WALSH BAY ARTS AND CULTURAL PRECINCT

STATE SIGNIFICANT DEVELOPMENT APPLICATION

SSDA 8671

APPENDIX 22:

MARITIME IMPACT ASSESSMENT REPORT

NSW GOVERNMENT

ARUP

Maritime Impacts Assessment Report

Summary

Objectives

The key objectives of this Maritime Impacts Assessment Report is to document the assessment undertaken by Arup of the following particular issues as required by the Secretary's Environmental Assessment Requirements (SEARs) for the Walsh Bay Arts and Cultural Precinct (WBACP) project:

- Extreme water level and wave impacts on public safety of public domain areas (including consideration of future sea level rise); and
- Impacts on Sydney Harbour users including detailing any berthing arrangements.

Methods, Results and Conclusions

Extreme water level inundation and wave overtopping are two potential risks to public safety on overwater structures. Site specific metocean (waves and water levels) conditions have been developed to inform this assessment. The findings show that the level of the pier/wharf apron deck area is above the present day and predicted future tidal and extreme 100yr ARI water levels. Inundation of the deck is therefore unlikely over the design life of the project. For the future scenario allowing for sea level rise, lower sections of the pier/wharf may experience some periodic wave overtopping onto the deck during an extreme 100yr ARI water level event. There is adequate provision for the overtopped water to drain away into the harbour to avoid significant landside ponding/buildup. During this rare event public access to the lower deck levels may be restricted. However, a more appropriate assessment of user safety is to consider wave overtopping for a more frequent 5yr ARI wave event at MHWS and in this case no overtopping is expected.

A qualitative assessment of the impact to harbour users indicates there will be a negligible impact to Sydney Harbour users resulting from the WBACP development and there are no proposed formal berthing facilities to be included in the scheme. A qualitative assessment of accidental vessel impact with the WBACP site identified that the site is at a low risk of vessel impact and the residual capacity of the existing structures should preclude structural failure in the event of an impact with all but large vessels.

Recommendations

- Consideration be given to further assess the structural redundancy of the existing wharf structures against medium size vessel impact to confirm the assumptions made in the qualitative assessment.
- Should any water-based construction be proposed to implement the works, the Harbour Master should be consulted to agree construction stage vessel exclusions zones.

Contents

1. Objectives of Assessment

Arup was engaged as the Maritime consultant on the WBACP project to provide general maritime advice on the design and implementation of the scheme. In accordance with the Secretary's Environmental Assessment Requirements (SEARs), the following specific assessment activities have been addressed in this assessment:

- Extreme water level and wave impacts on public safety of public domain areas (including consideration of future sea level rise); and
- Impacts on Sydney Harbour users including detailing any berthing arrangements.

A summary of the SEARs requirements and where they have been addressed in this report are shown in Table *1*.

Table 1: Summary of SEARs relevant to this assessment

SEARs No.	SEARs Requirement	Where addressed in this report
1	**Impacts on Harbour Uses** • Address the impacts on Harbour vessel movements and all users of Sydney Harbour • Detail any berthing arrangements	• Section 5.3
18	**Flooding, Climate Change and Sea Level Rise** • Address the potential risks from flooding, wave movements and sea level rise on the development and detail any proposed mitigation measures.	• Sections 5.1 and 5.2

2. Site and Project Descriptions

The NSW Government is committed to development of a public arts and cultural precinct at Walsh Bay. Infrastructure NSW is acting on behalf of the client, Arts, Screen and Culture Division in preparing this State Significant Development Application for the Walsh Bay project.

This SSDA will seek approval for the construction and operation of Pier 2/3 and Wharf 4/5 for arts and cultural uses with complementary commercial and retail offerings to activate the precinct.

The site generally comprises Pier 2/3, Wharf 4/5, and Wharf 4/5 Shore Sheds. The site has a street frontage to Hickson Road as shown in Figure 1. The site is part of the Walsh Bay area, which is located adjacent to Sydney Harbour within the suburb of Dawes Point.

Figure 1: Locality plan of the Project Site (red outline)

The Scope of the Project is as follows:

Pier 2/3

- The adaptive re-use providing for new arts facilities including performance venues for the Australian Chamber Orchestra, Bell Shakespeare and Australian Theatre for Young People;
- Retaining a large heritage commercial events/art space for events such as Sydney Writers Festival, Biennale of Sydney and a wide range of commercial and artistic events;
- A series of stairs, external lift and balconies designed as a contemporary interpretation of the original gantries reflecting the precinct's former industrial heritage
- Modifications to the roof

Wharf 4/5 (including Shore Sheds)

- Refurbishment of the ground floor arts facilities and its associated Shore Sheds for Bangarra Dance Theatre, Sydney Dance Company, Sydney Philharmonia, Gondwana and Song Company;
- New commercial retail opportunities; and
- A series of stairs, external lifts and balconies designed as a contemporary interpretation of the original gantries reflecting the precinct’s former industrial heritage
- Modifications to the roof

3. Site Analysis

3.1 Metocean Conditions

A Metocean Conditions Report has been prepared for the project which documents the methods used to develop site specific metocean design criteria, including water levels, wave heights and current flows. This report is included in **Appendix A**.

