CURRENT SCIENCE

Volume 118 Number 11 10 June 2020

GUEST EDITORIAL

Assessment and implementation of environmental flows

Healthy rivers, floodplains and wetlands support a wide range of valuable services to the society. These systems provide us freshwater, food, wood and fuel. They support primary production, nutrient cycling and soil formations. In addition, natural eco-systems regulate climate, water, extremes such as floods and droughts, and health. They also give cultural, social, spiritual and recreational benefits. However, in recent times, upstream withdrawals, hydro-projects and landuse–landcover (LU–LC) changes have greatly modified the magnitude, timing and duration of river flows. Water resources development has provided water–food–energy security to the society. It has almost eliminated famines and considerably reduced malnutrition. But at the same time, these developments have caused significant harm to the natural aquatic ecosystems. Rivers, wetlands, floodplains and estuaries are the world's most threatened ecosystems these days.

One of the reasons for the degradation of rivers and other components of ecosystem is that large amount of water is withdrawn or diverted to meet the growing water needs of the society. Humans require water for household needs, to produce food and goods, and to generate energy. In fact, it is impossible to think of any human activity that does not require water, directly or indirectly. Further, as the population is rising, demands for water are also rising. To meet these demands, progressively more water is being withdrawn from sources. In many cases, the withdrawals exceed the natural replenishment, making the use of resources unsustainable. In addition, return flow to sources such as rivers or aquifers is often loaded with toxic chemicals, heavy metals, pesticides, etc. and this further harms these eco-systems.

Impacts of a hydro-project on river flows downstream depend on the type of project. Multipurpose storage projects significantly alter flow regime; the changes depend on the purposes of the project. Typically, peak flows and volumes are substantially reduced downstream of storage projects that supply water for agriculture, drinking and industrial needs. Run-of-river (RoR) projects generate energy from flows as available. However, in many cases, RoRs use within-day storage to generate energy during peak hours. In some cases, river is nearly dry for some distance downstream of the project because almost entire flow is diverted to generate energy.

Hydro-infrastructure is needed to match water demands with availability, to provide reliable, adequate and good quality water for municipal and industrial uses, to irrigate crops, to generate energy and to provide safety against disasters. At the same time, it is also important to protect environment, realize benefits from ecosystem services and maintain biodiversity. There is also a trade-off between development (use of water to grow food, domestic use, industry and generate energy) and conservation of natural resources. As the natural systems are progressively modified, ecosystem services from them gradually decline but the economic benefits increase. As the degree of alteration increases, the economic benefits rise and reach a plateau after certain limit. It is noted that the sum of the two benefits reaches a maximum and then begins to decline. The point of maximum benefits can be considered as the optimum development. Importantly, the shapes of the benefit and cost curves depend upon the countries/regions and social choices.

The interaction between environment conservation and development and the concept of sustainable development entered the political agenda in many countries during the 1980s and 1990s. With the desire to maintain the natural ecosystems in healthy states, the concept of environmental flows began to take shape around the same time. It was recognized that certain minimum flows are needed to keep rivers healthy for the survival of the riverine communities. Further studies showed that instead of certain minimum flows, the whole flow regime, including sediment dynamics and habitats need to be considered. In view of its importance, environment has a dominant role in many sustainable development goals including sustainable water management (Goal 6) and ecosystems (Goals 14 and 15).

Many definitions of environmental flows can be seen in the literature. The definition adopted in the famous Brisbane Declaration (2007) states: 'Environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon these ecosystems'. Some authors prefer the term 'flows' rather than 'flow' because the former refers to a complete flow regime with temporal variations. An important concept here is the natural flow paradigm. It suggests that the communities living in a river in a region have adapted to the unregulated flows which are necessary to sustain biodiversity and ecosystem integrity. Changes in the natural flow regime adversely affect riverine, riparian and floodplain species; greater the changes, more is the harm.

In practice, rivers are regulated to different degrees to satisfy societal needs and E-flows can be viewed as a balance between development and conservation. E-flows also help maintain the river continuum – longitudinal and lateral. In recent times, E-flows have become an essential part of water resources development and are imbedded in water policy, planning and decision-making in all major nations.

