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# Hold the Sea Back—Is It Sustainable? Retrospective and Projection

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## ABSTRACT

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Men have waged an endless and relentless fight against encroachment of the sea upon their land; they even captured some space from the sea. Seldom have they raised the question whether the battle could ever be won. Conquests upon the sea have been admired and heralded as masterpieces of achievements in coastal civil engineering. But were these environmentally wise moves, and were/are they sustainable in our contemporary view of matters and today's scientific knowledge?

**ADDITIONAL INDEX WORDS:** Artificial nourishment, breaches, breakwaters, feeder berms, groins.

## WHO'S FIRST?

The Brussels-based French-language daily newspaper *Le Soir* organized for decennia, during July and August, shore resorts beach competitions for children along the North Sea coast of Belgium. The sand fortresses were built, by teams of six children of approximately the same age-group, lined-up along the beach, as the incoming tide started rolling in; the team's whose sand castle resisted longest to the onslaught of tide and waves won a major prize. I participated of course and, though my teams never captured the hoped-for croquet game, I gained one thing: my first lessons in coastal defense and learned another: the sea always won.

A significant part of the coasts of the European Union suffers from erosion damage (Table 1). It is no different elsewhere in the world, few coasts accrete.

In a remarkable milestone paper, Per Bruun (1972)<sup>1</sup> described the evolution of structures, or defenses, erected by men to protect their land, against the unrelenting attacks of the sea, and forestall it being gradually gobbled up. This advance of the sea holds nothing surprising to the geologist since a century of human time is but a fraction of a minute on a geological time scale. Waters have invaded coasts, in *transgressions*, and have retreated, in *regressions*, from land often. To Man who attempts to anchor his constructions on a "permanent" basis, this has meant the need to stop the sea's invasion. Yet, history has proven that only the sea will decide, if this metaphor is allowable, which town will drown—and scores of them have p.ex. along the coasts of the Channel and North Sea Harendycke, Scarphout in Belgium have disappeared, or been "lost" as some authors say<sup>2</sup>—and which once along a shore will become landlocked—e.g. Montreuil-sur-Mer and Brouages, in France.

Bruun (*op. cit.*) credited the Frisians with having erected

the first "walls" against the ever repeated attacks of the sea; he cited in this regard the writing of Plinius the Elder (23–79)<sup>3</sup>. Their earthen dikes were described by the Roman officer and naturalist as the protecting efforts from a group of wretched creatures living on mud heaps surrounded by the waters.

When this author challenged the primacy of the Frisians as inventors of the early dikes, he brought upon himself the ire of some Dutch colleagues who came close to feel that he was invading a private bailywick. Far be it for this writer to dispute the merits of Vierlinck<sup>4</sup> and his remarkable works on the constructions of dikes and protective structures, which he and many others duly recognized more than once.<sup>5</sup>

The Dutch reaction, for surprising and unjustified that it may be, is not unique. Haulot<sup>6</sup>, who discussed the relation between the economics of coastal tourism in Belgium and beach regression (1970–1980), in a lesser paper, presented in Bordeaux in 1978 at a forerunner of the *BORDOMER* series<sup>7</sup>, dealt with the coastal protection and beach restoration innovative efforts along the Belgian coast. He got a broadside cannon shot from some French researchers, because he spoke about a "mere 67 km of coasts" then when France has hundreds of kilometers of coast. This intervention too gave the impression of decrying a *crime de lèse-majesté!* The Belgian stretch of coast, if short indeed, is contrarily a unique site in that it presents all the problems and conflicts linked to coastal protection, economic uses, testing of traditional and newer approaches; it is a natural laboratory.

The Belgian researchers are to be credited with some forward thinking innovative approaches in coastal protection, distancing themselves from the traditional hard structure approach both in "elements" use, e.g. the *haro*<sup>8</sup>,<sup>9</sup> and methods. At the 6<sup>th</sup> International Congress on the History of Oceanography in Qingdao (People's Republic of China) the *haro*<sup>8</sup> got an indignant South African salvo because a somewhat

Table 1. *Beach erosion in EU.*

	Length (km)	Erosion (%)
Belgium (B)	64	40
Denmark (DK)	3,253	12
France (F)	2,600	46
F.R. Germany (D)	605	36
Greece (G)	2,739	41
Ireland (IRL)	2,019	19
Italy (I)	3,894	26
The Netherlands (NL)	407	45
Portugal (P)	782	51
Spain (E)	1,929	32
United Kingdom (UK)	3,680	19

similar approach had been tried in Durban and had, there, unfortunate results. They also did, in the early eighties, undertake the world largest artificial nourishment project on the beaches of Knokke (Belgium), which was highlighted as a “first”. If nobody challenged the size of the project, upset Americans pointed out that more than half a century before, such nourishment had been used on a northern California beach, while Russians and Ukrainians remarked that similar projects had been completed on the Black and Caspian seas. The authors of that birth assignment escaped unscathed from Egyptian fire, even though Cleopatra (69–30 BC) had Marc Anthony (83–30 BC)<sup>9</sup> order sand brought from Egypt to shore up a beach in the Middle East<sup>10</sup>. But Egyptians did bring forth that dikes had been built in Alexandria several centuries before the Frisians heaped up sand and mud to defend their realm.<sup>11</sup>

