Climate change impacts

On Clarence coastal areas

Clarence City Council December 2008

THE UNIVERSITY OF NEW SOUTH WALES
water research laboratory
Manly Vale N.S.W. Australia

SGS Economics & Planning

Published by: Clarence City Council

The authors of the report acknowledge funding provided by:

Tasmanian State Emergency Service

Clarence City Council

Australian Department of Climate change

This report has been prepared by:

SGS Economics and Planning Pty. Ltd.
ACN 007 437 729
119 Macquarie Street
Hobart 7000
phone: 03 6223 6006
fax: 03 6224 9009
email: sgstas@sgsep.com.au
web: www.sgsep.com.au

Water Research Laboratory
School of Civil and Environmental Engineering
University of New South Wales ABN 57 195 873 179
King Street, Manly Vale NSW 2093 Australia
Telephone: +61 (2) 9949 4488
Facsimile: +61 (2) 9949 4188
WRL Project No. 06071.02

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Executive Summary

This project was initiated by Clarence City Council in response to Council and community concerns about erosion of beaches and flooding events in coastal areas. The project is supported by the State Emergency Service and the Commonwealth Department of Climate Change.

The project has been overseen by an Integrated Assessment Project Manager within Council supported by a Steering Committee with representatives of the Council, funding agencies and State Government agencies. A Technical Reference Panel has reviewed all reports.

The purpose of this study is to provide an integrated assessment of climate change risks on coastal areas which includes:

- An investigation of community attitudes at the beginning of the project.
- Consultation with community groups, institutions, state government agencies re their awareness and response to climate change issues.
- A review of the literature covering experience with similar issues elsewhere.
- Assessment of 18 localities and infrastructure within Clarence City which may be vulnerable to coastal hazards, both at present and due to sea level rise and climate change into the future. Coastal hazards have been assessed for the present day, 2050 and 2100.
- Investigation of adaptive management options in response to present and future coastal hazards.
- Preparation and execution of a communication plan to inform the community of the findings, initiate discussion about the preferred response and report on community response.

This report brings together the findings of the technical assessment and socio-economic assessment published in separate, more detailed reports.

Community's perspective

A survey of the general public preceded by focus groups was conducted supplemented by interviews with business, government and community organisations.

At the time of the survey in early 2007, Clarence residents were aware of and concerned about climate change and sea level rise, but knowledge and concern were vague and impersonal with limited sense of impacts potentially affecting them directly, more so for non-coastal residents. A significant theme was the importance of beaches, and keeping them in their current state.

Estimates of coastal risks

The 18 coastal locations were assessed using six key and thirteen secondary variables. The following simplified mid and high sea level rise scenarios were used based on Intergovernmental Panel on Climate Change (IPCC) reports:

Sea Level Scenario	2050	2100
Adopted "Mid" scenario	0.2 m	0.5 m
Adopted "High" scenario	0.3 m	0.9 m

The primary risks of erosion/recession, wave runup and inundation were quantified (where relevant) for each location for a 100 year Average Return Interval (ARI) event (which is equal to a 1% Average Exceedance Probability (AEP) event). The results were expressed as **indicative** setbacks for erosion/recession and as elevations for wave runup and inundation. The findings are summarised in Tables E1, E2 & E3.

Table E 1. Indicative setback requirements to accommodate erosion risk

Location	Storm erosion	Foundation Zone	**Indicative setback** (m)				
			Present	2050		2100	
	m	m		mid	high	mid	high
Bellerive Beach	15	7	22	32	37	47	67
Clifton (Ocean) Beach	25	10	35	45	50	60	80
Cremorne (Ocean) Beach	15	10	25	45	50	70	90
Glenvar Beach*	10	7	17	27	32	42	62
Hope Beach, South Arm Neck	25	8	33	43	48	58	78
Howrah and Little Howrah Beaches	10	7	17	27	32	42	62
Mays Beach	10	5	15	25	30	40	60
Opossum Bay	10	7	17	27	32	42	62
Roches Beach, Lauderdale	25	5	30	50	55	75	95
Seven Mile Beach, western 1km	10	10	20	30	35	45	65
South Arm Beach (Halfmoon Bay)	10	10	20	30	35	45	65

Source: WRL modelling, Technical Report, Table 20.1 (storm erosion rounded to nearest 5 m.)

* may be limited by underlying rock

Table E 2. Wave runup estimates for 1% AEP (100 yr ARI) storm events

Location	Present	2050		2100	
		Mid	High	Mid	High
	(m, AHD*)	(m, AHD)	(m, AHD)	(m, AHD)	(m, AHD)
Bellerive	3.3	3.5	3.6	3.8	4.2
Clifton (Ocean) Beach, west	5.9	6.1	6.2	6.4	6.8
Cremorne (Ocean) Beach	4.7	4.9	5.0	5.2	5.6
Glenvar Beach	4.9	5.1	5.2	5.4	5.9
Hope Beach, South Arm Neck	6.1	6.3	6.4	6.6	7.0
Little Howrah Beach	2.6	2.8	2.9	3.1	3.5
Mays Beach	2.5	2.7	2.8	3.0	3.4
Opossum Bay	4.5	4.7	4.8	5.0	5.5
Roches Beach, Lauderdale	2.8	3.0	3.1	3.3	3.7
Seven Mile Beach west	2.6	2.8	2.9	3.1	3.5
South Arm Beach – Halfmoon Bay	3.9	4.1	4.2	4.4	4.8

* AHD = Australian Height Datum in Tasmania is based on mean sea level for 1972 at the tide gauges at Hobart and Burnie which was assigned the value of zero on the AHD

Source: WRL modelling, Technical Report Tables 19.1 to 19.5

Table E 3. Estimated sea level heights for 1% AEP (100 yr ARI) storm events

		2050		2100	
	Present	Mid	High	Mid	High
	(m, AHD)	(m, AHD)	(m, AHD)	(m, AHD)	(m, AHD)
Bellerive	1.8	2.0	2.1	2.3	2.7
Bicheno St, Pipe Clay Lagoon	1.8	2.0	2.1	2.3	2.7
Clifton (Ocean) Beach, west	2.3	2.5	2.6	2.8	3.2
Cremorne – Pipe Clay Esplanade	1/6	1.8	1.9	2.1	2.5
Cremorne (Ocean) Beach	2.0	2.2	2.3	2.5	2.9
Glenvar Beach	1.7	1.9	2.0	2.2	2.6
Hope Beach, South Arm Neck	2.4	2.6	2.7	2.9	3.3
Kangaroo Bluff	1.5	1.7	1.8	2.0	2.4
Lauderdale, South Arm Rd, Ralphs Bay	2.0	2.2	2.3	2.5	2.9
Little Howrah Beach	1.9	2.1	2.2	2.4	2.8
Mays Beach	1.8	2.0	2.1	2.3	2.7
Montagu Bay	1.5	1.7	1.8	2.0	2.4
Opossum Bay	1.7	1.9	2.0	2.2	2.6
Roches Beach, Lauderdale	1.8	2.0	2.1	2.3	2.7
Rokeby Waste Water Treatment Plant	1.8	2.0	2.1	2.3	2.7
Seven Mile Beach west	2.0	2.2	2.3	2.5	2.9
South Arm Beach – Halfmoon Bay	1.7	1.9	2.0	2.2	2.6
South Arm Neck – Ralphs Bay side	2.3	2.5	2.6	2.8	3.2

Source: WRL modelling

Experience from elsewhere

A literature review with over 300 citations was conducted to look at existing literature on adaptation to climate change with a special focus on impacts in coastal areas. It found that climate variability is not new: systems have been responding to variations in climate for centuries. Socio-economic systems can be very flexible and will likely respond most to extreme realisations of climate change: human systems can be the source of surprises.

The element of surprise and flexibility of responses means that the widest possible range of plausible futures should be explored. Climate change offers opportunity as well as risk. Multiple approaches and responses should be accommodated.

Adaptation can reduce impacts of sea level rise from a factor of 10 up to a factor of 100, and economic costs of adaptation would be minor compared to the damage avoided. Adaptive decisions will be made in response to both climate change and climate change **policy**. Policy affects responses in a variety of ways including affecting expectations. Perceptions of risk depend upon welfare valuations that depend upon expectations, so understanding and managing expectations is important.

Community involvement is important for decision-making on adapting to climate change in spite of the challenges this poses to decision makers. Experience has shown that when adaptation strategies are interactive, participatory and bottom up as well as top down, better outcomes are achieved. Community consultation can enhance the community's ability to cope, and maximise community support for policy measures (especially in the case of drastic measures)

Roles and responsibilities

Each level of government has a different set of roles and responsibilities in relation to responding to climate change induced risks and natural disaster management. Many arise in relation to assets and infrastructure held, and agency responsibilities and programmes rather than specific climate change responsibilities. Each level of government has active programs for reducing greenhouse gas emissions and other mitigation action. In the areas of adaptation and emergency/disaster management, key roles include:

Council:

- planning and development
- coordination of emergency management planning
- public health impacts arising from climate change
- managing its own assets and any Council lands that may be affected by coastal risks
- heritage
- Natural Resource Management
- informing its residents and other local stakeholders

State Government:

- natural disaster management
- Statewide planning policies and framework
- State infrastructure including state roads (eg South Arm Road)
- Any schools, hospitals and other facilities for state provided services that may be affected
- National parks and state reserves
- In future, water and related infrastructure, including water intakes, treatment and reticulation
- Oversight of public health issues

Australian Government:

- COAG National Climate Change Adaptation Framework to build understanding and adaptive capacity and reduce vulnerability in key sectors and regions
- National leadership in disaster management and mitigation
- Addressing impacts of change in portfolios such as Families, Housing community Services and Indigenous Affairs, Health and Ageing and Human Services.

Households and businesses have principal responsibility for safeguarding their property and assets against risks from natural disasters.

A framework for responding

Given uncertainties, but the high probability that the sea level will continue to rise over the long term, the issue to be addressed is: **How do we beneficially use coastal areas while recognising the long term need to protect, accommodate or retreat as sea levels rise**? While use may be practical and desirable for many years, there will come a 'trigger' when a response will be required to manage increasing risks.

The modelling and mapping of future risk areas in this report identifies the changing areas that will be affected by 100 year ARI (1% AEP) events as sea level rises over time **if nothing is done**. The most effective action would be effective mitigation of global greenhouse gas emissions, bringing the outcome from the high scenario that we are currently tracking to the medium or lower scenario over these time frames. Given the potential impacts that may be unavoidable and areas of present day risk, the maps in this report identify locations where active risk management will likely be required.

New Development

There is a developing practice around Australia to use the hazard associated with the estimated high range for sea level rise in 2100 to determine acceptable development when revising planning schemes to take climate change into account. For erosion, set backs would be established that allow for expected erosion over this time frame while ensuring continued foundation stability.

While setting floor levels to suit 2100 high scenario flood effects or set backs for erosion may be appropriate as a general 'deemed to comply' basis for development, it is suggested that the emphasis should be on **encouraging performance based responses that maintain acceptable levels of risk over the life of the structure**. Thus a dwelling designed to be moved back from a moving erosion face, piled to be stable in spite of erosion and capable of withstanding waves or a structure designed to be elevated readily as sea levels rise could also be acceptable.

For areas where risks cannot be managed realistically, eg where erosion threatens future development and protection is either impractical or undesirable, a freeze on development may be most appropriate.

New developments in areas identified as subject to longer term risk should clearly be notified that they will be subject to requirements to actively manage risk when unacceptable risk levels are approached, even if this is long after the end of the expected service life of the building.

Existing property

Setting standards for new development does not address the developing risk for existing property. At present there is limited requirement to manage increasing risk to existing property. When damage does arise from a storm or other extreme event, emergency relief may be provided, but this after-the-fact assistance is far more costly than risk management before the event, with a higher risk of injury or death.

With the philosophy of managed/adaptive approach with multiple interventions, it is unnecessary to construct protective works now for high sea level rise in 2100, particularly if the provision to upgrade is incorporated in the design. It is prudent, however, to consider a range of sea level rise scenarios for future planning, as most of the present day risk is due to inadequate past planning and risk assessment.

Successful coastal management will usually combine elements of *retreat, accommodate and protect.* For erosion, hard protection (in the form of seawalls) and soft protection (through sand nourishment, supplemented with groynes) are generally technically feasible and generally are expected to have benefit to cost ratios over one for most locations, for sea level rise scenarios to 2100. For inundation there are fewer options, but some reduction in flooding may be achieved by flood barriers and a substantial reduction in risk through hazard reduction and emergency planning. These also would generally have benefit cost ratios greater than one.

People choose to occupy or use coastal areas because of the substantial benefits these areas provide. They are attractive locations to live, work and play. **In the long term** it is appropriate that people who choose these areas and gain the benefits – even while knowing the long term risks – accept and pay the costs of managing the risks that they incur. It would be poor public policy to subsidise people to locate in areas of known increasing risk.

There is a need to allow existing owners to re-evaluate their choices and to suffer minimal losses from the changing conditions. As existing owners were not aware of the developing risk and are not in control of the causes of this developing risk, it is proposed that **for a period of 25 years, risk reduction and management measures be borne by the wider community.** After that time, the cost of further risk management measures would be the responsibility of those that benefit from coastal use or occupation. Risk management works undertaken by the Council could be paid for by a special coastal risk reduction rate in affected areas. Funding assistance from higher levels of government would be required during the 25 year transition period.

For existing property subject to developing risk, it is proposed that triggers be identified that would require an adaptation response to keep risks at acceptable levels. Triggers would be invoked where risks exceed agreed levels. Different triggers will be required for different risks – high water tables, inundation, and erosion – based on hazard maps for each risk, updated at least every ten years.

In this way the community will respond to actual changes in risk as the sea level rises or erosion progresses, not to events forecast for the distant future. Triggers should be soon enough to plan action and respond before risk becomes excessive, not sooner, managing the risk as it develops.

Managing the risk does not eliminate all risk; more extreme events will sometimes occur that exceed the capacity of the actions taken. Acceptable responses should:

1. Demonstrably reduce risk to defined acceptable levels for an estimated time period.
2. Be designed to be durable and effective for the estimated time period and/or have reasonably well known maintenance and operating costs for the design period.
3. Indicate the anticipated response at the end of the estimated extended period when risks again approach unacceptable levels.
4. In normal operation or in the event of failure, not adversely affect other properties, including integrity of property, continued beneficial use and cause no adverse health or safety risks to residents or users of other properties.
5. Allow practical emergency response to events that exceed design risk.
6. Identify the financial and operational capacity to meet any ongoing maintenance or operating costs.
7. Allow for the continued viability of valued coastal ecosystems where these have been identified and where their continued viability is achievable at a cost acceptable to the wider community.
8. Define the agreed trigger for follow up responses in the event of continued change.

Adaptive responses

Practical management options include:

- Planning controls for new development, which deal with:
    - Building setbacks
    - Minimum floor levels
    - Appropriate engineering assessments
    - Appropriate construction techniques (eg piled buildings, flood resistant materials)

  or
    - A development freeze in some locations (notably restricting development to the Stable Foundation Zone where shore protection would not be cost effective, there is limited development or there is room for setbacks)
- Physical works such as seawalls, groynes, dune management or sand nourishment, offshore breakwaters and/or surfing reefs, temporary or permanent flood barriers, reconstruction of public infrastructure (eg roads, other services above flood levels)
- Detailed emergency management and evacuation planning, with hazard reduction requirements for affected properties
- Providing community education and information to improve awareness and ability to cope
- Ongoing monitoring, analysis and review of findings
- Additional data collection or studies
- A timeframe for review – currently 5 years for Council planning schemes

These options are reviewed in detail for different risks for each location with a discussion of the implications of different choices including indicative costs. A summary of potentially feasible options is shown in Tables E4 & E5.

Areas affected by rising water tables that are dependent on septic tanks will require alternate sanitary arrangements before health risks arise. This would include above ground digesters or installation of a sewerage system, as proposed for Lauderdale.

In addition, an extensive list of general actions as well as further studies have been identified.

The last sections of the report review each of the areas assessed and consider responses. They are in three groups:

> **Priority areas currently at risk**: Roches Beach/Lauderdale, Cremorne, Bicheno Street, (Clifton Beach), South Arm Road at South Arm Neck
>
> **Areas with medium term risk (25-75 years)**: Clifton Beach, South Arm Beach (Half Moon Bay), Kangaroo Bay, Bellerive Beach, Rokeby and Droughty Point Road
>
> **Areas with longer term risk (75 years and beyond)**: Seven Mile Beach, Howrah and Little Howrah Beaches, Mays Beach, Montagu Bay, Opossum Bay, Glenvar Beach, Opossum Bay, Hope Beach

Table E 4. Inundation - potentially feasible adaptive management options

Location	Retreat, setbacks	Raise floors	Raise land levels	Short term flood barriers
Bellerive	✓	✓	✓	?
Clifton – Bicheno St, Pipe Clay Lagoon	?	✓	✓	✓
Cremorne – Pipe Clay Esplanade	?	✓	✓	✓
Glenvar Beach	✓	✓	x	n/a
Howrah and Little Howrah Beach	✓	✓	✓	?
Kangaroo Bay	n/a	✓	✓	?
Lauderdale - South Arm Road, Ralphs Bay	?	✓	✓	✓
Mays Beach	✓	x	x	n/a
Montagu Bay	n/a	n/a	✓	n/a
Opossum Bay	✓	✓	x	n/a
Rokeby and Droughty Point	x	x	✓	n/a
Seven Mile Beach west	✓	✓	✓	?
South Arm Beach - Halfmoon Bay	✓	✓	✓	?
South Arm Neck – Ralphs Bay side	x	x	✓	n/a

✓ Feasible subject to detailed studies
x Not feasible
? May be technically feasible, but may not be economically feasible
n/a not applicable

Table E 5. Erosion - potentially feasible adaptive management options

Location	Retreat, setbacks	Piled building	Seawall	Groynes, nourishment
Bellerive	?	✓	✓	?
Clifton (Ocean) Beach, west	✓	✓	?	?
Cremorne (Ocean) Beach	✓	✓	✓	✓
Glenvar Beach	✓	✓	✓	x
Hope Beach, South Arm Neck - ocean side	x	x	✓	x
Howrah and Little Howrah Beach	✓	✓	✓	?
Lauderdale - South Arm Road, Ralphs Bay	?	x	✓	x
Mays Beach	✓	✓	x	x
Opossum Bay	✓	✓	✓	x
Roches Beach, Lauderdale	✓	✓	✓	✓
Rokeby and Droughty Point	x	x	✓	x
Seven Mile Beach west	?	✓	?	?
South Arm Beach - Halfmoon Bay	✓	✓	✓	?

✓ Feasible subject to detailed studies
x Not feasible
? May be technically feasible, but may not be economically feasible
n/a not applicable

The results of the communication program will be compiled at the end of this project.

A section on conclusions and summary of recommendations is included at the end of this report.

1 Introduction

This project was initiated by Clarence Council in response to Council and community concerns about erosion of beaches and flooding events in coastal areas. Floods have occurred in low lying areas of Lauderdale in the 1970s and 1990s. A number of earlier investigations had been undertaken into erosion on Roches Beach to determine the underlying causes of erosion, and in particular if erosion of the beach that had occurred was episodic and transient or progressive, and what response would best address the issue.

More recently other evidence showed that rising sea levels may be contributing to sea water entering sewage pipes along coastlines. Thus additional concerns about sea level rise arising from climate change were added to the previously identified concerns about coastal erosion.

Council has undertaken a number of projects to try to deal with the issues facing the community in coastal areas. These are described in more detail in Appendix A and some reports are available via the Council website.

- Starting from 1992, through establishment of a network of Coastcare groups, developing agreement on Coastal Reserve Activity Plans to provide co-ordinated approach to managing public lands in coastal areas in conjunction with the community.
- Various Coastcare Projects from 1995-2005 with works undertaken as recommended in Clarence city Council Coastal Erosion Report 1994 for Clarence City Council by Coastal Engineer David Steane.
- Lauderdale Wetland project ran from 2001-2004 aimed at flood mitigation, bioremediation, habitat creation, a recreation trail (perimeter walking trail), and formation of a Wetland Care Group.
- Draft Lauderdale Foreshore Activity Plan 2004-2008. The plan remains in draft pending outcome of this Integrated Assessment of Climate Change Project. Two Coastal Risk Assessment studies arose from this plan:
  1. Geotechnical Risk Assessment "Storm Surges Causing Foredune Erosion on Roches Beach" by WC Cromer PL
  2. “Roches Beach Coastal Risk Assessment Study” Gerry Byrne

  These reports resulted in implementation of recommendations to build up all access ways onto Lauderdale Beach with sand, and constructing formal step accesses to the beach.

In addition to this work by Council, Pitt & Sherry Pty Ltd & D.G. Foster prepared a Coast Protection Study for Roches Beach, Lauderdale in 1998 for the Lands Department Tasmania.

With the continued strong local interest in further in-depth understanding of the coastal processes, risks and impacts on Lauderdale and the options to mitigate the risks, sources of funds were canvassed to investigate coastal risks more comprehensively. The State Emergency Service supported the initiative with a $45,000 grant. A submission to the (then) Australian Greenhouse Office for the Integrated Assessment of Climate Change on Urban Settlements Program was also successful.

In undertaking this project, Clarence City Council recognises that climate change is a reality and has taken the decision to assess risk, risk perception and vulnerability of the City to climate change events in foreshore areas, to explore adaptation options and to find out how to best communicate with its residents about the issue.

The project has been overseen by a Steering Committee with representatives of the Council, funding agencies and State Government agencies. The project is overseen by an Integrated Assessment Project Manager within Council. In addition, a Technical Reference Panel has reviewed all reports. The membership of the committee and technical reference panel is listed in Appendix B.

The purpose of this study is to provide an integrated assessment of climate change risks on coastal areas which includes:

- An investigation of community attitudes at the beginning of the project.
- Consultation with community groups, institutions, and state government agencies on their awareness and response to climate change issues.
- A review of the literature covering experience with similar issues elsewhere.
- Assessment of 17 localities and infrastructure within the City which may be vulnerable to coastal hazards, both at present and due to sea level rise and climate change into the future. Coastal hazards have been assessed for the present day, 2050 and 2100.
- Investigation of adaptive management options in response to present and future coastal hazards.
- Preparation and execution of a communication plan to inform the community of the findings and initiate discussion about the preferred response and report on community response.

Technical assessment work was undertaken by Water Research Laboratory (WRL) of the University of New South Wales in conjunction with Pitt & Sherry Consulting Engineers. The results of the technical analysis are provided in a separate report *Coastal Processes, Coastal Hazards, Climate Change and Adaptive Responses for Preparation of a Coastal Management Strategy for Clarence City, Tasmania*, WRL Technical Report 2008/04, November 2008.

Community and stakeholder consultation and the literature review were conducted by SGS Economics & Planning in conjunction with Myriad Research. A preliminary report *Socioeconomic Assessment and Response for Climate Change Impacts on Clarence Foreshores, Interim Report* SGS Economics & Planning, July 2007 contains the findings from this work.

This report brings the findings of these two reports together, adding additional analysis of the responsibilities of different levels of government as they stand under existing legislation, and consideration of the potential responses to the issues identified within an overall framework. This report does not provide the full technical analysis, detailed references and other documentation of the two source reports but presents a synthesis of the findings and implications. The reader is referred to these other reports if this detail is required.

This report:

- Identifies the study area and locations assessed
- Summarises earlier work on the community's views of climate change and responses
- Describes coastal risks, the process of estimating them and summary findings of requirements to accommodate erosion, wave runup and inundation risks

- Provides an overview of findings from elsewhere
- Discusses the roles and responsibilities of different levels of government and individuals under existing legislation
- Introduces a framework for responding to developing risks from climate change
- Presents the findings for each of the areas studied grouped into three groups: priority areas (currently at risk), areas with medium term risk, and areas with longer term risk. For each area risks are presented with maps for erosion and inundation, and the potential responses considered, with more detail provided for areas with the greater short term risk.
- Briefly describes the next stage of consultation, and
- Provides a brief overview of the conclusions and recommendations for policy makers

2 Clarence coastal areas

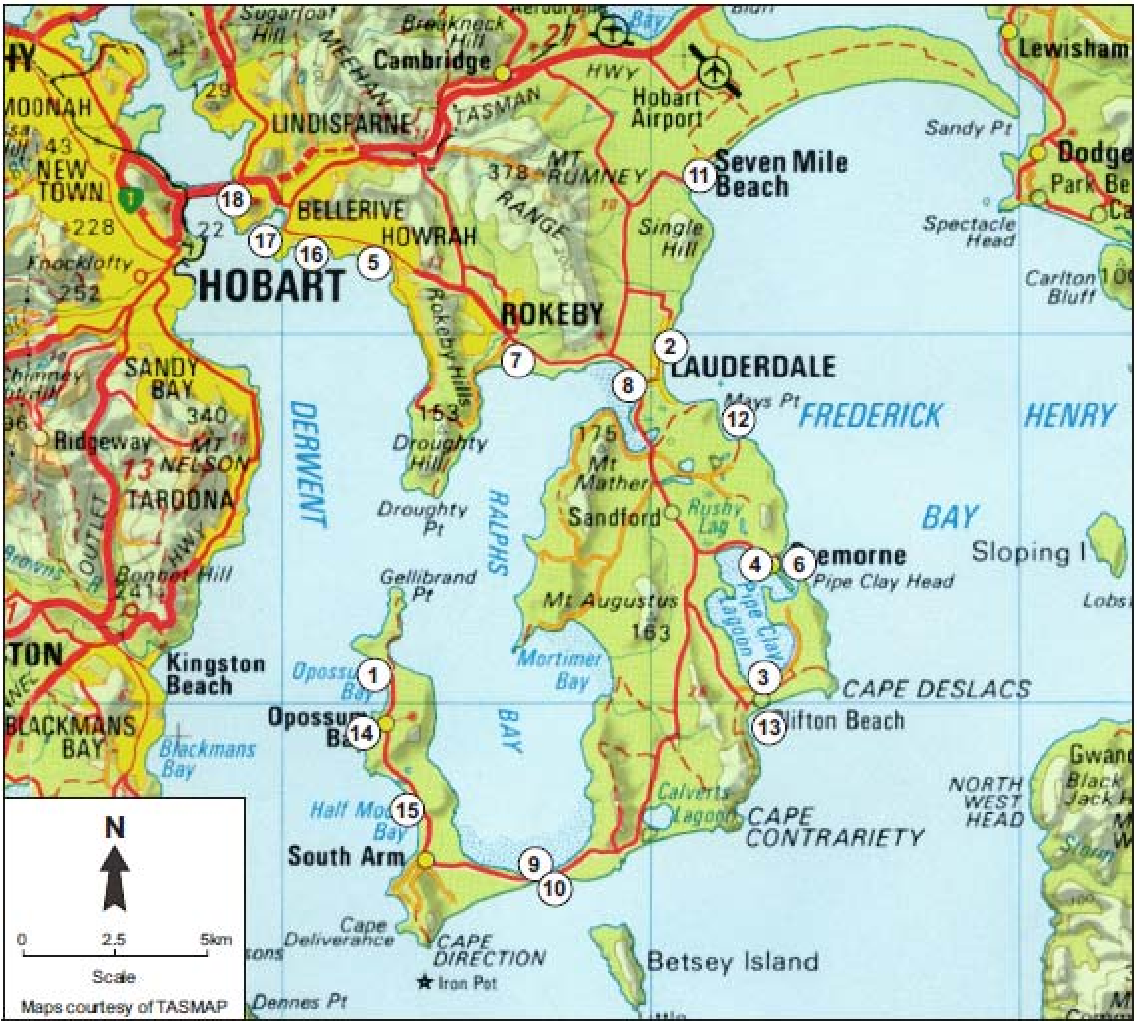
The City of Clarence is located to the east of Hobart as shown in Figure 1.

A list of locations for which infrastructure may be at risk from coastal hazards is shown in below. The list is based on WRL's initial site inspections and discussions with Council.

Bellerive Beach
Clifton – Bicheno St, Pipe Clay Lagoon
Clifton (Ocean) Beach, western 500 m only
Cremorne – Pipe Clay Esplanade
Cremorne (Ocean) Beach
Glenvar Beach
Hope Beach, South Arm Neck
Howrah and Little Howrah Beaches
Kangaroo Bay
Lauderdale - South Arm Road, Ralphs Bay
Mays Beach
Montagu Bay
Opossum Bay
Roches Beach, Lauderdale
Rokeby Waste Water Treatment Plant
Seven Mile Beach – western 1 km only
South Arm Beach (Halfmoon Bay)
South Arm Neck (Ralphs Bay side)

Erosion and haphazard protection works have been reported on Barilla Bay on Pitt Water (Sharples, personal communication, 2008). This is affecting freehold land, however, the present development densities are low, and there is no public access to these foreshores. Five Mile Beach, which also fronts Pitt Water on the northern side of the Seven Mile Beach spit is also eroding (Sharples, personal communication, 2008), however, there is no development at risk. Detailed assessment for both these locations was beyond the scope of this report, but may require consideration in the future.

Figure 1. Locations assessed



1. Opossum Bay
2. Roches Beach, Lauderdale
3. Clifton-Bicheno St, Pipe Clay Lagoon
4. Cremorne-Pipe Clay Esplanade
5. Little Howrah and Howrah Beaches
6. Cremorne (Ocean) Beach
7. Rokeby Waste Water Treatment Plant
8. Lauderdale-South Arm Rd, Ralphs Bay
9. South Arm Neck (Ralphs Bay side)
10. Hope Beach, South Arm Neck
11. Seven Mile Beach-western 1km only
12. Mays Beach
13. Clifton (Ocean) Beach, western 500m only
14. Glenvar Beach
15. South Arm Beach (Halfmoon Bay)
16. Bellerive Beach
17. Kangaroo Bay
18. Montagu Bay

WRL Report No. 2008/04	LOCATION	Figure 1.1

3 The community's initial perspective on climate change

A survey of the general public preceded by focus groups was conducted to analyse current knowledge, sentiments, opinion and attitudes in Clarence community regarding climate change events in foreshore areas; as well as factors determining a successful communication strategy around the issue.

Two focus groups were conducted and a survey of 300 Clarence residents was conducted in early 2007, 150 in coastal areas and 150 away from coastal areas. In addition, 20 interviews were conducted with businesses in coastal areas. Further interviews were conducted with business, government and community organisations.

Survey Findings

Clarence residents are aware of and concerned about climate change and sea level rise. However, both knowledge and concern are rather vague and impersonal; many people have not translated this into impacts potentially affecting them, their family and lifestyle immediately, more so for non-coastal residents. The community as a whole seems to approach climate change pragmatically. There are only a few people that are sceptical that climate change is happening.

Beaches are an important lifestyle factor for many of Clarence's residents and the main reason for many to live near the coast.

From the options available to Clarence City Council and other levels of government for responding to climate change events in its foreshore areas, the community strongly support (>80%):

- mitigate by cutting greenhouse gas emissions,
- provide information (maps, warning systems),
- provide shoreline protection,
- introduce planning controls that minimise flood risk for new development and
- limit development in high risk areas.

About half of the community supported but more than one quarter disagreed with:

- Making development in risk areas at the owner's risk
- Compensating owners for property damage or loss due to sea level rise
- Continuing to develop services, such as roads, water, sewage, in areas that are at risk

Roughly equal numbers of respondents agreed and disagreed with:

- Removing houses at risk
- Paying compensation to those whose property is devalued due to being located in defined risk areas

If the less widely supported measures were to be considered necessary and implemented by Council, they would need to be well justified and communicated in order to be accepted by the community. The same is true if Council should decide to take any measures going beyond those adaptation measures discussed above.

The preferences expressed for the different policy options suggest that the community place a greater emphasis on preventing physical damage, and are relatively less concerned about the loss of property value that policies or preventative actions may cause.

Where respondents that named protection measures elaborated their answers further, it is clear that they are calling for measures that would keep beaches in their current state. Protection measures that protect houses and infrastructure but result in the loss of beaches are unlikely to be welcomed to the same degree.

The survey showed that Clarence community trusts its Council and would like to see it in a leading role when taking on the issue of climate change. Residents want the Council to seek expert advice and involve non-government players in the solution (e.g. SES, environmental community groups, scientists). They also expect that the nature of climate change requires the Commonwealth and State Government to be involved in developing appropriate local responses to the effects of climate change with a preference for funding to come from Commonwealth taxes.

The funding preferences suggest the Clarence community accepts a responsibility for causing climate change, but also wants to see other polluters pay. The Polluter Pays Principle combined with burden sharing throughout the Australian society stands out as the preferred way of funding.

Stakeholder Interviews Findings

The interviews revealed that, although climate change and sea level rise are perceived as an upcoming issue, it is not being addressed yet. This is largely due to a perceived lack of reliable information about climate change and sea level rise at the local level combined with the assumption that related impacts are expected to happen too far in the future, with other more pressing immediate priorities. While many non-government groups are turning to the government at various levels for information and leadership, this is not being clearly provided.

