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Geological and oceanographic data determining the foreshore zone according to the Greek legislation

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Abstract

The available scientific field data of the marine and the coastal enviroment, (wind and wave field data, shallow area bathymetry, coastal area geomorphology and topography, etc.), in addition to deep and shallow wave prediction numerical modelling (by means of wind and bathymetry measurements), calculation of the nearshore wave height and maximum wave run up, were used to support the mapping of the innermost limit of the foreshore zone according to Greek legislation which defines that ‘the foreshore is the zone of land wetted by the highest however unexceptional sea wave run up’ and the Supreme Administrative Court standard case law. These methods were applied for two areas, which completely differ as regards the wind and the wave field, the geomorphological and topographical characteristics of the coastal area, suggesting different procedures for the determination of the innermost limit of the foreshore zone. The limits of the foreshore zones for both areas, resulting from the study, are compared to the limits set out by the authorised Administrative Commissions, which were published in the Official Gazette and also were applied by the local authorities for the management of the coastal area.

Keywords: Foreshore; Wave height; Wave run-up; Coastal geomorphology.

Introduction

The Legislative frame

According to the current Greek legislation in force (art. 1 par. 1 of Law 2971/2001 Official Gazette A΄285/2001) the foreshore is defined as ‘*the zone of land wetted by the highest however unexceptional sea wave run up*’. The previous legislation (art. 1 of Compulsory Law 2344/1940 Official Gazette A΄ 154/50) also determined the foreshore as ‘*the land zone wetted by the highest however unexceptional sea wave run up, which is the public domain and as such is owned, protected and administered by the State*’. Thus, Greek legislation establishes an administrative procedure for the binding definition of the foreshore delimitation line as an environmental phenomenon, and more specifically as ‘the highest but not unexceptional sea wave run up’ to a specific land zone (Supreme Administrative Court 1185/1996, 3778/2004, 2975/2004). Therefore, the Administration, whenever deciding on the foreshore, merely attests the existing state of facts as to the area between mean low water and mean high water in order to proceed to a substantiated delimitation.

Articles 3, 4, 5, 6, and 9 of Law 2971/2001 on *Foreshore, Coast and Alias* regulate both the procedure as well as the definition criteria for the foreshore, the beach and the old foreshore. More specifically, article 9 mentions some, but not all, of the environmental and other factors that the Administrative Commission (hereinafter Commission) takes into consideration after inspection. Furthermore, the 1089532/8205/BOO10 (Official Gazette B' 595) Joint Decision of the Ministers of Finance and of Environment, Physical Planning and Public Works specifies the factors that the Commission takes into account before delimiting the foreshore zone and the beach. These include the geomorphology of the land, the intensity and direction of the winds, the vegetation, the relief, the slope and the general qualitative structure of the coast.

It is evident that the existing legislative frame is restricted to a non-inclusive catalogue of environmental and other factors and criteria without, however, defining the scientific methodology that the Commission is bound to use for the evaluation of aforementioned environmental data, in order to scientifically substantiate its decision. In practice, the members of the Commission simply inspect the locus in quo so that they can form a more personal opinion on the morphology of the area, especially when mild weather conditions prevail, which makes access to the area easier. But the Commission is not obliged by the law to use specific scientific and technical methods before reaching its decision.

At this point it is important to highlight that under the current legislative frame the exclusion of oral testimonies from the proceedings to determine the old foreshore zone (art. 5 par. 3 of Law 2971/2001), amply demonstrates the legislative intent to introduce more objective criteria of definition.

In France, article 26 of Law 86-2 of January the 3rd 1986 on Management, Protection and Optimal Use of the coastline states that *'the foreshore limits are ascertained by the State upon inspection or use of information drawn from scientific studies'*. The above article is further specified by the 2004-309 Decree of March 29th 2004, which stipulates as information provided by scientific studies '*especially the topographical, meteorological, tidal, wave field data, as well as sedimentary, botanical, zoological or historical data*'.

It is necessary to stress that European Union Law, in other but similar cases where natural phenomena are involved, equally considers the use of scientific data important, e.g. the EC/92/43 Directive of May the 21st 1992 on *Conservation of Natural Habitats*, which has been transferred into Greek law by the Ministerial Decision 28/1998. Article 5 states that the Commission will decide '*on the basis of relevant and reliable scientific information'* and if there is no unanimity it will be decided *'on the basis of scientific data provided by both parties*.'

