Maroochydore Beach management strategy - an ADAPT pilot study

Optimising beach management options under uncertainty

A confidential Draft Report prepared for Sunshine Coast Council

9 July 2018

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Contents

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DRAFT REPORT | Maroochydore Beach management strategy - an ADAPT pilot study

Executive Summary

Key Points

- Aither and BMT were engaged by the Sunshine Coast Council (SCC) to assess the existing Maroochydore Beach management strategy and analyse future adaptation strategies related to the timing and scale of beach nourishment and the timing of seawall construction.

- Aither and BMT used ADAPT, an integrated physical and economic model of Maroochydore Beach combined with a sophisticated optimisation technique, to assess multiple beach management strategies against numerous climate-driven futures.

- The assessment found that the management strategy currently being implemented by the SCC is delivering significant benefits to Sunshine Coast residents, with a positive average net present value (NPV) of $4.1 million compared to the 'do nothing' approach.

- The optimal management strategy, comprising of more aggressive beach nourishment than currently initiated, has an average NPV of $15.6 million higher than the current strategy.

- The optimal strategy outperforms the current strategy across all 50 future scenarios. The optimal strategy is also much less risky, with a narrower distribution of possible outcomes.

- The analysis demonstrates the value of beach nourishment in mitigating the physical risks presented by erosion. Benefits to Sunshine Coast residents are driven by:

- significant recreational, tourism and non-use benefits from maintaining beach condition for longer with beach nourishment

- avoided costs from delaying the need to build a seawall.

- This analysis primarily reports the results from a SCC perspective. However, about two-thirds of the recreational benefits accrue to people who live outside the SCC. The distribution of benefits may be relevant for determining cost-sharing arrangements between the SCC and other stakeholders.

- The potential for inundation of assets behind the beach has not been modelled in this assessment. The impact of excluding asset protection benefits is likely to be limited, as all the strategies considered here include the construction of a seawall once the volume of beach sand falls below a threshold. In the future, modelling of land behind the beach may help to further inform when to build the seawall and identify the beneficiaries.

- The model outputs are sensitive to sea-level rise and cost of beach nourishment assumptions. Further work could be undertaken to understand these inputs better.

Background

Aither and BMT were engaged by the Sunshine Coast Council (SCC) to undertake a pilot evaluation of the existing Maroochydore Beach management strategy and analyse future adaptation strategies.

The SCC directs significant resources to Maroochydore Beach to manage persistent coastal erosion that affects social, cultural and economic values associated with the area. Coastal management and adaptation decision making, however, is inherently challenging. These challenges arise from the significant number of possible management strategies available to coastal managers, complex and uncertain physical processes affecting coastlines, and the numerous and varied values at risk.

The SCC and BMT have previously developed a way to accommodate some of the Maroochydore Beach management uncertainty through trigger-based approaches and monitoring techniques to identify changing risk profiles over time (e.g. Barnes et al. 2017). However, the management approach is still somewhat reactive. The future management of Maroochydore Beach is expected to require significant investment. It is therefore desirable that decision makers are given the best information and analysis to make investment decisions at the appropriate scale and time.

Approach

Aither and BMT have developed ADAPT, a robust and integrated approach to address the complex challenges of coastal adaptation decision making. The approach overcomes the limitations of the traditional 'deterministic' methods typically used to inform coastal management strategies. ADAPT provides confidence, understanding and clear insight for decision makers, stakeholders and the broader community through the:

- development of adaptive strategies that are flexible to changing circumstances and needs over time
- integration of the latest economic and engineering knowledge and techniques from other sectors
- assessment of a wide range of benefits and costs associated with thousands of management strategies to identify the one which performs the best across many potential futures.

Structure of ADAPT

ADAPT combines three modules:

An integrated model – The integrated model within ADAPT captures the relationships between a management strategy, beach condition and the associated benefits and costs.

Robustness testing – ADAPT evaluates the benefits and costs of each strategy over many different future scenarios. A robust management strategy performs well across a range of possible futures.

Optimisation – There are thousands of possible management strategies available to decision makers, especially when differences in timing and scale are considered. ADAPT uses a sophisticated peer-reviewed machine learning algorithm to intelligently generate and compare a large number of possible strategies based on their performance in robustness testing. ADAPT then returns the optimal strategy.

Applying ADAPT to Maroochydore Beach

The core of ADAPT is an integrated physical-economic model (Figure 1). The integrated model for this project was developed through consultation with the SCC and stakeholders including caravan park managers, Surf Club managers and the Surf Life Saving Queensland. These stakeholders helped to identify and validate the most relevant costs and benefits associated with Maroochydore Beach, and provided data in relation to the benefits and costs. Aither and BMT also drew on respected academic sources, and engineering and scientific data in developing the integrated model.
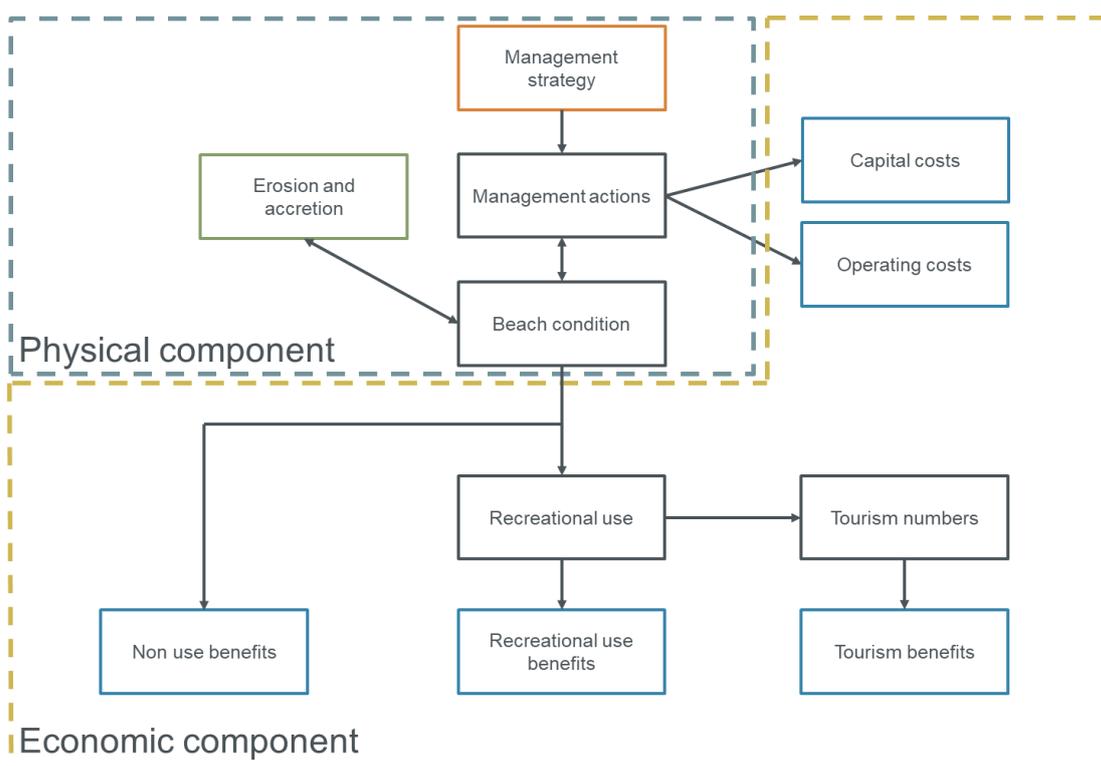
Source   Aither and BMT.

Note   Management strategy in orange; external factors in green; intermediate impacts in black; benefits and costs in blue.

Figure 1   Conceptual map of the integrated model

The physical component simulates the movement of sand based on a 20-year wave record and numerical modelling. Statistical analysis of the wave record and generation of other representative 20-year simulations of sediment transport introduces a probabilistic element to the model. Climate change is incorporated through the expectation that more sand will be needed to maintain the present-day shoreline position under sea-level rise scenarios. This model incorporates 50 different plausible future scenarios. Each scenario predicts beach erosion and accretion leading to different volumes of sand in the Maroochydore Beach compartment, ultimately affecting the condition of the beach.

The economic component of the model links beach condition – the volume of sand, exposure of coffee rock, and existence of a seawall – with different benefits and costs. The benefits include:

- **Recreational use benefits** – the benefits that people receive from using the beach for active and passive recreation, including events

- **Tourism benefits** – the benefits to local businesses in higher profits from the increase in tourism associated with the beach

- **Non-use benefits** – the benefits to local residents from knowing that the beach is in good condition, even if they never visit the beach themselves.

The costs of management actions include both capital and operating costs associated with seawall construction and beach nourishment.

Results

Aither and BMT found that the management strategy currently being implemented by the SCC is delivering significant benefits to Sunshine Coast residents, with a positive average net present value (NPV) of $4.1 million compared to the 'do nothing' approach (Table 1). Nourishment defers the costs and the severe reduction in benefits associated with seawall construction. Nourishment also slows the decline in the sand volume within the beach compartment, further increasing the benefits to SCC residents. Most of the benefits of nourishment to SCC residents are from their recreational use, with more visits and greater benefit per visit. However, there are also substantial benefits to SCC businesses from increased tourism and to SCC residents who benefit from knowing that the beach is in reasonable condition (even if they never visit the beach). Together, the benefits from nourishment combined with the avoided seawall construction costs more than compensate for the costs of nourishment.

However, the analysis suggests that altering this strategy could lead to even greater net benefits. ADAPT intelligently generated and compared one million possible management strategies across 50 possible futures to find the optimal strategy for Maroochydore Beach (Box 1). Compared to the current strategy, the optimal strategy involves significantly more frequent nourishment, at least until it becomes infeasible to maintain the beach due to sea-level rise. At this point, a seawall is constructed. The average NPV of the optimal strategy is about $16 million higher than the current strategy (and $20 million higher than the 'do nothing' strategy).

Box 1: The optimal strategy

The optimal strategy involves aggressive beach nourishment. Initially, sand is applied when the beach volume falls below about 290,000 m^3. Over time, climate change leads to sea-level rise, which contributes towards an increase in erosion relative to accretion. To protect against a run of unfavourable years, sand is applied so that an increasingly higher volume is contained within the beach compartment, up to about 570,000 m^3. Eventually however, erosion becomes so severe that any sand applied rapidly erodes. This makes maintaining the beach volume through nourishment less feasible, given constraints in the volume that can be applied in a single nourishment campaign. It also makes beach nourishment less desirable, and hence sand is not applied once the seawall has been constructed in later years.

The optimal strategy involves applying the maximum possible volume of sand, 100,000 m^3, when beach nourishment is triggered. This helps to maintain beach condition for as long as possible and exploits scale to reduce the unit cost of beach nourishment.

Table 1   Average benefits and costs under each strategy from a SCC perspective

	Current relative to 'do nothing'	Optimal relative to current
Benefits		
Recreational use	$5.6 m	$10.6 m
Tourism	$1.8 m	$1.8 m
Non-use	$1.2 m	$2.4 m
Avoided seawall construction costs	$1.7 m	$3.3 m
Costs		
Nourishment	$6.3 m	$2.5 m
NPV	$4.1 m	$15.6 m

Source   Aither and BMT analysis.

Note   All costs and benefits are average values, expressed as present values over a 40-year time horizon, with a 7 per cent discount rate.

Further analysis

The following compares the optimal strategy and current strategy in more detail. Figure 2 shows that additional beach nourishment under the optimal strategy manages to keep the average volume of sand on the beach relatively constant until 2040. Over the same period, the average volume of sand under the current strategy decreases consistently.
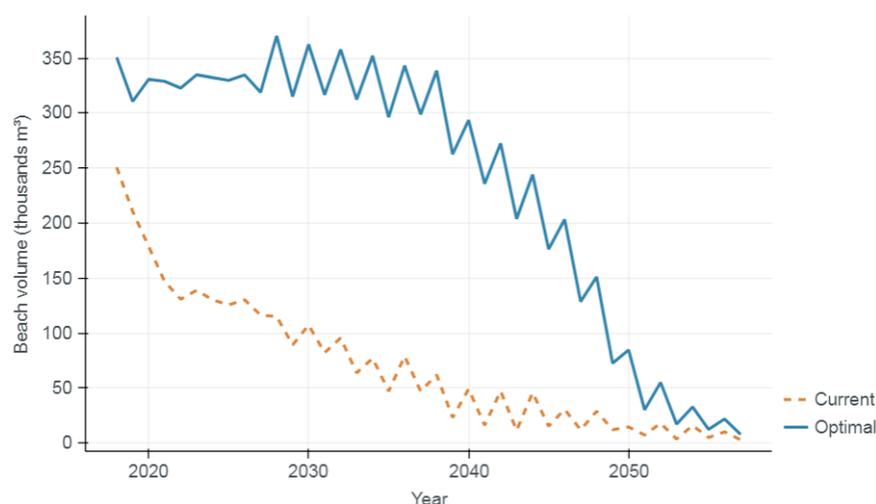
Source   Aither and BMT analysis.

Figure 2   Comparison of average beach sand volumes for optimal and current strategies

The top left chart in Figure 3 displays the average nourishment volume applied to the beach under the optimal and current strategies. The optimal strategy results in more beach nourishment on average in the initial years than the current strategy, which defers the construction of the seawall substantially.

After the seawall is constructed, an alternative trigger of zero applies, explaining the decline in nourishment towards the end of the timeframe.

The top right chart in Figure 3 illustrates that seawall construction is delayed until at least 2046 under the optimal strategy. By contrast, seawall construction would commence no later than 2042 under the current strategy.

The bottom left chart in Figure 3 shows that under the optimal strategy, there are initially high nourishment costs, which then decline after the first few years before increasing again. As seawall construction is deferred to later years, the costs of seawall construction peak between 2040 and 2050. Overall, costs are slightly lower under the optimal strategy than the current strategy.

