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Abiotic criteria for the heavily modified water bodies designation

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ABSTRACT: The Water Framework Directive 2000/60/EC promotes a new concept, the "heavily modified water bodies", to reconcile the different opinions of experts in civil engineering and ecological field. HMWB are primarily delineated by the extent of changes to the hydromorphological characteristics that (a) result from physical alterations by human activity and (b) prevent the achievement of good ecological status. The physical alterations taken into account are : transversal river works, as dams, weirs, sills; longitudinal river works, as embankments, banks regulation/consolidation works, etc; navigation channels; water intakes / discharges, river derivation.

The paper deals with are presented the quantitative criteria for hydro-morphological pressures assessment, as abiotic criteria for the preliminary heavily modified water bodies designation. Also, for the most important hydro-morphological alterations, some study-cases are presented.

KEYWORDS: water body, abiotic criteria, threshold, heavily modified.

1. Quantitative abiotic criteria for hydro-morphological pressures assessment

Many surface water bodies are substantially changed in character as a result of physical alterations by human activity. They will be designated in accordance with the provisions of Annex II of the WFD, as *heavily modified water bodies* (HMWB).

Nowadays, there are numerous concerns, especially in Europe, for river restoration, respectively for reaching the good ecological status of rivers which were disturbed by human activities and transformation of the HMWB in natural or near-natural water bodies.

The HMWB may be identified and designated where good ecological status is not being achieved because of impacts on the hydromorphological characteristics of a surface water resulting from physical alterations. The identification of HMWB must be based on the designation criteria set out in Article 4.3 of WFD.

According to the HMWB Guidance, the boundaries of HMWB are primarily delineated by the extent of changes to the hydromorphological characteristics that (a) result from physical alterations by human activity and (b) prevent the achievement of good ecological status. The paper is referring only to (a) – hydromorphological changes that indicate a provisional heavily modified water body. Within the HMWB identification and designation process, changes to hydromorphology resulting from "physical alterations" are relevant.

The designation process of heavily modified water bodies is based on biological data. Taking into consideration that, for the moment, no sufficient biological data is avail-

able, we have proposed some abiotic criteria relying on physical alterations type. For each hydro-morphological alteration type, the effects and quantitative abiotic criteria which define the pressure and, implicitly, the water body category are shown.

The physical alterations taken into account for HMWB provisionally designation are:

- Transversal river works
    - Dams / weirs / sills;
    - Reservoirs – hydropeaking;
- Longitudinal river works
    - Embankments, agricultural works, fish farming works, etc;
    - Banks regulation/consolidation works, cut-meandering works;
- Navigation channels;
- Water intakes, discharges, river derivation.

Each hydro-morphological alteration - hydraulic work - has different effects on environment : changes of hydrological regime, sediment transport, biota migration, disruption of lateral connectivity, etc. The parameters reflecting the pressure - abiotic criteria - and the threshold values for assessing potentially significant pressures of hydromorphological changes are presented in the Table 1. The result of the application of these criteria is the classification of the water bodies in different categories: non-HMWB, candidate to "heavily modified" and HMWB.

The water bodies candidate to „heavily modified" are the water bodies for which the physical alterations are not very important and the habitat is slightly modified. For these water bodies, an appropriate monitoring program will be set-up for obtaining supplementary data in order to redefine the water body category: either non-HMWB or HMWB.

The application of these quantitative criteria for hydro-morphological pressures assessment is the first stage of the heavily modified water bodies designation.

2. HMWB case studies

For each physical alteration, some study-cases are presented. For these studies, the paper shows the characteristics, the uses, the changes in hydromorphology resulting from "physical alterations", the effects of hydro-morphological alteration on water body, the application of abiotic criteria as threshold values (see Table 1) and the classification of the water body in: non-HMWB, candidate to HMWB or HMWB.

2.1 Stanca Costesti Water Body / Prut River

(1) Characteristics

Stanca-Costesti reservoir is located on the Prut river, which is the border between Romania and Moldova; it has a total volume of 1400 mil. m^3, out of which 665 mil. m^3 is flood defence volume (fig. 1).

