ORIGINAL PAPER

ATTEMPT AT IMPLEMENTING THE 2015 "ECOLOGICAL FLOW ASSESSMENT METHOD FOR POLAND" IN THE WIEPRZA RIVER CATCHMENT

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ABSTRACT

Safeguarding hydrological regimes appropriate for aquatic and water dependent ecosystems is necessary in order to achieve or maintain good ecological status (or good ecological potential) of water bodies, being an important task of sustainable water management. Water requirements of ecosystems are mainly represented by minimum required or ecological flows, which constitute a constraint to the use of water resources. The main objective of this paper is a comparison, in terms of economic effects, of the new ecological flow assessment method against the currently operational RZGW Szczecin hydro-biological method (2014), and the simplified hydro-biological method by Kostrzewa (1977). Another issue is to evaluate whether the ecological flow method is useful and applicable to water balance planning analysis. Computer simulation approach has been used. Calculated hydro-biological and ecological flow volumes were presented along the Wieprza River longitudinal profile and in the selected cross-sections. The time reliability of maintaining the flows as well as changes in volume of available water resources have been used to evaluate economic effects of the new method implementation. It has been proven that the application of ecological flow requirements causes a decrease in the available water resources for both existing and potential water users. Based on the results, selected issues have been discussed, related to the methodology of ecological flow determination, especially gaps and inconsistencies calling for additional assumptions.

Keywords: ecological flow, water requirements of aquatic and water dependent ecosystems, hydrological regime, water management, water balance

INTRODUCTION

There are many terms related to the size of flows that should be maintained in the river. Various denominations are used: minimum acceptable flow, required flow, biological and hydrobiological flows, ecological or environmental flows. There are various definitions of these flows and there are many different methods for calculating them (Tharme, 2003; Acreman and Dunbar, 2004; Acreman et al., 2014; Ustalenie metody szacowania… 2015; Pusłowska and Rycharski, 2015; Witowski et al., 2008; Więzik and Więzik, 2007; Grela and Stochliński, 2005; Parasiewicz and Dunbar, 2001). In this paper we use the term 'minimum required flow' as the translation of Polish '*przepływ nienaruszalny*' and 'ecological flow' as the Polish '*przepływ środowiskowy*' acknowledging relation of the latter with the Water Framework Directive and Guidance Document No 31.

In addition to the term "minimum required flow", which has been used in Poland at least since 1963 (KPRM, 1963), the term "ecological flow" has recent-

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ly appeared. Among the definitions used in Poland, it is worth recalling the definition of Kostrzewa (1977), as the most widespread and reflecting the general concept well: *minimum required flow is the amount of water expressed in m³ per second, which should be kept as a minimum in a given river cross-section for biological and social reasons (...)*. Noteworthy is also the formulation by Witowski et al. (2008): *minimum required flow refers to the threshold value of river flow, below which water flows should not be reduced as a result of human activity,* which emphasizes the importance of minimum required flow as a restriction in the use of water resources. In the English-language literature, there are also more extensive definitions, highlighting the features of the hydrological regime, which should be represented in the minimum required flow – flow magnitude, timing, frequency, duration and overall variability (Poff et al., 1997; Arthington et al., 2006; Poff and Zimmerman, 2010). For the "ecological flow", a short definition is proposed, directly indicating the relationship of this flow with the provisions of the Water Framework Directive, 2000/60/EC: *ecological flows are considered as a hydrological regime consistent with the achievement of the environmental objectives of the WFD in natural surface water bodies* – in the understanding of the European Commission (2015), whereas in Polish cocept *the ecological channel flow means the flow that conditions good status or potential of biological elements of water bodies* (Ustalenie metody szacowania… 2015).

The methods of determining the ecological flows, described in the literature, can be divided into four groups (Tharme, 2003):

a) **hydrological**, applying the selected flow characteristics, where the simplified method of Kostrzewa belongs (being the method which is the most widespread in Poland), and where the currently applicable derivative methods belong,

b) **hydraulic**, referring to the physical features of the flow phenomenon, such as velocity or depth, such as the method of estimating ecological flows in uncontrolled rivers, which is presently under analysis (MGGP, 2018),

c) **habitat simulation**, developed using models, based on the analysis of the availability of river habitats suitable for specific groups of organisms, where the proposal for estimating ecological

flows belongs (Ustalenie metody szacowania... 2015),

d) **holistic**, allowing the programming of river flow regime characteristics that are necessary for selected organisms or their groups.

Regardless of the manner of determining the minimum required or ecological flow, the intention of its introduction results from the idea of protecting the values or services of aquatic ecosystems. In the face of such intention, the required flow is always a limitation to the use (abstraction, storage) of water for other economic purposes, even if preserving such flow is not the priority in the hierarchy of water use, which is a common situation (OECD, 2015; EC, 2015). In Poland, the minimum required flow is currently the priority water use, which results from directives of Regional Water Management Authority (RZGW) directors, establishing the conditions for water use in water regions, and the obligation to maintain the minimum required flow applies to all licenced users (Water law of 2017; Journal of Laws Item 1566, article 403 passage 2 point 11).

The objectives of the present article are:

a) to assess of water management effects that would result from the change in the method of determining minimum required flow volume in Wieprza River and its tributaries, from the currently binding hydro-biological method (Rozporządzenie… 2014) into ecological flows (Ustalenie metody szacowania... 2015),

b) to analyse the applicability of this method in planning studies, such as the water-economic balance of surface waters,

c) to present the authors' comments on the proposed draft of the method for estimating ecological flows for Poland, currently under preparation (MGGP, 2018).

MATERIAL AND METHODS

Minimum required flow and ecological flow

Since 2014, uniform rules have been in force in the water regions in order to determine the minimum required flow volume set out in the directives of RZGW. In the Wieprza River catchment, as in the entire region of the Lower Oder and Western Borders, the RZGW Szczecin hydro-biological method should be used (QN_RZGW

(Rozporządzenie… 2014)). This method, like in other water regions, belongs to the group of hydrological methods and refers to the the simplified hydro-biological method by Kostrzewa (QNh) (Kostrzewa, 1977). According to this simplified method, the volume of the minimum required flow is the greater of the two values: the product of the average low flow (SNQ) and method's parameter (k parameter) or the lowest observed flow (NNQ). The k coefficient depends on the hydrological type of the river (lowland, transitional, montane), which is determined on the basis of the average unit runoff (SSq), and the catchment area enclosed with the considered cross-section. Changes in the value of parameter k take place in a stepwise way over the threshold value of the catchment area.

