DE GRUYTER OPEN

EUROPEAN SPATIAL RESEARCH AND POLICY

Volume 22 2015 Number 1

10.1515/esrp-2015-0016

Elżbieta KOBOJEK[*]

ANTHROPOGENIC TRANSFORMATION AND THE POSSIBILITY OF RENATURALISING SMALL RIVERS AND THEIR VALLEYS IN CITIES – ŁÓDŹ AND LVIV EXAMPLES

Abstract. Rivers used to serve important functions in the development of cities, and river valleys are a part of the urban space. Regardless of several centuries of anthropogenic influences large rivers and their valleys have remained the dominant elements of the cityscape. In the case of small rivers and valleys the situation has been different. The expansion of urban infrastructure often led to an elimination of rivers and their valleys from the developed area. In many cases rivers were directed down straightened concrete ditches and sometimes the locations of their channels were changed altogether. In the city centre, rivers were locked in underground channels, i.e. they vanished from the cityscape. Urban floods, so annoying for the inhabitants, usually occur within river sections which have been utilized intensively and covered with impermeable surface. Even though a river was hidden in underground interceptor pipes, a valley dip remains still accumulating rainfall. The aim of this article is to present the extent of transformation of small rivers and valleys within two large cities located on watersheds: Łódź and Lviv, and the contemporary utilization and the possibility of renaturalising them.

Key words: small river in the city, anthropopressure, urban flood, rivers valley management.

1. INTRODUCTION

Rivers used to serve important functions in the development of cities and river valleys are a part of the urban space. Regardless of several centuries of anthropogenic influences large rivers and their valleys have remained the dominant elements of the cityscape. Extensive valley floors, steep slopes and flat uplands right next to them defined the directions of spatial expansion.

[*] Elżbieta KOBOJEK, Łódź University, Faculty of Geographical Sciences, Department of the Built Environment and Spatial Policy, 31 Kopcińskiego St., 90-142 Łódź, Poland, e-mail: elakobojek@onet.eu

Flood prevention has always been a top priority but no one has ever tried to remove a river from the urban space. In the case of small rivers and valleys the situation has been different. The expansion of urban infrastructure often led to an elimination of rivers and their valleys from the developed area. In many cases rivers were directed down straightened concrete ditches and sometimes the locations of their channels were changed all together. In the city centre, rivers were locked in underground channels, i.e. they vanished from the cityscape. In extreme cases people even forgot about their existence and every time there is an areal flood, people are surprised and ask about what caused it. Urban floods, so annoying for the inhabitants, usually occur within river sections which have been utilized intensively and covered with impermeable surface (streets, squares, roofs). Even though a river was hidden in underground interceptor pipes a valley dip remains still accumulating rainfall. Overland flow in cities is higher (comparable to that of mountainous areas) because the sealed surface does not allow almost any infiltration. That is one of the major problems in anthropogenically transformed valleys within a city (Schmitt *et al*., 2004; Postnote, 2007; Zevenbergen *et al.*, 2010; Kundzewicz and Kowalczak, 2014).

In recent years there have been attempts to recreate the richness of the hydrological network to retain overland flow, improve the quality of the environment and the landscape. Renaturalization of a stream is a complex set of procedures, activities, building and maintenance actions and natural processes whose goal is to recreate the natural condition or close to natural condition of a river which had been engineered within existing limitations (Biernat, 2007; Czoch *et al*., 2010; Bańkowska *et al*., 2010). The large group of systemic renaturalization activities carried out in river valleys can be divided into the following priority areas: creating protective zones free of any business infrastructure for the streams; gradual reclaiming of floodplains by excluding them from intensive usage and, if possible, removal of business infrastructure; using floodplains to recreate the vertical distribution of the river (meanders, oxbows, islands); improving landscape feature of the stream. Renaturalization of rivers has several spatial, technical, legal-administrative, economic and natural limitations (Żelazo and Popek, 2002). Therefore the initiatives undertaken in cities are usually of the revitalization type where the goal is to recreate the ecological functions of streams by improving water quality and recreating the properties influencing the life and growth of various organisms. Such actions do not change the morphological features of the valley.

The aim of this article is to present the extent of transformation of small rivers and valleys within two large cities: Łódź and Lviv, and the contemporary utilization and the possibility of renaturalising them. In natural conditions, drainage zones displayed a richness of springs, wetlands, small streams and short rivers. Expanding cities gradually absorbed new streams and valleys and more and more area was being covered with impermeable material which had an influence on the functioning of the river network. Currently both cities have similar problems with surface water and are seeking ways of reintroducing rivers into the urban space.

