Integrated eco-hydraulics options for the recovery of life and safety in aquatic environments

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ABSTRACT: Traditional, expanded and integrated eco-hydraulics methods for the recovery of life and safety in aquatic environments are outlined. The concepts of riparian ecotones with biological restoration derived from the uncertainties in streamflow hydrographs, the REBRUSH strategy (Mendiondo 2000), are depicted with a real example. Life and safety discussions are centered on naturalization principles, conceptual strategy, assessment and eco-hydraulics techniques.

1 INTRODUCTION

Nowadays, fundamental principles of river channel restoration in a wide range of settings, principally from European and North America's case studies, summarize the current state of art on this subject. Conversely, a guide to manage river restoration in the Neotropics is still a challenge. Since the arrival of the Europeans on 1500s until today, South America is being seriously affected on river environments, especially in its three biggest basins : the Amazon, the La Plata and Orinoco international rivers and tributaries. Only these three systems are responsible of 47 % of all the Earth's freshwater flows, also carrying 13 % of the total of suspended solids delivered by all rivers to the oceans. However, South America has problems related to the rehabilitation of its riparian areas, either in uplands or in lowlands, which are degraded by deforestation, erosion from intensive agriculture, development of hydropower plants, urban concentration and navigation channels.

Likewise, the South America riparian habitats appear to have two constraints. First, there is a great diversity of natural responses which are frequently perceived in time series records and in rating curves of gauging stations, and whose uncertainties limit to a non straigthforward use of data. Second, the hydrological and hydraulic surveys with standardized data collection (i.e. from W.M.O. standards) historically have been applied to these environments, often paying little attention to the interrelation between a complex range of factors. For instance, both riparian vegetation and stream geomorphology rarely have been associated to hydrograph characteristics of river database. For that reason, the function of riparian behavior of uncertain hydrologic responses is one of the most challenging subjects of South American watercourses.

At the same time, any restoration guidelines, and especially those from successfully-projected criteria of the North Hemisphere, must thereby consider the above daunting constraints whether restoration of South America's watercourses is undertaken. Meanwhile, the guidelines of restoration of South America rivers and streams may deal with not only the well-behaved measures or the 'into-the-box-recipes' which usually put into consideration : (i) what are the river and stream channels of natural stable form ? , and (ii) how do these morphological characteristics vary by different rivers and river reaches ?, but also alternative conceptions of restoration emerged from regional South America's research. This later undoubtedly had better facilitate alternative 'out-of-the-box' interdisciplinary approaches, accordingly to the South America environmental issues, adding some new questions as: (iii) which insights on river environment restoration monitored with simple, standardized, transferable, non stationary and uncertainty-addressed data, can be derived?, and (iv) in how manner watercourses restoration can be addressed, regarding in maintaining ecological river behavior, i.e. resisting flood extreme events and minimizing economic

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costs by naturally-designed protection devices, as a way of a more resilient management option ?. The above answers deal with guiding principles rather than mitigating special problems, addressing the recognition of social and political demands, the implicit uncertainty in the restoration approach and a plea for more integrated approaches. The two later topics were addressed in Petts et al (1995), Brooks & Shields (1996) , Darby (1999) Mendiondo (2000), introducing new insights towards restoration principles. So, the objectives of this paper are: (i) the outlining of feasible guides and integrated strategies on environmental naturalization management and (ii) the proposal of alternative eco-hydraulics approaches on recovery of life and safety in aquatic environments.

