# Urban streams – ecological status or potential?

## Les cours d´eau urbains – un statut écologique ou une potentialité de développement ?

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## RESUME

L'identification de l´aspect écologique ou du potentiel des rivières est l´une des exigences de la politique européenne (DCE) et aussi l´action nécessaire dans le processus de maintenance, de planification et d´utilisation des ressources en eau. Pour le processus de réhabilitation des ruisseaux, comme le montre cet article à partir d´exemples de quatre ruisseaux de Prague, généralement la définition des structures d´eau profondément modifiées pourrait avoir des conséquences plus économiques qu'écologiques et environnementales. Par conséquent, on pourrait donner priorité à la réhabilitation des ruisseaux plutôt par courtes maintenances que par des maintenances de longue durée, lesquelles sont onéreuses et prennent beaucoup de temps. Dans le cadre de la DCE, les insuffisances pourraient aggraver les conditions actuellement pas très bonnes, et conduire au disfonctionnement de l´écosystème aquatique.

## ABSTRACT

Accurate identification of ecological status or potential of rivers is one of the key requirements of European Water Framework Directive and is a requisite underpinning decisions on sustainable use and planning of water resources into the future.

Drawing on four Prague urban stream examples, the paper illustrates the difficulties caused by the lack of a defined threshold between heavily modified and 'normal' (unmodified to moderately modified) water bodies. The assessment of the four urban creeks in Prague concludes that the major factor impacting on the benthic community is hydraulic stress, followed by altered morphology and missing suitable habitats. Chemical stressors appear to be less significant than flow and altered morphological conditions. Building on this understanding, the paper illustrates, by way of two approaches to the Directive definition of 'heavily modified' waterways, the significant environmental, ecological, economic and social implications of the ecological status or potential classification.

## KEYWORDS

Ecological potential, Heavily modified water body, Rehabilitation, Urban creek, Urban drainage.

## 1 INTRODUCTION

The present period is characterized by changes in our understanding of the environment and of effects of anthropogenic activities. The new attitude is reflected in water management legislation, such as the Water Framework Directive (2000/60/EC). The Directive defines a number of new terms. Ecological status (expression of the quality of the structure and functioning of aquatic ecosystem associated with surface water), ecological potential (expression of ecological quality of heavily modified water body) and heavily modified versus 'normal' water bodies are some of the most crucial. Although the Directive defines these terms, it does not define the threshold between these terms. The lack of a threshold between heavily modified and unmodified to moderately modified ('normal') water bodies is a serious deficiency, limiting the application of assessment methods. This is a significant problem especially in the case of small urban creeks, where the anthropogenic effect is more significant than the case of large rivers, which are the centre of interest of the Directive. The small rivers and streams are at the margin of the water manager's interests, even though in many countries they are the main elements affecting the river hydrological condition. The missing definition of the threshold raises the potential for inappropriate application of the Directive, leaving open possibilities for subjective assessment and divergence in opinions regarding stream and river restoration.

There is one basic question: How should the term heavily modified water bodies be understood? The Directive defines heavily modified water bodies as "a body of surface water which as a result of physical alterations by human activity is substantially changed in character." The definition does not define the meaning of physical alteration. Does it mean alteration of the water body morphology or alteration of the hydrology as well? Shall we call heavily modified water bodies only those water bodies which are channelised, or also those water bodies where morphology is changed not directly by humans, but as a result of secondary impacts, such as combined sewer overflows and stormwater discharges causing erosion of the stream channel and bank and changes to the morphology of the stream. Is this stream heavily modified or not?

Should rivers and streams having substantially changed hydrological conditions be termed 'heavily modified water bodies'? Changed hydrological conditions may comprise disturbance of the surface and ground water relation, or significant modification to the natural flow pattern as a result of human activities. Another question is how large the modification of water body needs to be, in order to call it heavily modified?

Identification of the threshold is necessary for effective decision making on river and stream rehabilitation or restoration, and on the assessment of ecological status or potential of water bodies. Finally it is important for identification of measures which shall improve the recent status.

