COASTAL HAZARD ADAPTATION STRATEGY FOR TOWNSVILLE CITY COUNCIL

Pilot Project

OCT 2012

GHD

Griffith UNIVERSITY

Queensland Government

City of Townsville

LGAQ

Australian Government

Department of Climate Change and Energy Efficiency

Scope and limitations

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Executive summary

This study considers the potential ongoing cumulative impacts of coastal hazards on the Townsville regional community in Far North Queensland. It considers both present extremes of climate and also projected changes in future climates up until the year 2100. The analyses include the effects of ocean inundation from storm tide events (both tropical cyclone and non-cyclonic events) together with long-term sea level rise and consideration of likely coastal recession due to erosion over time. The results are expected to be used for informing decision making that would lead to a *Coastal Hazard Adaptation Strategy (CHAS)* being implemented as part of future Council planning.

The study is a pilot project funded by the Commonwealth Department of Climate Change and Energy Efficiency's *Coastal Adaptation Pathways Program* undertaken in collaboration with the Local Government Association of Queensland (LGAQ), the Queensland Government and Townsville City Council (TCC). The Griffith University Centre for Coastal Management assisted GHD with some aspects of the analyses.

The results show that parts of the City of Townsville and surrounding coastal communities are under significant threat from coastal hazards over the 88 y study period, 2012-2100. This study represents the first step in identifying potential practical coastal adaptation strategies to respond to existing and future threats from coastal hazards in the region; these being categorized nominally as either *Defend*, *Retreat* or *Accommodate*.

The main objective of the study is to assist TCC decision makers in future planning and engineering responses to the potential threat of climate change. Key components of the project have included:

- Identifying regions likely to be affected by high coastal hazards (such as projected sea level rise and storm tide inundation) over the 88 y period to 2100;
- Assessing the vulnerability and risk to key Council and community assets through a comprehensive data gathering and mapping exercise;
- Developing potential coastal adaptation options to mitigate the impact of these hazards, e.g. construction of sea levees, storm tide gates, house raising or planned retreat; and
- Assessing the viability of adaptation options through stakeholder engagement and economic assessment.

A summary of the study process is depicted in the figure below:

The study has provided an assessment of over 150 separate potential adaptation options for 11 coastal Districts from Mutarnee in the north to Cungulla in the south (including Magnetic Island). For each district a series of TCC, State Government and Industry Stakeholder Workshops were completed followed by a robust economic assessment that has resulted in the identification of 'preferred' options for further future consideration.

Perhaps surprisingly, the 'optimal' timing of adaptation may be much sooner than otherwise anticipated. A number of locations (including the central Townsville area) show action is likely

desirable prior to 2030. A summary of the preferred adaptation option for each Locality is provided in the following table below . Each column indicates:

- The District and Locality;
- The preferred adaptation option from the economic assessment;
- The project net -present value (Project NPV) for each of the adaptation options assessed. The Project NPV represents the summation of all benefits and losses associated with a given option over the 88 y project period. Positive results indicate an economically viable option (i.e. where the benefits exceed the overall costs). Importantly it should be noted that while some Project NPV results may be negative, they may still be more viable (more positive) than *Maintain Status Quo* and thus reflect an overall benefit compared with undertaking no adaptation (for options assessed in BCA only);
- The Project NPV with adaptation – the Project NPV under *Maintain Status Quo*. Positive values within this column indicate if a given adaptation option is more financially viable than undertaking a *Maintain Status Quo* approach.
- The optimal time to implement a given adaptation option based on the maximum benefit cost ratios developed within the BCA; and
- The estimated present value of the investment cost required to implement each option considered during the BCA. The values provided are negative as they represent an overall cost (for options assessed in BCA only)..

The below table has also been colour coded to reflect economic viability as follows:

Postitive Project NPV Economically Viable Project.

Negative Project NPV but more economically viable than Maintain Status Quo

Economically unviable

District	Locality	Adaptation Option	NPV Project (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Townsville Inner Suburbs	Townsville Inner Suburbs	Defend Option 1	$724	$1,732	2027	$190
Townsville North	Industrial Area	Defend	$168	$386	2027	$13
River South	Oonoonba	Defend	$127	$277	2027	$10
Magnetic Island	Picnic Point WTP	Defend	$117	$255	2028	$1
Townsville North	Mt St John	Defend	$8	$21	2027	$3
Saunders Beach	Saunders Beach	Retreat	-$18	$60	2029	$75
Bushland Beach	Bushland Beach	Retreat	-$50	$12	2080	$24
Balgal Beach	Toomulla	Retreat	-$9	$11	2064	$8
Magnetic Island	West Point	Retreat	-$10	$9	2042	$8
Townsville North	Pallarenda	Accommodate	-$19	$8	2080	$16
Toolakea	Bluewater Beach	Retreat	-$3	$7	2034	$6
Magnetic Island	Horseshoe Bay	Retreat	-$13	$7	2036	$16
Bushland Beach	North Shore Green Field Development	Retreat	-$4	$5	2039	$3
Rollingstone	Rollingstone	Retreat	-$2	$4	2036	$3
Balgal Beach	Balgal Beach	Retreat	-$16	$3	2080	$11
Toolakea	Toolakea	Retreat	-$12	$3	2080	$8
Magnetic Island	Cockle Bay (Lots)	Retreat	-$0.2	$1	2027	$1
Rollingstone	Mutarnee	Retreat	-$1	$0.2	2053	$1
Magnetic Island	Picnic Bay	Defend	-$7	$0.1	2089	$3
Magnetic Island	Bolger Bay Pump Station	Defend	-$0.1	$0.0	2089	$0.1
Magnetic Island	Arcadia (Geoffrey Bay)	Retreat	-$7	-$0.7	2089	$5
Magnetic Island	Nelly Bay	Defend	-$7	-$2	2089	$4
South Land	Cungulla	Retreat	-$27	-$9	2047	$26

These recommended strategies represent a 'first pass' assessment of coastal adaptation options in Townsville and the pilot study has identified that there are a number of opportunities for future refinement of these analyses that could include:

- Refinement of the mapping methods used to define coastal erosion-prone areas, which in some areas have overly influenced the economic assessment outcomes;
- More detailed cost estimation and conceptual design of potential defend and accommodate adaptation options;
- Extension to include the advantages of considering a range of levels of protection rather than the single 1% AEP(1% AEP) criteria as prescribed here;
- Consideration of projected sea level rise uncertainly in the development and assessment of options;
- Consideration of community and industry response to climate adaptation (e.g. legal implications, revenue raising to fund potential options),
- The need to involve and inform the community in the coastal adaptation process.

Importantly, this pilot study for Townsville has identified that:

- The quality of the hazard assessment information (e.g. storm tide probabilities) for a region is a critical component that forms the foundation of the impact and economic analyses;
- Although CHAS studies are inherently complex undertakings, they will provide critically important information needed for strategy development, planning and implementation by coastal Councils for generations to come;
- The findings of a CHAS study will represent the first step in providing for coastal protection or adaptation plans for vulnerable coastal communities;
- Such work will underpin a significant investment in the future viability of coastal communities and as such is deserving of a high priority in Government funding allocations; and
- Councils with vulnerable coastal communities will recognise that they have a responsibility to ensure that the long term viability of 'at risk' localities can be based reliably on the outcomes of their CHAS study and its future revisions.

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List of acronyms

CHAS	Coastal Hazard Adaptation Strategy
CPM Act	Coastal Protection and Management Act 1995 (Queensland)
EHP	Department of Environment and Heritage Protection
LGAQ	Local Government Association Queensland
MCA	Multi-Criteria Assessment
MSL	Mean Sea Level
QCP	Queensland Coastal Plan
QPP	Queensland Planning Policy
SPA	Sustainable Planning Act 2009
SPP	State Planning Policy
TCC	Townsville City Council
TMR	Department of Transport and Main Roads

1. Introduction

Queensland has a highly dynamic and complex coastal zone, featuring shallow coastal margins and complex estuary systems with significant exposure to coastal hazards, including erosion, storm tide inundation and sea level rise. Many of Queensland's cities and towns are on the coast and are therefore particularly exposed to such hazards.

Climate change is expected to increase the frequency and intensity of these hazards along the coast. Queensland Government policy calls for coastal hazard risks to be addressed in planning and development decisions. However, dealing with hazards on a development by development basis is not efficient and will not provide a suitable holistic outcome for a community at risk. Adaptation strategies are intended to ensure a planned approach is taken to address coastal hazards for at risk communities from the immediate to long term.

Townsville City Council is the first Queensland Council to consider a Coastal Hazard Adaptation Strategy. The landmark pilot project has been undertaken by GHD, in collaboration with the Local Government Association of Queensland, Queensland Government, Townsville City Council and Griffith University, and is funded by the Commonwealth Department of Climate Change and Energy Efficiency's Coastal Adaptation Pathways Program.

The Townsville Coastal Hazard Adaptation Strategy (Townsville CHAS) has been developed to assist and inform Townsville City Council (TCC) on methods to minimise risks to both existing infrastructure and properties and new development in areas projected to be at high risk from coastal hazards by the year 2100.

While this report provides Townsville-specific detail of the risk and potential mitigation to ocean hazards, the overall CHAS process will be used to inform other Queensland coastal councils in undertaking their own future strategies/studies.

1.1 Guide to the CHAS Study Report

The CHAS Report forms one of three key deliverables for the Townsville CHAS pilot which includes development of:

- A *Compendium of Coastal Adaptation for Queensland Coastal Councils* (The Compendium) (GU/GHD, 2012) detailing options suitable for the Queensland coast that Local and State authorities can utilise;
- The *Townsville CHAS Study Report* (This Report) for possible future incorporation in Townsville City Council's (TCC) Planning Scheme, Infrastructure Plan, Community Plan and Financial Plan following additional collaboration with key stakeholders and the Townsville community; and
- A *Learnings Report* detailing project learnings and recommendations for updating the Queensland Coastal Adaptation Strategy Planning Guideline and assisting Queensland Coastal Councils in development of their own future strategies/studies.

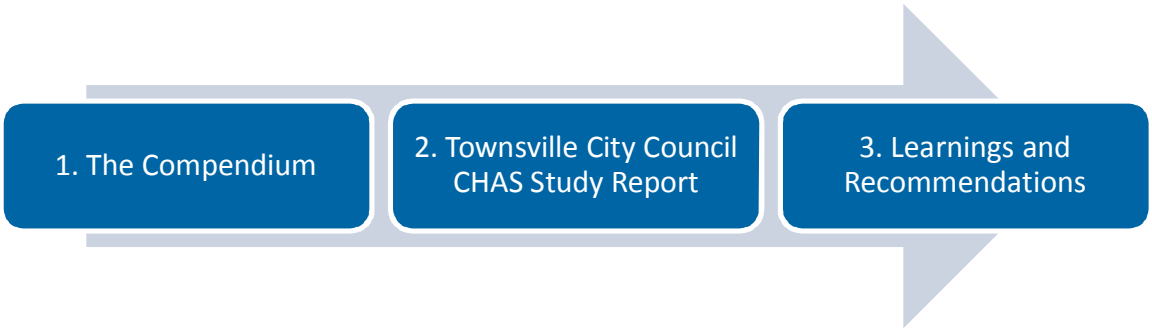

Figure 1 CHAS Pilot Study Deliverables

The main purpose of each section of the *Townsville CHAS Study Report* is summarised as follows:

- **Chapter 2: Coastal Hazards and the Townsville City Region:** This Chapter provides an overview of the coastal hazards currently and likely to be experienced within the Townsville region. The Districts and Localities investigated are introduced along with the method to identify and rank coastal adaptation options. Finally, a summary of the highest ranking adaptation option for each Locality is presented for future planning consideration.
- **Chapter 3: Adaptation Strategies:** This Chapter provides investigation of the coastal hazard risk to specific Districts, the potential adaptation options developed to mitigate these risks and the economic assessment results to indicate preferred strategies.
- **Chapter 4: Review and Revision of the Strategy:** This section provides recommendations relating to review of the strategy including opportunities to improve the assessment undertaken and the future refinement of options.

The report relies heavily on input from technical appendices developed over key stages of the project and includes:

- **Appendix A: Risk and Vulnerability Assessment;**
- **Appendix B Economic Assessment;**
- **Appendix C: The project Learnings and Recommendation Report;**
- **Appendix D Extent of Selected Adaptation Options;**

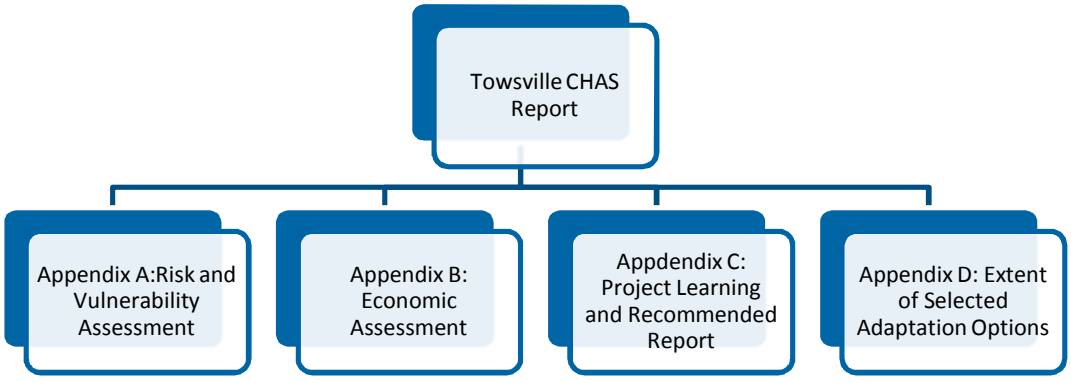

Figure 2 CHAS Study Report Layout

1.2 Purpose of the Strategy Study

1.2.1 What is the Townsville CHAS Study?

The *Townsville Coastal Hazard Adaptation Strategy* (Townsville CHAS) is the first stage in managing the increasing risk of coastal hazards to Townsville City Council's coastal communities. The Townsville CHAS seeks to understand the potential risks of coastal hazards to development, infrastructure and properties to the year 2100, and recommends ways to address these hazards. Strategies are proposed only for those urban areas that are located within a high coastal hazard area and projected to experience an intensification of development to 2100.

