# Climate Change Adaptation Options Assessment – Executive Summary

Developing flexible adaptation options for the Peron-Naturaliste Coastal region of Western Australian

Prepared for the Peron-Naturaliste Partnership

**September 2012**

ACIL Tasman

Economics Policy Strategy

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## ACIL Tasman Pty Ltd

ABN 68 102 652 148
Internet www.aciltasman.com.au

### Melbourne (Head Office)
Level 4, 114 William Street
Melbourne VIC 3000

Telephone (+61 3) 9604 4400
Facsimile (+61 3) 9604 4455
Email melbourne@aciltasman.com.au

### Brisbane
Level 15, 127 Creek Street
Brisbane QLD 4000
GPO Box 32
Brisbane QLD 4001

Telephone (+61 7) 3009 8700
Facsimile (+61 7) 3009 8799
Email brisbane@aciltasman.com.au

### Canberra
Level 2, 33 Ainslie Place
Canberra City ACT 2600
GPO Box 1322
Canberra ACT 2601

Telephone (+61 2) 6103 8200
Facsimile (+61 2) 6103 8233
Email canberra@aciltasman.com.au

### Perth
Centa Building C2, 118 Railway Street
West Perth WA 6005

Telephone (+61 8) 9449 9600
Facsimile (+61 8) 9322 3955
Email perth@aciltasman.com.au

### Sydney
Level 20, Tower 2 Darling Park
201 Sussex Street
Sydney NSW 2000
GPO Box 4670
Sydney NSW 2001

Telephone (+61 2) 9389 7842
Facsimile (+61 2) 8080 8142
Email sydney@aciltasman.com.au

## For information on this report

Please contact:

Nick Wills-Johnson
Telephone (08) 9449 9616
Mobile 0404 665 219
Email n.wills-johnson@aciltasman.com.au

## Contributing team members

David Campbell
Tess Metcalf
Simon Sagerer

John Söderbaum

Nick Wills-Johnson
Matt Eliot (Damara WA)
Glenn McCormack (Damara WA)

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# 1 Introduction

This report details the assessment of optimal adaptation strategies to respond to climate change challenges in the Peron-Naturaliste Region; from Point Peron in the City of Rockingham to Cape Naturaliste in the City of Busselton. The report has been commissioned by the Peron-Naturaliste Partnership (PNP), which comprises representatives from the nine local governments in the region (The Cities of Rockingham, Mandurah, Bunbury and Busselton, and the Shires of Harvey, Waroona, Dardanup, Murray and Capel) as well as State Government representatives from the Departments of Water, Transport, Planning and Environment and Conservation. The project, *Developing Flexible Adaptation Pathways for the Peron Naturaliste Coastal Region of Western Australi*a has been funded by the Australian Government represented by the Department of Climate Change and Energy Efficiency (DCCEE) *Coastal Adaptation Decision Pathways Projects: An Australian Government initiative* and is one of 13 projects who have received funding to develop leading practice approaches to better manage future climate risk to coastal assets and communities. -The aim of this project is not only to elucidate flexible adaptation options in respect of the particular case studies chosen in the analysis, but also to show how the relevant decisions were made; providing a source document for future analyses by local governments in the PNP region and beyond.

The PNP region is shown in Figure 1 (overleaf).

The report comprises three main parts:

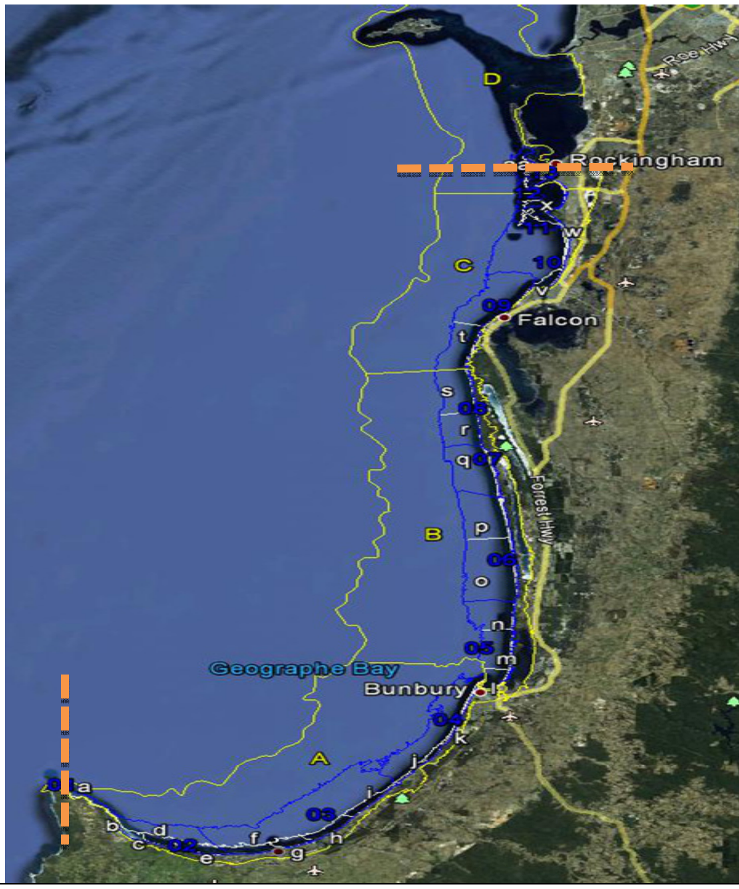
- A background discussion around the key economic concepts of value and methods of valuation.
- A region-wide assessment intended to provide an overall appreciation of the resource cost of climate change adaptation in the South West of WA.
- A detailed account of four case study investigations of adaptation strategy in four case study areas in the South West of WA.

