Ecological flows in the implementation of the Water Framework Directive

Compilation of case studies

referenced in CIS guidance document n°31

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Purpose of the document

This document gathers the Case studies that were collected throughout the drafting process of the CIS guidance document n°31 on "Ecological flows in the implementation of the Water Framework Directive".

These Case Studies reference existing practices and experiences in Member States and aim to illustrate Part III of the guidance document where the different steps of the WFD planning process are screened and guiding messages are developed to help Member States in considering ecological flows whenever and wherever relevant.

Lessons learned from these case studies are included in the relevant sections of the guidance document (see the following table).

Disclaimer

These case studies have not been subject to an evaluation and remain under the responsibility of their individual authors. They are not part of the guidance document endorsed by Water Directors.

List of case studies referenced in the CIS guidance document

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Case study 1 (Austria): Using Art. 5 information on hydrological pressures and impacts for the gap analysis”

1. Executive summary

For pressure and impact analysis Austria first of all defined the main typical pressures which are impacting the hydrological regime: water abstraction, impounding/ damming, water storage/hydropeaking, (river regulation/channelization). Their relevant “impact” parameters which had proven to be most important for the biological elements are alterations of quantity of flow, saisonal flow dynamics, daily flow fluctuations, flow velocity, water depth /wetted area. These parameter are seen as the relevant ones for eflow definition. In a first rough estimation a panel of experts set values for the parameters mentioned above which would ensure good ecological status for the biological elements with very high confidence and which would mean a failure of GES in any case. In the 1st pressure and impact analysis 2004 information was collected on the main pressures and pressure parameters mentioned above to define water bodies “not at risk”, “at risk” and “possibly at risk”. This also allowed to design the monitoring programme in a most efficient and cost-effective way. In preparing the 1st river basin management plans the biological monitoring results were compared to the environmental objective GES (GAP Analysis).

Austria in the meantime had developed biological assessment methods with specific metrics which are sensitive to hydrological and morphological alterations in addition to metric sensitive to physic-chemical impacts. Guide values for the eflow parameters (quantity of flow, seasonal flow dynamics, daily flow fluctuations, flow velocity, water depth /wetted area) were set for GES for all water body types, limit values for high status.

In the GAP analysis first of all water bodies are checked whether “good biological status” is failed. In case of a failure the next step is to compare the results for the different metrics to find out whether they indicate a hydrological, a morphological or a physic-chemical impact. In case that the hydromorphology sensitive metrics are responsible for a classification worse than good ecological status the hydromorphological information/data of the pressure & impact analysis are used to clarify the reason for failing good status and to carve out the responsible hydrological alteration. This type of procedure in Austria ensures the identification of the water use(r) causing the failure of GES, the designation of tailor-made and cost effective technical restoration programmes. It also ensures basic information/data needed for the Art. 4(3) test, the objective setting / application of exemptions acc. to WFD Art. 4(4) and 4(5).

For the 2nd pressure an impact analysis the values for the hydrological pressure/impact parameters were refined taking into account the limit/guide values set for HES and GES in the National Ordinance on Ecological Quality Objectives – Water Status Assessment.

2. General information

Member State(s): Austria

RBD(s): Danube (AT1000), Rhine (AT2000), Elbe (AT5000)

Location: nationwide

Time period (start/end):

2.1. Objective of the Case study

Efficient procedure to support the achievement of the environmental objectives of WFD with regard to alterations of the hydrological regime by using Art. 5 data hydrological pressures and impacts as supporting information for the Gap Analysis.

2.2. Policy and management context

According to WFD Annex V good ecological status requires – as a supporting element - a flow regime which ensures the achievement of the biological values set for good ecological status. “Eflow” (for GES) is a synonym for this kind of flow taking into account quantity and dynamics of water flow and connection to groundwater.

Quantity and dynamics of flow have to be described by type-specific hydrological/hydraulic parameters including temporal and spatial dimensions. These parameters are an important part of monitoring programmes and a substantial data base for the risk analysis acc. WFD Art.5 as well as the gap analysis.

To fulfil the requirements of WFD Art 5 i.e. data and information on hydrological as well as morphological pressures have to be collected and their impacts analysed. The results of the pressure/impact analysis and risk analysis are the basis for developing the monitoring programmes for the biological, physico-chemical and hydromorphological components acc. to WFD, Annex V, 1.3. The information required for the Art. 5 report together with the monitoring data are used for the gap analysis. In the gap analysis member states have to analyse for each water body whether there is a gap between the monitored (current) ecological status and the environmental objective of good ecological status. In case of a gap the reasons for failing the good ecological status (defined by biological values) are analysed using the hydromorphological pressure and impact information/data as well as hydromorphological monitoring data. These evaluations are also relevant for the designation of HMWBs in case that the failing of GES is proven by biological monitoring results and the reason for this is a result of physical alterations by human activity which had led to a substantial change in character.

While the impact and pressure analysis in 2004 was generally based on existing - usually limited - hydrological and morphological data /information the ensuing monitoring cycle starting in 2007 and the gap analysis in the frame of the 1st River Basin Management Plan provided a significant improvement with regard to hydromorphological data and eflow definition for the planning steps of the second cycle of the RBMP.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The task was to develop a procedure to support the achievement of the WFD objectives HES/GES/GEP with regard to hydrological requirements in an appropriate, efficient, cost effective way ("As quick and simple as possible but as detailed/complex as necessary").
According to WFD Annex V good ecological status requires – as a supporting element - a flow regime which ensures the achievement of the biological values set for good ecological status. "Eflow for GES" is a synonym for this kind of flow taking into account quantity and dynamics of water flow and connection to groundwater.
Quantity and dynamics of flow are to be defined in more detail by type-specific hydrological/hydraulic parameters including temporal and spatial dimensions.
When developing a methodology for the first Impact and Pressure Analysis in 2004 the main hydromorphological pressures altering the flow regime of Austrian rivers were identified: water abstraction, impounding, water storage/hydropeaking, flood protection (grade stabilizing; river regulation; channelization). Monitoring data of hydrological/hydraulic parameters were checked by an expert panel with regard to their relevance and informative value for the assessment of impacts on biology taking into account biological monitoring data from the last decades and the existing knowledge on the biological response reacting on hydrological and morphological alterations. In the evaluation process as well as for the definition of new parameters which are recommended for a future monitoring a special focus was laid on the selection of those parameters, which are the most crucial ones. The criteria for selection of appropriate data for monitoring was also the already availability or with an acceptable financial effort. The main parameters describing altered flow regimes which might lead to a failing of the type-specific biological values to be set for GES as required by WFD are:

Evaluation of existing hydromorphological and biological data led to the definition of the most crucial "factors" impacting biology: in case of

- water abstraction
    - downstream of the abstraction: altered low flows, missing of dynamic flows (monthly/seasonal variability including high flows), minimum water depth and flow velocities

  - upstream of the abstraction (when using a weir): reduced flow velocity
- water storage/hydropeaking: water level/flow fluctuations with unnatural min-max variations within one day and with unnatural increase and decrease velocities
- damming/impounding: reduced flow velocities upstream of the damming weir
- grade stabilizing structure: reduced flow velocities upstream
- channelization, river regulation: increase flow velocities

In the first monitoring cycle it was ensured that information on those factors are supplemented in case that it was not available yet. Based on this information and results of the biological monitoring we were able to define the parameters and values for the hydrological flow regime which ensure the achievement of the type-specific biological values set for good ecological status in all probability ("GES-eflow").

Eflow values were also defined in Austria for high ecological status ("HES-Eflow")

These "eflow" values do take into account the natural flow situation at each point of the river and are regulating the base flow (low flow situation), flow regime character/seasonal flow dynamics, minimum water depth, minimum flow velocities, variation of flow fluctuations.

In the GAP analysis first of all water bodies are checked whether "good biological status" is failed. In case of a failure the next step is to compare the results for the different metrics to find out whether they indicate a hydrological, a morphological or a physic-chemical impact. In case that the hydromorphology sensitive metrics are responsible for a classification worse than good ecological status the hydromorphological information/data of the pressure & impact analysis are used to clarify the reason for failing good status and to carve out the responsible hydrological alteration. This type of procedure in Austria ensures the identification of the water use(r) causing the failure of GES, the designation of tailor-made and cost effective technical restoration programmes. It also ensures basic information/data needed for the Art. 4(3) test, the objective setting / application of exemptions acc. to WFD Art. 4 (4) and 4(5).
For the 2nd pressure an impact analysis the values for the hydrological pressure/impact parameters were refined taking into account the limit/guide values set for HES and GES in the National Ordinance on Ecological Quality Objectives – Water Status Assessment.
The hydromorphological monitoring data which include the eflow parameters were evaluated. According to the deviation from the eflow values set for high and good ecological status, the risk of water bodies was assessed in 4 classes:

- no risk at all: flow parameters are in line with HES-eflow
- no risk: flow parameters are in line with GES-eflow and biological monitoring data (metrics for fish and benthic invertebrates sensitive to hydrological pressures) confirm good ecological status
- possibly at risk: eflow values unclear or below GES-eflow values and biological monitoring data (metrics for fish and benthic invertebrates sensitive to hydrological pressures) indicate moderate ecological status
- at risk: eflow values significantly below GES-Eflow values or even seasonally drying out and biological monitoring data (metrics for fish and benthic invertebrates sensitive to hydrological pressures) do not prove good ecological status

In the gap analysis for the 2nd River Basin Management Plan which Austria is just performing the pressure/impact information on hydrological impacts (missing eflows and eflow parameters set for HES and GES in particular) proved to be highly efficient and cost effective to achieve the objectives of WFD.

3.2. Temporal and spatial scales

Scale: national

3.3. Type of analysis or tool

3.4. Information and data requirements

The hydrological data/levels applicable for the individual river water bodies can be obtained from the Austrian Hydrological Atlas published annually or directly from the Hydrographical Departments at the Offices of the Provincial Governments. On an individual basis, the values shall be used for the river stretch under examination which have been measured over the longest-possible period, ideally over a period of at least ten years.
The hydrological characteristic values refer to the natural situation in the running water body which is unaffected by human impact and not to a flow situation which may have already been altered due to human intervention. This is why the designations of $MJNQ_{t\ natural}$ and $NQ_{t\ natural}$ have been selected. Corresponding comments in the Hydrological Atlas on the impact of the respective measuring points by way of water inflow or abstraction or by way of storage operations shall be considered accordingly.
For water bodies with no hydrological data available, the hydrological data is established via model calculations, as for example by way of conclusion-by-analogy using a representative gauging station situated in the same water body or by way of regionalization models.

The information on (reduced) flow velocities is derived from the provincial data bases which include i.a. the length of the impounded sections from the dam/weir up to the head of the backwater as set in the individual permit for water use

The information on water depth is derived from the provincial data bases. According to the national method of hydromorphological status assessment of Austrian rivers, the existence of the minimum water depth is one of the parameters of the assessment. Provincial data bases also include information on old permits with without any ecological flow requirements, so that the missing of minimum water depth, water velocities and base flow, dynamic flow can be derived with high confidence.

With regard to flow fluctuations due to water storage/hydropeaking, the information is derived from a scientific study in which all river stretches downstream the discharge of reservoirs were assessed. A method was developed to differentiate between natural flow fluctuations and their biological effects due to flooding and artificial fluctuations due to hydropeaking.

3.5. Testing of results

Procedure was used for developing the 2nd River Basin Management Plan

3.6. Current application of the method/initiative

Nationwide

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

Definition of eflow parameters and values for nationwide application defining the flow regime at HES and ensuring the achievement of the biological values set for GES is crucial for an efficient and cost effective way to achieve the environmental objectives of WFD.

Eflow definition can streamline the risk assessment as part of the pressure and impact analysis (acc. to WFD Art. 5) thus ensuring an cost efficient, effective and biological impact driven monitoring programme.

Art. 5 data/information on hydromorphological pressures and impacts are crucial for the gap analysis to prove that the failing of GES is due to hydrological alterations, to identify the water use(r) causing the failure and to define cost effective, tailor-made restoration programmes.

4. Contact information

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-

5. References

Study on flow fluctuations due to hydropeaking:
http://www.bmlfuw.gv.at/wasser/wasser-oesterreich/plan_gewaesser_ngp/umsetzung_wasserrahmenrichtlinie/schwallstudie.html)

Assessment Method for hydromorphological status of Austrian rivers:
http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2009/hintergrunddokumente/methodik/hydromorphologie.html

Designation of heavily modified water bodies:
http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2009/hintergrunddokumente/methodik/hmwb_bewertung.html

Ordinance on Ecological status assessment for surface waters:
http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2009/hintergrunddokumente/rechtsdokumente/ow_ziele.html

Pressure & Impact Analysis 2013 (Art.5 WFD):
http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2015/ist-bestand-2013/dokument/ist-bestand-2013.html

Case study 2 (Spain): "Development of the national regulation on ecological flows"

1. Executive summary

The approval of the European Water Framework Directive 2000/60/EC (WFD) by the European Council and Parliament brought a compulsory regulatory framework definition for the first time, establishing environmental objectives for all water bodies: continental, transitional and coastal. In the WFD nevertheless there is no explicit reference to ecological flows, even though it is assumed that ecological flow regimes must contribute to achieving the environmental objectives of surface water bodies. The Spanish Water Act establishes the ecological flows as a compulsory determination to be established in the River Basin Management Plans (RBMPs). In 2007, the Royal Decree 907/2007, of July 6th by which the Hydrological Planning Regulation (HPR) is approved, defined the main criteria for determining the ecological flow regimes in the Spanish river basin districts.

2. General information

Member State(s): Spain

RBD(s): Júcar River Basin District; EU Code for the RBD: ES080

Location: Spain

Time period (start/end): since 2007

2.1. Objective of the Case study

This case study will illustrate how ecological flows have been established as part of the Spanish legislation and recent regulations.

2.2. Policy and management context

Ecological flows are an essential element to achieve a sustainable management of water resources, while respecting the water environment. Nevertheless, it must be admitted that establishing ecological flow regimes might increase water-related conflicts, particularly in water scarce regions.

However, there is no explicit reference to ecological flows in the Water Framework Directive (2000/60/EC) (WFD), even though it is assumed that ecological flow regimes must contribute to achieving the environmental objectives of surface water bodies.

In Spain, the Water Act establishes that the river basin management plans will determine ecological flows, understanding as such those maintaining at least the fish life that would naturally inhabit or might inhabit in the river, as well as its riverbank vegetation. Fish fauna has been selected as the most sensitive one of the BQEs and as a key factor of the inter-relation among many BQEs. The Water Act also establishes that ecological flows will not be considered as a use, but as a restriction imposed with general character to water resources systems.

Integrating ecological flows in the Spanish water management poses a challenge for the years to come, particularly considering that these flows are not contemplated in the Spanish legislation as an environmental demand, which might not be met in specific circumstances, but as an environmental restriction to water use.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The regulatory framework of the ecological flow regime in Spain is defined by the Water Act which establishes in article 42 that the river basin management plans will compulsorily include:

Section 1.b.c': Water allocation and reserve of resources for current and future uses and demands, as well as for the conservation and recuperation of the natural environment. To this effect, they will be determined:

Ecological flows, understanding as such those maintaining at least the fish life that would naturally inhabit or might inhabit in the river, as well as its riverbank vegetation.

The Water Act also establishes in article 59.7 that ecological flows or demands will not be considered as a use but as a restriction generally imposed to water resources systems. However, the rule of supremacy of use for urban supply is applied to ecological flows. Finally, the Water Act indicates that ecological flows will be established in the river basin management plans. In order to establish them, river basin organisations will develop specific studies for each river section.

Royal Decree 907/2007, of July 6th, by which the Hydrological Planning Regulation (HPR) is approved, establishes in article 18 "ecological flows" the main criteria to elaborate and subsequently implement the ecological flow regime.

1. *The hydrological plan will determine the ecological flow regime in rivers and transition waters, including water needs for lakes and wetlands.*
2. *This regime will allow to sustainably maintaining the functionality and structure of water systems and associated terrestrial systems, contributing to achieve the good status or ecological potential in rivers and transition waters. In order to establish them, river basin organisations will develop specific studies in each river section.*
3. *The implementation process will be developed according to a public participation process that will bear in mind existing uses and demands and their licensing system, as well as good practices.*
4. *In the case of prolonged droughts a less demanding regime might be applied, as long as the conditions on the temporary deterioration of the water bodies are met. This exception will not be applied to areas of the Natura 2000 network or those included in the Ramsar wetlands list. In these areas it is considered a priority to maintain the regime, although the rule on supremacy of use for urban supply will be applied.*
5. *For determining the required year-on-year average flow in order to calculate the available groundwater resources, the ecological flow regime will be taken as a reference.*

Besides the Hydrological Planning Regulation (HPR), and due to the fact that the planning process and more specifically the elaboration of the river basin management plans is very technically complex process, a Hydrological Planning Instruction (HPI) has been developed. It was approved by Order ARM/2656/2008. The objective of this instruction is to establish the technical criteria for the homogenisation and systematisation of the elaboration works of the river basin management plans, according to what is established in the HPR (Estrela, 2011). This instruction develops, amongst other contents in the plans, the methods and procedures to follow in order to elaborate and implement the ecological flow regime in the HPR. To this end, the HPI contemplates and develops the following elements: objectives and components of the ecological flow regime, hydrological heavily modified water bodies, flow regime during prolonged droughts, water requirements in lakes and wetlands, repercussion of the ecological flow regime on water uses, public participation process of the flow regime and flow regime follow-up.

3.2. Temporal and spatial scales

This regulatory process started in year 2007 with the approval of Hydrological Planning Regulation (HPR) and it was developed in 2008 by means of the Hydrological Planning Instruction (HPI). Nevertheless this process is still alive since technical criteria established in the HPI can be modified as methods and procedures improve.

In the other hand, the regulatory process affects to river basins with different hydrological regime, as its fulfilment has to be complied throughout the Spanish territory, so the methods and procedures developed in the HPI have to be generalized enough to fit the specific hydrological regimes and casuistry in each river basin.

The river basin management plans, approved in Spain by means of royal decrees, establish the ecological flow regimes in the Spanish river basin districts according to the previously mentioned regulations.

3.3. Type of analysis or tool

The ecological flow regime, in accordance with the HPI, is formed by the following elements: minimum seasonal flows, maximum seasonal flows, flow change rates and flood-generating flows.

- The HPI suggests the combined use of hydrological methods and habitat simulation methods to determine the minimum seasonal flow. Regarding hydrological methods, it states that a 20-year (preferably consecutive) series of inflows representative of the natural regime will have to be used. The habitat simulation methods will have to be applied, at least, in 10% of the representative bodies. The sections will be selected by prioritising the most environmentally important bodies, the downstream sections of large dams or important diversions, etc.
- The maximum seasonal flows that must not be exceeded during the ordinary operation and management of hydraulic infrastructures would be defined using habitat information and swimming capacity of targeted fish species.
- Flow change rate, which entails a limitation in the flow variation per time unit, in order to avoid significant flow fluctuations in a short time due mainly to hydroelectricity stations has to be determined, according to HPI, based on the analysis of ordinary floods from daily average flows, at least 20 years long, by calculating the classified yearly series of change rates, both ascending and descending.
- The flood associated to the generating flow is associated to the full section flow of the river bed. According to the HPI, it will have to be defined including its magnitude, frequency, duration, seasonality and maximum change rate, both in the ascending and the descending curves of the flood hydrograph. The previous parameters will be obtained, preferably, from the statistical analysis of a representative series of the river's hydrological regime, and with at least 20 years' worth of data.

3.4. Information and data requirements

To determine minimum and maximum seasonal flows, it is required daily hydrological data in natural regime. This information is not usually easy to obtain and it can be determined using models or restitution of altered data series into natural regime.

The flow change rate determination needs a short time scale hydrological data to restrict the change rate in regards to hours or even less time. To this effect it must be considered that in river basins with small response time, the analysis has to be developed at least with hourly hydrographs and not daily ones, otherwise the flow change rates obtained will not be representative of the real flood regime.

The flood flow also needs at least hourly data as the statistical analysis use for its determination requires instantaneous maximum flow data.

3.5. Testing of results

The environmental flow regime established in the river basin management plans has been elaborated by following the criteria specified in the Hydrological Planning Regulation (HPR) and the procedures and methods established by the Hydrological Planning Instruction (HPI). In order to get a better achievement of environmental objectives and attention to the demands, this implementation will follow an adaptive tracking procedure that will adapt water management and even environmental flow regimes as methodologies for determining environmental flows and knowledge of specific conservation objectives are improved. And so some River Basin Authorities have established only part of the components of the environmental flow regime and have developed a not very deep public participation process in their first River Basin Management Plans as a first step to implement a flow regime, leaving part of the implementation process to following River Basin Management Plan cycles.

3.6. Current application of the method/initiative

The Hydrological Planning Instruction indicates that a follow-up of the ecological flow regime and their relationship with the ecosystems will be developed. This follow-up will have the aim of knowing the degree of compliance with the objectives and introducing some modifications of the defined regime. But it must be taken into consideration that the ecological flow regime should not be changed completely in each revision of the river basin management plan and only the necessary adaptations according to the experience gained since its implementation should be carried out.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

As a limitation to be mentioned could be that there are some elements of the flow regime whose methodologies need to be contrasted or more developed.

The experience gained during this time shows that there have not been great impacts on the consumptive water uses (irrigation and public water supply), despite the environmental improvement produced by the new ecological flow regimes, in respect of the plans approved in 1998, but in the other hand the implementation of ecological flow produces significant impacts on non-consumptive water uses, mainly hydropower generation.

4. Contact information

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5. References

Website referring to the case study: http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/planificacion-hidrologica/default.aspx

Estrela, T, 2011. The WFD and the River Basin Management Plans in Spain. Journal of Water Management. United Kingdom. Volume 164 Issue WM8 Pages 397-404 doi: 10.1680/wama:1000005.

Case study 3 (Austria): "Regulations concerning ecological flow with special regard to the National Quality Objectives Ordinance"

1. Executive summary

Quantity of flow consisting of a base flow and a dynamic share, flow velocity, water depth, daily water depth/flow fluctuations and wetted area (habitat extent and natural type characteristic) were identified to be the most relevant for ensuring the ecological and biological objectives of the WFD (HES, GES) and therefore combined for "eflow" definition taking into account river typology and site specific natural flow characteristics

Limit values for eflow were defined to describe the hydrological conditions for high ecological status.

Guide values for the eflow parameters were defined which have proved by evaluation of hundreds of biological and hydrological monitoring data that GES is ensured in all probability and the biological limit values set for fish, benthic invertebrates, phytobenthos as well as macrophytes with regard to good ecological status class. The hydrological eflow limit values as well as the guide values were included in national legislation (Ordinance on Ecological Status Assessment, issued in 2010).

2. General information

Member State(s): Austria

RBD(s): Danube (AT1000), Rhine (AT2000), Elbe (AT5000)

Location: nationwide

Time period (start/end): since 2010

2.1. Objective of the Case study

Definition and legal regulation of eflow limit and guide values which ensures the achievement of HES and the biological values of fish, benthic invertebrates, phytobenthos & macrophytes set for the GES in all probabilities.

2.2. Policy and management context

The risk analysis 2004/2007 showed that 10% of the Austrian rivers are failing good ecological status due to water abstractions without ensuring an ecological minimum flow. This is due to the fact, that the majority (>85%) of the ~2000 existing hydropower plants in Austria are diversion plants. They are lacking regulatory requirements for ecological minimum flow as their permit lasted from decades ago when there were no ecological requirements at all.
WFD requires to define hydrological conditions/values for high ecological status (Eflow for HES) as well as a definition of hydrological conditions which are consistent with the biological values set for the biological QE for each water body type (eflow for GES).

To fulfil the requirements of WFD, to ensure a consistent approach by the water authorities and planning reliability for those who want to abstract water from specific uses, standardized values are a prerequisite which ensure the achievement of the biological values for GES in all probability.
Based of the evaluation of hundreds of biological and hydro-morphological monitoring data

- limit values for eflow were defined for high ecological status
- guide values for relevant hydrological (and morphological) parameters were defined which ensure in all probability the achievement of the biological limit values set for fish, benthic invertebrates, phytobenthos as well as macrophytes with regard to good ecological status class.

All of them were included in national legislation (Ordinance on Ecological Status Assessment, issued in 2010.

The guideline values for ecological flow are to be understood as a more detailed definition of the objective - the hydrological conditions which are relevant for the achievement of the biological values of the GES in particular.

Usually the eflow values set for GES also fulfil the requirements of nature protection/Natura 2000 objectives.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The evaluation of hundreds of biological monitoring data sets proved that for the Austrian river types fish is the most sensitive and indicative biological quality element in case of hydrological alterations. Benthic invertebrates are also sensitive but less than fish. phytobenthos as well as macrophytes are even less sensitive in our river types. (That mean that e-flow values set for fish and benthic invertebrates ensure the achievement of good status of phytobenthos/macrophytes in any case).

When developing the methods to assess the ecological status for all biological quality elements according to the WFD we took care that assessment methods for fish as well as benthic invertebrates are also indicating reactions on hydrological alterations in rivers. We developed specific modules/metrics in the assessment methods to be able to distinguish between biological reactions on alterations of the physico-chemical conditions and on hydrological/ morphological conditions.
The development of the biological assessment methods were based on the evaluation of more thousand monitoring sites.

Quantity of flow consisting of a base flow and a dynamic share, flow velocity, water depth, daily water depth/flow fluctuations were identified to be the most relevant for ensuring the ecological and biological objectives of the WFD (HES, GES) and therefore combined for “eflow” definition taking into account river typology and site specific natural flow characteristics.

The ecological flow requirements are described in Art. 12 (high ecological status) and Art13 (good ecological status) of the National Ordinance on Ecological Quality objectives for surface waters. They are to be understood as a more detailed description of the normative definition of the hydrological quality element described in Annex V of the WFD with regard to the hydrological and some dependent morphological aspects.

In case of <u>water abstraction</u> the relevant parameters for GES are summarized under the term “ecological minimum flow” consisting of a base flow, a dynamic share, which have to fulfill specific habitat requirements quantity, dynamic, velocity and minimum depth. The values are derived from the evaluation of fish and benthic invertebrates monitoring data in particular and are qualified to ensure that the values of good ecological status set for fish and benthic invertebrates are achieved on a very high level of safety.
In Austria we use the term ecological minimum flow as these are the values required for the achieved of the good status for the BEQs.
NQ_t is defined by the lowest flow level observed over a longer series of years. Thus, NQ_t constitutes a “natural state of emergency” in the water body which naturally occurs only in very rare cases. If such a low flow level is upheld over a longer period of time due to anthropogenic impact, it can be assumed that the ecological status is not complied with.
In addition to the hydrological values, a minimum amount of water shall be warranted in the fish habitat which ensures the migrability of the concerned river stretch by way of respective water depth and flow velocity.
In order to ensure the interconnection of the habitat and the migrability of water bodies, a combination of hydrological characteristic values and the respective water depth and flow velocity (confer Ordinance Annex G) is required. These requirements shall, in any event, be taken into account by way of sufficient ecological minimum water flow. In near-natural river stretches, compliance with these values is to be ensured mainly through the water amount given off as

ecological minimum flow and not by way of artificially built-in structures. In stretches of waters which are modified due to anthropogenic impacts, the morphological shape of the river-stretch affected by water abstraction (structuring, width and depth variances) in connection with the establishment of the required ecological minimum flow shall be based on natural reference situations of the type of water body in question (with regard to wetted widths, or wetted surfaces in the case of $MJNQ_t$).
Base flow is to ensure that the respective type of water body shall be basically preserved with regard to the habitat dimension and that the passability of the stretch of water for fish is warranted.

With regard to the dynamic flow rate, the „dynamisation“ part has to ensure functions which are described in Art. 13 of the Ordinance:
a) The seasonal character of the natural bed-sediment relocation and thus a substrate composition is ensured which is typical of the water body,
b) Sufficient current/flow is ensured in times of spawning migrations,
c) Different habitat demands of individual age classes of most relevant organisms (species) are considered during different times of the year and
d) Oxygen and thermal conditions which are typical of the water body are ensured.

In the explanatory note to the Ordinance it is stated that this can be achieved in all probability when 20% of the natural daily flow is guaranteed in the river (NQt is not allowed to be undergone).

There is a general possibility to increase this „ecological minimum flow“ due to requirements due to other “non-ecological” requirements like tourisms (for whitewater-kayaking, rafting, …).

In case that a water body are already severely altered in morphology which had led to a designation as HMWB modelling is an appropriate tool to evaluate the flow requirements for GEP where the restoration of the ecological minimum flow calculated according to Art 13 of the Ordinance would not ensure good status of fish/benthic invertebrates. This can happen in cases where the flow calculated acc. Art 13 would lead to increased water levels resulting in flooding of existing spawning structures gravel banks which therefore would lose its functions and have a negative effect on fish population. Only in those exceptional cases lower flows than calculated according to Art 13 can be allowed ensuring good ecological status for fish.

For flow alterations due to water storage (impoundments, reservoirs/hydropeaking) daily water depth/flow fluctuations (rate of min – max daily flow, wetted area) and flow velocities proved to be the most relevant parameters, which therefore were regulated in the Austrian Ordinance for HES (Art. 12) and GES (Art. 13) with limit and guide values as well.

Based on experiences from the past and data evaluations/studies (existing regional guidelines, biological and hydrological monitoring of existing abstraction permits, monitoring results of flow restoration measures, targeted monitoring,…) the eflow limit values and GES guide values were defined by an expert panel of national and regional authorities supported by scientific experts.

During the participation process on the Ordinance on Ecological Objectives for Surface Waters and on the RBMP the regulations have been discussed with all parties involved (hydropower sector, NGOs, fisheries,…).
The ordinance was issued by the Federal Ministry of Agriculture, Forestry, Environment and Water Management in March 2010.

Legislative Text in detail:

<u>Quality objectives defining the high hydromorphological status</u>

Art 12. *(1) For the assessment of a high hydromorphological status of a surface water body, the individual components of hydrological regime, river continuity and morphology shall be used.*

(2) The status of hydrological regime, river continuity and morphology of a surface water body is rated as high if the following criteria are complied with:

1. *Only a very marginal water extraction is taking place. As very marginal shall be deemed a level of water extraction of up to 20% of the annual flow at the abstraction point.*

   In case that in the months of

   a) *October to March, the mean water flow occurring during winter months ($MQ_{Oct\text{-}March}$) or,*
   b) *in the months of April to September, the mean annual water flow (MQ)*

   is not exceeded, a level of water extraction accounting for less than 10% of the natural lowest daily minimum flow (NQ_t) is also deemed to be very marginal.
2. *There are no anthropogenic water-level fluctuations characterized by surge/downsurge phenomena.*
3. *Anthropogenic reductions of the mean flow velocity in the cross-section occur only occasionally and only at very short stretches.*
4. *River continuity is impacted by human activity only to such a marginal extent that unhampered migration of aquatic organisms typical of the water body and the natural transport of sediments in the streambed are possible.*
5. *Except for a few selective protections affixed at undercut-slope banks or bank slides, bank dynamics is not restricted.*
6. *Stream-bed dynamics is not restricted, there are no or merely isolated measures taken for the purpose of stream-bed stabilization.*

Guiding values used to define a good hydromorphological status

***Art 13.** (1) A hydromorphological status is rated as good if there are hydromorphological conditions under which the values laid down for the good status of the biological quality elements can be reached. Under the hydromorphological conditions described in Paras 2 to 6, the values relevant for the good status of biological quality elements and laid down in Sections 7 through 11 are reached in all probability. When determining the value for the hydromorphological conditions on the basis of the respective project documentation, it shall be examined, on a case-by-case basis, if the application of less stringent values with regard to the hydromorphological conditions will ensure the long-term compliance with values relevant for the biological quality components.*

(2) In all water bodies, the ecologically-required minimum flow ensures the level and dynamics of the current and the resulting connection to the ground water so that the values for the biological quality components laid down for a good status can be reached in all probability. These conditions shall be deemed as fulfilled, if

1. *There is a **permanent minimum flow rate** (base flow) which*
   a) *exceeds the value relevant for the natural lowest daily minimum flow ($NQ_{Residual\ flow} \geq NQ_{t\ natural}$),*
   b) *accounts for at least one third of the natural mean annual minimum flow ($NQ_{Residual\ flow} \geq 1/3\ MJNQ_{t\ natural}$) in water bodies for which the value for the natural lowest daily minimum flow is below one third of the natural mean annual minimum flow,*
   c) *accounts for at least half of the natural mean annual minimum flow ($NQ_{Residual\ flow} \geq 1/2\ MJNQ_{t\ natural}$) in water bodies for which the mean water discharge is below 1 m^3/s and the value for the natural lowest daily minimum flow is below half of the natural mean annual low flow*

*and reaches the values laid down in **Annex G** relevant for minimum water depth and minimum stream velocity in the natural fish habitat, and*

2. *there is, moreover, a **dynamic flow rate** generally following the natural flow dynamics of the water body over time to ensure that*
   a) *The seasonal character of the natural bed-sediment relocation and thus a substrate composition is ensured which is typical of the water body,*
   b) *Sufficient current/flow is ensured in times of spawning migrations,*

c) *Different habitat demands of individual age classes of most relevant organisms (species) are considered during different times of the year and*
d) *Oxygen and thermal conditions which are typical of the water body are ensured.*

Annex G: Ecological minimum water level in fish habitats (Sect 13 Para 2 Subpara 2)

By applying a minimum low of 50% of MJNQt, compliance with the values for minimum depths and minimum flow-velocity rates and thus the continuity of the water body can be ensured to a high extent. If this amount of water is given off, a measurement of depths and flow velocities is no longer required.

Fish region	*For the area of the rapid*	*For the thalweg*
	Minimum water depth T_{min} [m]	*Ø Minimum depth T_{LR} [m]* [3]
Epirhithral (> 10% slope)	*0.1*	*0.15*
Epirhithral (3-10% slope)	*0.15*	*0.20*
Epirhithral (≤3% slope)	*0.20*	*0.25*
Metarhithral	*0.20*	*0.30*
Hyporhithral	*0.20 (0.30* [2]*)*	*0.30 (0.40* [2]*)* [4]
Epipotamal	*0.30*	*0.40* [4]

[1] *The minimum depth applies in the specific spawning and developmental stages of the respective site-related dominant and sub-dominant fish species.*
[2] *The values written in brackets are applicable for the presence of Danube salmon.*
[3] *The determination of the minimum depth in the thalweg and the minimum depth for the habitat during the fish spawning season is to be carried out as follows: For a 200m-stretch which is characteristic of the water body, the maximum water depths in the thalweg at minimum and residual flow, respectively, shall be determined in the five most distinct riffles or rapids and in the five most distinct pools. This is to serve as a basis for the calculation of the respective depth in the thalweg for this river stretch at a certain flow level. The arithmetic mean made up of the ten values accounts for the respective mean depth in the thalweg in this river stretch in the event of flow at the time of the depth measurement.*
[4] *In the hyporhithral and epipotamal zones, higher minimum water depths are possibly required in the spawning season. These shall be taken into account individually, according to the site-related dominant and sub-dominant species of fish.*

Minimum flow velocities:

For the area of the rapid: v_{min} (m/s) [5]	*≥0.3*
Principal current in the migration corridor: v_{min} (m/s) [6]	*≥0.3*

[5] *Mean velocity in the cross-section*
[6] *The principal current serves the purpose of rheotactic orientation of fish. Most of the time, the fish-migration corridor is situated laterally, in the area of the channel line and in current areas exhibiting a velocity of 1m/s. The flow velocities are determined in the channel line in the area of the measured riffles or rapids and pools (measurement carried out vertically, 3-point measurement in 20%, 60% and 80% of total water depth, respectively).*

(3) For large rivers (Bio-region numbers 16, 17 and 18 according to Annex A1), anthropogenic fluctuations in water flow shall be assessed on a case-by-case basis. For all other water bodies, they shall not exceed a ratio of 1 to 3 between downsurge and surge, and the water covering of the river bed shall, during downsurge, account for at least 80% of the river-bed surface covered in times of surge.

(4) Anthropogenic reductions of the mean flow velocity in the cross-section at a rate of below 0.3 meters per second at annual mean flow (MQ) occur only at very short stretches.

(5) Anthropogenic migration barriers occurring in the natural fish habitat must be passable for fish all year long. Human impact on habitat connection shall only be marginal.

(6) Bank dynamics are limited in some areas, only short stretches of stream banks are stabilized, such as, e.g., local protective measures, and only short stretches of the river bed are restricted in their dynamics due to measures to stabilize the stream bed, such as ground sills. In this context, open substrate and dynamics between the artificial structures are possible.

3.2. Temporal and spatial scales

Scale: national

3.3. Type of analysis or tool

- Eflow definition which proved to be highly correlated to the WFD BQEs and objectives. Eflow requirements (relevant parameters) as well as limit values (for HES) and guide values (for GES) were derived from hundreds of biological and thousands of hydrological monitoring data ensuring a good correlation between biology and hydrology.
- General procedure how eflow values are defined and by which parameters for HEs and GES: to ensure, in all probability, the preservation of the type-specific characteristic of a given water body, the achievement of the environmental objectives of WFD, to streamline and ensure cost efficiency of hydrological monitoring efforts
- Fixing it by a legal regulation via an Ordinance to ensure that the there is a consistent nationwide application.

3.4. Information and data requirements

The hydrological data (MJNQt, NQt, …) applicable for the individual river water bodies can be obtained from the Austrian Hydrological Atlas published annually or directly from the Hydrographical Departments at the Offices of the Provincial Governments. The values are to be used for the river stretch under examination which have been measured over the longest-possible period, ideally over a period of at least ten years.
The hydrological characteristic values refer to the natural situation in the running water body which is unaffected by human impact and not to a flow situation which may have already been altered due to human intervention. This is why the designations of $MJNQ_{t\ natural}$ and $NQ_{t\ natural}$ have been selected. Corresponding comments in the Hydrological Atlas on the impact of the respective measuring points by way of water inflow or abstraction or by way of storage operations shall be considered accordingly.
For water bodies with no hydrological data available, the hydrological data are established via model calculations, as for example by way of conclusion-by-analogy using a representative gauging station situated in the same water body or by way of regionalization models. The method of determining the characteristic values shall be demonstrated in a reproducible and plausible way. In the topical decree with regard to the application of the Ecological Objective Ordinance it is recommended to have the method which is applied in order to determine the hydrological characteristic values reviewed at the Hydrographical Departments at the respective Offices of the Provincial Governments.
Information/data on altered flow velocities (impounded rivers, reservoirs) and water levels (water depth) as well as artificial flow fluctuations (river stretches affected by flow fluctuations) is derived from the hydromorphological assessment. This very valuable assessment was performed in Austria 2002-2007 for all rivers > 10 km^2 (33.000 river km in total) and was only able to be done, because the assessment really concentrates on those information which is really relevant and not on parameters “nice to have” (hydromorphological assessment method see) http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2009/hintergrunddokumente/methodik/hydromorphologie.html
These hydromorphological assessment data are collected in the National data base and also used as basis for the impact and pressure analysis and risk assessment.

3.5. Testing of results

Targeted monitoring programme

3.6. Current application of the method/initiative

Nationwide application of limit values for HES and guide values for GES. Evaluation and amendment planned for 2014/15.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

To define eflow for HES and GES biological monitoring data are indispensable. It is necessary for all water body types to identify those biological quality elements which are most sensitive to hydrological pressures and to develop specific metric reacting on hydrological alterations for those BQEs. Fish proved to usually be the most sensitive BQE to hydrological pressures.

Those hydrological parameters should be selected for eflow definition which are the most relevant ones for a good type-specific aquatic ecosystem functioning as required by WFD. This also allows to limit the hydro/morphological monitoring efforts to those parameters which are really meaningful and significant.

In contrast to a case by case assessment a uniformed procedure/method for eflow definition

- allows a type-specific approach taking into account the natural hydro-morphological characteristics of the water body type which is relevant for the good ecological functioning of the type-specific aquatic communities
- allows general discussion and ensures a common understanding by all stakeholders, NGOs and interested public
- allows the calculation of financial and other impacts on the respective sectors (like energy, agriculture, ..) which is crucial for the political decisions when developing the program of measures
- ensures planning reliability for new projects

Only by legally fixing eflow limit values for HES and guide values for GES (for example via an Ordinance) a nationwide consistent implementation can be ensured.

4. Contact information

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-

5. References

- wisa.bmlfuw.gv.at (http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2009/hintergrunddokumente/rechtsdokumente/ow_ziele.html)
- http://wisa.bmlfuw.gv.at/fachinformation/gewaesserbewirtschaftungsplan/ngp-2009/hintergrunddokumente/methodik/hydromorphologie.html

Case study 4 (Slovenia): "Criteria for determination and on the mode of monitoring and reporting on ecologically acceptable flow"

1. Executive summary

This case study describes the legislation developed for the implementation of ecologically acceptable flows in Slovenia. The "Decree on the criteria for determination and on the mode of monitoring and reporting on ecologically acceptable flow" was prepared on the basis of Article 71 of the Water Act in Slovenia (2002). The Decree consists of six chapters including general provisions, criteria, the mode of monitoring, supervision, penal provisions and transitional provisions. The Decree prescribes the use of either one of two approaches for the determination of an Ecologically Acceptable Flow (EAF), i.e., the hydrological approach and the holistic approach. The hydrological approach is based on the reversibility, quantity, length and duration of water abstraction, the ecological type of watercourse, and the ratio between the mean flow and mean low flow. A lower value of EAF may be determined on the basis of an holistic approach at the request of the applicant for the water right. The holistic approach evaluates the hydromorphological, biological and chemical characteristics of the river reach where the water diversion/abstraction occurs. The final determination of the EAF should also include the protection arrangements. The Decree has various advantages, disadvantages and weaknesses, but the content of it represents one of the first experiences in the EU of the preparation and implementation of a legal regulation on ecological flows.

2. General information

Member State(s): Slovenia

1.1 Objective of the Case study

The main objectives of the case study are to present the content of the "Decree on the criteria for determination and on the mode of monitoring and reporting on ecologically acceptable flow", and to describe the criteria and methods that are used for EAF determination in Slovenia. It also presents the advantages, disadvantages and weaknesses of the methods used.

1.2 Policy and management context

There are three organisations involved with the implementation of EAF in Slovenia. The **Ministry of Agriculture and the Environment of the Republic of Slovenia** has responsibility for water protection, use and management and the implementation of relevant EU legislation, e.g. the Water Framework Directive and Habitat Directive. With respect to the use of water, it handles initiatives for obtaining rights to water use on the basis of concession. The **Slovenian Environment Agency** is a body of the Ministry of Agriculture and the Environment and amongst its many roles, it is responsible for water quantity and quality monitoring and managing water rights. The **Institute for Water of the Republic of Slovenia** is a public research and development institution that supports The Ministry of Agriculture and the Environment of the Republic of Slovenia and The Slovenian Environment Agency with the implementation of EAF.

Hydrological data, such as the values of mean low flow and mean flow at the abstraction site are necessary data for the evaluation of EAF. Hydrological elements are necessary to determine the content of the concession/water permit instrument for the use of surface water in compliance with the law governing waters. The values of mean low flow and mean flow at the abstraction site shall be obtained from the database of national hydrological monitoring maintained by the Slovenian Environment Agency. If no national hydrological monitoring data exist for the abstraction site, an assessment of the mean low flow and mean flow is required.

If the Slovenian Environment Agency have historical flow data available, the EAF is determined according to their data, but if there are no data (especially for small streams where there is no hydrological monitoring) the applicant for water rights are required to conduct hydrological studies to provide the necessary flow data. The water right holder shall describe the mode of monitoring

the EAF in the Rules of Procedure applying to the operation and maintenance of water facility in accordance to the Law governing waters.
The EAF in the cases of existing water rights with no EAF shall be determined on the basis of an expert proposal prepared by the Institute for Water of the Republic of Slovenia.
A financial penalty is applied in cases for misdemeanours on legal entities of the Decree.

