ENVIRONMENTAL CONSIDERATIONS OF THE ALLUVIUM MANAGEMENT OF AXIOS (VARDAR) RIVER

Efthimios MOUTSIAKIS[1]
[1]*Environmentalist, Envicon, Anaximandrou 22, 542 50, Thessaloniki Greece*
Dimitrios KEHAGIAS[2]
[2]*Environmentalist, Envicon, Anaximandrou 22, 542 50, Thessaloniki Greece*

ABSTRACT

Some decades ago, large-scale reclamation projects took place in the Thessaloniki – Giannitsa plain in order to satisfy the needs for arable land, irrigation water and healthier living conditions for the local and the new population coming to the area. In addition, Axios River mouth and southern banks were diverted to the west in order to eliminate the risk of closing the seaport of Thessaloniki. Despite the success of these projects, the environmental cost proved to be significant due to the reduction of natural habitats, the pressures on freshwater availability and the degradation of the coastal area. Out of this new state of the environment, new risks and threats have been arisen that have initiated response processes. The sustained flooding potential of Axios River, the expansion of its Delta along with the need for environmental protection consist new driving forces that reinforce a new cycle of human interventions. Core of such a framework is the sediment depositions (alluvium) management. Through an unofficial partnership of State institutions and private investors, management of the deposits have a beneficial outcome for both of them. The State secures the desired hydraulic characteristics of the river while extracted sediments provide material for the construction industry. Weaknesses though during the implementation stage of these works leading to an insufficient internalisation of the environmental cost, have raised a series of arguments questioning the necessity itself as well as the overall benefit.

KEY WORDS

Axios River, hydraulic characteristics, sediment materials, driving forces, extraction works, environmental cost.

1. Preface

There is a growing awareness about the impacts of human activities on the function and state of the natural surrounding. There are evidences that continuing interference to the natural processes create feedbacks that influence in a negative way not only the integrity of the environment itself but also the conditions through which human networks are being developed.
Water systems, rivers in particular have faced significant pressure regarding their ability to support and reinforce an extensive amount of ecosystems. Route diversions, water overuse and the general exploitation of their banks have proved to be mechanisms with destabilization effect to the human well-being as well.

2. Spatial and basic hydraulic identification

Axios River is one of the most important rivers in Greece not only in terms of water and sediment supply but also because of its key position in the production system of the Thessaloniki – Giannitsa plain.

The river springs from the mountainous area west of Skopje and after a NW-SE flow direction, mouths in the Thernaikos Gulf, right outside the city of Thessaloniki (Fig. 1). It has a length of 380 km of which 74 km are within the Greek borders. Its basin counts for 23.7 km^2 of which 9% refers to the Greek side (Konstantinidis, 1989).

Historical data of flow measurements on Polikastron area, a few kilometers after the river enters Greece, indicate that the mean annual flow rate varies between 120 and 180 m^3/sec while seasonal differences are also substantial giving values between 20 m^3/sec during summer and 250 m^3/sec during spring (Konstantinidis, 1989). According to the same source, the potential of sediments flow rate is estimated for about 390m^3/km^2 of basin surface.

Modern estimations indicate that the mean annual flow rate arises up to 137 m^3/sec (Aggelopoulos and others, 2000).

Table 1. Mean annual flow rates on Axios River

	Flow rate (mean annual, m^3/sec)	**Time period**
Polykastron area	129.6	1927 – 1940, Foundation Co.
	166.0	1951 – 1962, Altigos 1962
	158.0 – 174.0	1980's, Konstantinidis 1989

The river appears a high annual and seasonal fluctuation concerning flow rates, resulting both meteorological conditions as well as anthropogenic interventions.

Kapsimalis and others (2005) accept that large-scale anthropogenic interventions the last 50 years such as dam construction, irrigation networks, reclamation projects, intensive agriculture and other human activities, caused a significant reduction to the fresh water as well as the sediment volumes reaching the Gulf. Consequently and in relation to the similar evolution of the other discharging rivers (Gallikos, Loudias, Aliakmonas), the entire Gulf has entered an "erosion face" and only the active river mouths evidence a minimal expansion of its Delta areas (Karageorgis and others, 2006).

