Intecsa-Inarsa

# Analysis of the implementation of Environmental Flows in the wider context of the River Basin Management Plans

**(Report drafted in the framework of the *Comparative Study of Pressures and Measures in the Major River Basin Management Plans. Task 3d: Water Abstraction and Water Use*)**

# Final deliverable

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# 1. Abstract and Key Messages

The upcoming Blueprint to Safeguard Europe's Water will aim to ensure good quality water in sufficient quantities for all legitimate uses, including ecosystems.

> *The quantity, quality and timing of water flows required to sustain ecosystems and the services they provide are together called environmental flows. From this perspective environmental flows appear as an important mechanism to protect and enhance the status of aquatic ecosystems and promote a sustainable water use, thus contributing to the achievement of EU water policy goals*.

The above text is extracted from the Discussion paper: ENVIRONMENTAL FLOWS AS A TOOL TO ACHIEVE THE WFD OBJECTIVES, which introduces the technical and scientific bases of environmental flows (foundations, key concepts, utilities), briefly describes assessment methods and finally addresses the role of environmental flows [eflows[1]] in the context of the Water Framework Directive [WFD]. Building on the conceptual framework set out in that Paper, this document explores the degree of implementation of this management tool (or measure) across Europe.

With the available information, two main eflows components have been screened: the minimum ecological flow [MEF] requirements; and the operational modification for hydro-peaking (this one mainly linked with hydropower exploitation). From the simple absolute minimum flow, genuine and more complex eflows regimes may include other aspects such as the hydrological variability (inter-annual and seasonal) and connectivity (both longitudinal and lateral), essential for proper structure and functioning of aquatic ecosystems.

The screening, starting from River Basin Management Plan Assessments [RBMPAs][2], has been extended by own assessment carried out in the framework of this contract –covering Spain and Portugal, with most of their plans in Public Consultation stage– and complemented by consulting a variety of other sources as national questionnaires and personal contributions, mainly from *Water Scarcity & Drought* Expert Group members.

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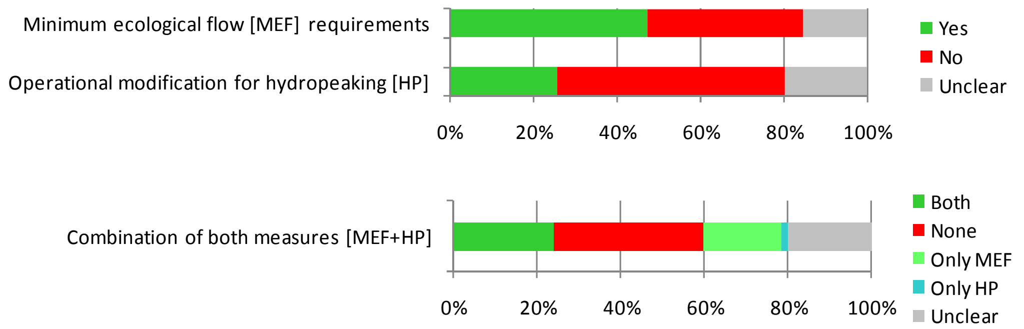
1 In literature, the expressions *environmental flows* and *ecological flows* are used with similar meaning. In this Report, the first expression has been preferred though the acronym eflows, compatible with both ones, is used.

On the other hand, eflows are frequently identified with *minimum flow* (either static or dynamic) which this report considers only one of various components of a genuine eflows regime (see section 4.5.6). Though this distinction is not only clear, when considered important to avoid confusion, the expression minimum flow or minimum ecological / environmental flow [MEF] is used.

2 Systematic assessment of RBMP carried out in the framework of the Compliance checking of the River Basin Management Plans.

**Fig. 1. Statistics of application of eflows components in European RBDs**



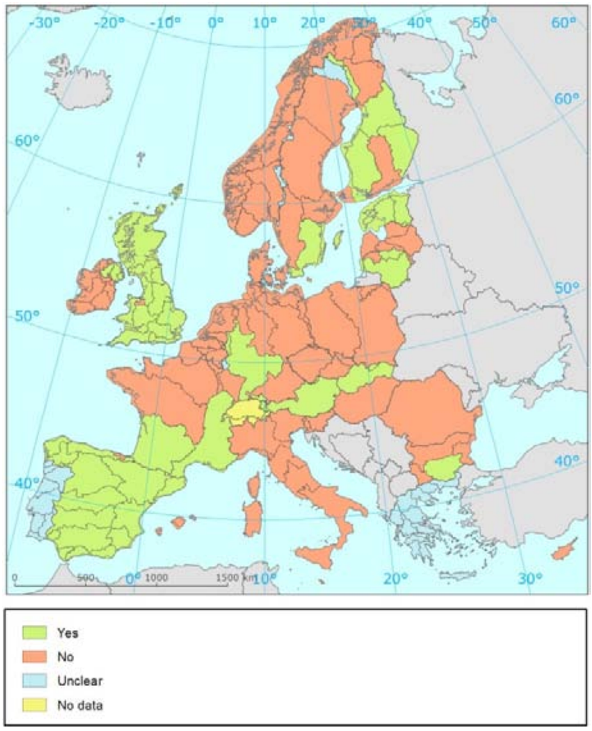

*Source: previous and own assessments*

According to these analysis, up to 88 River Basin Districts [RBDs] (47%) either have already implemented MEF (or similar tools)[3] or have planned it in the framework of the Programme of Measures [PoM], while other 69 (34%) show no explicit intention in this regard. Finally, in 29 RBDs (16%), available information is not sufficient to assess.

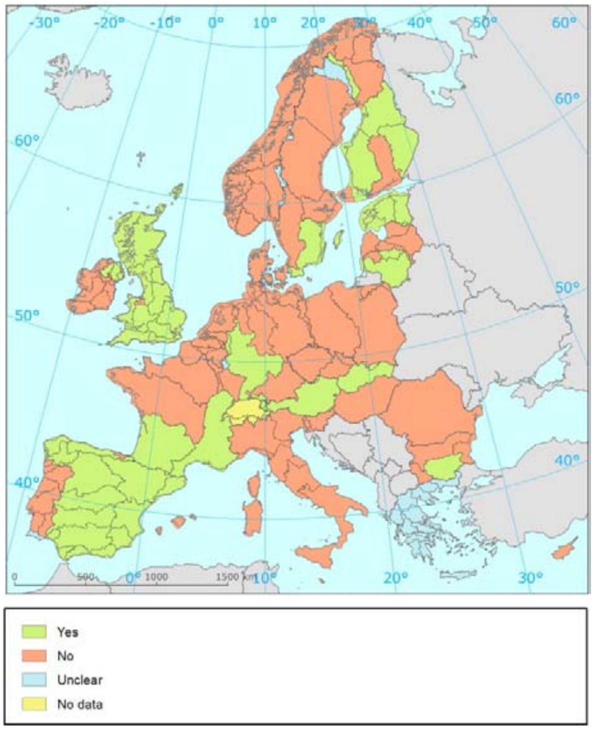
On the other hand, some kind of hydro-peaking conditioning scheme is considered in 48 RBDs (26%), while this is not so in 101 RBDs (54%) with 37 RBDs (20%) with unclear assessment. It must be pointed out that 45 RBDs (24%) have both measures either implemented or planned, 35 RBDs only MEF (19%) and 3 only HP (3%), while 66 have included neither of the two (35%).

3 The positive value may have quite different meanings with regard to the level of implementation (from a proposal in the PoM to full implementation) and scope (from all surface water bodies to some selected stretches).

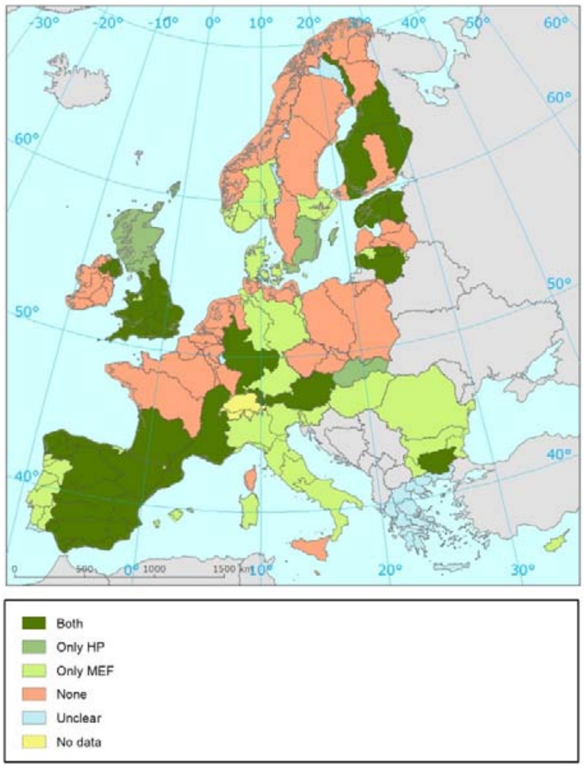
**Fig. 2. Maps of application of eflows components in European RBDs**




**Minimum ecological flows [MEF]**




**Operational modifications for hydro-peaking [HP]**




**Combination of MEF & HP**

*Source: previous and own assessments*

The potential (expected effectiveness) of MEF has also been evaluated at RBD level, with the intention to identify in which RBDs the implementation may be expected to contribute in a higher degree to environmental objectives[4]. The assessment (high / moderate / low) has been made on the basis of the information compiled in this study (see section 4.6), basically: RBMPAs, WISE data on abstraction and hydro-morphological pressures, national questionnaires, and expert judgment (including further assessment of RBMPs). The Water Exploitation Index - WEI (at national or RBD level) has also been used as a basic indicative of the existence of water scarcity problems and, so, of the convenience of preserving eflows in the general water allocation context of the basin. This work is done for all RBDs, even not assessed ones. The level of confidence has also been qualified.

# 2. Introduction

## 2.1. Main objectives of the assessment

Water abstraction and water use are a key pressure on many water bodies, in particular during temporary drought phenomena or in water scarcity prone areas. The current RBMPs have only partially dealt with water quantity aspects, and often only focused on the water supply for households and economic activities.

At present, we do not know the size of the projected gap in Europe between water demand and water availability. In this respect, the water and ecosystem accounts, developed together with the EEA, will quantify how much water flows in and out of the river basins. They are also expected to provide a comprehensive overview of water use and water availability, but it is still necessary to carry out a screening of measures taken to address pressures arising from water use.

This sub-task will provide detailed information on how **water scarcity and drought** (WS&D) and the **allocation of water for the ecosystems** are dealt in the RBMPs and, more generally, in the management of European river basins. It requires, where applicable, a closer look at Drought Management Plans [DMPs] and/or eflows assessment and provisions for implementation where applicable. The task is linked to the screening of RBMPs and is bound to feed to the Blueprint (policy options and impact assessment). The sub-task will also provide a comprehensive overview of pressures from water abstraction and measures addressed to mitigate its impacts. This analysis will inform the horizontal task.

This Report focuses on eflows while a similar one is dedicated to DMPs.

## 2.2. Definition of environmental flows and specific focus of this paper

The concept of **eflows** has been developed as a response to the degradation of aquatic ecosystems caused by overuse of water. There is still no uniform agreement for a definition of eflows but anyhow, there are always two key aspects of the concept included; the flow regime that should be considered; and the level of conservation for the ecosystem that is intended.

[4] Data on presence and impact of hydropower at RBD scale) has not been sufficient for a similar evaluation for operational modifications for hydro-peaking.

A combination of Arthington & Pusey and Tharme definitions (2003) might consider the most basic and relevant aspects of the concept of eflows[5]: "*Maintaining or partially restoring important characteristics of the* **natural flow regime** *(i.e. the quantity, frequency, timing and duration of flow events, rates of change and predictability/variability) in order to maintain specified, valued features of the ecosystem*".

This paper adopts a specific approach aimed at comprising the global requirement of water (quantity, quality and timing) that is set aside for the environment in order to maintain or restore water-dependent ecosystems, in the general context of water allocation within a basin. In comparison with the role of eflows as a tool to mitigate hydo-morphological impacts, this focus is more inclusive in two senses:

- It can also be applied to water bodies different from rivers, e.g. lakes & wetlands.
- Allocation refers to the process by which environmental requirements are granted in the general context of governance of the use of water within a basin / catchment.

From this perspective, eflows appear as an important mechanism to protect and enhance the status of aquatic ecosystems and promote a sustainable water use, thus contributing to the achievement of EU water policy goals.

## 2.3. Policy Background

The WFD is aimed at maintaining and improving the quality of aquatic ecosystems. It requires surface water classification through the **assessment of ecological status** –or ecological potential in case of Heavily Modified Water Bodies [HMWB] and Artificial Water Bodies [AWB][6]–, and chemical status. The quality elements that must be used for this assessment are divided into 3 groups: (1) biological elements; (2) hydromorphological elements supporting the biological elements; and (3) chemical and physical-chemical elements supporting the biological elements. The hydrological regime is one of the hydromorphological quality elements, considered a relevant variable that affects the ecological status, though it just have to be necessarily used when assigning water bodies to the High Ecological Status class:

**Table. 1. Hydrological regime and definition of status**

<table>
<tr><th>Category</th><th>Variable</th><th>Definition of High Status</th><th>Definition of Good Status</th></tr>
<tr><td>Rivers</td><td rowspan="2">Hydrological regime</td><td>The quantity and dynamics of flow, and the resultant connection to groundwater, reflect totally, or nearly totally, undisturbed conditions.</td><td rowspan="3">Conditions consistent with the achievement of the values specified for the biological quality elements in order to be classified as Good Status.</td></tr>
<tr><td>Lakes</td><td>The quantity and dynamics of flow, level, residence time, and the resultant connection to groundwater, reflect totally or nearly totally undisturbed conditions.</td></tr>
<tr><td>Transitional Waters</td><td>Tidal regime</td><td>The freshwater flow regime corresponds totally or nearly totally to undisturbed conditions.</td></tr>
</table>

[5] Adapted from Sánchez Navarro et al, 2012.

[6] Maximum Ecological Potential, as the reference conditions for HMWB and AWB, is intended to describe the best approximation to a natural aquatic ecosystem compatible with the hydromorphological characteristics that cannot change without significant adverse effects on the specified use or the wider environment.

**Table. 1. Hydrological regime and definition of status**

| Category | Variable | Definition of High Status | Definition of Good Status |
|---|---|---|---|
| Coastal Waters | | The freshwater flow regime and the direction and speed of dominant currents correspond totally or nearly totally to undisturbed conditions. | |

*Source: WFD CIS Guidance Document No. 10*

Though the flow regime required to achieve Good Ecological Status [GES] in river water bodies is not specified, it is unlikely to be reached if natural regime is significantly altered, as this will result in changes to the river ecosystem (e.g. physical habitat and sediment supply rates). Consequently, restoring a suitable flow regime may well be a necessary measure in an aquatic ecosystem that fails GES (Hirji and Davis, 2009). Moreover, eflows concept as defined previously is consistent with eflows necessary to reach the GES.

In this context, eflows could be defined as the hydrological regime necessary to achieve the values specified for the biological quality elements in order to be classified as Good Status, i.e. showing low levels of distortion resulting from human activity. Since proper functioning of aquatic ecosystems is linked with variation of flow types throughout the seasons and over the years, eflows regime should adequately consider different hydrological conditions (drought and wet years) in order to capture the inter-annual variability. Moreover, considering that biological populations have evolved according to typical ranges and patterns of the natural regimes, adequacy to the specificity of ecosystems in terms of magnitude, duration, frequency and timing of allocation must be guaranteed.

To sum up, it can be said that an eflows regime consistent with the GES must include the most relevant components of the hydrological regime to active the ecosystem dynamic and must reflect a large proportion of such natural regime.

Eflows are also bound to play a role in the process of identifying and designating a HMWB (Sánchez Navarro et al 2012), meaning "*a body of surface water which as a result of physical alterations by human activity is substantially changed in character*". A water body could be described as substantially changed in character if both morphology and hydrology are subject to substantial changes, especially when morphological changes are likely to be long-term. The concept of HMWB was introduced into the WFD in recognition that many water bodies in Europe have been subject to major physical alterations so as to allow for a range of important water uses of surface including navigation, flood protection, activities for the purpose of which water is stored (drinking water supply, power generation or irrigation) and recreation (Art. 4(3) (a)).

Finally, another two aspects of the relationship of eflows and WFD provisions must be pointed out:

1. Eflows should support the evaluation of **quantitative status of GroundWater Bodies** [GWB], since no significant damage to dependent terrestrial ecosystems or diminution of surface water chemistry and/or ecology may result from an anthropogenic water level alteration.
2. Eflows should secure hydromorphological standards to support the achievement of the conservation objectives that have been established for **Protected Areas**, preserving the ecological requirements of communities, habitats or species.

## 2.4. Linking eflows & DMP

The WFD places the integrity of freshwater ecosystems at the core of water management. For the purpose of protecting the environment is necessary to consider the water needs of aquatic ecosystems, thus contributing to preserve, protect and improve environmental quality and the rational use of water resources. Measures to prevent and alleviate drought consequences and water scarcity are thereby entirely appropriate within its context (WSDG 2006).

Although the WFD is not directly designed to tackle quantitative issues, its purposes include contributing to the mitigation of drought effects (art. 1. e) and the promotion of sustainable water use (art 1.b) and its environmental objectives include ensuring a balance between abstraction and recharge of groundwater (art 4.1(b)ii). Furthermore, water quantity can have a strong impact on water quality and therefore on good ecological and chemical status. In this respect, the Directive can be an instrument for addressing drought and water scarcity management (WSDEN 2008).

Water uses may alter natural conditions, affecting the associated ecosystems. It is therefore necessary to establish some criteria and general rules –in line with WFD requirements–- to make sure that water use is consistent with eflows, which ensure protection for the associated flora and fauna. By determining the characteristics of the vulnerable areas and their dependence on water, it will be possible to establish minimum and required water inputs for the maintenance and conservation of habitats and species. These minimum inputs could be defined within each DMP through indicators related to eflows, such as eflows regime, minimum water volumes in lake type water bodies or maximum abstractions from GWB with dependant riverine ecosystems and wetlands.

In addition to WFD Protected Areas, other natural ecosystems linked to water systems can present vulnerability to drought episodes. They can include:

- Plain areas that have a high evapotranspiration in the absence of water inputs.
- Lowlands near coastal areas easily invaded by marine waters with alterations in the ecosystems equilibrium.
- Geological areas dependent on groundwater springs.
- Areas linked to ephemeral or intermittent flows (surface inputs).
- Natural systems very close to the saturated level, and highly sensitive to variations in water levels.

During drought, a decrease in water inputs might endanger eflows, with an added risk of lowering water quality also affecting associated biological elements. Actions and measures that guarantee minimum eflows need to be established and monitored (measuring river flows, water levels in lakes and aquifers, physic-chemical parameters, and biological indicators), to ensure the survival of flora and fauna in these areas, in accordance with the WFD requirements, which include an obligation of no deterioration of the status of all water bodies.

## 3. Methodological approach and data sources

### *Phase 1*

The first step is the re-evaluation of other support studies and assessments for the Blueprint, some of them still in progress, to better adapt the output of the sub-task to the real needs of the Blueprint and its timing requirements.

The main documents and datasets that have been collected and analyzed are:

- Compliance checking of the River Basin Management Plans [2012]
- Water management, Water Framework Directive & Hydropower. WFD CIS Workshop, Issue paper [2011]
- Environmental Flows as a tool to achieve the WFD objectives. Discussion Paper [2012]
- Comparative analysis of methodologies for the implementation of environmental flows, according to the WFD. [2011]

### *Phase 2*

In this stage the **Data collected and information obtained in different sources will be crossed** to progress in the general understanding of the situation of eflows across Europe: implementation, pressures addressed, and other relevant features of the measure.

Depending on the results of these analyses, two complementary tasks would be carried out:

- Apart from RBMPs assessments, most of the available information deals with measures at the national or regional level. Occasionally it will be necessary to go back to RBMPs or to separate documents identified in the overview stage to clarify some aspects at the basin scale.
- Information interchange with some selected experts from the Water Scarcity & Droughts Expert Group or other institutions to confirm diagnosis at different levels and validate the identified links between pressures and measures.
- Relevant information and expert opinions have been collected in the CIS ECOSTAT Hydromorphology Workshop held in Brussels in 12th and 13th of June 2012. The workshop included a session on *Environmental flows in rivers affected by impoundments* , where some study cases at national and RBD level were presented.

This phase will also feed the horizontal task: measures database and factsheets, general assessment of effectiveness in different types of water bodies and at RBD scale and storylines. Study cases and specific examples will be provided under the envisaged overall coordination of Task 3.

### *Phase 3*

This phase is the Drafting of the **Final Report**. This report will include a summary of the work done and it is specifically designed to feed subsequent documents in the frame of the 2012 Blueprint for Water, giving policy recommendations and assessing impacts.

# 4. Environmental Flows in Europe

## 4.1. Initial screening of the RBMPs

The European Commission is currently assessing the compliance of RBMPs against the provisions of the WFD and carrying out a "bottom up" assessment of the plans. The compliance assessments is organised by topic templates, each of them answering a battery of specific questions, so that their results are expected to provide, in many cases, the basis or source of the data and information required for many of the Tasks under this Study Contract.

In relation to Sub-Task 3d, four topic templates contain significant information: **Measures related to hydromorphology**, **Strategy to deal with water scarcity and droughts**, **Assessment of Groundwater Status** and **Measures Related to Groundwater**. In the following pages the available assessment are reflected in summary tables and figures.

### 4.1.1. TOPIC: Measures related to hydromorphology

**HyMo-Q2) Which specific hydro-morphological measures are going to be taken (either to reach either GES or GEP)?**

Some options related with eflows are mentioned:

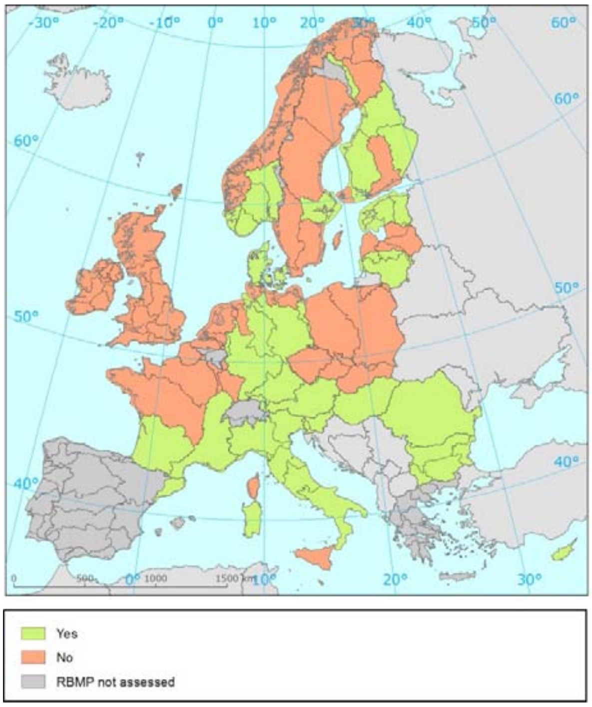
| | Hydromorphological measures to be taken related to eflows components | |
|---|---|---|
| | Setting minimum ecological flow requirements | Operational modifications for hydropeaking |
| True | 49 | 28 |
| False | 74 | 95 |

These two options may be identified with main components of an eflows regime and are described in more detail in section 4.5.6 and further analysed in the framework of PSI storyline in section 5.2). Three specific hydromorphological measures to be taken (to reach either GES or GEP) that may be linked to eflows components have been assessed. 49 RBMPs[7] (40%) have set MEF requirements, while 28[8] (23%) have considered operational modifications for hydropeaking.

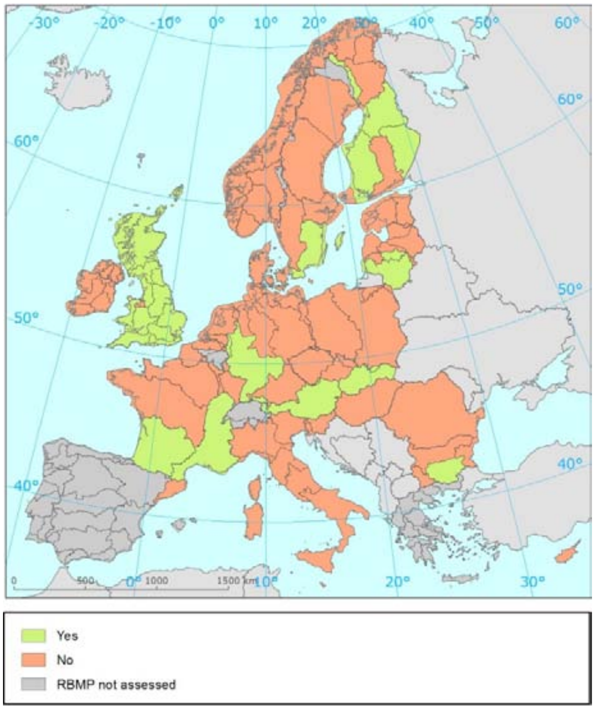
[7] AT1000, AT2000, AT5000, BG1000, BG2000, BG3000, BG4000, CY001, DE1000, DE2000, DE4000, DE5000, DE6000, DE7000, DK1, DK2, DK3, DK4, EE1, EE2, EE3, ES100, FIVHA1, FIVHA3, FIVHA4, FIVHA6, FRD, FRF, FRJ, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, LT1100, LT2300, LT3400, LT4500, NO5101, NO5102, NO5103, NO5104, RO1000, SE3, SI_RBD_1 & SI_RBD_2.

[8] AT1000, AT2000, AT5000, BG3000, DE2000, DE7000, FIVHA1, FIVHA3, FIVHA4, FIVHA6, FRD, FRF, LT1100, LT3400, SE4, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10 & UK12.

**Fig. 3. Which specific hydro-morphological measures are going to be taken (either to reach either GES or GEP)?**




**Setting minimum ecological flow requirements**




**Operational modifications for hydropeaking**

*Source: RBMP Assessmenst*

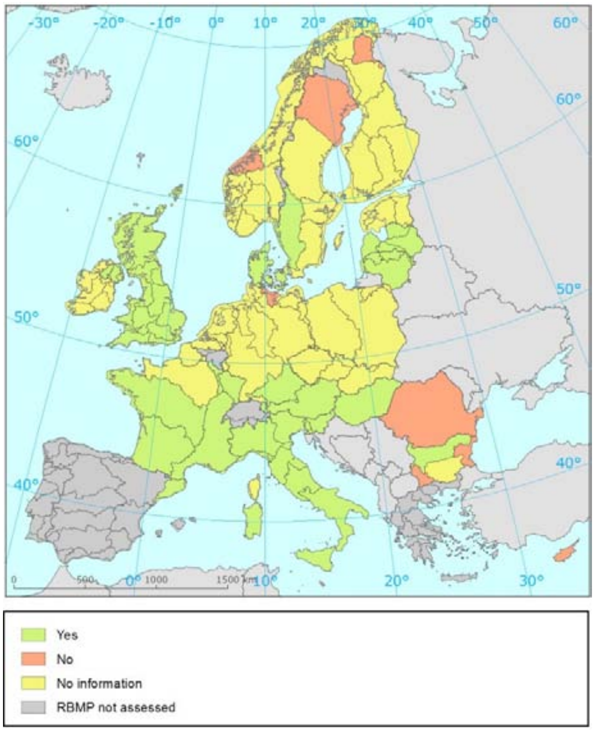
### HyMo-Q3) Are there general (national/regional) guidelines/regulations on the definition of an ecologically based flow regime?

| | Existence of general eflows guidelines / regulations |
|---|---|
| Yes | 50 |
| No | 9 |
| No info | 64 |

The existence of national and / or regional guidelines or regulations on the definition of an ecologically based flow regime has been established in 50 RBMPs[9] out of 123 (41%). In 4.5.1, detailed analysis of the coherence of these results with the information obtained in other sources is presented.

9 AT1000, AT2000, AT5000, BG1000, DE1000, DK1, DK2, DK3, DK4, ES100, FRB1, FRC, FRD, FRF, FRG, GBNIIENB, GBNIIENW, GBNINE, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, ITH, LT1100, LT2300, LT3400, LT4500, LVDUBA, LVGUBA, LVLUBA, LVVUBA, SE5, SI_RBD_1, SI_RBD_2, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

**Fig. 4.** **Are there general (national/regional) guidelines/regulations on the definition of an ecologically based flow regime?**




*Source: RBMPs Assessment*

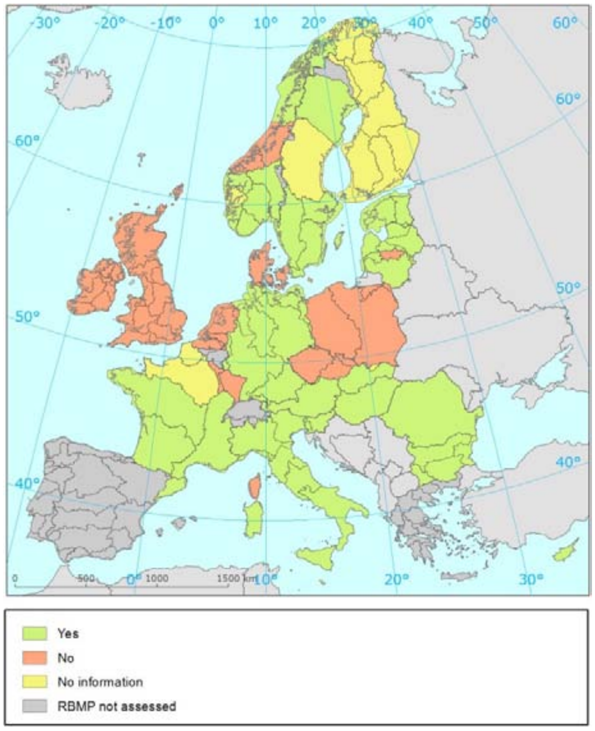
### HyMo-Q4) Besides the general guidelines/regulations on the definition of an ecologically based flow regime, are specific measures taken to achieve an ecologically based flow regime? (if positive, a description of measures should be given)

| | specific measures taken to achieve eflows regime |
|---|---|
| Yes | 61 |
| No | 45 |
| No info | 17 |

Specific measures have been taken to achieve an ecologically based flow regime in 61 RBMPs[10] (50%) and it must be pointed out that there is no coincidence with those basins where general guidelines or regulations are available, meaning that some RB Authorities should have established their own standards (see also section 4.5.1).

