10.2478/v10066-012-0004-9

ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN–POLONIA

VOL. LXVII, 1 SECTIO B 2012

Maria Curie-Skłodowska University in Lublin, Faculty of Earth Sciences and Spatial Management
Department of Hydrology

ZDZISŁAW MICHALCZYK, KATARZYNA MIĘSIAK-WÓJCIK,
JOANNA SPOSÓB, MAREK TURCZYŃSKI

The hydrological consequences of human impact in the Lublin Region

Hydrologiczne konsekwencje antropopresji na obszarze Lubelszczyzny

ABSTRACT

The Lublin Region is an area where local transformations in the natural environment, including the hydrosphere, occur. They result from the impact of agriculture, industry as well as water supply and sewage disposal. These activities lead to changes in the water network resulting from land improvement works, channel straightening and water runoff acceleration, as well as to the formation of local, both point and diffuse sources, of water pollution. The consequences of human impact are manifested in local transformations of the quality or quantity of water resources. As a result of intense groundwater draw-off, hydrogeological conditions are transformed, which is reflected in the persistence of depression cones of varied size and depth, noticeable in the vicinity of water intakes for Lublin, Chełm, Zamość and Kraśnik. The lowering of the first-level groundwater table also occurs as a consequence of the drainage of chalk and marl mine workings in Chełm and Rejowiec, whereas in the area of the hard coal mine both shallow and deep groundwater was transformed. It is important to indicate the consequences of human impact changes of water conditions as the hydrosphere resources should be used according to the principles of sustainable development.

Key words: water conditions, water management, land improvement works, human impact, Lublin Region

INTRODUCTION

Human activity leads to many changes in the natural environment, including the hydrosphere. These changes are both quantitative and qualitative and are caused by the direct use of water resources – water intakes and transfers, reservoir retention, coal mine drainage and land amelioration, or they result from indirect activities such as land use changes or river channel improvement. Although agricultural land use is predominant, various effects of economic activity can be seen in the Lublin Region, which also cause changes in the water conditions. It is very important to recognise the consequences of the changes during the period of economic transformation in the region. Hydrosphere resources should be used according to the principles of sustainable development.

RESEARCH AREA, AIM AND MATERIALS

The research area referred to as the Lublin Region is regarded as being located on the same territory as the Lublin Province, which is situated in the middle-eastern part of Poland. It has an area of 25,122.5 km^2 and is located in the middle of the interfluve between the Vistula and Bug Rivers, with a population of 2,160 million people. Physiographically, it is situated on the borderland between Eastern and Western Europe. In terms of surface relief, land-use structure and landscape, the Lublin Region can be divided into three zones (Chałubińska, Wilgat 1954): the northern, lowland zone (parts of Mazovia, Polesie and Podlasie), the middle, upland zone (the Lublin Upland and Roztocze) and the southern, lowland one (part of the Sandomierz Basin). These regions vary in terms of geological structure, surface relief, soil cover, climatic and hydrographic conditions and, consequently, landscape conditions (Wilgat 1968).

The Lublin Province has one of the lowest urbanisation rates in Poland, with 46.6% of the population living in 42 towns (*Statistical Yearbook*…, 2011). It is an agricultural area with a high predominance of agricultural land, especially in its upland part, where there is fertile soil made from loess and loess-like deposits as well as rendzina. Weak podzolic and pseudopodzolic soils developed on the sands, which are mostly wooded and are predominant in the lowland areas of the northern and southern part of the Lublin Region. The forest area constitutes only 22.6% of the region.

This article is based on field data collected during the second half of the 20th century in the archives of the Hydrology Department at Maria Curie-Skłodowska University (UMCS). The materials were complemented with data from the Institute of Meteorology and Water Management about river discharges, water quality documents obtained from the Voivodeship Inspectorate of Environmental Protection as well as data from the Central Statistical Office concerning water management. Very important information was obtained from industrial plants and institutions dealing with water supply and management.

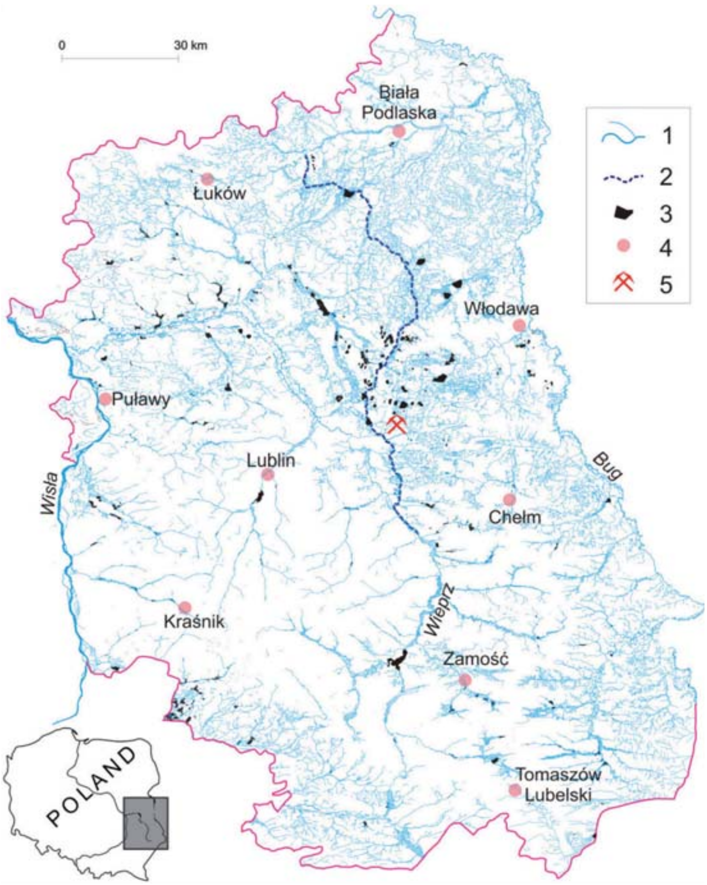

Fig. 1. Water network of the Lublin Region. 1. Water network, 2. Wieprz-Krzna Canal, 3. Lakes and water reservoirs, 4. Selected towns, 5. Bogdanka Coal Mine

