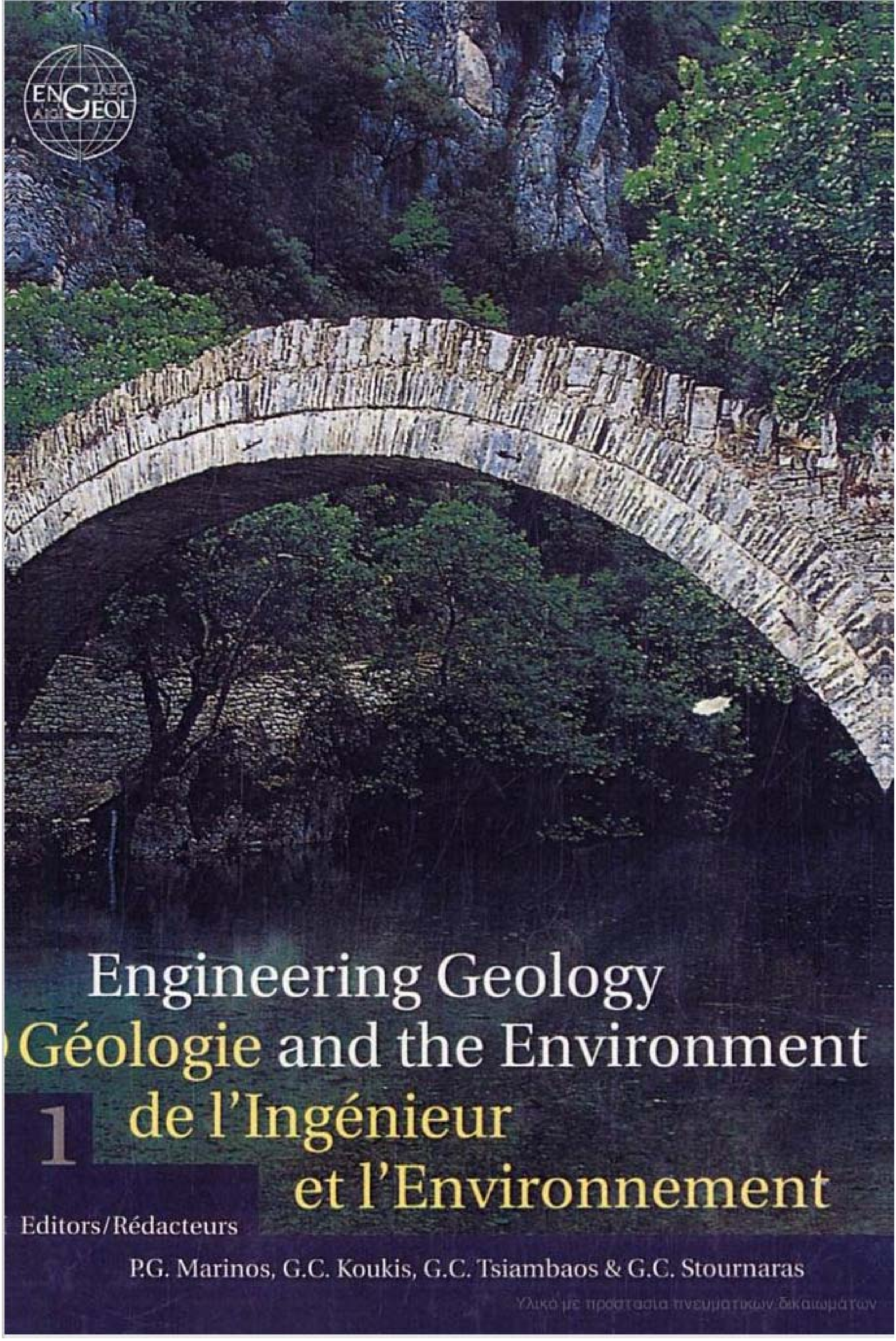

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Geomorphological investigation of the drainage network and calculation of the peak storm runoff (Qp) and sediment yield of Sarantapotamos and Katsimidi streams, Attica, Greece

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ABSTRACT: Drainage basins of Sarantapotamos and Katsimidi streams lie on western Attica (Greece) and their torrents cross the city of Elefsina. They belong geotectonically to the Sub Pelagonic zone and consist of Triassic - Jurassic carbonate rocks, interbedded schists and sandstones. This paper deals with the geomorphological and statistical study of the drainage systems, as well as the calculation of the peak storm runoff and sediment yield of all drainage basins in certain important places including the river exits. The statistical analysis showed that the drainage systems were influenced by lithology, as well as that the systems were in an advanced maturity stage of development. The peak storm runoff that was estimated, concerns the extreme values of the maximum probable peak storm runoff, with a 100 years recurrence period. The flood levels of the torrents and streams should be taken seriously into consideration in order to foresee and anticipate the necessary sewage and drainage work systems. The mean annual sediment yield of each one basin was also calculated and revealed that the draining capacity of the streams decreases with time, resulting in extensive floods after strong rainfalls in the wider area. Maintainance of the channels are finally suggested.

INTRODUCTION

The drainage basins of Sarantapotamos and Katsimidi streams lie in western Attica. They are surrounded by Pateras and Kitheronas mountains at west, Pastra mt at north and Parnitha mt in the northeast. The city of Elefsina lies on Thriasio Pedio (plain) downstream. It is one of the areas of Attica wwhich often suffers from storm floods. Sarantapotamos and Katsimidi torrents cross the city of Elefsina. The purpose of this paper is the geomorphological and statistical study as well as the calculation of the peak storm runoff and sediment yield of the above drainage systems in several places including the river mouths. Thus, the results of this study should be taken seriously into account for planning and constructing sewage and drainage work systems. The studied area belongs geotectonically to the Sub Pelagonic zone and consists of Triassic - Jurassic carbonate rocks, interbedded (malange) schists and sandstones (I.G.M.E. 1:50.000). The northeastern part of the drainage basin of Sarantapotamos consists of Upper Cretaceous limestones interbedded with marly limestones. In the mountainous part of this drainage basin from Panacto village up to Vilia there are extensive Late Paleozoic beds outcrops, consisting of alternating formations of volcanic tuffs, and shales. Almost the total area of Thriassio Pedio and the polje of Oinoi, consist of Quarternary deposits including alluvial and diluvial formations, consisting of red clays, conglomerates, alluvial fans, screes and talus cones which are loose or cohesive. The coastal areas of Thriasio Pedio consist of alluvial deposits and marly-sandy materials, covered by soil. Because of the action of alpine tectonism, the formations are strongly folded, while Late Paleozoic beds are overthrusted uppon Triassic limestones on the pediments of Pastra mountain.

