WORKING PAPER 103

An Assessment of Hydrology and Environmental Flows in the Walawe River Basin, Sri Lanka

Vladimir Smakhtin and Neelanga Weragala

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Please direct inquiries and comments to: *iwmi@cgiar.org*

Contents

Abstract

Quantification of hydrological processes and water requirements of aquatic ecosystems is required for many projects related to environmental security and efficient water use in agriculture. This also applies to the Asian monsoon region. This paper focuses on the Walawe River basin, located in a semi-arid zone of southern Sri Lanka. The two major reservoirs in the upstream and middle reaches of the river with a total capacity of 486 million cubic meters (MCM) have significantly affected the hydrology of the river, with associated adverse environmental and social consequences. The objectives of the study are to:

i. establish the hydrological reference condition (reconstruct the unregulated flow regime) and assess, against it, the impacts of land-use changes and water-resources development in the basin over the last 40 years, and

ii. quantify the environmentally acceptable flow regime, which needs to be incorporated into any future water resources development plan of the river basin.

The reference hydrology is simulated using a non-linear spatial interpolation technique based on observed rainfall and flow records. The environmental flows are approximated using a desktop method, based on simulated, unregulated daily flow time series and their flow duration curves. Both methods are applied at two sites along the main stream of the Walawe River, which are located below the two main reservoirs. The study is carried out in conditions of extreme data uncertainties and limitations, which are described and discussed in the paper. Based on the lessons learned in this case study, suggestions are made for improved quantification of water resources in Sri Lanka as a whole.

INTRODUCTION

The protection of the aquatic environment is high on the world water resources agenda. Most developing countries, however, still lack the technical and institutional capacity to establish environmental water allocation practices and policies. The existing methods of environmental flow assessment (EFA) are either complex and resource-intensive or not tailor-made for the specific conditions of a particular country, region or basin. Quantification of natural and present-day hydrology, associated with these assessments, is also lacking. To promote the emerging concepts of environmental flow assessment (EFA) and management, it is important, among other things, to change the still dominating perception of environmental demand as the least important factor, create awareness among responsible authorities about the existing EFA methodologies and processes that should be followed, and illustrate the applicability of these approaches through relevant case studies. It is equally important to quantify and illustrate the current status of hydrological alterations in river basins to identify data gaps and to suggest ways for improved quantification of water resources. The paper addresses these issues in the specific context of Sri Lanka. The study uses the Walawe River basin in southern Sri Lanka as an example.

STUDY AREA

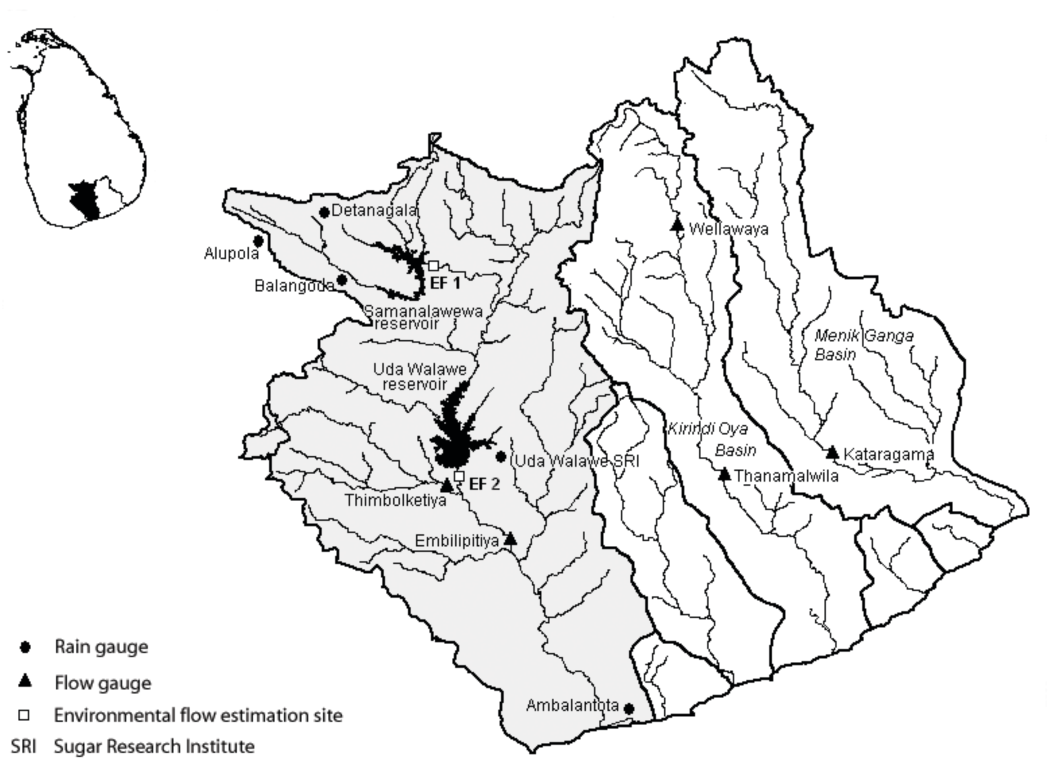
Walawe is the largest river basin (2,442 km^2) in southern Sri Lanka and it is one of the three main rivers flowing south in the area (Walawe, Kirindi and Menik), which, together with a few smaller catchments, form a group of basins known as the Ruhuna drainage area (figure 1). The total drainage area of Ruhuna is over 5,500 km^2.