WATER CIRCULATION CONDITIONS

The Lublin Region's climate has continental features which are manifested in temperature contrasts between the summer and winter, long summers and winters and high insolation. The region's water resources mostly come from precipitation and from the upper parts of the Vistula and Bug River catchments. Roztocze is an area with the highest feeding, with total annual rainfall exceeding 650 mm (Kaszewski 2008). The northern, lowland area and the upland Bug River areas have a rainfall of less than 550 mm. Evapotranspiration is not largely varied, and its annual value is estimated at approx. 450 mm (Jaworski 1968).

The Lublin Province's water network density is much varied. The density in the Lublin Upland and Roztocze is the lowest in Poland. The hydrographical network in the Łęczna-Włodawa Lake District and in the Dorohucza Depression is one of the most dense in Poland (Fig. 1). Apart from a natural and artificial runoff network – a drainage ditch system – there are over 70 water bodies in the Lublin Province which are deemed to be natural lakes. The lakes are small and are mainly situated within the Łęczna-Włodawa Lake District. The biggest one, Uściwierz, has an area of 284 ha, whereas the deepest one, Piaseczno, reaches 38.8 m. There are only two lakes – Białe Włodawskie and Piaseczno – with a capacity higher than 10 mln m^3. Several natural lakes have been converted into retention reservoirs as part of the Wieprz-Krzna Canal's system.

The western and eastern borders of the province are marked by the Vistula and the Bug Rivers (Fig.1). Their resources and regime are formed outside the Lublin Region. The Wieprz River crosses the middle of the interfluve between the Vistula and the Bug River and the whole of its basin is situated in the researched area. In the years 1951–2005, specific runoff from the Lublin Region was only 3.95 $dm^3 \cdot s^{-1} \cdot km^{-2}$, in the lowland part its value was 3.48 $dm^3 \cdot s^{-1} \cdot km^{-2}$, and in the upland part 4.13 $dm^3 \cdot s^{-1} \cdot km^{-2}$. During an average year the runoff from the Lublin Province area amounts to nearly 100 $m^3 \cdot s^{-1}$ of water. In a dry year it goes down to 50 $m^3 \cdot s^{-1}$, whereas in a wet year it exceeds 190 $m^3 \cdot s^{-1}$ (Michalczyk, Sposób 2011). The Vistula, which surrounds the province in the west, carries approx. 470 $m^3 \cdot s^{-1}$ of water, and the Bug River, which flows in the east, carries approx. 57 $m^3 \cdot s^{-1}$ of water. Surface water resources, except for boundary rivers, are small and show high seasonal and annual variability. The structural deficiencies of water used for the purposes of agricultural production occur in the lowland, i.e. northern part of the province (Wojciechowski 1965).

Hydrogeologically, the northern part of the Lublin Region belongs to Podlasie and the Mazovian Plain. Groundwater occurs in porous Tertiary and Quaternary deposits, and at deeper levels it is connected to a Cretaceous water body (Malinowski 1984; Michalczyk, Wilgat 1998). The groundwater table usually occurs at a depth of several metres. The abundance of first-level groundwater is low. Larger amounts of water can be taken from deeper water-bearing layers related to the Tertiary and Cretaceous deposits. Although the areas are intensely drained, waterlogged ground occurs locally.

The Lublin Upland and Roztocze belong to the hydrogeological Cretaceous area of the Lublin Region. The main water-bearing layer is formed by Upper Cretaceous deposits, and only locally by Tertiary or Quaternary deposits. The water is of high quality and is highly abundant. The yield of some springs in the river valleys of the regions is very high (Michalczyk 2001). Except for the river valleys, a first-level water table occurs at large depths. The Cretaceous water reservoir is intensely exploited at the local level, especially in the area of Lublin. In recent years, approx. 88 mln m^3 of groundwater has been withdrawn annually.

In the southern part of the province, which constitutes a part of the Sandomierz Basin, the usable groundwater level occurs in varigrained Quaternary deposits lying on Tertiary krakowieckie clays (the Podkarpacie hydrogeological region).

TRANSFORMATION OF WATER CONDITIONS

Human economic activity leads to environmental transformations whose effects, whether intended or unintended, show up later. The most important ones can be classified into:

- Hydrographic changes in undrained regions

Undrained basins occur in the Lublin Region in several areas. A majority of them is situated in the karst limestone rocks of the Chełm Hills and the Dorochucza Depression. Most undrained regions have been connected to river catchments through drainage ditch systems.