In the RZGW Szczecin method (Rozporządzenie… 2014), the minimum required flow is also defined as the higher of the same two values (1): the product of SNQ and the coefficient k and the NNQ, while the coefficient k depends on the average unit runoff, the catchment area, and parameters of the equation established for the RZGW. In this case, changes in the value of parameter k are continuous in nature.

$$QN_{RZGW} = \max \{k \cdot SNQ; NNQ\}$$
$$k = (f + d\,SSq)\,e^{aF^2} + c\,SSq + b \tag{1}$$

where:

QN_{RZGW} – minimum required flow according to the RZGW Szczecin method $[\mathrm{m^3 \cdot s^{-1}}]$,

SNQ, NNQ – average low and lowest flow in the analysed river cross-section $[\mathrm{m^3 \cdot s^{-1}}]$,

SSq – average unit runoff $[\mathrm{dm^3 \cdot s^{-1} \cdot km^{-2}}]$,

F – the catchment area up to the analysed cross-section $[\mathrm{km^2}]$,

e – the base of the natural logarithm,

a, b, c, d, f – parameters of the equation $[-]$, a = $-6.11 \cdot 10^{-7}$, b = 0.116, c = 0.0312, d = -0.0297, f = 0.866.

According to the newly proposed method (Ustalenie metody szacowania… 2015), the ecological flow (QSb), which provides sufficient habitat area for specific fish communities, is variable during the year, but it is constant in bio-periods, and it depends on the average low flow in bio-period ($SNQb$) and on

the method parameter, pb. The pb parameter is determined for subsequent bio-periods, and it depends on the ichthyologic type of the river, which in turn is associated with its abiotic type. In case of some ichthyologic types (III, IV, V) it depends also on hydro-morphological conditions favourable to the spawning of *Salmonidae* (2). For non-gauged rivers, in which the estimation of $SNQb$ flow in bio-periods would require advanced hydrological analyses (catchment models, techniques for transferring hydrological information), ecological flow is a function of average low flow and p parameter, whose values also depend on the bio-period, the ichthyologic type of the river, and the occurrence of *Salmonidae* (3).

$$QS_b = pb \cdot SNQb \text{ for gauged watercourses} \tag{2}$$

$$QS_b = p \cdot SNQ \text{ for non-gauged watercourses} \tag{3}$$

where:

QSb – ecological flow in the given bio-period $[\mathrm{m^3 \cdot s^{-1}}]$,

pb, p – parameters of the method in the bio-periods for gauged and non-gauged watercourses $[-]$.

The values of the method's parameters (pb and p) were determined based on the analyses in the MESO-HABSIM model (Parasiewicz et al., 2013), for selected reference sections of rivers, tested in the pilot studies. The results of the tests were adopted as the model for four ichthyologic types of rivers (I–IV), out of six types distinguished in Poland (Ustalenie metody szacowania… 2015). For ichthyologic type III, sub-type with *Salmonidae* spawning, no parameter values were determined.

Ichthyologic types, determined for the purpose of estimating ecological flows, include the following (Ustalenie metody szacowania… 2015):

I – montane and upland rivers and streams (abiotic types 2–4, 6–10),

II – flysch rivers (abiotic types 12 and 14),

III – lowland streams (abiotic types 16–18),

IV – lowland rivers (abiotic types 19–21),

V – inter-lake salmon rivers (part of the abiotic type 25),

VI – peat, lake-linking, and estuary rivers (abiotic types 22–24 and part of type 25).

The bio-periods designated during the year include: a) spring spawning (March–June), b) feeding (July–September), c) autumn spawning (October–December), d) wintering (January–February). In rivers, where there are no *Salmonidae*, the bio-period of feeding lasts from July to October, there is no autumn spawning season, and wintering starts in November.

SIMULATION CALCULATIONS

Determining minimum required and ecological flows

A model was developed that facilitates calculating minimum required flows in water-gauge cross-sections (according to the Kostrzewa and RZGW Szczecin methods) as well as ecological flows (Ustalenie metody szacowania… 2015). The basic data for the model include: the catchment area enclosed by the analysed cross-section, the series of daily flows in this cross-section, the abiotic type of the water body (JCWP) and the name of the reference river, in order to determine the ecological flow. Based on these data, the necessary hydrological characteristics are calculated, including the *SSQ, SNQ, NNQ,* and *SNQb* flows for the appropriate bio-periods. Next, parameters are determined: *k* in the methods of Kostrzewa and the RZGW, and *pb* for ecological flows – and finally, the values of minimum required and ecological flows are calculated, the latter in monthly periods. The values of hydrological characteristics for non-gauged cross-sections were calculated using the water balance model, in accordance with the accepted principles of hydrological information transfer.

The development of the model of ecological flows required the adoption of a number of assumptions, without which it was not possible to calculate the value of such flows. These assumptions were arbitrary, and they included the following:

a. **choosing a set of method's parameters for controlled and uncontrolled rivers**; It was assumed that by using the methods of transferring hydrological information in the water balance model it was possible to calculate the average low flow in bio-periods, even in non-gauged watercourses; this assumption made it possible to apply a uniform approach to estimating the ecological flow in all of the modelled watercourses;

b. **choosing the reference river and the value of *pb* parameters for watercourses of the ichthyologic type III**, in which the spawning of *Salmonidae* takes place; sandy lowland streams (abiotic type 17) constitute the vast majority of watercourses in the Wieprza River catchment, whereas salmon is the representative fish species – due to the lack of method's parameters for watercourse type III with *Salmonidae* spawning, such parameters were assumed as for non-spawning watercourses; another possible option was to adopt the parameters of a reference river characterized by salmonid fish spawning, but this would mean a change in the ichthyologic type, therefore this option was rejected;

c. **designating the reference river for watercourses of the ichthyologic type VI** (there are no parameters for this type of watercourses (Ustalenie metody szacowania… 2015)), including watercourses in areas under the influence of peat-forming processes (abiotic types 23 and 24) and estuary river sections in the Wieprza River catchment under the influence of salty water (type 22) – for the streams and brooks, parameters of the III ichthyologic type were assumed, and for larger watercourses, of the IV type;

d. **selecting the parameters for small watercourses**, not constituting JCWP, which were included in the water balance model – parameters such as those in neighbouring JCWP were adopted; an alternative solution was to adopt the parameters of the recipient, but this option was rejected due to differences in the flow magnitude of the recipient and tributary, and of their catchments.