The average benefits of each strategy are presented in the bottom right chart in Figure 3. Under the optimal strategy average benefits are unaffected by the condition of the beach or existence of the seawall until after 2040. Compared with the current strategy, the additional nourishment under the optimal strategy successfully maintains the beach condition to a higher level, increasing the average benefits received across all years.
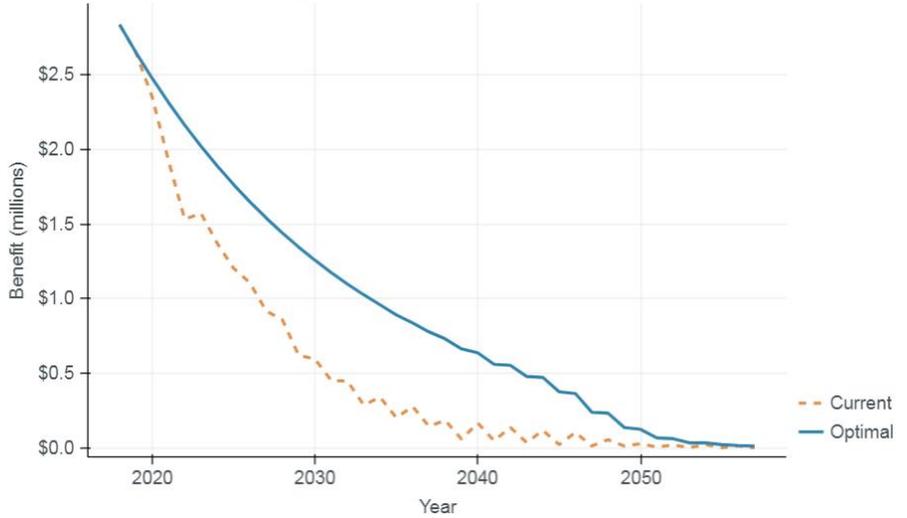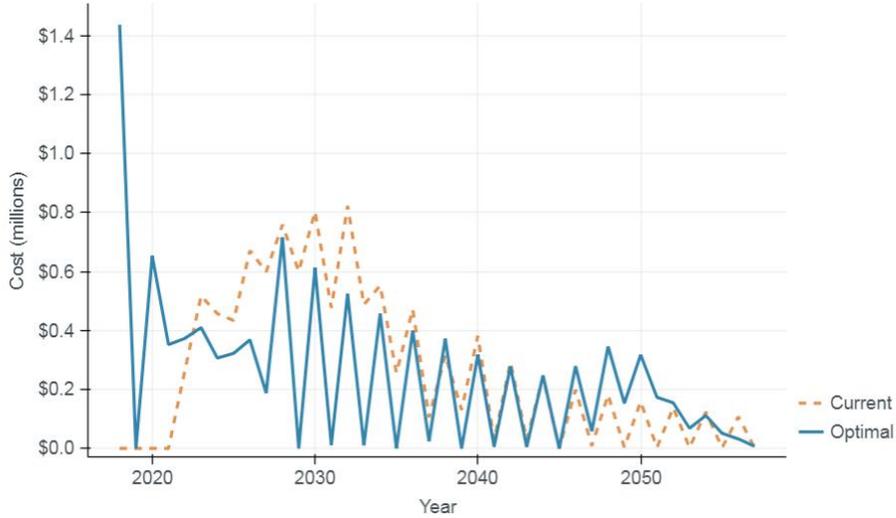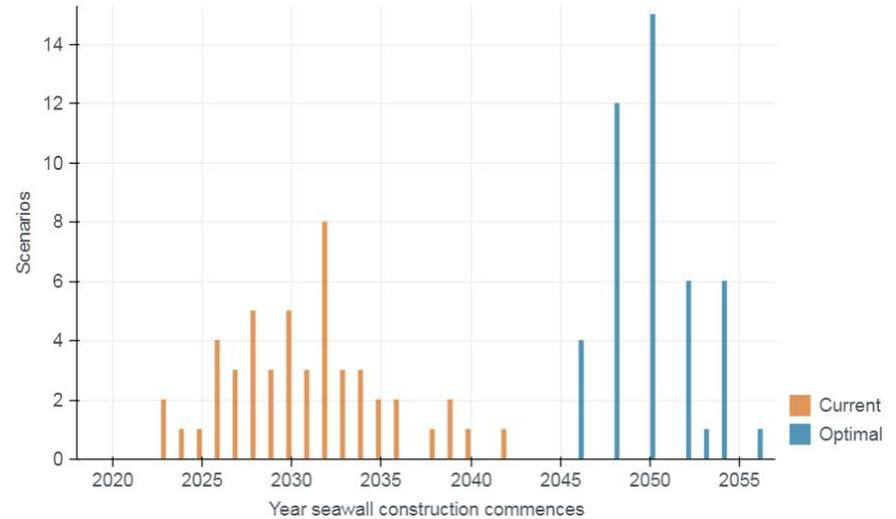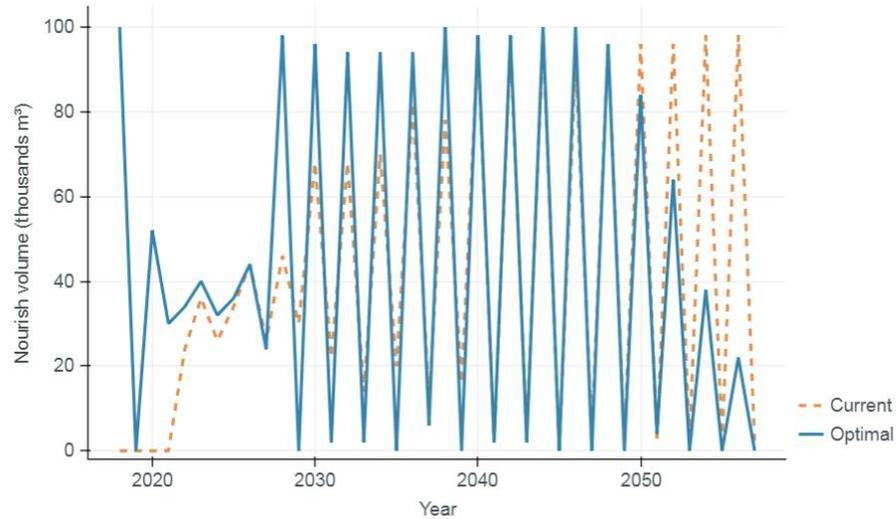
Source   Aither and BMT analysis.

Figure 3   Comparison of nourishment, seawall construction, present value costs and benefits for optimal and current strategies

Figure 4 shows that the optimal strategy outperforms the current strategy in all 50 modelled futures. The optimal strategy has an average NPV of $28 million, performing considerably better than the current strategy which has an average NPV of $12 million.
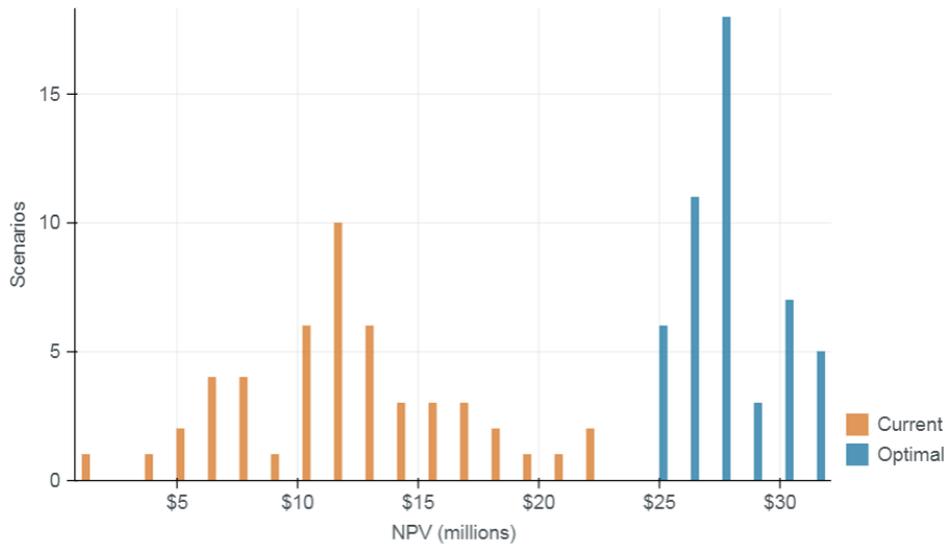
Source   Aither and BMT analysis.

Figure 4   Comparison of NPV distributions for optimal and current strategies

The previous analysis reports the results from a SCC perspective. However, about two-thirds of the recreational benefits accrue to people who live outside the Sunshine Coast region. The distribution of benefits may be relevant for determining cost-sharing arrangements between the SCC and other stakeholders (e.g. governments or the private sector) for beach nourishment.

Next steps

This pilot analysis undertaken by Aither and BMT focused on the optimisation of beach nourishment. While this analysis demonstrated the value of beach nourishment broadening the scope of assessment could provide further insights relevant to decision making and cost sharing arrangements. The scope of assessment could be expanded in a few key areas:

- The analysis considers Maroochydore Beach as a single compartment. Breaking up the beach into smaller units could help to understand the optimal location of beach nourishment. This would also help to develop a more refined relationship between beach condition and recreational value.

- The inundation of land behind the beach, the spatial distribution of assets, or the damages associated with inundation have not been modelled. In the future, modelling land behind the beach would be beneficial for understanding when to build the seawall and identifying the beneficiaries.

These additions could be easily incorporated into ADAPT, given it has been constructed in a modular nature to allow the physical and economic components to be refined as new information becomes available.

The model outputs are sensitive to sea-level rise and cost of nourishment assumptions. The assumed rate of sea-level rise data is based on projections reported by the Intergovernmental Panel on Climate Change (IPCC 2014), however the relationship between sea-level rise and beach erosion would benefit

from further site-based analysis and shoreline evolution modelling. This would improve confidence in the model outputs.

The cost of beach nourishment is based on historical estimates provided by SCC. While these estimates may be accurate, further interrogation of the costs of beach nourishment, including from alternative sand sources would be beneficial. If alternative sand sources are available, it might be feasible and desirable to sustain beach nourishment for longer than suggested in this assessment.

1.   Introduction

1.1.   Maroochydore Beach

In the context of the assessment described in this report, Maroochydore Beach is a 1.7 km stretch of shoreline between the Alexandra Headland Surf Lifesaving Club and the Maroochy Surf Club, Sunshine Coast, Queensland. The shoreline is characterised as a sandy beach with a relatively narrow dune and foreshore buffer that includes dune scrub vegetation and casuarinas.

Maroochydore Beach is an iconic Sunshine Coast tourism destination and carries significant social and economic value. The beach supports a range of passive and active recreation and regularly hosts state and national Surf Lifesaving events. The importance coastal management in the area also relates to the protection of several built assets, including the Aerodrome Road-Alexandra Parade state-controlled road corridor, subsurface water and electrical utilities, holiday parks, foreshore public space, pedestrian and cycle pathways, and beach access points (Figure 5).

Storm events and persistent periods of low natural sand supply cause a loss of the dune buffer and lowering of the beach elevation. Exposed coffee rock is often visible in the nearshore and upper beach area which is indicative of a receding shoreline on a geological timescale (e.g. Jones, 1992; Willmott, 2007). When Maroochydore Beach is in an eroded state the social and economic value of the area is reduced and the land-based assets have little protection from subsequent storm events. The threat to infrastructure, in particular the state-controlled road corridor, is greatest within the southern section of the study area. The threat is relatively lower to the north of the Maroochydore Beach Holiday Park due to a wider dune and vegetation buffer.

Forecast sea-level rise due to climate change is expected to place additional pressure on developed coastlines. Beaches that are 'fixed' and not able to naturally recede landward in response to gradual increases to mean sea level will narrow and lower over time. Maroochydore Beach is vulnerable to sea-level rise and future coastal management strategies will need to adapt if the present-day shoreline position and associated values are to be maintained.

Source   Nearmap (aerial imagery).

Figure 5   Maroochydore Beach and built assets

1.2.   Beach management

The SCC strategy and planning framework includes the Coastal Management Policy and Shoreline Erosion Management Plan (SEMP) which have been developed to assist in preserving and/or enhancing identified coastal values and assets. The SEMP is a 10-year action plan that describes the key coastal processes along the Sunshine Coast, identifies current shoreline erosion threats to council-controlled assets, and outlines preferred management options.

A general priority action identified by the SEMP is for 'ongoing maintenance, repairs, rehabilitation and identification of emergent issues' relating to existing structures and shoreline management operations. With this priority action in mind, SCC directs significant resources to Maroochydore Beach to manage persistent coastal erosion that impacts the social and economic values associated with the area. The current approved erosion management strategy for this coastal compartment is illustrated in Figure 6 and combines:

- Beach nourishment using sand from the lower Maroochy River at a cost of approximately $1 million per campaign (approximately every 2 years), and

- Development Approval for a 1.6 km rock revetment seawall to be constructed once beach nourishment is no longer viable and/or the risk to land based assets is unacceptable.
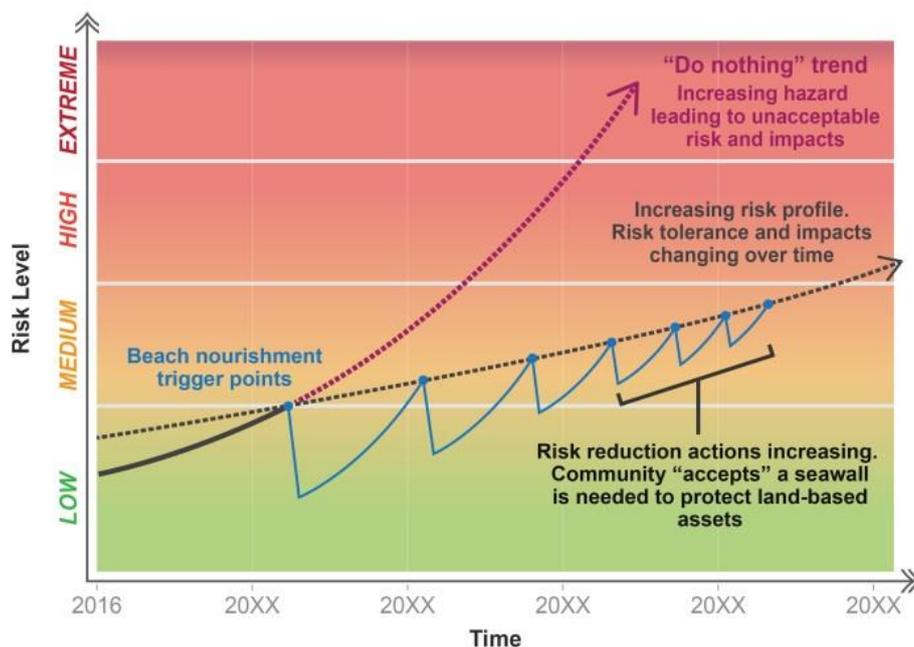
Source   Barnes et al. (2017).

