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1 Abstract

The aim of this report was to develop coastline a scenario for mitigation measures which will be adaptable to various types of coastline in Oreoklini. Based on the reports 3.3.4 and 3.3.5 (CVI and SocCVI (Alexandrakis et al 2019) a risk estimation related to coastal erosion, of the coastline has been made. Also an assessment of performance of shoreline protection methods that have been implemented until now is presented. Additionally this report presents two Environmental-friendly Measures Adoption scenarios. The first scenario deals with a large nourishment project in the area and the preservation of the coastal defenses implemented so far. The second scenario presents also a large nourishment plan but included also the removal of the detached breakwaters that have been constructed. Both scenario seems to work under some restrictions and assumptions. The main restriction for the successful implementation of the Environmental-friendly Measures Adoption measures are firstly a limitation of the coastal constructions and re-nourishment projects.

2 Introduction

The results of the two indices applied in D3.3.5 shows that the CVI ranks most of the coastline to the category of high vulnerability with the remaining part to the extreme categories i.e., Very Low and Very High. It seems to be controlled mainly by the morphological variables. On the other hand, the SocCVI characterises the coastline mainly as of Medium vulnerability. This is explained by the addition to the natural variables those expressing the socioeconomic value related to man-made structures and heritage sites. In areas where there are no human activities, the ranking is lower even if the area is more vulnerable in terms of its environmental setting. In addition to the above, the relative influence of each of the three sub-indices of the SocCVI index is presented graphically in Figure 6. As it is shown the three sub-indices presents only small differences between the sub-sections of the coastline. Moreover, the sub-indices of coastal characteristics (CC) seem to dominate the overall SocCVI score.

Based on those results the need of application of environmental friendly coastal defenses has been identified. This report has to develop two scenarios for mitigation measures which will be adaptable to various types of coastline in Oreoklini. The first scenario deals with a large nourishment project in the area and the preservation of the coastal defenses implemented so far. The second scenario presents also a large nourishment plan but included also the removal of the detached breakwaters that have been constructed. Both scenario seems to work under some restrictions and assumptions. Also an assessment of performance of shoreline protection methods that have been implemented until now is presented. Additionally this report presents two Environmental-friendly Measures Adoption scenarios. The main restriction for the successful implementation of the Environmental-friendly Measures Adoption measures are firstly a limitation of the coastal constructions and re-nourishment projects.

3 Study area

Larnaca district covers the central part of the southern shoreline on the island of Cyprus. Its share in the area of Cyprus under government control is 18%, share in the population 17% and it is occupying 23% of the coastline. From all the districts it is closest to the average of Cyprus regarding population density and change of the population – density of 122 inhabitants per sq Km being slightly lower than the whole Cyprus under government control, and the population change of 11.1% between 2001 and 2005 being the same as Cyprus as a whole. The town of Larnaca with 46,666 inhabitants represents 40% of the district and including the closest suburban municipalities of Aradippou and Livadia 62,997 inhabitants or 55% of the whole district. The town itself is third largest city in Cyprus after Nicosia and Limassol. Larnaca district is located in the central southern part of the island. It includes 94 Km of the Mediterranean coastline, mountain area of the Troodos Mountains covering much of the western part of the district and a small part of Mesaoria Plain in the north. It has patches of woodland in which eucalyptus, acacia, cypress, and lowland pine predominate. The terrain of the eastern and southern part is relatively flat whereas the western and northern part is mountainous. The area could be considered less mountainous than the Limassol and Paphos Districts. The highest elevation is 1,404m, on the border with Nicosia district.

Larnaca District as well as the rest of Cyprus have Mediterranean climate with warm and dry summers and mild winter. The summer season, which extends from May until September, is characterized by clear sunny sky and almost no rain. The winter season, starting in October up until March, is mainly windy with certain periods of heavy rains. Most of the rainfall occurs in winter with maximum in December (15 days with rain and 86.4 mm precipitation) and minimum in August (0.4 mm precipitation or practically no rain). The summer and winter monthly averages of air temperatures do not reach extreme values. In Larnaca minimum monthly average of air temperature is reached in February (11.7°C) and maximum in August (27.6°C). Agricultural areas, located mainly close to the coastline, produce barley, potatoes, fruits, vegetables, and nuts. Industry, located mainly in the town of Larnaca, produces milled flour, canned fruit and vegetables, beverages, wood and furniture, paper products and textiles. The coast in Larnaca District is mainly flat or slightly hilly. There is some sand a rocky beach along the coast, surrounded mostly with the agricultural areas.