Implications for Clarence Council

The survey was conducted over 18 months ago and there has been considerable public debate about climate change since. In addition, community responses were not based on well developed information about risks and responses. An informed public may respond differently to some questions. Further, community attitudes could change significantly in response to sea level rise and future extreme weather events and subsequent impacts on homes and infrastructure.

The impacts of greatest concern to the community are likely to be more frequent extreme storm surges, with associated coastal erosion and effects of rising ground water. For Lauderdale in particular, rising groundwater will lead to problems with existing septic tank systems (exfiltration).

Impacts are likely to remain *infrequent* enough in the short term – even if severe – that most past investments still have a relatively long service life ahead. Future long-lived investments in the earliest affected areas will have lifetimes close to or exceeding the time period for which these areas can remain as currently occupied.

Reductions in property values – and potential claims for compensation – can be minimised by permitting acceptable forms of development that recognise and adapt to identified risks. More extreme measures such as removal of existing structures are only likely to be justified and supported where there is a definable public benefit, not just a reduction in private risk. Protection measures are most supported where they protect the integrity of the beach, not just property.

Response options are assessed according to their economic viability. In most cases more detailed design study will be required. Responses to climate change may also contribute to resolving some other coastal management issues in Clarence.

This project seeks to provide communication of both technical information on risks and areas affected and the policy approach of Council (and other levels of government) in a clear, accessible and consistent manner. Clear guidelines have been provided for the communication of risk.

A comprehensive communication strategy will use of a variety of channels, with the appropriate channel for the intended effect and target group. Newsletters and the Eastern Shore Sun are good media for communication from the Council. Markers in the field, e.g. markers of past and expected flood levels on power poles, power boxes, etc. are a more effective means of informing the public than flood maps. Some targeted information channels (eg real estate agents for prospective buyers in high risk areas) would also be effective.

On site attended displays and workshops will allow more detailed, site-specific information and two way dialogue about alternative strategies, complementing mass one way communication.

4 Estimates of coastal risks

4.1 Overview

Coastal areas vary dramatically in their vulnerability to coastal risks whether arising from climate change or coastal processes that operate even without climate change. High, hard rocky coasts have low risk while low lying or softer landforms are more at risk. The degree of variability makes setting 'universal' setbacks or elevation standards questionable as they will be far too conservative in some areas and unsafe in others. As the community generally expects that development standards are there to make development 'safe', local standards based on evaluated risk are preferred.

The following sections outline the process of better defining the risks in coastal areas of Clarence. However **this is still a broad estimate of risks and risks to individual properties may vary significantly from those estimated**.

4.2 Coastal variables considered

The National Committee on Coastal and Ocean Engineering (NCCOE) (2004) lists six key environmental variables applicable to coastal engineering, namely:

1. Mean Sea Level
2. Ocean Currents and Temperature
3. Wind Climate
4. Wave Climate
5. Rainfall/Runoff
6. Air temperature

A growing body of research has found that ocean acidification (pH lowering) may be occurring, and this could be considered an additional key variable.

NCCOE (2004) also lists thirteen secondary or process variables applicable to coastal engineering, namely:

1. Local Sea Level
2. Local Currents
3. Local Winds
4. Local Waves
5. Effects on Structures
6. Groundwater
7. Coastal Flooding
8. Beach Response
9. Foreshore Stability
10. Sediment Transport
11. Hydraulics of Estuaries
12. Quality of Coastal Waters
13. Ecology

The key and secondary variables were combined into a matrix for project assessment.

4.3 Climate change scenarios

The Intergovernmental Panel on Climate Change (IPCC) have produced major reports in 1990, 1996, 2001 (Third Assessment Report (TAR)) and 2007 (Fourth Assessment Report (AR4)). The IPCC represents an international consensus position for planning purposes. The Fourth Assessment Report provides numerous sea level rise scenarios for 2090 to 2100 but no values for 2050.

Simplified "mid" and "high" sea level rise scenarios developed by WRL for engineering application are shown in Table 1. The basis for these is discussed in further detail in the Technical Report.

Table 1. Simplified Engineering Estimates of Global Sea Level Rise (by WRL)

Sea Level Scenario	**Year**	
	2050	**2100**
	(m)	(m)
Adopted "Mid" scenario	0.2	0.5
Adopted "High" scenario	0.3	0.9

Based on IPCC (2001, 2007) and NCCOE (2004)

IPCC (2007a, page 17) addresses an extreme scenario involving the total melting of the Greenland ice sheet (suggested timescale is millennia) which it estimates would elevate global sea levels by a further 7 m. Even more extreme postulations exist, including a rise of up to 70 m (GACGC, 2006) if all the world's ice sheets were to melt, however, the timescale is considered to be many millennia.

No reliable information is available showing local sea level rise for Clarence to differ substantially from the global projections. Hunter et al (2003) estimated that the land at Port Arthur (approximately 50 km east of Hobart) is rising at 0.2 ±0.2 mm/year upwards. There is no documented evidence of substantial subsidence of coastal land around Clarence, which could justify higher levels of relative sea level rise, than the global average values reported in IPCC.

4.4 Uncertainties

Global sea level rise (and temperature) are the only components of climate change of high relevance to the coastal zone, for which well developed quantified scenarios are available. There are still major uncertainties in both the modelling and future scenarios for sea level rise. There is high uncertainty in quantifying changes to atmospheric circulation, storm intensity and frequency which are also of high importance to the coastal zone. At present these are best considered through sensitivity analyses (Department for Environment, Food and Rural Affairs (DEFRA) UK, 2006).

Ongoing monitoring of credible climate change projections (eg IPCC) is needed, together with monitoring of local processes such as water level and beach change. The findings of this report should be revised within 10 years or following major revisions to climate change projections.

4.5 Coastal Processes

In this report, coastal hazards are defined as the consequences of coastal processes which affect the built environment or the safety of people. The following coastal processes are applicable to the study area and are assessed or discussed in subsequent sections:

- Astronomical tides (predicted tides)
- Tidal anomalies, through:
  - Barometric setup
  - Wind setup
  - Coastally trapped waves
- Ocean swell waves
- Local wind waves
- Wave setup
- Wave runup and overtopping
- Longshore sand transport (littoral drift)
- Onshore-offshore sand transport (beach erosion and recovery)

4.6 Hazards

The following coastal hazards may impact the study area:

- Beach erosion
- Shoreline recession (long term change due to waves or sediment budget)
- Unstable creek or lake entrances
- Wind blown sand (if it affects buildings or infrastructure)
- Coastal inundation
- Slope, cliff or bluff instability (not assessed – see below)
- Stormwater erosion
- Climate change, including sea level, changes to waves, wind and rainfall
- Tsunami (see below)
- Seawater ingress into groundwater table causing displacement of fresh water
- Potential acid sulfate soils (not assessed in this study)

The list is not exhaustive. Other risks could include sedimentation of navigation channels and marinas. Considerable discussion was provided in Sharples (2006) on slope instability, including citing previous landslide risk studies undertaken. A separate detailed geotechnical assessment could be undertaken as resources become available, but was not part of this study. It is noted that many of the soft rock foreshores around Clarence are eroding which needs to be considered in the geotechnical assessment.

Tsunami hazard is being assessed by the SES, Bureau of Meteorology (BOM) and Geoscience Australia. An overview of tsunami history is presented in the Technical Report but the risk has not been quantified.

4.7 Risk

In the absence of Building Code of Australia (BCA 2007) specifications for inundation or wave forces, design conditions for a 100 year Average Return Interval (ARI) event (which is equal to a 1% Average Exceedance Probability, AEP[1] event) (for inundation and erosion) are presented in this report for a 50 to 100 year design life and planning period. It is emphasised that a 100 year ARI event has a 39% chance of being exceeded over a 50 year period and a 63% chance of being exceeded over a 100 year period.

The 100 year ARI (1% AEP) benchmark is consistent with flood policies in most jurisdictions, however, there are compelling arguments for the use of a less common design event. In flood prone areas of NSW, nearly twice as much damage arises to property above this level than below[2].

Details of the calculations and underlying analysis are provided in the Technical Report by WRL.

4.7.1 Erosion and Recession Risk, Wave Runup

The erosion and recession hazard lines were calculated for a 100 year ARI (1% AEP) erosion event with present-day conditions and for 2050 and 2100. The results are tabulated in Table 2 showing the potential erosion from storms, and adding an allowance required to maintain a stable foundation zone giving a total setback required for safety. Also shown are the expected setbacks required in the future under the mid and high scenarios which incorporate additional expected long term recession arising from rising sea level and current rates of recession where applicable. Measurements are from the seaward face of the frontal dune. This has only been applied to buildings on sandy areas fronting exposed coastlines. Note that these are indicative for each location and the conditions along the beaches vary, in some cases substantially where there is underlying rock or existing seawalls.

Structures, roads and other infrastructure within these distances from the dune face are potentially at risk. Actual impacts for structures that are affected will vary with the building type, and the effects of any protection works, existing or proposed. Assets within the risk zone would be at risk **if no adaptation is undertaken** and, for future years, if the climate change projections and sea level rise in this report eventuate. Conversely, a more extreme event than the 100 year ARI (1% AEP) event could occur.

Responses to this risk are discussed in Section 7.5.3.

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[1] See Appendix 3 Terminology for discussion of the definition and use of these and other terms

[2] As cited in NSW Floodplain Development Manual (NSW Government, 2005) This does not mean that it is safer to build below the 100 yr ARI level than above. There are many more structures above than below the line and these may be less well designed to accommodate flooding. The main point is that being above the 100 yr ARI is not 'safe'.
Design ARI events for many hazards (eg many marine structures (AS 4997-2005), wind loads and earthquake in the Building Code of Australia (2007)) specify 500 year ARI (0.2% AEP)

Table 2. Indicative setback requirements to accommodate erosion risk

Location	Storm erosion	Foundation Zone	Indicative setback (m)				
			Present	2050		2100	
	m	m		mid	high	mid	high
Bellerive Beach	15	7	22	32	37	47	67
Clifton (Ocean) Beach	25	10	35	45	50	60	80
Cremorne (Ocean) Beach	15	10	25	45	50	70	90
Glenvar Beach*	10	7	17	27	32	42	62
Hope Beach, South Arm Neck	25	8	33	43	48	58	78
Little Howrah and Howrah Beaches	10	7	17	27	32	42	62
Mays Beach	10	5	15	25	30	40	60
Opossum Bay	10	7	17	27	32	42	62
Roches Beach, Lauderdale	25	5	30	50	55	75	95
Seven Mile Beach, western 1km	10	10	20	30	35	45	65
South Arm Beach (Halfmoon Bay)	10	10	20	30	35	45	65

Source: WRL modelling, Technical Report, Table 20.1 (storm erosion rounded to nearest 5 m.)

* may be limited by underlying rock

Areas affected by coastal erosion may also be at risk from wave runup. Wave runup can affect properties located directly on the dune or sea face of a rocky shore. It may also affect properties behind dunes where runup overtops the dunes. Erosion can bring properties into risk from wave runup either by undermining and lowering the protective dunes or bringing the active dune face closer to the property.

Estimated wave runup from a 1% AEP (100 yr ARI) event for the present and future dates under mid and high scenarios is shown in Table 3.

Table 3. Wave runup estimates for 1% AEP (100 yr ARI) storm events

Location	Present	2050		2100	
		Mid	High	Mid	High
	(m, AHD*)	(m, AHD)	(m, AHD)	(m, AHD)	(m, AHD)
Bellerieve	3.3	3.5	3.6	3.8	4.2
Clifton (Ocean) Beach, west	5.9	6.1	6.2	6.4	6.8
Cremorne (Ocean) Beach	4.7	4.9	5.0	5.2	5.6
Glenvar Beach	4.9	5.1	5.2	5.4	5.9
Hope Beach, South Arm Neck	6.1	6.3	6.4	6.6	7.0
Little Howrah Beach	2.6	2.8	2.9	3.1	3.5
Mays Beach	2.5	2.7	2.8	3.0	3.4
Opossum Bay	4.5	4.7	4.8	5.0	5.5
Roches Beach, Lauderdale	2.8	3.0	3.1	3.3	3.7
Seven Mile Beach west	2.6	2.8	2.9	3.1	3.5
South Arm Beach – Halfmoon Bay	3.9	4.1	4.2	4.4	4.8

* AHD = Australian Height Datum in Tasmania is based on mean sea level for 1972 at the tide gauges at Hobart and Burnie which was assigned the value of zero on the AHD

Source: WRL modelling, Technical Report Tables 19.1 to 19.5

To be at low risk from wave runup properties should be either 0.3m higher than the levels shown, or a significant distance behind dunes or other barriers. For locations not listed, wave heights are small, the shoreline is rocky or armoured or development is generally set well back. Individual structures in these locations may not comply with these conditions and may need detailed assessment.

4.7.2 Inundation Risk

The sea level heights for a 100 year ARI (1% AEP) event were calculated taking into account all the factors contributing (barometric set up, astronomical tides, and wave setup) for present-day conditions and for 2050 and 2100. These are shown in Table 4. Land areas below these levels are potentially subject to inundation during these extreme events. In practice, flood levels on many areas will be less than this as dunes or other restrictions prevent sea water from reaching low lying areas. This is particularly true where these areas are well inland. On the other hand, heavy rain can contribute to flooding of low lying areas and in some cases may even add to floods caused by sea water. More extreme events than 100 year ARI (1% AEP) may also occur.

Property located on land below the estimated sea levels may not be damaged by flooding, even where this occurs. In some cases flood depths are minor. In others, property floor levels may be elevated above flood levels. Detailed study is required of areas potentially at risk where significant property development is located to better quantify the value of property at risk.

Table 4. Estimated sea level heights for 1% AEP (100 yr ARI) storm events

		2050		**2100**	
	Present	Mid	High	Mid	High
	(m, AHD)	(m, AHD)	(m, AHD)	(m, AHD)	(m, AHD)
Montagu Bay	1.5	1.7	1.8	2.0	2.4
Kangaroo Bluff	1.5	1.7	1.8	2.0	2.4
Bellerieve	1.8	2.0	2.1	2.3	2.7
Little Howrah Beach	1.9	2.1	2.2	2.4	2.8
Rokeby Waste Water Treatment Plant	1.8	2.0	2.1	2.3	2.7
Lauderdale, South Arm Rd, Ralphs Bay	2.0	2.2	2.3	2.5	2.9
Seven Mile Beach west	2.0	2.2	2.3	2.5	2.9
Roches Beach, Lauderdale	1.8	2.0	2.1	2.3	2.7
Mays Beach	1.8	2.0	2.1	2.3	2.7
Cremorne (Ocean) Beach	2.0	2.2	2.3	2.5	2.9
Cremorne – Pipe Clay Esplanade	1.6	1.8	1.9	2.1	2.5
Bicheno St, Pipe Clay Lagoon	1.8	2.0	2.1	2.3	2.7
Clifton (Ocean) Beach, west	2.3	2.5	2.6	2.8	3.2
South Arm Neck – Ralphs Bay side	2.3	2.5	2.6	2.8	3.2
Hope Beach, South Arm Neck	2.4	2.6	2.7	2.9	3.3
South Arm Beach – Halfmoon Bay	1.7	1.9	2.0	2.2	2.6
Glenvar Beach	1.7	1.9	2.0	2.2	2.6
Opossum Bay	1.7	1.9	2.0	2.2	2.6

Source: WRL modelling

5 Experience from elsewhere

An extensive literature review *Climate Change and Coastal Management, A Literature Review*, (Dr Melissa Nursey-Bray with SGS Economics & Planning, 2007) was conducted to look at existing literature on adaptation to climate change with a special focus on impacts in coastal areas. It covers approximately 300 citations with a very brief summary provided in this section. For more detail and references see the full report.

After a brief look at the relevant policy making framework in Australia, the literature review highlights the core streams of thought in relation to the key concepts of climate risk, risk perception, vulnerability, resilience and adaptation. Specific case studies give insights into how coastal management in the context of sea level rise has been implemented in the field.

Climate variability is not new: systems have been responding to variations in climate for centuries. Socio-economic systems can be very flexible and will likely respond most to extreme realisations of climate change: human systems can be the source of surprises.

The element of surprise and flexibility of responses means that the widest possible range of plausible futures should be explored. Climate change offers opportunity as well as risk. Multiple approaches and responses should be accommodated. Analysis of adaptive decisions should recognise the next best alternatives to those decisions, showing the merit of proposed actions.

There is a need to build diverse information/knowledge bases that will support adaptation processes. A scientific and technical risk assessment needs to be accompanied by an assessment of risk perception in the community to assure the community's acceptance of measures taken to address the risk. Measures need to address both the scientifically assessed and the perceived risk.

Adaptive decisions will be made in response to both climate change and climate change **policy**. Policy affects responses in a variety of ways including affecting expectations. Perceptions of risk depend upon welfare valuations that depend upon expectations, so understanding and managing expectations is important.

Adaptation can reduce impacts of sea level rise from a factor of 10 up to a factor of 100 (Tol 2004), and economic costs of adaptation would be minor compared to the damage avoided. A number of approaches and measures can be applied as adaptation measures; the measures can be grouped into retreat, accommodate, protect and inform / communicate with the public. The adaptation strategy should consider and will likely contain measures from each of these categories. Mitigation measures are also seen as important.

A number of overall suggestions are made for assessing and implementing adaptation options. There is no one-size-fits-all-approach to adaptation to climate change. Several assessment frameworks are reviewed that can help with assessing options.

Questions that need to be answered by adaptation options are: (i) Adaptation to what? (ii) Who or what adapts? and (iii) How does adaptation occur? Planners should determine the attributes for differentiating adaptations, such as purposefulness, timing, temporal and spatial scope, effects, form and performance. Passive, reactive and anticipatory, spontaneous, planned and autonomous, technological, institutional or behavioural adaptation options should be provided for. Adaptation takes time and therefore clearly beneficial responses should not be postponed. However, it is important to achieve optimal timing for adaptation measures, demonstrating that when the benefits of adaptation are uncertain (e.g. because of uncertainty about impacts), it may in fact be optimal to postpone irreversible investments until more information is obtained.

Adaptations along the coast will be more beneficial if they are incorporated into existing strategies such as coastal zone management, disaster mitigation, land use planning and sustainable development programs, a process referred to in the literature as 'mainstreaming'. Adaptation should build on previous experiences in relation to disaster management. Monitoring and evaluation planning mechanisms should be embedded.

Institutional arrangements must support adaptation and be consistent with expected impacts. Otherwise climate change realities might not be fully acknowledged which in turn causes policy debate over whether adaptation is necessary or not, and support unrealistic expectations.

Mal-adaptive measures, defined as adaptive measures that have been implemented that fail to achieve their objective, should be avoided. Adaptation measures should not be impractical or prohibitively expensive.

Uncertainty and its impacts on decision making can be addressed by scenario based planning and by ensuring that adaptation policy is robust, and anticipates future impacts based on a wide array of predictions. Both no-regret and precautionary measures need to be undertaken within the framework of local government responses to sea level rise and potential climate impacts. Adaptive management, allowing policy makers to revise policies with changing circumstances, can be a useful tool.

Equity issues and the need to manage distributional effects can be addressed by introducing policies that spread the impact burden in an equitable way in the society and do not indiscriminately impose heavier burdens on some sectors of society and economy than on others.

Vulnerability and resilience assessments of socio-ecological systems can make important contributions to the selection of measures for adapting to climate change. Who and what are vulnerable in one period are not necessarily vulnerable (or vulnerable in the same way) in the next, and some exposures and sensitivities ('creeping hazards') develop slowly over time.

Community involvement is important for decision-making on adapting to climate change in spite of the challenges this poses to decision makers. Experience has shown that when [disaster] adaptation strategies are interactive, participatory and bottom up as well as top down, better outcomes for adaptation, preparedness and recovery are achieved. Community consultation can:

- Enhance the community's resilience or ability to cope, and
- Maximise community support for policy measures (especially in case of drastic measures)

A number of case studies show how adaptation is implemented on the ground. Guidelines published by the Dutch government for successful risk communication by provinces and councils to establish risk communication plans designed to enhance awareness, public participation and information on policy measures contain valuable information for communicating with Clarence community.

6 Roles and responsibilities

Each level of government has a different set of roles and responsibilities in relation to responding to climate change induced risks and natural disaster management. Each has responsibility within its own jurisdiction for natural disaster planning, preparedness and mitigation in relation to land, property and the environment, assets and infrastructure, agencies and programmes.

Australians expect their governments at all levels to do their best to ensure that their communities are as well protected from natural disasters as is reasonably possible, and that where disaster situations occur, communities are well served by effective response, relief and recovery arrangements. In relation to the role of governments, the State has constitutional responsibility for natural disaster management and has the laws and organisational arrangements in place to deal with such disasters. Local governments also have significant roles and responsibilities for natural disaster mitigation and management at the local level through the State arrangements.

The Australian Government and State Governments have established organisational arrangements and lines of reporting to undertake disaster mitigation and effectively prepare for and deal with a range of emergencies. Local government involvement is an integral part of these arrangements.

Relationships between the three spheres of government - along with non-government organisations and industry - are increasingly important for planning and operational aspects of emergency management that support community resilience.

The community and the individuals in it also have a significant role as they retain the primary responsibility for their own safety, including preparedness for emergencies, support voluntary activities and organisations and provide representation in councils.

6.1 Council's role

Council has a number of identified roles that will be affected by issues in coastal areas arising from climate change.

- planning and development
- coordination of emergency management planning
- public health impacts arising from climate change
- managing its own assets and any Council lands that may be affected by coastal risks
- heritage
- Natural Resource Management
- informing its residents and other local stakeholders

In Tasmania, the Local Government Act 1993 requires that councils provide for the health, safety and welfare of their communities, while the Emergency Management Act 2006 requires a Municipal Emergency Management Committee to coordinate emergency management in each municipal area.

Much of the response to climate change involves the prevention or management of situations in which property damage and risk to life and health may arise – ie emergency management. In 2003, the Council of Australian Governments endorsed the contemporary roles and responsibilities of all three spheres of government with respect to emergency management. The Australian Local Government Association also adopted this position. In summary, it was agreed that

"…local government's principal roles and responsibilities are:

- *ensuring all requisite local disaster planning and preparedness measures are undertaken*
- *ensuring an adequate local disaster response capability is in place, including local volunteer resources*
- *undertaking cost-effective measures to mitigate the effects of natural disasters on local communities, including routinely conducting disaster risk assessments*
- *systematically taking proper account of risk assessments in land use planning to reduce hazard risk*
- *undertaking public education and awareness, and ensuring appropriate local disaster warnings are provided*
- *ensuring appropriate local resources and arrangements are in place to provide disaster relief and recovery services to communities*
- *representing community interests in disaster management to other levels of government and contributing to*
- *decision-making processes, and*
- *participating in post-disaster assessment and analysis."*

Source: as provided by Tasmanian State Emergency Service

As a planning authority, councils have a statutory responsibility to ensure that outcomes from planning decisions promote the development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety.

Council normally has an obligation to fulfil its 'duty of care' when responding to identified risks. The duty of care owed by councils in relation to climate change is a rapidly evolving concept which may require councils to act with due diligence in a manner that is consistent with shifting legal and community expectations.

A council, although not under any statutory duty, may, by its action and conduct, place itself in such a position that it attracts a duty of care which calls for exercise of its powers. Thus, if a council assumes a special measure of control over the risk of danger in relation to climate change, which may be inherent in its general powers and functions as a public authority, it may then owe a duty of care to take reasonable steps to avoid any act or omission that could create or increase a foreseeable risk of injury or damage regarding climate change impacts.

While the evolving nature of the duty means that its exact content is still developing, to reduce the risk of exposure to litigation, councils need to be aware of and take into account the future effects of climate change across of a range of activities, and make at least a genuine and serious attempt to alleviate potential risks.

As knowledge and awareness of climate change grows, in the future it may become reasonable for councils to be obliged to undertake a growing number of actions and precautions in relation to climate change effects. As it stands, Council has no clear statutory obligation to protect established private property that becomes at risk from changed conditions, provided the original approval for development was consistent with the then prevailing Planning Scheme and that the Scheme was prepared with due regard to the known circumstances at that time.

The community survey showed a strong preference in the community for the Council to play an active role in responding to the expected changes, albeit with funding support from the State and Australian governments.

The main responsibilities under each of the currently identified roles are reviewed in the following sections. The review is not an exhaustive listing of all potential legal obligations of implications arising from climate change. Such a review is being conducted by the Local Government Associations in different states.

6.1.1 Clarence Planning Scheme 2007

Key objectives of the planning system are:

- To secure a pleasant, efficient and safe working, living and recreational environment for all Tasmanians and visitors to Tasmania; and
- To protect public infrastructure and other assets and enable the orderly provision and co-ordination of public utilities and other facilities for the benefit of the community.

Council has clear obligations to consider risks that may apply to new development and reflect this in the Planning Scheme. A number of specific risks are identified in the Planning Scheme through overlays, with specific provisions applied in identified areas. The Planning Scheme overlays include areas:

- Subject to Inundation
- Subject to Sea Level Rise and Storm Surge
- Coastal management areas subject to specific provisions

The Planning Scheme was amended early in 2008 to include revised overlays and provisions covering **Inundation** and **Sea Level Rise and Storm Surge**. These amendments were based on historic observed flood levels and preliminary assessments of coastal risk by Sharples.

Subject to Inundation Overlay

The purpose of the overlay includes identifying areas subject to inundation and to preclude development that will be affected by flood water or flows. The specified scope of the overlay applies to those catchments of significant watercourses within the City where the land is subject to potential inundation. As such it is not specifically aimed at flooding from the sea. However, many of the low lying areas of the overlay are also potentially subject to inundation from the sea and the final clause in the design requirements specifies that the effects of sea level rise must be included.

For areas within the overlay, development is discretionary and a permit is required for all use and development except within an existing building, those activities normally not requiring a permit and some other specified works. In addition to the usual Application Requirements an application for use or development under this overlay are required to be accompanied by a report, from a suitably qualified person, demonstrating that (based on a 1 in 100 year event):

(a) The proposal will not have a significant affect on flood flow;
(b) Any habitable areas of a dwelling will not be subject to inundation; and
(c) The development will not cause an unreasonable risk to the life of the users of the site or damage to property.

Specific Decision Requirements are:
(a) Mitigation measures should be sufficient to ensure habitable buildings will be protected from flooding;
(b) Any mitigation measures should also protect any protected environmental values and use of the water body or catchment.
(c) Mitigation measures should also be sufficient to consider the additional cumulative impact of sea level rise, as determined by any State published and adopted authority on the phenomenon.

The boundary of the overlay has been based on records of historic flood events and does not indicate potential flood extent from higher sea levels. The findings of the current project provide a basis for review of the inundation overlay in coastal areas.

Subject to Sea Level Rise and Storm Surge

The purpose of the overlay includes to control impacts on coastal infrastructure and development from sea level rise and storm surge. The scope includes coastal areas identified in *Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea Level Rise: Explanatory Report (Sharples 2004).*

For areas within the overlay, development is discretionary and a permit is required for all use and development except within an existing building, those activities normally not requiring a permit and some other specified works.

Where appropriate, the Council may refer an application to the Department of Primary Industries Water or successor (Coastal Marine Program) for comment.

In addition to the usual Application Requirements an application for use or development under this overlay must be accompanied by information to show, where relevant:
(a) Hazard risk can be mitigated through an identification of structural or siting methods to be used to avoid damage to or loss of buildings and other works.
(b) Development will not increase the level of risk of hazard for adjoining or nearby properties or public infrastructure.
(c) Risk of water pollution from storage or processing of effluent, dangerous goods and substances on the site can be mitigated.
(d) The need for future remediation works is minimised.
(e) Important natural features are adequately protected.
(f) Hazard risk can be mitigated through identification of measures to be used to modify the hazard.
(g) The health and safety of individuals is not placed at risk.

Specific Decision Requirements are:

(a) Suitable mitigation measures are to be used dependent upon the nature and assessable risk of the hazard.

(b) Council and other relevant bodies should be indemnified against future actions arising from the effects of sea level rise and storm surge activity where necessary.

The requirements do not specify a specific solution but take a performance based approach to assessment and approval. In the absence of specified solutions, the onus is on the applicant to assess risks and devise acceptable solutions.

The Sharples report used to define the overlay was based on a preliminary assessment of areas at risk. The current project provides a basis for reassessing and refining the defined areas.

Coastal management areas subject to specific provisions

The purpose of this overlay is to implement the provisions of the State Coastal Policy by protecting the natural and cultural values of the coast and promoting the sustainable use and development of the coast.

Development is prohibited within the frontal dune system, and within 50 m of any tidal flat, saltmarsh or lagoon, (excluding rehabilitation and conservation activities, aquaculture, works, structures and demolition associated with access to the water or foreshore). All other development is discretionary and a permit is required for all use and development except within an existing building, those activities normally not requiring a permit and some other specified works.

Where appropriate, the Council may refer an application to the Department of Primary Industries Water (Coastal Marine Program) or Marine and Safety Tasmania for comment.

Specific Decision Requirements are:

(a) The development should have regard to any coastal hazard, cultural or historic resource or feature of conservation value, including flora or fauna habitats.

(b) The coastal environment should be protected, especially including water quality, shoreline change, erosion or areas of visual sensitivity.

(c) Public access to the coast is to be facilitated through applications where possible.

(d) The coastal area should be stabilised and made safe where necessary.

(e) The use or development should be coastal dependent and appropriate to a coastal location.

This provision recognises the value of certain coastal ecosystems and land forms and seeks to protect them from development. However, it does not at this time recognise the way in which these landforms and ecosystems will respond to sea level rise and climate change by progressively moving inland, where possible. The current project identifies the need for a longer term adjustment to change.

6.1.2 Emergency management

Emergency management roles fall into three broad areas:

- Prevention/mitigation

- Preparedness
- Response and recovery

Prevention/mitigation

The Tasmanian Emergency Management Plan calls for risk management activities which include research, risk assessment and mitigation[3]. Per this plan, councils need to develop, implement and maintain a risk-based approach to municipal risks that addresses local issues and aligns with regional priorities.

Land use planning controls, are a significant prevention/mitigation activity.

Preparedness

Under the Emergency Management Act 2006, Council requirements for preparedness include:

- Form an Emergency Management Committee at the local government or regional level to institute and coordinate local emergency management plans, policies and review the management of past emergencies in their area
- Nominate or appoint workers to designated roles: Municipal Emergency Management Coordinator and Deputy; Community Recovery Coordinator and Deputy
- Establish/ maintain volunteer SES units and provide adequate resources
- Establish and maintain an approved municipal emergency management plan, reviewed every two years

Response and recovery

Councils are required to establish and provide resources for the purpose for managing an emergency including human resources, equipment and supplies that councils can provide, in accordance with the municipal plan.

To meet emergency management obligations, Councils need to integrate existing Council systems with the Emergency Management Committee, to form an emergency management framework.

6.1.3 Public health effects

Under the Public Health Act 1997, Councils must develop and implement strategies to promote and improve public health and ensure that the provisions of the Act are complied with.

Local authorities are responsible for ensuring suitable functioning of sanitary works (sewerage and septic tanks). Rising water tables are already expected to be affecting the functioning of some septic tanks in Lauderdale and other unsewered, low lying areas during heavy rain and flood conditions. With rising sea levels, this will get worse, with more areas affected and greater and longer lasting effects. In the worst case, the State Director of Public Health can declare an emergency and order the evacuation of the affected area.

[3] AS/NZS 4360 Risk Management and the Emergency Management Australia's Application Guidelines (Manual 5)

6.1.4 Council assets

Council is responsible for managing its own assets in coastal areas that may be subject to climate change risks. Many of these assets are located in coastal areas for good reason. Council assets potentially at risk include:

- **Roads, bridges and parking lots and associated signage, street lighting etc** – some are in coastal areas to serve coastal development and access to beaches and other coastal areas for the wider community
- **Sewer and storm water pipes, outlets and treatment facilities** – many are located on the coast to allow maximum use of gravity feed and for waste water outlets, by necessity prior to water recycling.
- **Parks, gardens, beaches, recreation and sports fields, change rooms, toilets and other amenities** – many are in coastal areas because filled wetlands or coastal plains provide the large, level areas required, otherwise often hard to find in Clarence.

In some cases, relocation is possible and desirable, as facilities reach the end of their service life. In other cases these assets will need to be maintained or even extended to serve coastal communities while remaining serviceable in spite of climate change impacts. The degree of commitment to the assets will be largely dependent on the future sustainability of the community served.

6.1.5 Heritage

The Planning Scheme has a heritage overlay that recognises the significance of heritage places and seeks to conserve and enhance them for the benefit of the community. While it seeks to control uses and development of identified heritage sites, the Scheme does not provide for active protection against natural hazards.

There are a few European built heritage places on coastal sites. More widespread are sites of cultural importance to the indigenous community, with middens concentrated along coastal fringes typically but not exclusively among coastal dunes. These sites are not generally mapped or otherwise identified.