10 AT1000, AT2000, AT5000, BG1000, BG2000, BG3000, BG4000, CY001, DE1000, DE2000, DE3000, DE4000, DE5000, DE6000, DE7000, DE9500, DE9610, DE9650, EE1, EE2, EE3, ES100, FRD, FRF, FRG, FRI, FRJ, FRL, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, ITH, LT1100, LT2300, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, MTMalta, NO1103, NO1104, NO5101, NO5102, NO5103, NO5104, NO5106, RO1000, SE1, SE3, SE4, SE5, SI_RBD_1, SI_RBD_2 & SK40000.

**Fig. 5. Besides the general guidelines/regulations on the definition of an ecologically based flow regime, are specific measures taken to achieve an ecologically based flow regime?**




*Source: RBMPs Assessment*

### HyMo-Q5) Is there information in the RBMPs on how the planned hydro-morphological measures will improve the ecological status/potential?

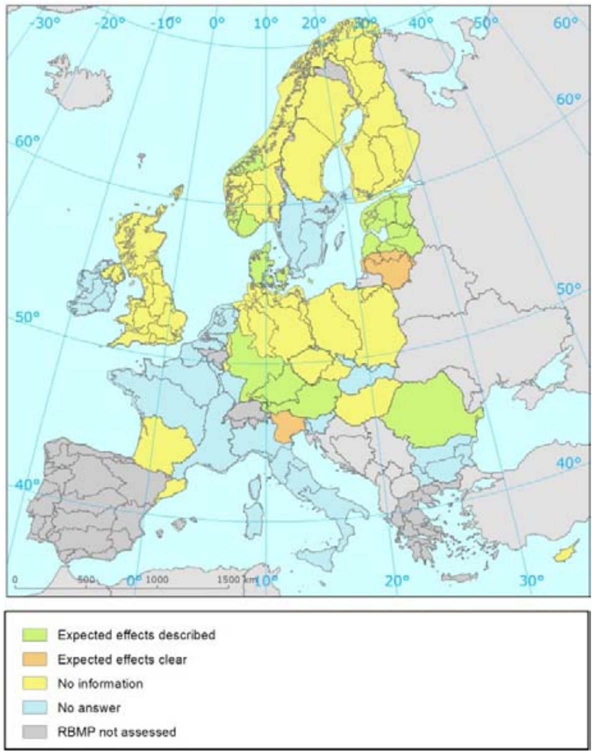
| | How the planned hydro-morphological measures will improve the ecological status/potential | |
|---|---|---|
| | Setting minimum ecological flow requirements | Operational modifications for hydropeaking |
| Expected effects are described | 20 | 11 |
| Expected effects are clear | 5 | 3 |
| No information / No answer | 98 | 109 |

Available information on how the planned hydromorphological measures will improve the ecological status/potential is explicit in only 44 RBMPs[11] (36%). With respect to those dealing with eflows

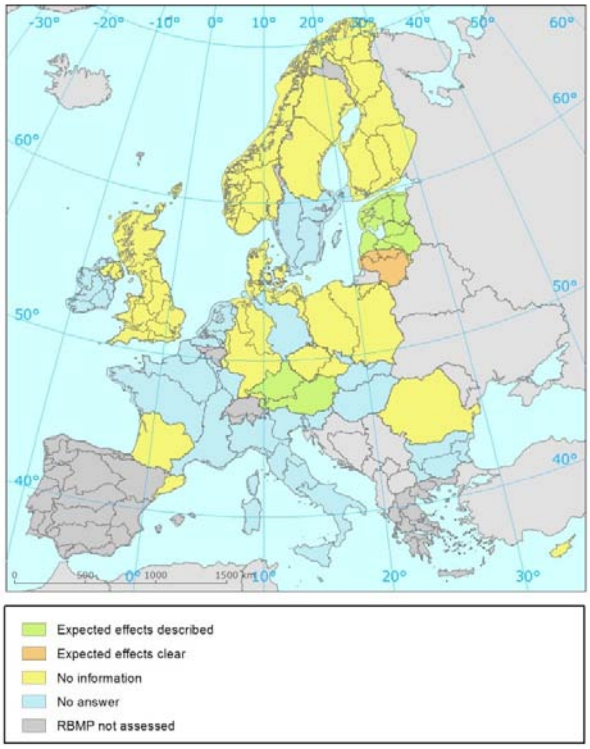
[11] AT1000, AT2000, AT5000, CZ_RB_1000, CZ_RB_5000, DE1000, DE2000, DE3000, DE4000, DE6000, DE7000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, EE1, EE2, EE3, FRI, FRJ, LT1100, LT2300, LT3400, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NO1103, NO1104, NO1105, NO5101, NO5103, NO5104, PL2000, PL6000, RO1000, SE1, SE2 & UK01.

components: 25 (20%) for setting MEF requirements[12], and 14 (11%) for operational modifications for hydropeaking[13].

**Fig. 6. Is there information in the RBMPs on how the planned hydro-morphological measures will improve the ecological status/potential?**




**Setting minimum ecological flow requirements**




**Operational modifications for hydropeaking**

*Source: RBMPs Assessment*

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12 AT1000, AT2000, AT5000, DE1000, DE2000, DK1, DK2, DK3, DK4, EE1, EE2, EE3, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NO1101, NO5103, NO5104 & RO1000 (expected effects are described); ITA, LT1100, LT2300, LT3400 & LT4500 (expected effects are clear).

13 AT1000, AT2000, AT5000, DE1000, EE1, EE2, EE3, LVDUBA, LVGUBA & LVLUBA (described); LT1100, LT2300 & LT3400 (clear).

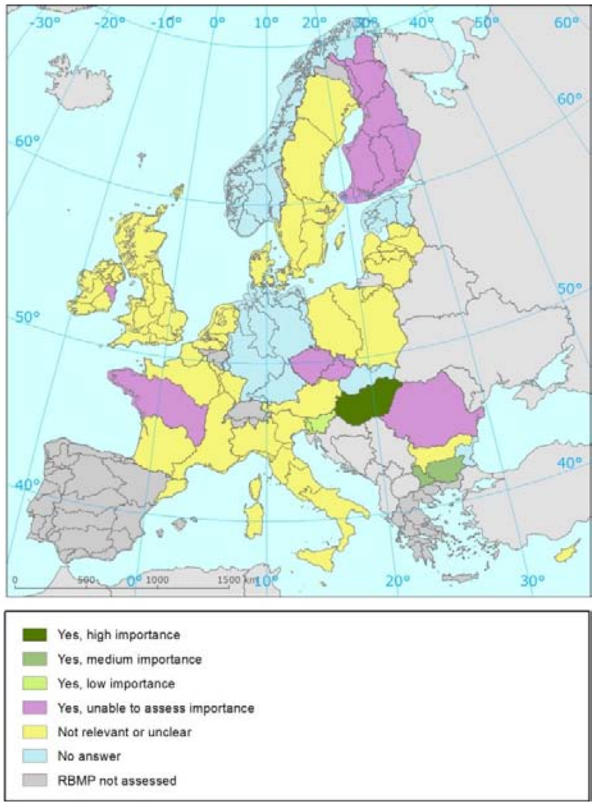
### 4.1.2. TOPIC: Strategy to deal with water scarcity and droughts

**WSD-Q5) Which measures have been included in the Programme of Measures?**

| | Which measures have been included in the Programme of Measures? |
|---|---|
| | Enhance the resilience of the ecosystems to WS&D |
| High | 1 |
| Medium | 2 |
| Low | 2 |
| Unable to asses | 14 |
| No information / No answer | 104 |

In the context of drought management, the enhancement of the resilience of the ecosystems to WS&D (supposedly by eflows) has been assessed in 19 RBMPs out of 123 (15%)[14].

**Fig. 7. Which measures have been included in the Programme of Measures? (resilience of ecosystem to WS&D)**




*Source: RBMPs Assessment*

14 HU1000 (high importance); BG3000 & BG4000 (medium importance); SI_RBD_1 & SI_RBD_2 (low importance); CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIVHA5, FIVHA6, FIVHA7, FIWDA, FRG, IEEA & RO1000 (unable to assess importance).

### 4.1.3. TOPIC: Assessment of Groundwater Status

**AGW-Q5) Which criteria specified in the WFD (Annex V) have been considered within the assessment of groundwater quantitative status and how?**

**5a)** The report provides information that the following conditions/impacts of groundwater abstractions have been considered when assessing groundwater quantitative status.

| | conditions/impacts considered when assessing groundwater quantitative status | | | | | | |
|---|---|---|---|---|---|---|---|
| | Available GWR not exceeded by LTA abstr. | Not GES achievement. for associated SWB | Significant diminution of SWB status | Significant damage for dependant SWB | Saline or water intrusion induced | Unclear | No criteria reported |
| True | 101 | 63 | 53 | 76 | 74 | 9 | 14 |
| False | 22 | 60 | 70 | 47 | 49 | 114 | 109 |

Most of RBMPs provide some kind of information on how impacts of groundwater abstractions have been considered when assessing quantitative status: 101 RBMPs[15] (82%) have assessed that available GWR is not exceeded by LTA abstractions; 63 RBMPs[16] (51%) have analysed if GES is not achieved for associated SWB; 53 RBMPs[17] (43%) if there is a significant diminution of SWB status; 76 RBMPs[18] (62%) if

15 AT1000, AT2000, AT5000, BEMaas_VL, BEschelde_VL, BG1000, BG2000, BG3000, BG4000, CY001, CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, DE1000, DE2000, DE3000, DE4000, DE5000, DE6000, DE7000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, EE1, EE2, EE3, ES100, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIVHA5, FIVHA6, FIVHA7, FRA, FRB1, FRB2, FRC, FRD, FRF, FRH, FRI, FRK, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, ITB, ITE, LT1100, LT2300, LT3400, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, MTMalta, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SE1, SE2, SE3, SE4, SE5, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

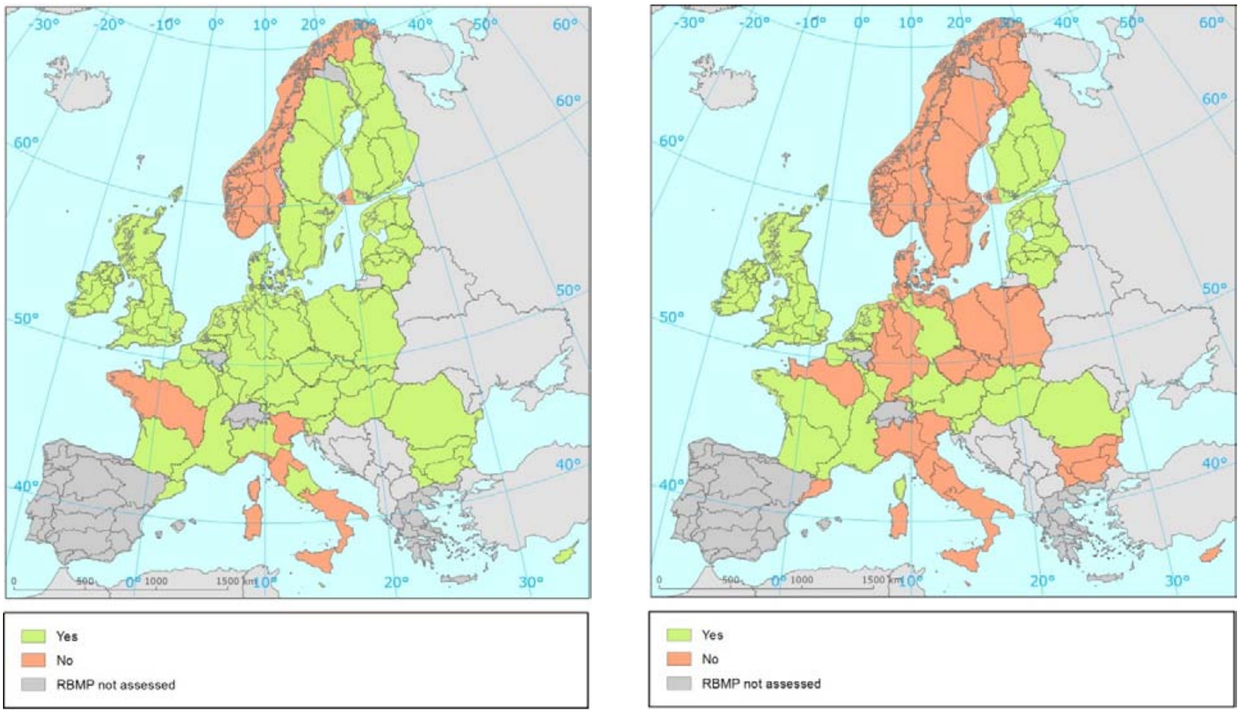
16 AT1000, AT2000, AT5000, BEMaas_VL, BESchelde_VL, DE1000, DE5000, EE1, EE2, EE3, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NLEM, NLMS, NLRN, NLSC, RO1000, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

17 BEMaas_VL, BESchelde_VL, DE1000, DE5000, EE1, EE2, EE3, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRH, FRK, FRL, GBNIIENB, GBNIIENW, GBNINE, ITE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SI_RBD_1, SI_RBD_2, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

18 AT1000, AT2000, AT5000, BEMaas_VL, BESchelde_VL, CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, DE1000, DE2000, DE3000, DE4000, DE5000, DE7000, DE9500, DE9610, DE9650, EE1, EE2, EE3, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRH, FRK, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SE3, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

there is significant damage for dependant SWB; and 74 (60%)[19] if saline or water intrusion has been induced.

**Fig. 8. Conditions/impacts of groundwater abstractions that have been considered when assessing groundwater quantitative status**

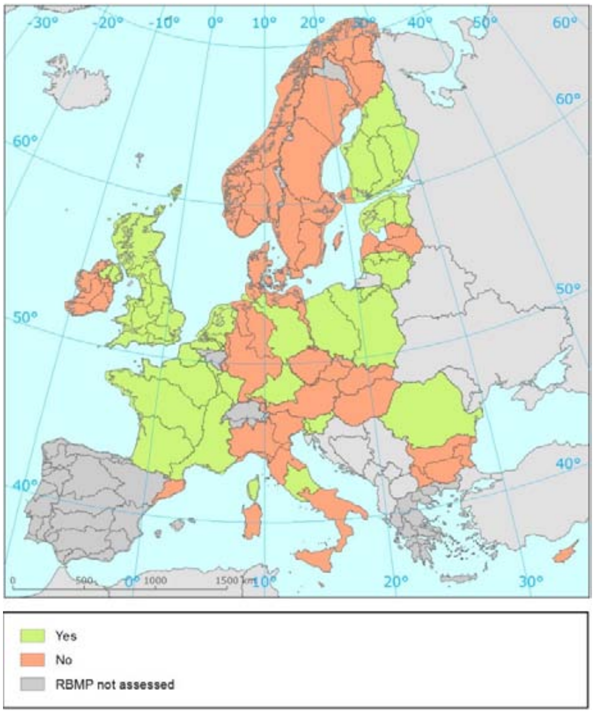



**Available groundwater resources not exceeded by long term average abstractions**

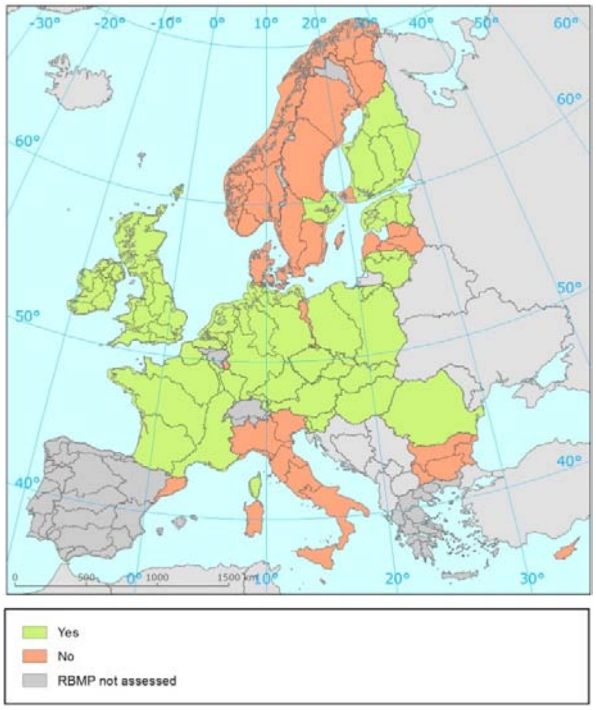
**Not achievement of environmental objectives for associated surface water bodies**

19 BEMaas_VL, BESchelde_VL, BG2000, CY001, DE1000, DE2000, DE5000, DE6000, DE9500, DE9610, DE9650, EE1, EE2, EE3, ES100, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIWDA, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRH, FRK, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SE1, SE2, SE3, SE4, SE5, SI_RBD_1, SI_RBD_2, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

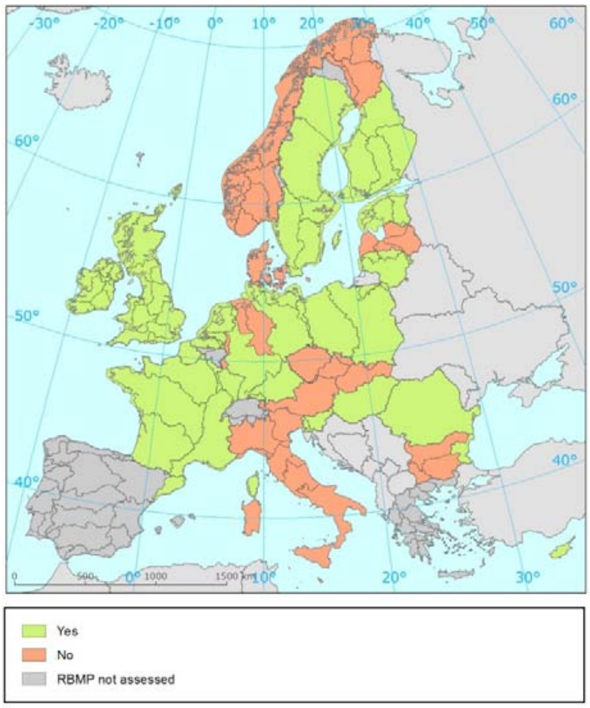
**Fig. 8.** **Conditions/impacts of groundwater abstractions that have been considered when assessing groundwater quantitative status**




**Significant diminution in the status of associated surface water bodies**




**Significant damage for dependant SWB**




**Saline or other water intrusions induced**

*Source: RBMPs Assessment*

**5b)** The report indicates that 'available groundwater resource' has been applied in accordance with Art 2.27 WFD[20] (so taking into account damage to terrestrial ecosystem)

| | Accordance with WFD definition of available groundwater resource |
|---|---|
| Fully | 54 |
| Partly | 10 |
| Unclear | 22 |
| No information provided | 37 |

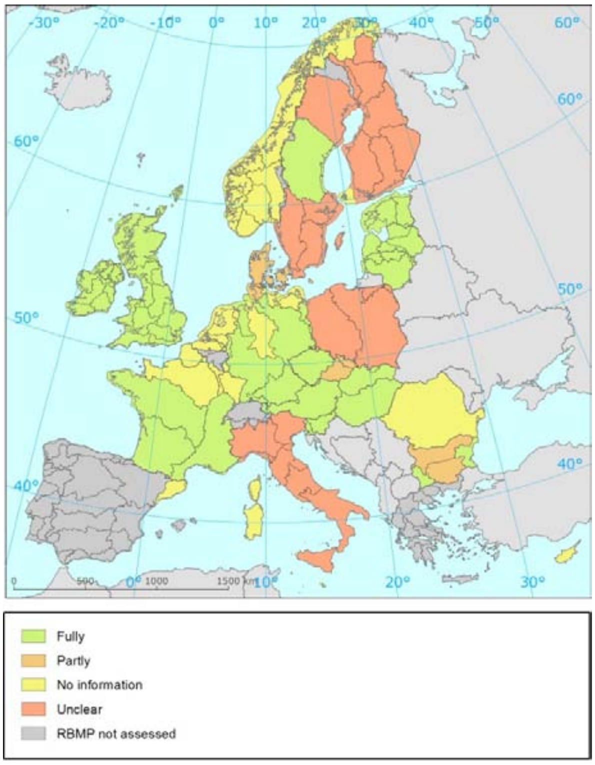
'Available groundwater resource' has been applied in accordance with Art 2.27 of the WFD –so taking into account flow required to achieve the ecological quality objectives for associated surface waters (eflows)– in 64 RBMPs, qualified as ‘fully’ in 54 cases[21] (51%) and ‘partly’ in 10 cases[22] (7%).

20 Available groundwater resource means the long-term annual average rate of overall recharge of the body of groundwater less the long-term annual rate of flow required to achieve the ecological quality objectives for associated surface waters specified under Article 4, to avoid any significant diminution in the ecological status of such waters and to avoid any significant damage to associated terrestrial ecosystems.

21 AT1000, AT2000, AT5000, BG2000, BG4000, CZ_RB_5000, DE1000, DE2000, DE3000, DE5000, DE6000, DE7000, EE1, EE2, EE3, FRD, FRF, FRG, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, LVDUBA, LVGUBA, LVLUBA, LVVUBA, SE2, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

22 BG1000, BG3000, CZ_RB_1000, CZ_RB_6000, DE9500, DK1, DK2, DK3, DK4 & FRL.

**Fig. 9. Accordance with WFD definition of available groundwater resource**




*Source: RBMPs Assessment*

**5c)** It has been reported that the needs of the terrestrial ecosystems associated to groundwater bodies have been assessed.

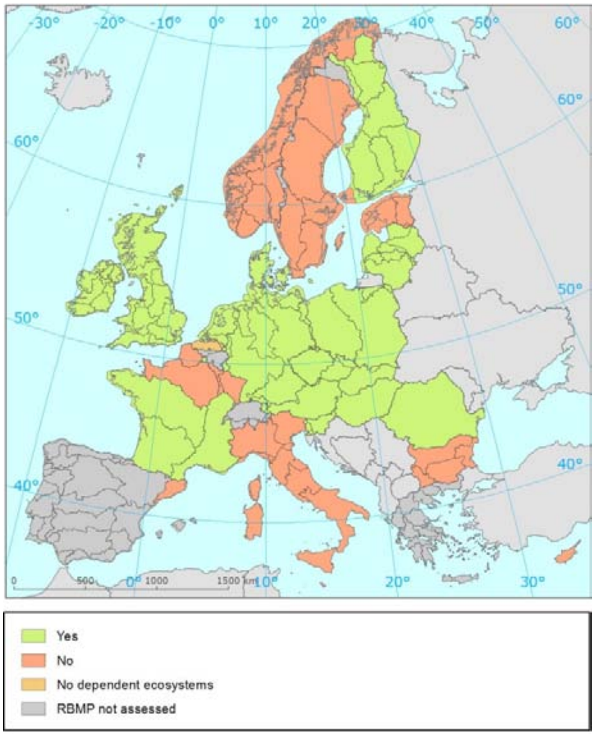
| | needs of associated terrestrial ecosystems have been assessed |
|---|---|
| Yes | 76 |
| No | 44 |
| No dependent ecosystems | 3 |

Most of RBMPs, specifically 76[23] out of 123 (62%), indicate that the needs of associated terrestrial ecosystems have been assessed to determine groundwater quantitative status. Only 3 RBMPs[24] declare that no dependent terrestrial ecosystem exists.

23 AT1000, AT2000, AT5000, CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, DE1000, DE2000, DE3000, DE4000, DE5000, DE6000, DE7000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIVHA5, FIVHA6, FIVHA7, FRB2, FRD, FRF, FRG, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

24 BE_Nordzee_FED, BEMaas_VL & BESchelde_VL.

**Fig. 10. Have the needs of the terrestrial ecosystems associated to groundwater bodies been assessed?**




*Source: RBMPs Assessment*

### 4.1.4. TOPIC: Measures Related to Groundwater

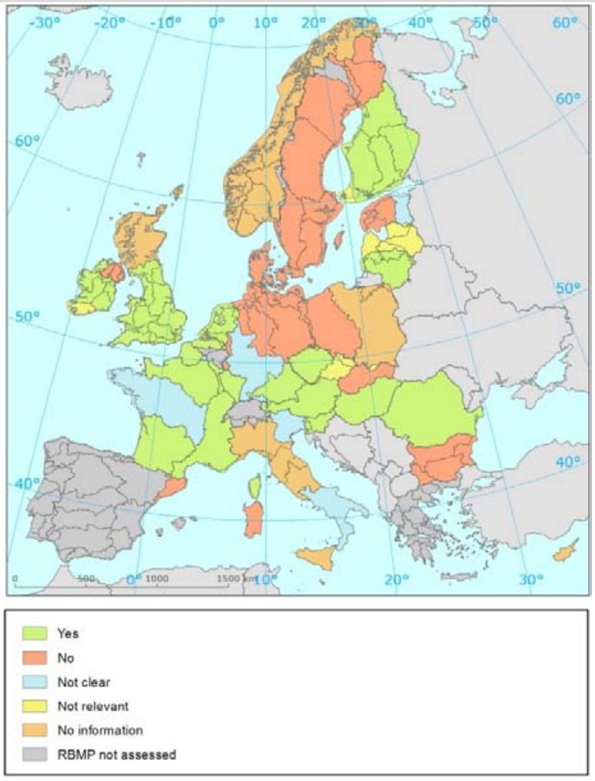
**MRG-Q3) Is there an indication that requirements from groundwater dependent terrestrial ecosystems have been taken into account in the definition of required measures?**

| | Requirements of groundwater dependent terrestrial ecosystem taken into account |
|---|---|
| Yes | 48 |
| No | 36 |
| Not relevant | 10 |
| Unclear | 6 |
| No info | 23 |

Requirements for dependent terrestrial ecosystems have been taken into account in the definition of required measures for groundwater in 48 RBMPs[25] out of 123 (39%).

25 AT1000, AT2000, AT5000, BEMaas_VL, BEShelde_VL, CZ_RB_5000, DE1000, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRC, FRD, FRE, FRF, FRH, FRK, GBNIIENB, GBNIIENW, HU1000, IEEA, IEGBNISH, IESE, IEWE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, RO1000, SI_RBD_1, SI_RBD_2, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11 & UK12.

**Fig. 11.** **Are requirements from groundwater dependent terrestrial ecosystems have been taken into account in the definition of required measures?**




*Source: RBMPs Assessment*

## 4.2. Pending issues not included in previous assessment

In the Sub-Task 3b (*Drivers for hydro-morphological alterations*) eflows are dealt with in the context of hydrological alteration and basically to establish minimum flows to be respected downstream of dams or weirs. By contrast, in the framework of this Sub-Task, eflows should play a wider role, aimed at the general preservation of good status of waters at the basin level, mainly in the context of WS-prone zones.

To improve the understanding of eflows across Europe, besides in depth assessment of RBMPs, other analysis at national or regional level could be necessary. So, if specific measures to achieve an ecologically based flow regime are taken, it is relevant to elucidate:

- The **scoping of eflows**, through identifying in which kind of WB are eflows being implemented: from stretches downstream of dams and weirs only (basically a hydro-morphological issue) to any other kind of surface WB (as a general water allocation issue).
- The state of **implementation** and the existence of a **monitoring scheme**. If eflows are not just proposed for future action in the PoM framework but have been applied for a certain time and there is a historical register linking eflows with changes in water status and indicators during a period long enough, some kind of **assessment of their effectiveness** may be feasible (Identification of Case Studies).

- The screening of **methodological approaches** (hydrological, hydraulic, habitat simulation, holistic, etc) which are being implemented in Europe. It may help, for instance, to establish assessment level and approximate costs.
- The **components** of eflows (MEF, seasonal variability, flood regime, hydro-peaking conditioning), since each of them addresses specific pressures and so may help to evaluate the expected effects of the measure.
- The characterization of the **implementation process** (if any).
- The identification of **linkages with other water quantity measures** (Water metering, Water savings, Illegal water use elimination, Economic compensations, Environmental conditioning , Increase in water availability , Joint exploitation).
- The existence of a specific treatment of eflows in **Protected Areas** (Natura 2000 sites and/or others) and specific expected effects.

## 4.3. Contributions from other documents

Other documents generated in a variety of projects & works supply relevant data and analysis, complementing RBMPAs and partially answering the pending questions. Jointly they provide a wider understanding of the actual and potential role of eflows as a Water Policy tool. The most significant ones, particularly those that contribute with specific description of the situation at country or basin level, are summarized below:

***Kampa, E., von der Weppen, J. and Dworak, T. 2011.* Water management, Water Framework Directive & Hydropower. Issue paper (final version).**

Paper generated in the framework of the CIS activity on the "Water Framework Directive and hydro-morphological pressures"

The document summarise key information on a variety of topics, some of them addressed to identify legal and technical requirements for environmental improvement. The information collected is based on the replies of MS to the EU questionnaire on Hydropower and WFD, filled in prior to the workshop that was held in Brussels, in September of 2011.

In total, 24 European States returned the Hydropower & WFD questionnaire: AT, BE (Wallonia), BG, CH, CZ, DE, ES, FI, FR, HU, IS, IT, LT, LU, LV, NL, NO, PL, PT, RO, SE, SI, SK and the UK. Three of them (CH – Switzerland, IS – Iceland & NO – Norway are not members of EU. On the other hand, no answer was received from EE, DK, GR, IE, MT & CY.

