

An Extended Method for Continuous Hydromorphological Assessment Applied in the Joint Danube Survey 3, 2013

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Abstract: An Extended method was applied during the International Commission for the Protection of the Danube River (ICPDR) Joint Danube Survey (JDS) 3, which was conducted in 2013, allowing a systematic continuous hydromorphological assessment for the navigable Danube River (rkm 2400). Based on the experiences of the JDS 2 hydromorphological survey from 2007 and the extended Water Framework Directive requirements, during the JDS 3 the hydromorphological features were re-assessed on a better spatial scale (10 rkm sections). This was achieved by using an adapted CEN methodology and was supplemented further by the results of the hydromorphological field measurements during the survey in 2013. This article focuses on the method development for continuous hydromorphological assessment of the Danube River.

Keywords: ICPDR JDS3, hydromorphology, methodology, CEN-standard

Introduction

The assessment of hydromorphology in Europe is based on methods developed during the past 30 years on smaller rivers (*e.g.* Werth 1987, Petts & Amoros 1996). Methods for large rivers were developed later (*e.g.* KERN *et al.* 2002) and the first European wide guiding standard was published in 2004 and supplemented in 2010 (CEN 2004, 2010) within the compendium of fresh water assessment standards supporting WFD approaches. The WFD requires the delineation of hydromorphologically intact river stretches as reference for the definition of heavily modified water bodies. Hydromorphological assessments should serve different purposes, (1) to describe and assess the conditions of riparian habitats in general to support ecological analysis, (2) to characterise the morphodynamic and hydrological situation, namely the impacts of dams with impoundments on the sediment balance and caused river bed incision further downstream, (3) to survey river engineering structures such

as rip-rap banks and groyne fields, and the change of planform of channels. There is a considerable increasing knowledge about this specific hydromorphological pressures along the Danube (HOLUBOVA *et al.* 2004, HOLUBOVA 2006, SCHWARZ 2008, HABERSACK *et al.* 2009) and Danube floodplains are subject of detailed analysis (SCHWARZ 2010).

In the last ten years the reliability of hydromorphological assessments and metrics on the biological quality elements (namely fish, macrozoobenthos and macrophytes) was discussed critically. It turned out that only selected parameters such as the depth-width and related flow variability, bars and channel features, the sinuosity in general and the substrate in combination with catchment parameters as well as the longitudinal and lateral connectivity can be used as measurable indicators. This should be considered for the further synthesis of both hydromorphological and biological results.

Methods

The method based on the CEN guidance standards (CEN 2004, 2010) was adapted to large rivers and consists of individual assessment of the three main parameter groups: “channel”, “banks” and “floodplain” (Table 2). The arithmetic mean of their ratings provides the overall assessment value. To adapt these general parameters to WFD requirements the so called three-digit approach (a rearrangement of single parameters into the three groups “morphology, flow regime and longitudinal continuum”) was applied. Further, several in-site measurements carried out by the Water Research Institute Bratislava, namely measurements and assessments of cross-sections, flow velocities, discharge and sediment samples, were used for the calibration of the results.

The assessment of the general planform and sinuosity was based on the main river engineering structures, longitudinal and lateral continuum disruptions, the floodplain with its adjacent land use, different navigation (and historical) maps covering the past 150 years, various satellite images covering

different water levels and seasons, hydrological and morphological background data as well as all field records.

The CEN assessment proposes a framework for reference conditions. For large rivers the preparation of detailed hydromorphological reference conditions is a huge task and would be affordable (e.g. SCHWARZ 2006). As for JDS2 the current assessment is based on the 10 river section types described already in 2003 by SOMMERHÄUSER *et al.* (2003). A more detailed description of the reference conditions was performed in JDS3 for 1. planform and slope, 2. substrate composition, 3. width-depth variability and 4. floodplains.