In the area there is an important natural monument– The Larnaca Salt lakes close to Larnaca International Airport. Along the Larnaca District there are five Natura 2000 Sites. The coastal strip belonging to the town of Larnaca is mainly under protection, and some remaining coastal areas are declared as tourist zones.

As Cyprus as a whole, Larnaca district is very rich in cultural heritage, especially from the ancient period. In district there are total 33 ancient monuments of first schedule (or first and second schedule) and 107 monuments of second schedule. From the tourist point of view the most important monuments of first schedule are the site and remains of the ancient town and necropolis of Kition and the Fort in Larnaca and the site and remains of a Neolithic settlement at Vouni in Choirokoitia (UNESCO World Heritage Site).

Cyprus is the third largest island in the Mediterranean, with a total coast length of 735 km. Around 110 km of the coastline (30%) under control of the Republic of Cyprus is subject to erosion. During the last three decades, the island experiences a very rapid touristic development, which is by 90% concentrated along the coasts (European Commission Report, 2009).

To prevent coastal erosion, it was decided in the late 70s to construct small-scale groynes and breakwaters of various types and sizes along the shoreline, initially on an experimental basis. These structures succeeded in protecting the coastal areas in front of them. However, they caused further erosion and shoreline retreat problems to neighbour areas (Shoukri et al., 2012).

Previous studies highlighted that many parts of the southern coastline of Cyprus Island are mainly exposed to adverse wave conditions and to sea level rise. In the 1970s to 1980s, there was a sharp increase in anthropogenic interventions in coastal areas. The construction of ports, fishery reserves or concrete jetties (e.g, Marina of Larnaka in 1969 and Marina in Zygi in 2012) were the main reasons for the serious changes seen along the coastline. In addition, the coastal quarries excavating material used in the building industry back in the 1960s and 1970s were still a major cause for the deterioration of the shoreline erosion. Furthermore, hotels and other touristic actions caused serious problems altering the area's hydrodynamics. The erosion phenomena of the coastal front seem to be a major issue presently, despite all actions and measures are taken for mitigation (Pranzini and Williams, 2013).

A number of breakwaters were constructed at various parts of Larnaca Bay and in Zygi Bay to protect the coastal front from deteriorating erosion, but in many occasions, the results were not desirable.

Two coastline zones located at the South East Region of Cyprus Island are selected as the study areas for the HERMES project. More precisely, this research is focused at the three coastal zones near Zygi village (5 km) and Oroklini and Ormideia shorelines (25 km), with a total shoreline length of 30 km.

Most of the rivers in Cyprus island originate from the Troodos region. The seasonal distribution of the run-off follows the seasonal distribution of precipitation, with a minimum in summer months and a peak value during the winter. As a result, the area is governed by the Eastern Mediterranean climate, which is characterized by warm, long-lasting summers and low-to-average annual rainfall. There are no rivers flowing continuously along their entire coastline length. Most rivers flow for 3 to 4 months a year and are dwindling for the rest of the year. Only parts of some rivers upstream of the Troodos area have a continuous flow (the rivers Xeros, Diarizos, Kargotis Marathasas, Kouris and Germasogeia)

Both study areas (Oroklini and Zygi) are located in the south-eastern region of the island. The area is affected less from the rivers' runoff and precipitation than the north-western region. There are some seasonal rivers flowing in these two basins, but during most of the year these rivers are dry. According to E-Hype model the river discharge in Oroklini Study area is 1-5 m_3/s and in Zygi study area is 0-1 m_3/s, with no rivers flowing in these two basins.

The small scale study area is located in the north-eastern part of the bayof the port of Larnaca. It has a total length of about 5.5 kilometers andis bounded by the eastern boundary of the port of Larnaca to the Communityboundaries of Oroklini - Pyla. The areaGulf of Larnaca has always suffered from erosion. The slopes of the seabed near the coastline are very mild in its order1: 125, along the beach near the Harbor of Larnaca, while as long aswe are moving away from him and approaching the area.

4 Data and methods

For the morphological analysis of the study area, topographic diagrams (1:5000), hydrographic charts (1:5000 and 1:25000) and satellite images from Google Earth were used. Detailed in situ morphological measurements were also considered by data from the environmental impact study for the construction of the 12 detached breakwaters in the area. These data included beach profiles along the shoreline extending from the upper beach limit to a mean water depth of 5 m. The subaerial and shallow parts of the profiles were obtained using a total station, while depths at the deeper parts were obtained using a small boat equipped with a portable echo sounder.The offshore wave climate (significant height and period) was estimated using the prognostic equations of CERC (1984) by utilizing the local offshore wind data statistics (mean annual frequencies of offshore wind speeds and directions for a 40-year time period) provided by the Wind and Wave Atlas of the Eastern Mediterranean Sea (Soukisian 2007) and other more recent sources (table 1).

