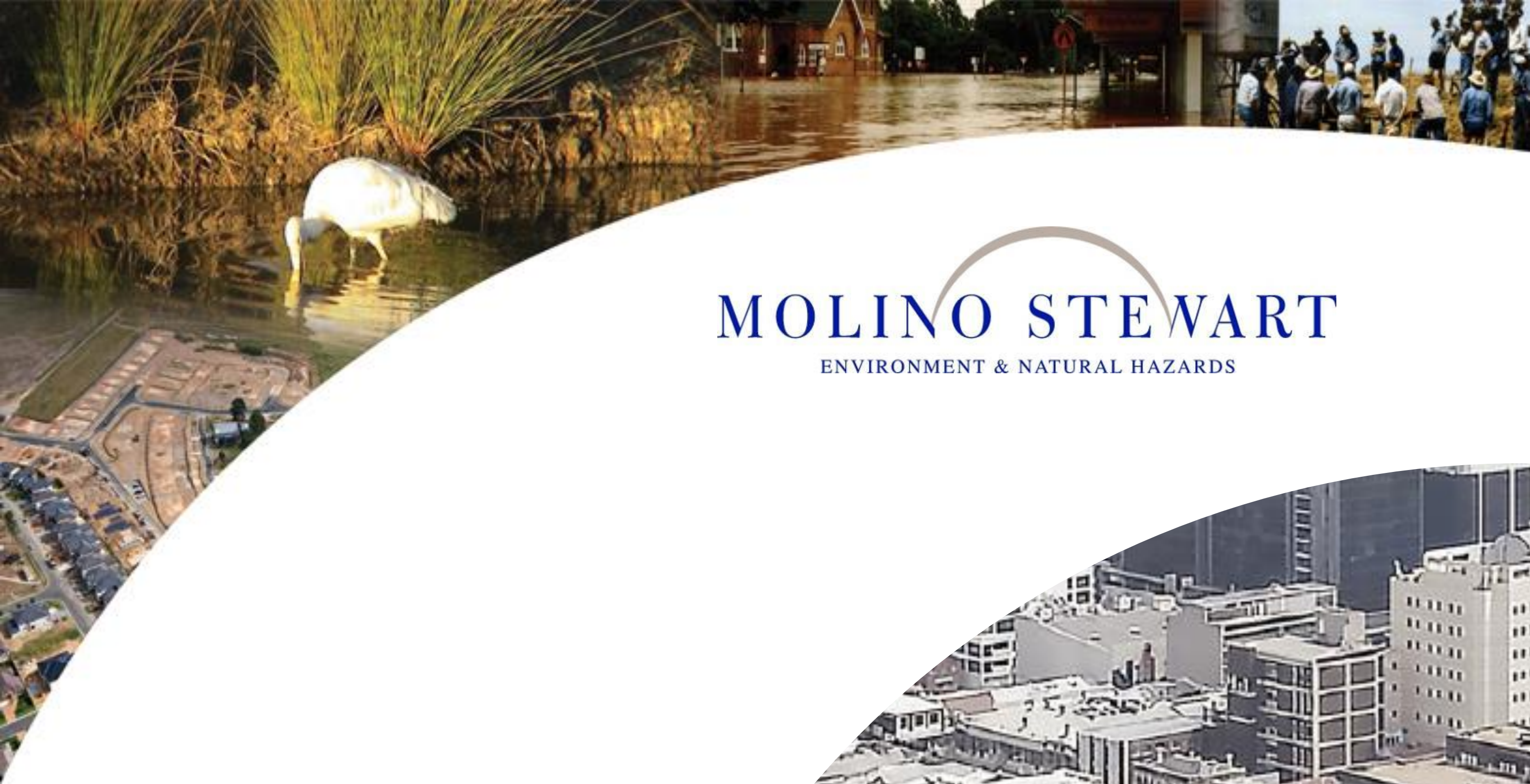

MOLINO STEWART

ENVIRONMENT & NATURAL HAZARDS

Powerhouse Museum Alliance

Parramatta Powerhouse

RTS Review - Flood

Parramatta Powerhouse

RTS REVIEW - FLOOD

for

Powerhouse Museum Alliance

by

Molino Stewart Pty Ltd

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NOVEMBER 2020

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 Precinct on the southern bank of the Parramatta River on Phillip Street, between Church Street and Wilde Avenue.

An Environmental Impact Statement (EIS) was prepared for the proposed museum and placed on Public Exhibition on 10 June 2020. Molino Stewart was commissioned by the Powerhouse Museum Alliance (PMA) to independently review the EIS, including its technical appendices, in relation to flood risks and their management. A report was prepared and accompanied the PMA submission to the EIS.

On 8 October 2020, Ethos Urban prepared a Response to Submissions (RTS) and Amended Proposal Report which was accompanied by a large number of technical appendices detailing amendments to the proposed design and operation of the museum or elaborating upon aspects of its design and operation so as to address all issues raised in the 1,303 received in response to the public exhibition of the EIS.

Molino Stewart was engaged by PMA to review the RTS report and technical appendices to determine whether the flood risk issues had been adequately addressed by the additional details provided and the design and operational amendments proposed.

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:

- Response to Submissions (RTS) and Amended Proposal Report
- Appendix A - Responses to Agency Submissions
- Appendix B - Architectural Drawings and Report)
- Appendix C - Landscape Drawings and Report
- Appendix E - Design Integrity Report
- Appendix J - Flood Risk and Stormwater Addendum
- Appendix N - Structural Statement
- Appendix R - Accessibility Statement

This report should be read in association with the Molino Stewart report on the EIS review.

It is noted that the Department of Planning Industry and Environment (DPIE), in a letter dated 16 October 2020, requested additional information from the proponent, including *"Updated Flooding Assessment confirming the FFL [finished floor level] of St Georges Terrace, flood impacts, suitability of proposed use and any recommendations for protection/evacuation if required."* The response to that letter was not posted on the DPIE website at the time this report was prepared and is therefore outside of its scope.