The Townsville CHAS is the first of its kind in Queensland. It outlines ways to address the coastal hazard risks projected to occur in the future along the Townsville coastline. The strategy does not prescribe definitive measures, but will help inform future planning and development decisions in areas at high risk from coastal hazards.

1.2.2 Why do we need the Townsville CHAS Study?

Certain communities are already at risk from coastal hazards such as coastal erosion and inundation, and from storm tide. As a result of climate change, rising sea levels will increase the severity and frequency of these hazard's impacts.

For the protection of future generations, Queensland coastal planning policy recommends that local councils start thinking now about how to minimise exposure to increased coastal hazard risks for new development while ensuring the risk of coastal hazards is avoided or mitigated for existing infrastructure and properties in areas projected to be at high risk from coastal hazards up to the year 2100. By developing a CHAS it will allow Councils to systematically analyse coastal risks and propose adaptation measures to mitigate the impacts, a process consistent with principles of good planning and risk management.

1.2.3 What is a Coastal Hazard?

For the purposes of the Townsville CHAS and in line with the Queensland Coastal Hazards Guideline (former) (DERM, 2012) coastal hazards addressed include:

- **Coastal erosion**: Shoreline recession due to sea erosion causing a permanent loss of land;
- **Storm tide inundation**: Temporary inundation of land by abnormally high ocean levels. Storm tide is the total water level obtained by adding the storm surge and wave set-up to the height of the astronomical tide; and
- **Sea-level rise inundation**—periodic or permanent tidal inundation of land due to a rise in the mean sea level. It is noted that sea-level rise has the potential to exacerbate existing coastal erosion and storm-tide inundation issues.

1.2.4 Defend, Accommodate, Retreat or Maintain the Status Quo?

All coastal hazards cannot be prevented but their damaging effects can be minimised through the development and implementation of adaptation strategies. Three coastal planning approaches are proposed to address risk in high coastal hazard areas through a CHAS: *Defend*, *Accommodate* or *Retreat*. It is unlikely that any one option will be implemented in isolation. Rather a combination of approaches will likely be implemented within the same local government area. In the process of assessing possible responses to coastal hazards, taking into account their costs and the views of the community, it may be appropriate for councils to

consider a "*Maintain* the *Status Quo*" approach where *Defend*, *Accommodate* or *Retreat* approaches are not viable.

The adaptation approaches and options available to pursue the approach objectives are discussed further below.

Defend: Protect sectors of the coastal hazard area with either hard or assimilating coastal engineering structures to reduce[1] or remove storm tide inundation or erosion risks,**.** *Defend* strategies may include maintaining the existing use or intensifying development on the land. Coastal defence may combine long-term strategies for defence and maintenance including regenerative and structural options such as beach nourishment, dune construction, dykes and storm tide barriers.

Accommodate: Maintain the current level of use within coastal hazard areas and raise the tolerance to periodic storm tide inundation or erosion events by means of innovative designs for buildings and infrastructure (e.g. elevating, strengthening or change in use). This entails undertaking actions that will reduce the impacts from coastal hazards to an acceptable level. Actions can generally be broken into two categories:

- Works that will allow the current use to continue (e.g. upgrading drainage works and raising land levels when the existing use is redeveloped); and
- Physical works and legislative amendments that provide for more appropriate future use of the land. For example changing the designated land use to one that can better tolerate the risk (e.g. rezoning land from residential to industrial use), or operational works to raise the height of developable land above the height of potential sea level rise.

In the context of the Townsville CHAS, *Accommodate* has generally been defined as the construction of coastal protection works such as seawalls to reduce erosion due to increases in projected mean sea level, combined with improved flood resilience from storm tide by undertaking property raising in regions affected.

Retreat: Includes actions to remove the assets at risk from the area impacted by the coastal hazard. This option could be achieved through various mechanisms such as relocating the community (e.g. through a land swap arrangement) or abandoning the area (e.g. through land purchase mechanisms or rezoning the land to an open space or recreational use).

Maintain Status Quo: Maintaining the status quo refers to a continuation of the existing use in an area while not supporting any further intensification of those uses. It does not restrict land owners from defending their own land (e.g. collaboratively with adjoining landowners) or *Accommodate* the impact of coastal hazards.. A decision to *Maintain* the *Status Quo* would necessarily be supported by actions such as:

- Planning scheme modifications (e.g. in the strategic framework) to reflect the decision not to intensify land use and indicate that redevelopment will not be supported once significant damage is sustained from an inundation event;
- Ongoing monitoring and review of hazards;
- Targeted public education on hazards;
- A hazard note on property searches;
- Regular review of the emergency plan of the Local and District Disaster Management Group, which recognises the changing risk profile;

[1] The current QCP requires immunity for the 100 y Return Period only. It is noted that water level events exceeding the 100 y Return Period are likely to occur during the study planning period 2012-2100.

- Regular update of the Council's infrastructure plan to reflect longer term intentions regarding services and infrastructure in the area as the risk profile changes; and
- Rates reduction of properties in the area.

1.2.5 Synergies with other legislation and strategies

The *Coastal Protection and Management Act 1995 (Coastal Act)* provides a framework for the coordinated management of Queensland's coastal resources and values in the coastal zone (DERM, 2012). One of the objects of the Coastal Act is ensure decisions about land use and development safeguard life and property from the threat of coastal hazards (s.3(c)). The Coastal Act also provides that one of the means to achieve its objects is to use other relevant legislation wherever practicable to achieve the objects of this Act (s.4(d)). Queensland Government policy requires that statutory instruments directed at planning and development decision-makers must be made under the Sustainable Planning Act 2009 (SPA).

The QCP is the primary statutory instrument under the Coastal Act containing policies directed at coastal land managers (generally local government) and policies directed at planning and development decision-makers under SPA (the State Planning Policy for Coastal Protection – SPP 3/11). At the time of publication, the Queensland Government was preparing a single State planning policy to incorporate all State planning interests and had suspended SPP 3/11 by way of the Draft Coastal Protection State Planning Regulatory Provision (Coastal SPRP). In relation to addressing coastal hazards through planning and development decisions, the Coastal SPRP contains similar policy outcomes to SPP 3/11 but without a direction that adaptation strategies must be completed by coastal local governments within five years. While no longer a statutory requirement, adaptation strategies are a practical means for local government to plan for areas at risk from the impact of high coastal hazards, now and in the future.

In accordance with SPA, local governments are required to plan for the impacts of coastal hazards, including the effects of sea level rise. Local government will need to ensure that when amending their local planning instruments for high coastal hazard areas, adaptation strategy outcomes are achieved (State of Queensland (DERM), 2012).. An overview of where the CHAS Study process in the overall planning framework is provided in Figure 3

The new City Plan

The new Townsville City Council planning scheme is currently being developed to amalgamate the two planning schemes of the former Thuringowa local government area and the previous Townsville local government area. The new City Plan will provide clear direction, certainty, and efficiency to industry and the community following the local government amalgamations in March 2008.

The Townsville Land Use Proposal was released in 2011 and defined the preferred settlement pattern for the City. The New City Plan is currently being drafted with the final state agency review and adoption anticipated during late 2013.

Wherever possible, recommendations within the Townsville CHAS will be reflected in the New City Plan such as land use zoning decisions, hazard mapping, code requirements and set-back overlays.

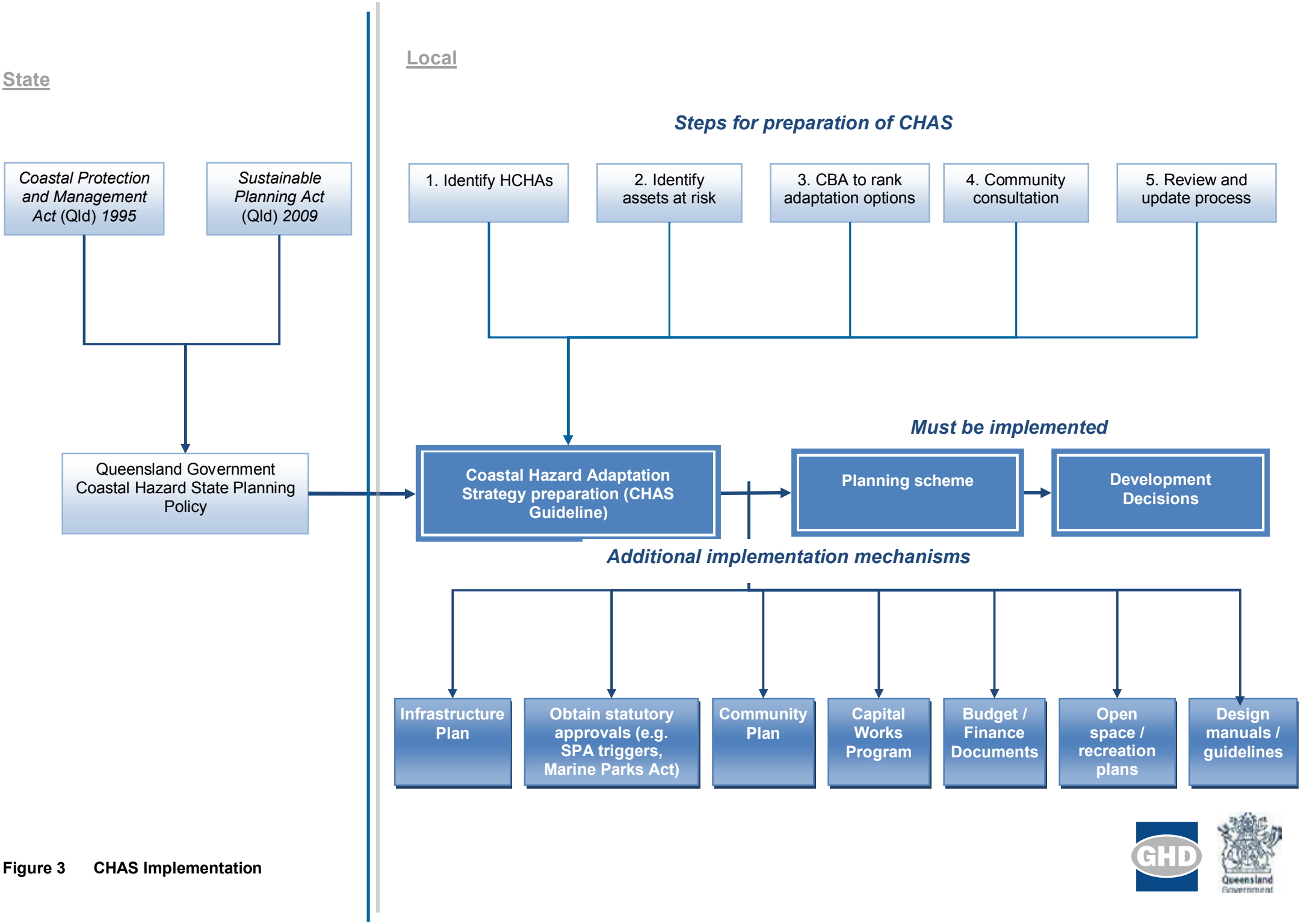

Figure 3 CHAS Implementation

1.2.6 Community consultation

A Communications and Stakeholder Engagement Plan (CSEP) was prepared for the pilot project in December 2011 to guide consultation and communication activities both internally (between members of the Core Project Team and the Project Board) and externally for all consultation activities. Key aspects of the plan included a comprehensive stakeholder listing, identification of potential stakeholder issues, key messages, communication protocols (covering communication with both internal and external stakeholders), appropriate communication tools (including approval protocols and timings), a community and stakeholder engagement program, evaluation and reporting requirements.

The CSEP proposed extensive community consultation including elected representative briefings, targeted community workshops, a free call project information line, web content and media releases. During the CHAS process it became apparent that the timeframe of the CHAS was too short to allow adequate community engagement as well as obtain the necessary support from Council. Subsequently, a decision was made by TCC to cancel all community consultation associated with the project until a later date.

It is noted that recommendations outlined in the CHAS have the potential to be politically sensitive and may require complex stakeholder engagement in order to both educate the community and capture stakeholder sentiment. As such, the recommended stakeholder engagement process should prescribe core engagement activities required throughout all phases of the CHAS process i.e. education preceding formal announcement, throughout the CHAS development and implementation phases.

1.2.7 Funding mechanisms for coastal adaptation

The issue of funding arrangements 'who pays' is an emerging issue and was raised in both the project Learnings Workshop and was also by the TCC Councilors . There was a general acceptance of the difficulty associated with identifying the stakeholder responsibility in sourcing funds. Ie Federal, State, Local and Industry. It is recognized that the responsibility for funding coastal hazard adaptation remains an important area for future consideration through all levels of government.