(2) Uses

The uses of the Stanca-Costesti reservoir are:

- Flood defence and flow regulation downstream reservoir. Stanca Costesti reservoir has a large capacity and asures a very good flow regulation and reduction of floods;
- Hydropower generation – power plant capacity = 32 MW (16 MW for Romania, respectively Moldova);

Table 1

Abiotic criteria for the prliminary HMWB designation						
No.	**Hydraulic works (Hydro - morphological alterations)**	**Effects**	**Parameters reflecting the pressure (*Abiotic Criteria*)**	**Pressure / SWB classification**		
				Low pressure / Non-HMWB	**Med. pressure / Candidate to HMWB**	**High pressure / HMWB**
1	**Transversal river works 1.1 weirs / dams / sills**	on hydrological regime, on sediment transport and migration of biota[1)]	Sills density (no. / km) or	≤ 1	2	≥ 3
			Height of the structure (cm)	< 20	20 – 50	> 50
	1.2 reservoirs - hydropeaking	on the low flow and biota	Low flow in river bed / Q*[2)] (%)	>100	100-50	< 50
		on hydrological regime, banks stability and biota	Water level gradient (cm) / hour	< 50	50-100	> 100[3)]
2	**Longitudinal river works 2.1 embankments, agricultural / fish farming works, etc**	on lateral connectivity, floodplain vegetation and spawning habitat	Length of dikes / Length of water body (%)	< 30	30 - 70	> 70
			Flood protected surface (in floodplain) / Floodplain surface (%)	< 30	30 - 70	> 70
	2.2 bank regulation / consolidation works, cutt-meandering works	on longitudinal river profile, on substrate structure and biota	Length of hydraulic works / Length of water body (%)	< 30	30 - 70	> 70
3	**Navigation channels**	on bed stability and biota	Width of (dredged) channel / Width of river bed (%)	< 20	20 - 50	> 50
4	**Water intakes, residual water flow, river derivation**	on the low flow, bed stability and biota	Abstracted or returned discharge / Multiannual average flow (%)	< 10	10 - 50	> 50
			Low flow in river bed / Q*[2)] (%)	> 100	100 - 50	< 50

[1)] only the migratory biota

[2)] $Q^* = Q_{95\%}$ (m^3/s)+ 0,1 for $Q_{95\%} > 200$ l/s ; $Q^* = 1{,}25 \times Q_{95\%}$ (m^3/s)+ 0,05 for $Q_{95\%} < 200$ l/s;

$Q_{95\%}$ - yearly minimum monthly flow with 95% probability (m^3/s)

[3)] frequency > 1 / day

- Water supply for Iasi town (Tutora intake on Prut river); the maximum capacity of the water intake is 6 m^3/s, also for irrigation of 140 000 ha, 70 000 ha for Romania, respectively Moldova.