2 FLOODING ISSUES

2.1 PUBLIC SUBMISSIONS

According to Figure 1 in the RTS Report, more than 200 public submissions (more than 20%) raised flooding as an issue (although Table 1 states it was 17% of submissions). The report summarises the flood issues raised into three categories:

- Constructing a significant public building on flood liable land is inappropriate and unacceptable. Recent flooding in the area this year affirmed the dangerous location chosen to position the building.
- The proposed use of the site as an entertainment venue, residential units and school dormitory is creating an unacceptable risk to life and property given the very short emergency warning time for this section of the Parramatta River and the lack of flood free access.
- The site puts at risk exhibitions and artefacts.

2.2 AGENCY SUBMISSIONS

Of the agency submissions, DPIE's Major Projects Group and DPIE's Environment, Energy and Science Group made separate submissions raising concerns about the management of flood risks. The City of Parramatta Council (CoPC) also raised issues in relation to flooding. The submissions by Australian Unity (owners of 32 Phillip Street) and PMA were included in the list of agency submissions and these also raised concerns regarding flooding.

There was much commonality between these submissions although not all issues were common to all agency submissions. Nevertheless, the specific concerns raised can be summarised as:

- Inadequate consideration of floods greater than the 1% Annual Exceedance Probability (AEP)
- Whether flood modelling excluded flood waters from the building above finished floor level
- Calibration of overland flood modelling with CoPC's overland flood model
- Insufficient detail on assumed blockage factors for underground pipe network
- Reliance on underground pipe network to alleviate overland flow problems
- Lack of detail regarding flood emergency response and lack of clarity whether evacuation or shelter in place is the proposed emergency response
- Lack of consideration of emergency response to floods greater than the 1% AEP event
- Lack of consideration of impacts of floods greater than 1% AEP event on museum collections
- Need to demonstrate that the structure can withstand flood forces
- Justification of the need for the proposed undercroft and more detail on how it is to be used
- Alternative and additional measures to evacuate the undercroft in a flood
- Pedestrian evacuation routes away from riverine flooding also being overland flow routes
- Lack of detail of safe and reliable evacuation provisions for people with mobility challenges
- Lack of detail regarding power supply and emergency power supply and its flood resilience
- Lack of detail on maintenance of climate control for collections during extreme floods.

3 DESIGN MODIFICATIONS AND CLARIFICATIONS

3.1 UNDERCROFT

The undercroft and its connection to other outdoor spaces has undergone significant design revision to not only address flood issues but also to better align with the aesthetic and design intent objectives from the design competition.

According to page 37 of the RTS Report:

The landscape design has been amended in response to the submissions received to enhance the relationship between the site and the river, and to better align the design with the principles of the competition scheme. In accordance with the project objectives, Powerhouse Parramatta will deliver a precinct that has multiple entry points and can be approached and connected from all sides, so that visitors and local communities will be encouraged to walk through the site. The amended design provides a sloped embankment that seamlessly bridges the level difference between the riverfront promenade and the PS1 terrace…

…The proposed public domain has been the subject of significant testing in consultation with Arup to ensure that the buildings are protected from flooding and the redevelopment of the site does not adversely impact neighbouring properties. Various design options and iterations in developing the initial and amended public domain, were therefore subject to detailed flood modelling and analysis which confirmed that the proposed undercroft area is the best and only outcome for the site to mitigate and appropriately manage riverine flooding (refer to the discussion in Section 5.8 below). Understanding that the proposed undercroft area is necessary to address and mitigate potential flooding, it has been designed to integrate with the public domain and contribute to the design excellence of the building. The area is largely screened by the new proposed sloped embankment, and is secured by operable metal mesh for the openings on the eastern and western ends of the undercroft. This integrates the undercroft area with the built and landscaped environments and enables it to be closed to the public except for managed Powerhouse programming. The use of the space will be carefully managed by the Powerhouse in line with any applicable management plans. All supportive infrastructure for an event will be temporary.

The RTS Report and Appendix J make it clear that the undercroft space is necessary to ensure riverine flood conveyance (EIS stated it was for flood storage) is maintained and the development does not adversely impact on flood levels on neighbouring properties. That is, the undercroft is needed to allow the river to flow downstream without blocking the passage of floodwaters which, were that to occur, would increase flood levels at properties upstream of the museum.

The proposed moveable and lockable screens are meant to find a balance between the space being useable for public programs and events, and for flood conveyance but also to ensure that it is not used inappropriately and becomes a space for vandalism, crime or improvised shelter.

The screen will remain closed at all times except when the space is being used for museum programs or in the event of a flood.

No detail is provided as to whether the screens will be manually, mechanically or electrically operated, whether that will be done at the undercroft or remotely and what will be the flood trigger for their opening.

3.2 BUILDING FLOOR LEVEL

There is a lower ground level at 2.5m AHD with a room which houses the hydrant sprinkler, pump and tank.

The undercroft levels now vary from 3.25m to 3.5m AHD grading upwards towards the stairs which lead to Civic Link.

There are no proposed changes to the ground floor and forecourt levels which will be maintained at 7.5m AHD.

The mezzanine level is at 13.2m AHD and Level 1 at 17.9m AHD.

3.3 OVERLAND FLOW MANAGEMENT

The broad strategy of managing local flooding through the provision of an enhanced underground pipe network has been maintained. There are no proposed changes to the pipe sizes and locations as set out in the EIS.

Design details have been included which ensure that overland flow paths between Phillip Street and the Parramatta River are kept separate from the pedestrian pathways from the river to the public domain spaces at ground level.

The existing overland flow path east of 32 Phillip Street will be eliminated and excess flows diverted down Dirrabarri Lane.

3.4 POWER SUPPLY

The proposed location of three pad mounted substations to supply electricity to the museum are now shown. These will be placed at a minimum of 7.5m AHD which is an improvement over the commitment in the EIS which was to place them at the 1% AEP flood level.

There are now details provided on emergency power arrangements. Page 42 of the RTS Report states:

"Critical electrical infrastructure within the buildings, such as main switchboards and back-up generators are located at Level 1 above this flood level. In extreme flood events where water levels exceed the Flood Planning Level, power supply to critical elements will be provided by the back-up generators which can provide emergency lighting and other essential services for up to 10 hours. Out of 10 lifts serving the museum, 8 will be connected to the back-up power supply."

