

AQUEOUS ENVIRONMENT AND EFFECTS ON THE CIVIL AREAS: THE CASE OF NAFPLIO

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Abstract

This paper made an effort through the data and conclusions drawn to highlight the impact of the water element, surface and groundwater in urban and suburban area of Nafplio. Through exploratory wells constructed for this reason, water - measurements and water - chemical analysis carried out, made a series of thematic maps which are dimensioned Spatiotemporal rain water flocking to urban and suburban area in case of extreme rainfall events, illustrating the depth, the direction of groundwater flow and the corrosivity of groundwater in relation to the foundations. The accuracy of the figures obtained for surface water and groundwater is a function of time series and the density of the network, and certainly is indicative and could be much more detailed if the network was denser. In any case, this work tries to highlight the value that may have similar operations on urban planning and foundations.

Key words: water points, corrosivity, Langelier indicator.

1. Introduction

This paper was prepared on the basis of hydrogeological work carried out under the project ‘‘Geo - thematic Information of urban and suburban areas of Greece - Pilot Applications’’ and the 6920/005 project which was implemented by the Directorate of Geological Mapping of IGME. The field work included water - measurements, groundwater sampling and research drilling. The laboratory work involved laboratory tests of water samples such as chemical analysis and measurements of underground water from urban and suburban area of Nafplio, all made in the chemical laboratories of IGME.

The final processing of hydrogeological data gathered and taken into account ‘‘other’’ parallel research conducted under this program (Geological mapping, geophysical prospection, geochemical work).

2. Topography – Hydrology Line

The area included in the topographic sheet ‘‘NAFPLIO 1:50.000’’ Edition GMS. The total area examined and directly affecting the rain water to urban and suburban area of Nafplio is 3,32 km². While urban and suburban area was estimated at 0,45 km². The altitude in urban and suburban area varies from 0.50 m to 62 m on slopes Palamidi. The geomorphologic relief has two settings. Bold



Fig. 1: hydrologic map of urban and suburban areas of Nafplio.

rocky and steep south and southeast and flat alluvial origin main new urban and suburban part of Nafplio. Basis of rainfall data of meteorological station Nafplio, which provides the largest time series measurements from 1900, the average amount of annual precipitation is estimated at 525, 3 mm. The direct nearest station of “Pyrgelas” is operating since 1981 and has annual average amount of precipitation 481 mm. Both stations have recorded rainfall of the same region. Their locations are sufficiently different in terms of conditions that could affect rainfall.

From the daily rainfall cards found that in the Argolic field are not unusual, highly events with intensity $i = 60-70 \text{ mm / h}$. The most common duration was around $20' - 40'$. The region which affects rain water to urban and suburban area, divided into five (5) sub areas (Figure 1).

Location “A” that extends in the north - north slope Palamidiou with surface drainage section $0,19 \text{ km}^2$ region of interest and is the most extensive $2,7 \text{ km}^2$. Location “C” with surface drainage $0,4 \text{ km}^2$.

Location “W” with drainage surface $0,4 \text{ km}^2$. Location “R” in the northern slope of Acronafplia with limited drainage area $0,01 \text{ km}^2$. In the following areas is not taken into account the extent of built areas (urban and sub-urban area). Based on the topography formed within the urban and sub-urban area are concentrated around the storm water drainage. The first pillar is powered by Sub’ ‘A” in which three small basins developed water streams. All the thirty streams form a total area of $0,19 \text{ km}^2$ drainage area of a common influx, the triangle of roads Nafplion - Nafplion and Argos - Aria. The second major rainwater drainage is important that primarily affects the new urban part of Nafplio. Powered by high hydro geological and surface storm water Sub’ ‘B”’. The catchment area is that many blind streams plains leading to sub-urban lowland Bampafonou area (north of the urban area). In sub - urban area Polygon the appropriate topographical conditions for convergence of all these sub-catchment with the main axis “exit” to the beach in place just north of the Municipal Parking. The catchment area “B” sub-surface accepts external inputs. A raw estimate in case of an incident rainfall intensity (i) = 70 mm / h and a $30'$ is that in the catchment area of the sub region “B”, not including external inputs can be collected on the 980.000 m^3 rain water which would seek “exit” to the sea in position between the Municipal Parking and the breakwater. Because water is not near