DRAINAGE SYSTEMS

The channels of Sarantapotamos and its main streams have been developed on carbonate rocks.
Drainage basins have a rough relief. They lie between mountain Pateras to the south and Kitheronas to the north. Altitudes are high (Pateras mt 1132 m, Pastra 1016 m), valleys are deep and the relief is variable. Karstification is extensive and in an advanced stage of development. Many, inner drainage basins and valleys were formed by karstification. The biggest Karst landform is the polje of Oinoi. The main axis of this plain is about 13Km long. The direction of the valleys is parallel to the axis of the alpine folds or the main tectonic lines and is affected by tectonism.

In the studied area three main fault systems can be distinguished. The faults of the first system are directed ENE-WSW and locally E-W. The second system includes faults directed NE-SW and the third one gives the most significant faults of NW-SE direction. The development of the big Neogene basins of Megara is due to these faults (Dounas, 1971).

Furthermore it must be mentioned that the studied area has been, affected by intensive karst erosion, because it was a land since Up.Cretaceous. The development of the main valleys and geomorphic processes has started after Alpine folding.

DRAINAGE NETWORK

A map of the drainage network at a scale of 1:50.000 was drawn in order to study the drainage network of Sarantapotamos and Katsimidi streams. This map includes the channels of the topographic map of HAGS completed by airphoto-interpretation and field

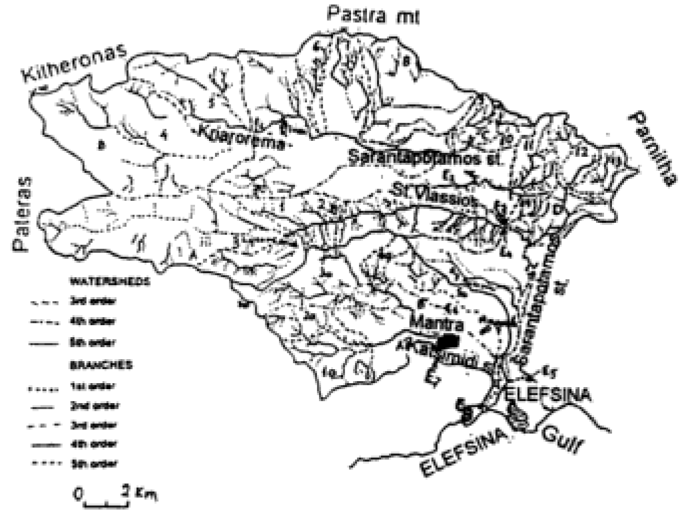

Fig. 1: Map of drainage network.

observations. Then the parameters of the drainage network were measured and calculated. All the data were classified in Tables1 and 2. The ordering of the streams was made according to A. STRAHLER'S system (1957). The drainage network is shown on the map of figure 1.

The drainage network of Sarantapotamos constitutes a 5th order drainage basin, which has an area of 256,364 Km^2. The western part of this drainage basin consists of two oblong 4rth order drainage basins which have a long, E-W axis, while the northwestern part consists of two smaller 4th order drainage basins.

We numbered fourteen 3rd order drainage basins. Some of them belong to 4rth order basins while others, such as 10 and 13, drain directly to 4rth and 5th order streams. An asymmetrical development of the drainage network basin B is observed north of the 4rth order stream a lot of 3rd order basins are developed ,while south to it part there are no streams. It has to be mentioned that in the drainage basin A numerous 1st and 2nd order streams drain directly to a 4rth order stream. This fact is of particular interest, because during strong rainfalls these streams supply water directly to the main channel of the drainage basin. This causes a rapid increase of the water level and serious flood problems. The shape of the drainage network is rectangular, showing the influence of

TABLE I: Morphometry of the drainage systems.

Basin	N1	N2	N3	N4	N5	SN	L1, km	L2, km	L3, km
Sarantapotamos									
1	18	6	1			48	7,0	3,0	4,0
2	6	2	1			9	2,1	0,9	0,1
3	15	3	1			19	2,0	3,0	3,0
4	10	4	1			15	8,0	6,0	7,0
5	9	2	1			12	4,0	1,5	2,0
6	3	4	1			15	4,0	4,0	3,5
7	12	5	1			18	5,0	4,0	3,5
8	15	3	1			18	9,5	3,5	2,9
9	9	4	1			14	4,0	3,0	1,5
10	9	2	1			12	5,1	1,0	2,5
11	21	3	1			25	10,0	5,0	0,1
12	16	3	1			9	4,0	1,0	1,0
13	8	2	1			11	7,0	3,0	3,9
14	11	2	1			15	5,8	2,1	2,5
A	96	23	3	1		136	39.1	7,1	7,1
B	59	21	5	1		76	33.5	19,0	19,0
C	40	9	3	1		53	18,0	9,1	4,0
D	32	9	3	1		45	18,3	5,1	6,4
Sa	227	64	14	4	1	310	116,9	54,1	39,6
Katsimidi									
1a	11	3	1			15	4,00	4,0	2,0
2a	12	3	1			16	5.00	1,8	5,0
3a	23	6	1			30	9,00	8,0	2,5
4a	7	2	1			10	2,10	1,8	0,2
5a	12	3	1			16	5.00	2,0	7,0
A'	23	6	2	1		32	10,20	8,8	7,0
B'	37	11	3	1		52	19,10	12,3	9,7
K	60	17	5	2	1	85	29,30	21,1	16,7

Basin	L4, km	L5, km	SL, km	$Rb_{1/2}$	$Rb_{2/3}$	$Rb_{3/4}$	$Rb_{4/5}$	WRb
Sarantapotamos								
1			14,0	3,0	6,0			4,5
2			3,1	3,0	2,0			2,5
3			8,0	5,0	3,0			4,0
4			21,0	2,5	4,0			3,3
5			7,5	4,5	2,0			3,3
6			11,5	0,8	4,0			2,4
7			12,5	2,4	5,0			3,7
8			15,9	5,0	3,0			4,0
9			8,5	2,3	4,0			3,1
10			8,6	4,5	2,0			3,3
11			15,1	7,0	3,0			5,0
12			6,0	5,3	3,0			4,2
13			13,9	4,0	2,0			3,0
14			10,4	5,5	2,0			3,8
A	12,0		65,3	4,2	7,7	3,0		3,0
B	13,0		84,5	2,8	4,2	5,0		1,7
C	1,0		32,1	4,4	3,0	3,0		2,7
D	4,0		33,8	3,6	3,0	3,0		2,2
Sa	20,0	17,2	247,8	3,5	4,6	3,5	4,0	3,0
Katsimidi								
1a			10,0	3,7	3,0			3,3
2a			11,8	4,0	3,0			3,5
3a			19,5	3,8	6,0			4,9
4a			4,1	3,5	2,0			2,8
5a			14,0	4,0	3,0			3,5
A'	4,0		30,0	3,8	3,0	2,0		2,9
B'	5,0		46,1	3,4	3,7	3,0		3,3
K	9,0	5,0	81,1	3,5	3,4	2,5	2,0	2,9

