FINAL DEMONSTRATION ACTIVITY REPORT

WP 5.3

THE CITY OF ŁÓDŹ
2006-20011

ANNEX 2

Demonstration Project 1:
The Sokołówka River - Restoration of a municipal river for stormwater management and improvement of quality of life

RIVER REHABILITATION PROJECT

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CONTENT:

1. Introduction

One of the major goals of the SWITCH Project in Łódź was to develop a conceptual and technical projects of the Sokołówka Park and rehabilitation of a stretch of the Sokoloka river between Zgierska and Teresy Reservoirs based on the concept of ecohydrology.

The proposed ecohydrological measures have been incorporated into a rehabilitation project involving c.a. 800 m long stretch of the Sokołówka River (Fig. 1) that will lead to a future development of the "Sokołówka River Valley Park".

The conceptual project was prepared within the SWITCH Project by the University of Łódź and the Technical University of Łódź, and completed in 2009. The technical project was completed in 2010 and is now ready for implementation (Fig. 2, Fig. 3).

The full project is available in Polish.

Figure 1. The Sokołówka River before its rehabilitation (photo M. Łapińska).

Figure 2. Planned "The Sokołówka River Valley Park" with rehabilitated river stretch.

2. Sokołówka River Valley Park

In 2007, an inventory of the trees in the Sokołówka valley between Zgierska Street and Al. Włókniarzy was prepared (Fig. 3). This document complements the landscape validation document, which employed real vegetation mapping through GIS and the concept of hemeroby. Both these documents provided a basis for the rehabilitation plan of the urban river valley and the *"Sokołówka River Valley" Park, Greenery Development and Layout of Park Alleys*.

The inventory of green resources has indicated that this area contains many valuable tree species, such as Populus x canadensis Moench, Populus x canescens S.M. and Acer platanoides. It also includes Carpinus, Acer and communities of Betula verrucosa, which established the park's pathways. Numerous, and indeed impressive, old oak trees constitute an excellent foundation for a city park.

In 2007, several ash-trees were moved to this area from other parts of the city where development plans were also being implemented.

The spatial management concepts anticipate that this area will become a semi-natural park, which will expose the existing trees and meadow vegetation communities. The work planned will be delivered in such a way that it will enable the protection and maintenance of the existing flora communities, including those introduced to the area, thus maintaining the existing biodiversity. The variety of the existing tree species determines the natural attractiveness of this area. Some of the trees will have to be removed due to their poor condition, while many of the others will be perceived as natural monuments.

Originally it was planned that a system of footpaths and greenery growing on the edge sections would be established during the first stage of the park's development, while the second stage was to include the development of a new and meandering river-bed, lighting and future sport and leisure facilities. Due to the ground works related to the river-bed reconstruction, the first stage will include river-bed-based works, which will provide the foundation for the layout of the park's paths. This should commence in 2013-14.

Figure 3. A fragment of the tree inventory in the area of the future Sokołówka River Park – in the region of Teresa Reservoir

The concept assumes the layout of the park's pathways will be composed of a main path surrounding the whole park area and internal footpaths that will connect individual sections of the park with a residential district. It is planned to cover the surface with a clay and gravel layer, which is typical for landscaped parks. Residents of the neighbouring housing estates are very interested in the park's development, and thus they will be involved in the planning of the transport system at the design stage.

New trees planned for the park are to enhance the existing greenery, diversify it and enclose the walking routes.

3. Ecohydrological rehabilitation of the Sokołówka River

The conceptual model for rehabilitation of the section of the Sokołówka river is presented at the figure 4.

3.1. Securing sustainable water flow

A project to rehabilitate urban rivers should consider the following crucial phases:

i) securing continuous water flow,

ii) restoring river carrying capacity by the reconstruction of the optimal physical structure of the river channel, and

iii) re-establishing other elements of stream health like riparian zones, backwaters, or floodplains.

Thus, the first phase in planning the rehabilitation of the Sokołówka system should include:

iv) preservation of the nearby water infiltration and retention areas by the developmentn of the Sokołówka Park,

v) establishing a sequential wetland system to improve water quality and control high flows and pollution, and

vi) increasing rainwater infiltration and retention in the catchment by substituting or complementing traditional stormwater systems with BMPs as well as preserving and extending green areas (green squares, grass patches, green belts along roads).