3.5 CLIMATE CONTROL

The Appendix B Architectural Report makes no mention of climate control.

Appendix A designates as MS7 the following issue raised in the Molino Stewart EIS review report:

"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."

The response to that issue in part states:

"There would not be any presentation spaces in the museum requiring AA climate control. Presentation Space 5 is the only space with A/B climate control."

This statement is at odds with Table 3 of the Powerhouse Precinct Parramatta International Design Competition Stage 2 Design Brief which is reproduced as Figure 1. That table indicates that three floors are to have AA climate control and four floors are to have A climate control with one of those with the capacity for an upgrade to AA climate control.

Page 131 of the design brief also requires the design to *"Contain a front-of-house circulation foyer that also forms an acoustic, light and climate lock."* The functioning of this space as a climate lock during a flood which enters the building has not been made clear in the RTS and supporting documents.

3.6 BUILDING STABILITY

Appendix N is a Structural Statement detailing how the building has been designed to remain structurally stable under the loads it would be subject to in a probable maximum flood.

Table 3 – Operational and Performance Requirements

Presentation Space	Floor Design Live Load (KPA)	Min Span (m)	Ceiling Design Load (metric tonnes)	Conditioning Standard	Logistics – Maximum Object sizing
P #1	20	35	10 tonnes	A	Capacity for direct load of large-scale objects in and out
P #2	20	35	10 tonnes	A	Capacity for direct load of large-scale objects in and out
P #3	10	35	10 tonnes	AA	Goods lift (6x3)
P #4	10	35	10 tonnes	AA	Access Hoist or equivalent for load in and out of large-scale objects
P #5	10	35	10 tonnes	AA	Goods lift (6x3)
P #6	10	35	10 tonnes	A*	Goods lift (6x3)
P #7	5	20	N/A	A	Goods lift (6x3)

* Space to have capacity for upgrade to AA Conditioning Standard.

Figure 1: Table 3 from Powerhouse Precinct Parramatta International Design Competition Stage 2 Design Brief

3.7 FLOOD EVACUATION ROUTES

Appendix B states:

"The updated design provides three points of evacuation from the undercroft, one along the east, one on the west, and another centred along the northern frontage. The lift which serves the undercroft is included for universal access, not evacuation. It is rated as a flood lift and can withstand exposure to water."

Appendix C justifies this design solution for access from the river side to the undercroft and from the undercroft to the podium thus:

"A ramp between the two levels was not possible given the site constraints and severely compromised the public domain experience. The cumulative path of travel, vertically and horizontally of more than 100m, created an unpleasant journey to its users. Therefore, a public lift is identified to be a far superior solution to increase accessibility between the Terrace and River level."

Inspection of the landscape and architectural drawings indicates that there is a continually rising pedestrian route from the riverside, through the undercroft and to the podium level at three locations as well as there being a lift between the undercroft and podium level at the eastern end.

The design details indicate that overland flow paths between Phillip Street and the River are now separated from the pedestrian paths from the River to podium level.

While the Dirrabarri Lane ramp will convey overland flows when the pipe network capacity is exceeded, it is separated from the stairs leading from the River to Dirrabarri Lane. There are also now alternative overland flood free paths from the undercroft to Civic Place so Dirrabarri Lane itself does not need to be used as an evacuation route.

Despite the statement in Appendix B that the undercroft lift is not included for evacuation, Appendix J states:

"The power supply to the building is likely to be operational until flood levels reach 7.5mAHD. Hence, access using the lifts would be

possible from the undercroft level until flood levels reach the lift area (at 3.3mAHD)."

This implies the lift is to provide flood evacuation capabilities.

3.8 FLOOD EMERGENCY RESPONSE

Section 8.3 of Appendix J outlines the proposed Emergency Management Strategy in response to floods. It consists of the following principles:

- Keep the undercroft closed except for Museum organised events and cancel events on the basis of appropriate flood warnings
- Design the paths from the river and the undercroft floor so that they have a continuously rising gradient to the public lift and to the public stair to Civic Place
- Shelter within the Museum Buildings if flooding isolates or threatens the building
- Move to the first floor of the building or higher via stairs and lifts if floodwaters threaten to enter the building
- Provide diesel generator as an emergency power supply and place it and the main switchboard above the Probable Maximum Flood (PMF) level so that essential power can be provided to the building, including the lifts, during a flood.

A commitment is made in Appendix J that:

"A detailed emergency response plan will be prepared in conjunction with the detailed design of the proposal.

The emergency management plan should, as a minimum, include:

- *Locations and levels of stairs, ramps and other available evacuation routes;*
- *Details of the proposed signage/alarms/PA systems in external spaces;*
- *Details of how the Building Management System (BMS) is linked with FloodSmart Parramatta;*
- *CCTV surveillance and site walkovers undertaken by staff to evacuate any people at lower lying levels;*
- *Management of undercroft screening/fencing being opened/retracted prior to a flood event;*
- *Management of lift flood gate at north-east corner of east building;*
- *Approach/assessment for programmable events being held in undercroft; and*
- *Post-flood event actions including inspections and maintenance activities."*

4 FLOOD MODELLING

4.1 TYPES OF FLOODING

The site is affected by both Parramatta River flooding and overland flows which travel to Phillip Street and then flow through the site to the River.

CoPC has modelled both types of flooding using a one-dimensional model and the rainfall and runoff methodologies on Australian Rainfall and Runoff (ARR) 1987. The levels produced by this model are those which are officially adopted by CoPC.

CoPC has commissioned a new two-dimensional flood model using the methodologies in ARR 2019. These results should be more accurate, but the flood study is only in a draft stage and its flood levels have not yet been adopted by CoPC.

Arup created a two-dimensional flood model which encompasses the site and areas upstream and downstream. It uses:

- inflows from CoPC's one-dimensional model for the Parramatta River upstream of Marsden Street Weir
- inflows from CoPC's one-dimensional model for Brickfield Creek.
- the one-dimensional flood model levels downstream of Charles Street Weir
- ARR 1987 rainfall and runoff
- Existing CoPC and private pipe network details in the overland flow catchments upstream of the site
- Proposed pipe networks, topography and building envelopes for the proposed development

The events which were modelled were the 5% AEP, 1% AEP, 1% AEP with climate change and the PMF.

