

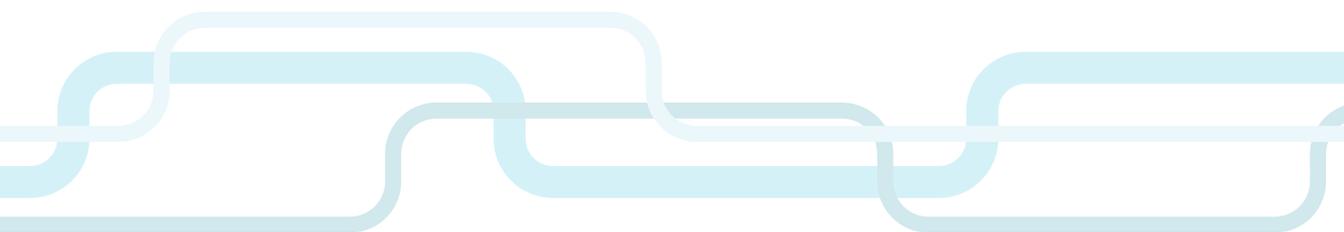


Food and Agriculture Organization
of the United Nations



Incorporating environmental flows into “water stress” indicator 6.4.2

**Guidelines for a minimum standard
method for global reporting**



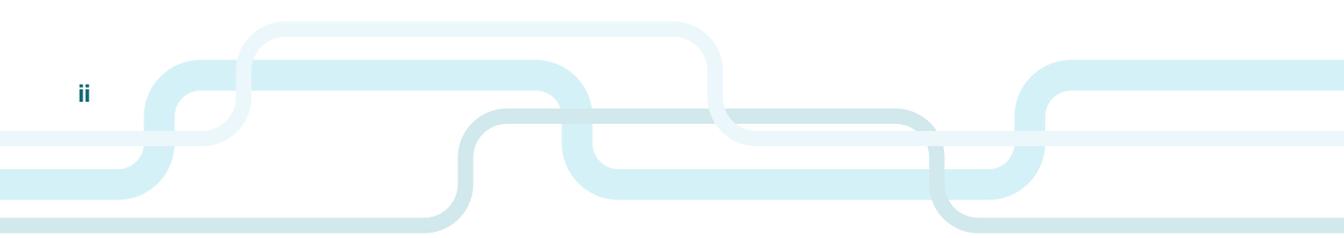
Incorporating environmental flows into “water stress” indicator 6.4.2

Guidelines for a minimum standard method for global reporting



By
Chris Dickens, Vladimir Smakhtin,
Riccardo Biancalani, Karen G. Villholth,
Nishadi Eriyagama & Michela Marinelli

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2019



Acknowledgements

This document is the outcome of a collaboration between the Food and Agriculture Organization of the United Nations, the International Water Management Institute, the United Nations University and the United Nations Environment Programme, in the context of the Integrated Monitoring Initiative for SDG 6 (GEMI) coordinated by UN-Water.

The authors wish to acknowledge the valuable oversight, guidance and inputs to this report provided by other FAO staff, particularly Olcay Ünver, Juan Calles Lopez, Jippe Hoogeveen, Lucie Chocholata and Soledad Bastidas.

They also wish to recognize the input from Alexandre Lima de F. Teixeira of the National Water Authority of Brazil, Zhao Zhongnan of the Ministry of Water Resources of China and Jonas Jägermeyr of NASA.

Special thanks go to all the experts who provided valuable comments and suggestions for improving the final text during the expert review exercise.

Financial support was provided by the Swiss Agency for Development and Cooperation (SDC) and the German Federal Ministry for Economic Cooperation and Development (BMZ) through the GEMI programme.



©Pixabay

1. Introduction

These guidelines are intended to assist countries to participate in the assessment of SDG 6.4.2 on water stress by contributing data and information on environmental flows (EF). These data are necessary for calculation of the SDG 6.4.2¹ indicator on water stress, for which countries are required to submit information to FAO who is custodian of this SDG indicator. This guideline provides a minimum standard method, principally based on the Global Environmental Flows Information System (GEFIS)², which is accessible via <http://eflows.iwmi.org>, and is the approach that will be used to generate the country EF data that will make up the global 6.4.2 report. Countries that have more comprehensive and accurate EF data will be able to make use of that data when checking the global dataset produced by FAO and also to add additional details to their Voluntary National report on SDG 6.4.2.

The types of reporting are outlined on the next page:

¹ <https://unstats.un.org/sdgs/metadata/files/Metadata-06-04-02.pdf>

² <http://eflows.iwmi.org/>

Global reporting on EF for SDG 6.4.2

FAO is required to periodically collect global data on water stress (SDG 6.4.2) and to report this to the UN IAEG (Inter-Agency and Expert Group on the SDGs). In order to do this, FAO makes use of global data sets on renewable water resources, water extractions from the system, and EF. This data is summarised per country and for major river basins and sent by FAO to each country.

Countries contribute to this global report by endorsing the global data for that country. Each country receives the EF data from FAO, and has the opportunity to lodge comment about its accuracy making use of the template provided by FAO. Where a country proposes corrections to the data set, these should be based on data that are at a greater level of confidence than what was used for the global data set (see the 6.4.2³ indicator method that details the “monitoring ladder” to achieve higher levels of confidence). For example, data generated using comprehensive EF methods such as mentioned under Section 4 can be used. There will not, however, be the facility for countries to change the global data set, which will be done by FAO.

This comment is returned by each country to FAO and represents the full extent of country contribution to the global report.

Voluntary National Review (VNR) on EF for SDG 6.4.2

Each country is invited by the Agenda 2030 to submit Voluntary National Reviews before the 2030 target date. It is anticipated that such VNR reports will contain a combination of the data used for the global report together with more detailed and higher confidence data, with Water Stress and EF data disaggregated to basin or sub-basin scale. In these reports, countries who have EF data determined at a higher level of confidence (see Section 4), can provide a more detailed assessment of the country situation with regard to EF and its relation to water stress as calculated using SDG 6.4.2. The UN has provided a guideline for countries to produce their VNR⁴.