Figure 6   Conceptual model of approved Maroochydore Beach management strategy

Beach Nourishment

Beach nourishment is currently the preferred coastal erosion management option for Maroochydore Beach. The primary intent of this activity is to maintain and enhance a buffer between coastal processes and land-based assets thereby delaying the need for an engineered seawall structure. A secondary outcome is the improvement to beach amenity and the associated social and economic benefits. An adequate beach width is also a requirement for hosting surf lifesaving events.

Since 2013, beach nourishment has been used several times to assist in protecting land-based assets and maintaining beach values (Figure 7). The works involve dredging marine sand from the Maroochy

River mouth (immediately north of the beach) and relocating the material to the beach via a slurry pipeline. This activity has helped to avoid extended periods of poor beach condition. However, there are environmental constraints that limit access to suitable sand for beach nourishment from the lower Maroochy River. Existing permits allow sand extraction of 100,000 m^3 every two years.

Source   BMT & Birdon Pty Ltd.

Figure 7   Dredging and Nourishment (clockwise from top left): Birdon Pty Ltd CSD Dogo in the Lower Maroochy River; Sand Delivery to Maroochydore Beach; Beach Condition after Nourishment Works; Beach Condition before Nourishment Works

Seawall Development Approval

Because of the limit on the volume of sand available for beach nourishment, and the likelihood of increased erosion pressure from sea-level rise, SCC has acknowledged that Maroochydore Beach may eventually require a rock revetment seawall to protect land-based assets.

To provide greater certainty for long-term management in the area, SCC has obtained a Development Approval (DA) for an adaptive management approach. The DA recognises that damage to land-based assets is unacceptable and that a seawall is required at an uncertain time in the future. The DA also sets triggers for the detailed design and construction of the seawall. The triggers are based on the beach and dune buffer width required to protect land-based assets which was informed by numerical modelling of design storm event erosion volumes. It was determined that once the land-based assets were within the area of immediate erosion risk from a design storm event, construction of a seawall would be required to prevent damage to land-based assets. In the interim, the beach and dune buffer width is monitored through aerial photography and/or on-ground surveys to determine whether triggers have been reached.

1.3. Report scope

As described above, SCC has developed a way to accommodate some of the Maroochydore Beach management uncertainty through the 'trigger-based' seawall DA and monitoring techniques to identify a changing risk profile over time. However, the management approach is still considered 'reactive' and the significant investment decisions regarding ongoing beach nourishment and the appropriate time to construct the seawall has not been subject to an economic analysis. The optimal timing of investment remains uncertain, primarily due to the difficulties in predicting the frequency and magnitude of natural events that cause the erosion. This uncertainty is compounded when considering longer term planning horizons and adaptation options in response to climate change induced sea-level rise.

To inform future investment decisions, Aither and BMT were engaged by SCC to undertake an evaluation of the Maroochydore Beach management strategy. Specifically, the evaluation seeks to answer:

- Does the current nourishment strategy represent value for money?
- Could the nourishment strategy be improved?
- Who are the beneficiaries of beach nourishment?
- When is the seawall trigger likely to be reached if beach nourishment continues in accordance with the existing permits?

These questions have been explored through a pilot of the ADAPT coastal adaptation model. Development of the model and evaluation of the Maroochydore Beach management strategy is presented in this report.

As this is a pilot study, not all benefits have been quantified and some elements of the physical modelling could be refined. For example, we have not modelled the potential for inundation of land behind the beach, the spatial distribution of assets, or the damages associated with inundation. Nevertheless, this assessment is underpinned by:

- knowledge gained through over a decade of monitoring and modelling the key physical processes that influence Maroochydore Beach condition, and
- state-of-the-art economic modelling techniques.

1.4. Report structure

The report is structured as follows:

- Section 2 describes the modelling approach
- Section 3 demonstrates how the ADAPT model is applied
- Section 4 documents the data and sources
- Section 5 outlines the beach nourishment strategies considered
- Section 6 presents the results
- Section 7 concludes by discussing the findings and potential for further research.

2. Approach

2.1. Complexity of coastal adaptation

Coastal adaptation decision making is typically challenging. These challenges arise from the significant number of possible management strategies available to coastal managers, complex and uncertain physical processes affecting coastlines and the numerous and varied values at risk.

There are numerous strategies for the protection and management of coastal assets. Typical strategies include seawalls, revegetation, sand nourishment, as well as early warning flood systems and land use planning. The number of strategies is further increased when timing and scale, or different combinations of strategies, are considered.

Coastal processes can be complex and uncertain. For example, the natural sand supply to beaches varies from year to year, and the timing and magnitude of storms that cause beach erosion cannot be forecast accurately. There is also uncertainty around future climate change, the effects of climate change on the global mean sea level, and the effect of a changing climate will have on the frequency of coastal inundation and erosion events.

There are also numerous values at risk with declining beach condition, including property and coastal assets, ecosystem services and social, recreational and amenity values. These values change over time and are affected in complex ways by the physical condition of the beach and surrounding areas.

2.2. Traditional approaches

Traditional decision-making approaches typically consider:

- only one or a few possible management strategies

- a single set of assumptions about the future

- a limited scope of benefits and costs, usually the simplest to measure.

Traditional decision-making approaches have a place and are effective where there are only a few possible strategies, the future can be accurately predicted, and there are a limited range of benefits and costs. However, they generally do not meet the challenges posed by the inherent complexities in coastal management and climate change adaptation.

For example, traditional decision-making approaches may understate the benefits of strategies by failing to consider social, recreational and amenity values. Additionally, they can create doubt when only one or two future climate scenarios are considered. This can lead to not taking actions which should be taken, often because investors cannot be convinced of the genuine benefits of investment. It can also damage the credibility of coastal managers with stakeholders and the broader community as the analysis ignores values that are meaningful to them.

2.3. ADAPT

Aither and BMT developed ADAPT to address the complexity in optimising coastal management strategies. ADAPT is a robust and practical coastal adaptation decision making tool. It provides

confidence, understanding and clear insight for decision makers, stakeholders and the broader community.

ADAPT has the following features:

- development of adaptive strategies that are flexible to changing circumstances and needs over time

- integration of the latest economic and engineering knowledge and techniques from other sectors

- assessment of a wide range of benefits and costs associated with thousands of strategies to identify the one which performs the best across many potential futures.

ADAPT is a general tool that can be modified for different coastal management and adaptation problems. The implementation of ADAPT for this project is discussed below.

2.4.   ADAPT components

The ADAPT model combines three core components:

Integration of physical and economic models – physical models predict physical outcomes, such as beach condition, based on physical variables, including waves, currents, sea-level rise and erosion. Economic models quantify financial, social and environmental values related to broader environmental conditions. The integration of physical and economic models within ADAPT allows for relationships between physical changes and economic values to be predicted with greater accuracy.

Robustness testing – Uncertainty regarding future conditions is inherent in many decision-making processes and acutely apparent when climate change is considered. Strategies that perform well under one climate scenario may perform poorly under other scenarios. To account for this, ADAPT evaluates each strategy over many different future scenarios. A robust management strategy is one that performs well across a range of possible futures.

Optimisation – When taking into account timing, scale, triggers and combinations of adaptation options there are thousands of possible management strategies available to decision makers. To avoid the possibility of selecting an inappropriate strategy it is necessary to assess how numerous strategies perform in numerous possible futures. Often this means testing thousands of strategies against thousands of futures. To undertake this testing manually would be difficult and very time consuming. Therefore, ADAPT uses a sophisticated peer reviewed machine learning algorithm to intelligently generate and compare a large number of possible strategies to find the optimal strategy.

3. Applying ADAPT components to Maroochydore Beach

3.1. Integrated model

The core of ADAPT is an integrated physical-economic model that captures the linkages between a management strategy, beach condition and the associated benefits and costs (Figure 8 Conceptual map of integrated model). The integrated model for this project was developed through consultation with SCC and stakeholders, who helped to identify the most relevant costs and benefits.
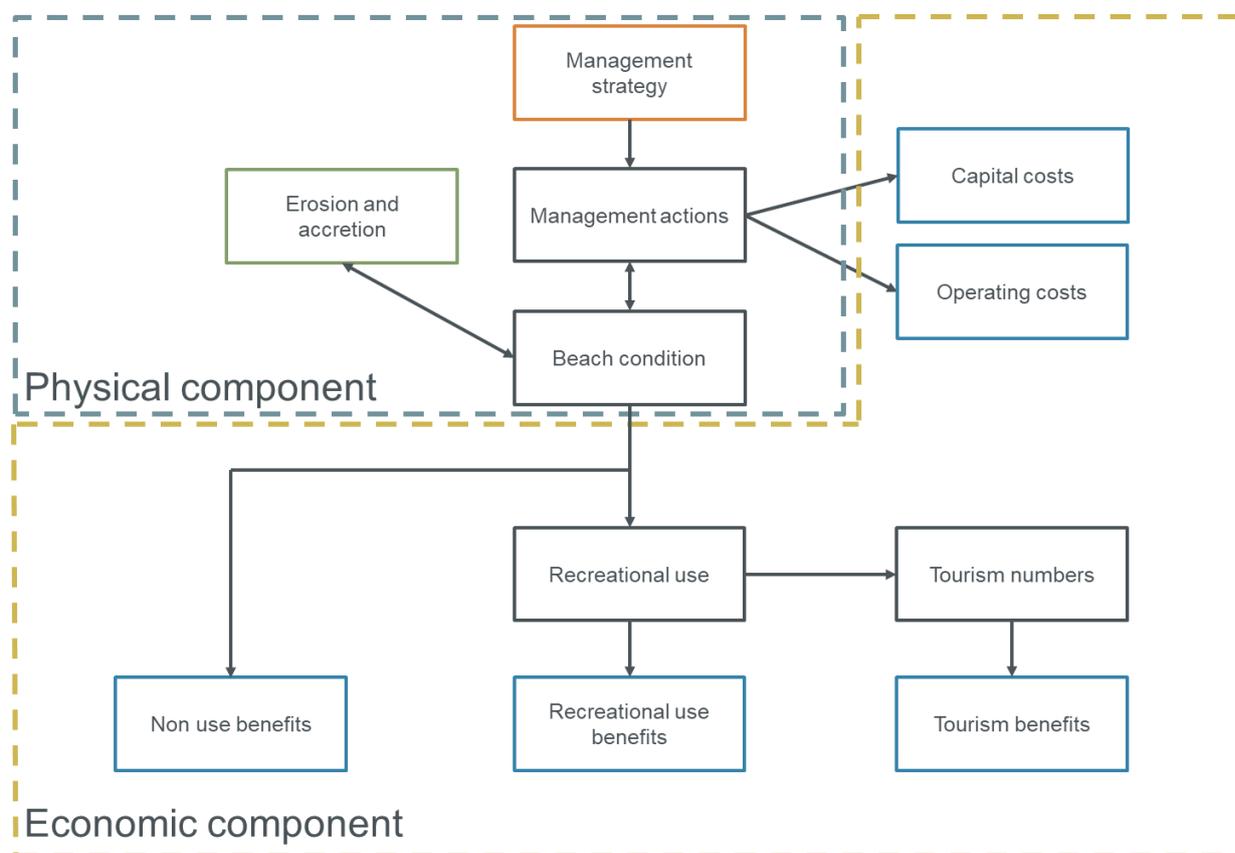
Source   Aither and BMT.

Note   Management strategy in orange; external factors in green; intermediate impacts in black; benefits and costs in blue.

Figure 8   Conceptual map of integrated model

Costs and benefits

Management actions lead to both **capital** and **operating costs**. There are several different benefits, all of which depend on beach condition:

- **Recreational use benefits** – based on recreational use and the average value per recreational use, calculated separately for locals and tourists

- **Tourism benefits** – based on recreational use by tourists, the proportion who would not visit the region without the beach, the average expenditure per tourist, and the average benefit per dollar of expenditure

- **Non-use benefits** – based on the local population and the average existence value per person.

The costs and benefits over time are discounted to reflect the fact that a dollar now is worth more than a dollar in the future.

Benefits not considered

As this is a pilot study, not all benefits have been quantified. We have not modelled the inundation of land behind the beach, the spatial distribution of assets, or the damages associated with inundation. Consequently, the asset protection benefits of the strategies are not considered. The impact of excluding asset protection benefits is likely to be limited, in this report, since all of the strategies considered include the construction of a seawall once the volume of the beach falls below a threshold. This limits damage to assets behind the beach.

In addition, we have not modelled the amenity benefits to people who are not on the beach, such as residents and visitors who have a view of the beach from apartments, caravan parks, and restaurants. Note that the amenity benefits to people on the beach will be captured in the recreational benefits. The exclusion of some amenity benefits means that the analysis may understate the benefits of beach nourishment.

ADAPT is constructed in a modular nature, allowing for the refinement or extension of the physical or economic components as new information becomes available. ADAPT would be suited to modelling asset protection benefits and amenity benefits to people who are not on the beach.

3.2.   Example of integrated model

This example illustrates the integrated model for Maroochydore Beach based on the 'do nothing' management strategy, which does not undertake beach nourishment but still starts constructing the seawall when the volume of sand falls below 50,000 m^3. This model only considers one future scenario.

Net accretion, management actions and beach condition

The sand volume on the beach in each year depends on natural sand supply, erosion, accretion, nourishment and the existence of a seawall. Figure 9 illustrates the net accretion volume and the beach sand volume over time.

