

Toward Integrated Water Management in the Middle Sava Basin

**Mladen Petrićec, Mira Filipović, Lidija Kratofil, Sandra Šurlan Popivić,
Željko Tusić**

ABSTRACT: The paper describes the evolution of the flood control system of the Middle Sava Basin, from its first design in the 1970's toward a more sustainable solution. The Middle Sava Basin is a broad alluvial valley along the Sava River, stretching from the Croatian state border in the west to the town of Stara Gradiška in the east. The whole valley is to a great extent endangered by floods, with several swampy plains flooded annually. The massive flooding in 1964 and 1966 prompted later comprehensive elaboration of flood protection measures. A multipurpose hydrotechnical solution was designed to protect the existing goods, ensure additional room for reclamation, urbanisation and traffic corridors, and create conditions for hydropower production, navigation and other water uses. From the very beginning, the most exposed plains have been left to retain flood flows and regulate the water regime. The first design was highly engineered, with isolated flood storages and considerable water control, which is now significantly altered for social, economic and ecological reasons. The modified solution protects smaller areas in a more natural manner. The preparations for the new evaluation are in progress. Instead of the further reclamation of swampy land for amelioration, there are serious recommendations in favour of keeping more connections between the rivers and their floodplains, and maintaining, or even restoring, more of the natural wetlands. It seems that many benefits can be gained from such approach due to economic potentials and environmental functions of these wetlands. To evaluate various water management alternatives suitable mathematical models will be applied.

KEYWORDS: the Middle Sava Basin, flood control, flood storage, floodplain, wetland preservation, integrated water management

1. Introduction

The area of the Middle Sava Basin is located at very heart of continental Croatia, along the Sava and Kupa Rivers, stretching from Zagreb and Karlovac in the west to Stara Gradiška in the east. It comprises of approximately 250 km of the Sava River flow and 140 km of the Kupa River flow, with the accompanying lowland area of about 400,000 ha. This is the region where the large urban centres of Zagreb, Sisak and Karlovac, together with about 400 smaller settlements have developed, which are now home to more than one third of Croatian population, where important traffic corridors have been built, and substantial agricultural surfaces established. For the most part, however, this area has retained its original, natural characteristics even today. It is a very heterogeneous area, with varying degrees of development, population density and lifestyle, starting from the Croatian capital of Zagreb and a number of other, fast developing towns to depopulated rural areas where natural environment is used in traditional ways for mere

survival. Parts of the area are protected in accordance with laws and conventions on nature protection (Nature Park and a Ramsar site of Lonjsko polje, a Ramsar site of Crna Mlaka, ornithological reserves of Rakita and Krapje Đol, etc.).



Fig. 1: Location map of the Middle Sava Basin

The Middle Sava Basin has always been prone to flooding. In the natural conditions, about 205,000 ha (3.6% of the entire national territory) were flooded annually, whereas extreme floods of the 100-year return period flooded even up to 292,000 ha (5.2% of the territory). It can be claimed that the development of the whole region is still to a large extent dependant on the status of water and the water regime, and that the solution of flood protection remains one of the dominant water management tasks as well as the prerequisite for the success of other activities.

The planned development of the Middle Sava water system commenced some 40 years ago. Now, after many years of delay, the activities on the solution's novation and its harmonization with today's principles of integrated water and land management have been initiated, since the original concept has to be adapted to the new circumstances and numerous changes that have taken place in the meantime - political (national independence, accession to the EU), socio-economic (war consequences, transitional economy) and environmental (strengthening of environmental protection).

2. Initial flood control concept of the Middle Sava Basin

The history of works carried out for the purpose of flood protection in the Sava River Basin goes back to the 19th century. The major flood of 1964, which struck particularly hard the city of Zagreb, took 17 lives and caused material damage equal to 9% of the national GDP, was instrumental in the development of the integrated Middle Sava flood control plan, within the framework of a wider regulation of the Sava River Basin. Economic objectives dominated the concept: the protection of existing goods, the provision

of space for new developments (urbanization, agriculture, traffic) and the creation of conditions for navigation, hydropower production, raising of water levels in minor watercourses and other water uses in the area.

