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# Climate Change Induced Sea Level Rise
# Sydney Heritage Fleet
# Pyrmont, NSW 2009

Report Number 610.10676-R2R1

16 December 2011

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PYRMONT NSW 2009

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# Climate Change Induced Sea Level Rise
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## EXECUTIVE SUMMARY

This report presents the results of a desk study investigating the risk associated with climate change induced sea level rise for the proposed development, and has been undertaken in accordance with SLR's Offer of Services, Sydney Heritage Fleet Bank Street, Pyrmont; Specialist Building / Environmental Technology Services (Ref. 610.10676 SHF P1 20110823, dated 23 August 2011).

This assessment is a requirement of the Director General's Requirements issued on 14 February 2011, and thus the objectives of this climate change induced sea level rise assessment are to;

- Meet the following Director General's Requirement:
  - An assessment of the risks associated with sea level rise on the proposal as set out in the *NSW Coastal Planning Guideline: Adapting to Sea Level Rise*
- Assess impacts related to projected sea level rise; and
- Determine the projected sea level rise estimates in relation to the proposed development's reduced levels and provide recommendations and adaptation measures regarding the proposed development design.

### Design

It is recommended that the design take into account the projections for sea level rise as identified in this report and that appropriate adaptation measures are adopted within the design. Below are examples of potential adaptation measures which could be included as part of the design:

- Raise the sea wall to defend against projected sea level rise. This option may need to be explored with the various key stakeholders associated with the area within which the development is located.
- Develop and construct a "flexible design" whereby in the future the ground floor can be raised.
- Establish all services (particularly electricity) above the projected inundation levels within the ground level building.
- Raise the height of the ground level as part of the current development to accomodate the projected higher sea levels.

### Operation

The sea wall has been identified as the potential primary defence against the projected sea level rise estimates. The maintenance of the sea wall should reduce the risk of the above discussed impacts.

Therefore, a sea wall maintenance program should be established within the general safety operation protocols at the site. This maintenance should be monitored by the onsite safety personnel.

The maintenance program should attempt to mitigate against a reduction in stability and erosion of the seawall.

### Recommendations

Based on this assessment and subsequent conclusions SLR Consulting makes the following recommendations:

- The design for the development should be reviewed in the context of the projected sea level rise data described within this report.

## EXECUTIVE SUMMARY

- The design for the development should be reviewed in the context of the design adaptation measures described within this report.
- A Management Plan should be developed which addresses:
  - Monitoring and Maintenance programs to reduce the risk of movement/erosion of the seawall.
  - Emergency response elements associated sea level rise, including inundation and extreme events e.g. wave run-up.

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# 1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR Consulting) has been commissioned by Crawford Architects on behalf of Sydney Maritime Museum Ltd (Client) to provide environmental assessment reports to support a Development Application (DA) for the Sydney Heritage Fleet (SHF), Bank Street, Pyrmont.

This report presents the results of a desk study investigating the risk associated with climate change induced sea level rise for the above proposed development.

This report has been undertaken in accordance with SLR's Offer of Services, Sydney Heritage Fleet Bank Street, Pyrmont; Specialist Building / Environmental Technology Services (Ref. 610.10676 SHF P1 20110823, dated 23 August 2011).

From the information provided by the Client, the following briefly describes the development:

- The development will comprise a non-profit making working museum and a home for the SHF.
- The site is located under the eastern pylon of the Anzac Bridge with a water frontage to Blackwattle Bay and a street frontage to Bank Street. Approximately half of the site adjacent to the bridge pylon will be occupied by the SHF and the other half to the east will become a community park. The land understood to be developed as a community park does not form part of this assessment.
- Located to the west of the bridge pylon is a freestanding Exhibition Pavilion with an attached refreshment kiosk and amenities also at sea wall/water level.
- The land based component of the project comprises two storage areas at sea wall/water level.
    - The first to store dragon boats operated by Dragon Boats NSW with direct access to a new boat ramp.
    - The second to store and operate small vessels owned by the SHF, which will also make use of the boat ramp.
- Directly above the boat storage areas are exhibition spaces, meeting rooms, amenities, and entry lobby and reception areas.
- Across from the entry courtyard fronting Bank Street is a single storey building with some mezzanine spaces over which are the SHF's maintenance workshops and storage areas which are required to service the SHF vessels. The roof of the maintenance areas will be "green", to provide sound insulation for the SHF's operations and a visually attractive landscape for the adjacent residential buildings.
- Where reference is made to the site being developed for commercial use, this terminology is used to differentiate from residential or industrial uses, and is not intended to construe a commercial (or business) venture.