The second phase, i.e. the reconstruction of the physical structure of the river channel, allows further regulation of instream hydraulics and thus, establishes a template? for the ecosystem processes and habitats for the immigration and/or reintroduction of abundant and diverse biota.

It is assumed that the third phase will not require much investment as it involves the natural processes of succession, provided that the first two phases have been completed successfully.

The folowing sections cover the general assumptions for the project of the Sokołówka River rehabilitation.

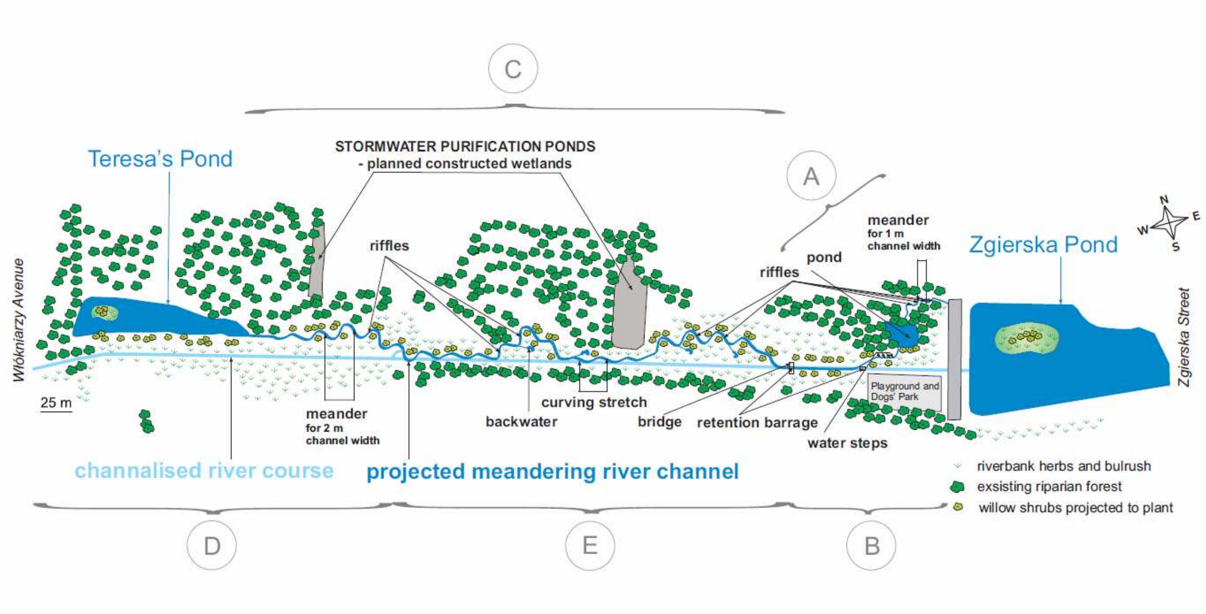

Figure 4. The Sokołówka rehabilitation project design (modified from Zalewski et al. 2009 and Łapińska et al. 2010)

3.2. Enhancement of the instream structure

In the rehabilitation section, the Sokołówka River flows in straight concrete channel of a trapezoidal profile, with a width of 0.8 m at the bottom, bank slopes of 1:1.5 m and a river slope of about 3.7-3 %o. The rehabilitation goal for this part of the Sokołówka is to enhance the structural and then the biological diversity of the river, and as a result, its ecological functioning and value. The feasible rehabilitation solution appears to be the replacement of a concrete drain with a newly constructed meandering channel of high structural diversity (Fig. 4) (Zalewski et al., 2009; Zawilski et al., 2009). The landscape characteristic allows to develop meanders on the right-side of the river valley, which are designed to be incorporated within the already existing riparian vegetation and the patches of basin forest, which still exist. A new channel will connect two existing artificial ponds: Zgierska Pond (1.4 ha, built in 2003) and Teresa Pond (0.44 ha, built in 2006).

Meander creation technique

On the basis of theoretical computations and field observations 2 meander models were designed for the Sokołówka project, one for a river width of 1 m (Fig. 5a) and the other for a river width of 2 m (Fig. 5b). The development of meanders needs significant space (6 m width for meander 4a and 12 m for meander 5b) not to disturb the existing land vegetation (mainly trees and shrubs), their sequences were planned in sites which hold sufficient open land (see Fig. 4 sector C). In order to connect the meanders with tree areas, thinner channel modules of SI <1.4 and >1 (curving stretches) were designed (Fig. 4). In this project the shape of the curved stretch was established by flattening the meander model for the 2 m width river. This resulted in a wavelength of $\lambda = 23$ m, although the width of the wave is not 12 m but 6 m.

