Infometrics

Real Options Analysis of Strategies to Manage Coastal Hazard Risks: Northern Units B-E

for Hawke's Bay Regional Council

November 2017

Contents

1. Summary

The Hawke's Bay Regional Council (HBRC), Napier City Council (NCC) and Hastings District Council (HDC) have convened a Technical Advisory Group (TAG) to develop strategies for adapting to coastal hazard risks caused by climate change.

Infometrics was requested by the TAG to look at whether the use of Real Options Analysis would provide worthwhile insight into the development of those strategies. Real Options Analysis is an expanded version of cost-benefit analysis that assesses whether there is value in waiting for more information before an expensive and possibly irreversible investment is undertaken, and whether an alternative investment might suffice in the meantime.

In the case of an increasing risk of coastal inundation for example, is it better for a community to retreat inland in the very near future (which is effective, but expensive), or is it better to construct some form of coastal defence that provides protection from most inundation scenarios for the next 20-30 years, and perhaps for much longer if the effects of climate change end up being less severe than anticipated?

The ROA provides the councils with a costing assessment that enables decision making that can be flexibly implemented over time as the climate changes and as its impacts increase. This ensures that decisions taken today do not create further risks which are costly to reverse in the future, and that a range of options have been assessed for their ability to meet community objectives over time.

The ROA complements Multi-Criteria Decision Analysis and the application of the Dynamic Adaptive Policy Pathways framework.

Broadly, the results demonstrate that a flexible investment strategy, enabling a change of course in the future, is more likely to deliver a lower cost outcome than pursuing a single option. The main results for each unit are presented below.

Our report on Unit L, Clifton to which the reader is referred, provides detail on the approach. Here we summarise the results for the northern units B-E. The protection options are:

- Q: Status quo
- R: Renourishment of the beach
- C: Control structures such as groynes and breakwaters, with renourishment
- S: Sea wall
- M: Managed retreat
- L: Retreat the Line
- B: Stopbanks
- F: Flood gates

Unit D: Westshore

For Unit D:Westshore, the ROA reveals that the choice between (R+C+C) and (C+C+C) is very finely balanced, depending critically on discount rates and the costs of protection. The MCDA results suggest that (R+C+C) has the edge in terms of value for money, but the pure MCDA scores favour eventually moving to managed retreat; either (R+C+M) or (R+M+M). However, there is a price attached to this extra security.

Unit C: Bayview and Unit B: Whirinaki

The results for Bayview and Whirinaki are very similar with the main difference being that the probabilities of (T&T scenario) climate change that are required to justify taking any defensive action are much lower for Whirinaki, although this difference is largely academic as in both cases all pathways begin with retaining the status quo (perhaps with beach renourishment) over the short term.

For both areas the ROA financial analysis generally favours (Q+C+C) just ahead of (Q+S+S). Although it is worth stressing that no decision on C or S is likely to be required for a few decades, the MCDA results tend to show that communities prefer control structures to sea walls.

Unit E: Pandora

For Pandora the (Q+B+B) has the least cost under ROA, although (B+B+B) is not far behind. The latter, however, lacks flexibility and also has a relatively low MCDA score – (B+B+M) ranks highest, but again lacks flexibility. Hence the best option in the short term is to retain the status quo, with stopbanks being the most likely choice in the medium term, given current knowledge.

Unit E: Ahuriri

The ROA results show that the least cost pathways are (Q+S+S) and (Q+C+S). The MCDA results support (Q+S+S) on the basis of value for money although (Q+S+M) has a slightly higher MCDA score. These two pathways differ only in the long term between a sea wall or managed retreat so no choice is required at this stage. However, given that the extended pathways demonstrate a case for (Q+C+S), a re-evaluation of control structures and a sea wall should be undertaken in the medium term.

A stand-alone summary page for all of the southern units follows.

Summary of Results

Summary of ROA Results for Northern Units

	Least expected cost	Highest MCDA	Best value for money	Most flexible	Total cost premium
Unit B: Whirinaki	Q+C+C	Q/R+C+S	Q+S+S	Q+C+C / Q/R+C+S	na $4.5m
Unit C: Bayview	Q+C+C	Q/R+C+M	Q+S+S	Q+C+C / Q+S+S	na $1.0m
Unit D: Westshore	R+C+C (C+C+C)	R+M+M	R+C+C	R+C+C / R+C+M	na $28m
Unit E: Pandora	Q+B+B	B+B+M	B+B+B	Q+B+B / Q+B+M	na $3.3m
Unit E: Ahuriri	Q+S+S	Q+S+M	Q+S+S	Q+S+S/ Q+C+S	na $0.4m

Q: Status quo, R: Renourishment of the beach, C: Control structures with renourishment, S: Sea wall, M: Managed retreat, L: Retreat the Line, B: Stopbanks

Notes

1. All future values are discounted (base rate is 3%). Investment costs for protection options use Tonkin & Taylor's 'medium' estimates. The values of assets lost under retreat options are treated as protection costs. There is no allowance for the possibility that assets might be replaced with cheaper structures. All pathways provide protection up to at least a 1% AEP scenario.

2. If there is no climate change adverse events that cause damage would be rare, so we assume that the 0.5% AEP scenario applies. If there is climate change, but no investment in protection, losses would be frequent, so we take the sum of the 0.5%, 1% and 10% AEP scenarios. Although both situations are unlikely they are useful for analytical purposes.

3. The least cost options may change under different assumptions about discount rates, values of potentially lost assets, protection costs or climate scenarios. In general the conclusion are robust to changes in assumptions. although a lower discount rate (which implies greater weight on the welfare of future generations) tends to strengthen the case for moving to managed retreat sooner rather than later. Owing to a lack of data we have not considered climate change scenarios other than the one used by Tonkin & Taylor.

