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The analysis of the impact of small retention on water resources in the catchment

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Abstract

The aim of this study was to analyse the impact of selected small water retention measures on surface and groundwater level in river basins. The study was limited to the analysis of measures like small water reservoirs, restoration of bogs and reconstruction of drainage systems in the river valleys. A few study cases were described.

Dutch SIMGRO numerical model describing the regional surface water and groundwater flow has been used for simulation modelling of different cases.

The result of the study has shown that small retention measures are a good and effective method to increase the ability to retain water in the small river basins. Construction of small water reservoirs and weirs on ditches and creeks and restoration of drained bogs can limit the fast outflow of precipitation and melting water from the catchment.

The study has proved that the small water retention measures can be helpful for flood protection and in decreasing of drought threats in small river basins.

Key words: *drought, flood, reservoirs, river basins, water retention*

INTRODUCTION

Small water retention as a method of storage of water to improve the water balance of small river basins and limit losses originating as a result of excess or lack of water becomes widely acknowledged. It is often stressed that small retention is a combination of technical and non-technical measures restoring the natural retention of small river catchments [MIODUSZEWSKI 2014].

The small water retention has not been clearly defined yet. Usually, it is defined as a group of measures implemented on agricultural and urban areas to decrease the speed of water circulation in the catchment. [WALCZAK *et al.* 1998; KOWALCZAK 2001; MIODUSZEWSKI 1998]. Moreover, it is the uncontrollable retention. The potential water retention capacity of the catchment can be increased but it cannot be controlled on a regular basis as it is possible while water management in multifunctional water reservoirs. The technical methods of small water retention include construction of weirs and reservoirs on ditches and canals to store and rise the water table in the streams and adjacent areas. It is possible to improve the water balance by implementation of special methods of water management on irrigation-drainage systems as well, for example by installing regulated outflow devices.

It is a fact that retention capacity of numerous catchments has decreased because of human activities like urbanization, changes in land use of the catchment, riverbed regulation, drainage systems [GUTRY-

-KORYCKA 2003; ŻBIKOWSKI, ŻELAZO 1993]. For instance, a number of drainage facilities have been established in Polish river valleys without accompanying technical devices allowing irrigation. It has been estimated that in Poland about 2 million hectares of permanent grasslands is equipped with a network of open ditches and most of them are located in lowlands small river catchments [MIODUSZEWSKI *et al.* 1996]. Systems of open ditches cause decrease of groundwater table level within the limits of the object what allows its use for agricultural purposes. Very often, when the catchment is made of permeable geological formations, system of open ditches decreases groundwater table level in the adjacent areas as well. Rapid water runoff from the drainage devices occurs usually during spring period and during the growing season there is not enough water for plants.

The question of how the small water retention measures can replace the so called large hydrotechnics and improve the water balance structure is often asked. Additionally, discussion on the possibility to carry on water management on the drained objects that might allow limiting the rapid water runoff from the catchment contributing to reducing the adverse effects of floods, flooding of farmlands and droughts is very vivid. There is no doubt that a single measure will not influence the water flow regime in a large water course but it can improve water conditions in a limited area. On the other hand, construction of a number of small facilities like weirs and small water reservoirs can cause visible changes in the hydrologic regime.

The analyses of measures and simulation modelling for the selected case studies have been performed to present the influence of small retention on water relations. Authors have limited the analysis to measures like construction of small water reservoirs, restoration of bogs and reconstruction of drainage systems in river valleys.

MATERIALS AND METHODES

Dutch SIMGRO numerical model describing the regional surface water and groundwater flow [QUERNER 1993] has been used for simulation modelling. The model has been widely used in studies carried on in the Institute of Land Reclamation and Permanent Grasslands. It has be subjected to many verification processes based on the field measurements and its usefulness in forecasting changes in water relations resulting from implementation of numerous technical measures and changes in land use in the catchment has been proven. SIMGRO model allows the complex simulation of the regional water flow in the saturation and aeration zones, surface water flow, actual evapotranspiration, water flow in water courses, layers of surface waters and ground waters as a function of atmospheric conditions, indicative evapotranspiration and groundwater intake. The regional model of groundwater flow known as SIMGRO has been made geographically schematic horizontally and vertically. The horizontal scheme allows diversification of land use and type of soil assigned to the nodes what allows spatial diversification of evapotranspiration and humidity in the aeration zone. Numerous subsurface layers are defined for the saturation zone. The detailed description of SIMGRO including all elements of the model is available in many publications [QUERNER 1988; QUERNER *et al.* 2010]. Not only processes connected with the natural water cycle in the catchment but also various forms of human economic activity causing changes of the processes or their intensity can be included in the model. Ability to include different ways of land use and management of surface water resources (variations in the hydrographic network) is particularly important. SIMGRO model operates within ArcView – GIS by using AlterrAqua interface. Geographical information (soil maps, maps of land use, hydrographic network etc.) can be implemented to the model. Modelling results are analysed together with the defined input data.

Forecasting modelling has been performed within greater scientific projects aiming at recognition of water cycle and evaluation of state of the environment as well as selection of measures for preservation of natural values of the catchment. Part of this research has been presented in this publication. It includes the forecasts of the influence of technical measures on water relations. Presented research results concern case studies:
- The Biebrza Central Basin: changes of the hydrographic network,
- The Dzierzbia River: construction of water reservoirs and weirs on water courses,
- The Turośl: water management of the drainage facility,
- Czarna Nowa: water management of the system of open ditches,
- Rów Tartaczny: reconstruction of the network of ditches.

Calculations for the above mentioned objects (catchments) were supposed to define the possibility to achieve impact on water relations as a result of implementation of selected technical measures. The research included the analysis of changes of groundwater table level and flow rate. Influence of variations in the amount of water use on the evapotranspiration as an element of the water balance has been also evaluated in selected case studies.

Calculations for the existing technical infrastructure have been performed for every object. The model has been verified basing on the field measurements of groundwater table level and/or flow rate in the water course. The verified model has been used to perform the scenario calculation of the planned (potential) measures. The analysis has been performed for differences of water levels or flow rates between the zero scenario (the existing conditions) and the planned technical measures.

CASE STUDIES AND RESULTS OF SCENARIO CALCULATIONS

The Biebrza Central Basin. Extensive peat bogs that are a valuable natural peat bogs and swamps complex, one of the largest in Central Europe cover the area. The area of the marginal stream valley called Bagna Biebrzańskie has largely preserved its natural or close to natural character with exceptionally high environmental value [MIODUSZEWSKI *et al.* 1996].