2 METHODOLOGY

As more and more rivers were naturalized, eco-hydraulics became necessary to ensure the scientific basis of eco-hydraulic dimensioning. In summary, river engineering shifts from pure user-technology towards biological structures and to hydraulic research, attempting (Fig. 1): (i) the traditional methods, based on morpho-hydraulics and ecology disciplines, (ii) the expansion of new approaches, supported by ecological goals, and (iii), alternative eco-hydraulics integrated strategies, coping with restoration uncertainties and stream techniques. In Figure 1, the solid frames are the conventional disciplinary backgrounds and the dotted frames are baseline requirements. The steps labeled as I, II, III and IV are from the REBRUSH strategy of Table 1 (Mendiondo, 2000)

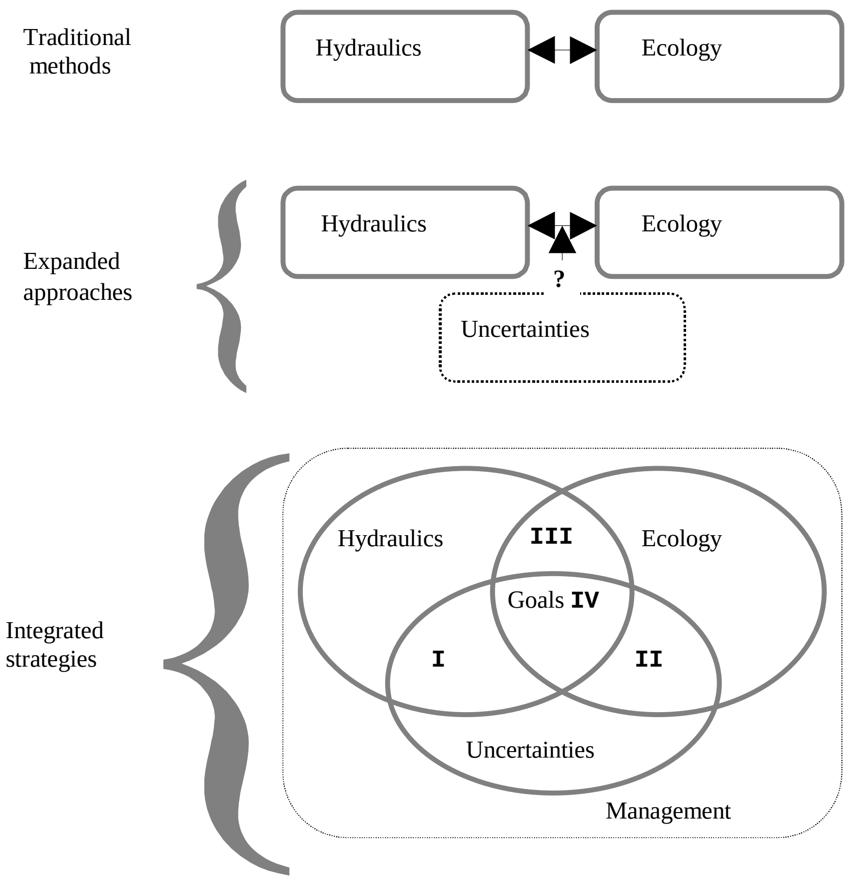

Figure 1. Eco-hydraulics options in perspective (Mendiondo, 2000). See explanation in the text.

All methods in Figure 1 are valid as well as complementary. Hereafter, brief commentaries are discussed and the reader could find extensive explanation about the topic in Mendiondo (2000).

