CHOOSING FROM ADAPTATION OPTIONS – MORE THAN A SHORT TERM COST BENEFIT APPROACH

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Abstract

Adaptation options available vary according to the specific risks, landforms and the character and density of development in an area. Most locations would have a variety of adaptation options available, each with different costs and outcomes. Selection that focuses on costs and benefits over a short term time horizon (20 years) may result in long term outcomes that are clearly unacceptable.

Some alternatives may provide a high level of protection and security at a moderate cost for a period of time, but if sea level continues to rise, the cost becomes higher and/or the degree of security declines. Further, while some forms of protection or adaptation allow for relatively gradual and graceful modes of failure, others can fail in catastrophic ways.

For example:

- Adaptation by raising structures and land levels means that increasingly extreme flood events will still not cause extreme damage or failure to most structures, even if a flood exceeds design levels.
- Protection via a levy or dike can lead to situations where the sea level is meters above the protected properties behind. While in the first instance this may be cost effective, over time, an increasingly high barrier is required. If the protection should be overtopped or fail in one location, the result could be catastrophic loss of property or life.
- Forms of adaptation that protect property but do not allow landforms and ecosystems to respond to changing sea levels may result in highly modified coastal areas that no longer retain many of the features most appealing to coastal residents and visitors. Walking along a sea wall is not the same as walking along a beach, and an abrupt change from terrestrial ecological communities to relatively deep water would have a different appeal from the currently rich and varied coastal environment of beaches, marshes and wetlands.

This paper outlines how broadening the considerations can lead to more sustainable solutions acceptable to both coastal communities and the wider community that use coastal areas.

Key Words: climate change, coastal, adaptation, policy, planning, cost benefit

Introduction

The options protection, adaptation and retreat are commonly presented as the summary options for responding to climate change. However, particularly within defence and adaptation there is generally a range of options available that offer quite different outcomes in terms of costs, benefits, risks and sustainability.

While a cost benefit approach may commonly be adopted to assess options, this paper argues that the *particular* risks and forms of failure and the long term sustainability of an adaptation or defence option need to be explicitly considered to ensure the optimal outcome. Examples of such considerations are described.

The approach presented in this paper was developed in part as a result of a project undertaken in the Clarence City Council area in Tasmania. It has not been adopted by that project at this time nor does it represent the policy of any level of government

The analysis reflects the conditions prevailing in the situation where the project was undertaken, other situations cited in the

literature and the experience of the authors in other coastal regions in Australia. While we consider the analysis to provide insights to many other coastal areas, we recognise that the range of circumstances arising from climate change in other locations will not be fully addressed.

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Scope of costs and benefits

A simple cost benefit approach to selecting options to respond to the effects of climate change in coastal area (principally sea level rise, storm surge and coastal erosion) would entail looking at the costs of each option and the benefits derived.

Direct costs include:

- coastal defences such as sea walls, groins, beach or dune nourishment
- changes to buildings to strengthen foundations, waterproof lower floors or ensure services are resistant to inundation
- raising buildings and services including access roads and even surrounding land areas to elevations above the risk level
- loss of otherwise serviceable structures or infrastructure and usable land if retreat is chosen

Costs can be minimised if changes are part of a normal replacement or upgrade cycle where expenditure would be incurred anyway. In this case, the cost is that of any higher specification of works, or possibly higher costs if relocation is involved.

In most cases the benefits are primarily continued use of the site and structures for an extended period without excessive risk of loss or damage.

Other costs may also be incurred, and these may accrue to the community, not just the properties directly affected by coastal risks. The costs include:

- loss of useable beaches or public access to the waterfront, if sea wall protection on private property becomes the low tide line
- loss of amenity of coastal areas as a result of highly modified landforms, isolation of the coast via barriers or degraded waterfront environment.
- long term maintenance, replacement or upgrading costs for protection works as sea level continues to rise
- loss of valued ecosystems, species, landforms or ecosystem services, among which are protection from storms and future erosion, water quality, fish breeding etc.