For the same probability event, riverine flooding is generally at a lower level on the site than overland flooding because of the elevation of the terrain over which the overland flooding flows. It is only after the river breaks over the banks upstream of the site in the 0.2% AEP and flows down Phillip Street that riverine flood levels begin to exceed overland flow levels at the site for a given probability.

4.2 RIVERINE FLOODING

The EIS compared the ARUP flood modelling with CoPC's adopted one-dimensional flood model results and its draft two-dimensional flood model results. It found that the ARUP model results for the existing case were about 0.1m lower than CoPC's adopted flood levels but a few hundred millimetres higher than the draft results in CoPC's two-dimensional model. This suggests that the model is suitable for assessing the impacts of the development when considering it uses the 1987 ARR rainfall and runoff adopted by CoPC's one-dimensional model but the modelling techniques of CoPC's two-dimensional model.

Appendix J sets out the impacts of the proposed modified design on surrounding flood levels and finds that in most places where it slightly increases flood levels these are in public spaces or the river where flooding is already deep.

The only exception to this is the underground carpark of the adjacent Meriton Suites at 330 Church Street under the modelled 1% AEP event with climate change. Under that scenario the flood level would be 40mm higher than under existing development conditions and would flood the underground carpark and building services through ventilation louvres. It does not flood in the 1% AEP event under current climate conditions but would flood under climate change conditions and existing development. This means that under climate change there would be a slightly increased chance of the underground carpark flooding due to the proposed development.

Appendix J states:

"This flood assessment has identified and tested a feasible option to mitigate the effects of this impact. This option will be assessed further during detailed design."

No further details are provided as to what that option might be.

4.3 OVERLAND FLOODING

The supporting documents to the EIS did not provide details about the overland flood modelling with regard to:

- How it compared with the CoPC modelled levels
- What assumptions were made regarding blockage of the underground drainage network.

This information is provided in Appendix J of the RTS Report. It states:

"Comparison has also been undertaken for the local overland flow flood levels at the development site as summarised in Table 7. The difference in peak flood levels between the MIKE11 model and the Powerhouse Museum Flood Model is generally in the order of 0.1 m for events up to the 1% AEP with climate change event. Hence, the results are relatively similar. For the PMF, the difference is in the order of 0.5 m."

Table 7 is reproduced here as Figure 2.

Table 7: Comparison of Overland Flow Flood Levels on Dirrabarri Lane

Flood Event (AEP)	UPRCT MIKE 11 Model	Powerhouse TUFLOW Model#
5%	6.89	6.97
1%	6.94	6.99
1% + Climate Change*	6.98	7.00
PMF	11.36	10.88

* UPRCT adopted 15% rainfall increase for the climate change scenario whilst the Powerhouse Museum Flood Model adopted 20% rainfall increase following ARR2019 recommendations

Results based on 100% pipe blockage scenario to match MIKE11 setup

Figure 2: Table 7 from Appendix J – Flood Risk and Stormwater Management Addendum

It is important to note that there is good correlation between the ARUP model and the CoPC model when it is assumed that there is 100% blockage of the underground drainage network. This has several critical implications.

It means that the ARUP model can be relied upon to give meaningful results.

It also means that CoPC's officially adopted 1% AEP flood level for the site is 6.98m AHD and is based on the assumption that none of the overland flows will be conveyed through the underground drainage network.

Parramatta DCP 2011 stipulates that minimum habitable floor levels need to be at or above the adopted 1% AEP flood level plus 0.5m freeboard. This is referred to as the flood planning level and at the site this is 7.48m AHD. It is on this basis that a minimum ground floor level and podium level of 7.5m AHD has been chosen for the museum.

It is worthwhile providing here a discussion about blockage and freeboard because CoPC's adopted position regarding both of these differs from ARUPs approach which is more clearly articulated in Appendix J of the RTS Report than it was in the EIS supporting documents.

4.3.1 Blockage

Following several floods over the past 25 years where blocked urban drainage infrastructure significantly exacerbated flooding, flood modellers began to test the sensitivity of drainage networks to blockage.

ARR 2019 provides guidance on the estimation of blockage factors for major bridges and culverts but does not cover small street drainage inlet structures such as those which surround the Museum site.

Local councils have adopted various blockage factors to be used when modelling overland flows within their local government area.

A 50% blockage factor is commonly adopted although some councils only adopt that for grated inlets and use a lower blockage factor of 10% or 20% for pits with an open, side inlet.

Appendix O to the EIS simply stated that the overland flow modelling included appropriate blockage factors for stormwater pits but did not state what those factors were.

Appendix J of the RTS report makes it clear that the ARUP overland flow modelling adopted 0% pipe blockage, 20% on-grade pit blockage and 50% sag pit blockage. These factors are similar to those used in many flood models but are not as conservative as CoPC's adopted 100% blockage of all inlets. The implications of this are discussed further in Section 4.3.3.

4.3.2 Freeboard

Section 7.2.2 of Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2013) states:

Freeboard is added to flood levels to provide reasonable certainty of achieving the desired level of service from setting a general standard or DFE [defined flood event]. It should be estimated in studies considering the following factors:

- *uncertainties in the estimates of flood levels…*
- *local factors that can result in differences in water levels across the floodplain...*
- *wave action is not considered in hydraulic models. Models assume flat surfaces and do not replicate the undulations in surface levels occurring in flood events...*
- *where the future climate has the potential to significantly increase risk.*

In effect, freeboard acts as a factor of safety. However, it should not be considered as giving additional protection beyond the DFE to which it is applied. A flood planning area is the extent of area below an FPL [flood planning level].

In other words, if the modelled 1% AEP flood level at the museum site is 7.0m AHD and a 0.5m freeboard is appropriate, then a floor level of 7.5m AHD can be considered to only to have flood immunity up to the 1% AEP flood.

Whether 7.0m AHD is the modelled 1% AEP flood level at the museum site is discussed in Section 4.3.3. The appropriate freeboard is discussed in the following paragraphs.