It taught this author two things: avoid assigning birth dates or paternity to any given ethnic group, and realize that clearly everyone has had to cope with the problem of coastal erosion and beach protection and restoration, but nobody has really solved it.<sup>12</sup>

### EVOLUTION OF APPROACH AND PHILOSOPHY

Well before the dawn of the Christian Era, sea-walls and dikes had been built to protect harbors. The record is pretty well established for the Mediterranean Lands and coastal protection goes probably back some 3000 years.<sup>13</sup> Sumerians, Greeks, Etruscans, Egyptians, Romans had engineers which dealt with the problem. Roman emperor Caligula’s (12–41)<sup>14</sup> “monster ship” did not make long cruises, but was eventually sunk to be used as an off-shore breakwater (Table 2a, 2b). It preceded, in that coastal protection type of approach, a common Dutch (Hollandish and Zeelandish) method of using old ships to secure harbors, disapproved of, however, by Vierlinck (*op. cit*)<sup>15</sup>. The famed Venetian murrazzi date from around the fourteenth century.<sup>16</sup> Dikes were built in Asia; those in Africa are rather new and date back at best to the colonial times. They are of course found, today, in Australia and the Americas.

Constructing dikes was a very hard undertaking in medieval times, and very serious business. Hundreds of workers were put to the task of breaking up the hard ground with hand spades, filling baskets with the loosened material and carrying it on man’s back to the dike site, either to construct

Table 2. *Coastal defense through history.*

(a) Classical and Medieval times.
Classical times
The Chinese Great Sea Wall
Greek & Etruscan rubble mounds
Egyptian dikes & Cleopatra’s home
Roman breakwaters & Caligula’s monster ship
Medieval times
The Frisians & The Zeeburgh
Venetian murrazzi
The great 13th century storm: Dijken, Ditches, Polders, Count Jan Bruges, Venice-of-the-north: glory, wealth, death, resurrection
(b) Coastal defense approaches and alternatives since the 19th century.
Lost towns of England & Lowlands
Hard coastal defenses: breakwaters, groins, seawalls, revetments, tetrapods, <i>et al.</i>
Soft approaches: to feed or not
The 40 miracle solutions:
let nature have its way
or try a new way?
or enroll nature
or open inlets
The economic trauma & plight “We’re going under”
Who is the culprit?

it or to repair it. And often the elevation, often levée to the French,<sup>17</sup> did not exceed a single meter. Dikes were a protection for the polders crisscrossed by a network of natural and man-made creeks or against the invading sea. In 1213 Philip of Alsace (1136/1140–1191), then the count of Flanders, issued an edict that whoever caused damage or destroyed dikes would have his right hand cut off and all his possessions confiscated. Vandalism and mischievousness, or storms, were not the only threat against dikes: rats were a real plague and their underground paths not infrequently would transform the dikes’ lower part in a gruyère-cheese like net of holes, thereby weakening them to the point of great vulnerability. The animals bear a considerable responsibility in the dikes giving way and gigantic floods occurring with the great storm of 1483.

Not only rats, but also rabbits sapped dikes with their underground conduits. Only after numerous floods had taken place due to weakened dikes, did Jeanne (15<sup>th</sup> century), countess of Flanders, allow her subjects to enter her grounds and dikes to organize anti-rabbits “posses”. Even today muskrats, who multiplied in the polders during the 20<sup>th</sup> century, are a matter of serious and continuous concerns for dike protection.

Military science, more precisely the art of attacking and defending fortified cities, contributed to approaches of coastal defense. The “golden times” of the reign of the archdukes Albert and Isabella (16<sup>th</sup>-17<sup>th</sup> centuries),<sup>18</sup> in the southern Low-Countries, was neither entirely that peaceful nor happy, regardless of the economic, artistic and cultural bloom. During four years the rulers laid siege to the port city of Ostend (Belgium). If the First World War fought in the area was appropriately labeled a horrible butchery, proportionately to the contemporary population, the Siege of Ostend (1601–04) was an equal carnage during which, besides the civilian population’s large losses, the military suffered some 100,000 ca-

sualties. The Spanish and Italian troops that set siege to the city, used as protection against the sea as “wave attenuators” (dampers) at foot of dunes and dikes, sausages or *salsiciones*, an Italian invention, similar to the sausages, still used today for the same purposes.<sup>19</sup> Another device to strengthen dikes was to back them up with steres.<sup>20</sup> A modern version of the sausage is the burlap bag filled with lean concrete.<sup>21</sup> Useable in regions of moderate tidal amplitude—thus on Black Sea and Mediterranean shores for instance—they are effective if the bottom slope is rather gentle; however filter material should be placed under the structure to prevent settling. On the beach at Vosseslag, near Bre[e]dene, just east of Ostend, Belgium, sausages were strewn individually in a couple of rows at the foot of badly eroding dunes. They were filled with sand.

