# Thesis booklet

**Nagy Zsuzsanna**

# DEFINITION OF THE MAIN HYDROMORPHOLOGICAL PARAMETERS INFLUENCING THE STATUS OF THE BIOLOGICAL QUALITY ELEMENTS FOR STREAMS IN HUNGARY

**Corvinus University of Budapest**

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The applicant met the requirement of the PhD regulations of the Corvinus University of Budapest and the thesis is accepted for the defence process.

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| Az iskolavezető jóváhagyása | A témavezető jóváhagyása |
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## 1. Foreword, Objectives.

The Water Framework Directive (WFD, the 2000/60/EC Directive) is an EU regulation to reach good water status for all waters in Europe till 2015 and to do the necessary steps for its execution. So thus the possible measures shall be listed, their ecological efficiency shall be assessed, and publicly accepted measures shall be executed. Moreover, a 3-level monitoring system is to be run. All proposed work is to be integrated in the frame of the river basin management plan, the first draft is to be ready for public consultation till 2008.

The 2000/60/EC Directive requires assessment of surface water bodies and the list of proposed measures in the light of the set environmental objectives.
So far, during the implementation of the WFD each stakeholder could experience the engineer-ecologist-biologist dependency. Civil engineer-planned measures shall be considered the preference curves of biological elements. The country-wide ECOSURV survey in Hungary (2004—2005) proved that Hungarian waters depend much more on habitat types then water chemistry, and hydromorphological parameters play a crucial role in water status.

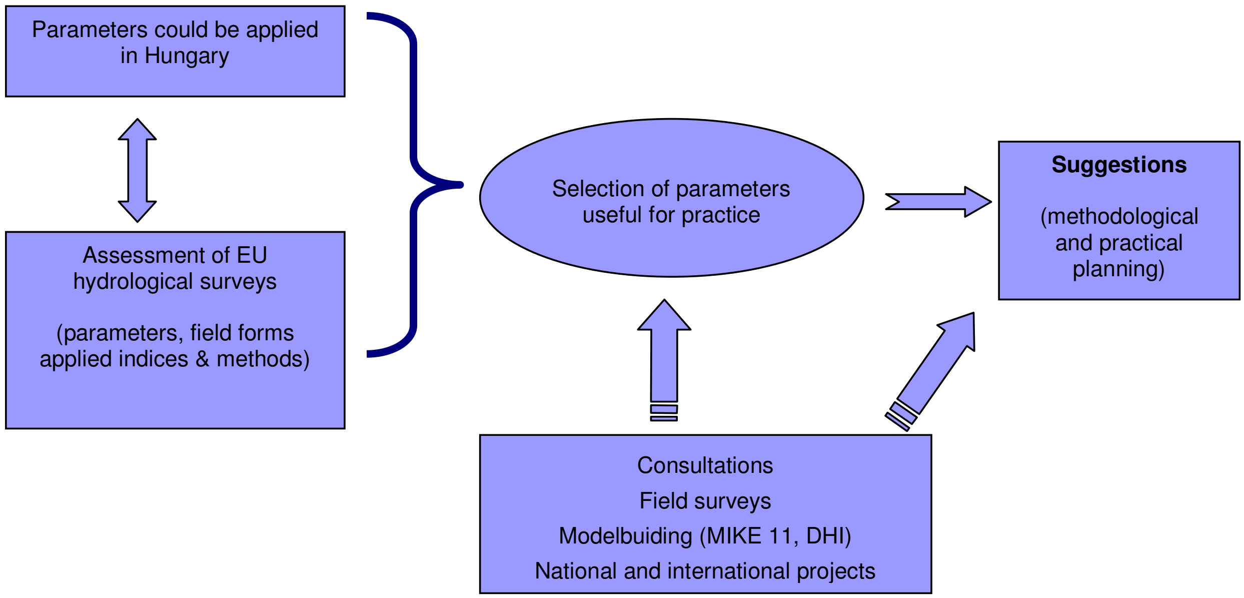
Data needed for status description and also for setting up environmental objectives are not complete: not only in hydrological and morphological sense but from the ecological point of view, too. These gaps must be filled by field surveys, measurements or reliable and objective expert judgements, or even by creditable model results.
Biological rare data are important elements for the proposed measures aimed status improvement, because costs, expected efficiency analyzes are based on them, and thus also the level of the need/must for the execution of these measures.