2. Detailed information

2.1 Practical Tasks

Water Framework Directive was transferred into Slovenian Water Act in 2002.
The Slovenian Water Act article 71 states that "in the case of a water abstraction that causes a decrease of water flow or a decrease in water level, an EAF should be determined" and therefore the need to determine EAF in Slovenia is readily apparent. On the basis of this article, the Decree on Criteria for Determination and on the Mode of Monitoring and Reporting of Ecologically Acceptable Flow (Decree) was adopted in 2009. The Decree was prepared by the Ministry for Agriculture and Environment of the Republic of Slovenia supported by the Slovenian Environment Agency and Institute for Water of the Republic of Slovenia, and it was negotiated and agreed by other sectors affected by the Decree in Slovenia.
The Decree consists of six chapters including general provisions, criteria, the mode of monitoring, supervision, penal provisions and transitional provisions. The chapter on **General provisions** include four articles where the content, application, exceptions and the meaning of terms used in Decree are defined. The Decree is not in use for heavily modified water bodies. The main terms used in the determination of an EAF are: 'Mean low flow (MLF)' at the abstraction site, which is defined as the arithmetic average of the lowest annual values of mean daily flow at that site over an extended monitoring period, usually the last 30 years. The other important term is 'Mean flow (MF)' at the abstraction site which is defined as the arithmetic average of the mean annual flow values at that site over an extended monitoring period, usually the last 30 years. The main terms which are important for determination of the EAF are:

- 'Point water abstraction' is a reversible abstraction where the water withdrawn returns to the watercourse immediately below the abstraction point or the impoundment;
- 'Short-term water abstraction' is a reversible abstraction where the water withdrawn returns to the watercourse at a distance measured along the watercourse line in a digital data layer at 1:5000 scale level, which is:
    - less or equal to 100 m in the case of abstraction from a watercourse classified in the ecological type with a catchment area equal to or less than 100 km^2, or
    - less or equal to 500 m in the case of abstraction from a watercourse classified in the ecological type with a catchment area larger than 100 km^2;
- 'Long-term water abstraction' is a reversible abstraction where the water withdrawn returns to the watercourse at a distance longer than in the case of short-term abstraction;
- 'Small-scale water abstraction' is an abstraction where the quantity of withdrawn water is equal or less than the MF at the abstraction site;
- 'Large-scale water abstraction' is an abstraction where the quantity of withdrawn water is larger than the MF at the abstraction site.
- Seventy-four ecological river types were defined using bioregions or large rivers, and nine natural environmental descriptors were recognised in the literature as being important for river community composition in Slovenia (Urbanič, 2011). River types were then classed into four groups based on their ecological types, depending on the sensitivity of the river ecosystem to water abstraction.
- 'Dry season' is the period during the following calendar months: December, January, February, June, July, August and September for the groups of ecological types 2, 3 and 4 and June, July, August and September for the group of ecological type 1.
- 'Wet season' is the period during the year which is not defined as a dry season.«

The chapter **Criteria for determination of EAF** consists of six articles that include information on how to determine an EAF, what sort of hydrological data are needed, what is the content of the study for the determination of an EAF, determination of an EAF in relation to protection arrangements and exceptions to the determination of EAF. For the determination of an EAF, especially articles 7, 8 and 9 are the most important.

Article 7 defines the determination of EAF on the basis of hydrological elements with the use of the following formula:
EAF = f * MLF
The values of f are defined in relation to:
- Whether it is a reversible or irreversible water abstraction,
- the duration of the reversible water abstraction,
- the quantity of water withdrawn, defined with reference to the value of the mean flow at the abstraction site,
- the ecological group type of the watercourse, and
- the ratio between the MF and MLF.

The f value shall be multiplied by 1,6 in the case of water use at a watercourse defined as group of ecological types 1 and 2 if the ratio between the MF and MLF at the abstraction site exceeds 20. In Table 1 the f values are presented for reversible water abstractions.

Table 1. The f values for reversible water abstractions.

	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^3s^{-1}	> 2.500 km^2 or sQs > 50 m^3s^{-1}
Point water abstraction					
1	0,7	0,7	0,5	0,4	
2	0,7	0,5	0,4	0,4	
3	0,5	0,4	0,3		
4					0,3
Short water abstraction all year or long water abstraction during the dry period					
1	1,2	1,2	1,0	0,8	
2	1,2	1,0	0,8	0,8	
3	1,0	0,8	0,7		
4					0,7
Long water abstraction in wet period					
1	1,9	1,9	1,6	1,3	
2	1,9	1,6	1,3	1,3	
3	1,6	1,3	1,1		
4					1,1

According to article 8, the EAF may be determined on the basis of a study, submitted after the application, by the applicant for the water right. The minimum requirements for the preparation of the study include:
- Description of the intended abstraction
- Justification for a different determination of an EAF
- Characterisation of the watercourse
- Definition of the micro location(s) within the section under consideration
- Description of the status of surface water body and the chemical and ecological status at the abstraction site
- Description of the hydromorphological characteristics
- Review of the sources of pollution upstream
- Review of other water uses
- Expert opinion on the value of the EAF
- Data sources and literature used in the preparation of the expert opinion on the EAF.

This approach also includes measurements, sampling and analyses of biological, hydrological, morphological and physico-chemical parameters of the river and riparian ecosystem according to methodologies for evaluation of ecological status. All elements from Water Framework Directive and Habitat Directive are included in the holistic approach for determination of EAF. The values of the EAF need to ensure the fulfilment of the following conditions in the river ecosystem:

- River flows shall be provided that do not deteriorate but ensure good chemical and ecological potential of surface waters;
- River flows shall be provided that preserve the streambed and habitats;
- Minimum acceptable flows shall be provided that preserve the aquatic and riparian ecosystems;
- Optimum flows shall be provided that ensure mesohabitats for the target groups and target species of organisms, i.e. for biological elements which will be most affected by the encroachment under consideration;
- Natural seasonal flow dynamics shall be provided.

Determination of the EAF in relation to the protection arrangements is described in article 9. The value of the EAF, determined on the basis of Articles 7 and 8, may change due to the opinion on the impact of activities on the fish status and the conditions of use arising from nature protection policies and guidelines under the nature preservation regulations.

The chapter '**The mode of monitoring and reporting'** of an EAF includes three articles. These discuss the validity of the EAF and the mode of monitoring and reporting of the EAF. The EAF should be valid throughout the year, except in situations when the natural flow at the abstraction site is lower than the EAF, but at that time water right holder should not abstract water. The water rights holder shall describe the mode of monitoring of the EAF in the 'Operating Rules' applying to the operation and maintenance of the water facility. On request, the water rights holder shall send the data to the Ministry or the inspector responsible for waters or to the water protection supervisor.

The implementation of the Decree is outlined in the '**Supervision'** chapter, including the need for assessments carried out by the inspectors responsible for waters and water protection supervisors in accordance with the regulations governing water.

In the chapter '**Penal provisions'** in article 15 financial penalties are detailed, including a fine of between EUR 4,000 and EUR 125,000 imposed for misdemeanours against the legal requirements of the Decree.

The '**Transitional and final provisions'** chapter includes 7 articles, and deals with water rights for the determination of the EAF, water rights without an EAF, exceptions to the determination of EAF for water rights, adjustments in providing and monitoring the EAF, deciding on the submitted initiatives or applications for water rights and adjustment of factors for the calculation of the EAF.

2.2 Temporal and spatial scales

The Decree was prepared at the national scale.

2.3 Type of analysis or tool

The most innovative aspects in the Decree are two approaches which were developed for the evaluation of EAF in Slovenia and both are consistent with Water Framework Directive and Habitat Directive.

2.4 Information and data requirements

There were limited relevant Decrees from elsewhere to use as evidence at the time of implementation of this Decree. The starting point for preparing the Decree was the study by Vrhovšek et al. (1994) where a new policy for evaluating the provision of a quantity and quality of water to remain in the running water was established. The EAF was defined as the quantity and quality of water that is needed to preserve the structure and the function of the river and riparian zone ecosystem and sufficient quantity of water to enable the survival and reproduction of aquatic organisms in different hydraulic habitats. A lot of knowledge of river ecology and hydrology were needed to prepare the studies at the Institute for Water of the Republic of Slovenia which were the basic documents for preparing the Decree. Later more determination of EAF was accomplished for different rivers via case studies and these data were also used for definition of factor f values in the hydrological method. One of the other important documents for preparing Decree was a paper prepared by Smolar-Žvanut *et al.* (2008).

The aim of the Decree was to develop simple methods that are widely applicable on different river types. The main advantages of the hydrological method are that it is a simple, fast and cheap

method, it is generic and widely applicable, it is useful for different types of rivers, it partly considers the sensitivity of different river types and is based on hydrological data.
The main disadvantages of the hydrological method are: the EAF is evaluated for only two periods of the year (i.e., the dry and the wet period) and it does not take into account the dynamics of natural flows and flood flows because the differences in values of EAFs are very small; it does not include the timing, magnitude, duration and frequency of different flows; and the method focuses mostly on the low flow values. The main advantage of the EAF assessment according to the holistic approach is that it includes the whole river and riparian ecosystem, with the use of an interdisciplinary team of experts, it is case-by-case specific, and prescribes the minimum requirements for the content of study. The main disadvantage is that it is very expensive because an EAF assessment requires at least a half to one year to complete.

2.5 Testing of results

The results were not tested, but the methods will be updated with the results from a new project (started in July 2014 and finished in July 2016) that will examine the link between the hydrological method for evaluation of EAF with WFD objectives for ecological status.

2.6 Current application of the method/initiative

The Decree was used as a basis for the development of a Decree on EAF in Bosnia and Herzegovina.

2.7 Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

In Slovenia, we have no many cases for assessment of EAF for lakes, so this methodology is not developed yet. The Decree on the River Basin Management Plan for the Danube Basin and the Adriatic Sea Basin (2011) also includes some limits for water abstraction for irragation and the use of water from small streams.
The hydrological method is specific for Slovenia, because the f factor is dependent on the ecological group type of the watercourse, but the holistic approach could be used elsewhere around the world. There are also some limitations for the replicability of the holistic approach, because it is based on expert knowledge. Although both methods from the Decree discussed in this paper have several limitations, they represent the first important step to improve the river status.
The development of EAF methods is dynamic and adaptive, has evolved over the corresponding time period and will undoubtedly continue to do so as research provides a better understanding of the relationships between flow and riverine ecosystems (Smolar-Žvanut et al. 2012).
The Slovenian government have made significant progress in developing the Decree on EAF. EAF provisions should not remain at the level of policy, but it is needed to start with its implementation through monitoring.
More case studies should be evaluated and also the monitoring of the ecological status at the sites with EAF should be undertaken to support the values of EAF determined according to Decree.

3. Contact information

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Case study 5 (Eurelectric): "Water Framework Directive classification study – River Tummel (Scotland)"

1. Executive summary

The River Tummel, in Perthshire, Scotland, is subject to hydromorphological alteration due to hydropower generation facilities run by Scottish and Southern Energy (SSE). The River Tummel is designated as a series of Heavily Modified Water Bodies (HMWB) and so these are required to achieve Good Ecological Potential (GEP). Using new e-flow standards produced in the UK it would be classified as Poor or Bad Ecological Potential because it does not meet the hydrological criteria. Similar to many water bodies that host high head hydropower generation in Scotland, the Tummel HMWB has lacked biological data to validate the classification and so SSE commissioned a study to collect macroinvertebrate and fish data at sites on the River Tummel and at reference locations on the nearby River Tay.

At present there are no biological standards set for GEP as this is dependent on a range of site specific factors. The decision was taken, therefore, to base the study on an assessment of Ecological Status rather than Potential. Application of existing WFD biological classification techniques for Ecological Status, albeit with restricted temporal and spatial resolution, demonstrated that the River Tummel site would probably be of Good Ecological Status or higher if classified using biological evidence rather than hydrology. Macroinvertebrate LIFE scores suggested evidence of low flow impact on some of the River Tummel sites but also at one of the unregulated reference sites on the River Tay. The use of real data from local reference sites is appropriate to important site-specific investigations to overcome the shortcomings of standard classification tools that are based on modelled predictions of reference condition. This study has proved valuable in presenting the site-specific impact of hydropower operation, and related flow modification, on biota and may lead to a wider programme of data collection at hydropower sites throughout Scotland.

2. General information

Member State(s): Scotland, UK.

RBD(s): Scotland RBD (UK01)

Location: Perthshire, Scotland.

Time period: since September 2013.

2.1. Objective of the Case study

The overall aim of the project was to collect biological data from water bodies that do not have any existing data and to compare biological condition, using standard biotic indices and current WFD classification tools, to the assessment of hydrology environmental standards. To overcome the shortcomings of the current WFD classification tools that are based on modelled predictions of reference conditions, real data from local reference sites were collected. The short-term aim was to assess the ecological status of a water body that has been classified as a Heavily Modified Water Body (HMWB) and to consider the relationship between ecological status and ecological potential. In the longer term, this may lead to a wider programme of data collection at a larger number of water bodies affected by SSE's hydro power generation throughout Scotland.

2.2. Policy and management context

For several years SSE have promoted the case that biological evidence is needed to validate classification results that are based on hydrology and/or other hydro-morphological data. Anecdotally there has been a strong perception that some water bodies were being significantly misclassified when hydrology was used without such evidence. In order to test this perception this study was commissioned as a trial to determine whether the biological evidence supported the hydrology based classification or not. As this trial has been successful it is intended that more work will be carried out on the Tummel and at other hydropower sites in Scotland.

The flow information is all available at the sites investigated and the maintained compensation flows experienced at the Tummel sites represent significantly less than in the proposed UK e-flows guidance. The case study represented a trial to investigate the technical feasibility of collecting ecological data at sites such as those on the Tummel. SSE has plans to use the trial to determine the level of monitoring that will be planned in the future and is well aware of the limited worth of one off sampling - especially for parts of the ecology such as macro invertebrates. Discussions are underway to look at programmes for gathering invertebrate samples in the Spring and Autumn at selected sites and over a number of seasons. Relevant control sites will also be included in the future analysis.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Biological sampling of fish and macroinvertebrates was undertaken by APEM Ltd at four locations on the River Tummel HMWB and two locations on the River Tay, downstream of Loch Tay, which was identified as a suitable reference site for comparison. All field work was undertaken between 17 and 19 September 2013. Rising river levels toward the end of the survey week meant that it was not possible to undertake the full fish survey at the River Tay reference sites.

Due to the relatively wide nature of the river channel at the surveyed sites, triple shock electric-fishing was conducted within a fixed enclosure measuring 8m x 4m. All fish captured were identified to species, measured and weighed. In keeping with the methodology used in the Interim SEPA Fish Classification Tool, data from the first run only were used, with a scaling factor of two applied. Two further fish survey methods (banner netting, timed runs) were carried out in order to provide a comparison between the enclosure method and more widely used techniques.

A single macroinvertebrate sample was collected at each of the sampling locations using a standard three-minute kick sampling procedure with one-minute timed hand search, consistent with the Environment Agency’s approach for use with RICT, and adopted by UKTAG in 2008 as the UK standard. Invertebrate samples were identified in one of APEM’s laboratories using a ‘mixed taxon level’ (MTL: species level for most taxonomic groups) approach, which provides a greater resolution of data than currently required by WFD classification, thus ‘future-proofing’ it to allow re-analysis at a later date if required.

3.2. Temporal and spatial scales

The case study is based on data from one sampling occasion only, and therefore the resulting WFD classification should be viewed with caution. Continued data collection over several seasons, as the WFD ideally requires, will provide a valuable dataset for future interpretation and comparison. The study was designed as a pilot project and therefore focussed on a single hydropower site on the River Tummel.

3.3. Type of analysis or tool

Macroinvertebrate data were used to calculate NTAXA, ASPT (both water quality indicators) and LIFE (a flow indicator) scores. These were compared to expected scores, based on the predictor variables collected in the field or derived from external sources, and used to classify the sites. Site classification was undertaken using the River InVertebrate Prediction and Classification System (RIVPACS) IV model within RICT (the River Invertebrate Classification Tool).

Fish data were used to determine WFD status based on the Interim SEPA Fish Classification Tool. Sampling methods were assessed by comparison of salmonid densities using the three alternate methods. It must be noted that, in regard to the species included (non-salmonid), in Scotland, the post glacial native fish populations are very limited compared to large areas of Europe and even England and Wales in comparison. The protocols used to collect fish data followed the latest fish classification tools used and produced by SEPA.

3.4. Information and data requirements

No additional sources of data were required for this study.

3.5. Testing of results

The study employed well-established macroinvertebrate sampling methods. In contrast, the enclosure fish survey method is less established and was tested via the implementation of two additional fish survey methods. Results demonstrated that the enclosure caught a higher density of salmonid fish than the other two methods on most occasions. In future work, it is recommended that the enclosure method is employed in conjunction with a timed run, to allow comparative data to be collected from sites at which high flows make the enclosure technique inappropriate.

The study as a whole was conducted as a pilot and further data collection, at a larger number of water bodies affected by hydro power generation throughout Scotland, will contribute to the evaluation of this approach.

3.6. Current application of the method/initiative

SSE intend to develop this pilot project into a broader scale programme in the hope that the data can help inform the development of a biologically based classification scheme that is credible to all parties in government, regulators and industry.

This programme will begin by completing the multi-season sampling approach for the Tummel and then by applying these techniques to other HMWBs across Scotland. When the standard sampling and assessment methodologies are modified by UK regulators then these changes can be incorporated into the programme.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The method can be applied to any flowing waters for which a suitable control is available. Data from the control, chosen to be as similar as possible to the impacted site in all aspects other than flow regulation, will enable confounding factors such as water quality impacts to be removed.

While the results are still provisional, SSE believe that this offers formal evidence to support the need for biological evidence to be required during classification and when considering the programme of measures. At sites below two dams on the River Tummel where the long established flows are less than half those now being proposed by the new ‘default’ UK e-flow standards we can see that the biological evidence shows few, if any, signs of a significant impact on the river ecology.

4. Contact information

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Case study 6 (Italy): "Assessing the ecological effects of e-flows in Alpine streams: the role of hydro-morphological and habitat indicators to overcome the limitations of biological ones"

1. Executive summary

Mountainous streams in the Alps are increasingly being exploited by water diversions for hydropower production. In Valle d'Aosta Region (Italy), the resulting alteration of flow regimes is causing relevant environmental impacts on freshwaters, and recently the awareness on this issue has been raised by the Regional Water Management Agency (Rocco and Santelli, 2010). The Regional Water Protection Plan (RAVA, 2006) aimed at ensuring the right balance between satisfying water needs for human activities and protecting or restoring the ecological status of water bodies, requiring minimum ecological flows (e-flows) to be released from existing and new water abstractions. Moreover, in 2008 an experimental programme was approved to assess minimum e-flows to be released from 28 water diversions owned by the main regional hydropower company, the Compagnia Valdostana delle Acque (CVA). As part of this programme, the Savara stream is used here as an example of assessment to support appropriate e-flow definition in Alpine streams. Specifically, incremental e-flow releases were implemented between 2009 and 2013, and annual e-flow schemes were compared to assess resulting ecological improvements. A pool of indices was applied at an annual scale, monitoring physico-chemical, biological and hydro-morphological quality elements, as well as habitat features of the stream. The results suggested, coherently with previous experiences, that in Alpine contexts physico-chemical water quality and biological indices, presently adopted for the classification of the ecological status of water bodies, are not appropriate to reflect the effects of hydrological alteration, and thus to develop suitable mitigation measures; to the contrary, approaches based on the analysis of hydro-morphological alteration and of habitat availability appear more suitable to compare the effects of different e-flow releases.

2. General information

Member State(s): Italy
RBD(s): ITB - Po Basin
Location: Valle d'Aosta Region
Time period (start/end): 2008-2013

2.1. Objective of the Case study

The case study evaluates the ecological benefits of e-flow implementation in the Savara stream, an Alpine watercourse of Valle d'Aosta (Italy). Incremental e-flow releases were conducted between 2009 and 2013 as a mitigation action of water diversion, and the ecological benefits provided to the aquatic community were assessed using a pool of indices.

2.2. Policy and management context

For the Valle d'Aosta rivers, the regional Water Protection Plan (RAVA, 2006) required minimum e-flows to be released from existing and new water abstractions. In 2008, an experimental programme was approved by the Regional Government to assess and evaluate the effectiveness of minimum e-flows released from 28 water diversions owned by CVA. As part of this programme, the Savara stream is used here as an example of e-flow implementation in Valle d'Aosta.

3. Detailed information

3.1. Practical Tasks

The regional Water Protection Plan (RAVA, 2006) requires the assessment and monitoring of water body ecological conditions by means of three indices, namely, Level of Pollution from Macro-descriptors (LIM), Extend Biotic Index (IBE) and the Fluvial Functional Index (IFF). More recently, the WFD has been transposed into the Italian law by the Legislative Decree N.152/2006 and the Ministerial Decree 260/2010, which define the technical standards for water body monitoring and for the classification of ecological status. Thus in Valle d'Aosta, streams have to be monitored through the application of a pool of indices, analysing the physico-chemical, biological and hydro-morphological characteristics of the watercourse. In addition to the abovementioned analyses, two habitat indices, namely the Index of Habitat Quantity (IHQ) and the Index of Habitat Stress Days (IHSD) were applied to assess the spatio-temporal habitat availability, in relation to the fish community (it has to be noted that similar approaches can be applied in relation to other communities). IHQ describes the relative amount of habitat loss due to flow diversion, and IHSD measures the increase of continuous duration of events when habitat bottlenecks create stress to the fauna (details in, Vezza et al., 2014). The two habitat indices (IHQ and IHSD) and an aggregate index of hydrological alteration (IIHA, Goltara et al., 2011), based upon the approach of the Indicators of Hydrological Alteration (IHA, Richter et al., 1997) and similar to the IARI methodology (ISPRA, 2011), were applied in the framework of the research project “Innovative methodologies for protection and environmental management of aquatic ecosystems in Alpine streams and lakes” (RAVA-DGR1339/2011). Existing monitoring data from (i) the experimental program of CVA, (ii) the regional Environmental Protection Agency (ARPA), and (iii) the stream gauge monitoring network were used in the analysis. This comprehensive study was carried out by the Politecnico di Torino (Department of Environment, Land and Infrastructure Engineering) in cooperation with the Italian Center for River Restoration (CIRF).

Table 1. List of indices used to monitor the Savara stream between 2008 and 2013

Index	Acronym	Reference	Ecological parameter
Level of Pollution from Macro-descriptors	LIM	D.L.152/99	Water physico-chemical quality
Extended Biotic Index	IBE	Ghetti (1997)	Benthic invertebrates
Fluvial Functional Index	IFF	Siligardi et al. (2007)	Hydro-morphological and biological characteristics
LIM to assess ecological status	LIMeco	D.M.260/2010	Water physico-chemical quality
Standardisation of river classifications, Intercalibration Common Metrix Index	STAR_ICMi	Buffagni and Erba (2007)	Benthic invertebrates
Intercalibration Common Metrix Index	ICMi	Mancini and Sollazzo (2009)	Diatoms
Macrophyte Biological Index for Rivers	IBMR	Haury et al. (2006)	Macrophytes
Ecological Status of Fish Communities Index	ISECI	Zerunian et al. (2009)	Fish
Morphological Quality Index	IQM	Rinaldi et al. (2013)	Geomorphology
Aggregate Index of Hydrological Alteration	IIHA	Goltara et al. (2011) Richter et al. (1997)	Hydrology
Index of Habitat Quantity	IHQ	Vezza et al. (2014)	Habitat
Index of Habitat Stress Days	IHSD	Vezza et al. (2014)	Habitat

3.2. Temporal and spatial scales

Both temporal and spatial scales were addressed to monitor the effects of e-flow implementation in the Savara stream. Between 2008 and 2013, possible variations of a wide range of ecological characteristics were recorded. Moreover, the mesohabitat scale, used to calculate habitat indices (Vezza et al., 2014), allowed the stream to be surveyed for a long stretch (600 m) to address larger spatial scales and to better observe habitat dynamics with flow.

3.3. Type of analysis or tool

Beside the common indices requested by the regional and national law under the WFD implementation scenario, analysing habitat availability demonstrated to be an innovative, efficient and flexible tool. Indeed, habitat indices can capture spatio-temporal alterations of habitat structure, and can link directly hydro-morphological alterations to the biotic components of aquatic ecosystems.

3.4. Information and data requirements

As part of an experimental program for e-flow implementation the ecological characteristics of the stream have been evaluated using existing monitoring data (water quality), biological communities (benthic invertebrates, macrophytes, diatoms and fish), hydro-morphological indicators (daily streamflow and morphological features) and by means of habitat indices derived from a meso-scale habitat simulation model (MESOHABSIM).

3.5. Testing of results

Analysing the response of different indices to e-flow releases (Table 2) led to important insights that could help setting future monitoring program in Alpine streams. Indices directly related to water quality (e.g., LIMeco), or whose metrics are related to a given biotic community as a bio-indicator of trophic conditions (IBE, ICMi, IBMR), showed a lack of response to evaluate e-flow implementation. This result is not surprising since the hydrological alteration has a negligible impact on water quality in the analysed stretch. A similar lack of response is shown by the benthic invertebrate index (STAR_ICMi), probably due to the lack of capacity to describe extensive components (e.g., the reduction of wetted area due to water diversion). The fish community index (ISECI) is affected by fish stocking and introduction of allochthonous species (*Salmo trutta*) and has a limited applicability in the Alpine area. Hence in overall, physico-chemical and biological indices, used for WFD classification, are not suitable for ecologically evaluating or comparing different e-flow releases in Alpine streams. IHQ and IHSD show a much clearer response to e-flow releases, even in the case of a limited reduction of hydrological alteration reported by IIHA.

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR-ICMi	ICMi	IBMR	ISECI	IQM	IIHA	IHQ	IHSD
2008	0	I (520)	II (8.6)	II (226)	-	-	-	-	-	-	0.59	0.18	0.05
2009	130 l/s	I (560)	II (9.0)	II (226)	-	-	-	-	-	-	0.73	0.55	0.31
2010	130 l/s	I (520)	II (8.8)	II (226)	I (0.95)	I (1+)	I (0.95)	I (0.87)	V (0.2)	-	0.72	0.51	0.24
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
2012	325 l/s	I (520)	II (9.0)	II (226)	I (0.98)	II (0.83)	I (0.89)	I (0.89)	V (0.2)	-	0.75	0.75	0.35
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

3.6. Current application of the method/initiative

A specific technical coordination group, composed by ARPA, RAVA and CVA is currently evaluating the experimental programme results. Further application of habitat indices is ongoing to test (i) index responses to different kind of pressures, (ii) index thresholds to determine ecological status, and (iii) index response in relation to different bio-indicators of the aquatic ecosystem.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The presented analysis can be extended to the whole Alpine area, in order to compare results. Our experience suggests that the ecological monitoring of Alpine streams needs consistent and representative indicators, which can be related to hydro-morphological alterations. Small hydropower is increasingly developed in Alps and the availability of effective tools can be of paramount importance for e-flow assessment and evaluation.

4. Contact information

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Case study 7 (Scottish Natural Heritage): "Defining e-flows for supporting viable populations of the species of Community interest *Margaritifera margaritifera*"

1. Executive summary

Freshwater pearl mussel (Margaritifera margaritifera L.) is endangered throughout its holarctic range, largely through human impacts such as pollution, river engineering and pearl fishing. As a result relatively few populations are sustainable and contain the range of ages needed to ensure viability. The best examples in EU countries are now protected as Special Areas of Conservation under the EC Habitats Directive, with the overall aim of achieving 'favourable conservation status' for this species. Pearl mussels have demanding environmental requirements, including the presence of salmonid hosts for the larval stage, low nutrient concentrations and relatively stable, well-sorted substrates. Flow regimes are also known to be critically important, directly and indirectly, yet there is little information on what constitutes 'ecological flows' for pearl mussels. Some information suggests that optimum flows for pearl mussels are in the range of 0.25-0.75 m s-1 and new research indicates that at low flows optimum habitat and pearl mussel densities occur at average near-bed velocities of 0.27-0.31 m s-1. Further research is urgently needed so that river basin management plans can define ecological flows for M. margaritifera that will allow the maintenance of recruiting populations.

2. General information

Member State: UK

RBD: Several

Location:

Time period:

2.1. Objective of the Case study

This case study describes the importance of defining environmental conditions consistent with the aim of maintaining viable populations of freshwater pearl mussel, *Margaritifera margaritifera* L. In particular, the case study presents some criteria for defining a flow regime consistent with the conservation of the species based on its life cycle and physical habitat requirements.

2.2. Policy and management context

Margaritifera margaritifera is protected under the Habitats Directive (Appendix II and Appendix V) and the Bern Convention (Appendix III). Measures taken pursuant to the Habitats Directive shall be designed to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest. Data provided by each country's national nature conservation agencies suggest that the main reasons for the decline in *M. margaritifera* are human impacts on aquatic systems. Changes to water bodies through river engineering, development of abstraction schemes, flow regulation, hydro-electric generation and fishery improvements, as well as inappropriate catchment management, have been widely cited as unfavourable for freshwater mussels Moorkens, 2010). According to the EU Biodiversity Strategy to 2020 Member States and the European Commission will further integrate species and habitat protection and management requirements into the EC Water Framework Directive (WFD). Ensuring ecological flows for maintaining ecological and geomorphological processes may be essential for species survival, both within and beyond the Natura 2000 Network.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Understanding the life cycle

The unusual life-cycle makes the freshwater pearl mussel particularly vulnerable to adverse conditions (Figure 1). Margaritifera margaritifera is one of the longest-lived invertebrates known: individuals can survive for over 100 years in central and western Europe (Bauer 1992) but life spans can be much shorter at the southern extreme of its range and much longer at the northern extreme.

Pearl mussel rivers are typically poor in calcium, mildly acidic, low in nutrients and suspended solids, well-oxygenated, with low levels of conductivity and with temperatures not exceeding 20o C. Low oxygen levels, eutrophication, high sediment loads and heavy metals are all known to be damaging to freshwater pearl mussels. However, although M. margaritifera is highly demanding in terms of river substrate and water quality, it occurs in a wide range of catchments from small, siliceous, oligotrophic rivers, often with a lake upstream, to large lowland mineral systems (Skinner et al., 2003).

Pearl mussels live buried or partly buried in coarse sand and fine gravel, inhaling water through their exposed siphons to filter out minute organic particles on which they feed.

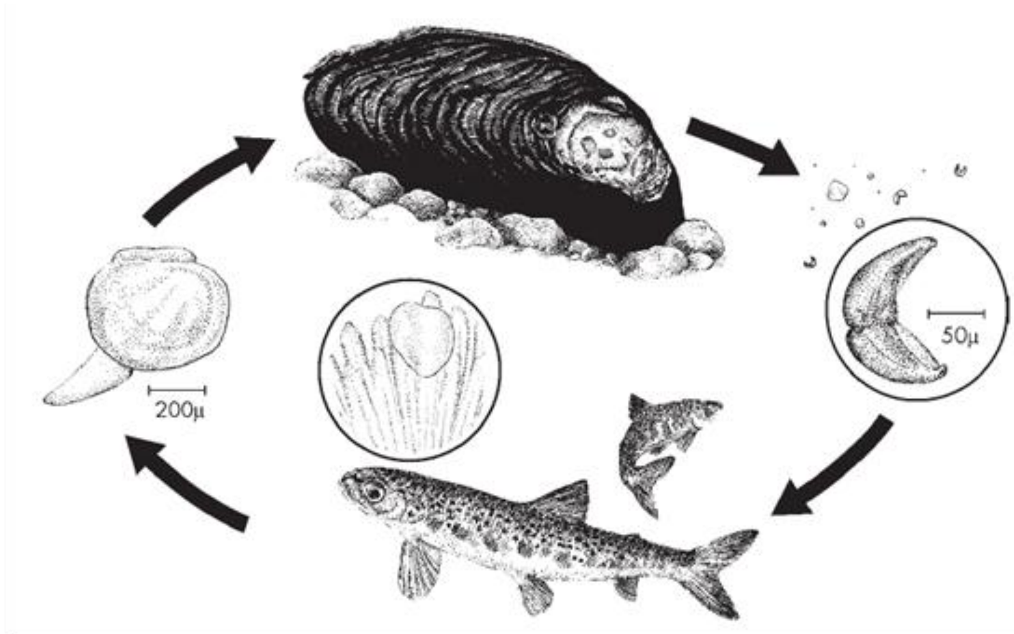

Figure 1: Mussel larvae, known as glochidia, are released in summer and attach themselves to the gill filaments of a juvenile salmonid. Here they encyst and grow until the following spring, when they drop off on to clean gravel and begin maturing. This association does not seem to harm the host fish, and facilitates mussel dispersal.

In early summer (June to July), the males shed sperm into the water, which is inhaled by the females. The fertilised eggs develop in a pouch on the gills for several weeks, and are released from July to September as tiny larvae known as glochidia. Each female ejects 1-4 million glochidia in a sudden, highly synchronised event, usually over 1-2 days (Hastie, 2001), probably induced by a threshold temperature, or other environmental cue. Almost all the glochidia are swept away and die, but a few are inhaled by juvenile Atlantic salmon and brown or sea trout. Infective glochidia can remain viable for up to six days (Ziuganov *et al*., 1994), but most attachments probably occur within a few hours (Young & Williams 1984). Glochidia attached to the gills of juvenile fish encyst, live and grow until they drop off the following spring.

Although pearl mussels are generally sedentary they can re-bury themselves if dislodged, and can also move slowly across sandy sediments. Most have about a third of their shells exposed, but some adults and virtually all juveniles burrow completely into the substrate and under loose stones (Hastie *et al*., 2000).

The importance of flow regime to favourable conservation status

In 2007 the conservation status of *M. margaritfera* was ‘unfavourable bad’, based on the Member States’ national reports submitted to the European Commission under Article 17 of the Habitats Directive for the period 2001-2006 (Figure 2).

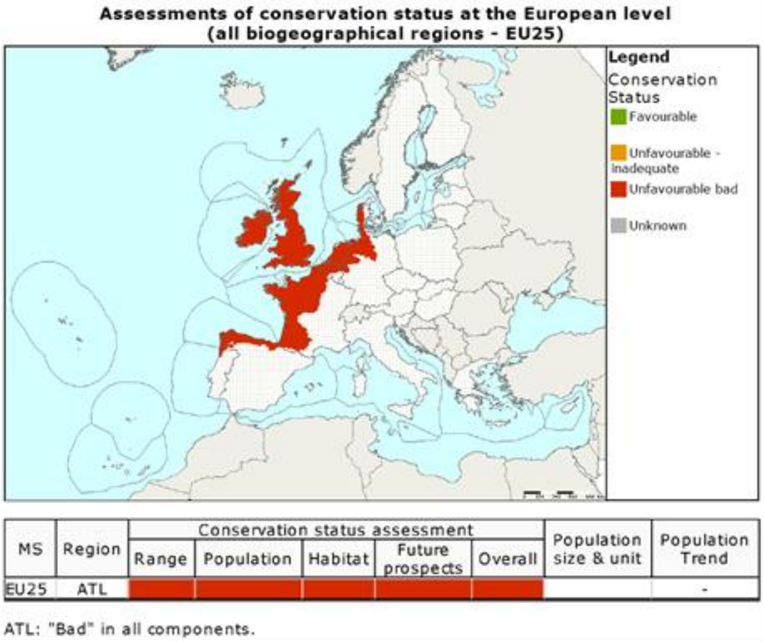

Figure 2: Conservation status of *M. margaritifera* based on an assessment by each Member State

According to Article 1 (i) of the Habitats Directive the conservation status of a species may be taken as favourable when i) ’population dynamics data indicate that the species is maintaining itself on a long-term basis as a viable component of its natural habitats’; ii) ‘the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future’; iii) there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis’.

Table 1 sets out the relationship between favourable conservation status (FCS), the biological concepts of population viability, and the specific role of the flow regime in providing all the elements *M. margaritifera* needs to survive (e.g. food quality and quantity, local distribution of fish hosts during the season of glochidial release, well-oxygenated sediments for juvenile survival and growth, and refuge from predators).

Table 1: The relationship between favourable conservation status (FCS), population viability and flow regime

FCS ASPECT	POPULATION VIABILITY	FLOW REGIME
Stable or increasing population size	All components of a population should have stable or positive trends, and not just the population as a whole. Age structures in a viable population should reflect both active recruitment and longevity. Initial juvenile survival is a critical issue. Food, physicochemical conditions in the hyporheic zone and substrate stability are important factors for juvenile survival.	Assessment of the effects of a hydrological regime requires consideration of all life stages, and, where required, targeting the analysis to crucial time periods (e.g. glochidia release and juvenile settlement).

	Potential fitness of individuals (e.g. growth, fecundity, mortality, movement) should be maintained. Fish host accessibility is essential.	The long-term survival of freshwater pearl mussel populations requires suitable conditions for fish hosts during the season of glochidial release (Bauer *et al*., 1991). Various estimates exist of necessary numbers of juvenile salmonids eg: Bauer *et al*. (1991) - 10-20 juvenile fish/100m^2; Ziuganov *et al*. (1994) - 10/100m^2; Geist *et al*. (2006) - ~30/100m2; Degerman *et al*. (2013) - <10/100m^2
	Food may be a limiting factor, as condition declines at high population densities. Mussel feeding is a complicated, dynamic process that may vary across habitats, species, and life stages and have important consequences for mussel populations. Unionoids appear to eat more than just plankton. Bacteria and dissolved organic matter may also be important food items.	Adequate flow to Provide a source of suspended food for filtering.
	Population should be sufficiently large to accommodate natural fluctuations and allow a healthy population structure.	Slight reduction in population size may be acceptable if it is a result of response to natural changes in habitat quality that are not caused by direct human action
The quality and continuity of habitat should be sufficient to allow mussels to survive and reproduce, and have a stable or increasing trend	Mussel beds should not be affected by limiting hydraulic conditions caused by direct human action. Maintain well-oxygenated sediments, free from siltation, for juvenile survival and growth, and refuge from predators.	In general, unionoid mussels occur in areas with moderate flow and naturally variable hydrological variation. The flow regime in mussel localities should be restricted to a range of variation that can be shown not to affect pearl mussels adversely. The presence of viable mussel populations downstream of reservoirs suggests that mussel fauna may be relatively resilient and adaptable, but limited by certain hydrological conditions.
		Low flows usually provide suitable areas for most individuals, but when flows drop to very low levels, mussels may be stranded and die, or be susceptible to illegal pearl fishing. Low flow in summer can allow the formation of algal mats and reduce interstitial–water column mixing. The exposure of shallow riffle areas and the aggregation of silt are indicators of poor conditions for both adult and juvenile mussels. Water flow in summer should therefore be sufficiently high to prevent low oxygen levels or heat stress, and to reduce the sedimentation of fine particles, especially in areas inhabited by juveniles.

		Measures of habitat stability, particularly shear stress at high flow, are strongly correlated with mussel occurrence from small to large rivers. Stable areas represent refugia from scour during floods and flow characteristics are important in determining habitats in which juveniles can settle. High water velocities can displace settling juveniles before they can burrow or attach to the substrate. Moderate flood-flows may have a positive effect in cleaning silt from gravel beds and riffles. Autumn flows can wash out algal mats and sediments accumulated over the summer, but severe floods can remove large numbers of mussels from their beds and are potentially disastrous for populations where recruitment is not taking place. In a study by Hastie *et al*. (2001) an estimated 1:100-year return period flood killed 4–8% of the pearl mussel population due to significant channel reformation and large-scale movements of substrates.
Connectivity within and between populations is maintained or enhanced	Consideration of connectivity and migration issues.	Consideration should be given to the dispersal and migration of fish hosts as well as the connectivity between suitable areas of mussel habitat.
		Encourage fish host accessibility especially during the season of glochidial release

3.2. Temporal and spatial scales

Hastie *et al*. (2000) described the small-scale habitat requirements (< 10 m), of *M. margaritifera* but noted that larger-scale habitat descriptors are also needed, because features of large river reaches or even catchments may be important determinants of mussel communities.

Freshwater pearl mussels are not mobile, and traditional simple hydraulic measures of depth and velocity change over a mussel bed with variation in discharge. A more complete assessment of the effects of a hydrological regime requires consideration of all life stages, and where required, targeting the analysis to crucial time periods. Historical time-series of flows taken from gauging station data can be combined with habitat model output to predict the temporal patterns of habitat that would have occurred during the period of record.

3.3. Type of analysis or tool

The conceptual analysis described here shows how different aspects of the flow regime (low flows, high flows, timing, etc.) influence the viability of M. margaritifera populations. Although this approach is more conceptual than quantitative it recognizes the inextricable link between FCS, key biological aspects of population viability and the flow regime.

Quantification of the potential habitat available for endangered freshwater mussels is a challenging task, as their habitat use and life cycles are very complex. Nevertheless, physical habitat modelling approaches can indicate limiting hydraulic conditions for species and provide a functional representation of habitat availability under different flows (e.g. mapping shear stress over time, or substrate stability). Linear regression models also can be used for modelling biological responses at the individual level (e.g. growth, fecundity, mortality). Multiplex modelling techniques can serve as a basis for a habitat management decision-making framework that will protect M. margaritifera.

3.4. Information and data requirements

It is well established that the distribution of unionoids is related to hydraulic conditions. It is therefore logical that they may be affected by flow modifications. Historical flow data often provide a good opportunity to estimate reference conditions. Time-series analysis allows characterization of typical and extreme hydrological conditions, and where linked with physical habitat analysis would help in understanding the presence and abundance of mussels.

Hydraulic models can be developed to simulate the effects of different flow characteristics (e.g. depth, current velocity or the occurrence of scour and deposition) on mussel populations using field data collected in streams for model validation.

3.5. Testing of results

Various studies in European rivers have reviewed the influence of habitat variables on freshwater pearl mussel distribution and abundance (e.g. Hastie *et al*., 2000; Geist and Auerswald, 2007; Österling *et al*., 2010; Degerman *et al*., 2013). As a result, the habitat requirements of *M. margaritifera* have received much attention and have formed the basis for guidance under development for CEN. However, further work is required, especially on the links between flow regimes and the sustainability of pearl mussel populations.

3.6. Current application of the method/initiative

Practical conservation measures for M. margaritifera are continuing throughout its present European range. These include legal protection, population estimates, habitat restoration, genetic studies, captive breeding, and reintroductions by adult translocation or by infecting host fish with glochidia. However, although many studies have demonstrated that hydraulic variables successfully predict mussel presence and abundance, designing ecological flows using these variables has been considered but not yet applied. However, recent studies on near-bed flow velocities (Moorkens and Killeen, in review) and new techniques for flow measurement (Quinlan et al., in press) may help to bring this a step closer.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The achievement of favourable conservation status for freshwater pearl mussel needs to consider population attributes, fish hosts, water quality and habitat characteristics. Flow regimes are a vital element in all of these..

Conceptual analysis provides a systematic framework for integrating information; this is particularly important in studies on M. margaritifera because of the complex life-cycle and the extensive amount of information that needs to be considered.

Changes in flow regimes can have significant implications for the viability of populations of M. margaritifera. Defining ecological flows for this species requires an understanding of how flow affects pearl mussels across the full range of low, medium and high flows.

NOTE: In the absence of detailed data on the links between pearl mussels and flow regimes, the following text (in draft) has been prepared for use in a European standard intended for publication by the European Committee for Standardization (CEN). This guidance recognises that depth, discharge and flow velocity are all important attributes to assess.

Draft text: Extract from the sections on 'Flow' in 'Guidance standard on monitoring freshwater pearl mussel (Margaritifera margaritifera) populations and their environment'

The information required varies greatly between rivers. Before carrying out work on river flow, users should determine what information is already available, and consult a hydrologist who can recommend the most appropriate methods for providing additional information needed in each river.

Depth and velocity data should be linked with the discharge in the river to which they apply. As river discharge is constantly changing due to precipitation it is essential also to relate this discharge rate to the flow ‘state’ using a flow duration curve.

The following are suggested options; the level of detail should be related to risk:

Measurements of discharge (m3 s-1) should be made at the same time as depth and velocity (including velocity near the bed of the river). If possible, a flow exceedance value should be derived from a flow duration curve.

Data on velocities and depths should be collected from a minimum of five cross-sections with the number appropriate to the river length and location of tributaries. The results should be expressed as median, maximum and mean values for each cross-section at a specific flow. The mean and median values for all the cross-sections should also be given. Data should be collected at a minimum of three different discharges. This relatively simple approach should not cover too wide a range of flows or extrapolation would not be appropriate.

Where a development proposal (e.g. a new abstraction) is likely to have a significant effect on flow, an appropriate hydraulic model should be produced to assess the potential effects on the mussel population. The outputs of the model should be related to mussel habitat.