4. Although for analytical purposes we assume review dates and transition periods in 2040-45 and 2070-75, in practice these dates may change. Review dates or trigger events (such as a given change in mean sea level) should be set in advance.

5. Finally we stress that our analysis is based purely on economic costs and avoided losses. Other than though the MCDA results it does not consider the social, cultural or environmental aspects of coastal hazard risks associated with climate change.

2. Unit D: Westshore

Fixed Pathways

We look first at the six pre-determined pathways established by the TAG. The question of interest is under what probability of climate change (T&T scenario) occurring is it better to do something rather than nothing. Table 1 shows the cut-off probabilities and the discounted investment costs plus residual expected losses.

Table 1: Pathway Cut-off Probabilities

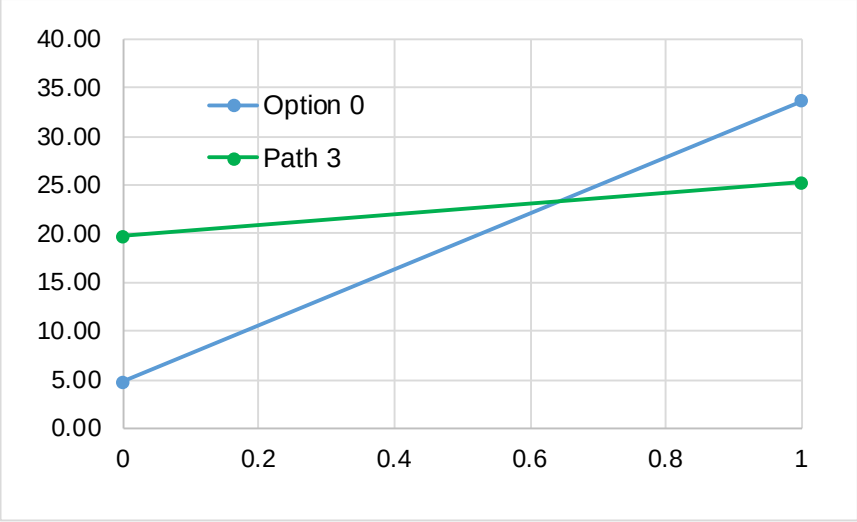
Pathway		Cut-off Probability	PV(cost +loss) $m
1	R+M+M	>100%	91.6
2	R+C+M	>100%	53.2
3	R+C+C	64.1%	25.2
4	R+C+S	79.7%	28.9
5	C+C+S	80.0%	29.0
6	S+S+S	89.6%	31.2

The four protection options are:

1. Renourishment of the beach (denote this as R)
2. Control structures such as groynes and breakwaters, with renourishment (C)
3. Sea wall (S)
4. Managed retreat (M)

Doing nothing (strictly speaking, existing measures would presumably continue to apply to deal with historic risks) is denoted as Option 0 in Figure 1, the blue line. If the probability of (T&T scenario) climate change is around 64% or more Path 3 (the green line) is preferred. Path 3 is closely followed by Path 4 which differs only in the long term when the choice is between options C and S.

Figure 1: Path 3 versus Do Nothing



Flexible Pathways

With the four generic protection options there are more than just six pathways or permutations although some are clearly silly. We look at 10 additional plausible pathways, as listed in Table 2. They are numbered 7-16. A suffix (T) indicates a transition cost when moving between options.

Table 2: Initial and Additional Pathways for Westshore

Option	ST	MT	LT	Discounted Investment Cost	Discounted Cost + Loss	End state	Cut-off probability cf end state
1	R	M	M	90.5	91.6	M	>100%
2	R	C	M	50.4	53.2	M	>100%
3	R	C	C	19.7	25.2	C	No soln
4	R	C	S	23.3	28.9	S	No soln
5	C	C	S	23.4	29.0	S	No soln
6	S	S	S	25.7	31.2	S	NA
7	R	S(T)	M	53.9	56.7	M	>100%
8	R	S(T)	S	24.4	29.9	S	No soln
9	C	C	C	19.8	25.3	C	NA
10	C	C	M	50.4	53.2	M	>100%
11	C	S(T)	S	29.1	34.6	S	>100%
12	C	S(T)	M	58.6	61.4	M	>100%
13	C	M	(M)	95.2	96.2	M	>100%
14	S	S	M	55.2	58.0	M	>100%
15	S	M	(M)	101.7	102.7	M	>100%
16	M	(M)	(M)	167.5	167.5	M	NA

Even with the expanded set of pathways Path 3 is still the least cost choice although Path 9 (C+C+C) is within $0.1m. Path 3 which begins with renourishment has a cheaper initial cost, but higher ongoing costs, while Path 9 begins with (and remains with) control structures which are more expensive initially, but have lower ongoing costs.

Some other interesting results that emerge from the ROA of the expanded set are:

- Of all the pathways that end in M, all are preferred to adopting M immediately for any valid probability of (T&T scenario) climate change.
- All of the pathways that end in a sea wall except Path 11 are lower cost than going straight to sea walls (Path 6).
- However, all pathways that end in S or M are inferior to those ending in C; namely Paths 3 and 9.

In summary then, if any action is taken (justified by a probability of T&T scenario climate change above 64%) the choice between Paths 3 and 9 is too close to call. Hence we look to additional analysis to arrive at a preferred choice.

Sensitivity Tests

The list of potential sensitivity tests is much larger than we can realistically expect to examine. Based on the results above and on the more comprehensive sensitivity tests examined for other units, we look at two alternative discount rates (1.5% and 6%) and at Tonkin & Taylor's 'high' and 'low' estimates for the costs of protection.

We also evaluate adopting managed retreat (M) after 2120 on all pathways that do not already incorporate it, to allow for the possibility that in the very long term retreat may be the only viable option. The result are summarised in Table 3.