2.1 *Traditional methods*

River restoration often requires that a straightened, widened, or constricted channel be reconstructed to more natural dimensions. Approaches for selecting average channel dimensions may be categorized as intuitive, empirical, or analytical. First, the intuitive approach is to use dimensions from stable reaches elsewhere in the catchment or from similar undisturbed reaches in the region. Second, empirical approaches include hydraulic geometry formulas. Hydraulic geometry relationships are most compatible with single-channel sand and gravel streams with using hydraulic geometry formulas to size restored channels are: (i) obtaining equations with coefficients based on streams with similar properties to the one being designed and, (ii) describing site hydrology with a single discharge and bed sediment with a single size. Notwithstanding, unstable channels, with aggrading or degrading profiles, will depart strongly from published relationships, i.e. no reliable restoration guides are available for rivers draining Oxisols basins in South America. Finally, analytical approaches for describing channels are based on the idea that a channel system may be described by a finite number of variables. Hey (1988) argues that 15 variables are required to fully specify the geometry of a natural river channel, i.e. the average velocity V, the mean depth d, the channel slope S, width W, maximum flow depth d_m, bedform wavelength λ, bedform amplitude Δ, sinuosity p, meander arc length z, discharge Q, sediment discharge Q_s, characteristic size of bed, right and left bank sediment, D, D_r and D_l, respectively, and valley slope S_v . Six of these 15 variables are independent and determined by the environment : Q, Q_s , D, D_r, D_l, and S_v , leaving 9 unknown variables : V , d , S , W , d_m, Δ, λ, p and z . To compute these unknown variables designers have only three governing equations available: continuity, flow resistance, and sediment transport. Since this leaves more unknowns than there are equations, the system is indeterminate. This indeterminacy of the stable channel design problem has been approached with: (i) the use of empirical formulas, (ii) assuming values for one or more unknowns, (iii) using structural controls to hold some variables constant, or (iv) ignoring some unknown variables by conceptually simplifying the channel system. The above excessively demands rich-data, expensive surveys, not often rich-information-ecological layouts, for practical naturalization purposes in regions very different from those in where the analytical formulae were initially derived. So, it introduces to how stable eco-channel formulae restoration relate to naturalization demands.

2.2 *Expanded approaches*

For expanding restoration management goals to feasibility, ecological theory and its definitions must be revisited (Vannote et al, 1980 ; Boetzalaer et al, 1991): rivers, ecotones, disturbance, resilience, re-naturalization concepts and their uncertainties. Rivers are viewed as systems in which water, nutrients, sediments and organisms pass through a certain section at a certain speed. Therefore, these pulse systems present biological variability during the flood-phase (potamophase) and the dry-phase (limnophase). Specifically, South America´s rivers have two characteristics. First, large rivers are dominated by transverse interactions between the main channel and the adjacent floodplain. Secondly, there is a strong dependence on the riparian and floodplain zones (Neiff, 1996).In this way, a characteristic of rivers is that maximum ecological diversity and productivity are associated with river´s margins as an ecotone system. This ecotone is a zone of transition between two ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of interaction between adjacent ecological systems. In management area, the role of the ecotone concept is to focus attention on the terrestrial system-lotic system boundary, so that to promote actions like flow and channel management to sustain ecotone processes, and controls on channel biota and on human activities for management at smaller scales.

In other hand, disturbance is any relatively discrete event, in time and in space, that disrupts ecosystem community or population structure and changes resources, substrate availability or physical environment, e.g. a flood. Then, the resiliency could be the ability of a disturbed community to recover to a state before the disturbance, both in time and/or in space. Conversely, resistance, as a related form of system stability, is the ability of a community to initially resist a disturbance. In other hand, recovery is the process of species returning to normal population levels after disturbance, in a normally way. Likewise, enhancement means to improve the current state of the ecosystem without reference to its initial state. However, restoration is a process that involves, quantitatively, management decisions and manipulation to enhance the rate of recovery. In this context, river restoration is a recovery enhancement and considers a technique to enable disturbed river ecosystems to stabilize at a much higher rate than through natural and biological recovery processes of habitat development and colonization. Particularly, the term rehabilitation is a mixture of enhancement and restoration.

Furthermore, if a natural condition could be defined qualitatively, i.e. a pristine image, the measures that help a system to back to nature in a naturalistic way are usually referred as renaturalization. How is it recognized the difference between natural and naturalistic ?. The former relates to a virgin-non-disturbed habitat with a proper ecosystem, either in flora or fauna ; contrary, the later refers to measures to restore degraded riparian corridors, under uncertainty requirements.

The uncertainty of a riparian data, i.e. discharge measurement, could be defined as the range in which the true value is expected to lie, expressed in a certain percentage of confidence level (Herschy 1985). Although the error in a result is therefore, by definition, unknown the uncertainty may be estimated if the distribution of the measured values about the true mean is known. It should be stressed that the statistical analysis of river flow data is only applicable if the field data have obtained acceptable principles and practices, as to the relevant national or international standards. On the contrary, indeterminacy is the situation when neither special parameter information is available nor a possible range of them when trying to apply book recipes or empirical formulae.

