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Avon Heathcote Tidal Barrier Pre-Feasibility Study

Christchurch City Council

Review of Final Report

| 2

17 AUGUST 2015

Review of Draft Final Report
Christchurch City Council

Document history and status

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Avon Heathcote Tidal Barrier Pre-Feasibility Study

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1. Introduction

1.1 Purpose

Christchurch City Council (Council) faces considerable challenge in remedying the adverse impacts that the Christchurch earthquakes have had on land drainage in the city, primarily as a result of land settlement and associated reduction in hydraulic gradient and capacity of the primary river network.

Council's Land Drainage Recovery Programme (LDRP) is undertaking a range of investigations aimed at developing an understanding of the extent and impact of changes as well as looking at remedial options that may contribute to management of impacts and/or restoration to pre-earthquake or better flood risk exposure.

One such study has been a pre-feasibility assessment of a tidal barrier on the Avon Heathcote estuary, aimed at determining technical feasibility of a barrier and establishing how consideration of a barrier should be progressed if it is determined potentially feasible.

Council engaged GHD in conjunction with NIWA to undertake this study which is summarised in the report *Avon-Heathcote Tidal Barrier Pre-Feasibility Study* report, dated July 2015.

Jacobs in conjunction with HR Wallingford have been asked to review and comment on the above report, both in its draft final and final version, to provide both specific commentary on the report but also broader commentary where relevant on the consideration of a barrier as part of Christchurch's long term stormwater management.

1.2 Scope of Review

The scope of the review agreed with Council is as summarised below:

- The review is to be based upon the information provided however commentary is expected to also be drawn from the experience of the principal reviewers.
- Specific review of cost estimates are excluded, however any commentary that may assist Council in its understanding of risks and certainty with regards to the cost estimates is welcomed.
- Checking of calculations is not expected.
- We understand that Council will act upon any recommendations made in the review report at its own discretion and until they are resolved to its satisfaction.

1.3 Format of Report

Our review commentary is provided in the form of commentary on the specific and technical details of the report in Section 2. In Section 3 we discuss the outcomes and recommendations of the report and provide commentary on Council's overall approach to flood management strategy development. Supplementary information is provided in Section 4 to provide an example of an adaptation strategy.

1.4 Limitations

The sole purpose of this report and the associated services performed by Jacobs is to assess sufficiency with respect to the objectives of the study and to provide independent commentary on the specific report outcomes as well as the consideration of use of a tidal barrier in its broader context, in accordance with the scope of services set out in the contract between Jacobs and Christchurch City Council. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

Items raised in this report are solely for Council consideration, to assist Council in determining an appropriate response or action (if any) in relation to the study work undertaken and reported.

We highlight that some of the comments presented in this review cover matters outside of the scope of GHD’s pre-feasibility study.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

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2. Detailed Technical Commentary

Our review of the draft final report raised many questions, the majority of which have subsequently been satisfactorily clarified or addressed.

Review of the final report finds few technical questions but has identified several areas where we see further commentary may assist the reader to better understand how a barrier would contribute to flood risk management.

Page and section numbers referenced relate to the final version of the report.