All questionnaires are available online at: http://www.ecologic-vents.de/hydropower2/background.htm. The most relevant questions for our Sub-Task are:

**How are legal requirements for minimum ecological flow set in your country?**

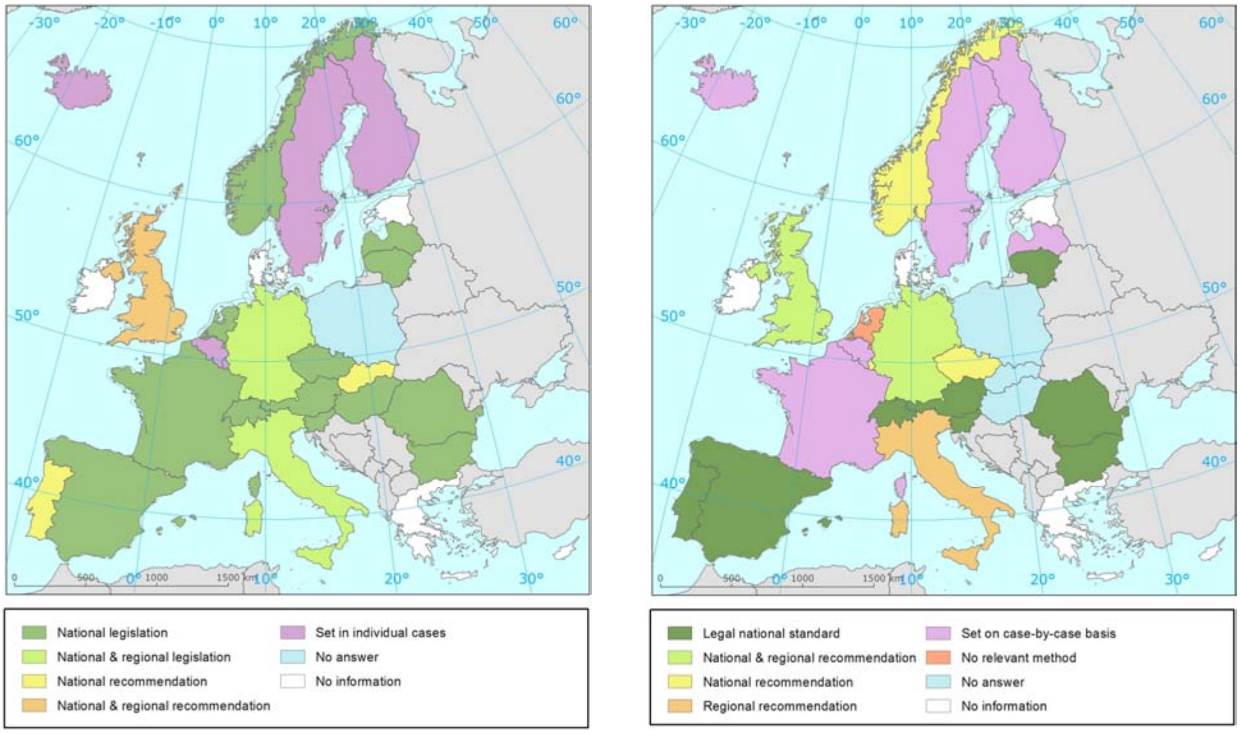
| Situation | Scale | States[26] |
|---|---|---|
| There is relevant legislation | National | AT, NL, RO, NO, LT, HU, BG, LV, IT, FR, DE, CH, CZ, ES, SI |

26 Problems of consistency (apparently incompatible responses) have been solved assigning the normative or technical framework of superior level (legislation / recommendation / case-by-case / none).

| Situation | Scale | States[26] |
|---|---|---|
| | Regional | DE, IT |
| There is no legal requirement but there is a relevant recommendation | National | UK, PT, CZ, SK |
| | Regional | UK |
| No legal requirement or recommendation but defined in individual cases | | LU, SE, NO, FI, DE, BE, IS |
| Generally no legislative means | | FI |
| There is a technical standard set by law | National | PT, LT, BG, AT, CH, ES, SI, RO |
| | Regional | |
| There is a recommendation | National | LU, UK, PT, NO, IT, DE, CZ |
| | Regional | UK, IT, DE |
| Set on case-by-case basis | | LU, SE, NO, LV, FR, FI, BE, IS, ES |
| No relevant method defined | | SE, NL, BG |

No answer on technical requirements for MEF in PL, HU, SK and RO.

**Fig. 12. How are legal requirements for minimum ecological flow set in your country?**



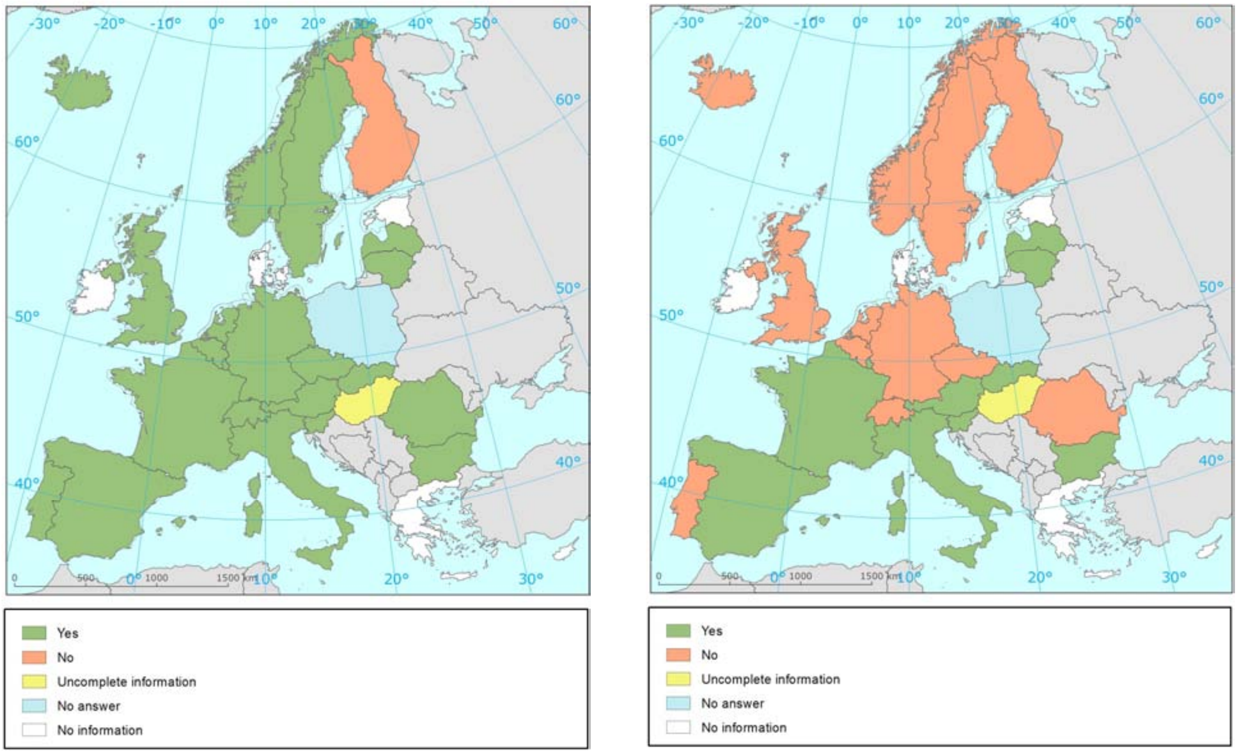

**Normative framework** **Technical standards**

*Source: "Water management, Water Framework Directive & Hydropower" [national questionnaires]*

### Does a minimum ecological flow requirement exist for every hydropower plant in your country?

| | | |
|---|---|---|
| New hydropower plants | Yes | LU, UK, SE, PT, NL, RO, LT, BG, LV, IT, FR, AT, DE, CH, BE, CZ, IS, ES, SI, SK, NO |
| | No | FI |
| Existing hydropower plants | Yes | LU, LT, BG, LV, IT, FR, (AT), ES, SI, SK |
| | No | UK, SE, PT, NL, NO, FI, DE, CH, BE, CZ, IS, RO |

**Fig. 13. Does a minimum ecological flow requirement exist for every hydropower plant in your country?**




**New hydropower plants** **Existing hydropower plants**

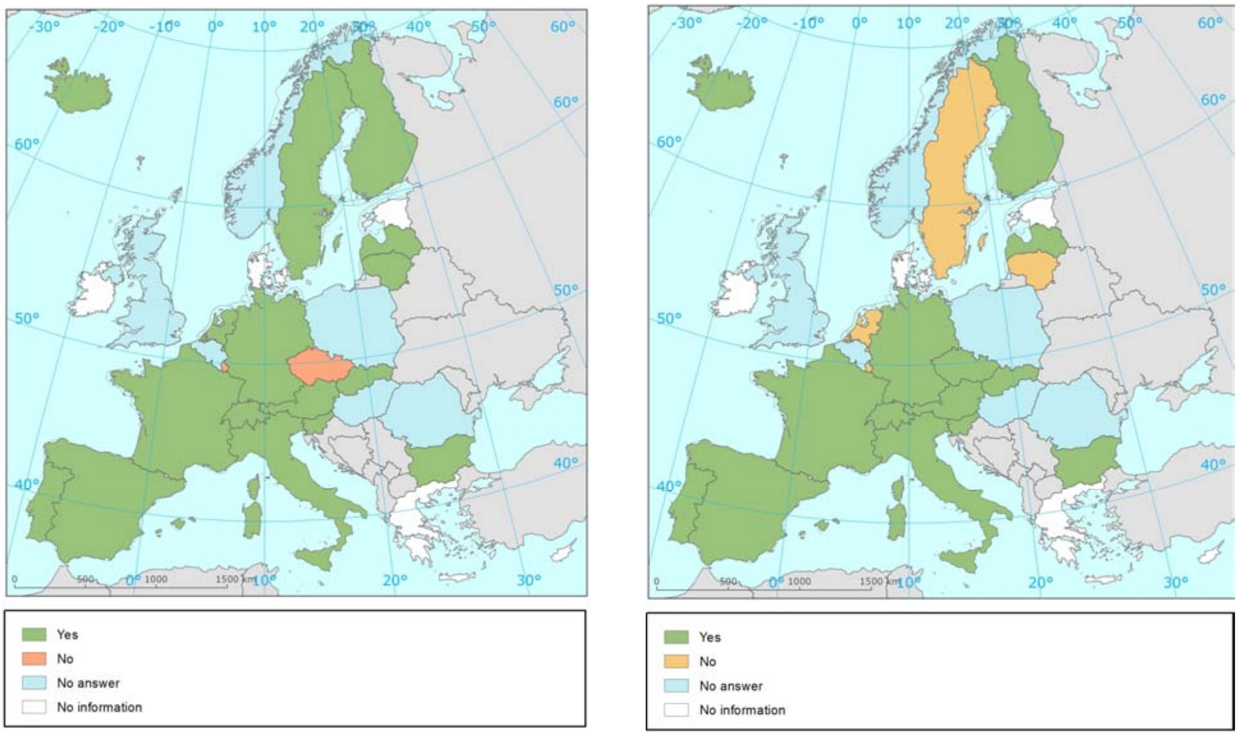
*Source: "Water management, Water Framework Directive & Hydropower" [national questionnaires]*

### Are the legal requirements related to a specific goal? [Ensure sustainable fish populations / Ensure ecological continuum / Other]

Not presented in the summary, may be relevant to determine which objectives are addressed by eflows. It has been screened through national reports.

| | |
|---|---|
| Ensure sustainable fish populations | AT, BG, CH, DE, ES, FI, FR, IS, IT, LT, LV, NL, PT, SE, SI & SK |
| Ensure ecological continuum | AT, BG, CH, DE, ES, FI, FR, IS, IT, LV, PT, SI, SK & CZ |

**Fig. 14. Are the legal requirements related to a specific goal?**




**Ensure sustainable fish populations** **Ensure ecological continuum**

*Source: "Water management, Water Framework Directive & Hydropower" [national questionnaires]*

Some countries (AT, DE, IT, LV & RO), establish goals that somehow may be identified with WFD environmental objectives[27].

### Is there an agreed method/approach in your country, which should be followed for setting minimum ecological flow? What method/methods is (are) applied to define minimum ecological flow in your country?

- Static definition[28], dynamic definition[29] & modelling: AT, CH, DE, FR, IT & UK.
- Static & dynamic definition: LU & LV.
- Static definition & modelling: BE.
- Dynamic definition & modelling: FI & PT.
- Only static definition: BG, CZ, LT, RO, SE & SK.
- Only dynamic definition: IS, NL, NO, & SI.
- Not fitting proposed categories: ES.

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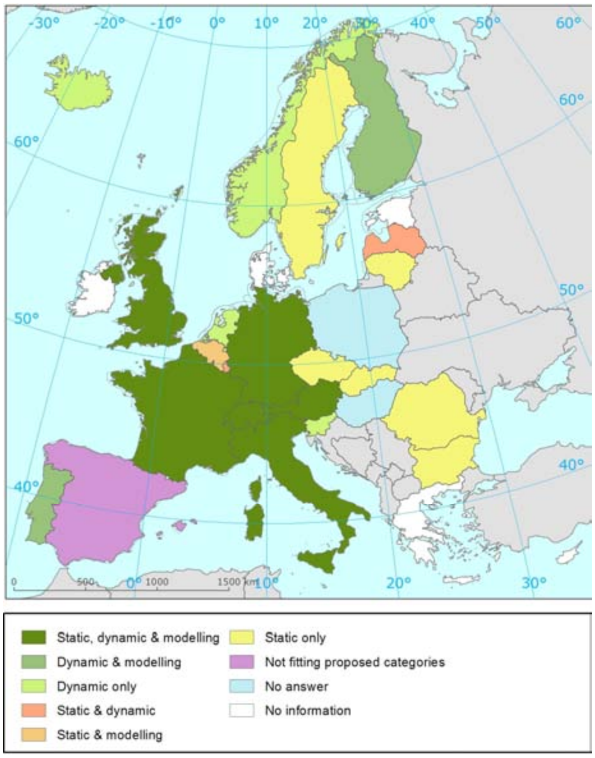
27 AT: Ensure good status/GEP; DE: the minimum flow based on the management objectives for WFD; IT ensure "healthy" and sustainable river ecosystems; LV: the lowest water level in the water reservoir up to which the function of water reservoir is permissible at normal exploitation circumstances of the hydroelectric station with 95% coverage or the ecological flowrate which is necessary for conservation and protection of natural biological resources of watercourse and the ecosystems ; RO: the flow needed in a river section for ensuring the natural living conditions of the existing aquatic ecosystems.

28 e.g. 5% of annual mean flow.

29 Different fixed minimum flow values distributed over the year.

**Fig. 15. What method(s) is(are) applied to define minimum ecological flow in your country?**




*Source: "Water management, Water Framework Directive & Hydropower" [national questionnaires]*

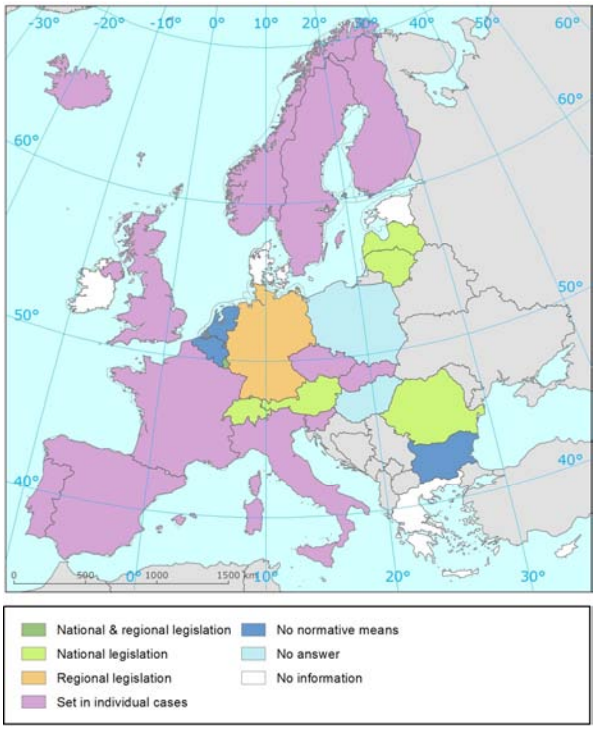
Several countries comment on the need for site specific considerations. Details on the methods applied to define MEF in different countries are presented in Annex. Section 4.4 summarizes methodologies on the basis of this document and other sources.

### Specific requirements for hydropeaking mitigation

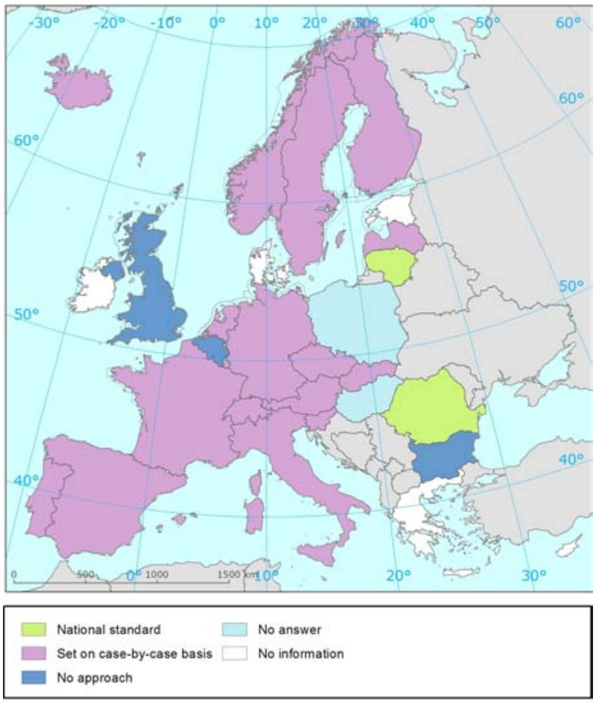
The country-specific recommendations and/or standards on hydropeaking mitigation include several specific requirements as summarised by the table below.

| Requirements included | | | Other options to mitigate impacts of hydropeaking | | |
|---|---|---|---|---|---|
| **Amplitude of flow fluctuation** | **Frequency of hydropeaking** | **Duration of rising and falling of hydropeaking** | **Compensation basins** | **Improvement of hydromorphological structures** | **Coordination of different plants' operation** |
| AT, FR, LV, LT, NL, NO, RO, SK | AT, FR, NO, RO, SK | AT, FR, LT, NO, RO | AT, FR, NO, RO, CH | AT, FR, NO, RO, CH | AT, FR, LV, LT, NO, RO, CH, SK |

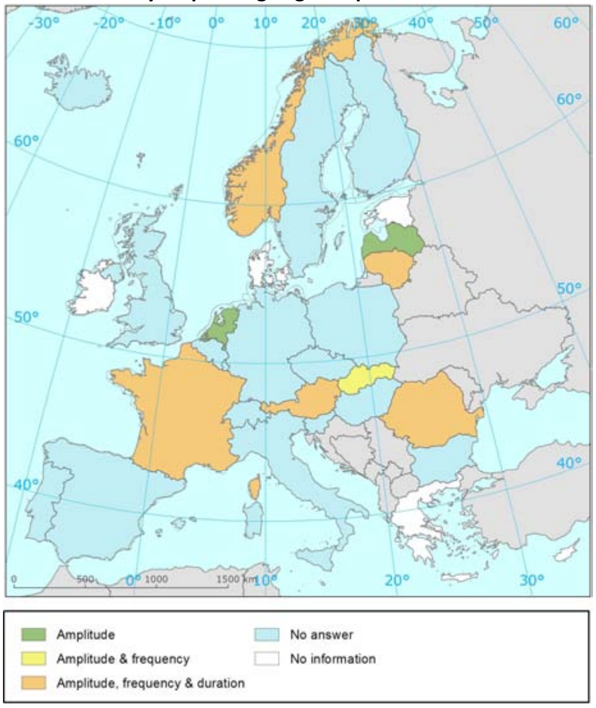
**Fig. 16. Specific requirements for hydropeaking mitigation**



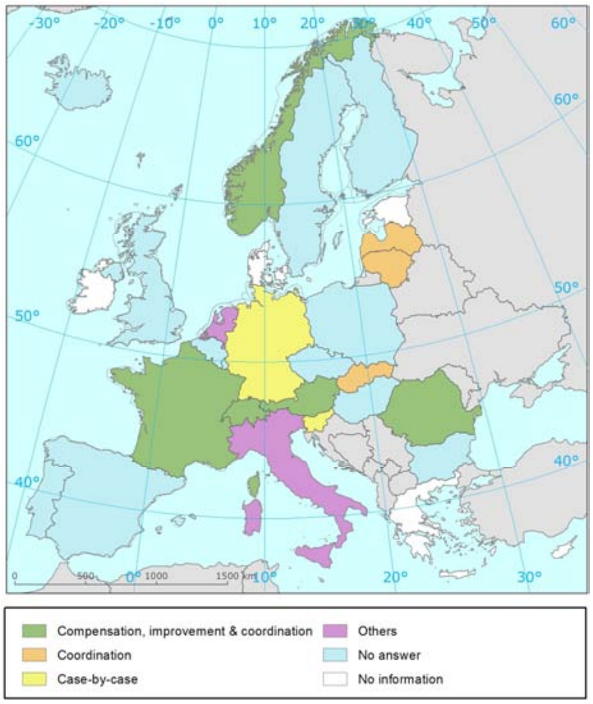

**Hydropeaking Legal requirements**




**Hydropeaking Technical requirements**




**Inclusion of requirements regarding**




**Other options for mitigation**

*Source: "Water management, Water Framework Directive & Hydropower" [national questionnaires]*

Several countries specify that the inclusion of all these requirements is defined on a case-by-case basis (e.g. AT, DE & NO).

***Sánchez Navarro, R. & Schmidt, G. 2012.* Environmental Flows as a tool to achieve the WFD Objectives. Discussion Paper.**

Paper generated in the framework of Service contract for the support to the follow-up of the Communication on Water scarcity and Droughts

This document aims to provide technical and normative bases to initiate the debate of eflows as part of the EU water policy, providing technical and scientific bases (foundations, key concepts, utilities) and the main types of assessment methods. The role of eflows to achieve the WFD objectives –such as the GES/GEP, the good quantitative status or GWB, or the conservation objectives of protected areas– is also analysed. Finally, a succinct overview of the situation of eflows in the MS is provided, based on the Questionnaire on Hydropower and the WFD (WFD CIS Issue paper, 2011) mentioned before.

***SEE Hydropower 2011.* Comparative analysis of methodologies for the implementation of environmental flows (EF), according to the WFD (Final Version)**

Outcome of the project "SEE HYDROPOWER, targeted to improve water resource management for a growing renewable energy production", in the frame of the South-East-Europe Transnational Cooperation Programme, co-funded by the European regional Development Fund (www.seehydropower.eu).

Between other activities the project is concern with the definition of policies, methodologies and tools for better water & hydropower planning and management and the establishment of common criteria for preserving water bodies over the South East Europe region countries. The Report includes a description of eflows assessment methods and scope from different countries (RO, IT, AT & SL) and their institutional framework (i.e., legislation, ecological parameters included, hydrological components, monitoring, objectives, etc.) with some illustrative best practice examples. These reports are summarized in section 6.

## 4.4. Summary of previous assessments

The existence of national/regional) **guidelines or regulations on the definition of an ecologically based flow regime** has been established in 50 RBMPs[30] out of 123 (41%). At the national level, there is some relevant legislation in AT, BG, CZ, ES, FR, HU, IT, LT, LV, NL, RO & SI, while recommendations are in place in PT, SK & UK. Other countries (BE, DE, FI, LU & SE) states that no legal requirement or recommendation exists but may be defined in individual cases. Finally, some regions of DE, IT h& UK have their own regulations. Finally, there is a technical standard set by law in AT, BG, ES, LT, PT, RO & SI.

Most countries have some kind of **methodologies to be applied for the definition of minimum ecological flow**, at least for the conditioning of hydropower plants exploitation. This minimum is only static (fixed minimum value) in BE, BG, CZ, LT, RO, SE & SK and dynamic (including seasonal variability) in AT, DE, ES, FR, IT, UK, LU, LV, FI, PT, NL, SI & LU. Eflows requirements are established for both existing and new hydropower plants in AT, BG, ES, FR, IT, LT, LU, LV, SI & SK, only for new plants in BE, CZ, DE, NL, PT, RO, SE & UK.

30 AT1000, AT2000, AT5000, BG1000, DE1000, DK1, DK2, DK3, DK4, ES100, FRB1, FRC, FRD, FRF, FRG, GBNIIENB, GBNIIENW, GBNINE, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, ITH, LT1100, LT2300, LT3400, LT4500, LVDUBA, LVGUBA, LVLUBA, LVVUBA, SE5, SI_RBD_1, SI_RBD_2, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

**Hydropeaking and its impacts** is one of the major concerns regarding the management of these facilities. The conditioning is usually set in a case-by-case basis, since no legal or technical recommendations are available. Only AT, DE, LU, LT, LV & RO have explicit national and /or regional requirements.

Attending the RBMPAs made in the framework of the Compliance checking, specific measures have been taken to achieve an ecologically based flow regime in 61 RBMPs[31] (5%) and it must be pointed out that there is no coincidence with those basins where general guidelines or regulations are available, meaning that some RB Authorities should have established their own standards. (see also section 4.5.1 and Table. 2). Two **specific hydromorphological measures to be taken (to reach either GES or GEP) that may be linked to eflows components** have been assessed. 49 RBMPs[32] (40%) have set MEF requirements, while 28[33] (23%) have considered operational modifications for. Nevertheless, less RBMPs include clear information on how these planned hydromorphological measures will improve GES / GEP: 25 (20%) for setting MEF requirements[34] and only 14 (11%) for operational modifications for hydropeaking[35]. On the other hand, available information on how the planned hydromorphological measures will improve the ecological status/potential is explicit in 44 RBMPs[36] (36%).

Further assessment have been carried out in the framework of this contract to extend the analysis to other RBMPs. Occasionally, this review has led to changes of the initial assessment as justified in Table. 5

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31 AT1000, AT2000, AT5000, BG1000, BG2000, BG3000, BG4000, CY001, DE1000, DE2000, DE3000, DE4000, DE5000, DE6000, DE7000, DE9500, DE9610, DE9650, EE1, EE2, EE3, ES100, FRD, FRF, FRG, FRI, FRJ, FRL, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, ITH, LT1100, LT2300, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, MTMalta, NO1103, NO1104, NO5101, NO5102, NO5103, NO5104, NO5106, RO1000, SE1, SE3, SE4, SE5, SI_RBD_1, SI_RBD_2, SK40000.

32 AT1000, AT2000, AT5000, BG1000, BG2000, BG3000, BG4000, CY001, DE1000, DE2000, DE4000, DE5000, DE6000, DE7000, DK1, DK2, DK3, DK4, EE1, EE2, EE3, ES100, FIVHA1, FIVHA3, FIVHA4, FIVHA6, FRD, FRF, FRJ, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, LT1100, LT2300, LT3400, LT4500, NO5101, NO5102, NO5103, NO5104, RO1000, SE3, SI_RBD_1, SI_RBD_2.

33 AT1000, AT2000, AT5000, BG3000, DE2000, DE7000, FIVHA1, FIVHA3, FIVHA4, FIVHA6, FRD, FRF, LT1100, LT3400, SE4, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK12.

34 AT1000, AT2000, AT5000, DE1000, DE2000, DK1, DK2, DK3, DK4, EE1, EE2, EE3, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NO1101, NO5103, NO5104, RO1000 (expected effects are described); ITA, LT1100, LT2300, LT3400, LT4500 (expected effects are clear).

35 AT1000, AT2000, AT5000, DE1000, EE1, EE2, EE3, LVDUBA, LVGUBA, LVLUBA, LVVUBA (described); LT1100, LT2300, LT3400 (clear).

36 AT1000, AT2000, AT5000, CZ_RB_1000, CZ_RB_5000, DE1000, DE2000, DE3000, DE4000, DE6000, DE7000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, EE1, EE2, EE3, FRI, FRJ, LT1100, LT2300, LT3400, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NO1103, NO1104, NO1105, NO5101, NO5103, NO5104, PL2000, PL6000, RO1000, SE1, SE2, UK01.

and section 4.5.2. According to these analyses, up to 86 RBDs (46%)[37] either have already implemented MEF (or similar tools) or have planned it in the framework of PoMs, while other 71 (38%)[38] shows no explicit intention in this regard and, finally, in 29 RBDs (16%), available information is not sufficient to assess. On the other hand, some kind of hydro-peaking conditioning scheme is considered in 48 RBDs (26%)[39], while this is not so in 101 RBDs (54%)[40] with 37 RBDs (20%) with unclear assessment. It must be pointed out that 43 RBDs (23%) have both measures either implemented or planned, 35 RBDs only MEF (19%) and 5 only HP (3%), while 66 have included neither of the two (35%).

**In the context of drought management**, the enhancement of the resilience of the ecosystems to WS&D (supposedly by eflows) has been assessed in 19 RBMPs out of 123 (15%)[41].

Most of RBMPs, specifically 76[42] out of 123 (60%), indicate that the **needs of associated terrestrial ecosystems have been assessed to determine groundwater quantitative status**. Only 3 RBMPs[43] declare

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37 AT1000, AT2000, AT5000, BG1000, BG2000, BG3000, BG4000, CY001, DE1000, DE2000, DE4000, DE5000, DE6000, DE7000, DK1, DK2, DK3, DK4, EE1, EE2, EE3, ES010, ES014, ES015, ES016, ES020, ES030, ES040, ES050, ES060, ES063, ES064, ES070, ES080, ES091, ES100, ES110, FIVHA1, FIVHA3, FIVHA4, FIVHA6, FRD, FRF, FRJ, FRM, HU1000, ITA, ITB, ITC, ITD, ITE, ITF, ITG, LT1100, LT2300, LT3400, LT4500, NO5101, NO5102, NO5103, NO5104, PTRH1, PTRH2, PTRH3, PTRH4, PTRH5, PTRH6, PTRH7, PTRH8, RO1000, SE3, SI_RBD_1, SI_RBD_2, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12, UKGBNIIENB, UKGBNIIENW, UKGBNINE

38 BEEscaut_RW, BEEscaut_Schelde_BR, BEMaas_VL, BEMeuse_RW, BENoordzee_FED, BERhin_RW, BESchelde_VL, BESeine_RW, CZ_1000, CZ_5000, CZ_6000, DE3000, DE9500, DE9610, DE9650, FIVHA2, FIVHA5, FIVHA7, FIWDA, FRA, FRB1, FRB2, FRC, FRE, FRG, FRH, FRI, FRK, FRL, GBNIIENB, GBNIIENW, IEEA, IEGBNISH, IESE, IESW, IEWE, ITH, LVDUBA, LVGUBA, LVLUBA, LVVUBA, MTMALTA, NLEM, NLMS, NLRN, NLSC, NO1101, NO1102, NO1103, NO1104, NO1105, NO5105, NO5106, PL2000, PL6000, PL7000, PL8000, PTRH9, SE1, SE2, SE4, SE5, SK30000, SK40000, UK01, UK02

39 AT1000, AT2000, AT5000, BG3000, DE2000, DE7000, EE1, EE2, EE3, ES010, ES014, ES016, ES020, ES030, ES040, ES050, ES060, ES063, ES064, ES070, ES080, ES091, ES100, FIVHA1, FIVHA3, FIVHA4, FIVHA6, FRD, FRF, LT1100, LT3400, SE4, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK12, UKGBNIIENB, UKGBNIIENW, UKGBNINE.