³ <http://www.sdg6monitoring.org/indicators/target-64/indicators642/>

⁴ Guideline to drafting a Voluntary National Review: <https://sustainabledevelopment.un.org/vnrs/>



2. Definition of environmental flow and scope of these guidelines

There are several definitions of environmental flow/s (EF/s). However, for the purpose of this document, and in the context of SDG indicator 6.4.2 that focuses entirely on the quantity of water, EF are defined as “..the quantity and timing of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being” (*Brisbane Declaration, 2017, adapted*)⁵.”

This definition spans the twin responsibilities of management, to balance **the use** and **the protection** of the water resource, i.e. it seeks to provide the flows that will protect ecosystems and the human use of those ecosystems. The approach used here, in providing EF data for the 6.4.2 indicator calculation which is essentially a water quantity indicator, does not explicitly mention water quality or social issues and also is only applied to rivers and not other ecosystems (lakes etc), which may or may not be

⁵ The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018) <https://www.frontiersin.org/articles/10.3389/fenvs.2018.00045/full>

included in the definition of indicator 6.4.2. This does not imply that the quality of freshwater flows, which are dependent on EF are not important and should not be taken care of. They are indeed taken into account by other targets and indicators, such as 6.3.2, 6.5.1 and 6.6.1. These broader aspects of EF should be included as part of integrated water resource management in any country, but for the purpose of the 6.4.2 indicator, they are not included here.

It is important to stress from the start that EF can and should be set for any river – whether in a natural condition or in a significantly altered state. Setting EF for a river in a natural state would imply establishing scientifically determined and socially acceptable limits of water resources development for that river - prior to developments taking place.

The diagram below (Figure 1) offers a simplistic view of what EF are. The EF form the foundation for water resource management and in many countries are guaranteed by law (sometimes together with basic human needs). All water in excess of the EF is the utilizable or “allocable” water that resource managers can allocate and deliver to agriculture, industry and domestic water users. However it has to be said that at river basin scale, the distribution of flows over time should also be considered in order to assess the appropriate environmental flow at higher levels of detail.

Figure 1 | A schematic view of water resources available, EF and utilizable water





©FAO/John Isaac

3. Overview of the indicator 6.4.2 (“water stress”)

The SDG 6.4.2 indicator with associated step-by-step methodology⁶ is the official indicator as approved by the IAEG-SDGs under the UN, with the FAO as custodian. This “water stress” indicator provides an estimate of pressure by all sectors on the country’s renewable freshwater resources. It is defined as the total freshwater withdrawn (TFWW) by all economic sectors divided by the difference between the total renewable freshwater resources (TRWR) and the environmental flow requirements (EFR), multiplied by 100. It thus describes how much water is left and available in the environment.

$$\text{Water Stress (\%)} = \frac{\text{TFWW}}{\text{TRWR} - \text{EFR}} * 100$$

⁶ GEMI – Integrated Monitoring of Water and Sanitation Related SDG Targets Step-by-step monitoring methodology for indicator 6.4.2. Latest update: 26 April 2017, available on <http://www.sdg6monitoring.org/indicators/target-64/indicators642/>.

TRWR includes internal (generated within a country) and external (generated outside but made available within a country) renewable freshwater resources. TRWR is the long-term average annual flow of rivers and recharge of groundwater measured as a volumetric unit (km^3/year) and taking into consideration any overlap between them⁷.

TFWW is the volume of freshwater extracted from its source (rivers, lakes, aquifers). It is estimated at the country level for the three main sectors: agriculture, municipalities and industries (including cooling of thermoelectric plants). It does not include direct use of non-conventional water, such as treated wastewater, agricultural drainage water and desalinated water. TFWW can, naturally, change with time and is estimated for any given year.

The EFR is synonymous with Environmental Flows (EF) - established to protect the basic environmental services of freshwater ecosystems. In the indicator formula (Equation 1), EFR is also measured in volumetric units or flows, to be compatible with TRWR. EF are often reported as percentage of long-term mean TRWR (or mean annual flow), which can be converted into the volumetric unit (km^3/year).

Water stress percent should not exceed a certain desired threshold, which needs to be defined as a societal choice. A low level of water stress (e.g. < 25 percent) indicates a situation where the combined water withdrawal by all sectors is marginal in relation to the resources and has, therefore, little potential impact on the resources or on the potential competition between users. A high level of water stress (e.g. > 75 percent) indicates a situation where the combined withdrawal by all sectors represents a substantial share of the total renewable freshwater resources, with potentially larger impacts on the resources and the environment and potential situations of conflicts and competition between users. Stress levels exceeding 100 percent mean that the total water withdrawals already exceed the “allocable” water amounts that are available and are tapping into the established / desired EF or non-renewable resources (like fossil groundwater), indicating an undesirable and unsustainable situation.

⁷ The overlap between river flow and groundwater recharge is largest where groundwater contributes significantly to river flow (i.e., a significant fraction of groundwater recharge is converted into river flow via baseflow), which happens in humid areas. The other extreme is in arid areas, where river flow may contribute to groundwater recharge. Not accounting for this overlap, may overestimate TRWR.

The 6.4.2 indicator requires the inclusion of just three numbers, as per Equation 1. Two of these numbers (TRWR and EFR), are based on long-term averages, and thus they may be seen as constants for a country (or a basin) for the duration of the SDG period until 2030. The general assumptions here are that i) impacts of climate change and upstream (external) impacts on the TRWR may be ignored for the period till 2030, and ii) the established EF remains unchanged for the same period. However, should a country consider that its long-term values are rapidly changing due to evolving climatic conditions, it will be able to reflect these changes in the data collection sheets provided by FAO annually.

