Our Ref: W4855:BCP/bcp
Contact: Dr Brett C Phillips

26th July 2012

Cardno (NSW/ACT) Pty Ltd
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The Manager,
Robertson + Marks Architects Pty Ltd
Ground Floor 11-17 Buckingham Street
SURRY HILLS NSW 2010

Attention: Mr Brian Mann

Dear Brian,

ADDENDUM TO THE FLOODING ASSESSMENTS OF THE SHEPHERDS BAY URBAN RENEWAL MASTERPLAN

Further to our recent discussions please we have extracted an indicative 100 yr ARI flood level and PMF at a series of nominated locations around each building (refer attached sheets for each Stage of the Masterplan.

Typically the 100 yr ARI overland flow depths are shallow (0.1 – 0.3 m depth) hence the 100 yr ARI flood level in m AHD reflect the terrain in the model. This was based on ALS data with an associated typical level of accuracy of +/- 0.15 m.

Also attached is a table which summarise the estimated 100 yr ARI flood levels, the resulting Flood Planning Levels (based on a 500 mm freeboard) and the PMF levels at each reference location. You will note that the Flood Planning Level is higher than the PMF level except for a number of locations near the planned overland flowpath between Ann Thorn Park and the Parramatta River.

Yours faithfully

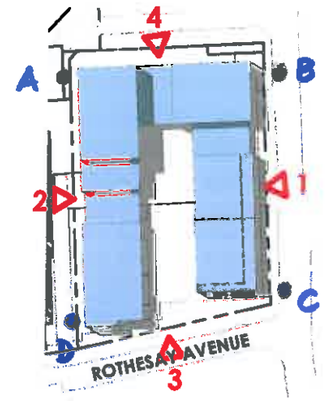
Brett C. Phillips

……
Dr Brett C. Phillips
Director, Water Engineering
for **Cardno**

					Attachment A
W4855 Shepherds Bay Flood Levels					
	Freeboard (m)	0.5			
Points	100yr FL	Flood Planning Level	PMF FL	Difference	PMF
	(mAHD)	(m AHD)	(mAHD)	(m)	Exceeds FPL?
	(a)	(b)	(c)	(c) - (a)	
1A	7.82	8.32	8.04	0.22	No
1D	4.05	4.55	4.08	0.03	No
1B	9.85	10.35	9.89	0.04	No
1C	4.05	4.55	4.52	0.47	No
2A	20.41	20.91	20.44	0.03	No
2B	20.80	21.30	20.87	0.07	No
2C	19.81	20.31	19.82	0.01	No
2D	14.39	14.89	14.40	0.01	No
3A	16.75	17.25	16.76	0.01	No
3B	10.41	10.91	10.43	0.02	No
3C	3.84	4.34	3.85	0.01	No
3D	2.59	3.09	2.70	0.11	No
4A	19.44	19.94	19.45	0.01	No
4D	20.27	20.77	20.28	0.01	No
4C	18.71	19.21	18.72	0.01	No
4B	12.44	12.94	12.47	0.03	No
5A	9.95	10.45	10.16	0.21	No
5B	11.83	12.33	12.28	0.45	No
5C	10.44	10.94	10.48	0.04	No
6A	12.10	12.60	12.11	0.01	No
6B	18.22	18.72	18.23	0.01	No
7A	5.94	6.44	6.62	0.68	Yes
7B	10.58	11.08	10.59	0.01	No
7C	5.54	6.04	5.57	0.03	No
8A	7.64	8.14	8.79	1.15	Yes
8B	10.61	11.11	10.79	0.18	No
8C	7.90	8.40	7.92	0.02	No
8D	5.51	6.01	6.61	1.10	Yes
9A	8.15	8.65	8.19	0.04	No
9B	5.18	5.68	6.73	1.55	Yes
9C	3.80	4.30	4.14	0.34	No
9D	2.47	2.97	2.77	0.30	No
9E	3.54	4.04	3.66	0.12	No
9F	4.61	5.11	4.77	0.16	No
9G	6.88	7.38	7.03	0.15	No
10A	8.88	9.38	8.90	0.02	No
10B	7.85	8.35	8.74	0.89	Yes
10C	5.20	5.70	6.74	1.54	Yes
10D	5.82	6.32	6.73	0.91	Yes
Note:	100 yr ARI flood levels in Constitution Road and Nancarrow Avenue reflect Council's 100 yr ARI drainage system upgrade ie. they are lower than would otherwise be the case. This is accentuating the flood level differences in the PMF when the overland flowpath is activated.				

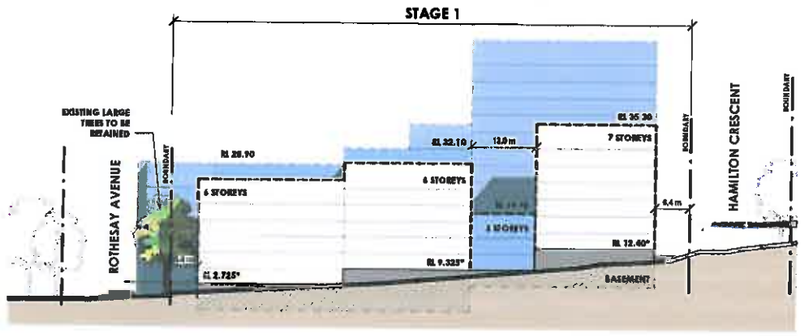
1.

A EA001-A **Key Plan 1**
1 : 2500

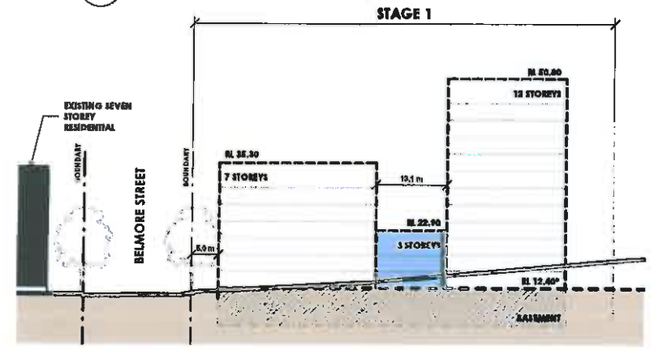


B EA001-A **1. Building Envelope Plan**
1 : 1000

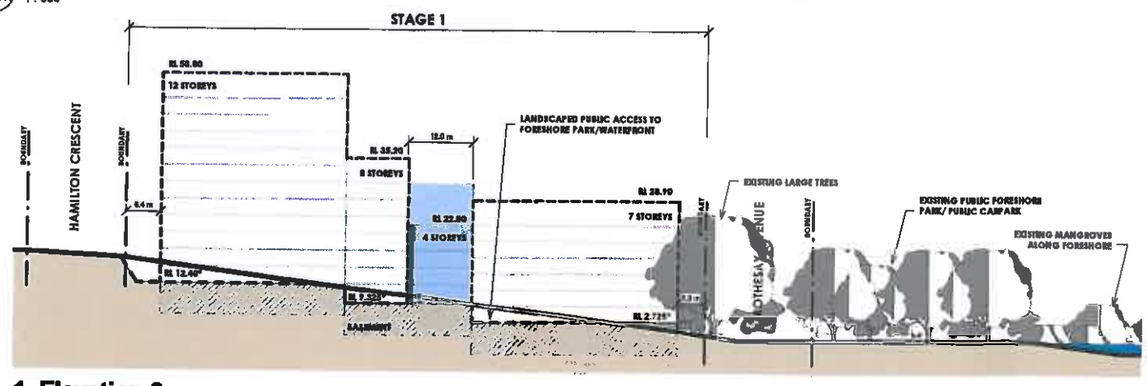
	Estimated 100yr ARI FL	PMF
A	7.82	8.04
B	9.85	9.89
C	4.05	4.52
D	4.05	4.08



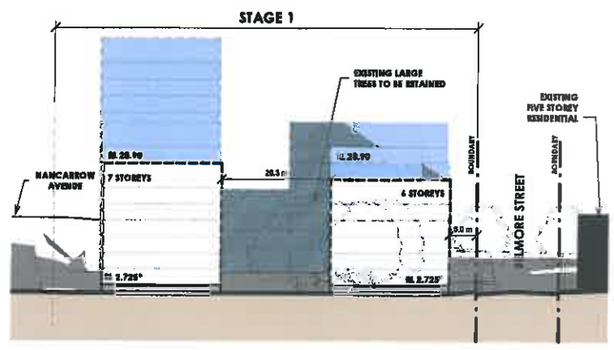
1 EA001-A **1. Belmore Street**
1 : 500



3 EA001-A **1. Nancarrow Avenue - South**
1 : 500



2 EA001-A **1. Elevation 2**
1 : 500



4 EA001-A **1. Rothesay Avenue**
1 : 500

NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

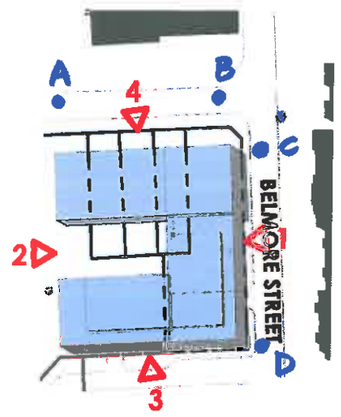
SHEPHERDS BAY URBAN RENEWAL

PREFERRED PROJECT MASTER PLAN
STAGE 1. BUILDING ENVELOPE CONTROL DIAGRAMS
EA001-A
Job no: 10088 , Date: 28/08/12 , Scale: As Indicated

ROBERTSON + MARKS

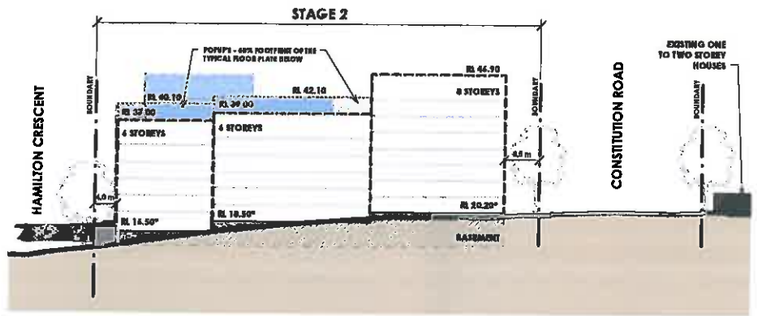
2.

A EA002-A **Key Plan 2**
1 : 2500

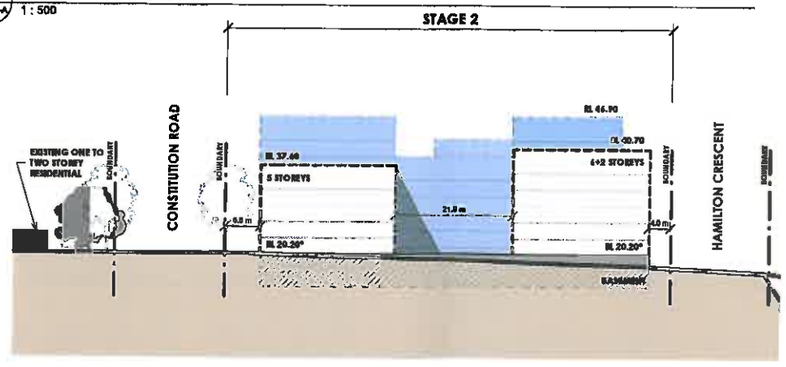


B EA002-A **2. Building Envelope Plan**
1 : 1000

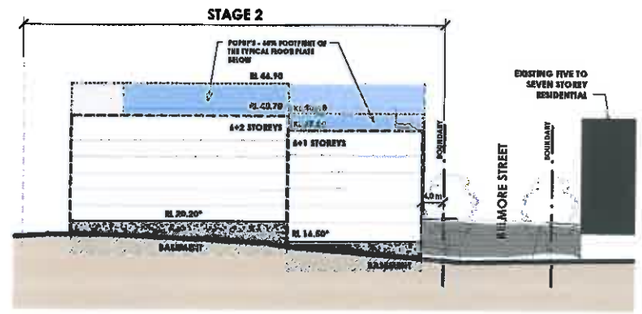
	Estimated 100 yr ARI FL	PMF
A	20.41	20.44
B	20.80	20.87
C	19.81	19.82
D	14.39	14.40



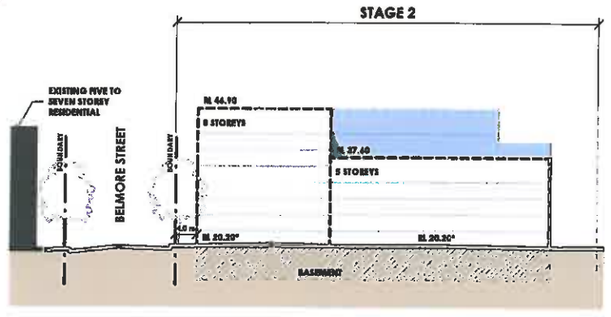
1 EA002-A **2. Belmore Street**
1 : 500



2 EA002-A **2. Elevation 2**
1 : 500



3 EA002-A **2. Nancarrow Ave - NORTH**
1 : 500



4 EA002-A **2. Constitution Road**
1 : 500

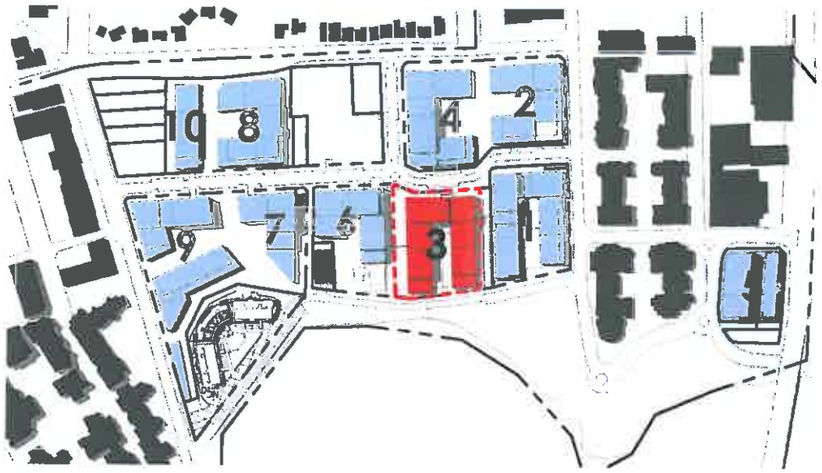
NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

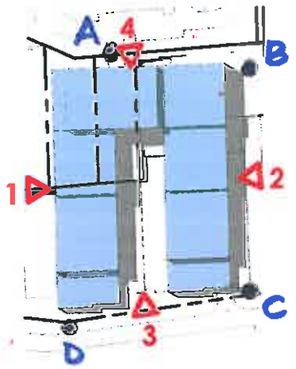
PREFERRED PROJECT MASTER PLAN
STAGE 2. BUILDING ENVELOPE CONTROL DIAGRAMS
EA002-A
Job no 1001 Date: 01/10/12 , Scale: As indicated

ROBERTSON + MARKS

3.