40 BEEscaut_RW, BEEscaut_Schelde_BR, BEMaas_VL, BEMeuse_RW, BENoordzee_FED, BERhin_RW, BESchelde_VL, BESeine_RW, BG1000, BG2000, BG4000, CY001, CZ_1000, CZ_5000, CZ_6000, DE1000, DE3000, DE4000, DE5000, DE6000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, ES015, ES110, FIVHA2, FIVHA5, FIVHA7, FIWDA, FRA, FRB1, FRB2, FRC, FRE, FRG, FRH, FRI, FRJ, FRK, FRL, FRM, GBNIIENB, GBNIIENW, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, ITA, ITB, ITC, ITD, ITE, ITF, ITG, ITH, LT2300, LT4500, LU2000, LU7000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, MTMALTA, NLEM, NLMS, NLRN, NLSC, NO1101, NO1102, NO1103, NO1104, NO1105, NO5101, NO5102, NO5103, NO5104, NO5105, NO5106, PL2000, PL6000, PL7000, PL8000, PTRH1, PTRH2, PTRH3, PTRH4, PTRH5, PTRH6, PTRH7, PTRH8, PTRH9, RO1000, SE1, SE2, SE3, SE5, SI_RBD_1, SI_RBD_2, UK11.

41 HU1000 (high importance); BG3000, BG4000 (medium importance); SI_RBD_1, SI_RBD_2 (low importance); CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIVHA5, FIVHA6, FIVHA7, FIWDA, FRG, IEEA, RO1000 (unable to assess importance).

42 AT1000, AT2000, AT5000, CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, DE1000, DE2000, DE3000, DE4000, DE5000, DE6000, DE7000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIVHA5, FIVHA6, FIVHA7, FRB2, FRD, FRF, FRG, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

that no dependent terrestrial ecosystem exists. Also most of RBMPs provide some kind of information on how impacts of groundwater abstractions have been considered when assessing quantitative status: 101 RBMPs[44] (82%) have assessed that available GWR is not exceeded by LTA abstractions; 63 RBMPs[45] (51%) have analysed if GES is not achieved for associated SWB; 53 RBMPs[46] (43%) if there is a significant diminution of SWB status; 76 RBMPs[47] (62%) if there is significant damage for dependant SWB; and 74 (60%)[48] if saline or water intrusion has been induced. Moreover, 'available groundwater resource' has been applied in accordance with Art 2.27 of the WFD –so taking into account flow required to achieve the ecological quality objectives for associated surface waters (eflows)– in 64 RBMPs, qualified as ‘fully’ in 54 cases[49] (44%) and ‘partly’ in 10 cases[50] (8%). Finally, requirements for dependent terrestrial

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43 BE_Noordzee_FED, BEMaas_VL, BESchelde_VL.

44 AT1000, AT2000, AT5000, BEMaas_VL, BESchelde_VL, BG1000, BG2000, BG3000, BG4000, CY001, CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, DE1000, DE2000, DE3000, DE4000, DE5000, DE6000, DE7000, DE9500, DE9610, DE9650, DK1, DK2, DK3, DK4, EE1, EE2, EE3, ES100, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIVHA5, FIVHA6, FIVHA7, FRA, FRB1, FRB2, FRC, FRD, FRF, FRH, FRI, FRK, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, ITB, ITE, LT1100, LT2300, LT3400, LT4500, LU2000, LVDUBA, LVGUBA, LVLUBA, LVVUBA, MTMalta, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SE1, SE2, SE3, SE4, SE5, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

45 AT1000, AT2000, AT5000, BEMaas_VL, BESchelde_VL, DE1000, DE5000, EE1, EE2, EE3, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, LVDUBA, LVGUBA, LVLUBA, LVVUBA, NLEM, NLMS, NLRN, NLSC, RO1000, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

46 BEMaas_VL, BESchelde_VL, DE1000, DE5000, EE1, EE2, EE3, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRH, FRK, FRL, GBNIIENB, GBNIIENW, GBNINE, ITE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SI_RBD_1, SI_RBD_2, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

47 AT1000, AT2000, AT5000, BEMaas_VL, BESchelde_VL, CZ_RB_1000, CZ_RB_5000, CZ_RB_6000, DE1000, DE2000, DE3000, DE4000, DE5000, DE7000, DE9500, DE9610, DE9650, EE1, EE2, EE3, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRH, FRK, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SE3, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

48 BEMaas_VL, BESchelde_VL, BG2000, CY001, DE1000, DE2000, DE5000, DE6000, DE9500, DE9610, DE9650, EE1, EE2, EE3, ES100, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FIWDA, FRA, FRB1, FRB2, FRC, FRD, FRE, FRF, FRG, FRH, FRK, FRL, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, PL2000, PL6000, PL7000, PL8000, RO1000, SE1, SE2, SE3, SE4, SE5, SI_RBD_1, SI_RBD_2, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

49 AT1000, AT2000, AT5000, BG2000, BG4000, CZ_RB_5000, DE1000, DE2000, DE3000, DE5000, DE6000, DE7000, EE1, EE2, EE3, FRD, FRF, FRG, GBNIIENB, GBNIIENB, GBNIIENW, GBNIIENW, GBNINE, HU1000, IEEA, IEGBNISH, IESE, IESW, IEWE, LT1100, LT2300, LT3400, LT4500, LVDUBA, LVGUBA, LVLUBA, LVVUBA, SE2, SI_RBD_1, SI_RBD_2, SK30000, SK40000, UK01, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

50 BG1000, BG3000, CZ_RB_1000, CZ_RB_6000, DE9500, DK1, DK2, DK3, DK4, FRL.

ecosystems have been taken into account in the definition of required measures for groundwater in 48 RBMPs[51] out of 123 (39%).

## 4.5. Completion of information gaps

### 4.5.1. Introduction

The pending issues stated in section 4.2 have been explored in greater depth. RBMPs assessments have identified basins / countries where hydromorphological measures related to eflows components are to be taken, and/or where national or regional regulations or standards exist.

In relation with the fundamental issue of the existence of general (national or regional) guidelines or regulations on the definition of an ecologically based flow regime, the RBMPs assessment are basically coherent with the Hydropower & WFD questionnaire, at least in the affirmative responses. But on the other hand, it can be appreciated that sometimes RBMPs do not clearly reflect that existing normative or technical standards related to eflows have been taking into account.

**Table. 2. Existence of legislation or guidelines or regulations on the definition of an ecologically based flow regime**

| | RBMPs Assessments | WFD& Hydropower questionnaire | |
|---|---|---|---|
| Country | Guidelines / regulations | Normative | Standards |
| AT | **Yes** | **National legislation** | **Legal national standard** |
| BE | No info | Set in individual cases | Set on case-by-case basis |
| BG | **Yes** (Danube) / No / No info | **National legislation** | **Legal national standard** |
| CY | Not assessed | No information | No information |
| CZ | No info | **National legislation** | **National recommendation** |
| DE | **Yes** (Danube) / No / No info | **National & regional legislation** | **National & regional recommendation** |
| DK[52] | **Yes** | No information | No information |
| EE | No info | No information | No information |
| ES | **Yes** | **National legislation** | **Legal national standard** |
| FI | No / No info | Set in individual cases | Set on case-by-case basis |
| FR | **Yes** / No info | **National legislation** | Set on case-by-case basis |
| GR | Not assessed | No information | No information |
| HU | **Yes** | **National legislation** | No answer |
| IE | No info | No information | No information |
| IT | **Yes** | **National & regional legislation** | **Regional recommendation** |
| LT | **Yes** | **National legislation** | **Legal national standard** |

51 AT1000, AT2000, AT5000, BEMaas_VL, BESchelde_VL, CZ_RB_5000, DE1000, FIVHA1, FIVHA2, FIVHA3, FIVHA4, FRA, FRB1, FRC, FRD, FRE, FRF, FRH, FRK, GBNIIENB, GBNIIENW, HU1000, IEEA, IEGBNISH, IESE, IEWE, LT1100, LT2300, LT3400, LT4500, NLEM, NLMS, NLRN, NLSC, RO1000, SI_RBD_1, SI_RBD_2, UK02, UK03, UK04, UK05, UK06, UK07, UK08, UK09, UK10, UK11, UK12.

52 Limits for water abstraction of groundwater has been set to 35% of annual re-charge, and 5% of river flow or 10-25% of annual median-minimum river flow. The abstraction needed for meeting demand for public water supply can exceed these norms if the status of the GWB is good or better and there is no risk not to achieve the good status objectives for that water body and related surface waters. 2. Moving the water abstraction to another groundwater source with better availability. 3. The water demand must be documented (source: RBMPA).

**Table. 2. Existence of legislation or guidelines or regulations on the definition of an ecologically based flow regime**

| | RBMPs Assessments | WFD& Hydropower questionnaire | |
|---|---|---|---|
| **Country** | **Guidelines / regulations** | **Normative** | **Standards** |
| LU | No info | Set in individual cases | **National recommendation** |
| LV | **Yes** | **National legislation** | Set on case-by-case basis |
| MT | No | No information | No information |
| NL | No info | **National legislation** | No relevant method |
| PL | No info | No answer | No answer |
| PT | Not assessed | **National recommendation** | **Legal national standard** |
| RO | No | **National legislation** | **Legal national standard** |
| SE | **Yes** / No / No info | Set in individual cases | Set on case-by-case basis |
| SI | **Yes** | **National legislation** | **Legal national standard** |
| SK | No info | **National recommendation** | No answer |
| UK | **Yes** | **National & regional recommendation** | **National & regional recommendation** |
| NO | No info | **National legislation** | **National recommendation** |

In any case, as hydrological regime is not an element to be explicitly considered when determining ecological status (see section 2.3), RBMPs may not adequately reflect neither the regulatory framework nor other technical aspects which are relevant for determining the present role and the potential of eflows. This observation suggests devoting more effort to the investigation of national strategies and the identification of study cases, with occasional further assessment of selected RBMPs.

### 4.5.2. Scoping of eflows

The aim is to identify in which kind of water bodies are eflows being implemented. Some possibilities arise. On the one hand, eflows may be only considered in stretches downstream of dams and weirs, turning it basically in a hydro-morphological issue. Alternatively it may be applied to any other kind of WB, so that eflows become a fundamental part of the entire **water allocation system at basin scale**.

Following the later approach, some MS have estimated eflows in all water bodies. This is the case of Spain (6.2.2) & Italy (in major basins, see 6.2). In the UK (England & Wales) water resource flow standards for rivers, lakes and estuaries have been developed by the UK Technical Advisory Group (UKTAG) (see 6.7). The Environmental Flow Indicator (EFI) may have similar effects in terms of preserving flows for the aquatic ecosystems by ensuring that water resource abstraction do not cause or contribute to the failure of WFD ecological status objectives.

In Estonia, RBMPs state that *some river bodies are subject to legal restrictions on water use, including prohibition of damming of the water body, regulation of flow rate & modification of flow regime*. Though there is no explicit mention to minimum flows, effects of the abovementioned measures may be similar since flows are allocated for environmental purposes. In relation to hydropeaking, Estonian Plans indicate that *water regime of existing impoundments on salmon rivers should be regulated in such a manner as to ensure a suitable water regime for salmonids downstream of the impoundment*[53].

In Portugal, the release of minimum flows has been already determined in selected dams of most basins. RBMPs include a variety of different measures –from monitoring programs to implementation, also including more dams and/or improved evaluation– while some of them (e.g. Minho and Lima) planned to develop base studies or assessments for all watersheds.

As far as eflows are a new element of water management, conflicts will emerge with previous rights holders. At this point, flow protection and restoration must be distinguished, that is, between the introduction of a cap on further abstraction or new infrastructure and the re-allocation of water from existing users to the environment. It is much easier to implement requirements on new users than to enact changes to existing use and there comparatively few successful international examples of the latter (WWF 2010). Establishing a cap or control on new uses before addressing the greater challenge of re-allocation is critically important.

Basin Authorities usually take into account the relevant **difference between pre-existent and new users**. For instance, this has been established at a national level for hydropower plants in CIS 2011 (see Fig. 13).

### 4.5.3. The identification of linkages with other water quantity measures

As seen in the previous section, river restoration requires re-allocation of water to the environment. If that is the objective, particularly in water stressed basins. Eflows has to be taken into account when operating existing infrastructure and, probably, other measures supporting the implementation should be considered in the framework of the PoM.

Some of these potential measures may be outlined:

- Removal or amendments of water rights from existing users, either voluntarily or through a compulsory process (WWF 2010).
- Reinforcement of controls on Illegal water use.
- Efficiency improvement: water metering and water savings.
- Economic compensations.
- Water transaction.
- Environmental conditioning.
- Increase in water availability through reutilization, desalination plants and joint exploitation.

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[53] *If such requirement has not been specified in sufficient detail in the current water permit, the respective permit should be amended after a reasonable period of advance notice. This is particularly relevant in the case of exploitation of water power when electricity is generated by using cyclical collection of water. In this case, the flow rates after the dam fluctuate radically during a short period of time (from sanitary flow rates to flow rates required by a generator) and breeding of fish downstream of the impoundment is hindered*. Texts in cursive, extracted from Koiva River Basin District Management Plan, approved on 1 April 2010 by the Government of the Republic (Order Nº 118). The content of the three Estonian Plans regarding minimum flows and hydropeaking are identical.

Though this issue has not been explores at European level, a study case reflecting the importance ot these links is presented in section 6.3.4.

### 4.5.4. State of implementation and the existence of a monitoring scheme

A distinction is the current state of implementation of eflows, from effectively implemented to proposed for future action in the framework of PoMs or other water management scheme.

On the other hand, the existence of monitoring networks is necessary to ensure compliance of the stated regime and to assess its effectiveness. Nevertheless, due to the short life of the RBMPs a proper assessment of their effectiveness in terms of a historical register linking eflows with changes in water status and indicators during a period long enough is not feasible.

In **Austria**, according to Austrian Water Act, since 1990 MEF is obligatory to get a new permit, but implementation is still pending in more than 85% of the abstraction points identified. Fish is considered the relevant biological quality element for monitoring and assessing the effectiveness of eflows. There are standard manuals for the assessment of fish fauna and other quality elements (macrophytes, phytobenthos & benthic invertebrate fauna). To assess the biological quality element fish fauna the Fish Index Austria (FIA) is to be used. FIA analyzes the deviation of the actual fish assemblage from historically and actually pre-defined reference fish assemblages according to river types using a combination of metrics.

In **Spain**, the regime eflows regime consequent to the Royal Decree 907/2007 and Order ARM/2656/2008 (see section 6.3.1) must be implemented in three steps: 1) development of technical studies; 2) public consultation and agreement, including a negotiation process at least in strategic SWBs; and 3) implementation and adaptive management. Only the first step is completed in most of RBDs though some of them have covered also the second step. The monitoring must link the level of compliance of the regime with an improved understanding of its relationship with the structure of aquatic and terrestrial ecosystems, so that future amendment of the regimes shall be solidly grounded.

In **France**, the Water Law (2006) imposes minimum values of flow in the range of 5% to 10% of mean annual flow to be applied in 2014 for all dams and weirs, though locally, these values can be increased based on study using microhabitat methodology. On the other hand, the licenses of the hydraulic works whose operation does not allow the preservation of migratory fish should be modified no later than 2014.

In **Italy**, the concept that the quantitative protection of the water resources became functional to the achievement of the qualitative goals for aquatic ecosystems was introduced in 1999 by the Legislative Decree nº. 152. In subsequent years, the imposition of a minimum flow to be guaranteed downstream water withdrawals became functional to the achievement of GES. Biological monitoring is made by local authorities in accordance to more recent decrees. However, they are not made for directly monitoring and assessing eflows effectiveness, with the exception of experimental activities carried out in pilot case studies.

In **Slovenia**, eflows needs to be determined and monitoring has to be assured by 2014. **Monitoring** must be performed by water right holders, while the Institute for Water of the Republic of Slovenia supports national authorities (the Agency of the Republic of Slovenia) with additional studies and monitoring. The effectiveness of eflows is globally assessed at the level of water bodies to achieve the good ecological status. On the other hand, the device or system for water withdrawal must be designed in such way that any withdrawal when the discharge is lower than eflows is not possible.

In **Romania**, the Water Law 310/2004 states that the owners of water intakes, dams and reservoirs are obliged to assure downstream a certain amount of water for aquatic environmental protection (sanitary discharge, that may be identified with eflows). No concrete technologies in monitoring and assessing eflows are used, others than those used for WBs ecological status/potential assessment according to WFD requirements.

The **UK** has introduced environmental flow policies in a stepwise manner over the last two decades. The Environmental Flow Indicator [EFI] is defined as a percentage deviation from the natural flow and is set at a level which is thought to support GES. Where it fails, more detailed assessment is required to understand if current abstractions and use of full licensed quantities are threatening the long term health of the river ecology. PoMs include the measure *Review and improve Environmental Flow Indicators*; in some cases, the measure *Improve flow estimates for surface water bodies* is also included. More detailed assessments are needed where reductions in abstraction were required. A more sophisticated set of limits has now been suggested under the WFD, with flow limits set according to river type, river condition goal, and time of year. Site-specific investigations are being undertaken to set releases from reservoirs, which were deemed too unique to be managed under generic rules.

### 4.5.5. The screening of methodological approaches

In CIS 2011 a screening of European methodologies has been completed (see Fig. 15). The proposed classification of methods to define minimum ecological are (included in Table. 4):

- Static definition (e.g. 5% of annual mean flow)
- Dynamic definition: different fixed minimum flow values distributed over the year
- Determination by modelling

Sánchez et al. 2012, propose four basic groups of methodologies –hydrological, hydraulic, habitat simulation and holistic– detailing their main features, so that this classification may be useful for better identifying their adequacy in terms of scope and objectives.

**Table. 3. Main features of the calculation methods**

| Ecosystem components addressed | Data needs | Expertise | Complexity | Resource intensity | Output resolution | Flexibility | Cost |
|---|---|---|---|---|---|---|---|
| **Hydrological** | | | | | | | |
| The whole ecosystem, non specific | **Low (mainly desktop)**<br>Historical flow records (virgin or naturalized)<br>Historical ecological data | **Low**<br>Hydrological<br>Some ecological expertise | Low | Low | Low | Low | Low |

**Table. 3. Main features of the calculation methods**

| Ecosystem components addressed | Data needs | Expertise | Complexity | Resource intensity | Output resolution | Flexibility | Cost |
|---|---|---|---|---|---|---|---|
| **Hydraulic** | | | | | | | |
| Instream habitat for target biota. | **Low-Medium (desktop limited field)**<br>Historical flow records<br>Hydraulic variables of representative cross-sections of the reach | **Low-Medium**<br>Hydrological<br>Some hydraulic modelling<br>Some ecological expertise | Low-Medium | Low-Medium | Low | Low | Low-Medium |
| **Habitat simulation** | | | | | | | |
| Primarily instream habitat for target biota. Some consider channel form, sediment transport, water quality, riparian vegetation, etc. | **Medium-High (desktop and field)**<br>Historical flow records<br>Numerous cross-sections data<br>Suitability habitat data for target species | **High**<br>Hydrological<br>Advanced level in hydraulic and habitat modelling.<br>Specialist ecological expertise on physical habitat-flow needs of target species | Medium-High | High | Medium-High | Medium | High |
| **Holistic** | | | | | | | |
| The whole ecosystem-all/most individual components. Some consider the groundwater, wetlands, estuary, floodplain, social dependence on ecosystem, instream and riparian components. | **Medium-High (desktop and field)**<br>Historical flow records<br>Many hydraulic variables - multiple cross-sections.<br>Biological data on flow and habitat-related requirements of all biota and ecological components | **High**<br>Hydrological<br>Advanced hydraulic modelling. Habitat modelling in some cases.<br>Specialist expertise on all ecosystems components<br>Some require social and economic expertise | Medium-High | Medium-High | High | High | High |

*Source: Sánchez et al, 2012, based on King et al, 1999*

Moreover, a three levels assessment framework is proposed, from simple desktop estimates of flow needs through to a highly sophisticated programme of research and modelling, to refine environmental flow targets for subsequent levels of sophistication as deemed necessary. While level 1 may be implemented widely across the country, levels 2 and 3 could be applied in high-priority sub-basins.

- Level 1. Involves basin-wide reconnaissance of eflows, using hydrological desktop methods grounded in an understanding of the linkages between flow regime and key riverine resources.
- Level 2. It might apply to selected sub-catchments where more detailed environmental flow specifications are required. Holistic methodologies would be most appropriate for application at this level, at which the majority of routine eflows assessments is likely to be conducted.
- Level 3. It is appropriate for situations that require a high degree of certainty before any operational changes can be made. Habitat modelling is a suitable approach at this level ideally within or in conjunction with some advanced holistic methodology.

When possible, the description of study cases (Section 5) will include references to both these type of method and level of assessment. Previous overviews has been completed to develop the following table.

Table. 4. **Methodological approaches across Europe**

| Country | Type of Method | Explanation / Comments[54] |
|---|---|---|
| Austria | Static + Dynamic + Modelling | Guide values for a "basic" minimum flow and additional "dynamic flow" (Ordinance on Ecological Status Assessment) or determination by modelling which proofs that good status for all biological elements is achieved. **(see also 6.1.1)**<br>A future aim is to combine Instream Flow Incremental Methodology [IFIM] with elements of holistic methodologies. |
| Belgium | Static + Modelling | Depends of the type of the watercourses (navigable or not navigable) |
| Bulgaria | Static | 10% of annual mean flow |
| Switzerland | Static + Dynamic + Modelling | Within a catchment area the minimum's can be optimised e.g., one rive no water - the other more water. |
| Cyprus | | No information |
| Czech Republic | Static | According to value of Q355 category is chosen and after minimum residual flow (MRF) is calculated which is based on values Q330, Q355 and Q364. If flow Q355 is < 0,05 $m^3/s$; MRF=Q330 0,05 - 0,5 $m^3/s$; MRF=(Q330 + Q355)0,5 0,51 - 5,0 $m^3/s$; MRF=Q355 > 5,0 $m^3/s$; MRF= (Q355+ Q364)0,5.<br>IFIM-based procedures are under development. |
| Germany | Static + Dynamic + Modelling | Hydrological indices, case-specific expert opinion, and a habitat simulation methodology: CASIMIR. Mean of minimum daily flows for each year, or a fraction thereof and expert opinion have been used to assess 100 flows. CASIMIR has been applied for benthic invertebrates as a benthic shear stress model, and new models are under development for fish habitat and riparian zone plant communities. |
| Denmark | | Hydrological methods: median Minimum Method |
| Estonia | | No information |
| Spain | Static + Dynamic + Modelling | For relevant locations double studies are carried out, using hydrological and ecological (IFIM) data. According to the results obtained, the most adequate results are used, on a case by case basis. **(see also 6.3.1)**<br>Hybrid and alternative methodologies, including an approach similar to IFIM with holistic elements and historical flow series, multivariate biomass models, Cubillo's Madrid Method, and the Basque Method; IFIM; hydrological indices, specifically the Basic Flow Method.<br>A future aim is to combine IFIM with elements of holistic methodologies |
| Finland | Dynamic + Modelling | In some cases: fish habitat and other habitat modelling based on the relationship between flows, water depth, substrate and the quality and quantity of available habitats.<br>EVHA and detailed approaches based on physical habitat for fish species.<br>There are no standard methods Look at presentation in Hymo Project |

54 In Blue, information from Environmental Flow Assessments for Rivers: Manual for the Building Block Methodology (Updated Edition). JM King, RE Tharme & MS de Villiers (Editors). Report to the Water Research Commission by Freshwater Research Unit University of Cape Town WRC Report No TT 354/08 August 2008.

**Table. 4. Methodological approaches across Europe**

| Country | Type of Method | Explanation / Comments[54] |
|---|---|---|
| France | Static + Dynamic + Modelling | The lower limit is 10% or 5% (law) The adapted ecological minimum flow is generally based on "micro-habitats method, EVHA" (Souchon & al.), which can be completed or replaced with modelling or extrapolations. But there are other possible methods adapted when this one doesn't fit with the type of river.<br>It depends on the type of the river. This ecological minimum flow can be differently distributed over the year, in a compatible way between use and species interests. **(see also 6.4)**<br>Habitat simulation methodologies, such as EVHA, AGIRE, ENSAT Toulouse Method. EVHA: applied in about 70 cases  Ongoing research is taking place into continuous fish population modelling within an IFIM framework. |
| Greece | | No information |
| Hungary | | No answer |
| Ireland | | No information |
| Iceland | Dynamic | |
| Italy | Static + Dynamic + Modelling | Details on MEF can be found in the regional water protection plans, included in the RBMPs. **(see also 6.2.1)**<br>Hydrological indices, including FDCA, daily and annual mean flows; IFIM; Tennant Method; Wetted Perimeter Method; Singh Method, and Orth & Leonard Method for regionalisation; hybrid approach using regionalisation of Q95 on the basis of geology and catchment area.<br>Hydrological indices & IFIM in resource-intensive applications are the most commonly applied.<br>Relationships between fisheries standing crop and environmental variables are under development. |
| Lithuania | Static | |
| Luxembourg | Static + Dynamic | 10% AMF or 30% MMF |
| Latvia | Static + Dynamic | Guaranteed rate of flow; summer 30 day period mean minimal flowrate with 95% coverage. |
| Malta | | No information |
| The Netherlands | Dynamic | A lot of different methods have been used: hydrological model, PAWN; alternative approaches, including HEP, a general habitat suitability scoring model, an ecotype classification (ECLAS), a physical habitat model (MORRES), a habitat suitability model (EKOS), and a policy and alternatives analysis model (AMOEBA);HSI type model; hybrid methodologies based on habitat simulation, such as a GIS-based microhabitat model |
| Norway | Dynamic | Different methods are being assessed. Ongoing R & D. A specific technical requirement to set minimum flow is not recommended in Norway due to large variations in river basins and the purpose of setting minimum flow. However, hydrological indexes are commonly used (e.g Q95 summer/winter in small scale HP).<br>Hybrid approaches based on habitat modelling, specifically RSS which includes the HEC-2 program, BIORIV I/II and HABITAT models, and temperature. RSS and microhabitat modelling is the most widely used approach. |
| Poland | | No information |

**Table. 4. Methodological approaches across Europe**

| Country | Type of Method | Explanation / Comments[54] |
|---|---|---|
| Portugal | Dynamic + Modelling | INAG has developed a simple method (based on historical flows) than can be used when there is not many knowledge about an area. The IFIM method is recommended. |
| Romania | Static | See **6.5.1**. |
| Sweden | Static | Commonly static but in some cases defined from fish migration. RSS is the most widely used but few environmental flow studies have been completed. |
| Slovenia | Dynamic | Ecological acceptable flow considers hydrological baseline, type of water abstraction, hydrological, hydromorphological and biological characteristics and information on protection regimes. Hydrological baseline considers value of mean minimum flow and mean flow at the location of water abstraction. Qes = f sQnp (Qes - ecological acceptable flow, f-factor depend on ecological type of watercourse, sQnp - mean minimum flow) It is also possible to choose interdisciplinary holistic approach. **(see also 6.6.1)** |
| Slovakia | Static | Q355 - Average daily water discharge during the reference period, achieved or exceeded during 355 days in the year |
| United Kingdom | Static + Dynamic + Modelling | The national guidance has been established by UK TAG. This includes a list of good practice mitigation measures. In relation to flow, the list includes maintenance of a proportion of the flow that would have naturally been exceeded 95 % of the time. The proportion depends on the river type but is typically about 85 %. It also includes provision of variable higher flows, depending on the needs of the site-specific ecological characteristics. These flows are defined on a case-by-case basis.<br>The minimum flow requirements may differ from scheme to scheme depending on ecological needs (eg whether or not fish migration needs to be supported) and on what flow can be provided without a significant impact on electricity generation. **(see also 6.7)**<br>Various methodologies: IFIM; hydrological tools (e.g. Micro LOW FLOWS); hydrological indices (e.g. Q95); Environmentally Prescribed Flow Method; hybrid and alternative approaches, including the Scott Wilson Kirkpatrick Method, Jones Peters Method, HABSCORE, RIVPACS, Biotopes/Functional Habitats methods; holistic methodologies, such as the River Babingley (Wissey) Method and expert panel approaches |

### 4.5.6. The components of eflows regime

The changing quantity of water flowing in a river (namely, flow regime) plays a primary role for structure and functioning of rivers, lakes, wetlands and groundwater dependent ecosystems, providing habitat and significantly influencing water quality and the geomorphic processes that shape river channels and floodplains (Sánchez et al. 2012).

From a basic and functional perspective, flow types are known as ‘environmental flow components’ or simply EFCs that can be broadly distinguished between base flows (including low flows) and high flows (or flood regime). Low flows control the water chemistry and also the connectivity, thereby restricting movement of some aquatic organisms. Because native species may be adapted to the extreme low flow events that naturally occur, these periodic events may allow natives to outcompete generalist invasive species that are not adapted to extreme low flows. On the other hand, high flows play a critical role in the structure and functioning of the aquatic ecosystem. Small floods allow fish and other mobile organisms to access floodplains and other areas that can provide significant food resources allowing for fast growth, offer refuge from high-velocity, or be used for spawning and rearing. Large floods can move significant amounts of sediment, wood and other organic matter, form new habitats, and refresh water quality conditions in both the main channel and floodplains.

A proposed eflows regime may include different components depending on which pressures / alterations need to be addressed. So this classification is particularly relevant for the SPI storyline. In Fig. 3 and Fig. 6 the provisions of some RBMPs in relation to specific hydro-morphological measures are presented, depending on the pressures / impacts addressed.