## 1.1 Objectives

This assessment is a requirement of the Director General's Requirements issued 14 February 2011, and thus the objectives of this climate change induced sea level rise assessment are to;

- Meet the following Director General's Requirement:
    - An assessment of the risks associated with sea level rise on the proposal as set out in the *NSW Coastal Planning Guideline: Adapting to Sea Level Rise.*
- Assess impacts related to projected sea level rise; and
- Determine the projected sea level rise estimates in relation to the proposed development's reduced levels and provide recommendations and adaptation measures regarding the proposed development design.

## 1.2 Scope of Work

The scope of this assessment was limited to the use of publicly available information and data on predicted sea level rise associated with the greater Sydney Harbour network. The data was then applied to the proposed development key physical characteristics to identify potential risks and impacts associated with predicted climate change induced sea level rise.

This report:

- Describes the proposed development and associated activities.
- Presents plans illustrating the position and configuration of the proposed development in relation to projected sea level rise.
- Identifies projected sea level rise for the development site area.
- Identifies potential risks to the proposed development associated with the sea level rise projections.
- Provides suggested responses and adaptation strategies which may be incorporated into both the design and operation of the development.

## 1.3 Methodology

The process and thus the methodology for this assessment is summarised below;

1. Desk-top review of sea level rise guidelines and relevant environmental policy instruments.
2. Desk-top review of all available climate change sea level rise data for Sydney Harbour for 2050 and 2100.
3. Assessment of select Reduced Levels of the proposed development against the projected 2050 and 2100 sea level rise levels.
4. Identification and qualitative evaluation of subsequent risks and impacts associated with projected sea level rise.

The following documents were reviewed as guidance material as part of this assessment;

| | |
|---|---|
| **DECCW** (2009) | *Derivation of the NSW Government's sea level rise planning benchmarks* |
| **DECCW** (2010a) | *Coastal Risk Management Guide: Incorporating sea level rise benchmarks in coastal risk assessments* |
| **DECCW** (2010b) | *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments* |
| **Department of Planning** (2010) | *NSW Coastal Planning guideline: Adapting to Sea Level Rise* |
| **Coastal Council of NSW** (2003) | *Coastal Design Guidelines for NSW* |
| **NSW Government** (1990) | *Coastline Management Manual* |
| **NSW Government** (1997) | *NSW Coastal Policy* |
| **NSW Government** (2005) | *Floodplain Development Manual* |
| **NSW Government** (2009) | *Reforms to coastal erosion management in NSW* |
| **NSW Government** (2009) | *NSW Sea Level Rise Policy Statement* |