A selected area of the Biebrza Central Basin with the area of ca. 36 000 hectares has been the object of modeling. The area is limited by the Rudzki Channel from the west, the Biebrza River from the south, Czerwone Bagno range from the east and surface watershed below Dręstwo and Tajno lakes from the north (Fig. 1). The hydrographic network on this area has been modified because of construction of a number of channels that aimed at drainage of the valley and its adjustment for agricultural purposes [MIODUSZEWSKI, OKRUSZKO 2012]. Water circulation has been modified and the Jerzgnia River was directed to the Woźnawiejski Channel while the Ełk River has been directed to the Rudzki Channel. This simplified water circulation caused the increased water runoff from the valley resulting in the decrease of groundwater table level and drying of peat bogs. Therefore, at least partial restoration of the historic hydrographic network and water retention in the valley is essential to preserve the natural value of the area.

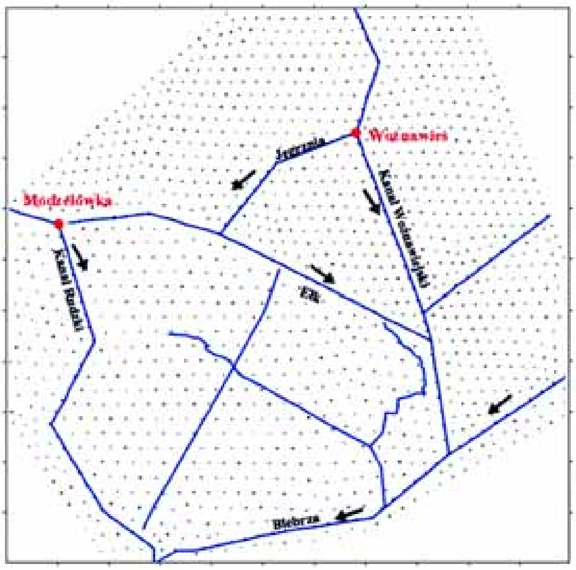

Fig. 1. Hydrographic network system of the study area; source: own elaboration

The simulated restoration measures aiming at recreation of the natural hydrographic system included directing water to its original riverbeds, increase of water level by construction of channels and removal of the existing drainage network and change of land use [MIODUSZEWSKI *et al.* 1996].

It has been assumed that construction of hydrotechnical facilities will allow direction of water to its old riverbeds and limitation of water outflow to the existing drainage channels. In other words, the aim was to increase and use the potential retention of old riverbeds. Construction of damming thresholds, permanent thresholds located on the ordinate 0.2 m below the land surface, was planned as an alternative solution, allowing preservation of high water level in the channels with low water flow.

Calculations were conducted for the weather conditions from years 1995–1996 with the assumption of different damming levels in the Rudzki and Woźnawiejski channels, different flow shares in two hydrographic nodes i.e. Modzelówka Node and Woźnawieś Node. Comparison of the calculation results for scenarios 0 and IV (Tab. 1) was the focus of this publication.

Table 1. Summary of the selected calculation scenarios

Scenarios	Water flow				Thresholds	
	Woźnawieś Node		Modzelówka Node		Woźnawiejski channel	Rudzki channel
	Woźnawiejski channel	Jegrznia	Rudzki channel	Stary Ełk		
0	30	70	30	70	–	–
IV	5	95	5	95	0.20	0.20

Source: own study.

SCENARIO 0 – it describes the natural conditions present in years 1995 – 1996. In this scenario surface water table level in water courses (rivers Ełk, Biebrza and Jerzgnia and channels Woźnawiejski and Rudzki) is consistent with the data from the field measurements. Distribution of water outflow from the Jegrznia River in the hydrographic node in Kuligi was divided in the proportion: 30% of water outflows by the river bed and 70% of water outflows by the Woźnawiejski channel. In the Modzelówka node total water outflow from the Ełk River is directed to the Rudzki channel. Old river bed of the Ełk River does not have connection with the Rudzki channel. This scenario was used only for the verification of the SIMGRO model [ŚLESICKA, QUERNER 1999].

SCENARIO IV – it was assumed that water flow in both hydrographic nodes is almost completely directed to the old river beds of Jegrznia and Ełk. This assumption is close to the complete blockage of both channels (only the flow of 5% of the total inflow volume). Additionally, existence of the damming facilities maintaining water level 0.2 m below the ground surface was assumed to maintain high water level in channels. This scenario reflects the conditions close to the ones that existed before the reconstruction of the historic (natural) hydrographic network i.e. before construction of Rudzki and Woźnawiejski channels.

Exemplary calculation results as spatial variations of the groundwater table level on September 1st, 1996 for scenarios 0 and IV are presented in Figure 2.

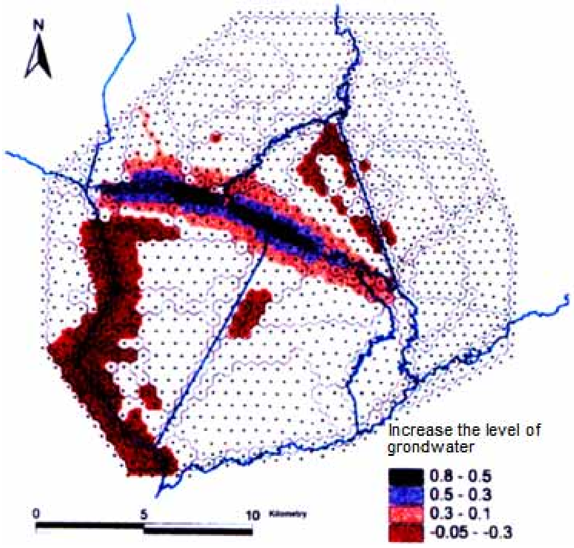

Fig. 2. The changes of groundwater level (scenario IV) on 1st of September 1996; source: own study

Calculation results indicate that the most effective way to increase groundwater table level is limitation of the drainage by the channels and adjustment of other water courses to increased flows. These changes are limited to the narrow zone along the water courses. Removal of the drainage facilities (all open ditches) has a significant but local impact on the groundwater table level in the drained area.

Evaluation of water demand resulting from performed restoration measures indicates that it can be increased by several times in a few areas. In the analyzed case study increase of water demand due to evapotranspiration is ca. 2 mm per year on the whole area (7 000 000 m^3). After implementation of changes in the hydrographic network, the valley will be partially flooded. It has been estimated that flooding of the valley equals construction of a water reservoir with the capacity of 36 000 000 m^3. Flooding of the valley usually occur in the beginning of the flood episode. Therefore, its impact on the flow rate in the Biebrza River below the discussed area is insignificant, as well as the water demand for evapotranspiration. It results from a large volume of water inflowing to the area with rivers.

