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Project AZ5220: Adaptation and planning strategies to mitigate the impact of climate change induced sea level rise, flooding and erosion at selected Defence sites

Executive Report - Phases 1 to 5

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Executive Summary

1. To make fully informed investment and estate planning decisions Defence must have a full appreciation of the opportunities, risks and constraints affecting its sites. Climate change and rising sea levels present potentially significant risks to key Defence sites and must be taken into account in future investment decisions.

2. Recognising the challenges posed by climate change, in 2011, Defence undertook an initial high level, first pass assessment of the risks posed by climate change induced sea level rise, storm surge and king tides to 38 sites. The Initial Assessment enabled Defence to decide which sites required more detailed investigations through a high level assessment of their likely risk exposure to climate change.

3. This second, more detailed study (Project AZ5220) focuses on 13 of the sites that were identified as at High or Very High risk in 2040 and 2070, and the Cocos (Keeling) Islands.

4. The strategic objectives of this study are to enable more effective long term resource allocation, increase the resilience of Defence assets to current and future extreme weather events and to proactively respond to possible changes in government policy. By taking action now to understand the risks and implications of climate change to selected sites, Defence may be able to assist in shaping future Commonwealth Government policy, rather than having onerous policy requirements imposed upon it.

5. This detailed assessment included consideration of the impacts of marine flooding (sea level rise, storm surge, king tide) estuarine flooding (extreme rainfall) and coastal erosion, depending on local conditions. Risks at each site were assessed and rated across eight themes: buildings; site access and internal roads; pier and marine infrastructure; runways and aviation infrastructure; utilities; environmental assets; contamination, and heritage.

6. The scope of this study excluded broader climate change impacts including those that may result from extreme wind and changes in the predominant wind direction, salt water intrusion into groundwater and estuaries, reduced average rainfall, ocean acidification and changes to fog conditions.

7. The assessment concluded that all sites are at risk of inundation in at least one timeframe. The highest rated risks at all sites have related to buildings, site access, internal roads and utilities. The next most significant risk categories were runways and aviation infrastructure and environmental assets. Table 1 presents a summary of the 2040 risk ratings by theme for the nine sites assessed.

Table 1 Summary of 2040 risk ratings by theme for the 14 sites assessed in Project AZS220.

Theme	[illegible]
Buildings	Medium - Very High (4 sites)
Site access and internal roads	Medium - Very High (7 sites)
Pier and marine infrastructure	Low - High (2 sites)
Runways and aviation infrastructure	Low - Very High (3 sites)
Utilities	Medium - Very High (4 sites)
Environmental assets	Low - Very High (2 sites)
Contamination	Low - Medium (10 sites)
Heritage	Low - High (2 sites)

8. High level adaptation options, including indicative costs, were developed for each site and prioritised to identify those which should be considered for implementation in the short term (i.e. within the next 10 years). To reduce flooding and erosion risk, all sites should consider developing inundation design specifications and adjusting maintenance specifications to incorporate consideration of the increased inundation levels and erosion extents. Protection or relocation of some assets, activities and functions should also be considered at each site.

9. This Executive Report and the attached site summary sheets should be read in conjunction with the detailed reports prepared for each site. The site reports and supporting GIS information provide Defence with important information that can be used to inform:

- the development of design specifications for new works and adjustments to maintenance specifications to incorporate consideration of increased inundation levels and erosion extents;
- strategic planning (e.g. Zone Plans and Base Development Plans); and
- prioritisation of remediation works or identifying requirements to protect areas of environmental or heritage significance.

10. This study does not provide a comprehensive review of Defence's exposure to all climate change risks and recommended adaptation approaches to managing them. Recognising this, the following recommendations are made to enable Defence to further understand, and prepare for, the risks posed by a changing climate:

- Investigate other risks that have been identified as relevant to the site but not covered in this assessment;
- Undertake an assessment of broader climate change risks on the Defence Estate, including training areas;
- Identify possible constraints on logistic requirements and supply chains in support of ADF operations and emergencies;
- Assess the broader implications of climate change on Defence's capability and operations;
- Continue consultation and engagement with relevant Commonwealth, territory, state and local government agencies to ensure effective preparation and response to the risks posed by a changing climate; and
- Undertake analysis (cost benefit or other) to prioritise adaptation measures for sites at very high risk in 2040, to enable their inclusion in the Major Capital Funding (MCF) list.

Acronyms

Acronym	
ACE CRC	Antarctic Climate and Ecosystems Cooperative Research Centre
AHO	Australian Height Datum
ARI	Average Recurrence Interval
BOM	Bureau of Meteorology
CKIHD	Cocos Keeling Islands Height Datum
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSE	Department of Sustainability and Environment (Victoria)
EPBC Act 1999	*Environment Protection and Biodiversity Conservation Act 1999*
IOT	Indian Ocean Territories
IPCC	Intergovernmental Panel on Climate Change
NICCARA	National Infrastructure Climate Change Adaptation Risk Assessment
SAMF	Site Assessment Methodology and Framework
TRG	Technical Reference Group

1.0 Introduction

1.1 Background

11. Defence's core business is defending Australia and its national interests. Estate planning is one of a number of critical tasks that Defence undertakes to ensure that its capability to achieve this is maintained. The Strategic Reform Program: Delivering Force 2030, sets the plan for reforming the Australian Defence Force by improving its efficiency and effectiveness, thereby creating substantial cost savings that can be redirected towards Defence capability.

12. Defence's estate is ageing and deteriorating in many areas requiring considerable capital investment in a constrained fiscal environment to support developing the future force outlined in the 2013 Defence White Paper. Defence cannot make fully informed investment decisions unless it has a full appreciation of the opportunities, risks and constraints affecting its sites. Climate change and rising sea levels present potentially significant risks to key Defence sites and, along with a range of other estate planning considerations, must be taken into account in future investment decisions.

13. Beyond supporting Defence's ability to defend Australia, the requirements for this project are driven by a number of key strategic initiatives at global, Commonwealth and Defence levels. At the Commonwealth level, the past several years has seen the Australian Government commence the development of policies and programs to help the community prepare for the impacts of climate change, with an initial focus on critical areas. Infrastructure was identified early as a particularly important sector for two fundamental reasons. Firstly, it underpins much of Australia's economic and social activity. The implications of the potential degradation in the capacity of infrastructure to deliver the range of services and benefits the community expects could be severe. Secondly, infrastructure tends to be long-lived. Therefore, the decisions made in the near term on design parameters, function and location will need to carry through into a world that could be significantly altered by climate change.

14. As a result of these factors, the Australian Government has assessed the potential impacts of climate change on infrastructure and how it can respond from both a top-down vulnerability and risk assessment approach and a bottom-up approach designed to assist proponents in protecting infrastructure. Through the Garnaut Climate Change Review (2007 and 2011) and the National Infrastructure Climate Change Adaptation Risk Assessment (NICCARA, 2008) the Government obtained a combined assessment of the impacts of climate change on significant infrastructure. This has led to work on amending the Rainfall and Run-off Handbook (the guidance provided by the Rainfall and Run-off Handbook underpins the design requirements for all Australian drainage and the design of flood protection of buildings, facilities and other infrastructure), looking at the degradation of cement under differing environmental conditions, developing an Australian Standard for climate change risk and adaptation and developing an approach to assess the economics of potential adaptation measures, furthering a practical bottom-up Government response to the challenge.

15. While it is critical that Defence primarily considers the impacts of climate change on its assets and capability, it is also the custodian of a number of sites containing environmental and heritage values listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) which could be adversely affected by climate change. In this respect this project is unusual, as Defence typically assesses the impact of its activities on the environment, whereas this project focuses on the impact of the environment on Defence infrastructure and, the environment itself. Under current legislation, Defence is unlikely to be liable for the protection of environment and non-built heritage assets from climate change impacts, as these impacts are likely to occur on a global scale. For example, if sea level rise negatively affects a threatened Ecological Community or midden, Defence is unlikely to be required to put in place mitigation measures as the impacts would be the result of natural processes, not Defence actions. However, climate change risks to environment and non-built heritage assets have still been assessed as reputational risks may arise from such impacts, legislative frameworks and management requirements may change in future and some environmental assets support important Defence training activities.

16. Recognising the challenges posed by climate change, in 2011 Defence undertook an initial assessment of 38 sites entitled *Assessment of the Impact of Climate Change Induced* Sea *Level Change on Significant* Defence *Bases* (the Initial Assessment). This assessment was a high level, first pass assessment which analysed the risks posed by climate change induced sea level rise, storm surge and king tides, however it did not include terrestrial flooding, coastal erosion, or other changes likely to be caused by climate change, in its scope. The 38 assessed sites were grouped into categories of risk - High or Very High in 2040, 2070 or 2100, or not considered at risk. A summary of the risk ratings from the Initial Assessment are included in Figure 1.

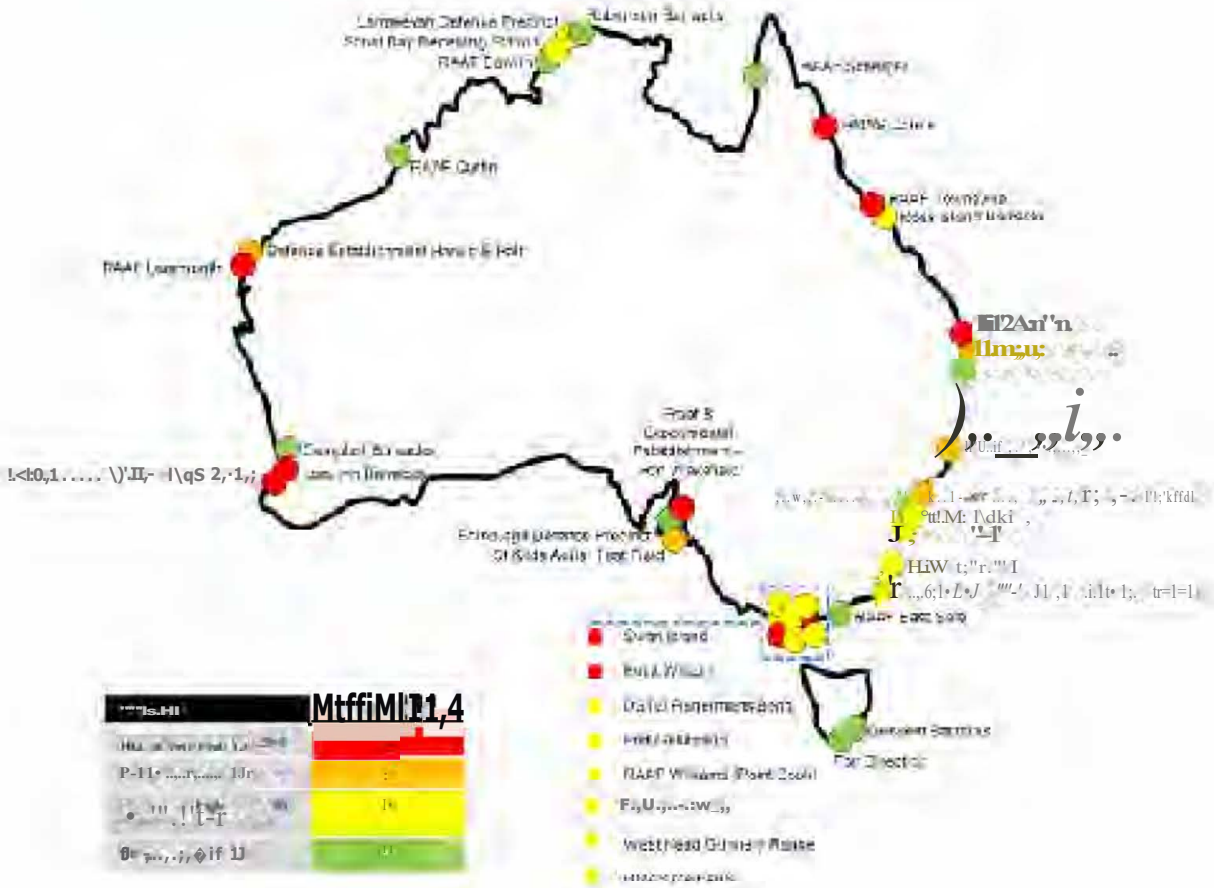


Figure 1 **Summary of risks from climate change induced sea level change at significant Defence bases from the Initial Assessment (Defence** 2011).

17. The Initial Assessment enabled Defence to decide which sites required more detailed investigations through a high level assessment of their likely risk exposure to climate change. This second, more detailed study has focussed on the 13 sites that were identified as at High or Very High risk in 2040 and 2070, and the Cocos (Keeling) Islands[1]. examining the 14 sites listed in Table 2.

Table2 **Defence sites assessed in Project AZ5220.**

- HMAS Cairns (Queensland)	- Damascus Barracks (Queensland)
- RAAF Base Townsville (Queensland)	- RAAF Base Williamtown (New South Wales)
- Garden Island West/ HMAS Stirling (Western Australia)	- Point Wilson Explosives Area (Victoria)
- RAAF Base Learmonth (Western Australia)	- Swan Island (Victoria)
- Defence Establishment Harold E Holt (Western Australia)	- Garden Island Defence Precinct (GIDP) (New South Wales)
- Cocos (Keeling) Islands (Indian Ocean Territories)	- Proof & Experimental Establishment (P&EE) Port Wakefield (South Australia)
- Bulimba Barracks (Queensland)	- St Kilda Transmitting Station (South Australia)

' Following the completion of Phase 1, Defence directed that the assessment of Leeuwin Barracks (INA) be replaced by an assessment of the Cocos (Keeling) Islands.

18. This more detailed study includes consideration of the impacts of terrestrial flooding and coastal erosion with the aim of helping Defence take the next step - from knowing which bases are likely to be at most risk, to understanding in more detail their actual risk exposure and which adaptation measures are likely to minimise these future risks. This will enable investment and planning decisions to be made with greater confidence. The outcomes of this study will provide input into decision making regarding the strategic basing principles and whether to invest in redevelopments and adaptation, or divest properties, and the financial planning to support this.

19. In examining the findings from this more detailed study, it is important to reaffirm that the selection of the sites for this study was based only on the consideration of the likely risk of climate change induced sea level rise, storm surge and king tides. It should not be assumed that the other 24 sites included in the Initial Assessment are not at risk from the impacts of terrestrial flooding, coastal erosion or other impacts of climate change.

1.2 The changing climate

20. Naturally occurring greenhouse gases help maintain environmental conditions which allow life to exist on Earth. However, human activities, predominantly the burning of fossil fuels, intensive agriculture and land clearing are causing greenhouse gas concentrations to rise above natural levels, further heating the planet. Atmospheric concentrations of carbon dioxide, a key greenhouse gas, are higher now than at any time in the last 420,000 years (DSE, 2009). These raised levels of greenhouse gases correspond closely to increases in fossil fuel burning and land clearance.

21. Australia has already experienced observable changes in climate. In 2012, the CSIRO and the Bureau of Meteorology (BOM) released a joint report, *State of the Climate.* Key points highlighted in the report include:

- Each decade has been warmer than the previous decade since the 1950s;
- Australian annual average daily mean temperatures have increased by 0.9 ℃ since 1910;
- Australian annual average daily maximum temperatures have increased by 0.75 ℃ since 1910;
- Australian annual average overnight minimum temperatures have warmed by more than 1.1 ℃ since 1910;
- There has been a trend over recent decades towards increased spring and summer monsoonal rainfall across Australia, higher than normal rainfall across the centre, and decreased late autumn and winter rainfall across the south;
- Global average mean sea level for 2011 was 210 mm above the level in 1880; and
- Global average mean sea level rose faster between 1993 and 2011 than during the 20th century as a whole (CSIRO and BoM, 2012).

22. These climatic changes pose significant threats to natural and built environments, including:

- Higher temperatures, increased humidity, flooding and subsidence are likely to lead to the accelerated deterioration of buildings, bridges and other structures;
- An increased frequency and intensity of extreme weather events, bushfires and temperatures is likely to disrupt key infrastructure such as roads, railways and energy and water assets;
- Increases in the frequency and intensity of destructive storms, flooding and bushfires are likely to increase insurance costs as the insurance and finance industries re-evaluate risks;
- Reductions in rainfall are likely to place communities and water intensive activities under increased stress, particularly when linked to higher temperatures and evaporation; and
- Rising sea levels and storm surge events are likely to cause inundation and erosion, affecting coastal infrastructure and environments.

23. Even with considerable future reductions in global greenhouse gas emissions, the lag in the climatic system means that many of these impacts are unavoidable, requiring communities and organisations to adapt to these impacts.

1.3 Project objectives and scope

24. The strategic objectives of this study are to enable more effective long term resource allocation, increase the resilience of Defence assets to current and future extreme weather events and to proactively respond to possible changes in government policy. By taking action to understand the risks and implications of climate change to selected sites, Defence may be able to assist in shaping future Commonwealth Government policy, rather than having onerous policy requirements imposed upon it.

25. To support these strategic objectives this study aims to enable Defence to understand and manage the risks associated with climate change induced sea level rise, flooding and erosion at selected sites. Its findings will enable Defence to develop and plan for adaptation options to reduce its exposure to these emerging risks.

26. Changes in sea level and extreme rainfall due to climate change are likely to increase the frequency and severity of flooding from both rainfall and storm surge events, and increase coastal erosion. This flooding and erosion could affect assets at the assessed sites, reducing capability. This study assesses the risk exposure of these assets to these projected climatic changes and provides a series of adaptation options to help mitigate risks.

27. The study focussed on the 14 sites listed in Table 2 with risks assessed across three timeframes (2040, 2070 and 2100). Risks at each site were identified and assessed under the following risk themes:

- Buildings;
- Site access and internal roads;
- Pier and marine infrastructure;
- Runways and aviation infrastructure;
- Utilities;
- Environmental assets;
- Contamination; and
- Heritage.

28. High level adaptation options, including indicative costs, were developed for each site and prioritised to identify those which should be considered for implementation in the short term (i.e. within the next 10 years).

29. Consideration of broader climate change risks was not included in this assessment. However, the risk assessment process outlined may be used to address these and other climate change risks. Elements that are not included in the scope of the study include climate change impacts resulting from:

- Changes in temperature, humidity or evaporation;
- Extreme wind and changes in the predominant wind direction;
- Salt water intrusion into groundwater and estuaries;
- Changes in ground water levels;
- Reduced average rainfall;
- Inland erosion;
- Ocean acidification; and
- Changes to fog conditions.

30. The assessment has relied upon high level site information provided to AECOM by Defence. Although the AECOM project team visited each site, detailed investigations of underground assets, environmental assets, heritage assets, or contamination issues, were not undertaken.

31. The majority of the risks assessed in the study relate to the impacts of climate change on built assets. The study does not focus on climate change impacts on land forms or vegetation and any associated affects to capability (i.e. impacts to terrain or vegetation that is required for specific training capability). However, where observed or noted by site personnel, comments have been provided regarding potential capability implications of the climate risks assessed.

32. In undertaking the risk assessment and developing and prioritising adaptation options, it has been assumed that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

2.0 Project Methodology

33. The study was guided by the process detailed in the Site Assessment Methodology and Framework (SAMF) developed for this study (refer to Appendix A). The SAMF provides a step-by-step methodology for the assessment of climate change induced sea level rise, flooding and erosion at the nominated 14 sites. By documenting the process it enables Defence to update the findings of this study and may also be used to assess other locations in a consistent manner. A summary of the four step process undertaken in this study is provided in Figure 2.

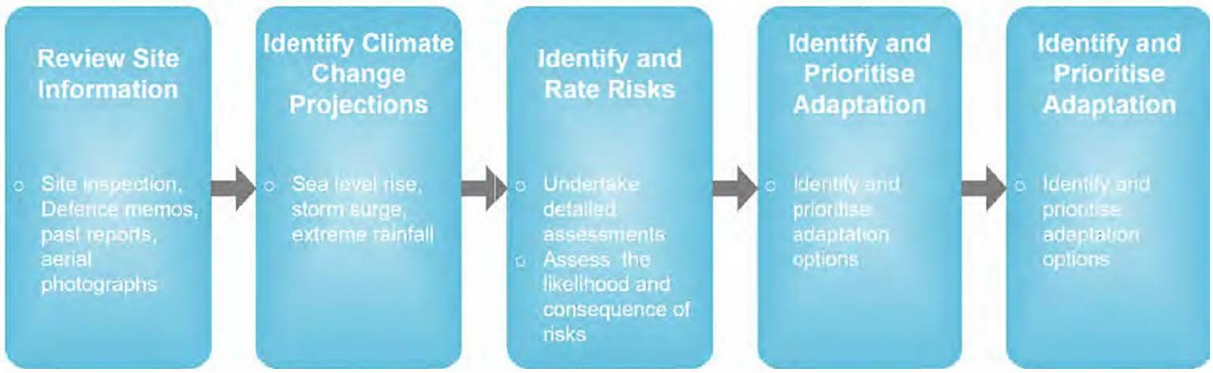


Figure 2 Sea level rise, flooding and coastal erosion risk assessment and adaptation planning methodology.

2.1 Review site information

34. A site inspection was undertaken to inspect the assets on site, engage with site personnel and gather data and reports to inform the assessment. The onsite consultation included discussions on the current use of the site, assets on the site and historic inundation and erosion issues. Data and information collected included high level environmental reports and heritage assessments, Defence site summary memos and design and spatial data. During this step, meetings were held with local stakeholders (i.e. local and/ or state government authorities) to discuss historical inundation and erosion issues and adaptation planning studies.

35. The information provided by Defence was supported by the acquisition of contour data and historical aerial photography (from state government agencies). Surveys of floor and ground heights of specific assets were also undertaken for this study. For each site, brief summaries were developed, including information relating to the landscape, infrastructure, site activities and environmental and heritage assets. The information collated and reviewed in this step formed the basis of the risk assessment and adaptation planning.

2.2 Identify climate change projections

36. Input from CSIRO, Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) and the Met Office (UK) informed and validated the selection of climate inputs for this assessment. Existing climate change projections for sea level rise and extreme rainfall were used to inform the detailed assessments of marine flooding, estuarine flooding and coastal erosion. For this assessment, the Intergovernmental Panel on Climate Change (IPCC) 'A1FI'[2] global greenhouse gas emissions scenario was used. This scenario assumes a 'Fossil Fuel Intensive' future with relatively high greenhouse gas emissions. Current global greenhouse gas emissions are tracking in line with the 'A1FI' emissions scenario pathway.

37. Within the A1FI projections, lower (50th percentile) and higher (95th percentile) projected values were used to assess the potential range of impacts at each site. To consider the implications of increases in extreme rainfall, an assessment was undertaken of each site's sensitivity to changes in run-off based on the 5 year Average

[2] A set of future emissions scenarios were prepared by the IPCC to develop global climate change projections. The scenarios used are from the *Fourth Assessment Report of the Intergovernmental Panel on Climate Change* where 'A1FI' assumes rapid economic growth with reliance on fossil fuels.

Recurrence Interval (ARI[3]) and 100 year ARI extreme rainfall events. A summary of the climate inputs used in this assessment are included in Table 3. More detailed discussion of the application of the projections is included in the technical reports developed for each site (refer to the individual site reports).

Table 3 Summary of climate inputs used in this assessment.

	2040	2070	2100	References
Sea Level **Rise**				
Lower	0.14 m	0.31 m	1.10 m	ACE CRC and CSIRO2012 Vermeer and Rahmstorf (2009).
Higher	0.20 m	0.45 m	1.43 m	
Increase in run off due to extreme rainfall				
Northern Queensland				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	
South **East** Queensland				
Lower	+20%	+30%	+50%	Rafter (2012) and Sandery, et al. (2009).
Higher	+40%	+50%	+70%	
Eastern New South Wales				
Lower	+20%	+30%	+40%	Rafter (2012) and Sandery, et al. (2009).
Higher	+40%	+50%	+60%	
Victoria				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	
Northern Western **Australia**				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+70%	
South **Australia**				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	

38. Storm surge was included in the consideration of extreme sea levels. This was based on historical records. In this assessment, the influence of cyclones was included in the consideration of extreme sea levels, specifically influences on storm surge, wind, wave run up and wave set up. These allowances have been based on historic records. In the Australian region, no categorical changes in the total numbers of tropical cyclones, or in the proportion of the most intense tropical cyclones, were observed; though there is considerable year-to-year and decade-to-decade variability. The 2012 CSIRO and the Bureau of Meteorology report, State *of the Climate,* indicated that there will be fewer tropical cyclones on average in the Australian region as a result of climate change but the proportion of intense cyclones is expected to increase. However, quantification of these changes is not currently available, therefore historical records have been used to inform extreme sea levels.

[3]Average Recurrence Interval (ARI) is the expected time between the evenls !hat exceed the given value (rainfall, water level, wave height etc.). It is sometimes referred to as the "return period" and is usually expressed in years. For example, the rainfall experienced during a 100 Year ARI storm event will on average only be exceeded once every 100 years. However, it does not mean it cannot happen more, or less, frequently than every 100 years.

39. Additional information relating to the climate information used for this assessment is provided in Appendix B.

2.3 Identify and rate risks

40. To identify the risks to each site, detailed site assessments were undertaken using the following steps:

- Determine the required studies:
- Determine inundation extents through modelling of current and future marine flooding and estuarine flooding;
- Determine the extent of coastal erosion through modelling the combined effects of short term erosion, long term erosion and erosion due to sea level rise; and
- Map the combined hazard areas.

41. Risks were identified for each site by comparing the areas at risk of inundation and erosion represented in the hazard maps, to the site summary information, aerial photographs and survey data.

42. The likelihood and consequence of each risk was rated and then used to calculate the risk level and rating. Table 4 summarises the risk level and rating system used for this assessment. The definitions of likelihood and consequence are outlined in the SAMF and are adapted from *the Defence Estate Risk* Assessment *Guidance - For Estate Maintenance* (Defence 2011).

Table 4 Definition of level and risk score for the assessment of the impact of climate change induced sea level rise, flooding and erosion at selected Defence sites (adapted from Department of Defence, 2011).

		Consequence				
		Severe (1)	Major (6)	Moderate (11)	Minor (16)	Negligible (21)
Likelihood	Almost Certain (1)	Very High (2)	Very High (7)	High (12)	Medium (17)	Low (22)
	Likely (3)	Very High (4)	High (9)	Medium (14)	Medium (19)	Low (24)
	Possible (5)	High (6)	High(11)	Medium (16)	Medium (21)	Low (26)
	Unlikely(7)	High (8)	Medium (13)	Medium (18)	Low (23)	Low (28)
	Rare (9)	High(10)	Medium (15)	Low (20)	Low (25)	Low (30)

43. For each site, the results of the risk assessment were presented in a table describing each risk and summarising the risk score for each timeframe (2040, 2070 and 2100). The risk score is a combination of the likelihood rating (L) and the consequence rating (C). Risk ratings for each timeframe assume that the location and type of assets at each site remain the same over time.

44. In the example provided in Table 5, in 2040 the likelihood of the risks to buildings is rated Almost Certain (A1) and the consequence is rated Moderate (M11), leading to a risk score of High (12). In 2070, the likelihood remains Almost Certain (A1), while the consequence increases to Major (M6), leading to a risk score of Very High (7). In 2100, the likelihood again remains unchanged (A1) and the consequence increases to Severe (S1) leading to a risk score of Very High (2).

Table 5 Example risk table providing a description of the risk and summarising the risk score for each timeframe (based on RAAF Base Townsville).

Risk Description	2040	2070	2100
Runways and **Aviation** Infrastructure Inundation and storm surge impacts restricting use of and damaging runways, taxiways and supporting infrastructure, reducing base capability.	High 12 L-A1 C-M11 (capab1hty)	Very High 7 L-A1 C-M6 (capab1hty)	Very High 2 L-A1 C-S1 (capab1hty)

45. For each timeframe, reference is also made to the organisational, base or activity related concerns (e.g. capability, occupational health and safety, environment and heritage etc.) that receive the greatest consequence

score. For the purpose of this risk assessment, the organisational, base or activity related concerns are referred to as 'consequence dimensions'. The example in Table 5 indicates that the 'capability' dimension underpins the Major consequence rating for each timeframe. The SAMF includes a list of, and definitions for, the consequence dimensions that were considered.

46. The summary of risks and initial ratings for each site were internally peer reviewed by senior AECOM project team members. The initial risk assessment findings were then presented at an internal workshop involving AECOM staff with climate change, coastal engineering, risk management and Defence experience. The workshop was used to enhance the risk assessment process by identifying gaps, discussing issues and challenging findings. Following the workshop, additional research and investigation was conducted in response to issues that were raised.

2.4 Identify and prioritise adaptation

47. Adaptation options were developed for each site by considering information from the site inspections (including input from Defence site personnel) and the AECOM project team's climate change adaptation and coastal engineering experience. The initial listing of adaptation options were interrogated at an internal project team workshop. Following the workshop, additional detail was added to the adaptation options including cost, implementation considerations and the potential for broader environmental and social impacts. The adaptation options for each site were then assessed to identify the priority actions for implementation in the next ten years. The options were prioritised under the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same. A workshop was then held with Defence to review the identified actions and the proposed priorities for implementation.

48. Site reports were prepared for each site to present the site specific risks and adaption responses and the associated technical work undertaken to determine the hazard areas. Site reports for the first phase were reviewed by the Technical Reference Group (TRG) which considered them from three different perspectives: coastal engineering (AECOM staff), emergency management and Defence Force activities (AECOM USA staff) and climate change (the Met Office). Feedback from these reviews lead to improvements in the structure and presentation of the findings. It was determined that additional reviews of the reports for remaining phases would not have added further value.

49. This Executive Report was then developed to present a summary of the project and findings. Site summary sheets have been developed to support the communication of the findings of the study, and are included in Appendix B. This Executive Report and the attached site summary sheets should be read in conjunction with the detailed site reports.

2.5 Cocos (Keeling) Islands variation

50. Following the completion of Phase 1, Defence directed that the assessment of Leeuwin Barracks (:NA) be replaced by an assessment of the Cocos (Keeling) Islands. The Cocos (Keeling) Islands are a group of 27 low lying coral atolls in the Indian Ocean approximately 2,950 km northwest of Perth, Western Australia. The Cocos (Keeling) Islands are not a Defence site, unlike the other sites assessed in this study. Defence owns and operates assets on the West Island, the focus of the assessment. Defence capability on West Island is supported by the assets and services provided by the Attorney General's Department, the Water Corporation and the local shire council including road maintenance, electricity supply, water and sewerage services, the jetty and the airport. Defence may undertake works to protect its assets on the island. However, long term adaptation would benefit from collaboration with affected stakeholders (e.g. local governments, Attorney General's Department or the Water Corporation) to ensure effective adaptation of necessary utilities and services that support Defence's capability on the island.

3.0 Findings

51. This section presents the findings of the risk assessment. The findings are presented for each risk theme (Section 3.1) and site (Section 3.2). with general observations of risks beyond the scope of the assessment provided (Section 3.3).

3.1 Summary by risk theme

52. This section presents a summary of the specific risks likely to be caused by climate change induced sea level rise, coastal erosion and inland inundation across the 14 sites according to the following risk themes:

- Buildings;
- Site access and internal roads;
- Pier and marine infrastructure;
- Runways and aviation infrastructure;
- Utilities;
- Environmental assets;
- Contamination; and
- Heritage.

53. Additionally, risk ratings for each risk theme at each site are provided consistent with the terminology presented in Table 4.

54. The majority of risks assessed in this study relate to the impacts of climate change on built assets. These assets support important capabilities and Defence is highly likely to be liable for protecting them from the impacts of climate change. A different approach has been taken to assess the implications to Defence of climate change affecting listed and indicative environment and non-built heritage assets. This is because the capability implications of climate change affecting these assets are less significant. In addition, under current legislation, Defence is unlikely to be liable for their protection from climate change impacts, as these impacts are likely to occur on a global scale. For example, if sea level rise negatively affects a threatened Ecological Community or midden, Defence is unlikely to be required to put in place mitigation measures as the impacts are the result of natural processes, not Defence actions. However, climate change risks to environment and non-built heritage assets have still been assessed as reputational risks may arise from such impacts, legislative frameworks and management requirements may change in future and some environmental assets support important Defence training activities (the assessment of which is beyond the scope of this study).

3.1.1 Buildings

55. Buildings are at risk from climate change induced inundation and coastal erosion at all assessed sites.

56. Buildings at the sites consist of a variety of construction materials including:

- Galvanised steel framed structures with coated or galvanised roof and wall cladding;
- Masonry block and brick structures with coated steel roof cladding;
- Prefabricated buildings elevated on steel frames; and
- Brick structures with ceramic tile roofs.

57. Some buildings have reinforced concrete slab floors, while others are supported on reinforced concrete. Timber cladding, stumps and decking are associated with some buildings.

58. Inundation is likely to damage, degrade and destabilise buildings, including below ground building structures (e.g. foundations or bunkers). The direct impact of waves during storm surge events may also damage buildings. Coastal erosion may destabilise, or lead to the complete loss of, buildings.

59. Specific physical impacts to buildings from inundation may include increased corrosion of wall cladding and reinforcement in concrete piles, increased deterioration of timber framing or other timber elements. undermining of foundations and water damage to the interior. Staff, materials and assets within buildings may also be at risk should a facility be inundated (e.g. documents, vehicles, plant and equipment).

60. The severity of the damage and flow-on implications will depend on the type and condition of the asset and the duration of inundation. The damage from short-term inundation may be limited to clean up costs and short term disruption to capability. Longer term, or more frequent, inundation may lead to more extensive damage (requiring the repair, replacement or relocation of assets) or have implications for the capability that the building supports (e.g. training, administration, maintenance, communications or storage).

61. Table 6 summarises the inundation and coastal erosion risk ratings to buildings at the sites assessed for the studied timeframes.

Table 6 Risks to buildings across all three timeframes for each site.

Site	2040	2070	
HMAS Cairns, Old	H	VH	VH
RAAF Base Townsville, Qld	VH	VH	VH
Garden Island West/ HMAS Stirling, WA	M	H	VH
RAAF Base Learmonth, WA	VH	VH	VH
Defence Establishment Harold E Holt. WA	VH	VH	VH
Cocos (Keeling) Islands, IOT	M	H	VH
Bulimba Barracks, Qld	H	VH	VH
Damascus Barracks, Old	H	H	VH
RAAF **Base** Williamtown, NSW	M	M	M
Point Wilson Explosives Area, Vic	M	M	VH
Swan Island, Vic	VH	VH	VH
Garden Island Defence Precinct, NSW	N/A	N/A	VH
P&EE Port Wakefield, SA	H	H	VH
St Kilda Transmitting Station, SA	M	M	VH

3.1.2 Site access and internal roads

62. Site access and internal roads are at risk from climate change induced inundation and coastal erosion at all assessed sites.

63. Inundation during storm surge and extreme rainfall events currently restricts access to HMAS Cairns, RAAF Base Townsville, RAAF Base Learmonth and Defence Establishment Harold E Holt. Sea spray has temporarily restricted use of the causeway leading to Garden Island West/ HMAS Stirling, restricting site access. Access to Swan Island, via the Bellarine Highway, may be at risk of inundation from current 100 year ARI storm surge events.

64. Internal roads are currently at risk of inundation in HMAS Cairns, RAAF Base Townsville, RAAF Base Learmonth, Defence Establishment Harold E Holt, Bulimba Barracks, Damascus Barracks, RAAF Base Williamtown, Point Wilson, Swan Island, P&EE Port Wakefield and St Kilda Transmitting Station. Additionally, roads supporting Defence's capability on the Cocos (Keeling) Islands are currently inundated during 100 Year ARI storm surge event. Internal roads at Garden Island Defence Precinct are not at risk of inundation until 2100. Climate change is likely to lead to more frequent and longer duration inundation, further restricting access to, and between, facilities at all sites (e.g. wharfs, fuel farms, storage and communication facilities). Additionally, more frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the pavement sub-base, increasing maintenance costs.

65. Coastal erosion is likely to destabilise the sub-base of roads at Garden Island West/ HMAS Stirling, and inundation and coastal erosion are likely to restrict access to the causeway in 2100. Roads in RAAF **Base** Learmonth, Defence Establishment Harold E Holt, Point Wilson and roads on Swan Island and the Cocos (Keeling) Islands are also at risk of coastal erosion in all three timeframes. In 2100, coastal erosion may affect the coastal road in P&EE Port Wakefield. Depending on the use of the roads and the severity of damage, there may be flow-on implications for capability at each site until repaired.

66. Table 7 summarises the inundation and erosion risk ratings to site access and internal roads at the sites assessed for the studied timeframes.

Table 7 Risks to site access and internal roads across all three timeframes for each site.

Site	2040	2070	2100
HMAS Cairns, Qld	VH	VH	VH
RAAF Base Townsville, Qld	H	H	VH
Garden Island West/ HMAS Stirling, WA	H	H	VH
RAAF Base Learmonth, WA	VH	VH	VH
Defence Establishment Harold E Holt, WA	VH	VH	VH
Cocos (Keeling) Islands, IOT	VH	VH	VH
Bulimba Barracks, Qld	VH	VH	VH
Damascus Barracks, Old	M	M	VH
RAAF Base Williamtown, NSW	M	M	H
Point Wilson Explosives Area, Vic	H	H	VH
Swan Island, Vic	VH	VH	VH
Garden Island Defence Precinct, NSW	N/A	N/A	VH
P&EE Port Wakefield, SA	VH	VH	VH
St Kida Transmitting Station, SA	M	M	H

3.1.3 Pier and marine infrastructure

67. Pier and marine infrastructure at HMAS Cairns, Garden Island West / HMAS Stirling, Defence Establishment Harold E Holt, Bulimba Barracks, Point Wilson, Garden Island Defence Precinct and on Swan Island and the Cocos (Keeling) Islands are at risk from climate change induced inundation and coastal erosion.

68. The ability to safely operate berthing facilities and wharfs is likely to be restricted by inundation and storm surge events, reducing capability including operational and maintenance activities. Land access to marine infrastructure may also be affected by inundation and erosion. Damage may also occur to berthing facilities and wharfs from the direct impacts of storm surge events and increased height of the corrosive splash zone. Specific physical impacts to marine infrastructure include an increased corrosion rate of reinforcement, steel and galvanised steel elements, marine borer degradation in timber piles at higher elevations and an increased rate of alkali-aggregate reaction (if the aggregate is susceptible). These impacts are likely to lead to an increased frequency of maintenance and repair.

69. Table 8 summarises the inundation and erosion risk ratings to pier and marine infrastructure at the sites assessed for the studied timeframes.

Table 8 Risks to pier and marine infrastructure across all three timeframes for each site.

Site	2040	2070	2100
HMAS Cairns, Qld	M	M	VH
RAAF Base Townsville, Qld	N/A	N/A	N/A
Garden Island West / HMAS Stirling, WA	H	H	VH
RAAF Base Learmonth, WA	N/A	N/A	N/A
Defence Establishment Harold E Holt, WA	M	M	H
Cocos (Keeling) Islands, IOT	H	H	VH
Bulimba Barracks, Qld	M	M	VH
Damascus Barracks, Qld	N/A	N/A	N/A
RAAF Base Williamtown, NSW	N/A	N/A	N/A
Point Wilson Explosives Area, Vic	M	H	VH
Swan Island, Vic	L	L	L
Garden Island Defence Precinct, NSW	M	M	VH
P&EE Port Wakefield, SA	N/A	N/A	N/A
St Kida Transmitting Station, SA	N/A	N/A	N/A

3.1.4 Runways and aviation infrastructure

70. Runways and aviation infrastructure at RAAF Base Townsville, Garden Island West/ HMAS Stirling, RAAF Base Learmonth, RAAF Base Williamtown and on Swan Island and the Cocos (Keeling) Islands are at risk from climate change induced inundation and coastal erosion.

71. The inundation of runways, taxiways, helipads and flight aprons will restrict their ability to support ADF air capability and other uses (e.g. co-located civilian services and emergency landing by ADF or civilian aircraft). Inundation will also affect supporting aviation infrastructure, including arrestor pits, refuelling facilities, ordnance storage, ordnance loading and maintenance facilities, reducing capability. More frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the runway sub-base, increasing maintenance costs.

72. Table **9** summarises the inundation and erosion risk ratings to runways and aviation infrastructure at the sites assessed for the studied timeframes.

Table 9 Risks to runways and aviation infrastructure across all three timeframes for each site.

Site	2040	2070	2100
HMAS Cairns, Qld	N/A	N/A	N/A
RAAF Base Townsville, Qld	H	VH	VH
Garden Island West/ HMAS Stirling, WA	L	L	M
RAAF Base Learmonth, WA	VH	VH	VH
Defence Establishment Harold E Holt, WA	N/A	N/A	N/A
Cocos (Keeling) Islands, IOT	VH	VH	VH
Bulimba Barracks, Old	N/A	N/A	N/A
Damascus Barracks, Old	N/A	N/A	N/A
RAAF Base Williamtown, NSW	VH	VH	VH
Point Wilson Explosives Area, Vic	N/A	NIA	N/A
Swan Island, Vic	L	L	L
Garden Island Defence Precinct, NSW	N/A	N/A	N/A
P&EE Port Wakefield, SA	N/A	N/A	N/A
St Kilda Transmitting Station, SA	N/A	N/A	N/A

3.1.5 Utilities

73. Electricity, water, communication, fire alarm and sewerage assets are at risk from climate change induced inundation and coastal erosion at all assessed sites.

74. Historic inundation has affected utilities at HMAS Cairns, RAAF Base Townsville, RAAF Base Learmonth, Defence Establishment Harold E Holt and St Kilda Transmitting Station including triggering fire alarm systems, disrupting power, communications networks and causing sewage overflows. Increased severity or frequency of inundation of utilities is likely to disrupt and damage essential services causing failure of electricity assets, overflowing of sewage, contamination of water supplies and disruption of communications, affecting capability. More frequent and longer duration inundation may destabilise the foundations of utility assets including antennas.

75. Where buildings and facilities are at risk from inundation or coastal erosion, it is expected their utility services will also be at risk. In addition, above ground assets (e.g. electricity switch rooms) and services on marine infrastructure are at risk of damage from inundation.

76. While not assessed in this study, climate change is likely to affect the viability of the freshwater lens on the Cocos (Keeling) Islands, its only natural freshwater resource. Sea level rise may lead to salt water intrusion into the freshwater lens and may also decrease the area of land available for collecting water to recharge the lens.

77. Table 1Osummarises the inundation and erosion risk ratings to utilities at the sites assessed for the studied timeframes.

Table 10 Risks to utilities across all three timetrames for each site.

Site	2040	2070	
HMAS Cairns, Qld	H	H	VH
RAAF Base Townsville, Qld	H	VH	VH
Garden Island West/ HMAS Stirling, WA	H	H	VH
RAAF Base Learmonth, WA	VH	VH	VH
Defence Establishment Harold E Holt, WA	VH	VH	VH
Cocos (Keeling) Islands, IOT	VH	VH	VH
Bulimba Barracks, Qld	H	VH	VH
Damascus Barracks, Old	M	M	VH
RAAF Base Williamtown, NSW	H	H	H
Point Wilson Explosives Area, Vic	M	H	VH
Swan Island, Vic	VH	VH	VH
Garden Island Defence Precinct, NSW	N/A	N/A	VH
P&EE Port Wakefield, SA	H	H	VH
St Kilda Transmitting Station, SA	H	H	VH

3.1.6 Environmental assets

78. Environmental assets are at risk from climate change induced inundation or coastal erosion at RAAF Base Townsville, Garden Island West/ HMAS Stirling, RAAF Base Learmonth, Defence Establishment Harold E Holt, RAAF Base Williamtown, Point Wilson, Swan Island and P&EE Port Wakefield.

79. As a land owner, Defence has an obligation to manage significant environmental assets. Sea level rise, coastal erosion and more frequent and intense rainfall events may affect the viability of some habitats. At particular risk are habitats that do not have space to retreat due to built environments (e.g. buildings and roads) or non-supportive natural environments (e.g. a cliff or waterway).

80. Garden Island West / HMAS Stirling contains significant flora and fauna species. It is listed as a Commonwealth Heritage Place for its natural values and the low, closed coastal forest that represents much of the island's vegetation has State Government Threatened Ecological Community status. This vegetation occurs mainly in the elevated portions of the site Which are not likely to be at risk of inundation.

81. RAAF Base Townsville is listed as a wetland in the Directory of Important Wetlands of Australia. While no protected flora species have been reported on the site, a rare plant (Aponogeton queenslandicus) has been identified in the adjacent Blakey's Crossing area. The adjacent ephemeral wetland west of the site (i.e. the Town Common) is listed on the Register of the National Estate and attracts protected migratory bird species.

82. RAAF Base Learmonth and Defence Establishment Harold E Holt are located on the North West Cape Which has been assigned National and World Heritage status by the Commonwealth and Western Australian Government. At both sites, threatened terrestrial and marine species, or their habitat, is known to occur.

83. RAAF Base Williamtown is located in an environmentally sensitive area. Habitat for fauna l species, listed as vulnerable under the *Threatened Species Conservation (TSC) Act 1995* occur on the site. In addition, significant migratory species protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999) utilise the region, particularly open wetlands and grassland habitats.

84. Point Wilson contains habitat for EPBC Act listed Threatened Species and Ecological Communities including two Commonwealth listed threatened species (e.g. Orange-bellied Parrot and the Fairy Tern) and Natural Temperate Grasslands of the Victorian Volcanic Plain (NTG VVP). The south-western shoreline is part of the Bellarine Peninsula Ramsar site providing habitat for approximately 53 bird species listed under the migratory provisions of the EPBC Act 1999.

85. Swan Island is a key winter habitat for the Commonwealth listed Threatened Orange-bellied Parrot. In addition, the site contains habitats that support large populations of shorebirds and seabirds. Many of these birds are listed under international migratory bird agreements including the Japan-Australia and China-Australia

migratory bird agreements and the Bonn Convention on Migratory Species, including the eastern curlew, ruddy turnstone, red-necked stint, sharp-tailed sandpiper, curlew sandpiper and the grey plover.

86. P&EE Port Wakefield is unique as the tidal zone represents a critical environmental asset that supports capability. Sea level rise may reduce the horizontal distance between the mean low and high tides, reducing the area for over water recovery. Additional environmental assets in P&EE Port Wakefield include habitat for significant flora and fauna species. Coastal erosion and semi-permanent tidal inundation may degrade habitat for the Samphire (Slender-billed) Thornbill, Beaded Glasswort communities and Subtropical and Temperate Coastal Saltmarsh communities, all of which are listed as vulnerable under the EPBC Act 1999. Habitats for approximately 30 bird species listed under the migratory provisions of the EPBC Act 1999 may also be at risk of degradation due to more frequent inundation.

87. While it is unlikely that climate change induced impacts to these environmental assets would trigger non-compliance with the EPC Act, climate change related damage to significant environmental values could present reputational risks to Defence. To properly assess these risks, further investigation would be required to determine the presence of threatened communities in the areas at risk of inundation and the specific risks and impacts as a result of more frequent and longer duration inundation events.

88. Table 11 summarises the inundation and erosion risk ratings to environmental assets at the sites assessed for the studied timeframes.

Table 11 Risks to environmental assets across all three timeframes for each site.

Site	2040	2070	2100
HMAS Cairns, Qld	NIA	NIA	NIA
RAAF Base Townsville, Qld	L	L	L
Garden Island West /HMAS Stirling, WA	L	L	L
RAAF Base Learmonth, WA	M	M	M
Defence Establishment Harold E Holt, WA	M	M	M
Cocos (Keeling) Islands, IOT	NIA	NIA	NIA
Bulimba Barracks, Qld	NIA	N/A	NIA
Damascus Barracks, Qld	NIA	NIA	NIA
RAAF Base Williamtown, NSW	M	M	M
Point Wilson Explosives Area, Vic	VH	VH	VH
Swan Island, Vic	VH	VH	VH
Garden Island Defence Precinct, NSW	N/A	N/A	N/A
P&EE Port Wakefield, SA	M	M	H
St Kilda Transmitting Station, SA	N/A	N/A	N/A

3.1.7 Contamination

89. Existing contamination and stored hazardous substances are at risk of mobilisation into surrounding soils, groundwater and waterways due to climate change induced inundation and coastal erosion at all assessed sites.