The La Plata and the Amazon systems are examples where South American rivers have inherent uncertainty in their hydrological database (Clarke et al. 2000). Parts of these errors are source of imprecise, ill-posed and insufficient knowledge of the dynamics of riparian area interactions, their succession behavior before and after floods. Also, some errors are due to the lack of relationships between ecology's and hydraulics' ancillary equations of riparian habitats, to make the subject suitable of being approachable as a dynamical system (Vannotte et al. 1980; Knight 1989; Brooks & Shields 1996). Then, either attempts or methodologies to restore and rehabilitate degraded South America streams and rivers will must cope with these uncertainties, and their relationships with hydraulics, geo-morphological and biological factors.

2.3 *Alternative integrated strategies*

Herein we consider two types of uncertainties, in streamflow hydrograph, that could be quantitatively estimated : (i) the uncertainty in a particular measurement of flow of a river channel, dependent of the unsteady river stage conditions, roughness of the bed and bends, energy slope, conveyance variation, and (ii) the uncertainty related to the interval confidence of the rating curve of the station being analyzed, i.e. the curve of observed measurements of flow in a cross section of the river channel. The relation between these two types of uncertainties is commented as follows.

Uncertainties affecting river flow are not new and were well documented by Chow (1959), as surface roughness, vegetation, channel irregularity, channel alignment, silting and scouring, obstruction, size and shape of the channel, stage and discharge, seasonal changes and suspended material and bed load. However, the use of flow uncertainties are only reported to hydraulics studies in flood levee capacity (Lee and Mays 1986; Fread 1991) but not to river restoration. One alternative way to link the gap between river restoration demands with uncertainty-addressed methods is the concept of R.E.B.R.U.S.H. : Riparian Ecotones with Biological Restoration derived from Uncertainties of Streamflow Hydrographs (Mendiondo 2000). The REBRUSH hypotheses relate four basic steps (Tab. 1). The REBRUSH has been developed from interdisciplinary strategies on natural systems, with emphasis in the following concepts : the flow uncertainties in natural channels (Chow 1959), the river continuum concept (Vannotte et al 1980), resiliency of natural systems with regard of variance and uncertainty, hydraulic uncertainties assessment (Lee and Mays 1984; Herschy 1985; Fread 1991), the statistical inference (likelihood) to analyze data sets (Efron and Tibshirani, 1993), the uncertain praxis in river restoration (Brooks and Shields 1996), the geo-morphological behavior, equifinality and uncertainties water-landscapes (Beven 1996), relation between floods' protection devices and restoration practices (Tönsmann 1996), integrating process hypotheses (Mendiondo & Tucci 1997) of degraded environments, the alternative out-of-the-box guide of Geobiohydrology (Kobiyama et al 1998), the inherent uncertainties in models and in natural environments (Clarke et al. 2000), with heterogeneous rating curves.

Table 1. Steps of REBRUSH eco-hydraulics approach for river restoration (Mendiondo 2000)

Step	Actions
I : Uncertainty model	Variance decomposition model due to roughness, conveyance and energy slope factors from the rating curves and/or observed time series
II : Ecotone likelihood	Mimicking of the rating curves by hydrodynamical randomizations
III : Resilient habitat	Balance of the variance decomposition model (Step I) and the probability interval of ecotone likelihood (Step II), obtaining a 'reference discharge'.
IV : Restoration goals	Assessment of the restored discharge from the reference discharge (Step III) and from original discharge, managing naturalization goals.