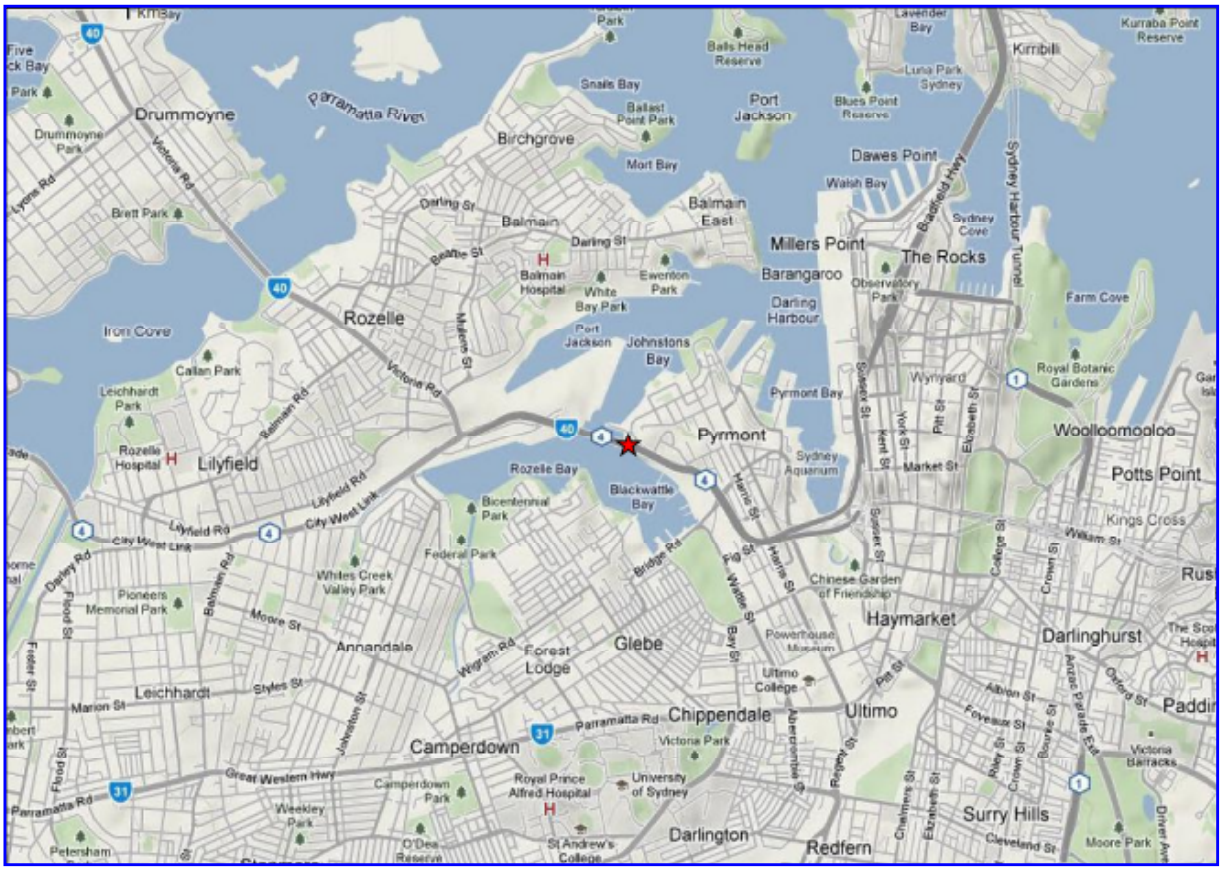
# 2 SITE DESCRIPTION

## 2.1 Site Location and Description

The Project Site is located off Bank Street, Pyrmont, NSW 2009, approximately 1.3 kilometres (km) west of Sydney Central Business District (CBD).

A Locality Map is provided below in **Figure 1**.