Table 3: Sensitivity Tests

	Pathway Choice		Cut-off v Do Nothing	
	1st	2nd	1st	2nd
Base Case	3	9	64.1%	64.5%
Discount rate 6.0%	Do nothing	3	--	>100%
Discount rate 1.5%	9	3	23.5%	27.6%
High investment costs	3	9	92.4%	>100%
Low investment costs	9	3	28.1%	35.9%
Retreat after 2120	3	9	95.0%	95.3%

With a 6% discount rate the best choice is to do nothing. So little weight is placed on future losses (or indeed future generations) that the largely upfront costs of protection are not justified. If this is unlikely to be acceptable to the community the next best choice, at an additional expected cost of $4.6m is Path 3 (R+C+C); essentially doing as little as possible.

With a 1.5% discount rate the preferred order in the base case swaps around. The option with the lower upfront costs (Path 3) is no longer so attractive. The difference in discounted total expected costs is $2.4m in favour of Path 9. For both pathways the probabilities of (T&T scenario) climate change required to justify taking protective action are much lower. More weight on future losses lowers the probability (of these losses occurring) that is required to justify taking action.

The 'high' estimates for the costs of protection have a larger impact on the upfront costs of control structures than on the upfront costs of renourishment, making Path 3 the best choice. Its cost advantage over Path 9 is $2.0m. More interesting perhaps is what happens to the cut-off probabilities. Even for Path 3 the probability is over 90%, implying that unless one is almost certain that (T&T scenario) climate change will occur, it is better to do nothing – at least in the interim until the next review date.

Unsurprisingly if the 'low' estimates for protection costs prevail Path 9 becomes more attractive with a cost advantage over Path 3 of $1.5m. And of course much lower probabilities of (T&T scenario) climate change are required to justify either of them.

Assuming managed retreat (M) in 2120 on paths 3-6, 8, 9, and 11 does not change the relative attractiveness of paths 3 and 9 over the other pathways. Although each is more expensive, the increment in (discounted) cost is not enough to alter the rankings.

On balance then the sensitivity tests do not help much in choosing between Paths 3 and 9, although they do confirm that none of the other pathways are preferred – at least not within the bounds of these sensitivity tests.

Value for Money

Table 4 takes the MCDA scores for the original six pathways and divides them into the investment costs to produce a measure of 'value for money'. The pathway with the lowest investment cost per MCDA point is Path 3, even though it has one of the lowest MCDA scores. In contrast the two pathways with the highest MCDA scores have the worst value for money.

Table 4: Value for Money

Pathway		MCDA Score*	Discounted Invest Cost ($m)	VFM ($'000/point)
1	R+M+M	65	90.5	1392
2	R+C+M	60	50.4	839
3	R+C+C	51	19.7	387
4	R+C+S	54	23.3	432
5	C+C+S	51	23.4	459
6	S+S+S	47	25.7	546

* These scores are provisional

This degree of inconsistency between the MCDA results and the ROA results is unusual. It may suggest that the community values the greater certainty of protection that eventual managed retreat provides. Whether it is worth the extra $30m (for Path 2) or $70m (for Path 1) is a question for the community to answer.

One safe inference, however, is that beginning with renourishment is common to Paths 1, 2 and 3, so that is clearly the best initial choice, retaining the flexibility to pursue options C and/or M at a later date.

The only slight complication is that Path 9 (C+C+C) was not considered in the MCDA selection so its value for money is unknown. Still we can infer from Paths 4 and 5 which differ only with regard to their short term configuration, that beginning with C produces a lower score than beginning with R. It seems likely therefore that Path 9 would have a lower MCDA score than Path 3. Accordingly starting with renourishment is still preferred.

Summary

The ROA reveals that the choice between Path 3 (R+C+C) and Path 9 (C+C+C) is very finely balanced, depending critically on discount rates and the costs of protection. The MCDA results suggest that Path 3 has the edge in terms of value for money, but the pure MCDA scores favour eventually moving to managed retreat. Fortunately a choice on the end option is not required at this stage. With relative costs being very close, there is no trade-off between cost and flexibility.

3. Unit C: Bayview

Fixed Pathways

Six exogenous pathways were established by the TAG. The question of interest is under what probability of climate change (T&T scenario) occurring is it better to adopt each pathway rather than doing nothing. Table 5 shows the cut-off probabilities and the discounted investment costs plus residual expected losses.

Table 5: Pathway Cut-off Probabilities

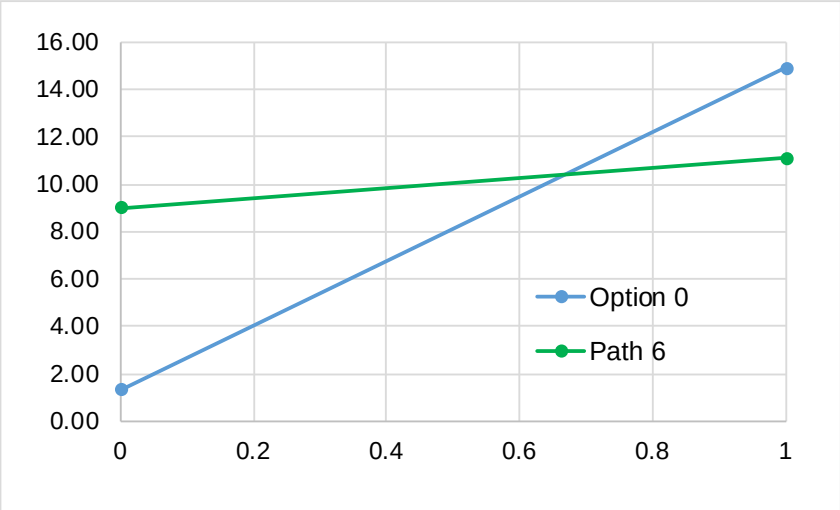
Pathway		Cut-off Probability	PV(cost +loss) $m
1	Q+M+M	>100%	21.34
2	Q/R+C+M	>100%	19.06
3	Q/R+C+C	80.7%	12.70
4	Q/R+C+S	98.0%	14.68
5	Q+S+M	>100%	17.32
6	Q+S+S	66.8%	11.10

