Urban River Design: A River Restoration Case Study

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Abstract. Human excessive requirements on functions of aquatic ecosystems cause that surface waters often suffer from significant morphological and hydrological alterations. Human induced hydromorphological changes of rivers belong among the most common ecological problems of the water bodies and they appear in all scales of river habitat. These changes have an impact in their ecological status and need to be solved in the near future. Successful sustainable river rehabilitation depends on the identification and understanding of key processes and anthropogenic stressors. These factors enable to estimate a proper longitudinal and lateral riverine system structure including stream habitat improvements at different scales. The article summarizes the basic principles of urban river restoration, that enables to approach to the state of dynamic stability and to increase the „absorbing capacity" of freshwater ecosystem. The authors also provide the background facts and principles of the restoration design of canalized reach of the River Trnavka, which flows through an urbanised part of the city Trnava. The Trnavka River has regulated flow regime affected by operation of Boleraz reservoir located 14 km in upstream direction. The river channel capacity equals to 50 $m^3.s^{-1}$ with return period 100 years and ecological flow is Q=0,150 $l.s^{-1}$. The heavily modified non-prismatic channel has stone and concrete stream banks. The authors have proposed increasing sinuosity of low flow channel and decreasing capacity of the oversized channel by using gravel matraces with planting different types of macrophytes. The main goal of the proposed river restoration measures was to increase aesthetic value of complex restoration design of close public space (the Rose Park) and to implement technical and biotechnical measures that may improve ecological conditions and management operation of the Trnavka River.

1. Introduction

The rivers represent one of the key components of urban places [1] and [2]. Their importance resulting from services provided to humans: water resources, fisheries, navigation and recreation [3] (Grimm, 2008). Urban rivers represent hybrid ecosystems with substantial abiotic alterations where returning to historic state is often very problematic [4]. A physical habitat and ecological functioning of natural systems are often significantly modified by human activities [5], [6] and [7]. The effect of multiple

anthropogenic stressors reduces the natural resilience and resistance capacity of freshwater ecosystems those enable them to recover from certain level of perturbation [5] and [8].

2. Materials and methods

2.1. A History of the Trnavka River

The Trnavka River is located in central part of the town Trnava in western part of the Slovakia (figure 1). In the 13th century, the Trnavka River flowed around the town and river was a part of the city defensive walls. The Trnavka River painted on the veduta from the 1727 is divided into two branches behind the northern city walls (right side of the Figure 2.). Behind the southern city walls was a junction of both branches next to the area of current Rose Park (circle on the Figure 2). Because of flood threat existence (the great flood occurred in 1909) the Trnava City Council began to plan increasing the level of flood protection. Building of systematic flood control measures started after the First World War and continued during the Second World War. The western branch of the river (originally behind the city walls) was transformed into partially underground closed conduit. The second branch of the river (originally in the city centre) has been completely transformed into underground conduit. One branch of the River was also left in the area of the Rose Park.

Figure 1. The situation of the researched territory of the Trnavka River [9]

2.2. History and current state of the Rose Park

The history of the park began in the 19th century, when at this place was a shooting range garden. There was a new building built in the part of garden in the second third of the 19th century, where the residents used to go to the concerts and walks.

The building of Emmer's Villa was constructed from 1767 to 1784 in baroque style and it is a part of today's park. The area of the shooting range garden is today a park known as Rose Park after the roses planted in the 60s of the 20th Century. A creator of the planting was Kornel Mahr. At present, the area is an important city park in the historical centre of the city, which is intensively used as a walking trail also for relax. It features a garden of Emmer's Villa, today a children's leisure centre, with a garden without a preserved historical appearance.

The current state of the designed reach of the river is presented in Figure 3. The researched reach of the Trnavka River is strongly altered. According to the Water Framework Directive is categorized as a heavily modified water body. It´s due to effect of the channel modification and pollution from overflow chamber of town sewage system. The prismatic compound channel has cross section of the trapezoidal shape. The bed width equals to 4.50 m, channel depth is 3.10 m and bankfull width equals 9.50 m. The V-shape low flow cross section is armoured with stones. The bank toe is stabilised by riprap and adjacent floodwalls are made from concrete. The biota of the ecosystem has low diversity and abundance. The chub (*Leuciscus cephalus*) is main representative of ichthyofauna in the river. The chub is considered as tolerant fish species in heavily contaminated river reaches [11]. The control measurement of physical-chemical characteristics of water has shown following values: BOD5 = 8.5

mg.l-1 , pH = 7.37, conductivity EC = 27 mS.m-1, Dissolved Oxygen concentration= 1 mg.l^{-1}. The results categorized water to the worst the 3rd quality class of physico-chemical parameters.