Table 1: wind Speed and direction

Wind Speed		Direction									
Bf	**knots**	**N**	**NE**	**NW**	**E**	**SE**	**S**	**SW**	**W**	**Undefined**	**%**
0	**0**	0,00	0,60	0,00	0,00	0,00	0,00	0,00	0,00	6,76	6,76
1	0,83	0,91	1,57	0,94	0,00	0,00	0,61	0,94	2,05	2,27	9,18
2	2,55	1,90	1,73	2,93	0,85	0,32	1,69	2,93	5,80	0,85	19,20
3	4,90	1,98	1,94	3,72	1,62	0,80	1,71	3,72	7,82	0,06	22,09
4	**8,65**	1,33	0,90	2,87	2,07	0,82	1,19	2,87	6,87	0,02	17,72
5	**13,17**	0,64	0,52	1,25	1,74	0,40	0,42	1,25	3,16	0,01	9,18
6	**18,00**	0,31	0,13	0,54	1,00	1,19	0,16	0,54	1,08	0,01	6,13
7	**23,57**	0,13	0,13	0,14	0,46	2,87	0,13	0,14	0,44	0,01	8,29
8	**29,89**	0,07	0,10	0,05	0,26	6,97	0,02	0,05	0,17	0,01	1,19
9	**33,91**	0,01	0,01	0,01	0,10	0,61	0,00	0,00	0,05	0,01	0,27
Total		7,28	7,61	7,20	8,11	14,09	5,94	12,45	27,44	10.02	100

The estimated offshore wave characteristics corresponding to a W direction (prevailing winds) were subsequently subjected to wave refraction and diffraction analysis and shoaling using numerical modeling. The required detailed bathymetry has been derived from a hydrographic chart (scale 1:5000), supplemented by the bathymetric data from Navionic. The model runs were performed with the use of a smaller and more detailed grid, with 7.5m spacing, so that the model was able to resolve the local hydrodynamics, taking into account the presence of the reef.The wave conditions selected and used hereinstudy as entry data in mathematical simulations for thecalculations.The wave conditions used in the estimations were selected based on their ability to transport sediments longshore and offshore, thus conditions are selected with Hs> 1.00m. additionally, the waves generated from wind from directions coming from the east, south (180o) and southeast was used.The wave data used are presented in table 2.

Table 2 Wave data

Wind Direction	Wind Speed U (kn)	Wind Coefficient U_A (m/s)	Annual Frequency %	Wave Fetch (km)	H_S (m)	T_S (s)
S	2	0,83	0,61	**420**	0,02	0,69
	5	2,55	1,69		0,16	2,12
	8,5	4,90	1,71		0,59	4,06
	13,5	**8,65**	1,19		1,86	7,18
	19	**13,17**	0,42		4,36	10,48
	24,5	**18,00**	0,16		5,96	11,61
	28-33	**23,57**	0,13		7,81	12,69
	34-40	**29,89**	0,02		9,90	13,73
	>41	**33,91**	0,00		-	-
SE	2	0,83	0,32	**232**	0,02	0,69
	5	2,55	0,80		0,16	2,12
	8,5	4,90	0,82		0,59	4,06
	13,5	**8,65**	0,40		2,13	7,50
	19	**13,17**	1,19		3,24	8,61
	24,5	**18,00**	2,87		4,43	9,55
	28-33	**23,57**	6,97		5,80	10,44
	34-40	**29,89**	0,61		7,36	11,29
	>41	**33,91**	0,11		8,35	11,77
E	2	0,83	0,85	**207**	0,02	0,69
	5	2,55	1,62		0,16	2,12
	8,5	**4,90**	2,07		0,59	4,06
	13,5	**8,65**	1,74		2,01	7,22
	19	**13,17**	1,00		3,06	8,29
	24,5	**18,00**	0,46		4,19	9,20
	28-33	**23,57**	0,26		5,48	10,05
	34-40	**29,89**	0,10		6,95	10,87
	>41	**33,91**	0,00		-	-

In terms of wave climate, the coastal area are exposed mainly to S, SE and SW wind-generated waves. Hence, the corresponding wave characteristics for the above wind directions were calculated and presented in Table 3, respectively, for: (a) the weighted average value with respect to the frequency of occurrence of all wind speeds and (b) the weighted average value of the highest four wind speeds. For the calculation of the maximum index value, in both cases the S wind speed value of 29.89 m/s was used to produce the highest wave event (annual frequency of occurrence=0.01%).