To contribute to adaptation option funding, LGAs have specific legislated authority to raise revenue or require construction of certain infrastructure through a limited range of rates and charges, under the Local Government Act 2009 and the Sustainable Planning Act 2009. These are the primary mechanisms for funding and provision of local government services and infrastructure:

- Rates and charges;
- Environmental levies; and
- Developer contributions and infrastructure agreements;

A number of external funding sources are available to LGAs; however, these funding sources or programs can be provided for very limited purposes and are dependent on the ongoing availability of funds from the body administering the program. The availability of funds and eligibility of the applicant must be investigated on a case by case basis:

- Natural Disaster Relief and Recovery Arrangements;
- Government borrowing (it must be recognised that this will require additional revenue raising through means such as special rates or levies in order to service the debt);
- Growth area bounds;
- Business improvement districts;

- Local government grants and subsidies programs; and
- Caring for our coasts.

For further detail on potential fund raising mechanisms the reader is directed to Section 8.3 of the *Compendium for Queensland Coastal Councils*, GU/GHD (2012)

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2. Coastal Hazards and the Townsville City Region

This Chapter provides an overview of the coastal hazards currently and likely to be experienced within the Townsville City Council region. The Districts and Localities investigated are introduced along with the method to identify and rank coastal adaptation options. Finally, a summary of the highest ranking adaptation option for each Locality is presented for future planning consideration.

2.1.1 Districts and Urban Localities

Coastal adaptation options have been developed for 11 separate coastal hazard districts (**Districts**) (refer Figure 6) which in turn have been sub-divided into urban localities (**Localities**) subject to coastal hazards (refer Appendix A) which have been allocated to provide logical 'cells' for coastal protection and adaptation based on coastal morphology and existing TCC planning regions.

For the purposes of the strategy, a Locality is an area that is:

- Allocated as an urban footprint or rural living areas in a regional plan; or
- Zoned as urban or rural residential purposes in a local planning instrument equivalent to one of the standard suite of zones for urban development as under Queensland Planning Provisions (where there is no regional plan urban footprint) or
- An existing settlement or township (not designated as above).

At the request of TCC a number of key infrastructure items such as waste water treatment plants have also been assessed as part of the Townsville CHAS.

2.1.2 Coastal hazards affecting Townsville

Sea Level Rise and Coastal Erosion

Townsville faces significant challenges from the threat of projected future sea level rise as depicted in Table 1 that provides a summary of the number of properties to be potentially inundated by the Highest Astronomical Tide (HAT) following a 0.8 m projected sea level rise by 2100. In small beach communities the losses due to sea level are typically associated with property being located within potentially erosion-prone areas. For Townsville Inner Suburbs and River South Districts this loss is due to property constructed in low-lying areas with the main focus of property inundation in the suburbs of Railway Estate and Oonoonba. A district-specific discussion of sea level rise risk is provided in Chapter 3.

Table 1 Number of properties potentially affected by a 0.8 m projected HAT sea level rise

District	Number of Properties Potentially Affected by HAT Sea Level Rise of 0.8 m
Rollingstone	21
Balgal Beach	334
Toolakea	147
Saunders Beach	167
Bushland Beach	291
Townsville North	254

Townsville Inner Suburbs	2830
River South	188
Stuart	7
South Land	156

Storm Tide

All severe weather systems are capable of producing a storm surge, which can increase coastal and ocean water levels for periods of several hours to days and significantly affect over 1,000 km of coastline (Harper 2001). Severe winds from these systems act to force ocean currents and waves towards the coast. The energy from these waves and currents are combined with the astronomical tide to produce a total water level (individual contributions from tide + surge + wave setup) which is defined as the storm tide (refer Figure 4). In addition, wave runup can lead to erosion and intermittent attack of the beachface and dune system. This CHAS study is critically dependent on the hazard information provided from a comprehensive investigation of tropical cyclone storm tide risk at Townsville for present and projected future climates (GHD/SEA 2007) as well as an assessment of non-cyclonic risks (Hardy et al. 2004)..

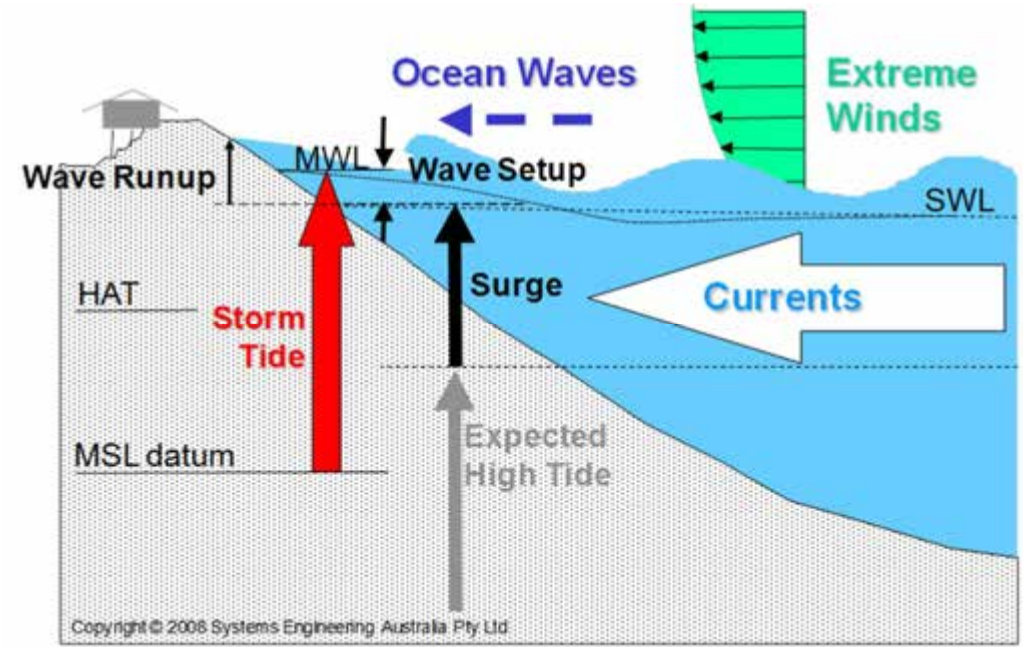


Figure 4 Water level components of an extreme storm tide (after Harper 2001).

The region from Rollingstone Beach to Cungulla is located within a very active zone of tropical cyclone (TC) occurrence and accordingly has a long history of encounters with severe tropical cyclones. Amongst the earliest recorded impacts of storm tide in Queensland is the 1884 event at nearby Bowen, and the infamous TC *Sigma* of 1896, named after one of the many vessels that sank at Townsville during the storm's passage (Holthouse 1971).

Many lesser events followed in the ensuing years but it was TC *Althea* in December 1971 that "raised our collective conscience to the storm tide threat in Queensland" (Harper 1999) with a 2.9 m storm surge arriving close to low tide that still managed to reach about 0.4 m above the Highest Astronomical Tide (HAT). While the major damage to Townsville was from wind, the loss of The Strand seawall and many vessels highlighted the reality that a major storm tide disaster had luckily been avoided through pure chance. In 2009, the remote and weak TC *Charlotte* in the Gulf of Carpentaria produced a widespread but relatively low magnitude storm surge (0.7 m) but this coincided with a period of King Tides (SEA 2009). The result was that ocean levels peaked at 0.4 m above HAT (4 cm above *Althea* levels) and the persistent wave

attack resulted in extensive erosion and damage. Most recently, TC *Yasi* in 2011 that crossed near Cardwell, still produced a storm surge of 2.63 m at Townsville, with levels again reaching 0.4 m HAT in spite of the peak levels also coinciding with a low tide (EHP 2011). Each of these events also produced even higher levels of impact at locations subject to wave setup and runup effects.

Figure 5 below provides the hazard profile posed by storm surge at South Townsville which indicates a 1% AEP tide plus surge event of approximately 2.6 m AHD (note: the 1% AEP storm tide, which allows for wave setup is approximately 2.9 m AHD at South Townsville). As shown below much larger surges could be expected for rarer events which could occur prior to 2100.

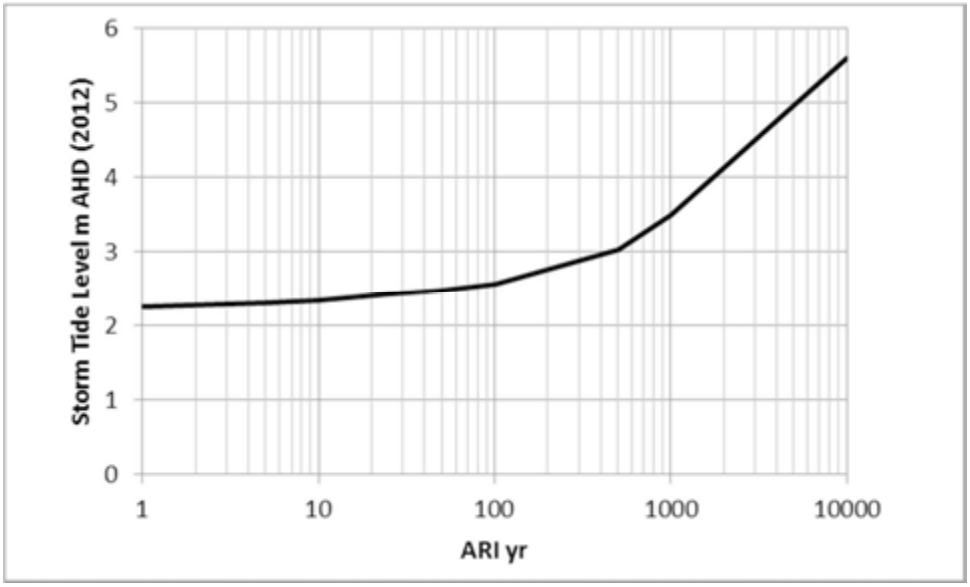
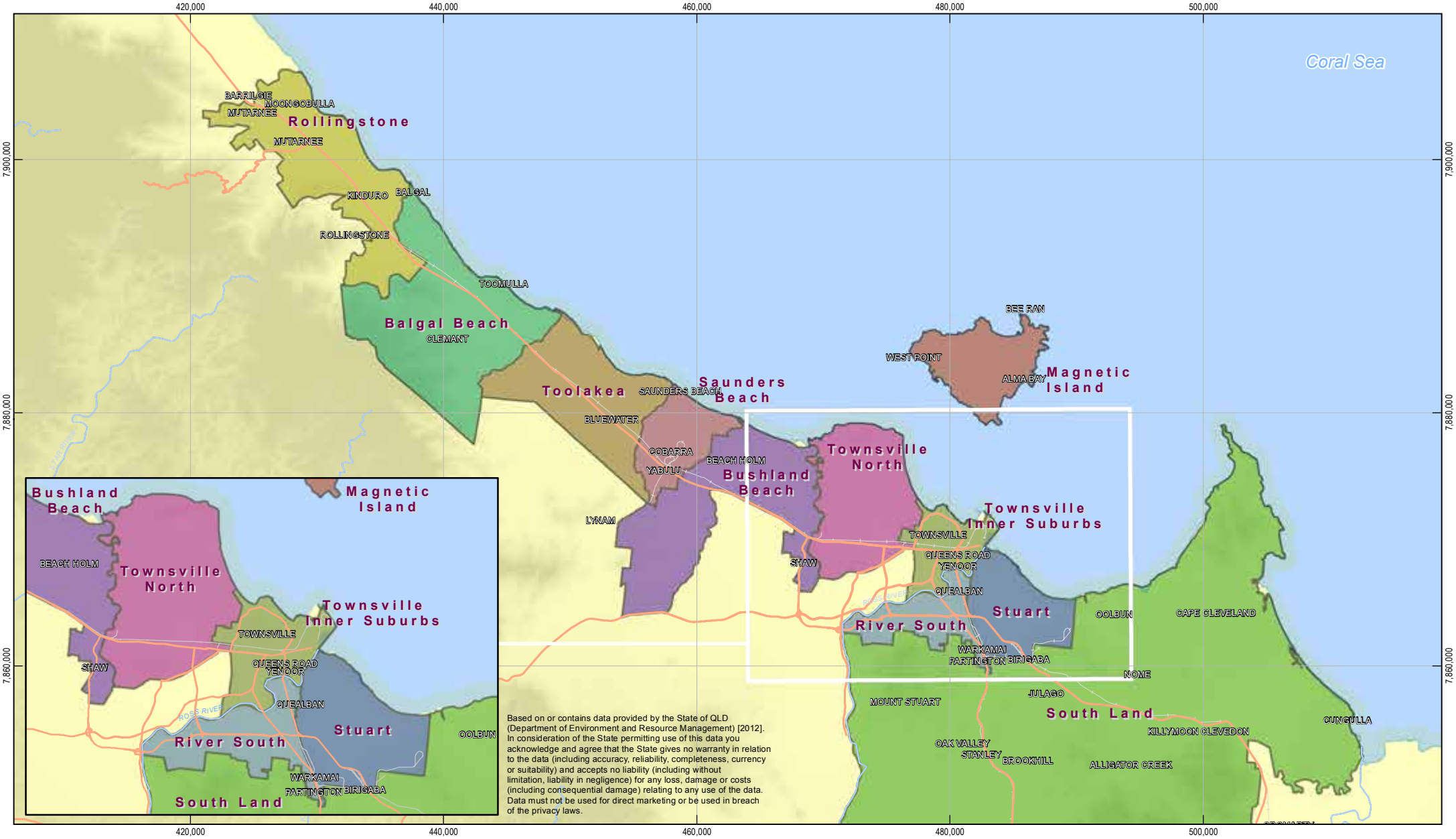


Figure 5 Combined non-cyclonic and tropical cyclone tide plus surge only return period curve for South Townsville (GHD/SEA 2007).



