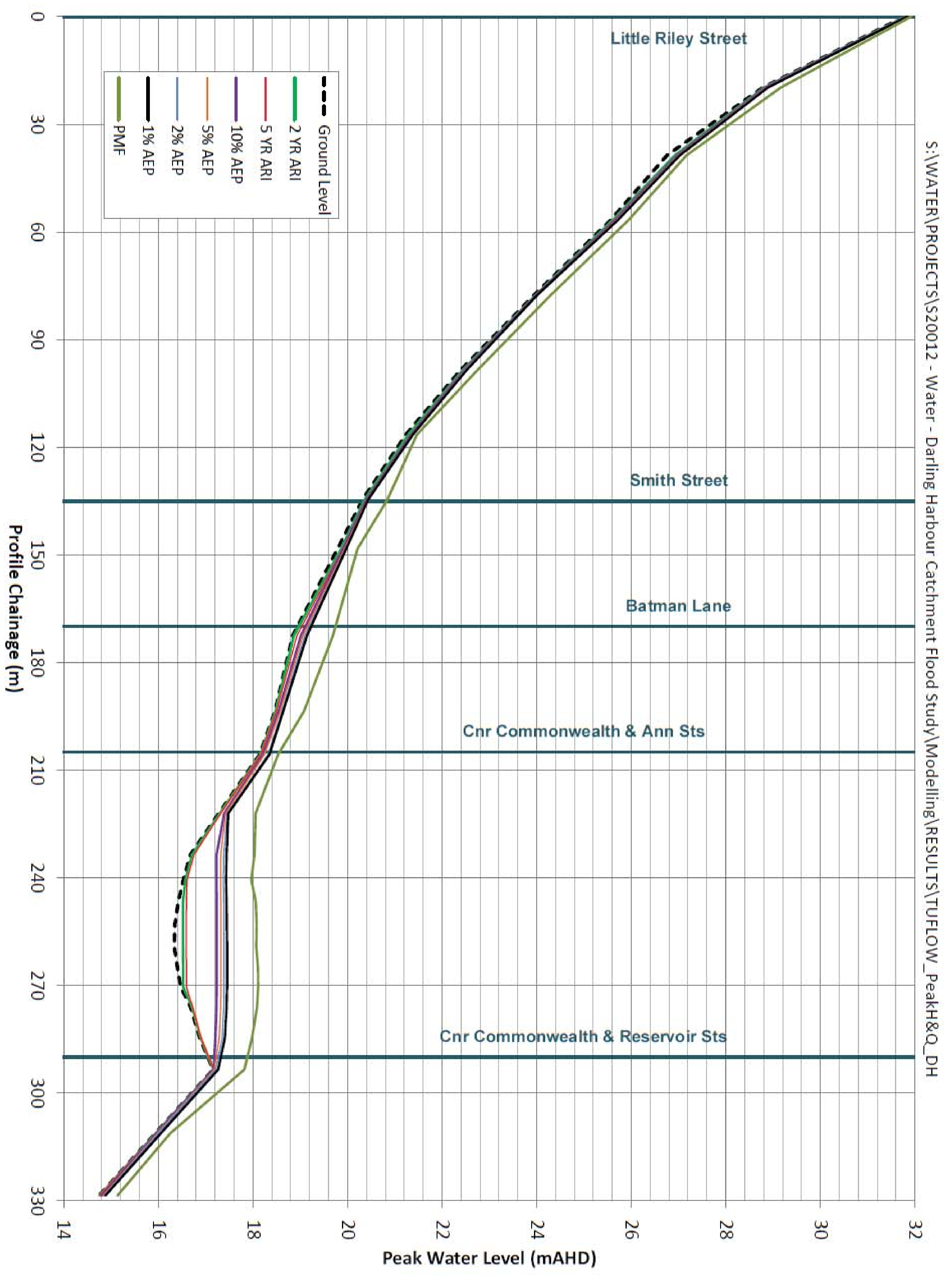


FIGURE 7-5
COMMONWEALTH STREET PROFILE - DESIGN EENT RESULTS



7.1.2 Catchment-Derived Flood Events

As presented in Section 6, a range of durations has been modelled and enveloped for each annual exceedance probability modelled. For complete catchment modelling, it is common for different durations to produce critical flood levels at different locations. Upper catchment reaches or isolated areas with small catchments will likely respond to a shorter duration event. Lower catchment reaches, catchment areas with large upstream detention volumes or large upstream areas will likely respond to longer storms with greater volume. Given a single duration is not appropriate to define critical conditions throughout the catchment, all durations are modelled and the results of each combined to form an envelope grid. This ensures that critical design flood conditions are presented in the mapping across the entire catchment.

Figure 7-6 shows the 1% AEP critical duration assessment for the Darling Harbour catchment. As shown, the majority of the catchment is critical for the 25 minute, 60 minutes and 90 minute storm durations. Table 7-3 shows the differences in flood level for individual storm durations compared with the maximum flood level envelope which combines all durations. The single storm duration which most represents the maximum flood levels across the study area is the 90 minute storm. This duration has therefore been selected as the critical duration for the sensitivity analysis and climate change modelling. For all design event modelling however, all storm durations have been modelled to most accurately produce a peak flood envelope.

Table 7-3 Critical duration assessment (peak flood level difference (m) from maximum envelope)

Location[#]	015min	025min	030min	045min	060min	090min	120min	180min	270min	360min	540min
H01	-0.25	-0.17	-0.15	-0.09	-0.05	-0.03	-0.02	-0.02	-0.02	-0.02	+0.00
H02	-0.19	-0.15	-0.12	-0.05	+0.00	-0.01	-0.02	-0.20	-0.23	-0.24	-0.25
H03	-0.07	-0.06	-0.07	-0.02	+0.00	+0.00	+0.00	-0.03	-0.03	-0.05	-0.04
H04	-0.09	+0.00	-0.02	-0.06	-0.02	+0.00	-0.02	-0.19	-0.24	-0.34	-0.38
H05	-0.03	+0.00	-0.01	-0.02	-0.01	-0.01	-0.02	-0.14	-0.19	-0.23	-0.24
H06	-0.25	-0.13	-0.15	-0.10	-0.02	-0.01	+0.00	-0.19	-0.29	-0.36	-0.44
H07	-0.05	-0.02	-0.03	-0.03	-0.01	+0.00	-0.01	-0.06	-0.10	-0.13	-0.15
H08	+0.00	+0.00	-0.01	-0.01	-0.01	+0.00	-0.01	-0.05	-0.06	-0.08	-0.09
H09	-0.08	-0.01	-0.03	-0.05	-0.01	+0.00	-0.01	-0.13	-0.19	-0.26	-0.30
H10	-0.16	-0.10	-0.10	-0.06	-0.01	-0.01	+0.00	-0.12	-0.14	-0.19	-0.23
H11	+0.00	+0.00	+0.00	-0.01	+0.00	+0.00	+0.00	-0.07	-0.08	-0.09	-0.09
H12	-0.08	-0.01	-0.02	-0.03	+0.00	-0.01	+0.00	-0.12	-0.18	-0.26	-0.30
H13	-0.01	+0.00	+0.00	+0.00	+0.00	-0.01	+0.00	-0.03	-0.04	-0.06	-0.07
H14	-0.01	+0.00	+0.00	-0.01	-0.01	+0.00	-0.01	-0.05	-0.06	-0.08	-0.09
H15	-0.01	+0.00	+0.00	-0.01	+0.00	+0.00	-0.00	-0.04	-0.05	-0.07	-0.08
H16	-0.05	+0.00	-0.01	-0.03	-0.01	+0.00	-0.02	-0.11	-0.14	-0.18	-0.20
H17	-0.01	+0.00	+0.00	-0.01	+0.00	+0.00	-0.01	-0.04	-0.04	-0.05	-0.05
H18	-0.05	+0.00	-0.01	-0.02	-0.01	-0.01	+0.00	-0.11	-0.16	-0.22	-0.25
H19	+0.00	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.10	-0.11	-0.13	-0.14
H20	-0.42	-0.17	-0.14	-0.07	+0.00	-0.02	-0.04	-0.29	-0.40	-0.51	-0.51
H21	-0.08	-0.01	-0.02	-0.02	+0.00	-0.01	+0.00	-0.12	-0.17	-0.24	-0.28
H22	-0.04	+0.00	-0.01	-0.02	-0.01	-0.01	+0.00	-0.08	-0.11	-0.14	-0.15

Location#	015min	025min	030min	045min	060min	090min	120min	180min	270min	360min	540min
H23	-0.01	+0.00	+0.00	-0.01	+0.00	+0.00	-0.01	-0.03	-0.05	-0.07	-0.07
H24	-0.36	-0.15	-0.13	-0.06	+0.00	-0.02	-0.04	-0.27	-0.36	-0.51	-0.62

Refer to Figure 7-1 for the reporting locations

The design flood results, as presented in a flood mapping series in Appendix A, are the maximum condition for all of the modelled durations. For each of the simulated design events, a map of peak flood level, depth and velocity is presented covering the study area.

7.1.3 Tidal Inundation

Limited tidal inundation modelling was undertaken for the 1 year ARI level for Sydney Harbour, which has a level of 1.2 m AHD. This tidal event does not directly pose any flood risk to locations within the study area. It is noted that there is limited sensitivity in Harbour water levels to frequency of design water level. The 1% AEP (100 year ARI) harbour water level is only 0.2 m higher than the 1 year ARI water level (Section 2.2.5, Table 2-3).

7.1.4 Potential Flooding Problem Areas

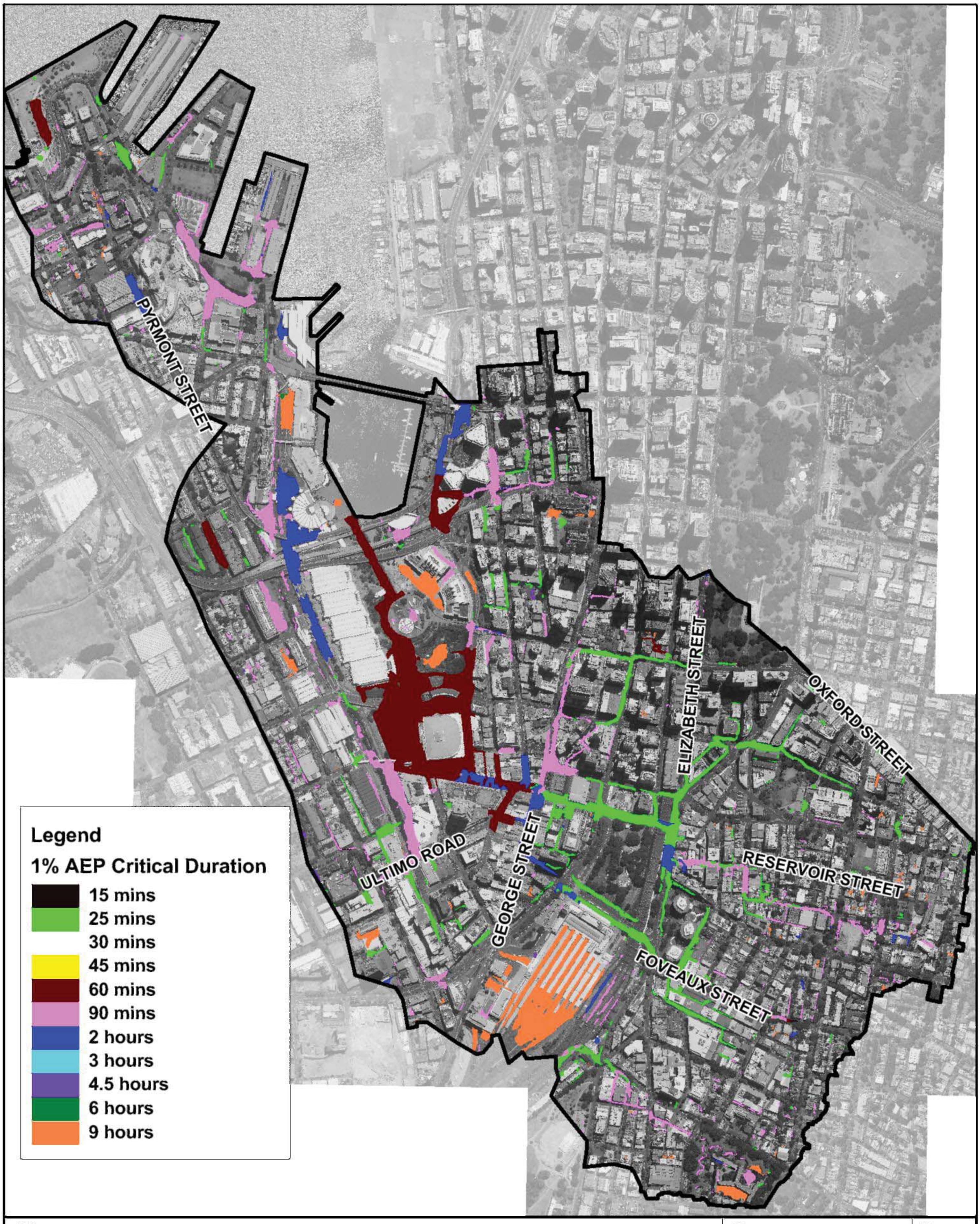
In simulating the design flood conditions for the Darling Harbour catchment, the following locations have been identified as potential problem areas in relation to flood inundation:

- **Commonwealth Street trapped low point (near Ann and Reservoir Streets)**
  Through the community consultation it was identified that Commonwealth Street has a trapped low point between Ann Street and Reservoir Street which is sensitive to pit blockage. In standard design modelling, the existing pit and pipe network has capacity to convey the 2 year and 5 year ARI events. The rise in the peak flood level (0.6 m) in the 10% AEP event from the 5 year ARI event indicates that the stormwater capacity is first exceeded in the 10% AEP event. The peak depth in this trapped point exceeds 0.9 m for the 1% AEP event.

- **Pyrmont Road trapped low point (near Jones Bay Road and Union Street)**
  Pyrmont Road between Jones Bay Road and Union Street (near The Star), has a trapped low point which is sensitive to pit blockage. In standard design modelling, the existing pit and pipe network has capacity to convey the 2 year and 5 year ARI events. The rise in the peak flood level (0.7 m) from the 5 year ARI event to the 10% AEP event indicates that the stormwater capacity is first exceeded in the 10% AEP event. The peak depth in this trapped point exceeds 1.0 m for the 1% AEP event.

- **Elizabeth Street**
  The Railway line along Elizabeth Street only allows flood water from the Surry Hills area to pass through to the lower catchment at the under rail bridges at Eddy Avenue, Hay Street and to a lesser extent Campbell Street.

  In the 1% AEP event, a peak flood depth of 0.5 m occurs on Elizabeth Street upstream of Hay Street and Campbell Street as a peak flow of 14 m^3/s is conveyed downstream (flow line Q05).



Title:

CRITICAL DURATION ASSESSMENT
1% AEP (100 year ARI)

Figure: 7-3

Rev: 1

0 375 750m

Approx. Scale

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In the 1% AEP event, a peak flood depth of 0.2 m upstream of Eddy Avenue as a peak flow of $5m^3/s$ is conveyed downstream. Upstream of Eddy Avenue the flood water has a peak velocity of 3 m/s.

At both locations upstream of railway, a significant risk is posed to the safety of pedestrians and motorists.

- **Hay Street (from Elizabeth Street to Haymarket)**
  Hay Street from Elizabeth Street downstream to Haymarket and Sydney Entertainment Centre has a peak depth of 0.7 m and a peak flow velocity of almost 3 m/s. This reach has a high provisional hydraulic hazard for the 1% AEP event and presents a significant potential risk to pedestrians, motorists and property.

- **Darling Harbour near Tumbalong Park and Chinese Gardens**
  At the Haymarket Tram station, the concentrated flow path along Hay Street spreads out and reduces in velocity. This flat area is the upper limit of the catchment which is demonstrated to be sensitive to sea level rise. In some sections, flood water depths exceed 1m in the 1% AEP event. In the 2 year and 5 year ARI events, there is very little flooding present in this area though the flood extent and flood depth starts to increase for the 10% AEP event and above.

7.1.5 Supercritical Flows and Conjugate Depths

As described, sections of the catchment have high velocity flow due to the low hydraulic roughness of the roads which convey the main flow paths and the steepness of the catchment. A catchment of this nature has a tendency to convey supercritical flow which may under-represent the maximum peak water level possible if a hydraulic jump is activated.

For the 1% AEP event, the conjugate depths were calculated for supercritical flow areas. Impact mapping was undertaken to determine the sensitivity of reported model results from the standard depths to the conjugate depths. It was found that conjugate flood levels rarely exceed the standard levels by more than 0.3 m.

Mapping and further discussion of conjugate depth analysis is found in Appendix E.

7.2 Comparison with Previous Studies

Section 2.2.2 outlined previous studies in the catchment including the Flooding and Stormwater report prepared by Hyder for the SICEEP area (Hyder, 2013). Table 7-4 presents a comparison of peak flood levels between the current study and those reported in the SICEEP study.

It is noted that the SICEEP study was undertaken for a different purpose and hence adopted a different methodology. Results between the different studies are therefore anticipated to have differences.

Table 7-4 Comparison of design results to Hyder study

Location	5 yr ARI		5% AEP		1% AEP		PMF	
	Current Study	SICEEP Study	Current Study	SICEEP Study	Current Study	SICEEP Study	Current Study	SICEEP Study
FLOOD LEVEL (mAHD)								
Tumbalong Green	2.64	2.70	2.89	2.80	3.18	2.80	4.57	4.20
Cnr Little Hay and Harbour Sts	3.15	3.05	3.26	3.10	3.34	3.25	4.63	4.60
Tram Station (Exhibition Centre)	2.85	2.80	2.95	2.80	3.09	2.80	4.47	4.00
Flow Path Under Anzac Bridge	2.44	2.40	2.46	2.40	2.69	2.50	3.50	3.50
Tram Station (Haymarket)	2.92	2.90	3.10	2.90	3.21	3.20	4.66	4.80

Peak flood levels from Hyder modelling are approximate only. They have been interpreted from peak flood level contours on design results mapping figures.

