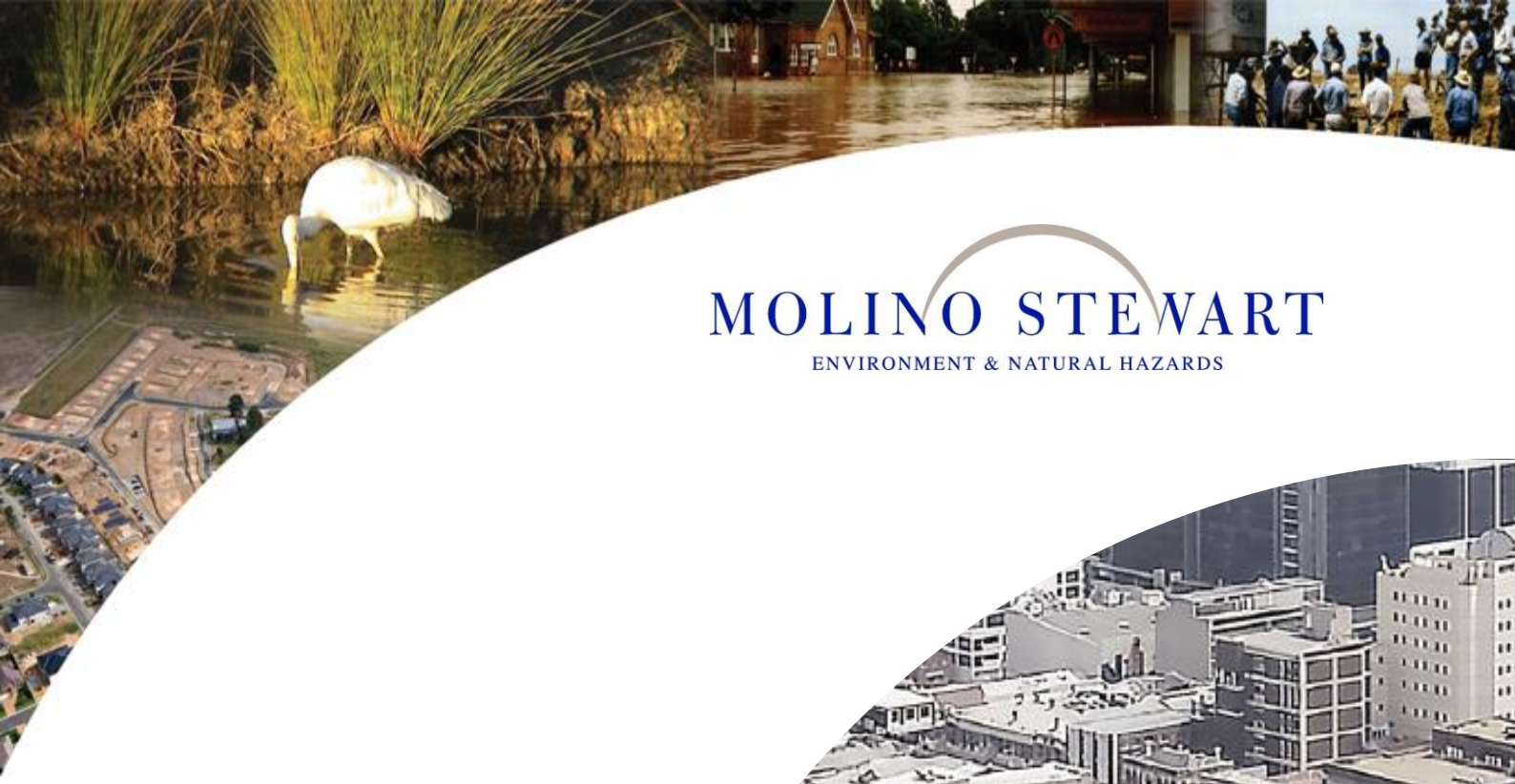

MOLINO STEWART

ENVIRONMENT & NATURAL HAZARDS

Powerhouse Museum Alliance

Parramatta Powerhouse EIS

Flood Risk Review

MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

Parramatta Powerhouse EIS

FLOOD RISK REVIEW

for

Powerhouse Museum Alliance

by

Molino Stewart Pty Ltd
ACN 067 774 332

JULY 2020

MOLINO STEWART PTY LTD ABN 95 571 253 092 ACN 067 774 332
PO BOX 614, PARRAMATTA CBD BC, PARRAMATTA NSW 2124 TEL: (02) 9354 0300 FAX: (02) 9893 9806
www.molinostewart.com.au

DOCUMENT CONTROL

Document Reference	1194 Phillip St Parramatta Powerhouse Museum EIS Review - Flood_v2
Project	Parramatta Powerhouse EIS
Document Type	Flood Risk Review
Author	Steven Molino

REVISION HISTORY

Date	**Version**	**Name**	**Comments**
17/072020	1.0	Steven Molino	Draft for internal review
28/07/2020	1.1	Steven Molino	Draft for client comment
31/07/2020	2.0	Steven Molino	Final

DOCUMENT APPROVAL

For Molino Stewart	
Name	Steven Molino
Position	Principal
For Powerhouse Museum Alliance	
Name	Kylie Winkworth
Position	Museum and Heritage Consultant

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1 INTRODUCTION

1.1 CONTEXT

In 2014, the NSW State Government announced the Powerhouse Museum would be moved from its location in Ultimo to Parramatta. A site was selected for the proposed Powerhouse District on the southern bank of the Parramatta River on Phillip Street, between Church Street and Wilde Avenue. The proposed new cultural precinct in Parramatta is expected to attract about one million people per year.

As it is located directly on the bank of the Parramatta River, the site is exposed to flooding from the both the river and local overland flooding in events as frequent as the 20 year ARI (Average Recurrence Interval) flood, but it is likely that minor flooding would occur even in more frequent events.

The Powerhouse Museum Alliance, as well as a number of community members, have raised concerns regarding the overall appropriateness of choosing to construct a major community development at this location.

Flooding can affect the proposed museum in many ways and carries a number of risks. These include:

- The risk posed to museum visitors and staff inside the building;
- The risk posed to people outside of the building, particularly in the public outdoor areas throughout the precinct;
- The risk posed to the museum collections from direct contact with flood waters
- The risk posed to museum collections which do not come in direct contact with floodwaters but which may suffer damage from increased humidity within a flooded building;
- The extent to which the proposed development will impact local flood behaviour, and potentially result in increased flood risk for the neighbouring properties;
- The risk posed by flooding to the proposed building, in terms of damage to property.

An Environmental Impact Statement (EIS) was prepared for the proposed museum and placed on Public Exhibition on 10 June 2010. Molino Stewart was commissioned by the Powerhouse Museum Alliance to independently review the EIS, including its technical appendices in relation to flood risks and their management.

1.2 SCOPE OF THIS REPORT

This report is based on a review of the following documents available on the Department of Planning Infrastructure and Environment (DPIE) Major Project Planning Portal:

- The report titled “Powerhouse Precinct Parramatta- international Design Competition - Stage 2 Design Brief”, which outlined the design requirements for the architectural competition, from which the Moreau Kusunoki Genton design was selected as the winner;
- Planning Secretary’s Environmental Assessment Requirements 10/2/2020
- Powerhouse Museum EIS
- Appendix B Architectural Plans
- Appendix C Landscape Report
- Appendix O Flood Risk and Stormwater

The review considered:

- The adequacy and accuracy of the flood modelling and the appropriate use of the flood model results (Section 2)
- The building and landscape design responses to the flood risks (Section3);
- The adequacy of the impact assessment and proposed mitigation measures in relation to flooding and its impacts on:
  - the museum building and its infrastructure;
  - museum collections;
  - museum visitors and staff;
  - people in the public domain (Section 4).

2 FLOODING AFFECTATION

2.1 TYPES OF FLOODING

The Powerhouse Museum site is affected by two types of flooding:

- Riverine flooding, where the Parramatta River rises and overflows onto the site;
- Overland flooding, where water which exceeds the capacity of the underground street drainage network runs through the streets and other open space areas between buildings on its way to the Parramatta River.

Figure 20 from Appendix O of the EIS (reproduced on the next page as Figure 1) shows the stormwater drainage catchments and underground pipe network which drain through the museum site to the River.

2.2 FLOOD MODELLING

As explained in Appendix O to the EIS, there is currently no publicly available accurate flood modelling for the site undertaken using contemporary flood modelling methods.

The City of Parramatta Council's (CoPC) officially adopted flood levels for the site are taken from a poorly documented, one dimensional computer model developed using 1987 rainfall and runoff methodologies. Council has recently commissioned a contemporary two dimensional flood model using 2019 rainfall and runoff methodologies. This has been peer-reviewed but cannot be used yet as it has not yet been formally endorsed and adopted by Council.

A preliminary two dimensional flood model was developed by Taylor Thomson Whitting (TTW) for early design work but Appendix O indicates that it was not fit for purpose.

Arup therefore developed a two dimensional flood model specifically for the project and this has been used for all of the flood assessment work in the EIS.

A major limitation of the Arup model is that it had to be calibrated against the flood levels adopted by CoPC and therefore had to use the 1987 rainfall and runoff methodologies.

Nevertheless, Arup was permitted to compare its its model results with those of the yet to adopted CoPC flood model which use the 2019 rainfall and runoff methodologies.

Figure 2, (Appendix O Figure 16) compares the flood levels along the Parramatta River through the CBD as estimated by the currently adopted CoPC model, the contemporary CoPC model and the Arup model. It shows the levels for the 5% annual exceedance probability (AEP) and 1% AEP floods and the probable maximum flood.

While the Arup levels differ from those of the other two models, the differences between all three models in the vicinity of the museum site are generally less than 0.5m. Furthermore, the riverine flood levels are lower than the overland flood levels up to the 1% AEP and therefore the accuracy of the riverine flood levels are not critical to the design of the building and any flood emergency response measures. Accordingly, it is my opinion that the Arup model and its results are suitable for use as an interim tool for providing indicative flood information for the site, the museum design and impact assessments in relation to riverine flooding until Council's contemporary flood model has been adopted.

