Assessment and Decision Frameworks for Seawall Structures

2013

Part A

Synthesis Report

SYDNEY COASTAL COUNCILS GROUP

Coastal Adaptation Decision Pathways Project **(CAP)**

The Sydney Coastal Councils Group (SCCG) is a voluntary Regional Organisation of Councils representing fifteen coastal and estuarine councils in the Sydney region. The Group promotes cooperation and coordination between Members to achieve the sustainable management of the urban coastal environment.

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Cover image: Coastal seawall. Provided by Douglas Lord

Assessment and Decision Frameworks for Seawall Structures

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Preface

Seawalls and protection structures are found at most developed locations around the 30,000 kilometres of the Australian coast. For many of these protection structures construction details are unknown and the capacity of the structures to withstand existing (or future) storm and inundation events is not well understood. Seawall and asset owners and coastal managers (usually local government) may be faced with determining development applications in areas protected by structures of unknown quality and origin (some approved and some not). Often there are issues relating to the ownership, responsibility and liability arising from structures that may be located on public or private lands (or both). Frequently, there is conflict between the coastal managers and the community who have varying impressions of their effectiveness.

This report has been prepared by the Sydney Coastal Councils Group (SCCG) with a grant administered through the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) under the Coastal Adaptation Decision Pathways (CAP) program.

The objectives are:

- to raise awareness of the issues relating to the adequacy of minor seawalls along the coast where no detailed design information or certification is available
- to increase awareness of the implications arising from these structures, and
- to provide guidance to local government in assessing and managing these structures at present and for a changing climate.

This report:

- identifies key risks and issues to local government associated with the management of these structures including potential ownership, responsibility and liability
- discusses available methods to determine the construction and condition of existing structures (including remote and innovative techniques as applicable)
- discusses the key design parameters for small seawalls
- discusses the way these design parameters change into the future with changing climate and the increasing potential for their failure
- discusses the primary failure modes for various types of walls and outlines opportunities for upgrading existing structures as appropriate
- identifies key triggers for initiating upgrading/replacement/removal, and
- recommends the inclusion of their ongoing condition and performance monitoring within Local Government asset management registers.

Outputs from the project are intended to be practical and for direct application by Local Government. This project has been overseen by a technical reference group (TRG) comprised of expertise from Local Government, state government, universities with coastal management expertise, and industry specialists.

EXECUTIVE SUMMARY

Existing seawalls and protection structures exist at many locations right around the Australian coast, where construction details are unknown and the capacity of the structures to withstand existing (or future) storm and inundation events is not well understood. Seawall/asset owners and coastal managers (usually local councils) are faced with determining development applications in areas protected by structures of unknown quality and origin (some approved and some not). Often the responsibility, ownership and liability arising from these structures are not clear, with many constructed entirely or in part on public land. Frequently there is conflict between the coastal managers and the community who have varying impressions of their effectiveness in providing protection and their impact on the public beach.

This project engaged leading consultants to prepare separate reports on determining the nature, condition, performance and suitability of existing structures; defining the key design parameters; discussing the way these may change into the future; outlining potential opportunities for upgrading existing structure as appropriate; identifying key triggers for their upgrading/replacement and economic aspects of their future performance. Expertise provided to the project through separate sub-consultancies includes academics, economists, geotechnical engineers and coastal engineers. The project has been reviewed on an ongoing basis by a National Technical Reference Group comprising expertise from local government, state government, universities with coastal management expertise and industry specialists.

Outputs from the project are intended to be practical and of direct application by local government. They include this summary report documenting the work completed, classification of types of walls and general design/condition indicators for various exposures, templates/checklists to assist local government in identifying, assessing and classifying existing structures, templates and guidelines for incorporating structures into an asset register (including ongoing monitoring, maintenance and upgrading).

Key sub-consultancies for the project are presented in detail in Appendices A to G and include:

- Literature review of existing seawall type, remote sensing techniques, options for upgrading and certification requirements. This literature review was undertaken through the Water Research Laboratory (WRL) at the University of NSW with access to their extensive water reference library. (Appendix A).

- Geotechnical assessment to discuss types of structures and their common failure modes. This study considered aspects of geotechnical failure (lateral loads, drainage, foundation conditions, etc.) that may reduce structure stability and/or lead to future failure with increasing sea levels. Typical opportunities for upgrading such structures as sea level rises are briefly addressed. This geotechnical assessment was undertaken by WorleyParsons together with Pells Sullivan Meynink. (Appendix B).

- Economic aspects of the decision-making process where a seawall already exists but the effectiveness of this protection option may be for a limited time period. This economic analysis was undertaken by Bond University under the direction of the Centre for Coastal Management

at Griffith University. While this work is preliminary, the spreadsheet model developed has been used to identify specific difficulties in selecting key variables and their impact on the modelling results. (Appendix C).

- In undertaking the data collation for the Sydney open coast case study at Bilgola Beach, remote sensing approaches (identified through the literature review) that may provide detail on a buried structure of unknown design were field tested. This field assessment utilised Ground Penetrating Radar (GPR) and air jetting to gain information on the structure of a buried rock seawall without disturbing the overlying dune and vegetation. (Appendix D).

- Case studies were undertaken to inform generic assessment methodologies that might be applied to similar structures elsewhere around the Australian coast. These included an open coast beach at Bilgola on the Sydney northern beaches; an estuarine foreshore at Clontarf within Sydney Harbour; and a review of the implementation of the Gold Coast seawall policy in south-east Queensland. These three case studies are included as Appendices E, F and G. Two of these studies include assessment of the derived structure designs for several seawalls at each location (Bilgola and Clontarf). These were prepared by the Water Research Laboratory at the University of New South Wales (Appendices E and F). Their objective was to develop a 'best estimate' cross-section for the various existing structures and then reverse engineer the design to try to determine whether they could be shown to satisfy current design standards and future conditions (i.e. certified). The third case study was a review of the development of the current Gold Coast seawall which has been constructed in sections over a period of approximately 40 years to a common design and alignment (Appendix G).

The report and Appendices provide detailed information, assessment techniques and discussion of issues on minor seawalls which can be accessed and applied as appropriate at various locations around the Australian coast. Each of the Appendices is a stand-alone document and underpins the broader discussion and recommendations in this report.

Key findings from the study highlight the extent of these structures, the reliance on them as protection works by communities and the issues relating to management, responsibility and liability that they may raise for local government.

The majority of these seawalls comprise rock or rubble, usually constructed in response to some erosion event in the past. Importantly, they have originally been constructed to address or attempt to address some perceived erosion/inundation threat to property. Many have little or no engineering input and are not appropriate to fulfil the intended task. Frequently they are constructed of undersize armour stone with no appropriate filter layer. Toe levels tend to be too high, resulting in undercutting and slumping as the beach erodes. Crest levels are generally too low, with wave and surge overtopping resulting in damage during storm events. This will worsen with future sea level rise. Most are constructed in isolation, with little or no consideration of end effects and the impact that this may have on erosion of adjoining and downdrift properties. Generally there are no design details available and no certification of the structure as fit for purpose. Many are fully or partially buried and therefore difficult to access and assess. A key finding of the analysis is that, even with detailed investigation, it is not usually possible to define fully the fabric of the seawall and to determine all key design issues. As such, it is likely that any post-certification of these structures would be either heavily qualified or not forthcoming.

Key concerns to local government are:

- who owns these structures
- who is responsible for which aspects of these structures
- what liability issues may result from their existence and ongoing impacts, and
- how should they be treated within the context of managing the beach sustainably for the benefit of the community.

It is desirable to resolve these issues so that in moving forward there is clarity to focus attention and investment on adaptation tasks. They are not simple to answer and will differ for each case, but need to be addressed.

In situations where these questions remain contentious and untested, the only answer may be provided through litigation. Outcomes will depend on whether the structures are on private or public land, who constructed them, who maintained them, who played what role during their inception, what knowledge was there of their presence and what contribution have they made to the present-day protection or erosion of the beach. In managing the coast for the future, it is not an appropriate position to simply ignore their existence.

As a matter of priority, each of these seawalls within a local government area needs to be identified and recorded within local government. This may be through the existing asset management records (or a similar register created for the purpose) so that condition and performance monitoring can be undertaken on a programmed basis, issues relating to their management addressed and appropriate decisions made as to their ongoing management and function. Data collection and distribution needs to be improved within council and across communities. Appropriate coastal databases need to be conceived and managed within a framework commensurate with responsibilities. At present, the lack of this information is frequently a constraint for local government decision making.

In the absence of a coastal management strategy adopted by council, the decision by individuals to protect their property without approval by whatever method they deem appropriate cannot be supported. Measures to protect properties should be informed and controlled by sound coastal engineering and planning principles. Protection is <u>one</u> option and should not be viewed as the <u>only</u> option available, particularly in sparsely developed or developing areas. If not addressed, the proliferation of minor, unapproved protection structures has the potential to pre-empt sound coastal management planning based on a strong coastal process understanding. Their existence raises an expectation and, in some locations, a reality of coastal protection as the only viable strategy. This becomes more significant given the scenario of climate change, receding sandy shorelines and higher ocean levels. In some jurisdictions state governments have moved through legislation and guidelines to address these issues, most commonly by trying to limit or prevent such future construction without approval. Ultimately, responsibility for managing these structures falls, or will fall, to local government. Additional legislative support may be needed to assist local government with this task and to remove current uncertainties. In terms of developing integrated coastal zone management plans that consider the whole coastal compartment, they may well prove to be the 'elephant in the room'.

This report provides some guidance for local government in identifying, monitoring and assessing these minor seawalls. It highlights the questions of ownership, responsibility and liability associated with these structures. It canvasses the issues resulting from future climate change and the impact this will have on their future performance. It includes practical tools such as checklists and templates to assist documentation and assessment of these structures for inclusion in an asset management system. Hopefully, it raises awareness of their unintended impact on ongoing foreshore coastal management that must be addressed.

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GLOSSARY

adaptation pathway	A strategy based on implementation of specific actions or works at future times as and when required to mitigate the ongoing impacts of changing climate or receding foreshores. The objective is to achieve the most economic use of land which will be increasingly at risk, without sterilising it unnecessarily. The pathway provides economic certainty to all stakeholders.
armour, armour size	Relates to the individual elements placed on the upper surface of a seawall or revetment to resist the forces of waves and currents on the seaward face. Increasing armour size relates to dimensions or submerged weight of units, commonly rocks.
assets	Commonly used to mean built assets or infrastructure (e.g. houses, roads, sewer lines etc.) but also applied to recognised environmental and recreational attributes considered of value.
beach state	The condition of a beach at a point in time (e.g. eroded, accreted) and usually defined by survey or photographic information. Will significantly affect the quantum of erosion and wave penetration at the back of the beach when a storm occurs.
briefing process	The technical letter engaging a professional to undertake a specific task or to provide specific advice e.g. an engineer certifying a seawall.
Certification	The written provision to an authority by a suitably qualified and experienced professional that an action has been undertaken or a structure built in accordance with the original design objectives and is fit for that purpose (e.g. an engineer signs a certificate stating that a seawall has been constructed in accordance with the design).
crest level	Refers to the highest point on a seawall or the front top edge of a natural sand dune. This level determines the extent of wave overtopping and inundation that will occur to landward.
design life	The period of time that a structure is designed to meet the design objectives. Usually, seawalls are designed for 25 or 50 years but may be longer. Regular maintenance is usually required over the design life.
failure	Used in engineering to describe a solution that does not achieve the original design objectives (e.g. a seawall that is destroyed in conditions less than the design storm event).
geotechnical	Pertaining specifically to soils and foundation stability.
mass gravity	Relating to a seawall which relies on the weight of the structure and frictional resistance at the base to resist any applied lateral loading.
minor structures	Term used within this report to describe that group of seawalls and revetments that have not been approved and/or where the details of the construction and materials used are not known. Commonly the definition is used to describe small structures placed to protect individual properties or assets by persons unknown.
outflanked	At the end of a seawall or where gaps exist in a discontinuous seawall, during storm events waves and erosion can penetrate behind the exposed ends of the seawall, causing collapse of the structure from the landward side.

revetment	An armoured sloping structure which protects the natural sloping land surface from erosion, designed to resist wave erosion and scour. See also seawall.
remote, remote sensing	Applies to data collection using sensors or methods not attached to the object being monitored (e.g. air photos, radar, echo sounding etc.).
rip-rap	Layers of small rocks randomly placed to armour a slope or surface and protect from erosion or scour of the underlying soil mass.
rock mattress	Layer of (usually) smaller sized rock placed along an exposed surface at the crest or toe of a seawall to resist erosion and scour. May be retained in mesh containers (e.g. gabions, reno mattress). See also rip rap.
scour	Erosion of sand by the flow of water, usually adjacent to a hard strata or structure. Commonly refers to the depth of erosion at the base of a seawall below the normal seabed level.
seawall	A structure separating land and water areas, designed to prevent erosion of the land by waves and currents and to retain the fill to the landward side. As used, also includes 'revetments' throughout this project report.
slope	Usually relating to the angle in cross-section of the beach face or the front surface of a seawall or revetment. The slope will contribute to the dissipation of incoming wave energy, affecting the wave runup levels which occur and the extent of wave overtopping.
trigger	Where a decision is not implemented until a particular event occurs or condition is met. (e.g. a seawall is to be removed when sea level rises 0.5 m above 1990 levels.)
toe	Refers to the lowest seaward edge of a seawall or revetment. Failure of the toe by undermining by waves and current is the most common cause of failure of coastal protection works along the coast that are not properly designed.
watertable	The top surface level of groundwater within a soil mass. This water exerts a pressure on the back of a seawall or revetment unless adequate drainage is provided through the seawall to relieve it.

