Assessment and Decision Frameworks for Seawall Structures

2013

Appendix C

Economic Considerations

SYDNEY COASTAL COUNCILS GROUP

Coastal Adaptation Decision Pathways Project **(CAP)**

The Sydney Coastal Councils Group (SCCG) is a voluntary Regional Organisation of Councils representing fifteen coastal and estuarine councils in the Sydney region. The Group promotes cooperation and coordination between Members to achieve the sustainable management of the urban coastal environment.

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Cover image: Coastal seawall. Provided by Douglas Lord

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SYDNEY COASTAL COUNCILS GROUP

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APPENDIX C PREFACE

This Appendix was prepared by The Centre for Coastal Management at Griffith University in association with Bond University for this Report titled *Assessment and Decision Frameworks for Seawall Structures*. The purpose of the information in this Appendix was to review the impact on the timing of decisions to upgrade or remove seawall structures based on an economic perspective. The engagement included the development of a preliminary spreadsheet-based decision-making tools which is not included in this Appendix. The tool has, however, been applied to realistic coastal values to test the sensitivity of the approach to various key input parameters. The author of the report was D. Anning. It has been published by Griffith Centre for Coastal Management as Report No 133 *Assessment and Decision Frameworks for Existing Seawalls – Economic Component* and was released in October 2012. It can be viewed also in that format.

The report has been included in its entirety within this Appendix and is a true reflection of the original advice provided by Griffith University to the project. No additions, edits or changes have been made to their final report, other than minor editorial and layout changes for consistency in appearance. References to sections, figures and tables are to those included within this Appendix.

As appropriate, information from this Appendix has been incorporated or referenced in the main report for this project.

EXECUTIVE SUMMARY

This appendix, in a cost-benefit framework, examines the costs and benefits associated with adaptation options in response to climate change projections, in locations where there is an existing coastal protection structure, but this structure will not be suitable over the planning assessment period. **It is not intended to be a standalone decision-making tool, and does not constitute professional advice**, but is developed to demonstrate how different assumptions about key variables may influence the selection of appropriate adaptation options. In conjunction with the other components of this report, it can also suggest appropriate further investigations necessary to provide more certainty to the appraisal of these options in a formal context.

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GLOSSARY

Assessment period - years over which assessment is undertaken. For this demonstration, the assessment period is until 2100, hence 88 years. It has implications for the costs of each option, as the differing design lives will mean that the options may have to be combined or repeated in order to provide protection over the full assessment period. For example, if a seawall of a given design has a design life of 50 years, and the assessment period is 100 years, then it will be assumed to be undertaken twice in the assessment period.

The assessment period is defined **prior** to the engineering assessment being conducted (e.g. 100 years), and the economic assessment is conducted over the same period. In the case of this model, the duration of the modelling is until 2100, for consistency with the physical assessment conducted by WRL (see Appendix E).

Planning period – the time period between the announcement of adoption of a planned retreat policy and the date by which the land must be vacated. It assumes that there is a temporal rather than spatial trigger to the retreat.

Travel cost method – a means of estimating the non-market value of recreation, through using their costs incurred to access the site as a proxy for an entry fee. Relies on the assumption that people with lower travel costs visit more frequently, and constructs a demand curve for recreation from which the **consumer surplus** can be estimated. See http://www.ecosystemvaluation.org/travel_costs.htm for further information

Consumer surplus – the difference between what a person has paid to access a recreational resource, and the theoretical maximum they would be willing to pay if required.

Discounting – accounts for the fact that people typically prefer benefits in the present day than at some time in the future. The present value of a future benefit is reduced by an annual percentage that reflects the strength of this time preference.

$$Present\ Value\ (PV) = Future\ Value\ (FV)\ \times \frac{1}{(1+D)^{-T}}$$

where D is the discount rate in decimal form, and T is the number of years in the future.

Net Present Value (NPV) – for each year the costs incurred are subtracted from the benefits, these are then converted to a present value through the process of discounting, and totalled over the assessment period.

Mean beach width – horizontal distance from the seawall structure to the mean shoreline position.

Acronyms

FV	Future Value
GIS	Geographic Information System
LIDAR	Light Detection and Radar
NPV	Net Present Value
SB	Storm Bite
SD	Storm Delay
SLR	Sea Level Rise
WRL	Water Research Laboratory, University of New South Wales

1. Scope

This document is developed as an appendix to the larger project report: *Assessment and Decision Frameworks for Existing Seawalls*, conducted under the Coastal Adaptation Decision Pathways funding program administered by the Department of Climate Change and Energy Efficiency.

It is intended for use by asset managers of coastal protective structures, and those responsible for coastal planning decisions with regard to the development and continuing occupation of land subject to coastal hazards such as inundation and erosion. In typical situations this will be the local council, with technical input from state government agencies.

The preliminary economic model described in this appendix is designed to assess the relative economic suitability of the differing adaption responses to climate change, and under differing assumptions about sea level rise (SLR), the timing of storm events, the growth of coastal property values and varying discount rates. It allows the model user to manipulate the inputs to the model, and thus perform sensitivity testing.

1.1 Stage in the Assessment Process

The economic modelling described in this document is designed for use in situations where some form of existing coastal protection structure/s is already in place, rather than cases where the installation of such a structure is under consideration, either to protect existing coastal assets or to enable development of previously undeveloped areas or the intensification of existing development.

The model described in this appendix assumes that an engineering assessment of the structure/s has already been conducted, providing some form of guidance as to the suitability of this structure both in the current day and under projected climate change scenarios and timeframes. The existing structure is not suitable for the assessment period, i.e. it will cease to provide the desired level of protection before this period is over. If the existing structure will provide protection over the entire life of the assessment, then the question is not about replacement of the structure, but of managing the impacts of the structure on the adjacent beach environment. Where such a structure is of unknown or questionable construction, the preferred outcome may be to remove it. This decision is outside the scope of the current model, and must be reached by the asset manager on the basis of professional advice from suitably qualified engineers.

Put simply, a problem has been identified. In some cases this review will be triggered by reaching the conclusion of the design life of the existing structure, in others it may be triggered by a storm event or the submission of a development application for land protected by the structure in question.

Expert advice from suitably qualified coastal engineers should be sought when conducting the assessment of the suitability of the existing structures, and the likely design life of the structure under various climate change projections. Information about the state of the beach now and its response in the future are also necessary inputs to the model.

1.2 Contextual Assumptions

This document is prepared using an economic cost-benefit modelling approach, rather than a more narrow financial approach.

It assumes that:

- all costs and benefits accruing to society are relevant to the decision under analysis, rather than simply the costs and benefits to the agency making the decision[1]
- the options included in the model are those that have already been screened for suitability by the engineering assessment and the initial stages of the coastal management planning process. For example, it is assumed that retreat is both legally and politically practical in the case study location, and there is no critical infrastructure that would prevent the adoption of such a policy. This may not hold in many coastal locations, as recently highlighted by Fletcher and Lord (2011)
- there is no physical barrier preventing natural retreat of the shoreline, i.e. that retreat would enable the beach to continue to provide amenity to beach users once the adjacent assets are removed.

[1] In some instances, the flows of revenue from the use of coastal locations may be more relevant than the value of the assets protected by the seawall. For example, the rates and land tax revenue from residential and commercial properties, and the lease income from public assets may be required to offset the costs of asset management. It is not possible to incorporate this into the model given the variability in land tenure and ownership.