Drawing on four Prague urban stream examples, the paper illustrates the difficulties caused by the lack of a defined threshold between heavily modified and 'normal' (unmodified to moderately modified) water bodies. The paper presents the results of assessment of the four creeks, and the application of the Directive procedure in determining the 'ecological status or potential' designation of the creeks. The paper then reviews the Directive procedure based designation in terms of the morphological, hydrological and chemical conditions of the waterways, and the physical, economic and ecological opportunities of restoration to 'natural' status. Finally, the paper illustrates, by way of two approaches to the Directive definition of 'heavily modified' waterways, the significant environmental, ecological, economic and social implications of the ecological status or potential classification.

# 2 METHODS

## 2.1 Study sites description

The four study streams are located in Prague (the capital of the Czech Republic) and all are impacted by urban drainage. The Botic and the Rokytka Creeks are affected mainly by combined sewer overflows. The other two creeks, the Zatissky and the Kosikovsky, are impacted by stormwater drain discharges. The level of morphological changes is significantly different across the study creeks. In addition, the modification of chemical and biological conditions in streams varies across the streams.

## 2.2 Assessment of ecological status/potential of streams

The condition of the streams was assessed by observation of water and sediment quality as indicators of chemical status. The state of the benthic community was used as an indicator of biological conditions and the hydromorphological state was assessed in terms of ecological flows for benthic community, flow levels and changes in stream morphology.

The chemical status was assessed in terms of the basic parameters of water quality ($NO_3^-$, $NO_2^-$, $NH_4^+$, $PO_4^{3-}$, pH, conductivity, $Cl^-$ ) and specific pollutants - heavy metals (Cu, Cd, Pb, Zn, Ni, Cr), which were monitored for both water and creek bed sediments. The assessment of chemical status was based on Czech legislation for parameters of water quality and on Slovak methodological guidelines for sediment quality (there are missing environmental quality standards for sediment quality in Czech Republic).

The benthic community was surveyed (Caletkova and Kominkova, 2005) to identify diversity, ASPT index, BMWP (Armitage et al, 1983).The benthic community was also assessed by predictive model HOBENT (Kokeš and Vojtíšková, 1999) to compare it with a reference conditions.

The morphological status of the streams was assessed by the method presented in LAWA, 2000. A modified version of this method (Chvostík, 2005), meeting the requirements of the EU - TC 230 WI 00230118 working guidelines, was used.

The range of ecological flows for benthic community was identified by using Instream Flow Incremental Methodology (IFIM) and its program PHABSIM (Stalnaker et al, 1995; Bovee, 1995, Caletková and Komínková, 2005; Jiřinec et al, 2001).

# 3 RESULTS AND DISSCUSION

The main goal of this paper is to explore the limitations and demonstrate the deficiency in the Directive in respect to urban creeks and consequently different approaches to their rehabilitation or restoration. Therefore, the results for monitored creeks are not presented for individual sampling sites, but for whole creeks or reaches of creeks, as minimal and maximal values to show the variation across the creeks. The results are discussed with respect to the Directive and its requirements.

## 3.1 Chemical status

### 3.1.1 Basic physical and chemical parameters

The most impacted basic chemical and physical parameters are $N\text{-}NO_3$, $N\text{-}NO_2$ and $N\text{-}NH_4$. The Environmental quality standard (Czech regulation 61/2003) is exceeded for $N\text{-}NH_4$ in the case of creeks affected by combined sewer overflows (the Botic and the Rokytka Creeks). In the case of creeks affected by stormwater discharges, $N\text{-}NH_4$ is within the standard. Other impacted parameters are $PO_4^{3-}$, BOD and COD, which reach high levels on all observed creeks irrespective of drainage type.

The basic chemical and physical parameters of water quality do not comply with the Environmental quality standards for any of the monitored creek. It means that according to the Directive, they fail to achieve good chemical status.

### 3.1.2 Specific pollutants- Heavy metals

Concerning concentrations of heavy metals in water, they are usually below environmental quality standards given by the Czech regulation 61/2003 in all studied creeks. There are some exceptions during rainfall events, when the level of heavy metals increase rapidly, especially associated with the first flush during the first minutes of rainfall. As a result, acute toxicological risks may occur.