7.3 Preliminary 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 effect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define hydraulic categories across Darling Harbour catchment. Approaches to define hydraulic categories that were considered for this assessment included partitioning the floodplain based on:

- Peak flood velocity;

- Peak flood depth;

- Peak velocity-depth product (sometimes referred to as unit discharge);

- Cumulative volume conveyed during the flood event; and

- Combinations of the above.

The definition of hydraulic categories that was considered to best fit the application within the Darling Harbour catchment was based on a combination of velocity, velocity-depth product and depth parameters. The adopted hydraulic categorisation is defined in Table 7-5 and is consistent with similar study catchments in the City of Sydney LGA (WMAwater, 2012a and 2012b).

Preliminary hydraulic category mapping for the 1% AEP and PMF design events is included in Appendix A (Figure A- 25 to Figure A- 26). 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 7-5 Provisional hydraulic categories

Hydraulic Category	Definition	Description
Floodway	Velocity * Depth > 0.25 m^2/s AND Velocity > 0.25 m/s OR Velocity > 1.0 m/s.	Areas and flowpaths where a significant portion of floodwaters are conveyed during a flood.
Flood Storage	NOT Floodway AND Depth > 0.2 m	Floodplain areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	NOT Floodway AND Depth < 0.2 m	Areas that are low velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

7.4 Provisional Hazard Categories

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

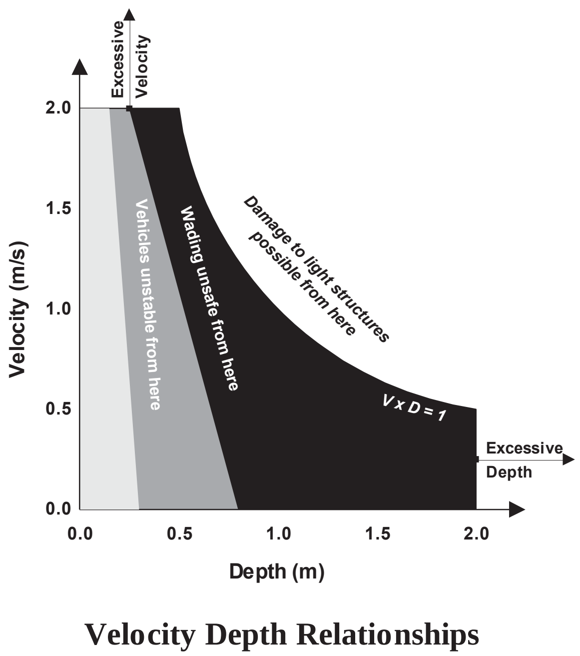
- **High hazard** – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- **Low hazard** – should it be necessary, trucks could evacuate people and their possessions; 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 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 7-7. The provisional hydraulic hazard is included in the mapping series provided in Appendix A for the 10%, 5%, 1% AEP and PMF events (Figure A- 27 to Figure A- 30).



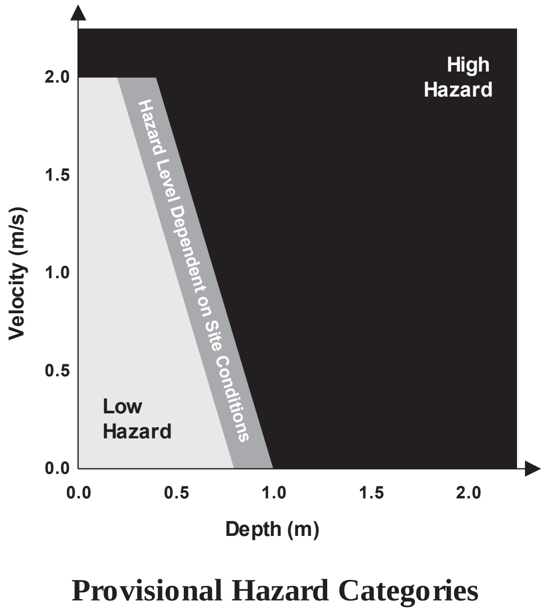


Figure 7-7 Provisional flood hazard categorisation

7.5 Flood Emergency Response Classification

The NSW Government's Floodplain Development Manual (NSW Government, 2005) requires flood studies and subsequent floodplain risk management studies to address the management of continuing flood risk to both existing and future development areas. Continuing flood risk may vary across a floodplain and as such the type and scale of emergency response does also. To assist the state emergency services with emergency response planning floodplain communities may be classified into the following categories:

- **High Flood Island** – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island includes enough land higher than the limit of flooding to provide refuge.
- **Low Flood Island** – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island is lower than the limit of flooding.
- **High Trapped Perimeter** – fringe of the floodplain. Road access may be cut by floodwater. The area includes enough land higher than the limit of flooding to provide refuge.
- **Low Trapped Perimeter** – fringe of the floodplain. Road access may be cut by floodwater. The flood island is lower than the limit of flooding.
- **Areas with Overland Escape Routes** – areas available for continuous evacuation. Access roads may cross low lying flood prone land but evacuation can take place by walking overland to higher ground.

- **Areas with Rising Road Access** – areas available for continuous evacuation. Access roads may rise steadily uphill away from rising floodwaters. Evacuation can take place vehicle and communities cannot be completely isolated before inundation reaches its maximum ;and

- **Indirectly Affected Areas** – areas outside the limit of flooding and therefore will not be inundated or lose road access. They may be indirectly affected as a result of flood damaged infrastructure or due to loss of services.

The flood emergency response classification is included in the mapping series provided in Appendix A for the full range of design events simulated (Figure A- 37 to Figure A- 43).

7.6 Conclusion

The TUFLOW hydraulic model has been applied to derive design flood conditions within the Darling Harbour catchment using the design rainfall and tidal conditions described in Section 6. The design events considered in this study include the 2 year ARI, 5 year ARI, 10% AEP (10-year ARI), 5% AEP (20-year ARI), 2% AEP (50-year ARI), 1% AEP (100-year ARI), 0.2% AEP (500 year ARI) and Probable Maximum Flood (PMF) events. The model results for the design events considered have been presented in a detailed flood mapping series for the catchment. The flood data presented includes design flood inundation, peak flood water levels and peak flood depths.

Provisional flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has been mapped for the 10% AEP, 5% AEP 1% AEP and the PMF events, in addition to the hydraulic categories (floodway, flood fringe and flood storage) for all modelled design events.

The flood inundation extents derived from the hydraulic modelling are shown in Appendix A.

8 SENSITIVITY ANALYSIS

A number of sensitivity tests have been undertaken on the modelled flood behaviour in the Darling Harbour catchment. In defining sensitivity tests, consideration has been given to the most appropriate tests taking into account catchment properties and simulated design flood behaviour. The tests undertaken have included:

- Hydraulic roughness;
- Blockage of the stormwater drainage system;
- Change in rainfall losses; and
- Changed tailwater level.

The rationalisation for each of these sensitivity tests along with adopted model configuration/parameters and results are summarised in the following sections.

As outlined in Section 7 the critical duration varies across the catchment. For the purpose of sensitivity testing the 1% AEP, 90-minute duration, design storm event has been used as the design base case.

8.1 Hydraulic Roughness

Sensitivity tests on the hydraulic roughness (Manning's 'n') were undertaken separately for the 1D stormwater network and for the 2D overland flow paths. Whilst adopted design parameters are within typical ranges, the inherent variability/uncertainty in hydraulic roughness warrants consideration of the relative impact on adopted design flood conditions. The potential uncertainty in selected parameter choice is different between sub-surface conduits which has much firmer guidance in literature versus overland flow paths which could feasible have greater variation.

Sensitivity analysis for the TUFLOW 2D overland flow path Manning's '*n*' values was assessed by applying a 50% increase and a 50% decrease in the adopted values for the baseline design conditions. Sensitivity analysis for the 1D sub-surface pipe network was assessed by applying a 20% increase and a 20% decrease in the adopted values for the baseline design conditions.

The results of the sensitivity tests on hydraulic roughness are summarised in Table 8-1 for the reporting locations indicated in Figure 7-1.

With regard to the TUFLOW 2D overland flow path hydraulic roughness, the model simulations show minor change (generally <0.05 m) in peak flood level for the variation in roughness values. It should be noted that the reduction in hydraulic roughness does not always reduce flood levels and conversely an increase in hydraulic roughness does not always increase peak flood levels which can be attributed to the timing of flows at the confluences of difference flow paths.

Variation of the hydraulic roughness of the pipe network results in changes to peak flood levels of less than or equal to 0.05 m. In the scenario where pipe roughness is increased, the pipe has a reduced capacity and more flow is conveyed via overland flow paths. In the scenario where the pipe roughness is reduced, the pipe is able to convey a higher flow reducing overland flows and overland flood levels.

Table 8-1 Changes in peak flood levels (m) for Manning's '*n*' sensitivity tests

Location	+ 50% Manning's '*n*' (2D Domain)	- 50% Manning's '*n*' (2D Domain)	+ 20% Manning's '*n*' (1D Domain)	- 20% Manning's '*n*' (1D Domain)
H01	+0.01	-0.01	+0.00	+0.00
H02	-0.07	+0.04	+0.03	-0.03
H03	-0.01	+0.04	+0.01	-0.01
H04	-0.01	+0.06	+0.01	+0.00
H05	-0.01	+0.02	+0.01	-0.01
H06	-0.02	+0.03	+0.04	-0.04
H07	+0.01	-0.03	+0.01	-0.01
H08	+0.03	-0.07	+0.00	+0.00
H09	+0.02	+0.02	+0.01	+0.00
H10	-0.01	+0.01	+0.02	-0.02
H11	-0.01	+0.09	+0.00	+0.00
H12	+0.05	-0.03	+0.02	-0.02
H13	-0.01	+0.02	+0.00	+0.00
H14	+0.03	-0.04	+0.00	+0.00
H15	+0.01	+0.10	+0.00	+0.00
H16	+0.02	+0.11	+0.01	+0.00
H17	+0.01	-0.01	+0.00	+0.00
H18	+0.00	+0.03	+0.00	+0.00
H19	+0.02	+0.02	-0.01	+0.00
H20	-0.05	+0.04	+0.05	-0.05
H21	+0.02	+0.02	+0.02	-0.01
H22	+0.05	+0.02	+0.00	+0.00
H23	+0.01	-0.01	+0.00	+0.00
H24	-0.04	+0.04	+0.05	-0.04

8.2 Stormwater Drainage Blockage

Structure blockages have the potential to substantially increase the magnitude and extent of property inundation through local increases in water level, redistribution of flows on the floodplain, and activation of additional flow paths. As outlined in Section 6, different pit blockages were considered for different magnitude storms, summarised as follows:

- 5 year ARI and more frequent: Grade Blockage 20%, Sag Blockage 50%
- Rarer than the 5 year ARI: Grade Blockage 50%, Sag Blockage 100%

Pit inlet blockage sensitivity was therefore separately assessed for 5 year ARI design event and also the 1% AEP design event. The blockage scenarios modelled are shown below:

- 5 year ARI: Grade Blockage 50%, Sag Blockage 100%
- 1% AEP: Grade Blockage 100%, Sag Blockage 100%.

The results of the sensitivity tests on blockages are summarised in Table 8-2 for the reporting locations indicated in Figure 7-1.

Table 8-2 Changes in flood levels for pit inlet blockage sensitivity tests

Location	5yr ARI Blockage - Grade 50%, Sag 100%	1% AEP Blockage - Grade 100%, Sag 100%
H01	+0.01	+0.32
H02	+0.00	+0.53
H03	+0.00	+0.26
H04	+0.56	+0.18
H05	+0.00	+0.12
H06	+0.62	+1.48
H07	+0.12	+0.10
H08	+0.00	+0.05
H09	+0.06	+0.11
H10	+0.00	+0.59
H11	+0.00	+0.02
H12	+0.01	+0.64
H13	+0.00	+0.03
H14	+0.00	+0.03
H15	+0.00	+0.06
H16	+0.01	+0.12
H17	+0.00	+0.03
H18	+0.02	+0.18
H19	+0.00	+0.05
H20	+0.00	+0.69
H21	+0.03	+0.46
H22	+0.00	+0.15
H23	+0.00	+0.04
H24	+0.01	+0.70

For the 5 year ARI event, if the level of pit blockage was used, the modelled peak water level would increase typically by less than 0.05 m. A higher sensitivity is exhibited in isolated trapped low points which are more reliant on the drainage network. Points H06 and H04 for example are trapped low points on Pyrmont Street and Commonwealth Street respectively. These points exhibit a high sensitivity to pit blockage.

For the 1% AEP event, blockage sensitivity analysis assumes a very extreme scenario where no water is allowed into the stormwater system via on-grade or sag pits. Upper catchment peak flood levels typically increase by less than 0.1 m. A much higher sensitivity is exhibited lower in the catchment. For the standard 1% AEP design event only 5.3 m^3/s overland flow drains from the catchment at flow line Q01 while a combined flow of 46 m^3/s is conveyed into Cockle Bay via pipes P5 to P10. This total peak flow of 46m^3/s is forced overland (since pits 100% blocked) and contributes to increased flood depths in the lower Darling Harbour area of approximately 0.6 m. This highlights the importance of maintaining capacity of the stormwater infrastructure in the area.

8.3 Rainfall Losses

Sensitivity analysis has been undertaken for rainfall losses by assessing both a 50% increase and decrease in rainfall losses (initial loss and infiltration). The fraction impervious parameter was not adjusted. The results of the sensitivity tests on rainfall losses are summarised in Table 8-3 for the reporting locations indicated in Figure 7-1.

The change in flood levels from rainfall loss changes is typically less than 0.01 m. The limited sensitivity to rainfall losses is due to the highly impervious nature of the catchment, whereby there is little opportunity for rainfall infiltration which translates to a negligible change in the amount of rainfall lost via pervious surfaces. Accordingly for the base case condition, losses are already relatively low across the catchment given the extent of impervious areas.

Table 8-3 Changes in peak flood levels (m) for rainfall loss sensitivity tests

Location	+ 50% Rainfall Losses	- 50% Rainfall Losses
H01	-0.01	+0.01
H02	-0.01	+0.01
H03	-0.01	+0.01
H04	+0.00	+0.00
H05	+0.00	+0.00
H06	-0.01	+0.01
H07	+0.00	+0.00
H08	+0.00	+0.00
H09	+0.00	+0.00
H10	-0.01	+0.01
H11	+0.00	+0.00
H12	+0.00	+0.00
H13	+0.00	+0.00
H14	+0.00	+0.00
H15	+0.00	+0.00
H16	+0.00	+0.00
H17	+0.00	+0.00
H18	+0.00	+0.00
H19	-0.01	+0.00
H20	-0.01	+0.01
H21	+0.00	+0.00
H22	+0.00	+0.00
H23	+0.00	+0.00
H24	-0.01	+0.01

8.4 Tailwater Level

Sensitivity analysis has been undertaken for tailwater by assessing both a 0.5m increase and decrease in the Harbour water level. The results of the sensitivity tests on tailwater are summarised in Table 8-4 for the reporting locations indicated in Figure 7-1.

Changes in flood levels from tailwater changes are limited to locations immediately connected to the Harbour by piped drainage. Points such as H02, H20 and H24 can change by up to 0.05m with revised tailwater conditions. Further upstream, the catchment is insensitive to tailwater assumptions.

Table 8-4 Changes in peak flood levels (m) for tailwater sensitivity tests

Location	+ 0.5m Tailwater	- 0.5m Tailwater
H01	+0.00	+0.00
H02	+0.03	-0.02
H03	+0.02	-0.01
H04	+0.00	+0.00
H05	+0.04	-0.03
H06	+0.00	+0.00
H07	+0.01	-0.01
H08	+0.00	+0.00
H09	+0.00	+0.00
H10	+0.03	-0.03
H11	+0.00	+0.00
H12	+0.02	-0.01
H13	+0.00	+0.00
H14	+0.00	+0.00
H15	+0.00	+0.00
H16	+0.00	+0.00
H17	+0.00	+0.00
H18	+0.00	+0.00
H19	+0.00	+0.00
H20	+0.05	-0.03
H21	+0.01	+0.00
H22	+0.00	+0.00
H23	+0.00	+0.00
H24	+0.05	-0.03

8.5 Conclusion

A series of sensitivity tests have been undertaken on the modelled flood behaviour of the Darling Harbour catchment. The tests provide a basis for determining the relative sensitivity of modelling results to adopted parameter values. The parameters assessed include:

- Hydraulic roughness;
- Stormwater drainage blockage;
- Design rainfall losses; and
- Tailwater level.

Results were shown to be generally insensitive to the values adopted for deriving the design flood levels and extents for the hydraulic roughness and rainfall losses tests, with the magnitude changes in flood level less than 0.10m. The limit of tailwater sensitivity is in low areas immediately connected to the Harbour by piped drainage.

The stormwater drainage blockage sensitivity tests represent an extreme scenario whereby there is 100% blockage applied to the drainage network, effectively eliminating all sub-surface drainage. The 100% blockage scenario indicates that flood levels may increase by up to 0.70 m in the 1% AEP design event in the lower catchment reaches. Significantly, this exceeds the standard 0.50m freeboard (if adopted) applied to the 1% AEP results to determine the Flood Planning Levels (FPL). These conditions may warrant further consideration in future floodplain management within the catchment.

9 CLIMATE CHANGE ANALYSIS

In 2009, the NSW Government incorporated consideration of potential climate change impacts into relevant planning instruments. The NSW Sea Level Rise Policy Statement (DECCW, 2009) was prepared to support consistent adaptation to projected sea level rise impacts. The policy statement incorporates sea level rise planning benchmarks for use in assessing potential impacts of sea level rise in coastal areas, as well as in flood risk and coastal hazard assessments. The benchmarks are a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100.

