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Multi-criteria Analysis of Climate Change Adaptation Options

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Regional Council Coastal Hazard Adaptation Strategy:
Multi-criteria Analysis of Climate Change Adaptation Options

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1 Introduction

1.1 Project background

Whitsunday Regional Council (WRC) is seeking to be one of the most advanced Councils in Queensland in regards to responding to coastal hazards and climate change. To achieve this goal, WRC is developing a Coastal Hazard Adaptation Strategy (CHAS) to assist in identifying and responding to coastal hazards in a way which minimises the risks to assets in the Whitsunday region.

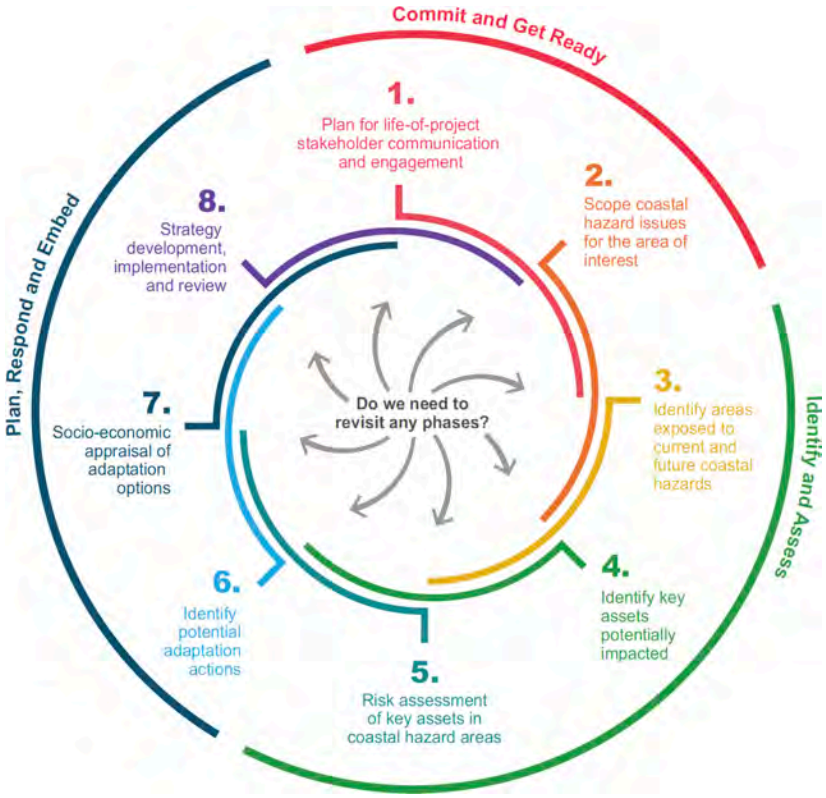
The strategy will enable more informed decisions about planning issues associated with coastal hazards and climate change. The objectives of the project are to:

- understand how climate change and coastal hazards affect coastal communities, local economy, natural environment and WRC operations (current and future impacts);
- identify areas likely to be exposed to current and future coastal hazards (e.g. storm tide, coastal erosion and inundation and sea level rise);
- assess the vulnerabilities and risks to key Council and community assets through a comprehensive data collection and spatial analysis process;
- develop potential coastal adaptation options to mitigate the impact of these hazards; and
- assess the viability of adaptation options through stakeholder engagement and economic analysis.

1.2 Phases of a CHAS

Each CHAS is delivered in eight phases which align with the $QCoast_{2100}$ Minimum Standards and Guidelines (the 'minimum standards'), provided by Local Government Association of Queensland (LGAQ) (see Figure 1). This document describes findings from Phase 7 of the minimum standards, the *Socio-economic appraisal of adaptation options* (the 'socio-economic appraisal'), carried out by Griffith University and Ian Edwards (the 'project team') (the full project team is list in Appendix A).

Figure 1: Recommended process for Coastal Hazard Adaptation Strategy (QCoast 2100, 2016)



1.3 Phase 7 of the CHAS: socio-economic appraisal

The previous phase of the CHAS (Phase 6) identified an inventory of potential options that can be applied to reduce or eliminate priority risks identified in a risk assessment undertaken in Phase 5 of the CHAS. The objective of this phase of the CHAS (Phase 7) is to undertake a socio-economic appraisal of these options in order to aid council determine preferred options to be employed.

In accordance with the minimum standards the socio-economic appraisal is undertaken in two steps:

1. Multi-criteria Criteria Analysis (MCA)

An MCA provides a qualitative framework that ensures that assessment criteria extend beyond financial criteria to incorporate community social, economic and environmental values. MCA provides a cost-effective platform to narrow down the range of identified adaptation options to a manageable number for which economic benefits and costs can be subsequently be analysed and compared. MCA is performed by screening each adaptation option through a range of qualitative or semi-quantitative criteria as discussed below.

2. Cost Benefit Analysis (CBA)

A CBA applies an economic lens to the filtered inventory of adaptation options identified from the MCA. It can assist in identifying the option that achieves maximum value for money benefit for a council. It identifies many costs and benefits of an option, including social and environmental values according to their net economic benefit. The costs and benefits of an option are forecast over the life of the project, costs are subtracted from benefits to determine the net present economic value (NPEV) of the project. The option with the greatest NPEV should provide the greatest net benefit to the community or the most economic use of resources (i.e. Benefit/cost ratio greater than one or a positive NPEV).

The socio-economic appraisal comprises of three stages, reported here; namely:

Stage 1. Online survey, designed to establish the criteria and scoring for a multi-criteria analysis (MCA) of adaptation options;

Stage 2. MCA process, based on survey results, to make recommendations for adaptation approaches [1] for two areas of interest (AOI): Wilson Beach and Bowen; and

Stage 3. Social cost benefit analysis (SCBA) for two adaptation approaches (in addition to modelling the base case, or business-as-usual) in the AOIs.

The key conclusions from these stages will be combined and synthesised in an appraisal report that will be prepared at the end of this phase.

The purpose of this document is to report on the methodology and findings from stages (i) to (iii), described above, and to also report back preliminary findings from a workshop held in the Proserpine between WRC and the project team on 30 September 2019. This workshop covered reporting of the results of stages (i) and (ii), above, and the initial discussions for stage (iii); namely consideration of the social costs benefit analysis of the agreed adaptation approaches.

1.4 Selection of areas of interest

Budget and time constraints limit areas of interest (AOIs) to two representative sites, which were agreed in consultations between WRC and the project team. Whilst limitations in similarities are acknowledged, Bowen was selected as a location representative of a heterogenous, larger and relatively buoyant socio-economy, e.g. Cannonvale and Airlie Beach; Wilson Beach was selected to represent smaller, more isolated communities, such as Dingo Beach and Hideaway Bay. Both Bowen and Wilson Beach were both identified as relatively particularly vulnerable to coastal hazards during a vulnerability assessment undertaken as part of Phase 4 of the WRC CHAS.

For the purposes of the socio-economic appraisal, geographically, Bowen consists of the Australian Bureau of Statistics (ABS) Statistical Area 2, which includes Queens Beach, Bowen, the peninsular to the east of Bowen, westwards to the Don River and southwards to the dwellings at Ocean View Drive (see Figure 1). The Wilson Beach AOI comprises the small hamlet only (see Figure 2; images are not at same scale).

[1] Through this report, the authors use the term ‘approaches’ when considering adaptation strategies, in contrast to the term ‘options’. When first considering the general strategy towards coastal hazard adaptation, an approach may define a general strategy: ‘sea-walls and levees to defend a community’, for example, and then provide a ‘first-pass’ cost benefit analysis on the general approach. Consideration of adaptation ‘options’ requires a higher level of definition than what is available through this process. For example, a cost benefit analysis of ‘options’ would include more defined maps and engineering plans (often called a ‘detailed business case’) to determine the locations, scale and construction of specific seawalls and levees.

Figure 2: Extent of the Bowen area of interest

Figure 3: Extent of the Wilsons Beach area of interest

1.5 Coastal hazards assessed

Adaptation approaches to two hazards are assessed here; that of storm tide inundation and erosion. It should be noted that 'sea level rise', widely predicted under climate change scenarios (IPCC, 2014), is not considered conceptually independent of either storm tide inundation and/or erosion, but as an additional factor in both types of risk. For example, the storm tide inundation risk area is comprised of additive measurements of Mean Sea Level, Highest Astronomical Tide, Storm Tide, Wave Set-Up and Sea Level Rise.

Both Bowen and Wilson Beach experience a high of risk from both storm tide inundation and coastal erosion. The key areas at risk are in Appendix 7.4.

The socio-economic appraisal will assess the risk to residential property, commercial property (which includes Council assets, such as offices and libraries), and community assets (for example, roads and wastewater treatment plants) at present day and years 2050 and 2100 for a range of Annual Exceedance Probabilities (AEPs).

1.6 Structure of this document

This document is structured in the following way. First, we detail the process methodology behind the Stage 1 survey (the intent, the audience, and the structure) and report on our recommendations from its findings. Next we report the methodology behind the MCA (Stage 2), explaining its purpose and benefits; the process of selecting the adaptation approaches to put forward to the MCA; and how the recommendations from the survey fed into it. We then justify the MCA scoring process, before presenting the MCA recommendations. The final sections of this document begin to assemble the identified social costs and benefits associated with the agreed adaptation approaches from the aforementioned workshop. As such, this document plays a 'reporting' function, rather than specifically making 'recommendations' for the SCBA stage of the CHAS Phase 7.

1.7 Supporting documents

The following documents prepared in previous phases of the CHAS have been applied to Phase 7:

- Climate Planning. (2019). *Whitsunday Regional Council Coastal Hazard Adaptation Strategy (CHAS): Proposed Adaptation Options Report*
- Climate Planning. (2019). *Whitsunday Regional Council Coastal Hazard Adaptation Strategy (CHAS): Risk Assessment Report*
- Climate Planning. (2018). *Whitsunday Regional Council Coastal Hazard Adaptation Strategy (CHAS): Methodology and Findings from Valuation of Key Assets*
- Edwards, I. (2019). *Whitsunday Regional Council Socio-Economic Vulnerability Assessment*

In addition, hazard maps provided by Climate Planning (see screen shots from Appendix 7.4) were used to both determine option feasibility and in the MCA workshop to help participants picture and consider the strengths and weaknesses of differing adaptation options. No formal critique of previous work and the hazard mapping has been undertaken. These are considered by the project team to be sound and approved by WRC for application to this phase of the CHAS.