a particular river, but the sum of all small basins of different streams was not easy to calculate the concentration of "years" (tc) of rain water at a given location as the entrance of the urban area. A raw estimate was based on the type "Snyders" (modified) $tc = Ct + (L + I) n / \sqrt{s}$ (in hours). In this assessment the water surface is perceived as a single basin. As the main watercourse flood line in the urban area, that extends up to the entrance of the urban area (near the road Nafplio-Argos). The "Time" tc concentration greater supply of rain water at the height of the road was estimated to be 20 since starting an intense rainfall episode features mentioned above. The third line of rain water drainage affecting the urban-sub-urban area located north of the polygon is fuelled by the Sub "C". A small catchment area compared with the previous two. The other two sub "D" and "R" are not creating targeted drainage lines within the urban-sub-urban area and rain are very dispersed.

3. Geological Structures

The region has been geologically mapped in the past the period 1964-68 and included in the geological map sheet "Nafplio" climate. 1:50.000 IGME ed. Fotiadis and Mitropoulos (2006) further improved the existing geological mapping and illustrate the new elements on a scale 1:5000. In analyzing the structure divided into three (3) modules (fig.2): a) Low unit (Paraftochthoni) neritic carbonate sequence of Middle Triassic-Liasic from pelagic nodular limestones, pelagic sediments and siliceous hornstone siltstones and a tectonic-sedimentary mélange of Malmo. b) Intermediate Unit, Flysch tectonic mélange of the Post-eocenic period (?) Upper section of the Cretaceous calcareous flakes along with a tectonic mesh of serpentine flakes and large pieces of Mid-Triassic – Liasic carbonates, detached from the underlying carbonate unit. These formations domain the mountains in the region of interest (Palamidi, Exostis, Lefkania, Prophet Elijah). The thicknesses of the modules based on both the drilling and stratigraphic data that is estimated to Low E. 160-180 m, the Intermediate E. \leq 60m. and Upper E. 180-220m. The flat part of the urban-suburban area of Nafplion is part of the tectonic draft of the Argolis area. Based on drilling performed, that the thickness of the granular sediment in some places is $>$ 280m. Previously in various research projects have been drilling throughout the Argolic Field which is a detailed analysis of drilled granular layers (Galeos 1967, Poulavasilis, Mimidis, Giannouloupoulos 1996).

In the flat part of the region of interest based on data from two research carried out drilling for water at shallower depths (48m) is interesting to note that the puncture was near the foot of the massif Palamidiou ($<$ 60m) Granular materials are thick $>$ 50m. The same pattern and at the foot Welfare and Prophet Elias with input from private drilling for water. This suggests that at least in this eastern margin of the sedimentary basin Argolic Field is determined by fluctuations in several large jumps.

4. Hydrogeological Conditions

The hydrogeology of the "Argolic Field" is been repeatedly studied and researched because of the great interest presented by the region since the early 1960s. Continued over-exploitation of groundwater in granular through the large number of private drilling have caused widespread salinization problems that exist today in length. Since many of these research work has been recovered enough (Zervas1965, Galeos1967, Theodoropoulos, Zaman 1970, Poulavasiliki, Mimidis, Giannouloupoulos 2000, Sampatakakis Fotiadis Kallergis 1995, Giannouloupoulos 2001, Maravegias 2000). Apart from studies and surveys on the water potential of Argolic Field, was developed and a significant number of individual studies.