Accordingly to traditional methods in eco-hydraulics, and given a rating curve defined by observed h(i)-Q(i) pairs of a gauging cross section of a river, where h(i) is stage and Q(i) is discharge, for the ith stage, says h(i), there is a variation coefficient of observed discharge $CV_Q(i)$, as a measure of uncertainty which depends on the variation coefficients of roughness C, energy slope S_f, geometrical conveyance K, and their respective covariances cov (C, S_f), cov(C, K) and cov(K, S_f). The standard deviation of discharges $s_Q(i)$ may be inferred by regression methods (and their estimated parameters α, β, ...,) or by the P probability of Q(i) from Monte Carlo or bootstrap simulations. The reference discharge $Q_{ref}(i)$ is obtained from the ratio between $s_Q(i)$ and $CV_Q(i)$, independently from each observed h(i), Q(i) pair in the rating curve. Finally, the restored discharge for the h(i) stage, $Q_{Rebrush}$ (i) is obtained from a weighed balance with a managing factor ϕ accordingly to renaturalization goals of the stream reach. These equations are also dependent on the Froude number , F_r , and the hydraulic radius, R (Mendiondo, 2000). For instance, given a explicit knowledge of the ancillary functions, with an appropriate restoration factor, it is worth noting that whichever $Q_{Rebrush}(i)$ discharge is not only dependent of roughness, slope and conveyance, but also of their variances. The later has an explicit differentiation of common hydraulics practice (see Chow 1959; Brooks and Shields 1996). In brief, the REBRUSH equations, through admitting variance decomposition as part of the system modeled, can be viewed as simple devices to manage the spatial allocation of elements introducing instream habitat´s diversity: e.g. techniques that re-create new and different bed form conditions along the river corridor, or different pools' and riffles' sequences enhanced by providing roughness elements along stream, with obstacles, with heterogeneous cross sections, new retention areas, etc., ever looking a pre-defined ideal situation. Thus, practical recommendations, physical and practical designs with natural channels, theory and applications and ecological insigths on riparian areas are being updated.

3 APPLICATION: ECO-HYDRAULICS OPTIONS IN REPRESENTATIVE BASINS

Integrated strategies on river restoration projects in South America, encompassing disciplines as hydrology, hydraulics, geomorphology and biology, linking the gap between trial-and-error approaches and the appraisal of post-designs, is still needed for real situations (Kobiyama et al 1998). For instance, the 50 % of GNP from all MERCOSUR South America countries, like Brazil, Argentina, Paraguay and Uruguay, is produced under highly-constrained environmental issues (Tucci

& Clarke 1998). These countries share the transboundary basin of La Plata System of a 3.1 million km2 area, inhabited by more than 100 million inhabitants, and with strong partnerships with the European Union. La Plata river discharges, which are 85 % of all European river discharges, have a hydropower energy capacity around 92000 MW, of which 53 % has been utilised or works are in progress to exploit it, relating to a increasing demand till year 2025. In the same way, the agricultural practices on MERCOSUR basins draining to the main hydropower stations, and despite continue pressure from agricultural education and resource protection agencies, still put a premium on planting and harvesting on all properties as they extend to the water's edge. These traditional practices overlap effects of basin management activities, in space and time, resulting in cumulative environmental effects from uplands to lowlands.

In uplands, increased erosion creates head-cut streams that widen and deepen with each passing year, forming small first-order watercourses with vertical banks of more than one meter high, of inexpressive riparian protection, under significant bank instability, and of a completely destroyed instream habitat (Mendiondo et al 1998). In addition, El Niño Southern Oscillation-ENSO global effects had even impacted on MERCOSUR developing economies, with high costs, e.g. U$S 78 million in União da Vitória, in 1983 (Tucci & Clarke, 1998), and U$S 430 million in Argentina's provinces because of the 1998 Paraná floods. In lowlands, and unfortunately for well intended flood control and drainage purposes, many of La Plata rivers have been straightened, leveed from their floodplain, deepened, over-widened, steepened, diverted, and altered in a manner to decrease their natural function and stability. In short, millions of dollars have been spent on hard engineering methods in South America riversides whose environmental function was often neglected. Since these sorts of impacts have received little attention through the twentieth century, South America impacted small streams and big rivers are perhaps among the most frequently disturbed and least often rehabilitated areas of the World, waiting for integrated protection strategies.