History informs us thus that originally the method to hold back the sea consisted in erecting hard structures; the sand and mud walls of the Frisians can be placed in this group.<sup>22</sup> One may label this the engineers’ solution as it answers to a problem by the obvious “simple” solution, valid on a short term basis. But then the concept of and concern for the environment are of rather recent vintage. Who should be too critical of erstwhile engineers when closer to us—the early nineties—there were heads of ministries’ departments who, appraised by field engineers that the shoreline of the Belgian coast was migrating landwards, pooh-pooed the report.<sup>23</sup> A couple of decades later, the field people’s predictions were found correct.

## COASTAL EROSION

The hard structures were used to such extent that for instance the Italian coast is said not to have a kilometer left of natural coast and hundreds upon hundreds of shorelines have been lined with breakwaters, groins, revetments, and the like.<sup>24</sup> The Venetian *murazzi* are famed for holding back waves and waters from the lagoon. Of Israel’s coast, all areas are polluted and one fourth has been artificially protected; much of the fault lies with the implant of several pleasure crafts harbors. And Portugal *déd* not fare much better.<sup>25</sup> However, geologists accurately pointed out that the “wall” solution may bring relief from coastal erosion in some specific sites, it nevertheless is costly, and temporary, and merely shifts the problem to an adjoining segment of the coast. And yet, the method is still called upon regardless of the established negative effects. Manuals from the US Army Corps of Engineers, and even UNESCO publications, advise property owners how to protect their beaches and describe hard structures that can be used at relatively low cost.<sup>26</sup> Clearly hard defenses must be continued to be used when the areas to be protected have special value, such as portuary and/or economic importance, as for instance in Essaouira, Morocco; similarly, the harbor of Charleston, South Carolina, USA, must be kept and were it not for hard defenses the city and harbor might conceivably be eradicated within a decade or even less were erosion and sea-level rise to continue at the present rate.

Combinations of hard and soft measures are occasionally a lesser evil, as shown in Canada where groins and dune re-

generation were jointly used. Combination approaches are not however always successful, proof in Lagos, Nigeria, where the dredging-artificial nourishment-groins option was a failure.

## Hard Structures

Dikes and breakwaters appear as the forerunners of coastal protection. Even if they have had geologically speaking pernicious-domino-effects, they were the logical step to engineers: stop the advance. They can, of course, be constructed from a variety of materials and several patented breakwater systems are on the market. One frequent disadvantage is that some of these require custom-tailored equipment which, understandably, strain the usually meager budgets still more.

Materials and designs include concrete boxes, gabions, Longard-tubes, Z-walls, and systems such as surgebreakers and sandgrabbers. Among traditional types, armored breakwaters are common while the stone rubble variety (Fr.: *brises-lame en enrochement*) uses a relatively inexpensive construction material found in situ; though this is possible in most cases, large rocks have been known to be trucked in to the site from considerable distances. The structure’s deformation can be avoided to some extent by placing filter material between the stones of rocks and the sand upon which they are placed. This also reins in settling. Smaller elements ought to be placed at the breakwater’s interior and thus armored and retained by the larger sized material.

When budget constraints are serious used rubber tires can be part of breakwaters, which constitutes in fact re-use of waste material. Where treated-timber piles can be driven deep enough in the sediment, to ensure their stability, the tires can be placed on them. As tires could float off the tops of the pile, in high water, horizontal ropes, or timber cross-pieces, keep them in place. Where the sediment allows reasonably deep driving or jetting, treated-timber sheet piling will make a reliable breakwater, groin or sill.

Besides the “fixed” breakwaters, floating breakwaters, frequently permeable, can be anchored at some distance from shore. On Oahu (Hawaiian Islands) permeable structures were placed several decades ago and offshore Brighton (England) floating structures were used as a protection at least as far back as 1902. Floating breakwaters can be built from used tires bolted or tied together. Local conditions govern the nature of fasteners; such conditions include waves generated up-and-down motion, and the required flexibility to ride on the water without rupturing. The type of anchor depends on tide and bottom characteristics; experience shows that piles last longest.

## The Soft Approach

In all fairness, it ought to be mentioned that the US Army Corps of Engineers has tried different methods to combat the aggression of the seas, and that Cambers has suggested the addition of sand to beaches.<sup>27</sup> Artificial nourishment both protects shorelines and rebuilds beaches. When the extension of the harbor of Zeebrugge was undertaken in the mid eighties on the Belgian coast, the tons of sand (over 800,000 m<sup>3</sup>) re-

moved from the off- and in-shore site were used to restore the all-but disappeared beaches of Heist, Duinbergen, Albert-Plage (Albert-Strand), Knokke, Zoute and Lekkerbek; they had been reduced to areas of a few square meters at high tide.<sup>28</sup> If indeed it had been the largest such undertaking at the time, many sand replenishments of beaches had taken place earlier covering areas in many sites around the world. They include northern California, Copacabana (Rio de Janeiro) in Brazil,<sup>29</sup> La Croisette<sup>30</sup> near Cannes in France, Scheveningen in The Netherlands, Sylt in Northern Germany, Ostia near Rome in Italy.