In Greece there exists a long standing unequivocal Supreme Administrative Court jurisprudence on matters of foreshore, coast and old foreshore definition that states: '(*delimitation of this) can be made by means derived from common or scientific experience such as is the inspection conducted by the Commission when it takes place at the right time*' and adds that '*the judgment of the Administration on the time of the formation of the old foreshore zone should be based on scientifically proven indications*' (case number 1185/1996, 3778/2004, 2975/2004, 3941/2000, 2954/1998). Thus, the delimitation of the foreshore is drawn from geomorphological, geological and sedimentary data (case number 1178/1994, 1508/2003), environmental (1306/2000) and geological studies (case number 751/2000, 3143/1992).

It is characteristic that in many cases the Supreme Administrative Court reaches the conclusion that some of the data gathered contradicts other data or that there is a lack of relevant data, thus rendering the building up of a judicial decision impossible. Thus, the Court proceeds and asks for the completion of the case file with scientifically validated data by ordering expert opinions on the matter (case number 751/2000, 1508/2003, 1178/1994). In other cases, interested parties take the initiative and submit to the Supreme Administrative Court data in order to support the Administration's decision with scientific arguments.

This proves the importance of providing reliable scientific data during the process of delimiting the foreshore zone, especially when the members of the Commission are objectively unable to form a scientifically valid judgment and thus evaluate the wind and wave data in relation to the geological or geomorphologic data of a specific coast.

The Greek Ombudsman has up to the present received a considerable number of citizen's reports and queries on the proceedings and criteria used by the Administration Commissions for defining the seashore. Thus we have decided to present some of them to a wider public by writing this paper.

The scope of the paper consists in demonstrating how the provision of geologic and oceanographic data, drawn from specialized studies, may help the authorized Administrative Commissions responsible for the definition of the foreshore and beach to delimit these areas, and at the same time reduce the error rate as well as the amount of litigation by affected land proprietors.

Methods

The wave height very close to the coastline as well as the maximum wave run up on the coastal area, are the critical oceanographic parameters, which can outline and determine the innermost limit of the modern foreshore, the zone that can be affected by the sea.

The maximum wave run up on the coast is determined by 1) the maximum energy effect of waves on the coast, at least annually, 2) the maximum sea level rise, 3) the water mass accumulation on the coastal area, caused by the sea level rise due to wind stretch and decrease in atmospheric pressure and 4) the geomorphology of the coastal area following the action of waves with high energy and high curvature.

The following assumptions were made in order to apply the requirement of the legislation, relating to modern foreshore zone determination[1]: 1) that the maximum considered wind speed and direction as well as the wave height and period produced affect the coastal area at least once annually, 2) that the maximum irregular wave run up on the coast is calculated from the previous mentioned data.

The wave characteristics, such as wave height, wave period, coast coefficient, as well as the maximum wave run up on the coast were estimated according to C.E.R.C. (1984) and MASE (1989) respectively.

The procedure of the determination of the wave height and the wave run up has been applied in two Greek coastal areas, which completely differ in their geomorphology, oceanography and meteorology. The proposed procedure includes:

a) oceanographic field data collection such as:
   - a1) wind speed and direction statistical data, derived from the Hellenic National Meteorological Service's measurement network,
   - a2) wave height and wave period derived from the Hellenic Centre for Marine Research's observation buoys,
   - a3) sea level measurements from the permanent tide gauges network of the Hellenic Navy Hydrographic Service,

b) Sequential aerial photographs,

c) Topographic and bathymetric archive

[1] defined according to Law 2971/2001 as '*the zone wetted by the highest however unexceptional sea wave run up*'.

and field data, collected from available hydrographic and bathymetric charts and field measurements, in order to reproduce the relief of the shallow underwater and the coastal area,

d) Geology and geomorphology data of the coastal and shallow underwater area (the quality and the grain size distribution of the sediments),
e) Wave height and wave period prediction for the deep-sea area. If no available field measurements exist, the C.E.R.C. (1984) wave prediction model, is applied ,
f) The maximum wave run up prediction (R_{max} according to MASE 1989), based on the wave height and the coastal area characteristics. The above, added to the sea level rise due to the tide, was used for the calculation of the maximum level of the coast that will be affected by the waves under extreme weather conditions.