2. Climate Change Impacts Considered

The impacts of climate change on coastal regions will differ both in terms of magnitude and timing, and cannot be predicted with a high degree of local certainty. There will also be site-specific differences that cannot be incorporated into this generic model.

This model is based on the assumption that the primary source of damage to coastal land in the study area is from a seaward direction, through the influences of shoreline recession, erosion and inundation from marine sources. There may be instances where the primary sources of inundation are from a landward direction, either via surface or groundwater. Whilst these may be exacerbated by coastal protection structures, they are considered to be issues for consideration in flood management rather than coastal asset management and planning.

Protection of an area from inundation will cease to be an effective approach once the land becomes saturated. Hence, elevation of the land should be considered in a full assessment, with exposure measured through GIS and LIDAR. For the purposes of this analysis, the spatial area protected by the wall is defined simply as a linear function of the length of the wall.

Specialist advice from coastal engineers should be sought in identifying the mechanisms of failure of the protective structure, and the implications for selection of appropriate remedies.

For the purposes of inputs into this analysis, the mechanism of the impacts is not actually important. What is important is the definition of the spatial extent of these impacts, and the timing of the impacts. The combination of these two factors will determine both the type and extent of the assets under threat, and the period of time until management intervention is necessary. The latter will have critical impacts on the value of the assets and the cost-benefit analysis of different management options.

2.1 Sea Level Rise-induced Shoreline Recession and Storm Erosion Impacts

In order to assess the economic impacts of the different management options, it is necessary to estimate the state of the beach and adjacent areas at different points in the future. This is then related to property values as described in the methodology section.

Sea level rise and shoreline retreat are assumed to occur in a lineal fashion for the period of assessment. The rates of SLR-induced shoreline recession are taken from the WRL approximations shown in Table 2.22 (Appendix E), reproduced here as Table 1.

Table 1 Rates of SLR-induced Recession, as Derived from Planning Guidelines

Planning period (year)	Sea level rise above 1990 level (m)	Sea level rise above present level (m)	Vertical profile rise (m)	Bruun Factor	Horizontal profile recession (m)
2050	0.4	0.33	0.33	38.9	13.2
2100	0.9	0.83	0.83	38.9	32.7

This represents a mean recession rate of approximately 0.35 m/year for the period of 2012-2050 (13.2 m/38 years) and a mean recession rate of 0.39 m/year for the period 2050-2100 ([32.7 m-13.2 m]/50 years). This represents a slight acceleration of SLR over the assessment period, relative to the figures recorded by satellite altimeters in the period 1990-2012.

A key uncertainty in modelling beach width is the stochastic nature of storm impacts. This is likely to have a more important influence on the state of the beach and structural integrity of the protective structures than incremental baseline erosion or accelerated shoreline recession due to SLR. This in turn will have influences on the timing and type of intervention necessary. Incorporating stochastic storm impacts (e.g. in a Monte Carlo simulation as per Cowell et al.(2006)) is far beyond the scope of this appendix.

For the purposes of this model, the design storm bite and the average slope of the beach are used to estimate the recession of the beach due to such an event. The gradual SLR component and the storm-induced shock component (storm bite – SB in the formula below) are then summed to give a total recession at a given time in the future

and

$$WMax_t = W_0 - (R \times t)$$

Thus:

$$WMin_t = W_0 - [(R \times t) + SB]$$

where W_0 is the current average beach width, R is the rate of shoreline recession due to SLR as defined above, and t is the period of time in the future.

In order to test sensitivity of the management options included to the timing of storm impacts, some measure of shoreline recession due to storm impacts is required**. For modelling purposes it is assumed that the design storm results in a total loss of the sandy beach area seaward of the protective structure.** It is also assumed that there is only a single storm event during the assessment period, which is a critical factor in the appraisal of all options. It is not possible to incorporate a stochastic factor to consider storm impacts in this preliminary model, though this is a suggested avenue of future development and research.

The encounter probability of the design storm event approaches 1 (i.e. a storm of sufficient intensity to erode the sandy beach area exposing the protection structure is likely to occur at least every year) as the time period is extended, and hence the likely range of beach widths is actually narrowed as the planning period lengthens. For example, by 2100 there is a 59% chance that a 1-in-100-year event has already occurred, relative to 2012. Assuming no other actions have increased the width of the beach (either through reducing erosion or moving the structures landward), it is more likely that the beach will be fully eroded than that the beach will be at *WMax* . **In the absence of certainty about storm timing, this model allows the user to adjust the timing of the design storm, in order to assess the effect on the selection of outcomes.** Results of testing the sensitivity of management options to storm timing are discussed later in this appendix.

Thus for any time(t) in the future, the beach width is either *WMax* or 0 m, depending on whether the planning period (t) is less than the user-selected delay before the design storm occurs. This variable is termed 'storm delay' and denoted SD in the modelling calculations.

2.1.1 Management actions considered

Broadly speaking, there are two classes of response to the exceedance of design parameters of existing seawalls and the shoreline recession and storm impacts described above. The first class is the enhancement of the protective structures either through retrofitting or replacement, and the second is the removal of the assets currently protected by the seawall and the seawall itself. The enhancement of the protective structures could take two different forms, one being the use of hard structures such as the seawall, the other being the use of sand in the form of beach nourishment. Nourishment is considered a form of protection, or a means of delaying an inevitable retreat decision.

Committing to one or other of the paths makes transition between strategies more difficult, if not impossible. It is unlikely and impractical to move from a strategy of retreat to one of protection, unless there is some critical infrastructure or geological structure that restricts the retreat strategy or makes the protection strategy more viable. In the event that protection decisions are made for such reasons, it would make sense to consider development in the area which is already protected.

Moving from a strategy of protection to one of retreat is simpler in a theoretical sense, but the timing of this decision, both in terms of the time when the decision is made and the lead time until the selected area must be vacant, will have large implications on the cost-effectiveness of this approach. Adopting or maintaining a protective strategy has a development feedback as this action suggests this land is safe. The risk exposure in the protected area thus increases, and the complexity and costs associated with removing this development increase in kind.

For the purpose of this appendix, it is assumed that:

- there is an appropriate and abundant source of sand for beach nourishment
- there are no political or legal obstacles to the use of this sand
- the cost of accessing and placing this sand is constant throughout the planning period.

Given these assumptions, the economic viability of long-term nourishment is a key determinant of its utility as a protection measure. Clearly, these assumptions will not be valid for all situations or locations and may need to be revisited in further applications of this model approach.

3. Methodology

In order to implement the model, a number of further assumptions must be made. These are outlined in turn in the following sections, with the resultant figures and fixed relationships employed in the spreadsheet model highlighted in yellow (not included). Those components which can be readily modified by the model user are highlighted in green.

3.1 Costs of Management Options

The costs associated with the necessary management interventions should be ascertained through seeking expert advice from coastal engineers, as part of a site-specific hazard definition study or management plan. In the absence of this information, some guidance may be sought from the technical advisors at state government level, or by examination of studies recently completed by other councils. Figures used in this appendix are indicative figures gleaned from technical experts. Routine maintenance or post-storm assessment is considered to be undertaken as part of the normal asset management program, and is thus excluded from the model calculations. Sunk costs, i.e. those already incurred in construction of the existing structure or alternative activities (e.g. dune rehabilitation) are also excluded.