What Appendix O does not provide is a comparison between the overland flood levels in Council's two models and those in the Arup model and yet it is Arup's overland flood levels which have been used for determining the ground floor level for the building.

It is noted that Appendix O includes a flood certificate from CoPC which covers the site and provides flood levels for selected cross sections. All of the listed cross sections are along the river and none are for the model cross sections in Phillip Street or Dirrabarri Lane.

Furthermore, an important consideration in overland flow modelling is the assumed blockage of pipes and inlet structures. Appendix O claims to have included appropriate blockage factors for stormwater pits in the flood modelling but does not state what those factors are.

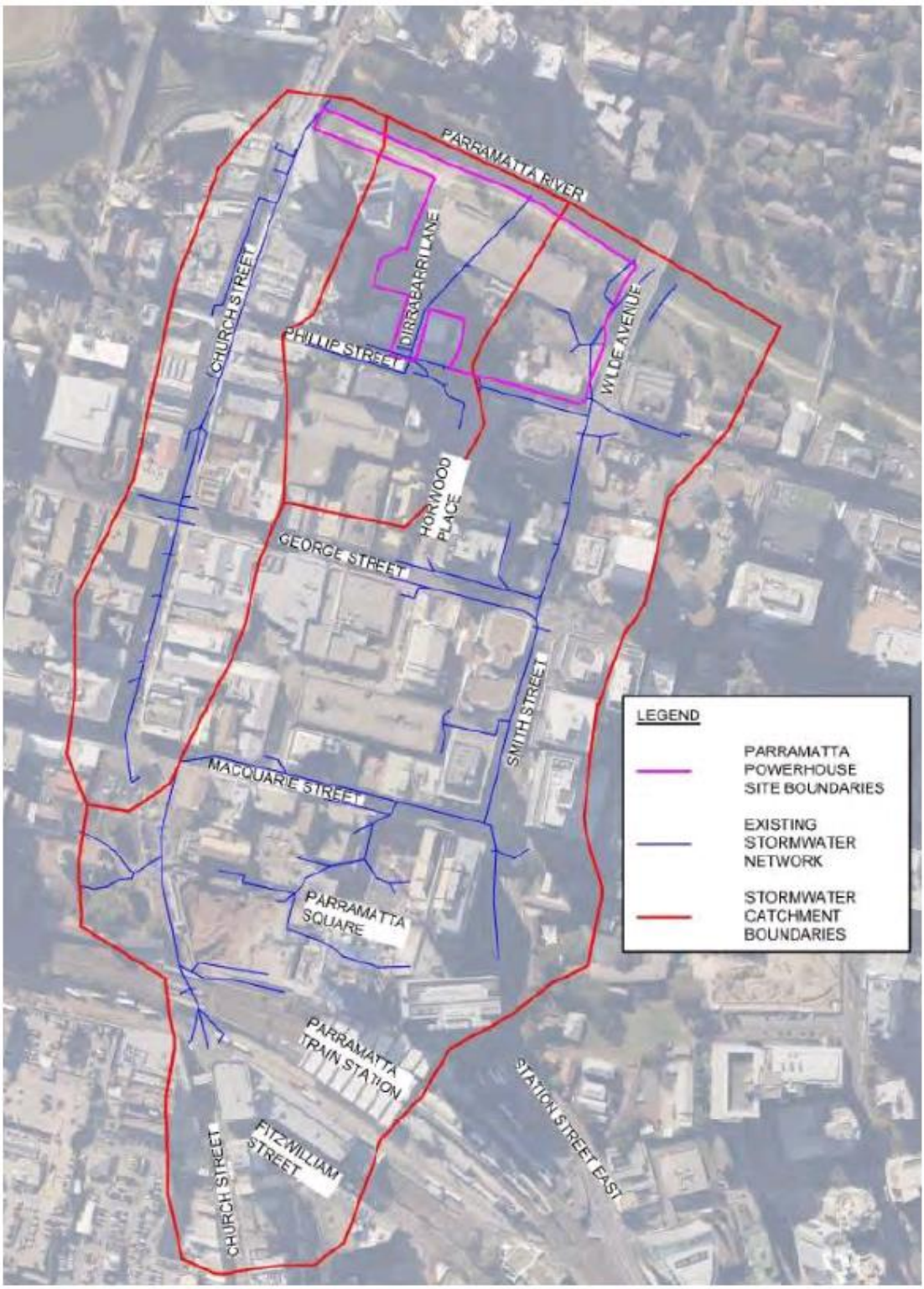

Figure 20: Existing stormwater drainage infrastructure catchment plan for areas in close proximity to the Powerhouse Parramatta development site

Figure 1: Stormwater Catchments and Pipes

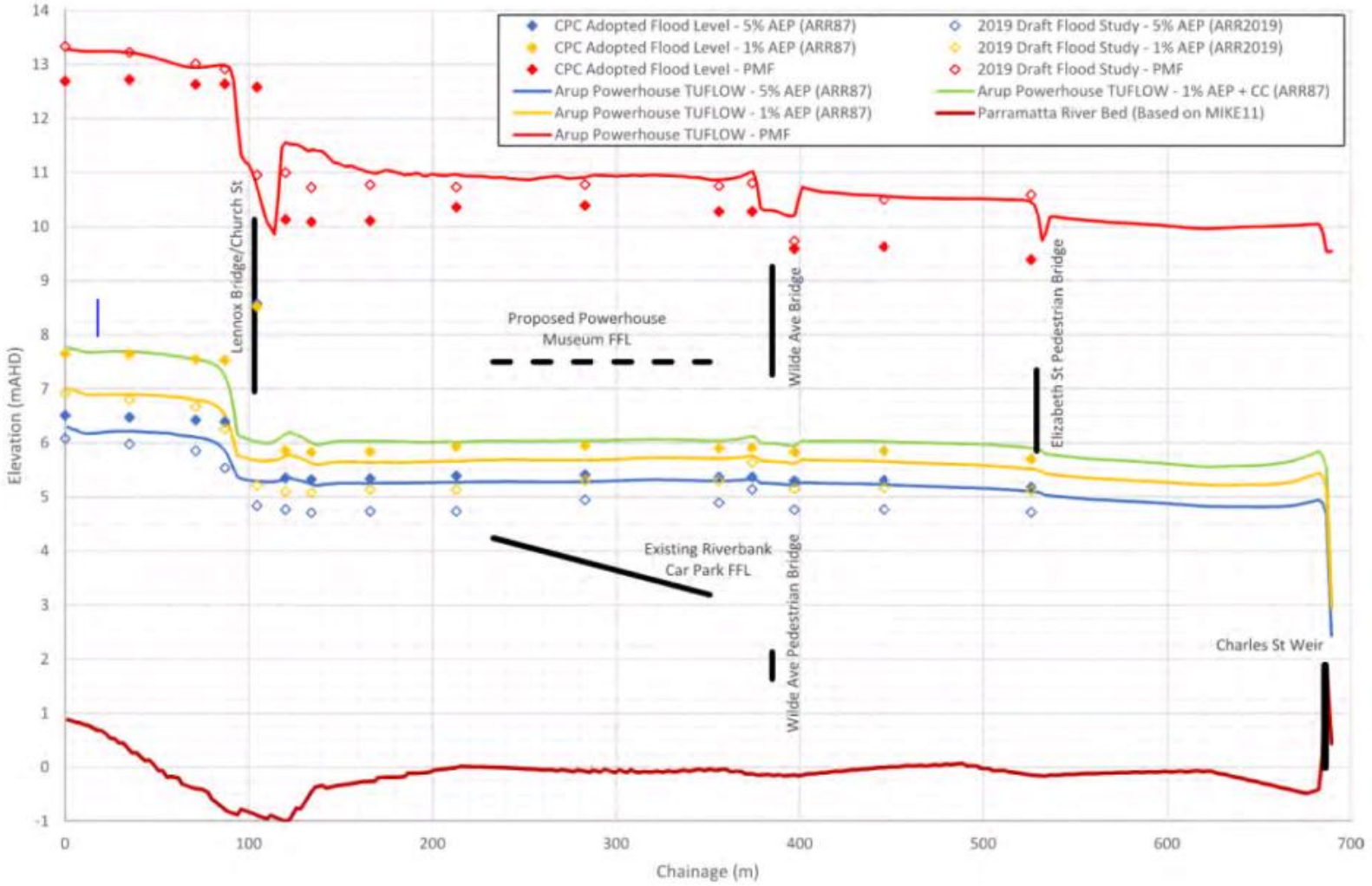

Figure 16: Parramatta River peak flood levels – longitudinal section comparing the results of the various flood model simulations of the river behaviour

Figure 2: Comparison of flood model results

It is my understanding that CoPC adopts a 100% blockage factor in its overland flood modelling which is certainly not what Arup has adopted and in this regard the Arup modelling is not consistent with Council's overland flood modelling approach. The criticality of this is discussed in more detail in Section 3.2.It is my opinion that detailed design must be based on Council's new flood model or one which is calibrated to it.

2.3 KEY FLOOD EFFECTS

All of the models show that the northern parts of the site are dominated by riverine flooding while the southern parts of the site are dominated by overland flooding.

For example, in a 5% AEP storm event, the peak flood level along Phillip Street is 7.0m AHD but a 5% AEP flood in the Parramatta River only reaches 5.3m AHD. However, the flood depths on the southern part of the site are less than 0.5m deep but on the northern parts of the site are more than 2m deep.

Figure 3, 4 and 5 are taken from Appendix O and show the flood levels and depths for the 5% AEP, 1% AEP and PMF. The only other flood event which has been modelled is the 1% AEP flood with climate change.