The five protection options are:

1. Status quo (denote this as Q)
2. Renourishment of the beach (R)
3. Control structures such as groynes and breakwaters, with renourishment (C)
4. Sea wall (S)
5. Managed retreat (M)

Bayview is unusual as in the short run until around 2045 the status quo (Q) prevails or it is accompanied by minor beach renourishment. In effect the default Option 0 (doing nothing) and Path 6 are the same thing until 2045. So no choice is required at this stage. This renders the cut-off probability for Path 6 of 66.8% redundant. Accordingly Figure 2 is also superfluous to current decision making, but one could re-interpret it as applying to 2040-45 if current relative costs and benefits prevail.

Figure 2: Path 6 versus Do Nothing



Flexible Pathways

With the five generic protection options there are various other pathways, not all of which are plausible. We look at seven others, listed in Table 6. They are numbered 7-13. A suffix (2) indicates that a second period cost has been brought forward.

Table 6: Initial and Additional Pathways for Bayview

Option	ST	MT	LT	Discounted Investment Cost	Discounted Cost + Loss	End state	Cut-off probability cf end state
1	Q	M	M	20.82	21.34	M	>100%
2	Q/R	C	M	17.92	19.06	M	>100%
3	Q/R	C	C	10.58	12.70	C	No soln
4	Q/R	C	S	12.57	14.68	S	No soln
5	QC	S	M	16.17	17.32	M	>100%
6	Q	S	S	8.99	11.10	S	NA
7	Q/R	S	M	18.73	19.87	M	>100%
8	Q/R	S	S	11.54	13.66	S	No Soln
9	Q	C	C	8.03	10.14	C	NA
10	Q	C	M	15.37	16.51	M	>100%
11	S(2)	S	M	25.03	26.17	M	>100%
12	S(2)	M	M	36.44	36.95	M	>100%
13	M	M	M	40.19	40.19	M	NA

With the expanded set of pathways Path 9 becomes the least cost choice, with Path 6 now second lowest. Path 9 needs a cut-off probability of (T&T scenario) climate change of 58.4% to justify it. It involves moving to option C in the medium term whereas Path 6 involves moving to option S, so they are fundamentally different approaches. Transitioning from one to the other as in Path 4 is more expensive.

Some other interesting results that emerge from the ROA of the expanded set are:

- Of all the pathways that end in M, all are preferred to adopting M immediately for any valid probability of (T&T scenario) climate change.

- Of the three pathways that end in a sea wall, the preferred one is Path 6.

Sensitivity Tests

The list of potential sensitivity tests is much larger than we can realistically expect to examine. Based on the results above and on the more comprehensive sensitivity tests for other units, we look at two alternative discount rates (1.5% and 6%) and at Tonkin & Taylor's 'high' and 'low' estimates for the costs of protection. We also look at imposing managed retreat (M) after 2120 on all pathways that do not already incorporate it, to allow for the possibility that in the very long term retreat may be the only viable option. The result are summarised in Table 7.

With a 6% discount rate the best choice is still Path 9 (Q+C+C), but it requires a higher probability of (T&T scenario) climate change to be justified. Indeed it is almost 90% so unsurprisingly the next cheapest option is to do doing nothing.

With a 1.5% discount rate the base order of preference is unchanged, but for both pathways the probabilities of (T&T scenario) climate change required to justify taking protective action are much lower. More weight on future losses lowers the probability (of these losses occurring) that is required to justify taking action.

Table 7: Sensitivity Tests

	Pathway Choice		Cut-off v Do Nothing	
	1st	2nd	1st	2nd
Base Case	9	6	58.4%	66.8%
Discount rate 6.0%	9	Do nothing	89.6%	--
Discount rate 1.5%	9	6	36.8%	37.6%
High investment costs	6	9	88.2%	92.9%
Low investment costs	9	3	24.0%	35.8%
Retreat after 2120	9	6	74.6%	83.0%

The 'high' estimates for the costs of protection reverse the preference order, with (Q+S+S) being preferred to (Q+C+C). If the 'low' estimates for protection costs prevail Path 9 is still preferred, but Path 3 (Q/R+C+C) is next cheapest. And of course much lower probabilities of (T&T scenario) climate change are required to justify either of them.

Imposing managed retreat (M) in 2120 on paths 3, 4, 6, 8, and 9 does not change the relative attractiveness of paths 6 and 9 over the other pathways. Although each is more expensive, the increment in (discounted) cost is too small to alter the rankings.

On balance the sensitivity tests confirm that Path 9 (if it is possible) is likely to be the least cost choice, but the fundamental conflict between adopting control structures (C) or a sea wall (S) in the medium term is unresolved. Fortunately both Paths 6 and 9 begin with the status quo (Q or Q/R) so a decision can be deferred.

Value for Money

Table 8 takes the MCDA scores for the original six pathways and divides them into the investment costs to produce a measure of 'value for money'.

