https://erjm.journals.ekb.eg
ISSN: 1110-1180

DOI: ---------

ERJ
Engineering Research Journal
Faculty of Engineering
Menoufia University

Building with Nature Approach as a Protection, Restoration and Development of Coastal Zone

Rania E. Mohamed *, and Mohamed M. Abd-El Mooty

Hydraulics and Irrigation Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.
**(Corresponding author: rania_mohamed@alexu.edu.eg)*

ABSTRACT

Building with nature means that the designs depend on making use of the natural processes, elements and materials available in the locality and work with nature. By applying the Building with Nature strategy, everything is in harmony with nature. This strategy says no to build more dams and dikes as dominant bulk walls against the sea, and yes to dunes and beaches in harmony with the sea. The strategy is more energy efficient and good for nature, and the environment. The strategy also aims to achieve a new flexible, dynamic balanced coastline consisting of dunes and beaches with a minimum of hard sea structures. A coastline where growth and erosion exist in equilibrium, minimally maintained by periodical sand nourishment. In the densely populated areas there is only a little space available for human demands. And at the same time there's the need to preserve or expand valuable environment, nature, and landscape. To solve this shortage of space, there are three solutions. Firstly, the third dimension is using more than before. Using height and depth, and multifunctional use of the existing space. The second solution is looking at possibilities in the existing hinterland, and a third solution is in the direction of the sea. The principles maintained can be applied in the regions with vulnerable densely populated coastal and delta zones. In addition, the sea level rise will be considered when designing the height of structures. Baltim coast is taken as a study case for applying the idea of building with nature. Suggestion for this application is presented in this paper.

Keywords: *sustainability; sea-level rise; Nile Delta; building with nature (BWN); dunes*

1. Introduction

In the present time, we are familiar with the hydraulic engineering infrastructures. Think of the breakwaters that protect harbors, and even groins that prevent coasts eroding. All of these infrastructures are designed by hydraulic engineers for a particular purpose. The problem comes when the infrastructure is harmful to nature or the living quality of people. For example, a groin designed to protect a particular stretch of coast from erosion but causing problems further along the coast, because it prevents all the sand transport. These problems are known to engineers and ecologists all over the world. But how do we move from single purpose design to multi-purpose designs and combine the worlds of engineering and ecology?

Building with Nature (BWN) is a new approach that combines hydraulic engineering and ecology. In addition, it allows us to move from single purpose designs to multi-purpose designs. This technique teaches us to build with Nature rather than just building in nature, to work effectively with public and private parties to realize nature-friendly and nature enhancing hydraulic infrastructure [1].

Building with Nature is using natural materials and working with natural processes in hydraulic design. It not only solves problems for nature that are created by infrastructural projects, it also seeks to create opportunities for nature, or restore ecosystems, while enhancing the design, operation and maintenance of the infrastructure. Moreover, based on the BWN approach, marine infrastructure development can be carried out adaptively, in line with natural dynamics systematically seeking win- win solutions. This leads not only to cost- effectiveness and flexibility, but also to a net environment gain. To do this, an integrated design approach is applied, drawing together an understanding of the natural physical processes, engineering design principles and ecological principles.

The building with nature can be applied to myriad works in all kinds of environments as long as thorough knowledge of local ecosystem is available. The range of application is illustrated by several publications [2-5].

2. Engineering Design Principles According to Building with Nature

When designing, each engineer seeks to reconcile the required function of the infrastructure with the hydraulic boundary conditions and load that it will experience. They do this to a required standard and reasonable cost. So theses represent two necessary principles for engineering design. The third principle is the structural integrity. The structure should satisfy its strength, stability, and stiffness. The fourth, reliability. That is the structure should continue to function smoothly and well and should not require many repairs. In general, the simpler the structure, the more likely it is to be reliable. This principle incorporates the idea of maintenance – that a structure can be maintained so that it remains reliable. Control of environmental variability principle is necessary to ensure access, connection or supply. The next design principle is implementibility. This principle requires checking whether it is feasible and reasonable to build and operate the structure. Another principle, that is not commonly applied is that of Adaptability. This means taking expected future changes in the function of an infrastructure into account in the design phase. The eighth design principle is resilience. Resilience capacity of the engineering structure to withstand a second shock, or sudden high load, of similar magnitude to the first and yet retain its structural integrity and continue to meet the functional requirements.