The area of lowland part of the urban - sub-urban area of Nafplio is like the rest of the field from successive Argolic granular aquifer. The mountain section is structured by independent water geo-

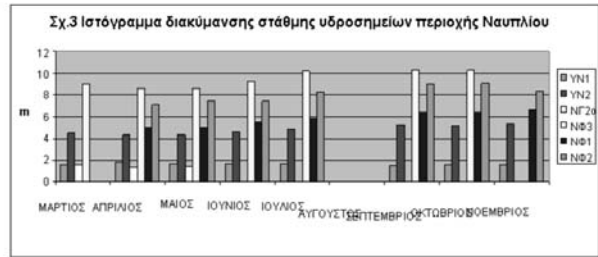


Fig. 2: (left): water level curves map; (right): water level histogram.

logical chambers but have hydraulic contact with the lowland aquifers. The work of water-measurements were level measurements of groundwater developed in eight (8) time series for March - April - May - June - July - September - October - November 2006. The water-measurements network is based on two research wells, a private drilling well and three private wells. It is estimated that the results would be better if there were more available water points. And the program under which it was given economic margins. Based on measurements made relative histogram was drawn (fig. 2) a reading which yields the following: All levels of the network show the same trends of diversification in the same series. The exception is the water point YN1 corresponding exploratory drilling in the park "position." This can be explained by the fact that the well in this location in close vicinity to the sea and as will be presented below will be confirmed by its chemicals.

The range of modulation level is different in water point water point. This is probably due to different local conditions of hydraulic conductivity of materials in which the aquifer is developed. It must be noted that this regarded to the shallow aquifer hydrostatic "free" level and not to deeper "pressure" aquifers which are developed in the area of Field Argolic basis of literature.

Based on the average level of each water points resulting from all the time series of measurements, prepared the map water level "curves" on a scale 1:5.000 (Fig. 2). An analysis of the features of this map is concluded that: The hydraulic gradient (i) the aquifer is very small indeed expect such a hydrogeological environment in close proximity to the sea and horizontal - sub horizontal layer development fine grain materials. The estimated values are between $i = 0,05\%$ and $i = 0,03\%$. Based on the overall slope of the aquifer shows that groundwater traffic of "exit" in the waters around the median volume of limestone Acronauplia. This movement regards the underground waters of eastern and north-eastern part of the urban and sub-urban area of Nafplio, while the north-west part is almost in static conditions compared to the adjacent sea. The hydraulic gradients are elusive because of their small values.

5. Sampling – Chemical Analysis

Simultaneously with the level measurements, groundwater sampling was performed at the same points of the network, in no-pumping conditions, as well as pH and temperature measurements. The water samples were analyzed at the chemical laboratories of IGME. There were an equal number of samples and time series water chemical analysis.

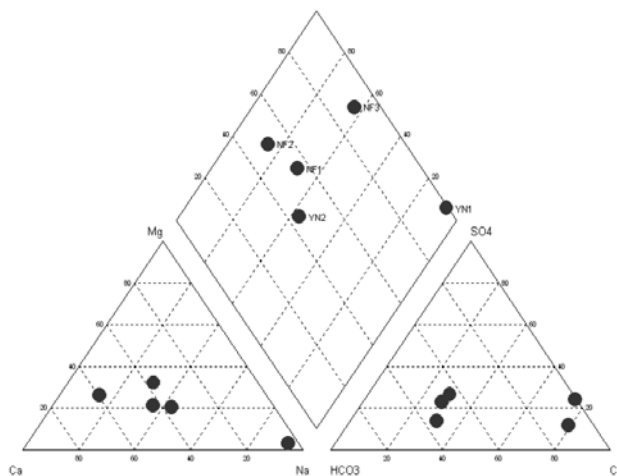


Fig. 3: Piper diagram.

Based on water chemical analysis and physic-chemical measurements were classification of water samples in Figure Piper, made histograms basic ion water chemical maps and estimated the ratio Langelier.