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0 2.5 5 10

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Watercourse
Road
Rail

TCC CHAS Districts
Balgal Beach
Bushland Beach
Magnetic Island
River South
Rollingstone
Saunders Beach
South Land
Stuart
Toolakea
Townsville Inner Suburbs
Townsville North

Townsville City Council
Coastal Hazard Adaptation Strategy

Job Number 41-24069
Revision A
Date 26 Oct 2012

Coastal Hazard Districts in Townsville City Council

Figure 6

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Level 9, 145 Ann Street Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: TCC/GHD, TCC CHAS Districts/2012. TCC, Rail/2011. GA, Watercourse © Copyright Commonwealth of Australia (Geoscience Australia)/2007. DERM, Place Names/2010, Elevation/2008. Created by:MSmith

2.2 Process to identify adaptation strategies

2.2.1 Overview

The following sections detail the steps that were undertaken throughout the Townsville CHAS Study to develop and assess adaptation options for each Locality. A summary of the process is outlined in Figure 7.

Figure 7 Key steps in the adaptation options development and assessment process.

2.2.2 Defining Coastal Hazard Areas for Townsville

High coastal hazard areas are defined as either:

- Erosion-prone areas within a coastal management district;
- Land that will be affected by the Highest Astronomical Tide (HAT) when a 0.8 m sea level rise allowance relative to 1990 levels is considered; or
- Land that is affected by more than 1 m of depth during a defined storm tide event, in this case the 1% AEP storm tide event occurring in 2100.

High coastal hazard area mapping layers for the Townsville CHAS were provided by EHP. It is noted that the datasets represent the so called 'bathtub' mapping approach whereby offshore water level values are mapped inland and thus do not consider the potential dynamics of inundation events that might either result in a reduction of a bathtub extent or an extension of it, depending on the specific situation.

2.2.3 Vulnerability and Risk Assessment

A coastal hazard risk assessment was undertaken to assess risk to infrastructure and risk to property. Social and economic risks to people (e.g. risk of isolation, risk to personal safety) were not included in the scope of this project but would represent significant costs and benefits associated with alternative land use and infrastructure decisions. The need to consider the full set of costs and benefits in land use decision making is reinforced in the National Strategy for Disaster Resilience (COAG, 2011). It would be useful for further adaptation planning to assess risks to people, including full social costs and benefits such as loss of life and injury, and the costs of emergency evacuation and recovery.

The vulnerability classifications adopted for this study are as follows:

- **Acceptable** risk – individuals and society can live with this risk without feeling the necessity to reduce the risks any further
- **Tolerable** risk – society can live with this risk but believe that as much as is reasonably practical the risks should be reduced further. Individuals may find this risk unacceptable and choose to take their own steps, within reason, to make this risk acceptable
- **Unacceptable** risk – individuals and society will not accept this risk and measures must be put in place to reduce risks to at least a tolerable level

Specific risk hazard thresholds to inform the vulnerability assessment are provided Appendix A.

2.2.4 Evaluation of Adaptation Options

Following the identification of high coastal hazard areas and associated risk to infrastructure and property, over 100 separate adaptation options were developed for the Localities considered. These options were refined through a series of Consultant, State Government, Townsville City Council and Local Stakeholder Workshops as detailed in Figure 8.

Key outcomes from the TCC Workshops, Stakeholder Workshop and Councillor Presentation are presented in the following sections.

Table 2 Key Option Assessment Milestones

Project Milestone	Date	Details
Project Workshop 1	(19/12/2011)	Approval of project economic methodology; Development of initial MCA criteria and weightings. Discussion surrounding intent of CHAS.
Internal GHD/TCC Adaptation Option Development Workshops	March 2012	Development of Localities and potential coastal adaptation options.
TCC Workshop 1	(26/04/2012)	Refinement of Localities and adaptation options.
TCC Workshop 2 (TCC Internal)	(25/05/2012)	Finalisation of Localities and potential adaptation options. This was provided to GHD on 28/05/2012 for compilation for Stakeholder Workshop and MCA.
Stakeholder Workshop	(15/06/2012)	Project overview and feedback from stakeholders on adaptation options from TCC Internal Workshop 2.
Councillor Presentation	(21/06/2012)	Presentation and overview of project to TCC Councillors.
Economic Assessment - MCA Workshop	(11/07/2012)	MCA scoring workshop held at GHD's office.
Economic Assessment - BCA	(March-August 2012)	BCA modelling of selected adaptation options.

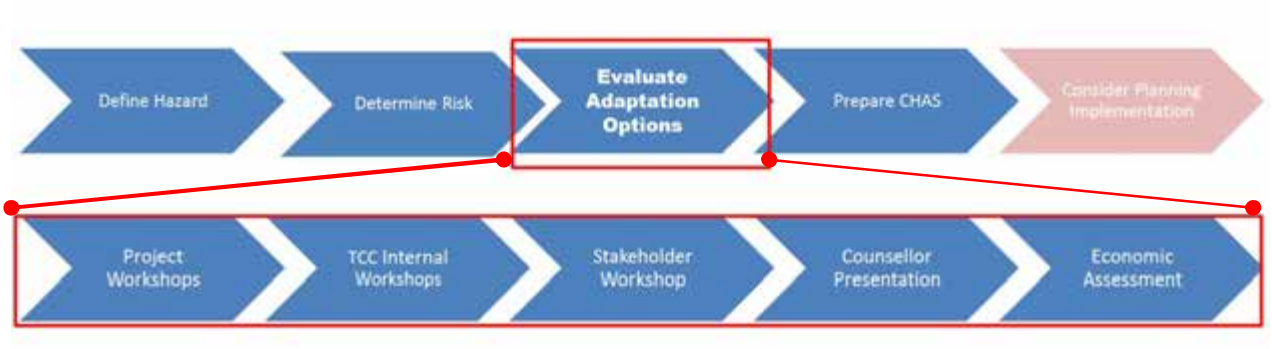

Figure 8 Key steps in the evaluation of adaptation options.

TCC Workshop 1 (26/04/2012)

The purpose of this workshop was for key TCC staff to provide feedback to the Project Team on a range of coastal hazard adaptation options for approximately 40 Localities within the Townsville LGA. The Project Team provided an overview of the work to date, including the method by which the adaptation options had been chosen. TCC staff were divided into three groups and asked to discuss and score the options. The desired outcome from the workshop was to agree on a set of adaptation options which would be used in the public consultation phase of the project. It was during this workshop that the issues surrounding the public

consultation timeframes were identified, resulting in the delay of public consultation (refer Section 1.2.6).

TCC Workshop 2 (25/05/2012)

The purpose of this workshop was to further discuss and consolidate the options discussed in Workshop 1 for provision to GHD. The outcomes from this workshop was a set of approximately 70 adaptation options for consideration within the Stakeholder Workshop and economic assessment.

Stakeholder Workshop (15/06/2012)

The purpose of the workshop was threefold:

- Inform Stakeholders of the project – why it is being undertaken, what it is, how it is being done including the process that has been undertaken to-date;
- Discuss the Localities and the options within these, the benefits, disbenefits and consequences of each of the options to understand stakeholder issues and further refine the options; and
- Review and document learnings where possible.

Key stakeholders present at this workshop included: GHD, TCC, EHP, The Great Barrier Reef Marine Park Authority, Ergon Energy, Defence, The Queensland Reconstruction Authority, Department of State Development, Infrastructure and Planning, Townsville Airport, Emergency Management Queensland, Queensland Parks and Wildlife Service, Department of Natural Resources and Mines, National Climate Change Adaptation Research Facility and the James Cook University Centre for Disaster Studies.

The Project Team provided an overview of the work to date, including the method by which the adaptation options had been chosen. During the workshop there was a general willingness from Stakeholders to be involved in providing feedback. Notable interest and input from Defence (Defence has existing adaptation study) was obtained during the workshop, with Defence and TCC indicating it would be preferable to work together on developing future solutions.

TCC Councillor Presentation

This presentation aims were twofold:

- To provide TCC Councillors with an overview of the project; and
- To seek feedback on potential issues with the project, concerns and recommendations.

The presentation was well received by the Councillors and there was a general appreciation for the risks posed by projected climate change to Townsville. A key point of discussion was the concern of ‘who pays’ given the cost associated with large-scale coastal adaptation.

2.2.5 Economic assessment of adaptation strategy options (BCA & MCA)

An economic appraisal was undertaken for each adaption option as presented in Appendix B The economic appraisal included a multi-criteria analysis (MCA) and benefit cost analysis (BCA). The economic appraisal focussed on assessing the merit of each option from a range of economic, environmental and social criteria.

Key components addressed within the Economic Report include:

- Summary of the internal project workshops;
- Development of the MCA criteria;
- Development of the MCA weightings and scoring;

- Provision of the MCA results including guidance on the highest scoring options for input to the BCA modelling;
- Development of the BCA modelling framework;
- Development of sea level rise asset losses and storm tide damages curves for coastal communities as a function of water level;
- Cost estimation of adaptation options for input to the BCA; and
- BCA modelling of Localities for selected adaption options from the MCA.

2.3 Overview of highest ranking adaptation strategies

A summary of the highest ranking strategies for each District is presented in Table 3. For full detail of each District and Locality please refer to the relevant sections of Chapter 3 as detailed in the far right column of Table 3.

Table 3 Overview of highest ranked strategies

District	Locality	Highest Ranked Strategy	Section
District A	Rollingstone		3.2
	Mutarnee	*Retreat*	3.2.3
	Rollingstone Beach	*Retreat*	0
District B	Balgal Beach		3.3
	Balgal Beach	*Retreat*	3.3.3
	Toomulla (including sewage treatment plant)	*Retreat*	0
District C	Toolakea		3.4
	Toolakea	*Retreat*	3.4.3
	Bluewater Beach	*Retreat*	0
District D	Saunders Beach		3.5
	Saunders Beach	*Retreat*	3.5.3
District E	Bushland Beach		3.6
	Bushland Beach, main residential area	*Retreat*	3.6.3
	North Shore, new development area	*Retreat*	3.6.4
District F	Townsville North		3.7
	Pallarenda	*Accommodate*	3.7.3
	Industrial Area	*Defend*	0
	Mt St John, sewage treatment plant	*Defend*	0
District G	Townsville Inner Suburbs		3.8
	The Strand	*Accommodate*	3.8.3
	Townsville Inner Suburbs (Townsville City: Ross Creek, South Townsville, Inner suburbs, Railway Estate, Rowes Bay,	*Defend Option 1*	3.8.4

District	Locality	Highest Ranked Strategy	Section
	Melrose Park, West End)		
District H	River South		3.9
	Oonoonba	*Defend*	0
District I	Stuart		3.10
	Stuart / Cleveland Bay sewage treatment plan	*Defend*	3.10.3
District J	South Land		0
	Cungulla	*Retreat or Maintain Status Quo*	3.11.3
District K	Magnetic Island		3.12
	Horseshoe Bay	*Retreat*	3.12.3
	Arcadia, Geoffrey Bay	*Retreat or Maintain Status Quo*	0
	Nelly Bay	*Defend or Maintain Status Quo*	0
	Picnic Bay	*Defend*	3.12.6
	Picnic Point, water treatment plant	*Defend*	0
	Cockle Bay (LOTS)	*Retreat*	3.12.8
	West Point	*Retreat*	3.12.9
	Bolger Bay Pump Station	*Defend*	3.12.10
	Radical Bay	*Accommodate*	0

2.3.1 Exclusions

A number of Localities initially identified for consideration within the CHAS were omitted throughout the course of the study following advice from TCC and EHP. Those areas excluded from the Townsville CHAS process are outlined in Table 4.

Table 4 Exclusions

District	Location	Reason for exclusion
District B – Balgal Beach	Balgal Beach South	Not intended for development intensification.
	Toomulla South	Not intended for development intensification.
District C – Toolakea	Aquaculture Area	Privately held property.
District D – Saunders Beach	Saunders Beach South	Not intended for development intensification.

District	Location	Reason for exclusion
District E – Bushland Beach	Batley Parade / Black River Settlement	Not intended for development intensification.
District F – Townsville North	Airport (Defence)	Defence jurisdiction.
	Shelley Beach/Northern Tip (Common)	Not intended for development intensification.
District G – Townsville Inner Suburbs	Marina/Casino	Privately held property.
	Port of Townsville	Port of Townsville jurisdiction.
District I – Stuart	Zinc Plant	Privately held property.
District J – South Land	Cleveland Palms	Not intended for development intensification.
District K – Magnetic Island	Nelly Bay Harbour	TMR jurisdiction.

3. Adaptation Strategies

This Chapter details the adaptation options assessed during the Townsville CHAS Study with each section providing a district-specific context:

- Introduction to the District and Localities considered;
- Potential existing and future risks due to sea level rise projections and the 1% AEP storm tide event, drawing upon the expansive set of vulnerability/risk mapping that has been conducted throughout the project (refer Appendix A);
- Detail of the adaptation options considered; and
- A summary of the MCA and BCA results leading to the recommended adaptation option (for detail of the Economic Assessment please refer to Appendix B).

