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Comparison of hydromorphological assessment methods: Application to the Boise River, USA

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SUMMARY

Recent national and international legislation (e.g., the European Water Framework Directive) identified the need to quantify the ecological condition of river systems as a critical component for an integrated river management approach. An important defining driver of ecological condition is stream hydromorphology. Several methodologies have been proposed from simple table-based approaches to complex hydraulics-based models. In this paper, three different methods for river hydromorphological assessment are applied to the Boise River, United States of America (USA): (1) the German LAWA overview method (Bund/Laender Arbeitsgemeinschaft Wasser/German Working Group on water issues of the Federal States and the Federal Government represented by the Federal Environment Ministry), (2) a special approach for a hydromorphological assessment of urban rivers and (3) a hydraulic-based method. The hydraulic-based method assessed stream conditions from a statistical analysis of flow properties predicted with hydrodynamic modeling. The investigation focuses on comparing the three methods and defining the transferability of the methods among different contexts, Europe and West United States. It also provides comparison of the hydromorphological conditions of an urban and a rural reaches of the Boise River.

1. Introduction

Depending on stream boundary conditions, hydromorphic processes of naturally undisturbed rivers determine the structural diversity and the framework upon which a wide range of biophysical processes interact (Brierley and Fryirs, 2000). Characteristic patterns and sequences, like step-pool or pool-riffle systems, are simple examples and exist in both longitudinal and transversal directions within river beds. Hydromorphological conditions near those that would naturally occur are considered basic requirements for good ecological conditions of rivers and provide a variety of habitats necessary for river ecosystems (Patt et al., 2009).

Due to different reasons, e.g., urban development, water diversion, dams and reservoirs, many river reaches are eminently degraded (Patt et al., 2009). Problems such as straightening, culverting, pollution, armoring (i.e., coarsening of the streambed surface), of river beds or impoundment often result in waters with poor aesthetics, without a recreational value, high maintenance requirements, poor water quality and limited ecologic diversity (DWA, 2009).[1]

Protecting, improving, enhancing or restoring hydromorphological conditions, according to the river type, is a main purpose of river management and restoration (Newson and Newson, 2000). A targeted approach requires adapted management and assessment methods (Bernotat et al., 2002). Assessment methods should define the deficits and potential of the hydromorphological conditions of an investigated river reach as well as show the need for action (Archer and Newson, 2002; Escobar-Arias and Pasternack, 2010). The results could also contribute for a better understanding of morphological and hydraulic correlations and the river ecosystem. Hence, this knowledge is important for habitat modeling or impact assessment of different measures and hydraulic constructions.

Numerous methods for stream ecological assessment and hence different categorization systems have been developed worldwide (Newson and Newson, 2000; Tharme, 2003; Bratrich, 2004; Gostner, 2012). The oldest approaches are biological assessment methods (see, Karr and Chu, 2000; EPA, 2012). Based on the conceptual approach, Bratrich (2004) distinguishes between holistic, representative and multiple practices. Tharme (2003) describes four distinct categories, hydrological and hydraulic rating, habitat simulation and holistic methodologies. Gostner (2012) outlines multivariate and multimetric approaches. Regarding hydromorphological assessment different approaches are in use, such as

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LAWA overview and on site survey (LAWA, 2000, 2002) in Germany, the Modular Stepwise Procedure in Switzerland (Buwal, 1998), Urban River Survey in Great Britain (Smurf, 2006), Système d'Evaluation de la Qualité du Milieu Physique (SEQ-MP) in France (Eau-Rhin-Meuse, 2000), Rapid Stream Assessment Technique (RSAT) (Stormwater Center O.J., 1996) and Stream Visual Assessment Protocol (National Reources Conservation Services, 1998) in the USA or Riparian Health Assessment – Stream and Small Rivers (Saskatchewan PCAP Greencover Committee, 2008) in Canada. Just a few of these assessment approaches are developed for urban waters and they may include important sociocultural issues, which may depend on hydromorphological issues such as accessibility or visibility of the river.