Notwithstanding that the NSW Floodplain Development Manual, 2005 recommends a 0.5m freeboard and that has been adopted by CoPC, Appendix J of the RTS Report states:

"When these factors are considered for Parramatta River flooding, a freeboard of 0.5m is suitable. However, when considered for overland flows from Phillip Street, a lower freeboard may be suitable.

A paper by the Office of Environment and Heritage (OEH) entitled "Local Overland Flooding – the NSW Experience" (2015) suggests that a freeboard of 0.3m for overland flooding may be more appropriate in some situations. The paper states 'studies should provide a breakdown of factors contributing to the proposed freeboard allowance to ensure transparency of the freeboard level adopted.'

The following factors relating to the overland flow conditions at the site are listed below as part of this consideration:

- *the depth of overland flooding is shallow and in the order of 0.3m to 0.4m;*
- *the depths have a limited sensitivity to rainfall intensity increases (see variations in flood level in Table 9) and are, therefore, not sensitive to inaccuracies in rainfall estimation;*
- *there are no 'local factors' of note (e.g. those not able to be simulated in a model);*
- *wave action from wind induced waves would be negligible but vehicle induced waves are possible;*
- *climate change increases to rainfall intensities have been included in the flood assessments and, as listed above, flood*

levels do not increase significantly with rainfall intensity increases;

- *there would be little or no increase in flood levels due to cumulative effect of subsequent infill development of existing zoned land as the levels are not sensitive to floodplain storage loss.*

Hence, given the nature of overland flooding in this site, an overland flow freeboard of 0.3m is justified."

The use of a 0.3m freeboard as opposed to a 0.5m freeboard has significant implications for estimating the chance of the museum and the public spaces flooding.

4.3.3 Flood Levels

Appendix J of the RTS report assesses the impacts of overland flooding based on the blockage factors assumed in the ARUP flood model and includes sensitivity analysis based on other blockage assumptions.

The presentation of the results is not entirely clear, however.

For example, there does not appear to be a single location where it is possible to compare the overland flood levels with and without the development, using the blockage factors adopted in the ARUP model.

Section 7.3.3 states:

"For the 5% AEP event, the modelling assessments indicate that the proposed stormwater network would result in a decrease in peak flood levels of up to 0.1m. As well, it is predicted that there would be a reduced flood extent for Phillip Street, Dirrabarri Lane as well as along the perimeter of 32 Phillip Street for these flood events due to the augmented underground drainage system (i.e. larger pipes and increased inlet pit capacity).

It is also predicted that for the 1% AEP afflux there would also be a reduction in peak flood levels on Phillip Street and Dirrabarri Lane of approximately 0.1m. The land located north and east of 32 Phillip Street would remain flood free for the 1% AEP event.

This flood assessment indicates that the development proposal would not cause adverse impacts on other development or properties for local flood events up to the 1% AEP.

For the 1% AEP event with climate change (i.e. 20% rainfall increase), there would be reduction in peak flood levels (in the order of 0.02m) on Phillip Street as well as decrease in flood extent on the properties located north and east of 32 Phillip Street.

There would be a small pocket of localised impact due to the project on the northwest corner of 32 Phillip Street (around 26mm) in the 1% AEP flood event with climate change. However, this impact would not affect the building at 32 Phillip St or the access to the building. Hence, the afflux is unlikely to result in any increased damage or reduced usage of the building and can be considered as a negligible impact."

While this compares relative flood levels with and without the development it does not provide the absolute flood levels. These have to be read from the flood maps in Appendix A which only provide a selection of spot levels. Interpretation of these maps has produced the flood levels in Table 1.

Table 9 of Appendix J (reproduced here as Figure 3), provides absolute flood levels but labels them as "no pipe blockage" and "100% pipe blockage". It is not clear whether the "no pipe blockage" scenario includes the pit blockage factors assumed by ARUP or not.

All of this information taken together reveals that:

- The proposed augmentation of the underground drainage network will reduce existing flood levels if the inlets have 50% or less blockage
- If there is 100% drainage network blockage, then the development would increase local overland flood levels in the 1% AEP flood by about 200mm.

In its submission to the EIS, CoPC states:

"Arup's approach to overland is reliant on substantial underground piped flow to alleviate overland flow flooding in certain areas of or near the site, at least for the less intense rainfall events. Given their propensity to become blocked, reliance on piped networks to reduce flooding is unsound and unsafe in this high intensity use area…

Table 1: ARUP Modelled Flood Levels (mAHD)

Event	**Development**	**Location**		
		Dirrabarri Lane	32 Phillip St	Phillip St near Wilde Ave
1% AEP	Existing	>6.8 and <7.0	7.0	>7.0 and <7.5
	Museum	7.0	7.0	7.0
1% AEP + Climate Change	Existing	>6.8 and <7.0	7.0	>7.0 and <7.5
	Museum	7.0	7.0	>7.0 and <7.5
PMF	Existing	10.9	11.0	11.0
	Museum	10.9	11.0	11.0

Table 9: Comparison of Freeboard provided for various flood events

Flood Scenario	**Peak Water Level (m AHD)**	**Freeboard from FFL of 7.5mAHD**
1% AEP		
River Flood Level	6.07	1.43m
Overland flooding – no pipe blockage	6.72	0.78m
Overland flooding – 100% pipe blockage	7.20	0.30m
1% AEP + Climate Change (approx. equal to current 0.25% or 1:400 AEP)		
River Flood Level	6.60	0.90m
Overland flooding – no pipe blockage	6.86	0.64m
Overland flooding – 100% pipe blockage	7.25	0.25m
0.13% AEP (1:800 AEP)		
River Flood Level	6.87	0.63m
Overland flooding – no pipe blockage	7.18	0.32m
Overland flooding – 100% pipe blockage	7.25	0.25m
0.1% AEP (1:1,000 AEP)		
River Flood Level	6.98	0.52m
Overland flooding – no pipe blockage	7.33	0.17m
Overland flooding – 100% pipe blockage	7.40	0.10m
0.05% AEP (1:2,000 AEP)		
River Flood Level	7.22	0.28m
Overland flooding – no pipe blockage	7.62	-0.12m
Overland flooding – 100% pipe blockage	7.66	-0.16m

Figure 3: Table 9 from Appendix J – Flood Risk and Stormwater Management Addendum

…The eastern and western overland flow routes must be properly formed and designed for conveyance and safety while the central area of the site must be raised or reformed to avoid this function. The redesign of the landform must not rely on pipes and culverts to convey the floodwaters to any significant degree. These should only be used for 'nuisance' flooding as part of the WSUD system"

In other words, CoPC rejects the development's reliance on underground pipes to convey overland flows from Phillip Street to the River. However, because the raised podium level blocks the overland flow path which currently exists to the east of 32 Phillip Street, the development can only increase flood levels in Phillip Street unless an alternative above ground overland flow path can be provided to take these flows when pipe conveyance is not available.