The Łęczna-Włodawa Lake District is especially prone to the transformation of water conditions. Originally, areas without surface runoff covered 463 km^2 of the Łęczna-Włodawa Lake District, which amounts to 43% of the subregion. Approximately 4,190 of such water bodies were identified here. The largest ones, with an area of more than 5 km^2, altogether covered 259.7 km^2 (56% of the undrained basins' area). Depressions larger than 2 km^2 constituted ¾ of the total area of undrained basins (Sposób, Turczyński 2009). The process of transformation of closed drainage basins is continued with varied intensity. In the last 200 years, undrained basins were connected to the runoff network, thus forming the catchments of watercourses which are nowadays called rivers (Bobrówka, Piwonia, Upper and Middle Włodawka, Krzemianka and Tarasienka). In the central part of the lake district area which encompasses Polesie National Park and its protection zone, for several years works have been carried out with an aim to close undrained basins and to restore their natural water circulation. Similar works were carried out on smaller water bodies in Sobibór Landscape Park. Such activities, especially those conducted in the south-western part of the Łęczna-Włodawa Lake District, can be thwarted by the expansion of black coal mining.

- Changes in the water network and land amelioration works

The transformations in the hydrographical network were related to attempts to drain the vast wetland in the northern part of the region. The changes were less connected with the use of the energy of flowing water. Dams were constructed in river channels, and there were numerous water wheels powered by ponded water. Such activities were carried out, e.g. in the area of Włodawa and the Włodawka River's valley, where part of the valley was converted into a pond in the early 19th century (Fig. 2). In the first part of the 19th century and in the early 20th century, the area of the reservoir was approx. 130 ha and the water object was a predominant feature of the Włodawa landscape. Prior to the Second World War, the pond was divided into several narrow and overgrown ponds.

Another example of human interference with the water network is what happened in the area of Lejno (Fig. 3), where one of the largest lakes (approx. 134.5 ha) of the Łęczna-Włodawa Lake District was located until 1861. As a result of drainage works (to create new meadow areas), what was left of the water body was only a small part of a reservoir called Kahiża [from the Polish word *kałuża* which means a "puddle"] which had an area of 6.1 ha and which appears occasionally. Connecting of the catchment with the Wieprz-Krzna Canal's system led to the lake's disappearance in the late 20th century (Mięsiak et al. 2005).

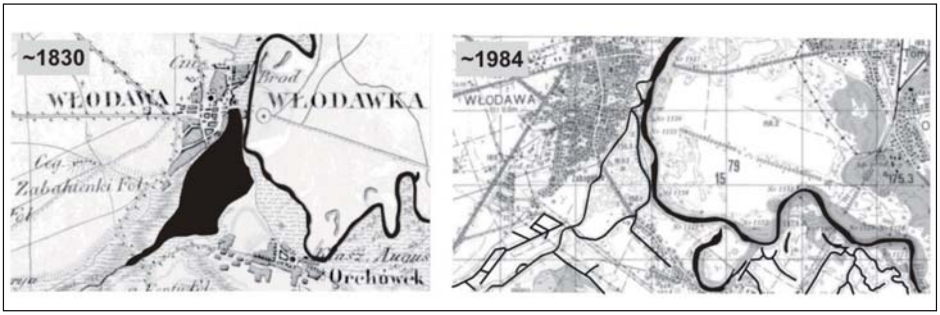

Fig. 2. Changes in the water network in the area of Włodawa (about 1830 and 1984) (Sposób et al. 2010)

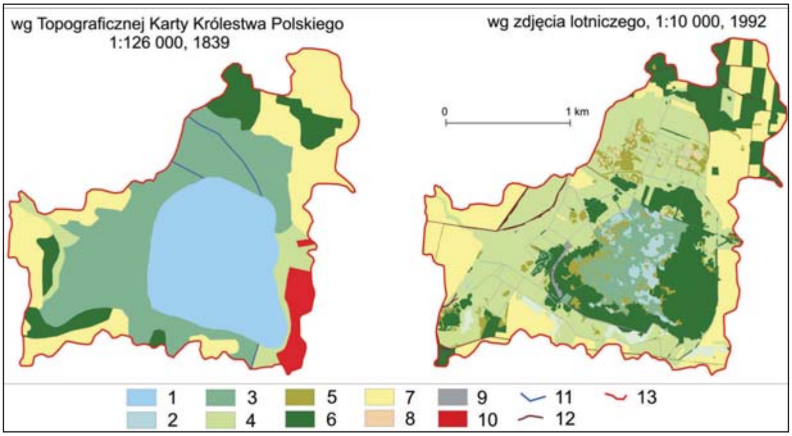

Fig. 3. Changes in water conditions in the Lejno marsh's catchment in 1839 and 1992 (Mięsiak et al. 2005), acc.to the Topographic Chart of the Kingdom of Poland from 1839, and acc. to aerial photography from 1992; 1. lake, 2. bog, 3. marsh, 4. meadow, 5. shrubs, 5. forests, 7. arable land, 8. peat-pits, 9. banks, 10. land development, 11. drainage ditches, 12. roads, 13. water divide

Basic and specific land improvement works concerning water aim both at irrigation and drainage. In principle, such works should not deplete the hydrosphere's resources, but research shows that land amelioration works can significantly contribute to the depletion of shallow water resources and thus to the overdrying of the green areas of Polesie.