While concentrations of heavy metals in water do not create a long term risk for aquatic ecosystems, their concentration in sediment may present a chronic toxicological risk. Table 1 shows minimal and maximal concentration of observed heavy metals in sediment of studied creeks. Toxicological risk assessment is based on the Slovak methodological guidelines (MPC –Maximum Permissible Concentration – guarantees survival of 95% of organisms, if this value is exceed the risk is not acceptable; TV-Target Value –is 1/100 of MPC value and does not cause any risk for ecosystem). For all creeks, the highest toxicological risk is caused by copper. In the case of the Botic Creek the MPC value is exceeded and as a result, the aquatic organisms are exposed to an unacceptable risk. The second risky element is zinc, which exceeds on most sites the TV concentration.

| **Stream** | **Drainage type** | **Cd** | | **Cu** | | **Cr** | |
|---|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | Min | Max |
| Botic Ck. | combined | 0.02 | 0.1 | 11.9 | 89.4 | 10.3 | 40.9 |
| Rokytka Ck. | combined | 0.09 | 0.42 | 20.1 | 47.0 | 12.9 | 29.4 |
| Zatissky Ck. | stormwater | 0.03 | 0.17 | 5.5 | 11.3 | 6.8 | 17.4 |
| Kosikovsky Ck. | stormwater | 0.07 | 0.09 | 18.3 | 47.1 | 13.7 | 24.4 |
| EQS | TV | 0.8 | | 36 | | 100 | |
| | MPC | 12 | | 73 | | 380 | |
| Stream | Drainage type | Pb | | Ni | | Zn | |
| | | Min | Max | Min | Max | Min | Max |
| Botic Ck. | combined | 9.7 | 50.0 | 8.3 | 16.6 | 36.2 | 156.2 |
| Rokytka Ck. | combined | 22.0 | 53.6 | 12.5 | 19.7 | 97.9 | 219.6 |
| Zatissky Ck. | stormwater | 6.5 | 31.6 | 7.4 | 13.5 | 30.3 | 115.9 |
| Kosikovsky Ck | stormwater | 18.4 | 29.9 | 12.5 | 21.3 | 87.9 | 224.0 |
| EQS | TV | 85 | | 35 | | 140 | |
| | MPC | 530 | | 44 | | 620 | |

Table 1: Concentration of heavy metals in sediment (mg/kg dry weight) of monitored creeks and value of environmental quality standards according to the Slovak methodological guidelines (TV – Target value, MPC – Maximum Permissible Concentration)

Neither of the combined sewer overflow creeks (the Botic and Rokytka) nor one of the stormwater discharge creeks (Kosikovsky) achieve the good chemical status level for

concentration of heavy metals. The Zatissky Creek complies with the Environmental quality standards for heavy metals in sediment and water.

## 3.2 Ecological status

### 3.2.1 Biological status

All the observed creeks are small and as a result, there is not a permanent fish population. Therefore the identification of biological status was based on assessment of benthic community. The Directive requires that the biological status is assessed according to a reference conditions. Identification of reference conditions in Europe, where most water bodies are moderately to highly modified, is a difficult task. While there are a number European predictive models which use reference sites or the best available sites for predicting benthic community composition in rivers and streams in natural and rural areas, there is not a suitable model available for the assessment of urban creeks, where often secondary equilibrium have developed and the biological community has adjusted to new conditions. Is it appropriate to use the same models for modified ecosystems as for natural or slightly impacted creeks, especially if the ecosystem has altered physical conditions? The results of using the predictive model show that all the observed creeks are far from reference conditions. The benthic community was also assessed by number of indexes (Table 2), which are in agreement with comparison with reference conditions and show very low to low medium quality of the benthic community on all studied creeks.

| **Stream** | **Drainage type** | **BMWP** | | **ASPT** | | **Diversity** | |
|---|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | Min | Max |
| Botic Ck. | combined | 35 | 48 | 4.3 | 5.3 | 1.3 | 1.7 |
| Rokytka Ck. | combined | 23 | 61 | 3.8 | 5.4 | 0.9 | 1.7 |
| Zatissky Ck. | stormwater | 5 | 54 | 2.5 | 4.9 | 0.5 | 2.1 |
| Kosikovsky Ck | stormwater | 17 | 62 | 2.6 | 6.2 | 0.2 | 1.5 |