Each principle requires you to think about the abiotic environment and its variability. Maybe by withstanding, controlling or regulating the variability, or considering the types of materials at the site or nearby. This brings us to the 9th principle, and most fundamental engineering design principle, understanding the abiotic environment sufficiently to determine appropriate hydraulic boundary conditions and loads.

3.Ecological Design Principles According to Building with Nature

What does nature- friendly design mean? in this part, we're going to focus on the ecological design principles as counterpoints for the engineering design principles. These principles will enable you to make the connection between hydraulic engineering design choices, and choices to restore or provide opportunities for the ecosystem. There are 11 ecological design principles. First, the principle of continuity. This relates to the continuity of water and sediment flows and land-water interfaces in the ecosystem. Second, the principle of no direct human disturbance. This aims to minimize direct human disturbance on the ecosystem. The third principle of indigeneity relates to the level of invasion of ecosystem by exotic species. Fourth, the principle of population viability. A species is viable when it has ability to persist. Fifth principle is opportunity for threatened species. So hydraulic structures can help by offering new habitats, restoring connectivity, and improving circulation, for instance. Sixth, the principle of trophic web integrity. Ecosystem are complex networks in which matter, energy and living begins interact.

The seventh principle is opportunity for ecological succession. Ecological succession is the natural change in species present in an ecosystem over time. The eight principle is zone integrity. The presence of the full range of zonal diversity is a condition for ecosystem health. Ninth, the principle of characteristic (in) organic cycles relates to the integrity of the throughputs of carbon, nitrogen, phosphorous and silicon in an ecosystem. The tenth principle of characteristic physical- chemical water quality aims to ensure that the natural distribution of water quality states is maintained over time and space. The last principle is resilience. Resilience is the capacity of the ecosystem to maintain its integrity following successive disturbances. Now, design for healthy and functional ecosystems are understood. In addition, these ecological design principles to deliver nature- friendly design can have applied.

4. Building with Nature - An Integrated Design Approach

Building with nature aims to use natural materials, forces and interaction to balance hydraulic infrastructure interventions and the needs and health of ecosystem, as possible as. Building with nature design process just like the conventional engineering design process and has 7 steps in an iterative process. Figure (1) illustrates the iterative design process of Building with nature. The same applies to the secondary headings. This is a mere example text. Up to three levels of headings are accepted.

The major differences in the two design processes are first, that in Building with nature, we look forward the need to include many actors or stakeholders with different perspective as well as multiple knowledge sources. So, we are accepting of uncertainty, recognizing that the natural systems are dynamic and the ecosystem can have unexpected responses.

5. Case Study

Baltim resort is the target study area and located 15 km eastward of Burullus inlet. It is also one of many

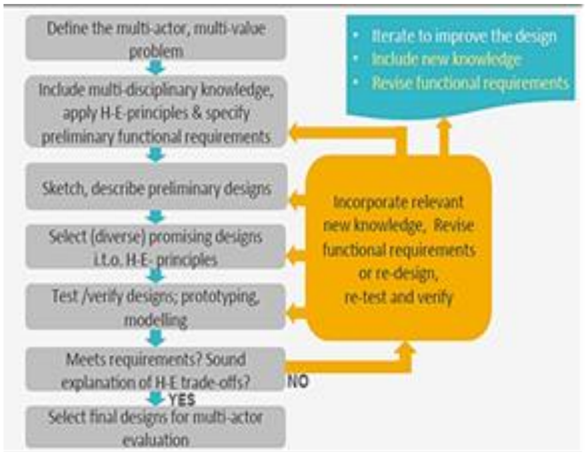


Figure 1- The Building with Nature Design Process

coastal places attract the people during the summer season to enjoy the sea, the sand and weather. It located between 31 °30' 00"N to 31 °40' 00"N latitudes (3492000 to 3600000) and 31°00′ 00″E to 31°15′00″E longitudes (318000 to 328000). The study area suffers from erosion problems along its coastline. These problems are mainly due to human activities (e.g. construction and development works along coastline), and natural factors (e.g. wind, wave, current and sea level rise). To reduce the erosion problems, coastal protection structures are introduced to reduce the wave heights behind the structure [6].