**Figure 1 Locality Map**



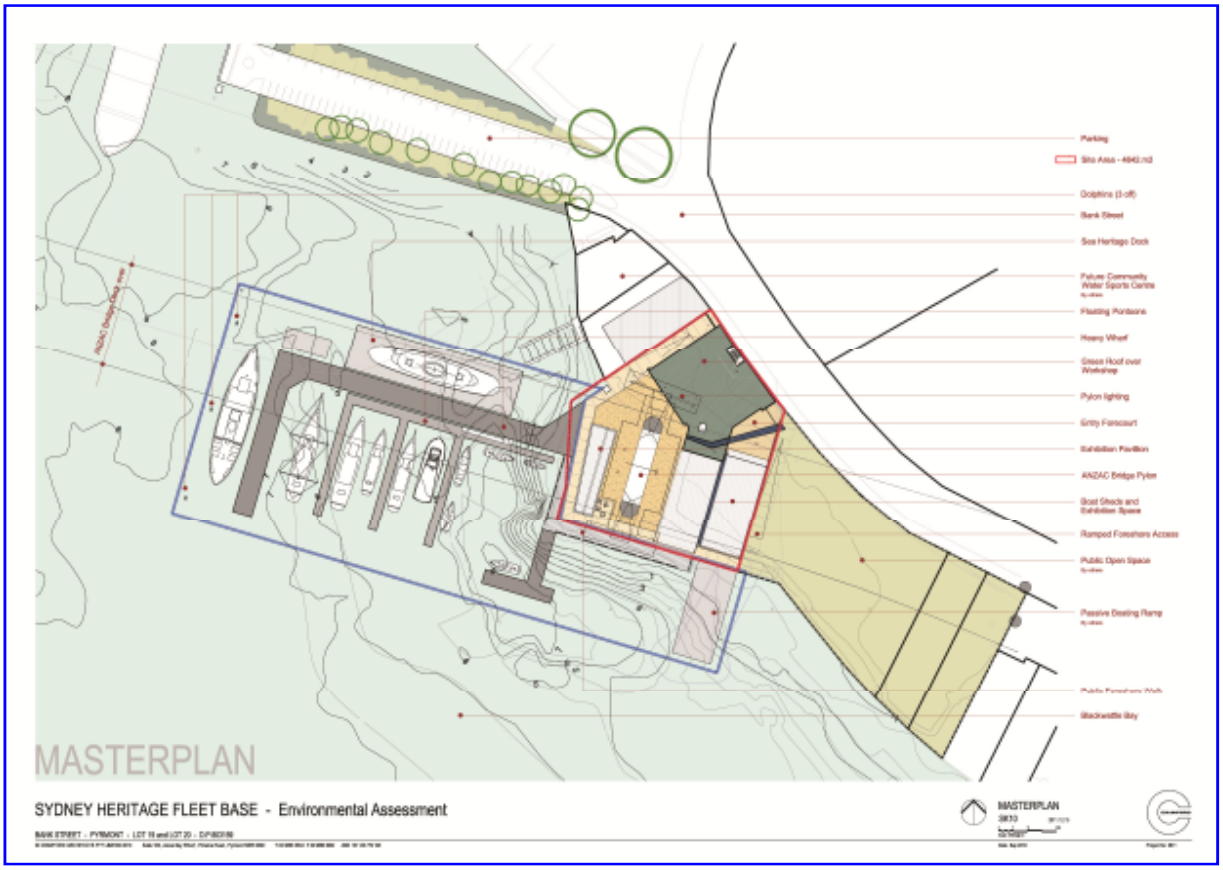

Source: SLR Consulting

The Project Site is a combination of two lots located beneath the eastern pylon of the Anzac Bridge, comprising Lot 19 and Lot 20 of Deposit Plan 803159. The area included within this DA is shown in **Figure 2** and is approximately 4,642 $m^2$ in area.

For clarity, throughout this report when both lots are being referred to, the term 'Project Site' will be used. If they need to be discussed individually the lots will be referred to by their associated lot and Deposited Plan number.

Two leases exist on the site, a land lease (identified in **Figure 2** by a red boundary) and a water lease (identified by a blue boundary). The public open space (shaded in green in **Figure 2**) is shown, although this is not included within this DA, and does not form part of this assessment.

**Figure 2 Site Plan**




Source: Crawford Architects

The Project Site is bordered to the south and west by Blackwattle Bay, to the north by Bank Street. The surrounding land uses include:

- North and Northwest: On the other side of Bank Street is Jackson's Landing residential and community estate.
- South and West: Blackwattle Bay borders the Project Site.
- Northeast: There is a small cluster of commercial buildings located on the opposing side of Bank Street.
- Southeast: A series of buildings operated by Poulos Bros Seafoods Pty Ltd, Bidvest Australia Pty Ltd, Hymix Australia Pty Ltd and the Sydney Fish Markets.

## 2.2 Project Description

The proposed development works shall incorporate the following:

- A two storey building with some mezzanine spaces.
- Located west of the bridge pylon is a freestanding Exhibition Pavilion with an attached kiosk and amenities.
- Boat sheds and vessel storage for dragon boating.
- Shipwrights and boat storage area which includes a machine shop, workshop, timber store, lunch room and amenities.