The proposed procedure resolves the requirements and the questions of the initial determination or the re-determination of the modern foreshore zone, according to the aforementioned legislation.

Results

The coastal areas studied were: Agia Marina, Saronikos Gulf, located at the 36th kilometer of the S-SW coast of Attiki district, E-SE coast of the Saronikos Gulf, and the Vromolimno area, located 10 kilometers from Skiathos town, on the S-SW coast of Skiathos Island, (Figs 1, 2 and 6). The selected areas are both S-SW oriented, but they are completely different as regards their physical, geomorphologic and oceanographic settings. The former, Agia Marina, is characterized by a narrow, steep, rocky coast, sharp sea bottom relief and very extensive fetch. The second area, Vromolimno, Skiathos Island, is characterized by a wide, sandy, smooth coastal zone, a smooth sea bottom relief and limited fetch.

Agia Marina, Attiki - Saronikos Gulf

The Agia Marina coastal area studied belongs to the E-SE coast of the Saronikos Gulf, between the kilometric locations 35.5 km and 36.5 km of the Athens – Sounion avenue (Fig. 2). The area is S-SW oriented and protected from the N, NW, WNW, NE, ENE and E winds. The effective fetch to the W and WSW direction varies from 1n.m. to 30 n.m., while to the S, SE and SW direction the fetch varies from 5 n.m., 120 n.m. to 200 n.m respectively.

According to decree No. 13/1963 *For the establishment of the beach from Vouliagmeni to the Lavrion area,* published in the official gazette of the Hellenic Republic, issue 6 B' (15-01-1963) and the topographical diagram which is attached, the modern foreshore limit in the study area of Agia Marina, Saronikos Gulf, between the kilometric locations 35.5 Km and 36.5 Km of the Athens – Sounion avenue, (Fig. 2), was determined at the level +9.6m up to +12m along the coast. Consequently the authorised committee, which determined the modern foreshore limit, accepted that the maximum sea level rise that affects the coast, due to the maximum wave run up and the tide as well, extends from +9.6m to +12m.

Geomorphology

The coast along the study area presents sharp relief, steep slopes varying between 20° and 30° and a narrow rocky beach zone, partially formed by human intervention, which varies from 8 to 17 m. wide. The steep sea bottom slope also varies between 7° and 10°. Along the coastal zone, landward of the narrow rocky beach zone, a 4 m height conglomerate rock can be seen to be eroded by wave action (Figs 3 and 4).

A narrow, coherent, coarse-grained, sandy layer, 30 to 40 cm thick, crosses the conglomerate 20° towards N-NW direction. A sandy–pebble layer without signs of marine erosion lies over the conglomerate, followed by schist. The sporadic, permanent, self-sown vegetation level begins from the lower limit of the schist, at +3.6 m to +4 m, (Fig. 4).

