ASSESSMENT AND DECISION FRAMEWORKS FOR EXISTING SEAWALLS

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Abstract.

This project is being undertaken with funding from the Commonwealth Department of Climate Change and Energy Efficiency through a Climate Change Adaptation Pathways Grant. The grant recipient is the Sydney Coastal Councils Group. Sea wall/asset owners and managers (often Local Government) are faced with determining development applications in areas protected by structures of unknown quality and origin (some approved and some not). Frequently, there is conflict between Council and the community over their effectiveness. This project will look at: ways to evaluate the condition of existing structures (including using remote/innovative techniques) as applicable; define the key design parameters; discuss the way these may change into the future; outline opportunities for future upgrading of any existing structures; and identify key triggers for upgrading or replacement as climate change progresses.

About the Sydney Coastal Councils Group

The Sydney Coastal Councils Group Inc. (SCCG) was established in 1989 to promote co-ordination between Member Councils on environmental issues relating to the sustainable management of the urban coastal environment. The Group consists of 15 Councils adjacent to Sydney marine and estuarine environments and associated waterways. Member Councils include: Botany Bay, Hornsby, Leichhardt, Manly, Mosman, North Sydney, Pittwater, Randwick, Rockdale, Sutherland, Sydney, Warringah, Waverley, Willoughby and Woollahra. The Group represents over 1.4 million Sydneysiders.

The aim of the SCCG is to promote cooperation between, and coordination of actions by member councils in consultation with the broader community on issues of regional significance concerning the sustainable management of the urban coastal environment.

The SCCG operates under 6 key outcomes statements:

- Build the role and capacity of member councils to sustainably manage the urban coastal environment.
- Coordinate and facilitate the exchange of information on integrated coastal and estuary management amongst member Councils.
- Represent and advocate member councils' interests on issues relating to regional, state and national coastal and estuarine management.
- Facilitate sustainable and integrated planning and management of natural and built coastal assets.

- Identify and address emerging regional coastal and estuarine issues through research and project development.

- Facilitate the exchange and development of knowledge and tools to enhance community awareness on sustainable coastal management.

Background to the project

The project is funded through the Coastal Adaptation Decision Pathways Project administered by the DCCEE. It is being undertaken by the Sydney Coastal Councils Group with a consortium including State Government Instrumentalities, Universities and specialists to deliver the project outcomes. The study is being overseen by a national Technical Reference Group (TRG) including representatives from State Government around Australia, the consulting industry and professional organisations.

The project focuses on practical issues relating to any protection structure. The outcomes will include consideration of future opportunities to upgrade a structure recognising that it may deteriorate with time and under current sea level rise scenarios, performance could be reduced. The economic component of the project addresses the trigger point concept, looking at the economics associated with upgrade decisions or, ultimately abandonment as sea level rises (when and how action should proceed).

Outputs from the project are to be practical and of direct application by Local Government including: classification of types of seawalls; general design/condition indicators for various exposures; templates/checklists to assist Local Government in identifying, assessing and classifying existing structures, and preparation of templates and guidelines for incorporating structures into an asset register (including ongoing monitoring, maintenance and upgrading). Practical demonstrations are being undertaken at two Sydney beaches (exposed and sheltered). Other locations may be included.

Objectives

Existing seawalls and protection structures exist at many locations where construction details are unknown and the capacity of the structures to withstand existing (or future) storm and inundation events is not well understood. Where coastal protection is deemed the most appropriate management option, the state of existing seawalls and other protection structures is an important consideration for decision making. Sea wall/asset owners and managers (usually Local Governments) are faced with determining development applications in areas protected by structures of unknown quality and origin (some approved and some not). Frequently there is conflict between the coastal managers and the community who have varying impressions of their effectiveness. Local Government does not always have the luxury of deferring decisions pending a detailed assessment of the structure which may be constructed on private land and in most instances is partially buried or sometimes not visible at all.