Real basins without restoration measures but with renaturalization goals were proposed in Mendiondo (2000). The site study is covered by the South Brazilian Basaltic Fan, representative of 300,000 km^2, between 49^o-56^o W and 24^o - 30^o S in Southern Brazil, Northeast Argentina and a small part of Paraguay. The soils are subtropical Oxisols, with precipitation ranging from 1400 to 1700 mm a year. Several studies have depicted environmental issues in this area (Mendiondo & Tucci 1997 ; Mendiondo et al. 1998 ; Mendiondo 2000). In the past, this humid subtropical biome was characterized by varied forest, dense drainage and rich clay soils. Throughout the last 25 years, the area has been mainly transformed by Soya bean production. Today, less than 10 % of natural vegetation remains as riparian forest in the incised valleys of headwaters. In average, this area has between 1.8 to 2.7 hectares of natural forest per capita. Forest clearance, poor cultivation practices and use of agrochemicals caused problems of soil erosion and water quality in streams. The basins are on Uruguay river headwaters and are representative of a expressive portion of Paraná river tributaries, draining to important hydropower stations. For instance, between 1965 and 1985 many dams were built in an area of approximately 300,000 km^2 , for energy production, on the Paraná tributaries which yields more than 50 % of all Brazil´s energy production. Small portions of natural rivers corridors remain in their natural state but with increasing degradation due to the high pressure from agriculture. In this case, estimated erosion yields of 1 ton/ha/yr, with an average sediment concentration of 100 mg/l is only valid for the big catchments. For ENSO effects, the later could raise between two and three orders of magnitude ! (Mendiondo et al 1998)

For restoration correspondence, there were selected 14 catchments, ranging from 388 to 10033 km2 area. Since 1941 to 1998, more than 2170 discharge measurements, with h-Q pairs, were collected by Brazilian River Agencies, spreading a database with more 17360 variables (including V, A, R, F_r, W and d). At all, near 5.5 km of river corridors need restoration techniques. The streams have channel slopes ranging from 0.5 % to 2 %, and with adjacent perpendicular slopes ranging from 2.5 to 15 % (Mendiondo et al 1998), and follow a B5 Rosgen (1996) classification,. The bed material size D_{50} is highly variable, depending whether pools or riffles are in the neighborhood of the sampling site, encompassing ranges from 0.2 to 1.2 mm. In uplands, the streams are moderately entrenched, incised in cohesive materials, with lower width/depth ratio. When undisturbed, these upland stream corridors are stable because of dense riparian vegetation. If agriculture is introduced intensively, these corridors experiment a by pass in their natural cycle so that to collapse their banks. At a sub-regional spatial scale, from 1 to 560 km^2, nested responses depict channel stability criteria from erosion in headwaters to deposition in seventh order basins. One of these basins, of a 20 km^2 area also with rating curve surveys (Fig. 2) is representative of those former, is proposed as a test case of REBRUSH's eco-hydraulics strategy. This upland stream is formed by washload rather than bedload watercourses. Furthermore, river sinuosity varies from 1 to 1.3, depending to site, location and stream order. Especially in headwaters´ basins, measured velocities of rating curves of Figure 2 present an hysteresis behavior with depth, accordingly to flood before or after ENSO events and bedforms. During real floods, survey measurements of average flow velocity versus river stages depicted overall values from 0.2 m/s during baseflows to 0,9 m/s near bankfull discharge. However, there are "sills" of maximum average velocities inside the mean channel, i.e. 0.6 - 0.7 m/s before 1992 ENSO floods, varying to 0.5-0.6 m/s after the 1992 ENSO. On the contrary, after the 1997 ENSO events, the maximum average velocities ranged between 0.7 to 0.9 m/s. The Manning´s roughness is 0.052 ± 0.017, but with a non linear function of the depth. Streams adjustments are non stable channels, with increasing failure by erosion and cumulative effects ranging from 300 to 900 m (Mendiondo 2000).