The NSW Government announced its Stage One Coastal Management Reforms in September 2012. As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks for use by local councils, but instead provides councils with the flexibility to consider local conditions when determining future hazards within their LGA.

It was agreed between Council and BMT WBM that the sea level rise benchmarks from the 2009 NSW Sea level Rise Policy Statement be adopted based on the conclusion that it was the best available information at the time of preparation of this report.

Worsening coastal flooding impacts as a consequence of sea level rise are of concern for the future. Regional climate change studies (e.g. CSIRO, 2004) indicate that aside from sea level rise, there may also be an increase in the maximum intensity of extreme rainfall events. This may include increased frequency, duration and height of flooding and consequently increased number of emergency evacuations and associated property and infrastructure damage.

The NSW Floodplain Development Manual (2005) requires consideration of climate change in the preparation of Floodplain Risk Management Studies and Plans, with further guidance provided in:

- Floodplain Risk Management Guideline – Practical Consideration of Climate Change (DECC, 2007); and
- Flood Risk Management Guide - Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (DECCW, 2010).

Key elements of future climate change (e.g. sea level rise, rainfall intensity) have been incorporated into the assessment of future flooding conditions in the Darling Harbour catchment for consideration in the ongoing floodplain risk management.

9.1 Potential Climate Change Impacts

The impacts of future climate change are likely to lead to a wide range of environmental responses in receiving waters such as Sydney Harbour. These are likely to manifest throughout the physical, chemical and ecological processes that drive local estuarine ecosystems.

The following changes in the physical characteristics of the Darling Harbour catchment have potential influence on the flood behaviour of the system and implications for medium and long term floodplain management:

- Increase in ocean boundary water level – sea level projections provide for a direct increase in tidal and storm surge water level conditions; and
- Increase in rainfall intensity – the frequency and severity of extreme rainfall events is expected to increase.

The model configuration and assumptions adopted for these potential climate change impacts are discussed in the following sections.

9.1.1 Ocean Water Level

As discussed in Section 1.3.1, the sea level rise planning benchmarks provided in the NSW Sea Level Rise Policy Statement (DECCW, 2009) have been adopted for this Flood Study.

The benchmarks are a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100 (DECCW, 2009). Based on these guidelines, design ocean boundary conditions were raised by 0.4 m and 0.9 m to assess the potential impact of sea level rise on flood behaviour in the Darling Harbour catchment for the year 2050 and 2100 respectively.

The sea level rise allowances provide for direct increases in these ocean water levels. Table 9-1 presents a summary of the adopted peak ocean water levels for 1% AEP design modelling for existing water level conditions and the 2050 and 2100 sea level rise benchmarks.

Table 9-1 Design peak Sydney Harbour water levels incorporating sea level rise

Existing (5% AEP Tide)	2050 (+0.4m)	2100 (+0.9m)
1.38 m AHD	1.78 m AHD	2.28 m AHD

9.1.2 Design Rainfall Intensity

Current research predicts that a likely outcome of future climatic change will be an increase in flood producing rainfall intensities. Climate Change in New South Wales (CSIRO, 2007) provides projected increases in 2.5% AEP 24h duration rainfall depths for Sydney Metropolitan catchments of up to 12% and 10%, for the years 2030 and 2070 respectively.

The NSW Government has also released a guideline (DECC, 2007) for Practical Consideration of Climate Change in the floodplain management process that advocates consideration of increased design rainfall intensities of up to 30%. In line with this guidance note, additional tests incorporating 10%, 20% and 30% increases in design rainfall have been undertaken.

9.2 Climate Change Model Conditions

A range of design event simulations have been undertaken incorporating combinations of increases in rainfall intensities and ocean water levels. A summary of the modelled scenarios for the 1% AEP design event is provided in Table 9 2.

Table 9-2 Summary of model runs for climate change consideration

Design Flood	Rainfall Intensity Increase	Sydney Harbour Peak Water Level (mAHD)
1% AEP 90 min duration	10%	1.38 (5% AEP Harbour Level)
1% AEP 90 min duration	20%	1.38 (5% AEP Harbour Level)
1% AEP 90 min duration	30%	1.38 (5% AEP Harbour Level)
1% AEP 90 min duration	0%	1.78 mAHD (+0.4m to 2050)
1% AEP 90 min duration	0%	2.28 mAHD (+0.9m to 2050)

9.3 Climate Change Results

The modelled peak flood levels for the climate change scenarios are presented in Table 9-3 for the reporting locations indicated in Figure 7-1. The impact of potential climate change scenarios on the standard design flood condition is presented in Figure A- 31 to Figure A- 35 as a series of maps showing increase in peak flood inundation extents from the baseline (existing) conditions.

Table 9-3 Changes in peak flood levels (m) for climate change scenarios

Location	10% Rainfall	20% Rainfall	30% Rainfall	2050 Harbour	2100 Harbour
H01	+0.01	+0.02	+0.03	+0.00	+0.00
H02	+0.07	+0.13	+0.22	+0.03	+0.07
H03	+0.04	+0.08	+0.11	+0.01	+0.08
H04	+0.05	+0.10	+0.14	+0.00	+0.00
H05	+0.03	+0.06	+0.08	+0.04	+0.07
H06	+0.10	+0.20	+0.31	+0.00	+0.00
H07	+0.02	+0.04	+0.06	+0.01	+0.02
H08	+0.01	+0.02	+0.03	+0.00	+0.00
H09	+0.04	+0.08	+0.11	+0.00	+0.00
H10	+0.05	+0.09	+0.13	+0.03	+0.06
H11	+0.00	+0.00	+0.01	+0.00	+0.00
H12	+0.07	+0.17	+0.27	+0.01	+0.06
H13	+0.01	+0.02	+0.02	+0.00	+0.00
H14	+0.01	+0.02	+0.02	+0.00	+0.00
H15	+0.01	+0.02	+0.03	+0.00	+0.00
H16	+0.03	+0.06	+0.09	+0.00	+0.00
H17	+0.01	+0.01	+0.02	+0.00	+0.00
H18	+0.04	+0.08	+0.12	+0.00	+0.00
H19	+0.02	+0.04	+0.05	+0.00	+0.00
H20	+0.12	+0.23	+0.32	+0.04	+0.11
H21	+0.04	+0.09	+0.13	+0.01	+0.02
H22	+0.03	+0.05	+0.09	+0.00	+0.00
H23	+0.01	+0.02	+0.02	+0.00	+0.00
H24	+0.12	+0.22	+0.32	+0.04	+0.11

The model simulation results show a general increase in peak flood levels along the major and some minor overland flow paths within the study area with increasing rainfall intensity, with increased peak flood levels particularly evident along the major overland flow paths. The 10% rainfall increase scenario which is closest to the regional estimate of future rainfall intensity increases for the Sydney region typically results in flood level increases of less than 0.10 m. Figure 9-1 shows the peak flood level profile for Darling Harbour (for the profile location refer to Figure 7-1). As shown, impacts on peak flood levels are minimal in the upper catchment, whilst higher increases are likely in areas toward the lower catchment near the Haymarket Tram stop and downstream to Cockle Bay.

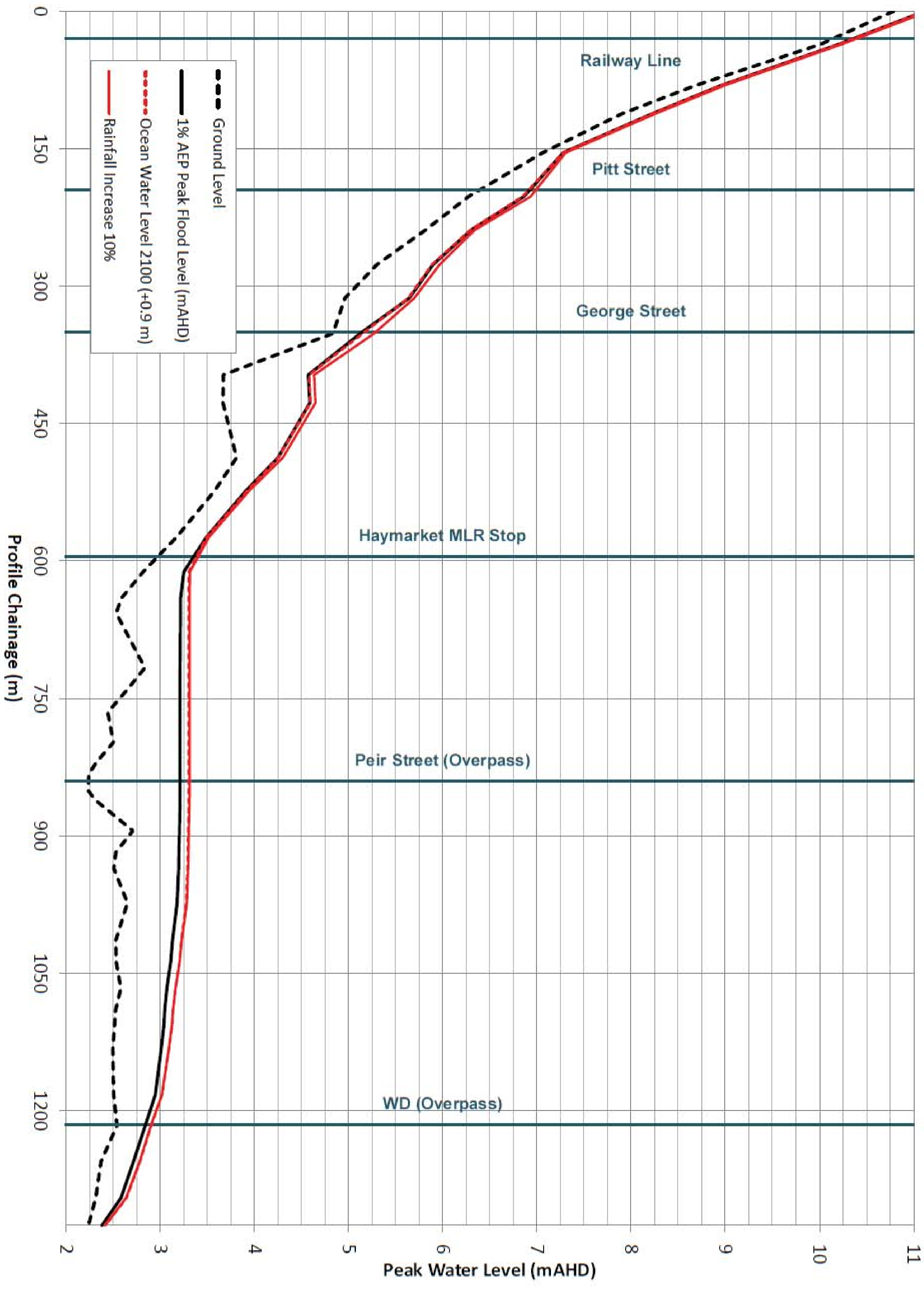
Figure A- 36 shows the results of Climate Change sea level rise on tidal inundation extent, which is typically limited in both magnitude and extent.

9.4 Conclusions

The potential impacts of future climate change have been considered for a range of design event scenarios as defined in Table 9-2. The impact of climate change scenarios on the standard design flood condition us presented in Appendix A as a series of maps showing the increase in peak flood inundation extents from the baseline (existing) conditions. The most significant impacts of climate change within the study area are associated with increased rainfall intensities.

The results of the climate change analysis highlight the sensitivity of the peak flood level conditions in the Darling Harbour catchment to potential impacts of climate change. Future planning and floodplain risk management in the catchment will need to take due consideration of the increasing flood risk under possible future climate conditions.

FIGURE 9-1
DARLING HARBOUR PROFILE - CLIMATE CHANGE SENSITIVITY



10 PROPERTY INUNDATION AND FLOOD DAMAGE ASSESSMENT

A flood damage assessment has been undertaken to identify flood affected property, to quantify the extent of damages in economic terms for existing flood conditions and to enable the future assessment of the relative merit of potential flood mitigation options by means of benefit-cost analysis. As part of the flood damage assessment a property database has been developed detailing individual buildings subject to flood inundation.

The general process for undertaking a flood damages assessment incorporates:

- Identifying properties subject to flooding;
- Determining depth of inundation above floor level for a range of design event magnitudes;
- Defining appropriate stage-damage relationships for various property types/uses;
- Estimating potential flood damage for each property; and
- Calculating the total flood damage for a range of design events.

10.1 Property Data

10.1.1 Location

Property locations have been derived from Council's cadastre information and associated detailed aerial photography of the catchment. Linked within a GIS system, this data enables rapid identification and querying of property details. A property database has been developed detailing individual properties subject to flood inundation.

10.1.2 Land Use

For the purposes of the flood damage assessment, property was considered as either residential or commercial. Commercial properties have been identified from the property survey. Public infrastructure and utility assets have been excluded from the damages assessment. Figure 10-1 shows the breakdown of residential versus commercial properties.

10.1.3 Ground and Floor Level

During the course of the flood study, a surveyor was engaged to survey the building floor levels for the cadastral parcels flagged from the preliminary PMF inundation assessment. Approximately 1400 cadastral parcels were flagged as requiring inclusion in the flood damage assessment for both the Darling Harbour and City Area studies. The floor level was surveyed for the lowest entrance level to the property. Properties with basement levels had the crest level of the basement surveyed. No internal building survey was undertaken.

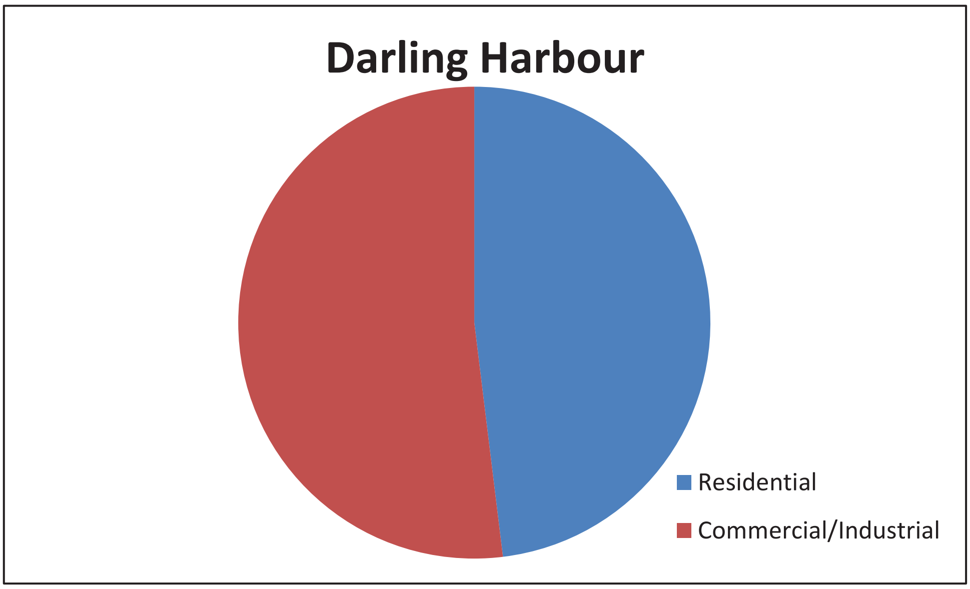


Figure 10-1 Proportion of residential and commercial properties in Darling Harbour

10.1.4 Flood Level

Design flood levels have been obtained for each property for the full range of design events modelled. Topography in the catchment can rapidly change meaning the flood level across a property may vary considerably. The flood level closest to the location of the lowest entrance was used as the critical flood level defining potential flood damages.

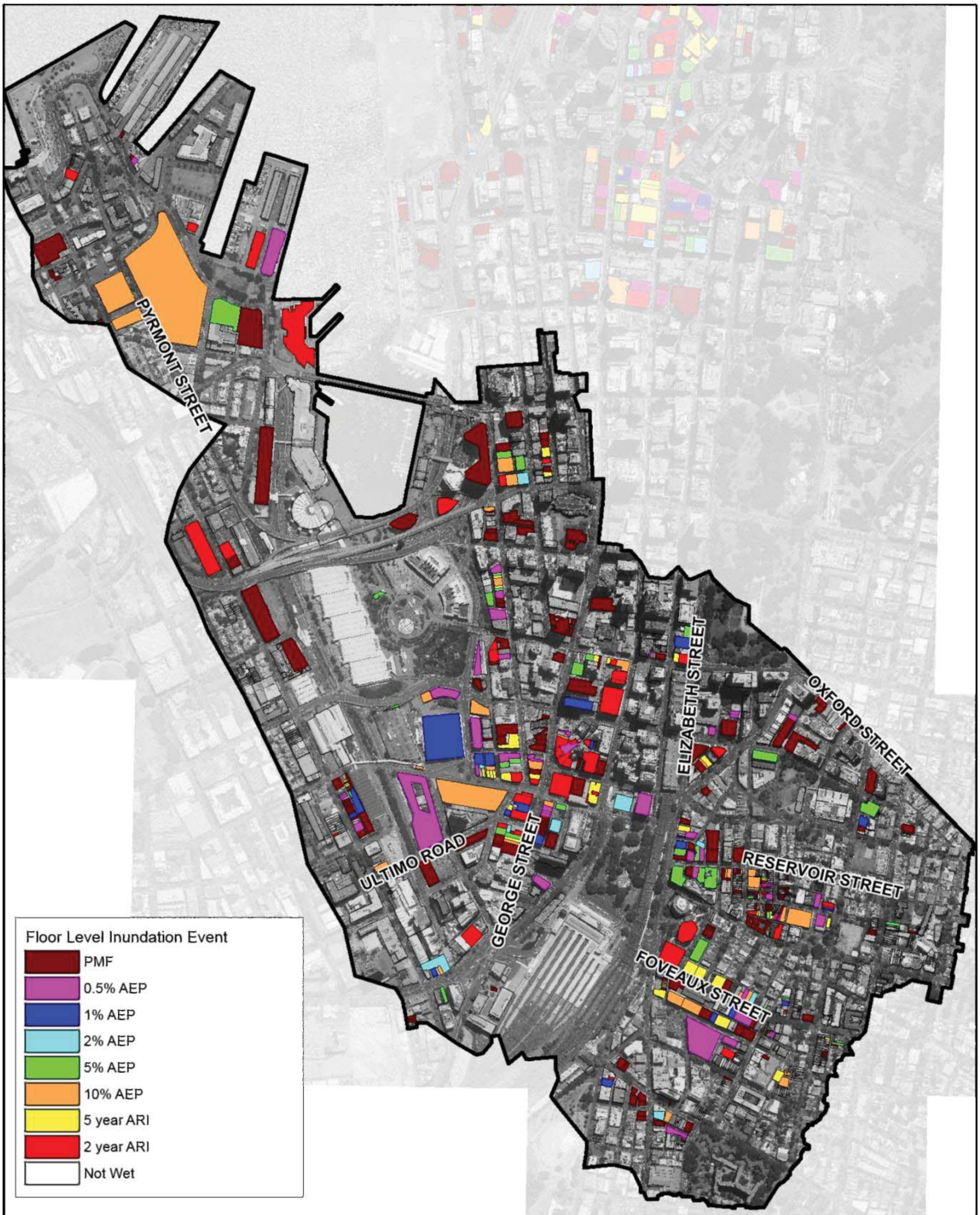
10.2 Property Inundation

A summary of the number of properties potentially affected by above floor flooding for a range of flood magnitudes is shown in Table 10-1.