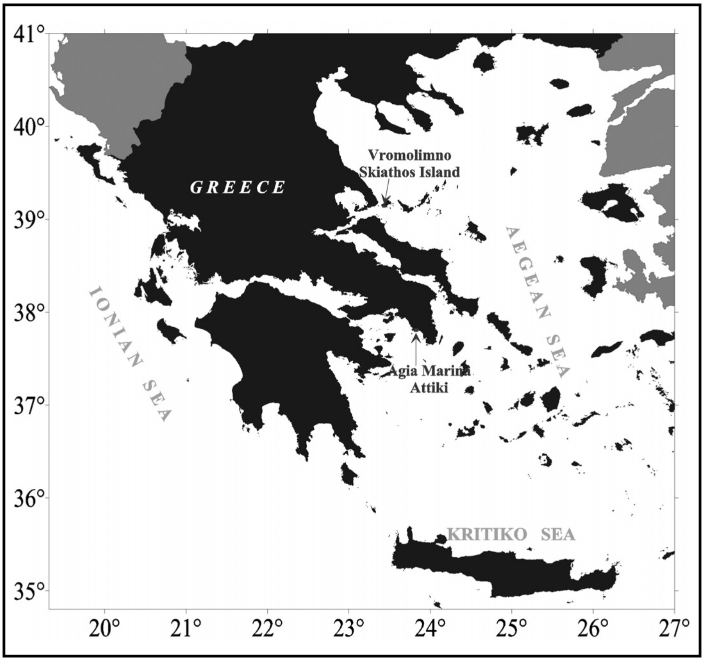

Fig. 1: Map of the study areas: Agia Marina, Saronikos Gulf, Attiki district and Vromolimno, Skiathos Island.

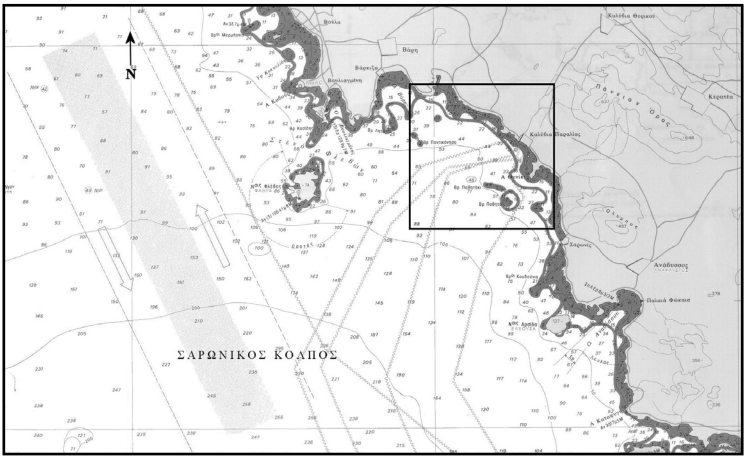

Fig. 2: Map of the study area: Agia Marina, Saronikos Gulf, Attiki district (Nautical chart 413, HNHS).

Wave height calculation

The extreme conditions[2] which are considered to prevail in the Saronikos gulf area are caused by the 8 Beaufort S, SE or SW winds, that present at least 0.011% annual frequency, according to the Hellenic National Meteorological Service statistical data sheet, Athens, Hellinikon airport meteorological station (Table 1).

[2] the very strong or stormy wind conditions which are observed at least once annually.

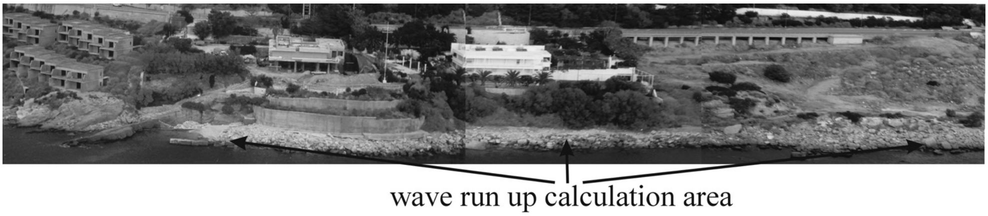

Fig. 3: Geomorphology of Agia Marina, Saronikos Gulf study area, as well as the wave run-up calculation area.

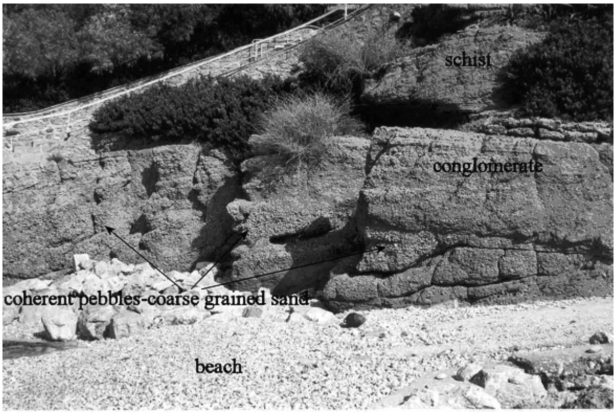

Fig. 4: Detailed geology and geomorphology of the Agia Marina coastal area.