Acronyms

ACCARNSI	Australian Climate Change Adaptation Research Network for Settlements and Infrastructure
CCTV	**C**losed **C**ircuit **T**ele**V**ision
CAP	**C**oastal **A**daptation Decision **P**athways program
DCCEE	Department of Climate Change and Energy Efficiency
GPR	Ground Penetrating Radar
HWM	High Water Mark
NCCARF	National Climate Change Adaptation Research Facility
NSW	New South Wales
PI	Professional Indemnity
SCCG	Sydney Coastal Councils Group
TRG	Technical Reference Group
UNSW	University of New South Wales
WRL	Water Research Laboratory

1. Study Approach

1.1 Objectives of the Project

This *Assessment and Decision Framework for Existing Seawalls* project aims to assist local and state government coastal managers to understand, from a practical perspective, the issues relating to small seawalls that are not appropriately designed and certified. The objectives are:

- to raise awareness of the issues relating to the adequacy of minor seawalls along the coast where no detailed design information or certification is available
- to increase awareness of the implications arising from these structures, and
- to provide guidance to local government in assessing and managing these structures at present and for a changing climate.

'This report is not intended as a guideline for the design and assessment of seawalls nor a comprehensive review of the climate change science. These matters are fully addressed elsewhere.'

The report:

- identifies key risks and issues to local government associated with the management of these structures including potential ownership, responsibility and liability (Appendix A, B, G and Chapters 2.2, 3, 5)
- discusses available methods to determine the construction and condition of existing structures (including remote and innovative techniques as applicable) (Appendix A, B, D, E, F)
- discusses the key design parameters for small seawalls (Appendix A, B, D, E)
- discusses the way these design parameters change into the future with changing climate and the increasing potential for their failure (Appendix A, B, D, E and Chapters 5, 6)
- discusses the primary failure modes for various types of walls; outlines opportunities for upgrading existing structure as appropriate (Appendix A, B, E, F)
- identifies key triggers for initiating upgrading/replacement/removal (Appendix C, D, E, F, G), and
- recommends the inclusion of their ongoing condition and performance monitoring within local government asset management registers (Chapters 3, 4, 5).

This report is not intended to be a guideline for the design and assessment of seawalls, nor a comprehensive review of the climate change science. Detailed manuals and regularly revised and updated publications are already available for these purposes (e.g. USACE 2012, IPCC 2007). Relevant manuals and approaches are discussed further in the appendices (e.g. Appendix A, Section 3.1).

Neither does it in any way endorse the use of seawalls in an ad hoc way to protect specific sections of foreshore. Such an approach is likely to be counter-productive, failing to provide the necessary protection when it is required, and possibly resulting in litigation to address unanticipated outcomes or loss of assets in adjacent beach areas.

Rather, the intent is to raise awareness of the potential issues arising from the existence of these structures and, where appropriate, to alert the coastal manager to potential signs of failure that might require detailed and expert professional assessment now and into the future as climate changes. The guidance provided in this report does not replace the need for that expert advice, but will assist the coastal manager in identifying the issues to be addressed and to ask the appropriate questions in the subsequent briefing process.

Figure 1 Minor protection structures can be constructed from a variety of materials which are not always appropriate or effective

Irrespective of the quality of construction, most seawalls have initially been built in response to a perceived erosion problem and are intended to minimise the landward excursion of the ocean.

As part of the project, checklists to assist coastal managers in addressing the various issues canvassed are included, and templates to assist in gathering information on a systematic basis to assist in monitoring and recording key design elements of these structures have been prepared.

While the project has been delivered by the Sydney Coastal Councils Group, the application of the information included is relevant nationally.

1.2 Methodology

1.2.1 Issues to be Addressed

The initial stage of the project focuses on identifying the key issues to local government arising from the proliferation of unapproved and/or undocumented coastal protection works. These structures are invariably constructed either a long time ago (prior to the need for engineering certification) or in reaction to some real or perceived threat from coastal hazards affecting the stability of an erodible shoreline. In the case of private structures, they are predominantly rock armoured revetments, although a variety of materials may also have been used including sandbags, car bodies, tyres, building rubble and timber poles (e.g. Appendix G, Section 2). Frequently they are constructed during or immediately following damaging storm events, utilising whatever materials are readily available, with limited consideration to sound engineering design practice and with limited resources. They may then be maintained, upgraded and extended during or following subsequent events without taking into account whether the materials originally used are appropriate to the demands placed on them or whether the original work provides an appropriate foundation for the additions.

To a property owner, usually the key issue is maintaining their land and hence the development (or potential) located thereon. As such, the initial response to emergency protection occurs when the erosion of the back beach approaches or actually reaches the seaward property boundary. As a result, such protection structures are preferentially placed seaward of the private boundary or along or close to that boundary.

To a council, this raises issues of ownership, liability and responsibility for the structures, impacts of the structures and the performance or failure of the structures in providing the anticipated level of protection.

The answers to these issues are invariably site specific, including such matters as:

- the timing of the original construction
- the location of the walls (public or private land or both?)
- past history of exposure
- maintenance history, and
- the local planning framework.

Often the resolution of these issues requires legal input, and final resolution may be through court proceedings.

The term 'minor protection structures' is solely to distinguish them from the more significant protection works under the clear control and management of local government, state instrumentalities or certain private and port authorities and where:

- the structure is well recognised
- design conditions are understood and
- regular maintenance, monitoring and management procedures are documented and implemented.

The intent is not to underestimate the importance of these 'minor structures', nor their propensity to become the preferred management strategy by default.

A significant concern to local government with these structures is the lack of documentation and verifiable information on their design and construction. Many are relatively small in size (both length and cross-section) and frequently they are inaccessible (particularly the structure toe and the landward face) or are completely buried. It is difficult to characterise the construction details and structure of these seawalls and therefore, equally vexing to determine their suitability or otherwise for the purpose intended. That they exist is evidence of past coastal hazards threatening assets deemed to be of value. Provided they are constructed on an erodible beach, when they are exposed to storm waves they will impact on the coastal processes and adjacent beach areas, irrespective of their performance in providing protection or of their subsequent failure. This again raises the potential legal issues relating to acceleration of erosion on adjacent land and subsequent liability, as well as the safety issues relating to an exposed and potentially unstable structure.

Figure 2 Often the failure or partial failure of a seawall or revetment is obvious. At other locations they may not even be visible except during storm events

Commonly, where a structure is of questionable construction, the owner/manager will seek to engage the services of a suitably qualified and experienced coastal or geotechnical engineer (or both) to examine, assess and, if possible certify the efficacy of the seawall where it is a necessary component of a single development approval or a broader management strategy. This in itself raises issues, given the problem of positively describing the structure (levels, slope, secondary armour layers, filter layer, cross-section, armour size and density, durability, porosity etc.) For professional liability and ethical reasons, the engineer in providing certification tends to be conservative in providing such assessment. In the recent past, the generally accepted practice in NSW, for example, in projecting coastal hazards for future timeframes (typically 50 years or 100 years), is simply to ignore the existence of these 'minor structures' that have not been designed, documented and certified. While understandable, this approach is also unrealistic as each of these structures, irrespective of their construction quality, was installed to limit the impact of coastal processes, and will correspondingly have some impact on adjacent lands, environment and amenity. Usually these added impacts are not seen as beneficial, particularly by the broader community.

To explore some of the key issues identified above, the approach within this project has been to engage a selection of expert technical consultants, all well recognised in their fields, to undertake specific studies of aspects relating to the identification, performance (present and future) and ongoing management of these minor seawalls (presented at Appendices A to G). Each of the sub-consultants was briefed to address specific issues or questions. In the main, they have focused on the minor, undocumented seawalls that are the core subject of this project. However, in addressing these there is appropriately the inclusion of information on a broader range of seawall construction types and designs. The reports were written to be used as 'stand-alone' appendices and, as such, have been included in their totality within this report. Some of these appendices are also finalised and published as reports in their own right by the companies engaged and where this has occurred, references to that report are included at the front of the relevant Appendix. Because of this preparation of each appendix as an individual unit of work there is, of necessity, some cross-over between the coverage included in each, providing access to the complementary and sometimes contrasting views of the consultants. Also, there is some repetition of information from one Appendix to the next so that they may be read in isolation. Each represents a body of professional advice, prepared by a leading consultant in that field. That advice has not been significantly altered or edited. The reader is encouraged to use the Appendices and to read them in their entirety where the subject matter is of particular interest. The following is a brief summary of these appendices and where appropriate, an outline of the approach the consultants were asked to take.

A key feature of the project methodology was the establishment of a National Technical Reference Group to provide feedback on the various aspects of the project. This reference group included leading practising engineers and government coastal managers from most jurisdictions. Their services were provided on a voluntary basis to review and comment on key aspects of the study as they became available. The role of the TRG was to:

- provide relevant local information and feedback on progress and final research and project outputs
- distribute and communicate information about the project though their networks, and
- provide feedback on the transferability of the project methodology and results to all jurisdictions.

1.2.2 Appendix A Literature Review

The literature review addressed existing seawall types, remote sensing techniques, options for upgrading and certification requirements. This literature review was undertaken through the Water Research Laboratory (WRL) at the University of NSW, with access to their extensive water reference library. The literature review is presented at Appendix A.

The literature review brief focused on:

- defining climate change adaptation within the context of seawall/revetment protection or upgrades
- identifying the key elements and failure modes for small coastal seawall/revetment structures
- remote sensing methods and examples that may be relevant to determining the structure of an existing seawall/revetment (e.g. ground penetrating radar, aerial survey)
- identifying likely impacts of climate changes on design parameters for small seawalls/ revetments (e.g. scour depths, wave height, water level, overtopping, changes to watertable)
- degradation levels of existing seawalls (design life, materials, change to exposure conditions etc.)
- adaptation pathways, options or triggers for existing seawall structures
- economic impacts on adaptation decision making.

Significant findings of the review include the identification of the main failure modes for seawalls and the corresponding coastal hazard resulting in those failures. The review highlights that anticipated climate change will alter the key design parameters, particularly through water level increases and changes to wind and corresponding wave patterns. Existing structures will be exposed more frequently to extreme conditions that they rarely, if ever, experience at present. Specifically, there is likely to be an increase in incident wave loading, seawall overtopping and increasing toe scour.

The literature review presents information relating to the potential upgrading of existing seawalls and the timing and approach to such upgrades. While modifications to address climate change are limited, they invariably result in increasing the mass and scale of an existing structure in the existing location. Generally, this may require larger armour size to resist increasing wave action, lowering of the toe of the structure to prevent undermining and increases to the crest levels to limit overtopping. The complexity of such upgrades is increased by the lack of information on the current structure and how it has been built.

A range of non-intrusive methods of evaluating structural aspects of an existing seawall have been identified and evaluated for their suitability in providing information to assist local government to assess a minor protection structure. The emphasis was on non-invasive techniques. Where a seawall is fully or partially buried, techniques that can be undertaken without excavating or exposing the structure were evaluated. These approaches were preferred in this context as:

- they do not disturb any beach accretion or revegetation that has been undertaken following a storm event, and
- they do not disturb or compromise the fabric of the structure.

Figure 3 A substantial rock armoured seawall has been constructed following storm erosion and is now buried beneath this revegetated sand dune

The general shortcomings of these approaches were evaluated and are presented in detail in Appendix A.

- Firstly, they usually provide information on a single aspect of the structure (such as toe level, crest level, slope or adjacent beach state) but do not provide details on all aspects of the structure. As such, they may be useful for answering specific questions resulting to a structure.
- Secondly, they are generally expensive and require the application of sophisticated approaches using quite varied specialist professional expertise. Such studies may be warranted to resolve particular issues but they do not provide a broad methodology for documenting the construction of such unknown existing minor seawalls.

Remote sensing methods discussed in detail in Appendix A were aerial photogrammetry; boreholes; CCTV cameras, fibre optic deformation sensors; RTK-GPS; ground penetrating radar; infrared thermography; jet probes; parallel seismic; pressure sensors; side scan sonar; step wave gauges; tail scour monitoring; ultra seismic and volumetric tanks. Each has applicability in particular locations or for specific data gathering and monitoring.

For the field case study of a typical rock armoured seawall buried beneath a sand dune on an open coast beach (Appendix E) the ground penetrating radar was trialled and verified with an air jet probe (air drilling) as documented in Appendix D.

The detailed Literature Review is included as Appendix A and includes a comprehensive reference list relevant to the project.

Potential Failure Modes of 'Minor' Seawalls and Revetments

1. Common Failure Modes

- Undermining of the structure toe during erosion events (most common cause of failure). Generally results from the toe being constructed at too high a level, commonly against an existing erosion slope following a storm event. Wave reflection from the structure face may increase scour levels at the toe as exposure increases.
- Sliding of the structure away from the retained fill. Generally results from poor design/ construction and/or excessive soil/groundwater forces against the structure.
- Overturning or tilting of the structure away from the retained fill. Generally results from poor design/construction and/or excessive soil/groundwater forces against the structure.
- Slip circle failure where the retained soil mass is unstable and moves along a failure plane below the seawall (slip failure).
- Loss of structural integrity when applied loads (soils, waves, currents) exceed the residual structure capacity. This commonly results from inadequate design (toe levels, crest level, armour size and type, structure slope etc.) Contributing causes include undersize armour, loss of armour interlocking, poor drainage, breakdown of materials over time, poor maintenance, etc.)
- Erosion of retained fill. Can result from wave overtopping, elevated groundwater landward of the structure, piping failure through or under the structure. Results in loss of the backfill material during backwash over the crest or through or under the wall where filter materials is inadequate. Once the fill is removed the crest is susceptible to wave overtopping and failure or the wall slumps or tilts landward.
- Degradation of the seawall materials e.g. corrosion, abrasion, fracture, weathering etc.
- Outflanking, where erosion beyond the end of a structure causes progressive failure of the structure from the unprotected ends.

2. Common Reasons for Failure

- Design failure - structure is not designed to withstand the applied impact, soil and hydrostatic loadings. Results in slumping of flexible structures and collapse of rigid structures.
- Load exceedance failure resulting from underestimation of the design conditions or an event that exceeds the adopted design condition.
- Construction failure where the structure is not built in accordance with the design intent.
- Degeneration/material failure where the structure has exceeded the design life, poor or incorrect materials have been used or adequate maintenance has not been undertaken.