1.8 Limitations

The process applied in this phase of the CHAS has been constrained by available budget and time. The project team has worked with WRC to identify an approach that, whilst not in all circumstances, is best practice provides a reasonable commercial alternative. As noted above an obvious limitation to work undertaken is the requirement to select representative areas of interest. Any other limitations and constraints specific to both the MCA and CBA will be identified in their respective reports.

2 Community survey (Stage 1)

2.1 Overview

The first stage of the socio-economic appraisal was to define the criteria against which coastal hazard adaptation approaches would be assessed in the Stage 3 MCA and to determine the relative weights, or scores, that these criteria should carry. To determine both the criteria and the scoring, we deployed an online survey (using SurveyGizmo) to elicit responses to:

a) understand the full scope of the criteria; and

b) enable a process to determine preferences for weighting the criteria in the MCA phase.

Online surveys are a cost-effective way of gathering community sentiment about land use planning issues in a structured way (Al-Kodmany, 2003). Whilst not as effective as carrying out a series of community workshops, due to budget constraints the project team considered it an acceptable method.

The survey also included questions to record respondents' organisations, whether they were speaking as an individual or on behalf of their organisation and additional, open-ended, questions designed to capture any additional comments or criteria concepts not already tested. The survey was open between 29 August 2019 and 17 September 2019, promoted in two email-outs. The two tranches of responses are reported together.

2.2 Criteria selection and testing

Our initial list of criteria for testing in the survey was defined by the $QCoast_{2100}$ document *Developing a Coastal Hazard Adaptation Strategy* (QCoast 2100, 2016), which suggests seven particular criteria as forming the basis of an MCA process. These are: (i) capital cost; (ii) environment or social impact; (iii) community acceptability; (iv) the ability of option to be reversible/adaptable in the future; (v) effectiveness over time; (vi) legal/approval risk; and (vii) technical viability.

In our survey, we:

a) separated 'social and environmental impacts' – determining social impact refers to *distributional* or *equity* issues associated with a particular adaptation options, whilst environmental impacts refer solely to habitat or ecological impacts;

b) included the criteria of 'economic impact', which refers to the impact of an adaptation option on the local and regional economy; and

c) included the criteria of 'property impact', which refers to the impact of adaptation strategy on direct, private costs to households and businesses.

Therefore, in all, 10 criteria were tested in the survey, against which respondents applied a score from a 'budget' of 100 points.

To independently verify the scoring applied to the criteria, we first tested respondents on three sets of value statements, which approximately aligned with the criteria statements. The purpose of testing the value statements was to triangulate both internalised and externalised opinions when it came to applying a score to the criteria. To illustrate: whilst it is likely individuals would rank 'property impact' highly, as they are possibly conceptualising the loss of their own property, it is important to verify the complexity of the values by testing statements that only obliquely refer to potential private losses. Conversely, with 'environmental' value statements, respondents can assume a 'warm glow' associated with rating environmental impact highly (Andreoni, 1990), only to place secondary importance to

environmental impacts when potentially faced with uncertainty or private property losses. The role of the value statements was to enable 'fine tuning' of the scores applied directly in the criteria scoring section.

2.3 Survey question summary

The following provides a broad summary of the questions presented in the online survey.

Questions 1 – 4: About the respondent: Name, email address, organisation, speaking as individual or on behalf of the organisation.

Questions 5 – 7: Value statements – three sets of value statements (aligned with the 10 criteria) ranked by the respondent in order of importance from a randomised list of statements presented all at once.

Questions 9: Criteria weighting and comments – respondent allocates a budget of 100 points towards the 10 (explicit) criteria. Additional comments were also elicited, in an open-ended question.

Questions 10 – 12: Additional criteria – respondent asked open-ended questions to recommend the additional criteria for the MCA.

2.4 Survey results

Partial results were not counted, as the intent of the methodology was to determine a correlation between value statements and criteria scoring.

2.4.1 Who responded

The number and source of respondents is shown below in Tables 1 and 2.

Table 1: Survey responses

Respondent	Responses	Percent
Council employee	16	26.7
Other	44	73.3

Table 2: Non-Council survey respondent community group affiliation

Community group	Responses
Gloucester Sports and Recreation Inc	18
Whitsunday Catchments Landcare	6
Conway Beach Progress Association	5
Not associated	4
Proserpine Chamber of Commerce	3
Canegrowers	3
Bowen Chamber of Commerce	3
Other	3
Hydeaway Bay Progress Association	2
Queens Beach Action Group	2
Reef Catchments	2

2.4.2 Value statement ranking

The raw data from the ranking of the three value statement sets are reported in Figures 4 – 6 below.

Figure 4: Value statement set 1 mean rankings

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
Our coastal habitats are incredibly important to the region's identity.	1		379	48
If there are approval constraints to coastal hazard mitigation actions, WRC should make efforts to change the planning framework.	2		257	48
WRC should set and implement its own priorities from a regional council perspective.	3		255	48
It is vital that any coastal management actions don't lock the region into following a particular pathway.	4		252	48
It is better we plan and spend less today, when there is greater uncertainty, than potentially more later, when we might know more about future coastal conditions.	5		246	48
Actions that safeguard economic activity should be prioritised over all other considerations	6		196	48
Community willingness to pay for actions that reduce exposure to coastal hazards should not be a consideration when devising adaptation options.	7		196	48
If necessary, to protect the community, WRC should raise funds for coastal hazards by borrowing money, or raising rates.	8		196	48
All coastal hazards can be mitigated by engineering solutions, given enough money.	9		183	48

Figure 5: Value statement set 2 mean rankings

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
Whitsunday residents need to be deeply engaged in the local planning and decision making processes of WRC.	1		330	47
It's better we fund long term coastal projects now, even under uncertainty, as it will be more cost-effective.	2		279	47
It is important that WRC's decisions prioritise the protection of vulnerable people and/or communities.	3		272	47
WRC should never make decisions that expose WRC to any legal risks.	4		250	47
As far as possible, coastal processes should be left to run their natural course.	5		239	47
We should remain flexible and quite short term with our options to enable us to respond easily to new coastal information.	6		231	47
The level of engineering, or disturbance required for to reduce coastal hazard risk, should not be considered a barrier to implementation.	7		193	47
Actions that limit the region's economic growth, should not be considered.	8		169	47
WRC should only consider projects where the costs of coastal adaptation or protection can be recouped from direct beneficiaries.	9		152	47

Figure 6: Value statement set 3 mean rankings

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
We should plan for the longer-term, even if future conditions are uncertain.	1		360	50
Our agricultural assets are as important to our region's economy as our built environment.	2		300	50
We should prioritise projects that WRC has the current capacity to implement.	3		293	50
A local community should ultimately be able to decide what coastal adaptation options are acceptable and should be implemented in their community.	4		272	49
WRC should always prioritise the environmental impact of decisions in the coastal zone over other impacts.	5		266	49
We should only implement decisions that can be changed as new information becomes available.	6		221	49
Protection of cultural heritage sites should be a high-priority.	7		212	49
WRC should spend all it can to protect coastal communities from erosion and inundation, whatever the costs.	8		171	49
If there's a reasonable chance of an action not getting approval it should not be considered.	9		134	49

2.4.3 Criteria scoring

The final criteria scoring averages, minimums, maximums and standard deviations are reported in Table 3.

Table 3: Respondent scoring of criteria from minimum standards document

Criteria	Average	Min	Max	StdDev
Environmental and social impact: Impact on the natural environment and on the cultural and social fabric of the Whitsunday region.	19.2	0.0	50.0	12.3
Property impact: Impact on Whitsunday homes and business premises.	13.7	0.0	40.0	10.4
Economic impact: Impact on the Whitsunday businesses and their capacity to generate profits and jobs.	12.7	0.0	58.0	9.6
Technical viability: The technical feasibility of an option, taking into consideration the magnitude of the job at hand and the capacity of the Council to implement it.	10.7	0.0	30.0	6.1
Effectiveness over time: Consideration of how long an option will be effective; e.g. will it only provide a short-term benefit that may require further action or an upgrade in the future.	11.7	0.0	40.0	8.3
Flexibility to new information: Can the option be reversed, enhanced, or redirected as new information comes to hand, or once implemented, is it effectively locked-in.	9.5	0.0	95.0	13.4
Community acceptability: Will be accepted by the community.	10.5	0.0	50.0	9.0
Raising additional funds: Will new (forms) of funding or finance be required to implement it.	8.2	0.0	30.0	6.5

2.4.4 Qualitative responses

Two further questions towards the end of the survey invited respondents to provide ideas for additional criteria for consideration in the MCA and a potential weighting for these suggestions. These qualitative responses are recorded

in Table 4 below. None of the additional statements revealed any requirement for the addition of a new criteria. Most referenced a preference for a specific coastal climate change adaptation option, or general strategy.