The Walawe River originates at an altitude of 2,395 m above sea level and travels 84.9 km southwards before it flows into the Indian Ocean near Ambalantota town (figure1). A characteristic feature of the basin is two wet seasons—from the northeast and southwest monsoons—with precipitation peaks in April and November. The mean annual precipitation (MAP) is 2,050 mm with uneven spatial distribution. Despite the high precipitation, parts of the basin experience water scarcity problems during February-March and July-October almost every year.

The Walawe basin features a variety of water-related issues—from massive irrigation development and increasing stress on the water environment to water quality and drinking water problems. The basin is undergoing extensive changes due to agro-ecological, socioeconomic and institutional developments. Livelihoods vary from area to area depending on the physiographic conditions and availability of land and water. Irrigation development has been the major strategy for livelihood enhancement of the people in the basin. Two major reservoirs for irrigation and hydropower generation are constructed on the main river (figure1): Samanalawewa (upstream, in 1993) and Uda Walawe (middle reaches, in 1957). With a total capacity of 486 MCM, they supply water for hydropower and irrigation. Water is also transferred out of the Walawe basin to develop irrigated agriculture in adjacent basins of the Ruhuna area.

The northern and northwest to western boundaries of the basin are in the mountain range, with steep valleys and multiple waterfalls. The area is relatively pristine and is a tourist attraction. However, tea plantations have replaced the natural vegetation that covered the mountains in the past and abandoned tea lands have been degraded by severe soil erosion. Newly introduced trees like pine and eucalyptus were planted under reforestation programs in the 1950s in this area because of its temperate climate. They have had a negative impact on the hydrology of the basin, causing some small streams to dry up.

FIGURE 1. Schematic map of the study area.



The coastal area is characterized by wetlands and lagoons, where drainage water containing agro-chemicals from irrigated lands in the middle part of the basin collects. Thus the lagoon areas, which are the feeding grounds of migratory birds from Siberia, are badly affected. The increasing trend of agro-chemical usage for irrigated agriculture by farmers is likely to have adverse impacts on the biodiversity of the lagoons and the livelihood of lagoon fishermen.

About 40 percent of the catchment area is irrigated land and 20 percent is under rain-fed agriculture. Expanding the irrigated area could lead to the loss of more than 5,000 ha of secondary forest, an important wildlife habitat. Human-elephant conflicts are aggravating due to this loss of wildlife habitat. Irrigation development has had negative impacts on the aquatic environment also. There is only very limited quantitative knowledge of these impacts and no attempt has been made to establish the objectives of environmental water management in the basin and to quantify associated environmental flow requirements or releases.

SIMULATING UNREGULATED RIVER HYDROLOGY

Estimation sites and data

It is agreed in eco-hydrology that environmentally acceptable flow regimes should mimic the natural (or, at least, *unregulated*) pattern of *flow variability* in a river (e.g., Poff et al. 1997). High flows of different frequency are important for channel maintenance, bird breeding, wetland flooding and maintenance of riparian vegetation. Flows in a moderate range may be critical for the cycling of organic matter from river banks and for fish migration. Low flows of different magnitude are important for algae control, water quality maintenance, use of the river by local people, etc.

The natural flow variability is best described by daily discharge time series. These time series have to be simulated for selected estimation sites where environmentally acceptable flow regimes are to be established using the simulated time series. These sites are further referred to in the text as "environmental flow" (EF) sites. EF site selection for the purpose of this study was done without a field visit, which would normally be required by comprehensive EFA methods. The selection is based primarily on their location relative to the existing reservoirs. Site 1 (EF1) is located immediately downstream of the Samanalawewa Reservoir and Site 2 (EF2) is downstream of the Uda Walawe Reservoir. The details of the EF sites are summarized in table 1.

TABLE 1. Details of the observation and estimation sites and observed daily data.

Site	River	Period of record	Catchment area (km$^{2)}$	Site type	Comment
Thimbolketia	Rakwana (Walawe basin)	1958-1967	232	Flow gauge	
Wellawaya	Kirindi	1956-1993	172	Flow gauge	
Kataragama	Menik	1977-1998	787	Flow gauge	Not used: Flow pattern is very different from other observed datasets.
Embilipitiya	Walawe	1942-1968	1,580	Flow gauge	Unregulated part of the record is 1942-1958, prior to Walawe dam construction.
Thanamalwila	Kirindi	1988-1998	749	Flow gauge	Not used: Data are inaccurate.
EF1: Samanalawewa	Walawe		353	EFA site	Approximately coincident with flow gauge 1806, for which only monthly time series are available ("Samanalawewa gauge," referred to in the text).
Samanalawewa (Inflow)		1992-1999	353	Dam site	Short record.
Samanalawewa (Outflow)		1992-1999	353	Dam site	Short, regulated record. Only used for comparison with the above.
EF2: Uda Walawe	Walawe		1,155	EFA site	No data on outflows from the reservoir available. Major limitation for comparison of unregulated and present-day regulated flows.
Detanagala	Walawe	1971-1999	n/a	Rain gauge	Inaccurate data.
Uda Walawe SRI*	Walawe	1981-1999	n/a	Rain gauge	
Ambalantota	Walawe	1960-1999	n/a	Rain gauge	
Alupola	Outside Walawe	1985-1999	n/a	Rain gauge	Inaccurate data.
Balangoda	Walawe	1990-2000	n/a	Rain gauge	

* Sugar Research Institute

Note: n/a = not applicable.

