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**Annex 10: Coastal and Marine Ecosystem Sector Fact Sheet – Seawalls**

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| **Sector** | Coastal and Marine Ecosystems |
| **Category** | Infrastructure installation |
| **Adaptation needs** | Addressing of sea level rise<br>Reducing the impact of wave action on coastal areas<br>Reducing risks to coastal populations |
| **Technology Name** | Sea Walls |
| **How this technology contributes to adaptation** | The main advantage of a seawall is that it provides a high degree of protection against coastal flooding and erosion. A well maintained and appropriately designed seawall will also fix the boundary between the sea and land to ensure no further erosion will occur – this is beneficial if the shoreline is home to important infrastructure or other buildings of importance.<br>As well as fixing the boundary between land and sea, seawalls also provide coastal flood protection against extreme water levels. Provided they are appropriately designed to withstand the additional forces, seawalls will provide protection against water levels up to the seawall design height. In the past the design height of many seawalls was based on the highest known flood level (van der Meer, 1998).<br>Seawalls also have a much lower space requirement than other coastal defenses such as dikes, especially if vertical seawall designs are selected. In many areas land in the coastal zone is highly sought-after; by reducing the space requirements for coastal defense the overall costs of construction may fall. The increased security provided by seawall construction also maintains hinterland values and may promote investment and development of the area (Nicholls et al., 2007b). Moreover, if appropriately designed, seawalls have a high amenity value – in many countries, seawalls incorporate promenades which encourage recreation and tourism.<br>When considering adaptation to climate change, another advantage of seawalls is that it is possible to progressively upgrade these structures by increasing the structure height in response to Sea Level Rise. It is important however, that seawall upgrade does not compromise the integrity of the structure. Upgrading defenses will leave a 'construction joint' between the new section and the pre-existing seawall. Upgrades need to account for this weakened section and its proper reinforcement.<br>Provided that they are adequately maintained, seawalls are potentially long-lived structures. The seawall in Galveston, Texas was constructed in 1903 and continues to provide coastal flood and erosion protection to the city to this day (Dean & Dalrymple, 2002). |
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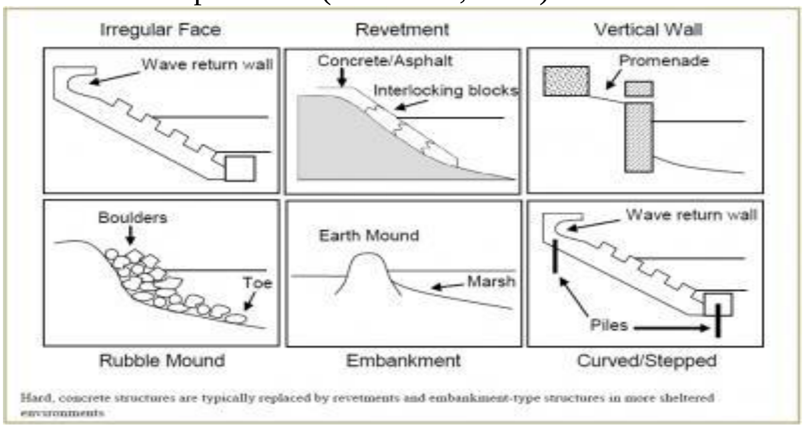
<td>Background/Notes, Short description of the technology option sourced from ClimateTechWiki, Seminars, etc</td>
<td>Seawalls are hard engineered structures with a primary function to prevent further erosion of the shoreline. They are built parallel to the shore and aim to hold or prevent sliding of the soil, while providing protection from wave action (UNFCCC, 1999). Although their primary function is erosion reduction, they have a secondary function as coastal flood defenses.
The physical form of these structures is highly variable; seawalls can be vertical or sloping and constructed from a wide variety of materials. Reinforced concrete is used for all the seawalls in Belize. They may also be referred to as revetments.
Seawalls are very widespread around the world's coasts and many ad-hoc seawalls are found in developing countries. In Belize, seawalls are found in sections of Belize City, Corozal Town, Caye Caulker, and Ambergris Caye, although none of these seawalls surround the city or town entirely. Here, we emphasize best practice guidance, although these principles could be used for more ad-hoc structures.