The main objective of my work was to assess the tracked the most important national and international literature, recent relevant research results as well as to carry out field surveys and to do modelling, and answer the following questions:

- Which are those most important parameters that influence the WFD related biological quality elements (BQEs) for streams in Hungary?
- What dataset exists for streams in Hungary, how and for what purpose can it be used? How can this dataset be improved?
- How could BQE monitoring results be used by civil engineers in the good-status aimed measure planning?
- What could the use of hydromorphological field-survey result?
- How can the running BQE monitoring results and the planned measures rejected due to bio-efficiency reasons be compared?

So the goal of my work was to prove that biological, hydrological and morphological aspects are equally important, completing each other in stream revitalisation.

## 2. Modules of the research




## 3. Material and methods

The topic has been worked out according to the following four main stream-lines:

1. Review and assessment of Hungarian and international biological, ecological, and engineering literatures. Survey and assessment methods were tracked considering different European assessment methods: critical literature review.
2. Assessment of the available basic information for Hungarian streams special in the light of the levels of evaluation (bottom-up and top-down approaches): use of MIKE model as a tool for data-suitability investigation in a pilot stream catchment level. Development of data-building replacement techniques, methodological suggestions.
3. Raking BQE status defining parameters for Hungarian streams, definition of basic parameters for biological status description.
4. Setting up direct linkage between bio-monitoring (in my pilot case: fish monitoring) actions and engineer-planning: improvement of eco-efficiency of proposed measures for river basin management plans – methodological and practical suggestions.

1.) I have carried out detailed literature review on recent publications and actions which are the most relevant to the described topic. Investigated the most important experiences, results gained from the Hungarian and as well as from the European WFD implementation. Special attention was paid to those Hungarian researches' outcomes which are oriented to streams. In a sub-chapter I briefly addressed the applied Hungarian term of ecological water demand, the so called „living water" expression. In the chapter "Material and Methods" I evaluated the actual interrelationship of biological and hydromorphological approaches. I have worked out the evaluation of seven hydromorhological protocols, such as Danish, German, French, Slovakian, Italian, Austrian and English ones. I have assessed the used parameters and indices applied. By using two-level SWOT method I have highlighted the possible level of their applicability.

2.) I have reviewed and assessed the recent outcomes of European researches (including of course also national ones), and with the help of my desk and field experiences I presented the special feature/condition of Hungarian researches.

During my field work on Mogyoródi, Rákos, Apátkúti and Morgó streams I collected information about the most important cross sections, littoral and instream (plant-structure) vegetation (macrophytons) and water levels. During fish-fauna monitoring I collected for each monitored reach in addition min. 3—3 characteristic cross-sections for which current (velocity) values were measured (maximum and average values by Global Trobe, FP101 model). Moreover the most important physico-chemical parameters were also measured: water temperature, pH (by HANNA ATC Piccolo instrument), conductivity (WTW LF 95 conductometer), dissolved oxygen (WTW 03 oxymeter). The electrofishing method was used (by RADET IUP-12, 4-15 A, 20–100 Hz). Additionally for each stretch water flow was calculated. During electrofishing we have followed the Hungarian fish monitoring protocol (MoEW 2001) and the CEN Protocol (EN 14011). Caught fish were measured by length and weight for total biomass calculation (used as basic input data for revitalisation actions in Czech Republic). In reaches where the length was 50m, habitat mapping was also done.

I have set up a MIKE 11 HD model for a Hungarian stream (Rákos stream) to assess the potentials of the use of model result. To assess how the possibly reachable level of results carried by the actual status of the maximum dataset is.