2. SCOPE OF STUDY AND METHODS

The study was conducted in two cities located on drainage divides. Lviv is located on the main European drainage divide of the Baltic and the Black Sea divides whereas Łódź on the divide between the Vistula and the Oder drainage basins. The cities have similar populations but are different in terms of area. Lviv has nearly 766,000 inhabitants and occupies 171 sq. km whereas Łódź has 725,000 inhabitants and occupies an area of 293 sq. km. Both cities are located in temperate climate zones with annual precipitation of 715 mm in Lviv and 650 mm in Łódź (Mucha and Wawer, 2010; Wibig, 2011). They also have distinctive city centres with very dense building distribution and a considerable share of artificial, impermeable areas.

The natural river network and the stages of its transformations were presented based on the analysis of historical and contemporary maps and literature. In the case of Łódź, maps published between late 18th century and mid-20th century as well as studies regarding the construction of factories and industrial plants were extremely useful (Puś, 1987; Rosin, 1989; Janik *et al*., 2012). Old photographs and designs for engineering the Łódka releazed by the Water and Sewage Company in Łódź have also been used. The information regarding the river network in Lviv were collected on the basis of maps from various periods of the city's development published in an atlas from 2012 (Shabliy, 2012).

The contemporary utilization of valleys, water problems and the scope of renaturalization works of rivers in Łódź is presented on the basis of urban survey conducted in 2013 and previous long-term observations and analysis of studies and designs for the drainage basins of the Bzura and the Sokołówka (Kujawa *et al*., 2003). The observations of the utilization of river valleys in Lviv were conducted in 2010.

3. VALLEYS AND RIVERS IN ŁÓDŹ

Łódź is located in the Vistula and the Oder drainage basins with the drainage divide running through northern and eastern parts of the city (figure 1). The local river network is composed of numerous small streams. Customarily, twenty streams running through the city are referred to as rivers (average annual flows from 0.01 to 0.7 m^3/s). Additionally, there are 36 named streams and many more smaller unnamed ones (Wierzbicki *et al*., 2010). The majority of the rivers have their springs at the foot of a hill located in the NE part of the city. The lengths of rivers within city limits vary from 12.5 to 22.5 km. The remaining streams measure in total between 2.8 and 7.5 km.