#	Pg	Section	Comment
1	8	2.0	A section discussing the tidal and fluvial flood risk exposure that Christchurch faces now and over time would assist in setting the scene for why a barrier is being considered would provide context when performance of a barrier is considered.
2	8	2.1	How a barrier assists to manage the flood risks associated sea level rise is self-evident, however some further elaboration on how it assists with river flooding would assist non-technical readers to better understand the mechanics of low-land flood defence with or without a barrier, the length of influence of the barrier and the interaction between river, estuary and estuary mouth.
3	14	3.0	An overview of the peak fluvial flood flows in both Avon and Heathcote rivers resulting from a range of return event storms would assist the reader to understand the scale of the river flooding problem and how it changes with more severe storms.
4	15	3.2	It is understood that a single sea-level rise target is used for the purposes of this study, in this case a 1 m increase in level projected to occur by 2115. We believe it would assist the reader if commentary were provided on the reality that change is likely to occur gradually and to a greater or lesser extent than foreseen at present, as this will assist in developing an understanding that an adaption strategy utilising a range of mitigation measures applied at different times will be required. It will also assist in demonstrating that a yes/no decision on a barrier is not required at this point in time and that use of a range of design events should be considered when testing the performance of any mitigation measures proposed. This latter point is critical to ensure the whole of life performance of solutions are understood and the limits of their effectiveness established. These matters are partially addressed in Section 13 – Conclusions.
5	31	4.4	The crest design heights stated for the barrier components are adequate for this study, however we would anticipate a long-term future-focussed assessment would likely lead to increases in design levels to gain maximum effectiveness, with resulting associated impact on costs (increase) and benefits (for example, possibly better performance in over-design events than other flood mitigation options).
6	44	5.2	The selection of a vertical lifting gate as the preferred gate arrangement to progress the pre-feasibility is well supported by the high-level comparative assessment presented in Table 6. We consider that it would be prudent to acknowledge that should a barrier be considered further, selection of a final preferred gate arrangement would be the outcome of detailed technical and financial assessment and stakeholder input. In this regard, a change of preferred gate type is foreseeable, which may impact on the reported economic feasibility based on the vertical lifting gate.

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#	Pg	Section	Comment
			Particular matters that might impact the preferred option are likely to include appearance, navigability, operational reliability and maintainability.
7	45	6.2	The selection of a dune embankment as the preferred embankment arrangement to progress the pre-feasibility is well supported by the high-level comparative assessment presented in Table 7. We consider that it would be prudent to acknowledge that should a barrier be considered further, selection of a final preferred embankment arrangement would be the outcome of detailed technical and financial assessment and stakeholder input. In this regard, a change of preferred embankment type is foreseeable, which may impact on the reported economic feasibility based on the dune embankment. Particular matters that might impact the preferred option are likely to include availability and cost of sand, particularly if offshore dredging and pumping is proposed, as well as value-add opportunities such as provision of public road access for life safety, operations and maintenance activities or recreational access. In this context, the scheme as presented is probably the minimum arrangement foreseeable and likely to increase.
8	49	7.2	The outlined barrier operating philosophies are sensible however we consider that it would be beneficial if further information was provided on the operational limitations of a barrier, so that an understanding of the duration of its effective use could gained. At some point in time, the high frequency of use will pose operational reliability risks that in turn reduce the overall flood risk mitigation of a barrier. Development of a full understanding of operational reliability under increased use should be considered in future assessments.
9	51	7.2.4	We concur with the conclusions of this section, that a combination of flood mitigation approaches including changing operations philosophies and/or changes in the level of service or risk mitigation provided will be required over time.
10	53	8.1	The nominal design criteria in terms of return period of design events and resulting crest levels are described. We concur these are appropriate for this assessment but highlight the need for specific and focussed review, agreement and quantifying of flood risk mitigation objectives, independently of and prior to consideration and assessment of all flood mitigation options.
11	57	8.5	In addition to the information provided, we consider it worthy of note the likely importance level of a barrier would be IL4 or IL5, requiring a high degree of integrity in all design, controls and operational aspects. Impacts of this are typically high levels of redundancy in equipment and power supply with a resulting need for substantive associated facilities with requisite land needs.
12	60	9.1.1	The sea level rise scenarios used for assessment are described. We concur these are appropriate for this assessment but highlight the need to assess all flood mitigation options against a broader range of flood and sea-level rise scenarios, including more significant changes than presently predicted, so as to learn about any limitations and the extent of their performance range, so that they are considered appropriately. This should be a focus area of future studies considering any/all flood mitigation options.
13	69	9.4.3	The methodology described for assessment of performance difference between barrier and no-barrier options, namely, identifying the number of houses that would need to be raised, is accepted for the purpose of this report, however we highlight that such an approach is likely to be impractical at this scale, particularly in the industrial areas. The report acknowledges this method is simplistic. The complexity and potentially cost of managing flood risk in the lower Heathcote catchment is therefore highlighted for future assessment.

