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Seasonal variation of water discharge and suspended sediment concentration of the Pinios River (Thessaly) during the hydrological year 2012/13

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Abstract

The current study examines flow (Q) and suspended sediment concentration (SSC) variations, based on monthly snapshots, of the Pinios River (Thessaly), which is one of the larger rivers in Greece, characterized by limited flow control (<10% of its catchment). Monthly measurements (flow velocities and water samples) during the hydrological year (October 2012 to September 2013) were conducted at two stations; one before the river enters its delta (Agia Paraskevi bridge at Tempi) and one close to its mouth (Palaiopyrgos bridge). Monthly flows at Agia Paraskevi range from 2.5 m^3/s to 206.7 m^3/s and are in a good agreement with available historical data for the period 1975/76-93/94, indicating a rather unchanged flow regime. The SSC values ranged from 3.5 mg/L to 165 mg/L at Agia Paraskevi and from 2.2 mg/L to 177 mg/L at Palaiopyrgos and, in general, follow the monthly trend of flow. The highest SSC value measured in February and April 2013 is attributed to a flood event and an upland slide, respectively.

Keywords: flow measurements, flood, upland slide, water balance, delta

1. INTRODUCTION

In Mediterranean coastal areas, such as river deltas, the socio-economic development is often based on conflicting human activities, as in the case of Pinios River delta, whose local economy is based on both agriculture in deltaic plain and tourism at Stomio, Mesagkala and Neoi Poroi [1]. These activities depend on surface water supply for irrigation purposes and the stability of the 'beach' front for the improvement of any recreational facilities, respectively. However, climate change [2] and human interventions [3] are expected to have an impact on coastal environments through changes in river fluxes and sediment transport; the former causes a reduction in water availability, while the latter is associated with coastline retreat.

The delta of Pinios River (drainage basin area 10.850 km^2) is located on the western coast of south Thermaikos Gulf (Figure 1), which is characterized by limited flow control (in only <10% of its catchment). The deltaic plain, which extends between the Lower Mount Olympus to the north and Mount Ossa to the south, covers an area of 69 km^2 [4], consisting of alluvial (Holocene) sediment

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deposits and characterized by vertical and lateral heterogeneity. In the case of Greek deltas, such as Pinios, where the marine environment is microtidal, delta formation is a result of the interaction between fluvial and wave processes, where the quantitative inter-relationship is given by the "discharge effectiveness index" [5]. It is worth mentioning that Pinios deltaic plain is among the most productive agricultural lands of the broader area and that many vacational settlements and small hotels built along the coastal front of the delta, north of the river mouth are endangered due to extensive coastal erosion in winter.

The aim of the present contribution is to investigate water and suspended sediment fluxes reaching Pinios deltaic plain, by monitoring on a monthly basis water flow and suspended sediment concentrations (SSC) and to compare them to available historical data.

Figure 1. A map of Pinios deltaic plain and the locations of sampling stations of Agia Paraskevi and Palaiopyrgos bridges (abstracted from Google Earth)

2. MATERIALS AND METHODS

In the present work, river flow and suspended sediment concentrations of Pinios River were measured on a monthly basis at two stations, one before the Pinios River enters its delta (Agia Paraskevi bridge at Tempi) and one close to its mouth (Palaiopyrgos bridge) (Figure 1), within the framework of the project Thalis – Daphne. Sampling campaigns covered the hydrological year from October 2012 to September 2013. The measurements at the bridge of Agia Paraskevi refer to riverine influxes prior to deltaic plain, while those at Palaiopyrgos bridge to the river outflow at sea. Both measurements were conducted in the middle of each month, within the same day, with only a few hours difference and should be considered as monthly snapshot values of the river flow and suspended sediment concentrations.

2.1. Water flow measurements

Flow depth and velocity were measured by current flow meters (Valeport BFM 001 & 002) across the two selected bridges to determine the water discharge in m^3/s. The discharge was calculated using the velocity-area method, which is recognized and has been applied to around 90% of the world's river discharges. At the two stations, the cross-section of the channel was surveyed monthly and not considered constant. Measurements were made over verticals spaced at intervals no greater than $1/15^{th}$ of the width across the flow. To obtain the mean velocity in the vertical the preferred USGS (United States Geological Survey) two points method was used; velocity is measured at 0.2-depth and 0.8-depth below water surface with the mean velocity taken as the average of these two values; the latter coincides with the theoretical logarithmic velocity distribution. In areas where water depth was <0.8 m, the velocity was determined at 0.6-depth below the surface, as independent measurements of surface and nearbed flow were impossible. The calculation of river flow (Q) from the velocity and depth measurements is made by the mean section method (Figure 2).