## Key economic concepts

The first element focuses on ideas and techniques. Since adaptation responses often involve assets that are not traded in marketplaces, such as parks and reserves, and since the valuation of these assets presents unique decision-makers, much of the focus of the discussion is on the valuation of non-market assets. The general conclusion of these discussions is that the various economic valuation techniques for non-market assets are far from perfect, and should be used with caution.

Greatest caution and scepticism should be reserved for "benchmark" or "best practice" values gained from other studies which suggest that a beach, say, "ought" to attract a value of $500,000 per hectare on account of its non-market value. Numbers such as this tend to get agreed on for the purposes of convenience regardless of their actual rigour. The issue is not just that the numbers are wrong in the context of specific areas, but that they misunderstand the nature of value as a concept in economics. For this reason, the report stresses the need to consider economic analysis as only one element in the decision-making process, and suggests that benchmark values ought to play a more limited role still.

Figure 1 **Peron Naturalist Partnership study region**




*Source:* Google Earth

The section on ideas and techniques also introduces two concepts that we have found useful in our consideration of adaptation strategies. The first is the notion of "value at risk". Consider the case of Sydney Harbour, affected by climate change. One approach to designing strategies could be to begin with an investigation of what the harbour is worth, and whether it is worth saving. However, this is not only very difficult, but, worse, it is pointless for decision-makers. Instead, one needs to look at what might happen in Sydney Harbour if sea levels rose; some housing would be affected, along with some transport links, but many of the aspects of the harbour which gives it value (like its views) would be largely unaffected. A value at risk approach looks at what climate change might do to an asset, and the costs of society from these impacts. It not only has a spatial element (the various parts of Sydney Harbour above) but also a temporal element; a house that is not affected by erosion for 50 years still has value by virtue of being habitable for several decades before it is abandoned, for example. In general, value at risk is much simpler to establish than value (we present some simple mathematical equations) and also provides a much more robust basis for decision-making.

The second notion we term "decision-relevant analysis". As noted above, benchmark values usually make for very poor economics, but, used within the correct context, they can still support robust decision-making. For example, consider a local government officer who needs to make a decision about protecting a beach from erosion. Surveying the local community is expensive, but, for the purposes of argument, suppose the officer can access a study detailing work undertaken in Melbourne suggesting that the beach might be worth $1 million, based on the value of roughly comparable beaches in Melbourne. This estimate might have an error band around it which renders it useless as a valuation tool (or even an estimate of value at risk), but if the only way to protect the beach is to spend $50 million on off-shore reefs, then even this highly imperfect estimate of value (at risk) might be good enough to make a decision not to save the beach; it is "decision-relevant" information. The same would be true if the numbers were reversed.

The decision-relevant approach is useful because it allows local government officers to make use of scarce resources more efficiently. For example, an initial assessment, based on imperfect benchmarks could be used by the local government officer without further study or consultation with the community to make decisions on all the "obvious" cases; say those where the ratio between value at risk and costs of protection was either greater than five to one or less than one to five. For these assets, the benchmark is decision-relevant. For those that remain (between one-to-five and five-to-one), the officer can then consider more detailed assessments, which take into consideration local factors. For those where the benefits and costs are very closely aligned, the local government in question could devote yet more resources to detailed discussions with the community; at each level, the decision-relevant information changes. The benefit of this approach is in the resources that are saved; rather than doing detailed work on all assets in the community (or the ones that people say are most important), the local government in question can focus its resources on the ones where it is hardest for an outside observer using generalist information to come to the "correct" decision.

# 2 Region-Wide Assessment

The second part of the project involves developing an understanding of the overall resource cost of adaption within the region as a whole, rather than to design strategy. This does not mean the cost of "saving" every inch of coastline, but rather the cost, in general terms, of protecting those assets where the value at risk exceeds the cost of protection, and engaging in a strategic retreat elsewhere.

Since the work is being undertaken at a regional level, it involves a number of key abstractions and simplifications from what would be expected in a more detailed, micro-level assessment. The first such simplification is on the assets, which are classed into several classes and then a single, representative value is applied to all assets in a given class. The second key simplification is that the location of the assets is not considered. This means that we assess the merit of protecting each asset class in its own right, without considering whether a protection mechanism along the shoreline would protect different types of assets behind it. Finally, the investigation examines assets at four snapshots in time, rather than as a continuous series over time.