1.2.3 Appendix B Geotechnical Considerations

The geotechnical considerations report discusses types of seawalls and their common failure modes. Specifically the brief for this study section considered aspects of geotechnical failure (lateral loads, drainage, foundation conditions, etc.) that may reduce structure stability and/or lead to future failure with increasing sea levels. Typical opportunities for upgrading such structures as sea level rises are also addressed. The broader descriptions of structure types extend beyond just the minor structures (typically rubble revetments) and incorporate different types of structure frequently employed along the coast and estuary foreshores. This geotechnical assessment was undertaken by Worley Parsons and is included at Appendix B.

There are many types of seawalls which are defined as shore parallel structures delineating the boundary between the land and the sea. The major purpose is to protect the landward area from the coastal processes and consequent hazards, particularly during storm events. Most commonly, minor protections structures discussed in this report are informally constructed flexible rubble revetments. Other types of structures described in Appendix B are:

- Anchored bulkhead walls.
- Free standing bulkhead walls.
- Rigid near-vertical concrete and blockwork gravity structures.
- Rigid sloping revetments.
- Semi-rigid sloping pattern-placed unit revetments.
- Flexible near-vertical mass gravity seawall.
- Flexible sloping rock rubble revetments.
- Flexible sloping sandbag revetments.
- Flexible sloping rock mattress revetments.
- Environmentally friendly seawalls.

Professional seawall design must consider all potential loads, including the stability of the retained soil mass as well as the applied storm wave loading. This requires a sound understanding of both the geotechnical and coastal processes.

Seawalls perform in a variety of ways, and there is no set design standard covering all situations, hence the need for considered expert advice. Unlike more regular engineering construction such as building or pavement design, there are not detailed design codes mandating all aspects of the design procedure. The design engineer therefore draws heavily on experience, testing and, where appropriate, laboratory modelling to provide a satisfactory degree of understanding of the likely design performance. While under most conditions the loadings exerted on a designed seawall are well within the capacity of the structure, under storm conditions the loads are significantly larger and can result in progressive or even catastrophic failure of under-designed structures.

The geotechnical report outlines the more common types of failures which are discussed in Section 3 of Appendix B. Typical signs indicating the onset of failure are discussed for each type of failure, together with a detailed assessment of the common failure types for each type of seawall identified.

The seawalls that are considered specifically in this project typically do not have detailed design drawings available. In considering the efficacy of these structures there are key aspects of the design that are significant. Similarly, there are key indicators of partial or potential failure relevant to particular types of designs that can be observed during routine inspections.

Section 5 of Appendix B includes a 'Seawall Preliminary Assessment Form' that is relevant to different structures and may be employed by council staff undertaking routine assessments. This template is not intended to provide a rigorous assessment of the performance of a seawall but rather, as part of a regular monitoring program, provides a practical means for documenting key features of the structures, assessing relevant changes and identifying potential or partial failures which can then be assessed by an appropriately experienced coastal or geotechnical engineer. As appropriate, the format of the form could be adjusted to cover the types of seawall known to exist within the particular local government area.

1.2.4 Appendix C Economic Considerations

The economic aspects of the decision-making process where a seawall already exists, but the effectiveness of this protection option may be for a limited time period, has been investigated and a preliminary Excel spreadsheet model developed to illustrate the impact of various assumptions and decisions on the economic analysis. This appendix was prepared by Bond University under the direction of the Centre for Coastal Management at Griffith University.

The cost benefit approach which incorporates real environmental and usage values for the beach areas has been used to assess the economics of various response strategies to future climate change. In addition to the types of response, the timing of the response has been assessed. The sensitivity analysis undertaken identifies specific difficulties in selecting key variables and their impact on the modelling results. The favourability of each option is impacted differently by the variation in the key parameters. For example, there is an obvious risk to effective management posed by the occurrence of a storm before a management decision has been made, or at a time that precludes strategic options such as efficient planned retreat. The high value assigned to the protection of property and assets underpins the computed Net Present Value (NPV) of a beach compartment for all management options. This high value is assigned irrespective of the current or potential future certainty of protection and reflects the property owners' and the broader community expectation that protection can be readily effected. Far less broadly recognised is the value of the beach itself to non-beachfront residents and non-users of the beach. This non-use value is a significant proportion of the total economic value of the beach.

> *There is an obvious risk to effective management posed by the occurrence of a significant storm before a management strategy/plan has been adopted, or at a time that precludes implementation of viable non-protection options.*

The model has been applied to a generic open coast beach situation using some of the actual values derived from the assessment of Bilgola Beach (Appendix E). The economic study is not intended to be a rigorous assessment of the Bilgola Beach situation and should not be interpreted as such. The adoption of some design values from a known location adds to the realism of the application. The significance of the analysis as presented serves to illustrate the difficulty in selecting the key variables and the impact they may have on the financial performance of the outcome.

In including the Bond University report at Appendix C, the SCCG has elected not to publish the underlying spreadsheet model in its current form, as it is not appropriate for application by inexperienced users or in the absence of detailed local knowledge and input data. SCCG and Bond University would consider making the spreadsheet available on application by persons interested in undertaking further development or research on the approach outlined.

1.2.5 Appendix D Site Field Data Collection

In undertaking the data collation for the Sydney open coast case study at Bilgola Beach, the more promising remote sensing approaches identified through the literature review that may provide detail on a buried structure of unknown design were field tested. This field assessment utilised Ground Penetrating Radar and air jetting to gain information on the structure of a buried seawall, without disturbing the overlying dune and vegetation. Specific field data collection and interpretation was under the direction of Dr. Leonhard Bernold, Associate Professor Civil and Environmental Engineering at the University of NSW. The application of the GPR at the site is part of ongoing research on the use and interpretation of GPR in coastal environments. Final reporting and interpretation was undertaken by the Water Research Laboratory at the University of New South Wales and their report is included as Appendix D.

The GPR data requires very specific and specialised interpretation. The approach was able to identify the location of the surface of specific armour stones (within the dune) and then identify the approximate crest level, seaward slope and toe level for the existing buried structure. This data was confirmed with the air jetting and allowed the development of a potential seaward surface profile to the wall. However, there were significant limitations, requiring assumptions to be included in the developed design profile to be assessed in Appendix E. For example:

- individual, large rocks are more easily resolved than agglomerations of rocks or layers of gravel
- the shape, size and density of the rocks cannot be determined, only the top surface is observed
- specific aerials are required for varying depth of resolution (this study was limited to depths less than 4 m below natural surface)
- the technique cannot be used when the soil mass is saturated (such as after rainfall or high tides) as the technique cannot resolve objects below the groundwater table
- GPR cannot resolve the thickness or number of layers of armour in situ
- clear access to the ground surface is required (low or sparse vegetation)
- a detailed description of the data collection undertaken, together with copies of the raw data collected at the Bilgola site, is included in Appendix D.

1.2.6 Appendices E and F Bilgola and Clontarf Case Studies

The case studies were undertaken to inform generic assessment methodologies that might be applied to similar structures elsewhere around the Australian coast and to identify those issues arising from the existence of these minor protection structures. These include a generic open coast beach assessment and estuarine beach assessment using coastal parameters and structures from existing beaches at Bilgola north of Sydney (Appendix E) and Clontarf within Sydney Harbour (Appendix F). These two case studies are not presented as detailed assessments of the structures at the nominated locations. To do this, further detailed data collection and modelling would be warranted to provide a defensible best assessment. Parameters from the two locations and details of existing structures have been adopted in the assessment. The purpose is to demonstrate the type of coastal assessment that could be undertaken given a certain level of understanding and guided by certain assumptions and budget constraints. The information incorporated in these Appendices is intended to inform the overall study and is a key component of the overall assessment. The main issues identified and proposed actions which could be implemented by local government to assist in documenting similar structures with a view to determining their efficacy are discussed in the remainder of the body of this report.

These two studies were prepared by the Water Research Laboratory at the University of New South Wales. Their objective was to develop a cross-section for the various structures selected and then reverse engineer the design to attempt to determine whether they could be shown to satisfy current design standards and future conditions (i.e. certified).

At Bilgola Beach four separate seawall structures were identified and assessed. The rock revetment overlain by a revegetated and reformed sand dune located to the north end of the beach and backed by private residential development is typical of the group of minor protection structures which are the focus of this study. It was initially constructed in response to an erosion hazard during storms and subsequently upgraded. It has not been exposed or further tested for many years and the actual fabric of the structure is not documented. In reality, there was considerably more information and documentation available for this seawall section than exists for the majority of similar structures around the Australian coast. The remote sensing and detailed literature review have provided further information that was used to define a probable design section for analysis. The missing information and the assumptions incorporated in the assessment suggest that significant protection may be provided by the structure. However, this was not sufficient to permit the certification of the structure as appropriate to current design standards. Two seawall sections that existed nearby to the south permitted a similar assessment to be undertaken of these seawalls fronting public land. While not constructed without approval on private land, they provided an opportunity to apply a similar assessment to a variety of minor structures. In each case, the assessment identified shortcomings with the designs for changing climate conditions. Again, neither structure could be certified.

When existing seawalls (such as earth-backed, rigid masonry structures and flexible rubble mound structures) are examined rigorously, significant unknowns are likely to remain, requiring various assumptions to be made.

A similar analysis was undertaken of three revetments fronting the public foreshore at Clontarf within Sydney Harbour, each of which was of different construction. The three seawalls assessed were found to be inadequate for future climate change and none of the three could be certified as adequate for present-day design conditions. While public structures, these seawalls are adjoined by many private walls constructed along seaward property boundaries and to different designs and standards. The majority of the existing private structures have not been appropriately designed or approved to protect the development on the properties where they are located.

As well as the retrospective assessment of the various seawalls at each location, WRL include in their reports a written description of the potential beach condition existing at each location for a design storm event occurring at present, in 2050 (with a sea level rise of 0.4 m) and in 2100 (with a sea level rise of 0.9 m). These descriptions show a progressive deterioration of these areas with failure of the seawalls, loss of houses, extensive inundation and permanent loss of the existing sandy beach.

The assessments undertaken and reported in Appendices E and F are comprehensive and typical of the type of assessment that could be undertaken for councils trying to determine the adequacy of existing unapproved seawalls. Details of the approach used may vary between consultants. It includes some assessment of the emergency works that can be undertaken as and when the identified structures begin to fail, and outlines appropriate monitoring strategies that can be undertaken to increase the understanding of these structures and to identify imminent failures.

Figure 4 A variety of private seawalls constructed to varying designs and standards along private property boundaries in Sydney Harbour

1.2.7 Appendix G Gold Coast Case Study

The third case study was a review of the implementation of the Gold Coast seawall policy in south-east Queensland, and is restricted to consideration of the open coast beaches. This assessment was undertaken by the Griffith University Centre for Coastal Management and is included here as Appendix G.

The Gold Coast seawall has been constructed in sections over a period of approximately 40 years to a specified design and to a nominated alignment. Where the seawall is fronting private property, the cost of construction and certification is borne by the property owner. The need to construct the wall is triggered by a development application for the site. Where it fronts public lands (such as foreshore reserves or road ends) the cost and responsibility for construction lies with the Gold Coast City Council. The rationale of the approach was to ensure the construction of a continuous protection wall securing upgraded development and public lands throughout the city with costs shared. In addition to the wall construction, the council has also relied on the use of ongoing beach nourishment to maintain usable beach areas seaward of the seawall and to limit the exposure and impact of severe storms on the seawall.

While this case study does not specifically fit the focus of this project (i.e. minor protection structures without approval and of unknown design) it does highlight many of the issues relating to the implementation of a seawall in small, disjointed sections. It also raises issues relating to the adoption of a protection strategy for a long, sandy beach under the prospect of rising sea levels and ongoing foreshore recession.

The study incorporates a review of the history of foreshore protection works along the Gold Coast. Records show concerns with erosion of the foreshore dating back to 1900 and the implementation of protection works since that time. These early works were of varying construction and on differing alignments. Severe storms during the late 1960s and early 1970s led to the development and implementation of the current coastal policy around that time. The length of coastline requiring protection totals approximately 31.5 km. After 40 years there is currently 17.7 km of the seawall in place (approximately56%) with 11.4 km of public seawall and 2.3 km of private seawall remaining to be completed. Of the completed wall approximately 20% of the public wall and less than 70% of the private sea wall has been certified. Based on a typical historical construction cost of $2,300 per metre of seawall, there is approximately $31.7 million required to construct the remaining necessary public and private seawalls and an additional estimated $26 million to upgrade private and public seawalls that do not have a current certification.

> *The location of the protection wall thus delimits a safer zone of use and avoids the projection of properties further on the beach. The Gold Coast seawall is thus regarded as the last line of defence against the sea (Smith 1987).*

In addition to uncertainties relating to the completed wall sections there is also concern that the original 1960s design may not be adequate for severe storm events, particularly given the current projections for climate change which were not incorporated within those designs. There would appear to be the need for upgrade of the existing design (and constructed sections) to ensure appropriate protection from storm erosion into the future. At present the efficacy of the strategy is reliant on the maintenance of a viable sand buffer between the seawall alignment and the ocean. The fragility of that sand buffer has been demonstrated during recent storms that have exposed sections of the seawall. The requirement for regular beach nourishment is likely to continue to increase into the future. Current advice to council has indicated that provided an adequate beach width is maintained, those sections of certified seawall can continue to perform as a last line of defence to 2050.

The ongoing disjointed nature of the seawall poses difficulties should a severe storm event occur prior to completion of the missing wall sections. Where properties are unprotected, erosion is likely to extend landward of the seawall alignment. This could expose properties behind the protection structure to erosion and may compromise the integrity of the walls themselves at locations where they are outflanked. Some beachfront property owners have indicated a desire to have council acquire the power to instruct the owners of property landward of the missing seawall sections to have their sections of wall constructed.