6.1.6 Natural Resource Management

Councils are participants in the Natural Resource Management (NRM) framework, which has participation by all three levels of government. NRM deals with a wide range of environmental management issues associated with the management of natural resources including air, water, land, plants, animals and micro-organisms and the systems they form.

Within this framework, local government is committed to[4]:

- achieving sustainable NRM outcomes.
- regional approaches to natural resource management.

[4] LGAT Policies: http://www.lgat.tas.gov.au/site/page.cfm?u=461

- using its planning processes and powers to deliver local priorities and assist the achievement of regional outcomes.
- considering natural resource management (NRM) priorities and community expectations in making decisions about resource allocation, recognising a need for long-term resource investment from multiple stakeholders.

The impacts of climate change on coastal areas will have significant effects on coastal ecosystems, in particular those that are unable to retreat inland with rising sea levels.

6.2 State Government Role

The Tasmanian Government recognises the need to take action now to adapt to the impacts of climate change. All spheres of government have responsibility for action and the Tasmanian Government is committed to working with local government and local communities to identify and implement local adaptation measures.

The Tasmanian Framework for Action on Climate Change (2008) sets out a policy framework for Tasmania to ensure that future action is guided by research and analysis, targets, common objectives and principles. The framework recognises the need for the State's response to climate change to evolve over time as new actions come online and as new advances in science and policy emerge.

The framework is guided by six principles:

- Leadership
- Equity and shared responsibility
- Best practice
- Accelerated outcomes
- Creative thinking and innovation
- Openness and transparency

It accepts that all spheres of government have responsibility for action, and identifies the need for cooperative focus on:

- Ensuring scientific research provides a firm foundation for action
- Giving individuals, communities and businesses appropriate information, resources, skills and incentives to plan and adapt to climate change and manage their own risks
- Providing an appropriate emergency response
- Managing risks to public infrastructure, assets and values, protecting industry and the community against health and biodiversity risks.

The Tasmanian Government is a key partner in the *Climate Futures for Tasmania* project led by the Antarctic Climate and Ecosystems Cooperative Research Centre. This project will provide climate projections through to 2100 and enable industry and provide key information to the Tasmanian community on climate change impacts.

As part of the framework, eight priority areas for action have been identified:

1. Government leadership

2. Consolidating Tasmania's position as the renewable energy State
3. Planning for future changes
4. Protecting Tasmania's natural stores of carbon
5. Improving Tasmania's transport system
6. Innovations in agriculture
7. Becoming energy smart
8. Building resilient and adaptive communities.

The Tasmanian Climate Action Council will provide high level, independent advice to the Premier on climate change issues as they affect Tasmania.

A partnership agreement with local government on climate changes has been developed to guide future collaborative actions by the two spheres of government, and the Climate Change Community Grants Program will help Tasmanians work together in their local communities to find climate change solutions.

6.2.1 Natural Disaster Management

The Tasmanian Government has primary responsibility within its own jurisdiction for natural disaster management in the interests of community safety and well-being. This involves responsibility for:

- developing, implementing and ensuring compliance with comprehensive disaster mitigation policies and strategies in all relevant areas of government activity, including land use planning, infrastructure provision, and building standards compliance
- strengthening partnerships with and encouraging and supporting local governments to undertake disaster risk assessments and mitigation measures
- ensuring provision of appropriate disaster awareness and education programmes and warning systems
- ensuring that the community and emergency management agencies are prepared for and able to respond to natural disasters and other emergencies
- maintaining adequate levels of well equipped and trained career and volunteer disaster response personnel
- ensuring appropriate disaster relief and recovery measures are available, and
- ensuring that post-disaster assessment and analysis is undertaken.

The State Emergency Management Controller (currently the Commissioner of Police) can authorise inspections to identify and assess risks, and provide a requirement for the owners/occupants to develop an emergency management plan or require that the risks be managed. Failure to comply can result in a fine. To date this power has not been exercised in respect to management of coastal risks.

6.2.2 Planning

The Tasmanian Government is responding to climate change and sea level rise though a number of planning instruments and initiatives as follows:

State Coastal Policy 1996

Principle 3 of the State Coastal Policy 1996 is to protect the natural and cultural values of the coast which includes recognising the susceptibility of the coast to sea-level rise. Outcome 1.4.3 requires development of policies to respond to climate change and sea-level rise.

Draft State Coastal Policy 2008

The State Coastal Policy has been reviewed and a more succinct policy with an implementation guide to ensure consistent implementation across planning schemes has been drafted for referral to the Resource Planning and Development Commission (RPDC) for assessment. Outcome 4.11 of the draft policy proposes that development in areas at risk from the adverse impacts of climate change occurs only where the risks are satisfactorily managed.

The draft implementation guide proposes to require areas of high and moderate risk from climate change, sea level rise and storm surge to be mapped and the planning scheme to contain adequate provisions and standards to address predicted effects.

Standard Schedules Project

The aim of this project is to draft a suite of standard schedules for new planning schemes to accompany the planning scheme template introduced in 2003. Use and development standards to mitigate against climate change and sea-level rise have been included in a draft schedule covering flooding, sea level rise, storm surge and coastal recession. Application of the schedule will rely on detailed mapping of the areas potentially affected.

Regional Land Use Strategies

The Tasmanian Government is funding the preparation of regional land use strategies in partnership with the councils in each region. These initiatives will provide a regional approach to implementation of the State Coastal Policy, and policy responses to climate change and sea level rise. Mapping of the areas potentially affected by sea level rise, storm surge and coastal recession will be an important input into the regional strategies and the review of zoning in coastal areas. The mapping will also provide the basis for applying the standard schedule.

RPDC Planning Advisory Note

Planning advice is issued by the RPDC on matters affecting the administration and approval of planning schemes. A checklist attached to the RPDC Planning Advisory Note No.3 *Supporting Information for Planning Schemes* includes a requirement for planning schemes to make adequate provision for the effects of climate change. The same checklist applies to planning scheme amendments.

Review of Planning System

In March 2008, the Government announced a review of the planning system to streamline decision making by reviewing the roles and functions of the Minister, State agencies, RPDC, the Resource

Management and Planning Appeals Tribunal (RMPAT) and the new Environment Protection Authority.

The Premier has specifically directed the steering committee to report on the mechanisms available in the planning system that can ensure adequate coverage of climate change issues.

6.2.3 Other agency responsibilities

In addition to those areas mentioned above, state government agencies will have responsibilities for the following areas that may be affected by climate change in coastal areas:

- State infrastructure including state roads (eg South Arm Road)
- Schools, hospitals and other facilities for state provided services
- National parks and state reserves
- In future, water and related infrastructure, including water intakes, treatment and reticulation
- Oversight of public health issues. As noted earlier, the State Director of Public Health can declare an emergency and order the evacuation of areas deemed to have major public health risks.

6.3 Australian Government Role

The Australian Government has a wide scope of programs for both climate change mitigation and adaptation. Specifically the Department of Climate Change was created in 2007 to address aspects of climate change mitigation, adaptation and shaping a global solution. In addition, the Australian Government plays a national leadership role in conjunction with the states in disaster management and mitigation.

6.3.1 Climate change mitigation

Through the Department of Climate Change the Australian Government has embraced a comprehensive plan of action to reduce national emissions. Key elements include:

- A commitment to reduce Australia's greenhouse gas emissions by 60 per cent on 2000 levels by 2050
- Implementing a comprehensive Carbon Pollution Reduction Scheme by 2010 to deliver these targets
- Setting a 20 per cent target for renewable energy by 2020 to dramatically expand the use of renewable energy
- Investing in research and development on low emissions technologies
- Helping households and businesses to use energy more wisely
- Managing our land to reduce emissions

A range of specific programs have been developed to encourage mitigation including under the *Clean Business Australia* initiative and *Australia's Farming Future Climate Change Research Program.*

6.3.2 Climate change adaptation

The Australian Government has also acknowledged that even a strong and comprehensive approach to emissions will not avoid some level of climate change. The COAG National Climate Change Adaptation Framework supports enhanced research into climate change science and potential impacts. This Framework has two priority areas for potential action:

1. Building understanding and adaptive capacity. This comprises significant new actions to identify and fill knowledge gaps to enable effective adaptation action at the national and regional levels, including:
   - Support for significant adaptation initiatives currently underway including the National Climate Change Adaptation Flagship (the Flagship) hosted by CSIRO and the National Climate Change Adaptation Facility (the Facility) based at Griffith University's Gold Coast campus;
   - improved regional climate change information and tools for decision makers; and
   - integrated vulnerability assessments of climate change impacts.

2. Reducing vulnerability in key sectors and regions, in particular, water resources, biodiversity, coastal regions, agriculture, fisheries, forestry, health, tourism, and settlements. This will include:
   - addressing critical knowledge gaps, much of which would be coordinated through the 'centre for adaptation';
   - building sector relevant tools and information; and
   - developing and implementing climate change action plans for vulnerable sectors.

The Australian Government is also responding to climate change through a number of funding and research initiatives specifically being led by DCC:

- Digital Elevation Modelling at a high resolution to feed into the 'First Pass National Coastal Vulnerability Assessment'
- Local Adaptation Pathways Program; grants for local governments to assess climate change risks and develop adaptation plans
- Reviewing the Australian Rainfall and Runoff Handbook
- National Infrastructure Climate Change Adaptation Risk Assessment
- Review of the Building Code of Australia - '*An Investigation of Possible Building Code of Australia (BCA) Adaptation Measures for Climate Change'*

Other Australian Government Departments/Agencies that have responsibilities for climate change or adaptation [relevant to settlements & infrastructure] even though they are not specifically tasked with climate change responsibilities include:

- Department of Environment, Water, Heritage & the Arts through energy efficiency measures to reduce greenhouse gas emissions
- Infrastructure Australia
- Department of Infrastructure, Transport, Regional Development and Local Government
- Attorney-General's Department – Emergency Management Australia

6.3.3 Disaster management and mitigation

The COAG decision in 2002 on emergency management, in summary stated that:

> *"…The role of the Commonwealth Government in natural disaster management is to provide national leadership in collaborative action across all levels of government in disaster research, information management and mitigation policy and practice: to reduce the risks and costs of disasters to the nation; to mobilise resources when state and territory disaster response resources are insufficient; and to provide national support for disaster relief and community recovery.*
>
> *In particular, the Commonwealth Government has a major role in:*
> - *coordinating national strategic emergency management policy, in collaboration with the state and territory governments and local government*
> - *undertaking natural disaster research of national significance*
> - *identifying national priorities for natural disaster mitigation, in collaboration with other levels of government*
> - *providing support for disaster risk assessment and mitigation measures, in conjunction with the states, territories and local government*
> - *providing operational support for disaster response to the States and Territories where their individual resources are insufficient*
> - *providing a national disaster relief and recovery framework and resources on a cost-sharing basis with the other levels of government, and*
> - *providing vital information services such as meteorological, hydrological, geophysical and other geo-data services that support warnings and disaster management.*
>
> *The Commonwealth also has a continuing role in:*
> - *providing national leadership on mitigation strategies and assessment*
> - *providing financial assistance to states, territories and local government for cost-effective, priority disaster risk management*
> - *providing financial assistance to states, territories and local government to assist them in meeting their disaster mitigation responsibilities leading to an overall reduction in damage and costs, thereby benefiting all Australians and all levels of government."*

This Australian Government role is achieved through a number of specific agencies and initiatives with emergency response overseen by the Attorney General's Department. Funding assistance to the States is provided through the *National Disaster Relief and Recovery Arrangements* overseen by Emergency Management Australia within this agency. Logistical and other field support may be provided by the Department of Defence.

6.3.4 Other agency responsibilities

As with the State, a number of Australian Government agencies may bear responsibilities arising from climate change or adaptation, even though they may not be specifically tasked with climate change responsibilities. These could include:

- Families, Housing, Community Services and Indigenous Affairs (FaHCSIA) through support of individual and families adversely affected by climate change even if not in the context of a disaster;
- Department of Health and Ageing through increased health demands
- Department of Human Services through effects on employment and income assistance arising from climate change.

6.4 The role of individuals, industry & the community

Dealing with emergency events is not simply a matter for governments. Individuals, families, businesses and the community as a whole play a role in determining how well communities are safeguarded from natural disasters and the degree of resilience of communities.

The collective actions, or inaction, of individuals, families, businesses and community bodies can have a major influence on the severity of a disaster's impact. In significant disasters, disaster management career personnel and volunteers do not, and never will have, the capacity to simply 'solve' the disaster threat for every individual at risk. Nor do governments and charitable agencies have the ability or responsibility to fully offset the financial losses incurred by families and individuals in the course of a natural disaster.

Households and businesses have principal responsibility for safeguarding their property and assets against risks from natural disasters. It is their role and responsibility to attain the highest degree of physical and financial self-reliance, before, during and after a disaster. In particular they should:

- be fully aware of the risk of natural hazards to the home and regular activities
- arrange where available for adequate insurance to cover likely risks in their area
- make plans and preparations for dealing with a disaster situation
- ensuring adequate design standards are applied for risks in the location for any new construction or renovation and considering acceptability of structures when purchasing
- minimise hazard risk factors in and around the home/workplace environs, and
- find out what local plans are in place in the event of a disaster.

Local communities can take a wide range of actions to become more resilient and, in particular, should:

- promote high levels of awareness of natural hazard risks in the community and the collective preparations and actions that should be taken in the event of a disaster
- provide active support for government and community efforts to minimise the possible consequences of disasters, such as natural hazard risk reduction measures, and
- provide a culture of support and recognition for volunteers.

The private sector and professional and research organisations also have roles to play in natural disaster management, particularly in risk assessment and mitigation.

7 A framework for responding

7.1 Overall objective

Very long term predictions (hundreds to tens of thousands of years) suggest sea level may rise several metres with a worst case suggesting rises of up to 70 m[5]. Clearly it is inappropriate to exclude all use of land below this level 'just in case'. The actual level of rise will depend on the effectiveness of measures to reduce green house gas emissions. The rate of rise is subject to significant uncertainties, even over the relatively short term of 25-50 years.

Given these uncertainties, but the high probability that the sea level will continue to rise over the long term, the issue to be addressed is: **How do we beneficially use coastal areas while recognising the long term need to protect, accommodate or retreat as sea levels rise**? While use may be practical and desirable for many years, there will come a 'trigger' when a response will be required to manage the increasing risks.

7.2 Managing climate change risk

The modelling and mapping of future risk areas in this report identifies the changing areas that will be affected by 1% AEP events (100 year ARI) as sea level rises over time **if nothing is done**. These are related to sea level rises associated with three scenarios (low[6], medium and high) for 2050 and 2100 based on analysis by the IPCC. **The most effective action would be effective mitigation of global greenhouse gas emissions, bringing the outcome from the high scenario that we are currently tracking to the medium or lower scenario over these time frames.**

The community survey strongly supported mitigation as a major priority. This project does not address mitigation strategies as these are being dealt with elsewhere. In general the response to date both locally and internationally is consistent with the high scenario.

Given that residents of Clarence, Tasmania or even Australia cannot control global response, and both global response and the accuracy of modelling will develop over time, these scenarios are almost certain to be revised long before 2050. Nonetheless, the maps of areas that would be affected (presented in the sections on individual coastal locations in Sections 8, 9 and 10) provide the best available indication of the potential for impacts over these time periods. **These maps identify locations where active risk management will be required**. Furthermore, substantial areas have been identified as being at risk now. In most cases further work will be required before any specific response is made.

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[5] The Future Oceans – Warming Up, Rising High, Turning Sour, German Advisory Council on Global Change (WBGU), (GACGC 2006)

[6] Present day risk is used as a proxy for the 'low' scenario.

7.2.1 New development

The Planning Scheme needs to recognise these identified revised risks. The question is: What level of caution should be applied for future developments?

There is a developing practice around Australia to use the hazard associated with the estimated high range for sea level rise in 2100 to determine acceptable development when revising planning schemes to take climate change into account[7]. For erosion, set backs would be established that allow for expected erosion over this time frame while ensuring continued foundation stability.

Such a level substantially exceeds usual safety margins for most of the service life of the buildings, intending to ensure low levels of risk normally associated with development will still apply by 2100 after allowing for the 'maximum' expected sea level rise and other climate change effects.

The arguments for adopting this relatively cautious approach are usually summed up as applying the "precautionary principle". Practical arguments for adopting this level of caution include:

- **Uncertainty** – while using the high scenario may seem conservative, recent evidence shows sea level rise and greenhouse gas (GHG) emissions are following the high scenario. They could go higher, sooner.
- **Service life** – while the initial service life of the development (typically 50 years for a dwelling) may be less than the period to 2100, reinvestment and renewal typically extends the life of structures well beyond that. The infrastructure to serve the building may also have a longer service life.
- **Low marginal cost** – The extra cost of allowing for additional safety factors, for example by lifting buildings further above flood levels, is relatively low at the time of construction but much higher if the building has to be lifted once built.

While setting floor levels to suit 2100 high scenario flood effects or set backs for erosion may be appropriate as a general 'deemed to comply' basis for development, it is suggested that the emphasis should be on **encouraging performance based responses that maintain acceptable levels of risk over the life of the structure**. Thus a dwelling designed to be moved back from a moving erosion face, piled to be stable in spite of erosion and capable of withstanding waves or a structure designed to be elevated readily as sea levels rise could also be acceptable.

Some structures with a shorter service life may need to meet lesser standards: garden sheds, pergolas, boat sheds, etc. provided they are relocated or demolished before risks increase to the point where they represent a hazard to others.

In general it is not proposed that land use zoning be changed specifically in response to climate change risk. The appropriate zoning of land should respond to the broad range of planning considerations and key coastal management considerations are already identified. New development should be subject to conditions specified in the overlays that ensure levels of risk are acceptable, but this can be achieved in most locations with appropriate responses. In this way,

[7] The actual numbers adopted for sea level rise has varied according to jurisdiction as thinking unfolds, ranging from 0.4m to 1.0m for 2100.

areas subject to potential hazards may be occupied for many years before further adaptation responses are required, including, potentially, retreat.

For areas where risks cannot be managed realistically, eg where erosion threatens future development and protection is either impractical or undesirable, a freeze on development may be most appropriate.

In particular, it is recommended that opportunities to permit coastal ecosystems to evolve inland with rising sea levels be identified and changes made to the Planning Scheme to accommodate this where necessary and practical. The significance of this is discussed further below.

Even property development approved with the expectation that it will face acceptable levels of risk up to 2100 may face increasing and unacceptable risk if it exists beyond that time. If sea levels rise faster than expected, this could even occur sooner than 2100. An approach to managing risk in the longer term is also required. In particular, developments in areas identified as subject to longer term risk should clearly be notified that they will be subject to requirements to actively manage risk when unacceptable risk levels are approached, as described in the following sections.

7.2.2 Existing property

Setting standards for new development does not address the developing risk for existing property. At present there is limited requirement to manage increasing risk to existing property. When damage does arise from a storm or other extreme event, emergency relief may be provided, but this after-the-fact assistance is far more costly than risk management before the event. It also has higher risk of injury or death.

Given the current and foreseeable, systematic, long term development of increased risks in coastal areas, it is appropriate and less costly to actively manage risks to existing assets in these areas, including natural assets, through protection, accommodation or retreat. For example, individual property owners should be encouraged to consider whether to reinvest in existing, low lying structures or to demolish and rebuild in a way that reduces risk.

The philosophy of managed/adaptive approach with multiple interventions responds to risks in a number of smaller steps as they develop. With this approach, it is unnecessary to construct protective works now for high sea level rise in 2100, particularly if the provision to upgrade is incorporated in the design. It is prudent, however, to consider a range of sea level rise scenarios for future planning, as most of the present day risk is due to inadequate past planning and risk assessment.

For erosion, hard protection (in the form of seawalls) and soft protection (through sand nourishment, supplemented with groynes) are generally technically feasible (subject to additional studies) and are expected to have benefit to cost ratios well over one for most locations, for all sea level rise scenarios to 2100. For inundation for existing buildings there are fewer options, but some reduction in flooding may be achieved by flood barriers and a substantial reduction in risk through hazard reduction and emergency planning. These are also expected to have benefit cost ratios greater than one. Retreat from existing, serviceable structures generally has a benefit to cost ratio of less than one.

The economic factors of adaptive management need to be balanced against environmental and social factors to achieve the optimum outcome. An example of a social factor is the continued availability of a recreational beach for use by non-beachfront residents, although this too has an economic value, albeit harder to quantify. Successful coastal management will usually combine elements of *retreat, accommodate and protect.*

7.3 Equity and responsibility

Foreshores have a mix of public and private land, and are used by both local residents and those from outside the area.

People choose to occupy or use coastal areas because of the substantial benefits these areas provide. They are attractive locations to live, work and play. **In the long term** it is appropriate that people who choose these areas and gain the benefits – even while knowing the long term risks – accept and pay the costs of managing the risks that they incur. It would be poor public policy to subsidise people to locate in areas of known developing risk.

Many locations will be subject to hazards from climate change that otherwise would be at low risk from coastal hazards. The current owners and occupants of these properties – who chose these properties without being aware of these long term risks – will be disadvantaged by climate change effects largely beyond their control.

There is a need to allow existing owners to re-evaluate their choices and to suffer minimal losses from the changing conditions, while ensuring in the future that coastal property owners factor in the costs associated with managing developing risk.

As existing owners were not aware of the developing risk and are not in control of the causes of this developing risk, it is proposed that **for a period of 25 years, the cost of risk reduction and management measures be borne by the wider community. After that time, the cost of further risk management measures would be the responsibility of those that benefit from coastal use or occupation.** This condition should eventually be applied to all coastal property titles. Risk management works that continue to be undertaken by the Council could be paid for by a special coastal risk reduction rate in affected areas.

It is likely to be well beyond the means of Clarence City Council to meet the costs of risk management and reduction measures on its own, and equally inequitable for coastal councils to bear the costs of changes brought on by global changes. Council may even require assistance to meet the costs of adapting its own infrastructure. Assistance from the State and Australian Governments will be required.

At this time there are no formal programs designed to directly address this issue. Further, it is a situation that will be repeated around the state and around the country, making substantial demands on the wider community and will have to compete with other government spending priorities. These costs may, however, have some claim on revenue raised from the Carbon Pollution Reduction Scheme – although the many other claims on these funds are also known –

with the effect that those emitting these gases compensate those who are losing out. Whatever the source of funds, arguably some dedicated climate change adaptation funding will be required.

Thus it may take some time before a formal or structured response becomes available, and even then it may not fully meet the costs involved. However, it is desirable that the situation is clarified as early as possible both to keep risks manageable and to allow coastal communities to plan with some certainty for their futures.

The approach to managing and reducing risk is described in detail below.

7.4 Risk management triggers and responses

For existing property subject to increasing risk, it is proposed that triggers be identified that would require an adaptation response to keep risks at acceptable levels. Triggers would be invoked where risks exceed agreed levels. This could be where a 100 yr ARI (1% AEP event) is likely to lead to significant damage to some property or where more extreme events would make emergency responses difficult.

Acceptable levels of risk

The issue of acceptable levels of risk may need to be the subject of community debate before being set. While there are guidelines associated with some areas of risk, (typically those embodied in design and engineering standards, and those associated with traffic management to cite two examples) and have been developed in some other jurisdictions (Victoria WorkCover Authority, NSW Department of Planning, WA Environmental Protection Authority) developing risks arising in coastal areas from climate change for existing structures in Tasmania may need to be considered as having a distinct set of issues.

In general it is accepted that levels of acceptable risk are higher where risks are taken on voluntarily (skydiving) than when imposed (nuclear reactor built next door). Living in coastal areas is a voluntary risk. Living in bush fire prone areas is similarly if not more risky than living in coastal areas. Many have chosen to live in areas of demonstrably high risk. The most important thing – from the point of view of those taking on these risks – is that those making the choice are aware of the risks and how to minimise them.

From the community point of view, the most significant consideration is that those making these choices not impose unacceptable risks and costs on the rest of the community. This means that the wider community has an interest in seeing these risks managed and kept to an acceptable level.

The level of risk accepted may be higher where potential damages to property represent a modest part of total property values and the chance of total loss is low. Higher risk is also acceptable where the chance of injury or loss of life is low, even if property is lost. Arguably reducing risk of injury and to life can be achieved by good storm warning systems and emergency management, even where property risks are high.

It is entirely possible that different communities may choose different levels of risk. While the overall framework for managing coastal risks should be consistent, there is no reason why the chosen risk level may not be different.

"*In the south west of the Netherlands, the delta plan has been implemented with the aim of guaranteeing protection against the North Sea storm event which has an estimated 1 in 10,000 chance of occurring each year. For most of the river dykes along rivers such as the Rhine and the Ijssel, the accepted design event is the 1 in 1250 event. Along the Meuse, where flooding has been a lesser problem, measures are being taken to reduce the average chance of water damage to towns to 1 in 250 per year.*"

Different triggers will be required for different risks: high water tables, inundation, and erosion. Hazard maps are required for each of these risks, derived from the maps in this report.

We propose that the hazard maps are reviewed with each update of the Council Planning Scheme, or a maximum of every ten years to determine what areas are 'triggered'. In addition, if a major storm event has a significant impact on the coastline, a response may also be triggered between these reviews.

In this way the community will respond to actual changes in risk as the sea level rises or erosion progresses, not to events forecast for the distant future. Triggers should be soon enough to plan action and respond before risk become excessive, not sooner. The action taken should manage the risk as it develops – it need not all be done immediately.

Managing risk should ensure that risks to the wider community are avoided where possible and the risk to life is minimised. Managing the risk does not mean elimination of all risk. More extreme events can and will occur from time to time that exceed the capacity of the actions taken. However, if suitable actions are taken these more extreme events will be relatively rare and the damage and safety impacts remain manageable.

Managing risk also does not mean avoidance of all costs of damage. Rather it would seek to ensure that, where adaptation in the short term is likely to cost less than likely damages arising from risks, property owners are aware and able to act, where necessary with support from the wider community.

7.4.1 Criteria for acceptable response

Risk management responses should be flexible and allow creative solutions to local circumstances. However, while being flexible, they need to conform to certain minimum conditions to be acceptable. Acceptable responses should:

1. Demonstrably reduce risk to defined acceptable levels for an estimated time period
2. Be designed to be durable and effective for the estimated time period and/or have reasonably well known maintenance and operating costs for the design period
3. Indicate the anticipated response at the end of the estimated extended period when risks again approach unacceptable levels

4. In normal operation or in the event of failure, not adversely affect other properties, including integrity of property, continued beneficial use and cause no adverse health or safety risks to residents or users of other properties
5. Allow practical emergency response to events that exceed design risk
6. Identify the financial and operational capacity to meet any ongoing maintenance or operating costs
7. Allow for the continued viability of valued coastal ecosystems where these have been identified and continued viability is achievable at a cost acceptable to the wider community.
8. Define the agreed trigger for follow up responses in the event of continued change

7.5 Adaptive Responses

IPCC (2001) listed three classes of adaptive management options, namely:
- Retreat
- Accommodate
- Protect

Practical management options include:
- Planning controls for new development, which deal with:
  - Building setbacks
  - Minimum floor levels
  - Appropriate engineering assessments
  - Appropriate construction techniques (eg piled buildings, flood resistant materials)
  - **Or**: a development freeze in some locations
- Physical works such as seawalls, groynes, dune management or sand nourishment, offshore breakwaters and/or surfing reefs, temporary or permanent flood barriers, reconstruction of public infrastructure (eg roads, other services above flood levels)
- Detailed emergency management and evacuation planning, with hazard reduction requirements for affected properties
- Providing community education and information to improve awareness and ability to cope
- Ongoing monitoring, analysis and review of findings
- Additional data collection or studies
- A timeframe for review – currently five years for Council planning schemes

Planning controls deal with new construction and major renovations. Other responses are required to address developing risks for existing structures and services. These are discussed in more detail for different risks in the following sections.

The following sections discuss potential responses to different risks and some of the implications including indicative costs, as order of magnitude estimates only. This study was undertaken for most of the coast of the Clarence local government area. Therefore, broad and rapid assessment techniques were used which need to be followed with further detailed studies and monitoring. While costs are expressed in terms of dollars per dwelling potentially affected, these are indicative as this study was not undertaken down to the level of single houses. At this time full cost benefit analysis has not been provided as there is insufficient information to do this. However, it is strongly recommended that such analysis be undertaken before actual adaptation responses are initiated.

Cost benefit calculations

The cost is the cost of any works required to protect property or other assets, including natural assets (eg beaches). This includes capital costs plus any maintenance costs over the life of the investment, including consideration of the effective life of the protection before upgrading or renewal is required. Other costs may include a loss of amenity if a beach or access to a beach is lost to residents, or loss of ecosystem services and bio-diversity values if a wetland is lost.

The benefit is the avoided loss or damage to property, and potentially injury or death avoided. A full calculation would consider:

- Each property separately as they all face different degrees of hazard (being at different degrees of exposure ie elevations and distance back from the shore) and different susceptibilities (form of construction, foundation, etc.). This can be simplified by grouping properties with similar exposures and susceptibilities together after they have been assessed.
- In any given year, a given property (or group of similar properties) faces a range of potential flood or erosion risk levels, each with a different probability and with a different level of expected damage. This full scope of damage and probabilities needs to be integrated to calculate a net expected damage for that year.
- However, unlike static risks, with climate change the risk rises slightly each year, with the result that the damage for any given property will rise and additional properties are brought into the calculation as time goes by. As changes are slow enough, the calculation can be simplified by looking at the rising risk profile, say each decade, at least for the first 50 or so years. As the rate of change is expected to increase in later years, the interval for these changes may have to be reduced.
- The timing of costs and expenditures to allow for interest/discounting future costs and benefits.

Other benefits may be retention of a beach or foreshore access that otherwise may have been lost, or continued provision of environmental services if these are retained with some options.

Calculating this with any degree of accuracy is complex and requires substantially more information than is available from this project. Even without calculating this in detail some broad observations are possible:

- In many situations very high cost but very low frequency events may dominate total costs. Thus it may be that the highest costs are associated with damaging one in 200 or 500 year events rather than 'minor' effects from 100 yr ARI events. Evidence from insurance claims from riverine floods shows this pattern.
- Houses unlikely to be affected much before 2100 (ie just below or outside the 100 year ARI line in 2100) are likely to have very low risk for most of this century, with almost all damage occurring near the end of the period. There is little justification for spending on protection works for these properties until very much closer to the time when these properties are at risk.
- Properties at risk at present will face escalating risks to the level of certain, serious damage in some cases for sea levels expected for the high scenario in 2050 and in almost all cases when sea levels associated with the 2100 high climate change scenario occurs[8], albeit the likelihood of these costs and expected annual costs will rise steeply in the later years.

[8] These sea levels may or may not be reached on this particular date.

7.5.1 Inundation

Modelling and mapping from this project provides initial indications of land that may be subject to inundation under a 1% AEP event. Further work is required to determine the depth of inundation in different areas and actual properties likely to be affected after taking into account building heights, hydraulic behaviour and rainfall contributions.

Inundation triggers

It is proposed that properties in areas expected to be flooded by events with a 1% AEP would be required to manage risks effectively. Responses are discussed in **Section 7.5 Risk management responses.** Affected areas would be determined and mapping revised at least every 10 years.

The extreme water level due to inundation is likely to persist for approximately two hours at the peak of the tide, though ponds of water may persist much longer in some locations.

A number of different options are available for responding to risks of inundation. They have substantially different costs and benefits, as well as other implications for effective risk management, community amenity and sustainability.

Dikes and levees

Dikes, levees and other flood barriers are sometimes proposed and used to keep floods from encroaching on low lying land. Large areas of the Netherlands are protected in this way as are coastal areas in coastal USA (eg. Louisiana). London has a flood barrier on the Thames and one is under construction for Venice on its lagoon.

The development of walls to hold back the sea can provide protection for a given peak sea level from high tides and storms. Structures of modest height may be quite affordable. But the cost of these structures increases with the square of the height. Thus a structure twice as high costs four times as much. Therefore if sea levels rise and continue to rise, costs will continue to escalate in the long term, potentially becoming increasingly hard to justify. The catastrophe in New Orleans from hurricane Katrina had been predicted and proposals to upgrade the levees prepared, but were rejected by government as being too costly. The eventual cost of damage was much higher.

Dikes may also not be effective on their own. If sea water levels are frequently close to or above land levels behind the dike, as they will be in the longer term, pumping will be required to keep the water from coming to the surface from under the dike. This is particularly likely in sandy coastal areas in Clarence where permeability is relatively high. If dikes are chosen for protection in the long run in these sandy areas, pumps will need to operate there **forever**. In the event of an extended power failure, such as may happen in a severe storm event, water can penetrate these areas from below.

Dikes and levees should be designed to withstand a more severe event than a 1% AEP (100 year ARI) event. For example, the Netherlands use a 0.01% AEP design event for North Sea protection. This is because the consequences of failure would be catastrophic, with large sudden flooding arising from a breach or overtopping of the protection. Maintaining levels of protection at the desired levels of safety has proven challenging in many jurisdiction where dikes and levees have been used.