3.1 Interpretation of Results

Within each section that follows accompanying tables provide a summary of:

- The adaptation options considered during the Townsville CHAS economic assessment;
- The MCA score developed during the MCA Workshop based on a number of economic, social and environmental criteria by the key project technical offices. Here higher scores reflect a more preferable option;
- The project net -present value (Project NPV) for each of the adaptation options assessed. The Project NPV represents the summation of all benefits and losses associated with a given option over the 88 y project period. Positive results indicate an economically viable option (i.e. where the benefits exceed the overall costs). Importantly it should be noted that while some Project NPV results may be negative, they may still be more viable (more positive) than *Maintain Status Quo* and thus reflect an overall benefit compared with undertaking no adaptation (for options assessed in BCA only);
- The Project NPV with adaptation minus the Project NPV under *Maintain Status Quo*. Positive values within this column indicate if a given adaptation option is more financially viable than undertaking a *Maintain Status Quo* approach.
- The optimal time to implement a given adaptation option based on the maximum benefit cost ratios developed within the BCA; and
- The estimated present value of the investment cost required to implement each option considered during the BCA. The values provided are negative as they represent an overall cost (for options assessed in BCA only);

For full detail of the MCA/BCA process the reader is directed to Appendix B.

3.2 District A – Rollingstone

'In the district of Rollingstone it is expected that planning scheme modifications and landuse changes may optimally enable a retreat from the 1% AEP storm tide event and sea level rise by 2100'.

3.2.1 Description

District A – Rollingstone – is the northernmost coastal hazard district within the TCC CHAS, incorporating the settlements of Crystal Beach, Mutarnee, Moongabulla, Kinduro and Rollingstone. The majority of the district is designated rural. District A includes two Localities of Mutarnee and Rollingstone Beach with the extent of each provided in Sheet 1 of Appendix A.

3.2.2 Coastal risks and vulnerability in Rollingstone

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Rollingstone District is provided in Sheet 1 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- The existing risk to property and infrastructure due to current HAT influences is limited;
- A 1% AEP storm tide event under current and future climate conditions can result in acceptable risk to property in both the Mutarnee and Rollingstone Beach Locality;
- By 2100 up to 5 and 17 properties[2] may be affected by either sea level rise or storm tide in Mutarnee and Rollingstone Beach respectively; and
- There is limited major infrastructure impacted within this district by 2100 due to the 1% AEP storm tide event or projected sea level rise.

3.2.3 Assessed Strategies for Mutarnee

Two strategies were considered for Mutarnee – *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat.***

Detail of each option considered for Mutarnee along with a summary of the MCA and BCA results is provided in Table 5.

[2] This includes residential, rural residential, commercial and industrial landuses.

Table 5 Strategies considered for Mutarnee

Strategy	Description	MCA score	Project NPV (M)	NPV Project – NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land swap – agriculture to be moved out of inundated area Planning scheme modifications	70	-$0.6	$0.2	2053	$0.5
Maintain Status Quo	Property searches – include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	10	-$0.83	NA	NA	NA

3.2.4 Assessed Strategies for Rollingstone Beach

Three strategies were considered for Rollingstone Beach – *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for Rollingstone Beach along with a summary of the MCA and BCA results is provided in Table 6.

Table 6 Strategies considered for Rollingstone Beach

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Coastal protection - including beach nourishment, seawalls and groynes either on their own or in combination. Raise as required to protect existing caravan park Land filling to raise above designated flood protection level – natural higher areas to be further raised above permanent inundation level House retrofitting and design standards – raising habitable floor level, improved design and usage of appropriate construction materials. Improving flood resilience of public infrastructure – localised raising , and /or improved drainage and /or improved capping of connecting roads would also be required to maintain access Planning scheme modifications	50	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption / land use change – land purchase and resumption and/or land swap for land that is permanently inundated Planning scheme modifications – land-use change for areas not developed yet but under permanent risk Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat	86	-$2	$4	2036	$3
Maintain Status Quo	Property searches – include a hazard note Planning scheme modification Public education Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	21	-5	NA	NA	NA

3.3 District B – Balgal Beach

'In the district of Balgal Beach it is expected that planning scheme modifications and landuse changes may optimally enable a retreat from the 1% AEP storm tide event and sea level rise by 2100'.

3.3.1 Description

District B – Balgal Beach – encompasses the area between Balgal Beach Road and Leichardt Creek. District B includes the settlements of Balgal Beach and Toomulla (including the Toomulla sewage treatment plant). Outside the beach communities of Balgal and Toomulla landuse is typically rural, open space and recreation.

District B includes the Localities of Balgal Beach and Toomulla. The undeveloped land south of Balgal Beach and Toomulla has been excluded from the study as detailed in Table 4 (refer Appendix A for the extent of these Localities).

3.3.2 Coastal risks and vulnerability in Balgal Beach

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Balgal Beach District is provided in Sheet 2 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- The existing risk to property due to the 1% AEP storm tide and HAT influences is limited with the exception of potential coastal areas adjacent to the community of Balgal Beach;
- The 1% AEP storm tide event under future climate conditions poses an unacceptable risk of above floor flooding to property within Balgal Beach. Risk to property at Toomulla is limited;
- By 2100 up to 97 and 228 properties may be affected by either sea level rise (primarily due to coastal erosion) or the 1% AEP storm tide in Toomulla and Balgal Beach respectively;
- The 1% AEP storm tide event under current and future conditions has the potential to cause unacceptable risk to the Toomulla Wastewater Treatment Plant (WTP); and
- Coastal road and underground services infrastructure is likely to be affected by 2100 due to the 1% AEP storm tide event and projected sea level rise.

3.3.3 Assessed Strategies for Balgal Beach

Three strategies were considered for Balgal Beach – *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for Balgal Beach along with a summary of the MCA and BCA results is provided in Table 7.

Table 7 Strategies considered for Balgal Beach

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Beach nourishment Dune construction – beach construction and regeneration. Increase height and width of dunal area (dune crest at storm tide level) without removing the possibility of the creek changing its course Seawalls – seawall at the south/west side of the northern properties along the creek to minimise risk of creek crossing through the community Planning scheme modifications – for remaining land under threat to avoid new development in hazard zone House retrofitting and design standards – house retrofitting and design standards for central and southern Balgal where affected by storm tide. Retrofitting for fluvial flooding at North Balgal	52	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated for north and south Balgal Land use change – land use change for areas not developed yet but under permanent risk Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – to reflect land-use change	79	-$16	$3	2080	$11
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	20	-$19	NA	NA	NA

3.3.1 Assessed Strategies for Toomulla

Two strategies were considered for Toomulla – *Accommodate* and *Retreat* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for Toomulla along with a summary of the MCA and BCA results is provided in Table 8.

Table 8 Strategies considered for Toomulla

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	House retrofitting and design standards – modify house so habitable floor levels are above the defined storm tide level Improving flood immunity of public infrastructure –raise connecting roads between two parts of Toomulla and highway for sea level rise Coastal protection – seawall along beach between headlands. Potential creek mouth relocation, training wall to prevent erosion	35	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Retreat	Land purchase and resumption / land use change – land purchase and resumption and/or land swap for land that is permanently inundated Planning scheme modifications / flood proofing public infrastructure – land-use change for areas not developed yet but under permanent risk. Planning scheme modifications to reflect land-use change. Connecting road and services will need to be maintained during the period of retreat	60	-$9	$11	2064	$8

3.4 District C – Toolakea

'In the district of Toolakea it is expected that planning scheme modifications and landuse changes may optimally enable a retreat from the 1% AEP storm tide event and sea level rise by 2100'.

3.4.1 Description

District C – Toolakea – includes the settlements of Toolakea and Bluewater Beach incorporating the land between Leichardt and Althaus Creeks. The Toolakea district has been sub-divided into the following Localities: Toolakea , Bluewater Beach and the large aquaculture operation located in the north of the district along Verrall Road (excluded from the study as detailed in Table 4). The extent of each Locality is provided in Appendix A.

3.4.2 Coastal risks and vulnerability in Toolakea

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Toolakea District is provided in Sheet 3 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- The existing risk to property and infrastructure due to current HAT influences is negligible with the exception of low lying coastal areas within the Bluewater Beach and Aquaculture Localities;
- By 2100 up to 22 and 120 properties may be affected by either sea level rise (primarily erosion) or the 1% AEP storm tide event in Bluewater Beach and Toolakea respectively;
- The 1% AEP storm tide event under current climate conditions poses limited of risk of above floor flooding to property;
- There is limited impact to coastal infrastructure due to present climate tidal influences; and
- There is a risk to key coastal infrastructure within the estimated coastal erosion-prone zone due to sea level rise.

3.4.3 Assessed Strategies for Toolakea

Three strategies were considered for the Toolakea Locality– *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for the Toolakea Locality along with a summary of the MCA and BCA results is provided in Table 9.

Table 9 Strategies considered for Toolakea

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Coastal protection – including beach nourishment, seawalls and groynes either on their own or in combination. Raise as required to protect from sea level rise House retrofitting and design standards – retrofit the defined storm tide affected property Improving flood immunity of public infrastructure – increase level of road to maintain access	54	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Retreat	Land purchase and resumption / land-use change – land purchase and resumption and/or land swap for land that is permanently inundated Flood proofing public infrastructure – connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – land-use change for areas not developed yet but under permanent risk. Planning scheme modifications to reflect land-use change	79	-$12	$3	2080	$8

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	20	-15	NA	NA	NA

3.4.4 Assessed Strategies for Bluewater Beach

Two strategies were considered for the Bluewater Beach Locality–*Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for the Bluewater Beach Locality along with a summary of the MCA and BCA results is provided in Table 10).

Table 10 Strategies considered for Bluewater Beach

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Land-use change – land-use change for areas not developed yet but under permanent risk Planning scheme modifications – to reflect land-use change	65	-$3	$7	2034	$6
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	10	-10	NA	NA	NA

3.5 District D – Saunders Beach

'In the district of Saunders Beach it is expected that planning scheme modifications and landuse changes may optimally enable a retreat from the 1% AEP storm tide event and sea level rise by 2100'.

3.5.1 Description

District D – Saunders Beach – encompasses the land between Althaus Creek and Alick Creek. The Saunders Beach settlement borders Althaus Creek in the north of the district. A nickel treatment plant and associated tailing dams are located near Yabulu.

The Undeveloped land south of Saunders Beach (Saunders Beach Undeveloped) has been excluded from the study area as detailed in Table 4. The nickel plant that resides within this 'undeveloped' area is outside the 2100 1% AEP storm tide extent and thus has not been explicitly considered within the scope of this project. The extent of each Locality is provided in Appendix A.

3.5.2 Coastal risks and vulnerability in Saunders Beach

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Saunders Beach District is provided in Sheet 4 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- The existing risk to property and infrastructure due to current HAT influences is limited with the exception of low lying areas within the Saunders Beach Undeveloped Locality;
- By 2100 up to 166 properties may be affected by either sea level rise or the 1% AEP storm tide event at Saunders Beach
- The 1% AEP storm tide event under current climate conditions poses a risk of above floor flooding to a number of properties at Saunders Beach;
- The 1% AEP storm tide event under future climate conditions poses a significant risk of above floor flooding a properties at Saunders Beach; and
- There is a risk of inundation to key road infrastructure into Saunders Beach due to projected sea level rise.

3.5.3 Assessed Strategies for Saunders Beach

Three strategies were considered for the Saunders Beach Locality–*Accommodate, Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for the Saunders Beach Locality along with a summary of the MCA and BCA results is provided in Table 10).

Strategies considered for Saunders Beach are presented in Table 11 and include

Table 11 Strategies considered for Saunders Beach

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Coastal protection – including beach nourishment, seawalls and groynes and for Saunders Beach a sea levee either on their own or in combination. Raise habitable floor levels to reduce sea level rise impacts. House retrofitting and design standards – retrofit the defined storm tide affected property Improving flood immunity of public infrastructure – maintain access road Planning scheme modification – restrict further development in hazard areas	56	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Retreat	Land purchase and resumption land-use change – land purchase and resumption and/or land swap for land that is permanently inundated Improving flood immunity of public infrastructure –land-use change for areas not developed yet but under permanent risk. Connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – to reflect land-use change	76	-$18	$60	2029	$75

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	20	-77	NA	NA	NA

3.6 District E – Bushland Beach

'In the district of Bushland Beach it is expected that planning scheme modifications and landuse changes may optimally enable a retreat from the 1% AEP storm tide event and sea level rise by 2100'.

3.6.1 Description

District E – Bushland Beach – includes the existing Bushland Beach residential centre and proposed development areas at North Shore. The majority of the Bushland Beach district is residential and is located on the periphery of Townsville centre. It is bound by Alick Creek to the north and Bohle River to the south.

The Bushland Beach district includes the Bushland Beach and North Shore Localities while the small coastal community of Black River Settlement on Batley Parade has been excluded from the study area as detailed in Table 4. The extent of each Locality is provided in Appendix A.

3.6.2 Coastal risks and vulnerability in Bushland Beach

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Saunders Beach District is provided in Sheet 5 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- The existing risk to property and infrastructure due to current HAT influences is limited although it is noted there are existing erosion issues at the southern end of Bushland Beach as advised by TCC;
- The 1% AEP storm tide event under current climate conditions poses a risk of above floor flooding to property along the esplanade at Bushland Beach and a number of properties along Pacific Avenue ;
- By 2100 up to 286 properties may be affected by either sea level rise or the 1% AEP storm tide at Bushland Beach with the majority of this property residing within the estimated coastal erosion-prone area; and
- Infrastructure within erosion-prone zones along Bushland Beach are likely to be affected by 2100.

3.6.3 Assessed Strategies for Bushland Beach

Three strategies were considered for the Bushland Beach Locality– *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for the Bushland Beach Locality along with a summary of the MCA and BCA results is provided in Table 12.