The current policy adopted by council has ensured the security of the development adjacent to the beach for the prevailing weather conditions over the past 40 years. More than 40% of the seawall remains to be constructed, highlighting the extent of the commitment needed for long-term beach protection and the difficulties in achieving this in a progressive fashion. Should a significant storm event occur in the short term before the protection is complete then it is still likely that substantial damage to unprotected areas could occur. It is also likely that such an event would result in litigation between community members and with the Gold Coast City Council as liabilities are determined. To maintain protection to the existing development and along the existing alignment will require an increasing commitment by all parties to maintenance and upgrade of the seawall and to ongoing beach nourishment as climate changes.

The Gold Coast City Council is currently addressing these complex issues. Similar concerns may arise in other local government areas around Australia where protection structures are permitted to proliferate, potentially locking local government into a long-term protection strategy. The issues highlight the urgency in determining and adopting a long-term beach management strategy for all coastal locations.

2. MANAGING MINOR COASTAL PROTECTION STRUCTURES

2.1 NATIONAL PERSPECTIVE

The shoreline of the Australian mainland (excluding islands) is estimated at approximately 30,000 km (Short and Woodroffe 2009). Half the length of this coastline comprises some 10,000 sandy beaches which are eroded from time to time and remain susceptible to increasing recession from any future sea level rise. There are more than 1000 tidal estuaries located at river mouths and an estimated 1500 smaller streams and tidal creeks.

The construction of protective structures to retain key assets and protect public and private property boundaries has been a practice widely undertaken around the coastline since the first European settlement. Governments at various times constructed protective seawalls to divide the sandy beach from the back beach, to provide access, limit erosion and protect assets. Many of these works were substantial and related to maritime transport, which was the key method of transport and trade in the early colonies. One example is the construction of the Macquarie Pier at Newcastle, relocating the Hunter River entrance and joining Coal Island (now Nobbys Head) to the mainland to stabilise the location of the river entrance. This work was one of the first major public works undertaken in Australia and construction lasted 28 years from 1818 to 1846 (Coltheart 1997). Construction of the substantial stone revetment was essentially by trial and error, with many reported episodes of damage to the partially completed structure by storm waves necessitating an increase in the rock size used as the works progressed. Early coastal protection designs were simple and frequently failed, requiring their upgrading over time.

At locations around the coast, development progressed and residential subdivisions were created too close to the beach. Early decisions were made in good faith without a full understanding of the natural fluctuation of the sandy foreshores and their sensitivity to works that interfere with the natural flow of sands or alter the coastal processes. More recently, this trend has continued on an opportunistic basis, ignoring the current state of knowledge on coastal planning and management and under a scenario of a changing climate and sea level rise. A significant impediment to current coastal management is the legacy of these early decisions to permit the use of foreshore lands for purposes that may not be sustainable. More recent decisions (such as in South Australia and Tasmania) have resulted in conversion to freehold of essentially illegal shack development constructed on public land in remote areas. This has extended the length of inappropriate coastline at threat and encourages further ad hoc protection works as owners protect these now valuable assets. In NSW state government has handed responsibility for care and control of many estuarine seawalls to local government, together with the landward foreshore reserves. Many of these structures, while constructed by government, are now in excess of 100 years old and in poor repair, having reached the end of their economic lifecycle. The replacement of these seawalls (some of which are heritage structures) will be at great cost to local government over a relatively short time period. The need for the retention of many of these structures needs to be reassessed, providing an opportunity to alter the shape and location of the shorelines and to return some urban estuary foreshores to a more natural and friendly, vegetated state.

The number and value of properties at risk on the open coast continues to increase. Invariably, the response as this hazard has been realised through emergency protection works and following storms is to try and avoid the loss of property. Protection works have been constructed and upgraded over 200 years since European settlement. For example, at the Gold Coast (Appendix G) erosion protection works commenced in the early 1900s and are still being constructed and upgraded to protect residential development along the Gold Coast City shoreline. Historically these works have been undertaken by individuals, groups of residents, community groups, as emergency responses and with support of all three spheres of government.

For many of these minor protection structures their ownership, the responsibility for their performance and maintenance and any potential liability arising from their failure is increasingly unclear. Structured and coastal process-based coastal management strategies are needed to address these issues before they are settled through litigation.

Figure 5 Many seawalls are constructed during storms as an emergency response to the threat posed to existing development. Few are ever removed once the threat has passed

Settled shorelines and estuaries now include foreshore protection works and entrance training structures around Australia. Some of these have been constructed as major public works projects but many more to provide localised protection, foreshore stability or access. For these localised, minor protection works usually no approvals were given and no designs were prepared, work being undertaken on an opportunity basis using available materials. There is no audit of the number and length of these structures nationally but it is likely they would be measured in thousands of kilometres. As urban areas develop and property prices increase, these minor works proliferate and are upgraded with the clear objective of protecting the private asset. These protection efforts often preceded the broader consideration of regional coastal management. Frequently, impacts on adjacent and nearby shorelines (particularly downdrift) have been ignored. As sea levels rise these minor seawalls will be more frequently exposed to more severe wave conditions, higher ocean water levels and elevated groundwater. Ultimately, they will need to be upgraded or they will fail to provide adequate protection. At many locations the construction of these protection works has resulted in an expectation that foreshores will be protected, even where this may not be the appropriate or sustainable management approach into the future. These unapproved protection works are determining the future shoreline management, locking in future expenditure and causing the loss of coastal reserves and beaches.

2.2 Local Government Issues

Where coastal protection structures have been constructed by persons unknown (either a long time ago or without any formal approval) it is usual that no detailed design information is available to council. Frequently:

- the location and fabric of the structures is unknown as they are not formally recorded in the council records or asset management register
- they may be constructed on private land or on Crown land (or partly both)
- they may be fully or partially buried, increasing the difficulty in assessing their effectiveness and impacts.

Key issues affecting their future management are:

- ownership
- responsibility for their ongoing performance and liability
- potential liability arising from damage to adjacent property or members of the public
- ongoing sustainable management of the beach to prevent adverse impacts.

The complexity involved in gathering the relevant information and implementing an appropriate response, often many years after the seawall was constructed, can result in delays in responding or possibly no action being taken by the managing authority. In most jurisdictions legislation exists to empower or require councils or the state to address these structures and where appropriate to have them removed or made safe. That these issues have not been resolved at many locations around the coast may in the long term create liability issues for government (e.g. Egger vs. Gosford Shire Council 1989, 67 LGRA 304 at 323). This case, while relating to a seawall council knew to be constructed, is generally accepted as having put local government on notice as to the potential adverse impact of improperly sited or constructed coastal protection structures. The ruling sets a basis for the standard of care in coastal management from that time forward.

Failure to respond can also lead to unrealistic expectations from the community and property owners that such self-protection is permissible and ongoing.

A key objective of this project is to raise awareness amongst coastal managers that these issues need to be addressed.

It is important that coastal management should be undertaken on a regional (system) basis in a rational manner, rather than on a local or individual property basis. The objectives and interests of the whole community need to be taken into account as the beach is a community asset usually under the care and control of local government.

These issues are discussed in more detail in Chapters 3, 4 and 5 of this report and illustrated through the independent assessments undertaken and reported in the Appendices.

Figure 6 Private seawalls can be constructed as a landscape feature without due consideration to storm loadings. This elevated toe is exposed above the HWM on the public beach

3. Roles and Responsibilities for the Management of Seawalls

3.1 Public vs. Private Land

A fundamental purpose of seawalls and revetments is to delineate the boundary between the land and the water. Where structures are constructed to protect private property and no planning or approval process is engaged, the construction invariably is located as far seaward as practical in order to prevent any loss of the private property. This is at odds with normal coastal planning practice where any protection structures are usually located as far landward as possible to minimise the frequency and severity of wave impacts, to allow the natural intertidal and back beach areas to fluctuate under normal conditions and to prolong the time until the seawall is permanently within the wave zone on a receding beach or as sea level rises.

Many of these structures have been constructed in haste in response to storm events. They are frequently located along the property boundary, with the structure part on the public beach or reserve and partly located on the private property. Often they are located entirely on the public land, preserving the private property and alienating a section of public land.

The existence of these private structures on public land is generally not approved, and under relevant legislation in most jurisdictions, council or the state would have the right to have the illegal structures removed. Rarely is this remedy pursued. While it may be a difficult position for a government to order the removal of a structure that has been constructed many years ago, recently constructed seawalls are also permitted to remain. Again, the question of a local authority being seen to remove the only protection that exists for a resident's home is not appealing. Should the protection structure be removed (however ineffective or inappropriate) and the property is subsequently damaged or lost shortly after, then the community sympathy may well lie with the property owner.

However, issues for council may well arise from allowing the structure to remain. By neglecting to pursue the removal remedy, government may be perceived to be providing tacit approval to the potentially ineffective protection works. Questions then arise as to where the responsibility lies for ongoing maintenance and necessary upgrading of the structure. These issues may be further exacerbated by the location of the structure partly or fully on public land and in many cases the possible involvement (however minor) of the council or government in the initial construction.

Further complications arise in relation to safety issues relating to the structures that could well result in litigation for liability arising if members of the public suffer injury or damage as a result of a failed structure. The introduction of small size rock and the potential for it to be distributed along an otherwise sandy beach during storms is beyond the control of the authority managing that public space. In permitting the approval of poorly designed and unapproved structures along the foreshores, there is a further risk that they may adversely impact adjacent properties during storm events. The purpose of a seawall is to prevent the erosion of the land behind the seawall. In doing so the erosion and sand supply otherwise gained from the back beach may be transferred elsewhere. Erosion and scour depths are likely to be exacerbated immediately seaward of a seawall during storms (i.e. on the public beach). The occurrences of 'end erosion', where erosion rates are increased at the end of a protected section of coast line, are well documented. Such erosion usually occurs most severely at the downdrift end of a structure and may result in an increase in the erosion of adjacent properties, above what would have occurred had the isolated protection works not been there. Again, this raises the prospect of litigation between the adjacent property owners or between the property owners and the local government authority that allowed the structures to remain.

Figure 7 Increased erosion commonly results adjacent to the ends of a seawall (end effects) as a result of the sand deficit moving alongshore past the seawall and the loss of sand supply from the now protected dune

There is no simple action to avoid the issues which could arise, other than the development and implementation of a coastal management plan or strategy for the beach compartment. The adopted management plan provides certainty as to how the beach will be managed into the future and, if protection options are preferred, steps should be taken to have the existing structures brought to an appropriate standard and integrated with other planned protection works.

Where the strategy does not permit protection works, then the appropriate measures should be taken for the removal of unapproved works and structures located on public land. This should be done in consultation with the property owners, allowing them appropriate time to transition to the requirements of the adopted strategy.

3.2 OWNERSHIP OF SEAWALLS ON A RECEDING COASTLINE

There is significant public debate at present relating to the ownership and right of access to property once it has been eroded by the sea. Where the property is defined by a high water mark (HWM) boundary then the legal boundary oscillates (in plan position) with the high water mark from time to time. Under a regime of coastal recession and in the absence of intervention, the boundary would move landward as the shoreline recedes. One issue is whether intervention is permitted to prevent the landward movement of the high water mark through construction of seawalls or other artificial shoreline protection measures. It is clear that such structures must, in part at least, be located below the high water mark and on public land (the exception may be for a vertical seawall such as sheet piling). The ownership, responsibility for management and maintenance of that portion of the seawall below HWM is not clear.

For right line property boundaries the boundary would appear better defined, although this becomes less clear when the beach recedes so as to be wholly located on the private land, restricting public access and use of the amenity. At some locations on a receding coast and/or a rising sea level, the entire property may eventually be below high water. There is currently legal discussion as to whether private property once eroded by the sea (partly or wholly) reverts to public ownership under the Public Trust doctrine (e.g. Thom 2004, Jackson 2011, Corkill 2012). If this were proven to be the case, then seawalls constructed on private land once outflanked or failed could become the responsibility of local government to manage.

Figure 8 Unapproved structures often encroach beyond the private property boundary onto the public beach

3.3 Construction/Approval History

In order to manage these minor protection works it is necessary to understand their origin and fabric, and to determine who is primarily responsible for them.

Recommendation 1 - *Councils audit and review the coastal protection structures currently existing along their foreshores and incorporate consideration and management of these into their current asset management register and coastal management plans as appropriate.*

The first step requires a detailed audit of existing protection structures within the local government area. This information may already exist for major structures and possibly some minor structures located on public foreshores. Frequently those structures that are located wholly or predominantly on private land and which have not been formally approved by local government are ignored. While it can be argued that council has no responsibility for these and accordingly, no liability that might ensue from their existence, it is likely that this position will become increasingly difficult to sustain. Sea level rise and consequent shoreline retreat will bring these structures progressively into the active foreshore area. It is likely they will be more frequently impacted by waves and there will be an increase in failure and damage both to public and private assets as a result. Not to acknowledge their existence may not be a sufficiently strong position to avoid potential litigation.

A preferred approach is to identify, locate, and document these structures. For those that are not clearly owned by local government, a decision must then be taken to determine the responsible party for their ongoing maintenance or removal (as appropriate) in accordance with the adopted management strategy. It is likely that for such cases legal advice may be required to guide council. The position established and taken by council should then be conveyed to individuals and the broader community.

Recommendation 2 - *Where council believes that they are not the owner of the structure, measures should be taken to identify the responsible party or owner and to advise them of that decision and their ongoing obligations. Legal advice may be required to assist council to determine this issue.*

Information from council or historical records should be reviewed to try and determine the role of various stakeholders in the construction of protection works. This is often complex, with input and funding, materials and advice coming from a range of sources, particularly during emergency response to storms. Each case will be different and may alter the legal position relating to ownership, responsibility and liability that could arise. This information should be clearly documented (where it exists) and should underpin the position taken by council.

In most cases the available information relating to the structures, their construction and performance will be sparse. In this case it is recommended that council implement monitoring programs to bolster the information available for determining the efficacy or otherwise of particular structures. A recommended monitoring approach and information to be recorded is discussed in more detail in Chapter 4.2.

