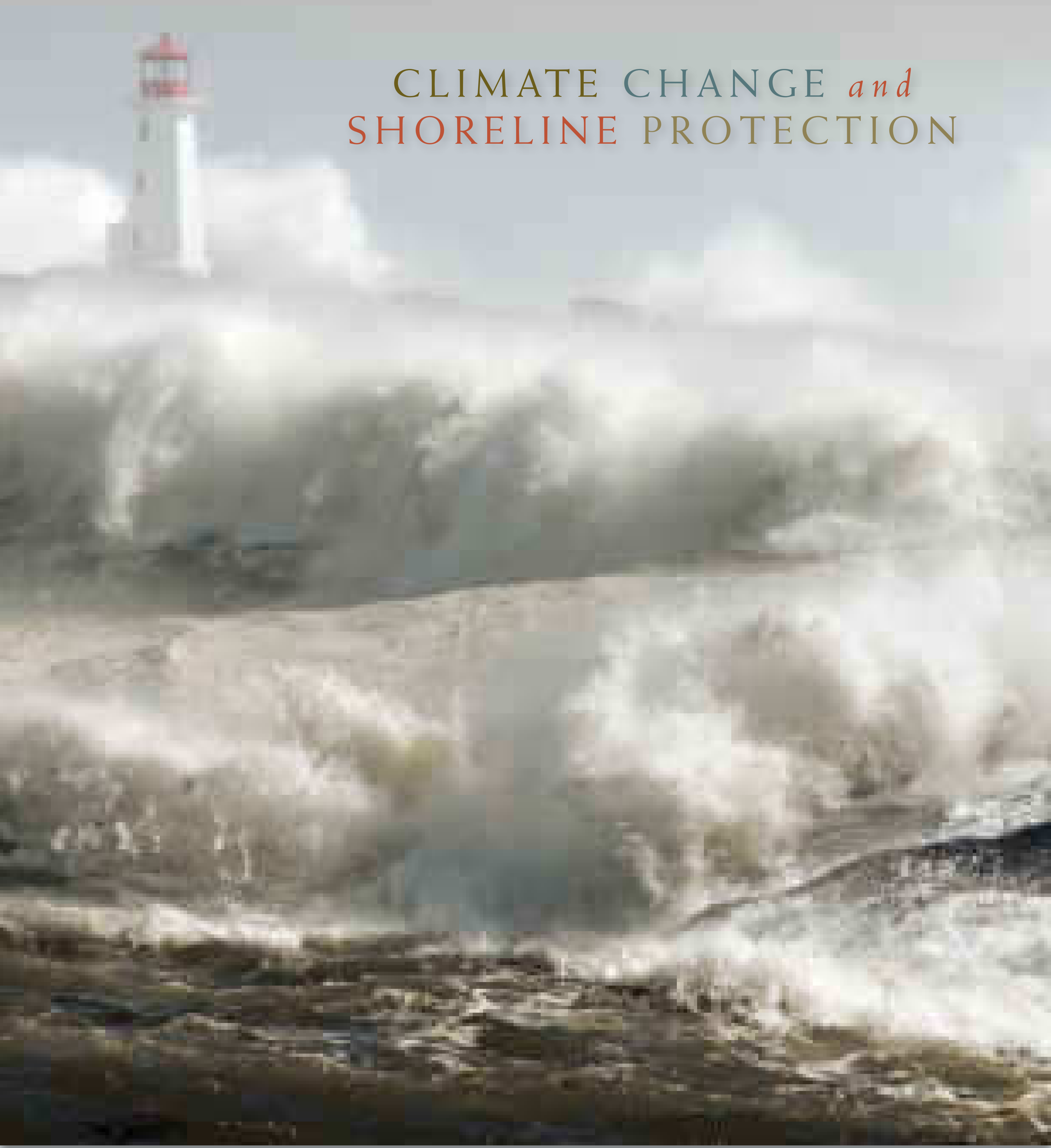
CLIMATE CHANGE *and* SHORELINE PROTECTION



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CLIMATE CHANGE *and* SHORELINE PROTECTION

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ACASA is a non-profit organization formed to coordinate project management and planning for climate-change adaptation initiatives in Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland and Labrador. ACASA is supported through the Regional Adaptation Collaborative, a joint undertaking between the Atlantic provinces, Natural Resources Canada, and regional municipalities and other partners.

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"The edge of the sea is a strange and beautiful place. All through the long history of Earth it has been an area of unrest where waves have broken heavily against the land, where the tides have pressed forward over the continents, receded, and then returned. For no two successive days is the shore line precisely the same. Not only do the tides advance and retreat in their eternal rhythms, but the level of the sea itself is never at rest... Today a little more land may belong to the sea, tomorrow a little less. Always the edge of the sea remains an elusive and indefinable boundary."

Rachel L. Carson
The Edge of the Sea

CLIMATE CHANGE *and* SHORELINE PROTECTION

Contents

INTRODUCTION

Sea level is rising in Atlantic Canada and will continue to rise in the coming century. Coastal erosion will increase dramatically as sea levels rise. Safety margins, or safe setback distances, that protected our coastal communities and their infrastructure for the last 100 years are now gone. To weather the next 100 years, we need new and different approaches. Difficult decisions will be necessary. In some places, the natural process of erosion will be allowed; retreat from the shoreline will be the only option. In other places, the societal cost of retreat will be too large, and a defence strategy will be needed.

A hard, armoured shore is not the only way to defend the shoreline. Other approaches—such as development regulations, sand management, dune restoration, and beach nourishment—are important ways to help maintain the natural beauty of the shore.

