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Ecological quality classes of river hydromorphology in Poland

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Abstract: This work presents rules and results of classifications of hydromorphological status of watercourses used presently in Europe. The Water Framework Directive introduced an obligation to monitor hydromorphological elements of rivers, which include hydrological regime, river continuity and bed morphology. European standards require somewhat different quality indicators and the way of their assessment for such investigations. Classification of status and ecological potential shall include categories and types of rivers, however, the methods existing so far do not provide such a distinction. Assessment of much differentiated features and attributes, as well as the requirement of presenting the outcome in *EQR* form, within limits from zero to one, cause that all the studied parameters, which are very diverse, must be conveyed to numerical form. The MHR method takes into account the above conditions and proposes a classification which includes limit values for five classes of status and four classes of ecological potential. It assumes limit values of classes lowering from natural watercourses through heavily modified to artificial.

Key words: *class boundaries, classification of ecological status, ecological potential, ecological quality ratio, hydromorphological river survey*

INTRODUCTION

Water Framework Directive WFD (Directive 2000/60/EC) introduced an obligation to carry out assessment and classification of ecological status of natural watercourses as well as ecological potential of heavily modified and artificial watercourses. It presumes that by the year 2015 all the uniform water bodies in EU

member countries will meet at least high (class I) or good (class II) ecological status and good ecological potential (WFD Article 4.1). Assessment shall be based on numerous elements characterizing the river and its surroundings. Evaluation of each element should be expressed in the form of ecological quality ratio (*EQR*), which ranges from 0.0–1.0. Thus it turned out to be necessary to define the limit values between five classes of ecological status of natural watercourses and four classes of ecological potential of heavily modified and artificial watercourses. The limit value between class II and III shows whether the requirement described above, included in the Directive, has been met.

CLASSIFICATION OF NATURAL RIVER STATUS OF WATERCOURSES ACCORDING TO THE WATER FRAMEWORK DIRECTIVE AND EUROPEAN STANDARDS

Water Framework Directive 2000/60/EU requires defining the ecological status of rivers based on biological, hydromorphological (hydrological regime, continuity of river and bed morphology) and also physicochemical elements (WFD Annex V point 1.1). It contains definitions for high, good and moderate status. Is required (WFD Annex V point 1.4.2) distinguishing 5 classes of ecological status of natural watercourses and 4 classes for ecological potential of heavily modified (HMWB) and artificial (AWB) watercourses (Tab. 1). Heavily modified and artificial watercourses, according to Article 4.1 and 4.3 of WFD, can not get a good ecological status because of their negative impact on inland navigation, recreation, flood protection, regulation of waters, widely understood environment, or on existing international treaties, but they should achieve at least a good ecological potential in the year 2015.

In order to ensure comparability of the monitoring results, ratings of the studied quality elements shall be expressed as coefficients of ecological quality (Ecological Quality Ratio – *EQR*). They present relations between a settled status of the studied watercourse, and reference status (natural) corresponding to the conditions of anthropogenically unchanged watercourse. The coefficient is expressed as a numerical value ranging from zero to one, whereas high ecological status is described with values close to one and bad status with values close to zero (WFD Annex V point 1.4.1). Each Member State will define its *EQR* limit values for separated quality classes for each category of watercourses (natural, heavily modified and artificial). They are to be defined for all studied elements and indices. It enables to determine the elements which require changes, and the Member States can introduce their own classification of elements.

Water Framework Directive does not define the conception of natural status. It should correspond to reference conditions which were not specified for river hydromorfology in the process of intercalibration exercises conducted in Europe.

Table 1. Classification of ecological status for surface waters (WFD Annex V point 1.4.2)

Classification of ecological status of natural watercourses	
status (class)	colour code (on maps)
Very good	blue
Good	green
Moderate	yellow
Weak	orange
Bad	red
Classification of ecological potential of heavily modified and artificial watercourses	
status (class)	colour code (on maps)[1)]
Good and above	green-grey stripes
Moderate	yellow-grey stripes
Poor	orange-grey stripes
Bad	red-grey stripes

[1)] For heavily modified watercourses light-grey stripes are used, for artificial dark-grey.

A reference status may refer to a given river state from the period preceding the industrial revolution (18th century) or intensification of agriculture (middle of 20th century), or pragmatic approach based on attainable ecological conditions.