90. RAAF Base Townsville, Garden Island West / HMAS Stirling, RAAF Base Learmonth, Defence Establishment Harold E Holt, Bulimba Barracks, Damascus Barracks, RAAF Base Williamtown, Point Wilson and P&EE Port Wakefield have existing contamination which is at risk of inundation or coastal erosion. Inundation and erosion may cause the mobilisation of existing contaminants into surrounding soils, groundwater and waterways. This may affect the human health and environmental values of neighbouring properties or waterways.

91. In addition to existing contamination issues, hazardous substances are transported, stored, handled, used and disposed of at each site. Inundation and erosion damage to storage arrangements of these substances may result in the mobilisation of contamination. Potential contaminants include hydrocarbons, solvents associated with equipment and vehicle maintenance, heavy metals, polyaromatic hydrocarbons (PAH), ordnance, perfluoroctane sulfonate (PFOS), perfluoroctanoic acid (PFOA), benzene, toluene, ethyl benzene and xylene (BTEX), phosphates, solvents and asbestos. Sources of greatest risk across the sites include fuel stores and pipes, dangerous goods stores, workshops, maintenance facilities, underground storage tanks, wastewater treatment facilities and landfills.

92. To properly assess these risks, further investigation is required into the presence of existing contamination in the areas at risk of erosion and inundation at each site, and the effects of more erosion and more frequent and longer duration inundation.

93. Table 12 summarises the inundation and erosion risk ratings to contamination at the sites assessed for the studied timeframes.

Table 12 Risks to contamination across all three timeframes for each site.

Site	2040	2070	2100
HMAS Cairns, Qld	M	M	M
RAAF Base Townsville, Qld	M	M	VH
Garden Island West/ HMAS Stirling, WA	M	M	H
RAAF Base Learmonth, WA	M	M	M
Defence Establishment Harold E Holt, WA	M	M	M
Cocos (Keeling) Islands, IOT	N/A	L	M
Bulimba Barracks, Qld	M	M	M
Damascus Barracks, Qld	M	M	M
RAAF Base Williamtown, NSW	M	M	M
Point Wilson Explosives Area, Vic	M	M	M
Swan Island, Vic	M	M	M
Garden Island Defence Precinct, NSW	N/A	N/A	H
P&EE Port Wakefield, SA	M	M	M
St Kilda Transmitting Station, SA	L	L	L

3.1.8 Heritage

94. Heritage assets are at risk from climate change induced inundation and coastal erosion at HMAS Cairns, RAAF Base Townsville, Garden Island West/ HMAS Stirling, Defence Establishment Harold E Holt, Bulimba Barracks, RAAF Base Williamtown, Point Wilson, Swan Island, GIDP and P&EE Port Wakefield.

95. Defence has an obligation to maintain and protect heritage assets with Indigenous values (e.g. Aboriginal midden sites of significance) and sites of historic built assets (i.e. early European settlement assets) that are listed on the Register of the National Estate and / or the Commonwealth Heritage List.

96. At Garden Island West/ HMAS Stirling, the Cliff Point Historic Site and the J Gun Battery are both on the Register of the National Estate, are Commonwealth Heritage Places and the latter site is also listed on the Heritage Council of Western Australia's Places Database. These heritage sites are at risk of damage from coastal erosion.

97. Defence Establishment Harold E Holt contains Indigenous heritage sites along the coast that are at risk of coastal erosion and inundation and buildings of heritage value that are likely to be affected by inundation. There are buildings on Cocos (Keeling) Islands listed on the Commonwealth Heritage List and the Register of National Estate (e.g. West Island Elevated Houses), however, it is not known if Defence's assets on the island are listed.

98. RAAF Base Williamtown is listed on the Commonwealth Heritage List for its Historic and Indigenous heritage values. Inundation and increased exposure to salinity may damage or degrade Indigenous or historic heritage values assets (including hangars and accommodation buildings).

99. Swan Island is included on the Register of the National Estate and the Commonwealth Heritage List for its historic heritage values. Inundation and coastal erosion may damage or degrade historic built heritage assets, including the historic fort, increasing management and maintenance requirements.

100. Garden Island Defence Precinct is included on the Commonwealth Heritage List for historic heritage values. It is also listed on the NSW State Heritage Register (SHR). No heritage assets are at risk of inundation in 2040 and 2070. Some heritage assets in Garden Island Defence Precinct are at High risk in 2100.

101. No listed heritage assets were identified at HMAS Cairns, RAAF Base Townsville, Bulimba Barracks, Point Wilson or P&EE Port Wakefield. However, they contain non-listed heritage assets that may be damaged or degraded by inundation, increasing maintenance requirements or leading to relocation costs.

102. Table 13 summarises the inundation and erosion risk ratings to heritage at the sites assessed for the studied timeframes.

Table 13 Risks to heritage across all three timeframes for each site.

Site	2040	2070	2100
HMAS Cairns, Qld	M	M	M
RAAF Base Townsville, Qld	L	L	L
Garden Island West/ HMAS Stirling, WA	L	L	VH
RAAF Base Learmonth, WA	N/A	N/A	N/A
Defence Establishment Harold E Holt, WA	H	H	H
Cocos (Keeling) Islands, IOT	NIA	NIA	NIA
Bulimba Barracks, Qld	M	M	M
Damascus Barracks, Qld	N/A	NIA	N/A
RAAF Base Williamtown, NSW	M	M	M
Point Wilson Explosives Area, Vic	H	H	H
Swan Island, Vic	M	H	H
Garden Island Defence Precinct, NSW	N/A	N/A	H
P&EE Port Wakefield, SA	L	L	M
St Kilda Transmitting Station, SA	N/A	N/A	N/A

3.2 Summary by site

103. This section provides a summary of the risks at each site, focussing on the risk themes rated High or Very High in 2040. The findings in this section should be read in conjunction with the detailed site reports.

3.2.1 **Risks** to **HMAS** Cairns, Qld

104. Table 14 presents a summary of the risks for HMAS Cairns across all three timeframes and for all risk themes examined.

Table 14 Summary of the inundation risks for HMAS Cairns across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation and storm surge impacts restricting access to site, use of internal roads and damaging roads, reducing base capability.	Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Damage and loss of access to berthing facilities and wharfs from inundation and storm surge events reducing base capability and functionality. The ability to safely operate berthing facilities and wharfs may be restricted by inundation.	**Medium 16** L-P5 C-M11 (capability)	**Medium 16** L-P5 C-M11 (capability)	Very High 2 L-A1 C-S1 (capability)
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	**N/A**	**N/A**	**NIA**
Utilities Inundation may disrupt essential services to the site including electricity, communications, water and sewerage,· reducing base capability and functionality.	High 11 L-P5 C-M6 (capability)	High 11 L-P5 C-M6 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Environmental Assets The site contains no listed or indicative environmental assets or remnant vegetation.	**N/A**	**N/A**	**N/A**
Contamination Inundation may result in the mobilisation of contamination into surrounding soils, groundwater and Trinity Inlet.	**Medium 21** L-P5 C-M16 (E&H)	**Medium 21** L-P5 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)
Heritage Inundation may damage or degrade historic heritage values.	**Medium 21** L-P5 C-M16 (E&H)	**Medium** 17 L-A1 C-M16 (E&H)	Medium 17 L-A1 C-M16 (E&H)

105. HMAS Cairns currently experiences marine and estuarine flooding and climate change is likely to increase these hazards, resulting in the site having a Very High risk rating in 2040. The site is not at risk of coastal erosion as it is not directly exposed to wave induced coastal processes.

106. Site capability is supported by the Kenny Street Facility (located approximately 500 m west of HMAS Cairns), two accommodation facilities (Northern Heritage and Las Palmas, 3 km north-west), and the Queerah Magazine and Ordnance Loading Area (located approximately 6 km south). Due to its proximity to HMAS Cairns, the Kenny Street Facility has been included in the hazard mapping undertaken for this site. The accommodation facilities and the Queerah Magazine and Ordnance Loading Area are not included in this assessment.

107. Storm surge levels are likely to reach 2.34 m AHO in 2040 and 3.57 m in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood levels of up to 3.32 m in 2040 increasing to greater than 3.58 m in 2100.

108. Buildings at HMAS Cairns are at High risk in 2040, increasing to Very High in 2070.

109. In 2040, 13 buildings are at risk of inundation during a combined 100 year ARI storm surge and extreme rainfall event including the Non Explosives Store (0030), Bosuns Store (0026), Divers (0025), Transport Store (0018), Boat store (0042), RAN Store / Workshop (0043), FOS Store / Workshop (0044), Administration (0045), Hydrant Storage Shed, Central (0047), Boat store (0027) and the adjacent building (0029). In 2070, an additional four buildings will be at risk of inundation (Stores (0005), Cold room (0009), TS Endeavour (0062) and the adjacent Office).

110. In 2100, all buildings at HMAS Cairns except the OFI Diesel Pumphouse (0101) and the area within the Bund Wall (0107), including Tanks (0102, 0103, and 0104) will be at risk of inundation.

111. All buildings at the Kenny Street Facility are at risk of inundation across all three timeframes.

112. More frequent and longer duration inundation will restrict capability and damage building assets including increased corrosion of roof and wall cladding and reinforcements in concrete piles, undermining of foundations and subsidence due to erosion and water damage to interiors and equipment housed in the buildings.

113. Site access and internal roads at HMAS Cairns are at Very High risk in all three timeframes.

114. Inundation impacts are likely to continue to restrict access between HMAS Cairns and the Kenny Street Facility (e.g. along Draper Street and Kenny Street). This inundation will affect the ability of staff and suppliers to access site facilities and cause damage to road surfaces and foundations, reducing capability. Access to the assets at the southern section of the site are at greatest risk in 2040 and 2070 including the TS Endeavour (0062), Switch Room (0048 and adjacent substation) and the sugar wharf access bridge (0012). In 2100 access to all assets will be restricted by inundation.

115. Utilities at HMAS Cairns are at High risk in 2040, increasing to Very High in 2100.

116. Inundation is likely to disrupt essential services including electricity and water supply, information technology, communications and sewerage. Back up electricity generators are positioned on the first floor of the Command Administration building (001) and so are not at risk of direct damage due to inundation. However, the fuel supply for the generators is located on the ground floor which, if inundated, may limit the effectiveness of the generators.

3.2.2 Risks to RAAF Base Townsville, Qld

117. Table 15 presents a summary of the risks for RAAF Base Townsville across all three timeframes and for all risk themes examined. A more detailed description of these risks is presented in the sections below.

Table 15 Summary of the inundation risks for RAAF Base Townsville across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation and storm surge impacts restricting use of internal roads and damaging roads, reducing base capability.	High 12 L-A1 C-M11 (capability	High 12 L-A1 C-M11 (capability	Very High 7 L-A1 C-M6 (capability)
Pier and Marine Infrastructure There is no pier or marine infrastructure at this site.	N/A	N/A	N/A
Runways and Aviation Infrastructure Inundation and storm surge impacts restricting use of and damaging runways, taxiways and supporting infrastructure. Inundation reducing base capability.	High 12 L-A1 C-M11 (capability/ OH&S)	Very High 7 L-A1 C-M6 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Utilities Inundation may disrupt essential services to the site including electricity, communications, water and sewerage reducing base capability and functionality.	High 9 L-L3 C-M6 (capability/ OH&S)	Very High 7 L-A1 C-M6 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets Potential degradation of wetland habitats.	Low23 L-P7 C-M16 (E&H)	Low23 L-P7 C-M16 (E&H)	Low23 L-P7 C-M16 (E&H)
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and marine environment.	Medium 16 L-P5 C-M11 (E&H)	Medium 14 L-L3 C-M11 (E&H)	Very High 7 L-A1 C-MG (E&H)
Heritage Inundation may damage historic built heritage values.	Low26 L-P5 C-N21 (E&H)	Low26 L-P5 C-N21 (E&H)	Low26 L-P5 C-N21 (E&H)

118. RAAF Base Townsville currently experiences marine and estuarine flooding and climate change is likely to increase these hazards, resulting in the site having a Very High risk rating in 2040. Coastal erosion is not expected to directly affect RAAF Base Townsville during the time periods assessed. In 2100, the extent of coastal erosion is anticipated to reach Cape Pallarenda Road, immediately north of the site.

119. Storm surge levels are likely to reach 3.20 m AHO in 2040 and 4.43 m AHO in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood levels of 3.54 m in 2040, increasing to up to 4.56 m in 2100 in parts of the site.

120. Buildings at RAAF Base Townsville are at Very High risk across all three timeframes.

121. Inundation is likely to damage, degrade and destabilise buildings, including below ground building structures. Specific physical impacts to buildings may include increased corrosion of roof and wall cladding, increased corrosion of reinforcement in concrete piles and grouted masonry block walls, undermining of foundations and water damage to the interior. Inundation impacts are likely to restrict the use of buildings and storage facilities affecting capability including operational activities, training and maintenance.

122. In 2040, 27 buildings are at risk of inundation during a combined 100 year ARI storm surge and extreme rainfall event including the Fire Extinguisher Training Facility (0530), Fuel Tanker Maintenance (0500), Ground Support Equip Building (101), Liquid Dry Breathing Oxygen Store (0418), MEOMS Fuel Farm (0439), Sqn Ops (0473), Tech Maintenance (0470), Ammo Store (231), Fire Station (125) and Offices (145).

123. In 2070, an additional six buildings will be at risk of inundation (5 AVN B Sqn Tech Support Troop (800), ALER Centre (120), ALER Centre Eastern Building (120), BOM Offices (Northern building) (BM1), Missile Prep Area (140) and Unnamed BOM infrastructure (BM3 / BM4)). Six more buildings are at risk in 2100 (1 CLS HQ and Warehouse (248), 5 AVN A/B Sqn RPS Warehouse (291), 5 AVN Patch Paint Facility (272), General and Battery Store (0118), Sikorsky Aircraft office (354) and BOM Offices - BM1).

124. RAAF Base Townsville currently experiences inundation of internal roads, restricting access to key assets in the centre of the site including the fuel farm and air traffic control. This inundation will increase to a High risk in 2040 and a Very High risk in 2100. While short term access is achieved across Runway 07/25, this requires closing the runway and frequent heavy traffic across the runway may lead to increased maintenance requirements. Additionally, more frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the pavement sub-base, increasing maintenance costs. Inundation impacts are not likely to affect site access.

125. Runways and aviation infrastructure at RAAF Base Townsville are at High risk in 2040, increasing to Very High risk in 2070. Inundation of runways and taxiways may restrict their use, reducing capability. The main runway, Runway 01/19, is not at risk of inundation until 2100, however, inundation has historically affected arrestor pits on the main runway. The second runway, Runway 07/25, is likely to experience inundation in all three timeframes, with the entire runway at risk in 2100. More frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the runway sub-base, increasing maintenance costs.

126. Inundation will also affect supporting aviation infrastructure, including refuelling, ordnance storage and loading and maintenance, reducing capability.

127. Utilities at RAAF Base Townsville are at High risk in 2040, increasing to Very High risk in 2070. Historic inundation has caused issues with fire alarm systems, communications and overflow of the ageing sewerage infrastructure. Inundation is likely to damage essential services including electricity and water supply, information technology, communications, fire alarm systems and sewerage.

3.2.3 Risks to Garden Island West / HMAS Stirling, WA

128. Table 16 presents a summary of the risks for Garden Island West/ HMAS Stirling across all three timeframes and for all risk themes examined. A more detailed description of these risks is presented in the sections below.

Table 16 Summary of the inundation and erosion risks for Garden Island West/ HMAS Stirling across all three timeframes and for all risk themes.

Risk Theme	**2040**	**2070**	**2100**
Buildings Inundation, erosion and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	Medium 17 L-A1 C-M16 (capability)	High **12** L-A1 C-M11 (capability)	Very High **2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, erosion and storm surge impacts restricting access to site, use of internal roads and damaging roads, reducing base capability.	High **9** L-L3 C-M6 (capability)	High **9** L-L3 C-M6 (capability)	Very High **2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Damage and loss of access to berthing facilities and wharfs from inundation, erosion and storm surge impacts reducing base capability and functionality. The ability to safely operate berthing facilities and wharfs may be restricted by inundation.	High **9** L-L3 C-M6 (capability)	High **9** L-L3 C-M6 (capability)	Very High **2** L-A1 C-S1 (capability)
Runways and **Aviation** Infrastructure Inundation and erosion may restrict use of and damage the helicopter facility, runway reducing capability.	**Low23** L-U7 C-M16 (capability)	**Low23** L-U7 C-M16 (capability)	Medium **21** L-P5 C-M16 (capability)
Utilities Inundation may disrupt essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.	High 9 L-L3 C-M6 (capability)	**High 9** **L-L3** **C-M6** **(capability)**	Very High **2** L-A1 C-S1 (capability)
Environmental Assets Significant environmental assets are assumed to be in the elevated portions of the site not at risk of inundation.	**Low28** L-U7 C-N21 (E&H)	**Low28** L-U7 C-N21 (E&H)	**Low28** L-U7 C-N21 (E&H)
Contamination Inundation and erosion may result in the mobilisation of contamination into soils, groundwater and marine environment.	**Medium 21** L-P5 **C-M16** (E&H)	**Medium 19** L-L3 **C-M16** (E&H)	High **12** L-A1 C-M11 (capability)
Heritage Inundation and erosion may damage European settlement heritage assets located near the shoreline.	**Low23** L-U7 C-M16 (E&H)	**Low23** L-U7 C-M16 (E&H)	Very High 4 L-L3 C-S1 (E&H)

129. Garden Island West/ HMAS Stirling currently experiences limited marine flooding, and coastal erosion is affecting the stability of the coast across the island. Climate change is likely to increase extreme sea levels at the site to between 1.76 m and 3.47 m AHD in 2040 and between 2.99 m and 4.99 m in 2100, resulting in the site

having a High risk rating in 2040. Due to the site's fast draining sandy soils and there being no reported history of flooding due to extreme rainfall events, estuarine flooding was not assessed in detail at this site.

130. Site access and internal roads at Garden Island West/ HMAS Stirling are at High risk in 2040 increasing to Very High risk in 2100.

131. Inundation of the causeway entry point on the island may affect staff and supplier access from the mainland. Currently, use of the causeway is restricted during storm events due to spray issues, rather than being due to direct inundation. In 2100 the road on Garden Island West which leads to the causeway is at risk of inundation.

132. The shoreline in the vicinity of the causeway has a complex environment that is unstable and subject to dramatic seasonal variations. However, there is currently insufficient data to undertake erosion modelling of the area with an acceptable level of certainty for this study.

133. Inundation of Dampier Road and Karangie Loop is likely to restrict access to, and between, facilities across the site and cause damage to road surfaces and foundations. This may affect the ability of staff to access key facilities, reducing capability. Land access to the northern areas of the site are at greatest risk across all three timeframes, including Area A (Receiving Station), Area B (Explosives Area), Area D (non explosives areas) and Area E (Training for Fire Fighting and Damage Control).

134. Coastal erosion may affect access to the Armaments Wharf in 2040 and 2070. In 2100, coastal erosion is likely to destabilise the sub-base of the road near Area B and Area D, restricting access and increasing maintenance.

135. Wharf, pier and marine infrastructure at Garden Island West/ HMAS Stirling are at High risk in 2040, increasing to Very High risk in 2100. The ability to safely operate the Magnetic Measurement Range (80100) and the Armaments Wharf is likely to be restricted by inundation and storm surge events, reducing capability. Berthing facilities and wharfs could be damaged by the direct impacts of storm surge events and increased exposure to salt water. Specific physical impacts to marine infrastructure include an increased corrosion rate of reinforcement and galvanised steel elements and an increased rate of alkali-aggregate reaction (if the aggregate is susceptible). These impacts are likely to require an increased frequency of maintenance and repair.

136. Inundation may also affect access to the service tunnel on the Wickham Road Pier and the lower deck of the Diamantina Pier (80086). The utility services contained on the lower deck of the pier may also be inundated, causing significant and costly damage and restricting capability. The height of the lower deck is below the 2010 100 year ARI flood level (1.23 m compared to 1.56 m). Although the lower deck has a raised wall and drainage that will provide some protection from inundation from sea levels above 1.23 m, this protection is unlikely to prevent inundation from a sea level height of 1.56 m. Detailed design information is required to confirm this conclusion.

137. Utilities at Garden Island West/ HMAS Stirling are at High risk in 2040, increasing to Very High risk in 2100. Inundation is likely to severely damage services on the lower deck of the Diamantina Pier (80086). Additionally, in ground assets including sewerage, power and communications may be at risk along sections of the eastern shore that are at risk of erosion.

3.2.4 Risks to **RAAF Base** Learmonth, WA

138. Table 17 presents a summary of the risks for RAAF Base Learmonth across all three timeframes and for all risk themes examined.

Table 17 Summary of the inundation risks for RAAF Base Learmonth across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	**Very** High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	**Very** High 2 L-A1 C-S1 (capability/ OH&S)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting access to the site and use of internal roads and damaging roads, reducing base capability.	**Very** High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure There is no pier or marine infrastructure at this site.	**N/A**	**N/A**	**N/A**
Runways and **Aviation** Infrastructure Inundation and storm surge may restrict use of, and damage, runways, taxiways and supporting infrastructure, reducing capability.	**Very** High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	**Very** High 2 L-A1 C-S1 (capability/ OH&S)
Utilities Inundation, storm surge and erosion may disrupt and damage essential services at the site including electricity, communications, water and sewerage utilities, reducing base capability.	**Very** High 4 L-L3 C-S1 (capability/ OH&S)	Very High 4 L-L3 C-S1 (capability/ OH&S)	**Very** High 2 L-A1 C-S1 (capability/ OH&S)
Environmental **Assets** Potential degradation of habitats that support threatened species, through inundation, storm surge and erosion.	**Medium 14** L-P3 **C-M11** (E&H)	**Medium 14** L-P3 **C-M11** (E&H)	**Medium 14** L-P3 C-M11 (E&H)
Contamination Inundation, storm surge and erosion may result in the mobilisation of contamination into soils, groundwater and the marine environment.	**Medium 16** L-P5 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)
Heritage The site does not contain any identified listed or indicative heritage assets.	**N/A**	**N/A**	**NIA**

139. RAAF Base Learmonth currently experiences marine and estuarine flooding and climate change is likely to increase these hazards, resulting in the site having a Very High risk rating in 2040. Coastal erosion is not expected to directly affect RAAF Base Learmonth during the time periods assessed. The Air Weapons Range and the Solar Observatory associated with the site have not been included in this assessment as per Defence's instruction.

140. Storm surge levels are likely to reach 4.50 m AHD in 2040 and 5.73 m AHD in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 1.90 m in 2040, increasing to above 3.00 m in 2100 in parts of the site.

141. The majority of buildings at RAAF Base Learmonth are at Very High Risk in 2040 across all three timeframes. Inundation is likely to damage, degrade and destabilise buildings, including above and below ground building structures. Specific physical impacts to the buildings may include increased corrosion of roof and wall cladding, increased corrosion of reinforcement in concrete slabs, foundations or pads, increased corrosion of cavity ties in brick walls, water damage to interior, requiring increased frequency of maintenance and repair. Inundation impacts are likely to restrict the use of buildings affecting capability, including air operations and exercise deployments.

142. In 2040, 32 buildings are at risk of inundation during a combined 100 year ARI storm surge and extreme rainfall event including the Maritime Technical Operations Building (C0144), Exercise Aviation Refuellers Office (E0189), Accommodation Airman (A0007), Warehouse (A0037), Briefing Room (A0038), Explosives Ordnance Office (80265), Fighter/ Strike Technical Maintenance Building (80270), Fighter/ Strike Operations Building (80271), Gun Munitions Preparations (D0125), QRAF Ready Room (H0202), Airfield Lighting Equipment Room (H0200) and five married quarters.

143. In 2070, an additional two buildings will be at risk of inundation (Communications Centre (A0030) and ACS Workshop and Storage Facility (A0074). Six more buildings are at risk in 2100 (Accommodation Block Officers (A0185 and A0186), Prefab Accommodation (A0289 and A0290), Guard House - South Gate (A0297) and Explosives Storage Area (D0124).

144. Site access and some internal roads at RAAF Base Learmonth are at Very High risk in all three timeframes. Inundation of the Minilya Exmouth Road may affect staff and supplier access to the site from the north (i.e. Exmouth) and from the south. In 2040, coastal erosion is likely to destabilise the Minilya Exmouth Road, causing the loss of the structure, restricting access to the site from Exmouth.

145. Inundation of internal roads is likely to restrict access to, and between, facilities across the site affecting the ability of staff to access key facilities, reducing capability. Assets in the north and east of the site at are greatest risk in 2040 and 2070 including the Maritime Technical Operations Buildings, Aerial Array and the Mobile Air Traffic Control Support Building. In 2100, inundation is likely to restrict access to all buildings at the site during extreme weather events. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations.

146. Runways and aviation infrastructure at RAAF Base Learmonth are at Very High risk in all three timeframes. The runway and taxiways are currently at risk of inundation during a 100 year ARI storm event. Additional aviation assets that are also at risk in each timeframe include the Ordnance Loading Aprons, EO Missile Ammunition Preparation (80260), Explosives Ordnance Bomb Preparation (80262), Quick Reaction Alert Facilities 1 & 2 (H0201 and H0203) and the adjoining traverses. In 2070, the Mobile Air Traffic Control Support Building (F0272) is likely to be at risk of inundation. In 2100, the Helipad (A0209) is likely to be at risk of inundation. More frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the runway sub-base, increasing maintenance costs.

147. Some utilities at RAAF Base Learmonth are at Very High risk in all three timeframes. Specific assets at greatest risk of inundation in 2040 are the Transformer Compound (A0063), Approach Power House (A0080), Emergency Pump Station (A0152) and Substations Number 1 (A0079), 13 (A0142) and 20 (E0259). Inundation may disrupt and damage these essential services at the site as well as communications, water and sewerage utilities, reducing base capability.

148. There are existing soil and groundwater contamination issues being managed at the site including the Waste Drum Site in northern section of site, the Windmill Bore Landfill, the WAPET Landfill, a UST near the residential area, and Hydrocarbon Contamination Bore 9 and Bore 10. Inundation and coastal erosion mobilising contamination at RAAF Base Learmonth is a Medium risk in all three timeframes.

149. Damage of storage arrangements for hazardous substances may result in the mobilisation of contamination into surrounding soils, groundwater and the marine environment. Potential contaminants include metals, total petroleum hydrocarbons (TPH), benzene, toluene, ethyl benzene and xylene (BTEX), organophosphorous pesticides (OPPs), polycyclic aromatic hydrocarbons (PAH), anionic surfactants, polychlorinated biphenyls (PCBs), semi volatile organic compound (SVOCs) other organic compounds, and asbestos.

3.2.5 Risks to Defence Establishment Harold E Holt, WA

150. Table 18 presents a summary of the risks for Defence Establishment Harold E Holt across all three timeframes and for all risk themes examined.

Table 18 Summary of the inundation risks for Defence Establishment Harold E Holt across all three timeframes and for an risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	**Very** High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, erosion and storm surge impacts restricting access to the site, and the use of internal roads and damaging roads, reducing base capability.	**Very** High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation, erosion and storm surge impacts, restricting access and damaging pier infrastructure, reducing base capability.	**Medium** 16 L-P5 C-M11 (capability)	**Medium 16** L-P5 C-M11 (capability)	High 6 L-P5 C-S1 (capability)
Runways and **Aviation** Infrastructure This site does not contain runways or aviation infrastructure.	**N/A**	**N/A**	**N/A**
Utilities Inundation and storm surge may disrupt and damage essential services to the site including electricity, communications, water and sewerage utilities, reducing base capability and functionality.	**Very** High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	**Very** High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets Potential degradation of habitats that support threatened species through inundation, storm surge and erosion.	**Medium 14** L-P3 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)
Contamination Inundation, storm surge and erosion may result in the mobilisation of contamination into **soils,** groundwater and the marine environment.	**Medium 16** L-P5 C-M11 (E&H)	**Medium 14** L-L3 C-M11 (E&H)	**Medium 14** L-L3 C-M11 (E&H)
Heritage Inundation, storm surge and erosion may damage Indigenous and historic built heritage values.	High 11 L-P5 C-M6 (E&H)	High 11 L-P5 C-M6 (E&H)	High 11 L-P5 C-M6 (E&H)

151. The assessment of Defence Establishment Harold E Holt focussed on Area A (VLF transmission site) and Area B (station headquarters and HF transmission site). Site capability is supported by Area C (Naval HF Receiving Station, located approximately 50 km south of Area B). Area C is not included in this assessment as the initial 2011 assessment concluded that it was not at risk from sea level rise and storm surge due to it being located 40 m above AHD.

152. The current 100 year ARI combined extreme rainfall and storm surge event is likely to inundate the majority of Area A, the HF Transmitter site and some buildings in Area B. In 2040, 2070 and 2100, the depth of inundation

is likely to increase across both areas. Coastal erosion impacts are likely to be limited to the dune systems, affecting perimeter roads in both areas.

153. Storm surge levels in Area A are likely to reach 5.20 m AHD in 2040 and 6.43 m AHD in 2100. Storm surge levels in Area Bare likely to reach 4.30 m AHD in 2040 and 5.53 m AHD in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of up to 2.90 m in 2040, increasing to 4.80 min 2100 in parts of Area A. In Area B inundation depths may reach 0.50 min 2040 and up to 1.80 min 2100.

154. The buildings in Defence Establishment Harold E Holt (Area A and Area B) are primarily clad with coated steel or have masonry block work walls. Older buildings appear to have painted steel beam supports, with newer buildings constructed on concrete slabs.

155. Some buildings at the site are at Very High risk across all three timeframes. Inundation is likely to damage, degrade and destabilise buildings, including above and below ground building structures. Specific physical impacts to the buildings may include increased corrosion of roof and wall cladding, increased corrosion of reinforcement in concrete slabs and walls, increased corrosion of reinforcement in masonry block walls. Additionally, increased exposure to moisture can increase alkali-aggregate reaction in susceptible concrete, cause damage to building interiors and lead to an increased frequency of maintenance and repair.

156. Inundation impacts are likely to restrict the use of buildings, affecting capability, including communications. Coastal erosion is likely to affect the buildings associated with the Refuelling Pier (i.e. Pier Utility Shed (A807)).

157. In 2040, 40 buildings are at risk of inundation during a combined 100 year ARI storm surge and extreme rainfall event including the VLF Transmitter/ Helix House (A0015), Base Power Station (A0013), Winch Houses (Tower 1 (A0260), 2N (A0268), 2S (A0269), 3 (A0261), 4N (A0270), 4S (A0271), 5 (A0262), GE (A0272), 6W (A0273), 7 (A0263), SN (A0274), SS (A0275), 9 (A0264), 10N (A0276), 10S (A0277), 11 (0265), 12E (A0278) 12W (A0279), Power Plant Lunch Room (A0815), and Satellite Communications Centre (A0099).

158. In 2070, one additional building will be at risk of inundation (Public Works Store (A0818)). Seven more buildings are at risk in 2100 (BEQ 4 Seabreeze Resort Hotel - Leased (A0116), Warehouse No 2 (A0157), Commissariat (A0161), B.E. Quarters No 2 (A0165), Sewer Treatment Plant Room (A0168), Pest Control Facility (80240) and the DGPS Antennas Building.

159. Site access and internal roads in Defence Establishment Harold E Holt (Area A and Area B) are at Very High risk in all three timeframes. Inundation of Murat Road, leading to Area A and running through Area B, may affect staff and supplier access from Exmouth.

160. Inundation of internal roads during extreme weather events is likely to restrict access to, and between, facilities, particularly assets across Area A (i.e. the Base Power Station (A0013), Refuelling Pier (80001) and the VLF Transmitter/ Helix House (A0015)). Within Area B, access to the HF Transmitter Station buildings is likely to be restricted. Restricted access to these key facilities is likely to reduce capability. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations.

161. In all three timeframes, coastal erosion is likely to affect the road on the north boundary of Area A and the eastern boundary road in the VHF Transmitter Station in Area B, causing destabilisation and loss of the road. Coastal erosion may also restrict access to the Refuelling Pier (80001).

162. Some utilities in Defence Establishment Harold E Holt (Area A and Area B) are at Very High risk in all three timeframes. Inundation and erosion is likely to disrupt and damage essential services including electricity supply, communications and water and sewerage utilities, restricting capability. More frequent and longer duration inundation may destabilise the foundations of communications assets including antennas. Specific assets at greatest risk of inundation in 2040 include Electrical Sub-Stations (A (A0014), C (POL) (A0016), VLF T-5 (A0024), VLF T-6 (A0025), VLF T-7 (A0026), T-8 (A0027)), VLF Transmitter/ Helix House (A0015), Base of Tower 7 (A0026), Base Power Station (A0013), AC units pad (A0160) and Mechanical Plant Building (A0160).

163. Heritage assets in Defence Establishment Harold E Holt (Area A and Area B) are at High risk in all three timeframes. Indigenous heritage sites are known to exist north and south of the Refuelling Pier (DMO Mission) (80001) in Area A and in the south-east section of the HF Transmitter Station in Area B. Numerous buildings in the Area B administration precinct also have heritage value. Inundation, storm surge impacts and erosion may damage or degrade identified heritage sites, increasing management and maintenance requirements.

3.2.6 Risks to Cocos (Keeling) Islands, IOT

164. Table 19 presents a summary of the risks for Cocos (Keeling) Islands across all three timeframes and for all risk themes examined.

Table 19 Summary of the inundation risks for Cocos (Keeling) Islands across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce capability and functionality during and following flood events.	**Medium 14** **L-L3** **C-M11** **(capability)**	**High 12** L-A1 C-M11 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, erosion and storm surge impacts restricting access to facilities across the island and damaging roads, reducing capability.	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation and storm surge impacts restricting access to, and use of, pier and marine infrastructure, reducing capability.	**High 12** L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	**Very** High 7 L-A1 C-M6 (capability
Runways and **Aviation** Infrastructure Inundation and storm surge may restrict the use of, and damage, the runway, taxiways and supporting infrastructure, reducing capability.	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Utilities Inundation and storm surge may disrupt and damage essential services to the site including electricity, communications, water and sewerage utilities, reducing capability.	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets No indicative or listed environmental assets have been identified at the site.	N/A	N/A	NIA
Contamination Inundation, storm surge and erosion may result in the mobilisation of contamination into soils, groundwater and the marine environment.	N/A	Low23 L-U7 C-M16 (E&H)	Medium 19 L-P3 C-M16 (E&H)
Heritage The site does not contain any identified listed or indicative heritage assets.	N/A	N/A	N/A

165. Within the Cocos (Keeling) Islands, Defence has operational interests on West Island, including managing a small number of built assets. Defence capability on West Island is supported by assets and services provided by the Attorney General's Department, the Water Corporation and the local shire council including road maintenance, fuel supply, electricity supply, freshwater water supply, sewerage services, the jetty and the airport. While Defence is not responsible for the maintenance or protection of these assets, the assets have been included in this assessment in recognition of the support they provide to Defence's capability. In addition, the most effective adaptation options for the island are likely to require cross agency engagement.

166. This assessment is focussed only on the West Island. Storm surge levels are likely to reach up to 2.95 m CKIHD in 2040 and 4.18 m CKIHD in 2100[4]. Due to the site's fast draining sandy soils and inundation impacts being dominated by marine flooding, inundation from extreme rainfall events was not assessed in detail at this site.

167. With the exception of the settlement area, the majority of the island is currently at risk of inundation during a 100 year ARI stom, surge event. This hazard area will increase in 2040 and 2070, to cover most non-residential, built assets in 2100 (i.e. the fuel farm, runway, jetty and sewage treatment plant). In 2040, coastal erosion is likely to cut off access from the settlement to the north and the south of the island. Coastal erosion is also likely to damage accommodation and fuel installations in 2040.

168. Some roads across Cocos (Keeling) Islands, including Sydney Highway, are at Very High risk in all three timeframes. During storm surge events, inundation is likely to restrict access to facilities north and south of the settlement area, including the communications area, the jetty and the fuel farm, reducing capability. Increased frequency and duration of inundation, and erosion, are likely to increase the degradation of roads including potholing, rutting and undermining of the pavement sub-base.

169. Pier and marine infrastructure on Cocos (Keeling) Islands are at High risk in 2040, increasing to Very High risk in 2100. The ability to safely operate the Rumah Baru jetty is likely to be restricted by inundation and storm surge, reducing capability. Restricted access to the jetty is likely to affect the supply of goods and materials to the island. Berthing facilities and the jetty could be damaged by the direct impacts of storm surge events and increased exposure to salt water. Specific physical impacts to the marine infrastructure include an increased corrosion rate of reinforcement, increased rate of alkali-aggregate reaction (if aggregate is susceptible), increased corrosion rate of steel and galvanised steel elements and erosion around piles and the boat ramp. These impacts are likely to require an increased frequency of maintenance and repair.

170. The runway and aviation infrastructure on Cocos (Keeling) Islands are at Very High risk in all three timeframes. The runway and taxiways are currently at risk of inundation during 100 year ARI storm surge events, reducing capability. More frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the runway sub-base, increasing maintenance costs.

171. Some utilities on Cocos (Keeling) Islands are at Very High risk in all three timeframes. Specific assets at greatest risk include the Communications Building, fuel farm, the Sewage Treatment Plant and Substations No. 3 and No. 5. In 2100, the Powerhouse and associated transformers and Substations No. 4 and No. 20 are also at risk of inundation during 100 year ARI storm surge events. Inundation is likely to disrupt and damage these essential services. In addition, more frequent and longer duration inundation may damage or destabilise footings for communications assets including antennas. In 2040, coastal erosion is likely to completely erode the land surrounding the fuel farm leading to loss of the structure. This would significantly affect electricity generation and refuelling of aircraft.

172. While not assessed in this study, climate change is likely to affect the viability of the island's freshwater resource (i.e. the freshwater lens). Sea level rise may lead to salt water intrusion into the freshwater lens and may also decrease the area of land available for collecting water to recharge the lens.

• Cocos Keeling Island Height Datum

3.2.7 Risks to Bulimba Barracks, QLO

173. Table 20 presents a summary of the risks for Bulimba Barracks across all three timeframes and for all risk themes examined.

Table 20 Summary of the inundation risks for Bulimba Barracks across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	**High 12** L-A1 C-M11 (capability)	**Very High 7** L-A1 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation restricting access to site, use of internal roads and damaging roads, reducing base capability.	**Very High 7** L-A1 C-M6 (capability)	**Very High 7** L-A1 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Damage and loss of access to berthing facilities and wharfs from inundation and storm surge events reducing base capability and functionality. The ability to safely operate the wharf may be restricted by inundation.	**Medium 16** **L-P5** **C-M11** **(capability)**	**Medium 16** **L-P5** **C-M11** **(capability)**	**Very High 2** L-A1 C- S1 (capability)
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	**NIA**	**NIA**	**N/A**
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.	**High 12** L-A1 C-M11 (capability/ OH&S)	**Very High 7** L-A1 C-M6 (capability/ OH&S)	**Very High 2** L-A1 C-S1 (capability/ OH&S)
Environmental **Assets** The site contains no listed or indicative environmental assets or remnant vegetation.	**NIA**	**NIA**	**NIA**
Contamination Inundation may result in the mobilisation of contamination into surrounding soils, groundwater and the Brisbane River.	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 14** L-L3 C-M11 (E&H)
Heritage Inundation may damage or degrade historic built heritage values.	**Medium 21** L-P5 **C-M16** (E&H)	**Medium 21** L-P5 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)

174. The majority of Bulimba Barracks is currently at risk of inundation during a 100 year ARI event. Climate change is likely to increase this hazard. The site has a Very High risk rating in all three timeframes. The site is located on Brisbane River and is not directly exposed to wave energy and wave induced coastal processes. Therefore, coastal erosion is not expected to occur so potential changes to, and impacts of, coastal erosion were not assessed at this site.

175. Storm surge levels in the Brisbane River are likely to reach 2.40 m AHD in 2040 and 3.63 m AHD in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 0.70 min 2040, increasing to above 1.50 min 2100 in parts of the site.

176. The buildings at the Bulimba Barracks site are mix of metal, brick, masonry or timber clad structures with metal roofs. There are also prefabricated buildings, elevated on steel base frames positioned on concrete pads or brick or concrete block structures.

177. Some buildings at Bulimba Barracks are at High risk in 2040, increasing to Very High in 2070. In 2040, 18 buildings are at risk from inundation from 100 Year ARI storm surge, river flow and extreme rainfall events including workshops (A002, C001 0002 and 0003). Toilets (A003). OFFR's Sleeping Accommodation (8014), Air Compressor Shelter (C018), Admin Bldg (C022), Store Q Store/Hobby Hut (0004), Gatehouse (0006), Conference/Training Room (8013), Workshop/Paint Shop (C002, C015), Stores (C004, C009, 0001 and 0007) and the Pumphouse (8026).

178. In 2070, an additional two buildings are at risk (R & F Sleeping Accommodation (A010) and Admin Bldg (Naval Cadet HQ) (8015)), with all buildings at the site at risk in 2100.

179. Inundation is likely to damage, degrade and destabilise buildings, including below ground building structures. Specific damage may include increased corrosion of wall cladding, increased corrosion of reinforcement in concrete slabs and walls, corrosion of reinforcement in masonry block walls, alkali-aggregate reaction in susceptible concrete, salt crystallisation damage to brick and mortar. Additionally, flooding may cause damage to building interiors, leading to an increased frequency of maintenance and repair. Inundation impacts are likely to restrict the use of buildings, affecting Defence capability including maintenance and logistics activities.

180. Site access and internal roads in Bulimba Barracks are at Very High risk in all three timeframes. Inundation impacts are likely to restrict access to the site from Apollo Road. This inundation may affect the ability of staff and suppliers to access the site.

181. Inundation of internal roads is likely to restrict access to, and between, facilities across the site and cause damage to the surface of roads and vehicle parking areas and their foundations. This may affect the ability of staff to access key facilities, reducing capability. Access to the stores and workshops in the western half of the site and the Naval HQ SQ are at greatest risk in 2040 and 2070. In 2100, access to all assets will be restricted by inundation.

182. Some utilities in Bulimba Barracks are at High risk in 2040, increasing to Very High in 2070 and Very High in 2100. Inundation is likely to disrupt or damage essential services including electricity and water supply, information technology, communications and sewerage.

3.2.8 Risks to Damascus Barracks, QLD

183. Table 21 presents a summary of the risks for Damascus Barracks across all three timeframes and for all risk themes examined.

Table 21 Summary of the inundation risks for Damascus Barracks across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, the use of internal roads and damaging roads, reducing base capability.	Medium 17 L-A1 C-M16 (capability)	Medium 17 L-A1 C-M16 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.	**NIA**	**NIA**	**NIA**
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	**NIA**	**NIA**	**NIA**
Utilities Inundation may disrupt and damage essential services at the site including electricity, communications, water and sewerage utilities, reducing base capability and functionality.	Medium 14 L-L3 C-M11 (capability / OH&S)	Medium 14 L-L3 C-M11 (capability/ OH&S)	**Very** High 2 L-A1 C-S1 (capability/ OH&S)
Environmental **Assets** No indicative or listed environmental assets have been identified at the site.	**NIA**	**NIA**	**NIA**
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and the marine environment.	Medium 16 L-P5 C-M11 (E&H)	Medium 16 L-P5 C-M11 (E&H)	Medium 16 L-P5 C-M11 (E&H)
Heritage No indicative or listed Indigenous or historic built heritage values have been identified at the site.	**NIA**	**NIA**	**NIA**

184. The majority of the unbuilt portion of Damascus Barracks is currently at risk of inundation during a 100 year ARI event storm surge, river flow or extreme rainfall event. This hazard area will increase in 2040 and 2070, covering most built assets in 2100. The site has a High risk rating in 2040 and 2070, increasing to Very High in 2100. The site is not directly exposed to wave energy and wave induced coastal processes, therefore, coastal erosion is not expected to occur. For this reason, potential changes to, and impacts of, coastal erosion were not assessed at this site.

185. Storm surge levels are likely to reach 2.10 m AHD in 2040 and 3.33 m AHD in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 0.40 m in 2040, increasing to above 1.10 m in 2100 in parts of the site.

186. Some buildings at the site are at High risk in 2040, increasing to Very High in 2100.

187. In 2040, 16 buildings are at risk of inundation during 100 Year ARI storm surge, river flow and extreme rainfall events including Stores (A007, A009, A013, A017, 8001, 8002, 8005, 8006, 8025 and 8039), Computer Room (demountable) (8033), Barber Shop (8046), Gatehouse (8054), Pumphouse (on former A007), two new Land 121 buildings (on former A009 and north west of former A007) and the open storage at A035. In 2070, one additional building is at risk (the new Land 121 building west of A014). In 2100, all buildings at the site will be at risk of inundation except the Store (8003) and the Land 121 Hydrant Booster (east of former A007).

188. Inundation is likely to damage, degrade and destabilise buildings, including above and below ground building structures. Specific damage may include increased corrosion of roof and wall cladding, increased corrosion of reinforcement in concrete slabs, increased corrosion of metal fasteners or structural elements and water damage to interiors and equipment housed in buildings. Increased exposure to moisture can increase alkali aggregate reaction in susceptible concrete and salt crystallisation to brick and mortar. These impacts will lead to an increased frequency of maintenance and repair. Inundation impacts are likely to restrict the use of buildings, affecting capability, including logistics activities.

189. Site access to, and internal roads at, Damascus Barracks are at Medium risk in 2040, increasing to Very High risk in 2100. Inundation of Sugarmill Road, north and south of the site entry will affect staff and supplier access.

190. Inundation of internal roads during extreme weather events will restrict access to, and between, facilities, reducing capability. More frequent and longer duration inundation of roads is likely to damage the surface and foundations of roads and paved vehicle parking areas.

191. Some utilities at Damascus Barracks are at Medium risk in 2040, increasing to Very High in 2100 when all utilities at the site are at risk. Inundation is likely to disrupt and damage essential services including electricity supply, communications, water and sewerage utilities, restricting capability.

3.2.9 Risks to RAAF Base Williamtown, NSW

192. Table 22 presents a summary of the risks for RAAF Base Williamtown across all three timeframes and for all risk themes examined.

Table 22 Summary of the inundation risks for RAAF Base Williamtown across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability during and following **flood** events.	**Medium 17** L-A1 C-M16 **(capability)**	**Medium 17** L-A1 C-M16 (capability)	**Medium 17** L-A1 C-M16 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, the use of internal roads and damaging roads, reducing base capability.	**Medium 17** L-A1 C-M16 **(capability)**	**Medium 17** L-A1 C-M16 **(capability)**	High 12 L-A1 C-M11 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.	**N/A**	**N/A**	**N/A**
Runways and **Aviation** Infrastructure Inundation may restrict the use of, and damage, runways, taxiways, OLA's and supporting infrastructure, reducing capability.	Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)
Utilities Inundation may disrupt and damage essential services at the site including electricity, communications, water and sewerage utilities, reducing base capability.	High 12 L-A1 C-M11 (capability/ OH&S)	High 12 L-A1 C-M11 (capability/ OH&S)	High 12 L-A1 C-M11 (capability/ OH&S)
Environmental Assets Inundation may cause degradation of protected habitats and the threatened species they support.	**Medium 19** L-L3 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and the marine environment.	**Medium 14** L-L3 C-M11 (E&H)	**Medium 14** L-L3 C-M11 (E&H)	**Medium 14** L-L3 C-M11 (E&H)
Heritage Inundation may damage or degrade listed Indigenous or historic built heritage values.	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)

193. Some assets and unbuilt sections of RAAF Base Williamtown are currently at risk of inundation during a 100 year ARI event. The extent or depth of inundation from such an event, as a result of climate change, is not likely to increase significantly. The site has a Very High risk rating in all three timeframes. The potential for coastal erosion to impact the RAAF Williamtown site was considered, however, given the existing sand dune system is approximately 40 m high and separates the site from the coast by approximately 2.0 km it is unlikely to be affected by coastal processes. As a result, detailed modelling and historical assessments of coastal erosion were not undertaken for this site.