Seawalls form a defining line between sea and land. They are frequently used in locations where further shore erosion will result in excessive damage, e.g. when roads and buildings are about to fall into the sea. However, while they prevent further shoreline erosion, they do not deal with the causes of erosion (French, 2001). Seawalls range in type and may include steel sheetpile walls, monolithic concrete barriers, rubble mound structures, brick or block walls or gabions (wire baskets filled with rocks) (Kamphuis, 2000). Some typical seawall designs are shown in Figure 1. Seawalls are typically, heavily engineered, inflexible structures and are generally expensive to construct and require proper design and construction supervision (UNFCCC, 1999).


Figure 1: Variation in design type of seawalls (Source: Adapted from French, 2001)
The shape of the seaward face is important in the deflection of incoming wave energy; smooth surfaces reflect wave energy while irregular surfaces scatter the direction of wave reflection (French, 2001). Waves are likely to impact the structure with high forces and are also likely to move sand off- and along-shore, away from the structure (Kamphuis, 2000). Since seawalls are often built as a last resort, most are continually under severe wave stress.
Seawalls usually have a deep foundation for stability. Also, to overcome the earth pressure on the landward side of the structure, 'deadmen' or earth anchors can be buried upland and connected to the wall by rods (Dean & Dalrymple, 2002).</td>
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| **Implementation assumptions, How the technology will be implemented and diffused across the subsector?** | Seawall construction is possible on a community scale. There are many examples of ad-hoc construction to protect individual properties and communities, but such seawalls are likely to give much less consideration to the water levels, wave heights and wave loadings during an extreme event.<br>This is largely because these events are hard to foresee without a well-developed science and technology base. For example, traditional seawall construction methods in Fiji involved poking sticks into the ground to create a fence, behind which logs, sand and refuse would be piled to pose a barrier to the sea. This type of traditional construction has shown to have low effectiveness against significant events, however, and in many cases, these defenses are washed away during extreme events (Mimura & Nunn, 1998). Although it is possible to construct traditional, low technology seawalls at a community level, these structures have been shown to afford lower levels of protection against extreme events than designs with a solid science and technology base. They have also been known to exacerbate existing problems.<br>A degree of technical guidance would be of benefit in the design and construction of effective seawalls. This would improve their effectiveness during extreme events and would also help to reduce adverse impacts on adjacent coastlines.<br><br>At present, the advice given in developing countries for modern seawall construction appears to be informal, if given at all. If effective design and construction is to occur, local communities must be given at least basic design guidance. This may come from government or voluntary organizations.<br><br>Seawall maintenance is likely to be possible at a community level when given appropriate training. This may include educating maintenance engineers on the likely failure mechanisms, how often to survey the structure, what to look for and how to identify weaknesses in the design. If major weaknesses are found, it may be necessary to employ a professional organization to repair the structure in the most effective manner.<br>In Belize, the seawalls in Belize City, Corozal Town, Ambergris Caye, and Caye Caulker could all be extended and elevate by one or two feet. However Dangriga Town and Placencia are also at sea level and could benefit from seawall construction. |
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| **Costs** | A study by Linham et al. (2010) indicates that the unit cost of constructing 1 km of vertical seawall is in the range of US$0.4 to 27.5 million. The study found seawall costs for around ten countries. Most were developed country examples, although a number of newly developed and developing countries, such as Egypt, Singapore and South Africa were also found. The variation of the heights of the seawalls is similarly reflected in the variation in the construction costs.<br>Some of the best unit cost information is given by the English Environment Agency (2007), for unit costs relevant to the UK. This source gives an average construction cost for seawalls of US$2.65 million (at 2009 price levels). This cost includes direct construction costs, direct overheads, costs of associated construction works, minor associated work, temporary works, compensation events and delay costs.<br><br>Variation in costs between projects is a result of numerous factors, such as:<br>Design height is a major factor affecting costs per unit length of seawall. Height affects the volume of materials required for construction and the build time<br>• Anticipated wave loadings will affect how resilient the structure needs to be; deeper waters and exposed coasts cause higher wave loadings which will mean the structure needs to be more robust, thus higher costs<br>• Single or multi stage construction; costs are lower for single stage (Nicholls & Leatherman, 1995)<br>• Selected seawall design and the standard of protection desired. Certain design features will increase costs and more robust seawalls will be more costly<br>• Construction materials (e.g. rubble blocks, pre-cast concrete elements, metal, soil, etc.)