Coefficients of ecological quality are defined for all the studied elements. Limit values of ecological potential classes for heavily modified watercourses should be accordingly lower in relation to ecological condition of natural watercourses and the lowest for artificial watercourses. However there is no method for calculating *EQR* that would consider all the studied elements of quality. According to WFD Annex V point 1.4.2 it is recommended for each category of waters to be expressed by the lower value received from biological and physicochemical monitoring, and presented on the maps as given in table 1. Hydromorphological elements are treated as supporting the classification, while there are no clear indications in the directive as to their place in the classification. It is completely inexplicable, because they are these elements that in a considerable manner decide about the condition of biological elements. Difficulties in classifying numerous biological elements, which emerged in the last years during intercalibration exercises, aiming at classification of biological elements, show that such approach will not permit to determine which water bodies in the year 2015 will not get a good status or ecological potential. It should be remembered that defining the limit value of classes, realized by each Member State, can be treated as a scientific implementation of political decision.

Created according to Common Implementation Strategy for the Water Framework Directive Guidance (CIS-WFD, 2003) Document No. 10 „River and lakes – typology, reference conditions and classification systems" ecological status suggests limiting the classification of hydromorphological elements of the class very

good and not distinguishing the remaining classes. However, documents created according to CIS-WFD do not constitute effective legal acts in European Union and do not enable different actions. Analysis of methods used in Member States for setting quality class boundaries (DE WILDE and KNOBEN, 2002) contained in Attachment Guidance No. 10 finds it impossible to delimit them for each river type. Recommended here is distinguishing the classes for groups of water types. Among mentioned elements surveyed during assessment of ecological status there are also hydrological regime, continuity of river and bed morphology. In France, inclusion of hydromorphological elements into the general assessment is obligatory, in other EU countries applied at times. In many countries *EQR* is defined also for numerous elements, not only as the total rate of all elements. Status close to *EQR* = 1 constitutes reference conditions. As the most important they treat a threshold value between good and moderate status (class II/III) (good – moderate boundary), omitting limit values for classes IV and V (poor and bad).

Guidance document No. 21 (CIS-WFD, 2009) requires also informing European Commission about the hydromorphological elements classification. These data are put into the Water Information System for Europe (WISE) which is the elementary database on waters for the European Environmental Agency (EEA).

The standard EN 14614:2004 lists 10 features (assessment categories), which shall be included during assessment of hydromorphology of rivers, and requires distinguishing of five quality classes. They differ from those given by the WFD. They also include the river valley, but exclude hydrological regime and the river continuity. The project of standard prEN 15843 (2009) presents ways of assessment of the above 10 core features and 11 subsidiary features, and contains limit values for three and for five quality classes (1 – near natural, 2 – slightly modified,

Table 2. Limit values of naturalness classes used in various methods for assessment of eco(hydro)-morphology of rivers

Country, source	Limit values of naturalness classes (points)				
	I	II	III	IV	V
Austria, WERTH [1987]	1,0–1,7[1)]	1,8–2,2	2,3–2,7	2,8–3,2	3,3–4,0[2)]
Germany, FRIEDRICH *et al*. [1998]	1,0–2,6[1)]	2,7–3,5	3,6–4,4	4,5–5,3	5,4–7,0[3)]
Poland, ILNICKI and LEWANDOWSKI [1995]	>4,25	3,50–4,24	2,75–3,49	2,00–2,74	<1,99
Poland, OGLĘCKI and PAWŁAT [2000]	4,21–5,0	3,41–4,2	2,61–3,4	1,81–2,6	1,0–1,8
Czech Republic, MATOUŠKOVÁ [2003]	1–1,5	1,5–2,5	2,5–3,5	3,5–4,5	4,5–5
Slovakia, BLASKOVIČOVÁ *et al*. [2004]	1,0–1,7	1,8–2,5	2,6–3,4	3,5–4,2	4,3–5,0
Czech Republic, LANGHAMMER [2008]	<1,7	1,8–2,5	2,6–3,4	3,5–4,2	>4,2
Poland, WYŻGA *et al*. [2008]	1,0–1,79	1,8–2,59	2,6–3,39	3,4–4,19	4,2–5,0
prEN 15843, [2009]	1<1,5	1,5<2,5	2,5<3,5	3,5<4,5	4,5–5,0

[1)] Class I and II, [2)] Class VI and VII, [3)] Seven-point assessment, not five-point as in other methods.