194. Storm surge levels are likely to reach 1.70 m AHD in 2040 and 2.93 m AHD in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 1.10 m in 2040, increasing to 1.20 min 2100 in parts of the site.

195. Runways and aviation infrastructure at RAAF Base Williamtown are at Very High risk in all three timeframes. Inundation is likely to restrict the ability to use taxiways, Ordnance Loading Areas (OLA's) and hangars. While the runway is not at risk of inundation directly, access via taxiways will be restricted. More frequent and longer duration inundation may lead to increased degradation, rutting, potholing and undermining of the runway sub-base. Resulting damage may reduce base capability during and following flood events and increase maintenance costs.

196. Specific aviation assets at risk across all three timeframes include the Hornet Maintenance Hangar (A011), 2 OCU Technical Service Hangar (A019), ABDR - Hangar (A0025), Technical Services Hangar (A0141), 77 SQN Maintenance Hangar (A0279), Drop Tank, Engine Trolley Store (A0343), Motor Vehicle Storage Hangar (A0357), Ordnance Loading Aprons (21, 22, 23 and 24), Airmovements Cargo Hangar (A0176), Aircraft Shelters (B (A0206), D (A0204), A (A0207), E (A0203), C (A0205) and LIF (A0334)), Maintenance Hangar - Barrier (A0237), AEWC Hangar (A0585) and the FA/18 Washdown Shelter (A0596).

197. Some utilities in RAAF Base Williamtown are at High risk in all three timeframes. Inundation is likely to disrupt and damage essential services including electricity supply, communications, water and sewerage utilities, restricting capability. Specific utilities at risk from 2040 include substations, Ground Telecommunications Equipment SPO (A0274), ATCSR Power Centre (A0403), ACWRF Plant Building (A0646), Trade Waste Treatment Plant (A0480), and the EASTROC Leg Power House (A0537).

198. Site access and internal roads at RAAF Base Williamtown are at Medium risk in 2040 and 2070. In 2100 the risk increases to 2100 as a result of the tidal inundation of Nelson Bay Road. The inundation of Nelson Bay Road and Medowie Road may affect staff and supplier access to the site.

199. Inundation of internal roads during extreme weather events is likely to restrict access to, and between, facilities, or immediate surrounds. Specific internal roads at risk include Townsend Avenue, Knox-Knight Road, McNamara Drive, Parker Road, Paget Road, Kinninmont Road and the road to Duckhole Hill. Restricted access across the site is likely to affect capability. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations, including potholing and rutting of asphalt assets.

3.2.10 Risks to Point Wilson Explosives Area, Vic

200. Table 23 presents a summary of the risks for Point Wilson Explosives Area across all three timeframes and for all risk themes examined.

Table 23 Summary of the inundation risks for Point Wilson Explosives Area across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	Medium 17 L-A1 C-M16 (capability)	Medium 17 L-A1 C-M16 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting use of internal roads and damaging roads, reducing base capability.	High 12 L-A1 C-M11 (capability	High 11 L-P5 C-M6 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Erosion impacts to berthing facilities and wharfs. Resulting damage may reduce capability and increase the frequency of maintenance and repair.	Medium 11 L-U7 C-M6 (capability)	High 11 - 1 L-P5 C-M6 (capability)	Very High 7 L-A1 C- M6 (capability)
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	N/A	N/A	N/A
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.	Medium 13 L-U7 C-M6 (capability)	High 11 L-P5 C-M6 (capability)	**Very** High 2 L-A1 C-S1 (E&H)
Environmental Assets Inundation, storm surge and erosion impacts may degrade habitat for Commonwealth Listed Threatened Species and migratory birds.	**Very** High 7 L-A1 C-M6 (E&H)	Very High 7 L-A1 C-M6 (E&H)	**Very** High 2 L-A1 C-S1 (E&H)
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater, neighbouring properties and the marine environment.	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)
Heritage Inundation may damage Indigenous and historic heritage assets.	High 9 L-P3 C-M6 (E&H)	High 9 L-P3 C-M6 (E&H)	High 9 L-P3 C-M6 (E&H)

201. Based on the risk assessment, a limited number of assets and a third of the unbuilt areas of the Point Wilson are currently at risk of inundation during a 100 year ARI event. Climate change is likely to increase the extent and depth of inundation to cover approximately half of the site and most built assets. The site has a Very High risk rating in 2040 with tidal inundation and inundation from 100 year ARI events likely to degrade environmental assets, restrict the use of, and damage, buildings, roads, pier and marine infrastructure and utilities, reducing capability.

202. Storm surge levels at the site are likely to reach 1.60 m AHO in 2040 and 2.83 m AHO in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 0.50 m in 2040, increasing to above 1.70 m in 2100 in parts of the site.

203. Internal roads in Point Wilson are at High risk of inundation in 2040 and 2070, increasing to Very High risk in 2100. Twentynine Mile Road between the Princess Freeway and the site is not expected to be at risk of inundation in the timeframes assessed. However, access to Point Wilson via Twentynine Mile Road and Point Wilson Road, is dependent on the serviceability of the Princes Freeway between Melbourne and Geelong, which was designed to a 30 year ARI flood immunity. Consequently access to Point Wilson could become restricted due to more frequent flood events than the 100 year ARI event examined.

204. Inundation of internal roads during extreme weather events is likely to restrict access to, and between, facilities. Specific internal roads at risk include the Twentynine Mile Road leading to the jetty, hardstand and access roads to explosive storages Def1 (A0005) and Def3 (A0007) and the perimeter roads. Restricted access across the site is likely to affect capability. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations, including causing potholing and rutting of asphalt surfaces. In addition, erosion may destabilise a small portion of the eastern perimeter road in the northern corner of the site.

205. Pier and marine infrastructure in Point Wilson are at Medium risk of inundation and erosion, increasing to High in 2070 and Very High in 2100. Sea level rise will increase the height of the corrosive splash zone, impacting the jetty and its abutments. The jetty could also be damaged by the direct impacts of storm surge events. Coastal erosion may also occur in the immediate vicinity of the jetty abutments. Specific physical impacts to the marine infrastructure include an increased corrosion rate of reinforcement and galvanised steel elements, an increased rate of alkali-aggregate reaction (if the aggregate is susceptible) and destabilisation of the abutments. These impacts are likely to require an increased frequency of maintenance and repair and reduce site capability.

206. Some utilities in Point Wilson are at Medium risk of inundation in 2040 increasing to Very High risk in 2070 and 2100. Inundation is likely to disrupt and damage essential services including electricity supply, communications, and water and sewerage utilities, restricting capability. Specific utilities at risk in 2040 include those associated with Explosives Storage Def3 (A0007) and, as a result of coastal erosion, the utilities servicing the jetty.

207. Coastal erosion and semi-permanent inundation due to sea level rise is likely to degrade habitat for Commonwealth Listed Threatened Species or Ecological Communities including two Commonwealth listed threatened species that have been recorded at the site (e.g. Orange-bellied Parrot and the Fairy Tern). Habitats for approximately 53 bird species listed under the migratory provisions of the EPBC Act 1999 are also likely to be at risk of inundation. In 2100, more frequent exposure to salt water as a result of tidal inundation is likely to cause irreversible damage to approximately half of the Natural Temperate Grassland of the Victorian Volcanic Plain (NTG WP), a Threatened Ecological Community, located at the site.

208. While the site is not listed on the Commonwealth Heritage List, it does contain Victorian Aboriginal Heritage sites and historical (non-Indigenous) archaeological sites registered on the Victorian Heritage Inventory. Tidal and storm surge inundation is likely to damage or degrade identified heritage sites, increasing management and maintenance requirements. Specific assets at risk include:

- VHI No. H7821-0009 - an indistinct shallow circular ditch approximately 20 cm deep and 2.5 m wide (located approximately 1 km south of the northern boundary and 300 m west of the coast);
- HPW8 - Point Wilson Structural Remains - VHI No. H7821-0026. A former house or hut but with little remains of the structure with the exception of some scattered bricks and a small brick platform (located approximately 160m south of Cargo Storage (U14)); and
- two Indigenous artefact sites (7721-0154 and 7721-0155, located approximately 60 m west of Twentynine Mile Road and between 100 m and 130 m north of Hardstand (Def5)(U5)).

3.2.11 Risks to Swan Island, Vic

209. Table 24 presents a summary of the risks for Swan Island across all three timeframes and for all risk themes examined.

Table 24 Summary of the inundation risks for Swan Island across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation, storm surge and erosion impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage will reduce base capability and functionality during and following storm events.	**Very** High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting site access, use of internal roads and damaging roads, reducing base capability.	**Very** High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation, storm surge and erosion impacts to jetties causing damage and increasing the frequency of maintenance and repair.	**Low 22** L-A1 C-N21 (capability)	**Low22** L-A1 C-N21 (capability)	**Low 22** L-A1 C-N21 (capability)
Runways and **Aviation** Infrastructure Inundation and storm surge impacts restricting use of and damaging the helipad.	**Low 22** L-A1 C-N21 (capability)	**Low22** L-A1 C-N21 (capability)	**Low 22** L-A1 C-N21 (capability)
Utilities Inundation, storm surge and erosion impacts disrupting and damaging essential services to the site including electricity, communications, water and sewerage reducing base capability and functionality.	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)
Environmental Assets Inundation and storm surge impacts may degrade habitat for Commonwealth Listed Threatened Species and listed migratory species.	**Very High 7** L-A1 C-M6 (E&H)	**Very High 7** L-A1 C-M6 (E&H)	**Very High 7** L-A1 C-M6 (E&H)
Contamination Inundation, storm surge and erosion impacts may mobilise contamination into **soils,** groundwater and marine environment.	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)
Heritage Inundation, storm surge and erosion impacts will damage historic heritage assets.	**Medium 16** L-P5 C-M11 (E&H)	High 11 L-P5 C-M6 (E&H)	High 11 L-P5 C-M6 (E&H)

210. Currently, a 100 year ARI storm surge event would inundate the majority of the Swan Island and approximately half of the built assets. The extent and depth of inundation from such an event, as a result of climate change, is likely to increase in each timeframe, affecting almost all built and environmental assets in 2100.

211. The coastal processes acting on the beaches facing Port Phillip Bay are complicated by the management of Queenscliff Harbour Marina to the south of Swan Island. The current management practices are providing protection along the southern coast as sand continues to accumulate (i.e. accrete) northward along the coast. The

findings of the coastal erosion assessment indicate that the coastline exposed to Port Phillip Bay is likely to be at continued risk of coastal erosion with the extent, and number of assets at risk increasing in each timeframe. The majority of assets at risk of coastal erosion are concentrated near the jetties and the historic fort.

212. Storm surge levels are likely to reach up to 3.20 m AHO in 2040 and 4.43 m AHO in 2100. Due to the site's fast draining sandy soils, inundation from extreme rainfall events was not assessed in detail at this site.

213. The buildings on Swan Island have either primarily metal clad, timber, brick, rendered brick or concrete walls. Roofs are generally metal. Buildings located at or near ground level appear to be built on a concrete slab, while elevated buildings are either on stumps (timber or concrete) or steel sub-frames.

214. Some buildings on Swan Island are at Very High risk across all three timeframes. Inundation and erosion are likely to damage, degrade and destabilise buildings. Specific physical impacts to the buildings may include increased corrosion of roof and wall cladding, increased corrosion of reinforcement in concrete slabs and an increase in the corrosion rate of metal fasteners or structural elements. Increased exposure to moisture can increase alkali aggregate reaction in susceptible concrete. Inundation may also increase the rate of degradation of stumps and building foundation elements. Additionally flooding may cause damage to building interiors, leading to an increased frequency of maintenance and repair. Inundation and erosion impacts are likely to restrict the use of buildings, affecting capability.

215. Site access to, and internal roads across, Swan Island are at Very High risk in all three timeframes. Inundation of Bridge Street leading to the causeway, and the causeway itself, may affect staff and supplier access to the site. Inundation of internal roads, including Main Road, during extreme weather events is likely to restrict access to, and between, facilities and their immediate surrounds. Restricted access across the site is likely to affect capability. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations, including causing potholing and rutting of asphalt assets.

216. Land access to Queenscliff is limited to the Bellarine Highway. Access to Swan Island would therefore be restricted if the Bellarine Highway is inundated. The Bellarine Highway is most vulnerable approximately 2.5 km west of the causeway to Swan Island. At this point, the northern side of the road is exposed to Swan Bay, with the land between the road and the coast at only 1 m AHO. Using extreme sea level values for Port Philip Bay (excluding wave setup) the Bellarine Highway is likely to be vulnerable to the existing 100 year ARI extreme sea level. This assumes that the extreme sea level from Port Philip Bay is able to fully propagate into Swan Bay. To more accurately assess the risk of this key access road, specific tidal and storm surge inundation levels would need to be modelled considering the bathymetry, wind fetch and potential introduction of swell waves specific to that section of coast.

217. Some utilities on Swan Island are at Very High risk in all three timeframes. Inundation is likely to disrupt and damage essential services including electricity supply, communications, and water and sewerage utilities, restricting capability. Specific utilities at risk in 2040 include assets 28, 110, 145, 146, 147 and an unspecified utility asset adjacent to asset 1054. In addition, utilities associated with 67 buildings are at risk from inundation in 2040. In 2100, more than 100 buildings and associated utilities are likely to be affected by inundation and erosion.

218. Semi-permanent inundation is likely to degrade habitat for Commonwealth Listed Threatened Orange-bellied Parrot. In addition, more frequent inundation may degrade habitats that support large populations of shorebirds and seabirds. Many of these birds are listed under international migratory bird agreements including the Japan-Australia and China-Australia migratory bird agreements and the Bonn Convention on Migratory Species, including the eastern curlew, ruddy turnstone, red-necked stint, sharp-tailed sandpiper, curlew sandpiper and the grey plover.

219. The site is included on the Register of the National Estate and the Commonwealth Heritage List for its historic heritage values. Inundation and coastal erosion may damage or degrade historic built heritage assets, increasing management and maintenance requirements. In 2040, 31 built heritage assets are at risk of inundation, increasing to 34 assets in 2100. Coastal erosion is likely to destabilise, or cause the loss of 4 heritage assets in 2070, with the number of assets at risk increasing to 10 in 2100.

3.2.12 Risks to Garden Island Defence Precinct, NSW

220. Table 25 presents a summary of the risks for the Garden Island Defence Precinct (GIDP) across all three timeframes and for all risk themes examined.

Table 25 Summary of the inundation risks for Garden Island Defence Precinct across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	**NIA**	**NIA**	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation and storm surge impacts restricting site access, use of internal roads and damaging roads, reducing base capability.	**NIA**	**NIA**	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation and storm surge impacts to berthing facilities and wharfs. Resulting damage may reduce capability and increase frequency of maintenance and repair.	Medium 19 L-L3 C-M16 (capability)	Medium 19 L-L3 C-M16 (capability)	Very High 2 L-A1 C-S1 (capability)
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	**NIA**	**NIA**	**NIA**
Utilities Inundation may disrupt and damage essential services including electricity, communications, water and sewerage, reducing base capability and functionality.	**NIA**	**NIA**	Very High 2 L-A1 C-S1 (capability)
Environmental Assets There are no listed or indicative environmental assets identified at the site.	**NIA**	**NIA**	**NIA**
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and the marine environment.	**NIA**	**NIA**	High 12 L-A1 C-M11 (E&H)
Heritage Inundation may damage historic heritage assets.	**NIA**	**NIA**	High 12 L-A1 C-M11 (E&H)

221. The risk of inundation from high tide events and 100 year ARI storm surge events were assessed at GIDP. Risks associated with extreme rainfall were not assessed at this site due to its small catchment size. Additionally, the risk of coastal erosion was not assessed as the site is not directly exposed to wave induced coastal processes and has significant coastal protection.

222. Storm surge levels are likely to reach up to 1.83 m AHD in 2040 and 3.06 m AHD in 2100. Based on the risk assessment, the site is at Medium risk from a 100 year ARI storm surge event in 2040 and 2070 as a result of the direct impacts of storm surge events on marine infrastructure and increased exposure to salt water. In 2100, almost the entire site is at risk of inundation leading to a Very High risk to buildings, utilities, internal roads and access to the site from Cowper Wharf Road.

223. The site is not currently at risk of tidal inundation. This is not anticipated to change until 2100, when tidal inundation will affect the majority of the site excluding the Cruiser Wharf, Oil Wharf, buildings south and west of Fleet Headquarters and the elevated assets at the north of the site.

224. The buildings in GIDP have primarily metal clad upper walls or brick, rendered brick or masonry sheet walls. Roofs are generally metal though some brick buildings have clay tile roofs. Buildings located at or near ground level appear to be built on a concrete slab, while elevated buildings are either on stumps (timber or concrete) or steel sub-frames.

225. No buildings in GIDP are at risk of inundation in 2040 or 2070. The majority of buildings in GIDP are at Very High risk of inundation in 2100. Inundation is likely to damage, degrade and destabilise buildings. Specific physical impacts to the buildings may include increased corrosion of roof and wall cladding, metal elements, cavity ties in brick walls and reinforcement in grouted masonry block walls, degradation of steel base frames, substructures and concrete footings / pads and increased alkali-aggregate reaction in susceptible concrete. Additionally, flooding may cause damage to building interiors, leading to an increased frequency of maintenance and repair. Inundation impacts are likely to restrict the use of buildings, affecting capability.

226. Site access to, and internal roads in, GIDP are not at risk of inundation in 2040 and 2070. The risk posed by inundation to site access and roads is Very High in 2100. Inundation of Cowper Wharf Road may affect staff and supplier access to the site in 2100.

227. Inundation of all internal roads, except Hill Road, during storm surge events will restrict access to, and between, facilities affecting capability. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations, including causing potholing and rutting of asphalt surfaces.

228. Pier and marine infrastructure in GIDP are at Medium risk in 2040 and 2070, due to the impacts of an increase in the height of the corrosive splash zone. In 2100, the risks from an increase in the corrosive splash zone and from direct inundation to pier and marine infrastructure increase to Very High. A 100 year ARI storm surge event may lead to inundation of the boat ramp near the Fleet Base East entry gate in the south west corner of the site in 2040 and 2070.

229. In 2100, all marine infrastructure is at risk of inundation in a 100 year ARI storm surge event. The Captain Cook Dry Dock, berthing facilities and wharfs could be damaged by the direct impacts of storm surge events and increased exposure to salt water. Specific physical impacts to marine infrastructure include an increased corrosion rate of reinforcement and galvanised steel elements and an increased rate of alkali-aggregate reaction (if the aggregate is susceptible). These impacts are likely to require an increased frequency of maintenance and repair, reducing site capability.

230. No utilities have been identified as at risk of inundation in 2040 and 2070. The majority of utilities in GIDP are at Very High risk of inundation in 2100. Inundation is likely to disrupt and damage essential services including electricity supply, information technology, communications, water and sewerage utilities, restricting capability. Consideration of the impacts of sea level rise on groundwater and the integrity of the underground services tunnels was not included in the scope of this assessment (refer to Section 3.4.9). However, we did attempt to access information on the depth of these assets from site personnel, but information was not forthcoming. Further investigation would be required to assess the vulnerability of the tunnels and the assets they house.

3.2.13 Risks to Proof and Experimental Establishment (P&EE) Port Wakefield, SA

231. Table 26 presents a summary of the risks for P&EE Port Wakefield across all three timeframes and for all risk themes examined.

Table 26 Summary of the inundation risks for Proof & Experimental Establishment Port Wakefield across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation, storm surge and erosion impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting use of internal roads and damaging roads, reducing base capability.	Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.	N/A	N/A	N/A
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	N/A	N/A	NIA
Utilities Inundation and erosion may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.	High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)
Environmental **Assets** Tidal inundation may reduce the tidal flat area available for over water recovery. Inundation, storm surge and erosion impacts may degrade habitat for Commonwealth Listed Threatened Species, migratory birds and national and state significant vegetation species.	**Medium 16** L-P5 C-M11 (capability/ E&H)	**Medium 16** L-P5 C-M11 (capability/ E&H)	High 9 L-L3 C-M6 (capability/ E&H)
Contamination Inundation and erosion may result in the mobilisation of contamination into **soils,** groundwater, and the marine environment.	**Medium 17** L-A1 C-M16 (E&H)	**Medium 17** L-A1 C-M16 (E&H)	**Medium 17** L-A1 C-M16 (E&H)
Heritage Inundation and erosion may damage indicative historic heritage assets.	Low 22 L-A1 C-N21 (E&H)	Low22 L-A1 C-N21 (E&H)	**Medium 17** L-A1 C-M16 (E&H)

232. Based on the risk assessment, many built assets and the majority of the low lying, unbuilt areas of the site are currently at risk of inundation during a 100 year ARI storm surge and extreme rainfall event. Climate change is likely to increase the depth of inundation and marginally increase the extent of inundation in 2100. However, assets located in the elevated northern section of the site are likely to remain unaffected in all three timeframes. The site has a Very High risk rating in 2040.

233. Storm surge levels are likely to reach up to 3.30 m AHD in 2040 and 4.53 m AHD in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 1.50 m in 2040, increasing to above 2.80 m in 2100 in parts of the site.

234. The buildings in P&EE Port Wakefield are constructed from a mix of brick, rendered brick, concrete, stone and fibre cement sheet cladding. Roofs are generally metal though a few structures have concrete or tile roofs.

235. Some buildings are at High risk of inundation in 2040 and 2070, increasing to Very High risk in 2100. Inundation is likely to damage and degrade stumps and foundations of buildings. Specific physical impacts to the buildings may include increased corrosion of wall cladding and fixings and increased corrosion of reinforcement in concrete slabs. Increased exposure to moisture can increase alkali aggregate reaction in susceptible concrete. Additionally, flooding may cause water damage to building interiors, requiring an increased frequency of maintenance and repair. Inundation impacts are likely to restrict the use of buildings, affecting capability.

236. Internal roads in P&EE Port Wakefield are at Very High risk of inundation across all three timeframes. The direct access road to the site (Range Road) is unlikely to be inundated at any of the three timeframes. However, access to Range Road is via the Port Wakefield Highway, which originates from Adelaide. While not investigated in detail, the road may be subject to overtopping in the existing 100 year ARI event, and this becomes more likely to occur as runoff increases as a result of climate change in future years. Inundation of the Port Wakefield Highway is likely to restrict access to the site from Adelaide.

237. There is a mix of sealed and unsealed roads in P&EE Port Wakefield. Inundation of internal roads during extreme weather events is likely to restrict access to, and between, facilities. Specific internal roads at risk include the coastal road and those roads leading to Overland Battery Building (A0080), Victor Battery (502413W) - safety shelter (A0076), Forward Battery (A0028) and the entire Bald Hill road around the newly acquired property. In 2100, coastal erosion may destabilise localised areas of the coastal road. The majority of at risk roads are unsealed. More frequent and longer duration and inundation can lead to increased degradation, rutting and potholing of road surfaces and undermining of their sub-base.

238. Some utilities in P&EE Port Wakefield are at High risk in 2040 and 2070, increasing to Very High in 2100. Inundation is likely to disrupt and damage essential services including electricity supply, communications, and water and sewerage utilities, restricting capability. More frequent inundation may increase the corrosion rate of steel and metal materials in towers, water tanks, plant and drainage assets. Increased exposure to moisture can also increase alkali aggregate reaction in susceptible concrete, increasing requirements for maintenance and repair.

239. Some environmental assets in P&EE Port Wakefield are at Medium risk in 2040 and 2070, increasing to High risk in 2100. The tidal zone represents a critical environmental asset that supports capability. Sea level rise may reduce the horizontal distance between the mean low and high tides, reducing the area for over water recovery.

240. Additional environmental assets include habitat for significant flora and fauna species. Coastal erosion and semi-permanent tidal inundation may degrade habitat for the Samphire (Slender-billed) Thornbill, Beaded Glasswort communities and Subtropical and Temperate Coastal Saltmarsh communities, all of which are listed as vulnerable under the EPBC Act. Habitats for approximately 30 bird species listed under the migratory provisions of the EPBC Act may also be at risk of degradation due to more frequent inundation.

3.2.14 Risks to St Kilda Transmitting Station, SA

241. Table 27 presents a summary of the risks for St Kilda Transmitting Station across all three timeframes and for all risk themes examined.

Table 27 Summary of the inundation risks for St Kilda Transmitting Station across all three timeframes and for all risk themes.

Risk Theme	2040	2070	2100
Buildings Inundation impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.	**Medium 17** L-A1 C-M16 (capability)	**Medium 17** L-A1 C-M16 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, use of internal roads and damaging roads, reducing base capability.	**Medium 17** L-A1 C-M16 (capability)	**Medium 17** L-A1 C-M16 (capability)	High 12 L-A1 C-M11 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.	NIA	NIA	NIA
Runways and **Aviation** Infrastructure There are no runways or aviation infrastructure at this site.	NIA	NIA	NIA
Utilities Inundation may disrupt and damage the Ground Reflection Range and essential services at the site including electricity, communications and water, reducing base capability and functionality.	High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)
Environmental **Assets** There are no listed or indicative environmental assets identified at the site.	NIA	NIA	NIA
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and neighbouring properties.	Low26 L-P5 C-N21 (E&H)	Low26 L-P5 C-N21 (E&H)	Low 26 L-P5 C-N21 (E&H)
Heritage No indicative or listed Indigenous or historic built heritage values have been identified at the site.	NIA	NIA	NIA

242. Based on the risk assessment, almost all assets and two thirds of the unbuilt areas of the St Kilda Transmitting Station are currently at risk of inundation during a 100 year ARI storm surge and extreme rainfall event. Climate change is likely to increase the extent and depth of inundation to cover approximately three quarters of the site and almost all built assets. The site has a High risk rating in 2040 and 2070, increasing to Very High in 2100.

243. As St Kilda Transmitting Station is not directly exposed to coastal processes, coastal erosion risks have not been assessed at this site.

244. Storm surge levels at the site are likely to reach 2.74 m AHO in 2040 and 3.97 m AHO in 2100. When combined with increases in runoff from extreme rainfall events, the site is likely to experience flood depths of more than 0.05 min 2040, increasing to above 1.70 min 2100 in parts of the site.

245. The buildings in St Kilda Transmitting Station are constructed from a mix of metal cladding, brick, or concrete cement sheets, with metal roofs. Buildings located at or near ground level are built on a concrete slab.

There are a number of temporary 'building' structures which are predominantly metal structures (e.g. caravans). Some buildings are at Medium risk of inundation in 2040 and 2070, increasing to Very High risk in 2100.

246. Inundation is likely to damage, degrade and destabilise buildings. Specific physical impacts to the buildings may include increased corrosion of wall cladding, increased corrosion of reinforcement in concrete slabs an increase in the corrosion rate of metal fasteners or structural elements and water damage to equipment housed in the buildings. Increased exposure to moisture can increase alkali aggregate reaction in susceptible concrete. Additionally, flooding may cause damage to building interiors, leading to an increased frequency of maintenance and repair. Inundation impacts are likely to restrict the use of buildings, affecting capability.

247. Internal roads in St Kilda Transmitting Station are at Medium risk of inundation in 2040 and 2070. This risk rating increases to High in 2100. Inundation of the main access road (St Kilda Road) during a 100 year ARI storm surge and extreme rainfall event may reduce staff access to the site, affecting capability.

248. The internal roads at the site are unsealed tracks. All internal roads are currently at risk of inundation during extreme weather events restricting access to, and between, facilities. Restricted access across the site is likely to affect capability and the ability of security to patrol the site. In recognition of the task based nature of current site uses (i.e. it is not a permanently occupied site), in rating the risks to site access and internal roads it has been assumed that activities can be delayed or undertaken elsewhere during an inundation event.

249. More frequent and longer duration inundation of roads is likely to damage road surfaces and foundations, including causing potholing and rutting, leading to an increased frequency of maintenance and repair.

250. Utilities in St Kilda Transmitting Station are at High risk in 2040 and 2070 and Very High risk in 2100. In addition to the Ground Reflection Rage, utilities assets at the site include essential services (e.g. power and water supply) and wooden and metal antenna arrays of varying age and condition. Inundation is likely to disrupt and damage essential services including electricity supply, communications, and water utilities, restricting capability. Specific impacts to antennas include increased corrosion of steel elements, reinforcement in concrete plinths and foundations, and the undermining of foundations leading to the destabilisation of assets. Inundation may also increase insect, fungal and bacterial damage to timber and increase the dimensional changes and stresses to timber. These impacts will lead to an increased frequency of maintenance and repair.

3.3 General risk observations

251. This section highlights other potential issues that were identified but not investigated in detail as they were beyond the scope of this assessment. While the inclusion of these issues would provide a more complete assessment of the climate risks to each site, their inclusion in the scope of this study would significantly increase the complexity of the study and therefore the time and cost required to complete it. Other potential issues include:

- *Condition and vulnerability of key utilities supplied to* sites, *for example local power exchanges, communications networks, water supply and treatment.* Defence may be able to protect utility assets on each site from inundation, however, if the supply to the site is inundated Defence operations may still be affected. Engagement with supply authorities would be required to undertake specific risk assessments of infrastructure critical to supporting Defence's operations;
- *Changes in the seasonal occurrence of* extreme *rainfall* events *(i.e. cyclones).* RAAF Base Townsville supports training operations that are scheduled for the drier months of the year. Changes to the seasonal occurrence of extreme rainfall events may restrict the site's ability to be used for training;
- *Impacts of extreme wind and potential changes to the occurrence of extreme wind events.* Past extreme wind events have damaged assets at the assessed sites (e.g. at RAAF Base Townsville extreme wind from Cyclone Yasi collapsed a storage tank and damaged roof sheeting on a hangar). Climate change may alter the frequency and intensity of extreme wind events, although current projections for this climatic variable are uncertain;
- *Impacts of other climate variables on capability.* Climate change induced changes to the frequency and intensity of extreme wind events, the predominant wind direction, average temperatures, ocean acidity, solar radiation or average rainfall may also affect the sites;
- *Existence of significant environmental values in inundation hazard zones and the reputational risks of failing to protect them.* While it is unlikely that climate change induced impacts to these environmental assets would trigger non-compliance with the EPBC Act, climate change related damage to significant environmental values could present reputational risks to Defence. Further investigation would be required to identify if significant communities exist in hazard zones, the effects of more frequent and longer duration inundation and the reputational risks of failing to protect them;
- *Changes to the risk profile of bird strikes at RAAF Base Townsville.* Due to the frequent presence of standing water, and the adjacent wetlands, aircraft bird strikes are a current issue at the site. Increased areas of standing water as a result of more frequent, or severe, inundation may increase the incidence of bird strikes, affecting fauna and site capability;
- *Impacts of* sea /eve/ *rise on ground water levels and soil subsidence.* Increased frequency of inundation and increased sea levels may worsen existing subsidence issues at some site (e.g. HMAS Cairns) or create new issues affecting the stability of built assets (e.g. road and building foundations), underground services and structures (e.g. cables, conduits and pits) and degrade vegetation, affecting capability. Increased sea levels may also reduce the viability of the freshwater lens on Cocos (Keeling) Islands - West Island;
- *Potential risks of damage to wharf structures or* services *from waterborne debris or loose ships entering* sites. This risk may result from a combination of extreme wind or increasing water levels leading to ships breaking their moorings or sending windblown debris into waterways;
- *Potential for contamination to* enter Defence sites. This risk may result from flood waters mobilising and transporting contamination from neighbouring sites onto Defence land;
- *Potential change to flood* extents *resulting from coastal erosion caused by cyclonic events.* The dune systems adjacent to RAAF Base Learmonth and Defence Establishment Harold E Holt Area A and Area B provide some protection from coastal inundation by limiting the volume of water that can inundate the site (as storm surge will be constrained to the existing waterway breaks in the dune system). Should the dune system be significantly damaged, the speed and extent of inundation from tidal waters and storm surge events is likely to increase;
- *The ability for* Defence *to respond to community aid relating to natural disasters.* Defence provides significant support in the provision of community aid during natural disasters. Inundation and erosion risks may restrict the ability of Defence to provide this support;

- *Potential tong lead time to recover from damage caused by extreme weather events at* Cocos *(Keeling) Islands.* Due to the remote nature of the *Cocos* (Keeling) Islands, there may be long lead times for the delivery of required materials or resources to recover from damage to key assets as a result of extreme weather events;
- *Duration of inundation at specific locations on a site, or within built structures.* The length of time that an asset, or its foundations, are inundated will affect the amount of damage done to its structure and the length of time required to repair or remediate it. More detailed investigation of local drainage networks and asset specific drainage is required to determine the duration of inundation; and
- *Reduced clearance for navigation below the Swan Island causeway bridge.* Sea level rise will affect the clearance beneath the causeway bridge impacting on the size of, or timeframes available for, vessels to navigate to and from Swan Bay.

4.0 Adaptation Options and Recommendations

252. This section presents the recommended adaptation responses for the assessed sites. Changes to Australian design standards including the Rainfall and Run-off Handbook[5] are an example of current, ongoing adaptation guidance to support organisations to adapt their built assets to a changing climate. However, as there are long lead times to the finalisation of such standards (5-10 years). Defence may need to adjust its own design standards to ensure that climate risks are duly considered for new projects or for the existing asset portfolio. This could be implemented in part through a change to the Defence Estate Quality Management System, for example, prompting the consideration of greater allowances for marine and estuarine flooding, improved asset drainage, improved storage of hazardous and critical materials, and material selection.

253. For all adaptation options, Defence needs to consider the need for engaging with affected stakeholders (e.g. local governments or adjacent property holders) to discuss potential adaptation options, their effectiveness and opportunities for potential cost sharing arrangements. In addition, works planned at each site, but not commenced, should consider the findings of this study as a basis for opportunities to incorporate adaptation options.

254. Adaptation options are grouped into the following themes:

- **Investigations** - Specialist assessments and explorations of site, or asset, specific issues and solutions to address the identified risks (i.e. inundation or erosion);
- **Policy** and procurement - Changes to existing site policy, standards and guidelines including procurement specifications;
- **Behavioural** - Adjustments to existing processes, operational systems and procedures including emergency management procedures; and
- **Physical** / engineered - Significant physical changes or engineered solutions to existing assets and functions.

255. Having a range of adaptation solutions is not enough to enable decision making, even when supported by a robust risk assessment process - they must also be prioritised for implementation. A Multi-Criteria Analysis (MCA) of adaptation options for the site was undertaken by the AECOM project team to provide this. The criteria, score and definitions used are presented in Table 28.

256. For each adaptation option identified, the scores for each criterion were added to reach an overall priority rating score. The 'urgency' criterion was weighted (x2) to add emphasis to the actions designed to address current risks to the site. Consistent with the risk rating process, the lower the prioritisation score, the higher the priority for implementation. The overall priority rating score was used as a first filter to rank and assess the potential timing for implementation of adaptation options. Defence should consider existing programs and budgetary commitments before finalising the timing for implementation of each adaptation option.

257. The adaptation options with a priority rating score of 10 or less (60%+ of the potential ratings score) should be considered for implementation in the short term (i.e. within the next 10 years). These options have been prioritised under the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same. All adaptation options, including those with a priority rating score of greater than 10, should be reviewed every five years and re-assessed for potential implementation based on any change in the rate of sea level rise or changes to site assets or activities. Section 4.1 includes adaptation options that could be delivered centrally by Defence to assist adaptation at all sites. In addition, Section 4.2 to Section 4.15 includes a summary of the prioritised adaptation options for each site. The individual site reports include a full listing of the adaptation options identified for each site. The findings in this section should be read in conjunction with the detailed site reports.

[5] The guidance provided by the Rainfall and Run-off Handbook underpins the design requirements for all Australian drainage and the design of flood protection of buildings, facilities and other infrastructure.

Table 28 Adaptation prioritisation criteria and weighting.

	High (1)	Medium (2)	Low (3)
Effectiveness to Reduce Risk	High potential to reduce risk to multiple Defence operations and / or asset types and / or to reduce multiple risks	Moderate potential to reduce risk to a Defence operation and / or asset	Potential to reduce risk is low or uncertain
Cost	Cost is Minor ($0-$500K)	Cost is Moderate ($500K-$15M)	Cost is Major (>$15M)
Significance of Action	Several adaptation actions rely on this being done first or they will no longer be required if this action is implemented or is the primary treatment of risk to a critical asset	Another adaptation action relies on this being done first or implementation means another adaptation action may no longer be required	Does not influence or is not necessary to support other adaptation actions
Community Acceptance	Potentially no conflict with communities for implementation and / or will provide broader social and environmental benefits	Possible conflict with communities for implementation and / or may provide broader social and environmental benefits	Likely conflict with communities for implementation and / or may generate negative social and environmental impacts
Urgency (x2 weighting)	Should be completed within the next 10years to avoid current risk	Should be completed before 2040 to avoid risk	Should be completed before 2070 to avoid risk

4.1 Adaptation options for all sites

258. Some adaptation options can be more efficiently implemented centrally by Defence, rather than at a site or asset specific level. Table 29 lists adaptation options that would benefit all sites.

Table 29 Priority adaptation options to be implemented centrally.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, runways, aviation infrastructure, pier and marine infrastructure, roads and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, runways and aviation infrastructure, pier and marine infrastructure, utilities and contamination.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring procedures to account for increased damage and corrosion. The regularity of condition assessments may need to be increased for vulnerable assets such as buildings, runways and aviation infrastructure, pier and marine infrastructure and roads. The maintenance treatments may need to be more proactive to prevent an acceleration of asset degradation. Options include increasing the strength of protective coatings of assets exposed to higher groundwater and salt water concentrations.	Buildings, site access and internal roads, runways and aviation infrastructure, pier and marine infrastructure, utilities, contamination and heritage.	$50K-$100K to adjust central maintenance specifications. There is likely to be an ongoing increase to maintenance costs compared to a baseline of no climate change, however it cannot be quantified.

4.2 Adaptation options for HMAS Cairns, Qld

259. Current site constraints, including existing inundation issues, will potentially limit the long term value of adaptation investment at this site. Identified adaptation options are therefore focussed on minimising the consequences of inundation events over the next 60 years to allow relocation of base capabilities to other sites beyond 2070. The priority adaptation options for implementation at HMAS Cairns are included in Table 30.

Table 30 Prioritised adaptation options tor HMAS Cairns.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Relocate activities and functions Accept flooding in low lying buildings and move activity and function to another part of the site or region. Buildings suggested for activity function relocation are those affected in 2040, such as the Kenny Street Facility.	Buildings.	$100K-200K to develop master plan to relocate activity functions. Substantial expenditure required to design and construct new buildings / facilities and perform remediation of any contamination. Costs cannot be determined without identifying the assets to be relocated and the remediation requirements.
South west drainage upgrade Increase the drainage capacity, pumping and outfall levels in the south west drainage system.	Buildings, and utilities.	$1.1 M to construct new drainage channel, install pump station and revegetate.
Building protection **works** Undertake building protection works, including improved asset drainage, tanking protection works and raising height of building floor levels. This redevelopment of the built assets should be staged to respond to the rate of sea level rise.	Buildings.	$SOK- $100K to plan and design height changes, depending on number of assets. The cost of implementing physical changes would be dependent on the specific structures, their use, and height change required.
Raise height of access roads Engage with relevant authorities to raise key access roads across Cairns.	Site access and internal roads.	Negligible cost to undertake engagement.

4.3 Adaptation options for RAAF Base Townsville, Qld

260. Identified adaptation options are focussed on keeping the water out of the site to protect assets. The priority adaptation options for implementation at RAAF Base Townsville are included in Table 31.

Table 31 Prioritised adaptation options for RAAF Base Townsville.

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Flood protection - north, west and south of runway Increase the flood protection and drainage capacity around the western, northern and southern fringe of the site using the perimeter roads where practical as levees and install supporting flood gates and pumps. This will assist in limiting the volume of water entering the site from the west and south of the site. The design should consider potential destabilisation issues posed by increases in groundwater levels. The levee should run from the northern end of the runway along the western and south-western perimeter roads and along the southern perimeter road (parallel with Ingham Road) to Area F Office and GE Workshop (0356).	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets, contamination and heritage.	$13.5M for design and construction of 9.5 km of levees and installation of pumping system.
Relocate activities and functions Accept flooding in low lying areas and move activity and function to another part of site or region. Buildings and facilities suggested for activity or function relocation are those impacted by the existing extreme flood level. Remediation of any contamination at vacated sites should accompany relocation of activities and functions especially where mobilisation of contamination into surrounding soils, groundwater and marine environment may occur.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities and contamination.	$100K-$200K to develop relocation masterplan. Specific relocation costs will be dependent on asset function and remediation requirements.
Storage of hazardous materials guidance Review guidance for the storage of critical and / or hazardous materials within structures located in defined inundation boundaries. Determine alternative locations for storage of hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.
Runway flood protection - the eastern taxiway Increase the flood protection and drainage capacity along the eastern perimeter of the site on the eastern side of the taxiway.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets, contamination.	$1.5M to construct 2.1 km drainage channel.
Review emergency management plans Periodically review emergency management plans to respond to an increased scale of inundation impacts and where required, increase the response capacity.	Buildings, site access and internal roads, runways and aviation infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of these plans.

4.4 Adaptation options for Garden Island West / HMAS Stirling, WA

261. Identified adaptation options are focussed on protecting access to the site, protecting use of marine infrastructure and minimising the impacts of erosion. In the longer term, relocation of a portion of the Dampier Road and some buildings in the accommodation area may be required. The priority adaptation options for implementation at Garden Island West / HMAS Stirling are included in Table 32.

Table 32 Prioritised adaptation options tor Garden Island West/ HMAS Stirling.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Road flood protection Increase the flood protection and drainage capacity: - Along the middle section of Dampier Road; - Along the northern section of Dampier Road between Area B and Area D; and - Along the north-eastern section of Karangie Loop.	Site access and internal roads.	$13.7M to increase height of 4.7 km of roads assuming 15 m width and along the same alignment.
Armaments Wharf erosion protection Establish natural erosion protection interventions to protect Grenadier Road and Dampier Ave access to the Armaments Wharf and its abutment. Specifically, enhance the existing dune stabilisation with vegetation, monitor the erosion extent and use sand renourishment of the beach to reduce any permanent erosion. The existing limestone rock wall provides some initial protection but is insufficient to prevent future erosion caused by sea level rise.	Pier and marine infrastructure, site access and internal roads.	$250K for stabilisation. $50K per annum in ongoing monitoring and re nourishment.
Relocate activities and functions Accept flooding in low lying areas and move activity and function to another part of site or region. Buildings suggested for activity function relocation are those impacted by the 2040 extreme flood level. Remediation of any contamination at vacated sites should accompany relocation of activities and functions especially where mobilisation of contamination into surrounding soils, groundwater and marine environment may occur.	Buildings, site access and internal roads, pier and marine infrastructure, runways and aviation infrastructure, utilities and contamination.	$1 00K-$200K to develop master plan to relocate activity functions. Substantial expenditure required to design and construct new buildings / facilities and perform remediation of any contamination. Costs cannot be determined without identifying the assets to be relocated and the remediation requirements.

4.5 Adaptation options for RAAF Base Learmonth, WA

262. Identified adaptation options are focussed on protecting specific assets in the short term while planning longer term measures to keep water out of the site. The priority adaptation options for implementation at RAAF Base Learmonth are included in Table 33.

Table 33 Prioritised adaptation options for RAAF Base Learmonth.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Asset specific flood protection Increase the flood protection and drainage capacity of the following assets to ensure reliability during inundation events: - Fuel Farm (EO152); - Fuel Approach Power House (A00S0); and - Airfield Lighting Equipment Room 36 (H0200).	Buildings, runways and aviation infrastructure, utilities and contamination.	$1 00K-$250K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Utilities - network reliability Isolation of electrical and communications systems to ensure network performance and self-sufficiency when elements of the system are affected by inundation.	Utilities.	$1 00K-$250K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Relocate activities and functions Accept flooding in low lying areas and move activity and function to another part of site or region. Buildings and facilities suggested for activity or function relocation are those impacted by the 2040 extreme flood level. Remediation of any contamination at vacated sites should accompany relocation of activities and functions especially where mobilisation of contamination into surrounding soils, groundwater and marine environment may occur.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities and contamination.	$1 00K-$200K to develop relocation masterplan. Specific relocation costs will be dependent on asset function and remediation requirements.
Review emergency management plans Review existing emergency management plans to incorporate increased inundation and erosion impacts over time and update the need for increased response capacity when required.	Buildings, site access and internal roads, and runways and aviation infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of these plans.
Site flood protection - levee Increase the height of the levee protection on the eastern side of the site. Install pumps and improve storage capacity onsite. The levee should be designed to reduce flood exposure up to the 2100 100 year ARI inundation level. Design of the levee would need to consider the potential change in flood levels that may result if the dune protection is lost.	Buildings, site access and internal roads, runways and aviation infrastructure and utilities.	$15.5M to adjust 12 km levee and $GM to excavate additional storage capacity (50,000m^3) and install pumps.

4.6 Adaptation options for Defence Establishment Harold E Holt, WA

263. Identified adaptation options are focussed on limiting the amount of water entering the site and ensuring capability can be maintained during inundation events. The priority adaptation options for implementation at Defence Establishment Harold E Holt are included in Table 34. In recognition of the limitations of the terrain data used for the assessment of this site (refer to Section 5.2), prior to implementing adaptation options, it is recommended that LiDAR data covering the entire floodplain be 'flown' and the findings of this assessment be validated using a single, common terrain data set and aerial photography covering Area A and Area B.

Table 34 Prioritised adaptation options for Defence Establishment Harold E Holt.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Utilities - resilience of supply Determine the vulnerability of key utilities supplied to, and between the sites (i.e. fuel supply, power generation, communications, water supply and treatment).	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.
Asset specific flood protection **works** Undertake flood protection works for specific assets in Area A: - Base Power Station (A0013); and - VLF Transmitter/ Helix House (A0015). Building protection works may include improved asset drainage, tanking protection works, raising the height of building floor levels or altering the use of the facilities to locate sensitive aspects to high floors.	Buildings and utilities.	$50K-$250K to plan and design measures. The cost of implementing physical changes would be dependent on the specific measures required.
Utilities - network reliability Isolate electrical and communications systems to ensure network performance when elements of the system are affected by inundation.	Utilities.	$1 00K-$250K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Review emergency management plans Review existing emergency management plans to incorporate increased inundation and erosion impacts over time and update the need for increased response capacity when required. This should include ensuring temporary accommodation and rations are available for personnel at the HF Transmitter Station at Area B.	Buildings, site access and internal roads and pier and marine infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of these plans.

4.7 Adaptation options for Cocos (Keeling) Islands, IOT

264. Identified adaptation options are focussed on protecting the communications facility, ensuring sufficient fuel supply is available to run back up power and that access is maintained. The priority adaptation options for implementation at Cocos (Keeling) Islands are included in Table 35.

265. While not Defence assets. the roads, runway, jetty and water and power supply are critical to supporting Defence's capability on the island. Defence should consider engaging with affected stakeholders (e.g. local governments, Attorney General's Department or the Water Corporation) to ensure effective adaptation of the required utilities and services.