3.2 Sydney Harbour Vessel Traffic

3.2.1 General

The site is located on the southern shore of Sydney Harbour, approximately 300m to the west of the Sydney Harbour Bridge. The two existing wharves extend approximately 200m into the harbour from the shore. There are a large number of recreation, commercial and public transport vessels operating on the harbour, a significant proportion of which will pass by the WBACP site under normal operations.

Of the transiting vessel traffic, Sydney Ferries vessels and large vessel commercial traffic (cruise vessels, bulk cargo vessels, bulk liquids vessels) will follow broadly defined routes based on the origin and destination ferry wharves. The proximity of these routes in relation to the site are discussed below. Small vessel commercial traffic including construction vessels and tourist charter vessels operate on an ad-hoc basis and do not follow standard routes.

3.2.2 Sydney Ferry Network

Figure 3 shows the Sydney Ferry network in the vicinity of the WBACP location. It can be seen that a number of ferry routes transit past the site.

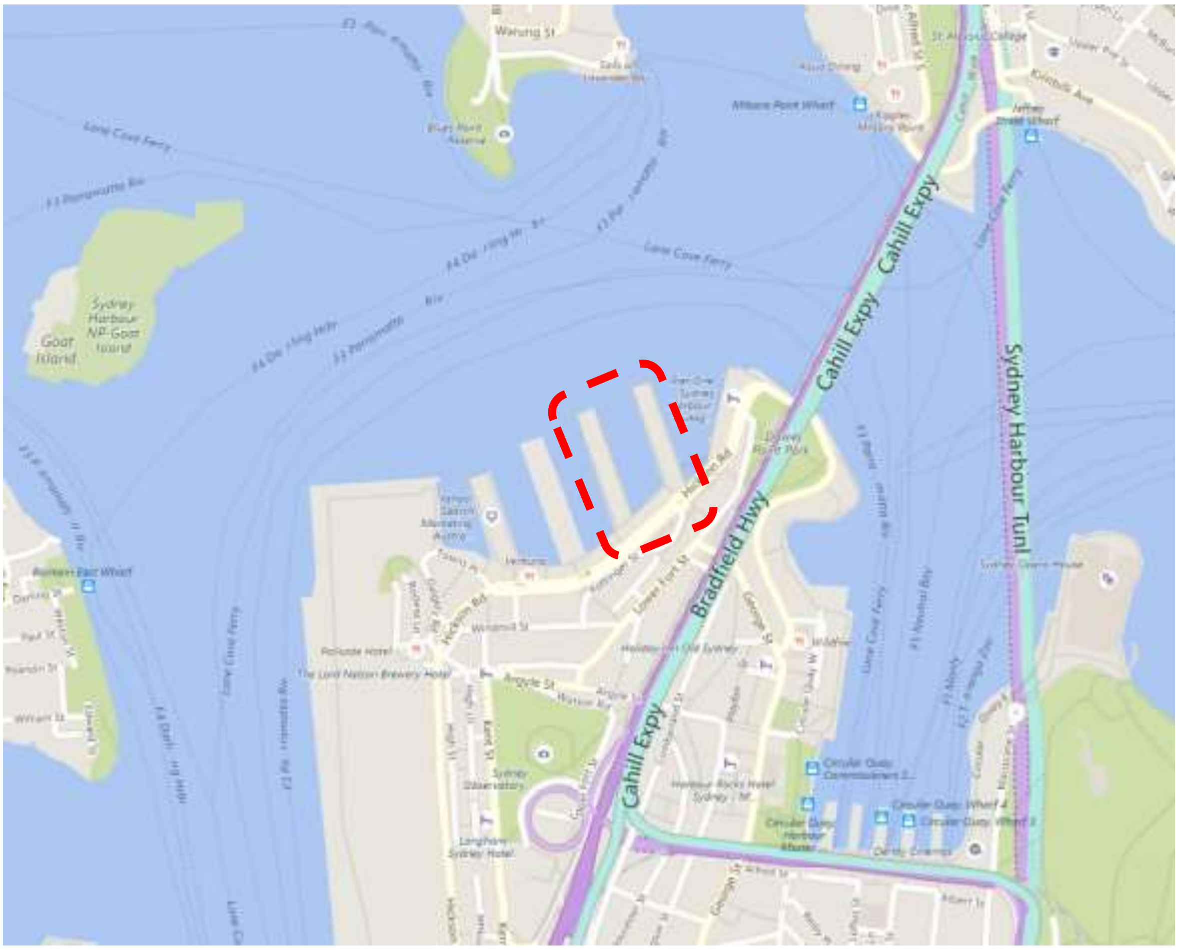

Figure 2: Sydney Ferries Network (background image source: Microsoft Bing Maps)

3.2.3 Commercial Vessel Activity

A number of commercial wharves are located to the west of the WBACP site, requiring vessels to transit past the site on approach and departure. These wharves are shown on Figure 4 and include:

- Gore Bay – bulk liquid import facility.
- White Bay Cruise Terminal – cruise terminal mainly handling domestic vessels.
- Glebe Island – bulk cargo facility.