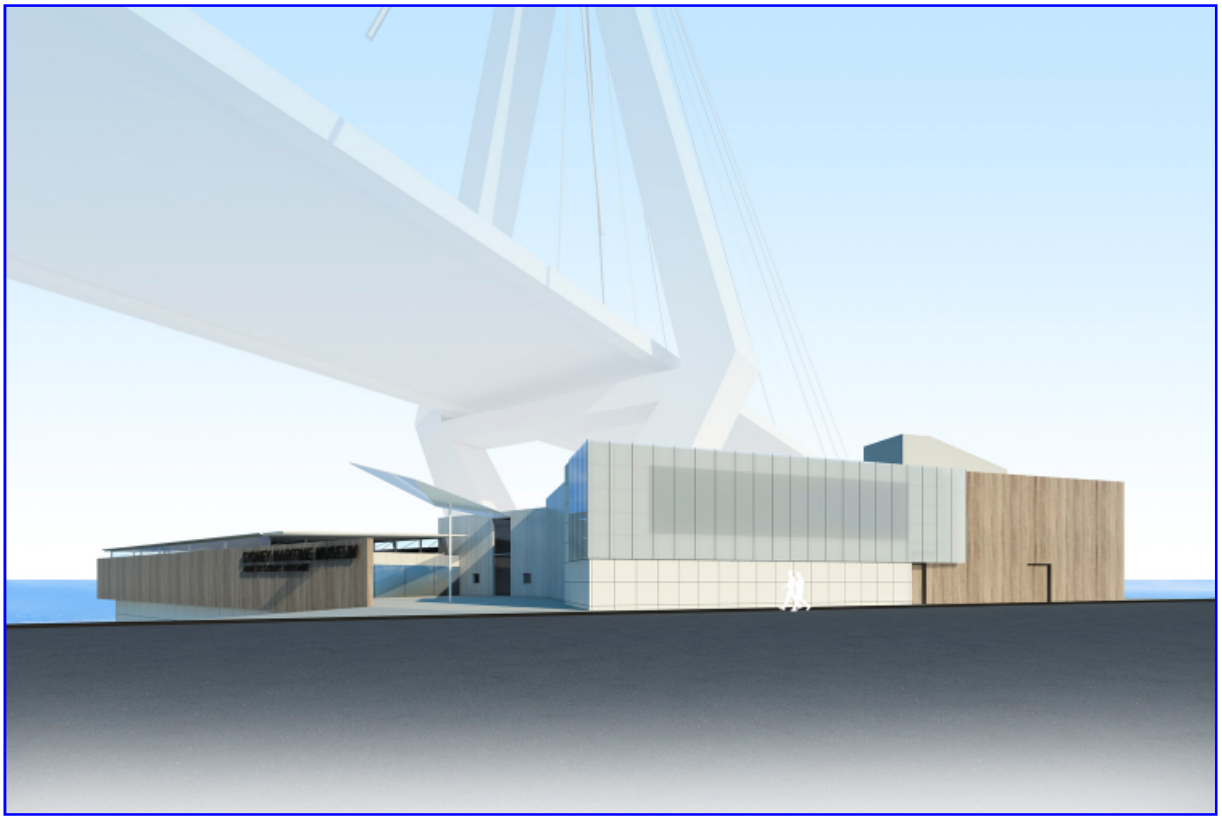
- Directly above the storage areas are exhibition spaces, meeting rooms, amenities, and entry, lobby and reception areas.
- Restoration and maintenance workshop, including a metal fabrication workshop, coal stores, garbage and recycling stores, paint and flammable goods store.
- Working living museum.
- Lay apart stores and electrical workshop.
- The mezzanine which incorporates amenities.
- Heavy wharf.
- Floating pontoons.

**Figure 3** and **Figure 4** below show design perspectives for the proposed development from the proposed public open space and from Bank Street, respectively.

**Figure 3 View of Proposed Development from Public open space**

Source: Crawford Architects

**Figure 4 View of Proposed Development from Bank Street**



Source: Crawford Architects

# 3 LEGISLATION AND GUIDANCE

The Director General Requirements states the following in regards to this climate change assessment:

- An assessment of the risks associated with sea level rise on the proposal as set out in the NSW *Coastal Planning Guidelines: Adapting to Sea Level Rise*

This guideline adopts the NSW sea level rise planning benchmarks outlined in the *NSW Sea Level Rise Policy Statement' (2009)*, which indicates that sea level rise along the NSW coast relative to 1990 mean sea levels are projected to increase as follows:

- 0.4m by 2050
- 0.9m by 2100

# 4 THE EXISTING ENVIRONMENT

The project site is bordered by Blackwattle Bay to the west and south, with the Anzac Bridge spanning over the site crossing the Bay to the west. To the north Blackwattle Bay joins the greater Sydney Harbour network which includes Fort Denison.

Currently, there is no publicly available detailed current sea level information pertaining to Blackwattle Bay. Contact was made with a representative of the City of Sydney Council, regarding their Blackwattle Bay flood study due to be released in June 2012, however, they were unable to release any sea level data for use in this assessment.

A sea level rise vulnerability study, completed at Fort Denison was identified as the most relevant and contemporary paper available, *Fort Denison Sea Level Rise Vulnerability Study* (Coastal Unit, October 2008). Fort Denison lies approximately 4kms north-east of the site, and the study completed is a detailed quantitative assessment of historical tidal data recorded at Fort Denison over a 100 year period.