Table 35 Prioritised adaptation options tor Cocos (Keeling) Islands.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Utilities - network reliability Expand backup fuel capacity and isolate electrical and communications systems to ensure network performance when elements of the system are impacted by inundation.	Utilities.	$30K-$50K to undertake detailed assessment and determine vulnerability, required works and associated costs.
Redevelopments of the site Ensure future redevelopments of the site to accommodate changes in capability (e.g. increased operational presence) include consideration of future inundation and erosion risks. Restrict re-development in low lying areas and preserve areas that are needed for protective works.	Buildings, site access and internal roads, pier and marine infrastructure, runways and aviation infrastructure and utilities.	Negligible additional cost to include in re-development planning.
Review emergency management plans Review existing emergency management plans to incorporate increased inundation and erosion impacts over time and update the need for increased response capacity when required. This may include ensuring temporary accommodation and rations are available at the communications facility.	Buildings, site access and internal roads and utilities.	$15K-$50K to review inundation risks as part of regular reviews of these plans.

4.8 Adaptation options for Bulimba Barracks, Qld

266. Identified adaptation options are focussed on enhancing drainage of water from the site and minimising the impacts of inundation when it occurs. In the longer term the site will require greater protection from sea level rise and tidal inundation from the Brisbane River. The priority adaptation options for implementation at Bulimba Barracks are included in Table 36.

Table 36 Prioritised adaptation options for Bulimba Barracks.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Site flood protection - improve local drainage Improve local drainage in the western portion of the site. This may include lowering an internal road and installing culverts to enhance the drainage of local catchment flood water through the west portion of the site into the Brisbane River.	Buildings, utilities.	$875K to improve 350 m of drainage with supporting culverts.
Storage of critical and/ or hazardous materials guidance Review guidance for the storage of critical and / or hazardous materials within structures located within the defined inundation boundaries. Determine alternative locations for storage of critical and / or hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.
Utilities - network reliability Isolate electrical and communications systems to ensure network performance and self-sufficiency when elements of the system are affected by inundation.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within site boundary only.
Utilities - resilience of external supply Determine the vulnerability of key utilities supplied to the site (i.e. local power exchanges, communications networks, water supply and treatment). Develop an approach to manage the risks associated with identified vulnerable utilities. This may include adjusting Defence emergency response plans, enhancing back-up systems and engaging with external service providers to understand their emergency responses.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.

4.9 Adaptation options for Damascus Barracks, Qld

267. Identified adaptation options are focussed on reducing the amount of water entering the site, enhancing drainage of water from the site and minimising the impacts of inundation when it occurs. Due to the site's low elevation, maintaining operational capability during 100 year ARI inundation events, in 2100, will require relocating the capability, or building a levee to protect the entire site. The priority adaptation options for implementation at Damascus Barracks are included in Table 37.

Table 37 Prioritised adaptation options for Damascus Barracks.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Site flood protection - upgrade local drainage Improve local drainage infrastructure to ensure effective dispersion of water from the site. Due to the flat terrain at the site, the installation of sumps and pumps at two low points on site is recommended.	Buildings, site access and internal roads, utilities and contamination.	$1.GM to upgrade approximately 1.5 km of drains and install supporting pumps.
Storage of critical and/ or hazardous materials guidance Review guidance for storage of critical and / or hazardous materials within structures located within the defined inundation boundaries. Determine alternative locations for storage of critical and / or hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.
Site flood protection - drainage upgrades (south west) Deepen and line the drainage channel in the south west corner of the site to contain flow from upstream catchment in the perimeter drainage channel and prevent spill over of water into Damascus Barracks. Install a one way flapped culvert in the same location to maintain site drainage and prevent backflow of water into the site.	Buildings, site access and internal roads, utilities and contamination.	$170K to undertake design and construction works.
Site flood protection - drainage upgrades (north **east)** Upgrade the culvert in the north east corner of the site to a larger diameter and install flaps to stop tidal back flow. This will assist with more frequent, lower impact flood events.	Buildings, site access and internal roads, utilities and contamination.	$325K to undertake design and construction work. The cost of these works may be funded by the local drainage authority.

4.10 Adaptation options for RAAF Base Williamtown, NSW

268. Identified adaptation options are focussed on enhancing the local drainage network at the site and ensuring future asset design and maintenance consider the risk of more frequent inundation. The priority adaptation options for implementation at RAAF Base Williamtown are included in Table 38.

Table 38 Prioritised adaptation options for RAAF Base Williamtown.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Surface water management strategy Prepare a site wide drainage strategy that allows for overland flow paths and flow conveyance to manage local flooding. This strategy will identify the required upgrades to local drainage to reduce the risk.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, contamination and heritage.	$200K to undertake comprehensive assessment of onsite surface drainage. Depending on the outcomes of the study, capital works costing between $4.5M and $7.5M may be recommended.
Utilities - network reliability Ensure the resilience and self sufficiency of the utilities at the site to maintain reliability during inundation events. For example, during inundation events supply of electricity is maintained to assets that require an uninterrupted supply.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within site boundary only.
Utilities - resilience of external supply Determine the vulnerability of key utilities supplied to the site (i.e. local power exchanges, communications networks, fuel supply, water supply and treatment).	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.
Storage of critical and/ or hazardous materials guidance Review guidance for the storage of critical and / or hazardous materials within structures located within the defined inundation boundaries. Determine alternative locations for storage of critical and / or hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.

4.11 Adaptation options for Point Wilson Explosives Area, Vic

269. Identified adaptation options for Point Wilson focus on protecting the built assets, while maintaining access to the jetty in the longer term. The planned redevelopment of the site provides an opportunity to cost effectively adapt many of the assets likely to be affected by inundation and ensure the site is climate resilient. The priority adaptation options for implementation at Point Wilson are included in Table 39.

Table 39 Prioritised adaptation options tor Point Wilson.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Redevelopments of the site Ensure future redevelopments of the site to accommodate changes in capability include consideration of future inundation and erosion risks.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, contamination and heritaoe.	Negligible additional cost to include in re-development planning.
Site flood protection - levee Construct a flood levee (approximately 500 m in length) around the centralised structures on the site to prevent inundation (e.g. explosives storage and loading areas). The levee should be designed to reduce flood risk up to the 2070 inundation level.	Buildings, site access and internal roads, utilities.	$200K to undertake design and construction works to build to protect from 2070 inundation levels. $500K to build to protect from 2100 inundation levels.

4.12 Adaptation options for Swan Island, Vic

270. The priority adaptation options for Swan Island focus on protecting built assets in two main areas and assets and ensuring continued active engagement in the sand management practices for the Queenscliff Harbour Marina. The priority adaptation options for implementation at Swan Island are included in Table 40. In the longer term (2100), consideration will need to be given to relocating capability from the site or undertaking significant works to elevate or protect all assets at the site.

Table 40 Prioritised adaptation options tor swan Island.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Maintain engagement with sand management practices Continue to engage with Parks Victoria to ensure that Defence is actively involved in the sand management practices for the Queenscliff Harbour Marina (e.g. sand bypass and dredging). Defence should seek to have this maintained (or enhanced) or have early warning of changes to enable investigation of potential impacts to coastal erosion risks in Swan Island.	Buildings, site access and internal roads, utilities, contamination and heritage.	Negligible cost to undertake consultation.
Site flood protection - south levee Construct a flood levee around the southern cluster of structures to prevent inundation (approximately 2.2 km in length). The levee should be designed to reduce flood risk up to the 2070 inundation level. The levee should be designed to work with existing dune / landforms which may require some strengthening, to ensure it can provide flood protection. An underground cut-off wall may be required to prevent the flow of water under the levee. The design of the cut-off wall may vary greatly depending on the actual position of the water table. A geotechnical investigation to establish the water table position and soil porosity would be required to enable an accurate estimation of the required cut off wall dimensions and associated costs.	Buildings, internal roads, utilities, contamination and heritage.	$4.2M to undertake design and construction works to protect from 2070 inundation levels. $6M to build it to protect from 2100 inundation levels.
Site flood protection - north **levee** Construct a grassed flood levee around the northern cluster of structures to prevent inundation (approximately 1 km in length). The levee should be designed to reduce flood risk for the 2070 inundation level initially. The levee should be designed to work with existing dune / landforms which may require some strengthening, to ensure it can provide flood protection. An underground cut-off wall may be required to prevent the flow of water under the levee. The design of the cut-off wall may vary greatly depending on the actual position of the water table. A geotechnical investigation to establish the water table position and soil porosity would be required to enable an accurate estimation of the required cut off wall dimensions and associated costs.	Buildings, internal roads, utilities, contamination and heritage.	$2M to undertake design and construction works to build to protect from 2070 inundation levels. $3M to build it to protect from 2100 inundation levels.

Adaptation Options	Risk Relevance	Indicative Cost 1$2013\
Upgrade causeway and raise Main Road To maintain access to the site during a 100 storm surge event, upgrade, or replace the causeway with consideration of 2100 high tide levels. This option assumes that access to and from the site would still be restricted during 2100 storm surge events, but will provide protection from 2070 inundation levels. The causeway may need to be upgraded to enable cost effective transport of construction materials for levee construction. Upgrading the causeway should be supported by the raising the height of Main Road (approximately 1.5 km in length) to maintain access across the site under 2070 inundation levels.	Site access and internal roads.	Causeway:Between $22.SM to $28M depending on configuration (i.e. new bridge or redevelopment of existing causeway and road). Main Road: $3.6M to design and construct to protect from 2070 inundation levels. $6.9M to build it to protect from 2100 inundation levels.
Review emergency management plans Undertake an initial review of emergency management plans to ensure they respond to an increased scale of inundation impacts, including restriction of access to the island.	Buildings, site access and internal roads, runways and aviation infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of existing plans.
Coastal protection **works** Install coastal protection works including beach renourishment, sea walls and off shore coastal protection works along parts of the north and eastern shores of Swan Island to prevent further erosion. These protection works should be designed to mitigate coastal erosion based on 2070 storm conditions.	Buildings, pier and marine infrastructure, utilities, contamination and heritage.	Initial investigation cost $200K. Cost of implementing recommendations may range from $100K to $7.SM depending on action).

4.13 Adaptation options for Garden Island Defence Precinct, NSW

271. As the inundation risks to the Garden Island Defence Precinct are minimal until 2100, there are limited priority adaptation options required as listed in Table 41.

272. In the longer term (2100), consideration will need to be given to relocating capability from the site or undertaking significant works to elevate or protect all assets at the site.

Table 41 Prioritised adaptation options for Garden Island Defence Precinct.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Utilities - resilience of underground utilities Determine the vulnerability of underground utilities at the site (e.g. utility service tunnels). Sea level rise and increased storm surge heights may affect the stability or integrity of utility service tunnels leading to flooding and damage to utilities.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.

4.14 Adaptation options for Proof and Experimental Establishment Port Wakefield, SA

273. Identified adaptation options for P&EE Port Wakefield focus on protecting existing assets and planning for the longer term relocation of selected assets and the coastal road. The priority adaptation options for implementation at Point Wilson are included in Table 42.

Table 42 Prioritised adaptation options for Proof & Experimental Establishment Port Wakefield.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Asset specific protection works Undertake asset protection works including, improved asset drainage, tanking protection works and raising the height of asset floor levels. These works should be staged to respond to the rate of sea level rise. Specific assets that should be protected include Explosives Storehouse HE (508509R) (A0079), Drop Test Tower Control Building (A0104), Drop Test Tower 20M (A0105) and Storage Shed (A0139), Propellant Magazine (509292K) (A0084), Victor Battery (502413W)- safety shelter (A0076), Winch Building (502411A) (A0078) and Winch Shed (A0098).	Buildings and utilities.	$50K-$100K to plan and design protective works, depending on the number of assets. The cost of implementing physical changes would be dependent on the specific structures, their use, height change or protection measures required.
Plan relocation of **assets** As at risk assets reach the end of their design life, relocate them to areas within the site that are not at risk of inundation. Plan for the relocation of at risk assets with consideration of their current condition, remaining useful life and exposure to inundation and erosion risks.	Buildings, utilities and contamination.	$50K-$100K to review asset condition and plan for relocation. Negligible additional cost to include relocation in re-development planning.
Utilities - network reliability Isolation of electrical and communications systems to ensure network performance and self-sufficiency when elements of the system are affected by inundation.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Review emergency management plans Undertake a review of emergency management plans to ensure they respond to an increased scale of inundation impacts, including short term protection of assets (e.g. sandbagging, powering down assets) and resourcing for clean-up activities (e.g. remediation of the coastal road).	Buildings, site access and internal roads, utilities, and contamination.	$15K-$50K to review inundation risks as part of regular reviews of existing plans.

4.15 Adaptation options for St Kilda Transmitting Station, SA

274. Identified adaptation options for St Kilda Transmitting Station focus on adjusting existing business processes and constructing flood protection measures to protect existing and future built assets. The priority adaptation options for implementation at Point Wilson are included in Table 43.

Table 43 Prioritised adaptation options for St Kilda Transmitting Station.

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Site Flood Protection - Table Drain Construct a table drain around the Ground Reflection Range. This drain should be designed to divert rainfall flows around the Ground Reflection Range toward the site's existing outlet in the west of the site. Existing drainage provisions under the western access road should be upgraded along with the installation of tidal gates at the existing outlet from the site.	Utilities.	$380K to undertake design and construction works.
Review emergency management plans Undertake a review of emergency management plans to ensure they respond to an increased scale of inundation impacts, including use of the flood barriers for the turntable at the Ground Reflection Range and restriction of access to the site.	Buildings, site access and internal roads, utilities, and contamination.	$15K-$50K to review inundation risks as part of regular reviews of existing plans.

5.0 Supporting Information

275. This section provides an overview of the limitations of the assessment and the quality of data used. The technical information supporting the site reports provides specific detail on the data used for each study.

5.1 Assessment limitations

276. This risk assessment has been conducted using contemporary climate science for sea level rise and increase in rainfall intensity. Climate projections contain inherent limitations and uncertainty (refer to Appendix B). Sensitivity testing was undertaken to determine the potential changes in consequences due to varying assumptions in both sea level rise and increase in runoff associated with increased rainfall intensity. These results were reviewed and a risk averse scenario adopted.

277. This risk assessment has used models that simulate flooding and coastal processes including erosion and inundation. Estimates of inundation and erosion hazard areas have been calculated using the output of these models, which is dependent on the accuracy of input data. Data availability issues were encountered in some areas which required a modelling approach to be employed that overcame the limitations but also ensured the risks were not underestimated. These limitations have been documented in the technical reports.

278. In addition, the methodology applied has included the use of the Bruun Rule, an empirical rule to estimate a component of shoreline recession. While widely used, the rule is based on assumptions that have not been followed in some locations, preventing the application in those areas (e.g. rocky shorelines and hard coastal protection structures). This issue affects the estimation of shoreline recession due to sea level rise, however, the lack of a viable alternative has necessitated the use of engineering judgment to compensate for this shortcoming as is documented in the technical reports. The assessment focussed on the primary impacts of erosion. The scope of the assessment did not include the investigation of secondary impacts (e.g. landslips) caused by the primary erosion impacts, which may increase the potential extent of inundation.

279. These limitations provide an appreciation for the complexity of the modelling, and the dependence of the results on the modelling software, empirical tools and analysis being undertaken. However, within the scope of the scenarios being modelled, this assessment has provided the most accuracy possible given the limitations of the data and tools available.

280. Assessments of the risk exposures of environmental and heritage assets and contamination issues were based on a desktop review of information provided by Defence from previous studies (e.g. Heritage Management Plans and the Contamination Site Register) and do not reflect all studies undertaken at the site. An assessment of the current presence or condition of these assets, or issues, was not undertaken as a part of this assessment, the results of which may influence the conclusions made in this study.

5.2 Quality of data used

281. Previous studies conducted by AECOM and others have been utilised in the assessment of the impacts of climate change at the sites being assessed. This includes wave, tide and rainfall data, topographical and climate information. The main issue encountered with the use of external data was not related to accuracy, but rather the availability of site (or region) specific data. Where this has occurred, an approach has been taken to ensure risk is not underrepresented in the results.

282. Of the sites assessed, the terrain data at Defence Establishment Harold E Holt Area B was most difficult to access. To develop the inundation models for this site several terrain data sets with varying accuracy and levels of detail were pieced together (i.e. digital elevation model (DEM) imagery from Landgate, computer-aided design (CAD) contour lines and field survey of the dune system). This approach was required as a single, high resolution, accurate terrain data set was not available for this site. As such, there is lower confidence in the results of the inundation modelling for this area when compared to Defence Establishment Harold E Holt Area A or the other Defence sites assessed as a part of Project AZ5220. The flood level information developed is suitable for the purposes of this assessment. However, it is recommended that LiDAR data covering the entire floodplain should be obtained prior to implementing adaptation options (e.g. emergency management planning, undertaking detailed design or construction works). Having the area 'flown' to create a single, common terrain data set and aerial photography that covers Area A and Area B would provide greater confidence that adaptation measures will reduce risk levels as per their design. Due to its proximity, RAAF Base Learmonth should also be considered in the development of LiDAR data in this region.

6.0 Conclusions and Recommendations

6.1 Project overview

283. Climate change and rising sea levels present potentially significant risks to key Defence sites and, along with a range of other traditional estate planning considerations, must be taken into account in future investment decisions. Recognising the challenges posed by climate change, in 2011 Defence undertook a high level, first pass assessment which analysed the risks posed by climate change induced sea level rise, storm surge and king tides at 38 Defence sites. This initial study identified that 14 sites were at high or very high risk of marine flooding from sea level rise, storm surge and king tide in 2040 and 2070.

284. To better understand the risks at sites identified in the initial study to be at greatest risk, Defence commissioned a second stage of work to undertake more detailed investigations. This second study, entitled *Adaptation and planning strategies to mitigate the impact of climate change induced* sea *level rise, flooding and erosion at selected Defence* sites (Project AZ5220), has broadened the focus to include marine flooding (sea level rise, storm surge, king tide), estuarine flooding (extreme rainfall) and coastal erosion. This study also considers adaptation planning in response to these risks.

285. The study has assessed in detail 13 of the 14 bases at high or very high risk in 2040 and 2070 and Cocos (Keeling) Islands. The detailed findings for each site are designed to influence decision making regarding the strategic basing principles and whether to invest in redevelopments and adaptation, or divest properties, and the financial planning to support this. This Executive Report and the attached site summary sheets should be read in conjunction with the detailed reports prepared for each site.

286. The findings of the study support the strategic objectives of enabling more effective long term resource allocation, increasing the resilience of Defence assets to current and future extreme weather events and proactively responding to government policy. By taking action to understand the risks and implications of climate change to selected sites, Defence may be able to assist in shaping future Commonwealth Government policy, rather than having onerous policy requirements imposed upon them.

6.2 Key findings for each site

287. To reduce flooding and erosion risk, all sites need to develop inundation design specifications and adjust maintenance specifications to incorporate consideration of increased inundation levels and erosion extents. Relocation of some activities and functions may also be required at each site.

HMAS Cairns

- HMAS Cairns currently experiences marine and estuarine flooding and climate change is likely to increase these hazards, resulting in the site having a Very High risk rating in 2040. Inundation is likely to damage and degrade buildings, roads and utilities at this site and restrict access to pier and marine infrastructure. The site is not at risk of coastal erosion.
- The site should adapt to limit flood damages out to the year 2070, then consider full transition of capability to another location.

RAAF Base Townsville

- RAAF Base Townsville currently experiences marine and estuarine flooding and climate change is likely to increase these hazards, resulting in the site having a Very High risk rating in 2040. Inundation is likely to damage and degrade buildings, roads, runways and utilities at this site. Coastal erosion is not expected to directly affect RAAF Base Townsville.
- The site should adapt by keeping water out of the site through the installation of flood barriers and upgrading drainage and pumping facilities to maintain operation of the runway, site access and minimise impacts to buildings.

Garden Island West **/ HMAS** Stirling

- Garden Island West/ HMAS Stirling currently experiences limited marine flooding. Coastal erosion is affecting the stability of the island's coast. Climate change is likely to increase these hazards, resulting in the site having a High risk rating in 2040. Inundation is likely to damage and degrade pier and marine infrastructure, roads, and utilities at this site. Extreme rainfall events do not pose inundation risks at this site.

- The site should adapt through increased flood protection and realignment of Dampier Road to ensure continued access to facilities. In the longer term, redevelopment of marine infrastructure including the Wickham Road Pier and the lower deck of the Diamantina Pier will be required.

RAAF Base Learmonth

- RAAF Base Learmonth currently experiences marine and estuarine flooding and climate change is likely to increase these hazards, resulting in the site having a Very High risk rating in 2040. Inundation is likely to damage and degrade buildings, roads, runways and utilities at this site. Coastal erosion is likely to affect site access in 2040 and affect a historic landfill resulting in the possible mobilisation of contamination.
- The site should protect key utilities to ensure that it maintains self-sufficiency during extreme weather events while planning longer term engineering solutions to keep water out of the site.

Defence Establishment Harold E Holt

- The majority of Area A and low lying parts of Area Bare currently at risk of a combined 100 year ARI storm surge and extreme rainfall event. Inundation is likely to damage and degrade buildings, roads, pier and marine infrastructure, utilities, heritage and environment assets at this site, resulting in the site having a Very High risk in 2040. Coastal erosion impacts are likely to be limited to perimeter roads, Indigenous coastal heritage assets and access to the pier.
- The site should focus on protecting key utilities and maintaining capability during inundation events.

Cocos (Keeling) Islands

- With the exception of the settlement area, the majority of the island is currently at risk of a 100 year ARI storm surge event, resulting in the site having a Very High risk in 2040. Inundation is likely to damage and degrade buildings, roads, pier and marine infrastructure, runways and aviation infrastructure and utilities at this site. In 2040, coastal erosion is likely to cut off access from the settlement to the north and the south of the island. Coastal erosion is also likely to damage accommodation and fuel installations in 2040.
- The site should adapt by protecting the communications facility, ensuring sufficient fuel supply is available to run back up power, and that access is maintained. Defence should also consider engaging with affected stakeholders (e.g. local governments, Attorney General's Department or the Water Corporation) to ensure effective adaptation of the utilities and services that support Defence's capability on the island.

Bulimba Barracks

- The majority of Bulimba Barracks is currently at risk of inundation during a 100 year ARI event. Climate change is likely to increase this hazard. The site has a Very High risk rating in all three timeframes. The site is not at risk of coastal erosion.
- The site should adapt by enhancing drainage of water from the site and minimise the impacts of inundation when it occurs. In the longer term the site will require greater protection from sea level rise and tidal inundation from the Brisbane River.

Damascus Barracks

- The majority of the unbuilt portion of Damascus Barracks is currently at risk of inundation during a 100 year ARI event storm surge, river flow or extreme rainfall event. This hazard area will increase in 2040 and 2070, covering most built assets in 2100. The site has a High risk rating in 2040 and 2070, increasing to Very High in 2100. The site is not at risk of coastal erosion.
- The site should adapt by reducing the amount of water entering the site, enhancing drainage of water from the site and minimising the impacts of inundation when it occurs. Due to the site's low elevation, maintaining operational capability during 100 year ARI inundation events, in 2100, will require either relocating the capability, or building a levee to protect the entire site.

RAAF Base Williamtown

- Some assets and unbuilt sections of RAAF Base Williamtown are currently at risk of inundation during a 100 year ARI event. The extent or depth of inundation from such an event, as a result of climate change, is not likely to increase significantly. The site has a Very High risk rating in all three timeframes. The site is not at risk of coastal erosion.

- The site should adapt by enhancing the local drainage network at the site and ensuring future asset design and maintenance considers the risk of more frequent inundation.

Point Wilson Explosives Area

- A limited number of assets and a third of the unbuilt areas of the site are currently at risk of inundation during a 100 year ARI event. Climate change is likely to increase the extent and depth of inundation to cover approximately half of the site and most built assets. The site has a Very High risk rating in 2040 with tidal inundation and inundation from 100 year ARI events likely to degrade environmental assets, restrict the use of, and damage, buildings, roads, pier and marine infrastructure and utilities, reducing capability.
- The site should focus on protecting the built assets, while maintaining access to the jetty in the longer term. The planned redevelopment of the site provides an opportunity to cost effectively adapt many of the assets likely to be affected by inundation and ensure the site is climate resilient.

Swan Island

- Many assets and unbuilt sections of Swan Island are currently at risk of inundation during a 100 year ARI event. The extent and depth of inundation from such an event, as a result of climate change, is likely to increase, affecting almost all built and environmental assets in 2100. Coastal erosion is also likely to continue to affect the site causing the destabilisation or complete loss of some buildings, roads, marine infrastructure and associated utilities. The site has a Very High risk rating in all three timeframes.
- The site should focus on protecting built assets in two main areas, maintain site access and ensuring continued active engagement in the sand management practices for the Queenscliff Harbour Marina. In the longer term (2100), consideration will need to be given to relocating capability from the site or undertaking significant works to elevate or protect all assets at the site.

Garden Island Defence Precinct

- The GIDP site is at Medium risk from a 100 year ARI storm surge event in 2040 and 2070 as a result of the direct impacts of storm surge events on marine infrastructures and an increased height of the corrosive splash zone. In 2100, almost the entire site is at risk of inundation leading to a Very High risk to buildings, utilities, pier and marine infrastructure, internal roads and access to the site from Cowper Wharf Road.
- As the inundation risks to the Garden Island Defence Precinct are minimal until 2100, the priority adaptation options are limited to better understanding the risks to underground utility assets and reviewing maintenance specifications and monitoring procedures to ensure they consider future inundation risks. In the longer term (2100), consideration will need to be given to relocating capability from the site or undertaking significant works to elevate or protect all assets at the site.

Proof and Experimental Establishment Port Wakefield

- Many built assets and the majority of the low lying, unbuilt areas of the Proof & Experimental Establishment Port Wakefield are currently at risk of inundation during a 100 year ARI storm surge and extreme rainfall event. Climate change is likely to increase the depth of inundation and marginally increase the extent of inundation in 2100. However, assets located in the elevated northern section of the site are likely to remain unaffected in all three timeframes. The site has a Very High risk rating in 2040.
- The site should focus on protecting existing assets and planning for the longer term relocation of selected assets and the coastal road.

St Kilda Transmitting **Station**

- Almost all assets and two thirds of the unbuilt areas of the St Kilda Transmitting Station are currently at risk of inundation during a combined 100 year ARI storm surge and extreme rainfall event. Climate change is likely to increase the extent and depth of inundation to cover approximately three quarters of the site and almost all built assets in 2100. The site has a High risk rating in 2040 and 2070, increasing to Very High in 2100 with tidal inundation and inundation from 100 year ARI events likely to restrict the use of, and damage, buildings, roads, and utilities, reducing capability.
- The site should focus on adjusting existing business processes and constructing flood protection measures to protect existing and future built assets.

6.3 Next steps for Defence

288. The study has developed information to assist Defence to make investment decisions that consider potential future risks to assets. This will help to ensure effective investment by limiting the potential of making significant investments in assets that are likely to experience inundation and erosion risks during their lifespan. It will also build Defence's resilience to current and future extreme weather events and ensure Defence is proactively responding to government policy. With this aim, the study has developed a suite of information for each base including:

- Inundation hazard maps for existing conditions, 2040, 2070 and 2100;
- Coastal erosion hazard maps for 2040, 2070 and 2100;
- Supporting GIS data for the hazard maps;
- Listing of assets at risk for 2040, 2070 and 2100 (including information of surveyed floor levels of built assets);
- Description and rating of risks to assets at each site for 2040, 2070 and 2100; and
- A list of prioritised adaptation options, including high level cost estimates.

289. This information has been developed for Defence to inform:

- the development of design specifications for new works and adjustments to maintenance specifications to incorporate consideration of increased inundation levels and erosion extents. This could be achieved at the base level, or centrally through the Defence Estate Quality Management System embedding consideration of changes to inundation and coastal erosion risks into central decision making processes;
- strategic planning (e.g. Zone Plans and Base Development Plans); and
- prioritisation of remediation works or identifying requirements to protect areas of environmental or heritage significance.

290. This study does not provide a comprehensive review of Defence's exposure to all climate change risks and recommended adaptation approaches to managing them. Recognising the narrow focus of the study (i.e. inundation impacts from marine flooding (sea level rise, storm surge, king tide), estuarine flooding (extreme rainfall) and coastal erosion at 14 sites), the following recommendations are made to enable Defence to further understand, and prepare for, the risks posed by a changing climate:

- Investigate other risks that have been identified as relevant to the site but not covered in this assessment (e.g. impacts of other climate variables on capability and the impacts of sea level rise on ground water levels and soil subsidence);
- Undertake an assessment of broader climate change risks on the Defence Estate, including training areas. This could start with assessing the risks of extreme rainfall and coastal erosion at the other 24 sites studied in the initial assessment and sites that provide unique climates or geographies that support training capability;
- Identify possible constraints on logistic requirements and supply chains in support of ADF operations and emergencies;
- Assess the broader implications of climate change on Defence's capability and operations, for example the need for, and ability of, Defence to respond to community aid relating to natural disasters and implications for international security requirements;
- Continue consultation and engagement with relevant Commonwealth, territory, state and local government agencies to ensure effective preparation and response to the risks posed by a changing climate; and
- Undertake analysis (cost benefit or other) to prioritise adaptation measures for sites at very high risk in 2040, to enable their inclusion in the Major Capital Funding (MCF) list.

Appendix A

Site Assessment Methodology and Framework

Table of Contents

1.0 Introduction

1.1 Purpose

1. This document has been developed to guide the delivery of the Department of Defence's (Defence's) *Adaptation and planning strategies to mitigate the impact of climate change induced* sea *level rise, flooding and erosion at selected Defence sites* (Project AZ5220). It provides a step-by-step methodology for the assessment of climate change induced sea level rise, flooding and coastal erosion.

2. The methodology is applicable for:

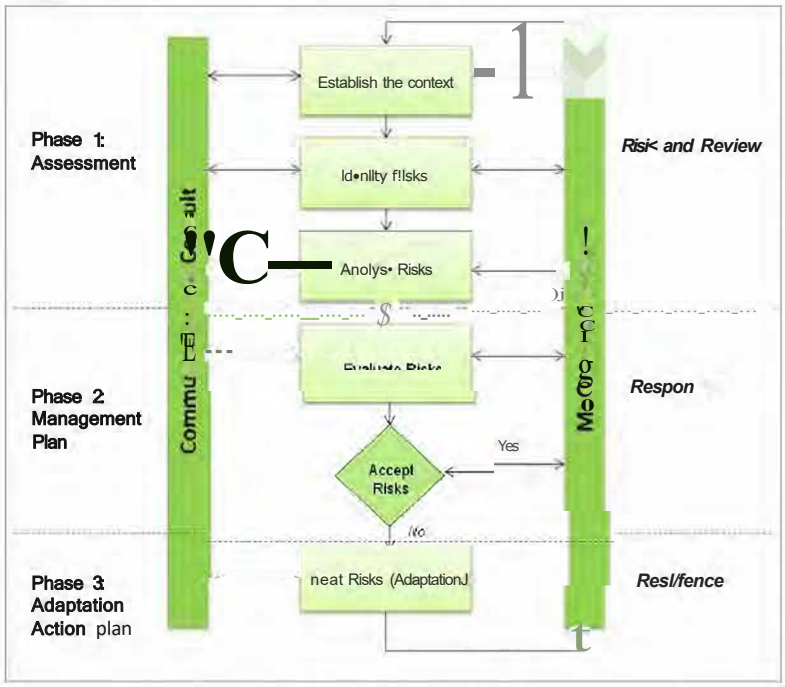
- Assessing the risk of inundation and coastal erosion;
- Risk assessments at a site, or asset, that has not been previously assessed; and
- Reviewing and updating a previous site, or asset, risk assessment.

1.2 The Risk Assessment Process

3. To ensure that Defence can effectively prepare for the risks posed by a changing climate, risks need to be identified and assessed systematically.

4. The Department of Environment (formerly the Australian Greenhouse Office) developed a climate change risk management framework entitled *Climate Change Impacts & Risk Management: A Guide for Business and Government* (Commonwealth of Australia, 2006). This work is being enhanced by the *Australian Standard for Climate Change Adaptation for Settlements and Infrastructure* (AS 5334-2013). The DoE framework and AS 5334-2013 are consistent with the principles *of* the AS/NZ 31000:2009 Risk management - Principles and guidelines which is illustrated in Figure 1.

Figure 1 Standard risk management prooess.1



[1] Adapted from AS/NZ 31000:2009

5. There are three phases in the risk management process:

- Phase 1 (Assessment) is the risk identification phase. In Phase 1 the context for the risk assessment is established by clarifying objectives, determining success criteria against which risks can be evaluated and selecting relevant climate change scenarios. Risks are then identified and analysed by determining their likelihood and consequence ratings;
- In Phase 2 (Management Plan), risks are evaluated and ranked in terms of their severity, identifying those risks that will be the focus of adaptation planning; and
- Phase 3 (Adaptation Action Plan) involves identifying treatment options for priority risks. In this final phase, adaptation options are identified and incorporated into forward planning and implemented.

2.0 Climate Change Risk Management Process

6. Figure 2 illustrates the steps to be undertaken to deliver this risk assessment, and notes the section of this document which provides the methodology for delivering each Step. The five steps are:

- Step 1: Establish the context;
- Step 2: Identify the risks;
- Step 3: Analyse the risks;
- Step 4: Evaluate the risks; and
- Step 5: Treat the risks (adaptation).

7. This approach completes the 3 phases of the standard risk management process with Steps 1 to 3 completing Phase 1, Step 4 completing to Phase 2 and Step 5 completing Phase 3. The approach outlined in this methodology is consistent with Engineers Australia's (2004) *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering* where relevant to the scope of this assessment.

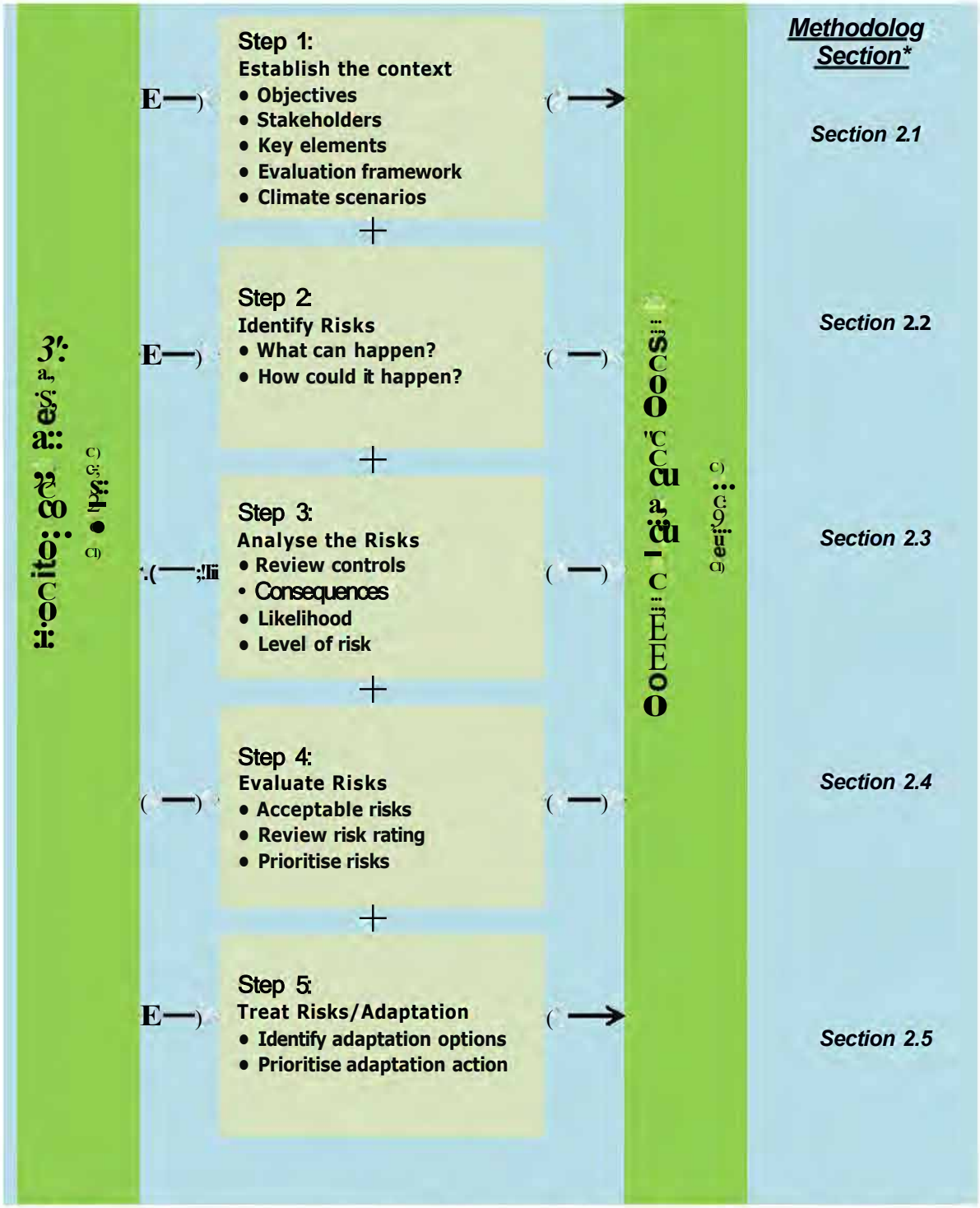


Figure 2 The risk management process with reference to the sections of the methodology providing more detail in this report.

• Section 1.0 is the introductory chapter, induding the purpose of ltie Site Assessment Methodology and Frameworlc

2.1 Step 1: Establish the Context

8. To establish the context for the risk assessment, the following factors must be defined:

- The objectives and scope of the assessment;
- The stakeholders to be engaged or consulted to deliver the assessment;
- The key dimensions used to guide the assessment;
- The evaluation criteria used to undertake the assessment; and
- The climate change scenarios used to undertake the assessment.

2.1.1 Objectives and Scope

9. The objective of this study is to enable Defence to understand and manage the risks associated with climate change induced sea level rise, flooding and erosion.
1Q. The findings of this study will enable Defence to develop and plan for adaptation options to reduce exposure to risks arising from the impacts of sea level rise, flooding and erosion on its sites.
11. Risks identified will be informed by projected changes to sea level and extreme rainfall arising from climate change.
12. Risks will be assessed across three timeframes (2040, 2070 and 2100).
13. Consideration of broader climate change risks will not be included in this assessment. However, the risk assessment process outlined may be used to address these and other climate change risks. To assess other climate risks additional detail would need to be added to Section 2.3.1 to guide the detailed site assessments. Elements that are not included in the scope of the study include climate change impacts resulting from:

- Changes in temperature. humidity or evaporation;
- Reductions in rainfall;
- Ocean acidification; and
- Salt water intrusion into groundwater and estuaries.

2.1.2 Stakeholders

14. Internal stakeholders for this assessment include Defence environment or other risk managers, operational and base managers and personnel who operate or reside at the facilities being assessed. Defence stakeholders will provide input into the data collection process, risk identification and adaptation planning components of the assessment.
15. Interviews and workshops with key Defence personnel will be held to gather input and assist in building awareness of the risks posed by climate change.
16. External stakeholders, including technical experts, will be involved in the risk assessment through the provision of data and technical reviews.

2.1.3 Key Dimensions

17. To efficiently identify and analyse the risks, a set of dimensions has been identified which outline Defence's key organisational, base and activity related concerns. These dimensions will be used to prompt expert and stakeholder input and make sure that all important issues are raised.
18. While the dimensions can be altered for individual risk assessments, it is intended that they will be consistent with Defence's existing risk management process and terminology, for consistency and ease of internal communication.
19. The dimensions, outlined in Table 1. which will be used for this assessment, are similar to those used for other Defence risk assessments such as the Risk Managed Works in the Estate Maintenance program (formerly Facilities Operations (FACOPS)).

Table 1 Description of dimensions for Project AZS220 Adaptation and Planning Strategies to Mitigate the Impacts of Climate Change Induced Sea Level Rise, Flooding and Erosion at Selected Defence Sites (adapted from Department of Defence, 2011).

Risk Dimension	Description
Capability	- Capacity of the facility to support the user unit in delivery of its primary outputs. - Impact on the ability of the Australian Defence Force (ADF) to protect Australia and fulfil its national security obligations. - Impact on the ADF's ability to train and equip for war and for the conduct of peacetime operations. - Impact on the ability of Defence to develop its capability as detailed in the 2009 Defence White Paper. - Impact on civil (non-Defence) capability as a consideration for shared facilities.
Occupational health and safety (staff and public)	- Impact on the physical and psychological well-being of Defence employees, contractors, communities in Defence regions and the public in general.
Legislative compliance	- Compliance with regulatory requirements and the impact of failing to comply. Including but not limited to federal, state, territory, local, foreign treaty, indigenous land use agreements, Defence Instructions or contracts. - The impact or potential impact of performing or failing to perform some obligation is where the importance of compliance arises. Matters for consideration include: • whether Defence is currently breaching one or more legislative or other obligations; • whether Defence, in the absence of some remedial work to the estate will shortly be contravening a legislative or other obligation; or • whether the estate needs work to be completed within or by some specified time to ensure that Defence remains compliant with all obligations.
Environment and heritage	- Impact on the environment, including contamination, damage to flora and fauna, fire, noise, soil damage and erosion, greenhouse gas emission, bio-diversity, feral animals and water quality. - Environmental management in the strategic context of Defence business. - Impact on Heritage includes impacts on sites listed on the National Heritage List, Commonwealth Heritage List, Register of the National Estate and sites that are thought to have heritage significance but have not been formally assessed. Sites can have historic, indigenous or natural heritage values.
Financial efficiency	- An assessment of the potential for increased costs that would be incurred if the works were not performed in the preferred funding year. This includes costs directly related to the project itself and any flow on costs that may result if the works are not performed. - Short-term cost of prevention vs. long-term cost of recovery. - This would also cover reductions in costs and return on investment (i.e. shorter payback period if work performed now, costs now for long term savings.) - Cost estimates should be inclusive of GST.

Risk Dimension	Description
Personnel	- Impact on Defence employees in the context of staff morale, staff retention and productivity.
Reputation	- Impact on Defence's reputation in managing the estate, political and media attention to Defence estate matters. community concerns or actions over activities. - Impact on compliance with Government commitments as opposed to specific government policy/ legislation.

2.1.4 Evaluation Criteria

20. This risk assessment framework is based on the following three documents:

- The Australian Greenhouse Office's *Climate Change Impacts and Risk Management - A guide for Business and Government.*
- Australian *Standard for Climate Change Adaptation for Settlements and Infrastructure* (AS 5334-2013); and
- The Department of Defence's *Estate Risk Assessment Guidance - For Estate Maintenance* (4_250 Estate Risk Assessment Guidance 110118.doc).

21. The guiding principles for this risk assessment are:

- Risks identified are to be informed by recent sea level changes compared to the long term average (last 20 years compared to last 100 years) and projected climate change induced sea level rise and extreme rainfall for 2040, 2070 and 2100.
- Each risk rating will be the combination of consequences and likelihood, which are determined in accordance with Table 3, Table 4 and Table 5:
  - Table 3 outlines the qualitative measure of consequence for each Dimension;
  - Table 4 outlines the qualitative measure of likelihood; and
  - Table 5 defines the risk level and score according to identified risks' consequences and likelihood;
- Adaptation options will be developed for risks identified as medium. high and very high in 2040; and
- The hierarchy for the focus of adaptation planning is outlined in Table 2. The primary focus of adaptation planning and options will be risks identified as medium. high and very high in 2040.

Table2 Focus of adaptation planning based on identified risk levels.

Focus for adaptation plannina	Time horizon	Level of Risk
Primary	2040	Very High High Medium
Secondary	2070	Very High
Tertiary	2100	Very High

Table3 Definition and Scores of Consequence Ratings for Each Risk Dimension for Project AZ5220 Adaptation and Planning Strategies to Mitigate the Impacts of Climate Change Induced Sea Level Rise, Flooding and Erosion at Selected Defence Sites (adapted from Department of Defence, 2011).

Consequence: If the climate change Induced sea level rise risk / erosion / flooding occurs In the Identified timeframe ...					
Rating Risk dimension	Severe (1)	Major (6)	Moderate (11)	Minor (16)	Negligible (21)
Capability	All activities cease AND unable to conduct missions or training activities OR all activities cease AND major unacceptable delays in delivery of capability. AND For major assets resumption not possible within 24 hours. For important assets resumption not possible within 7 days. For support assets resumption not possible within 28 days.	Some activities curtailed AND Missions or training activities can be conducted however in a significantly degraded state. AND For major assets resumption not possible within 24 hours. For important assets resumption not possible within 7 days. For support assets resumption not possible within 28 days.	Some activities curtailed AND missions, training or Cadet activities can be conducted however one or more of the significant requirements of the mission or training would not be met. AND For major assets resumption not possible within 24 hours. For important assets resumption not possible within 7 days. For support assets resumption not possible within 28 days.	Minimal activities curtailed AND missions, training or Cadet activities can be conducted with minor degradation to several mission or training requirements. OR Minor delays or minor performance degradation.	Minimal activities curtailed AND missions, training or Cadet activities can be conducted with minor degradation to one mission or training requirement. AND Negligible performance impact.
Occupational health and safety	One or more fatalities or life threatening injuries or illness. OR Public or staff exposed to a severe, adverse long-term health impact or life-threatening hazard.	One or more major injuries or illness requiring major surgery or resulting in permanent disablement. OR Public or staff exposed to a hazard that results in major surgery or permanent disablement.	One or more injuries or illness requiring treatment by a physician or hospitalisation. OR Public or staff exposed to a hazard that could cause injuries or moderate adverse health effects.	One or more injuries or illness requiring treatment by a qualified first aid person. OR Exposure of public and staff to a hazard that could cause minor injuries or minor adverse health effects.	Minor injury or ailment that does NOT require medical treatment by a physician or a qualified first aid person.

Consequence: If the climate change Induced sea level rise risk / erosion / flooding occurs in the identified timeframe ...					
Rating	Severe (1)	Major (6)	Moderate (11)	Minor (16)	Negligible (21)
Risk dimension					
[illegible]	Potential exposure to significant damages involving one or more persons, AND/ OR prosecution with maximum penalty imposed.	Potential exposure to large damages or awards AND / OR prosecution with 50% to maximum penalty imposed.	Some legal constraints imposed with up to half of maximum fine imposed. OR Non Compliance with Department Policy.	Minor technical legal challenge OR legal breach AND/ OR minor damages or monetary penalty.	Minor technical breach but no damages AND / OR no monetary penalty.

Consequence: If the climate change induced sea level rise risk / eros-ion I flooding occurs in the identified timefnune••.					
Rating Risk dimension	Severe (1)	Major (6)	Moderate (11)	Minor (16)	Negligible (21)
	Heritage Listed Assets or Areas: Irreversible and extensive damage is caused to a World Heritage Listed Area, a Commonwealth Heritage Listed Site, a National Heritage listed Site, a Register of the National Estate Site or a Defence Heritage Listed area or asset. OR Significant Environmental Assets: Irreversible and extensive damage is caused to a Matter of National Environmental Significance under the EPBC Act (e.g. endangered species, Ramsar listed wetland of international importance, marine environment).	Heritage Assets or Areas (not listed): Irreversible and extensive damage is caused to an area or asset that is not Heritage listed but that has heritage values. OR Environmental Assets or Areas: Irreversible and extensive damage is caused to a non-environmentally significant (as per the EPBC Act) area or asset. OR Heritage Listed Assets or Areas: Significant damage is caused to a Heritage Listed area or asset that involves either extensive remediation or will take more than 10 years to recover. OR Significant Environmental Assets or Areas: Significant damage is caused to an environmentally significant (as per the EPBC *Act)* area or asset from which it will take more than 10 years to recover.	Moderate damage to the environment or a heritage listed asset or area. which is repairable. The resource or asset will take up to 10 years to recover.	Minor damage to the environment or heritage asset or area that is immediately contained on-site. It will take less than 2 years for the resource or asset to fully recover or it will only require minor repair. OR Disturbance to scarce or sensitive environmental or heritage resources.	Negligible damage that is contained on-site. AND The damage is fully recoverable with no permanent effect on the environment or the asset. It will take less than 6 months for the resource to fully recover.