In other words, all the suggested restoration measures causes significant changes in water conditions in the valley of central Biebrza that can increase soil humidity that is essential for preservation of the natural value of peat bogs. Implementation of these measures causes increase of retention capacity of ground and surface waters. Their small influence on water flow in the Biebrza River results from the fact that it is a large catchment and the river carries on large amounts of water in comparison to the amount of retained water. Implementation of these measures causes increase of the potential retention capacity of ground and surface waters.

The Dzierzbia River catchment. The Dzierzbia River catchment is situated in a topographically varied area (the edge of the moraine). It covers the area of ca. 30 km^2. Good topographical conditions for construction of small water damming reservoirs occur in the catchment. The catchment was the exemplary object for the analysis of the impact of the construction of small water reservoirs and damming of water courses on water conditions. Scenario calculations included:

– calculations for the present state of the land use of the catchment as a reference condition,
– construction of 16 reservoirs with the capacity ranging between 20 000 m^3 and 180 000 m^3 – capacity of the reservoirs was adjusted to the real conditions existing in the location site. Steady level of the top of the weirs were planned i.e. manual flow regulation was not possible,
– construction of damming devices on the river and its tributaries – for the need of modelling it was assumed that damming devices were located in sites and managed in a way that allow maintaining the steady water level at 0,2 m below the ground level,
– evaluation of the impact of the hydraulic characteristics of the valve construction on limiting the maximal flows.

Map of the analysed catchment with the location of the reservoirs has been presented in Figure 3. Research has been carried out for atmospheric conditions that occurred in years 1977, 1979 and 1980. These years vary in scope of precipitation amount and flow rate.

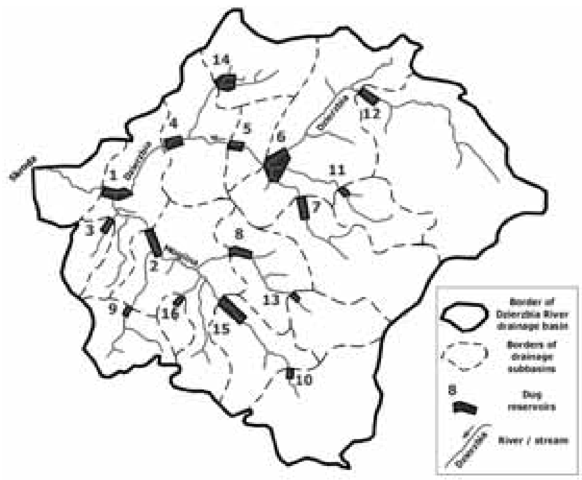

Fig. 3. Localization of planned reservoirs in the catchment; source: own elaboration

Results of calculations indicate that maintaining the high water level in the river significantly influence groundwater table level on the area of whole catchment (Fig. 4). On the other hand, water reservoirs that cover small area cause the increase of groundwater table level only in the adjacent area. (Fig. 5).

Water reservoirs significantly influence the flow rate in the mouth section of the river (Fig. 6). It is worth to mention that the impact is varied and it depends mainly on the character of weather changes (precipitation). For instance, in 1979 above mentioned

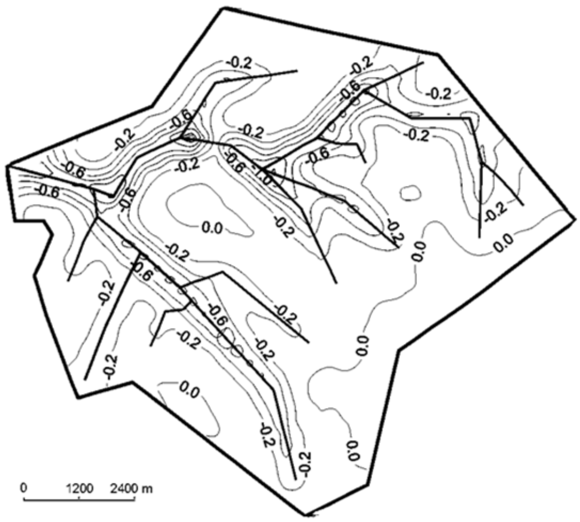

Fig. 4. Changes in the groundwater level after construction of weirs; source: own study

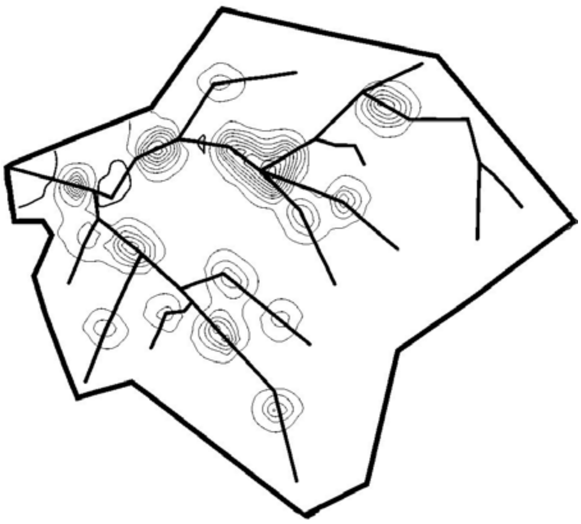

Fig. 5. Differences between groundwater level with natural flow and water levels after constructed 16 reservoirs; source: own study

reservoirs decreased the flow rate that resulted from the fact that high flow rate occurred in April 1979 when the reservoirs were filled in. Very effective decrease of temporarily high flows can be observed if during the rest of the year flow rate is low.

Calculations showed that the influence of the reservoirs on the flow rate depends also from the hydraulic characteristics of the valve devices (Fig. 6). Calculations performed for this object were conducted for two scenarios (scenario I and scenario II) that differ in scope of the output of the construction.