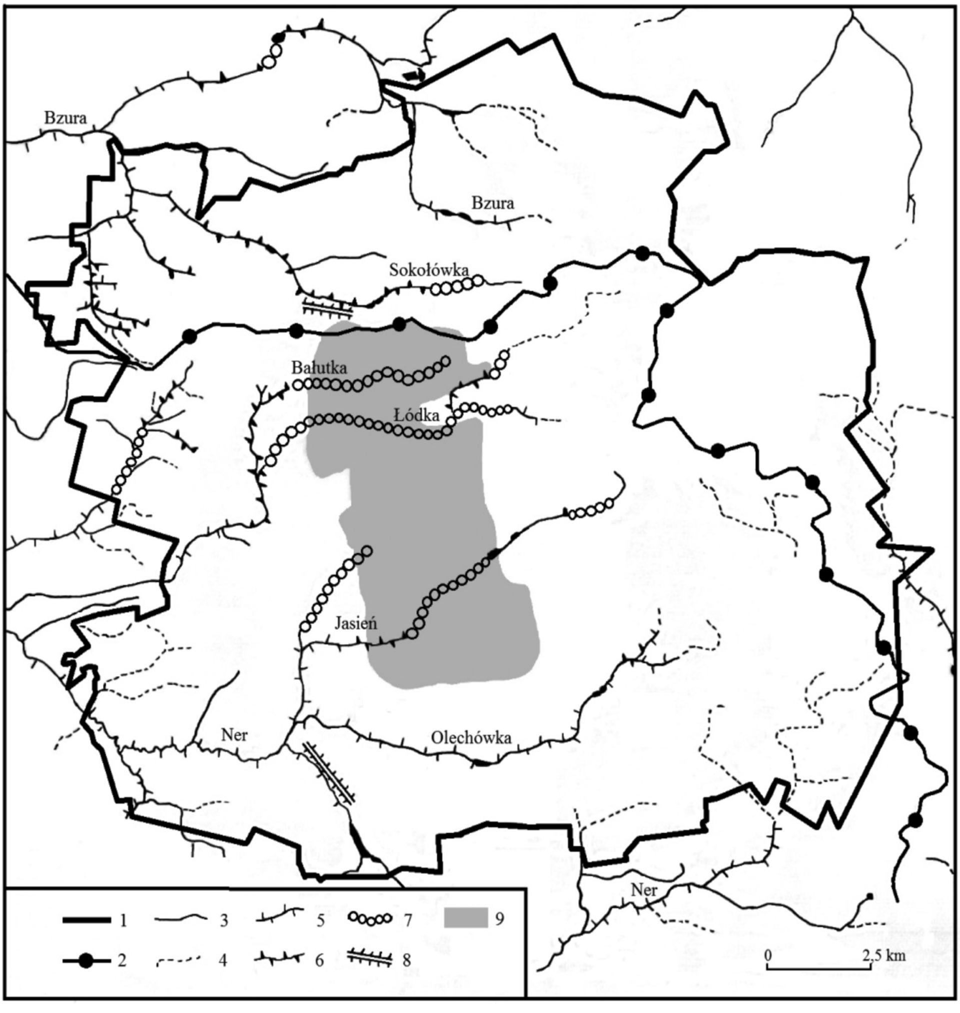

Fig. 1. Surface waters and river channel engineering methods in Łódź
1 – urban boundary, 2 – the watershed of the Vistula and the Oder, 3 – rivers, 4 – seasonal water-courses, 5 – regulated rivers, organic riverbank consolidation, 6 – regulated rivers, concrete riverbank consolidation, 7 – river in the underground canals, 8 – embankment, 9 – compact built-up downtown area
Source: author's elaboration based on Bieżanowski (2001), Jokiel and Maksymiuk (2002), Kobojek (2013)

In their natural state, Łódź rivers were narrow (1–2 m) and not too deep (0.3–1 m) but they featured high gradients of 4–8‰ (Koter, 1988). The valleys changed along their courses. Upper sections of the rivers flowed in deep narrow valleys with steep slopes and had the highest gradients. In today's city centre, the valleys became wider, their slopes became gentler and their gradients more even. In the western part of today's Łódź rivers formed wide valleys floors where they meandered and formed backwaters after spring thaws. Obviously the most convenient location for urban development was in the middle section (Kobojek, 2013).

The oldest part of the town was built in the 15th century within the flat area at the feet of Łagiewniki Hills. When in the early 19th century the idea arose to build a centre of textile industry in Łódź, its proponents emphasized the availability of surface waters (rivers and springs) among other advantages of the location. Rivers were used in weaving shops and their clean waters were a vital resource for manufacturing textiles. During the construction of industrial complexes, small rivers did not pose a significant technical problem which is why, if necessary, their fragments were moved and their former channels were buried. Today, this poses a significant problem in wet years. It is often the case that intensive showers result in water running through cellars according to the former natural channel. The introduction of the steam engine in 1839 in factories and the ongoing urban development of the city resulted in turning the rivers into sewers. The construction of a city sewage system did not start until 1925. The system utilized river channels as discharge routes for residential and industrial waste water together with rainfall collected through street outlets. In time, considerable sections of the rivers running through the dense city centre were directed through underground channels and vanished from the cityscape (figure 1). They remain underneath the streets or developed areas (figures 2, 3).

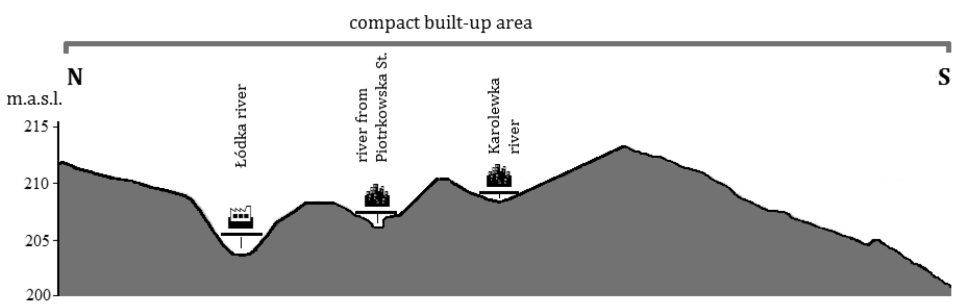

Fig. 2. Rivers valleys in a hypsometric profile of the centre of Łódź in longitudinal distribution
A factory was built within the axis of the valley of the Łódka in 19th century
The stream valleys from Piotrkowska Street and the former springs
of the Karolewka were covered and developed with buildings
Source: author's elaboration