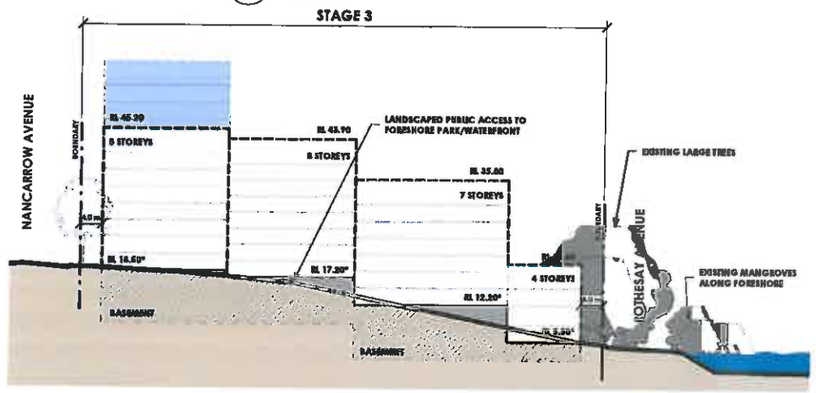


A EA003-A **Key Plan 3**
1 : 2500

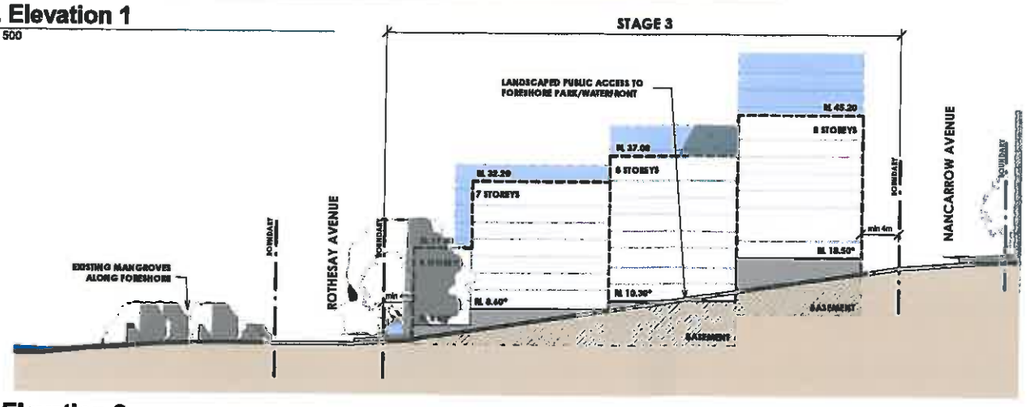


	Estimated 100 yr ARI FL	PMF
A	16.75	16.76
B	10.41	10.43
C	3.84	3.85
D	2.59	2.70

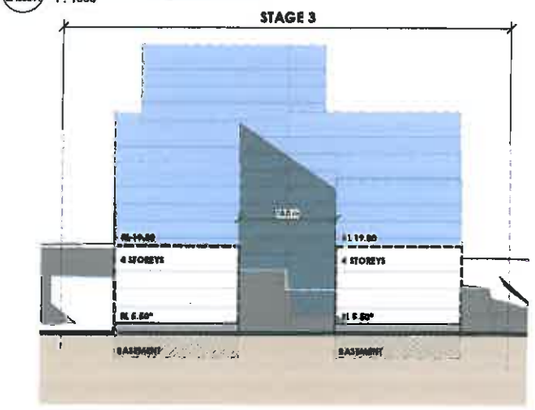
B EA003-A **3. Building Envelope Plan**
1 : 1000



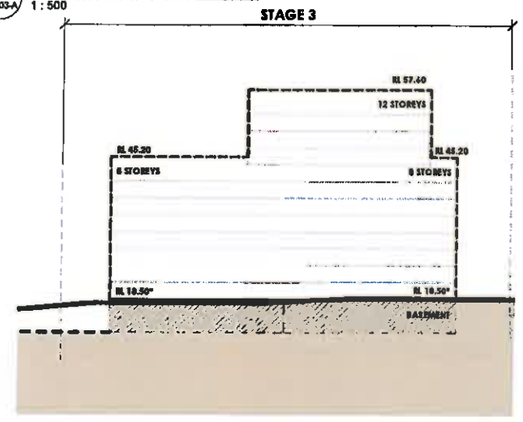
1 EA003-A **3. Elevation 1**
1 : 500



2 EA003-A **3. Elevation 2**
1 : 500



3 EA003-A **3. Rothesay Avenue**
1 : 500



4 EA003-A **3. Nancarrow Avenue - South**
1 : 500

NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

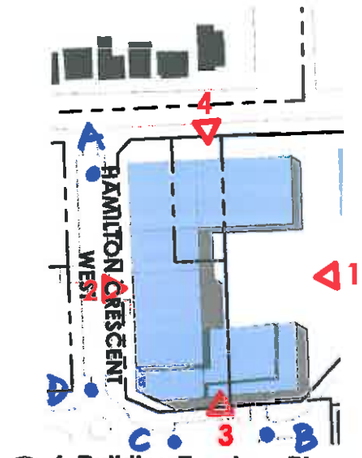
SHEPHERDS BAY URBAN RENEWAL

PREFERRED PROJECT MASTER PLAN
STAGE 3. BUILDING ENVELOPE CONTROL DIAGRAMS
EA003-A
Job no. 10088 , Date: 03/10/12 , Scale: As indicated

ROBERTSON + MARKS

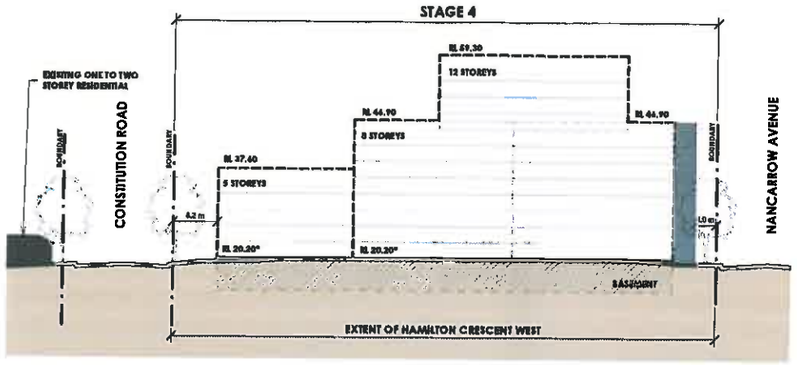
4.

A EA004-A **Key Plan 4**
1 : 2500

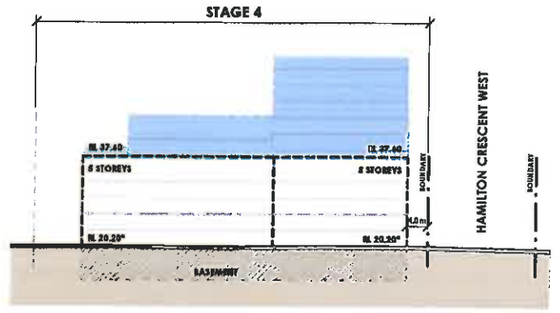


B EA004-A **4. Building Envelope Plan**
1 : 1000

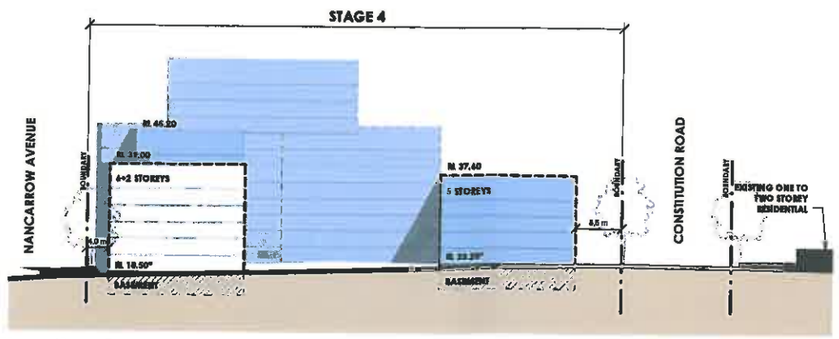
	Estimated 100 yr ARI FL	PMF
A	19.44	19.45
B	12.44	12.47
C	18.71	18.72
D	20.27	20.28



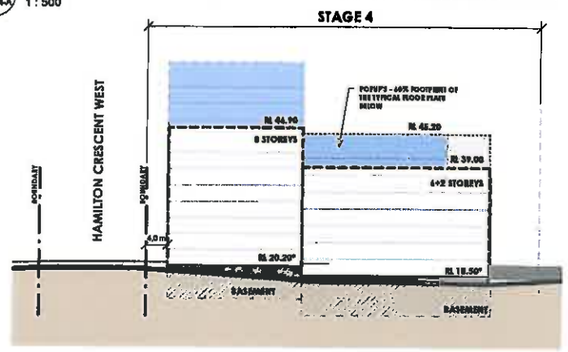
1 EA004-A **4. Hamilton Crescent - East**
1 : 500



3 EA004-A **4. Constitution Road**
1 : 500



2 EA004-A **4. Elevation 2**
1 : 500



4 EA004-A **4. Nancarrow Ave - NORTH**
1 : 500

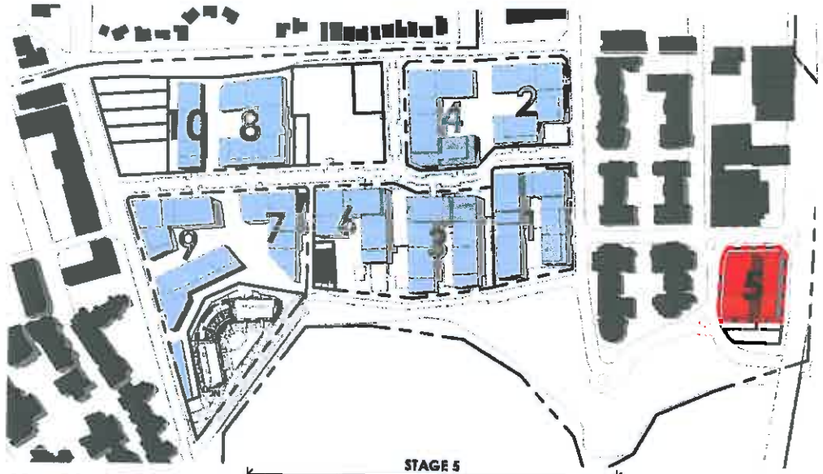
NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

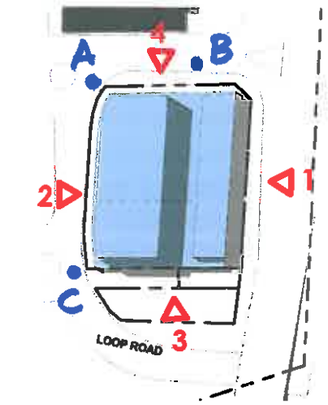
PREFERRED PROJECT MASTER PLAN
STAGE 4. BUILDING ENVELOPE CONTROL DIAGRAMS
EA004-A
Job no 10060 Date: 01/10/12 Scale: As indicated

ROBERTSON + MARKS

5.

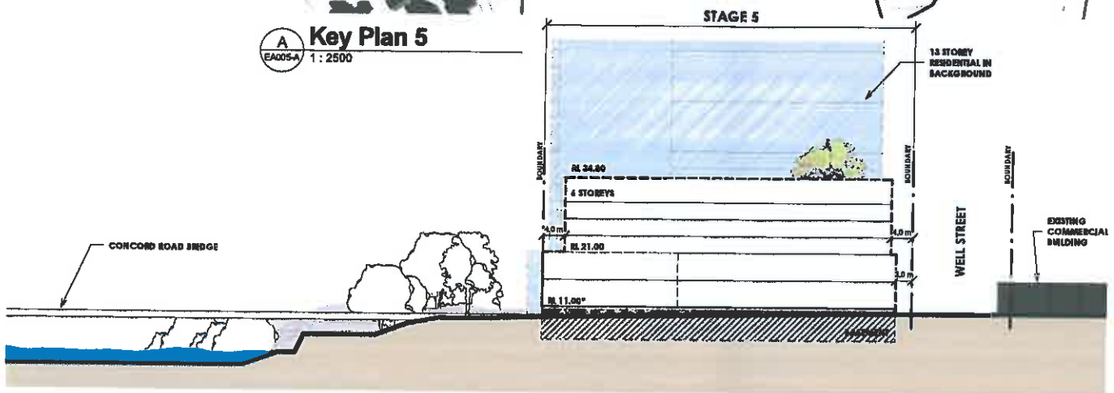


A EA005-A **Key Plan 5**
1 : 2500

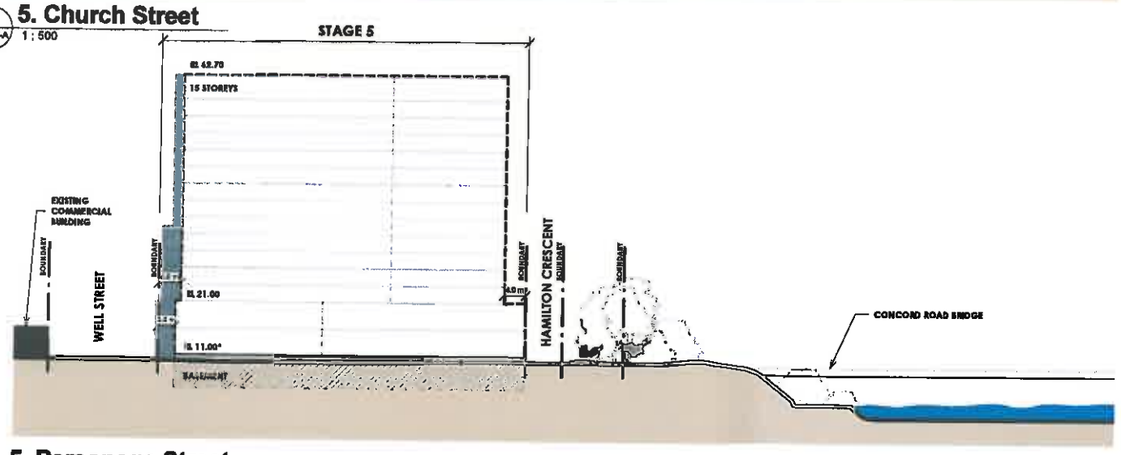


B EA005-A **5. Building Envelope Plan**
1 : 1000

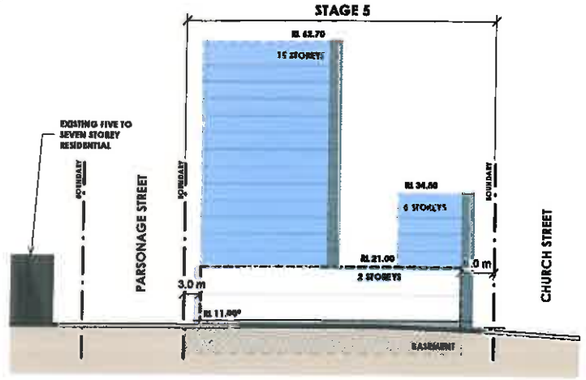
	Estimated 100 yr ARI FL	PMF
A	9.95	10.16
B	11.83	12.28
C	10.44	10.48



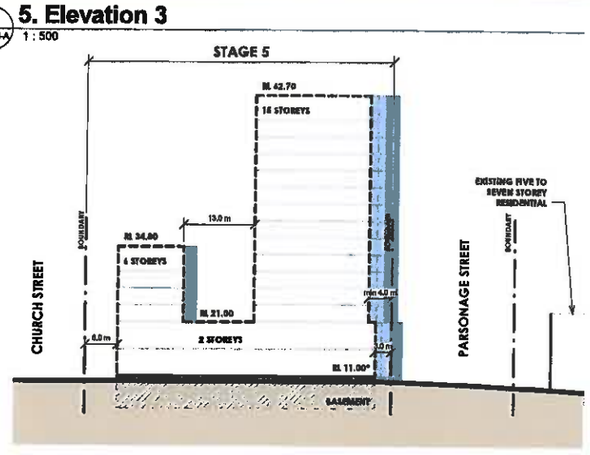
1 EA005-A **5. Church Street**
1 : 500



2 EA005-A **5. Parsonage Street**
1 : 500



3 EA005-A **5. Elevation 3**
1 : 500



4 EA005-A **5. Well Street**
1 : 500

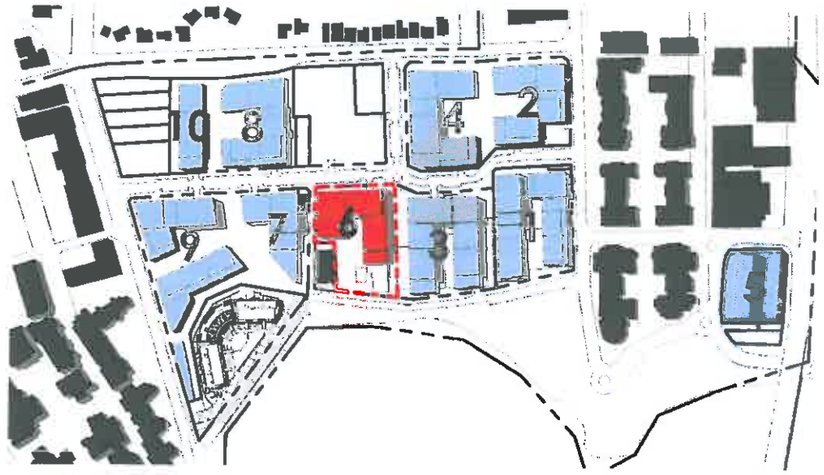
NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

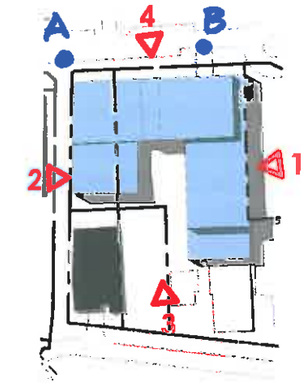
PREFERRED PROJECT MASTER PLAN
STAGE 5. BUILDING ENVELOPE CONTROL DIAGRAMS
EA005-A
Job no: 13048 Date: 01/10/12 Scale: As indicated

ROBERTSON + MARKS

6.