This document provides guidance only to the derivation of the EFR/EF and not the other components of Indicator 6.4.2.

BOX 1

Summary of existing approaches to estimate EF

The EF concept entered water management discussions in the mid to late 20th century after extensive dam construction led to large scale obstruction of free-flowing rivers and a noticeable loss of ecosystem services and natural habitats and biodiversity. Initial concerns were related to the impact of dams on game-fish species such as salmon, leading to the concept of minimum flows in the rivers (or minimum instream flows). Over subsequent decades, the concept of EF has evolved to encompass river flow variability, river connectivity (longitudinal and lateral), ecosystem services and human well-being and many methods have been developed to quantify EF.

There have been many reviews of these methods, but perhaps the most pragmatic and accessible is that of Acreman and Dunbar (2004) who categorized EF methods into four main groups of increasing complexity: 1) Look-up tables – methods that define EF by rule-of-thumb based on simple indices; 2). Desktop analysis – methods that are based on statistical analysis of time series of available data (either only hydrological data or hydrological data with ecological data); 3) Functional analysis – methods that link aspects of hydrology with ecology (i.e. direct response of species); and 4) Hydraulic habitat analysis and modeling – methods that link hydraulic characteristics with ecology. A comprehensive and recent review of EF methods is given by Horne *et al.* (2017).

BOX 1 (CONTINUED)

It is difficult to provide definitive evidence in support of the performance of different EF methods since there are many factors that guide the selection of a particular methodology. These factors include the scale and objective of the study; the level and quality of data available; and the resources including expertise available to carry out the study. While look-up tables and desktop methods tend to be more suitable for quick assessments or large-scale studies with low involvement of stakeholders, the other two groups of methods are more suited to local and regional studies, where more data are available and there is more interaction with local experts and stakeholders. In general, the latter two can be regarded as producing outputs of higher confidence, as they normally require site-specific field investigation. These methods are more “defendable in court” but take longer time to implement (months to over a year) for single river basins making it difficult to obtain a national estimate for all rivers.

For SDG reporting, at a global reporting level, desktop approaches using global datasets are most appropriate, although the option remains for individual countries to undertake assessments at a higher level of confidence and to report these (see Section 1). This guideline describes a global model (GEFIS available on <http://eflows.iwmi.org>) that is used for global reporting but can also be used by countries for general information on EF for countries and major basins.



4. Ecological Management Classes (EMCs)

It is necessary to include consideration of ecosystem state in estimation of EF for the Water Stress indicator. This is done by making use of the Ecological Management Class (EMC) system as described below.

In order to assess the state of an ecosystem, Kleynhans and Louw (2008) suggested that an “ecological category” can be used “...to define and type the ecological condition of a river in terms of the deviation of biophysical components from the natural reference condition”. This concept, originally developed in South Africa was adjusted to other regions and global conditions (Smakhtin and Anputhas 2006; Smakhtin and Eriyagama, 2008) and is now adopted by the UN Environment Assembly (UNEA) as the “Ecological Status Class” system (UN Environment, 2017). The Ecological Management Class (EMC), as used in this document, incorporates the above definition of ecological category but explicitly adds a management perspective. The EMC may thus be defined as the “*ecological condition of a river in terms of the deviation of biophysical components from the natural reference condition that will result from implementation of a particular management objective*”.

Classes A and B (see Table 1) represent *natural (unmodified) or largely natural conditions*, where no or limited modification has occurred or should be allowed from a management perspective. Class C is defined as *moderately modified*, where the modifications are such that they generally have a limited impact on the ecosystem integrity, although sensitive species are impacted. *Largely modified ecosystems* (class D) show considerable modification from the natural state where sensitive biota in particular are reduced in numbers and expanse and where community structure is substantially but acceptably changed. *Seriously modified ecosystems* (class E) are in poor condition where most of the ecosystem's functions and services are lost. This class is considered unacceptable from a management perspective as it represent ecosystems that are being used unsustainably⁸.

It is generally accepted that it will not be possible to sustain 100 percent of the condition that existed in a natural ecosystem before development started, and thus it becomes appropriate to accept some degree of decline in the quality of an ecosystem. Thus society needs to choose which of the EMCs are appropriate for each river. This reflects the trade-off that society must make, between the health of the ecosystem on the one hand, and a measure of what decline will be acceptable to society based on the benefits derived from developing the river. Different levels of EF are required to maintain a river in either a pristine state, its present state or an upgraded/ degraded state from its present condition. Table 1 provides an indication of how the ecosystem will respond to different management perspectives, dividing the range of options into five discrete EMC classes (from A to E).

⁸ Note: Some variation exists in previous representations of the EMC system. Sood *et al* (2017) as well as Kleynhans and Louw (2008) and others have used an A-F classification, while UN Environment (2017) has only A-E. However the concept remains the same, with the latter report simply combining classes E & F as these are both considered unsustainable and are not legitimate management objectives. This guideline makes use of an A-E classification

Table 1**Description of Ecological Management Classes (EMC)**

adapted from Sood et al, 2017 by merging Class E & F as these are both unsustainable

EMC	Most likely ecological condition	Management perspective
A (natural)	Natural rivers with minor modification of in-stream and riparian habitat	Protected rivers and basins. Reserves and national parks. No new water projects (dams, diversions) allowed
B (largely natural)	Slightly modified and/or ecologically important rivers with largely intact biodiversity and habitats despite water resources development and/or basin modifications	Water supply schemes or small irrigation developments present and/or allowed
C (moderately modified or “fair” condition)	The habitats and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present	Multiple disturbances associated with the need for socio-economic development, e.g. dams, diversions, abstractions, habitat modification and reduced water quality
D (largely modified)	Large changes in natural habitat, biota and basic ecosystem functions have occurred. Low species richness and enhanced presence of intolerant species. Alien species prevail	Significant and clearly visible disturbances associated with basin and water resources development, including dams, diversions, transfers, major abstractions, habitat modification and water quality degradation
E (seriously modified)	Habitat diversity and availability have declined. Ecosystems have been completely modified and basic ecosystem functions are failing. A strikingly reduced species richness. Only tolerant species remain. Alien species have invaded the ecosystem.	High human population density and extensive water resources exploitation is taking place with inadequate and/or polluted water in the ecosystem. This status is not acceptable from the management perspective. Management interventions are necessary to restore flow patterns and to ‘move’ the river to a higher management category
Ramsar sites	Preservation and sustainable use of wetlands	Convention on Wetlands (1971) and the Fourth Ramsar Strategic Plan (2015)