Data should be presented as flow per metre bankfull width as a standard for all mussel populations that do not have continuous level or discharge recorders. Flow per metre bankfull width requires estimated discharge data and a number of river width measurements and may sometimes be undertaken without entering the river. A range of mussel habitats can also be compared using this simple standardized approach. The width is based on bank-top features that indicate the level of the bankfull flow, and a mean of 10 measurements at any one site should be taken. The flow of the river or the volume of water is then divided by the number of metres in the bankfull width (m3 s-1 m-1) to provide a hydraulic indicator of the quality of the flow characteristics over the mussels. Although this technique has some limitations it provides within- and between-river comparisons for all sizes of river simply and inexpensively where more sophisticated monitoring is missing.

Discharge or level measurements should be made continuously using non-intrusive methods.

4. Contact information

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Case study 8 (Italy): "Defining e-flows for the conservation of the endangered crayfish (*Austropotamobius pallipes*) complex"

1. Executive summary

Austropotamobius pallipes complex (also known with its common name of white-clawed crayfish) is currently classified as an endangered species and it is included in Annexes II and V of the Habitat Directive (92/43/EEC). Italian local populations have significantly decreased over the last decades, and are currently located in streams with high ecological status (defined by indicators used for WFD classification). The project LIFE+ "Conservation and recovery of *Austropotamobius pallipes* in Italian Natura 2000 sites" (CRAINat, EU LIFE08 NAT/IT/000352) implemented specific actions for the protection and conservation of *A. pallipes* in Lombardia and Abruzzo Regions, Chieti and Isernia Provinces, Gran Sasso e Monti della Laga National Park. In particular, actions C.22 and C.23 aimed at assessing the environmental flow requirements for *A. pallipes* to protect existing local populations. In this case study, the Droanello brook (Lombardia region) is used as an example of e-flow assessment. A meso-scale habitat simulation model (MesoHABSIM, Parasiewicz, 2007) was used for e-flows assessment, since the approach adapts well to high gradient streams, can describe complex morphology and involves a large range of habitat descriptors (Vezza et al., 2014b). Detailed schemes of flow management for individual water diversions were defined to represent habitat changes over time and to identify stress conditions for *A. pallipes* created by persistent limitation in habitat availability. Establishing flow recommendations for small streams that may not have available ecological and flow data is important, and the presented methodology provides a tool where few are currently available. As such, it can be used for development of regional or national rules for the conservation of the endangered *A. pallipes* complex, as well as for defining more site specific flow management criteria.

2. General information

Member State: IT

RBD: ITB - Po Basin

Location: Lombardia Region

Time period: since 2010

2.1. Objective of the Case study

The case study presents a possible methodology to assess habitat and e-flow requirements for *A. pallipes* complex. In particular, biological and hydro-morphological data from unimpacted streams in Italian Natura 2000 sites (Lombardia and Abruzzo regions) were analyzed to build mesohabitat suitability models, to quantify habitat alteration and to define e-flow schemes.

2.2. Policy and management context

The general objective of the LIFE+ CRAINat project is to preserve and support local populations of *A. pallipes*, through the production of juveniles in breeding centres to increase the genetic variability, the conservation and restoration of suitable habitat and the definition of e-flows. For the latter, the definition of common methodologies between northern and central Italy will provide guidelines for the protection of *A. pallipes* that can be transferred to other Italian or Mediterranean regions.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

According to Vezza et al. (2014b), stream surveys was carried out to describe mesohabitats characteristics. Mesohabitats, which commonly correspond to hydro-morphological units (HMU, e.g., pools, riffles, rapids), reflect the interplay between hydraulics and river morphology and can be inferred by visual observation of surface flow characteristics and verified by water depth, flow velocity and substrate types. The HMU polygons were delineated in a GIS environment and both mesohabitat-scale features (HMU type, cover sources, gradient) and random samples of water depth, flow velocity and substrate composition were recorded. To build mesohabitat suitability models, crayfish were collected by hand during night and by quantitatively sampling each previously mapped HMU. After measurements, crayfish were released in the same sampled HMU and classified in adult and juvenile life stages by estimating age composition according to Ghia et al. (2014). The obtained habitat models were then applied to selected streams to classify each mesohabitat into suitability categories, and to develop habitat-flow rating curves (Fig. 1). Finally, habitat time series analysis, derived from not altered streamflow time series, was used to define Habitat Stressor Thresholds (HST) and to develop detailed e-flow schemes (Fig. 2). Specifically, the analysis was carried out to identify stress conditions for *A. pallipes* created by persistent limitation in habitat availability , (Parasiewicz et al., 2013). The analysis was carried out by Politecnico di Torino, in collaboration with Università degli Studi di Pavia and FLUME s.r.l. (Aosta, Italy).

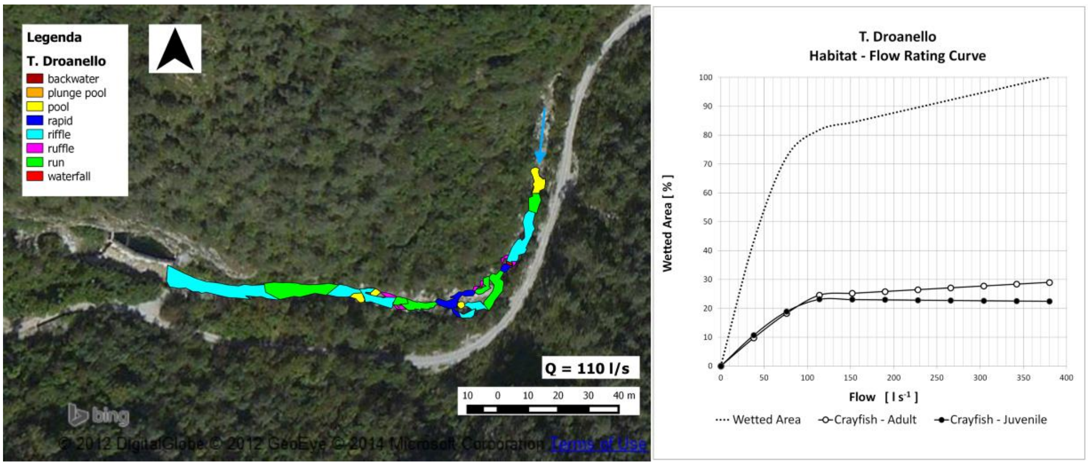

Figure 1. The case study of Droanello brook. MesoHABSIM model application to build habitat-flow rating curves for *A. pallipes* (adult and juvenile life stages). Details on field data collection and model application are reported in Vezza et al. (2014b).

3.2. Temporal and spatial scales

In addition to rating curves, the definition of the reference habitat time series is an important, final element needed for the full determination of e-flows. The MesoHABSIM model emphasizes the temporal scale by statistically analysing habitat time series to establish habitat stressor thresholds (HST, Fig. 2). This analysis is based on the assumption that habitat is a limiting factor, and events occurring rarely in nature create stress to aquatic fauna and shape the community. Identification of HST considers not only the magnitude of an impact (i.e., the amount of diverted water), but also provide a means of quantitatively measuring duration and frequency of stress events. This helps to identify the longest period that a habitat event is allowed to continue before reaching catastrophic conditions (see Parasiewicz et al., 2013 for details).

The results of HST analysis are then used to develop habitat augmentation strategies, i.e., short-term flow increases, aimed at reducing continuous duration of habitat events which are stressful for the fauna. In general, we recommend that e-flows shall follow the natural reference pattern and fall within the identified criteria. Such approach maintains some portion of natural system dynamics and offers flexibility in implementation. Once the allowable duration of released flow is exceeded, the strategy calls for release of water for at least two consecutive days that will increase the amount of habitat and stop the continuous duration. This strategy can be summarized in operational rules and used for individual hydropower facilities (Fig. 2).

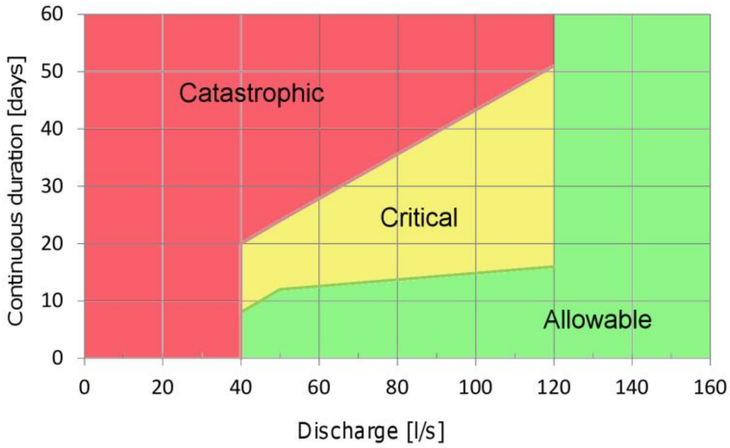

Figure 2. E-flow scheme for the Droanello brook. A possible e-flow option would be to allow hydropower generation with environmental flow release in the bypass section of 50 l/s with two-day interruptions every three weeks (catastrophic duration, red area in the graph). Once the inflow drops below this discharge value, the operation would cease until there is an increase to 120 l/s for two consecutive days. This conservative scenario, which aims to avoid subsistence flow, is one of the available options.

In the presented work, the spatial scale was also addressed. Mesohabitat suitability models were build using data from seven morphologically different streams, located in a large territory (northern and central Italy). Specifically, biological and hydro-morphological information were collected in the field from unimpacted streams and used to calibrate and validate predictive habitat models for the conservation endangered crayfish *A. pallipes* complex.

3.3. Type of analysis or tool

Information on *A. pallipes* ecological requirements is needed to quantify habitat loss, to simulate restoration scenarios and to implement effective e-flow strategies (Vezza et al., 2014a). Until now, meso-scale habitat models have been built to identify the habitat and e-flow requirement for fish and no applications are currently available for crayfish. Moreover, habitat time series analysis showed its usefulness to describe how physical habitat changes through time and to identify stress conditions created by persistent limitation in habitat availability.

3.4. Information and data requirements

We analyse mesohabitat use of *A. pallipes* in reference streams and brooks located in the Italian pre-Alps (Lombardia region) and in the mountainous areas of the Gran Sasso e Monti della Laga National Park (Abruzzo region). Field data collected in seven morphologically different streams were used to calibrate and validate habitat models for the endangered crayfish A. pallipes complex. To collect streamflow data for hydrological analyses, flow was continuously monitored by HOBO© pressure transducers.

3.5. Testing of results

Habitat models, which performed well in both calibration and validation phases (Vezza et al., 2014a), demonstrated to be transferable among different streams with different morphologies, and are regarded as valuable predictive tools. Results indicated that fine substrate (as proportion of gravel and sand), shallow water depth and cover (as presence of boulders, woody debris and undercut banks) revealed to be important for the occurrence of *A. pallipes*. The flow management schemes, to be developed to support *A. pallipes* populations, may be strongly dependent on the type of hydropower facility, inflow, and size of the stream. Figure 2 reports a simulation for the Droanello brook, hypothetically regulated by a small hydropower plant without storage capacity.

3.6. Current application of the method/initiative

Mesohabitat scale adapted well to describe habitat use by crayfish in small streams of the Italian pre-Alps and Apennines, and mesohabitat predictive models showed interesting potentials for future applications (Ghia et al., 2013). Ongoing activities include the evaluation of models extrapolations potentials in other Mediterranean streams of Central Italy (Gran Sasso e Monti della Laga National Park).

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

Meso-habitat simulation models applied for crayfish can be used to support e-flows implementation and habitat restoration actions, which are critically needed (i) to protect local populations of endangered species, (ii) to implement recent water laws, such as the European Water Framework Directive, and (iii) to cope with the present lack of available instruments. Specific negative impacts on *A. pallipes* can be detected, allowing restoration strategies to be focused on this especially threatened species.

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Case study 9 (Greece): "Estimating the minimum ecological flow downstream of the Gadouras reservoir (Rhodes Island) for conserving the local Gizani (*Ladigesocypris ghigii*) populations"

1. Executive summary

The project proposed a modified flow regime for river Gadouras (Rhodes Island – Greece) in order to maintain necessary levels of water in instream pools found to be critical for the survival of a particular endemic fish species (Ladigesocypris ghigii – c. Gizani), after a reservoir construction and operation. Expert judgment and hydraulic modelling were utilized. Four sites upstream of the dam and 5 sites downstream were selected for sampling fish and record quantitative and qualitative data. The Mike11 hydraulic model was used to simulate a particular river stretch and propose the modified ecological flow regime. Telemetry stations were installed in two sites downstream of the dam. Moreover, adaptive e-flow management has been proposed according to wet/dry periods, wet/dry years and water level fluctuations in the artificial lake. Through field surveys, it was estimated that a threshold water depth of 20cm is necessary to act as an alarm and initiate the ecological flow discharge from the dam. The rate of water withdrawal in dry periods for the area has been observed to be 3cm/day and the mean-depth of the pools was 1.5m - 2m. This indicated that in dry periods of the year, eflow of slightly less than 300m3/h (calculated as the necessary flow to retain more than 20cm depth in the pools) should be released from the dam for 6 consecutive days. With this as a starting point, hydraulic and hydrological data were integrated in the Mike11 software in order to simulate dry/wet years, different water levels in the reservoir, wet/dry periods, different water needs and the changes provoked by these different flow regimes (+/- 30% water supply). During the wet period, the telemetry stations monitoring the water levels have been used as warnings when water falls to the critical level of 20 cm in order to release eflow in the same concept.

2. General information

Member State(s): EL

RBD(s): 14

Location: Aegean Islands

Time period (start/end): 10/2011 to 12/2012

2.1. Objective of the Case study

Four major objectives were included in the Gadouras dam case study: (i) Monitoring of the current state of Gizani populations downstream of the Gadouras reservoir, (ii) assessment of the minimum flow requirements of the Gizani populations for maintaining their functionality throughout each year and ensure their survival during low flow (near-dry or dry) summer conditions, (iii) proposing an eflow schedule to the dam operator according to the previous eflow assessment, (iii) pilot implementation of a flash flood, monitoring fish responses and further readjustment of the eflow proposal.

2.2. Policy and management context

According to the Joint Ministerial Decision 49828/2008, ecological flows should be assessed and provided downstream of hydropower plants or reservoirs for ensuring ecosystem integrity and prevent deterioration of aquatic communities. Although ecological flows are acknowledged as a crucial part of an Environmental Impact Assessment in regulated river systems, the current definition of ecological flows according to the Greek legislation is only hydrological, without addressing the requirements of aquatic communities.

Ladigesocypris ghigii (Gizani) is a Rhodes Island endemic fish species, included as a priority species in the Habitats Directive 92/43/EEC, mentioned in the Red Book of Endangered Species of Greece and also protected by the Greek Presidential Decree 67/1981. The particular case study was part of a LIFE project including, inter alia, public participation in informational meetings, brochures and other promoting material enhancing local awareness about Gizani populations.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The methodology adopted by the Hellenic Centre for Marine Research (HCMR) resulted in an eflow schedule, applied by the dam operator, with relative adjustments for wet/dry periods, wet/dry years and water level fluctuations in the artificial lake. This schedule has been applied annually for the protection of the Gizani populations.

3.2. Temporal and spatial scales

Gadouras is a typical Mediterranean temporary river, which becomes dry during almost every summer. The current study was conducted to ensure the survival of the Gizani populations under critically reduced (near-dry or dry) flow conditions of the summer period, by maintaining more than 20cm depth in specific instream pools, through an recurrent eflow release by the dam operator. The study addresses the needs of Gizani populations downstream of the reservoir and the schedule is annual with adjustments proposed for wet/dry years or unexpected declines in the water level.

3.3. Type of analysis or tool

Through field surveys, it was estimated that more than 20cm water depth is necessary to maintain the species populations in the pools of the river in near-dry flow conditions. In close collaboration between the HCMR and the dam operators, the methodology applied included the following steps:

1. *Establishment of two telemetry stations for the continuous monitoring of water levels* - The first station was established in Rhodes 1 (1km downstream of the dam) and the second in Rhodes 2 (3km downstream) (fig. 1).
2. *Estimation of the time necessary for the water to reach and fill the pools, which provide habitat for the Gizani populations* - For this purpose, the dam operators opened the eflow valve for 6 consecutive days and continuous measurements in combination with the data provided by the two telemetry stations indicated that with the standard flow provided by the eflow valve, the water filled “Rhodes 1” in 2.5 days and “Rhodes 2” in 4 days.
3. *Estimation of the time for water withdrawal from the two sites (Rhodes 1 and 2)* - The minimum time for withdrawal was observed in Rhodes 2 and calculated at 3cm/day. Considering that the mean depth of the pooling areas is 1.5m to 2m, it was estimated that these pools, which constitute Gizani’s habitats need 50-60 days to dry completely. This indicated that during the dry period (May-October), flow release from the e-flow valve should be applied every 40 days to prevent desiccation of the pools.
4. *Input of field data into the Mike11 hydraulic model, calibration and estimation of the necessary flow to retain more than 20cm water depth in Gizani’s pools* - an eflow of approx. 300m^3/h should be released from the dam for 6 consecutive days, according to the water level in the reservoir and the period of the year, in order to counterbalance the water withdrawal in the pools (fig. 2).

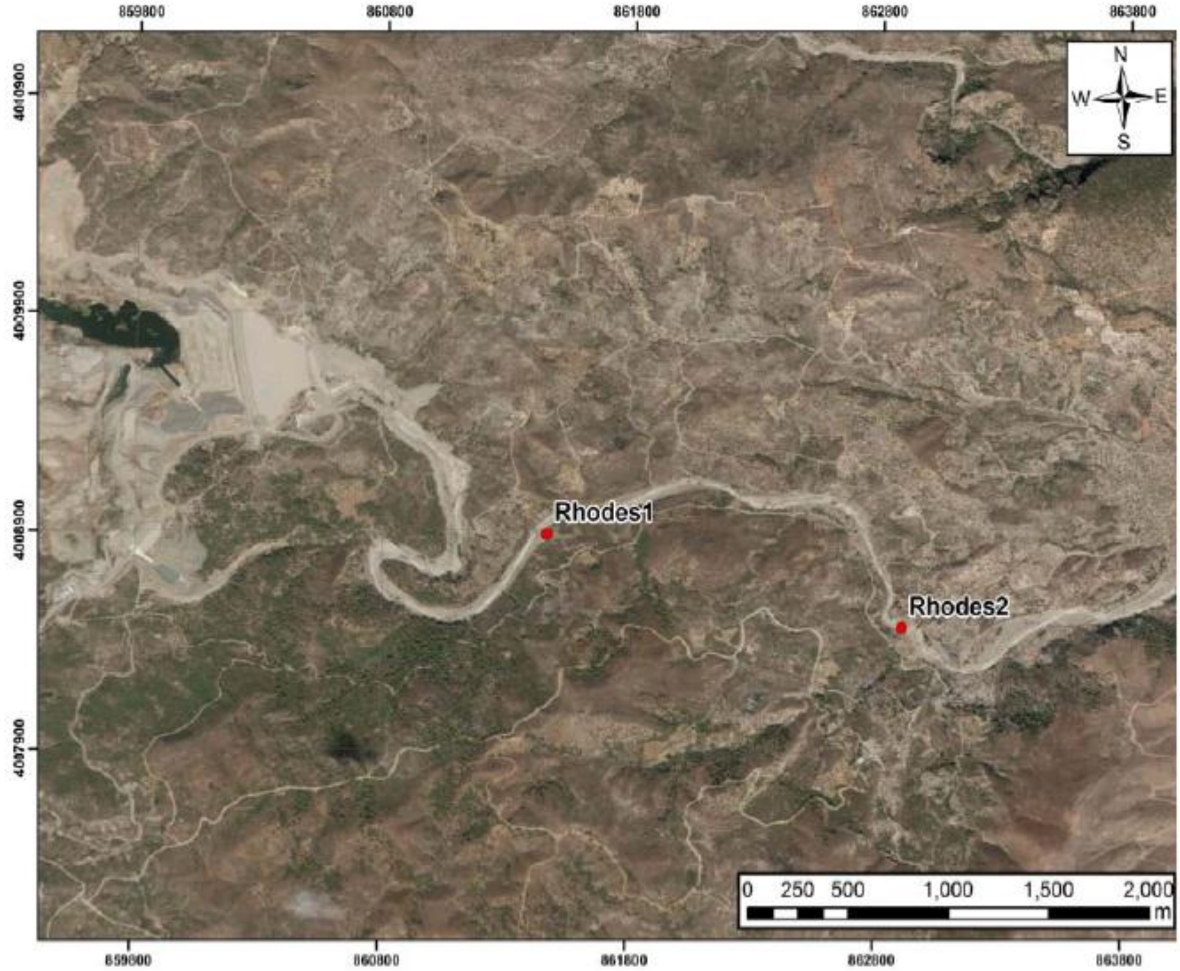

Figure 1: The two sites (Rhodes 1 and Rhodes 2) downstream of the Gadouras dam, where the telemetry stations have been established

3.4. Information and data requirements

Physicochemical measurements regarding (total hardness, HCO^-_3 CO^{2-}_3, Ca, Mg^{2+}, Na^-, K^+, Cl^-, total P, total N, SiO_2, PO^{3-}_4, NO^-_2, NO^{2-}_3, NH^+_4 were undertaken in four sites upstream, three sites downstream and one site located inside the reservoir for estimating the general water quality of the river length. Field surveys from experienced ichthyologists were undertaken in the same sites in order to assess the abundance of Gizani populations and address their minimum water flow requirements (more than 20cm water depth in the pools). Application of the Mike11 software enabled the visualization of the consequences of the different flows applied to the river bed and the pool areas and the estimation of the flow, which should be released in order to meet the Gizani's needs.

3.5. Testing of results

Monitoring by ichthyologists was undertaken at each site, one year after application of the eflow schedule by the dam operator. Gizani populations were well maintained during the dry season and fish survival was ensured. In combination with the eflow application, an artificial introduction of Gizani populations from the upstream parts of the river has been proposed to be applied during the wet season. Monitoring is currently performed in an annual basis by local or HCMR experts.

	Periods		
	May - June	July - September	October
Level **117m** valve opening	6 in for 2 days and 4 in for 4 days	6 in for 6 days	6 in for 2 days and 4 for 4 days
Level **110m** valve opening	7 in for 2 days and 4 in for 4 days	5 in for 6 days	7 in for 2 days and 5 in for 4 days
Level **100m** valve opening	10 in for 2 days and 7 for 4 days	10 in for 6 days	10 in for 2 days and 7 infor 4 days
Level **90m** valve opening	15 in for 2 days and 10 for 4 days	15 in for 6 days	15 in for 2 days and 10 in for 4 days

3.6. Current application of the method/initiative

The proposed eflow schedule is being routinely applied by the dam operator, with adjustments for wet/dry periods or wet/dry years. This method has not been replicated yet in other WBs.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

This method provides a baseflow required for a specific fish species, with a slight divergence from a typical eflow assessment. However, it is a good alternative and can be replicated in similar semi-arid environments, typical of the Mediterranean region, where desiccation of water is a critical issue for the survival of aquatic communities. There are no limitations for the application of the particular method. The telemetry stations are not as expensive as they were in the past and their establishment and data feedback is much easier. Moreover, as cost-effectiveness is another critical issue of an eflow assessment, this method can be utilized as a cost-effective alternative, when funding for more complicated assessments is insufficient.

Lessons learned and issues to be improved for future applications:

1. The application of the method, although not directly linked to the requirements of the Habitats Directive 92/43/EEC, is expected to lead to a "favorable conservation status" for the populations of Gizani, as described in the Directive.

2. The proposed ecological flow was not compared to natural/historical hydrological data due to lack of such long-term records for the particular river. However, a combination of the current method with a comparison to natural/historical records (where available) is expected to raise the method's accuracy.
3. Geomorphic effects of dam in the pools were not estimated in the current study
4. Hydrological effects of the proposed eflow were not estimated beyond 3km (from Rhodes 2 to estuaries), as the river becomes naturally dry beyond that point. Moreover, the target of the study was to maintain the populations of Gizani and no such populations were observed further downstream of Rhodes 2 during the biological sampling. However, in a possible replication of the case study, the whole river length could be accounted for more "safe" eflow proposals.

4. Contact information

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5. References

http://www.life-Gizani.gr/pages/en/lifefysh/index.htm

Case study 10 (United Kingdom): "Eflows to achieve High Ecological Status"

1. Executive summary

High Hydrological Regime helps to define High Ecological Status. As part of identifying WBs at High Ecological Status, Hydrological Regime needs to be assessed. Four tests were developed to assess High Hydrological Regime.

These tests look at standards for abstraction, discharges, reservoir land use in upstream catchment area and urban land use in upstream catchment area.

2. General information

Member State(s): UK

RBD(s): All river surface water bodies

Location: National

Time period (start/end): since 2007

2.1. Objective of the Case study

The hydromorphological quality element requires explicit consideration in the classification of High Ecological Status (HES). The hydromorphological quality element for river water bodies consists of three components: hydrological regime, river continuity and morphological conditions. Hydrological Regime has been assessed using the steps described below and results reported as High status hydrological regime.

2.2. Policy and management context

The classification of Water Framework Directive Ecological Status for surface water bodies (rivers, lakes and estuaries) is based on the assessment of three quality elements:

- Biological Quality
- Physico-Chemical Quality
- Hydro-Morphological Quality

The relationship between these three elements in the overall classification of Ecological Status (High, Good, Moderate, Poor, Bad) is shown in Figure 1, taken from WFD CIS Guidance.

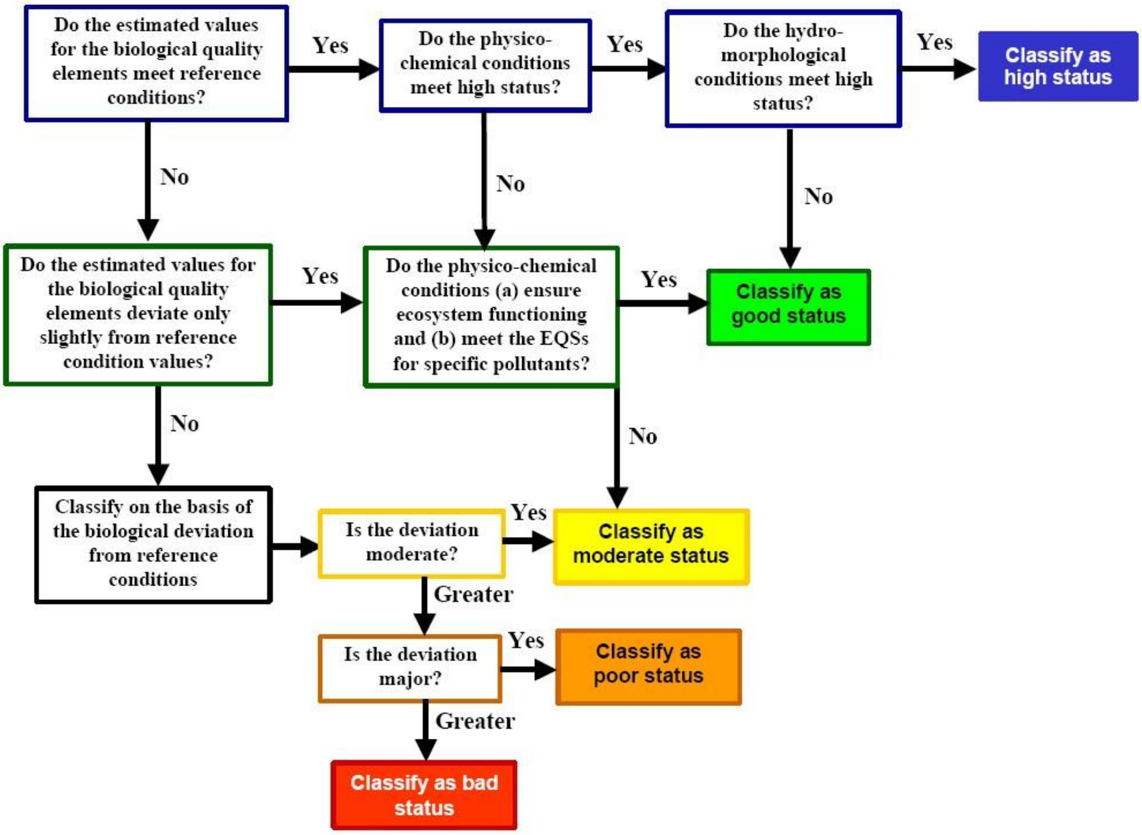


Figure 1: The relative roles of the three quality elements in the classification of ecological status

The hydromorphological quality element requires explicit consideration in the classification of High Ecological Status (HES). It has a direct bearing on High Status classification in its own right, in contrast with the supporting role it plays to biological elements for other ecological status categories. If all three elements – biological, chemical and hydromorphological – meet HES criteria, the water body will be classified as such and the WFD requires that it is managed to prevent any status deterioration. For water bodies not classed as HES, the WFD sets a 'default' environmental objective of achieving Good Ecological Status (GES) by 2015 which may require measures to improve or restore where this is currently not being achieved. Alternatively if a water body is designated as Heavily Modified or Artificial the environmental objective is Good Ecological Potential (GEP).

The hydromorphological quality element for river water bodies consists of three components: hydrological regime, river continuity and morphological conditions. In order for the hydromorphological quality element to meet High Status requirements, all three of its components must pass their respective criteria. WFD Annex V provides definitions of quality elements with respect to high status. The criteria given for the hydromorphological quality elements are as follows:

- **Hydrological regime** *"The quantity and dynamics of flow, and the resultant connection to groundwater, reflect totally, or nearly totally, undisturbed conditions".*
- **River Continuity** *"The continuity of the river is not disturbed by anthropogenic activities and allows undisturbed migration of aquatic organisms and sediment transport.*
- **Morphological conditions** *"Channel patterns, width and depth variations, flow velocities, substrate conditions and both the structure and condition of the riparian zones correspond totally or nearly totally to undisturbed conditions.*

The first of these three components has been assessed using the steps described below and results reported as high status hydrological regime. The second and third components will be assessed by morphologists. Only those water bodies that pass the 'high' criteria for all three components will be classified at high status for hydromorphology.

Policy and management:
WBs achieving High Hydrological Regime status must not deteriorate from this status *if* the overall Ecological Status is at High. This is now embedded in Environment agency agreed policy (Managing Water Abstraction) on new abstractions so that High Hydrological Regime can be maintained where the WB is at High Ecological Status.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Environment Agency local staff provided information on flows and artificial influences via the RAM (Resource Assessment Management) ledger (MS Excel based system). This information was provided to EA head office staff.

EA head office staff loaded this data into an Arc GIS mapping system called Water Resource GIS (WRGIS) that automatically performed a series of tests and provided results as to the outcomes of these tests.

Test results were collated to provide an indication of whether WB is High Hydrological Regime. Test results and High status results are available as maps in WRGIS for staff to view nationally.

Test results and High status results were exported to Excel spreadsheets to be submitted and held in web based central RBMP data store called the Catchment Planning System (CPS).

3.2. Temporal and spatial scales

Tests are carried out at the WB scale. A national dataset was built from these WB scale assessments. Assessments were undertaken using long term flow records, six years of artificial influence data and regularly updated land use data.

3.3. Type of analysis or tool

To pass the **hydrological regime** component the water body must exhibit little or no deviation from natural conditions. Four categories of anthropogenic influence are tested independently, with the final outcome determined by the worst case result (one out all out). These four tests are:

- **Actual abstraction** within 5% of Qn95
- **Actual discharge** within 5% of Qn95
- Total surface area of **reservoir** must be less than 1% of upstream catchment area
- **Urban and sub-urban area** less than 20% of upstream catchment area and urban area must be less than 10% of upstream catchment area.

Full methodology of the four tests is given in Annex I.

Example of test results for specific water body, GB103023074710 (Allen from Source to West Allen) are presented in Figures 1 & 2.

Fig 1: Location map of GB103023074710 Allen from Source to West Allen

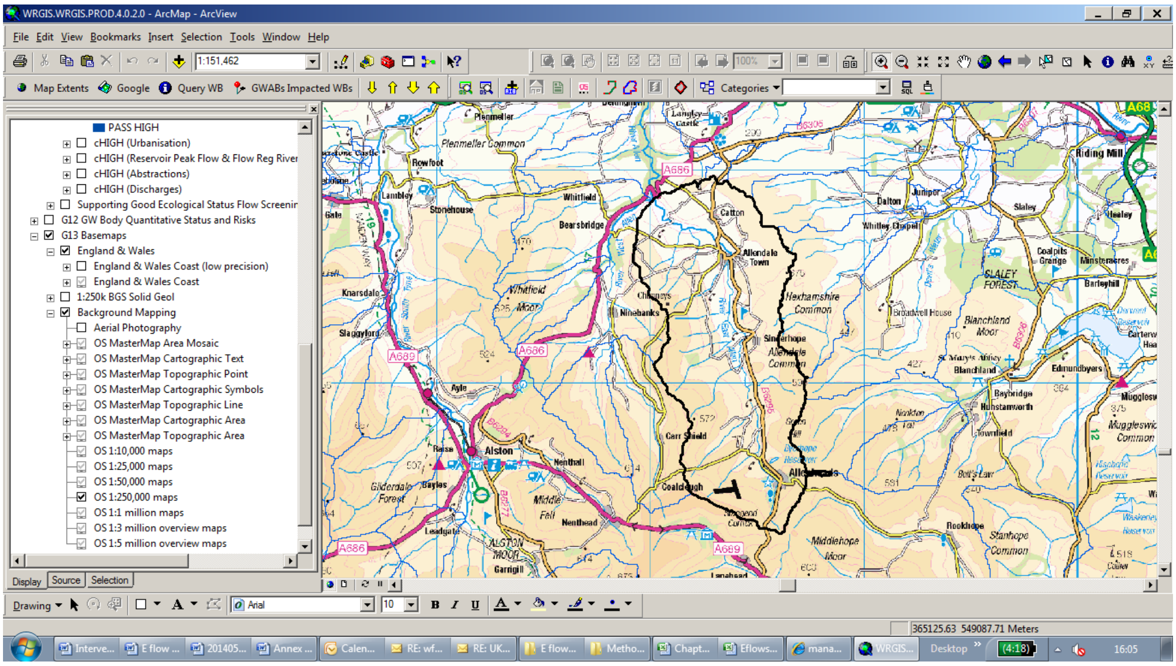
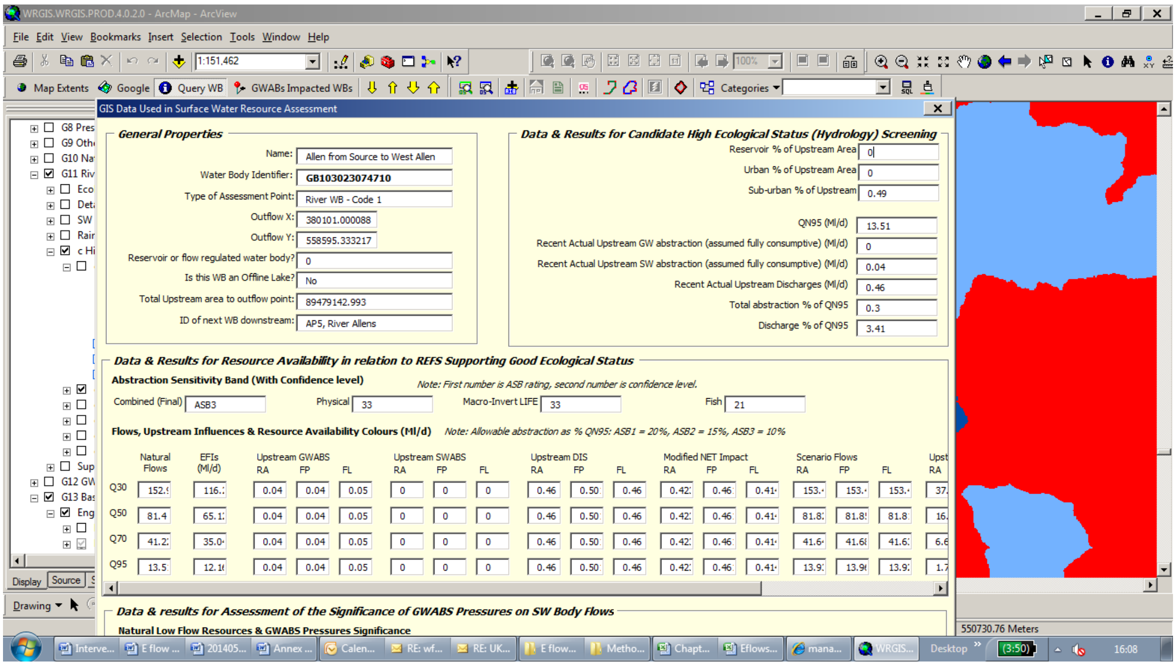


Fig 2: Data table of WRGIS data showing results of four tests for GB103023074710 Allen from Source to West Allen (top right hand box). All four tests are passed as they fulfil the criteria stated above.



3.4. Information and data requirements

To use WRGIS a number of datasets were required including

- Naturalised flow data. This is a modelled dataset based on a long running observed flow data;
- Abstraction and discharge data, based on records from operators but modelled if no records were existing;

- Nationally held land use records.

These have been locally collated since 2007 and incorporated into a national dataset. This national dataset was used to calculate compliance with the four tests for High Hydrological Regime. This is easily reported.

3.5. Testing of results

WRGIS datasets are locally reviewed annually and the best available observed and modelled data is included in this dataset.

Minimal testing has been undertaken of the High Hydrological Regime results. This is because while there are 1482 WBs in England calculated to be at High Hydrological Regime in 2013, there are believed to be less than five WBs in England at overall High Ecological Status. This means that identifying High Hydrological Regime is not a required dataset in determining the Ecological Status result in most WBs.

3.6. Current application of the method/initiative

The method remains in place and is used to calculate High Hydrological Regime for current and future classifications. The WRGIS data is updated annually as new data becomes available.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The use of four tests to determine High Hydrological Regime can be used in other areas. A substantial amount of operational work is required to form a useable baseline of flow, artificial influence and land use data. Once this data is in place tests can be automated and run quickly.

Maintaining consistent databases since 2009 has allowed the reprocessing and direct comparison with interim classifications.

4. Contact information

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Case study 11 (Italy): "GES-Flow estimation - the case of the Arno River Basin"

1. Executive summary

River Basin Management planning in the Mediterranean area entails pivotal challenges mainly related to the high runoff variability that strongly depends from seasonal fluctuations, a phenomenon that is exacerbated by climate change. Therefore, the effective risk assessment of the probability of not reaching the WFD objectives has to take, not only the water body environmental status into consideration, but also its water balance conditions. This case study aims at producing useful outputs and testing the feasibility of quantitative indicators (extracted from the approved Water Balance Plan) by comparing them with Minimum Vital Flow data and a first approximation of GES-Flow.

2. General information

Member State(s): Italy

RBD(s): Northern Apennines (ITC)

Location: Arno river basin

Time period (start/end): 2010 ongoing

2.1. Objective of the Case study

The main aims of the test case are:

- evaluate the gap between GES-flow or rather: an hypothetical approximation of such a flow) and the current situation over a wide portion of the basin;
- analyze the correlation between the above estimated gap and the monitored ecological status, according to WFD environmental parameters;
- assess the risk of not reaching the objectives set out in the WFD by comparing water bodies' environmental status and water balance data.

The Case Study outputs might not only support planners in the process of setting water body status objectives and of choosing the most cost-effective combination of measures, but they might also provide useful information to apply exemptions and improve water resources management.

Namely the main output of the case study will be the test application of a procedure to assess whether a water body will reach the good status objective on the basis of quantitative parameters derived from the Water Balance Plan. At the same time the monitoring data, collected in accordance with Directive 2000/60/EC, will feed into the Water Balance Plan database updating it and highlighting critical conditions. The pilot testing activity aims at conveying the following key messages:

- underline the need to correlate water bodies environmental status analysis (GES) with Minimum Vital Flow (MVF, see par. 3.1);
- emphasize the necessity to update water balance data at water body scale carrying out in depth quantitative status assessments when critical conditions arise;
- highlight the opportunities triggered by
- such a process for a better operational and strategic management of water resources.

2.2. Policy and management context

The analysis was carried out in the second cycle of river basin management planning in the Northern Apennines River Basin District in Italy. As the European Commission recommended in the "*Report on the Implementation of Water Framework Directive (2000/60/EC) River Basin Management Plans*" COM 2012 (670): "it is necessary to integrate quantitative aspects in water management and apply ecological flow regimes to ensure that authorities and users know how much water and which flow regime is needed to achieve good ecological status". Therefore, a prompt review is needed in the second cycle 2015-2020. The case study builds upon a detailed analysis of the water bodies' conditions taking their quantitative status into consideration. The analysis, on the basis of data availability, will be further applied on the rest of the District's territory.

The Arno River Basin Authority that, in accordance with Italian legislation, is entitled to coordinate River Basin Management Plans in the Northern Apennines River Basin District, has carried out the testing activity.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

To date there are no experiences in Italy as regards to the assessment of GES flow and GEP flow. However, a Decree of the Ministry of Environment of July 28, 2004 defines the requirements for water balance and Minimum Vital Flow (MVF) computation. The latter were extensively applied in the Arno river basin. The following steps describe the procedure for Minimum Vital Flow estimation:

- Statistical analysis of river discharge time series (daily data, 1930-2010).
- Observation of 7 consecutive days discharge series (Q7) - yearly minimum, at each river gauge station.
- Estimation, of optimal probabilistic distribution fitting for Q7 time series at each river gauge station.
- Assessment of 2 years return time values for such fitted probabilistic distributions (Q7,2).
- Regionalization of Q7,2 values to ungauged river networks according to geomorphological and geological parameters (related basin dimension, length and area ratio, hydraulic properties of soil).
- Compliance check between Q7,2 values and biological condition of predominant species in a sample of test reaches.
- Assumption of verified Q7,2 as MVF for each river network.

Together with the MVF, an average discharge-duration curve is available, derived from a similar hydrologic regionalization procedure, for every river network. The study builds upon a detailed analysis of water abstractions and returns over the entire basin that allowed the production two different discharge-duration curves:

- A "measurable" discharge-duration curve, obtained by including abstracted and returned water volumes;

- A "natural" discharge-duration curve, obtained by excluding abstracted and returned water volumes.

The latter was assumed as the (first) hypothetical estimation of GES Flow. It is clear that such a curve does not fit with all requirements of a correct definition of GES-Flow. However, it was considered as the best starting hypothesis in order to statistically evaluate and compare water bodies' discharge regime and their environmental status.

MVF and the average "natural" discharge-duration curve are available for a high number of reaches of the Arno river network. Fig. 1 describes the distribution of the upstream basin areas of the analyzed reaches.

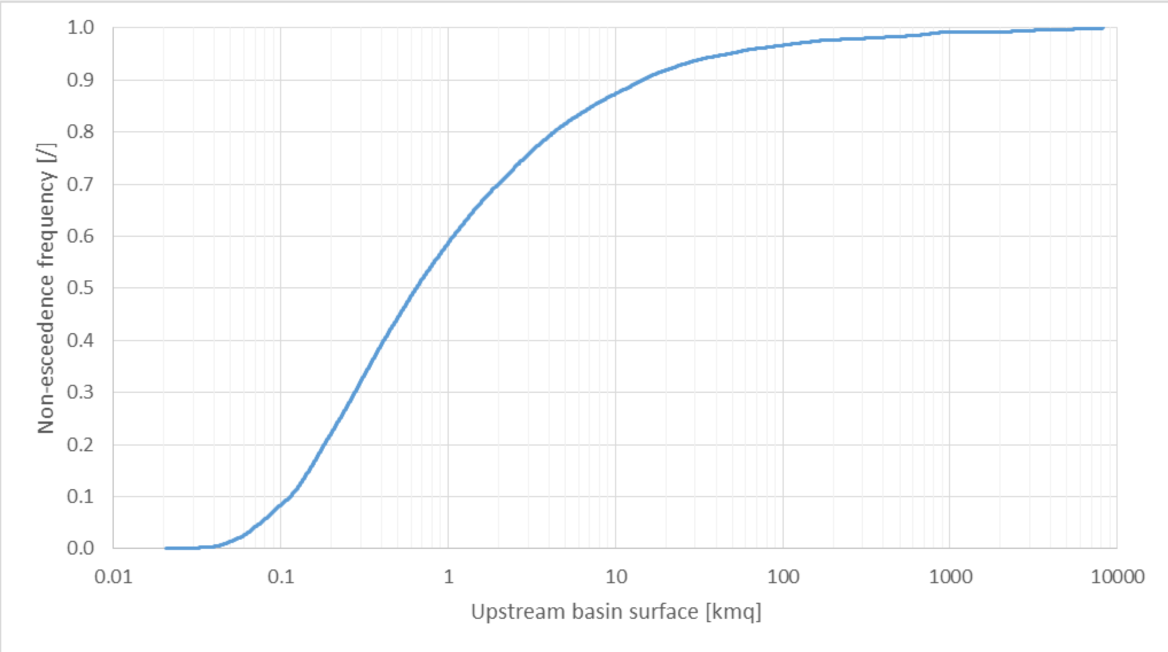

Fig. 1 – Cumulative Distribution Curve of the upstream basin areas of analyzed reaches (34.000 units)

The comparison among MVF, hypothetical GES-Flow and ecological status was carried out at water body scale coherently with the assumptions, building blocks and planning procedures of the Northern Apennines River Basin District Management Plan. The Arno River Basin comprises 341 water bodies, with an upstream catchment's dimension ranging from a few to 8000 square km.