Table 12 Strategies considered for Bushland Beach

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Coastal protection – including beach nourishment, seawalls and groynes either on their own or in combination. to provide erosion and storm tide protection House retrofitting and design standards – raise habitable floor levels Improving flood immunity of public infrastructure – maintain access road Planning scheme modifications – amend planning scheme to allow no future building below storm surge levels	50	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Retreat	Land purchase and resumption / land-use change – land purchase and resumption and/or land swap for land that is permanently inundated Improving flood immunity of public infrastructure – land-use change for areas not developed yet but under permanent risk. Connecting road and services will need to be maintained during the period of retreat Planning scheme modifications –to reflect land-use change	76	-$50	$12	2080	$24
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard areas	20	-62	NA	NA	NA

3.6.4 Assessed Strategies for North Shore

Three strategies were considered for the North Shore Locality– *Defend, Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for the North Shore Locality along with a summary of the MCA and BCA results is provided in Table 13.

Table 13 Strategies considered for North Shore

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Land filling above flood level – raise any low lying land prior to development Improving flood immunity of public infrastructure – ensure North Shore Bld is constructed at a level above inundation or raise above inundation level Planning scheme modifications – amend planning scheme to allow no future building below storm surge levels Relocating access road to higher land	50	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated. Connecting road and services will need to be maintained during the period of retreat Land-use change – land-use change for areas not developed yet but under permanent risk Planning scheme modifications – to reflect land-use change	75	-$4	$5	2039	$3
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard areas	40	-9	NA	NA	NA

3.7 District F – Townsville North

'In the district of Townsville North a combination of retreat from coastal hazard areas and coastal protection of key assets may optimally defend against the 1% AEP storm tide event and sea level rise by 2100'.

3.7.1 Description

District F – Townsville North – is bound by Bohle River to the north and Rowes Bay residential area to the south. The district contains conservation, industrial and aviation uses including the Townsville Airport and associated navigation facilities, the Townsville RAAF Base and other land controlled by the department of defence, and residential communities at Pallarenda and Mount Louisa.

Townsville North contains five Localities: Pallarenda, Industrial, Mt St John WTP , Townsville Airport and the Northern Tip/Common/Shelley Beach areas. As detailed in Table 4, both the Northern Tip and Airport have been excluded from full assessment within the CHAS process. The extent of each Locality is provided in Appendix A.

3.7.2 Coastal risks and vulnerability in Townsville North

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Townsville North District is provided in Sheet 5 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- Infrastructure adjacent to Pallarenda, Townsville Airport and the Mt St John WTP may be subject to unacceptable inundation during the existing HAT influence, although this is likely to be in low lying areas where development is limited;
- The 1% AEP storm tide event under current climate conditions poses a significant risk of above floor flooding to property within the Industrial Area;
- By 2100 up to 122 and 124 properties may be affected by either sea level rise or the 1% AEP storm tide event in Pallarenda and the Industrial Area respectively; and
- Key Infrastructure in Pallarenda, Mount Saint John and the Industrial area may be affected by projected sea level rise, this includes a key water supply pipeline that services Magnetic Island.

3.7.3 Assessed Strategies for Pallarenda

Three strategies were considered for the Pallarenda Locality– *Accommodate, Retreat* and *Maintain Status Quo* with the preferred options from the CHAS process identified as ***Accommodate.***

Detail of each option considered for the Pallarenda Locality along with a summary of the MCA and BCA results is provided in Table 14. The extent of coastal protection works associated the Pallarenda *Accommodate* option is provided in Appendix D.

Table 14 Strategies considered for Pallarenda

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	House retrofitting and design standards – raising habitable floor level against the defined storm tide inundation from creek Improving flood immunity of public infrastructure – connecting road and services to south. Localised raising, and /or improved drainage and /or improved capping of connecting roads along seaward side will protect houses at front, and maintain service . Redesign of golf course to incorporate sea level rise Coastal protection – including beach nourishment, seawalls and groynes either on their own or in combination to provide protection from storm tide erosion and inundation for those blocks that are inundated by king tides and sea-level rise Land swap – nursing home could be used for another purpose that doesn't require as high a level of access from safety perspective as nursing home Planning scheme modifications – amend planning scheme to allow no future building below 1% AEP storm tide levels. Relocating access road to higher land	69	-$19	$7	2080	$16

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption (of whole community not just property affected) – land purchase and resumption and/or land swap for land that is permanently inundated Land-use change – land-use change for areas not developed yet but under permanent risk Planning scheme modifications – planning scheme modifications to reflect land-use change Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat	68	-$45	-$22	2080	$41
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard areas	20	-23	NA	NA	NA

3.7.4 Assessed Strategies for the Industrial Area

Two strategies were considered for the Industrial Area Locality– *Defend* and *Accommodate,* with the preferred option from the CHAS process identified as ***Defend.***

Detail of each option considered for the Industrial Area Locality along with a summary of the MCA and BCA results is provided in Table 15. The extent of coastal protection works associated the Industrial Area *Defend* option is provided in Appendix D.

Table 15 Strategies considered for industrial area

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Coastal protection – sea levees to protect Industrial Area and provide for expansion Land filling above flood level – land filling for new areas	70	$168	$386	2027	$13
Accommodate	Building retrofitting and design standards – raising the operation level of industrial areas Improving flood immunity of public infrastructure – raise, and /or improve drainage and /or improve capping of roads locally Retrofit industry – protect hazardous operations from storm surge	10	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

3.7.5 Assessed Strategies for Mt St John WTP

Two strategies were considered for the Mt St John Locality– *Defend* and *Accommodate* with the preferred option from the CHAS process identified as ***Defend.***

Detail of each option considered for the Mt St John Locality along with a summary of the MCA and BCA results is provided in Table 16. The extent of coastal protection works associated the Mt St John *Defend* option is provided in Appendix D.

Table 16 Strategies considered for Mt St John

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Sea dykes / bund walls – protect buildings to north of STP to allow for STP expansion	70	$8	$21	2027	$3
Accommodate	Building modifications – moving buildings within the site to higher ground	10	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

3.8 District G - Townsville Inner Suburbs

'In the district of Townsville Inner Suburbs a combination of sea levees, storm tide gates, seawalls and beach nourishment may optimally defend against the 100 y Return Period storm tide event and sea level rise by 2100'.

3.8.1 Description

District G – Townsville Inner Suburbs – stretches from Cranbrook and Heatley in the west to Townsville Central City and the Port of Townsville in the east. It is bordered by the Ross River to the south and extends north to Castle Hill and North Ward. The Townsville Inner Suburbs District include the Townsville CBD, the Aitkenvale sub-regional centre, the Currajong and Aitkenvale industrial areas, community and government precincts, as well as a number of inner residential neighbourhoods.

The Townsville Inner Suburbs includes two Localities: The Strand and the Townsville Inner Suburbs (Townsville City: Ross Creek, South Townsville, inner suburbs, Railway Estate, Rowes Bay, Melrose Park and West End). As detailed in Table 4, both the Breakwater Marina and Port of Townsville have been excluded from full assessment within the CHAS process. The extent of each Locality is provided in Appendix A.

3.8.2 Coastal risks and vulnerability in the Townsville Inner Suburbs

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Townsville Inner Suburbs District is provided in Sheet 7 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- Existing HAT influences may cause periodic issue to infrastructure adjacent to Ross Creek and Railway Estate;
- There is limited risk to property within the Strand from the 1% AEP storm tide event;
- There is significant risk posed by the existing 1% AEP storm tide event to infrastructure and property, particularly within Railway Estate and adjacent to Ross Creek;
- Projected sea level rise poses a significant threat to the Townsville Inner Suburbs with up to 2764 properties affected by 2100;
- The 1% AEP storm tide event under projected sea level rise and climate change poses significant threat to the Townsville Inner Suburbs with 3372 properties affected by 2100; and
- There are significant infrastructure assets at risk due to projected sea level rise and climate change impacts.

3.8.3 Assessed Strategies for The Strand

Throughout the project TCC have indicated that the current coastal protection strategy (which involves periodic beach nourishment to supplement the existing seawall and artificial headland configuration) will be continued at The Strand, a culturally significant area of Townsville.

3.8.4 Assessed Strategies for Townsville Inner Suburbs (Rowes Bay, Melrose Park, South Townsville and Railway Estate)

Two strategies were considered for the Townsville Inner Suburbs Locality. This included three *Defend*, two *Accommodate* and a *Retreat* Option. The preferred option from the CHAS process identified as ***Defend Option 1.***

Detail of each option considered for the Townsville Inner Suburbs Locality along with a summary of the MCA and BCA results is provided in Table 17. The extent of coastal protection works associated the Townsville Inner Suburbs *Defend 1* is provided in Appendix D.

Table 17 Strategies considered for Townsville City

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend 1	Seeks to defend Railway Estate, Rowes Bay and the rest of the city by creating new roads/levees Ross River levee Sea dikes and storm tide barrier at Ross Creek (Defending here forms part of protection for the overall city in combination with Defence works at Rowes Bay and Railway Estate) Defend watercourse by providing sea dikes at Rowes Bay for all potential developable land taking into account drainage paths. Includes residential area along seafront, cemetery, and industrial area east of airport. Accommodate foreshore of Rowes Bay. (defending here forms part of protection for Melrose Park etc)	72	$724	$1,732	2027	$190

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend 2	Defend 2 seeks to defend Railway Estate, Rowes Bay and the rest of the city from storm tide, while accommodating the defined storm tide inundation within North Ward Ross River levee – defend by raising road levels (Railway Ave, Boundary St) Sea dikes and storm tide barrier at Ross Creek (defending here forms part of protection for the overall city in combination with Defence works at Rowes Bay and Railway Estate) Defend Captains Creek and accommodate at North Ward. Improving flood immunity of public and private infrastructure – raise housing habitable floor levels. Increase height of public infrastructure (roads) Planning scheme modifications – increase minimum housing habitable floor levels	61	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Defend 3	Defend 3 seeks to, defend the city while accommodating in Rowes Bay and accommodation/ retreat in Railway Estate Raise Railway Avenue and Boundary Street to act as levees – defend by raising road levels (Railway Ave, Boundary St) Sea dikes and storm tide barrier at Ross Creek (Defending here forms part of protection for the overall city in combination with Defence works at Rowes Bay and Railway Estate) Improving flood immunity of public and private infrastructure – raise housing habitable floor levels. Increase height of public infrastructure (roads) Planning scheme modifications – increase minimum housing habitable floor levels	53	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate 1	Flood proofing public and private infrastructure – localised dykes to protect against permanent inundation. To maintain access and services. Cemetery - ground water drainage option need to be provided to maintain dry plots or consider above ground Coastal protection – including beach nourishment, seawalls, sea dykes and groynes either on their own or in combination. to protect against erosion along foreshore Planning scheme modifications – to limit development to areas above the defined storm tide level Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Land use change – land-use change for areas not developed yet but under permanent risk. Connecting road and services will need to be maintained during the period of retreat. Re-zone existing residential properties in affected areas. Dearness Road is inundated but does not cut access, alternate routes are still maintained. Planning scheme modifications to reflect land-use change. Raise habitable floor level and low lying areas to maintain access	31	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Accommodate 2	Similar to Defend 3 but coastal protection works to protect against seal level rise only.	26	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Improving flood immunity of public and private infrastructure – localised dykes to protect against permanent inundation. To maintain access and services. Cemetery - ground water drainage option need to be provided to maintain dry plots or consider above ground Coastal protection – including beach nourishment, seawalls, sea dykes and groynes either on their own or in combination. to protect against erosion along foreshore Planning scheme modifications – to limit development to areas above the defined storm tide level Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Land use change – land-use change for areas not developed yet but under permanent risk. Connecting road and services will need to be maintained during the period of retreat. Re-zone existing residential properties in affected areas. Dearness Road is inundated but does not cut access, alternate routes are still maintained. Planning scheme modifications to reflect land-use change Raise habitable floor level and low lying areas to maintain access	55	-$216	$792	2027	$1,132

3.9 District H – River South

'In the district of River South a combination of sea levees and infrastructure upgrades may optimally defend against the 1% AEP storm tide event and sea level rise by 2100'.

3.9.1 Description

District H – River South – incorporates those areas south of Ross River to the north of the Bruce Highway, River South includes one Locality, Oonoonba.

3.9.2 Coastal risks and vulnerability in River South

Coastal hazard vulnerability and risk mapping of property and infrastructure for the River South District is provided in Sheet 8 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- Existing HAT influences may cause periodic issue to infrastructure and property adjacent to Ross River and Abbot St including low-lying areas of Old Oonoonba;
- Unacceptable risk posed by the existing 1% AEP storm tide event to property is limited to Old Oonoonba;
- Sea level rise poses a significant threat to Oonoonba with up to 182 properties affected by 2100;
- The 1% AEP storm tide event under projected sea level rise and climate change poses significant threat to the Oonoonba with 363 properties affected by 2100; and
- Infrastructure assets (railway) are at risk due to projected sea level rise and climate change impacts.

3.9.3 Proposed strategy for Oonoonba

Three strategies were considered for the Oonoonba Locality– *Defend*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Defend.***

Detail of each option considered for the Oonoonba Locality along with a summary of the MCA and BCA results is provided in Table 18. The extent of coastal protection works associated the Oonoonba *Defend* option is provided in Appendix D.