Specific land improvement works concerning water comprise: natural watercourses, artificial drainage and irrigation streams with channel beds that are 1.5 m wide in the lower course, pipelines of less than 0.6 m in diameter, levees on irrigated land, drainage, sprinkling machines with portable pumps, fish ponds, etc. In total, improved land in the Lublin Province covers an area of 318 thousand ha, which constitutes 5.0% of such land in Poland (Table 1). A large majority of arable land is drained (over 124 thousand ha) and only 0.3 thousand ha is irrigated. Dewatering prevails on meadows and grazing land. Of 167.1 thousand ha, only 47.3 thousand ha were irrigated, and the remaining area was dewatered (including 30.3 thousand ha – *via* drainage).

Basic land improvement works comprise: constructing and exploiting of retention reservoirs, building large channels carrying water to land improvement systems, constructing barrages and weirs, embankments, water intakes and pumping stations. The length of regulated rivers and channels in the Lublin Province is almost 4,900 km, with 3,470 km of rivers. It represents 6.6% and 8.6% respectively, of the total length of rivers and channels in Poland (Table 2). It should be emphasised that the usable storage capacity of the Lublin reservoirs retaining water for the purposes of agriculture is over 66 mln m^3, which constitutes nearly ¼ of such capacity in Poland.

Table 1. Area of improved arable land in Poland and in the Lublin Province – as of 31 December 2009 (*Environmental Protection,* 2010)

	In total		Arable land			Meadows and grazing land		
			in total	incl.		in total	incl.	
	thousand ha	% of the total area of arable land		drained areas	irrigated areas		drained areas	irrigated areas
			thousand ha					
Poland	6420.9	39.8	4630.3	3981.8	47.8	1790.6	400.9	364.4
Lublin Region	318.0	20.1	150.9	124.2	0.3	167.1	30.3	47.3
% share in Poland	5.0		3.3	3.1	0.6	9.3	7.6	13.0

Table 2. Basic land improvement works in Poland and in the Lublin Province – as of 31 December 2009 (*Environmental Protection,* 2010)

	Rivers and channels		Levees		Usable capacity of water reservoirs dam^3	Dewatering pumping stations	
	length	incl. regulated rivers	length	protected area thousand ha		number	impact zone thousand ha
	km						
Poland	74060	40411	8492	1093.3	270109	585	598.7
Lublin Region	4876	3477	199	27.3	66433	23	18.9
% share in Poland	6.6	8.6	2.3	2.5	24.6	3.9	3.2

The total length of channels and feeding channels in the Lublin Province is 409.7 km. The length of irrigation channels of the Wieprz River's catchment is 255.30 km in total, with the main channels amounting to 224.88 km, and small ones – to 30.42 km. In the Bug River's catchment, the length of channels is 151.40 km, and in the direct catchment of the Vistula River it is 3 km (*Water Management Programme…*, 2003). Irrigation channels were mainly built in the north-eastern part of the province, which is the most threatened with water shortage. The feeding channels are aimed at carrying water from the Wieprz-Krzna Canal to retention reservoirs or to lakes performing the same function, e.g. Białe Sosnowickie and Czarne Sosnowickie.

The Wieprz-Krzna Canal, which is 139.9 km long, is the longest canal in Poland and has been operating since 1961. It connects the middle course of the Wieprz River with the waters of the Krzna Południowa. To meet its water needs, in the years 1976–2007 approx. 3 $m^3 \cdot s^{-1}$ of water on average was taken from the Wieprz River in Borowica (Michalczyk 1988; Michalczyk, Wilgat 1998). The canal's impact zone covers 3,770 km^2 (15% of the province area). Due to considerable technical equipment degradation, the canal fulfils its role as an object for irrigating and retaining water only to a small extent. This can be seen from the usage analysis of water drawn into the Wieprz-Krzna Canal in the years 1993–2007, which is as follows: the feeding of reservoirs 38.9%, feeding of ponds 30.9%, watering of grassland 3.1%, losses 27.1%. The distribution of water from the canal over the area of the Łęczna-Włodawa Lake District has changed the qualitative features of the hydrosphere in the western part of the subregion (Janiec 1994).

- Retention

In the Lublin Region there are 202 man-made reservoirs (*Water Management Programme…*, 2005), the majority of which (92 objects) are located in the Wieprz

River's catchment. The most numerous group of retention reservoirs (160) is made up of waterholes, ponds and other water bodies that are small in area and volume ($V<0.2$ hm³). Two reservoirs were created as a consequence of the damming of rivers: Zalew Zemborzycki was formed on the Bystrzyca River and has a volume of 6.3 mln m^3, and Nielisz was formed on the Wieprz River and is 19.84 mln m^3 in volume (Pichla, Jakimiuk 2008). Retention reservoirs in the Wieprz-Krzna Canal's system play an important role in water management in the Lublin Region; these are reservoirs created on lakes: Dratów, Krzczeń, Skomielno, Wytyckie, and reservoirs constructed at the turn of the 1960's and 1970's, i.e. Zahajki (1968), Mosty (1969), Opole (1970) and Żelizna (1971) in the northern part of the province.

The retention capacity of the main catchments in the region is estimated at approx. 250 hm^3, however, its use for practical purposes is slight and amounts to 22% of the estimated value on average. This situation is to be improved as a result of constructing the Oleśniki reservoir, which is 32 mln m^3 in volume, on the Wieprz River, as well as creating 41 next, smaller water objects, each having a volume of 100 thousand m^3.