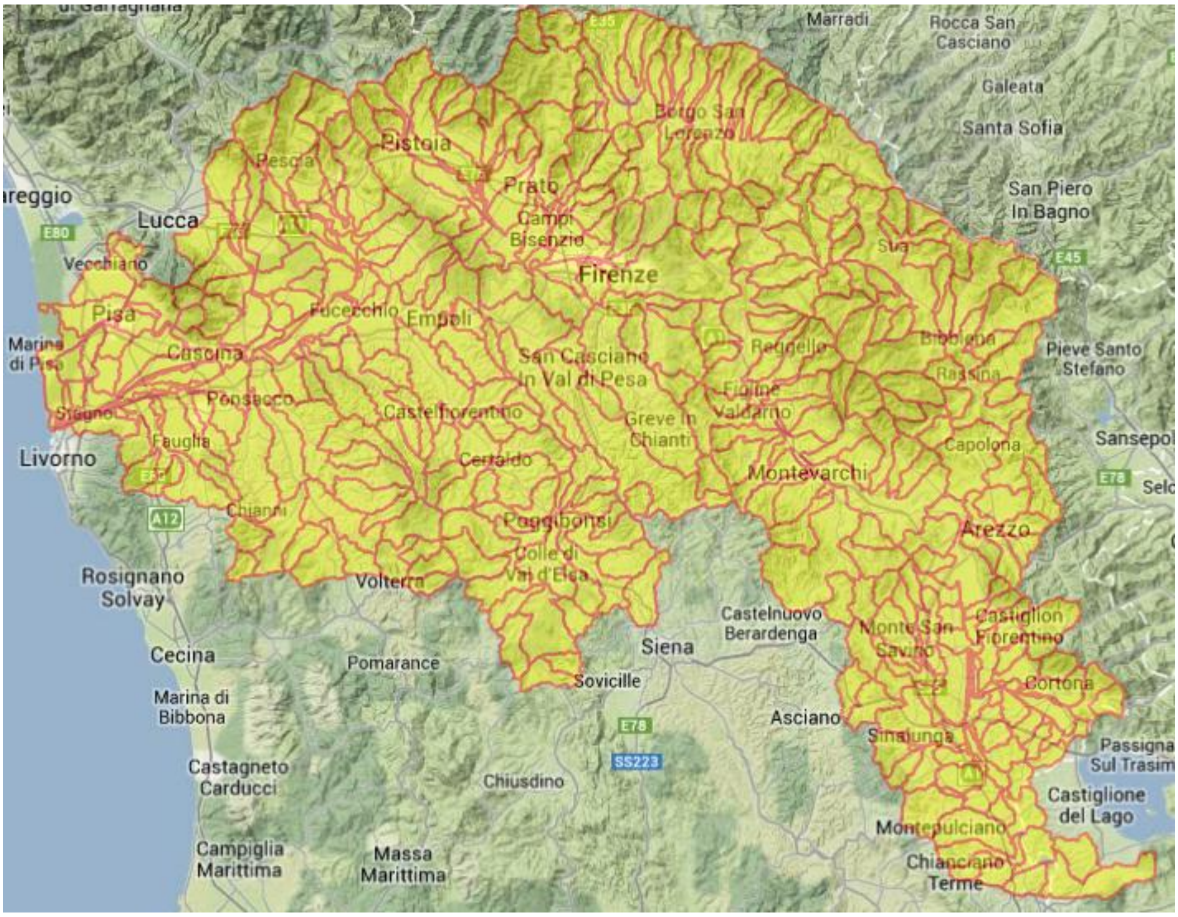

Fig. 2 – Upstream catchment of water bodies in the Arno River basin

The assessment foresees the comparison between synthetic parameters, related not only to the MVF but also to the more complex analysis of discharge regimes, and the environmental status classification in accordance with the WFD requirements (monitoring cycle 2010-2012). The parameters were selected taking into consideration the list of Indicators of Hydrologic Alteration (IHA) for non-contemporary regime (Martìnez and Fernàndez, 2010),
The following parameters were analyzed:

Id	Parameter	Unity of meas.	Comment	Reference to IHA
P1	Average yearly discharge values	Cm/s	Very basic parameter. Significant only to analyze the possible correlation with GES	Normal values – magnitude – M1
P2	Average yearly discharge values in the summer period (July-August-September)	Cm/s	Very basic parameter. Significant only to analyze the possible correlation with GES. The reference to the summer period (simplified by the choice of three consecutive months, July, August, September) takes in account the seasonal discharge regime typical of the rivers of central Italy	Normal values – magnitude – M2
P3	Relative number of days when flows are below the threshold set by the estimated MVF	%	Expressed as ratio (in percentage) between days with discharge less than MVF and total number of days. The parameter should reflect the	Droughts – duration – IAH19

			temporal progression of drought periods	
P4	Relative number of days when flows are below the threshold set by the estimated MVF in the summer period (July-August-September)	%	Expressed as ratio (in percentage) between days with discharge less than MVF and total number of days in the three months JAS. The parameter should reflect the temporal progression of drought periods limited to summer months, when the combination of high temperatures and low discharge could be dangerous for the survival of many biological species.	Droughts – duration – IAH20
P5	Absolute value of distance, expressed in volume, between the actual discharge-duration curve and the average "natural" discharge-duration curve	%	Expressed as ratio (in percentage) calculated as difference (in volume, as absolute value) between the average discharge-duration curve and the monitored discharge-duration curve, over the average discharge-duration curve. It expresses the distance (in positive or negative sense) of yearly discharge values from a first hypothesis of GES-Flow	Normal values – variability – V1
P6	Deficit (sum of negative values), expressed in volume, between the real discharge-duration curve and average "natural" discharge-duration curve	%	Expressed as ratio (in percentage) calculated as difference (in volume, only negative values) between average discharge-duration curve and actual discharge-duration curve, over average discharge-duration curve. It represents the distance (only as deficit, in negative direction) of yearly discharge values from a first hypothesis of GES-Flow	Droughts – magnitude – IAH16
P7	Deficit (sum of negative values), expressed in volume, between actual discharge-duration curve and average "natural" discharge-duration curve in the summer period (July-August-September)	%	Expressed as ratio (in percentage) calculated as the difference (in volume, only negative values) between average discharge-duration curve during the summer period (July, August, September) and actual discharge-duration curve, over average discharge-duration curve. It represents the distance (only as deficit, in negative direction) of summer discharge values from a first hypothesis of GES-Flow in the same period	Droughts – magnitude – IAH16
P8	Number of floods	Num.	Number of days with a discharge value over a defined threshold related to a flood event. The threshold is estimated as discharge value corresponding to a 2-years return period.	Floods – duration – IAH 13

Tab. 1 – List of analyzed hydrological parameters

All parameters were compared with the environmental status classification in order to assess:

- How significant the estimated natural average discharge-duration curve is for the GES-Flow computation;

- Ability of each single parameter to quantify the gap between GES-flow and registered7modelled flow regimes;
- Potentiality of each single parameter in order to confirm, the risk of failure of reaching the directive's objective.

The following graphs, illustrate the case of a single water body (Bisenzio river, upstream basin of 345.4 sq. kms).

Fig. 3 – Geographical location of the Bisenzio river's downstream reach (Water body IT09CI_N002AR083fi3)

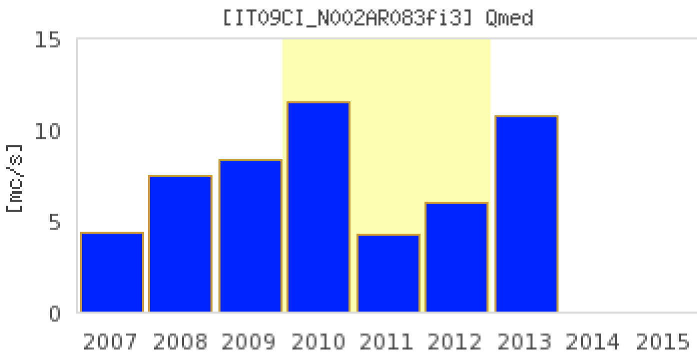

Fig. 4 – Annual values of the parameter P1 – yearly average discharge

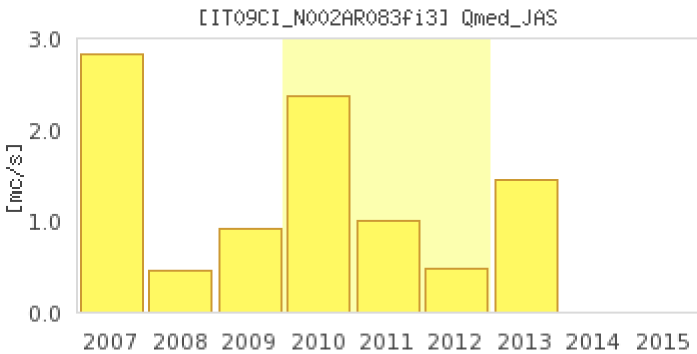

Fig. 5 – Annual values of the parameter P2 – Summer average discharge

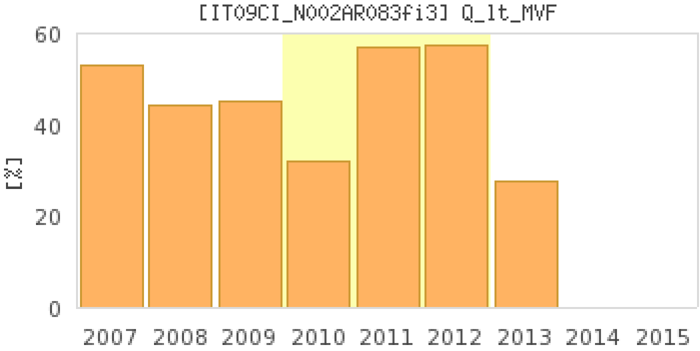

Fig. 6 - Annual values of the parameter P3 – fraction of days/year with discharge below MVF

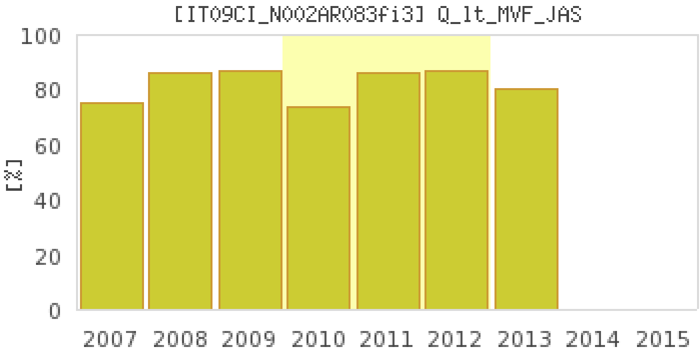

Fig. 7 - Annual values of the parameter P4 – fraction of days/Summer with discharge below MVF

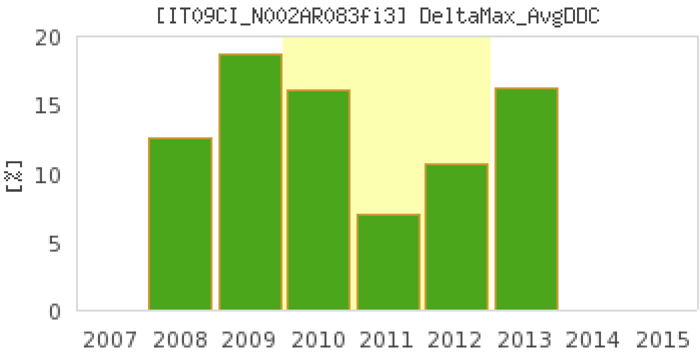

Fig. 8 - Annual values of the parameter P5 – Distance between annual discharge-duration curve and natural average discharge-duration cuve

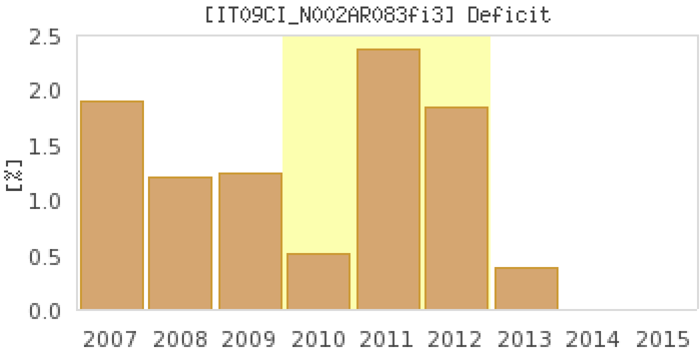

Fig. 9 - Annual values of the parameter P6 – Distance between annual discharge-duration curve and natural average discharge-duration curve

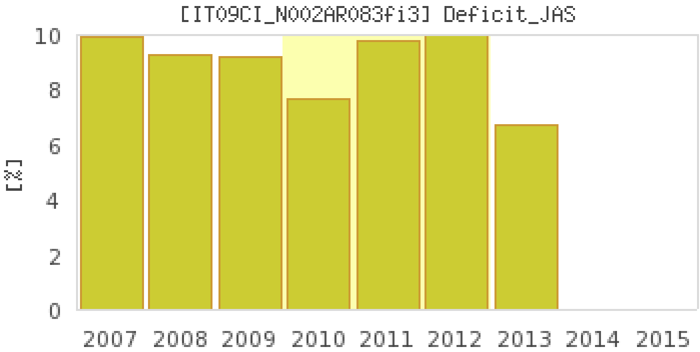

Fig. 10 - Annual values of the parameter P7 – Distance during Summer months between annual discharge-duration curve and natural average discharge-duration curve

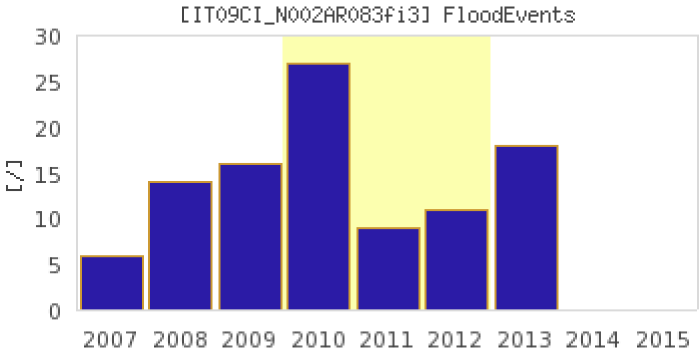

Fig. 11 - Annual values of the parameter P8 – Yearly number of flood events

3.2. Temporal and spatial scales

The application scale mirrors the hydrological variability that characterizes the examined basin. In the case in question, it is necessary to refine the spatial resolution to the order of magnitude of 100 m (which is the reference dimension of the hydrological model calculation grid) whereas as regards to the temporal scale the daily resolution was chosen. Only on the base of this temporal calculation interval, it is possible to correctly evaluate extreme phenomena like floods or prolonged droughts.

The chosen reference scale for the analysis is the water body in accordance with the Water Framework Directive approach, the comparison between hydrological parameters and GES was carried out with reference to a sample of surface water bodies, with a dimension ranging from 10 to 8000 sq. km. Data were derived from the Northern Apennines River Basin District Management

Plan. Figure 12 illustrates the cumulated frequency distribution of basin surface for the analyzed sample.

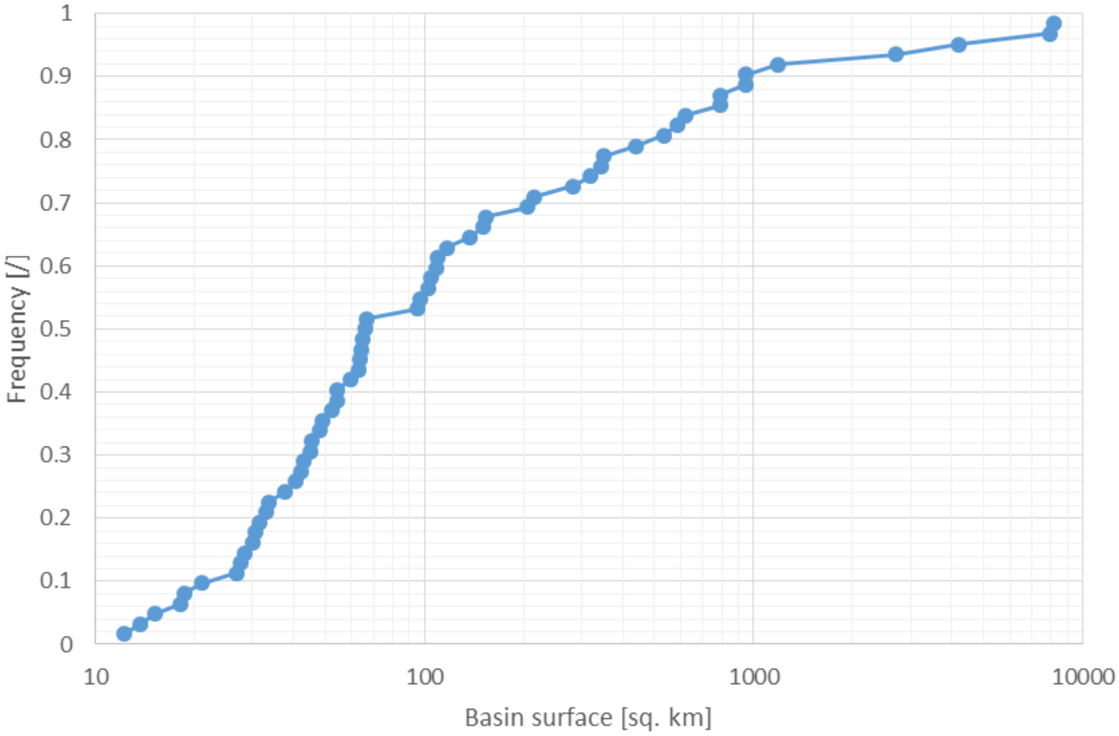

Fig. 12 – Cumulative distribution frequency of upstream catchment area for the selected water bodies

The selected set of water bodies comprises a wide range of cases, with a higher percentage of medium-small basins (surface between 30 and 70 sq. km).

Only 61 out of 341 water bodies of the Arno Basin were analyzed due to the availability of reliable monitoring data. Only water bodies with at least one quality monitoring station, with verified data of ecological status for one or more years between 2010 and 2013, have been taken into account.

Moreover, the analysis is limited to natural water bodies even if there is a considerable number of HMWB in the Arno River Basin; for this specific category the gap evaluation between monitored status and GEP needs a specific analysis which is not included in the present work.

3.3. Type of analysis or tool

The work foresees following key stages:

- Extraction/reconstruction of daily discharge time series for each water body through:
    - Collection of runoff historical time series measured between 1993-2013 for a limited set of water bodies (12 cases);
    - Model reconstruction for a larger set of time series (49 cases).
- Definition of the above described hydrological parameters for each water body.
- Selection of those years with at least one value of ecological status assessment (classes: high – good – sufficient – poor – bad status), depending on the availability of quality monitoring data.

- Comparison between water balance parameters and the environmental status conditions: for each hydrological parameter, a comparison between cumulative distribution frequencies clustered by different ecological status values was performed, obtaining a conditional distribution depending on quality assessment.
- Production of a risk scale, based on the above mentioned factors, to assess the achievement of the river basin management plan's objectives.

3.4. Information and data requirements

The hydrological model uses the following data:

- Hydro-meteorological data at daily timescale -200 gauge stations
  - precipitation
  - Temperature
  - humidity
  - radiation
  - wind speed

- abstractions and returns for human use (households, industrial, agriculture)
- digital topographic database (DTM)
- vector-layer of the surface water bodies network
- abstractions and returns points
- GIS layer of soil properties (field capacity)
- GIS layer of the drainage area of water bodies

Hydro-meteorological data are collected on a regular and organized basis whereas abstractions' and returns' data require specific collection campaigns and accurate data organization given their heterogeneity and their different reliability level. The approach adopted for data processing foresees an accurate evaluation of the data quality and the integration of missing information (fluctuation in time, trend, differences among licensed/declared/real abstraction, etc) and follows precisely described procedures.

The ecological status is based on the quality monitoring cycle 2010-2012. Updated data (including 2013 values) were collected by the Arno River Basin Authority, in the framework of its coordination activity during the 2nd cycle of RBMP (2010-2015), with reference to the WISE reporting schemas. It is worth noting that similar datasets are available for each water body of each river basin district in the same format.

3.5. Testing of results

The following graphs synthetize the main results for each parameter:

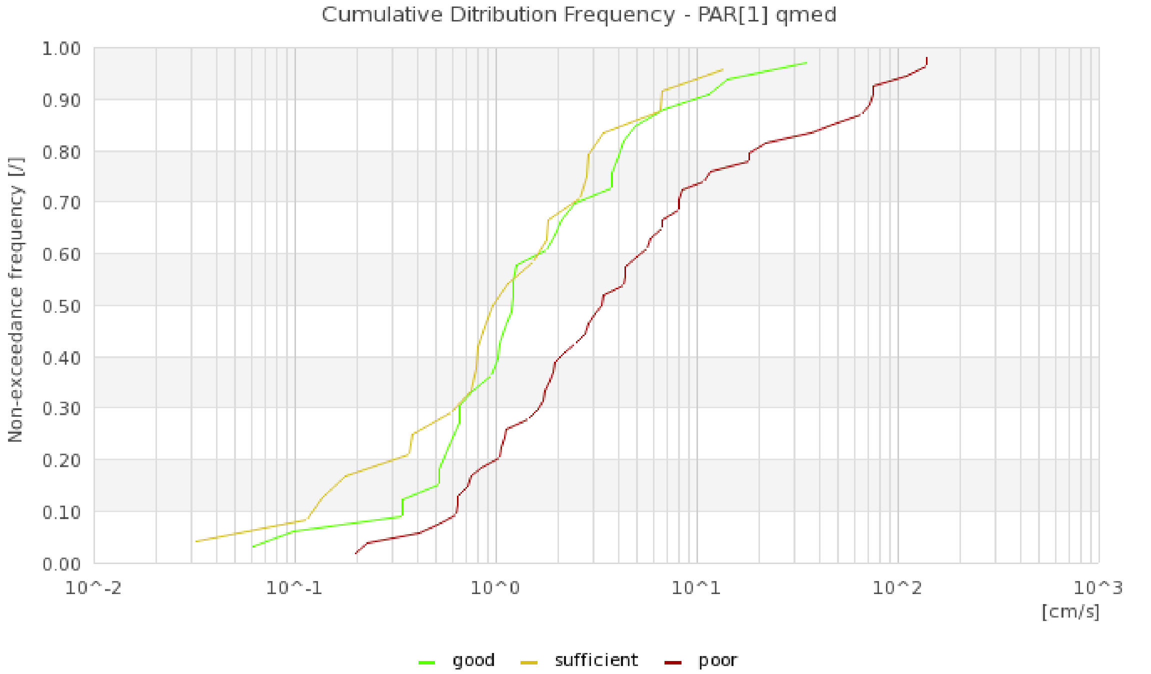

Fig. 13 - Parameter 1 – Annual average discharge

As mentioned in table 1, the average annual discharge is an extremely simple hydrological parameter, that does not properly explain several aspects of the flow regime. The clear distance between cumulative distributions related to water bodies in a good or sufficient ecological status, and cumulative distributions related to water bodies in a poor ecological status, could be explained by the fact that downstream water bodies (larger basin surface, higher average discharge) show a worse ecological status. Fig. 14 explains the relationship between upstream catchment area and annual (or summer) average discharge.

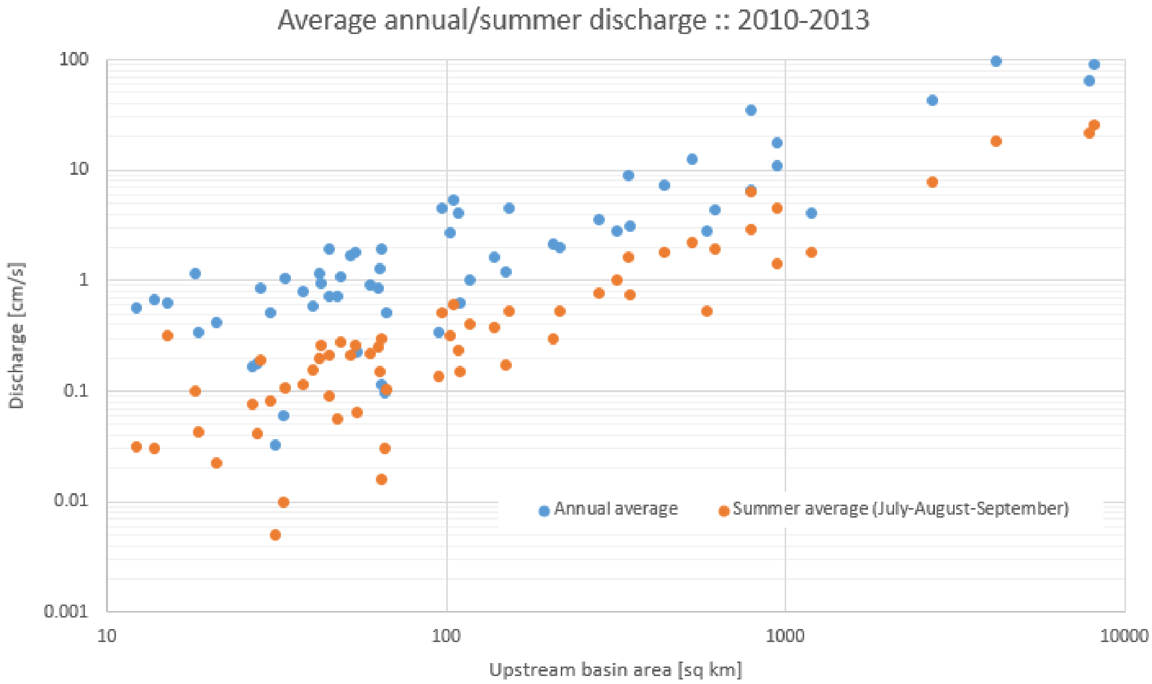

Fig. 14 – Scatter plot of upstream catchment area vs. yearly/Summer average discharge for the selected water bodies

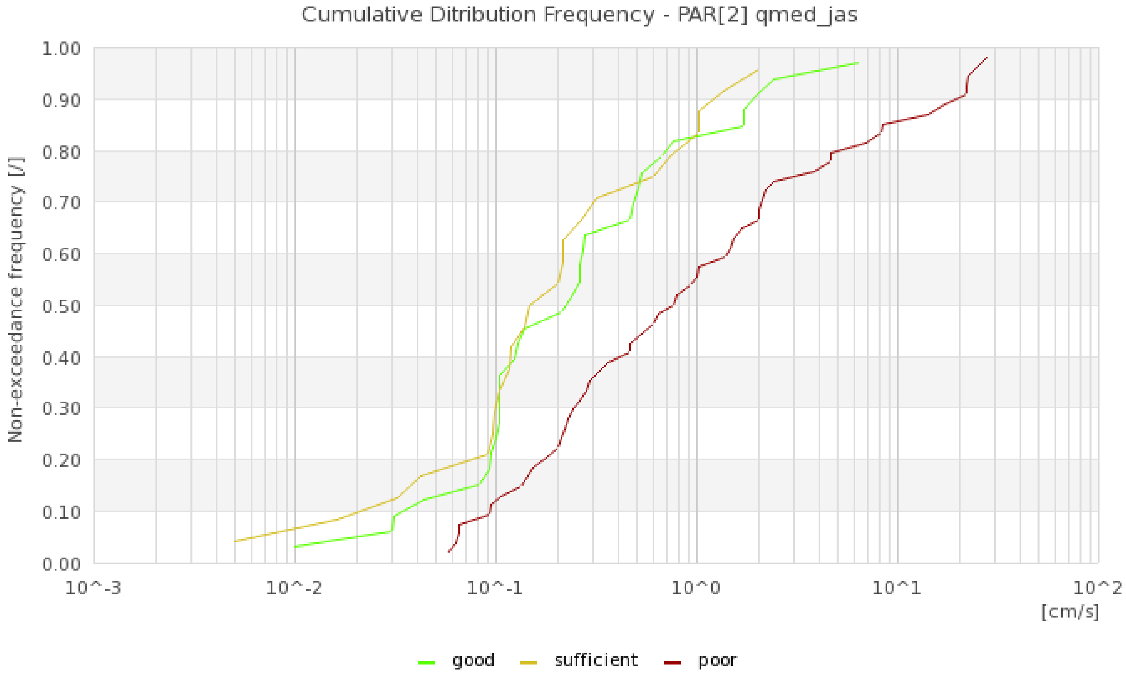

Fig. 15 - Parameter 2 – Summer average discharge

Likewise, the average summer discharge is a very simple hydrological parameter that depends from the basin size and the base flow regime. The relative position of the three cumulative distribution curves (good or sufficient ecological status, and poor ecological status) could be explained with similar considerations.

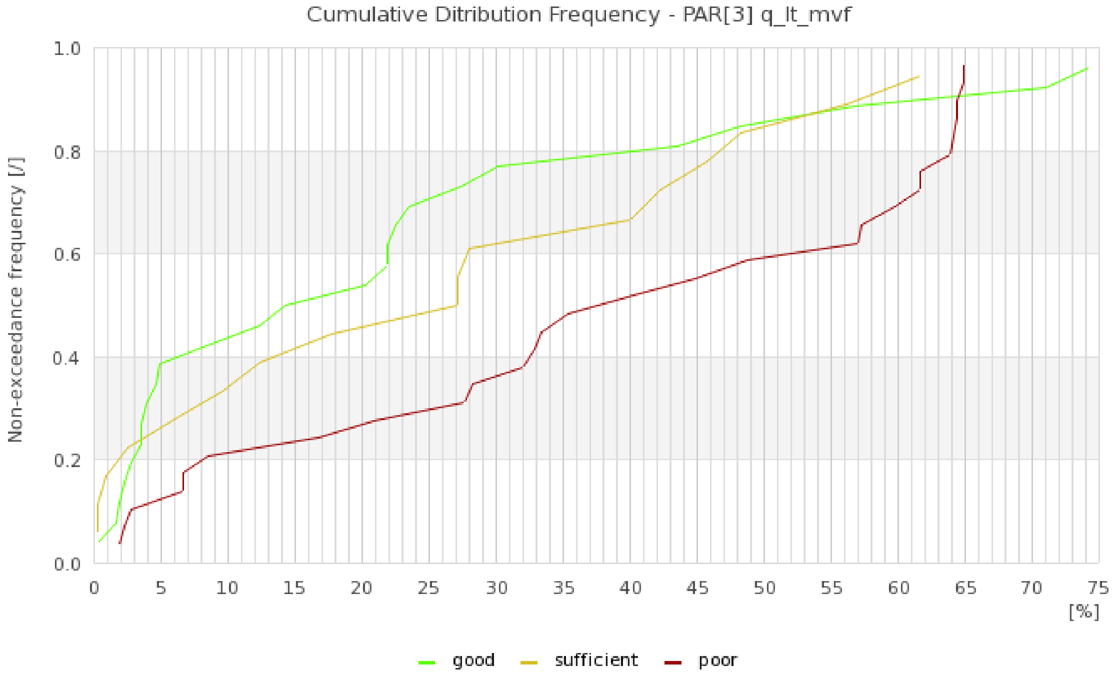

Fig. 16 - Parameter 3 - Relative number of days in which flows are below the threshold set by the estimated MVF

Even if Minimum Vital Flow only describes one of the aspects defining ecological status, the analyzed parameter shows a better ability to characterize the different ecological conditions. For example, in the large majority of cases a poor ecological condition was registered together with a parameter value above 50% of days with a discharge lower than MVF (*de facto*, a condition of severe drought). The clear different shape of the cumulative distribution curves seems to support that hypothesis. Moreover, the increasing distance between good-to-sufficient status and sufficient-to-poor status supports the potential use of the parameter also for a quantitative estimation of the risk of failure to reach the good status objective.

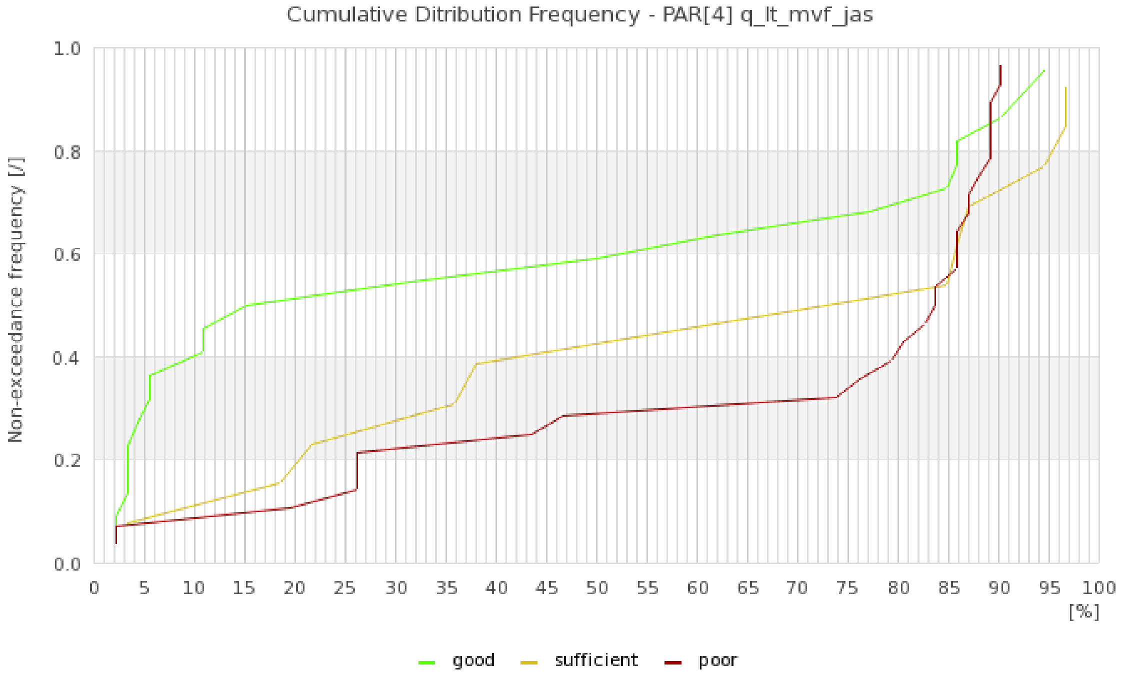

Fig. 17 - Parameter 4 - Relative number of days in which flows are below the threshold set by the estimated MVF in the summer period (July-August-September)

What has been said for the above parameter is confirmed for parameter 4. The three different curves are even more detached. It is worth to consider that the analysis focuses on the summer months, therefore the parameter's calculation reflects a specific discharge seasonality, which is typical of the Arno basin but is very common to many catchments of the Mediterranean area. Therefore, the inclusion of this parameter could acquire a general validity.

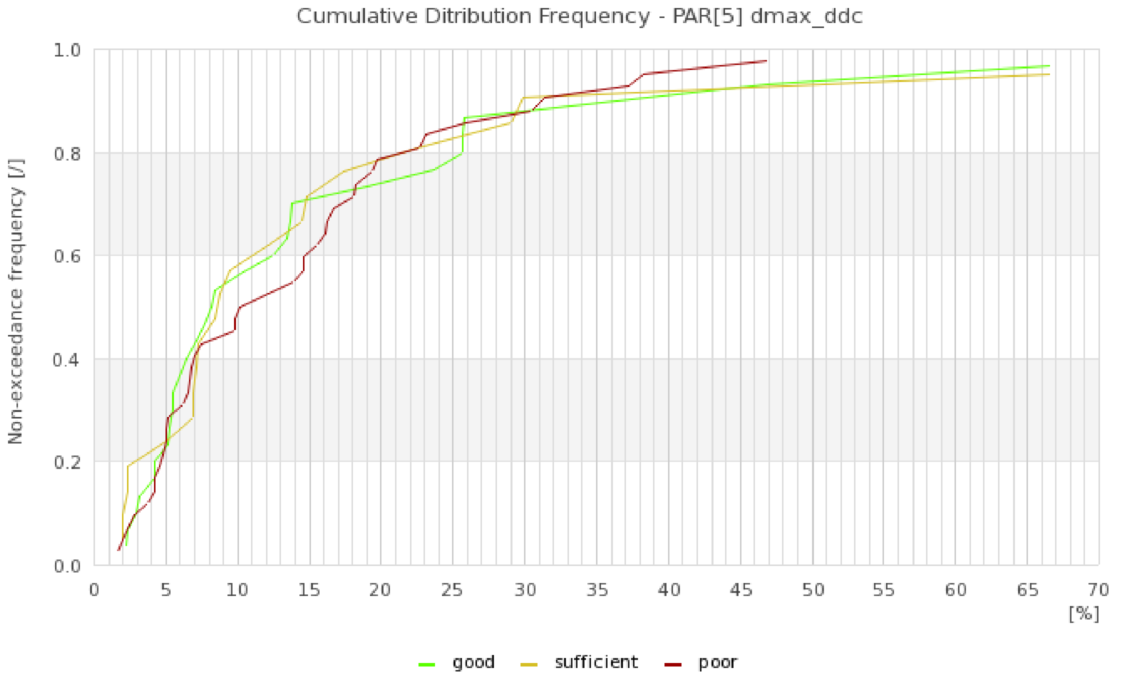

Fig. 17 - Parameter 5 – Absolute value of distance, expressed in volume, between actual discharge-duration curve and average "natural" discharge-duration curve

The graph shows no clear evidence of correlation between the cumulative distribution curves and different ecological status. The small difference between "good-sufficient" and "poor" curves' trend for lower parameter values (below 20%) disappears for higher percentages. The sum of absolute values of distance (that means, including negative and positive differences as well) between theoretical GES-Flow and the actual discharge-duration curve probably associates cases of dry and wet years, wrongly combining very different hydrological conditions with opposite effects on the ecological status of the river.

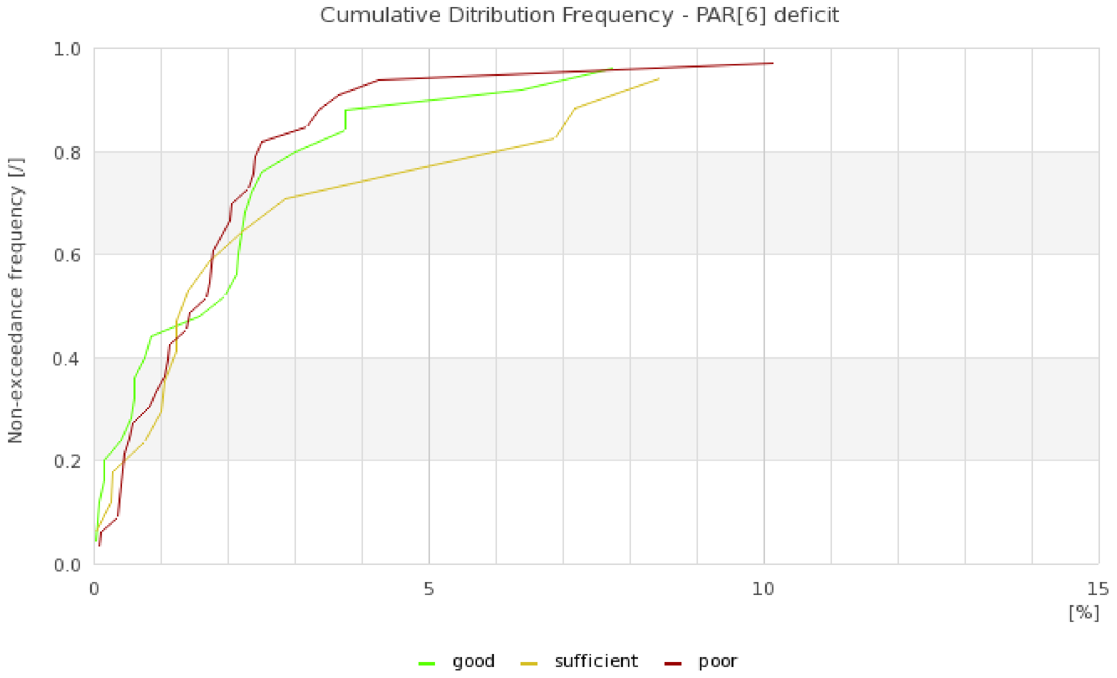

Fig. 18 - Parameter 6 – Deficit (sum of negative values), expressed in volume, between actual discharge-duration curve and average "natural" discharge-duration curve

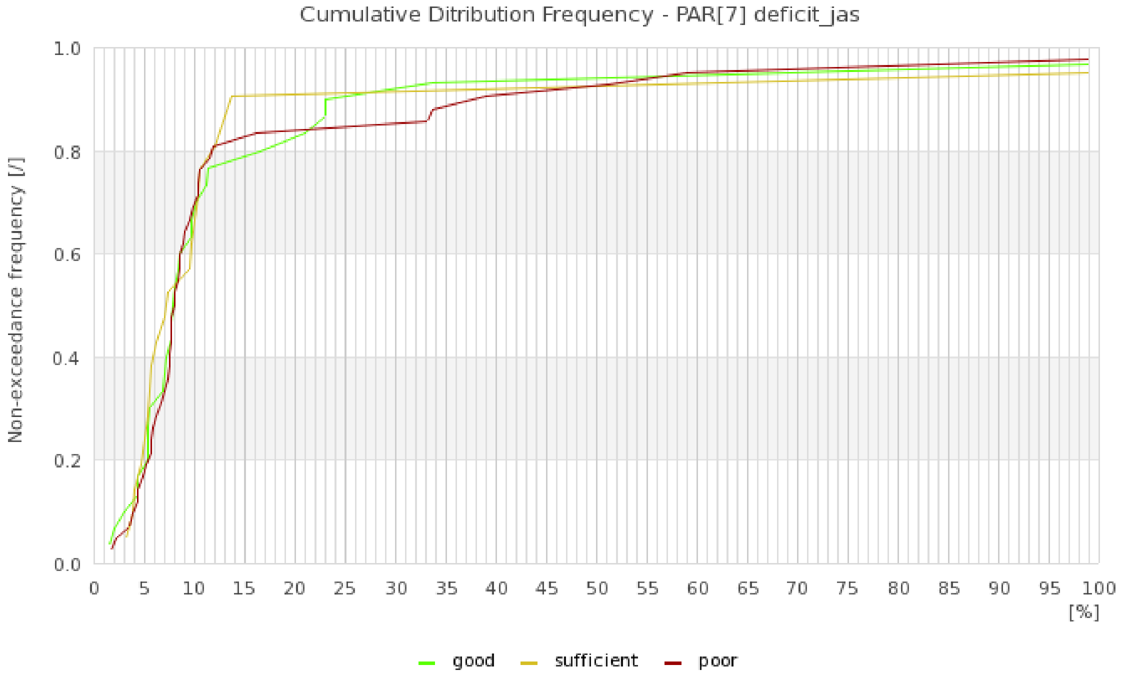

Fig. 19 - Parameter 7 – Absolute value of distance, expressed in volume, between actual discharge-duration curve and average "natural" discharge-duration curve

No better indications can be deducted for the "deficit" parameter, showing overlapping cumulative frequency distribution curves for the three different ecological conditions. The parameter P7, limited to the summer months confirms the same observation.

