Conserving Critical Environmental Flows

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Flow as the Dominant Influence on River Ecology

Water flow has been described as the 'master variable' or 'maestro variable that orchestrates pattern and process' in stream and river ecology, as it has a dominant role in shaping and sustaining fundamental properties of riverine ecosystems[1]. The structure and complexity of physical habitat in streams (e.g. channel geometry, the arrangement of pool and riffle habitats, types and stability of substrate), water quality and energy sources are heavily shaped by water flow[1,2,3]. For example, flood flows help maintain channel geometry and groundwater inputs sustain base flows on watercourses during dry periods (Figure 1). The distribution, abundance and diversity of aquatic biota is in turn strongly influenced by in-stream aquatic habitat, water quality and energy sources[1,4]. Flows also directly trigger migration and reproduction in many aquatic biota, such as fish (Figure 1). Water flow therefore has both direct and indirect roles in sustaining the integrity of stream and river ecosystems[1] (Figure 2).

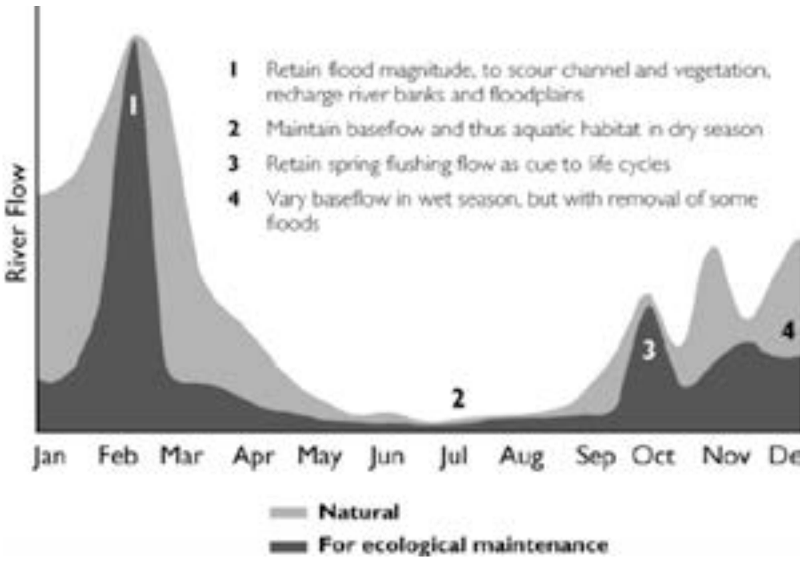

Figure 1. Example of an environmental flow recommendation. Light grey shows the natural (pre-disturbance) flow pattern, and the dark grey shows the allocated environmental flow to sustain key ecosystem processess at different times of the year. Source: Postel & Richter 2003.

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Sustaining Key Natural Processes

The 'Natural Flow Regime'[1] is the long-term natural pattern of water flow in a river that sustains the integrity of stream and river ecosystems. Where hydrological alterations (e.g. water extraction, water diversion, water releases) are managed so that natural patterns of variation in key aspects of the natural flow regime are maintained (e.g. magnitude of flood flows, duration of base flows, duration and frequency of cease to flow periods in ephemeral watercourses; Figure 1), then it is likely that the ecological integrity of the river will also be maintained (Figure 2). However, significant changes to the natural flow regime (e.g. truncation of major flood flows, reversal of timing of flow events, constancy of water release in a naturally variable system) will likely result in long-term, significant and cascading impacts on the ecological integrity of a stream or river[1,4].