Basin	L1-	L2-	L3-	L4-	$RL_{2/1}$	$RL_{3/2}$	$RL_{4/3}$	$RL_{5/4}$	WRL-
Sarantapotamos									
1	0,4	0,5	4,0		1,3	8,0	0,0		4,6
2	0,4	0,5	0,1		1,3	0,1	0,0		0,7
3	0,1	1,0	3,0		7,5	3,0	0,0		5,3
4	0,8	1,5	7,0		1,9	4,7	0,0		3,3
5	0,4	0,8	2,0		1,7	2,7	0,0		2,2
6	1,3	1,0	3,5		0,8	3,5	0,0		2,1
7	0,4	0,8	3,5		1,9	4,4	0,0		3,1
8	0,6	1,2	2,9		1,8	2,5	0,0		2,2
9	0,4	0,8	1,5		1,7	2,0	0,0		1,8
10	0,6	0,5	2,5		0,9	5,0	0,0		2,9
11	0,5	1,7	0,1		3,5	0,1	0,0		1,8
12	0,3	0,3	1,0		1,3	3,0	0,0		2,2
13	0,9	1,5	3,9		1,7	2,6	0,0		2,2
14	0,5	1,1	2,5		2,0	2,4	0,0		2,2
B	0,6	0,9	3,8	13,0	1,6	4,2	3,4		3,1
C	0,5	1,0	1,3	1,0	2,2	1,3	0,8		1,4
D	0,6	0,6	2,1	4,0	1,0	3,8	1,9		2,2
Sa	0,5	0,8	2,8	5,0	1,6	3,3	1,8	1,2	1,6
Katsimidi									
1a	0,4	1,3	2,0		3,7	1,5	0,0		2,6
2a	0,4	0,6	5,0		1,4	8,3	0,0		4,9
3a	0,4	1,3	2,5		3,4	1,9	0,0		2,6
4a	0,3	0,9	0,2		3,0	0,2	0,0		1,6
5a	0,4	0,7	7,0		1,6	10,5	0,0		6,1
A'	0,4	1,5	3,5	4,0	3,3	2,4	1,1		2,3
B'	0,5	1,1	3,2	5,0	2,2	2,9	1,5		2,2
K	0,5	1,2	3,3	4,5	2,5	2,7	1,3	1,1	1,6

TABLE II: Morphometry of drainage basin.

Basin	Au,km^2	L,km	W,km	P, km	D N/km^2	F km/km^2	D1	F1
Sarantapotamos								
1	20,416	12,25	2,0	16,5	2,35	0,69	0,88	0,34
2	1,937	5,50	4,8	5,2	4,65	1,57	3,10	1,08
3	6,992	5,00	2,8	13,0	2,72	1,14	2,15	0,29
4	38,643	10,80	5,7	8,5	0,39	0,54	0,26	0,21
5	16,062	4,80	1,4	18,1	0,75	0,47	0,56	0,25
6	4,562	4,90	1,3	11,5	3,29	2,52	0,66	0,88
7	5,062	5,54	2,5	12,1	3,56	2,47	2,37	0,99
8	18,622	5,60	5,8	19,0	0,97	0,85	0,81	0,51
9	2,125	2,65	1,2	6,0	6,59	4,00	4,24	1,88
10	4,062	3,50	2,0	9,0	2,95	2,12	2,22	1,26
11	6,250	4,25	2,5	11,0	4,00	2,42	3,36	1,60
12	8,997	3,75	2,8	11,0	1,00	0,67	1,78	0,44
13	4,437	3,75	2,8	10,0	2,48	3,13	1,80	1,58
14	1,687	3,50	1,1	7,0	8,89	6,16	6,52	3,44
A	64,044	16,00	4,3	51,9	2,12	1,02	1,50	0,61
B	125,119	21,62	8,0	59,4	0,61	0,68	0,47	0,27
C	7,374	4,25	3,0	12,0	7,19	4,35	5,42	2,44
D	18,871	6,50	6,3	21,0	2,38	1,79	1,70	0,97
Sa	264,356	29,50	9,5	143,0	1,17	0,94	0,86	0,44
Katsimidi								
1a	7,062	4,60	3,2	14,0	2,12	1,42	1,56	0,57
2a	4,562	5,25	2,3	12,0	3,51	2,59	2,63	1,10
3a	14,312	7,00	3,2	23,2	2,10	1,36	1,61	0,63
4a	2,000	2,20	1,1	7,1	5,00	2,05	3,50	1,05
5a	16,749	7,10	2,1	17,0	0,96	0,84	0,72	0,30
A'	19,068	9,10	3,2	24,2	1,68	1,57	1,21	0,53
B'	20,687	13,50	3,7	35,1	2,51	2,23	1,79	0,92
Ka	61,816	13,80	8,2	41,0	1,38	1,31	0,97	0,47