5a. Piper diagram

Shows the ‘average’ prices of water chemical analysis carried out in water points the ‘network’. From this diagram shows that:

- Samples from the water points NF1 and NF2 are classified in the field of “slightly chloridic and sulphate – calcareous and magnesium” water.
- Samples from water point YN1 are classified in the field of “super-chlorate-sodium” waters.
- Samples from water point YN2 are classified in the field of bicarbonate and magnesium.
- Samples from water point NF3 are classified in the field of strongly “chloride and sulphate-magnesium and calcareous” water. These water chemical data are in agreement with the isochlorion curves maps data and the effect of the shallow aquifer from sea intrusion.

5b. Histograms

Prepared total seven (7) histograms of which two related to pH and temperature outdoors and the other ions NO₃, NO₂, NH₄, Na and Cl.

Histogram pH

Prices of water point’s network showed different price trends during the time series and irregular fluctuations. This can be interpreted as the effect of price which is not due to physical water chemical factors (e.g. wet - dry season) but likely to exogenous factors.

In several cases there was a combination of increased prices with little prices NO₃ pH. The higher values observed in almost all time series in water point YN1.

Histogram of rural temperature

The temperature measurements were rural in 2006 by month March to November. Besides a sharp temperature difference must be attributed to a malfunction of the body or exogenous cause of the

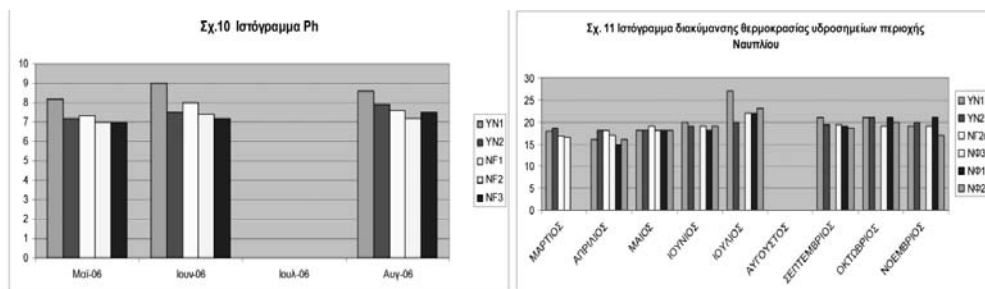


Fig. 4 (left): Ph histogram; (right): temperature histogram.

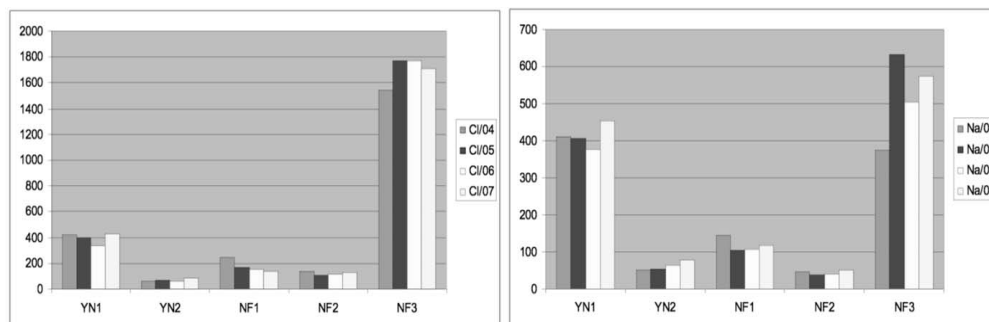


Fig. 5 (left): Cl histogram; (right): Na histogram.

price 27° C in July 2006 in water point YN1, the other two values are “trends.” Lower prices seen in the months March - April - May and peak in June to October (fig.4). The first three months represent a time period and supply the months June to October the dry season.

Na and Cl histograms

The water points YN1 and NF3 present consistently the largest values compared to the other all the time series samples. The high prices of Na and Cl are due to natural water penetration which is quite intense and widespread in the whole region of Argolida Field.