The still water levels (Australian Height Datum – AHD) calculated within the Fort Denison Study are represented as Average Reoccurrence Intervals (ARI) over a 100 year period (excerpt is shown in **Appendix A Table 2**. Low, Medium and High still water levels selected for use during this assessment are:

- Low Still Water Level = 1.045 (ARI 0.05)
- Medium Still Water Level = 1.315 (ARI 5)
- High Still Water Level = 1.435 (ARI 100) (1 in 100 year storm surge occurrence)

The above calculated ARIs include recorded tidal anomalies most likely caused from major storm events (pg. 22-23). The 100 year ARI event is thus representative of the required 1 in 100 year storm surge event.

# 5 IMPACT ASSESSMENT

All impacts and risks identified within this chapter are relevant to the operational phase of the proposed development.

## 5.1 Identified Environmental Impacts and Effects

This assessment has identified the potential impacts to the development associated with climate change induced sea level rise. The assessment considers 2050 and 2100 climate change projections, thus the impacts identified will relate to the operations and maintenance of the site.

## 5.2 Environmental Impacts

To determine the projected sea level rise, still water levels at the proposed development (incl. Storm surge) and the NSW planning benchmarks (0.4, 2050 and 0.9, 2100) were added to the current still water levels calculated as part of the Fort Denison Sea Level Rise Vulnerability Study (presented in **Appendix A Table 2**). The projected increases in sea level were then compared with the RLs of the proposed Sydney Heritage Fleet Buildings to determine potential impacts. The comparative results are presented in **Appendix A.**

**Appendix B**, **Attachments 2, 3 and 4**, presents the interpreted spatial extent of inundation associated with current still water levels, projected sea level rise 2050 and projected sea level rise 2100, respectively. **Appendix B, Attachment 5** is a conceptual cross section through the site showing the SHF building (using the provided RLs) for the Ground floor and the projected sea water level for the 100 year ARI projected still water levels.

Below is a summary of the development areas which may potentially be affected by the projected climate change induced sea level rise in relation to the low, medium and high still water projections:

- The 1 in 100 storm surge event (worse case) indicates:
  - 2050 projection: inundation will pass the SHF Ground Floor by 23.5cm
  - 2100 projection: inundation will pass the SHF Ground Floor by 73.5cm
- The low and medium projections for sea level rise indicate the following inundation details:
  - 2050 Medium still water projection
    - Above the Pylon footing by 20cm
    - Above the SHF Ground Floor by 11cm
  - 2100 Low still water projection
    - Above the pylon footing by 45cm
    - Above the SHF ground floor by 34cm
  - 2100 Medium still water projection
    - Above the pylon footing by 71cm
    - Above the SHF ground floor by 61cm

**Table 1** below represents potential environmental impacts associated with sea level rise (as outlined by the *NSW Coastal Planning Guideline: Adapting to Sea Level Rise)* and an assessment as to whether these generic impacts could affect the site and associated proposed development, along with a rationale in the “explanation” column. .

**Table 1 Table of Potential Sea Level Rise Risks**

| Impact[1] | Applicable | | Explanation/description |
|---|---|---|---|
| | Yes | No | |
| Sea level and increased tidal range | ☒ | ☐ | The results presented in the previous section, indicate that parts of the subject site may become permanently or semi-permanently inundated with water. The worst case scenario for sea level rise projections show that in 2050 and 2100 (M and H projections) the ground level of the SHF Building could be inundated.<br>Note that the above worst case scenarios do not necessarily suggest that the site could be permanently inundated but rather that there is a risk from significant flooding and possible significant intervals of inundation.<br>There is a significant risk that as early as 2050 the site may become semi-permanently inundated by sea water. There is also a greater risk that by 2100 the site may become permanently inundated with water, or receive a high volume of water at regular intervals.<br>See **Appendix A, Attachment 2, 3 and 4** for projected water levels on the subject site. |
| Soft coast erosion | ☐ | ☒ | Due to the positioning and presence of the sea wall (given that it is maintained) it is unlikely that the predicted sea level rise will cause soft coast erosion. |
| Beach and foredune loss and/or migration and bluffs | ☐ | ☒ | This site does not contain beach or dunes |
| Shoreline recession | ☐ | ☒ | This site does not contain beach or dunes however if the sea wall was eroded there may be potential that this impact could become a risk for the site |
| Beach realignment | ☐ | ☒ | There is no beach at this site |
| Coastal flooding | ☒ | ☐ | See the description for sea level and increased tidal range |
| Slope instability | ☐ | ☒ | There is not likely to be impacts to slope<br>For further details regarding run-off see the Water Sensitive Urban Design Report (SLR 2010) |
| Groundwater elevation and/or salinisation | ☒ | ☐ | Due to sea level rise and inundation periods there could be the potential for elevated groundwater and salinisation<br>Given the low-lying and relatively flat nature of the site it is expected that the groundwater would remain at a reasonably high level. However, no information is currently available on the depth or quality of groundwater beneath the site.<br>Therefore it is not possible to tell the effect that sea level rise may have on the sites groundwater levels, and thus what the risk to site might be. |
| Wave Run-up | ☒ | ☐ | Wave run-up is defined as the vertical height above the still water level to which water from an incident wave will run up the face of a structure.<br>If there is sufficient wave activity from water craft and/or residual swells in the bay then compounded with projected sea level rise, wave run-up at the development could occur. |