4 DISCUSSION

In South America's water resources issues, it is a common circumstance that the designer must decide, accordingly to naturalization purposes and budgetary conditions, of how manner he/she attempts in relapsing into indeterminacy, and/or in only defining ecological goals, and/or in coping with inherent restoration uncertainties. For example, to carry a short-term research with application requirements based upon a 'present state condition', it is worth putting more effort in "guiding principles, goals and strategies for river renaturalization" rather than "the computation of specific numerical methods of river to be naturalized". Anyway, whichever life's and safety's recover plan on South America riparian areas must provide flexible conditions so that the above two actions would be complemented with an heuristic timetable able to encompass all the questions posed in attempts (i), (ii), (iii) and (iv) written in the Introduction section of this paper, and providing multidisciplinary further gains addressed through : (v) driving river naturalization principles and goals to implement under very different environments, legal constraints and culture; (vi) selecting conceptual strategy and simple assessment for knowledge transference, and (vii) recommending techniques to prevent, mitigate and/or restore the life and safety of these aquatic environment. In the following, some discussions are outlined based on German and Brazilian exchange.

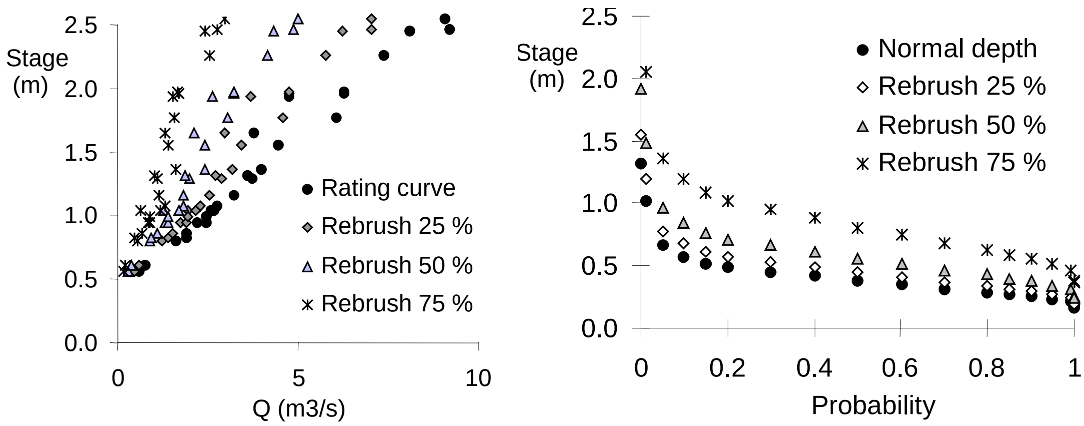

Figure 2. Left : Eco-hydraulics restoration options. Right : long-term scenarios (Mendiondo, 2000).

4.1 *Naturalization principles and goals*

This first baseline context is needed as a multipurpose management revision for the catchment, the riverine area and the river system. For example, the German experience (Tönsmann, 1996) derived from 'Leitbild' Concept, presents the steps of: i) establishment of model image, ii) preliminary assessment, iii) survey and evaluation, iv) pre-design with possible options, v) final design and acquisition of permits, vi) planning of project execution, and vii) construction and supervision. For evaluating these steps, and regarding South America environment, a restoration research plan could work two additional short-time phases: vii) opinions of, and brainstorming with, naturalization experts, and viii) the legal constraints, with focus in restoration goals as conservation of nature, water resources management, improved quality of landscape and model image. For instance, comparisons of some specific articles of the German Bundesforschungsansage für Naturschutz und Landschaftsökologie (Communication of the Federal Council of Research for the Conservation of the Nature and Landscape Ecology) of year 1989 with the Brazilian National Law 9433/97 of Management of Water Resources of year 1997, is really a good example of in how manner both law and economics constraint environmental restoration management when using of integrated eco-hydraulics options.