Consideration of failure modes

Even with defence or adaptation, there remain some risks associated with coastal development. While designs may withstand a 1% annual exceedance probability (AEP) event (typically used as a design parameter for structures), more severe events occur at times. When this happens, the consequences to property may be vastly different for different defence or adaptation options.

While some alternatives provide a high level of protection and security at a moderate cost for a period of time, if sea level continues to rise, the cost becomes higher and/or the degree of security may decline. Further, while some forms of protection or adaptation allow for relatively gradual and graceful modes of failure, others can fail in catastrophic ways.

An example will illustrate these issues.

Where the principal risk is inundation for low lying land away from the immediate threats of erosion or storm waves, two main options may be considered:

- raising structures and services above expected inundation levels
- building a dyke or levee to keep the rising sea back

Adaptation by raising structures and land levels means that increasingly extreme flood events will not cause failure or major damage to most structures, even if a flood exceeds design levels. As sea levels rise, the area is likely to be subject to relatively modest damage from flooding, even in events that exceed 1% AEP expectations. Loss of life is relatively unlikely and emergency planning is likely to be effective.

Land levels can be raised again in the future as sea levels continue to rise, maintaining the same levels of modest risk. If the rate of sea level rise accelerates, or it becomes clear that it is not cost effective or desirable to continue raising land levels, then planned retreat can still occur over a reasonable period of time, allowing investments in dwellings and other structures to be managed toward eventual abandonment or relocation inland if practical.

Protection via a levy or dike may be far more cost effective in the short term than raising general land levels in an extensive low lying coastal area. While in the first instance this may be cost effective, over time, an increasingly high barrier will be required. Eventually this can lead to situations where the sea level is meters above the properties behind.

If the protection should be overtopped or fail, even in one location along the perimeter, the result could be catastrophic loss of property or life.

Because of the collective nature of this form of defence, and because of the potentially high cost of failure, it is normal to design the defence to withstand a 0.25% AEP or even, as in the Nehterlands, a 0.01% AEP event (Delta Committee 1962).

It may be tempting to take these lower probability thresholds as implying the option is safer that designing for a 1.0% AEP. However, the total risk is the probability of exceeding the design event multiplied by the damage that is expected if the design threshold is exceeded. When this is taken into account, dikes and levees are much less clearly attractive.

Once committed to dikes or levees as a solution, it is hard to change strategy. However, in the long term, practical limitations, political dissention or cost may make it harder to sustain the low probability of failure required for this option to be attractive:

- In the Netherlands, there are areas along the three main rivers where inundation risks may exceed the 0.25% AEP design criteria at times. In these areas the authorities have considered establishing emergency flood areas that would bear the brunt of controlled inundation due to failures rather than have uncontrolled flooding affecting densely populated areas (Witte, E. (2004), *Quick scan cost benefit analysis of Emergency Flood Areas*).

- The levees protecting New Orleans never were designed to such high standards as the Netherlands, but it is clear that they did not even sustain the intended design levels (due too poor maintenance etcetera). Even now it is questionable that the rebuilt defences are adequate to protect against future storm events of a similar severity to Katrina.

Arguably the most likely ‘exit’ strategy from dikes and levees is the unwillingness to rebuild after a major failure in an area. A possible exit strategy would be a gradual retreat while erecting a second or third defence line of dikes.

This is not to argue that dikes and levees are never the right option for defence. However, they are most likely to be appropriate if:

- there is likely to be long term commitment to a high level of development in the area to justify the rising long term costs

- other options are not viable or cost effective

- the area will remain ultimately defendable and

- there are compelling reasons why this area rather than a less vulnerable, higher nearby areas should attract development.

Similar considerations also apply to some of the options associated with response to erosion and storm surge.

Consideration of wider benefits

Forms of adaptation that protect property but do not allow landforms and ecosystems to respond to changing sea levels may result in highly modified coastal areas that no longer retain many of the features most appealing to coastal residents and visitors, in particular, beaches but also wetlands. The community survey of Clarence City residents clearly showed that importance that residents placed on the beaches of the City (Myriad Research, 2007).

The process of 'armouring' the coastline in the US is graphically described by Titus (1998).