The volume of sand on the beach starts at 300,000 m^3. In this particular future scenario in 2021 and 2041, there is a substantial net gain in natural sand supply to the beach, which provides a buffer for erosion in subsequent years. However, in the remaining years there is typically a net loss of sand on the beach, both due to coastal processes in this scenario and the increasing erosion due to sea-level rise. As there is no beach nourishment in any year (Figure 10 top left), the beach erodes and is unable to recover.

In 2030, the seawall trigger is reached, leading to the commencement of seawall construction (Figure 10 top right). The construction of the seawall takes two years to complete, leaving the beach unprotected until 2032. Throughout these years, the volume falls below zero, with erosion continuing into the foreshore. While inundation to the areas behind the beach are not modelled explicitly, this

indicates potential for damage to the foreshore area and beyond. Once the seawall construction is completed, the volume of sand on the beach cannot fall below zero, providing protection to all assets behind the seawall. As a result, the volume of sand on the beach does not go below zero after 2032.
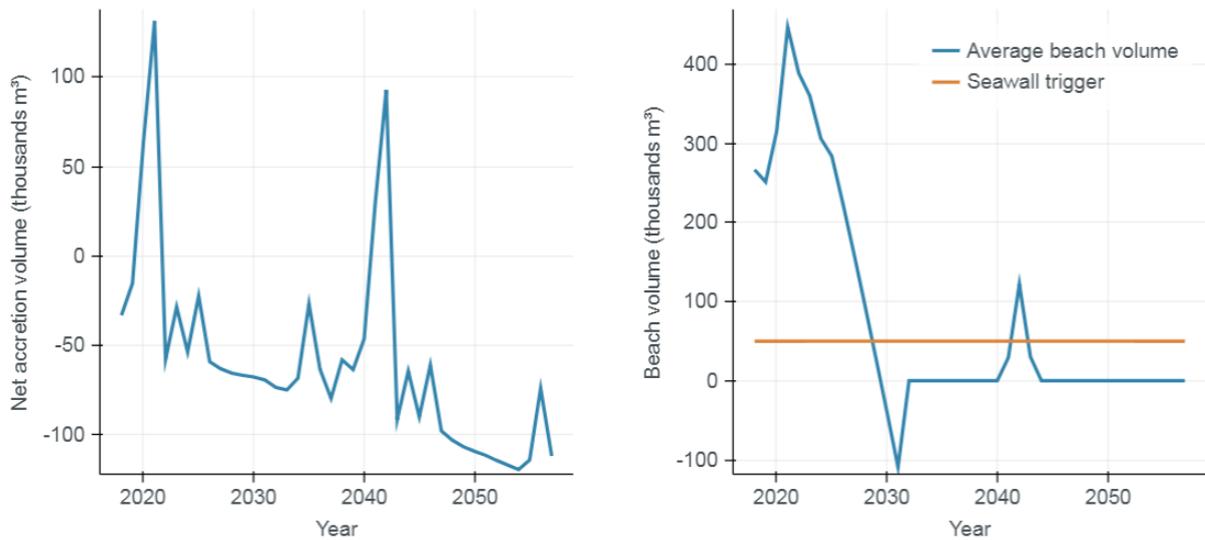
Source   Aither and BMT analysis.

Figure 9   Net accretion and beach volume

Costs and benefits

The costs to SCC residents in managing Maroochydore Beach over time are displayed in Figure 10 (bottom left). In this scenario seawall costs are incurred in 2030 and 2031, and the cost of construction is split evenly over each year (the slight decline in the figure is due to discounting). Under the 'do nothing' strategy there is no beach nourishment and therefore no beach nourishment costs are incurred.

Figure 10 (bottom right) shows the benefits received by SCC residents from the Maroochydore Beach over time. Recreational use benefits contribute to approximately 70 per cent of benefits, with the remaining 30 per cent being divided fairly evenly between tourism and non-use benefits. The total benefits received follows the sharp decline in the volume of sand on the beach, reaching zero by 2030. This is largely due to the following effects:

- When the volume of sand on the beach falls below 140,000 m^3, both recreational use and the value per recreational use are reduced by 20 per cent of their current values.

- When the volume of sand on the beach falls below 80,000 m^3 (the earliest point when coffee rock is first exposed), or seawall construction has been completed, the non-use benefits associated with the beach are zero. Also, both recreational use and the value per recreational use are reduced by 50 per cent of their current values.

- When the volume of sand on the beach falls to zero, it is assumed that there are no benefits received.

The discount rate will also lead to decreasing benefits over time, as all values are expressed in present value terms. There is a small amount of benefit received between 2041 and 2043, which is associated with the significant accretion of sand onto the beach discussed above.

Under the 'do nothing' strategy, the net present value (NPV) from the Maroochydore Beach is approximately $19 million. This is a result of significant benefits received within the first ten years, and seawall costs being deferred until 2030 and 2031.
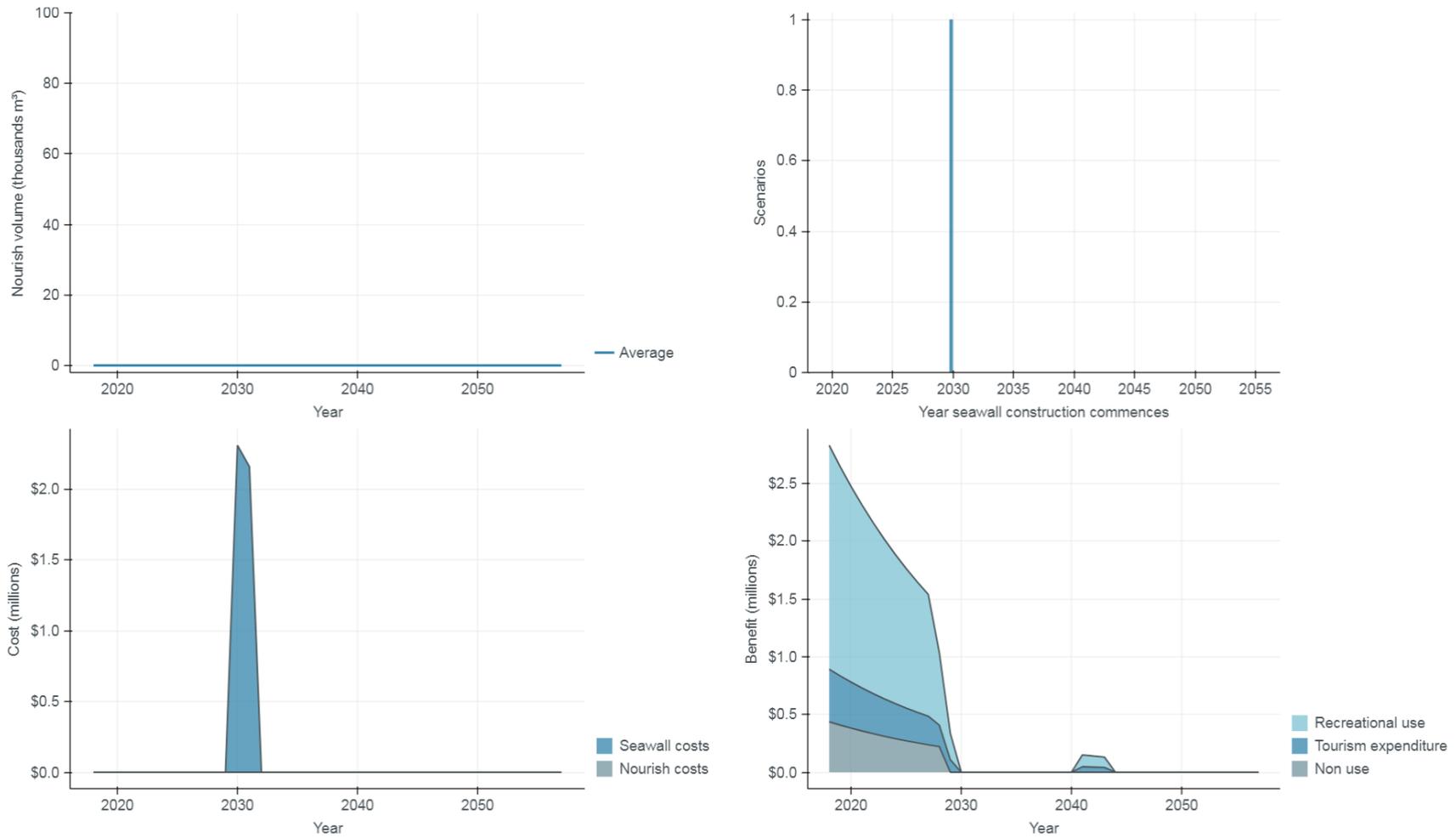
Source   Aither and BMT analysis.

Figure 10 Nourishment, seawall construction, present value costs and benefits

3.3.   Robustness testing

The example in the previous subsection illustrates the application of the integrated model under one possible future. There are many possible futures, and a strategy will generally perform differently under different futures. To account for this, ADAPT evaluates each strategy over many different future scenarios. This avoids selecting a strategy based on performance in one possible future alone.

Table 2 shows the NPV under different futures, as well as the average across all futures. Over 50 different futures, the 'do nothing' strategy has an average NPV of $8 million. In this example, if only the first future was considered, the estimated NPV of the beach to SCC residents would be substantially exaggerated ($19 million versus $8 million). There would also be no evidence of the range of possible NPVs that could eventuate under the 'do nothing' strategy, therefore it would not be possible to assess the risk of undertaking this strategy.

Table 2   Performance of the 'do nothing' strategy across futures – example only

Future	NPV
Future 1 (from previous example)	$19 million
Future 2	$8 million
Future 3	$4 million
...	...
Future 50	$10 million
Average NPV across futures	**$8 million**

Source   Aither and BMT analysis.

3.4.   Optimisation

The example in the previous subsections relates to a single strategy, in this case 'do nothing'. There are many possible strategies to manage the beach. The challenge is to find the strategy that maximises the wellbeing of SCC residents, as indicated by average NPV. ADAPT can compare a large number of possible strategies to find the optimal strategy (Table 3).[1] For this application, one million strategies were generated and evaluated for 50 possible futures. These strategies were compared, and the optimal strategy identified. This provides confidence that all plausible options have been appropriately considered.

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[1] As this is a pilot study, we have assumed risk neutrality. However, ADAPT can be easily modified to capture risk aversion.

Table 3   Performance across strategies – example only

Strategy	Average NPV across futures
Strategy 1 ('Do nothing')	$8 million
...	...
Strategy 326 174	**$28 million**
...	...
Strategy 1 000 000	$13 million

Source   Aither and BMT analysis.

4. Data sources

The previous section outlines the structure of the integrated model for Maroochydore Beach. This section details the data behind the physical and economic components of the integrated model.

Aither and BMT have obtained the data from the best and most relevant sources available, from rigorous academic sources through to community input. Where possible we have used multiple lines of evidence and carefully considered the appropriateness of all data used in the model.

4.1. Physical model

The physical model estimates the sand volume moving into and out of the Maroochydore Beach unit, with the volume remaining within the beach unit used a measure of beach condition. This is illustrated conceptually in Figure 11.

Figure 11 Net accretion and beach volume

The longshore sediment transport modelling is based on a 20-year directional wave record (from the so-called 'Brisbane Waverider Buoy'), two-dimensional spectral wave modelling, and a calibrated

application of the CERC-formula[2] to estimate headland bypassing at Point Cartwright, which controls the natural sand supply to Mooloolaba Bay and Maroochydore Beach. A summary of the 20-year timeseries output from the sediment transport model is provided in Figure 12. This output is used as a proxy for the sand transport volume into the Maroochydore Beach unit, noting that ADAPT uses annual total volumes rather than a continuous timeseries[3]. Key features of the 20-year timeseries include:

- A positive 'Headland Bypassing Volume' indicates times when sand bypassing occurs at Point Cartwright and there is a natural supply of sand to Maroochydore Beach, transported by the prevailing net-northerly longshore processes.

- An extended non-shoaling period between 2004 and 2010 during which time a significant volume of sand was being stored at the headland and Buddina Beach to the south (indicated by the negative 'Headland Storage Volume'). During this period the prevailing wave climate did not promote sand bypassing at Point Cartwright. This period also coincided with significant shoreline recession at Mooloolaba Bay and Maroochydore Beach (see Figure 13).

- The persistent shoaling event that commenced in 2011 and continued until early 2013. During this period the sediment transport model estimates a volume in excess of 250,000 m^3 bypassing the headland and therefore supplying the beaches to the north.

- From early 2013 to present-day, the prevailing wave climate has supported ongoing bypassing of the headland. This suggests a relatively steady natural supply of sand to Mooloolaba Bay and Maroochydore Beach for this period.

This sediment transport model was originally developed by BMT for the Queensland Department of Transport and Main Roads (WBM Oceanics, 2004, 2005; Voisey et al. 2013). The tool has been used for over ten years in an 'operational mode' to forecast the potential for sand bypassing Point Cartwright and the onset of shoaling of the Mooloolaba Harbour Entrance. When shoaling is forecast, the Department of Transport and Main Roads order hydrographic surveys to determine whether the mobile sand shoal is likely to impact navigation. Consequently, the model has been subject to continual validation (against the hydrographic survey data) and refinement to improve its predictive skill. It is therefore believed to be a robust indicator of sand transport at Point Cartwright, which gradually moves into Mooloolaba Bay, and ultimately toward the Maroochydore Beach unit.

For integration with ADAPT, statistical analysis of the 20-year wave record, and generation of other representative estimates of sediment transport, was undertaken to introduce a probabilistic element to the model. In total, ADAPT incorporates 50 different plausible 20-year estimates of natural supply to Maroochydore Beach. Each year the annual sand volume into and out of the beach unit is calculated, leading to different volumes of sand within the Maroochydore Beach compartment which ultimately affects the condition of the beach.

In addition to natural sand supply, the physical model also captures forecast changes to mean sea level due to climate change and the expectation that on developed coastlines more sand will be needed to maintain the present-day shoreline position under sea-level rise scenarios.

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[2] The CERC-formula was developed by the US-Corps of Engineers and relates the immersed weight of the longshore sediment transport rate to the longshore wave energy flux (Shore Protection Manual, 1984).