The wave height which can be expected to be observed at a 250-500 m distance from the coast, in the deep sea area and under the influence of the 8 Beaufort, very strong or stormy SW winds, is 4.1 m, according to the data contained in Table 1. Lower wave heights, 2.3 - 3.6 m, can be expected to be observed under the other wind directions (SE, S or W). Wave height was not calculated for wind force greater than 8 Beaufort due to the absence of notable frequencies, on the Hellenic National Meteorological Service statistical data sheet.

With the application of the wave prediction model in the deep sea area, 250-500 m from the coast, it is logically to be expected that the wave height in the shallower area will be less due to sea bottom relief effect, reflections and attenuation etc.

Long term wave height and wave period measurements taken from the Hellenic Centre Marine Research observation buoy, were used in order to verify the accuracy of the previously mentioned wave height predictions. These measurements were obtained for the POSEIDON project, by the corresponding buoy, moored at the 37° 53' 18.8'' N, 23° 41' 19.9'' E position, a few kilometers to the north of the study area.

The above area shows identical morphological and oceanographic characteristics to the study area (similar effective fetch, bathymetry and wind field). The measurements that were used include wind speed and direction, maximum and significant wave height and wave period. Figure 5 presents the plots of these 2500 measurements of the previously mentioned parameters, obtained between October 1998 and October 1999.

These measurements present that a) the significant wave height in the area during October 1998 and October 1999 did not exceed 2.1 m, b) the maximum wind speed was 17.5 m/sec (8 Beaufort) as well as the corresponding wind direction 170° (S wind), c) the maximum wave height during this period did not exceed 3.7 m, and d) the wave period was 4.5 s.

The previously mentioned calculations were verified during the extreme weather conditions which prevailed during November 22nd and 23rd, 1999. The stormy S and SW winds which were observed, raised the sea level 3.6 m over the mean sea level. This level corresponds to the maximum sea level rise, calculated by the wave prediction model used and the measurements obtained during the periods October 1998 and October 1999.

The deep-sea maximum wave height calculated by the C.E.R.C. (1984) wave prediction model, coincides with the maximum wave height measured by the observation buoy. The maximum wave run up on the coast that was calculated according to the MASE (1989) prediction model did not exceed +3.5 m, assuming that the maximum wave height was 3.7 m, the wave period was 4.5 s and the mean slope was 10° (sea bottom - coast area). Assuming that the sea level rise due to the tide does not exceed 3 cm (mean high water level – mean sea level) according to the Piraeus tide gauge, the uppermost sea level that affects the coast does not exceed +3.6 m.

Consequently, the upper limit of the modern foreshore zone should be the +3.6 m

Table 1
Wind force, direction frequency % and the corresponding wave height (m)*
(Athens Hellinikon airport meteorological station, time period 1955-1987).

	Direction frequency %				Wave height			
Wind force (Beaufort)	**SE**	**S**	**SW**	**W**	**SE**	**S**	**SW**	**W**
6	0.055	0.131	0.066	0.077	1.7	2.3	2.6	1.4
7	0.011	0.022	0.011	0.011	2.2	2.9	3.3	1.8
8	0.000	0.011	0.011	0.000	2.8	3.6	4.1	2.3

* *The directions and the extreme wind force conditions that affect the study area are mentioned.*