Table 8 Value for Money

Pathway		MCDA Score	Discounted Invest Cost ($m)	VFM ($'000/point)
1	Q+M+M	62	20.82	336
2	Q/R+C+M	64	17.92	280
3	Q/R+C+C	51	10.58	207
4	Q/R+C+S	57	12.57	220
5	Q+S+M	60	16.17	270
6	Q+S+S	48	8.99	187

The pathway with the lowest investment cost per MCDA point is Path 6, even though it has the lowest MCDA score. As for other areas exposed to coastal hazards there seems to be strong community support for eventual managed retreat (Paths 1, 2 and 5), but their expected discounted cost is around twice as much as Path 6. Unfortunately Path 9 was not part of the initial set of pathways and hence has no MCDA score, but we can probably infer that it would be very similar to that for Path 3.

As Path 2 has the highest MCDA score and Path 3 has the second best VFM, we would infer that on balance building control structures in the medium term (after 2040) has a slight edge over building a sea wall. Nonetheless, remaining with the status quo, with or without beach renourishment, is the best strategy for the short term. Come 2040 the options should be re-evaluated.

Summary

The ROA reveals that the eventual (after 2040) choice between building control structures or a sea wall generally favours the former. The MCDA results support this inference, although pathways that end in managed retreat receive a higher ranking when cost is not considered. Fortunately no decision on control structures or a sea wall is required – indeed it is not advised – for a few decades, or until some pre-determined trigger point (such as the amount of sea level rise) is reached.

4. Unit B: Whirinaki

Fixed Pathways

We start by looking at the six pre-determined pathways established by the TAG. The question of interest is under what probability of climate change (T&T scenario) occurring is it better to adopt each pathway rather than doing nothing. Table 9 shows the cut-off probabilities and the discounted investment costs plus residual expected losses.

Table 9: Pathway Cut-off Probabilities

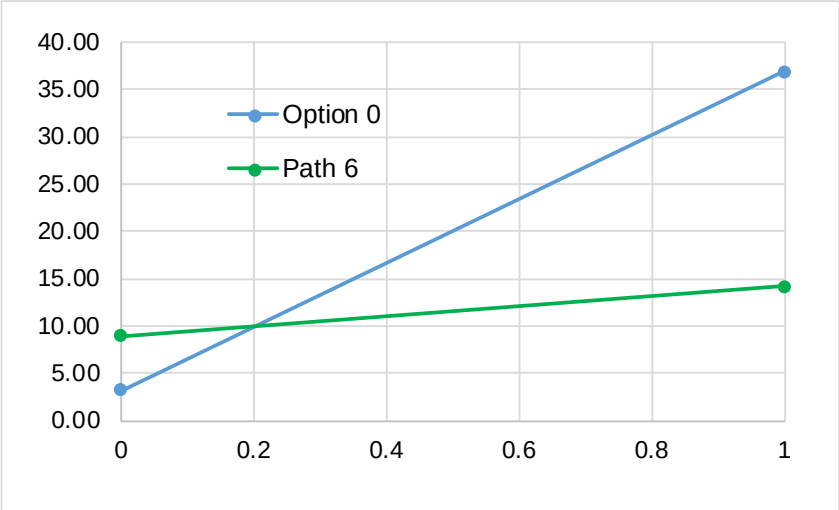
Pathway		Cut-off Probability	PV(cost +loss) $m
1	Q+M+M	85.5%	32.29
2	Q/R+C+M	61.7%	25.39
3	Q/R+C+C	25.8%	15.76
4	Q/R+C+S	32.8%	17.74
5	Q+S+M	55.9%	23.64
6	Q+S+S	20.2%	14.16

The five protection options are:

1. Status quo (denote this as Q)
2. Renourishment of the beach (R)
3. Control structures such as groynes and breakwaters, with renourishment (C)
4. Sea wall (S)
5. Managed retreat (M)

The six pathways for Whirinaki are the same as for Bayview, but all require a much lower probability of (T&T scenario) climate change to be preferred to doing nothing – noting that all pathways are effectively the same as doing nothing until 2040. Figure 3 illustrates, but it is redundant until 2040, and even then only if current relative costs and benefits still apply.

Figure 3: Pathway 6 versus Do Nothing



Flexible Pathways

With the five generic protection options there are various other pathways, not all of which are plausible. We look at seven others, listed in Table 10. They are numbered 7-13. A suffix (2) indicates that a second period cost has been brought forward.

Table 10: Initial and Additional Pathways for Whirinaki

Option	ST	MT	LT	Discounted Investment Cost	Discounted Cost + Loss	End state	Cut-off probability cf end state
1	Q	M	M	30.39	32.29	M	>100%
2	Q/R	C	M	21.80	25.39	M	>100%
3	Q/R	C	C	10.58	15.76	C	No soln
4	Q/R	C	S	12.57	17.74	S	No soln
5	QC	S	M	20.05	23.64	M	>100%
6	Q	S	S	8.99	14.16	S	NA
7	Q/R	S	M	22.81	26.19	M	>100%
8	Q/R	S	S	11.54	16.72	S	No Soln
9	Q	C	C	8.03	13.20	C	NA
10	Q	C	M	19.25	22.83	M	>100%
11	S(2)	S	M	28.91	32.50	M	>100%
12	S(2)	M	M	45.98	47.88	M	>100%
13	M	M	M	58.93	58.93	M	NA

Again echoing Bayview, under the expanded set of pathways Path 9 becomes the least cost choice with a cost advantage over Path 6 of $1m.

Some other results that emerge from the ROA of the expanded set are:

- Of all the pathways that end in M, all are preferred to adopting M immediately for any valid probability of (T&T scenario) climate change.
- Of the three pathways that end in a sea wall, the preferred one is Path 6.

Sensitivity Tests

Table 11 presents some selected sensitivity tests, covering two alternative discount rates (1.5% and 6%), Tonkin & Taylor's 'high' and 'low' estimates for the costs of protection, and imposing managed retreat (M) after 2120 on all pathways that do not already incorporate it. This allows for the possibility that in the very long term retreat may be the only viable option.