Dikes or levees are typically located close to the natural shoreline to protect the maximum area of land behind them. As the sea level rises, the face of the dike will become the low water line, with no tidal beach or shallows on the outer side. The height of the dike will increase the separation of those on the coast from the sea, changing the character of the coastline in areas where these are used. This will make the area very different from the current beachside environment of most coastal areas in Clarence at risk of inundation.

Low sea walls or levees may be appropriate for reducing flood risk in the short term for infrequent peak events while the sea level remains below land level most of the time, but are unlikely to be viable as long term protection for land in Clarence coastal areas as sea levels rise. If dikes or levees are to be considered for protection from inundation in the long term, the following conditions should be met:

- there is likely to be long term commitment to a high level of development in the area to justify the rising long term costs
- other options are not viable or cost effective
- the area will remain ultimately defendable and
- there are compelling reasons why this area rather than a less vulnerable, higher elevation areas nearby should attract continued development and occupation.

Short term reducing or impeding hydraulic linkage (flood barriers)

There are a number of locations where low lying land is separated from the foreshore by dunes, roads or other higher land. This land is generally linked to the sea by storm water outfalls, stream outlets or other channels. In extreme flood events, low areas in the dune front, roads or elsewhere may also allow water to flow from the sea onto the land.

During storms, sea level peaks lasting a few hours may not be sufficient to flood the inland areas to the same levels as the maximum open water height through these sometimes limited hydraulic connections. Further, by restricting the inland flow of water, maximum flood heights from sea water flooding may be reduced. This can be achieved by ensuring storm water pipes have one way flow caps on the ends, restricting water entry during storms and floods through some channels (eg to the Lauderdale Canal) and maintaining dune heights, roads or other land levels well above maximum flood heights. In some instances, raising road heights is desirable to maintain access during storms, and can act as an effective barrier for flood events. The seaward face of the road would need to be protected against erosion.

An indicative cost would be $400 per m of suburban roads raised 0.5 m and $600 per m of road for suburban roads raised 1 m. Major highways would be more expensive, $1500 per m or more including hardening the seaward face depending on the height and level of exposure to waves. The cost of preventing water entry to storm water pipes and through streams and canals has not been estimated and would take site specific assessment.

While impeding hydraulic linkage may reduce flooding from the sea, it may **increase** flooding from heavy rain events. Past floods have usually found both rain and high sea levels occurring together. Fresh water is less damaging than sea water, but flooding would not be prevented entirely. As sea levels rise, the capacity for rain water to drain away is reduced, raising the likely height of rain driven flooding events, even when the sea is kept at bay. For this reason, reducing the hydraulic linkage is seen as a short term measure only. The safest long term response is to raise the level of developed land and/or any structures in low lying areas.

Raising land levels and structures

The most secure and sustainable response to rising sea levels for developed low lying land is to raise the land level. For any new development or major redevelopment in affected areas, this would be controlled by the Planning Scheme. While building new structures with floor levels above expected flood heights would reduce damage, raising the land level in general would further reduce risks and maintain access and use of the property even during events with high sea levels.

The cost of raising land levels will depend on the availability and cost of suitable fill. Sometimes fill material is even available for free. Costs of placing and grading may be quite modest, with higher costs for the load bearing area under the structure where consolidation and suitable material is required. An indicative cost to raise land level by up to 1 m may be $10 - $30/m2, perhaps 10% of the market value of land in many areas. Additional costs may be incurred under foundations or for edges that may face erosion from flood water.

In general the cost of raising land used for agricultural purposes will be too high to justify. Agricultural land that is flooded by sea water will require restoration to be useable. Frequent flooding would make even this expenditure unviable, leaving agricultural land to revert to tidal areas as sea levels rise.

For existing structures, it may be possible to raise the structure and rebuild the foundation underneath if the structure is of high value and lifting costs are acceptable. More often, it would be more cost effective not to reinvest in older structures for a period of time and rebuild when the building structure and fabric have reached the end of their normal service life.

An alternative for structures below the expected flood level that have substantial remaining service life would be to waterproof lower levels and services where possible. A variety of technologies have been used to achieve this depending on the form of construction, flood depths anticipated etc.

Preparation for floods

For properties where the land remains vulnerable to inundation, the property should be kept free of floating/movable materials, polluting materials and chemicals. Services should be capable of inundation without damage. Where the level of 1% AEP floods exceed floor levels, different levels of response to flood warnings would be required ranging from short term protection (eg sandbags) to evacuation. Removal of the building may be warranted where it may be in danger of movement causing damage to other structures.

In locations where property is at risk of inundation and road access may be lost in the event of a flood, evacuation may be required upon notice of an extreme event.

Other options

While raising land and structures above flood levels is most appropriate for many situations, it should not be seen as the only response or best response for all cases. Other possible solutions include floating structures, tethered to prevent damage to surroundings or waterproof structures capable of being inundated with acceptable levels of clean up or damage.

In some cases retreat may be the chosen response as described for agricultural land above. If a structure is relatively isolated and would require either substantial filling of a large area or lifting of a long access road, the cost may not warrant the investment. If the land can serve other uses of value to the community, such as a tidal wetland as sea levels rise, then it may be preferable for this to become the future use. Areas of value to the community in this way should be identified in a systematic way so that if owners are interested a suitable price can be negotiated for the property.

A summary of potentially feasible adaptive management options for inundation is shown in Table 5. Detailed development and design needs to be undertaken before implementing most of these options.

Table 5. Inundation - potentially feasible adaptive management options

Location	Retreat, setbacks	Raise floors	Raise land levels	Short term flood barriers
Bellerive	✓	✓	✓	?
Clifton – Bicheno St, Pipe Clay Lagoon	?	✓	✓	✓
Cremorne – Pipe Clay Esplanade	?	✓	✓	✓
Glenvar Beach	✓	✓	x	n/a
Howrah and Little Howrah Beach	✓	✓	✓	?
Kangaroo Bay	n/a	✓	✓	?
Lauderdale - South Arm Road, Ralphs Bay	?	✓	✓	✓
Mays Beach	✓	x	x	n/a
Montagu Bay	n/a	n/a	✓	n/a
Opossum Bay	✓	✓	x	n/a
Rokeby and Droughty Point	x	x	✓	n/a
Seven Mile Beach west	✓	✓	✓	?
South Arm Beach - Halfmoon Bay	✓	✓	✓	?
South Arm Neck – Ralphs Bay side	x	x	✓	n/a

Table only includes 14 areas with significant inundation risk.
✓ Feasible subject to detailed studies
x Not feasible
? May be technically feasible, but may not be economically feasible
n/a not applicable

7.5.2 Rising water tables

Rising water tables pose increased risks of flooding due to heavy rains and can lead to the failure of septic tank systems and attendant health risks. Areas affected by rising water tables have not been identified by this project and will require further assessment by monitoring existing bores, septic tank performance or other investigations. When this work is complete, it may be appropriate to prepare maps identifying areas unsuitable for septic tank systems.

In principle, it may be possible to reduce the effects of rising water tables by pumping groundwater to the sea to lower water tables. While this may have some short term merit, it would be a relatively expensive and unsustainable practice if used as the main solution forever. Given the lack of detailed assessment of ground water levels and inflow to the areas affected, this option has not been costed.

Areas affected by rising water tables that are dependent on septic tanks will require alternate sanitary arrangements before health risks arise. This could include above ground digesters or installation of a sewerage system. Investment in a sewerage system would only be warranted if the community has a sufficiently long term future in spite of sea level rise. Given the potential to raise land levels in most locations, this is likely to be the case in all areas currently zoned for residential development and associated commercial areas. However, the merit of providing sewerage to isolated individual dwellings is less certain. These may require above ground treatment if sewerage cannot be justified. Council has already committed to provision of sewerage to Lauderdale.

7.5.3 Beach erosion and storm surge

Most beaches experience episodic erosion in response to storms followed by rebuilding in the periods that follow. Some beaches experience progressive erosion (or accretion) over the long term. With sea level rises, progressive erosion (recession) will become more prevalent as beaches respond to new conditions. The anticipated long term erosion fronts have been estimated and mapped for different locations **in the absence of any protection works or beach nourishment that may reduce erosion rates**. Detailed assessment for individual properties may generate slightly different hazard line locations. The level of bedrock strongly influences the erosion risk for properties located over it and this is not well established for many locations.

New development would normally be restricted to landward of the hazard lines. Buildings might be permitted seaward of the hazard lines shown if:

- Detailed assessment for an individual property by a coastal engineer varies the hazard line location;
- Rock is present beneath a veneer of sand, with the location and level of rock mapped and considered by a coastal engineer and/or geotechnical engineer;
- Buildings are constructed on piles, with design input from a coastal engineer, together with a structural and/or geotechnical engineer;
- A protection scheme is implemented (eg sand nourishment or seawall).

To reduce risk from wave runup, new development should be built with habitable floor levels at least 0.3 m above the estimated wave run-up levels. Habitable floor levels may be below this level if:

- The structure is protected by a dune barrier which has sufficient sand volume , crest height and continuity to prevent wave runup and inundation reaching it.
- The lower portions of the structure are constructed of flood resistant materials and are designed to withstand the water forces.
- For roads, alternative routes or other emergency contingency plans exist.

Erosion Triggers

While setbacks for new development should have regard to these long term trends and the expected erosion up to about 2100, existing property should also respond when more immediate threats are apparent. Mapping shows numerous properties within the present day risk zone.

Development needs to be kept far enough from the erosion face at any given time to ensure that in the event of a series of severe storms, the property is not likely to be undermined and fail. The hazard line for the present day shows the potential erosion effects of a series of severe storms with a combined 1% AEP while still maintaining stable foundation conditions. This is the basis of the erosion hazards mapped for each area. Properties shown as at risk now may require some adaptive response in the short term where detailed investigation confirms the locations at risk.

After a single severe storm event the erosion face may well be closer than this and further response would be required.

Areas subject to erosion are generally also subject to wave run-up. In some cases, harder, non erosive areas will also be subject to wave run-up while not vulnerable to erosion. While run-up hazard has been estimated in terms of height reached, it is generally difficult to map this as it depends on the land height and inland gradient, both of which may be subject to change.

On continuously upward sloping land (eg Opossum Bay) it is preferable for development to be sited above the wave runup level. This may not be practicable on low land behind higher dunes fronting the coast (eg Roches Beach, Seven Mile Beach) and not necessary provided frontal dunes are preserved and maintained.

Vulnerability to wave run-up is affected by dune height and depth, and this can change significantly after a major storm or series of smaller storms. It is recommended that when erosion risks are assessed in detail for vulnerable beaches that wave run-up risk also be assessed. Further, after major storm events, potentially vulnerable areas should be reassessed by Council officers (possibly in conjunction with coastcare or other community groups) to assess whether the height is now below run-up estimates. If dune heights or bulk have been substantially reduced, this could trigger an early response.

Beach and dune nourishment, revegetation

Beach and dune nourishment brings more sand into the system to offset losses and beach slope changes from erosion and sea level rise. It can be quite effective in protecting against damage in the short to medium term. It requires a cost effective (and environmentally acceptable) source of suitable sand. Subject to detailed studies and monitoring, ongoing replenishment may be required, however, for some schemes, particularly where groynes are used, replenishment may not be needed.

Building up and revegetating the dunes adds to dune stability and resists sand loss from wind and smaller storms. Maintaining dune height may be essential to defend against storm surge on beaches exposed to large storm waves. A large storm will not be significantly deterred from eroding the face of the dunes by vegetation and the dune may then collapse, but the presence of vegetation can increase the volume of sand available in a dune to resist erosion. This can be counteracted by maintaining sufficient dune depth. Dune vegetation can be protected at access to beaches via hardened entry points as have been established already at several locations.

The indicative cost for beach nourishment is \$15/m^3 but potentially ranging from \$5 to \$50 /m^3. The cost per linear metre of beach will depend on the particular beach and volume of sand required for different projected time frames and sea level projections. An additional cost of about \$150 per m of beach would be incurred for vegetating the enlarged dunes. An indicative lifetime may be decades, but detailed assessment is required for each beach.

Groynes

Groynes are artificial barriers extended into the sea at right angles to the shore. These can reduce erosion and trap sand being carried along the shore (longshore drift). As such they can be effective in extending the life of beach nourishment. In some cases they may trap and build sand on the beach even without nourishment. They can have the undesired effect of increasing net erosion rates in the areas down stream. In some locations they may also have other adverse environmental impacts.

They need to be made to resist degradation from storms and have traditionally been made from rock or concrete. More recently groynes have also been formed from giant sandbags which are less abrasive and may be considered by many to be more attractive. They are also cost effective and easier to place and relocate.

An indicative cost for groynes is about \$5000 per m with typical length about 100 m. Well designed and constructed structures should have a long lifetime, with minimal maintenance except where sea level rise necessitates raising the level of protection.

Shore protection, hardening

Shore protection can consist of vegetating existing dunes (as discussed above in conjunction with dune nourishment) or protecting soft sediment shorelines with erosion resistant facings (hardening). These may be rock, concrete structures, or could use geotextiles or sandbags of various types and sizes.

There is a significant risk with shore protection of protecting one section of coast but actually increasing erosion in others. This arises because the sand on a beach may move along the shore. The protected areas no longer supply sand further down the beach and the erosion in the unprotected areas then accelerates. Hardened surfaces may also reflect waves, increasing the damage caused by waves from some directions in storms, whether sand or erodible rock.

Hardened shorelines using rigid masonry or concrete based on soft sediments or even soft rock can be undermined if not well designed and deeply set into the surface. Poorly designed and undermined sea walls are quite common and rebuilding them is usually very difficult and expensive. For these reasons, dune protection needs to be carefully designed in each specific situation.

The analysis and design of any shore hardening should address a whole section of coast, not a single property or even a short section that may be threatened in the short term. Given the damage that poorly designed or constructed protection can do to adjacent coastal areas, and its danger to beach users and surrounding properties, it may even be argued that shore protection that is not professionally designed, built and monitored should be prohibited.

Rock structures require ongoing maintenance, typically after storms and/or at intervals of 10 to 20 years. Hard rock and concrete walls take up less space on beaches of limited width, but are more expensive to repair if they fail. Loose rock structures require a much wider base but are more easily repaired if disturbed by a major storm.

An indicative cost for rock structures are $100 per tonne, provided suitable rock is available. The rock structure must consider future sea level rise through increased wave height on the structure over time. This will lead to requiring larger rocks, and increased wave runup will lead to a higher crest and larger overall structure.

If dune protection by hardening is continued over long periods of time while the sea level rises, there will be no further injection of sand into the shore system and eventually the hardened dune face will be the low water shoreline. At that point there is no longer a beach. This can greatly devalue the attractiveness of a 'beachside suburb' and consequently property values.

The runup levels for sandy beaches will also generally increase if seawalls are built.

Foundation underpinning and resistance to waves

It is possible to construct structures that are able to withstand erosion of the shoreline and the direct impacts of waves. Coastal structures may be built on piles and either set above the significant wave height or built sufficiently robustly to withstand wave impacts. The indicative cost to pile a new house is $50,000.

Planned retreat

Progressive retreat recognises that the most sustainable coastal form will reflect the form that will emerge under natural conditions. For sandy shores, dunes will move inland to add sand to the coastal system, rebuilding to continue to protect the area behind.

Progressive retreat means the loss of prime coastal property. In spite of this, it may prove to be the lowest cost long term alternative available, especially if the cumulative cost of maintaining a shoreline against increasingly severe erosive forces into the future is considered. This is particularly the case where there is a single row of houses and they are vulnerable to erosion or inundation from both the front and back sides as occurs in several locations in Clarence.

The cost of planned retreat is high, but can be diminished to the cost of land if a process of planned disinvestment occurs. For properties at risk where the cost of protection is very high, it would not be prudent to add improvements or even to renew features such as kitchens and bathrooms when they become substantially aged. The properties would be reduced to the status of 'shacks', which many began as, rather than full time occupied principal residences. In this way, when the property is finally abandoned, the main loss is in the land value. If the land has a public benefit as open space or public beach, this may be recognised in a re-purchase by the public.

A summary of potentially feasible adaptive management options for erosion is shown in Table 6. Detailed development and design needs to be undertaken before implementing most of these options. Further details on the options are provided in the body of the report.

Table 6. Erosion - potentially feasible adaptive management options

Location	Retreat, setbacks	Piled buildings	Seawall	Groynes, nourishment
Bellerive	?	✓	✓	?
Clifton (Ocean) Beach, west	✓	✓	?	?
Cremorne (Ocean) Beach	✓	✓	✓	✓
Glenvar Beach	✓	✓	✓	x
Hope Beach, South Arm Neck, ocean side	x	x	✓	x
Howrah and Little Howrah Beach	✓	✓	✓	?
Lauderdale - South Arm Road, Ralphs Bay	?	x	✓	x
Mays Beach	✓	✓	x	x
Opossum Bay	✓	✓	✓	x
Roches Beach, Lauderdale	✓	✓	✓	✓
Rokeby and Droughty Point	x	x	✓	x
Seven Mile Beach west	?	✓	?	?
South Arm Beach - Halfmoon Bay	✓	✓	✓	?

Table only includes 13 areas with significant erosion risk.
✓ Feasible subject to detailed studies
x Not feasible
? May be technically feasible, but may not be economically feasible
n/a not applicable

7.5.4 Salt water intrusion

Salt water intrusion into fresh groundwater can make water supplies unusable. This may make the user dependent on other water sources. If the saline water comes into the root zone of the vegetation, the form of vegetation cover may change dramatically.

In general, salt water intrusion does not present immediate danger to health or property. Eventually high salt levels can have a corrosive effect on foundations and buried infrastructure. However, by this time risks from inundation will be of greater concern. For these reasons it is not proposed that hazard maps be developed for this risk.

7.5.5 Other monitoring, detailed assessments and studies

The following are recommended for the entire Clarence City and relevant local areas. They are grouped by purpose and listed in indicative order of priority in each group, based on the potential benefit expected.

Improving accuracy of risk assessment:

1. Consideration needs to be given to detailed modelling of inundation with analysis of hydraulic performance in areas identified as at significant risk. This would cost approximately $50,000 to $100,000 per locality and clarify the extent of inundation risk for properties set further back from the shoreline.

2. Bedrock depths need to be determined and mapped for Glenvar and Opossum Bay Beaches, Little Howrah and around Bambra Reef at Roches Beach and eventually extended to all Clarence Beaches. This information may already be available for some areas. This will allow the extent of erosion risks in these areas to be better estimated.

3. Flood studies on creeks may be required where riverine flooding may compound sea water inundation.

4. An analysis of the historical change of Clarence beaches (apart from Roches Beach which has been completed) needs to be undertaken using satellite photos and/or photogrammetric analysis of aerial photos. Regular beach surveys need to be undertaken, subject to the findings of the planform analysis, which should include analysis of the collected data. Such a program is being undertaken by Council at Roches Beach, Lauderdale. This will help estimate the extent of long term average erosion rates and later serve as a baseline for comparison to assess the effectiveness of any protection measures.

5. The extent of beach rotation is unknown for Clarence beaches. The first stage would be analysis of historical aerial photos (as above) with more frequent satellite photos for recent and future periods. Ongoing monitoring as per Roches Beach can be applied to other priority beaches. This will allow erosion risk estimates to be improved.

6. A program of systematic visual observation or instrument measurement of wave heights on key Clarence beaches and relating this to offshore waves would improve the certainty of beach erosion and wave runup modelling.

7. A more detailed assessment of groundwater use and aquifer flows would allow identification of most vulnerable bores in unconfined sandy aquifers as conditions change.

Monitoring developing risk:

8. The sea level rise projections in revisions to the IPCC documents need to be monitored and the implications of major revisions need to be considered.

9. Lagoons and offshore areas should be monitored through regular bathymetric surveys.

10. The existing network of instrumented bores in Roches Beach, Cremorne and Seven Mile Beach may need to be extended, with measurements of average and extremes of salinity recorded to establish baseline conditions and to monitor changes permitting systematic and reliable assessment of groundwater issues as they develop.

11. The implications of sea level rise for foreshore and estuarine ecology require further study.

12. Ensure adequate monitoring of ground water quality around former landfill sites subject to rising water tables.

Detailed assessment to select actions/responses and responding to known risk:

13. With current sea level rise projections, development proposals for any land below 10 m Australian Height Datum[9] (AHD) and/or within 500 m of the coast needs at least a cursory consideration of whether more detailed assessment is required. The 10 m level is suggested as it is readily identifiable on Council's GIS system and above any calculated wave runup level within the foreseeable 100 year planning period used in this report. Road access to sites also needs to be considered, for even if a site itself is above any inundation level, access to the site may be restricted during storm events.

14. A forecasting and warning system for prediction of inundation of roads and buildings by high tides combined with large waves and strong winds is desirable. The basis for such systems already exist at the Bureau of Meteorology, but need to be better integrated into coastal emergency planning and made available to residents of areas at risk.

15. Potential dune breach locations need to be identified from a detailed analysis of available LIDAR data.

16. Vegetation management plans need to be prepared and implemented for all dune areas not currently maintained by community groups.

17. An inventory of potential sand reserves for future beach nourishment needs to be developed and investigated. Studies for access and in-principle approvals need to be initiated.

18. Suitable quarries for rock protection need to be identified and the suitability of their rock for coastal protection needs to be determined.

19. A more detailed sediment budget and littoral drift calculations on ocean beaches (Clifton to Seven Mile) is needed as input to the design of any sand nourishment / groyne scheme.

20. An estuary process study of Pipe Clay Lagoon would determine if it is a sink for marine sand and would strengthen assessment of options for stabilising the entrance, including the decision to do nothing.

[9] Australian Height Datum in Tasmania is based on mean sea level for 1972 at the tide gauges at Hobart and Burnie which was assigned the value of zero on the AHD

8 Priority areas – currently at risk

The following areas have significant numbers of properties at risk under current conditions and represent the priority areas for action:

- Roches Beach/Lauderdale
- Cremorne
- Bicheno Street, Clifton Beach
- South Arm Road at South Arm Neck

While small numbers of properties are at risk in other locations, they do not require the scale of response of those listed above. Their needs are considered in Sections 9 and 10.

For each location there is a context description, a description and maps of hazard areas, discussion of the nature of the risk and a discussion of possible responses in this location.

Consideration of individual house vulnerability (eg floor levels for inundation or foundations on rock for erosion) are beyond the scope of this study. Indicative numbers of houses at risk are shown for each area. Damage for individual properties in the event that a 100 yr ARI (1% AEP) event occurs could vary from nil to rendering a dwelling uninhabitable. In most cases, it will be a small part of the total value of the property.

While hazards are mapped for three dates (present, 2050 and 2100), there is a rising probability of a damaging event occurring each year between these dates, as well as a higher level of damage expected each year for events of a given frequency. More property is also affected each year.

Possible responses are identified including consideration of indicative cost, preliminary assessment of the effects of the response in this situation and long term prospects. **In all cases, additional work is required** to:

- Define the risk for individual properties, (the current estimates are based on indicative estimates for each location)
- Determine the preferred response, based on more detailed studies and consultation with the community and a detailed cost benefit analysis
- Identify funding sources for further studies and larger works.

A summary of specific recommended actions is included in Section 12, Conclusions and summary of recommendations.

8.1 Lauderdale and Roches Beach

Lauderdale is based on a low lying sandy isthmus between Ralph's Bay and Frederick Henry Bay. Roches Beach faces the more energetic Frederick Henry Bay, and is backed by low dunes, varying in height and width between the beach and housing behind. The Ralph's Bay side is a shallow low energy bay with no significant dunes. A canal briefly joined the two bays, but the ocean end quickly closed from sand drift. It remains as an artificial tidal lagoon open at the Ralphs Bay end.

Most housing development in Lauderdale is on the hind dunes along Roches Beach or on the spoil from the canal excavation. Additional development continues on higher rocky ground along and off Bayview Road to the south, as well as some commercial development along South Arm Road facing Ralphs Bay. There are also a number of houses on larger properties in the area.

Three major hazards resulting in risk have been identified for the area:

- Storm surge and erosion along Roches Beach
- Inundation from Ralphs Bay
- Rising water tables leading to failing septic tanks

8.1.1 Roches Beach: Storm surge and erosion

Risk Assessment

The main Roches Beach is approximately 3500 m long and Roches Beach north, between Bambra reef and the sailing club is approximately 800 m long. Roches Beach has been subject to repeated erosion and rebuilding cycles. Earlier studies have shown evidence of net erosion over a forty year period. While the contribution of different causes remains uncertain, it may be driven by any combination of:

- Adjusting to past sea level rise (post ice age) or recent sea level rise
- Long shore drift
- Storm cut and rebuild
- Beach rotation
- Changes in sea grass colonies that may trap or release sand

To the extent that processes not related to climate change have contributed to coastal erosion in the past, it is expected that they will continue in the future. Sea level rise from climate change will contribute additional erosion along this shore, ensuring progressive erosion at faster rates unless some beach 'protection' is provided. The erosion of the face of the dunes with subsequent collapse of the dune creates a significant short term risk from storm surge at some locations.

Modelling indicates that under current conditions, a series of storms with a combined 1% AEP (100 year ARI) erosion effect could remove 100 m3 of sand per m of beach, leading to an average erosion of about 25 m inland. This could put approximately 19 of the houses directly behind the dunes at risk as indicated by Figures 2, 3 & 4. However, by 2050, most houses behind the dunes could be at risk.

Figure 2. Erosion and recession hazard lines, Roches Beach, north section

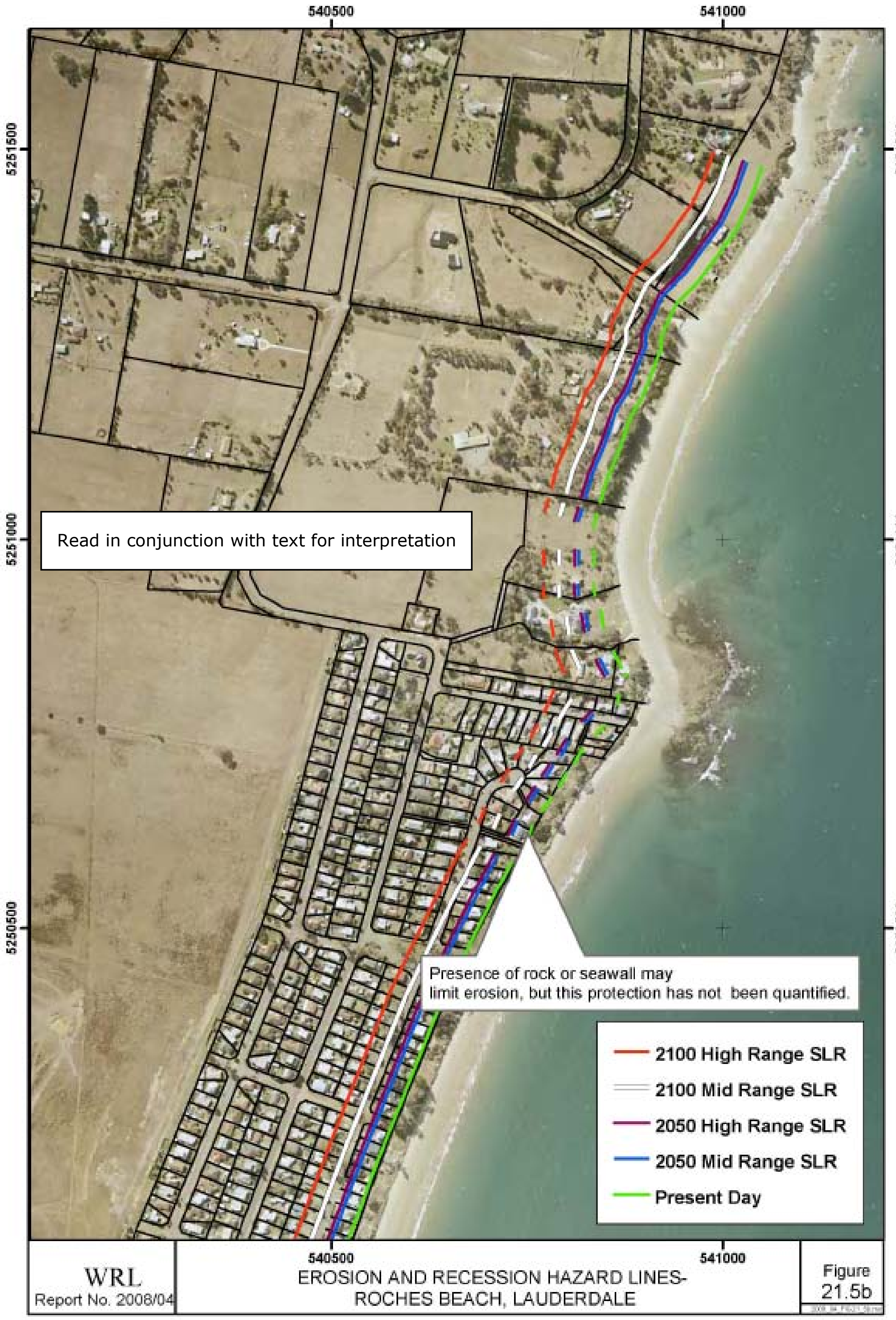


Figure 3. Erosion and recession hazard lines, Roches Beach, central section

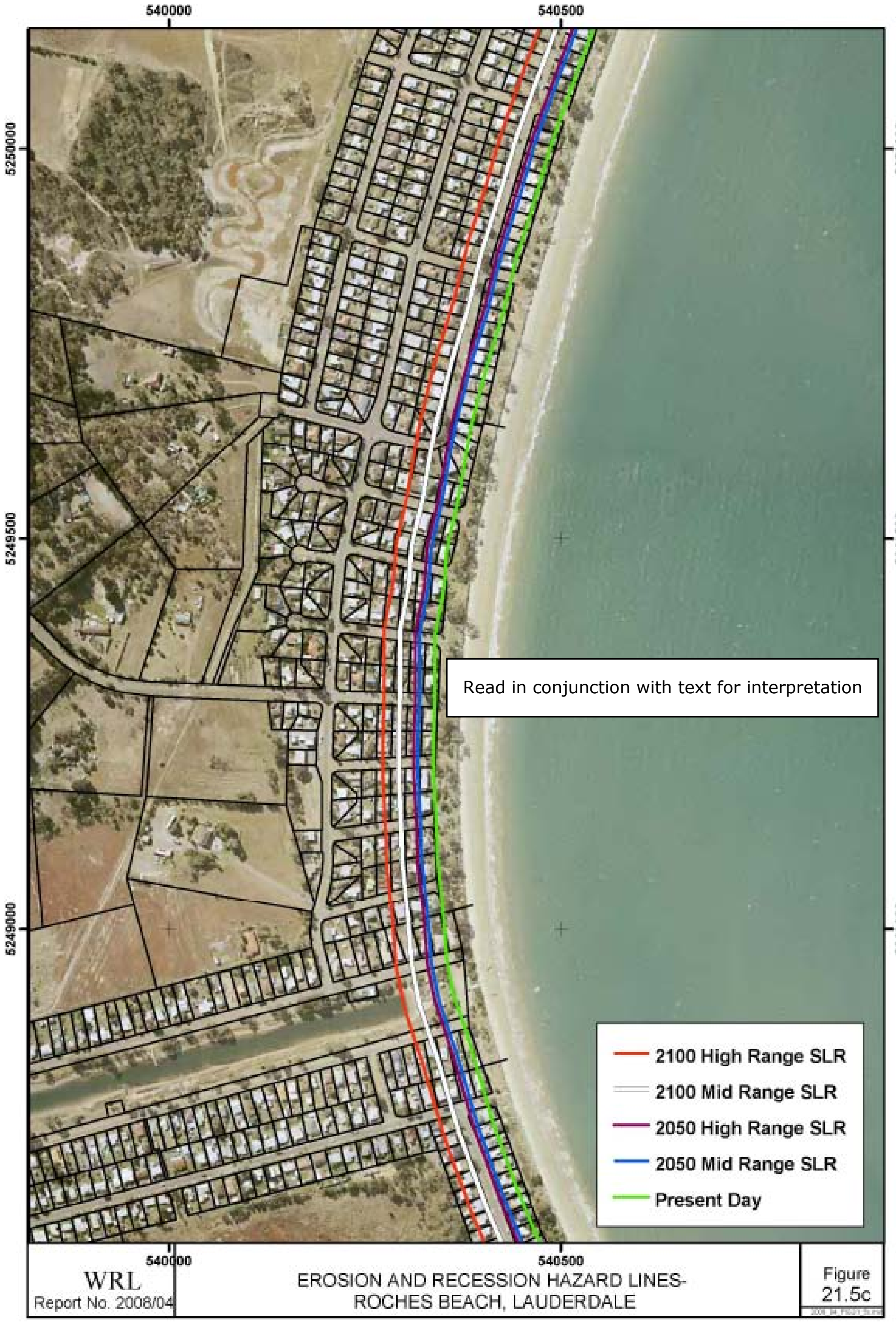
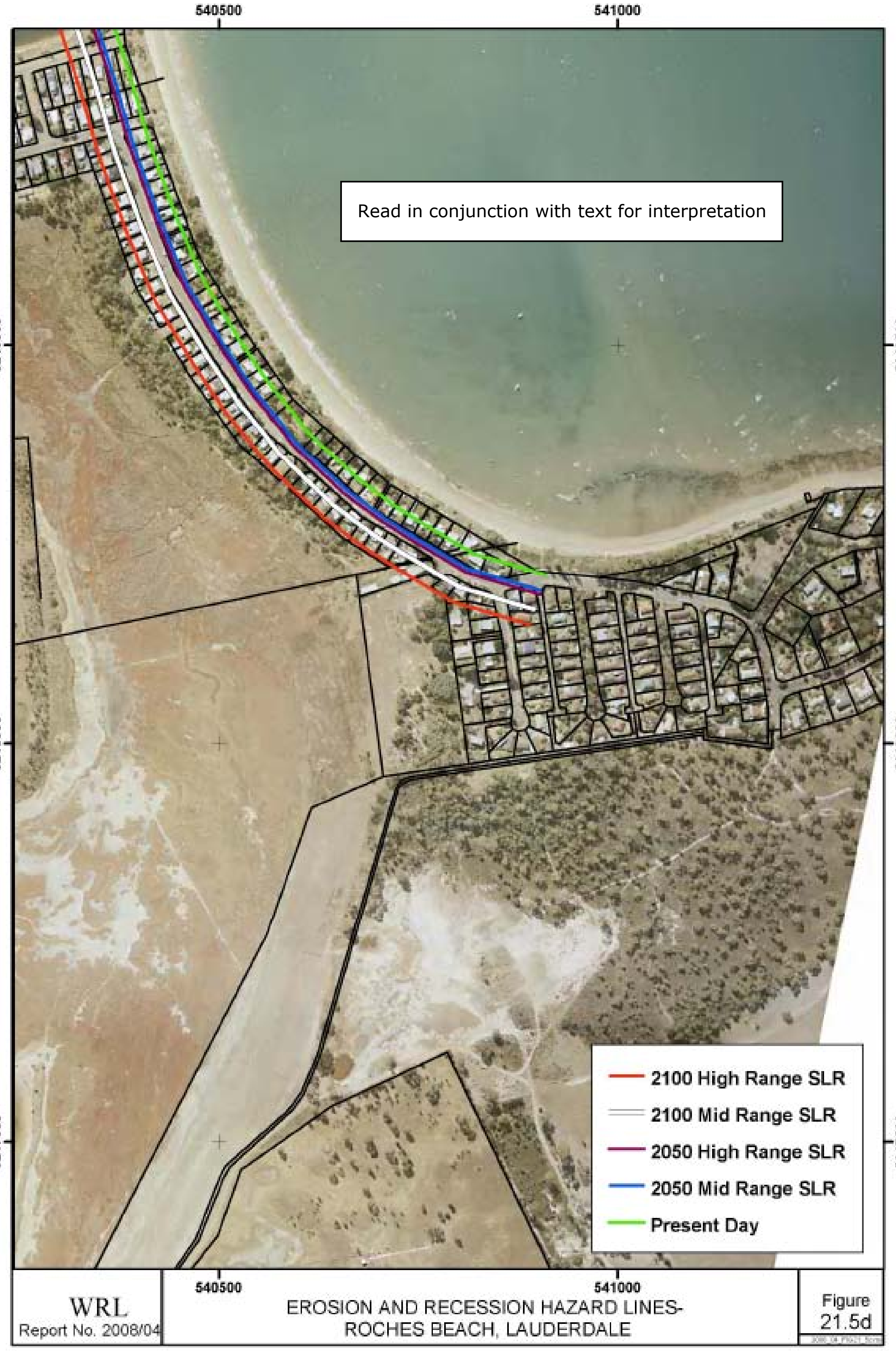


Figure 4. Erosion and recession hazard lines, Roches Beach, south section



In addition to erosion, wave run up may affect some houses directly behind the dunes. An estimated present day wave run up is 2.8 m AHD while average dune height is estimated to be about 3.5 m. Where dunes are lower than 2.8 m, some waves may over top them. The 2100 high scenario estimates wave run up of 3.7 m AHD.