Table 18 Strategies considered for Oonoonba

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Coastal protection – dyke to defend against permanent inundation level (not storm tide). Provision of drainage solution with sump and pump systems is standard practice for dyke design. House retrofitting and design standard – raise habitable floor level Land filling above flood level – raising land above permanent inundation level Improving flood immunity of public infrastructure – rail elevated (pier) to allow overland flood. Protect public infrastructure (roads, water, sewer, power) (Note: The cost of upgrading rail infrastructure has not been assessed) Planning scheme modifications – no intensification of old Oonoonba Land use changes – buyback for worst affected areas. Building Standards	54	$127	$277	2027	$10

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption / land-use change – land purchase and resumption and/or land swap for land that is permanently inundated Improving flood immunity of public infrastructure – rail elevated (pier) to allow overland flood. Protect public infrastructure (roads, water, sewer, power) Planning scheme modifications – Land-use change for areas not developed yet but under permanent risk. Connecting road and services will need to be maintained during the period of retreat. Planning Scheme Modifications to reflect land-use change	61	-$84	$66	2027	$221
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	20	-150	NA	NA	NA

3.10 District I – Stuart

'In the district of Stuart a combination of sea levees and infrastructure upgrades may optimally defend against the 1% AEP storm tide event and sea level rise by 2100'.

3.10.1 Description

District I – Stuart – encompasses the Cleveland Bay Sewage Treatment Plant, Zinc Plant and coastal areas east of the Bruce Highway. The majority of land within the district provides for environmental conservation and industrial usage with the exception of the Cluden residential area.

As detailed in the Table 4 the zinc plant has been excluded from the full CHAS assessment.

3.10.2 Coastal risks and vulnerability in Stuart

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Stuart District is provided in Sheet 9 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- Existing HAT influences may cause periodic issue to infrastructure however his is typically limited to low lying undeveloped areas;
- HAT influences under sea level rise projections are likely to affect the Sturt/Cleveland Bay WTP by 2100; and
- The 1% AEP storm tide event is likely to affect the Sturt/Cleveland Bay WTP. Under projected climate change, an unacceptable risk of inundation will be posed to the WTP during the 1% AEP storm tide event.

3.10.3 Strategies considered for Stuart / Cleveland Bay sewage treatment plant

Two strategies were considered for the Cleveland Bay STP– *Defend* and *Accommodate* with the preferred option from the CHAS process identified as ***Defend.***

Detail of each option considered for the Cleveland Bay STP Locality along with a summary of the MCA results is provided in Table 19. It is noted that for the Cleveland Bay STP a detailed BCA was not conducted due to limitations in the available GIS data extents for this location (for further details please refer to the Learnings Report provided in Appendix C).

Table 19 Strategies considered for Stuart / Cleveland Bay sewage treatment plant

Strategy	Description	MCA result
Defend	Coastal protection – construction of sea levee to protect components of the sewage treatment plant Improving flood immunity of public infrastructure – raise road to maintain access, sewer lines/pump stations to site to be upgraded if necessary dyke to protect low-lying areas of plant Land filling above flood level – land filling required if future expansion is required	40
Accommodate	Coastal protection – construction of sea levee to protect components of the sewage treatment plant (less area protected than the defend option) Improving flood immunity of public infrastructure – raise road to maintain access, sewer lines/pump stations to site to be upgraded if necessary Increase level of existing dyke to protect low lying areas of the plant	30

3.11 District J – South Land

'In the district of South Land it is expected that planning scheme modifications and landuse changes may optimally enable a retreat from the 1% AEP storm tide event and sea level rise by 2100'.

3.11.1 Description

District J – South Land –incorporates the areas of Cape Cleveland, Alligator Creek, Woodstock, Nome, Mount Elliot and Cungulla. South Land includes defence, rural, rural residential and green space uses. Local centres are located at Alligator Creek, Woodstock and Cungulla.

District J includes the Locality of Cungulla. As detailed in Table 4 The Cleveland Palms residential community located to the north of Alligator Creek has been excluded from the full CHAS assessment process.

3.11.2 Coastal risks and vulnerability in South Land

Coastal hazard vulnerability and risk mapping of property and infrastructure for the South Land District is provided in Sheet 10 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- Existing HAT influences result in limited impact to property and infrastructure assets;
- The 1% AEP storm tide event under currently climate conditions results in limited risk to property in Cungulla;
- By 2100 up to 156 properties may be affected by projected sea level rise at Cungulla, primarily within estimated erosion-prone areas;
- By 2100 up to 255 properties are estimated to be impacted by above floor flooding during the 1% AEP storm tide event; and
- It is likely that key road infrastructure required to access Cungulla will be affected by 2100. It is noted that the EHP provided mapping for the 2100 sea level rise and 1% AEP storm tide event provides detail for coastal Cungulla only.

3.11.3 Proposed strategy for Cungulla

Three strategies were considered for the Cungulla Locality– *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat or Maintain Status Quo***. Detail of each option considered for the Cungulla Locality along with a summary of the MCA and BCA results is provided in Table 20. The extent of the Cungulla Locality is provided in Appendix A.

Table 20 Strategies considered for Cungulla

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Coastal protection – including beach nourishment, seawalls, sea dykes and groynes either on their own or in combination to protect against foreshore erosion Improving flood immunity of public infrastructure – raise road to maintain access (including access to AIMS along Cape Cleveland road) or flood proof road (eg resilient material) House retrofitting and design standards – raise habitable floor level above defined storm tide level	44	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	NA
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Land-use change – land-use change for areas not developed yet but under permanent risk Planning scheme modifications –to reflect land-use change (no intensification)	74	-$27	-$9	2047	$26
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area.	25	-18	NA	NA	NA

3.12 District K – Magnetic Island

'In the district of Magnetic Island a combination of retreat from coastal hazard areas and coastal protection may optimally defend against the 1% AEP storm tide event and sea level rise by 2100'.

3.12.1 Description

District K – Magnetic Island – consists of isolated settlements separated by rocky headlands and sandy bays. The majority of the island is dedicated to environmental conservation with residential and tourism accommodation restricted to Picnic, Nelly and Horseshoe Bays and Arcadia.

There are nine Localities within the Magnetic Island District – Horseshoe Bay, Arcadia (Geoffrey Bay), Nelly Bay, Picnic Bay, Picnic Point WTP , Cockle Bay (indicated as 'Lots' within Appendix A), West Point, Bolger Bay Pump Station, and Radical Bay. As detailed in Table 4 Nelly Bay Harbour has been excluded from the full CHAS assessment process.

3.12.2 Coastal risks and vulnerability in Magnetic Island

Coastal hazard vulnerability and risk mapping of property and infrastructure for the Magnetic Island District is provided in Sheet 11 of each of the relevant Map Series of Appendix A. Review of the mapping indicates:

- Property within the West Point, Nelly Bay and Horseshoe Bay may be subject to periodic risk of tidal inundation;
- Property with Horseshoe Bay, Nelly Bay, Picnic Point/West Point Localities are likely to affected by the 1% AEP storm tide event;
- By 2100, 37 (Horseshoe Bay), 61 (Geoffrey Bay), 44 (Nelly Bay), 47 (Picnic Bay) and 26 (West Point) properties are estimated to be affected by sea level rise or the 1% AEP storm tide event;
- The majority of infrastructure servicing Magnetic Island is located along the coastal fringe including key road access, the Picnic Bay WTP and the Bolger Bay pump station. While this infrastructure is periodically affected currently by the 1% AEP storm tide event, it is estimated that projected sea level rise may lead to unacceptable risk by 2100;
- That coastal protection works in Pallarenda will need to align closely with the overall Strategy for Magnetic Island due to the location of key trunk water and sewage supply pipelines.

3.12.3 Proposed strategy for Horseshoe Bay

Three strategies were considered for the Horseshoe Bay Locality– *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat***.

Detail of each option considered for the Horseshoe Bay Locality along with a summary of the MCA and BCA results is provided in Table 21. The extent of the Horseshoe Bay Locality is provided in Appendix A.

Table 21 Strategies considered for Horseshoe Bay

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Beach nourishment – beach nourishment for erosion protection Improving flood immunity of public infrastructure – raise road to maintain access House retrofitting and design standards – Properties to east of Horseshoe Bay will lose beach access. Raise habitable floor level above defined storm tide level	49	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only
Retreat	Land purchase and resumption land-use change – land purchase and resumption and/or land swap for land that is permanently inundated. Land-use change for areas not developed yet but under permanent risk Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – to reflect land-use change	79	-$13	$7	2036	$16

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	28	-20	NA	NA	NA

3.12.4 Proposed strategy for Arcadia (Geoffrey Bay)

Three strategies were considered for the Arcadia (Geoffrey Bay) Locality– *Accommodate*, *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat or Maintain Status Quo***.

Detail of each option considered for the Arcadia (Geoffrey Bay) Locality along with a summary of the MCA and BCA results is provided in Table 22. The extent of the Arcadia (Geoffrey Bay) Locality is provided in Appendix A.

Table 22 Strategies considered for Arcadia (Geoffrey Bay)

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Accommodate	Coastal protection – buried seawall abutting road and beach nourishment (as necessary) for erosion protection along beach front. Raise existing Harbour Wall and extend to higher ground to protect from permanent inundation and defined storm tide Improving flood immunity of public infrastructure – upgrade Marine Parade at Hordern Ave providing tidal gates to stop inundation near bowls club. Assume Sooning St Bridge is above defined flood level and access is maintained House retrofitting and design standards – raising habitable floor levels above defined storm tide level. Raising land filling above flood level for bowls club when redeveloped	45	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Land-use change – land-use change for areas not developed yet but under permanent risk Planning scheme modifications –to reflect land-use change	79	-$7	-$1	2089	$5
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	28	-6	NA	NA	NA

3.12.5 Proposed strategy for Nelly Bay

Two strategies were considered for the Nelly Bay Locality– *Defend* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Defend of Maintain Status Quo.***

Detail of each option considered for the Nelly Bay Locality along with a summary of the MCA and BCA results is provided in Table 23. The extent of the Nelly Bay) Locality is provided in Appendix A while the extent of coastal protection works associated with the Nelly Bay *Defend* option is provided in Appendix D.

Table 23 Strategies considered for Nelly Bay

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Coastal protection – sunken seawalls along roadside to provide erosion and defined storm tide protection along beach front catering for future development. Beach nourishment from Gustav Creek Improving flood immunity of public infrastructure – raise and protect The Esplanade to maintain access and provide protection for landward housing from erosion and the defined storm tide House retrofitting and design standards – raise habitable floor level for lot 1a (Backpackers Hostel) to above the defined storm tide level	60	-$7	-$2	2089	$4
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	35	-6	NA	NA	NA

3.12.6 Proposed strategy for Picnic Bay

Strategies considered for Picnic Bay

Four strategies were considered for the Picnic Bay Locality– *Defend, Accommodate, Retreat* and *Maintain Status Quo* with the preferred options from the CHAS process identified as ***Defend***

Detail of each option considered for the Picnic Bay Locality along with a summary of the MCA and BCA results is provided in Table 24. . The extent of the Picnic Bay Locality is provided in Appendix A while the extent of coastal protection works associated with the Picnic Bay *Defend* option is provided in Appendix D.

Table 24 Strategies considered for Picnic Bay

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Sea levee, storm gated culvert structure and sea wall for erosion protection.	64	-$7	$0	2089	$3
Accommodate	Coastal protection – buried seawalls with beach nourishment to provide erosion and defined storm tide protection along beach front catering for future development Improving flood immunity of public infrastructure – raise and protect The Esplanade to maintain access and provide protection for landward buildings from erosion and the defined storm tide Building standards/retrofit – raise habitable floor levels above the defined storm tide level	48	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Land-use change – land-use change for areas not developed yet but under permanent risk Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – to reflect land-use change	79	-$8	-$1	2089	$3
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	20	-7	NA	NA	NA

3.12.7 Proposed strategy for Picnic Point wastewater treatment plant

Two strategies were considered for the Picnic Point WTP– *Defend* and *Accommodate* with the preferred option from the CHAS process identified as ***Defend.***

Detail of each option considered for the Picnic Point WTP along with a summary of the MCA and BCA results is provided in Table 25. The extent of coastal protection works associated the Picnic Point WTP *Defend* option is provided in Appendix D.

Table 25 Strategies considered for Picnic Point water treatment plant

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Coastal protection – construct sea dyke around plant If expansion required Improving flood immunity of public infrastructure – subsequent upgrades are mindful of hazard when setting levels for vulnerable plant and buildings.	50	$117	$255	2028	$1
Accommodate	Coastal protection – provide sea wall around plant to protect against sea level rise hazard but not the defined storm tide inundation Land filling above the defined flood level Improving flood immunity of public infrastructure – subsequent upgrades are mindful of hazard when setting levels for vulnerable plant and buildings.	10	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

3.12.8 Proposed strategy for Cockle Bay Lots[3]

Two strategies were considered for the Cockle Bay Lots – *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat.***

Detail of each option considered for the Cockle Bay Lots along with a summary BCA results is provided in Table 26. It is noted that due to the limited number of options developed for this location direct assessment in the BCA was undertaken.

Table 26 Strategies considered for Cockle Bay (Lots)

Strategy	Description	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption – land purchase and resumption and/or land swap for land that is permanently inundated Land-use change – land-use change for areas not developed yet but under permanent sea level rise risk Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – to reflect landuse change	-$0.2	$0.9	2027	$0.8
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	-1	NA	NA	NA

[3] Shown as 'LOTS' within Appendix A.

3.12.9 Proposed strategy for West Point

Two strategies were considered for the West Point Locality – *Retreat* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Retreat.***

Detail of each option considered for West Point along with a summary of the MCA and BCA results is provided in Table 27.