3.2 Benefit of Protection Options

The sections below first describe the assumptions necessary in consideration of protection options. These may take the form of hard structures, or the use of beach nourishment. The benefits of these options are largely to be found in the value of the properties or assets they protect, and hence some measure of property prices is required. This begins with the current value of protected property, but must also incorporate some assumptions about how these values will change due to both environmental and management interventions. The following sections outline the assumptions employed in this assessment.

Property prices are commonly assumed to grow over time, with the rate of growth displaying a degree of variability, but typically greater than inflation, i.e. growing in real terms. This appendix also takes this assumption, but adjusts the future value of property by accounting for predicted changes in the state of the beach. These changes are likely to have strong influences on selection of adaptation options.

The number of properties is considered fixed for the purposes of the scenarios presented below, that is, it is assumed that there is no intensification of development and that there is only one type of infrastructure in the study area.

3.2.1 Housing markets and beach width

It is assumed that the value of coastal property is directly linked to the state of the beach, and that changes in the beach width will therefore have flow-on effects on the value of coastal property. These effects will be most strongly felt on the beachfront properties, which are the most likely to be affected by shoreline recession and the various adaptation responses.

3.2.1.1 Minor erosion of the beach

It is assumed that for a given 10% reduction in beach width, property values diminished by approximately 2.6%. (Rinehart and Pompe 1994). This holds only for marginal changes in beach width, i.e. changes where the initial width of the beach is significant. **This relationship is used to diminish future property values, up to the point at which the beach becomes severely eroded**.

3.2.1.2 Major erosion of the beach

This capitalised amenity value is assumed to begin to diminish rapidly once the width of the beach reaches a critical width (Wc). This is the minimum width of the beach (average annual value at high tide) that allows the beach to provide the same amenity value. In practice it will vary considerably between users and non-users, and within these groups. Dedicated community surveys would be required to define this relationship, and even then assumptions would need to be made that this relationship was stable over the life of the assessment.

For the purposes of the case study, this critical width is assumed to be 20 m, though surveys would be required to adequately identify whether this assumption holds for the location under consideration.

Anning (2012) and Burgan (2003) report that beach frontage in Australian property markets commands an environmental premium of around 40% on adjacent, non-beachfront properties. Market evidence (and evidence using their proxy, rateable land value) also seems to support the assumption that highly eroded beaches will have a strong influence on adjacent property prices.

Under a protection policy, once the critical width is reached, the capitalised amenity value of the property is assumed to be reduced immediately by 40%, but to not undergo any further reductions. This is because the property still retains many other attributes that are not affected by the presence of sand, such as access to pleasant views and providing shelter.

3.2.1.3 Storm damage and complete erosion of the beach

When impacted by a storm event with an average recurrence interval (ARI) of 100 years, the erosion scarp may typically move landward by up to 20 metres, depending on the state of the beach, dune height and exposure to the storm waves when the storm is experienced. This may result in the loss of or damage to land and buildings behind the existing seawall structures, though it is difficult to predict the amount of damage, and also the extent to which this damage will affect the value of the property. For example, if there are sufficient building setbacks, this may not affect the use or value of the property to any measurable extent. Landowners and property purchasers may also be operating under the assumption that action will be taken to protect their property, and hence discount the risk of damage in their purchase decision. The information required to develop such an inclusion would require technical and site-specific engineering expertise, whereas this economic model is designed for broader application in the absence of complete information. **The potential further reduction in property values due to direct physical impacts is therefore not built into the current form of the model.**

The beach width is assumed to recover after a storm over a period of six years, with 50% recovery in the first year after the storm impact, and 10% per annum over the next five years. This rate of recovery, if any, will vary by location, the extent of erosion that results, subsequent weather conditions and the beach type (e.g. high littoral drift coastline or pocket beach with little headland bypassing).

In effect, the 'no intervention' option presented in the case study shows the upper bounds of this potential damage, as it assumes that all properties within the affected area are completely demolished once the storm scarp encroaches behind the existing seawall structure. This option is described further in the next section.

3.2.1.4 Nourishment impacts on beach width

Two forms of nourishment are considered, termed minor and major nourishment.

Minor nourishment is assumed to increase the beach width by 10 m, and is undertaken to maintain beach amenity. In order to achieve this increase in exposed beach width, it is necessary to nourish the entire beach profile. Typically, two thirds of the nourishment volume is below mean sea level (MSL), and 15 m^3 of nourishment is required to increase the exposed beach width by a metre (with an assumed dune height of 5 m above MSL. Thus, increasing the beach width by 10 m would require 150 m^3 per metre of beach length.

Major nourishment is undertaken to increase the erosion buffer on the beach to the point that it can accommodate the storm demand. In most cases, this will involve increasing the beach width above the starting value. To estimate the volume required to provide 250 m^3 of sand on the beach at the conclusion of the nourishment campaign, it is assumed that the beach is nourished out to a width of 70 m as observed originally, and an additional 20 m of beach width is added to provide the additional storm buffer required (100 m^3 divided by a dune height of 5 m). This follows the same rules as for minor nourishment. It is assumed that this increased beach width results in both increased property values and recreational amenity values.

3.3 Benefits of Retreat Options

3.3.1 Housing markets and planned retreat

A retreat can either occur as an unplanned response in the aftermath of a severe storm or as a planned response to avoid the costs or other adverse effects of shore protection. There are a number of factors that can change in the implementation of a planned retreat policy, such as the delay before implementation, which can in turn be either a time or trigger-point measure, e.g. removal of property in 10 years or when the erosion scarp is within 10 m of the property boundary. The degree of compensation paid to displaced landowners, if any, and the way in which this compensation is paid, are also key components of the retreat option. This model takes a simple definition of the policy option, with a time delay trigger for implementation. It defines a number of time periods in the selection of retreat as an adaptation option. These are, in order:

- the decision delay period (TL)
- the planning period (PP) and
- the implementation period.

The first is denoted TL in the model, and is the time between the present day and the adoption of a retreat policy.

The second is denoted PP, and is the time between adoption of the policy, and the time when the structures and infrastructure begin to be removed and the property can no longer be used for the intended purpose. It assumes that this will be delayed until the latest possible time, i.e. that property owners will seek to maximise the use of their property until it becomes unsafe to continue the activity or occupation of the land.

The third period is the time allocated to undertake the removal itself. In most cases it will be assumed to be short, though in cases where there is a high level of development or infrastructure which is difficult to relocate this assumption may not hold. It is assumed to be less than one year for modelling purposes.

3.3.1.1 Assumptions incorporated into the model for planned retreat

It is assumed that the value of residential property will be reduced in a gradual and linear fashion from the start of the implementation period over the remaining time until the land must be vacated, i.e. over the **planning period**.

It is assumed that the owners of the properties subject to a new policy of planned retreat will be compensated their full market value at the time the announcement of the policy is made, i.e. at the end of the **decision delay**.[2]

3.3.2 Housing markets and unplanned retreat

Retreat can either be a planned process that allows for the depreciation and decay of existing assets, or can be in response to a catastrophic event, e.g. Hurricane Katrina, 2010 floods in Grantham (Lockyer Valley). Given the longevity of buildings and infrastructure, and the economic investments associated with their use and construction, retreat typically requires a longer lead time and higher degree of planning than adopting a protection policy. Unplanned retreat has substantially greater costs in the short term, even with the reduced value of the land after erosion impacts, and should be avoided. Long lead times lead to more efficient and effective outcomes.