EF to maintain the present day EMC

It is possible to estimate the EF that, if provided in a river, will support that river in its present day EMC. The present day EMCs, ranging from A – E (Table 1), will vary between and along rivers based on their existing ecological state, as driven by the local presence of stressors that impact negatively on the river ecosystem, as well as on the biodiversity to be found in that river. It is thus necessary to know the present- day EMC in advance and to use that EMC as a framework for setting the EF. Note that the EF required to support the *present day EMC* is used to calculate the water stress index in SDG 6.4.2.

Ideally, the present-day EMC would be determined on-site for a single river or even part of a river by assessing the changes that have taken place to the ecosystem as a result of developments. Such assessments require the input of detailed ecosystem data including estimates of the quantity and quality of water, the habitat and biological changes that are taking place, acknowledging the drivers of change (developments etc.). Many countries are already undertaking such assessments (recently described by UN Environment (2017)), however, in order to provide a global dataset as a first estimate of the present day river ecosystem condition or EMC, the model in this guideline (GEFIS) makes use of a global dataset produced by Vörösmarty *et al.* (2010).

Vörösmarty *et al.* (2010) considered 23 drivers (grouped under 4 themes) to calculate an “Incident Biodiversity Threat Index” to rivers. The four themes were catchment disturbance, pollution, water resource development, and biotic factors. The index considers aggregated impact due to anthropogenic drivers directly (such as pollution, dam development, etc.) and indirectly (such as land use change, non-native fish, etc.), each of which is mapped globally. The resulting data for Incident Biodiversity Threat is represented in a global map at 0.5 degree spatial resolution, which is available at the <http://www.riverthreat.net/data.html> website (last viewed: June 2018).

The approach used in this guideline does not consider water pollution nor catchment disturbance factors, and thus considers only a part of the Vörösmarty index, i.e. only Water Resource Development and Biotic Factors to estimate the EMC (see Table 2). Details of this approach are provided in Sood *et al.*, (2017). A combined index of “threat” to freshwater river ecosystems ranges from 0 to 1 (0 being no threat and 1 being the

highest threat). The index was grouped into 5 classes 0-0.25, 0.25-0.5, 0.5-0.65, 0.65-0.75, >0.75 to represent EMCs of A, B, C, D, and E, respectively. The index classification was similar to Vörösmarty *et al.* (2010). According to Sood *et al.* (2017), a moderate threat level is reached when the index is above 0.5. This essentially corresponds to EMCs C and D in Table 1. The authors also suggest a high threat level is represented by an index value of 0.75 or greater, which corresponds to an E EMC in Table 1.

The present day EMCs (Figure 2) that are used to determine the global EF, are thus based on the present day ecological condition as determined by Vörösmarty *et al.* (2010). The EF that is then determined will be that amount of water required to maintain the river in the same condition that it is at present.

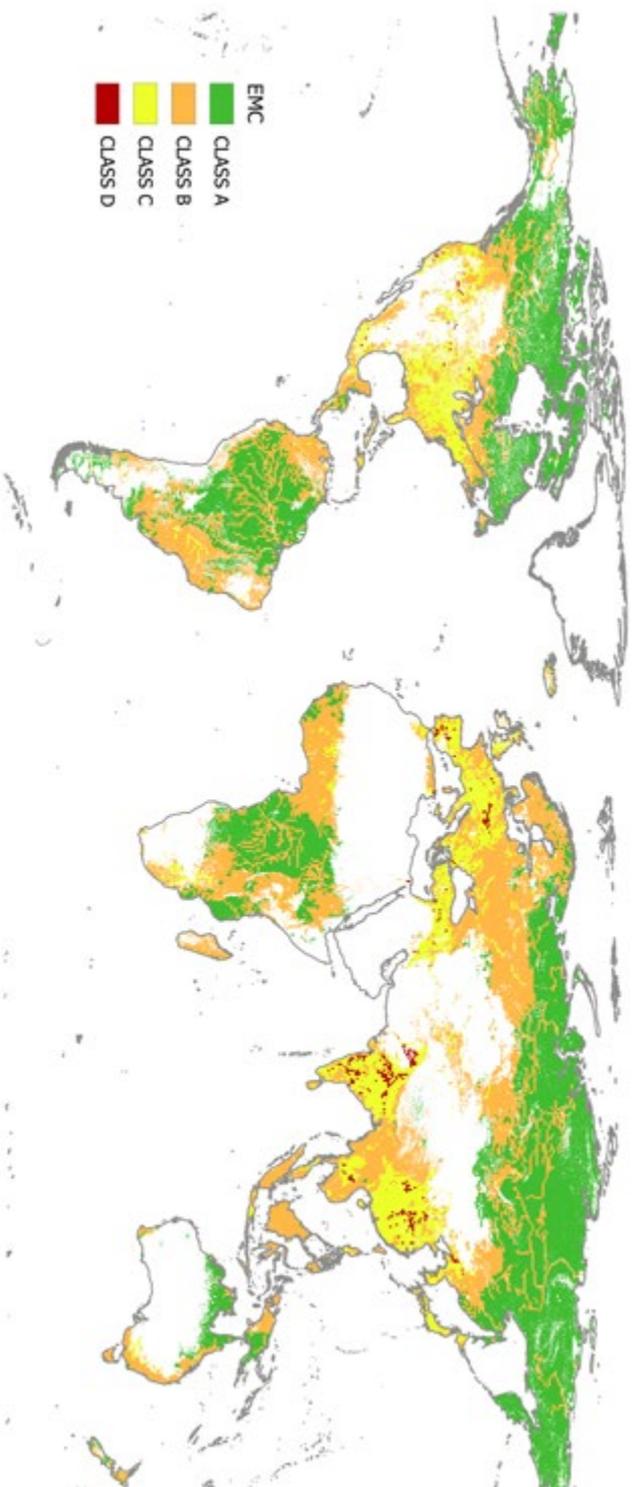
Countries however have the option to manage these rivers systems, and to either improve the river EMC in order to ensure greater resilience, or to allow the EMC to degrade if the country chooses to maximise the use of some ecosystem services at the expense of others. A country should not, however, plan for a river to be in an E EMC as this is regarded to be unsustainable and as such in contradiction with the aims of Agenda 2030.