On the contrary, hydraulic studies (Pavlidis and others, 2000) of the upper banks of the river have concluded that, even after the extensive human interventions, the river has a strong deposition behavior, which has lifted the riverbed level diverting its route in places, increasing the flooding potential. Critical role to this behavior has the Elly Dam, which creates a calm section upstream, increasing the sediment deposition phenomena. Downstream,

towards the river mouth and especially around the delta plain, the river seems to suffer from a retreat.
Measurements of the period 1997 – 1998 indicate that, compare to historical data, the mean annual water discharge reduced by 40% from 4.95 X 10^9 m^3 to 3.0 X 10^9 m^3 (Karageorgis, Anagnostou, 2001). In addition to that, sediment deposited seawards of the river mouth (Fig. 2) has accumulated at a rate of 1.4 X 10^6 m^3/y which is four times less than the accumulation rate calculated through historical data (Kapsimalis and others, 2005).

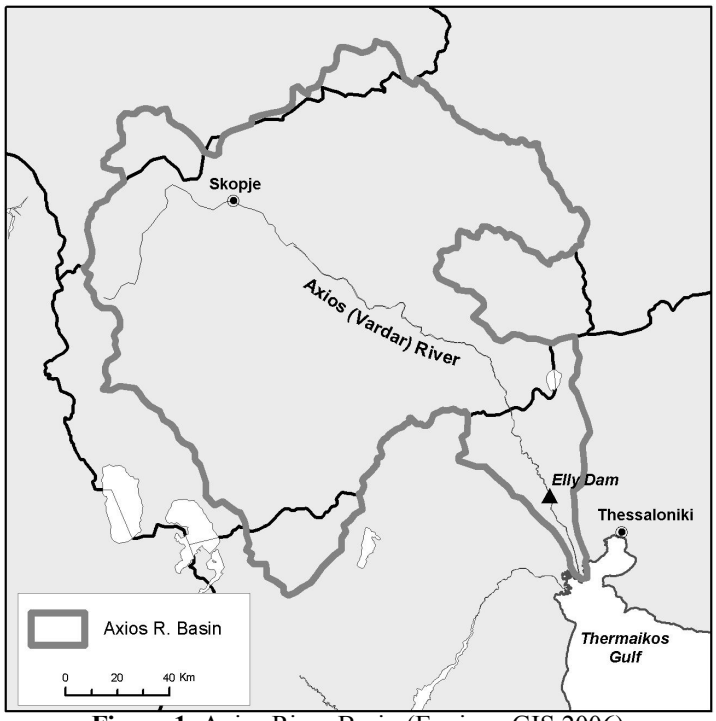

Figure 1. Axios River Basin (Envicon GIS 2006)

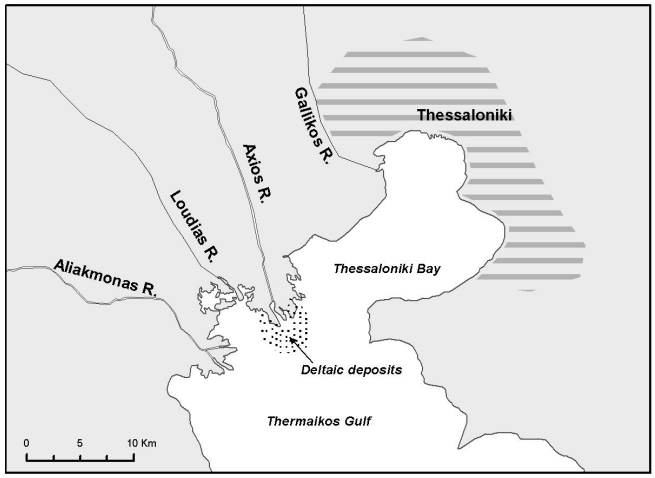

Figure 2. Deltaic deposits at the Axios River mouth
(after Kapsimalis and others, 2005, Envicon GIS 2006)

3. Ecological asset and the protection framework

Axios River supports a rich and dynamic ecological asset. Even after the large-scale diversion projects some decades ago, river managed to recover and to become once again the habitat of a numerous amount of species of flora and fauna. Its importance arises from the fact that:

- Delta area supports a variety of biotopes important for many endangered and rare birds and for the reproduction and resting of several species on their migratory movements.
- Riverbanks support in places, dense forests essential for the reproduction, hunting and resting of birds.

Due to its high ecological value, the river is now a subject of protection both on international as well as on national level (Fig. 3). Delta area along with a big part of the riverbanks, are being protected:

- By the Ramsar Convention.
- The European Natura 2000 Network (Directive 92/43/EC).
- The Directive 79/409/EC as an area of special interest for birds
- The Barcelona Convention while

Implementation of the Directive 60/2000/EC, concerning the holistic management of the rivers in the basin level, could provide a framework for an overall approach of the relation between development and environmental protection.