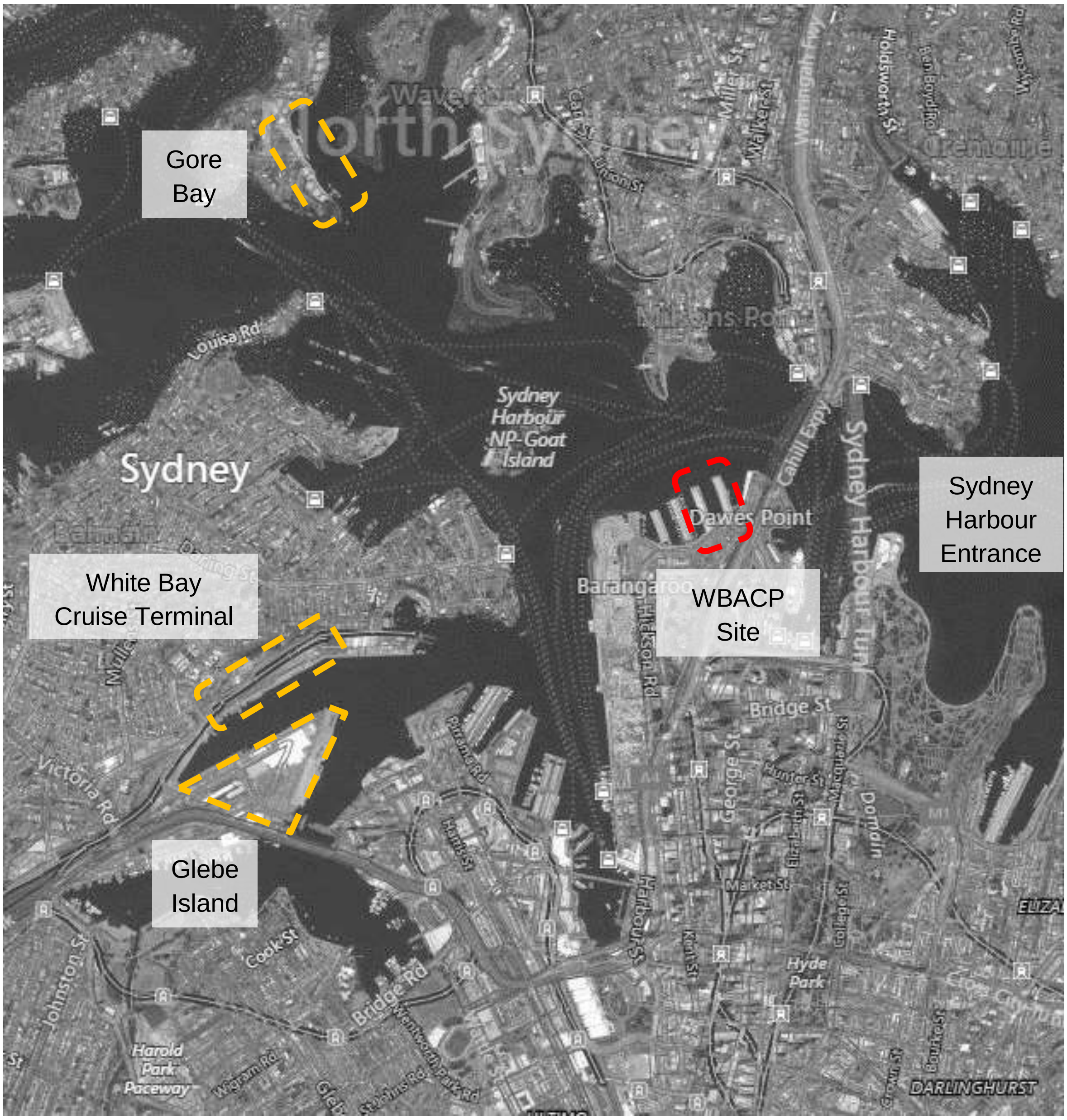

Figure 3: Commercial Wharves West of Sydney Harbour Bridge (background image source: Microsoft Bing Maps)

As the vessels transiting to the identified commercial wharves typically follow a prescribed navigation route and can be reasonably expected to continue for the foreseeable future the design of the WBACP development should accommodate the vessel generated wake waves and consider the scenario of accidental vessel impact.

3.3 Maritime Environment

The WBACP development includes the re-use of two existing wharves. As maritime structures, the design of wharves must respond to the specific issues associated with the marine environment to ensure a structurally sound, constructible, durable end result that provides the optimum and safe user experience. As the wharves are existing state-heritage listed structures, no change to their design is proposed.