Table 2: Assessment of biological status of creeks by their benthic community

### 3.2.2 Hydromorphological status

The assessment of morphological status of studied creeks is summarized in Table 3. In the case of the Botic and the Rokytka Creeks, the assessment was undertaken for study reaches of 2.5 km and 1.5 km length respectively. In both cases, had the whole creek been assessed, there would have been a significant increase in the reaches identified as fully artificial. The Kosikovsky and the Zatissky Creeks were studied for their whole length.

| **Stream** | **Drainage type** | **1.** | **2.** | **3.** | **4.** | **5.** |
|---|---|---|---|---|---|---|
| Botic Ck. | combined | 24 | 50 | 16 | 8 | 0 |
| Rokytka Ck. | combined | 0 | 0 | 80 | 20 | 0 |
| Zatissky Ck. | stormwater | 5 | 15 | 40 | 30 | 10 |
| Kosikovsky Ck. | stormwater | 0 | 0 | 30 | 40 | 30 |

Table 3: Morphological assessment of creeks as a percentage belonging to each quality class (1-natural, 5-fully artificial)

The river continuum of all study creeks are modified by one or more of the following structures: ponds, storm retention basins, reservoirs or weirs. The results show that the morphology of the creeks is altered, raising the question whether the alteration is sufficient to change the water body category from ‘normal’ to ‘heavily modified’?

The Directive fails to provide guidance on the scale and level of modification to the morphology at which the water body should be designated as 'heavily modified'.

The range of optimal ecological flows (range of flows supporting the highest diversity of organisms and their life stages) for each creek is listed in Table 4.

| **Stream** | **Drainage type** | **Ecological Flow** | | |
|---|---|---|---|---|
| | | Minimal | Maximal | Optimum |
| Botic Ck. | combined | 0.11 – 0.12 | 0.80 – 0.83 | 0.20 – 0.22 |
| Rokytka Ck. | combined | 0.15 – 0.17 | 0.91 – 0.93 | 0.36 – 0.40 |
| Zatissky Ck. | stormwater | 0.02 - 0.03 | 0.62 – 0.64 | 0.04 – 0.05 |
| Kosikovsky Ck | stormwater | 0.03 – 0.04 | 0.50 – 0.55 | 0.05 – 0.06 |

Table 4: Minimal and maximal ecological flow ($m^3/s$)

Assessment of creek flows against the pattern of optimal ecological flows required to sustain community structures indicates that maximum permissible flows are exceeded during wet periods and minimum required flows are not met during dry periods. The failure to meet maximum and minimum flow requirements occur with higher frequency for urban as compared to pre-urban conditions (Komínková et al, 2005) due to the high percent of impervious surfaces in watershed and consequent changes in the hydrology of the watersheds. The changes in hydrological conditions of the streams raise questions. Does alteration of hydrological conditions count as physical alteration of the water body character?

Assessment of creek flows against the ecological optimal flows required to sustain community structures indicates that the major factor impacting on the benthic community is hydraulic stress, followed by altered morphology and missing suitable habitats.

While chemical stressors may gain importance during accidental spills or rain events, they generally appear to be less significant than flow and altered morphological conditions. All of these stressors combine and may have a synergistic effect on aquatic biota. There may be insufficient time for recovery of the ecosystems, leading to increased severity of impacts on the aquatic community and ecosystems functions.

The final assessment is highly dependent on whether the creeks are heavily modified or not. The levels of altered morphology of the studied creeks are typical of many urban creeks in Europe and elsewhere. Therefore, the inadequate definition of heavily modified water body threshold is a widely shared problem in water management.

The paper illustrates, by way of two approaches to the Directive definition of 'heavily modified' waterways, the significant environmental, ecological, economic and social implications of the ecological status or potential classification.