Consequence: If the climate change induced sea level rise risk / erosion / flooding occurs in the identified timeframe...					
Rating / **Risk dimension**	**Severe (1)**	**Major (6)**	**Moderate (11)**	**Minor (16)**	**Negligible (21)**
[illegible]	> 200% increase in project cost in the following year, i.e. next year it will cost more than 3 times as much. OR For cost savings, potential payback period of 1 year is not realised. OR Flow on costs that are greater than 200% of the cost of the project.	> 100 % increase in project cost in the following year, i.e. more than double the cost. OR For cost savings, potential payback period of 2 years is not realised. OR Flow on costs that are > 100% of the project cost.	Between 60%-100% increase in the project cost in the following year. OR For cost savings. potential payback period of 5 years is not realised. OR Flow on costs that are 60-100% of the cost of the project.	Between 20%-60% increase in project cost in the following year. OR For cost savings, potential payback period of 10 years is not realised. OR Flow on costs that are less than 60% of the cost of the project.	Less than 20% increase in project cost in the following year. OR For cost savings, there is little or no payback realised. OR No or minimal flow on costs.
[illegible]	Serious negative effect on staff morale affecting all staff associated with the structure, with significant loss of productivity, > 5 days lost. OR A high number (> 80%) of the affected staff are highly likely to be reconsidering their continued service or employment within Defence. OR Industrial action is about to be taken.	Major negative effect on staff morale, affecting more than half the staff associated with the structure with major loss of productivity, > 1 day lost. OR Over 50% of affected Staff are likely to be reconsidering their continued service or employment within Defence OR Threat of industrial action.	Moderate negative effect on staff morale, affecting less than half the staff associated with the structure, with some loss of productivity, < 1 day lost. OR Some (up to 50%) of staff impacted may be reconsidering their continued service or employment within Defence OR Employee representative involvement.	Minimal effect on staff morale, affecting a small number (<25%) of staff associated with the structure with possible minor productivity loss. OR Staff are unlikely to be reconsidering their continued service or employment within Defence.	Little or no impact on personnel in any area.

Consequence: If the climate change Induced sea level rise risk / erosion / flooding occurs in the identified timeframe ...					
Rating	Severe (1)	Major (6)	Moderate (11)	Minor (16)	Negligible (21)
Risk dimension					
Reputation	Detrimental international media reports. OR Subject of international government attention. OR Non realisation of a government commitment.	Sustained detrimental national or state media reports. OR Subject of a number of parliamentary questions and ministerials. OR Sustained community outrage.	Limited detrimental national or state media reports. OR Subject of a parliamentary question or ministerials. OR Organised community concerns and complaints.	High profile detrimental local media reports. OR Subject of local government action. OR Random substantiated complaints from the community.	Low profile detrimental local media reports. OR Trivial substantiated complaints from the community.

Table4 Definition and score of likelihood ratings for the assessment of the impact of climate change induced sea level rise, erosion and flooding on Defence sites.

Rating	Descriptor
Almost certain (1)	Assels have a > 90ob chance of being impacted by inundation in a 100 year ARI flood event or by erosion in the identified time period (2040, 2070, 2100) if lhe risk is not mitigated.
Likely (3)	Assets have a 60-90% chance of being impacted by inundation in a 100 year ARI flood event or by erosion in the identified time period (2040, 2070, 2100) if the risk is not mitigated.
Possible (5)	Assets have a 40-60% chance of being impacted by inundation in a 100 year ARI flood event or by erosion in the identified time period (2040, 2070, 2100) if lhe risk is not mitigated.
Unlikely (7)	Assets have a 10-30% chance of being impacted by inundation in a 100 year ARI flood event or by erosion in the identified time period (2040, 2070, 2100) if the risk is not mitigated.
Rare (9)	Assets have a > 10ob chance of being impacted by inundation in a 100 year ARI flood event or by erosion in the identified time period (2040, 2070, 2100) if lhe risk is not mitigated.

Tables Definition of risk level and risk score tor the assessment of the impact of climate change induced sea level rise, flooding and erosion at Defence sites (adapted from Department of Defence, 2011).

		Consequences				
		Severe (1)	Major (6)	Moderate (11)	Minor (16)	Negligible (21)
Likelihood	Almost certain (1)	Very High (2)	Very High (7)	High (12)	Medium (17)	Low(22)
	Likely (3)	Very High (4)	High (9)	Medium (14)	Medium (19)	Low(24)
	Possible (5)	High (6)	High (11)	Medium (16)	Medium (21)	Low(26)
	Unlikely (7)	High (8)	Medium (13)	Medium (18)	Low (23)	Low(28)
	Rare (9)	High (10)	Medium (15)	Low (20)	Low (25)	Low(30)

2.1.5 Climate Change Scenarios

22. The Intergovernmental Panel on Climate Change (IPCC) 'A1FI' SRES[2] greenhouse gas emissions scenarios will be used for this assessment. The 'A1FI' is a higher emissions growth scenario. Only the 'A1FI' scenario will be used for 2040 as the current rate of global greenhouse gas emissions lies near or above the 'A1FI' emissions scenario (Raupach, M.R. and Canadell, J.G., 2010). The projections for each SRES scenario provide a range of values for changes to climate variables. The mean value (i.e. 50th percentile) and high value (95th percentile) from projections for each variable will be used. Projections of future climate are in comparison to the average climate relative to the 30-year period centred on 1990 unle[ss] otherwise noted.

23. The climate related variables that will be considered for this assessment are sea level rise and extreme rainfall events. Specific information on the climate data to be used is included in Section 2.2.2.

[2] A set of future emissions scenarios were prepared by the IPCC to develop global dimate change projections. The scenarios used are from the *Special Report on* Emissions *Scenarios (SRES)* (2000).

2.2 Step 2: Identify Risks

24. In this Step, a list of risks will be compiled for each base or activity that is being assessed. This list will draw upon the information listed in Section 2.2.2, will address each of the dimensions (refer to Section 2.1.3) and will be reviewed by relevant technical specialists.

25. The methodologies that will be taken to complete this Step are described below.

2.2.1 Define Climate Change Risks

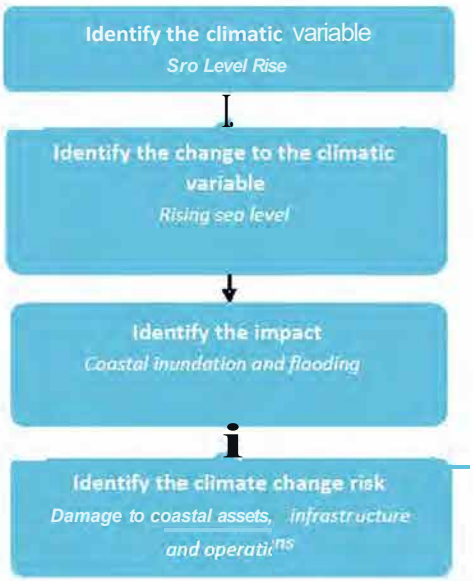
26. A risk can be defined as the chance of something happening that will have an impact on objectives (Commonwealth of Australia, 2006). A climate change risk for Defence is therefore a climate-related event or phenomenon which affects its objectives, either negatively (in the traditional meaning of risk as a hazard or a loss), or positively (implying a potential opportunity).

27. Climate change risks do not arise directly from changes in climatic variables, but from a causal chain as illustrated in Figure 3. A change in a climatic variable could have a range of impacts to Defence, such as on capability maintenance, the natural environment, staff well-being, operating costs, capital costs and reputation.

28. Many of the risks presented by climate change in the short term are not likely to be new risks. Instead, climate change is likely to alter the frequency (likelihood) or severity (consequence) of known risks. For example, coastal land managers already need to manage the risk of flooding, storm surge and erosion, and climate change is likely to increase the frequency and intensity of such events.

29. While climate change will alter the profile of some existing risks, it will also present new risks, particularly in the medium to long term. For example. rising sea levels may expose new areas to the risk of inundation and erosion that were not previously threatened.

Figure 3 An example of the link between climate change, its Impacts and the risks it may pose (adapted from Commonwealth of Australia, 2006).



2.2.2 Collate **Risk** Identification Information

30. A variety of spatial, climatic and site information is required to identify, and inform the analysis of, the risks posed by sea level rise, flooding and erosion to Defence sites. The required data and its intended sources are identified in Table 6 and described in more detail below.

Table6 Information required for the risk assessment.

Information category	Information required	Source
Spatial data	Survey data (including ground surface, bathymetry and hydraulic structures)	- Department of Defence - Third party providers
	Hydrologic and hydraulic models	- Department of Defence - State government water management authorities - Field survey
	Coastal and oceanographic information	- Department of Defence - Third party providers - Field survey
	Historic aerial photography	- Department of Defence - Third party providers
Site data	Summary of site information	- Department of Defence - Past studies focussed on the site - Base Fact Sheets
	Asset information (including GIS maps and reports)	- Department of Defence - Field survey - Modelled outputs
	Existing risk profile and controls of site (including environmental management risks)	- Risk manager - Department of Defence - Past studies focussed on the site - Environmental Management System (EMS)
Climate data	Climate change projections (e.g. sea level rise and extreme rainfall)	- CSIRO - State government environmental management departments (e.g. Victorian Department of Sustainability and Environment)

Spatial data

31. Survey data, including ground surface, bathymetry and hydraulic structures is the most critical data set required for the assessment. Detailed survey information will be required to undertake the modelling for both the extent of inundation and erosion. Various survey techniques are available to collect this data including aerial processes such as LiDAR and photogrammetry and field survey. Where possible, existing data (including LiDAR) will be used primarily, supplemented with field survey data.

32. Hydrologic and hydraulic models will be used to determine flood levels and flood extents.

33. Coastal and oceanographic information, including tide levels, storm surge and wave conditions will be used to determine the extreme sea level and the extent of marine flooding.

34. Interpretation of historic aerial photography will be used to determine changes in the coastline over time. For sites where historic aerial photography exists, the long shore transport component of the coastal erosion assessment will be undertaken.

Site data

35. A summary of site information, including the activities, services and capability that the site supports, will be required to inform the risk analysis, particularly in relation to the rating of consequences.

36. Asset information, including the location, elevation, condition of built and natural assets may be in GIS format or contained in specialist studies and will be required to undertake the potential damage assessment for each site.

37. Existing risk profiles, including environmental management, operational and occupational health and safety risks and existing controls will be required to ensure that existing risk controls are considered during risk evaluation (Step 4) and risk treatment/ adaptation planning (Step 5).

Climate data

38. Existing climate change projections for sea level rise and extreme rainfall will be used to inform the detailed assessments of marine flooding, estuarine flooding and coastal erosion.

39. To inform the analysis of the impacts of sea level rise at each site, the CSIRO and Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) provided projections with upper and lower values for 2040 and 2070 based on the 95th and 50th percentile values under the A1FI emissions scenario. Recognising the range in projections of sea level rise for 2100, a lower and upper figure was selected. The lower figure of 1.10 m sea level rise was selected to maintain consistency with national coastal planning policy and a higher sea level projection of 1.43 m (mean value by Vermeer and Rahmstorf (2009)) will be used to provide a plausible upper bound for 2100. In recognition of the accuracy of the available elevation data (approximately +/-0.25 m), sea level rise projections adjusted for regional variability (i.e. a range from -0.04 m to +0.06 m by 2070) will not be applied.

40. To consider the implications of increases in extreme rainfall, each site's sensitivity to changes in run off based on the 1 in 5 year and 1 in 100 year extreme rainfall events will be assessed. Change in runoff will be the focus as there are no climate change projections available for changes to the 100 Year average recurrence interval (ARI) (Rafter, 2012). To estimate the potential changes in runoff, information provided by CSIRO (Rafter, 2012) and Sandery, et al. (2009) will be utilised.

41. A summary of the climate inputs to be used in this assessment are included in Table 7.

42. Climate change projections for wind (including extreme wind speed and changes in direction) are inconclusive for the Australian region. CSIRO studies for Victoria and southern Australia indicate that the magnitude of the projected changes in sea levels due to altered circulation patterns are within 10 cm of current climate extreme sea levels (Mcinnes et al., 2011 and Wang et al., 2010). No similar studies for North Queensland or south west Western Australia are currently available.

43. Storm surge will not be included in the consideration of extreme sea levels. This will be based on historic recorded data. In this assessment, the influence of cyclones will be included in the consideration of extreme sea levels, specifically influences on storm surge, wind, wave run up and wave set up. These allowances are based on historic recorded data.

44. In the Australian region, no categorical changes in the total numbers of tropical cyclones, or in the proportion of the most intense tropical cyclones, have been found in observed records; though there is considerable year-to-year and decade-to-decade variability. Recent research indicates that there will be fewer tropical cyclones on average in the Australian region as a result of climate change but the proportion of intense cyclones is expected to increase. Quantification of these changes is not currently available (BoM and CSIRO 2012, Abbs 2012 and Callaghan & Power 2010).

Table7 Summary of climate inputs to be used in this assessment.

	2040	2070	2100	References
Sea Level Rise				
Lower	0.14 m	0.31 m	1.10 m	ACE CRC and CSIRO2012 Vermeer and Rahmstorf (2009).
Higher	0.20 m	0.45m	1.43 m	
Increase in run off due to extreme rainfall				
Northern Queensland				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	
South East Queensland				
Lower	+20%	+30%	+50%	Rafter (2012) and Sandery, et al. (2009),
Higher	+40%	+50%	+70%	
Eastern New South Wales				
Lower	+20%	+30%	+40%	Rafter (2012) and Sandery, et al. (2009).
Higher	+40%	+50%	+60%	
Victoria				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	
Northern Western Australia				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+70%	
South Australia				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	

2.2.3 Compile Base Specific Risk Lists

45. The above information will be collated and reviewed to identify risks by:

- Reviewing existing risk registers (e.g. EMS, risk management system, Occupational Health and Safety (OH&S)) and recorded risks that directly relate to wave or tidal activity (e.g. inundation, damage to assets) or areas that are close to the coastal zone and may be made worse by being inundated (e.g. contaminated land);
- Reviewing past reports, studies and information relating to each of the risk dimensions that may be impacted by sea level rise or flooding or erosion (e.g. base capability, environmental and heritage assets);
- Identifying additional points of interests for the site, particularly in areas along the coastal zone including buildings and other structures (above and below ground), utility infrastructure, main site access and egress points, drainage infrastructure (including outfalls); and
- Considering the topography of the site, highlighting natural drainage pathways and existing areas of flood risk that may be worsened by sea level rise, flooding or erosion.

46. A list of risks will be documented in a table against the following set of risk themes consistent with the Initial Assessment (refer to Appendix B for an example):

- Buildings;
- Site Access and internal roads;
- Pier and marine infrastructure;
- Runways and aviation infrastructure;
- Utilities;
- Environmental assets;
- Contamination; and
- Heritage.

47. When identifying and phrasing risks each risk descriptor will include:

- A verb rather than just nouns (e.g. "road access may be cut-off' rather than just "road access"); and
- A cause and effect statement (e.g. "inundation of the road may lead to access being cut-off").

48. Each risk statement will be reviewed to ensure that it can be understood by someone who has not been involved in the risk assessment process. Where no risk is identified for a theme then this will be stated to make it clear that it has been considered in the assessment.

2.3 Step 3: Analyse Risks

49. In this Step of the process, risks identified for each site will be analysed by completing the following:

- Undertaking detailed site assessments;
- Identifying and reviewing the current controls:
- Rating the consequences of each risk;
- Rating the likelihood of each risk; and
- Calculating the risk level and rating.

50. In addressing the uncertainty related to climate change projections, the process to be used in this assessment will estimate the consequences of a range of increases in key variables (e.g. sea level rise, extreme rainfall) independently of the likelihood. A separate analysis of the likelihood of future conditions will be undertaken giving consideration to the uncertainty of the projections used. Once the consequences and likelihood have been independently determined the final risk levels and ratings will be determined.

2.3.1 Undertake Detailed Site Assessments

51. To undertake the detailed site assessments, the following steps will be undertaken (each of which is explained further below):

- Determine the required studies;
- Determine inundation extents (marine flooding, estuarine flooding);
- Determine extent of coastal erosion (short term, long term, due to sea level rise);
- Map hazard areas;
- Determine secondary impacts (environment, heritage, contamination, utilities); and
- Undertake flood damage assessment.

52. To deliver the detailed site assessments stakeholders at each site will be engaged through the following methods:

- Introductory letters outlining the project objectives and activities will be distributed to contacts at each site by the Defence project manager;
- Initial consultation calls will be made to each site to introduce the project objectives. desired outcomes, data requirements and site support required. Critical site personnel will also be identified and contact details obtained;
- Identified critical personnel will be contacted for an initial interview regarding coastal climate risks and adaptations options for each site and to ensure relevant data and information is obtained within the required timeframes; and
- Interviews during the site inspection, the current use of the base, the assets on the base (e.g. type, location, condition and elevation) and historic inundation or erosion issues will be discussed in more detail.

Determine the required studies

53. Recognising the unique characteristics of each site, not all sites require every element of the detailed assessment (e.g. marine flooding, estuarine flooding and coastal erosion). To determine which sites require which study, site topography and aerial photography will be used to answer the following questions:

- Is the site located in proximity to the coast? If yes, an assessment of marine flooding is required;
- Does the site have a large off-site catchment flowing through it? If yes, an assessment of local catchment (estuarine) flooding is required; and
- Does the site have an 'exposed' coastline? If yes, an assessment of coastal erosion is required.

Determine inundation extents

54. Inundation can be caused by two main mechanisms, marine flooding or estuarine flooding, both of which Will be assessed in this study. The process for undertaking these assessments is outlined below.

Estuarine flooding

55. Estuarine flooding is generally caused by extreme rainfall on site or upstream of the site. Climate change impacts such as increased rainfall intensity and sea level rise will increase the level of inundation due to estuarine flooding. The extent of estuarine flooding will be determined using hydrologic and hydraulic modelling (refer to Table 8 for an explanation).

56. We will use a process that ensures sites with high sensitivity to increased rainfall intensity and sea level rise are investigated more thoroughly and those with low sensitivity are addressed to an appropriate level of analysis to ensure cost and time efficiencies and robustness of results. To identify the potential sensitivity at each site we will utilise the following methodology:

- Multiply the inflows from the hydrologic modelling by medium and high scenarios for increases in rainfall intensity/ flows (informed by climate projections);
- Increase sea levels by the specified modelled sea level rise for 2040, 2070 and 2100;
- Run the hydraulic model for each combination of scenarios (for example, undertake four test runs on the 2100 event; medium sea level rise+ medium rainfall intensity, medium sea level rise+ high rainfall intensity, high sea level rise + medium rainfall intensity and high sea level rise + high rainfall intensity);
- Determine the extent of inundation for each of these model runs;
- Determine the consequences for each model run by comparing the difference in the inundation levels from each model run; and
- Sites that are not sensitive to an increase in rainfall intensity will require no additional investigation for detailed change in inundation levels or extent for each scenario.

57. For sites which are more sensitive to increases in rainfall intensity (where there is a significant increase in inundation levels or extents), we will undertake a more detailed investigation. For these sites, the projected changes in extreme rainfall will be applied to the inflows, then the hydraulic model will be re-run for 2040, 2070 and 2100 to determine the projected extent of estuarine flooding.

58. This is a more defensible approach than basing the assessment primarily on a particular increase in rainfall intensity, since there is considerable uncertainty regarding extreme rainfall projections. The approach suggested investigates the sensitivity of the sites to different magnitudes of increase in extreme rainfall events, and in cases where the inundation extent is not sensitive to these increases (e.g. where assets are already on elevated land), the site will be considered to be able to accommodate even the most extreme climate change projections without having to attempt estimating how likely these may be. In cases where the inundation extent is very sensitive to small changes in the magnitude of extreme rainfall events, more consideration will be given to the likelihood of these changes occurring. In these cases inundation extents will be generated based on the most relevant projections as outlined in Section 2.2.2.

59. Inundation due to marine and estuarine flooding doesn't always occur independently; sometimes one weather event can cause both marine and estuarine flooding (e.g. a tropical cyclone). We will review the potential for these events to be related (based on previous work) and determine an appropriate sea level for the hydraulic modelling used to determine the estuarine flood extent.

Tables **Explanation of estuarine modelling techniques to be used (using RAAF Base Townsville and HMAS Cairns as examples).**

Type of modelling	Explanation of process to be used
Hydrologic modelling	The XP RAFTS model will be used at HMAS Cairns and RAAF Base Townsville. Topographic data will be required to define the catchments for a hydrologic model. Due to the size of the relevant catchments, it is not feasible to collect detailed survey information for a hydrologic model. Contour data will be used for this purpose, with 10 metre contour intervals beina sufficient (althouah a one metre contour interval is preferred).
Hydraulic modelling	There are two main hydraulic models utilised in Australia, MIKE Flood and TUFLOW. Where an existing model is available for a site it will be utilised. In the absence of a readily available model TUFLOW will be used to create any new hydraulic models required. Should a new model be required to be built, it will be done using the following information: - Topographic data. A Digital Elevation Model (DEM) is required for each hydraulic model. This will be based on a combination of aerial and field survey. The accuracy of the DEM will influence the accuracy of the results of the hydraulic model. - Land use. Aerial photographs will be used to determine the land use and define a 'roughness' layer for the model. Areas such as roads, buildings and heavy vegetation will be defined, as these will influence the flow of water. - Inflows. These will be obtained from the results of the hydrologic modelling. - Downstream water level. This is one of the most complicated components of the hydraulic modelling to be undertaken for these sites (due to the proximity to the coast line) and will be determined in the marine flood modelling stage. Consideration will be given to the type of storm event which causes estuarine inundation at each site. For example, in north Queensland, estuarine inundation is often associated with a cyclonic event, which is also associated with high sea levels.

Marine flooding

60. Marine flooding is due to the following coastal processes:

- Astronomical tide;
- Storm surge (caused by low pressure systems, storm events, cyclones and tsunamis); and
- Wave run-up and set-up (caused by high winds and waves).

61. The first step is to determine the existing (i.e. current) marine flooding extents. Recorded water level data from the tide gauges will be used to provide a historic record of sea-levels (which include astronomical tide and storm surge). In addition, many investigations have been undertaken on the Australian coastline to determine localised extreme sea-levels. These include analysis of data collected in the field, including water levels, wave characteristics and current profiles. Historical data and recent findings from investigations will be used to undertake an extreme value analysis to determine the current 100 year ARI sea-level.3 In addition to the extreme sea levels, available historic wind and wave data will be reviewed to determine the appropriate level of wave run-up and set up. For sites in which the coastal erosion assessment is being undertaken (e.g. Garden Island West/

[3] Similar to estuarine flooding, the 100 year ARI event is generally used to define the extent of inundation for planning purposes

HMAS Stirling and RAAF Base Townsville) this will be computed using SBEACH.4 To determine the possible future changes in extreme sea levels (i.e. beyond the historic levels) for each site, consideration will be given to:

- Sea level rise projections;
- Changes in water levels due to changes in cyclone frequency and intensity); and
- Changes in wind speed and changes in wind direction.

Coastal erosion

62. Coastal erosion can be caused by three different mechanisms: storms, waves or currents running parallel to the coast line, and sea-level rise. These three mechanisms are defined as:

- Recession of the coast line due to storms (short term coastal erosion);
- Recession of the coast line due to longshore transport (long term coastal erosion due to waves or currents running parallel to the coast line); and
- Recession of the coast line due to sea-level rise.

63. The net recession of the coastline can be determined by summing the recession due to these three mechanisms. The following methodologies will be used to determine the coastal erosion (or recession) rates.

Short term coastal erosion

64. Short term coastal erosion is the combination of vertical erosion of the beach profile and the horizontal recession of the coastline that occurs during a storm event. During a large storm event, sand can be moved from the beach to deeper water. Over time, the beach profile generally returns to the original configuration as sand is redistributed.

65. The extent of short term coastal erosion will be determined using the program SBEACH. This approach is endorsed by the Victorian Department of Sustainability and Environment and was used for the Coastal Spaces - Inundation and Erosion Investigation for the Glenelg Shire Council.

Long term coastal erosion

66. Long term coastal erosion refers to historical changes in the shoreline position where the shoreline is receding landward over time. It is primarily due to longshore transport induced by waves or currents running parallel to the coast line. Longshore transport is the movement of sand parallel to the shore. This can be either the erosion or deposition of sand from coastal processes such as tides, waves or currents.

67. The extent of the potential long term coastal erosion rate will be determined by analysing historic aerial photography to determine the changes in shoreline position over time. This approach is endorsed by the Victorian Department of Sustainability and Environment and was used for the Coastal Spaces - Inundation and Erosion Investigation for the Glenelg Shire Council.

[4] SBEACH, an acronym for Storm induced Beach Change was developed at the US Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory (Larson et al, 1990) to calculate beach and dune erosion under storm water levels and wave action. SBEACH is an empirical based program that calculates the net cross-shore sand transport rate in four zones from the dune or beach face, through the surf zone and into the offshore past the deepest break-point bar produced by short period incident waves. The wave model is relatively sophisticated and computes shoaling, refraction, breaking, breaking wave re-formation, wave and wind induced set-up and set-down and run-up.

Recession due to sea level rise

68. Increases in sea level can lead to erosion of unconsolidated (soft) sands. Bruun (1954, 1962 and 1983) hypothesised that a beach assumes a profile that is in equilibrium with the incoming wave energy, therefore, a rise in sea level would cause the profile to adjust. Utilising 'Bruun's Rule', it is possible to determine the potential erosion due to sea level rise. This takes into consideration the magnitude of the sea level rise and the profile of the beach.

69. Bruun's rule will be used as a basis for determining the extent of coastal erosion due to sea-level rise where unconsolidated sands are present.

Map hazard areas

70. Once the extent of inundation and coastal erosion has been determined, the existing conditions and the appropriate climate change conditions will be mapped to determine the hazard areas for each site. These maps will assist the risk identification and analysis process as well as enabling effective communication of the outcomes. These maps will identify the 100 year ARI (Average Recurrence Interval) event, which is also known as the 1% Annual Exceedence Probability (AEP) flood event. In addition, the maps will illustrate the areas at risk of inundation or erosion during a 100 year ARI storm event (i.e. 1% AEP).

Determine condition of existing assets

71. Another important element of the risk profile of each site is the condition of existing assets. The maps illustrating the hazard areas will be used to identify the assets at risk of increased deterioration due to sea-level rise, flooding and erosion. Once these assets have been identified, a desktop assessment will be undertaken to review the following (where it is available for each site):

- Assets that are deemed to be at risk from climate change;
- Clarification of the expected future exposure conditions (associated with sea level rise and storm surge) at 2040. 2070, and 2100 for each of these assets;
- Construction history of assets, and any previous condition assessments;
- Future use requirements of assets from Defence (consequences of failure); and
- Photographic records.

72. The desktop review will analyse the data collected for each asset and identify the likely impact on service life from modelled inundation and erosion risks and the associated increase in exposure (likelihood of failure). More detailed assessments (including sampling of concrete and other materials) could be undertaken for specific assets, however these will not be undertaken as a part of this assessment.

Determine secondary impacts

Environment. Heritage and Contamination

73. Defence has an obligation to manage significant environment and heritage assets on its estate. Sea level rise, inundation and coastal erosion may affect the viability of habitats, affect heritage sites or lead to the activation and transport of existing contaminated land or groundwater. These issues may result in impacts for the Defence site or put neighbouring properties or waterways at risk (e.g. for mobilisation of contaminants from HMAS Cairns during a flood event may spread to the Great Barrier Reef World Heritage Area or the Cairns Marine Park). Using the inundation and erosion extents for each site and data gathered from stakeholders, an assessment of the likely risks related to environment, heritage and contamination will be made.

Access and Utilities

74. Using the site specific data gathered, the critical service infrastructure (including site access, power, water infrastructure, sewer infrastructure and drainage infrastructure) that services each site will be identified (i.e. service infrastructure entering or exiting the site). Following the identification of hazard areas, a qualitative assessment of the infrastructure which may be at risk for each timeframe will be undertaken. This will include determining the potential for critical infrastructure supplying the site (e.g. potable water supply, sewer, power) to be affected by either inundation or erosion. The potential risk of site access or egress being compromised during a severe weather event will also be considered.

Undertake flood damage assessment

75. Once the hazard areas have been mapped for the existing conditions and for the 2040, 2070 and 2100 climate change scenarios, assets (both natural and built) which are within the hazard zones will be identified. Where data is able to be obtained (either from Defence or through the follow up site survey), the finished floor level (FFL) for buildings will be compared to the flood level at that location, to determine the depth of 'above floor flooding'.

76. The results of the flood damage assessment will be represented in GIS format. These maps will be prepared for the existing conditions and for the 2040, 2070 and 2100 climate change scenarios.

77. A report will be prepared to accompany these figures. This report will include a commentary on the assets within the hazard zone at each base, and how climate change may affect the inundation or erosion of these assets. No economic assessment of the damages will be undertaken within the scope of this study.

2.3.2 Review Current Controls

78. Consideration will be given to the existing controls that are in place to manage risk. Controls may include regular monitoring programs, scheduled service or maintenance or replacement programs. For example if an area of a site periodically floods, current controls could include keeping drainage structures clear of debris and detouring traffic around affected areas. For each risk, relevant controls that are in place will be identified and consideration will be given to their effectiveness in managing the current level of risk.

2.3.3 Rate the Consequences

79. Appropriate estimations of consequences ensures that risks which could cause significant loss or disruption, but which have a low likelihood rating, gain the necessary priority (through a high overall risk rating) to ensure that they are prepared for and managed. Consequence evaluations also ensure that risks which are highly likely, but have little consequence, are acknowledged without being prioritised.

80. The hazard maps developed in Step 3 will be used to inform the consequence rating process. Factors to consider in determining consequence ratings for climate change risks are provided below:

- Timing - The timing of the extreme event or risk occurrence, such as day or night, weekday or weekend, can determine the number of people and services effected and therefore exacerbate the consequence of the risk;
- Changes in base population - The number of people potentially affected can change over time as base populations change. Consequence ratings should be re-evaluated over time to reflect these changes;
- Location - Where a risk occurs can significantly affect its consequence. For example, if a base of high importance is affected or critical infrastructure is interrupted, the significance of that risk occurring in one area over another could vary greatly;
- Cascading consequences - Understanding the flow-on implications of risks provides a 'systems' view of the risk sequence and helps to provide a comprehensive appreciation of the full spectrum of risks and their relationship to each other. This approach also allows the assessment to identify 'hub risks' which have many flow-on effects that therefore should be prioritised for management and mitigation of the subsequent effects; and
- Concurrent events - Appreciating the possibility of multiple risks or events occurring simultaneously, whether climate related (e.g. a storm surge event) or not climate related (e.g. equipment failure) can ensure appropriate preparation for small likelihood but extreme consequence situations.

81. The consequence of a given risk is rated on a descending scale (negligible (21), minor (16), moderate (11), major (6) or severe (1)). In determining the consequence rating, each Dimension outlined in Section 2.1.3 will be considered. As explained previously, these dimensions represent Defence's priority areas, and when combined with consequence scales, enable the consequence of the risk to be described in relation to Defence's long term objectives.

82. Table 3 provides guidance for assessing the consequence of risks. This guidance has been prepared to enable comparisons of consequence ratings between dimensions (i.e. a 'severe capability' consequence is comparable with a 'severe reputation' consequence). When the consequences of a risk relate to multiple dimensions, the rating given will be that of the Dimension that receives the greatest consequence or lowest score (e.g. if a risk has a minor (16) 'Financial' consequence and a severe (1) 'Capability' consequence then the rating for that risk would be severe (1)). A short statement justifying the consequence rating given to each of the identified risks will be provided.

83. If a risk has no consequence for a particular Dimension it will be allocated an NIA rating.

2.3.4 Rate the Likelihood

84. Factors to determine the likelihood ratings for climate change risks are listed below:

- Timing - Climate science generally considers changes to climate variables over time. Such changes over time can suggest an increase in the likelihood of a risk transpiring over that timeframe. The timeframes used for this assessment will be 2040, 2070 and 2100;
- Climate data inputs (including emissions scenarios)- Consideration will be given to the climate data used as inputs into the determination consequences. This data may be specific projections (e.g. from 'A1 FI' or 'B 1' scenarios) or information from other published studies or assessments;
- Causal relationships - If a risk occurring would be the direct result of another occurrence then its likelihood is based on that of its catalyst. For example loss of power to a site may disrupt flood mitigation pumping. Therefore, if the likelihood of power being cut to the site is 'possible', then the likelihood of flood mitigation pumping being disrupted should also be 'possible'; and
- Uncertainty vs. confidence - Using modelled climate variables presents a range of uncertainties, which requires a flexible and creative approach (Commonwealth of Australia, 2009). The degree of uncertainty differs between variables, with some more certain than others. Where the collective body of research provides projections of similar outcomes, this contributes to the level of overall confidence in the change. Focusing on confidence, rather than uncertainty, allows for informed estimations of probability as well as prudent and diligent risk management.

85. The risk assessment includes an assessment of the likelihood of the risk occurring for the proposed time horizon (i.e. 2040, 2070 and 2100) that would result in the identified consequences. A statistical analysis will be undertaken to consider the likelihood of a given consequence (i.e. flood extent) based on the probability of the projections. A short justification of the likelihood rating given to each identified risk will be documented and rated in line with the guidance provided in Table 4.

2.3.5 Level of Risk

86. The qualitative risk level for each identified risk (e.g. 'Very High' or 'Medium') will be determined by combining the consequence and likelihood rating in accordance with the risk assessment matrix provided in Table 5. Contrary to ISO 3100:2009 the higher the score, the lower the risk. This approach has been taken to ensure consistency with the Department of Defence *Estate Risk Assessment Guidance - For Estate Maintenance (4_250 Estate Risk Assessment Guidance 110118.doc).* For example:

- A risk assessed as having a "Major" Consequence and a "Possible" likelihood is allocated a Risk Level of HIGH and a Score of 11; and
- A risk assessed as having a "Severe" Consequence and an "Unlikely" likelihood is also allocated a Risk level of HIGH and has a Score of 8.

2.4 Step 4: Evaluate Risks

87. The next steps for Defence in the risk management process will be to evaluate the risks, determine which risks are acceptable, and which risks require treatment and are a priority for such treatment. The evaluation includes a review of the risk ratings to ensure they are consistent across sites and themes. Any risks found to have been over-rated or under-rated will be adjusted to show the agreed priority.

88. Once the risk ratings have been evaluated and finalised. consideration will be given to the priority of response. The following are the example default management responses in relation to **assessed risk** levels (Commonwealth of Australia, 2006):

- Very **High** risks demand attention at the most senior level and cannot be simply accepted as a part of routine operations without executive sanction;
- **High** risks are the most severe that can be accepted as a part of routine operations without executive sanction but they will be the responsibility of the most senior operational management and reported upon at the executive level;
- **Medium** risks can be expected to form part of routine operations but they will be explicitly assigned to relevant managers for action, maintained under review and reported upon at senior management level; and
- **Low** risks will be maintained under review but it is expected that existing controls will be sufficient and no further action will be required to treat them unless they become more severe.

89. For this assessment, adaptation options will be developed for risks identified as medium, high and very high in 2040.

2.5 Step 5: Treat Risks (Adaptation)

90. The aim of adaptation planning is to identity and prioritise solutions to reduce the identified risks to each site. Adaptation options may include:

- Re-design of built infrastructure (e.g. roads, bridge, buildings, in-ground infrastructure);
- Relocation of built infrastructure (e.g. roads, bridge, buildings, in-ground infrastructure);
- Shore protection (e.g. seawalls, gabions);
- Protection of select key infrastructure;
- Protection of natural and heritage assets (e.g. vegetation); and
- Relocation of utilities (e.g. water treatment and supply, electricity, telecommunications).

91. The following hierarchy will be used to identity adaptation options:

1. Avoiding the risk;
2. Removing the source of the risk;
3. Changing the likelihood;
4. Changing the consequences;
5. Transferring or sharing the risk with other parties; and
6. Accepting the risk.

92. A workshop (within the AECOM project team) with individuals with expertise in climate change, coastal engineering and the Defence estate will be used to develop a comprehensive list of adaptation options. For each adaptation option an indicative estimate of the cost and likely implementation timeframe will be identified. This ideas development process will be supplemented by input from Defence stakeholders through on-site workshops.

93. Having a range of adaptation solutions is not enough to enable decision making, even when supported by a robust risk assessment process - they must also be prioritised for implementation. A Multi-Criteria Analysis (MCA) of adaptation options for the site was undertaken to provide this. The criteria, score and definitions used presented in Table 9.

94. For each adaptation option, the scores for each criterion were added to reach an overall priority rating score, with the 'urgency' criterion weighted (x2) to add emphasis to the most urgent actions to reduce risk. Consistent with the risk rating process, the lower the score, the higher priority for implementation. The overall priority rating score was used as a first filter to rank and assess the potential timing for implementation of adaptation options. Defence should consider existing programs and budgetary commitments before finalising the timing for implementation of each adaptation option.

95. The adaptation options with a priority rating score of 10 or less (60%+ of the potential ratings score) should be prioritised for implementation in the short term within the next 5 years. The adaptation options with a priority rating score of greater than 10 should be reviewed every 5 years and re-assessed for potential implementation based on any change in the rate of sea level rise or changes to site operations (function and activities).

Table 9 Adaptation prioritisation criteria and weighting.

	High (1)	Medium (2)	Low (3)
Effectiveness to Reduce Risk	High potential to reduce risk to multiple Defence operations and / or asset types and / or to reduce multiple risks	Moderate potential to reduce risk to a Defence operation and / or asset	Potential to reduce risk is low or uncertain
Cost	Cost is Minor ($0-$500K)	Cost is Moderate ($500K-$15M)	Cost is Major (>$15M)
Significance of action	Several adaptation actions rely on this being done first or they will no longer be required if this action is implemented or is the primary treatment of risk to a critical asset	Another adaptation action relies on this being done first or implementation means another adaptation action may no longer be required	Does not influence or is not necessary to support other adaptation actions
Community Acceptance	Potentially no conflict with communities for implementation and / or will provide broader social and environmental benefits	Possible conflict with communities for implementation and / or may provide broader social and environmental benefits	Likely conflict with communities for implementation and / or may generate negative social and environmental impacts
Urgency weighting	Should be completed within the next 10 years to avoid current risk	Should be completed before 2040 to avoid risk	Should be completed before 2070 to avoid risk

96. Some adaptation options may not be needed if other more significant options have been implemented. For example the implementation of whole of site flood protection (levee and pumping around whole site) may negate the benefit (or risk reduction) of implementing a levee for just a portion of the site.

3.0 Monitoring and Review

97. Each step of the process requires review to ensure that:

- The findings are correct. accurate and up to date (including technical information, standards and climate projections);
- Agreed actions arising from the risk assessment are completed, including more detailed studies or assessments of particular risks, as required; and
- The process is carried out within the required timeframe and adheres to the objectives set out in Step 1 - Establishing the Context.

98. Internal project reviews will be undertaken at the completion of each Step. Project update memos will be issued fortnightly to Defence to ensure ongoing monitoring of the delivery of each step.

99. Formal reviews from Defence will be sought at the following steps:

- Step 1: review and confirmation of this site assessment methodology and framework;
- Step 3: through the onsite workshops and engagement input will be sought on the initial identification and analysis of risks; and
- Step 5: following the provision of a draft report presenting the findings and recommendations for the assessment a workshop will be held to gather feedback from Defence. There will also be an opportunity after the workshop for Defence to consider the report and provide a consolidated set of feedback before the assessment is finalised.

100. Beyond this assessment, ongoing monitoring and review of risks and adaptation planning needs to occur. This will need to include monitoring of changes to climate projections and observed rates of change in sea level. For example, if the rate of observed sea level rise increases to the point that projections used for 2040 are likely to be significantly surpassed, then the adaptation solutions for 2070 will need to be reviewed and potentially brought for.vard for early implementation.

4.0 Consultation and Communication

4.1 Consultation

101. Consultation is an important part of the risk management process. Consulting with relevant stakeholders adds value to each stage of the process to gain input and verify findings. In identifying the people who may contribute to the process, those undertaking the risk assessment should consider if they:

- Are a source of relevant information on either Defence, its activities, climate change or specific technical processes or assets;
- Are an owner or manager of key assets or capabilities;
- Have authority to implement or influence outcomes from the risk assessment; or
- Will assist in the efficient delivery of the process through allocation of resources or authority to access information or physical locations.

102. In addition to the site specific engagement activities listed in section 2.3.1, a Canberra based workshop will be facilitated to consider the broader context and potential implications of the findings for Defence, including potential national level policy responses and other uses of the findings (i.e. training or communication).

4.2 Communication of Findings

103. The findings of the assessment will enable Defence to understand their risk exposure and identify adaptation measures to minimise these future risks. The findings will be important for informing investment and strategic planning decisions.

104. This section provides high level guidance on the communication of the assessment's findings to ensure opportunities for more informed decision-making are not missed. This guidance is structured around the project deliverables (i.e. communication tools) as outlined in Table 10. The need to develop a formal communication plan should be assessed upon the completion of project and as more specific communication issues are identified.

105. There are likely to be sensitivities associated with the communication of Defence·s risk exposure due to the nature of the risks likely to be identified. These sensitivities include scepticism of the findings, accessibility of information to support decision-making and broader stakeholder communication.

106. The risk of scepticism will be addressed through the implementation of a robust methodology to guide the implementation of the assessment (this document), provision of technical findings and through the review of the methodology and the assessment's findings by technical industry leaders external to the project team. This review process will be referenced in the Executive Report and Assessment Report.

107. To ensure the findings are accessible to support decision making, they will be presented for both technical and non-technical audiences. For example, the development of Site Reports will contain site specific technical detail providing tailored information to site or regional officers. The Site Summary Sheets will provide the findings in a non-technical way to assist in broader stakeholder engagement.

Table 10 Guidance on the communication of climate risk and adaptation findings.

Communication Tool	Description of Tool	Audience	Purpose of Communication
Executive Report	A brief report providing an outline and summary of the findings of the Assessment Report	- Executive Committees (e.g. Defence Environment Management Forum) - Regional Forums (e.g. Senior Environment Manaaer Forum)	- Communicate key strategic risks and opportunities to senior decision-makers and the Minister
Assessment Report	A report detailing the methodology, findings (including risk themes) and recommendations of the assessment	- Directorate Leaders (e.g. in Estate Strategic Planning Branch, Environment and Engineering Branch and Capital Facilities and Infrastructure Branch)	- **Raise awareness** - Reference document - Develop cooperation and advocacy for adaptation planning - Inform strategic adaptation and planning decision makina
Site Report (including GIS plans)	A report detailing the site specific findings including the results of each assessment, ratings for all risk themes across all timeframes, recommendations and supporting GIS plans	- Senior ADF Officers - Local Defence Support Group representative - Regional or Site Environment Officers	- Develop cooperation and advocacy for adaptation planning - Influence policy and behaviour change - Inform site specific adaptation and planning decision makina
Site Summary Sheet	A brief document providing a visual summary of the site specific findings	- Senior ADF Officers - Local Defence Support Group representative - Regional or Site Environment Officers	- **Raise awareness**
Multimedia Presentation of findings (i.e. slide show)	An electronic slideshow providing an outline and summary of the findings of the Assessment Report	- Executive Committees (e.g. Defence Environment Management Forum) - Regional Forums (e.g. Senior Environment Manaaer Forum)	- **Raise awareness**
Site Fact Sheet	A brief document providing concise summary information relating to the site specific findings	- Senior ADF Officer - Local Defence Support Group representative - Regional or Site Environment Officers	- Develop cooperation and advocacy for adaptation planning - Influence policy and behaviour change

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Appendix A

Glossary

Appendix A Glossary

A1FI	IPCC global emissions scenario that assumes a 'Fossil Intensive' future with relatively high greenhouse gas emissions
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoE	Department of Environment
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FACOPS	Facilities Operations
GST	Goods and Services Tax
IPCC	Intergovernmental Panel on Climate Change
OH&S	Occupational Health and Safety
SLR	Sea Level Rise
Storm Surge	The increase in sea level due to a severe storm event. This includes an allowance for barometric pressure changes and wind. The storm surge estimates are based on past historical storm events and are taken to be the 1 in 100 year ARI storm event where available

Appendix B

Risk Assessment Table

Appendix B

Table 11 Example risk identification and analysis table, including two example risks.

		2040			2070			2100	
Risk description	**Consequence**	**Likelihood**	**Risk Ratin g**	**Consequence**	**Likelihood**	**Risk Ratin g**	**Consequence**	**Likelihood**	**Risk Rating**
Buildings									
Damage to structural integrity of coastal buildings due to storm surges undermining footings and erosion caused by tidal movements	Minor 16 (capability)	Possible 5	**Medium 21**	Moderate 11 (capability)	Almost Certain 1	**High 12**	Major6 (capability)	Almost Certain 1	**Very High 7**
Site Access and Internal Roads									
Inundation, erosion and storm surge causing internal roads to be inundated and eroded, temporarily or permanently restricting access.	Moderate 11 (capability)	Almost Certain 1	**High 12**	Moderate 11 (capability)	Almost Certain 1	**High 12**	Moderate 11 (capability)	Almost Certain 1	**High 12**
Pier and Marine Infrastructure									
Runways and Aviation Infrastructure									
Utilities									
Environmental Assets									
Contamination									
Heritage									

Appendix B

Site Summary Sheets

Appendix B Site Summary Sheets

Phase 1

- HMAS Cairns. Qld
- RAAF Base Townsville, Qld
- Garden Island West/ HMAS Stirling, WA

Phase 2

- RAAF Base Learmonth, WA
- Defence Establishment Harold E Holt, WA
- Cocos (Keeling) Islands, IOT

Phase 3

- Bulimba Barracks, Qld
- Damascus Barracks, Qld
- RAAF Base Williamtown, NSW

Phase 4

- Point Wilson Explosives Area, Vic
- Swan Island, Vic
- Garden Island Defence Precinct, NSW

Phase 5

- Proof & Experimental Establishment Port Wakefield, SA
- St Kilda Transmitting Station, SA

HMAS CAIRNS

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Maritime operations	Berthing facilities, maintenance facilities, medical centre, training facilities	RAN
Accommodation	Messing accommodation, offices	RAN
Logistics	Wharfs, storage facilities, fuel storage, refuelling facilities	RAN

HMAS Cairns is 6.6 ha in size and is located 1 km south of the Cairns CBD. HMAS Cairns is a Fleet Base in operational support of Royal Australian Navy Patrol Boats and amphibious and hydrographic ships. Base capability is supported by three other sites: the Kenny Street facility, two accommodation facilities (Northern Heritage and Las Palmas) and the Queerah Magazine and Ordinance Loading Area. Due to its proximity, the Kenny Street facility has been included in the assessment.

HMAS Cairns faces onto Trinity Inlet which provides access to the Coral Sea. The Great Barrier Reef World Heritage Area, Great Barrier Reef Marine Park and Cairns Marine Park are adjacent to this site. One heritage building is listed on this site (TS Endeavour). The site contains no listed environmental assets. Environmental values are limited to areas of recruiting mangroves on the seawall and surrounds and the Commonwealth protected migratory bird species which occasionally stop on the foreshore areas and mudflats.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 1 in 100 year stonn surge and extreme rainfall event was assessed at the site. The risk of coastal erosion was not assessed due to the protected location of the site and its rock wall shoreline.

This site is currently prone to inundation during extreme rainfall events and cyclones resulting in the suspension of operations.

In 2040, there is a Very High risk that inundation and storm surge impacts will damage some roads, and restrict access to the site and the use of internal roads, reducing base capability.

In 2040, some buildings are at High risk of inundation, increasing to Very High in 2100. Inundation will damage and degrade above and below ground structures.

Inundation may damage electricity, communications, water and sewerage utilities, reducing base capability.

In 2100, pier and marine infrastructure are at Very High risk from inundation and storm surge damage and loss of access to berthing facilities and wharfs. Safe operation of berthing facilities and wharfs may be restricted.