A system of four phases of detached breakwaters has been implemented since 1990 to protect the resort from erosion. The total length of protected coast is about 7 to 8 km. The number of segments in the whole system is 14 detached breakwaters, nine breakwaters were constructed in the period 1993-2002, with these dimensions (4-7-ton dolos, 250-300 m length, 220m far from the coast, with 300-400m gap between them, 3-4m water depth, and 2.5m crest level). Additional five breakwaters were constructed after 2003 with the same characteristics. Moreover, nine short groins with (75-100m length, and 250-300m apart) constructed on the west of Kitchener drain [7]. "Figures 2 & 3" show the protection works along the coast of Baltim resort (detached breakwaters and groins) west and east of Kitchener drain.

Beach profiles are utilized in the present study to understand the variations in seabed levels and shoreline position. In addition, they were used to determine rate of shoreline and seafloor changes. Therefore, beach profiles are an important tool for elucidating long-term trends, such as erosion and accretion, and for predicting the morphology of coastal landforms in the future [8].

Figure 2- Protection works along the coast of Baltim resort (detached breakwaters and groins) west of Kitchener drain

Figure 3- Protection works along the eastward coast of Kitchener drain

For the previous reasons, shoreline and beach-nearshore profiles were surveyed between 2004 and 2012 along the study area, covering a time span of 9 years. Profiles were surveyed in the fall (September/ October). Figure 4 shows profile numbers are defined according to the coastal research institute (CoRI) and the profile location along the coastline. "Figures 5,6,7" show some examples of the beach profiles measured at various positions along the Baltim resort [8]. They display the cross-shore profile changes over time in response to hydrodynamic processes (e.g. wind, waves, tide, and wave induced currents). The sandbars grow in the surf zone. Bar system is predominantly parallel to the shoreline, formed in shallow water as a response to the action of hydrodynamic variables. In addition, their position usually controls the wave-breaking zone and represents a natural barrier against high wave forcing.

Waves and wave-induced currents are the critical forces in sand transport and deposition. Wave action along the Egyptian Mediterranean coast is seasonal in strength and direction. The prevailing wave directions are NNW, NW and WNW (almost 69%) due to northwest winds.

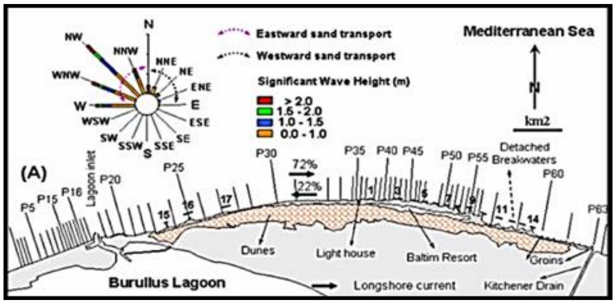


Figure 4- The Surveyed Beach Profiles Positions Along the Nile Delta Coastline (Labeled P1 To P63)

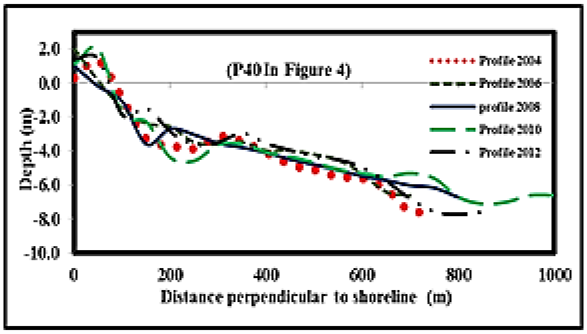


Figure 5- The Surveyed Beach Profile (P40) At Baltim Resort for Years (2004,2006,2008,2010,2012)

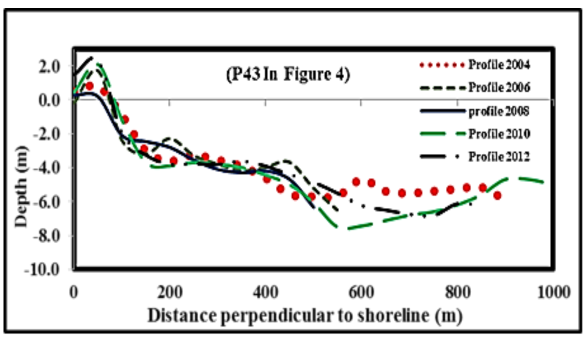


Figure6- The Surveyed Beach Profile (P43) At Baltim Resort for Years (2004,2006,2008,2010,2012)