Fig. 3. A former factory and now the Manufaktura shopping centre was built within the bottom of the Łódka valley, river, channel in the underground canals
Source: photograph by E. Kobojek

The channels of two rivers with the strongest connection with Łódź (the Łódka and the Jasień) have also undergone considerable transformation. 15.6 km out of 20 km of the Łódka's total length remains within city limits. In its upper section, the river flows through a trapeze ditch in a clearly defined valley but soon enters a covered channel built in 1931 only to emerge later down its course (figures 4, 5). In the city centre it again runs in a covered channel, sections of which were built in 1917 and 1967, for 5.3 km (Bieżanowski, 2001). It re-emerges only in the Józef Piłsudski Park in the western part of the city but runs through an engineered concrete channel. Until the 1930s the area of the park was one of the wettest and during spring thaw one of the most often flooded sections of the valley. Construction works in the park started in 1927. The wetland area of the valley was buried and hardened and sections of the channel were moved by a few dozen metres. The designers used low-lying elements of the relief and created a complex of park and recreation ponds. Today, it is the biggest city park in Łódź.

The Jasień was one of the most important rivers of industrial Łódź. Its entire course (12.6 km) falls within city limits. In early 19th century the depth of the river reached 1.15 m and the gradient in the upper section was 8‰ (Koter, 1988). In 1825 new textile plants were established along the Jasień which used the river's water for manufacturing processes but after the introduction of the steam engine in 1839 the river became less useful (Jaskulski, 1995). Within a few years the

Fig. 4. Straight, regulated part of the river in the park
Source: photograph by E. Kobojek

Fig 5. Pond within the bottom of the Łódka river valley in the municipal park
Source: photograph by E. Kobojek

Jasień became a stream collecting street waste water. Data from 1860 showed that the river's depth decreased to 30–40 cm and its spring moved west by 1 km (the river became shorter). In the final decade of the 19th century Scheibler's factory was established directly on the channel of the Jasień. The river ran underneath the factory floor enabling discharge of waste water. Its channel was dislocated outside the factory and directed through a covered channel as late as in the 1960s. Today, the Jasień is an engineered stream for discharging rainfall. A part of it runs through a covered channel and its lower section through an engineered and reinforced channel (figure 1).

Old streams function in the city centre only during infrequent surface supply and discharge of storm water system. Additionally, as a result of intensive exploitation of groundwater, their levels decreased considerably (up to a few dozen metres) which in turn resulted in the disappearance of various springs and small streams which used to combined into large groups and cut through hill sides. Transformations of the streams spurred changes in the valleys. Lower, wetland parts of the valleys were buried and hills were levelled which resulted in levelling of the surface. No evidence of many of the buried streams can be found today within the cityscape, in the case of some there are only a few low-lying areas.

Rivers and valleys located at the outskirts of today's city have been transformed the least. The valley of the Ner in the south of the city was urbanized relatively late because of a big distance from the expanding factory settlements. Engineers built ponds with a total area of 11.5 ha which soon became a major attraction of the inhabitants. Today, the spring area of the Ner in SE part of the city lost its natural character and some sections of its channel are only used for discharging rainfall. Yet, further down, the river meanders and its banks are overgrown with rich plant life. The river valleys in the northern part of the city, in an area with the most diverse relief, neither were engineered.

There are two types of floods in the city. Typical high water level due to overflowing rivers occurs mainly in the lower sections of rivers in the outskirts of the city. The larger area of the city with insulated surface is threatened with city floods resulting from exceptionally high rainfalls. Significant communication problems occurred often during extreme rainstorms as a result of large pools in the city centre which always occur in the same locations. Problems usually arise at the intersections of streets located within the axes of valleys buried in the early 20th century. Large pools also form at the intersection of Strykowska and Wojska Polskiego Streets (figure 6). This node was built within the axis of the valley of the Łódka and there are hills descending exactly towards the valley's axis. In 2013 a flood storage pond was constructed underneath the intersection.

City floods in Łódź are mainly a result of: inability to discharge excess rainfall because of drainless dips with sealed floors; too few street inlets; too small diameters of some culverts and engineered channels. The sewer system can efficiently decrease the degree of flooding only when it works properly and if it corresponds to water discharge rates. Therefore, it is necessary to properly distribute street inlets and recreate retention properties of city streams to limit unfavourable hydrological events.