Basin	S	Er	C	H, m	Conf.	H(tot.)	Rh	Rn
Sarantapotamos								
1	6,13	0,58	0,43	974	300,	674	0,06	0,29
2	1,15	0,29	0,22	562	260	302	0,05	0,34
3	1,79	0,60	0,37	976	370	606	0,12	0,42
4	1,89	0,65	2,58	1340	338	1002	0,09	1,40
5	3,56	0,94	1,34	1020	338	682	0,14	0,63
6	3,92	0,49	0,30	940	280	660	0,13	0,77
7	2,22	0,46	0,28	894	260	634	0,11	0,69
8	0,97	0,87	1,03	760	240	520	0,09	0,88
9	2,21	0,51	0,15	700	210	490	0,18	0,61
10	1,75	0,65	0,34	660	210	450	0,13	0,72
11	1,70	0,66	0,25	886	160	726	0,17	0,60
12	1,34	0,90	1,00	886	540	346	0,09	0,67
13	1,34	0,63	0,40	883	540	343	0,09	1,26
14	3,18	0,42	0,11	540	120	420	0,12	0,69
A	3,72	0,56	0,47	974	120	854	0,05	0,48
B	2,70	0,64	1,65	1340	200	1140	0,05	1,11
C	1,42	0,72	0,14	700	200	500	0,12	0,61
D	1,04	0,75	0,42	886	160	726	0,11	0,75
Sa	3,11	0,61	0,85	1020	0	1020	0,03	0,80
Katsimidi								
1a	1,46	0,65	0,47	388	160	228	0,05	0,67
2a	2,28	0,46	0,29	842	160	682	0,13	0,74
3a	2,19	0,61	0,48	842	200	642	0,09	0,65
4a	2,00	0,73	0,20	451	338	400	0,18	0,41
5a	3,38	0,65	1,05	551	70	481	0,07	0,88
A'	2,84	0,54	0,60	840	80	760	0,08	0,94
B'	3,70	0,38	0,40	842	80	762	0,06	0,89
Ka	1,68	0,64	0,73	842	0	842	0,06	0,95

tectonism, while only that of the northeastern part is dendritic .

TABLE III: Characteristics of the hydrographical basins and their concentration time.

BASIN NAME	CONCENTRATION TIME		RAINFALL UNIFORMITY COEFFICIENT		
	HOURS	MINUTES	FANTONI	SPECHT	FRUHLING
E1	2,97	178	0,29	0,72	0,54
E2	5,18	311	0,14	0,67	0,42
E3	3,72	223	0,25	0,71	0,51
E4	5,86	352	0,08	0,64	0,32
E5	6,07	364	0,08	0,63	0,31
E6	2,79	168	0,49	0,77	0,62
E7	2,71	163	0,51	0,78	0,63
E8	4,05	243	0,27	0,71	0,52

The second stream named Katsimidi is smaller than Sarantapotamos and belongs to the 5th order too. Its drainage basin lies northern of the Sarantapotamos basin. It is constituted by two 4rth order drainage basins whose long axes have an E-W direction. The shape of the drainage network is dendritic (Tables I and II).

Both streams drain a broad area of Western Attica and flow into the Gulf of Elefsina. They follow an almost parallel direction through Thriassion Pedion and 1,5 Km just before the city of Elefsina one stream bends eastwards and the other westwards, flowing into the sea.

CALCULATION OF THE PEAK STORM RUNOFF (Qp) OF SARANTAPOTAMOS AND KASTIMIDI STREAMS DRAINAGE BASINS

According to the division system of the Directory of Hydrology and Natural Resources of the Ministry of Industry, the studied area belongs to the hydrological department of Attica (06). This is a very general division and that is why we performed a more detailed study whose results are presented below:

In order to calculate the maximum storm runoff (Qp) and the sediment yield of Sarantapotamos and Katsimidi streams, it is necessary to estimate these parameters, not only at the river exits, but also at certain places of the drainage basins. This is important to estimate the participation of each basin to the total discharge. We divided the drainage basins in 8 parts, which correspond to groups of drainage sub-basins that drain certain geographic areas or lie next to cities. The peak storm runoff (Qp) and the sediment yield, were calculated at the exits of these drainage sub-basins. These locations are shown on the map of Figure 1 as E1,E2.... E8.. The E1 measuring station is near Vilia village and measures the runoff and sediment yield of the drainage basins of Kitheronas mountain. E2 station estimates surplus quantities that come from mountain Pastra. E3 station estimates the participation of the St.Vlassios stream, which is the longer tributary of Sarantapotamos and drains the northern slopes of mount Pateras, while E4 station is that which comes from Pamitha mountain, E6 and E7 stations estimate the runoff of 4th order drainage basins of Katsimidi stream near Mandra city. Finally E5 and E8 estimate the total discharge of Sarantapotamos and Katimidi streams correspondingly.

Geometry, basin concentration time and the uniformity coefficient of these drainage basins were estimated. The results are given in Table III. The last two coefficients are particularly necessary for the determination of peak storm runoff and therefore for the flood studies. As it is mentioned below these parameters are necessary for the study and analysis of the water-balance of each studied drainage basin.

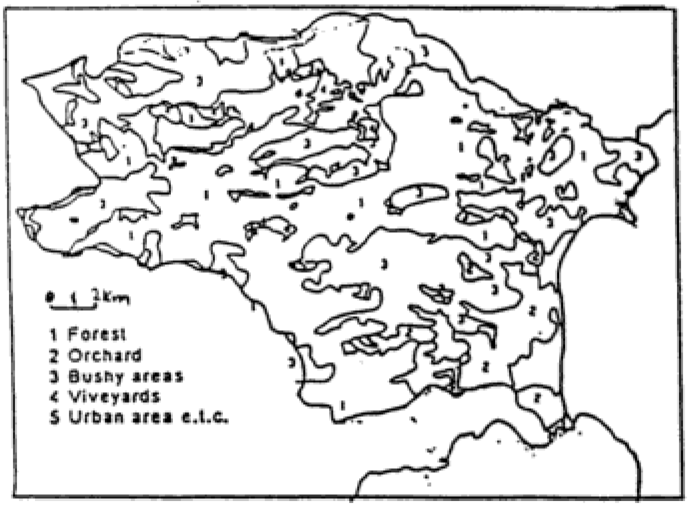

Fig. 2: Map of land use/ cover.

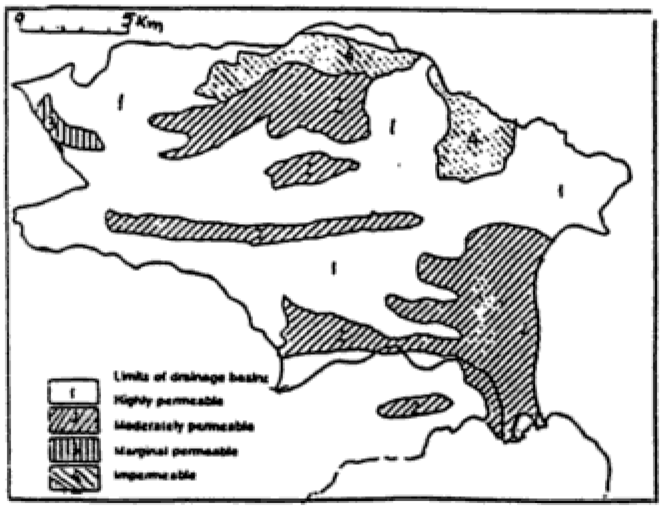

Fig. 3: Map of permeability classification.