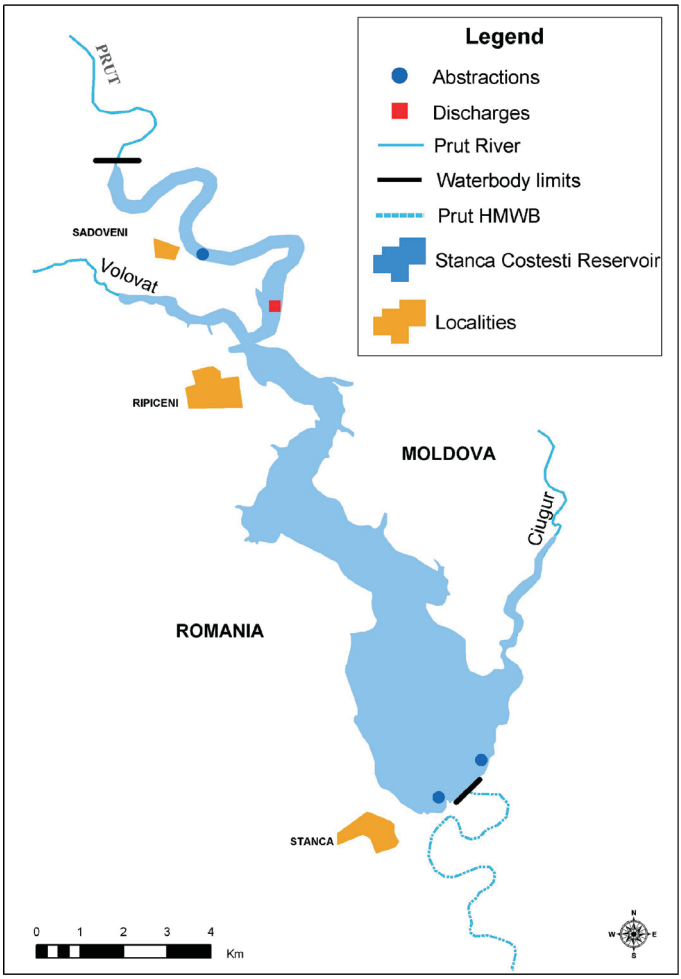

Fig. 1 Stanca Costetasi water body / PRUT River

(3) Significant Physical Alterations

- direct physical alterations on river channel or bed – by dam and hydropower station construction;
- indirect alterations – are referring at the pressures of the construction downstream reservoir, as well as on riparian zone.

(4) Changes in the Hydromorphological Characteristics of the Water Bodies

- change of water category - change of river to dammed reservoir;
- change in flow regimes ($Q_{low\ flow}$ = 1.8 m^3/s, $Q_{95\%}$ = 9.0 m^3/s) and sediment transport;

- downstream reservoir, the river bed recorded important morphological changes (thalweg lowering 50-60 km length downstream reservoir);
- affecting the migratory biota - obstacles for sturgeon (Acipenseridae) and waller (Silurus glanis).

(5) Abiotic criteria

- Criteria 1.1 related to the height of the structure, which exceeds the threshold value of 50 cm.
- Criteria 1.2 related to the low flow in river bed : the ratio $Q_{low\ flow}$ / Q* = 1.8 / 9.1= 19.78 (%) is below the threshold value of 50 %. Q* is calculated as $Q_{95\%}$ + 0.1, for $Q_{95\%}$ > 200 l/s.
- Criteria 1.2 related to the water level gradient :

The mean water level gradient is 93 cm / hour and the maximum water level gradient is 234 cm/h.

(6) Classification of water body

Stanca Costesti reservoir is HMWB, due to the change of water category (change of river to dammed reservoir) and according to criteria 1.1. Also, the river sector downstream Stanca Costesti is HMWB, according to criteria 1.2.

2.2 Crasna confluence – Siret confluence Water Body / Barlad river

(1) Characteristics

The water body is 116 km length on the Barlad river and includes the old meander, which is in the present a flood derivation (fig. 2).

(2) Uses

The uses of this water body on the Barlad river are:

- Flood defence;
- Water supply.

(3) Phsical Alterations

- Water intakes – supply discharge for 9 users.
- Flood protection works
    - 116 km of dikes ;
    - flow diversion for flood defence carried out on the old river, for a maximum flow of 260 m^3/s.
- river bed regulation works of 116 km length.

(4) Changes in the Hydromorphological Characteristics of the Water Bodies

- The engineering works done on the Barlad river affect the lateral connectivity, floodplain vegetation and spawning habitat, the longitudinal river profile, the substrate structure - due to velocity regime modification - and biota.
- The transformation of the old meander in flood derivation, on 13 km of length, in Munteni -Tecuci area, has modified the morphological characteristics of the river bed, as well as the flow regime.

(5) Abiotic criteria

- Criteria 2.1. embankments works: 116 / 116 = 100 %, the threshold value exceeds 70.
- Criteria 2.2. regulation works: 116/ 116 = 100 %, the threshold value exceeds 70.

(6) Classification of water body

Taking into account the criteria 2.1 and 2.2, the water body analysed is heavily modified.