Risk from erosion and storm surge is uneven along the beach. Some areas have higher, deeper and better vegetated dunes than others. Housing sitting partly on the foredune is more vulnerable than housing located further behind.

Much of the housing behind the dunes and all of the housing in the second row behind the dunes is outside of the hazard zone at present, but most would be in the hazard zone by 2100 under the high scenario, where long term erosion coupled by the effects of rising sea level would extend erosion about 95 m inland, potentially affecting about 195 houses. About 125 of these would be potentially at risk even with the mid range scenario for 2100.

The development of risk along Roches Beach is sporadic and episodic. Risk will be highest if there are several severe storms in short succession. Storm events and periods of dune rebuilding will continue, with the changes at times rapid and other times conditions will appear stable or even accreting.

In conditions with no development, dunes on an eroding coast will normally move inland. Given the closeness of development to the foredunes, there is little scope for dunes to migrate inland naturally. Without intervention, they are likely to lose height and depth and eventually cease to function as protection against storm surge for the dwellings behind.

Potential responses and preliminary cost estimates

Potential responses to storm surge and erosion include:

- New houses within the erosion hazard zone need to be constructed on piles, or otherwise restricted to the *Stable Foundation Zone*. This zone may be secured for the foreseeable future to the line of existing houses if work is undertaken to protect existing dwellings.
- Beach and dune nourishment, revegetation
- Groynes (supplementing dune nourishment)
- Dune protection and hardening
- Progressive retreat

Beach and dune nourishment would retain the current ambience of the area and be most acceptable to the wider Clarence community that use the beach. **Minor** sand nourishment in the form of dune raising could somewhat reduce risk in the short term. Indicative costs to raise the dune by 1 m (10 m^3/m of sand) would be $150 per m of beach provided a suitable sand source can be accessed. The additional cost to revegetate the raised dune would be $150 per m of beach. This gives a total cost of about $1.3 million or a cost of about $68,000 per dwelling protected.

More extensive sand nourishment would be needed to bring hazard lines for a 1% AEP event level clear of all properties at present and in the long term with sea level rise. The estimated sand quantities with associated costs would be needed to counteract future sea levels rise[10] is shown in Table 7, (excluding the cost of revegetation).

Table 7. Estimated quantities and costs for sand nourishment

Time	SLR (m)	Sand m3/m of beach	Cost/m @$15/m3	Total cost (million)	Dwellings potentially protected	Cost /dwelling
Present	0.0	40	$600	$2.6	19	$136,000
2050 mid	0.2	80	$1200	$5.2	108	$48,000
2050 high	0.3	120	$1800	$7.7	108	$71,000
2100 mid	0.5	200	$3000	$12.9	125	$103,000
2100 high	0.9	360	$5400	$23.2	195	$119,000

In practice sand nourishment would be undertaken in stages as required to maintain adequate levels of protection subject to actual sea level rise and rates of erosion experienced. An amount somewhere between the present and the 2050 high case would probably be required to provide reasonable protection for the next 25 years. The above estimates are at best indicative of the long term cost based on today's prices.

Subject to detailed design involving net present cost scenarios, it may be prudent to retain sand on the beach with a series of groynes. The littoral drift makes groynes or offshore breakwaters (in conjunction with nourishment, or standalone) a feasible option for Roches Beach. This could take the form of augmentation of the existing rock outcrops (eg Bambra Reef) with additional groynes needed between. Groynes would change the character somewhat but could retain beach sand longer before additional nourishment is required. There may be objections to these works on environmental grounds.

Indicative groyne length would be 100 m spaced at 500 m. At a cost of $5,000 per m, this would amount to $500,000 per groyne, giving a total cost for groynes of $3.5M for the 3500 m long main Roches Beach and a further $1M for the 800 m long Roches Beach north. This translates to about $237,000 per dwelling potentially protected today, or $40,000 per dwelling protected in 2050. Detailed design and assessment would be needed to confirm feasibility, effectiveness, cost and environmental acceptability. The combination of extra expenditure and visual impact may make groynes unattractive in the short term (ie. the next 25 years) unless nourishment alone proves to be too short lived.

The cost of dune nourishment and groynes is generally less or roughly similar to the cost of piling for new dwellings (approx $50,000). Piling is not an option for existing dwellings.

Seawalls are a technically feasible option, but costs are high (Table 8) and in the short term, not cost effective. They could be placed on the frontal dune, where they would substantially affect the character of the beach, or be as a buried terminal protective structure. Community attitudes on preserving public access along the foreshore need to be tested as erosion may mean there would be no accessible beach in the long term. This option is unlikely to be attractive for managing risk for the next 25 years.

[10] The Technical Report provides details of the basis of this calculation.

Table 8. Estimated costs for sea walls

Time	SLR (m)	Cost/m @$15/m3	Total cost (million)	Dwellings potentially protected	Cost /dwelling
Today	0	$4300	$18.5	19	$974,000
2100 high	0.9	$7900	$34.0	195	$174,000

Planned retreat is likely to be considered only if the cost of protection in the long term exceeds the value of property protected. This does not appear to be likely for properties affected by erosion up to about 2100 for the high scenario.

8.1.2 Ralphs Bay: Inundation

Inundation of low lying areas of Lauderdale is most likely to arise from Ralphs Bay. This side of the isthmus lacks the dunes of Roches Beach. In general, land levels to the Ralphs Bay shore are lower. However, in the event that the dunes are lost due to erosion, inundation is also possible from the Roches Beach side.

Lauderdale has already experienced low level flooding events in 1974 and 1996 (see Figures 5 and 6 below) albeit these were primarily driven by rainfall combined with high tides that contributed to a reduced rate of drainage. Water from Ralphs Bay at times has crossed the South Arm Road at Ralphs Bay during peak tide and storm events in the last few years. These flood events have been occurring about every 15-20 years.

At present these events have been nuisance floods causing little if any property damage. Most development remains unaffected on higher parts of the suburb. With sea level rise, the frequency of nuisance floods will increase. The maximum height of floods will also increase.

The height of a flood with a 1% annual exceedance probability (1% AEP - a low frequency event not experienced in recent times) is **currently** estimated to be about 2.0 m AHD. This allows for local wind and wave effects in the area. An additional freeboard of 0.3 m above this level is recommended even for today's flood level.

Figures 7 & 8 show the potentially flood affected areas for Lauderdale. Not all of the 161 properties below the 2.0 m AHD contour would be affected. Sea water will not have time to reach areas further from the shore during the peak period. Even in areas that are flooded, not all development would be affected or damaged if floor levels are higher above the ground level than the water depth and if structures have waterproof foundations. Many houses below the 2.0 m contour would have only a few centimetres of water with few consequences. However, 101 houses are on sites that would be more than 0.3 m below the flood level.

A less frequent but more extreme event could occur, raising flood levels higher. Rainfall may add to flood levels back from the shore. Access to South Arm and the southern parts of Lauderdale could be affected, and access to the north of Lauderdale may be limited to the north end.

Figure 5. Lauderdale, July 1974 Rain plus high tide event

Figure 6. Lauderdale, October 1984 Storm inundation event from Roches Beach

Figure 7. Lauderdale, Inundation areas, from Ralphs Bay, north section

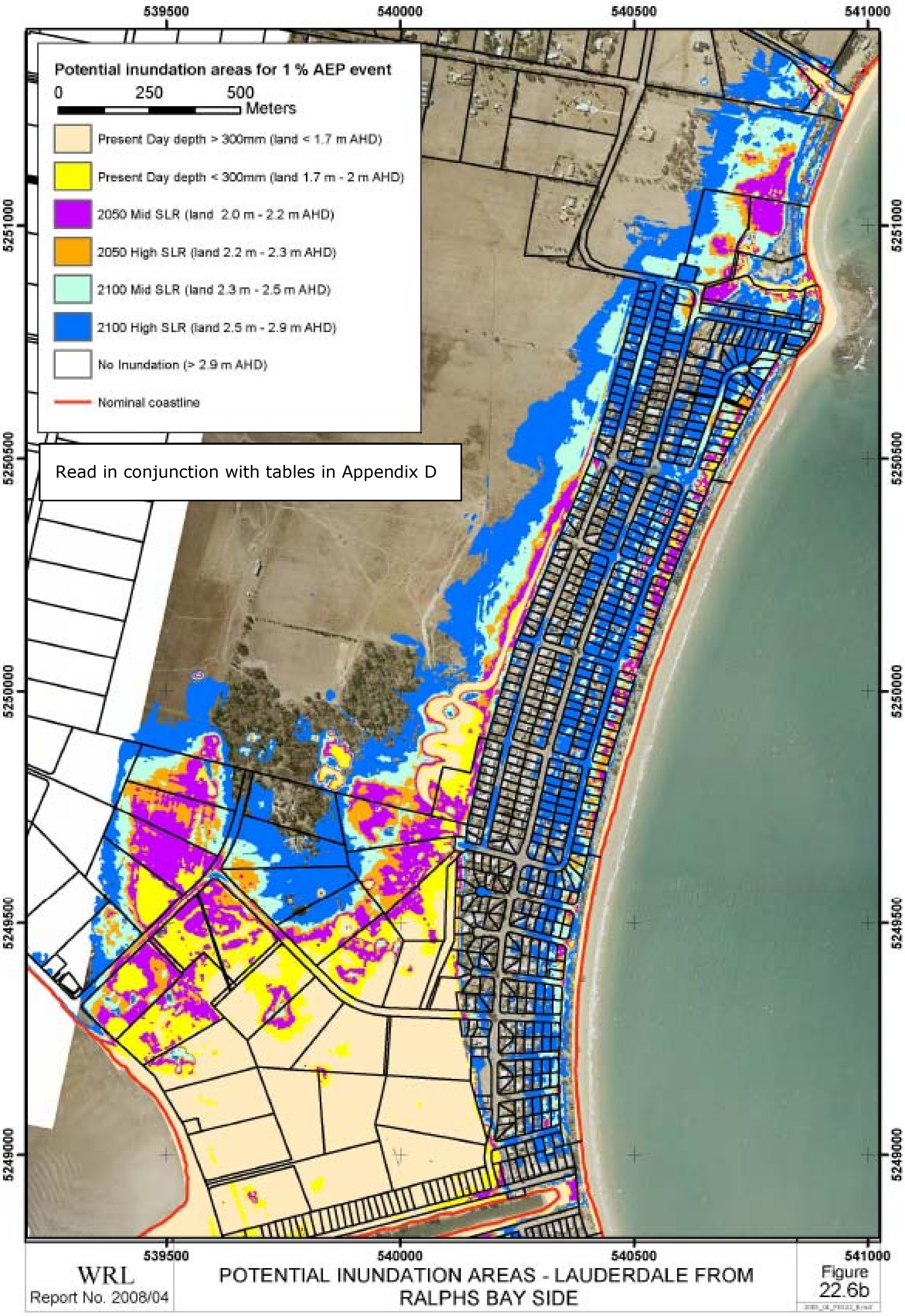
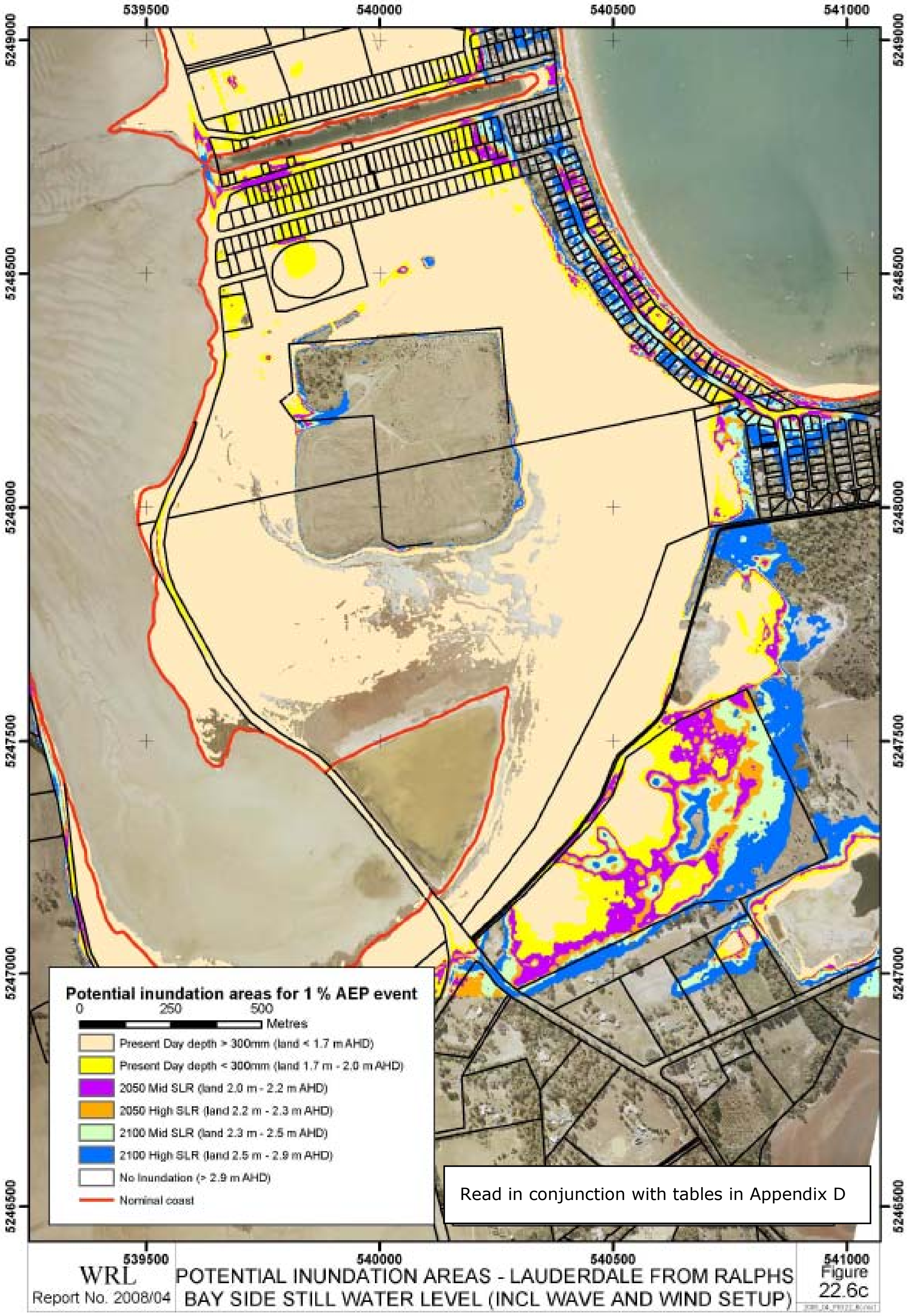


Figure 8. Lauderdale, Inundation areas, from Ralphs Bay, south section



Raising the South Arm Road would substantially reduce flood flows into the area, especially if this were supported by closing access to the canal and putting one way flow caps on all stormwater pipes. Raising the South Arm Road and protecting it from erosion on the Ralphs Bay side could cost of the order of $3.0 to $8.0 million depending on the level and other factors. This would not only benefit Lauderdale but all of the South Arm peninsula, so it is inappropriate to allocate this cost to the protection of property in Lauderdale alone. Nonetheless, even if the cost was considered only for dwellings potentially affected the cost would be modest at about $22,000 per dwelling.

This would provide substantial reduction in flooding risk to the area for the next 25 years. In the long term developed land will have to be raised above flood levels. Any new construction or major renovations should be required to be at safe elevations.

Raising other key access and suburban roads will also be required in the longer term. This may cost of $400 per m of road raised 0.5 m and $600 per m of road for suburban roads raised 1 m. There are approximately 10 km of low roads in Lauderdale, giving an indicative road raising cost of $6M if all roads require raising 1 m, which is unlikely. Raising suburban roads will not reduce inundation, but would be required if the suburb is to remain serviceable in the long run, say by having new properties built to a higher level.

With increasing sea water flood height and frequency, without intervention, some land areas will change in character with terrestrial vegetation being replaced by salt marsh vegetation. By 2100, the lowest lying land will be inundated at every high tide, potentially creating new habitat for water birds and some fish breeding grounds, but displacing some existing terrestrial areas. Part of Ralphs Bay that currently serve this purpose will be permanently too deep to provide wading bird habitat and existing shoreline saltmarshes will be also inundated permanently. Given the habitat significance of parts of Ralph’s Bay, this new tidal area will be a vital place for species retreating shoreward.

However, there is an old landfill site on the southern edge of Lauderdale that may have increased levels of leachate when the base of the landfill becomes permanently under water. This may adversely affect adjacent areas and water quality of the rising bay and should be monitored.

8.1.3 Lauderdale: Rising water table

Rising sea levels will result in rising water tables, even before flood risks become significant. This is important for the suburb as there are no sewers and properties depend upon septic tanks for liquid waste treatment and disposal. With rising water tables these will no longer function and significant health risks will arise if the situation were not addressed. Clarence City Council has already committed to provision of a sewer system for Lauderdale at a cost of about $10 million for 1000 properties or about $10,000 per property served.

The design needs to be capable of withstanding inundation by sea water. This may required special provisions to ensure that sea water does not enter the system through low level drainage inlets in houses during floods. Special provision to avoid this may be required for low lying properties. This requires further technical assessment.

This project did not have the resources to determine water table depths across the area. It is likely that water tables will rise in line with average sea levels. A sewerage system would likely be required within 25 years even if the Council had not undertaken to proceed with the project at this time. Given that Lauderdale is likely to remain viable up to about 2100, with adequate protection measures likely to be cost effective, investment in sewerage for the suburb appears to be justified.

8.2 Cremorne, Ocean Beach & Pipe Clay Esplanade

Cremorne township mostly consists of a low lying area with a dune backed beach that extends into a spit forming part of the enclosure of Pipe Clay Lagoon. Ocean Beach and the spit are about 1300 m long. The shacks originally established on the spit have developed into substantial houses. Dwellings at the south of the spit are not serviced by a made road but can be reached only on a hard sand shelf on the lagoon side of the spit which can be under water at high tide.

Three major hazards have been identified for the area:

- Storm surge and erosion along Ocean Beach
- Inundation from Pipe Clay Lagoon
- Rising water tables leading to failing septic tanks

8.2.1 Ocean Beach: Storm surge and erosion

Risk Assessment

There are approximately 27 houses on Cremorne spit and 25 on the beachfront north of the spit, giving a total of approximately 52 beachfront houses. Modelling indicates that under current conditions, a series of storms with a combined 1% AEP (100 year ARI) effect could erode the dunes removing up to 80 m3 per m of beach. This would cause an average erosion of 15 m inland, sufficiently to place nine of the 52 houses on the Ocean Beach side at risk. By 2050, 36 houses (mid-scenario) to 38 houses (high scenario) would be in the hazard zone, rising to 44 houses (mid) to 53 (high) by 2100. This is shown in Figure 9.

No study comparable to that at Roches Beach has been undertaken to determine if there is long term recession of the beach. It is expected that processes not related to sea level rise will continue to contribute to coastal erosion in the future if this has been occurring in the past. Sea level rise will contribute additional erosion along this shore, leading to progressive erosion at faster rates unless some beach protection is provided. An allowance has been made for recession at the same rate as the relatively nearby Roches Beach.

It should be strongly emphasised that these are at best indicative estimates, that storm events and periods of dune rebuilding will continue, and that the changes may at times be rapid and other times conditions appear stable or even accreting. Risk will be highest if there are several severe storms in short succession.

Present day wave run up in a 1% AEP (100 year ARI) event is estimated to be 4.7m AHD. An additional 0.3 m freeboard is recommended for building floor levels above this. Properties are potentially at risk from wave run up if they are below this level, depending on how far back from the shoreline they are placed. Average dune height is estimated to be 6.5 m. By 2100 for the high scenario wave runup increases to 5.6m AHD.

Figure 9. Erosion and recession hazard lines, Cremorne, Ocean Beach

Risk from erosion and storm surge is uneven along the beach. Some areas have higher, deeper and better vegetated dunes than others. Housing across the street or on the backside of the dunes is generally outside of the hazard zone at present.

If development on the dunes is to be protected, there is little scope for dunes to migrate inland naturally. Without intervention, they are likely to be undermined by storms and eventually collapse. This will reduce the protection afforded to dwellings along the Esplanade. The spit may become more mobile if housing is not present.

Potential responses and preliminary cost estimates

Potential responses to storm surge and erosion hazards include:

- New houses within the erosion hazard zone need to be constructed on piles, or otherwise restricted to the *Stable Foundation Zone*. This zone may be secured for the foreseeable future to the line of existing houses if work is undertaken to protect existing dwellings.
- Beach and dune nourishment, revegetation
- Groynes (supplementing dune nourishment)
- Dune protection and hardening
- Progressive retreat

Beach and dune nourishment would retain the current ambience of the area and be most acceptable to the wider Clarence community that use the beach. Minor sand nourishment in the form of dune raising could somewhat reduce risk in the short term. Indicative costs to raise the dune by 1 m (20 m^3/m of sand) would be \$300 per m of beach provided a suitable sand source can be accessed. The additional cost to revegetate the raised dune would be \$150 per m of beach. This gives a cost of about \$0.6 million or a cost of about \$11,000 per dwelling.

More extensive sand nourishment would be needed to bring hazard lines for a 1% AEP event level clear of all properties at present and in the long term with sea level rise. The estimated sand quantities with associated costs that would be needed to counteract future sea levels rise[11] is shown in Table 9 (excluding the cost of revegetation).

Table 9. Estimated quantities and costs for sand nourishment, Cremorne Beach

Time	SLR (m)	Sand m3/m of beach	Cost/m @$15/m3	Total cost (million)	Dwellings potentially protected	Cost /dwelling
Present	0	50	$750	$1.0	9	$108,000
2050 mid	0.2	100	$1500	$2.0	36	$54,000
2050 high	0.3	150	$2250	$2.9	38	$77,000
2100 mid	0.5	250	$3750	$4.9	44	$111,000
2100 high	0.9	450	$6750	$8.8	53	$166,000

In practice sand nourishment would be undertaken in stages as required to maintain adequate levels of protection subject to actual sea level rise and rates of erosion experienced. An amount

[11] The Technical Report provides details of the basis of this calculation.

somewhere between the present and the 2050 high case would probably be required to provide reasonable protection for the next 25 years. As always with nourishment, it depends on the continuing availability of a supply of sand. The above estimates are at best indicative of the long term cost based on today's prices.

In conjunction with nourishment, a minimum of two groynes/training walls would be needed, one at the southern end of Cremorne beach to prevent excessive loss of nourishment sand into Pipe Clay Lagoon, and one at the northern end to reduce sand loss. Indicative cost would be $5000 per m for each 100 m groyne, giving a groyne cost of $1M. Additional intermediate groynes may improve the performance of nourishment.

Groynes would change the character somewhat but would retain beach sand longer before additional nourishment is required. The southern groyne may alter *Cremorne Point* surf break, but not necessarily detrimentally. There may be objections to these works on environmental grounds.

The cost of groynes translates to about $111,000 per dwelling protected present day or $19,000 per dwelling by 2100. Detailed design and assessment would be needed to confirm feasibility, effectiveness, cost and environmental acceptability. This is likely to be required for protection for the next 25 years otherwise nourishment alone is expected to be short lived. Adding the two costs (nourishment to 2025 plus groynes) gives an estimated $127,000 per dwelling protected. This is more than the cost of piling for new dwellings (approx $50,000) but piling is not an option for existing dwellings.

Seawalls are a technically feasible option, but costs per protected property are high, particularly in the short term (Table 10). Additional expenditure would be required again after 2100 at a higher cost, but less cost per property. Given that houses are built directly on the dunes along much of the beach, seawalls would need to be placed on the frontal dune, where they would substantially affect the character of the beach. Community attitudes on preserving public access along the foreshore need to be tested as erosion may mean there would be no accessible beach in the long term. This option is unlikely to be attractive for managing risk for the next 25 years due to the relatively high cost but may be required if an acceptable source of sand cannot be identified.

Table 10. Estimated costs for sea walls, Ocean Beach

Time	SLR (m)	Cost/m @$15/m3	Total cost (million)	Dwellings potentially protected	Cost /dwelling
Today	0	$6,000	$7.8	9	$867,000
2100 high	0.9	$10,000	$13.0	53	$245,000

In addition to the recession hazard from the Ocean Beach side, there will also be erosion hazards from the Pipe Clay Lagoon side, and costs associated with keeping the road above water. The cost of a seawall to reduce erosion on the Pipe Clay Lagoon side of the spit is estimated to be about $2000 per m for a length of 400 m ($0.8 m). Raising the road about 1 m could cost about $600 per m ($0.24 m). This would serve approximately 20 dwellings on the spit at a cost per dwelling of about $50,000, on top of the Ocean Beach side protection. Consideration should also be given to rebuilding the training walls at the mouth of the lagoon, subject to detailed design studies and community input, unless planned retreat is proposed for properties on the spit.

Planned retreat is likely to be considered if the cost of protection in the long term exceeds the value of property protected. This appears to be possible for properties on the spit as the higher estimates of cost start to approach the level of some property values.

Given this degree of uncertainty about the long term viability of development on the spit, a development freeze should be considered for properties on the spit until a comprehensive management strategy is developed. If a protection strategy cannot be devised, retreat of houses should be considered when they become threatened by the erosion scarp. Mandatory coastal engineering assessment should be invoked for all development applications outside the *Stable Foundation Zone* north of the spit.

8.2.2 Cremorne: Inundation

Risk Assessment

The height of a flood with a 1% annual exceedance probability (1% AEP - a low frequency event not experienced in recent times) is **currently** estimated to be about 1.9m AHD. This allows for local wind and wave effects in the area. An additional freeboard of 0.3 m above this level is recommended even for today's flood level.

Figure 10 shows the potential inundation areas for Cremorne. Not all of the 95 properties below the 1.9 m contour may be affected if floor levels are higher above the ground level than the water depth and if structures have waterproof foundations. Only 15 houses would be on properties inundated more than 0.3 m for the 1% AEP event. However, an even less frequent but more extreme event could also occur, raising flood levels higher. Access to the township would also be affected with no alternative routes available.

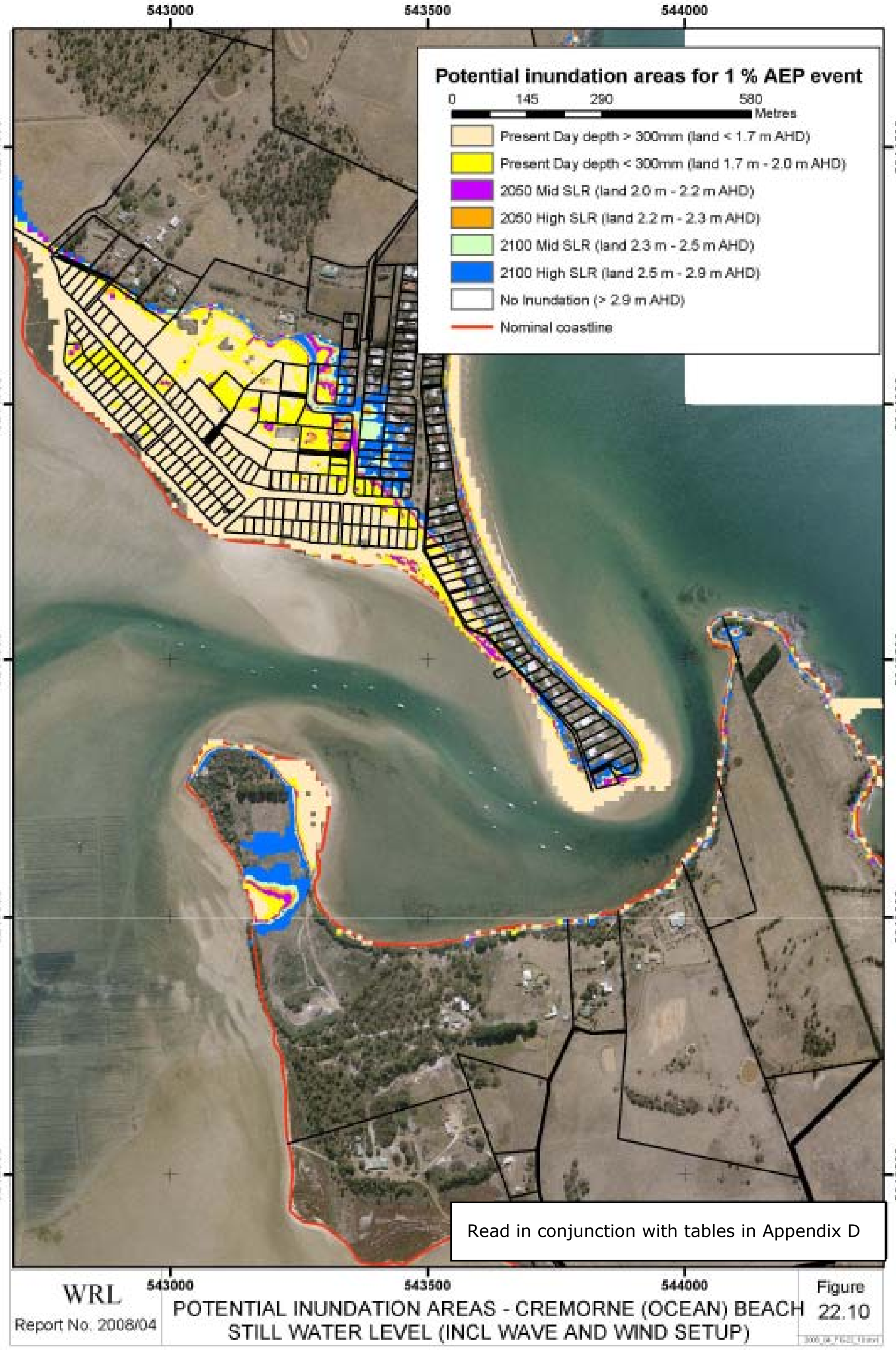
By 2100 flood levels for a 1% AEP (100 yr ARI) event are estimated to be 2.8 AHD. Up to 118 homes are below the 2.8 m contour with most flooded in excess of 0.9 m in a 1% AEP event.