At the regional level, erosion is a far more pervasive issue than flooding; while around 800 hectares of residential land would be subject to an increase in flooding risk (from one in 500 to one in 100), a strip roughly 200 metres wide is at risk from erosion along the whole extent of the coastline. The value at risk of the affected assets along this section of coastline is approximately $1.2 billion. Of these, a little more than $1.1 billion of assets are worth saving, as a cost of around $100 million, giving a benefit cost ratio of approximately ten to one if the protective structures are built right now. This would rise if their timing were optimised, and the general findings are robust to several changes in assumptions detailed in the report.

A corollary of this finding is that around $100 million in assets are not worth saving. In land area terms, this equates to around 85 per cent of the affected region. In practice, where this farmland and/or nature reserve sits behind more valuable settled areas, the protection afforded to the settled areas will also affect the less valuable land (though not from incursion of salt-water flooding). However, in many instances, local farming communities will need to consider the value of protection very carefully, given its costs. This will form a key component of the community discussions that will follow our project.

The results of this part of the study are shown in Table 1and Table 2 overleaf.

Table 1 **Value at risk**

| | 2030 | | 2040 | | 2050 | | 2070 | | 2100 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area (ha) | VAR ($'000) | Area (ha) | VAR ($'000) | Area (ha) | VAR ($'000) | Area (ha) | VAR ($'000) | Area (ha) | VAR ($'000) | Area (ha) | VAR ($'000) |
| Community infrastructure | 21.8 | $117,924 | 5.9 | $23,876 | 10.0 | $29,823 | 27.7 | $45,435 | 28.1 | $18,517 | 93.5 | $235,575 |
| Residential land | 37.4 | $122,830 | 29.6 | $72,056 | 64.0 | $115,505 | 165.7 | $164,274 | 278.2 | $110,682 | 575.0 | $585,347 |
| Commercial land | 7.0 | $37,984 | 4.9 | $19,620 | 8.9 | $26,676 | 22.0 | $36,143 | 28.6 | $18,835 | 71.5 | $139,258 |
| Development land | 13.4 | $66,697 | 1.8 | $6,129 | 3.9 | $9,117 | 13.3 | $16,026 | 48.2 | $21,535 | 80.6 | $119,504 |
| Rural residential land | 0.1 | $18 | 0.0 | $6 | 0.2 | $16 | 3.4 | $193 | 13.2 | $289 | 16.9 | $523 |
| Rural and agricultural land | 89.6 | $7,301 | 31.3 | $1,702 | 74.9 | $2,914 | 275.8 | $5,844 | 486.4 | $3,595 | 958.0 | $21,356 |
| Parks, recreational & conservation areas and beaches | 1,901.5 | $62,615 | 193.3 | $4,712 | 264.1 | $5,150 | 467.9 | $6,226 | 583.1 | $2,820 | 3,409.8 | $81,523 |

Table 2 **Costs and protection decisions**

| | 2030 VAR ($'000) | Save? | 2040 VAR ($'000) | Save? | 2050 VAR ($'000) | Save? | 2070 VAR ($'000) | Save? | 2100 VAR ($'000) | Save? |
|---|---|---|---|---|---|---|---|---|---|---|
| Community infrastructure | $2,719 | Yes | $742 | Yes | $1,249 | Yes | $3,463 | Yes | $3,513 | Yes |
| Residential land | $4,678 | Yes | $3,704 | Yes | $8,004 | Yes | $20,714 | Yes | $34,778 | Yes |
| Commercial land | $876 | Yes | $610 | Yes | $1,118 | Yes | $2,755 | Yes | $3,573 | Yes |
| Development land | $1,671 | Yes | $231 | Yes | $490 | Yes | $1,666 | Yes | $6,020 | Yes |
| Rural residential land | $11 | Yes | $6 | No | $19 | No | $422 | No | $1,649 | No |
| Rural and agricultural land | $11,195 | No | $3,915 | No | $9,364 | No | $34,475 | No | $60,801 | No |
| Parks, recreational and conservation areas | $237,683 | No | $24,158 | No | $33,019 | No | $58,484 | No | $72,887 | No |

Sensitivity analysis within the context of the region-wide assessment show that the results are broadly robust to changes in several of the assumptions, including discount rate. In the case of changes to the discount rate, increasing it means that the number of assets worth protecting (now) shrinks; protection for those not affected until the end of the study period becomes less viable as discount rates increase. However, the results of the analysis above hold broadly true with discount rates up to ten per cent when one adopts a rolling 20-year (or so) horizon for responses; making responses around 20 years before the Phase One model suggests the relevant climate change effect is likely to occur.