3. Overview Comments

3.1 Comments on Report Conclusions

The reference questions are provided below in ***bold italics,*** followed by the report findings and then *comments arising from this review in italics*.

What form would a barrage(s) take?

The study has concluded that a structure with lifting gates would be most suitable. This is the simplest option to build and is probably the most robust.

The general arrangement presented is considered potentially appropriate and sufficient for the purpose of this assessment however significant work is required to fully understand and decide upon a preferred scheme arrangement.

*It is therefore recommended that the barrier general arrangement discussed be presented and considered as a **potential conceptual arrangement**.*

Where would a barrage(s) be best located?

The study has considered two sites (Redcliffs and Shag Rock) and has selected Redcliffs as the best option.

This appears to be the best site however significant work is required to fully understand and decide upon a preferred scheme arrangement.

*It is recommended that at this preliminary stage, the preferred location be indicated as a **zone** rather than a specific alignment.*

Will a barrage(s) work?

The study concludes that the barrier will work. The proposed barrier attempts to minimise the impacts on the tidal regime and therefore environmental conditions within the estuary.

It is agreed that a barrier will work. The approach of minimising the impact on the tidal regime was successfully used for barrier options on the Thames estuary in England, which is also a sensitive area.

However there is a conundrum: the barrier will work under present day conditions but would be difficult to justify on benefit cost considerations. When the sea level has risen by 1m, it would be easier to justify the barrier on benefit cost considerations but the suggested method of operation (closing on every tide) is unlikely to be acceptable because it would have severe adverse impacts on the estuary and may not be sustainable from an operation and maintenance point of view.

We concur with the concluding remarks of the report indicating the need to consider a barrier, among all other flood mitigation options, as part of a broader adaptation strategy for Christchurch's overall and long term flood management strategy.

We provide an example of a potential adaptation strategy in Section 4 of this report.

What are the benefits of a barrage(s)?

The study indicates that a barrier would not be cost beneficial under present day conditions compared with the cost of alternative flood mitigation measures but that it would under the scenario of 1m of sea level rise, concluding there is sufficient evidence to warrant further consideration of a barrier as part of a wider flood management strategy.

We concur with this conclusion and further suggest that the next step in assessment is a high level city-wide consideration of flood risk mitigation options which in turn will identify the more specific investigations required of all feasible flood mitigation options considered worthy.

We also recommended that the performance of a barrier and the alternate flood defence methodologies be tested against a broader range of flood / climate change scenarios to learn about the performance of each *approach across the range of foreseeable events, including over-design events or more extreme sea level rise scenarios.*

We note also that Councils planned spend on stopbanks and pump stations under the LDRP over the coming 1-3 years is of ***significant*** *importance when considering the cost/benefits of a barrier vs other solutions. If implementation of these assets continues as planned, then the sunk value of these assets may skew the overall assessment of cost/benefit and Council may find that they "paint" themselves into a default strategy.*

The importance of having an overall and long term flood management strategy in place before committing to significant infrastructure expenditure cannot be more strongly highlighted.

What are the potential costs for construction and whole of life for a barrage(s)?

Estimated costs are provided.

We have not commented on costs however note the potential for detailed design performance criteria and public expectations to increase the complexity and scale of the work required.

We also highlight the importance of understanding the vulnerability and therefore cost-risk exposure of all flood mitigation options considered, to earthquake, tsunami, extreme flooding, etc, as these elements are all foreseeable in the operational life time of the assets that are built.

A model similar to that used in SCIRT to "value" the resilience of an option may be useful to assist in understanding the vulnerabilities of the various options to such events.

When will a barrage(s) be required and how long will it last in the face of sea level rise (durability and flood risk)?

The report indicates that a barrier is technically feasibly but would not be economically justifiable at present based on a high level comparison with alternative flood mitigation measures but may be needed when the sea level has risen by 1m. The need for an adaptable operational strategy is identified.