Figure 2. The Trnavka River in 1727 [10]

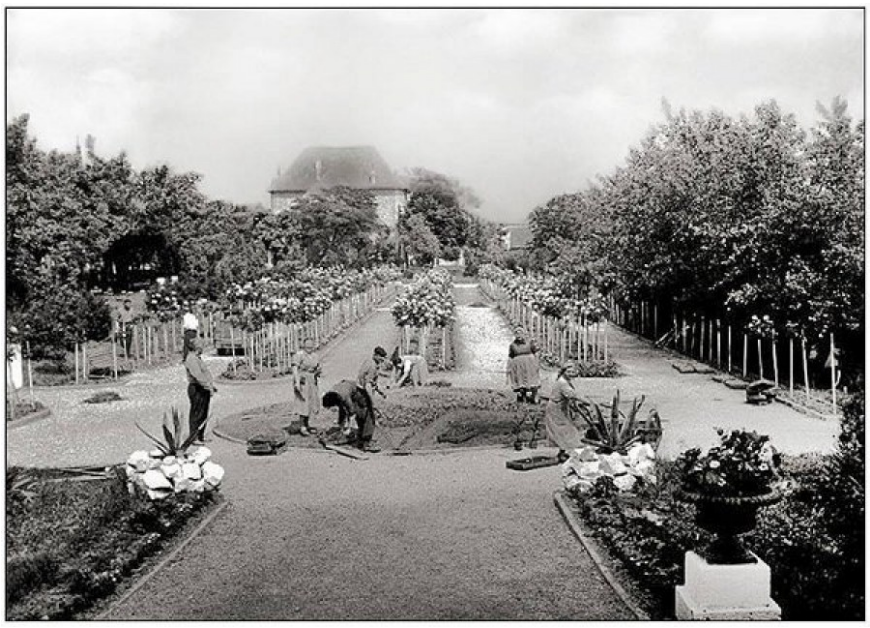

Figure 3. The Rose Park in the 60s of the 20th Century [10]