To obtain background hydrological information for the assessment of the environmental requirements of the Walawe River, this study has primarily made use of available, *observed hydrometeorological daily records*. Only five gauges with daily and monthly *unregulated* flow data have been identified in the Ruhuna group of catchments (figure 1 and table 1). "Unregulated" implies that the flow is not affected by major structures like Lunugamwehera, Uda Walawe, Samanalawewa, etc. (It is certainly not possible to find a completely un-impacted flow dataset given the number of small tanks in each river catchment.) The preliminary screening and visual analysis of these time series have shown that only three of these datasets are usable while others contain inaccurate values or have short records or other deficiencies. However, even the quality of the selected flow datasets remains highly questionable (Weragala and Smakhtin 2004).

In addition to flow data, several observed, daily rainfall datasets have been used, as described below. Although there are a number of rainfall stations in the basin, most of them have short records of 10 to 15 years or are located far from the sites where simulation is required, and therefore are of little use. The details of the rainfall stations used are also listed in table 1 and their locations are shown in figure 1. In general terms, the lack of hydro-meteorological data collection stations and the inaccuracy of data in existing datasets of the basin are real constraints to water resources assessment or any detailed hydrology-related study.

Spatial interpolation of observed records

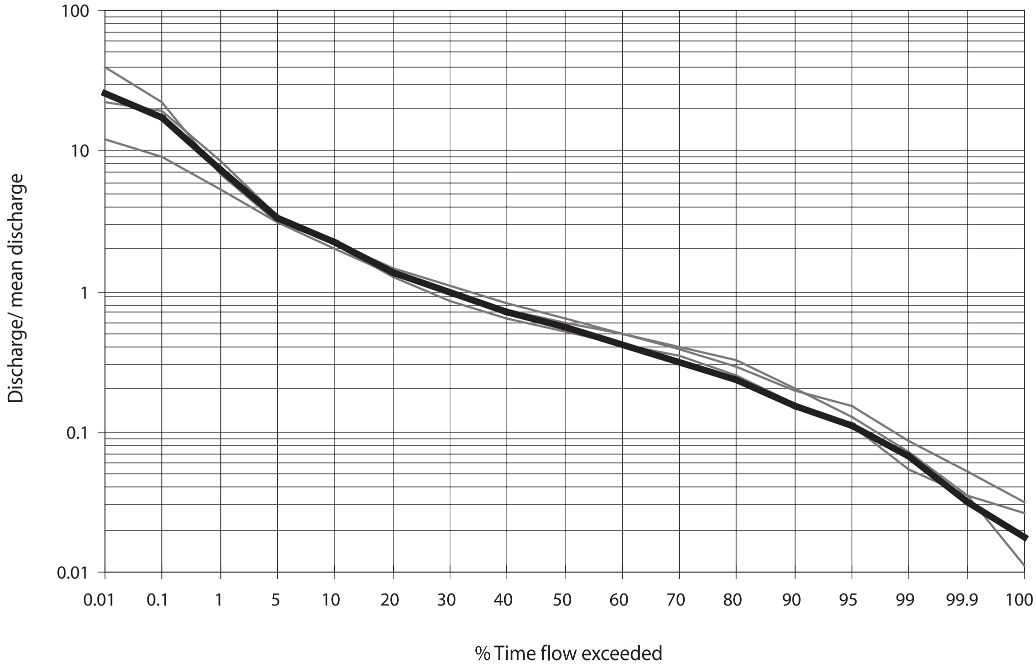
The method of data generation for the sites employs a parsimonious, non-linear spatial interpolation of observed streamflow data developed by Hughes and Smakhtin (1996) and successfully applied in the past at many locations throughout the world for various water resources problems, including EFAs. The examples include, but are not limited to, Hughes and Münster 2000 (South Africa), Weragala and Smakhtin 2004 (Sri Lanka), Metcalfe et al. 2005 (Canada), and Smakhtin and Shilpakar 2005 (Nepal). Some of these studies (e.g., Hughes and Smakhtin 1996 and Weragala and Smakhtin 2004) have shown that in conditions of limited input data, the technique performs as good as more complex hydrological models.

This technique makes an intensive use of flow duration curves. A flow duration curve (FDC) is a cumulative distribution of river flows; a relationship between any given discharge value and the percentage of time that this discharge is equaled or exceeded. It is normally calculated from available, observed or simulated flow time series. But because the shape of the curve is determined by rainfall pattern, catchment size and physiographic characteristics, land-use type, and the state of water resources development, the primary assumption of the simulation approach is that the effects of all these factors may be built into a FDC *prior* to the simulation of the actual flow time series (Smakhtin 2000). The components of this approach, therefore, include: (i) technique(s) to establish representative FDCs for different types of ungauged river catchments and (ii) technique(s) by which the established FDCs may be transformed into actual continuous flow time series for any further analysis.