It is our recommendation that an adaptable city-wide flood management strategy is developed where decisions are based on thresholds (such as a critical level related to flooding or the number of closures of the barrier per year) and monitoring is implemented to identify when these thresholds might occur. A simplified example of an adaptation strategy is provided in Section 4.

Until the performance range of all flood management options is understood and the various combinations of flood management options assessed, it may be premature to state when a barrier is best applied and for how long it will remain viable.

Council's current LDRP planned spend will impact directly on when a barrier may be most beneficial.

What impacts will a barrage(s) have?

The impacts will be small under present day conditions apart from landscape, where the impact would obviously be significant. However as closures become more frequent, the tidal regime will be adversely affected and the impacts on tidal flows and levels, water quality and ecology could be significant.

The assessment of impacts appears reasonable.

We note that the impacts of the alternate option of no barrier will also be significant so future assessment should aim to demonstrate the ***difference*** *in effects and whether they are significant or not.*

The impacts of frequent barrier closures on morphology and ecology are likely to be as significant as the sea level rises, and an overall scheme involving stopbanks as well as a barrier will be required.

What are the risks associated with construction and operation of barrage(s)?

Temporary works during construction are identified as a critical stage because of the narrowing of the estuary at the barrier site caused by temporary works.

The assessment of risks appears reasonable however particular concerns that have been identified and that need further investigation include:

- *The need for adequate foundations for the barrier structure in view of the foundation material and the risk of earthquakes*
- *The need for suitable arrangements for undertaking maintenance work on the gates, as this could temporarily narrow the gate opening by one-third and affect flows and sediment transport;*
- *The adequacy for flood forecasts and warning for closing the barrier, bearing in mind that the barrier must be closed at low tide in advance of a storm event.*
- *the operational reliability once barrier closure frequency increases*

What other investigations are required to consent and construct a barrage(s)?

The report recommends that a flood management options report is produced together with public consultation on the options and then to further develop the barrier option if it remains a favourable concept.

We agree with this approach in general, however it is recommended that focus be applied to better definition of the fluvial and tidal flood risk exposure, need for a risk based management approach with adaptability as a key priority and to promote understanding of the performance range of flood management options, whether they be engineered or planned, so that they can be better combined over time to provide an integrated long term flood management strategy for Christchurch.

The significance of a barrier project will require well planned and extensive consultation in order to determine the form and appearance of an acceptable barrier arrangement and to gain consent.

It is recommended that this report should contain a full options appraisal that covers:

- *Definition of the fluvial and tidal flooding scenarios contemplated and corresponding nominal "design" events and "over design" events to be considered, including consideration of the joint probability of tidal and fluvial events, incorporating an adaption component that evaluates the sensitivity of proposed solutions to more severe events so that the performance limitations of all flood defence approaches are learned*
- *Development of design and performance criteria for all flood management options considered including design events, level of service, adaptability criteria, evaluation of community impacts, etc. against which performance of all flood management options are tested;*
- *Identification of all potential options including those with and without a tidal barrier, including upland storage, channel capacity increase, stopbanks, barrier, pumping, inundation areas and planned retreat*
- *Development of methodology to assess resilience performance under other natural events including earthquake, tsunami, stop bank breach, etc so that the impacts and costs of damage and repairs are incorporated into overall cost/benefit analysis*
- *Definition and modelling of the baseline condition of flooding and flood damage which would be used to assess the benefits of the options. The damages are normally expressed in terms of average annual damages and a range of flood return periods are required;*
- *Modelling of the options and calculation of the benefits in terms of damages avoided;*
- *Calculation of the cost of each option;*
- *Benefit cost analysis for each option using the benefits obtained from the options modelling in order to evaluate the viability of the options;*
- *An assessment of the positive and negative impacts of each option;*
- *An overall appraisal, possibly based on multi-criteria analysis, that includes the benefit cost ratio plus an assessment of other benefits and adverse impacts including landscape, ecology, social, etc.*
- *The appraisal will provide a score for each option which will enable the best options to be selected based on the highest score. Whilst the benefit cost ratio will be an important element of the appraisal, other important factors that are difficult to monetise (for example, landscape) must also be included.*
- *Full and city wide consultation*

In practice the number of feasible conceptual arrangements is likely to be small. Some information is provided on likely feasible options in previous reports and we anticipate it includes upstream offline storage, main river capacity improvements, main river stopbank improvements, pump stations and connecting piped infrastructure and possibly a tidal barrier.