The mean annual height of precipitation is 374,5mm and the mean annual temperature is 18,3°C according to the measurements of the Meteorological Station of Elefsina for the observation time-period 1958 - 1992.

Based on the maximum 24 hour rainfalls we estimated, according to Gumbel analysis, the expected rainfall height for a recurrence period of 25, 50 and 100 years, as below.

62,2	< 25 <	113,0
69,4	< 50 <	121,1
76,6	< 100 <	139,2

Calculations

In order to calculate the runoff curve number or the specific runoff coefficient (CN) for every elementary homogeneous part of soil area of Sarantapotamos of the drainage basins and Kastimidi streams we carried out the following analyses:

a) We drew a map of land use/cover, using the data of HAGS. The map was completed by field observation, (Figure2). We can distinguish the following categories. 1. Forest, 2. Annual cultivation, 3. Bushy areas, 4. Vineyards, 5. Uncultivated areas and urban areas. The results of the land use/cover are shown classified in Table IV.

b) A hydrolithologic classification map was drawn. The lithological formations were classified in 4 categories according to the permeability coefficients. These categories are: 1. permeable formations, 2. moderately permeable formations, 3. low permeable formations, 4. impermeable formation. Figure 3 and Table V show the results of the hydrolithologic classification of the geological formations of each studied basin.

c) We calculated the runoff curve number (CN). This determination is a derivative of the land use/cover diagram in figure 2 and the hydrolithologic classification diagram in figure 3. Data from airphotos and satellite photos of the studied area were used (Sojuzcarta, scale 1:210.000, 1984).

The runoff curve numbers (CN) which was accepted for every combination of land use and hydrolithologic classification was calculated by the method of S.C.S. of the U.S.A. The diagram in figure 4 shows five (5) categories of the runoff curve numbers. For each category we used a single mean runoff curve number. The spreading of each one of the above five runoff curve number categories in the eight studied drainage basins of Sarantapotamos and Katsimidi

TABLE IV: Land uses/cover of the surface of the hydrographic basins (5 categories).

	FOREST AREA	ANNUAL CULTIVATIONS	BUSHY AREA	VINE PLANTS AREA	DESERT LAND & URBAN AREA
BASIN NAME	PERCENT-AGE %	PERCENT-AGE %	PERCENT-AGE %	PERCENT-AGE %	PERCENTAGE %
E1	26,00		54,00	7,00	13,00
E2	34,00		42,00	8,00	16,00
E3	72,50	2,50	16,00	4,00	5,00
E4	54,00	1,00	28,00	5,00	12,00
E5	49,61	4,60	30,00	4,59	11,20
E6	74,00	6,00	18,00	-	2,00
E7	36,00		59,00	1,00	4,00
E8	48,00	14,00	34,50	0,50	3,00

TABLE V: Permeability classification of geological formations of the hydrographic basins.

	HIGHLY PERMEABLE	MODERATELY PERMEABLE	MARGINALLY PERMEABLE	IMPERMEABLE
BASIN NAME	PERCENT-AGE %	PERCENT-AGE %	PERCENT-AGE %	PERCENT-AGE %
E1	63,80	19,20	9,90	7,10
E2	48,10	27,90	5,10	18,90
E3	75,90	24,10		
E4	60,60	25,10	2,60	11,70
E5	55,83	31,03	2,39	10,75
E6	61,70	38,30		
E7	92,30	7,70		
E8	61,90	38,10		

TABLE VI: Runoff Curve Number of the hydrographic basins.

	RUNOFF CURVE NUMBER (CN)					
BASIN NAME	30-35 m2	49-62 m2	67-74 m2	75-84 m2	85-95 m2	MEAN CN OF BASIN
E1	24430704	6107676	6616649	12215352	1526919	53
E2	46294255	6255980	27526314	42540666	2502392	59
E3	48674097	1921346	12168524		1280897	42
E4	124518752	14170977	43442177	45068354	5110844	51
E5	124998559	18820036	58858361	45068354	5110844	53
E6	13614449	1793123	6397684	332060		46
E7	18750331	1056357	507864			35
E8	35259379	6855990	12386873	1901241	1209881	46

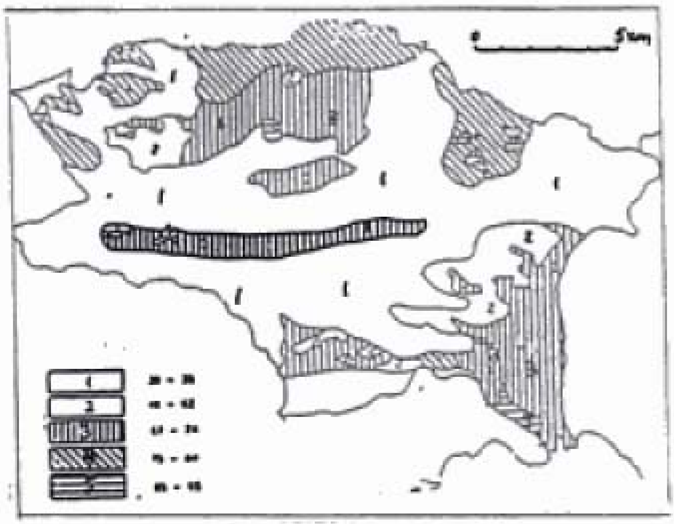

Fig. 4: Map of specific runoff coefficisent. 1)30-35, 2)36-62 ,3)63-74 ,4)75-84 ,5)85-95

streams, is shown in diagrams (Fig. 4) and the mean (CN) in table VI.

CALCULATION OF THE PEAK STORM RUNOFF (Qp) OF SARANTAPOTAMOS AND KASTIMIDI STREAMS DRAINAGE BASINS

According to the division system of the Directory of Hydrology and Natural Resources of the Ministrv of Industry, the studied area belongs to the hydrological department of Attica (06). This is a very general division and that is why we performed a more detailed study whose results are presented below:

In order to calculate the maximum storm runoff (Qp) and the sediment yield of Sarantapotamos and Katsimidi streams, it is necessary to estimate these parameters, not only at the river exits, but also at certain places of the drainage basins. This is important to estimate the participation of each basin to the total discharge. We divided the drainage basins in 8 parts, which correspond to groups of drainage sub-basins that drain certain geographic areas or lie next to cities. The peak storm runoff (Qp) and the sediment yield, were calculated at the exits of these drainage sub-basins. These locations are shown on the map of Figure 1 as E1,E2.... E8,. The E1 measuring station is near Villa village and measures the runoff and sediment yield of the drainage basins of Kitheronas mountain. E2 station estimates surplus quantities that come from mountain Pastra. E3 station estimates the participation of the St.Vlassios stream, which is the longer tributary of Sarantapotamos and drains the northern slopes of mount Pateras, while E4 station is that which comes from Parnitha mountain, E6 and E7 stations estimate the runoff of 4th order drainage basins of Katsimidi stream near Mandra city. Finally E5 and E8 estimate the total discharge of Sarantapotamos and Katimidi streams correspondingly.