Recommendation 3 - *For minor structures where no certification or design details are available, councils implement a relevant and ongoing monitoring regime to collate data and to gain a better understanding of their history, construction, current performance and likely future performance in providing the requisite level of protection.*

3.4 Implementation of the Coastal Management Strategy

Once a coastal management plan has been prepared and adopted, it is necessary for all future protection works and beach management measures to accord with that strategy. This does not mean that the all elements of the strategy must be implemented immediately and this can include the removal of existing inappropriate protection works. In accordance with the plan, elements of the strategy will need to be implemented at an appropriate time, largely determined by changes to coastal processes and the shoreline as climate changes.

Recommendation 4 - *Structures identified as being ineffective, incompatible with the asset management and coastal management plan or which are dangerous should be removed.*

Just as it is important in developing a sustainable management strategy for the future that existing ad hoc, unapproved or self–interested decisions are not allowed to guide the overall strategy, so it is equally important that as the strategy is implemented, activities or works that are not in accordance with that strategy are not permitted to prevent its implementation.

The elements of any coastal protection strategy under a scenario of changing climate and receding shorelines are well understood. They include some mixture of protection, relocation or adaptation of current land uses in a pre-determined manner. The implementation pathway will be directed by the rate and impact of climate change and economic considerations. The basis for the implementation of elements of the strategy must be clearly understood by all stakeholders in the process at the time the plan is adopted. This understanding provides the necessary certainty to the process and will allow the optimal use of coastal resources as the plan is implemented.

Figure 9 A steel pile and timber plank, cantilevered seawall constructed at the back of the public beach. Erosion behind the wall is backfilled with car tyres

4. The Structures

4.1 Types of Structures

Figure 10 Erosion exposes the crest of a buried seawall which was not visible prior to the storm. The structure and level of the toe are not readily discernible

The focus of this project is the identification and assessment of minor seawall structures, usually built without any detailed design and often without approval. Of most concern are those seawalls constructed in response to storm events, usually along the seaward boundary of private property and usually intended to protect an isolated areas where the beach has eroded. Many of these date back to the 1960s, with some much earlier. However, they continue to be placed and upgraded on some beaches and estuary foreshores to the present. Some times their implementation has included assistance from local government (funding, materials, construction) or they may have been constructed entirely by local government in response to an emergency. Others have been constructed by community, perhaps with the assistance of emergency services and many by individual property owners.

A review of the types of seawalls generally constructed along Australian beaches and estuary foreshores was summarised in Chapter 1 and presented in detail in Appendix B. The different types of structures experience different external loads and work in different ways. There is a clear difference in the design of a structure that is only required to withstand wave and current forces, effectively armouring a sloping, stable soil mass and a near vertical structure that must both support a substantial soil/groundwater surcharge loading and resist varying wave and water levels loading on the seaward side. The design of these structures, which are substantial and which experience severe storm loads while protecting valuable assets, should not be undertaken by trial and error.

A detailed discussion of the formation of a rock seawall fronting private properties at Bilgola Beach is presented in Appendix D and Appendix E. The initial construction was undertaken as a response to storm erosion more than 40 year ago. That initial structure was damaged in 1974, with loss of property and subsequently upgraded by the local residents. Some engineering input was obtained for this upgrade and it is likely that some council support was provided in terms of materials and construction assistance. The existing seawall is buried under a revegetated dune system and extends from the private properties onto the public beach area at depth. While more records and information were accessible for this structure than at many locations, review of the records and further field assessment to try and determine the fabric of this seawall and its effectiveness were inconclusive. Issues relating to ownership, responsibility and liability arising from the existence of this seawall remain unanswered. The majority of these structures tend to be rock/rubble armoured seawalls, frequently with inadequate crest and toe levels (determined by the beach levels and escarpment at the time of construction). They usually have inadequate or no filter layers underlying the armour which is often of poor quality and/or inadequate armour size. The material used for construction often includes whatever can be obtained readily at the time/cost and that can be placed utilising available equipment or manually. Some are substantial but many are inadequate.

Other seawalls are often found in metropolitan areas and have been constructed by local government or communities (or both) either to address some perceived threat or as landscaping features separating back beach reserves and facilities from the sandy beach. Again, examples of a number of these structures were examined at Clontarf and Bilgola and are reported here in Appendices E and F. These types of wall are usually linked to the development of the back beach area and can date back over 100 years. Invariably there are no design details or cross-sections available. They have frequently already exceeded any reasonable design life for this type of structure (usually 25 to 50 years) and were not constructed with any consideration of current design standards. Their construction type is highly variable including substantial gravity walls of heritage construction using dressed sandstone blocks, vertical concrete retaining walls, rock armoured revetments, sheet piled structures (with or without anchors) and dry stone walls with little or no mortar. As the origin of some of these structures was from a landscape or retaining wall perspective, they have not been constructed with the primary objective of providing protection from ocean waves but more simply to limit the upper extent of wave runup. The propensity for their failure will increase with climate change and the frequency and severity of coastal process exposure. In the main, these structures are recognised as being within the care and control of local government (or some other government agency) and are most commonly identified in the local government asset register with a nominated replacement value. Frequently there is no formal process for monitoring their condition and performance within that asset register and no firm strategy for future upgrading or replacement. Many of the smaller structures are not listed and recorded, with the question of ownership and responsibility for their performance remaining 'undetermined'. By their existence, they tend to be seen to delineate a boundary between beach and back beach, which is gradually upgraded and strengthened as required. They do not necessarily represent the optimal location for protection works, particularly as sea level continues to rise.

Included in this assessment are those seawalls and revetments that exist generally along the foreshores of estuaries, constructed by both public land managers and private land owners for the express purpose of fixing the location of the estuary foreshore. Again, many of these were constructed long ago to define estuarine foreshore areas when the coastal towns and cities were developed. They may entail tens and even hundreds of kilometres of foreshore protection (e.g.

Sydney Harbour). While commonly consisting of rock armoured revetments or rip-rap, they can cover a wide range of construction types and standards. These estuarine seawalls present additional issues to be managed by local government.

- Firstly, they are constructed in generally sheltered locations (little or no ocean swell exposure) and sometimes with a reduced tidal range due to attenuation of the tides as they move through the estuary. They tend to be of much lighter construction than open coast works. With the increase in navigation within the estuaries over recent years, many of these structures have been subject to increased wave loadings generated by vessels (particularly commercial and public transport), resulting in an increasing rate of deterioration and failure. They are now exposed to larger waves and more frequent wave conditions from these vessels. This will be further exacerbated as sea level rises.

- Secondly, the natural response of the foreshores of an estuary to an increase in sea level will be to migrate landward (erode/recede). This is not compatible with the construction of seawalls to fix the foreshore location and is complicated by the use of high water mark property boundaries in many estuary locations (e.g. NSW Coastal Council 2000, Thom 2004, Clerke 2004). Where the seaward boundary of private land is determined from the landward excursion of the high water mark, property owners have a vested interest in stabilising and, if possible, relocating seaward the legal property boundary. Unless adequately managed, the longer-term risk is for waterway and estuary foreshores to become fully protected with hard structures, resulting in progressive loss of estuarine foreshore habitat and restricted access to the tidal foreshores and the waterways as climate changes and sea levels rise.

4.2 Record Keeping

4.2.1 Asset Management Systems

The asset management system establishes a key component of record keeping relating to the performance, condition and replacement of all infrastructure under the care and control of local government. Major coastal protection works and coastal landscaping/recreation structures are clearly covered by the varying legislative requirements in jurisdictions for councils to prepare and update asset management plans and to make financial allowance for their future maintenance and/or replacement. However, the responsibilities for maintenance and upgrading/replacement/ removal of the minor seawalls discussed in this report are less clear. It is unlikely that most of these structures fronting private property are currently incorporated in formal asset management registers.

The failure to identify and manage these minor protection structures has the potential to result either in a financial loss to the council (through their failure to provide protection) or a resultant loss of reputation where council is perceived by the community to not be meeting their responsibilities to provide protection from natural disasters when a significant failure eventuates. The issues relating to the ownership, liability and responsibility for these structures (discussed in Chapter 2) need to be determined prior to their testing and/or failure during a significant storm event. Otherwise litigation between the community and local government is likely to ensue.

A new International Standards Organisation (ISO) 5500x series (based on the British Standard's requirements specification for the optimal management of physical assets) will for the first time provide an international standard for Asset Management. It will be published in three parts which will align and integrate with other major management systems specifications, ensuring an integrated asset management approach. These include ISO 9001 for Quality Management, ISO 14001 for Environmental Management and ISO 31000 for Risk Management.

This suite of ISO Asset Management Standards will comprise:

- ISO 55000 which will provide the overview, concepts and terminology relevant to Asset Management
- ISO 55001 which will specify the requirements for good Asset Management practices, i.e. the Asset Management System
- ISO 55002 which will provide interpretation and implementation guidance for such an Asset Management System.

The four key principles of asset management are clearly stated in the Draft International Standard ISO 5500 released in November 2012.

1. **Assets exist to provide value to the organisation and its stakeholders**. Asset management focuses on assets and the value they can provide to the organisation. Irrespective of the ownership or construction/approval process, each seawall along the coastline has been constructed at some expense to address a coastal erosion problem (either real or perceived). Structures built by local government and with approval must be incorporated in an asset management system. Other structures should be identified through an audit process and a decision taken as to whether they are the responsibility of local government to manage and maintain. Then a decision must be taken whether to incorporate them in the Asset Management Register. Whether council is the owner or responsible for future management, the existence, condition and performance of these structures will impact on the council finances and resources when storm events occur. This future commitment of both resources and action from local government is increasingly likely as climate and sea levels change.
2. **Asset management transforms strategic intent into technical and financial decisions, plans and activities**. Asset management decisions (technical, financial and operational) collectively assist the achievement of the organisation's strategic objectives. Amongst this is the role of local government in planning for and managing the coastline for the whole community through the preparation and implementation of coastal zone management plans. These require a clear identification of the strategic protection measures that may be implemented and the appropriate standard to which they should be constructed, monitored and maintained. Where protection is not a favoured option then protection works constructed without approval should be identified and removed prior to their failing in a storm event. It is not appropriate to allow the long-term management strategy to be determined through the implementation of works that are not in accordance with the overall management philosophy.
3. **Leadership and workplace culture help determine value realisation**. Leadership and commitment from all levels of management are essential for establishing, operating and improving asset management within an organisation. The future role of these minor protection

structures needs to be determined and appropriate steps taken to either incorporate them in the management strategy or to remove them from the active beach area if that is the favoured approach. To ignore their existence and/or wait until such time as they fail is likely to involve the council in additional and unnecessary expenditure through emergency works, remediation or litigation. While their management may require some hard decisions these should not be postponed, they will only be addressed through the local government authority.

4. **Asset management provides assurance that assets fulfil their required function**. This duty arises from the governance process within an organisation. Its origin is in the stewardship responsibility between the top management of the organisation, in this case the local government authority and its stakeholders. This responsibility highlights issues in managing minor protection works which, while expected to perform during storm events, may not be demonstrably appropriate due to a lack of key construction and performance data. Their failure at a critical time can involve the local authority in considerable cost through emergency management, rectification and damages. Potential safety issues to the public and loss of assets remote from the seawall location can involve local government in expensive and ongoing litigation.

These four principles are presented and discussed in an article published by Engineers Australia (2013) and can readily be considered in terms of the management of protective seawalls or revetments.

Within each jurisdiction there exist state asset management guidelines and policies which establish the appropriate approach and detail required for asset management plans to be prepared by local government. Recent additions include, for example:

- In NSW the Department of Premier and Cabinet Division of Local Government has produced a 'Strategic Plan 2011 to 2015'. This lists as Goal 6 'New South Wales is a recognised leader in Local Government Infrastructure Asset management'. This plan lists indicators and strategies for reaching these goals. For example it states that by March 2013 all councils in NSW will be assessed as having asset management systems that meet national asset framework requirements.
- In Queensland the Department of Infrastructure and Planning in September 2010 published 'A Guide to Asset Accounting in Local Governments'. This guide seeks to clarify and simplify important elements in the asset accounting process, advising that old concepts are no longer sufficient to address the issues being faced, with the new approach emphasising long-term asset management plans and long-term financial forecasts.
- In Tasmania the 'Tasmanian Local Government Asset Management Policy' was published in February 2012 by the Local Government Division, Department of Premier and Cabinet. This policy forms part of the Local Government Financial and Asset Reform Project, a partnership between federal, state and local governments. The project is developing frameworks for long-term financial planning and asset management in all Tasmanian councils that will assist councils to develop and implement:
  - an asset management policy
  - asset management plans for major asset classes, and
  - a long-term financial plan.

Similar state policies and guidelines are applicable to all local government jurisdictions. These will form the basis for preparation of asset management registers and plans for councils in each state. It is important that in preparing these, local government staff look beyond the minimum requirement to the broader objectives outlined through the standards at a national and international level. The performance of coastal protection works during storms is paramount to the retention of the coastal amenity and the protection of the community and assets, including infrastructure. Irrespective of their location (private or Crown land) or the identified responsibility of the various stakeholders, we would argue that these minor protection structures should be incorporated initially in the asset management register and ultimately considered in the asset management plan and subsequent forward funding allocations.

Recommendation 5 - *Councils review their asset management processes specifically in relation to coastal protection structures of all types, determining their future role and how they are proposed to be managed as climate changes. As appropriate future maintenance, upgrading and replacement/removal should be addressed.*

4.2.2 What is Required and What is Recorded?

In determining the types of information that need to be gathered and recorded, these minor protection structures may be assessed in the same way as any asset under the care and control of local government. The following key questions need to be addressed:

1. What protection structures do we manage and where are they located?
   Initially an audit of the local government area is required to identify and document the currently existing structures. This may be difficult as no formal records may exist, some buried or submerged seawalls may not be visible, while others may be located on private property. All available information should be gathered, collated and archived such that it is readily recoverable and added to a database, preferably within the asset management process. Sources for information may include council records, reports, site inspection, historical plans, historical vertical aerial photography, oblique photography, newspapers and community consultation. Where warranted, additional field data collection may be required to determine the location and the condition/structure of existing seawalls. Where doubts exist about responsibility for the seawall, effectiveness and/or validity, these issues should be addressed. Legal advice may be required to resolve specific issues.