3 – moderately modified, 4 – extensively modified, 5 – severely modified). The different names of classes show they do not affiliate with the classification of ecological status from WFD. The above classification does not distinguish categories and types of rivers (Tab. 2).

EXISTING METHODS OF DETERMINING THE MODIFICATION EXTENT IN RIVER HYDROMORPHOLOGY

In majority of river hydromorphology assessment methods created in Europe during the last 25 years, the assessment of natural river status was calculated by scoring of the chosen features. It was usually arranged in 1–5 point scale. In some countries a very good status means 1 point, in others 5 points. The scores created a ground for distinguishing 5, sometimes 7 categories of natural river status. In a monitoring conducted in Germany, the class of studied watercourse was based on separately prepared point assessment of indicators: river bed and valley dynamics subsystems, considering hierarchy of criteria and the rule of minimum. It directly led to defining classes without applying of their limit values. At the beginning 7 classes were allotted (Gewässergüteatlas…, 2002), later on joining class 1 with 2 and 6 with 7 led to the division into 5 classes required by WFD.

Arithmetic means based on features assessment decided on watercourse naturalness category. The limit values of categories (classes) were defined by authors in various ways (Tab. 2). These were always values quantified in scores on 1–5 scale. Natural, heavily modified and artificial watercourses were not distinguished. Our comparison of nine used limit values for five quality classes shows their similarity. Averaged limit values show that class I includes 17%, class II – 20%, class III – 22,5%, class IV – 27,5% and class V – 12,5% of the researched watercourses. Requirement to obtain at least good ecological status would theoretically be fulfilled by only 40% of the investigated rivers. Characteristics of hydromorphological status a river obtained in this way are listed in table 3. It presents the percentage of five classes of naturalness in watercourses of total length 43 922 km. It is thus a very representative picture for Central Europe, where the largest range of research (33 000 km) included German rivers. Data for the Brandenburg Province bordering Poland were picked out (1 707 km). Considerable were also the range of investigations conducted in Austria (4 915 km) and on the Danube River (2 584 km). In Poland, the widest range of investigations (1 376.1 km) included rivers and waterways of the Wielkopolska Region. On smaller scale investigations were also carried out in Lower-Silesia, Warmia-Masuria, Masovia, on short sections of Oder and Vistula rivers as well as in the Tatra Mountains.

Our analysis of rivers length percentage in sequent ecological status classes has led to the following conclusions: the total share of length of studied rivers in I and II quality class ranges from 0–80%, what allows to distinguish four groups of

Table 3. Percentage length of surveyed rivers in respective hydromorphological naturalness classes

River	Length of river studied km	Source	% share of naturalness classes				
			I	II	III	IV	V
Warta Konin – Kostrzyn	406	ILNICKI and LEWANDOWSKI [1997]	10	27	50	11	2
Noteć: Bydgoski Canal – Santok	203		2	28	55	15	0
Górna Noteć Waterway	146		0	6	37	39	18
Wielkopolska Region waterways, in total	755		6	25	50	16	3
16 waterways total	621,1	LEWANDOWSKI [2000]	2	14	45	37	2
Rivers of Austria except Danube	4 915	MUHAR *et al*. [2000]	6	15		79	
Brandenburg, Germany	1 707	Bock *et al*. [2002]	22	13	13	30	22
Germany – medium and larger watercourses	33 000	Gewässergüteatlas [2002]	10[1)]	11	19	27	33[2)]
Jeziorka	63,7	OGLĘCKI and PAWŁAT [2000]	42	38	8	12	0
Wkra	18,0	OGLĘCKI *et al*. [2003]	0	57	43	0	0
Widawa	103	ADYNKIEWICZ-PIRAGAS and TOKARCZYK [2004]	0	10	77	13	0
Pisa Warmińska	8,5	GRZYBOWSKI [2007]	0	58	18	12	12
Weisseritz – Germany	102,5	WEISS *et al*. [2008]	0	0	3	10	87
Rolava – Czech Republic	36,6		34	30	18	9	9
Dunajec	17	WYŻGA *et al*. [2008]	36	36	0	27	0
Danube	2 584	SCHWARZ [2008]	0	38	31	28	3

[1)] Classes 1 and 2 combined, [2)] Classes 6 and 7 combined.

rivers. The best ecological status (>50% share) was demonstrated by Pisa Warmińska, Dunajec, Rolava (Czech Republic), Jeziorka and Wkra in Masovia, occurring in the areas of lesser anthropogenic pressure. In these investigations only about 20–30% of the length of the studied watercourses was classified in I and II class. As to Górnonotecka Waterway in Kuyavia and Weisseritz River in Germany sections classified as very good and good status.