Section 7.3.6 of Appendix J states:

"In terms of post-development flood impacts on Phillip Street and Dirrabarri Lane under the full pipe blockage scenario, a peak flood level increase (compared to existing conditions) in the order of 60mm is expected to occur for the 5% AEP and 1% AEP events, and 65mm for the 1% AEP with climate change event.

However, as stated above, in this scenario there would be extensive and regular flooding of the building at 32 Phillip Street in both the existing case and the case with the proposed development. The flood immunity of the building at 32 Phillip Street in this scenario would be very low. The flood depth in the building would be more than 0.25m for the 5% AEP flood level in the existing case in this scenario. The additional flood depth of 60mm under this scenario in a 1% AEP flood event would be an additional depth in an already flooded building."

There would appear to be two problems with these statements.

Firstly, Table 7 of Appendix J (Figure 2 of this report) indicates that the existing flood level at Dirrabarri Lane from the ARUP model with 100% blockage in the 1% AEP flood 6.99m AHD and Table 9 (Figure 3) indicates post development the flood level would increase to 7.2m AHD. This is more than a 200m increase in flood level, not 65mm.

Secondly, the suggestion that the incremental flooding would not have a significant impact on 32 Phillip Street because it would already be flooding under existing conditions is the wrong way to look at the impacts. What the increased water level means is that the level which floods the building will be exceeded in a more frequent flood than currently occurs and therefore 32 Phillip Street is more likely to be flooded.

4.3.4 Flood Immunity

Table 9 (Figure 3) also includes an analysis of available freeboard to the ground floor of the Museum from both riverine and overland flooding based on different drainage network blockage scenarios.

There is no question that as far as riverine flooding goes the ground floor has flood immunity up to about the 0.1% AEP (1 in 1,000) flood.

The immunity available from overland flooding is highly sensitive to the degree of blockage assumed in the underground drainage network and the amount of freeboard which should be applied to overland flows in this area.

If CoPC's standards of 100% blockage and 0.5m freeboard are applied, then the building would flood in a flood which is 200mm lower than the 1% AEP flood. Judging by the levels set out in Table 7 of Appendix J (Figure 2) this could be as frequent as a 5% AEP (1 in 20) event or even more frequent.

If 100% blockage is assumed but a 0.3m freeboard is acceptable then the ground floor is immune up to the 1% AEP flood.

If there is no pipe blockage and a 0.3m freeboard is accepted, then it has immunity to the 0.125% AEP (1 in 800) flood. Although it is noted that the ARUP model assumes some blockage of the drainage network so the immunity may not be as good as 1 in 800.

5 DISCUSSION

The additional information provided in the RTS and its appendices has made it easier to assess the flood risks associated with the development than was able to be done with the information provided in the EIS and its addenda.

Furthermore, there have been significant design modifications which have mitigated some of the risks.

The following considers the risks from flooding and their status based on the information in the RTS and appendices.

- Risk to Neighbouring Properties
- Risk to Collections
- Risk to Life

5.1 RISK TO NEIGHBOURING PROPERTIES

It is common practice to ensure that developments do not increase flood hazards on neighbouring properties up to and including the 1% AEP flood. In larger floods it is usually not practical to ensure flooding is not exacerbated by development.

5.1.1 Riverine flooding

The modelling results presented in Appendix J suggest that in all events up to the 1% AEP riverine flood, the only significant increases in offsite flood levels will be in the river itself or public open spaces.

It does flag that under climate change conditions there would be a 40mm increase in flooding at 330 Church Street in the 1% AEP flood. This means that the basement car park would be more likely to flood.

The report foreshadows a possible solution to this but does not provide details.

The provision of the undercroft space as an area of flow conveyance is critical to the development achieving this low risk to neighbouring properties.

While the provision of lockable screens to the undercroft space reduces the risk to life from the development it does increase the risk to neighbouring properties because there is a chance that the screens will not be open when a flood rises to podium level.

No information has been presented to date on how the reliable and safe opening of the screens will be ensured and what the implications are for neighbouring properties if the screens fail to open.

5.1.2 Overland flooding

The development proposal relies heavily on the provision of an enlarged underground drainage network to take the overland flows which currently flow down the east side of 32 Phillip Street and those which run along the east of the Museum site.

Should the inlets to these drains block more than the 20-50% assumed in the ARUP model then the development will increase flood levels in Phillip Street and increase the impacts on neighbouring properties, particularly 32 Phillip Street.

CoPC argues strongly in its submission to the EIS that no reliance should be placed on underground drainage to manage overland flows. It states, "*reliance on piped networks to reduce flooding is unsound and unsafe in this this high intensity use area.*"

5.1.3 Outstanding matters

Blockage risk is the key issue which needs to be resolved for both riverine and overland flows.

a) Retractable screen reliability

In the case of riverine flows it still needs to be demonstrated that the design and operation of the retractable screens to the undercroft have a sufficiently low probability of not opening and by so doing increasing flooding on neighbouring properties. The fail-safe mechanisms for their opening must not place lives at risk either through inadvertently providing shelter for the public in the undercroft or by operators having to enter floodwaters to open the screens.

b) 330 Church Street mitigation measures

Detail needs to be provided on the mitigation measures proposed to ensure that the building at 330 Church Street will not be worse off under climate change.

c) Drainage inlet blockage

In the case of overland flows, a decision needs to be made as to what is an acceptable blockage factor to apply to the underground pipe network when assessing potential impacts on neighbouring properties. Impacts are highly sensitive to this factor. The blockage factors assumed by ARUP suggest that neighbours will be better off after the development but application of CoPC's recommended blockage factors indicate that neighbours would be considerably worse off.