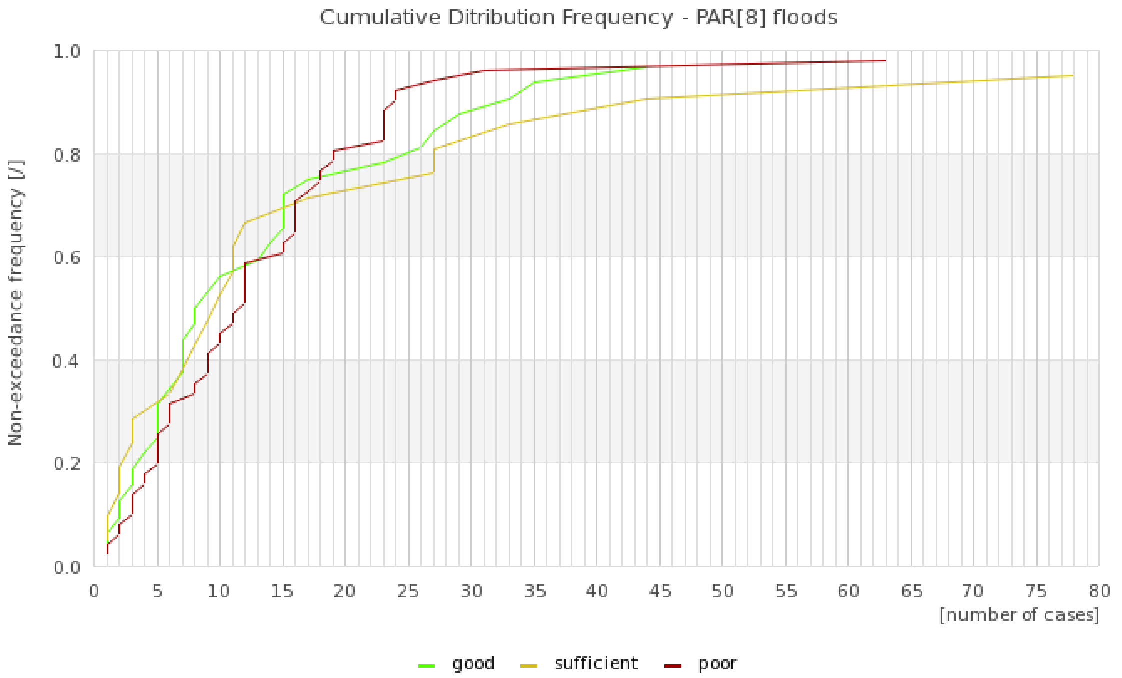

Fig. 20 - Parameter 8 – Yearly number of flood

Flood events can be very dangerous for the biological habitat and can influence the ecological status, a fact that is confirmed by quality assessments carried out on a certain number of water bodies. However, the parameter related to the number flood events does not show any clear connection with a different ecological status: there is no clear dissimilar conditional distribution, the cumulative distribution curves are overlapping each other all over the range of the parameter's values.

3.6. Current application of the method/initiative

A planning procedure that includes the use of the above described hydrological parameter is currently tested in the Arno River Basin; the possibility to further apply it to other basins belonging to the Northern Apennines River Basin District is being evaluated with the aim of homogenizing the risk assessment methodology.

The procedure will be used in the 2nd cycle RBMP; it entails the following steps:

- evaluation of the application of exemptions on the basis of the temporary deterioration of water bodies due to exceptional hydrological conditions in accordance with Art 4.6 by carrying out a gap analysis and comparing hydrological data with average reference values:
    - Environmental Status = moderate or poor or bad

      AND
    - exceptional hydrological conditions: medium-high deviation from the reference values of the selected parameters (P3, P4).

If the above situations occur we will verify:

- which are the ecological and chemical parameters that cause the failure to reach GES;
- how these values can be compared with the deviations form reference hydrological conditions.

The innovation potential entailed in this case study is the procedural connection and systematization of an approach that takes into consideration the hydrological conditions of water bodies from a quantitative point of view bearing in mind the "Blueprint to safeguard Europe's Waters Resources" Com (2012) 673, specific objectives on the implementation of water accounts and ecological flows. Up till now both the requirement of Art 5 of the Water Framework Directive and the WISE reporting schemas as reported in accordance with the implementation of the first cycle did not include quantitative data. This issue is particularly relevant for the hydrological regime of the water bodies belonging to the Northern Apennines River Basin District and has direct effect and influence on the achievement of the "good" status objective.
Risk of not reaching the good status objective is estimated by comparing the water body environmental classification with one or more water balance quantitative parameters divided in classes. The following table illustrates the behavior of the parameter "percentage of summer days runoff below MVF" indicated with P3:

Environmental Status/Hydrological Parameter	P3 < 10%	10% < P3 < 40%	40% < P3 < 60%	P3 > 60%
High		Review local MVF estimation	Review local MVF estimation	Review local MVF estimation
Good			Review local MVF estimation	Review local MVF estimation
Moderate	Risk of not reaching the	Exemption in accordance with		Review local MVF estimation

	objectives	Art. 4.6 - Possible		
Poor	High risk of not reaching the objectives	Risk of not reaching the objectives	Exemption in accordance with Art. 4.6 - Possible	
Bad	High risk of not reaching the objectives	High risk of not reaching the objectives	Risk of not reaching the objectives	Exemption in accordance with Art. 4.6 - Possible

Tab. 2 – Use of parameter P3 for risk estimation

The following combinations highlight critical conditions:

- a good-to-high environmental status and poor hydrological conditions (comparison with MVF): a review of local MVF estimation is suggested;
- a bad environmental status associated with optimal hydrological conditions: in this case runoff regime does not seem to influence the water body's poor quality. Therefore, anthropic pressures are hindering the achievement of good status.
- A bad environmental status associated with poor hydrological conditions; this is the case where exemptions pursuant to Art 4.6 may be applied.

3.7. Lessons learned - Conclusions – Recommendations for application within the concept of Eflows

- Even if MVF only takes into account one of the aspects determining GES-Flow, it can be stated that it is a valid parameter to assess the gap from GES conditions.
- Further analysis is needed for the definition of GES-Flow: the gap between the natural average Discharge-Duration curve and the yearly registered (or modeled) curves is not related to different (lower) ecological status.
- Parameter P3 and P4 (number of days with Q < MVF, over the whole year or limited to summer months) can be a valid choice in order to assess the degree of divergence from historical or predicted reference conditions regarding the flow regime. That means, this parameter could represent a quantitative measure of the gap of actual status from GES, and therefore the choice of a threshold (e.g. 50%) to define risk of objective's failure or to apply art. 4.6 conditions (prolonged drought).

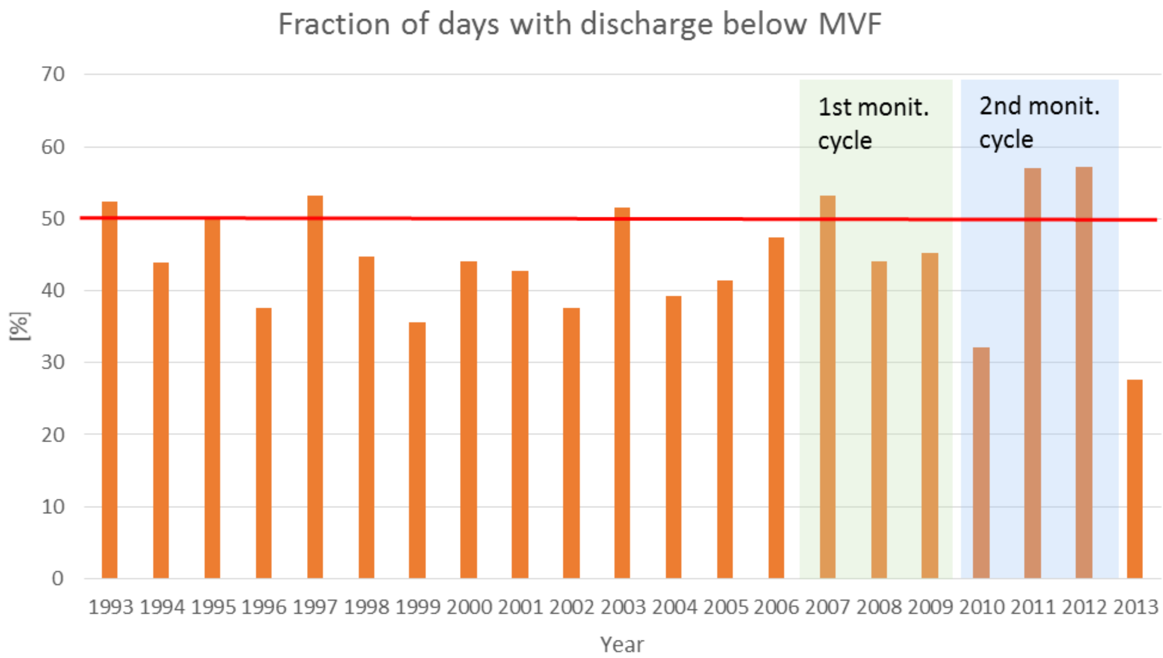

Fig. 21 – P3 parameter - Bisenzio river. The highlighted areas indicate the monitoring cycle time series. Only the 2nd monitoring cycle registered two consecutive years with P3 values above 50%: this could be an evidence to recur to the prolonged drought exemption in accordance with art. 4.6.

- The test case is replicable whenever water balance detailed data are available. Application to HMWBs may be limited because the runoff regime is influenced by the hydraulic works management practices that outweigh the hydrological factor.

4. Contact information

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- http://www.adbarno.it/
- References
- Water Balance Plan, Arno River Basin Authority

Case study 12 (United Kingdom): "Environmental Flow Indicators – Development and use in indicating compliance with Good Ecological Status"

1. Executive summary

The Environment Flow indicator (EFI) is used in England and Wales to indicate where flows in surface water bodies support or don't support Good Ecological Status.

2. General information

Member State(s): UK (England)

RBD(s): All river water bodies not designated as WRHMWB

Location: All

Time period (start/end): Since 2006

2.1. Objective of the Case study

This case study illustrates the details behind the development of the Environment Flow indicator (EFI). This is used in England and Wales as an indicator of when flows are supporting Good Ecological Status.

2.2. Policy and management context

The Environmental Flow Indicator (EFI) plays a crucial role in the management of Water Resources in England and Wales.

– EFIs are used to indicate where abstraction pressure may start to cause an undesirable effect on river habitats and species. They don't indicate where the environment is damaged from abstraction.

– Compliance or non-compliance with the EFI helps to indicate where flow may or may not support Good Ecological Status.

– The EFI is not a target or objective for resolving unsustainable abstractions. It is an indicator of where water may need to be recovered. The decision to recover water in water bodies that are non-compliant with the EFIs should only occur when supported by additional evidence to provide ecological justification.

– In Catchment Abstraction Management Strategies (CAMS) EFIs help to indicate where water may be available for future abstraction without causing unacceptable risk to the environment.

The Environmental Flow Indicator (EFI) is a percentage deviation from the natural river flow represented using a flow duration curve. This percentage deviation is different at different flows. It is also dependant on an assessment of the ecological sensitivity of the river to changes in flow. This differing sensitivity is represented by the application of Abstraction Sensitivity Bands (ASBs).

The EFI is calculated within the Resource Assessment and Management (RAM) framework. This assessment gives an indication of where and when water is available for new abstractions. Where the assessment fails a 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.

Resource availability is expressed as a surplus or deficit of water resources in relation to the EFI. This is calculated by taking the natural flow of a river, adding back in discharges and taking away existing abstractions. This results in a scenario showing both a recent actual and fully licensed river flow. The difference between the fully licensed scenario flow and EFI gives us the amount of water which is available for abstraction and when it is available.

The Environment Agency abstraction regime uses fixed 'hands-off flows'. These give a more effective use of water from the environment by enabling abstraction to cease at set flows, but also enable abstraction from periods of time when more water is available. The EFI is defined for four conditions, ranging from naturally low (Q95) to naturally higher (Q30) flows. To help manage abstraction at higher flows and protect flow variation greater percentages of flow is allowed to be abstracted.

3. Detailed information

3.1. What is the EFI?

Flow standards for the Water Framework Directive (WFD) developed by the UK Technical Advisory Group (TAG) have been adapted to set the EFI. The EFI is set through expert opinion and at a level to support good ecological status. The adaptation was necessary for the Environment Agency to use it within the existing abstraction regulatory regime.

UK TAG (2008) identified the percentage deviation from natural flow (that supports GES) 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 Table 1.

Table 1: Flow standards for UK river types for supporting good ecological status given as the percentage allowable abstraction of natural flow (UKTAG, 2008).

Water Resources Standards for Rivers and Good Status					
River Types	Season	Flow > QN60	Flow > QN70	Flow > QN95	Flow < QN95
		(% change allowable from the Natural Flow)			
A1 *Predominantly clay*	April - Oct	30	25	20	15
	Nov - March	35	30	25	20
A2 (downstream) B1, B2, C1, D1,*Chalk catchments; predominantly gravel beds; base-rich Hard limestone and sandstone; low-medium altitude; some oligotrophic hard rock*	April - Oct	25	20	15	10
	Nov - March	30	25	20	15
A2, C2, D2 *Chalk catchments; predominantly gravel beds; base-rich. Non-calcareous shales; pebble bedrock; Oligomeso-trophic; Stream order 1 and 2 bed rock and boulder; ultra-oligo trophic torrential*	April - Oct	20	15	10	7.5
	Nov - March	30	25	20	15
Salmon spawning & nursery (not chalk rivers)	April - Oct	25	20	15	10
	Nov - March	20	15	Flow > QN80 10	Flow < QN80 7.5

This was translated for use within the Resource Assessment Methodology to be used in the Environment Agency's Water Resources work.

3.2 Abstraction Sensitivity Bands

One of the first steps in the translation was to develop a way of representing the different river types and different sensitivities of rivers. Some issues were recognised with the existing 'Environmental Weighting' (EW) system and the opportunity was taken develop a new system alongside the introduction of the flow standards from UK TAG. These were called Abstraction Sensitivity Bands (ASB).

ASB are formed of a combination of 3 typologies based on Macroinvertebrates, Physical habitat and Fish communities. They are applied to each river water body.

3.2.1. Macroinvertebrate Typology

This uses expected LIFE (Lotic Invertebrate Flow evaluation) scores (Extence 1999). These were generated once for all sites used as part of a National macro-invertebrate monitoring network (General Quality Analysis or GQA sites). The calculation method used (based on Clarke et al., 2002) weights all taxa based on their likely presence within the sample. Data was supplied for the 3 seasons separately. Due to known errors with this technique for certain types of sites, the ability to override the score using another method was included.

Further analysis of the data generated the eLIFE score bands to be used for each ASB:

ASB1 (low) = <6.51
ASB2 (moderate) = 6.51 – 7.25
ASB3 (high) = >7.25

A level of confidence at 0.05 was applied to the classification of sites. So, for each season the LIFE score position was noted and any that were within 0.05 of the band top or bottom were considered to have been mis-classified and were flagged as low confidence. When all three seasons results were not in agreement they were combined to form a final confidence rating as follows:

2 high and 1 low = moderate confidence
2 low and 1 high = moderate confidence

All the GQA macroinvertebrate sites and their abstraction sensitivity band (ASB) colours were mapped in Arcview GIS alongside WFD water bodies. Where more than one biology site fell within a water body the final result was taken from the site with the most sensitive ASB. Where a water body had no biology site associated with it data was transposed from the nearest reach within the catchment with biology data that was of the same stream order (so assumed to be of a similar catchment size). Low confidence was assigned to all those waterbodies with transposed data.

3.2.2 Physical Typology

For full details of the physical typology please refer to Section 2 of the Sniffer report (Acreman et al., 2005). The classification is based on TWINSPAN analysis of macrophyte survey data collected at over 1500 sites nationally throughout the 1980s and early 1990s. The initial classification yielded 10 community types but this was simplified within the report to 8 types.
Correlations between the macrophyte community types and physical variables and Principle components analysis allowed the predictive physical variables to be identified. Confidence bands were latter assigned using a similar approach to that adopted for the macro-invertebrate typology.

3.2.3. Fish Typology

The fish typology enabled the assessment of the sensitivity to low flows in respect of fish community / river type. The general method for developing a typology follows that used in the FAME (Fish-based Assessment Method for the ecological status of European rivers) project and the Environment Agency flow criteria project (SC020112).

Derivation of the fish community typology was based upon flow guilds rather than on each individual species. The National Fish Population Database (NFPD) was interrogated and the samples classified based on the percentage abundance of salmon, trout, rheophilic cyprinids (B), eurytopic “a”, eurytopic “b”, barbel, grayling and rheophilic minor species. The samples were classified as followed.

Classification scheme:

I. samples with only brown trout recorded (validated by absence of rheophilic minor species);
II. samples with >50% salmon and trout as secondary species;
III. samples with >50% trout with salmon the next most common species;
IV. samples with >50% trout with rheophilic cyprinids and rheophilic minor species as next most common;
V. samples with >50% rheophilic cyprinids;
VI. samples with >50% eurytopic “a” species;
VII. samples where eurytopic “b” is dominant guild;
VIII. samples where grayling was the most dominant;

IX. samples that didn't match any of these criteria were assessed by the most dominant guild and the overall make-up of rheophilic versus eurytopic guilds and sorted into the most appropriate of the types above.

The eight fish community types were then translated into three abstraction sensitivity classes for the RAM framework (Table 2).

Table 2: Summary of translation of fish types into ASB sensitivity ratings and justification of classification.

Fish community type	Sensitivity rating	Justification
1) Salmon dominated	ASB 3 Highly sensitive	Salmonids are highly sensitive to the effects of reduction of low flows through abstraction - effects of dewatering and temperature increases
2) Trout dominated	ASB 3 Highly sensitive	As above
3) Trout + rheophils	ASB 3 Highly sensitive	As above - note this type covers the upper reaches of many east coast rivers which in being upper reaches of rivers are sensitive to abstraction.
4) Trout only	ASB 3 Highly sensitive	As above
5) Rheophilic cyprinids	ASB 2 intermediate sensitivity	Whilst still rheophilic these species are probably less sensitive to reductions in low flows than salmonids and often occur in habitats that are less susceptible to abstraction impacts.
6) Eurytopic "a"	ASB 1 lower sensitivity	Lowland eurytopic cyprinids have lower sensitivity to flow reduction and probably have a different response to flow reduction than rheophilic species.
7) Eurytopic "b"	ASB 1 lower sensitivity	This eurytopic guild is only found in very large lowland river reaches that are probably the least sensitive to flow reduction - although consideration must still be given to the effects of flow reductions in these reaches e.g. connectivity
8) Grayling	ASB 3 Highly sensitive	Predictions indicate that this community represents groundwater fed chalk streams (e.g. upper parts of Thames, Hull, Test, Itchen, and Hampshire Avon). These habitats are very sensitive to abstractions and are often covered by conservation legislation.

Analysing the abiotic characteristics of the fish monitoring sites enabled predictions to be made for sites with no data. Many of the WFD water bodies and sub-catchments for RAMv4 do not have any fish monitoring sites associated with them. A single assessment point for each body was therefore used to determine a fish-type and ASB class prediction using generated abiotic characteristics. Confidence of the prediction was also assigned based upon the probability of membership within a group. Given that the predictive models have some level of potential error associated with them, some ground-truthing of the GIS predictions was undertaken to fully validate the predictive sensitivity assessment.

3.2.4 Combining the scores to generate a final ASB

Once the 3 separate typology results had been generated or transferred so each water body had complete data a final ASB needed to be finalised. A matrix of results and their associated confidence from the 3 typologies was created and a number of rules were trialled to generate a final ASB for each water body.

The final ASB was then reviewed by local and National teams. Overrides could be applied to the generated data if they fell within certain guidelines.

3.3. Use of the EFI

The Environment Agency abstraction regime uses fixed 'hands-off flows'. These give a more effective use of water from the environment by enabling abstraction to cease at set flows, but also enable abstraction from periods of time when more water is available. The EFI is defined for four conditions, ranging from naturally low (Q95) to naturally higher (Q30) flows. To help manage abstraction at higher flows and protect flow variation greater percentages of flow is allowed to be abstracted. Table 3 shows the percentages of flow to be abstracted at three different sensitivities to abstraction (abstraction sensitivity bands) at different flows.

Table 3: Percentage allowable abstraction from natural flows at different abstraction sensitivity bands.

	high flow	→		low flow
Abstraction Sensitivity Band	**Q30**	**Q50**	**Q70**	**Q95**
ASB3. high sensitivity	24%	20%	15%	10%
ASB2. moderate sensitivity	26%	24%	20%	15%
ASB1. low sensitivity	30%	26%	24%	20%

The EFI is used in the hydrological classification for WFD to identify the water bodies where reduced river flows may be causing or contributing to a failure of good ecological status. This is called the compliance assessment. Compliance has been assessed at low flows (Q95) using recent actual (denaturalising the natural flow taking into account abstractions and discharges operating at their recent actual rate) scenario.

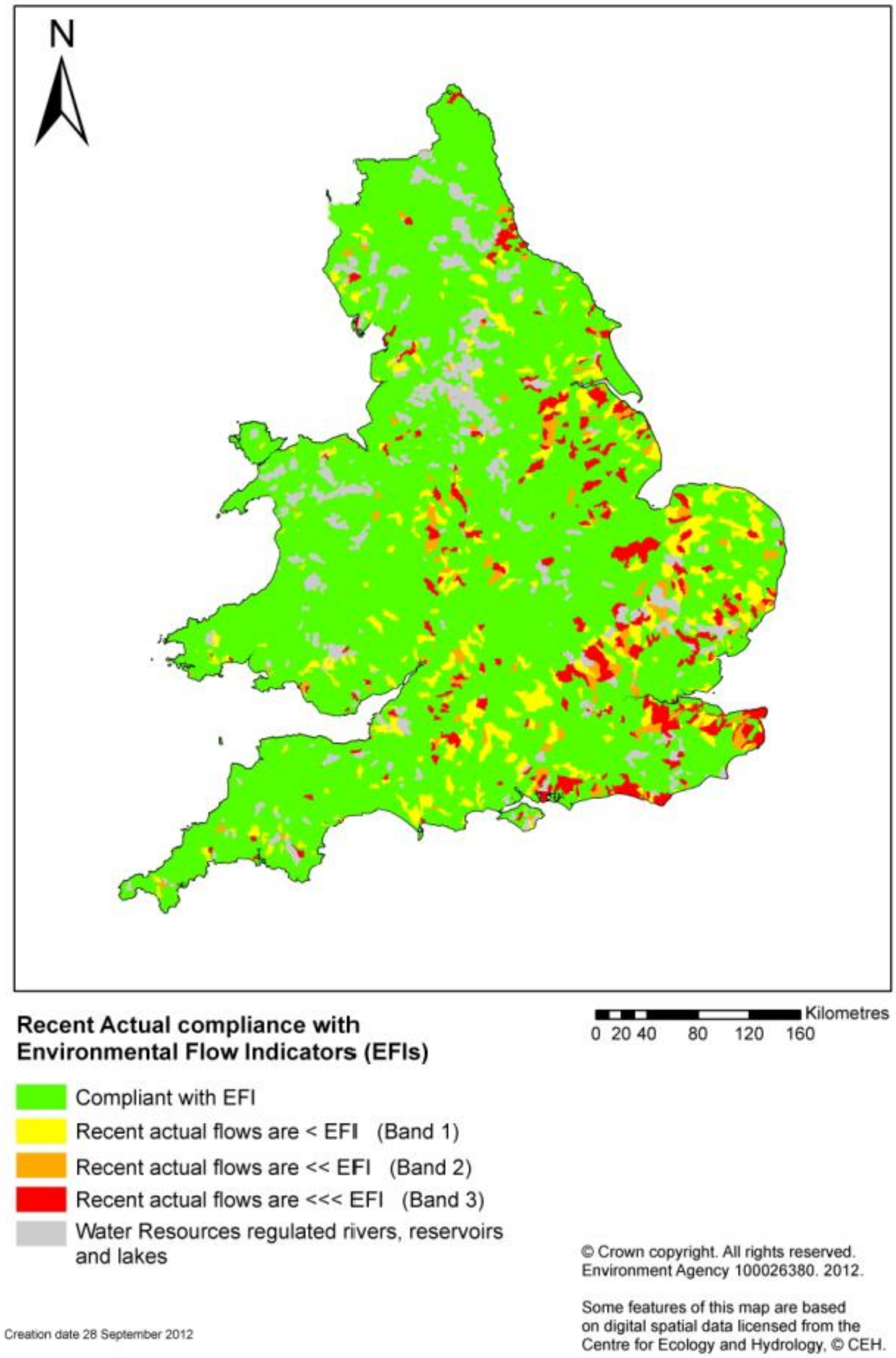
The compliance assessment shows where specific scenario flows are below the EFI, and indicates by how much. This is used to identify areas where flows may not be supporting good ecological status and target further investigation of what measures are needed to achieve good ecological status.

The degree of non-compliance has been split into three compliance bands, each band indicating the certainty that flow conditions does not support good ecological status. The compliance bands help to prioritise action where the abstraction pressure, and therefore the risk of not supporting good ecological status are greatest. The percentage below natural flow for each compliance band is shown in Table 4 and the compliance results mapped for each water body are shown in Figure 1.

Table 4: The percentage difference from natural flows for each compliance band and how this relates to supporting good ecological status (GES). Percentages given are the range below natural flow for the relevant abstraction sensitivity band.

	Flow adequate to support GES	**Flow not adequate to support GES**		
Abstraction Sensitivity Band	*Compliant with EFI*	*Non-compliant Band 1* (up to 25% below the EFI at Q95)	*Non-compliant Band 2* (25-50% below the EFI at Q95)	*Non-compliant Band 3* (more than 50% below the EFI at Q95)
ASB3. high sensitivity	<10%	<35%	<60%	>60%
ASB2. moderate sensitivity	<15%	<40%	<65%	>65%
ASB1. low sensitivity	<20%	<45%	<70%	>70%

Figure 1: Map of England and Wales showing compliance with the EFI at Q95. (September 2012 compliance figures).



Compliance against the EFI is only the starting point in determining whether measures for flow are required in order to support Good Ecological Status. Following the compliance results local teams have then undertaken investigations on non-compliant water bodies which have identified if, and what action is required.

3.4. Future Development

The current approach using the EFI will continue for the next round of River Basin Planning though it will be subject to a review as part of the environmental standards review planned for 2018.

This is to be linked with Government proposals to reform the Abstraction Licensing system in England and Wales – which includes examination of environmental limits used in abstraction licensing and how the balance between abstractors and the environment is to be managed into the future taking account of future pressures from climate change, and from an increased demand for water.

3.5. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows.

There are a number of learned lessons from the development and application of the EFI and previous flow objectives in Abstraction management in England and Wales. Some of these are detailed below:

- The use of a generic high level flow target is simple and allows for an effective management of licensed abstraction. However, comparing its application at the local level with local data and an evidence base can lead to it being considered as inaccurate or incorrect. Ideally a system needs to encompass both a simple methodology which can be used for permitting, but which has a better link to evidence and data which may be available locally.
- Application of any ecological target is strongly influenced on the hydrological methodologies to which it is applied. Hydrological tools often have error margins which are greater than 'allowable' deviations in an environmental target. Agreement of things such as a 'standard' period for flow naturalisation can make the difference between whether a particular flow is considered to be 'ok' or not.
- The use of ecological flow targets as strict standards can also be a challenging area. Applying set 'standards' can make the process very simple and transparent. However this doesn't recognise the uncertainties in application of standards at a local level and making them locally relevant. Where water is in abundant supply these uncertainties are less likely to be challenged. Where there is greater competition between water users and the environment there is usually a greater pressure for any control placed to be more precise. The use of local data and analysis to inform this becomes of higher significance.

4. Contact information

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Case study 13 (United Kingdom): “Eflows in the RBMP process”

1. Executive summary

Eflow are considered in the English river basin planning process. Generic national flow standards are used to generate classification results and screen to see which WBs require further investigation. When identifying measures and setting objectives a site-specific flow regime is identified to achieve environmental objectives in that WB.

2. General information

Member State(s): UK

RBD(s): All river, lake and transitional water bodies in England.

Location: National

Time period (start/end): since 2007

2.1. Objective of the Case study

To be able to easily produce classification results and identify where further investigation is needed without extensive resource, whilst considering eflows at a WB scale where measures have been identified as being required.

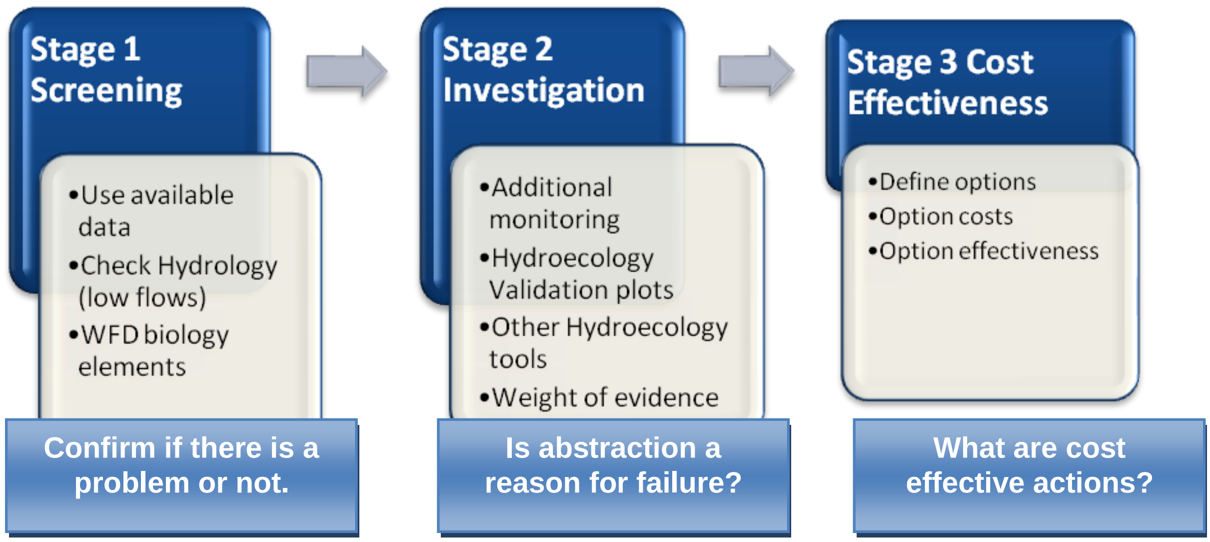
2.2. Policy and management context

Generic standards for required environmental flows for WFD have been agreed via UKTAG and with Central Government.

Assessments of compliance with these flow standards have been undertaken on a national basis with local operational input. Compliance results were used to generate classification results which are included in RBMPs and also communicated locally and nationally to stakeholders.

Local investigations to determine any ecological impact of flow classification result based on generic standards, and other ‘Reasons For Failure’ data have taken place. This follows the process outlines in Figure 1.

Figure 1: Water Framework Directive Investigation Stages for water bodies which are non-compliant for flow.

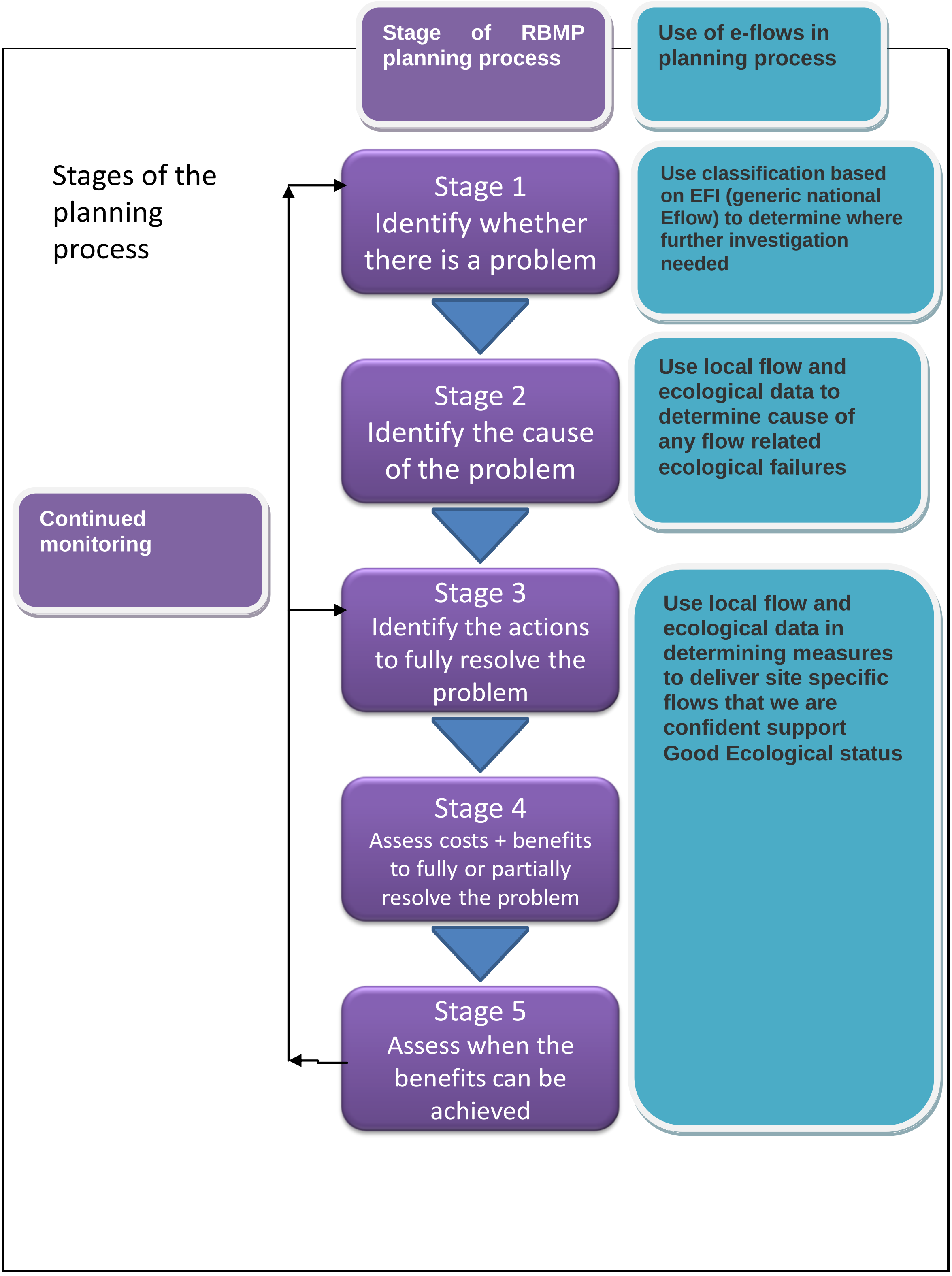


The WFD investigations which have been undertaken on flow non-compliant water bodies have thrown up a mix of results with some water bodies concluding that the current flow (even though non-compliant) is supporting GES, some where the failure of GES is supported and many where the evidence is inconclusive. This was the anticipated outcome and demonstrates the complexities with applying a high level target to local situations. The local analysis does provide more weight behind any need to undertake action on abstraction licences to move towards Good Ecological Status.

These local investigations have outputted local measures to agree and implement suitable eflows tailored to each WB. These proposed measures and have been considered as part of the RBMP objective setting process. The local measures are due to be implemented during the second river basin cycle or third cycle where there is appropriate justification. A flow chart demonstrating how eflows feed into the RBMP process is shown in figure 2.

Continued monitoring after measures have been implemented is planned to detect any change in status caused by the measures. This is intended to track ecological response to altered or improved eflow and give confidence that measures are effective. If no positive ecological response is identified then measures to alter or improve eflows further can be considered.

Figure 2: Stages of RBMP planning process with Eflow input



3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Tasks:

- Generation of generic compliance results with national scale eflow standards – undertaken by national EA teams.
- Local investigations, identification of suitable e-flow regime for each WB, measures to achieve this suitable eflow regime, measures assessment and measures implementation – led by local EA environmental planners with technical support from local EA ecologists and hydrologists. Local stakeholder groups also involved to agree and support measures.

3.2. Temporal and spatial scales

Compliance assessments and local data analysis have been undertaken 2011 – 2013. Local decisions taken 2013-2014.

3.3. Type of analysis or tool

Water Resource GIS (WRGIS) was developed to undertake national scale calculations of eflow compliance.

Various hydro-ecological tools were used in order to determine whether the lack of achievement of eflows was impacting ecology. These included Hydro Ecological Validation tools (see Annex I for more information).

Where flows were shown to be divergent from a suitable eflow regime and this was impacting the ecology, various methodologies were used to determine what a suitable eflow should be.

A more recent methodology for determining eflows downstream of HMWB impoundments has been developed by UKTAG. This includes consideration of different aspects of a natural flow regime and attempts to emulate these aspects in a modified flow regime.

3.4. Information and data requirements

To use WRGIS a number of datasets were required. These have been locally collated since 2007 and incorporated into a national dataset. This national dataset was used to calculate compliance with a standard eflow. This is easily reported.

This assessment was quick to do once local data had been incorporated and only looks at low flows. It does not take into account any more detailed information about the typology of the river and is a very broad brush screening exercise.

To undertake local investigations into these assessments and identify measures to achieve WB specific eflows, extensive local data was required. This included:

- Modelled and observed hydrological data relevant to the WB
- Observed ecological data relevant to the WB including ecological monitoring and River Habitat Survey data

Where only limited data was available, this led to less confidence in WB specific identified e flows. Identification of WB specific eflow and subsequent objective setting relies on predicting the ecological response to flow changes which can be uncertain.

3.5. Testing of results

Initial compliance with generic eflows were reviewed and updated according to local understanding.

Local investigations into non-compliance with generic were reviewed by national teams.

A comparison was undertaken comparing where generic eflows were not achieved to those WBs where investigations have shown that flows were impacting the ecology. This comparison showed that although there was overlap between the two datasets, the datasets were not identical and therefore comparison to generic eflows will not always predict where ecological impacts have taken place.

This analysis will be incorporated into the review of the generic eflow standards (the EFI) to see where it can be made more likely to be predicting where ecological impacts have taken place.

Additional ecological tools to predict where ecological impact may be occurring are also being developed.

3.6. Current application of the method/initiative

Measures based on national screening and local investigations are currently being assessed and may be implemented in the next river basin cycle.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The initiative can be replicated in other areas. Initial national screening used generic eflow standards requires a considerable initial local resource input to review and record flow and artificial influence data over a number of years before screening can be undertaken.

Local agreement with stakeholders is vital in agreeing a suitable WB specific eflow and deifying, assessing and implementing measures to achieve this.

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Case study 14 (France): “Rhone flow restoration”

1. Executive summary

The physical restoration of the French Rhône River started in 1999 and has combined so far minimum flow increases (by a factor up to 10) in four reaches bypassed by artificial channels (total length 47 km) and the dredging and/or reconnection of 24 floodplain channels.
Due to the original characteristics of the Rhône restoration at the international level (strong physical changes in multiple sites; data-rich situation before and after restoration; collaborating stakeholders) the project was a unique occasion to test quantitative ecological predictions.
This case study provides evidence of the effects of flow restoration on habitats, fish and invertebrates in multiple sites. Observed changes confirmed quantitative predictions. The case study also provides general lessons in terms of monitoring strategies, social processes associated with the restoration, effects of restoration in a context of global warming, and effectiveness of bioassessment tools.

2. General information

Member State(s): France

RBD(s): Rhone

Location: French Rhone

Time period: 1999-2014

2.1. Objective of the Case study

The original objective was to recover the characteristics of a large river and a diverse floodplain, an objective that is consistent with others that appeared during the project (evolution of the national legislation and WFD).

2.2. Policy and management context

The Rhône River is managed by the "Compagnie Nationale du Rhône", a public organism whose private share has largely increased. The restoration project resulted from a combination of national, regional and local initiatives (and funding). The monitoring is now part of a regional "Rhone Scheme".

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Minimum flow increases in four reaches bypassed by artificial channels (total length 47 km) and the dredging and/or reconnection of 24 floodplain channels. Some of the reaches are HMWBs, others are not.
The restoration is ongoing and the measures will finally concern a total of eight reaches distributed along the French Rhône River (total length ~120 km)

3.2. Temporal and spatial scales

~120 km of the French Rhone at different sites
Restoration started in 1999. Monitoring (physical data, fish invertebrates) spans 1985-2014.

3.3. Type of analysis or tool

Hydraulic Habitat modeling, generalized habitat models, social analysis

3.4. Information and data requirements

This case study occurred in a data-rich context (physical and biological data).

3.5. Testing of results

Changes in densities of fish and invertebrate taxa were significant and generally well predicted using generalized habitat models (eg Lamouroux & Olivier, in press; Mérigoux et al., in press). WFD indicators showed mixed responses depending on the restored site.

3.6. Current application of the method/initiative

Lessons from the flow restoration are already available and the restoration is ongoing

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

This case study (described in Lamouroux et al., submitted to Freshwater Biology) provides evidence of the ecological effects of flow restoration and their predictability (habitat modelling for fish and macroinvertebrates). It provides other general lessons:

* monitoring strategies: a power analysis (Vaudor et al., in press) quantified that several biological surveys before and after restoration are needed to increase the power of detecting changes. Typically >4 surveys distributed over several years before and after restoration were needed to have a chance of detecting population-level changes. These results support the idea of sustained monitoring in selected flow experiments across Europe (see also Olden et al., 2014).

* social processes show commonalities and differences among restored sites, and illustrate the interactions between the local and national levels.

* effects of restoration occur together with effects of warming in some sites, supporting the need for controls or equivalent.

4. Contact information

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5. References

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Case study 15 (EurEau): "Implementing eflows in a drinking water reservoir (example of the Aabach Reservoir)"

1. Executive summary

The management of drinking water reservoirs is a complex task of water quantity and water quality aspects. About 10 % of the drinking water supply in Germany origins from reservoirs, mostly in mountainous regions, where groundwater extraction is not possible. Due to that fact, the security of water supply for 8 Mio. inhabitants was (and still is) in the main focus of reservoir operation. With introduction of the German standard specification for dams (DIN 19700) and the Water Framework Directive (2000/60/EC) (WFD) also other aspects like the ecological status of the downstream reaches are becoming more important.

In this context, the usual practice of releasing a low constant outflow to meet minimum ecological requirements has to be discussed. On the one hand, the necessary requirements for the ecological flow (eflow) are to be defined. On the other hand, eflows can (but not always) be in contradiction to other tasks of the operation of drinking water reservoirs, e.g.:

1.) Due to the lack of groundwater resources in the rocky mountainous regions, drinking water reservoirs do often have no other backup sources. During the last decades the water consumption per capita was reduced down to 120 liter per day in Germany. The total losses in the drinking water networks were reduced to less than 7 %. In summary, often no other sources than the reservoir volume itself can be mobilized for the necessary eflows. This can affect the security of the drinking water supply in a whole region.

2.) The management of the drinking water reservoirs is also determined by water quality aspects. During the summer period, the reservoir is thermally stratified. The raw water should usually be extracted from the hypolimnion to meet acceptable conditions for the water purification. To avoid a collapse of the hypolimnion, typically the reservoir volume should not be lowered under a certain water level. This important boundary condition for producing potable water limits the degree of water release for other purposes.

To overcome these problems (besides others), several attempts were set up for several drinking water reservoirs. One of the most elaborated case studies is the application of eflow at the Aabach Reservoir in North-Rhine Westphalia, Germany.

A variety of field tests were conducted to find the basic requirements for the eflow. During the field tests, the local flow pattern as well as the behaviour and development of trouts and macrozoobenthos were analysed. On this basis, a concept for the necessary eflow was developed and tested also on site. The flow pattern can strongly be influenced by hydromorphological measures. Especially the placement of woody debris supports the effect of eflows. The final design of eflows and hydromorphological measures was completed in 2004. As a result, the population of trouts could be doubled within one decade. Coupling of eflow (seasonal variable and near to nature floods) with hydromorphological measures helps to reduce the demand of water for the eflow to only 10 % of the available mean annual water resources in the Aabach catchment. This examples shows, how eflow can be established without reducing the security of water supply of a drinking water reservoir under the normal spread of hydrological conditions. During extreme dry situations, like the winter and spring period in 2014, the delivery of drinking water still has to be preferential, otherwise the security of the water supply for the affected inhabitants have to be reduced unduly.

2. General information

Member State(s): Germany

RBD(s): Rhine

Location: Bad Wünnenberg, North-Rhine Westphalia, Germany.

Time period: 1991 - 2004.

2.1. Objective of the Case study

The overall aim of the project was the development of an integral management plan for all functions of the Aabach Dam. One main topic was the application of a sufficient concept for eflows downstream the Reservoir and its connection to the other tasks of the reservoir like water supply security and flood protection. First analyses of the fish population, especially trouts, showed, that the conditions for a stable population were not given. The monotonous flow pattern and dynamics in the river sections impeded the self-reproduction of fish stocks. Therefore a method had to be developed to determine the necessary eflow to support the self-reproduction of fish and to increase the habitats for macrozoobenthos. In order to keep a high standard for the water supply security, the amount of water for the eflow cannot be exceeded over certain limits. To bridge that gap, further measures for much better hydromorphological conditions have to be identified and analysed.

