Technical Note 5

HOW CAN A RIVER BE HYDROLOGICALLY RESTORED?

Author: Fernando Magdaleno Mas

CIREF centro ibérico de restauración fluvial

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Fernando Magdaleno, CIREF, CEDEX and Technical University of Madrid, Spain.

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Degradation of river systems is nowadays a worldwide worry. Human uses in and around rivers have altered many of their natural processes and dynamics, but especially the natural occurrence of their flow regimes. On this basis and considering the leading role played by hydrology in the river´s structure and functioning, this document discusses how hydrological restoration should be incorporated to river restoration, and which are the most adequate strategies to design and implement the restored (functional) flows in rivers.

1. Why flow restoration?

Restoration of a river´s flow regime should be the **first step in any attempt to recover its ecological integrity**. Flow pattern determines more than any other physical or environmental feature the structure and spatial-temporal functioning of the river system (Bunn & Arthington, 2002; Poff et al., 2006) (fig.1). Links between the river´s flow regime and its overall status may be assessed by means of the mutual interactions between the hydrological and the ecological components of the system.

2. Is river hydrology adequately considered in restoration?

The scientific and technical acknowledgement of the aforementioned influence of flows on the river´s status has been a reality during the last decades. This has driven to many different attempts to identify those flow events most relevant for the protection of the river´s critical ecological processes. With that goal, hundreds of methods and methodologies for the determination of minimum flows (later to be known as environmental or instream flows) were designed from the 70´s and 80´s up to this date (Tharme, 2003; Acreman & Dunbar, 2004; Magdaleno, 2005, 2009). Moreover, almost none of those procedures have proven effective for the conservation or restoration of the river´s values and functions.

High complexity and variability, inherent to river systems, hinder the selection of universally-valid mechanisms to protect river flows. On this basis, and despite the recent advances in the legal and technical definition of environmental flow requirements in different countries (eg Spain), **hydrological restoration may be considered a not-well developed aspect of river restoration**. This deficiency may hamper the success of