Figure 1. Shoreline retreat in North Lake, Prince Edward Island. Ongoing coastal erosion forced the abandonment of Cape Road. (photo credit: PEI Transportation and Infrastructure Renewal).

Figure 2. Seawall constructed to protect the Point Prim Lighthouse in Prince Edward Island. (photo credit: Don Jardine)

Living with the Coast

The sea is powerful. Japan, New Orleans, and even Atlantic Canada (Hurricane Juan and Hurricane Igor) have felt its power in recent years. The sea is constantly changing our coasts, through the actions of tides, storm waves, storm surges, and tsunamis. In undeveloped areas (places without buildings and people), these events are simply part of natural coastal processes. Only in developed coastal areas do they cause problems.

Despite the challenges, people want to live near the water—for the vistas, the air, and the shoreline. Coastal waters also provide valuable resources (fish, oil and gas, aquaculture, tourism, and transportation links) that support local and regional economies. As a result, communities, businesses, and industries have developed along our coasts, and they have great historic and societal value. Their presence in the coastal zone has led to the construction of "coastal defences." Infilling, reshaping, and armouring of the shoreline can provide protection against coastal hazards such as flooding, erosion, sedimentation, and storm damage. But not all coastal-defence approaches provide enough benefit to justify their cost. Erosion along undeveloped shorelines does not warrant protection in most cases because the land is of little value. Erosion in developed areas, though, threatens important infrastructure. The value of the land and the cost of repairing or replacing the infrastructure is often enough to justify, and in some cases require, shore protection. Atlantic Canada's shorelines have changed significantly in the past few decades. Dune systems in both Prince Edward Island and New Brunswick have experienced dramatic losses (Brackley Beach and Bouctouche). Increased vulnerability to storm surges, flooding, and erosion damage (as was experienced in the December 2010 storm) are signs that the coast is under stress. Climate change will only create greater challenges.

Many communities in Atlantic Canada face difficult decisions. What infrastructure should they maintain? What should they abandon? What should they protect? Where will they retreat? These questions apply to key roads, bridges, and water works, as well as homes and cottages. What is needed is adaptation, or strategies for living with the coast and preparing for the effects of climate change.

Adaptation strategies can be either proactive (used in advance, or anticipation) or reactive (used in response). In this paper, we will focus on proactive measures that can moderate the risks of future climate change. These measures include:

- Considering climate change in coastal management planning
- Adopting strategies to moderate harm caused by coastal hazards (retreat, defend, …)
- Developing and adopting standards that help planners, engineers, and architects build infrastructure that can handle increasingly severe coastal hazards

Figure 3. Eroding bluffs in the Town of Souris, Prince Edward Island. (photo credit: Don Jardine)

Climate Change and Coastal Hazards

Coastal flooding, erosion, salt marsh migration, sedimentation, and storm damage are all common coastal hazards in Atlantic Canada. These hazards are influenced by a number of factors:

- Waves are often the main driving force for coastal erosion. Waves are one of the key forces considered in the design of coastal structures. They also contribute to coastal flooding.
- Currents are generated by tides, river flow, wind-driven currents, surges, and ocean circulation.
- Water levels (including tides, surges, seiches, and relative sea-level rise) have an important influence on all coastal processes. In open waters, waves are controlled by the wind speed, direction, duration, and fetch (the distance wind can travel over water). On the Atlantic coast, wave heights of 10 m or more commonly occur during storms. At the coast, waves start to break when they reach a depth equal to twice their height. Inshore of the surf zone, wave heights are limited to roughly one-half the water depth. Out in deep water, a 30 cm increase in water levels has a relatively small influence on a 10 m-high storm wave. At the shore, however, it is a different matter altogether. A typical shore protection, for example, might be built at or above the ordinary high-water mark. Day-to-day waves will not reach such a structure, but severe storms (and their associated storm surge) will, bringing breaking waves with them. These waves increase in size in direct proportion to water levels and the amount of sea-level rise.
- Ice cover (along with wave action) is one of the most important considerations in the design of coastal structures.
- Sediment budgets affect all of these mechanisms in a more indirect manner. The physical condition of the shore has a large influence on the effects of a given wave, water level, or ice condition. For example, the presence of a wide sand beach provides a buffer to keep wave action away from coastal properties. It can encourage the development of shore-fast ice that protects infrastructure from ice forces. It can cover and protect the toe of eroding bluffs to limit bank erosion. The sediment budget—the balance of supply and removal of sediments to and from the shore—controls the health of the beach.

Figure 4. Wave action at Prince Edward Island National Park. (photo credit: Don Jardine)

Many of our coastal areas are already under stress, suffering from coastal erosion, flooding, and development pressures. Climate change threatens to intensify these concerns.

Sea-Level Rise

Relative sea level has risen about 30 cm over the past century and will increase in coming years because of climate change. The Intergovernmental Panel on Climate Change (IPCC 2007) offers a range of predicted sea-level rise over the next 100 years. Based on the best information we have right now, sea level in much of Atlantic Canada may rise between 60 and 76 cm, but could be as much as 120 cm in this century.

Sea-level rise increases the chance of coastal flooding. Higher seas mean that the vertical distance between the water level and land or shore protection structures (i.e., freeboard) is less. Water is more likely to reach land, roads, or buildings during storm events. At the same time, wave height is higher by virtue of the water's being deeper.