4. Regulatory Context

4.1 Federal and State Government Legislation

The following government legislation covers the design of the WBACP development.

Work Health and Safety (WHS) Act 2011

Section 22 (WHS Act) – Duty of Designers to ensure that designed plant substance or structure is without risk to Health & Safety of Persons:

- Who use the product
- Who construct the product
- Who decommission the product
- Who maintain the product

5. Methods, Assessment and Results

5.1 Water Levels Impact Assessment Including Sea Level Rise

5.1.1 Wharf Levels

The following finished floor/deck levels is proposed across the pier/wharf apron, which match existing:

Pier 2/3 apron - +2.1mAHD (Pier 2 length) to +3.44mAHD

Wharf 4/5 apron - +2.04mAHD (southern end of Wharf 4) to +3.4mAHD

5.1.2 Design Water Levels

AS 4997 **[Ref.1]** recommends that the minimum deck level should be based on the 100 year average return interval (ARI) elevated water level over the design life, plus a suitable freeboard to allow for wave action.

Present day 100yr ARI water level - +1.44mAHD

2067 100yr ARI water level - +1.94mAHD

The deck level should also be above the Mean High Water Springs (MHWS) level including an allowance for the greater of the 5yr ARI wind generated wave or passing vessel generated wave. The relevant wave properties are as follows:

5yr ARI wind maximum wave height, H_{max} - 0.6m (0.4m H_s x 1.5)

Passing vessel wave height (H) - 0.6m

The common critical wave height is therefore 0.6m. The interaction of the wave with the wharf structures can be assessed as a 0.3m increase in water level (half the wave height above the water level). The actual and modified MHWS tidal levels are:

Present day MHWS - +0.67mAHD

Present day MHWS + wave crest - +0.97mAHD

2067 MHWS - +1.17mAHD

2067 MHWS + wave - +1.47mAHD

5.1.3 Assessment of Site Water Levels

The deck level of the wharf deck area is above the present day and predicted future tidal and extreme 100yr ARI water levels. Inundation of the deck is therefore unlikely over the design life of the project.

For the future scenario allowing for sea level rise, lower sections of the pier/wharf may experience some periodic wave overtopping onto the deck during an extreme 100yr ARI water level event. However, during this rare event wave overtopping is expected to be relatively minor in magnitude and there is adequate provision for the overtopped water to drain away into the harbour to avoid significant landside ponding/buildup.

5.2 Wave Impact Assessment

5.2.1 Structural Design

AS 4997 **[Ref.1]** recommends normal maritime structures to be designed for the 500 year ARI wind generated wave climate, which was determined to have a significant wave height (Hs) of 0.6m and 2.96s peak wave period (Tp). As the wharves are existing structures and these estimated design wave characteristics are sufficiently small no impact is expected.

5.2.2 User Safety

As discussed above, for the future scenario allowing for sea level rise, lower sections of the pier/wharf may experience some periodic wave overtopping onto the deck during an extreme 100yr ARI water level event. During this rare event public access to the lower deck levels may be restricted. However, a more appropriate assessment of user safety is to consider wave overtopping for a more frequent 5yr ARI wave event at MHWS and in this case no overtopping is expected.

5.3 Impacts on Harbour Users

5.3.1 Harbour Navigation

5.3.1.2 Construction Phase

Given the constrained landside access for construction there is potential that major construction works associated with the project will be undertaken from the water using marine plant and an offsite prefabrication. This form of construction has the beneficial effect of reducing construction truck traffic.

The marine plant would likely consist of a number of construction barges to transport prefabricated components from a waterside prefabrication yard located elsewhere in Sydney Harbour and barge mounted cranes and contractor’s amenities. There is sufficient space between Pier 2/3 and Wharf 4/5 to locate the construction plant without projecting out past the existing wharves into the main harbour area. A vessel exclusion zone would need to be established around the site for the duration of the maritime construction works, this is not expected to impact on existing harbour users and access could be maintained to existing berthing facilities on adjacent wharves however it is likely that berthing would be restricted in the area between Pier 2/3 and Wharf 4/5 – as shown in Figure . The Harbour Master would need to be consulted on any temporary vessel exclusion zones enacted in Sydney Harbour.

Figure 4: Assumed construction works vessel exclusion zone

Transport barges operating between the WBACP site and an offsite prefabrication yard will need to operate in Sydney Harbour. This is unlikely to generate a large number of barge movements given the scale of the development and is a typical method of transporting materials for maritime construction in the harbour. Construction traffic would need to follow the Harbour Master's Directions which provides standard protocols that must be adopted by all commercial vessels operating in Sydney Harbour.

5.3.1.2 Operation Phase

The proposed design does not alter the footprint of the existing Pier 2/3 or Wharf 4/5 structures. RMS have retained the right to berth super yacht vessels alongside Pier 2/3 and Wharf 4/5 within the area bound by the two wharves, however there is no ferry or commercial vessel berthing provision at these wharves in the site area.