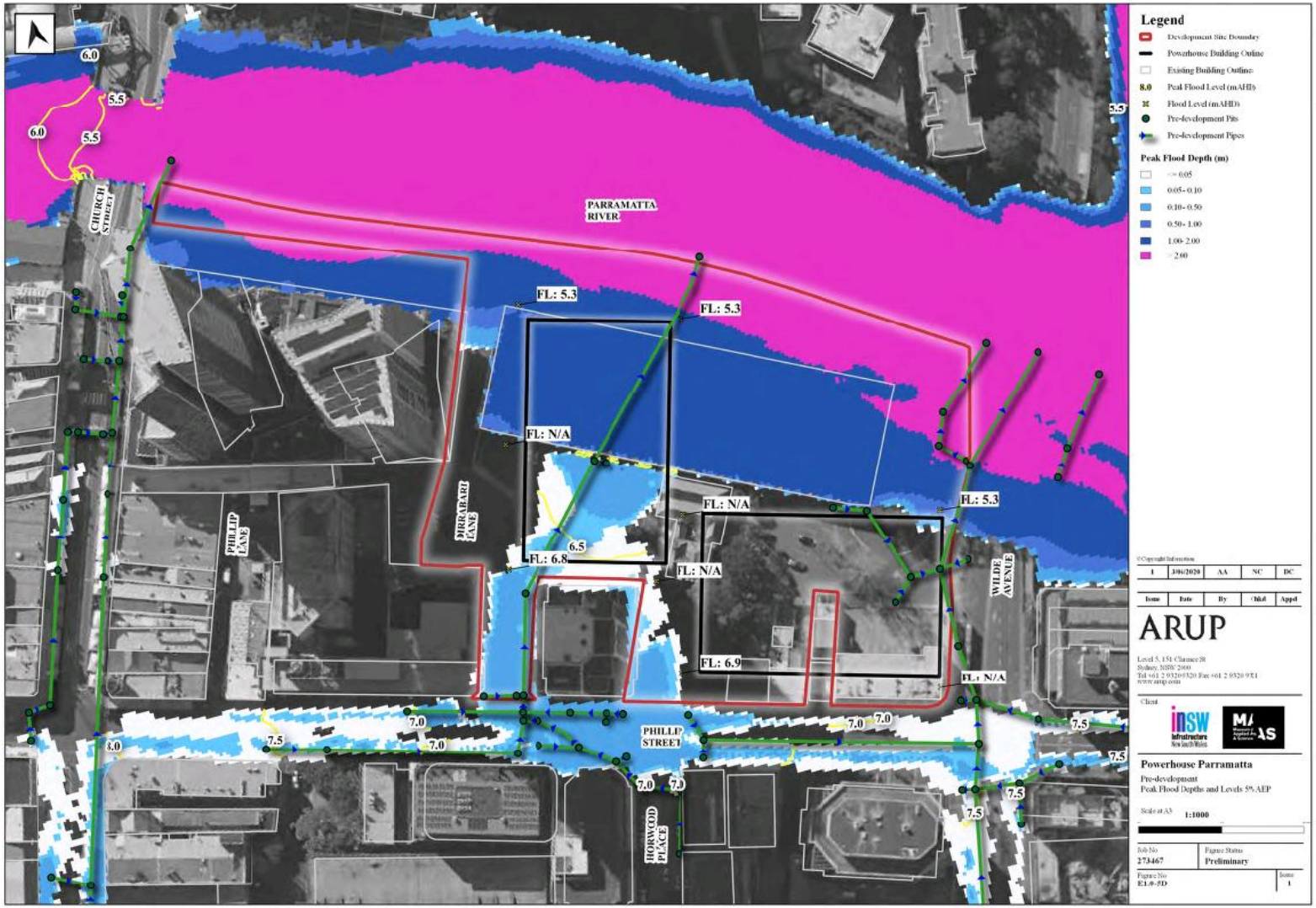

Figure 3: 5% AEP Flood Levels and Depths

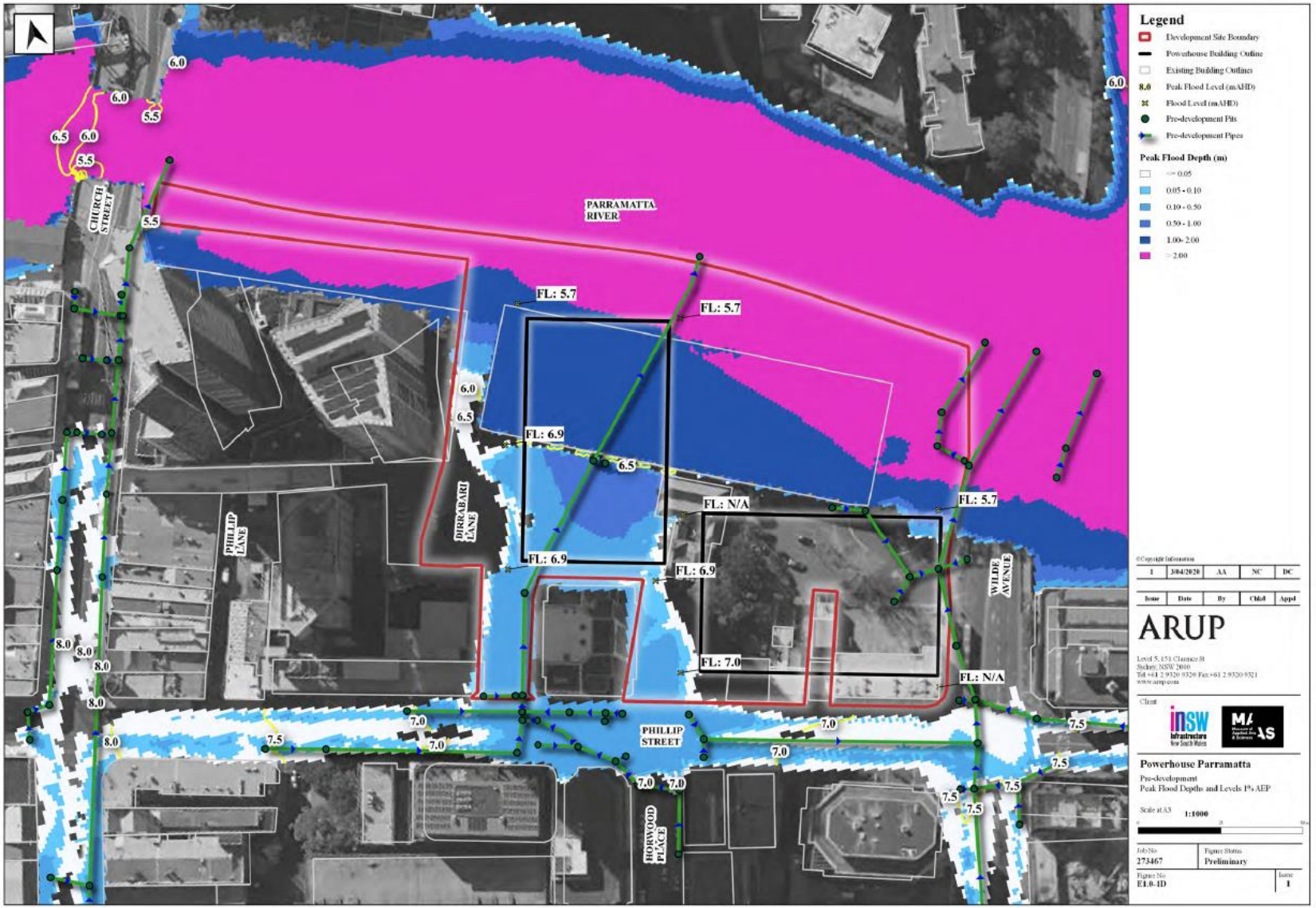

Figure 4: 1% AEP Flood Levels and Depths

Figure 5: PMF Flood Levels and Depths

3 DESIGN RESPONSE TO FLOODING

3.1 RESPONSE MEASURES

Appendix B – Architectural Plans makes no reference to flooding. Appendix C – Landscape Report discusses the design response to flooding and focussed solely on the 1% AEP flood. It proposes an undercroft space under the western building and an undercroft space under the terrace north of the eastern building. The EIS states that the purpose of these undercrofts is to ensure that there is no loss of flood storage or flood conveyance compared to the current riverside spaces in the 1% AEP flood. Their function is illustrated in Figure 6.

With regard to other design responses to flooding they are discussed in the most detail in Appendix O. Section 8.4 of Appendix O summarises the flood risk management strategy as:

"The Powerhouse Parramatta development proposal seeks to provide passive flood protection of the development up to the 1% AEP plus 0.5 m freeboard, which is also a requirement stipulated by the Parramatta DCP 2011. To facilitate the tie-in of the development Finished Floor Level (FFL) with the surrounding ground elevation, there would be modification to the existing ground levels as part of the regrading works undertaken for the public domain. The flood risk management strategy proposed herein strives to achieve a balance whereby the impact of the civil works on existing flood storage and flow conveyance on site can be reduced to a minimum, and consequently the adverse impacts on neighbouring properties would be negligible.

The main challenge, therefore, is to replicate the existing flood behaviour for both mainstream flooding from Parramatta River as well as the Parramatta CBD overland flow flooding. Our proposed approach seeks to manage these two flooding mechanisms concurrently but separately making use of the undercroft spaces, open spaces at similar levels to the riverbanks and located below the built form of the Powerhouse Parramatta development.

The strategy is to make use of the architectural undercroft spaces together with the open landscape area north of the buildings to provide mainstream flood storage and maintain existing elevations. The overland flow flooding that is known to occur on the existing on-grade car park shown in Figure 17 must be mitigated, principally by raising ground levels, to facilitate the new West Building. The displaced overland flow flooding will be managed with new conveyance infrastructure.

Further, the Ø600 mm trunk drainage will be relocated to facilitate the new building footprint. Hence, the proposed flood risk management strategy serves to offset the negative effects generated by these changes to the pre-development flood behaviour."

Figure 7 shows the proposed arrangements for managing overland flows.

In relation to power supply Appendix O states:

"Consideration has also been given to the locations and elevation of proposed development substations to mitigate against a flood risk as described in Section 7.6. The minimum Endeavour Energy requirement for substation flood protection is the 1% AEP flood level and advice has been provided to the electrical engineering team to achieve this outcome. Efforts will also be made to exceed this level of flood protection where reasonably practical to offer enhanced risk mitigation."