WATER BALANCE ANALYSES

In order to assess the water management effects that would result in replacing the minimum required flow calculated using the RZGW Szczecin method with ecological flows (Ustalenie metody szacowania… 2015), simulation studies were carried out using the model of the water management balance of the Wieprza River catchment (PRO-WODA, 2016). The water management balance of surface waters, taking into account the impact of groundwater exploitation, was carried out in the multiyear period of 1990–2013

with a 10-days time step. The calculations took into account the basic principles of dynamic water economy balance (Pusłowska-Tyszewska and Tyszewski, 2014), including the allocation of water in the water balance cross-sections according to the adopted hierarchy of water use. The most important use was to maintain the minimur required or ecological flows. The Wieprza River and its tributaries (of the second and third order) have been modelled. 114 users abstracting surface water were included; a total of 457 balance cross-sections were analysed, describing: the hydrographic nodes, the locations of water users and hydrotechnical structures as well as boundaries of water bodies. Based on the results of simulation studies, the criteria for assessing the level of fulfilling the users' water demands, including minimum required and ecological flowswere calculated, as well as the volumes of returnable and non-returnable available water resources, with several levels of reliability.

RESULTS

The RZGW Szczecin hydro-biological flows, ecological flows as well as simplified hydro-biolog-ical flows by Kostrzewa and *SNQ* are presented in Figures 1–3. Figure 1 shows the results of calculations in the water gauge section of Stary Kraków on Wieprza River (at kilometre 22.2, catchment area 1 473.4 km², abiotic type 19 and ichthyologic type IV). Hydro-biological and ecological flows clearly differ from each other. Ecological flows calculated on the basis of two different reference rivers, the Drava river, with salmonid fish spawning and Świder, without spawning also have different values, which indicates the significance of selecting the reference river. The biggest difference, 2.67 m³ · s⁻¹, occurs in the autumn spawning bio-period, that is in November and December. In Figure 2, using the example of the Kwisno water gauge located in the upper Wieprza River (at kilometre 116.8, catchment area of 94.4 km², ichthyologic type III and abiotic type 17), the comparison was made between the controlled river's ecological flow and the hypothetical uncontrolled river situation. A disturbing phenomenon is the different nature of the required water regime as well as significant differences in the value of *QS* in different bio-periods. Figure 3 presents the variability of hydro-biological and ecological flows along the course of the Wieprza river.
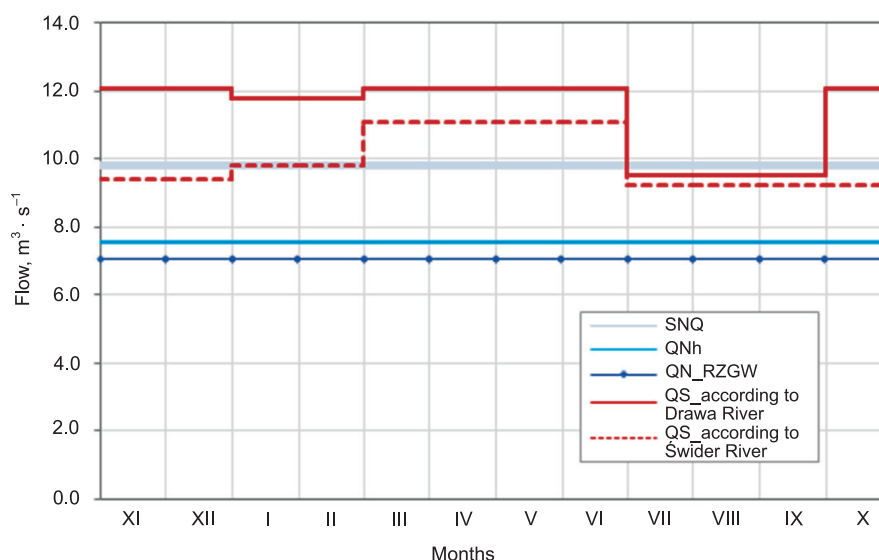

Fig. 1. Minimum required and ecological flows for Stary Kraków gauge station on the Wieprza River (*QN_RZGW*, *QNh* – hydro-biological flow according to the method of the *RZGW* Szczecin and the simplified Kostrzewa method, respectively; *QS* according to Drawa, *QS* according to Świder – ecological flows for a river with and without spawning of salmonid fish; *SNQ* – mean value of annual low flows in the 1990–2013 period)
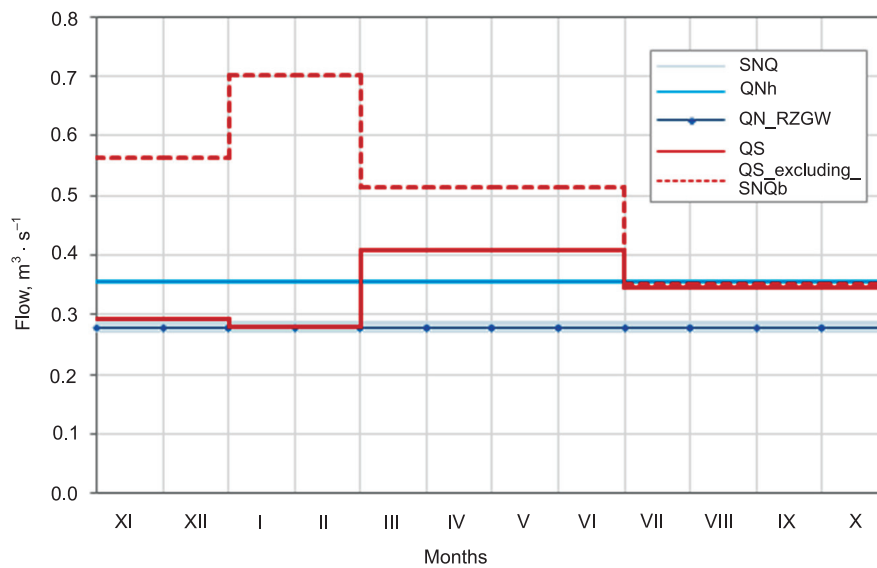
Fig. 2. Minimum required and ecological flows for Kwisno gauge station in the Wieprza River (QN_RZGW, *QNh* – hydro- -biological flows according to the method of RZGW Szczecin and the simplified Kostrzewa method; *QS*, *QS*_without_*SNQb* – ecological flows for a controlled and uncontrolled river respectively; *SNQ* – average value of the annual low flows in the 1990–2013 period)
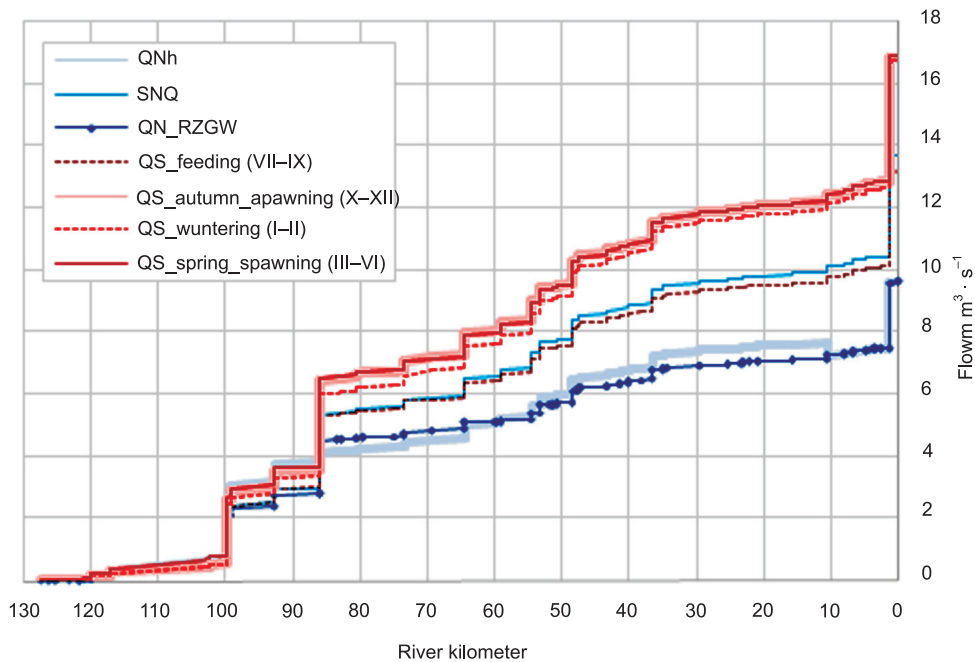