Potential responses and preliminary cost estimates

Any new development should be sited above the inundation level plus a freeboard of 0.3m. The indicative cost to raise a new house having a footprint of 150 m^2 by 1 m (at initial construction) is $30,000.

Consideration should be given to raising Cremorne Avenue and Pipe Clay Esplanade, providing a new road and/or providing a minor seawall. This would reduce flood risks to low lying areas in the short term keeping risks manageable for the next 25 years, but raising land and floor levels would be the only sound strategy in the long term. Council has undertaken works in the past and has surveyed the foreshore on several occasions from 1981 to 1997.

Figure 10. Cremorne Beach, Inundation areas ocean side event



An indicative cost for suburban roads raised 1 m is $600 per m of road. There are approximately four km of low roads in Cremorne, giving a total cost of approximately $2.4M. It is unlikely that all roads would need to be raised to this extent.

A seawall on the Pipe Clay Lagoon side would cost approximately $2,000 per m, and may need to extend for three km along Cremorne Avenue and Pipe Clay Esplanade, not counting the 400 m along the spit itself. This would amount to a cost of $6M. These costs equate to about $70,000 to $90,000 per dwelling potentially protected. In addition, in the long term all new dwellings should be built above the inundation level and existing buildings only redeveloped or improved if raised above inundation levels.

Most of the inundation prone land in Cremorne is developed. It is unlikely to be attractive to leave any land for encroachment by wetlands.

Cremorne - Rising water table

Rising sea levels will result in rising water tables, even before flood risks become significant. There are no sewers and properties depend upon septic tanks for liquid waste treatment and disposal. With rising water tables these will no longer function and significant health risks will arise if the situation in not addressed.

This project did not have the resources to determine water table depths across the area. It is likely that water tables will rise in line with average sea levels. A change from existing septic tanks is likely to be required for many properties within 25 years. Given that most of Cremorne is likely to remain viable up to about 2100, with adequate protections measures likely to be cost effective, investment in sewerage for the suburb may be worthwhile, subject to investigation of the cost of provision.

8.3 Clifton – Bicheno St, Pipe Clay Lagoon

Bicheno Street follows the southern edge of Pipe Clay Lagoon and provides access to the peninsula that forms the south eastern enclosure of the lagoon with a large number of properties, including oyster farms to the north and some Clifton Beach residents to the south.

Risk Assessment – Inundation

The street bounds the shallow southern edge of the Lagoon and is not subject to erosive wave action. However, the road and the property along it are very low lying. The road has been flooded in a number of recent high tide/storm events.

The height of a flood with a 1% annual exceedance probability (1% AEP - a low frequency event not experienced in recent times) is **currently** estimated to be about 1.8m AHD. This allows for local wind and wave effects in the area. An additional freeboard of 0.3 m above this level is recommended even for today's flood level.

Figure 11 shows the potential inundation areas for Bicheno Street. Not all of the 21 properties below the 1.8 m contour would be affected. Not all development would be affected or damaged if floor levels are higher above the ground level than the water depth and if structures have waterproof foundations. There are nine houses on properties that are 0.3 m below the 1.8 m flood depth. Other properties would have only a few centimetres of water with few consequences. However, an even less frequent but more extreme event could also occur, raising flood levels higher.

By 2100 flood levels for a 1% AEP (100 yr ARI) event are estimated to be 2.7 AHD. There are an estimated 26 homes on land below the 2.7 m contour, with most of these potentially flooded to a depth of 0.9 m or more.

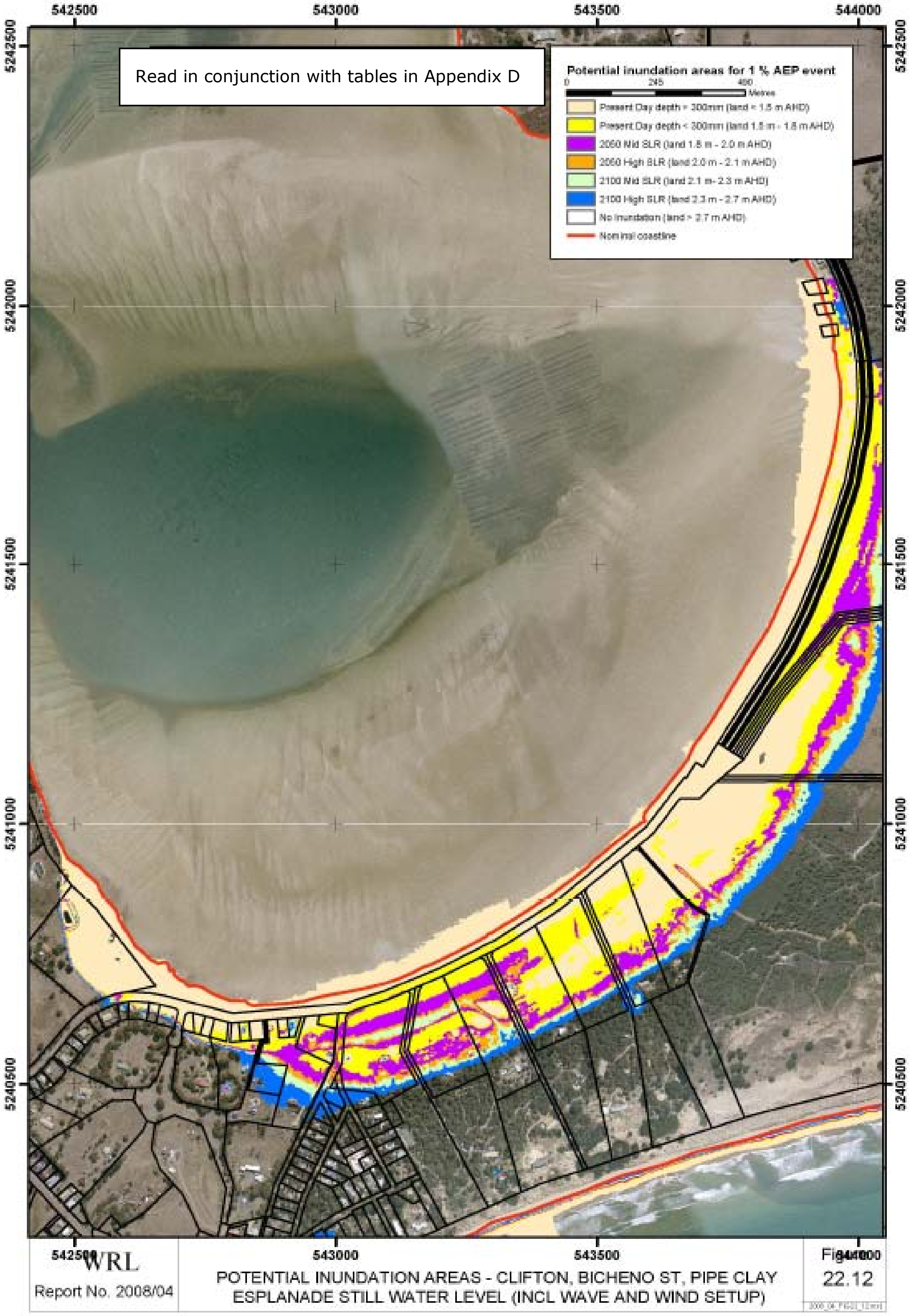
Bicheno Street services houses in Clifton for approximately 1 km and extends for another 2 km to the north-east to provide access to numerous other rural houses, north Clifton Beach and the eastern shores of Pipe Clay Lagoon. Access to the township would be affected with no alternative routes available. There are approximately 90 properties which require access along the low section of Bicheno Street.

Potential responses and preliminary cost estimates

Occasional inundation of Bicheno Street needs to be planned for, or the road needs to be raised at an indicative cost of $400 per m for 0.5 m and $600 per m to raise it 1 m. This gives a cost to raise it by 1m for 3 km of approximately $1.8M or approximately $20,000 per property served by the road.

Arguably the western end of the road is the highest priority as it serves the most properties and has the potential to reduce flooding to those properties. In addition, private roads extending off Bicheno Street are also subject to inundation and some would have to be lifted to secure access.

Figure 11. Clifton Beach, Bicheno Street, Inundation areas



A minor edge wall for the road should be considered at an indicative cost of $600 per m. This would amount to $1.8M ($20,000 per property) if extended the total distance of 3 km or a lesser amount if only the more critical parts of the road are protected.

Elevating the road would reduce the risk of sea water flooding the 21 houses in the short term. It may increase the risk of flooding by heavy rain, but given the limited catchment, this is not expected to be a major hazard. Any new development/redevelopment should be sited above the inundation level. In the long term, low lying properties will have to be raised to protect them from inundation. However, given the size of the properties and relatively low intensity of development, this is unlikely to be cost effective for many. More realistically, properties will elevate only the dwelling and access roads and a limited area around the dwelling. It is likely that surrounding low lying land will eventually become tidal wetlands unless there is a push to intensify development and raise the area in general.

8.4 South Arm Neck, Ralphs Bay

The South Arm Highway traverses the South Arm Neck along a stretch of road only just above high tide. It is bounded by Ralphs Bay to the north and high dunes separating it from Hopes Beach facing the open sea to the south. The road is the only route serving the residents of South Arm and Opossum Bay.

Risk assessment – inundation

The north side of the neck is not subject to significant threats from erosion. The road has been flooded by sea water on several occasions recently (eg in August 2007 and March 2008). When impassable, the residents of South Arm and Opossum Bay are isolated from the rest of the peninsula and emergency services.

The estimated flood height for a present day 1% AEP (100 yr ARI) event is 2.6m. The road elevation is about 1.5 m AHD. Figure 12 shows the potential inundation areas along this section of the road showing that it may be flooded for over 3 km of its length for depths in excess of 0.3 m even with present day conditions. The length of road flooding would not be much greater in 2100, but with a flood height of 3.5m AHD, flood depths would be entirely impassable for the full 3 km length. Apart from loss of access, repeated flooding or wave action on the road edge will lead to deterioration and increased road maintenance costs.

In addition, nesting Pied Oystercatchers roost in the area between the road and the bay, and are forced onto the road during higher tide events, even if the road is not flooded, putting this local population under threat.

Potential responses and preliminary cost estimates

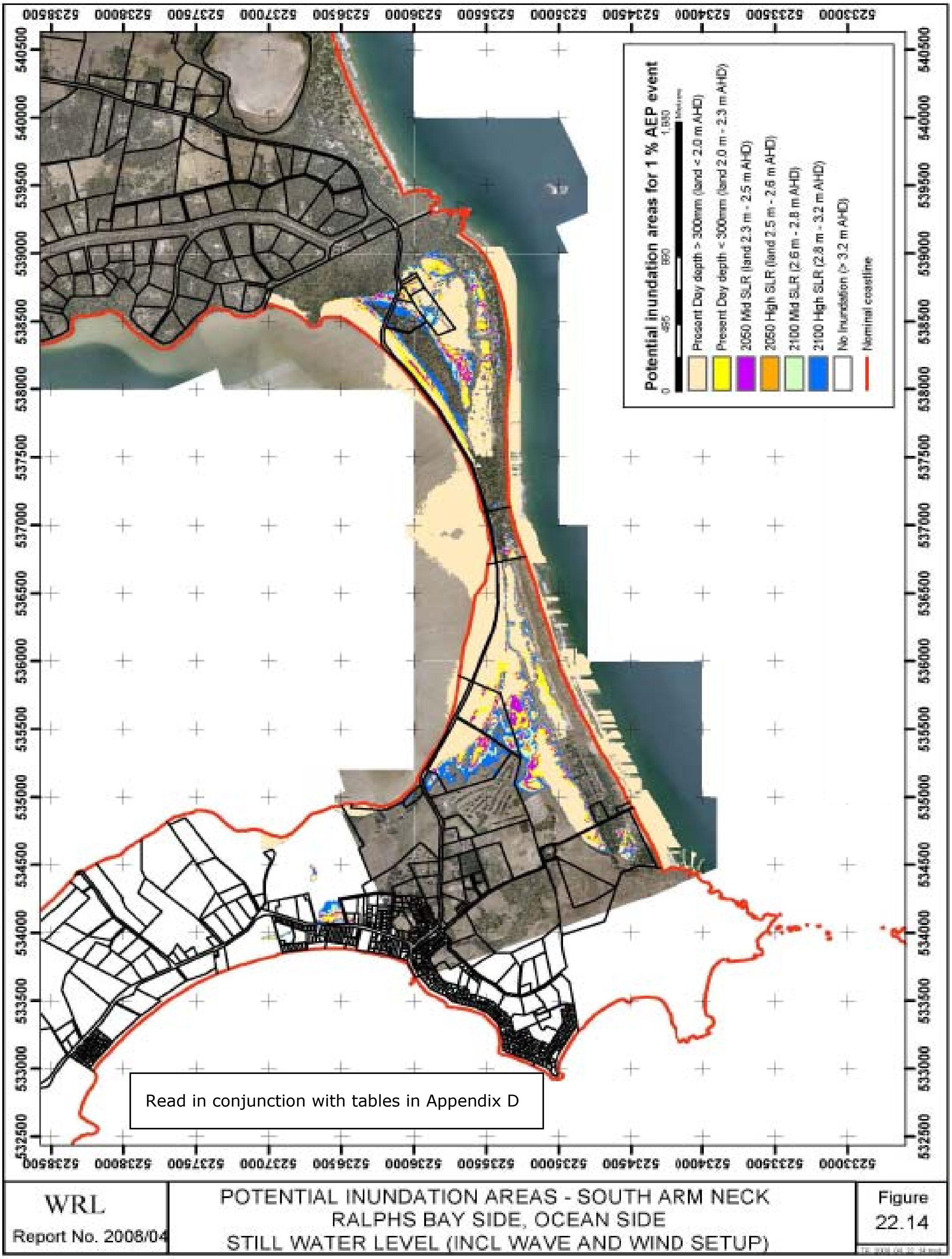
A study has been undertaken by the Department of Infrastructure Energy and Resources (DIER) to consider raising the road and protecting it with a seawall for waves from the Ralphs Bay side. Some of the results of the study were published in a paper[12], with three suggested levels of response and indicative costing for each.

Water depth advisory signage	$30,000
Batter protection to reduce road deterioration	$1.5M
Raise the road to 1.8 m AHD (inundation about one in eight year, present day)	$2.7M
Raise the road and batter protection	$4.2M
Raise the road to 2.6 m AHD (one in 20 year event, 2050 mid range sea level rise)	$9.2M

The dune elevation and sand volume should be monitored and maintained to prevent oceanic breakthrough from Hope Beach. There is sufficient sand buffer to prevent breakthrough from the ocean side even with 0.9 m of sea level rise and a 100 year ARI (1% AEP) storm event, however, this needs to be monitored and reviewed as the consequences of such a breakthrough are serious.

[12] Sea level rise implications and adaptation for South Arm Secondary Road, Hobart, Blacka, M, Carley, J, Lester, D, Williams B IPWEA Conference Responding to Sea Level Rise, July 2008

Figure 12. South Arm at South Arm Neck, Inundation areas



9 Areas with medium term risk

Areas with medium term risk are those where significant numbers of properties are likely to be at risk over a time period of 25 – 75 years. Within these areas there may be a few structures at risk in the shorter term. Areas deemed to be at risk in the medium term are:

- Clifton Beach
- South Arm Beach Half Moon Bay
- Kangaroo Bay
- Bellerive Beach
- Rokeby and Droughty Point Road

In many cases the risks to property will not arise until the normal end of life of existing structures is reached. The estimation of future risk allows any renewal to occur with adequate provision for the developing risk.

The format for this section is similar to that for priority areas, but with less detailed treatment for each location. Additional studies are generally not warranted for these areas at this time, except for some of the localised risks discussed in some sections.

9.1 Clifton Beach

Clifton Beach is the settlement most exposed to the open sea, receiving the highest wave energy of any settled beach area in Clarence. Settlement is much less extensive than Lauderdale or Cremorne, which affects both the number of properties at risk and feasible responses.

Risk assessment – erosion

The modelling of potential erosion impacts shows the potential for large losses of sand from a 1% AEP (100 yr ARI) series of storms, removing of the order of 150 m3 of sand per m of beach. This would result in erosion of about 25 m from the shore. Three houses may presently be at risk from such an event along the western 500m of the 2.1 km beach. This could increase to 12 by 2100 assuming the high range for sea level rise. This is shown in Figure 13.

In addition, present day wave run up from an extreme event of up to 5.9 m AHD could affect some of the houses at Clifton. By 2100, wave run up would reach 6.8 m under the high scenario above the estimated average dune height. High sea level rise combined with a major storm pose a low risk of a breach through to Pipe Clay Lagoon. There is currently sufficient sand buffer to prevent this.

Elevations of properties are such that there is no expected risk of inundation. However, access to numerous properties is via Bicheno Street which is potentially subject to inundation (discussed in Section 8).

Potential responses and preliminary cost estimates

Initially, minor sand nourishment in the form of dune raising could be undertaken. Indicative costs to raise the dune by 1 m (10 m^3/m of sand) would be $150 per m of beach provided a suitable sand source can be accessed. The additional cost to revegetate the raised dune would be $150 per m of beach. If this were done for the 2.1 km of beach, the total cost would be about $0.6 M or over $200,000 each for the three properties protected.

Major sand nourishment for the western ~1000 m would be feasible, which would require the bay to be split with a groyne structure, otherwise the whole bay (2.1 km) would need to be nourished (at twice the cost of nourishing 1000 m). The character of Clifton Beach would be altered by this groyne. Table 11 shows the estimated quantities and costs for nourishment.

These quantities and costs are large by the standards of other Clarence beaches, due to Clifton's higher wave climate. Additional studies would be needed to confirm these quantities.

In addition, there is the cost of the groyne. This would need to be approximately 200 m long and would cost approximately $15,000 per m, giving a cost of $3M. With this added, the costs per property range from about $1M to $1.6M per property generally exceed the value of the property being protected. This arises as a combination of the relatively large quantities of sand required and the low intensity of development.

Figure 13. Erosion and recession hazard lines, Clifton Beach

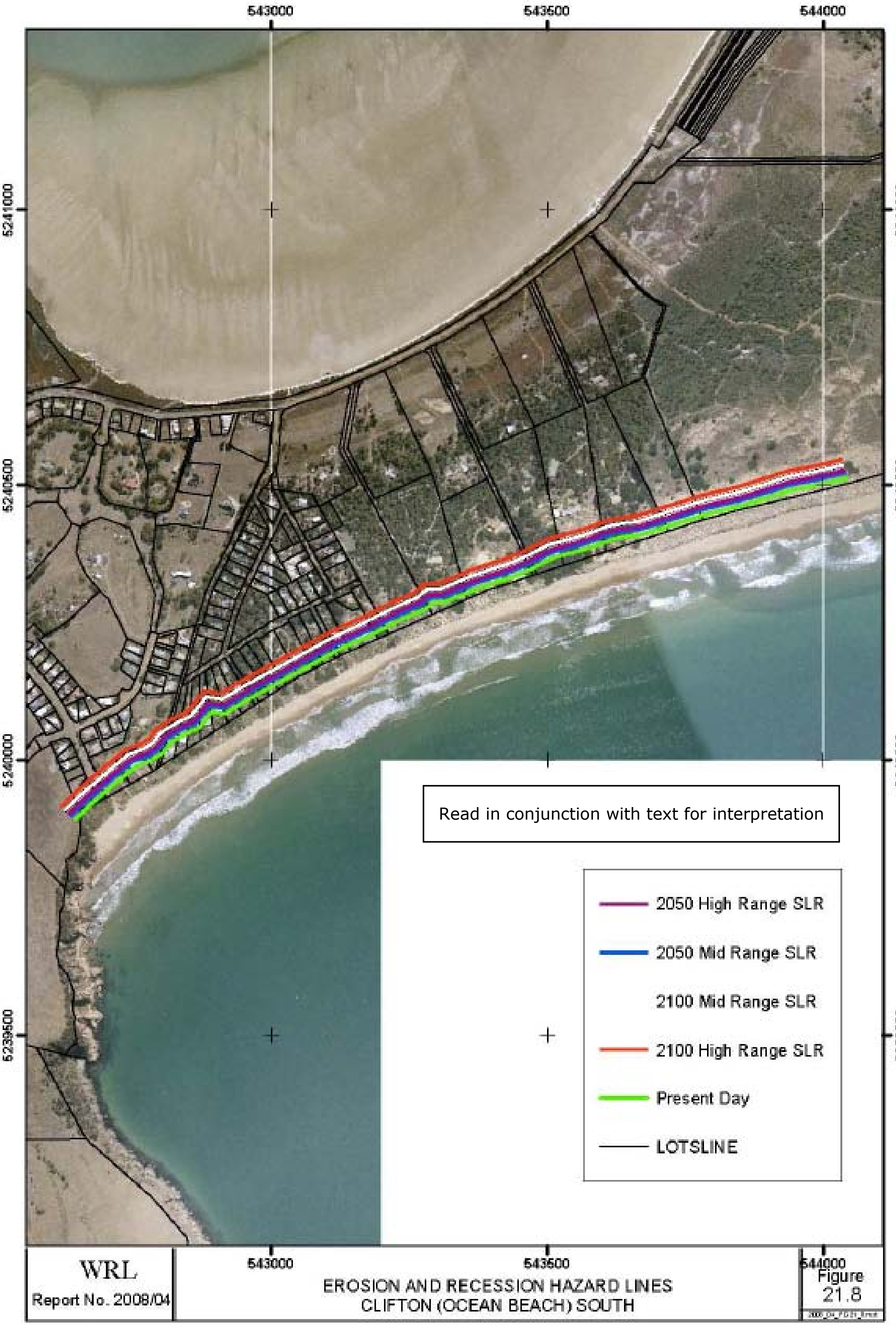


Table 11. Estimated quantities and costs for sand nourishment, Clifton Beach

Time	SLR (m)	Sand m3/m of beach	Cost/m @$15/m3	Total cost (million)	Dwellings potentially protected	Cost /dwelling
2050 mid	0.2	220	$3300	$3.3	3	$1,100,000
2050 high	0.3	330	$4950	$5.0	7	$710,000
2100 mid	0.5	550	$8250	$8.3	10	$825,000
2100 high	0.9	990	$14850	$14.9	12	$1,237,500

Alternatively, a seawall could be constructed to protect property, with estimated costs shown in Table 12. Subject to detailed design and siting, it may need to be constructed from concrete rather than rock armour due to the likely large armour sizes needed. This would again substantially alter the character of the beach, potentially leading to its loss in the long term.

Another possibility would be a terminal protective structure which would require a major excavation of the dunes. It would not stop long term recession but would not disturb the current beachfront while providing significant defence before eventual retreat.

Table 12. Estimated costs for sea walls, Clifton Beach

Time	SLR (m)	Cost/m @$15/m3	Total cost (million)	Dwellings potentially protected	Cost /dwelling
Today	0	$8,900	$8.9	3	$3,000,000
2100 high	0.9	$14,000	$14.0	12	$1,200,000

In the long term the cost of the sea wall is 25% less than the cost of nourishment plus a groyne.

Given the very high costs for protecting property, it would be prudent to consider a development freeze on properties seaward of the *Stable Foundation Zone* if a coherent strategy cannot be developed. At the very least, new houses not in the *Stable Foundation Zone* should be on engineer designed piled footings. The most plausible long term strategy is to redevelop dwellings that reach the end of their life further inland, a practical proposition for all but three properties given the long narrow blocks.

Planning should consider relocating the surf life saving club house further landward when it reaches the end of its service life and/or it becomes damaged by storm erosion.

New houses should also be above the inundation level from the lagoon side and the dune crest should be monitored and maintained so that it is above the design wave runup level.

9.2 South Arm Beach Half Moon Bay

Development is distributed in a few pockets of concentration but is generally sparse for most of the beach.

Risk assessment

Erosion from a 1% AEP (100 year ARI) **erosion** event could remove 10 m from the shore potentially affecting about 9 houses mostly at the northern end of the beach. With rising sea levels contributing further to erosion, by 2100 with high sea level rise erosion could reach as far as 65 m inland affecting up to 43 houses. This is shown in Figure 14.

Wave run up in an extreme event is estimated to reach 3.9 m AHD for present day. By 2100 this would rise to 4.8 m AHD. The height of the coastal dunes and distance inland of development will determine the extent to which properties may be affected. Coastal dunes are quite high for much of the area.

Properties affected by erosion and wave run up occur at three relatively short stretches of the beach, in the north, south and lower-middle reaches of the beach. In addition to houses there are a number of smaller outbuildings built essentially on the front of the dunes that are at risk.

Under 1% AEP (100 year ARI) storm conditions, sea levels could reach 2.0 m AHD. The potential inundation area map (Figure 15) shows approximately five houses located on sites below the 2.0 m contour line. However, only two dwellings are located on land expected to be inundated by more than 0.3 m. By 2100 for the high sea level rise scenario, 1% AEP flood levels reach 2.9m AHD. All eight affected properties are at the north of the beach.

Potential responses and preliminary cost estimates

For the fourteen houses located at the north end potentially affected by erosion and inundation by 2100, a short seawall of approximately 250 m length costing approximately $1.5M could protect the houses at risk and extend from the existing headland. This would cost approximately $100,000 per dwelling. There are also a number of vacant properties in the risk zone.

Housing should be excluded from the inundation prone area near the north end. If housing is protected by a sea wall, any new development or redevelopment should be built at levels above the inundation zone allowing 0.3 m freeboard.

New houses in the central part of the bay should be set back behind the *Stable Foundation Zone* hazard line where there is sufficient room on the block. For the small number of sites where this is not possible, retreat may be the most feasible option as protection costs would be prohibitive for the existing low densities. However, few of these sites are at immediate risk. Any future subdivision proposals should incorporate a detailed coastal engineering study, so that new development is sited beyond the hazard zones for the planning period.

Figure 14. Erosion and recession hazard lines, South Arm Beach, Halfmoon Bay

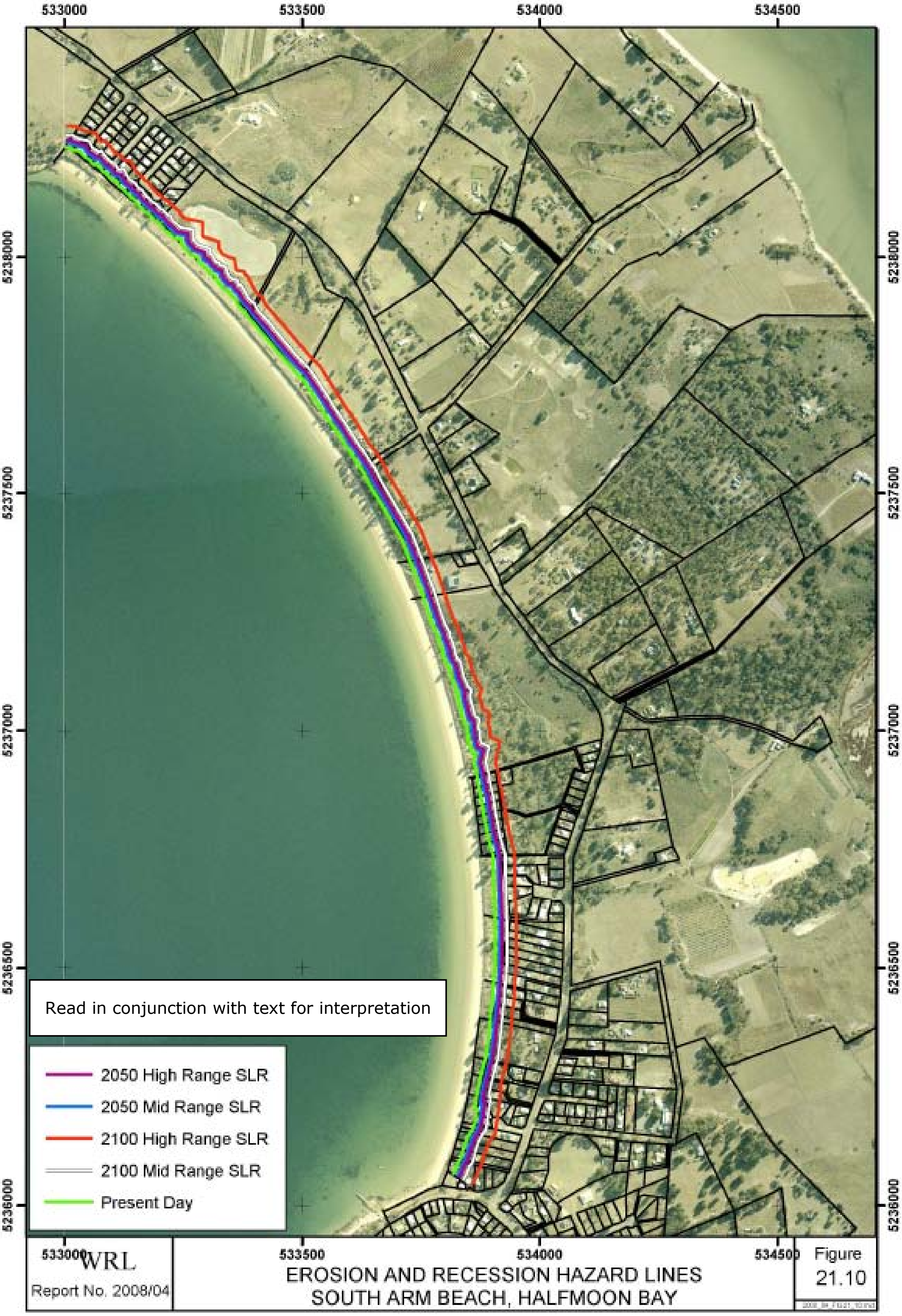
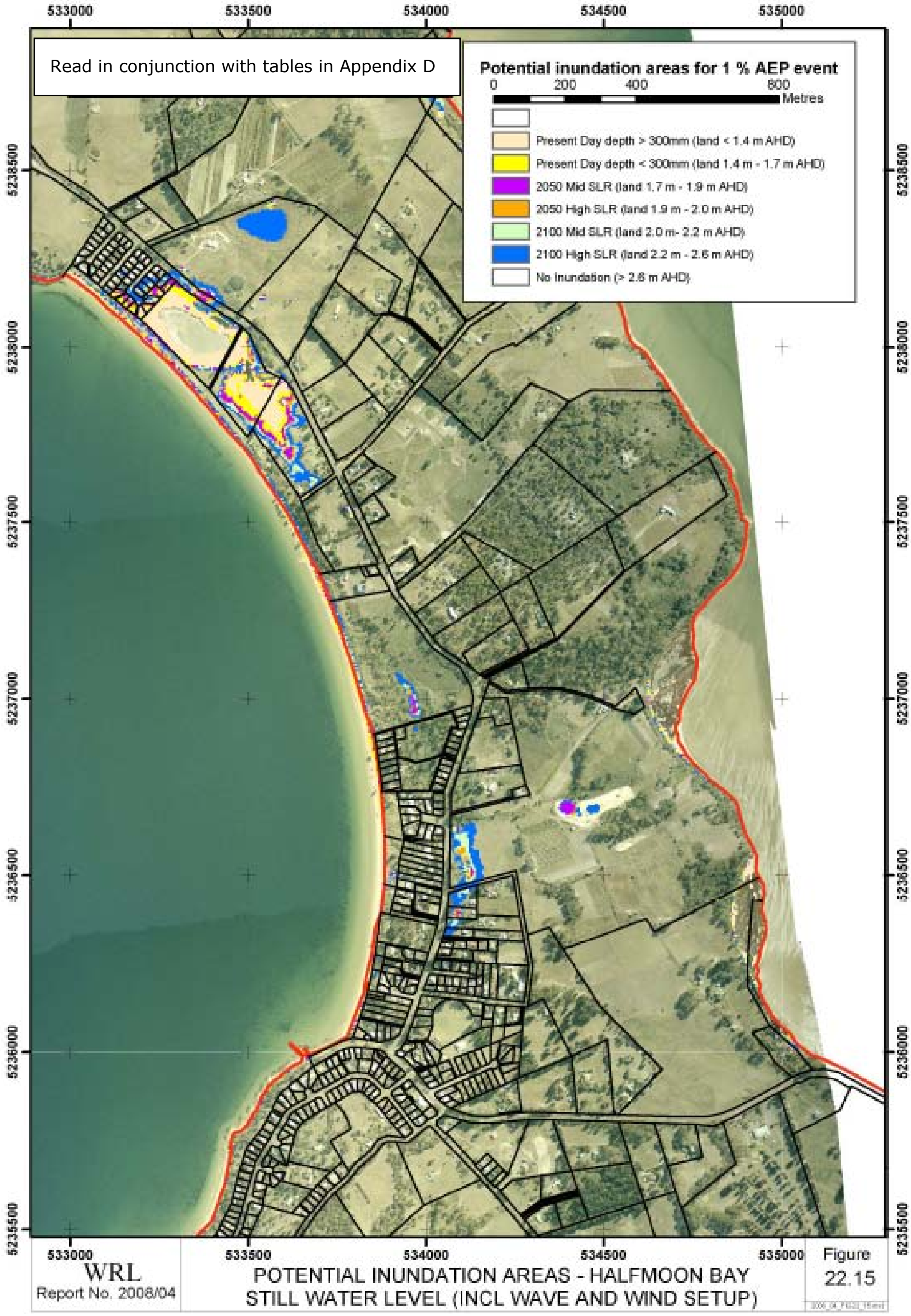


Figure 15. South Arm Beach, Halfmoon Bay, Inundation areas



9.3 Kangaroo Bay

Kangaroo Bay is mostly surrounded by undeveloped land used for natural areas, sports fields and car parks. To the south east, the Bellerive Yacht Club has shore facilities and moorings and the southern edge is bounded by the Bellerive Boardwalk and the backs of shops in Bellerive Village. The shoreline is generally armoured and relatively low lying. A major sewer main runs along the top of the shoreline to the north of the bay.