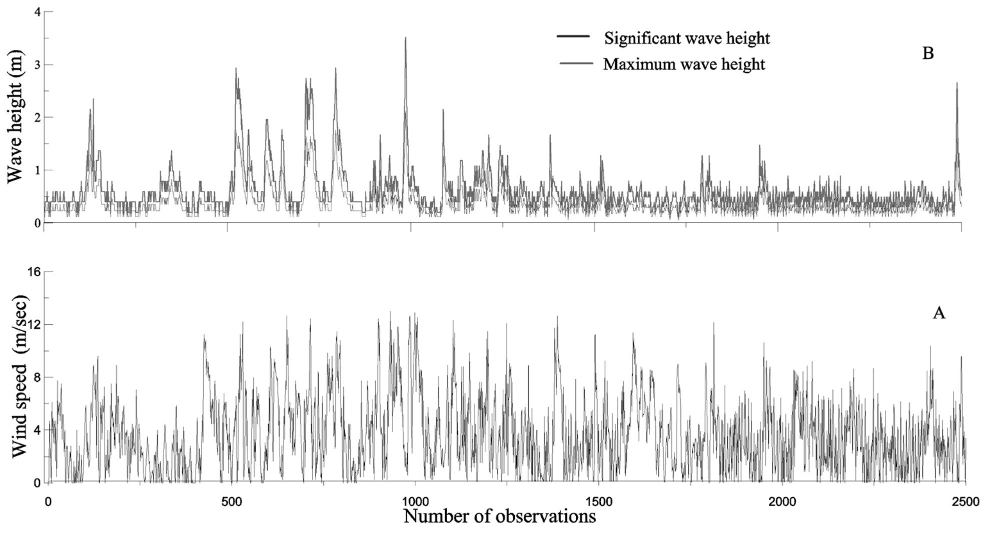

Fig. 5: Plots of the wind speed measurements (A), as well as of the significant and the maximum wave height measurements (B).

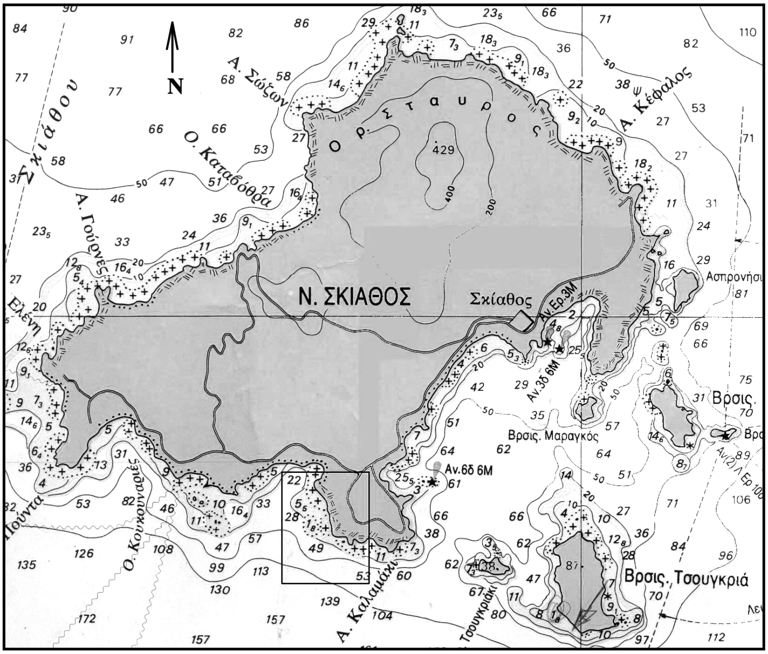

Fig. 6: Map of the study area: Vromolimno, Skiathos Island (Nautical chart 312, HNHS).

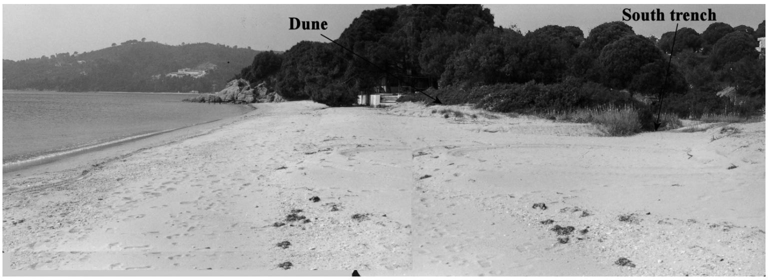

Fig. 7: Geomorphology of Vromolimno, Skiathos Island. Northern part of the of the smooth sandy beach and the dune with self-sown dendroid or bushy vegetation, Vromolimno area, Skiathos Island.

level according to the available data and Law 2971/2001.

Vromolimno - Skiathos Island

The area is located on the inner section of the Platanias bay, in the south of Skiathos Island, with a S-SSW orientation (Figs 1 and 6). The effective fetch towards W, SW WSW and SSE directions was calculated at18 n.m., 10 n.m., 35 n.m., and 32 n.m. respectively. This area is very well protected from the N, NW, WNW, NE, ENE and E winds due to the low hills (30m to 84m height) which surround the bay.