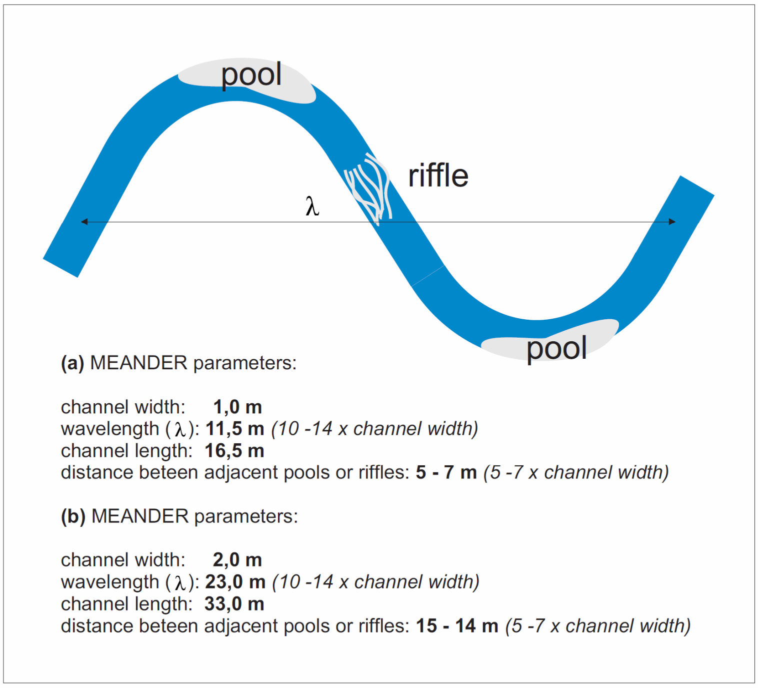

Figure 5. Models of meanders applied in the Sokołówka rehabilitation project: (a) parameters for model of meander for 1m width river, (b) parameters for model of meander for 2m width river (after Leopold and Langbein 1966, changed)Pool-riffle sequence formation

Creating river meanders (horizontal features) usually resulted in recreation of 'vertical meanders' in the form of pool-riffle sequences (Callow and Petts 1992, MRRT 2002) (see Fig. 5). This should be done by the river itself, however, the process is closely related to substrate size, its erosion, deposition and stream shaping discharge. Streams with mainly sand or silt laden beds, like the Sokołówka, do not develop this feature. Therefore in case of the Sokołówka project it is advised, firstly, to produce artificial and stable riffle placements as an excellent habitat enhancement technique for sandy bottomed sections, and secondly, to introduce bottom material, coarser than sand, which would increase the river's potential to form natural riffles in the areas of meander inflection and allow the new river to establish pool-riffle sequences itself. The benefits expected to be gained through meanders include: channel stability; slope, velocity and shear stress reduction; habitat quality, quantity and diversity (pool-riffle sequence creation); nutrient circulation and water quality; biodiversity; productivity; aesthetics values.

Pool-riffle sequences are a significant diversifying feature of stream habitats of great biological importance (Schlosser 1987). Pools and riffles tend to maintain higher levels of biodiversity and biomass, e.g. with regard to fish, than any other more uniform stream parts like, e.g. runs (Fig. 6) (Łapińska 2006, Zalewski et al. 1998, Zalewski 2002, Zalewski and Wagner-Lotkowska 2004), and are important in nutrient cycling and thus stream water quality maintenance (Goldman and Horne 1983).