2.2. Policy and management context

Besides technical specifications the German standard specification for dams (DIN 19700) contains also ecological aspects of dam operation. The need of a dynamic minimum flow to retain the ecological function of the downstream river is mentioned. Methods and examples how to determine the dynamic minimum flow requirements are not described in the standard specification.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The investigation was split up into four phases. In phase I, a preparative study was conducted over two years. Water was released from the reservoir in a range from 20 l/s up to 3000 l/s. The effect of the different water releases on the biota and the physical-chemical condition in the downstream sections of the Aabach river was measured. Additionally, the structural quality of the water bodies was examined.

In phase II an operational model for the necessary eflow was developed. The aim was to meet the typical seasonal flow pattern of the river catchment and to estimate the effect on the biota and the hydromorphology in the downstream river sections. A fixed artificial flush was designed to investigate the large-scale effect of a dynamic flow release. The developed concept of eflow was tested for a sufficient security of drinking water supply with the help of long-term reservoir simulations.

The fixed artificial flush was refined to an artificial flood wave in phase III. If the flood flush is coming too fast, fish damage can occur. To avoid this, the shape of the artificial flood wave is oriented on the potential natural flood behaviour of the Aabach catchment and allows fish and macrozoobenthos to reach stagnant water zones right in time. In the earlier phases of the project, the important role of local flow diversity on the biota was recognized. To determine the positive effect of local flow diversity quantitatively, deadwood was placed in a river section of a length of 90 m. The conditions of hydromorphology, especially the structural quality of the water body, were mapped during and nearly half a year after the installation of woody debris. Also the water quality (saprobic index) and the fish population (electric-fishing) were measured in the same time periods. The results show, that the developed design of eflow together with the placement of woody debris has significant positive effects: The structural quality of the water body was improved by one level. The saprobic index was increased from class II (moderately polluted) to class I-II (slightly polluted). Even in the short period of monitoring the population of trouts could be increased significantly.

In the last phase IV, the developed eflow was continued and further hydromorphological measures were designed, especially on sites along the downstream river with poor ecological conditions. Also a final inventory and evaluation of the hydromorphological and biological state of the river was carried out.

3.2. Temporal and spatial scales

The Aabach Reservoir in North-Rhine Westphalia, Germany, serves for drinking water supply and flood protection. The height of the dam is 45 m and the total volume is 20.5 Mio.m³. A volume of 17.5 Mio. m³ is dedicated for the drinking water supply of about 200 000 consumers. The remaining volume of 3 Mio. m³ is reserved for flood protection. The total catchment of the reservoir covers an area of 35 km². The examination area to study the effect of eflow was extended over a length of 20 km downstream of the Aabach reservoir. The study started in 1991 and was completed in 2004. After the end of the project check studies are conducted nearly every year.

3.3. Type of analysis or tool

The main method for the investigation was testing the effect of eflow in the field. During several test phases with different flow releases from the reservoir the effect on flow pattern (flow measurements), macrozoobenthos (comparable method prior to ASTERICS/PERLODES) and fish (electric-fishing) were studied. The methods were also applied during the monitoring phase of testing the developed eflow and the placement of woody debris. The hydromorphological status of the river was calculated by assessing the structural quality of the river sections (e.g. LANUV working sheet no. 18). To study the hydraulic effect of the different measures, several approaches (e.g. GIPPEL et al., 1996) were implemented in the hydraulic model STAU from Braunschweig University. Hydrological reservoir simulations were carried out with the model WinMBM.

3.4. Information and data requirements

No additional sources of data were required for this study.

3.5. Testing of results

In the last phase of the project, the developed eflow was tested with a final inventory and evaluation of the hydromorphological and biological state of the river. The effect of eflow is still under review with the help of the regular WFD-monitoring program. The monitoring for the lower Aabach stream section shows the following results:

The ecological status of the parameter fish has been measured with the method FibS (INSTITUT FÜR BINNENFISCHEREI e.V., 2008). It has increased from moderate in 2010 to good in 2013. The ecological status of the parameter macrozoobenthos (ASTERICS/PERLODES) is still moderate, but already nearby the value good. Here also other effects like the material of the riverbed are influencing the evaluation. The status of macrophytes and phytobenthos were also improved from unsatisfactory to good/very good and from unsatisfactory to moderate respectively.

These results show that a monthly varying minimum discharge together with an artificial flood during autumn and accompanying hydromorphological measures in the downstream river sections can increase the ecological status of the river significantly. The water demand for the necessary eflow covers only 10 % of the available water resources in the Aabach catchment and does not endanger the security of water supply in quantity and quality.

3.6. Current application of the method/initiative

The developed eflow concept for the Aabach Reservoir is in operation since the completion of the study in 2004.

Due to the importance of the sometimes concurring tasks eflow, flood protection and drinking water supply, the Association of Drinking Water from Reservoirs (ATT), a non-profit association of reservoir operators in the Federal Republic of Germany and the Grand Duchy of Luxembourg, has developed a guideline for the Integrated Management of Drinking Water Reservoirs (2009). The appropriate consideration of eflows is one main topic in this guideline. Beside the Aabach Reseroir case study, two other examples for good practise are given.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The study of Aabach Reservoir shows, that it is possible to combine competing tasks of reservoir management like drinking water supply and eflow. Establishing an appropriate concept of eflow can also be in accordance to the needs for a secure drinking water supply. For example, the usual practice of a constant water release throughout a year can lead to relatively high water flow during the summer period and puts additional stress to the management of the hypolimnion. In many cases the concept of eflow could allow the reduction of water releases during dry periods in accordance to the natural flow conditions in the catchment. The reduced water withdrawal could help to protect the hypolimnion during the critical time in the late summer.

The coupling of eflow with hydromorphological measures like the placement of woody debris shows a very high potential for reaching good ecological conditions in the downstream sections of a reservoir. With the help of these additional measures and a smart design of eflow (e.g. seasonal changing releases and near to nature flood events), the demand of water for an appropriate eflow can be minimized. The case study of Aabach Reserervoir shows, that an eflow of only 10 % of the available mean annual water resources can already be sufficient. During extreme dry situations beyond the normal spread of hydrological conditions (e.g. the winter and spring period in 2014) the delivery of drinking water still has to be preferential, otherwise the security of the water supply for the affected inhabitants have to be reduced unduly.

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5. References

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Case study 16 (Eurelectric): “Granö case study”

1. Executive summary

A recommendation for ecological flow in a 2.5 km river stretch at the Granö hydropower plant has been developed based on hydraulic simulations. The purpose of the ecological flow is to provide good spawning conditions for salmon and sea trout.
The simulations provided water depths and velocities throughout the stretch, and areas were classified according to criteria for habitat classes using Froude numbers, which describe the relationship between depth and flow. The method was verified by in-situ measurements in the same river stretch. Based on the simulations, a recommendation of a flow of 2.3 m^3/s was established, which provides a combination of close to optimal conditions for spawning, and a high cost-effectiveness. This level is a base flow, and should potentially be combined with flow peaks, especially in the migration season. Flow peaks will be designed in terms of magnitude, frequency etc. in the next steps of the restoration process of the old river bed.

The most important conclusion of the study is the existence of a peak in the relationship between flow and area of suitable habitat, a flow above which more water is not favourable (with this specific purpose). The reason is that the water depth and/or flow velocity become too high to fit the criteria for salmon/sea trout spawning grounds.

2. General information

- Member State(s): Sweden
- RBD(s): River Mörrumsån
- Location: Granö, Blekinge County, Sweden.
- Time period (start/end): 2013-04-01 – 2013-10-01

2.1. Objective of the Case study

The method used for suggesting an ecological flow at Granö illustrates a practical process for setting a flow based on ecological effect and cost-effectiveness, in cases where the purpose of the ecological flow is to create favourable hydraulic conditions for given aquatic species. In this particular case the objective is focused on salmonid fish species, if the goal is aquatic ecosystems in its entirety, other types of analysis may be required.

The flow of River Mörrumsån has been diverted for power production at the Granö hydropower plant since the plant’s construction in 1959. A release of 50 l/s in combination with 6 weirs creates impoundment lakes and ensures that the 2.5 km stretch bypassed by the canal does not run dry.

The river stretch has potential spawning grounds for salmon and sea trout, but they would require a larger flow and physical restoration in order to reach their potential. A need for restoring the potential of the spawning grounds have been triggered by a recent decision to build fish passages at downstream dams, enabling migration access between the sea and the Granö stretch. Hydraulic simulations have been carried out to provide input to the establishment of an ecological flow for the stretch.

3. Detailed information

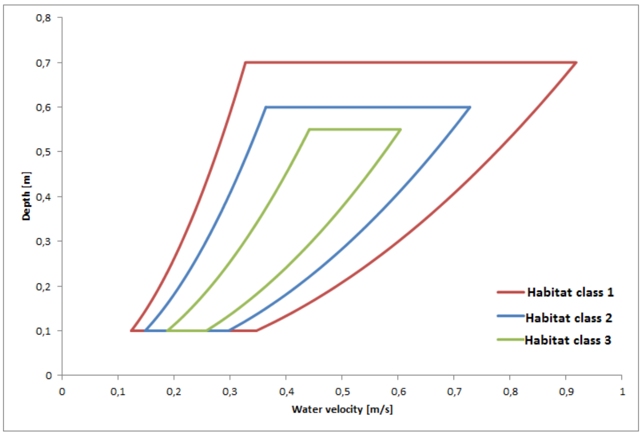
3.1. Practical Tasks (in case of methods and/or procedures)

The process of evaluating different flows was based on hydraulic habitat simulations in the river section.

Habitat classification was done using Froude numbers to describe the relation between water depth and velocity, with three habitat classes (corresponding to standardized habitat classification in

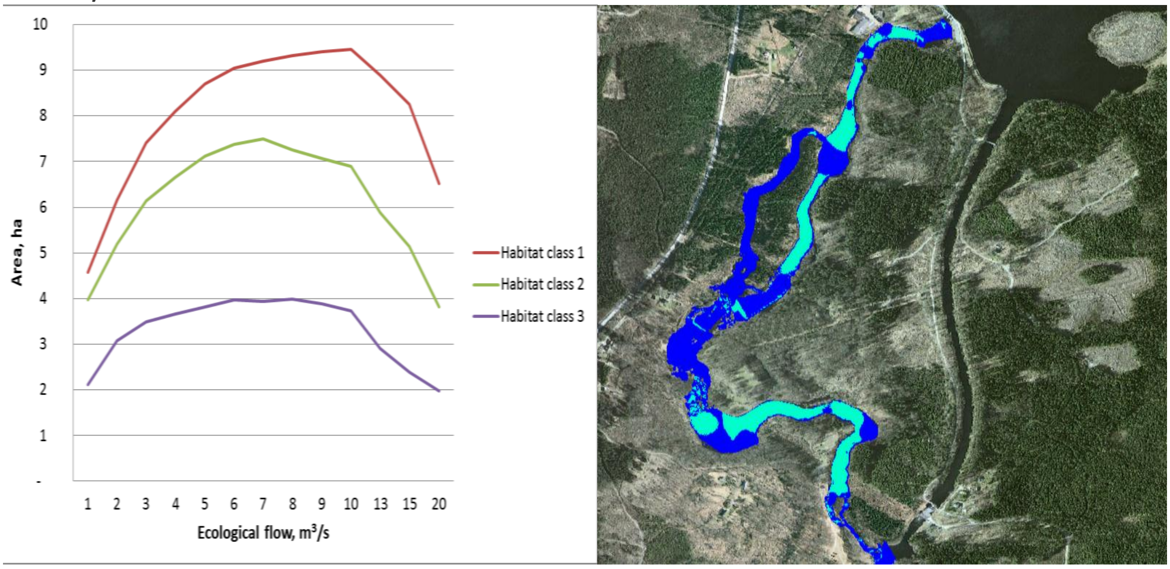
Sweden). A similar approach has been used in, for example, the Okanagan River in Canada (Long, 2009) and the Girnock Burn in Scotland (Moir, 1998).

Figure 1. Habitat classification using Froude numbers for hydraulic criteria. Higher number indicates better conditions.



Simulations were carried out for a water flow of 1 – 20 m^3/s. The mean annual minimum flow at this point of the river is 9.5 m^3/s. The graph below presents the habitat classes resulting from different flow levels, along with a map indicating habitat classes 2 and 3 at a flow of 2.3 m^3/s.

Figure 2. Graph of results of the hydraulic simulations (left) and example of distribution of habitat class 2 + 3 at 2.3 m^3/s



A peak was identified at 7 m^3/s, flow releases above this result in increasingly large areas with higher water velocities and depths than ecologically desired. At 2.3 m^3/s, the resulting potential spawning area was around 75% of the maximum, making a flow of 2.3 m^3/s a very cost-effective alternative. Any flow higher than this has a large marginal cost for additional ecological benefit.

3.2. Temporal and spatial scales

The spatial extent of the ecological-flow study is limited to the 2.5 km river stretch from Granö dam to the tailrace outlet below the power house. After this point, there is no water diversion from the river, and since the power station operates on a run-of-river basis, there are no hydrological-regime impacts from the Granö plant downstream of this point.

The Granö hydropower plant has an installed capacity of 9 MW, with a head of 19 m. The average annual generation is 32 GWh, and the mean annual river flow is 27 m^3/s. The ecological flow is to be applied on a permanent basis, with seasonal flow changes as deemed necessary.

3.3. Type of analysis or tool

Using data from the Swedish Land Survey[1] to set up an elevation model, 2-dimensional hydraulic calculations were carried out in TeleMac2D. The calculations result in water depth and velocity in a grid with spatial resolution 2 m.

3.4. Information and data requirements

The hydraulic simulations are based on elevation data and the roughness of the bottom substrate in the river stretch. The roughness can, to an acceptable level of detail, be analysed from satellite imagery, but field studies and inventories provide better data.

In water-filled sections, bottom micro-topography cannot be derived from remotely-sensed data. For such sections the elevation model must, therefore, be adjusted based on field studies or sonar surveys for longer stretches.

3.5. Testing of results

The method and the results for Granö have been verified by in-situ measurements and habitat classification, conducted for small sections of the same river stretch. The same habitat classes were used, with good coherence between the measurements and the simulations. Compared to measurements and manual habitat classification, the simulations can assess the entire stretch with very limited resources.

The applied method has proven useful and reliable based on the validations. It has given a possibility to evaluate flow levels expressed as size of spawning grounds for the target species at various flow releases.

3.6. Current application of the method/initiative

Similar simulations have been carried out for a number of small- and large-scale hydropower stations in Sweden. An ecological flow is planned to be released at the Granö hydropower plant starting in 2018 (when downstream fish ladders will be ready, and thus motivate the release of the ecological flow).

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The most important conclusion of the study is the existence of a peak in the relationship between flow and area of suitable habitat, a flow above which more water is not favourable (with this specific purpose). The reason is that the water depth and/or flow velocity become too high to fit the criteria for salmon/sea trout spawning grounds.

A distinction should be made between aiming to restore to natural conditions, and optimising the area of potential salmonid spawning grounds in the river stretch under study. As a result of the dams and reservoirs, River Mörrumsån, like most regulated rivers, has large areas of former spawning grounds now located in deeper, slow-moving waters. On the other hand, the studied section at the Granö power station is steeper and used to be rapids with conditions too turbid for salmonid spawning.

The simulations show that by limiting the flow to 8 – 25% of the annual mean flow, water velocity and depth combine to create optimal conditions for salmon and sea-trout spawning in this section. Based on the simulations, at 2.3 m^3/s approximately 5.5 ha of good habitat (class 2 and 3) is produced, and at 7 m^3/s the maximum of 7.5 ha is produced.

[1] Lantmäteriet

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5. References

Long, K, Newbury, R. 2009. Using hydraulic characteristics of sockeye salmon spawning areas in designing the Okanagan River restoration project. 105th Annual Meeting of the Cordilleran Section, Geological Society of America, May 7-9, 2009. Kelowna, British Columbia.

Moir, H.J., C. Soulsby and A. Youngson. 1998. Hydraulic and sedimentary characteristics of habitat utilized by Atlantic salmon for spawning in the Girnock Burn, Scotland. Fisheries Management and Ecology.

Case study 17 (Netherlands): "Minimum discharge at the Common Meuse"

1. Executive summary

2. General information:

Estimation of the ecological effects of minimal discharges based on a River Habitat Simulation Model (RHASIM).

Member State(s): Netherlands

RBD(s): Meuse

Location: Border Meuse/Common Meuse. Time period (start/end): 2006

2.1. Objective of the Case study

The study shows the effect of various flow regimes on the quality of habitat of an indicator species that has been affected by different pressures, among others strong, unnatural alterations in the hydrological regime. These consequences are expressed in a habitat suitability index in terms of "area of suitable surface per species or development stage."

2.2. Policy and management context

The Common Meuse is characterized by high fluctuations in natural run-off, combined with abrupt fluctuations due to the lack of coordination between the management of water level and operation of hydropower plants upstream in the Meuse catchment. Discharge is divided amongst Flanders and the Netherlands, laid down in the Meuse Discharge Treaty between both countries, signed in 1995. The national competent authority – Rijkswaterstaat – effectuates water division conform the treaty (see table 1): during common low flow periods the minimal discharge of 10 m3/s is guaranteed; however in case of extreme droughts, it has to drop below.

Table 1: Discharges agreed in the Meuse Discharge Treaty

Meuse discharge [m3/s]	Flemish use [m3/s]	Dutch use [m3/s]	Discharge Common Meuse [m3/s]
130	35	35	60
100	25	25	50
60	25	25	10
30	10	10	10
20	6,7	6,7	6,7

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The Common Meuse is a section of the Meuse that forms the border between the Netherlands and Belgium. It has been designated as protected area under the Habitat Directive. The river has large potential for morphologic development. As this river section is non-navigable, no channel maintenance takes place, meaning that free shore erosion and sedimentation may trigger morphological processes. This augments the diversity of habitat environment and increases the potential for characteristic species – in short, it has a positive effect on the ecological quality of the Common Meuse.

On the other hand, in the vicinity of the Common Meuse many human activities are taking place, with high economic and social value, namely industry, agriculture, horticulture, energy plants, drinking water production, etc. All these activities require certain water quantities. During periods of low discharges the demand for water exceeds largely the water supply: water supply is under pressure. The supply required by different users has to be cut down, which causes large damage. The nature in the Common Meuse is one of the stakeholders and, like for all other stakeholders, the water supply for it has to be reduced. Rijkswaterstaat tries to supply the nature with sufficient water, but when the available discharge is to low, also the nature suffers due to the unsufficient discharge. However, even worse than low discharges are abrupt, unnatural discharge fluctuations due to the lack of coordination between the management of water level (for the navigation) and the operation of hydropower plants upstream in the Meuse and her tributaries. They cause enormous fluctuations: within an hour the discharge can rise from less than 10 m^3/s to more than 160 m3/s, exceeding largely the fluctuations caused by rainstorms. These fluctuations cause drift of macro invertebrates and juvenile fish, and drowning of organisms living on dry shores close to the water course.

3.2. Temporal and spatial scales

The temporal scale has been determined by the indicator species life cycle. This means that both a monthly and an annual scale have been incorporated.

The spatial scale is demarcated by the size of the river stretch: around 40 km. Abiotic conditions are set per grid cell by 5 x 20 meter.

3.3. Type of analysis or tool

The River Habitat Simulation Model (RHASIM) generated objective and quantitative information relevant for determining minimal discharge acceptable for the nature. The model shows the effects of low flows on the extent of suitable habitat surface for target species. The results should be interpreted as a relative index, meaning that the added value can mainly be found in the comparison of discharge regimes. The target species in this study is the barbel fish. All life stages of the barbel have been incorporated. If discharge is modified, many factors determining the quality of habitat also change.

The main indicators for the quality of habitat are part of the RHASIM: flow velocity, water level and substrate quality.

The outputs are applied in GIS for the spatial analysis. The comparison of total area of suitable habitat shows the thresholds for the target species. Additional information (other methods and field data) allow to reach the desired insights in appropriate minimal discharges.

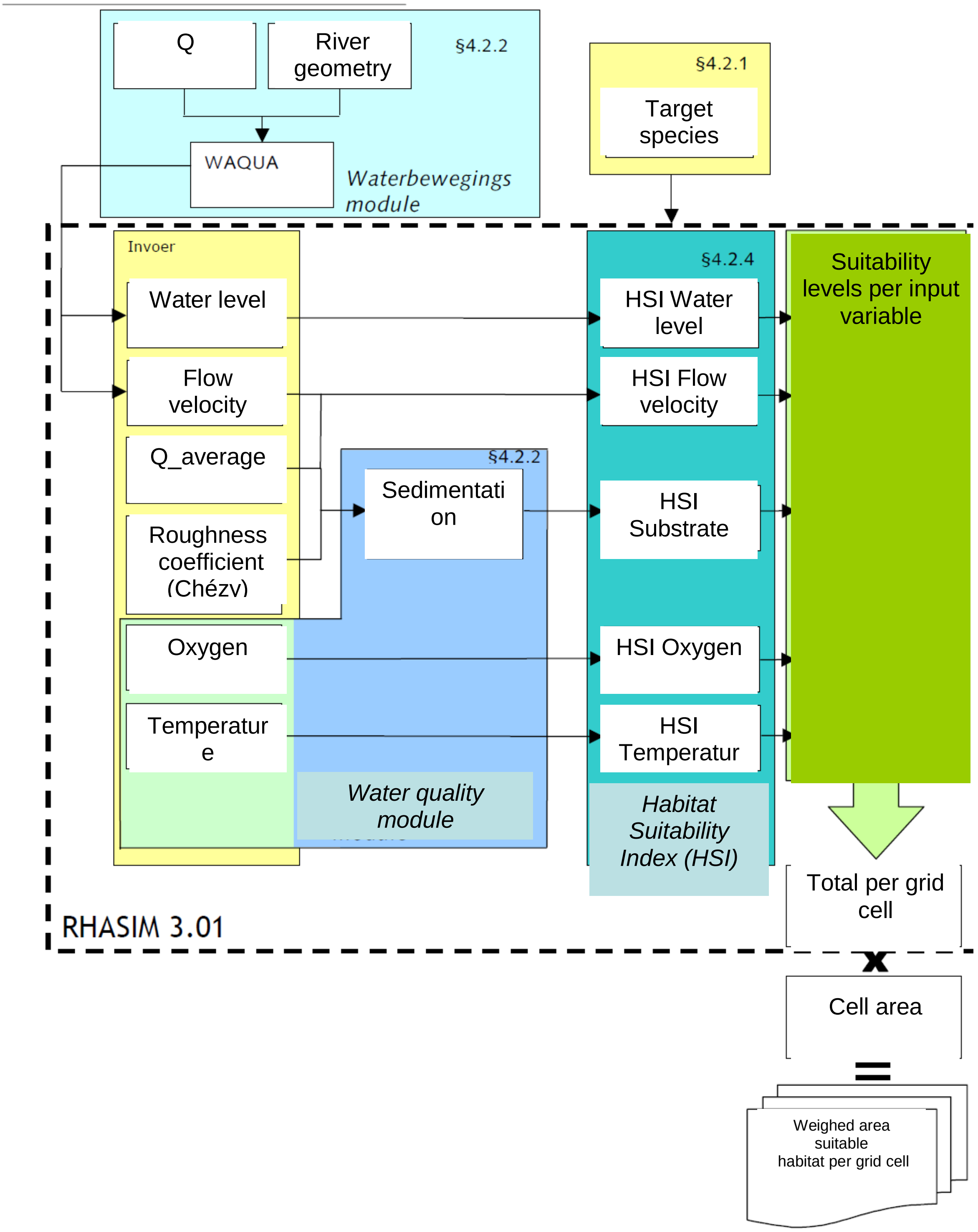
3.4. Information and data requirements

The RHASIM consists of three components:

- A discharge module
- Water quality module
- Habitat Suitability Indices.

An overview of the data requirements can be found in figure 1.

Figure1: data requirements for river habitat simulation model application



3.5. Testing of results

The reliability of the model has been researched in four steps:
- comparison with on-site situation,
- statistical sensitivity analysis,
- discharge model reliability check,
- comparison and completion of information by use of additional methods.

This reliability analysis has indicated that the model structurally overestimates the area of suitable habitat, for each stage of the target species life cycle. Spawning area, however, has been well indicated.
In terms of location, the model shows output that is well in line with on-site measurements.
Many of the flaws of using the habitat method can be neutralized by combining the output with on-site information and, for example, the wet-perimeter method.

3.6. Current application of the method/initiative

The insight in the target discharge for the full benefit of the ecologic potential in the Common Meuse has largely improved. As a matter of fact, the study gave a scientific confirmation of water division scheme incorporated in the Meuse Discharge Treaty based on expert judgment. The implementation of the treaty, has resulted in an enormous improvement of seasonal flow regime for the nature.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

General conclusions:
The combination of applied methods led to the best results. Experts on the local level deal with internal conflicting objectives – even within target species. The clear output of the used method could be used as a starting point for transboundary cooperation.

Conclusion on the results:
The applied method offered good insight in the effects of minimal discharges on the ecological quality of a river expressed in Habitat Suitability Index for target species.

4. Contact information

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Case study 18 (Spain) “Methodology for e-flows assessment”

1. Executive summary

When facing the works for the new RBMPs under the WFD –conscious of the strategic role of e-flows in the achievement of environmental objectives, particularly critical in water scarce basins–, the former Spanish Ministry of Environment decided to incorporate the technical and scientific expertise developed so far to provide greater robustness to e-flows regimes.
The Spanish technical approach has demonstrated to be consistent for dealing with environmental water allocation at RB scale, starting from an improved knowledge of hydrological cycle and the functioning of aquatic ecosystems.

2. General information

Member State(s): Spain

RBD(s): ES010 Minho-Sil; ES014 Galician Coast; ES017 Cantábrico Oriental; ES018 Cantábrico Occidental; ES020 Duero; ES030 Tagus; ES040 Guadiana; ES050 Guadalquivir; ES060 Andalusia Mediterranean Basins; ES063 Guadalete and Barbate; ES064 Tinto, Odiel and Piedras; ES070 Segura; ES080 Jucar; ES091 Ebro; ES100 Internal Basins of Catalonia

Location: all surface water bodies (river and transition type) of mainland Spain

Time period: since 2007

2.1. Objective of the Case study

This case study will display the combination of technical tools that have been used for the assessment of e-flows in Spain.

2.2. Policy and management context

The requirement to incorporate environmental flows in the RBMPs was already contained in the Water Act of 1985. The first Spanish river basin management plans, approved in 1998, used a very simple approach based on the establishment of a static minimum flow that was generally estimated as a percentage of the natural discharge in the river stretch.
When facing the works for the new RBMPs under the WFD –conscious of the strategic role of e-flows in the achievement of environmental objectives, particularly critical in water scarce basins–, the former Spanish Ministry of Environment decided to incorporate the technical and scientific expertise developed so far to provide greater robustness to e-flows regimes. An Expert Group (EG) was launched to substantiate the methodologies to be applied, whose conclusions became the basis for the e-flows contents in the Hydrological Planning Regulation (HPR approved by Royal Decree 907/2007).

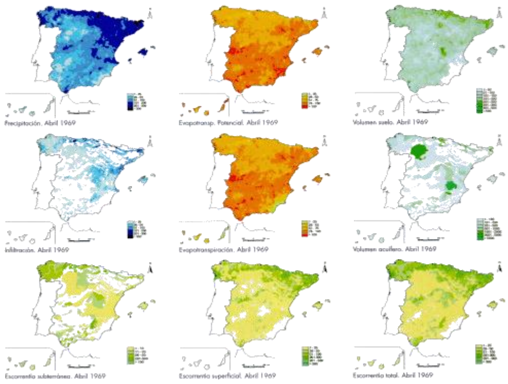
3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

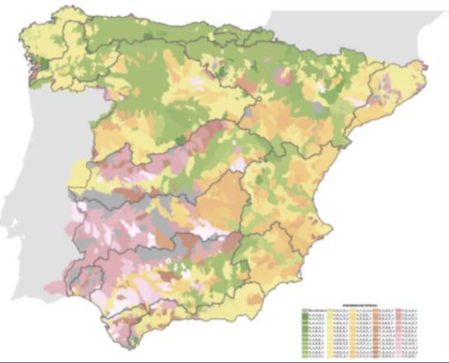
For the implementation of the methodologies developed by the EG, public tenders were called so that some private companies specialized in water engineering and environment. The former Ministry of Environment coordinated the works in the inter-community River Basin Districts (RBDs, those including land from more than one Autonomous Community) pararelly with the River Basin Authorities (RBAs) and the technical support of the Centre for Public Studies and Experimentation (CEDEX). Intra-community RBDs have developed their own works under similar conditions.

The methodological approach is based in the Instream Flow Incremental Methodology (IFIM), which integrates concepts of water-supply planning, analytical hydraulic engineering models, and empirically derived habitat-versus-flow functions. The main tasks involved are summarized as follows.

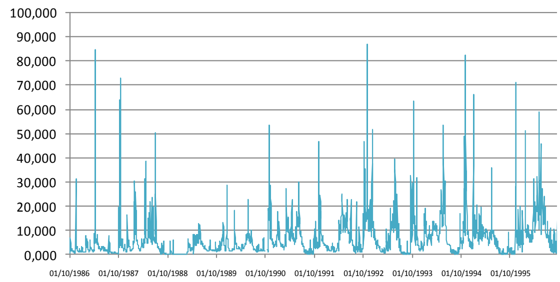
Water resources assessment, which has been primarily made with the SIMPA model at a national scale, obtaining monthly series. This model has been developed by the Centre for Hydrographic Studies (CHS) of the CEDEX, dependant on the Ministry of Public Works.
Other RBDs have used alternative rainfall-runoff models as PATRICAL in Jucar RBD and TETIS (on a daily basis) in the Basque Country. These models use distributed information on soil and climate parameters and offer time series of runoff at any point of the drainage network.



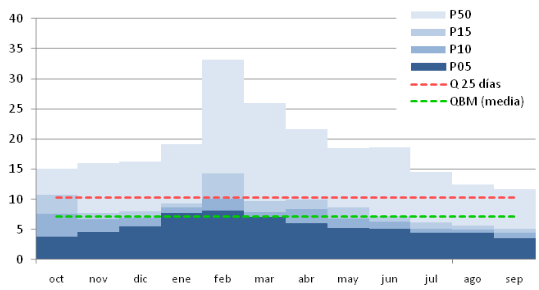
Hydro-regionalization carried out by CHS on the basis of SIMPA datasets, with the objective of grouping sub-basins with similar hydrological patterns. This similarity has been taken into account as a representative criterion for the selection of surface water bodies (SWBs) for habitat modelling and also for extrapolation purposes.



Building of daily series under a natural regime, by modifying monthly data by using statistical distribution patterns obtained by different methodological approaches, starting from non-altered gauging stations located nearby or in similar hydro-regions.



A pack of hydrological methods has been applied to all the river-type SWBs, including QBM (Basic Maintenance Flow), Q25d (lowest mean flow value found in the year for a group of 25 consecutive days) and significant percentiles of the classified flow series.



Assessing hydrological alteration by comparing, when possible (available gauging station), natural and altered series by means of the tool IAHRIS which calculates and combines up to 21 different hydrological indexes, to determine SWBs with a severe degree of distortion on natural flows, so anticipating potential conflicts between existing water uses and e-flow regime.

ASPECTO		CODIGO	DENOMINACIÓN	Parámetro del que proviene
VALORES HABITUALES	MAGNITUD	IAH 1	Magnitud de las aportaciones anuales	P1
		IAH 2	Magnitud de las aportaciones mensuales	
	VARIABILIDAD	IAH 3	Variabilidad habitual	P4
		IAH 4	Variabilidad extrema	P2
	ESTACIONALIDAD	IAH 5	Estacionalidad de máximos	P3
		IAH 6	Estacionalidad de mínimos	
AVENIDAS	MAGNITUD Y FRECUENCIA	IAH 7	Magnitud de las avenidas máximas	P5
		IAH 8	Magnitud del Caudal Generador del Lecho	P6
		IAH 9	Magnitud del Caudal de conectividad	P7
		IAH 10	Magnitud de las avenidas habituales	P8
	VARIABILIDAD	IAH 11	Variabilidad de las avenidas máximas	P9
		IAH 12	Variabilidad de las avenidas habituales	P10
	DURACION	IAH 13	Duración de avenidas	P11
	ESTACIONALIDAD	IAH 14	Estacionalidad de avenidas (12 valores, uno para cada mes)	P12
SEQUÍAS	MAGNITUD Y FRECUENCIA	IAH 15	Magnitud de las sequías extremas	P13
		IAH 16	Magnitud de las sequías habituales	P14
	VARIABILIDAD	IAH 17	Variabilidad de las sequías extremas	P15
		IAH 18	Variabilidad de las sequías habituales	P16
	DURACION	IAH 19	Duración de sequías	P17
		IAH 20	Nº de días con caudal nulo (12 valores, uno para cada mes)	P18
	ESTACIONALIDAD	IAH 21	Estacionalidad de sequías (12 valores, uno para cada mes)	P19

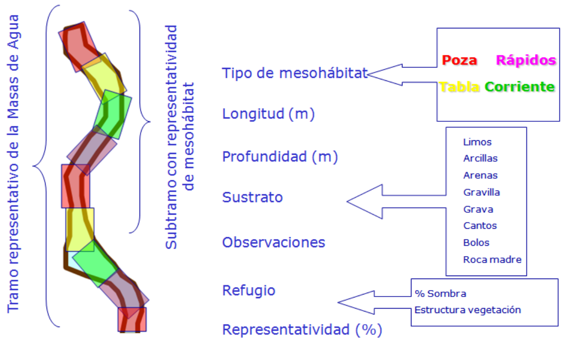
21 ÍNDICES

Índice desglosado por tipo de año, como resumen se ofrece el valor ponderado

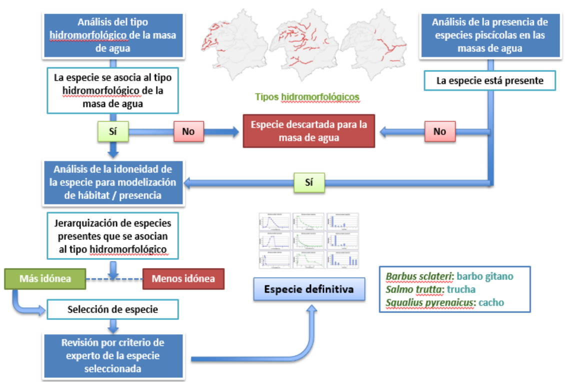
Índice especificado a nivel mensual, como resumen se ofrece la media anual

Selection of SWB for habitat modelling (just over 10% of river-type SWBs) under agreed criteria. Those considered strategic for the general water allocation in the RBD and / or remarkable for their environmental significance must be included. Representation of main hydro-regions must also be ensured.

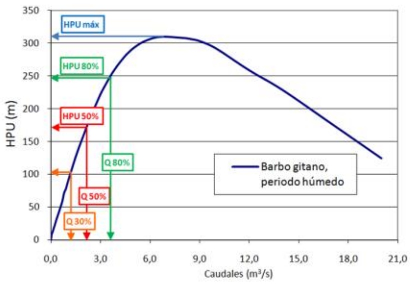
Field works for habitat modelling, including selection of a representative river reach (containing all significant meso-habitats), topographic survey, flow measurement (once in low waters and once in high waters), characterization and mapping of the substrate in the river bed.

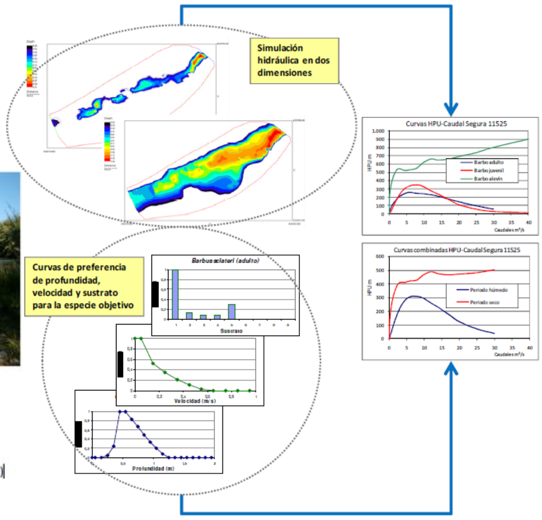


Selection of fish indicative species, meaning those characteristic of pristine river conditions. Only native species are considered and priority is given to endangered species, sensitive to habitat alteration, vulnerable and/or listed in Annexes II and IV of the Habitat Directive 92/43/EEC. Other criteria for selection are current presence (but also historic reference) and suitability index curves availability though, when necessary, new curves have been developed.

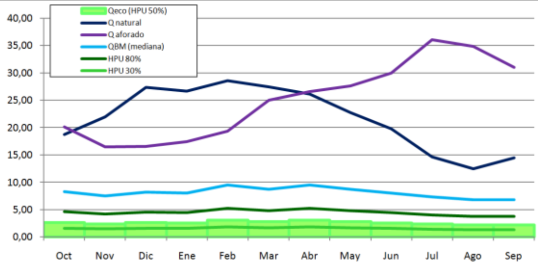


Habitat modelling, using physical habitat simulation software (PHABSIM, RHYHABSIM River2D). Significant (according to HPR) Weighted Usable Area percentages have been established.

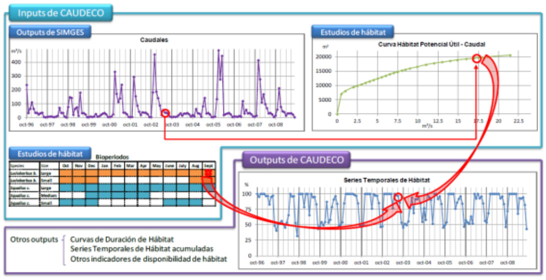




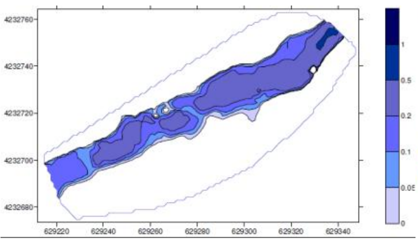
Analysis of hydrological and habitat modelling results and proposal of minimum e-flows regime. Different seasonal distribution formulas were tested against natural and altered regimes.

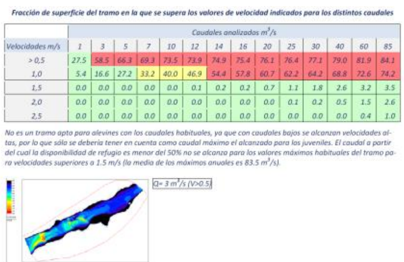


Analysis of the effect of e-flows in water allocation, with the help of the Aquatool-DMA Decision Support System (DDS), integrating minimum e-flows as a general restriction to water uses (but human supply) as established in Spanish Water Act. Simulation models have been developed including infrastructures, water resources and demands. Some RBs have used the specific module CAUDECO, part of the DSS, which also integrates the WUA calculations.



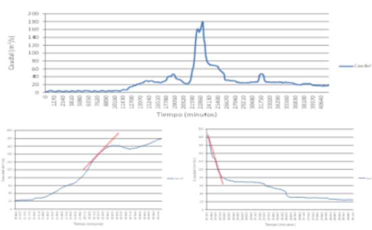
Other tasks:
Testing of **river continuity** under the proposed flow regime.
Establishment of **maximum flows**, assuring that water velocity is compatible with the maintenance of suitable habitat for all live stages.
Assessment of other elements of e-flows regime: **programmed floods** to restore river configuration and connection to floodplains and **rate of change** (hydro-peaking conditioning).
Proposal of **prolonged drought regime**.




Fracción de superficie del tramo en la que se supera los valores de velocidad indicados para los distintos caudales

	Caudales analizados m³/s													
Velocidades m/s	1	3	5	7	10	12	14	16	20	25	30	40	60	85
> 0,5	27.5	58.5	66.3	69.3	73.5	73.9	74.9	75.4	76.1	76.4	77.1	79.0	81.9	84.1
1,0	5.4	16.6	27.2	33.2	40.0	46.9	54.4	57.8	60.7	62.2	64.2	68.8	72.6	74.2
1,5	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.7	1.1	1.8	2.6	3.2	3.5
2,0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	1.5	2.6
2,5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0

No es un tramo apto para alevines con los caudales habituales, ya que con caudales bajos se alcanzan velocidades altas, por lo que sólo se debería tener en cuenta como caudal máximo el alcanzado para los juveniles. El caudal a partir del cual la disponibilidad de refugio es menor del 50% no se alcanza para los valores máximos habituales del tramo para velocidades superiores a 1.5 m/s (la media de los máximos anuales es 83.5 m³/s).



3.2. Temporal and spatial scales

Monthly water resources series were built for the period 1940/41–2005/06. For water allocation purposes, a shorter one (starting in 1980/81) was used to account for the climate change effects.
Based on the monthly data gathered, daily series were built for the most appropriate period of 20 years (more reliable datasets).
The spatial unit used was the surface water body. When habitat modelling was carried out, a representative river reach was selected (length between 200 m and 800 m, being 20 times greater than average width).

3.3. Type of analysis or tool

The main tools used in the process are mentioned in the section 3.1. Some of them have been developed specifically to nurture the water planning process, as regulated by HPR, namely:

- SIMPA, first used in the Spanish White Paper on Water (2000). A description of the model can be found in http://hercules.cedex.es/hidrologia/pub/doc/SIMPABangkok.pdf
- AQUATOOLDMA based on previous tools (SIMWIN) but incorporating answers to problems of the new cycle. More information in http://www.upv.es/aquatool/aquatooldma_E.html
- IAHRIS to assist in determining the degree of hydrologic alteration and the definition of HMWBs. Further information in http://www.ecogesfor.org/IAHRIS_en.html

3.4. Information and data requirements

- Geo-spatial data on climate and soil parameters, gauging stations registers and reservoir exploitation datasets where necessary to feed and calibrate the SIMPA model. After completing the hydrologic calculations of e-flows, some RBOs made adjustments in SIMPA datasets.
- Specific topographic survey and on-site field works were necessary to characterize river habitats for modelling.
- Information on fish populations was processed to select target species, as well as suitability curves for them.
- Characterization of hydraulic scheme and its operation, water rights and water uses. This information proceeds from RBMPs.

3.5. Testing of results

Throughout the different stages, validation tests have been made to ensure consistency of successive determinations. Coordination allowed methodological interchanges among the different teams involved, jointly identifying mistakes and practical problems and offering solutions to overcome them.

Public consultation within RBMPs documents and active involvement promoted during the WFD implementation process represents an additional test for the data and assumptions underlying e-flows regime. Nevertheless, the definitive testing of the results will be the achievement of expected objectives, once the implementation of e-flows regime is completed.

3.6. Current application of the method/initiative

The development of technical studies is only the first stage of e-flows regime implementation and must be followed by: 2) public consultation and agreement, including a negotiation process at least in strategic SWBs; and 3) implementation and adaptive management (PHR, section 3.4).

The Spanish RBMPs include e-flows regimes as part of their regulations (document "*Normativa*"), supported by a specific Annex describing works and main results. Nevertheless, the situation is uneven regarding the advance of the process (only some RBDs have covered also the second step) and the components of the e-flows regime.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The Spanish technical approach has proven to be consistent for dealing with environmental water allocation at RB scale, starting from an improved knowledge of hydrological cycle and the functioning of aquatic ecosystems.

On the other hand, in water scarce RBDs as most of the Spanish ones, is particularly important to assess the impact of e-flows implementation in water uses. DSS are helpful tools to feed public consultation and negotiation processes.

One limitation for replication is that the availability of natural regime flow series is a pre-condition. Water resources' modelling is a time-consuming activity but there are available tools and experience of application.

Uncertainty may arise from the occasionally significant difference between the results of hydrological methods and habitat modelling, being the later very sensitive to the target species that have been chosen.

The use of more holistic methodologies including the consideration of other biological quality elements would be desirable. In particular, advances in the application of IFIM methodology to fish communities (better than target species) would respond to WFD definition of quality elements for fish fauna.

Also for the future, well designed 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.

4. Contact information

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5. References

In addition to the websites mentioned in section 3.3 (specific tools), RBMPs include annexes presenting works on e-flows. Access is possible from this link http://www.magrama.gob.es/es/agua/temas/planificacion-hidrologica/planificacion-hidrologica/planes-cuenca/default.aspx

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Case study 19 (Spain): "Extrapolation of the minimum e-flows regime to the Cantabrian water bodies"

1. Executive summary

The water authorities from the Eastern and Western Cantabrian River Basin Districts, in coordination with other competent authorities and agencies, have designed a methodology for the extrapolation of the minimum e-flows regime to all the water bodies of the Cantabrian river basins. This methodology combines hydrologic methods and habitat modelling methods. The resulting minimum e-flows have been incorporated to the River Basin Management Plans (2009-2015), currently in force.