Catchment of Turośl. The catchment of Turośl with the area of 9.1 km^2 is situated on the Kurpiowska Plain. It is a typical lowland catchment with the significant share of organic soils (Fig. 7). The planned and implemented drainage system consists mainly of the network of open ditches. The aim of the research was to check up the possibility of increasing water

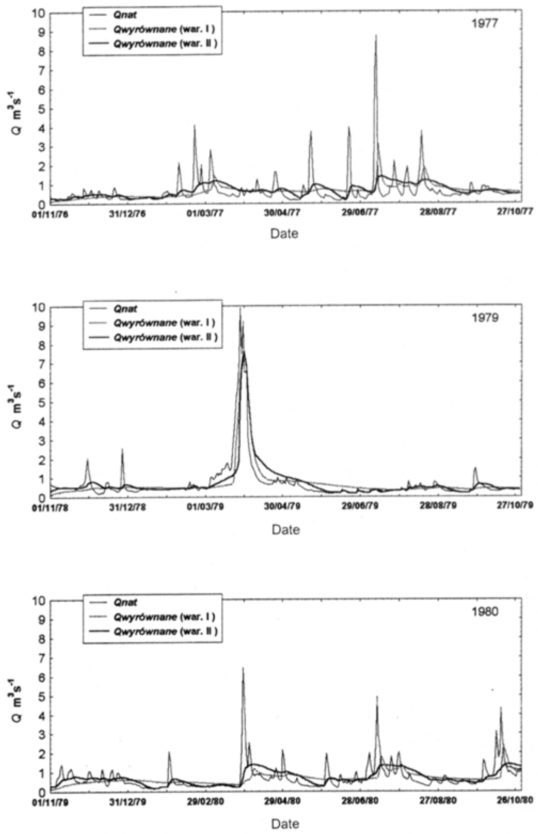

Fig. 6. Flow hydrographs of stream: natural and simulated by 16 reservoir system in for different submerged overfall outflow coefficients (scenario I and II); source: own study

retention of the small catchment by limiting the rapid water runoff in the ditches [KOWALEWSKI 1989].

The central part of the catchment is relatively flat and it covers nearly 50% of the river basin. The valley is covered by organic soils, mostly peat of low thickness, rarely exceeding 1.5 m. Permeable geological formations lying below are mainly fine and medium sands. Plateau beyond the limits of the valley are built of similar formations.

Whole area of the valley is used as meadows and pastures while upper parts of the catchment adjacent to the valley (apart from the drainage object) are covered by coniferous forests or used as low quality arable lands.

Calculations were performed for climatic conditions from 1994 and the amount of precipitation and other meteorological data to estimate evapotranspiration were obtained from the adjacent meteorological station.

It has been assumed that objects with a defined threshold located below the ground surface will be constructed in every ditch. This assumption is fulfilled if water inflow to the ditches is significant enough (e.g. after precipitation). With water inflow bigger than the capacity of ditches water discharge to lower situated ditches occur. During the vegetation period, with lack of precipitation alimentation of

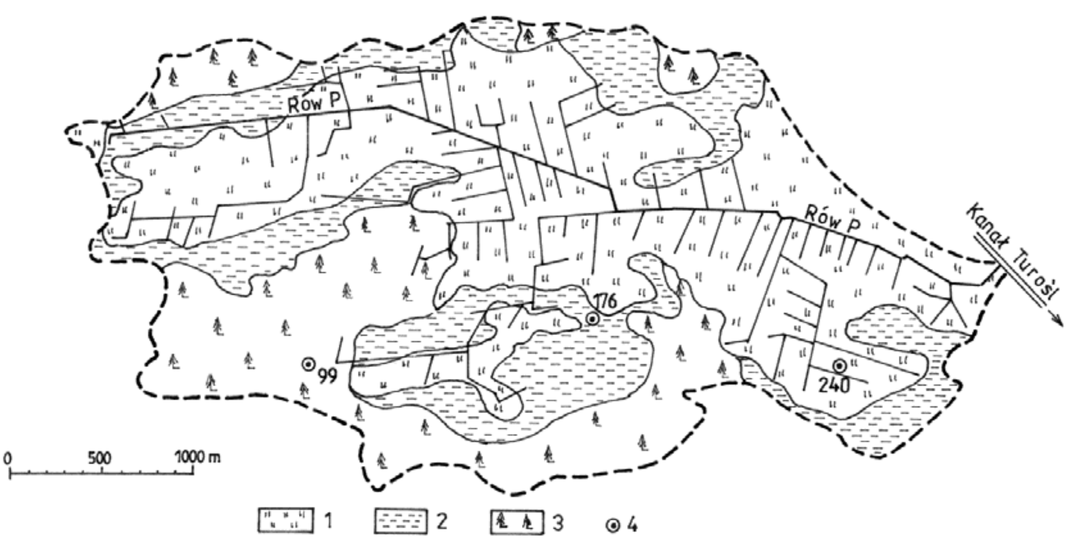

Fig. 7. The map of the river basin; *1* – grassland, *2* – arable, *3* – forest, *4* – chosen point of numerical net; source: own elaboration

groundwater layer by the water from the ditch occur and water level in the ditch can drop even below the threshold. Calculations were performed for the following scenarios:

I – free water outflow from ditches, precipitation as measured in the meteorological station;

II – water damming in ditches, precipitation as in scenario I;

III – free water outflow, precipitation decreased by 25% in comparison to the actual ones;

IV – water damming in ditches, precipitation as in scenario III.

Analysis of the calculation results indicate that the kind of the measure implemented for exploitation of the valley drainage system significantly influences the water resources of the object (Fig. 8). A visible increase of groundwater table level due to maintenance of water damming in the ditches occurs in the whole area of the catchment – in the valley as well as on the plateau (scenarios I and II). In the end of the vegetation period, depending on the location of the node, groundwater table level maintains between 0.2 and 0.6 m in relation to the free outflow. Even more significant influence of water damming in ditches can be observed during dry years (decreased precipitation in scenarios III and IV in comparison to scenarios I and II). For example, groundwater table level in node 240 in scenario IV is similar to scenario II despite the fact that in scenario IV significantly lower amount of precipitation was assumed.