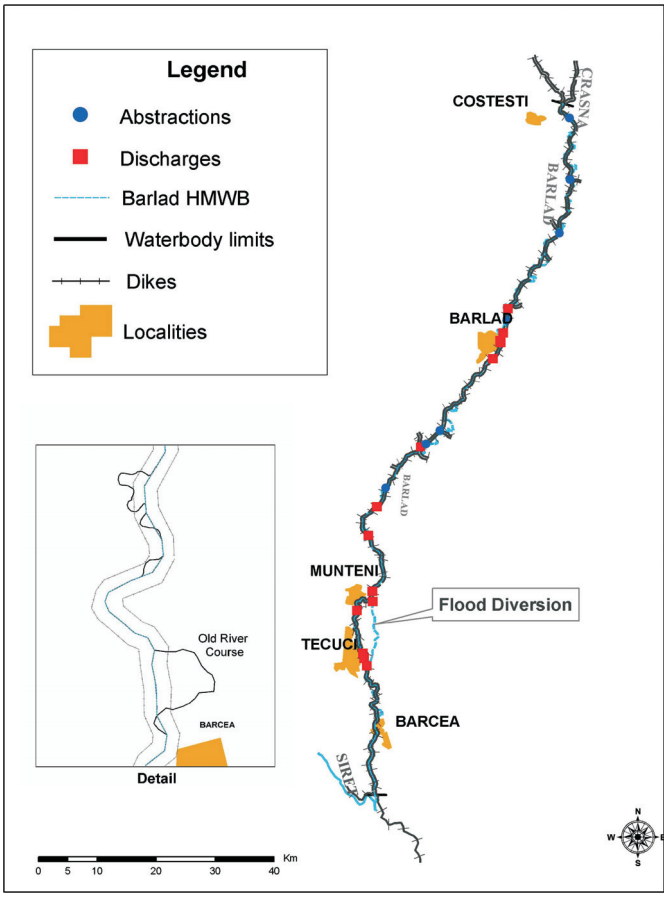

Fig 2. CRASNA confl. - SIRET confl. water body / BARLAD River

2.3 Chiciu – Isaccea Water Body / Danube river

(1) Characteristics

The length of the water body is 278 km. The Danube on the analysed sector is navigable, the width of dredged channel varies between 120 and 180 m, as against the width of river bed at mean flow, which is 400 – 1000 m.

Also there are 20 water intakes from Danube for irrigation, industry and urbanisation (fig. 3).

(2) Uses

- Flood defence;
- Navigation;
- Water supply.

(3) Physical Alterations

- Embankments and straightening works;
- Dredged channel;
- Harbours: Calarasi, Cernavoda, Macin, Galati and Braila.

(4) Changes in the Hydromorphological Characteristics of the Water Bodies

- Changes in morphology are caused mainly by flood protection works and navigation, by construction of embankment along almost the whole sector;
- The main effects are recorded on habitat and biota.

(5) Abiotic criteria

- Criteria 2.1. Embankments works: Length of dikes / Length of water body (%) = 221 / 278 = 0.79 , the threshold value exceeds 70 %.

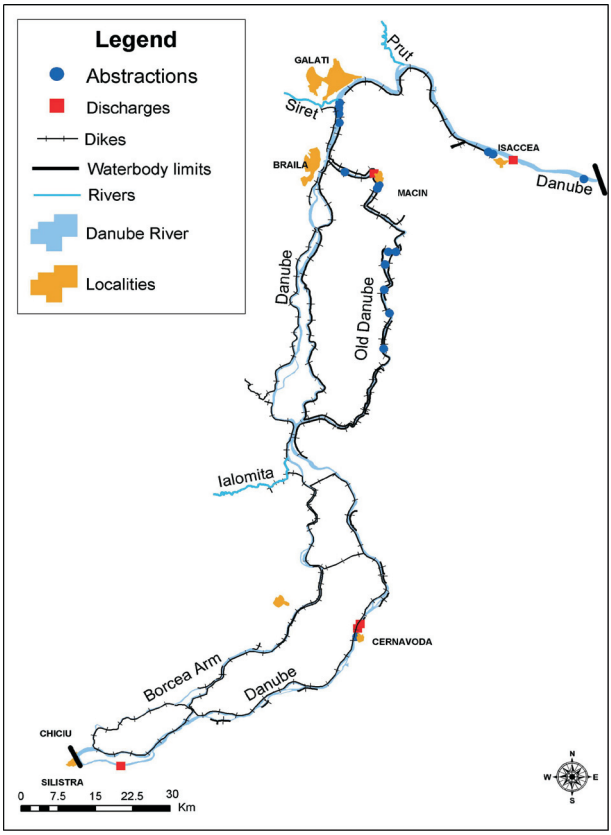

Fig. 3 Chiciu - Isaccea water body / DANUBE River

- Criteria 3 Navigation channels: The width of dredged channel varies between 120 m and 180 m. The width of river bed varies between 400 m and 1000 m. In average, the ratio 150 / 700 = 21 %.