Figure 10-2 shows the spatial distribution of properties potentially affected by above floor flooding and the design event which first results in above floor flooding for individual properties.

Table 10-1 Number of properties affected by above floor flooding for various design flood events.

Design Flood	Residential	Commercial	Total
2 yr ARI	30	28	58
5 yr ARI	56	57	113
10% AEP	68	86	154
5% AEP	97	110	207
2% AEP	95	116	211
1% AEP	111	133	244
0.2% AEP	131	170	301
PMF	235	283	518



Title:

Flood Damage Assessment
Floor Level Inundation Event

Figure: 10-2

Rev: 1

0 375 750m

Approx. Scale

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10.3 Flood Damages Assessment

10.4 Types of Flood Damage

The definitions and methodology used in estimating flood damage are summarised in the Floodplain Development Manual. Figure 10-3 summarises the "types" of flood damages typically considered. The two main categories are 'tangible' and 'intangible' damages. Tangible flood damages are those that can be more readily evaluated in monetary terms, while intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are further divided into direct and indirect damages. Direct flood damages relate to the loss, or loss in value, of an object or a piece of property caused by direct contact with floodwaters. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

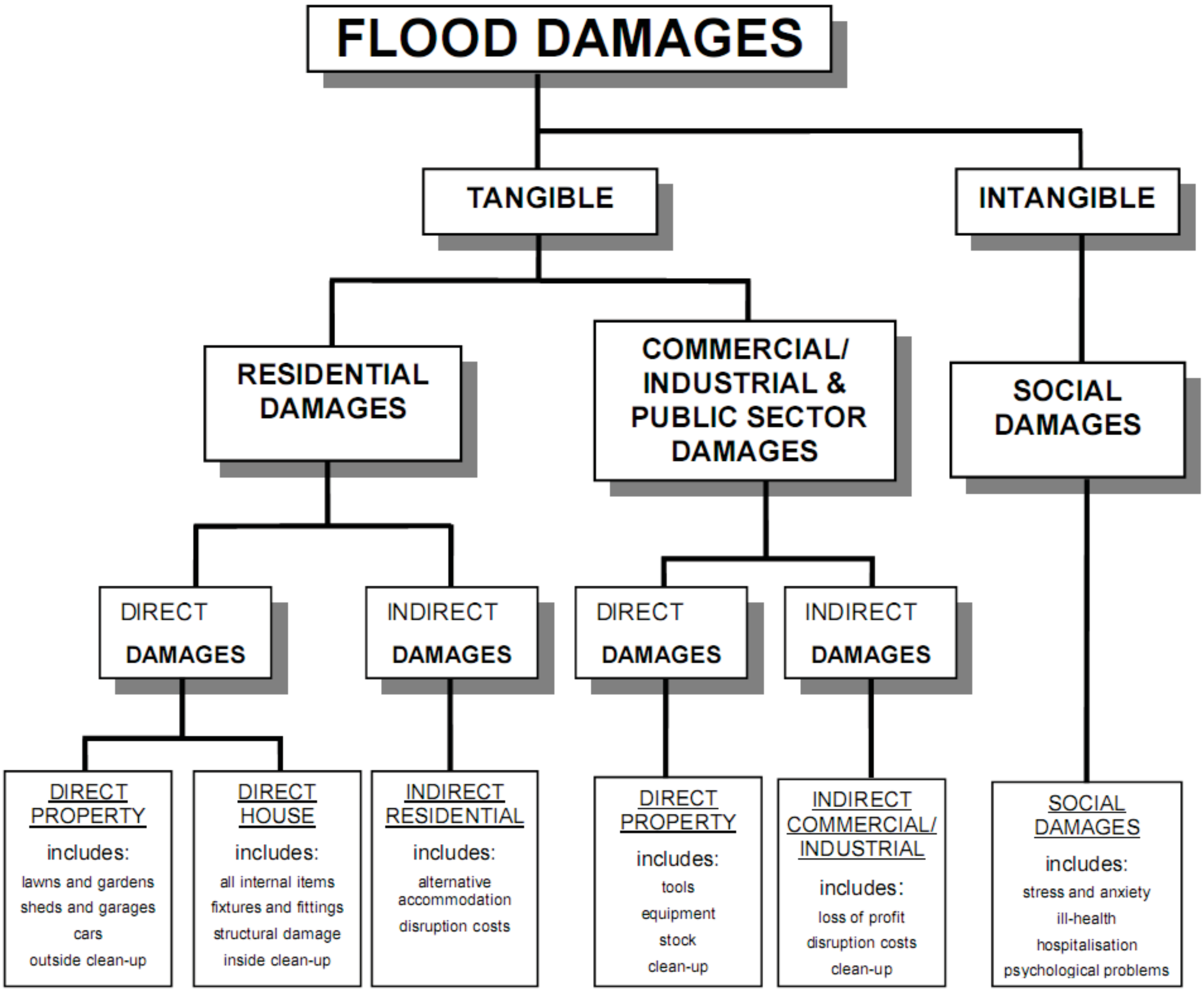

Figure 10-3 Types of Flood Damage

10.4.1 Basis of Flood Damage Calculations

Flood damages have been calculated using the database of potentially flood affected properties and a number of stage-damage curves derived for different types of property within the catchment. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type. Residential damage curves are based on the OEH guideline stage-damage curves for residential property. Commercial damage curves are based upon Queensland Government Guidance on the Assessment of Tangible Flood Damages (DNRM, 2002)

Different stage-damage curves for direct property damage have been derived for:

- Residential dwellings (categorised into small, typical or raised categories); and
- Commercial premises (categorised by size [small, medium, large] and damage class [1-5]).

Apart from the direct damages calculated from the derived stage-damage curves for each flood affected property, other forms of flood damage include:

- Indirect residential, commercial and industrial damages, taken as a percentage of the direct damages;
- Infrastructure damage, based on a percentage of the total value of residential and business flood damage; and
- Intangible damages relate to the social impact of flooding and include:
    - inconvenience,
    - isolation,
    - disruption of family and social activities,
    - anxiety, pain and suffering, trauma,
    - physical ill-health, and
    - psychological ill-health.

The damage estimates derived in this study are for the tangible damages only. Whilst intangible losses may be significant, these effects have not been quantified due to difficulties in assigning a meaningful dollar value.

The Average Annual Damage (AAD) is the average damage in dollars per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the AAD).

Table 10-2 Estimated flood damages

Design Flood	Properties	Event Damage	Contribution to AAD
2 yr ARI	58	$2,571,975	$306,902
5 yr ARI	113	$4,029,967	$700,466
10% AEP	154	$11,441,196	$666,085
5% AEP	207	$14,606,865	$604,211
2% AEP	211	$17,538,070	$465,607
1% AEP	244	$21,066,735	$190,151
0.2% AEP	301	$29,370,102	$200,541
PMF	518	$52,186,311	$81,471
Total AAD			**$3,215,435**

The total estimated flood damage to occur in a 1% AEP local catchment flood event is $21.1 million, increasing to an estimated $52 million worth of damage for the PMF. The annual cost of flooding is estimated to be approximately $3.2 million. It is noted that this damage estimate is strongly biased by the cost of two very large commercial properties. With the omission of these two commercial properties the AAD would be revised down to $2.3 million.

The sensitivity of the damage estimate to climate change has been assessed for the 1% AEP event. Table 10-3 shows the increased number of properties affected and the increase in estimated event damage for the climate change scenarios assessed in Section 9.

Table 10-3 Flood damages sensitivity to climate change

Design Flood	Properties	Event Damage
1% AEP	244	$21,066,735
10% Rainfall	+ 25	+ 16%
20% Rainfall	+ 56	+ 34%
30% Rainfall	+ 79	+ 53%
2050 Harbour	+ 0	+ 0%
2100 Harbour	+ 4	+ 2%

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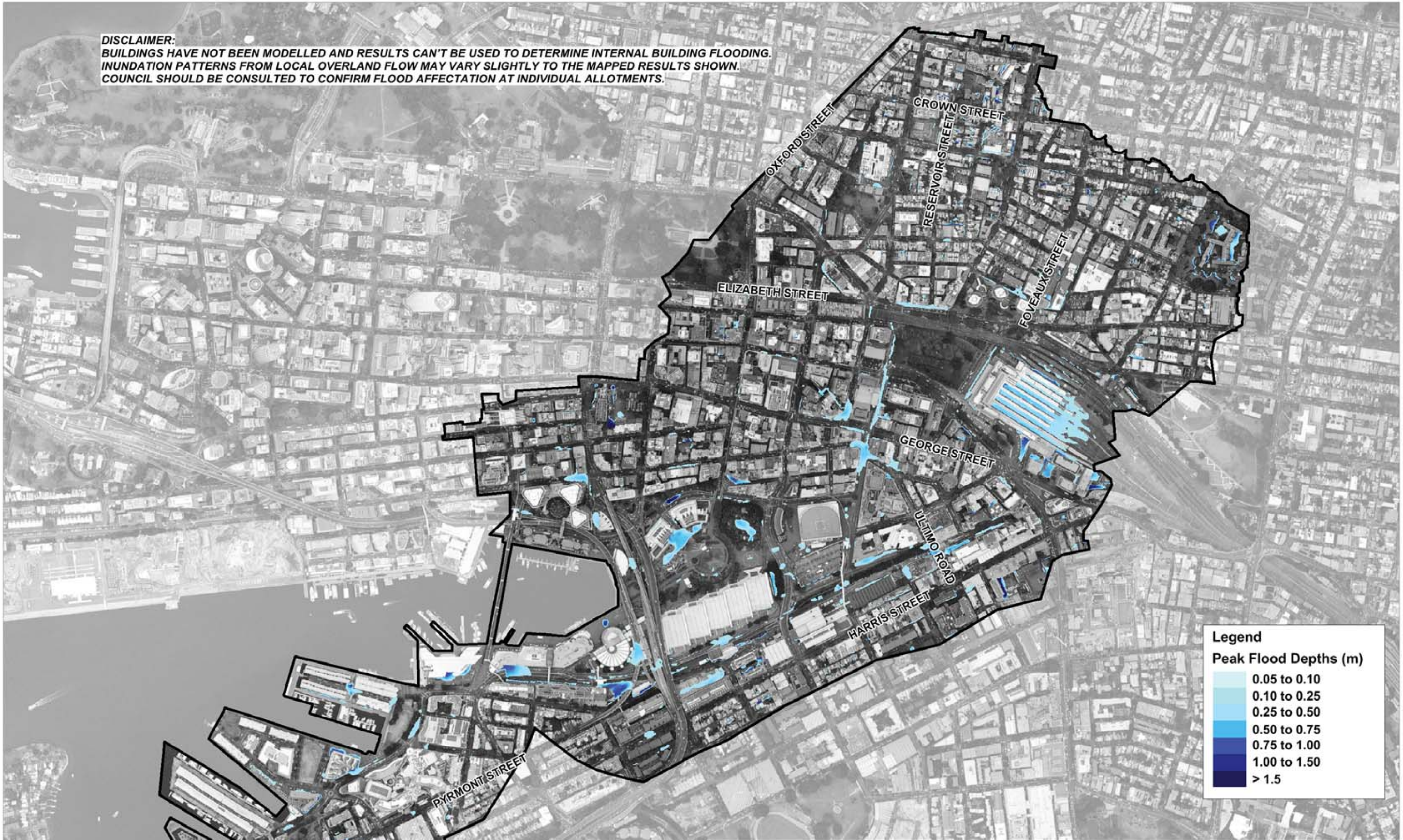
APPENDIX A: DESIGN FLOOD MAPPING



Title:
Peak Flood Depth
2 year ARI

Figure: A-1

Rev: -

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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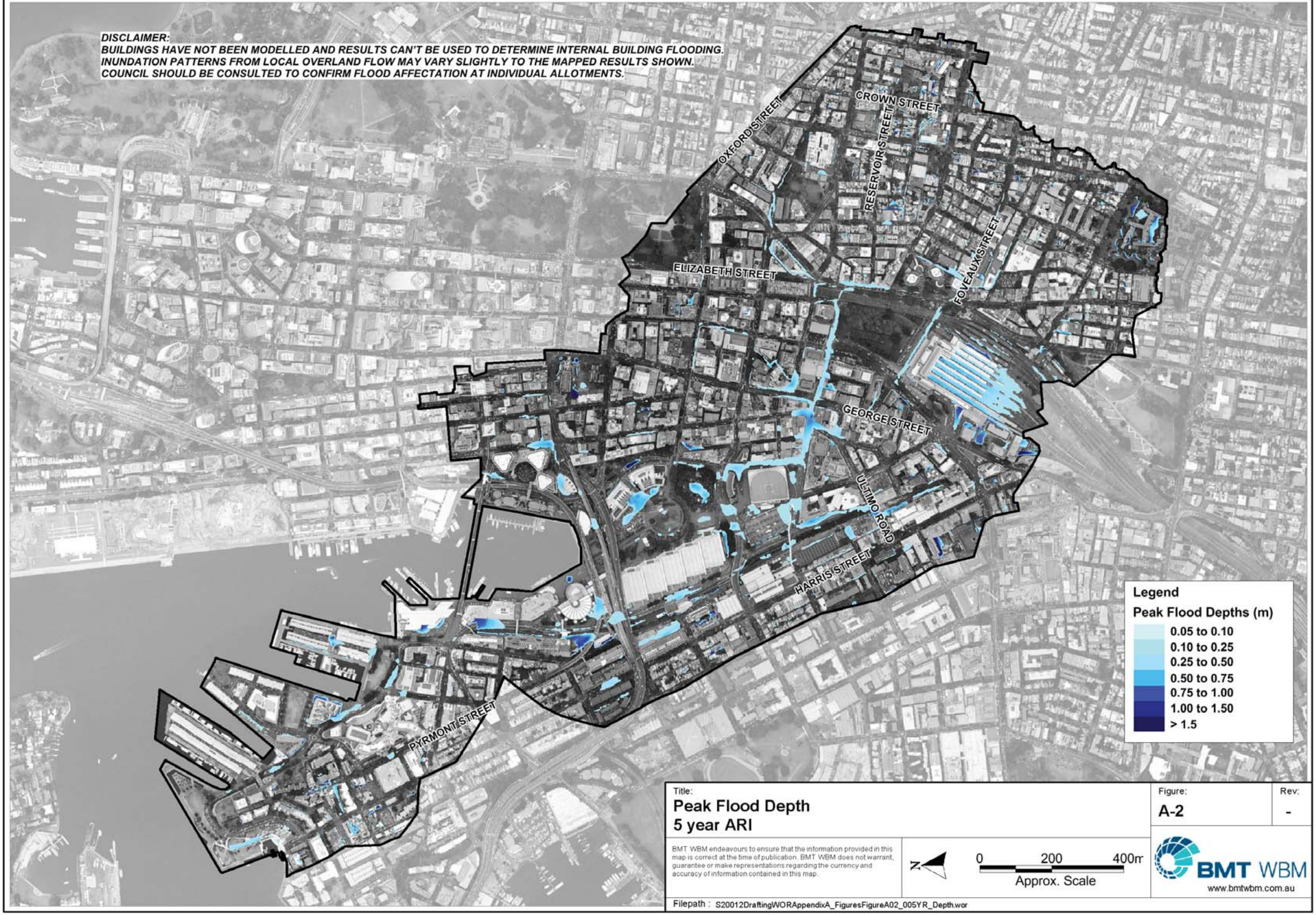