Fig. 6. The intersection located on the floor of the Łódka valley
Source: photograph by E. Kobojek

In recent years, actions were taken towards recreating retention properties of the valleys and improving the city's ecological conditions. There are no plans for extracting channels from underneath the city centre and renaturalization is being conducted on valleys located outside of the area. The works mainly include recreation and appropriation of reservoirs as Łódź rivers used to have many mill ponds. The Sokołówka, which measures 13.4 km, was the first river where the works were started. Its environment was anthroponegically transformed to a lesser extent. The plan for its renaturalization included the formation of 11 reservoirs of 0.1 to 2 ha (6 already operate) and 8 meanders (Kujawa *et al.*, 2003). Two dry reservoirs will receive flood waves during rainstorms. Their goal was to provide a basis for extending the residential district and equipping it with a rainfall discharge system. The programme may have a positive influence not only through increasing the retention properties of the drainage basin but also by increasing the naturally active area located near residential areas. Additionally, it will provide new areas for relaxation for the inhabitants.

The valleys of the Bzura and the Łagiewniczanka are some of the least transformed forms in the city. Neither of the rivers has been engineered for discharging water from the city rainfall sewer system. This in combination with the fact that the drainage basin has low degree of sealing is why the authorities are planning to build infiltration ditches which will discharge excess rainfall water. Gradually seeping through the soil it will gravitationally supply the river further on. This will improve retention and increase the share of underground supply in the total water balance. Locations which require the construction of traditional rainfall interceptors will receive wetlands at their outlets. Those are sedimentation-filtration structures which work as small waste treatment plants. There is also a plan to conduct natural regulation of the upper section of the Bzura. The plan will include corrections of longitudinal gradients at sections with gradient over 5‰. To do that the constructors will build 20–30 cm high wooden-stone partitions with added individual boulders. This will result in impoundment and improvement of water air saturation which will intensify self-purification processes. It has been suggested to assign the Bzura and the Łagiewniczanka the status of ‘small stream reserve in suburban areas’.

4. RIVERS AND VALLEYS IN LVIV

Lviv is located on the main European drainage divide which runs almost directly through the centre of the city south-eastward from the north (figure 7). Many springs where streams originate are located at the feet of the hills where the divide developed. A major portion of those springs is located in the south-eastern part of the city. The Poltva River, which runs towards the north-east, and the Zubra, which runs towards the south, are the main rivers of Lviv. Other streams present in Lviv maps are defined as brooks (Kobzjak and Mielnik, 2012). Within the city there are two wide valley formations: the valley of the Poltva in the central and north-eastern part of the city and the Bilohorska dale in the western part (figure 8) as well as a series of narrow valleys of streams which run southward.

The centre of Lviv is located in the dale of upper Poltva, surrounded by three hills 100-metre high (figure 9). The 1,100-metre-wide dale floor is flat and it used to be marshy and boggy.

The Poltva served a very important defensive and economic function between the 13th and the 18th centuries which is why its natural course was changed early. The moat of the mediaeval city was already partly supplied using the Poltva. Its channel was moved eastward. The Ortysha, a right-bank tributary of the Poltva, disappeared from the cityscape already in the 15th century after it was transformed into a moat surrounding the south-eastern part of the city.