Table 2

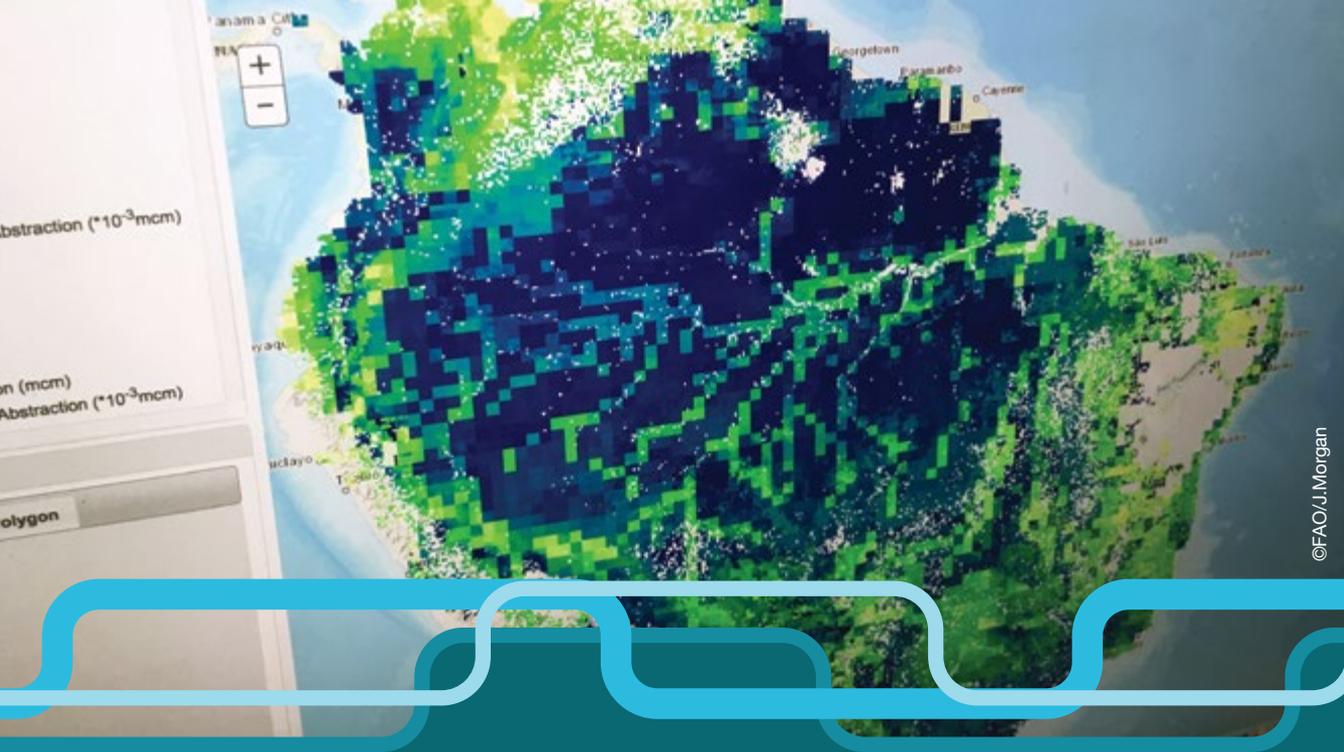
Themes and factors used by Vörösmarty *et al.* (2010) to calculate their "Incident Biodiversity Threat" for rivers, as refined by Sood *et al.* (2017).

Themes and factors	
Water resource development	Biotic factors
Dam density	Non-native fish (%)
River fragmentation	Non-native fish (#)
Consumptive water loss	Fishing pressure
Human water stress	Aquaculture pressure
Agricultural water stress	
Flow disruption	

Figure 2 | Estimated present day EMCs based on the Incident Biodiversity Threat of Vörösmarty et al 2010.



Source: Sood et al., 2017



5. Recommended approach to EF estimation – the Global Environmental Flow Information System (GEFIS)

As noted in Section 1, this guideline is intended to assist countries to work with global data sets of EF that are used to estimate the global water stress index (SDG 6.4.2). It also provides countries with an entry into understanding the EF of their rivers that may be used for management of water resources, in particular understanding how much water can be sustainably withdrawn from a river.

The approach described in this guideline uses the Global Environmental Flow Information System (GEFIS, available at <http://eflows.iwmi.org>) to provide quick estimates of EF (as a percentage of long-term mean annual unregulated river flow or as volumetric units (Mm^3/year)) for any part of the world - with a spatial resolution of 0.1 degree. The model makes use of time series of unregulated flow simulated by the global hydrological model PCR-GLOBWB (version 2.0; Wada *et al.* (2016)). These time series are used to construct a flow duration curve (FDC) - a plot that shows percentage of time the flow in a river is likely to equal or exceed a given flow value. A FDC

is a simple illustration of historic flow variability which is the key component in any EF concept and method, as it indicates seasonal and inter-annual variability.

