COMPARISON OF METHODS TO ASSESS ENVIRONMENTAL FLOWS : A REVIEW

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ABSTRACT

Ecosystems have their own way of existence based on water and they provide numerous goods and services essential for life. The variation of hydrological regimes is vital in sustaining the native biodiversity and the integrity of the aquatic ecosystems. However this interlinkage is being violated by flow manipulation structures all over the world. Most critical flow alteration structures, which affect on ecosystems, are the barriers across river beds such as dams. The environmental flow has the ability to prevent the possible environmental degradation or reverse the degradation already occurred up to a certain extent depending on the degree of flow manipulation. It also can secure the ecosystem sustainability up to some extent. It is needed to quantify the environmental flow in a riverine system to allow how much of water should be allocated for this purpose. Therefore, it is important to create awareness about the existing Environmental Flow Assessment (EFA) methodologies. This paper aims to emphasize the importance of EFA, review the methods developed to assess environmental flows and compare their capabilities and limitations.There are several EFA methods available and they are categorized based on the approach they used as hydrological, hydraulic, habitat and holistic methods. Tennant method, Tesman method, Flow duration curve method and Range of Variability Approach are hydrological methods that depend on historical flow records. Wetted perimeter method and riffle analysis method are hydraulic rating methods that assume a relationship between discharge and hydraulic geometry. Habitat Quality Index and Instream Flow Incremental Methodology are habitat methods that assume relationship between hydraulic parameters, biological requirements and discharge. Downstream Response to Imposed Flow Transformation (DRIFT) and Building Block Methodology (BBM) are holistic methodologies, which consider the whole riverine ecosystem. Though Hydrological methods and Hydraulic methods are easy to apply and inexpensive, their outcome is not much reliable because they do not have any bilogical view and they are not flexible to assess variation of the ecosystem over time. Compared to above two methods, habitat methods and holistic methods provide much reliable outcome, but holistic methods provide the most reliable outcome, as they look at the whole riverine ecosystem while habitat methods target only few species. Among holostic methodologies, BBM is the most reliable and widely applying method. In overall, it is important to identify the nature of the riverine ecosystem that is going to be assessed for environmental flow quantification before selecting a suitable method.

***Key words*:** Environmental flow, Ecosystem sustainability, Environmental flow assessment, Flow manipulation

1. INTRODUCTION

An ecosystem, which provides numerous goods and services (1) has sustainability based on water. Freshwater demand increases as population increases. Therefore, water management becomes a major necessitate, hence many flow alterations has been made all over the world (2, 3, 4). In this case, even rivers can become seasonal from perennial (6). As downstream flow change, downstream ecosystems have to confront problems because ecosystems always interlinked with hydrology (5, 7) and tend to respond to hydrological changes. Environmental flows are necessary for the sustainability of fresh water ecosystems. To promote environmental water allocations, it is important to create awareness about the existing environmental flow assessment (EFA) methodologies (8). This paper aims to emphasize the importance of EFA, review methods developed to assess environmental flows and compare their possibilities, limitations to identify the suitability of them under given situations.

2. Methods for the Assessment of Environmental Flows

It is important to get an idea about the environmental flow requirement of a river system or a segment of a river for the allocation of environmental flow. A number of EFA methods have been developed with this objective. These methods can be classified based on the approach used to quantify the environmental flow. As an example, Hydrological methods are based on past flow data, Hydraulic methods assume relationship between hydraulic measuresand flow regime, Habitat methods consider hydraulic conditions, which meet specific habitat requirement of discharge for biota, and Holistic methodologies consider the water requirement of whole riverine ecosystem.

Among these methods, Hydrological methods are the simplest, inexpensive and quick, which use desktop approaches. They are always criticized for lack of ecological point of view (6, 9). Tennant method is one of the oldest and widely used methods (10). It assumes a linear relationship between flow and stream environment. A study based on this method has concluded that at least 10% of the mean annual flow is needed to survive the system and 30% is satisfactory (10, 11). Tessman has modified the tenant method as to apply more different stream patterns (5, 12). Several law flow indices have been developed upon the Flow duration curves (FDC) and termed as environmental flow (5). Shifting FDC method which is an extension of flow duration curve method, is for situations where no enough data (14). Range of Variability Approach (7) has been introduced considering importance of full range of flow regime to maintain the ecosystem integrity.

Hydraulic rating methods are recommended when the past flow records are absent. These methods are not suitable for assessing seasonal flow requirements (5, 9, 11) and are not well suited for braided rivers (9) since it results a single value as environmental flow recommendation and uneven nature of hydraulic parameters of bridal river.

Wetted perimeter method is most used one among hydraulic methods (9). Inflection point of the graph of wetted perimeter versus discharge is considered as the minimum flow requirement point. This method has further developed to get the exact inflection point (5). Riffle analysis method is a modification of wetted perimeter method considering fish migration (5).