Geometry, basin concentration time and the uniformity coefficient of these drainage basins were estimated. The results are given in Table III. The last two coefficients are particularly necessary for the determination of peak storm runoff and therefore for the flood studies. As it is mentioned below these parameters are necessary for the study and analysis of the water-balance of each studied drainage basin.

TABLE II: Morphometry of drainage basin.

Basin	Au,km^2	L,km	W,km	P, km	D N/km^2	F km/km^2	D1	F1
Sarantapotamos								
1	20,416	12,25	2,0	16,5	2,35	0,69	0,88	0,34
2	1,937	5,50	4,8	5,2	4,65	1,57	3,10	1,08
3	6,992	5,00	2,8	13,0	2,72	1,14	2,15	0,29
4	38,643	10,80	5,7	8,5	0,39	0,54	0,26	0,21
5	16,062	4,80	1,4	18,1	0,75	0,47	0,56	0,25
6	4,562	4,90	1,3	11,5	3,29	2,52	0,66	0,88
7	5,062	5,54	2,5	12,1	3,56	2,47	2,37	0,99
8	18,622	5,60	5,8	19,0	0,97	0,85	0,81	0,51
9	2,125	2,65	1,2	6,0	6,59	4,00	4,24	1,88
10	4,062	3,50	2,0	9,0	2,95	2,12	2,22	1,26
11	6,250	4,25	2,5	11,0	4,00	2,42	3,36	1,60
12	8,997	3,75	2,8	11,0	1,00	0,67	1,78	0,44
13	4,437	3,75	2,8	10,0	2,48	3,13	1,80	1,58
14	1,687	3,50	1,1	7,0	8,89	6,16	6,52	3,44
A	64,044	16,00	4,3	51,9	2,12	1,02	1,50	0,61
B	125,119	21,62	8,0	59,4	0,61	0,68	0,47	0,27
C	7,374	4,25	3,0	12,0	7,19	4,35	5,42	2,44
D	18,871	6,50	6,3	21,0	2,38	1,79	1,70	0,97
Sa	264,356	29,50	9,5	143,0	1,17	0,94	0,86	0,44
Katsimidi								
1a	7,062	4,60	3,2	14,0	2,12	1,42	1,56	0,57
2a	4,562	5,25	2,3	12,0	3,51	2,59	2,63	1,10
3a	14,312	7,00	3,2	23,2	2,10	1,36	1,61	0,63
4a	2,000	2,20	1,1	7,1	5,00	2,05	3,50	1,05
5a	16,749	7,10	2,1	17,0	0,96	0,84	0,72	0,30
A'	19,068	9,10	3,2	24,2	1,68	1,57	1,21	0,53
B'	20,687	13,50	3,7	35,1	2,51	2,23	1,79	0,92
Ka	61,816	13,80	8,2	41,0	1,38	1,31	0,97	0,47

Basin	S	Er	C	H, m	Conf.	H(tot.)	Rh	Rn
Sarantapotamos								
1	6,13	0,58	0,43	974	300,	674	0,06	0,29
2	1,15	0,29	0,22	562	260	302	0,05	0,34
3	1,79	0,60	0,37	976	370	606	0,12	0,42
4	1,89	0,65	2,58	1340	338	1002	0,09	1,40
5	3,56	0,94	1,34	1020	338	682	0,14	0,63
6	3,92	0,49	0,30	940	280	660	0,13	0,77
7	2,22	0,46	0,28	894	260	634	0,11	0,69
8	0,97	0,87	1,03	760	240	520	0,09	0,88
9	2,21	0,51	0,15	700	210	490	0,18	0,61
10	1,75	0,65	0,34	660	210	450	0,13	0,72
11	1,70	0,66	0,25	886	160	726	0,17	0,60
12	1,34	0,90	1,00	886	540	346	0,09	0,67
13	1,34	0,63	0,40	883	540	343	0,09	1,26
14	3,18	0,42	0,11	540	120	420	0,12	0,69
A	3,72	0,56	0,47	974	120	854	0,05	0,48
B	2,70	0,64	1,65	1340	200	1140	0,05	1,11
C	1,42	0,72	0,14	700	200	500	0,12	0,61
D	1,04	0,75	0,42	886	160	726	0,11	0,75
Sa	3,11	0,61	0,85	1020	0	1020	0,03	0,80
Katsimidi								
1a	1,46	0,65	0,47	388	160	228	0,05	0,67
2a	2,28	0,46	0,29	842	160	682	0,13	0,74
3a	2,19	0,61	0,48	842	200	642	0,09	0,65
4a	2,00	0,73	0,20	451	338	400	0,18	0,41
5a	3,38	0,65	1,05	551	70	481	0,07	0,88
A'	2,84	0,54	0,80	840	80	760	0,08	0,94
B'	3,70	0,38	0,40	842	80	762	0,06	0,89
Ka	1,68	0,64	0,73	842	0	842	0,06	0,95

The mean annual height of precipitation is 374,5mm and the mean annual temperature is 18,3°C

TABLE III: Characteristics of the hydrographical basins and their concentration time.

BASIN NAME	CONCENTRATION TIME		RAINFALL UNIFORMITY COEFFICIENT		
	HOURS	MINUTES	FANTONI	SPECHT	FRUHLING
E1	2,97	178	0,29	0,72	0,54
E2	5,18	311	0,14	0,67	0,42
E3	3,72	223	0,25	0,71	0,51
E4	5,86	352	0,08	0,64	0,32
E5	6,07	364	0,08	0,63	0,31
E6	2,79	168	0,49	0,77	0,62
E7	2,71	163	0,51	0,78	0,63
E8	4,05	243	0,27	0,71	0,52

Table VII. Maximum 24 hour runoff (Q).