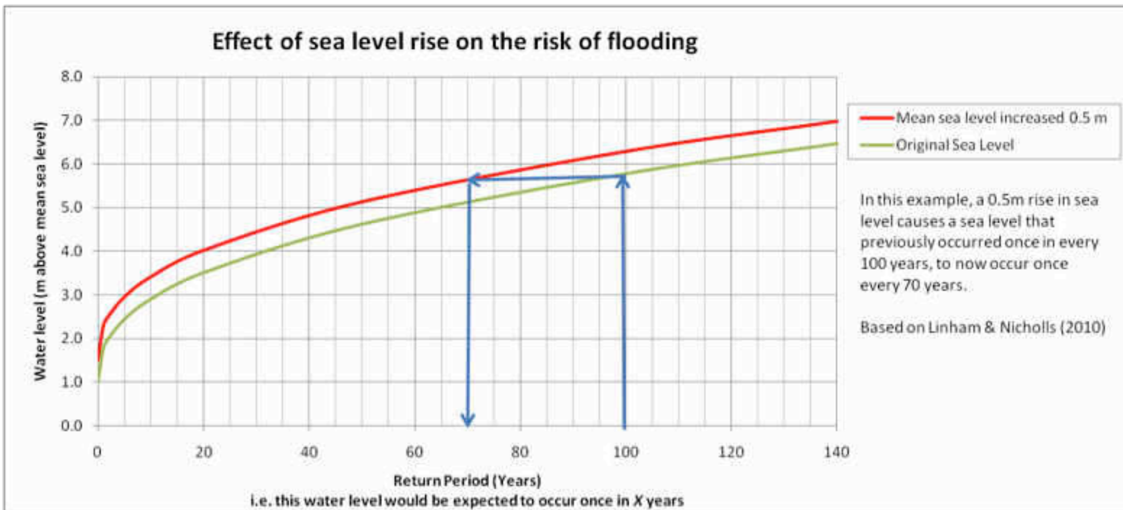

Figure 5. Sea level rise increases the frequency of occurrence of extreme water levels.

Changing Storminess

Changing climate means changing weather patterns and the potential for changes in storm intensity. With climate change, more-frequent and -intense rainstorms are expected. Changes may be happening offshore as well. Storm conditions offshore from Halifax show increasing wave heights over the last 40 years (Fisheries and Oceans Canada 2012; analysis by author). While we cannot be certain that the cause is climate change (rather than better wave-measuring devices or procedures), this trend does support the common perception that severe storms are becoming more frequent and more intense offshore from Halifax.

Figure 6. The road at Queensland Beach (Nova Scotia) after Tropical Storm Noel. (photo credit: Geological Survey of Canada, http://www.nrcan.gc.ca/earth-sciences/natural-hazard/other-natural-hazards/storm-impact/noel/9658)

Figure 7. Storm surge from Hurricane Juan (2003) washed rail cars into Halifax Harbour. (photo credit: Roger Percy and Andre Laflamme)

Coastal Squeeze

As sea levels rise, estuaries and salt marshes have to move inshore in order to survive. However, their movement is blocked when the shoreline has been "hardened" through development (revetment, roads, and communities). This is called "coastal squeeze."

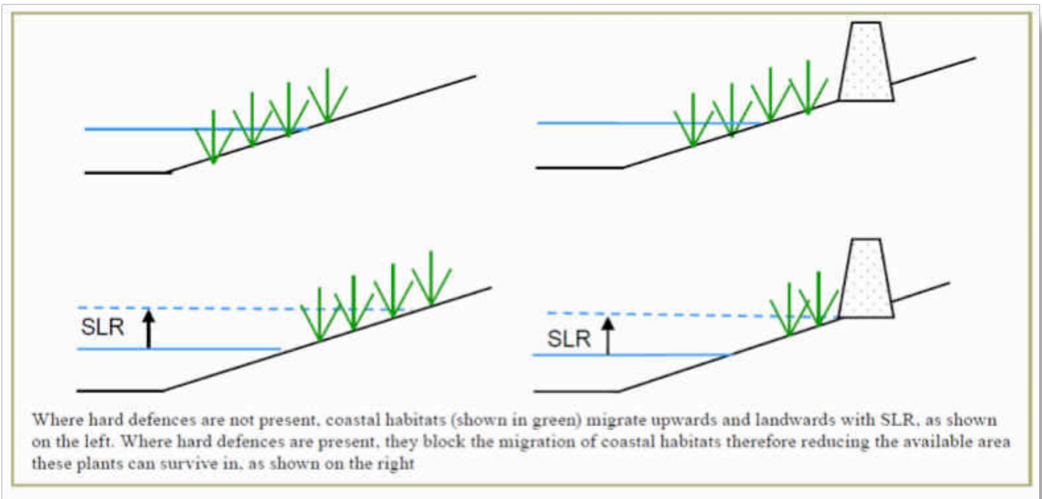

Figure 8. The process of "coastal squeeze" from sea-level rise (SLR). (Linham and Nicholls 2010)

Erosion

Beaches are always adjusting to ever-changing wave conditions. Beaches that are able to spread wave energy across the entire beach equally are in balance or equilibrium (Wang and Kraus 2005). On these beaches, the forces acting to move sand onto the beach (wave-generated currents) are balanced against the offshore forces of gravity and offshore flows such as undertows. Steep winter storm waves pull sand offshore to the break point where bars form, steepening the beach face. Milder summer conditions push sand onshore, resulting in wider, milder beach slopes. Beaches in equilibrium are concave shaped, with the slope of the beach slowly increasing in the landward direction.

Rising sea levels disrupt this balance. Water at any distance from the new shoreline will now be deeper than it was before sea-level rise. The only natural way the beach can re-balance is to erode, adding sediment to fill the bottom to a depth consistent with equilibrium and the new (higher) water level (USACE 2002).