**Table. 5. Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| **River Basin District** | | | |
| AT1000 | Yes | Yes | Based on RBMPAs. There are national legislation & technical standard for MEF and national legislation for HP, while technical standard for HP are set in individual cases.[55] |
| AT2000 | Yes | Yes | |
| AT5000 | Yes | Yes | |
| BEEscaut_RW | No | No | Based on RBMPAs (when available) and supported by national information. |
| BEEscaut_Schelde_BR | No | No | |
| BEMaas_VL | No | No | |
| BEMeuse_RW | No | No | |
| BENoordzee_FED | No | No | |
| BERhin_RW | No | No | |
| BESchelde_VL | No | No | |
| BESeine_RW | No | No | |
| BG1000 | Yes | No | Based on RBMPAs. There are national legislation & technical standard for MEF, while regarding HP, no normative means nor technical approach have been set. |
| BG2000 | Yes | No | |
| BG3000 | Yes | Yes | |
| BG4000 | Yes | No | |
| CY001 | Yes | No | Based on RBMPA. No national information |
| CZ_1000 | No | No | Based on RBMPAs. There are national legislation and also technical recommendation regarding MEF, while for HP both are set in case-by-case basis. |
| CZ_5000 | No | No | |
| CZ_6000 | No | No | |

55 Reinforced by Ofenböck, 2012.

Table. 5. **Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| DE1000 | Yes | No | Based on RBMPAs. There are national & regional legislations & technical standards for MEF, while HP is regulated by regional legislation, being technical standard set in individual cases. |
| DE2000 | Yes | Yes | |
| DE3000 | No | No | |
| DE4000 | Yes | No | |
| DE5000 | Yes | No | |
| DE6000 | Yes | No | |
| DE7000 | Yes | Yes | |
| DE9500 | No | No | |
| DE9610 | No | No | |
| DE9650 | No | No | |
| DK1 | Yes | No | Based on RMPAs. There is no national information on the existence of regulations or technical standards for MEF or HP to contrast with. |
| DK2 | Yes | No | |
| DK3 | Yes | No | |
| DK4 | Yes | No | |
| EE1 | Yes | Yes | Based on RBMP (own assessment)[56]. There is no national information on the existence of regulations or technical standards for MEF or HP. |
| EE2 | Yes | Yes | |
| EE3 | Yes | Yes | |
| GR01 | Unclear | Unclear | Greek Plans have not been submitted so far. On the other hand, no information has been found on the existence of regulations or technical standards for MEF or HP (no answer to the questionnaire on WFD & Hydropower). |
| GR02 | Unclear | Unclear | |
| GR03 | Unclear | Unclear | |
| GR04 | Unclear | Unclear | |
| GR05 | Unclear | Unclear | |
| GR06 | Unclear | Unclear | |
| GR07 | Unclear | Unclear | |
| GR08 | Unclear | Unclear | |
| GR09 | Unclear | Unclear | |
| GR10 | Unclear | Unclear | |
| GR11 | Unclear | Unclear | |
| GR12 | Unclear | Unclear | |
| GR13 | Unclear | Unclear | |
| GR14 | Unclear | Unclear | |

[56] Original assessment has been changed for HP since Estonian RBMPs indicate that suitable water regime for salmonids downstream of the impoundment must be ensured (see Section4.5.2).

Table. 5. **Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| ES010 | Yes | Yes | Own assessment based on RBMPs submitted to Public Consultation or, if still pending, in national information and/or personal knowledge. According to national legislation, all two components have to be considered in the framework of RBMPs if relevant[57]. Maximum flows to be determined in specific cases (downstream of dams which may induce a seasonal inversion of natural regime). |
| ES014 | Yes | Yes | |
| ES015 | Yes | No | |
| ES016 | Yes | Yes | |
| ES020 | Yes | Yes | |
| ES030 | Yes | Yes | |
| ES040 | Yes | Yes | |
| ES050 | Yes | Yes | |
| ES060 | Yes | Yes | |
| ES063 | Yes | Yes | |
| ES064 | Yes | Yes | |
| ES070 | Yes | Yes | |
| ES080 | Yes | Yes | |
| ES091 | Yes | Yes | |
| ES100 | Yes | Yes | |
| ES110 | Yes | No | |
| FIVHA1 | Yes | Yes | Based on RBMPAs. Normative & technical standards are established on a case-by-case basis, both for MEF and HP. |
| FIVHA2 | No | No | |
| FIVHA3 | Yes | Yes | |
| FIVHA4 | Yes | Yes | |
| FIVHA5 | No | No | |
| FIVHA6 | Yes | Yes | |
| FIVHA7 | No | No | |
| FIWDA | No | No | |

57 Assessment for HP regarding ES100 (Catalan River Basin District) has been changed. In the *Pla sectorial de cabals de manteniment de les conques internes de Catalunya* establishes a fixed exchange rate of flow (increase and decrease) which cushions and attenuates alterations in flow regime in stretches affected by dams.

**Table. 5. Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| FRA | No | No | Based on RBMPAs in BRD reported, and own assessment in FRM[58]. There is national legislation regarding MEF, while technical standards are set on case-by-case basis. For HP, regulation & standards are set in individual cases. Construction underway of an indicator of hydrologic perturbation due to hydropeaking events[59]. MEF in the range of 5% to 10% of mean annual flow to be applied in 2014 for all dams and weirs. |
| FRB1 | No | No | |
| FRB2 | No | No | |
| FRC | No | No | |
| FRD | Yes | Yes | |
| FRE | No | No | |
| FRF | Yes | Yes | |
| FRG | No | No | |
| FRH | No | No | |
| FRI | No | No | |
| FRJ | Yes | No | |
| FRK | No | No | |
| FRL | No | No | |
| FRM | Yes | No | |
| HU1000 | Yes | No | Based on RBMPAs. National legislation on MEF. |
| GBNIIENB | No | No | Based on RBMPAs, exclusively. There is no information on the existence of regulations or technical standards for MEF or HP (no answer to the questionnaire on WFD & Hydropower). |
| GBNIIENW | No | No | |
| IEEA | No | No | |
| IEGBNISH | No | No | |
| IESE | No | No | |
| IESW | No | No | |
| IEWE | No | No | |
| ITA | Yes | No | Based on RBMPAs. Regarding MEF, there are national and regional legislation & regional technical recommendation, while there are legal requirements for HP, being technical standard set in individual cases. |
| ITB | Yes | No | |
| ITC | Yes | No | |
| ITD | Yes | No | |
| ITE | Yes | No | |
| ITF | Yes | No | |
| ITG | Yes | No | |
| ITH | No | No | |
| LT1100 | Yes | Yes | Based on RBMPAs. There are national and technical recommendation, both for MEF and HP. |
| LT2300 | Yes | No | |
| LT3400 | Yes | Yes | |
| LT4500 | Yes | No | |

58 The disposition 5.2.5 indicates that competent authorities define and update, based on data acquisition, the flow characteristics of dry years (QMNA5) and minimum biological flows (rates and conditions to ensure the survival and development of species in the river). These values serve as reference for permits and licenses and for the definition of quantitative targets at the nodal points.

59 Baran 2012.

**Table. 5. Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| LU2000 | Unclear | Unclear | RBMPA (LU2000), own assessment and national information are not sufficiently clear[60]. |
| LU7000 | Unclear | Unclear | |
| LVDUBA | No | No | Based on RBMPAs. There are national legislations both for MEF and HP, while technical requirements are set on case-by-case basis. |
| LVGUBA | No | No | |
| LVLUBA | No | No | |
| LVVUBA | No | No | |
| MTMALTA | No | No | Based on RBMPAs. No national contrast information found. |
| NLEM | No | No | Based on RBMPAs. There is national legislation on MEF but no relevant method is reported. No normative means for HP, though technical requirements may be set on case-by-case basis. |
| NLMS | No | No | |
| NLRN | No | No | |
| NLSC | No | No | |
| NO1101 | No | No | Based on RBMPAs, when assessed (if not, qualified as unclear). There are legislation and technical recommendation at national level for MEF. Regarding HP, legal or technical requirements may be set in individual cases. |
| NO1102 | No | No | |
| NO1103 | No | No | |
| NO1104 | No | No | |
| NO1105 | No | No | |
| NO5101 | Yes | No | |
| NO5102 | Yes | No | |
| NO5103 | Yes | No | |
| NO5104 | Yes | No | |
| NO5105 | No | No | |
| NO5106 | No | No | |
| NOFIVHA5 | Unclear | Unclear | |
| NOFIVHA6 | Unclear | Unclear | |
| NOSE1 | Unclear | Unclear | |
| NOSE1TO | Unclear | Unclear | |
| NOSE2 | Unclear | Unclear | |
| NOSE5 | Unclear | Unclear | |
| PL1000 | No | No | Generalization based on the 4 RBMPAs assessed. No national information found to contrast with. |
| PL2000 | No | No | |
| PL3000 | No | No | |
| PL4000 | No | No | |
| PL5000 | No | No | |
| PL6000 | No | No | |

60 RBMPA (LU2000) concludes that neither MEF nor HP are measures to be taken to reach GES / GEP. The document "*Plan de gestion pour le Grand-Duché de Luxembourg. Rapport final*", which includes both RBD (Rhine & Meuse), does not mention the existence of measures related to eflows' components, though it is stated the importance of establishing minimum ecological flows in the context of drought and in relation to hydropower. Nevertheless, taking into account the existence of national legislation and / or standards for both components (according to national legislation, MEF are set in individual cases, with national technical recommendation available, while there are national & regional legislation for HP being technical requirements set on case-by-case basis), the assessment is uncertain.

Table. 5. **Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| PL6700 | No | No | |
| PL7000 | No | No | |
| PL8000 | No | No | |
| PL9000 | No | No | |
| PTRH1 | Yes | Unclear | Own assessment based on RBMPs submitted to Public Consultation. Different situations (some reservoirs have MEF) but further studies and implementation to be developed in the framework of PoM. No mention of other eflows components.<br>There are National recommendation & Legal national standard for MEF, while HP legal & technical requirements are set in individual cases. |
| PTRH10 | Unclear | Unclear | |
| PTRH2 | Yes | Unclear | |
| PTRH3 | Yes | Unclear | |
| PTRH4 | Yes | Unclear | |
| PTRH5 | Yes | Unclear | |
| PTRH6 | Yes | Unclear | |
| PTRH7 | Yes | Unclear | |
| PTRH8 | Yes | Unclear | |
| PTRH9 | Unclear | Unclear | |
| RO1000 | Yes | No | Based on RBMPA. National leg. & standards for MEF& HP |
| SE1 | No | No | Based on RBMPAs, when assessed (if not, qualified as unclear). National legislation and technical standards set in individual cases both for MEF and HP. |
| SE1TO | Unclear | Unclear | |
| SE2 | No | No | |
| SE3 | Yes | No | |
| SE4 | No | Yes | |
| SE5 | No | No | |
| SENO1102 | Unclear | Unclear | |
| SENO1103 | Unclear | Unclear | |
| SENO1104 | Unclear | Unclear | |
| SENO5101 | Unclear | Unclear | |
| SI_RBD_1 | Yes | No | Based on RBMPA. There are National legislation & standards for MEF, while for HP both are set in individual cases |
| SI_RBD_2 | Yes | No | |
| SK30000 | No | Yes | Based on RBMPA. National recommendation for MEF; for HP legal and technical requirements are set in individual cases |
| SK40000 | No | Yes | |
| UK01 | Yes | Yes | RBMPAs and own assessment.<br>In Scotland (UK01&02), PoMs include some water demand & resources measures to reduce abstraction pressures. Though no eflows or similar tools are explicitly mentioned in PoM, |
| UK02 | Yes | Yes | |
| UK03 | Yes | Yes | |
| UK04 | Yes | Yes | |

**Table. 5. Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| UK05 | Yes | Yes | SEPA applies regulations regarding water abstraction limits and HP conditioning[61] so that assessment has been changed. Also for the rest of UK RBDs, original MEF assessment has been changed[62]. In England & Wales, Annex C: *Actions to deliver objectives*, includes the measure: *Review and improve Environmental Flow Indicators* intended to identify where water may need to be recovered to support GES; in some cases, also *Improve flow estimates for surface water bodies*. In North Ireland, water flow standards have also been set. HP measures considered in all RBMP but Dee's (UK11). original HP assessment for NI has also been changed[63]. There are national and regional recommendations on MEF but legal requirements in HP are only set in individual cases (no approach for definition of standards). |
| UK06 | Yes | Yes | |
| UK07 | Yes | Yes | |
| UK08 | Yes | Yes | |
| UK09 | Yes | Yes | |
| UK10 | Yes | Yes | |
| UK11 | Yes | No | |
| UK12 | Yes | Yes | |
| UKGBNIIENB | Yes | Yes | |
| UKGBNIIENW | Yes | Yes | |
| UKGBNINE | Yes | Yes | |
| **Countries** | | | |
| Austria | Yes | Yes | National legislation and standards on MEF and also National legislation on HP, being technical requirements set on case-by-case basis |
| Belgium | No | No | Only RBMPs for the Flemish part assessed. MEF set only in individual cases and no normative means nor technical approach for HO available. |
| Bulgaria | Yes | Yes | National legislation and standards on MEF. Operational modifications for HP proposed according to RBMPAs though, in principle, there is no normative means. |
| Cyprus | Yes | No | No information on the existence of national regulation for MEF or HP. |

61 Hands-off flow requirements (water level at which an abstraction must cease (or reduce), and compensation flow (minimum release of water below a reservoir/loch, provided for environmental mitigation) may be of application in license assessment (*Regulatory Method (WAT-RM-01) Regulation of Abstractions and Impoundments).* Licensing for run-off hydropower schemes includes low & high flows and variability conditioning (*Guidance for developers of run-of-river hydropower schemes*):

62 Water resource flow standards for rivers, lakes and estuaries have been developed by the UKTAG. These are **limits aimed at ensuring that water resource activities do not cause or contribute to the failure of WFD ecological status objectives**. These standards have been set for each status class on the basis of the best available information on ecological impacts as recommended by UKTAG. These standards have been used to classify the hydrological status of rivers and lakes. In order to assess whether a standard has been exceeded, water balance calculations have been undertaken, including both known abstractions and discharges, to determine the degree of change from natural river flows or lake levels.

63 Under the *Water Abstraction and Impoundment (Licensing) Regulations* (NI) 2006, all hydroelectric schemes require a license to abstract water. NIEA consult externally with Northern Ireland Water, Loughs Agency, Department of Culture, Arts and Leisure (DCAL) Rivers Agency and internally with Natural Heritage, Built Heritage and Hydrology teams about the possible impacts of the scheme before issuing a license. **All environmental impacts are considered and mitigation measures are included in any license issued**. The amount of water permitted for abstraction will depend upon the scale and nature of the project and site-specific fishery, nature conservation protection designations and WFD water resource flow standards. Getting the balance right between supporting hydropower development and protecting and improving the water environment is a key challenge for this and future River Basin Management Plans.

**Table. 5. Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| Czech Republic | No | No | There are national legislation and also technical recommendation regarding MEF, while for HP both are set in case-by-case basis. |
| Germany | Yes / No | Yes / No | There are national & regional legislations & technical standards for MEF, while HP is regulated by regional legislation, being technical standard set in individual cases. |
| Denmark | Yes | No | There is no national information on the existence of regulations or technical standards for MEF or HP to contrast with the assessments.. |
| Estonia | Yes | Yes | There is no information on the existence of regulations or technical standards for MEF or HP to contrast with the assessments. |
| Spain | Yes | Yes | Only one RBD assessed but completed by own assessment. According to national legislation, all two components have to be considered in the framework of RBMPs if relevant. Maximum flows to be determined in specific cases (downstream of dams which may induce a seasonal inversion of natural regime). |
| Finland | Yes / No | Yes / No | Normative & technical standards are established on a case-by-case basis, both for MEF and HP. |
| France | Yes / No | Yes / No | All RBMPs assessed but FRM (Mayotte), covered with own assessment. There is national legislation regarding MEF, while technical standards are set on case-by-case basis. For HP, regulation & standards are set in individual cases. Construction underway of an indicator of hydrologic perturbation due to HP events. |
| Greece | Not assessed | Not assessed | No information available. Plans pending. |
| Hungary | Yes | No | National legislation on MEF, no information on MEF standards, nor legal or technical requirements on HP to contrast with the assessments. |
| Ireland | No | No | There is no information on the existence of regulations or technical standards for MEF or HP to contrast with the assessments. |
| Italy | Yes | No | Regarding MEF, there are national and regional legislation & regional technical recommendation, while there are legal requirements for HP, being technical standard set in individual cases. MEF not reported only in ITH (Sicily). |
| Lithuania | Yes | Yes / No | There are national and technical recommendation, both for MEF and HP. |
| Luxembourg | Unclear | Unclear | MEF are set in individual cases, with national technical recommendation available. Regarding HP, there are national & regional legislation, being technical requirements set on case-by-case basis. Assessed as unclear |
| Latvia | No | No | There are national legislations both for MEF and HP, while technical requirements are set on case-by-case basis. |
| Malta | No | No | There is no information on the existence of regulations or technical standards for MEF or HP to contrast with the assessments. |

**Table. 5. Components of eflows considered at river basin and / or country scale**

| RBD / Country | Minimum ecological flow [MEF] requirements | Operational modification for hydropeaking [HP] | Complementary information |
|---|---|---|---|
| Netherlands | No | No | There is national legislation on MEF but no relevant method is reported. No normative means for HP, though technical requirements may be set on case-by-case basis. |
| Norway | Yes / No / Unclear | No / Unclear | RBMPA only partially assessed. There are legislation and technical recommendation at national level for MEF. Regarding HP, legal or technical requirements may be set in individual cases. |
| Poland | No | No | Only partially assessed (generalization based on the 4 RBMPAs). There si no national information found to contrast with. |
| Portugal | Yes[64] | No | Covered with own assessment based on RBMPs submitted to Public Consultation. There are National recommendation & Legal national standard for MEF, while HP legal & technical requirements are set in individual cases. |
| Romania | Yes | No | National legislation and standards on both MEF and HP though the later not referred to as a measure in the only RBMPA (Danube). |
| Sweden | Yes / No / Unclear | Yes / No / Unclear | Only partially assessed. National legislation and technical standards set in individual cases both for MEF and HP. |
| Slovenia | Yes | No | There are National legislation & standards for MEF, while for HP both are set in individual cases. |
| Slovakia | No | Yes | National recommendation for MEF; for HP legal and technical requirements are set in individual cases |
| United Kingdom (Scotland) | No | Yes | There are national and regional recommendations on MEF but legal requirements in HP are only set in individual cases (no approach for definition of standards). HP measures considered in all RBMP but Dee's (UK11). SEPA (Scotland) |
| United Kingdom (England & Wales) | Yes | Yes | |
| United Kingdom (North Ireland) | Yes | Yes | |

### 4.5.7. Treatment of eflows in Protected Areas

Protected areas under European, national or regional legislation or included in the RAMSAR List of Wetlands may be particularly sensitive to low flows or water tables. Eventually, appropriate and specific measures to maintain or restore a state of favorable conservation of habitats and species have to be adopted, responding to their ecological requirements and maintaining long-term ecological functions on which they depend, in accordance with respective regulations. The determination and implementation of eflows in these areas should not refer exclusively to the very extent of them, but also the hydrographic system elements that can have a significant impact.

In **Spain**, regulation explicitly states that if registered as protected areas, water deviation should not prevent the implementation of standards and objectives under which it was established protected area. This is also true for lakes and wetlands, whose water needs have to be assessed. On the other hand, the

[64] Unclear in insular territories.

possibility of relaxation of eflows regime during prolonged drought episodes, issued in the Spanish standard, is not available if WB are linked with some Protected Area.

In **Italy** (Veneto Region), a naturalness index increases the hydrological component of the eflows assessment, proportionally to the naturalistic value of the considered area. In **Slovenia**, the rapid assessment method is not valid if the running water is in a preserved or legally protected area or if endangered or protected species of flora and fauna are present in the river or in the riparian zone. In this context, some important ecological assets to be preserved have been identified in **Romania** (see study case in section 6.5.1). Finally, **Estonia** has prohibited damming of water bodies, altering the flow regime and regulating the flow rate is so-called 'salmon rivers' (spawning areas and habitats of salmon, river trout, sea trout and grayling); in the case of Natura 2000 sites (rivers) and lakes on the site, the provisions of protection rules or management plan should be followed.

## 4.6. Evaluation of the potential (expected effectiveness) of eflows at RBD scale

In the context of general water allocation, an evaluation of the expected effectiveness of MEF (high, moderate & low) has been carried out[65]. The potential role of eflows as a tool to preserve environmental condition compatible with GES / GEP is higher in those RBDs where abstractions exert a higher relative pressure on natural resources.

The main sources and criteria for this analysis are summarized in the following points:

- The Water Exploitation Index - WEI (at national or, preferably, at RBD level) as a basic indicative of the existence of water scarcity problems. Two different limits have been set out to assess the magnitude of water scarcity:

| Potential | National WEI | RBD WEI |
|---|---|---|
| high | WEI>30% | WEI>25% |
| moderate | 30%>WEI>20% | 25%>WEI>15% |
| low | WEI≤20% | WEI≤15% |

  These limits are based on previous studies. WEI data has been provided by EEA and are subject to a certain degree of unevenness since the nature of the base information can be diverse and / or correspond to different time periods.

65 Information on indicators of potential impact of hydro-peaking (basically, presence of hydroelectric dams) at RBD level was rather incomplete, so that a similar assessment has not been feasible.

- WISE information on % SWB with significant water abstraction pressures, also as an index related to the magnitude of pressures in relative terms. Limits have been fixed by correspondence with percentiles (75 y 50) of the series of values above absolute 0 that have been regarded as no information:

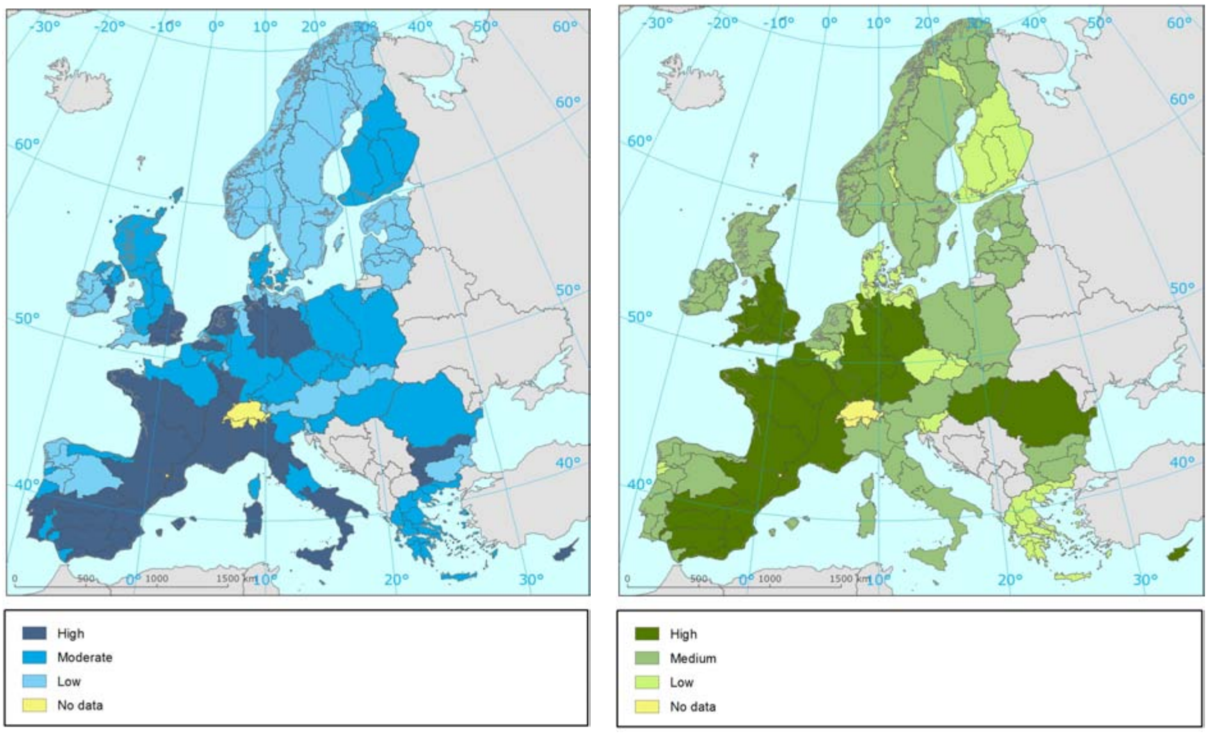
| Potential | % affected SWB |
|---|---|
| high | %SWB > 18,5% |
| moderate | 18,5% > %SWB > 8,3% |
| low | %SWB ≤ 8,3% |

Though these ranges and percentiles are somewhat arbitrary, they are also significant in relative terms.

- Expert judgement on the relevance of water scarcity problems, both from RBMPAs (template on strategy to deal with water scarcity & droughts) and / or from own assessment of RBMP and other information sources.

These criteria have been combined in a flexible way to render a single value of effectiveness. Results are presented with an evaluation of the level of confidence (high / medium / low), based on the completeness of data (high meaning RBD values for WEI + WISE information on %SWB affected + consistent expert judgement) and their internal consistency at RBD level.

**Fig. 17. Maps of potential / expected effectiveness of MEF in European RBDs**




**Potential / Expected effectiveness of MEF** **Level of confidence of the effectiveness assessment**

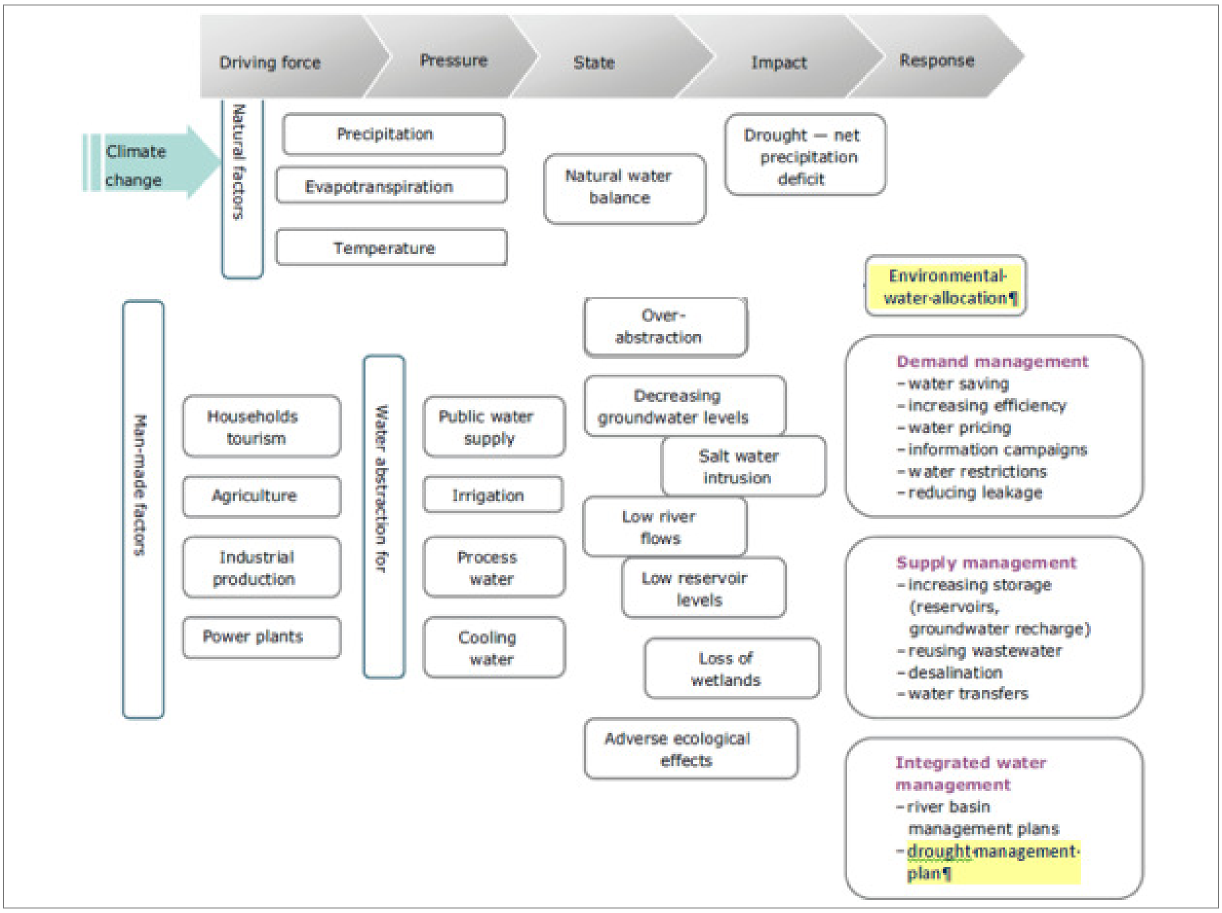
*Source: own assessments*

# 5. Linking measures with PSI storyline

## 5.1. Overview

The DPSIR framework is useful in describing the relationships between the origins and consequences of environmental problems and has been identified as a suitable framework for determining pressures and impacts under the WFD (Borja et al. 2006). The following figure depicts these basic relationships.

**Fig. 18. Eflows & DMPs under the DPSIR conceptual framework**




*Source: adapted from EEA 2008*

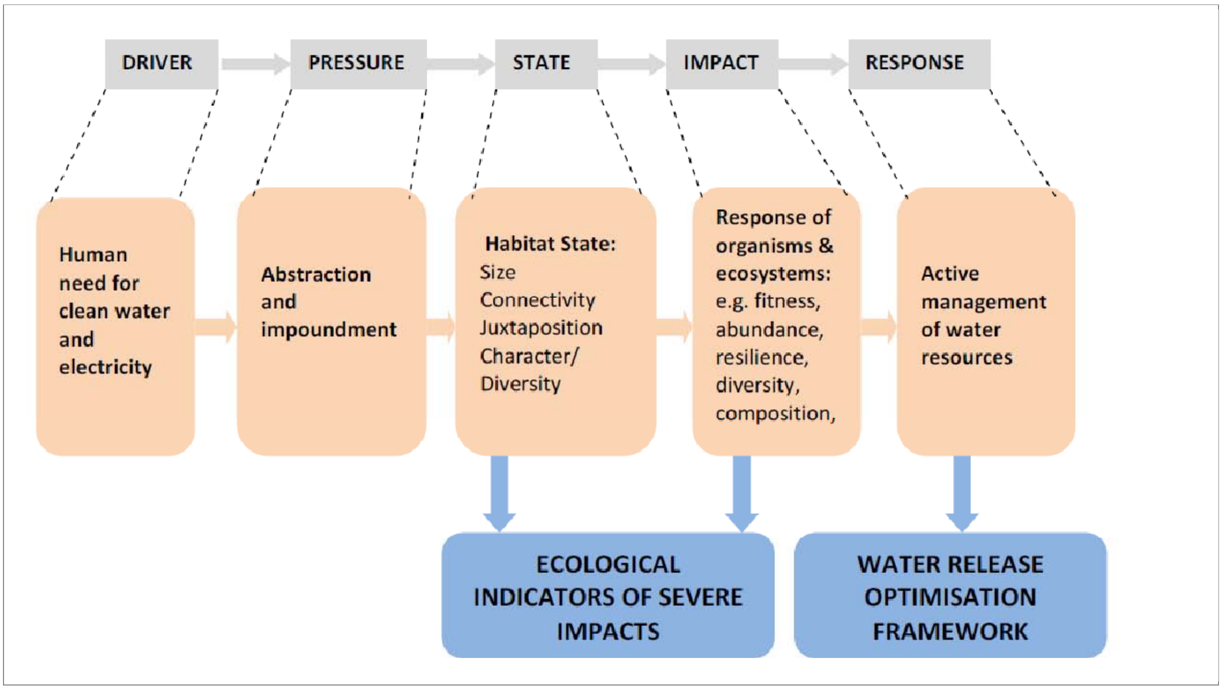
The framework allows identifying the level and the factors to which proposed measures focus (drivers, pressures, impacts) and helps to carry out a qualitative assessment of the level of ambition of a particular water management policy for a given country or river basin.