Water point YN1 (in the “Park”) is directly affected by the water penetration that occurs through the high permeable limestone volume of Acronafplia. The water point NF3 presents the highest rates in Na and Cl due to salinization that characterize generally the “granular” aquifers of Argolic Field. In the other water points, the effect of the sea seems to be very limited. In water point YN2 the three variations to prices well above the period 1 / 2007, 2 / 2007 8 / 2007 in comparison with other time series should be attributed to external factors as pollution since are being shown similar increases in the prices of NO₃-and SO₄ -.

NO₂, NH₄, NO₃ histograms

From the histogram of NO₂ ion (fig.6) is shown that there are no effects of pollution in the same period at all water points. In what water points recorded values higher than the limit, there is no correlation between time and is a local phenomenon.

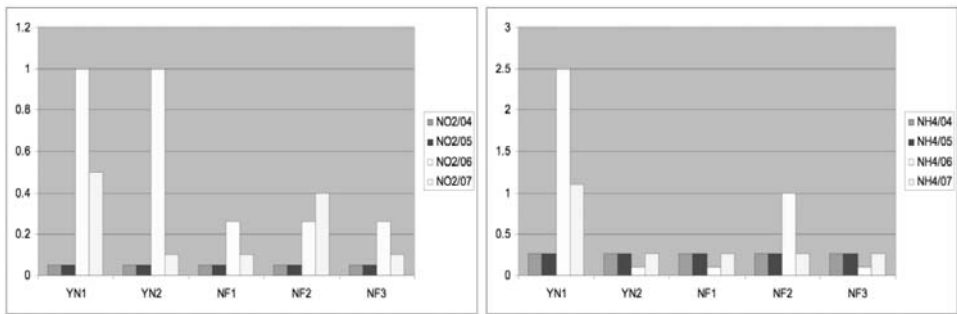


Fig.6: (left): NO₂ histogram; (right): NH₄ histogram.

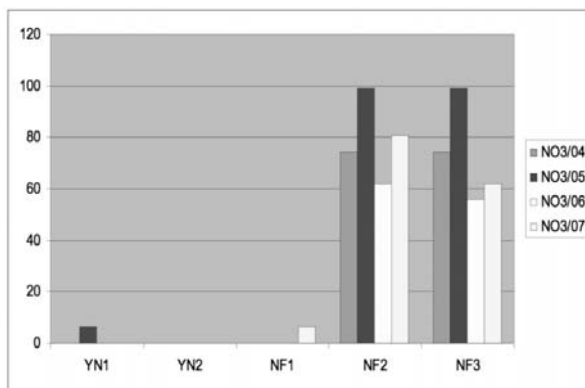


Fig. 7: NO₃ histogram.

The water point YN1 presents the most intense and frequent aggravating prices in the NO₂. Here are water points NF3 and NF2.

The water point YN1 terms of location is within the urban area of Nafplio. While water points NF3 and NF2 facing the suburban area with rural areas. Looking at the histogram of NH₄ ion (fig.6) found that only water point which shows prices beyond the limits of even a single episode, is in water point NF2. From the histogram of NO₃ (fig.7) shows that the highest frequency to pollution by nitrates occurs primarily within water point NF3 and secondly in water point NF2. Also charge very high prices but a limited number of time series, the water point YN2.

Analyzing the spatial and temporal distribution of these values in NO₃ concluded that the effects of this pollution would be caused by agricultural activities (fertilization) after both water point NF3 and NF2 are within the farms are cultivated and fertilized regularly (citrus).

5c. Water chemical Na and Cl maps

The equivalent curves of Cl⁻ was around 200 ppm while the Na²⁺ of 40 ppm (fig.8). Both maps show that the increase in both Cl⁻ and the Na²⁺ occurs from two different geographical "fronts", the SSE and N (Akronafplia - Skipjack). Based on the equivalent curves in the urban area the average values of Cl⁻ and Na²⁺ range ≥ 320 ppm, respectively. In the "sub - urban area" the average values of these ions have greater range (100 - 1100ppm for Cl⁻ and 80 - 400 ppm for Na²⁺). This is certainly a water chemical environment with highly saline ground water whose NaCl's source is the sea-water.