I have assessed the available system of biological, hydrological and morphological data. There is a need for hydrological data procreation – I have developed a new theoretical method as a possible solution. Data were obtained from the Ministry of Water and Environment (MoEW), VITUKI, Middle-Danube Environmental and Water Authority, and from the Main Environmental, Nature and Water Inspectorate.

3.) Based on my model results and my pilot studies I summarized the importance of parameters, made suggestions for the required dataset considering the practical engineering work as well. The parameters needed for ecological status description were determined with the help of national and international biologists formulated group, which was asked to fill a questioner (UK RHS field protocol) separately which was reshaped a bit to Hungarian conditions.

*Applied method*: the parameters occurred in RHS had to be evaluated (using the value range 0–3) in the light of its Hungarian presence and abundance of the certain BQE: indifferent (0), less important (1), important (2), extremely important (3). The extremely important meant that the parameter has basic influence on the actual investigated BQE. The main goal of this investigation was to create such a parameter list which shows an objective expert judgement, containing all expert found most the important influencing factors: indeed it is a list containing the 3–3 points given parameters.

4.) I have carried out field investigation on the mentioned streams and reflected on the result-applicability in practice by the help of biologist-engineer cooperation. .I paid special attention to the ecological flow questions, by integrating engineer and biological aspects, too. Using the international literature I have improved the Rechenberg (2004) method for ecological-efficiency of stream reconstruction and tested for a pilot area, too.

## 3. Results

According to the method described in the chapter of Material and Method I have got the following results:

### 3.1. Critical comparison of the European hydromorphological protocols:

- I have reviewed and assessed the main hydromorphology related European literatures, carried out a comparison pointing out main approaches by listing their common involved parameters:

size of the catchment, littoral and floodplain vegetation related information, bed and bank character, as well as flow related parameters.

- I have pointed out the advantages and disadvantages of the use of field forms in their state-of-the-art:

| *Advantage* | *Disadvantage* |
|---|---|
| - Depending on the number & quality of parameters they can provide further useful information.<br>- Basic data can be extracted from a central database, therefore this field-check is needed only (e.g. water release).<br>- If the registered data could constitute part of a deliberate integrated dataset, they could be considered very valuable background information for any further assessment (e.g. habitat-modelling)<br>- Datum of field forms could provide sufficient information for many further work (e.g. 1-D habitat model)<br>- By fixation of certain parameters EU-wide comparison could be carried out.<br>- Integration certain hydromoprhological parameters into the Hungarian biomonitoring system can carry challenging opportunities. | - Data collection for each stretch is time consuming also in case of having minimal number of parameters to be assessed: 40 minutes/50 m length – if cross section and water level are also registered for further use (as my own experiences show).<br>- Morphological development of the stream stretch is to be considered, therefore fixed points shall be determined.<br>- Adaptation of parameters to be monitored and assessed method shall be done.<br>- There is no experience for long-term practical use of hydromorphological field form for streams having conditions similar to Hungarian.<br>- Filling up detailed even a well structured hydromorphological field forms is time and labour work consuming task. |

I stated that

- adaptation of other country's field form and protocol can be successfully used after careful preparation works,
- experiences gained in other countries could help the Hungarian method development, but
- the use of any of these protocols in their original form brings extra data management and assessment work, and due to the lack of other relevant data this approach is not suggested to be used.