The potential role of eflows as a management tool can be roughly illustrated from the DPSIR framework:

Certain human activities create a water demand (**Driving force**) that requires the development of infrastructures as diversion weirs & dams, whose presence and operation (**Pressure**) produce a modification of the natural flow regimes that affects the biophysical conditions of ecosystems (**State**). These changes result in negative effects (**Impact**) such as loss of biodiversity or degradation of natural areas. Those responsible for making decisions (**Response**) try to minimize or mitigate impacts that may influence each of the links in the process. One of these responses may be the establishment of an Environmental Water Allocation Scheme: helping to restrict water use [**reducing the pressure**], to define the maximum limits of hydrologic alteration to maintain a certain biological condition [**defining the state**] and may appear as a basic tool for the recovery of certain species affected by the modification of aquatic habitats [**correcting the impact**].

Bradley, D, Cadman, D. & Milner, N, 2012 have developed a conceptual model with two major aims: *1) to identify simple, field measurable indicators that can be used together with other environmental data to form the weight of evidence needed to identify where flow changes are causing major and severe impacts consistent with Poor and Bad status; 2) to propose a framework to design releases from impoundments in order to optimise the ecological benefits, to minimise adverse ecological impacts, and to enhance the ecological potential on heavily modified water bodies (HMWBs)*. The connections between the hydrological effects of human water use and impacts on aquatic biota are structured adopting the DPSIR framework (grey), by defining river flow impacts and management (pink), while the ecological indicators and the optimisation framework (the expected project's products) are shown in blue.

**Fig. 19. Eflows & DMPs under the DPSIR conceptual framework**




*Source: Bradley, D, Cadman, D. & Milner, N, 2012*

## 5.2. PSI storyline for eflows

In the following table, the links between possible elements of an eflows regime and the PSI storyline are basically outlined.

**Table. 6. Eflows and PSI Storyline**

| Measure (component of eflows) | Pressures addressed | State (altered) | Impacts |
|---|---|---|---|
| Setting minimum ecological flow requirements (absolute or considering seasonal variability) | • Abstractions of surface water and also groundwater (affecting dependant SWB), leading to a significant reduction in discharge.<br>• Over-allocation to supplies with insufficient release of flows for environmental purposes. | Flows significantly below natural condition with subsequent modification in the distribution and availability of in-stream habitat (width, depth, substrate, stream velocity). | • Loss of natural configuration of low water channel (even disappearance); loss of lateral and longitudinal connectivity.<br>• Rupture of aquatic communities composition (invertebrates and fish populations leading even to extinction): limitation for spawning and migration.<br>• Damage to riparian ecosystems, eventually with introduction of invasive species.<br>• Deterioration of physical and chemical quality due to lower dilution capacity.<br>• Loss of scenic and recreational values. |
| Operational modifications for hydro-peaking to reduce adverse impacts | Hydropower plants` exploitation causing sharp fluctuations (rise and fall) of flow outside the range of natural variation. | Rapid variations of flow magnitude and velocity, leading to impoverishment of biological communities. | • Instability of river beds and modified zonation of habitats.<br>• Wash out of aquatic species in rising phase and strand in the receding phase.<br>• Risk to the safety of persons and property. |
| Programmed flood regime to restore river configuration and connection to floodplains. | Alteration of flooding regime linked to operation of dams or water transfers to other catchments. | Absence of natural floods (high and/or small), inducing alteration of solids flow dynamics (sediment transport and deposition) and, as a consequence in the stability of river channel configuration. | • Loss of sediments reaching the river mouth that may cause retreat of the coastline and deterioration of coastal ecosystems and fisheries.<br>• Affection to fluvial ecosystems (aquatic and terrestrial) in river bed, banks and floodplains.<br>• Impediment to natural vegetation recruitment on river banks and floodplains.<br>• Greater risk of economic and human losses in case of catastrophic floods (false sense of security of population). |

Table. 6. Eflows and PSI Storyline

| Measure (component of eflows) | Pressures addressed | State (altered) | Impacts |
|---|---|---|---|
| Setting maximum flows in dry seasons. | Natural regime alteration linked to operation of dams, mainly when river is used to convey great amounts of water for irrigation or other uses. | Flows in dry season are regularly above natural, even to the virtual disappearance of low water period or seasonal flow inversion. | • Detrimental effects on aquatic species, mainly fish: wash out of eggs and juveniles; risk of invasion of non-native species.<br>• Displacement of riparian biological community because of enlargement of the low water channel. |

*Source: own*

# 6. Case studies[66]

## 6.1. Austria

### 6.1.1. Regulations, assessment methods and monitoring

In Austria, both the effects of existing hydropower plants on environment and the economic impacts of environmental restoration on hydropower sector has been assessed in the framework of RBMPs. The majority of stretches impacted by water abstraction has not been designated as HMWB but, on the contrary, eflows regimes and other measures have been designed to ensure the achievement of GES.

According to Austrian Water Act, since 1990 MEF is obligatory to get a new permit, but implementation is still pending in more than 85% of the 2.586 abstraction points identified. In addition, hydro-peaking is affecting 78 river stretches, almost all of them failing to reach GES.

| | Number of river stretches | Length km | % of river net |
|---|---|---|---|
| Water abstraction | 2.586 | 3.331 | 10,6 |
| Impoundment | 574 | 1.064 | 3,5 |
| Hydro-peaking | 78 | 802 | 2,6 |
| River fragmentation (barriers) | > 2.000 (28.000 barriers) | | |

Actual researches show that about 67% of Austrian rivers are at risk of not reaching GES because of significant hydro morphological pressures and impacts. The main factors for this are deficits in longitudinal continuity combined with deficits of the habitats.

Two complementary studies have been carried out supporting the drafting of RBMPs:

- Impacts of existing hydropower plants on environment: fish, macroinvertebrates, ecological status…
- Impacts of restoration on hydropower sector, assessing loss of energy under different scenarios with respect to restoration of continuum, ecological minimum flow and minimization of the effects of

66 Based on Ofenböck G., 2012 and SEE Hydropower 2011.

hydropeaking by changing operation mode of the facilities[67]. As a consequence of the proposed measures, the hydropower production will decrease about 15% for small hydro power and about 9% for hydropower bigger than 10 MW.

Regarding HMWB designation, some possible adverse effects on hydropower sector have been identified: loss in base load generation and loss in peak load generation/ancillary services, as well as the associated investment costs. A basic scheme for determining significance of these impacts is proposed:

| | |
|---|---|
| Significant | loss of base load generation >> 3% of $HP_{tot}$ Austria<br>Any loss of peak load generation/ ancillary services |
| Not significant | loss of base load gen. < 3% of $HP_{tot}$ Austria<br>Investment costs for constructions fish pass, spawning ground, compensation reservoirs, reconnection of side arms may be supported by financial support schemes |

The majority of stretches impacted by water abstraction have not been designated as HMWB. This category has been limited to impoundments and storage reservoirs, SWBs affected by hydropeaking (but only in case that the change of operational mode is the only possibility to restore GES) and, finally, those failing GES due to water abstraction to fill storage reservoirs for peak load production.

According to the gradual achievement of objectives by 2015 almost 150 recycled hydropower lines are to improve the ecological status or potential by special measures. The loss of energy production has been estimated below 1%.

If not designated HMWBs, **MEF** has been established based on guideline values aimed at the achievement of GES in all probability and by the application of modelling. Two specific components are considered necessary:

- Basic flow must be available at all times to ensure the preservation of natural type and habitats – natural low flow conditions (natural mean daily low flow - NQt) and also the river continuity (minimum depth and minimum flow velocity).
- Dynamic share reflecting the natural discharge dynamics over the year to ensure: natural bed-sediment relocation, type-specific substrate, sufficient stream velocity in times of spawning migrations, different habitat demands of individual age classes of key organisms and type-specific oxygen and thermal conditions

The criteria for the high hydro morphological status regarding water management, continuity of the river and morphology are stated in the *Austrian Regulation for Ecological Quality Objectives of surface waters* (BGBI.II Nr. 99/2010). A very minimal water withdrawal is acceptable (as a guideline it is up to 20% of the annual water amount). From October to March rivers must not show less discharge than the average for

[67] Energiewirtschaftliche und ökonomische Bewertung potentieller Auswirkungen der Umsetzung der EU-WRRL auf die Wasserkraft (Stigler et al., 2005).

winter months, while from April to September discharge must be above annual average. Otherwise, the water abstraction threshold is set to less than 10% of the natural lowest discharge per day (LQd)[68].

For good hydro morphological status, the quantity and dynamics of the flow and the resulting connection to the groundwater must ensure that values specified for the biological quality elements will almost certainly be achieved. The guiding values and criteria for good ecological status are summarized below:

### Minimum flow

| | Natural mean annual flow < 1 $m^3/s$ | Natural mean annual flow > 1 $m^3/s$ |
|---|---|---|
| Ecological flow | lowest daily flow (natural) | |
| | 50% mean annual low flow | 33% mean annual low flow |

(the stricter value has to be applied)

### Dynamic fluctuations

| | |
|---|---|
| at least 20% of the actual discharge have to be released to maintain natural flow variability | |
| Anthropogenic discharge fluctuations | Separately evaluated for large rivers. |
| | All other rivers:<br>no hydro peaking ratio higher than 1:3<br>at least 80% of the river bed covered by water at all times. |
| Anthropogenic reductions of flow velocity | Velocities less than 0.3 m/s (for mean discharge) appear only sporadically and on short segments. |
| Anthropogenic barriers | passable the whole year and the habitat connection is only slightly modified |

### Minimum water depth[69]

| Fish region | For the area of the rapid<br>Minimum water depth Tmin [m] | For the thalweg<br>Ø Minimum depth TLR [m][3] |
|---|---|---|
| Epirhithral (>10%gradient) | 0.1 | 0.15 |
| Epirhithral (3-10% gradient) | 0.15 | 0.20 |
| Epirhithral (≤3% gradient) | 0.20 | 0.25 |
| Metarhithral | 0.20 | 0.30 |
| Hyporhithral[70] | 0.20 (0.30) | 0.30 (0.40) |
| Epipotamal | 0.30 | 0.40 |

68 Other conditions: there are no fluctuations caused by human impact concerning hydropeaking; anthropogenic reductions in flow velocity in the cross section occur only rarely and locally; continuity only slightly influenced by human activities (undisturbed migration of the typical aquatic organisms and transport of sediments in the river bed); the majority of the river bank dynamics unrestricted; sediment dynamic is perfectly possible (none or only very limited action on the river bed stabilization).

69 Applies in the specific spawning and developmental stages of the respectivesite-related dominant and sub-dominant fish species.

70 The values written in brackets are applicable for the presence of huchen (*Hucho hucho*).

**Minimum flow velocity**

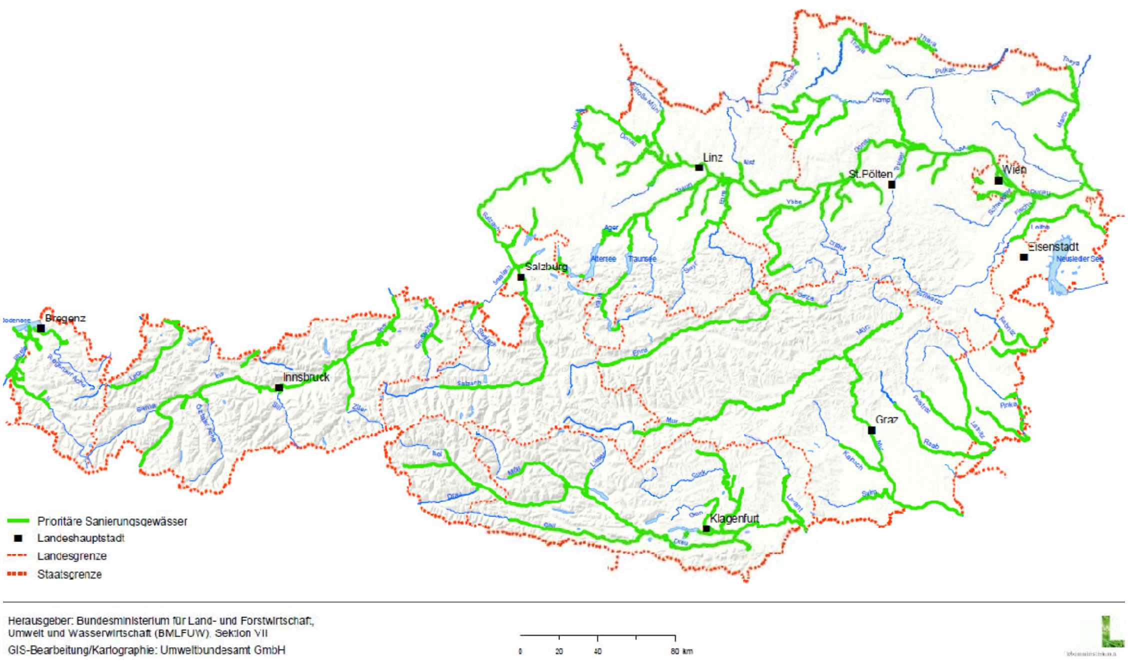
| | | |
|---|---|---|
| For the area of the rapid (m/s) | ≥0.3 | Mean velocity in the cross-section |
| Principal current in migration corridor (m/s) | ≥0.3 | 3-point measurement in 20%, 60% & 80% of total water depth |

There are many important parameters which have to be considered when quantifying eflows. The diversity of species is relevant for all biological components (additional to density, and other factors) and is assessed for: phytoplankton, macrophytes, phytobenthos, benthic invertebrate fauna and fish fauna. Furthermore, river typical processes (e.g. sediment transport, fish migration) are also taken into account.

Though there are no detailed restrictions, the Quality Objective Act states that in case of water use (e.g. hydropower) flow regime, frequency, timing magnitude and duration of the residual flow is just allowed in a size that the quality components does not change into a worse status.

The implementation of MEF is considered in the framework of a stepwise approach for restoration, aimed at bringing back river continuity and achieving GES, with the priority of preserving corridors for medium distance migratory fish.

**Fig. 20. Priority restoration stretches in relation to hydromorphological pressures**




*Source: Lebensministerium*

Regarding **hydropeaking**, guidelines values are intended to guarantee achievement of GES in all probability. Though some general conditions have been established –anthropogenic fluctuations in water flow shall not exceed a ratio of 1 to 3 between downsurge and swell, while 80% of the riverbed must remain covered during downsurge–, in large rivers, no general recommendation is considered acceptable so that case-by-case decisions are to be adopted.

The best indicator for assessing an impact - that is that group of organisms, which responds to this impact most sensitive - is the most indicative biological quality element.

**Table. 7. Significance of quality components (hydromorphological load)**

| | Physical and chemical quality components | Hydro-morpholo-gical quality components | Phyto-plankton | | Makro-phytes | Benthic invertebrate fauna | Fish fauna |
|---|---|---|---|---|---|---|---|
| Morphological changes | | high | | | low | low | high |
| Only changes in the streambed | | high | | | high | low | |
| Residual flow | | high | low | | | low | high |
| Hydropeaking | | high | low | | | low | high |
| Impoundment | | high | low | | | high | low |
| Continuity interruption | | high | | | low | high | |

*Source: Annex B, Quality Objective Act*

As shown in previous table Fish monitoring is the relevant instrument for monitoring and assessing effectiveness of eflows (see Table 14). There are standard manuals for the assessment of fish fauna and other quality elements (macrophytes, phytobenthos & benthic invertebrate fauna), called “Leitfäden”.

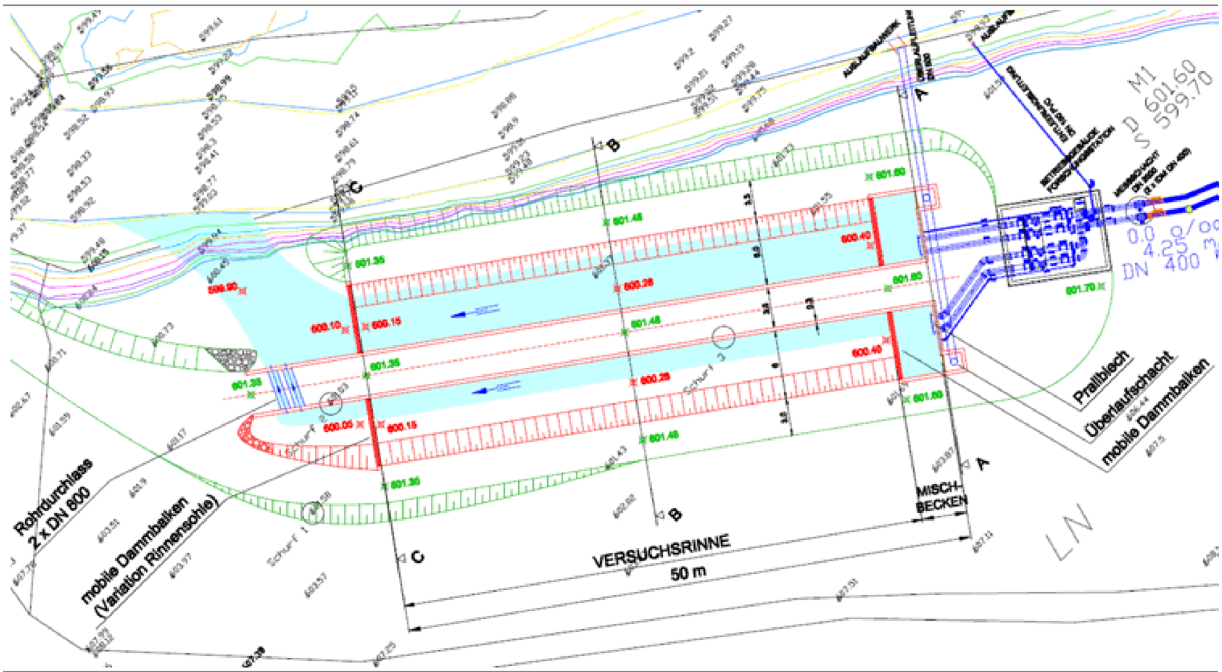
To assess the biological quality element fish fauna the **Fish Index Austria** (FIA) is to be used. FIA analyzes the deviation of the actual fish assemblage from historically and actually pre-defined reference fish assemblages according to river types using nine metrics: percentage of dominant species, percentage of subdominant species, percentage of rare species, presence of reproductive guilds, presence of flow preference guilds (further named as number of flow-guilds), FRI, biomass, population structure of dominant species and subdominant species. River types were established by means of cluster analysis resulting in 8 different fish zones in 9 different geographical regions, i.e. fish bioregions.

### 6.1.2. Best practice example: the new HYTEC test facility

There is an important knowledge gap on the effects of hydropeaking (different ratios, frequency, swell and downsurge velocities) and associated ecological impacts. This research is crucial to develop efficient mitigation measures.

The link between hydropeaking and GES is going to be tested in a pilot station equipped with two identical experimental channels each with around 40 meters long and 6 meters wide, with a maximum capacity of 125 l/s each (HyTEC - Hydromorphological and Temperature Experimental Channel) [http://hydropeaking.boku.ac.at].

**Fig. 21. Diagram of the system**




*Source: http://hydropeaking.boku.ac.at/hytec.htm*

The response of aquatic organisms to different swell and downsurge phenomena are going to be analysed under strictly controlled conditions. The main questions to be dealt with are:

- Drift and stranding of larvae and juvenile fish (brown trout and grayling)
- Effects of different morphological conditions on hydropeaking impacts

## 6.2. Italy[71]

### 6.2.1. Regulations, assessment methods and monitoring

The first studies were carried out in 1995 by a technical commission established by the Po RBA. This commission defined the first provisional rules to quantify flows to be guaranteed after diversion works

[71] Based on SEE Hydropower 2011.

inside and the possible indicators for monitoring its application. In 1999 Italian legislators established the normative bases for the quantitative protection of the water resources, functional to the achievement of the qualitative goals for aquatic ecosystems that should be defined by RBAs in the framework of Regional Water Protection Plans (WPP) –aimed at ensuring the equilibrium of water balance as defined by the RBA– through the quantification of the site-specific parameters. In this context, in 2002, the Po RBA established the qualitative objectives for the Po river basin and quantitatively defined eflows and the modalities for its implementation. These general criteria were adopted by the regions located in the Po river basin and implemented in the WPPs.

The Ministerial Guidelines for the definition of eflows[72] have been issued only in 2004, leaving the definition of rules for eflows calculation to the WWPs. For this reason in Italy there is no single standard methodology. Generally it consists of a basic hydrological component, proportional to the mean annual discharge, corrected by means of some coefficients that take different environmental aspects into account (morphology of the riverbed, functional uses, quality objectives defined by the Water Protection Regional Plans). Three families of methods may be applied

- **Expeditious regional methods**, based on hydrological data to quantify the basic component of the flow, can be subdivided into three different approaches: 1) Hydrological and morphological approach uses variables and data of the river basin; 2) Hydrological approach uses river annual medium flow data; 3) Statistical approach uses natural flow duration curve of the river.
- **Experimental methods** that aim to determine the relation between flow and habitat quality, generally concerning the predetermination of reference species. These methods are useful to provide an estimate of the correction factors.
- **Hybrid methodologies** that include biological data. These methodologies are often used in pilot case studies.

In the **Veneto Region**, eflows are regulated by the WPP approved in November 2009. Art. 42 of this Plan states that for the Po river basin eflows are quantified as determined with the **Bylaw nº 7/2002** issued by the Po RBA. The general expression is based on the quantification of one basic hydrological component proportional only to hydrological parameters and of an environmental component which takes into account ecological aspects (see equation (4.1)).

$\mathbf{EF} = \mathbf{EF_{HYDRO}} \cdot \mathbf{K_1} \cdot \mathbf{K_2} \cdot \ldots \cdot \mathbf{K_n}$ [l/s] where

$\mathbf{EF_{HYDRO}}$ is the hydrological component of eflows which is generally proportional to the mean annual discharge and to the catchment area
$\mathbf{K_i}$ are environmental correction factors quantified on the basis of ecological considerations or experimental activities on pilot case studies.

Bylaw nº 7/2002 computed eflows as follows:

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72 Environmental flow is defined as "*the instantaneous discharge which has to be determined along an homogeneous stretch of a river to ensure the safeguard of its physic features, the maintenance of the chemical water characteristics, the presence of the typical biocenosis corresponding to the natural local conditions*".

$\mathbf{EF} = \mathbf{k} \cdot \mathbf{MQ_{sp}} \cdot \mathbf{S} \cdot \mathbf{M} \cdot \mathbf{Z} \cdot \mathbf{A} \cdot \mathbf{T}$ [l/s] where

**k** is an experimental parameter function of each hydrographical area (0.08-0.12);
$\mathbf{MQ_{sp}}$ is the specific average inter-annual flow rate ($l/s/km^2$);
**S** is the catchment area ($km^2$);
**M** is the morphological parameter (0.7-1.3); it expresses the need for adaptation of eflows to hydrological component to the specific riverbed morphology and local runoff regime; it considers the riverbed slope, morphological types, presence of pools and permeability of the substrate;
**Z** is the maximum value among the three parameters N, F and Q, where:
**N** is the naturalistic parameter (≥1), the higher the naturality of the river, the higher the value of the parameter). It can assume values greater than 1 in presence of WBs located in national parks or regional natural reserve, Ramsar or Nature 2000 areas or characterized by significant scientific, natural, environmental and productive interests;
**F** is the fruition parameter (≥1), the higher the fruition for certain uses linked to GES (e.g. tourism, fishery, bathing), the higher the value of the parameter;
**Q** = the water quality parameter (≥1), the higher the pollution of the river, the higher the value of the parameter). It may have values greater than 1 if specific quality objectives have to be reached and pollutants need to be diluted;
**A** is a parameter related to the interaction between surface and underground water (0.5-1.5); lower if water table contributes to the formation of eflows, higher otherwise). Analysis to verify interaction must be carried out at least for water bodies characterized by highly permeable substrate.
**T** is a parameter related to the time modulation, due to particular exigencies during the time of the year (fish spawning, tourism, etc.).

For new water concessions the whole eflows (hydrological & environmental) is contemporary to the concession grant, while for existing water concessions hydrological component must be respected by 31 of December 2008 while correction factors will be in force by 31 of December 2016. According to activities planned by the regional WPP, the regions carry out the monitoring and investigations necessary to verify the effectiveness of water releases downstream diversion works. For constant water releases, monitoring is realized through a direct measurement of the instantaneous discharge next to withdrawal spots.

This formula is the most exploited in Italy for its ease of application and cheapness. It was derived by comparing theoretical and experimental data collected in ten sub-basins, which were considered sufficiently representative of climatic, hydrological and geomorphological aspects within the basin.

Since the correction factors have not to be applied until 2016, the following parameters are defined for the basic hydrological component:

$\mathbf{MQ_{sp}}$ = 30 $l/s/km^2$;
**k** = 0.14

The Bylaw no. 7/2002 suggests increasing water releases during critical periods for fish populations (e.g. the first phase of the life cycle and reproduction periods), periods which may vary depending on the basin's characteristics, species of reference and climate. At the same time, abrupt discharge fluctuations must be avoided in the riverbed, while diversification of the flow regime may instead be required to mitigate stress on biological communities caused by the constancy of the hydraulic regime.

| Fish species | Critical period |
|---|---|
| Salmonids in Alpine area | November – January |
| Salmonids in Apennine area | December – February |
| Cyprinids | May – July |

One specific application for the **Piave river basin** consists of a basic hydrological component ($EF_{HYDR}$), proportional to the mean annual discharge, corrected by means of some coefficients that take different environmental aspects into account.

$\mathbf{EF} = (\mathbf{k_{BIOL}} + \mathbf{K_{NAT}}) \cdot \mathbf{EF_{HYDR}}$ [$m^3$/s] where

$\mathbf{k_{BIOL}}$ is an indicator of ecosystem stress and it is expressed as a weighted sum of three sub-indices:

$\mathbf{k_{BENT}}$ is the benthic index, taking values between 0.2 and 1.0. Its quantification is based on the assessment of macro invertebrates' trophic structure;

$\mathbf{k_{FISH}}$ is the ichthyological index which assesses the habitat needs of fish species which are present in the river stretch, modulating the released of water quantity; it's equal to zero if fishes are naturally absent;

$\mathbf{k_{MORP}}$ is the morphological index which corrects the released flow on the basis of the prevalent granulometry. It's equal to zero in presence of concrete river bed.

$\mathbf{k_{NAT}}$ is the naturalness index, increasing eflows proportionally to the naturalistic value of the area

| Values naturalness index depending on type of territory | |
|---|---|
| 0.5 | National/regional/local river parks |
| 0.4 | National parks |
| 0.3 | Regional park and natural reserve |
| 0.2 | Protected landscape regional area of provincial jurisdiction |
| 0.1 | Protected landscape regional area of local jurisdiction |
| 0.0 | Areas not included in the previous categories |

$\mathbf{EF_{HYDR}}$ is the hydrological component, which is calculated as follows::

$\mathbf{EF_{HYDR}} = \boldsymbol{\mu} \cdot \boldsymbol{\rho} \cdot \boldsymbol{\Pi} \cdot \mathbf{S} \cdot (\mathbf{MQ_{sp}} \,\mathbf{/\ 1.000})$ [$m^3$/s] where

**S** is the catchment area;

**μ** is a coefficient, function of the catchment area; set by the formula $\mu = 1.62 \cdot S^{-0.15}$

**ρ** is a reduction coefficient of Q355; set equal to 0,33

**Π** is the perpetuity index, equals to the ratio between Q355 and the mean discharge; set equal to 0,33

$\mathbf{MQ_{sp}}$ is the specific average inter-annual flow rate (l/s/$km^2$).

$\mathbf{K_{BIOL}}$ and $\mathbf{K_{NAT}}$ are listed for each homogeneous section of the Piave river, being the sum of both always greater than one. However, the RBA has conventionally established that, during periods characterized by natural low discharges (between 1st June and 31th August and between 1st December and 28th February), eflows are limited to the hydrological component.

The **Tagliamento river basin** is divided into four homogeneous areas (A, B, C, D) and defined specific minimum flow rate per unit area (ranging from 3 to 6 l/s/km$^2$) which has to be released after diversion works. These values have been calculated for each homogeneous area by multiplying the specific discharge Q355 with a reduction coefficient equal to 0.33.

Finally, with reference to the rivers for which MEF was not determined (e.g. **Brenta river**), the reference values to ensure downstream diversion works are 4 l/s/km$^2$ for a catchment area lower than 100 km$^2$; and 3 l/s/km$^2$ for a catchment area higher than 1.000 km$^2$.

Different alpine regions (also outside the Veneto Region) are carrying out "experimental" methods:

- **PHABSIM**, modelling method based on the relationship between some river habitat parameters (water depth, flow velocity, temperature and sediment) and the range of preference of the desired spectrum of fish species.
- **Habitat Quality Index (HQI)**, model based on multiple regressions, linking the so called bearing capacity (potential biomass) for Salmonids of a river stretch with a great number of different environmental parameters.
- **Pool Quality Index**, model derived from the HQI method, based on the maximisation of the hydraulic diversity: the higher the number of pools in a torrent, the lower the reserved flow is.

### 6.2.2. Best practice example: Cordevole & Mis rivers

The **Cordevole river** is tributary of the Piave river in the Dolomites region with a length of 70 km and a catchment area of approximately 868 km$^2$. The hydrological regime is pluvio-nival (high levels from May to June and low levels from January to February), though the highest rainfall intensity occurs during autumn resulting in significant flood events. There are four barrages along the main stretch and numerous water withdrawals.