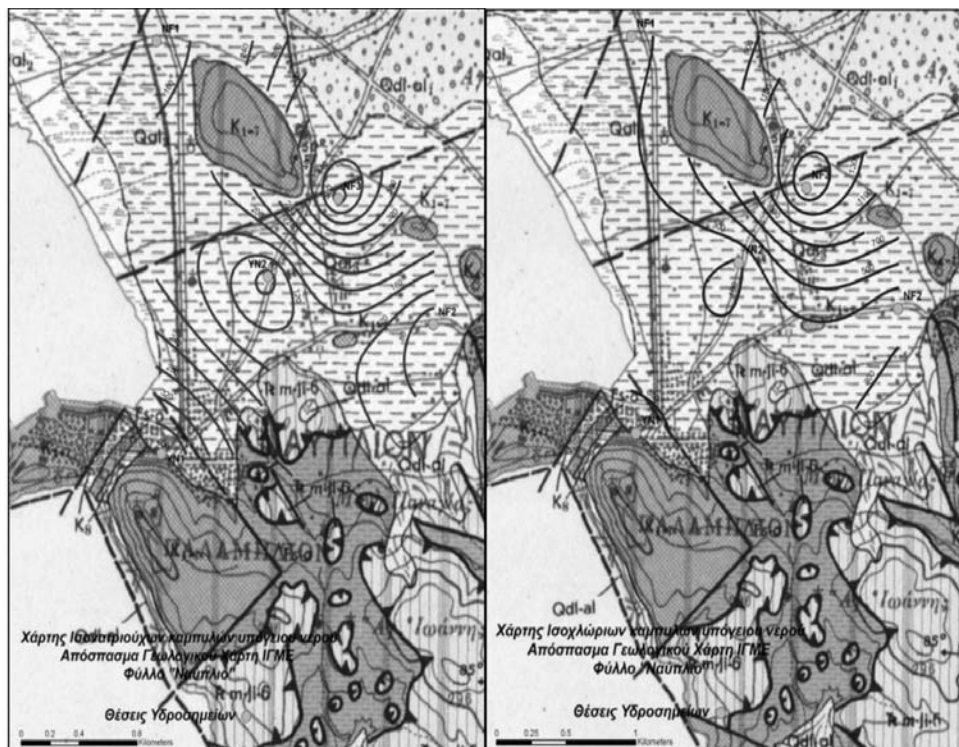


Fig. 8: (left): Water chemical Na map; (right): Water chemical Cl map

5d. Ion relationship $Ca + Mg / K + Na$

The above ion relationship is known that is used to detect areas of enrichment of water, combined of course with other physicochemical parameters. In this case sought only in general terms to provide some interpretations on the spatial and temporal conditions of enrichment of survey because of the time series data are not sufficient. Based on Table III price for each and every water point time series reveal that:

- All prices in water point YN1 are <1 . This means that the groundwater in the location of this water point not directly but are enriched downstream part of the wider aquifer. This certainly confirms the prevailing conditions of urbanization widely round the water point which certainly does not allow direct effects of percolation and enrichment in this part of the groundwater.
- Prices in water point YN2 for March and April 2006 indicate that groundwater is enriched directly in this region. In all other time series of prices show that enrichment is weakened and represents underground water aquifer downstream part.
- In NF1, NF2 and NF3 water points, the values suggest that groundwater in their regions enriched directly by percolation. Summary can be argued that the two drilling for water that are paving to a depth of 40 meters underground water is not directly enhanced by direct water penetration phenomena (in particular this is the area YN1) but by lateral loads. Unlike in the areas of water points NF1, NF2 and NF3 groundwater has a local origin, representing that the shallow aquifer due to the shallow wells, as opposed to two drilling for water supplies that have identified other than water