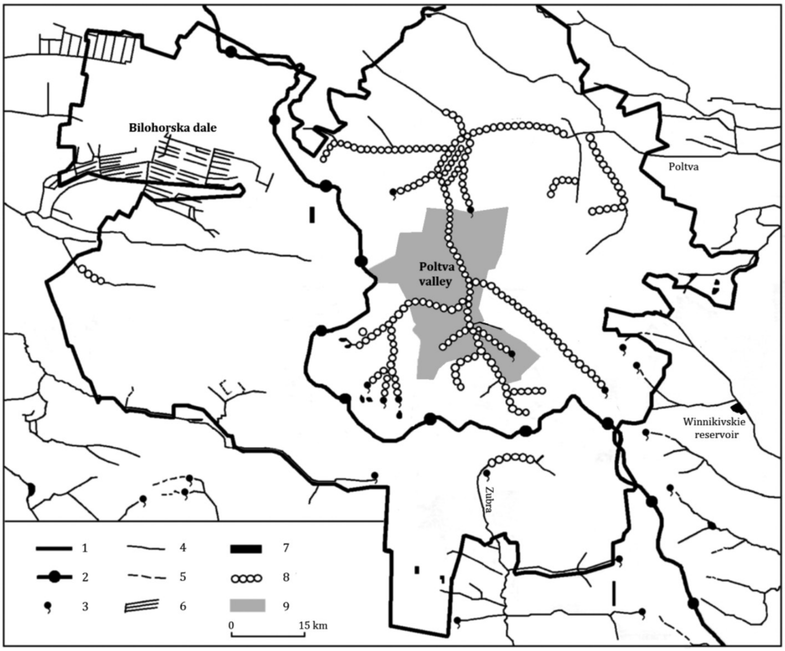

Fig. 7. River network in Lviv
1 – urban boundary, 2 – the main European watershed of the Baltic Sea and the Black Sea, 3 – springs, 4 – rivers, 5 – seasonal water-courses, 6 – drainage ditches, 7 – artificial ponds, 8 – river in underground canals, 9 – compact built-up downtown area
Source: author's elaboration based on Kobzjak and Mielnik (2012)

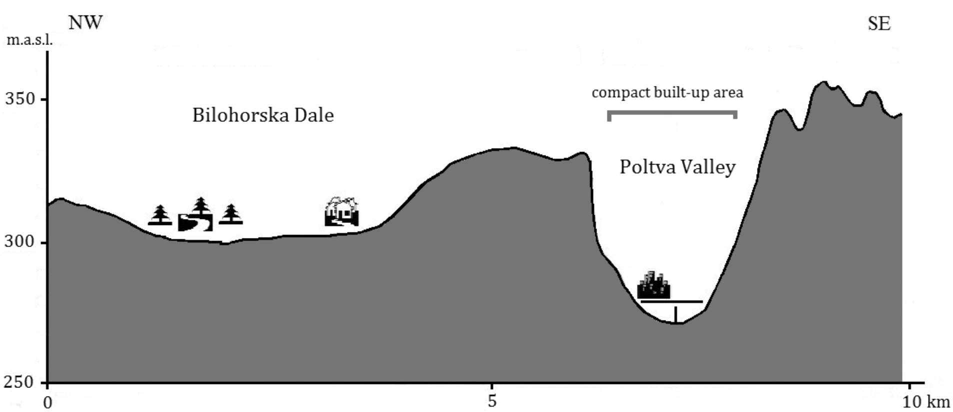

Fig. 8. Lead hypsometric elements in Lviv
The Poltva in the centre of the city is hidden in an underground canal and its valley is densely built-up; the Bolihorska dale in the eastern part has low urban density and its western part is mostly occupied with city green areas
Source: Source: author's elaboration

Fig. 9. The centre of Lviv located in the valley of upper Poltva
Source: photograph by E. Kobojek

As the longitudinal gradient of upper Poltva is high reaching 13‰ in its first kilometre, several mills operated on that section for many centuries. Most of them were removed already at the turn of the 19th century. Even bigger changes occurred in late 19th century as the river was included into the city sewer system and it was hidden in an underground interceptor for 15 km while streets were built above on the surface (Lylo and Lylo-Otkowicz, 2005). The underground river flows even today underneath Shevchenka Ave. (former Akademicka Street) and Freedom Ave. The shape of the Mickiewicz Square is a remnant of the old channel of the river. There it would divide into two channels and form a small island. In consecutive years more sections of the Poltva and its tributaries were directed underground within the limits of the developing city. Formerly marshy valley was dried, new surface was laid and channels dislocated. The centre of Lviv no longer features any river and the valley has been completely built up (over 90% of the area). The building of the Lviv Opera was also built in the valley of the Poltva, parts of it even in the river's old channel (figure 10). In 1900 the river rushed into the theatre's cellars flooding the engine room. There was an actual threat that the building might tilt and collapse, fortunately the structure was strong enough. The river re-emerges only in the north-eastern part of the city. Its discharge levels have been lowered by 80% as the

Fig. 10. The bulding of the Lviv Opera was built in the valley of the Poltva
Source: photograph by E. Kobojek

water is used by residential and industrial complexes. Normally, the Poltva discharges only 400–500 l of water per second but up to 60,000 l/s during rainstorms.

In the north-western part of the city there is a marshy wide low-lying area called the dale of the Bilohorski Brook filled with peat. It is now dehydrated by a system of drainage ditches (figure 7). The surface is partly occupied by a forest complex but in its eastern part there is a new complex of single-family houses being built. The dale includes the largest number of endangered hygrophytes plants from the red book of Ukraine (Zagulskiy *et al*., 2012).