The effects on river ecosystem induced by  a fixed water release of 600 l/s from two of these infrastructures (Ghirlo and San Cipriano's dams) have been monitored in a significant stretch by a variety of morphological investigations: river width, water depth, substrate, bottom and surface vegetation cover, habitat types (pool, run or riffle), number of discontinuities, chemical and biological analysis, quantitative fish sampling using electric fishing method and quantitative macro-benthonic sampling. Periphyton cover assessment has been carried out, including quantification of the "Extended Biotic Index" at 12 monitoring stations and chemical measurements collected at 6 monitoring stations. Further research has been conducted to assess surface runoff alterations due to infiltration phenomena, to quantify the flow regime of the Cordevole river and to calibrate hydraulic models for fishing habitat simulations (micro-habitat method);

The application of the method PHABSIM was selected to quantify the optimal water release from the dams. The PHABSIM method is based on the premise that stream dwelling fish prefer a certain range of depths, velocities, substrates and cover types, depending on the species and life stage, and that the availability of these preferred habitat conditions varies with streamflow. With input from streamflow, substrate, and cover type measurements, PHABSIM will quantify habitat availability (measured as WUA -

Weighted Usable Area) over a range of flows. This method demonstrated that a constant release of 600 l/s could be sufficient at the maintenance of a good quality condition for salmonids.

The simulation of different flow rates in five different river stretches indicated a low influence of water discharge on habitat quality for different brown trout's vital stages (fry, juvenile, adult), while in "egg stage" sensitivity to discharge variations was higher. This study showed that water releases of at least 350 to 400 l/s (lower tan conservatively fixed 600 l/s) could be sufficient for the maintenance of a good quality condition for brown trout's habitat during its life stages.

Water releases have helped to maintain river continuity even in drought situations. Neither quantitative macro-benthonic sampling nor salmonid monitoring, subsequent to releases has shown significant variation. The value of 10.3 to 26.6 g of salmonid biomass per $m^2$, recorded prior to releases in March 1996, remained constant during the subsequent sampling. This demonstrated that the fish population has improved proportionally with the increase of the wetted area.

The **Mis river** is another tributary of the Piave river. In this case, releases from the Mis dam have clearly improved the fish population in terms of quantity when compared with pre-release values. As regards salmonid biomass, the value of 3 $g/m^2$ recorded prior to 1997 rose during the 1998 to 2002 observation period to the decidedly higher variable values of a minimum 13 $g/m^2$ and a maximum 45 $g/m^2$. Moreover, the structure of the salmonid community displayed a positive variation and was supported by the presence of marble trout *Salmo (trutta) marmoratus*, a native highly esteemed and useful species for the considered section of the river Mis. The measurements also investigated the presence of the grayling *Thymallus thymallus* which returned to good population levels in this area, also used for spawning. The biological water quality showed a positive increase.

The initial MEF established by the Piave RBA was of 1m3/s, but this value was subsequently decreased to 0.5 – 0.7m3/s due to drought conditions. Pre-release values are unknown.

## 6.3. Spain

### 6.3.1. Regulations, assessment methods and monitoring

Environmental water allocation is a mandatory component of Spanish RBMP. Therefore, environmental flows have been assessed in all the Spanish RBD, but their implementation is still pending. ).Regarding Considering hierarchical approaches suggested above, the first two levels of assessment have been extensively applied.

In Spain, according to the provisions of Water Law 1/2001, article 42 b) c'), RBMP shall include the water allocation and reserves for current and future uses and demands and for the preservation or restoration of the natural environment, and this will involve determining the environmental flows, defined as those that maintain at least fish life that naturally inhabit or could inhabit the river and its riparian vegetation.

Spanish regulation of water planning (Royal Decree 907/2007) incorporates and expands in article 3 j) the definition of environmental flows included in Water Law 1/2001, linking it to the concepts of GES and GEP introduced by the WFD, and incorporates in article 18 the regulations related to the establishment and implementation of an environmental flow regime. This regulation provides that RBMP shall also include environmental water needs for lakes and wetlands.

Moreover, Spanish regulation of water planning provides that in determining the annual rate of flow required for the calculation of available groundwater resources, environmental flow regimes shall be taken as reference (since according to the WFD the available groundwater resources do not include water requirements to achieve the ecological quality objectives for associated surface waters), to avoid any significant diminution in the ecological status of such waters and to avoid any significant damage to associated terrestrial ecosystems.

For the **assessment of environmental flows**, the Ministry of Environment, supported by a broad group of experts of various universities, research centers and water and nature conservation authorities, developed a methodology that provides the basic technical procedures. This methodology is mandatory (Order ARM/2656/2008) just for the RBMP of inter-communitarian basins (those whose territory is divided among several autonomous communities), but most of the intra-communitarian river basin districts have followed the same methodology or a similar one. The methodology establishes that the environmental flow regime should consist not only in a fixed minimum flow throughout the year, but also in its seasonal distribution. It also states that downstream water infrastructures other components such as a maximum flow, a flood regime and a rate of change (hydro-peaking conditioning) shall be assessed.

Minimum flows and their timing have been assessed in most river basin districts by combining hydrological methods, whose application allows a widespread and generalized use throughout the river basin district, with the habitat modelling for one or several target species in specific river segments.

According to the Ministry of Environment methodology, hydrological methods shall be applied by defining moving averages or percentiles between 5 and 15% on representative hydrological series that characterize the natural regime and are defined daily scale. On the other hand, habitat modelling shall be performed on a sufficient number of water bodies, with a recommended minimum of 10% of the total river water bodies of the basin district, covering at least one segment in each of the most representative types, especially in regard to differences in the flow regime. The minimum flow distribution throughout the year shall be determined by adjusting the minimum flows obtained by hydrological methods to the results of habitat suitability modelling, according to one of the following criteria:

a) Consider the flow corresponding to a threshold of weighted usable-habitat area in the range 50-80% of the maximum weighted usable-habitat area.
b) Consider the flow corresponding to a significant change of slope in the curve that relates weighted usable-habitat area and discharge.

In the case of water bodies with a high degree of hydrologic alteration that present a conflict between existing uses and instream flows, the threshold used to establish the minimum flow regime can be in the range 30-80% of the maximum weighted usable-habitat area for the analyzed target species (although in some river basin districts the minimum threshold of 50% has been maintained in altered water bodies when they were located in protected areas, such as Natura 2000 sites). The degree of hydrologic alteration has been estimated by calculating indices of hydrologic alteration, following various methodologies, such as IHA or IAHRIS.

As for the assessment of the water requirements of lakes and wetlands, it shall be based on the physical variables that better reflect the structural and functional characteristics of each lake, as groundwater levels or tidal flows. The numerical criteria from which to formulate the proposals of water requirements, such as percentiles, return periods, presence or absence of taxa or reproductive success, shall have as reference the natural conditions and make it possible to achieve conditions consistent with the functions and environmental objectives pursued.

Spanish regulation of water planning stipulates that, in case of **prolonged droughts**, a less demanding flow regime may apply, as long as it meets the conditions on temporary deterioration in the status of bodies of water in accordance with the WFD. This exception does not apply to the areas included in the Natura 2000 Network or in the Ramsar List of Wetlands of International Importance. In these areas priority will be given to the maintenance of instream flows, although the rule on supremacy of use for populations supply will apply.

The implementation of this less demanding flow regime must be made progressively. Accordingly, the adaptation from the ordinary regime shall be proportional to the situation of the water system, as defined by the indicators established in the Special Plan of Action in Situations of Alert and Eventual Drought of each river basin district, and avoiding, in any case, irreversible deterioration of aquatic ecosystems and associated terrestrial ones.

Spanish legislation establishes that environmental flow regimes shall be those that make it possible to maintain in a sustainable way the functionality and structure of aquatic ecosystems and the associated terrestrial ones, contributing to achieve GES or GEP in water bodies. It is therefore considered a key element in achieving the objectives of the WFD.

- To achieve these objectives, environmental flows must meet the following requirements:
- Provide suitable habitat conditions to satisfy the needs of the different biological communities typical of aquatic and terrestrial ecosystems through the maintenance of the ecological and geomorphological processes required to complete their life cycles.
- Provide a temporal pattern of flows for the existence, at most, of slight changes in the structure and composition of the aquatic ecosystems and associated habitats and to maintain the biological integrity of the ecosystem.

Legislation also provides that, in achieving these objectives, priority shall be given to those related to protected areas, then to those related to natural water bodies and finally to those referred to heavily modified water bodies. In fact, in Natura 2000 sites or in wetlands of the Ramsar List, environmental flows shall be appropriate to maintain or restore a favorable conservation status of habitats or species, responding to their ecological requirements and maintaining long-term ecological functions on which they depend, and in the case of species protected under European, national or regional legislation, as well as in the case of habitats also protected by European, national or regional legislation, the aim of environmental flow regimes shall be protect and maintain the ecological functionality of these species (breeding, rearing, feeding and resting areas) and habitats according to the requirements and guidelines contained in the respective regulations.

Environmental flows and environmental water needs are necessary for determining the ecological status of surface water bodies, although as hydromorphological elements supporting the biological elements they only distinguish between good and high ecological status. Environmental flows and environmental water needs are also necessary for determining the status of groundwater bodies, since they shall be taken as reference in determining the annual rate of flow required for the calculation of available groundwater resources.

Environmental flows have been proposed for future action in the PoM framework. Most of the RBMP include actions such as programs for the implementation of the environmental flow regimes, programs to adapt the hydraulic infrastructures, programs for the monitoring of the environmental flows (including the study of instream flows, analysis of the accomplishment of established environmental flow regimes, monitoring of biological indicators, analysis of the economic effects on energy production and water demands), etc. Other quantity measures included in PoM of Spanish RBMP will indirectly contribute to the implementation of environmental flow, mainly those designed to increase the availability of resources and reduce pressures on superficial flows and overexploited aquifers, such as water metering, water efficiency and saving, illegal water use elimination, water recycling, desalination, raising awareness, etc.

### 6.3.2. Best Practice Example: Public involvement in the Andalusian Mediterranean Basin

In Spanish water planning, after the development of the technical studies for assessing the environmental flows in all water bodies, a second phase consisting in a process of consensus is been addressed (to date, some of the Spanish river basin districts have already completed it). This process of consensus is usually defined by various levels of action (information, public consultation and active participation) in those cases that significantly condition water allocations and reserves of the RBMP. Finally, river basin districts will have to implement the environmental flow regimes and establish a monitoring scheme for the assessment of their effectiveness.

As example of best practice in Spain of assessment and active involvement of all interested parties according to article 14 of the WFD, Andalusia Mediterranean Basins has successfully concluded both phases of the process.

The Andalusia Mediterranean Basins is an intra-communitarian river basin district located in southern Spain that covers an area of 17,952 km2 along a strip about 50 kilometres wide and 350 long, and consists of a set of basins that originate in the Betic Mountains and drain into the Mediterranean Sea. The combination of natural resource scarcity and intense human pressures results in the inability of the aquatic environment to meet the heavy demands required by the existing socio-economic model, which leads to a situation of water deficit present widely throughout the basin district, many aquifers with problems of overexploitation and poor water quality, difficulties in supplying the demands in dry periods, and a widespread deterioration of water environment and associated ecosystems that threatens the achievement of the objectives of the WFD.

Therefore, environmental flows have been considered in the Andalusia Mediterranean Basins RBMP as a key element in achieving the objectives of the WFD in many water bodies that currently fail to meet good status. Moreover, environmental flows being one of the elements of the RBMP with the highest incidence on both the conservation status of water bodies and the availability or scarcity of water resources for its users, the active involvement of all interested parties has been considered absolutely necessary for their implementation.

Thus, in the Andalusia Mediterranean Basins environmental flows have been assessed following the methodology proposed by the Ministry of Environment, that is using hydrological methods and habitat modelling (32 reaches) to estimate the minimum flow regime in the 133 river water bodies, and also determining the maximum flows, the flood regime and the rate of change (hydro-peaking conditioning) downstream of the main reservoirs. In most water bodies, the minimum flow regime consisted of a single proposal, but for some it was considered necessary to take two: a transitional minimum flow regime, to apply on the horizon 2015, and a final minimum flow regime, which corresponds to the stage where the measures included in the PoM that are necessary to enable its implementation have been carried out. Furthermore, the environmental water needs of 5 lakes and wetlands have been assessed by combining hydrological criteria, such as percentiles, and hydrobiological criteria, such as presence or absence of taxa, reproductive success, etc.

The process of consensus defined by various levels of action (information, public consultation and active participation) has been applied in 19 strategic water bodies, which are those that significantly condition water allocations and reserves of the RBMP. The process has been carried out to coincide with the period of public consultation of the Andalusia Mediterranean Basins RBMP (from 22 May 2010 until 22 November of that year), during which analysis documents were prepared, stakeholders have been identified, and there have been seven negotiating tables, an internal one with the water authorities and six with the stakeholders of each of the exploitation systems, and a series of meetings with the groups concerned. The results of the process have been subsequently incorporated to the RBMP.

### 6.3.3. Best Practice Example: compatibility of eflows and hydropower development in the Upper Ter River

This Study case is based on Munne et al 2010, complemented with information from the website http://aca-web.gencat.cat/aca/appmanager/aca/aca/ and personal presentation in CIS ECOSTAT Hydromorpholgy Workshop (12th and 13th June 2012).

The Catalan Water Agency (Agència Catalana de l'Aigua - ACA) launched in June 2005, **Sector Plan for Environmental Flows in the Inland Basins of Catalonia** (PSCMCIC) (approved by Resolution MAH/2465/2006). The Plan defines an eflows regime in 320 stretches of the river system, capable of maintaining performance, composition and structure of stream ecosystems in good condition. It is understood that this assessment should be independent of possible financial, productive and / or social constraints.

By contrast, **Zonal Implementation Plans** should analyze human activities and their level of compatibility with the PSCMCIC, taking into account any compensation formulas, implementation strategies, the importance of activities and social sensitivity. These plans must be drawn through a process of active participation of users, governments, environmental organizations and the general public.

In Upper Ter, the consultation process has followed the pattern of phases and sessions, established for all Catalonian basins. Meetings were held between March-April 2007 (briefings in Ripoll, Ribes de Freser and St. Joan de les Abadesses) and December 2009 (final return session in Girona). As an indicator of the number of agents involved, may be said that the last session was attended by 36 people representing many different social organizations, private companies, and administrations

The main singularity of the upper reaches of the river Ter is the **high density of hydroelectric plants** (85 identified in 131 km of river) of small production and flowing regime that seriously alter the state of the river. The water is retained and derived from its course in sequence along the river axis, causing long stretches with little flow or completely dried, combined with areas of backwater. After analyzing the allocations in the light of their administrative status, hydrological constraints and the characteristics of the facilities, hydropower plants have been classified in terms of their compatibility with eflows implementation.

**Table. 8. Number of hydropower plants classified according to possible strategies for implementation of eflows in the upper Ter**

<table>
<tr><th colspan="2">Type of exploitation. strategy</th><th>nº</th><th>%</th></tr>
<tr><td>Compatible. Plants currently compatible with eflows without changing infrastructure nor concession</td><td rowspan="4">Agreement without costs</td><td>6</td><td>7%</td></tr>
<tr><td>Flexibility without investment. Plants where a relaxation of the abstraction (compatible with eflows) is possible without loss of production nor new investments</td><td>8</td><td>9%</td></tr>
<tr><td>Flexibility with moderate investment. Plants where a relaxation of the abstraction (compatible with eflows) is possible without loss of production and with moderate investment, recoverable through increased production (acceptable pay back)</td><td>20</td><td>24%</td></tr>
<tr><td>Extension of concession. Plants where a relaxation of the abstraction (compatible with eflows) is possible but an extension of the concession is necessary to avoid loss of production or unrecoverable investment.</td><td>10</td><td>12%</td></tr>
<tr><td rowspan="2">Pay back not acceptable. Flexibility requires a high investment and the pay back is not acceptable.</td><td>Eflows could be reduced</td><td>18</td><td>21%</td></tr>
<tr><td rowspan="2">Production loss, damage on use, high cost</td><td>14</td><td>16%</td></tr>
<tr><td>Disagreement of users. Users do not agree to previous options.</td><td>9</td><td>11%</td></tr>
</table>

*Source: based in Implementing environmental flows in Catalan rivers. Cost analysis and impact on use*

Different scenarios were assessed, with the conclusion that no significant damages in terms of production loss and potential increase of greenhouse effect emissions, because of implementing eflows. On the other hand, good status can be restored in rivers (ecological services will be recovered).

| | Pessimistic scenario | Optimistic scenario |
|---|---|---|
| Estimated hydropower production loss | 42.2 GWh/year | 7.8 GWh/year |
| % of production loss in the upper Ter river (223 GWh / year) | 19% | 3% |
| Increasing greenhouse gas emissions (0.45 KT/GWh) | 18,890 T $CO_2$ /year | 3,510 T $CO_2$ /year |
| % of increasing greenhouse gas emissions in Catalonia (60 million T/year) | 0.03% | 0.01% |

To assess the economic impact of implementing eflows, three cost components have been evaluated: investment costs required to adapt the facilities; indirect cost of replacement to restore losses of production (this cost is assumed by the concession holder and recovered); and, finally, the possible compensation for loss of earnings to be paid to the private owners entitled to the administrative concession (questionable, considering the current legislation).

| | Implementation cost (M€ / year) | Cost per person (€ / inhabitant . year) |
|---|---|---|
| Electricity production cost to restore production loss (0.075 €/kWh) | 1.02 | 9 |
| Investment cost to improve turbines and hydropower efficiency | 4.45 | - |
| Economic compensation cost (Worst scenario - without any agreement achieved) | 1.35 | 11 |
| TOTAL | | Best scenario: 9 €<br>Worst scenario: 20 € |

Considering that the riverside population of High Ter is about 118.000 people (39.500 households), this would cost about 9 € / person. year, and in the worst case, in which compensation due to loss of earnings of private activity, the cost could amount to 20 € / person. year.

The costs of implementing eflows calculated can be compared with the willingness to pay from the population in the recovery of eflows in areas with per capita income similar to that of Catalonia or Spain (California, New Mexico, Puerto Rico), ranging from 6,7 and 80 $ / person.year (4,3 and 51 € / person. year) and even 252 - 377 $ (161 and 241 € / person.year) for the full recovery of aquatic ecosystems. Both the 9 and the potential 20 € / person.year calculated for the implementation of eflows in the upper Ter, can be regarded as NO disproportionate cost.

### 6.3.4. Andalusia Mediterranean Basin: measures for the implementation of eflow regimes

In the documentation generated in the framework of the eflows assessment included in the RBMP of the District, some measures necessary to enable implementation of flow regimes have been identified, presented and discussed with stakeholders. Some of them are included in the templates prepared for consultation and consensus which also include a simulation of compliance of the proposal once PoM will be implemented. In the summary document of the process, some specific or general measures are explicitly mentioned:

- Program for the adaptation of regulation and deviation infrastructures for the compliance of eflow regime
- Incorporation / adaptation of environmental conditioning to water abstraction permits
- Programs to optimize water consumption and reduce high uptake needs: upgrading and modernization of irrigation scheme; upgrading of urban networks
- Promotion of the development of joint supply systems
- Rationalization of extractions in overexploited aquifers
- Reuse of regenerated resources for urban non-priority uses, agricultural irrigation and golf courses
- Desalination in coastal areas with sustainability problems
- Actions for the increase of water availability: regulation works (new and re-growth), internal transfers, joint exploitation; external resources
- Other initiatives to increase the availability of resources: correction of saline discharges to Guadalhorce reservoir, waterproofing of Benínar reservoir.

- Hydro-morphological restoration of river channels (this measure has been characterised as crucial to achieve the GES in many stretches where de-configuration of river channel is particularly severe (around 500 km).
- Elimination of silting in dams transferring exceeding flows to La Viñuela reservoir
- Rehabilitation of Paredones weir

In fact, most of the measures aimed at quantitative targets are also necessary to reach flow regimes compatible with GES. One major goal of the Plan is to lead GWBs to good quantitative status, which implies taking into account flow required to achieve the ecological quality objectives for associated surface waters. Considering that 32 out of 65 GWBs (48%) are currently in bad quantitative status, considerable management and financial effort have to be assumed to meet objectives.

But also a variety of measures included in the pack of governance are fundamental. In addition to those previously mentioned, other relevant measures must be highlighted: consumption metering and control system, application of recovery cost principle, public awareness in sustainable use of water and protection of aquatic ecosystems, increase in control and surveillance of rivers and wetlands.

With the intention to minimize socio-economic impact, water efficiency measures and the substitution of fresh water consumption by non conventional resources have been the preferred strategic option. Nevertheless, in the Upper Guadalhorce river basin (hosting the Natural Reserves of Campillo and Archidona lagoons, both Ramsar sites) and the neighbour Fuente de Piedra lagoon basin (a particularly remarkable Ramsar site), it has been necessary to propose a deep reconversion and regularization process in the irrigated area, that should lead to a dramatic reduction of water consumption in agriculture. This measure is unavoidable to reverse the unsustainable exploitation of groundwater and restore aquatic ecosystems, both in rivers and wetlands. On the other hand, water needs for these lagoons has been assessed in the framework of RBMP[73]; Laguna de Fuente de Piedra is one of the study cases included in Sánchez Navarro & Viñals, 2012.

Finally, conditions for water interchanges are regulated by the Andalucía Water Act (Ley 9/2010, de 30 de julio, de Aguas de Andalucía), introducing the Public Water Banks as a new legal entity, through which public bids for water rights may be done to meet a variety of purposes, specially for reaching GES / GEP of water bodies.

## 6.4. France[74]

### 6.4.1. Methodological approach to hydropeaking

In France, the estimated abstraction of water (2009) sums up to 33,4 billion $m^3$(17% of total flowing resources) being hydropower responsible of 64% of this volume, while the rest is extracted for human supply (17%), Industrial use (10%) and irrigation (9%).

[73] http://www.juntadeandalucia.es/medioambiente/site/portalweb/menuitem.7e1cf46ddf59bb227a9ebe205510e1ca/?vgnextoid=c93d943e04443310VgnVCM2000000624e50aRCRD&vgnextchannel=75b3e6f6301f4310VgnVCM2000000624e50aRCRD&lr=lang_es

[74] Based in Baran 2012, Baran et al., 2012 & Chanseau et al. 2012.

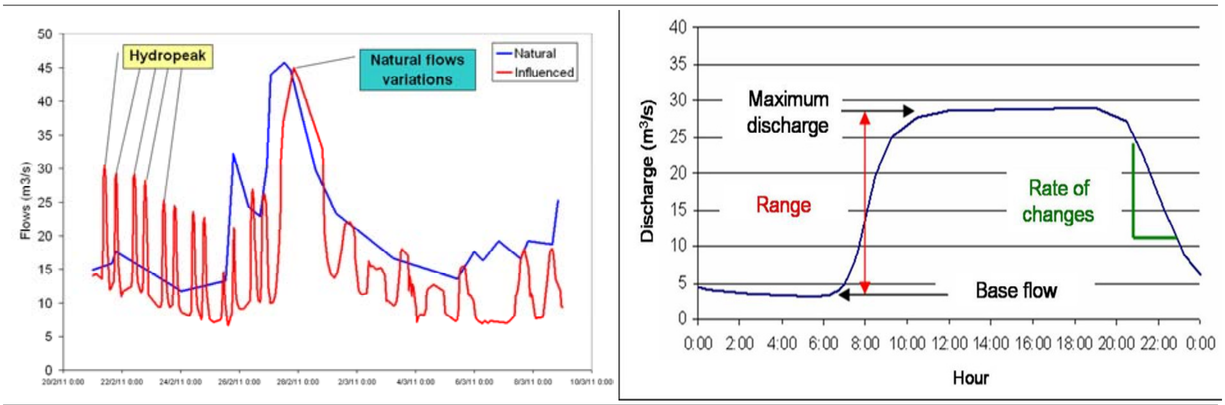
Hydro electrical production ranges between 60 to 70 TWh (13% of total). More than 150 hydroelectric schemes affecting around 3.000 km of river streams are managed by hydropeaking in France, under two types of schemes: organized in line (e.g. Durance, Dordogne, Truyère) or with high-head storage (Alpine and Pyrenean mountains)

ONEMA (Office national de l'eau et des milieux aquatiques) is developing a methodological approach aimed to the identification and quantification of changes of flow regime and the consequent habitat alteration, Identification and quantification of changes of flow regime with two priorities: low flows and hydropeaking. Based on these analyses, mitigation measures are proposed to increase low flow values and/or to change locally the hydropeaking management.

## 1. Identifications of flow modifications induced by hydropeaking

The characterization of the hydrological disturbance starts from the hourly flow analysis of gauging stations' data aimed at identifying each flow variation and differentiating natural ones from those caused by hydropeaking. Each hydropeak is characterized by base flow, maximum flow, range and rate of change. Later, the number and statistical characteristics of the episodes are dealt with in a yearly basis. Hourly, daily and weekly hydropeaks events are also processed statistically.

**Fig. 22. Analysis of flow variation**

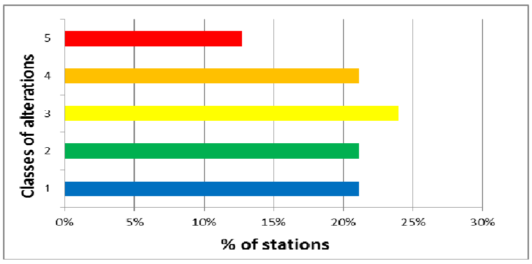



*Source: Balan 2012*

With the support of tis strong analytical basis, the construction of the so-called **Index of hydrological perturbation** is currently under development. The index evaluates the hydrological perturbations, enabling to analyse their evolution along a stream or between years, but not to assess ecological effects. 80 stations (46 of them with strong alterations of flow regime) in 50 French streams were analysed under a six levels of hydrologic perturbation due to hydropeaking events scheme.

**Fig. 23. Proposed levels for the Index of hydrological alteration and first assessment**

| | | |
|---|---|---|
| 0 | | Hydrology natural or hardly disturbed |
| 1 | **Blue** | Noticeable hydrologic perturbation |
| 2 | **Green** | Hydrologic perturbation marked |
| 3 | **Yellow** | Hydrologic perturbation very marked |
| 4 | **Orange** | Severe hydrologic perturbation |
| 5 | **Red** | Very severe hydrologic perturbation |




*Source: Balan 2012*

## 2. Identifications of habitat alterations and monitoring ecological effects

Two types of impacts on fish habitat depending on morphology of stream have been identified and studied, by the characterization of fish habitats using hydraulic models and habitat preference curves of species and life-stages:

**Mountain steep stream**. In Lez river, downstream Eylie power plant. Medium Discharge 1 $m^3/s$. The hydrologic perturbation is very marked, with maximum discharge of 4 $m^3/s$ (≈4 times MD) and between 150 and 300 hydropeaks per year. Some negative impacts have been identified: low trout densities and biomass compared to non-affected streams; fry recruitment negatively related to the number of hydropeaks during emergence period. It's suspected that habitat conditions during hydropeaks are limiting for juveniles and adults

**Braided streams**. Two streams analysed:

First stretch. Medium Discharge 20 m3/s. Hydrologic perturbation very marked, maximum discharge 35 $m^3/s$ (≈1,8 times MD), between 150 and 300 hydropeaks per year.

Second stretch. Medium Discharge 20 m3/s. Hydrologic perturbation marked or very marked, maximum discharge 340 $m^3/s$ (≈3,2 times MD), between 100 and 240 hydropeaks per year.

Hourly variations on wetted perimeter may dewater fish habitats on shallow shoreline areas so trapping fry in disconnected secondary channels. Monitoring has allowed quantifying mortality of eggs, with up to 30% of total salmonid redds affected. Stranding and trapping of fry in disconnected secondary channels has led to a mortality rate of 6.000 fry/year on 6 km of stream.

3. **Proposal and assessment of mitigation measures,**

Two types of measures are proposed:

**Changes on hydropeaking management**: limiting the number of hydropeaks during specific biological periods and also limiting the magnitude of maximum flow (to 2 times MD) and the discharge down ramping rate of change to 30 $m^3/s/h$ (20 $m^3/s/h$ in spring). At the same time base flow has to be increased specially in winter and spring.

**Changes on stream morphology**, acting on connectivity, river banks and the topography of gravel bar to ensure permanent supply of secondary channels.

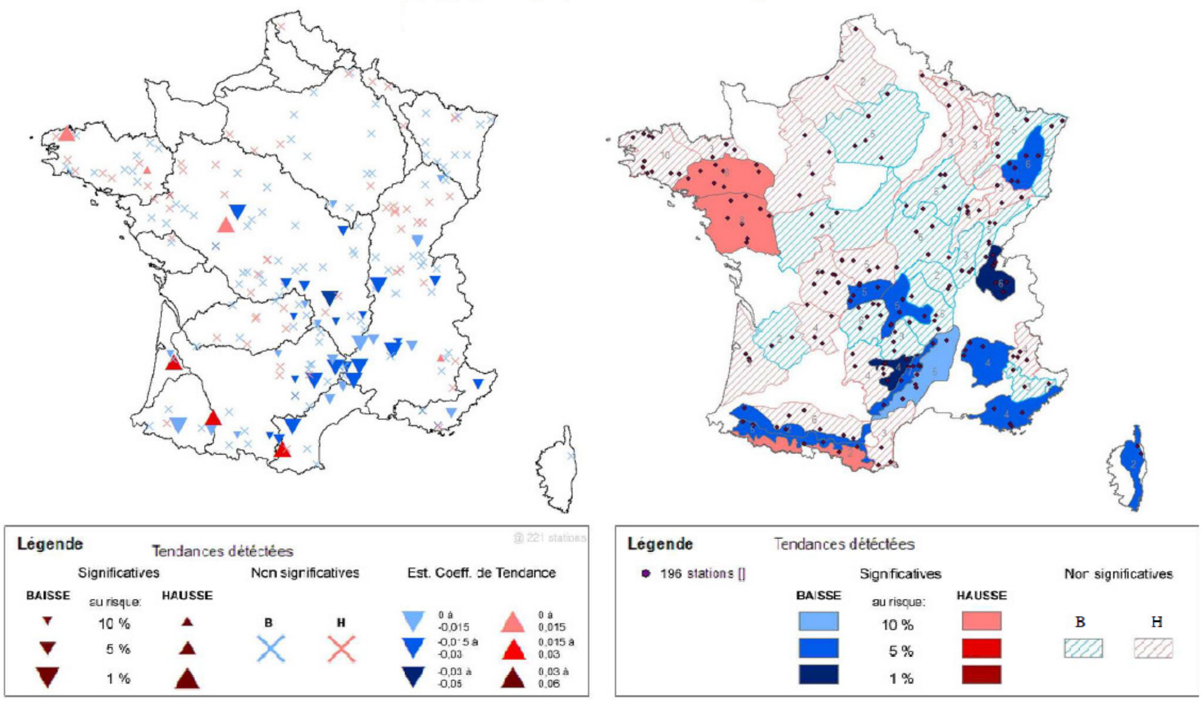
These measures have proved to be effective: only 5% of salmonid redds have been dewatered, instead of 30% without base flow increase, with significant decrease of fry mortality in connected secondary channels. On the other hand, losses of electricity production varied between 0,5 % to 2,0% of the total potential of peak production (when organised in line, only the production of the last hydropower plant is really affected).