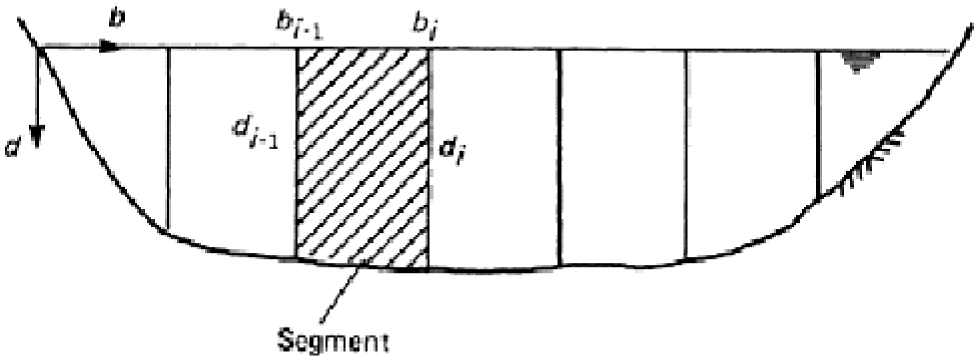

Figure 2. Calculating river flow – Mean section method [6]

In this method averages of the mean velocities in the verticals and of the depths at the boundaries of a section sub-division are taken and multiplied by the width of the sub-division, or segment:

$$Q = \Sigma q_i = \Sigma \bar{u}.a = \sum_{i=1}^{n} \frac{(\bar{u}_{i-1} + \bar{u}_i)}{2} \frac{(d_{i-1} + d_i)}{2} \quad b_i - b_{i-1}$$

where b_i is the distance of the measuring point (i) from a bank datum, n are the sub-areas, q_i (m^3/s) is the discharge at the different sub-areas, u (m/s) is the mean velocity, d (m) is the water depth at the limits of each segment [6,7].

2.2. Suspended sediment concentration

For the estimation of suspended sediment concentration, water samples were collected monthly at 0.5-depth below surface, with the use of Niskin sampling bottle. The samples were filtered through pre-weighed Millipore membrane filters (mixed cellulose esters types with 8 μm and 0.45 μm pore diameter) [8], using a Nalgene filtration apparatus. After filtration of the water samples the filters, placed on individual Petri dishes, were kept in a desiccator to dry and weighed with a Mettler Toledo balance (0.0001 g accuracy). Subsequently, SSC was calculated by the ratio of the suspended material held on the filter to the volume of filtered water.

3. RESULTS AND DISCUSSION

The monthly snapshot values of the measured freshwater flows (Q) together with suspended sediment concentrations (SSC) at the two sampling stations are presented in Table 1. On the basis of the monthly snapshot values of the flows, the wet (November - April) and the dry (May - October) periods of the hydrological year have been identified and given in Table 2.

Table 1. Monthly snapshot values of flow (Q in m^3/s) and suspended sediment concentrations (SSC in mg/L) at Agia Paraskevi $_{(A)}$ and Palaiopyrgos $_{(P)}$

	O	N	D	J	F	M	A	M	J	J	A	S
Q_A	4.2	14.1	69.5	74.4	206.7	128.2	97.2	34.2	23.8	2.7	2.5	3.5
Q_P	5.6	19.1	75.8	74.4	216.6	127.9	85.9	47.7	36.3	11.0	9.3	10.1
SSC_A	16.3	47.0	100.0	35.0	165.0	110.0	141.0	70.8	33.6	3.5	10.47	14.2
SSC_P	8.9	34.0	88.0	23.1	177.0	94.0	122.0	43.0	17.9	2.2	5.0	8.2

Table 2. Monthly snapshot values of flow (Q in m^3/s) and suspended sediment concentrations (SSC in mg/L) at Agia Paraskevi (A) and Palaiopyrgos (P) and related mean values for the dry and wet seasons

	ANNUAL	WET season (NOV-APR)			DRY season (MAY-OCT)		
	mean	min	max	mean	min	max	mean
Q_A	55.1	14.1	206.7	98.4	2.5	34.2	40.2
Q_P	60	19.1	216.6	100.0	5.6	47.7	47.4
SSC_A	61.8	35.0	165.0	99.7	3.5	70.8	48.7
SSC_P	52.0	23.1	177.0	89.7	2.2	43.0	39.3

Monthly flows during wet season range from 14.1 to 216.60 m^3/s with the highest occurring in February (flood event) and March, while during the dry season varied from 2.5 to 47.7 m^3/s with the lowest (<2.7 m^3/s) measured in July and August (Table 1).