In conclusion their were no limit values applied so far, will not allow the vast majority of watercourses to fulfill WFD requirement to achieve in the year 2015 at least a good status of natural rivers or a good ecological potential for heavily modified and artificial watercourses. The Water Framework Directive foresaw it already in the Article 4.4. Thus, essential is development of different rules allowing to describe limit values of classes (Tab. 1).

Currently it has been assumed in Germany that a significant morphological change in rivers occurs only when on large sections of surface water bodies the two worst classes in the seven-class system, so currently only class V are found (Raport…, 2009). Considering the data summarized in table 3, this would apply to

33% of the rivers in Germany and less than 5% of the Danube River and Polish rivers.

CREATION OF ECOLOGICAL QUALITY CLASSES IN THE MHR METHOD

MHR methodology (ILNICKI *et al*., 2009) recognizes as a natural state of watercourses their state in Poland from the mid-twentieth century before the intensification of agriculture. It should be remembered that the vast majority of rivers in Central Europe and Poland from the 19th century was and remains subjected to various pressures. A good status or ecological potential will usually apply only to parts of rivers. Limit values always constitute the sole decision of each Member State and are different in each country. The conception used in the WFD corresponding totally or nearly totally to undisturbed conditions, and show low levels of distortion resulting from human activity can hardly be deemed accurate (WFD Annex V point 1.2).

Because it is impossible to set limit values for all landscapes, catchment size and abiotic type, for the hydromorphology of rivers, a principle of separating classes limit values differentiated for natural watercourses, heavily modified and artificial was adopted. In that case a statistical analysis of the results of rivers hydromorphology assessment was applied according to ILNICKI and LEWANDOWSKI (1997) method, which allowed a normal distribution of the allotted classes (LEWANDOWSKI in press).

In the MHR method it was recognized as inappropriate to use features of the principle "one out – all out", useful mostly in assessing groundwater chemical status. Also forbore was the use of weights for calculating indicators. In assessment protocols the calculation of *EQR* is based on all of the tested indicators and elements. In the MHR method, the reference conditions were related to natural watercourses which were classified on the basis of *EQR* in the upper interval of the very good status. In order to assess properly the ecological status of watercourses and to prepare plans of water management in river basins, it was necessary to establish limit values of all five classes of ecological status and four classes of ecological potential. It enables localization of river sections requiring implementation of corrective actions and renaturization. It was found impossible to compare *EQR* limit values established for watercourses hydromorphology and for various biological status components. The method proposes setting the limit values for 5 ecological status classes and 4 classes of ecological potential (Tab. 4).

The MHR method was checked in 2009 on 11 uniform water bodies located in the Wielkopolska Region, Warmia and Masuria and Ziemia Kłodzka. With the total length of 358.2 km they mainly included natural watercourses, to a little extent heavily modified (23.7 km) and artificial watercourses (7.8 km). Their ecological quality ratios ranged from 0.40–0.92. Their mean value for the natural watercourses

Table 4. Project of temporary classboundaries of ecological state and potential (ILNICKI *et al*., 2009)

Watercourses	Ecological status or potential	Classification according to WFD Annex V point 1.4.2	*EQR* classboundaries
Natural	ecological status	reference condition	0.90–1.00
		high (class I)	0.77–0.89
		good (class II)	0.58–0.76
		moderate (class III)	0.39–0.57
		poor (class IV)	0.21–0.38
		bad (class V)	0.00–0.20
Heavily modified	ecological potential	good and above	>0.50
		moderate	0.35–0.49
		poor	<0.21–0.34
		bad	<0.21
Artificial	ecological potential	good and above	>0.45
		moderate	0.31–0.45
		poor	0.15–0.30
		bad	<0.15

was 0.69 and for the artificial watercourses 0.40 only. Figure 1 shows the distribution of *EQR* values obtained with the reference to the proposed limit values of watercourses (ILNICKI *et al*., 2009).