5.2 RISK TO COLLECTIONS

The collections are at risk from flooding from direct contact with floodwaters and with indirect impacts from changed humidity conditions.

Section 8.3.2 of Appendix J states:

"The museum will house valuable collections. The design of the building has reflected the value of these collections by creating a ground floor level that would have an immunity of approximately 1 in 800 AEP (or 0.12%) including an allowance for freeboard.

Only Presentation Space 1 will be located on this ground floor. All other presentation spaces within museum will be located on floors that sit above the PMF level.

During flood events, some presentation spaces could be closed so that the humidity of the air in those presentation spaces can be maintained with air-conditioning.

Given the small fraction of presentation spaces below the PMF level, the warning time available for river flooding and the low probability of flooding of the ground floor, the likelihood of flood damage to the collections housed in the museum would be low."

Each of the above statement warrants some discussion.

With regards to the flood immunity of the ground floor, that is highly dependent on what is assumed to be the likely degree of blockage of the underground drainage system and what is an appropriate amount of free board to be provided.

The 1 in 800 AEP nominated applies if it is assumed there is no blockage of the underground pipe network and a 0.3m freeboard is applied. If 100% blockage and 0.5m freeboard is adopted as recommended by CoPC, the flood immunity is probably not even a 1 in 20 AEP. This highlights that the flood immunity provided is very sensitive to these assumptions.

It is correct that only presentation space 1 will be at ground level and all other presentation spaces will be above the PMF level. It therefore follows that only those items on level 1 will be at risk of direct damage from flooding. However, it is not correct to say that the likelihood of damage to these items is low. The available warning time for extreme riverine flood events may be as little as two hours. Furthermore, the building is more likely to be flooded by overland flows than riverine flooding and there will be virtually no warning that overland flows are likely to enter the building. Additionally, some of the items on display in the P1 space will be large items which would not be able to be moved in a short space of time. Finally, the rapid flooding of the building from overland flows means that the focus of staff is likely to be on the quick and safe evacuation of people to the upper floors rather than the relocation of exhibits.

Therefore, should water enter the building it is likely that many items on display on the ground floor will suffer some direct flood damage.

It is possible that closure of other spaces may provide some stabilisation of humidity levels which would afford some protection to items which need high standards of climate control. Given that the three substations providing power to the building will be at ground level, grid power will be lost when floodwaters enter the building, if not beforehand. Appendix J states *"The generator capacity is sufficient to provide emergency lighting and other essential* *services for up to 10 hours. Out of 10 lifts serving the museum, 8 will be connected to the back-up power supply."* It is, therefore, not clear whether the emergency generator would have capacity to run the air-conditioning systems at all. In any case, if the substations flood, power is likely to be lost for more than 10 hours. Ten hours of emergency power is appropriate for managing the safety of occupants during what is likely to be short duration flooding, it would not be sufficient to run air conditioning for the duration of the ensuing power outage.

What is also unclear is the climate control standards which need to be maintained in these spaces. The Stage 2 Design Brief stipulates all spaces (including Presentation Space 1 which cannot be closed off from the ingress of water), need to have A or AA class climate control. The foyer is also to provide a climate air-lock. The RTS Appendix A, however, indicates that A/B climate control will be provided.

In addition to the uncertainties discussed above, no actual analysis has been done to determine what specific collections or items are likely to be at risk from direct or direct flood impacts, what the consequences would be to the value of those collections or items and what is an appropriate probability of damage to expose them to.

Even a 1 in 800 chance of damage per year may be deemed too great for some items given their value and the design life of the building which exceeds 100 years. The chance of a flood reaching or exceeding the 1 in 800 level in 100 years is about 12%.

5.2.1 Outstanding matters

a) Drainage inlet blockage

As with the risk to neighbouring properties, the probability of the collections being exposed to flooding is highly sensitive to how blocked drainage inlets are during a flood. A resolution is needed on what is an appropriate assumed inlet blockage factor for assessing flood levels post development.

b) Freeboard

Similarly, the probability of floodwaters entering the building is highly sensitive to the freeboard assumed for overland flows in the flood risk analysis.

c) Climate control

Clarification is needed on the climate control standards which need to be achieved for the integrity of the collections and items housed in the museum and whether the emergency generator and internal space isolation features within the building design can maintain those levels in the event of a flood that disables the substations supplying electricity to the building.

d) Potential flood damage

Someone with expertise in the conservation of museum collections and items needs to assess the potential damage which could be caused to items likely to be displayed in the various parts of the Parramatta Powerhouse should they be exposed to direct contact with flood waters or variations to humidity levels which flooding and power loss poses.

e) Acceptable chance of damage

An objective evaluation of an acceptable chance of direct or indirect flood damage needs to be made for various categories of collections and items taking into account their cultural, heritage and monetary values and the ability of them to be repaired or replaced. The RTS describes a 12% chance of damage over the life of the museum as an acceptably low probability. Others, with expertise in the valuation of museum collections and an understanding of how they could be damaged by flooding, may see this as an unacceptably high probability. Any different assumptions about freeboard or blockage are only likely to make the estimated chance of flood damage even more likely than 12%.

f) Design review

After an appropriate risk framework for protection of the collections and items has been established, the museum design needs to be reviewed to determine how that can be achieved, if at all. This analysis needs to use blockage factors and freeboard values which have been accepted as appropriate for the estimation of flood levels at the site.