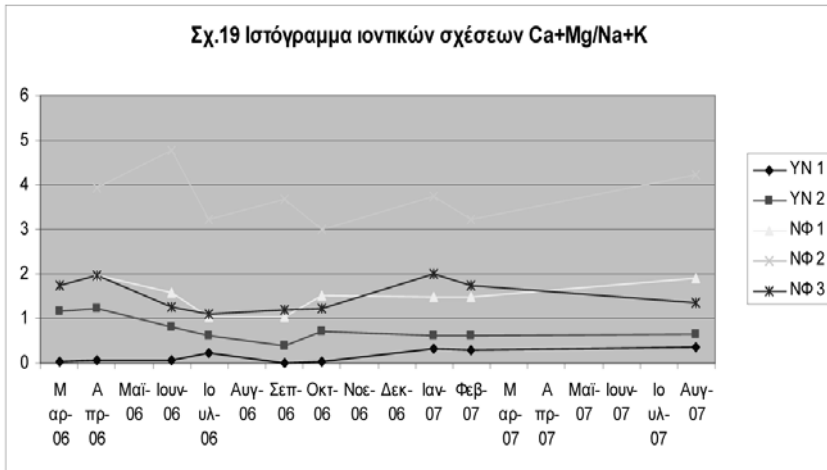


Fig. 9: Ion relationship Ca + Mg / K +Na histogram .

TABLE I - CA + MG / NA + K					
Date of Sampling	YN1	YN2	NΦ1	NΦ2	NΦ3
Mar/06	0,031	1,168	-	-	1,739
Apr/06	0,075	1,225	1,964	3,94	1,957
Jun/06	0,057	0,820	1,575	4,768	1,271
Jul/06	0,227	0,606	1,026	3,241	1,100
Sep/06	0,016	0,393	1,041	3,680	1,188
Okt/06	0,033	0,701	1,513	2,985	1,222
Jan/07	0,307	0,628	1,484	3,744	1,989
Feb/07	0,275	0,617	1,487	3,234	1,740
Aug/07	0,346	0,637	1,890	4,218	1,340
Average Values	0,152	0,755	1,497	3,726	1,505

and shallow aquifer water from a deeper aquifer. Most documents this situation is the relevant figure (Fig. 9).

5e. Corrosivity of groundwater

The indicators used to monitor the corrosivity of water and the case of groundwater near Nafplio, are two:

- The index Ryznar: used to determine deposition of CaCO₃ in water at any temperature up to 93 ° C and prognosis of erosive capacity of water.
- The index Langelier: to control the erosive capacity of water or salt deposition. Proposed a "saturation index" (saturation index, Si). The definition requires knowledge of the alkalinity

of the Ca ions concentration, of pH, temperature, TDS. Positive values mean Si deposition CaCO_3 or other salts, dissolving negative values and the values $\text{Si} = 1$ neutral state. The determination of the Index results from $\text{Si} = \text{pH} - \text{pH}_s$ (where the actual pH and pH_s where the saturation).

Much of the foundations of buildings in urban low (coastal) area of Nafplion located throughout the year or periodically within the saturated zone of the aquifer by changes of the hydrostatic level.

From Table I we suggest that in locations where there are two water points YN1 and YN2 several building foundations may be located permanently or periodically within the saturated zone of the aquifer. The boundaries of this residential area, which is susceptible to this phenomenon, can be identified through the preparation of maps of equal-level curves relate to different periods.

The map which is presented in this report (fig. 8) refers to “average” values for each water point network. The diagram of the variations in levels for each water point (Fig. 8) shows that variations in level are not equivalent (downward or upward) to all water points and at the same time series. But in the same direction except water point YN1 which is directly affected by the upward and downward movements of the sea.

The study was considered useful to determine the saturation index (Langelier).

YN1	YN2	NΦ1	NΦ2	NΦ3
2,4	1,8	1,5	1,3	1,2

Based on the average values of physicochemical parameters of the samples taken outdoors and workshops identified the following indicators for each water point.