[3] For the purposes of this assessment the 20-year wave record has been duplicated to provide a 40-year time horizon.
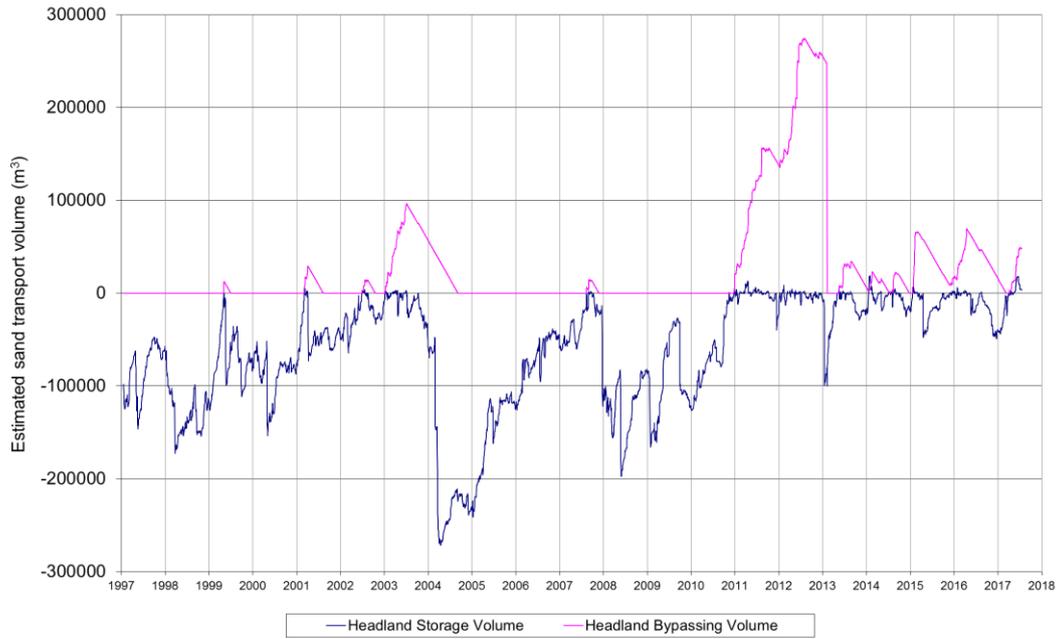
Source   BMT and Queensland Department of Transport and Main Roads.

Figure 12 Estimate of sand volume bypassing Point Cartwright and naturally supplied to Mooloolaba Bay and Maroochydore Beach

Figure 13 Shoreline recession at Maroochydore Beach in late 2011 following a persistent period low sand supply

4.2.   Economic model

The data for the economic component of the integrated model were obtained from various sources:

- Consultations with stakeholders provided data regarding historical beach use by tourists and locals, and how this would change with the beach condition.

- A review of the economic literature provided data on the value of recreational beach use, the value of tourist expenditure, and the existence value of the beach.

- Previous reports on the Maroochydore Beach provided data on costs.

The data and sources are listed in Table 4.

Table 4 Data used in the economic component of the integrated model

Benefit/Cost	Parameter	Value	Source	Comment
Recreational use benefits	Annual beach use	360,000	Surf Life Saving Queensland	
	Proportion of beach use by tourists	50%	Alexander Heads SLSC	
	Average value per recreational use (locals)	$10.8	Raybould et. al. (2013)	Original study $8.5 (2008 AUD)
	Average value per recreational use (tourists)	$20.5	Raybould et. al. (2013)	Original study $16.2 (2008 AUD)
	Reduction in value and beach use at 140 000 m3	20%	Statistical analysis based on Surf Life Saving Queensland data	
	Reduction in value and beach use with coffee rock exposure or seawall	50%	Alexander Heads SLSC	
Tourism benefits	Average expenditure per recreational use (tourists)	$15.4	Raybould et al. (2013)	
	Average benefit per dollar of expenditure	$0.165	Tourism Research Australia (2017)	
Non-use benefits	Average existence value per person (once off payment)	$22.7	Silberman et. al. (1992)	Original study $9.5 (1992 USD)
	SCC population	294,367	ABS (2016)	
Nourishment cost	Fixed cost	$187,500	BMT	
	Variable cost	$12.5 / m^3	BMT	
Seawall construction cost	Length of seawall	1300m	BMT	
	Cost of seawall	$8000 / m	BMT	
General	Discount rate (real)	7%	By assumption	

5. Beach nourishment strategies

This section provides an overview of the strategies reported in the pilot study. All strategies have the same seawall trigger, with seawall construction commencing if the beach sand volume falls below 50,000 m^3. Consistent with permits, the volume of beach nourishment cannot exceed 100,000 m^3 every two years. This constraint applies to all strategies.

5.1. 'Do nothing' strategy

The 'do nothing' strategy was introduced in Section 3. It was constructed for the purpose of comparison only and does not resemble any actual strategy under current use. It has the following features:

- **Nourishment trigger** – There is no nourishment trigger in this strategy, and the beach will never receive nourishment.
- **Nourishment volume** – Not applicable.

5.2. Current strategy

The current strategy is described in Section 1. It has the following features:

- Nourishment trigger – Nourishment occurs if the beach sand volume falls below 100,000 m^3.
- Nourishment volume – When the nourishment trigger is met, 100,000 m^3 of nourishment volume will be applied to the beach in the current year (with one campaign permitted every two years).

5.3. Optimal strategy

This subsection describes the structure of the optimal strategy. Under the current strategy, the existing nourishment trigger is specified by a single volume of sand for the beach. In determining an optimal strategy, we have allowed for more freedom in the nourishment trigger by allowing the trigger volume to change after each ten-year period (Table 5). Furthermore, we have allowed for separate nourishment trigger values to apply when there is no seawall (or construction has not been completed), and when there is a completed seawall. This reflects the fact that the optimal nourishment trigger may change over time, depending on the circumstances. As per the current strategy, there is a single threshold value for the nourishment volume.

Each strategy is characterised by different values for A through to J. The values for the optimal strategy are determined by ADAPT and reported in Section 5.

Table 5   Structure of the optimal strategy

Parameter	Value
Nourishment trigger	

Parameter	Value
Seawall does not exist	
2018 – 2027	A m³
2028 – 2037	B m³
2038 – 2047	C m³
2048 - 2057	D m³
Seawall exists	
2018 – 2027	E m³
2028 – 2037	F m³
2038 – 2047	G m³
2048 - 2057	H m³
Nourishment volume	J m³

Source: Aither and BMT.

6. Maroochydore beach – ADAPT results

ADAPT was used to find the optimal management strategy for Maroochydore beach. The optimal strategy maximises the wellbeing of SCC residents, as indicated by average NPV. ADAPT was also used to compare the strategies in terms of beach condition, management actions, and costs and benefits.

Appendix A provides further analysis of outcomes under each strategy including the extent of uncertainty in beach condition and a disaggregation of costs (into seawall and nourishment) and benefits (into recreational use, tourism and non-use).

The results presented in this section and Appendix A focus on the benefits and costs to SCC residents. Appendix B takes a broader perspective, incorporating the impacts on people who live outside the SCC. This may be relevant in determining equitable cost sharing arrangements.

6.1. ADAPT - the optimal strategy

ADAPT applied a machine learning algorithm to intelligently generate and compare one million possible management strategies to find the optimal strategy for Maroochydore Beach (Table 6). The optimal strategy involves aggressive beach nourishment. Initially, sand is applied when the beach volume falls below about 290,000 m^3. Over time, climate change leads to sea level rise, which contributes towards an increase in erosion relative to accretion. To protect against a run of unfavourable years, sand is applied at increasingly higher beach volumes, up to about 570,000 m^3. Eventually however, erosion becomes so severe that any sand applied rapidly erodes. This makes maintaining the beach volume through nourishment less feasible, given constraints in the volume that can be applied. It also makes beach nourishment less desirable, and hence sand is not applied once the seawall has been constructed in later years.

The optimal strategy involves applying the maximum possible volume of sand, 100,000 m^3, when beach nourishment is triggered. This helps to maintain beach condition for as long as possible and exploits scale to reduce the unit cost of beach nourishment.

Table 6   Optimal strategy

Parameter	Value
Nourishment trigger	
Seawall does not exist	
2018 – 2027	293,000 m^3
2028 – 2037	482,000 m^3
2038 – 2047	567,000 m^3
2048 - 2057	522,000 m^3
Seawall exists	

Parameter	Value
2018 – 2027	does not apply
2028 – 2037	does not apply
2038 – 2047	does not apply
2048 - 2057	0 m^3
Nourishment volume	100,000 m^3

Source   Aither and BMT analysis.

6.2.   Strategy comparison summary

Optimal strategy compared to 'do nothing' strategy

Compared to the 'do nothing' strategy, the current strategy represents a significant improvement, with an average NPV (across futures) of about $4 million (Table 7). Nourishment defers the costs and the severe reduction in benefits associated with seawall construction. Nourishment also slows the decline in the sand volume of the beach, further increasing the benefits to SCC residents. Most of the benefits of nourishment to SCC residents are from their recreational use, with more visits and greater benefit per visit. However, there are also substantial benefits to SCC businesses from increased tourism and to SCC residents who benefit from knowing that the beach is in reasonable condition (even if they never visit the beach). Together, the benefits from nourishment combined with the avoided seawall construction costs more than compensate for the costs of nourishment.

Optimal strategy compared to current strategy

The current beach management strategy being implemented by SCC has a positive NPV, however the analysis suggests that altering this strategy will lead to even greater benefits. Compared to the current strategy, the optimal strategy involves significantly more frequent nourishment, at least until it becomes infeasible to maintain the beach due to sea-level rise. At this point a seawall is constructed (Section 5.4). The average NPV of the optimal strategy is about $16 million higher than the current strategy (and $20 million higher than the 'do nothing' strategy).

Table 7   Average benefits and costs under each strategy from a SCC perspective

	Current relative to 'do nothing'	Optimal relative to current
Benefits		

	Current relative to 'do nothing'	Optimal relative to current
Recreational use	$5.6 m	$10.6 m
Tourism	$1.8 m	$1.8 m
Non-use	$1.2 m	$2.4 m
Avoided seawall construction costs	$1.7 m	$3.3 m
Costs		
Nourishment	$6.3 m	$2.5 m
NPV	$4.1 m	$15.6 m

Source   Aither and BMT analysis.

Note   All costs and benefits are average values, expressed as present values over a 40 year time horizon, with a 7 per cent discount rate.

The following subsections compare the strategies in greater depth, starting with the current strategy and the 'do nothing' strategy.[4]

6.3.   In-depth strategy comparisons

Current strategy versus 'do nothing' strategy

Figure 14 shows the average volume of sand on the beach over time under the current and 'do nothing' strategies.

In general, there is a net loss of sand with erosion exceeding accretion. This accelerates over time due to sea-level rise. Combined with the lack of any nourishment, the erosion leads to a rapid loss of sand from the beach in the 'do nothing' strategy. While the seawall trigger is reached quite early, the delay in construction leaves the beach is exposed for two years. As a result, in several futures, the volume of sand on the beach falls below zero (not shown in Figure 14), indicating the possibility for damage to land-based assets behind the beach (note that these potential costs are not quantified in this report). Furthermore, the early construction of the seawall, increases the magnitude of erosion for all future years. After the seawall has been constructed, the future of the beach is quite certain in the 'do nothing' strategy, and there is always close to zero sand on the beach.

Nourishment of the beach under the current strategy helps to maintain the condition of the beach to an extent. For the first several years the average volume of sand on the beach is identical, since no nourishment takes place under either strategy. After 2022 the current strategy will maintain the average volume of sand on the beach at a significantly higher level due to nourishment, avoiding the rapid decline evident under the 'do nothing' strategy. After 2040 the average volume under the current strategy approaches zero, as the erosion due to sea-level rise is too large for nourishment to

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[4] Note that all benefits and costs are reported in present values (after discounting), which is one reason why the costs and benefits tend to decline over time in the figures.