The preference order is not sensitive to the discount rate (for values between 1.5% and 6.9%), although the magnitude of the cost difference between Paths 9 and 6 is negligible (less than $0.2m) when the discount rate is 1.5%.

The order remains unchanged under the high investment cost scenario, but under the low investment cost scenario Path 3 (Q/R+C+C) has the second lowest expected cost. This also occurs for Bayview.

Imposing managed retreat (M) in 2120 on paths 3, 4, 6, 8, and 9 does not change the relative attractiveness of paths 6 and 9 over the other pathways. Although each is more expensive, the increment in (discounted) cost is too small to alter the rankings.

Table 11: Sensitivity Tests

	Pathway Choice		Cut-off v Do Nothing	
	1st	2nd	1st	2nd
Base Case	9	6	16.8%	20.2%
Discount rate 6.0%	9	6	21.1%	28.4%
Discount rate 1.5%	9	6	11.6%	11.2%
High investment costs	9	6	38.7%	51.7%
Low investment costs	9	3	8.0%	13.4%
Retreat after 2120	9	6	26.4%	29.8%

The ROA comes out strongly in favour of Path 9 (Q+C+C) from a cost perspective, but the second lowest cost pathway, Path 6 (Q+S+S) is fundamentally different beyond the short term, implying limited flexibility unless the more expensive Path 4 (Q/R+C+S) is considered. Can the MCDA results help choose between them?

Value for Money

Table 12 takes the MCDA scores for the original six pathways and divides them into the investment costs to produce a measure of 'value for money'.

Table 12 Value for Money

Pathway		MCDA Score	Discounted Invest Cost ($m)	VFM ($'000/point)
1	Q+M+M	59	30.39	515
2	Q/R+C+M	60	21.80	363
3	Q/R+C+C	56	10.58	189
4	Q/R+C+S	62	12.57	203
5	Q+S+M	59	20.05	340
6	Q+S+S	48	8.99	163

The pathway with the lowest investment cost per MCDA point is Path 6, with Path 3 not far behind, even though these two pathways have the lowest MCDA scores – the same as occurs for Bayview. Whereas for Bayview, however, the options that end with managed retreat have the highest MCDA score, for Whirinaki Path 4 ranks highest. Its VFM is also relatively good.

There seems to be a community preference for adopting control structures in the medium term, although that preference switches to a sea wall or retreat in the long term. Balancing MCDA scores, flexibility and cost suggests that Path 3 (from the original six) is the best strategy at this stage.

Summary

The ROA reveals that eventually the choice is between building control structures or a sea wall, with the former dominating in most scenarios. The MCDA results support this inference, even if a sea wall is ultimately selected. As for Bayview though, it is recommended that no decision on control structures or sea walls is made for a few decades, or until some pre-determined trigger point (such as the amount of sea level rise) is reached.

5. Unit E: Ahuriri

Fixed Pathways

We look first at the six initial pathways established by the TAG. Although Path 6 has the lowest cost, its margin over Path 4 is not great. There is a degree of trade-off – incurring the cost of beach renourishment and control structures in the short-medium term so that the cost of a sea wall can be postponed.[1] Of course for both pathways the probability of (T&T scenario) climate change that is required to justify taking action is largely meaningless as in the short term they both involve option Q.

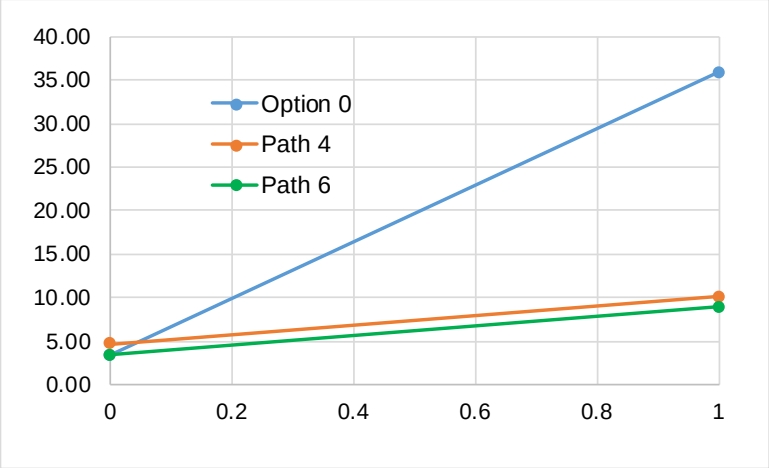
Table 13: Pathway Cut-off Probabilities

Pathway		Cut-off Probability	PV(cost +loss) $m
1	Q+L+M	27.7%	15.31
2	Q+L+S	8.0%	10.72
3	Q/R+C+M	29.8%	16.08
4	Q/R+C+S	4.4%	10.16
5	Q+S+M	27.5%	15.43
6	Q+S+S	<0.0%	8.93

The six protection options are:

1. Status quo (denote this as Q)
2. Renourishment of the beach (R)
3. Control structures such as groynes and breakwaters, with renourishment (C)
4. Sea wall (S)
5. Managed retreat (M)
6. Retreat the line (L)

Figure 4: Pathways 4 and 6 versus Do Nothing



[1] Some loss estimates in these calculations have been revised by Tonkin & Taylor since those originally provided to the TAG.

Flexible Pathways

With the five generic protection options there are various other pathways, not all of which are sensible. We look at 10 others, listed in Table 14. They are numbered 7-16.