Walking along a sea wall is not the same as walking along a beach, and an abrupt change from terrestrial ecological communities to relatively deep water would have a different appeal from the currently rich and varied coastal environment of beaches, marshes and wetlands.

The benefits of allowing coastal landforms and ecosystems to adapt are explored in more detail in a companion paper by Sharples et al 2008. In summary, allowing natural adaptation of coastal landforms:

- Provides a buffer zone in which coastal flooding and erosion can occur without impacting on infrastructure & assets further inland
- Provides public access to the coast with its public amenity value.
- Serves a conservation/ecological function by allowing natural coastal processes to continue in the coastal strip, which is the "active" transitional zone between land and sea where such processes are most active and rates of change are highest.
- By maintaining the ecological function, environmental services such as acting as fish nurseries and water filtration are maintained.

However, aspects not explored in that paper are the wider context within which coastal communities develop. These are explored further in the following section.

Community response in a changing coastal environment

Coastal communities are commonly clustered around one or more of:

- beaches (often in coves),
- river mouths or
- sheltered bays.

As sea levels rise, these features would normally adapt and change, while retaining the essential characteristics that made them attractive.

However, because of the intensity of settlement, often directly in the path of this change, there will generally not be scope to permit this adjustment without the substantial retreat of property from the path of this adjustment.

Waterfront and near waterfront land that is subdivided and serviced, even with just roads and electricity is very valuable, even before it is developed. Once developed, total property values roughly double, making it hard to justify retreat unless protection costs are very high[1].

Therefore it is likely that most coastal communities that are developed beyond a certain extent will choose to defend their existing areas rather than relocate substantial development. Where this results in hardened sea walls instead of beaches and other natural landforms, it will lead to significant loss of the original character of the community. Over time, it will develop a new

[1] The dynamics of property values in coastal areas as sea levels rise and protection costs are included are discussed at further length in the companion paper *Bearing the cost – setting price signals and cost sharing to ensure a soft landing*, Attwater et al. 2008

character that may be attractive but will certainly be different.

Less developed communities that have a strong attachment to beach fronts and have landforms that permit their landward migration as sea levels rise may chose to restrain major development to higher elevations, leaving room for beaches, wetlands and offshore islands to evolve over time, moving inland as sea levels rise. This is feasible in these areas if much of the land is not serviced and occupied, especially if the future costs of protection are factored in.

If this strategy is adopted, these communities are likely to retain a more natural coastal character, something that will become less common as time goes by, giving them an unusual and increasingly valuable attractiveness compared to communities with hardened shorelines.

Throughout much of south eastern Australia, lightly developed areas with a potential to allow the coastline to adapt naturally are becoming increasingly rare outside of national parks. Wherever opportunities exist to allow natural shoreline evolution, they should be rated highly as areas where this evolution should be given priority, unless there are compelling reasons to allow development in the area. This would require adopting a policy of planned retreat of any development and infrastructure that already exists, and clear identification that future development that does occur will be subject to such a policy.

This approach has been adopted for beaches and wetlands in Maine, USA (Department of Environmental Protection, Maine, 1992), where beaches in particular are a relatively uncommon part of the coastal landscape.

These longer term dynamics should be factored into any assessment of the choice of options to respond to sea level rises.

Requirements for success

The benefits of retaining the natural coastal processes fall primarily to the wider community, not the local land holders whose properties may be imminently threatened by sea level rise. Further, the longer term effects of higher risk approaches to protection are likely to fall to future property holders, not the current ones.

For these reasons, the wider community needs to have a substantial say in the selection of the protection, adaptation or retreat option selected. Where this choice provides benefits to the wider community at the expense of local residents, the wider community needs to bear their share of the cost[2].

Conclusion

Defence options that will require repeated upgrading but which generate the risk of catastrophic failure in the long term should only be pursued if there is likely to be long term commitment to a high level of development, the site will remain ultimately defendable and there are compelling reasons why this site rather than a less vulnerable adjacent site should attract the development.

Where there are relatively scarce, highly valued coastal ecosystems which are capable of being sustained by migrating inland, it will be preferred to plan for retreat.

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