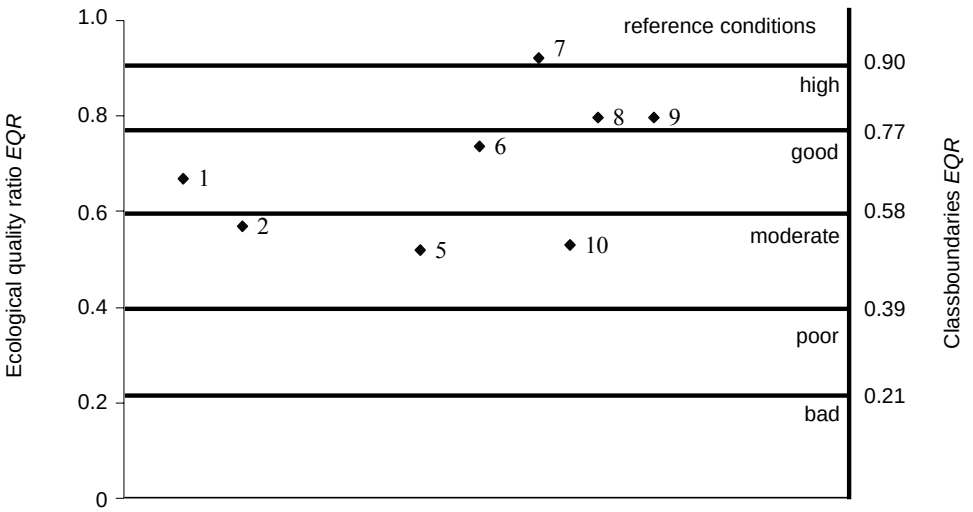

Fig. 1. Results of natural watercourses ecological status assessment made using MHR method in 2009: *1* – Biała Lądecka from Kobyla to Morawka, *2* – Mała Wełna from Gorzuchowskie Lake to Tributary from Rejowiec, *5* – Nysa Kłodzka from Biała Lądecka to Ścinawka, *6* – Orzechówka, *7* – Pasłęka from Drwęca Warmińska to Pierzchała Reservoir, *8* – Junikowski Creek, *9* – Wirynka, *10* – Września

DISCUSSION

The Water Framework Directive requires that the assessment of ecological status and potential is carried out for uniform water bodies allocated by the Member States. For this purpose it recommends the use of biological elements (aquatic flora, benthic invertebrates and ichthyofauna), hydromorpological elements (hydrological regime, river continuity, river channel morphology), chemical and physicochemical elements (thermal conditions, oxygenation, salinity, acidification, nutrients) and specific pollution element, called priority substances. Biological elements and priority pollutants (hazardous) are considered as basic evaluation criteria, the remaining are viewed as supporting elements. In classification of the ecological status of rivers, the omission of information on the waterflow, river channel morphology and its association with floodplain, which are crucial for the living conditions of organisms, is difficult to justify. After all, the water hydromorphological and physicochemical elements decide on the living conditions of aquatic organisms. Regardless of this the CIS-WFD (2003) recommends limiting the scope of hydromorphological elements to determine the classes of high and good ecological status. This means failing to use important information collected for the remaining watercourses and makes it impossible to localize sections of rivers which need an improvement of their status or ecological potential.

So far there is a lack of methods allowing to identify quality classes for most of the above biocenotic elements, as well as a method for collective presenting rating for all the biological elements of a water body. Moreover, the assessment of biological elements will present different outcomes for different biological elements, as the optimal life conditions for phytoplankton, fish and macrophytes are not the same. The practice of classifying biological elements will demonstrate the need to change the classification rules established in the WFD. What can be done at once do this today, is shown on the example of France and Germany (Reference Index), where in addition to macrophytes (*RI*) indices in two remaining modules: diatoms – *DI* infusorial index for flowing waters and phytobenthos without diatoms – *BI* assessment index, are also encountered.

An ecological status expresses the structure quality and functioning of the surface waters ecosystem. An ecological potential describes the state of heavily modified or artificial water body. It indicates that the changes in hydromorphological characteristics, necessary to achieve good ecological status, are in contradiction with the requirements of navigation, water storage, flood protection and river regulation (WFD Article 4(3)) and other types of human activity. In WFD the introduction of the conception of ecological potential derives from the assumption that the heavily modified and artificial watercourses can not achieve good ecological status. Limit values of ecological potential classes should hence be lower than the values of ecological status. For these reasons, the MHR method takes on the separation of all classes of status as well as of ecological potential (Tab. 4). Distribution of the

evaluation results obtained for the studied uniform water bodies (Fig. 1, 2) confirms the validity of such a claim. All the previous methods of river hydromorphology assessment (Tab. 2, 3) recognized five classes or categories of natural river status, however without distinguishing heavily modified and artificial watercourses. Such watercourses were classified as class IV and V.