### 6.4.2. Methodological approach to minimum flows

A recent analysis of the evolution of low flow at large scale during the 3 last decades can be found in Giuntoli and Renard[75], 2010, showing evidence of significant changes in low flow conditions. An increasing drought severity is observed over several regions of southern France while, conversely signs of decreasing severity appear in some of the north-western regions (Brittany and Pays de la Loire). Except for these regions there is no evidence of an increase in drought severity in northern France, nor in regions with snowmelt regimes.

[75] Identification des impacts hydrologiques du changement climatique: constitution d'un réseau de référence pour la surveillance des étiages. Rapport 2010 (Ignazio GIUNTOLI and Benjamin RENARD, 2010). Département Eaux. Unité de Recherche Hydrologie- Hydraulique. Groupement de Lyon

**Fig. 24. Variation of annual minimum flow**




*Source: Extrêmes hydrologiques et variabilité climatique (Benjamin Renard, Xun Sun, Ignazio Giuntoli, Antoine Bard, Jean-Philippe Vidal, Eric Sauquet, Michel Lang (Cemagref, UR Hydrologie-Hydraulique 2012*

The French Water Law impose minimum values of flow in the range of 5% to 10% of mean annual flow to be applied in 2014[76] for all dams and weirs, though locally, these values can be increased based on study using microhabitat methodology. On the other hand, the licenses of the hydraulic works whose operation does not allow the preservation of migratory fish should be modified no later than 2014.

Modifications of flow regime are important in France for a large part of water bodies, but no direct relationships have been established so far with biological index related to ecological status assessment of water bodies.

## 6.5. Romania[77]

### 6.5.1. Regulations, assessment methods and monitoring

In Romania, according to the provisions of ***Water Law 310/2004 article 64(1)***, the owners of water works (water intakes, dams and reservoirs) are obliged to assure downstream a certain amount of water for water uses (servitude flow) and also for aquatic environmental protection (sanitary discharge, that may be identified with eflows). The quality elements for the assessment of the ecological status of rivers are:

[76] Loi sur l'eau et les milieux aquatiques du 30 décembre 2006.

[77] Based on SEE Hydropower 2011.

| Quality elements | Parameters measured in the River |
|---|---|
| biological elements | composition and abundance of aquatic flora;<br>composition and abundance of benthic invertebrate fauna;<br>composition, abundance and age structure of fish fauna; |
| hydro-morphological elements | hydrological regime:<br>quantity and dynamics of water flow;<br>connection to groundwater bodies;<br>river continuity;<br>morphological conditions:<br>river depth and width variation;<br>structure and substrate of the river bed;<br>structure of the riparian zone; |

There is no legal regulation on computing the **eflows assessment**. Nevertheless, as mentioned before, the Water Law establishes obligations on assuring eflows and defines the following terms:

- Sanitary discharge ($\mathbf{Q_{san}}$) is the minimum discharge required for continuous flow, in a section on a watercourse, to provide/assure the natural life conditions for the existing aquatic ecosystems.
- Servitude discharge ($\mathbf{Q_{serv}}$) is the minimum flow required to be continuously supplied in a section on a watercourse, downstream a dam, consisting of the sanitary discharge and the minimum discharge necessary for the downstream water users.

$\mathbf{Q_{serv}} = \mathbf{Q_{san}} + \Delta\mathbf{Q}$. where $\Delta\mathbf{Q}$ is the amount of water required by the other downstream water uses.

Due to the lack of a legally implemented formula for $\mathbf{Q_{san}}$, several formulas are currently being in use in Romania. In general, the Romanian studies started with ecological models, trying to find the relationship between habitat conditions (e.g. river channel shape, flow velocity) required for conservation and development of fish and a certain amount of water (discharge).

In the first RBMP, standing on the available studies done by the research institutes, eflows was considered to be the minimum between $\mathbf{Q_{95\%}}$ (yearly minimum monthly mean discharge with 95% probability of occurrence, which is already available for all Romanian rivers) and 10% out of the mean discharge averaged on many years:

Eflows $\geq \mathbf{Q_{95\%}}$ eflows $\geq \mathbf{Q_{med}}.0,1$

Another formula, proposed by A. Galie (2006) was used in the draft of the first RBMP (submitted to the EC in 2004) but was not legally implemented. The formula links the required habitat for fish (water velocity and depth) to $Q_{95\%}$ and tries to prove that the dilution flow $Q_{95\%}$ is close to minimum eflows required by fish.

Eflows = $\boldsymbol{\alpha}.\mathbf{Q_{95\%}} + \boldsymbol{\beta}$, where $\boldsymbol{\alpha} \geq 1$ and $\boldsymbol{\beta} \geq 0$, both coefficients depending on the river and measuring stations. For the analysed measuring stations, the following two equations were derived, applicable for river basins with a surface area less than 3.000 km$^2$:

Eflows = $Q_{95\%} + 0,1$ if $Q_{95\%} \geq 200$ l/s

Eflows = $1,25.Q_{95\%} + 0,05$ if $Q_{95\%} < 200$ l/s

At the moment (2011), the calculation of eflows in Romania bases on hydrologic data and biological quality components, namely fish, but considered only indirectly since $Q_{95\%}$ seems to be close to minimum eflows as the method by A. Galie tried to prove. In the future, the Romanian experts will carry out more studies for choosing an eflows value to ensure a better correlation with the biological elements. Taking in consideration the diversity of species, processes that occur in aquatic ecosystems (as e.g. reproduction periods), maintenance of habitat conditions and river channel shape as well as other parameters are therefore planned for the future.

***M.O. nº 9/2006 for the approval of the methodology for development plans and water use restrictions during deficit/draught periods*** stipulates that: *"Determination of the necessary minimum flow rate should be done on sectors or areas"* and "*the setting up of the synoptic diagram and required-minimum flow graphic"* should be prepared separately for summer and winter. The preliminary program of restrictions on economic objectives will include *"flows necessary for the water uses on characteristic steps of restriction situations for the periods of water shortage at source. There are 2-4 steps/stages of restriction and in case of multiple sources are elaborated possible scenarios"*.

The criteria for adopting the most appropriate operational decisions that lead to less damage for the uses whose operation capabilities are affected and on the overall national economy too:

a. reduction in steps of the flows abstraction for irrigation
b. temporary reduction of the minimum value for sanitary flow, with a maximum of 50%
c. reduction of the flows allocated for fish farms
d. reduction in steps of the flows for industrial uses
e. partial or total restriction of water supply to industrial uses with more weight in the processes wich generate water pollution
f. intermittent restriction of the water supply for domestic use and livestock farms

The Romanian legislation considers indirectly that eflows are critical for health of the rivers (ecological integrity of riverine ecosystems), ensuring that the biological quality elements achieve the thresholds set up for the good ecological status respectively the good ecological potential. There are no other objectives of eflows assessment than the WFD goals, regarding surface and groundwater bodies and protected areas.

Water related species and habitats require a certain amount of water in order to maintain a viable population or a favourable conservation status, not necessarily only those from natural protected areas. Annex 4 point 5 of the WFD mentions that the register of protected areas should include "areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection, including relevant Natura 2000 sites designated under Directive 92/43/EEC and Directive 79/409/EEC".

Indirectly, both Directives (and Birds Directive also) dictate/recommend "preserving" a certain amount of water for aquatic creatures. Ensuring these "water environmental requirements" assures the water ecosystem durability. Important ecological assets in the Romanian watercourses are:

- Endemic fish species (endangered rare species) whose survival depends on the existence of a minimum flow in the river bed (e.g. *Romanichthys Valsanicola* living in Valsan river within the Arges River basin);
- Species of fish that survive in waters with high flow velocity, low temperatures and high oxygen saturation (e.g. salmonids: trout, grayling, huck);
- Requirements to preserve the natural conditions of rivers to allow movement of fish upstream and downstream of barriers: *Danfordi Eudontomyzon* and *Cottus gobio* species (e.g. Cormaia and Valea Pietrelor River within the Somes-Tisa River Basin);
- Migratory fish species that migrate long distances upstream (longitudinal connectivity) to spawn and some of which migrate to the sea for breeding and then return to the river and other species that live in the sea and whose reproduction is placed in fresh water (e.g. sturgeons from the Danube river);
- Many benthic invertebrates activity depend on a regular cycle of temperatures throughout the year (e.g. insects from *Plecoptere* family due to low temperatures that delay their metamorphosis);
- Fish species that spawn on the vegetation from the river bank (lateral connectivity); these species do not tolerate high flow rates during this period because these might wash away fish eggs and transport them downstream;

In addition, many aquatic creatures coordinate their reproductive cycles with seasonal flood frequency. The floods provide areas with stagnant water, shallow and the banks covered with vegetation and shade where juvenile fish can feed and hide from big predators. If eflows would have a form of hydrograph (varying in time) with peaks during breeding time of the significant fish species, the implementation of eflows will be beneficial. Lateral connectivity will benefit also if eflows would have such shape.

Other benefits than the already mentioned ones are:

- Improvement of ecosystem functions;
- Saving costs associated with additional water treatment or improvement of the flow parameters for surface and groundwater bodies;
- Protection of groundwater bodies;
- Productivity growth in fisheries and aquaculture;
- Facilitate development of tourism and recreation activities;
- Improvement of human health;
- Unquantifiable environmental values;
- Contribution to fulfilment of other legal requirements;
- Mitigation of climate change impact;
- Mitigation of flood risk.

### 6.5.2. Best practice example

In Romania, a best practice example concerning eflows has not been determined yet, but the collaboration among biologists and engineers should be intensified in future. The evaluation of the risk of failing the environmental objective has been done at the WB level based on DPSIR approach. The identified significant pressures have been taken into account, considering a baseline scenario, as well as their impact on the water bodies. The following risk categories were considered:

- pollution with organic substances,
- nutrient pollution,
- pollution with hazardous substances and
- hydro-morphological alterations;

In the first RBMP, the risk assessment has been done for:

- WBs' status/potential characterization, taking into consideration that for some WBs there were no methods and/or monitoring data according to the WFD provisions, and the WBs' grouping was not possible to be used (low confidence);
- establishing the supplementary measures;
- application of cost effectiveness and cost-benefit analyses;
- application of exemptions in reaching the environmental objectives. (River Basin Management Plan, 2009)

Public information, consultation and participation activities have been undertaken. During 2008, the program of measures has been presented and discussed with stakeholders in every river basin authority, having in view the measures for reducing the pollution from agglomerations, industry and agriculture for reducing the impact of hydromorphological alterations. During 2009, other meetings were organized with stakeholders in order to ensure the process of consultation of the drafts of the RBMPs.

## 6.6. Slovenia[78]

### 6.6.1. Regulations, assessment methods and monitoring

The **Decree** *on Criteria for Determination and on the Mode of Monitoring and Reporting of Ecologically Acceptable Flow* (OG RS, No. 97/2009) was adopted in 2009. It includes, besides some general provisions (application, exceptions, terms, penalties), the criteria for determination eflows and the mode of monitoring and reporting. If ecological flows for existing water use (before the decree adoption) had not been defined with water permits and concession contracts, it must be assessed in accordance to the decree.

Nevertheless, the regime can be determined with lower values to preserve 85% of current electricity production, but a study in such cases is obligatory and compatibility with WFD objectives must be ensured. In this case, already granted concessions and owner rights can claim for compensation because of jeopardizing of financial viability of realized investments to the Small Hydro Power (SHP). By 2014 eflows needs to be determined and monitoring has to be assured. By then, it is planned to recognize all discrepancies and to realize proper measures (adoption of the decree, possibilities of compensations for reduction of electricity production etc.).

78 Based on SEE Hydropower 2011.

The methodology for ecological flows assessment in Slovenia was developed in research projects by the Institute of Water of the Republic of Slovenia and part of this approach was used in decree, as a compromise between experts' point of view and practical implementation. Two kinds of assessments are recognised:

- The **'rapid assessment method'** (Article 7) is based on the use of basic hydrological data, and site information including an inventory of habitats, and ecological and morphological information.
- The **'detailed assessment method'** (Article 8) uses similar information, but in addition requires the sampling of zoobenthos and periphyton in different aquatic habitats of the relevant sections of river. This method is applied when the proposal is influenced by any one or more of the factors given in the list below:
  - If the running water is in a preserved or legally protected area.
  - If there are rare, endangered or protected species of flora and fauna in the running water or in the riparian zone.
  - If the spawning grounds are threatened by water use.
  - If the river reach is affected by the water use over a long river section (e.g., more than 200 m for rivers with a catchment area of more than 100 km$^2$).
  - If the water abstraction is not returned to the river further downstream and is larger than 20% of mean annual minimum flow.
  - If the public interest demands multi-designation use of the water
  - If during the application of the rapid assessment method raise any of the issues outlined.

Environmental flows shall be calculated on the basis of hydrological elements by the following formula:

**EF** = **f** · **MALQ$_d$** where

**MALQ$_d$** is the arithmetic average of the lowest annual mean daily flow (LQ) on the spot over a longer observation period (usually at least 30 years).
**f** is a coefficient depending on reversibility, size of the catchment, ecological type group (1 to 4), length of the river section (short is less than 100 m in catchments ≤ 100 km$^2$ and less than 500 m in catchments > 100 km$^2$), the quantity of abstracted water (refered to the value of the mean flow at the abstraction site: MQ <> 50 m$^3$/s when catchment area > 1.000 m$^3$) and the ratio MQ/MALQ$_d$.

| | Size of catchment area | | | | |
|---|---|---|---|---|---|
| Ecological group type | <10 km$^2$ | 10 – 100 km$^2$ | 100 – 1.000 km$^2$ | 1.000-2.500 km$^2$ and sQs < 50 m$^3$/s | > 2.500 km$^2$ or sQs > 50 m$^3$/s |
| | Point abstraction | | | | |
| 1 $^{(1)}$ | 0.7 | 0.7 | 0.5 | 0.4 | |
| 2 $^{(1)}$ | 0.7 | 0.5 | 0.4 | 0.4 | |
| 3 | 0.5 | 0.4 | 0.3 | | |
| 4 | | | | | 0.3 |
| | Short abstraction all year or long withdrawal in dry period | | | | |
| 1 $^{(1)}$ | 1.2 | 1.2 | 1.0 | 0.8 | |
| 2 $^{(1)}$ | 1.2 | 1.0 | 0.8 | 0.8 | |
| 3 | 1.0 | 0.8 | 0.7 | | |
| 4 | | | | | 0.7 |

| | Size of catchment area | | | | |
|---|---|---|---|---|---|
| Ecological group type | <10 km$^2$ | 10 – 100 km$^2$ | 100 – 1.000 km$^2$ | 1.000-2.500 km$^2$ and sQs < 50 m$^3$/s | > 2.500 km$^2$ or sQs > 50 m$^3$/s |
| | Long abstraction in wet period | | | | |
| 1 (1) | 1.9 | 1.9 | 1.6 | 1.3 | |
| 2 (1) | 1.9 | 1.6 | 1.3 | 1.3 | |
| 3 | 1.6 | 1.3 | 1.1 | | |
| 4 | | | | | 1.1 |

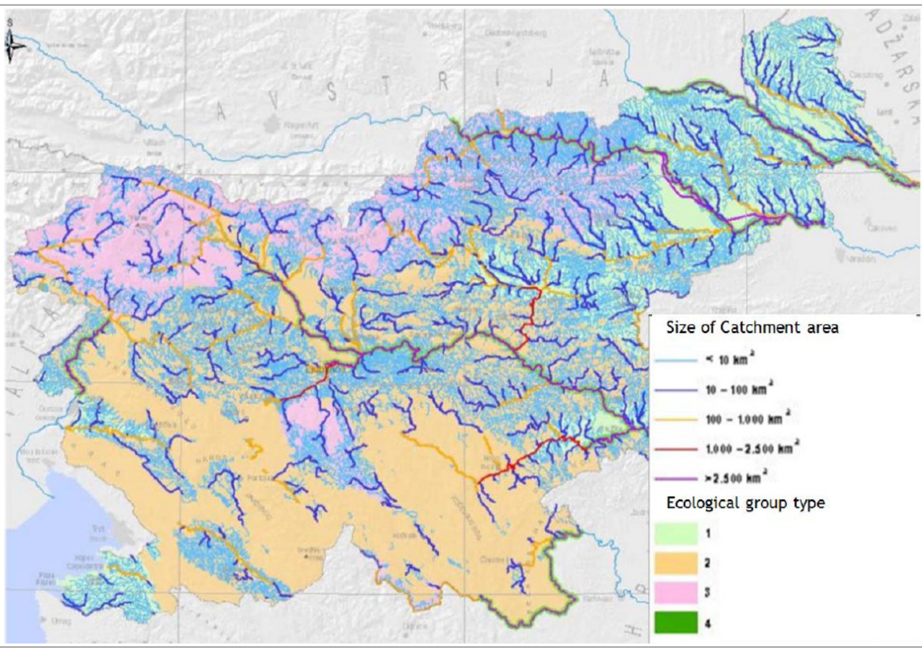
(1) Factor f is multiplied by 1.6, if ratio between MQ and MALQ$_d$ at the withdrawal location is higher than 20.

For long withdrawals, factor f depends on the period of the year:

| Ecological group type | oct | nov | dec | jan | feb | mar | apr | may | jun | jul | aug | sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | wet | wet | dry | dry | dry | wet | wet | wet | dry | dry | dry | dry |
| 2, 3, 4 | wet | wet | wet | wet | wet | wet | wet | wet | dry | dry | dry | dry |

To support water users to define environmental flows, the Ministry of the Environment and Spatial Planning prepared data layers with ecological types of rivers and the size of catchment area (see Figure).

**Fig. 25. Ecological group types of Slovenian rivers (Ministry of Environment and Spatial Planning, 2009)**




*Source: adapted from SEE Hydropower 2011*

If determined according to the Article 7 on the basis of hydrological elements, assessment does not include the diversity of species, processes in aquatic ecosystems, maintenance of habitats and river channel shape.

In determined according to Article 8, all parameters of the river ecosystem are taken into account. The requirements for the study for the determination of eflows are exhaustive, as detailed in Annex 3 of the abovementioned Decree, including not only a description of the intended use and a complete description of the watercourse, habitat , status and pressures but also a proposal of the environmental objectives. The expert opinion on the value of eflows must include an explanation and substantiation of:

- the compliance with the conditions decisive for the determination;
- the methodology, data and criteria to be used, and the definition of dry and wet seasons;
- the measurements and sampling carried out, including justification of the selected sampling sites;
- the results of monitoring, including the lists of taxa considered in the ecological status assessment (if being conducted) and also the data and criteria used;
- the data and criteria, and individual parameters analysed for the final expert determination of the value of eflows;
- the parameters decisive for the final expert determination of the value of eflows.

The study must be submitted by the initiator or applicant for water right and shall be examined by the Institute for Water of the Republic of Slovenia that may approve it or prepare a final expert proposal.

The **monitoring** must be performed by water right holders, which shall describe it in the rules of procedure applying to the operation and maintenance of the water facility. On request, the water right holder shall send the data to competent administration. The Institute for Water of the Republic of Slovenia supports national authorities (the Agency of the Republic of Slovenia) with additional studies and monitoring.The effectiveness of eflows is assessed only at the level of water bodies to achieve the good ecological status, but there is no assessment of the effectiveness for each water right. The explanation of the hydrological monitoring elements shall contain: the explanation and rationale for the used measuring equipment, which shall comply with internationally recognised standards in the field of hydrometry; if an acoustic Doppler flow-meter is used, evidence of the competency of the person conducting measurements; when other measuring equipment is used, evidence that it is calibrated according to internationally recognised standards.

The device or system for water withdrawal must be designed in such way that any withdrawal when the discharge is lower than eflows is not allowed. If the foregoing is not feasible, the owner of the water rights has to assure continuous or daily monitoring of parameters. For new Small Hydro Power plants or when a renovation is taking place, a state of the art IT system and technical solutions should be implemented.

### 6.6.2. Best practice examples: Rizana & Koritnica rivers

Today, the **Rizana river** is the most important source of water supply for the Slovenian coastal area, where population growth and the development of tourism has substantially increased the ecological impact on the watercourse. There are water abstractions for drinking water, fish farms, irrigation and industry as well as some uncontrolled water abstractions for the irrigation in summer, globally exceeding the water capacity of the river. The consequences can be observed primarily in the summer period when, due to the deterioration of the aquatic environment, there were several cases of fish kills.

In 1986, on the basis of hydrologic calculations, the Ministry of the Environment and Spatial Planning determined 0.110 $m^3/s$ as the minimum flow value in summer dry period. A multidisciplinary eflows assessment – independent researches, dealing with hydrology, hydraulics, morphology, biology and landscape architecture were in the working group –was commissioned in 1996.

A flow duration curve from minimum and mean monthly flows, based in complete hydrological and hydraulic analyses has been built. A complete package of biological analyses was carried out, revealing d that the chosen minimum flow of 0.110 $m^3/s$ was too low, causing the growth of phytobenthos and a decrease in zoobenthos diversity.

Very low summer flows were a direct result of high level of abstraction along the watercourse combined with the intergranular porosity of the substrata. This has led to the deterioration of the aquatic flora and fauna. Taking into consideration the hydrological, ecological, landscape and morphological characteristics and habitat evaluation, a minimum flow value for the dry summer period of 0.160 $m^3/s$ was proposed, aimed at reducing pollution levels, and enabling the maintenance of ecological balance both in the river and in the riparian zone. Water users were not involved in the study.

The calculated MEF in dry period according to the decree would be 0.26 $m^3/s$ –MQ of 0.22 m3/s, factor f of 1.2 (catchment is 100 to 1.000 $km^2$, ecological type 2, irreversible withdrawals as irrigation– but since it would significantly impact the production based on existing water rights it may be reduced to the proposed value.

Možnica Small HydroPower Plant has been in operation on the **Koritnica river** since 2003, with the installed flow of 2.5 $m^3/s$. The impoundment has a 13 m wide inclined concrete dam with lateral abstraction. The abstraction of water from the riverbed takes place in a relatively short section, at a distance of 300 m. Koritnica river flows through the Natura 2000 site of the Triglav National Park and the Soča river and its tributaries. In addition to the marble trout, three other fish species occur in the section of the Možnica SHPP.

For the purpose of determining the minimum flow the parameters supposed to be of key importance (hydrological, morphological, physical, chemical and biological) were chosen. During the summer of 2005, less than 10% of the discharge measured above the dam was flowing downstream of the dam. The most important criteria are the ecological and morphological ones in order to preserve a similar diversity of different aquatic habitat types as in the section above the water abstraction and ensure the dynamics of different water flows during the year. On the basis of the diverse characteristics of the watercourse, the value of 0.2 $m^3/s$ should be ensured in the section where water abstraction for the Možnica SHPP takes place. The natural dynamics of water flow, which forms the downstream riverbed and preserves the ecological diversity of the ecosystem, should be maintained during medium and high water flows.

## 6.7. United Kingdom

### 6.7.1. The Environmental Flow Indicator

The UK has introduced environmental flow policies in a stepwise manner over the last two decades. The Environmental Flow Indicator (EFI) plays a crucial role in the management of water resources in England and Wales. This standard was determined by comparing flows to water availability determined in the framework of Catchment Abstraction Management Strategies (CAMS). The process identified those catchments where further water was available for abstraction, those where no more water was available, and those where abstraction was already judged to exceed sustainable limits. This standard was used in catchment-based assessments across the country as a basis for capping future licenses, enabling the rapid introduction of a cap across the country.

EFI is defined as a percentage deviation from the natural flow represented using a flow duration curve. This percentage deviation changes with different flows, and also changes depending on an assessment of the sensitivity of the river to changes in flow.  It is calculated within the Resource Assessment and Management (RAM) framework, which gives an indication of where and when water is available for new abstractions. Where it fails, more detailed assessment is required to understand if current abstractions and use of full licensed quantities are threatening the long term health of the river ecology.

To set the EFI, Environment Agency has used information developed to set flow standards for the WFD by UK Technical Advisor Group (TAG) (Acreman et al, 2005 and UK TAG, 2008). The EFI is set at a level which is thought to support GES. The outputs from UK TAG WFD 48 provided the percentage deviation from natural flow for differing river 'types' and at different flows: low flows (Q95) and flows above Q95. A summary of the outputs from this report is given in the following table.

**Table. 9. Recommended standards from WFD 48 for UK River types for achieving Good Ecological Status given as % allowable abstraction of natural flow.**

| Type | | Flow > Q95 | | Flow < Q95 | |
|---|---|---|---|---|---|
| | | Mar - Jun | Jul - Feb | Mar – Jun | Jul – Feb |
| 1 | A1 | 25 | 30 | 15 | 20 |
| 2 | A2 | 15 | 20 | 10 | 15 |
| 3 | B1, B2, D1 | 20 | 25 | 15 | 20 |
| 4 | C2, D2 | 15 | 20 | 10 | 15 |
| | | Oct – Apr | May – Sep | Oct – Apr | May - Sep |
| Salmon spawning & nursery (not chalk rivers) | | 15 | 20 | 10 | 15 |

1) Predominantly clay. South East England, East Anglia and Cheshire plain
2) Chalk catchments; predominantly gravel beds; base-rich
3) Hard limestone and sandstone; low-medium altitude; some oligotrophic hard rock
4) Non-calcareous shales; pebble bedrock; Oligomesotrophic; Stream order 1 and 2 bed rock and boulder; ultra-oligotrophic torrential

This was translated for use within the RAM framework, so that the water resource availability is expressed as a surplus or deficit of water resources in relation to the EFI. **Natural flow** is calculated by starting with a gauged flow/recent actual flow and adding back in the abstractions and taking out the discharges; or alternatively from other surface water or groundwater models. Starting from the natural flow, two scenarios are also generated: **recent actual scenario**, taking into account abstractions and discharges operating at their recent actual rate; and **full licensed scenario**, with abstractions operating at their full licensed limit and discharges at their recent actual rate.

The relationship between the fully licensed scenario flow and EFI approaches the amount and timing of water availability.

The Environment Agency abstraction regime uses fixed 'hands-off flows' (implying cease of abstraction), but also enable to divert water from periods of higher availability. Percentages of flow allowed for abstraction is set in the following table at different levels of flow from Q30 (relatively high flows) to Q95 (low flows) and three different Abstraction Sensitivity Bands (ABS).

Table. 10. Percentage allowable abstraction from natural flows at different sensitivity bands

| | Q30 | Q50 | Q70 | Q95 |
|---|---|---|---|---|
| ASB3 'high' | 24% | 20% | 15% | 10% |
| ASB2 'moderate' | 26% | 24% | 20% | 15% |
| ASB1 'low' | 30% | 26% | 24% | 20% |

These ASBs are assigned to each waterbody in England and Wales. Each of the ASB has a different EFI associated with it allowing less abstraction in more sensitive sites and more in sites with lower sensitivity. Each of these sensitivity bands was developed from assessment of 3 components:

- Physical typology – using the river 'types' used in WFD 48.
- Macroinvertebrate typology – using expected LIFE scores
- Fish typology – using identification of a fish 'guild' expected under particular physical parameters.

Scores and confidence ratings from each component are combined to give the overall ASB for the waterbody.

**CAMS ledgers** contain details of all the abstraction licences (volumes and location and discharges) and are updated every time a new licence is issued, changed or revoked and to inform future licensing decisions. The EFI is detailed for each CAMS catchment and is available on the Environment Agency's internet site, detailing the hands off flow and other conditions that will be applied to licence applications. It also includes any local constraints that potential abstractors will need to be aware of such as higher levels of environmental protection for designated conservation sites, or where local information has shown that different amounts of water are available in the catchment.

The WRGIS is the central system where abstraction, discharge, natural flows and complex impacts information from the CAMS ledgers is uploaded. The WRGIS uses this information to calculate the current resource availability for each waterbody at the four flow percentiles above mentioned.

In the framework of **implementation of WFD**, the EFI is used in the hydrological classification to identify the waterbodies where flow may be causing or contributing to a failure of GES. This is called "compliance assessment" and shows where the scenario flows are below the EFI, and indicates by how much. This has been used to identify areas where flows may not be supporting GES and is being used to help target measures for further investigation and assessment of what measures are needed.

For initial assessment compliance has been checked at low flows (Q95) recent actual scenario. The degree of non-compliance has been split into three compliance bands:

**Table. 11. Compliance abstraction sensitivity bands in the UK**

| | Flow adequate to support GES | Flow not adequate to support GES – Low - Moderate Confidence (uncertain) | | Not adequate to support GES – High Confidence (quite certain) |
|---|---|---|---|---|
| | | Non-compliant Band 1 | Non-compliant Band 2 | Non-compliant Band 3 |
| Abstraction Sensitivity Band | Compliant with EFI | (up to 25% below the EFI at Q95) | (25-50% below the EFI at Q95) | (up to 50% below the EFI at Q95) |
| ASB3 'high' | <10% lower than natural flow | <35% lower than natural flow | <60% lower than natural flow | >60% lower than natural flow |
| ASB2 'moderate' | <15% lower than natural flow | <40% lower than natural flow | <65% lower than natural flow | >65% lower than natural flow |
| ASB1 'low' | <20% lower than natural flow | <45% lower than natural flow | <70% lower than natural flow | >70% lower than natural flow |

### 6.7.2. Further assessments

The EFI is not a target or objective for resolving currently unsustainable abstractions, but an indicator of where water may need to be recovered. Flow recovery from water bodies that are non-compliant with the EFIs should only occur when supported by additional investigations to provide ecological justification and where costs are not disproportionate.

So, a more detailed assessment is needed in cases where reductions in abstraction were required. One example is the reduction of water abstraction on the River Itchen to meet the requirements of the EU Habitats Directive. A more sophisticated set of limits has now been suggested under the WFD, with flow limits set according to river type, river condition goal, and time of year.

Site-specific investigations are being undertaken to set releases from reservoirs, which were deemed too unique to be managed under generic rules (UKTAG, 2008; Acreman and Ferguson, 2010).

The national guidance to define MEF is available online[79]. This includes a list of good practice mitigation measures. In relation to flow, the list includes maintenance of a proportion of the flow that would have naturally been exceeded 95 % of the time. The proportion depends on the river type but is typically about 85 %. It also includes provision of variable higher flows, depending on the needs of the site-specific ecological characteristics. These flows are defined on a case-by-case basis.

Recently, a significant conceptual and technical advance has been made in Bradley, Cadman & Milner 2012.

79 http://www.wfduk.org.

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