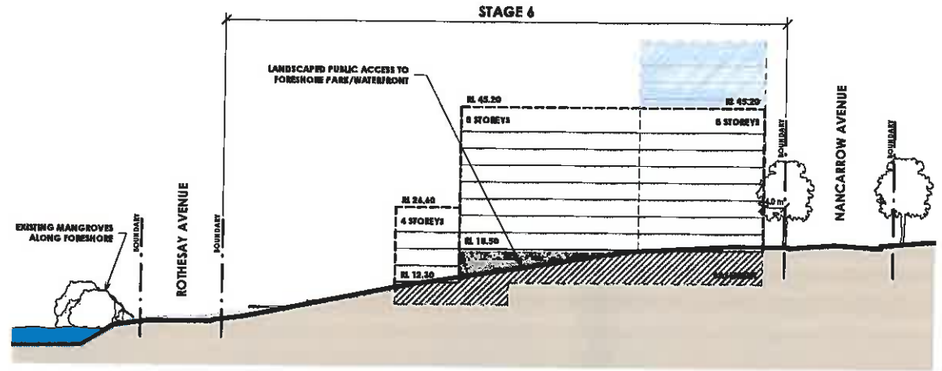
A EA006-A **Key Plan 6**
1 : 2500



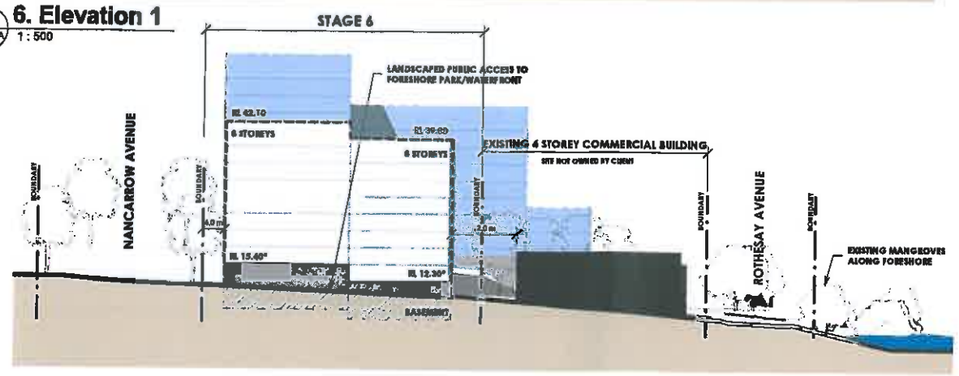
B EA006-A **6. Building Envelope Plan**
1 : 1000

Estimated 100 yr ARI FL | PMF

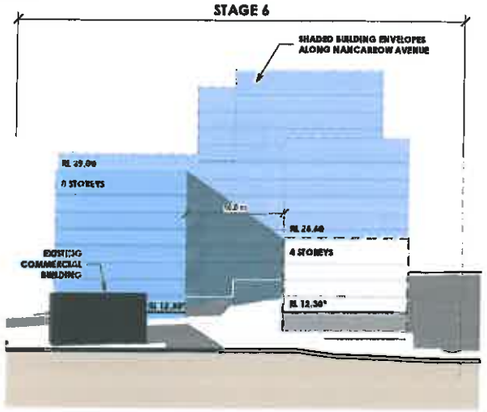
A	12.10	12.11
B	18.22	18.23



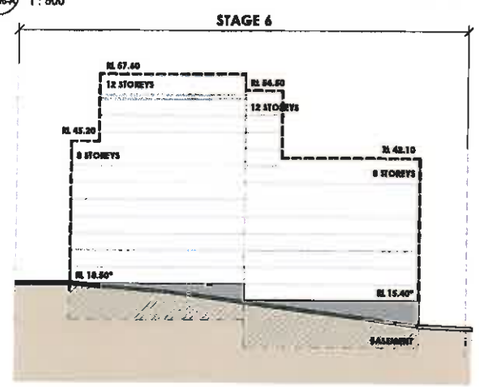
1 EA006-A **6. Elevation 1**
1 : 500



2 EA006-A **6. Elevation 2**
1 : 500



3 EA006-A **6. Rothesay Avenue**
1 : 500



4 EA006-A **6. Nancarrow Avenue - South**
1 : 500

NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

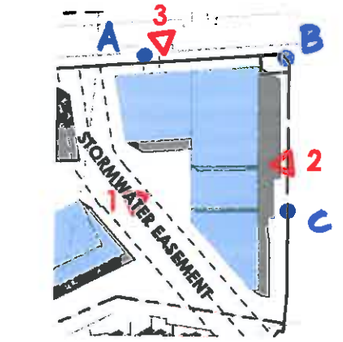
SHEPHERDS BAY URBAN RENEWAL

PREFERRED PROJECT MASTER PLAN
STAGE 6. BUILDING ENVELOPE CONTROL DIAGRAMS
EA006-A
Job no: 10088 , Date: 01/10/12 . Scale: As indicated

ROBERTSON + MARKS

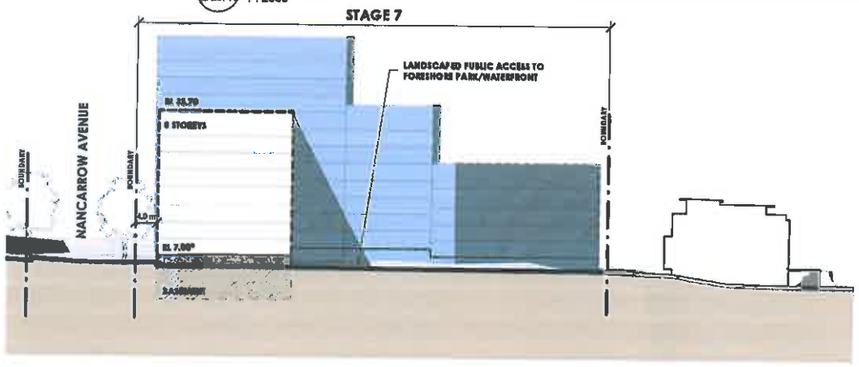
7.

A EA007-A **Key Plan 7** 1 : 2500

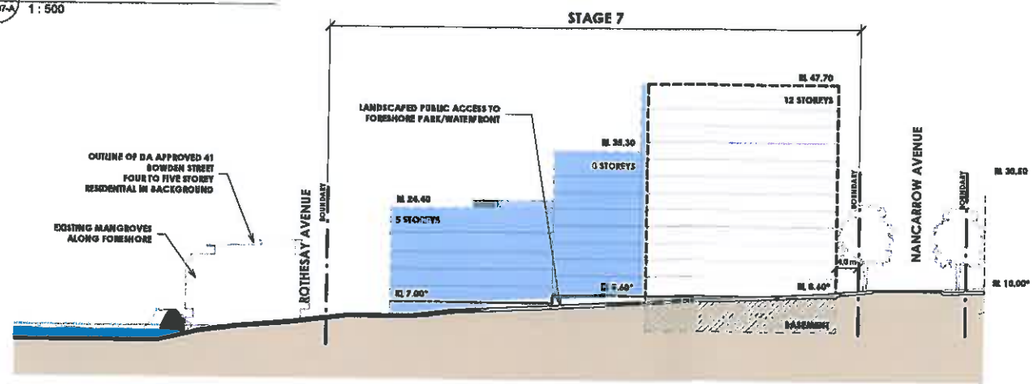


B EA007-A **7. Building Envelope Plan** 1 : 1000

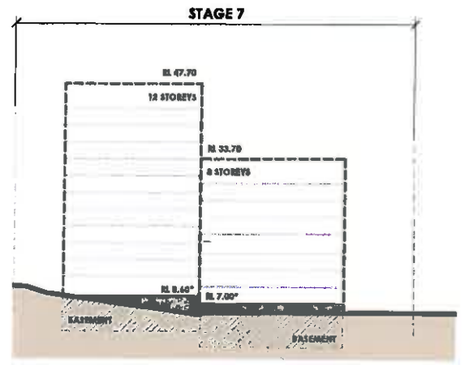
	Estimated 100 yr ARI FL	PMF
A	5.94	6.62
B	10.54	10.59
C	5.54	5.57



1 EA007-A **7. Elevation 1** 1 : 500



2 EA007-A **7. Elevation 2** 1 : 500



3 EA007-A **7. Nancarrow Avenue - South** 1 : 500

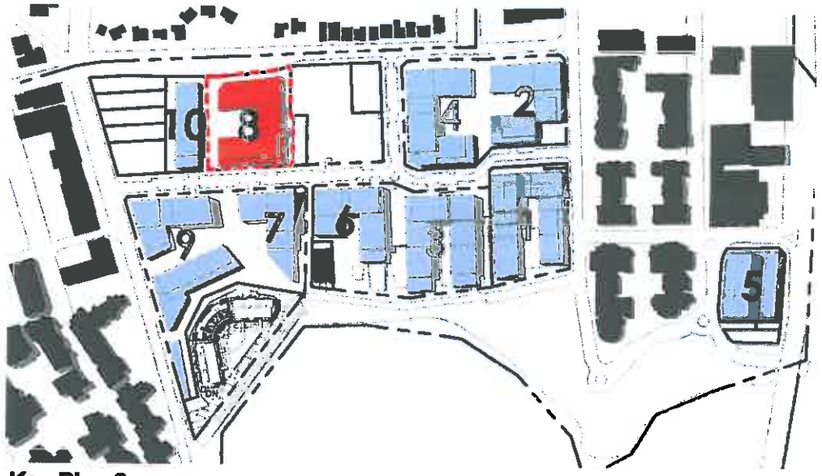
NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

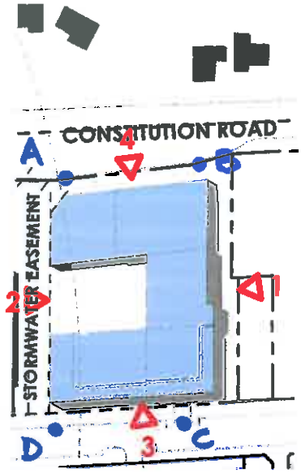
PREFERRED PROJECT MASTER PLAN
STAGE 7. BUILDING ENVELOPE CONTROL DIAGRAMS
EA007-A
Job no 10013 Date: 01/10/12 Scale: As indicated

ROBERTSON + MARKS

8.

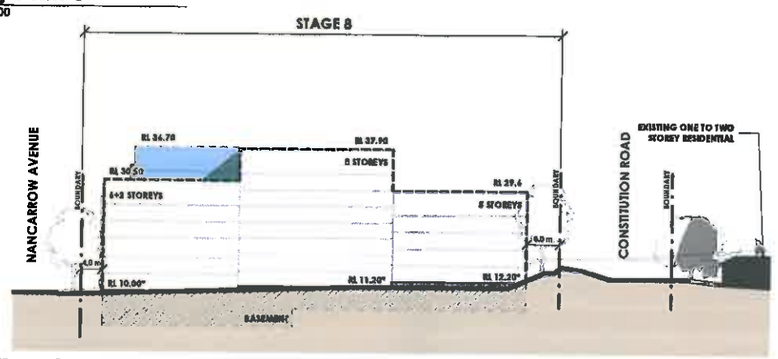


A EA008-A **Key Plan 8**
1 : 2500

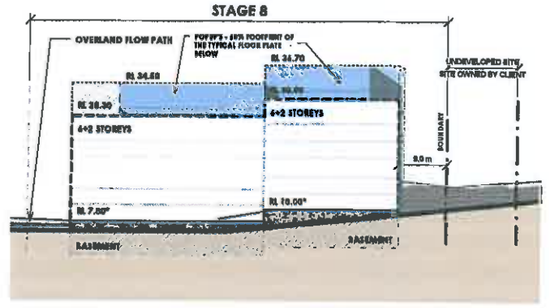


B EA008-A **8. Building Envelope Plan**
1 : 1000

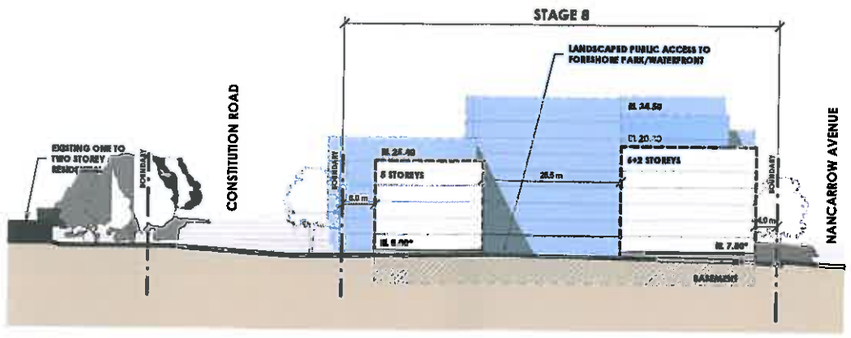
	Estimated 100 yr ARI FL	PMF
A	7.64	8.79
B	10.61	10.79
C	7.90	7.92
D	5.51	6.61