Table 4: Summary of qualitative responses

Comment (summarised)	Criterion / comments
A local community should have input into decisions, but not have total say.	'Community acceptability' criteria
Cultural heritage needs to be balanced with other criteria.	'Social impact' criteria
Better to invest our energy in working with nature to enhance its systems to our benefit than heavily engineer, at great cost, the protection of homes or infrastructure that won't last the test of time unless we keep 'doubling down' on protections.	'Environmental impact' criteria
Council should be working towards a long-term plan including identification of areas for retreat to ensure our coastal ecosystems are retained in acceptable levels.	Considered to be an adaptation response
We shouldn't expect other regional communities i.e Collinsville to have their rates increased to do works to protect the coastal communities.	'Social impact' criteria (distributional impact)
• Bolstering emergency services as an adaptation options (specifically access of sea rescue) • Investment in innovation to develop creative responses to drive climate change adaptation at cheaper cost. • Community needs to be told of the cost of defending some assets, to make informed choices about what to save or otherwise. • Retreat should be considered, rather than sinking money into undefendable positions. • Stricter planning controls in the coastal areas to ensure local community will not be responsible for adaptation that defends private assets.	Considered to be specific climate change adaptation options
Climate change is not an issue.	Not engaging with the issue

2.4.5 Quantitative analysis

To determine a final, recommended score for each of our criteria for the MCA stage—based on both the value statement rankings (section 2.2.1.2) and the direct criteria scores (section 2.2.1.3)—we applied the following method:

i) Results of the survey were downloaded to MS Excel.

ii) Partial survey responses were excluded.

iii) The completed results were analysed in two distinct groups: council employees and others (non-council employees).

iv) Social and legal/approval criteria lines were generated based on the standard deviation around aggregated value statement mean.

v) Council respondent criteria were weighted and adopted as initial baseline and normalised to 100.

vi) This normalised weighting was then adjusted to reflect material difference to other weighting's mean ranks from the value statements, e.g. Effectiveness weighting of 12 was reduced by 1, due to lower ranking from 'other'; Economic weighting of 11 reduced by 2, due to significant variance with value statements

2.4.6 Qualitative summary

We found that the criteria scores *broadly* consistent between Council and Non-Council respondents, with the exception of:

a) property impact (more important to non-council); and

b) community acceptability (more important to non-council)

The full comparison between Council and non-Council respondents is reported in Table 5. Departing from the minimum standards, we tested 'environment' and 'social' as separate criteria. These value statements and criteria scoring ranked quite differently, therefore, we believe it supports their inclusion as two separate criteria.

The value statements were *broadly* consistent with criteria scores, with the key differences being (value statement/criteria):

- Council: Economic (4/8)
- Council: Community acceptability (9/3)
- Council: Flexibility (10/6)
- Non-council: Effectiveness over time (6/3)
- Non-Council: Flexibility (7/4)

Table 5: Weighting and ranking comparison between Council and non-Council respondents

Criterion	Weighting			Rank		
	Council	Non-council	Comparison (%)	Council	Non-council	Comparison
Environment	15	16	(0.05)	1	1	0
Effectiveness over time	12	9	0.26	2	6	-4
Technical	11	9	0.24	3	9	-6
Economic	11	10	0.12	4	4	0
Social	10	9	0.05	5	5	0
Property impact	**10**	**13**	**(0.37)**	**6**	**2**	**4**
Legal / approval	8	9	*(0.00)	7	8	-1
Funding	8	6	0.16	8	10	-2
Community acceptability	**8**	**10**	**(0.35)**	**9**	**3**	**6**
Flexibility	7	9	(0.28)	10	7	3
Total	**100**	**100**				

Key output or recommendation: The scores for the assessment criteria, as presented in Table 6, are submitted to the multi-criteria analysis.

Table 6: Final recommendation for scores for multi-criteria analysis

Criterion	Council	Non-	Recom'n	Adj	Justification
Environment	15	16	**15**	-	
Effectiveness over time	12	9	**11**	(1)	To reflect non-council disparity
Technical	11	9	**11**	-	
Economic	11	10	**9**	(2)	Significantly higher than VS but political importance
Social	10	9	**10**	-	
Property impact	10	13	**11**	1	Skew towards higher score of non-council
Legal / approval	8	8	**8**	-	
Funding	8	6	**8**	-	
Community acceptability	8	10	**10**	2	Reflect significantly higher VS ranking and weighting of non-council
Flexibility	7	9	**7**	-	
Total	**100**	**100**	**100**	**-**	

3 Multi-criteria analysis (Stage 2)

MCA (often referred to academic literature as Multi-Criteria Decision Making, or MCDM) is a general technique for the comparative assessment of alternative projects based on several criteria. The method is designed to help decision-makers to integrate the different impacts, based on the preferences and scores of stakeholders, analysts and actors concerned. An MCA is concerned with structuring and solving decision and planning problems involving multiple criteria, which maybe quantifiable, unquantifiable, or both and which maybe conflicting or synergistic (Pohekar & Ramachandran, 2004).

Use of MCA is based on the assumption that there is often not an easily determined optimal solution for a problem and it is therefore necessary to use decision-maker's preferences to differentiate between solutions. The MCA is, therefore, necessarily subjective and inevitably must result in a compromise. Nevertheless considered accessible, consultative, iterative, and generally robust, particularly where significant uncertainty in future conditions exists (Triantaphyllou, 2000).

There are 4 general steps to carrying out MCA in the context of climate change adaptation approaches assessment (Triantaphyllou, 2000):

1) Determine the feasible options;

2) Determine the relevant, or appropriate criteria;

3) Attach numerical measures to the relative importance of the criteria and to the impacts of the alternatives on these criteria; and

4) Process the numerical values to determine a ranking of each alternative.

3.1 MCA methodology

3.1.1 Selection of adaptation options

The first stage of our MCA was to determine a list of *feasible* adaptation approaches in the coastal zone for the two AOIs, Wilson Beach and Bowen. Our initial list of adaptation approaches was drawn from the *Whitsunday Regional Council Coastal Hazard Adaptation Strategy (CHAS): Proposed Adaptation Options Report* (the 'options report') prepared by Climate Planning (2019). The responses determined in this report comprised a comprehensive list of potential options that may be applied at some point in the future in some location in the WRC region; i.e. it represented a relatively exhaustive list containing approaches that may be viable at the two AOIs. Coastal adaptation responses (whether considered options or approaches) are generally classified in a decision tree, summarised in Figure 7 below. Refer to the options report for the full list and description of coastal adaptation responses.

Figure 7: Decision tree for coastal management options (summary, adapted from Climate Planning, 2019)

The options report also developed assessment criteria for the "screening of options […] to eliminate clearly non-viable adaptation options" (Climate Planning, 2019, p. 7), therefore the feasibility of an option provided a first-pass 'yes/no' decision point for inclusion in the MCA. The decision-making framework is shown in Table 7 below.

Table 7: First-pass feasibility assessment framework for coastal hazard adaptation approach (Climate Planning, 2019)

2019	Description
Priority (P)	The adaptation option is considered a priority for the area of interest.
Feasible/ relevant (F)	The adaptation option is feasible or relevant for the area of interest.
Not feasible (N)	The adaptation option is not feasible for the area of interest.
Unsure (U)	Unsure of the feasibility of the adaptation option for the area of interest.
Not applicable (NA)	The adaptation option is not applicable to the area of interest.

Our feasibility assessment was based on local knowledge, aerial photography/Google Maps, expert judgement and a review of coastal hazard maps for sea level rise (SLR) and storm tide risk today, at 2050 and 2100. This assessment took place in workshops between the project team and the consultancy, Climate Planning, on 18 and 19 September 2019.

The full and final feasibility assessment is reported in the datasheets in Appendix 7.2. Reported below in Tables 8 and 9 are key justifications for feasibility assessments and inclusion in the MCA for Bowen and Wilson Beach:

Table 8: Key justifications for adaptation approach inclusion in MCA for Bowen

Strategy	Broad approach	Adaptation approach	Feasibility	Justification
Defend	Regenerative	Beach nourishment; dune construction and regeneration; riparian corridors restoration and generation	N	Area for regeneration too large; lack of certainty; area not naturally sand-dune/beach habitat; region not affected by large, continuous flow rivers
		Mangroves	U	Lack of certainty; location likely not to support mangroves, or enable sufficient natural migration of mangrove in response to projected sea level rise
	Engineering	Artificial reefs; detached breakwaters; groynes and artificial headlands	N	Area already well-protected by headlands; insufficient longshore drift for sand replenishment from groynes
Accommodate	All adaptation approached considered feasible			
Retreat	All adaptation approaches considered feasible			

Table 9: Key justifications for adaptation approach inclusion for MCA for Wilson Beach

Strategy	Broad approach	Adaptation approach	Feasibility	Justification
Defend	Regenerative	Dune construction and regeneration; riparian corridors restoration and generation	N	Area not naturally sand-dune/beach habitat; region not affected by large, continuous flow rivers
		Mangroves	U	Location may not support mangroves
	Engineering	Artificial reefs; detached breakwaters; groynes and artificial headlands	N	Area already well-protected by headlands; insufficient longshore drift for sand replenishment from groynes
Accommodate	All adaptation approached considered feasible			
Retreat	All adaptation approaches considered feasible			

3.1.2 Scoring of MCA options

To derive the final MCA score for each of the adaptation approaches considered 'feasible', or 'unsure', we used the weighted sum method for approach assessment (Triantaphyllou, 2000). Our general application of this method is as follows:

1) Finalise list of 'feasible' and 'unsure' adaptation approaches in rows of a datasheet.

2) List assessment criteria and criteria scores (as recommended in Section 2) in columns of the datasheet.

3) Apply a prioritisation score for each adaptation approach against each assessment criteria. We applied a score of 100 to the most appropriate adaptation approach, zero to the least appropriate, and then scored the remaining approaches in between 1 and 99. (In this regard, consistent with the determination of feasibility, the expert judgement of the project team and Climate Planning was applied. Expertise and experience 'in the room' incorporated coastal hazards adaptation solutions, economic analysis and regional planning in addition to a working knowledge of the WRC region and its socio-economy).

4) Apply a written justification for each prioritisation score.

5) Multiply the prioritisation score by criteria score for each of the assessment criteria.

6) Total the product of prioritisation score and criteria score along the rows for each adaptation approach.

7) Rank the adaptation approaches by the final score applied.

8) Run a sensitivity analysis by adjusting the criteria weighting score (see Section 3.2.2 below).

3.2 Multi-criteria analysis results and recommendations

3.2.1 Multi-criteria analysis output

The results of our MCA process (rankings) is reported below in Table 10 for Bowen and Table 11 for Wilson Beach. The full prioritisation score for each adaptation approach and the written justification for each score is in Appendix 7.2.