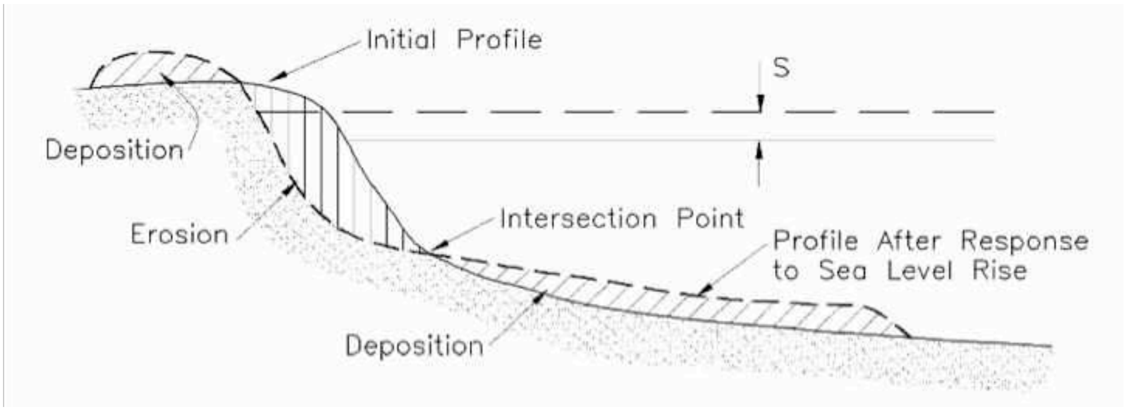

Figure 9. Beach profile response to sea-level rise according to the Bruun rule. (USACE 2002)

The rate of shoreline erosion from water level and wave action is related to both the rise in sea level and the shape of the beach (slope) (Bruun 1962, 1988). On typical sandy shores, for example, erosion can be 50 to 200 times the sea-level rise (this ratio is highest for mild beach slopes and high-energy wave conditions) (USACE 2002). Considering that sea level has risen 30 cm in the last 100 years, this could account for some 15 m of erosion from sea-level rise alone. Predicting real rates of erosion is much more complex than this simple approach, but it can help us understand the response of the beach profile to sea-level rise.

Figure 10. Erosion in Victoria, Prince Edward Island. (photo credit: Don Jardine)

Winter ice is also an important factor. It offers natural shoreline protection from wave action. However, warmer temperatures mean less winter ice. Warmer weather in northern areas such as Labrador will also cause melting of permafrost, resulting in dramatic increases in shoreline erosion.

Coastal Protection

While we are still unsure of the exact size and timing of predicted climatic changes, one thing is clear: we are moving into a period of increased uncertainty. Predicting future conditions based on what we have seen in the past is no longer sufficient. We have to change our designs and the way we make decisions in this climate of increased uncertainty. At its simplest, the response to coastal hazards is to make a decision to either defend the shoreline or retreat and abandon the infrastructure. Some consider abandonment and re-naturalization of the coast the only "correct" approach. A more pragmatic approach recognizes that there will always be coastal infrastructure—whether as an inherited legacy or as part of new development. Here the role of coastal-zone management comes into play. As a society, we need to make informed and strategic decisions about how to live with our coasts. Rather than simply viewing the problem as one of protect or abandon, we should consider a broader range of choices (DEFRA 2008):

1. Hold the Line: Implement or maintain shore-protection works along the existing waterfront or coastline for existing infrastructure and development.
2. Advance the Line: Move the first line of defence further offshore, creating sheltered waters that can reduce coastal hazards while creating recreational and environmental benefits.
3. Managed Realignment: Make strategic decisions about where and how to retreat from the shoreline. This can include new rules for building development, defining areas at risk of flooding and erosion, and establishing coastal setbacks.
4. No Active Intervention: Make a conscious decision not to intervene along the coast.

Some analysts have stated that while protection may be easier for communities in the short term, it can prove to be a more disruptive approach in the long term (Titus and Strange 2008). This could be the case, but the true level of disruption can depend on the type of protection. Poorly designed and poorly built shore protection can offer only a short-term defence against erosion and flooding and can, in some instances, actually worsen conditions. If an area is experiencing long-term erosional pressures, abandonment and retreat may be preferable to shoddy shore-protection works. As well, protection can make it difficult to consider retreating in the future. Short-term retreat can offer greater flexibility, as shoreline protection can still be adopted later (Titus and Strange 2008).

No matter the choice, one must consider more than just a single property or structure when making decisions about coastal hazards. It is necessary to look at the entire coastal system. This includes considering changes to sediment budgets, estuary constrictions, shoreline hardening, and dredging and disposal practices. Local land use, farming practices, and development can also have a big impact on erosion—sometimes a greater impact than storm action or sea levels. Evaluating choices is not a one-time task. It is an ongoing process that requires prioritizing hazards and opportunities, with ongoing monitoring and analysis.

Coastal defences and shore protection can include everything from policies (such as building-code requirements and setbacks) to coastal structures. Adaptation will require a wide range of approaches that are suited to different situations. See Figure 11 for some of the available adaptation approaches (including those that are complementary and competing).