The proposed solution was based on the imitation of centuries-old natural flood processes in the Middle Sava Basin, whose lowest parts are naturally suitable for flood retention due to their geomorphologic characteristics (pronounced natural depressions), and also due to the way in which the flood defence system of the Sava was developed - starting downstream and continuing towards the upstream section. Downstream of the town of Stara Gradiška the flood control system was already defined by dikes constructed along the Sava. It was therefore necessary to adopt the postulate that any works or interventions in the Middle Sava area must not deteriorate the flood status of the lower Sava.

It has been estimated that under those conditions the volume of about 1,975 hm³ of 100-year flood were relieved into the natural expansion areas. These huge water quantities, had they remained in their river beds, would have caused enormous increase in maximum flows and water levels and endangered the defence of the downstream areas. Instead of complete exclusion of floodplains, a solution was devised which used the natural characteristics of the terrain, i.e. the excess of floodwater was allowed into spaces which were under natural conditions often flooded. It was an original approach, since retaining spacious lowland areas to receive floodwater was not a technical solution applied at the time.

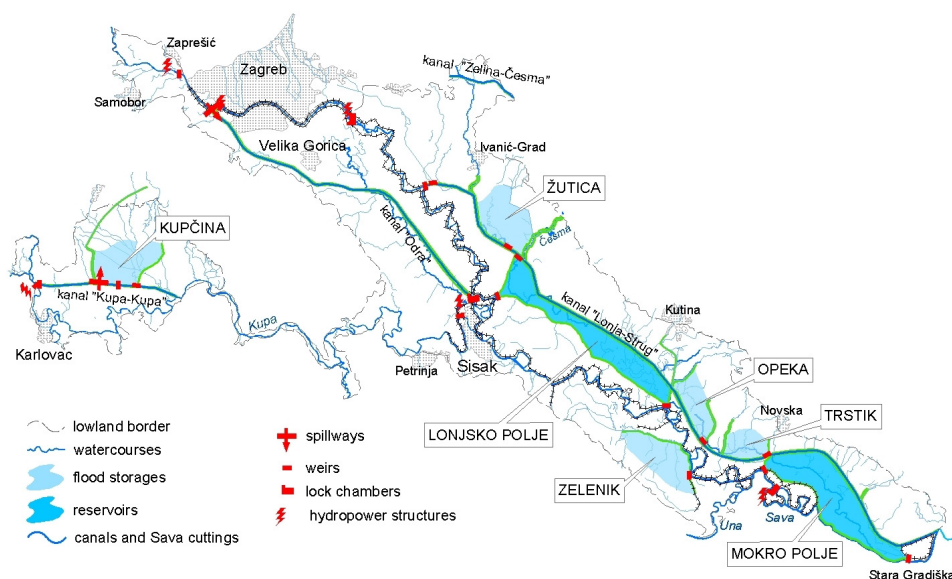


Fig. 2: Initial flood control solution of the Middle Sava Basin

The core of the solution were the flood storages in the Kupa and Sava lowlands, of sufficient retention capacity for the relief of excess flood waves. 58,800 ha of flood storages were planned (Lonjsko polje, Mokro polje, Zelenik, Kupčina), which by their total designed volume of 1,805 hm³ provided the required level of protection. Apart from the flood storages, the system comprised of three relief canals (Odra, Lonja-Strug, Kupa-Kupa), which made up for the limited flow rate on some stretches of the main

watercourses and redirection of excess water into flood storages, and about 15 structures for water distribution control under flood conditions. Additionally, there were earlier constructed dikes along the larger watercourses, which had to be continuously rebuilt and reconstructed, if necessary. The system was generally designed to provide protection from the predicted 100-year flood, whereas larger urban centres, i.e. Zagreb, Karlovac and Sisak, were defended from 1000-year flood.

The intention was to achieve the maximum possible reduction of floodplains and the complete control of floods. All other parts of the area had to be protected and made suitable for urban or economic purposes through water management works.

3. Implementation of the flood control solution of the Middle Sava Basin (period 1965 – 1980)

The implementation of the designed solution soon started. It can even be claimed that the processes of solution elaboration and investment works proceeded simultaneously. Under extreme expert, financial and organizational efforts in the first years the basic “skeleton” of the system was created, with largest water management works ever conducted in the Sava River Basin. The works continued more slowly until the beginning of 1980’s, after which the construction activities generally came to a halt.