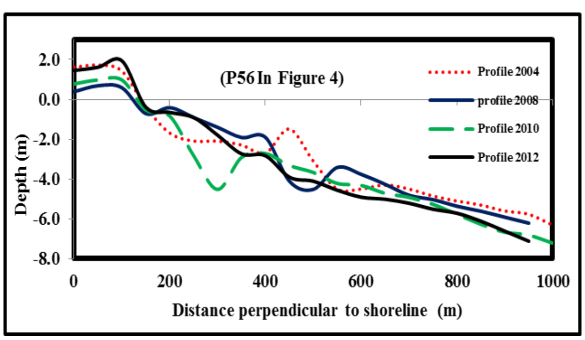


Figure7. The Surveyed Beach Profile (P56) At Baltim Resort for Years (2004, 2008,2010,2012)

The predominated wave height is 2.5 m and 7-8 sec wave period and the maximum wave height reaches 3.3 m with the probability of occurrence for one time at least per year. The tide along the delta coast is a semi-diurnal micro tidal regime with an average range 25-30 cm, and the maximum tidal range is 50 cm [9].

Statistical analysis of the tide measurements along the Egyptian North coast during the period from 1943 to 2000 indicated that the rate of sea level rise ranges between 1.6 mm and 5.3 mm included the land subsidence as shown in Table (1) [10].

Coastal projects have been implemented to protect some parts of the Nile Delta coast through hard and soft structures from sea level rise and storm events. It is unclear whether the construction of hard defenses along the coast will remain cost effective in the face of accelerated sea level rise and anticipated increases in extreme weather events.

Table 1- Estimated Average Annual Seal Level Rise (cm) Relative to Year 2000 Sea Level, [10]

City	Year IPCC Scenario	2025	2050	2075	2100
Temperature (C°)	A1F1	1.2	2.2	3.2	4.0
Alexandria		13.0	34.0	55.0	72.0
Burullus		14.75	37.5	60.3	79.0
Port Said		27.9	68.8	109.6	144.0

The east coast of Kitchener drain is reinforced through Building with nature. Two alternatives are applied in the study area. The first alternative is realized by a dune beach expansion in front of the sea barrier. Figure (8) shows the suggested solution (dune beach expansion). This solution combines safety, nature development and recreation. In addition, this solution can protect the area from sea level rise phenomena.

The second solution is Sand-Engine. It uses natural dynamics to distribute a huge sand nourishment along the coast, combating erosion and improving flooding safety. In addition, it increases recreational space along the coast and provides opportunities for the ecosystem. Figure (9) shows the suggested shape and location of sand nourishment.

The engineering and ecological principles are applied for two alternatives (sand engine and dune-beach expansion). "Tables 2 and 3" show the engineering and ecological principles for dune-beach expansion solution.

Figure 8 - The First Alternative (Dune Beach Expansion)

Figure 9 - The Second Alternative (Sand Nourishment)

Table 2- The Engineering Principles and How These Principles Are Applied on The Dune-Beach Expansion Solution

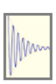
Sand engien Engineering principles		Checkboxes Max -Min					Explanation
	Requisite standard					x	Meet the flood protection, and by nourishing the coast with sand we add additional safety
	Control variability			x			Coastal erosion is combatted but not controlled
	Reasonable costs			x			It depends on the place where you can obtain the nourished sand. If the sand can get from offshore, the cost is low. on the other hand, if the sand is imported from far places, the cost is high.