According to act No. 155/14-11-1990 *Determination of the limits of the modern foreshore zone and the beach of the Vromolimno area, Skiathos Island, Prefecture of Magnesi*a, of the Prefect of Magnesia, published in the official gazette of the Hellenic Republic, issue 670 D' (30–11-1990) and the topographic diagram attached, the modern foreshore limit in the study area of Vromolimno, Skiathos Island, (Fig. 6), has been

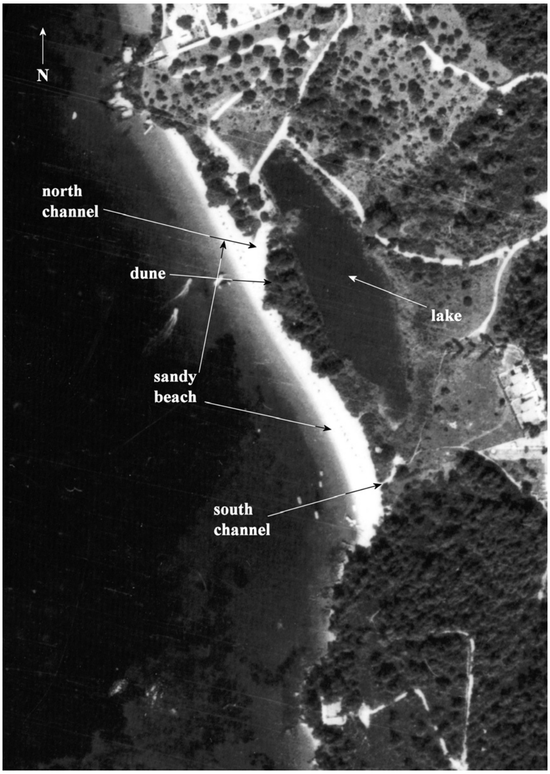

Fig. 8: Extract from the aerial photograph of Vromolimno, Skiathos Island (HMGS 1988).

determined approximately at the level +1.0m along the coast. Consequently the authorized committee, which determined the modern foreshore limit, has accepted that the maximum sea level rise that affects the coast, due to the maximum wave run up, as well as the tide, extends up to 1.0m.

Geomorphology

Gneiss schists surround the coastal area (FERENTINOS, 1972). Along the coastal zone, an elongated 2m height dune has developed parallel to the coastline (Figs 6 and 7). Landwards, adjacent to the dune is a 14000 m^2 small, elongated, brackish lake, known as Vromolimno Lake. The lake has openings to the sea and is supplied with fresh salt sea water via two channels at the each end of the lake: the north and the south channel. The dune, the lake and the north and the south contact channels are recognisable on Hellenic Military Geographic Service aerial photos of the years 1945, 1956, 1960, 1980 and 1988. Up to the last decade the lake was in contact with the sea through these sandy channels, 0.6 to 1m wide (Figs 7 and 8).

The sea bottom slope along the shallower coastal area varies from 0.8° to 1°, while sea bottom rises and reefs far from the coastline (Fig. 6). The slope of the beach area varies from 1° northwards to 1.5° southwards. The sandy beach consists of medium to coarse grained sand. The mean grain diameter varies from 0.25 to 0.75 mm and the grains are very well sorted by the wave action. The previously mentioned sandy material contains shell and skeletal fragments of marine foraminifera (PEHLIVANOGLOU & KARAMITROU, 2003). These data indicate the marine influence on the sandy material, the

Table 2
Wind force frequency % versus wind direction (Skopelos, 1955-1996).*

	Wind speed	Frequency % of the wind force			
Wind force (Beauf).	(m/sec)	SE	S	W	SW
7	13,9-17,1	0,056	0,133	0,055	0,033
8	17,2-20,7	0,011	0,033	0,033	0,033
9	20,8-24,4	0,00	0,00	0,022	0,022
10	24,5-28,4	0,00	0,00	0,011	0,011

*Only the extreme conditions and the directions that affect the area are mentioned.

accumulation and the sorting according to the grain size due to wave action.

Landwards of the sandy beach, in the area of the dune, medium to fine grained sand prevails, partially mixed with humus. Remarkably developed dendroid or bushy vegetation is observed on the dune area according to the Hellenic Military Geographic Service aerial photos (Fig. 8) as well as terrestrial photos (Fig. 7).