The observed monthly/seasonal variation is similar to that referred to other Greek river systems, whose catchment area is located east to Pindos mountain chain, where water discharge levels have their maxima between November and April and their minima between May and September [9]. As shown in Figure 3, the recent measurements at Agia Paraskevi station are in good correlation with historical data (1962/63–1981/82, available from the Public Company of Electricity) of Aliakmon River; the latter presents common hydrological and climate properties to the neighboring catchments. The profound increased value of February 2013 is associated with a river flood (estimated water discharge >200 m^3/s), while the corresponding average value refers to a period of 20 years.

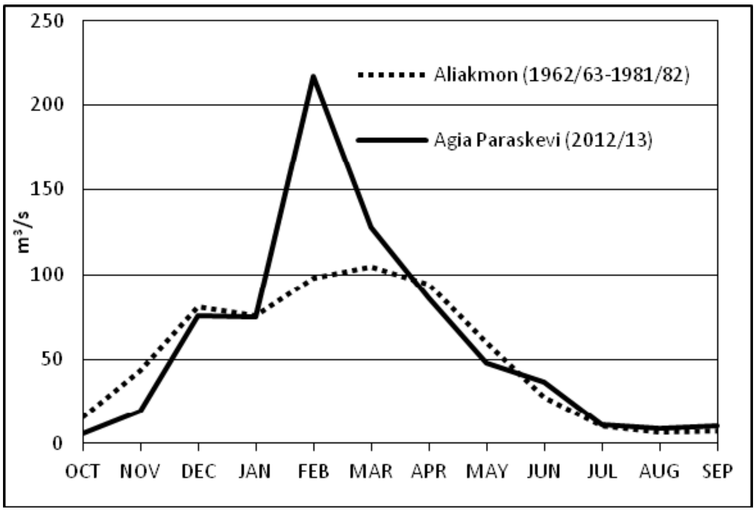

Figure 3. Comparison of Pinios discharge (this study) with that of Aliakmon water flow (data from Public Company of Electricity)

At Agia Paraskevi station, the water flow measurements of 2012/13 are in a good agreement (r^2=0.8) with the monthly means of the period 1975/76-1993/94 (Figure 4), indicating a rather unchanged regime. The reduction of water flow during summer period has been attributed to the intensive use of water in the agricultural plain of Thessaly, before the river enters Tempi Valley [10]. On the other hand, monthly flows at Palaiopyrgos stations are higher, from 4.6% (during wet season of 2012/13) up to 75.5% (during dry season of 2012/13), than Agia Paraskevi (Figure 6); these differences are explained by the fact that more than 20 springs located downstream of Agia Paraskevi station [11] contribute to river's freshwater flow.

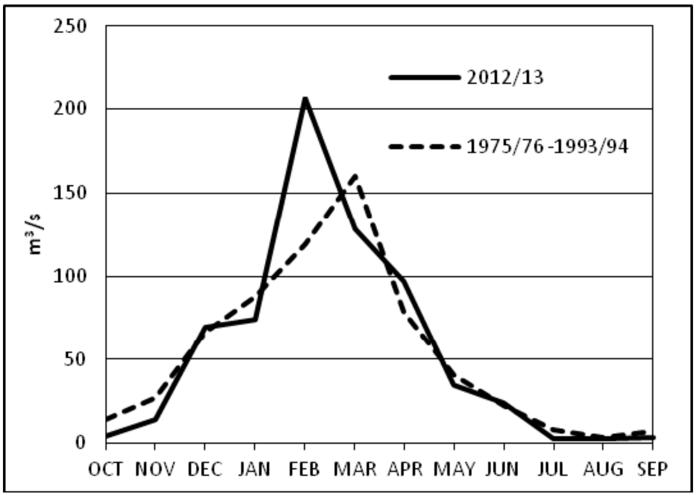

Figure 4. Monthly water flow (this study) together with historical data [12] at Agia Paraskevi Station

The monthly SSC values present also a seasonal variation, being in a very good agreement with those of flow, as shown in Figure 5. Their statistical correlation (r^2) in both sampling locations, i.e. Agia Paraskevi and Palaiopyrgos, are very good being 0.81 and 0.86, respectively. During the wet season of 2012/13, the SSC ranges from 23.1 mg/L to 177 mg/L with the highest value observed in February (flood event) and in April, while during the dry seasons SSC is <3.5 mg/L, with the lowest measured in July and August (Table 1).