The conducted scenario calculations of the groundwater table level indicate that the kind of the measure implemented for exploitation of the valley drainage system significantly influences the water resources of the small river catchment. Start of the damming water in ditches in early spring can significantly limit the outflow and decrease groundwater table level. This phenomenon is particularly visible during dry years with low precipitation and significant evapotranspiration. Increase of water resources results

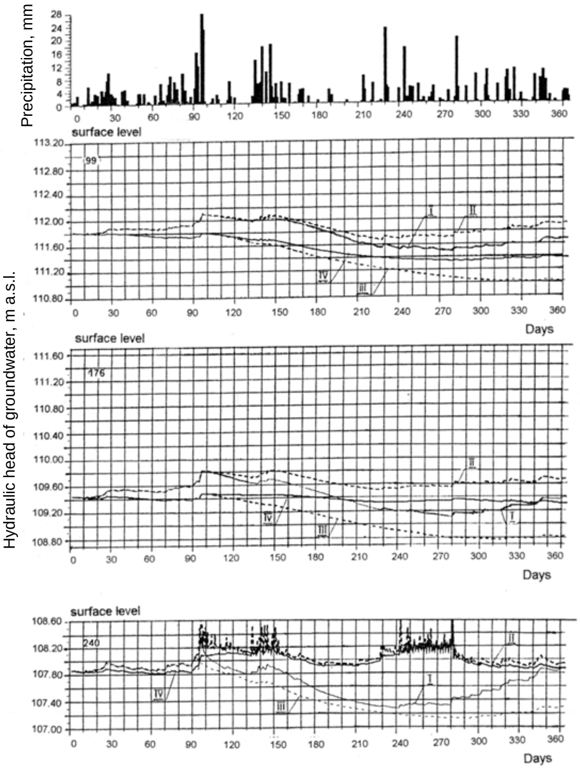

Fig. 8. Calculated groundwater levels at given nodes 99, 176, 240 – for different scenarios; source: own study

from the capacity of ditches only to a limited degree. The most significant factor is groundwater retention in soil within the drained object and in the geological deposits in the adjacent areas. It has been estimated that additional 42 mm of water can be obtained with use of regulated outflow what in terms of the whole catchment gives the capacity of 386 000 m^3. Significant part of the retained water is used by plants covering the area of the valley in the process of evapotranspiration. However, while long periods without precipitation water outflow from such small river drops to zero.

Czarna Nowa drainage system. The drainage system is composed of the Czarna Nowa River and the basic ditches parallel to the river bed with gauge ranging between 200 and 500 m (Fig. 9). The area of the valley is covered by permanent grasslands and wet leafy forests. Shallow half-bog – mineral and silty – peaty soils occur. They are under layered by fine and medium grained sands. Layer of sand is an aquifer with thickness up to 15 m and filtration coefficient $k_{śr}$ = 5 m·d^{-1}. Ability to carry on an active water management (improvement of water balance) basing on very thin network of ditches constructed parallel to the existing natural water courses has been analysed in this case study.

Only a set of simplified calculations aiming at verification of groundwater table level in the extreme weather conditions (varied level of evapotranspiration) with and without water damming in ditches and in the water course was conducted. During wet periods and with low evaporation (0.5 m·d^{-1}) in most cases groundwater table level is high and ranges between 0.02 and 0.2 m below the ground while in the areas with local terrain elevations it can reach 1.0 m. During dry periods with evaporation 4 times higher (2 m·d^{-1}) groundwater table level decreases in comparison to the previous scenario and ranges between 0.05 and 0.2 m while under the primary conditions (without water damming) it decreased by 0.4–0.8 m.

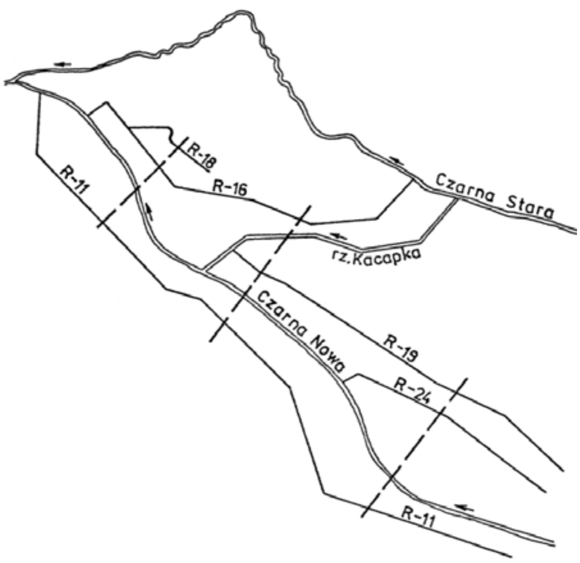

Fig. 9. The map of the Czarna Nowa study area; source: own elaboration

Based on the above mentioned facts, one can conclude that even with high evaporation groundwater table level can be maintained on a high level by water damming in water courses. Construction of weirs properly selected and distributed along the water course is essential for improvement of water balance. As the network of ditches is not very dense there is no possibility to carry on the typical ascension irrigation in a traditional manner i.e. closure of valves after drought and while low groundwater table level. Therefore, after outflow of melting water (precipitation) it is necessary to close the valves and maintain water in ditches (during periods with high evapotranspiration) up to the ground level.

Rów Tartaczny catchment. Upper part of the catchment of the area of 45 km^2 was considered. Drainage object with a network of open ditches is located in this part of the valley (Fig. 10). The drained part of the valley has very irregular banks. Its width ranges from 100 m in the upper river course to 1 800 m in the lower part. The valley is filled with peat deposits with thickness of 2–4 m. Filtration coefficient of the peat ranges between 0.10 and 0.64 m·d^{-1}. The area of the valley is used as permanent grasslands. A diluvia plateau from the Middle Poland glaciation is adjacent to the valley. Denivelations between the area on the border of the catchment and the drained valley reach up to 30 m. The plateau and the layer underlying the peat are built of the sandy glacial till. Apart from permanent grasslands in the valley, forests and arable lands cover the plateau.

Variation of the groundwater table level and outflow from the catchment in case of reconstruction of the selected elements of the drainage system was analyzed. The reconstruction included the following variants:
- construction of the dug reservoir with the area of 80 hectares,
- elimination of the part of ditches from the drainage system,
- elimination of the detailed ditches and simultaneous permanent water damming in the basic ditches.

Variations in groundwater table level or variations of the flow rate in the individual scenarios relate to the calculations performed for the present state of the land use in the catchment.

Research on the influence of the water reservoir proves its limited range of influence on the groundwater table level. Groundwater table level significantly increases only in the areas adjacent to the reservoir. The reservoir visibly influences the total water outflow from the catchment (Fig. 11) and the flow rate. The reservoir decreased the flood wave as well as the total water outflow. In addition, the removal of part of the ditches and construction of damming devices has been analyzed. The results are presented in Figure 12.

The calculations included following scenarios:
- scenarios 1, 2, 3 – the existing network of ditches with various damming levels: 1 – damming up to the level of 0,2 below ground level, 2 – 0.8 m, 3 – 1.2 m;
- scenarios 1, 2, 3 – liquidation of small ditches and preservation of the main water courses with various damming levels: 1 – damming up to the level of 0.2 below ground level, 2 – 0.8 m, 3 – 1.2 m.