Wave Height Calculation

Wind speed and direction data from the Skopelos Island meteorological station, the nearest to the Skiathos Island meteorological station of the Hellenic National Meteorological Service network were used, in order to estimate the extreme conditions which prevail at least once annually in the Vromolimno area. The measurement period was from 1956 to 1997.

The 8 Beaufort S, W and SW winds present remarkable annual frequency (0.066%) according to the Skopelos Island meteorological station observations. It is suggested that these conditions fulfill the requirements of Law 2971/2001 for '*the highest however unexceptional sea wave run up'*. 9 or 10 Beaufort winds present a very low annual frequency, so it was assumed that they do not fulfill the legislation's requirements (Table 2).

The most extensive fetch, 35 n.m. was observed towards the WSW direction, thus this was suggested as the most convenient input for wave height calculation. Assuming that a) an 8 Beaufort (20 m/sec) wind blows at least 4.5 h, b) the effective fetch does not exceed 35 n.m., and c) the wave period is 7.2 s, then the maximum wave height calculated according to C.E.R.C. (1984) wave prediction model would be 3.3 m in the deep sea area.

Suggesting that the mean slope of the shallow sea bottom and the coastal area is 1°, the coefficient of the coast was calculated ($\xi_{0=}$0.08257) as well as the maximum wave run up on the coast R_{max}= +1.20 m, according to MASE (1989).

According to the Skopelos tide gauge's continuous records, from 1999 up to date, the mean sea level rise due to the tide (mean high water level - mean sea level) was estimated at +0.14 m (HNHS, 2006).

Therefore the uppermost sea level that affects the coast does not exceed +1.34m, including the sea level rise due to the maximum wave run up as well as the tide .

Consequently, the upper limit of the modern foreshore zone of the Vromolimno area, Skiathos Island, should be the +1.34 m level according to the available data and Law 2971/2001.

Conclusions

The suggestion which is mentioned in the official gazette of the Hellenic Republic, issue 6 B' (15–01-1963), that the level of the modern foreshore of the Agia Marina, Saronikos Gulf area, which was determined by the authorized committee, between the kilometric locations 35.5 km and 36.5 km of Athens - Sounion avenue, reaches the level +9.6m and/or to +12m on the coastal area, cannot be confirmed from the available field and laboratory geomorphological, bathymetric, meteorological, and tidal measured data or by wave measured and predicted data.

On the contrary, according to the field measurements and the laboratory wave height predictions, the maximum wave height with the sea level rise on the coastal area due to wave run up and the tide that affects the coast does not exceed +3.6m. Consequently, the innermost limit of the modern foreshore zone which is defined by the law as *'the zone wetted by the highest however unexceptional sea wave run up'*, is much lower than the level mentioned in the previous paragraph and therefore should be determined at the +3.6 m level according to the available data and Law 2971/2001.

Also the suggestion which is mentioned in the official gazette of the Hellenic Republic, issue 670 D' (30–11-1990), act No. 155/14-11-1990 *Determination of the limits of the modern foreshore zone and the beach of the Vromolimno area, Skiathos Island, Prefecture of Magnesia*, that the modern foreshore, determined by the authorized committee, reaches the level +1.0m, cannot be confirmed from the available field and laboratory geomorphological, bathymetric, meteorological, and tidal measured data or from wave measured and predicted data.

According to a) the laboratory wave height predictions, b) the maximum wave height and c) the sea level rise on the coastal area due to the wave run up and the tide that affects the coast, it has been suggested that it reaches the +1.34m level.

Therefore, the innermost limit of the modern foreshore zone, which is defined by the law, is higher than the level mentioned in the previous paragraph and therefore should be determined at the +1.34 m level according to the available data and Law 2971/2001.

The previously mentioned characteristic cases of modern foreshore determination indicate the essential contribution of dedicated scientific studies in the estimation of the uppermost limit of the sea level rise that affects the coastal area. Both cases indicate the incorrect estimation (either over-estimation or under-estimation) by the authorised committees, of the maximum sea level rise on the coastal zone.

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