Rehabilitation and Creation in urban rivers. Objectives and Techniques

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1. Introduction

Urban rivers may show varying degrees of disturbances caused by human activities that range from hydrological changes, such as increased peak flows and loss of base flow and flooding areas, water quality degradation by contaminants of urban runoff or even overflows from sewers systems and trash disposal, to complete loss of the former natural river channel and riparian habitats due to channelization or culverting. These changes may result from local urban pressures but can also reflect modifications on the river basin. In most of the cases, these changes may extend a long way downstream from the area of original impact.

Urban rivers present an opportunity for rehabilitation and redevelopment that will enhance the quality of the river and adjacent urban areas. The application of adequate rehabilitation techniques must be integrated with other type of interventions on urban areas.

This paper briefly describes the fundamental steps in rehabilitation of urban rivers, according to the URBEM project activity chart: the site definition, the formulation, the strategies and the development of technical options for urban river rehabilitation, description of consequences of, and the description of urban rehabilitation and the monitoring of rehabilitated urban river.

2. Site definition in urban river rehabilitation

Urban river rehabilitation projects can be focused on the rehabilitation of a river reach or extend to include interventions on the river basin area.

For the definition of the site the three basic hydromorphological elements described in Water Framework Directive (WFD) should be considered: the hydrological regime (quantity and dynamics of water flow and connection to groundwater bodies), the river continuity and the morphological conditions (river depth and width variation, structure and substrate of the river bed and structure of the riparian zone). Therefore for the site definition it will be necessary to gather all pertinent data related with the above mentioned elements. As each element may impose different types of control and influence on the river system the site limits may not be unique. Consequently it is not easy to find general and simple criteria to help find the border cross sections for the site.

3. Formulation of river rehabilitation

The identification of the modifications occurred on the river is the basis to understand a complex system with many interacting variables and to define the measures to be applied to rehabilitate the river.

The following three steps are recommended to formulate the urban river rehabilitation: 1) to assess the present situation, including the river basin and the river channel and bank elements; 2) to assess the previous situation, by two possible ways - i) the previous river regime is obtained gathering data base and historical facts and documents or ii) a previous reference situation is obtained by comparison of neighbour unchanged river basins or by theoretical reasoning and 3) to compare both situations in order to identify the modifications occurred, during all history, by the presence of urban areas in the river basin.

Considering the hydromorphological aspects, it is necessary to characterize the hydrological regime, the flow conditions and the channel flow processes in the river. The channel flow processes includes the characterisation of bed and banks and the hydraulic structures. The only way to collect the required data is to survey the site. For important structures the design documents should be referred to, where hydraulic computations may be included.

In urban river rehabilitation, different cases of urban pressure can occur, and for each case different spatial extent of assessment is necessary.

Case 1 – Urban area much smaller than the river basin

The impact of urban activities on the river may be felt on the part of catchment where the urban area is settled. In this case, only a part of the river may be changed during the past.

Case 2 – Urban area covering the major part of the river basin

The urban influence on the river depends on the location of the urban area in the catchment. If the urban area is in the upstream part of the catchment, it may significantly alter the river network in the whole catchment, not only in the urban area, but also in the downstream part. If the urban area is in the downstream part of the river network the consequences to the upstream part are not felt.

Case 3 – Urban area covering the entire river basin

If the river basin is fully urbanized the river net may be turned completely artificial. Indeed, large towns may occupy more than one river basin imposing strong pressures on various river systems and make rehabilitation progressively more difficult.

4. Strategies for urban river rehabilitation

Urban river rehabilitation approaches must include the appropriate types of interventions to rehabilitate river and urban areas together.

The fundamental question is about the strategy for the river rehabilitation. There is the intention to renaturalise the river to a pre-urban state? In Europe this means there is the intention to recover centuries of history. Only in rare cases this is an attainable strategy.

The most common strategy is to restore some aspects of the previous river environment. The main scope of the river rehabilitation must be to obtain good combinations of interventions to restore as much as possible the "natural" conditions of the river.

The "natural" river conditions are very difficult to define. A relative broad set of conditions are possible, turning a fuzzy concept. Consequently, even in a team of river experts there will raise different strategies, and by this reason it is easily found different parallel strategies. The combination of strategies for the river itself and other strategies of urban rehabilitation, when that exists, leads to a great number of set of options for the rehabilitation.

It is important to remark it is possible to consider an extension of the strategy to recover "natural" conditions: do no obtain the original conditions but to obtain completely new conditions where the natural forces and processes are used to "create" a river environment like natural. We may designate this river rehabilitation more as "river creation". When this process is not scientifically sound there will be problems to solve in the future, because they will be needed additional interventions to maintain the "created" river.

5. Development of technical options for urban river rehabilitation

The following steps are recommended to define and support options for urban river rehabilitation: 1) identify measures for the river basin, river channels and banks, or both and 2) design the measures including the amount and type of work, costs, duration of the intervention, and so on.