Table 14: Initial and Additional Pathways for Ahuriri

Option	ST	MT	LT	Discounted Investment Cost	Discounted Cost + Loss	End state	Cut-off probability cf end state
1	Q	L	M	11.36	15.31	M	>100%
2	Q	L	S	5.68	10.72	S	>100%
3	Q/R	C	M	11.88	16.08	M	>100%
4	Q/R	C	S	4.68	10.16	S	No Soln
5	QC	S	M	11.22	15.43	M	>100%
6	Q	S	S	3.45	8.93	S	NA
7	Q/R	S	M	12.07	16.27	M	>100%
8	Q/R	S	S	4.30	9.78	S	No Soln
9	Q/R	L	M	12.21	16.15	M	>100%
10	Q/R	L	S	6.53	11.75	S	>100%
11	Q	C	M	11.04	15.24	M	>100%
12	Q	C	S	6.83	9.31	S	No Soln
13	Q	M	M	21.87	24.21	M	>100%
14	Q/R	M	M	22.71	25.06	M	>100%
15	L	M	M	25.62	27.63	M	>100%
16	M	M	M	42.50	42.50	M	NA

Path 6 is still the least cost pathway, but it is closely followed by Paths 8 and 12 which reinforce the close call between incurring some relatively low costs in the short term for some longer term cost reduction.

Sensitivity Tests

Some selected sensitivity tests are reported in Table 15. Overall the preference for Path 6 or 12 remains, except under the low discount rate where Path 8 (Q/R+S+S) edges out Path 12 (Q+C+S) – the usual result where a lower discount rate advances the case for earlier more expensive action.

Table 15: Sensitivity Tests

	Pathway Choice		Cut-off v Do Nothing	
	1st	2nd	1st	2nd
Base Case	6	12	<0%	1.3%
Discount rate 6.0%	6 & 12 are tied		<0%	<0%
Discount rate 1.5%	6	8	<0%	<0%
High investment costs	6	12	1.5%	3.6%
Low investment costs	6	12	<0%	<0%
Retreat after 2120	6	12	7.2%	8.6%

Value for Money

Table 16 takes the MCDA scores for the original six pathways and divides them into the investment costs to produce a measure of 'value for money'.

Table 16 Value for Money

Pathway		MCDA Score	Discounted Invest Cost ($m)	VFM ($'000/point)
1	Q+L+M	54	11.36	211
2	Q+L+S	51	5.68	111
3	Q/R+C+M	58	11.88	205
4	Q/R+C+S	58	4.68	81
5	Q+S+M	65	11.22	173
6	Q+S+S	61	3.45	57

The difference between the VFM of the pathways that end in retreat compared to those that rely on a sea wall is dramatic. Fortunately, although Path 5 has the highest MCDA score, Path 6 is not far behind and delivers far better value for money. Thus overall Path 6 seems to be the best choice, bearing in mind of course that the status quo prevails for the next few decades, so flexibility is high. After that a seawall is common to both pathways, and it is not until around 2070 that a decision on S or M is required – based on current knowledge. There seems to some appetite for incurring some short term cost by way of beach renourishment followed by control structures in order to defer the cost of a sea wall.

Summary

The ROA results show a preference for Path 6 (Q+S+S) or Path 12 (Q+C+S), although the case for a degree of earlier intervention via Q/R in the short term is also quite strong. The latter is also apparent in the MCDA results, but the case for Path 6 is stronger. However, given that the extended pathways demonstrate a case for Path 12 (Q+C+S), the C versus S option should be revaluated in the medium term.

6. Unit E: Pandora

Fixed Pathways

There are four initial pathways for Pandora - see Table 17.[2] The key risk for Pandora is flooding rather than erosion so two new defence options are introduced, stopbanks and a flood gate. The latter, however, generates the most expensive (investment cost plus expected loss) pathway. Path 3 with stopbanks is the preferred choice and requires the lowest probability of (T&T scenario) climate change to be preferred to doing nothing. Path 1 which begins with the status quo, is the next cheapest; the cost of managed retreat, even many decades into the future, offsetting its initial short term advantage. See Figure 5.

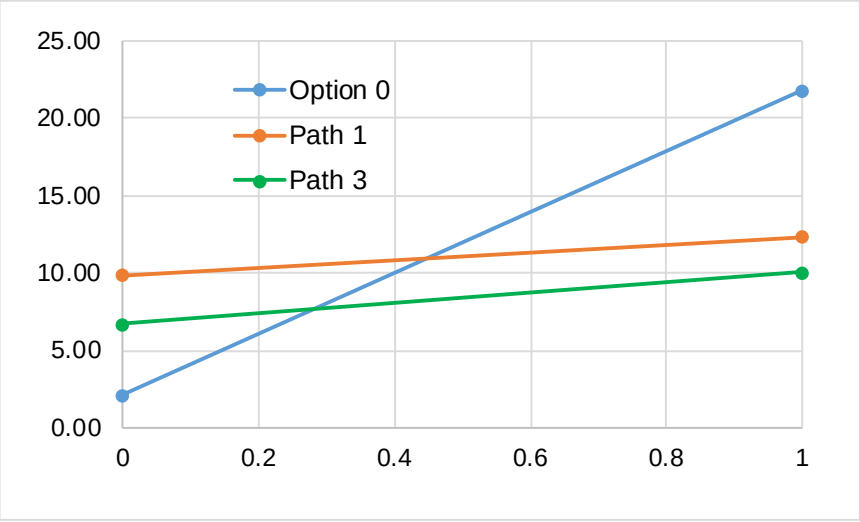
Table 17: Pathway Cut-off Probabilities

Pathway		Cut-off Probability	PV(cost +loss) $m
1	Q+B+M	44.9%	12.36
2	B+B+M	50.9%	13.39
3	B+B+B	28.2%	10.08
4	B+F+F	83.0%	19.05

The four protection options are:

1. Status quo (denote this as Q)
2. Stopbanks (B)
3. Flood gate (F)
4. Managed retreat (M)

Figure 5: Pathways 1 and 3 versus Do Nothing



[2] Some loss estimates in these calculations have been revised by Tonkin & Taylor since those originally provided to the TAG.