Table 27 Strategies considered for West Point

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Retreat	Land purchase and resumption / land-use change – land purchase and resumption and/or land swap for land that is permanent inundated. Land-use change for areas not developed yet but under permanent risk Improving flood immunity of public infrastructure – connecting road and services will need to be maintained during the period of retreat Planning scheme modifications – to reflect land-use change	75	-$10	$9	2042	$8
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	10	-18	NA	NA	NA

3.12.10 Proposed strategy for Bolger Bay Pump Station

Two strategies were considered for the Bolger Bay Pump Station Locality– *Defend, Accommodate* with the preferred option from the CHAS process identified as ***Defend***

Detail of each option considered for the Bolger Bay Pump Station Locality along with a summary of the MCA and BCA results is provided in Table 28. The extent of the Bolger Bay Pump Station Locality is provided in Appendix A while the extent of coastal protection works *Defend* option is provided in Appendix D.

Table 28 Strategies considered for Bolger Bay pump station

Strategy	Description	MCA score	Project NPV (M)	NPV Project - NPV Maintain Status Quo (M)	Optimal Year of Adaptation Implementation	PV Cost of Adaptation Investment (M)
Defend	Sea dykes – provide bund around plant if expansion required Land filling above defined flood level	70	-$10	$9	2042	$8
Accommodate	Sea dykes – provide bund around plant. Suggest subsequent upgrades are mindful of hazard when setting levels for vulnerable plant and buildings.	0	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only	Assessed via MCA only

3.12.11 Proposed strategy for Radical Bay

Two strategies were considered for the Radical Bay Locality– *Accommodate* and *Maintain Status Quo* with the preferred option from the CHAS process identified as ***Accommodate.***

Detail of each option considered is provided in in Table 29.

For Radical Bay a full BCA was not undertaken as part of the CHAS as the area is currently undeveloped. Should redevelopment occur the existing and future coastal and ocean hazards identified during the CHAS should be used to inform the design and approval process.

Table 29 Strategies considered for Radical Bay

Strategy	Description	MCA result
Accommodate	Land use planning – keep new development outside hazard areas Coastal protection – buried seawall to protect against erosion	65
Maintain Status Quo	Property searches include a hazard note Planning scheme modification Public education Allow natural processes Consider public response Property owners responsibility Rates reduction of properties within coastal hazard area	35

4. Review and Revision of the Proposed Strategy Options

The Townsville CHAS study represents the first of its kind completed for coastal Councils in Queensland. The project has been valuable in identifying and developing processes to:

- Identify coastal areas at risk;
- Develop adaptation options to mitigate risks;
- Communicate risks and potential adaptation measures to key stakeholders and the community; and
- Provide an economic methodology that can be utilised to assess the viability of these options moving into the future.

Importantly, it must be recognised that this CHAS study is likely the first in a potentially long line of future increasingly detailed adaptation assessments that will need to be conducted to develop viable options for the Townsville community.

Being both a Pilot Study and also the first coastal hazard adaptation study completed for TCC, throughout the process there has been a number of areas where future refinement will lead to better estimates of likely cost and timing for implementation. A number of these key items are detailed in the following sections.

For the interested reader, Appendix C provides a full detailed assessment of Learnings from the Pilot project. Many of these learnings should be adopted in future revision and update of the Townsville CHAS Study.

4.1 Review and Update of the Townsville CHAS Study

4.1.1 Refinement of Coastal Hazard Areas, Wave Setup, Runup and Freeboard Allowances

Throughout the economic assessment it became apparent that the recommended options (particularly the timing) are highly sensitive to the extent of estimated sea level rise projections and coastal erosion-prone areas. The most sensitive regions are the small coastal communities sited on the frontal dune system, i.e. the Northern Beaches and Cungulla. It is recommended that future CHAS studies for the Townsville area look to more accurately estimate erosion-prone extents over the period 2012 -2100.

For example, EHP-supplied hazard surfaces utilised here assumed the following rules for wave-related elevation impacts over and above tide plus storm surge and sea level rise:

- Application of the GHD/SEA (2007) wave setup elevation within 200 m of the “coastline”;
- Application of wave setup elevation and a nominal wave runup elevation of +1 m within 50 m of the “coastline”;
- A nominal “freeboard” uncertainty allowance of +0.3 m for 2010, rising to +0.35 m by 2100 for areas exceeding 200 m from the ‘coastline’..

Also, while ‘bathtub’ mapping of surfaces outside of the erosion-prone areas was utilised for the Townsville CHAS assessment, future work could be undertaken using hydrodynamically modelled storm tide levels such as those currently held by TCC for tropical cyclone impacts (GHD/SEA, 2007) and future modelling under projected sea level rise.

In summary, the accuracy of the results from the economic assessment (particularly the BCA) is largely dependent on how well the coastal hazard areas are defined. Effort applied in improving the estimates of likely future coastal hazards will lead to improved estimates of viable coastal adaptation. The present assumptions are likely to result in conservative estimates of the actual impacts and thereby overstate the risks in many areas.

4.1.2 Refinement of the Economic Assessment

The economic assessment completed for the Townsville CHAS provides a detailed and robust framework for assessing the potential benefits and costs to the community into the future. Where practical, it is recommended that the cost estimation and design of adaption options be further investigated and refined over time for input to the BCA. This may include the identification of interim measures, collaboration with non-TCC stakeholders and improved conceptual adaptation designs.

There also remains much uncertainty over social and legal costs associated with the implementation of coastal hazard adaptation, e.g. market value of property, willingness to pay, compensation and indirect impacts to the economy. Where practical, new research in this field and available examples of coastal adaptation should be incorporated into the economic assessment/CHAS Study process. It is recommended in future that the sensitivity of BCA results to the aforementioned be assessed by undertaking various scenarios of potential community and legal response to climate change adaptation.

4.1.3 Further Investigation of Options

Options developed for the Northern Beaches and Cungulla did initially consider *Accommodate* however due to the limited timeframe and budget of the Townsville Pilot these options were not fully considered within the BCA. In future there may be opportunity to revisit these options to determine if they are economically viable.

The conceptual design of *Defend* and *Accommodate* options has been developed based on protection to the arbitrary 1% AEP storm tide event, as required in the project Scope of Works. It is recommended that further assessment be undertaken to design coastal protection infrastructure to an immunity level that reflects the **risk** to property and key infrastructure within the Townsville Region. This would be achieved by allowing the immunity level to be a variable in the analyses rather than a fixed value.

4.1.4 Consideration of Sea Level Rise Uncertainty

There is inherent uncertainty in the rate of projected sea level rise moving into the future. It is recommended that the Townsville CHAS be refined in response to the available science i.e. the International Panel on Climate Change Report 5 due in 2013-2014.

If significant infrastructure works are to be considered for future construction, it is recommended that the planning period be extended beyond 2100.

4.1.5 Community Consultation

Throughout the project it was generally recognised by TCC that the timeframe of the CHAS was too short to allow adequate community engagement as well as obtain the necessary support from Council. It is recognised that community consultation will form a major component in undertaking coastal hazard adaptation. It is recommended that Community and Stakeholder Engagement Plan developed as a component of this CHAS Study be refined or implemented in future amendments of the CHAS study.

4.1.6 Update of the Townsville City Plan

Where practical, recommendations and issues identified throughout the CHAS Study should be considered for implementation in appropriate sections of the Townsville City Plan. While no longer mandatory, the findings of the CHAS Study address significant future planning and engineering challenges for the region and should be further considered in future revisions of the planning scheme in accordance with SPA.

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5. Conclusion

The Townsville Coastal Hazard Adaptation Strategy study represents the first of its kind undertaken for any Queensland coastal Council that provides guidance on potential climate adaptation measures for Townsville City and a framework that other coastal Councils can adopt or modify to meet their requirements.

This CHAS study recommendations are critically dependent on the knowledge available of the coastal hazard risks for the Townsville region and the various associated assumptions.

Development of Adaptation Options

Detailed coastal hazard, vulnerability and risk mapping for property and infrastructure under existing and future ocean hazards (refer Appendix A) has provided the basis for the development of over 150 separate adaptation options for 11 separate coastal Districts within the Townsville City Council coastal region. These options have been developed under three broad categories, *Defend*, *Accommodate* and *Retreat* through a series of Consultant, State Government, Townsville City Council and Local Stakeholder Workshops.

Economic Assessment

The aforementioned workshops have been used to refine and filter potential options down to a manageable number for economic appraisal via a combination of Multi-Criteria Assessment and Benefit-Cost Analyses. The economic assessment presented here provides a robust and repeatable method on which future CHAS studies can be based and, as will likely be necessary, made more detailed over time. A number of interesting conclusions can be drawn from the economic appraisal:

- The timing of adaptation is highly related to sea level rise and in small coastal beach communities the extent of erosion-prone areas. It is recommended that further work be undertaken to more accurately map changes in erosion-prone area extent over time.
- For smaller coastal communities the economic assessment suggests that *Retreat* is a more viable option for implementation. For regions with significant infrastructure and asset value *Defend* is considered more viable.
- The time required to act may be sooner than initially thought with options such as Townsville *Defend* having an optimal economic implementation timing within the next 25 y;
- There is significant effort required to ensure adequate representation between the interplay of incremental asset losses due to projected sea level rise and subsequent storm tide events that affect the remaining assets; and
- While an optimal year for implementation may be indicated from the BCA results, for many locations there is a wider 'window' in which options will still be economically viable. Importantly this economic viability will need to be considered with the knowledge that delayed action may result in the loss of community assets and sentiment.

Specifically, results from the BCA indicate:

- As expected, the economic viability of undertaking a *Maintain Status Quo* approach is limited and other forms of adaptation should be preferred over this option (although there are some exception mentioned below);
- In 5 Localities, there exists an adaptation option that when implemented would result in a positive economic outcome: This includes:

  - Mt St John (*Defend*);
  - Industrial area (*Defend*);
  - Townsville Inner Suburbs (*Defend Option 1*);
  - Oonoonba (*Defend*); and
  - Picnic Point WTP (*Defend* Option).

- In 18 Localities, it was found that none of the adaptation strategies considered would be considered as economically viable. However, in 14 of these 18 Localities the assessment indicates there is potential to reduce the damage or loss associated with the *Maintain Status Quo* approach by funding *Defend*, *Accommodate* or *Retreat* adaptation options in these areas;
- In the remaining four (4) study areas invested in the BCA, none of the adaptation options considered produced an outcome that was greater than the *Maintain Status Quo* result These areas were:
- Cungulla;
- Arcadia (Geoffrey Bay);
- Nelly Bay; and
- Bolger Bay Pump Station.

The results at these four locations indicate that none of the adaptation options investigated are economically viable.

It is recommended that future CHAS study revisions aim to better quantify cost estimations of potential adaptation options, the method to assess the process of retreat/abandonment and also the methods to define coastal hazard areas, particularly the use of hydrodynamically modelled storm tide extents and improved methods of coastal erosion zones. Each of the aforementioned has been shown though the course of the CHAS Study to significantly influence the 'optimal' timing for implementation.

A number of additional issues and recommendations relating to the economic assessment are provided in Appendix B and Appendix C.

Selected Adaptation Options

The highest ranking coastal hazard adaptation options for Townsville area are provided in Table 3. In the case of *Defend* or *Accommodate* options being the most preferred for a given Locality the indicative extent of works is provided in Appendix D.

Funding

Based on the results of the BCA it is estimated that a number of adaption options may require considerations of funding prior to 2030. It should be recognised that these cost estimates represent the first stage in estimating the true cost of adaptation. They should not be soley relied upon for financial planning. Further studies must be undertaken to refine the current estimates.

Community Consultation

Initially the CHAS scope of works was proposed to include extensive community consultation including elected representative briefings, targeted community workshops, a free call project information line, web content and media releases. During the CHAS process it became apparent that the timeframe of the CHAS was too short to allow adequate community engagement as well as obtain the necessary support from Council. Subsequently, a decision was made by TCC to cancel all community consultation associated with the project until a later

date. It is noted that recommendations outlined in the CHAS have the potential to be politically sensitive and may require extensive stakeholder engagement in order to both inform the community and capture stakeholder sentiment. As such, the recommended stakeholder engagement process should prescribe core engagement activities required throughout all phases of the CHAS process i.e. education preceding formal announcement, throughout the CHAS development and implementation phases. In designing a community education and consultation program, emphasis must be placed on the long lead times before action is considered necessary (typically 25 to 80 years).

Closing Remarks

CHAS studies are inherently complex undertakings that will provide critically important information needed for strategy development, planning and implementation by coastal Councils for generations to come. Throughout the Townsville CHAS Study pilot project process it has become clear that the complexity of the investigation required a very significant level of effort and data in order to assemble the most basic yet essential set of information capable of addressing the study requirements. The findings of the CHAS study represent the first step in providing coastal protection or adaptation plans for vulnerable coastal communities. This work will underpin a significant investment in the future viability of coastal communities and as such is deserving of a high priority in Government funding allocations. Councils responsible for vulnerable coastal communities should recognise that they have a responsibility to ensure that the long term viability of 'at risk' localities can be based reliably on the outcomes of their CHAS study and its future revisions.

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Appendices

Appendix A Vulnerability/Risk Assessment

Appendix B Economic Assessment

Appendix C Learnings Report

Appendix D Extent of Selected Adaptation Options

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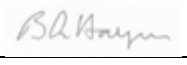
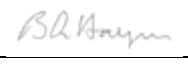
2	M.Smith	B.Harper		B.Harper		26/10//2012

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