(6) Classification of water body

The water body Chiciu - Isaccea is candidate to "heavily modified", according to criteria 2.2 and HMWB, according to criteria 2.1.

2.4 Water Body downstream Paltinu reservoir – Prahova confluence / Doftana river

(1) Characteristics

- The length of this water body is 22 km. It no direct physical pressures, only indirect ones, from upstream, caused by the Paltinu reservoir. This lake has a volume of 53 x 10^9 m^3/s and a surface of 197.5 ha; the reservoir strongly regulates the downstream hydrological regime (fig. 4).
- The main uses of reservoir are water supply (3.1 m^3/s), hydropower generation (Installed Capacity = 10.2 MW; Installed discharge = 14 m^3/s), irrigation (1400 ha) and flood defence.

(2) Uses of water body downstream Paltinu reservoir

- Recreation;
- Water intakes for Campina area (350 l/s).

(3) Physical Alterations

- Modification of morphology, sediment transport and flow regime downstream Paltinu reservoir caused by dam construction. The minimum flow downstream reservoir is 200 l/s.

(4) Changes in the Hydromorphological Characteristics of the Water Bodies

- in connection with the artificial flow regime, the impact on riparian vegetation and bank morphology is substantial;
- the impact caused by the flow discharge downstream reservoir is recorded until the confluence with Prahova river.

(5) Abiotic criteria

- Criteria 1.2 related to the low flow in river bed : the ratio $Q_{low\ flow}$ / Q* = 36 % is below the threshold value of 50 %. In the above relation $Q_{low\ flow}$ = 0.2 m^3/s, Q* = 1.25 x $Q_{95\%}$ + 0.05 = 0.55 m^3/s - for $Q_{95\%}$ > 200 l/s and $Q_{95\%}$ = 0.4 m^3/s.
- Criteria 1.2 related to the water level gradient : the mean water level gradient is 75 cm / hour and the maximum water level gradient is 105 cm/h.

(6) Classification of water body

According to both criteria, the water body downstream Paltinu reservoir – Prahova confl. is HMWB.

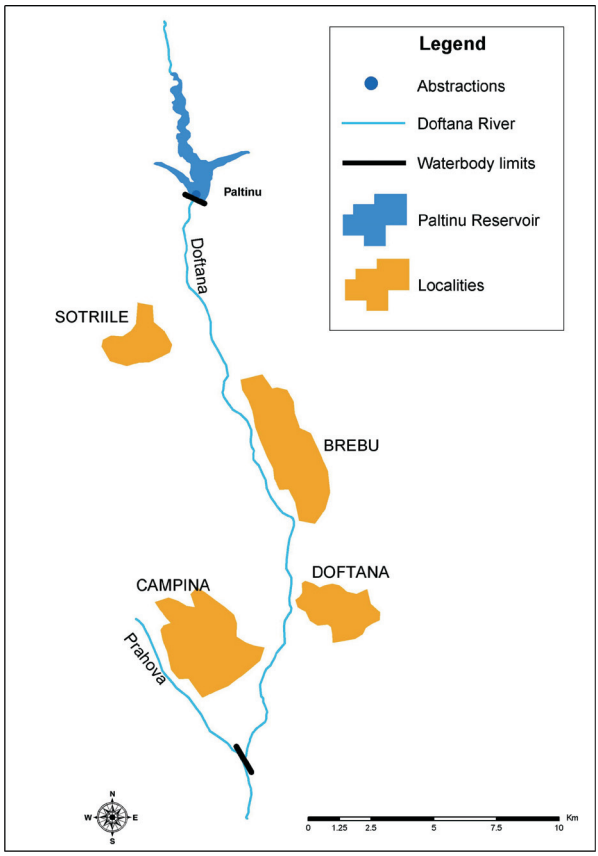

Fig 4. Paltinu water body / Dpftana River

2.5. Ogrezeni – upstream Mihailesti Reservoir Water Body / Arges river

(1) Characteristics

- The length of the water body is 7.4 km.
- The Crivina water intake for Bucharest City is from Ogrezeni storage lake, on Arges river (fig. 5). The average abstracted discharge is about 8.64 m^3/s and the minimum low flow downstream Ogrezeni lake is 0.12 m^3/s.
- The multiannual average flow is 43.0 m^3/s and the yearly minimum monthly flow with 95% probability is 7.7 m^3/s.