Parameters for overall assessment according to the CEN standard

The following Table 2 shows the detailed parameters and scoring for the overall assessment. Following the CEN standard, specific parameters are assessed in a scheme with five classes, but some parameters are assessed only in a scheme with three classes (1,3,5), as described in the scoring tables of the sec-

Table 1. Basic “Danube River Section Types” delineation as background for the definition of hydromorphological reference conditions

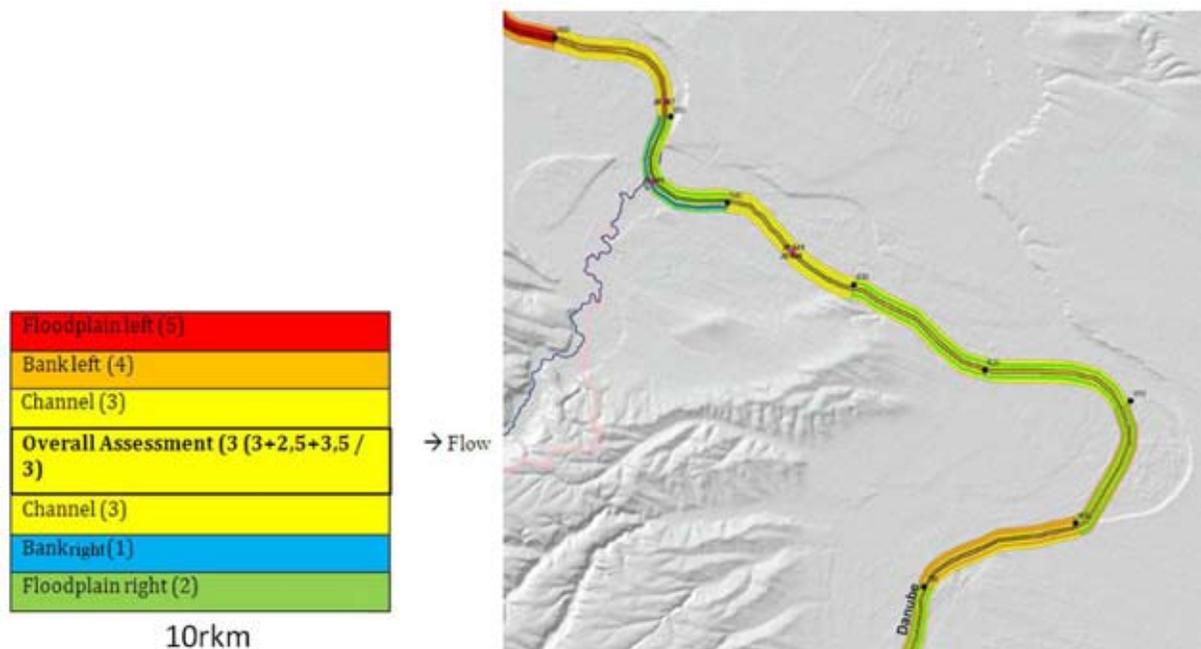
Danube River Section Type	Description
Section Type 1: Upper course of the Danube River	Upper course of the Danube River (rkm 2786: confluence of Brigach and Breg – rkm 2581: Neu Ulm).
Section Type 2: Western Alpine Foothills of the Danube River	Western Alpine Foothills of the Danube River (rkm 2581: Neu Ulm – rkm 2225: Passau) with two sub-sections split in Regensburg.
Section Type 3: Eastern Alpine Foothills of the Danube River	Eastern Alpine Foothills of the Danube River (rkm 2225: Passau – rkm 2001: Krems).
Section Type 4: Lower Alpine Foothills of the Danube River	Lower Alpine Foothills of the Danube River (rkm 2001: Krems – rkm 1807: Gönyü/Klišská Nemá) with two sub-sections split at Devin/Morava confluence.
Section Type 5: Hungarian Danube River Bend	Hungarian Danube River Bend (rkm 1807: Gönyü/ Klišská Nemá – rkm 1497: Baja) with three sub-sections including the Danube River bend breakthrough and stretches upstream and downstream.
Section Type 6: Pannonian Plain of the Danube River	Pannonian Plain of the Danube River (rkm 1497: Baja – rkm 1075: Bazias) with three sub-sections split at Drava and Sava confluences.
Section Type 7: Iron Gate on the Danube River	Iron Gate on the Danube River (rkm 1075: Bazias – rkm 943: Turnu Severin).
Section Type 8: Western Pontic section of the Danube River	Western Pontic section of the Danube River (rkm 943: Turnu Severin – rkm 375.5: Chiciu/Silistra).
Section Type 9: Eastern Wallachian section of the Danube River	Eastern Wallachian section of the Danube River (rkm 375.5: Chiciu/Silistra – rkm 100: Isaccea).
Section Type 10: Danube Delta	Danube Delta (100 rkm: Isaccea – 0 rkm on Chilia arm, rkm 0 on Sulina arm and rkm 0 on Sf. Gheorghe arm).