4.1 Beach profile

The elevation of the design berm or known as berm height should in general correspond to the natural berm crest elevation. If the design berm is lower than the natural one, a ridge will form along the crest,which, when overtopped by high water will produce flooding and ponding on the berm. A design bermhigher than the natural berm will create a beach face slope steeper than the natural beach and may resultin formation of scarps that having bad effects on sea turtle nesting and recreational beach use. The naturalberm height can be measured by examining beach profile surveys of existing and historical conditions atthe project site. When survey data indicate alongshore variations in the natural berm height, arepresentative berm height may be determined either by visual observe of plots showing the alongshorevariations or by computing an average profile shape.To determine the nourished volume for a healthy beach condition, depth of closure is such a vitalcomponent that never be lacked. Generally, the value of depth of closure can be determined using theempirical formula of Hallermeier (1981).

$$D_c = 2.28H_e - 68.5\left(\frac{H_e^2}{gT_e^2}\right) \tag{1}$$

where, g is the acceleration of gravity (m/s^2), H_e is the storm wave height before breaking (m), and T_e is the corresponding wave period.

4.2 Application of equilibrium profile methods to nourished beaches

By using the equilibrium beach profile concepts described in Dean (1991), we can develop an alternative method for determining the compatibility of the fill. This method has the advantage of including the effects of the forces that shape the natural and altered beach profiles. The dependence of sediment scale factor *A* on sand diameter *d* leads to some interesting consequences relative to beach nourishment. When a volume V of fill sand per unit length is added to the native beach profile, it is assumed that it will equilibrate eventually to form $h = A_F*y_{2/3}$. Depending on the fill and native sediment scale parameters, A_F and A_N , respectively, and the volume added, the nourished beach profile can be intersecting, nonintersecting, or submerged, as presented in Figure 4.