Coastal Protection

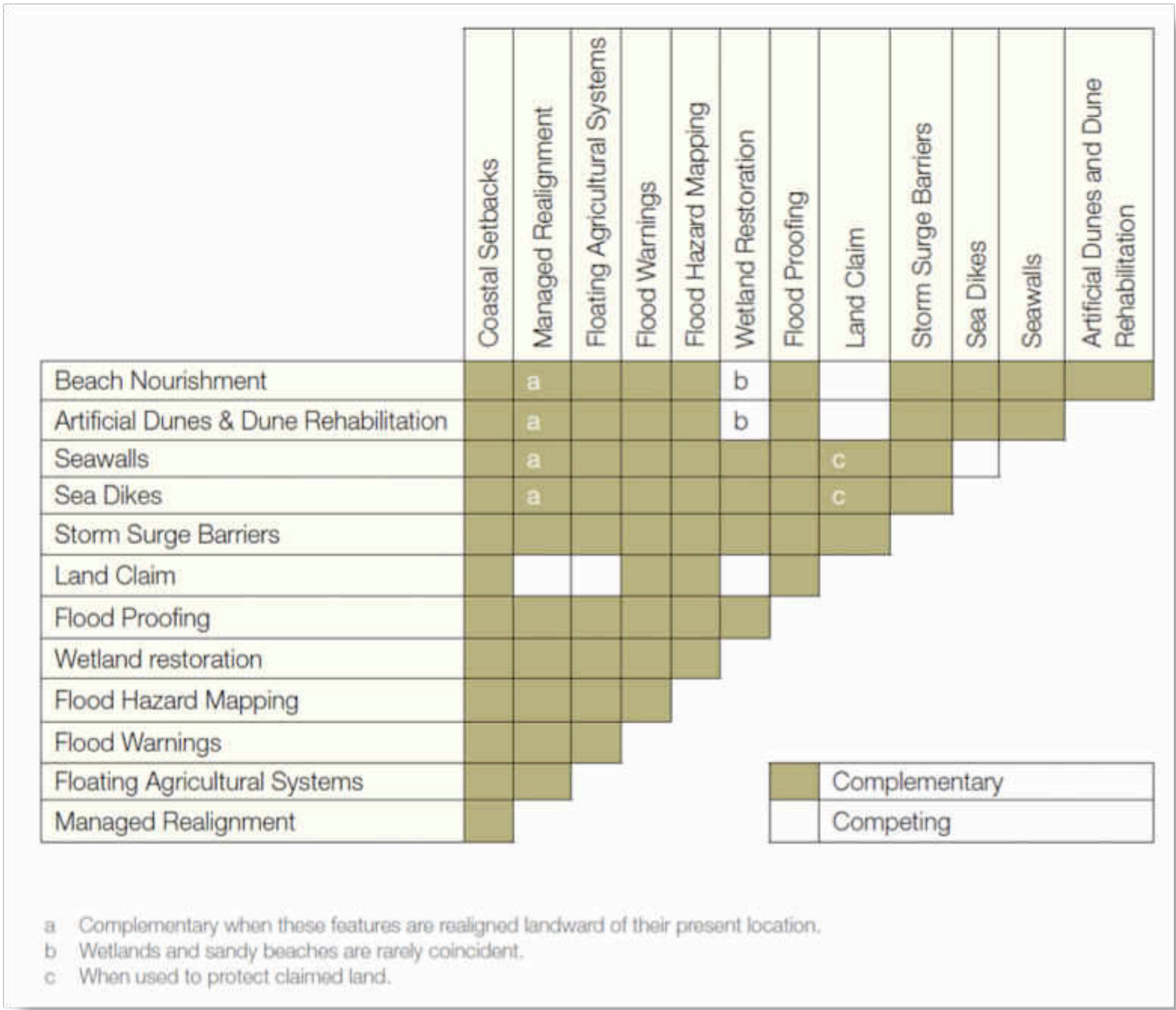

Figure 11. A portfolio of coastal adaptation technologies. (Linham and Nichols 2010)

Coastal structures and shore protection systems can fail. Some of the common causes are:

- Overtopping—high waves and water levels carry water over the structure, damaging the top of the structure and landward facilities
- Structural damage—the structure itself breaks or unravels from storm loading
- Flanking—erosion at either end of the structure triggers instability
- Scour—erosion at the bottom of the structure leading to structural failure
- Geotechnical instability—failure of the structure through sliding, overturning, or other geotechnical failures

Hard Protection

Hard protection, or the armouring of the shoreline, is what comes to mind for many people when they think of coastal protection. The basic concepts of this type of sea defence are quite simple: replace or cover the eroding, low-lying shoreline with a human-made structure that is both large enough and strong enough to protect against storm damage and flooding.

Hard protection can take the following forms:

- Shoreline armouring—seawalls or bulkheads built of armour stone, concrete, or piling
- Flood protection works—dykes, tide gates, storm-surge barriers to prevent floodwaters from entering reaches of an estuary
- Super-elevation—raising the elevation of flood-prone lands to allow development, or raising the elevation of the development itself to be out of harm's way

Figure 12. Three different types of residential shore protection are present along the west shore of Cape Breton: gabion baskets (foreground left), concrete retaining wall (centre) and armour-stone revetment (far distance).

Note that the term "shoreline protection" is often a misnomer. When an eroded natural shoreline is replaced with armour stone, the shoreline has not been protected. The shoreline has been replaced and the shoreline position has been protected. True shoreline protection is more likely to be accomplished with hybrid and soft protection techniques as described in the next section.

Seawalls of Northwest Arm

Halifax, Nova Scotia

Hurricane Juan, Tropical Storm Noel, and other storms have damaged the stone walls lining Northwest Arm at the Dingle and Horseshoe Island Park in Halifax. Repairs to the stone walls are often needed. Wave and water-level conditions at the seawalls have been studied, as well as the present condition of the seawalls and how climate change will affect them.