Title:
Peak Flood Depth
5 year ARI

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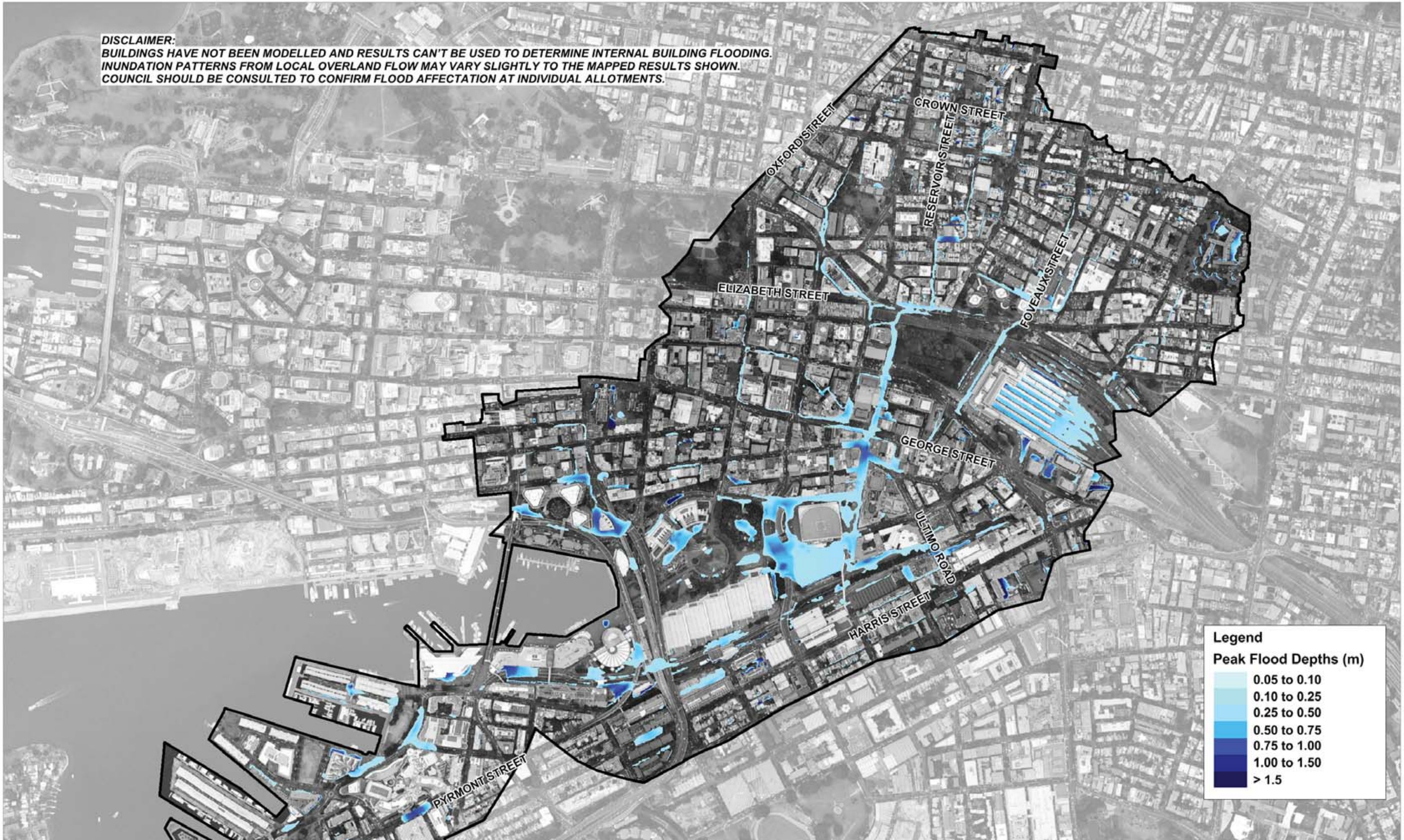

Title:
Peak Flood Depth
10% AEP (10 yr ARI)

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N

0 200 400m
Approx. Scale

Figure: A-3

Rev: -

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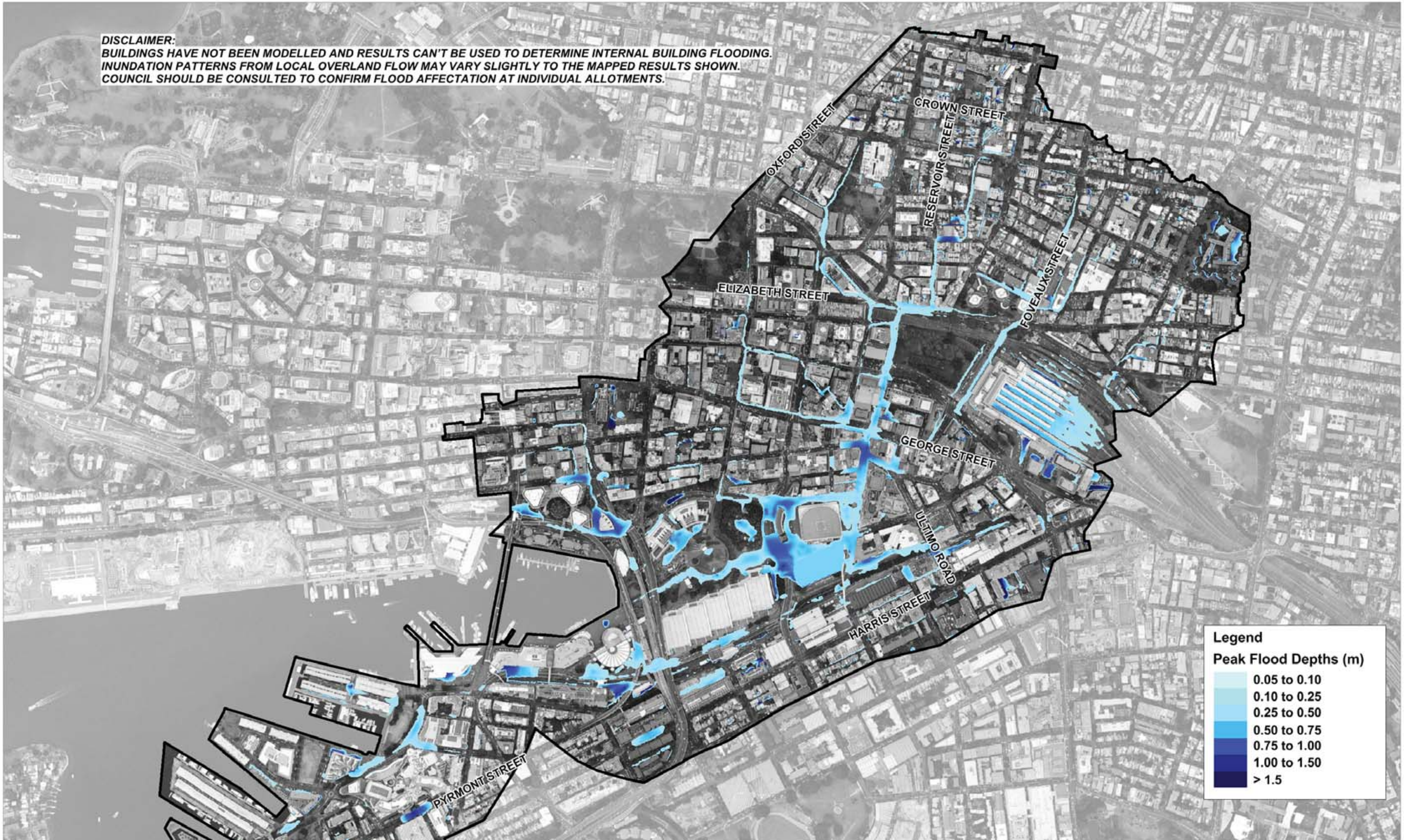
Filepath : S20012DraftingWORAppendixA_FiguresFigureA03_010YR_Depth.wor



Title:
Peak Flood Depth
5% AEP (20 yr ARI)

Figure: A-4

Rev: -

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N

0 200 400m
Approx. Scale

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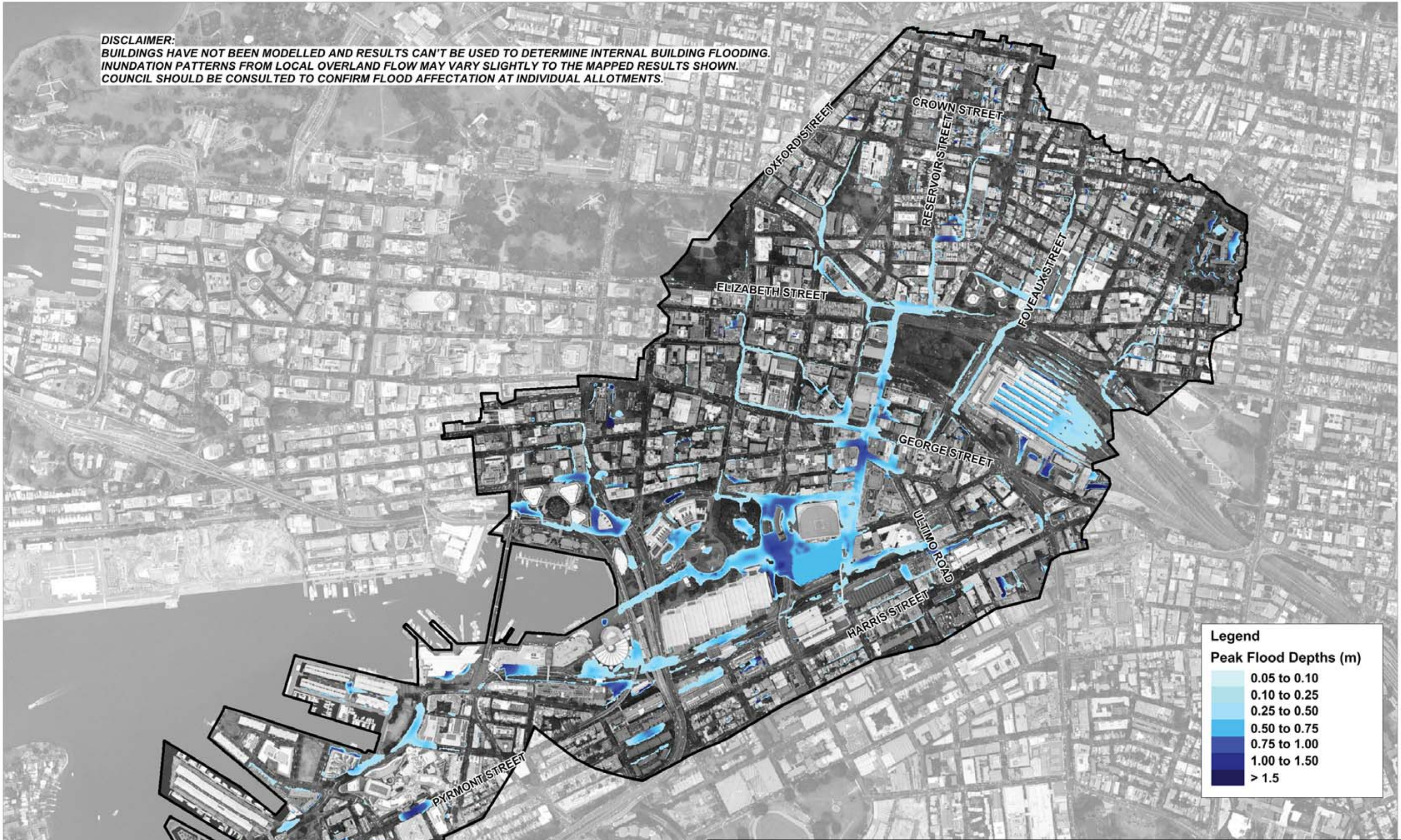
Filepath : S20012DraftingWORAppendixA_FiguresFigureA04_020YR_Depth.wor



Title:
Peak Flood Depth
2% AEP (50 yr ARI)

Figure: A-5

Rev: -

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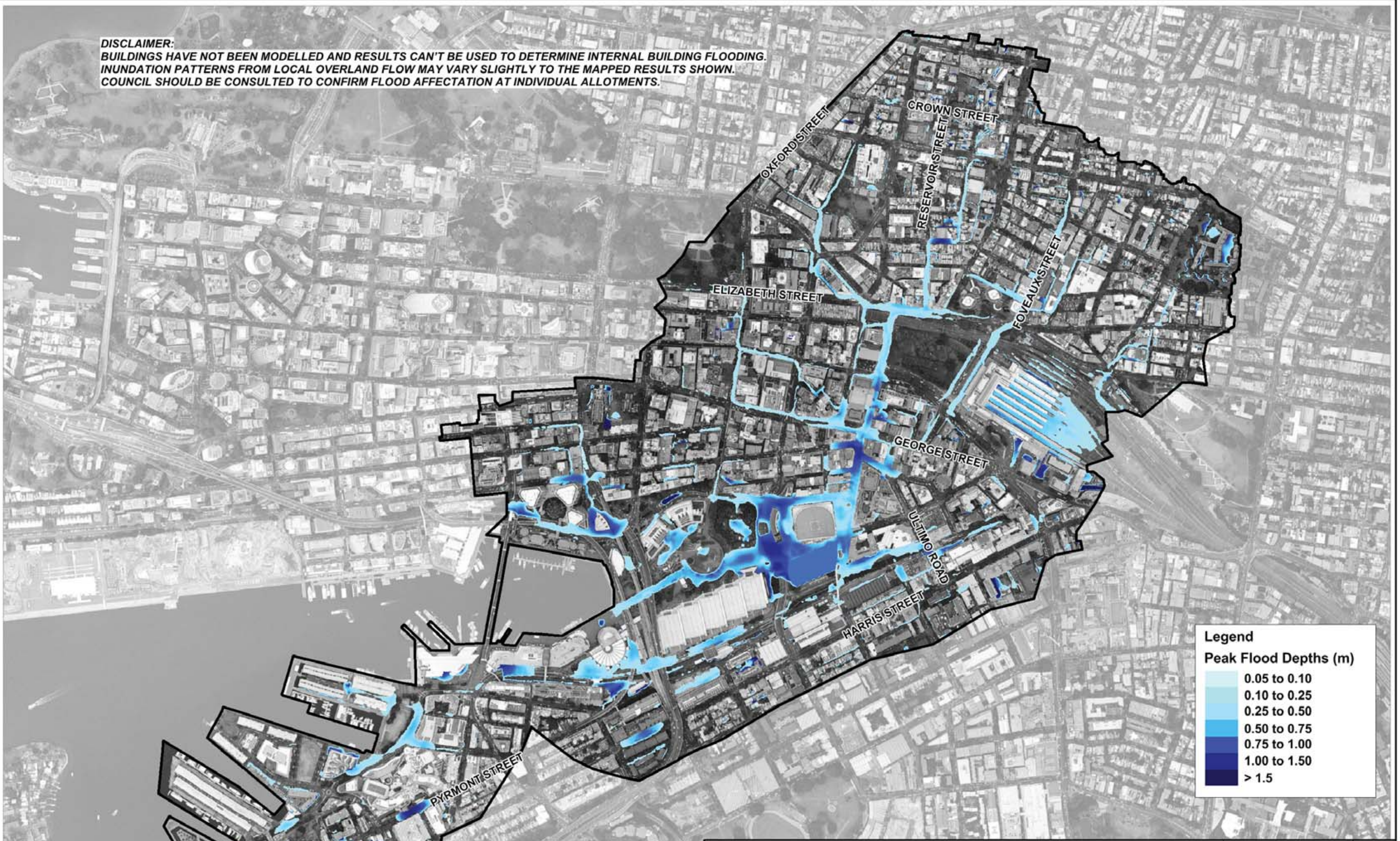
Filepath : S20012DraftingWORAppendixA_FiguresFigureA05_050YR_Depth.wor



Title:
Peak Flood Depth
1% AEP (100 yr ARI)

Figure: A-6

Rev: -

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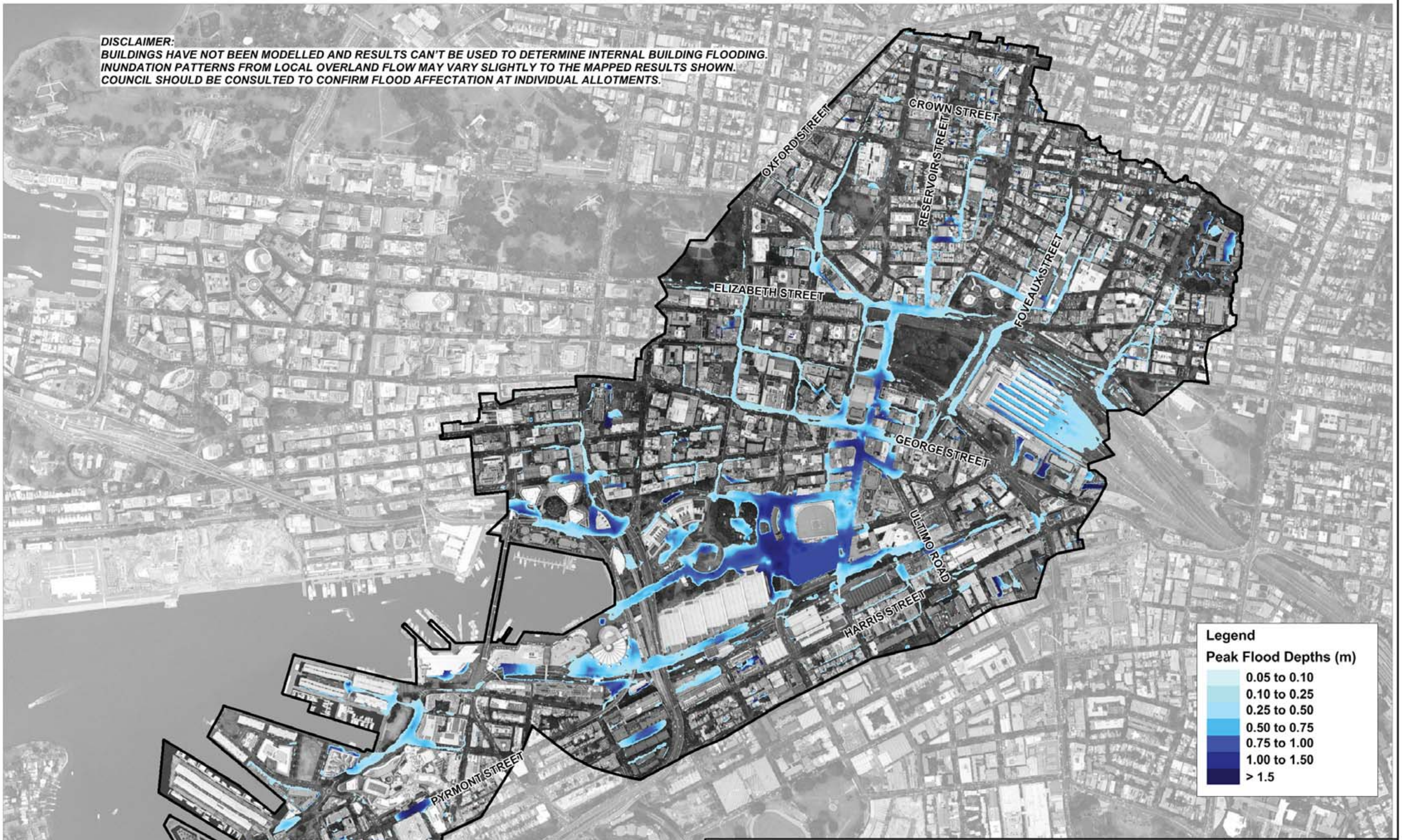
Filepath : S20012DraftingWORAppendixA_FiguresFigureA06_100YR_Depth.wor