Also, a new, separate strategy for water management in the areas with the highest water deficiency is to increase retention capacity. *Water Management Programme for the Lublin Province* (2003, 2005), apart from storing water, aims to slow down its circulation. Constructing small reservoirs (of up to 5 mln m^3) and complementary equipment (e.g. weirs and gates) is planned, as well as is phytomelioration – tree-planting, afforestation and the protection of marshes and waterholes. Altogether, it is projected that 236 new, small and medium-sized water reservoirs will be built, of a total volume amounting to approx. 120,000 m^3, and 123 damming structures and other complementary objects. Supplementary works will include irrigation, restoration of reclaimed land and the creation of new, ecological areas.

The level of development of hydro-power engineering in the Lublin Region is one of the lowest in Poland. The hydropower capacity of rivers (excluding the Vistula and the Bug Rivers) are estimated at 707.22 GWh (3% in Poland). In the province there are 17 operating water power stations which have a capacity of up to several hundred kilowatts. Most of them use the existing damming equipment, which was built-in mainly for retention, amelioration and breeding purposes. The majority of such objects are located in the catchment of the Wieprz River, and power plants which have the largest installed capacity are situated in Nielisz (max. 370 KW), Tarnogóra (max. 200 KW) and Zwierzyniec (132 KW). Altogether, 13 power plants operating on the Wieprz River and its tributaries produce 1,155 KW, which constitutes 87% of the total water power generated in the region. The location of the existing power plants refers to the old watermills formerly situated in this area.

WATER SUPPLY AND SEWAGE DISPOSAL

The surface water of the Lublin Province is prone to quantitative changes and chemical composition transformation caused by water withdrawal, drop of sewages and the inflow of waters from waste disposal sites that are often located in river valleys. Approximately 97 mln m^3 of surface water has been drawn-off for production purposes in recent years on an annual basis, of which as much as 87.5 mln m^3 is withdrawn annually by the Puławy Nitrogen Plant. In total, approximately 366 mln m^3 of surface water and groundwater is drawn annually for the purposes of the national economy and population, of which 163 mln m^3 is used for irrigation annually.

For municipal purposes only groundwater is used, of which 87.7 mln m^3 is exploited annually. The water-pipe network in the Lublin Province is 18,900 km long and it supplies water to 339 thousand buildings. Urban water mains serve 941.5 thousand users, which amounts to 93.8% of the urban population. Annual water usage by households *per capita* equals 32.1 m^3 for the Lublin Region (Environmental *Protection,* 2010).

Surface water and groundwater, once withdrawn and used, is returned to rivers in the form of sewage and industrial effluents in a quantity of 150 million m^3, including 77 mln m^3 of cooling water annually. The length of the sewage network is 4,100 km, with connections to 94 thousand buildings. Nearly 86% of the urban population uses the sewage network (*Environmental Protection,* 2010). The situation is much worse in rural areas, where, in some communes, the length of the sewage network is insufficient. Part of the raw sewage is discharged from rural areas directly into the rivers. This is disadvantageous, especially during low-flow periods. In 2010 municipal and domestic sewage was treated in 290 municipal and communal sewage treatment plants. The largest quantities of sewage were carried into the power treatment plants in Lublin, Zamość, Chełm, Puławy and Biała Podlaska.

THE CONSEQUENCES OF GROUNDWATER EXPLOITATION

Water supply for the inhabitants of the Lublin Region as well as for most industrial plants is based on groundwater. In the vicinity of groundwater intakes, hydrogeological conditions are being transformed, which is reflected in the forming of persistent depression cones of different sizes and depths. The effects of intense exploitation of groundwater in the area of municipal intakes for Lublin and Chełm as well as Zamość and Kraśnik are particularly visible. The lowering of the first-level groundwater table is also caused by the drainage of chalk and marl mine workings in Chełm and Rejowiec. In the vicinity of the Bogdanka Coal Mine, transformations occur in both shallow- and deep-level waters. The area and depth of local depression cones both depend on the quantity of the exploited groundwater and the amount of precipitation.

The intense exploitation of groundwater in the area of Lublin led to the lowering of the water table level in the city and in the neighbouring areas (Fig. 4). For many years the Lublin depression cone has been getting deeper and larger, and its maximum area (201 km^2) was recorded in 1992 (Michalczyk 1997). Since 1993 it has been slowly refilling, and its area has become smaller. In the last decade (2001–2010), the water table level was lowered on the area of 120 km^2. Relatively small and shallow depression cones continue to exist near water intakes in Zamość, Kraśnik, Łęczna, Tomaszów, Hrubieszów, Bychawa, and Bełżyce.

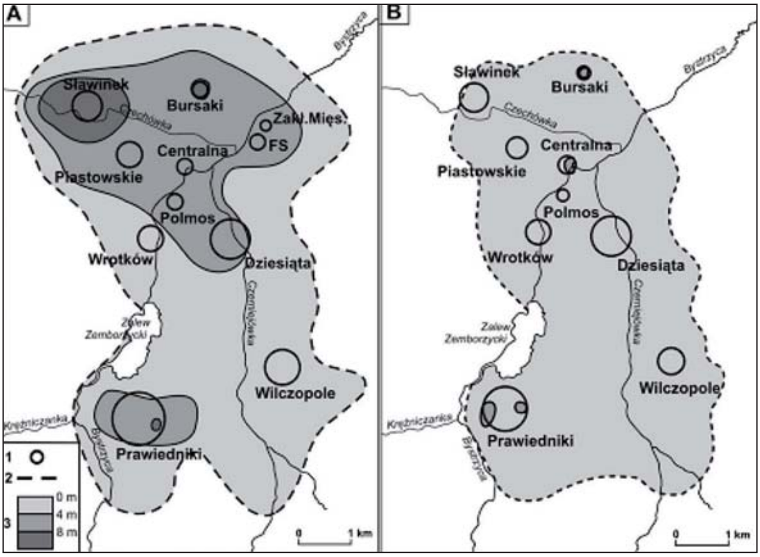

Fig. 4. The area of the depression cone and the amount of groundwater table level lowering in Lublin (Michalczyk 2005). A. in the years 1955–1995, B. in the years 1955–2004; 1. intakes and the amount of groundwater intake (symbol area = 2,000 m^3·d^{-1}, 2. areas of lowered water table level, 3. amount of groundwater table level lowering