Fig. 3. Hydro-biological and ecological flows along the Wieprza River (*QN_RZGW*, *QNh* – hydro-biological flows according to the method of RZGW Szczecin and the simplified Kostrzewa method respectively; *QS*_feeding (VII–IX), *QS*_autumn spawning (X–XII), *QS*_wintering (I–II), *QS*_spring spawning (III–VI) – ecological flows in respective bio-periods; *SNQ* – average value of the annual low flows in the 1990–2013 period)

In most of the length of the Wieprza river, the lowest values of the minimum required flows were obtained using the RZGW Szczecin method. There are two exceptions to this rule, both in the upper course of the river (see: Fig. 3):

a) from km 103 to 99, where the ecological flow during wintering is the minimum requirement,

b) from km 86 to km 59 (about 25 km), below the cross-section in which Kostrzewa's parameter k changes from 1.27 to 0.77, and the flow calculated using the Kostrzewa method is the smallest.

The hydro-biological according to the RZGW Szczecin method is equal to NNQ on a much longer section of the Wieprza river than in the case of the Kostrzewa method – these are respectively sections from km 54 and from km 10 to the estuary. Contributing to this are high specific runoff of the Wieprza River ($SSq = 10.9$ dm$^3 \cdot$ s$^{-1} \cdot$ km^{-2} at the gauge of Stary Kraków), significant contribution of groundwater supply in river flows, high retention capacity of the catchment (especially its upper part) and climatic conditions. All these factors together shape the flows, which are characterized by low variability (unit runoff at Stary Kraków gauge amounts to $SNq = 6.65$ dm$^3 \cdot$ s$^{-1} \cdot$ km^{-2} and $NNq = 4.79$ dm$^3 \cdot$ s$^{-1} \cdot$ km^{-2}).

With the exception of the upper part of the catchment, the largest are ecological flows. Variable in the annual cycle, the highest values are recorded in bio-periods of spring and autumn fish spawning. For the Wieprza River section of the ichthyologic type IV, in both periods these values are very close to each other (± 2% difference), but in the upper section (type III, *pb* in the absence of *Salmonidae* spawning) the differences reach around 30%.

In the upper course of the Wieprza River, the smallest ecological flows occur during winter (January–February), while in the remaining part, in the summer (that is, the feeding period). The ecological flows in winter are not significantly lower than during spawning (the difference being up to 10%, see: Fig. 3). In the absence of data on the specific requirements of fish species during the wintering (Ustalenie metody szacowania… 2015), such high values are not justified. They may, however, point to significant differences between the hydrological regimes of the Wieprza River and the Drawa River, which was adopted as representative thereof.

The maximum increase in the ecological flow in relation to *QN_RZGW* is 76%, in the lower section of Wieprza, in the spring spawning bio-period. In the summer, ecological flows are about 20% lower than during spawning periods, and simultaneously from 7 to 37% higher than the hydro-biological calculated according to the RZGW Szczecin method (Rozporządzenie... 2014).

The effects for the water management and water, resulting in the adoption of hydro-biological or ecological flows determined by individual methods, are described by the **time** reliability of maintaining these flows and non-returnable and returnable available resources of surface waters (Pusłowska-Tyszewska et al., 2017). Available resources have been calculated for the existing state of water use in the Wieprza River catchment.

Returnable resources determine the amount of water that can be abstracted in the analysed cross-section, provided that it is entirely returned to the river immediately below this section, and this intake will not change the water supply of existing users, including minimum required or ecological flows.

Non-returnable resources signify the amount of water that can be used (the user's water loss or transfer to another watercourse) and this will not aggravate the water supply to the users, either in the analysed cross-section or downstream.

Time reliability for maintaining of minimum required and ecological flows in the sections of Kwisno and Stary Kraków on the Wieprza River is shown in Figure 4. Figure 5 shows reliable flows, with particular time reliabilities, in subsequent days of the hydrological year (after applying a 5-day moving average), and against that background, the volume of RZGW Szczecin hydro-biological flow and ecological flows. Figure 6 – lists the available returnable resources.