Table 10: Final multi-criteria assessment rankings for Bowen

Approach	Specific option	MCA score	MCA Ranking
Regenerative options	Mangrove planting	5945	4
Coastal engineering options	Sea dykes and levees	4450	10
	Sea walls	5030	7
Coastal settlement design options	Climate resilient design	5700	5
	Elevated buildings	4740	8
	Raised land levels	3570	12
Planning options	Land use planning	7460	1
	Development setbacks	5060	6
	Limited development	4740	8

	Redefining planning objectives (zoning)	6230	2
	Land swap	3390	13
	Land buy-back	4000	11
	Land surrender	5970	3
	Compulsory land acquisition	2740	14

Table 11: Final multi-criteria assessment rankings for Wilson Beach

Approach	Specific option		MCA Ranking
Regenerative options	Beach nourishment	5780	3
	Mangrove planting	6060	1
Coastal engineering options	Sea dykes and levees	5100	7
	Sea walls	5030	8
Coastal settlement design options	Climate resilient design	5720	4
	Elevated buildings	4840	9
	Raised land levels	3490	12
Planning options	Land use planning	1430	14
	Development setbacks	5180	6
	Limited development	5190	5
	Redefining planning objectives (zoning)	1030	15
	Land swap	3610	11
	Land buy-back	4440	10
	Land surrender	5980	2
	Compulsory land acquisition	2740	13

3.2.2 Sensitivity analysis

We performed a sensitivity analysis on the criteria weighting scores. A sensitivity analysis is a check of how uncertainty in the output of a mathematical system can be divided and allocated to different sources of uncertainty in its inputs (Sassone & Schaffer, 1978).

We assessed the sensitivity of the MCA final output scores through adjusting the assessment criteria scores as detailed in Table 12. (Note: that the full results are not re-produced here, as the changes to the output were marginal; only the key results are reported.

The initial results displayed little sensitivity to the lines of analysis undertaken and as such were adopted unchanged.

Table 12: Summary of sensitivity analysis for multi-criteria analysis for Bowne and Wilson Beach

Criteria	Explanation	Result
Standard deviation	Weightings resident beyond one standard deviation of mean normalised to one standard deviation.	No material change from MCA weightings.
No weighting	Weightings equalised	For Bowen no material change from MCA weightings. For Wilson Beach, a slight increase in preference for non-hard engineering options.
Community acceptability/ Property impact Adjustment	Weighting of community acceptability and property impact increased until weighted score of hard engineering option (seawall or levy) ranked in top two.	For Bowen almost need to increase weightings of each criteria by 150% for seawall. For Wilson Beach need to double weighting for levy.
Environment/economy adjustment	Environment weighting decreased by increase in economic weighting until weighted score of hard engineering adaptation option ranked in top two.	For Bowen and Wilson Beach need to adjust weightings by 8 (reduce environment by approx. 50%; increase economy by close to 90%).

Key output or recommendation: The multi-criteria analysis recommendations from Table 10 (Bowen) and Table 11 (Wilson Beach) are accepted.

4 Multi-criteria analysis results workshop

4.1 Overview

The results of the MCA were presented to a broad range of WRC employees in Proserpine at a workshop held on 30 September 2019 (for participant list, see Appendix 6.3). The objective of the workshop was to enable participants to raise any significant concerns with the methodology and/or the weighting applied to the MCA and subsequent results.

No specific concerns or changes to the weighting or MCA results were raised and, as such, were accepted as valid for the purposes of this analysis.

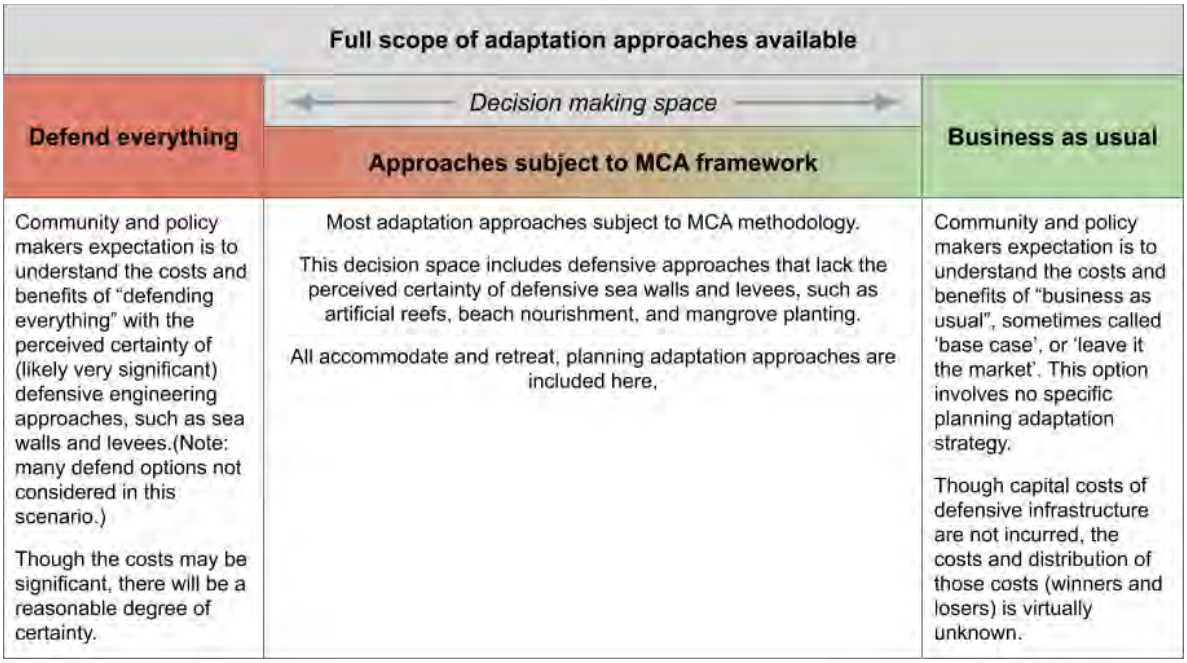
Whilst the MCA was applied to the selection of adaptation approaches for further analysis (in the SCBA) it should be noted that some approaches expected to be low priority in the MCA were also selected at this point; with particular reference to defensive engineering approaches, including sea walls and levee. These approaches, when adopted in widespread fashion around urban and suburban areas, tend to be perceived as having a high degree of certainty around their defensive capabilities [2].

This further high-level analysis was considered an important step in communicating the (likely) extremely high capital and maintenance costs of these approaches. Whilst not strictly in accordance with minimum guidelines it was considered within the room that such divergence was justified from a stakeholder engagement and communications perspective.

The effect of this decision-making process was a developing community and WRC expectation that three adaptation approaches be considered in SCBA: (i) 'business-as-usual' (strategic planning cycle and enabling market corrections); (ii) 'protect everything with certainty' (sea walls and levees); and (iii) remaining adaptation approaches as recommended by the MCA process. Options (i) and (ii) represent two 'default' options for the community – the cost of doing nothing and the cost of doing everything. The space in-between, is, in effect, the 'decision making space' (see Figure 8).

[2] Sea walls and levees was scored at 90 out of 100 in the MCA in terms of "Effectiveness over time", second only to complete retreat. This approach also scored highly (80) in terms of impact on property. Note that the terms of this project cover the period of time to 2100. Further sea level, beyond 80cm, may continue depending on GHG emissions scenarios.

Figure 8: Decision making space for Whitsunday Regional Council multi-criteria assessment



4.2 Workshop participants

The minimum guidelines caution about the composition of participants in an MCA and note that "shortfalls can be mitigated through very careful selection of workshop participants" (QCoast 2100, 2016, p. 34). Although a broader range of residents were surveyed regarding the MCA criteria, given time constraints, status of community engagement and the sensitivity of the subject matter, the project team highly recommended limiting participation of the workshop to council employees only. Such limitation would also enable manageable participation of relevant expertise in the form of frank, technical discussion. This advice was accepted by WRC.

The full attendee list is in Table 14, in Appendix 7.3.

4.3 Adaptation approaches

The workshop spent time considering the 'defend everything' and the recommended approaches from the MCA. It is useful to consider these in the framework presented in Table 13. Adaptations fall into two broadly recognised categories: *strategic* and *autonomous* (Buckwell, 2015; Callaway, Naess, & Ringius, 1998; T. Carter, Kenkyū, & Kankyō, 1994). Interpretation of the distinctions should not be strictly enforced; instead the categorisation is defined by particular set of characteristics, as set out in Table 13. It should also be acknowledged this classification is further dependent on individual spatial and temporal perception. For example, for a singular household, an autonomous adaptation (with the attendant characteristics from Table 13) might be to become 'storm-ready' and informed of the nature of a particular impending peril, perhaps by taping windows and securing property. A more strategic adaptation would be to invest in raising floor levels to protect habitable areas from a quantifiable, but non-specific risk of flooding.

Conversely, if such an adaptation is not mandated in any state building code, from the perspective of a planning agency this adaptation would be classified as an autonomous, non-coordinated, micro-level incremental change. Importantly, Callaway et al. (1998) note small-scale, generally private responses to climate changes should not necessarily be classified as 'unplanned'. The myriad adjustments undertaken by households and businesses may well be emergent or autonomous (that is, they have not been directed by clearly articulated public policy), but the benefits and costs have been evidently rationally determined at a micro-level, taking the same conceptual risk assessment approach as any larger entity.

Table 13: Comparison of the attributes of strategic and autonomous climate change adaptations. Such a comparison is further dependent on relative temporal and spatial scale of the subject. Sources from Park et al. (2012), Callaway, Naess, & Ringius (1998), Carter et al. (1994) and Leary (1999).

Strategic / Planned	Autonomous
"A discrete process that fundamentally (but necessarily irreversibly) results in change in […] a system from one form, function or location to another" (Park et al., 2012, p. 119).	"The essence and integrity of an incumbent system or process remains intact" (Park et al., 2012, p. 119).
Adaptions are co-ordinated between public (or quasi-public) agencies and private agents.	Adaptations are not coordinated neither between public and private agents, nor between communities of private agents.
Adaptions are informed by a benign public policy and the science community. (Administrative rationalism)	Agent adaptations are informed by localised and limited knowledge and tend to be emergent from individual decisions.
Adaptions are pre-emptive and planned to account for the extent of future climate change at a defined point in time.	Agent adaptions tend to be reactive to current or recent past events and only. No account is given to the extent of climate change and a given future point in time.
Adaptations tend to be transformative and large-scale and therefore tend to be more complex and subject to greater risks and costs.	Adaptations are incremental and at the micro level and therefore tend to be less complex and present a lower risks and costs.
Adaptations require higher capital costs that require explicit recognition in organisational financial plans, budgets and reports.	Adaptations do not demand high capital costs and can therefore be opaquely subsumed into business-as-usual operations, which does not require specific reporting.