However, admittedly, the works undertaken in Rio de Janeiro were aimed at providing more beach space for the recreationists than to protect the beach which shrank (shrinks) considerably when the waves are strong, though re-establishes itself in the matter of some weeks when the weather calms down. Preliminary modeling had been done in Lisbon, Portugal, before 2 millions cubic meters of somewhat coarser sand were deposited offshore and another 1½ millions were hydraulically sluiced unto the beach. Apparently there has been no need to recharge Copacabana, although this author during his 1998 sojourn in Niteroi and Rio remained unconvinced that such operation may not become necessary to maintain the widths.<sup>31</sup>

Closer to the present, an artificial nourishment project was carried out near Cadiz, Spain close to the Guadiaro River mouth. To insure a [longer] retainment of the deposited materials, sand collectors have been installed, plants have been placed on dunes and foot bridges constructed so that tourists do not walk on sandbars.<sup>32</sup> Charlier and De Meyer provided a list of completed and planned projects in a 1984 paper (co-authored by Decroo), taken up anew in 1998.<sup>33</sup>

Materials to rebuild a beach are not usually as available as may be believed and have often to be brought to the site from considerable distances on land or source points at sea, though mine or quarry tailings have been known to be used, p.ex. in England. Dredged materials are not uniformly suitable, not only in regards to grain size but also to composition; nocive metals may be present in port dredgings.<sup>34</sup> Materials include sands, gravel, shales and shingles. The procedure is expensive and has to be repeated as the sea takes away the man-deposited materials. The widely heralded new philosophy came under fire because, not any more than breakwaters and groins, does it provide a permanent solution. Beach draining was proposed as an alternative and won over some beach managers; a certain number of systems are currently on the market. Bruun and others also recommended, in some instances, back-passing or by-passing<sup>35</sup> wherein accumulated materials—which in some sites block access to an inlet, e.g. Hillsboro Inlet on the Florida East Coast—are transferred from one side of an inlet or obstacle to the other sediment-starved side.<sup>36</sup>

Taking a look at the Black Sea environment, the shores of the Republic of Georgia have also been the site of important erosion and artificial feeding.<sup>37</sup> The pebbles of some beaches have been mined to provide construction material for buildings and roads needed to answer the heavy touristic demand of the balmy resorts. In a 20 year period (1945–1965) more than 30 millions of cubic meters were removed on a 300 km

stretch, regardless of the simultaneous construction of barrages on the rivers that feed the beaches. The starvation suffered by these generated a yearly erosion running from three to five meters. Engineers turned to the usual hard structures to counter the catastrophic landwards migration of the shoreline, yet to no avail, as the erosion spread longitudinally in 20 years (1961–1981) from 155 to 220 km. The approach was switched to artificial nourishment with gravel and pebbles quarried on land and trucked to the sea. An original load of half a million cubic meters was placed, in three years time, for instance on the beach of Gagra (southeast of the famed resort of Sochi). A new beach 50 m wide was thus rebuilt, but according to echoes, the effort was hardly sustainable, as not less than 70,000 m<sup>3</sup> are added yearly. The Georgians have attempted as well to protect their shoreline by creating artificial beaches.<sup>38</sup> The coast has suffered considerable damage because hard structures were put in place to protect rail-lines but also towns between 1961 and 1981. The new Soviet policy inaugurated in 1981 planned to support a balanced budget of beach-forming material for each “cell”, viz. morpho-dynamic subsystem. The load from rivers was increased and claims are made that erosion decreased as 110 ha of beaches were restored.

In the autonomous republic of Abkhazia (Georgia), Pitsunda is the site of a mastodont hotel complex that has nothing to envy to Spanish resorts. What was obviously ignored was a consultation with geologists. The development is all but sustainable from a geodynamic viewpoint: the Bzibi River dejection cone is in fragile equilibrium on the northern flank of a steep sloped canyon plunging rapidly towards the greater depths of the Black Sea. If a submarine slide occurs, town and hotels and other touristic infrastructure will take an all-but-merry dive and disappear under the water.

Problems arising from anthropic interference in the natural processes of sedimentation, and efforts to protect beaches have been examined by Russian writers, confirming the magnitude of the problems and the philosophy proposed to reach a sustainable *compromis* with nature and . . . men.<sup>39</sup>

More recently feeder-berms have been placed slightly offshore. Instead of nourishing directly a beach, materials are placed at a rather short distance from the low-water line. As materials are removed from the beach by waves and transported offshore, their trajectory stumbles on an obstacle, the berm, the velocity of transport is reduced and at least part of the load is deposited as incoming sediments are picked up from the berm and carried to the beach. The technique has been implemented in a few locations among which De Haan (Den Haan, Le Coq) in Belgium. It can be labeled: “cooperate with nature, do not fight it”. Some less aesthetic, less large approaches have been proposed, e.g. the “Beachbuilder Technique”, but never tested due to lack of funding.<sup>40</sup> A disincentive to the method is that the beach will be unattractive to the eye and not entirely accessible while it is being rebuilt.