5.3 RISK TO LIFE

5.3.1 External

The redesign of the undercroft and its connections to the podium level has significantly reduced the risk to life for people external to the building by:

- using screening to exclude people from the undercroft except in for Museum sanctioned events. This significantly reduces the likelihood of people sleeping or sheltering from the rain in this area and allows its use to be ceased ahead of forecast flooding.
- making changes to paths, stairs and the undercroft floor grading ensures that there are continuously rising pedestrian paths from the river or the undercroft to the podium level. This significantly reduces the risk of people having to walk towards rising floodwaters to reach safety
- providing a lift between the undercroft and podium provides an access route for mobility impaired evacuees from the River level and undercroft to the podium level
- providing of an emergency generator means that it is possible to keep the lift operational should there be loss of power supply to the building due to flooding or any other reason although it is not clear whether this is one of the eight lifts which will be provided with emergency power
- detailing the stairs leading to the podium level keeps overland flows separate from pedestrian routes meaning that people fleeing rising river levels do not have to negotiate walking against overland flows

5.3.2 Internal

Risks to people inside the building have been reduced by:

- adopting a shelter in place strategy during floods which threaten or isolate the building will reduce the risk of people trying to leave the building and having to travel through hazardous floodwaters adjacent to the building or elsewhere in Parramatta CBD and its surrounds
- providing of an emergency generator means that lighting and other essential services can be maintained in the building during a flood, making sheltering in place both a more attractive and practical proposition
- using the generator to keep the internal lifts operational, should there be loss of power supply to the building due to flooding or any other reason, will ensure mobility impaired occupants have a reliable means of reaching levels within the building which are above the PMF. It is not clear, however, whether the eight lifts provided with emergency power will be spread between both buildings
- setting out a sound flood emergency response strategy which can form an appropriate basis for a detailed flood emergency response plan.

5.3.3 Outstanding Matters

There remain four residual risks to life which need further consideration and resolution.

a) Operation of the undercroft screens

It is not clear whether these screens will be manually, mechanically or electrically retracted and whether that will be able to be done remotely. As the impacts on neighbouring properties is highly dependent on the retraction of the screens, it will be important that there are fail-safe mechanisms and procedures for ensuring their retraction. It will also be important that their retraction does not place lives at risk by requiring people to enter areas which are flooding are or threatened by flooding nor that their premature opening creates an opportunity for the public to take shelter in the undercroft.

b) Lift operation during floods

There is insufficient detail provided to know whether the emergency power to the lifts covers lifts in both buildings and the lift from the undercroft.

c) Fire safety

There is a combined hydrant sprinkler, pump and tank room at a level below 2.5m AHD. Presumably, once this gets flooded there would be no fire services in building. It is not clear from the drawings what flood level these are protected from but it would be expected that once flooding exceeded the ground floor level this room would fill with water, if not before.

A situation could develop where there is a fire in the building, but people are not able to safely evacuate due to it being surrounded by floodwaters and the fire suppression system does not delay the fire spread.

d) Flood probability

An important consideration in assessing the acceptability of risk to life is the frequency that people are exposed to flooding. As explained in Section 5.2, this frequency is highly sensitive to assumptions about drainage network blockage and freeboard. Having a 12% chance of having to implement the flood emergency response plan over the life of the building is likely to be acceptable, having to implement it several times is probably not.

6 CONCLUSIONS AND RECOMMENDATIONS

The provision of more detailed information about the building design and flood modelling assumptions since publication of the EIS has allowed a better assessment to be made of the flood risks to people and property.

The redesign of building features, particularly the undercroft and its connections to the podium level have significantly reduced the flood risks to people outside the building.

Similarly, the provision of an emergency generator and the adoption of a shelter in place strategy greatly reduces the risks to people inside the building.

The means of managing risks to people could now generally be considered to be acceptable although further clarification is needed on:

- How the undercroft screens will be operated reliably without compromising the safety of those operating them or inadvertently encouraging people to shelter in the undercroft
- Whether the provision of emergency power to lifts will cover both buildings and the undercroft lift
- How building fire safety will be maintained when there is critical fire service infrastructure below 2.5m AHD
- How often the building is likely to flood

There remain important unanswered questions regarding the chance of the development making flooding worse for neighbouring properties. In particular:

- More detail is required on the design and operation of the undercroft screens to ensure that their failure to open does not make flooding worse for neighbouring properties and that fail-safe opening mechanisms do not compromise the safety of those opening the screens
- More detail is needed on mitigation measures to protect 330 Church Street from increased flood impact if climate change occurs
- A decision needs to be made on an appropriate blockage factor to be applied to underground drainage when designing measures to manage overland flows.

There is still considerable work to be done to demonstrate that the museum's collections can be provided with an appropriate level of flood protection at this site.

- The decision about drainage network block has implications for the degree of protection afforded to the collections
- A decision also needs to be made about the appropriate amount of freeboard to use to take into account modelling uncertainties
- Clarity and transparency is required around the standard of climate control planned for the development and whether this is adequate to protect the collections
- Clarity is required as to whether the emergency generator and/or other building design features will be able to maintain climate control standards during extreme floods
- Clarity is required on the impact of flood events on museum operations
- A clearer picture is required of the potential direct and indirect damage which flooding could pose to collections and items
- An objective assessment is required of an acceptable probability of loss or damage to categories of Museum contents taking into account their various values
- A review of the museum design is required to determine how, if at all, it is possible to provide the collections with the degree of flood protection deemed necessary

It is apparent that the chance of neighbouring properties and the museum collections being damaged by flooding and the flood emergency response procedures having to be implemented is highly sensitive to assumptions in the flood modelling.

Arup has provided a defensible rationale for choosing the drainage network blockage factors and freeboards it has used in its modelling and assessments. However, these are far less conservative than those applied by CoPC to all other developments in Parramatta CBD.

Given the sensitivity of the flood risk assessments to these factors, their selection needs careful consideration.

Furthermore, even using the least conservative assumptions, there is greater than a 12% chance that floodwaters would enter the ground floor of the museum during its design life. This itself may be unacceptable depending on what the consequences of that flood might be on collections and these have not yet been properly determined. However, if CoPC's more conservative assumptions are adopted then modelling suggests that the museum could flood several times in its lifetime and neighbouring properties would flood more often than without the Museum development. This would clearly present unacceptable risks to people and property.

It is therefore recommended that the aforementioned investigations and decisions are required before development consent is granted to the Parramatta Powerhouse Museum as it might not be possible to achieve acceptable flood risks at the site.

7 REFERENCES

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019: Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia).

City of Parramatta Council, 2011: Development Control Plan (DCP)

NSW Department of Infrastructure, Planning and Resources, 2005: NSW Floodplain Development Manual (the Flood Manual).

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.