Both storm surge and waves often overtop the seawalls and cause structural damage. Some of the original walls at Horseshoe Island are now almost 100 years old, built when sea levels were 30 cm lower than they are today. Clearly, as sea levels continue to rise, these walls will have to be rebuilt to a higher elevation to provide the same level of protection. At the same time, the walls have to be made stronger to withstand future wave conditions. But how much higher and how much stronger?

A statistically based optimization process was used to determine the cost (both capital and maintenance) over the next 50 years for a given wall design and sea-level rise prediction. Using climate change scenarios developed by the International Panel of Climate Change and adapted to the Halifax region by scientists at Natural Resources Canada in Dartmouth, we were able to develop the best wall designs that incorporate climate-change scenarios. This is an example of proactive adaptation, in which the effects of future climate change have been anticipated in the design process and the design of the infrastructure has been adapted accordingly. Detailed design work for the first section of wall repairs (at Sir Sanford Fleming Park) has started and will finish in 2011.

Figure 13. Typical high-tide conditions, Northwest Arm, Halifax.

Figure 14. Seawall damage, Northwest Arm, Halifax.

Cow Bay Causeway

Cole Harbour, Nova Scotia

Heading east out of Cole Harbour toward Osborne Head, the Cow Bay Road crosses a 500 m-long causeway built over a cobble barrier beach. Protected by an armour-stone revetment, this causeway has become a maintenance problem over the past decade. Storm waves often overwash the road, carrying with them stones and debris. Waves have ripped up the asphalt road surface several times, and the frequency of storm damage has been increasing. Two factors are causing much of this damage: sea-level rise is shrinking the distance between the causeway and the water level (freeboard), and offshore storm conditions are intensifying, bringing larger waves to shore.

Building a more-effective armour-stone barrier or raising the roadbed of the causeway were both considered as possible solutions. Using a similar approach to that used at Northwest Arm, an optimized design was developed that minimizes total costs (capital and maintenance) over the next 30 years. In the long term, abandoning the causeway and moving the road further inland is likely. For now, rebuilding the protective barrier to withstand higher water levels and bigger waves was the most cost-effective approach for the next 30 years.

Figure 15. Cow Bay Causeway after Tropical Storm Noel, November 3-4 2007. (photo credit: D. Mercer, http://www.nrcan.gc.ca/earth-sciences/natural-hazard/other-natural-hazards/storm-impact/noel/9658)

Salt Marsh Trail

Cole Harbour, Nova Scotia

The Cole Harbour estuary, just east of Halifax, allows a fascinating look at how people can influence a tidal estuary. Before the 1700s, Cole Harbour was an open estuary. In the 1750s, the Acadians built dykes in the upper marshlands to farm marsh hay. In the late 19th century, more dykes were built, including one near the mouth of the estuary. Heavy flapper gates would close during flood tide, leaving much of the marsh dry for pasture and haying. Around 1912, the Intercolonial Railway built a causeway across the marshland, cutting the estuary in two. When the dyke was dynamited in 1917 in efforts to restore trout and salmon runs to the estuary, the salt marshes re-flooded but remained blocked by the rail causeway. With the mouth of the estuary still blocked by what remained of the dyke, the sea created a new entrance to the estuary further to the east. The Trans-Canada Trail now follows the path of the abandoned rail bed and is a popular recreational resource.

Figure 16. Flooding and erosion of Salt Marsh Trail, January 2010. (photo credit: Cole Harbour Parks and Trails Association)

The rail causeway is now 100 years old. Sea levels are some 30cm higher now than when the causeway was built. Maintaining the causeway is on ongoing job that is getting harder as the years go by. High water levels and storm waves regularly damage the causeway. Three options were considered:

1. Keep the trail where it is but rebuild it in a way that reduces ongoing maintenance costs.
2. Take an adaptive management approach that keeps the trail by using culverts and innovative design features such as fords that restore natural circulation patterns and improve water quality and aquatic habitat.
3. Start the planning process to abandon the causeway in favour of a new land route to the north.

As with so many coastal issues, the decision-making process is complex. Making changes to a coastal feature or development is more than simple economics. Community values and their efforts to maintain the status quo must be respected.

One of the biggest challenges facing coastal planners and policy makers in coming years is how to be proactive in adaptation to climate change. Sometimes it is easier to decide not to rebuild a structure after a storm destroys it than to decide on a course of action based on changing climatic conditions—even though in many cases the best decisions may arise from the latter.

Soft Protection

In many ways, the best protection for an eroding shoreline is to build a beach in front of it or to use some other measure to reduce the damaging effects of storms. Often, this means re-establishing a beach that used to exist; but it can also involve building a beach where none existed before.

Soft protection typically involves one or more measures that lessen the damaging effects of storms while improving nearshore sediment stability or abundance.

Beach nourishment is a key part of many soft protection initiatives. In the southern United States, beach nourishment is often undertaken. Sand, found either offshore or on land, is dredged or trucked to re-establish the beach. The success of this approach depends on the amount of sediment introduced and the sequence of storms that follow. Re-establishment of dunes and offshore reefs can also provide increased protection against coastal hazards without placing structures on the shore.

Plantings, sand fences, and traffic control are proven ways to help establish and maintain a healthy dune system. The dunes can then offer a sacrificial protection against storm events.

Figure 17. Typical beach nourishment operation—a dredge pumps sand onshore while bulldozers distribute the new sand (photo credit: USACE)

Crowbush Golf Course

Lakeside, Prince Edward Island

The north shore of Prince Edward Island has taken a severe hammering from storms over the past 20 years. The dunes at Brackley Beach have disappeared, and erosion is common.