The application of the model as an illustration in this appendix incorporates an option that considers unplanned retreat, which is termed 'No intervention'. Under this scenario the total value of property is lost once the beach is eroded beyond the existing seawall structure.

3.4 Recreational Value of the Beach (in front of the Seawall)

Coastal protection measures have positive outcomes in terms of protection of landward assets, but also the potential for negative impacts on the adjacent beach environment.

Surf Life Saving Australia maintains a database of records from lifesaving patrols. Attendance records for 2011 estimate that 77,974 beach visits were made to Bilgola Beach. This includes only weekends and public holidays. Pittwater Council also employs lifeguards who patrol on weekdays. Lifeguard

[2] The timing and value of this compensation payment is critical to the assessment of retreat as a policy option. Understanding the market response to a planned retreat policy is critical to understanding this value, and would require dedicated economic research and community consultation.

records indicate a total of 108,387 beach visits in 2011, for a total of 186,361visits over the year (Surfguard, 2012) These records do not include approximately five months of visitation over the cooler months, **and hence the total visitation is likely to be in the order of 250,000 per annum.**

In order to convert this to a value for recreational use, a value for a beach day is required. There is little existing data about the value of beaches in Australia, and hence proxy data must be employed to estimate the value of the beach for non-beachfront beach users. Anning (2012) reports on the application of a travel cost model of beach visitation to Manly Ocean Beach and Collaroy-Narrabeen beach, from which recreational values (consumer surplus[3]) were estimated. It is considered that the results for Collaroy-Narrabeen are most appropriate for benefit transfer, as Manly receives a very high proportion of tourist visitation, and many of these visitors travel by ferry, thus incurring higher travel costs than is considered normal for Sydney beaches.

Beach-day values derived by Anning (2012) are reproduced in Table 2. Lower bounds (Model 1 results) only incorporate the direct costs of a beach visit. Model 4 includes a measure of the value of time spent in travel to and from the beach. This uses a proportion of the wage rate (25%), and does not include the value of time spent on the beach as this is assumed to be leisure time and thus not interchangeable with time spent in paid employment.

Table 2 Consumer Surplus Estimates for Beach Recreation at Selected Sydney Beaches

(after Anning 2012)

	Model 1 - travel costs include only fuel and parking or ticket costs (AUD$ 2008)		**Model 4** - Model 1 components plus time costs (AUD$ 2008)	
Beach	Consumer surplus estimate	Standard error	Consumer surplus estimate	Standard error
Collaroy-Narrabeen	2.72	0.56	10.28	2.59
Manly Ocean Beach	9.2	1.92	16.18	2.98

Multiplying the visitation estimate (250,000) by the estimated value of each beach visit (Collaroy-Narrabeen CS point estimate ± standard error) gives a minimum bound for the recreational value of Bilgola Beach of AUD$540,000 per annum (2009 figures, unadjusted for inflation), and a maximum bound of AUD$3.2 million p.a. **This model employs the upper bound point estimate, $10.28 per beach visit, as this figure is more consistent with other published studies of this nature.** The number of visits is assumed to increase in the same manner as the value of the property.

3.5 Summary of Assumptions Incorporated into the Model

Table 3 summarises the assumptions about the relationship between the state of the beach and the effect on both the protected asset value and the recreational value of the beach itself. Under a retreat scenario, the protected values are assumed to also be affected by the policy announcement, as previously described. Recreational values are assumed to be preserved by a retreat option.

[3] Consumer surplus in this context is the difference between the amount that people pay to visit a location, and the maximum amount they would be willing to pay for the same experience.

Table 3 Summary of Value Assumptions for Management Alternatives

Beach width	Less than 0 (post-storm)	0<Width<Wc	Wc<Width<W	Width>W
Value assumption for protective responses	Protected value is reduced by 40%, recreational value is completely lost	Protected value is reduced by 40%, recreational value is reduced by 75%	Protected value and recreational value are reduced by 2.6% for every 10% loss in beach width	Protected value and recreational value are increased by 2.6% for every 10% increase in beach width

4. Generic Beach - Case Study - Scenario testing

The basic model can be used in a standard cost-benefit assessment. The greater advantage of explicitly outlining the costs and benefits of the alternatives may be in the ability to perform scenario testing. This section explores a number of alternative options, and the extent to which the options are affected by varying the model inputs. It can be used to test the point at which the preferred option changes due to the inputs and assumptions.

The associated spreadsheet-based model presents an analysis of options for the management of an existing seawall structure. They are based on a common site description (i.e. a single location), but examine different possible interventions, and the sensitivity of these options to variability in the inputs to the model. Seven alternative management options are considered, with their net present value (NPV) calculated over the course of the assessment period. Sensitivity to key input parameters is included in the following section.

4.1 Option 1 – Minor Protective Works, Without Nourishment

Describes minor repairs and upgrades that have a shorter design life, and must be undertaken more than once in the assessment period. Costs associated are site access costs (per property) and capital construction costs (per linear metre of shoreline). Benefits are the protection of property, with the possible negative impact of a loss of beach width and associated recreational values.

4.2 Option 2 – Major Protective Works, Without Nourishment

Major works which involve replacing the entire structure, and are undertaken only once in the assessment period. All cost and benefit components are as per Option 1.

4.3 Option 3– Planned Retreat

The decision is made to not allow any further development of the adjacent area, and that the existing building should be removed at some time in the future. Costs associated are site access costs and the value of compensation to the displaced landowners. This assumes that the landowners were not previously subject to a retreat policy, and that compensation is required. Compensation is paid at the full market value of the properties at the time the policy is announced[4]. Benefits are derived from maintaining the recreational value of the beach, as it is assumed that the existing seawall structure/s are removed, and the beach can recede naturally, thus maintaining a natural beach width without nourishment.

[4] This is a critical factor in the economic appraisal of the retreat option, and the appropriateness of this assumption should be considered carefully in assessing the results of this exploratory analysis.

4.4 Option 4 – Minor Periodic Nourishment

The beach is nourished repeatedly over short (10-year) periods to maintain a usable beach. No investment is made in protective infrastructure. The beach is nourished with relatively small volumes, equivalent to 10 m of additional beach width. Costs associated are site access costs and the costs of sand using a rule-of-thumb of 10 m^3 of sand nourishment for every metre of extra beach width.

4.5 Option 5 – Major Nourishment

No investment in protective infrastructure is made, and the beach is nourished to accommodate the storm demand volume, i.e. so that it is wider than the original beach profile. It is assumed for the sake of this modelling exercise that the preferences for beach width scale upwards in the same manner as they are lost, i.e. that they increase by 2.6% for every 10% increase in beach width. Costs associated are site access costs and the cost of sand. Benefits include the protection of property values and the potential to increase the value of property and recreation through provision of a wider beach.

4.6 Option 6– Protect and Nourish

This option combines Option 2 and Option 4. Only major capital works are included in these assessments, as the investment in nourishment is unlikely to be made if major works have been considered too expensive.