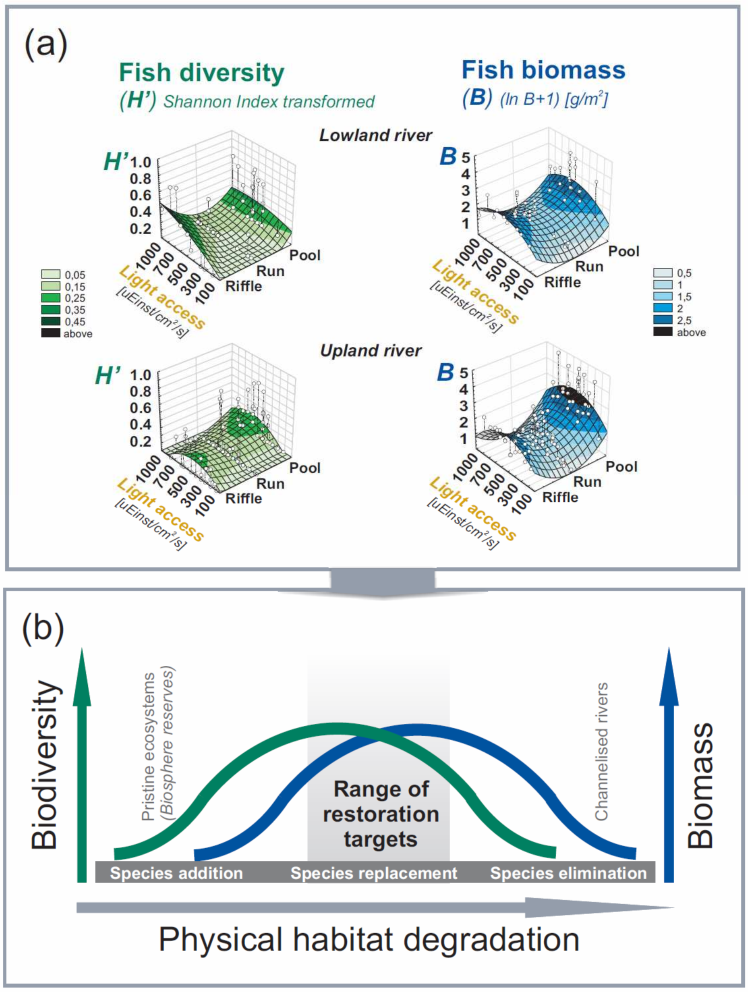

Fig. 6. (a) The relationship between light access to stream habitats and fish biomass (B) and diversity (H') (after Łapińska 1996 and Zalewski 2002, changed), (b) intermediate river restoration concept (after Zalewski and Welcomme 2001, changed).

New Sokołówka channel design

A new river channel (Fig. 4) (Zalewski et al., 2009, Zawilski et al., 2009) will start below Zgierska Pond in the form of a high gradient narrow width (up to 1m) stream entering the small pond (c.a. 500 m^2), with differing depths up to a max. depth of 1 m, developed in a natural land depression between existing forest patches (Fig. 4 sector A). The c.a. 50 m long stretch flowing into the pond will be meandering (2 full meanders) and 4 stable riffles will be placed in those areas of meander inflection. It is expected that the water depths in the riffles will be at least about 0.10 m, while in the pools the depth will be up to 0.25 m. Due to the steep slope, the next section of this channel, i.e. the one connecting the pond with the old Sokołówka channel (Fig. 4 sector B), will be almost straight but with 4 stony steps on the river bed to diversify its flow pattern.

In order to ensure that the lower and wider meandering river stretch planned (up to 2 m width, Fig. 4 sector C) will be carrying enough water, the effective discharge was computed. This resulted in the necessity to conduct additional water from Zgierska Reservoir by pipe directly to the new stream and pond (Fig. 4 sector A) and to create the retention area in the first section of the old channel (Fig. 4 sector B). This 124 m long section of the old channel, and also half of the newly designed stream, will cumulate water to maintain a constant inflow to the river created and to absorb the stormwater peaks. This solution allows to plan meanders and curving stretches for the river with the width of about 2 m, and where it now flows into Teresa Pond (Fig. 4 sector C). In total for this stretch, 9 model meander modules (3 sections of 3 modules), connected by curving stretches, were projected.

Previously, Teresa Pond was supplied from the channelized Sokołówka by underground pipe (culvert on 540 m of the section, Fig. 4). In the new design the pipe is removed and the majority of the water flow redirected by the new meandering stream into the pond. As the new channel is connected with the remainder of the unburied section of the old channelized stream, the river continuity will be maintained. However, some retention is also planned for this section to keep a sufficient flow during dry periods (Fig. 4 sector D).