Soft engineering has its limits. In several North American sites—with Florida the star example—the option to dredge sand offshore for beach nourishment is not sustainable and the operation has triggered increased erosion. This author has brought this point to the fore in warning of the top importance to be given to source sites.

A philosophy, which has gained (1990–present) as many followers as opponents, has been widely publicized by Pilkey<sup>41</sup>, it can be summed up in a short slogan: “Let nature have its way”.<sup>42</sup> In other words, accept that shorelines are retreating and that land loss is inevitable. Property owners are most vocal in as much the philosophy encompasses the loss of homes, shops, entertainment facilities, and the abandon of streets, and infrastructures. Compensation guarantees and offers has not generally moved them to a more realistic attitude. Nevertheless, some States, on North America’s southeast coast, have proceeded with a landwards transfer (1995–present) of the construction line, including abandon of existing constructions. The idea of rolling back coastal areas construction lines<sup>43</sup> got a foothold in Caribbean Islands where maintaining beaches is among the foremost problems.<sup>44</sup>

Where in the period pre-dating the 19<sup>th</sup> century, and during the pre-World War II years, the hard structures, from rubble-mound breakwaters to a variety of groins, sea-walls, et al. were thought of as the only solution, nowadays (1990–present) there is no longer a single philosophy nor a single approach. Planners have taken a new look at marshes and dunes. There is no further need either to create more agricultural land. This has led to the construction of artificial, or new dunes, or the rehabilitation of severely damaged dunes. Yet, at the same time, barrier breaching has been implemented in some regions: destroyed or crumbling reinforced toes of dunes, are no longer repaired, instead channels are left open, even opened-up, to let the sea penetrate the barrier and exhaust its energy naturally; the practice has been successfully tested for instance near Belgium’s border with France, in Northern France and the Wash region of England.<sup>45</sup> In regions where a network of creeks exist, expansion of salt marshes, greatly modified in the past by anthropic action, may be considered, as they absorb a considerable amount of wave energy. In The Wash region (England), this permits to dispense with embankments.

Pilkey and co-workers compiled a list of 40 ways—but there are more, some being variants thereof—currently on the market to counter shoreline retreat, and often to restore beaches (Table 3). All have not equal merits; few are actually environment friendly. Devices that are proposed as alternatives to hard structures, or even straight beach nourishment, belong, in a general way, to one of two groups: those placed or acting in the water, and those placed on the beach. Of the first group’s twenty only the seabee and the beach protector tire mat do not cause downdrift beach erosion, which are also the only two that do not impact on water quality. There are 21 devices in the second group. They fare better than the other group’s members; here eleven do not impact on downdrift beaches and 18 don’t affect negatively water quality. Alas all but five cause erosion of fronting beaches. To the latter group Berossin<sup>®</sup> ought to be added; it apparently does not cause erosion of downdrift or fronting beaches nor does it impact on water quality.

Are they “sustainable”? Much here depends on the interpretation of the concept and this author confesses on his lack of authority to pass judgment. But several most probably are. Yet, in view of the negative impact, or even the unproven

efficiency, many may be set aside as not one of the best available “solutions” (Table 4).

## TRY-OUTS AND FALL-OUTS

After peace was restored following the bloodbath of the Second World War, engineers, concerned with the shrinking of beaches and the obvious inefficiency on a long term basis and high costs of maintenance and repairs of hard structures, decided to try out several of the solutions proposed by academe as well as by private concerns. Results were often not encouraging: de-watering has met with some satisfactory outcomes and may still be occasionally called upon. Artificial beach nourishment has been tried-out all around the globe and efforts there concentrate on how to limit the [often rapid] loss of deposited material.

The Beach Management System<sup>®</sup> claims to absorb that part of wave energy causing erosion and reducing backwash on the active beach face.<sup>46</sup> The system creates an unsaturated zone in the beach sand. Water from the wave run-up percolates downwards and deposits the suspended sand grains on the beach face. On the Danish North Sea the system created a stable shoreline some 20 to 25 m seaward of the installation that was put in place in the Fall of 1985. The system is site specific and eroded areas, due to heavy storms, are reclaimed and restored along the stabilization line.