SUMMARY OF ADAPTATION OP·TIONS

Current site constraints, including existing inundation issues will potentially limit the long term value of adaptation investment in this site. Identified adaptation options focus on minimising the consequences of inundation events over the next 60 years to allow relocation of base capabilities to other sites. Adaptation options include:

- Adjust design for new works or development of buildings, pier, marine infrastructure and utilities to incorporate greater allowance for marine and estuarine flooding.
- Review and adjust maintenance specifications and monitoring to account for increased damage and corrosion.
- Accept flooding in low lying buildings and move activity and function to another part of the site or region. Buildings suggested for activity or function relocation are those affected in 2040, such as those at the Kenny Street Facility.
- Increase the drainage capacity, pumping and outfall levels in the south west drainage system.
- Raise the height of building floor levels. The redevelopment of the built assets should be staged to respond to the rate of sea level rise.

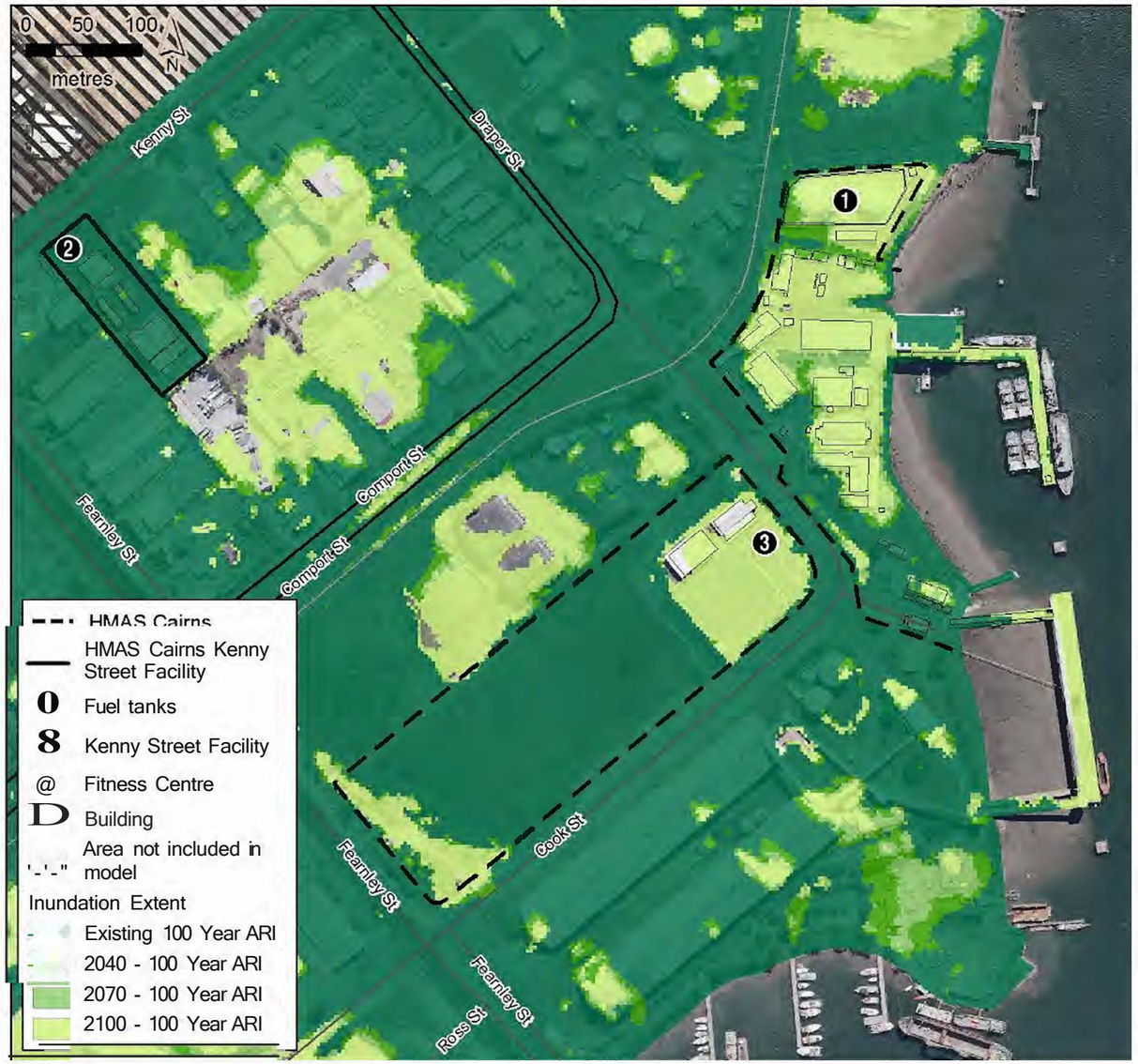

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall event at HMAS Cairns (and the Kenny Street Facility) for existing conditions, 2040, 2070 and 2100.

HMAS CAIRNS

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	2.14m	2.34m	2.59 m	3.57 m
Increase in run off due to extreme rainfall	-	20%	30%	40%
Coastal erosion (m recession)		Not assessed at this site		
Buildings Inundation and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		**High 12** L-A1 C-M11 (capability)	**Very High 7** L-A1 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation and storm surge impacts restricting access to site, use of internal roads and damaging roads, reducing base capability.		**Very High 7** L-A1 C-M6 (capability)	**Very High 7** L-A1 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Damage and loss of access to berthing facilities and wharfs from inundation and storm surge events reducing base capability and functionality. The ability to safely operate berthing facilities and wharfs may be restricted by inundation.		**Medium 16** L-P5 C-M11 (capability)	**Medium 16** L-P5 C-M11 (capability)	**Very High 2** L-A1 C-S1 (capability)
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		N/A	N/A	N/A
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.		**High 11** L-P5 C-M6 (capability/ OHS)	**High 11** L-P5 C-M6 (capability/ OHS)	**Very High 2** L-A1 C-S1 (capability/ OHS)
Environmental Assets The site contains no listed or indicative environmental assets or remnant vegetation.		N/A	N/A	N/A
Contamination Inundation may result in the mobilisation of contamination into surrounding soils, groundwater and Trinity Inlet.		**Medium 21** L-P5 C-M16 (E&H)	**Medium 21** L-P5 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)
Heritage Inundation may damage or degrade historic heritage values.		**Medium 21** **L-P5** **C-M16** (E&H)	**Medium 17** **L-A1** **C-M16** (E&H)	**Medium 17** **L-A1** **C-M16** (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. OmAHD was mean sea level in 1971. The changes in storm surge levels include sea level rtse and do not indude consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prtoritised under the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the charactertstics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, pier and marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and/or foundations/footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, wharf and marine infrastructure, site access and internal roads, and utilities.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as buildings, pier and marine infrastructure and roads. The maintenance treatments may need to be more proactive to prevent an acceleration of asset degradation. Options include increasing the strength of protective coatings of assets exposed to higher groundwater and salt water concentrations.	Buildings, wharf and marine infrastructure, site access and internal roads, utilities, contamination, and heritage.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20%.
Relocate activities and functions Accept flooding in low lying buildings and move activity and function to another part of the site or region. Buildings suggested for activity function relocation are those affected in 2040, such as the Kenny Street Facility.	Buildings.	$1 00K-$200K to develop relocation masterplan. Specific relocation costs will be dependent on asset function and remediation requirements.
South west drainage upgrade Increase the drainage capacity, pumping and outfall levels in the south west drainage system.	Buildings, and utilities.	$1.1 M to construct new drainage channel, install pump station and revegetate.
Building protection works Undertake building protection works, including improved asset drainage, tanking protection works and raising height of building floor levels. This redevelopment of the built assets should be staged to respond to the rate of sea level rise.	Buildings.	$SOK- $100K to plan and design height changes, depending on number of assets. The cost of implementing physical changes would be dependent on the specific structures, their use, and height change required.
Raise height of access roads Engage with relevant authorities to raise key access roads across Cairns.	Site access and internal roads	Negligible cost to undertake engagement.

RAAF BASE TOWNSVILLE

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Airfield operations	Runways, taxiways, operations buildings, flight apron, hangars, maintenance facilities, fuel storage	RAAF, Army
Logistics	Storage facilities	RAAF, Army
Accommodation	Messing accommodation, offices	RAAF,Army
Training	Education facilities	RAAF, Army

RAAF Base Townsville is 4 km west of the Townsville CBD and 0.2 to 3 km from the coast, and enables the concentration and mounting of ADF operations from Australia's north-east. The site is a joint user airfield and provides civilian domestic air services for Townsville. It has an extensive network of roads and some suburban style infrastructure.

The site is on a coastal flood plain with an elevation of between 2 to 5 mAHD, and contains a nationally important wetland. Although there are no protected heritage assets on the site, it has high heritage value. An ephemeral wetland west of site is listed on the register of National Estate. Soil and groundwater contamination exists on site.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 1 in 100 year storm surge and extreme rainfall event was assessed at the site. The risk of coastal erosion was also assessed.

A majority of the undeveloped areas of the site are currently at risk of combined 1 in 100 year storm surge and extreme rainfall events. This hazard area will increase in 2040 and 2070, covering most built assets in 2100.

Coastal erosion is not likely to affect the base in the time periods assessed, encroaching only to Cape Pallarenda Road, north of the site.

As the site has low elevation, there is a Very High risk of some building inundation in 2040. Inundation is likely to damage, degrade and destabilise above and below ground building structures.

Risks to some internal roads, runways, taxiways and supporting aviation infrastructure will increase from High in 2040 and 2070 to Very High in 2100.

In 2040 there is a High risk that inundation will disrupt some power, water and sewerage utilities, restricting capability. Inundation may also mobilise existing soil contaminants affecting environmental values in the adjacent site. This risk will increase to Very High in 2100.

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for RAAF Base Townsville focus on keeping the water out of the site to protect assets:

- Adjust designs for new works or redevelopment of buildings, aviation infrastructure and utilities.
- Review maintenance specifications and monitoring to account for increased damage and corrosion.
- Increase flood protection and drainage capacity along north, west and south site perimeters {e.g. use perimeter roads as levees and install flood gates and pumps).
- Accept flooding in low lying areas and move activity and function to another part of site or region.
- Review guidance for storage of critical and/or hazardous materials in structures at risk of inundation.
- Increase the flood protection and drainage capacity along the eastern perimeter, east of the taxiway.
- Periodically review emergency management plans to respond to an increased scale of inundation impacts and where required, increase response capacity.

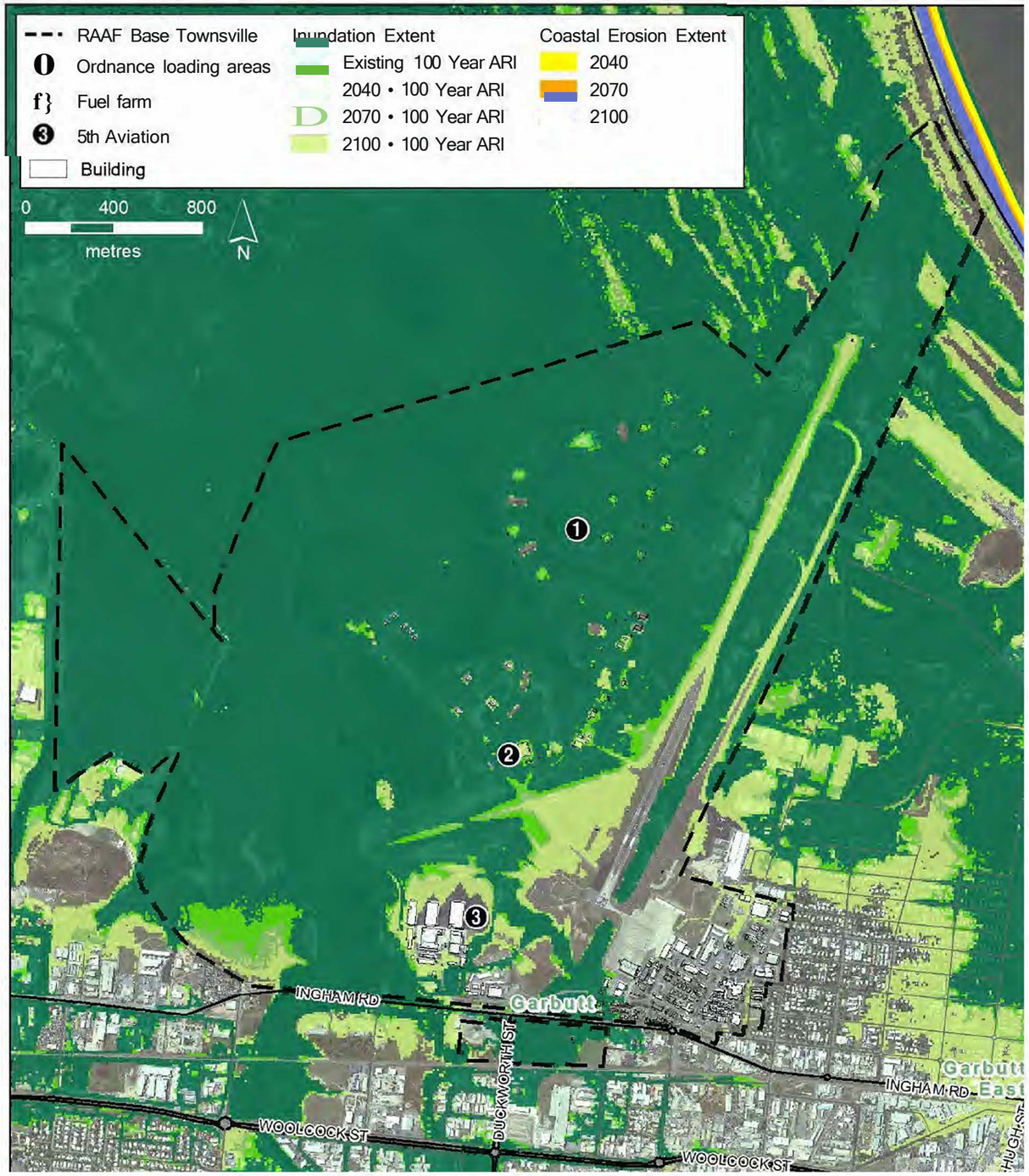

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall event and erosion extents at RAAF Base Townsville for existing conditions, 2040, 2070 and 2100.

RAAF BASE TOWNSVILLE

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	3.00 m	3.20 m	3.45m	4.43 m
Increase in run off due to extreme rainfall	-	**20%**	30%	40%
Coastal erosion (m recession)	-	28m	41 m	95m
Buildings Inundation and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation and storm surge impacts restricting use of internal roads and damaging roads, reducing base capability.		High 12 L-A1 C-M11 (capability	High 12 L-A1 C-M11 (capability	Very High 7 L-A1 C-M6 (capability)
Pier and Marine Infrastructure There is no pier or marine infrastructure at this site.		**NIA**	**N/A**	**N/A**
Runways and Aviation Infrastructure Inundation and storm surge impacts restricting use of and damaging runways, taxiways and supporting infrastructure, reducing base capability.		High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 2 L-A1 C-S1 (capability)
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage reducing base capability and functionality.		High 9 L-L3 C-M6 (capability/ OHS)	Very High 7 L-A1 C-M6 (capability/ OHS)	Very High 2 L-A1 C-S1 (capability/ OHS)
Environmental Assets Potential degradation of wetland habitats.		**Low23** L-P7 C-M16 (E&H)	**Low23** L-P7 C-M16 (E&H)	**Low23** L-P7 C-M16 (E&H)
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and neighbouring properties.		**Medium 16** L-P5 **C-M11** (E&H)	**Medium 14** L-L3 **C-M11** (E&H)	Very High 7 L-A1 C-M6 (E&H)
Heritage Inundation may damage historic built heritage values.		**Low26** L-P5 C-N21 (E&H)	**Low26** L-P5 C-N21 (E&H)	**Low26** L-P5 C-N21 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 mAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not indude consideration of changes in other dimatic factors (e.g. wind speed, southward tracking of cyclones, etc). Coastal recession is due to storm surge, longsllore transport and recession due to sea level rise. The selection process for dimate projections was consistent ,,;;tt, guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been priOfitised IIlder the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics Oe. assets and capabili1y) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, aviation infrastructure and utilities (including drainage, plumbing, sewerage, telecommunications). This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and/or foundations/footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets, contamination and heritage.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as runways, roads and buildings. Maintenance treatments may need to be adjusted to prevent an acceleration of asset degradation. Options include increasing the strength of protective coatings of assets exposed to higher groundwater and salt water concentrations.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets, contamination and heritage.	$50K-$100K to adjust central maintenance specifications.
Flood protection - north, west and south of runway Increase the flood protection and drainage capacity around the western, northern and southern fringe of the site using the perimeter roads where practical as levees and install supporting flood gates and pumps. This will assist in limiting the volume of water entering the site from the west and south of the site. The design should consider potential destabilisation issues posed by increases in groundwater levels. The levee should run from the northern end of the runway along the western and south-western perimeter roads and along the southern perimeter road (parallel with Ingham Road) to Area F Office and GE Workshop.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets, contamination and heritage.	$13.5M for design and construction of 9.5 km of levees and installation of pumping system.
Relocate activities and functions Accept flooding in low lying areas and move activity and function to another part of site or region. Buildings and facilities suggested for activity or function relocation are those impacted by the existing extreme flood level. Remediation of any contamination at vacated sites should accompany relocation of activities and functions especially where mobilisation of contamination into surrounding soils, groundwater and marine environment may occur.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities and contamination.	$1 00K-$200K to develop relocation masterplan. Specific relocation costs will be dependent on asset function and remediation requirements.
Storage of hazardous materials guidance Review guidance for the storage of critical and/or hazardous materials within structures located in defined inundation boundaries. Determine alternative locations for storage of hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.
Runway flood protection - the eastern taxiway Increase the flood protection and drainage capacity along the eastern perimeter of the site on the eastern side of the taxiway.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets, contamination.	$1.5M to construct 2.1 km drainage channel.
Review emergency management plans Periodically review emergency management plans to respond to an increased scale of inundation impacts and where required, increase the response capacity.	Buildings, site access and internal roads, runways and aviation infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of these plans.

GARDEN ISLAND WEST/ HMAS STIRLING

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Maritime operations	Naval and submarine berthing facilities, magnetic measurement facilities, maintenance facilities, fuel storage	RAN
Accommodation	Live in and messing accommodation, offices	RAN
Logistics	Wharves, armament and other storage facilities	RAN
Operations	Command Buildings and Communication Centre (ADF) Helicopter airfield, fleet support, naval aviation	RAN
Training	Education facilities, Fire Ground, Sub-escape, Submarine Escape Training Centre, Training unit and ANZAC support centre	RAN

Located in Cockburn Sound, 60 km south-west of Perth, Garden Island West/ HMAS Stirling covers approximately 1092 ha housing Navy's west coast operations. Concentrated largely on the southern section, occupying approximately 30% of the island, it is the largest RAN base. HMAS Stirling provides operational and logistical support to RAN ships, submarines and aircraft. Access to the island is via a causeway.

Garden Island is Commonwealth Heritage Listed for its natural and European heritage values.

SUMMARY OF RISKS

The risk of coastal erosion and inundation from sea level rise and a 1 in 100 year storm surge was assessed at the site. Extreme rainfall events do not pose inundation risks due to the island's sandy soils.

Currently, flooding from storm surge events is restricted to the immediate coastal area.

Some site access, internal roads and pier and marine infrastructure are at High **risk** of inundation from sea level rise, storm surge and coastal erosion in 2040 and 2070, with risks increasing to Very High in 2100. Inundation and erosion will damage and restrict access to, and safe operation of, marine infrastructure.

There is a High risk of inundation and erosion restricting access to, and damaging, some buildings in 2070, increasing to Very High in 2100.

In 2040 and 2070, there is High risk that inundation will disrupt or damage some electricity, communications, water and sewerage utilities, reducing base capability. This **risk** increases to Very High in 2100.

In 2100, there is a Very High risk that European heritage assets will be damaged.

SUMMARY OF ADAPTATION OPTIONS

Adaptation options focus on protecting access to the site and use of marine infrastructure and minimising the impacts of erosion. In the longer term relocation of a portion of Dampier Road and some buildings in the accommodation area may be required. Priority adaptation options are:

- Adjust the design specifications for any new works or development of buildings, pier and marine infrastructure and utilities to incorporate greater allowances for marine flooding.
- Review maintenance specifications and monitoring to account for increased damage and corrosion.
- Increase the flood protection and drainage capacity along Dampier Road and the Karangie Loop.
- Establish natural erosion protection interventions to protect Grenaier Road and Dampier Road access to the Armaments Wharf and its abutment.
- Accept flooding in low lying areas and move activity and function to another part of site or region.

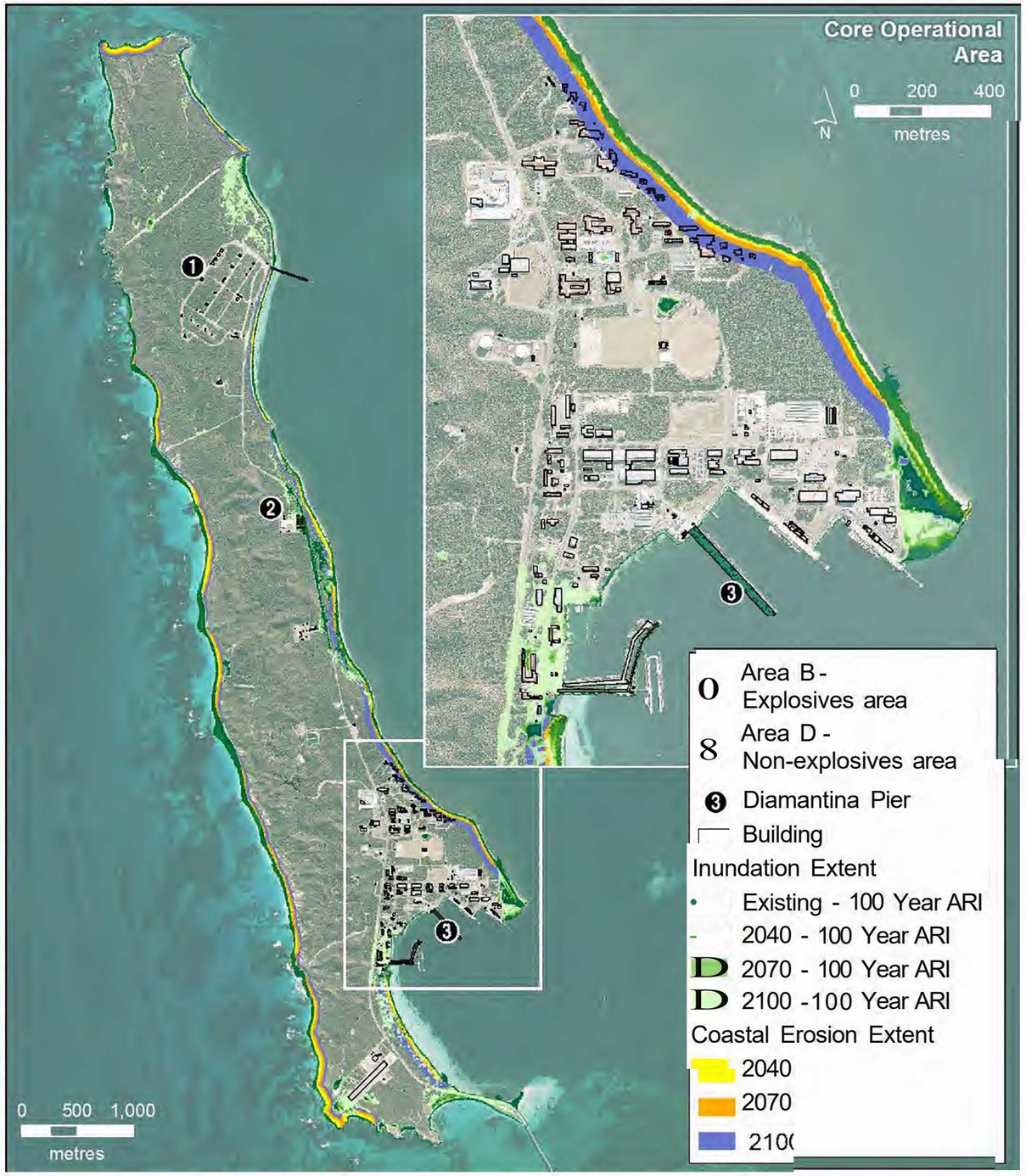

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall event and erosion extents at Garden Island West/ HMAS Stirling for existing conditions, 2040, 2070 and 2100.

GARDEN ISLAND WEST/ HMAS STIRLING

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge (m)	1.56 to 3.27	1.76 to 3.47	2.01 to 3.72	2.99 to 4.70
Increase in run off due to extreme rainfall		Not assessed at this site		
Coastal erosion (m recession)	-	up to 47	up to 69	up to 91
Buildings Inundation, erosion and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		**Medium 17** **L-A1** **C-M16** **(capability)**	**High 12** L-A1 C-M11 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, erosion and storm surge impacts restricting access to site, use of internal roads and damaging roads, reducing base capability.		**High 9** L-L3 C-M6 (capability)	**High 9** L-L3 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Damage and loss of access to berthing facilities and wharfs from inundation, erosion and storm surge impacts reducing base capability and functionality. The ability to safely operate berthing facilities and wharfs may be restricted by inundation.		**High 9** L-L3 C-M6 (capability)	**High 9** L-L3 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Runways and Aviation Infrastructure Inundation and erosion may restrict use of and damage the Helicopter Support Facility, runway reducing capability.		**Low 23** L-U7 **C-M16** (capability)	**Low 23** L-U7 **C-M16** (capability)	**Medium 21** L-P5 **C-M16** **(capability)**
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.		**High 9** L-L3 C-M6 (capability)	**High 9** L-L3 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Environmental Assets Significant environmental assets are assumed to be in the elevated portions of the site unlikely to be at risk.		**Low28** L-U7 **C-N21** (E&H)	**Low28** L-U7 **C-N21** (E&H)	**Low28** L-U7 **C-N21** (E&H)
Contamination Inundation and erosion may result in the mobilisation of contamination into soils, groundwater and marine environment.		**Medium 21** L-P5 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)	High 12 L-A1 C-M11 (E&H)
Heritage Inundation and erosion may damage European Settlement heritage assets.		**Low23** L-U7 C-M16 (E&H)	**Low23** L-U7 C-M16 (E&H)	**Very High 4** L-L3 C-S1 (E&H)

The heights ciffer between the east and west coast of the island. Extreme sea level heights are in metres Australian Height Datum (AHD), the datum for altitude measurement in Australia. O mAHD was mean sea level in 1971. Changes in stonn surge levels indude sea level fise and do not include consideration of changes in other climatic factors (e.g. „„;nd speed, southward tracking of cyclones, etc). Coastal recession is due to stonn surge, longshore transport and recession due to sea level fise. The selection process for climate projections was consistent „„;th guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been I)lioritised under the assumption that Defence continues to occupy the site in the longer tenn (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Options	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, pier and marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and/or foundations/footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, pier and marine infrastructure, runways and aviation infrastructure, utilities, environmental assets, contamination and heritage.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as wharves, roads and buildings. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation such as increased cathodic protection to respond to a higher splash zone due to sea level rise.	Buildings, site access and internal roads, pier and marine infrastructure, runways and aviation infrastructure, utilities, contamination and heritage.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20%.
Road flood protection Increase the flood protection and drainage capacity: • Along the middle section of Dampier Road; • Along the northern section of Dampier Road between Area B and Area D; and • Along the north-eastern section of Karangie Loop.	Site access and internal roads.	$13.7M to increase height of 4.7 km of roads assuming 15 m width and along the same alignment.
Armaments Wharf erosion protection Establish natural erosion protection interventions to protect Grenadier Road and Dampier Ave access to the Armaments Wharf and its abutment. Specifically, enhance the existing dune stabilisation with vegetation, monitor the erosion extent and use sand renourishment of the beach to reduce any permanent erosion. The existing limestone rock wall provides some initial protection but is insufficient to prevent future erosion caused by sea level rise.	Pier and marine infrastructure, site access and internal roads.	$250K for stabilisation. $SOK per annum in ongoing monitoring and renourishment.
Relocate activities and functions Accept flooding in low lying areas and move activity and function to another part of site or region. Buildings suggested for activity function relocation are those impacted by the 2040 extreme flood level. Remediation of any contamination at vacated sites should accompany relocation of activities and functions especially where mobilisation of contamination into surrounding soils, groundwater and marine environment may occur.	Buildings, site access and internal roads, pier and marine infrastructure, runways and aviation infrastructure, utilities and contamination.	$100K-$200K to develop relocation masterplan. Specific relocation costs will be dependent on asset function and remediation requirements.

RAAF BASE LEARMONTH

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Airfield operations	Runways, taxiways, flight apron, hangars, operations buildings	RAAF
Logistics	Storage facilities, fuel storage, warehouse	RAAF
Accommodation	Live in and messing accommodation, offices	RAAF

RAAF Base Learmonth is 2,550 ha in **size** and is located 32 km south of Exmouth, in the North West Cape, Western Australia. The site is on freehold Commonwealth land and is a part of a total Defence land holding of 19,000 ha in the region, with associated attached properties including the Learmonth Air Weapons Range. The Air Weapons Range has not been included in this assessment.

The site is used by the RAAF to support mounting forward operations and exercise deployments as required, but does not currently house any RAAF Units. The site contains accommodation for permanent base staff and up to 290 operational personnel, and has basic medical facilities. The site has a civilian air terminal which provides commercial aviation services, including fuel storage and support facilities for commercial airlines.

The Commonwealth and the Western Australian State Government have assigned National and World Heritage status to the North West Cape. Water for use on the site is drawn from a bore that supports several Commonwealth and state protected stygofauna species. Soil and groundwater contamination exists on site.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 100 year ARI storm surge and extreme rainfall event was assessed at the site. The risk of coastal erosion was also assessed.

The majority of the site is currently at risk of combined 100 year ARI storm surge and extreme rainfall events. The hazard area will increase in 2040 and 2070, covering the majority of built assets in 2100.

Coastal erosion is not likely to directly affect the base in the time periods assessed. In 2040 it is likely to affect the Minilya Exmouth Road and in 2100 it may affect a historic landfill on the site.

There is a Very High risk of building inundation in all three timeframes. Inundation is likely to damage, degrade and destabilise above and below ground building structures.

Risks to some internal roads, runways, taxiways and supporting aviation infrastructure are Very High across all three timeframes.

In all three timeframes there is a Very High risk that inundation will disrupt and damage electricity, water and sewerage utilities, restricting capability.

SUMMARY OF ADAPTATION OP'TIONS

The priority adaptation options for RAAF Base Learmonth focus on protecting specific assets in the short term while planning longer term measures to keep water out of the site.

- Adjust designs for new works or redevelopment of buildings, aviation infrastructure and utilities.
- Review maintenance specifications and monitoring to account for increased damage and corrosion.
- Undertake asset specific flood protection to maintain critical utilities (i.e. fuel and electricity).
- Isolate electricity and communication utilities to ensure network performance and self-sufficiency when elements of the system are affected by inundation.
- Periodically review emergency management plans to respond to an increased scale of inundation impacts and where required, increase response capacity.
- Commence planning for increasing the height of the existing levee along the north, east and south site perimeters.

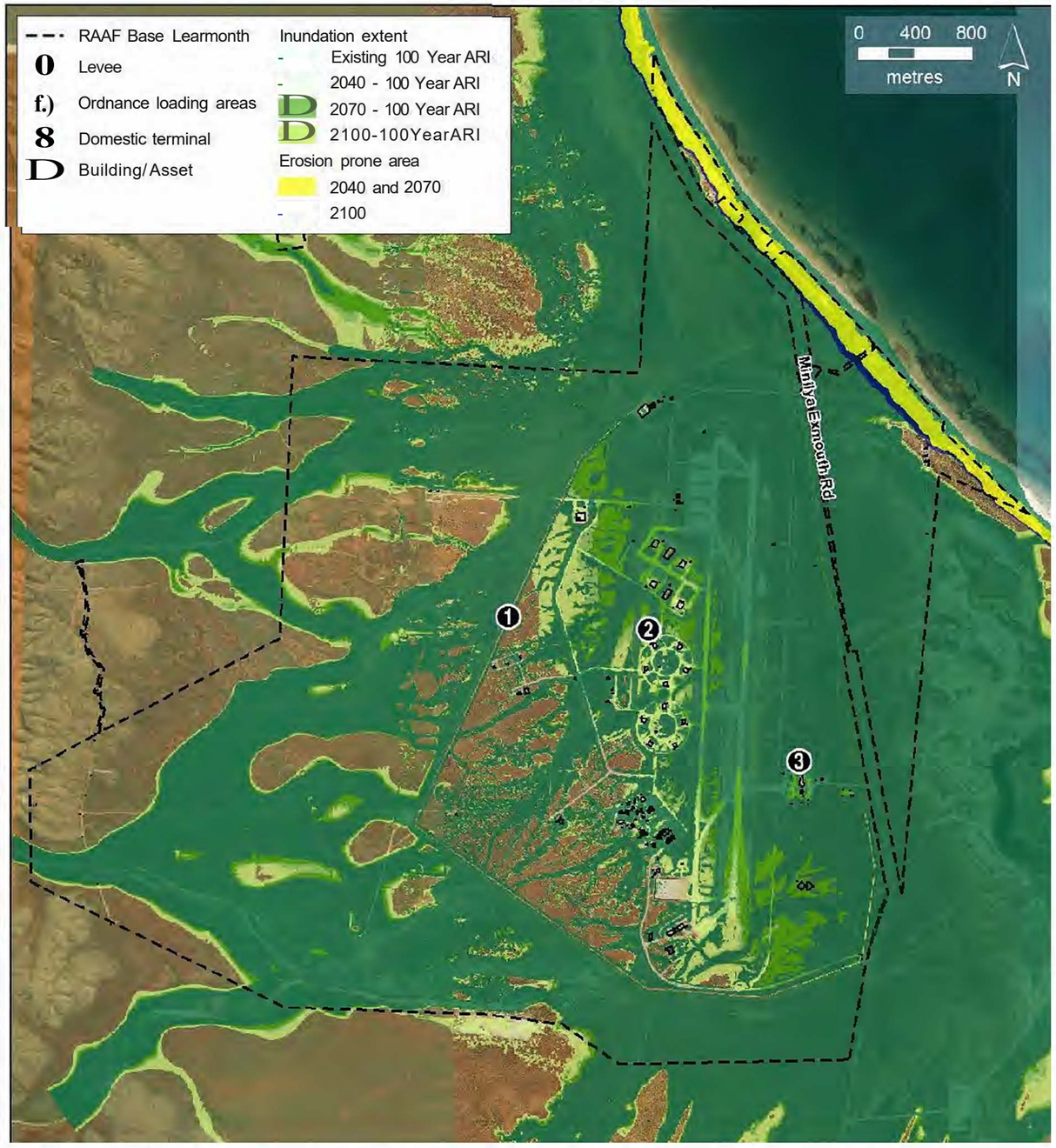

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall event and erosion extents at RAAF Base Learmonth for existing conditions, 2040, 2070 and 2100.

RAAFBASELEARMONTH

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	**4.30 m**	**4.50 m**	**4.75m**	**5.73 m**
Increase in run off due to extreme rainfall	**-**	**20%**	**30%**	**70%**
Coastal erosion (m recession)	**-**	up to 132 m	up to 135 m	upto189m
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		Very High 2 L-A1 C-S1 (capability/ OH&S)	**Very** High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Site Access and Internal **Roads** Inundation, storm surge and erosion impacts restricting access to the site and use of internal roads and damaging roads, reducing base capability.		Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.		**NIA**	**NIA**	**N/A**
Runways and Aviation Infrastructure Inundation and storm surge may restrict the use of, and damage, runways, taxiways and supporting infrastructure, reducing capability.		Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Utilities Inundation, storm surge and erosion may disrupt and damage essential services at the site including electricity, communications, water and sewerage utilities, reducing base capability.		Very High 4 L-L3 C-S1 (capability/ OH&S)	Very High 4 L-L3 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets Potential degradation of habitats that support threatened species, through inundation, storm surge and erosion.		**Medium 14** L-P3 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)
Contamination Inundation, storm surge and erosion may result in the mobilisation of contamination into soils, groundwater and the marine environment.		**Medium 16** L-P5 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)	**Medium 14** L-P3 C-M11 (E&H)
Heritage The site does not contain any identified listed or indicative heritage assets.		**NIA**	**NIA**	**NIA**

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. OmAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not indude consideration of changes in other dimatic factors (e.g. wind speed, southward tracking of cyclones, etc). Coastal recession is due to storm surge, longshore transport and recession due to sea level rise. The selection process for dimate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been priOfitised under the assumption that Defence continues to occupy *the* site in the longer term (i e. 90 years) and that the characteristics Oe. assets and capability) of *the* site remain *the* same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, aviation infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and/or foundations/footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, environmental assets and contamination.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets (e.g. buildings, aviation infrastructure and utilities) and protective assets (e.g. levee, drainage channels and flood gates). Maintenance treatments may need to be adjusted to be more proactive in preventing acceleration of asset degradation.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities and contamination.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20%.
Asset specific flood protection Increase the flood protection and drainage capacity of the following assets to ensure reliability during inundation events: • Fuel Farm (EO152); • Fuel Approach Power House (A0080); and • Airfield Lighting Equipment Room 36 (H0200).	Buildings, runways and aviation infrastructure, utilities and contamination.	$1 00K-$250K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Utilities - network reliability Isolation of electrical and communications systems to ensure network performance and self-sufficiency when elements of the system are affected by inundation.	Utilities.	$1 00K-$250K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Relocate activities and functions Accept flooding in low lying areas and move activity and function to another part of site or region. Buildings and facilities suggested for activity or function relocation are those impacted by the 2040 extreme flood level. Remediation of any contamination at vacated sites should accompany relocation of activities and functions especially where mobilisation of contamination into surrounding soils, groundwater and marine environment may occur.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities and contamination.	$1 00K-$200K to develop relocation masterplan. Specific relocation costs will be dependent on asset function and remediation requirements.
Review emergency management plans Review existing emergency management plans to incorporate increased inundation and erosion impacts over time and update the need for increased response capacity when required.	Buildings, site access and internal roads, and runways and aviation infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of these plans.
Site flood protection - levee Increase the height of the levee protection on the eastern side of the site. Install pumps and improve storage capacity onsite. The levee should be designed to reduce flood exposure up to the 2100 100 year ARI inundation level. Design of the levee would need to consider the potential change in flood levels that may result if the dune protection is lost.	Buildings, site access and internal roads, runways and aviation infrastructure and utilities.	$15.SM to adjust 12 km levee and $6.SM to excavate additional storage capacity (50,000m^3) and install pumps.

DEFENCE ESTABLISHMENT HAROLD E HOLT

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Communications	Communications centre, station headquarters	RAN
Logistics	Pier, warehouse, storage facilities, power station	RAN
Administration	Squadron headquarters	Army

Defence Establishment Harold E Holt, Area A and Area B, occupy a combined area of approximately 4,120 ha and are located 5 km north of Exmouth. The site operates point to point communication circuits with surface ships and international navy bases and a relay station for one way submarine communications.

The site is jointly manned by the RAN and civilian personnel. Area A of the site houses the very low frequency transmission site, a pier and a power plant. Area B incorporates the station headquarters, the high frequency transmission site and the main Communications Centre. Site capability is supported by Area C 'Naval HF Receiving Station' (located approximately 50 km south of Area B) which is not included in this assessment.

The Commonwealth and the Western Australian State governments have assigned National and World Heritage status to the North West Cape. Area A and Area B contain listed European Settlement heritage assets. Area B also contains buildings with heritage value. Threatened terrestrial and marine species, or their habitat, are likely to occur on the site. Soil and groundwater contamination exists on the site.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 100 year ARI storm surge and extreme rainfall event was assessed at the site. The risk of coastal erosion was also assessed.

The majority of Area A and low lying parts of Area B (including the HF Transmitter grounds) are currently at risk of combined 100 year ARI storm surge and extreme rainfall events. The hazard area will increase in 2040 and 2070, covering most built assets in 2100.

Inundation is likely to damage, degrade and destabilise above and below ground building structures (e.g. footings for communication towers and antennas).

Coastal erosion impacts are likely to be limited to perimeter roads, indigenous coastal heritage assets and access to the pier.

In all three timeframes there is a Very High **risk** that inundation will disrupt and damage electricity, communication, water and sewerage utilities, restricting capability. Site access is a Very High risk in all three timeframes.

Indigenous and historic built heritage values are at High risk of inundation and erosion impacts in all three timeframes.

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for Defence Establishment Harold E Holt Area A and Area B focus on protecting specific assets and maintaining capability during inundation events.

- Adjust designs for new works or redevelopment of buildings and utilities.
- Review maintenance specifications and monitoring to account for increased damage and corrosion.
- Determine the vulnerability of key utilities supplied to and between the sites (i.e. fuel supply, power generation, communications, water supply and treatment).
- Undertake asset specific flood protection to maintain critical utilities (i.e. electricity supply and communications).
- Isolate electrical and communication systems to ensure network performance when elements of the system are inundated.
- Periodically review emergency management plans to respond to an increased scale of inundation impacts and where required, increase response capacity.

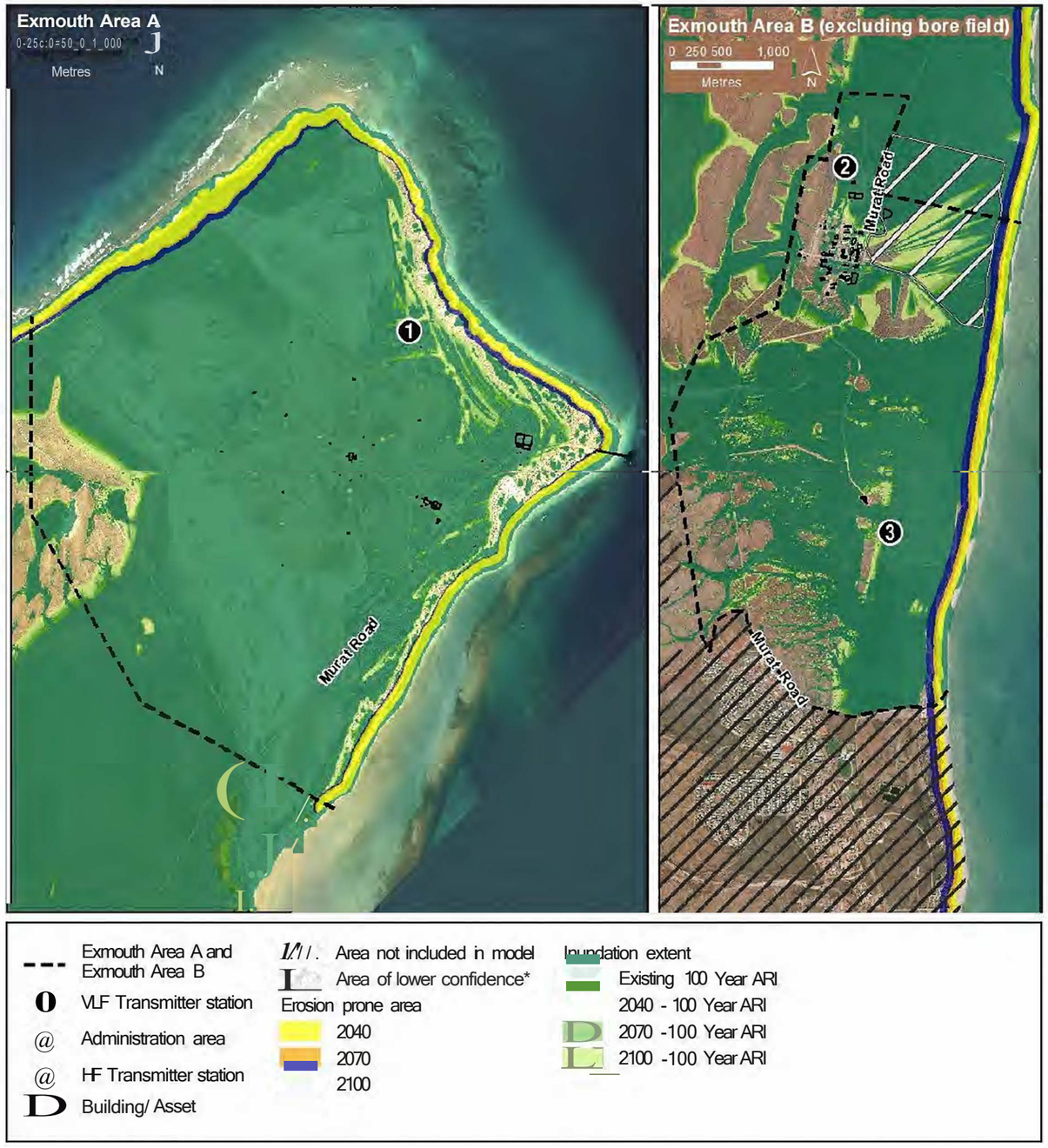

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall event and erosion extents at Defence Establishment Harold E Holt Area A and Area B for existing conditions, 2040, 2070 and 2100.

•oue to terrain data limitations, there is less confidence in the outputs of the flood modelling in this specific area.

DEFENCE ESTABLISHMENT HAROLD E HOLT

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge (m)	5.00 (A) 4.10 (B)	5.20 (A) 4.30 (B)	5.45 (A) 4.55 (B)	6.43 (A) 5.53 (B)
Increase in run off due to extreme rainfall	-	20%	30%	70%
Coastal erosion (m recession)	-	201 (A) 74 (B)	206 (A) 107 (B)	277 (A) 180 (B)
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, erosion and storm surge impacts, restricting access to the site, and the use of internal roads and damaging roads, reducing base capability.		Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation, erosion and storm surge impacts restricting access and damaging pier infrastructure, reducing base capability.		**Medium 16** L-P5 **C-M11** (capability)	**Medium 16** L-P5 **C-M11** (capability)	High 6 L-P5 C-S1 (capability)
Runways and Aviation Infrastructure This site does not contain runways or aviation infrastructure.		**NIA**	**N/A**	**N/A**
Utilities Inundation and storm surge may disrupt and damage essential services to the site including electricity, communications, water and sewerage utilities, reducing base capability and functionality.		Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets Potential degradation of habitats that support threatened species, through inundation, storm surge and erosion.		**Medium 14** L-P3 **C-M11** (E&H)	**Medium 14** L-P3 **C-M11** (E&H)	**Medium 14** L-P3 **C-M11** (E&H)
Contamination Inundation, storm surge and erosion may result in the mobilisation of contamination into soils, groundwater and the marine environment.		**Medium 16** L-P5 **C-M11** (E&H)	**Medium 14** L-L3 **C-M11** (E&H)	**Medium 14** L-L3 **C-M11** (E&H)
Heritage Inundation, storm surge and erosion may damage Indigenous and historic built heritage values.		High 11 L-P5 **C-M6** (E&H)	High 11 L-P5 **C-M6** (E&H)	High 11 L-P5 **C-M6** (E&H)

Specific extreme sea level heights and coastal erosion distances are presented for Area A (A) and Area B (BJ. Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum Wllich is the datum for altitude measurement in Australia. O mAHD was mean sea level in 1971. The changes in stonn surge levels include sea level rise and do not include consideration of changes in other climatic factors (e g. wind speed, southward tracking of cyclones, etc). Coastal recession is due to storm surge, longshore transport and recession due to sea level rise. The selection process for climate projections was consistent 'Mth guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised assurrong Defence continues to occupy the site in the longer tenn (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, roads, utilities and marine infrastructure. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and/or foundations/footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, contamination and heritage.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as buildings, roads, utilities and marine infrastructure. Maintenance treatments may need to be adjusted to be more proactive in preventing acceleration of asset degradation. Options include increasing the strength of protective coatings of assets exposed to higher groundwater and salt water concentrations.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, contamination and heritage.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20%.
Utilities - resilience of supply Determine the vulnerability of key utilities supplied to, and between the sites (i.e. fuel supply, power generation, communications, water supply and treatment).	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.
Asset specific flood protection works Undertake flood protection works for specific assets in Area A: • Base Power Station (A0013); and • VLF Transmitter / Helix House (A0015). Building protection works may include improved asset drainage, tanking protection works, raising the height of building floor levels or altering the use of the facilities to locate sensitive aspects to high floors.	Buildings and utilities.	$50K-$250K to plan and design measures. The cost of implementing physical changes would be dependent on the specific measures required.
Utilities - network reliability Isolate electrical and communications systems to ensure network performance when elements of the system are affected by inundation.	Utilities.	$1 00K-$250K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Review emergency management plans Review existing emergency management plans to incorporate increased inundation and erosion impacts over time and update the need for increased response capacity when required. This should include ensuring temporary accommodation and rations are available for personnel at the HF Transmitter Station at Area B.	Buildings, site access and internal roads and pier and marine infrastructure.	$15K-$50K to review inundation risks as part of regular reviews of these plans.