The part of the city near the divide was rich in small natural and artificial reservoirs (figure 11). In the 16th century in Lviv there were 40 ponds but the number decreased in the following centuries. In the mid-19th century there were 20 ponds and only a few at the turn of the 20th century. Some of the former ponds were built up or drained which is why they gradually lost their retentive and recreational functions. In recent years some of them have been renovated (e.g. the fountain in the Stryiski Park) or restored (the fountain in front of the Opera house within the river's axis). The Vynnykivske Lake flood storage pond on the Marunka is the largest water area in direct vicinity of Lviv's eastern border.

The rivers and valleys in the centre of Lviv have undergone considerable anthropogenic transformation. Should the Poltva be brought to the surface, it would change the entire landscape of the old town. It would be necessary to separate river

Fig. 11. Pound in the Stryiski Park
Source: photograph by E. Kobojek

and rainfall waters and construct a new storm water system. Such a project would be expensive and it would require a reconstruction of the city's public transport system as the city's thoroughfares run directly over the channel. It seems that the only solution today would be to improve the quality of discharge in the river. Valleys at the outskirts of the city which have undergone lesser transformations have higher natural chances. Partly protected green areas are being designed there. The biggest green area is to be created in the dale of the Bilohorski Brook and in the spring section of the valley of the Zubra (Krupa and Dubina, 2012). Unfortunately the plans do not take into account to improve the ecological quality of the surface section of the Poltva in the NE part of Lviv.

5. CONCLUSIONS

Revitalization of river valleys in cities is an extremely difficult task. That mainly applies to valleys of small rivers which have undergone considerable anthropogenic transformations and have been built up with various structures.

Studies show that regardless of human influence river valleys are a place where the most valuable ecosystems have remained. However, the costs of revitalising the valleys are often too high for city budgets. The implementation of revitalization activities also faces many obstacles as ecological aspects are often in conflict with economic needs. Usually, a project whose goal is to extract a river from its underground canal means narrowing communication routes and protests from the residents. There are some good examples of revitalizations of river areas in cities around the world but it is difficult to find one model of revitalization as all cities are different. Therefore, it is necessary to look for individual solutions. Revitalization of valleys should be treated as a contemporary stage of evolution of river valleys in cities which consists of reintroduction of their natural functions and strengthening the bond between the city and the river. Projects should mainly depend on the size and type of the valley, the degree of transformation and the role within the city fabric. In some cases, the only option is to improve the purity of the water. Renaturalization processes of valleys cannot only focus on the natural aspect. They also need to consider the urban development, economic, social and cultural aspects. Revitalization activities should be preceded with extensive natural and historical studies, assessment of the influence on specific elements of the cityscape and the city's functioning.

The examples of Łódź and Lviv indicate that it is not possible to reveal the entire small river, which now serves the role of a sewer, within a dense city centre. However, it is possible to improve the valleys in the outskirts as that is where the most valuable and diverse environment with the highest ecological potential has been preserved.

Disorganized developments which usually result in permanent degradation of natural and sometimes even landscape assets still pose a significant threat for valley environments. Even those small river valleys attract developments. Sometimes marshy parts of flood plains are covered with additional material and become a place where new houses are being built.

Renaturalization processes belong to long-term tasks, which sometimes can be started with marking river courses which are now hidden in underground interceptors in maps of city centres. It is necessary to re-inform people about the river and the valley and inform them about the results of overbuilding them in the city. Today, reliable knowledge and efficient exchange of information between the authorities and the society is becoming a good starting point for making even difficult and costly decisions.

REFERENCES

BAŃKOWSKA, A., SAWA, K., WASILEWICZ, M. and ŻELAZO, J. (2010), 'Analiza barier i ograniczeń w renaturyzacji rzek i dolin', [in:] WIĘZIK, B. (ed.), *Prawne, administracyjne i środowiskowe uwarunkowania zagospodarowania dolin rzecznych*, Bielsko-Biała: Wyższa Szkoła Administracji, pp. 97–119.

BIERNAT, S. (2007), 'Rewitalizacja dolin rzecznych w miastach', *Prace Komisji Krajobrazu Kulturowego PTG*, 7, pp. 255–265.

BIEŻANOWSKI, W. (2001), *Łódka i inne rzeki łódzkie*, Łódź: Towarzystwo Opieki nad Zabytkami, Oddział w Łodzi, ZORA.

CZOCH, K., KULESZA, K. and WALCZYKIEWICZ, T. (2010), 'Renaturyzacja i rewitalizacja rzek i potoków jako element zrównoważonego rozwoju dolin rzecznych', [in:] WIĘZIK, B. (ed.), *Prawne, administracyjne i środowiskowe uwarunkowanie zagospodarowania dolin rzecznych*, Bielsko-Biała: Wyższa Szkoła Administracji, pp. 121–136.