4.7 Option 7– No Intervention: Allow Recession then Abandon

The beach is allowed to recede without intervention. Property prices and recreational value decline steadily, until the decision is made to relocate the properties. This takes place once the beach scarp has been eroded, that is, after a major storm event, with the assumption that there is full compensation paid.

5. Model Inputs

There are a number of parameters which can be adjusted to test their influence on the economic appraisal of each outcome. The selection of site specific values that are informed by technical expertise will enhance the usefulness of this process. For the purposes of this sensitivity analysis exercise, the base-case figures employed are those for Bilgola Beach (NSW), and are shown in Table 4. Mean beach width for Bilgola is 70 m, based on the work by Andy Short (Short, 2007). This is assumed to be correct for 2012, although the exact date of assessment is unknown.

Table 4 Starting Values for Sensitivity Analysis of Appraisal Results

Parameter	Assessment period (AP)	Storm delay (SD)	Protection decision delay (TL)	Planning period for retreat (PP)	Growth rate in values/ costs (G)	Discount rate (D)
Description	Years over which the assessment is undertaken	Years until the 1-in-100 year storm event occurs	Years that the decision is delayed	Years between the decision and the retreat of infrastructure	Real growth rate of land values, above inflation	Represents the fact that future costs and benefits are not considered equally as important as current-day figures
Unit of measurement	Years	Years	Years	Years	Percent (decimal fraction in spreadsheet)	Percent (represented as a decimal fraction in spreadsheet)
Starting value	88	25	10	30	0.00	0.04

6. Sensitivity Testing Results

This section presents in graphical form the results of sensitivity testing for key parameters, in terms of their net present value over the assessment period. For each test described hereafter, a single parameter is varied, whilst all other parameters take the prescribed values displayed in Table 4.

It should be noted that these results are relevant only to the case study parameters and assumptions which were included in the model for demonstration purposes. They do not constitute a true appraisal of these options either for the demonstration site or any other location. They are presented to explore the influence of key parameters on the relative favourability of different management options.

6.1 Sensitivity to Discount Rates

The selection of appropriate discount rates and sensitivity testing rates are typically suggested by Treasury guidelines issued by the relevant state government. The base-case figure employed here is derived from the NSW Government Guidelines for Economic Appraisal (NSW Government, 2007), which suggests the use of discount rate of 7% per annum, with sensitivity testing at rates of 4 and 10%. The lower bound is preferred due to the nature of the project. The use of discount rates in assessment of projects with long timeframes and intergenerational equity issues is a matter of some debate in the environmental economic and climate change literature. Some have argued that the use of a positive discount rate discriminates against future generations, and that a very low, zero, or negative discount rate is more appropriate. This is the approach taken in the Stern Review of the economic impacts of climate change (Stern, 2006), which adopts an effective discount rate of 1.4%, substantially lower than that typically used in government benefit cost analysis. This appendix does not attempt to resolve this issue, but tests discount rates in the range of 0-10% per annum.

The substantial influence of discount rates is to reduce the relative contribution of future costs and benefits on the NPV of each option. This is clearly demonstrated by Table 5, which shows the relative value of a dollar of benefit (or cost) at different time periods, when subject to the range of discount rates examined in this illustrative exercise. It can be seen that the relative contribution of future values to present value calculations decreases substantially at high discount rates and long time periods.

Table 5 Present Value of Future Values - Relative

	Discount rate (% per annum, in decimal form)										
Year	**0**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**	**0.1**
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62
10	1.00	0.91	0.82	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39
15	1.00	0.86	0.74	0.64	0.56	0.48	0.42	0.36	0.32	0.27	0.24
20	1.00	0.82	0.67	0.55	0.46	0.38	0.31	0.26	0.21	0.18	0.15
25	1.00	0.78	0.61	0.48	0.38	0.30	0.23	0.18	0.15	0.12	0.09
30	1.00	0.74	0.55	0.41	0.31	0.23	0.17	0.13	0.10	0.08	0.06
35	1.00	0.71	0.50	0.36	0.25	0.18	0.13	0.09	0.07	0.05	0.04
40	1.00	0.67	0.45	0.31	0.21	0.14	0.10	0.07	0.05	0.03	0.02
50	1.00	0.61	0.37	0.23	0.14	0.09	0.05	0.03	0.02	0.01	0.01
60	1.00	0.55	0.30	0.17	0.10	0.05	0.03	0.02	0.01	0.01	0.00
70	1.00	0.50	0.25	0.13	0.06	0.03	0.02	0.01	0.00	0.00	0.00
80	1.00	0.45	0.21	0.09	0.04	0.02	0.01	0.00	0.00	0.00	0.00
88	1.00	0.42	0.18	0.07	0.03	0.01	0.01	0.00	0.00	0.00	0.00

Sensitivity to the selection of discount rates is presented in Figure 1. It shows that all options become relatively less attractive as discount rates increase, due to the discounting of future streams of benefits.

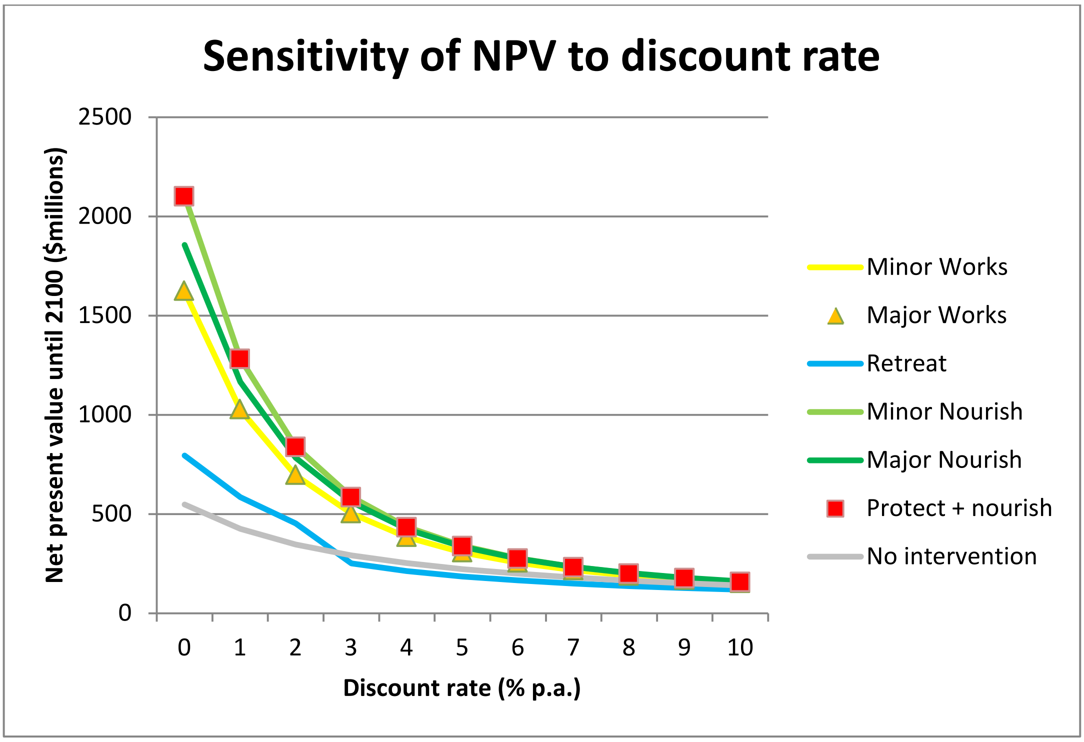

Figure 1 Sensitivity of Options to Discount Rate Variability

The relative impact is greater on those options which involve nourishment, as these options are most effective in preserving (and indeed increasing) the streams of benefits in the more distant future. Under lower discount rates, these still contribute to the NPV calculation in a substantive manner. Under high discount rates, they have a relatively minor contribution.