The rehabilitation solution described will result in the elimination, achieved by burying of c.a. 300 m of the old channel (Fig. 4 sector E), with c.a. 300 m remaining for retention and connectivity purposes (Fig. 4 sector B and D), and the creation of c.a. 466 m (c.a. 297 m with typical meander modules plus c.a. 169 m as a curving stretch of the river) of a new meandering channel (Fig. 4 sector C), significantly enhancing river diversity and carrying capacity. The channel slope of the new river is expected to be reduced to 2 %o, and the river depth is expected to be maintained at around 0.3-0.5 m. Due to the sandy bottom and the high infiltration rate it is recommended that the whole channel bed should be sealed using an impermeable bituminous mat.

Backwater creation

The key stressor in the Sokołówka basin is its retention pattern that may not guarantee sufficient discharge into the new channel. In the Sokołówka basin 100% of the stormwater is carried to the stormwater drainage system. In order to increase the new river's water retention, and thus maintain the river flow and create refuges for biota during low discharges, a series of backwaters connected to certain meanders were planned. Four backwaters with thesurface of 15-20 m^2 and up to 1 m deep were designed (see Fig. 4 sector C). In each backwater, native littoral vegetation (such as *Juncus sp., Typha sp., Scirpus sp., Phragmites sp., Sagittaria sp., Nuphar sp., Glyceria sp., Carex sp., Scirpus sp., Iris sp., and Lemna sp.*) will be planted in moderate densities, so as not to allow too dense growth, which would cause oxygen depletion and habitat reduction. It is also recommended that the macrophyte biomass is controlled by having it removed seasonally.

The benefits expected through backwater creation include: water quality and quantity; habitat quality, quantity and diversity; aesthetics values.

3.3. Enhancement of the river riparian zone

The Sokołówka is a lowland and mainly sandy bottomed river. Sediment size is a factor that is significant not only for the development of meanders but also for the maintenance of the necessary state of equilibrium by the river. In fluvial systems this means that the erosion and transport of riverbed material are determined by river gradients and currents that have to be in a dynamic equilibrium (Callow & Petts 1992). River regulation/channalisation increases the gradient and thus the current which causes an increase in erosion and sediment transport until the impaired reach achieves a new state of equilibrium. That is why it is necessary to consider any self-adjustments of the new channel while undertaking rehabilitation procedures (Gordon et al., 1992).In urban river rehabilitation projects the goal is not to let the river change its shape by itself as this might be dangerous for the surrounding inhabited area. For the above reasons bank stabilization techniques in the form of optimal riparian zones of high value (Ward & Viens, 2001) should be implemented just after the new channel excavation.

Optimal complexity of riparian vegetation

The actual vegetation of the Sokołówka valley at the rehabilitation site consists of: ruderal thickets, ruderal forest, nitrofilous riverbank thickets, and gardens, but also higher value communities with hornbeam and oak trees, marshy forest patches**,** riverbank herbs and bulrushes were mapped (Kurowski & Kiedrzyński, 2009; Kiedrzyński & Kurowski, 2009). In general to enhance river biological processes the riparian vegetation of optimal, thus intermediate, complexity is advised (Intermediate Complexity Hypothesis – Zalewski et al., 1994, 2001). It was found that in the case of small rivers, comparable to the Sokołówka, an optimal energy pathway leads to high biota (e.g. fish) diversity and biomass reaches values between 300 to 700 µEinst $cm^{-2}s^{-1}$, with an optimum of c.a. 500 µEinst $cm^{-2}s^{-1}$ (Fig. 6a). This means that both river banks can not be fully covered by bank shrubs and trees and certain patterns might be advisable. For the new Sokołówka channel the optimal riparian vegetation complexity means 30-40% of canopy cover, and thus about 40-60% of the banks should be covered by vegetation (mainly shrubs and/or trees) (Łapińska, 1996).

The Intermediate Complexity Hypothesis with its experimental verification provided the conceptual background for the formulation of the Model of Intermediate Restoration. It states that the highest biodiversity and productivity of, e.g. fish populations, occur at an intermediate level of human disturbance, due to the greater light and nutrient inflow, so it might be sufficient to implement the rehabilitation process only up to this range, where both parameters are high, and not necessarily to full ecosystem recovery (Zalewski & Welcomme, 2001; Fig. 6b).