In addition, Greek state applies a regulatory framework towards the protection of this area, which is identified by the following:

- Adoption of the European Directives and the international conventions has initiated Common Ministerial Acts and Decree-laws with an objective to describe the land uses within the area of interest, as a mean to enhance protection. Axios Delta area is protected by the CMA 14874/3291/6.7.98 and also there is a DL under preparation to characterize the area as national park.
- Consequent upon the CMA implementation is the formation of the Delta Managerial Authority with an objective to guide and monitor development pressures within the protection area.
- Physical Planning through all its spatial levels of implementation, integrates the international and national guidelines related to the protection of the surface waters and the wetlands. In the lower spatial level of a Municipality, planning sets land uses, which in the case of river areas align to the related CMAs, if exist or propose new ones. For Axios River, planning of the corresponding Municipalities takes into account the related CMA and the draft DL.
- Regarding development pressures, each new project or activity within the protected area (broader Delta area or near riverbanks) has to have an Environmental Impact Assessment study, which initiates the Environmental Licensing of the project or activity. Responsible for the licensing is the Directorate of Environment and Planning of the Region and in some cases the Ministry of the Environment.

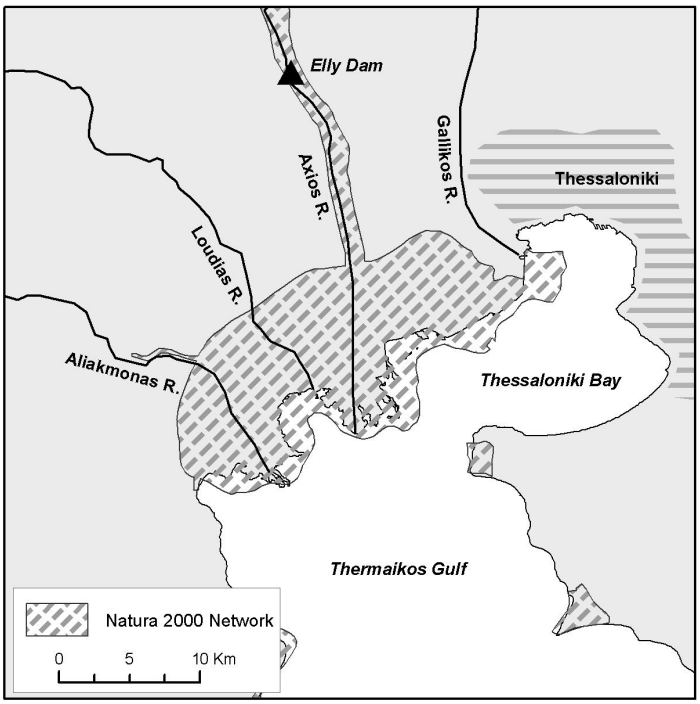

Figure 3. The Natura 2000 Network in the Thermaikos Gulf area (Envicon GIS, 2006)

4. The cycle of "Driving Forces"

Historically Axios River had a strong deposition behavior on its southernmost banks, which formed the Thessaloniki - Giannitsa plane throughout the centuries. In modern times and while the river mouth was situated right outside the city of Thessaloniki, this behavior was recognized as a major threat. Continuing expansion of the river delta would eventually close the entrance of the Thessaloniki seaport. The seaport of Thessaloniki is of strategic importance not only for Greece but for big parts of the Balkans as well, as a major gateway to the hinterland. In addition, new population coming from the east needed space and a healthier living environment.

Greek state, in order to satisfy the needs, implemented during the 1920's and 1930's large-scale reclamation projects. Among them, the southern section of the river along with its mouth was diverted towards the west. These projects were a success in many aspects. Sedimentation rates in the closer seaport area decreased, big land areas became arable and the living conditions for thousands inhabitants were improved. During the next years new projects took place (dams, irrigation networks, intensive agriculture), which boosted the socio-economic welfare of the region.

As a result to these interventions, the entire river entered a new functional face, which in general may be spatially designated by the Elly Dam.