Table 2. Assessment parameters for the overall continuous assessment (using 10 rkm segments)

Parameter	Values/ descriptions
Channel	
Planform	1 = 0 % to 5 % of reach length with changed planform. 2 = > 5 % to 15 % of reach length with changed planform. 3 = > 15 % to 35 % of reach length with changed planform. 4 = > 35 % to 75 % of reach length with changed planform. 5 = > 75 % of reach length with changed planform.
Substrates/sediments (Natural substrate mix or character altered)	1=Near-natural mix (nearly disappeared due to dam draping of coarse material and regular dredging). 3= Natural mix/character slightly to moderately altered. 5=Natural mix/character greatly altered.
Erosion/deposition character	1 = Erosion/deposition features reflect near-natural conditions (<10 % of the features expected are absent). 3 = Erosion/deposition features reflect moderate deviation from near-natural conditions (10 % to 50 % of the features expected are absent). 5 = Erosion/deposition features reflect great deviation from near-natural conditions (≥ 50 % of the features expected are absent).
Impacts of artificial in-channel structures within the reach (impoundments, groynes)	1 = Flow character not, or only slightly, affected by structures within the reach. 3 = Flow character moderately altered. 5 = Flow character extensively altered.
Reach-based and local impacts of sluices and weirs on the ability of biota (e.g. migratory fish) to move and sediment to be transported	1 = No structures, or if present they have no effect (or very minor effect) on migration or on sediment transport (stretches far from dams). 3 = Structures evident, but having only minor or moderate effects on migratory biota and sediment transport. 5 = Structures that in general are barriers to all species and to sediment transport.
Banks	
Extent of reach affected by artificial bank material (% of bank length)	1 = Banks affected by 0 % to 5 % hard, artificial materials. 2 = Banks affected by > 5 % to 15 % hard, artificial materials. 3 = Banks affected by > 15 % to 35 % hard, artificial materials. 4 = Banks affected by > 35 % to 75 % hard artificial materials. 5 = Banks affected by > 75 % hard artificial materials.
Land cover in the riparian zone (% of bank length)	1 = 0 % to 5 % non-natural land cover in riparian zone. 2 = > 5 % to 15 % non-natural land cover in riparian zone. 3 = > 15 % to 35 % non-natural land cover in riparian zone. 4 = > 35 % to 75 % non-natural land cover in riparian zone. 5 = > 75 % non-natural land cover in riparian zone.
Floodplain	
Land cover beyond the riparian zone (in narrow valleys and gorges without floodplain limited to adjacent buffer strip of 50 m)	1 = 0 % to 5 % non-natural land cover beyond the riparian zone. 2 = > 5 % to 15 % non-natural land cover beyond the riparian zone. 3 = > 15 % to 35 % non-natural land cover beyond the riparian zone. 4 = > 35 % to 75 % non-natural land cover beyond the riparian zone. 5 = > 75 % non-natural land cover beyond the riparian zone.
Degree of lateral connectivity of the river and floodplain (Extent of floodplain not flooded regularly owing to engineering)	Is over-bank flooding likely to occur (or likely to have occurred historically) naturally in the reach? Yes/No. If No – N/A. If Yes, the score is used: 1 = 0 % to 5 % of the reach is affected by flood dikes or other measures impeding flooding of floodplain (e.g. channel and bank regrading). 2 = > 5 % to 15 % as above. 3 = > 15 % to 35 % as above. 4 = > 35 % to 75 % as above. 5 = > 75 % as above.
Degree of lateral movement of river channel	Is the river likely to move laterally within its floodplain in the absence of any man-made constraints? Yes/No. If No – N/A. If Yes, the score is used: 1 = 0 % to 5 % of the reach is constrained. 2 = > 5 % to 15 % of the reach is constrained. 3 = > 15 % to 35 % of the reach is constrained. 4 = > 35 % to 75 % of the reach is constrained. 5 = > 75 % of the reach is constrained.