Title:
Peak Flood Depth
0.2% AEP (500 yr ARI)

Figure: A-7

Rev: -

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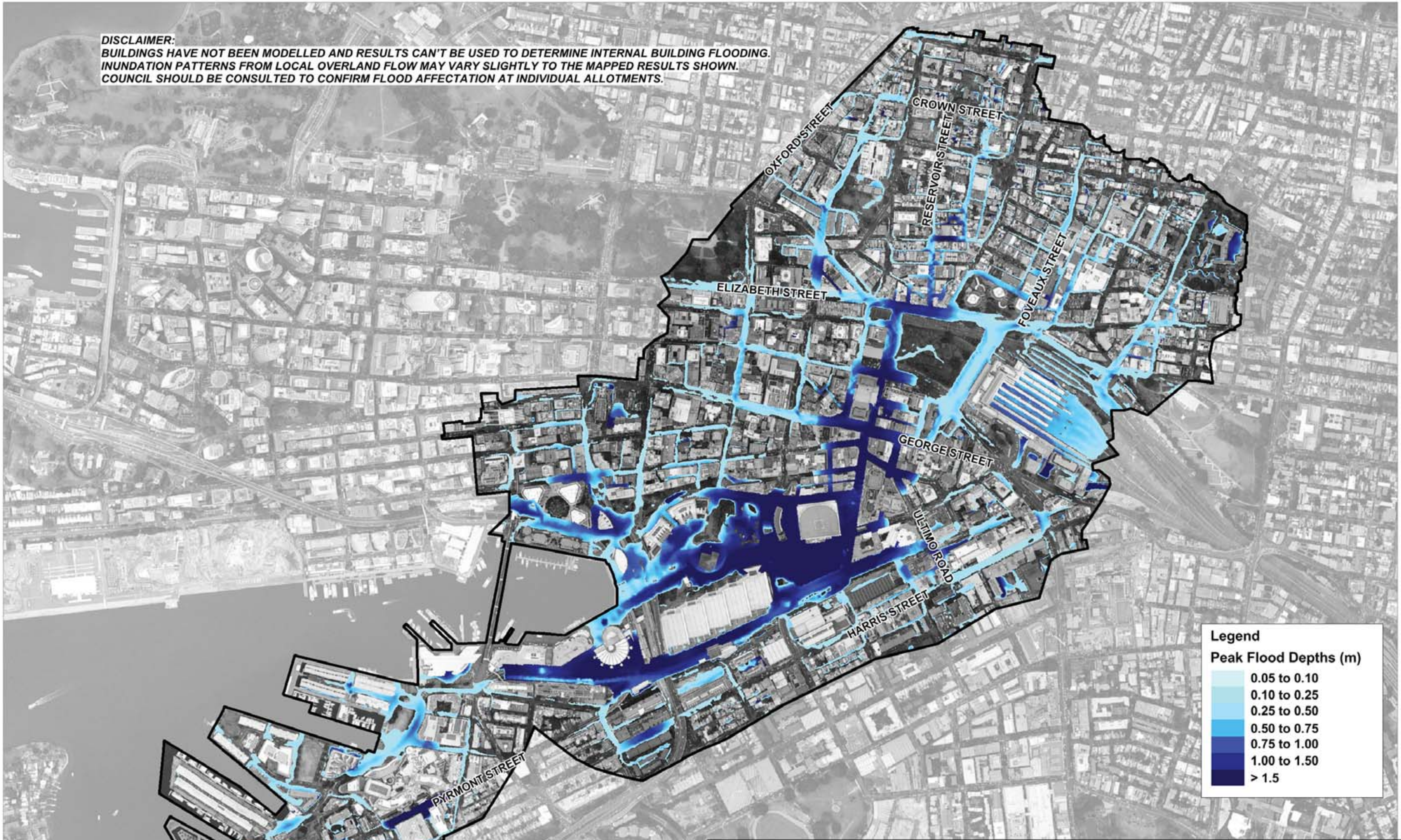
Filepath : S20012DraftingWORAppendixA_FiguresFigureA07_500YR_Depth.wor



Title: Peak Flood Depth Probable Maximum Flood (PMF)	Figure: A-8	Rev: -

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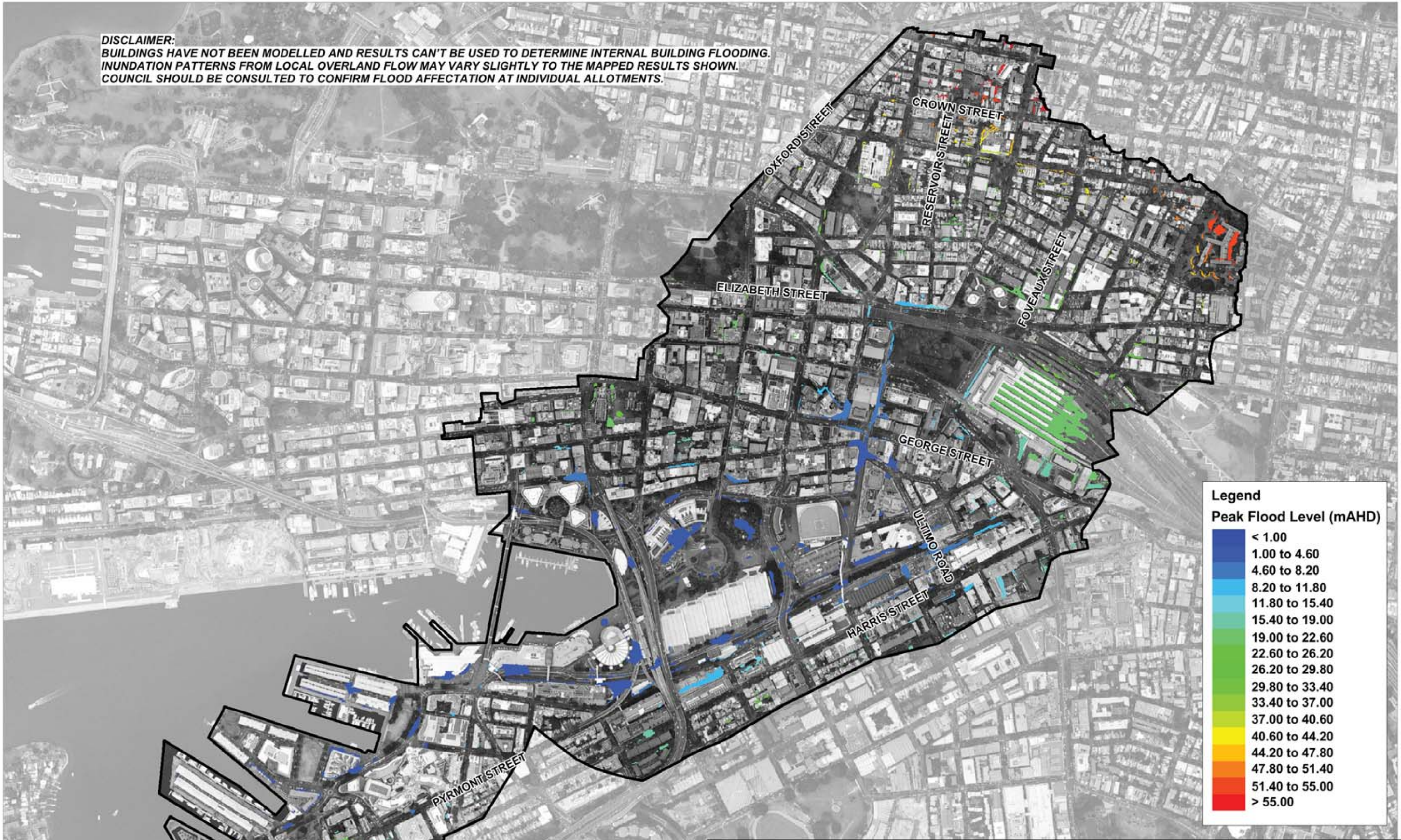
Filepath : S20012DraftingWORAppendixA_FiguresFigureA08_PMF_Depth.wor



Title:
Peak Flood Level
2 year ARI

Figure: A-9

Rev: -

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Filepath : S20012DraftingWORAppendixA_FiguresFigureA09_002YR_Level.wor

Title:
Peak Flood Level
5 year ARI

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Figure: A-10

Rev: -

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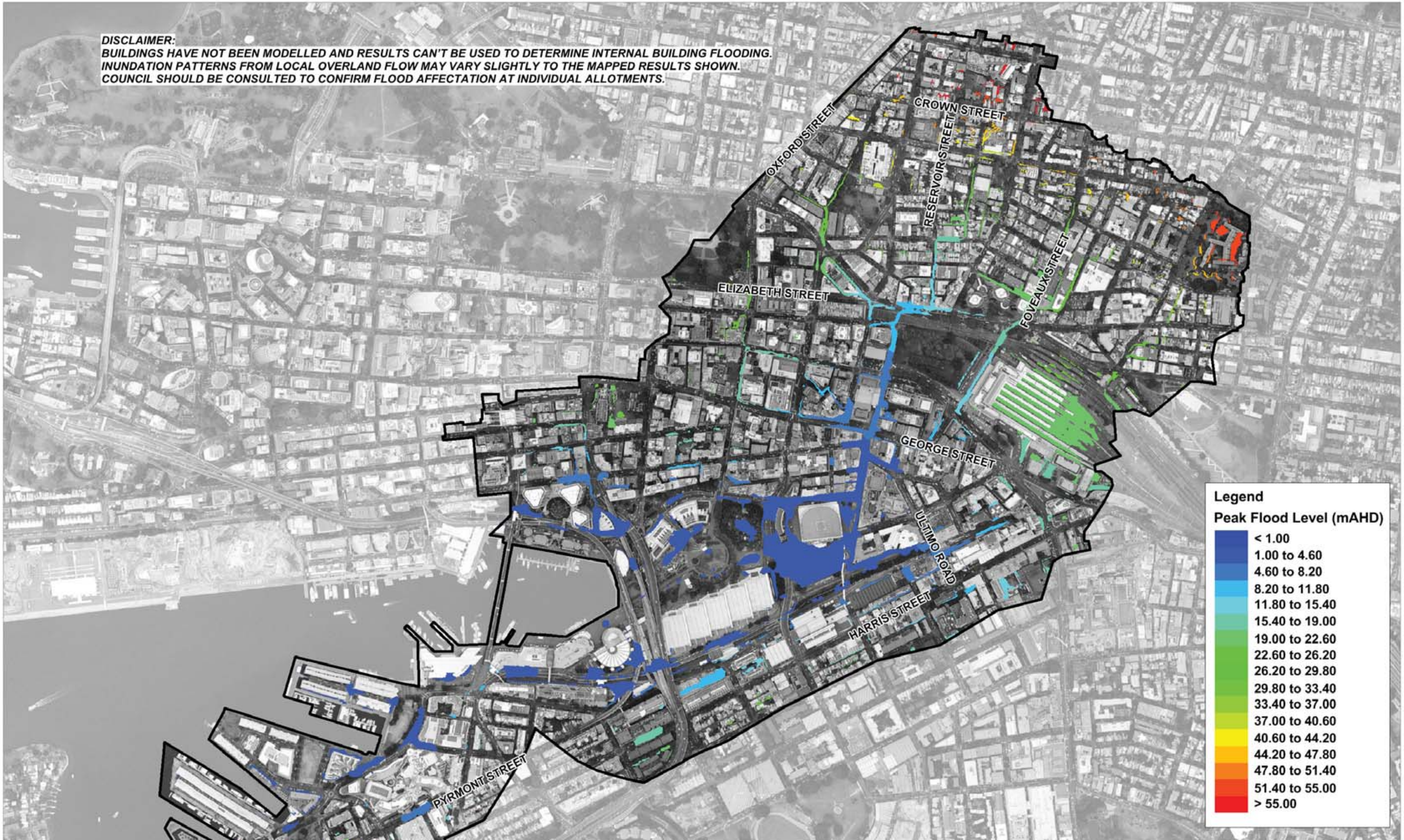
Filepath : S20012DraftingWORAppendixA_FiguresFigureA10_005YR_Level.wor



Title:
Peak Flood Level
10% AEP (10 yr ARI)

Figure: A-11

Rev: -

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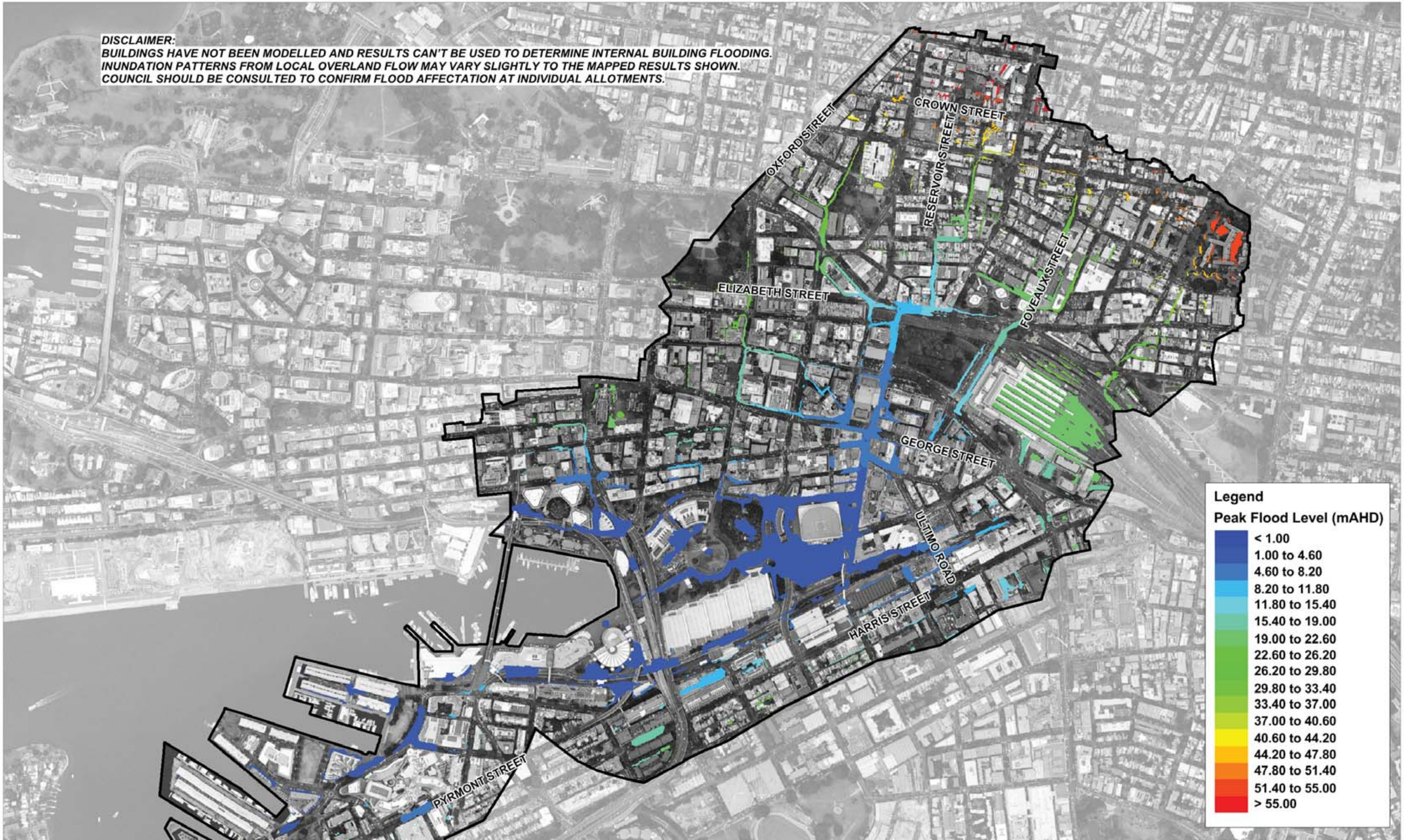
Filepath : S20012DraftingWORAppendixA_FiguresFigureA11_010YR_Level.wor



Title:

Peak Flood Level
5% AEP (20 yr ARI)