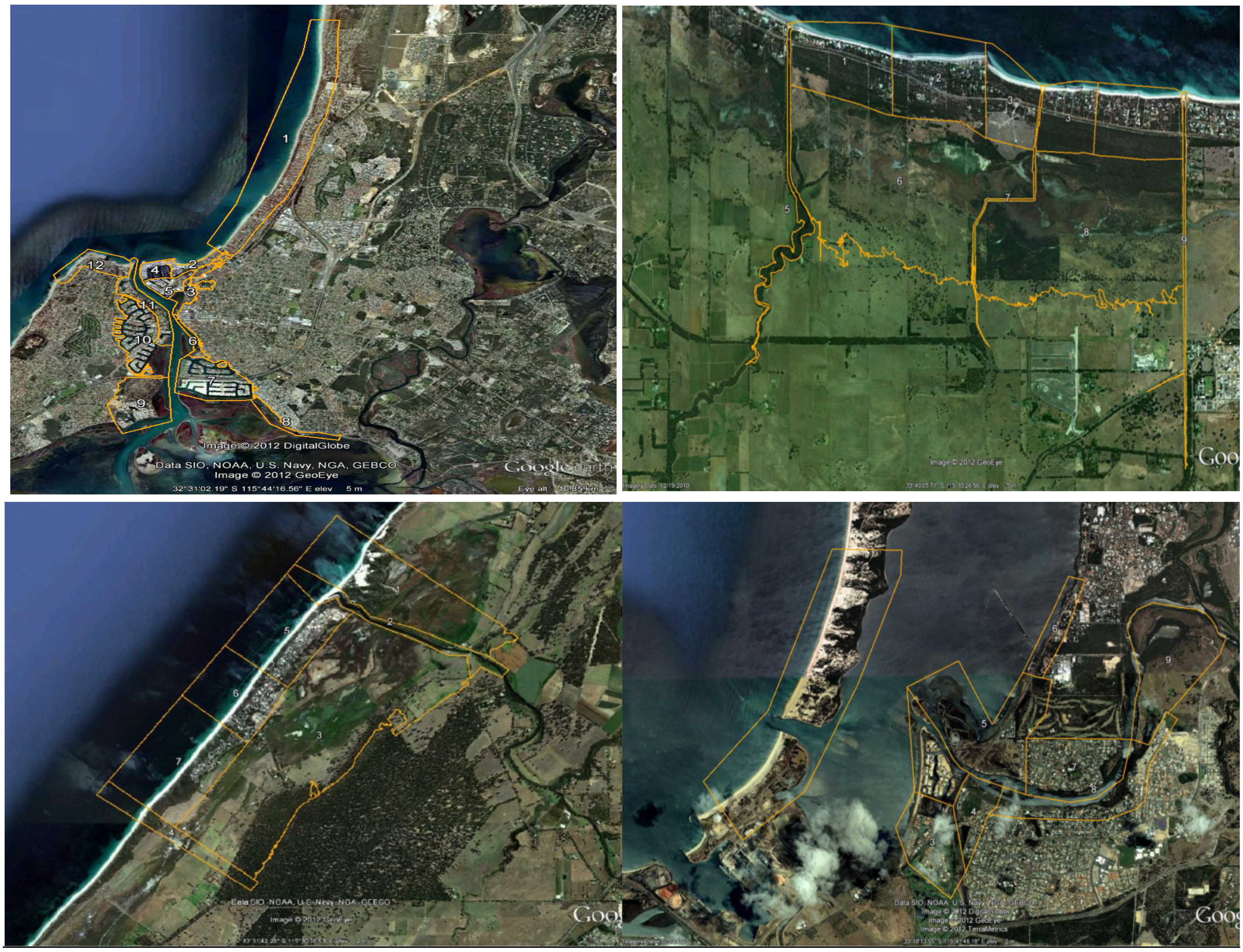
This suggests that timing of responses, and the decision-making around responses could be a key consideration for policymakers going forward. For example, a one-hundred year time horizon could be used for considering future land uses and a need to reserve particular strategic land that is currently unused. The same time horizon could be used for considering more detailed data collection to support future decision. That is, Phase One of the project could be run periodically, based on updated data, with the same 100-year time horizon, to highlight needs for more information in future as well as keeping track of predictions and their accuracy. A 20-year time horizon could be used to begin more detailed thinking about what kinds of measures to adopt (essentially repeating the work in this report in a more systematic manner) and to begin the process of examining environmental, heritage and other issues associated with protection that can be time consuming, but not overly costly. A ten-year time horizon could be used for work with the community on what ought to be done and how the community will fund and govern the process. A five year time horizon could be used to plan for and commit funds, and then the actual application of those funds would be based on the construction schedule of the relevant protection mechanism (if the protection mechanism was indeed physical). Staging the thinking process about climate change adaptation in a manner such as this is likely to reduce the overall costs relative to benefits substantially, as well as leading to much better decisions than are likely to occur from a knee-jerk reaction to a perceived crisis made in an environment of limited information about the extent of that crisis. The next stage of the process of climate change strategy formulation within the PNP community that begins once this report is complete and has been endorsed by the PNP partners can begin the process of thinking about different time horizons and ongoing processes, such as those outlined above.

# 3 Case Studies

The third part of the report is the four case studies, intended to inform strategy for the relevant local governments. Here again, there is a strong emphasis on the “how to” side, and a detailed description of methodology. Unlike the region-wide analysis, the case studies have a temporal (that is, effects occur on an annual basis) and a spatial element; we differentiate between locations, and consider assets together than would be protected together.