3.2 DISCUSSION

3.2.1 Ground Floor Levels

The document correctly states that Parramatta DCP requires that minimum floor levels need to be 0.5m above the 1% AEP flood level, but the DCP makes no distinction between overland flooding and riverine flooding. The 0.5m freeboard is to account for uncertainties in the modelling and irregularities in the flood surface.

Flood Response Study

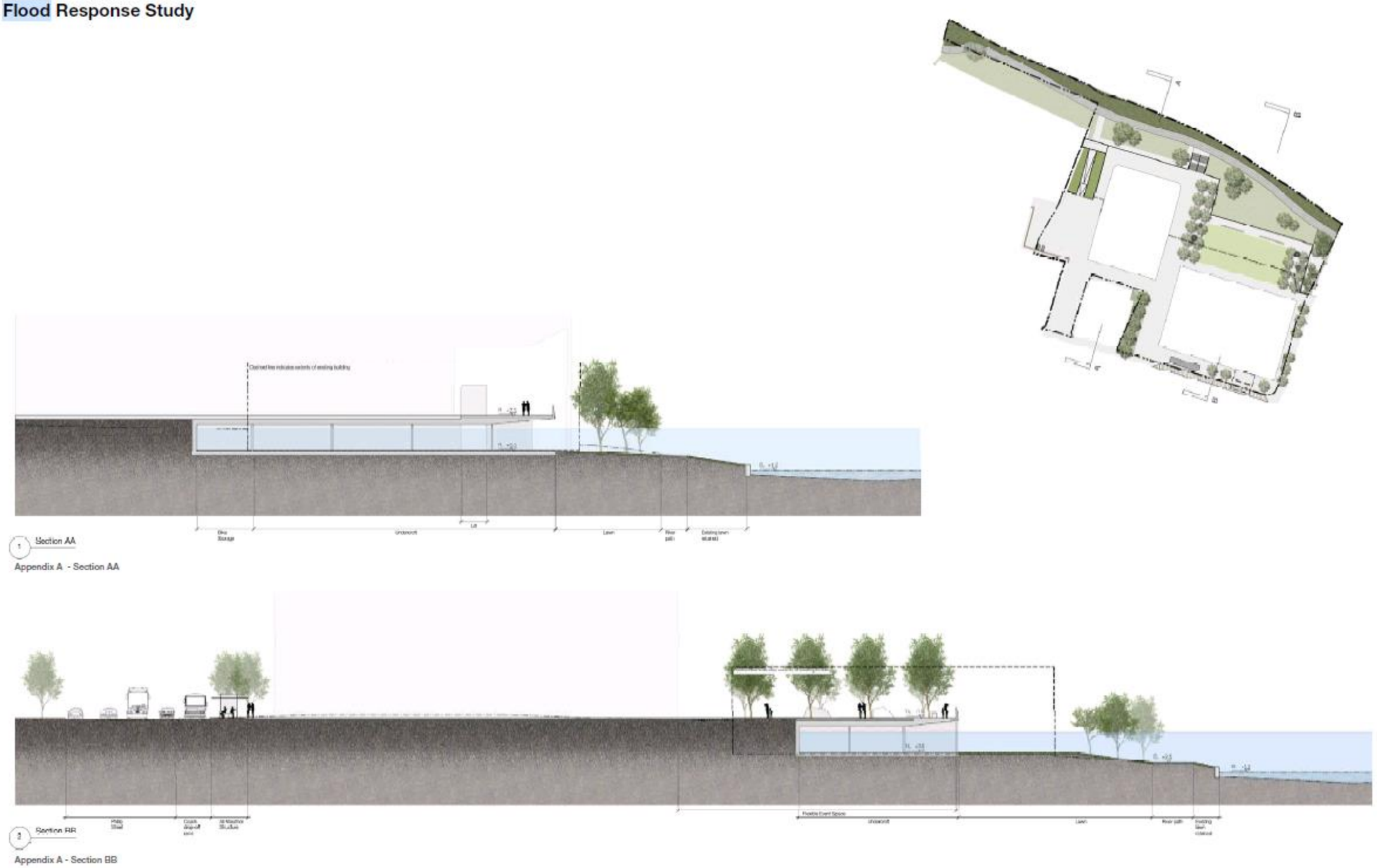

Figure 6: Undercroft Flood Spaces

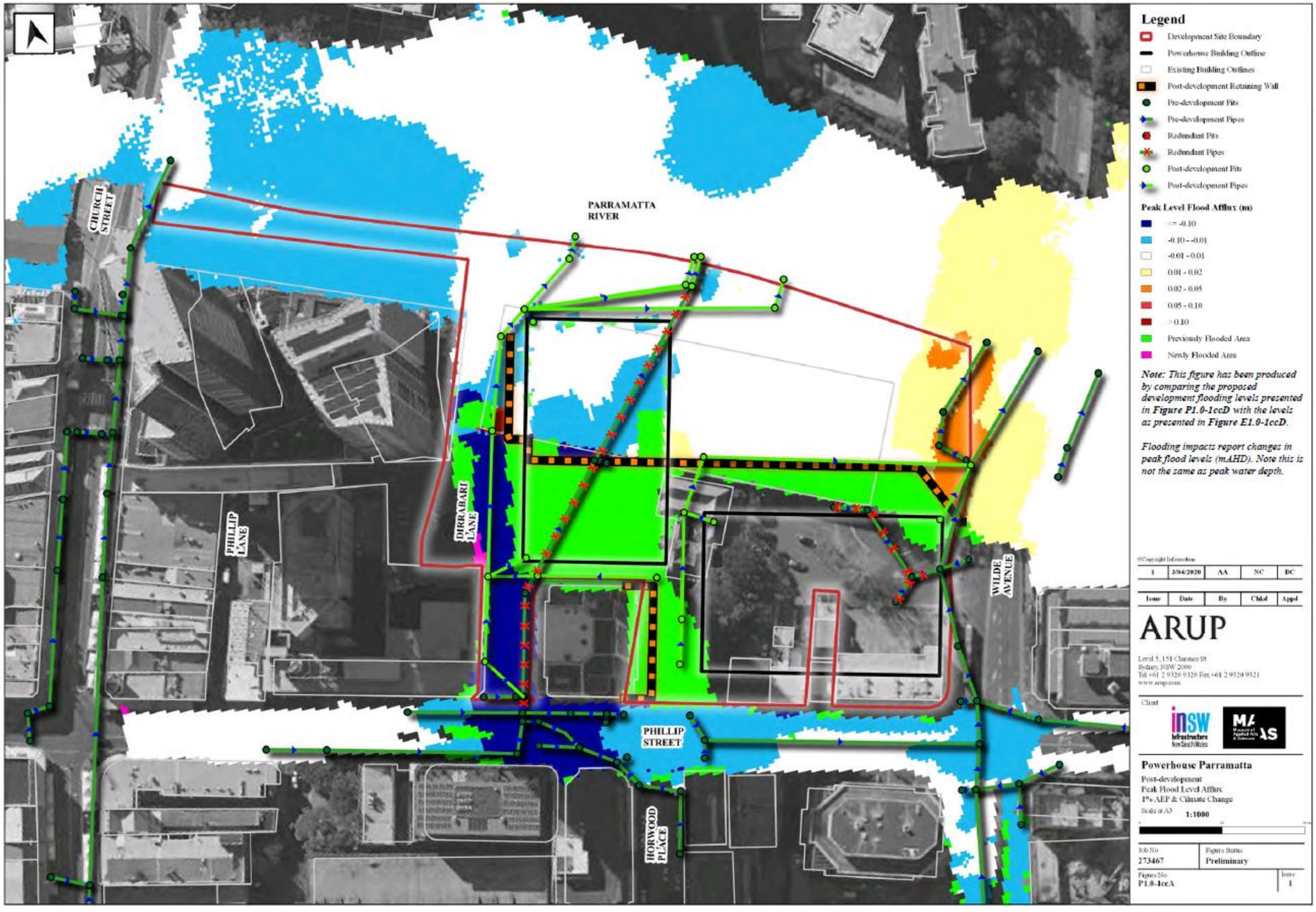

Figure 7: Proposed Arrangements for Managing Overland Flows

The latter because flood models assume a smooth flood surface whereas in reality flood surfaces are anything but flat with waves and turbulence caused by wind, obstructions, debris and vehicle wash.

Therefore to suggest that the museum is being given a greater level of protection than the 1% AEP is misleading. It should also be emphasized that the levels of the 1% AEP flood events referred to in the document as the basis for setting minimum floor levels do not take into consideration the effects of climate change.

Another important consideration in setting the minimum floor levels is knowing what blockage factors have been adopted in the overland flood modelling for the following reason.

The existing stormwater flows pond in Phillip Street and flow in a 600mm diameter pipe under Dirrabarri Lane to the river. When the flows to the low point exceed the capacity of the pipe the water rises until it reaches the high point in Dirrabarri Lane and the high point in Willow Grove and flows to the existing multideck carpark where again ponds before overflowing to the River.

If the inlet to the 600mm diameter pipe is partially blocked, less water will get into the pipe and more water will have to flow overland to the river in the same storm event. This means that any blockage in the pipe will increase the depth of ponding in Phillip Street and the depth of flows towards the river. A 100% blockage will mean all the flows go overland and maximise the flood depths in Phillip Street and along the overland flow path.

Because Arup has not stated what blockage factor it has assumed and it provides no comparison of its overland flow levels with those of Council, it is not possible to tell whether the overland flow levels it has based the floor levels upon are reasonable estimates. If they have underestimated the blockage factor then they will have underestimated the flood levels and underestimated the floor levels.

In addition to the above issues, it appears that, in setting the floor levels, no consideration was given to the impacts of floods greater than the 1% AEP event.

Such floods do occur. In 2010 and 2011 several locations in Queensland and Victoria experienced 0.5% (1 in 200) AEP floods, some 0.2%, the Pine River a 0.1% AEP flood and the Lockyer Valley an estimated 0.05% (1 in 2,000) AEP flood. It is noted that a PMF would reach a maximum level of 11.5m AHD which would make it 4m deep in the building.