The Beachbuilder<sup>®</sup> approach holds promise if one considers *in vitro* indications but we remain still far, and regrettably so, from a pilot attempt to implement the approach.<sup>47</sup> On the other hand Berossin<sup>®</sup> has been tested and commercialized. The manufacturer claims that results are satisfactory. Other methods have been tested under laboratory conditions.<sup>48</sup>

Finding sustainable solutions is a priority of small islands, particularly those of the Pacific ocean where land often is barely a few meters above the present sea-level. In this regard there is a growing dissatisfaction with current trends which are geared to national solutions. Small islands, whether independent states or dependencies, the need is for multinational approaches. Bruce Potter of the Island Resource Foundation similarly stressed the urgent need in regional programs to incorporate dependencies of larger states into regional island sustainable development fora. Would it not be a step forward to call on some international organizations to fund coordinated efforts in coastal protection instead of the prevailing piecemeal national approach? To mind comes for instance the granting of \$150.5 million for sixteen projects by the GEF?<sup>49</sup> In this group the Danube/Black Sea Basin Strategic Partnership on Nutrient Reduction received a grant of \$29.7 million—towards a total project cost of \$41.3 million. The new program claims to demonstrate a trend towards more strategic partnerships and a more programmatic approach. The emphasis is laid on the integrated ecosystem approach and public involvement in project design and implementation.<sup>50</sup>

Some examples of successful soft engineering can be taken from the Caribbean, Tunisia, Philippines. On Anguilla, Antigua, Barbuda and Nevis new structures are being implant-

Table 3. *Potential negative impacts associated with alternative devices (cf. Journal of Coastal Research, Special Issue no. 26, 1998, p. 270, McQuarrie and Pilkey).*

Device	Harm Beach Access	Erosion of Downdrift Beaches	Erosion of Fronting Beaches	Potential Hazard to Swimmers	Impact on Water Quality	Impairs Aesthetics
<b>IN WATER</b>						
Atlas Shoreline Protection System	X	X		X	X	
Beach Prisms		X		X	X	X
Beachsaver Reef		X		X	X	
Menger Submerged Reef		X		X	X	
MOTO		X		X	X	
Pep Reef		X	X	X	X	
Sealift		X		X	X	
Shoreprotector		X		X	X	
Surge breaker		X		X	X	
Temple Beach System	X	X		X	X	X
Waveblock		X		X	X	
Waveshield		X		X	X	X
Wave Wedge		X		X	X	
Beach Cones		X		X	X	
Beach Protector Tire Mat						
Burns Beach Erosion Device		X		X	X	
Cegrass		X		X	X	
Coil System		X		X	X	
Seabee				X		
Seascape		X		X	X	
<b>ON THE BEACH</b>						
Brush Fence		X		X	X	X
Holmberg Undercurrent Stabilizer		X	X	X	X	
Parker Sand Web	X	X				X
Shoreline Construction Corp.		X	X	X	X	
Stabilito		X	X			X
High Energy Return Wall		X	X	X		X
Marine Bin Walls		X	X	X		X
Ravens Retaining Wall		X	X	X		X
Wave Buster		X	X	X		X
Z-wall		X	X	X		X
HDSI	X					X
Stabeach	X					X
Biodune Sand Gel			X			
Dune Guard			X			X
Fabric Fence			X			X
Nicolon Geotube			X			X
Soukup Rubber Tire Revetment			X			X
Subsurface Dune Restoration System			X			X
Triton Marine Mattress						X
Beachbuilder Technique	X					X
Stabler Disks						X

ed at a safe distance from the active beach zone; the option has been strongly recommended in other Caribbean islands especially considering climate-change and variation. The approach has been implemented in India and The Seychelles, and advocated for the Philippines. In the latter specific coastal vegetation has been successfully used for re-vegetation in eroding areas (for instance vetiver grass); the natural zonation of coastal vegetation was conserved with halophilic plants near the beach, while further inland, trees and shrubs could be planted in a series of near-parallel belts.

Dune restoration has been praised as a soft engineering approach; it has a proven a successful method in Mahdia, Tunisia, occasionally combined, as in northern France and Belgium, with beach nourishment.<sup>51</sup>

## SUSTAINABILITY

Beaches are eroding, and cliffs retreating, worldwide; the sites where accretion occurs are far less numerous. This has been repeated ad libitum. Nature, waves, rising sea-level, changing climates, and not forgetting man, have caused shorelines shifts. Stopping the migration is probably not possible; alleviating the problem, or "mitigating" it, to cite the expression of Psuty and some others, is probably conceivable.<sup>52</sup>

The problems encountered along the rim of the Black Sea are, of course, not different from those in other locations around the world, nor even from those found around several lakes. Cliffs are being fritted down as well in Eforie as along

Table 4. *Coastal defense: types of low cost defense strategies and approaches.*

<b>Hard Structure (static)</b>
Wooden stakes
Cement plates
Old tires
Tree trunks
Old ships
<b>Soft approaches (dynamic)</b>
Minor nourishment
By-passing
Back-passing
De-watering
Beds of algae
Removal of existing overly aggressive structures
<b>Alternative approaches</b>
Dune building or restoration
Inlet opening or re-opening
Artificial reefs (old cars, tram/train carriages)
Transformation in planted areas of clay dikes
Rolling back of construction line
<b>Patented systems</b>
<i>None is inexpensive and most will not be affordable for cash-strapped countries</i>

the coasts of France whether it is near Cayeux or Fécamp, or in Northern California along famed highway 101, or for that matter in Northwest Spain. Beaches are retreating landwards in Mamaia, The Netherlands, Belgium, France, the Ukraine, the Carolinas, Florida, Java or Bali alike. Hence suggestions apply everywhere but solutions must be site-specific, and especially be long-term, and not stop-gap.