Downstream of the Dam and especially at the lower plains, reduction of the freshwater volumes and of sediment materials reaching the Gulf, formed a

new state of coastal environment increasing the risk of seawater intrusion with consequences to the natural habitats as well as the human activities. However and despite the estimated "erosion face" of the greater Gulf area, river mouth continues to expand although in a much slower rate, while evidence of depositions along the riverbanks alter locally its hydraulic performance. Note that, Axios River in its lower part is an artificial stream, constructed with a certain flux capacity. Any evolution, even through the natural processes, leading to a hydraulic state different of what was initially designed, is not considered preferable.
Upstream of the Dam the river functions in a relatively diverse pattern, where tense sedimentation of the riverbanks and several local diversions increase the flood potential threatening human activities along its route.

Through this cycle of driving forces that emerged actions, which created impacts leading the river's environment to a new state, the initial needs have been met indeed and the identified risks have been eliminated. New feedbacks though seem to sustain the cycle and initiate new round of response processes.
Several surveys state that:

- Since the river delta continues to expand, although in a lower rate than before, sedimentation of the nearby seabed continues, lowering the Gulf depth, putting navigation in stake in the midterm future. Proof of this behavior is the recorded distance increment between the initial river mouth (1930's) and the modern delta edge (1985) of about 4,400m (Konstantinidis, 1989)
- Moreover, depositions along the riverbanks create small-scale diversions increasing the flood potential, which consists a risk for the human activities at the riverside areas. Especially at the lower plains, the artificial riverbanks should sustain the initially designed hydraulic characteristics. Floods recorded the last 50 years are those of 1979 where maximum flow rate was 1070 m^3/sec and of 1963 where maximum flow rate was 1550 m^3/sec (Pavlidis, 2000). Recently (2002, 2003), high precipitation also caused local scale flooding.
- On the contrary, the general "erosion face" of the Gulf, leading the nearby coastal environment to degrade, emerges the need for a new framework through which human activities are being developed. Reduction of water volumes and sediment materials reaching the Gulf is strongly correlated to water storage upstream, intensive agriculture and sediment extraction works along the route.

5. Meeting the needs

Axios River consist a major opportunity as a natural asset that support landscapes of high ecological value, enhances water supply, reinforce agriculture, tourism and other economic activities.
The response process to the new state of the river's environment aims at stabilizing a system, which seems to loose balance leading to new risks for

the human networks and the natural resources. Part of this process is to secure a level of hydraulic functioning in order to:

- Eliminate the flood potential, which is sustained by the sediment depositions along the route even after the notable reduction of the sediment volumes carried by the flow.
- Protect the technical characteristics of the artificial route at the lower plains, which are threatened by the natural processes: depositions, diversions, vegetation.
- Keep navigation in the inner Thermaikos Gulf safe, a future risk but still existed, although there are evidences that the Gulf has entered an "erosion face".

While at the same time, Gulf discharging volumes of freshwater and sediment materials have to be secured in order to avoid and maybe reverse further degradation of the coastal environment.

Consequently, response integrates actions. An action framework applied the last decades relies upon the concept of the *controlled sediment extraction*. According to that, sediment extraction from the riverbank should be focused only to recent deposits that create barriers, increase the riverbed level and in general create preconditions for an unfavorable flow diversion. Recent deposits refer to the sediment accumulation phenomena altering the "accepted" hydraulic characteristics of the stream. These characteristics are specified basically by the concept that the stream has a certain and determined flux capacity. Hence, extraction works, as part of an action framework should be oriented in meeting those necessities.

At the same time the outcome of such works which is sand, clay, and other fine and coarse grained material consist an important commercial opportunity with several uses in the construction industry. That economic dimension has initiated a managerial pattern, which could generally be described by the collaboration of the State authorities on one hand and the private sector on the other. In this unofficial partnership, the State secures river conservation in order to eliminate potential risks while an economic sector invests to that, getting resources as revenue.

6. The pattern of sediment extraction works

Sediment extraction has been, for decades now, an activity of high importance for the construction industry of the broader Thessaloniki area, where lives nearly 10% of the country's population.

Core of the production procedure is the superficial extraction of the sediments both from the banks and the riverbed. Heavy machinery is being used such as excavators, trucks and bulldozers and in some cases pumping installations.

Then, extracted material is carried to a treatment plant – called laundry - situated in the riverside where is further processed. This process results to material separation according to its granule weight using water flow. Sand is the basic outcome with the highest commercial demand. Other fine-grained material (clay) has also a commercial use while coarse-grained material (pebbles, cobbles) is for dumping.

This procedure has a small geographical range; it has relatively low operational costs, does not demand high investments and thus it is operated by small sized companies.
Sand extracted from Axios bank is considered of very good quality and of low production cost. Low cost comes from the fact that extraction is applied only to the superficial deposits, which leads to low investments on machinery and technology and also from the fact that environmental cost is not internalized in the degree that it should be.