Capital works options are also affected moderately, as the costs incurred (fixed in year 10) are not affected to the same degree by discounting as the benefit stream (which lasts for 88 years).

It can be seen that there is a large difference in the NPV of options at low discount rates. Those options which involve retreat are much lower than the protective options. The costs associated with retreat are substantial, whether it is a planned or unplanned process. Low discount rates mean that when these options are undertaken a long time in the future they still have significant impacts on the relative attractiveness of the options.

There is also a difference between the 'hard protection' options and those that account for beach amenity. Those options which involve nourishment have the highest NPV for all discount rates, as they preserve the value of the protected land and retain the recreational value of the beach.

6.2 Sensitivity to Shoreline Recession and Storm Timing

The sea level rises considered should incorporate the planning benchmarks outlined by the relevant state authority. A current summary of these is given in Table 6, and can provide the basis for appropriate shoreline recession calculations in other jurisdictions. These figures are subject to periodic review and should be checked prior to commencing any analysis.

Table 6 Sea Level Rise Allowances in Policy

Jurisdiction	2050	2100	Comment
Commonwealth		1.1	a
Queensland	0.3	0.8	b
New South Wales	0.4	0.9	Policy
Victoria		0.8	Policy (under revision for existing towns)
Tasmania			c
South Australia	0.3	1.0	Policy
Western Australia		0.9	d
Northern Territory	0.3	0.8	e

Source: modified from (Lord & Gordon, 2011)

a) No official policy, but the figure was used in national vulnerability assessment. Suggested that higher levels should be considered in a risk assessment
b) Draft policy for 2100. Previous policy gave the 2050 level
c) No official policy, though considered a priority
d) For 2110, slightly less for 2100
e) Not official policy, but suggested for consistency with Qld.

Consideration should also be given to higher levels of sea level rise, based on the best available science, for risk management purposes. The degree of sensitivity to higher levels of SLR will identify those solutions which are less robust under uncertainty.

Sensitivity to shoreline recession due to SLR is not tested in this appendix, as the influence of storms is considered to be a much greater driver of economic outcomes. Sensitivity of the management options to the timing of the storm impact is presented in Figure 2. It should be noted that this illustration model assumes only one storm event during the assessment period. In reality, the response of the beach may be dictated by storm recurrence and intensity, and that this storm is a 1-in-100-year event. A more advanced model would include stochastic storm impacts over the entire period.

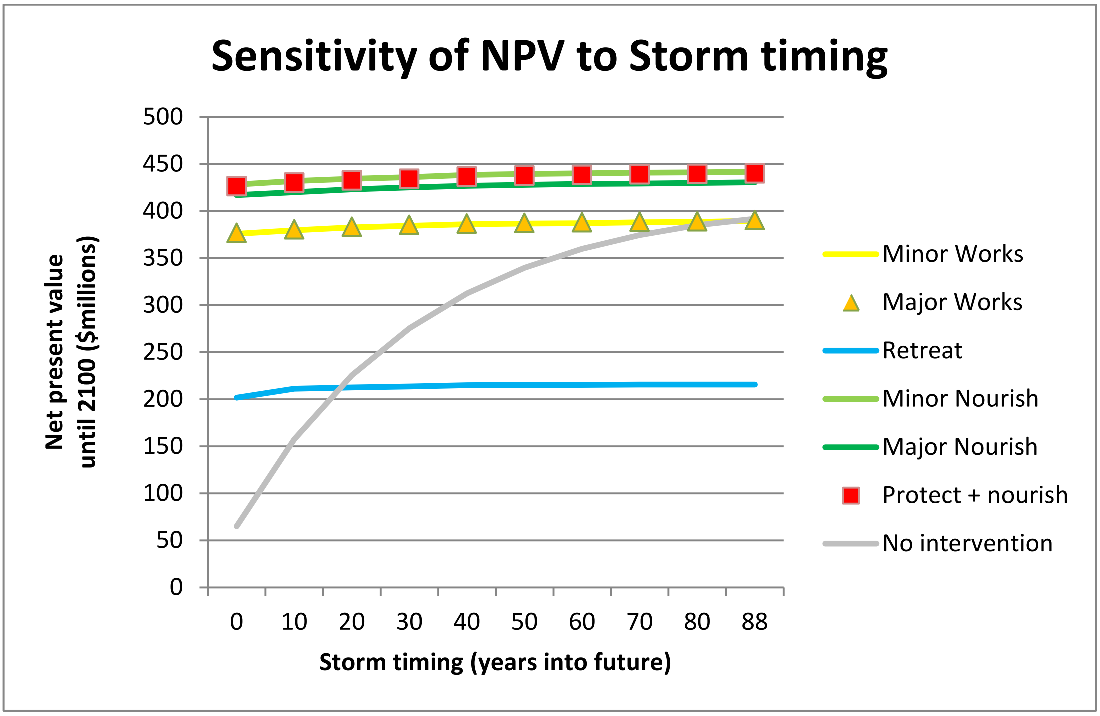

Figure 2 Sensitivity of NPV to Storm Impact Timing

It can be seen that whilst most options remain relatively unchanged, the 'No intervention' option has very low NPV when the storm occurs in the near future. This is because the costs associated with the removal of properties are incurred at the time of the storm impact. When the storm impact occurs in the near future, this cost is not discounted heavily. When this storm impact occurs a long time into the future, this cost has been discounted such that it is a relatively minor consideration (Table 5). The sensitivity of this option to storm timing is a demonstration of the risk associated with the 'do nothing' management option, from a societal perspective.

6.3 Sensitivity to Delaying the Decision

Delaying the decision about the management response to climate change impacts is the next input parameter tested, with results presented in Figure 3.

Retreat becomes relatively more favourable with a delayed decision, as the discounting process reduces the cost impacts of both the compensation paid and the reduction in property value assumed to take place when the policy is announced. Hard protection options are relatively unaffected by the delay in intervention, though the present value of costs is reduced through discounting.

Soft protection options become less attractive with a delayed decision, as there is a greater probability that the storm impact has occurred before the management intervention. For the options involving minor nourishment, this means the application of sand after a storm impact will be 'harm minimisation' rather than potentially improving the beach beyond the original state.