Hard structures are not “sustainable”, both in the sense that even the most formidable armors may be destroyed—and examples abound on all coasts—and that they solve—at least temporarily—a location’s problem, but create a new one elsewhere. Thus this approach ought to be abandoned, no matter who much despair this may cause civil engineers and construction companies. Existing structures ought not to be removed: they will eventually crumble or be buried by sedimentary processes. Jetties can be maintained there where shipping needs them, but perhaps preferably built à claire-voie,<sup>53</sup> and, in ports, permeable breakwaters, p.ex. made out of haros®, are less damaging. Segmented breakwaters, placed off-shore cause less subsequent damage than other structures and may be installed in case other solutions are inadequate.<sup>54</sup> The armored protection ought to be used only where needed in harbors, for berthing installations, to create a calm water basin, or where an economic complex must be maintained and thus protected. This applies equally to some areas where multi-million-euros tourism and/or recreational infrastructures exist which cannot conceivably be moved inland or merely abandoned.

In this regard decision-makers must be inflexible versus wild, viz. unauthorized, un-licensed, illegal, constructions, even if this causes distress to well-heeled, politically-powerful groups or individuals; as an example an entirely planned community erected without a permit in a charming, but fragile cove near Valencia, Spain, was condemned, and construc-

tions and infrastructure removed, but in La Panne’s Westhoek Natural Reserve (Belgium) if the burgomaster who had issued the permit and thus violated laws and regulations, went to prison, the multi-storied buildings were not sloped and the damage done not rectified.

Artificial nourishment of beaches is a possible, yet expensive, solution in sites where maintaining a beach is an economic necessity. It is a—if we dare use the word—palliative measure, because no sooner has the feed material been placed, than erosion starts anew, and in some recorded instances the entire new cover has been removed by one severe storm. It is important to “anchor” the new cover—with plantations for instance—but perhaps even wiser to feed a berm established at short distance from the low water line of the shore, rather than the beach itself. This author is aware that such measures are costly and pose problems for some countries, such as Romania. Furthermore, if “sustainable”, they are not free of adverse consequences and require wise planning.<sup>55</sup> Thus the material must be selected so that grain size is slightly coarser than the original sand cover. The source point of the fed material is of capital importance. Dredging must not be done too close to the shore, lest erosion will be increased, but care must be taken that the natural capacity of replenishment not be exceeded, and that benthonic life not be destroyed beyond recuperation; studies have been conducted, in the United States, for instance, which indicate that minimum three years are commonly required for benthic life to be restored. Artificial nourishment is thus neither a panacea nor an approach to engage in lightly.

One should look towards the dune and/or salt-marsh systems as sustainable solutions. Dunes constitute a primary protective barrier against the advance of the sea. They have been damaged in numerous locations, especially by bulldozing and habitat construction. Rebuilding of dunes and creation of artificial dunes is an affordable and sustainable method for coastal protection. Opening up, preferably in connection with existing waterways networks—if present—, of channels will reduce wave energy which pounds hard barriers, whether these are protective of dunes or not. This is a soft approach in harmony with nature. There is no reason why it could not be adopted along the Black Sea shores, barring of course a *levée de boucliers* on the part of property and business owners which could be compelled de plier bagage. Compensation would of course have to be paid to them. In areas where the system has been tested, the results have proven highly encouraging.

Similarly the loss of wetlands, salt-marshes and the like, has been catastrophic for ecosystems, reducing also biodiversity, and has contributed to exacerbating coastal erosion. The most spectacular losses, on a yearly basis, are perhaps well those registered since many years in Louisiana. However polderization and expansion of agricultural surfaces are at the origin of losses of saltwater- and brackish-water expanses. Not only are the marshes and wetlands fundamental areas of bio-production, they are also important wave energy attenuators (dampers). Recreation of the wetlands is an affordable, sustainable and nature-friendly approach to the coastal erosion problems.

Some manufacturers have placed artificial seaweed on the

market. Their effectiveness has been subject to controversy, even though European varieties are said to have some success as wave breakers and sand gatherers.<sup>56</sup>

The line of construction must be moved inland, wherever possible, behind the natural or reconstructed dune barrier, if present, so that buildings and roads do not interfere with the natural processes. This requires, undoubtedly, economic sacrifices and political courage, but in the long run, will prove a wise move. Dunes ought to be anchored by appropriate plantations, especially with those species which are “sand retainers”; plantations may also be placed on the beach itself, such as the lattenhaffen, not unusual on the beaches of Northern France and Belgium. At the limit, wood and concrete sheets “groins” may be placed on the beach as a mild and narrow protection against exceptional tides and storms.<sup>57</sup>

Be it mentioned, *en passant*, that no matter all the talk, and publications, about new methods to counter the relentless and inexorable advance of the sea, especially those in harmony with nature, there has been for decades a dearth of funds to test new proposals which seem to hold promises. *In vitro* experimenting is fine, but results remain unconvincing to purse-string holders until a field try-out has been attempted. The artificial sea-weeds approach as coastal protection got a severe blow after a Scripps-La Jolla study, even if the European variety encountered some approval on this side of the Atlantic. This author thinks in regards to approaches worthy of field testing of Berosin, Beachbuilder, Cornic, and some others.