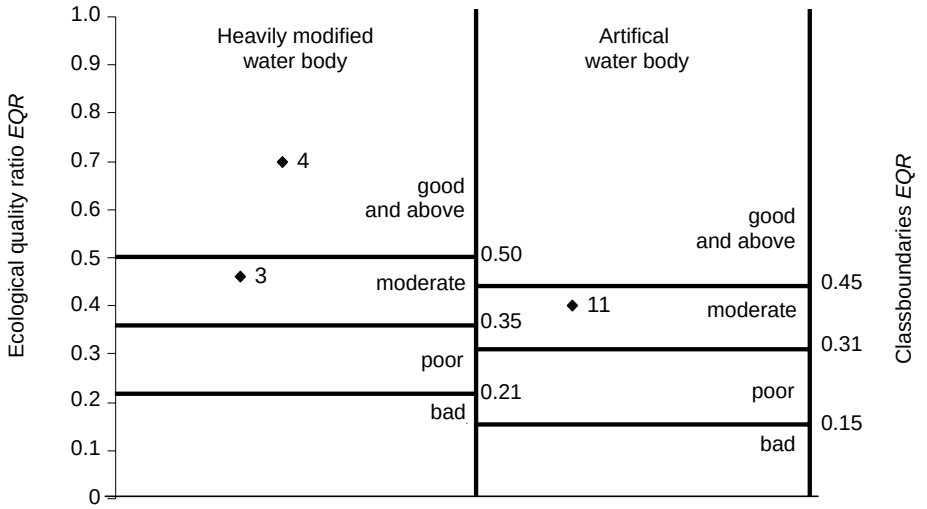

Fig. 2. Results of ecological potential assessment for heavily modified and artificial watercourses conducted in 2009 using MHR method; *3* – Meszna above Bawół Creek, *4* – Meszna from Tributary from Babiń to mouth, *11* – Ślesiński Canal

CONCLUSIONS

1. The methods used for river hydromorphology assessment in Europe so far are not fully compatible with the requirements of the WFD and the European Standards 14 614 and 15 843. This applies to both selection of the features examined (quality elements) and to limit values of quality classes. For this reason, there was a necessity to develop a new method for River Hydromorphological Monitoring (MHR).

2. The MHR method applies limit values of quality classes, different for natural, heavily modified and artificial watercourses. It allows separating all 5 classes of status and 4 classes of ecological potential of watercourses. This enables the practical use of river hydromorphological elements in the development of water management plans in river basins, and preparation of reports for European Commission and European Environmental Agency.

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STRESZCZENIE

Hydromorfologia rzek w Polsce – klasy jakości stanu ekologicznego

Słowa kluczowe: *hydromorfologia rzek, potencjał ekologiczny, stan ekologiczny, wartości graniczne klas jakości, współczynnik jakości ekologicznej*

W pracy przedstawiono zasady i wyniki stosowanych dotychczas w Europie klasyfikacji stanu hydromorfologicznego cieków. Ramowa Dyrektywa Wodna wprowadziła obowiązek monitorowania elementów hydromorfologicznych rzek,

do których zaliczono reżim hydrologiczny, ciągłość rzeki oraz morfologię koryta. Normy europejskie określają wymagane w takich badaniach nieco odmienne wskaźniki jakości i sposób ich oceny. Według klasyfikacji stanu i potencjału ekologicznego powinny być uwzględnione kategorie i typy rzek, natomiast według dotychczasowych metod nie ma takiego rozróżnienia. Ocena bardzo zróżnicowanych wskaźników i atrybutów oraz wymóg prezentowania wyniku w formie *EQR* w granicach od zera do jedności powoduje, że wszystkie badane parametry, które są bardzo zróżnicowane, muszą być doprowadzone do formy liczbowej. W metodzie MHR uwzględnia się powyższe uwarunkowania i proponuje klasyfikację, zawierającą wartości graniczne pięciu klas stanu oraz czterech klas potencjału ekologicznego. Zakłada się w niej, że wartości graniczne klas zmniejszają się od cieków naturalnych poprzez silnie zmienione do sztucznych.

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