The above values show that all sites are represented by water points network is important to heavy deposition of salts and corrosion on all metal construction, reinforced concrete, etc. contact for a long time in the underground water.

6. Conclusions-Results

6a. Hydrologic Conditions

The area of investigation because of geomorphological terrain is separated into two physiographic units: mountain and plain. This differentiates physiography and conditions in rain water in the urban area of Nafplio.

The flat section formed by two lines on rain water drainage that may affect the urban area of Nafplio. The first pillar is powered by a drainage catchment area of $0,17 \text{ km}^2$ small size and quantities of rain water can be generated by a strong global rainfall is negligible.

The second line of drainage is important and affects mainly the new urban part of Nafplio. The surface drainage area is $2,7 \text{ km}^2$. But the volume of rain water and contribute to “external” basins through two entrances, which identified the site Bampafono. In an episode of rainfall intensity (i) = $70 \text{ mm} / \text{h}$ and for 30 minutes, which occur in Argolic Field can create a rain water volume equal to about 980.000 m^3 . These quantities are based on the topography of the urban and peri-urban area will cross the new part of the city of Nafplion which is defined between the City Parking and the new breakwater and will end at sea (Fig. 2). The above amounts did not take into account the rain water that would enter from the two entrances at the region of Bampafono, and which is estimated to be clearly higher.

Because surface water is not considered a specific area but is the sum of small basins different streams was not easy to calculate the concentration of “years” (tc) of rain water as described above in a given topographic position (e.g.; the “entrance” of the urban area). An approximate estimate is based on the type of Snyder's (modified) $tc = Ct + (L + l) n / \bar{O} S$ (in hours). Considering as a single basin of this water surface with the main watercourse flood line in the urban area “B” and that extend up to the entrance of the urban area (near the road Nafplion - Argos), the “concentration time” (tc) of the largest providers of rain water at the rate of road Nafplion - Argos was estimated to be 20’ from the moment you start an episode of intense rainfall.

Of course all the above references to surface water and flood their impact on urban and suburban area of Nafplio are conceptual in nature as the primary data available for these estimates were made were few. The aim, however this report is to demonstrate that these hydrologic sizes in urban areas can be identified and exploited to the course of an urban planning area.

6b. Groundwater

The groundwater grows shallow in most of the urban area of Nafplio. Evaluating the average values of all time - series (measured from the five (5) water points “network”) we conclude that the level of groundwater varies on average between measurements to 0.27 m at the low sites (coastal) and 2.25 m in high. Also according to the depth of the aquifer large number of building foundations of the urban area is always in the saturated part of the aquifer throughout the year.

A number of foundations are also building in magazines saturated part of the aquifer (wet season). And finally to higher places and especially in the slopes of the urban and suburban area, the foundations of buildings are in the “ventilation zone” of the aquifer. As a result they are only affected by the percolation of surface waters to the “saturated” zone.

The demarcation of the three (3) these subregions the area of research in which the foundations accept a varying degree the influence of underground water could be achieved if there was a utilitarian scale water points denser network monitoring. The network water points which were used, we provide only an indicative list of conditions on the water level fluctuation during the hydrological year and spatial variations in urban and suburban area of Nafplio.

Regarding the groundwater chemicals based on the calculation of the index Ryznar, the groundwater has throughout the period of measurements such a quality characterized by pH values ranging between 7 and 9 in all water points and all time series sampling.

This is interpreted that at the foundations of reinforced concrete and steel stockades only salt deposition occurs and not erosion.

In conclusion these findings, the overall assessment is that by ensuring a monitoring network denser and longer time series of measurements, at least three (3) hydrological years can provide a reliable and use-based data on the structure of the aquifer and the quality characteristics they affect the foundations. Also while in the present investigation there were no measurements of water run-off and their impact on urban and suburban environment of Nafplion is estimated that in a multi-level research on the Geoenvironment should not be missing references to floods but a downstream part of the wider aquifer. This certainly confirms the prevailing conditions of urbanization beyond.

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