2. What is their value to the community?
   Frequently, asset managers relate the value of a structure to its replacement value on the assumption that it will need to be replaced at the end of its design life or if it fails or is damaged. The actual replacement cost will depend on the design conditions, materials, construction process, exposure, design strategy and design life. For the minor structures considered in this report the asset value based on the replacement cost is not a good approach, as the structure may currently provide limited protection and may not be an element of the approved coastal management strategy. Each location must be considered on its merits (e.g. value of assets and infrastructure protected, likelihood of damage, maintenance/upgrade costs, cost of retaining or

losing beach amenity etc.). It is possible that existing structures deemed to be inappropriate and/or inadequate may need to be considered of negative value, requiring expenditure on rectification and/or removal.

3. What is their condition?
   The condition of a seawall relates to its ability to provide the expected protection. This is often poorly defined for the minor seawall structures discussed in this report, where design information is not available and the structure of the wall cannot be positively determined. This issue has been addressed through several of the Appendices to this report (Appendices D, E and F and in Chapter 5). Determining the construction/condition of these seawalls and their ability to be certified as providing an acceptable level of protection raises a major issue for planning future management through maintenance, upgrading and replacement. Again, this will require structure-by-structure merits-based assessment. Where the failure of the structure is not acceptable, immediate upgrade or replacement may be warranted. Where the failure results in minor or localised damage only, a strategy of monitoring and assessing performance data may be sufficient at present.

4. What management actions are required?
   Once an audit is completed and the responsibility for management of each structure is determined, the appropriateness of the structure in terms of a broader management strategy should be considered. Where the structure is protecting public infrastructure/assets and this is the longer-term strategy recommended, then appropriate measures to monitor and maintain the structure should be implemented. Where the longer-term strategy is not for protection then either the structures should be removed or an appropriate trigger for their future removal should be developed and progressively implemented.

5. When should these be done?
   Audit and identification of the ownership and responsibility for existing seawalls should be a priority. Once incorporated in the asset register an ongoing management, monitoring and maintenance strategy must be implemented. The initial objectives are to obtain additional information on the structure and performance of the seawall. In conjunction with the maintenance/upgrade strategy, regular performance reviews should be completed. Appropriate funding should be provided through the asset management plan to ensure that the requisite standard of ongoing protection is continued.

6. What will it cost?
   Costing must include all aspects of the management of the seawall to ensure its performance. This includes monitoring, maintenance, upgrading and replacement, restoration of recreational amenity and environmental values as required. There is a close link between the performance, the maintenance/replacement expenditure for coastal protection structures and the weather. For example, more frequent occurrence of extreme/damaging events will significantly increase these costs. This is further exacerbated by climate change, which will result in the need for future upgrades (irrespective of storm occurrence) and is dependent on the rate of future change for key coastal parameters affecting the performance of a structure (e.g. sea level, wind velocity and direction, ambient wave conditions, ground level etc.) These economic issues may be examined through economic modelling (Appendix C).

7. What is the long-term plan?
   In the long term, planning for protection structures must be coordinated between the key elements of the asset management strategy and the coastal management strategy. Where key assets/infrastructure or values (such as roads, utilities, recreation amenities, ecological sites etc.) are dependent on the protection provided, it is critical that these assets are not compromised through inappropriate failure of protection. Likewise, the inappropriate retention of protection works within areas designated in a coastal management plan for progressive recession under climate change may compromise those objectives. Consistency is required between the protection strategy and the management of the coast. Long-term management of coastal protection structures must be on a whole-of-life basis, incorporating costs for future replacement or removal as appropriate and the lifecycle of the assets being protected.

Recommendation 6 - *Councils identify and address the legal implications relating to ownership, responsibility and liability potentially arising from each structure.*

Checklist for Documenting and Managing Minor Seawalls

1. Documenting/managing existing minor structures

- Determine location, construction and history of known existing structures (beach-by-beach audit).
- Establish position on legality/ownership/ responsibility – seek legal advice as necessary.
- Determine whether individual structures are the responsibility of local government to manage and maintain.
- Document information relevant to existing seawalls and incorporate into asset management system and plan.
- Develop and implement ongoing monitoring strategy to inform asset management plan
- Monitor and document the seawalls during and following storm events, recording performance indicators (e.g. wave runup levels, damage, adjacent erosion), and key design parameters (e.g. toe levels, description of elements of construction, slope).

2. Longer-term response

- Prepare Coastal Management Plan or Strategy.
- Continue to monitor coastline on regular basis to identify any 'newly' constructed seawalls that are not approved.
- Identify additions/upgrades to existing seawalls and document.
- Implement appropriate measures to remove superfluous structures and/or restore the beach amenity.

3. Following a significant storm/erosion event

- Undertake any relevant emergency response to isolate/stabilise structures and minimise potential risk to the public.
- Program repairs or removal of structures that are damaged, as appropriate.
- If structure is not under council control, ensure that the entity/person responsible is aware of their obligations.
- Implement any 'triggers' in coastal management plan (e.g. remove/ upgrade/ reconstruct).

4.2.3 Monitoring and Review

Once the existence of a protection structure is known or identified (through audit), additional information that may be of assistance in future decisions relating to the viability or otherwise of the structure should be collected and recorded for future reference. Ideally, this will involve the documentation of the seawall through a register, either contained within the council asset management system or, if preferred, as a sub-register associated with that system. The difficulties in assessing and certifying a seawall through either inspection or remote sensing methods are fully addressed in Chapter 1.1 and discussed in detail through Appendices A, D, E and F. Where time and opportunity permits, significant detail can be recorded through ongoing monitoring of the structures on a regular basis and immediately following storm events. Appropriate monitoring is discussed in detail in Chapter 5.2 of Appendix A.

Seawall monitoring information can be divided into two main types:

- Condition monitoring
- Performance monitoring.

Condition monitoring is intended to initially obtain information relating to the key design parameters for the structure and then on a regular ongoing basis to identify any changes in these parameters. It can include regular written monitoring reports. The condition monitoring should be programmed at regular intervals as appropriate, irrespective of storm occurrence.

Performance monitoring is intended to provide information showing whether the structure is performing the protection role for which it is intended. It is usually undertaken during or immediately following a storm event, with the express purpose of assessing the performance of the structure during those conditions.

When completed, monitoring information should be collated into a brief report, recording details of the person collecting the data, time and date of inspections or records, and then be incorporated into the council seawall register together with relevant photographs. The value in the monitoring data will increase over time.

A typical Seawall Assessment Form is included at the end of Appendix B. This form is intended for field use by staff with limited experience in seawall design and performance. The purpose of the form is to:

- assist in identifying the type of seawall being inspected
- indicate signs showing the wall is under stress and/or failing
- measure and record key design values for the structure that may not be readily accessible or visible at all times.

The form is designed to assist the user in noting and recording weather conditions, seawall condition and changes. Over time, these records will provide valuable insight into the way the seawall is performing and changing. Completion of the information in the form is intended as a guide only, and should be supplemented with photographs, measurements and notes as considered appropriate.

Typical Seawall Monitoring for Rock Armoured Structures

1. Condition Monitoring

- Photographs showing the structure and surrounding beach (low tide preferable).
- Written description of exposure and condition. Completion of observation sheets where used.
- Scour levels and toe levels (if exposed).
- Crest levels and notes on any damage to crest (dislodgement of units, slumping).
- Slope of the face and any damage (slumping, loss of armour, damage to individual armour units etc.)
- Measurement of size of armour units (typical) including mass and material where known. Number of layers (where visible). Condition of armour units.
- Filter layer (where present and if visible) with description of type (e.g. small rock, graded filter, geotextile etc.)
- Documentation of dislodgement or movement of armour stones.
- Changes from previous monitoring inspections (upgrading of armour, extension of wall, raised crest height, damage to adjacent or landward areas, etc.)

2. Performance Monitoring (storms or post-storm)

- Description of weather and ocean conditions on site (inspection repeated at high and low tide where possible).
- Photographs and description of performance of the seawall (stability, wave reflection, overtopping, estimated water depth, etc.)
- Measurement and observations of level and extent of wave overtopping (post-storm if necessary).
- Eroded beach levels at toe of structure (post-storm).
- Observations and documentation of any damage to the structure, back beach area, beach fronting or adjacent to the structure.
- Broad scale or remote survey data of the areas (e.g. photogrammetric plotting, LiDAR data, hydrographic and ground survey).
- Summary of recorded weather including wind velocities, wave height, wave period, tide levels (recorded and actual), wave overtopping, runup levels, scour levels. As appropriate these will need to be collated following the inspection.

5. Adequacy of Existing Structures

5.1 Need for Certification

Where an engineering structure is designed and constructed to a recognised engineering standard, it is normal to seek certification from a suitably qualified and experienced engineer with either involvement in the original design and/or construction, or who is familiar with the type of structure to be certified and can satisfy themselves that the structure achieves an appropriate performance standard. It is this certification that provides confidence to the owner and the approval authority that the structure as it exists is fit for purpose. In providing the certification, the certifier may need to undertake certain investigations, calculations and/or seek information from other relevant professionals. The certification may be viewed by a council or property owner as de facto insurance, with the backing of the professional indemnity insurance of the certifier that the certification has been appropriately undertaken. In many areas of engineering the certification process is relatively straightforward, with the type of work, quality, materials and expected loadings to be used in the design and construction set down clearly in relevant codes and standards.

In coastal engineering and, in particular, seawall/revetment design this is more difficult, as no standards or codes are available, each structure effectively being a 'one off'. The owner of the structure is relying on the protection provided by the structure for an agreed design period or condition. Similarly the approving authority (often local government) is relying on the fact that the development or building under consideration will be safe from coastal processes and can be considered viable for the design/planning life of the development.

For the minor seawalls under consideration in this study, it is usually the case that no certification of the structure exists. They may have been constructed many years ago during periods of major storm events and beach erosion, or more recently as an attempt to limit erosion of property or to protect infrastructure. Appendix G (Figures 1 and 2) shows seawall construction along the Gold Coast from the early 1900s. It was not until around 1970 that a standard seawall design was agreed for the Gold Coast and much more recently that the certification of all sections has been required.

Most commonly, there is no design information available for these minor seawalls, and in many cases the structures are under-designed and possibly already damaged during past erosion events. Their suitability to provide acceptable protection against coastal erosion during storm events now and in the future is questionable, and there is often friction between property owners, community and the approval authority as to the appropriateness of the protection provided. Other ad hoc structures may be substantial and have withstood past erosion events, but there remains doubt as to the standard of protection and their ability to accommodate rising sea levels in the future. Where the structure must be relied upon for protection, a usual approach is to engage an appropriately qualified and experienced engineer to undertake an assessment and provide appropriate certification. This process is not straightforward. Where there is a good record of the fabric of the seawall, how it has been constructed and of what materials, it may be possible to assess the suitability to withstand future storm events. Good records of the performance of the structure during storm events and regular monitoring of the key elements of the structure can assist this process.

5.2 CURRENT CERTIFICATION ISSUES

While certification is generally sought and obtained for new structures, there are issues that still need to be considered in relying on that certification.

Certification is generally provided in good faith and on the basis of the best knowledge and understanding at the time the certificate is prepared. As time passes, the science progresses and the relevance of the certification may decrease. Best practice will continue to develop and change. An example is provided through the Gold Coast case study (Appendix G) where seawalls have been progressively constructed to a particular design and alignment over a period of around 40 years. Over that period in excess of 50% of the coastline has been protected by a constructed seawall. Of that total length, only 20% of the public seawall has certification while approximately 75% of the private seawall is certified. However Griffith University advises that *The seawall was, of course, designed without incorporating current sea level rise projections, and to date there has been no specific reassessment of the design of the wall under sea level rise constraints*. The certification of individual wall sections may lose currency. After an extended time period they may represent a design no longer considered as best practice, for example not incorporating allowance for increasing sea levels. Where structures are protecting significant investment and the 'as built' design is well understood, it is prudent to undertake regular condition assessment and possibly re-certification of the structure over time. This may entail significant upgrading to provide what is now considered an appropriate standard of protection.

In many cases there will be no records and it may not be possible to determine the construction of the seawall which may be fully or partially buried. Several such structures (open coast and estuarine) were selected for this project and the consultant engaged (Water Research Laboratory) was asked to assess the likely seawall cross-section, determine appropriate design conditions and then to assess the structures for a range of future sea level scenarios (Appendix D, E). For each of the seven seawalls assessed (except one) there were no design details available, although varying amounts of information were available from historical records and photographs. These data were augmented with field assessment and remote sensing to develop a 'best estimate' design section for each seawall which were then assessed, indicating varying potential for these structures to fail into the future. For each of the unknown structures the consultants advised that *When existing seawalls (such as earth-backed, rigid masonry structures and flexible rubble mound structures) are examined rigorously, significant unknowns are likely to remain, requiring various assumptions to be made. Accordingly,* ***it is unlikely that a professional coastal engineer would issue a certificate declaring the suitability of such a structure*** *... to provide adequate protection during a design event, without clarification of these unknowns* (Appendix E, Section 2.7).

Where certification for a new structure is to be relied upon it is usual practice to obtain certification from the designer of the seawall, even though they may not have been involved in the construction phase. It is common in local government to engage an external design service to prepare the drawings and specification but for the construction or supervision then to be undertaken in-house using council resources, often some time after the design/approval has been completed. This may create a 'disconnect' in the certification process as the designer is unable to certify (at a later stage or as required) that the structure was built in accordance with the original design intent. Significantly, during construction, issues often arise from site conditions, availability of materials or available plant requiring modifications to the original design and placement procedures. In such cases, should a failure occur, the first defence of the designer may be that the seawall was not built strictly in accordance with the original design and specification. To avoid this possibility it is prudent to involve the designer during the construction phase and to obtain certification from them that the structure has been built in accordance with their design intent and specification.