There are four case study areas; in Mandurah, Eaton-Australind, Peppermint Grove Beach and Siesta Park-Marybrook. The areas, and the different feasible adaptation measures, were chosen in conjunction with the PNP Senior Officers. The case study areas are shown in Figure 2.

Figure 2 **Case study areas and sub areas**

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Perhaps the key element in the case studies is how the analysis was undertaken, as the methodology, rather than the findings, is perhaps the key legacy of this report. In devising our methodology, we were motivated by two key aspects associated with adaptation to climate change:

- It is often not necessary to act immediately in response to climate change, and thus any methodology needs to be able to encapsulate the ability of decision-makers to wait before acting and, perhaps more importantly, to provide an input into the decision of when to invest.
- Climate change is subject to considerable uncertainty, and it is crucial that this uncertainty be brought to the centre of the analysis. If it is not, solutions might be optimised to a single "most likely" scenario, but not be robust to even small changes that will inevitably occur to projected scenarios in the future.

The "standard" way of considering investment in infrastructure in Australia (and elsewhere) is to consider the flow of benefits from an investment, in net present value terms, against its likely investment cost; a benefit cost assessment. However, such an approach is inadequate in the face of the two key aspects of climate change noted above, as it is unable to answer the question of when construction ought to occur, or to treat uncertainty in anything but a superficial way, through sensitivity analysis.

For this reason, we have made use of a real options framework, which is designed precisely with the two issues above in mind. Real options effectively answers the question "how should a decision maker choose her investment (and operation; an aspect not relevant here) options given all that is known at present about how the future might unfold?". By contrast, a benefit cost analysis answers the question "what return might a decision maker expect from an investment made at point in time x, given a single (or small collection of probability-weighted; something rarely done in practice) scenario for the future?". The outputs of a real options analysis are much richer than for a benefit cost analysis and include the optimal timing of investment, the value of that investment and an indication of the statistical confidence (that is, robustness) of the results. In practice, a real options analysis can also often favour solutions that are robust over a range of potential outcomes over solutions that are perfectly tailored to only one.

There are several ways in which a real options analysis can be done, and a considerable literature examining the equivalence between them. We make use of an approach by Longstaff & Schwarz (2001) which overcomes some technical issues with "classical" real-options analysis in terms of the number of sources of uncertainty that can be accommodated, and the complexity with which a real options approach is implemented. In practice, the approach follows these five steps for each option and asset in each case study area:

1. A climate change model is used to generate several thousand different future scenarios, which map out how climate change might affect the region over the coming century. The physical changes are then converted into scenarios for value at risk for each asset in each case study area over the same timeframe.
2. The Net Present Value (NPV) of a stream of benefits that (that is, improvements in value at risk) that occur from implementing a particular adaptation option for each asset in each case study area in each year for each scenario is compared with the stream of benefits (that is, value at risk) of doing nothing in each case. This is called the "NPV difference".
3. The real options model, recognising that uncertainty about the future exists at every point in time, uses information from all the scenarios to form an expectation of the NPV difference at each point in time for each scenario, based upon the NPV difference that is actually calculated for that point in time. It thus captures how a decision-maker might answer the question "where will climate change take us next?"
4. The real options model then compares the net benefit of acting (that is, NPV difference minus the cost of the option) in each time period in each scenario with the expectation of the net benefit of acting in the next time period. Through a process of backwards induction (from the last period to the first) it then shows all of the periods when it pays to act now for each scenario; when the current net benefit is greater than the expectation of the future net benefit. We choose as our optimum (in each scenario) the earliest of these cases.[1]
5. Finally, the model collects all of the optimum solutions (that is, one from each scenario) for each option into a histogram which shows when the optimal timing is given all the information available (the mean of the distribution, in most cases) and, from the shape of the histogram, the level of confidence in these conclusions. The value of the option is an average across all of the scenarios, once the value in each has been converted to the same form via discounting.

The five stage process outlined above is undertaken for each option for each asset in each case study area. It is also used for combinations of options, particularly where a particular solution involves a staged approach, to establish when the different stages ought to be undertaken. The results of this analysis are summarised overleaf.

[1] The methodology does not require that the earliest case be chosen. For a profit-making investment, for example, the maximum difference between current and expected future benefits could be used. By using this approach, we are assuming that local governments do not wish to act too early, but are risk averse, rather than benefit maximising, and would prefer to protect early rather than risk the assets under their stewardship. This assumption should be recalled when examining model results; the model can produce early intervention recommendations when the value of the asset is high and the cost of protection is low, and the results do not imply that action must be taken by the relevant date.

The results of the case studies are shown in Table 3 to Table 6, which show the options that are economically viable. Where no option is viable in that sub area, it is not shown. By viable, we mean that the options are chosen in at least some of the scenarios by the real options algorithm, at some year during the 100-year timeframe under analysis. Table 3 shows the capital cost of each option, its operating cost, the optimal year for implementing the option and the net benefit (the reduction in value at risk it provides minus the cost of the option) it produces. The final column shows the percentage of scenarios in which the option is viable (as defined above). This is an important checking mechanism for the robustness of results, as discussed below.