As there is no change to the existing berthing arrangements at the site the development will generate negligible vessel traffic.

This combined with the planned footprint of the existing wharves remaining the same as the existing configuration means there is no change to the navigable area of Sydney Harbour resulting from the development. Therefore the impact to harbour users during the operational phase of the WBACP development is considered negligible.

5.3.2 Accidental Vessel Impact Assessment

A high level assessment of an accidental vessel impact has been undertaken to inform the likely level of risk to the WBACP project.

5.3.2.1 Vessel Categorisation

The harbour vessel fleet can broadly be grouped into three categories as follows for the purpose of this assessment:

- Large vessels (cruise, container, bulk liquid vessels);
- Medium vessels (ferries, commercial vessels, construction barges, etc)
- Small vessels (yachts, pleasure boats, etc)

5.3.2.2 Vessel Impact Assessment

<u>Large Vessel Impact</u>

Large vessels are typically under significant external control (tug vessels and local pilots) and draft-restricted to the deep water channel away from the wharves, therefore the probability of these vessels impacting with the structure is very low. However, the impacts loads associated with these vessels would be very high, such that protection against large vessel impact is unlikely to be economically feasible. There are no historical examples of large vessel impact with wharf structures in Sydney Harbour, except during berthing operations.

<u>Medium Vessel Impact</u>

Medium vessels are typically under the control of trained personnel, however they are unlikely to be draft-restricted and operate in increased numbers in the area around the wharves compared to large vessel traffic. The likelihood of vessel impact with the wharf is therefore higher than that for large vessels, but still considered a low probability of occurrence. A review of reported maritime safety incidents in Sydney Harbour undertaken by Arup for another project identified no previous instances of ferry or commercial vessels impacting a structure.

Unlike the protection of bridge piers which cater for reasonably well defined vessel impact paths, any protection provided to the wharves would need to accommodate vessel impact over a wide range of potential impact approach angles - this would increase the extent, complexity and hence cost of any protection measures. The existing wharf structures were likely originally designed as heavy duty industrial wharves with some allowance for lateral impact berthing loads. It is therefore not unreasonable to expect the structural system to have a degree of structural redundancy such that a vessel impact may result in damage to the wharf but would unlikely result in structural failure or collapse and should be confirmed. The buildings are set back approximately 10m from the edge of the structure and are unlikely to be directly damaged in the event of an impact. Any vessel impact would likely be focused around the ends of the wharves and therefore is unlikely to prevent people evacuating to land after an incident. Therefore, the probability of an impact is considered low and the hazard to wharf occupants in the event it did occur is also considered to be low.

Small Vessel Impact

The highest probability of impact with the structure is from the small vessel group which encompasses the largest number of vessels manoeuvring in Sydney Harbour. These vessels are not draft-restricted in this area and are often operated by the public with varying degrees of competency and training. These vessels are typically of lightweight construction and would undergo significant deformation on impact compared with the relatively stiff wharf structure which would likely receive only minor and localised damage.

6. Conclusions and Recommendations

6.1 Extreme water level and wave impacts on public safety of public domain areas

Extreme water level inundation and wave overtopping are two potential risks to public safety on overwater structures.

The level of the pier/wharf apron deck area is above the present day and predicted future tidal and extreme 100yr ARI water levels. Inundation of the deck is therefore unlikely over the design life of the project.

For the future scenario allowing for sea level rise, lower sections of the pier/wharf may experience some periodic wave overtopping onto the deck during an extreme 100yr ARI water level event. There is adequate provision for the overtopped water to drain away into the harbour to avoid significant landside ponding/buildup. During this rare event public access to the lower deck levels may be restricted. However, a more appropriate assessment of user safety is to consider wave overtopping for a more frequent 5yr ARI wave event at MHWS and in this case no overtopping is expected.

6.2 Impact on Harbour Users

The proposed scheme does not include any formal provision for vessel berthing and there is therefore unlikely to be any vessel traffic generation to and from the site as a result of the development (noting RMS retain the right to use the existing wharf structures for super yacht berthing).

Considering construction and operational phases of the project, the probability of large vessel impact is very low and it would likely be prohibitive to design for the impact loads. The probability of medium vessel impact is increased compared to large vessels but still considered very improbable. The damage resulting from an impact is unlikely to cause failure of the wharf structure, which has significant structural redundancy, or damage to the buildings which are setback from the edge of the wharf. The risk to wharf occupants is considered very low. The highest probability of impact arises from small vessels. However an impact from this vessel category is unlikely to cause anything other than minor localised damage and presents very low risk to wharf occupants.

6.3 Recommendations

- Consideration be given to further assess the structural redundancy of the existing wharf structures against medium size vessel impact to confirm the assumptions made in the qualitative assessment.
- Should any water-based construction be proposed to implement the works, the Harbour Master should be consulted to agree construction stage vessel exclusions zones.