All the measures including water damming significantly influence the water outflow from the catchment despite that drainage system covers only a small part of the catchment (Fig. 10, 12). Decrease of water outflow is caused by the increased water up-

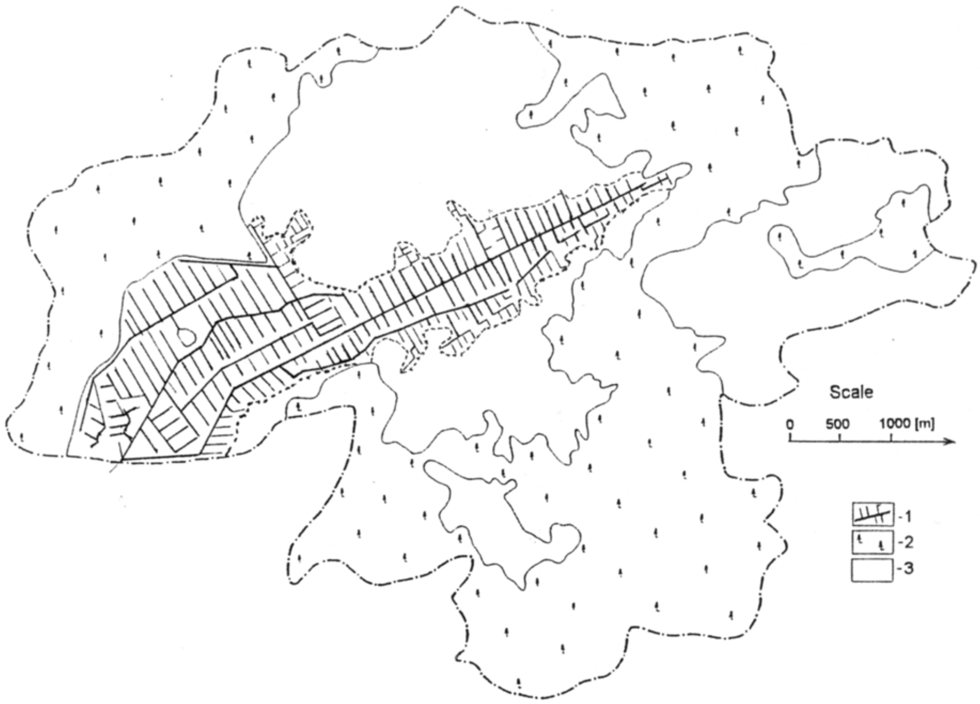

Fig. 10. The catchment of Tartaczny Channel; *1* – grassland, *2* – forest, *3* – arable land; source: own elaboration

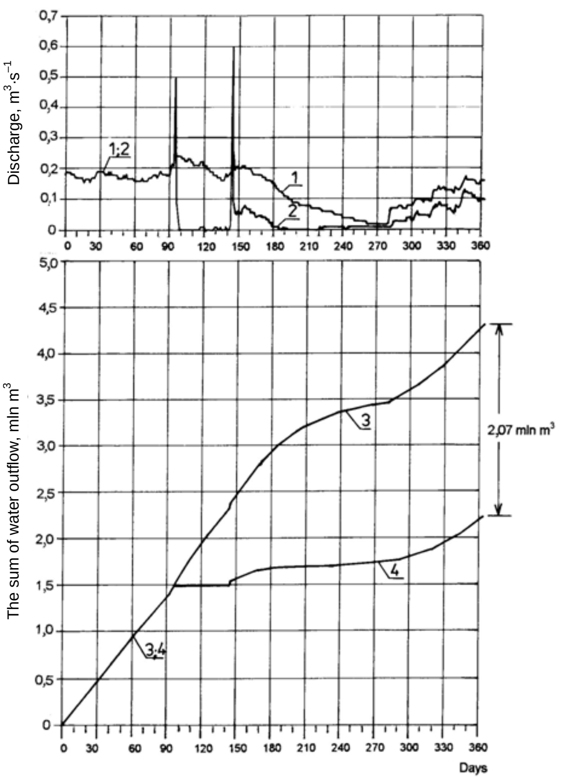

Fig. 11. Daily and total discharge changes from the catchment after construction of reservoir; *1* – daily discharge with existing drainage system, *2* – daily discharge water reservoir, *3* – sum of total outflow with existing drainage system, *4* – after reservoir construction; source: own study

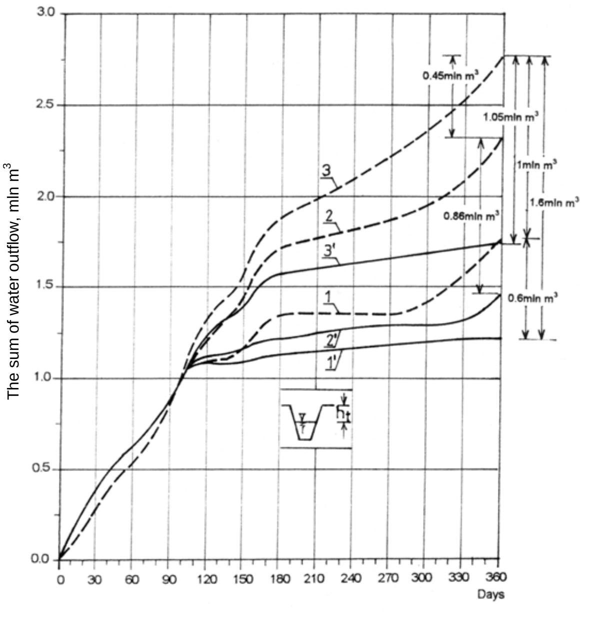

Fig. 12. Total outflow from the catchment with existing drainage system and also with ditches system filled up for different retention; 1 – existing system *ht* = 0.2 m, 2 – existing system *ht* = 0.8 m, 3 – existing system *ht* = 1.2 m, 1' – ditches system filled up *ht* = 0.2 m, 2' – ditches system filled up *ht* = 0.8 m, 3' – ditches system filled up *ht* = 1.4 m; source: own study

take by plants. Elevated groundwater table level significantly decreases the problem of water deficit during droughts.

DISCUSSION OF THE RESULTS

Despite a large interest in the problem of small retention, the literature concerning obtained effects and results for improvement of the structure of water balance is limited. Typically, authors state its positive influence on limitation of flooding and droughts but they do not point out the detailed correlations [BŁACHUTA *et al.* 2011; BURSZTA-ADAMIAK 2012; MROZIK, PRZYBYŁA 2013; ŻELAZO 2006]. The positive effect on the groundwater table level and decrease of flow rate during floods is clearly visible in the above mentioned case studies.