Table 2-continued: The Engineering Principles and How These Principles Are Applied on The Dune-Beach Expansion Solution

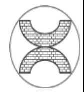
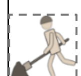
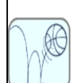
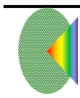
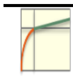
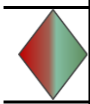
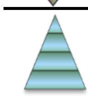
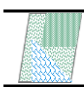
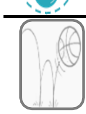
Sand engien Engineering principles		Checkboxes Max -Min					Explanation
	Structural integrity					x	It is accommod-ated by using natural materials (sand) and its processes to combat erosion and coastal defense.
	Reliability				x		By providing natural material and using natural processes, the project should continue to function with limited maintains
	Implemen-tability					x	The experience of construction companies, meant that they could construct the project
	Adaptab -ility					x	The design explicitly considers future needs
	Resilience					x	By nourishing the beach with a large amount of sand, there is sufficient sediment in coastal profile to respond effectively to a series of storm events
	Appropriate boundary conditions and loads				x		A full range of representative wave conditions is used in the numerical model runs in the testing phase of the design

Table 3- The Ecological Principles and How These Principles Are Applied on The Dune-Beach Expansion Solution

Ecological principles		**Checkboxes**					**Explanation**
		Min- Max					
	Continuity					x	The project enhances water and sediment flows and provides more gradual transitions between land and water
	No-direct human disturbance					x	The project aim is to reduce the human disturbance by recurrent sand nourishment
	Indigenousness / Endogeneity			x			The project is providing new physical habitats, we do not yet Know which species will colonize which habitat
	Viability of populations			x			Effects on population unclear, will have to be determined through monitoring
	Opportunity for threatened species				x		Unclear and under monitoring
	Trophic web integrity			x			Its contribution to Trophic web integrity will have to be determined through monitoring
	Opportunity for ecological succession					x	It also facilitates the emergence of pioneer ecosystem stages
	Zone integrity					x	Gradually land-water transitions, uninterrupted natural processes
	Characteristic (in)organic cycles			x			uncertain. Because the sand deposited by the project derives from the bottom of the sea, its chemical composition and interaction with the atmosphere could cause unexpected effects.
	Characteristic physical-chemical water quality			x			It is uncertain, reaction of sediments in the atmosphere and water column may be unexpected, otherwise natural processes and dynamics may be generated stronger currents in place more sheltered regions elsewhere
	Resilience					x	By reducing the frequency of sediment nourishment, the Ecosystem can recover and can potentially achieve dynamic equilibrium.

On the other hand, Tables 4 and 5 show that the engineering and ecological principles for sand engine alternative.

Table 4- The Engineering Principles and How These Principles Are Utilized for The Sand Engine Solution

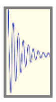
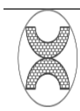
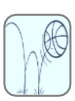
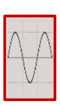
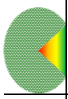
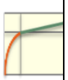
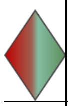
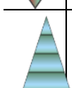
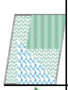
Engineering principles		**Checkbox** Min- Max					**Explanation**
	Requisite standard					x	Meet the flood protection, and by nourishing the coast with sand we add additional safety, and add recreational space
	Control variability					x	Control the coastal erosion
	Reasonable costs				x		Dunes occur naturally on sandy beaches, but the nourished sand is needed. If the sand can get from offshore, the cost is low. on the other hand, if the sand is imported from far places, the cost is high
	Structural integrity					x	It is harmonized by using natural materials (sand) and its processes to combat erosion and coastal defense
	Reliability				x		By providing natural material and using natural processes, the project should continue to function with limited maintance
	Implementability					x	The experience of construction companies, meant that they could construct the project
	Adaptability					x	The design explicitly considers future needs
	Resilience					x	By nourishing the beach with a huge volume of sand, there is sufficient sediment in coastal profile to respond effectively to a series of storm events. In addition, the dunes add additional protection from flooding for the landward.
	Appropriate boundary conditions and loads				x		By using the numerical model, A full range of representative of wave conditions is used in the design phase

Table 5- The Ecological Principles and How These Principles Are Utilized for The Sand Engine Solution