The implementation of ecological flows (Ustalenie metody szacowania… 2015) instead of *QN_RZGW* will result in a significant reduction of both returnable and non-returnable resources in the whole Wieprza River catchment. In the Kwisno cross-section, at the flow of *QN_RZGW*, small volume of returnable resources occur with the 98% reliability, whereas for ecological flow, similar resources appear with a much lower reliability (80%). In the Stary Kraków cross-section, the reduction of returnable resources with relia-
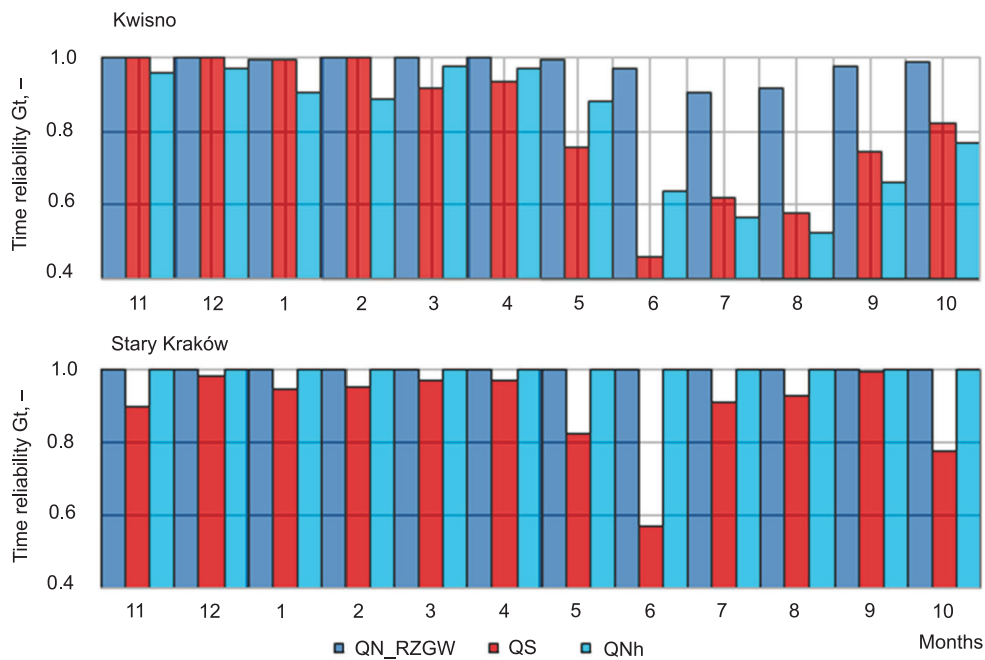
Fig. 4. Time reliability (*Gt* [–]) for hydro-biological flow and ecological flows (*QNh*, *QN*_RZGW, *QS*) in Kwisno and Stary Kraków cross-sections
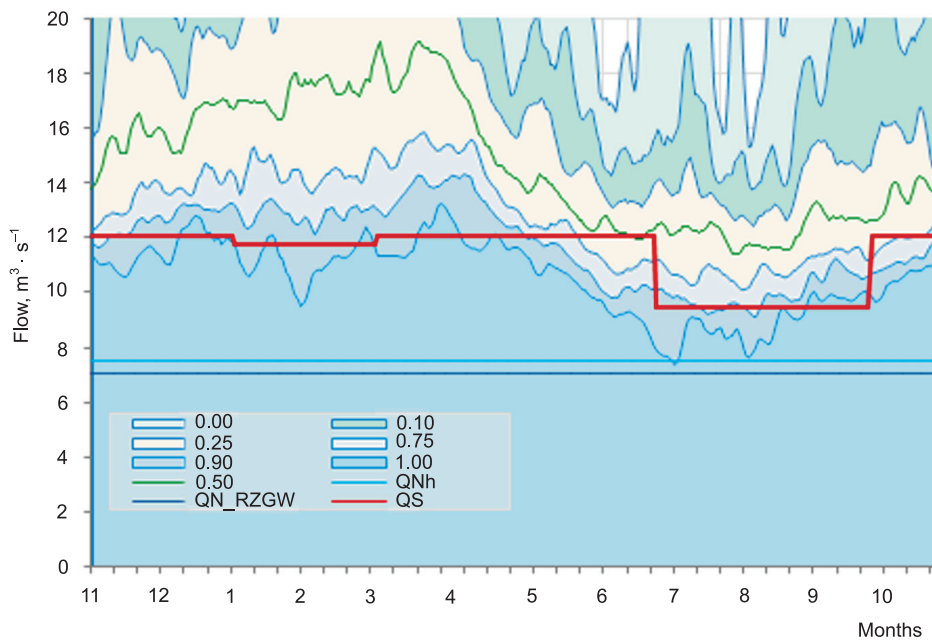

Fig. 5. Comparison of hydro-biological, ecological and reliable daily flows smoothed over 5 days: Stary Kraków cross-section (*QN_RZGW*, *QNh* – hydro-biological flows according to the method of the RZGW Szczecin and the simplified Kostrzewa method respectively; *QS* – ecological flows; 0.00–1.00 – reliable flows of 0–100% reliability in the 1990–2013 period)
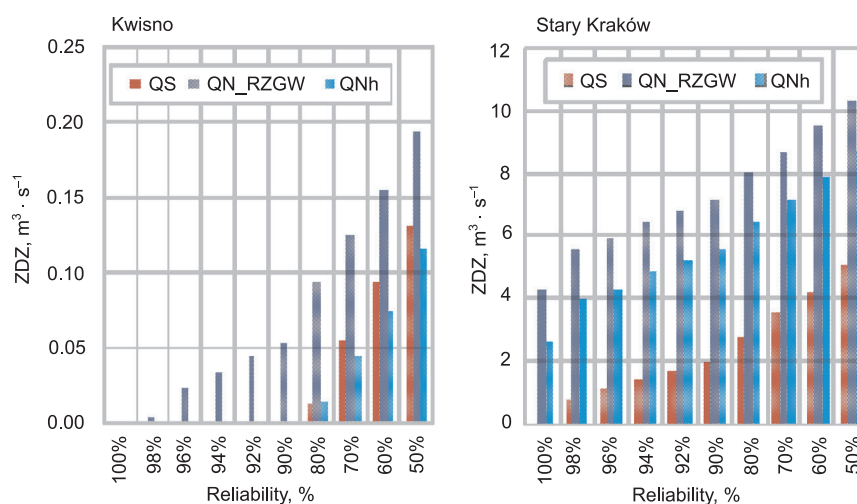
Fig. 6. Returnable available water resources (*ZDZ*) with specified time reliability for hydro-biological and ecological flow requirements – Kwisno and Stary Kraków cross-sections (*QN_RZGW*, *QNh* – hydro-biological flows according to the method of the RZWG Szczecin and the simplified Kostrzewa method respectively; *QS* – ecological flows)

bility from 98 to 50% is about 5 m³ · s⁻¹. The results of water balance calculations (PRO-WODA, 2016) have also shown a significant reduction in the time reliability of water supply for various users in some parts of the catchment.