The first approach takes into account the morphological and hydrological alteration of the study creeks and defines physical alteration as substantial change in stream character. This approach designates study creeks as 'heavily modified' (requiring only restoration to good ecological potential). According to this approach ecological potential of all study creeks is designated as moderate (they do not achieve good chemical status). This approach accepts that morphology and hydrology of the creeks is altered. Consequently, the chemical stressors become the biggest concern in the aquatic ecosystem and the restoration of the creeks to good ecological potential has to focus on achieving good chemical status only. It means that sources of pollution have to be controlled at source or intercepted within the sewer system to improve the chemical status of receiving water bodies. But in this case, there is not a need to undertake restoration of the river channel and banks, nor is there a need to ameliorate the changes in hydrology of the creeks.

The second approach takes into account only the morphological alteration and assumes that the physical alteration of the creeks is not a substantial change in stream character. This approach designates the study creeks as 'normal' (requiring restoration to good ecological status) and assesses their ecological status as poor to bad. The study of the creeks identified the major factors impacting on the benthic community as the hydraulic stress, followed by altered morphology and missing suitable habitats. The rehabilitation of the creeks should therefore start with the application of measures in the watershed which would decrease the amount and rate of water directly entering the streams during rainfall periods from the drainage systems. While end of pipe measures such as retentions basins, decrease the peak discharges entering receiving waters, they do not solve the problem of increased volume of discharge. Other more sustainable approaches include the reduction in area of impervious surfaces, but these measures are only practical in new development areas. Measures decreasing the amount of impervious surfaces or effective impervious surfaces (directly connected to water body) lead to improvement of hydrological conditions of streams by rehabilitating connection between surface and ground water, thereby reducing the number of non-acceptable discharges and potential for streambed erosion (Walsh et al 2005). The changes in watershed should be than follow by rehabilitation of river channel and banks to provide more suitable habitats for aquatic organisms. In case of this approach the elimination of chemical stress is one of the last tasks of the restoration, because it's low significance. The chemical stress is partly eliminated already by some of the measures mentioned above.

## 4 CONCLUSION

The identification of ecological status or potential of water bodies is a primary step guiding water management decisions about the sustainable development of the water body as well is need to accomplish the Directive requirements on quality of surface water bodies. The Directive requires that all surface water bodies reach a good ecological status ("the values of biological elements for the water body type show low level of distortion resulting from human activity") or good ecological potential in case of heavily modified or artificial water bodies ("the values of relevant biological quality elements are slightly change as compared with the closest comparable surface water body type, given the physical conditions which results from the heavily modified characteristic of water body") by 2015.These requirements necessitate the improvement of the ecological state or potential of the study creeks by their rehabilitation or restoration. The level of rehabilitation or restoration is dependent on the assessment of the streams and on their identification as "normal" or heavily modified water bodies.

In this stage of decision making the deficiency in the Directive is becoming crucial not only from an environmental and ecological point of view, but also from economical and social points of view. In the case of the four Prague creeks, rehabilitation of heavily modified water bodies to achieve good ecological potential has to focus on achieving good chemical status only; it means that sources of pollution have to be intercepted within the sewer system to improve the chemical status of receiving water bodies. But in this case, there is not a need to undertake restoration of the river channel and banks, nor is there a need to ameliorate the changes in hydrology of the creeks. The cost of improving the state of the studied creeks will be significantly lower in this case, than in the case where the water body is designated as 'normal'.

In the case of 'normal' water bodies, disconnection of sources of chemical pollution is not the only action which should be taken. The study of the creeks identified the major factors impacting on the benthic community as the hydraulic stress, followed by altered morphology and missing suitable habitats. The rehabilitation of the creeks

should at start with the application of measures in the watershed which would decrease the amount and rate of water directly entering the streams during rainfall periods from the drainage systems. The changes in watershed should then be followed by rehabilitation of river channel and banks to provide more suitable habitats for aquatic organisms.

The suggested measures show that there are significant differences between rehabilitation of creeks in cases identified as heavily modified and those identified as "normal". The financial cost of these differences is significant. The economical aspect may become crucial for final assessment of river status or potential and the water managers decision may reflect more the economical benefit than the ecological and environmental benefits, especially if the deficiency in the Directive allowed this and leaves to personal opinion what is "unreasonably expensive" to achieve good status. To avoid misleading trends in water management and to effectively promote the environmental benefits of the Directive it is necessary to clearly identify the threshold between "normal" and heavily modified water bodies.

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