**3.2. Hydromorphological and biological related results by the RHS based assessment**

The parameters needed for ecological status description were determined with the help of the group formulated by national and international biologists, whom were asked to fill a questionnaire (UK RHS field protocol) separately which was reshaped to Hungarian conditions. The following answers came out, the jointly found most important parameters are the following:

- Integration of **ecological approach** into hydromorphological and biological monitoring programmes is needed.
- Each BQE is determined by **geophysical parameters (e.g. basic rock)**
- The following listed **parameters** and processes are to be highly recommended to consider in monitoring activities due to their **influence on BQEs' living condition:**

  — Width and quality of **buffer zone**[1]**, because it is** influencing the abundance of water organisms much more than the land use

[1] Delineation of buffer zone (*Where does it start?*) at Hungarian streams are especially interesting question due to their geographyscal positions, wether puffer zone is worth being linked to small water river bed, medium river bed or high water river bed. The risen question needs further researches (e.g. to continuation of Kalicz et al. 2004. work), so thus it has not dealt in detail in this present dissertation.

— Effects of the **arboreal littoral vegetation** are shown in reduction of potential load, in fluctuation of daily water levels by its transpiration, and in fluctuation of daily and yearly dissolved oxygen by shadowing the water surface. Additionally, in providing woody debris material to the stream. [However the played role of herbaceous vegetation must be considered also (Kalicz et al. 2004), but I did not take it under assessment separately. Due to keeping the RHS form structure, its influence appears cumulatively e.g.).

— There is no special need to integrate data gathering about land use & land use change into BQE monitoring, it can be read from air images easily, and the effect obviously appears in discharge volume, and on the other hand the actual discharge can be calculated from the measured current and cross section so the optimal discharge capacity of the stream bed is plannable.

— **Water extraction** plays an extremely important role – and especially in providing the minimum flow –, therefore it these shall be registered correctly, as well as the occurrence of standing waters or pools. Beside water extraction the *natural water loss* shall be considered, particularly if the littoral vegetation is rich in the hot periods. Thus the stream *maintenance work* can influence the ecological flow (but it shall need further investigation especially for Hungarian cases)–, therefore further studies suggested to *focus on lowland natural streams* and *irrigation/excess surface water channels.*

— Data gathering about **pollutant**s is also important

— **Waste water recharge** affects the water level and its permanency (continuity of recharge in time is the dynamical physical control factor of water ecosystems) and plays an important role in potential load (but regarding nutrient load the possible positive effect of the Waste Water Directive is expected).

— **Straightening** shall be considered as important anthropogenic factor influencing living biotas. So thus its today feature, and also whether the restoration (or in which level) is reasonable (however it was human intervention might result a valuable today vegetation and community) shall be assessed.

— Effect of **water vegetation (and its removal)** appears in modification of flowing conditions as well as in providing shelter area, therefore its removal naturally modifies instream conditions. As Danish research (Sand-Jensen–Friberg–Murphy 2006) also pointed out, further assessment of vegetation removal is needed, especially regarding timing, spacing, and applied techniques in order to be able to provide good water status continuously for a certain watercourse.

— **Continuity** of the ecological corridor means longitudinal connectivity (where vertical connectivity may also have an effect), which influences migration of fish population as well as sediment transport processes.

— **Materials of bed and bank fixation** influence BQEs by determining habitat-types much more then its technical solution.

— **Debris dam, logs** could influence hydromorphology by creating different habitat character (e.g. POM accumulation, pool formulation). But here, the necessity of deliberate stream maintenance must be emphasized.

— **Valley** form determinates the feature of the stretch, the run-off conditions (length and time of run-off, type of flood wave, etc.), as well as the width of floodplain.

— **Cross section** determinates hydraulic features as well as influences instream physical conditions. Moreover, it defines the possible water levels.

— In case of investigation the effect of **longitudinal section,** the valley and surface slopes are important, often are considered as boundary conditions.