Figure 4. The recent state of the Trnavka River

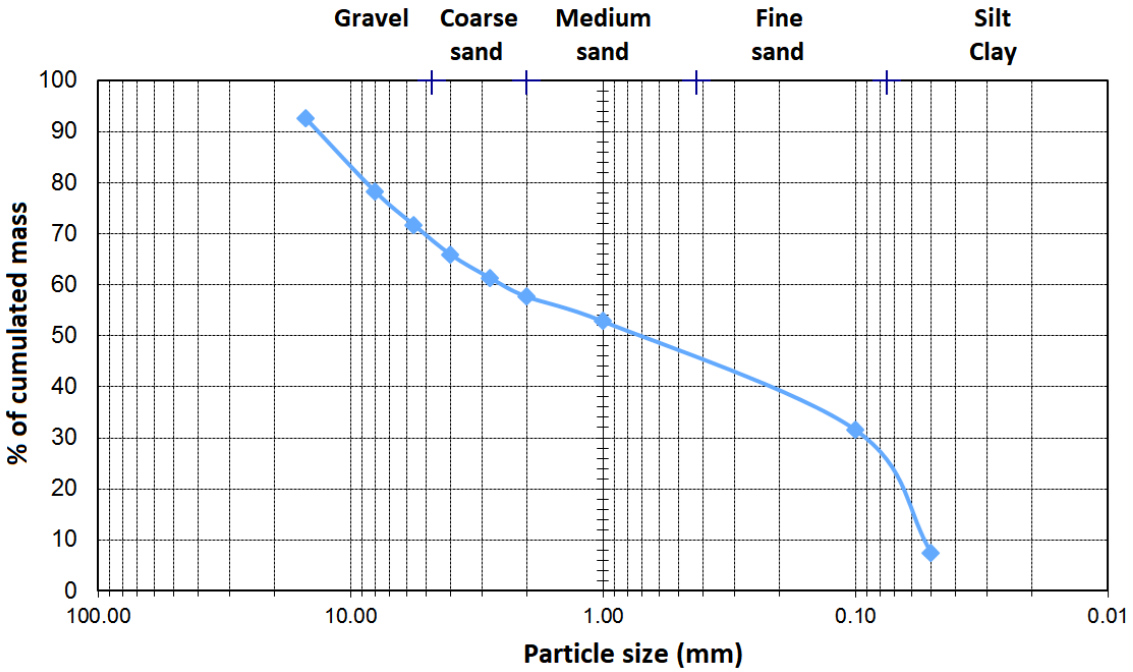

Figure 5. Particle size distribution curve of the sediments

3. Results and discussions

3.1. The Trnavka River restoration design

To improve ecological conditions of low flow channel we analysed bedload sediments granulometry (Figure 5.) with prevailing representation of fine material (sand, clay and silt). The goal of the low flow channel narrowing was to increase mean velocity that enable transport of fine grained material.

Such way we increase the share of gravel and coarse sand and eliminate accumulation of fine material from overflow chamber of town sewage system. The goal of the increasing of low flow channel sinuosity (Figure 6.) is to improve morphology and material diversity. The cross section modification design is presented in Figure 7. Excavated bed material is substituted with stones to form the toe stabilisation element. Rest of the bed and part of the bank is built from mixture of gravel and sand. The surface is covered by jute geotextile on which the macrophytes. The main goals of the measures are: reduction of water pollution, forming shaded areas, creation a refugia for ichtyofauna, enables the contact with river by pier design (Figure 8.) and increasing an aesthetic level of the riverscape.