It is therefore clear that flood events greater then the 1% AEP flood could cause significant impacts on the museum's collections and the people within the museum. However, no consideration was given to the risk from these larger events when setting the floor levels, and whether the development should be afforded a higher level of flood protection than offered by strict compliance with the minimum floor levels stipulated in Parramatta DCP.

While setting minimum floor levels at the PMF level might not be realistic, failure to consider the full range of consequences of flooding up to the PMF is contrary to the provisions of the NSW Floodplain Development Manual (2015).

3.2.2 Overland Flow Paths

The response to managing overland flows is in part driven by the need to set the ground floor levels of both buildings above the existing ground levels on site just to meet the 1% AEP plus 0.5m freeboard requirement.

The problem this creates is that it effectively raises the overflow points that flows in Phillip Street currently rely upon to reach the river. To prevent the water ponding to greater depths in Phillip Street, the design response has been to provide more and larger underground pipes to convey water from Phillip Street to the River and to provide better defined overland flow paths between Phillip Street and the River as shown in Figure 7.

This solution itself has two problems.

The first is that it relies upon the inlets to the pipes and the pipes themselves remaining unblocked. Although Appendix O says that the modelling was undertaken with an appropriate amount of assumed pipe blockage, it does not stipulate what that amount was. It is therefore difficult to determine whether the proposed solution can be relied upon to achieve its

objective of not making flooding worse for neighbouring properties. This is another requirement of the Parramatta DCP.

The second problem this presents is that it directs the overland flows along designated pedestrian connections between the river and Phillip Street (Figure 8). This means that should people by the riverside need to evacuate to escape a rising river, they may be confronted by a torrent cascade cascading down each of their possible escape routes.

This is an unacceptable design solution, particularly when considering that some of the evacuees may be children, people with walking aids (e.g. wheelchairs), and families with prams According to the flood hazard classification proposed by Smith at al. (2014) and adopted in the Australian Rainfall and Runoff Guidelines (Ball et al., 2019), children and elderly people are at risk of life when exposed to floodwaters as shallow as 0.5m, or even lower depths if flow velocity is in excess of about 1m/s (which is common along overland flow paths). There are no specific thresholds for people in wheelchairs and prams, but it is likely that these groups would be at risk at even lower values of depth and velocity.

Furthermore, the overland flow path down Dirrabarri Lane is also the designated emergency vehicle access.

While it is acknowledged that there is already some overland flow down existing pedestrian links, the development should mitigate this risk rather than exacerbate it.

3.2.3 Undercroft Spaces

While the undercroft spaces are designed to ensure the development does not increase flood levels in the Parramatta River in the 1% AEP flood, they may present a serious flood risk to life.

It is quite reasonable to expect that during inclement weather, museum patrons, or more likely, members of the public could take shelter in the undercroft areas. However, as shown in Figure 9, there are two problems in leaving these shelters once flooding commences.

The first is that it is necessary to walk down towards the river before being able to walk up to flood free ground.

The second is that the routes up are designed as overland flow paths.

People sheltering within these spaces may not appreciate just how high and how quickly the river can rise and they become entrapments in which people drown or they drown trying to leave them.

3.2.4 DCP Provisions

Section 2.4.21 of Parramatta DCP 2011 sets out objectives, design principals, and design controls for development on flood liable land.

The DCP provisions are numerous so Table 1 simply highlights those which the development proposal is inconsistent with.

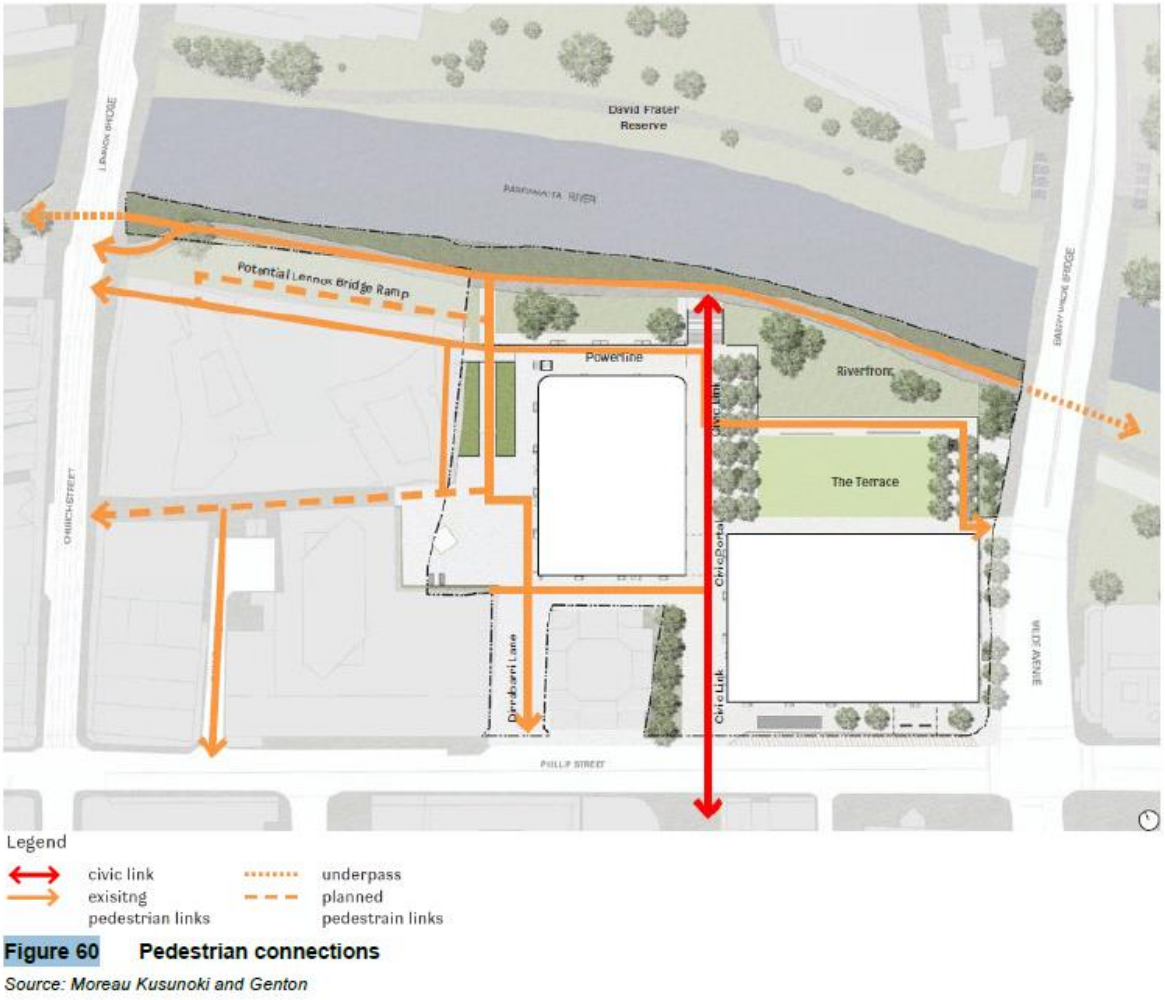

Figure 60 **Pedestrian connections**

Source: Moreau Kusunoki and Genton

Figure 8: Pedestrian Connections

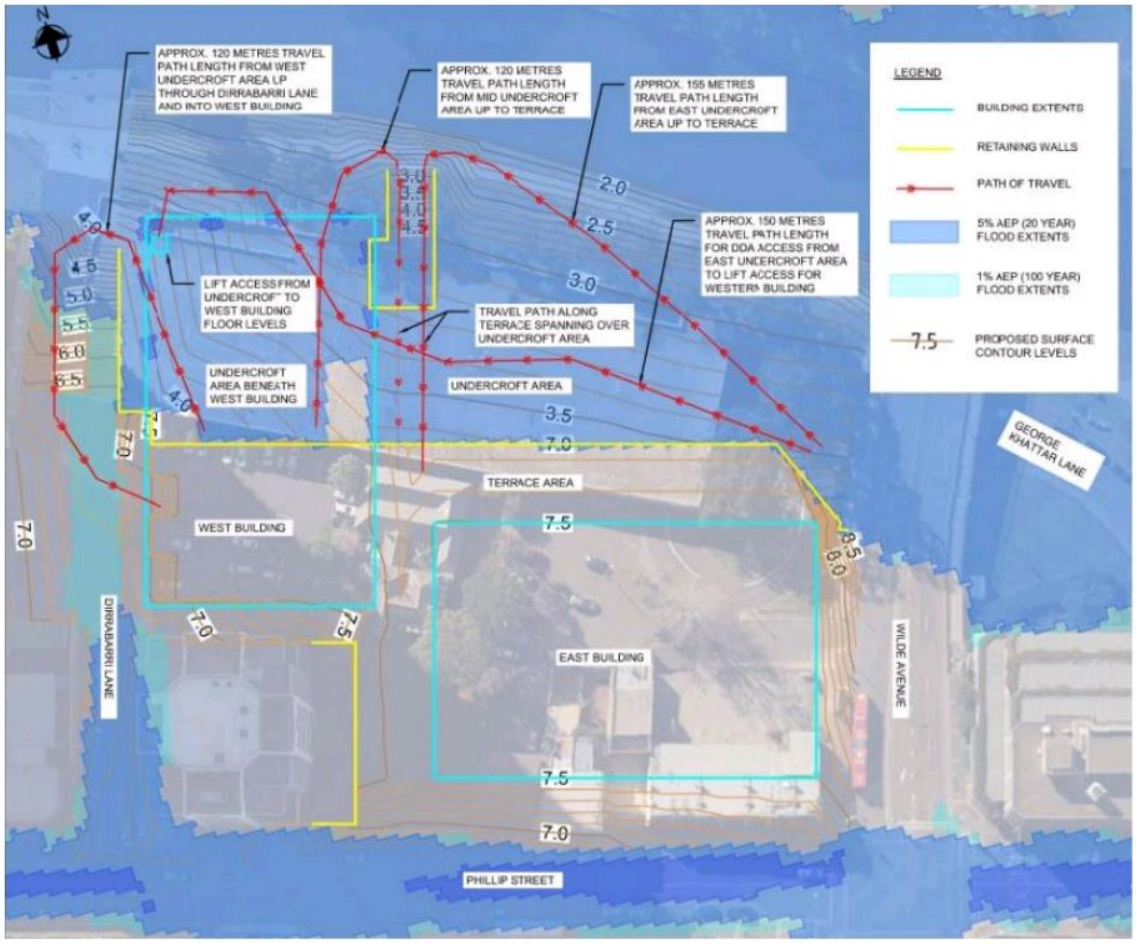

Figure 80 Flood evacuation assessment

Source: Arup

App O- Flood Risk a....pdf Environmental Impa....pdf

Figure 9: Flood Evacuation Assessment

Table 1. Analysis of compliance between the Parramatta DCP 2011 flood risk provisions and the proposed development