2. General information

Member State(s): Spain
RBD(s): Eastern Cantabrian River Basin (ES017) and Western Cantabrian River Basin (ES018)
Location: Cantabrian River Basin
Time period (start/end): Since 2009

2.1. Objective of the Case study

This case study describes the extrapolation of the minimum e-flows regime to all the water bodies of the Cantabrian River Basin, starting at the regime established in a selection of water bodies (10% from the total). For this calculation, hydrologic and habitat modelling criteria have been incorporated.

2.2. Policy and management context

The Spanish legislation regulates, through several rules, the process to establish the e-flows regimes, consisting of three phases: the development of technical studies, the agreement process and the implementation and adaptive monitoring of the e-flows regime.
In relation to the development of the technical studies, the Hydrological Planning Regulation (HPR), approved by Order ARM/2656/2008, determines that a temporal distribution of the minimum flows must be defined. For that, the hydrologic methods will be applied and the outcomes should be adjusted by the habitat suitability in the representative fluvial sections for each river type.
The inherent complexity of this process and the high number of water bodies corresponding to the river category in each river basin district, recommend a simplification of the methodology in order to obtain the e-flows regimes in every water body, compliant with all the guarantees and maintaining the ecological meaning of the obtained results.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The Directorate-General for Water of the former Ministry of Environment and Rural and Marine Affairs, in cooperation with the Hydrological Planning Offices from the River Basin Authorities and the CEDEX (Centre for Public Works Studies and Experimentation), carried out several studies to estimate an e-flows regime in a selection of water bodies (10% from the whole river basin district), combining the hydrologic methods with the habitat modelling. Moreover, the minimum e-flows were calculated with the hydrological methods in each water body.

Moreover, the CEDEX produced the national map of hydro-regions, considering those areas with a similarity in the seasonal and annual hydrologic functioning.

Based on these studies, the Cantabrian River Basin Authority, with the subsequent cooperation of the Basque Agency of Water, designed and applied a methodology in order to extrapolate the e-flows regime with ecological significance to all the bodies of the Eastern Cantabrian and Western Cantabrian River Basin Districts.

3.2. Temporal and spatial scales

The study was applied to all the water bodies of the Cantabrian coast, formed by lots of small and independent basins characterised by short rivers and with relatively abundant flows. In the Cantabrian coast, both the Eastern Cantabrian and Western Cantabrian River Basin Districts have been defined, with an area of 5.794 km^2 and 19.002 km^2, respectively.

The methodology described in this case study was applied in the definition of the e-flows regimes set out in the Eastern and Western Cantabrian River Basin Management Plans 2009-2015, currently in force.

Moreover, this methodology is being used in the monitoring programmes and in the improvement of the e-flows regimes in the second cycle of the hydrological planning.

3.3. Type of analysis or tool

The first step was to calculate the minimum e-flows in a selection of water bodies (10% of the total), by the combination of the hydrologic methods and the habitat modelling. The methodology used for that is the one applied in most of the Spanish River Basin Districts, obtaining as a result the flow associated to the 25-30-50-80% from the maximum of the most restrictive species weighted useful area (WUA) in each selected water body.

The second step was to calculate, for each selected water body, the ratio between each flow associated to the WUA, above mentioned, and the minimum monthly average e-flow in natural regime.

After this step, the average value of that ratio for each River Basin District was also calculated (the Cantabrian River Basins are hydrologically homogeneous: more or less the 80% of its water bodies are within the same hydro-region).

As a result, the extrapolation factors were derived for the different WUA (25%, 30%, 50% and 80%).

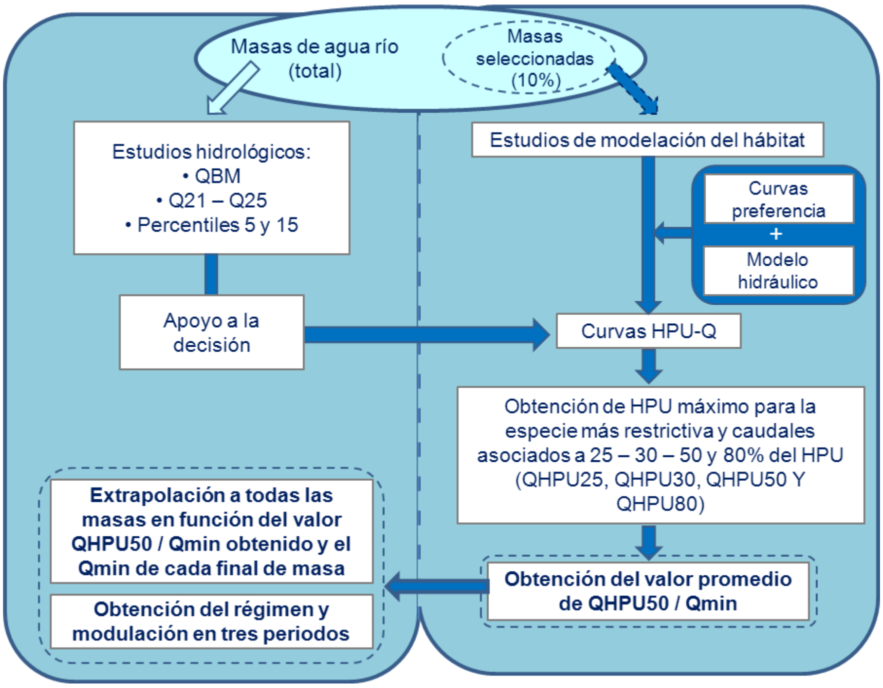
	K80	K50	K30	K25
Extrapolation factor	0,70	0,39	0,22	0,19

The derived coefficients were multiplied by the minimum monthly average flow of each water body at its end. In this way, it was obtained a minimum flow linked with a particular value of the WUA. In the study area, it was selected the coefficient K50 as the most appropriate factor for every water body. In other words, the minimum e-flows regime is considered equivalent to the 50% of the WUA.

In order to transform the minimum flow into a regime useful to provide the needed seasonal and annual variability, the choice was to apply the Palau's variation factor.

$$F\ \text{var}\ 1 = \sqrt{\frac{Qi}{Q_{\min}}}$$

This method allowed getting a minimum e-flow regime with a different value every month of the year. Finally, these flows were modulated in order to get outcomes for three homogenous periods: high waters (months of January, February, March and April), medium waters (months of May, June, November and December) and low waters (months of July, August, September and October).



QBM: Basic maintenance flow.
Q21 y Q25: Moving average of order 21 and 25.
Curvas HPU-Q: WUA-F curves. Ratio between the Weighted useful Area Curves (WUA) and the Flow curves.
QHPU: Flows associated to each Weighted Useful Areas.
Qmin: Minimum monthly e-flow regime under natural conditions.

Figura 1. Calculation of the minimum e-flows regime in the Eastern Cantabrian River Basin District.

Moreover, in order to establish the e-flows regime in emergency situations due to drought conditions, the criterion set out in the HPR which determines that the estimated flow have to allow maintaining, at least, of the 25% of the maximum weighted useful area, was applied. Therefore, in these cases the K25 coefficient was applied.

Those water bodies protected under the Natura 2000 network or the Ramsar Convention of Wetlands of International Importance, which minimum e-flows regime were calculated under an ordinary hydrologic regime maintain them

3.4. Information and data requirements

The following information was used:

a) The hydrologic series corresponding to the period 1980/1981 to 2005/2006 originated from the SIMPA II model (Spanish Integrated System for Rainfall-Runoff Modelling), with a monthly basis. In order to obtain the daily series, data from a set of representative monitoring stations under a natural regime were selected.

b) The preference curves of the target species, linking the weighted useful area with the flow regime, taking into consideration the habitat suitability curves.

c) The national hydro-region map (by CEDEX).

3.5. Testing of results

It was carried out a study of the guarantees of the initially obtained minimum e-flows in the selected water bodies. In order to validate the results, it was considered that the annual guarantee should be higher than the 85% and the monthly guarantee higher than the 50 % every month. These criteria were taken into account in the flows final estimation for these water bodies.

Moreover, comparatives between the proposed minimum e-flows and the registered flows in the gauge stations have been performed in order to validate the applied methodology.

3.6. Current application of the method/initiative

The minimum e-flows regimes calculated by this methodology are included in the normative content of the Eastern and Western Cantabrian River Basin Management Plans, approved by a

Royal Decree. The implementation of these regimes is being carried out according to the settings of the legislation in force.

Furthermore, the Spanish legislation provides, in the River Basin Management Plans monitoring networks, the evaluation of the compliance level of the e-flows regime. Currently, this evaluation is being carried out by the competent authorities (Cantabrian River Basin Authority and Basque Water Agency), permitting the evaluation of the convenience of carrying out modifications in the methodology.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The designed methodology is considered acceptable for the Cantabrian River Basin Districts, while it allows the simplification of the minimum e-flows calculation procedure, ensuring the ecological significance and its compliance with the requirements established in the legislation in force.

This methodology could be implemented in other river basin districts. In that case, it should be crucial to analyse whether all regions in the river basin district are hydrologically homogeneous. If this is the case, the extrapolation factor can be calculated with the average values of all the water bodies (as it was done in the Cantabrian river basin). On the contrary, it is necessary to calculate different extrapolation factors for the separated regions in terms of hydrologic functioning.

4. Contact information

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  Tel: +34 945 011 700

5. References

- Websites referring to the case study:
  Página Web de la Confederación Hidrográfica del Cantábrico: http://www.chcantabrico.es/index.php/es/actuaciones/planificacionhidrologica/planes-hidrologicos-2009-2015/parte-espanola-de-la-demarcacion-hidrografica-del-cantabrico-oriental
  Página Web de la Agencia Vasca del Agua: http://www.uragentzia.euskadi.net/u81-0003/es/contenidos/informacion/2013_aprobacion_hidrologico/es_def/index.shtml

Case study 20 (Spain): "Assessment of the integrity and effectiveness of the e-flows proposed for the middle section of the Duero River"

1. Executive summary

Assessment of the integrity and effectiveness of the e-flows proposed for the middle section of the Duero River, in the stretch between Bocos and the Pisuerga River. In this section of the river there are many water uses, such as small hydropower plants, and some areas with important abstraction pressures for agriculture and livestock uses. The Canal del Duero is a large channel that supplies of water to more than 200,000 people in Valladolid. It is also a stretch of the Duero river affected by river regulation in the Cuerda del Pozo dam which affects some hydro-morphological quality indicators. River sectioning problems arise from numerous uses in this area. There are also protected areas included in the Natura 2000 sites and protection of water supply for different uses. In this area there have been various hydrologic studies to establish e-flows and it is worth to compare these values with the outcomes of the field works.

2. General information

Member State(s): Spain

RBD(s): Duero River Basin (ES020)

Location: Valladolid, Spain

Time period (start/end): Since June 2013)

2.1. Objective of the Case study

The purpose of the case study is to investigate if the e-flows defined in the RBMP with the hydro-biological methods are consistent with the achievement of the ecological objectives of the water bodies affected. In addition, this case study tries to explain the follow-up phase of the implementation of the e-flows.

2.2. Policy and management context

The biggest problem when defining the e-flows are the technical difficulties also found monitoring the WB in which there are not enough or at all gauge stations. Nevertheless, the legal rights acquired by some users may be limited, affecting in some cases the management of the reservoirs storing water for the summer months. There are several problems regarding e-flows compliance, especially in dry autumns when reservoirs do not release water and the quantity of rain is not enough to maintain the e-flows. Furthermore, in these periods the channels require higher extraction rates which affect in turn, the circulating flows in the river downstream the dams. In the studied section of the Duero River there are five Water Bodies affected: DU-344, DU-345, DU-346, DU-347 and DU-376.

The main aim of this case study is to discuss the definition of e-flows proposed in the guidance. If the e-flows should contribute to the good status of the water bodies, the case study wants to show the possibility of meeting the e-flows requirements without meeting the WFD objectives, failing to reach the good status. For this reason it seems more appropriate to link the e-flows regime to the status of certain fish species and the conservation status of the Natura 2000 habitats that might otherwise be represented in the biological quality indicators. This is what it claims to do the Spanish environmental flow methodology (based on the WUA for certain fish species or the conservation status of Natura 2000 habitats) to the concept proposed by the Guidance on e-Flows.

The environmental objectives of these water bodies must ensure that the hydro-morphological quality indicators are within the proper range, basically in terms of river continuity measured with different indexes: a) the river continuity index (CI), which assesses if fish fauna can migrate upstream a physical barrier in the river; b) the lateral continuity index (ICLAT), which assesses the capacity of fish fauna to move laterally in the river even if there are natural barriers; and c) the hydrologic alteration index (AHI), which assesses the hydrologic alteration in the affected river sections.

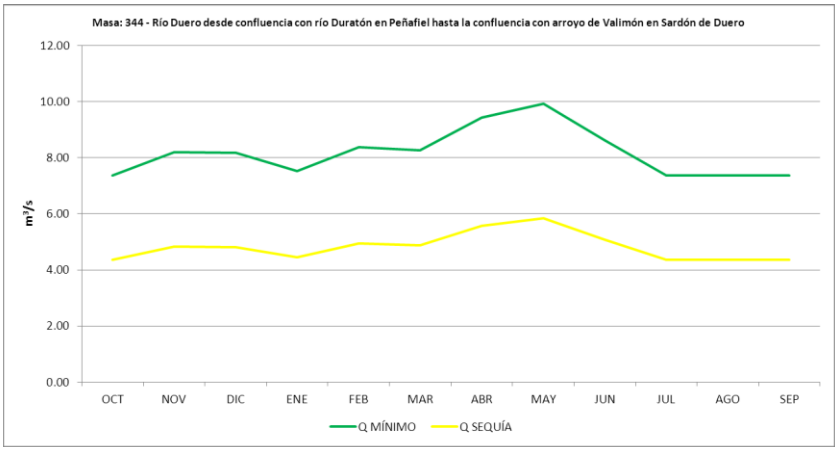
To reach the values of good and high ecological status in the water bodies of section 1, it is required the permeability of the physical structures responsible for the above indicators. In some cases (water bodies 345, 346, 376) it has been also noticed the failure of the Hydrologic Alteration Index (AHI), an index related to the circulating flow. In these cases the annual evolution of the index (from 2009 to 2012) does not provide a high degree of confidence. On the other hand we have got the case of the WB 347, which is the biological indicator of aquatic flora based on diatoms (IPS), which ecological status classification is moderate.

Thus we see that in this section of the river Duero not all indicators of WB status are sensitive to minimum e-flows.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

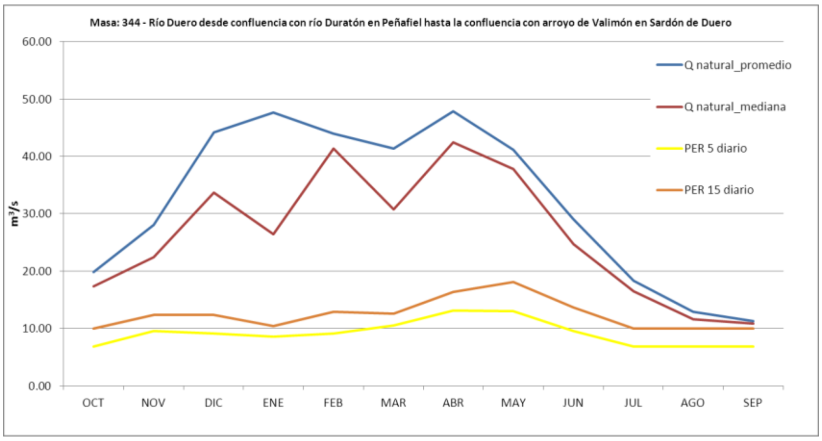
The minimum e-flows, fixed in the RBMP have been obtained with hydrologic and hydro-biological methods. As an example of the information available, we include the minimum e-flows set in the RBMP that were obtained with hydrological and hydro-biological methods and are as follows for the WB DU-344



The Central Government provides the RB Authorities with the methodology of calculation. In turn, the RB Authorities are in charge of the implementation and assessment. All water users are required to implement e-flows indirectly because their enforcement may limit the water use.

In order to compare these e-flows, we show the natural flow and main statistic values: daily values of the natural flow regime: its percentile rates 5 and 15, median (red line) and average (blue line), daily values, and naturally flow regime.

In the case of the WB DU-344 the minimum e-flow is a volume equal to 25% of the total volume flowing in natural conditions in the water body (see the chart below).



3.2. Temporal and spatial scales

The WB is the selected scale to work with, as it was established by the Spanish Water Act. The control point where meet the flows required is the Quintanilla gauge station EA 2132, in the final third of the DU-344 WB. The values of the gauge station are measured every ten minutes, so that monitoring is nearly continuously. The monitoring process is carried out in the SAIH network, the Spanish Automatic System of Hydrologic Information.

3.3. Type of analysis or tool

The working methodology is exposed in Annex 4 of the RBMP. The charts summarizing the water bodies under study (using river habitat modeling methods) are listed in Appendix II of that Annex.

The references to study the minimum e-flows regime have been the IFIM methodology and the Spanish IPH (instruction for water planning) have been followed. The hydro-biological and hydrological index were obtained using the simulation results in 1-dimensional or 2-dimensional systems, using short series of the natural hydrologic regime, restored to daily flows. The most innovative aspect of the methodology was to define e-flows for better living conditions of the most sensitive species (usually fishes). A more restrictive criterion has been applied to pursue the conservation status of the aquatic ecosystems, not only the achievement of the good status of a water body (Article 18 of RPH).

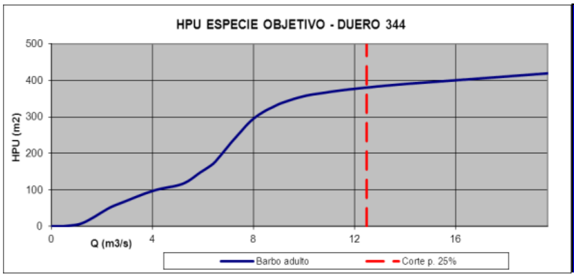
The most remarkable legislation regarding the establishment of e-flows is composed by: Article 42 of the Consolidated Text of the Water Act (Royal Decree-Law 1/2001); Article 26 of the National Hydrological Plan (Law 10/2005, of July 5th); Article 18 of the Water Planning Act (Royal Decree 907/2007, of July 6th); and Section 3.4 of the IPH (Order/ARM/2656/2008, of September 10th).

3.4. Information and data requirements

It has been used two different methodologies. On the one hand, the hydrological methodology, which only uses statistical data of circulating flows. On the other hand, the methodology using WUA curves based on various fish species.
Hydrological methodologies work out on natural resources obtained from historical models based on rainfall data. These simulated data are contrasted with the real data of circulating flows recorded in gauge stations. In this section of the river, there are several gauge stations, some of them collecting data since 1911 and others since 1975. Therefore, the degree of adjustment is considered appropriate.

Hydro-biological methods require to carry out fish fauna monitoring campaigns using different techniques such as electric fishing, to make some surveys about the rivers and defining preference curves of the identified species. The revision of the historical series of circulating flows in natural regime is also necessary for the application of hydrological methodologies. The listed fish species identified in this section of Duero River are: *Barbus bocagei, Squalius carolitertii, Cyprinus carpio, Gobio lozanoi, Alburnus alburnus, Gambusia holbrooki, Lepomis gibbosus* and *Micropterus salmoides*.

Hydro-biological methods are linked to the most demanding fish species in the section of the river. A hydro-biological study was conducted in the WB DU-344 where the target species was the adult barbel (*Barbus bocagei*) since it is the most restrictive one.



% HÁBITAT POTENCIAL ÚTIL (HPU)	Caudal (m^3/s)
Q 80% HPUmax (series anuales de datos diarios)	8.179 m^3/s
Q 50% HPUmax (series anuales de datos diarios)	6.648 m^3/s
Q 30% HPUmax (series anuales de datos diarios)	5.093 m^3/s
Q 25% HPUmax (series anuales de datos diarios)	3.923 m^3/s

Besides these water bodies affecting natural areas included in Natura 2000 sites, the impacts of the e-flows regime were also assessed in the Natura 2000 site "LIC 5200043 RIBERAS DEL RÍO DUERO Y AFLUENTES", where the following habitats as defined in Directive 92/43/EEC and related to the water environment are present:

- 3240: Alpine rivers and their ligneous vegetation with *Salix elaeagnos (the conservation status of these habitats is related to indicators of hydromorphological quality IC and AHI);*
- 3250: Constantly flowing Mediterranean rivers with *Glaucium flavum* (*The conservation status of these habitats is related to indicators of hydromorphological quality IC and QBR);*
- 3260: Water courses of plain to montane levels with the *Ranunculion fluitantis*
- and *Callitricho-Batrachion* vegetation *(its representation in this river section is limited);*
- 91E0: Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-*
- *Padion, Alnion incanae, Salicion albae*)
- 92 A0: *Salix alba* and *Populus alba* galleries;
- 92D0: Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)
- 6430: Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels;
- 91B0: Southern riparian *Fraxinus angustifolia* y *Fraxinus ornus (*c*onservation criteria for this habitat are more linked to the restriction of DPH occupancy and its police area and the change of land use for agricultural and urban activities to e-flows).*

3.5. Testing of results

These minimum e-flows have been monitored since June 2013, the date of the approval of the RBMP. The monitoring is done in the gauge station of Quintanilla. The following table set the minimum e-flows for each month (in m^3/s), highlighting in green colour those months when the e-flows regime is reached.

	2013							2014	
Station code	JUN	JUL	AGO	SEP	OCT	NOV	DEC	JAN	FEB
Duero in Quintanilla EA 2132	8,62	7,36	7,36	7,36	7,36	8,2	8,18	7,52	8,38

Minimum e-flows at the Cuerda del Pozo dam, which is controlled by the river basin authority, have been monitored since June 2013 and the results of implementation are as follows:

	2013							2014	
Reservoir	JUN	JUL	AGO	SEP	OCT	NOV	DEC	JAN	FEB
Cuerda del Pozo	0,58	0,53	0,53	0,53	0,53	0,61	0,72	0,7	0,72
	0,29	0,27	0,27	0,27	0,27	0,3	0,36	0,35	0,36

3.6. Current application of the method/initiative

We are studying the gaps detected, what they should and how they can affect the status of bodies of water. In the Duero river basin, we have set minimum e-flows in 710 WB. Within these, 24 are located in WB with gauge stations and other 20 are immediately downstream the reservoirs.

Currently, the studies modeling the habitat have been performed in 30 WB. Furthermore, the effect of the e-flows in 40 Natura 2000 sites with protected habitats associated with water (MedWetRivers Life project) has been assessed. The whole process counts on the participation of the different stakeholders involved, with the main aim to review the problems detected in the establishment of the minimum e-flows, identifying problems that may arise in the implementation of the minimum e-flows and their effect on existing uses and previous rights.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

Some questions about e-flows require study in our opinion:

a) Coherence between current state of water bodies, defined e-flows, circulating flows in altered regime and the conservation status of ecosystems / species linked to water;
b) Hydro-biological methods: effectiveness of the identified values in order to maintain good conservation status of ecosystem;
c) Consistency of e-flows in relation to existing fish species and their life cycle; weighted useful areas (WUA) of the species present and their relation to environmental objectives;
d) Implementation of e-flows lower than those determined by the methodology in hydropower diversion extractions with short channels (less than 300 m) and its impact on the fish fauna.
e) Coherence between “e-flows” definition in the Guide (the flow regime consistent with the achievement of the environmental objectives of the WFD) with the conservation status of ecosystems / species linked to these water bodies and their environmental objectives

4. Contact information

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  Angel J. González. (oph@chduero.es) +34983215405

5. References

- Websites referring to the case study:
  http://www.mirame.chduero.es/
  http://www.mirame.chduero.es/DMADuero_09_Viewer/viewerShow.do?action=showViewer&featureType=Segmentos_Rio&waterBodyID=344

http://www.chduero.es/

Methodology:
http://www.chduero.es/Inicio/Planificaci%C3%B3n/Planhidrol%C3%B3gico2009/PlanHidrol%C3%B3gico/Anejo4Caudalesecol%C3%B3gicos/tabid/556/Default.aspx

Results:
http://www.mirame.chduero.es/DMADuero_09/index.faces

Duero Automatic System of Hydrologic Information:
http://www.saihduero.es/main.php

Duero RBMP –establishment of e-flows:
http://www.chduero.es/Inicio/Planificaci%C3%B3n/Planhidrol%C3%B3gico2009/PlanHidrol%C3%B3gico/Anejo4Caudalesecol%C3%B3gicos/tabid/556/Default.aspx

Other useful sites:
http://www.chduero.es/Inicio/Planificaci%C3%B3n/Planhidrol%C3%B3gico2009/PropuestaPlanHidrol%C3%B3gico/Anejo2Inventrech%C3%ADdricos/tabid/503/Default.aspx

Case study 21 (Slovakia): "Use of Water Resource Balance as a tool for the assessment of the quantitative relation between water requirements (including the minimum balance discharge) and water resources"

1. Executive summary

Water resource balance is a tool used in Slovak Republic regularly for the assessment of the real status of water utilization on one side and water resources on another one. In surface water quantitative water resource balance one of the key parameters is the minimum balance discharge (representing guaranteed flow, could be considered as e-flow), which is considered on the side of water demands.

2. General information

Member State(s): Slovak Republic

RBD(s): SK 40000/Danube; SK 30000/Vistula

Location: Slovakia

Time period (start/end): 2010 to 2012

2.1. Objective of the Case study

The study is describing the assessment of water resources in Slovakia towards the water requirements, and what role in this balance the parameter „minimum balance discharge (MQ)“, representing the ecological flow is playing.

2.2. Policy and management context

The eflows implementation is being realized according to the activities of the CIS working groups. The national coordinator in Slovakia is the Ministry of Environment of Slovak Republic. The institutions participating in the preparation of River Basin Management Plans are sharing in the implementation of eflows. Currently, Slovakia is in the phase of reevaluation of the eflow values and their consecutive implementation into the planning and decision-making processes. According to WFD main goal – to achieve the good status of waters, the parameter MQ being in this phase in Slovakia considered to represent the E-flow, is a limit used in the frame of ecological protection of the streams, mainly against possible overexploitation of water in the streams, as well as a supporting evaluation tool in connection with ecological assessment, including BQE assessment (fishes).

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The Water Resource Balance (VHB) has been in Slovakia used as a background in the frame of the regular water planning since 1973; after the implementation of WFD into the national legislation the methodology of VHB has been revised as well, although in the WFD the quantitative status of the surface water bodies was not sufficiently included. The updated methodology of VHB was elaborated on Water Research Institute (in cooperation with Slovak Hydrometeorological Institute), approved by the Ministry of Environment in 1994. Legally, the VHB is supported in the Water Act (Act No. 364/2004 Coll. as later amended) and its implementing regulations. Regarding to this Act the reporting obligation results for touched users with withdrawals or recharges in the quantities higher than stated limits. The amounts of the withdrawals and recharges reported compose one of the main inputs of VHB. Eflow is represented by the value of minimum balance discharge (MQ), which is considered to be one of the inputs on the side of water demands. According to the Water Act no. 364/2004 Coll., this flow represents a flow, which allows general use of surface water and provides the functions of the watercourse and protection of aquatic ecosystems in it. Actually it is being interconnected with BQE evaluation (fishes).

3.2. Temporal and spatial scales

The study describes VHB, which is being performed in a year cycle, by evaluation of the previous calendar year, while the processing itself is made in a month step. Spatially the whole territory of Slovakia is assessed, in the 12 main sub-basins, using the data processing in the network of 137 balance profiles, selected according to the space cover of the Slovak territory, to record the important locations from the point of view of water utilization concentration, influence of water reservoirs and water transfers and also the availability of the hydrological backgrounds with the maximum connection to the existing network of water-gauging stations. The assessment by the sub-basins is suitable also due to the complex hydrological balance of water resources as well as due to historical aspect (long-term tradition of annual hydrological assessment by main sub-basins). The balance profiles have been selected in a way to cover the areas with important influence by water utilization (water reservoirs, water transfer, etc.) or which may be at the risk of water scarcity.

3.3. Type of analysis or tool

The basis of VHB is based on the assessment of the relationship between the water demands and water resources and its quality during the previous year, while the water demands represents the real withdrawals from the surface waters and groundwaters and the recharge of the waste waters and special waters. The aim is to make the objective, factual and time actual assessment and express the status and the possibilities of water resources utilization during the previous year and in this way to provide the binding background for the water management for the next period.
The VHB has been processed separately for the surface waters and for groundwaters, for quantity and quality of water. This study is further focused on the water resource balance of the surface water quantity only.
The utilization realized in the past year represents the reported amounts of used surface water and groundwater and recharge of the waste waters and special waters in terms of the Water Act. The limit values for the reporting of the withdrawals are 15 000 m^3 per year or 1 000 m^3 per month.

Water balance calculation:

At each balance profile the following characteristics are evaluated:

- Effect of water utilization - change of discharge - X
- MQ – minimum balance discharge
- MPP – minimum needed discharge is an indicator, which includes the water demands form the side of water users as well as the demands for guaranty of minimum balance discharge MQ.

(MPP = MQ – X)

- E – influenced discharge – discharge measured in a water balance profile or value derived from a discharge measured in a water-gauging station.
- ENP – discharge influenced by reservoirs and water transfers - This value of discharge is that one, which would flow through the given profile, if there was no utilization of water but influenced by operation of water reservoirs or water transfers only (ENP = E – X)
- C – natural discharge (scavenging)

Natural discharge is the discharge value adjusted for the water utilization as well as for influence by water reservoirs and water transfers. That means, this would be the discharge flowing through the given profile in natural conditions.

- Balance status (BSC, BSENP) - a non-dimensional parameter which is calculated for 2 alternatives:
    - The balance status of natural discharges – evaluation of what the balance situation would be during the natural discharges with consideration of

realized abstractions and discharging of water in evaluated year (BSC = C / MPP),

- The balance status for the river influenced by reservoirs or water transfers (BSENP = ENP / MPP).

The following classification is used for water balance:

BSC (BSENP)	>	1, 1		- category A – active balance status
1, 1	>	BSC	> 0, 9	- category B – tense balance status
0, 9	>	BSC	> 0	- category C – passive balance status

➢ Water resource capacity - (KZC, KZENP) represents the value of discharge, which was in water balance profile in given time above the value of MPP. In case that the water resource capacity obtains a negative value, the water demands or the MQ requirements were not covered.

The outputs are presented by the assessment of the water bearing of the year, the amount of the withdrawals from surface waters and groundwater, the amount of recharged waste water, the water reservoirs and water transfers, the balance status for natural discharges with considering of the realized withdrawals and water recharges during evaluated year and the balance status on the streams with consideration of the effect of water reservoirs and water transfers and considering of the realized withdrawals and water recharges during evaluated year.

Concrete example of the outputs of VHB: In table 1 we can see the number of water balance profiles (from the whole number of 137 evaluated profiles), which were in tense and passive status during the period 2010-2012. Year 2010 was extremely wet in Slovakia, followed by extremely dry period 2011 - 2012.

Tab. 1 Tense and passive states in water balance profiles in Slovakia in 2011 and 2012

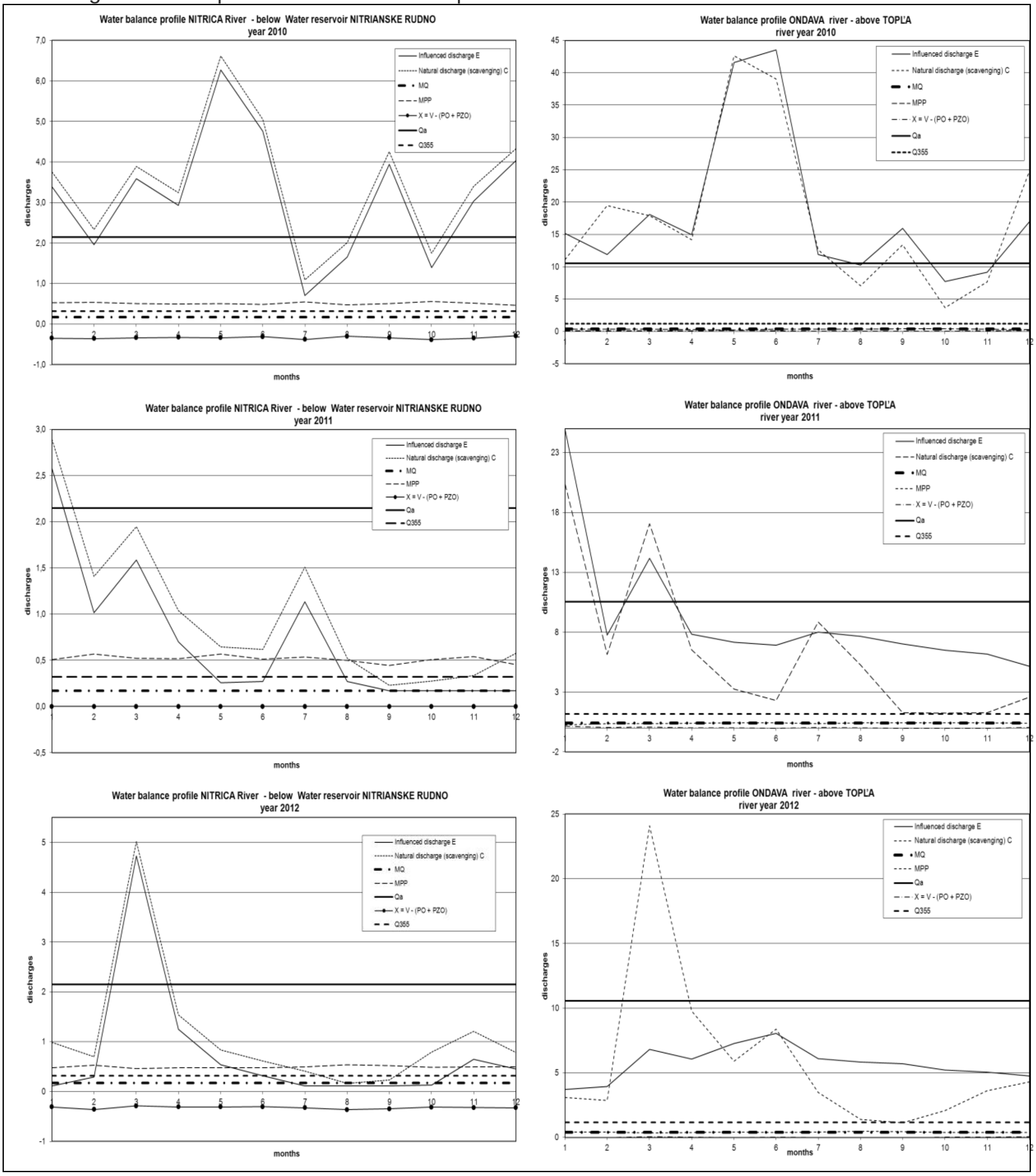
Year	Number of profiles with tense balance status		Number of profiles with passive balance status	
	BSC	BSENP	BSC	BSENP
2010	0	1	2	0
2011	7	5	5	0
2012	7	6	9	4

The examples of the graphic analyses of the courses of monthly values of natural discharge, influenced discharge, water demands – MQ and water utilization expressed by change of discharge X, as well as long-term values Q_a (mean long-term discharge) and Q_{355} (355-day discharge) are presented in the fig. 1. The examples show the situation in years 2010, 2011 and 2012 in two water balance profiles situated under the water reservoirs Nitrica- Nitrianske Rudno (on left side) and Ondava – above Topľa (on right side).

We can see the situation in wet year 2010 - water resources can cover the demands without any problems. However in 2011 at the profile Nitrica – Nitrianske Rudno, the last third of the year the influenced discharges are decreasing to the value of MQ, and in 2012 (which was extremely dry year) the influenced discharge was even lower than the value of MQ, what means an extraordinary situation, which needs an extra permission for water reservoir operating in the critical time, or after assessment of the passed year it is subject for the revision of the measures.

The second profile in both dry years 2011 and 2012 is showing the increasing discharge influence of water reservoir during low flow period, when the natural discharge would be close to value Q_{355}, but the water reservoir operating is improving the discharge situation in the river channel under the dam.

Fig. 1 Course of natural and influenced discharge, MQ, needed discharge MPP, change in discharge X – examples in 2 water balance profiles in 2010-2012



3.4. Information and data requirements

The necessary inputs into the VHB are the following:

A, Withdrawals of surface waters and groundwaters - are provided by the users annually in monthly time step. Groundwater withdrawals are assigned to the river in the normal direction and they are calculated as a sum to the nearest downstream balance profile.

B, Recharge of waste water – reported if the amount is more than 10 000 m^3/year or 1000 m^3/month.

C, Minimum balance discharge MQ – is a water balance value, with a character of a preferred demand on water resource guaranteed in term of the protection of the environment. It represents the conservation of the conditions for the biological stability of the river and its close surroundings and guarantees the general usage of the water, which does not need the permission of water management bodies. The values of the minimum balance discharge for particular water balance profiles are determined according to the procedure approved by the Ministry of Environment of Slovak Republic.
Determination of MQ:

a) For the river reaches with regulated runoff: In the dam profiles MQ = Q_{355}, unless it is not stated otherwise by operative rules or by another reason; in other reaches the value of MQ is variable, the controlled increase of runoff by reservoir is disappearing steadily down to the point where the effect of reservoir is undetectable.

b) Other river reaches: MQ is determined as follows:

$MQ = (Q_{min\ mes} + Q_{100.min.d})/2$, where $Q_{min,mes}$ is the value adopted from a probability field of mean monthly discharges for the high degree of guaranty, usually 98% and $Q_{100.min.d}$ is the balanced value of the minimal mean daily discharge with the mean occurrence probability once in a 100 years, determined by statistical methods. The counted value should meet also the condition: $½\ Q_{364} < MQ < Q_{355}$

D, Monthly evaporation from reservoirs,
E, Mean monthly influenced (measured) discharges in water balance profiles,
F, Mean long-term monthly unaffected (natural) discharges – representing the reference period 1961-2000 (used since 2006), serve for the supplementary assessment of water bearing of particular months.
G, Mean monthly changes of water volumes in the reservoir – are determined on the base of water volume change in the reservoir between the first day of the given month and first day of the next month.
H, Mean monthly values of water transfer.

3.5. Testing of results

The methodology is used for annual assessment. In case of problems, the input data are controlled again, especially the data about monitored discharges and data about water utilization. The data on water utilization used for VHB are used for payments as well. The balance status, evaluated permanently as passive or tense is making a signal for review of the original measures or to set the new ones.

3.6. Current application of the method/initiative

This methodology of the water resource balance assessment is currently valid in Slovakia, supported by the Water Act. The values of the ecological flow (MQ) are being revised; currently the revaluation of the values is ongoing, according to actually used reference period and taking the ecological and economical consequences. The ecological status evaluation has been made in the water balance profiles as well as the evaluation of fish monitoring. Afterwards, the profiles with score worse than 2 (very good) have been checked for water balance status and hydrological characteristics (e.g. water bearing coefficient). In case that hydrological or balance status are seen as a possible reason of worsen ecological status, further investigation in these profiles should be done, identifying if MQ has been ensured or to consider whether the MQ value is sufficiently designed. However situation may be caused also by natural hydrological conditions or temporal overexploitation of water resources. The detailed analyses of the reasons should lead to appropriate measures proposal for next RBMP.

Beside this assessment in Slovakia also the perspective water resource balances are elaborated. These, in principle, are using the prognosis of water utilization on the side of water demands and discharge characteristics with high probability of exceedance (or guaranty, in case of water reservoirs) on the side of water resources, or even the simulation of the discharges using the chronological discharge series 50-year or more. The data series influenced by predicted climate change can be also used. The value of MQ can be also entered differently in month step.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

If the amount of withdrawal is less than the limit, the data are not reported and do not enter into the evaluation of water balances. This leads to some underestimation of the real demands for water.

VHB is a good tool for the monitoring of the functioning of the measures set in the previous period (operation of water reservoirs, water transfer, etc.). The disadvantage is that it is evaluated retrospectively for the previous period, as users are reporting the withdrawals annually. It is therefore not possible to use this assessment for operational purposes. Following the evaluation, however, if the problem is identified, the cause is being looked for – if the measure is set in given area, and whether it is sufficient, or whether the problem arises because of another reason, then for the next programming period the measures are reconsidered.

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5. References

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Case study 22 (Eurelectric): “Edeforsen case study”

1. Executive summary

The Edeforsen case study shows the possibility to improve ecological status/potential at a site with considerable impact from hydropower operations with flow modification in Ljusnan river. Abstraction of water to a hydro power plant, would increase fish spawning possibilities in the natural part of the river due to reduced flow velocity. The impact on the hydrological regime is caused by operations of large reservoirs in the upper part of Ljusnan. 2009-12-22 Mellanljusnan was classified as good ecological status and Edeforsen as bad and the water body downstream as poor ecological status. These water bodies should be designated as HMWB due to hydromophological alterations. The case shows that the environmental objective can be reached at Edeforsen with a diversion of water during the winter. A more natural regime could be achieved if an old hydro power facility was replaced by a plant with higher capacity and would also enable new renewable electricity production.

2. General information

Member State(s): Sweden, SE

RBD(s): Bothnian Sea RBD (SE2)

Location: Ljusdal’s Municipality, Gävleborg’s County Administration

Time period: Work can be started when environmental license is obtained.
(Application sent Nov 2012, negotiations by April 2014.)

2.1. Objective of the Case study

The objective of the case study is to describe a possibility to improve ecological status/potential in a part of one of the large hydropower rivers in Sweden. The actual water body, Edeforsen, is located downstream Mellanljusnan which is a protected river stretch and Natura 2000. The water body is classified as natural water although the impact from large storage reservoirs in upper Ljusnan affects the flow regime to a large extent. Both the Edeforsen water body and Mellanljusnan should be designated HMWB due to hydromorphological alterations. In the planned development of the old hydro power plant environmental considerations have been in focus. Increased capacity of a new hydro power plant would result in reduced hydromorphological pressure locally in the natural river stretch enabling habitats for fish and other fauna. Authorities in Sweden have mainly used expert judgements in status classification. Achieving GES would require a change in the hydrological regime enabled by changes in water regulation management of reservoirs in upper Ljusnan river. A changed reservoir operation in Ljusnan would affect the Swedish electricity system.

2.2. Policy and management context

The utilization of the head and power of water, has historically been used for operating a mill, wool spinning and log driving. Since 1910 there has been a hydropower plant and a dam built across the river. License for a new hydropower plant was applied for to the Environmental Court in November 2012. A new plant would enable an ecological hydrological regime in the natural part of the river. The project thereby enables reaching WFD objectives. In the juridical process authorities, NGO:s and property owners are against the project and advocate demolishment. Arguments presented in the process it is stated that demolishment would improve environmental status and because of the protected river stretch Mellanljusnan. A demolishment scenario would not result in a natural flow regime.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

In the work with the environmental impact assessment investigations have been executed. Parts included in the investigations are hydrology, hydraulic conditions, connectivity, habitat and possible restoration measures.

Investigations have shown that water velocity, in the natural part of the river, today is too high for all fish species. Spawning grounds and winter habitat are very limited due to high velocity. Old dredging during the log driving era also limit the habitats. Riparian zones lack large boulders breaking the strong currents. High velocity is caused by high discharge in the regulated river and by the fact that the river is narrow at the site. Through the construction of a fish way, fish migration will be made possible which is not the case at the current situation. Through restorations the fish growing area will be to 5120 m^2 and spawning area 1050 m^2 . This increase should be compared with the situation today where there is no spawning area at all at the site. The new ecological flow regime in the restored rapids will be 100 m^3/s during summer and 20 m^3/s during winter. Hydropower production will be limited to winter, during summer all water will be used for the ecological flow.
Figures 1 and 2 illustrate the weighted usable area (WUA), the amount and quality of habitat in Edeforsen for various life stages of grayling and trout, during the winter and summer respectively.