The project will assist Local and State Governments to evaluate the robustness and condition of existing seawalls for coastal climate change protection and outline possible options for further upgrades to bring the level of protection into line with planning decisions as climate change progresses. In many Local Government areas, information relating to these structures, many of which were built many decades ago is sparse. Frequently, there is no design report describing the structure, the conditions for which it has been designed or the materials used. There are generally no works as executed drawings confirming what actually exists or the design conditions it was constructed to achieve. More often than not, there is little or no monitoring information in the records documenting the changing condition of the structures or their performance during severe or design events. Importantly, the project will provide guidance on how to incorporate such structures into Council asset management systems, including on-going monitoring and assessment of their condition and performance.

The key components of the project are:

- A detailed literature review to determine the existing state of knowledge and the approaches nationally and internationally to the monitoring and asset management of these minor structures. The literature review will also address methods of determining the extent and fabric of in situ structures and look at the options available for upgrading structures that are deemed to be performing satisfactorily at present.

- Reporting of geotechnical issues and the potential impact of sea level rise (e.g. higher water tables, depleted sand store seaward of the structure, increased wave conditions and overtopping and extreme sea levels) on existing structures.

- Review of non-invasive or remote sensing approaches to quantify and assess the relevant characteristics of existing seawalls that may be buried or partially buried or inaccessible. This will include on-ground assessments of the effectiveness of structures at a number of locations, including but not limited to Sydney and the Gold Coast (final selection of case sites are yet to be confirmed).

- Preliminary economic analysis of various decision pathways that may determine the future continuation of a protection strategy and its impact on coastal development options. This must include an assessment of the design life (in terms of the fabric and performance of existing works), opportunities for upgrades and when and how such action should be taken.

- Development of guidance material to assist Councils in deciding the effectiveness (or otherwise) of an existing structure for coastal protection. This guidance is not intended to replace a detailed condition report prepared by a suitably qualified and experienced engineer, but rather to assist Council in identifying those seawalls that may be of concern so that such assessment if necessary can be appropriately planned.

- Templates and checklists will be developed for assessing suitability, monitoring and maintenance, to determine investment strategies and business cases for sea defence structures that can be incorporated in Council's asset register. As appropriate, issues to be addressed through a professional appraisal will be identified and incorporated into generic draft briefs for use by Council.

- Guidance towards the development of a national standardised approach for assessing and upgrading existing seawalls to accommodate future climate change, particularly sea level rise.
- Dissemination of the findings of the study through Local Government and the industry generally by preparation of technical papers and presentations to coastal management experts and managers.