The results of the appraisal will identify the best combination of flood management options and their recommended timing of implementation and operational functionality. The supplementary information provided on adaptability in Section 4 provides a simplified example of the type of master planned outcomes contemplated.

The next stage would be public consultation, to obtain feedback on the options and assist with selection of the preferred option. It is noted that public understanding of the risk exposure is occurring with the release of the Natural Hazard Planning section of the Replacement District Plan, particularly in areas at risk of fluvial or tidal flooding.

If a barrier were to form part of an integrated long term flood management strategy for Christchurch, the design would be further developed as indicated in the report.

3.2 Review Summary

The report concludes that a barrier is feasible from a technical perspective, possibly marginal from an economics perspective in the short term, but that it is worthy of further consideration as part of a city-wide flood management strategy.

We concur with these conclusions.

4. Example of an Adaptation Strategy

Flood management options that take account of climate change can be considered as a sequence of interventions over time rather than a single set of interventions implemented at the same time. This is because some interventions (such as raising of stopbank crest levels) may only be needed as the sea level rises fluvial flows increase.

In the case of Christchurch, the report has indicated that it is cheaper to provide flood protection using stopbanks under present day conditions but a barrier may be more beneficial in the future. In this case a suitable option might be to improve the stopbanks now and build a barrier later.

Alternatively, there may be resistance to raising stopbanks in Christchurch, and the preferred approach might be to build a barrier now and improve the stopbanks later in order to limit the number of closures of the barrier.

These two options are shown on the diagram below. Note that these are theoretical options for illustrative purposes only. The numbers are samples and are not the result of any analysis.

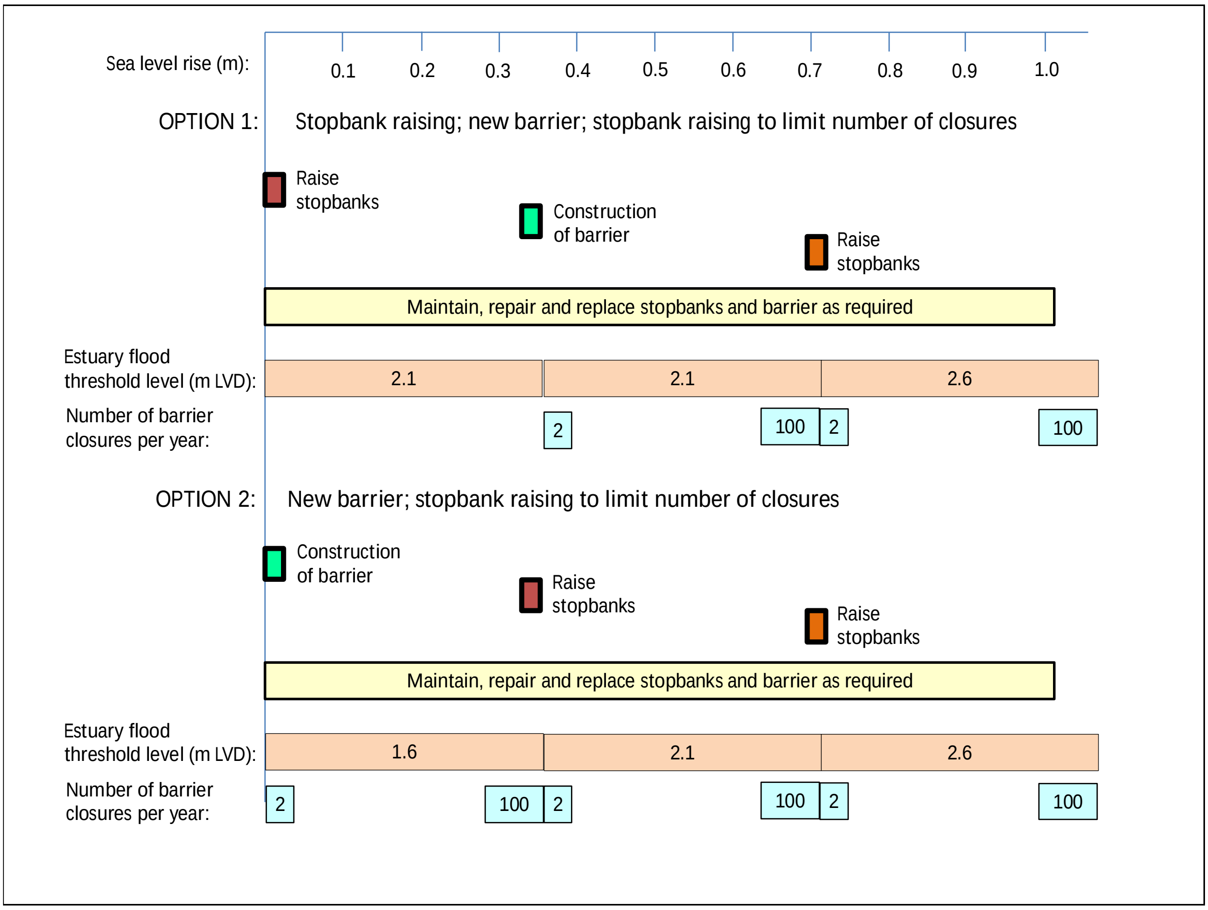
The diagram shows the interventions that would be needed as the sea level rises. Note that the diagram shows interventions against sea level rise and not time.