Proposals exist for the future substantial development of the eastern side of the Bay.

Risk assessment

The bay is relatively sheltered and combined with the armouring of the shorelines, erosion is not a risk.

A 1% AEP (100 yr ARI) event would result in sea levels of 1.8 m AHD. Figure 16 shows the potential inundation areas that may be affected. These include the parking lot used by the Bellerive Yacht Club and other areas adjacent to the club, the parking and service areas of the backs of shops in Bellerive Village and the area overlying the piped stream outlet running past Rosny College. Mostly these will be affected with water levels less than 0.3 m for a 1% AEP event under present day sea levels.

Potential responses

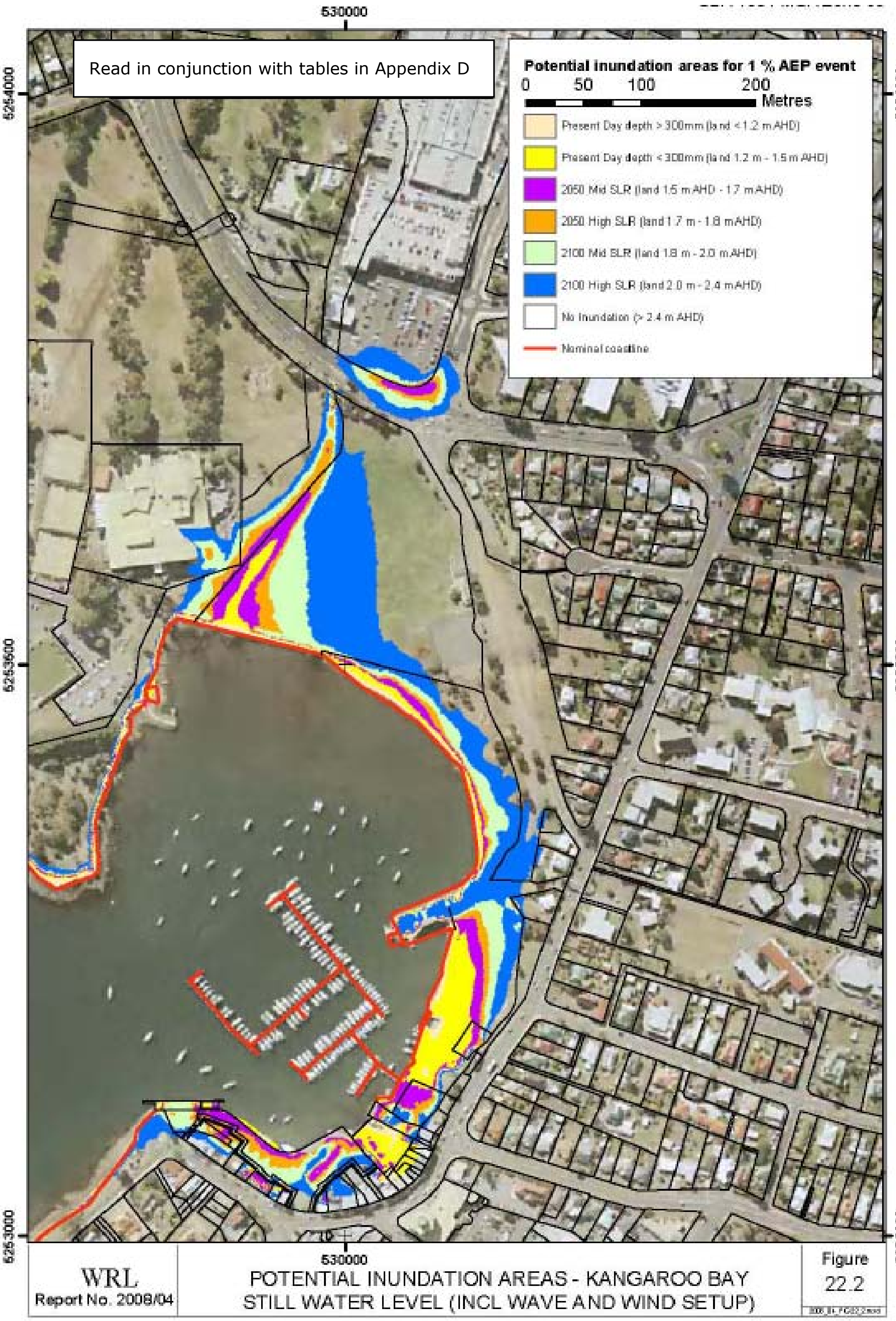
Starting from 2050 increasing areas will be at risk of inundation. While these are currently not developed, the inundation level needs to be considered in any future development. Wave runup needs to be considered for any structures very close to the shoreline.

Much of the land is and is expected to remain as public open space including the sports fields, a foreshore walkway and bicycle path and the Bellerive Boardwalk. To retain this use in the long term, ground levels will have to be raised.

Parts of Rosny Hill Road near the junction of Bligh Street and the adjacent shopping centre car park are also expected to be flooded in extreme events after 2050. In the longer term these will have to be raised. This should be a consideration at the time of any major road works in this location.

By 2100 the boardwalk in Bellerive Village and the lower areas of businesses in the Village will be affected by frequent flooding if not raised.

Figure 16. Kangaroo Bay, Inundation areas



9.4 Bellerive

Bellerive Beach is backed by dunes for much of its length, with the dunes generally higher at the eastern end. At the western end, in the area between the beach and the Bellerive Oval, the dunes are greatly reduced to absent. The western 200 m of the beach, where dunes are absent, is faced with a sea wall.

Risk Assessment

Two houses may presently be at risk due to **erosion** if the seawall at the west fails. (Figure 17) However, before the houses are lost, a significant suburban street would also be lost as well as a heavily used car park. It is also not known for certain how much of the land at the western end is on an erodible base or rock.

By 2100, without protection and assuming an erodible base, high sea level rise could increase the number of houses at risk to 12, most at the western end (if affected) and some behind the dunes near the Oval.

Erosion would see the heavily used 'urban' beach retreat, and if not defended, the roads behind the dunes would be threatened.

Approximately 13 houses presently may be at some risk due to **inundation** under 100 year ARI (1% AEP) storm surge (Figure 18). Only two are on land likely to experience water more than 0.3 m deep. All properties at risk of inundation are behind the dunes to the east of the Oval. Inundation risk from the sea is reduced in practical terms as the area is poorly linked to the sea. Most sea water would have to flow in through storm water outlets to reach this area behind the dunes unless the dunes become heavily eroded. However, in heavy rains the bicycle path adjacent to these houses currently floods with rainwater which may pond for several days. This rainfall contribution combined with an extreme sea event, makes the estimated flooding more likely.

By 2100 with high sea level rise, as many as 61 houses could be at risk of inundation.

Potential responses

New development should be above the design inundation level, however, the frontal dune is the primary protection, and if it remains above the runup level, the inundation risk to houses behind it is low. The dune should be monitored and maintained so that it is above the design runup level where possible.

Figure 17. Erosion and recession hazard lines, Bellerive Beach

Figure 18. Bellerive Beach, Inundation areas

For the sections of beach without a seawall, minor sand nourishment in the form of dune raising could be undertaken. Indicative costs to raise the dune by 1 m (10 m^3/m of sand) would be $150 per m of beach provided a suitable sand source can be accessed. The additional cost to revegetate the raised dune would be $150 per m of beach. The length of the dune backed portion of the beach is about 1000 m, giving a total cost of about $300,000. This may need to be repeated to maintain the dunes over the longer term.

There is a short length of seawall fronting Victoria Esplanade in the western corner of the beach. Planning needs to be undertaken for replacement of this seawall at an indicative cost of $2000 per m or a total of about $400,000. The road and several houses near this are at risk of inundation in the longer term, which should be considered in the design of the seawall replacement.

Much of the work required for Bellerive Beach is to protect the important public asset of the beach and roads as well as the houses behind. After considering the contribution to protecting the public assets, the cost per dwelling protected would be modest.

9.5 Rokeby and Droughty Point Road

Rokeby foreshore and the Droughty Point Road have limited development except for a few houses to the west of the Clarence Plains Rivulet and the Rokeby sewage treatment plant. Industrial development is generally near the road and well back from the shoreline.

Risk Assessment

Due to the clay content of foreshore sediments, there is little potential for dynamic equilibrium or beach rebuilding following storm erosion, but rather a trend of **ongoing recession**. The historic rate of this recession should be estimated from aerial photos, and future long term change of the beach needs to be monitored.

Droughty Point Road is subject to inundation around the bridge over Clarence Plains Rivulet essentially following the course of the rivulet floodplain (Figure 19). No developed property is in areas likely to be affected by sea water flooding. There may be some risk that the addition of rainwater runoff added to high sea events could flood some additional areas that are occupied.

Potential responses

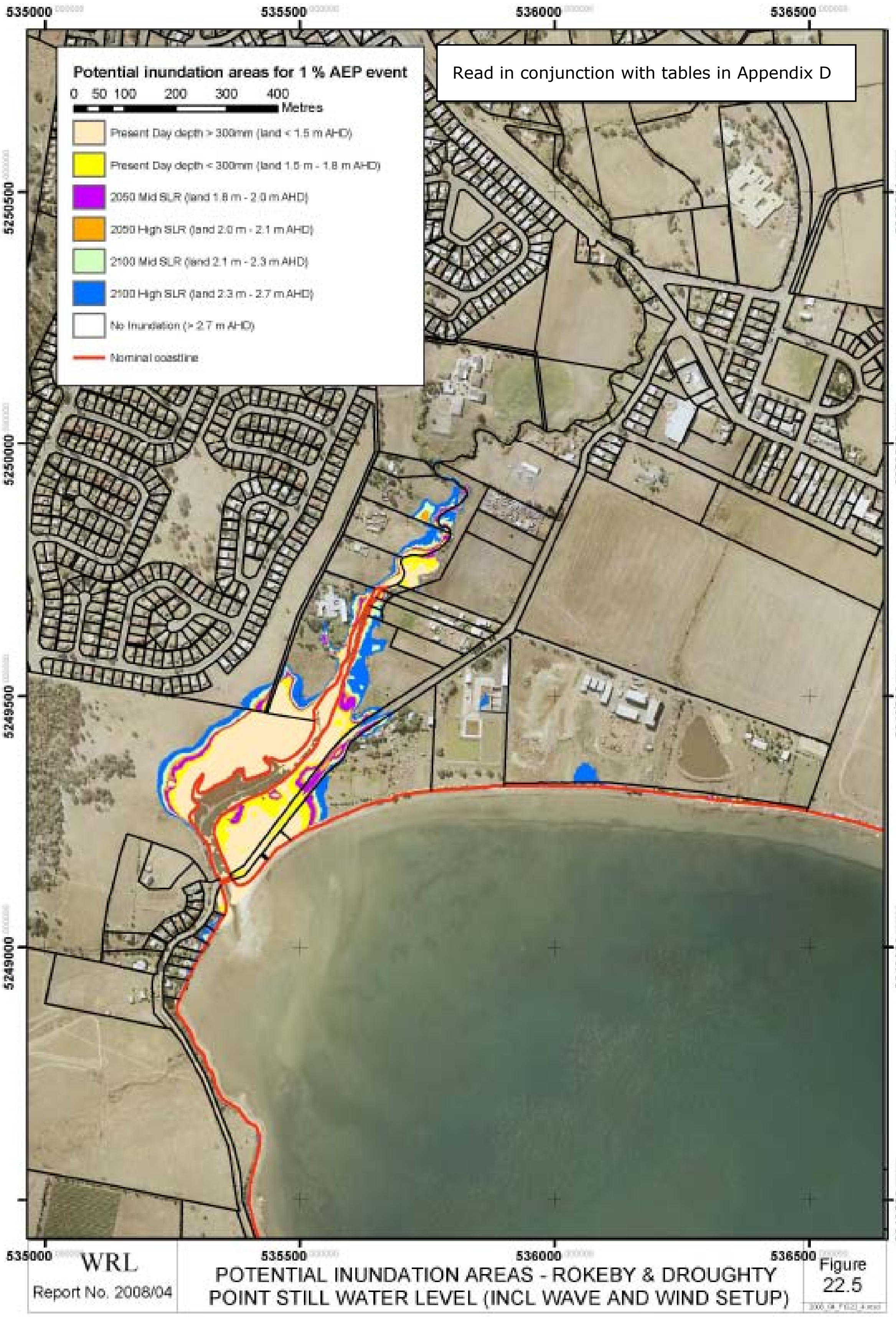
The low wave climate and low public usage means that a relatively minor seawall would be feasible to stop recession. New seawalls (if allowed) should be designed by coastal and structural engineer. There has been some haphazard (demolition concrete) armouring of Rokeby Beach to the east, but no development is at risk. If existing foreshore structures are damaged, options are mandated removal or engineer design of replacements. These works should be engineer designed and formalised, or removed.

For Droughty Point, new buildings should be above the design inundation level.

Inundation needs to be considered in the design of a replacement for the bridge. The present location and shoreline armouring prevents meander of the mouth.

The design inundation level needs to be considered in future plant design and operation for the sewage treatment plant. Some wave runup calculations may also need to be considered.

Figure 19. Rokeby and Droughty Pt, Inundation areas



10 Areas with longer term risk

These areas are seen to have relatively little risk before about 75 – 100 years from the present. The trigger for significant action is likely to be beyond the life of most existing structures. Here the discussion about possible actions is more tentative because of the relatively long times before impacts occur and responses are required.

Areas in this category are:

- Seven Mile Beach
- Howrah and Little Howrah Beaches
- Mays Beach
- Montagu Bay
- Opossum Bay
- Glenvar Beach, Opossum Bay
- Hope Beach

10.1 Seven Mile Beach

Seven Mile Beach is a beach side suburb with some broad similarities to Lauderdale but with several key differences:

- There are far fewer properties directly backing onto the dunes and most that do are set further back
- There is less threat of flooding from 'behind' as it has only one coast
- There is limited evidence of progressive erosion and some for accretion of the beach

Risk Assessment

The historic change to the beach front has not been studied in detail. There is some evidence that it is benefiting from accretion. However, this should be studied so that future impacts of sea level rise can be better assessed. It is possible that ongoing accretion may outpace the effects of sea level rise, however, this is not presently known.

There is generally sufficient buffer against expected erosion from storm events and sea level rise and there is probably only one house that may be potentially at risk due to a present day 100 year ARI erosion event, which could remove 10 m of the shoreline (Figure 20). If there is assumed to be no net accretion or erosion with stable sea level, this would increase to 11 by 2100 with high sea level rise causing some net erosion. These effects are all at the southern end of the beach. If the shoreline has been accreting, the future erosion risk may not be different from the present day risk.

The presence of low or no dunes at the western end makes this area vulnerable to inundation. Sea levels in a 1% AEP (100 yr ARI) event are estimated to be 2.0 m AHD for the present day. There are no houses within the 2.0 m contour line (Figure 21). By 2100 under the high sea level rise scenario, flood levels could reach 2.9 m. There are 84 houses on properties below the 2.9 m contour, but not all would be affected as they are too far inland to be reached during the flood peak, and others that are would have only minor levels of flooding. Some properties may be affected after 2050 but mostly toward the end of the century. There may also be occasional road access disruptions but alternative routes are generally available.

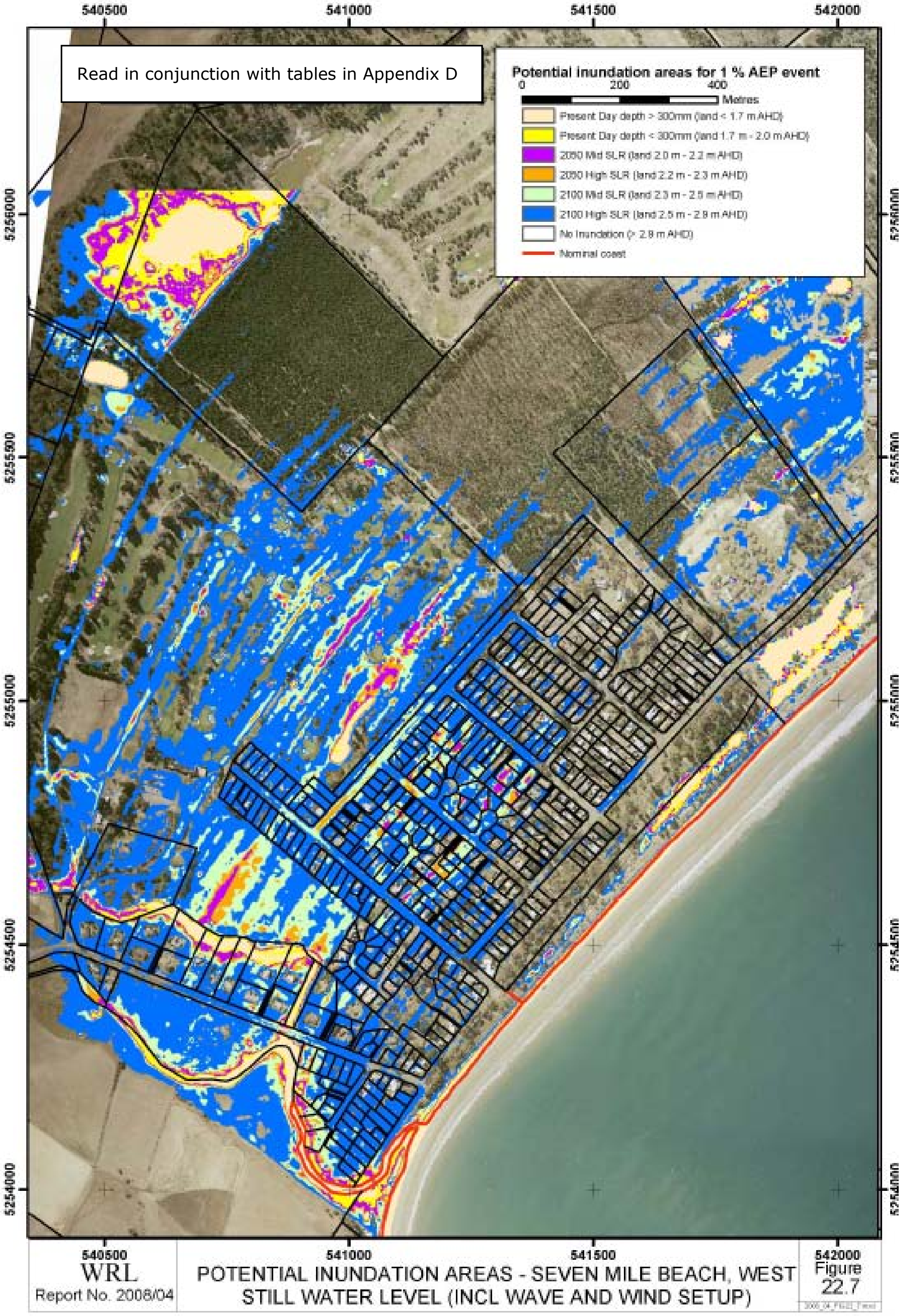
Possible responses and preliminary costs

The bridge over Acton Creek needs to consider inundation in the design of a replacement.

The presence of bridge abutments prevents further meander of the mouth. A levee and/or training wall around the creek mouth may be needed to maintain a barrier to inundation near the creek mouth. Indicative costs are $10,000 per m for 200 m.

Figure 20. Erosion and recession hazard lines, Seven Mile Beach

Figure 21. Seven Mile Beach, Inundation areas



10.2 Howrah and Little Howrah Beaches

Howrah Beach is approximately 1.2 km long, while Little Howrah is approximately 200 m long. Seawalls fronting private property prevent beach access between the two beaches except at low tide. The structures on this area are built on rock behind. A seawall also fronts public land backing Little Howrah Beach, continuing around the back of the rocky foreshore to the south.

Risk Assessment

A series of storms with a 1% AEP (100 yr ARI) impact are estimated to erode about 10 m of shoreline on average for these beaches. However, the height and depth of the dunes varies substantially along the shoreline leading to different outcomes at different places along the beach. In addition, some sections of the shore are armoured, and much of the area between Howrah Beach and Little Howrah Beach is underlain by rock.

Risks to property will arise if the armouring on Little Howrah Beach fails. If this occurs, Tranmere Road would be potentially threatened so works will be required to reinstate and reinforce the sea wall here. Erosion risk lines are shown in Figure 22.

Wave runup along Howrah Beach is estimated to reach 2.6 m in a 1% AEP (100 yr ARI) storm event. This is unlikely to affect property along most of the beach. However, wave run up under the high sea level rise scenario in 2100 would reach 3.5 m and may affect some of the houses on the rocky areas between the beaches, and properties near the water at the ends of the beaches. If erosion is not countered and the dunes have been lost, wave runup may affect other properties further back from the shore.

Inundation levels from a 1% AEP (100 yr ARI) storm event are estimated to reach 1.9 m AHD under present day conditions. Potential inundation areas shown in Figure 23 show only two properties below this level, and flood depths are likely to be minimal. By 2100 under the high sea level rise scenario, a 1% AEP (100 yr ARI) event would reach 2.8 m affecting up to nine properties.

There is both present day and developing risk of inundation of the sports fields and other open spaces behind Howrah Beach. At present they are isolated from the beach by the dunes, of varying height along the shore. As such, they may not be subject to the level of flooding shown due to weak hydraulic linkage to the sea. Most flooding would arise from inflows through storm water pipes. However, these fields currently flood from heavy rain. As with Bellerive, the combination of heavy rain and some inflow of sea water could result in flooding of these areas.

Figure 22. Erosion and recession hazard lines, Howrah & Little Howrah Beaches

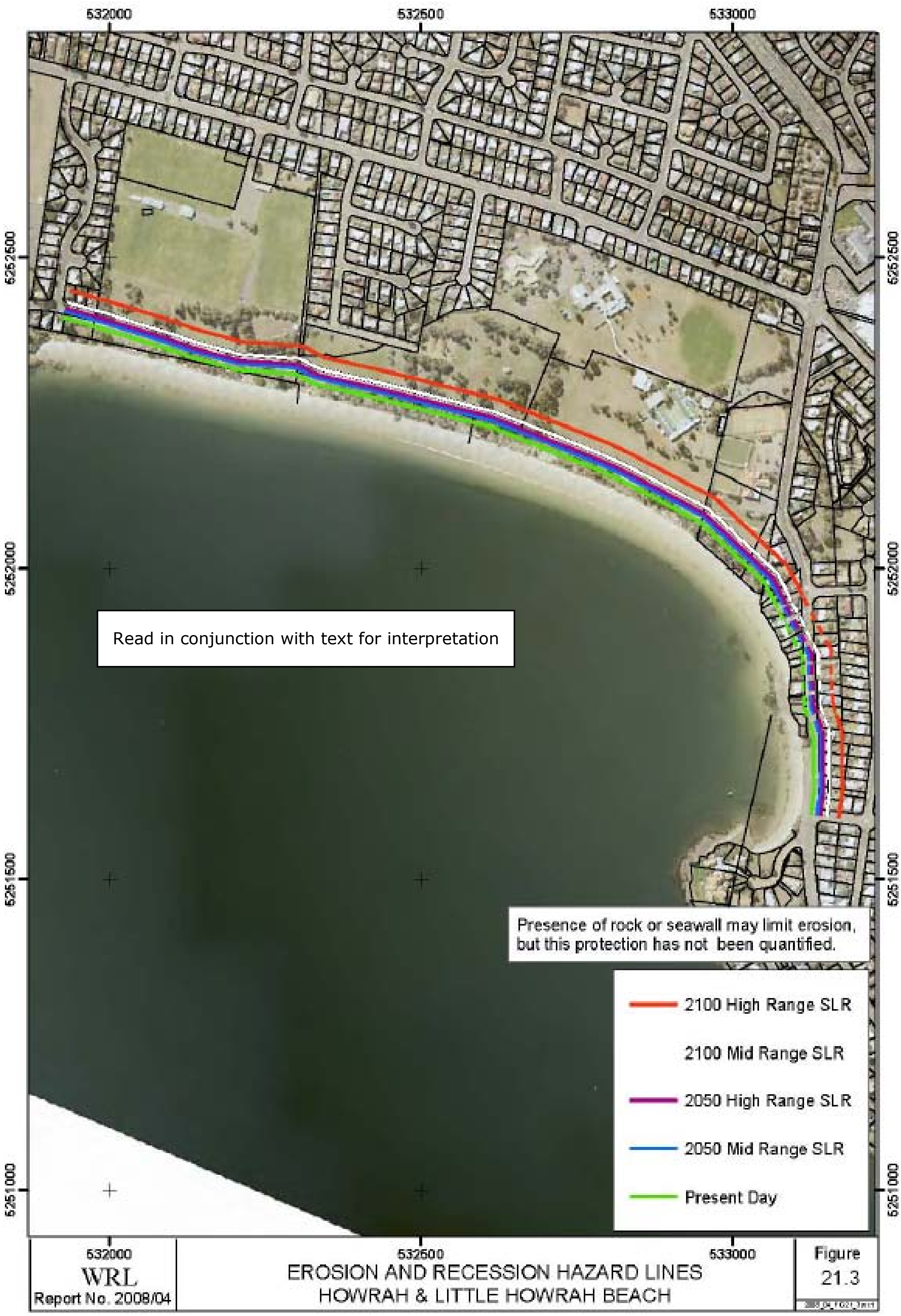
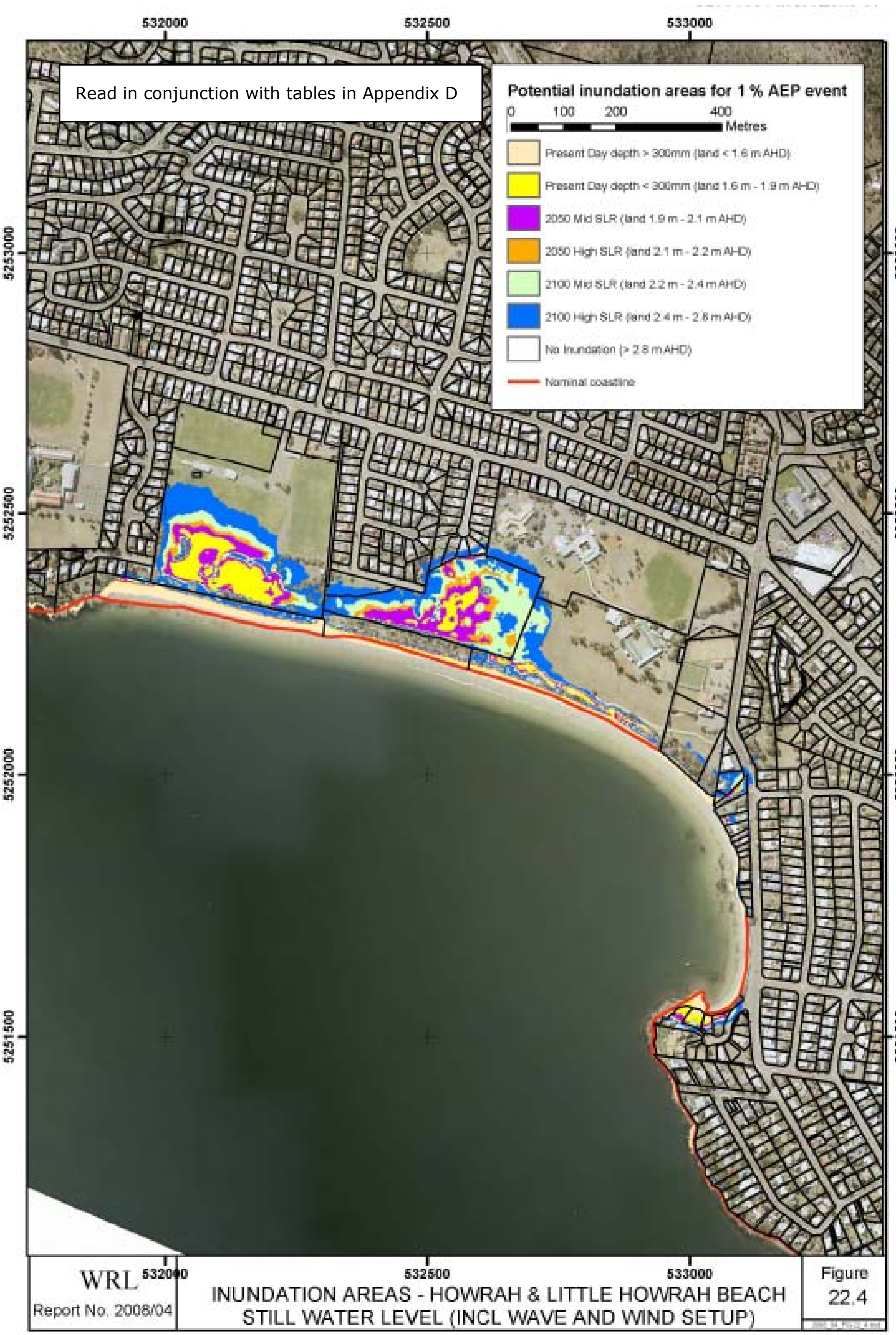


Figure 23. Howrah & Little Howrah Beaches, Inundation areas



Potential responses

New development should be above the design inundation level.

For the sections of beach without a seawall, minor sand nourishment in the form of dune raising could be undertaken. Indicative costs to raise the dune by 1 m (10 m3 of sand /m of beach) would be $150 per m of beach provided a suitable sand source can be accessed. The additional cost to revegetate the raised dune would be $150 per m of beach. The cost to maintain the dune system without erosion to 2100 is summarised in Table 13.

Table 13. Estimated quantities and costs for sand nourishment, Howrah Beach and Little Howrah Beach

Time	SLR (m)	Sand m3/m of beach	Cost/m @$15/m3	Total cost (million)
2050 mid	0.2	100	$1500	$2.1
2050 high	0.3	150	$2250	$3.2
2100 mid	0.5	250	$3750	$5.3
2100 high	0.9	450	$6750	$9.5

The cost would be 15% less if only Howrah Beach is nourished. This is would not be justified only on the basis of protecting houses, but to potentially save damage from inundation of the sports fields and to maintain a valued public urban beach. If a catchment of 10,000 residents uses the beach, then the cost per resident would be between $200 and $950 per resident over the next 90 years.

Should the sportsfields need major renovation or renewal in the future, the opportunity should be taken to raise them to a higher level.

10.3 Mays Beach

Mays Beach is a relatively isolated location with little current development.

Risk assessment

A series of storms with a 1% AEP (100 yr ARI) impact are estimated to erode about 10 m of shoreline on average for this beach. Two buildings are potentially within the resulting risk zone (Figure 24). This could increase to eight with high sea level rise in 2100.

Wave run up on Mays Beach could reach 2.5 m for a 1% AEP (100 yr ARI) storm event. The impact on buildings will depend on their height and setback from the shore, and the height of any protecting dune front.