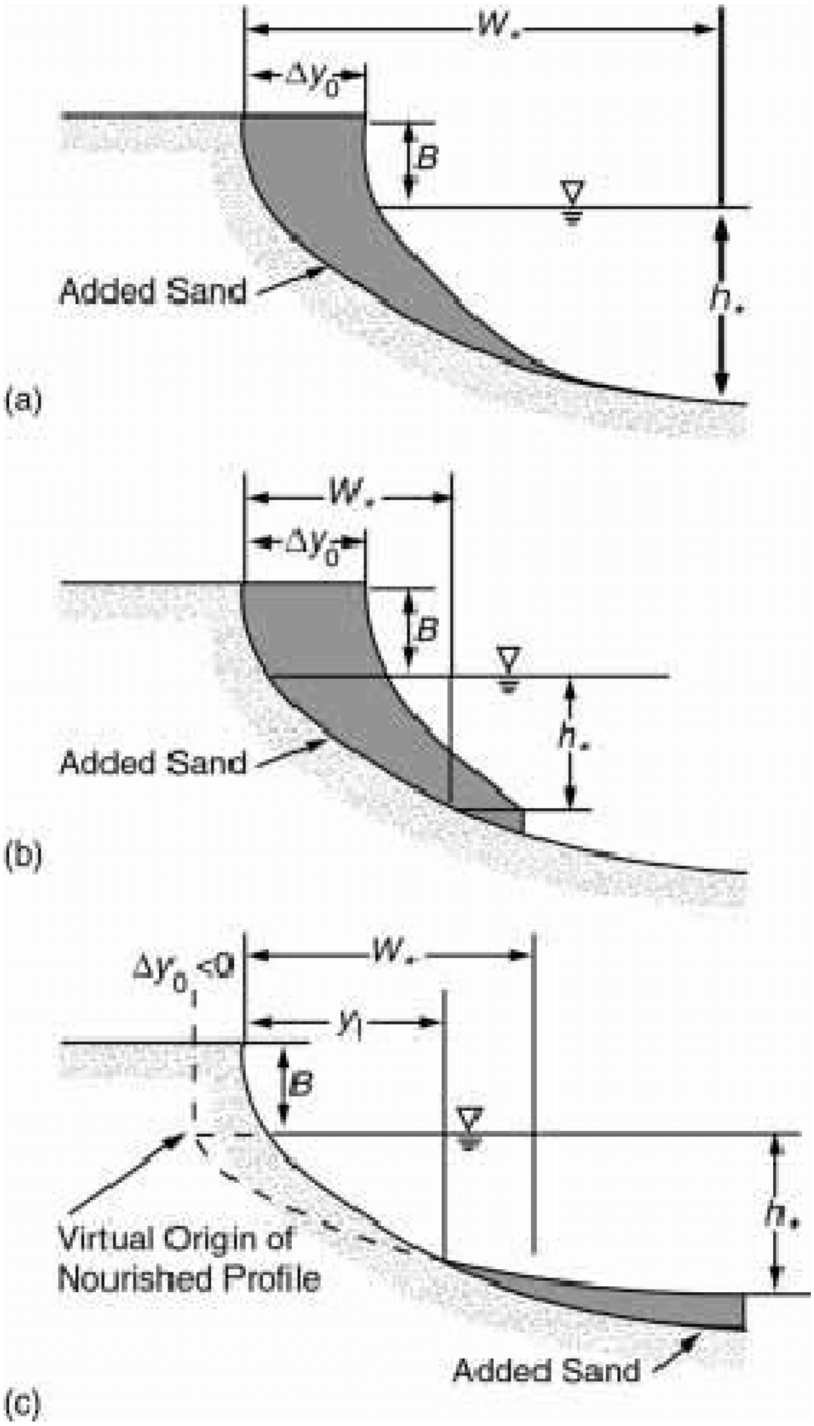

Figure 1:Three types of nourished beachprofiles (from Dean (1991))

Derived from equilibrium beach profile concepts, beach fills using coarser sand will require less sediment to provide the same equilibrium dry beach width than fills using sediment that is finer than the native sand.

There are three types of possibly nourished profiles depending on the volumes added and on whether the nourishment is coarser or finer than that originally present on the beach.

(a) Intersecting profile $A_F > A_N$;

(b) Nonintersecting profile;

(c) Submerged profile $A_F < A_N$.

It is clear that the grain size of native sand is coarser than that of fill sand providing a non-intersecting profile, where the nourished profile does not intersect the native profile before closure depth. To account for beach width with different composite sand sizes, the added distance of W_{add} as a function of depth y is given by

$$W_{add}(y) = y^{\frac{3}{2}}\left[\left(\frac{1}{A_F}\right)^{\frac{3}{2}} - \left(\frac{1}{A_N}\right)^{\frac{3}{2}}\right] \tag{2}$$

Where: A_N is the *A* parameter for native sand A_F is the *A* parameter for fill sand.

When the fill material is finer than the native sand, W_{add} is positive, which produces a design profile that is gentler in slope than the native profile. Conversely, for fill that is coarser than the native beach, W_{add} is negative which produces a steeper design profile. For non-intersecting profiles with a dry beach after equilibrium the volume per unit length of beach required to produce a dry beach of width *W* may be estimated as

$$V = WB = \frac{3}{5}\left(\frac{D_C}{A_F}\right)^{\frac{5}{2}}\left(A_N\left[1 + W\left(\frac{A_F}{D_C}\right)^{\frac{3}{2}}\right]^{\frac{5}{2}} - A_F\right) \tag{3}$$

For intersecting profiles, the volume per unit length of beach required to advance the beach a distance *W* after equilibration can be estimated by

$$V = WB + \frac{\frac{3}{5}(W)^{\frac{5}{2}}A_N A_F}{\left(A_F^{3/2} - A_N^{3/2}\right)^{\frac{2}{3}}} \tag{4}$$

For submerged profile, the volume of sand per unit length of shoreline that must be placed before there is any dry beach after equilibrium is estimated as

$$V = WB = \frac{3}{5}\left(\frac{D_C}{A_F}\right)^{\frac{5}{2}}(A_N - A_F) \tag{5}$$

the volume placed is less than that given by the above equation, a submerged profile is produced after equilibration. Where: A_N is the A parameter for native sand, A_F is the A parameter for fill sand, W is beach added width, D_c is depth of closure, B is berm height.

Table 3: The maximum, weighted average (W.A.) and the weighted average of the 4 higher values of the significant offshore wave(W.H.A.).