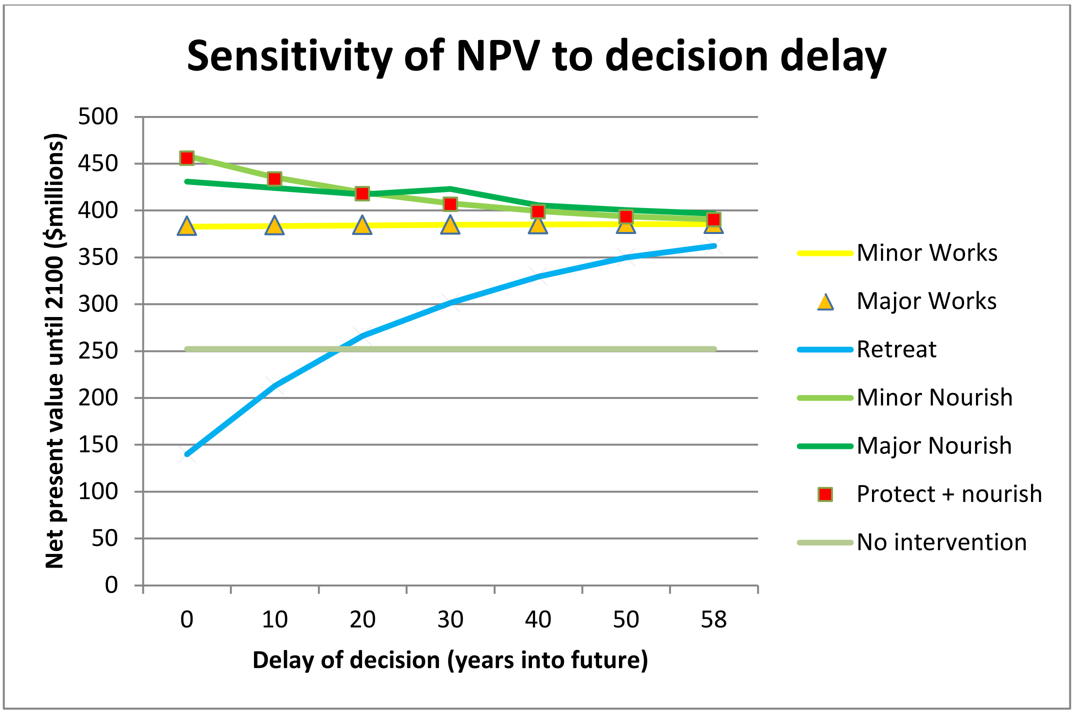

Figure 3 Sensitivity of NPV to Delaying the Decision

For the Major Nourishment option, the costs of adding sufficient sand to provide a buffer for the next design storm event increase substantially after a storm event. If major nourishment actions are taken soon after the storm impact (i.e. in a reactive manner), then the volume of sand required increases dramatically, and thus the costs become significant. Thus there is both a risk associated with delaying the decision if this is the preferred option, and a benefit to proactive planning of this intervention.

The analysis of delaying the decision fails to consider the fact that the delay reduced the time available for planning the retreat process, as it assumes that this process occurs over 30 years. As such, the decision delay is only considered up to 58 years into the future, given a fixed assessment period of 88 years will still allow for a relatively gradual retreat process. In reality, the urgency of the response to accelerated shoreline recession or storm impacts may dictate shorter planning periods, and hence a consideration of the impact of these.

The extent to which changing the planning period affects the outcome for the planned and 'no intervention' option is presented in Figure 4. Other options are not presented in this figure, as they are assumed to not be affected by the planning period. It can be seen that the 'no intervention' option is unaffected by the time allowed for retreat, as it is assumed to be an immediate response to a storm impact, and this storm impact timing remains fixed at 25 years in the future.

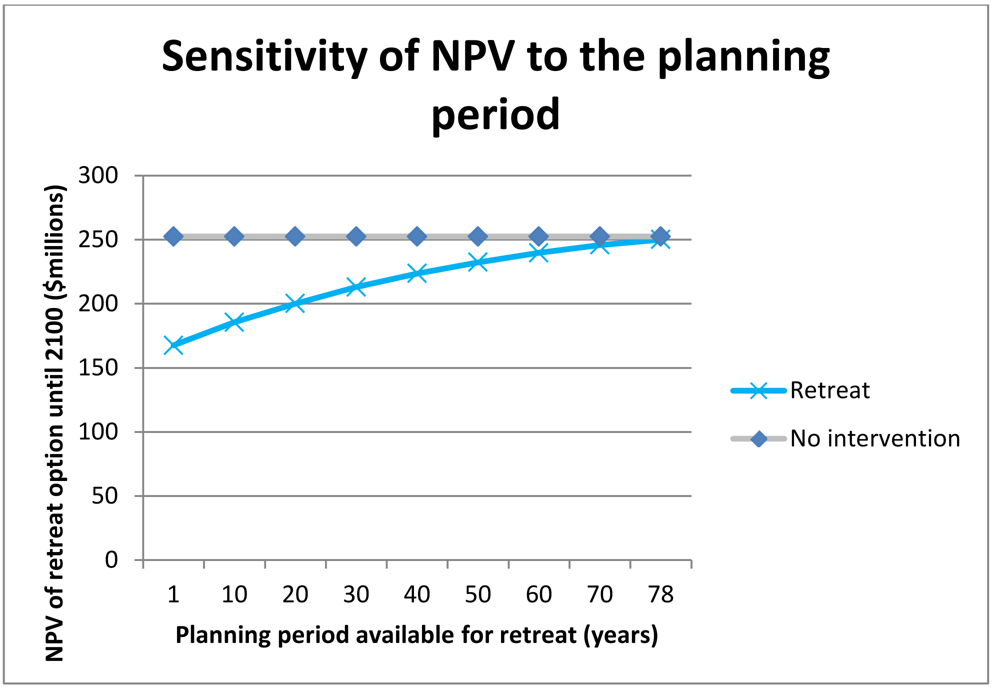

Figure 4 Sensitivity of NPV of Retreat to Planning Period

The favourability of the 'no intervention' option is higher than that of planned retreat for all planning periods, given the assumptions included in the model. This is due to the fact that full compensation in a planned retreat scenario is paid at the time of the policy announcement, whereas under a 'no intervention' scenario this compensation is paid at a lower rate (reduced by 40% due to storm damage depression), and at a fixed date (25 years into the future). The compensation paid under a planned retreat scenario increases each year due to the assumption of future property growth, and is always higher than the value paid under a 'no intervention' scenario.

This outcome is highly dependent on both discount rates and the assumptions about future property value growth. It also takes the assumption that full compensation is both legally required and paid to the property owners, though there does not appear to be any legal obligation for any compensation, except under strict circumstances and in certain jurisdictions.

Greater research into alternative planned retreat schemes is required, to consider arrangements that are legally, socially and economically beneficial. Some possibilities include the payment of partial compensation at the time of policy announcement, with continued payments over the duration of the planning period (e.g. 40% when announced, the remaining 60% over the planning period), or full compensation but deferred until the end of the planning period. These would have substantial influences on the appraisal of the policy choice.

6.4 Sensitivity to Property Market Assumptions

Given the assumptions about the protected values and the high level of benefits associated with these assets, these figures overwhelm any consideration of storm impacts or costs associated with management interventions, with the exception of those also linked to property values (i.e. costs associated with retreat options).

Figure 5 displays the extent of this sensitivity, and demonstrates that the assumptions of an ever-increasing coastal property market are drivers of the decision outcomes. When negative growth rates are considered, the difference between the management options is greatly reduced, to the extent that the retreat options merit further consideration.