A local depression cone formed around the municipal and industrial water intakes for Chełm in the late 1980s. It covered an area of 60 km^2. In the 1990s, further significant changes took place in the water circulation conditions. Limiting water draw-off solely to the cement plant's area, the shutdown of many industrial water intakes and the lowering of water draw-off led to a contraction of the depression cone's area by half (Fig. 5). A smaller and shallower depression sink is situated in Rejowiec Fabryczny, where groundwater that circulates in Upper Cretaceous marls is exploited for the purposes of the cement plant and the drainage of its exploitation hollow.

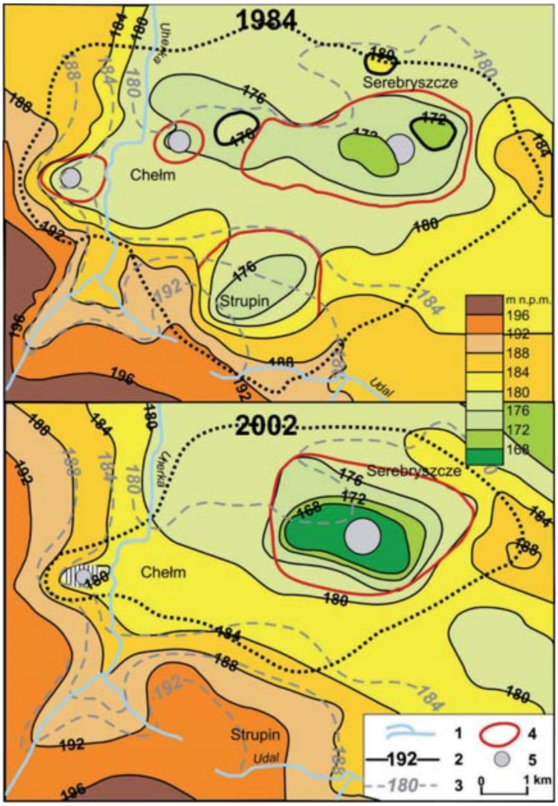

Fig. 5. Location of the water table in the area of Chełm (Michalczyk 2003). A – in 1963 and 1984, B – in 1963 and 2002; 1. rivers, 2. water-table counters, 3. water-table counters in 1963, 4. impact zone of water intakes, 5. lowering of the groundwater table level by over 4 m, 6. draw-off of groundwater – symbol's area represents 2,000 $m^3 \cdot d^{-1}$

Considerable transformations in water conditions occur around shafts and water intakes in the area of the Bogdanka Coal Mine (Wilgat et al. 1991, Michalczyk, Zarębski 1995, Michalczyk et al. 2007). The surface features are transformed as a result of hard coal caving. As a consequence, subsidence basins and flood lands are formed, e.g. "Nadrybie" and "Szczecin" (Fig. 6), with areas of 20.3 ha and 150 ha respectively, which mainly change due to varied water inflow. In the area of subsiding ground, the conditions of the occurrence and circulation of waters change. A lowering of the usable level of groundwater table led to a change in the hydraulic gradients and a relocation of underground watersheds, and, as a result, to a change of the river and lake catchment areas. In order to ensure safe conditions for coal exploitation, pressure of the waters of the Carboniferous and Jurassic strata should be lowered. Their exploitation resulted in the persistence of very deep depression cones in both water-bearing strata. Mine water, which has higher mineralisation values, is discharged into the Świnka River, which causes changes in the natural composition of waters, especially in low-flow periods.

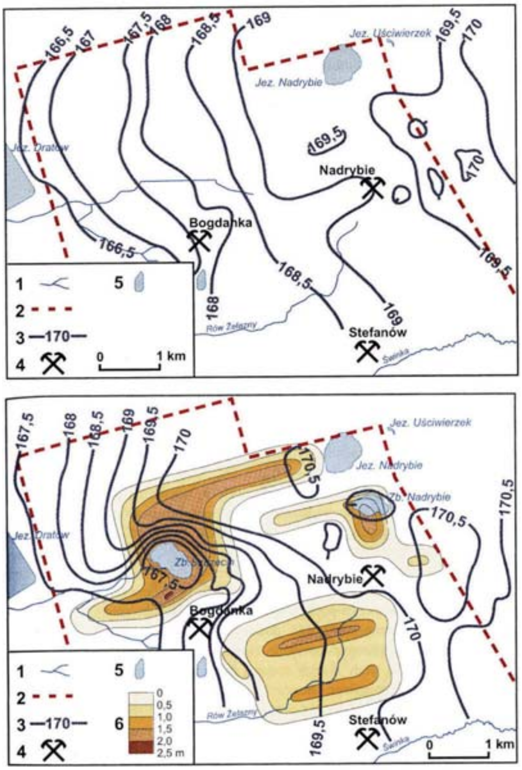

Fig. 6. Changes in water conditions in the area of the Bogdanka Coal Mine in 1984 and 2006 (Michalczyk et al. 2007). 1. river network, 2. mining land's area, 3. water-table counters, 4. mine-shafts, 5. natural and man-made water reservoirs, 6. ground lowering