The target river biodiversity value can be obtained by compromising between biodiversities typical of a small, lowland river in the region (reference), fish species that can positively react to the habitat constraints (species tolerance) and expectations of the citizens (mostly requests of local anglers). The expected biodiversity value sets the most precise framework for the restoration of a riparian zone. It needs to serve as a sustainable habitat at least for the chosen target species, taking into account their different preferences towards river bank structures, types of in-stream vegetation and its biomass. For example, a river channel that serves three of the most common species: stone loach, gudgeon and roach, should ideally offer a sequence of habitats from sandbanks and highbanks, to intermediate (10-20gm^{-2}) and high (>50 gm^{-2}) densities of instream macrophytes, and with a riparian zone covered by grass and/or trees.

Besides the maintenance of the fish biodiversity in the rivers, other benefits offered by the riparian vegetation include: irradiance and stream temperature reduction; increased stream oxygenation, decreased streambank erosion and channel scour, increased infiltration of surface runoff, increased self-purification rate (water quality) and water retention (quantity), shelters/refuges for plants and animals, provision of organic matter and allochtonous food supply, increased invertebrate production, and aesthetics values.

3.4. Enhancement of the river basin functioning

The rehabilitation of urban streams by the enhancement of instream habitats or riparian zones is unable to improve the instream ecological condition up to the level of WFD regulations because it does not match the scale of the degradation process. The major degradation process in urban areas reflects the degree of imperviousness, the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater drainage pipes (Walsh et al., 2005; Marzluff et al., 2008). This dramatically impacts upon stream discharge and the hydrological regime through long term periods of droughts and short periods of high storm water events that destabilize the stream's physical and biological structure and instream ecological processes (Minshall, 1988). Thus artificial wetlands are a crucial element of water improvement in the rehabilitated river systems .

In urban river ecosystems, ponds and wetlands provide an important pollutant control function (Rocha 2004). In case of the Sokołówka rehabilitation site, the 2 existing and 1 planned pond, are of high value, however, frequent dredging of the polluted sediments is advised. In order to improve the basin potential in this section, which will trap pollutants, it is planned to transform two stormwater purification ponds (c.a. 500 m^2 and 300 m^2 , Fig. 4) into constructed wetlands. The future wetland design is based upon an existing project concerning the sedimentary/biofiltration system already under construction on the Sokołówka channel near Folwarczna Street with oil separators. Its role is the purification of stormwater through the flushing of oil substances, heavy metals, dioxins, nutrients and suspended solids before they enter the river water. in order to increase the removal of N-compounds it is also proposed to include several denitrification walls in the river basin, especially along the new created meanders (Bednarek & Zalewski, 2007).

The benefits expected through the creation of wetlands include: landscape diversity, habitat quality, quantity and diversity; interception and processing of nonpoint source pollutants, water quality and quantity; increased infiltration and groundwater inflow to stream; decreased sediment load and contaminants to stream.

4. References

Bednarek A. & Zalewski M., 2007. Potential effects of enhancing denitrification rates in sediments of the Sulejow reservoir. Environment protection Engineering. 33/2: 35-43

Callow P. & Petts G.E. (eds)., 1992. The Rivers Handbook. Hydrological and Ecological Principles. Vol.1. Blackwell Science, 526 pp.

Kiedrzyński M. & Kurowski J.K., 2009. Roślinność rzeczywista doliny Sokołówki w Łodzi (na odcinku ul. Zgierska - ul. Żabieniec) - mapa 1: 5 000. Katedra Geobotaniki i Ekologii Roślin UŁ. Actual vegetation of the Sokołówka River valley in Łódź (on part between Zgierska-Żabieniec streets) - map 1: 5 000. Department of Geobotany and Plant Ecology, university of Łódź, Poland.

Kurowski J.K. & Kiedrzyński M., 2009. Komentarz do mapy roślinności rzeczywistej stref ekotonowych doliny Sokołówki w Łodzi (na odcinku ul. Zgierska - ul. Żabieniec). Katedra Geobotaniki i Ekologii Roślin UŁ. 20 str. Comment to the map of actual vegetation of ecotonal zones of Sokołówka River valley in Łódź (on part between Zgierska-Żabieniec streets). Department of Geobotany and Plant Ecology, University of Łódź, Poland. 20 pp

Leopold L.B. & Langbein W.B., 1966. River meander. Scientific American 214: 60-70

Łapińska M., 1996. Przestrzeń jako czynnik limitujący zespoły ryb w rzece nizinnej i wyżynnej. Praca doktorska, Katedra Ekologii Stosowanej, UŁ. Space as a limiting factor for fish communities in lowland and upland river systems. Doctoral Thesis, Department of Applied Ecology, University of Łódź, Poland.