Direction	Value	f (%)	Ua (m/s)	Hs (m)	Tp (s)	Dc (m)	Lo (m)	H_b (m)	d_b (m)
S	Max	0.01	29,89	9,90	13,73	18,95	294,05	11,02	12,70
S	W.A	5.94	6,04	0,91	5,01	1,83	39,21	1,09	1,16
	W.H.A		21,55	7,14	12,32	13,94	236,95	8,13	9,15
SE	W.A	14.09	18,68	4,60	9,67	8,91	145,73	5,19	5,90
	W.H.A		22,53	5,55	10,28	10,61	164,89	6,18	7,11
SW	W.A	12.45	6,64	0,64	3,68	1,24	21,14	0,72	0,81
	W.H.A		20,11	1,92	5,31	3,47	43,91	2,03	2,47

Note: wave period (Tp), height (Hs), length (Lo), breaking height (Hb) and depth (db) for the different frequency of occurrence (f), wind speed (Ua) and direction (S, SE and SW)

Sediment data were used from the study that was used for the design and construction of the breakwaters in the area. From the analysis of the results of the granulometric analysis conducted for this study the sediments are mostly fine sand, with average grain diameter D_{50} = 0.12 mm.

For the estimation of wave parameters in the coastal area. The model used is based on finite differences (FD)and therefore the RANS (Reynolds-AveragedNavier Stokes) and wave action balance equations. The geographical scale of analysis used is the area wider area of Oreoklini- Larnaca for large or small scale computations. The input data for the analysis was the bathymetry, the model boundaries with their boundary condition, the wind field and sedimentology. The output files of the model are ASCII files.

The estimation of wave run up ($R_{2\%}$) has been made with the use of Stockton's et. al. (2006), formula, since it has been proved, elsewhere, on the basis of field measurements and coastal imaging analysis that it provides better results than other approaches (Vousdoukas et al 2012 , Alexandrakis & Poulos 2014).

$$R_{2\%} = 1.1\left(0.35\,\beta\sqrt{\frac{H_o}{L_o}} + \frac{\left[H_oL_o(0.563\beta^2+0.004)\right]^{1/2}}{2}\right) \text{(all beaches)} \quad (6)$$

$$R_{2\%} = 0.043\,\sqrt{H_oL_o} \text{ (dissipative beaches)} \quad (7)$$

where, H_o is offshore significant wave height (m); Lo is offshore wave length (m), and β is beach slope (in rads).

5 Current situation

The maximumoffshore characteristics of the wind-generatedwaves approaching from SE and S directions (0.11% and0.02% annual frequency of occurrence, respectively) havesignificant wave height in excess of 8 m and a period of 11 s.Correspondingly, the most frequent waves are SE origin (6.96% frequency ofoccurrence) waves and have significant height 5.8mand periods less than10.44 s. The most frequent wavesfrom the S (1.71%) and E (2.07%) are characterized bysmall significant wave heights/periods. Wave propagation schemes and wave height estimations from the coastal engineering study for the detached breakwaters are shown in figure 2.

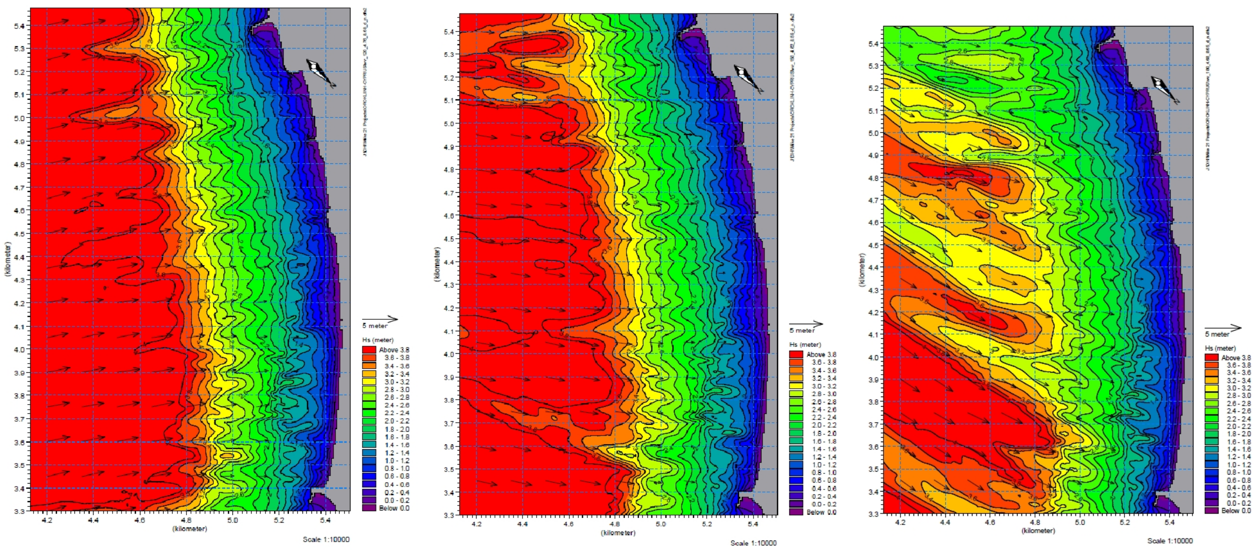

Figure 2: Wave heights for S, SE and E maximum waves.