Table 3 (overleaf) presents the results for Mandurah. For the coastal areas, the model suggests that seawalls (staged) are the most appropriate solution. In reading the results, note that the optimal year and net benefit results are based on the scenarios where the option is viable (one minus the "let expire" percentage).[2] If the first stage of a staged process has only limited ability to protect from erosion because sea levels are rising too fast for it to be effective for long, this results in it being unviable in a large number of cases, and skews the results for the optimal timing and the net benefit. In these cases, the answer is to start with the second stage.

In the estuarine areas (all those except Sub Areas 1,2,4 and 12), relatively small-scale, localised solutions are preferred over region-wide solutions such as flood-gates across the estuary mouth on the basis of cost compared to value at risk saved. However, it should be noted that these larger structures would also protect other areas not included in the case study.

One aspect of interest not shown in Table 3 is Sub Area 10 (Port Mandurah Estate), where the least expensive option is to put flood-gates across the mouth of the canal estate. The value at risk in this area is not worth the $43 million required for flood gates, based on our analysis. However, if the residents of that area thought otherwise, this would appear to be a prima-facie case for a localised levy to fund this intervention. It should be noted, however, that the extent of the flooding is unlikely to result in houses being lost, but is rather likely to affect gardens, and structures such as jetties and boat moorings. In this context, the residents of this estate may prefer to wear the flood risk.

[2] The "let expire" cases are those scenarios where the model indicates a particular options will never be viable.

Table 3 **Mandurah viable options summary**

| | Option | Capital Cost | Operating Cost | Optimal Year | Net benefit | % let expire scenarios |
|---|---|---|---|---|---|---|
| Sub-Area 1 - Northern beaches | Large enclosing groynes - Small groynes (phase 1) | $10,000,000 | $100,000 | 12 | $35,755,000 | 25.70% |
| | Large enclosing groynes - Intermediary "T" groynes (phase 2) | $10,800,000 | $108,000 | 30 | $13,599,000 | 16.00% |
| | Large enclosing groynes - Offshore reef with 90 % gap (phase 3) | $8,300,000 | $83,000 | 38 | $10,552,000 | 6.00% |
| | Large enclosing groynes - Offshore reef with 75% gap (phase 4) | $12,100,000 | $121,000 | 57 | $1,674,000 | 80.00% |
| | Large enclosing groynes - Offshore reef with 60% gap (phase 5) | $12,100,000 | $121,000 | 57 | $1,674,000 | 80.00% |
| | **Total cost of groynes option, not staged*** | $66,100,000 | $708,000 | 8 | $28,511,000 | 55.00% |
| | Seawall - Small seawall (phase 1) | $4,600,000 | $46,000 | 23 | $4,979,000 | 92.20% |
| | Seawall - extension downwards of small seawall (phase 2) | $2,200,000 | $22,000 | 12 | $34,310,000 | 28.30% |
| | Seawall - Large seawall (phase 3) | $16,100,000 | $161,000 | 26 | $19,850,000 | 6.40% |
| | **Total costs of seawalls option, not staged** | $21,600,000 | $229,000 | 11 | $50,898,000 | 4.00% |
| Sub Area 2 - Seashells | Increase seawall to medium (phase 1) | $1,100,000 | $11,000 | 8 | $11,855,000 | 38.00% |
| | Increase seawall to large (phase 2) | $510,000 | $5,100 | 23 | $10,863,000 | 0.00% |
| | **Total costs of seawalls option, not staged** | $1,500,000 | $16,100 | 7 | $27,132,000 | 2.30% |
| Sub area 3 - CBD | Use roads as part of drainage system (Ormbsby Tce) | $200,000 | $2,000 | 49.5 | $1,127,000 | 0.00% |
| | Build flood levee (Ormsby Tce, Beam Rd & Mandurah Tce). Change structural requirements on houses to make flood-proof | $916,000 | $- | 68 | $437,000 | 0.00% |
| | Build flood levee (Ormsby Tce, Beam Rd & Mandurah Tce). Change foundations to make flood-proof (west of Ornsby Tce Levee & west of Man Tce Levee). | $756,000 | $- | 68 | $459,000 | 0.00% |
| | Seawall for coastal flooding (Mandurah CBD only) | $470,000 | $9,400 | 67 | $496,000 | 0.00% |
| | Improve drainage system to deal with flooding (Seashells - Beams, Shannon, Stewart, Ormsby, CBD - Hackett, Cooper, Mandurah, Peel, Rockford) | $1,230,000 | $12,300 | 53 | $893,000 | 0.00% |
| Sub area 4 - MOM | Raise and strengthen sea walls | $1,140,000 | $14,500 | 3.5 | $61,247,000 | 5.80% |
| Sub area 5 - Peninsula | Raise walk area | $110,000 | $- | | | |
| | Flood wall (raise existing walls) | $1,640,000 | $28,400 | 67 | $319,000 | 0.00% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sub area 7 - SE canal estate | Sea wall prior to building houses. Fill low land | $1,740,000 | $28,000 | 65 | $534,000 | 0.00% |
| Sub area 8 - Creery Wetland Foreshore | Strengthen embankment | $240,000 | $7,200 | 55 | $177,000 | 0.00% |
| | Add wall | $180,000 | $1,800 | 41 | $297,000 | 0.00% |
| Sub area 9 - SW canal estates | Sea wall prior to building houses / sea wall to prevent channel movement | $1,100,000 | $11,000 | 41 | $1,331,000 | 0.00% |
| Sub area 11 - Western Foreshore | Flood gates at Old Mandurah Bridge and Dawesville Channel (would also serve 6,7,10 & 11) | $2,600,000 | $- | 59 | $439,000 | 0.00% |
| | Flood gates at entrance to residential canal area | $1,600,000 | $16,000 | 56.5 | $617,000 | 0.00% |
| Sub area 12 - Halls Head | Large enclosing groynes - Small groynes (phase 1) | $1,600,000 | $16,000 | 8 | $1,291,000 | 85.70% |
| | Large enclosing groynes - Small groynes (phase 2) | $1,300,000 | $13,000 | 20.5 | $881,000 | 79.70% |
| | 1Large enclosing groynes - Intermediary "T" groynes (phase 3) | $2,400,000 | $24,000 | 18.5 | $1,285,000 | 62.30% |
| | 1Large enclosing groynes - Offshore reef with 50% gap (phase 4) | $7,900,000 | $79,000 | 14 | $1,226,000 | 96.10% |
| | **Total cost of groynes option, not staged** | $11,300,000 | $122,000 | 2.5 | $1,353,000 | 95.60% |
| | 2) Seawall - Small seawall (phase 1) | $1,100,000 | $11,000 | 10.5 | $753,000 | 93.50% |
| | 2) Seawall - Extension downwards of small seawall (phase 2) | $550,000 | $5,500 | 12 | $3,331,000 | 34.20% |
| | 2) Seawall – Large seawall (phase 3) | $2,800,000 | $28,000 | 25.5 | $1,713,000 | 20.40% |
| | **Total costs of seawalls option, not staged** | $4,100,000 | $44,500 | 5 | $5,615,000 | 12.50% |