1. The above impacts are based on a list provided in *NSW Coastal Planning Guideline: Adapting to Sea Level Rise* and the projected sea level rise estimates detailed within this report

## 5.3 Adaptation and Mitigation Measures

### 5.3.1 Design

It is recommended that the design take into account the projections for sea level rise as identified in this report and that appropriate adaptation measures are adopted within the design. Below are examples of potential adaptation measures which could be included as part of the design:

- Raise the sea wall to defend against projected sea level rise. This option may need to be explored with the various key stakeholders associated with the area within which the development is located.
- Develop and construct a “flexible design” whereby in the future the ground floor can be raised.
- Establish all services (particularly electricity) above the projected inundation levels within the ground level building.
- Raise the height of the ground level as part of the current development to accomodate the projected higher sea levels.

### 5.3.2 Operation

The sea wall has been identified as the potential primary defence against the projected sea level rise. Therefore it is recommended that as part of the operations and maintenance regime of the site, that monitoring of the sea wall be undertaken to assess for the impacts described in Table 1 above. In addition it is recommended that the entity responsible for maintaining the site stay up to date with actual sea level rise trends.

# 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

This climate change induced sea level rise assessment has been conducted in accordance with the *NSW Coastal Planning Guideline: Adapting to Sea Level Rise* as required by the Director General's Requirements issued 14 February 2011.

The core objective of this assessment was to determine the projected sea level rise estimates in relation to the proposed development's reduced levels and provide recommendations and adaptation measures regarding the proposed development design.

The following conclusions are based on the findings of this assessment.

- It is possible that the ground floor level of the proposed development could potentially be intermittently and/or permanently inundated for both the 2050 and 2100 projection period, if they occur.
- Below is a list of the potential environmental impacts which have been identified through this assessment:
  - Sea level and increased tidal range.
  - Coastal flooding.
  - Groundwater elevation and/or salinisation.
  - Wave Run-up.

Within **Section 5.3** of this report suggested adaptation measures are discussed in regards to the above impacts.

## 6.2 Recommendations

Based on the above assessment and subsequent conclusions SLR Consulting makes the following recommendations;

- The design for the development should be reviewed in the context of the projected sea level rise data described within this report.
- The design for the development should be reviewed in the context of the design adaptation measures described within this report.
- A Management Plan should be developed which addresses:
  - Monitoring and Maintenance programs to reduce the risk of movement/erosion of the seawall;
  - Emergency response elements associated sea level rise, including inundation and extreme events e.g. wave run-up.

# 7 LIMITATIONS

The following information will assist in understanding the uncertainties relating to the interpretation of the data obtained during this investigation and the recommendations presented in the report, and help with assessment and interpretation of the report.

The services undertaken consist of a desktop review, with the intention of providing projected sea level rise estimates at the site. These estimates are based on the NSW sea level rise planning benchmarks outlined in the *NSW Sea Level Rise Policy Statement' (2009)*, which indicates that sea level rise along the NSW coast relative to 1990 mean sea levels are projected to increase as follows:

- 0.4m by 2050.
- 0.9m by 2100.

All sea level rise estimates were made using tidal data and Average Reoccurrence Intervals (ARIs) gained through a detailed study completed at Fort Denison, Sydney Harbour. This study is titled *Fort Denison Sea Level Rise Vulnerability Study* (Coastal Unit, October 2008).

SLR Consulting assumes no responsibility for the quality or accuracy of data obtained from external sources, or for occurrences outside the scope of works defined in this report.