The core part of the GEFIS method is the procedure that allows a FDC from the natural setting to be modified by a simple rule of thumb to generate a number of FDCs that represents realistic scenarios of reduced flow including the present day flow. These are then related to and represent prescribed / negotiated desired conditions of a river ecosystem i.e. the EMC. The procedure for adjustment of the FDC is described in detail in Smakhtin and Anputhas (2006) and Smakhtin and Eriyagama (2008). In essence, it performs a stepwise shift of a FDC, so that the total EF are reduced with declining EMC, while some features of natural flow variability are retained. The higher the EMC, the more water is needed for ecosystem maintenance and the more of the flow variability needs to be preserved.

Thus, the GEFIS provides a number of alternative EF estimations:

- The EF required to maintain the ecosystem in its present condition (present day EMC) (see Figure 4)
- The EF required to maintain the ecosystem in any alternative condition or class (from A - pristine, to D - largely modified).

Figure 3 | Lateral shift of a flow duration curve

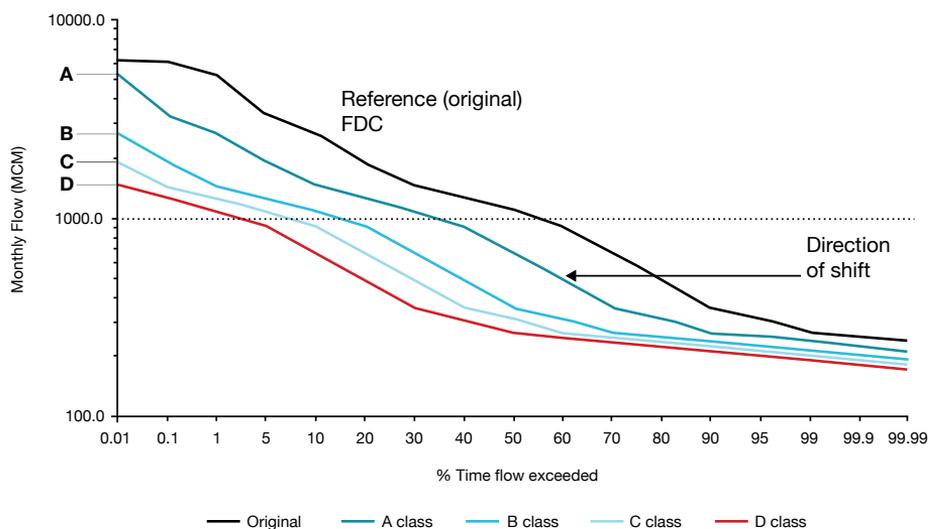
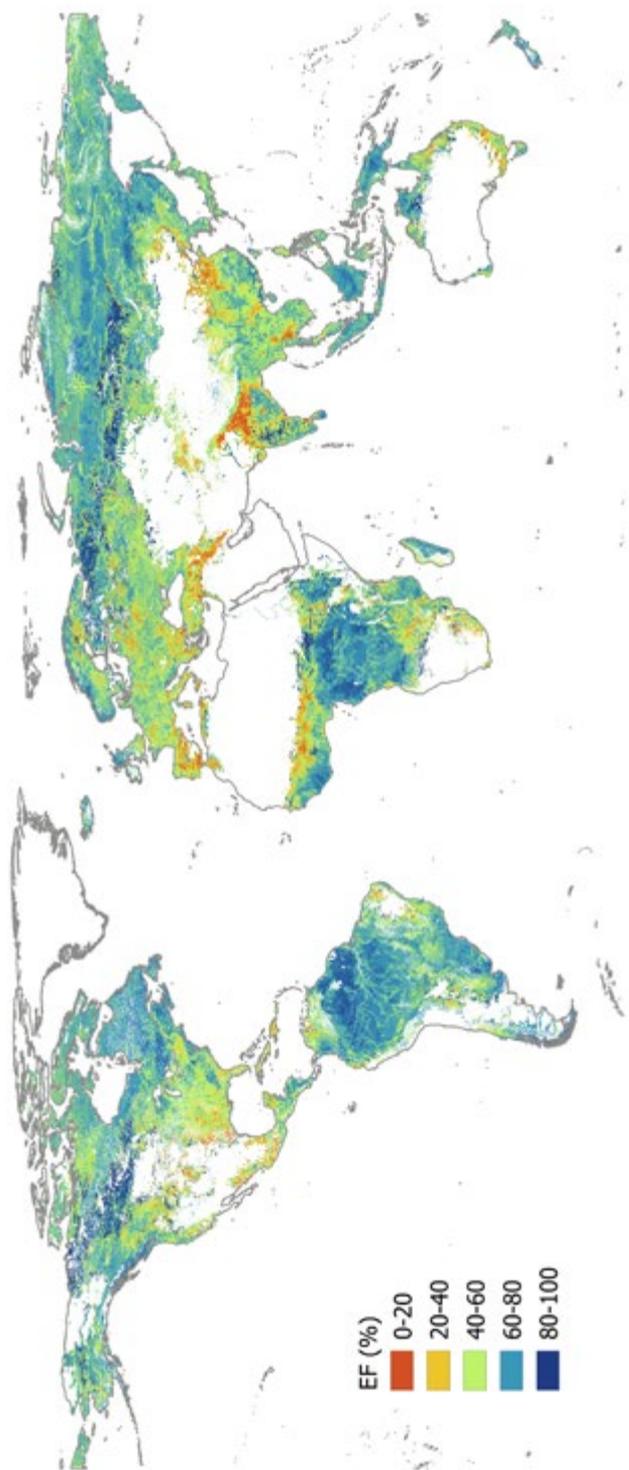


Figure 4 | EF as a percentage of mean annual natural flow for present day EMC



The 6.4.2 water stress indicator is designed to indicate the present day water stress, and thus it is the present day EMC that is appropriate to use here. A country may independently make use of the other estimations of EF to consider different scenarios, but these should not form part of the water stress calculation.