In Option 1, the stopbanks are raised so that the threshold of flooding is increased from the present day level (stated as 1.56 m LVD in the report) to 2.1 m LVD. When the sea level rises so that a level of 2.1 m LVD becomes the critical threshold level for flooding, the barrier is commissioned. Note that the barrier must be designed and constructed in advance of this date so that it is available when required.

As the sea level continues to rise, the barrier closes more frequently. If for example, it is decided that 100 closures per year is the maximum that can be accepted, the stopbanks must be raised when this threshold is reached. Hence the stopbanks are further raised to give a flood threshold level of 2.6 m LVD. At this point the number of closures per year drops from 100 to 2.

In Option 2, the sequence is reversed so that the barrier is built first and stopbank raising occurs later, to limit the number of closures of the barrier. Thus, when the number of barrier closures reaches 100 per year, the stopbanks are raised so that the threshold level of flooding is increased from 1.56 m LVD to 2.1 m LVD. The number of barrier closures per year drops at this point from 100 to 2 because the sea level can be allowed to rise to 2.1 m LVD before the barrier is closed.

As the sea level continues to rise and the number of closures increases, the stopbanks are further raised to 2.6 m LVD when the number of barrier closures once again reaches 100 per year. In this way the number of closures per year is limited to 100 by successive raising of stopbanks.



The above diagram indicates the types of flood management strategy that might be suitable for Christchurch. They are simplified for illustrative purposes.

Another important factor to consider is the life of engineering structures and the need for repairs and replacements in the future. These should be taken into account in the overall flood management plan.

Bearing in mind that engineering structures may need major repairs or replacement within the same timescale as the climate change scenario (i.e. 100 years), decisions regarding raising or realigning stopbanks will be affected by their condition and residual life. For example, if a section of stopbank is in poor condition, it may be necessary to replace it rather than raise the existing structure.

The adaptation strategy should therefore take account of the expected design life of new structures and the estimated residual life of existing structures when planning the order and timing of interventions.

The adaptation strategy should also consider the effect of incremental changes on the morphology and ecology of the estuary, and mitigate adverse impacts as far as possible.

One great benefit of an adaptation strategy is that it responds to the actual change that occurs. If the sea level rise occurs more slowly than indicated in the scenarios, the dates of the interventions can be delayed.