Estimating flow duration curves for EF sites

For ungauged sites (like EF sites in this study) FDCs may be constructed by means of hydrological regionalization (e.g., Smakhtin et al. 1997). If a graphical approach is used, for example, the FDCs from available gauged catchments in a physiographically homogeneous region may be standardized by some "index" flow (e.g., long-term mean discharge) and plotted on one graph. Each FDC is represented by several flows at fixed percentage points to cover the entire range of probabilities. By averaging the standardized ordinates of all curves for each of the fixed percentage points, the average regional curve may be calculated. In this study, three observed flow datasets (table 1) were used to calculate a regional FDC standardized by their long-term, mean daily discharge using the simple averaging procedure described above. The standardized curves and an average "regional" FDC are shown in figure 2. To estimate the actual (dimensional) FDC at each EF site, it is necessary to have an estimate of the mean annual runoff (MAR) for unregulated conditions for each site first. A long-term, mean daily discharge is then derived from the MAR for each site and the ordinates of the regional FDC are multiplied by this discharge. The MAR values at each EF site were estimated as described below.

FIGURE 2. Normalized flow duration curves constructed from observed flow data (thin lines) and the average (regional) curve (thick line).



EF1

The monthly time series for the Samanalawewa gauge (table 1) was used. These data are available for the period from 1960 to 1989, prior to the construction of the Samanalawewa reservoir in 1993. Therefore, the flow record is not affected by the flow regulation and may be used as the basis for the estimation of unregulated MAR. The estimated MAR obtained from this record was found to be 553 MCM. The mean daily discharge calculated from this MAR is 17.5 $m^3 s^{-1}$.

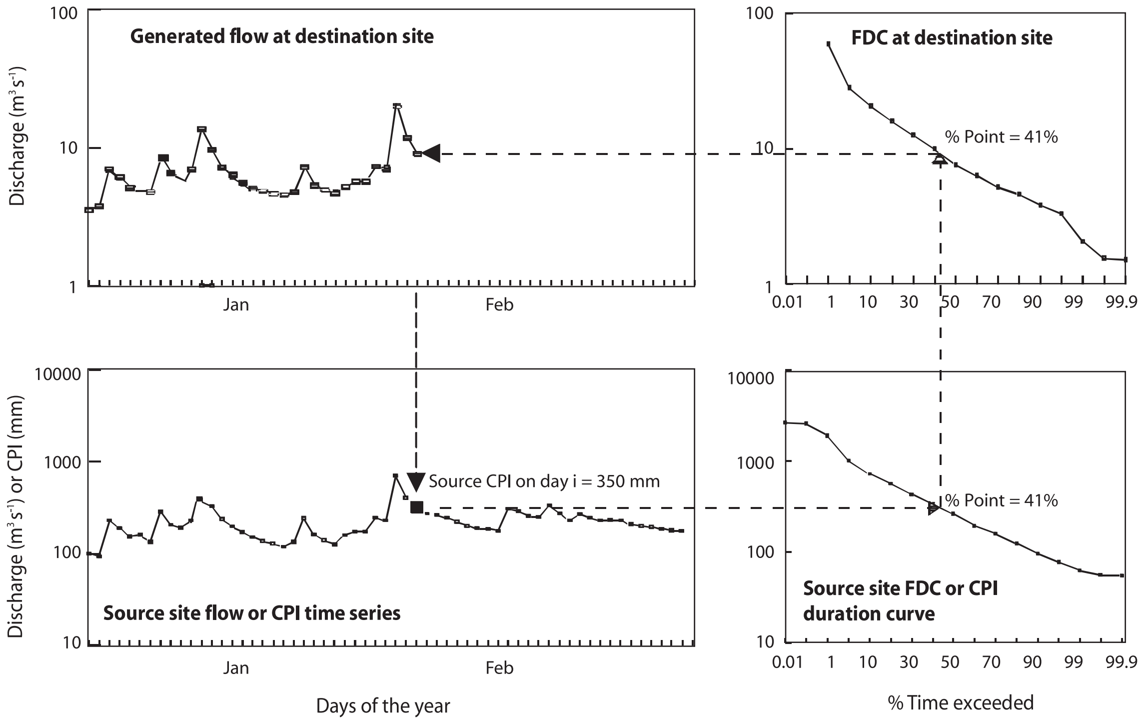
EF2

The monthly time series of inflows to Uda Walawe reservoir was used. The data on inflows to Uda Walawe reservoir exist for the period from 1960 to 1999, but to be consistent with the EF1 site, only the data for the period from 1960 to 1989 were used. Considering, similarly to EF1, that no major reservoirs were in place upstream of the Uda Walawe dam during this period, the record may be seen as being representative of unregulated flow conditions. The estimated MAR obtained from this record was 1,431 MCM and the corresponding mean daily discharge was 45.4 $m^3 s^{-1}$.