Stepwise procedure to follow in EF reporting

The steps for each country to follow in the EF assessment and reporting process are as follows:

1. FAO provides countries with an Excel spreadsheet containing the GEFIS-derived country and EF data for the present day EMC as reported in the GEFIS website (<http://eflows.iwmi.org>).
2. Each country should endorse this EF dataset making use of the template provided by FAO. Where a country chooses to reject either a part or the entirety of the EF data, it should enter appropriate comments and provide reasons, preferably backed up with credible data.
 - a. A country can provide its own EF estimations in the FAO report template, but these will not immediately change the global data set. Such data will be used for SDG reporting, and later to refine the GEFIS data for the next reporting period, as appropriate.
3. The EF value for the country or for a basin, can then be used for calculating the water stress indicator (SDG 6.4.2).
4. As noted in Section 1, countries may periodically submit Voluntary National Reviews, where the country will be free to provide data based on its own evaluations. In such reviews, the global data set can be challenged and the alternative situation, based on the country's own evidence, can be described. It would be expected that the evidence provided would be at a higher level of confidence than the global data provided by the GEFIS model.

Additional useful features of GEFIS

The GEFIS website provides additional functionality that is not used for estimation of Water Stress, however may be useful in guiding a country to

an enhanced water management strategy incorporating EF. Thus, a country may consider options for improvement of the EMC, and the tool can then estimate the implications for EF required to attain such EMC. Also, the website provides additional information such as volumetric units and base flows.

Importantly, as EF often are partially or fully supplied by discharge from groundwater (so-called base flow), EF conditions can be seriously impacted by abstraction from groundwater in the river basin in question. Rivers, especially in temperate zones, are sustained by groundwater discharge during the dry season. Also, springs are generated from groundwater outflow and can give rise to significant rivers, which are very sensitive to groundwater exploitation. The GEFIS provides an option to calculate the sustainable groundwater that can be abstracted in a basin under a given EMC (Sood *et al.*, 2017).

For country reporting on EF to the FAO, aggregated data per country are required, however the GEFIS model allows estimation of EF at any scale, from grid data at 0.1 degree spatial resolution to either basin or administrative scales. Ideally, EF should be determined for each homogenous section of a river because the EF for a mountain stream will be different to the EF for a lowland river, and a tributary could have a different EF to the main-stem river. This scale of information would be useful for in-country river management purposes where the allocation of water resources is being undertaken.

It has to be considered however that the GEFIS system, as a global model, is not always suited for application in smaller river basins, and that its outcome should always be validated before being used for planning purposes.

Expertise needed

Relevant persons in each country will receive an Excel spreadsheet reflecting the EF for that entire country and for the major basins. The receiving country is required to verify this data, and to accept or reject it with reasons provided in the reporting sheet provided by the FAO. Where

a country does not have a history in the estimation of EF, it may not have the expertise required to evaluate the data provided, in which case it may find it necessary to simply accept what has been provided, at least for the time being. Where, or when, a country has the capacity and is already conducting its own in-house assessments of EF, it will then be in a position to critically examine the data that is provided.

Typically, the most basic evaluation of the EF data will require person/s with an understanding of the state of the river ecosystems, and another person who is skilled in the application of EF desktop models.

Where a country wishes to be more involved in the management of EF through use of the more comprehensive methods of EF assessment, then the expertise that will be required will include a range of biophysical experts. This will include 5-7 local and / or international experts conversant with ecological aspects of water resources in that country (e.g. an inland fisheries specialist, an aquatic ecologist, a hydrologist, a fluvial geomorphologist, a water resources engineer), working together with government representatives who can articulate the vision for the particular water resource in question and then develop the EF requirements to meet that vision.

Limitations and further considerations for EF assessment and reporting

EF and estuaries

This guideline describes only the EF assessment for rivers and does not include estuaries. The determination of EF for estuaries is very different to rivers, and the resulting EF for an estuary may be very different from the contributing upstream river. Sometimes the EF that is set for an estuary will require that the EF of the upstream river is adjusted in order to provide for the downstream estuary. This detail is however only appropriate for National reporting on the SDGs, and not for the global report and so is not considered further here. At a national level however, it is important that countries consider the impact of providing water for downstream estuaries when managing river EF.

EF for international rivers

Many rivers cross international boundaries. The GEFIS dataset that is submitted to countries by the FAO is based on the present day EMC irrespective of international boundaries. For management of rivers at a country level, it is usually necessary to consider transboundary agreements to align EF estimations on both sides of the border and to facilitate overall basin management.

Limitation of the GEFIS data set

The method described here is based on the GEFIS model that is in turn based on a number of global datasets and accordingly produces outputs that are only as good as those global datasets. It must be recognised that local management may require data of greater accuracy, especially where these data are being used for costly infrastructure development and critical ecosystem and habitat protection. In this case, it would be appropriate for the country to engage experts to conduct a more confident estimation of EF using more holistic methods (see Box 1).

As noted earlier, this GEFIS data does not consider change in total renewable freshwater resources (TRWR) and EF that is likely to take place before 2030, either due to climate change or due to a change in the EMC from the present day. When it becomes necessary, and global water resource data sets have been updated, then the GEFIS global database will be updated.

Setting an EF target above or lower than the present day EMC

The EF for the present day EMC (provided this is between A-D) is the only value that should be contributed to the SDG 6.4.2 water stress indicator. However, this data and information provided by the GEFIS, affords a country the opportunity to alter its management strategy to move towards greater sustainability, while at the same time balancing the need to use and to protect the water ecosystem.