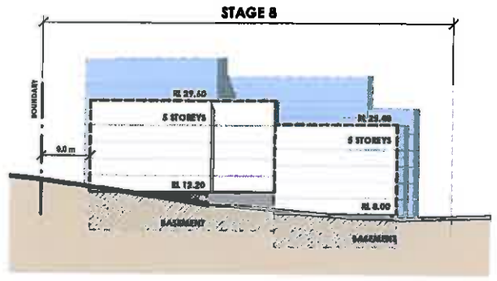
1 EA008-A **8. Elevation 1**
1 : 500



3 EA008-A **8. Street elevation - Nancarrow Ave - NORTH**
1 : 500



2 EA008-A **8. Elevation 2**
1 : 500



4 EA008-A **8. Constitution Road**
1 : 500

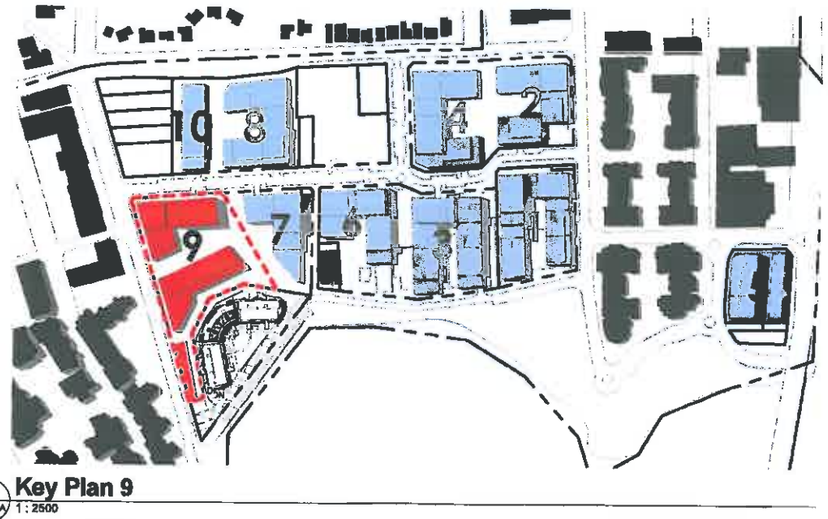
NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

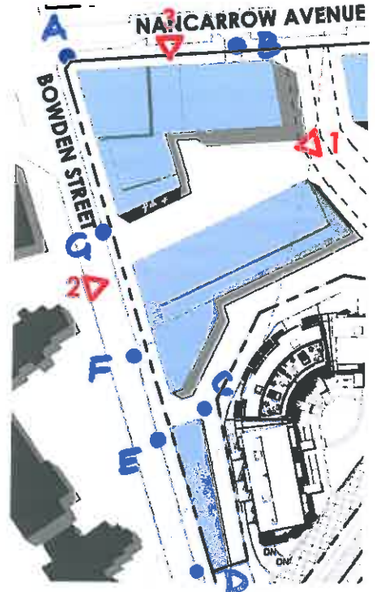
PREFERRED PROJECT MASTER PLAN
STAGE 8. BUILDING ENVELOPE CONTROL DIAGRAMS
EA008-A
Job no: 10088 Date: 01/10/12 Scale: as indicated

ROBERTSON + MARKS

9.

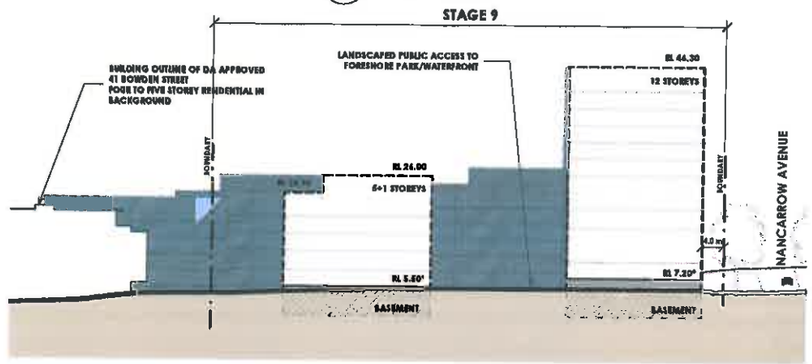


A EA009-A **Key Plan 9**
1 : 2500

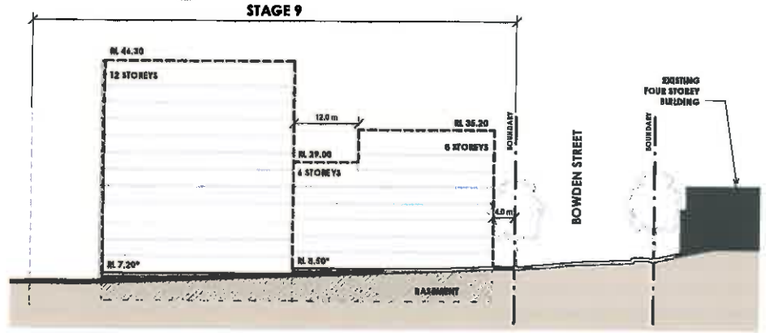


B EA009-A **9. Building Envelope Plan**
1 : 1000

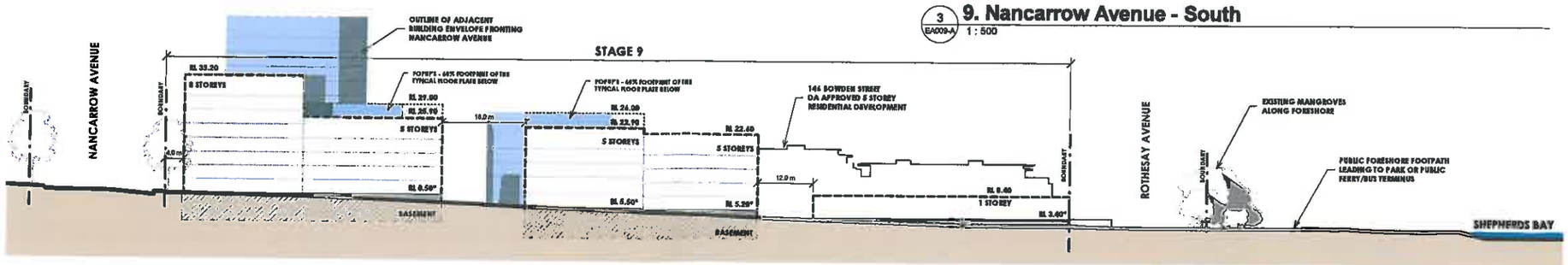
	Estimated 100 yr ARI FL	PMF
A	8.15	8.19
B	5.18	6.73
C	3.80	4.14
D	2.47	2.77
E	3.54	3.66
F	4.61	4.77
G	6.88	7.03



1 EA009-A **9. Elevation 1**
1 : 500



3 EA009-A **9. Nancarrow Avenue - South**
1 : 500



2 EA009-A **9. Bowden Street**
1 : 500

NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

PREFERRED PROJECT MASTER PLAN
STAGE 9. BUILDING ENVELOPE CONTROL DIAGRAMS
EA009-A
Job no. 10088 , Date: 01/10/12 , Scale: As indicated

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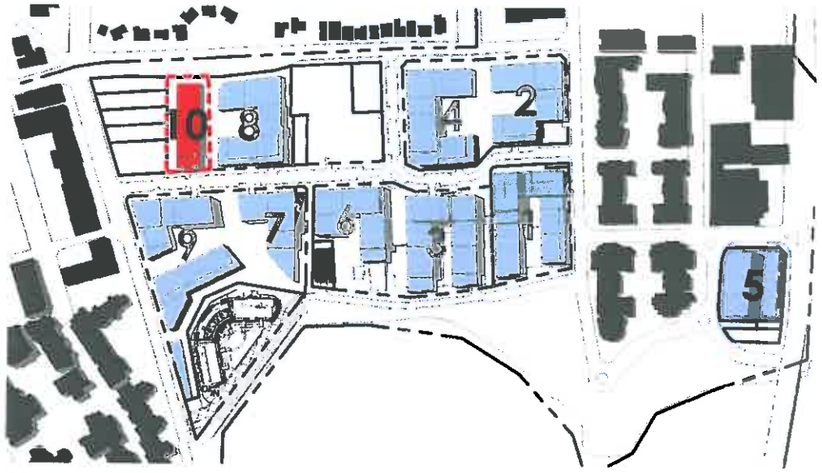
10.

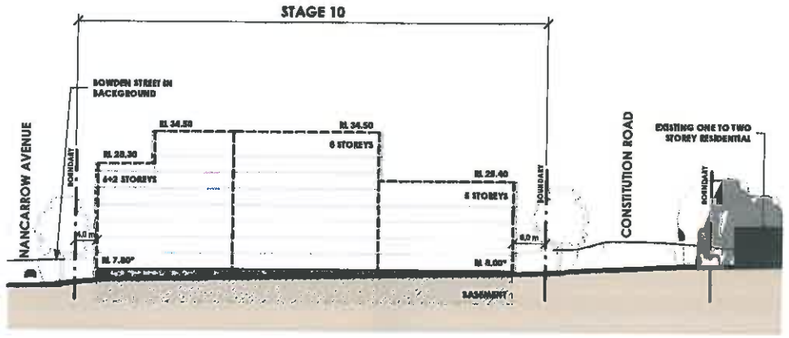


A EA010-A **Key Plan 10**
1 : 2500

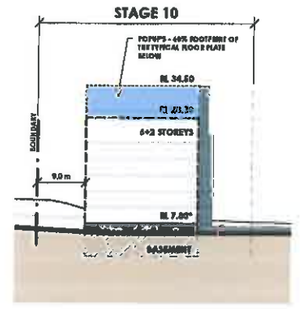
B EA010-A **10. Building Envelope Plan**
1 : 1000

Estimated 100 yr ARI FL | PMF

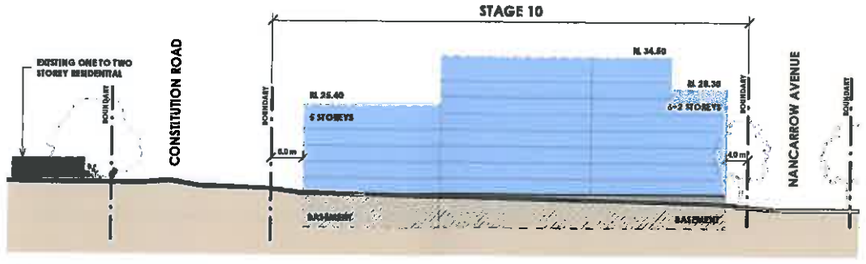
A	8.88	8.90
B	7.85	8.74
C	5.20	6.74
D	5.82	6.73



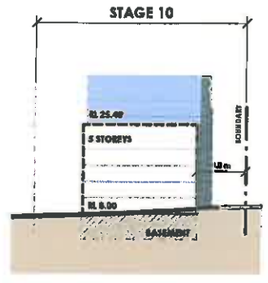
1 EA010-A **10. Elevation 1**
1 : 500



3 EA010-A **10. Nancarrow Ave - NORTH**
1 : 500



2 EA010-A **10. Elevation 2**
1 : 500



4 EA010-A **10. Constitution Road**
1 : 500

NOTE: SCALED TO A1 SIZE SHEET. * ASSUMED GROUND RL AS PER METHOD OF DEFINING HEIGHT (PG 33, Fig 12)

SHEPHERDS BAY URBAN RENEWAL

PREFERRED PROJECT MASTER PLAN
STAGE 10. BUILDING ENVELOPE CONTROL DIAGRAMS
EA010-A
Job no: 10080 , Date: 01/10/12 , Scale: As indicated

ROBERTSON + MARKS

Our Ref: W4855:BCP/bcp
Contacts: Dr Brett C Phillips / Garry Neville

6th July 2012

The Manager,
Robertson + Marks Architects Pty Ltd
Ground Floor 11-17 Buckingham Street
SURRY HILLS NSW 2010

Attention: Mr Brain Mann

Dear Brian,

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FLOODING ASSESSMENT OF THE SHEPHERDS BAY URBAN RENEWAL FINAL MASTERPLAN

Further to our recent discussions please find attached the results of our assessments of flooding under Existing Conditions and under the updated Final Masterplan for the urban renewal of Shepherds Bay.

1. BACKGROUND

1.1 Bowden Street and Ann Thorn Park Catchments

Investigations of overland flooding problems within the Ann Thorn Park catchment have been undertaken by Ryde City Council since 2001.

In January 2002 a Meadowbank River Catchment Drainage Masterplan was prepared for the Bowden Street, Ann Thorn Park and Well Street catchments by the Rose Consulting Group. As part of the investigations detailed models of the existing drainage system were assembled using the DRAINS urban drainage package.

In June 2004, Cardno Willing prepared a Flood Study Report for the proposed residential development of 146 Bowden Street, Meadowbank that assessed local drainage requirements and overland flows from Nancarrow Avenue discharging onto the development site.

There have been various estimates of the impact of the Ann Thorn Park detention basin and uncertainty regarding the magnitude of 100 yr ARI overland flows downstream of Constitution Road. In view of this uncertainty Cardno Willing assembled an **xprafts** rainfall/runoff model of the Bowden Street and Ann Thorn Park catchments to estimate 100 yr ARI runoff for input into a detailed **xpswmm2D** hydrodynamic model of the lower reaches of the Bowden Street and Ann Thorn Park catchments (Cardno Willing, 2007)

An **xprafts** model was assembled of the Bowden Street and Ann Thorn Park catchments. The subcatchment boundaries were guided by the subcatchment boundaries identified by the Rose Consulting Group in 2002. In the vicinity of the development site the catchment was subdivided based on observations of the potential overland flowpaths during the field inspection.

The **xprafts** model was run for a range of 100 yr ARI storm burst durations up to and including the 3 hour storm burst. It was concluded that the critical storm burst duration was 1.5 hours.

While the estimated peak 100 yr ARI flow at Richard Johnson Crescent using **xprafts** was greater than the peak 100 yr ARI flow reported for the DRAINS model or estimated using the Rational Method, the peak 100 yr ARI flows estimated downstream of the Ann Thorn Park detention basin using **xprafts** were all lower than the reported estimates for DRAINS and the Rational Method.

While it was of interest to assess the sensitivity of the estimated peak 100 yr ARI flows downstream of Ann Thorn Park to the magnitude of the piped flow routed under the basin, the behaviour of the Ann Thorn Park detention basin included in the **xprafts** model had no impact on the assessment of overland flooding because the Ann Thorn Park detention basin was included in the hydraulic model that assesses the interaction of the piped drainage system and the surface overland flows.

Total 100 yr ARI hydrographs were exported from the **xprafts** model at the boundary of the hydraulic model. Local 100yr ARI hydrographs exported at key locations within the boundaries of the hydraulic model.

A local two-dimensional (2D) hydrodynamic model of the Ann Thorn Park detention basin and the floodplain downstream of Constitution Road (including the lower reaches of the Bowden Street drainage system) was assembled using the two-dimensional unsteady flow (**xpswmm2D**) hydrodynamic program.

In the 2007 study it was proposed to convey the existing overland flows entering the site in two new flow paths in a similar manner to the approach proposed in the 2004 Cardno Willing study.

The first flow path was along the eastern side of the site in the zone between the rear of the proposed buildings and the site boundary. It was proposed to install an outlet chamber at the end of the existing box culvert to direct flows along this flow path. The flow path would generally be formed by trimming the existing bank along the site boundary and providing a flood wall at the rear of the proposed buildings along the edge of the oil pipeline easement. This minimises any structures within the oil pipeline easement. Flows would be directed into a new 24 m long 1.2 m (W) x 0.75 m (H) RCBC installed beside Council's existing drainage easement via a 1.5 m x 3.0 m grated inlet.

The second flow path was also to be formed in the zone between the rear of the proposed buildings and the site boundary to direct overland flows west and along the south western side of the site.

At the south western end of the site it was proposed to prevent 100 yr ARI overland flows from entering the access ramp by creating a local high point in the proposed connector road.