Crowbush Golf Course, on PEI's north shore, is a links-style course. The focus of a links course is the coast, the dunes, the vistas, and the winds. Severe winter storms in 2001 washed away a large portion of dune that protected two salty ponds at the 6th and 8th tees. Storm waves, carrying with them sandstone cobble, devastated the fairways and tee boxes. The layout of the course and bounding properties is such that retreat is not an option.

Coastal protection was needed to protect course infrastructure during severe events but not detract from the links character of the course. The dunes in front of the two ponds were rebuilt using a low-lying armour-stone core that was buried in a reconstructed sand dune. Following construction, planting the dune with marram grass helped stabilize the dune and gave a natural appearance. The exposed north shore of PEI is a large-scale erosional system. Nothing about the dune restoration changes the overall erosional nature of this entire shoreline. Severe storms such as those of December 2010 can wash away the dune, but the underlying armour stone remains in place to protect landward infrastructure. Maintenance is required from time to time to replenish the dune. There will eventually come a time when it no longer makes sense to hold this position. For now, a valuable tourism resource continues to serve the community.

Figure 18. Marram grass established on rebuilt dune (over buried revetment) at Crowbush Golf Course.

Figure 19. Fairway view with protection works hidden from view at Crowbush Golf Course four years after construction.

Panmure Island Causeway

Panmure Island, Prince Edward Island

The causeway to Panmure Island on PEI's east coast is built over a sand spit. This spit is formed naturally from sand that moves down the shore from Panmure Island Provincial Park to Panmure Island. Here it forms a large shoal at the entrance to Georgetown Harbour.

Over the years, the eastern shore of Panmure Island has eroded tens of metres. The iconic Panmure Lighthouse has been moved landward several times as part of a coastal retreat strategy. Panmure Island forms a headland that controls the position of the Panmure Spit. As the headland erodes, less of the sand coming from the north is trapped on the spit and more ends up in the Georgetown Harbour shoal. The Panmure Spit becomes narrower, resulting in the loss of sand dunes and erosion of the roadbed.

A buried revetment was placed along the edge of the road to protect the causeway. Like at Crowbush Golf Course, sand was built up over top and planted with marram grass to encourage dune re-stabilization. The protection works have been successful, and the road has remained open through increasingly frequent and severe winter storms. The next phase of this project is to restore the beach in front of this protection. This will depend on beach's sediment budget—the balance of sand entering and leaving this coastal system. While there haven't been any big changes to the supply of sand to this beach, erosion of the headland at Panmure Island means that more of the sand is leaving the beach. Work to re-establish the headland at Panmure Island using an armour-stone spur and reef construction are under consideration.

Figure 20. Panmure causeway May 2009, showing some armour-stone exposure and erosion of the rebuilt dune.

Hybrid Techniques

Control structures can act as artificial headlands to form embayments or pockets that trap beach sediments. This can be done with various techniques, such as groynes, detached offshore breakwaters, or artificial reefs.

If there is a large enough supply of sediments to the shoreline, construction of artificial headlands or other control structures can, by itself, be an effective defence against coastal hazards. Combining beach nourishment with control structures often proves to be a more reliable and cost-effective means of soft protection.

Figure 21. Hybrid protection at Basin Head, PEI: buried revetment covered with sand dune and marram grass.

Figure 22. Examples of hybrid shore protection in Portugal using beach fill contained by artificial headlands and offshore detached breakwaters. (Direccion general de puertos y costas 1988)

Regional Sediment Management

There is a growing understanding of the importance of regional sand management. In much the same way that the study of water resources takes the entire watershed into account, regional sand management looks at all the things that influence sand moving on and off the beach. These include erosion from upland sources, sediment transport through streams and rivers to estuaries, and the migration of sand along the shore and offshore. Rain, snow, runoff, freeze-thaw cycles, bluff erosion, sediment transport, and the actions of tides and waves are the driving processes behind regional sediment management. Climate change and sea-level rise will affect all of them.

Coastal Resilience

Coastal resilience is the capacity of a system to absorb changes while having the same basic structure and function. In coastal areas, building coastal resilience requires a broad perspective; it affects land use planning, infrastructure, and social and economic aspects of communities. Flexibility, adaptability, and durability are all needed to create coastal communities well adapted to climate change and coastal hazards. Building coastal resilience means:

- Building resilient infrastructure that does not collapse under extreme events but still provides some protection and can be repaired
- Building government resources to support coastal communities, including research and development, advance warning systems, regulations, zoning and permitting, communication and transportation networks, utilities, and emergency response systems
- Developing a resilient socio-economic system, which involves open communication with communities and stakeholders to better understand their risk and enlist their cooperation

GOING FORWARD

We need to ensure that government and the public are informed by the best available research and data.

Climate Scenarios and Monitoring

We need local climate-change predictions.

As well, we need better measurements of past and present-day conditions. Better information on waves and water levels is important. Currently, only a handful of permanent water-level gauging stations are operating in Atlantic Canada. For example, there is just one permanent gauge in Prince Edward Island (at Charlottetown). Measuring storm surge and extreme water levels along the north, east, and west shores of the island must rely on gauges located hundreds of kilometres away. Data on offshore wave conditions is even sparser. Computer models and remote sensing data are making great strides in improving our predicting water levels and understanding our nearshore waters. But there is still a need for reliable, long-term measurements.

Research into the Design of Coastal Defences

So far, little effort has been spent on solutions that help us respond to climate change. One of the biggest challenges is predicting the long-term and large-scale response of shorelines to climate change. This includes understanding the interaction between the natural and built environments.

At l'Institut National de Recherche et de Sécurité (INRS) in Quebec City, a new research facility is being built to look at the large-scale effects of waves and water levels on coastal infrastructure. It will be large enough to overcome many of the scaling issues that plague existing facilities.