The western part of the area has been nourished in order for the coast reaches the original width. Subsequently, in the coastal front of the western section has been shielded with natural boulders to eliminate erosion. In the eastern part 5 detached breakwaters with natural boulders parallel to the coastline along the isobath of about -3 m. Thebreakwaters will have a length of 100 m and the gap between them will range from 1.4 m up to5.4 m, while their stepis at + 0.40 m from the average sea level.In the remaining area 7 more detached breakwaters from natural bouldersparallel to the coastline along the isobath of about -3 m, with length of 100 m and a gap between them from 6.6 m to 12.5 m, and their step at + 0.40 m were built, with the exception of one whose step was at + 0.90 m to protect the most eroded areaand has a length of 200m. Eastward the removal of groynes was implemented.

Based on the numerical modeling since the area of construction the constructed breakwaters reduced the wave energy that the area received but did not had significant effects in reducing erosion, so the problems remains. This is due to the fact that sediment supplies in the area are limited due to the drought of the area but also due to the man-made contractions in the coastal zone.

Moreover in the area there are ongoing constructions in the beach (figure 3), mainly for tourism purposes, which reduce the beach width even more.

Figure 3. Innervations in the beach zone

In other areas coastal erosion continuous to erode the coastline (figure 4, left), while as mitigation measures the construction of boulder revetments(figure 4, right) were implemented. All mitigation measures in the area addressed the erosion problem sporadically and in most cases insufficient.

Figure 4. Ongoing erosion (left) and Boulder revetments (right)

6 Scenarios

The first scenario for the Larnaca and Oreoklini area deals with a large nourishment project in the area and the preservation of the coastal defenses implemented so far. The second scenario presents also a large nourishment plan but included also the removal of the detached breakwaters that have been constructed.

There are two ways to extract anddump sand onto nourished beaches. The first way is dredgingsand from the seafloor using a pump that suctions fluidizedsand and places it in the area to be nourished. Once thesediment is dumped, it is distributed with appropriatemachines. In the second method, the sand is taken fromterrestrial deposits (quarries, quaternaries dunes, marshes,etc.) by backhoes or frontal loaders and transported bytrucks.

In our case, the sand was provided by a restorationproject in a nearby salt marsh. Therefore, the sand has amarine origin, although the extraction process was notperformed with a dredge but with a backhoe. During theunloading process, the sand piles were extended bybulldozers and redistributed by the surge depending on thesize of the grain and other parameters.

The environmental parameters established in the European Regulations for the Evaluation of Environmental Impact were assessed. During the execution phase, the total impact takes a negative value, but the impact is reversible and compatible with the environment. During the functioning phase, the total environmental impact was small as well but of a positive sign. Some improvements to the beach are made from socioeconomical and environmental points of view. Those are theincrease of recreational value of the beach, and the area behind the beach will be better protected after the project's completion. In addition, if proper material will be used there will be no changes to the sand's density, grain size and color (the slope of the beach was visibly increased but only for a short period. As for the littoral dynamics, they will be altered, because the volume of newly added sand is relatively small. Finally, since the long-term data on the natural fluctuation in the presence and abundance of populations of marine organisms (due to storm waves, winter mortality, etc.) are often not available, an assessment of the effects of sand nourishment projects is difficult to complete in most cases. Nevertheless, monitoring campaigns and evaluations of the environmental impact of beach nourishment and scraping projects must be carried out not only during construction but also after the project has been completed. These kinds of studies are the only way to obtain data that can be useful for creating measures to diminish the environmental impact of replenishment activities in the future.As can be seen in Table 3, the values of depth of closure are ranging from 3.5m to 8m according tothe wave direction and wave height period. For the estimations the maximum values are use, which correspond to 0.01% annual frequency S origin waves.