Drainage basin name	Maximum probable 24 hour runoff (Q) in mm		Maximum probable 24 hour runoff (Q): m^3/24 hour	
	normal conditions	wet conditions	normal conditions	wet conditions
E1	28.1	67,0	1430302,9	3407725,0
E2	38.8	77,5	4849764,8	9693638,5
E3	10.8	45.2	692154,1	2896963,8
E4	25.1	63,7	5824509,1	14788890,2
E5	27.4	66,2	6926585,9	16738294,3
E6	16,8	53,8	372596,9	1190041,7
E7	3.6	31,9	73144,1	647889,9
E8	17,0	54,0	979294,9	3109642,3

Table VIII Correlation between the height and intensity of rainfall and the duration of rainfall, using the curve H = Hhour x t ^0,333

Rainfall duration in hours	Rainfall duration in min	Rainfall height in mm	Rainfall intensity in mm/hour
0.1	6	22,440	224,403
0,15	9	25,684	171,228
0,2	12	28,266	141,332
0,25	15	30,447	121,788
0.3	18	32,353	107,842
0,4	24	35,605	89,013
0,5	30	38,352	76,704
0.6	36	40,752	67,921
0,7	42	42,899	61,284
0.8	48	44,850	56,062
0.9	54	46,644	51,826
1	60	48,309	48,309
1,5	90	55,293	36,862
2	120	60,852	30,426
2.5	150	65,546	26,218
3	180	69,648	23,216
4	240	76,650	19,163
5	300	82,563	16,513
6	360	87,731	14,622
7	420	92,352	13,193
8	480	96,551	12,069
9	540	100,413	11,157
10	600	103,999	10,400
12	720	110,509	9,209
15	900	119,033	7,936
20	1200	131,000	6,550
24	1440	139,200	5,800
30	1800	149,938	4,998
40	2400	165,012	4,125

according to the measurements of the Meteorological Station of Elefsina for the observation time-period 1958 - 1992.

Table IX

Drainage basin name	Basin concentration Time (Tc) in min	Rainfall intensity (i) with a duration equal to the basin concentration time in mm/hour
E1	178	23,4
E2	311	16,12
E3	223	20,1
E4	352	14,85
E5	364	14,51
E6	168	24,36
E7	163	24,84
E8	243	19,01

Based on the maximum 24 hour rainfalls we estimated, according to Gumbel analysis, the expected rainfall height for a recurrence period of 25, 50 and 100 years, as below.

62,2	< 25 <	113,0
69,4	< 50 <	121,1
76,6	< 100 <	139,2

Calculations

In order to calculate the runoff curve number or the specific runoff coefficient (CN) for every elementary homogeneous part of soil area of Sarantapotamos of the

Calculation of maximum 24 hour runoff (Q)

The runoff curves of wet and dry periods were calculated by the known equations as the S.C.S. method proposes.

The maximum 24 hour runoff (Q) are calculated and the final results are presented in table VII. The results are based on the maximum 24 hour rainfall which resulted by the rainfall analysis according to Gumbel, with recurrence period 100 years both in wet and dry soil conditions before the rainfall.

Calculation of the maximum peak storm runoff (Qp)

In order to estimate the maximum peak storm runoff of the 8 drainage basins of Sarantapotamos and Katsimidi streams, it is necessary to know the mean rainfall intensity (i) of duration equal to the total basin concentration time Tc of each basin which is defined as the maximum rainfall height that happened at time Tc in the basin, with recurrence period of 25, 50 or even 100 years.

In order to calculate the rainfall height - rainfall duration and rainfall intensity (i) - rainfall duration curves, we used the maximum 24 hour rainfall according to Gumbel analysis, for various recurrence periods. We accepted height-duration curves according to Montana:

$$H = a \cdot t^b$$

for t = 1 hour it is Hhour = a and

$$(1) \qquad H = Hhour.t^b$$

where:

H=height of a rainfall duration in time t

b =usually 0,333 up to 0,50

Equivalent:

$$(2) \qquad i = H/t = Hhour \cdot t^{b-1}$$

Curves (1) and (2) are straight lines in logarithmic scale.

The rainfall height - rainfall duration and rainfall intensity (i) - rainfall duration curves according to 24 hour rainfall resulted by Gumbel method for rainfalls that took

TABLE XI: Runoff model of maximum 24 hour rainfall and peak storm runoff

BASIN NAME	MEAN ANNUAL RAINFALL (mm)	MAXIMUM 24 HOURS RAINFALL (P) (mm)			MAXIMUM RAINFALL AT CONCENT-RATION TIME (Tc) (mm)	CONCENT-RATION TIME (Tc) (min)	MEAN RUNOFF CURVE NUMBER (CN) %			Ia=0.2*S			P-Ia (with P at 100 years)			MAXIMUM 24 HOUR RUNOFF (Q) (mm)	MAXIMUM 24 HOURS RUNOFF (Q) (m3)	MAXIMUM 24 HOURS RUNOFF (Q) (mm)	MAXIMUM 24 HOURS RUNOFF (Q) (m3)	MAXIMUM PROBABLE PEAK STORM RUNOFF (Qp) (m3/sec)	MAXIMUM PROBABLE PEAK STORM RUNOFF (Qp) (m3/sec)
							NORMAL COND	WET COND	DRY COND	NORMAL COND	WET COND	DRY COND	NORMAL COND	WET COND	DRY COND	Normal conditions with restoration period 100 years	Normal conditions with restoration period 100 years	Wet conditions with restoration period 100 years	Wet conditions with restoration period 100 years	Normal conditions with restoration period 100 years	Wet conditions with restoration period 100 years
		25 Years	50 Years	100 Years	100 Years																
E1	374,5	113	121,1	139,2	69,38	178	53	73	33	44,68	19,08	101,91	94,52	120,12	37,29	28,10	1430302,87	66,95	3407724,96	175,99	240,47
E2	374,5	113	121,1	139,2	83,55	311	59	77	39	35,10	14,99	80,06	104,10	124,21	59,14	38,76	4849764,81	77,47	9693638,52	331,39	432,70
E3	374,5	113	121,1	139,2	74,85	223	42	62	24	71,43	30,50	162,94	67,77	108,70	-23,74	10,81	692154,13	45,23	2896963,79	148,59	223,40
E4	374,5	113	121,1	139,2	87,06	352	51	71	32	48,05	20,52	109,60	91,15	118,68	29,60	25,07	5824509,05	63,66	14788890,22	492,46	682,58
E5	374,5	113	121,1	139,2	88,08	364	53	72	33	45,44	19,40	103,64	93,76	119,80	35,56	27,39	6926585,91	66,20	16738294,29	537,87	737,35
E6	374,5	113	121,1	139,2	68,00	168	46	67	27	59,51	25,41	135,75	79,69	113,79	3,45	16,83	372596,93	53,76	1190041,71	68,97	99,83
E7	374,5	113	121,1	139,2	67,33	163	35	55	19	95,83	40,92	218,58	43,37	98,28	-79,38	3,60	73144,14	31,89	647889,93	48,57	77,65
E8	374,5	113	121,1	139,2	76,96	243	46	67	27	59,24	25,30	135,12	79,96	113,90	4,08	17,00	979294,92	53,97	3109642,35	140,45	203,10

TABLE XIV: Sediment yield estimation of the hydrographic basins.