This period in the system’s development can rightly be named the ‘building’ period. Over 60 km of relief canals with accompanying dikes and two sluices, Prevlaka and Trebež I, were constructed, the retention area of Lonjsko polje was given its first contours by the construction of lateral dikes, and a simultaneous extension of the existing river embankments was carried out. The primary goal was flood protection of the large urban centres of Zagreb, Sisak and Karlovac. In case of Zagreb, the desired protection level was achieved, whereas the towns of Sisak and Karlovac still have unsatisfactory, although improved safety levels.

Although attention was paid to the multi-purpose character of the solution from the very start, which, apart from flood protection, included a number of other purposes, such as the creation of conditions for amelioration works, electricity production, navigation, etc., the priority in the socio-economic conditions at the time was agriculture. The drainage of excess water was carried out in the major portion of formerly protected lowland areas, and a number of agricultural polders were established, particularly in the agricultural surfaces of Črnc polje (46,000 ha) and Lonjsko polje (79,000 ha), where it was possible to organize safe agricultural production.

It is estimated that in the said period about 40% of all works planned by the project were carried out, and the water management effects achieved were functionally even greater. The conducted works reduced the frequently flooded surfaces to approximately 120,000 ha, and the safety from floods was significantly improved in the rest of the area. In the last three decades the constructed structures proved very efficient in case of extreme floods.

4. Redesigning the flood control solution of the Middle Sava Basin

All initially constructed structures were built as part of a clearly defined future solution. However, the same as with any complex, long-term, expensive project, this solution too had to undergo changes.

Already the first studies anticipated with foresight the necessity for harmonizing the solution with future changes. The efforts were made to make the initial concept flex-

ible, so that it could adapt to the evolved requirements of flood protection and economic conditions, which at the time could not have been reliably anticipated.

This proved extremely useful, particularly today when water management makes efforts for the continuation of the flood control system, after about two decades of delay. Due to exceptional socio-economic significance of the entire area, it is the task of water management now to finalize the defence system and provide necessary safety to the population and economic subjects active in the area. Here somewhat changed criteria must be the starting point in relation to the original concept. Today's objective is sustainable flood protection, i.e. achievement of economically justified safety levels regarding the population and material goods, and the creation of preconditions for future economic development, while simultaneously encouraging preservation and improvement of the ecological status of watercourses and floodplains.

During 1980's and 1990's new concepts were analyzed and developed in accordance with the principle of sustainable water management, which takes into account a wide spectrum of needs, including protection of natural ecosystems and maintenance of biodiversity. Two well elaborated concept solutions can be singled out, and are described below - one with predominantly economic standpoint, and the other with environmental views of long-term further development of the system.

4.1. The concept of cost rationalization

This solution is the continuation of the engineering approach to flood protection of the Middle Sava Basin which was applied in the original design, with modifications to accommodate experiences gained from the operation of the partially constructed system. By monitoring and analyzing the system's operation, it was realized that a solution with larger floodplains and less restrained flood flows can be more suitable and rational than the strictly controlled flood processes within isolated flood storages. Since the designed flood storages still did not have fully constructed dikes which would define them spatially, the conclusion was that exactly this fact can be used to change the initial solution by redesigning the retention areas.

The basic difference between the modified solution and the original project lies in the manner how the flood storages of Lonjsko and Mokro polje are established. The original solution anticipated these areas with full flood control, maximally reduced surfaces and higher depths of retained water. The modified solution proposed the following crucial changes:

- enlargement of floodplains at Lonjsko polje by approx. 7 000 ha;
- free flow of relieved flood water along Mokro polje;
- lowering of maximal water depths in the flood storages.

Another important change was related to the design and functioning of the Lonja-Strug canal, which was originally planned along the Lonjsko and Mokro polje in the length of 105 km. At its upstream end, the canal receives waters fed at the sluices of Prevlaka and Palanjek, then waters of numerous minor tributaries, and finally at Stara Gradiška transfers these waters back to the Sava River. The rationalized solution uses the functionality of already constructed canal parts. However, a further construction of this rather sizeable structure, accompanied by high embankments, is abandoned. The natural watercourses of Lonjsko and Mokro polje are used for transport of fed water. The filling of flood storages occurs gradually, and thus achieves the return to almost natural flow regime through these areas.