Parramatta DCP provisions	**Compatibility of proposed development**
Objective O.8: "to minimise the risk to life by ensuring the provision of appropriate access from areas affected by flooding up to extreme events."	The design of the undercroft areas and the provision of evacuation routes which lead down to the river and then up overland flow paths fail to meet this objective. No provision appears to have been made for the evacuation of people, including those with mobility impairments and families with prams, inside the building or external to the building to a place above the reach of the PMF
Principal P.1: "New development should not result in any increased risk to human life."	As above.
Principal P.2: "The additional economic and social costs which may arise from damage to property from flooding should not be greater than that which can reasonably be managed by the property owner, property occupants and general community."	The value of the assets within the museum are significantly greater than those in an ordinary commercial or residential building and many of them are irreplaceable. Such losses cannot be reasonably managed by the community.
Principal P3:"New development should only be permitted where effective warning time and reliable access is available for the evacuation of an area potentially affected by floods to an area free of risk from flooding.	As for P1.
For open space development below the 1% AEP level a design control is "Reliable access for pedestrians required during a 20 year ARI peak flood."	The undercroft areas fail to meet this requirement.

.

3.2.5 Draft LEP Provisions

CoPC has developed a draft planning proposal for the Parramatta CBD which will soon be placed on public exhibition. Until it is placed on exhibition the draft LEP provisions do not need to be considered but it is noted that the version of the draft LEP on the CoPC website has Section 7.6L which deals with floodplain risk management. It states:

(1) The objective of this clause is to enable occupants of buildings in identified areas that have particular evacuation or emergency response issues to:

(a) shelter within a building above the probable maximum flood level; or

(b) evacuate safely to land located above the probable maximum flood level.

(2) This clause applies to land identified on the Floodplain Risk Management Map (as shown coloured blue).

(3) The consent authority must not grant consent to the erection of a new building or significant alterations and additions to existing buildings on land to which this clause applies unless, in addition to being satisfied of the matters mentioned in clause 6.3 (3) in relation to the development on the land, the consent authority is satisfied that the building:

(a) contains either:

(i) an area that is:

a. located above the probable maximum flood level, and

b. connected to an emergency electricity and water supply, and

c. of sufficient size to provide refuge for all occupants of the building (including residents, workers and visitors), or

(ii) flood free pedestrian access is available between the building and land that is above the probable maximum flood level; and

(b) has an emergency access point to the land that is above the 1% annual exceedance probability event, and

(c) is able to withstand the forces of floodwaters, debris and buoyancy resulting from a probable maximum flood event.

Taking the proposed museum site into consideration, it clearly does not have flood free access to land that is above the PMF level. Accordingly, to satisfy the requirements of these draft LEP provisions, a new building on the site would have to have an area inside the building which is above the PMF and has (a) sufficient floor area to provide refuge to residents, workers and visitors, and (b) emergency electricity and water supply

The design as presented would satisfy the requirements on the availability and size of a refuge area above the PMF level, however nothing in the EIS or supporting documents indicates that it would be provided with emergency electricity and water supply to facilitate safe sheltering within the building. It should not be difficult to do this but it appears to be an oversight in the flood provisions described to date.

Similarly, it should be possible to design the building to have an emergency access point to land above the 1% AEP flood level and to also be built to withstand flood forces up to the PMF.

Each of the above needs to be conditioned to minimise risk to life, if the project is approved.

3.2.6 International Competition Stage 2 Design Brief

In January 2020 the NSW Government released a brief to inform the international tendering process for the proposed museum's architectural design.

Flood risks are dealt with throughout the brief, and are discussed more in detail in Appendix 3 (Stormwater and Flooding, page 248), which explains how the design is expected to address impacts from flooding (overland and riverine), as well as the associated risk to life. A shelter in place refuge is requested within the building above the PMF level, although there are no specific requirements about its capacity, access or structural soundness in a PMF.

There are numerous flood provisions in the brief and most have been addressed in the design which is presented in the EIS. Table 2 provides an analysis of where the design does not meet the flood provisions of the brief or where the provisions and response create a problem.

Table 2: Design Brief Flooding Deficiencies

Design Brief Parts and Sections	Comments
Part 2	
Section 4.3 (Presentation Spaces #3, #4 and #5, page 132) states that *These spaces should be highly flexible and adaptable, to cater for a range of layouts and media, and function appropriately to display, in rotation, the Collection of the Museum as well as international collections and exhibitions. These spaces will incorporate the highest level of climatic control (rated as AA) suitable for the display of the Museum's Collection and the loan of international collection objects and exhibitions. The floor height and level of all these spaces should be positioned to above the PMF (Probable Maximum Flood level, as defined in the technical appendices) to ensure the security of the Collection.*	The concern on the protection of the museum collection from flood damages and dampness is addressed in this section, and it translates into specific brief requirements. However these requirements do not apply to Presentation Space #1 and #2. The reasons for this exclusion are not made clear in the design brief. It is noted that AA class climate control for museums, art galleries, libraries and archives require a 50% average relative humidity with 5% short term fluctuations. Temperatures are to be maintained between 5^{o}C and 25^{o}C in humidity with 2^{o}C short term fluctuations and 5^{o}C seasonal fluctuation. It is beyond my expertise to assess whether it is possible to maintain these specifications within the upper levels of the building when flood waters enter the lower levels of the building, taking into account that there is likely to be failure of power supply in such a flood. The EIS and supporting documents do not provide any details about how this will be achieved during a flood nor does it assess the impacts should it not be achieved.
Part 3	
Section 3.4 (Public Domain and Open Space) states that *The public domain will need to consider the flood-prone nature of the site and fully integrate flood resilience principles into its design. Flood mitigation and egress infrastructure should not be single-use but part of the use of the site day-to-day.*	The public domain space includes undercroft areas which do not have flood safe egress and can become entrapments in a rapidly rising flood. The proposed pedestrian links between Phillip St and the River are also designated overland flow paths. This creates safety hazards in both overland flow events and riverine floods.
Section 3.5 (Access and Movement) The second paragraph states that *Topographic level changes across the site will be a significant challenge to delivering universal accessibility (compliant to AS1428), routes for vehicular servicing, emergency vehicle access and flood/emergency egress.* This is picked up again under the guidelines	The plans presented in the EIS do not allow an appreciation of the extent to which this requirement is fulfilled in the design of the flood/emergency egress. If the strategy is to take shelter in place, it is assumed that the egress routes mentioned are to reach the refuge area within the building from all parts of the site exposed to flooding. This assumption is confirmed in Part 2- Section 3.7 of the brief.

subsection: *Ensure any flood egress routes are fully integrated into the daily use of the site and serve a purpose day-to-day.*	In this case there does not appear to be any provision for access to higher levels for mobility-impaired building occupants if there is a loss of power supply during a flood, which is likely to be the case (particularly if the substation is designed to the 1% AEP event)
Extract from Section 3.7 (Flooding)	Comment
Subsection "FLOODING"	
The development will provide accessible routes to points of refuge	The museum will cater to a diverse audience including people with mobility impairments (e.g. people using wheelchairs and walkers) and other disabilities, school children, and parents with prams. The current design does not appear to have included ramps to reach the building levels above the PMF. The alternative would be to rely on elevators and escalators to be powered with emergency power supply but there does not appear to be any provision for that. It will also be important that outdoor areas be designed to have continuously rising access routes to Phillip Street which avoid overland flow paths so that all people can evacuate away from a rising river flood without getting trapped by floodwaters. The current design does not do that
The development must ensure that the existing overland flow to the west of the site is maintained, with a minimum 12m width. This sits predominantly within the existing easement on the west of the site	The proposed design appears to have allowed as 12m set back from the western site as required. However, this is also identified as a major pedestrian route and an emergency vehicle access. This is not appropriate and such access needs to be away from overland flow paths.
Subsection "GUIDELINES"	
Design the public domain to fully integrate flood mitigation, egress routes to points of refuge. Elements should be designed to be multi-functional and part of the site's day-to-day use. *Seek innovative design solutions and appropriate material and landscaping selection which increase the site's capacity to recover after a flood event.*	The lower outdoor areas, and particularly the undercroft area, have not been designed to have continuously rising access routes to Phillip Street which avoid overland flow paths so that people can evacuate away from a rising river flood without getting trapped by floodwaters.