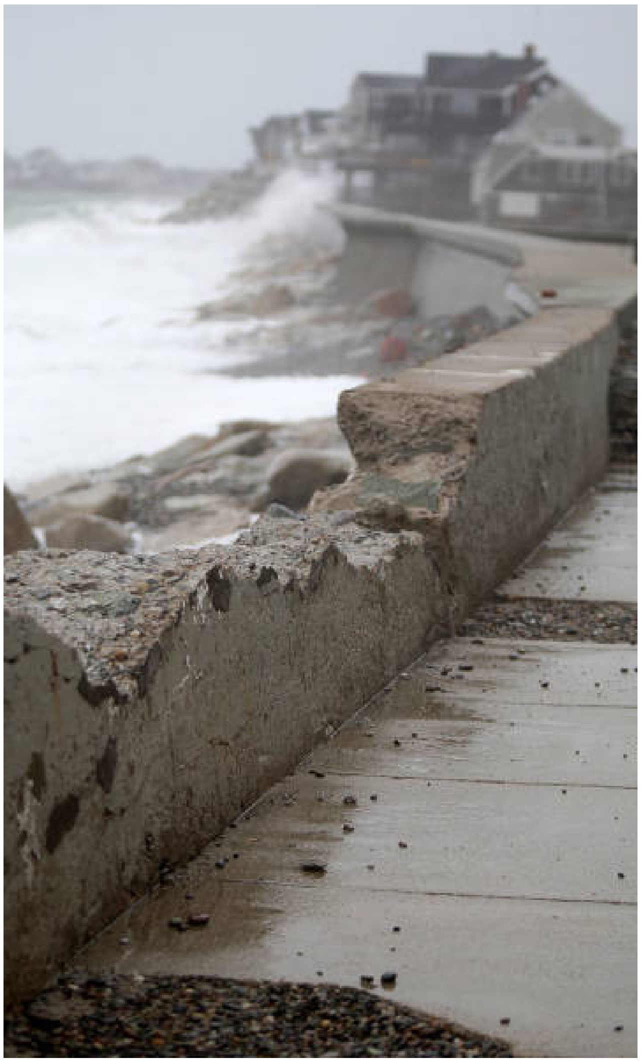

Plate 1. . Seawalls deteriorate with age and damage from storm events.

A recent report assessed more than 1,300 seawalls and other coastal barriers along the Massachusetts coast (USA). Overall, 92 percent were considered stable, but over 100 were in urgent need of repair. The report noted that most sea walls were older than 50 years — a sea wall's expected life and most were in need of substantial upgrading to accommodate climate change. The anticipated cost to the state is quoted as in excess of one billion dollars. Source: Boston Globe, April 4th 2011.

Discussion

Use of a Seawall

Coastal protection structures have been constructed since the earliest periods of human civilization. The first harbour of Alexandria with associated breakwaters and seawalls was constructed by the Minoans, west of Pharos Island around 1800 BC. In Great Britain, evidence of coastal works and seawalls to limit inundation, date back to the Roman occupation. In Japan, there is documentation of the Ohwada Domari (harbour) from 1172 AD This construction includes an artificial island and protection structures comprising 1.4M m^3 of earth and rock (Kraus ed.1996).

Traditional protection works in Australia are comparatively more recent, following European settlement and based largely on the experience in Great Britain where a rapid growth in shipping and associated infrastructure was occurring around that time. The construction of the Macquarie Pier, closing off the southern entrance channel to the Hunter River at Newcastle and joining Nobbys Head to the mainland was the first major public works infrastructure constructed in Australia, commenced in 1818 and completed almost thirty years later (Strachan et. al. 1997).

Seawalls are generally constructed to provide protection to land, assets or people on their landward side. They are not seen as the only appropriate solution to an erosion problem. On a sandy ocean beach where the sole objective is the protection of existing or proposed development and the maintenance of the sandy beach amenity for community use is also highly valued, a range of other options are available that should be appropriately considered. The use of a seawall is generally the solution of last resort, effectively drawing a line beyond which the ocean cannot be allowed to proceed, protecting the land behind rather than the beach.

They have usually been placed in response to some actual coastal erosion event or to address a perceived threat prior to it occurring. Often the community perception that a seawall causes erosion and loss of the beach is misinformed, an incorrect correlation being drawn between the pre-existing storm damage and the apparent reduction in the beach width and level once a seawall is constructed. While a vertical smooth faced seawall, placed well forward in the dynamic swept prism of the beach and impacted directly by storm waves may result in substantial wave reflection and increased scour of sand adjacent to the seawall, as well as significant wave overtopping heights, this does not need to be the case. Appropriately designed sloping seawalls with a rough surface and porosity, can reduce wave reflections and wave run-up levels below those that would exist on a natural, saturated sandy beach or vertical sand erosion escarpment. If sited sufficiently landward on a stable beach, they are only exposed during extreme erosion events – a last line of defence –and may remain buried and vegetated for much of the time. The pending shoreline recession likely to occur with sea level rise may make this scenario less likely in the long term as shorelines translate landward.