DISCUSSION AND CONCLUSIONS

The comparison of the volume of minimum required flow determined by the RZGW Szczecin method, and of ecological flows (Ustalenie metody szacowania… 2015) leads to a conclusion that in the majority of watercourses in the Wieprza River catchment, ecological flows (*QS*) are higher. The increment in the value of the ecological flow, in relation to *QN_RZGW*, increases with the increase of the catchment area. The introduction of ecological flows in place of current requirements would result in a significant reduction in resources that can be used to supply users with water. In view of the substantial change in the volumes of required flows, it is worth paying attention to the reservations that may be raised by the proposed method of estimating ecological flows (Ustalenie metody szacowania… 2015).

1. The application of the method for estimating ecological flows, related to field research and the use of the MESOHABSIM model, is a time-con-

suming and costly approach. This approach has a good substantive basis, however, there are no reports on the effects of its application in the subject literature. In addition, due to the local nature of the correlation between the flow rate and the area of useful (appropriate) habitats for fish, the values of ecological determined for the given section should not be transferred to cross-sections that are not covered by the field studies. Therefore, it is not possible to recommend such an approach for general use when issuing water permits. However, according to the authors, it is possible to recommend it for overused rivers, or those with significantly deteriorated morphological conditions, as well as for sections downstream hydrotechnical facilities that can significantly change the regime of flows.

2. The formula for calculating the ecological flow in bio-periods (2) has been proposed on the basis of studies in individual cross-sections of rivers with selected ichthyologic types, including the results of 2–3 field measurement campaigns. The number of cross-sections that have been analysed is far too small to draw conclusions as to the correctness of the assumption that *pb* coefficients have similar values for watercourses belonging to the same ichthyologic type.

3. Verifying the formula for determining ecological flows in uncontrolled watercourses, carried out in the Kwisno water gauge cross-section, showed high differences in *QS* values (for gauged and non-gauged situation), 95–150% from November to February and from 3 to 26% in other months of the year (see: Fig. 2). In the case of the Stary Kraków cross-section, the values given in the study (Ustalenie metody szacowania… 2015) vary from 2 to 91% in different bio-periods. This fact raises doubts as to the truth of the assumption about the similarity of *pb* (or *p*) coefficients for rivers belonging to the same ichthyologic type.

4. Reference watercourses designated for lowland rivers (ichthyologic type IV) are Drawa and Świder, depending on the occurrence of *Salmonidae* spawning. A comparison of the *QS* value determined for both cases (occurrence or absence of *Salmonidae*), carried out for the Stary Kraków cross-section, indicates that significant differences in *QS* (20–30%) occur in the winter (November–February), and in the remaining bio-periods, they amount to 3 and 9%. Since only the river without salmon spawning was indicated as reference watercourse for type III, the estimation of the difference in *QS* values depending on salmon prevalence for type IV, may give an indication of how much *QS* would change in small watercourses if the missing parameters of the method were determined.

5. The consequence of using *QS* in place of *QN_RZGW* currently in force would be a significant reduction in the degree of ensuring the required flows, satisfying water needs of the users (which was not analysed in the article) and a decrease in the volume of available surface water resources. Because low flows in rivers to a large extent originate from groundwater supply, the change in the volume of minimum required flow also affects the available groundwater resources (Herbich et al., 2013). The decision to increase the requirements regarding the volume of flows should be preceded by a thorough analysis of the effects, as well as a discussion with water users about possible solution to the conflict between the ecological and economic use of water. Obtaining confirmation that the implementation of *QS* flows leads to an improvement in the welfare of fish populations and other organisms that form river ecosystems is a necessary element in making a rational decision.

By treating the discussed results of comparative analyses and water balance analyses in selected sections of the Wieprza River as a starting point for consideration of minimum required and ecological flows in Poland, some more general issues should be noted. The first of these is a question about the role of ecological flows in water management. The information presented at the conference "Wdrożenie metody szacowania przepływów środowiskowych w Polsce" ("Implementation of the method for estimation of ecological flows in Poland", Grela, 2018) indicates that they will replace minimum required flow in water permits, that is, they will be included in the basic instrument of water resources management, which water permits are. However, this concept has not been introduced in the provisions of the Water Law (Journal of Laws of 2017 item 1566), therefore the use of ecological flows in this role is not a foregone conclusion. It may turn out that they will become a model of water requirements for aquatic and water-dependent ecosystems, and they will serve as a benchmark for comparisons in the existing flow regime.

The definition of the minimum required flow is still not included in the Water Law. On the other hand, the values of the minimum required flow are determined in two specific cases (Article 403 passage 7 and 8):

a) for water permits issued for the purposes of the keeping or breeding fish or other organisms – the minimum required flow is to amount to 50% *SNQ*,

b) in the case of returnable water use, the minimum required flow can be reduced by 50% *SNQ*.

This is a drastic reduction of requirements in relation to the minimum required flows currently in force in the water regions. Furthermore, reduction of the minimum required flow is allowed without simultaneously imposing any requirements related to the river bed morphology in order to ensure ecological continuum of the section between the intake and discharge of water from the user. Unfortunately, good practice examples of solutions to such cases that implement the precautionary principle have not been used (for instance, requirements in force in the region of Lower Oder and Western Borders (Rozporządzenie... 2014)). In the Wieprza River catchment, both in Kwisno and

Stary Kraków cross-sections, and in most of the water balance sections, lowering the minimum required flow by 50% *SNQ* or up to 50% *SNQ* would lead to flows much lower than *NNQ*. Therefore, there is cause for concern that the permissible reduction of the minimum required flow will be conducive to excessive exploitation of surface water resources, and in the absence of requirements related to the morphology of the channels, they will endanger the continuity of watercourses and their ecological functions.

Definition of ecological flows proposed now (Madej, 2018), namely: *Ecological flow is a natural flow modified in such a way as to provide people with access to water at a level essential to life and development, while ensuring adequate water volume for maintaining habitats and biotopes in good status in the aquatic and water-dependent ecosystems. The status defined in the Water Framework Directive and the Habitats Directive is considered to be a good status*, has some imperfections, according to the authors of the present article. Such a definition may suggest that *providing water for development* is more important than *keeping the aquatic and water- dependent ecosystems in good status*, which is not consistent with the provisions of the WFD. This definition does not indicate the protection of aquatic ecosystems and the achievement and maintenance of good water status as an objective of introducing ecological flows. This may be conducive to neglecting protection for the sake of economic goals only. Furthermore, it introduces the vague concept of the *amount of water necessary for people to live and develop*.