have a substantial effect. When combined with beach nourishment under the current strategy, the seawall is effective in preventing the volume of sand on the beach from falling below zero in most futures, protecting land-based assets behind the beach.
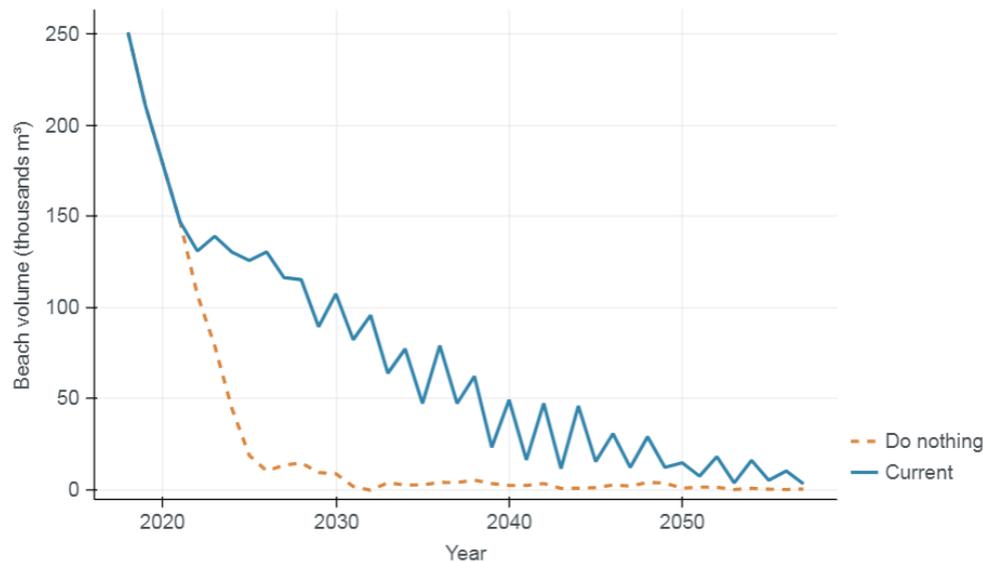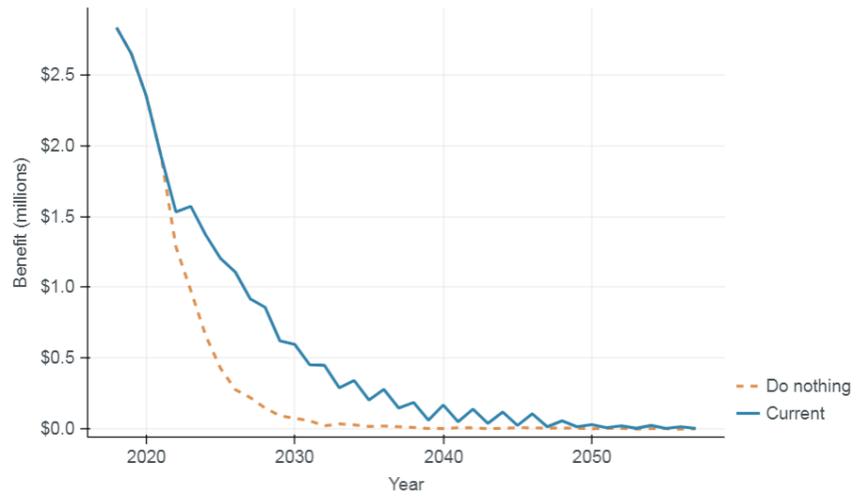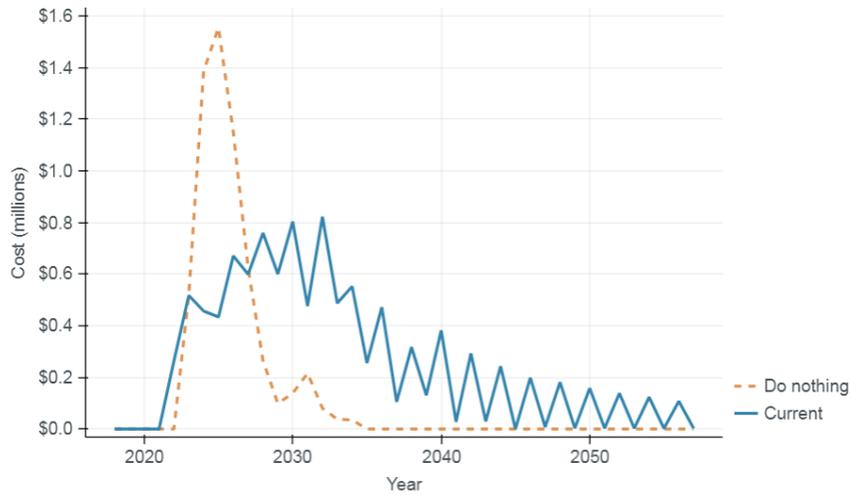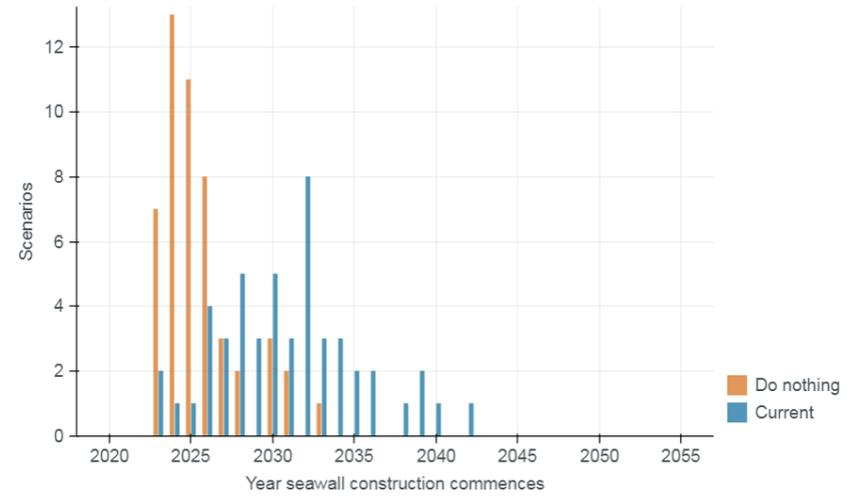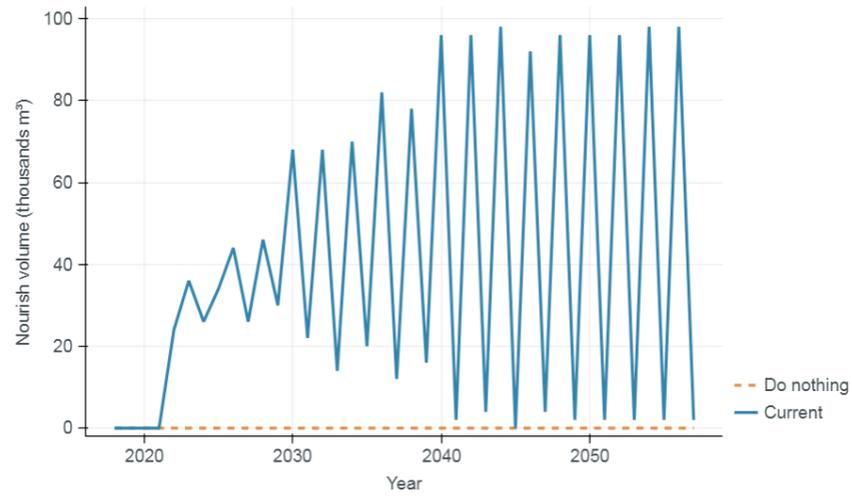

Source   Aither and BMT analysis.

Figure 14   Comparison of average beach sand volumes for current and 'do nothing' strategies

Figure 15 illustrates the average nourishment volume applied over time under the current strategy. Initially, the average volume of sand on the beach is above the trigger, and beach nourishment is not undertaken in most futures. Over time the volume falls and the trigger is reached in a larger proportion of futures. After 2040 the trigger is almost always reached. Beach nourishment follows an alternating pattern due to the constraint that no more than 100 000 m^3 of nourishment volume can be applied every two years. This nourishment helps to defer seawall construction from 2025 on average under the 'do nothing' strategy to 2032 on average under the current strategy.

Under the 'do nothing' strategy the early construction of a seawall generates significant costs. Some of these costs are avoided under the current strategy by deferring seawall construction. However, average costs are higher overall due to additional investment in beach nourishment.

In terms of benefits, the rapid decline in the volume of sand on the beach, combined with the existence of the seawall reduces recreational use and related values and eliminates any non-use benefits associated with the beach by 2030 under the 'do nothing' strategy. By contrast, the average benefits are better maintained under the current strategy and are not significantly affected by worsening beach condition until 2030.
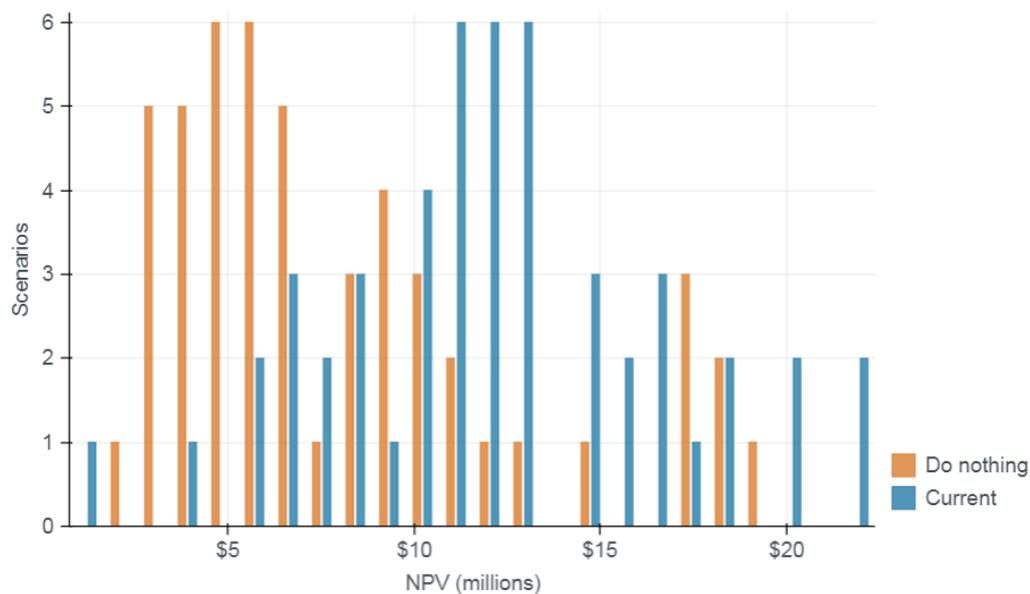
Source: Aither and BMT analysis.

Figure 15 Comparison of nourishment, seawall construction, present value costs and benefits for current and 'do nothing' strategies

As discussed in Section 2, each strategy is evaluated over 50 futures to test robustness. The current strategy outperforms the 'do nothing' strategy in 82 per cent of futures.

Figure 16 compares the distributions of NPVs under the current and 'do nothing' strategies. The current strategy has an average NPV of $12 million, performing substantially better than the 'do nothing' strategy which has an average NPV of $8 million. This indicates that the increase in costs associated with nourishment under the current strategy are more than offset by the reduction in seawall construction costs and increased benefits received by SCC residents, at least on average. This highlights the importance of beach nourishment in managing the Maroochydore Beach, and that the current strategy is making a positive difference for SCC residents.

Both strategies have a high degree of exposure to physical risks from erosion. For example, as there is no nourishment of the beach under the 'do nothing' strategy, the outcomes are entirely determined by natural erosion and accretion. In most futures the erosion dominates accretion, even in the short run, and the average NPV is low. However, there are several futures where accretion initially dominates. This causes the distribution to be skewed towards lower values. Overall, there is a 1 in 10 chance of the average NPV being less than $3 million and the same chance of average NPV being greater than $17 million under the 'do nothing' strategy. This is only slightly better under the current strategy, which reduces the risks of damage to the beach but presents risks of undertaking beach nourishment when the costs exceed the benefits, due to sand applied being rapidly eroded.

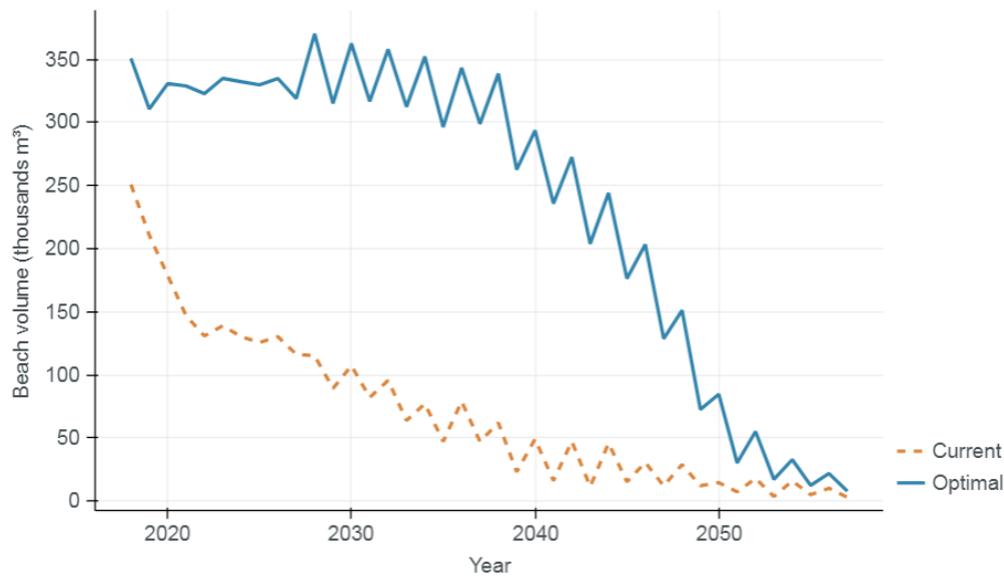Source   Aither and BMT analysis.

Figure 16   Comparison of NPV distributions for current and 'do nothing' strategies

The previous analysis establishes that the current strategy is worthwhile. The following assesses whether there is potential for further improvement by comparing the optimal strategy and the current strategy.

Optimal strategy versus current strategy

Figure 17 shows that additional beach nourishment under the optimal strategy manages to keep the average volume of sand on the beach relatively constant, and close to the initial volume of sand until 2040. In this same time the average volume of sand under the current strategy decreases consistently.

After 2040 the average sand volume under the optimal strategy begins to decline and approaches the same level as under the current strategy by 2050.

Figure 17   Comparison of average beach sand volumes for optimal and current strategies

Figure 18 displays the average nourishment volume applied to the beach under the optimal strategy. Initially the trigger is above the volume of sand on the beach, and nourishment almost always occurs. Over the first ten years the average volume of nourishment declines, as the beach has a sufficient volume of sand and the trigger is not always reached. In subsequent years, the trigger for nourishment is generally reached. After the seawall is constructed, an alternative trigger of zero applies, explaining the decline in nourishment towards the end of the timeframe. As a result, the optimal strategy results in more beach nourishment on average in the initial years that the current strategy, which defers the construction of the seawall substantially, and less in later years.

Seawall construction is delayed until at least 2046 under the optimal strategy. By contrast, seawall construction would commence no later than 2042 under the current strategy.

Under the optimal strategy, there are initially high nourishment costs, which then decline after the first few years before increasing again. As seawall construction is deferred to later years, the costs of seawall construction peak between 2040 and 2050. Overall, costs are slightly lower under the optimal strategy than the current strategy.