4.3.1 Adaptation approaches for Bowen

The workshop considered the adaptation approaches (two planned, one autonomous) for Bowen to be put forward to SCBA to be:

1. Full protection, using a combination of sea walls and levees, protecting Queen's Beach on the north of the Bowen peninsular from the mouth of the Don River, extending eastwards to The Pocket, then southwards through the wetlands to Denison Park; protection of the harbour, protection along the sea front along Thomas Street, continuing north westwards in front of Norris Street.

2. A combination of buy-backs, land-swaps, and medium term protection by a sea wall in front of Thomas Street (the main town of Bowen is already considered at risk of inundation from storm tide). The buy-backs can be augmented by nuances, such as buy-backs to lease-back; that is property in the risk areas are secured, but leased back until thresholds are reached when evacuation is deemed most appropriate. In the longer term, the normal strategic planning process will limit further development in greenfield areas that are at risk of coastal hazards.

3. The 'business-as-usual', whereby the market (through land values and insurance market implications) and future strategic planning processes encourage unplanned, autonomous adaptations and reduction of inappropriate development in the risk areas (see Table 13). Business-as-usual approaches may also entail significant works to the sewerage systems of the town, as parts of the network would begin to suffer salt-water intrusion, long before any property itself is at direct risk of storm tide and SLR.

4.3.2 Adaptation approaches to Wilson Beach

The workshop considered the adaptation approaches (two planned, one autonomous) for Wilson Beach to be put forward to SCBA to be:

1. Full protection, using a combination of sea walls and levees, protecting the beach front of the hamlet and levees through the mangrove wetland through the north of the hamlet. The access road may require uplift.

2. A combination of buy-backs and land-swaps. The buy-backs can be augmented by nuances in policy, such as buy-backs to lease-back; that is property in the risk areas are secured, but leased back until thresholds are reached when evacuation is deemed most appropriate. No new land will be likely opened to new development at Wilson Beach.

3. The 'business-as-usual', whereby the market (through land values and insurance market implications) is augmented by autonomous adaptations, such as raising of land.

Key output or recommendation: The options presented in Section 3.4.1 (Bowen) and 3.4.2 (Wilson Beach) be subject to detailed social cost benefit analysis in Stage 3 of the socio-economic appraisal.

5 Conclusion

The recommendations from the MCA in the 'decision making space' are broadly supported by the climate change adaptation literature. The degree of uncertainty in the changes for which adaptation is necessary has implication on the scale, timing and types of adaptations that are most appropriate. Failing global action and the potential for 4.8°C of warming and more than a metre of sea level rise by 2100 requires radically different adaptation approaches and responses to one experiencing just 1.5°C of warming and 0.26m of sea level rise (IPCC, 2014).

However, if an adaptation is implemented in a way that is inflexible to new information and the current and future benefits are uncertain (as new conditions may not transpire), assessing the benefits of such an adaptation becomes problematic and sometimes counter-intuitive (Leary, 1999).

To account for this, Leary (1999) puts forward a high-level cost benefit framework for judging the net value of climate change adaptation in light of climatic uncertainty, paraphrased below :

a) Adaptations with entail large irreversible costs, which provide limited present benefits, and which can be delayed until there is greater certainty, should be delayed.

b) Conversely, adaptations that might reduce vulnerability in the future, but create present benefits, "are a good place to start".

c) Investments should be targeted at those that maintain options, flexibility and opportunities to learn and adapt into the future.

The next stage (3) in socio-economic analysis is to undertake a SBCA on the options presented in 4.3.1 and 4.3.2: business-as-usual, defend everything and a series of buy-backs and land-swaps, with the potential for construction of localised responses to the current day hazards.

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7 Appendices

7.1 The project team

The research team members have extensive experience in economics, accounting, spatial planning, and coastal management, particularly in the context of climate change adaptation in the Indo-Pacific region. The team members have a great track record and reputation in working on both large- and smaller-scale projects in a wide range of industries, and for government, non-government and the not-for-profit sectors, as evidenced in each member's list of publications and prior projects (see individual CVs in Annex B). The project team members have successfully collaborated in the past on a number of industry-facing and government-sponsored projects.

7.1.1 Professor Christopher Fleming

Lead Investigator

Christopher Fleming is a Professor and MBA Director at Griffith Business School, a founding member of the Griffith Centre for Sustainable Enterprise, a member of Griffith University's Cities Research Institute, a member of Griffith University's Australian Rivers Institute and of the Griffith Climate Change Response Program.

An applied micro-economist with teaching, consulting and public policy experience, Christopher's research and consulting interests include, social and economic project/program evaluation, natural resource and environmental economics, sustainable development, the economic determinants of subjective wellbeing and the sustainable management of natural resources. Christopher is currently the economics lead on *EcoAdapt in the Pacific*, a five-year project that aims to identify appropriate climate change adaptation interventions in the coastal zone of Pacific island states and territories in Melanesia.

Prior to joining Griffith Business School, Christopher worked as a senior consultant for MainStream Economics and Policy, and Marsden Jacob Associates, as well as a senior advisor within the Sustainable Development Policy Group of the New Zealand Ministry for the Environment.

7.1.2 Ian Edwards

Project manager

Ian Edwards is an independent climate change consultant. He specialises in the socio-economic and financial implications of climate change adaptation. He is a chartered accountant with twenty years' experience in national and international financial services. He has worked across a broad spectrum of the financial industry including accounting public practice, investment banking and reinsurance. His career has focused predominantly on affecting system change at a multinational scale, which has afforded him strong analytical, financial, information technology and project management skills. Ian has worked on climate change adaptation projects both within Australia (state and local governments) and internationally (NGOS, development banks and universities).

7.1.3 Andrew Buckwell

Economic analysis and digital engagement

Andrew Buckwell is a Senior Research Assistant at Griffith Business School. He is an applied environmental economist by training, with significant experience in field research design, execution and analysis, and consulting – specialising in benefit cost and policy analysis. He also has teaching experience at under-graduate and Masters level. Andrew is currently deployed as a research environmental economist (including in the field) on two global, multi-disciplinary projects: *EcoAdapt in the Pacific*, which is a five year project engaged in the identifying and valuing appropriate ecosystem-based adaptions to climate change, mainly focussed on Vanuatu; and a global primary forests preservation project, which has a focus on researching community livelihoods and addressing gaps in forest protection, which case studies in the Democratic Republic of Congo, the Brazilian, and Melanesia.

Prior to joining Griffith Business School, Andrew spent 12 years as a senior digital and web professional, gaining extensive experience in digital strategy, marketing and communications, user experience design, agile project management and solutions implemention, content strategy, and social media marketing.

7.1.4 Maggie Muurmans

Stakeholder engagement, workshop facilitation and infographic production

Maggie Muurmans has over 19 years' experience in community conservation and sustainable livelihood development in Europe, Latin America, Asia and Oceania. Her projects include the establishment of community conservation areas, protected area management and alternative livelihood development. She also manages a coastal community engagement program on the Gold Coast which reaches over 9000 community members each year.

Maggie has successfully implemented debt-for-nature swaps, micro-credit systems and fishery alternatives. Her experience also extends to comprehensive coastal community engagement, education and conservation programs.

Maggie has received a number of national and international awards for her work. She has also extensive experience in event management, capacity building activities and workshop facilitation for all levels of community and governance.

7.1.5 Dan Ware

Coastal process management and GIS

Dan Ware is a Research Fellow from Griffith University's Centre for Coastal Management and Climate Change Response Program, working on design of ecosystem-based adaptation for small island developing states in Melanesia. He is a geographer, with experience in coastal planning and climate change risk assessment and is working on a PhD in the history of coastal planning and management on the Southern Gold Coast.

Dan is an active contributor to the development of Australian coastal management policy and practice, holding leadership positions with local stakeholder groups. Dan is currently a technical advisor on climate change and sustainable development for the Melanesian Spearhead Group and the Infrastructure and Settlements Expert Advisor for the LGAQ Climate Resilient Councils program. Dan has held previous roles as Director of the Surfrider Foundation Australia, as a member of the Queensland Committee of the Australian Coastal Society, and as President of Gold Coast Surf Council.

Prior to joining the Griffith Centre for Coastal Management, Dan led a climate and sustainability consulting team for Sinclair Knight Merz where he worked on climate risk assessment and adaptation planning policy for Infrastructure and State and Local Government Clients.