7. References

1. Standards Australia, AS 4997-2005 Guidelines for the design of maritime structures

Appendix 1 – Metocean Conditions Report

Infrastructure NSW

Walsh Bay Arts and Cultural Precinct

Metocean Conditions Report

248794-10-REP01

Issue 2 | 13 September 2017

Job number 248794

Arup
Arup Pty Ltd ABN 18 000 966 165

Arup
Level 10 201 Kent Street
PO Box 76 Millers Point
Sydney 2000
Australia
www.arup.com

ARUP

Document Verification

ARUP

Job title	Walsh Bay Arts and Cultural Precinct			**Job number** 248794
Document title	Metocean Conditions Report			**File reference** -
Document ref	248794-10-REP01			

Revision	**Date**	**Filename**	248794-10-REP01 Metocean Conditions Report_Draft.docx		
Draft	12 Oct 2016	**Description**	Draft for client comment		
			Prepared by	Checked by	Approved by
		Name	Sam Isaacs	David Dack	David Dack
		Signature			
Issue 1	9 Nov 2016	**Filename**	248794-10-REP01 Metocean Conditions Report_ISSUE.docx		
		Description	Issue 1		
			Prepared by	Checked by	Approved by
		Name	Sam Isaacs	David Dack	David Dack
		Signature			
Issue 2	13 Sep 2017	**Filename**	248794-10-REP01[02] Metocean Conditions Report.docx		
		Description	Reissue with minor amendments		
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

1 Introduction

1.1 Background

Arup has been engaged by Infrastructure NSW (INSW) on behalf of Arts NSW to provide maritime engineering design inputs and advice for the Walsh Bay Arts and Cultural Precinct (WBACP) project. Arup's scope includes establishing the site-specific design water levels, wave climate and ocean currents in the harbour to inform the project. The metocean climate is documented in this report.

1.2 Site location

The site generally comprises Pier 2/3, Wharf 4/5, and associated shore sheds and the adjoining waterway, as shown in Figure 1

Figure 1: Site location plan (source: Google Maps)

1.3 Assumptions

Arup has made the following assumptions to determine the site specific metocean environment:

- The maritime structures have a 50 year design life;
- Vessels berthing facilities are not included within the WBACP development but an existing jetty is located on the eastern face of Pier 2/3;
- Existing vessel traffic procedures in Sydney Harbour in the area of the WBACP site will not significantly change over the life of the project.

2 Water Levels

2.1 Sea level rise allowance

The report *Climate Change in Australia*, **[Ref 1]** documents regional sea level rise predictions based on the most recent IPCC AR5 projections. The upper limit projects for Sydney are shown in Table 1. These values are in line with previous 2009 NSW State Government Sea Level Rise Policy guidance which was withdrawn as official guidance in 2012.

Table 1: Sydney sea level rise predictions (RCP8.5)

Year	Sea level rise relative to 1995 levels
2030	0.2
2050	0.4
2070	0.6
2090	0.9

Based on an interpolation of values identified in Table 1 the sea level rise in 2067 is predicted to be +0.57m relative to 1995 levels.

To obtain a sea level rise allowance from present day to 2067 (50 year design life), the 0.57m benchmark needs to be adjusted to account for an observed sea level rise of around 3mm/yr between 1995 and 2017 (i.e. approx. 0.07m). A design sea level rise value of 0.5m has therefore been assumed over the design life of the project.

2.2 Tide levels

The following present-day astronomical tide levels (Table 2) are taken from the Australian National Tide Tables (2017) for Fort Dennison **[Ref 2]**. Predicted tide levels for 2067 incorporating sea level rise are also provided.

Table 2: Present day and future tide levels at Fort Dennison, Sydney (2017 and 2067 projection)

Tidal Levels	Present Day		Year 2067[2]	
	(m CD[1])	(m AHD)	(m CD)	(m AHD)
Highest Astronomical Tide (HAT)	2.10	1.17	2.61	1.68
Mean High Water Springs (MHWS)	1.60	0.67	2.11	1.18
Mean High Water Neaps (MHWN)	1.40	0.47	1.91	0.98
Mean Water Level (MWL)	1.00	0.07	1.51	0.58

Tidal Levels	Present Day		Year 2067[2]	
	(m CD[1])	(m AHD)	(m CD)	(m AHD)
Mean Low Water Neaps (MLWN)	0.60	-0.33	1.11	0.18
Mean Low Water Springs (MLWS)	0.40	-0.53	0.91	-0.02
Lowest Astronomical Tide (LAT)	0.00	-0.93	0.51	-0.42

1. CD = Chart Datum which approximates to LAT and is about 0.93m below AHD.
2. Based on sea level rise allowance of 0.5m.

2.3 Extreme water levels

An increase in the predicted ocean water levels is likely to occur during the passage of a severe storm due to barometric effects and wind setup. The combined effect of barometric setup and wind setup is referred to as storm surge.