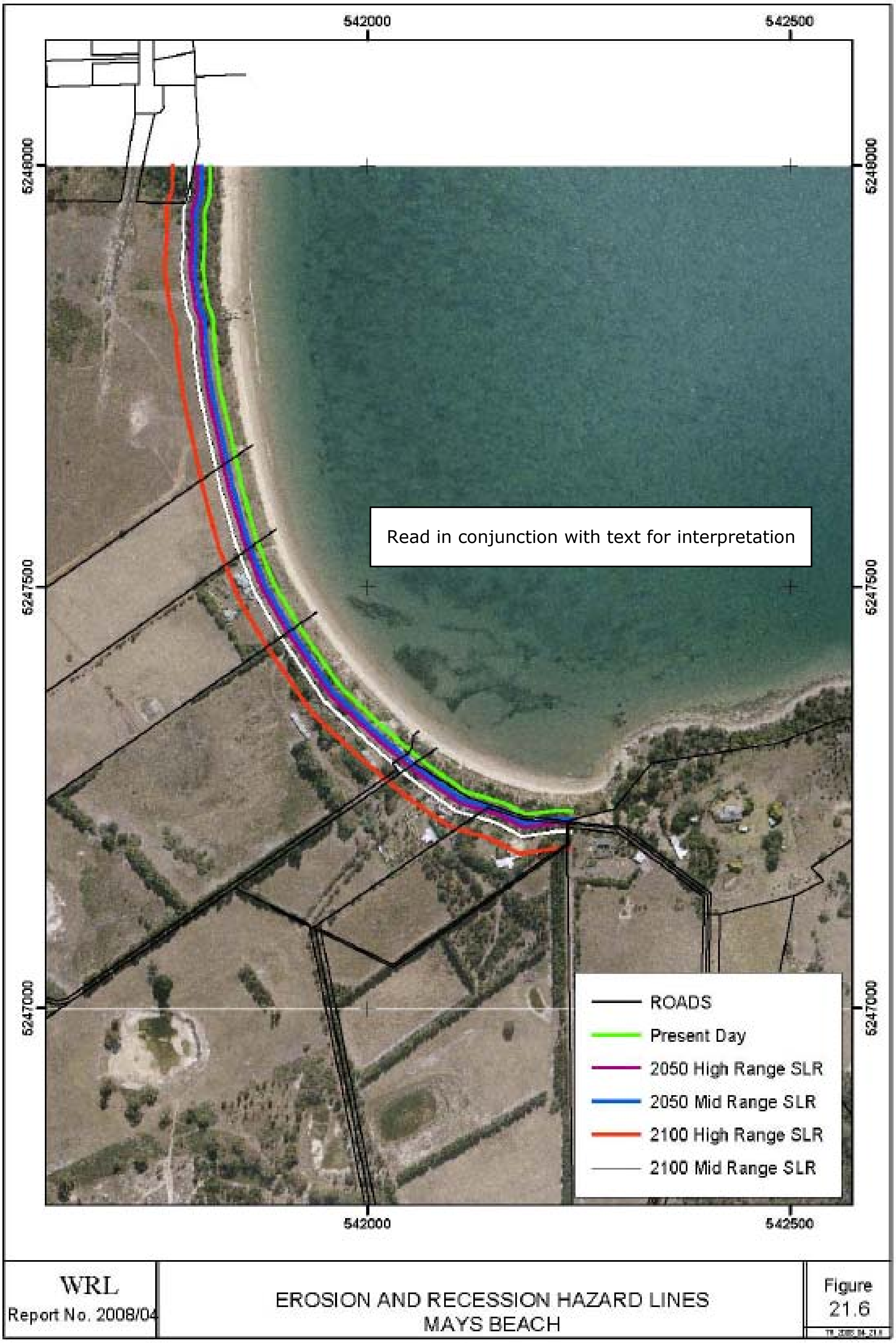
Flood heights from a 1% AEP (100 yr ARI) storm event are estimated to reach 1.8 m AHD under present day conditions. Potential inundation areas shown in Figure 24 show no developments on land below this level. By 2100 under the high sea level rise scenario, a 1% AEP (100 yr ARI) event would reach 2.7 m, with no structures at risk from inundation.

Potential responses

The sparsely developed area would not be able to justify the cost of erosion protection. There is ample room to relocate structures back from the hazard zone. New development should be located behind the *Stable Foundation Zone* hazard line, and above the wave runup level for a designated planning period (say 50 or 100 years). Existing development may need to be relocated should the erosion scarp approach.

Any future sub division proposals should incorporate a detailed coastal engineering study, so that new development is sited beyond the hazard zones for the planning period.

Figure 24. Erosion and recession hazard lines, Mays Beach



10.4 Montagu Bay – inundation

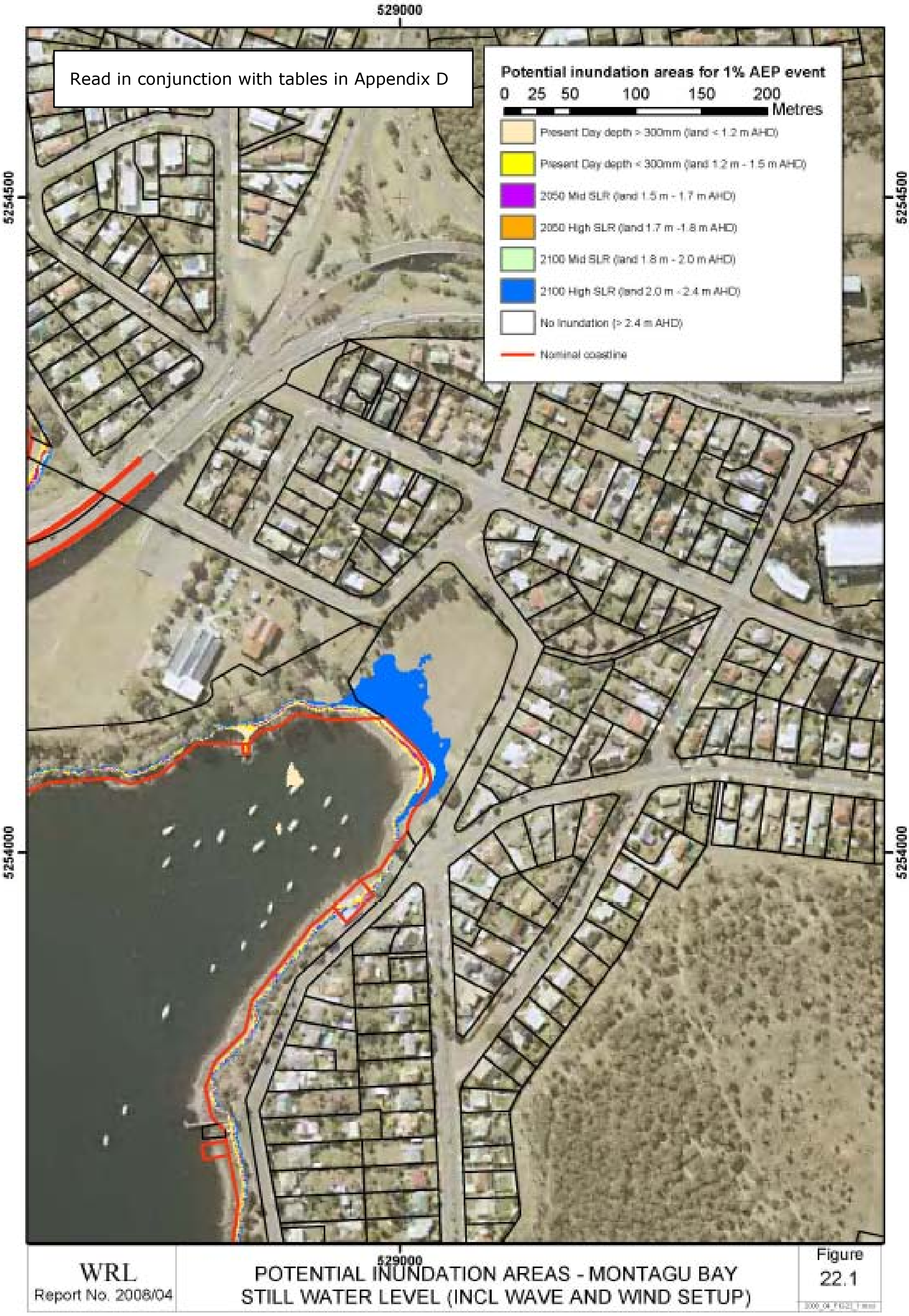
Montagu Bay has an undeveloped low lying foreshore backed by a suburban road. The shoreline is generally armoured and subject to relatively low energy waves.

Risk assessment

Given the armouring of the coast and low energy waves, erosion is not a significant risk in Montagu Bay.

Some areas around Montagu Bay will be subject to inundation by 2100 under the high scenario (Figure 25). The foreshore area affected is not zoned for development. No action is required.

Figure 25. Montagu Bay, Inundation areas



10.5 Opossum Bay, Opossum Bay Beach and Glenvar Beach

Opossum Bay Beach and Glenvar Beach are developed on a rocky slope above a beach with many properties developed right down to the beach. Because of the steep rocky terrain, there is limited risk of either erosion or inundation in the sense of flooding. However, there are numerous structures (houses, boatsheds and seawalls) below the present day 1% AEP event runup limit of 4.5 m AHD for Opossum Bay Beach and 4.9 m AHD for Glenvar Beach. In many cases the lower levels have already been abandoned as habitable space. Future run up limits for 2100 under the high scenario sea level rise are estimated at 5.5 m AHD and 5.9 m AHD for a 1% AEP event. An additional 0.3 m freeboard for construction of buildings is required.

The steep terrain means that there is sufficient space to rebuild houses up the hill for a 100 year planning period although some properties have little undeveloped land upslope. Where room is available, the steepness of the land means that there would be minimal additional cost associated with adapting the houses to any sea level rise up to 1 m.

The steep beach gradient and proximity to tidal currents mean that there are doubts about the feasibility of sand nourishment, which would require additional feasibility studies. Similarly, groynes could only be considered feasible with further studies on littoral drift.

New development should be sited above the wave runup level, and sufficiently set back from the foreshore to accommodate present and future coastal hazards. Damaged and unsound existing development should be removed to ensure public safety.

Community attitudes on preserving public access along the foreshore need to be tested as in this location, any effective protection works would effectively exclude foreshore access or bring the public directly next to private dwellings at occupied levels. Subject to the findings, consideration needs to be given to planned retreat of foreshore structures and possibly repurchase of the seaward portion of allotments.

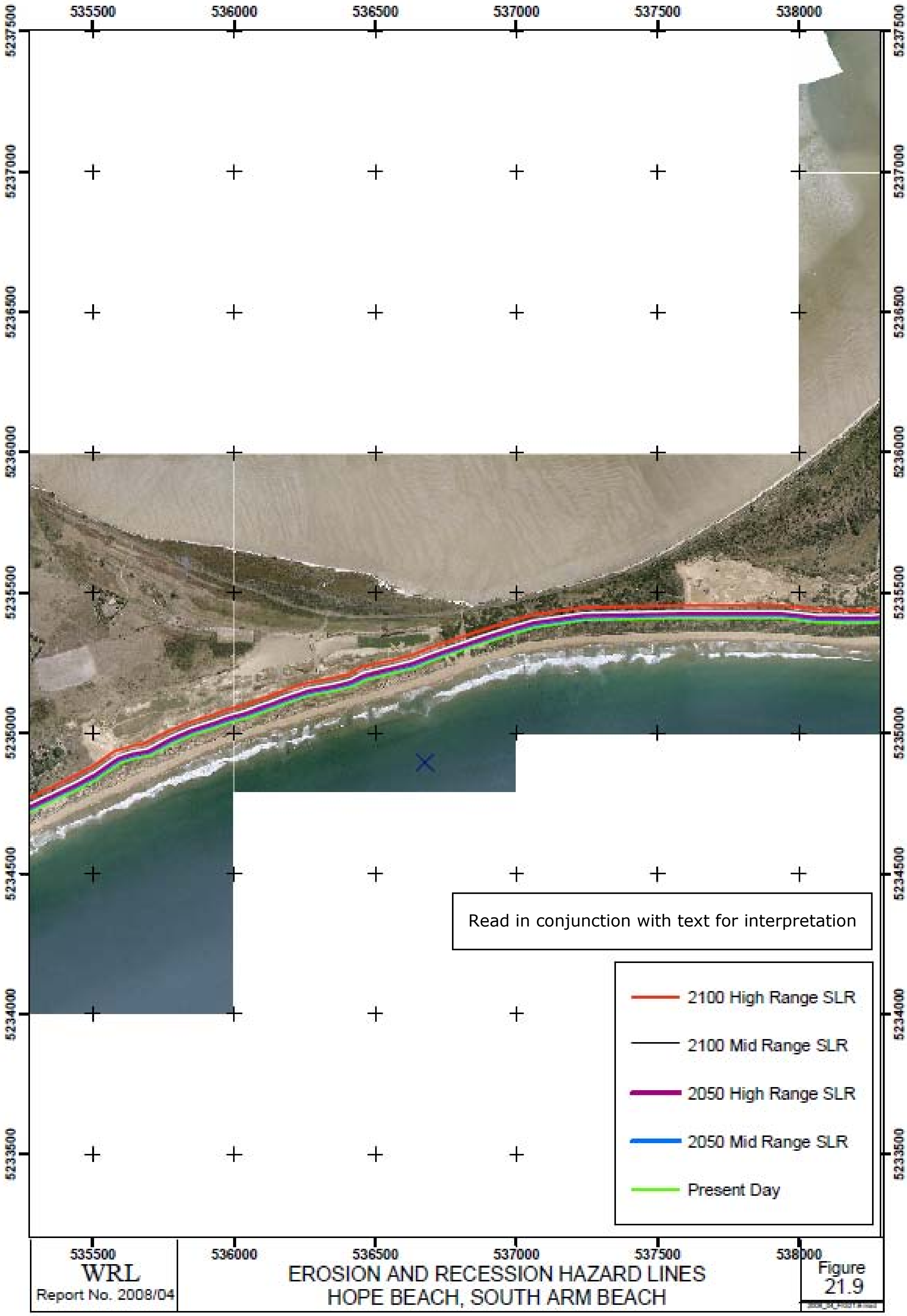
A policy on boatsheds and seawalls on the foreshore needs to be developed with consideration of community attitudes – both direct residents and other users of the beach. If these structures are to be allowed, the policy should specify that they should be designed by a coastal engineer in conjunction with a structural engineer. If existing foreshore structures are damaged, options are mandated removal or engineer design of replacements.

10.6 Hope Beach

Hope Beach is an undeveloped beach open to the Southern Ocean. The integrity of the dunes behind the beach is important for maintaining the continuity of the neck.

A series of storms with a 1% AEP (100 yr ARI) impact are estimated to erode about 25 m of shoreline on average for this beach for present day events. Modelling shows that the dune height and bulk should be sufficient to prevent the neck being breached by long term erosion combined with a 1% AEP (100 yr ARI) series of events up to 2100. However, given the importance of this area, the development of the dune system and beach should be monitored. Hazards lines are shown in Figure 26.

Figure 26. Erosion and recession hazard lines, Hope Beach



11 Community consultation

As noted in Section 3, early in the project a survey of the general public preceded by focus groups was conducted to analyse current knowledge, sentiments, opinion and attitudes in Clarence community regarding climate change events in foreshore areas.

Much of the work during the project since has involved technical analysis, and it has been important to ensure that this has been accurate and is clearly presented prior to public release to avoid misinformation or confusion.

This integrated report presents the findings of the technical analysis and will provide the basis for public discussion of the findings and proposed responses.

A communications plan has been developed to make the information available to stakeholders including:

- State and Australian Government – primarily through representation on the steering and technical committees but supplemented by other meetings and discussion
- Ongoing briefing of councillors and all relevant council staff – through direct communication, briefings and workshops
- State government agencies and community organisations – through briefings and follow up email broadcasts
- Banks, insurance and real estate industry – through presentations and follow-up email broadcasts
- Residents of affected areas – through letterboxed brochures, displays and community meetings in the local areas, access to reports on the web site
- Wider community of Clarence – through the mail outs to ratepayers and the general press
- Broader southern Tasmanian community – through the general press
- Local Government Association of Tasmania (LGAT) and other coastal councils in Tasmania – through direct briefings to LGAT.

A final report will be issued which includes an overview of the results of these activities, with particular emphasis on the response of residents of affected areas.

12 Conclusions and summary of recommendations

This report provides a preliminary assessment of the risks to coastal areas both at present and for climate change scenarios to 2050 and 2100 for 18 coastal locations in Clarence. This is sufficient to identify which of these areas are likely to have significant risk and the broad timing of that risk. It can usefully be used to amend the Planning Scheme for controls on development in areas identified as being subject to coastal hazards.

The analysis shows that there is significant present day risk in four locations:

- Lauderdale/Roches Beach (erosion, inundation and high water table)
- Cremorne (erosion, inundation, high water table)
- Clifton (Bicheno Street) – (inundation)
- South Arm Neck – inundation of the highway

Potential responses for each of these locations have been noted as well as the actions required to begin to address the identified risks.

The level of detail in the analysis is not sufficient to provide parcel-by-parcel risk assessments for the main risks identified. These may vary according to individual site conditions including such factors as underlying soil/rock conditions, height and depth of immediately adjacent dunes (which vary along a beachfront), local wave exposure (which also varies along a beachfront), elevation of the specific dwelling and its structure. The assessment is also not sufficiently detailed to specify in every case the preferred response, or to allow works to be designed or undertaken without further investigations in most cases.

For the remaining areas there are only minor or no present day risks but some risks expected to develop between now and 2100.

For developing climate risk, it will be important to track changes in the scientific assessment of actual changes and revised scenarios. These may indicate that change is occurring more or less quickly than currently anticipated, may introduce more understanding of factors currently only partly explored (eg ocean acidity), and may better quantify some of the expected but less well defined changes such as storm intensity and frequency. Where significant changes are seen, the impact on the risk assessment needs to be considered.

The following table summarises the recommended actions from the report, broadly grouped as:

- Changes to planning and development controls that can occur immediately
- Short term works where risks are evident and hazards current
- Further studies for priority areas to define hazards and expected risks to the extent necessary to complete cost benefit assessments
- Studies where action is warranted to allow technical design of works
- Implement cost effective, well designed works
- Ongoing studies of change and effectiveness of initial responses and works
- Develop long term responses to changing risks arising from climate change based on evidence of actual climate and sea level changes and effectiveness of protection.

1-2 years	Erosion	Inundation	Other/general
Changes to planning and development controls	Modify the Planning Scheme to control development in all erosion hazard zones up to 2100 high scenario. Controls would require any proposed development to cope with potential erosion effects by piling or other acceptable means or to provide more detailed site assessment that shows the estimated hazard zone does not apply to the particular site (eg because of adequate rock base).	Modify the Planning Scheme to control development in all inundation hazard zones. Controls would require any proposed development to cope with potential flood heights up to the 2100 high scenario by elevating structures and ensuring foundations exposed to saline water are resistant to degradation, or other acceptable responses.	Modify the Planning Scheme to control development to cope with wave run-up hazard. Controls would require any proposed development to cope with potential wave run-up up to the 2100 high scenario by elevating structures or ensuring adequate set back. Property within erosion hazard zones and within 50 m of the shoreline would be subject to assessment for wave runup.
Short term works where risks are evident and hazards current	Assess dune heights along priority beaches (Roches Beach, Cremorne) in detail from LIDAR data, field confirmation. Nourish and revegetate any low, narrow areas. Beach scraping may be sufficient for short term actions.		Review and if necessary modify the emergency management plan for the area. Develop and Implement vegetation management plans for areas not currently managed.
2-5 years			
Further studies for priority areas to define hazards and expected risks to the extent necessary to complete cost benefit assessments	Use photogrammetry to assess historic and future changes in 3D, and apply to update findings of wave modelling. Do priority beaches first but include other beaches with potential risk. Determine and map bedrock depths for Glenvar and Opossum Bay Beaches, Little Howrah and around Bambra Reef at Roches Beach and eventually extended to all Clarence Beaches. This may reduce extent of defined hazard area. Maintain and extend beach monitoring programs to all beaches with significant potential erosion hazard. Determine availability of sand for larger scale nourishment and suitable rock for coastal protection including provisional planning and environmental approvals from acceptable sources.	DIER to assess the cost benefit of reducing inundation risk for South Arm Road at Ralphs Bay and South Arm Neck given expected flood heights, duration and frequency of events, the number of properties affected and a comparison with other priorities for road funding (including the demands of other affected coastal roads). The evaluation should include potential benefits of reduced inundation of property behind the road at Lauderdale. The results should be communicated to residents of the peninsula and to Clarence City Council. Conduct hydraulic linkage studies for inundation from Ralphs Bay to Lauderdale, Pipeclay Lagoon to Bicheno Street and Cremorne and Bellerive Beach. Identify all points of connection and capacity as well as technical potential and cost to reduce sea water inflows. Determine dwellings affected and depth, potential for damage and cost to raise dwellings. This includes raising South Arm Road or otherwise limiting sea water flood entry.	Monitor ground water conditions for salinity and effectiveness of septic tanks. Record water levels to AHD, look at trends and compare to sea level changes, changes in runoff, etc. Monitor frequently initially and modify in accordance with findings of fluctuations. Report at least annually. Test community attitudes on access to foreshore areas where protection may be required as part of assessment of feasible options. Develop a policy on boatsheds and seawalls on the foreshore with consideration of community attitudes – both direct residents and other users of the beach. Monitor longshore sediment transport and the dynamics of sediment movement to and from Pipeclay Lagoon to better assess feasible options.
Cost benefit analysis and design studies where action is warranted to allow engineering design of any works	Undertake detailed modelling along the beach length for priority beaches to develop nourishment plan. This would consider extent of present day nourishment required and triggers for future top ups. Confirm cost of nourishment to provide present day protection and assess cost benefit for priority beaches.	Based on the hydraulic linkage study, prepare a cost benefit analysis and develop a detailed plans for minimising flood access to areas threatened by inundation. This would include consideration of raising coastal roads as barriers, limiting backflows from the sea through storm water outflows, or further storm water management possibilities such as extending the existing storm water retention basins or wetlands.	Inform residents of risks and proposed responses and seek input into selection of options as part of the development of response plans after the technical studies are complete. Assess redevelopment options for structures affected by hazards when renewal required (eg bridges at Seven Mile Beach, Rokeby, sewage treatment plants, Clifton Surf Life Saving Club, etc.)
Implementation of cost effective, well designed works	Nourish to the extent that sand is available and it is assessed as cost effective.	Undertake cost effective works as identified.	
5-25 years	**Erosion**	**Inundation**	**Other/general**
Ongoing studies of change and effectiveness of initial responses and works	Monitor beach change for priority beaches and those with medium term risk to determine trends and long term	Supplement coast risk assessment with riverine/rainfall flood risk studies for selected locations.	Monitor IPCC reports for actual changes to sea level rise and climate changes and forecasts.

	effectiveness of any nourishment undertaken. Based on response, consider need for and likely viability of using groynes to improve effectiveness.		Monitor changes to local area sea levels. Monitor ground water conditions around former landfill sites. Monitor bathymetric changes of lagoons and offshore areas. Monitor changes to coastal ecological communities.
Develop long term responses to changing risks arising from climate change based on evidence of actual climate and sea level changes and effectiveness of protection.	Develop a preferred long term plan for response to the erosion hazard for priority beaches based on more detailed studies of technical feasibility, cost, acceptable risk and community consultation. Over time develop similar plans for areas with medium term risk. If clear plans are developed for long term protection for some erosion hazard areas, controls on development may be relaxed. For areas where erosion hazards cannot be cost effectively managed, an ongoing development freeze and a long term plan for retreat would be developed.	Develop preferred long term plan for protection, accommodation or retreat from inundation hazard based on more detailed studies of technical feasibility, cost, acceptable risk and community consultation. Plan for the evolution of land currently not zoned for development as sea levels rise. This may include permitting inundation with sea water at high tides to establish new salt marshes and wetlands or other responses. Plan for the elevation of public lands used for recreation, etc. (ie, not natural areas) at long term risk of inundation.	Develop response to high water table impacts on properties dependent on septic tanks as water tables rise.

Appendix A Clarence Council coastal management initiatives

- Construction of protective and dune forming fences and board walks under various Coastcare Projects from 1995-2005. The projects had partial success at Bellerive-Howrah, Seven Mile Beach but failure at Lauderdale. Works were undertaken as recommended in Clarence City Council Coastal Erosion Report 1994 for Clarence City Council by Coastal Engineer David Steane. Total cost of materials was $50,000 with Coastcare community in kind labour of about $100,000.

- A project to create a Lauderdale Wetland ran from 2001-2004 at a value of $300,000. The multipurpose project was aimed at flood mitigation, bioremediation, habitat creation, a recreation trail (perimeter walking trail), and formation of a Wetland Care Group. The project involved the design of the site, consultation with the community, development of the wetland, revegetation and weed management, community participation and an on going monitoring and maintenance program. It was supported by TAFE and Community in kind support of $200,000.

- Establishment of a network of Coastcare groups, developing agreement on Coastal Reserve Activity Plans to provide strategic approach to managing the protection of natural values of the coast via revegetation, weeding, fencing and formalising access ways and awareness projects plus monitoring programmes via Tasmarc etc. Clarence City Council has allocated $30,000 per year over the last 5 years to support the groups in their protection works plus on-ground technical support over the last 15 years (approx $30,000 in kind per annum) Other programs included trapping windblown sand at the bottom of Howrah beach with mini groynes (prior to it disappearing onto Howrah Road) and transporting the trapped sand to northern end of beach; protective training wall at the end of Howrah Beach.

- Draft Lauderdale Foreshore Activity Plan 2004- 8 Officers time and materials are estimated at $100,000. Extensive consultation (over 2 years involving interviewing each resident bordering the Coastal Reserve (approx 100) often in weekends, 2 information sessions in the Lauderdale Hall, specifically developed brochure to all residents, draft plan to all residents, close consultation with Lauderdale Coast Care Group) The outcome was a detailed set of activities to enhance the natural and protective values of the Lauderdale Foreshore. As yet the plan remains in draft pending outcome of this Integrated Assessment of Climate Change Project.

- Two Coastal Risk Assessment studies arose out of issues raised in the Lauderdale Foreshore Activity Plan at a cost of $10,000:
  Geotechnical Risk Assessment "*Storm Surges Causing Foredune Erosion on Roches Beach*" by WC Cromer PL and "*Roches Beach Coastal Risk Assessment Study*" Gerry Byrne

- Implementation of some recommendations in Gerry Byrne Report at a cost of $30,000. This included building up all access ways onto Lauderdale Beach with sand, and constructing formal step accesses to the beach. Community interest supported applying for funding to do a comprehensive second pass Integrated Assessment of Climate Change Coastal vulnerability.

- Project valued so far at $350,000 plus $100,000 in kind Clarence City Council support.

Appendix B Project Committees

Technical Reference Group

Mark Hemer
Climate Change Research Group
Centre for Australian Weather and Climate Research:
A partnership between CSIRO and the Bureau of Meteorology

John Hunter
Antarctic Climate & Ecosystems Cooperative Research Centre,

Chris Sharples
Principal Investigator
Australian Coastal Geomorphic and Stability Mapping Project
School of Geography and Environmental Studies (Spatial Science)
University of Tasmania,

Alasdair Wells
Policy Analyst
Strategic Policy Division
Department of Primary Industries and Water

Steering Committee

Clarence Council
Andrew Rumsby
Dan Ford
Daryl Polzin
Gary Rumbold
John Stevens

Commonwealth of Australia
various personnel, Adaptation and Land Management Division
Department of Climate Change

Tasmania State Government
Jason Whitehead
Department of Environment

Olivia Hill
Department of Primary Industry and Water

Chris Beattie
State Emergency Service

Local Government Association of Tasmania
Christine Materia

Appendix C Terminology for Risk

Average Recurrence Interval (ARI): The average time between events (eg large wave height or high water level). Also known as *Return Period.*

Annual Exceedance Probability (AEP): The probability (expressed as a percentage) that an event (eg large wave height or high water level) will be equalled or exceeded in a given year.

Project Life (N): Also known as *planning timeframe* or *planning horizon.*

Encounter Probability: The chance of exceedance over the project life.

The use of ARI, though superficially simple, has been criticised as misleading some stakeholders, who may believe that the event will recur only at regular intervals. This is particularly the case when it is described as *Return Period,* which connotes some sort of regularity in the event.

AEP has been enshrined in many policies and regulations (Sections 3.2 to 3.6), in particular a 1% AEP, which is reasonably well understood. However, AEPs less than this are harder to comprehend. For example, 0.02% AEP is generally more difficult to comprehend than the equivalent 5000 year ARI. Generally both AEP and ARI values are used in this report.

Encounter Probability (Probability of Exceedance) for Given ARI/AEP and Project Life

ARI	**10**	**20**	**50**	**100**	**500**	**1000**	**2000**	**10000**
AEP	**9.5%**	**4.9%**	**2%**	**1%**	**0.5%**	**0.1%**	**0.05%**	**0.01%**
Project Life (years)	**Probability of Exceedance (%) for Design ARI (years)**							
1	10.00%	5.00%	2.00%	1.00%	0.20%	0.10%	0.05%	0.01%
5	40.95%	22.62%	9.61%	4.90%	1.00%	0.50%	0.25%	0.05%
10	65.13%	40.13%	18.29%	9.56%	1.98%	1.00%	0.50%	0.10%
20	87.84%	64.15%	33.24%	18.21%	3.92%	1.98%	1.00%	0.20%
50	99.48%	92.31%	63.58%	39.50%	9.53%	4.88%	2.47%	0.50%
100	100.00%	99.41%	86.74%	63.40%	18.14%	9.52%	4.88%	1.00%

Other terms and acronyms frequently used

AHD – Australian Height Datum, in Tasmania is based on mean sea level for 1972 at the tide gauges at Hobart and Burnie which was assigned the value of zero on the AHD scale of elevation

SLR – Seal level rise

GHG – greenhouse gases

Appendix D Inundation depths and average recurrence intervals

The following tables relate to the potential inundation figures in Sections 8, 9 and 10. The figures are:

The tables provide indicative inundation depths for the shaded areas, and the Average Recurrence Interval (ARI) of potential inundation for the shaded areas.

The indicative ARIs for potential inundation with future sea level rise based on the shaded areas in the figures are shown in Table D1. The equivalent AEPs are shown in Table D2. The indicative depths of potential inundation with future sea level rise based on the shaded areas of the figures are shown in Table D3, for a 100 year ARI (1% AEP) event (blue cells in Tables D1 and D2.

Table D 1. Indicative Average Recurrence Interval (ARI) of inundation on maps

Colour	Depth	Indicative ARI of inundation (years) for sea level rise				
		Present SLR=0.0m	**2050 mid** SLR=0.2m	**2050 high** SLR=0.3m	**2100 mid** SLR=0.5m	**2100 high** SLR=0.9m
Beige	d>0.3m	100	15	5	0.7	0.01
Yellow	d<0.3m	100	15	5	0.7	0.01
Purple	d<0.3m	800	100	40	5	0.1
Orange	d<0.3m	2,000	300	100	15	0.3
Light blue	d<0.3m	15,000	2,000	700	100	2
Dark blue	d<0.3m	800,000	100,000	40,000	5,000	100

Table D 2. Indicative Average Excedance Probability (AEP) of inundation on maps

Colour	Depth	Indicative AEP of inundation for sea level rise				
		Present SLR=0.0m	**2050 mid** SLR=0.2m	**2050 high** SLR=0.3m	**2100 mid** SLR=0.5m	**2100 high** SLR=0.9m
Beige	d>0.3m	1.0%	6.5%	18.1%	76.0%	100.0%
Yellow	d<0.3m	1.0%	6.5%	18.1%	76.0%	100.0%
Purple	d<0.3m	0.125%	1.0%	2.5%	18.1%	100.0%
Orange	d<0.3m	0.05%	0.33%	1.0%	6.5%	96.4%
Light blue	d<0.3m	0.0067%	0.05%	0.143%	1.0%	39.4%
Dark blue	d<0.3m	0.000125%	0.001%	0.0025%	0.02%	1.0%

Table D 3. Indicative inundation depths of shaded areas in 100 yr ARE (1% AEP) event

Colour	Greater or less than	Indicative potential inundation depth (m) for sea level rise				
		Present SLR=0.0m	**2050 mid** SLR=0.2m	**2050 high** SLR=0.3m	**2100 mid** SLR=0.5m	**2100 high** SLR=0.9m
Beige	greater than	0.3	0.5	0.6	0.8	1.2
Yellow	less than	0.3	0.5	0.6	0.8	1.2
Purple	less than	-	0.2	0.3	0.5	0.9
Orange	less than	-	-	0.1	0.3	0.7
Light blue	less than	-	-	-	0.2	0.6
Dark blue	less than	-	-	-	-	0.4

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