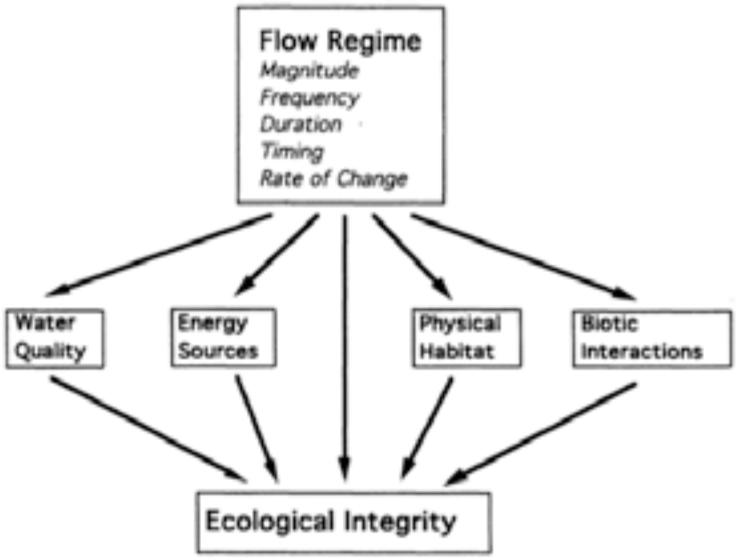

Figure 2 The components of the natural flow regime directly and indirectly sustain the integrity of aquatic ecosystems. Source: Poff et al. 1997

Five critical components of the natural flow regime regulate ecological processes in riverine ecosystems[1] (Figure 2):

- *magnitude*: the volume of water moving past a set location per unit of time
- *frequency*: how often a flow above a certain magnitude recurs
- *duration*: the period of time of a specific flow condition
- *timing* (or *predictability*): regularity of specific flow conditions, generally with respect to seasonal predictability, and
- *rate of change* (or *flashiness*): how quickly flow changes from one magnitude to another (e.g. the slope of the rising or fallings limbs of a hydrograph).

Four ecological principles of natural flow regime have been identified to illustrate how altering flow regimes affects aquatic biodiversity in streams and rivers[4]:

- principle 1: flow is a major determinant of physical habitat in streams, which in turn is a major determinant of biotic composition (i.e. the natural flow regime supports natural habitat characteristics and natural patterns of biodiversity in streams and rivers)
- principle 2: aquatic species have evolved life history traits and strategies in direct response to natural patterns of variation in flow (i.e. species are adapted to the natural flow regime)
- principle 3: the natural flow regime provides for natural patterns of longitudinal (i.e. along the length of a river) and lateral (i.e. from a river to a floodplain) hydrological connectivity in streams and rivers, and that maintenance of this connectivity is essential for the viability of riverine and floodplain species and ecological communities, and

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- principle 4: the invasion success of exotic, introduced and pest species (e.g. pest aquatic weeds such as para grass and salvinia; and pest aquatic animals such as eastern gambusia and tilapia) is increased within increasing alteration of flows (i.e. maintenance of the natural flow regime limits the invasion success of pest aquatic species).

High and low flows are important in all types of streams (i.e. perennial, intermittent and ephemeral) for the reasons described above, with low flows considered to be highly vulnerable to impact compared to high flows[5]. For example, a slight reduction in low flow can greatly reduce the amount of dry-season riffle habitat in a base-flow watercourse, whereas a slight reduction in a high flow will have a comparably lower effect on habitat availability. However, in intermittent and ephemeral streams, cease to flow (i.e. zero flow) is also a critical component of the natural flow regime[5]. Many aquatic faunal groups that inhabit ephemeral streams require dry periods to complete their life history (e.g. fairy and tadpole shrimps)[6], and dry stream beds provide habitat for specialised faunal groups[7]. The timing, duration and frequency of cease to flow periods can therefore be equally as important as the timing, duration and frequency of flow events in ephemeral streams.

Methods Used to Understand Flow in Stream and Rivers

The assessment of how much water a river needs to maintain some level of ecological function originated about 30 years ago. Thus, many of the available methods pre-date the development of the natural flow regime paradigm, and thus the flow recommendations that can be derived from some methods may relate to only a sub-set of the components of the natural flow regime. Furthermore, the formal definition of 'environmental flow' as 'the quantity, quality and timing of water flows required to sustain freshwater ecosystems and the livelihoods and well-being that depend on these ecosystems' was not formerly endorsed until 2007[8]; thus, historically the objectives of setting environmental flows in rivers may not have been to preserve key aspects of the natural flow regime. Consequently, there are a large number of approaches for setting flow recommendations for rivers and streams across a wide range of different contexts, although the extent to which they adequately assess the key aspects of the natural flow regime, or even have the natural flow regime as the objective, is highly variable[9].