### 3.3 Results obtained from the running MIKE model

There are lack of data regarding time series of Hungarian streams for water flow (Q) or water level (H): i) not only for long term but also for short time period and ii) not only at country level but for

pilot-areas, too. However there is a need for such basic information for WFD implementation, to reduce gaps is essential to be able to set up correct environmental objectives, forecast and track the measure caused changes (even in some cases the best guess can be applied).
Data procreation –on one hand– can be based on hydrological analogy: adaptation data, deriving from a hydrological investigated area, to the unknown one. I have carried out a series of trial for Mogyorod creak with the following results:

1. Considering WFD approach the analogical water body of Mogyoródi stream could be the certain reach of Rákos creak, on where there is just only one water gauging station. This station (namely Peel gauging station), due to the upstream fishpond effect shows the operational order of the fishponds. However this is also important parameter but it means that there is no available time-series about natural flow regime – so thus the application of hydrological analogy had to be rejected.
2. Other possible solution could be the use of the Q–H curve. Due to the fact there is no measured Q and H values for the few-year period, it is also not applicable in our case.
3. The third approach origins from the fact that certain amount of precipitation occurs in river bed. Dataset of Hungarian streams are – due to the fact they are not highly integrated into the national hydrological monitoring system – set from scattered measured data. It is also true that for each measured water level (H) some precipitation related value (P) can be added, P–H curve could be established. Ordering precipitation values to each characteristic water level[2]. To ensure sufficient data I have developed the ***method*** of ***proportioning the characteristic water levels and precipitation values***, by setting up P–H curve as:
    - Measured water levels are shown on the horizontal axis
    - Water level related precipitation values are on the vertical axis in such a way that the daily precipitation values (in mm) are reduced by a run-off coefficient determined by upstream catchment.

Anyhow the delay of runoff shall be counted, but in case of small catchments the reaction time is small (maximum few hours), so in our case this phenomenon can be neglected. Accordingly the use of the mentioned method time-series of the natural flow for a certain stream can be re-constructed.

Beside all, ecological flow of streams can be assessed in an other way: taking consideration what the certain stream shows on its reference site. For stretches having natural flow conditions the precipitation–ecological water level relationship can be applied. Upon the facts that wet and dry periods were shown also for our rivers (Vágás 1994), BQEs are able to adapt to this changing conditions in a certain level, and the ecological demand of BQEs vary in time (and in some cases in space) I suggest the introduction of the **flexible ecological minimum** expression. Therefore I can see the need to modify the ´´living-water´´ based water resource management.

### 3.4 Integrated results

- Special dataset of streams are made of a series of scattered data measured at different gauging stations and in different times as well. I have done my work on this basis and got the following results:
    - Used HD module of MIKE 11 software as a tool for a certain pilot area to test modelling possibilities for streams, and I have found that the national monitoring datum in the present state-of-art in Hungary are not sufficient for wider status analysation purposes, WFD aims can not be fully supported by the use of this dataset. My results showed that in case of having sufficient quality data (e.g. cross sections, flow, slope) model could be set up and used for multipurpose such as scenario- and multi level (micro—macro)-habitat analyses.

[2] Jellemző vízállás (intervallum) alatt az adott biológiai elem fejlődési szakaszaihoz rendelt tolerancia intervallummal kifejezett vízmennyiségi értéket értem