Figure: A-12

Rev: -

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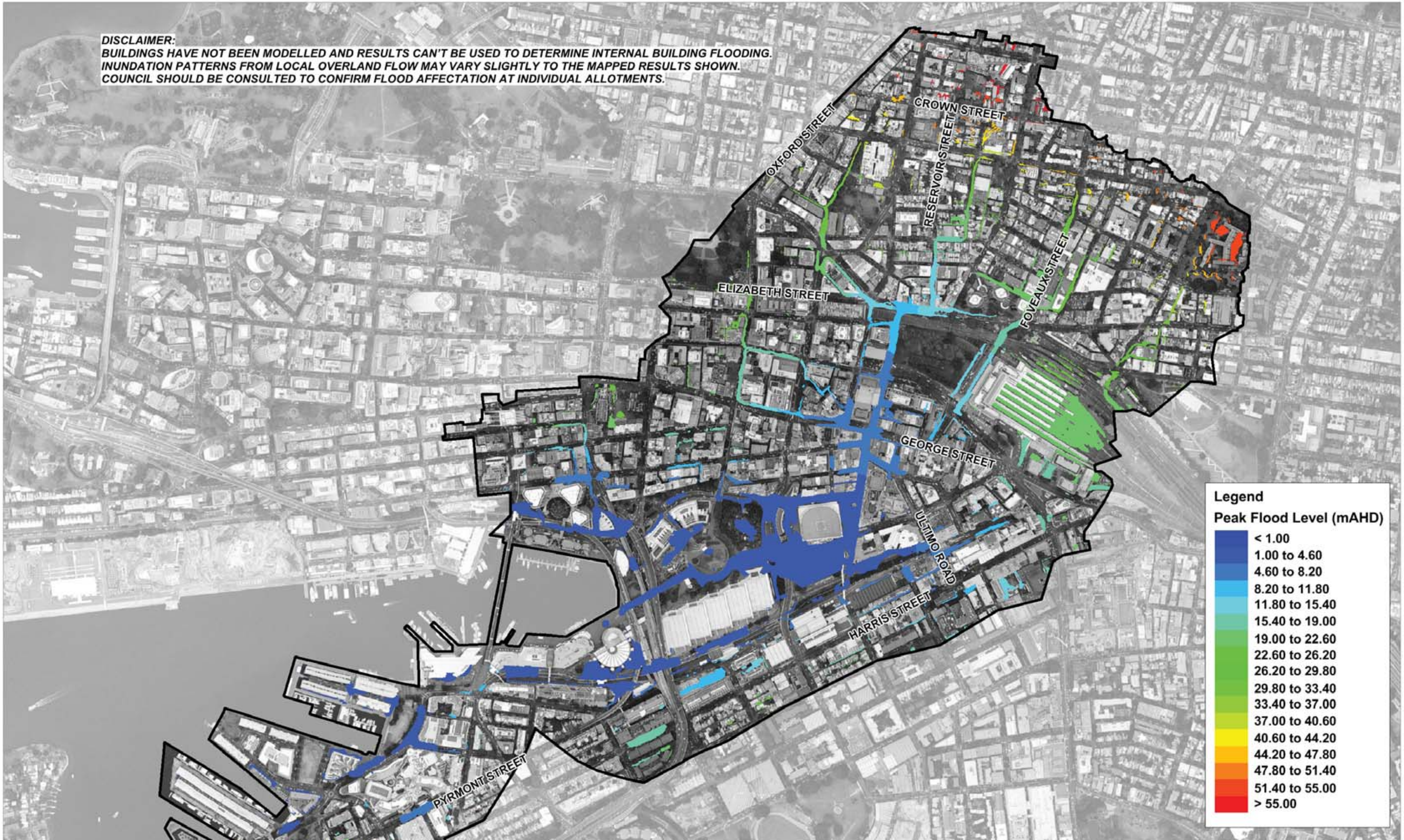
Filepath : S20012DraftingWORAppendixA_FiguresFigureA12_020YR_Level.wor



Title:
Peak Flood Level
2% AEP (50 yr ARI)

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N

0 200 400m
Approx. Scale

Figure: A-13

Rev: -

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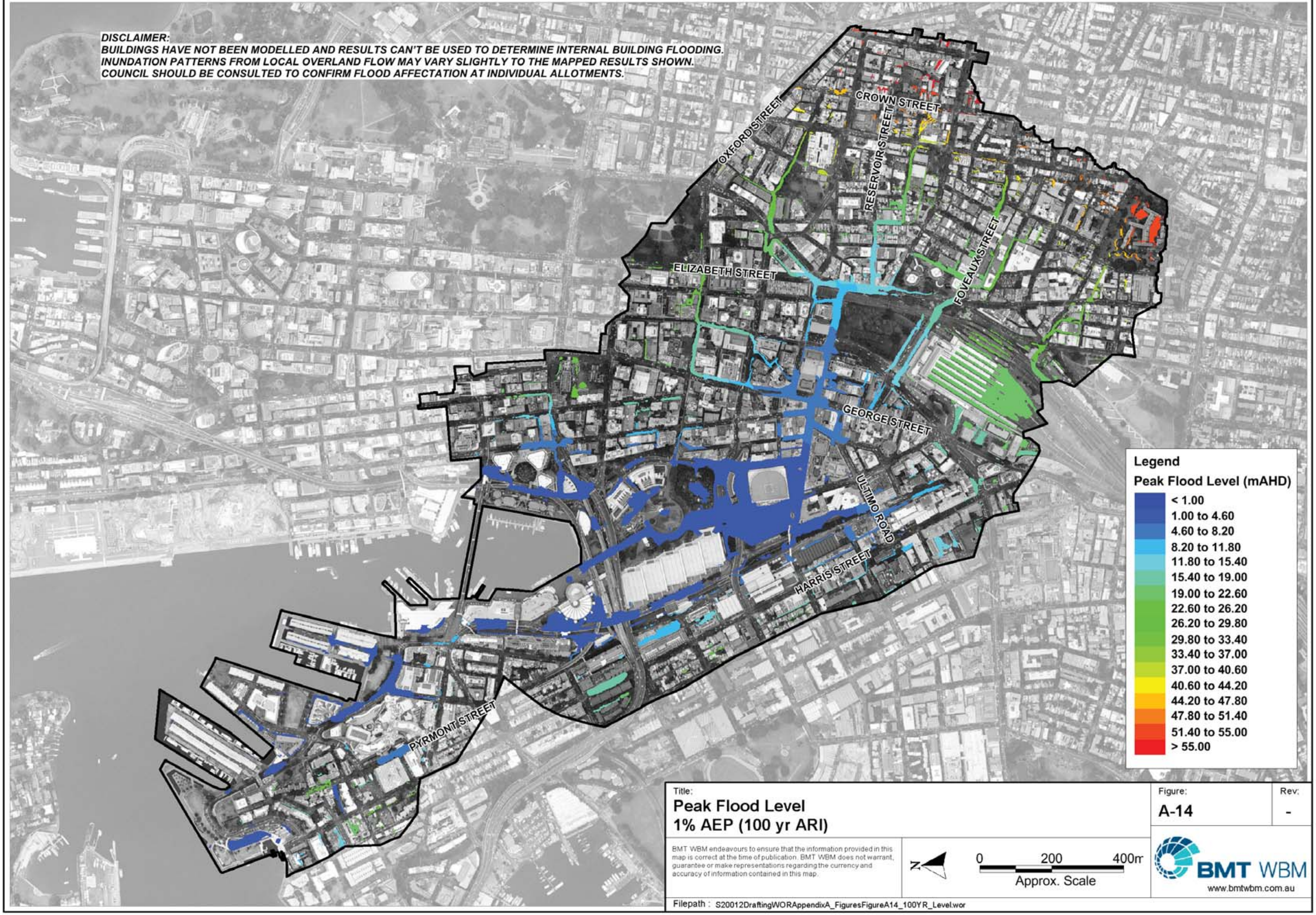
Filepath : S20012DraftingWORAppendixA_FiguresFigureA13_050YR_Level.wor



Title:
Peak Flood Level
1% AEP (100 yr ARI)

Figure: A-14

Rev: -

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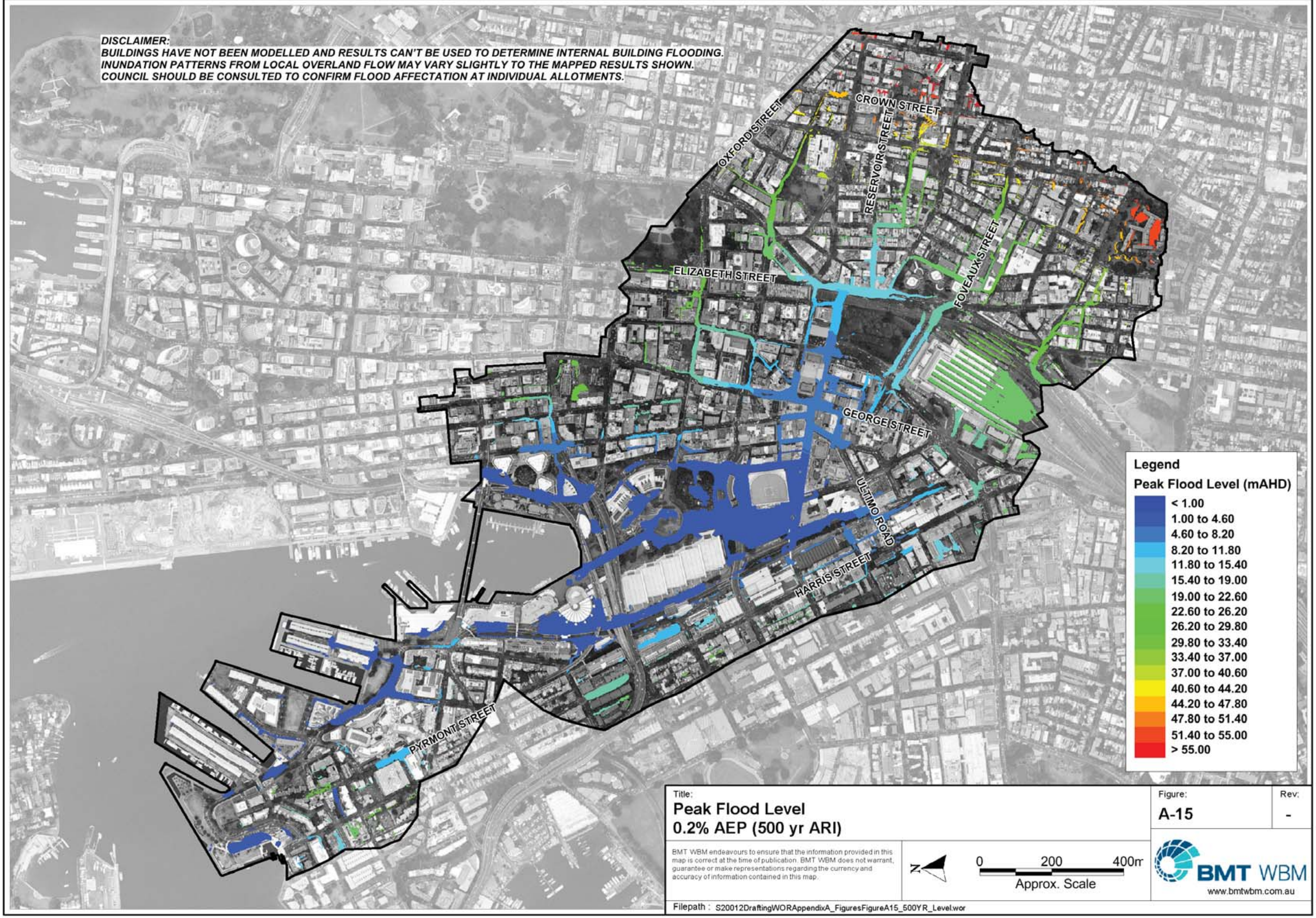
Filepath : S20012DraftingWORAppendixA_FiguresFigureA14_100YR_Level.wor



Title:
Peak Flood Level
0.2% AEP (500 yr ARI)

Figure: A-15

Rev: -

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Filepath : S20012DraftingWORAppendixA_FiguresFigureA15_500YR_Level.wor

Title:
Peak Flood Level
Probable Maximum Flood (PMF)

Figure: A-16

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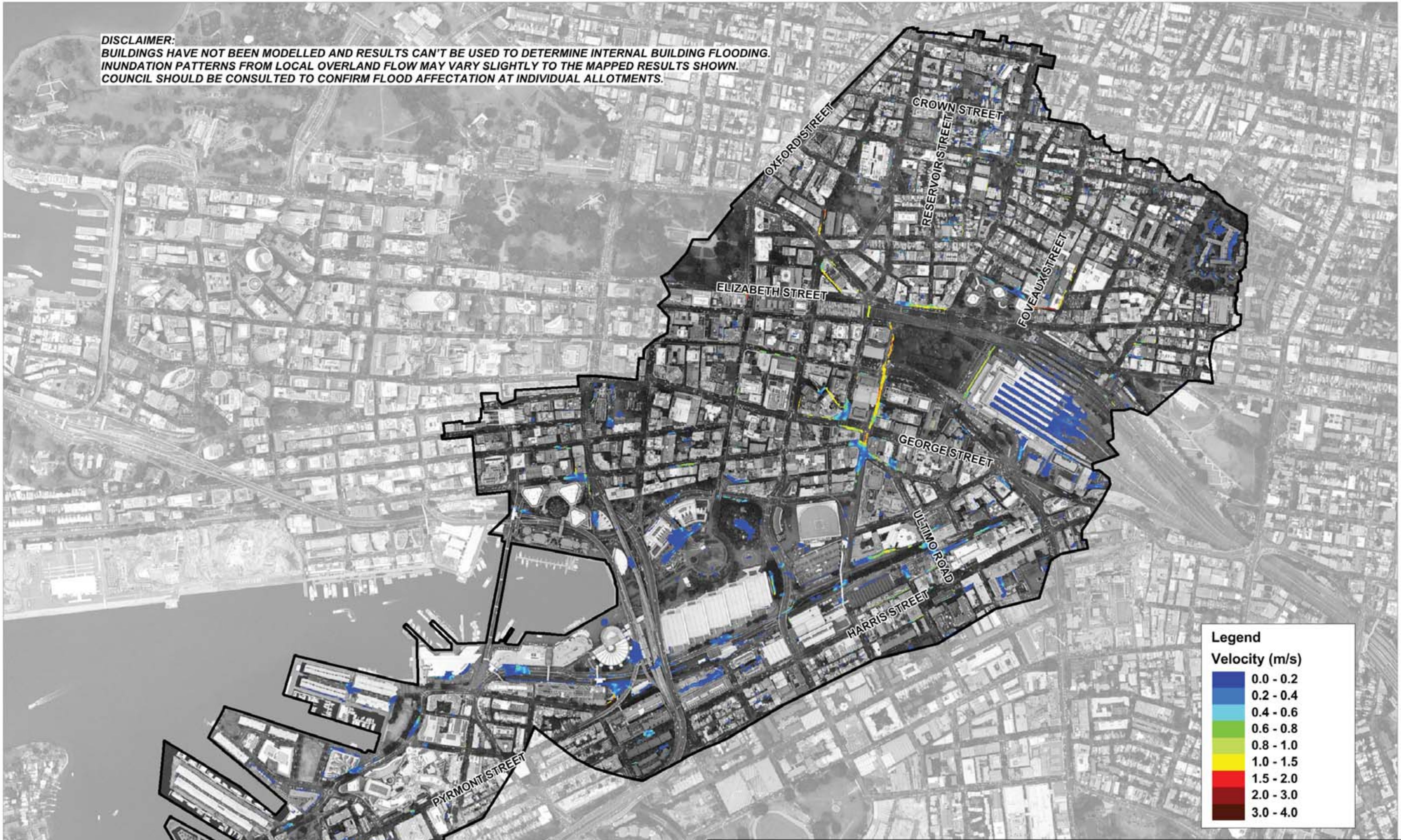
Filepath : S20012DraftingWORAppendixA_FiguresFigureA16_PMF_Level.wor



Title:
Peak Flood Velocity
2 YEAR ARI

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Figure: A-17

Rev: -

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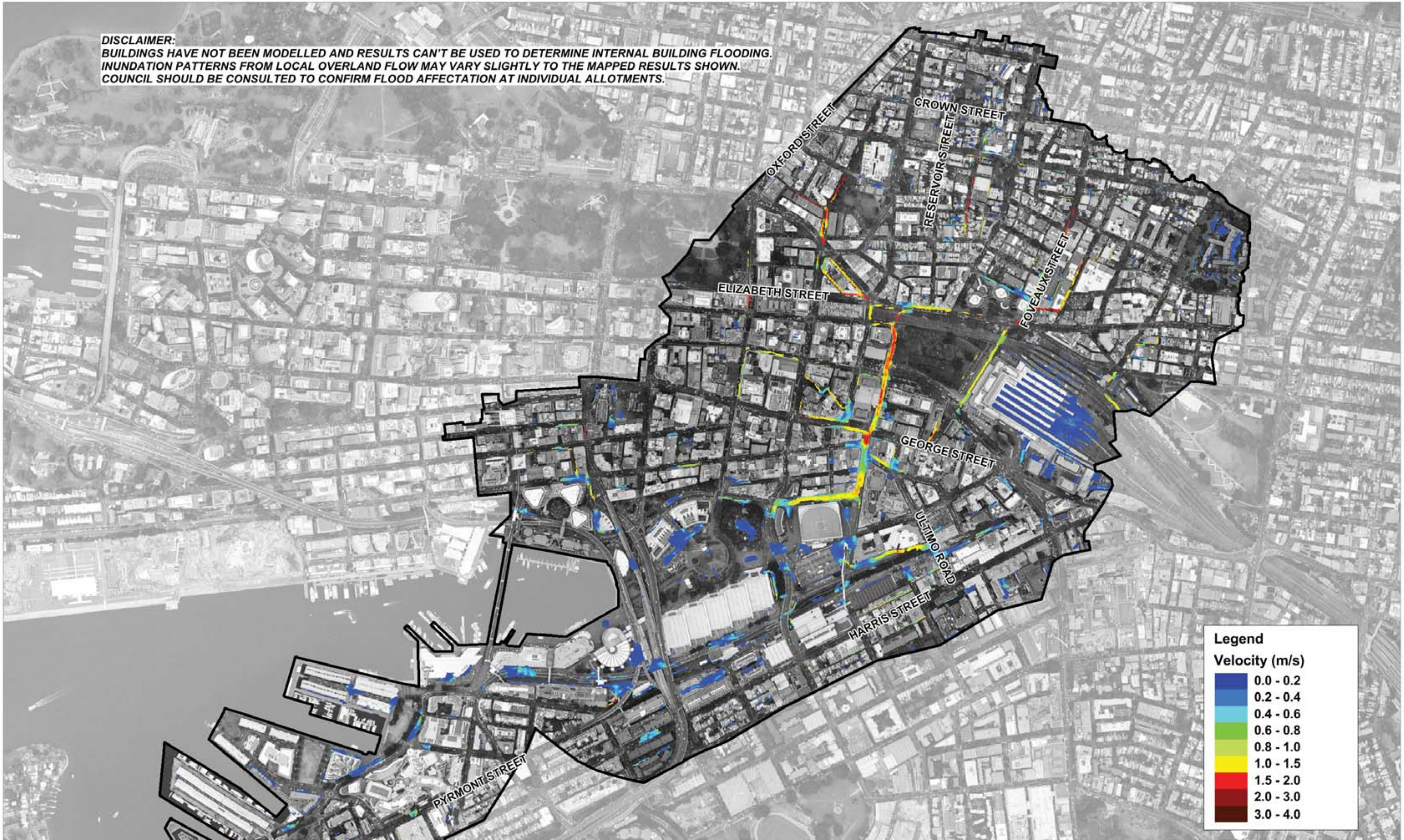
Filepath : S20012DraftingWORAppendixA_FiguresFigureA17_002YR_Velocity.wor