4.2 *Conceptual strategy and assessment*

Second, with a rapid application, the conceptual strategy emphasizes the gathering of insights, the feasible conditions of the restoration project be adequately designed and easy numerical process. In short, a feasible Research Plan takes precedence in assessing: first, simple results those could be properly interpreted, in the same way, by European, North American and South America' s Water Resources Institutions, i.e. the change of rating curves (stage-discharge empirical relations) due to naturalization works, and, second, practical river problems often social-demanding, i.e. mitigation of downstream floods. The friendly-user, standard eco-hydraulics based model, addressing the above topics was developed under the REBRUSH eco-hydraulics strategy (Mendiondo, 2000) as a option of the recovery of life and safety in aquatic environments. This strategy requires only of time series records and river rating curves. Likewise, it is worth mentioning that this strategy depicts what assessments are needed, so that a river reach could feasibility approximate, by restoration actions on the roughness, the energy slope, the geometrical conveyance and their respective relationships, to a pre-degraded stage targeted by a naturalization goal. However, this REBRUSH assessment does not say which type of final channel or design it will have, because the later is a management of a decision making process derived from strong interrelations between engineers, landowners and water resources’ laws whose relationships serve as inputs for finding the restoration goals oriented by REBRUSH . For this limitation, the REBRUSH strategy must be considered as an alternative approach working with, and depending on, multidisciplinary goals. In this way, and having ready the computer program (Mendiondo, 2000), short-actions are available as accounting how much biodiversity the multidisciplinary restoration goals introduce in existing rating curve uncertainty decomposition model (Step I of REBRUSH equations); and simplifying this incorporation of biodiversity through weighed management actions (i.e. REBRUSH’s Step IV) those are simpler to be understood by traditional hydrologists.

4.3 *Eco-hydraulics techniques*

Third, restoration techniques recommendations will be thinkable through an information exchange round of discussions; thus, techniques selected must be components of a system designed to naturalize specific functions and values of the stream corridor, linking restoration assessment life and safety goals. In short, this scope emphasizes: i) instream practices, ii) streambank treatment and iii) channel reconstruction. Life- and safety restoration experience points, i.e. large wood debris, brush and log shelters, boulder clusters, weirs and spills, fish passages, lunker structures, tree cover, bank shaping and planting, branch packing, brush mattresses, joint plantings, live ´stucks´ (crib-walls, stakes, fascines, etc.), revetments (log, boulder, tree, etc), creation of retention and flooding areas, maintenance of hydraulic connections, stream meander restoration, reactivation of furcation channels, activation of old river bows, reactivation of floodplains through dismantling dikes, etc.

Particularly, both conceptual strategy and integrated assessment, through REBRUSH eco-hydraulics approach, accept the introduction of new components that alter, i.e. the wetted perimeter roughness, the bed slope and the hydraulic conveyance of a selected corridor. In other hand, the life and safety goals address the target picture of the river corridor. By combining targets demands with environmental assessments, a recursive decision making process takes place, until the quantitative assessment approximates to qualitative goals. However, not all the techniques are appropriate for all stream corridors. For that, REBRUSH's options will neither design nor depict all the universe of restoration techniques. Conversely, it does help in introducing basic guidelines for life and safety recovery exclusively under the context of eco-hydraulics environmental assessment strategies, only for the corridors in question, and with proper discussion of the limitations, advantages and disadvantages of each case.

5 CONCLUSIONS

Traditional methods are based on the relationship between hydraulics and ecology, relapsing into indeterminacy, i.e. more unknown than governing equations. Moreover, expanded approaches enhance ecological goals, accepting uncertainty constraints but only in a qualitatively manner, i.e. looking for a pristine, non degraded condition before alteration. Alternatively, integrated strategies quantitatively cope with eco-hydraulics uncertainties in a management framework, i.e. assessing geo-bio-hydrological relationships from in situ data, under a decision making process and for life's and safety's recovery purposes. This later example, through one possible approach as REBRUSH strategy, offers some insights to link the gap between short-term hydraulics demands and long-term life and safety recovery options. Thus, multidisciplinary opportunities are recommended.

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