The search is on to find the most sustainable approach and from all current indications and the lessons of history, the closest we can come to sustainability is to work with nature, not as we have done for centuries, against it. A *Protocol* was drawn up by Scots for undeveloped coasts; it may well be applied to other coasts whenever possible and adapted to individual sites, as it is an aid to the identification of the sustainable development potential of coasts. It advises, an important feature, the early involvement of scientists in site care and site identification.<sup>58</sup> This protocol suggests to assess the nature of a proposed development for resource use, to identify potential sites and relevant *Process Defined Management Units* (PDMU), rank these potential sites within the context of sustainable development within the PDMUs, make a decision on final site[s] selection, and undertake an *Environmental Impact Assessment* (EIA) on the site[s] selected. Quoting a UK House of Commons Report: it is “time to declare and end to the centuries-old war with the sea and to seek a peaceful accommodation with our former enemy”. A wise recommendation is “to anticipate and plan a policy of managed realignment [rather] than to suffer the consequences of a deluded belief that we can maintain indefinitely an unbreachable Maginot Line of towering sea walls and flood defences”.<sup>59</sup>

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<sup>3</sup> Caius Plinius Secundus. For a modern version of his writings, see Pline, 1966, *Histoire Naturelle.* Paris, Belles-Lettres.

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<sup>5</sup> CHARLIER, R.H.; BRUUN, P.; CHAINEUX, M.C., and MORCOS, S., 2003, Coastal protection, since when? *Proceedings VI th International Congress History Oceanography.* [in press]; Charlier, R.H., 2001. 3000 years of coastal protection. *Proceedings 1st International Symp. Seas and Oceans (Sczeszin, Poland, Sept. 2001)*, I, 91–98.

<sup>6</sup> HAULOT, A., 1975. *Tourisme et environnement.* Verviers, Marabout “Collection Université”, and other articles.

<sup>7</sup> BORDOMER, a series of international conferences held in Bordeaux in 1992, 1994, 1997, was an outgrowth of another series dealing with exploitation of ocean resources which took place also in Bordeaux in 1974 and 1978.

<sup>8</sup> The *haro*, a proprietary product, is a block with a large central opening, allowing part of the incoming wave to pass through. An assemblage constitutes thus a permeable breakwater, as opposed to the traditional rubble-mound one. Pertinent company literature is available from professor J. De Rouck, department of civil engineering, University of Ghent, or from HAECON NV, 110, Deinsesteenweg, Drogen B-9012 Belgium. A brief description can be found in Charlier, R.H. and De Meyer, C.P., 1998, *Coastal Erosion. Response and Management:* Heidelberg, Springer Verlag, pp.205–207. Critique uttered at the 6<sup>th</sup> International Congress History Oceanography is reproduced in the paper by Charlier, Bruun, Chainoux and Morcos, “Panorama of Coastal Protection” currently in press (*Journal Coastal Research*).

<sup>9</sup> MARCUS ANTONIUS.

<sup>10</sup> The event is often labeled an anecdote, though Turkish, and Mediterranean, coasts specialist Erdal Ozhan has not denied its accuracy.

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<sup>14</sup> Caius Caesar Germanicus, known as Caligula, Roman emperor.

<sup>15</sup> CHARLIER, R.H., BRUUN, P., CHAINEUX, M.-C.P., and MORCOS, S., 2003. Panorama of coastal protection: *Journal Coastal Research* [in press].

<sup>16</sup> GRILLO, S., 1989. *Venice Sea Defences.* Venice, Ed. Arsenale.

<sup>17</sup> *cf.* the levees along the Mississippi in the USA, particularly in Louisiana. The word has become a standard geological term.

<sup>18</sup> An anecdote holds that the siege was not expected to last long, so the archduchess Isabella vowed not to change her shirt till it was over. The coloration of her garment can best be imagined: to commemorate the “feat”, it was given to the skirt color of some horses (“Isabella Color”).

<sup>19</sup> *cf.* US Army Corps of Engineers, several dates, *Low Cost Coastal Protection:* Washington, US Army Corps of Engineers; Charlier, R.H. and De Meyer, C.P., 2000, To feed or not to feed, that is often the question: *Int. Journal Environmental St.*, 55, 1, 1–23.

<sup>20</sup> A *stere* is a European measure of wood equivalent to one cubic meter of wood. The word also indicates the cage-like contraption in which wood is piled for measurement. In this instance cages and their filling were kept together. It may thus be considered as a vertical wooden breakwater back-up one meter high.

<sup>21</sup> lean concrete=sand-cement mixture

- <sup>22</sup> see note 3.
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