Adaptation options for coastal environments: engineering

Any organisation developing an adaptation plan should explore a range of possible adaptation options. In general, there are five broad adaptation responses to climate change and increased risk of inundation and erosion in the coastal zone:

1. avoidance
2. managed retreat
3. accommodation or limited intervention
4. hold the line
5. loss acceptance.

Within the first four of these response categories there are a variety of potential adaptation options.

In this section, we explore **engineering options for adaptation**. In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works strategies such as seawalls, levees and desalination plants. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation damage. These approaches differ from other types of approaches in that they require significant commitments of financial and social resources and create a physical asset.

In describing engineering adaptation options it is important to recognise that, while such projects will involve professional engineers, the contribution engineers can make to adaptation planning is not limited to engineered options. In fact, many options may be hybrid approaches; professional engineers can make important contributions to these, such as development of emergency management and evacuation systems, or the design of artificial reefs which combines ecosystem and engineering knowledge and expertise.

Table 1 below describes the most widely considered engineering adaptation options, together with some hybrid approaches that do not fit as well into other categories. Many of these options are also used to deal with current coastal hazards such as erosion and inundation.

The information contained in Table 1 is arranged as follows:

- Column 1: Examples of potential engineering adaptation options
- Column 2: Climate stressors that can be addressed by each particular option
- Column 3: Examples of benefits from each option (including direct and indirect benefits)
- Column 4: Examples of risks associated with each option (including the potential for maladaptation).

The purpose of Table 1 is to provide quick and high level information on available engineering adaptation options and therefore promote understanding as well as contextualise broader issues around each option (risk, benefit etc.).Table 1 is indicative only, and is not designed to enable an adaptation option to be selected in isolation. The final selection of an adaptation option requires detailed knowledge of the location, such as its current and future uses and social, environmental and economic values, and of its specific climate risks, including temporal and spatial aspects associated with those risks.

Selected options should match the identified risks, the resources available, and the values that are important to stakeholder groups as well as the broader goals of the organisation. It is important to consider any opportunities that might derive from the selected options and any co-benefits that can be achieved. Environmental outcomes should be explored and taken into account, with options that deliver poor outcomes either discarded or given a low priority.

Three other documents in this series provide information on adaptation options in:

- *Adaptation options: Planning*
- *Adaptation options: Ecosystem management*
- *Adaptation options: Social, community and education measures*.

The infographics *Why should we adapt to sea-level rise?* and *How can we adapt to sea-level rise?* also contain useful information. C-CADS has guidance on developing a suite of adaptation options and how to sequence their implementation (*C-CADS Step 3 Identify options*). Once options have been identified, they should be assessed and those most appropriate for the chosen level of acceptable risk identified (*C-CADS Step 4 Assess options*). Once options are prioritised, more detailed consideration, planning and design of each option may be required.

Additional information on engineering adaptation options can be obtained from *Information Manual 7: Engineering solutions*.

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Table 1: Examples of engineering adaptation options including the climate stressor being addressed, and the benefits and risks associated with each option.

Adaptation options	**Climate stressors being addressed**	**Benefits**	**Risks**
Design and construct a seawall to prevent beachfront infrastructure from being undermined and lost through excessive beach erosion	• Sea-level rise, storm surge and associated beach erosion	• Avoids damage to infrastructure during extreme events • Well-designed seawalls can provide hard substrate as potential habitat, can also help to ensure access to the beach	• Displacement of beach and associated amenity, potential effects on local economy from loss of tourism • Wall may interfere with longshore transport and there may be possible end effects of the wall • Risk of wall failure
Construct levees to reduce flooding along estuaries and coastal streams.	• Changes in rainfall, sea-level rise.	• Reduced flooding of built-up areas	• Transfer of risks to other areas • Changing hydrology can change erosion risk • Can cause a disconnect between estuary and surrounding wetlands • Risk of overtopping and levee failure
Raise sewage pumping stations, and associated electricity supply, above flood and storm surge levels	• Changes in rainfall, sea-level rise and storm surge	• Reduce risk of sewage pollution and sewerage failure	• May require a shift from gravity to pumping that will increase operational costs and create pollution risks during power outages • Unsightly infrastructure may be aesthetically displeasing
Design and implement improved road surfaces and materials to reduce likelihood of degradation from heat and excess rainfall	• Sea-level rise, storm surge, intense rainfall events	• Reduced maintenance and rebuilding costs	• Initial increased costs