Łapińska M., Zalewski M., Wagner I., Krauze K., Frątczak W. 2010. Ecohydrological bases for Urban River Remediation - Sokołówka River case study. 5th SWITCH Scientific

Conference 2010 Sustainable Water management Improves Tomorrow's Cities' Health: achievements and way forward. Łódź 13-16 October 2010, (poster).

Marzluff J.M., Shulenberger E., Endlicher W., Alberti M., Bradley G., Ryan C., ZumBrunnen C. & Simon U. (eds)., 2008. Urban Ecology: An International Perspective on the Interaction Between Humans and Nature. Springer-Verlag.

Minshall G.W., 1988. Stream ecosystem theory: a global perspective. Journal of North American Benthological Society 7:263-288

MRRT (Manual of River Restoration Techniques). 2002. The River Restoration Centre, Silsoe, Beds, MK45 4DT Great Brittain. Web edition: www.therrc.co.uk/rrc_manual_pdf.php

Rocha J., (ed.). 2004. URBEM - Urban River Basin Enhancement Methods. New techniques for urban river rehabilitation - Incorporation of wetlands, floodplains and sustainable urban drainage methods into urban schemes. Recommendations. Work Package 8. EVK-CT-2002-00082, October 2004, Report 8.2. www.urbem.net

Walsh J.Ch., Fletcher T.D., Ladson A.R. 2005. Stream restoration in urban catchments through redesigning stormwater systems: looking to the catchment to save the stream. Journal of North American Benthological Society 24(3):690-705

Ward J.V. & Wiens J.A., 2001. Ecotones of riverine ecosystems: role and typology, spatio-temporal dynamics, and river regulation. Ecohydrology & Hydrobiology 1:25-36

Water Framework Directive. 2000. (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy). OJL 327, 22 December 2000, pp. 1-73.

Zalewski M., Bis B., Frankiewicz P., Łapińska M., Puchalski W. 2001. Riparian ecotone as a key factor for stream restoration. Ecohydrology & Hydrobiology 1(1-2):245-251

Zalewski M., Puchalski W., Frankiewicz P., Bis B. 1994. Riparian ecotones and fish communities in rivers - Intermediate Complexity Hypothesis. In Cowx I.G. (ed.) Rehabilitation of Freshwater Fisheries. Fishing News Books, Oxford, pp. 152-159.

Zalewski M., Wagner I., Łapińska M., Krauze K., Frątczak W. 2009. Ekohydrologiczne podstawy renaturyzacji rzeki Sokołówki. Załącznik 18 str, W: Zawilski M, Sakson G., Wierzbicki P. Koncepcja przebudowy koryta rzeki Sokołówki na odcinku od zbiornika Zgierska do przepustu pod Aleją Włókniarzy. Projekt dla Wydziału Gospodarki Komunalnej, Urzędu Miasta Łodzi (umowa 342/74/2009), 37 str. Ecohydrological bases for Sokołówka River restoration. Annex 18 pp. In: Zawilski M, Sakson G., Wierzbicki P. Concept of Sokołówka river channel reconstruction on part from Zgierska street up to culvert at Włókniarzy Avenue. 37 pp.

Zalewski M. & Welcomme R. 2001. Restoration of sustainability of physically degraded fish habitats - The Model of Intermediate Restoration. Ecohydrology & Hydrobiology 1(3): 279-282. Special Issue: Ecohydrology as a Tool for Restoration of Physically degraded Fish Habitats.

Zawilski M, Sakson G., Wierzbicki P. 2009. Koncepcja przebudowy koryta rzeki Sokołówki na odcinku od zbiornika Zgierska do przepustu pod Aleją Włókniarzy. Projekt dla Wydziału Gospodarki Komunalnej, Urzędu Miasta Łodzi (umowa 342/74/2009), 37str. Zawilski M, Sakson G., Wierzbicki P. 2009. Concept of Sokołówka river channel reconstruction on part from Zgierska street up to culvert at Włókniarzy Avenue. 37 pp.