*Note – includes stages not shown as they are unviable

The model results for Siesta Park-Marybrook are shown in Table 4.

Table 4 **Siesta Park-Marybrook viable options summary**

| Sub area | Option | Capital cost | Operating Cost | Optimal Year | Net benefit | % let expire scenarios |
|---|---|---|---|---|---|---|
| Sub area 1 - West of Siesta Park | Single large groyne | $4,000,000 | $40,000 | 4 | $5,639,000 | 13.00% |
| | Multiple smaller groynes | $2,000,000 | $20,000 | 4 | $7,844,000 | 7.80% |
| Sub area 2 - Siesta Park | Extend existing groyne into single large groyne | $3,600,000 | $36,000 | 15.5 | $5,940,000 | 10.50% |
| | Multiple smaller groynes | $1,900,000 | $19,000 | 15.5 | $7,122,000 | 3.90% |
| Sub area 3 - Locke Estate | Multiple smaller groynes | $2,500,000 | $25,000 | 37 | $652,000 | 56.40% |
| Sub area 4 - W. Buayanup | Single large groyne | $3,400,000 | $34,000 | 4 | $5,842,000 | 13.80% |
| | Multiple smaller groynes | $1,800,000 | $18,000 | 4 | $7,578,000 | 9.70% |
| Sub area 5 - Lennox Drain | put up gates to prevent storm surges and raise levees | $5,300,000 | $53,000 | 14 | $2,158,000 | 0.00% |
| Sub area 8 - E. Wetland | Pump fresh water in to create lakes | $13,700,000 | $137,000 | 1 | $51,967,000 | 0.00% |
| | Partition land to seal off low-lying areas and allow them to become salt-affected | $1,400,000 | $14,000 | 1 | $67,188,000 | 0.00% |

In Siesta Park-Marybrook, the four coastal areas have two potential solutions apiece, but both provide essentially the same service, and differ only in their costs and net benefits. For this reason, the less expensive options are preferred in each case.

Inland, the high cost of protection compared to the low value at risk generally means that protection is not warranted. Here, in Sub Area 8, much of the value that makes it worth protecting comes from development land in the South East corner (a proposed new residential estate and commercial properties), which could be protected by raising and filling at a cost of around $500,000. Since it is not yet developed, these costs would logically need to be paid by the developer to ensure efficient allocation of resources.

The viable options for Peppermint Grove Beach are shown in Table 5 (overleaf). The results are very similar to those for Siesta Park, with a recommendation to protect the settled areas, but with only half of the agricultural land being recommended for protection, as this plot of land has a lower-cost protection option. It is worth noting that Sub Area 3 could only be viably protected if the intervention in Sub Area 4 is also undertaken, as otherwise, seawater could still flood into the land.