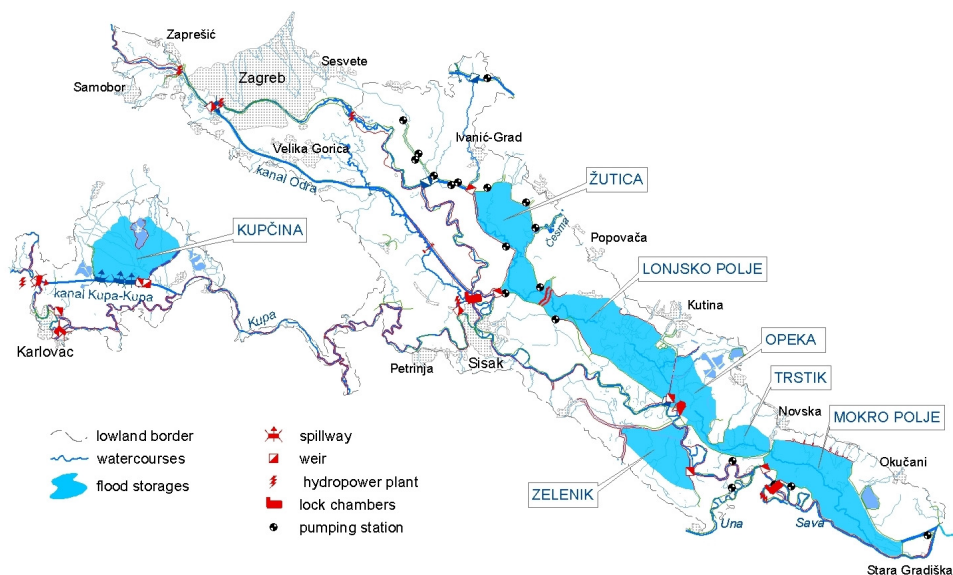


Fig. 3: Rationalized flood control solution

The proposed changes significantly lower the costs of the system's construction, since the building of a great part of dikes and canals as well as few distributing structures is abandoned. The protection level remains the same, and the defended area is not significantly smaller. Additionally, these changes contribute to a better protection of natural values, and are an important step towards environmentally acceptable flood management.

This modified solution was used as a basis for carrying out regular water management works in the Middle Sava region for a long time.

4.2. The concept of further environmental protection and enhancement

The first serious attempt to restore and further develop the Middle Sava system after the end of the homeland war started with the development of the Environmental Impact Study intended to re-evaluate the existing solution concept from the environmental impact viewpoint. The obligation to carry out such analysis comes from the Programme of Physical Planning of the Republic of Croatia, which determines that 'the basic principle of integrated approach to physical planning includes environmental protection as a continuous and in all segments present component'. Therefore, any major intervention in space must be analyzed according to the requirements and criteria of environmental protection. In this case, it primarily applies to the environmental functions of floodplains in view of the general increase in ecological awareness and efforts to preserve the remaining natural environment and protect the existing biotops and biodiversity.

The lowlands of Lonjsko and Mokro polje, which for centuries were considered of very little importance, have been recognized as particularly interesting and important part of the natural and cultural heritage. By proclaiming the area a Nature Park, the Republic of Croatia expressed its interest in the preservation of this unique community, with possesses natural and cultural values developed over centuries by local population's traditional lifestyle. Biological features are characterized by typical wetland flora and

fauna, rich in bird species. So far, 744 plant species have been described, including aquatic plant communities of international importance, and 250 bird species, a great number of which is protected by international conventions.

The Environmental Impact Study, by using these values as the starting point, proposes a number of possible modifications of individual parts of the flood control system, with the aim to minimise the impact and improve the status of the environment. Specifically, the following modifications are suggested:

- retaining of the natural water regime of Odransko polje (preservation of approx. 20,000 ha of natural floodplains);
- retaining of the natural water regime of the Zelenik area (preservation of additional 10,000 ha of natural floodplains);
- enlargement of the Kupčina flood storage by approx. 1,000 ha;
- enlargement of Lonjsko polje flood storage by additional 530 ha;
- retaining of a part Sava River floodplains upstream of the city of Zagreb;
- retaining of natural connections between the Sava River and Mokro polje at the Trebež mouth and in river stretch upstream of Stara Gradiška;