The identification of the adequate rehabilitation measures must attend to the multiple and conflicting uses of urban rivers and be in appropriate balance in order to minimise disturbances to the consolidated urban areas.

The detailed quantification of costs associated with the interventions may raise important questions leading to alternative measures or new designs. Iterations are expected until a consensual solution is obtained.

To achieve the "good ecological potential" of urban streams a new approach is required. In the past, many rivers were stabilised and hardened with concrete and steel in order to accommodate navigation and to protect urban uses from flooding and erosion. River banks were typically designed for a single purpose. Today there is a growing support for ecology and multiple uses as well as an interest in using “soft engineering” on river bed and banks at appropriate locations. A more natural approach needs to be taken to manage and design channel form and function. Such an approach incorporates flood conveyance concerns, aquatic habitat, riparian habitat, water quality, recreation and aesthetics.

Stream bank protection designs that incorporate vegetation can satisfy these multiple objectives. Natural channel design can be accomplished with soil-bioengineering measures that use a combination of living plant material and mechanical means to achieve specific engineering functions. However in cases that “soft engineering” may present limitations, classical river engineering techniques may be the only alternative.

The definition of river rehabilitation options must be framed within physical constraints. There are different types of physical constraints, some associated to the river channel (like minimum or maximum permissible hydraulic parameters, singularities on the river bed, water quality standards compliance, ecological maintenance, etc.) or river basin (permission on or not of water transfers, maintenance or not of some land cover, etc.) other with urban features (historical buildings or infra-structures, administrative subjects, social status, etc.). The identification of constraints is a multi disciplinary task, implying some consultation outside the technical teams.

6. Description of the consequences of urban river rehabilitation

Rivers adjust their characteristics in response to any change in the environment. Therefore, evaluation of river responses is essential to guaranty the success of the rehabilitated urban river. For this, the use of fundamental principles of river engineering is necessary to characterize the hydromorphological conditions of the urban river, before and after rehabilitation.

The geometric characteristics of the cross sections, the longitudinal slope and the discharges running in the reach are the basic parameters to collect and analyse.

The adequate values of the river discharges to be considered in the evaluation of the consequences of technical options are the minimum discharge, eventually zero; a set of three discharges between minimum and bankfull discharge; the bankfull discharge and a few flood discharges (for instance the floods with return periods of T = 5, 10, 20, 50 and 100 years).

The analysis of river hydraulics, sediment transport and river channel changes may be done through the application of mathematical models or, in the simple cases, using simple hydraulic equations or other empirically derived.

LNEC was involved in the analysis of the consequences of successful urban river rehabilitation in river Fervença, in Bragança, Portugal, Figure 1.

Before (view from right bank)

After (view from centre of river)

Figure 1: A rehabilitated urban river (Fervença, Bragança, Portugal)

7. Monitoring of rehabilitated urban river

The effectiveness of a project is determined by comparisons between pre- and post-development conditions, and applying evaluation criteria through indicators of success. The monitoring cost involved in this process is money well spent specially if information is disseminated and used to create public awareness to the need of river rehabilitation projects. Demonstration of cost-effective environmental benefits is particularly important to persuade the public and their representatives to support river rehabilitation interventions.

From the technical point of view, the lessons learned during the monitoring process can be used in revising the intervention and the operation of controllable systems.

In URBEM project it was proposed a set of parameters for monitoring guidance. The hydromorphological controlling factors or parameters are presented in Table 5.1.

Other controlling factors are the physico-chemical, the biological, the social and the economical. The first group include the thermal conditions (T), oxygenation conditions (O), salinity (S_a), acidification status (pH), nutrient conditions (N), turbidity (T_u) and pollution by other substances (P_{ss}) all with a monitoring frequency of 3 months, more pollution by priority substances (P_{ps}) with 1 month for monitoring frequency.

The biological controlling factors are the compositions and abundance of aquatic flora (CA_{af}) and benthic invertebrate fauna (CA_{bif}) more composition, abundance and age structure of fish fauna (CA_{ff}) and also riparian vegetation (RV) all factors with 3 years as monitoring frequency.

The social factors are the flooded area (F_a) and the flood risk ($H_f V_f$), both having 6 years monitoring frequency.

Finally the economical factors are the flood damage cost (FC) and the annualized maintenance cost (MC) respectively with 6 and 3 years monitoring frequency. The maintenance of the interventions should be done based in the results of the monitoring.

Table 5.1 Hydromorphological controlling factors in urban river rehabilitation techniques and monitoring frequency

Parameter name	**Descriptor**	**Monitoring frequency**
River discharge	Q	Continuous
River slope	S	6 years
Subterranean discharge	Q_{sub}	3 months
Head loss	ΔH	6 years
River depth	H	Continuous
River width	B	6 years
Median grain size of aluvionar bed	D_{50}	6 years
Median grain size of aluvionar bed	D_{b50}	6 years
Cross sections	Z(x,y)	6 years
Sediment transport capacity of river	Q_s	6 years

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