Generating continuous streamflow time series

Once a FDC is established, it may be converted into an actual continuous flow time series by a non-linear spatial interpolation algorithm developed by Hughes and Smakhtin (1996). The method uses the data from one or more "source" (gauged) sites and transfers these data through the FDCs to the "destination" site, where the flow time series is required. The main assumption of the algorithm in its original form is that flows occurring simultaneously at sites in a reasonably close proximity to each other correspond to similar percentage points on their respective FDCs. For each selected source and destination site, tables of discharge values are generated for each month of the year for the 17 fixed percentage points on the corresponding FDC (from 0.01% to 99.99%). The core of the computational procedure includes the estimation of the percentage point for each day's flow at the source site and the identification of flow for the equivalent percentage point from the destination site's FDC (figure 3). The discharge tables are used to "locate" the flows on corresponding curves and log-interpolation is used between fixed percentage points. If several source sites are used, the procedure is repeated for each of them and the final destination discharge value on that day is calculated as a weighted average of values obtained using individual source sites. The choice of source flow data is almost always limited and/or obvious, considering the scarcity of gauged records in data-poor regions.

FIGURE 3. Illustration of the spatial interpolation procedure.



If no suitable source flow gauge(s) with observed records can be identified in the vicinity of the destination site, use may be made of more readily available rainfall records. In this case, both source flow time series and source FDC (bottom two graphs in figure 3) are replaced by a rainfall-related function, reflecting the status of catchment wetness. The function is known as Current Precipitation Index (CPI). It reflects daily precipitation input in rainy days and an exponential depletion of catchment moisture during days with no rainfall (Smakhtin and Masse 2000).

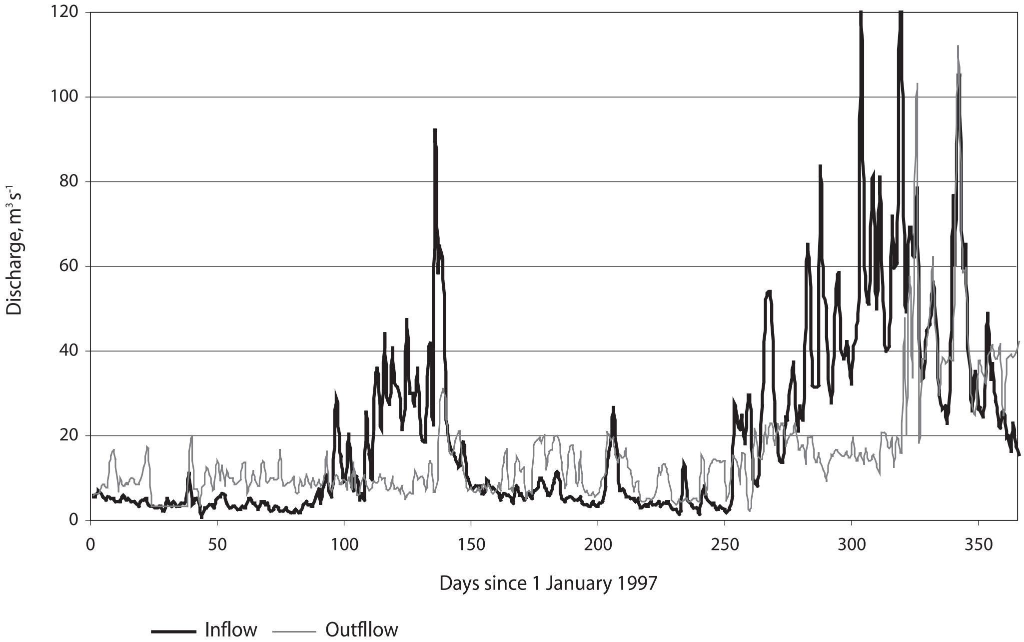
$$CPI_t = CPI_{t-1} K + R_t \quad (1)$$

where R_t is the catchment precipitation (mm) for day t and K is the recession coefficient, which varies in a small range and has limited impact on the resultant time series. Since no suitable flow gauges with "unregulated" daily data in the vicinity of EF sites are available in the Walawe basin, the use has to be made of rainfall data from the nearest rain gauges (table 1), as described below.