7. The arisen arguments

Until recently, after exhausting a position – rich in sand, the activity was moving up or downstream in order to find new deposits while obligations for rehabilitation of the disturbed area were practically inexistent. There wasn't any overall plan to provide specific guidelines through the spatial identification of the needs, while licensing was focusing on preserving the hydraulic integrity of the river flow locally and didn't include profound environmental terms.
This production pattern in relation to the insufficiencies of the responsible authorities had consequent repercussions to the morphological – esthetical and ecological character of the riverside areas, which raised arguments about the necessity of those activities. They have been formed two groups of thinking:

- The first one accepts the fact that the river needs conservations which means removal of the sediment deposits, considering the risks of flooding and the – not welcoming – over expansion of the Delta. On this framework, sediment extraction activities help the river to flow on an accepted pattern while environmental considerations should be considered seriously.
- The second one accepts that the protection of the ecological character of the river should be the first priority and sediment extraction works, if needed, should be limited and only under strict licensing terms.

8. Environmental considerations and managerial acts

It is accepted that the pattern of sediment extraction works, poses a notable pressure on the riverside environment. It targets the bank areas rich in sand no matter the land cover (e.g. forest, marshland), lowers significantly the riverbed in places while neighboring areas are left unchanged, alters the hydraulic characteristics of the river occasionally and generally has a highly disturbing effect on the ecosystem.
On the contrary, it has practically no pollution impact and by the time the activity stops, ecosystem has the ability to recover in a few years. Additionally, it is estimated that these activities succeeded in conserving the river and in lowering the risks of flooding in the riverside areas.
Taking these impacts – negative or positive – into account, last decade licensing of these activities have shifted towards the integration of a more solid environmental context. Alignment of the Greek environmental law to the European standards in relation to an increased pressure from several

institutional bodies related to the river function as well as the uprising role of the public, have emerged a series of actions towards a better integration of the environmental concerns into these activities:

- In 2000, the Directorate of Works Construction Control of the Region of Central Macedonia (DEKEKM) conducted a preliminary study for the "Flux Improvement of the Axios River" at its southern plains, from the Elly Dam and downstream. Having as prototype the Foundation and Co. project and taking in mind the modern situation, this study set the preferable hydraulic outline of the river. This preliminary study became the basic inflow not only for the Master Plan study that followed but also for all the sediment extraction works applied at this area.
- In 2002, a general master plan was approved by the Ministry of Environment, the "Axios River Sediments Management Action Plan", with a geographical extent of the southernmost part of the river and an objective to specify areas suitable for sediment extraction. Criteria were the need for conservation in order to decrease the potential risk of flooding along with the environmental protection of high value areas. This plan is fully implemented today and licensing on that area follows its predictions and guidelines.
- The new categorization of works and activities regarding the environmental licensing as launched in 2002 with the CMA 15393/2332/5.8.02, sets higher licensing standards. Through an opinion-round procedure, licensing takes into account the considerations of a big range of State institutions related to the river and outcome a series of obligations.

Although the above general protection and conservation framework regarding sediment deposits management in Axios River could be considered adequate, there are notable weaknesses.

- The managerial master plan has a geographical range covering about a third of the river length inside the Greek borders. There should be an extension upstream the Elly Dam where deposition phenomena are considered stronger; extraction activity is growing as well as the pressure for more.
- The master plan itself has to be updated. The river has a strong dynamic and its state alters unpredictably.
- Monitoring and control of these activities is considered inadequate and environmental terms, derived from the given environmental licenses, are usually not implemented in their full extent.
- Consequently, environmental cost is not internalized, activities continue to work in low cost, sediment material of high quality continue to be sold in low price, this natural resource is running out and the overall benefit is still under question.

9. Conclusions

Sediment extraction activities on Axios River could be considered critical because they consist an economic activity of high importance for the construction sector while at the same time preserve the river reducing the potential risk of flooding and protecting the bay of Thessaloniki.

At the same time, weaknesses of the State institutions to shape an efficient framework for these activities, along with the insufficient monitoring regarding the correct implementation of the given environmental licenses increase the degradation threat of the ecological asset and lead gradually to the exhaustion of this natural resource. Hence, sediment extraction activities on Axios River could be considered that rely upon a three-dimensional problem: the need for environmental protection, the need for the river conservation and finally the need for sediment material for the construction industry at the broader area.

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