Flexible Pathways

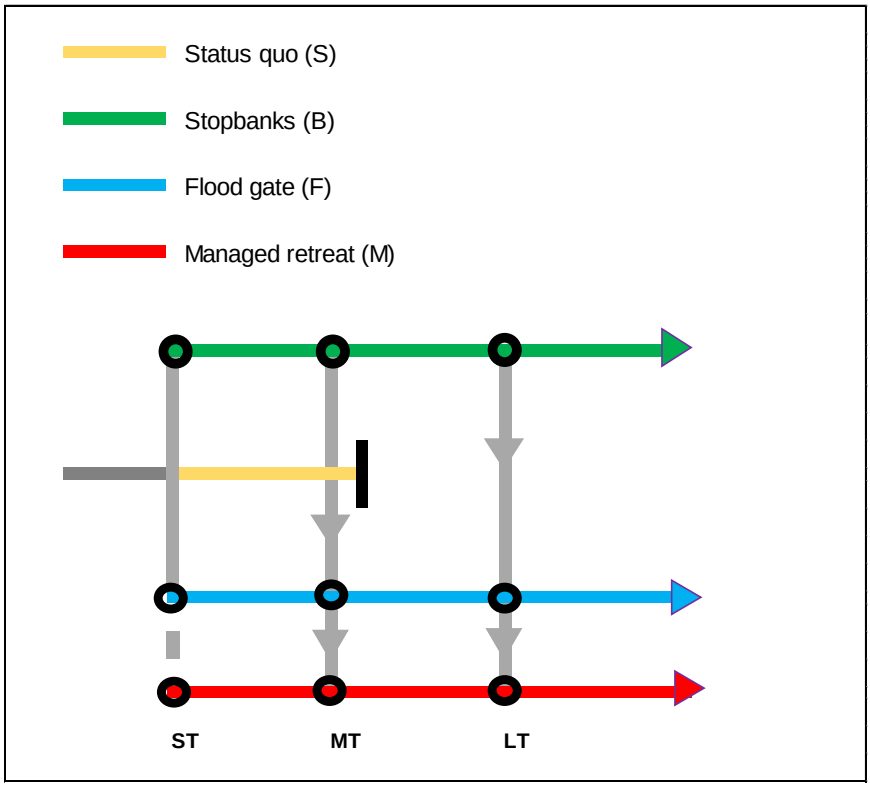
Table 18 presents seven more permutations, with Path 11 being the only one to be preferred to Path 3. Essentially it combines the cost-effective long term protection provided by stopbanks with the short term advantage of no action.

Table 18: Initial and Additional Pathways for Pandora

Option	ST	MT	LT	Discounted Investment Cost	Discounted Cost + Loss	End state	Cut-off probability cf end state
1	Q	B	M	9.85	12.36	M	>100%
2	B	B	M	10.88	13.39	M	>100%
3	B	B	B	6.74	10.08	B	NA
4	B	F	F	15.71	19.05	F	NA
5	B	F	M	20.78	23.29	M	>100%
6	Q	F	M	18.83	21.33	M	>100%
7	B	M	M	16.85	18.22	M	>100%
8	F(2)	F	M	32.84	35.34	M	<0%
9	F(2)	M	M	46.62	48.00	M	<0%
10	M	M	M	20.78	23.29	M	NA
11	Q	B	B	5.71	9.05	B	No soln

The options are illustrated in Figure 6.

Figure 6: Pathways Map for Pandora



Sensitivity Tests

The standard sensitivity tests are presented in Table 19, including managed retreat after 2120 if not already implemented. The preference order is unchanged except for in the scenario with a 6% discount rate where the second least cost pathway is Path 1 which is Q+B+M. Path 11 is Q+B+B and Path 3 is B+B+B. This is an unusual result as it is usually the lower discount rate that favours the case for earlier managed retreat, but in this case the higher discounting of the cost of managed retreat outweighs the higher discounting of the residual loss if Path 3. However, the difference in total cost plus loss between Paths 1 and 3 is only $0.65m, so within error margins.

Table 19: Sensitivity Tests

	Pathway Choice		Cut-off v Do Nothing	
	1st	2nd	1st	2nd
Base Case	11	3	21.9%	28.2%
Discount rate 6.0%	11	1	19.1%	31.0%
Discount rate 1.5%	11	3	18.3%	20.5%
High investment costs	11	3	30.2%	37.9%
Low investment costs	11	3	13.6%	18.5%
Retreat after 2120	11	3	30.2%	36.4%

Value for Money

Table 20 takes the MCDA scores for the original four pathways and divides them into the investment costs to produce a measure of 'value for money'. Contrary to the results for neighbouring Ahuriri the pathways that end in retreat are clearly favoured by the community, but deliver less value for money than Path 3.

Path 2 has the highest MCDA score, but is clearly less flexible than Path 1. Path 3 is also less flexible. Although managed retreat is the nominal end point of Path 1, given various review dates it is not – and should not be – a certainty at this stage.

Table 20 Value for Money

Pathway		MCDA Score	Discounted Invest Cost ($m)	VFM ($'000/point)
1	Q+B+M	51	9.85	193
2	B+B+M	54	10.88	202
3	B+B+B	49	6.74	138
4	B+F+F	45	15.71	349

Summary

If it is possible to retain the status quo in the short term and then move to stopbanks (Path 11, Q+B+B), the ROA reveals that this pathway has the lowest expected total cost plus residual loss. It also does not preclude Path 1 which has the second highest MCDA, but eventually moves to managed retreat. Thus these two pathways constitute a flexible approach, as opposed to Path 2 which has the highest MCDA score, but delivers less flexibility and less VFM by going straight to stopbanks.