COCOS (KEELING) ISLANDS - WEST ISLAND

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Communications services	Communications building, antennas	RAAF
Air maritime surveillance	Workshop, crew room, ground support equipment storage	RAAF
Accommodation	Live in accommodation	RAAF

The Cocos (Keeling) Islands are a group of 27 low lying coral atolls in the Indian Ocean approximately 2,950 km northwest of Perth, Western Australia. The group of islands comprise 1,400 ha of emerged lands and 26 km of coastline. Only two islands are inhabited, Home Island and West Island. Defence has operational interests on West Island (which is approximately 620 ha in size), including managing a small number of built assets.

Cocos (Keeling) Islands are part of the Australia Indian Ocean Territories. Defence capability on West Island is supported by the assets and services provided by the Attorney Generals Department, the Water Corporation and the local shire council including road maintenance, electricity supply, water and sewerage services, the jetty and the airport. West Island is the focus of this study.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a 100 year ARI storm surge event was assessed at the site. The risk of coastal erosion was also assessed.

With the exception of the settlement area, the majority of the island is currently at risk of a 100 year ARI storm surge event. This hazard area will increase in 2040 and 2070, covering most non-residential built assets in 2100.

In 2040, coastal erosion is likely to cut off access from the settlement to the north and the south of the island. Coastal erosion is also likely to damage Defence accommodation and the island's fuel farm in 2040.

The runway and some internal roads are at Very High risk in 2040, 2070 and 2100. Inundation is likely to damage these sealed surfaces and their foundations.

Inundation is likely to restrict access to, and safe operation of, the Jetty, reducing capability.

In 2040 there is a High risk that inundation will disrupt some power, water and sewerage utilities, restricting capability. While not assessed in this study, climate change is likely to affect the viability of the Island's freshwater resource (i.e. the freshwater lens).

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for Cocos (Keeling) Islands focus on protecting the communications facility, ensuring sufficient fuel supply is available to run back up power, and that access is maintained:

- Adjust designs for new works or redevelopment of buildings and utilities.
- Review maintenance specifications and monitoring to account for increased damage and corrosion.
- Expand backup fuel capacity and isolate electrical and communications systems to ensure network performance when elements of the system are impacted by inundation.
- Periodically review emergency management plans to respond to an increased scale of inundation impacts and where required, increase response capacity.
- Ensure future redevelopments of the site to accommodate changes in capability (e.g. increased operational presence) incorporate future flood and inundation impacts.

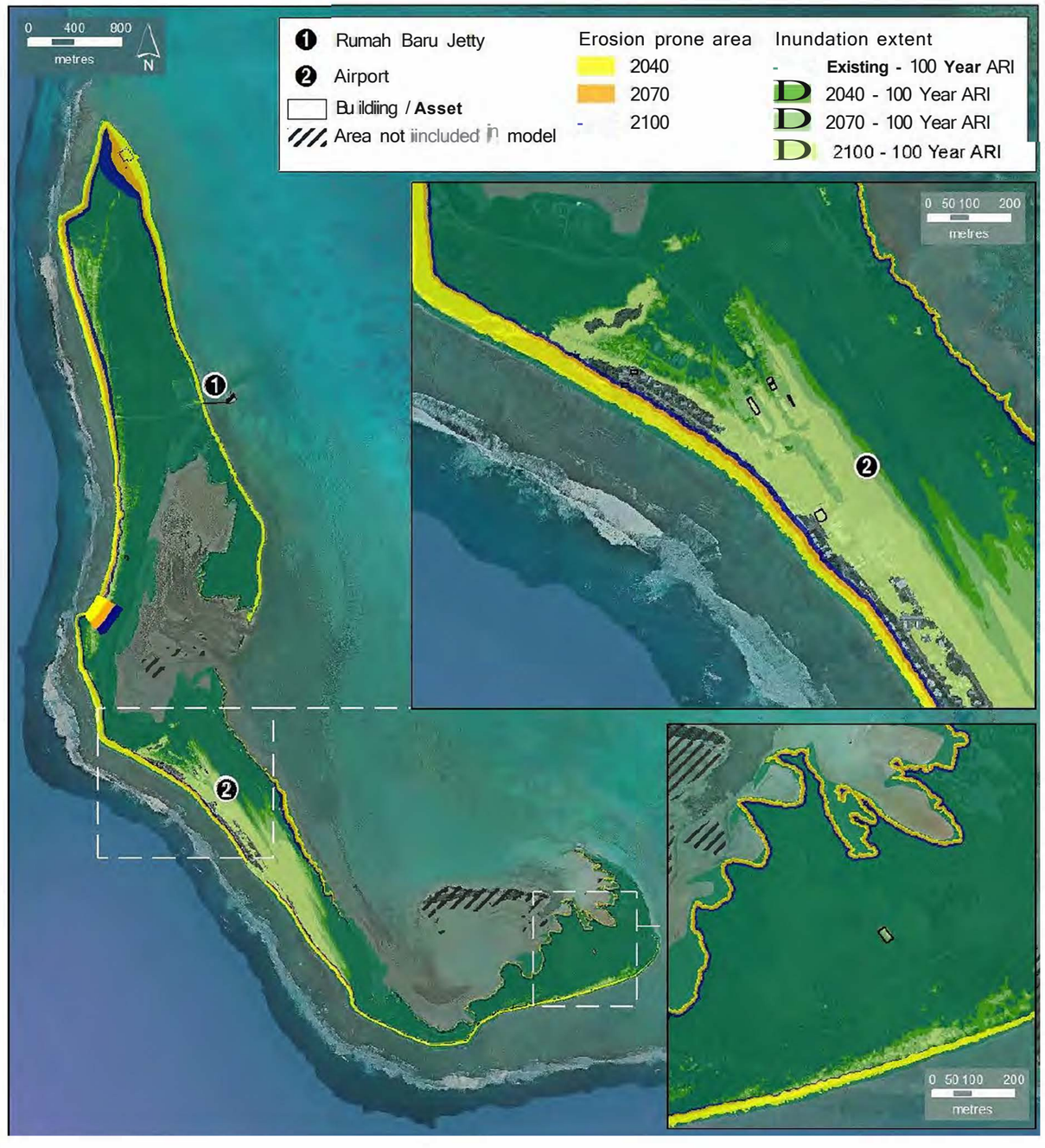

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and erosion extents at Cocos (Keeling) Islands - West Island for existing conditions, 2040, 2070 and 2100.

COCOS (KEELING) ISLANDS -WEST ISLAND

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge (m)	1.70 to 2.75	1.90 to 2.95	2.15 to 3.20	3.13 to 4.18
Increase in run off due to extreme rainfall		Not assessed at this site		
Coastal erosion (m recession)	-	up to 95	up to 205	up to 327
Buildings Inundation and storm surge impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce capability and functionality during and following flood events.		Medium 14 L-L3 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, erosion and storm surge impacts restricting access to facilities across the island and damaging roads, reducing capability.		Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation and storm surge impacts restricting access to, and use of, pier and marine infrastructure, reducing capability.		High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)
Runways and Aviation Infrastructure Inundation and storm surge may restrict the use of, and damage, the runway, taxiways and supporting infrastructure, reducing capability.		Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)	Very High 2 L-A1 C-S1 (capability)
Utilities Inundation and storm surge may disrupt and damage essential services to the site including electricity, communications, water and sewerage utilities, reducing capability.		Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets No indicative or listed environmental assets have been identified at the site.		N/A	N/A	NIA
Contamination Inundation, storm surge and erosion may result in the mobilisation of contamination into soils, groundwater and the marine environment.		N/A	Low23 L-U7 C-M16 (E&H)	Medium 19 L-P3 C-M16 (E&H)
Heritage The site does not contain any identified listed or indicative heritage assets.		N/A	N/A	N/A

The extreme sea level heights differ between the west and east coast of the island and are in metres CKIHD. CKIHD refers to Cocos (Keeling) Islands Height Datum. Om CKJHD is the locally determined mean sea level at Port Refuge (Home Island). The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). Coastal recession is due to storm surge, longshore transport and recession due to sea level rise. The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under the assumption that Defence continues to occupy the site in the longer term (i e. 90 years) and that the charactenstics o.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, pier and marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads and utilities.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as buildings, roads, utilities and marine infrastructure. Maintenance treatments may need to be adjusted to be more proactive in preventing acceleration of asset degradation such as increased cathodic protection to respond to a higher splash zone due to sea level rise.	Buildings, site access and internal roads and utilities.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20%.
Utilities - network reliability Expand backup fuel capacity and isolate electrical and communications systems to ensure network performance when elements of the system are impacted by inundation.	Utilities.	$30K-$50K to undertake detailed assessment and determine vulnerability, required works and associated costs.
Redevelopments of the site Ensure future redevelopments of the site to accommodate changes in capability (e.g. increased operational presence) incorporate future flood and inundation impacts. Restrict re-development in low lying areas and preserve areas that are needed for protective works.	Buildings, site access and internal roads, pier and marine infrastructure, runways and aviation infrastructure and utilities.	Negligible additional cost to include in re-development planning.
Review emergency management plans Review existing emergency management plans to incorporate increased inundation and erosion impacts over time and update the need for increased response capacity when required. This may include ensuring temporary accommodation and rations are available at the communications facility.	Buildings, site access and internal roads and utilities.	$15K-$50K to review inundation risks as part of regular reviews of these plans.

BULIMBA BARRACKS

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Logistics	Storage facilities, Maintenance	**JLU, RAN**
Accommodation	Unit Headquarters, offices, live in accommodation	JLU, RAN

Bulimba Barracks is 23 hectares (ha) in size, 4 km east of the Brisbane Central Business District (CBD).

The site has a 650 m frontage to the south bank of the Brisbane River. Currently the barracks are Headquarters to Joint Logistics Unit - South Queensland and Navy Headquarters - South Queensland (HQ SQ).

The majority of the buildings at the site are located on the western side of the site, with the naval buildings located in the eastern portion of the site. The Defence Estate Review identifies some parts of Bulimba Barracks for potential disposal and the *Brisbane City Council City Plan 2000* identifies Bulimba Barracks as a future residential development opportunity.

The site has low ecological values, containing no remnant vegetation. There are no Commonwealth, National or Defence registered heritage values associated with Bulimba Barracks. However, Bulimba Barracks and its World War II hangars are listed on the Brisbane Heritage Register.

SUMMARY OF RISKS

The risk of inundation from sea level rise and 100 year ARI storm surge, river flow and extreme rainfall events were assessed at the site. The risk of coastal erosion was not assessed as wave induced coastal processes do not directly affect the site.

The majority of Bulimba Barracks is currently at risk of inundation during a 100 year ARI event. Climate change is likely to increase this hazard. The site has a Very High risk rating in all three timeframes. This rating relates to the risk of inundation of roads, restricting access to, and between, facilities across the site and causing damage to the surfaces and foundations of roads and vehicle parking areas.

Inundation is likely to damage, degrade and destabilise buildings, including below ground building structures, affecting capability.

Inundation is likely to disrupt essential services including electricity and water supply, information technology, communications and sewerage. The risk to buildings and utilities is High in 2040, increasing to Very High in 2070.

The ability to safely operate berthing facilities and the wharf is likely to be restricted by inundation, reducing capability including maintenance activities, a Medium risk in all three timeframes.

SUMMARY OF ADAPTATION OPTIONS

The following priority adaptation options for Bulimba Barracks focus on enhancing drainage of water from the site and minimising the impacts of inundation:

- Adjust designs for new works or development of buildings, utilities and pier and marine infrastructure to incorporate greater allowances for river and estuarine flooding.
- Review and adjust maintenance specifications and monitoring to account for increased damage and corrosion.
- Improve local drainage in the west portion of the site to enhance the drainage of local catchment flood water through the site into the Brisbane River.
- Review guidance for the storage of critical and / or hazardous materials located within the hazard areas and determine alternative storage locations.
- Isolate electrical and communications systems to ensure network performance and self-sufficiency when affected by inundation.
- Determine vulnerability of key utilities supplied to the site.
- Periodically review emergency management plans.

Figure 1: Inundation extents as a result of 100 Year ARI storm surge, river flow and extreme rainfall events at Bulimba Barracks for existing conditions. 2040, 2070 and 2100.

BULIMBA BARRACKS

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	2.20 m	2.40m	2.65m	3.63 m
Increase in run off due to extreme rainfall	-	40%	50%	70%
Coastal erosion (m recession)		Not assessed at this site		
Buildings Inundation impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		**High 12** L-A1 C-M11 (capability)	**Very High 7** L-A1 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, the use of internal roads and damaging roads, reducing base capability.		**Very High 7** L-A1 C-M6 (capability)	**Very High 7** L-A1 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Damage and loss of access to berthing facilities and wharfs from inundation and storm surge events reducing base capability and functionality. The ability to safely operate the wharf may be restricted by inundation.		**Medium 16** L-P5 C-M11 (capability)	**Medium 16** L-P5 C-M11 (capability)	**Very High 2** L-A1 C- S1 (capability)
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		NIA	NIA	N/A
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage reducing base capability and functionality.		**High 12** L-A1 C-M11 (capability/ OH&S)	**Very High 7** L-A1 C-M6 (capability/ OH&S)	**Very High 2** L-A1 C-S1 (capability/ OH&S)
Environmental Assets There are no listed or indicative environmental assets or remnant vegetation at this site.		NIA	NIA	NIA
Contamination Inundation may result in the mobilisation of contamination into surrounding soils, groundwater and the Brisbane River.		**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 14** L-L3 C-M11 (E&H)
Heritage Inundation may damage or degrade historic built heritage values.		**Medium 21** L-P5 C-M16 (E&H)	**Medium 21** L-P5 C-M16 (E&H)	**Medium 19** L-L3 C-M16 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 m AHO was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, pier and marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, contamination and heritage.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as buildings, roads, utilities and pier and marine infrastructure. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation such as more frequent painting of vulnerable structures or increased cathodic protection to respond to a higher splash zone due to sea level rise.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, contamination and heritage.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20% compared to a baseline of no climate change.
Site flood protection - improve local drainage Improve local drainage in the western portion of the site. This may include lowering an internal road and installing culverts to enhance the drainage of local catchment flood water through the west portion of the site into the Brisbane River.	Buildings, utilities.	$875K to improve 350 m of drainage with supporting culverts.
Storage of critical and / or hazardous materials guidance Review guidance for the storage of critical and / or hazardous materials within structures located within the defined inundation boundaries. Determine alternative locations for storage of critical and / or hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.
Utilities - network reliability Isolate electrical and communications systems to ensure network performance and self-sufficiency when elements of the system are affected by inundation.	Utilities.	$50K-$1 00K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within site boundary only.
Utilities - resilience of external supply Determine the vulnerability of key utilities supplied to the site (i.e. local power exchanges, communications networks, water supply and treatment). Develop an approach to manage the risks associated with identified vulnerable utilities. This may include adjusting Defence emergency response plans, enhancing back-up systems and engaging with external service providers to understand their emergency responses.	Utilities.	$50K-$1 00K to undertake detailed assessment and determine vulnerability.

DAMASCUS BARRACKS

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Logistics	Storage and maintenance facilities	Army
Administration	Offices	Army

Damascus Barracks is 60 hectares (ha) in size and is 11 km east of the Brisbane Central Business District (CBD). The site is used by the Army for Joint Logistic support through warehousing and distribution of Defence equipment and supplies.

A Land 121 Vehicle Roll Out Facility has been recently constructed in the south-west section of the site. The limited number of buildings on the site are dominated by large warehouses and stores which were built in 1945.

Large portions of the site are undeveloped. However, the high water table and boggy ground present difficulties for development. There are four water storage dams on site, two of which appear to be fed by ground water or natural springs, maintaining a constant water level.

No listed or indicative environmental assets or heritage assets have been identified on this site.

SUMMARY OF RISKS

The risk of inundation from sea level rise and 100 year ARI storm surge, river flow and extreme rainfall events were assessed at the site. The risk of coastal erosion was not assessed as wave induced coastal processes do not directly affect the site.

The majority of the unbuilt portion of Damascus Barracks is currently at risk of inundation during a 100 year ARI event. This hazard area will increase in 2040 and 2070, covering most built assets in 2100.

There is a High risk of building inundation in 2040, increasing to Very High in 2070 and 2100. Inundation is likely to damage, degrade and destabilise buildings, including below ground building structures, affecting capability.

Inundation of roads is likely to restrict access to, and between, facilities across the site and cause damage to the surfaces and foundations of roads and vehicle parking areas. The risk to site access and internal roads is Medium in 2040 and 2070 increasing to Very High in 2100.

Inundation is likely to disrupt essential services including electricity and water supply, information technology, communications and sewerage. The risk to utilities is rated Medium risk in 2040 and 2070, increasing to Very High in 2100.

SUMMARY OF ADAPTATION OPTIONS

The following priority adaptation options for Damascus Barracks focus on reducing the amount of water entering the site, enhancing drainage of water from the site and minimising the impacts of inundation:

- Adjust design specifications for new works or development of buildings, roads and utilities to incorporate greater allowances for river and estuarine flooding.
- Review and adjust maintenance specifications and monitoring to account for increased damage and corrosion.
- Review guidance for storage of critical and/or hazardous materials located within hazard areas and determine alternative storage locations.
- Deepen and line the drainage channel in the south west corner of the site to prevent spill over of water from the channel into the site.
- Upgrade the culvert in north east corner of the site to a larger diameter and install flaps to stop tidal back flow.
- Improve local drainage infrastructure to ensure effective dispersion of water from the site.
- Ensure future redevelopments incorporate future flood and inundation impacts.

Figure 1: Inundation extents as a result of 100 Year ARI storm surge, river flow and extreme rainfall events at Damascus Barracks for existing conditions, 2040, 2070 and 2100.

DAMASCUS BARRACKS

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	1.90 m	2.10m	2.35m	3.33 m
Increase in run off due to extreme rainfall	-	40%	50%	70%
Coastal erosion (m recession)		Not assessed at this site		
Buildings Inundation impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, and the use of internal roads and damaging roads, reducing base capability.		Medium 17 L-A1 C-M16 (capability)	Medium 17 L-A1 C-M16 (capability)	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.		NIA	NIA	NIA
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		NIA	NIA	NIA
Utilities Inundation may disrupt and damage essential services at the site including electricity, communications, water and sewerage utilities, reducing base capability and functionality.		Medium 14 L-L3 C-M11 (capability/ OH&S)	Medium 14 L-L3 C-M11 (capability/ OH&S)	Very High 2 L-A1 C-S1 (capability/ OH&S)
Environmental Assets There are no listed or indicative environmental assets or remnant vegetation at this site.		NIA	NIA	NIA
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and the marine environment.		Medium 16 L-P5 C-M11 (E&H)	Medium 16 L-P5 C-M11 (E&H)	Medium 16 L-P5 C-M11 (E&H)
Heritage No indicative or listed Indigenous or historic built heritage values have been identified at the site.		NIA	NIA	NIA

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. OmAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. Wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent With guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have beeo prioritised under the assumption that Defence continues to occupy the sije in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, roads and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations/footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, utilities, contamination.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as roads. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation, such as more frequent painting of vulnerable structures.	Buildings, site access and internal roads, utilities, contamination.	$50K-$1 00K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20% compared to a baseline of no climate change.
Site flood protection - upgrade local drainage Improve local drainage infrastructure to ensure effective dispersion of water from the site. Due to the flat terrain at the site, the installation of sumps and pumps at two low points on site is recommended.	Buildings, site access and internal roads, utilities and contamination.	$1.6M to upgrade approximately 1.5 km of drains and install supporting pumps.
Storage of critical and / or hazardous materials guidance Review guidance for storage of critical and / or hazardous materials within structures located within the defined inundation boundaries. Determine alternative locations for storage of critical and / or hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.
Site flood protection - drainage upgrades (south west) Deepen and line the drainage channel in the south west comer of the site to contain flow from upstream catchment in the perimeter drainage channel and prevent spill over of water into Damascus Barracks. Install a one way flapped culvert in the same location to maintain site drainage and prevent backflow of water into the site.	Buildings, site access and internal roads, utilities and contamination.	$170K to undertake design and construction works.
Site flood protection - drainage upgrades (north east) Upgrade the culvert in the north east comer of the site to a larger diameter and install flaps to stop tidal back flow. This will assist with more frequent, lower impact flood events.	Buildings, site access and internal roads, utilities and contamination.	$325K to undertake design and construction work. The cost of these works may be funded by the local drainage authority.

RAAF BASE WILLIAMTOWN

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Air operations	Runways, taxiways, flight apron, hangars, operations buildings	RAAF
Logistics	Storage facilities, fuel storage	RAAF
Training	Education facilities	RAAF

RAAF Base Williamtown is 986 hectares (ha) in size and is located 13 km north of the Newcastle Central Business District (CDB). The site is an aircraft maintenance and operations facility. The site capability is supported by the Salt Ash Weapons Range (SAWR) (located approximately 6 km north east of the base) which is not included in this assessment.

RAAF Base Williamtown is the home of major elements of the Australian Defence Force air defence and strike capability. Core activities at the site include aircraft flying operations and training, maintenance, air defence command and control and operational, logistical and infrastructure support services. Currently the base supports a working population of approximately 3,700 defence personnel and civilians.

RAAF Base Williamtown is located in an environmentally sensitive area. The site is listed on the Commonwealth Heritage List for its Indigenous and historic built heritage values.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 100 year ARI storm surge, river flow and extreme rainfall event was assessed at the site. The risk of coastal erosion was not assessed as wave induced coastal processes do not directly affect the site.

Some assets and unbuilt sections of RAAF Base Williamtown are currently at risk of inundation during a 100 year ARI event. The extent or depth of inundation from such an event, as a result of climate change, is not likely to increase. The site has a Very High risk rating in all three timeframes with inundation restricting the use of, and damaging, runways, taxiways and supporting aviation infrastructure, reducing capability.

Inundation is likely to disrupt and damage essential services including electricity and water supply, information technology, communications and sewerage. The risk to utilities is rated High in all three timeframes.

Inundation of roads is likely to restrict access to, and between, facilities across the site and cause damage to the surfaces and foundations of roads and vehicle parking areas. This is a Medium risk in 2040 and 2070, increasing to a High risk in 2100 as a result of tidal inundation of Nelson Bay Road.

SUMMARY OF ADAPTATION OPTIONS

The following priority adaptation options for RAAF Base Williamtown focus on enhancing the local drainage network at the site and ensuring future asset design and maintenance considers the risk of more frequent inundation:

- Adjust designs for new works or development of utilities and buildings, runways and aviation infrastructure to incorporate greater allowances for river and estuarine flooding.
- Review and adjust maintenance specifications and monitoring to account for increased damage and corrosion.
- Prepare a site wide drainage strategy, and undertake recommended capital works to enhance local drainage at the site.
- ensure the resilience and self sufficiency of the utilities at the site to maintain reliability during inundation events.
- Determine the vulnerability of key utilities supplied to the site.
- Review guidance for the storage of critical and / or hazardous materials within hazard areas and determine alternative storage locations.

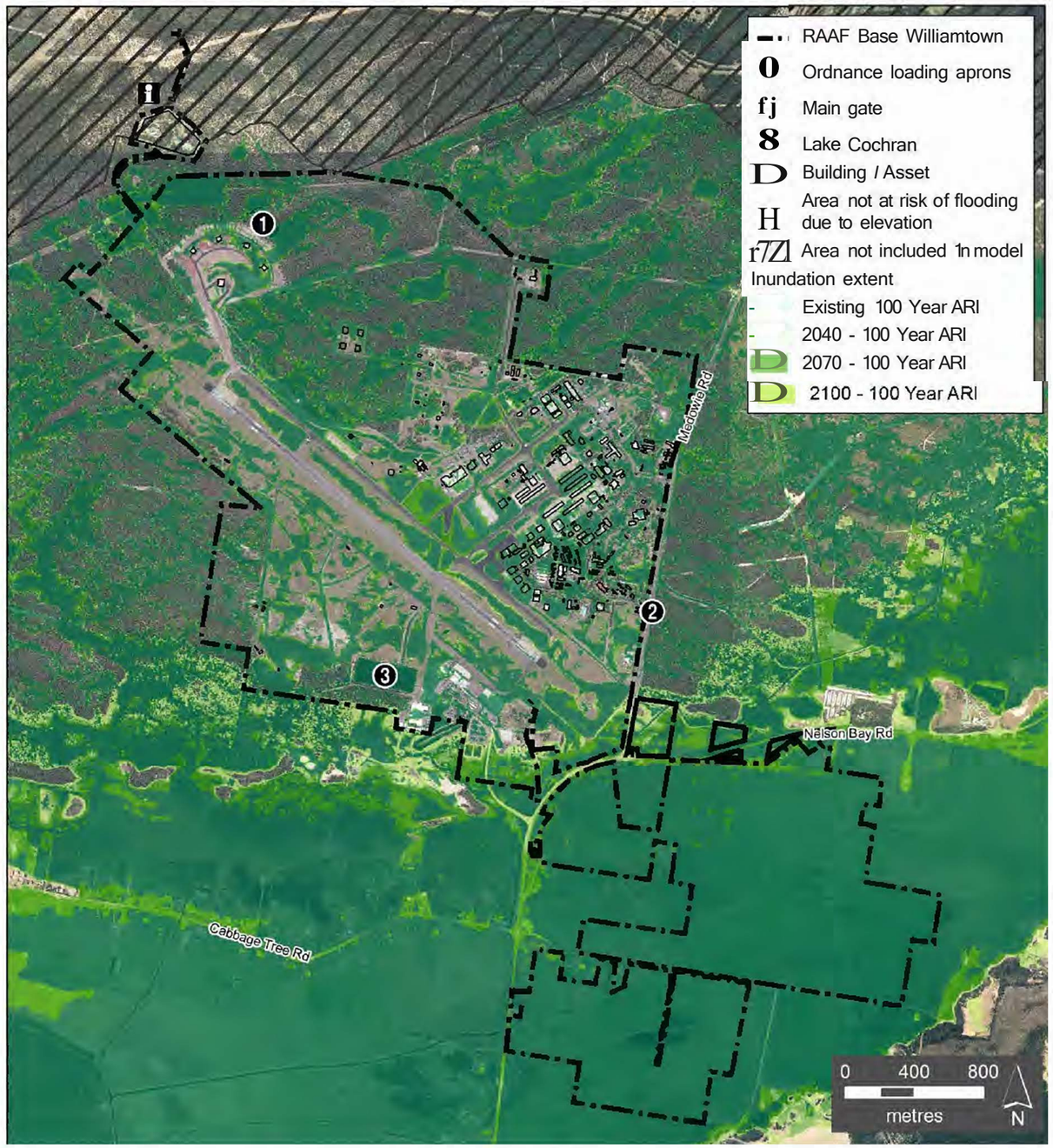

Figure 1: Inundation extents as a result of 100 Year ARI storm surge, river flow and extreme rainfall event at RAAF Base Williamtown for existing conditions, 2040, 2070 and 2100.

RAAF BASE WILLIAMTOWN

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	1.50 m	1.70 m	1.95m	2.93 m
Increase in run off due to extreme rainfall	-	40%	50%	60%
Coastal erosion (m recession)		Not assessed at this site.		
Buildings Inundation impacts to buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability during and following flood events.		Medium 17 L-A1 C-M16 (capability)	Medium 17 L-A1 C-M16 (capability)	Medium 17 L-A1 C-M16 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, the use of internal roads and damaging roads, reducing base capability.		Medium 17 L-A1 C-M16 (capability)	Medium 17 L-A1 C-M16 (capability)	High 12 L-A1 C-M11 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.		N/A	N/A	N/A
Runways and Aviation Infrastructure Inundation may restrict the use of, and damage, runways, taxiways, OLA's and supporting infrastructure, reducing capability.		Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)
Utilities Inundation may disrupt and damage essential services at the site including electricity, communications, water and sewerage utilities, reducing base capability.		High 12 L-A1 C-M11 (capability/ OH&S)	High 12 L-A1 C-M11 (capability/ OH&S)	High 12 L-A1 C-M11 (capability/ OH&S)
Environmental Assets Inundation may cause degradation of protected habitats and the threatened species they support.		Medium 19 L-L3 C-M16 (E&H)	Medium 19 L-L3 C-M16 (E&H)	Medium 19 L-L3 C-M16 (E&H)
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and the marine environment.		Medium 14 L-L3 C-M11 (E&H)	Medium 14 L-L3 C-M11 (E&H)	Medium 14 L-L3 C-M11 (E&H)
Heritage Inundation may damage or degrade listed Indigenous and historic built heritage values.		Medium 16 L-P5 C-M11 (E&H)	Medium 16 L-P5 C-M11 (E&H)	Medium 16 L-P5 C-M11 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 mAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southWard tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under the assumption that Defence continues to occupy the sije in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, pier and marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, contamination and heritage.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as buildings, roads, utilities and pier and marine infrastructure. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation, such as more frequent painting of vulnerable structures.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, contamination and heritage.	$50K-$100K to adjust central maintenance specifications. Ongoing increase to maintenance cost of 10-20% compared to a baseline of no climate change.
Surface water management strategy Prepare a site wide drainage strategy that allows for overland flow paths and flow conveyance to manage local flooding. This strategy should identify the required upgrades to local drainage to reduce the risk.	Buildings, site access and internal roads, runways and aviation infrastructure, utilities, contamination and heritage.	$200K to undertake comprehensive assessment of onsite surface drainage. Depending on the outcomes of the study, capital works costing between $4.5M and $7.5M may be recommended.
Utilities - network reliability Ensure the resilience and self sufficiency of the utilities at the site to maintain reliability during inundation events. For example, during inundation events supply of electricity is maintained to assets that require an uninterrupted supply.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within site boundary only.
Utilities - resilience of external supply Determine the vulnerability of key utilities supplied to the site (i.e. local power exchanges, communications networks, fuel supply, water supply and treatment). Develop an approach to manage the risks associated with identified vulnerable utilities. This may include adjusting Defence emergency response plans, enhancing back-up systems and engaging with external service providers to understand their emergency responses.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.
Storage of critical and / or hazardous materials guidance Review guidance for the storage of critical and / or hazardous materials within structures located within the defined inundation boundaries. Determine alternative locations for storage of critical and /or hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.

POINT WILSON EXPLOSIVES AREA

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Administration	Offices	Army
Logistics	Storage facilities, jetty	Army

The Point Wilson Explosives Area (Point Wilson) is on the north shore of Port Phillip Bay, 13 km north-east of the Geelong Central Business District (CBD) in Victoria. The site is 400 ha in size and houses a wharf, constructed in the late 1950s, and administrative buildings.

Point Wilson previously catered for the importation, exportation, and trans-shipment of Defence Explosive Ordnance (EO). The Point Wilson jetty has been non-operational since February 2008 due to its condition. Defence is currently planning to redevelop the jetty and supporting infrastructure to return the site to operation.

The south-western shoreline is part of the Bellarine Peninsula Ramsar site. The site contains habitat for the endangered Orange Bellied Parrot and other migratory bird species. There are known Indigenous and historic heritage assets at the site. The site is listed on the Commonwealth Heritage List for its natural heritage values.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 100 year ARI storm surge and extreme rainfall event was assessed at the site. The risk of coastal erosion was also assessed.

Approximately a third of the site is at risk of 100 year ARI storm surge and extreme rainfall events. This hazard area will increase in 2040 and 2070, covering almost half of the site in 2100.

There is a High risk of some internal roads being inundated in 2040, restricting access to explosive storage areas. This risk will increase to Very High in 2100, with access to the jetty restricted.

Inundation is likely to damage, degrade and destabilise above and below ground building structures. This risk is rated Medium in 2040 and 2070, increasing to Very High in 2100.

Coastal erosion may destabilise the jetty abutments and potentially damage utilities servicing the jetty. This risk is rated Medium in 2040, increasing to High in 2070 and Very High in 2100.

Semi-permanent inundation and coastal erosion may degrade Commonwealth Listed Threatened Species, a High risk in all three timeframes. Inundation may damage or degrade Indigenous and historic heritage assets. This risk is rated High in all three timeframes.

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for Point Wilson focus on protecting the built assets, while maintaining access to the jetty in the longer term:

- Adjust designs for new works or the redevelopment of buildings, marine infrastructure and utilities.
- Ensure future redevelopments of the site to accommodate changes in capability include consideration of future inundation and erosion risks.
- Review maintenance specifications and monitoring procedures to account for increased damage and corrosion.
- Construct a flood levee around the centralised structures on the site to prevent inundation (e.g. explosives storage and loading areas).
- Review guidance for storage of critical and/or hazardous materials in structures at risk of inundation.

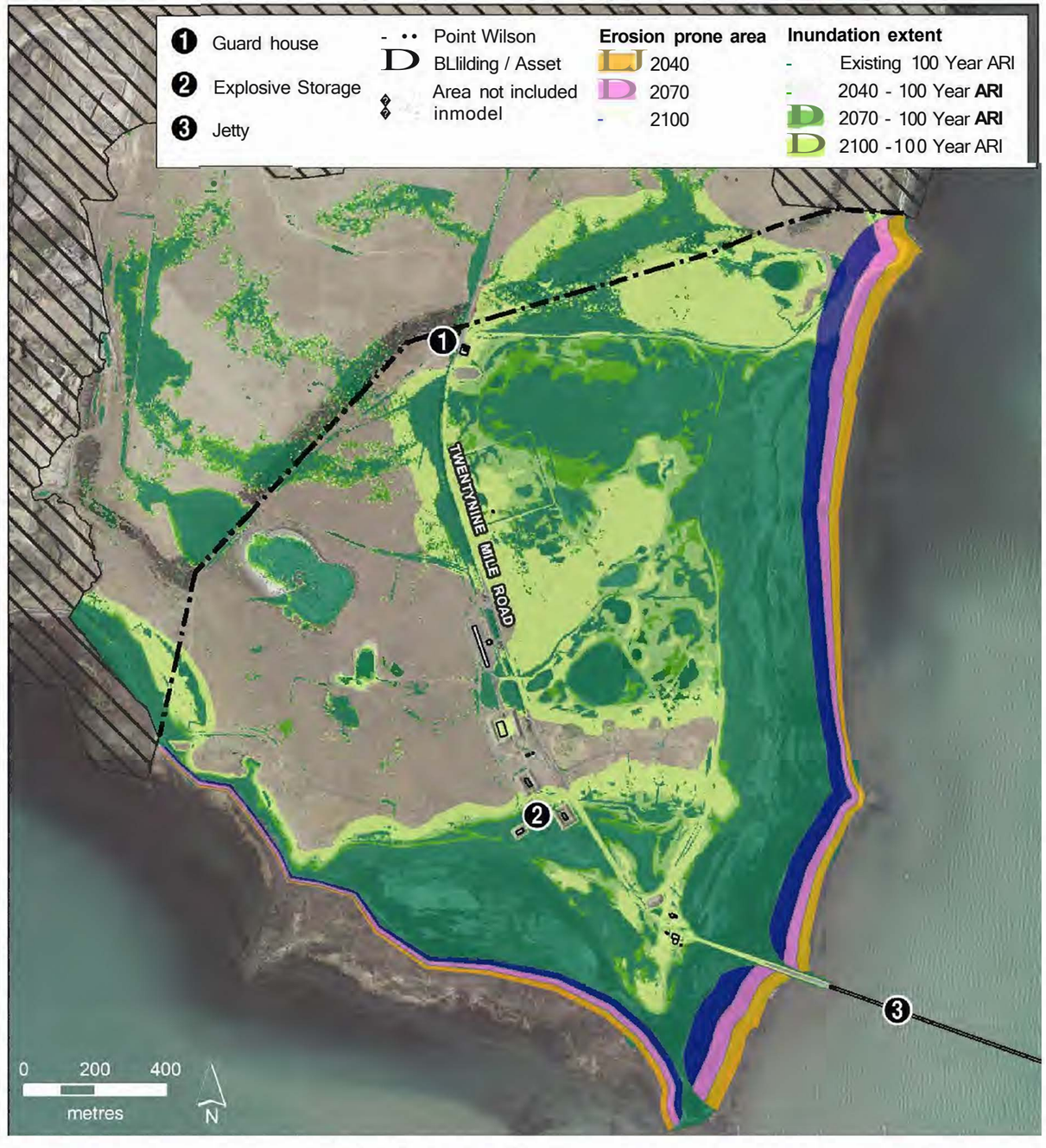

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall events and erosion extents at Point Wilson Explosives Area for existing conditions, 2040, 2070 and 2100.

POINT WILSON EXPLOSIVES AREA

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	1.40 m	1.60 m	1.85m	2.83 m
Increase in run off due to extreme rainfall	-	20%	30%	40%
Coastal erosion (m recession)	-	Up to 46 m	Up to 91 m	Up to 163 m
Buildings Inundation and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		**Medium 17** L-A1 C-M16 (capability)	**Medium 17** L-A1 C-M16 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting use of internal roads and damaging roads, reducing base capability.		**High 12** L-A1 C-M11 (capability	**High 11** L-P5 C-M6 (capability	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Erosion impacts to berthing facilities and wharfs and reduced clearance for berthed vessels. Resulting damage may reduce capability and increase the frequency of maintenance and repair.		**Medium 13** L-U7 C-M6 (capability)	**High 11** L-P5 C-M6 (capability)	**Very High 7** L-A1 C-M6 (capability)
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		**NIA**	**NIA**	**N/A**
Utilities Inundation may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.		**Medium 13** L-U7 C-M6 (capability)	**High 11** L-P5 C-M6 (capability)	**Very High 2** L-A1 C-S1 (capability)
Environmental Assets Inundation, storm surge and erosion impacts may degrade habitat for Commonwealth Listed Threatened Species and migratory birds.		**Very High 7** L-A1 C-M6 (E&H)	**Very High 7** L-A1 C-M6 (E&H)	**Very High 2** L-A1 C-S1 (E&H)
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater, neighbouring properties and the marine environment.		**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** **L-P5** **C-M11** (E&H)
Heritage Inundation may damage Indigenous and historic heritage assets.		**High 9** L-P3 C-M6 (E&H)	**High 9** L-P3 C-M6 (E&H)	**High 9** L-P3 C-M6 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 mAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, environmental assets, contamination and heritage.	$250K to adjust central design specifications.
Redevelopments of the site Ensure future redevelopments of the site to accommodate changes in capability include consideration of future inundation and erosion risks.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, contamination and heritage.	Negligible additional cost to include in re-development planning.
Maintenance specifications Review maintenance specifications and monitoring to account for increased damage and corrosion. Regularity of condition assessments may need to be increased for vulnerable assets such as roads and buildings. Maintenance treatments may need to be adjusted to prevent an acceleration of asset degradation. Options include increasing the strength of protective coatings of assets exposed to higher groundwater and salt water concentrations.	Buildings, site access and internal roads, pier and marine infrastructure, utilities, environmental assets, contamination and heritage.	$50K-$100K to adjust central maintenance specifications.
Site flood protection - levee Construct a flood levee (approximately 500 m in length) around the centralised structures on the site to prevent inundation (e.g. explosives storage and loading areas). The levee should be designed to reduce flood risk up to the 2070 inundation level.	Buildings, site access and internal roads, utilities.	$200K to undertake design and construction works to build to protect from 2070 inundation levels. $500K to build to protect from 2100 inundation levels.
Storage of hazardous materials guidance Review guidance for the storage of critical and / or hazardous materials within structures located in defined inundation boundaries. Determine alternative locations for storage of hazardous materials as required.	Buildings and contamination.	$15K-$50K to adjust materials guidance.

SWAN ISLAND

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Training	Indoor and outdoor facilities	Department of Defence
Accommodation	Live in and messing accommodation	Department of Defence
Administration	Offices	Department of Defence

Swan Island is in the southern part of Port Phillip Bay, just north of Queenscliff, 53 km south of Melbourne and is approximately 330 ha in area. The island is linked by one, single lane causeway across Rabbit Island to Queenscliff.

The eastern arm of the site contains Defence training facilities, office buildings, residences and a number of heritage listed buildings. Approximately 43 ha of the western arm of the island is leased to the Queenscliff Golf Club. The site has high heritage value, is included on the Register of the National Estate and the Commonwealth Heritage List and is a key winter habitat for the Orange Bellied Parrot.

SUMMARY OF RISKS

The risks of inundation from sea level rise and a 1 in 100 year storm surge and coastal erosion were assessed at the site. The risk of inundation from extreme rainfall events was not assessed due to the site's fast draining sandy soils.

A majority of the site is currently at risk from a 1 in 100 year storm surge event. This hazard area will increase in 2040 and 2070, covering almost all built assets in 2100.

Coastal erosion is likely to affect the site causing the destabilisation or complete loss of some buildings, roads, marine infrastructure and associated utilities. The current management of the Queenscliff Harbour Marina is providing some protection along the southern coast of Swan Island as sand continues to accumulate (i.e. accrete) northward along the coast.

As the site has low elevation, there is a Very High risk of some building inundation in 2040, 2070 and 2100. Inundation is likely to damage, degrade and destabilise above and below ground building structures.

Risks to site access (e.g. via the Bellarine Highway and the causeway) and some internal roads are rated Very High in all three timeframes.

In 2040, 2070 and 2100, there is a Very High risk that inundation will disrupt power, water and sewer utilities, restricting capability. Semi-permenant inundation may also degrade habitat for Commonwealth Listed Threatened Species, a Very High Risk in all three timeframes.

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for Swan Island focus on protecting built assets and ensuring continued active engagement in the sand management practices for the Queenscliff Harbour Marina:

- Adjust designs for new works or redevelopment of buildings, marine infrastructure, roads and utilities.
- Review maintenance specifications and monitoring procedures to account for increased damage and corrosion.
- Continue to actively engage with Parks Victoria to ensure that Defence is aware of the sand management practices for the Queenscliff Harbour Marina.
- Construct ring levees to protect the eastern and western groupings of built assets.
- Upgrade the causeway and raise Main Road to maintain access to the site.
- Periodically review emergency management plans to respond to an increased scale of inundation impacts.
- Undertake coastal protection works along sections of the north and eastern shores of Swan Island to prevent further erosion.

In the longer term (2100), consideration will need to be given to relocating capability from the site or undertaking significant works to elevate or protect all assets at the site.

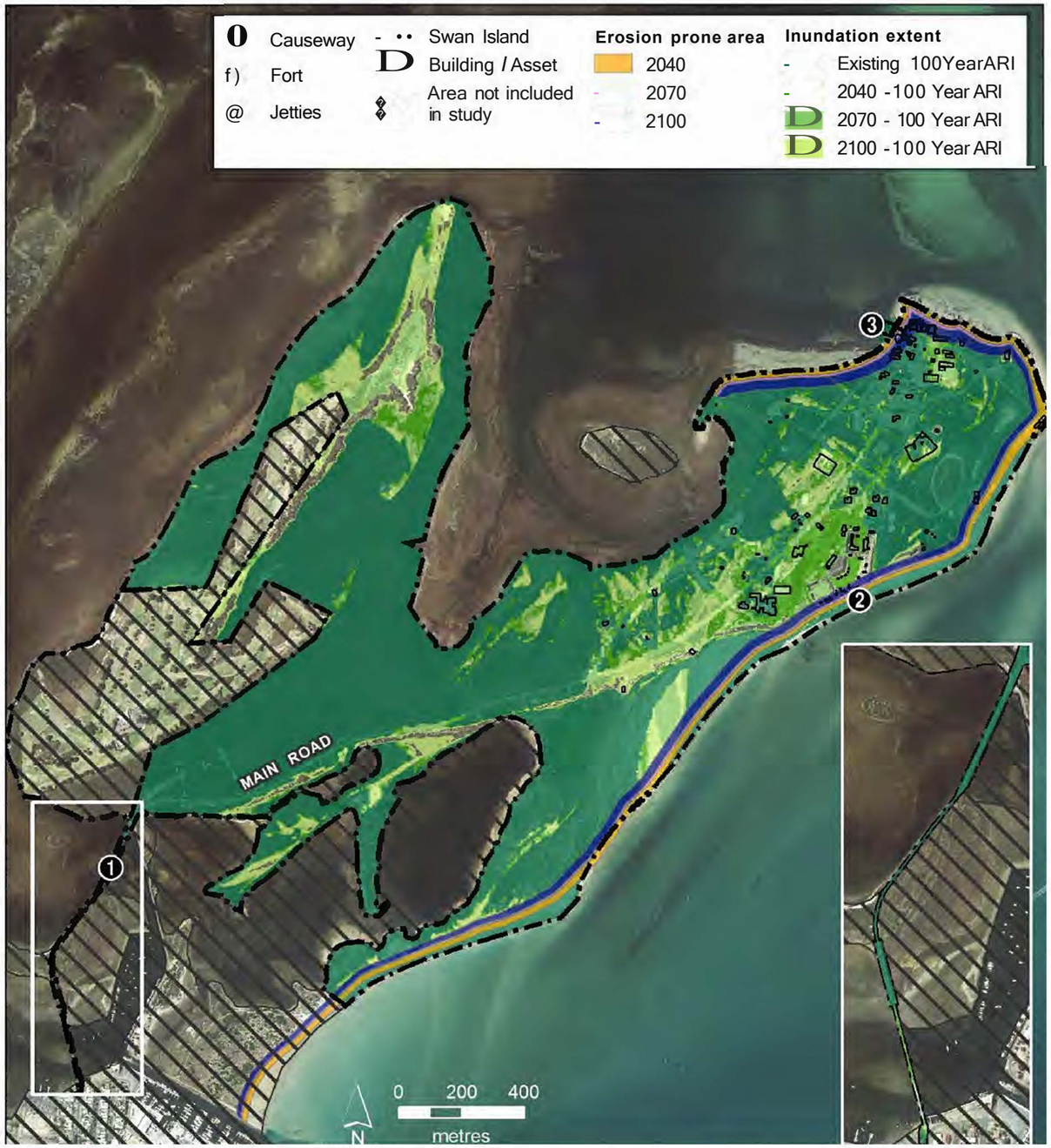

Figure 1: Inundation extents as a result of a 100 Year ARI storm surge event and coastal erosion extents at Swan Island for existing conditions, 2040, 2070 and 2100.