Three hydraulic models were assembled and run. These were models of:

- Existing (2007) conditions (comprising the Ann Thorn Park drainage system and the upgraded Bowden Street drainage system)
- The proposed development at 146 Bowden Street with an amended stormwater measures to manage / convey 100 yr ARI overland flows entering 146 Bowden St;
- Existing conditions with the inlet in Ann Thorn Park substantially upgraded.

Each model was run and various plots of 100 yr ARI flood depths, velocities, velocity x depth and flood levels were prepared.

It was concluded that the 100 yr ARI overland flow downstream of Nancarrow estimated in the 2004 study was highly conservative in comparison with the 100 yr ARI overland flow downstream of Nancarrow estimated in the 2007 study.

It was found that the estimated 100 yr ARI velocity x depths of overland flooding within the development site are less than 0.4 m^2/s except in the eastern swale between the culvert outlet and the grated inlet to the proposed new stormwater culvert that conveys overland flows beneath the proposed road to the Parramatta River. It is proposed to exclude pedestrians from this swale by installing walls and fencing as appropriate. The proposed measures would also safeguard egress from the site via Rothesay Avenue in events up to 100 yr ARI.

It was found that the estimated 100 yr ARI depths of overland flooding under the proposed development condition is typically 0.3 – 0.4 m in the western areas of the site where the approach grades are flatter than 1(V):5(H). While the flood depths in the eastern swale are deeper access to this swale will be limited by the boundary fence and the proposed walls and fencing.

In 2007 further studies were commissioned and undertaken by Ryde City Council and were reported in the following documents:

- Golder Associates (2007a) “Revised Slope Assessment, Constitution Road Embankment”, Letter report, prepared for Ryde City Council, 26 February 2007

- Golder Associates (2007b) “Embankment Breach Assessment, Constitution Road Embankment”, Letter Report, prepared for Ryde City Council, 8 June 2007

- City of Ryde (2007) “Ann Thorn Park, Flood Study Review and Flood Management Strategy”, Report, prepared by Public Works Group Catchments & Asset Unit, June, pp 17

The Golder studies highlighted a major issue with the potential failure of Constitution Road during a 100 yr ARI event that could release a floodwave that would pose an immediate threat to workers and the existing buildings located between Constitution Road and Nancarrow Ave. It was also noted by Cardno Willing, 2008 that the peak flows under the breach scenarios is of short duration and the peak flow would be attenuated by downstream buildings (assuming these buildings remaining intact during an event) and confined overland flow paths before it reaches 146 Bowden St. The diversion wall at 146 Bowden Street will be designed to withstand the hydrostatic and hydrodynamic forces under these conditions.

It is our understanding that in late 2008 Ryde City Council adopted the following strategy to address the risk posed by the potential failure of Constitution Road during a major storm as identified in the qualitative risk assessment reported by Golder Associates, 2007b (refer attached Council drawings):

- Immediately lower Constitution Road by up to 2.45 m to avoid breaches in a major storm (see attached road longitudinal section);
- Construct an upgraded trunk drainage pipeline from Richard Johnson Crescent to the Parramatta River; and
- Construct a 16 m wide overland flowpath route above the upgraded pipeline from Constitution Road to the Parramatta River

It is our understanding that the timing of the construction of the upgraded pipeline and overland flowpath is unknown and will be subject to redevelopment of affected properties between Constitution Road and 146 Bowden Street.

The consequence of the immediate lowering of Constitution Road prior to upgrading of the trunk drainage line will be to increase the frequency of overland flooding downstream of Constitution Road in events up to a 100 yr ARI event. While the risk to persons occupying or working in downstream properties that is posed by a sudden failure of Constitution Road in a 100 yr ARI event or greater (as identified in the qualitative risk assessment reported by Golder Associates, 2007b) is eliminated this lowering of risk in major events is partially offset by the increased risk to persons occupying or working in downstream properties that is posed by more frequent overland flooding downstream of Constitution Road.

An assessment of the potential impacts of climate change induced sea level rise and rainfall increases on flooding of 146 Bowden Street was also undertaken in 2009.

2. OUR METHODOLOGY

The hydrological and hydraulic models that have been already assembled have been extended to create a 1D/2D hydraulic model that includes the lower reaches of the Porters Street subcatchment.

The inputs to the study comprised:

(i) All information on the Bowden St and Ann Thorn Park catchments collected during the previous assessments;
(ii) A copy of the model(s) assembled previously by Cardno Willing;
(iii) Details on the Porters Street drainage system (these have been provided progressively by Council in a number of instalments);
(iv) A copy of available Aerial Laser Scanning (ALS) data provided by Council of the Porters Street subcatchment.
(v) Available information on the updated Masterplan.

The various tasks that have been undertaken are outlined as follows:

Preliminaries

(i) An inception meeting with Client and other team members was held to discuss the project, receive advice on the issues of concern and to discuss any initial concepts for stormwater management previously formulated by others;
(ii) A visit to view the study area was undertaken.

Information Collation, Review and Assessment

(iii) All available relevant information identified as study inputs above and any additional data that may be required was progressively collated and reviewed;

Flooding Assessment – Existing Conditions

(iv) The Bowden St and Ann Thorn Park catchment hydrological model was de-archived and re-run to confirm it gives reported estimates of the 100 yr ARI and PMF flows;
(v) The model was extended to include the Porters St subcatchment;
(vi) The hydrological model was run to estimate flood flows in the 5 yr ARI, 100 yr ARI and PMF events under Existing Conditions

(vii) The hydrological model was modified to represent the Masterplan scenario and run for the 5 yr ARI, 100 yr ARI and PMF events;

(viii) The impact of a 30% increase in 100 yr ARI rainfall on runoff under Masterplan Conditions was assessed;

(ix) Using the supplied detailed survey and/or ALS data and supplied data on existing drainage assets, the **xpswmm2D** model of the Bowden St and Ann Thorn Park catchment was extended to include the Porters St subcatchment;

(x) The hydraulic model was run to estimate flood flows in the 5 yr ARI, 100 yr ARI and PMF events under Existing Conditions;

(xi) the hydraulic model was updated to represent the Masterplan scenario including the proposed trunk drainage upgrade and planned overland flowpaths and was run for the 5 yr ARI, 100 yr ARI and PMF events;

(xii) The impact of a 0.9 m sea level rise on river levels and a 30% increase in 100 yr ARI rainfall on runoff under Masterplan Conditions was assessed.

It should be noted that Existing Conditions was based on the following conditions:

- It was assumed that the approved works on 146 Bowden Street are in place – development of this site is due to commence in the immediate future – but that the lowering of Constitution Road and/or provision of an overland flowpath from Constitution Road to the Parramatta River is not in place; and
- Details on the Porters Street drainage system that were provided progressively by Council up and until 24 August 2010.

The Masterplan Conditions was based on the following elements:

- The approved works on 146 Bowden Street are in place;
- The lowering of Constitution Road as detailed in Ryde City Council drawing titled “Constitution Road, Road and Drainage Reconstruction Plan” dated June 2008;
- Provision of an overland flowpath from Constitution Road to the Parramatta River based on the updated Masterplan;
- Upgrade of the trunk drainage from Ann Thorn Park to the Parramatta River based on the alignment and the trunk drainage design undertaken for the updated Masterplan;
- Upgrade of local drainage within the Ann Thorn Park catchment as defined in the DRAINS model supplied by Council titled “3_Ann Thorn_Proposed Full Upgrade from Belmore St to 146 Bowden.drn” dated 22 April 2010;
- Additional inlets in the vicinity of the Nancarrow Ave low point to remove any inlet limitations;
- Inclusion of proposed drainage augmentation works associated with the Stage 1 development immediately west of Belmore Street and fronting Rothesay Ave;
- The development layout given in the updated Masterplan prepared by Robertson + Marks and dated October 2011 – this Masterplan excludes any sites not owned; and
- Existing conditions were adopted for sites not owned.

3. RESULTS

3.1 Flood Depths

The estimated peak flood depths were plotted for the critical 90 minute storm burst for the 5 yr ARI and 100 yr ARI events. The critical storm burst for the PMF was 60 minutes.

3.2 Flood Velocities

The estimated peak flood velocities were plotted for the critical 90 minute storm burst for the 5 yr ARI and 100 yr ARI events. The critical storm burst for the PMF was 60 minutes.

3.3 Flood Velocity x Depths

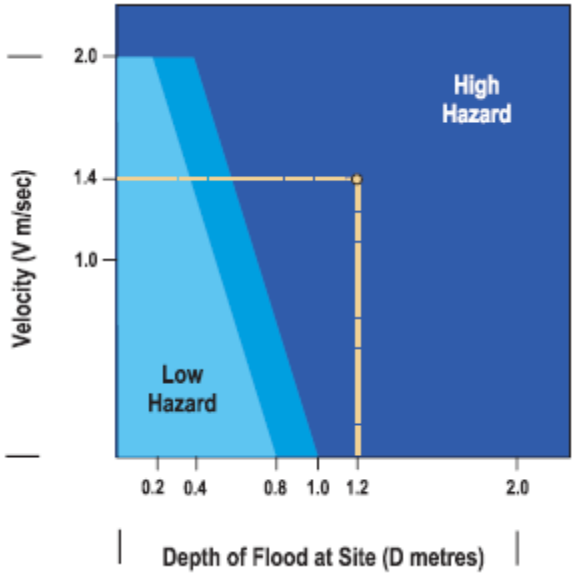
Three zones of velocity x depth were identified based on the following criteria:

Velocity x Depth	Comment
≤ 0.4 m^2/s	This is typically adopted by Councils as a limit of stability for pedestrians
0.4 – 0.6 m^2/s	Unsafe for pedestrians but safe for vehicles if overland flood depths do not exceed around 0.3 m
> 0.6 m^2/s	This is typically adopted by Councils as a limit of stability for vehicles

3.4 Flood Hazard

Experience from studies of floods throughout NSW and elsewhere has allowed authorities to develop methods of assessing the hazard to life and property on floodplains. This experience has been used in developing the Floodplain Development Manual to provide guidelines for managing this hazard. These guidelines are shown schematically below.

To use the diagram, it is necessary to know the average depth and velocity of floodwaters at a given location. If the product of depth and velocity exceeds a critical amount (as shown below), the flood flow will create a high hazard to life and property. There will probably be danger to persons caught in the floodwaters, and possible structural damage. Evacuation of persons would be difficult.



Provisional Hazard Categories
(after Figure L2, NSW Government, 2005)

By contrast, in low hazard areas people and their possessions can be evacuated safely by trucks. Between the two categories a transition zone is defined in which the degree of hazard is dependent on site conditions and the nature of the proposed development.

This calculation leads to a provisional hazard rating. The provisional hazard rating may be modified by consideration of effective flood warning times, the rate of rise of floodwaters, duration of flooding and ease or otherwise of evacuation in times of flood.

3.5 Results

The estimated 5 yr ARI peak flow depths, overland flow velocities, velocity depths and flood hazards in the study area under Existing Conditions are presented **Figures 1, 2, 3** and **4** respectively.

The estimated 100 yr ARI peak flow depths, overland flow velocities, velocity depths and flood hazards in the study area under Existing Conditions are presented **Figures 5, 6, 7** and **8** respectively.

The estimated PMF peak flow depths, overland flow velocities, velocity depths and flood hazards in the study area under Existing Conditions are presented **Figures 9, 10, 11** and **12** respectively.

The estimated 5 yr ARI peak flow depths, overland flow velocities, velocity depths and flood hazards in the study area under Masterplan Conditions are presented **Figures 13, 14, 15** and **16** respectively.

The estimated 100 yr ARI peak flow depths, overland flow velocities, velocity depths and flood hazards in the study area under Masterplan Conditions are presented **Figures 17, 18, 19** and **20** respectively.

The estimated PMF peak flow depths, overland flow velocities, velocity depths and flood hazards in the study area under Masterplan Conditions are presented **Figures 21, 22, 23** and **24** respectively.

A comparison of the results for Existing and Future Conditions that the planned drainage augmentations up to and including Ann Thorn Park in combination with additional inlets in the Nancarrow Ave low point are able to prevent all but minor local overland flows down the proposed overland flowpath between Constitution Road and Shepherds Bay ie. the design intent is met. While overland flows would flow down the flowpath between Constitution Road and Shepherds Bay in the PMF the planned drainage augmentations will reduce the extent of High hazard flooding in comparison with Existing Conditions.

It was also noted that the inclusion of proposed drainage augmentation works associated with the Stage 1 development immediately west of Belmore Street and fronting Rothesay Ave in combination with sufficient inlet capacity to avoid inlet limitations is able to reduce the extent of flood inundation in what is an existing trapped low point.

4. PARRAMATT RIVER FLOOD LEVELS AND CLIMATE CHANGE

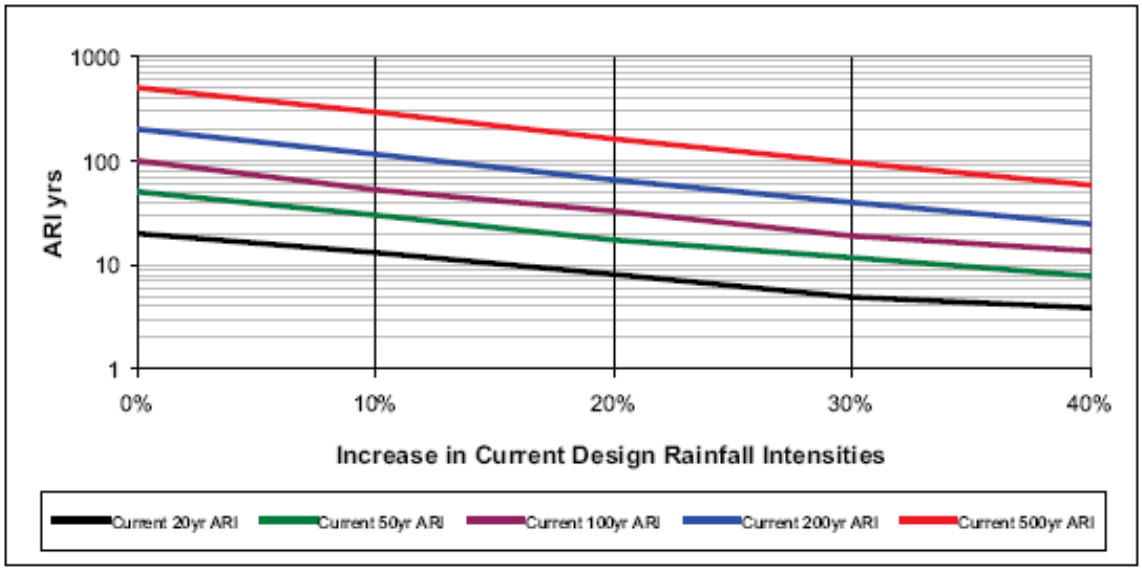
4.1 Practical Consideration of Climate Change

In October 2007 the then NSW Department of Environment and Climate Change (DECC) released a guideline titled “Practical Consideration of Climate Change”.

As discussed in the guideline, climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations.

Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 m to 0.91 m by between 2090 and 2100.

In addition, climate change impacts on flood producing rainfall events show a trend for larger scale storms (rainfall totals for the 40 year average recurrence interval (ARI) 1 day storm events) tend to increase by 2030 and 2070. The diagram below shows the potential impacts of changes in current design ARIs due to increases in rainfall. CSIRO is currently undertaking further work in the area of shorter duration rainfall events which is expected to lead to further advice in this area in the future.