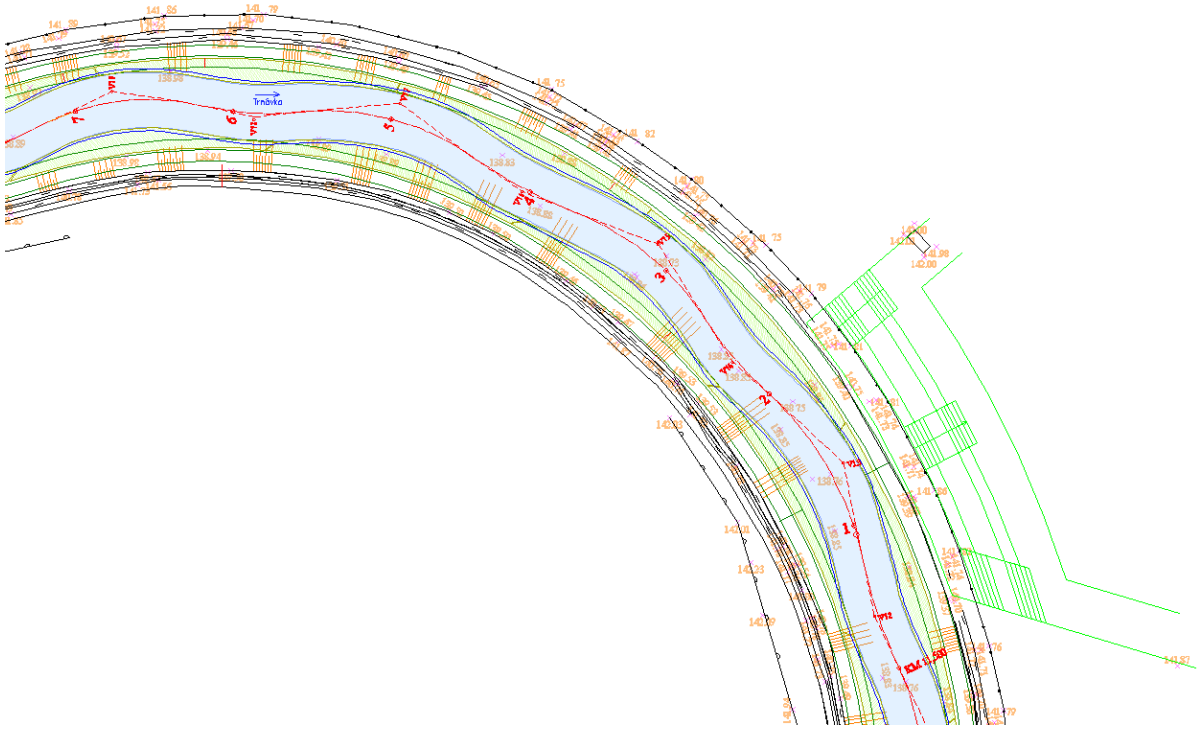

Figure 6. Plan view on designed sinusoidal low flow channel

The specific problem remains the planting of macrophyts in the Trnavka River. The planting is designed as a rotation of monoculture blocks and herb mixtures - similar to natural rivers, where competitive species can push at the expense of a varied mixture of herbs under suitable conditions. The concept is based on the gradual natural selection of competing strong taxa and the subsequent development of herbal patterns. Herbal plantings will ensure colour dynamics in space, structural diversity, which also increases the user's attractiveness of the space and the possibility of social contacts. The species richness of planting contributes to increasing the biodiversity and sustainability of the restored area and brings significant economic benefits: reducing the financial costs of maintenance and renewal (10-15 years) of planting: reduction of irrigation requirements (certain parts), fertilization and labour.

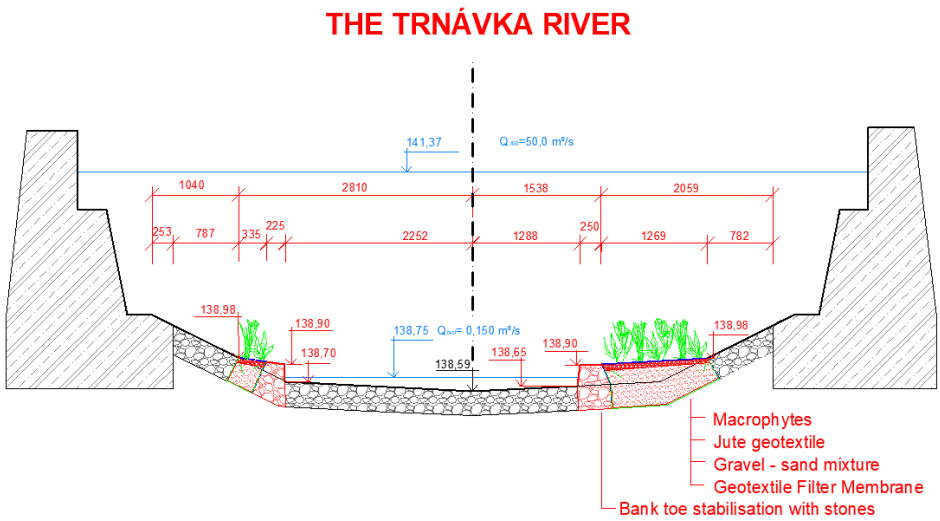

Figure 7. Designed changes of cross section

3.2. The Rose Park reconstruction design

From the point of view of the greenery composition, the park's design consists of five functional and compositionally different complexes: the Strelecka Street, The Kalokagatie Gardens, the rosarium in form of a promenade, the free park area with a picnic meadow and the Trnavka River. The Kalokagatie garden is a formal part of the park created as a modern form of a historical analogy of the baroque garden. The rose promenade is also a formal part with a modern arrangement of rosarium, water elements, perennial beds and resting areas with pergolas and a collection of climbing roses. The park area with picnic meadows has the modest character connecting all parts of the park to each other. Two new tree alleys are designed to surround the park from two sides. One of them copies the channel of the Trnavka River and the other indicates the covered second branch of the original river. The surroundings of the river Trnavka are supplemented by perennial beds with prevalence of ornamental grasses.

Figure 8. Visualisation of the restored channel reach of Trnavka River

Figure 9. Visualisation and plan view of the Rose Park reconstruction

4. Conclusions

The river restoration in urban spaces belongs among difficult river engineering tasks. We have to solve compromise between keeping the flood protection level and improvement of the ecological condition in the river during design process. The task is more difficult in case of space limits in riparian zone. The main goals of the proposed river restoration measures were to increase aesthetic value of restoration design in context of close public space reconstruction (the Rose Park) and to implement technical and biotechnical measures that should improve ecological conditions and management operation of the Trnavka River.

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