7.2 Full MCA scores and justifications

Appendix 7.2a: Multi-criteria analysis for Bowen

Criteria:	Feasibility	Environment	Env weight	Env justification	Effectiveness over Time	Eff weight	Effectiveness justification	Technical	Tech weight	Technical justification	Economic	Econ weight	Economy justification	Social	Social weight	Social justification	Property Impact	Property weight	Property justification	Legal/Approval	Legal weight	Legal justification	Funding	Funding weight	Funding justification	Community Acceptability	Community weight	Comm Accept justification	Flexibility	Flex weight	Flexibility justification	TOTAL MCA Score	Total Weighting
Weighting			15			11			11			9			10			11			8			8			10			7			100
Defend																																
Regenerative Options																																
Beach nourishment	N																															
Dune construction and regeneration	N																															
Riparian corridors restoration and generation	N																															
Mangrove forests	U	100	1500	Mangoves (where feasible) allow for maximum ecological function / flexibility	20	220	Mangroves are subject to high levels of uncertainty over time	100	1100	Technically feasible in the right conditions	20	180	Mangroves are moderately cost effective, however allocated areas for new mangroves can be costly	100	1000	Mangrove construction provides public goods benefits	15	165	Mangrove is likely to provide only limited further defensive capability at Bowen	80	640	Response requires few legal approvals	80	640	Response is reletively cheap to implement	50	500	Response likely considered to be subject to a high degree of uncertainty and scepticism by community	0	0	Response is slow to build protection; if in appropriate, response is slow to rectify	5945	4
Coastal Engineering Options																																
Artificial reefs	N																															
Detached breakwaters	N																															
Groynes and artificial headlands	N																															
Sea dykes or levees	F	20	300	Sea dykes generally unsympathetic to EF/CP, but provide for some natural migration	90	990	Built infrastructure subject to low levels of uncertainty over a given period of time. Beyond this set period uncertainty is greater	0	0	High level of technical speciality required to constructed effective dykes / levees	80	720	Sea dykes and levees are expensive, but enable existing footprint to be retained	20	200	Dykes and levees provides public goods benefits, which are mostly exploited by private land onwers	100	1100	Defensive options have the least impact on property	20	160	Response subject to significant and wide ranging approvals	10	80	Response can be significantly costly to implement	80	800	Engineered defense response will be highly acceptable by community	10	100	Once response is in place, there are low levels of flexibility if deeemed ineffective	4450	10
Seawalls	F	0	0	Seawalls generally unsympathetic to EF/CP	90	990	Built infrastructure subject to low levels of uncertainty over a given period of time. Beyond this set period uncertainty is greater	10	110	High level of technical speciality required to constructed effective sea walls	100	900	Sea walls are expensive, but enable existing footprint to be retained	70	700	Sea walls provides public goods benefits (defending public parks etc), but are mostly exploited by private land onwers	90	990	Defensive options have the least impact on property	20	160	Response subject to significant and wide ranging approvals	10	80	Response can be significantly costly to implement	100	1000	Engineered defense response will be highly acceptable by community	10	100	Once response is in place, there are low levels of flexibility if deeemed ineffective	5030	7
Coastal Settlement Design Options																																
Climate resilient design	F	80	1200	CRD is a built-environmental response that enables ecological functions to continue	0	0	Response likely to eventually be ineffective to inevitable SLR	40	440	Climate resilient design is moderately feasible in most circumstances	50	450	Retrofitting can be expensive, but costs not born by WRC	10	100	Costs are born by private land owner, leading to distribution impacts	50	550	Response enables properties to remain in situ, but costs put on private property owners	70	560	Response requires few legal approvals	100	800	Response requires expediture from private land property owners; none by WRC	90	900	Maintaining property rights likely to be popular, however costs are born by private property onwers	70	700	Response is reasonably fekible to future information and conditions; however flexibility is limited by limits to adaptation	5700	5
Elevated buildings	F	80	1200	Elevated buildings is a built-environment response that enables ecological functions to continue	10	110	Response likely to eventually be ineffective to inevitable SLR	30	330	Depending on the type of property, raising floor levels can be difficult	50	450	Retrofitting can be expensive, but costs not born by WRC	10	100	Costs are born by private land owner, leading to distribution impacts	50	550	Response enables properties to remain in situ, but costs put on private property owners	70	560	Response requires few legal approvals	80	640	Response requires expediture from private land property owners; none by WRC (apart from development approvals)	70	700	Maintaining property rights likely to be popular, however costs are born by private property onwers	10	100	Once building is elevated, there are no further options available if not effective enough	4740	8
Raise land levels	F	30	450	Raising land levels can result in a disruption to ecological functions by altering flow and tides, but preserves erosion risk	10	110	Response likely to eventually be ineffective to inevitable SLR	10	110	High level of technical speciality required to constructed effective sea walls	50	450	Retrofitting raised land levels can be very expensive, but costs not born by WRC	10	100	Costs are born by private land owner, leading to distribution impacts	50	550	Response enables properties to remain in situ, but costs put on private property owners	20	160	Response subject to significant and wide ranging approvals	80	640	Response requires expediture from private land property owners; none by WRC (apart from development approvals)	60	600	Maintaining property rights likely to be popular, however costs are born by private property onwers	40	400	Once building is elevated, there are no further options available if not effective enough; further raising is somewhat possible	3570	12
Planning Options																																
Land use planning	F	90	1350	Managing future development in Bowen likely to be highly sympathetic to environment	90	990	Managing future development in response to SLR projections will reduce property exposure over time	80	880	With new dwellings planned, reducing CHR with expanding population likely to be highly effective	50	450	Removal of public or private land from the CHZ entails a significant economic cost	70	700	Significant social impact experienced from land retreat	50	550	Significant property impact associated with voluntary / involuntary surrender	50	400	Planning instruments subject to range of competing legal and state and federal interest tests	80	640	Radical strategic planning processes can be lengthy and expensive	50	500	A planning scheme will go thorugh usual consultation process	100	1000	With significant likely future development, response is very flexible	7460	1
Development setbacks	F	90	1350	Managing future development in Bowen likely to be highly sympathetic to environment	70	770	Managing future development in response to SLR projections will reduce property exposure over time	20	220	Response will have limited effectiveness on low-lying areas of Bowen	50	450	Removal of public or private land from the CHZ entails a significant economic cost	20	200	Limited social impact of response, though some limits on development flexibilities	30	330	At Bowen development set backs will have limited impact; but no account made for future damages	50	400	Response subject to some legal challenge	80	640	Can be achieved through business as usual planning processes	50	500	Response likely to be considered acceptable as no compulsory surrender considered	20	200	With likely future development, response is flexible only in the short term	5060	6
Limited development	F	90	1350	Managing future development in Bowen likely to be highly sympathetic to environment	90	990	Managing future development in response to SLR projections will reduce property exposure over time	20	220	Response will have limited effectiveness on low-lying areas of Bowen	10	90	Removal of public or private land from the CHZ entails a significant economic cost	20	200	Limiting further development can increase property values in short- to medium- term	30	330	At Bowen limiting development will have limited impact; but no account made for future damages	40	320	Limiting development subject to potential legal challenges	80	640	Can be achieved through business as usual planning processes	50	500	Limiting development to existing footprint likely to be highly acceptable to Wilson's Beach community	10	100	With significant property already present, limiting future development only has limited potential	4740	8
Redefining planning objectives (rezoning)	F	90	1350	Managing future development in Bowen likely to be highly sympathetic to environment	90	990	Managing future development in response to SLR projections will reduce property exposure over time	40	440	Rezoning land out of further development likely to be effective; risks remain from existing property	20	180	Removal of public or private land from the CHZ entails a significant economic cost	70	700	Significant social impact experienced from land retreat	30	330	Significant property impact associated with voluntary / involuntary surrender	25	200	Planning instruments subject to range of competing legal and state and federal interest tests	80	640	Radical strategic planning processes can be lengthy and expensive	50	500	Response likely to be considered a surrender; communities significiantly disrupted	90	900	With significant likely future development, response is very flexible	6230	2
Land swap	F	90	1350	Removing property from CHZ will enable EF/CP to continue	90	990	Removing property from CHZ removes all risk / uncertainty	10	110	Land swaps - finding alternative areas - are diffcut to implement	0	0	Removal of public or private land from the CHZ entails a significant economic cost	30	300	Private property owners are compensated for loss	0	0	Significant property impact associated with voluntary / involuntary surrender	10	80	Response subject to significant and wide ranging approvals	20	160	Land swaps demand considerable effort on behalf of WRC	20	200	Response likely to be considered a surrender; communities significiantly disrupted	20	200	Once response is implemented there is "no going back"	3390	13
Land buy-back	F	90	1350	Removing property from CHZ will enable EF/CP to continue	90	990	Removing property from CHZ removes all risk / uncertainty	10	110	Land buy backs have proven to be difficult to find support in the community	10	90	Removal of public or private land from the CHZ entails a significant economic cost	30	300	Private property owners are compensated for loss	0	0	Significant property impact associated with voluntary / involuntary surrender	10	80	Response subject to significant and wide ranging approvals	10	80	Response requires significant effort on behalf of WRC	80	800	Private property owners will be compensated in voluntary deal.	20	200	Once response is implemented there is "no going back"	4000	11
Land surrender	F	90	1350	Removing property from CHZ will enable EF/CP to continue	100	1100	Removing property from CHZ removes all risk / uncertainty	80	880	Voluntary removal of privoate property from the CHZ is straightforward	0	0	Removal of public or private land from the CHZ entails a significant economic cost	10	100	Significant social impact experienced from land retreat	0	0	Significant property impact associated with voluntary / involuntary surrender	100	800	Response is voluntary	80	640	Response is voluntary	90	900	Response is voluntary	20	200	Once response is implemented there is "no going back"	5970	3
Compulsory land acquisition	F	90	1350	Removing property from CHZ will enable EF/CP to continue	90	990	Removing property from CHZ removes all risk / uncertainty. However compulsory aquisition adds complexity	10	110	CLA is difficult to implement	10	90	Removal of public or private land from the CHZ entails a significant economic cost	0	0	Significant social impact experienced from land retreat	0	0	Significant property impact associated with voluntary / involuntary surrender	0	0	Response subject to significant and wide ranging approvals	0	0	Response requires significant effort on behalf of WRC	0	0	Compulsory nature of response likely to be unpopular	20	200	Once response is implemented there is "no going back"	2740	14