As discussed, at least part of the security provided by certification is the backing of the professional indemnity insurance of the certifier. However, the nature of this insurance is not widely understood and is significantly different to other insurance policies. Usually, the coverage provided by the policy is only valid for claims lodged within the year covered by the policy, not for claims in subsequent years against works or services provided during that year. While the responsibility for acting properly and in a professional manner can be raised at any future time (professional negligence), the Professional Indemnity (PI) policy must be renewed each year to provide this ongoing insurance protection for the service provided and must be current in the year the claim is lodged. Other differences may arise from the way in which the policy is detailed (whether claims are cumulative or the cover level resets following a claim in any year of coverage, matters covered by the insurance, no claim limit adopted, number of employees, locations and type of service provided by the consultancy). While these issues are beyond the scope of this report, expert advice should be obtained if the intention is to ensure PI insurance cover to a particular level is accessible across the project life.

Where no certification is available and either certification cannot be obtained or is heavily qualified, providing little certainty as to future performance, a local government authority faces a dilemma. Every opportunity should be taken through the asset management system to identify such structures and to develop a firm position/strategy in respect of their future management, replacement or removal.

Certification for an existing structure without approval or design details should be sought from a suitably experienced and qualified engineer. A definition of a Coastal Engineer and the appropriate qualifications and experience are outlined in Appendix B of the Engineers Australia 'Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering' (NCCOE 2012(a)). In particular, relevance should be given to experience in the design and construction of seawalls and revetments. Where the structure is retaining fill material or there are concerns with foundation or slope stability, geotechnical engineering expertise should also be sought. The letter of engagement should clearly identify the purpose for the certification and the design standard to be achieved. Generally, such certification will be either conditioned or refused, depending on the available information on the structure and the potential exposure to storm waves and surge. The likely impact of failure would be considered.

In preparing the certification it is usual for an engineer to adopt a conservative approach, recognising the unpredictability of coastal processes and the need for an appropriate factor of safety. Engineering advice is governed by the Engineers Australia Code of Ethics (NCCOE 2012(b)) which states *As engineering practitioners, we use our knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future. In doing so,* ***we strive to serve the community ahead of other personal or sectional interests***. Members of Engineers Australia are committed to practice in accordance with this Code of Ethics.

Any conditions attached to the certification should be carefully considered. Where certification is refused, the reasons for that refusal should be considered. There may be an opportunity to upgrade the structure to address any concerns. Alternatively, where the seawall is to be relied on for protection as part of an ongoing strategy, then it may need to be reconstructed.

5.3 Responsibility/Liability of Local Government

A key objective of this project is to raise awareness within local government and with coastal managers as to the likely implications (for them) of the existence of these minor protection works. Critical to this is the identification of who 'owns' the structure, and this may not be easily determined. Again, it is dependent on the location of the structure (on public land, Crown land or both), who built it, when it was built, who funded it, what service it is providing and who has continued to maintain or upgrade it. It is not uncommon for such works to have been constructed by federal, state or local authorities, individuals or community groups, and may have had some involvement from all three. Also important are perceptions as to the responsibilities for and history of such works.

It is common along the coast and estuaries for properties adjoining waterways (where boundaries are defined by High Water Mark) or adjoining foreshore reserves with fixed boundaries, to encroach on the public space beyond their legal boundaries. This encroachment again raises issues for local government as the existence of such encroachments and/or protection works raises liability issues for communities using what are essentially public lands. These works may also potentially impact to the detriment of adjoining or nearby lands during storms. Where practical, such encroachments should be removed to restore public access. Where this is not practical or where such protection works are essential to the existence of the development and so cannot readily be removed, then consideration should be given to providing a lease to the property owners over the affected public land. Such leases could include conditions requiring appropriate insurance against injury or damage, rights to public access to and across the leased portion, regular lease review, maintenance of protection structures and, as appropriate, a sunset clause on the lease.

Figure 11 Ad hoc coastal protection works and landscaping constructed seaward of the property boundaries with resulting loss of the once sandy beach and public foreshore access

Related issues of responsibility and liability are significant and warrant detailed legal consideration and advice beyond the scope of this project. Local government and coastal managers considering these issues are urged to obtain the appropriate professional advice before acting. The following discussions is not a substitute for such advice but is presented from a coastal management perspective to highlight the complexity and potential issues posed by the continued existence of such structures.

Recommendation 7 - *Where liability issues are identified, council enter into discussions with local residents regarding these issues and potential outcomes. Ideally this should be undertaken within a framework of developing and implementing an overall coastal management strategy for the beach compartment.*

The resolution of these questions will cover a broad range of possibilities and will likely be different for individual cases. Many of these questions may not be answerable other than through litigation following a perceived failure of one or more parties to have acted appropriately resulting in an identifiable loss to another party. The proliferation of these structure around all sections of the coast and the impending potential landward movement of sandy beach areas as a result of changing climate will certainly result in these issues taking a higher priority and occurring more frequently as seawalls are exposed, damaged and, in many instances, fail. It is critical, therefore, that relevant information is routinely obtained about these structures and that they are included by local government in an asset management system, progressively monitored and documented. Ultimately, it is necessary for a clear, defensible position to be taken as to where responsibility and liability lies.

Possibilities relating to location for seawalls include, but are not limited to, the following:

- seawall constructed on private property/ies with appropriate access via the private property/ies for future repairs and maintenance
- seawall constructed on private property/ies but requiring access from adjacent private land or public lands for future repairs and maintenance
- seawall constructed partly on private and partly on public lands (commonly the crest is on private land with the seawall face and toe on the public beach)
- seawall constructed wholly on public land but only protecting private property
- seawall constructed wholly on public land and protecting both public infrastructure and private property
- seawall constructed partly or wholly seaward of high water mark, common along estuary foreshores and with increasing frequency along receding open coasts.

Where a seawall is known or thought to exist but the precise location is unknown as it is buried or inaccessible, then investigations may be required to ascertain the location. This is more easily undertaken following a significant erosion event when the seawall is more likely to be partly or fully exposed.

There is currently a significant discussion relating to the potential for future changes to the ownership of these structures as foreshores recede and many will move from the dune to be located on the beach or in the sea. These issues were discussed in Section 3.1 relating to ownership of seawalls on a receding coast. It must also be recognised that the impacts of such seawalls are not limited solely to the protection or otherwise of the land they protect. They have the capacity to change erosion rates on the public lands seaward of their location and to increase erosion and alter alongshore sand movement on sections of the beach (public and private) remote from their location.

Similarly, there are a range of other matters that may determine/influence ownership of these minor seawalls. They include but are not limited to:

- who is responsible for the care and control of the land on which the seawall is constructed
- the seawall was funded by a known entity (commonly the owner of the land)
- origin of the seawall is unknown or cannot be determined with certainty
- funding/construction were from a variety sources e.g. local government contribution but constructed on private property, emergency services or defence services assistance, community project during a storm event etc.
- seawall is constructed as an ongoing response from a group of residents as erosion affects individual properties; ownership is not clearly with any individual owner/s.

In considering a response, a local government authority needs to distinguish between potential responsibility for ad hoc seawalls and potential liabilities that may result from the existence of such structures.

Responsibility relates to the obligation identified for undertaking whatever activity is required to appropriately manage and maintain the asset, or to remove it if it is deemed superfluous, illegal or dangerous. The actions required become manageable once the decision is made to accept or reject ownership of the asset. If council accepts responsibility, it should be clearly identified as a council asset in their asset management system, and then procedures may be put in place for ongoing management, maintenance, budgeting and responsibilities for the asset.

Liability relates to the statutory obligations faced by council in doing or failing to do anything relating to the structure that results in damage or harm. This liability includes but is not limited to loss of property, environmental damage or injury to persons. The liability may arise irrespective of whether the council is seen to be the owner/manager of the seawall or whether it is constructed on public or private land. It may result from a failure to appropriately undertake responsibility relating to the management of a council seawall or failure to fulfil some other statutory responsibility relating to a structure for which council is not directly responsible. Actions establishing negligent liability are serious, with potential fines, damages and other penalties a possibility. Potential actions for liability are varied and could include, but are not limited to, failure to prevent:

- loss of property resulting from an inappropriate structure or failure to maintain or upgrade a structure
- injury or death to persons relying on protection from the structure
- injury or death to members of the public from a deteriorating or damaged structure

- impacts affecting property or persons remote from the structure as a result of the influence of the structure on natural processes (downdrift erosion, loss of beach etc.)
- failure to remove an illegal structure where the council is the relevant approving authority
- failure to prevent significant environmental damage caused by a structure
- failure to take appropriate measures to prevent damage to the structure itself.

5.3.1 Remove or Upgrade?

One risk from the proliferation and retention of unapproved or ad hoc seawall protection is that this process can drive an overall coastal management strategy. It may become a default protection strategy, encouraging an increase of assets within the at risk area so that protection becomes the only affordable option in the short term. The future management strategy for a beach compartment may be determined by a limited number of individuals with vested interests in maintaining the development potential of their properties in the short term. Considerations of economic and environmental issue are bypassed and the final management strategy adopted may not reflect the best option for a particular beach compartment. Where unapproved or ineffective structures are not consistent with the overall coastal objectives, they should be removed.

Where certification of an existing structure is not possible, limited opportunities are available if the structure is to become an element of an overall coastal management strategy:

- The structure may be immediately replaced or upgraded to provide the required protection security.
- The manager may decide to retain the structure while acknowledging the limited protection provided. A strategy for replacement or future upgrading of the seawalls could form part of that strategy. Consideration of the risk posed by failure of the structure should be a key consideration.
- The structure should be removed.

5.3.2 Public Safety

Irrespective of the issues surrounding ownership and responsibility for seawalls which are accessible to the public, safety is paramount. Ad hoc structures located on or adjacent to the public beach are likely to be damaged as and when wave erosion occurs. Frequently, structures are built at the natural beach level existing after a storm event and the toe is undercut as the beach erodes, destabilising the face of the seawall and putting at risk anyone at the toe of the seawall. Similarly, the use of undersize armour stone and/or poor packing of the armour may result in individual rocks moving when disturbed, again posing a risk to anyone on or near the structure.

Figure 12 The historic existence of a seawall or revetment should not necessarily result in the structure being upgraded or even retained

Inappropriate use of materials, including such things as undersize stone, rubble, car bodies etc. may become dislodged from the structure during storms and spread across and become buried within the beach. There are many locations where injuries have occurred through exposure of foreign materials within the beach or with collision with loose and mobile rock on and in the surf zone of an otherwise sandy beach.

Where such structures are accessible and exposed local government with responsibility for managing the beach area should implement an ongoing strategy of monitoring the condition of the structure and removing or addressing any identified hazards.

6. Long-term Coastal Planning

6.1 Coastal Management Plan or Strategy

The minor seawall structures addressed in this project are not implemented as part of an integrated coastal management strategy and plan. In evaluating these structures and determining future management actions it is necessary to place them within this planning context. If they are to form an integral part of an overall protections strategy then this should be developed, approved and adopted for the whole coastal compartment, not just for the individual structure in isolation. If they are not in keeping with the aims and objectives of the adopted plan they should be reconstructed, upgraded or removed as appropriate.

Recommendation 8 - *Councils develop and adopt a coastal management plan, which clearly defines the future approach to sustainable management of the beaches and estuary foreshores under their control, identifies permissible activities and works and is conveyed to relevant stakeholders and community to ensure ongoing certainty in the use and management of coastal foreshores to mitigate future coastal hazard risk.*

In the absence of an integrated coastal management plan for a foreshore compartment, there is always the risk that individual actions, while well intentioned to protect individual properties, can become the de facto coastal strategy imposed on the whole community. This is not good planning and can result in protection that may seem appropriate in the short term, but cannot be maintained in the longer term under the scenario of rising sea levels. The proliferation of such structures around the Australian coast and estuary foreshores can only be adequately addressed through the preparation and implementation of coastal management planning. The minor structures discussed in this report and how they should be integrated or managed forms but one small part of this overall process.

Coastal management planning is a well-defined process using a risk-based approach. It should be underpinned by a sound understanding of the coastal processes which shape the shoreline within a coastal compartment. Without this detailed understanding, there is the risk that measures and works introduced on the coastline may have unintended and frequently adverse impacts on the coastal system. These impacts may be localised, such as loss of a beach area, loss of access or destruction of habitat. Significantly they may result in adverse impacts at other locations along the coast at a distance of many kilometres from the management site (e.g. downdrift beach erosion through intersection of alongshore transport, inundation resulting from changes to estuary entrances, loss of seagrass and other habitat and changes to the recreational usage).

Coastal management planning is entrenched in legislation and practice in each state and territory of Australia. While there are variations between jurisdictions relating to funding and approval processes, the preparation of management plans is based on the same process succinctly summarised in steps and reproduced here as Figure 13.