<br>• Proximity to and availability of raw construction materials<br>• Availability and cost of human resources including expertise<br>Maintenance costs are another significant and ongoing expense when a hard defense is selected. These costs are ongoing for the life of the structure and are therefore likely to result in significant levels of investment through a project's lifetime. Continued investment in maintenance is highly recommended to ensure defenses continue to provide design levels of protection (Linham et al., 2010).<br>It has been noted that construction and maintenance costs are likely to increase into the future in response to SLR (Burgess & Townend, 2004; Townend & Burgess, 2004). This is caused by increases in water depth in front of the structure, which in turn causes increased wave height and wave loading on the structure. |
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| **Country social development priorities** | • . National Agenda for Sustainable Development (2013).<br>The increased security provided by seawall construction also maintains hinterland values and may promote investment and development of the area (Nicholls et al., 2007b). Moreover, if appropriately designed, seawalls have a high amenity value – in many countries, seawalls incorporate promenades which encourage recreation and tourism |
| **Country economic development priorities – economic benefits** | • . National Integrated Coastal Zone Management Plan (2013)<br>The National Integrated Coastal Zone Management Plan recognizes the need for Shoreline Stabilization. While the Plan advocated that the most efficient and cost effective method of shoreline stabilization in Belize is by natural methods, via mangrove protection, it also recognizes the need for both soft and hard technologies to achieve the objective. The construction of manmade structures such as seawalls can also be used, but are discouraged because they cause isolation of the two environments. A policy or regulations to govern the construction of piers, sea walls, jetties, groynes, harbor arms and other hard structures is needed |
| **Country environmental development priorities --environmental benefits** | • Belize's National Environment Action Plan – 2015-2020<br><br>As well as fixing the boundary between land and sea, seawalls also provide coastal flood protection against extreme water levels. Some are used for recreational purposes since the widths are wide enough to facilitate family gatherings and social visits. Properties located behind the seawalls are afforded protection from wave action and erosion, and thus their values are maintained. |
| **Social benefits** | Seawalls incorporate promenades which encourage recreation.<br><br> |
| **Other considerations and priorities (such as market potential)** | Coastal communities tend to remain where they are, so the governments may decide that building seawalls is a cheaper option than to try to relocate entire communities. Decisions may be based on the status of the community, or the economic activities underway in the area. |
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| **Capital costs (per facility)** | A study by Linham et al. (2010) indicates that the unit cost of constructing 1 km of vertical seawall is in the range of US$0.4 to 27.5 million.<br>According to the English Environment Agency (2007), which estimates unit costs relevant to the UK compute an average construction cost for seawalls of US$2.65 million (at 2009 price levels). Today's cost is US$ 2,92 million.<br>Because the areas where seawalls are most likely to be utilize in Belize sits mainly on soil that are peaty, silt and peaty clay, causes the cost of construction of a seawall, 1 km, to be increased by 30%. Thus the cost for Belize would range between $$0.52 million US to $35.75 million US with an average cost of $18.14 million US |
| **Operational and Maintenance costs (per facility)** | Maintenance costs are ongoing for the life of the sea wall and are therefore likely to result in significant levels of investment through a project's lifetime. If proper annual maintenance is conducted, costs might reach 5 to 10% of construction costs.<br>Maintenance costs are estimated at 10 % of construction costs (CBA, 2015). Operating cost is attributed to the cost of an attendant which controls access to sections of the seawall as in the Tourism Village in Belize City. |
| | Soil stabilization method that combines hard structures with more natural materials ♦ Cost = shoreline or marsh planting + price of breakwater installed<br>Plant / Unit / Cost Range ($/unit) / Cost Installed ($/unit)<br>Smooth cordgrass) / Plug / $1.25 / $2-3 Plug $3Gallon<br>Marshay cordgrass / Plug / $1.25 / $2-3 Plug $3 Gallon<br>Mangrove / Gallon pot / $10 / $5 Gallon<br>Salt grass / Plug / 2" - $.60, 4" - $1 / $2 Plug $3 Plug<br>Bitter panicum / Node / $1 / $2 Plug $3 Plug<br>Freshwater species / Gallon pot / $5-6<br> |
| | There are services delivered by seawalls, but this cannot be measured. The supply capacity might therefore be considered as the cumulative value of the lives, properties, and infrastructure that is protected by the seawall. |
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| **Up scaling potential** | Engineering technology enables seawalls to be extended relatively easily. The levels of seawalls can be raised in response to increased wave action and sea level rise, and the can be extended on the ends to enclose larger areas. |
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