Barometric setup occurs due to the often intense low pressure systems that generate large storms. This reduction in air pressure over the water surface results in a local rise of the water level. Wind setup is a result of the wind inducing wind shear stresses on the water, which in turn generate currents. When these currents are impeded by the coast, a resulting increase in the water level occurs.

Present day design still water levels at Fort Denison based on a statistical analysis of measured historical records are provided in Table 3 below based on Watson P.J and D.B Lord (2008) **[Ref 3]**. The extremes analysis is based on water level data measured continuously at Fort Denison for over 100 years. The data reflects the astronomical tide levels as well as anomalies or variations from the predicted tide from storm surge and freshwater flows (assumed very minimal). Similarly, the data inherently incorporates climate change induced sea level rise over this timeframe.

Predicted extreme sea levels for 2067 incorporating sea level rise are also provided in Table 3, based on allowance of 0.5m sea level rise over the 50 year design life (refer Section 2.1).

Table 3: Extreme water levels at Fort Dennison, Sydney (present day and year 2067)

Average Recurrence Interval (ARI) (years)	Present Day Extreme Still Water Level[2]		2067 Extreme Still Water Level[3]	
	(m CD[1])	(m AHD)	(m CD)	(m AHD)
0.02	1.90	0.97	2.40	1.47
0.05	1.98	1.05	2.48	1.55
0.1	1.93	1.00	2.43	1.50
1	2.17	1.24	2.67	1.74
10	2.28	1.35	2.78	1.85
50	2.34	1.41	2.84	1.91
100	2.37	1.44	2.87	1.94

1. CD = Chart Datum which approximates to LAT and is about 0.93m below AHD.
2. From Watson P.J and D.B Lord (2008)
3. Based on sea level rise allowance of 0.5m.

3 Wave Climate

3.1 General

The local wave climate at the site is primarily influenced by two key phenomena, wind and vessel generated waves:

- Wind waves are generated by wind blowing across the free surface of the ocean, transferring energy into the water mass through both shear and pressure effects. The size of the resulting wave is a function of the wind speed, the amount of time the wind blows, and the fetch distance over which the wind acts.
- All vessels generate a pattern of waves as they move through the water. The characteristics of these waves is a function of the vessel speed, hull shape and water depth.

3.2 Wind-generated waves

The *Young and Verhagen* method for predicting wave growth in inland waters, reservoirs and lakes has been used to estimate the wave climate at the two site locations using the CRESS program tool which assumes fetch limited conditions **[Ref 4]**. This method uses empirical formulae developed from a large set of field measurements to transform the extreme wind speed, fetch and average water depth along the fetch into an extreme significant wave height and period for the various return periods and directions.

The fetch orientations and distances shown in Figure 2 were adopted for the assessment. A constant water depth of 15m over the fetch distance was used for the assessment.

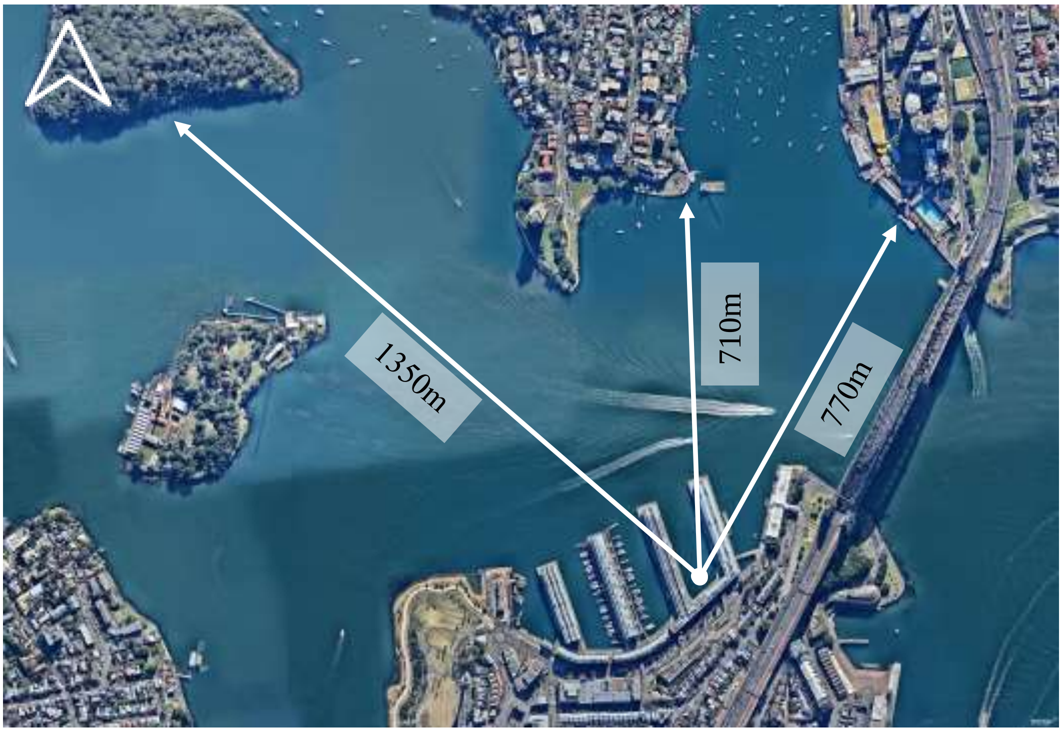

Figure 2: Wave hindcasting fetch parameters

In the absence of available site-specific wind data, the wind climate at the site has been established for various ARIs based on regional 3-seconds wind speed values recommended in AS1170.2 **[Ref 5]**. Table 4 summarises the results.