Habitat methods are an extension of hydraulic methods (5, 6, 9). The difference is that the determination of flow requirement is based on hydraulic parameters that are related with specific and pre-selected target species. These methods are accurate and flexible than above two (9) but it requires more fieldwork, costly and targets only specific species (6). Habitat Quality Index (HQI) is to predict trout standing crop in streams in Wyoming, Canada based on a large data set about 36 streams. However, it has not proven its suitability to apply for other streams in Canada. Instream Flow Incremental Methodology (IFIM) is a decision support system works under five steps; problem identification, planning, implementation, analysis and resolution. It depends on a computer model namely, Physical Habitat SImulation Model (PHABSIM). IFIM and PHABSIM have been developed separately but parallel to each other.

Holistic methodologies are the approaches which consider the whole riverine ecosystem and this holistic idea was raised with Brisbane declaration in 1991. These methods need experts in different fields. Building Block Methodology (BBM) is based on the concept that flows within the complete hydrological regime can be described with their magnitude, duration, timing and frequency (6). Geomorphology, water quality, vegetation, aquatic invertebrates, fish, ground water and social use are the areas focused to EFA. Downstream Response to Imposed Flow Transformation (DRIFT), consists of four models andaccording to the model, modification of component of flow regime affects the riverine ecosystem. DRIFT depends on present day hydrology.

3. COMPARISON OF METHODS

Table 1 descibes the comparison of available types of EFA methods. Though Hydrological methods and Hydraulic methods are simple, quick, easy to apply and inexpensive, their outcome is not much reliable because they do not have any bilogical point of view and they are not flexible to assess variation of the biotic factors of ecosystem over time. Most of the hydrological methods are confined to a data set of selected geographical area and hydraulic methods confined to water requirements of target species, mostly having economical value such as trout fish. Appling hydrological methods is sometimes create practical problems because absence of continous long term data records specially under date poor environments, as they totally depend on

past flow data. Hydraulic methods are very rare to apply except wetted perimeter method.

Table 1: Comparison of EFA method catogories

Type of method	Simple and quick	Low cost	Desktop approac h	Reliable outcome	Less data requirement	Not confined to pre determined area/ data set/ species	Flexible and applicable
Hydrological methods				✘	✓	✘	✘
Hydraulic rating methods			✘	✘	✓	✘	✘
Habitat simulation methods	✘	✘	✘	✓	✘	✘	
Holistic methodologies	✘	✘	✘		✘	✓	

Compared to hydrological and hydraulic rating methods, habitat methods and holistic methods provide much reliable outcome. Out of the two, holistic methods provide most reliable outcome as they look at whole riverine ecosystem while habitat methods look only towards target species. Holistic methods require more field work to collect data since they use, holistic approaches. Both habitat methods and holistic methods can assess variation of ecosystems over time. But they comsume a considerable time and money. There are no any methods consider groundwater, social and cultural aspecs and other related ecosystems etc. other than holistic methodologies.

DRIFT consider scioeconomical, environmental and hydrological factors as well as BBM. DRIFT lies on present day hydrology while BBM lies on observed or modeled historical flow data or expert judgement. But DRIFT mostly depends on computer models compared to BBM. Among holistic methodologies, BBM is the most accepted and most commonly and sucessfully used method [15, 16]. It considers whole riverine ecosystem and the human livelihood depend on it, there is a strong link with the hydrological regime, it is possible to depend under reliable data set, modeled data or expert judgement, outputs can be generated at several levels of resolution (e.g. monthly discharges, percentages of virgin/present mean annual rainfall), flexible and depends upon existing condition, state robust recomendations, transparent, clear and well documented.

4. CONCLUTIONS

Environmental flows must recieve a significant attention when manipulating river flow, for the long term sustainability of related ecosystems and long term benefits. Therefore, environmental flow allocation and giving priority for ecological considerations are extreamly important. Among hundreds of environmental flow assessment methods, holistic methods are the most suitable, since they consider whole riverine ecosystem including social, cultural and economic significance while other methods have narrow point of view on the whole system. Holistic methods provide more reliable recommendation on environmental flow allocation, though the process is not simple. BBM is the most widely used and successe holistic method as it considers each and every component which needs flow allocation and for its flexibility and great reliability. In overall it is important to identify the nature of the riverine ecosystem before assessment for a successful environmental flow recommendation.

Environmental flow studies in to Sri Lankan river basins are better to direct towards holistic methodologies. More importantly it is better to develop less comprehensive methods which require minimum data to assess environmental flows because of lack of the data records and less reliability of existing data records. Time and cost effectiveness of the methodologies also should be considered.

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