6.1 Results and discussions

In order to obtain the most appropriate value of beach nourished volume and take a whole inspection of this measurement, the study is recommended to measure the volume in two cases by altering thevalue closure depth due to the impact of the breakwaters. The measuring nourished volume in the case that the grain size of fill sand is the same with the present one. (D_N=1.2mm). Note that the planned nourished beach length in the Oreoclini Beach isapproximately 8kilometres. This value is used to calculate the total required sand for beachnourishment project in the area.

Table 4. Total volume of different depth of closure values

Scenarios	**Dc (m)**	**Grain size (mm)**	**A_F**	**A_N**	**Berm height (m)**	**Added beach width (m)**	**Beach length (m)**	**Volume dry m3**	**Volume Wet (m)**	**Volume per m (m^3/m)**	**Total volume ($10^6 m^3$)**
Removal	18,95	1,2	0,1	0,12	2,3	100	8000	18564	7415	259,79	2,078
Current	13,94	1,2	0,1	0,125	2,3	100	8000	8642	3441	120,84	0.976

The volume of fill material for the scenario of the removal of the breackwaters,is demanding more berm width and much nourished volume to create a beach profile with healthy conditions in respect to the one of the current state.

This study can be summed up briefly that the value of fill volume to nourish Oreoklini beach is affected by plenty of factors. Indeed, in this study, the related quantities of beach profile such as bermheight, berm width and depth of closure could be specified by mean of representing the average existingbeach shape of various plots along the project site. Thus, depth of closure is directly affected by thevariation of wave height due to seasonal changes. This leads to the point that wave data and crosssectionalbeach profiles should be inspected seriously. Characteristics of fill materials must be examinedas well, the grain size of fill material will take the decision as to which the method will be proper most tothe design beach profile. Based on this study, further methods to nourish the beach need to be conductedin order to avoid inefficiency and waste of expenditure.

7 Conclusions

Beach nourishment is the engineered process of pumping or dumping sand on a beach to replace eroded sand, or to protect against future erosion. Beach nourishment can also be used to widen a naturally narrow beach.Beach nourishment is most suitable on beaches that provide natural protective services and culturally or economically important coastal access. Beach nourishment might also be apt for beaches that are the most susceptible to erosion due to rising sea levels or increased storm impacts. One advantage of nourishment is that it can maintain the width of an eroding beach. Nourishment can also replace sediment supply loss, such as from sand mining or from dammed rivers. Nourishment is also environmentally preferable to armoring a beach with seawalls, especially in the short term. Beach nourishment might also increase public access to beaches by maintaining or expanding the beaches themselves. Proponents of beach nourishment argue that it is less expensive than competing strategies, such as retreat. Regardless, it is still very expensive, perhaps even more so than other options, depending on what backs the beach.

However, beach nourishment is known to have deleterious impacts on environmental conditions. For instance, nourishment can cause increased turbidity and sediment suspension in surrounding waters. Murky, turbid water can threaten the affected marine species and habitats. Nourishment can also cause environmental impacts to the areas from which the sand is sourced, especially if dredging is involved. In California, beach nourishment can cause sediment to unnaturally accumulate in the submarine canyons offshore of the coastline. Beyond direct environmental concerns, beach nourishment has had the effect of encouraging development in certain especially hazardous areas. Another drawback of beach nourishment projects, is that they can be politically unpopular and can prompt public opposition. Further, beach nourishment alone will not safeguard beaches, especially those impacted by reduced sediment supply from dammed rivers upstream. Similarly, sand mines can reduce sediment supply, prompting more beach nourishment in affected areas than would otherwise be required. Detractors also argue that nourishment is a misnomer because the name does not reflect the potential damage these projects can do to the coast.

Finally, beach nourishment is sometimes disfavored because it benefits a few landowners at the expense of the public at large. Specifically, public funds are typically used to finance nourishment projects under the guise that they will increase beach access or at least maintain existing public beaches. But nourishment projects typically act to protect the few wealthy landowners whose homes are imperiled by eroding beaches and rising seas instead, with limited protective benefits for public property. Legal Considerations Beach nourishment projects require several permits and are subject to several national and European laws. Beach nourishment is a common strategy that has been employed throughout California and the United States, Italy, Spain and recently in Greece.

For the Larnaca Oreoclini area the proposed project is to maintain the constructed detached breakwaters since they reduce the wave energy in the area, but mainly due to the fact that nourishment sand volumes will be scientifically increased in order to fill the gaps in sediments from their removal. Another alternative can be the reduction of the height of the structure and made them submerged in order to reduce aesthetics impacts.

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