The average benefits under the optimal strategy are unaffected by the condition of the beach or existence of the seawall until after 2040. Compared with the current strategy, the additional nourishment under the optimal strategy successfully maintains the beach condition to a higher level, increasing the average benefits received across all years.
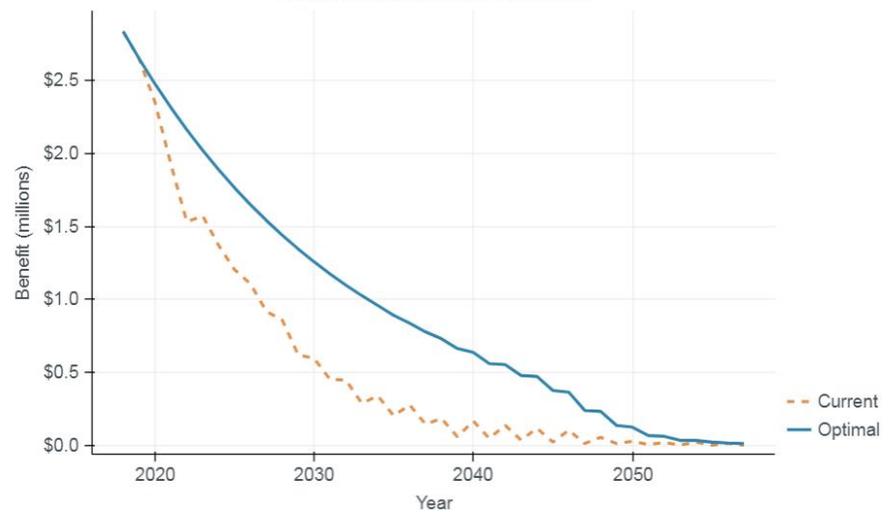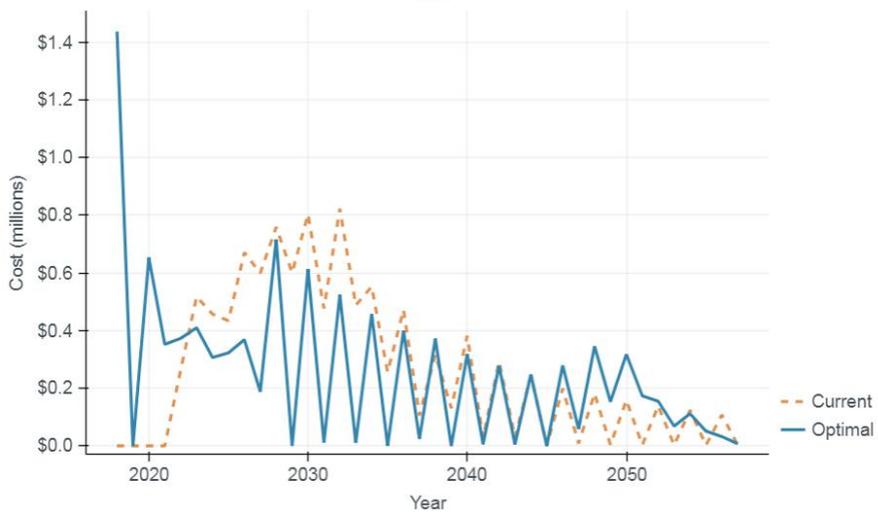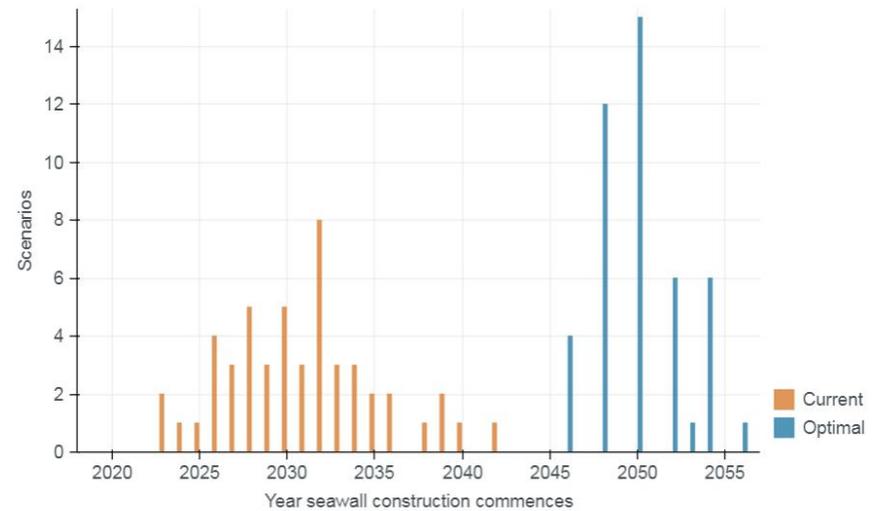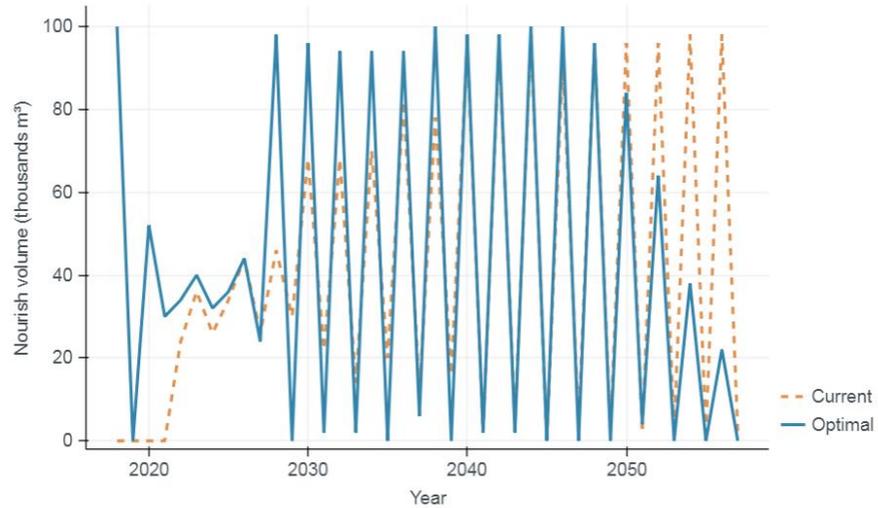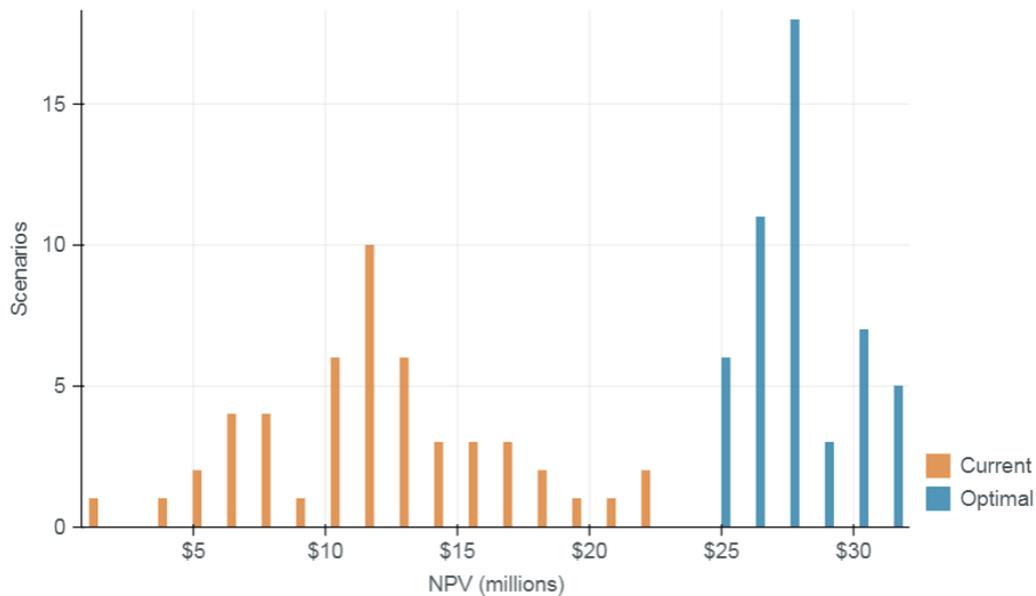
Source   Aither and BMT analysis.

Figure 18   Comparison of nourishment, seawall construction, present value costs and benefits for optimal and current strategies

Figure 19 shows that the optimal strategy outperforms the current strategy in all futures. The optimal strategy has an average NPV of $28 million, performing considerably better than the current strategy which has an average NPV of $12 million.

The optimal strategy is also much less risky, with a narrower distribution of possible NPVs. There is a 1 in 10 chance of the NPV being less than $26 million and the same chance of NPV being greater than $30 million. This shows that beach nourishment under the optimal strategy has been effective in mitigating the physical risks presented by erosion.

The analysis quantifies the potential value in implementing an adaptive beach management strategy that allows the nourishment trigger to adjust over time and in response to changing circumstances.

Source   Aither and BMT analysis.

Figure 19   Comparison of NPV distributions for optimal and current strategies

7.   Conclusions

7.1.   Discussion

Complex or simple representations of the physical environment can be incorporated into ADAPT. Furthermore, the modular framework allows the physical and economic components to be refined as new information becomes available. In the case of Maroochydore Beach, existing models of the physical environment could be readily integrated within the ADAPT framework. These models, together with a substantial amount of beach monitoring data and aerial imagery dating back to the 1950s, provided a robust baseline understanding of the key coastal processes that influence Maroochydore Beach condition.

The application of ADAPT to evaluate the current Maroochydore Beach management strategy demonstrates that beach nourishment is delivering significant benefits to Sunshine Coast residents, with a positive average net present value (NPV) of $4.1 million compared to the 'do nothing' approach. Nourishment defers the costs of seawall construction and the severe reduction in benefits associated with a poor beach condition. In this context alone, the current strategy is considered to represent value for money.

Most of the benefits of nourishment to SCC residents are from their recreational use, with more visits and greater benefit per visit. However, there are also substantial benefits to SCC businesses from increased tourism and to SCC residents who benefit from knowing that the beach is in reasonable condition (even if they never visit the beach). Together, the benefits from nourishment combined with the avoided seawall construction costs more than compensate for the costs of nourishment.

The analysis suggests that altering the current strategy could lead to even greater net benefits and further delay the need for a seawall. The optimal strategy determined by ADAPT involves significantly more frequent nourishment, at least until it becomes infeasible to maintain the beach due to sea-level rise. At this point, a seawall would be constructed to protect land-based assets. The average NPV of the optimal strategy is about $16 million higher than the current strategy (and $20 million higher than the 'do nothing' strategy).

Regarding the estimated timing of seawall construction, under the 'do nothing' strategy the seawall trigger is reached, on average, by 2025 (and always before 2030). The current strategy delays the average year of construction to 2032 (and always before 2042). Under the optimal strategy, the average year of construction is 2050.

This application of ADAPT has reduced investment uncertainty by considering multiple futures and one million management strategies, all undertaken in accordance with existing permits. However, it is noted that the modelling approach is sensitive to the following key assumptions:

- Statistically, the wave conditions recorded over the past 20-years will be representative of future conditions.

- Sea-level rise will occur at rates forecast by the IPCC (2014) and currently recommended for Queensland planning studies (~0.8 m of sea-level rise by 2100).

- The gradual increases to mean sea level will cause the beach to narrow and lower over time, requiring an increased volume of sand to maintain the present-day shoreline position.

- The capital costs associated with recent beach nourishment campaigns are representative of future costs.
- The recreational use, tourism and non-use benefits for Maroochydore Beach can be estimated using information from the sources listed in this report.

7.2.   Next steps

This pilot analysis undertaken by Aither and BMT focused on the optimisation of beach nourishment. While this analysis demonstrated the value of beach nourishment broadening the scope of assessment could provide further insights relevant to decision making and cost sharing arrangements. In addition to the potential refinements identified above, the scope of assessment could also be expanded in a few key areas:

- The analysis considers Maroochydore Beach as a single uniform unit. Breaking up the beach into smaller units could help to understand the optimal location of beach nourishment. This would also help to develop a more refined relationship between beach condition and recreational value.
- The inundation of land behind the beach, the spatial distribution of assets, or the damages associated with inundation have not been modelled. In the future, modelling land behind the beach would be beneficial for understanding when to build the seawall and identifying the beneficiaries.
- Extending the analysis to include other key management actions and investment decisions that contribute to the social and recreational value of the broader precinct.

These additions could be easily incorporated into ADAPT, given it has been constructed in a modular nature to allow the physical and economic components to be refined as new information becomes available.

7.3.   Qualifications

Aither and BMT have competed the pilot analysis described in this report to inform Maroochydore Beach management decision making. Changes to the current management strategy may require further assessment and/or other detailed analyses to fully understand the operational feasibility, beach response, costs and benefits.

This analysis and overall approach specifically caters for Maroochydore Beach and may not be applicable beyond this scope. For this reason, any other third parties are not authorised to utilise this information without further input and advice from Aither and BMT.

To complete the pilot analysis, Aither and BMT has relied on information supplied by others as referenced throughout this report. The accuracy of the results presented in this report is therefore dependent upon the accuracy and interpretation of this information.

The following points should also be understood when using the information provided in this report:

- Physical and economic modelling for this pilot is based on industry best-practise techniques; however, it is not possible to precisely forecast all future scenarios, the associated costs and benefits, and impacts to community wellbeing.

- The inferred beach condition is based on a net annual volume within the defined Maroochydore Beach unit. Natural fluctuations in beach condition will occur on daily or weekly timescales which is not captured by the modelling approach.

- Elements of the physical model is based on previous work undertaken by BMT on behalf of the Queensland Department of Transport and Main Roads. The use of this information is subject to the conditions of the agreement.

- The model outputs are sensitive to sea-level rise and assumed beach response. The assumed rate of sea-level rise is based on projections reported by the Intergovernmental Panel on Climate Change (IPCC 2014), however the relationship between sea-level rise and beach erosion would benefit from further site-based analysis and shoreline evolution modelling.

- The cost of beach nourishment is based on historical estimates from the SCC. While these estimates may be accurate, further interrogation of the costs of beach nourishment, including from alternative sand sources would be beneficial. If alternative sand sources are available, it might be feasible and desirable to sustain beach nourishment for longer than suggested in this assessment.

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Appendix A – Supplementary analysis

This appendix provides further analysis of outcomes under each strategy including the extent of uncertainty in beach condition and a disaggregation of costs (into seawall and nourishment) and benefits (into recreational use, tourism and non-use).