Indicative Change in Design ARI as Rainfall Intensities Increase
(after McLuckie et al, 2005)[1]

DECC, 2007 recommends that the following sensitivity analyses are undertaken:

- Sea level where relevant to a study area:
  - 0.18m (Low Level Ocean Impacts
  - 0.55m (Mid Range Ocean Impacts
  - 0.91m (High Level Ocean Impacts

- Rainfall intensities. Increases of:
  - 10% in peak rainfall and storm volume
  - 20% in peak rainfall and storm volume
  - 30% in peak rainfall and storm volume

until more work is completed in relation to the climate change impacts on rainfall intensities.

[1] McLuckie, D., Lord, D. and Gibbs, J. (2006) "Climate Change – The Future is Uncertain, Practical Consideration of Climate Change in Flood Risk Management in NSW", proceedings, 46th NSW FMA Conference, Lismore, March.

4.2 NSW Sea Level Rise Policy Statement

The NSW Government has released its NSW Sea Level Rise Policy Statement. The policy statement outlines the Government's objectives and commitments to sea level rise. It outlines the support that the Government will provide to coastal communities and local councils to prepare and adapt to rising sea levels.

The primary objective of the Sea Level Rise Policy Statement is to minimise the social disruption, economic costs and environmental impacts resulting from long-term sea level rise. To achieve these objectives, the NSW Government proposes to:

1. promote an adaptive risk-based approach to managing sea level rise impacts;
2. provide guidance to local councils to support their sea level rise adaptation planning;
3. encourage appropriate development on land projected to be at risk from sea level rise;
4. continue to provide emergency management support to coastal communities during times of floods and storms; and
5. continue to provide updated information to the public about sea level rise and its impacts.

To support this adaptive risk-based approach, the NSW Government has adopted a sea level rise planning benchmark. This benchmark is intended to enable consistent consideration of sea level rise within an adaptive risk-based management approach. There is no regulatory or statutory requirement for development to comply with the benchmark. The benchmark's primary purpose is to provide guidance to support consistent consideration of sea level rise impacts, within applicable decision-making frameworks. This will include strategic planning and development assessment under the *Environmental Planning and Assessment Act 1979* and infrastructure planning and renewal.

The NSW sea level rise planning benchmark is an increase **above 1990 mean sea levels** of 40 cm by 2050 and 90 cm by 2100. This was established by considering the most credible national and international projections of sea level rise and takes into consideration the uncertainty associated with sea level rise projections. The NSW Government intends to periodically review this planning benchmark, based on updated information, such as the release of future Intergovernmental Panel on Climate Change assessment reports.

The NSW Government intends that the sea level rise planning benchmark be used for purposes such as:

- incorporating the projected impacts of sea level rise on predicted flood risks and coastal hazards;
- the designing and upgrading of public assets in low-lying coastal areas where appropriate, taking into account the design life of the asset and the projected sea level rise over this period;
- assessing the influence of sea level rise on new development;
- considering the impact of sea level rise on coastal and estuarine habitats, such as salt marshes, and identifying valuable habitats at most risk from sea level rise; and
- assessing the impact of changed salinity levels in estuaries, including implications for access to fresh water.

In its Draft Technical Note on the Scientific Basis of the 2009 Sea Level Rise Benchmark, the NSW Government states that an analysis of tide gauge records from around the world has found that during the 20th century (1870–2001), global sea level rose by 17 cm at a rate of 1.7±0.3 mm per year, with the rate of sea level rise accelerating during the 20th century. Recent data (1993–2007) shows the current global average annual sea level rise to be 3.4 mm per year. Form 1990 to 2010 this equates to around a 0.06 m global average sea level rise.

4.3 Parramatta River Flood Levels

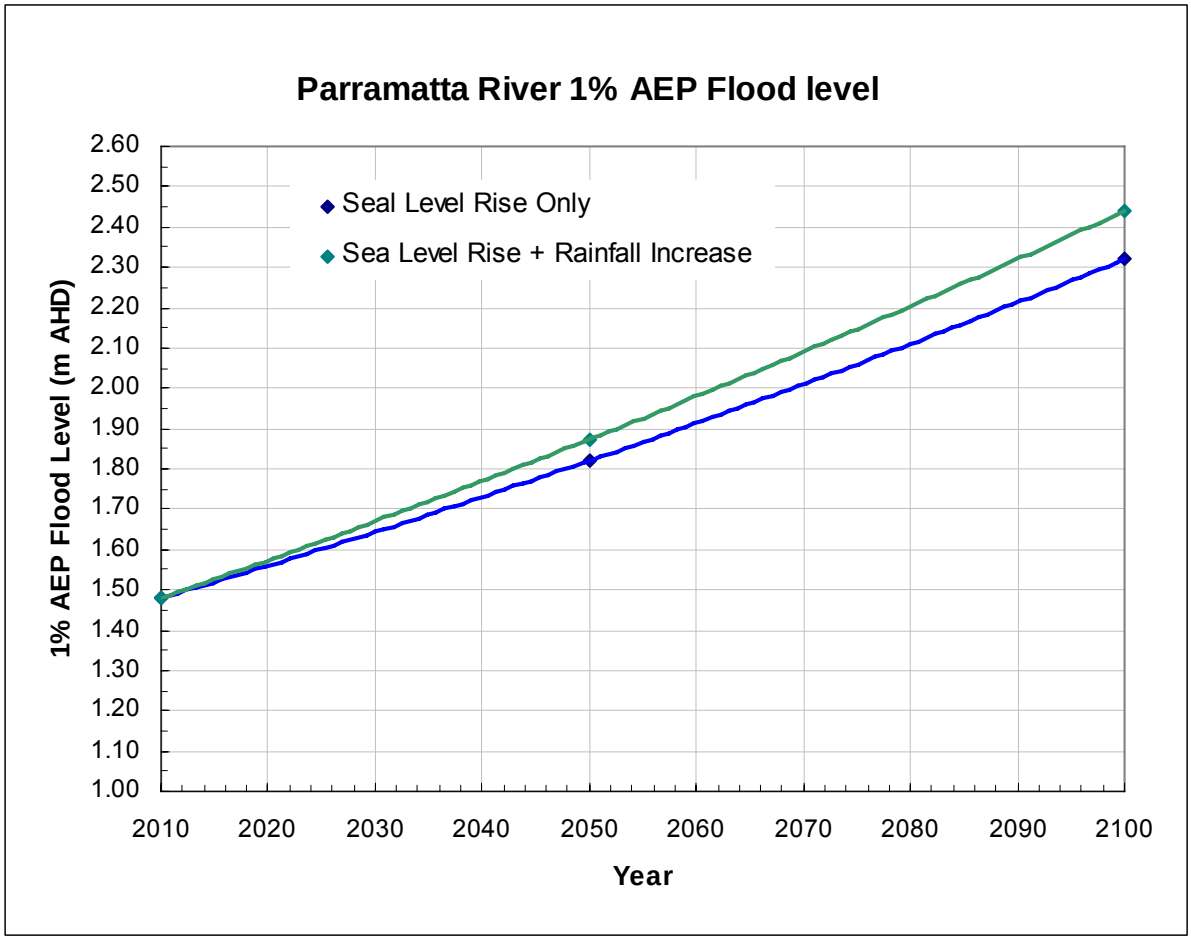
In March 2005 the Lower Parramatta River Floodplain Risk management Study was released by Parramatta City Council. Cross referencing the location of cross sections as given in Figure 4.1 (SKM, 2005) and the modelling results given in Appendix B (SKM, 2005) indicates that the cross section at Chainage 11578 crosses 146 Bowden St. The reported 1% AEP and PMF flood levels at this cross section are:

100 yr ARI flood level	1.42 m AHD
PMF level (approx 1,000,000 yr ARI)	1.80 m AHD

Assuming that the 100 yr ARI flood level is based on 1990 mean sea levels then in 2010 the benchmark 100 yr ARI level would be 1.48 m AHD based on a 0.06 m increase in sea level since 1990. The corresponding 100 yr ARI flood levels in 2050 and 2100 would be 1.82 m AHD and 2.32 m AHD allowing for the NSW sea level rise planning benchmark (excluding the impact of rainfall increases).

The impact of changes in rainfall on 100 yr ARI flood levels in the Parramatta River was based on fitting relations to the reported 5 yr ARI, 20 yr ARI, 50 yr ARI, 100 yr ARI and PMF peak flows and flood levels at Chainage 11578. It was estimated that a 30% increase in 100 yr ARI rainfall would increase the 100 yr ARI flood level by 0.12 m. For assessment purposes it was assumed that this increase would occur linearly from 2010 to 2100.

The predicted variations in the estimated 100 yr ARI Parramatta River flood level at 146 Bowden Street with sea level rise and as a result of rainfall increases are plotted below.



4.4 Overland Flood levels

In accordance with the current DECC guidance, the Masterplan Conditions model was also run with a 30% increase in the 100 yr ARI rainfall intensities.

The estimated 100 yr ARI peak flow depths, overland flow velocities, velocity depths and flood hazards under a 30% increase in the 100 yr ARI rainfall intensities in the study area under Masterplan Conditions are presented **Figures 25, 26, 27** and **28** respectively.

A comparison of the results for Masterplan Conditions with and without climate change adjusted rainfall intensities indicate that the planned drainage augmentations up to and including Ann Thorn Park in combination with additional inlets in the Nancarrow Ave low point are able to prevent all but minor local overland flows down the proposed overland flowpath between Constitution Road and Shepherds Bay under a 100 yr ARI climate change scenario.

It was also noted that a 30% increase in 100 yr ARI rainfall intensities locally increases flooding in the vicinity of the Stage 1 development to a minor extent.

5. CONCLUSIONS

It was concluded that:

(i) The planned drainage augmentations up to and including Ann Thorn Park in combination with additional inlets in the Nancarrow Ave low point are able to prevent all but minor local overland flows down the proposed overland flowpath between Constitution Road and Shepherds Bay under Masterplan Conditions including under a 100 yr ARI climate change scenario ie. the design intent is met;

(ii) While overland flows would discharge down the flowpath between Constitution Road and Shepherds Bay in the PMF the planned drainage augmentations will reduce the extent of High hazard flooding in comparison with Existing Conditions;

(iii) The proposed drainage augmentation works associated with the Stage 1 development immediately west of Belmore Street and fronting Rothesay Ave in combination with sufficient inlet capacity to avoid inlet limitations is able to reduce the extent of flood inundation in what is an existing trapped low point; and

(iv) A 30% increase in 100 yr ARI rainfall intensities locally increases flooding in the vicinity of the Stage 1 development to a minor extent.

We would be pleased to further discuss our proposal with you upon your request.

Yours faithfully

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Dr Brett C. Phillips
Director, Water Engineering
for **Cardno**