THE QUALITY OF SURFACE WATER AND GROUNDWATER

The quality of surface water and groundwater is shaped by human activity. Pollutants flow from diffuse, point and linear sources. On agricultural land, mostly diffuse pollution sources occur due to the imprudent usage of fertilisers and plant protection agents. Sewage and post-treatment wastewater discharge sites, as well as septic tanks, are point sources of pollution. Raw sewage discharged from rural households directly to rivers or the aeration zone pose a large problem for the Lublin Region, which is caused by insufficient sanitation of the rural areas. There are considerable discrepancies between the length of water-pipe network and that of the sewage network in rural areas (8:1). In towns, the disparity is lower (3:1) (*Report*…, 2011).

According to the currently applicable provisions, the quality of surface water is presented by means of five classes (I–V); there are also additional indications of a lower-than-good state or potential. Among the Lublin Region's rivers that are monitored, most watercourses are class III in terms of ecological criteria, which denotes a medium quality.

Of the four lakes in the Lublin Region that were examined in 2010, two, namely Białe Włodawskie and Kleszczów, were of the highest quality. Both in 2010 and in the previous years (2008, 2009), particular indices or lake waters in total were classified as meeting the highest class I or II – excellent or good quality (*Report*…, 2011). Good water quality was identified in Wspólne and Uścimowskie lakes, however, in the latter, the total nitrogen value standards were exceeded.

In 2010, the quality of groundwater was measured in 61 points. In the majority of cases the water met the criteria for class III – which means it is of satisfactory quality (65.5% of all measurement points). In 7 sites, class V was registered – which denotes bad quality water (11.5%). No excellent quality – or class I – waters were reported (*Report*…, 2011).

Firm actions aimed at preventing groundwater and surface water pollution as well as quantitative protection of its resources determine the proper functioning of the environment and further satisfying of water needs in the province.

***

The area of the Lublin Province stands out in Poland for its small surface water resources and its relatively large resources of good-quality groundwater. The extent of transformation of water conditions is still relatively small, mainly due to the region's agricultural character. Large groundwater resources and their high quality create an opportunity for the rational management of environmental resources, including the incredibly valuable water and peat-bog ecosystems. Considerably large parts of Polesie – lakes and wetlands – as well as vast river valleys have been included in the Natura 2000 network and are covered by various environmental protection measures. Furthermore, there are numerous natural groundwater outflows, i.e. springs, mainly located in river valleys, which are unique in hydrological, environmental and cultural terms. It should be noted that economic activity creates local problems related to the maintenance of a high-quality natural environment. The province's resources, which vary spatially, make it necessary to implement resource-efficient water management and to prevent negative changes in the hydrosphere in terms of the quantity and quality of water as well as its circulation system. The conflicts which arise about the use of water for municipal, industrial, mining, agricultural and environment-protection purposes require that carefully weighed decisions be taken, and in compliance with the EU Water Directive.

REFERENCES

Chałubińska A., Wilgat T., 1954: *Physiographic Division of the Lublin Province*. The 5th National Meeting of the Polish Geographical Society – Guide, Lublin, 3–44 (in Polish).

Environmental Protection, 2010, Central Statistical Office, Warsaw, 126–210 (in Polish).

Janiec B., 1994: *The Influence of the Wieprz-Krzna Canal on Transferring Pollution into the Water Environment*, [in:] *The Natural Environment in the Wieprz-Krzna Canal's Impact Zone*. The University of Life Sciences Publishing House, The Free Polish University Society, Lublin, 59–68 (in Polish).

Jaworski J., 1968: *Spatial Variability of the Average Annual Evapotranspiration in Poland*. Papers of the Polish Institute of Hydrology and Meteorology, 95, 15–28 (in Polish).

Kaszewski M. B., 2008: *Climatic Conditions of the Lublin Region*. The Maria Curie-Skłodowska University Publishing House, Lublin, 1–60 (in Polish).

Malinowski J., 1984: *Utility Water*, [in:] *Mineral Resources of the Middle-Eastern Poland*. Geological Publishing House. Warsaw, 197–211 (in Polish).

Michalczyk Z., 1988: *Impact of Water Intake to the Wieprz-Krzna Canal on the Flow Rate of the Middle Course of the Wieprz River*. Geographical Documents, 4, Wrocław, 39–50 (in Polish).

Michalczyk Z., (ed.), 1997: *Strategy for the Use and Protection of Water in the Bystrzyca's Basin. Hydrographic Research as the Source of Knowledge about the Environment*, Vol. 5. The Maria Curie-Skłodowska University Publishing House, Lublin, 1–192 (in Polish).

Michalczyk Z., (ed.), 2001: *Springs of the Lublin Upland and Roztocze Region*. The Maria Curie-Skłodowska University Publishing House, Lublin, 1–298 (in Polish).

Michalczyk Z., 2003: *State of Water Conditions and their Changes in the Area of Chełm*, [in:] *Man and Water*, T. Szczypek, M. Rzętała (eds.). The Polish Geographical Society Publishing House, Katowice Branch, Sosnowiec, 91–100 (in Polish).