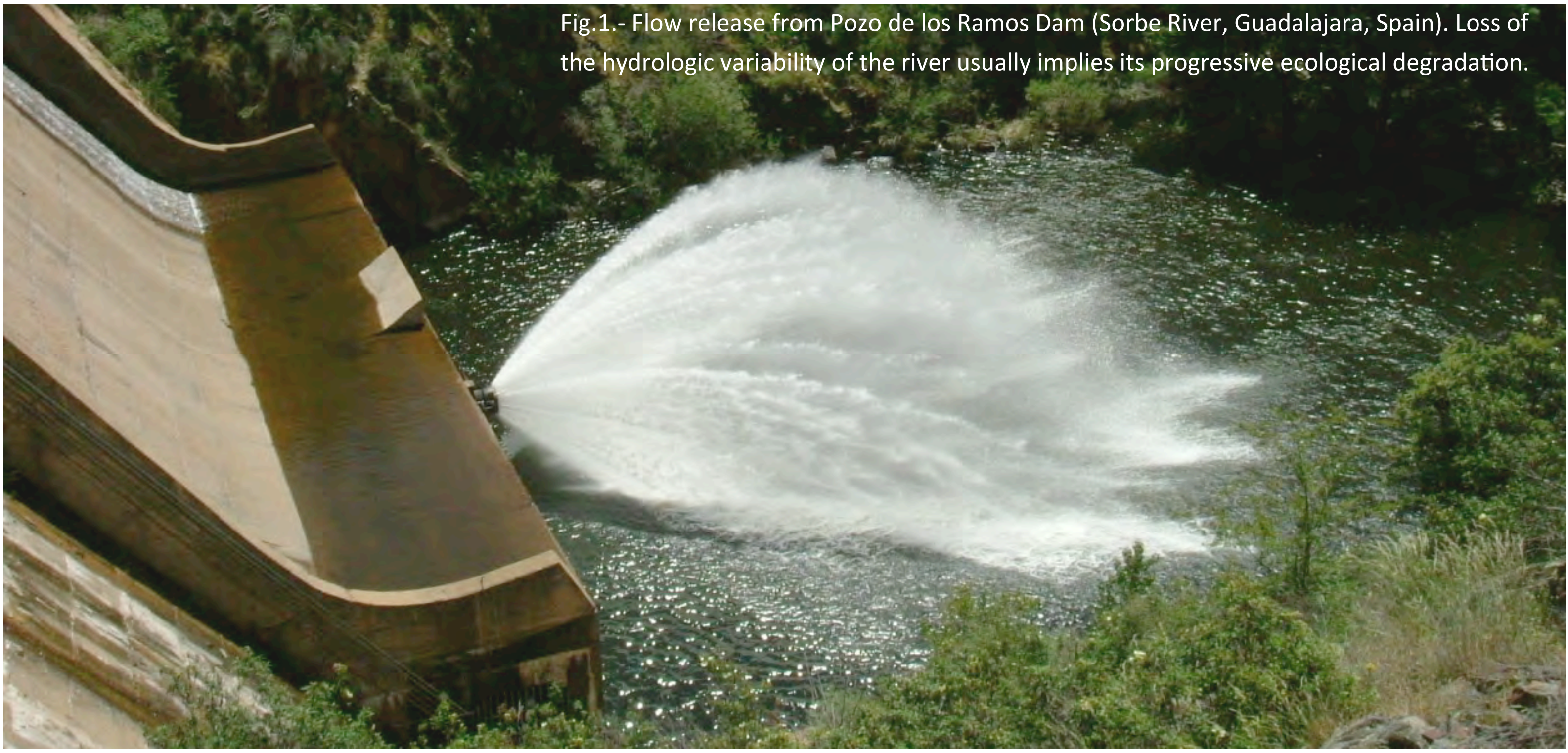

Fig.1.- Flow release from Pozo de los Ramos Dam (Sorbe River, Guadalajara, Spain). Loss of the hydrologic variability of the river usually implies its progressive ecological degradation.

Fig.2.- Linking the flood regime with the ecomorphological pattern of the river may be essential to guarantee the adequate status of the river system. This especially for channels whose overall functioning is highly dependent on those types of hydrological events (Yesa River, Huesca, Spain).

many restoration initiatives worldwide, and should thus be adequately discussed, promoted and implemented.

3. How can we understand flow patterns?

A river´s flow regime may be understood as the aggregation of a wide set of hydrological events (summer and winter low flows, winter high flows, ordinary and extraordinary floods and droughts, etc.). The occurrence of all those events is determined by the physical, environmental and hydro-meteorological features of the river´s watershed.

Complexity of flow regimes is common to most basins, but frequently reaches a maximum in dryland areas (such as Mediterranean areas), where inter and intra-annual flow variability is especially high. Due to flow complexity, **first recommendation to be done for the river´s hydrological restoration is to fulfill detailed analyses of its flow dynamics** (natural or altered). This would comprise the identification, at least, of three inter-annual types of flows: those associated to wet, normal and dry years, and two intra-annual types: monthly and daily flows.

From this basic analysis of the flow variability, it would be possible to deepen in the characteristics of the temporal flow dynamics, and to identify the trends which better describe the long-term functioning of the flow regime. In fact, there already exists a number of free software to develop that early analysis in a simple and well-structured manner (eg, IHA – Richter et al., 1996; ELOHA – Poff et al., 2010; IAHRIS – Martínez Santa-María & Fernández-Yuste, 2006; Fernández-Yuste et al., 2012).

4. How designing flow restoration?

Once the inter and intra-annual flow pattern is characterized, hydrological restoration should comprise the identification of those flow components more directly linked to the physical and ecological attributes of the river system (ie, morphology, habitats, species, physico-chemical conditions, etc.). This identification may be hard to do, since many of the interactions and synergies between flow and ecomorphology are still unknown. However, some interactions have already been studied and described, partially if not completely. This is the case of the river´s morphodynamics (fig.2), and some biological groups, such as certain fishes, invertebrates, riparian stands and even riparian birds (Arthington et al., 2006; Magdaleno, 2011).

For instance, in the specific case of fishes and invertebrates, communities are highly dependent on temporarily-varied minimum flows, especially during critical biological cycles (migration, reproduction, spawning, egg incubation and hatching, etc.). Those minimum flows contribute to the existence of favorable ecological and physico-chemical conditions, and are thus very positive for their conservation or improvement. Similarly, temporarily-varied maximum flows would be necessary to avoid colonization of natural habitats by alien species and deterioration of native communities. But also adequate ramping rates would be important to avoid stress to aquatic organisms, along with attraction flows, during biologically critical periods, which enable the species´ normal behavior (in terms of local and regional migrations, physical growth or interaction with other aquatic organisms).

Regarding riparian vegetation, key hydrological events would be those which allow the connection between the channel and its riparian areas, those responsible for the river´s morphology, and those with capacity to disperse seed and propagules and to create conditions for the early growth of seedlings and saplings. Being riparian plants one of the preferred habitats for riparian birds, the referred events would also be essential for bird communities. Riparian birds may also be favored by other flows; eg those protecting native fishes in the case of fish-eating bird species.