JANIK M., KUSIŃSKI, J., STĘPNIEWSKI, M. and SZAMBELAN, Z. (2012), *Łódź na mapach 1793–1939*. Łódź and Warszawa: Wydawnictwo Jacek Kusiński.

JASKULSKI, M. (1995), *Stare fabryki Łodzi*, Łódź: Towarzystwo Opieki nad Zabytkami, Oddział w Łodzi, ZORA.

JOKIEL, P. and MAKSYMIUK, Z. (2011), 'Hydrology', [in:] LISZEWSKI, S. (ed.), *The Łódź Atlas*, Łódź: Łódź City Council, map IX.

KOBOJEK, E. (2013), 'Environmental Determinants of Development and Physiography of Łódź', [in] HABREL, M. and KOBOJEK E. (ed.), *Lviv and Łódź at the Turn of XXth Century. Historical Outline and Environmental Determinants of Urban Development*, Łódź: Łódź University Press, pp. 111–132.

KOBZJAK, P. and MIELNIK, I. B. (2012), 'Hydrographic Network', [in:] SHABLIY, O. (ed.), *Lviv. Complex Atlas*, Kyiv: Kartographia.

KOTER, M. (1988), 'Warunki naturalne', [in:] ROSIN, R. (ed.), *Łódź. Dzieje miasta*, vol. 1, Warszawa and Łódź: PWN, pp. 18–56.

KRUPA, P. I. and DUBINA, W. I. (2012), 'General Layout of Development of Lviv till 2025', [in:] SHABLIY, O. (ed.), *Lviv. Complex Atlas*, Kyiv: Kartographia.

KUJAWA, I., ZALEWSKI, M. and ZAWILSKI, M. (2003), *Projekt generalny rzeki Sokołówki*, Łódź: Wydział Gospodarki Komunalnej UML, AQUA PROJEKT s.c.

KUNDZEWICZ Z. W. and KOWALCZAK, P. (2014), 'Urban Flooding and Sustainable Land Management – Polish Perspective', *Prace Ekorozwoju – Problems of Sustainable Development*, 9 (2), pp. 131–138.

LYLO, I. and LYLO-OTKOWICZ, Z. (2005), *Spacer Lwowem*, Kyiv: Baltia Druk.

MUCHA, B. P and WAWER, J. (2010), 'The Role of Terrain Relief, Buildings and Green Spaces in the Diversification of Lvivs Local Climate', *Miscellanea Geographica*, 14, pp. 111–119.

POSTNOTE (2007), 'Urban Flooding', July, www.parliment.uk/documents/post/postpn289.pdf (3.12.2014).

PUŚ, W. (1987), *Dzieje Łodzi przemysłowej*, Łódź: Muzeum Historii Miasta Łodzi.

ROSIN, R. (ed.), (1998), *Łódź. Dzieje miasta,* Warszawa and Łódź: PWN.

SCHMITT, T. G., THOMAS, M. and ETTRICK, N. (2004), 'Analysis and Modeling of Flooding in Urban Drainage System', *Journal of Hydrology*, 299, pp. 300–311.

SHABLIY, O. (ed.), (2012), *Lviv. Complex Atlas*, Kyiv: Kartographia.

WIBIG, J. (2011), 'Annual Precipitations in Łódź in 1931–1998', [in:] LISZEWSKI, S. (ed.), *The Łódź Atlas*, Łódź: Łódź City Council, map X.

WIERZBICKI, P., WAACK-ZAJĄC, A. and KOŚKA, T. (2010), 'Układ hydrograficzny miasta Łodzi', *Zeszyty Naukowe Politechniki Łódzkiej, Budownictwo*, 61, pp. 145–156.

ZAGULSKIY, M. M., KAGALO, O. O. and SENTSHINA, B. W. (2012), 'Plants Species from the Red Book in Ukraine', [in:] SHABLIY, O. (ed.), *Lviv. Complex Atlas*, Kyiv: Kartographia.

ZEVENBERGEN, C., CASHMAN, A., EVELPIDOU, N., PASCHE, E., GARVIN, S. and ASHLEY, R. (2010), *Urban Flood Management*, London: CRC Press, Balkema.

ŻELAZO, J. and POPEK, Z. (2002), *Podstawy renaturyzacji rzek*, Warsaw: Wydawnictwo SGGW.