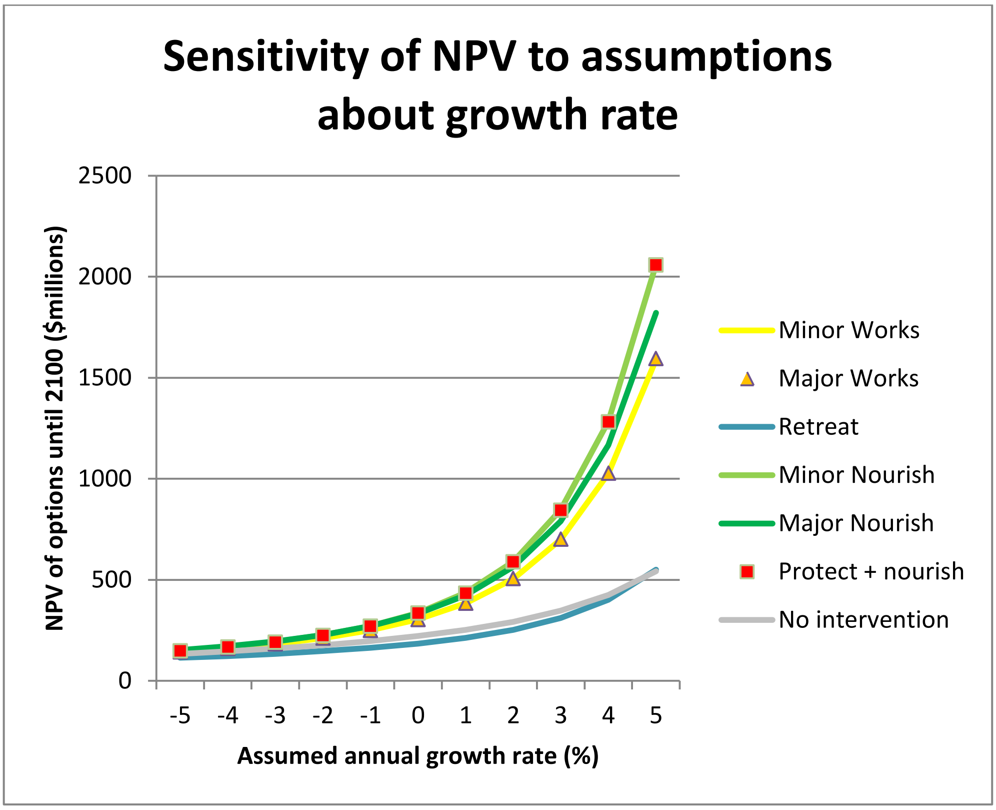

Figure 5 Sensitivity of NPV to Property Market Assumptions

7. Conclusions, Limitations and Additional Work Required

It can be seen from the sensitivity analysis that the favourability of each option is impacted differently by the variation in key parameters. Key among these is a parameter over which the manager has no control, the timing of storm impacts. The sensitivity analyses presented here, though simple and based on a number of assumptions that require further testing, demonstrate that there is an obvious risk to effective management posed by the occurrence of a storm before a management decision has been made, or at a time that precludes strategic options such as efficient planned retreat.

It can also be seen that the high level of benefits assumed through protection of property drives the NPV of all options. This fails to consider the fact that these protective benefits may not actually exist, as the existing structure may not adequately protect the adjacent assets in any meaningful way. In the absence of complete knowledge of the protection provided by the seawall structure, this model essentially considers only the protection buffer provided by the existing beach width. Ideally, the protective benefits should be weighted by some measure of the effective protection provided by the structure. This would greatly influence the outcomes, to the extent that further discussion about the implications of these analyses is probably not warranted.

Also not included in the model, but critical to the selection of appropriate options, is the value of the beach to non-beachfront residents and non-users of the beach. This non-use value has a number of components, as shown in Figure 6, and can comprise a significant proportion of the total economic value (TEV) of a natural resource such as a beach.

Whilst there is some available proxy data to estimate the recreational value of beaches, there is little information about the way in which users and non-users of beaches will respond to a loss of sand from these locations, either in terms of severity (total or partial loss) or duration. This information is critical to the selection of appropriate adaptation options, as the sensitivity of beach users to the loss of sand informs the appropriate nourishment response.

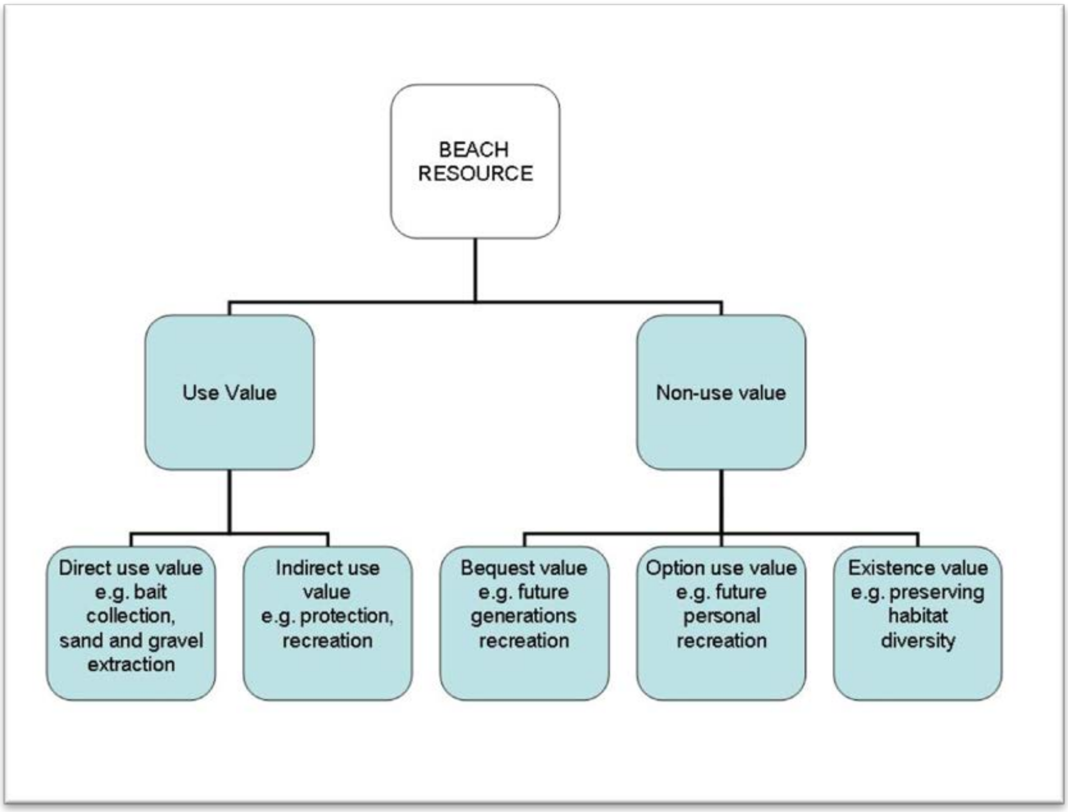

Figure 6 Components of the Total Economic Value (TEV) of a Beach Resource

(Anning 2012)

Non-market economic expertise is required to adequately assess the value of coastal proximity in a given region, most likely through a hedonic pricing approach. Dedicated surveys would also be necessary to understand community willingness to accept retreat as an option. This desire has not been strongly expressed in the past. There are also legal challenges to the implementation of retreat as a policy. It is not possible to predict the market response to persistent and serious impacts such as those predicted under climate change scenarios, though these will be key drivers of the selection of adaptation options. This is a critical area of research, though not one that is easily addressed.

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