Extract from Appendices	Comment
Appendix 1	
Power Supply *Substations, main switchboards, backup power UPS and generator systems shall be designed to withstand floods and ensure operation of the facility on the upper levels during 1:100-year flood level at RL7.5. and where possible the Probable Maximum Flood (PMF).*	The EIS says that the museum will be supplied with power from a pad mounted substation and that Endeavour Energy's design standard in relation to flooding is the 1% AEP event. It is acknowledged in the EIS that an effort will be made to place the substation at a higher level but there is no commitment to do so. In order for the building to be used as a refuge during extreme floods and for the AA Climate Control to be maintained to protect collections, the back-up power supply should be fully functioning up to the PMF, not only in the 100 year ARI.
Appendix 3 – Stormwater and Flooding	
3. Flood Levels and Floor Levels *The majority of Presentation Spaces should be designed to be above the overland PMF (RL11.3) to ensure they are suitable for display of some Museum Collection items.*	This applies to all presentation spaces except Presentation Space #1, which is at RL 7.5m and appears to be the only one containing items which could not be relocated to higher levels during a flood emergency, because of their size and weight. It is my opinion that this arrangement should be revisited to ensure that all presentation spaces hosting items of the museum collections are above the overland PMF level.
3. Flood Levels and Floor Levels *Careful consideration is required at the northern extent of the Precinct to ensure hydraulic flows and flood storage capacity are maintained on the site. Any development within the flood storage capacity zone would be required to withstand forces of floodwater, debris and buoyancy up to the 1:100 year ARI, whilst not impeding hydraulic storage capacity.*	The rates of rise of flood waters in the streets and in the river are such that it is unlikely to be practical or safe in most circumstances to evacuate the building during a flood. Accordingly, the building needs to provide a safe refuge above the reach of the PMF. Part of that provision will be ensuring that the building remains structurally stable in the PMF. Accordingly, the building needs to not only be able to withstand the listed forces in a 1% AEP flood but also in a PMF. Nothing is the EIS documentation suggests that is proposed.
6. Flood Evacuation *The design for the Precinct must be capable of providing a clear and reliable access for pedestrians to an area of refuge above the PMF level. This can be achieved either on the site (i.e. a second storey) or off the site. Note that much of Parramatta CBD will be inundated to a significant depth during the PMF.* ***Guidance Note: The general***	This section indicates that the preferred flood emergency response strategy for visitors outside the building is horizontal evacuation, while only people that are located within the building are assumed to take shelter at the higher levels. Given the flood extent of the PMF, the relatively quick rate of rise and the fact that Phillip Street, as well as most streets in the

expectation is that pedestrian evacuation for people within Powerhouse buildings can be accommodated within the building on levels above the PMF, whereas pedestrian evacuation from the public domain would be through clear and accessible routes to areas external to the Precinct	CBD, would likely be cut by local flooding by the time an evacuation order is issued (I think that horizontal evacuation is not a safe option for any of the people within the premises). Horizontal evacuation of the people in the outdoor areas would likely require these to walk through floodwaters in Phillip Street, or having to walk along the river edge toward Church Street. In both cases, the risks of having to walk through high hazard floodwaters would be excessive. As such it is my opinion that all the people in the premises would need to take shelter within the museum buildings, in a designated refuge above the reach of the PMF. For such refuge to be a safe shelter in a PMF, it would have to satisfy the previously mentioned requirements to reduce the risks of SIP. Of these requirements, the most basic and important are that: • the building where the refuge is located would need to be structurally sound in a PMF event. I have not seen this requirement in the Stage 2 Design Competition Brief. • the refuge would need to provide a minimum of $2m^2$ of floor surface area for each evacuee, and have capacity for all visitors and staff that are on the premises at any one time. The brief suggests that the site may be used to host functions with up to 10,000 people. • The refuge must be accessible by people with mobility impairments and parents with prams. This would either be by means of ramps or by provision of emergency power supply to provide mechanical means of access • There must be an emergency power supply • There must be an emergency water supply The EIS is currently silent on all of the above matters. The outdoor areas should be designed to have continuously rising access routes to the flood refuge within the building and to Phillip Street which avoid overland flow paths so that people can evacuate away from a rising river flood without getting trapped by floodwaters. This

	was one of the principle design criteria for any outdoor developments along the river frontage. The design presented in the EIS does not meet this requirement. As stated above, evacuating to the building refuge may be the only option as Phillip Street may flood before the river rises, however there may be instances in which the river would flood the outdoor public areas when the building is closed.

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4 IMPACT ASSESSMENT

This chapter considers the adequacy of the impact assessment both in terms of the SEARs which were issued but also how the EIS has addressed the various impacts associated with flooding.

4.1 SEARS

Flooding is the subject of specific matter 12 in the SEARs. It reads:

12. Flooding, drainage and stormwater

The EIS shall include:

- *an assessment and proposed management of the stormwater, drainage, flooding and groundwater issues associated with the site, environs and the proposed development, including:*
  - *stormwater and drainage infrastructure, including a stormwater management plan, water sensitive urban design, roof gardens, green walls, and MUSIC link model (for water quality)*
  - *assessment of flood risk in accordance with the guideline contained in the NSW Floodplain Development Manual 2005, including potential effects of climate change, sea level rise and an increase in rainfall intensity and integration with Council's wider flood risk management planning and flood modelling*
  - *the potential impact of the development on groundwater levels, rates of flow, flow paths and quality.*
- *an integrated water management strategy that incorporates waste water, rainwater and stormwater runoff. The strategy must outline opportunities for the use of integrated water cycle management practice and principle, and demonstrate water sensitive urban design and any other water conservation measures*
- *consideration as to how the proposal responds to City River and Civic Link precinct access and egress requirements, including evacuation in flood.*

Flooding is also mentioned in matter 11 Transport, traffic, parking and access (operation) which states, in part:

…details of emergency vehicle access arrangements and a response to flood evacuation (up to and including the probable maximum flood) for pedestrians, cyclists and vehicles.

These requirements are appropriate as far as they go and, in theory, assessment of flood risk in accordance with the requirements of the NSW Floodplain Development Manual should result in the consideration of all social, environmental and economic risks due to flooding for the full range of flood events.

However, in my opinion both matter 6 Heritage and Archaeology and matter 7 Aboriginal cultural heritage are potentially deficient. Both of them focus on the impacts that the built form and its construction may have on Aboriginal and non-aboriginal cultural heritage items and values. What the SEARs have failed to recognise is the ongoing operational impacts that the museum will have on heritage values and there is no explicit requirement in the SEARs for these to be assessed.

However, the operation of the museum will place items of high, and often unique, cultural and heritage value in the floodplain and expose them to the risk of damage from flooding. This could be direct damage from contact with flood waters but could also be indirect damage through the pervasion of humidity within the building.

This failure to recognise the need to assess the operational impacts of the museum on cultural and heritage items and the mitigation of those impacts is a serious shortcoming of the SEARs.

4.2 EIS

4.2.1 Impacts on Museum Collections

Notwithstanding that the SEARs have failed to explicitly require the assessment of the impacts of flooding on the museum collections, they do require "*assessment of flood risk in accordance with the guideline contained in the NSW Floodplain Development Manual."*

To meet that requirement the EIS would need to consider all of the social, economic and environmental risks posed by the full range of floods up to the PMF. Therefore, implicit in this requirement is the need to assess the impacts of floods exceeding the 1% AEP flood on the museum's collections.

The EIS fails to do that.

There is a real risk that flood waters will enter the museum. For example a flood with a 1 in 500 chance of occurrence per year has about a 1 in 6 chance of occurring in the next 80 years. Such a flood would enter the ground floor of the museum to a considerable depth and leave a deposit of contaminated silt within the building.

The ground floor is proposed to exhibit large items which would be difficult to move out of the way of the rising flood waters, even if there were sufficient time (which there would not be). These items would be directly damaged by the floodwaters.

The proposal to locate the museum's substation at the 1% AEP flood level would mean that the building would be without power in such an event. Unless an emergency back up power supply is provided, this would compromise the museum's ability to maintain the required AA class climate control needed for the protection of items housed on the higher levels above the direct reach of the flood waters.

Furthermore, the penetration of flood waters into the building and their infiltration into all porous materials in the lower parts of the building would cause a humidity spike within the building which could take weeks or even months to lower.

None of these realistic potential impacts have been assessed in the EIS nor any mitigation measures to reduce these risks have been mentioned.

4.2.2 Impacts on People

The EIS only considers flood risks to people up to the 1% AEP flood. Specifically it states:

"Arup confirm that the design of the proposed development does not present increased risk to public safety for people within the building. The buildings and main entrances are designed above the recommended flood level, and as such the only key consideration for the evacuation of the site is the Riverfront area and foreshore that has been designed to accommodate inundation by floodwaters."

In other words no consideration has been given to what risks flooding poses to people if it exceeds the 1% AEP flood level and enters the building. This is contrary to the requirements of the NSW Floodplain Development Manual and therefore the EIS fails to meet the requirements of the SEARs in this regard.

The EIS goes on to say:

Arup recommends an early warning system, using rainfall forecasts will be used to determine if the under-croft space should be open for use, which would form part of a daily procedure prior to opening Powerhouse Parramatta. This daily review could be supported by on-site observations and permanent warning signage within the Riverfront area, as well as other potential audible and visual warning devices…Following the evacuation of the Riverfront and foreshore spaces, people would be expected to shelter in place…The detailed emergency planning measures will be confirmed in an emergency plan to be developed prior to the commencement of operations.

The focus of this is all about getting people from the public spaces which are below the 1% AEP flood level to public spaces which are above that level and sheltering there. However, there is no consideration as to what happens to these people if the water levels keep rising as they can do.

Once floodwaters enter the building there is also the need for protecting the people who are inside the building and enabling them to reach higher levels in the building above the reach of floodwaters. There appears to be no provisions for ramps in the building to assist people to do this so they will have to use the stairs if the escalators and elevators are not working. These mechanical devices are certainly unlikely to be working if the substation is installed at the ground floor level and no alternative emergency power supply has been provided as appears to be the case.

The EIS has no discussion about these real possibilities and how they will be mitigated, nor the fact that the building will be occupied 24 hours of the day which only increases the probability that people will be trapped in the building by flooding.

With regard to the areas outside which are below the 1% AEP flood level, the evacuation routes which have been provided for them to the podium level go down towards the rising river before requiring pedestrians to walk up overland flow paths. This is totally inadequate and does not address the SEARs requirement to consider evacuation up to the PMF.

EIS Table 1 which maps the Secretary's Requirements to the relevant sections of the EIS where they are addressed, says that the PMF access requirement is addressed in sections 2.1.3, 4.8 and 6.4 of EIS but none of them make reference to egress in a PMF. It also maps it to Appendix F. Appendix F says it is in Section 5.10 in the Appendix but that has not reference to flooding. In fact it states that emergency vehicles will access the river via the access route at the end if Dirrabarri Lane but fails to mention that that will be an overland flow path in frequent flood events.