In those situations where the present day EMC is in an "E" class, which is considered to be unsustainable and thus should not be included in

management strategies, then an EF based on these EMCs will be lower than required to sustain the river and thus the water stress estimated would be an underestimate. In this situation a country should adjust their EF for at least a "D" class.

A country may decide to adopt a different objective to the present day conditions and may aim for an alternative EMC for each basin, either dropping to a "D" class or being elevated to a more natural condition ("A" or "B"), remembering that an "E" class is considered unsustainable and should not form part of a management objective. The most appropriate way to approach this would be to decide on a future EMC that would service the country best and in the most sustainable way. To do this would require bringing together experts on river ecosystems with other stakeholders to choose the desired EMC for each basin or river segment in the country. Setting such a vision, objective and targets needs to be done following a systematic process; guidance to which can be found in Horne *et al.* (2017), Dickens *et al.* (2018) and Dollar *et al.* (2010).



6. Conclusions

This guideline provides an entry into understanding and assessing the EF data required for estimating the SDG 6.4.2 water stress indicator. It gives an introduction to making use of the Global Environmental Flows Information System (GEFIS) as a first-level estimation of the EF for a country. For those countries with little capacity, this data as provided by the FAO can be accepted and used for inclusion in the 6.4.2 estimation. However, where it is known that this data is not of sufficient accuracy to reflect the situation in a basin or country, countries are free to make use of more accurate data in a comment on the data submission form but also in more detail during presentation of their Voluntary National Review.

References

- Acreman, M. C. and Dunbar, M. J.** (2004). Defining environmental river flow requirements – a review, *Hydrol. Earth Syst. Sci.*, 8: 861-876, <https://doi.org/10.5194/hess-8-861-2004>
- Arthington, A.H., Bhaduri, A., Bunn, S.E., Jackson, S., Tharme, R.E., Tickner, D., Young, W. Acreman, M., Natalie Baker, N., Capon, S., Horn, A., Kendy, E., Poff, N.L., Richter, B., Ward, S.** (2018). The Brisbane Declaration and Action Agenda on Environmental Flows. *Front. Environ. Sci.* 6:45. doi: 10.3389/fenvs.2018.00045
- Dickens, C, Smakhtin, V, McCartney, M, O'Brien, G and Dahir, L** (2018). *Defining and Quantifying National-Level Targets, Indicators and Benchmarks for Management of Natural Resources to Achieve the Sustainable Development Goals (SDGs)*. Preprints (www.preprints.org) Posted: 28 November 2018. doi:10.20944/preprints201811.0611.v1.
- Dollar, E.S.J, Nicolson, C.R., Brown, C.A., Turpie, J.K., Joubert, A.R, Turton, A.R., Grobler, D.F. And Manyaka, S.M.** (2010). The development of the South African Water Resource Classification System (WRCS): a tool towards the sustainable, equitable and efficient use of water resources in a developing country. *Water Policy* 12: 479–499.
- Horne, A.C., Webb, J. A., Stewardson, M.J., Richter, B. and M. Acreman.** (2017). *Water for the Environment*. Elsevier, Academic Press. ISBN: 978-0-12-803907-6.
- Kleynhans, C.J. and Louw, M. D.** (2008). *River EcoClassification: Manual for EcoStatus determination*. Report No. TT 329/08. Water Research Commission, South Africa.

- Sood, A.; Smakhtin, V.; Eriyagama, N.; Villholth, K. G.; Liyanage, N.; Wada, Y.; Ebrahim, G.; Dickens, C.** (2017). *Global environmental flow information for the sustainable development goals*. Colombo, Sri Lanka: International Water Management Institute (IWMI). IWMI Research Report 168. 37 pp.
- Smakhtin, V., Anputhas, M.,** (2006). *An Assessment of Environmental Flow Requirements of Indian River Basins*. IWMI Research Report 107. International Water Management Institute, Colombo, Sri Lanka.
- Smakhtin V., Revenga C., Döll P.** (2004). A pilot global assessment of environmental water requirements and scarcity. *Water International*, 29(3):307-317.
- Smakhtin, V. and Eriyagama, N.** (2008). Developing a software package for global desktop assessment of environmental flows. *Environmental Modelling & Software*, 23: 1396-1406.
- Smakhtin, V., Das, S., Arunachalam, M, Sivaramakrishnan, K.G., Unni, K.S., Joshi, G, Chatterjee, A., Behera, S., Gautam, P.** (2007) *An Assessment of Ecological Value and Condition of India River Basins for Estimation of Environmental Water Demand*. IWMI Research Report Series, N114, Colombo, Sri Lanka, 34 pp
- UN Environment,** (2017). *A Framework for Freshwater Ecosystems Management Vol. 1 Overview and Country Guide for Implementation*. UN Environment.
- Vorosmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden S, Bunn SE, Sullivan CA, Liermann CR, Davies PM.** (2010). Global threats to human water security and river biodiversity. *Nature*, 467(7315):555-61.
- Wada, Y., de Graaf, I. E. M. and van Beek, L. P. H.** (2016). High-resolution modeling of human and climate impacts on global water resources, J. Adv. Model. *Earth Syst.*, 8: 735–763

These guidelines are intended to assist countries to participate in the assessment of SDG 6.4.2 on water stress by contributing data and information on environmental flows (EF). These data are necessary for calculation of the SDG 6.4.2 indicator on water stress, for which countries are required to submit information to FAO who is custodian of this SDG indicator. The guidelines provide a minimum standard method, principally based on the Global Environmental Flows Information System (GEFIS), which is accessible via <http://eflows.iwmi.org>, and is the approach that will be used to generate the country EF data that will make up the global 6.4.2 report. Countries that have more comprehensive and accurate EF data will be able to make use of that data when checking the global dataset produced by FAO and also to add additional details to their Voluntary National report on SDG 6.4.2.



UNITED NATIONS
UNIVERSITY

UNU-INWEH

Institute for Water,
Environment and Health