- I determined hydromorphological parameters specifically influencing WFD related BQEs abundance. Therefore I highly recommend such *water body-tpye based monitoring* which consider also the listed parameters: with and quality of buffer zone (range of refraction, vertical and longitudinal connectivity, canopy parameters), discharge fluctuation resulted water recharge and abstraction, littoral and instream vegetation, cross and longitudinal section (especially the steps higher then 20 cm)
- It is a fact that for instance fishes *require certain flood wave* in spawning period, which is a certain water flux, so thus ´their requested so called *maximum water current´* is crucial for the population [e.g. in case of *Leuciscus leuciscus* the required value is approximately 1,20 m/s (Just et al. 2005)]. Ensuring this flux in spring period is required because of environmental protection. But this same current (velocity) in other period of the year is too much. Certain fish species e.g. the protected *Misgurnus fossilis* is able to survive even the 0 water level for a certain period in the mud of the stream (Sebestyén 1963). Considering the fact that i) the dry and wet periods (Vágás 1994) can also can be shown for streams as well with high certain level, and ii) the adaptation capacity of the biological elements I suggest the **flexible ecological flow** (**FE-Flow**) approach. Therefore there is a basic need for knowing water level/discharge fluctuation even it is ready as just a partial information. The baseflow can be measured quickly with one observation (assuming the continuous flux from groundwater), as well as the investigation of run-off effect on water level and velocity (yearly minimum, maximum and average values). As my recently listed statements show definition of **ecological flow** (punctually the certain cross section related water level and current) most probably should be based on the **tolerance levels of BQEs**. The possible solutions which could be done at certain area hydrological and by water resource-management interventions shall be checked.
- Designing works are not usually followed by its monitoring establishment (or the project budget is not enough for monitoring) although it could provide valuable information for any kind of further assessment. Therefore setting up efficiency linkage between the planned measures by forecasting indicators and the realized, monitored one and building this into the planned measures of RBMPs are suggested. Thus it is recommended to monitor not only BQEs, but hydromorphology, too. Firstly multi-element and different time related monitoring solution can be tested in order to be able to select the best variant – also that which can provide reasonable result for technical and monetary feasibility impact studies.
- My HD model results and field investigations have pointed out the fact that work should be focused on the relationship of water current (velocity) and water level instead of ecological water flow for habitat status description and on the use of this information for determination minimum downstream flow. The actual term of ´´living water´´ could be modified, I suggest the introduction of terms of the **tolerant level based** so called **ecological water current and water level**, which are climatic and meteorological based interval values, therefore they are suitable for objective planning and efficiency analyse uses.
- I have assessed the differences in the approaches of the status assessment and of its adaptation into practice by comparison of two pilot areas (in Hungary and in the Czech Republic) which have similar geophysical conditions. The gained results show that the connectivity rate can be seen well from the fish monitoring result, so the review of the watercourse-network especially from the nature protection point of view selected BQE indicator can be expedient, in order to see what are the limiting factors of good water status at the certain stretch.
- Assessment result of field works and hydromorphological protocols showed that monitoring result could be used for ecological efficiency study of the proposed measures (for which I worked out practical guideline): restoration of small water level connected stream bed shall be based on good status providing parameters. But for effective planning preference curves of protected species are needed to know, adaptation of international literature must be carried out, the missing data should be gathered. Adaptation of the preference curve of

certain BQEs are based on the fact that Hungary has different geographical position, as well as different hydrological condition. However, for example parameters of *Salmo trutta* for stream reconstruction are well known from German literature (e.g. the needed current for spawning), these values can not be applied directly in Hungary: values will differ, because the fish species in Hungary do not reach the same length and weight.

- I have stated that the **method of hydrological analogy** used for water body delineation and status determination **is not suitable for environmental objective-set up exclusively**, because in addition to the hydrological parameters the morphological status of the bed is also significant.

## 4. Conclusions, suggestions and applicable results in practice

There is actual need for data replacement. Providing supplementary data to the national database as well as to the EU integrated data management system. Interpretation of available data from one area of specialisation to an other one could be solved, especially in the light of the good status objectives required by the Water Framework Directive. Since January 2007 the operative monitoring has been running aiming data gathering on water bodies at risk. Therefore carrying out deliberate data transport from this activity is to be considered (such registration of water levels, cross sections, currents for natural flow fluctuation definition). Thus I highly recommend setting up gauging stations which are in relevant pilot areas for water resource management, too. To be able to investigate also such stretches which are not influenced by any upstream human activity. Taking into consideration this approach a run-off model can be set for pilot area, could serve as analogue site for other catchments. Beside these, objective results can be gained for i) climate scenarios, ii) planned revitalisation measures, including the evaluation of the considered water management solutions, interventions –e.g. following the line done already for big rivers (e.g. Koncsos 2006) . To help this process based on my field works,

— I developed a simple graphical solution for further stream assessment, a method for the determination of water surface shadowed rate, and

— I have improved the Rechenberg (2004) method by integrating fish monitoring results into the eco-efficiency assessment in order to help setting up better environmental objectives.

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