EF1

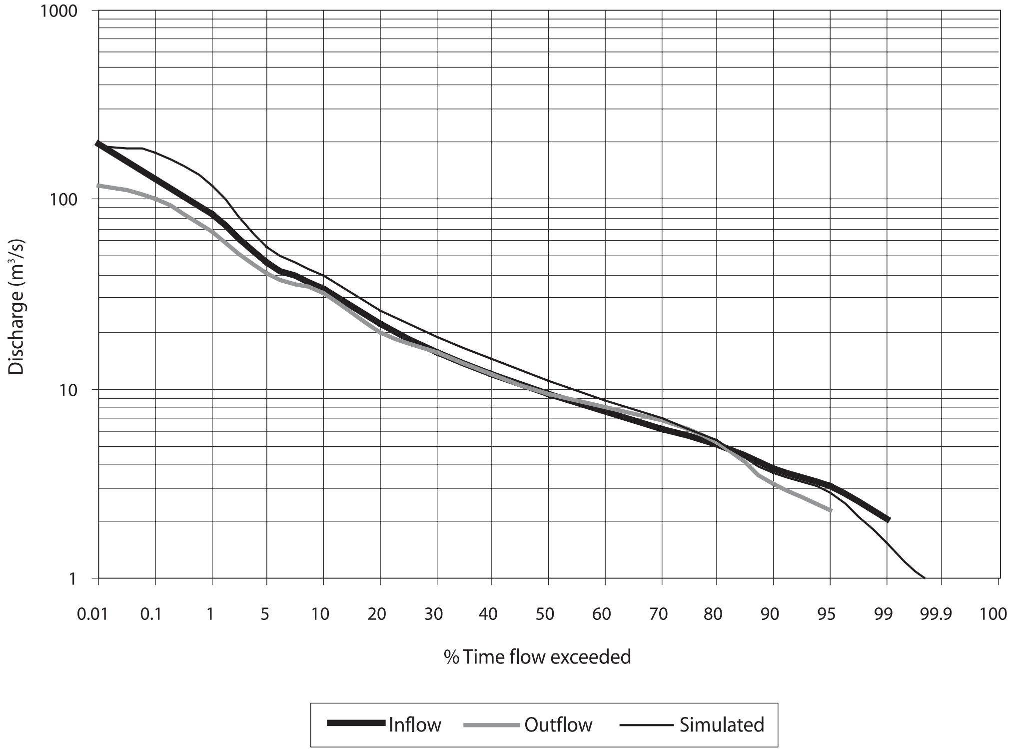
In principle, the time series representing unregulated flow conditions at the EF1 site is available. It is the time series of inflows to Samanalawewa. But this time series is rather short (table 1) and more importantly, its origin is unknown. Most likely this is the time series that was calculated by the Irrigation Department of Sri Lanka from the water balance of the reservoir. The outflow time series is also available for the same limited period. The comparison of both time series shows that the flows downstream of Samanalawewa have been modified and most of the high flows, in particular, have been lost or reduced (figure 4). Low flows, on the contrary, have increased, although less significantly. An attempt was made to simulate a longer representative time series of daily flows at Samanalawewa. The longest suitable source time series for this is the daily rainfall at the Detanagala rainfall gauge (figure1 and table1). However, visual analysis of its observed times series has shown that it is significantly out of phase with the measured inflow to

FIGURE 4. Extracts from measured inflow and outflow hydrographs at site EF1 (Samanalawewa).



Samanalawewa. Other rainfall time series are either from far away stations (e.g., Ambalantota and Uda Walawe Sugar Research Institute) or (e.g., Alupola) show inaccurately high values. The only other suitable gauge is Balangoda, which was used. But its record is limited to only 10 years, so the extension was only possible from the period 1990-2000. It, however, allowed a suitable time series for Samanalawewa to be generated with high flows slightly overestimated, as illustrated by the simulated FDC shown in figure 5.

FIGURE 5. Flow duration curves for measured inflow, measured outflow and simulated time series site EF1 (Samanalawewa).



EF2

Daily flow time series at the EF2 site has been simulated using the time series of two rain gauges, Uda Walawe Sugar Research Institute and Ambalantota. Both have relatively long records (table 1) and were found to have similar (although not identical) temporal variability patterns. The latter is important considering that there is no observed time series downstream of the Uda Walawe Reservoir against which a comparison of simulations could be made. The similarity between selected rain source sites suggests that they both reasonably well reflect the pattern of catchment wetness dynamics. This in turn will result in a representative simulated flow sequence that adequately reflects the flow, which could have been measured. A comparison has also been made between a FDC representing simulated time series of 1960-1999 and a FDC based on the observed record at Embilipitiya flow station prior to Uda Walawe dam construction (table 1). Although no direct comparison between hydrographs is possible due to non-overlapping records of both datasets, the FDCs were found to be very similar.

ASSESSMENT OF ENVIRONMENTAL FLOWS

One way of maintaining flow variability across the full flow regime is to protect the flow across the entire FDC. Some of the earlier developed EFA methods may be interpreted from this angle and subsequently used in this study. A Range of Variability Approach (RVA; Richter et al. 1997)) is an example of the technique where the role of hydrological variability in structuring and maintaining a freshwater-dependent ecosystem is raised to the highest level. Thirty-two hydrological parameters, which jointly reflect different aspects of flow variability, are estimated from a natural, daily flow time series at a site of interest. It is further suggested that in a modified (ecologically acceptable) flow regime, all 32 parameters should be maintained within the limits of their natural variability. For each parameter, a threshold of 1 standard deviation (SD) from the mean is suggested for use as a default arbitrary limit for setting environmental flow targets in the absence of other supporting ecological information. The RVA may be applied as a desktop tool. It ensures that sufficient water is available for human uses and accepts that it will not be possible to maintain the full range of natural streamflow variability in regulated or otherwise affected river systems.

The choice of parameters in the RVA is, however, subjective and excessive compared to the level of subjectivity involved. Smakhtin and Shilpakar (2005) argued and illustrated that the approach can be modified and rationalized without losing the major concept. In essence, modifications to the RVA are made to reduce the number of flow parameters, express them all as flows on the FDC and, following the RVA default threshold, assume that the attained value of each selected parameter should be:

$$(\text{mean} - 1\ \text{SD}) \leq \text{RVA parameter} \leq (\text{mean} + 1\ \text{SD}) \qquad (2)$$

In most of the impacted river basins, including Walawe, it is the overall reduction of flows that is the problem. It is, therefore, the first part of (2) above, which is of primary importance. This is a low-threshold condition: (mean –1 SD) ≤ parameter.