There are significantly more publications considering the problem of natural retention of the catchment. Interesting monographs [GUTRY-KORYCKA 2003; SOMOROWSKA 2011] as well as empirical relations presenting the impact of land use and its spatial management on the probable size of the retention have been published [CHANG 2006]. A lot of attention focused recently to the problem of forest influence on water cycle. Usually authors prove that forests limit the high water flow but they do not stress that the role of forest can vary and depend on the terrain denivelations and types of soils [CHANG 2006].

Calculations presented for the selected case studies prove the complex nature of this problem. It has been clearly shown that, in case of large catchments (e.g. the Biebrza River catchment), restoration measures implemented on a significant area do not significantly influence high and low water levels. It results from the fact that the area of the measures implementation is relatively small in comparison to the whole catchment. Therefore, inflow of large amount of water to the river causes that the measures do not influence the situation below the restored section of the water course. In contrast, all the above mentioned measures cause increase of soil humidity on the studied area and are the important element of the measures for protection of natural values of the peat bog valley.

Construction of 16 reservoirs in the Dzierzbia catchment will not cause any significant changes in the hydrologic regime as the catchment is relatively large and the potential reservoirs have limited capacity. In contrast, construction of one reservoir in the Rów Tartaczny catchment causes the significant decrease of flood wave. But the catchment of Rów Tartaczny is relatively small.

In all the case studies presented above the role of damming devices located in the river bed and its tributaries and in the drainage ditches is significant. These kinds of measures positively influence the structure of water balance and, what is even more important, they are an important element that can replace the traditional irrigation. Common adjustment of the valley drainage systems to retention of water during spring is the measure that ensures multiple benefits. Not only it limits the outflow from the catchment but, in case of large catchments, it can have a visible impact on the flow rate in lower parts of the river. These measures can effectively limit the negative impact of drought during periods without precipitation. Regulated outflow from the drainage systems has been used on the drained objects also for limitation of the transport of nitrogen and phosphorous [GILLIAM, SKAGGS 1986]. Also inhibition of water outflow from ditches contributes to protection of water quality in rivers on the agricultural lands [BERNINGER *et al.* 2012; CAMPBELL, OGDEN 1999].

Research and analysis prove that implementation of small retention measures is rational due to improvement of the structure of water balance, limitation of the impact of excess and lack of water and protection of water quality. However, it is a complex process and it is not always possible numerically prove all the benefits due to the small scale of the measures. The amount of retained water depends on many natural factors i.e. type of soil, geology, land use and spatial management but also on hydraulic capacity of the damming device, climatic conditions and mostly on the size and distribution of precipitation. The potential water retention capacity can be seriously influenced by the type of soil and agricultural use of the catchment.

The calculations presented above, as well as the data obtained from other publications, confirm the possibility to regulate water relations with use of small water retention measures. Particularly positive effects can be obtained while limiting the negative impact of droughts on the agricultural productivity. The calculations indicate a significant increase of evapotranspiration that has been also conformed in many other publications. Small retention measures influence the problem of floods to a slightly lower degree. The possibility of limiting the effects of high water flow depends not only on the retention capacity and flow rate but also on atmospheric conditions occurring before the elevation of water level. It results mostly from the fact that in such cases we deal with uncontrollable retention. Similar conclusions have been presented by many authors [KOWALEWSKI 2008; QUERNER 1993; ŻELAZO 2006].

The results presented above are the part of a contemporary trend of modernization and reorganization of rules of water management not only in rural but also in urban areas. The characteristic feature of this trend is water retention in the areas where water resources origin. Retention of water from precipitation and snow melting in the catchment including the agricultural lands, forests and urban areas is the basic element that can limit the negative impact of droughts and contribute to increase the protection from the maximal flood flows.

CONCLUSIONS

1. Small retention measures are a good and effective method to increase the ability to retain water in the catchment. The effects of the improvement of the structure of water balance are clearly visible in small

catchments if the implementation process covers most of the catchment area.

2. Increase of the potential retention capacity of the catchment can be obtained by different measures. Construction of small water reservoirs and construction of damming devices that can limit the fast outflow of precipitation and melting water is very effective.

3. Restoration of the peat bogs by liquidation of the drainage system as well as inhibition of water outflow in large catchments does not significantly influence the hydrologic regime of the catchment. On the other hand, it can visibly improve water conditions what is essential to preserve the natural values of wetlands.

4. Modernization of the existing drainage systems in river valleys is advisable. The drainage systems should be modified in a way allowing the rational local water resources management as not only agriculture but also natural environment can benefit.

REFERENCES

BERNINGEER K., KOSKIAHO I., TATTARI S. 2012. Constructed wetlands in finish agricultural environments: balancing between effective water protection, multi-functionality and socio-economy. Journal of Water and Land Development. No 17 p. 19–30.

BŁACHUTA J., KAMIŃSKI W., KOWALCZAK P., ROSA J., ZGRABCZYŃSKI J. 2011. Podręcznik dobrych praktyk w gospodarce wodnej w terenach nizinnych – wybrane zagadnienia [Handbook of good practices in water management in lowlands – selected problems]. Poznań. Biuro Projektów Biprowodmel. Tapescript pp. 66

BURSZTA-ADAMIAK E. 2012. Analysis of the water capacity of green roots. Journal of Water and Land Development. No 16 p. 3–10.

CAMPBELL C.S., OGDEN M.H., 1999. Constructed wetlands in the sustainable landscape. New York. John Wiley and Sons. ISBN 0-471-10720-4 pp.270

CHANG M. 2006. Forest hydrology. New York. Taylor and Francis. ISBN 0-8493-5332-7 pp. 474.

GILLIAM J.W., SKAGGS R.W. 1986. Controlled agricultural drainage to maintain water quality. Journal of Irrigation and Drainage Engineering. Vol. 112. Iss. 3 p. 254–263.

GUTRY-KORYCKA M. 2003. Theoretical basis of shaping various forms of retention. [In: Role of catchment retention in shaping rain floods]. Eds. M. Gutry-Korycka, B. Nowicka. Warszawa. UW p. 320.

KOWALCZAK P. 2001. Hierarcha potrzeb małej retencji w zlewni Warty. Hierarchy of spatial needs of small retention in the Warta basin. Warszawa. IMGW pp. 125.