Among the variables that influence ecosystem of a river, flow is the master variable that controls its evolution, structure and functions. Channel and floodplain morphology is also shaped by fluvial processes, determined by streamflow. Hence, flow is considered an appropriate indicator of river ecosystem integrity. Time series of flows may be available at the required location or can be estimated from the data of a nearby site. Hence, hydrological methods were the earliest employed tools to estimate E-flows. Indices based on flow data, for example, Q_{95} (flow which is equal led to or exceeded 95% of the time), are frequently used to define E-flows.

In E-flow assessments, fish are widely used as indicator species. Fish occupy many levels of trophic chain in freshwater. Fish depend on availability and diversity of fluvial habitats. During their life, fishes undergo and respond to single or cumulative effects of events impacting habitats. Due to consistent ecological response, composition and status of fish community can be used to evaluate and ecologically validate specific E-flows.

Keeping in view the relevance and importance of correctly assessing E-flows, recent times have seen evolution of various methods, approaches and frameworks. Interestingly, more than 200 E-flow assessment methods have been developed that range from simple methods that use hydrologic data alone to the methods that use data from various sectors, and utilize multi-disciplinary expertise. Where improved E-flow assessments are needed, hydraulic rating methods can be applied. These methods use the relationship between the flow and hydraulic characteristics of a cross-section, such as flow depth, velocity and wetted perimeter. Wetted perimeter is an easily measurable physical indicator that changes when the flow regime is altered. In the wetted perimeter method, graph of the wetted perimeter versus flow is plotted. Breakpoint, where significant reduction in the wetted perimeter (or habitat quality) occurs with fall in flow, is identified and the corresponding flow is minimum E-flow.

Habitat simulation models link flow, hydraulic features and physical habitat requirements of species. These models make integrated use of hydrological, hydraulic and biological response data and link alterations to flow regime to the changes in habitats to produce physical habitat-discharge curve. This information is used to convert flow time series to habitat time series.

The Building Block Method assumes that the riverine communities depend on building blocks (or basic elements) of the flow regime for survival and growth. Hence, such elements of natural flow regime are to be retained to ensure a healthy river. These elements typically include low flows, medium flows, high flows and very high flows. When these building blocks are combined, a flow regime that maintains the river in a pre-specified condition is created. Some 'frameworks' have also been developed for providing a broader strategy for E-flows assessment (e.g. the Ecological Limits of Hydrological Alteration or ELOHA framework).

In assessment of E-flows, a common assumption is that location-specific statistically derived relationships exist between certain hydrological and ecological variables. However, at times, hydrological variables alone explain only a small part of the ecological variability. Experience shows that a smaller proportion of total flow is required to maintain eco-system in rivers having high variability in flow regimes compared to those with stable regimes.

Implementation of E-flows is challenging due to many reasons. Usually, different regulatory bodies look after different components of environment, e.g. rivers, fishery, wetlands, wild life, forests, etc. Importance of these components changes during the course of a river. Allocation of water for E-flows in an over-allocated system is challenging because supplies to existing uses will have to be reduced and this typically results in economic loss and resistance. In a few systems, water for environmental needs was found by purchasing water rights, dam reoperation and improving agriculture water use efficiency.

In India, E-flow science is in infancy and needs support from government and scientific community. We need to create and strengthen hydro-biological databases and develop indicators that respond to flow. Studies to estimate E-flows are needed to cover all major rivers in the country. E-flow programmes require sustainable funding and suitable mechanisms are to be created. A comprehensive strategy may be developed for E-flows assessment under Integrated Water Resources Management.

Final decision on E-flows is a societal choice backed up by scientific analysis. As we have limited experience in implementing E-flows in India, adaptive management is recommended. This involves assessing E-flows, implementing them, monitoring the outcomes and using the feedback to revise the assessments. It is advisable to follow a phased approach; many successful programmes began with simple approaches in selected locations, and then evolved.

Sharad K. Jain

(Formerly with National Institute of Hydrology, Roorkee)
Civil Engineering Department,
IIT Roorkee,
Roorkee 247 667, India
e-mail: s_k_jain@yahoo.com