The selected parameters (flows) for an EF site may be located on its annual, period-of-record FDC. The percentage of time that each of these flows is exceeded is then estimated directly from the curve. Table 2 summarizes the results of this analysis for the EF2 site, upstream of which major water transfers in the basin occur from the Uda Walawe Reservoir. The number of RVA parameters in the modified method is equal to 16 (table 2), as opposed to the original 32. However, even this number may be reduced, for all practical purposes, as long as the entire range of flows for the construction of the FDC is covered. To illustrate this point, in this study only 6 parameters have been used (shaded rows in table 2). Others have either not been used or not estimated as superfluous.

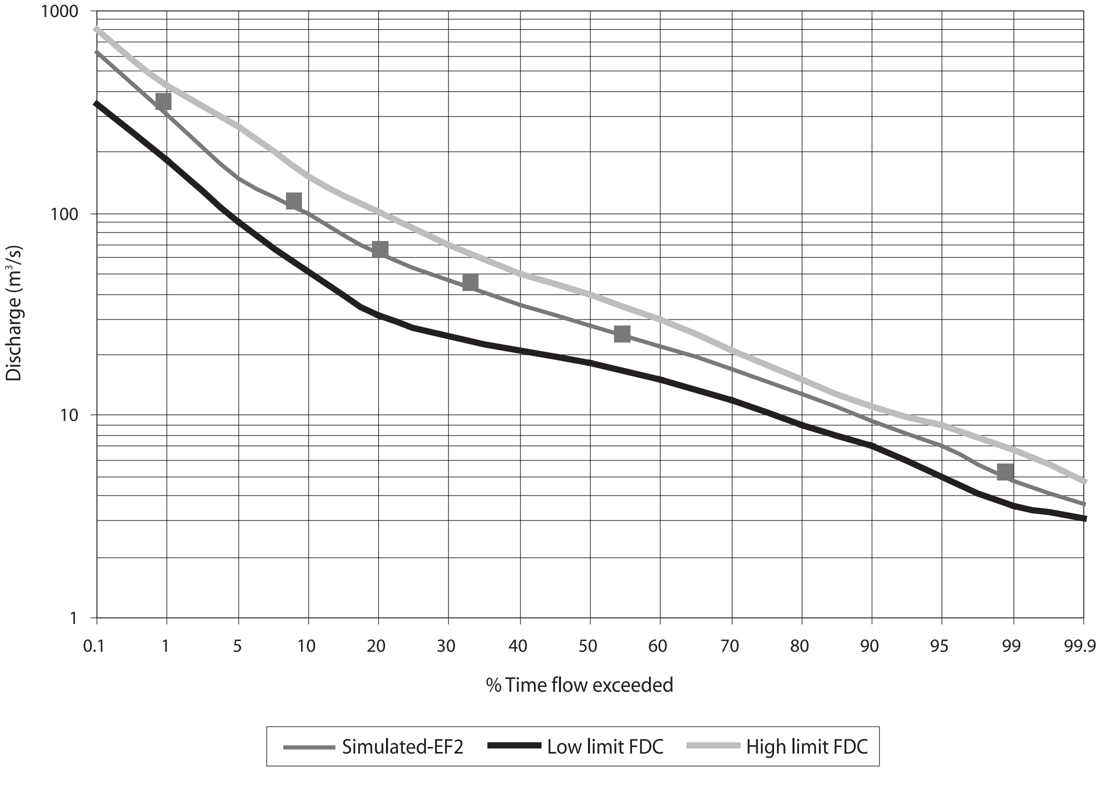
It has been assumed that the 6 selected flow parameters are exceeded the same amount of time in the modified (target) flow time series as in the 6 original parameters in the unregulated flow time series (table 2). The resultant “high-limit” and “low-limit” FDCs for the EF2 site may be estimated and plotted (figure 6). These FDCs are the summaries of environmental flow regimes in which the selected 6 flow parameters are at their highest ([mean+ 1 SD]) or lowest ([mean –1 SD]) acceptable default RVA limits.

Each “environmental FDC” can also be converted into a complete time series of environmental flows. The conversion could be easily done by using the same spatial interpolation approach described earlier and illustrated by figure 3. The interpretation of this approach needs only a minor change. The destination site now is an EF with a FDC representing the environmental flow regime (e.g., figure 6, lower curve). The source site is the same EF site but with a FDC and the actual time series, representing an unregulated, originally generated flow regime.

TABLE 2. Selected RVA parameter analysis for site EF2.