Despite the large number of flow assessment methods available, all of them can be classified into one of four general categories[8,10]:

- **hydrological methods**, which are based on analyses of historic (measured or simulated) stream flow data to calculate various hydrological metrics that can be used as flow recommendations or assist in developing flow recommendations. An advantage of hydrological methods is that, providing long-term hydrological data is available, these methods are the simplest, quickest and least expensive way to provide information on threshold flow levels[8]. Some examples of hydrological methods include the Montana method[11], Indicators of Hydrological Alteration[12], and Percentage of Flow Analysis[13].
- **hydraulic rating methods**, which are based on a known relationship between a hydraulic measure of a river and discharge. Wetted perimeter (e.g. the wetted-perimeter method) or water depth are typically the hydraulic measures of interest, as these relate to aquatic habitat availability in riverine systems.
- **habitat simulation methods**, which are based on known relationships between the level of flow in a river and the 'optimum' physical habitat for a particular species of special management interest (e.g. a fish of conservation value, or fishes of fishery value). Habitat simulation methods employ a wide range of modelling approaches, including habitat models, bioenergy models, and generic models that integrate hydraulic and biological components.
- **holistic methods**, which are more accurately described as flow assessment frameworks than specific methods, as holistic methods may incorporate multiple lines of evidence from multiple assessment methods to formulate environmental flow objectives and recommendations. For example, many of the holistic methods incorporate one or more of the hydrological methods with other approaches, such as expert panels. Some examples of holistic methods include the Building Block method[14,15], Downstream Response to Imposed Flow Transformation[16], and Ecological Limits of Hydrological Alteration[17].

Types of Natural Flow Regimes in Australia

A continental-scale classification of hydrologic regimes for Australia, based on 120 metrics describing ecologically relevant characteristics of natural flow regimes for 830 stream gauging stations, identified 12 distinct classes of flow regime type[18]. These flow regime types differered in the seasonal pattern of discharge, degree of flow permanence, magnitude and frequency of flood flows, and other aspects of flow predictability and variability. There was strong geographic distinction in distribution of the flow regime types, with geographic, climatic and some catchment topographic factors being the major determinants of differences between flow regime types.

Strong regional differentiation in flow regime types across Australia indicates that aquatic biota in different regions are differentially adapted

to local flow conditions, including natural patterns in abiotic factors that are strongly coupled with flow, such as flow-temperature linkages. It is therefore critical that the ecological significance of the local natural flow regime type is understood when performing flows assessment or developing a flows strategy.

Benefits of an Ecological Approach to Developing Environmental Flow Strategies

The assessment of environmental flows is intrinsically an ecological exercise, requiring collaboration between aquatic ecologists and hydrologists, and potentially other discplines depending on the specific situation (e.g. hydrogeologists where groundwater-surface water interactions require assessment and management). However, the aquatic ecological processes to be sustained by flows assessment, and the likely ecological responses to a given environmental flow strategy, are often overlooked when aquatic ecologists versed in environmental flow assessment are not involved.

There has been increasing need to assess environmental flows for a wider range of development types than traditional dam / water extraction projects:

- urban development that results in significant changes to run-off patterns
- water release projects, such as for coal seam gas projects, including proposed releases to highly ephemeral watercourses, and
- projects that reduce the size and therefore run-off volumes of upstream catchment areas.

Sound environmental management and confident decision making require the rigorous evaluation of available data, and in the case of flow data, this may be measured historical flow data or modelled data reflecting anticipated changes to flows in response to a specific development scenario. The rigorous evaluation of such data for the purpose of environmental flows assessment, and development of defensible environmental flow strategies, must adopt a collaborative approach where ecologists play a critical role in balancing environmental outcomes with economic and social outcomes.

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