Ecological principles		**Checkboxes** Min- Max					**Explanation**
	Continuity					x	Continuity of water and sediment flows and land-water interfaces in the ecosystem are not interrupted
	No-direct human disturbance			x			The dune ridge and detached breakwater is used for walking or riding, representing direct human disturbance. However, this is of low intensity and does not appear to be affecting the health of dune vegetation.
	Indigenousness / Endogeneity					x	The beach nourishment is providing new physical habitats; we do not yet Know which species will colonize which habitat. Dunes occur naturally on sandy shores, they offer biotopes that would have occurred naturally, potentially enhancing endogeneity
	Viability of populations			x			Effects on population unclear, will have to be determined through monitoring
	Opportunity for threatened species						For nourished area (beach) Unclear and need monitoring. For dunes, they occur naturally on sandy shores they provide a habitat for threatened species with a preference for this biotope
	Trophic web integrity				x		The trophic web integrity of dune fields that are constant in one successionary stage is often impoverished
	Opportunity for ecological succession				x		It also facilitates the emergence of pioneer ecosystem stages. For dunes, the pioneer stage suffers as humans seek to fix dunes in position for their own convenience
	Zone integrity					x	The beach and dunes are unimpeded in their exposure to winds, waves and surges. This implies that natural zonation can occur
	Characteristic (in)organic cycles				x		Uncertain, but excessive nitrogen pollution in the air can cause the dune become denser
	Characteristic physical-chemical water quality					x	Dunes occur naturally on sandy shores and are important in filtering the rainwater down to the groundwater. On a beach they also help to develop a freshwater lens to combat salt water intrusion in the groundwater. Accordingly, they play an often-underestimated role in maintaining characteristic physical-chemical water levels.

6. Conclusions

Building with nature aims to use natural materials, and work with natural processes in hydraulic design. It not only solves problems for nature that are created by infrastructural projects, it also seeks to create opportunities for nature, or conserve ecosystems, while enhancing the design, operation and maintenance of the structure as possible as. This means Engineering and Ecological principles (H-E principles) should applied before Building with nature. The east coast of Kitchener drain is reinforced through Building with nature. Two alternatives are applied in the study area. The first alternative is realized by a **dune beach expansion** in front of the sea barrier. The second solution is **Sand-Engine**. After that, the engineering and ecological principles are applied for the two alternatives.

7. References

[1] R. Waterman, "Land in Water, Water in Land: Achieving Integrated Coastal Zone Development by Building with Nature," *Terra et Aqua,* 107, June 2007.

[2] H. De Vriend, et al, "Sustainable hydraulic engineering through Building with Nature," Journal of Hydro-environment Research, Vol. 9, pp. 159-171, 2015.

[3] A. Mol, T. De Wachter, and M. Huygens, "Eco-plume: operational pro-active environmental management of dredging," Proceedings of CEDA Dredging Days, Rotterdam, 2015.

[4] H. De Vriend, and M. Van Koningsveld, "Building with Nature: Thinking, acting and interacting differently," EcoShape, Building with Nature, Dordrecht, the Netherlands, 2012.

[5] Y. Meersschaut, W. Parker, J. Peters, and Y. Plancke, "A dredging and disposal strategy for managing the Western Scheldt's morphology and ecology," Proceedings of WODCON XVII, Hamburg, 2004.

[6] A. Soliman, H. Moghazy, R. Eid, "Sustainable solution for the protection of Alexandria Coastline, Egypt," Proceedings of 12th International Conference on the Mediterranean Coastal Environment, MEDCOAST 2015, Varna, Bulgaria, 2015.

[7] W. Ali, M. Kaiser, S. Kholief, M. El-Tahan, "Assessment of coastal changes along Baltim resort (Egypt) using remote sensing and DSAS method," Egyptian Journal of Aquatic Biology and Fisheries, 2017.

[8] R. Eid, "Hydrodynamic and Morphodynamic Modelling of Nearshore Sandbars (Study Case Burullus Area)," PhD. Thesis, Faculty of Engineering, Alexandria University, 2019.

[9] M. Abd-El-Mooty, R. Kansoh, and R. Mohamed, "Modelling of morphodynamic instabilities in Surf Zone," Proceedings of 13th International MEDCOAST Congress on Coastal and Marine Sciences, Engineering, Management and Conservation, MEDCOAST 2017, Malta, 2017.

[10] I. El Shinnawy, et al, (2010) "Vulnerability to climate changes and adaptation assessment for coastal zones of Egypt," Proceeding of the First International Journal on Coastal Zone Management of River Deltas and Low Land Coastlines, Alexandria, Egypt, pp.145-160.