Table 4: Adopted extreme wind speeds used in wave hindcasting

Average Recurrence Interval (ARI, years)	**North** **Directional wind speed (m/s 1hr)**	**North East** **Directional wind speed (m/s 1hr)**	**North West** **Directional wind speed (m/s 1hr)**
1	17.7	17.7	21.0
5	18.9	18.9	22.4
50	23.0	23.0	27.3
100	24.2	24.2	28.7
500	26.5	26.5	31.5

These values have been checked against extremes developed from Fort Denison wind speed records and these give a reasonable match with the wind code recommendations. Therefore, the wind values in Table 4 have been adopted in the wave hindcasting estimation.

The results of the wave hindcasting are shown in Table 5.

Table 5: Wind generated wave climate

ARI	NW		N		NE	
	Hs [m]	Tp [s]	Hs [m]	Tp [s]	Hs [m]	Tp [s]
1	0.4	2.46	0.2	1.9	0.3	1.95
5	0.4	2.53	0.3	2.0	0.3	2.01
50	0.5	2.78	0.3	2.2	0.3	2.20
100	0.5	2.84	0.3	2.2	0.3	2.26
500	0.6	2.96	0.4	2.3	0.4	2.35

1. H_s = significant wave height, defined as the average of the highest 1/3 of waves generated during the storm duration
2. T_p = peak wave period, defined as the wave period with the highest frequency in the wave spectrum.

The wave height values in Table 5 are significant wave heights, defined as the average of the highest 1/3 of waves generated during the storm duration. The maximum wave height, H_{max} of the largest waves in the wave train are defined as 1.5 x Hs **[Ref 6]** for short narrow wind fetch distances.

3.3 Vessel-generated waves

Ferry vessels form a large proportion of the vessel traffic transiting the site and based on experience can cause significant vessel wake compared to slower and less frequent larger vessels which will tend to transit at a greater distance. Therefore the assessment has been based on a range of ferry vessel types that are representative of commercial tourist and public ferry vessel operations.

The wave characteristics of vessel generated waves as a result of vessels passing the WBACP site have been calculated using the Australian Maritime College Vessel Wave Prediction Tool **[Ref 7]**.

The site is located within a harbour speed limit zone of 15 knots. A vessel passing speed of 15 knots has been assumed unless the vessel service speed is lower than this. A constant water depth of 15m over the vessel wash propagation fetch has been adopted. The results of the analysis are shown in Table 6.

Table 6: Passing vessel generated waves

Vessel	**Vessel Length [m]**	**Vessel Hull form [-]**	**Vessel Displacement [t]**	**Service speed [kts]**	**Passing speed [kts]**	**Passing distance [m]**	**Max wave height [m]**	**Wave period [s]**
Freshwater Class Ferry	70m	Monohull	1140t	18kts	15kts	100m	0.6	2.8s
SuperCat Fast Ferry	35m	Catamaran	60t	24kts	15kts	45m	0.20	2.6s
Lady Class Ferry	45m	Monohull	383t	12kts	12kts	45m	0.4	2.5s

4 Currents

Based on a review of AUS Chart 202 **[Ref 8]** a design current of 0.5kts (approximately 0.25m/s) shall be assumed at the WBACP site, running in either direction parallel with the shoreline.

5 References

1. CSIRO and BOM (2015), *Climate Change in Australia*
2. Australian Hydrographic Service, 2017 Tide Tables
3. Watson P.J and D.B Lord (2008), *Fort Denison Sea Level Rise Vulnerability Study*, a report prepared by the Coastal Unit, NSW Department of Environment and Climate Change.
4. Coastal and River Engineering Support System (CRESS) program – v4.0.5, developed by the Netherlands Ministry of Public Works (Rijkswaterstaat), IHE-Delft and TU-Delft.
5. AS/NZS 1170.2:2002 - Structural design actions Part 2: Wind actions
6. AS4997:2005 – Guidelines for the design of maritime structures
7. Macfarlane, G.J., Bose, N. and Duffy, J.T., 2012, “Wave Wake: Focus on vessel operations within sheltered waterways”, Proceedings of the SNAME Annual Meeting, Providence,, Rhode Island, 24-26th October 2012.
8. AUS Chart 202 Port Jackson (Central Sheet), Australian Hydrographic Service, 2002