While analysing the needs of aquatic ecosystems, one must not neglect water quality issues (Brisbane Declaration, 2007) or abiotic conditions shaping the habitats of organisms. Ensuring the requirements of ecosystems in terms of the amount of water (for instance, flows that are no less than ecological flow) – without the appropriate morphological features of the channel or the relevant parameters of water quality – is not enough for the good status of the ecosystems. It should be emphasized, however, that increasing the flow requirements can not compensate for an inadequate quality or insufficient area of habitats that are useful for organisms. At the same time, this does not preclude the possibility of reducing the volumes of ecological flows or minimum required flows on some sections of rivers, provided that good habitat conditions are formed in the riverbed.

It is not only the minimum amounts of water ensuring the survival of organisms that are important for the functioning of aquatic ecosystems (Brisbane Declaration, 2007). Flood flows (freshets) are shaping morphological elements of river channels, their depth, width and routes, they are creating nesting and feeding conditions for water-marsh birds, and they are forming humidity conditions of valley habitats, controlling the development of vegetation that is not adapted to high soil moisture. The role of freshets was also appreciated in the EC guidelines (2015), where it was found that in defining ecological flows we can not limit ourselves only to low flows. The definition of ecological flows needed for floodplain ecosystems (Ustalenie metody szacowania… 2015) failed to specify the size of the minimum required flow, duration and moment of occurrence. We cannot agree with Grela's thesis (2018) that flood flows can be an element of ecological flows only where it is possible to shape flows through hydrotechnical structures. According to the authors, ensuring the desired water regime in the zone of high flows is associated primarily with limiting interference in hydrological phenomena (for instance, retention in reservoirs, filling of ponds, transfers of water (Pusłowska-Tyszewska and Tyszewski, 2014b)). This does not preclude the use of hydrotechnical facilities to support high water levels for the protection of ecosystems that are water dependent (Tyszewski et al., 1995). Activities in this area must take into account flood protection requirements. At the same time, it should be noted that the introduction of high flow requirements in a manner analogous to the maintenance of minimum required or ecological flows (that is, a rigid specification of the time interval in which flows of a certain magnitude are to be maintained) can lead to a significant reduction of available water resources. Furthermore it does not ensure that a freshet occurs in the volumes desired for the purposes of ecosystem protection if, for instance, the flood surge appears outside the defined season. Only the application of an adaptive approach to determining the magnitude of the required flow, according to which the flow depends on the current hydrological conditions (Pusłowska-Tyszewska and Rycharski, 2015), offers the opportunity to meet the requirements of ecosystems without unjustified limitation of satisfy-

ing the needs of water users. Current communication techniques (that is to say, providing users with current flow requirements) are quite sufficient to implement such an approach.

REFERENCES

Acreman, M., Dunbar, M.J. (2004) Defining ecological river flow requirements – a review. Hydrology and Earth System Sciences, 8(5), 861–876.

Acreman, M.C., Overton, I.C., King, J., Wood, P., Cowx, I.G., Dunbar, M.J., Kendy, E., Young, W., (2014). The changing role of ecohydrological science in guiding ecological flows. Hydrological Sciences Journal, 59(3–4), 433–450.

Arthington, A.H., Bunn, S.E., Poff, N.L., Naiman, R.J. (2006). The challenge of providing ecological flow rules to sustain river ecosystems. Ecological Applications, 16, 1311–1318.

Brisbane Declaration (2007). The Brisbane Declaration. Ecological Flows are Essential for Freshwater Ecosystem Health and Human Well-Being. Declaration of the 10th International River symposium and International Ecological Flows Conference, Brisbane, Australia, 3–6 September 2007.

Grela, J. (2018). Uwarunkowania procedury praktycznego wdrożenia przepływów środowiskowych w Polsce. Konferencja „Wdrożenie metody szacowania przepływów środowiskowych w Polsce", 21 marca 2018, Warszawa.

Grela, J., Stochliński, T. (2005). Zastosowanie metody IFIM do wyznaczania przepływu nienaruszalnego. Aura, 8.

Herbich, P., Kapuściński, J., Nowicki, K., Rodzoch, A. (2013). Metodyka określania zasobów dyspozycyjnych wód podziemnych w obszarach bilansowych z uwzględnieniem potrzeb jednolitych bilansów wodnogospodarczych – Poradnik metodyczny. Ministerstwo Środowiska.

European Commission (2015). Ecological flows in the implementation of the Water Framework Directive. CIS guidance document nº 31. Technical Report - 2015 – 086. European Union, 2015.

Kostrzewa, H. (1977). Weryfikacja kryteriów i wielkości przepływu nienaruszalnego dla rzek Polski. Mat. Bad. IMGW, Gospodarka wodna i ochrona wód.

KPRM. (1963). Szczegółowe wskazówki metodyczne dotyczące opracowywania planów regionalnych w zakresie gospodarki wodnej. Warszawa: Komisja Planowania Rady Ministrów.

Madej, P. (2018). Analiza metody szacowania przepływów środowiskowych w Polsce i podstawy jej weryfikacji. Konferencja „Wdrożenie metody szacowania przepły-

wów środowiskowych w Polsce", 21 marca 2018, Warszawa.

MGGP. (2018). Materiały Konferencji „Wdrożenie metody szacowania przepływów środowiskowych w Polsce", 21 marca 2018, Warszawa.

OECD (2015), Water Resources Allocation: Sharing Risks and Opportunities, OECD Studies on Water. Paris: OECD Publishing.

Parasiewicz P., Rogers J. N., Gortazar J., Vezza P., Wiśniewolski W. & C. Comglio. (2013). Applications of the MesoHABSIM Simulation Model. In: Maddock I., Harby A., Kemp P., Wood P. Ecohydraulics: an integrated approach. John Wiley & Sons Ltd. 109–124.

Parasiewicz, P., Dunbar, M.J. (2001). Physical Habitat Modelling for Fish: A developing approach, Large Rivers, 12 (24), Arch. Hydrobiol. Suppl., 135/2–4, 239–268.

Poff, L.N., Zimmerman J.K.H. (2010) Ecological responses to altered flow regimes: a literature review to inform the science and management of ecological flows Freshwater Biology, 55, 194–205.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., Stromberg J.C. (1997). The natural flow regime. Bioscience, 47, 769–784.