Table 3. Assessment parameters for the WFD three-digit assessment (10 rkm segments)

Digit1-3	Parameter (Values/ description compare previous table 2)
1 Morphology	
	Planform
	Erosion/deposition character
	Substrates/sediments (Natural substrate mix or character altered)
	Extent of reach affected by artificial bank material (% of bank length)
	Land cover in the riparian zone (% of bank length)
	Land cover beyond the riparian zone (in narrow valleys and gorges without floodplain limited to adjacent buffer strip of 50 m)
	Degree of lateral connectivity of the river and the floodplain (Extent of floodplain not allowed to flooded regularly owing to engineering)
	Degree of lateral movement of the river channel
2 Flow regime	
	Impacts of artificial in-channel structures within the reach (impoundments, groynes)
3 Longitudinal continuity	
	Reach-based and local impacts of sluices and weirs on ability of biota (<i>e.g.</i> migratory fish) to move and sediment to be transported

**Fig. 1.** Visualisation of sample results in a colour ribbon map (compare assessment classes in section *Parameters for overall assessment according to the CEN standard*). The flow direction is from left to right and each segment is with length of 10 rkm

ond CEN standard (CEN 2010). These classes are not equivalent to the five WFD status classes and the overall assessment differs significantly (worst case or one-out all-out principle assessment for the biological components). The five class overall assessment (arithmetic mean) of channel, banks and floodplain features intervals of 1 for the classes 2-4 and 0.5 for the first (reference conditions) and last (worst case) classes:

Assessment class boundaries:

- 1.0 to 1.4= Class 1 Reference conditions (blue) “Near-natural”
- 1.5 to 2.4= Class 2 (green) “Slightly modified”
- 2.5 to 3.4= Class 3 (yellow) “Moderately modified”
- 3.5 to 4.4= Class 4 (orange) “Extensively modified”
- 4.5 to 5.0= Class 5 (red) “Severely modified”

Three-digit code assessment for WFD reporting

This specific assessment focuses on the three main

hydromorphological quality elements given in the WFD (morphology, flow regime and longitudinal continuity). It is rearranging parameters of the overall assessment scheme for channel, banks and floodplain, and should be used only as additional (parallel) information also to keep the compatibility between the JDS 2 (ICPDR 2008) and the national inventories. As result the three-digit code looks like a combination of the three WFD elements “111” or “233” or “555” (from the best over a medium to the worst assessment).

Conclusions and Outlook

By applying the described method in the Joint Danube Survey 3 of ICPDR (www.danubesurvey.org), a concise hydromorphological assessment of the navigable Danube River from Kelheim (rkm 2415) to the Danube Delta (rkm 0) will be available. In contrast to the JDS 2, with its individually long assessment stretches (between 17 and 150 km) and only limited information (e.g. for the parameter group “banks”

only the degree of bank revetments (rip-rap) was recorded), the JDS 3 approach allows a systematic assessment of 10 rkm segments and includes more parameters (e.g. for “banks” the riparian zone (bank vegetation)). During the JDS 3 the Danube River was subdivided into 241 segments with length of 10 rkm following the current navigation map plus 18 segments for the additional Delta branches (Kilia (11) and St. Gheorge (7)). In addition, the 10 rkm long assessment segments can be applied for any further interdisciplinary JDS analysis or other purposes, e.g. sediment and nutrient fluxes, monitoring of habitats and species or floodplain assessments.

Together with the site measurements now a wide range of hydromorphological parameters can be further used within the WFD assessments and, in particular, for river management and restoration potential. The results will be published by ICPDR in summer 2014 by the official JDS3 publication. An overview map will characterise the whole Danube according to the five class assessment scheme (colour ribbon map, see Fig. 1).

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