N	Modified RVA parameter	Mean ($m^3 s^{-1}$)	% time flow exceeded (for selected points only)	SD ($m^3 s^{-1}$)	Low (Mean –1 SD) ($m^3 s^{-1}$)	High (Mean + 1 SD) ($m^3 s^{-1}$)
1	Mean: January	39.3		16.9	22.4	56.2
2	Mean: February	27.1		15.4	11.7	42.6
3	Mean: March	30.9		13.9	17.0	44.9
4	Mean: April	43.7	32.0	19.2	24.5	62.9
5	Mean: May	50.3		23.1	27.2	73.5
6	Mean: June	31.3		13.5	17.8	44.7
7	Mean: July	28.8		9.5	18.5	37.6
8	Mean: August	25.6	54.0	8.7	16.9	34.3
9	Mean: September	31.4		16.0	15.4	47.4
10	Mean: October	66.4	19.0	34.5	31.9	101.0
11	Mean: November	118.5	7.5	65.2	53.3	183.6
12	Mean: December	67.2		35.0	32.3	102.2
13	1-day minimum	5.14	98.3	1.5	3.6	6.7
14	30-day minimum					
15	1-day maximum	339.6	0.8	86.1	253.5	425.7
16	30-day maximum					

FIGURE 6. Flow duration curves illustrating unregulated flows and estimated high and low thresholds of ecologically acceptable flows for site EF2 (Uda Walawe). (Markers show the location of the 6 flow parameters.)



This conversion and simulation of environmentally acceptable flow time series could be useful if the present-day flow time series downstream of the Uda Walawe reservoir is also available (they may then be compared and visualized). The authors, however, could not locate such a time series during the course of the study. It is possible that an approximation of such times series could be made on the basis of discussions with relevant specialists knowledgeable about the operating rules of the Uda Walawe dam. It is, however, possible to suggest that given the extensive water diversions from Uda Walawe, very little water is flowing at EF2 at all times. Therefore, it is unlikely that the RVA low-limit target is met.

CONCLUSIONS

The study illustrated how the required hydrological information can be generated for the locations where EFA is intended—quickly and in conditions of limited observed data (which is the typical case in most of Sri Lanka). This hydrological information (natural flow time series) is necessary regardless of the type of EFA method chosen and can also be used for different engineering applications. Simulating the *daily* streamflow hydrology of river basins is a particularly difficult case (compared with monthly modeling, for example), due to the complexity of hydrological processes at this scale and increased data requirements associated with it. At the same time, it is daily flow analysis which will be more needed in the future as the demand for accuracy increase and as new tasks are added to the agenda for water resources management. Assessment and maintenance of environmental flow requirements of rivers and wetlands have become the accepted concept in several countries in the world and are slowly emerging as such in Sri Lanka. Such assessment methods primarily use daily flow data.

This study attempted to adjust one hydrology-based, desktop EFA method to the Sri Lankan context using the Walawe River as an example. It is shown that this method is too elaborate for the level of subjectivity associated with it, but may be successfully simplified without losing its major concept—preservation of flow variability. Similarly, other hydrology-based desktop methods developed elsewhere need to be re-calibrated/tested in a different physiographic environment (like the monsoon-driven flow regimes of Sri Lanka) before they can be reliably applied. There is, therefore, a need to further develop/modify and test existing methods in specific river basins.

The development of environmental flow programs and requirements of other water resources projects will place more focus on detailed daily flow data. The situation regarding the availability of this type of data is particularly bad in developing countries, including Sri Lanka. On the other hand, countries like Sri Lanka provide an ideal opportunity for establishing a nationwide program of daily data assessment. This fits well with the major, international hydrological initiative known as Prediction in Ungauged Basins (PUB), in which Sri Lanka is actively involved (Weerakoon and Herath 2002). Such countries are relatively small and face no international data sharing issues. Weerakoon and Herath (2002) indicate that only 52 stations measure flow in Sri Lanka at present. But in the past, there were 142 stations measuring flow (Nakagawa et al. 1995). These data could prove very useful for extracting various flow characteristics and for regionalization. The approach that may be used for a nationwide program for the provision of hydrological *daily* time series could include:

- Identification of all observed *daily* and *monthly* time series in the country (covering past or current periods), which could be treated as nonregulated and which have at least 20 years of data.

- Calculation of several flow indices from *monthly* FDCs. The indices should cover the entire FDC and could include flows exceeded 5, 25, 50, 75 and 95 percent of the time, or similar indices.

- Establishing regression models for each of these indices with climate and catchment physiographic parameters to allow their estimation for ungauged sites.

- Establishing regression relationships between similar indices calculated from monthly and daily FDCs. The established regressions should allow the possibility to estimate a few base points on daily FDCs, whereas other flows will be estimated by means of extrapolation/ interpolation.

- Identification of representative, long *daily* flow records of *rainfall stations,* which will be used as "source sites." These could be used when necessary to generate daily flow time series. The approach can be verified on several independent datasets in Sri Lanka.

Weeragala (2004) has illustrated how a similar but simpler approach could be used to simulate representative monthly flow time series for ungauged river basins in Sri Lanka. Even the provision of monthly hydrological data for ungauged river basins would be a major step forward if it is available as a database covering the entire country at some regular spatial resolution. Many water resources applications, including desktop EFA assessment methods, could be based on such data.

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Postal Address
P O Box 2075
Colombo
Sri Lanka

Location
127, Sunil Mawatha
Pelawatta
Battaramulla
Sri Lanka

Tel.
+94-11 2787404

Fax.
+94-11 2786854

E-mail
iwmi@cgiar.org

Website
http://www.iwmi.org

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