Title:
Peak Flood Velocity
5 YEAR ARI

Figure: A-18

Rev: -

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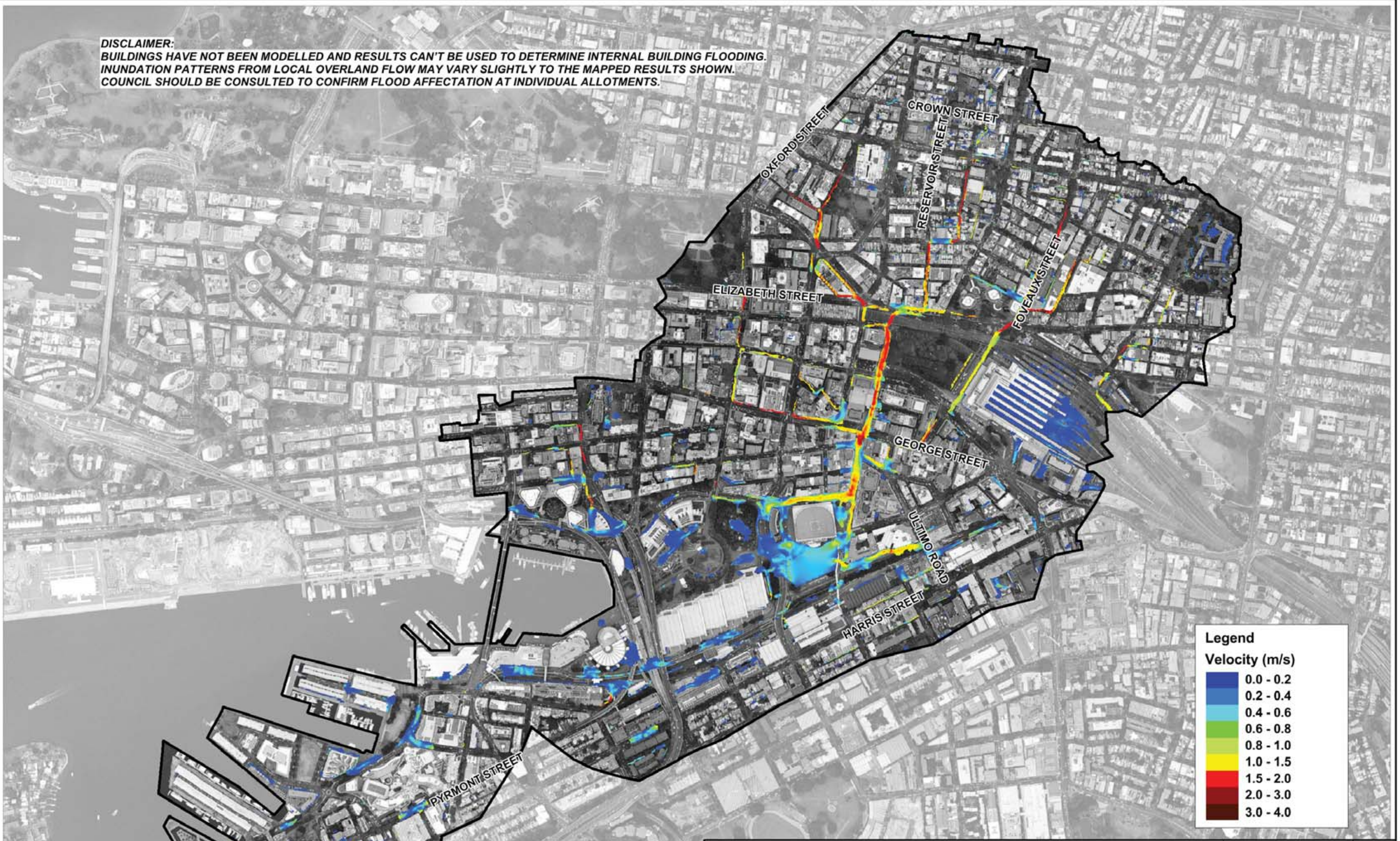
Filepath : S20012DraftingWORAppendixA_FiguresFigureA18_005YR_Velocity.wor



Title:
Peak Flood Velocity
10% AEP (10 yr ARI)

Figure: A-19

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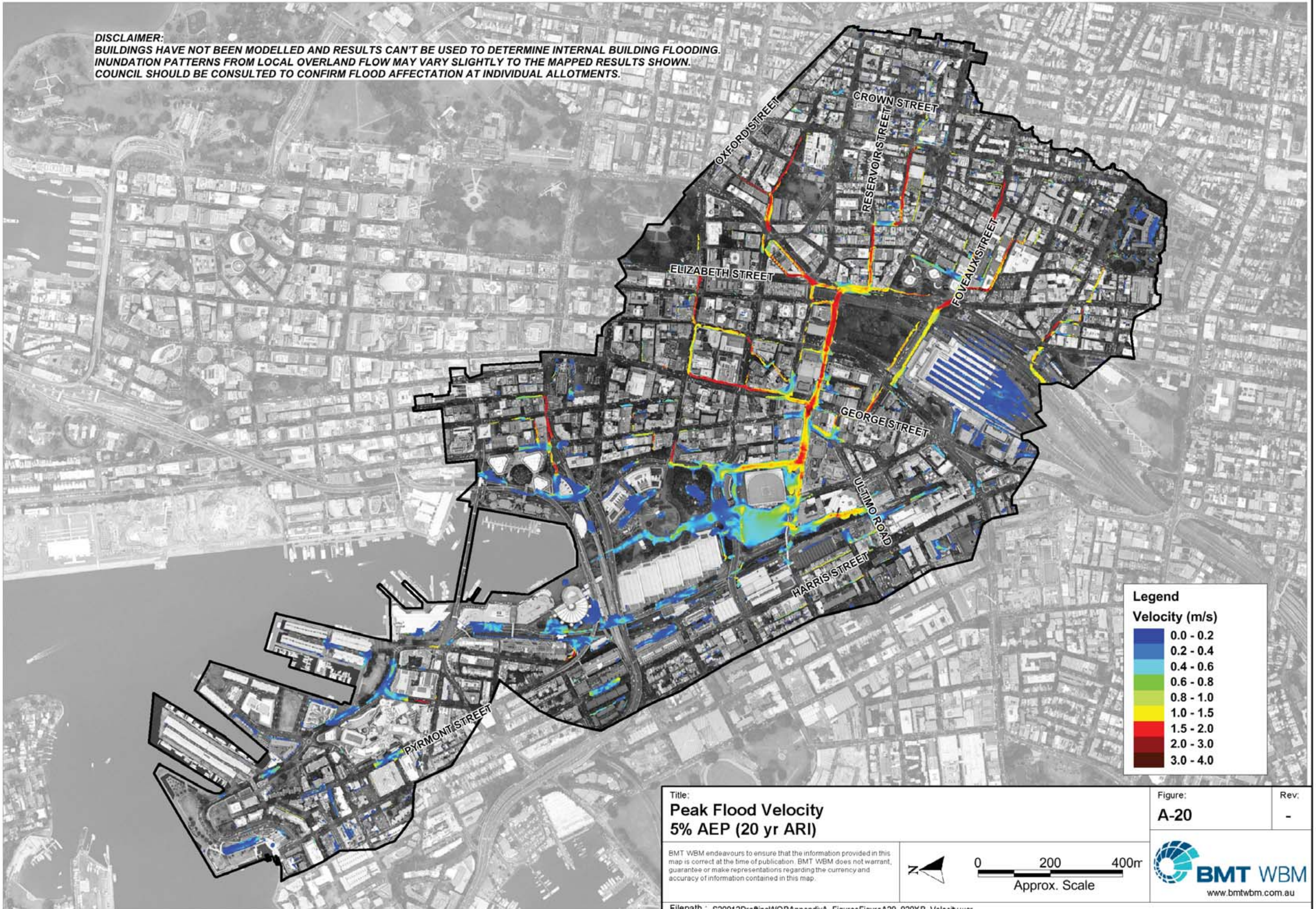
Filepath : S20012DraftingWORAppendixA_FiguresFigureA19_010YR_Velocity.wor



Title:
Peak Flood Velocity
5% AEP (20 yr ARI)

Figure: A-20

Rev: -

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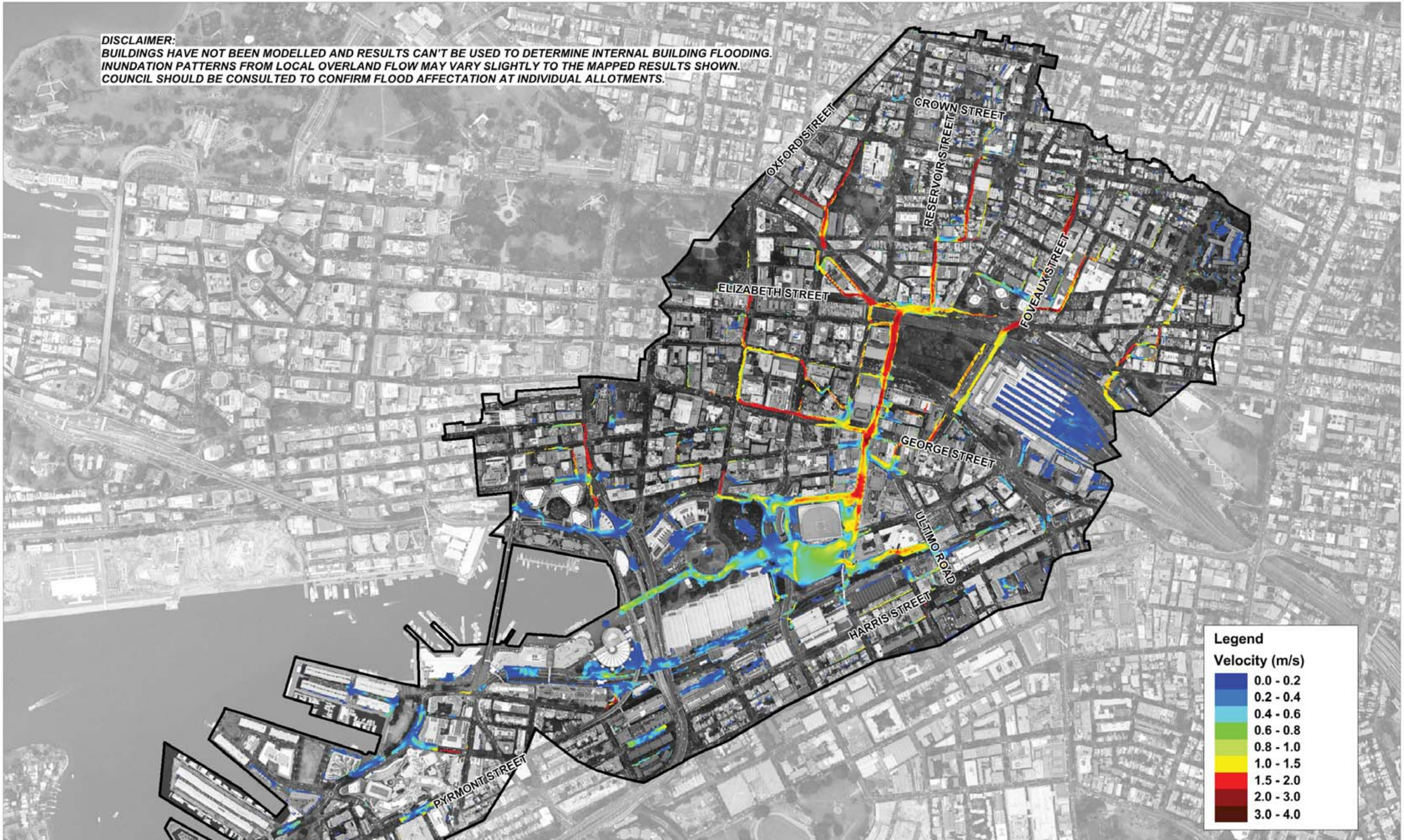
Filepath : S20012DraftingWORAppendixA_FiguresFigureA20_020YR_Velocity.wor



Title:
Peak Flood Velocity
2% AEP (50 yr ARI)

Figure: A-21

Rev: -

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N

0 200 400m
Approx. Scale

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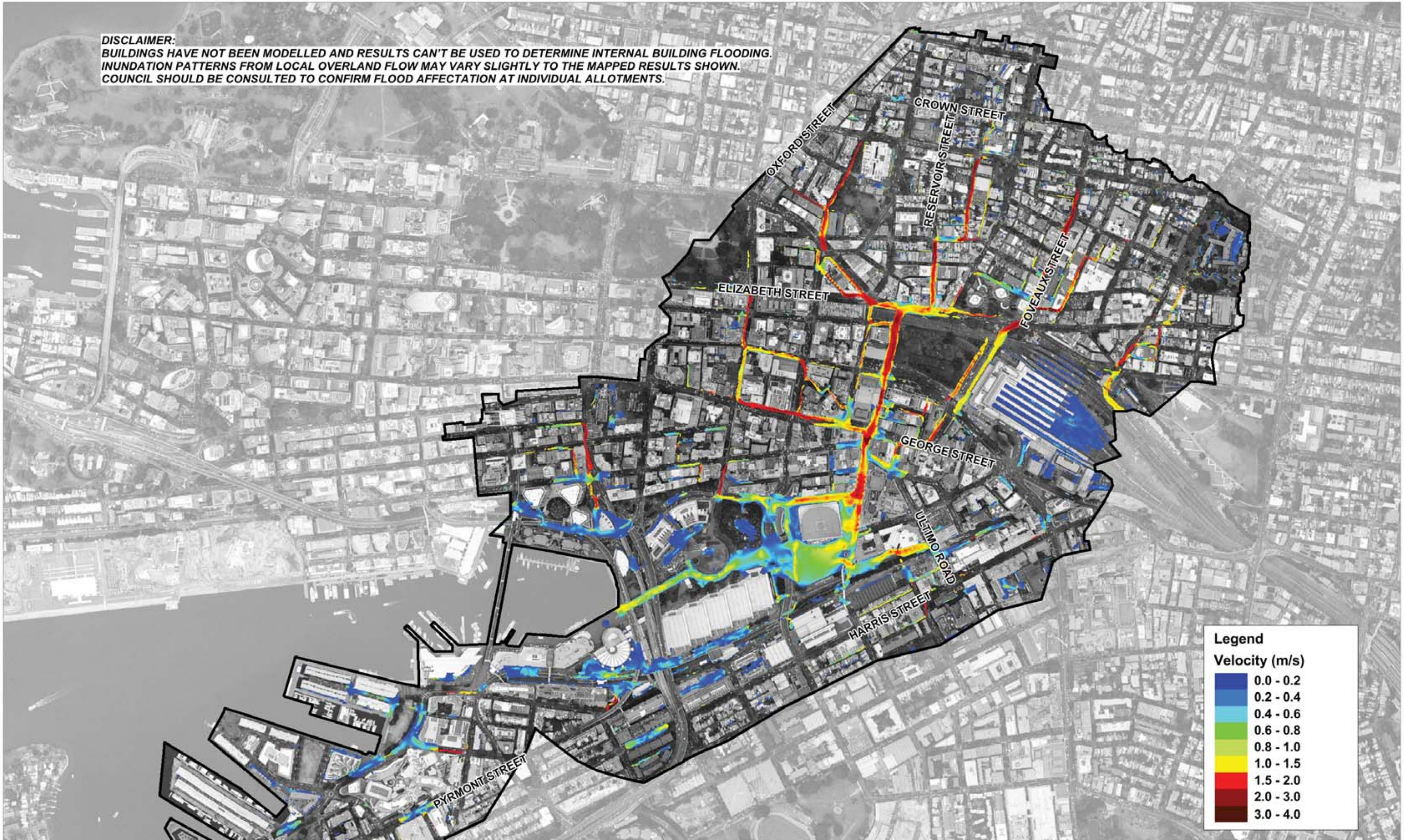
Filepath : S20012DraftingWORAppendixA_FiguresFigureA21_050YR_Velocity.wor



Title:
Peak Flood Velocity
1% AEP (100 yr ARI)

Figure:
A-22

Rev:
-

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Filepath : S20012DraftingWORAppendixA_FiguresFigureA22_100YR_Velocity.wor