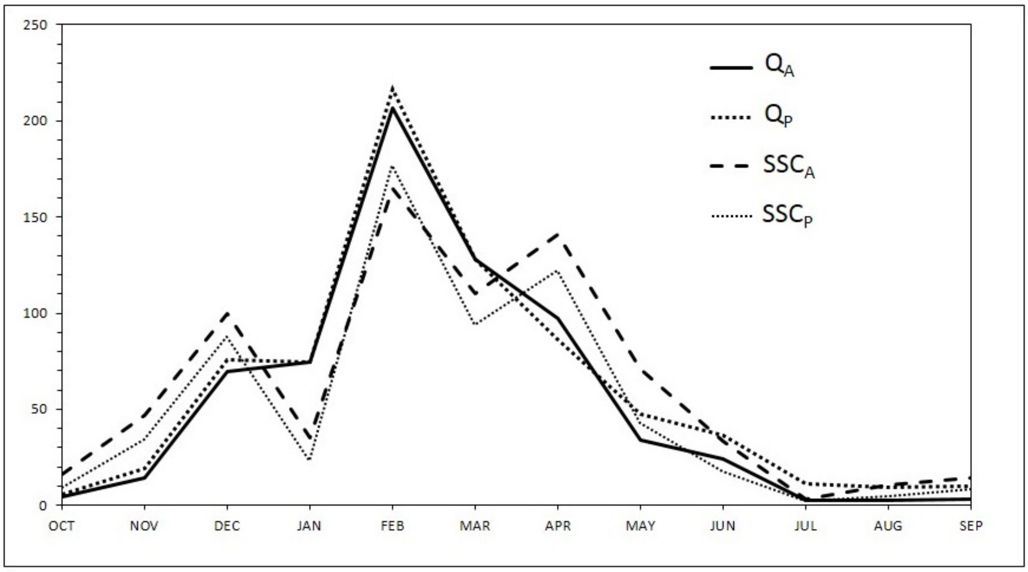

Figure 5. Monthly variations of water flow (m^3/s) and SSC (mg/L) [Q: flow; (A): Agia Paraskevi and (P): Palaiopyrgos)

Moreover, the high concentrations of SSC measured in April 2013 are attributed to a land slide incident that took place near Palaiochori village, some 110 km upstream of Agia Paraskevi station. Finally, monthly SSC at Palaiopyrgos station (located near to its mouth) are consistently lower by 12% (wet season) and 52% (dry season) than at Agia Paraskevi, with the exception of February during which their difference is positive although very small (7%) (Figure 6). This variation indicates deposition of suspended sediment during river's deltaic course, most probably due to decreased (if not minimized) slope gradients [13].

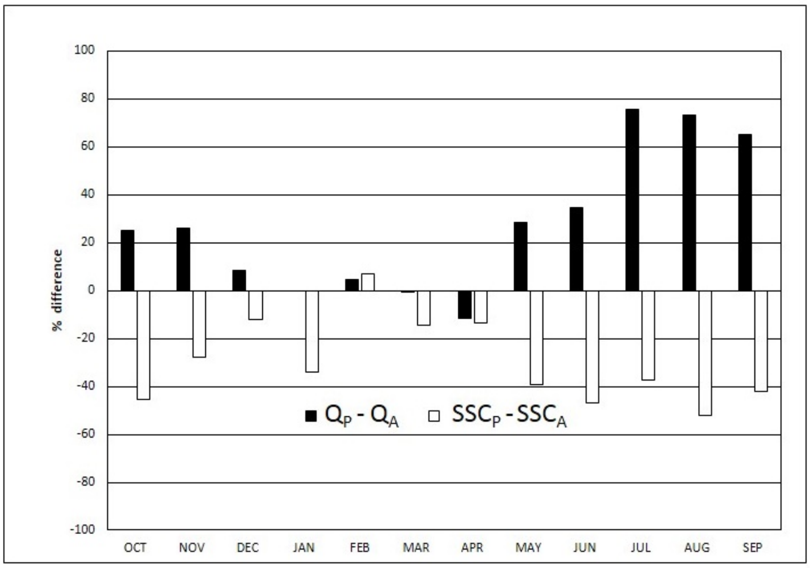

Figure 6. Differences (expressed as percentages) of monthly flow and SSC, during the hydrological year 2012/13, for the stations Palaiopyrgos and Agia Paraskevi

4. CONCLUSIONS

The Pinios River flow and associated suspended sediment concentrations for the hydrological year 2012/13 demonstrate a seasonal variation similar to other Greek river systems; thus, water discharge levels are highest between November and April and those of SSC in February and April. The intensive use of water for agriculture in Pinios basin, especially in Thellaly agricultural plain, also contributes to the reduction of water flow during summer. The measured flows during the hydrological year of 2012/13 are in a good agreement with monthly means of the period 1975/76-1993/94, indicating a rather unchanged flow regime. A better understanding of current and future water balance and sediment influx requires continuation of monitoring with more advanced techniques (e.g. across flow velocity profiling, weekly collection of water samples).

5. ACKNOWLEDGEMENTS

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