SWAN ISLAND

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	3.00 m	3.20 m	3.45 m	4.43 m
Increase in run off due to extreme rainfall		Not assessed at this site		
Coastal erosion (m recession)	-	Up to 38 m	Up to 42 m	Up to 70 m
Buildings Inundation, storm surge and erosion impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage will reduce base capability and functionality during and following storm events.		**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting site access, use of internal roads and damaging roads, reducing base capability.		**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation, storm surge and erosion impacts to jetties causing damage and increasing the frequency of maintenance and repair.		**Low22** **L-A1** **C-N21** **(capability)**	**Low22** **L-A1** **C-N21** (capability)	**Low22** **L-A1** **C-N21** (capability)
Runways and Aviation Infrastructure Inundation and storm surge impacts restricting use of and damaging the helipad.		**Low22** **L-A1** **C-N21** **(capability)**	**Low22** **L-A1** **C-N21** (capability)	**Low22** **L-A1** **C-N21** (capability)
Utilities Inundation, storm surge and erosion impacts disrupting and damaging essential services to the site including electricity, communications, water and sewerage reducing base capability and functionality.		**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)	**Very High 2** L-A1 C-S1 (capability)
Environmental Assets Inundation and storm surge impacts may degrade habitat for Commonwealth Listed Threatened Species and listed migratory species.		**Very High 7** L-A1 C-M6 (E&H)	**Very High 7** L-A1 C-M6 (E&H)	**Very High 7** L-A1 C-M6 (E&H)
Contamination Inundation, storm surge and erosion impacts may mobilise contamination into soils, groundwater and marine environment.		**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** L-P5 C-M11 (E&H)	**Medium 16** **L-P5** **C-M11** (E&H)
Heritage Inundation, storm surge and erosion impacts will damage historic heritage assets.		**Medium 16** L-P5 C-M11 (E&H)	**High 11** L-P5 C-M6 (E&H)	**High 11** L-P5 C-M6 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. OmAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under *the* assumption that Defence continues to occupy the site in *the* longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of *the* site remain *the* same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, marine infrastructure and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, utilities, environmental assets, contamination and heritage.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring procedures to account for increased damage and corrosion. The regularity of condition assessments may need to be increased for vulnerable assets such as buildings and roads. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation, such as more frequent painting of vulnerable structures.	Buildings, site access and internal roads, (e.g. bridges and causeways), utilities, contamination and heritage.	$50K-$100K to adjust central maintenance specifications. There is likely to be an ongoing increase to maintenance costs compared to a baseline of no climate change, however it cannot be quantified.
Maintain engagement with sand management practices Continue to engage with Parks Victoria to ensure that Defence is actively involved in the sand management practices for the Queenscliff Harbour Marina (e.g. sand bypass and dredging). Defence should seek to have this maintained (or enhanced) or have early warning of changes to enable investigation of potential impacts to coastal erosion risks in Swan Island.	Buildings, site access and internal roads, utilities, contamination and heritage.	Negligible cost to undertake consultation.
Site flood protection - south levee Construct a flood levee around the southern cluster of structures to prevent inundation (approximately 2.2 km in length). The levee should be designed to reduce flood risk up to the 2070 inundation level. The levee should be designed to work with existing dune/ landforms which may require some strengthening, to ensure it can provide flood protection. An underground cut-Off wall is required to prevent the flow of water under the levee. A geotechnical investigation would be required to determine design and accurate costs of the cut-Off wall.	Buildings, internal roads, utilities, contamination and heritage.	$4.2M to undertake initial investigation, design and construction works to protect from 2070 inundation levels. $6M to build it to protect from 2100 inundation levels.
Site flood protection - north levee Construct a grassed flood levee around the northern cluster of structures to prevent inundation (approximately 1 km in length). The levee should be designed to reduce flood risk for the 2070 inundation level initially. The levee should be designed to work with existing dune / landforms which may require some strengthening, to ensure it can provide flood protection. An underground cut-Off wall is required to prevent the flow of water under the levee. A geotechnical investigation would be required to determine design and acurate costs of the of cut-Off wall.	Buildings, internal roads, utilities, contamination and heritage.	$2M to undertake initial investigation, design and construction works to build to protect from 2070 inundation levels. $3M to build it to protect from 2100 inundation levels.
Upgrade causeway and raise Main Road To maintain access to the site during a 100 storm surge event, upgrade, or replace the causeway with consideration of 2100 high tide levels. This option assumes that access to and from the site would still be restricted during 2100 storm surge events, but will provide protection from 2070 inundation levels. The causeway may need to be upgraded to enable cost effective transport of construction materials for levee construction. Upgrading the causeway should be supported by the raising the height of Main Road (approximately 1.5 km in length) to maintain access across the site under 2070 inundation levels.	Site access and internal roads.	Causeway: Between $22.5M to $28M depending on configuration (i.e. new bridge or redevelopment of existing causeway and road). Main Road: $3.6M to design and construct to protect from 2070 inundation levels. $6.9M to build it to protect from 2100 inundation levels.
Review emergency management plans Undertake an initial review of emergency management plans to ensure they respond to an increased scale of inundation impacts, including restriction of access to the island.	Buildings, site access and internal roads.	$15K-$50K to review inundation risks as part of regular reviews of existing plans.
Coastal protection works Install coastal protection works including beach renourishment, sea walls and off shore coastal protection works along parts of the north and eastern shores of Swan Island to prevent further erosion. These protection works should be designed to mitigate coastal erosion based on 2070 storm conditions.	Buildings, utilities, contamination and heritage.	Initial investigation cost $200K. Cost of implementing recommendations may range from $100K to $7.5 m depending on action).

GARDEN ISLAND DEFENCE PRECINCT

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Maritime operations	Command and control centres, berthing facilities	RAN
Accommodation	Live in and messing accommodation, offices	RAN
Logistics	Wharfs, storage facilities	RAN
Training	Education facilities	RAN

The Garden Island Defence Precinct (GIDP) is 1 km north of Kings Cross Railway Station and 1 km east of the Sydney Central Business District (CBD).

The site is used by the RAN and accommodates ADF command and control, Navy operations, field training and ship repair and maintenance. Garden Island was an island until the gap between Potts Point and the southern shore of Garden Island was reclaimed to enclose the basin in which the Captain Cook Dry Dock was constructed.

One third of the site is listed on the Register of the National Estate. The GIDP is included on the Commonwealth Heritage List for historic heritage values.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a 100 year ARI storm surge event was assessed at the site. Risks associated with extreme rainfall and coastal erosion were not assessed at this site, due to its small catchment size and the existing coastal protection.

The site is at Medium risk from a 100 year ARI storm surge event in 2040 and 2070 increasing to Very High risk in 2100. In 2100, almost the entire site is at risk of inundation leading to a Very High risk to buildings and utilities.

In 2100, inundation from a 100 year ARI storm surge event will damage all internal roads (except Hill road) and restrict access to the site from Cowper Wharf Road. This **risk** is rated Very High in 2100.

The risk to pier and marine infrastructure is Medium in 2040 and 2070 as a result of the direct impacts of storm surge events and an increased height of the corrosive splash zone. In 2100, a 100 year ARI storm surge event will inundate all marine infrastructure increasing the risk to Very High. Inundation may result in the mobilisation of contamination leading to a High risk in 2100.

The risk to historic heritage assets is High in 2100, with inundation likely to damage assets increasing management and maintenance requirements.

SUMMARY OF ADAPTATION OPTIONS

As the inundation risks to the site are minimal until 2100, there are limited priority adaptation options required, including:

- Further investigate the potential risks to underground services.
- Review maintenance specifications and monitoring procedures to account for increased damage and corrosion of wharfs.

In the longer term, consideration will need to be given to relocating capability from the site or undertaking significant works to elevate or protect all assets at the site.

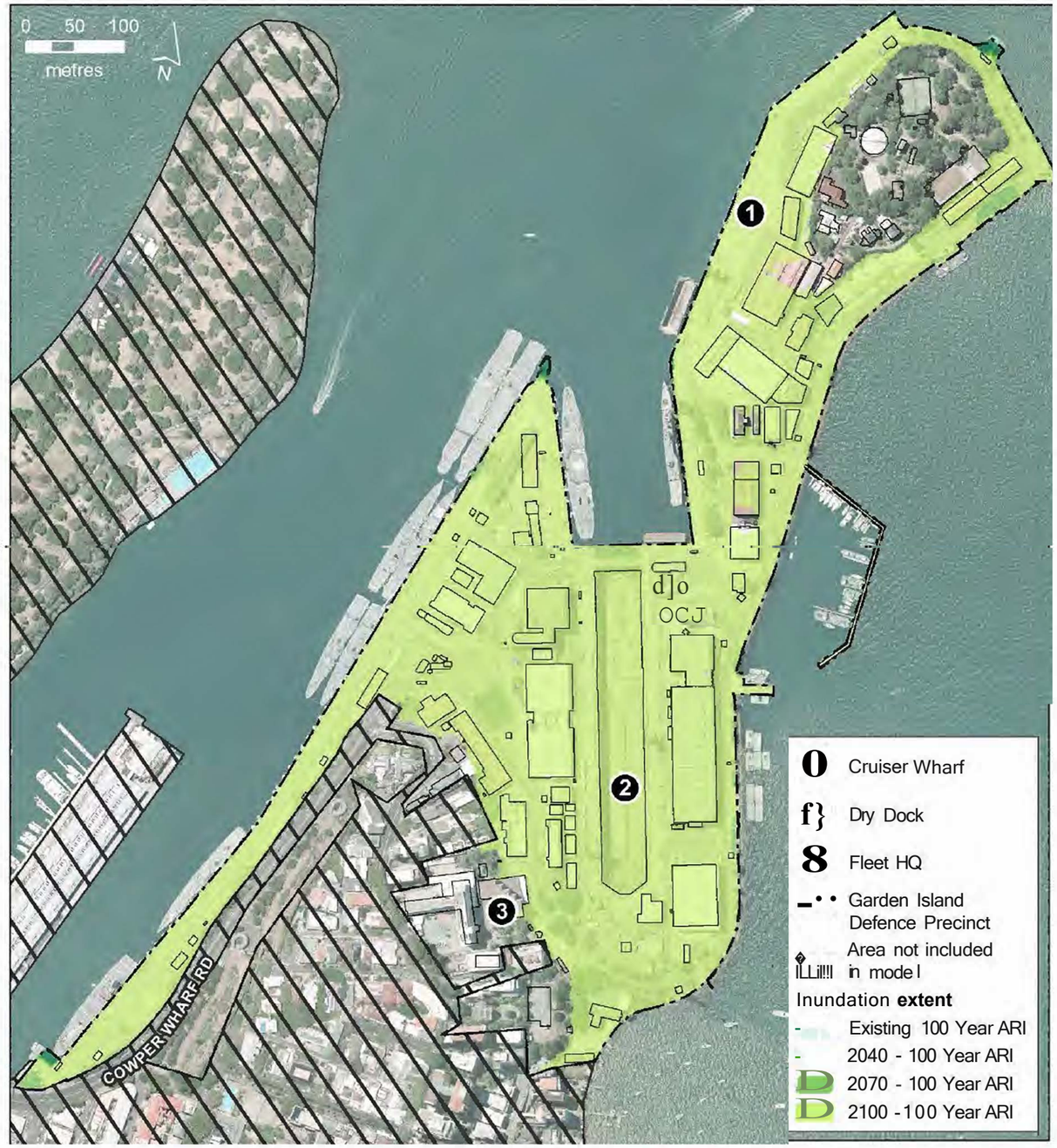

Figure 1: Inundation extents **as a** result of a 100 Year ARI storm surge events at Garden Island Defence Precinct for existing conditions. 2040, 2070 and 2100.

GARDEN ISLAND DEFENCE PRECINCT

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	1.63 m	1.83 m	2.08 m	3.06 m
Increase in run off due to extreme rainfall		Not assessed at this site		
Coastal erosion (m recession)		Not assessed at this site		
Buildings Inundation and storm surge impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		NIA	NIA	Very High 2 L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation and storm surge impacts restricting site access, use of internal roads and damaging roads, reducing base capability.		NIA	NIA	Very High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure Inundation and storm surge impacts to berthing facilities and wharfs. Resulting damage may reduce capability and increase the frequency of maintenance and repair.		Medium 19 L-L3 C-M16 (capability)	Medium 19 L-L3 C-M16 (capability)	Very High 2 L-A1 C-S1 (capability)
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		NIA	NIA	NIA
Utilities Inundation may disrupt and damage essential services including electricity, communications, water and sewerage, reducing base capability and functionality.		NIA	NIA	Very High 2 L-A1 C-S1 (capability)
Environmental Assets There are no listed or indicative environmental assets identified at the site.		NIA	NIA	NIA
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and the marine environment.		NIA	NIA	High 12 L-A1 C-M11 (E&H)
Heritage Inundation may damage historic heritage assets.		NIA	NIA	High 12 L-A1 C-M11 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 mAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been priolitised under the assumption that Defence continues to occupy the s e in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Utilities - resilience of underground utilities Determine the vulnerability of underground utilities at the site (e.g. utility service tunnels). Sea level rise and increased storm surge heights may affect the stability or integrity of utility service tunnels leading to flooding and damage to utilities.	Utilities.	$50K-$100K to undertake detailed assessment and determine vulnerability.
Maintenance specifications Review maintenance specifications and monitoring procedures to account for increased damage and corrosion. The regularity of condition assessments may need to be increased for vulnerable assets such as wharfs. Maintenance treatments may need to be adjusted to prevent an acceleration of asset degradation. Options include increasing the strength of protective coatings of assets exposed to higher splash zones.	Pier and marine infrastructure.	$50K-$100K to adjust central maintenance specifications. There is likely to be an ongoing increase to maintenance costs compared to a baseline of no climate change, however it cannot be quantified.

PROOF & EXPERIMENTAL ESTABLISHMENT PORT WAKEFIELD

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Weapons testing and research	Artillery, research and development facilities, storage facilities	JLC, DSTO

Proof & Experimental Establishment (P&EE) Port Wakefield is a 5,000 hectare site located 90 km north-west of Adelaide, with a 30 km coastline along the Gulf of St Vincent.

The site is occupied by the Explosive Ordnance Branch (EOB) in the Joint Logistics Command. An additional area of 19,200 hectares of the Gulf, directly to the west of the site, is under the control of P&EE Port Wakefield. The facility proof tests ammunition, fuses, projectiles and gun components manufactured in Australia and overseas.

The marine areas at P&EE Port Wakefield provide significant habitat for internationally and nationally significant migratory and aquatic bird species. Historic heritage sites are located on this base, however they are not listed as significant national or state assets.

SUMMARY OF RISKS

The risk of coastal erosion, inundation from sea level rise and a combined 100 year ARI storm surge and extreme rainfall event was assessed at the site. The risks of coastal erosion were also assessed.

Many built assets and the majority of the low lying, unbuilt areas of the site are currently at risk of inundation during a 100 year ARI storm surge and extreme rainfall event. Climate change is likely to increase the depth of inundation and marginally increase the extent in all three timeframes. Some buildings are at High risk of inundation in 2040 and 2070, increasing to Very High risk in 2100.

Internal roads in P&EE Port Wakefield are at Very High risk of inundation across all three timeframes. Inundation of internal roads during extreme weather events is likely to restrict access to, and between, facilities.

Some utilities in P&EE Port Wakefield are at High risk in 2040 and 2070, increasing to Very High in 2100. Inundation is likely to disrupt and damage essential services including electricity supply, communications, and water and sewerage utilities, restricting capability.

The risk to environmental assets is Medium in 2040 and 2070, increasing to High in 2100. The tidal zone represents a key environmental asset that supports capability. Sea level rise is likely to reduce the area available for over water recovery. Inundation and erosion may also degrade habitats that support threatened species.

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for P&EE Port Wakefield focus on protecting existing assets and planning for the longer term relocation of select assets and the coastal road:

- Adjust designs for new works or redevelopment of buildings, roads and utilities (including towers).
- Review maintenance specifications and monitoring procedures to account for increased damage and corrosion.
- Review emergency management plans to respond to an increased scale of inundation impacts.
- Isolate electricity utilities to ensure network performance and self-sufficiency when elements of the system are affected by inundation.
- Undertake asset specific flood protection to address existing risks.
- Plan for the relocation of at risk assets with consideration of their current condition, remaining useful life and exposure to inundation and erosion risks.

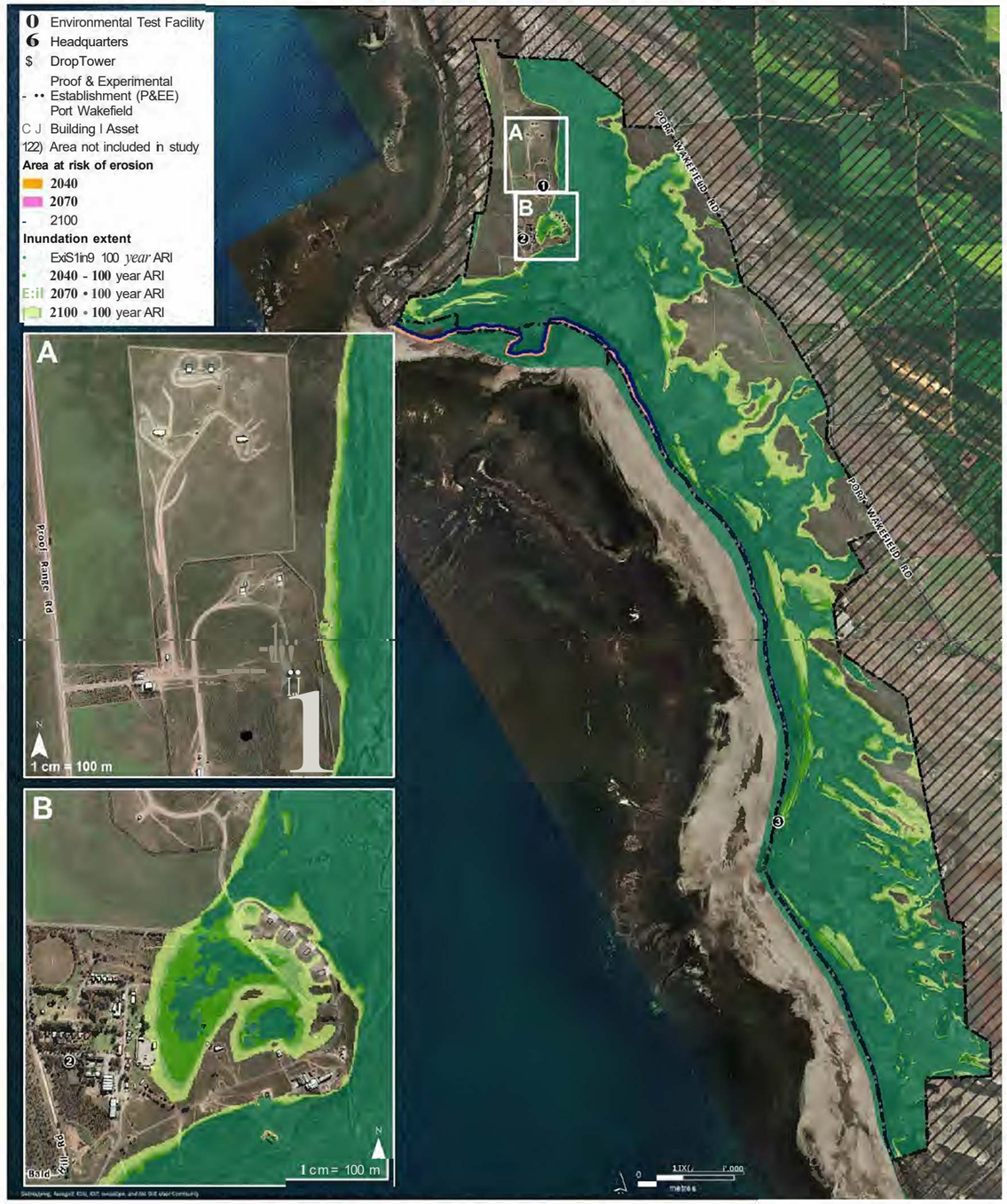

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall events and erosion extents at Proof & Experimental Establishment, Port Wakefield for existing conditions, 2040, 2070 and 2100.

PROOF & EXPERIMENTAL ESTABLISHMENT PORT WAKEFIELD

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	3.10 m	3.30 m	3.55m	4.53 m
Increase in run off due to extreme rainfall	-	20%	30%	40%
Coastal erosion (m recession)		Up to 21 m	Up to 41 m	Upto120m
Buildings Inundation, storm surge and erosion impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	**Very** High 7 L-A1 C-M6 (capability)
Site Access and Internal Roads Inundation, storm surge and erosion impacts restricting use of internal roads and damaging roads, reducing base capability.		Very High 7 L-A1 C-M6 (capability)	Very High 7 L-A1 C-M6 (capability)	**Very** High 2 L-A1 C-S1 (capability)
Pier and Marine Infrastructure There are no piers or marine infrastructure at this site.		N/A	N/A	N/A
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		N/A	N/A	N/A
Utilities Inundation and erosion may disrupt and damage essential services to the site including electricity, communications, water and sewerage, reducing base capability and functionality.		High 12 L-A1 C-M11 (capability)	High 12 L-A1 C-M11 (capability)	Very High 7 L-A1 C-M6 (capability)
Environmental Assets Tidal inundation may reduce the tidal flat area available for over water recovery. Inundation, storm surge and erosion impacts may degrade habitat for Commonwealth Listed Threatened Species, migratory birds and national and state significant vegetation species.		Medium 16 L-P5 C-M11 (capability / E&H)	Medium 16 L-P5 C-M11 (capability/ E&H)	**High 9** L-L3 C-M6 (capability/ E&H)
Contamination Inundation and erosion may result in the mobilisation of contamination into soils, groundwater, and the marine environment.		**Medium** 17 L-A1 C-M16 (E&H)	**Medium** 17 L-A1 C-M16 (E&H)	**Medium 17** L-A1 C-M16 (E&H)
Heritage Inundation and erosion may damage indicative historic heritage assets.		**Low22** L-A1 C-N21 (E&H)	**Low22** L-A1 C-N21 (E&H)	**Medium** 17 L-A1 C-M16 (E&H)

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 mAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under *the* assumption that Defence continues to occupy the site in *the* longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of *the* site remain *the* same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, roads and utilities. This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, utilities, and contamination.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring procedures to account for increased damage and corrosion. The regularity of condition assessments may need to be increased for vulnerable assets such as buildings, roads and utilities. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation, including more frequent inspections of vulnerable structures.	Buildings, site access and internal roads, utilities, and contamination.	$50K-$1 00K to adjust central maintenance specifications. There is likely to be an ongoing increase to maintenance costs compared to a baseline of no climate change, however it cannot be quantified.
Asset specific protection **works** Undertake asset protection works including, improved asset drainage, tanking protection works and raising the height of asset floor levels. These works should be staged to respond to the rate of sea level rise. Specific assets that should be protected include Explosives Storehouse HE (508509R) (A0079), Drop Test Tower Control Building (A0104), Drop Test Tower 20M (A0105) and Storage Shed (A0139), Propellant Magazine (509292K) (A0084), Victor Battery (502413W)- safety shelter (A0076), Winch Building (502411A) (A0078) and Winch Shed (A0098).	Buildings and utilities.	$50K-$1 00K to plan and design protective works, depending on number of **assets.** The cost of implementing physical changes would be dependent on the specific structures, their use, height change or protection measures required.
Plan relocation of **assets** As at risk assets reach the end of their design life, relocate them to areas within the site that are not at risk of inundation. Plan for the relocation of at risk assets with consideration of their current condition, remaining useful life and exposure to inundation and erosion risks.	Buildings, utilities and contamination.	$50K-$1 00K to review **asset** condition and plan for relocation. Negligible additional cost to include relocation in re-development planning.
Utilities - network reliability Isolation of electrical and communications systems to ensure network performance and self-sufficiency when elements of the system are affected by inundation.	Utilities.	$50K-$1 00K to undertake detailed assessment and determine vulnerability, required works and associated costs. This refers to utilities within the site boundary only.
Review emergency management plans Undertake a review of emergency management plans to ensure they respond to an increased scale of inundation impacts, including short term protection of assets (e.g. sandbagging, powering down assets) and resourcing for clean-up activities (e.g. remediation of the coastal road).	Buildings, site access and internal roads, utilities, and contamination.	$15K-$50K to review inundation risks as part of regular reviews of existing plans.

ST KILDA TRANSMITTING STATION

BASE OVERVIEW

Activity	Infrastructure	Principal Occupant
Research	Antenna array, research and development facilities	DSTO

St Kilda Transmitting Station (St Kilda) is a 218 hectare site located 25 km north-west of Adelaide. The Defence Science and Technology Organisation (DSTO) uses the site for experimental radio frequency trials. Approximately half the site is used as an antenna testing area. There are a number of buffer paddocks that are undergoing revegetation, or being used for grazing.

While not staffed on a permanent basis, during experiments DSTO personnel may undertake 24 hour onsite monitoring. Management and maintenance of the site is the responsibility of Defence Support - South Australia (DS-SA).

No listed or indicative environmental or heritage assets have been identified on this site.

SUMMARY OF RISKS

The risk of inundation from sea level rise and a combined 100 year ARI storm surge and extreme rainfall event was assessed at the site. As St Kilda Transmitting Station is not directly exposed to coastal processes, coastal erosion risks have not been assessed at this site.

Two thirds of the unbuilt areas of the site are currently at risk of inundation during a 100 year ARI event. Climate change is likely to increase the extent and depth of inundation to cover approximately three quarters of the site and almost all built assets in 2100. Some buildings are at Medium risk of inundation in 2040 and 2070, increasing to Very High risk in 2100.

Utilities in St Kilda Transmitting Station are at High risk in 2040 and 2070 and Very High risk in 2100. Inundation is likely to disrupt and damage essential services including electricity supply, communications, and water utilities, restricting capability.

Internal roads in St Kilda Transmitting Station are at Medium risk of inundation in 2040 and 2070, increasing to High risk in 2100. Inundation of the main access road (Radar Road) may affect staff access to the site, affecting capability.

Inundation mobilising contamination in St Kilda Transmitting Station is a Low risk across all three timeframes.

SUMMARY OF ADAPTATION OPTIONS

The priority adaptation options for St Kilda Transmitting Station focus on protecting the built assets:

- Adjust designs for new works or redevelopment of buildings, roads and utilities (including antennas).
- Review maintenance specifications and monitoring procedures to account for increased damage and corrosion.
- Review guidance for storage of critical and / or hazardous materials in structures at risk of inundation.
- Construct a table drain around the Ground Reflection Range to prevent inundation from extreme rainfall events.
- Periodically review emergency management plans to respond to an increased scale of inundation impacts.
- Ensure Defence is informed of the implications of major developments that may affect the site's inundation risk profile (i.e. changes in management practices of the salt pans and development of the Northern Expressway).

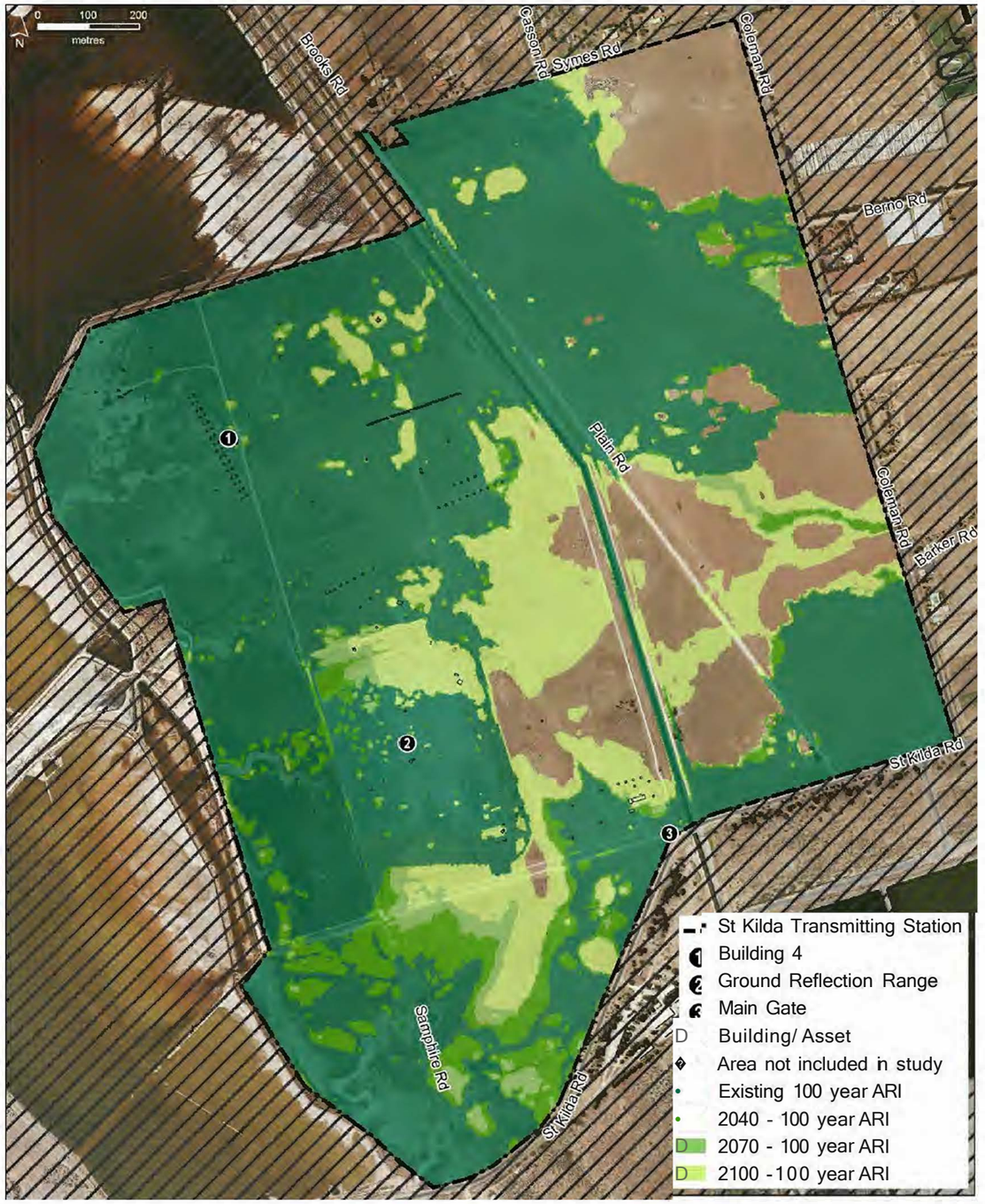

Figure 1: Inundation extents as a result of combined 100 Year ARI storm surge and extreme rainfall events at St Kilda Transmitting Station for existing conditions. 2040, 2070 and 2100,.

ST KILDA TRANSMITTING STATION

RISK DESCRIPTION	Now	2040	2070	2100
Extreme sea level including storm surge	2.54 m	2.74m	2.99 m	3.97 m
Increase in run off due to extreme rainfall	-	20%	30%	40%
Coastal erosion (m recession)		Not assessed at this site.		
Buildings Inundation impacts to some buildings causing damage and degradation of above and below ground building structures. Resulting damage may reduce base capability and functionality during and following flood events.		**Medium 17** **L-A1** **C-M16** (capability)	**Medium 17** **L-A1** **C-M16** (capability)	**Very High 2** L-A1 C-S1 (capability)
Site Access and Internal Roads Inundation impacts restricting access to the site, use of internal roads and damaging roads, reducing base capability.		**Medium 17** **L-A1** **C-M16** (capability)	**Medium 17** **L-A1** **C-M16** (capability)	High 12 L-A1 C-M11 (capability)
Pier and **Marine** Infrastructure There are no piers or marine infrastructure at this site.		**N/A**	**N/A**	**N/A**
Runways and Aviation Infrastructure There are no runways or aviation infrastructure at this site.		**N/A**	**N/A**	**N/A**
Utilities Inundation may disrupt and damage the Ground Refleciton Range and essential services at the site including electricity, communications, water and sewerage, reducing base capability and functionality.		High 12 L-A1 C-M11 (capability)	**High 12** L-A1 C-M11 (capability)	**Very High 7** L-A1 C-M6 (capability)
Environmental Assets There are no listed or indicative environmental assets identified at the site.		**N/A**	**N/A**	**N/A**
Contamination Inundation may result in the mobilisation of contamination into soils, groundwater and neighbouring properties.		**Low26** L-PS **C-N21** (E&H)	**Low26** L-PS C-N21 (E&H)	**Low26** L-PS C-N21 (E&H)
Heritage No indicative or listed Indigenous or historic built heritage values have been identified at the site.		**N/A**	**N/A**	**N/A**

Extreme sea level heights are in metres AHO. AHO refers to Australian Height Datum which is the datum for altitude measurement in Australia. 0 mAHD was mean sea level in 1971. The changes in storm surge levels include sea level rise and do not include consideration of changes in other climatic factors (e.g. wind speed, southward tracking of cyclones, etc). The selection process for climate projections was consistent with guidance provided in AS5334 Australian Standard for Climate Adaptation for Settlements and Infrastructure. The proposed adaptation options have been prioritised under the assumption that Defence continues to occupy the site in the longer term (i.e. 90 years) and that the characteristics (i.e. assets and capability) of the site remain the same.

PRIORITISED OPTIONS FOR IMPLEMENTATION WITHIN NEXT 10 YEARS

Adaptation Option	Risk Relevance	Indicative Cost ($2013)
Inundation design specifications Adjust the design specifications for any new works or development of buildings, roads and utilities (including antennas). This could be achieved through changes to the Defence Estate Quality Management System. Design specifications should incorporate greater allowances for marine and estuarine flooding including the location of assets and buried services, improved asset drainage, improved storage of hazardous and operational materials, consideration of design for permanent inundation of assets and / or foundations / footings and flexibility to increase heights or strengthen protection (including material selection) as sea levels increase over time.	Buildings, site access and internal roads, utilities, and contamination.	$250K to adjust central design specifications.
Maintenance specifications Review maintenance specifications and monitoring procedures to account for increased damage and corrosion. The regularity of condition assessments may need to be increased for vulnerable assets such as antennas and roads. Maintenance treatments may need to be adjusted to be more proactive to prevent acceleration of asset degradation, such as more frequent inspections of vulnerable structures (e.g. the Ground Reflection Range).	Buildings, site access and internal roads, utilities, and contamination.	$50K-$100K to adjust central maintenance specifications. There is likely to be an ongoing increase to maintenance costs compared to a baseline of no climate change, however it cannot be quantified.
Site Flood Protection - Table Drain Construct a table drain around the Ground Reflection Range. This drain should be designed to divert rainfall flows around the Ground Reflection Range toward the site's existing outlet in the west of the site. Existing drainage provisions under the western access road should be upgraded along with installation of tidal gates at the existing outlet from the site.	Utilities.	$380K to undertake design and construction works.
Review emergency management plans Undertake a review of emergency management plans to ensure they respond to an increased scale of inundation impacts, including use of the flood barriers for the turntable at the Ground Reflection Range and restriction of access to the site.	Buildings, site access and internal roads, utilities, and contamination.	$15K-$50K to review inundation risks as part of regular reviews of existing plans.
Be informed of major developments likely to affect the site's risk **profile** Ensure Defence has an understanding of the implications of major developments that may affect the site's inundation risk profile. This includes liaising with state and local governments on changes to the management practices of the salt pans and proposed works for the Northern Expressway which may affect flooding on the site.	Buildings, site access and internal roads, utilities and contamination.	Negligible cost to undertake consultation.

Appendix C

Additional Climate Information

Appendix C Additional Climate Information

1. This appendix provides context for the climate information used in this assessment.

2. Climate projections are produced by simulating the effects of 'emissions scenarios' using 'climate models'. The Intergovernmental Panel on Climate Change (IPCC) has prepared emission scenarios for the 21st century. Each scenario is based on assumptions about demographic, economic and technological factors likely to influence future greenhouse gas emissions.

3. Climate models are mathematical representations of the Earth's climate system based on well-established laws of physics. The effects of each emissions scenario can be simulated using climate models. For each emissions scenario as developed for the IPCC Fourth Assessment Report: Climate Change 2007, there are projections available from up to 23 global climate models. These emissions scenarios are due to be updated in the development of the Fifth Assessment Report due to be released in 2014. In addition, further analysis has been undertaken by research bodies to develop projections for differing timeframes and regions.

4. In selecting appropriate climate inputs for risk assessments and adaptation planning, the Australian Standard for Climate Adaptation for Settlements and Infrastructure AS5334 provides the following guidance:

- Climate data should be selected for best performance in the region;
- Relevant and authoritative climate projections data should be used;
- The data used, and the process and reasons for determining its relevance to the risk assessment to be undertaken, should be recorded;
- It is preferable to provide a range of future scenarios to guide the risk assessment; and
- The selection of climate variables to be assessed should be determined by the climate sensitivity of a range of asset types, activities and locations.

5. For this assessment, climate change projections for sea level rise and extreme rainfall were used to inform the detailed assessments of marine flooding, estuarine flooding and coastal erosion.

6. The IPCC 'A1FI' global emissions scenario has been used as a basis for selecting climate projections. This scenario assumes a 'Fossil Intensive' future with relatively high greenhouse gas emissions. Current greenhouse gas emissions are tracking in line with the 'A1FI' emissions scenario pathway.

7. To inform the analysis of the impacts of sea level rise at each site, the CSIRO and Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) provided projections with upper and lower values for 2040 and 2070 based on the 95th and 50th percentile values under the A1FI emissions scenario. Recognising the range in projections of sea level rise for 2100 (refer to Figure 3), a lower and upper figure was selected from other supporting research. A lower figure of 1.10 m sea level rise was selected to maintain consistency with national coastal planning policy. A higher sea level projection of 1.43 m (mean value by Vermeer and Rahmstorf (2009)) was selected to provide a plausible upper range for 2100. In recognition of the accuracy of the available elevation data (approximately +/-0.25 m), sea level rise projections adjusted for regional variability (i.e. a range from -0.04 m to +0.06 m by 2070) were not applied.

8. To consider the implications of increases in extreme rainfall, each site's sensitivity to changes in run off based on the 5 year ARI and 100 year ARI extreme rainfall events was assessed. Changes to runoff from extreme rainfall events was focussed on as there are no climate change projections for changes to the average recurrence interval (ARI) available for the sites or timeframes assessed (Rafter, 2012). To estimate the potential changes in runoff information provided by CSIRO (Rafter, 2012) and Sandery, et al. (2009) was utilised.

9. A summary of the climate inputs used in this assessment are included in Table 44. More detailed discussion of the application of the projections is included in the technical reports developed for each site (refer to the individual site reports).

Table 44 Summary of climate inputs used in this assessment.

	2040	2070	2100	References
Sea Level Rise				
Lower	0.14 m	0.31 m	1.10 m	ACE CRC and CSIRO2012 Vermeer and Rahmstorf (2009).
Higher	0.20 m	0.45 m	1.43 m	
Increase in run off due to extreme rainfall				
Northern Queensland				
Lower	+10%	+20%	+30%	Rafter (2012), Sandery, et al. (2009) and Hennessey et al (2008).
Higher	+20%	+30%	+40%	
Southern Queensland				
Lower	+20%	+30%	+50%	Rafter (2012) and Sandery, et al. (2009).
Higher	+40%	+50%	+70%	
Eastern New South Wales				
Lower	+20%	+30%	+40%	Rafter (2012) and Sandery, et al. (2009).
Higher	+40%	+50%	+60%	
Victoria				
Lower	+10%	+20%	+30%	Rafter (2012) and Sandery, et al. (2009).
Higher	+20%	+30%	+40%	
Northern Western Australia				
Lower	+10%	+20%	+30%	Rafter (2012), Sandery, et al. (2009) and DSE (2008).
Higher	+20%	+30%	+70%	
South Australia				
Lower	+10%	+20%	+30%	Rafter (2012), Sandery, et al. (2009) and DSE (2008).
Higher	+20%	+30%	+40%	

10. Storm surge was included in the consideration of extreme sea levels. This was based on historic recorded data. In this assessment, the influence of cyclones was included in the consideration of extreme sea levels, specifically influences on storm surge, wind, wave run up and wave set up. These allowances have been based on historic recorded data. In the Australian region, no categorical changes in the total numbers of tropical cyclones, or in the proportion of the most intense tropical cyclones, have been found in observed records; though there is considerable year-to-year and decade-to-decade variability. The 2012, CSIRO and the Bureau of Meteorology report, State of the Climate, indicated that there will be fewer tropical cyclones on average in the Australian region as a result of climate change but the proportion of intense cyclones is expected to increase. However, quantification of these changes is not currently available.

11. For information, the inputs for this assessment are presented with other climate projections from a variety of authors and scenarios. This information is provided to illustrate that there are a range of possible outcomes regarding the extent that climate variables may change. Figure 3 compares the projections considered in this assessment to other projections for sea level rise.

12. Table 45 compares the increases in run-off due to extreme projections considered for this assessment to other projections for changes in extreme rainfall. This highlights the limited range of climate projections available for changes in extreme rainfall.

Figure 3 Comparison of sea level rise projections.

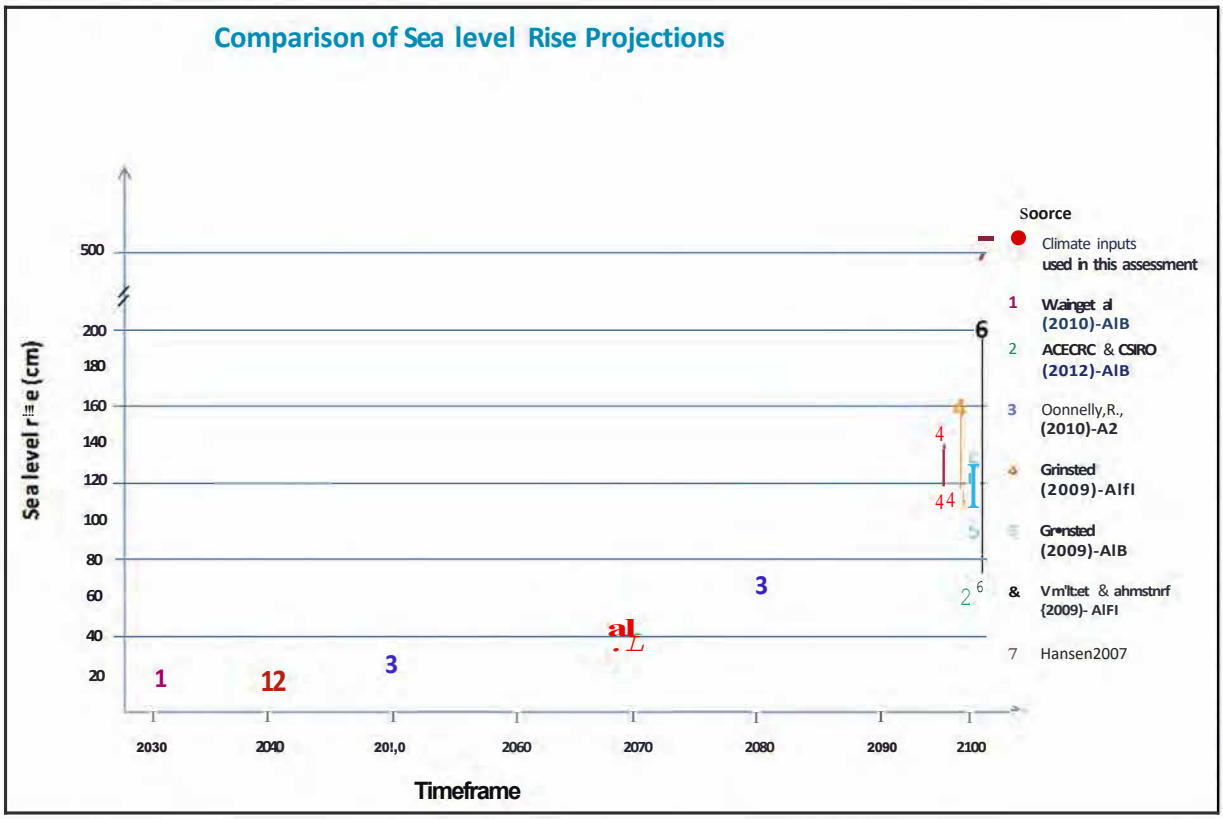

Table 45 Comparison of extreme rainfall projections for each region assessed (where no figures are provided for a given year, this indicates that no climate projections are available foe that year).

Increase in run off due to extreme rainfall (measure used in this assessment) For Northern Queensland	Lower		+10%		+20%		+30%
	Higher		+20%		+30%		+40%
% change in 20-year return level for 1-day rainfall totals (based on A2 emissions scenario) For northern Queensland - Sandery et al (2009)				-5% to +30%		0%to +25%	
% change in 10-year return level for 1-day rainfall totals (based on A2 emissions scenario) For northern Queensland - Rafter (2012)				-4% to +28%		-16% to +27%	
% change in 50-year return level for 1-day rainfall totals (based on A2 emissions scenario) For northern Queensland - Rafter (2012)				-7%to +34%		-11% to +42%	
Change in rainfall intensity (defined as the heaviest 1% of 24-hour rainfall) For Townsville - Hennessey et al (2008)		-9% to +6% (A1B)			-30% to +20% (A1FI)		

Projections [illegible]							
Increase in run off due to extreme rainfall (measure used in this assessment) For Northern Western Australia	Lower		+10%		+20%		+30%
	Higher		+20%		+30%		+70%
% change in 20-year return level for 1- day rainfall totals (based on A2 emissions scenario) North West - Sandery et al (2009)				-9.5% to +23.5%		-1.8% to +44.2%	
% change in 10-year return level for 1- day rainfall totals (based on A2 emissions scenario) North West - (Rafter 2012)				-7%to +18%		-3%to +28%	
% change in 50-year return level for 1- day rainfall totals (based on A2 emissions scenario) North West - (Rafter 2012)				-13% to +33%		-4%to +77%	
Increase in run off due to extreme rainfall (measure used in this assessment) For South East Queensland	Lower		+20%		+30%		+50%
	Higher		+40%		+50%		+70%
% change in 20-year return level for 1- day rainfall totals (based on A2 emissions scenario) South East Queensland - Sandery et al (2009)				-16% to +35.7%		-26% to +59.6%	
% change in 10-year return level for 1- day rainfall totals (based on A2 emissions scenario) South East Queensland - (Rafter 2012)				-12% to +24%		-22% to +54%	
% change in 50-year return level for 1- day rainfall totals (based on A2 emissions scenario) South East Queensland - (Rafter 2012)				-21% to +54%		-32% to +70%	
Increase in run off due to extreme rainfall (measure used in this assessment) For Eastern New South Wales	Lower		+20%		+30%		+40%
	Higher		+40%		+50%		+60%
% change in 20-year return level for 1- day rainfall totals (based on A2 emissions scenario) Eastern New South Wales - Sandery et al (2009)				-5.0% to +44.2%		-13.9% to +45.1%	
% change in 10-year return level for 1- day rainfall totals (based on A2 emissions scenario) Eastern New South Wales - (Rafter 2012)				-8% to +31%		-9%to +37%	
% change in 50-year return level for 1- day rainfall totals (based on A2 emissions scenario) Eastern New South Wales - (Rafter 2012)				-1% to +64%		-19% to +65%	

Increase in run off due to extreme rainfall (measure used in this assessment) For Victoria	Lower		+10%		+20%		+30%
	Higher		+20%		+30%		+40%
% change in 20-year return level for 1- day rainfall totals (based on A2 emissions scenario) Victoria - Sandery et al (2009)				-26.6% to +23.3%		-4.1% to +32.1%	
% change in 10-year return level for 1- day rainfall totals (based on A2 emissions scenario) Victoria - (Rafter 2012)				-25% to +24%		-2%to +30%	
% change in 50-year return level for 1- day rainfall totals (based on A2 emissions scenario) Victoria - (Rafter 2012)				-29% to +32%		-8%to 38%	
Change in rainfall intensity (99th percentile) For Melbourne - (DSE, 2008)		-7.7% to +15.2% (A1B)			-24.9% to +48.9% (A 1FI)		
Increase in run off due to extreme rainfall (measure used in this assessment) For South West (South Australia)	Lower		+10%		+20%		+30%
	Higher		+20%		+30%		+40%
% change in 20-year return level for 1- day rainfall totals (based on A2 emissions scenario) South West - Sandery et al (2009)				-3.2% to +24.5%		-7.0% to +38.2%	
% change in 10-year return level for 1- day rainfall totals (based on A2 emissions scenario) South West - (Rafter 2012)				-3% to +23%		-5% to +23%	
% change in 50-year return level for 1- day rainfall totals (based on A2 emissions scenario) South West - (Rafter 2012)				-5%to +22%		-10% to 32%	

Appendix C References

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