Table 5 **Peppermint Grove Beach viable options summary**

| Sub area | Option | Capital cost | Operating Cost | Optimal Year | Net benefit | % let expire scenarios |
|---|---|---|---|---|---|---|
| Sub area 3 - Southern wetlands | Encourage dune growth in southern part to protect coast (dune fencing). Maintain dune buffer by building groynes (to pinch point south of study area). Raise access road to town. Subdivide into cells to prevent salt-water flow | $10,285,000 | $100,000 | 2 | $5,240,000 | 1.70% |
| Sub area 4 - Higgins Cut | Fill the channel to the beach | $780,000 | $- | 1 | $4,046,000 | 0.00% |
| Sub area 5 - North Pepp Grove | Build groynes and manage dunes | $2,032,760 | $20,328 | 5.5 | $17,474,000 | 7.50% |
| Sub area 6 - Central Pepp Grove | Build groynes and manage dunes | $1,649,432 | $16,494 | 5.5 | $14,030,000 | 5.80% |
| Sub area 7 - South Pepp Grove | Build groynes and manage dunes | $1,649,432 | $16,494 | 5.5 | $10,451,000 | 2.70% |

It is worth pointing out that, in both Peppermint Grove Beach and Siesta Park-Marybrook, we do not consider the value of the land lost to either a freshwater lake or to salt incursion (once levees are in place), as it is unclear at this early, desktop stage of the analysis, where the levees would go. Once this further investigation is undertaken, it may mean that the areas (in both case studies) which the model indicates ought to be protected are no longer favoured, as benefits would be reduced.

Table 6 provides a summary of the viable options at Eaton-Australind.

Table 6 **Eaton-Australind viable options summary**

| | Option | Capital cost | Operating Cost | Optimal Year | Net benefit | % let expire scenarios |
|---|---|---|---|---|---|---|
| Sub area 3 - Sth Pelican Point | Crest wall. Rock Revetment surrounding Pelican Point. Large seawall around exposed section of Pelican Point | $4,500,000 | $55,000 | 66 | $70,000 | 0.00% |
| Sub area 4 - Sporting Precinct | Zone to require future buildings to be flood-proof (assumed potential for 22 lots @ $40,000 per lot) | $880,000 | $- | 1 | $2,221,000 | 0.00% |
| | Fill oval to raise its level | $900,000 | $- | 1 | $5,258,000 | 0.00% |
| | Protect oval with a levee | $240,000 | $- | 1 | $4,415,000 | 0.00% |
| Sub area 5 - Bridge & Commercial | Raise the road and bridge and use road embankment as a levee. Armour the coastal strip (revetment). Large seawall along coastal strip. | $5,310,000 | $18,100 | 9 | $918,000 | 0.00% |

Eaton-Australind presents particularly challenging results because so few of the options are viable. This suggests considerable work will need to be done with local communities to determine how best to address climate change. It is worth noting, however, that the more populated areas (Sub Areas 6,7 and 8) all slop upwards from the river and estuary, and so the number of houses actually at risk from flooding is relatively few. This is not true of Pelican Point, which is relatively low-lying. However, most of the value in this area is in private housing which, like Port Mandurah, presents a prima-facie case for discussing with residents the option of a localised levy to pay for the protection of their homes.

The model results also present important findings from the perspective of expanding Eaton to the east. Protecting this land from flooding would cost around $200 million, which is not viable given its current land use. It is imperative that the full costs of any new development be paid by a developer, not only to prevent future liabilities for the relevant local government, but also to ensure that land resources are allocated efficiently amongst their various possible uses. In this instance, allowing the expansion of Eaton eastwards without these costs being part of the equation would be poor policy.

A final point is worth noting. The climate modelling suggests that the Leschenault Peninsula may be eroded away, but only at the very end of the study period. For this reason, the region is affected only by flooding during our study period. However, if during the intervening century, sea levels rise more quickly than the model suggests, clearly the impacts on Eaton Australind will be much more profound.

# 4 Conclusions and next steps

In the report, we discuss several next steps in the process of implementing the findings of our study. One key initial step will be to review the data which have formed an input into Phase One of the overall project (summarised in our report) as there are several instances along the coastline where it would appear that the available data poorly reflect the situation on the ground. In terms of processes associated with adaptation, the most crucial next step is discussions with the affected local communities to ascertain how their views differ from the analysis in our report, and to answer the key question of who pays for the different interventions. The latter is a question of resource allocation within a community, for which economics (with the exception of the economic efficiency arguments above which support private property owners paying for the protection of their own property) does not have clear answers, particularly when it comes to assets used by the whole community. Differing views from those outlined in our report should also be brought into the decision-making process, because, as we note at the outset, economics is not the only tool which ought to be used in making adaptation decisions.

A corollary of the above is the need for institution-building. The current project has involved a steep learning curve for the consultants and the PNP partners, and it is likely that the challenges of the next stages involving local communities will increase the gradient of these curves. During the course of our work, we have spoken with stakeholders from outside the region, including local government officers from other coastal regions facing similar issues, and it is clear that there is no ready wellspring of knowledge to draw from in this respect. This report alone cannot act as that wellspring, within the PNP region or outside it, and for this reason, we would urge that the PNP Partners not stop with this report, but devise an institutional structure, however modest, such that the learnings from the process can be maintained, and promulgated to the wider community.