(2) Uses

- Flood protection;
- Urbanisation.

(3) Physical Alterations

- Dam of Ogrezeni storage lake as upstream limit of the water body analysed;
- Crivina intake for water supply of Bucharest City.

(4) Changes in the Hydromorphological Characteristics of the Water Bodies

- The alteration of the hydrological regime is caused by the upstream flow regulation works and abstractions;
- The most important hydromorphological change is related to Crivina water intake.

(5) Abiotic criteria

- Criteria 4 related to the ratio between the abstracted discharge and the multiannual average flow : 8.64 (m^3/s) / 43.0 (m^3/s) = 20 %. The ratio (%) exceeds the threshold value of 10 %.
- Criteria 4 related to the low rate flow in river bed : the ratio $Q_{low\ flow}$ / Q* = 0.12 / 7.8 = 1.5 % is below the threshold value of 50 % ; Q* = $Q_{95\%}$ (m^3/s) + 0.1 = 7.8 m^3/s, for $Q_{95\%}$ > 200 l/s.

(6) Classification of water body

Taking into account both criteria, the water body is designated as HMWB.

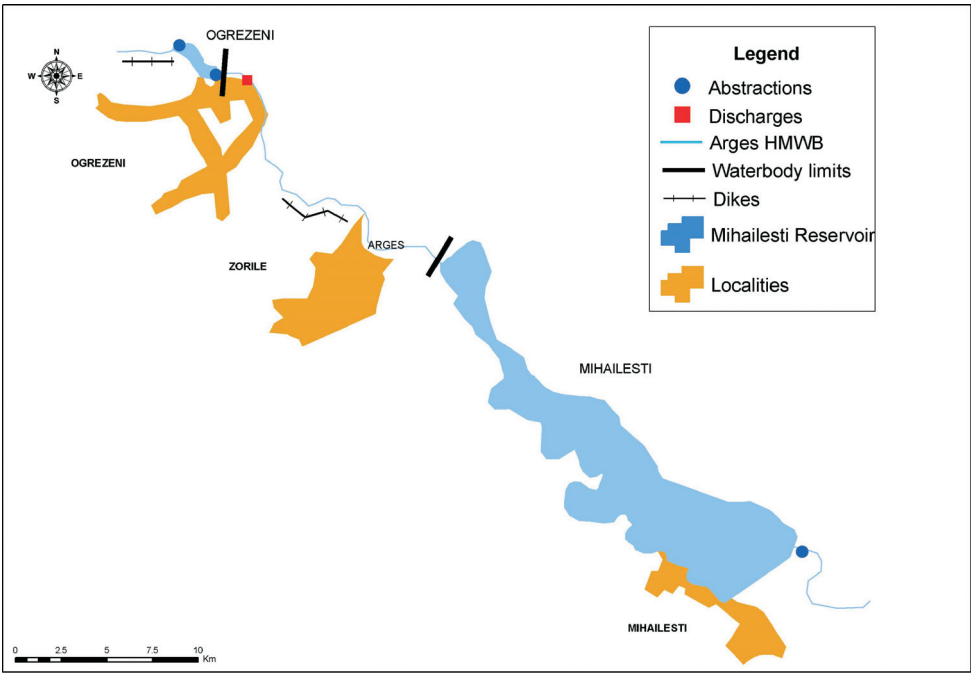

Fig. 5 Ogrezeni - upstream Mihailesti Reservoir water body / ARGES River

3. Conclusions

One key purpose of the Directive is to prevent further deterioration, protect and enhance the status of aquatic ecosystems. The success of the Directive in achieving this purpose and its related objectives will be mainly measured by the status of "water bodies". Therefore, the HMWB identification and designation process is very important.

The abiotic criteria for assessing the hydro-morphological pressures on water bodies is based on physical alteration types and their effects on aquatic ecosystems. By the abiotic criteria application, three categories of water bodies result : non-HMWB, candidate to HMWB and HMWB. The water bodies candidate to „heavily modified" will be supplementary monitorised to decide if they are not- HMWB or HMWB.

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