5 CONCLUSIONS

This report identified and evaluated flood risks to people and property for the proposed new cultural precinct in Parramatta. The analysis was informed by a review of the following publicly available documentation:

- The report titled "Powerhouse Precinct Parramatta- international Design Competition - Stage 2 Design Brief", which outlined the design requirements for the architectural competition, from which the Moreau Kusunoki Genton design was selected as the winner;
- Planning Secretary's Environmental Assessment Requirements 10/2/2020
- Powerhouse Museum EIS
- Appendix B Architectural Plans
- Appendix C Landscape Report
- Appendix O Flood Risk and Stormwater

The review considered:

- The adequacy and accuracy of the flood modelling and the appropriate use of the flood model results (Section 2);
- The proposed building and landscape design responses to the flood risks (Section3);
- The adequacy of the impact assessment and proposed mitigation measures in relation to flooding and its consequences on:
  - the museum building and its infrastructure;
  - museum collections;
  - museum visitors and staff;
  - people in the public domain.

The main findings are summarised below.

5.1 FLOOD MODEL

The City of Parramatta Council is currently in the process of finalising a new accurate two-dimensional flood model, however this has not been officially released. For the proposed development, a dedicated flood model was prepared by Arup and used for all of the flood assessment work in the EIS.

It is my opinion however that the model developed by Arup and its results should only be used as an interim tool for providing indicative flood information for the site, and that a more detailed and comprehensive assessment should be undertaken once the model from Council is released.

The limitations of the Arup model are:

1. The model is calibrated against an old one-dimensional model (i.e. the Upper Parramatta River Catchment Trust model). The results of such model are limited by the age of the software and the fact it used superseded methodologies (Australian Rainfall and Runoff), developed in 1987 and that have now been extensively updated.
2. The Arup model does not clarify the assumptions that were used in terms of stormwater system blockage, when simulating overland flood behaviour and peak levels on site. It is my understanding that Council uses a 100% blockage assumption when assessing overland flood behaviour. Arup used a different, unspecified, blockage percentage, this would have resulted in lower flood levels on site, particularly in the more frequent flood events (up to the 1% AEP event), which are those used to inform the design of the building.

5.2 BUILDING AND LANDSCAPE DESIGN

The analysis encompassed multiple aspects of the proposed development. These are summarised in the following subsections.

5.2.1 Ground Floor Levels

The first aspect was ground flood levels. In compliance with Parramatta DCP, the ground floor levels of both buildings were set at the level of the 1% AEP flood plus 0.5m freeboard. This is a standard approach used to place the ground floor of new residential and commercial

development above the reach of flood events as frequent as 1 in 100 per year. The additional 0.5 freeboard is to account for uncertainties in the way the peak level of the 1% AEP flood. The EIS report however suggests that the museum is being given a greater level of protection that the 1% AEP, which is incorrect and misleading.

In addition to the above, it is important to reiterate that the ground floor level was obtained from the Arup model of local overland flooding, however it is not clear what percentage of pipe blockage was used by Arup in calculating that level and the 1% AEP overland flood level may be higher than estimated.

Finally, we note that in setting the ground floor level, no consideration was given to events greater than the 1% AEP, which although relatively rare could cause extensive damage to the building facilities and, more importantly, its contents. Given the value of the museum collection and the fact that this could not be replaced if damaged by a flood, I believe it is imperative to give some consideration to the risk from everts greater than the 1% AEP, rather than strictly complying with the minimum floor levels stipulated in Parramatta DCP. The proposed development is significantly more vulnerable than any residential or commercial building in Parramatta because of the number and diversity of people it will host, and the value of its contents.

5.2.2 Overland Flow Paths

The development proposes to convey any overland flooding running from Phillip Street to the River into larger underground stormwater pipes, and to direct any excess flow along the pedestrian connections between the River and Phillip Street.

The ability to rely on amplified underground pipes to ensure the development does not increase flood levels on neighbouring properties is highly dependent on the blockage factors assumed in the modelling but these are unstated. Whatever proportion flows underground there will remain a substantial flow above ground.

This means that people evacuating from the rising river along these pedestrian connections could be confronted by a torrent cascading down each of their possible escape routes. This is an unacceptable design solution, especially considering that some of the evacuees would have mobility impairments or would be parents with children and infants.

5.2.3 Undercroft Spaces

The proposed undercroft spaces may represent a serious risk to life. During a rainfall event people may take shelter in these spaces but they may become trapped there as the Parramatta River rises. This is because the evacuation routes from these spaces go down towards the river before rising to Phillip Street. A continuously rising evacuation routes needs to be provided from these spaces to an area above the reach of the PMF without walking through an overland flow path.

5.2.4 DCP and draft LEP Provisions

The increased risk to life due to potential overland flow running down pedestrian evacuation routes or to patrons being trapped in the undercroft spaces are inconsistent with the DCP provisions, namely with Objective O.8, Principal P1 and Principal P3. This is also inconsistent with Section 7.6L of the draft LEP. The potential damage to the museum collections is also arguably insufficiently addressed (DCP Principal P2).

In order to comply with the draft LEP provisions, the new building would need to ensure that the indoor refuge area is structurally safe, is located above the PMF level, is capable of hosting and can be accessed by all the museum patrons and staff, and has emergency electricity and water supply. The EIS provides no evidence that these requirements were addressed.

5.2.5 Power Supply

The EIS indicates that it is proposed to supply power to the museum through a pad mounted substation at the 1% AEP flood level. No mention is made of how power will be supplied

to the building in larger flood events to ensure occupants can reach levels above the PMF and safely shelter in them or how the class AA climate control will be maintained.

5.2.6 Stage 2 Design Brief

There are numerous flood provisions in the brief and most have been addressed in the design which is presented in the EIS. However, some requirements do not seem to have been considered (Table 2). The most important deficiencies are listed below:

- Providing protection from flood damages to the museum collections up to the PMF (Section 4.3 of the Design Brief). Presentation Space #1 and #2 have their ground floor below the PMF level. Protection against humidity through class AA climate control is also required, but no evidence is provided to show how this would be achieved during a flood.
- The previously mentioned issues regarding flood risk to life and suitable pedestrian evacuation routes are clearly inconsistent with the relevant parts of Section 3.4 (Public Domain and Open Space), Section 3.5 (Access and Movement), and Section 3.7 (Flooding).
- The flood refuge should be within a building structurally stable in the PMF and be accessible to people with mobility impairments. This is not discussed in the EIS or evidenced in the plans.

5.3 IMPACT ASSESSMENT

It is my opinion that matter 6 Heritage and Archaeology and matter 7 Aboriginal Cultural Heritage of the SEARS are potentially deficient as the impacts of the museum operation on cultural heritage items and value are not addressed. These include placing items of unique heritage value in the floodplain and expose them to the risk of damage from flooding.

However, the SEARS requires that flood impacts are assessed in accordance with the NSW Floodplain Development Manual, which requires all of the social, economic and environmental impacts to be considered for all flood events up to the PMF. This report has demonstrated that the EIS fails to give any consideration to events greater than the 1% AEP when setting the ground floor level of the proposed buildings, and when assessing risk to people within the building.

Specifically, the EIS appears to assume that the museum patrons will be safe inside the building, when any flood greater than the 1% AEP would enter the premises. People could move to the higher levels however to do this they would have to rely on escalators and elevators (particularly people with mobility impairments and parents with prams), which require access to electricity. However, in all large floods a power outage is likely to be experienced and the EIS does not clarify whether an alternate power supply would be available.

Furthermore, the direct impacts of floods on collections on the ground floor and the indirect impacts of increased humidity, in an environmental in which loss of power will compromise the class AA climate control, have not been assessed at all.

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APPENDIX A – GLOSSARY

This report utilises the terminology used in the NSW *Floodplain Development Manual* (2005). The following Glossary is drawn from that Manual and additional sources.

Acronym	Full Name	Description
AEP	Annual Exceedance Probability	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e., a one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI) (NSW Department of Infrastructure, Planning and Resources, 2005).
AHD	Australian Height Datum	A common national surface level datum approximately corresponding to mean sea level (NSW Department of Infrastructure, Planning and Resources, 2005).
ARI	Average Recurrence Interval	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (NSW Department of Infrastructure, Planning and Resources, 2005).
BoM	Bureau of Meteorology	The Bureau of Meteorology is Australia's national weather, climate and water agency (BoM, 2020).
DCP	Development Control Plan	A Development Control Plan provides detailed planning and design guidelines to support the planning controls in the Local Environmental Plan developed by a council (NSW Planning Portal, 2020).
EFBC	Extended Final Business Case	See report for specific context.
FEMP	Flood Emergency Management Plan	A formal plan to reduce the risk to people and property from flooding through planning, preparedness, response and recovery.
NSW SES	New South Wales State Emergency Service	NSW State Emergency Service (SES) is an emergency and rescue service dedicated to assisting the community (NSW SES, 2020).
OSD	On Site Detention	Means of detaining stormwater on site. Can be achieved with dams, detention basins, water storage tanks.
PMF	Probable Maximum Flood	The PMF is the largest flood that could conceivably occur at a particular location,

		usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF defines the extent of the flood prone land, or floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study (NSW Department of Infrastructure, Planning and Resources, 2005).
RL	Reduced Level	Relative level of the building feature above the accepted height datum.
SEARs	Secretary's Environmental Assessment Requirements	Critical State significant infrastructure (CSSI) projects are high priority infrastructure projects that are essential to the State for economic, social or environmental reasons. When an application for approval of a declared CSSI project is made, the Secretary of the Department of Planning and Environment is required to issue environmental assessment requirements (SEARs) that cover environmental impact assessment (NSW Planning and Environment, 2015).
SIP	Shelter in Place	Taking shelter within a building or a structure above the reach of floodwaters (also referred to as vertical evacuation)
UPRCT	Upper Parramatta River Catchment Trust	See Bewsher Consulting, 2003
WSUD	Water Sensitive Urban Design	An approach that integrates the urban water cycle into urban design to improve environmental impacts and aesthetics.