Most usually, calculation of habitats´ or species´ flow requirements is done by combining a range of methods and methodologies. Among them, hydrological, habitat simulation and holistic procedures are some of the most common today. Hydrological methods frequently offer a simple way to calculate an initial range of flows, applying some statistical algorithm to the non-altered (registered) temporal flow series. Habitat simulation offers the alternative of modelling convenient ranges of flows by devising how different water levels would allow the existence of the necessary amount and quality of river habitats for target habitats or species. Holistic methodologies incorporate hydrological and habitat modelling to a broader scenario where other ecological, geomorphological or even social-based water demands are also considered. Nonetheless, many of the aforementioned procedures were initially designed to just supply minimum environmental flows in rivers, and do not adequately describe which flows should be re-introduced in the system to actually achieve its hydrological restoration. In other words, **only those procedures which have a robust ecohydrological foundation should be used to restore river´s flows** (Stewardson & Gippel, 2003; Richter, 2010; Poff et al., 2010). With that aim, different works explore regionally the specific water requirements of different flora and fauna species during the aforementioned most critical life stages. In order to translate water needs in terms of water management, it is important to determine the main features of those critical flow events (eg, magnitude, frequency, duration, seasonality and rate of change).

After the identification of the basic features of core flow events for the ecosystem, it would be time for its integration in a "functional" flow regime (fig.3), which could also include recommendations in terms of sediment regime, water quality, etc. **This regime should allow certain uses of the river´s waters, and be feasible for water planners and managers; otherwise, it will be very hard to assure its perdurability**. At the same time, the improvement or restoration of the flow regime should be preferably structured on the basis of an appropriate inter and intra-annual variability, offering


Fig.3.- Maintenance of a "functional" flow regime is crucial to keep the physical heterogeneity of the channel, and to optimize the river biodiversity and the ecosystem services sustained by the river system (Minchones Gorge, Cáceres, Spain).

the necessary flexibility to water managers, in order to face natural or human-based irregularities in water offer and demand. Additionally, the consecution of the social and environmental targets of the restored flow regime must focus on avoiding intense and prolonged water stresses in the river ecosystem. The restored flow pattern must be committed in a significant percentage of time along the year, in order to minimize irreversible damages on the ecosystem and to foster the ecosystem´s resilience when facing changing flow conditions. The ecosystem´s thresholds should never be overcome in terms of overcritical (punctual) or critical (prolonged) water stress.

5. Conclusions

Hydrological restoration can only be reached when re-introducing in the river systems a range of ecologically-based flow events, directly related to its non-altered flow regime and matched to the river´s ecological integrity. Those flows should be adequately released, in terms of space and time, and reach all the necessary sections of the river environment. The detailed assessment of the historical dynamics of the flow pattern and the ecological requirements of the river´s habitats and species would allow, in most cases, the restoration of the flow regime and the maintenance of strategic water uses. Only the improvement or restoration of a functional flow regime can stop or reverse the progressive ecological impoverishment typical of largely regulated or abstracted rivers. Successful river restoration can only be achieved when effectively based on long-lasting hydrological restoration.

6. References

Acreman, M. & Dunbar, M.J. 2004. Defining environmental river flow requirements – a review. Hydrology and Earth System Sciences 8(5): 861-876.

Arthington, A.H., Bunn, S.E., Poff, N.L., Naiman, R.J. 2006. The challenge of providing environmental flow rules to sustain river ecosystems. Ecological Applications 16: 1311–1318.

Bunn, S.E., Arthington, A.H. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30: 492–507.

Fernández Yuste, J.A., Martínez Santa-María, C., Magdaleno, F. 2012. Application of hydrologic alterations in the designation of heavily modified water bodies in Spain. Environmental Science & Policy 16: 31-43.

Magdaleno, F. 2005. Caudales ecológicos: conceptos, métodos e interpretaciones. Monografía CEDEX M-82. Secretaría General Técnica, Ministerio de Fomento. 194 p.

Magdaleno, F. 2009. Manual técnico de cálculo de caudales ambientales. Colegio de Ingeniero de Caminos, Canales y Puertos. 240 p.

Magdaleno, F. 2011. ¿Debe el agua de los ríos llegar al mar? Una gestión medioambiental del agua en España. Ed. Los libros de la Catarata - Fundación Alternativas. 106 p.

Martínez Santa-María, C. & Fernández Yuste, J.A. 2006. Índices de alteración hidrológica en ecosistemas fluviales. Monografía M-85 CEDEX. Secretaría General Técnica, Ministerio de Fomento. 178 p.

Poff, N.L., Richter, B.D., Arthington, A.H., Bunn, S.E., Naiman, R.J., Kendy, E., Acreman, M., Apse, C., Bledsoe, B.P., Freeman, M.C., Henriksen, J., Jacobson, R.B., Kennen, J.G., Merritt, D.M., O'Keefe, J.H., Olden, J.D., Rogers, K., Tharme, R.E., Warner, A. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55: 147–170.

Richter, B.D., Baumgartner, J.V., Powell, J., Braun, D.P. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. Conservation Biology 10(4): 1163-1174.

Richter, B.D. 2010. Re-thinking environmental flows: from allocations and reserves to sustainability boundaries. River Research and Applications 26(8): 1052-1063.

Stewardson, M.J. & Gippel, C.J. 2003. Incorporating flow variability into environmental flow regimes using the flow events method. River Research & Applications 19: 459–472.

Tharme, R.E. 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications 19: 397–441.

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