Figure 1 5 yr ARI Flood Levels – Existing Conditions

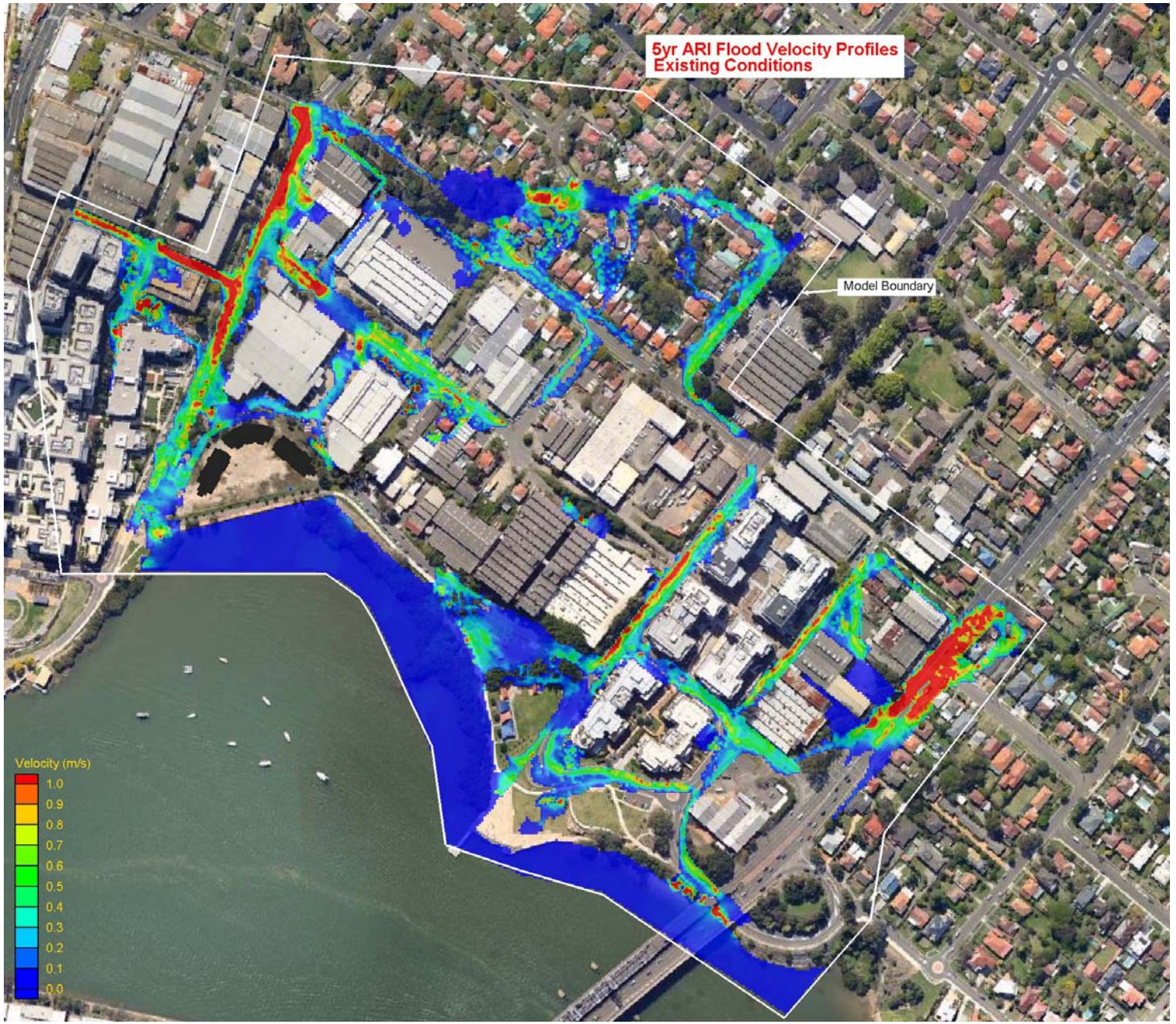

Figure 2 5 yr ARI Flood Velocities – Existing Conditions

Figure 3 5 yr ARI Flood Velocity x Depth – Existing Conditions

Figure 4 5 yr ARI Flood Hazard – Existing Conditions

Figure 5 100 yr ARI Flood Levels – Existing Conditions

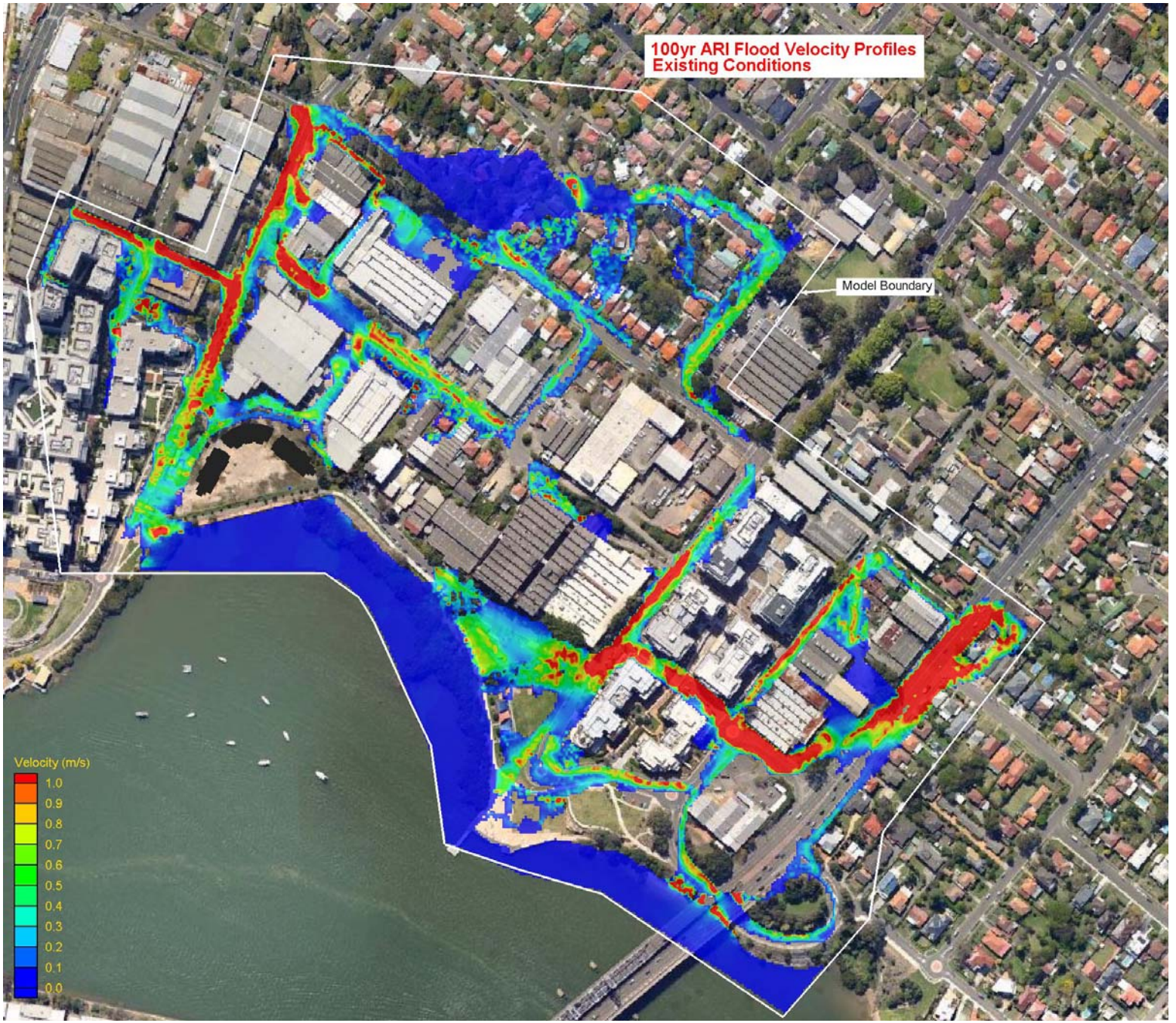

Figure 6 100 yr ARI Flood Velocities – Existing Conditions

Figure 7 100 yr ARI Flood Velocity x Depth – Existing Conditions

Figure 8 100 yr ARI Flood Hazard – Existing Conditions

Figure 9 PMF Flood Levels – Existing Conditions

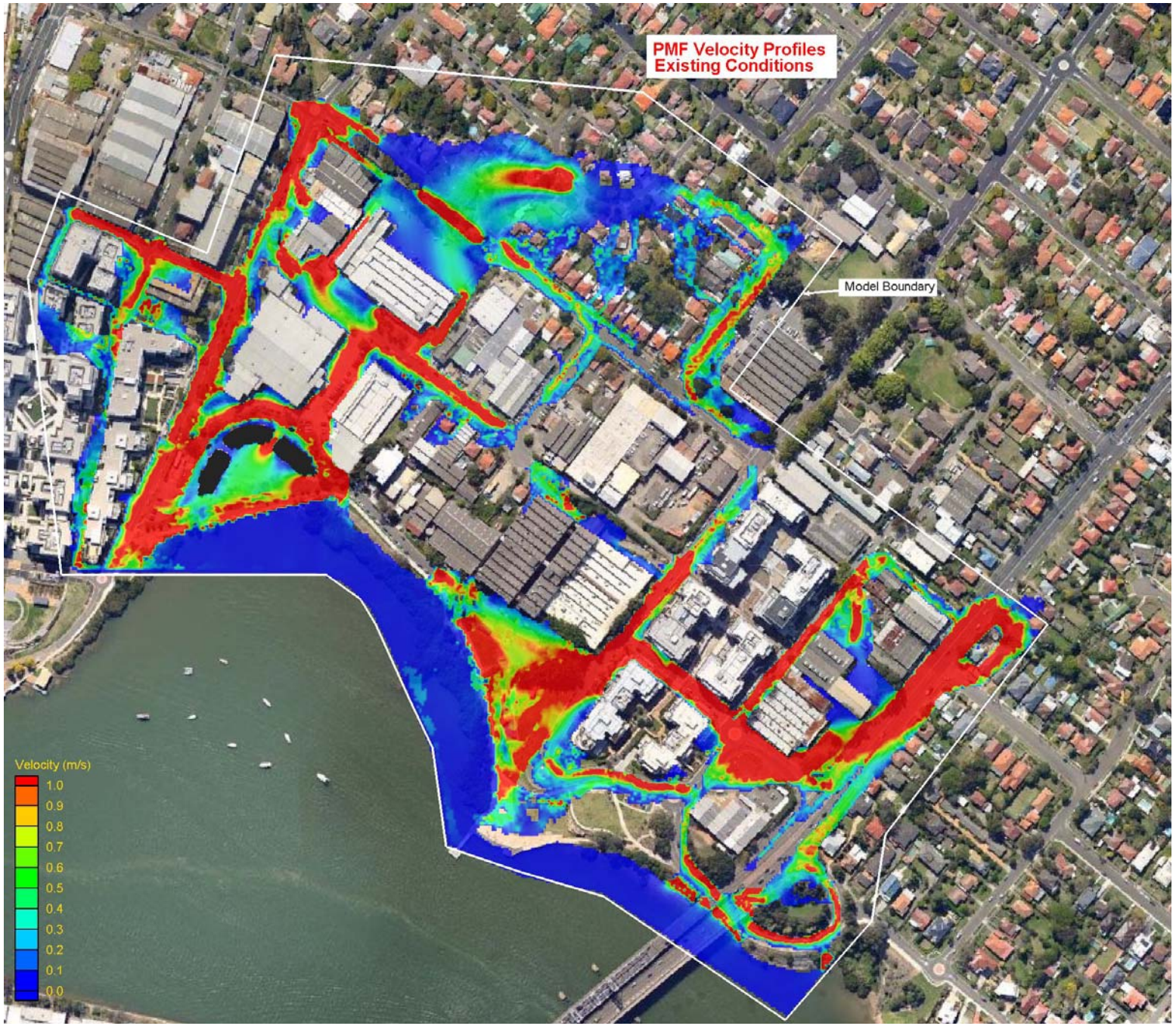

Figure 10 PMF Flood Velocities – Existing Conditions

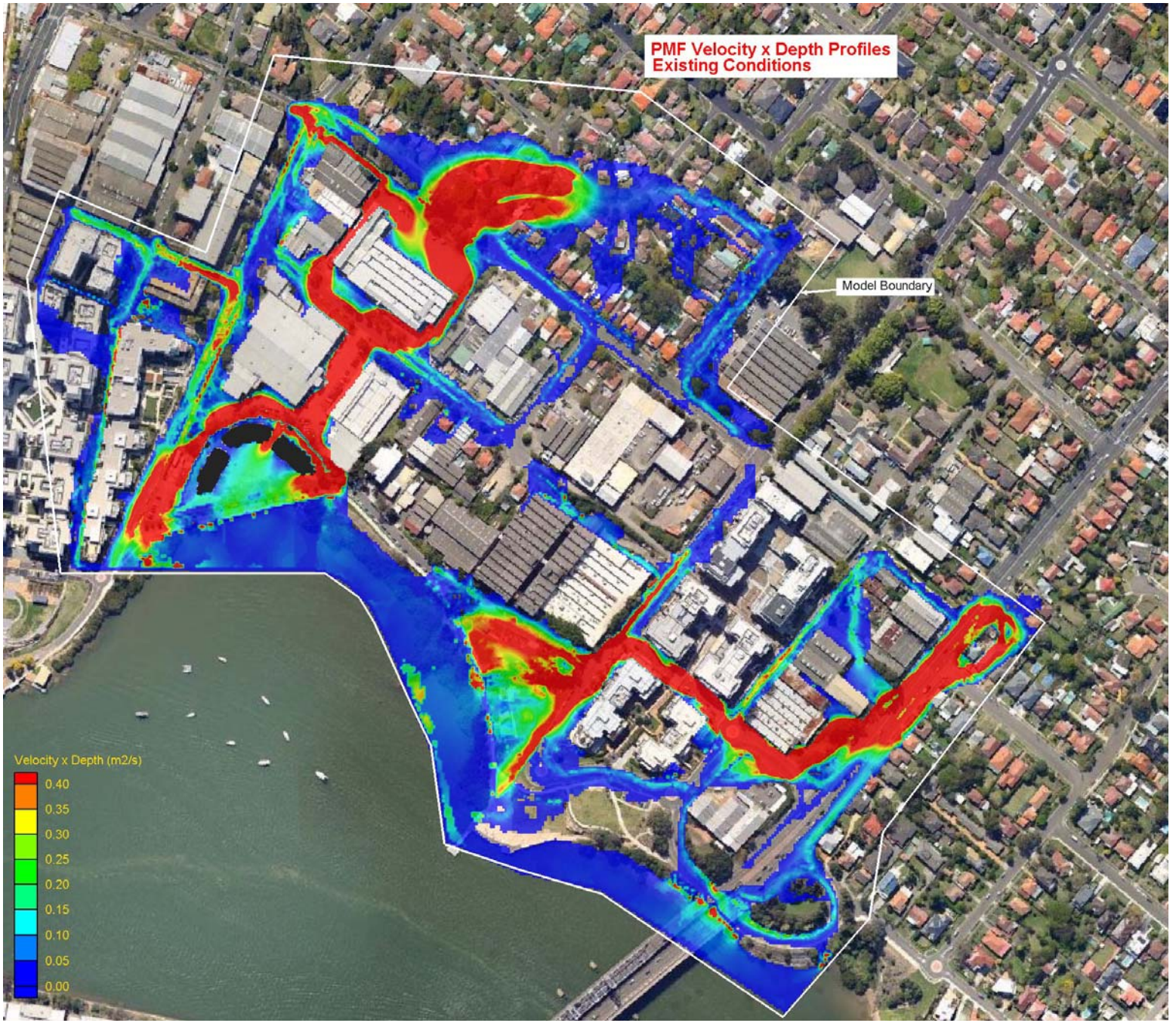

Figure 11 PMF Flood Velocity x Depth – Existing Conditions

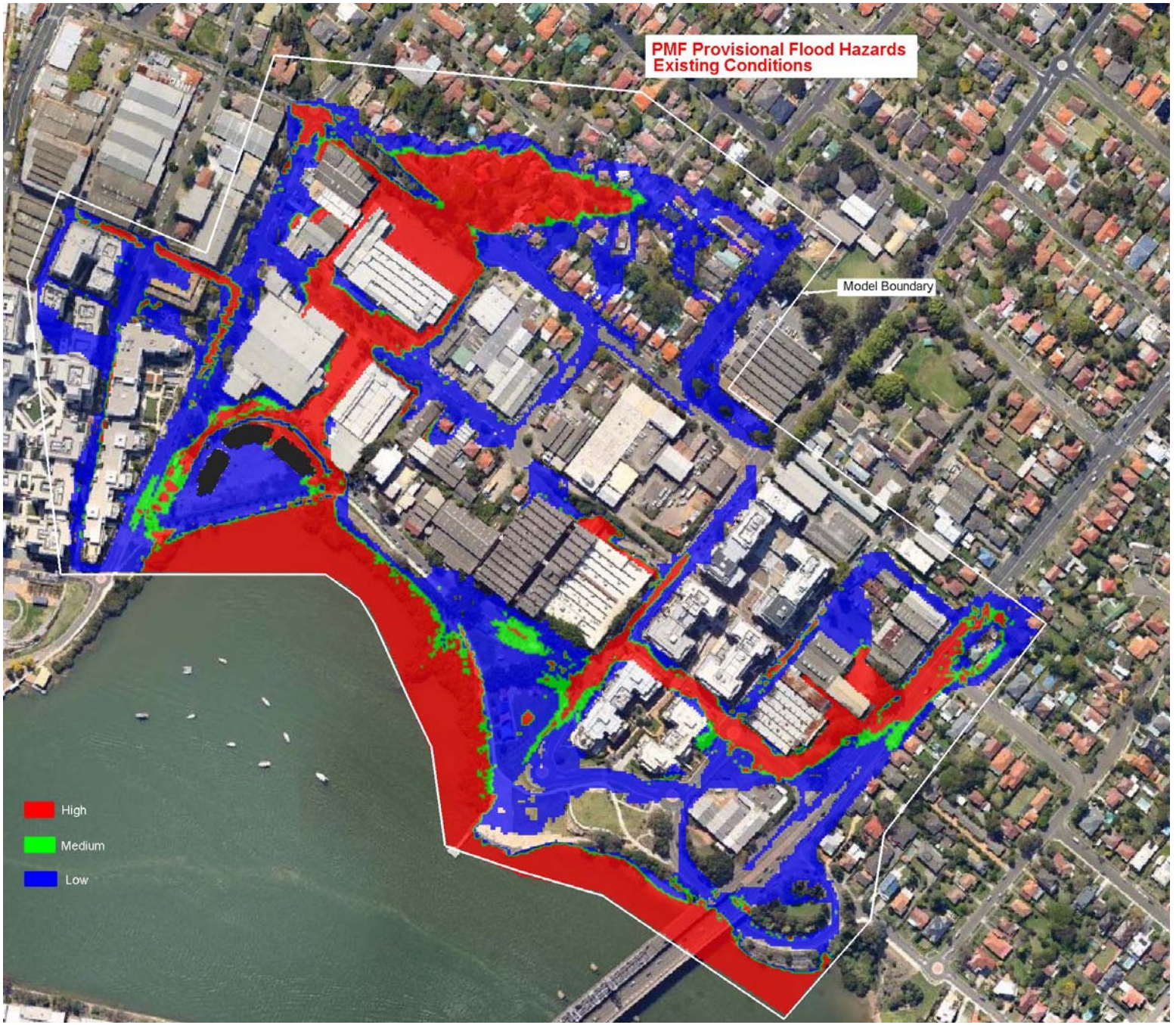

Figure 12 PMF Flood Hazard – Existing Conditions

Figure 13 5 yr ARI Flood Levels – Future Conditions

Figure 14 5 yr ARI Flood Velocities – Future Conditions