Adaptation options	**Climate stressors being addressed**	**Benefits**	**Risks**
Nourish beach to maintain beach width and reduce landward erosion.	• Increase in coastal beach erosion (both storm related and long-term)	• This can help maintain: i.) beach amenities and associated tourism activities ii.) the foundation stability of the infrastructure close to the shore line	• Expensive to continue for the long-term. • Nourishment sand is mixed with native sand in the redistribution process, and the final colour of the beach becomes a blended colour affecting visual impact
Construct groynes to interrupt the wave-driven longshore sediment transport resulting in reduction in erosion and/or reduction in erosion and/or updrift accretion	• Increase in coastal beach erosion (both storm related and long-term)	• By trapping sediment, groynes may increase the volume of sediment on a beach to the updrift side of the groyne • By increasing the volume of sand on a beach, groynes may contribute to the resilience of a beach during an erosion event	• *Downdrift effects on the coastline:* groynes can interrupt the longshore transport of sand and accrete the updrift shoreline, concurrently reducing the feed of sand to downdrift areas, which can cause shoreline erosion • *Social impacts*: Some communities may object to groynes due to the aesthetics and the barrier to walking along the beach
Combination of groynes and beach nourishment	• Increase in coastal beach erosion (both storm-related and long-term)	• In long beaches, construction of groynes can reduce the amount of sand required for beach nourishment	• Groynes can interrupt the longshore transport of sand
Raising the crest height or changing the crest details of existing sea walls (inclusion of wave reflectors) or breakwaters	• Inundation due to sea-level rise and storm surge	• If developments are protected by existing seawalls or breakwaters, then this option will provide an opportunity to monitor sea level over the years and make adjustments to the structure as required	• Unsightly infrastructure may be aesthetically displeasing • May be an expensive and only short-term (in decades) solution – needs to be part of a long-term strategy not a standalone solution

Adaptation options	Climate stressors being addressed	Benefits	Risks
Construction of attached or detached breakwater can help managing major estuaries and port and harbour entrances	• Inundation due to sea-level rise and storm surge, erosion of coastal margins	• Breakwaters can reduce wave energy and longshore currents and as a consequence: i.) stabilise estuary or port/harbour entrances ii.) reduce erosion and increased beach width	• Large attached breakwaters can cause major disruption to sediment transport processes, particularly if there is a dominant longshore drift. • Can create safety hazards for swimmers • Can interrupt surf breaks and other forms of coastal recreation
Construction of submerged artificial reefs	• Increase in coastal beach erosion (both storm related and long-term)	• Submerged artificial reefs function through wave dissipation and wave refraction; this leads to less energy in the lee of a reef resulting in salient growth in the beach. Submerged reefs are more effective in areas with small tidal ranges	• Poorly designed and positioned submerged reefs can accelerate erosion if placed too close to the shore by 'compressing' the surf zone and increasing alongshore currents • Can create safety hazards for swimmers • Can interrupt surf breaks and other forms of coastal recreation
Construction of storm surge and tidal barrages in estuaries	• Inundation due to sea-level rise and storm surge, changes in rainfall	• Storm surge and tidal barrages have been used world-wide to generate power, to prevent coastal flooding due to elevated storm surge levels during extreme events, to prevent the encroachment of sea water into estuaries and to reclaim arable land from the sea	• Impact on local ecology where saline habitats may turn fresh • Entrance closure as a result of deposition from littoral drift seaward of the structure

Adaptation options	Climate stressors being addressed	Benefits	Risks
Train estuary entrance by constructing entrance breakwaters	• Increased littoral drift towards entrance mouth due to increase in wave power	• Untrained entrances to estuaries that may become prone to closure as a result of climate change may be 'improved', or kept open by the construction of entrance breakwaters	Entrance breakwaters constructed on littoral drift coasts have the potential to cause 'downdrift' erosion by reducing sediment input and by altering beach alignments through nearshore wave diffraction
Dredge estuary entrances	• Increased littoral drift towards entrance mouth due to increase in wave power	• Dredging has been used in estuaries to create navigable channels and to keep untrained entrances open. As a management option, it may be effective in adapting to climate change	• Expensive
Identify contaminated sites in areas at risk and establish clean-up procedures, or implement options that reduce exposure	• Sea-level rise, flooding	• Improved local human and waterway health • Reduced risk of litigation	• Potential for local contamination during clean-up • Cost blowouts
Increase capacity of storm water management system by adopting water sensitive urban design (WSUD) principles such as development of on-site stormwater detention (OSD)	• Increased rainfall	• Engineered water detention basins can store water after rainfall and therefore reduce the immediate flow of rainwater into the stormwater system	• Needs policy support to be embedded in the local government development policy

Adaptation options	Climate stressors being addressed	Benefits	Risks
Develop green infrastructure (trees, green roof and vertical gardening in buildings) around coastal urban areas to reduce heat island effects	• Increased temperature in urban areas	• Urban infrastructure can retain heat and radiate during night time not allowing the surrounding environments to cool down. Planting trees can provide shade and increase evapotranspiration and reduce heat retention • Green roofs and vertical gardening can provide shading and increase evapotranspiration as well as reduce thermal demand of the building	
Construct desalination plant to diversify water supply sources in the coastal zone	• Increased drought or decrease in rainfall	• Desalination plants can help to adapt to the increase in water demand over the coming decades, together with reduction in freshwater resources due to increased drought or reduction in average rainfall	• Expensive and require large capital investment

Further reading:

Griffith University Centre for Coastal Management and GHD Pty Ltd, 2012: Coastal Hazard Adaptation Options – A compendium for Queensland Coastal Councils. Report prepared for the Department of Environment and Heritage Protection. Accessed 12 June 2016. [Available online at https://www.townsville.qld.gov.au/__data/assets/pdf_file/0015/7035/Coastal_Hazard_Adaptation_Options.pdf].

Engineers Australia, 2012a: Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering, 3rd edition. Prepared by the National Committee on Coastal and Ocean Engineering, Engineers Australia. Accessed 12 June 2016. [Available online at https://www.engineersaustralia.org.au/sites/default/files/content-files/2016-12/vol_1_web.pdf].

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