The primary design objectives of a seawall for protection are:

- To limit the landward excursion of waves during a storm event and thus protect the assets located on their landward side.
- To limit the volume and extent of wave overtopping during storms which may result in flooding or damage to assets located landward of the structure.
- To retain and stabilise the land behind the wall so that it can be used.
- To minimise the adverse impacts from the seawall either along the beach or immediately seaward of the seawall.
- To minimise the damage to the structure and hence maintenance requirements over the design life.

An experienced coastal engineer designing a seawall for coastal protection will give due consideration to these objectives through the choice of such things as design loadings (wind, waves, water level), crest heights, toe levels, armour size, materials, slope, local sediment transport rates and a maintenance regime. Such considerations are tempered by the location, budget, availability of materials and the significance of failure over the design life.

Plate 2. . Seawalls along Clontarf Beach, Sydney Harbour

Individual seawalls with varying crest and toe heights constructed along a MHWM property boundary. They Include sloping and vertical structures constructed from brick, lightweight concrete blocks, concrete and stone. Photo Credit: Coastal Environment Pty Ltd, 2011.

However, many structures providing coastal protection have not been designed or constructed in accordance with sound engineering principles. Frequently they are built by individuals or groups of residents in response to a storm event or in anticipation of damage occurring. They frequently have not been based on a sound understanding of the design principles and the physics of the storm loadings on the structure. The key areas of failure for such structures are:

- Insufficient toe design and depth. These seawalls are often constructed at the beach level at the toe of the escarpment some time after a storm event. Often the level of the toe is several metres above that required for protection against wave erosion and, depending on the type of structure, this can result in sudden and complete failure during the event that is supposedly being resisted.

- Too low a crest level resulting in substantial overtopping and: erosion of the sediments behind the wall: or direct damage to the wall crest or the assets being protected. Significant overtopping can result in failure of the structure.

- Inappropriate and often undersized construction materials. In particular the use of rock or rubble for armouring often relies on available material and ease of handling, rather than appropriate consideration of the required size and volume of material to resist the wave forces. Often the materials used are clearly inappropriate. The authors have seen structures along the NSW coast incorporating such things as sandbags, hay bales, clays and fine sediments, timber, car bodies, old steel roll-a-doors and one example painstakingly constructed from empty beer bottles. Frequently, the original structure has failed or slumped with additional material or a new wall constructed over the top, an iterative approach to design.

Plate 3. Belongil Spit 2009.

Seawalls may be constructed from a range of materials. Not always appropriate or effective. This photo shows erosion at Byron Bay during 2009. Various types of materials used for past seawall protection are exposed and include car bodies (1970s) small rock (1970 to present), geotextile containers (2000 to present) and building rubble (1980s). Photo credit: David Clark.

However, they are often constructed and maintained with great passion, requiring substantial effort in adverse conditions. Many were part of a community effort to assist an individual or individuals in times of peril and their social value outweighs their effectiveness as a protection structure. That they have not subsequently failed during lesser events may result in a false sense of security and confidence in the protection they provide.

This exacerbates the dilemma faced by Local Government when evaluating their effectiveness.

Climate Change impacts

As climate change progresses, there is a need for ongoing revision of the applicable design conditions for coastal protection structures. While the main change will result from sea level rise, for design purposes this has been simplified by the adoption of benchmark allowances in most Australian jurisdictions for the periods to 2050 and 2100. These will need to be applied for future design purposes. In NSW a sea level rise of 0.4 m to 2050 and 0.9m to 2100 is mandated in the State Government Sea Level Rise Policy Statement (NSW Government 2009).

However, there are other impacts arising from climate change and the response of coastal systems to changing weather patterns. There will also most likely be changes to ocean circulations which will further affect weather. These can vary from location to location and as yet are ill defined for design purposes. The impact on design parameters include:

- intensification of severe storms and change in their range of occurrence;

- changes to wind velocities, frequency, duration and net direction; and

- associated changes in wave climate, including potential changes in direction, frequency distribution wave height distribution and wave periods.