Pracownia Gospodarki Wodnej PRO-WODA. (2016). Opracowanie projektu warunków korzystania z wód zlewni rzeki Wieprzy. Szczecin: Raport dla RZGW w Szczecinie.

Pusłowska-Tyszewska, D., Rycharski, M. (2015). Wymagania wodne ekosystemów zależnych od wód jako podstawa określenia przepływów nienaruszalnych/środowiskowych. Część I: Koncepcja. Gospodarka Wodna, 12, 371–376.

Pusłowska-Tyszewska, D., Rycharski, M., Oświęcimska-Piasko, Z., Teodorowicz, M. (2016). Wymagania wodne ekosystemów zależnych od wód jako podstawa określenia przepływów nienaruszalnych/środowiskowych. Część II: Przykłady z Narwi i Baryczy. Gospodarka Wodna, 2, 48–60.

Pusłowska-Tyszewska, D., Tyszewski, S. (2014b). Wymagania ekosystemów wodnych i zależnych od wód w zarządzaniu zasobami wodnymi. In: K. Banasik, L. Hejduk, E. Kaznowska, Hydrologia w inżynierii i gospodarce wodnej. Warszawa : Komitet Gospodarki Wodnej PAN, 247–258.

Pusłowska-Tyszewska, D., Tyszewski, S., Duda, R., Kiejzik-Głowińska, M., Treichel, W., Nawalany M. (2017). Bilans wodnogospodarczy wód powierzchniowych. In: D. Pusłowska-Tyszewska, S. Tyszewski, Środowiskowe aspekty udostępniania gazu ze skał łupkowych. Gdańsk: Wydawnictwo Politechniki Gdańskiej, 45–76.

Pusłowska-Tyszewska, D., Tyszewski, S. (2014a). Bilanse wodnogospodarcze na potrzeby opracowania warunków korzystania z wód zlewni rzecznych na przykładzie Jeziorki. In: K. Banasik, L. Hejduk, E. Kaznowska, Hydrologia w inżynierii i gospodarce wodnej. Warszawa : Komitet Gospodarki Wodnej PAN, 259–270.

Ramowa Dyrektywa Wodna (2000). Dyrektywa 2000/60/WE Parlamentu Europejskiego i Rady z 23.10.2000 r. ustanawiająca ramy wspólnotowego działania w dziedzinie polityki wodnej.

Rozporządzenie nr 3/2014 Dyrektora RZGW w Szczecinie z dnia 3 czerwca 2014 r. w sprawie ustalenia warunków korzystania z wód regionu wodnego Dolnej Odry i Przymorza Zachodniego. (Dz. Urz. Woj. Zachodniopomorskiego 2014.2431, Dz. Urz. Woj. Lubuskiego 2014.1139, Dz. Urz. Woj. Pomorskiego 2014.2237).

Tharme, R.E. (2003) A global perspective on ecological flow assessment: emerging trends in the development and application of ecological flow methodologies for rivers. River Research and Applications, 19(5–6), 397––441.

Tyszewski, S., Okruszko, T., Pusłowska, D., (1996). Propozycja metodyki określania sposobu wykorzystania zasobów wodnych zlewni o szczególnych walorach przyrodniczych na przykładzie Górnej Narwi – część I i II. Materiały VII Seminarium Naukowego z cyklu „Ochrona jakości i zasobów wód" pt. „Zasady racjonalnej gospodarki wodą". Październik 1996, Zakopane.

Ustalenie metody szacowania przepływów środowiskowych w Polsce. Etap II – Raport końcowy (2015), Warszawa: KZGW.

Ustawa Prawo wodne z dnia 20 lipca 2017 r. (Dz. U. poz. 1566).

Więzik, U., Więzik, B. (2007). Hydrobiologiczna metoda określenia przepływu nienaruszalnego. Innowacyjne rozwiązania techniczne i organizacyjne w przedsiębiorstwach wodociągowo-kanalizacyjnych. Materiały konferencji naukowo-technicznej, Bielsko-Biała, Szczyrk, 10–12 października 2007, 71–86.

Witowski, K., Filipkowski, A., Gromiec, M.J. (2008). Obliczanie przepływu nienaruszalnego – poradnik. Warszawa: IMGW.

PRÓBA ZASTOSOWANIA OPRACOWANEJ W 2015 ROKU „METODY SZACOWANIA PRZEPŁYWÓW ŚRODOWISKOWYCH W POLSCE" W ZLEWNI RZEKI WIEPRZY

ABSTRAKT

Zapewnienie reżimu hydrologicznego odpowiadającego wymaganiom ekosystemów wodnych i od wody zależnych jest niezbędne dla utrzymania lub osiągnięcia dobrego stanu/potencjału wód i należy do priorytetów zrównoważonej gospodarki wodnej. Wymagania ekosystemów odwzorowywane są najczęściej w postaci przepływów nienaruszalnych lub środowiskowych, które stanowią ograniczenie w wykorzystaniu zasobów wodnych. Celem artykułu jest porównanie gospodarczych skutków zastosowania metody szacowania przepływów środowiskowych, obecnie obowiązującej metody RZGW w Szczecinie i najbardziej znanej w Polsce metody Kostrzewy (1977), a także ocena przydatności i możliwości zastosowania metody przepływów środowiskowych w analizach planistycznych. Analizy przeprowadzono na podstawie badań symulacyjnych. Wielkości obliczonych przepływów nienaruszalnych i środowiskowych przedstawiono w profilu podłużnym i w wybranych przekrojach Wieprzy. Skutki wdrożenia przepływów środowiskowych oceniono poprzez gwarancje czasowe ich utrzymania oraz zmiany wielkości gwarantowanych zasobów dyspozycyjnych wód powierzchniowych. Stwierdzono, że w większości przekrojów bilansowych w zlewni Wieprzy zastosowanie przepływów środowiskowych spowoduje zmniejszenie dostępności zasobów wodnych zarówno dla istniejących, jak i perspektywicznych użytkowników wód. Na podstawie uzyskanych wyników przedyskutowano wybrane zagadnienia związane z metodyką określania przepływów środowiskowych, szczegółową uwagę zwrócono na nieścisłości i luki w proponowanej metodzie.

Słowa kluczowe: przepływy nienaruszalne/środowiskowe, wymagania wodne ekosystemów wodnych i zależnych od wód, reżim hydrologiczny, gospodarowanie wodami, bilans wodnogospodarczy