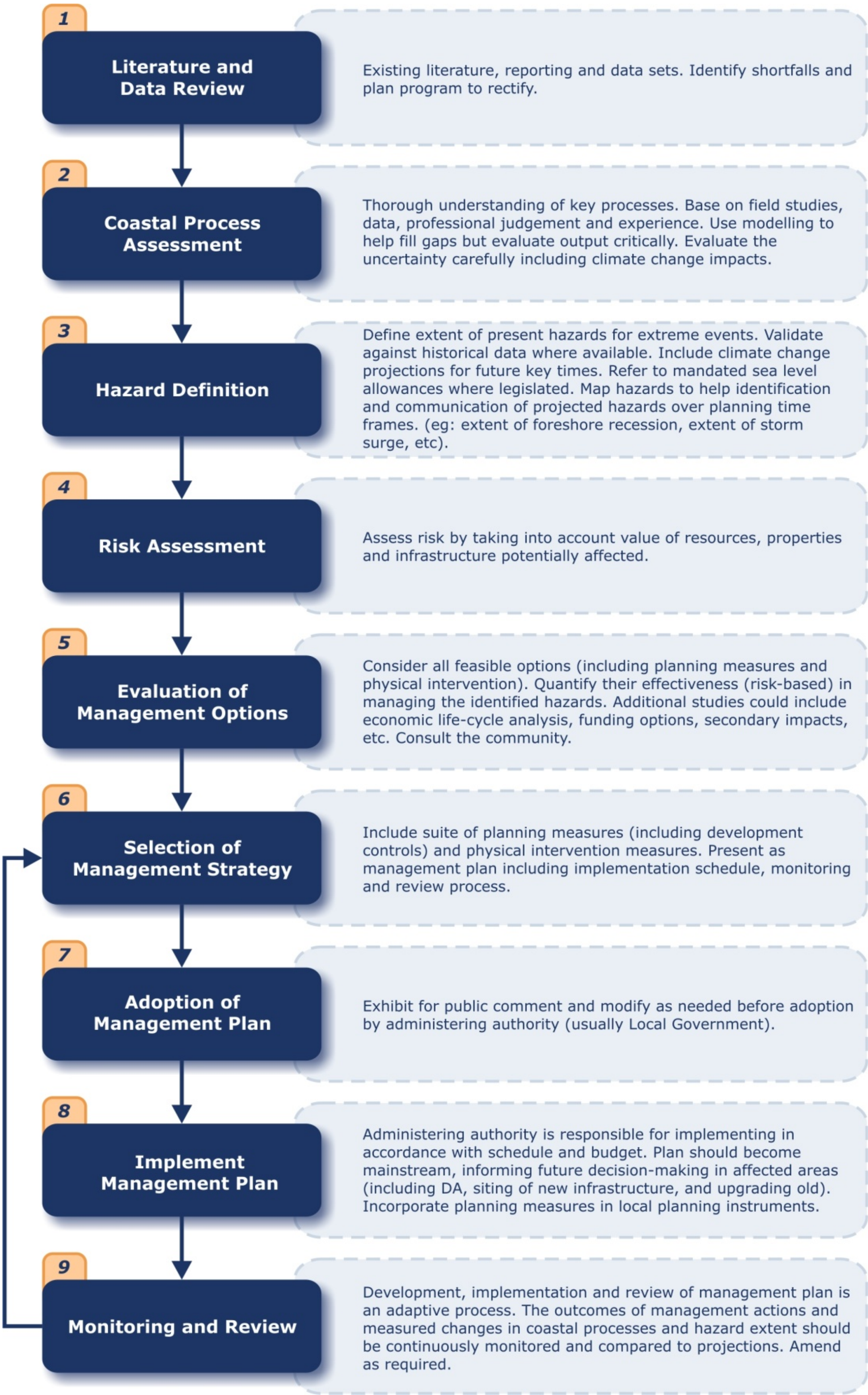

Figure 13 Key Stages in the Coastal Management Process

Adapted from NCCOE 2012(c), Figure 1 Page 6

This management process is based on an understanding of the coastal processes affecting and shaping the coastline now and into the future (steps 1 and 2), definition of the hazards and risks to existing land use and how these might change into the future (steps 3 and 4), evaluation of all management options including structural and planning measures for present and future conditions (steps 5 and 6) and implementation and application of the selected strategy through an adaptive management plan.

The consideration of protection options and how/if they are an appropriate component of the longer-term strategy should be undertaken in steps 5 and 6 of the process **prior** to their implementation. As is often the case with the minor and unapproved coastal protection structures, they should not be driving the process or determining the final outcome.

6.2 Performance Issues

Where the retention of protection structures have been determined to be appropriate and in keeping with the overall coastline management plan or strategy, the issues of maintaining, upgrading and replacing these existing structures into the future need to be managed.

The overall issues relating to the future management and upgrade of minor protection works are common to the management and upgrade of formal protection works that have been designed and approved. The difference is in the uncertainties associated with the minor works which are generally not consistent with modern design standards. Hence, the opportunity to upgrade these structures to accommodate future sea level rise and/or wave overtopping are limited. Complete replacement may be the only option.

There is no simple universal upgrade strategy for protection structures. Each location needs to be evaluated and addressed on it merits. Decisions should be underpinned by rigorous monitoring information. The typical opportunities to upgrade the protection works and to extend their design life as climate changes are discussed in Appendices A and B. Possible responses for specific locations are addressed through the case studies in Appendices E, F and G.

This is where the Coastal Management Plan can be critical in specifying the appropriate design standard for effective seawalls, promoting a clear discussion of costs and impacts, and community acceptability and willingness to accept and finance (in whole or part) the necessary structures. The plan can also identify the future sea level rise, storm severity and frequencies that might trigger upgrades or removal as appropriate. The economic analysis (Appendix C) identified the critical impact of storm timing for the best economic outcome. Any decision to adopt a protection strategy will have consequential flow-on effects on property values and expectations of a long-term commitment by government to maintain the structures. Whether this is practical or achievable must be considered at the time the strategy is adopted. Where adverse impacts are likely at present or in the future then, so far as practicable, mitigating measures should be incorporated in the strategy (such as sand nourishment, providing future access, offset areas for habitat etc.)

Adaptation options for flexible, rock armoured structures relate to:

- measures to raise the crest levels to reduce overtopping and landward damage
- measures to upgrade the size of armouring and so increase the factor of safety of the structure to wave impacts
- measures to armour or lower the toe to address potential increased scour against the structure, and
- beach nourishment to provide an erosion buffer and recreational amenity, if there are available sources of sand.

The timing and urgency of such upgrades will be site specific, dependent on the condition of the structure, what is being protected and the frequency and severity of storm impacts.

The review of coastal protection structures provides an opportunity to review the need for those structures. In many locations they are maintained and upgraded simply because they exist. In particular, in low hazard areas (such as estuary foreshores backed by public land) this may not be the best option, given current available funding and rising maintenance costs. In certain locations there may be an alternative option available through removal of sections of the hard foreshores protection and reverting those foreshores to a 'softer' and more natural shoreline through the use of flatter slopes and appropriate revegetation. Because hard foreshore protection was once deemed necessary, it does not mean that is still the best or only solution.

If the management strategy calls for the removal of the structure at some future time, then there should be clearly defined and measurable trigger conditions that precede the removal. These could include time-based triggers (at a nominated future time), physical triggers (reduction in beach width or volume) or could be linked to a certain sea level rise. Where the structure is expected to fail then the trigger may be based on a condition report or an economic measure of ongoing maintenance costs. It is essential that the trigger is well known and understood by all stakeholders and that it is implemented at the appropriate time.

6.3 Economic Considerations

Economic consideration will generally determine the practicality of a suite of beach management measures that comprise a management plan. Land use decisions being taken at present and which include those decisions by council to upgrade or intensify existing development and land use, will have significant impacts on both revenue and expenditure associated with future coastal management. These issues are explored in Appendix C.

In addition to the anticipated changes in climate, the variability in coastal systems and particularly the frequency or otherwise of extreme storm events will have a marked impact on the selection of the optimal coastal strategy. While certain costs in implementing management measures can be postponed, it is important that the long-term intent of the management strategy is clearly understood and defensible. There is little logic in protecting vulnerable areas or in intensifying development in areas that cannot be protected in the future.

6.4 BEYOND THE DESIGN LIFE

All coastal protections structures exist and perform in the harshest of environments. They are subjected to high winds, high salinity, large waves and currents on a regular basis. During storm events these conditions are extreme and frequently exceed the design allowances. It is generally not economic to design a structure to withstand all damage during an extreme event when the structure may not be subjected to that event during its design life (typically 25 to 50 years).

Normal design practice allows for a certain amount of damage to the structure during the selected design event (commonly defined as 5% to 10% damage for a rock armoured structure). It is also possible that the selected design event could be exceeded during the life of the structure, with higher damage resulting and potentially, failure. The use of flexible rubble structures for coastal protection has traditionally been favoured in response to this design dilemma. They are able to absorb damage without catastrophic failure and can be readily maintained following a severe event by the addition of more armour stone. Other types of seawalls also experience deterioration over time resulting from excessive loadings, material degradation (corrosion, abrasion, fracture etc.) and settlement. All coastal protection structures require careful monitoring and regular maintenance to maintain the design protection level as the structure ages.

<u>Initial design and coastal management planning should allow for this maintenance cost (whole-of-lifecycle costing) and for the eventual removal and/or replacement of these structures.</u>

While protection is a favoured option for developed urban areas, climate change may result in the ongoing provision of protection becoming unviable as sea level rises and wave forces on the protection works increase. At certain locations protection will not be an option indefinitely and may ultimately result in the abandonment of some currently developed localities as the cost and practicality of protection becomes prohibitive. While it is prudent planning to identify such locations in preparing a management strategy, the longer-term scenario should not be used as the sole reason for precluding continuation of current land use. The climate change sciences advise that sea levels will continue to rise well beyond the current 2100 timeframe. However, in non-urban areas where settlement is sparse it may be preferable to restrict further future development (including protection structures) in areas that may not be viable under a rising sea level. In this case, relocation now may be more economic than future protection.

7. Conclusions and Recommendations

7.1 Conclusions

The existence of minor coastal protection structures without certification or approval poses particular difficulties for local government. Council responses should consider the three issues of:

- ownership
- responsibility, and
- liability

that they present.

Where they are located on Crown Land or public land within care and control of council, the issue of ownership and responsibility for ongoing maintenance is not necessarily clear. It is common for protective seawalls to be constructed by individual landowners to protect their property but the seawall is located on Crown land. Where no approval has been sought or given then this issue needs to be resolved. Frequently, such structures are not formally recognised and are not included within the local government asset management system. Usually, no action is taken to incorporate these in a broader coastal management plan, or to remove them. Failure to address this issue early may result in unforeseen liability and responsibility as these structures fail in the future.

Where seawalls are located either partially or wholly on private property then the question of ownership and responsibility for future maintenance needs to be determined. In some jurisdictions, council may have the power and arguably, the responsibility, to ensure that such structures are removed where they have not gone through the formal approval process. Such seawalls were usually constructed in response to some threat or perceived threat from coastal processes which may return during similar or future weather conditions. In some local instances they are simply old works, constructed and maintained since times preceding the need for such formal approvals or are landscape features that have become seawalls as foreshores recede.

These seawalls may be ineffective, ultimately failing, with damage to the assets they are supposedly protecting. A seawall is designed to resist and minimise the landward incursion of coastal processes during severe events. However, this may result in the transfer of storm impacts to adjacent land (seaward or further along the coast), with loss of public amenity and environmental values or, possibly, contribute to damage to adjacent property or assets. As the climate changes, these structures will be subject to more intense and increasingly frequent coastal impacts. In particular, any rise in sea level over time will result in an increase in the frequency of exposure of such structures, raised groundwater levels putting additional loading on the landward side of the walls, increased wave scour at the base of the structures allowing larger waves to impact them and potentially, an increase in wave runup levels and overtopping volumes above those which are currently observed. The risk of failure of these seawalls will progressively increase.

The issue is highlighted when councils are requested to approve developments relying on the protection provided by such seawalls. Local residents, who may have been responsible for the installation of the protection works or who have purchased the property in the belief that the seawall is providing protection, may genuinely believe that the level of risk to their property has been addressed. Where council is the owner or manager of the structure, then there may be an expectation that the design and future maintenance/upgrading would be undertaken by council as and when required. In both these cases, the usual response of council is to request a certification (from an appropriately qualified engineer) that the structure is 'fit for purpose'. This requires consideration of the appropriate design conditions at the time, the structure and condition of the seawall, the remaining design life of the structure and the changes that are likely to occur to present design criteria over that design life. Where the key components of the seawall cannot be determined, then an engineer is unlikely to issue a certification, or at best to condition that certificate. Independent assessment of a variety of unapproved structures documented in the Appendices to this report suggests that this is a likely outcome. The uncertainty of determining precisely the key elements of an existing structure will frequently preclude the issue of an engineering certificate for the structure.

It is important that informal and unapproved protection works are assessed and incorporated in accordance with the council asset management plan and currently adopted coastal management plan. If existing protection works are not compatible with the preferred management approach, are inadequate or are unsafe, then appropriate steps should be taken for their removal or upgrade as appropriate. It is not appropriate to simply fail to acknowledge the role of these structures in shaping the shoreline.

To neglect the existence of these minor works may potentially result in legal liability for councils should the protection works be damaged or fail. Liability can attach to the loss of the property being protected, damage to adjacent lands or development, and injury to the community resulting from the failure or the spread of remnants of the failed structure along the beach and in the surf zone.

7.2 Recommendations

It is recommended that:

1. Councils audit and review the coastal protection structures currently existing along their foreshores and incorporate consideration and management of these into their current asset management register and coastal management plans as appropriate.

2. Where council believes that they are not the owner of the structure, measures should be taken to identify the responsible party or owner and to advise them of that decision and their ongoing obligations. Legal advice may be required to assist council to determine this issue.

3. For minor structures where no certification or design details are available, councils implement a relevant and ongoing monitoring regime to collate data and to gain a better understanding of their history, construction, current performance and likely future performance in providing the requisite level of protection.

4. Structures identified as being ineffective, incompatible with the asset management and coastal management plan or which are dangerous, should be removed.

5. Councils review their asset management processes specifically in relation to coastal protection structures of all types, determining their future role and how they are proposed to be managed as climate changes. As appropriate, future maintenance, upgrading and replacement/removal should be addressed.
6. Councils identify and address the legal implications relating to ownership, responsibility and liability potentially arising from each structure.
7. Where liability issues are identified, council enter into discussions with local residents regarding these issues and potential outcomes. Ideally this should be undertaken within a framework of developing and implementing an overall coastal management strategy for the beach compartment.
8. Councils develop and adopt a coastal management plan, which clearly defines the future approach to sustainable management of the beaches and estuary foreshores under their control, identifies permissible activities and works and is conveyed to relevant stakeholders and community to ensure ongoing certainty in the use and management of coastal foreshores to mitigate future coastal hazard risk.

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