Note that all benefits and costs are reported in present values (after discounting), which is one reason why the costs and benefits tend to decline over time in the figures.
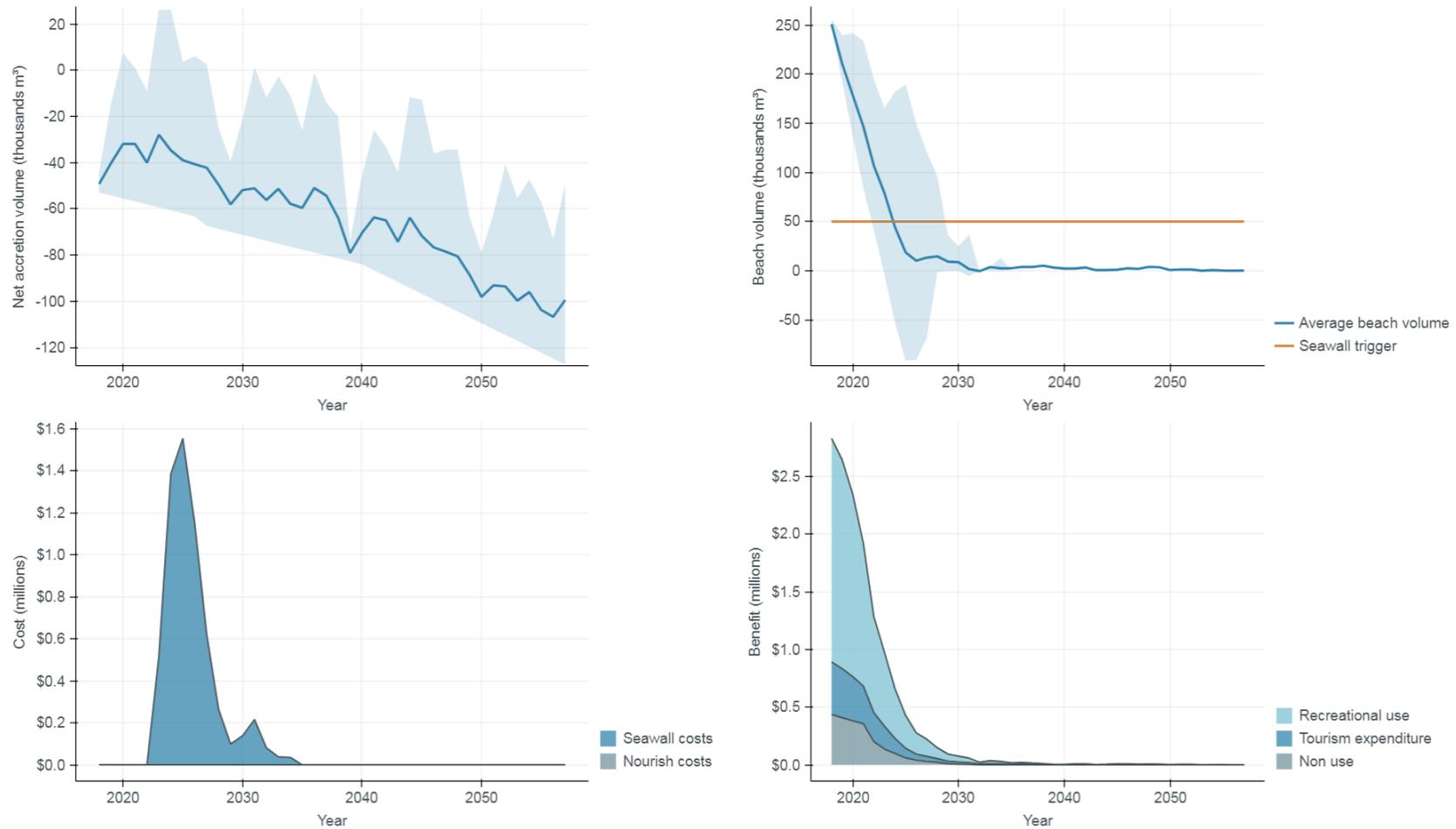
Source: Aither and BMT analysis.

Notes: The dark blue line is the average annual volume across futures. The shaded region is the 10th to 90th percentile range.
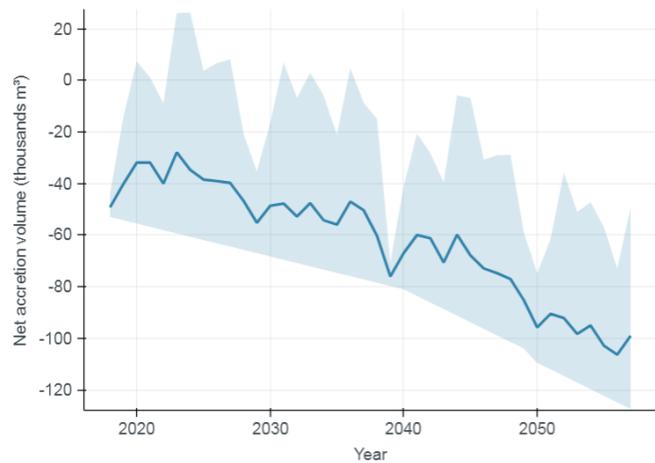
Figure 20   Net accretion, beach sand volume and present value costs and benefits under 'do nothing' strategy
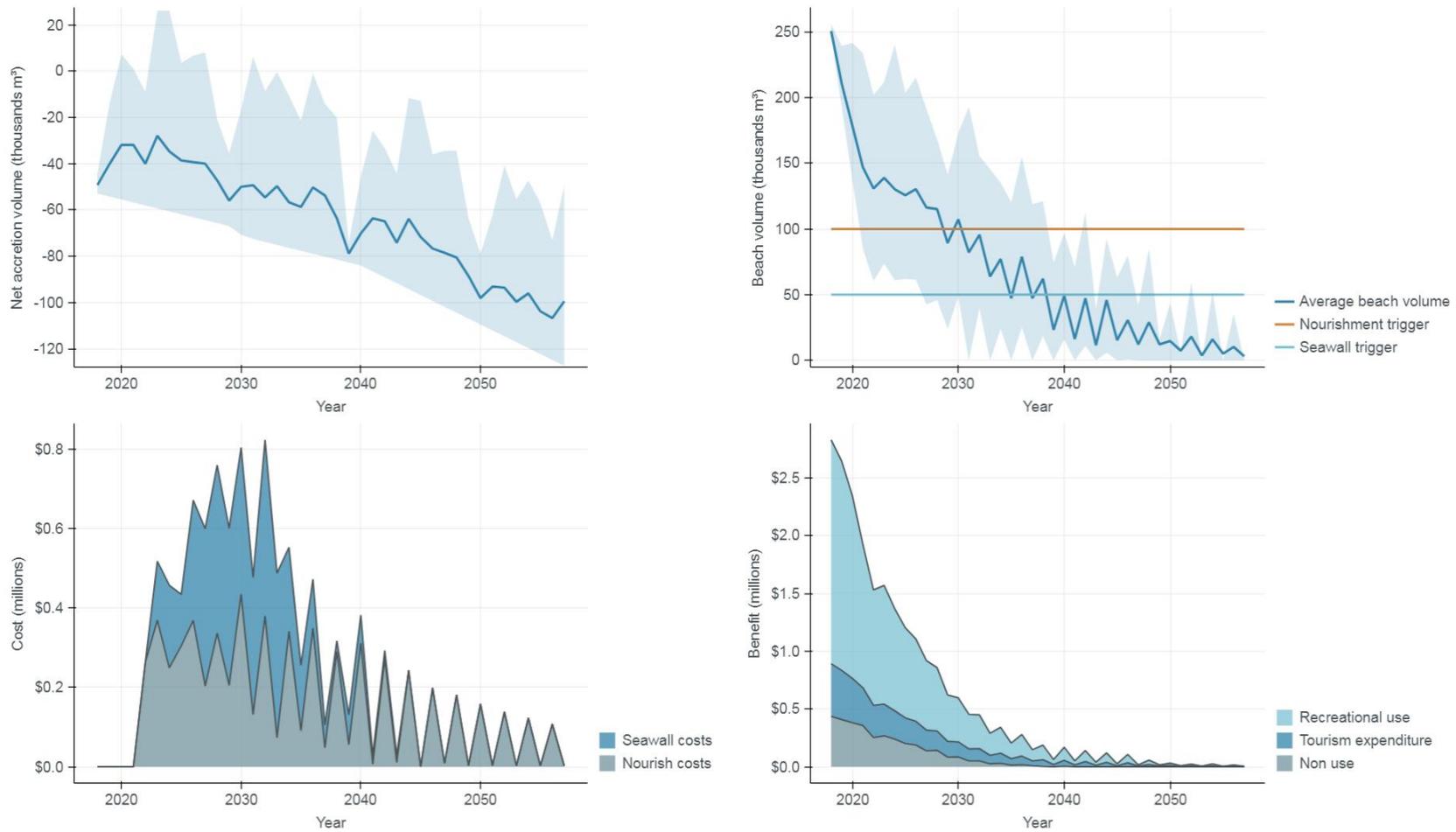
Source: Aither and BMT analysis.

Notes: The dark blue line is the average annual volume in each year. The shaded region is the 10th to 90th percentile range.

Figure 21   Net accretion, beach sand volume and present value costs and benefits under current strategy
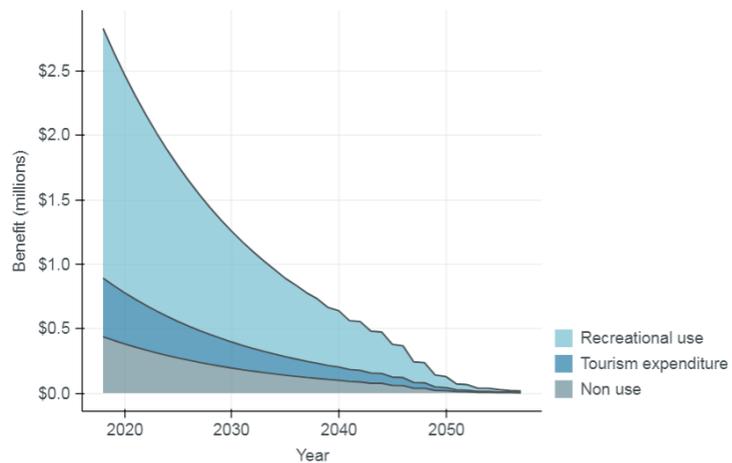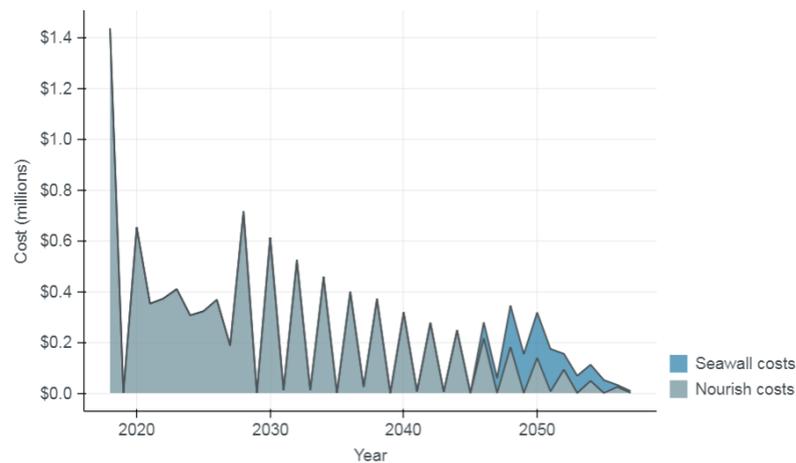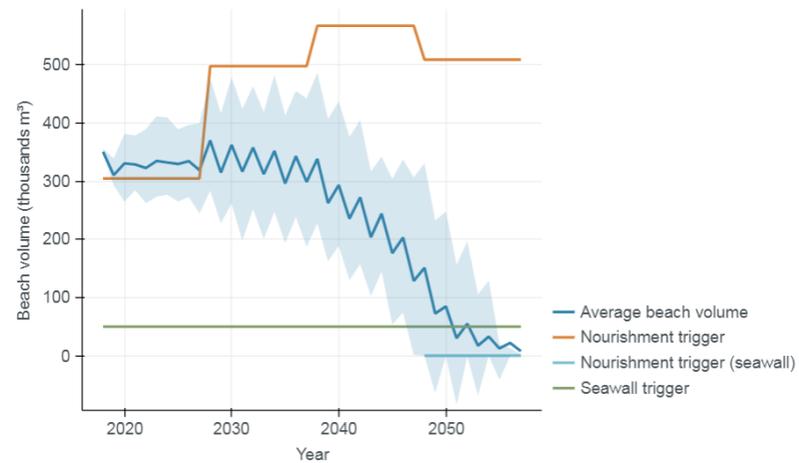
Source: Aither and BMT analysis.

Notes: The dark blue line is the average annual volume in each year. The shaded region is the 10th to 90th percentile range.

Figure 22   Net accretion, beach sand volume and present value costs and benefits under optimal strategy

Appendix B – Global analysis

The previous analysis reports the results from a SCC perspective, and does not include benefits and costs to people who live outside the SCC – residents of other parts of Queensland, other Australian states and territories and other countries. When the interests of people who live outside the SCC are considered, the average NPV for the current strategy increases to about $13 million (Table 8). The average NPV of the optimal strategy is also higher, at about $34 million relative to the current strategy (and $47 million relative to the 'do nothing' strategy). This is because almost two thirds of the recreational use benefits of the beach accrue to people who live outside the SCC.

The other benefits and costs are unchanged, with the exception of tourism benefits, which fall to zero. This is partly because tourists who visit the SCC due to Maroochydore Beach would likely have spent their money elsewhere if they were deterred from visiting the SCC due to the poor condition of the Maroochydore Beach. This expenditure would have similar benefits to businesses outside the SCC, hence there is no overall tourism benefit from a global perspective.

Table 8   Average benefits and costs under each strategy from a global perspective, relative to the 'do nothing' strategy

	Current relative to 'do nothing'	Optimal relative to current
Benefits		
Recreational use	$16.3 m	$30.9 m
Tourism	$0.0 m	$0.0 m
Non-use	$1.2 m	$2.4 m
Avoided seawall construction costs	$1.7 m	$3.3 m
Costs		
Nourishment	$6.3 m	$2.5 m
NPV	$12.8 m	$34.2 m

Source   Aither and BMT analysis.

Note   All costs and benefits are average values, expressed as present values over a 40 year time horizon, with a 7 per cent discount rate.

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