Appendix 7.2b: Multi-criteria analysis for Wilson Beach

Criteria:	Feasibility	Environment	Env weight	Env justifications	Effectiveness over Time	Eff weight	Eff justification	Technical	Tech weight	Tech justification	Economic	Econ weight	Econ justification	Social	Social weight	Social justification	Property Impact	Property weight	Property justification	Legal/Approval	Legal weight	Legal justification	Funding	Funding weight	Funding justification	Community Acceptability	Community weight	Community acceptability justification	Flexibility	Flex weight	Flexibility justification	TOTAL MCA Score	Total Weighting
Weighting			**15**			**11**			**11**			**9**			**10**			**11**			**8**			**8**			**10**			**7**			**100**
Defend																																
Regenerative Options																																
Beach nourishment	F	50	750	Beach nurishment can enable ecological functioning, however, environmental cost associated with continuous replenishment	30	330	Beach nourishment is subject to high levels of uncertainty, both from a CP perspective and future commitment to ongoing funding	80	880	Technically feasible in the right conditions	70	630	Beach nurishment enables retreat to be avoided, but has moderate ongoing costs indefinitely into the future	70	700	Beach nurishment provides public goods benefits, which are mostly exploited by private land onwers	90	990	Defensive options have the least impact on property	25	200	Response subject to significant and wide ranging approvals	5	40	Response is moderately expensive, but will require continual, indefinite funding	70	700	Defense response likliey to be acceptable to community, but lacking certainty compared to engineered options	80	560	Nourishment rates are highly flexible in their application	**5780**	**3**
Dune construction and regeneration	N																															
Riparian corridors restoration and generation	N																															
Mangrove forests	U	100	1500	Mangoves (where feasible) allow for maximum ecological function / flexibility	20	220	Mangroves are subject to high levels of uncertainty over time	100	1100	Technically feasible in the right conditions	50	450	Mangroves are moderately cost effective, however allocated areas for new mangroves can be costly	100	1000	Mangrove construction provides public goods benefits	30	330	Mangrove is likely to provide only limited further defensive capability at Wilson's Beach	90	720	Response requires few legal approvals	80	640	Response is reletively cheap to implement	10	100	Response likely considered to be subject to a high degree of uncertainty and scepticism by community	0	0	Response is slow to build protection; if in appropriate, response is slow to rectify	**6060**	**1**
Coastal Engineering Options																																
Artificial reefs	N																															
Detached breakwaters	N																															
Groynes and artificial headlands	N																															
Sea dykes or levees	F	20	300	Sea dykes generally unsympathetic to EF/CP, but provide for some natural migration	90	990	Built infrastructure subject to low levels of uncertainty over a given period of time. Beyond this set period, uncertainty is greater	0	0	High level of technical speciality required to constructed effective dykes / levees	80	720	Sea dykes and levees are expensive, but enable existing footprint to be retained	70	700	Dykes and levees provides public goods benefits, which are mostly exploited by private land onwers	100	1100	Defensive options have the least impact on property	20	160	Response subject to significant and wide ranging approvals	10	80	Response can be significantly costly to implement	95	950	Engineered defense response will be highly acceptable by community	10	100	Once response is in place, there are low levels of flexibility if deeemed ineffective	**5100**	**7**
Seawalls	F	0	0	Seawalls generally unsympathetic to EF/CP	90	990	Built infrastructure subject to low levels of uncertainty over a given period of time. Beyond this set period, uncertainty is greater	10	110	High level of technical speciality required to constructed effective sea walls	100	900	Sea walls are expensive, but enable existing footprint to be retained	70	700	Sea walls provides public goods benefits (defending public parks etc), but are mostly exploited by private land onwers	90	990	Defensive options have the least impact on property	20	160	Response subject to significant and wide ranging approvals	10	80	Response can be significantly costly to implement	100	1000	Engineered defense response will be highly acceptable by community	10	100	Once response is in place, there are low levels of flexibility if deeemed ineffective	**5030**	**8**
Coastal Settlement Design Options																																
Climate resilient design	F	80	1200	CRD is a built-environmental response that enables ecological functions to continue	0	0	Response likely to eventually be ineffective to inevitable SLR	60	660	Climate resilient design is moderately feasible in most circumstances	50	450	Retrofitting can be expensive, but costs not born by WRC	10	100	Costs are born by private land owner, leading to distribution impacts	50	550	Response enables properties to remain in situ, but costs put on private property owners	70	560	Response requires few legal approvals	100	800	Response requires expediture from private land property owners; none by WRC	70	700	Maintaining property rights likely to be popular, however costs are born by private property onwers	70	700	Response is reasonably felxible to future information and conditions; however flexibility is limited by limits to adaptation	**5720**	**4**
Elevated buildings	F	80	1200	Elevated buildings is a built-environment response that enables ecological functions to continue	10	110	Response likely to eventually be ineffective to inevitable SLR	30	330	Depending on the type of property, raising floor levels can be difficult	50	450	Retrofitting can be expensive, but costs not born by WRC	10	100	Costs are born by private land owner, leading to distribution impacts	50	550	Response enables properties to remain in situ, but costs put on private property owners	70	560	Response requires few legal approvals	80	640	Response requires expediture from private land property owners; none by WRC (apart from development approvals)	70	700	Maintaining property rights likely to be popular, however costs are born by private property onwers	20	200	Once building is elevated, there are no further options available if not effective enough	**4840**	**9**
Raise land levels	F	30	450	Raising land levels can result in a disruption to ecological functions by altering flow and tides, but preserves erosion risk	10	110	Response likely to eventually be ineffective to inevitable SLR	10	110	High level of technical speciality required to constructed effective sea walls	30	270	Retrofitting raised land levels can be very expensive, but costs not born by WRC	10	100	Costs are born by private land owner, leading to distribution impacts	50	550	Response enables properties to remain in situ, but costs put on private property owners	20	160	Response subject to significant and wide ranging approvals	80	640	Response requires expediture from private land property owners; none by WRC (apart from development approvals)	70	700	Maintaining property rights likely to be popular, however costs are born by private property onwers	40	400	Once building is elevated, there are no further options available if not effective enough; further raising is somewhat possible	**3490**	**12**
Planning Options																																
Land use planning	F	10	150	As few new dwellings are likely in Wilson's Beach, LUP will have a low impact on CHRR	10	110	As few new dwellings are likely in Wilson's Beach this unlikely to effective	10	110	With few nes dwellings planned, reducing CHR with existing footprint is difficult	10	90	Removal of public or private land from the CHZ entails a significant economic cost	10	100	Significant social impact experienced from land retreat	10	110	Significant property impact associated with voluntary / involuntary surrender	10	80	PLanning instruments subject to range of competing legal and state and federal interest tests	10	80	Radical strategic planning processes can be lengthy and expensive	50	500	Any change to the planning scheme will go through the normal, contested consultation process	10	100	With little likely future development, response is not flexible	**1430**	**14**
Development setbacks	F	90	1350	Removing property from CHZ will enable EF/CP to continue	50	550	Removing property from CHZ removes all risk / uncertainty	20	220	With few nes dwellings planned, reducing CHR with existing footprint is difficult	20	180	Removal of public or private land from the CHZ entails a significant economic cost	60	600	Limited social impact of response, though some limits on development flexibilities	40	440	In Wilson's Beach, development set backs will have limited impact; but no account made for future damages	50	400	Response subject to some legal challenge	80	640	Can be achieved through business as usual planning processes	60	600	Response likely to be considered acceptable as no compulsory surrender considered	20	200	With little likely future development, response is not flexible	**5180**	**6**
Limited development	F	90	1350	Limiting development at Wilson's Beach will prevent greater CHR	90	990	As few new dwellings are likely in Wilson's Beach this unlikely to effective	20	220	With few nes dwellings planned, reducing CHR with existing footprint is difficult	10	90	Removal of public or private land from the CHZ entails a significant economic cost	20	200	Limiting further development can increase property values in short- to medium- term	30	330	In Wilson's Beach, limiting development will have limited impact; but no account made for future damages	40	320	Limiting development subject to potential legal challenges	80	640	Can be achieved through business as usual planning processes	95	950	Limiting development to existing footprint likely to be highly acceptable to Wilson's Beach community	10	100	With little likely future development, response is not flexible	**5190**	**5**
Redefining planning objectives (rezoning)	F	10	150	As few new dwellings are likely in Wilson's Beach, redfining planning objectives will have a low impact on CHRR	10	110	As few new dwellings are likely in Wilson's Beach this unlikely to effective	10	110	With few nes dwellings planned, reducing CHR with existing footprint is difficult	10	90	Removal of public or private land from the CHZ entails a significant economic cost	10	100	Significant social impact experienced from land retreat	10	110	Significant property impact associated with voluntary / involuntary surrender	10	80	Planning instruments subject to range of competing legal and state and federal interest tests	10	80	Radical strategic planning processes can be lengthy and expensive	10	100	Response likely to be considered a surrender; communities significiantly disrupted	10	100	With little likely future development, response is not flexible	**1030**	**15**
Land swap	F	90	1350	Removing property from CHZ will enable EF/CP to continue	90	990	Removing property from CHZ removes all risk / uncertainty	10	110	Land swaps - finding alternative areas - are diffcut to implement	0	0	Removal of public or private land from the CHZ entails a significant economic cost	30	300	Private property owners are compensated for loss	20	220	Significant property impact associated with voluntary / involuntary surrender	10	80	Response subject to significant and wide ranging approvals	20	160	Land swaps demand considerable effort on behalf of WRC	20	200	Response likely to be considered a surrender; communities significiantly disrupted	20	200	Once response is implemented there is "no going back"	**3610**	**11**
Land buy-back	F	90	1350	Removing property from CHZ will enable EF/CP to continue	90	990	Removing property from CHZ removes all risk / uncertainty	30	330	Land buy backs have proven to be difficult to find support in the community	10	90	Removal of public or private land from the CHZ entails a significant economic cost	30	300	Private property owners are compensated for loss	20	220	Significant property impact associated with voluntary / involuntary surrender	10	80	Response subject to significant and wide ranging approvals	10	80	Response requires significant effort on behalf of WRC	80	800	Private property owners will be compensated in voluntary deal.	20	200	Once response is implemented there is "no going back"	**4440**	**10**
Land surrender	F	90	1350	Removing property from CHZ will enable EF/CP to continue	100	1100	Removing property from CHZ removes all risk / uncertainty	80	880	Voluntary removal of priovate property from the CHZ is straightforward	0	0	Removal of public or private land from the CHZ entails a significant economic cost	0	0	Significant social impact experienced from land retreat	10	110	Significant property impact associated with voluntary / involuntary surrender	100	800	Response is voluntary	80	640	Response is voluntary	90	900	Response is voluntary	20	200	Once response is implemented there is "no going back"	**5980**	**2**
Compulsory land acquisition	F	90	1350	Removing property from CHZ will enable EF/CP to continue	90	990	Removing property from CHZ removes all risk / uncertainty. However compulsory aquisition adds complexity	10	110	CLA is difficult to implement	10	90	Removal of public or private land from the CHZ entails a significant economic cost	0	0	Significant social impact experienced from land retreat	0	0	Significant property impact associated with voluntary / involuntary surrender	0	0	Response subject to significant and wide ranging approvals	0	0	Response requires significant effort on behalf of WRC	0	0	Compulsory nature of response likely to be unpopular	20	200	Once response is implemented there is "no going back"	**2740**	**13**

7.3 Workshop attendance list

Table 14: List of workshop attendees (30 September 2019)