Michalczyk Z., 2005: *Hydrogeological Consequences of Human Impact in the Area of Lublin*, [in:] *Hydrogeology of Urbanised and Industrialised Areas*, Vol. 2. Papers of the Earth Sciences Department of the University of Silesia No. 37. The University of Silesia Publishing House, Sosnowiec, 113–120 (in Polish).

Michalczyk Z., Chmiel S., Chmielewski J., Turczyński M., 2007: *Hydrological Consequences of the Exploitation of Hard Coal Deposits in the Area of Bogdanka (Lublin Coal Basin)*. Newsletter of the Polish Geological Institute, 422, 113–126 (in Polish).

Michalczyk Z., Sposób J., 2011: *Water resources of Poland and their state in Lublin district*. The Archives of the Commission of Protection and Formation of the Natural Environment, Lublin, 8, 104–111.

Michalczyk Z., Wilgat T., 1998: *Water Conditions in the Lublin Region*. The Maria Curie-Skłodowska University Publishing House, Lublin, 1–167 (in Polish).

Michalczyk Z., Zarębski K., 1995: *Water Exchange in the South-Western Part of the Łęczna-Włodawa Lake District – in the Area of the "Bogdanka" Coal Mine*, [in:] *Contemporary Problems in Hydrogeology*, Vol. 7, part 2. Kraków–Krynica. The AGH (Mining and Metallurgy) University of Science and Technology, 119–126 (in Polish).

Męsiak K., Turczyński M., Szwajgier W., 2005: *Environmental Transformations in Lake Lejno Catchment Basin*. Limnological Review, 5, 175–182.

Pichla A., Jakimiuk S., 2008: *The Strategy for the Development of Water Retention of the Lublin Province in Comparison with Poland*, [in:] *Selected Problems in Water Retention*, J. Gliński, Z. Michalczyk (eds). The Maria Curie-Skłodowska University Publishing House, Lublin, 51–60 (in Polish).

Report on the State of the Environment in the Lublin Province in 2010. Environment Monitoring Library, Lublin, 2011, 20–62 (in Polish).

Sposób J., Turczyński M., 2009: *Transformation of undrained areas into catchments of imposed water circulation – Łęczna–Włodawa Lake District*. [in:] *Water Resources and their Protection*, The Circulation of Water and Matter in River Catchments, R. Bogdanowicz, J. Fac-Beneda (eds.). Gdańsk, 111–121 (in Polish).

Sposób J., Michalczyk Z., Mięsiak-Wójcik K., Turczyński M., 2010: *Evaluation of Changes of the Use of the Łęczna-Włodawa Lake District Water Resources on the Basis of Historical Cartographic Materials and Chronicles*. [in:] *Changes in Water Conditions in Historical Times,* (eds) A. Kaniecki, A. Baczyńska. Geographical and Geological Studies and Papers, 9. Bogucki Science Publishing House, Poznań, 167–186 (in Polish).

Statistical Yearbook of the Republic of Poland, GUS, Warszawa 2011, pp. 910.

Water Management Programme for the Lublin Province, part 1, 2003. Foundation "Water Expertise Centre", Lublin, 1–269 (in Polish).

Water Management Programme, part 2 and 3, 2005. Foundation "Water Expertise Centre", Lublin, 1–178 (in Polish).

Wilgat T., 1968: *General Hydrogeographical Map of the Lublin Province*, Annales of Maria Curie-Skłodowska University, sec. B, XX, 10, 223–242 (in Polish).

Wilgat T., Michalczyk Z., Turczyński M., Wojciechowski K., 1991: *Łęczna–Włodawa Lakes. Studies of the Documentation Centre for Physiography*, XIX, 23–140 (in Polish).

Wojciechowski K. H., 1965: *Shortages and Surpluses of Water in the Lublin Province*, Annales of Maria Curie-Skłodowska University, sec. B, vol. XVIII, Lublin, 249–263 (in Polish).

STRESZCZENIE

Lubelszczyzna jest obszarem, gdzie zaznaczają się lokalne przekształcenia środowiska przyrodniczego, w tym również hydrosfery. Są one efektem wpływu rolnictwa, przemysłu oraz gospodarki wodno-ściekowej. Ich oddziaływanie prowadzi do zmian sieci wodnej w wyniku melioracji, prostowania biegów rzek, przyspieszania odpływu wody, a także do powstawania lokalnych, punktowych i obszarowych ognisk zanieczyszczeń wód. Konsekwencje antropopresji uwidoczniają się w lokalnych przekształceniach ilości lub jakości zasobów wodnych. Następstwem dużych poborów wody podziemnej są przekształcenia warunków hydrogeologicznych, których odzwierciedleniem jest utrzymywanie się różnej wielkości i głębokości lejów depresyjnych, obserwowanych w sąsiedztwie ujęć Lublina, Chełma, Zamościa oraz Kraśnika. Obniżenie zwierciadła wody podziemnej pierwszego poziomu następuje także w wyniku odwodnień wyrobisk górniczych kopalni kredy i margli w Chełmie i Rejowcu, a w rejonie kopalni węgla kamiennego nastąpiło przekształcenie zarówno płytkich, jak i wgłębnych wód podziemnych. Rozpoznanie konsekwencji zmian antropogenicznych stosunków wodnych jest istotne ze względu na wykorzystywanie zasobów hydrosfery, które powinno być realizowane zgodnie z zasadami zrównoważonego rozwoju.

Słowa kluczowe: stosunki wodne, gospodarka wodna, melioracje, antropopresja, Lubelszczyzna