In Europe, the Water Framework Directive (WFD) is the fundamental basis for any water policy related action. The WFD describes quality elements for the classification of the ecological status of rivers. These include among others hydromorphological features such as hydrological regime, river continuity and morphological conditions (EU, 2000).[2]

Purpose of this paper is to compare the application of three different hydromorphological assessment methods for quantifying river conditions in urban and rural setting. The three assessment methods vary by spatial resolution, number of parameters describing the river conditions and the evaluation algorithm. However, their main difference is the distinct input data. These methods are the LAWA overview method (LAWA, 2002), a special approach for urban rivers developed at the Karlsruhe Institute of Technology (KIT), (Koenig, 2011; Engels, 2009; Miethaner et al., 2008) and a statistical analysis based on hydraulic variables predicted with hydrodynamic modeling (Tomsic et al., 2007). These methods are applied to an urban and a rural reach of the Boise River (Idaho, USA) flowing within (urban reach) and just downstream (rural reach) of the City of Boise, respectively. The first two methods are developed for European rivers, which have a relatively long history of anthropogenic alterations. Consequently, this analysis may provide information on the transferability of these methods to other contests. The hydromorphological assessment with the hydraulic-based method includes a statistical analysis of different hydraulic variables and the Hydromorphological Index (HMID) (Gostner, 2012). Main purpose of the study is to investigate the applicability of such an analysis and to recognize most informative parameters in order to gain information of the hydromorphological condition. Furthermore, this investigation presents a hydromorphological assessment and comparison between urban and rural reaches of the Boise River.

2. Study area

2.1. Basin description

The Lower Boise River (Fig. 1) is approximately 100 km long and it extends through urban areas and agricultural land from Lucky Peak Dam to the confluence with the Snake River (MacCoy and Blew, 2005). It provides irrigation water to about 1300 km^2 of agricultural land. The natural runoff of the Boise River consists of low flows from late July through February, increasing flows during March and high flows from snowmelt runoff in April, May and June. Occasional high flows of short duration occur during winter due to rainstorms.

Three large dams (Anderson Ranch, Arrowrock, and Lucky Peak completed in 1950, 1915 and 1954, respectively) in the upper basin significantly alter the flow and sediment regime of the lower river. The dams are primarily managed for irrigation, recreation, and flood control. The Boise Diversion Dam (built in 1906 and completed in 1908) diverts water into the New York Canal that can divert 71 m^3/s for the irrigation use. The total water diversions for the irrigation are about 79 m^3/s between Lucky Peak Dam and Glenwood Bridge in the City of Boise (Egger et al., 2007). The dams also reduce peak flows that historically scoured channels and built gravel bars in the river (MacCoy and Blew, 2005). The regulated bankfull discharge is 184 m^3/s at the Glenwood Bridge gage station, which is located within the City of Boise. The flow is rarely exceeded at the Glenwood Bridge gage because larger discharges may flood urban areas. As a result of the reduced flows in the Boise River, streambed sediment mobility is limited, which caused armoring of the streambed. Cottonwood trees and hardwood species colonize stream banks and stabilize former fluvial surfaces, which resulted in narrowing the river channel.

The historical Boise River floodplain was wide braided morphology, and a high potential for channel movement. Historic braided and meander reaches are now primarily a single-thread channel with current bankfull width estimated to be less than half of the historical bankfull width in the Lower Boise River (MacCoy and Blew, 2005). The topography of the floodplain has been altered by intermittent levees built by local landowners, Ada and Canyon Counties and local flood control districts (USACOE, 1995).[3] Many of the historic sloughs and meanders have been filled in or converted into irrigation or drainage ditches (MacCoy and Blew, 2005). Riprap has been added along the Boise River, especially in urban areas, which further canalized the river (USACOE, 1995). Gravel pits filled with water are present along the river and are heritage of gravel mining.

2.2. Study reaches

The urban reach extends from Glenwood Bridge to the head of Eagle Island and is 2.6 km long (Fig. 1). This river section is narrowed, and straightened. Anthropogenic activities highly impacted this reach. Urban development encroachment, stabilized riprap, and a diversion dam may have limited longitudinal and lateral ecological connectivity, e.g., aquatic species migration during low flows.

Conversely, the rural reach is a 2.4 km long river section located at the downstream end of Eagle Island and the urban reach. It is a sinuous and braided reach with side bars and limited urban development and confinement. Farm lands are further away from the river and the floodplain area (Fig. 1). It has natural banks without riprap protection and typical riverbed and bank structures, like for example sand banks. Dense vegetation provides different habitats in the surrounding land and on the banks.

2.3. River classification

According to the Rosgen classification scheme (Rosgen, 1994) both reaches are type C. Type C streams have low gradient (<2%), meandering with a riffle/pool morphology, high width/depth ratio > 12, a sinuosity > 1.2 and a broad flood plain. However at low flows (fall and winter), the rural reach is often braided, tending to type D channel with a width/depth ratio > 40 (Idaho Department of Environmental Quality, 2001; Rosgen, 1994). Table 1 shows the hydrological and morphological characteristics of the study area.

3. Methods

3.1. LAWA (2002) method: Overview survey

The LAWA, a German Working Group on water issues of the Federal States and the Federal Government represented by the

[2] European Union.

[3] United States Army Corps of Engineers.