Figure 15 5 yr ARI Flood Velocity x Depth – Future Conditions

Figure 16 5 yr ARI Flood Hazard – Future Conditions

Figure 17 100 yr ARI Flood Levels – Future Conditions

Figure 18 100 yr ARI Flood Velocities – Future Conditions

Figure 19 100 yr ARI Flood Velocity x Depth – Future Conditions

Figure 20 100 yr ARI Flood Hazard – Future Conditions

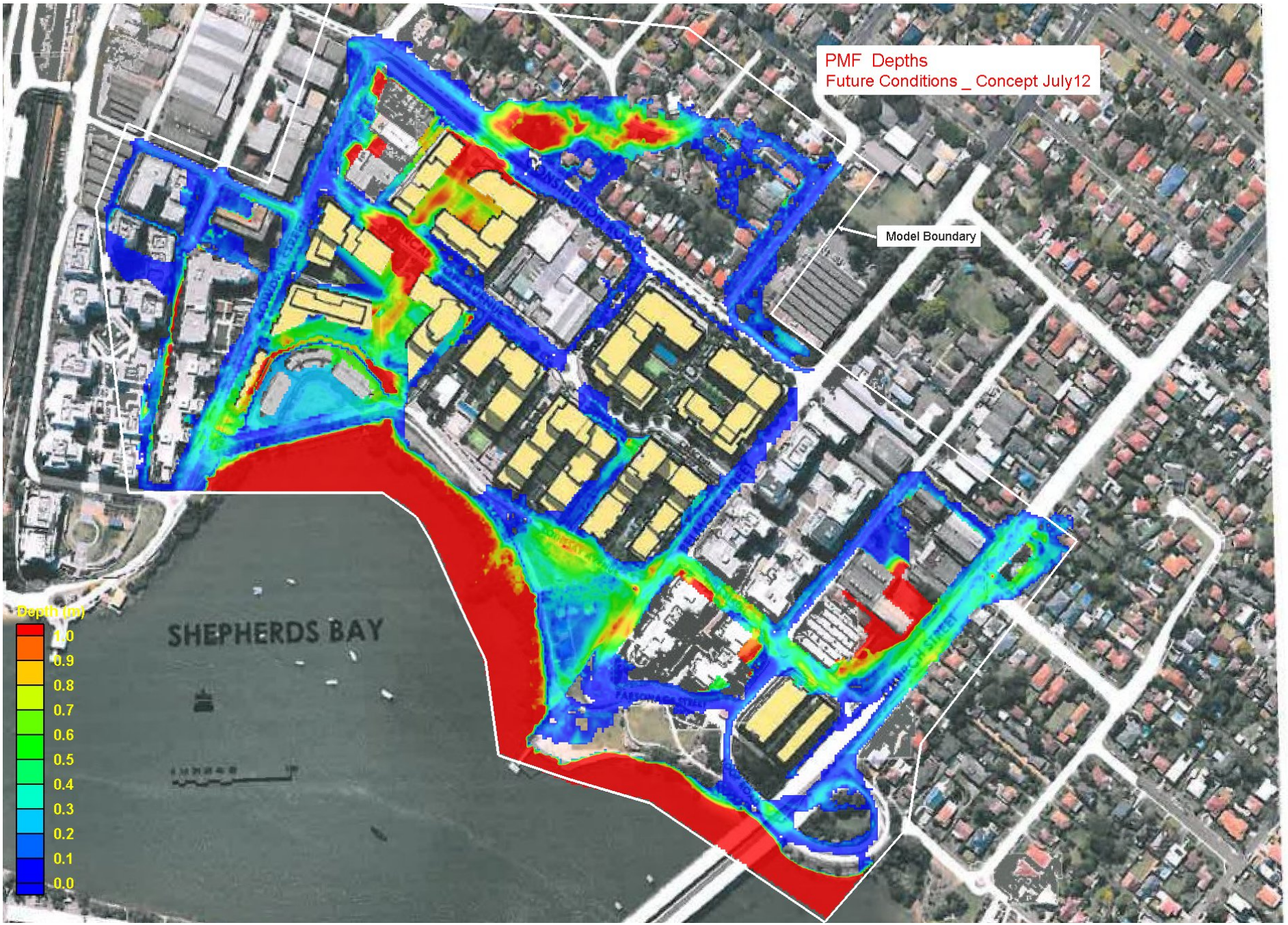

Figure 21 PMF Flood Levels – Future Conditions

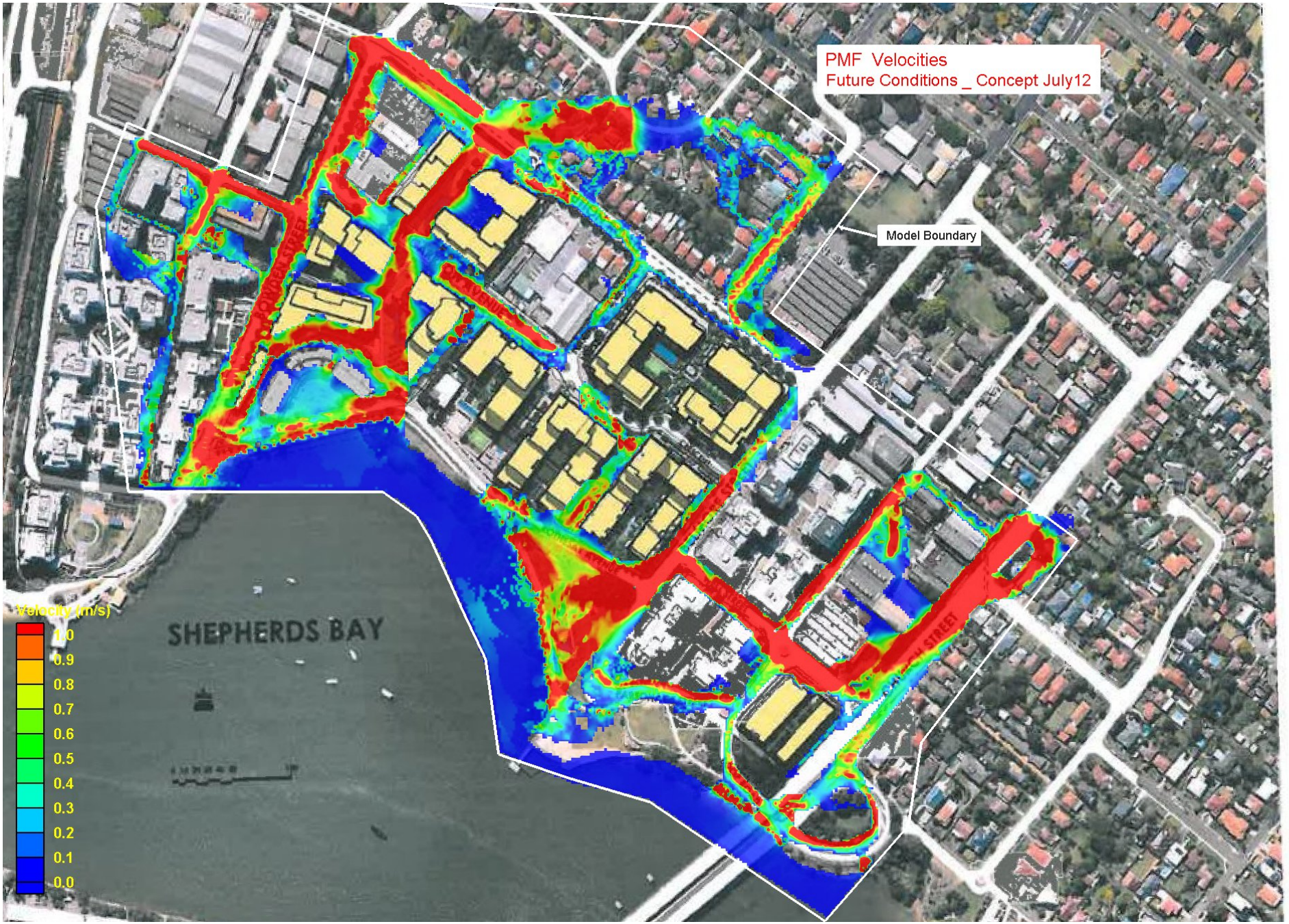

Figure 22 PMF Flood Velocities – Future Conditions

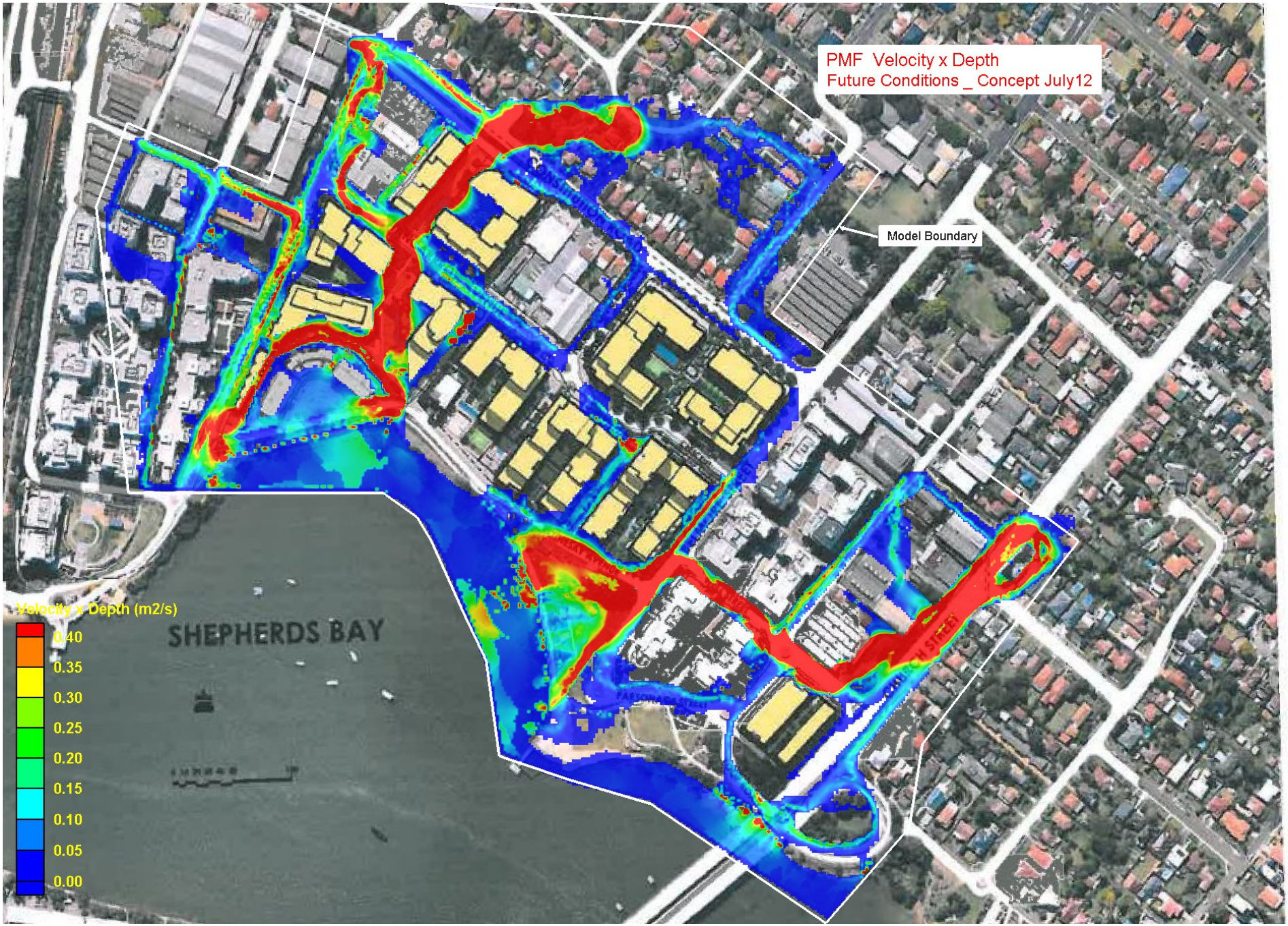

Figure 23 PMF Flood Velocity x Depth – Future Conditions

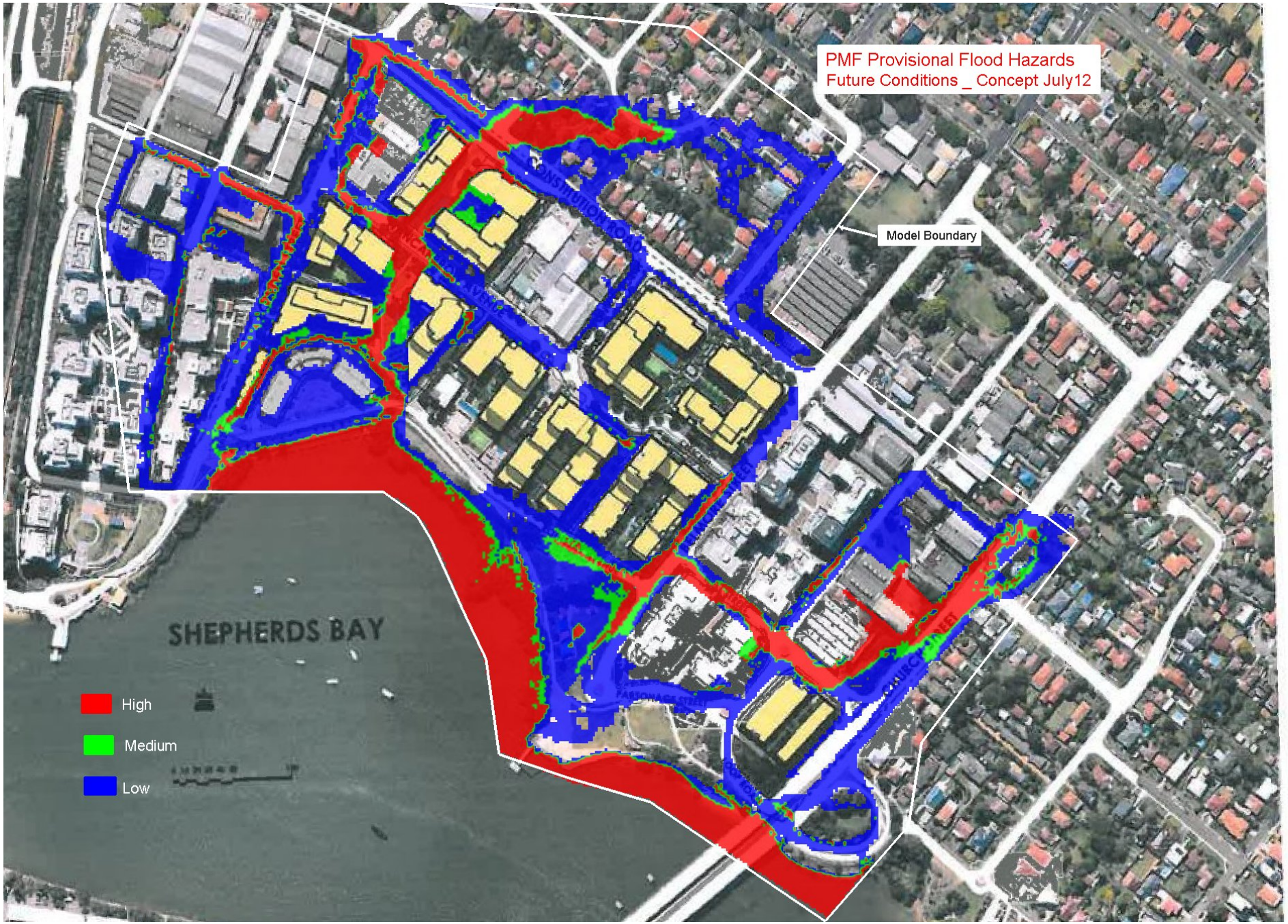

Figure 24 PMF Flood Hazard – Future Conditions

Figure 25 100 yr ARI Flood Levels – Future Conditions + 30% Increase in Rainfall

Figure 26 100 yr ARI Flood Velocities – Future Conditions + 30% Increase in Rainfall

Figure 27 100 yr ARI Flood Velocity x Depth – Future Conditions + 30% Increase in Rainfall

Figure 28 100 yr ARI Flood Hazard – Future Conditions + 30% Increase in Rainfall