		High erosivity geological formations	Moderate erosivity geological formations	Low erosivity geological formations	Basin geological coefficient (y)	Mean annual rainfall height	Mean relative density of geologic formations	Weight of mean annual sediment yield of the basin	Volume of mean annual sediment yield of the basin
BASIN NAME	BASIN AREA (m2)	(K1) AREA (m2)	(K2) AREA (m2)	(K3) AREA (m2)	(-)	(m)	(-)	(ton/Year)	(m3/Year)
E1	50897300	9772282	8652541	32472477	0,341	0,3745	2,50	800,2	320,1
E2	125119607	34908370	30028706	60182531	0,447	0,3745	2,50	2580,8	1032,3
E3	64044865	15434812		48610053	0,317	0,3745	2,50	936,3	374,5
E4	232311105	58310087	33220488	140780530	0,383	0,3745	2,50	4105,9	1642,3
E5	252856154	78455136	33220488	141180530	0,432	0,3745	2,50	5037,1	2014,8
E6	22137315	8478592		13658723	0,445	0,3745	2,50	454,2	181,7
E7	20314552	1564221		18750331	0,169	0,3745	2,50	158,7	63,5
E8	57613364	21950692		35662672	0,443	0,3745	2,50	1177,2	470,9

Fig.5.Map of inclination.

Where:
G: mean annual sediment yield in (t/km^2), p: mean annual rainfall height in (m), and, y: geological coefficient determined by the following equation:

$$y = (K_1 \,.\, p_1) + K_2 \,.\, p_2) + (K_3 \,.\, p_3 \qquad (4)$$

where:
K_1, K_2, K_3: erosivity coefficients, of the three main categories of rocks.
p_1, p_2, p_3: corresponding proportions of area in which every rock category appears, to the total area of the drainage basin. These result from geological mapping.

Various rock formations were classified in three main categories according to their erosivity. The area of each category in every basin is shown in Table XII.

Therefore the mean geological coefficient of each studied basin is calculated according to equation (4). This coefficient is included in the above Table XII.

According to the data of this paper it is given:
1) The area of each drainage basin is shown in the final Table XIV.
2) The mean annual rainfall in the studied basins, which is equal to 374,5 mm or 0,3745 m.

Using equation (3) we calculated the mean annual sediment yield of each basin (Table XIII). The same Table includes sediment yield expressed in cubic meters per year. (For the calculation is accepted mean relative rock density, d=2,5).

Each data and parameter of sediment yield calculation for all studied drainage basins are shown in the final Table XIII.

Many times this sediment yield which has been estimated above, fills up the stream channels locally. As a results the draining capacity of these streams decreases and therefore there is a danger of extensive floods especially after strong rainfalls. That is the reason why the channels, especially in problem relevant to floods areas, should be maintained and regularly cleared and opened.

DISCUSSION - CONCLUSIONS

The drainage basins of Sarantapotamos and Katsimidi streams lie in western Attica. The number of the channels of the 3rd and 5th order basins of Sarantapotamos stream, is the theoritically expected, according to the first law of Horton (1945). In the 4th order basins, A and B, there is a reduction of 22% and 10% compared to the theoretically expected correspondingly, and the very short mean length of the branches that is observed are also caused by lithology. There is no deviation in the number and length of the streams of Katsimidi.

The bifurcation ratio (Rb) is between 2,2 and 5,8, showing well developed drainage network. The index S=L/W show the existance of very long basins, except that of Parnitha mt. The drainage density (D) is medium to very high. Basin B has the lower values of density as well as its 3rd order basins, due to karstification. The drainage frequency and density values are medium to high, influenced by lithology.

The study of the D1 and F1 values of the 3rd order basins showed that F1 values are clearly lower that the corresponding D1. This reveals an advanced maturity stage of development of the drainage systems.

The conservation values of the channels (C) are high. This shows the lithological effect and that the drainage systems belong to a mature stage of development.

The relief values (Rh) are high, showing high gradients of slopes, mainly of the basins of Parnitha mt.

The relief roughness (Rn) has high values and this is caused by lithology and the high gradients, because of the altitude of the watersheds.

The maximum 24 hour runoff (Q) of each basin was calculated and the final results were presented in table XI. The results are based on the maximum 24 hour rainfall which resulted by the rainfall analysis according to Gumbel, with recurrence period 100 years both in wet and dry soil conditions before the rainfall.

The rainfall height - rainfall duration and rainfall intensity (i)-rainfall duration curves according to 24 hour rainfall resulted by Gumbel method for rainfalls that took place in the area with recurrence period T of 100 years and the rainfall height - rainfall duration curve $H=Hhour.t^{0,333}$ are given in table VIII.

The peak storm runoff of each basin was calculated according to the present land use/cover conditions and presented in Table XI. It must be mentioned that the calculated values of storm runoff refer to the extreme values of the maximum probable peak storm runoff that might ever happen in the area of the drainage basins of Sarantapotamos and Katsimidi streams in extreme circumstances and rarely. There should however been taken seriously into account in order to foresee and anticipate the flood levels of the torrents and streams, as well as for the planning of the sewage and draining work systems. Furthermore it must be mentioned that the channels of the streams of the area must be maintained and cleaned regularly from time to time.

The mean annual sediment yield of each one basin was calculated and shown in Table XIII. Each data and parameter of sediment yield calculation for all studied drainage basins are shown in the final Table XIV.

Occusionally, sediment yield fill up the stream channels locally and the draining capacity of the streams decreases resulting in extensive floods in the wider area, especially after strong rainfalls. Therefore, it is suggested that the channels, especially in problem relevant to floods areas, must be maintained and regularly cleared and opened.

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