Invited	Position	Directorate	Response
Adam Folkers	Manager Health, Environment & Climate	Community & Environment	Attended
Monica Regan	Environment Officer	Community & Environment	Attended
Julie Giguere	Environment Officer	Community & Environment	Attended
Stephen Fernando	Chief Financial Officer	Office of the Mayor & CEO	Apology
Katie Coates	Management Accountant	Office of the Mayor & CEO	Attended
Shane Neville	Manager Strategic Planning	Planning & Development	Attended
Matthew Twomey	Senior Development Assessment Officer	Planning & Development	Attended
Melanie Davis	Executive Officer Economic Development	Office of the Mayor & CEO	Apology
Libby Humphrey	Asset Coordinator	Corporate Services	Attended
Joanne Vlismas	Engagement & Marketing Coordinator	Office of the Mayor & CEO	Attended
Peter Stapleton	Treatment Operation Manager	Engineering Services	Apology
Yestin Hughes	Principal Engineer – Civil & Environmental - Whitsunday Water	Engineering Services	Attended
Jessica Cristaudo	Coordinator Transport Planning & Assets	Engineering Services	Apology
Michael Downing	Coordinator Capital Project Delivery	Engineering Services	Attended
Mark Callaghan	Manager Parks & Gardens	Customer Experience	Apology
Alicia Palmer	Disaster Management Coordinator	Engineering Services	Apology
Sandra Black	Community Development Officer	Engineering Services	Apology
Scott Hardy	Manager Natural Resource Management	Community & Environment	Apology
Elouise Lamb	Project Officer Economic Development & Grants	Office of the Mayor & CEO	Attended
John Gwydir	Executive Manager Roads and Drainage	Engineering Services	Attended
Vashti Sawdy	Laboratory Technician	Engineering Services	Attended
Jason Bradshaw	Acting Director Corporate Services	Corporate Services	Apology

7.4 Examples of hazard maps used in MCA analysis

A dynamic application, Tableau Reader, that enables the user to select various coastal hazard attributes (erosion, storm tide inundation, sea level rise and annual exceedance probabilities (AEP)) was used to spatially scrutinise the impacts of coastal hazards on Bowen and Wilson Beach. Screen shots of examples of the maps (screenshots below) are provided below. The tool developed by Climate Planning incorporates coastal hazard layers produced by WBM BMT in Phase 3 of the CHAS overlaying satellite imagery of the region

7.4.1 Storm tide inundation

The following figures (9 and 10) provide examples of maps for projected sea level rise at 2050 for Bowen and Wilson Beach.

Figure 9: Exposure to storm tide inundation to 2050 for Bowen

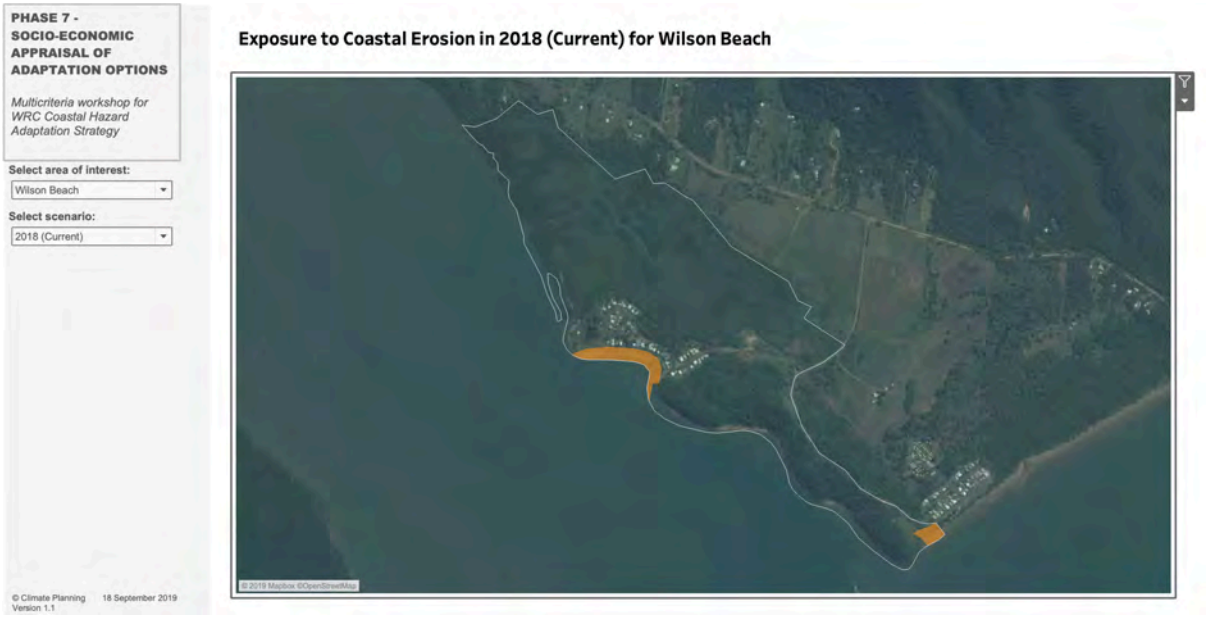
Figure 10: Exposure to sea level rise in 2050 for Wilson Beach

7.4.2 Coastal Erosion

The following figures (11 and 12) provide examples of maps for current coastal erosion. Coastal erosion as at 2050 and 2100 was also analysed.

Figure 11: Exposure to coastal erosion in 2018 for Bowen

Figure 12: Exposure to coastal erosion for Wilson Beach



7.4.3 Storm tide inundation

The following figures (14 and 15) provides AEP 1% screenshots for 2050. AEPs 0.2% and 0.5% for current, 2050 and 2100 were also analysed when assessing the feasibility of the adaptation responses.

Figure 13: Exposure to 1% AEP storm tide inundation in 2050 for Bowen

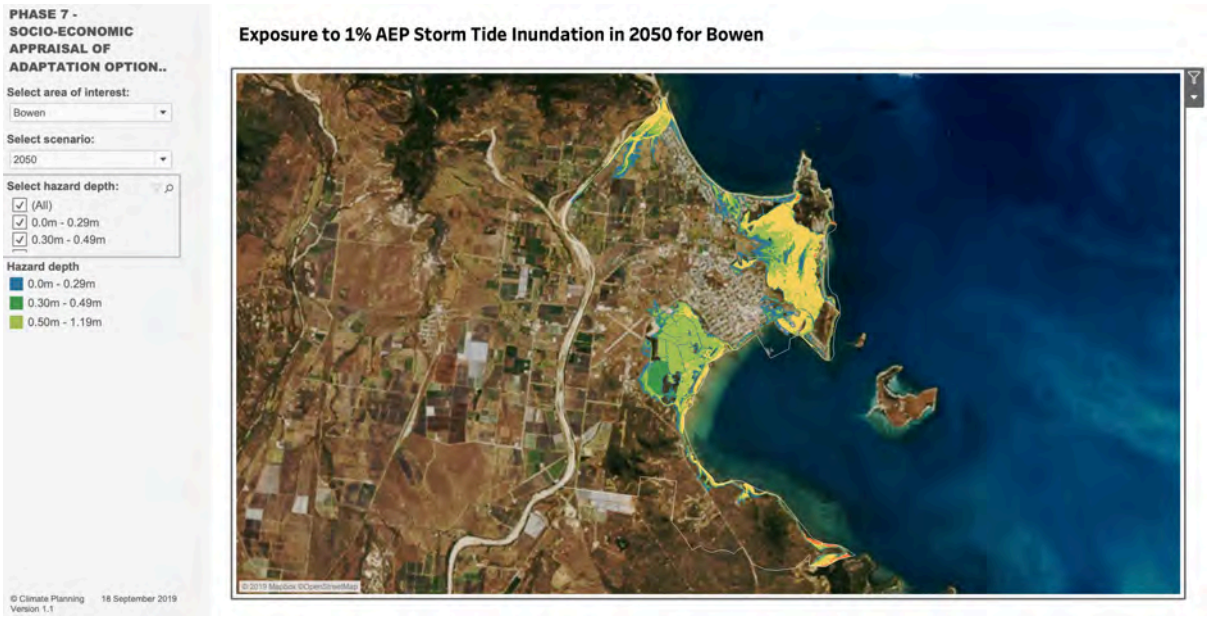
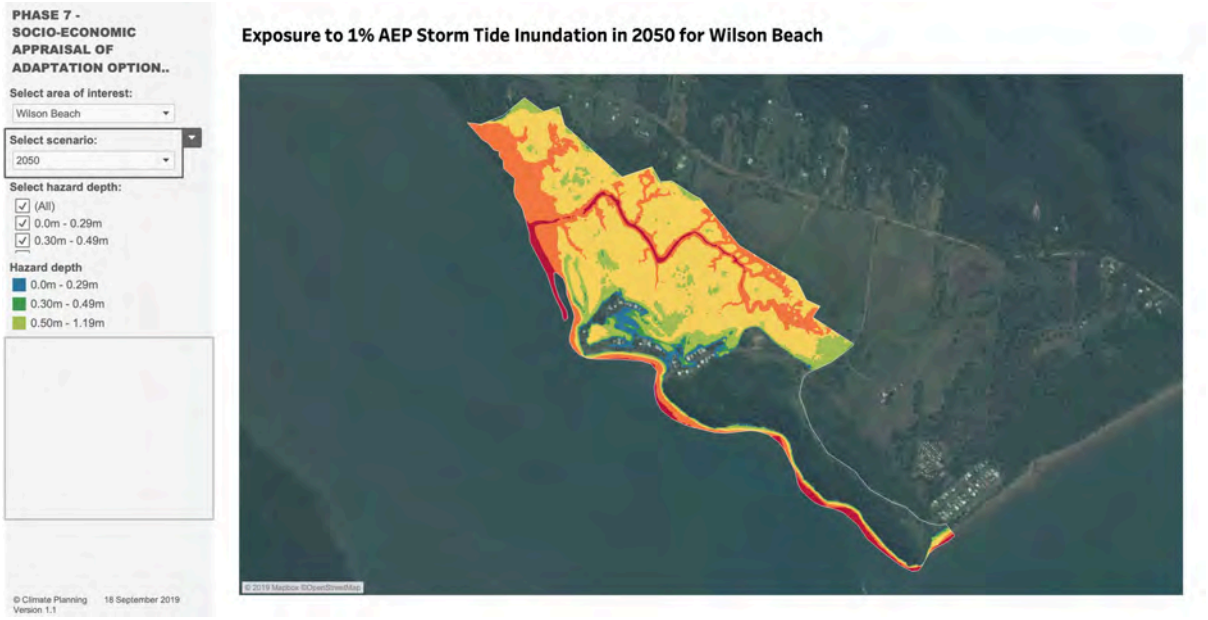


Figure 14: Exposure to 1% AEP storm tide inundation in 2050 for Wilson Beach



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