All work conducted and reports produced by SLR Consulting are prepared for a particular Client's objective and are based on a specific scope, conditions and limitations, as agreed upon between SLR Consulting Australia and the Client. Information and/or report(s) prepared by SLR Consulting may therefore not be suitable for any use other than the intended objective.

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Investigations are conducted in a conscientious and professional manner. The nature of the task, however, and the likely disproportion between any damage or loss which might arise from the work and any report prepared as a result and the cost of our services is such that SLR Consulting cannot guarantee that all issues of concern have been identified.

Thus while SLR Consulting carries out the work to the best of our ability, SLR Consulting totally excludes any loss or damages which may arise from services provided to the client or any other parties.

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# 8 CLOSURE

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Sydney Maritime Museum Ltd. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR Consulting.

SLR Consulting disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

# 9 REFERENCES

Coastal Unit (2008) *Fort Denison Sea Level Rise Vulnerability Study*

Coastal Council of NSW (2003) *Coastal Design Guidelines for NSW*

DECCW (2009) *Derivation of the NSW Government's sea level rise planning benchmarks*

DECCW (2010a) *Coastal Risk Management Guide: Incorporating sea level rise benchmarks in coastal risk assessments*

DECCW (2010b) *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments*

NSW Department of Planning (2010) *NSW Coastal Planning guideline: Adapting to Sea Level Rise*

NSW Government (1990) *Coastline Management Manual*

NSW Government (1997) *NSW Coastal Policy*

NSW Government (2005) *Floodplain Development Manual*

NSW Government (2009) *Reforms to coastal erosion management in NSW*

NSW Government (2009) *NSW Sea Level Rise Policy Statement*

NSW Department of Planning (2010) *NSW Coastal Planning Guidelines: adapting to Sea Level Rise*

**Table 2 Sydney Harbour Still Water Levels (excerpt)**

| ARI (years) | Maximum Level (mAHD) |
|---|---|
| 0.02 | 0.965 |
| 0.05 | 1.045 |
| 0.1 | 1.095 |
| 1 | 1.235 |
| 2 | 1.275 |
| 5 | 1.315 |
| 10 | 1.345 |
| 20 | 1.375 |
| 50 | 1.415 |
| 100 | 1.435 |
| 200 | 1.455 |

Reference: Fort Denison Sea Level Rise Vulnerability Study (Coastal Unit, October 2008)

**Table 3 Projected Sea Level Rise – Sydney Harbour**

| **Still Water Levels (AHD)** | | | **2050 (AHD)** | **2100 (AHD)** |
|---|---|---|---|---|
| | | | PLUS 0.4 | PLUS 0.9 |
| **L** | ARI 0.05 | 1.045 | 1.445 | 1.945 |
| **M** | ARI 5 | 1.315 | 1.715 | 2.215 |
| **H** | ARI 100 | 1.435 | 1.835 | 2.335 |

**Projected Sea Level Rise Calculations and Tables**

**Table 4 Projected Site/Building Inundation**

| | Current Sea Level (AHDm) | | | Future Sea Level 2050 (AHDm) | | | Future Sea Level 2100 (AHDm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H |
| **Average Reoccurrence Interval (ARI) years** | **0.02** | **5** | **100** | **0.02** | **5** | **100** | **0.02** | **5** | **100** |
| **Pylon Footing** | 0.455 | 0.185 | 0.065 | 0.055 | -0.215 | -0.335 | -0.445 | -0.715 | -0.835 |
| **SHF Ground FFL** | 0.555 | 0.285 | 0.165 | 0.155 | -0.115 | -0.235 | -0.345 | -0.615 | -0.735 |
| **SHF First Floor FFL** | 3.855 | 3.585 | 3.465 | 3.455 | 3.185 | 3.065 | 2.955 | 2.685 | 2.565 |
| **SHF Second Floor FFL** | 7.155 | 6.855 | 6.765 | 6.755 | 6.485 | 6.365 | 6.255 | 5.985 | 5.865 |
| **SHF Workshops Flat Roof** | 10.455 | 10.065 | 10.065 | 10.055 | 9.785 | 9.665 | 9.555 | 9.285 | 9.165 |

The highlighted ORANGE cells in the matrix above are projected inundation levels. A summary of the projected inundation levels for the proposed development using the RL's provided is listed below:

# Appendix B

Report Number 610.10676-R2R1

**Attachment 1-5 (Maps)**