These changes are likely to be outside the currently understood natural variability of climate and until better defined, can best be addressed through a systematic risk based approach to design (e.g. NCCOE 2005).

The majority of informal protection structures have not been designed or have developed in response to hazards over an extended period. Most do not incorporate consideration of climate change and will provide lower levels of protection and experience increased rates of failure as climate changes.

Crest and toe levels

The majority of seawalls worldwide that fail do so because of toe failure. Invariably, during an extreme erosion event, the scour at the toe of the wall undercuts the toe and causes slumping and then collapse. This is particularly relevant for older designs and for informal structures built without design, invariably on a sediment substrate.

Increasing sea levels during storm events and as a result of future climate change most likely will result in landward movement of the nearshore profile with an increase in water depth and lower scour levels. At some locations where there is a strong sediment supply and limited shoreline recession, the opposite may occur with a build-up of the toe level mirroring the sea level rise and a reduction in scour.

Crest levels of seawalls incorporate a design allowance for freeboard above the still water level, to limit the amount of wave overtopping during storms. Existing structures that incorporate minimal freeboard or where overtopping cannot be allowed, will require an increase in the crest level to maintain protection or some other adaptation measure to reduce the incident wave conditions. Where scour depths also increase, there will be an increase in the incident wave height and run-up levels and overtopping may exceed the simple increase predicted from sea level rise alone.

Plate 4. Wave overtopping Fairy Bower, June 2003.

Photo credit: UNSW Water Research Laboratory.

Deterioration of structures

The structures to be considered in this project are invariably maintained as and when damaged, if at all. They are unlikely to include a rigorous monitoring and maintenance regime which is an essential component of any seawall protection strategy.

The materials used to construct a seawall are subject to degradation over time and this may reduce the ongoing level of protection. Coupled with a climate change scenario resulting in increased water levels, possibly increased wave heights at the structure and subsequent increase in the frequency of wave attack, the apparent level of protection can be significantly decreased and degradation increased. In the worst case it can result in failure of the structure. Monitoring programs should incorporate regular inspection of materials and maintenance/replacement as required. Typical causes of degradation include:

- Erosion, wear and abrasion (geotextiles, sandstone armour etc.).
- Fracture (unsound rock, concrete armour units, poured concrete elements)
- Bio degradation and ultra violet radiation (wood, brush matting, textiles, plastics)
- Corrosion (concrete reinforcing, steel sheet piling, fittings and fixtures, support beams).

One of the key outputs from the project will be to identify characteristics of a seawall to be monitored and recorded through Council asset maintenance registers.

Economic Considerations

The cost of seawall construction can become a major driver in the decision making process for consideration of maintenance, replacement or alternative options assessment. Preliminary economic analysis of various decision pathways that may determine the future continuation of a protection strategy and its impact on coastal development options will be examined in this project. This analysis will include the development of a dataset of the type of cost information that is currently held in asset management systems and the additional information that is needed to make appropriate economic analyses.

Guidelines will be developed for undertaking economic analysis for specific case studies based on the information obtained on the current state of particular seawalls; the impact of sea level rise on the viability of the design; the cost of replacement in time frames governed by either the structural integrity or climate vulnerability of the wall, and a broader evaluation of the economic benefit of the coastal protection provided by the seawall.

Conclusions

The project is still in the early stages with briefing of various experts to undertake components of the work in progress. The project will progress swiftly and is programmed for completion by June 2012. The key outcomes and findings of the project may be presented to this conference next year.

The Sydney Coastal Councils Group are keen that the project is focussed on practical outcomes that will assist Local Government in managing the numerous coastal protection structures in their area of responsibility and hopefully to improve the way in which these may be factored into future climate change adaptation decisions. We would welcome feedback, information relating to relevant assessment processes or asset management procedures employed by Local Government and, importantly relevant case studies or examples that may be incorporated in the project. Anyone with a particular interest in the project and the capacity to contribute should contact:

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