Policy and Planning that Incorporate Climate Change

Planning is the key step in implementing a rational response to the coastal impacts of climate change. Integrated coastal zone management initiatives have been underway in Canada for the last 10 years. Originating from within Fisheries and Oceans Canada, this initiative focuses on marine resources (fisheries) and the factors that affect them. In other countries, the term "integrated coastal zone management" is much broader and includes a strategic approach to planning coastal protection.

Nova Scotia has recently released a State of the Coast report, and New Brunswick has a coastal planning policy. Halifax Regional Municipality has taken a lead role in integrating climate change issues into its planning processes. Coastal hazards and the effects of climate change (notably relative sea-level rise) are becoming an integral part of their municipal planning processes.

Public Involvement in the Development and Implementation of New Strategies

Public awareness of climate change and the threat it poses for our coastal areas is high. Storms, like Hurricanes Juan and Igor, and recent storm surges regularly remind the public of our vulnerability. The public is also deeply connected to coastal areas and concerned about how they are managed. Planners and policy makers need to ensure that the public is involved in developing strategies to deal with coastal climate change. *cont'd*

Implementation of Best Practices

To allow better management of our coastal regions, we need to develop and use best practices. The long-term goals for Atlantic Canada should be to develop integrated shoreline management plans (ISMP). These plans provide a way to manage and balance technical information and tools to form an adaptive response to the effects of climate change on the coastal zone.

Integrated shoreline management plans are successful because they include not only the technical aspects but also the community that lives, works, and plays in the affected area. Developing and maintaining an effective stakeholder engagement process is the key to properly identifying and addressing the issues and opportunities at hand. The process must get everyone involved in planning the future of our coasts.

Developing and implementing a policy for managing the coast goes hand-in-hand with developing new ways to design, evaluate, and build coastal protection works. We need new approaches that view coastal protection as an important part of shoreline management—not piecemeal armouring of individual properties. Considering the big picture makes it easier to adopt and integrate hybrid and soft shore protection, along with sediment-budget remediation, to restore the shorelines rather than just armouring them.

Best-practice approaches can cost more, at least in the short term. Often, it takes more time, more effort, and more money to put in place a sustainable coastal protection scheme than it does to build a simple revetment. We can't expect that many of these soft-engineered responses will be built without a policy framework that considers sustainability.

LINKS AND RESOURCES

A Coastal Areas Protection Policy for New Brunswick

http://www.gnb.ca/0009/0371/0002/coastal-e.pdf%20

Guide to Considering Climate Change in Environmental Assessment in Nova Scotia

http://www.gov.ns.ca/nse/ea/docs/EA.Climate.Change.Guide.pdf

Guide to Considering Climate Change in Project Development in Nova Scotia

http://www.gov.ns.ca/nse/ea/docs/Development.Climate.Change.Guide.pdf

State of Nova Scotia's Coast Report

http://www.gov.ns.ca/coast/

Prince Edward Island and Climate Change: A Strategy for Reducing the Impacts of Global Warming

http://www.gov.pe.ca/photos/original/env_globalstr.pdf

Newfoundland and Labrador's Climate Change Action Plan 2005

http://www.env.gov.nl.ca/env/climate_change/

United Nations Educational Scientific and Cultural Organization. Sea Level Rise and Variability—A Summary for Policy Makers

http://unesdoc.unesco.org/images/0018/001893/189369e.pdf

US Army Corps of Engineers (USACE). Sea Level Change Considerations for Civil Works Programs. Guidance and policy for sea-level change adaptation, Engineering Circular 1165-2-212 (2011)

http://corpsclimate.us/etl.cfm

United Nations Environment Program and the Global Environment Facility Technologies for Climate Change Adaptation—Coastal Erosion and Flooding

http://tech-action.org/Guidebooks/TNA_Guidebook_AdaptationCoastalErosionFlooding.pdf

Natural Resources Canada Coast Web

http://gsc.nrcan.gc.ca/coast/index_e.php

Environment Canada Climate Change Science and Research

http://www.ec.gc.ca/sc-cs/

IPCC: Climate Change 2007: Working Group II: Impacts, Adaption and Vulnerability

http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html

United Nations Educational, Scientific, and Cultural Organization (UNESCO). Sustainable Development in Coastal Regions and Small Islands

http://www.unesco.org/csi/

National Oceanic and Atmospheric Administration (NOAA) Adapting to Climate Change: A Planning Guide for State Coastal Managers

http://coastalmanagement.noaa.gov/climate/adaptation.html

UK Department of Environment, Food and Rural Affairs (DEFRA) Flooding and Coastal Change

http://www.defra.gov.uk/environment/flooding/

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Fisheries and Oceans Canada. 2012. *Integrated Science Data Management.* **http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/index-eng.html.**

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: *Synthesis Report Summary for Policymakers.*Geneva, Switzerland: IPCC.

Linham, M., & Nicholls, R. 2010. *Technologies for Climate Change Adaptation: Coastal Erosion and Flooding.* Roskilde, Denmark: UNEP Riso Centre on Energy, Climate and Sustainable Development. **http://tech-action.org/Guidebooks/TNAhandbook_CoastalErosionFlooding.pdf**

Titus, James G., and Elizabeth M. Strange, eds. 2008. Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea-Level Rise. EPA 430-R-07-004 Washington, DC: US Environmental Protection Agency. **http://www.epa.gov/climatechange/effects/coastal/background.html**

USACE (US Army Corps of Engineers). 2002. Coastal Engineering Manual. Washington, DC: US Army Corps of Engineers, Coastal and Hydraulics Lab.

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