The following minor, but environmentally important works are also proposed:

- flow restoration in the floodplains (culverts, stills, weirs, openings in forest roads);
- arrangement of excavation localities according to ecological and aesthetic standards;
- adaptation of revetments to become resting places for small animals;
- restoration of natural river corridors (e.g. Lonja - Trebež - Strug);
- restoration of parts of former floodplains (several meanders of the Sava, such as Mlaka, Košutarica, Drenov Bok, Trebež);
- re-naturalization of parts of protected areas (e.g. Okučani, Prašnik, eastern part of Zelenik area, areas along the dikes of Lonjsko polje, areas south of the Kupa-Kupa canal, etc.).



Fig. 4: The Middle Sava solution as proposed by the Environmental Impact Study

The objective of proposed modifications is to retain as many as possible remaining unprotected areas in the natural water regime, with occasional flooding. The Study points out that the proposed changes would open up great potentials for the development of the new form of tourism based on preserved traditional architecture and lifestyle, and beautiful forest landscapes criss-crossed by pastures and open wetlands, exceptionally rich with birds and other fauna, as a rare remains of the past and the natural state. Other uses for natural floodplains are noted as well, such as grazing, fishing, sustainable forest cutting and the production of biomass. Special water management significance is reflected in the wetland areas' great natural capacity for water purification via nutrient removal, and replenishment of groundwater via seepage of floodwater from spacious retention areas.

5. Conclusions

The fact that the Middle Sava system is not completely constructed does not present a disadvantage at this moment, but the opposite. Many aspects and factors of influence, not present or impossible to anticipate and take into account at the time of the original concept are today clear, and can be used to define desirable characteristics of the future system.

It is evident that expectations are high for the continuation of the system's construction, which needs to provide sustainable protection from floods to the existing goods, create conditions for a better life and new developments, but do so without endangering the sustainability of the vital ecosystems. All this requires comprehensive analysis and verification of the solution. There are ongoing discussions about the two described development scenarios, which have numerous common denominators as well as open dilemmas which need to be resolved by additional studies. The future solution should be looked for in the area between these two concepts. It will have to be a compromise between the interests of various users in the Middle Sava area. The size of floodplains and the level of flood flow control are still the main existing dilemmas.

From the standpoint of safety, there is the obligation to achieve the prescribed level of flood protection of especially sensitive areas (1000-year for large towns, disposal sites for dangerous substances, chemical and food industrial plants, and a 100-year for other settlements, highways and state roads). For other parts of the area it is necessary to re-evaluate goals and determine economically justified safety levels, which particularly applies to agricultural surfaces, where the drainage is still unsolved. Past experiences indicate that major amelioration interventions aimed at initializing intensive agricultural production are justified only if there are subjects strong enough to support such production, capable of developing and maintaining new amelioration systems. There are considerations that some local communities in impoverished and depopulated areas of the Middle Sava Basin may find their development opportunity in the traditional agriculture and its combination with alternative sources of income, offered by preserved environment, if the Government recognizes such orientation and adequately supports it.

The vital criterion for the valuation of the solution depends on the development strategies for individual areas of the Basin, which is a political issue, but even so must have socio-economic and environmental footing. All stakeholders should participate in the analyses of potential scenarios and the selection of the final solution. Nature protection presents an increasingly important boundary condition, since a part of the area has been proclaimed a Nature Park. In principle, all economically feasible modifications directed at environmental protection and enhancement, which have no negative consequences for local life and economic circumstances, seem acceptable.

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Authors:

Mladen Petrićec, Dr.Sc., Croatian Water, Zagreb, Ulica grada Vukovara 220, Croatia, petricec@voda.hr

Mira Filipović, Croatian Water, Zagreb, Ulica grada Vukovara 220, Croatia, fmira@voda.hr

Lidija Kratofil, Croatian Water, Zagreb, Ulica grada Vukovara 220, Croatia, klidija@voda.hr

Sandra Šturlan Popović, Croatian Water, Zagreb, Ulica grada Vukovara 220, Croatia, ssandra@voda.hr

Željko Tusić, Water Management Engineering Bureau, Ulica grada Vukovara 220, Zagreb, Croatia, zeljko.tusic@vpb.hr