KOWALEWSKI Z., BOROWSKI J., ŚLESICKA A. 1989. Badania modelowe podstawowych systemów odwadniająco-nawadniających w dolinach rzecznych. W: Budowle i urządzenia w systemach melioracyjnych dolin rzecznych [Modeling research on the basic drainage – irrigation system in the river valley. In: Constructions and devices in drainage systems in river valleys]. Workshop materials. Falenty. IMUZ p. 211–224.

KOWALEWSKI Z. 2008. Plan działania w zakresie małej retencji. W: Wybrane problem retencji wodnej [Plans and measures in scope of small retention. In: Selected problems of water retention]. Eds. J. Gliński, Z. Michalczyk. Lublin. UMCS p. 61–73.

MIODUSZEWSKI W., SZUNIEWICZ J., KOWALEWSKI Z., CHRZANOWSKI S., ŚLESICKA A., BOROWSKI J. 1996. Gospodarka wodna na torfowisku w dolinie Środkowej Biebrzy [Water management on a peat bog in the Biebrza Midlbasin]. Falenty. Wydaw. IMUZ. pp. 84.

MIODUSZEWSKI W., QUERNER E., KOWALEWSKI Z., ŚLESICKA A. 1996. Wpływ eksploatacji dolinowego systemu melioracyjnego na zasoby wodne małej zlewni rzecznej [Impact of exploitation of valley drainage system on water resources in small river catchments]. Zeszyty Naukowe Akademii Rolniczej we Wrocławiu. Nr 4 p. 265–278.

MIODUSZEWSKI W., QUERNER E., KOWALEWSKI Z., ŚLESICKA A. 1997. The impact of water level control in drainage systems on groundwater levels in river basins. Journal of Water and Land Development. No 1 p. 37–48.

MIODUSZEWSKI W. 1998. Reconstruction of retention capacity of small river basins as a protection measure against floods and droughts. International Agrophysics. Vol. 12. No 4 p. 259–270.

MIODUSZEWSKI W., OKRUSZKO T. 2012. Protection of wetlands – the example of conflicts. Journal of Water and Land Development. No 16 p. 35–42.

MIODUSZEWSKI W. 2014. Small (natural) water retention in rural areas. Journal of Water and Land Development. No 20 p. 19–30.

MROZIK K., PRZYBYŁA C. 2013. Mała retencja w planowaniu przestrzennym [Small retention in spatial planning]. Poznań. Wydaw. PRODRUK. ISBN 978-83-64246-06-7 pp. 216.

QUERNER E. 1988. Description of a regional groundwater flow model SIMGRO and some application. Agricultural Water Management. No 14 p. 209–218.

QUERNER E. 1993. Aquatic weed control within an integrated water management framework. Report 67. Wageningen. DLO Winand Staring Centre pp. 203.

QUERNER E. 2000. User's manual for groundwater model SIMGRO. Wageningen. DLO Winand Staring Centre. Draft Report pp. 97.

QUERNER E., MIODUSZEWSKI W., POVILAITIS A., ŚLESICKA A. 2010. Modelling peatland hydrology: three cases from Northern Europe. Polish Journal of Environmental Studies. Vol. 19. No. 1 p. 149–160.

ŚLESICKA A., QUERNER E. 1999. Modelling of groundwater dynamics in the Central Biebrza Basin. In: Assessment of the effect of changes in water management within Central Biebrza Basin. Eds. W. Mioduszewski, M. Wassen. Falenty. Wydaw. IMUZ p. 31–55.

SOMOROWSKA U. 2011. Wpływ stanu retencji na odpływy z nizinnej zlewni [Impact of the state of subsurface retention on the outflow from the lowland catchment]. Warszawa. UW. pp. 151.

SZAJDA-BIRNFELD E., PŁYWACZYK A., SKARŻYŃSKI D. 2012. Zielone dachy. Zrównoważona gospodarka wodna na terenach zurbanizowanych [Green roofs. Sustainable water management in urban areas]. Wrocław. UP. pp. 181.

WALCZAK R.T., GLIŃSKI J., SŁAWIŃSKI C., LAMORSKI K. 1998. Agrophysical methods of water retention control in the rural areas. International Agrophysics. Vol. 12 p. 277–284.

ŻBIKOWSKI A., ŻELAZO J. 1993. Ochrona środowiska w budownictwie wodnym. [Environmental protection in hydroengineering]. Materiały informacyjne. Warszawa. Agencja Wydaw. FALSTAFF pp. 156.

ŻELAZO J. 2006. Renaturyzacja rzek i dolin [Restoration of rivers and valleys]. Infrastruktura i Ekologia Terenów Wiejskich. Nr 4 (1) p. 11–31.

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Analiza oddziaływania małej retencji na zasoby wodne zlewni

STRESZCZENIE

Słowa kluczowe: *bilans wodny, mała retencja, systemy melioracyjne, zbiorniki wodne*

Omówiono wpływ wybranych działań małej retencji na ograniczenie zagrożeń powodowanych suszą lub powodzią. Na podstawie badań modelowych oceniono wpływ małych zbiorników wodnych i piętrzeń wody w sieci rowów na odpływ rzeczny oraz poziom zwierciadła wód gruntowych.

Zwiększenie potencjalnej zdolności retencyjnej zlewni rzecznej może być osiągnięte różnymi metodami. Skuteczna jest budowa małych zbiorników wodnych oraz budowli piętrzących wodę i ograniczających szybki odpływ wód opadowych i roztopowych.

Renaturyzacja obszarów bagiennych poprzez likwidację systemu odwadniającego, a również hamowanie odpływu wody w dużych zlewniach nie wywiera istotnego wpływu na reżim hydrologiczny zlewni. Może natomiast znacznie poprawić warunki wodne niezbędne do zachowania walorów przyrodniczych cennych obszarów mokradłowych.

Wskazana jest modernizacja istniejących systemów melioracji dolinowych w celu umożliwienia racjonalnego gospodarowania miejscowymi zasobami wody. Przynosi to korzyści rolnictwu, jak również środowisku przyrodniczemu, w tym ochronie zasobów wody.

Przedstawione wyniki badań wpisują się we współczesny trend unowocześnienia i reorganizacji zasad gospodarowania wodą, szczególnie na terenach rolniczych, ale również na obszarach zurbanizowanych. Cechą charakterystyczną tego trendu jest retencjonowanie wody na obszarach powstawania zasobów wody. Zatrzymywanie wody z opadów atmosferycznych, topnienia śniegu w zlewni, w tym na terenach rolniczych, leśnych i zurbanizowanych, jest podstawowym elementem ograniczania skutków suszy i ochrony przed zwiększaniem się maksymalnych przepływów powodziowych.