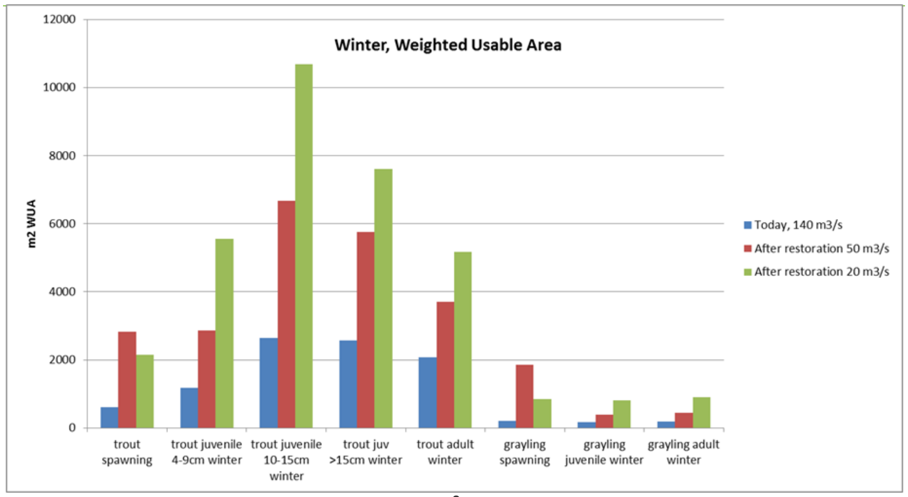

Figure 1. Illustrates weighted usable area (m^2) for winter conditions

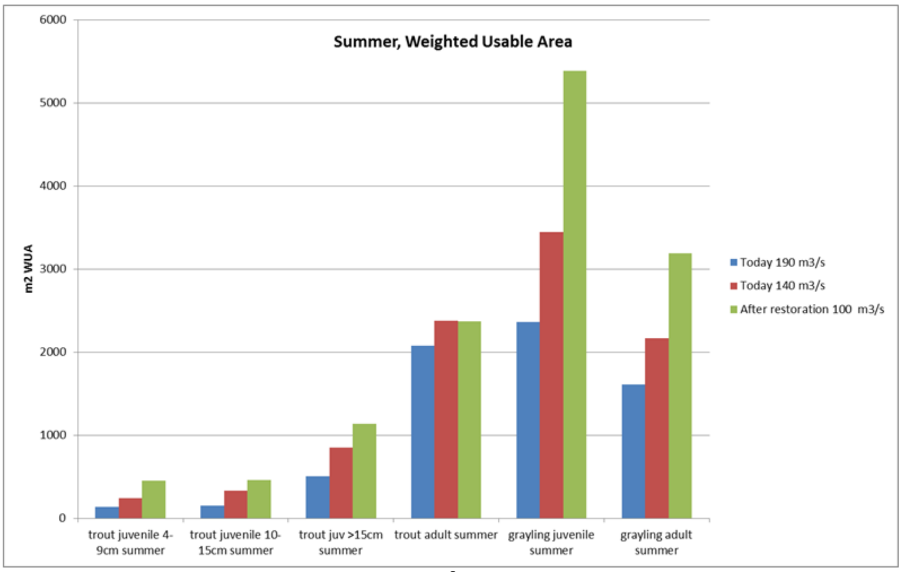

Figure 2. Illustrates weighted usable area (m^2) for summer conditions

Through biotope measures in the natural part of the river, construction of two fish ways and an additional spillway not affecting the natural river stretch will ensure good environmental ratio. The current constructions at Edeforsen, dam and HPP prevent fish migration. The old turbines, cause high mortality at downstream fish passage. With the new turbine the mortality rate will decreased.

3.2. Temporal and spatial scales

The study of ecological flow is limited to a 400 meter river stretch in Ljusnan river. The river is one of the large hydropower rivers in Sweden, with 23 large hydropower plants. The degree of regulation at Edeforsen is 24 %, reservoir capacity 1 400 million m^3. The Edeforsen hydropower plant, is a run of the river plant. With the planned installation production of electricity will increase from 3 GWh to 23 GWh due to abstraction of water to the power plant during winter.
Downstream Edeforsen there are nine hydro power plants in the main river. The dams prevent fish migration, so therefore there are no anadromus fish (salmon and trout) at this location.

3.3. Type of analysis or tool

Expertise on fish ecology have studied and modelled habitats finding possibilities for improving environmental conditions. Estimation of habitats for different seasons and life stages of brown trout (Salmo trutta) and grayling (Thymallus thymallus) was carried out at Edeforsen, with the help of field measurements of topography, three dimensional hydraulic modelling with Mike3D FM and a fish habitat model (FISU). The model results suggest the modified spill scheme and physical habitat rehabilitation measures in the channel proposed would mitigate the effects of high water velocity and would offer improved habitats for reproduction of the local fish species.

3.4. Information and data requirements

Possibility to describe baseline conditions has been looked into. However since the morphology of Edeforsen was heavily altered as early as in the 19th century (watermills, enhancing measures for floating logs etc) sufficient data for a baseline “habitat description” hasn´t been possible to collect. Data need includes information on topography, electro fishing and bottom fauna. No data were found from national databases. The national electro fishing database showed that no investigations had been carried out at the site. Earlier habitat inventory made by authorities stated that habitats for older trout was relatively good at Edeforsen and that spawning grounds are less good for trout. 95 % of the area is affected by dredging for log driving. Due to the lack of information, inventories had to be performed.

3.5. Testing of results

The topography of the river bed was a bit difficult to measure as the discharge is mostly quite high. Estimations had to be done. Testing have not been carried out yet, as the project is not completed. The project is primarily focusing on

a) recovering high quality habitat of original stream fauna such as bullhead, trout and grayling as indicators of a well-functioning stream water ecology.

b) recovering the possibility for fish and benthic fauna to migrate to- and from Edeforsen similar to conditions before anthropogenic impact. Adjustments may be needed if monitoring show this is necessary for achieving the ecological objectives.

3.6. Current application of the method/initiative

The case shows a possibility to find win-win solutions in part of a river affected by hydro power generation with unnatural flow regime. Negotiations in Environmental Court were held April 2014. This case will give good experience in restoration, fish migration and local flow control. It makes it feasible to do extensive environmental investigations and measures as electricity production will increase. This motivates extensive environmental investigations and measures.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The aim of the case is to show how development of hydropower can enable achievement of ecological objectives (GES). Within the classification made by the Swedish water management, biological quality elements have not been used. Classification is made as expert judgements based on the hydro morphological alterations. In the application to the Environmental Court, the Environmental Impact Assessment present the comprehensive investigations. The objective was understanding of how ecosystems could be improved. The results from hydraulic modelling have shown possibilities improving ecological status in the river stretch.

4. Contact information

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Case study 23 (Spain): "Implementation strategies and cost/benefit analysis for compliance with an e-flow regime in the Ter River affected by several small hydropower plants"

1. Executive summary

Approach used by the Catalan Water Agency when implementing an e-flow regime to restore good ecological status in the upper Ter River, modified by 85 weirs and water diversion for hydro-electric production. E-flows were calculated using hydrological and habitat-based methods. Several implementation strategies were analyzed and their associated economic costs and benefits calculated. The proposed measures could reduce energy production by 13 and 31 GWh/year. The cost of recovering this energy is approximately 1.02 and 2.63 M€/year. However restoring e-flows provides environmental services and social benefits that should also be considered. When comparing the expected costs with the expected social benefits, we found that the costs were unlikely to exceed the range of what society is willing to pay for the recovery of river ecosystems. Therefore, the restoration of e-flows in the upper Ter River has reasonable costs and is likely to be a socially desirable policy.

2. General information

Member State(s): Spain

RBD(s): ES100

Location: Ter River (NE. Spain)

Time period (start/end): 2007 to 2010

2.1. Objective of the Case study

The case study illustrates one approach to the design of different strategy for the compatibilisation of existing uses (mainly water derivations for hydroelectric production) with the implementation of e-flows. It also shows a methodology to estimate potential production losses in the case that the objective e-flows were respected, as well as the possible costs that might arise. It also describes an estimate of the benefits of implementing e-flows.

2.2. Policy and management context

Catalonia has more than 940 weirs and dams along 6,265 Km of rivers and streams, causing a high impact in comparison with the natural conditions once existing. To remediate this, in 2006 the Government of Catalonia approved a Plan to restore e-flows (ACA, 2005). E-flows were defined as an environmental objective, and mandatory for new water uses, but for existing uses its implementation was obstructed by significant administrative and economic challenges.

On the one hand, water rights for most hydropower facilities in the upper Ter River are historic uses and valid until 2061. On the other hand, their abstractions have been subject to criticism from other users, especially environmental organizations.

Therefore the e-flow regime cannot be implemented immediately, but requires a review process with technical and economic analysis and public participation to integrate the competing points of view.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

First of all, e-flow regimes were calculated by using hydrological methods in 320 river stretches in all Catalan rivers. Later, this work was validated in 25 selected stretches using the Instream Flow Incremental Methodology (IFIM) (ACA, 2006; 2008). These simulations provided additional information for establishing the e-flow regime, and also suitable tools for the implementation process.

We evaluated the technical and economic implications of implementing the e-flow requirements for each hydropower facility. To analyze the compatibility of each facility with the e-flow, we first defined the available flow as the difference between the circulating flow and the e-flow. The second step was to compare the available flow with the flow used by each facility. This analysis allowed us to classify the hydroelectric facilities according to the difficulty in meeting e-flow requirements without affecting electricity production or with the least possible cost. We calculated potential production loss and cost of the implementation of e-flows. We also estimated social benefits using society's willingness to pay (WTP) (Honey-Rosés, 2008).

Implementation strategies were discussed in a participatory process that involved water users and multiple public agencies, environmental groups and interested parties. The proposed implementation strategies were (in order of priority): a) Some facilities can maintain the same annual energy production by modifying the timing in which water is taken. This may requires a slight modification in their water rights, and in some cases, structural changes, b) The owner may be allowed to renew their rights in exchange for the progressive adoption of the e-flow requirements, c) With holders that manage small and large hydroelectric dams, reduced energy production in one facility can be offset by an increase in production in another, d) E-flows can be reduced, but always maintaining at least a minimum (60%) of potential useful habitat for fish species identified with models of habitat simulation, except in areas with special protection for aquatic species or habitats.

Once the strategies were agreed, and each facility classified, the plan for implementing the e-flow requirements in the upper Ter River was drafted as a policy defining e-flows in respect with each diversion point, and subjected to public information.

3.2. Temporal and spatial scales

E-flow calculation was carried out for the entire river basin district. But the cost and implementation strategies analysis are proposed for basins or sub-basins with similar characteristics and management problems.

The Ter River is located in northeastern Catalonia, with a drainage area of 3,275 km2 and characterized by a Mediterranean climate. Two large dams located in the middle of the basin divide the Ter watershed in two major sub-basins with different physiographic and hydrological conditions. In the upper Ter basin, water is repeatedly removed from the main river bed to produce hydropower but it is not consumed. Downstream the reservoirs system, the river discharge drops considerably since a large percentage is diverted to supply the Barcelona Metropolitan Region. Additional hydropower facilities remain in the lower Ter basin, however water management is largely driven by other issues. Therefore, the implementation strategies of e-flows and technical and economic analysis in this sub-basin have a different approach.

In this case study we focus on the upper half of the Ter basin, from its headwaters to the Sau reservoir. This covers 1,522 km², and the length of the main stream is 119 km. It has a good chemical status, and is located near natural area with scarce human pressures. The only pressure detected in this area is due to 85 hydropower facilities with a power generating capacity between 0.5 and 2 MW each and an average annual production 204 GW/h. River flow is repeatedly retained and derived from its bed by small weirs between 3 and 10 m and located one after another (every 1 or 2 km.). Moreover the 42% of the study area is located within a Protected Area (Natura 2000) and other environmental protection types (e.g. trout genetics protection) with an important number of weirs (37 out of 85) located inside these areas.

3.3. Type of analysis or tool

The hydrological methods applied to calculate e-flows were: Q95 and Q90, QBM (Palau, 1994), and RVA (Richter et al, 1997). The results provided by the QBM method were finally selected to define the base e-flow. This base flow was modulated monthly to obtain a flow variation similar to the natural flow regime. We characterized the temporal variability of monthly contribution with the natural daily flow (1940 to 2000). The type of hydrological flow regime was defined by clustering the nearest or the most similar river flow for different sections of rivers grouped in hydroregions. The defined e-flow follows this pattern but is simplified by grouping some months to facilitate the implementation and monitoring.

We quantified the availability of physical habitat for native fish species under low flow conditions by using two hydraulic simulation software (RHYHABSIM © 1999 (Jowet, 1997), and RIVER 2D © 2006, (Steffler & Blackburn, 2002).

The most innovative aspects were the compatibility and cost analysis. The compatibility analysis has been done in terms of median flow values. We considered that wet years outweigh dry years. The analysis cost includes electricity replacement cost, investment cost and possible compensation cost.

Potential loss production resulting from implementation of e-flows in the upper Ter was estimated analyzed at about 13.6 GWh/year, (0.2% of annual hydropower production in Catalonia). To estimate the replacement cost it has been considered the average production cost of electricity in Spain, which would correspond to the cost of production in restitution for the loss of production which is about 0.075 €/kWh. To determine the investment costs we grouped the facilities depending on the magnitude of work required to optimize the production and respect the e-flow, and an estimated cost was associated with every group. The investment should be amortized over a maximum period of 15 years. For economic viability, return on investment should translate into increased hydroelectric production, or extending the using period. Finally the direct implementation cost would be determined by any compensation for loss of earnings to the production condition on owners of water rights. These costs were estimated by calculating the lost profits until the end of the use period. The price considered to assess hydropower production was 0.0806 €/KWh.
To estimate social benefits of e-flows we reviewed two databases to identify appropriate studies relevant to our context in Catalonia. When looking for other studies that reported WTP values for river restoration, we sought to find those that were most similar to our study area. We eventually narrowed in four studies that specifically estimated willingness to pay estimates for e-flows. To assess the transferability of results from other sites we compared regions that had similar population, income per capita, and river length.

3.4. Information and data requirements

The calculation of e-flows used average daily flows returned to the natural system by using a rainfall-runoff model (National Weather Service, 2002), for a period of 20 years (1980 - 2000). The circulating flow was calculated using the average daily flow of a representative hydrological data of 10 years. An important part of the work was to gather data on the characteristics of hydroelectric facilities in the area, and his water rights. This was one of the main obstacles.

3.5. Testing of results

E-flows calculated with hydrological methods were tested using habitat simulation methods. And some values of the e-flows were reduced after the public participation and cost analysis.

In the firsts public meetings, users and environmentalist discussed all toghether the strategies to harmonize existing water uses with the proposed e-flows. We conclude that the meetings can be more productive if we carried out separately.

3.6. Current application of the method/initiative

A policy document for the implementation of e-flows was drafted, that followed a public information process, and we respond to the allegations received. However, it has not yet been approved because of political changes and economic problems in the ACA. We are currently working to reach individual agreements with users while we are waiting to approve the legislation requiring the compliance with the e-flows widely.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of E-flows

Water managers have little guidance and experiences in establishing e-flow, especially how to negotiate its implementation with water users while at the same time considering both costs and benefits. In many cases, flow regime restoration may be associated with economic costs.

This case study presents a methodology for implementing a policy of e-flows in circumstances in which there are pre-existing water rights. Our method estimated the associated costs of implementing e-flows, including the loss of hydropower production. Several implementation strategies were analyzed, and costs and benefits were compared by using WTP values in similar areas. Our experience suggests that the public consultation with stakeholders, a design of adaptation strategies, and the identification of likely costs and benefits, are useful steps for implementing e-flows policies. This same approach may be adapted to other basins with similar water uses.

The rational use of natural resources and the need to reconcile public and private interests in the issue of establishing e-flows must be present in the implementation process and policy decisions. E-flows may be established without compensation if these do not affect the final economic balance concerning production. A review of the benefits found in similar locations suggests that Catalonia would make net gains by implementing e-flows in the Ter River since the likely benefits per person are higher than the likely costs.

4. Contact information

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5. References

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Case study 24 (Norway): "Trial regulations for defining ecological flow in River Alta"

1. Executive summary

In Norway, the system of trial regulations based on temporary rules of operation has been applied in more than 30 rivers nationwide. Among these, the River Alta is regarded as one of the most successful cases. Trial regulations are mainly recommended in rivers of particular importance and when it is considered necessary to test out the effects of various flow regimes in practice, before the ecological flow requirements are finally decided. In The River Alta the main focus has been on safeguarding the wild Atlantic salmon stocks. Norway has international obligations under the NASCO convention to protect the Atlantic salmon, taking into account the best scientific advice available. In large rivers such as the River Alta, the salmon has a generation time of 5-7 years, which means that the long-term effects of hydropower might not be detectable before long time, often 10 years or more. The biological response time must therefore be taken into consideration when the trial regulations are planned. Sufficient time and resources must be allocated, and the purpose and objectives of the trial regulations should be clearly defined and consented. In the Alta case, the trial period was organized as a stepwise and adaptive learning process with the active involvement and commitment of the key stakeholders and research institutions, which has been crucial for the success.

2. General information

Member State: Norway.

RBD(s): Finnmark, N9002.

Location: River Alta.

Time period: 1987 to 2010.

2.1. Objective of the Case study

The objective of the River Alta case study is to illustrate the use of trial regulations based on temporary rules of operation for defining the ecological flow (eflow), in a river with complex natural conditions, and when knowledge is limited at the time when the license is granted.

2.2. Policy and management context

In Norway, the license terms and rules of operation, including the eflow requirements, are usually decided for 30 years when the permit is granted. The ecological flow is decided individually in each licensing case. The ecological flow requirements may be set as constant, variable or conditional. Assessing e-flow is normally a compromise between ecological, economic and social factors (e.g. fish, fishing, landscape, costs). For small hydro power plants (< 10 MW), it is common to use Q95 (summer/winter), but the effects are not well documented. For large hydro power plants (> 10 MW), the effects on the river system are usually well documented, and a combination of methods, including the Building Block Method (BBM) are used for assessing the eflow based on a sufficient data set of hydrological and biological data. In order to ensure flow dynamics, other factors are also taken into account, such as residual flow from the unregulated catchment area and maximum turbine capacity, which typically varies between 150-300% of QM.

The license for the Alta hydropower plant (150 MW, approx. 670 GWh/year) was granted to Statkraft by a Royal Decree in 1979, pursuant to the Watercourse Regulation Act (1917). Due to the limited knowledge about the river ecology, and the uncertainties in defining the optimal ecological flow at the time when the license was granted, it was decided that the rules of operation should be given temporarily for 5 years. During the trial regulation period, the purpose was to try out different regulation regimes in practice and monitor the effects before concluding on the permanent rules. The trial period was later extended for two more consecutive periods, until the permanent license terms were authorized in 2010. The license terms can be revised again 30 years after the permit was given. Use of trial regulations based on temporary rules of operation is mainly considered a relevant strategy in rivers with important interests that may be particularly sensitive to changes in the flow pattern, such as anadrome fish, prioritized nature types and endangered species.

In The River Alta the main focus has been on safeguarding the Atlantic salmon (*Salmo salar*) stocks from the impacts of the hydropower development. Norway has international obligations under the NASCO convention to protect the salmon, taking into account the best scientific advice available. It was acknowledged that a stepwise learning process with active involvement of the key stakeholders and research institutions was the road to follow. An important part of this strategy was the establishment of the "Regulation Council" with interdisciplinary experts from the Directorate for Nature Management (DN), the Alta Salmon Fisheries Organization (ALI), and the Norwegian Water Resources and Energy Directorate (NVE). The role of the Council was to give professional advice in the operation of the hydropower plant, especially during the critical winter period. Part of the purpose was also to collaborate closely with Statkraft and facilitate exchange of knowledge and competence building among the operative personnel. In parallel, a number of research projects and studies were conducted to strengthen the knowledge about the river ecology and dynamics, and document the effects of the various trial regulation regimes.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

The River Alta is one of Norway's most important rivers for Atlantic salmon. In 2007, the river was designated as a national Atlantic salmon river, which implies that activities that might harm the salmon are no longer permitted. It is also famous for sport fishing and attracts visitors both nationally and from abroad. The Sautso canyon where the river flows is one of the largest river gorges in Northern Europe. About 20 km of the river is classified as heavily modified due to impacts from hydropower.

The river has its source on the Finnmark plateau. The catchment area is about 7390 km^2 and the average water flow at the mouth is 88 m^3/s. Salmon and sea trout can migrate 47 km from the sea to the outlet of the power station, which also was the upper limit of anadromous fish before regulation. From the intake reservoir Virdnejávri to the outlet of the power station, the river is drained on a distance of approx. 2,5 km. The reservoir has two separate intakes at different depths at 10 m and 82 m below highest regulated water level. The two intakes make it possible to control the water temperature in the river downstream. In the winter, the water coming from the lowest intake is several degrees warmer than the surface water, resulting in varying unnatural ice cover of river below the power plant. This has periodically caused unusually high increase of fixed algae, which in turn has affected the bottom fauna and the salmon stocks negatively. Furthermore, changes in the fish metabolism and energy budget have also been documented as effects of lack of ice-cover.

In the first years of operation, stranding due to sudden drops in the water level was the main cause of increased mortality in salmon juveniles. In addition, reduced water temperature in the upper reaches of the river in the spring may have caused the smolt in this area to migrate later than those further down the river, and this may have lead to increased mortality due to predation. There are several other explanations for increased mortality in juvenile salmon as a result of the regulation, such as increased energy loss among the pre-smolts, and predation from other fish species such as grayling, and from mammals and birds because of reduced ice cover.

In the upper 7 km section, just downstream of the power station outlet, salmon juvenile densities were reduced by 80 % from pre-regulation levels to minimum levels in 1992–1996 (Ugedal et al. 2008). After changing the operation based on the increased knowledge and experiences, this resulted in a partial recovery of juvenile densities during 1997–2005, although not entirely back to pre-regulation levels. In contrast, the general trend in the middle part of the river was a linear increase in juvenile densities during 1981–2005. Spawning and recruitment in the upper section has increased in recent years, partly due to the introduction of catch-and-release angling. Today, the condition of the salmon population is classified on a catchment scale as good and for sea trout as very good. The conditions in the river may be regarded as comparable to those before the regulation (close to good ecological condition for fish), with exceptions for the river reach nearest to the outlet of the power plant.

The physical environmental improvements can be related to the measures that were identified during the trial period, and which are now formalized in the rules of operation, and which applies to the river downstream the power station. The operation attempts to keep natural water temperatures early in the winter, thus creating virtually normal ice coverage of the river, while draining should be done by gradually increasing the flows in late winter. The minimum eflow requirement in the winter is set to 16 m^3/s, while in the summer the flow shall be at the same level as the inflow from the catchment area. The water flows should be kept stable and sudden changes must be avoided. In order to ensure sufficient water flow in case of unforeseen shutdown of the power plant, a bypass valve has been installed.

The environmental measures described above do not have any significant effects on the power production.

3.2. Temporal and spatial scales

Extensive and detailed studies on the river ecology and species level were carried out before, during and after the hydropower development. The scale and focus of the surveys have varied somewhat, but during the entire period, the salmon's lifecycle and ice conditions in the river have been key issues. The justification for taking on a comprehensive and research-oriented approach can be derived from the importance of the river, especially the value of the Atlantic salmon, the controversy of the hydropower development, and the need for solid documentation.

In large salmon rivers such as the River Alta, the salmon has a generation time of 5-7 years, which means that long-term effects of hydropower will not be detectable before relatively long time, often more than 10 years. The assessment of impacts will also be dependent on sufficient documentation of the conditions before the development.

Some of the surveys and research that was carried out in Alta has transfer value to other rivers with similar conditions. The main trade-off of selecting this approach is the relatively high costs; considerable time and resources have been spent in the process. This must be calculated for when planning trial regulations. However, in the case of Alta, no one could predict from the start that the process would take more than 20 years.

3.3. Type of analysis or tool

The methods were selected to detect relationships between environmental variables and salmon stocks. Systematic studies on e.g. hydrology, freshwater biology (bottom fauna, salmon stocks and migration behavior, microalgae etc.), birds of prey, water temperature, ice coverage were conducted. The study methods included hydrological monitoring, biological field surveys, electro-fishing, fish telemetry surveys, modeling, and laboratory experiments. Spawning pits were counted by means of helicopter observations and diving. Reference stations were established in comparable rivers. The trial regulations were carried out in close collaboration between the key stakeholders; the responsible authorities, Statkraft and the NGOs, and also involving the research institutions. The substantial R&D activities, including several Ph. Ds, on the regulation effects and possible mitigation measures, enabled a good knowledge basis for the adaptive management and the final permanent rules of operation in 2010.

3.4. Information and data requirements

Most of the information and data were collected from national databases and through a number of site-specific surveys. The surveys were partly requested by the Directorate for Nature Management and partly initiated by Statkraft. Most of the surveys were funded by Statkraft, while other got financial support from the Norwegian Research Council. Since the process to some extent was "research driven", it might be argued if all the data and surveys were really necessary for deciding on the ecological flows. However, it is not questionable that the comprehensive surveys and research that was carried out have been important for ensuring the quality of the decisions.

3.5. Testing of results

The results from the surveys were directly applied inn the trial operations, and the effects were monitored. The temporary rules of operation were changed as a result of the trial regulations.

3.6. Current application of the method/initiative

In River Alta, the results and experiences from the trial period formed the basis of the permanent license terms and rules of operation that were finally approved in 2010 and that are currently in use. The system of trial regulations based on temporary rules of operation has been applied in more that 30 rivers nationwide. A review carried out in 2009 shows that the results vary considerably from river to river. I some cases, the water flow regimes have been changed several times during the relatively short trial period (normally 5 years), which have made it difficult to monitor and document the effects, particularly in anadrome rivers. Other problems may be related to lack of systematic follow-up from the responsible authorities in the trail period. (Glover et al. 2009). The eflow requirements for river Alta include both a lowermost accepted minimum operational flow, dynamic components (e.g. for trigging fish migration), restrictions on ramping rates and mitigations to enable build-up of ice cover during the long winter season.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The River Alta is regarded as one of the most successful cases regarding the use of trial regulations for defining the eflow. Trial regulations are mainly recommended in rivers of particular importance and when it is considered necessary to test out the effects of various flow regimes in practice, before the eflow requirements are decided. One of the lessons learned is that the ecology in high latitude rivers can be vulnerable to even small changes in the water flow and other impacts from hydropower. Secondly, the biological response to various regulation regimes can take long time, as is the case for Arctic salmon. Thus, sufficient time and resources for the trial period must be allocated to accommodate for this. The purpose and objectives of the trial regulations must be clearly defined and consented. The experiences from Alta show that a stepwise and adaptive learning process, with the active involvement and commitment of the key stakeholders and the research institutions, has been crucial for the success.

In the Norwegian screening of revision of terms for prioritization of 187 regulated catchments, river Alta was recommended as one of only 17 catchments considered to have high values concerning environment and impacts from hydropower, but with minor remaining restoration potential (Sørensen et al 2013). Several of these catchments (category 2.2) are national Atlantic salmon rivers and may be considered as best practise regulated rivers in Norway, with modern level of minimum flow requirement and/or modern restrictions on operational flow requirement to the lower anadromous part of the catchments.

4. Contact information

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- Relevant web pages: Environmental status – River Alta (http://www.statkraft.no/Images/Altaelva%20February%202010%20GB_tcm10-7428.pdf)

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Case study 25 (Norway): "National screening for prioritization of revised Eflow requirements with highest benefit in regulated rivers"

1. Executive summary

Ca. 430 Norwegian hydropower (HP) licenses may be revised by 2022. To facilitate the handling of these cases, a national screening project of 187 regulated (sub-) catchments was carried out by NVE and NEA in 2012-2013. Based on the specified methodology and the national priority criteria, the directorates recommend high priority (1.1) to 50 of the regulated catchments and 53 catchments for lower priority (1.2). A substantial restoration potential was identified by requirement for mitigation measures like minimum flow (ca 86 %), reservoir and run-off river restrictions (57% and 34 % respectively). HP production loss from minimum flows for achieving desired environmental benefits was only roughly estimated in this desktop study, for the 102 priority catchments, by use of by-passed Q95 summer/winter to be released at the most valuable river reaches. The total HP production loss, for the priority rivers might then be in the range of 2.3 to 3.6 TWh/year (1.8-2.8 % of the mean annual production in Norway), with about 15 rivers which alone might accounts for more than 75 GWh of power loss each.

2. General information

Member State: Norway.

RBD(s): all in Norway

Location: 187 catchments included

Time period: 2012 to 2014.

2.1. Objective of the study

A Norwegian screening project of 187 regulated (sub-)catchments (revision units), which includes 395 hydropower (HP) licenses, aiming at identifying the catchments with highest potential for restoration of environmental values according to the priority criteria was carried out in 2012-2013. This project was initiated by the two Ministries and carried out in collaboration between the Norwegian Energy and Water Directorate (NVE) and the Norwegian Environmental Agency (NEA).

The main aim has been to categorize and cluster HP licenses in revision units, to group catchments/sub catchments into priority categories, focusing on the potential for environmental restoration by minimum flow/Eflow, restrictions on reservoir and/or run-of river operations as appropriate measures related to national important environmental benefits.

2.2. Policy and management context

In the mandate for the project given by the Ministries, NVE and NEA were asked to provide a national overview and selection of catchments where mitigation measures affecting HP is considered to give the highest environmental benefit. The project mandate also stated clearly that the total reduction of power production should be kept at a moderate level. Eflow for achieving desired environmental benefits was roughly estimated based on the default values of Q95 summer/winter, and pointed out the most important inter-annual reservoirs in Norway. However, this national screening did not intend to estimate the HP reduction in detail.

Norway has a mean annual hydropower (HP) production of 130 TWh, and is among the countries in the world with the highest share of energy from HP. Many of our largest HP constructions are from the 1950's and 60's when environmental knowledge and consideration was not as prominent as today. Minimum flow was often not a requirement in these old regulations.

Hydromorfological alterations due to HP are among the most frequent impacts on ecological status in our water bodies, and more than 2500 water bodies are significantly impacted by river regulation. Impact from HP represents the dominating impact factor in several of the river basin districts. Environmental flow is considered to be one of the key measures for environmental improvements in many of these rivers, and therefore also for the implementation of the Water Framework Directive (WFD) in Norway. Sweden, Finland and Norway were in 2012 the European countries with the highest share of HMWB due to HP (Kampa et al, 2012)

The terms of the licenses and corresponding environmental requirements can be changed every 30 years by revision. Ca. 430 HP licenses may be revised by 2022, representing an annual HP production of approx. 80 – 100 TWh. To facilitate the handling of these cases, the Ministry of Petroleum and Energy (MPE), in collaboration with the Ministry of the Climate and Environment (MCE), completed a national guideline for revision of licenses (MPE) 2012. This guideline included priority criteria (where and when minimum water flow should be prioritized) e.g. rivers with important national interests like fish, biodiversity, recreational use and/or tourism.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

As part of the project, a multicriteria-methodology for ranking environmental values and impact from HP operation on a catchment scale, was developed (Table 1).

Table 1. Multicriteria metrix used for ranking value-impact score for fish, biodiversity and recreation at catchment scale.

	Impact from HP on Biodiversity/Fish/Recreation			
Value	Severe	High	Medium	Low
Very high	VI5	VI5	VI4	VI2
High	VI5	VI4	VI3	VI1
Medium	VI4	VI3	VI1	VI1
Low	VI2	VI1	VI1	VI1

A value-impact (VI) score (low – very high [1-5]) where defined for all catchment for each of the main environmental topics; 1) fish/fishing, 2) other freshwater related biodiversity and 3) landscape/recreation. The Norwegian method include elements of, but not a complete ecosystem service approach, by focusing also on restoration potential of e.g. landscape aesthetics and other user interests such as recreation and fishing (more than the quality elements linked to WFD). The work was published in a national report in October 2013, with factsheet which describe and categorise each of the 187 revision units (Sørensen et al, 2013).

3.2. Temporal and spatial scales

This project covered regulated catchment with a HP production between 80-100 TWh.

3.3. Type of analysis or tool

Based on the specified methodology and the national priority criteria, the directorates recommend high priority (1.1) to 50 of the regulated catchments. Further, 53 catchments recommended for lower priority (1.2). The remaining 84 catchments were recommended not to be prioritized for revision with new mitigation measures affecting HP. Of the non-priority category only 17 catchments is considered to have high values concerning environment and impact from HP, but with minor remaining restoration potential (2.2). Several of the 2.2 catchments are national Atlantic salmon rivers and may be considered as best practise regulated rivers in Norway, with modern level of minimum flow requirement and/or modern restrictions on operational flow requirement to the lower anadromous part of the catchments. The length of the regulated rivers and/or size of regulated lakes are typically longer and larger in the priority (1.1 and 1.2) versus the non-priority (2.1) catchments. The HP production is also on average considerable higher in priority catchments (> 700 GWh/yr vs approx. 120 GWh/yr in non-priority catchments).

Except for the northernmost RBD; Finnmark, all regions in Norway have catchments in all categories, including several recommended as high priority (Figure 1).

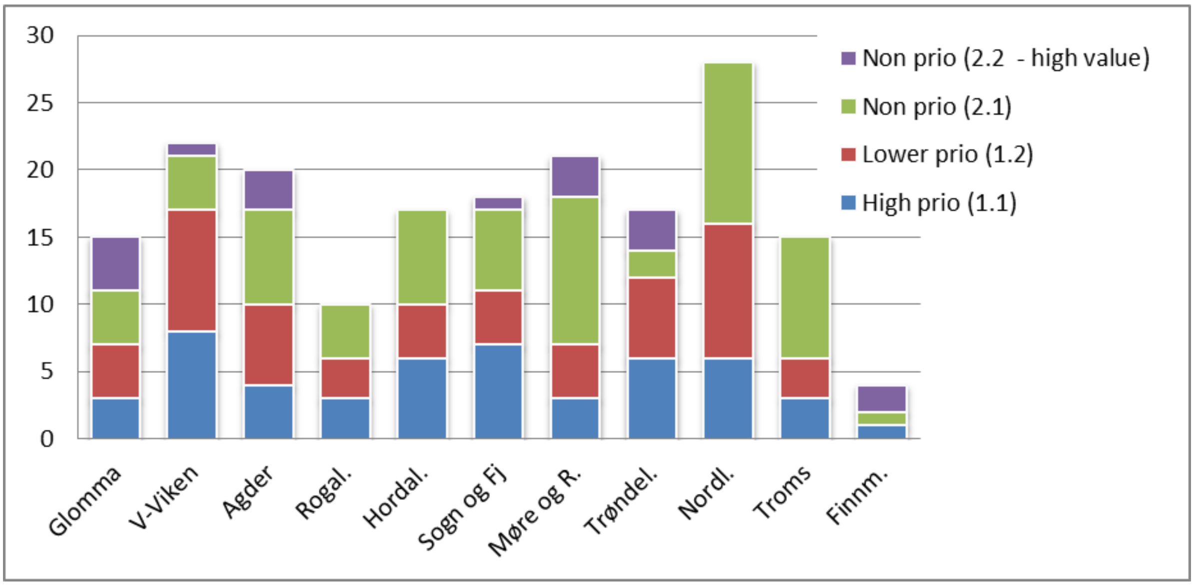

Figure 1. Number of regulated catchments in priority categories in the 11 River Basin Districts (RBD) in Norway.

The national screening revealed that a considerable part of the regulated catchments have remaining challenges and need revision of terms, to reduce negative impact on national important environmental values specified in the national guideline. For most of the priority catchments (103 of 187), restoration potential is considered as high for fish/fishing (VI-score of 3-5 for ca 52 % of the 187 catchments) and landscape/recreation (VI-score of 3-5 for ca 43 % of the 187 catchments), and lower for biodiversity like e.g. habitat for eel and pearl mussel (VI-score of 3-5 for ca 36 % of the 187 catchments).

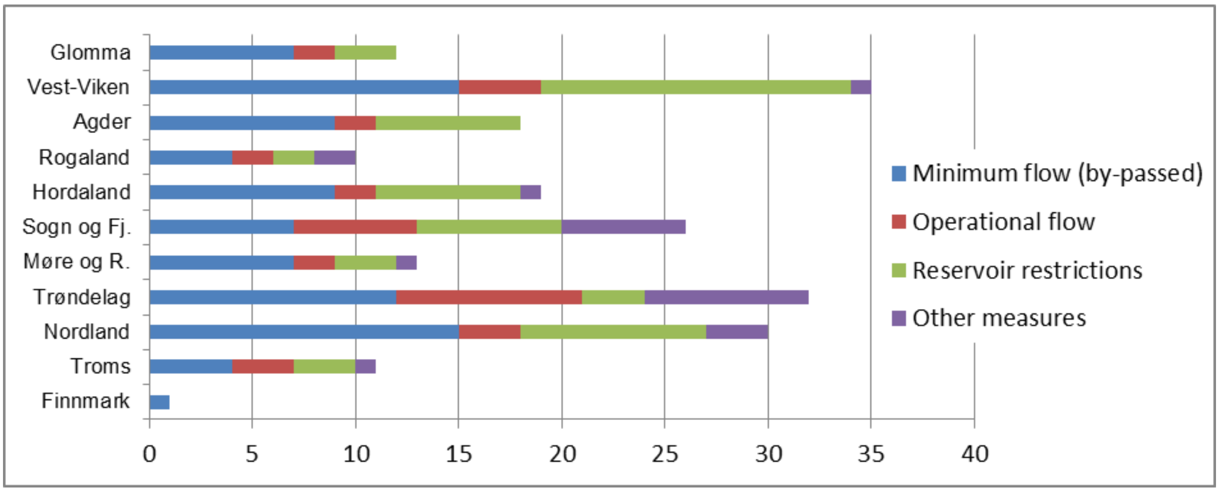

Figure 2. Regional distribution of mitigation measures (number thereof) affecting HP production, recommended in the prioritised revision units.

The project has identified a substantial restoration potential and need for revision of terms (Fig 2), to enable requirement for mitigation measures like minimum flow (ca 86 %), reservoir and run-off river restrictions like operational flow restrictions on HP turbines with outlet to rivers (57% and 34 % respectively of the priority catchments). Adverse effect on HP production is in most catchments considered not to be significant by restrictions on magazine or run-off river operations, but in general this mitigation measure was to a large extent mainly for improvement of landscape aesthetic reasons, and therefor not part of the primary WFD objects.

All the existing environmental restrictions (nationwide) limits the total HP production in Norway by approx. 1 TWh, equivalent to slightly less than 1% of the average annual production. These restrictions (mainly minimum flow requirements in modern licenses) are to a small extend part of the licenses covered by the national screening.

For almost 40 % of the priority catchments, consequences for power generation are relatively small (power loss of 0-5 GWh for each catchment). The total HP production loss, for the priority rivers are in the range of 2.3 to 3.6 TWh / year (1.8-2.8 % of the mean annual production in Norway), with about 15 rivers which alone accounts for more than 75 GWh of power loss each. However, more differentiated minimum flow requirements and on-site assessments than the Q95 standard is likely to reduce the power loss as Eflow for achieving desired environmental benefits was only roughly estimated.

3.4. Information and data requirements

All available and relevant national datasets have been compiled into an interactive GIS system (VassdragsAtlas) to make expert judgment as transparent as possible.

3.5. Testing of results

The project's multi-criteria decision analysis (MCDA) valuation and weighting methodology have been evaluated in light of a recent review of the use of MCDA in hydropower and water regulation projects in Norway. The multi-criteria structure methodology of the revision screening project have been modelled using Bayesian Network (BN) software in order to evaluate potential biases implicit in the combination of criteria hierarchy, impact scoring, value functions and weighting (Barton et al., 2014).

3.6. Current application of the method/initiative

The methodology and recommendations from the national screening have revealed that loss of power generation is only acceptable if environmental benefit from e.g. Eflow is significant enough in a national context. This has been an important national requirement for objective settings in the river basin management plans for Norway, according to handling HMWBs and WFD in the coming planning cycle (Norwegian HMWB guide, 2014). Measures like Eflow and magazine restrictions reducing HP production, will therefore as a starting point mainly be mitigation requirements for environmental objectives in the high-priority catchments (1.1) within 2021 as a national guideline (KLD and OED, 2014). These are catchments with significant restoration potential for important fish populations (mainly Atlantic salmon and/or large inland trout) and/or important freshwater related biodiversity (e.g. pearl mussel, nature types) relatively to estimated HP production loss. However, national authorities still give some flexibility for regional divergent prioritisations. Still, a major management challenge is remaining to fully incorporate environmental flow requirement as an integrated part of WFD in Norway, as one of the major HP producers in Europe.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The project made an assessment of other important factors that may affect the outcome of revision of terms and likelihood to change of Eflow such as; upgrading and expansion, flood conditions, security of supply and the effect of climate change. Upgrading and expansion (U/E) of the existing regulations and hydroelectric power plants and new power production could in principle help to compensate for the loss of power due to environmental measures. Nationwide, the total U/E-potential is approx. 7.5 TWh / year, including 3.9 TWh in catchments covered by this screening. Production potential of new HP projects applied for by June 2013 is approx.14 TWh. Wind power projects in process are approx. 39 TWh. In addition, there are already given licenses for several TWh renewable hydro and wind (2010-2013) still not put into operation.

Climate change has led to changes in runoff pattern and discharge in Norway. The usable inflow for HP in the period 1981-2010 increased by ca. 3.3 % nationwide as compared to the previous 30-year period. However, the variations are significant both regionally and at river basin level. Future climate change scenarios based on different climate models point towards further increase, and show the order of 2-16 % increase in runoff in all parts of Norway for the period 2021-2050, as compared to 1961-1990.

Measures like Eflow will as a starting point in Norwegian RBMPs mainly be accepted as mitigation requirements for environmental objectives in the high-priority catchments (1.1) within 2021 as a national guideline, leading to a roughly estimated production loss up to 1,7 TWh.

4. Contact information

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Important links:

- Vassdragsatlas
- Norwegian screening of revisions

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Case study 26 (Spain): "The use of multidisciplinary models to optimise the e-flows regime in the Tormes river basin"

1. Executive summary

Multidisciplinary models are useful tools to combine different disciplines when addressing Integrated Water Resources Planning and Management. By coupling models for water resources management, water quality modelling and habitat analysis, it is possible to optimise e-flows regimes while considering the legal constrains in river basins. To do so, we propose a methodology in which the water allocation model solves the allocation problem through network flow optimisation, and considers the environmental flows in selected river stretches; the water quality model performs the water quality evolution in rivers and reservoirs; and the habitat model provides Habitat Time Series for each available Weighted Usable Area-Flow curve. This approach was applied to the Tormes Water Resources System. The results demonstrate the potential of the methodological framework to reach a balanced solution for the key aspects of the river basin, by defining water management rules that simultaneously maintain water supply, aquatic ecosystem and the water quality requirements of the WFD. It represents also a good tool for water planners in order to complete the RBMP since it relates the water uses with the water quality standards to reach the good ecological status and potential of the water bodies.

2. General information

Member State: Spain

RBD: Duero River Basin District; A1003

Location: Tormes Water Resources System

Time period (start/end): October 1996 to September 2009

2.1. Objective of the Case study

The objective pursued in this case of study is the application of a methodological framework comprised of three combined models. It aims to integrate aspects of water allocation, water quality and environmental requirements under the European legislation framework into decision making. This helps in providing useful criterions to distribute water resources in the Tormes Water Resources System (TWRS).

2.2. Policy and management context

In order to achieve the good status of surface water bodies according to the European Water Framework Directive, the water quality reference conditions and the process to define environmental flow regimes are established in the Ministerial Order 2656/2008 of September the 10th. Referring to e-flows, the process involves the scientific work to define the e-flow regimes components (minimum and maximum flows, flows exchange rate, etc.); the agreement process in which the stakeholders are involved (affected water users, environmental associations, etc.), which can result in the modification of the initially designed e-flow regimes to avoid disproportionate impacts on previous water uses; the establishment of the agreed e-flow regimes; and their monitoring to ensure the accomplishment of the initial objectives. All the process has to be handled by the River Basin District Authorities, and more specifically by the Water Planning Offices. With reference to minimum e-flows, the Spanish legislation requires the application of habitat simulation to establish them with a range of 50% to 80% of the maximum WUA in normal years, or 30% of minimum during severe drought or in water bodies with severe hydrological alteration. The BQE are represented by the fish fauna, taking into account that it represents the maximum sensitiveness to water quality changes and taking also into account the link between the fish fauna and the other BQEs.

In regard to water quality, it has to be controlled by means of appropriate waste water treatments on the demands return flows, and the water management rules laid down by the EU. These tasks are undertaken by the Water Commission and the Water Planning Office of the River Basin District

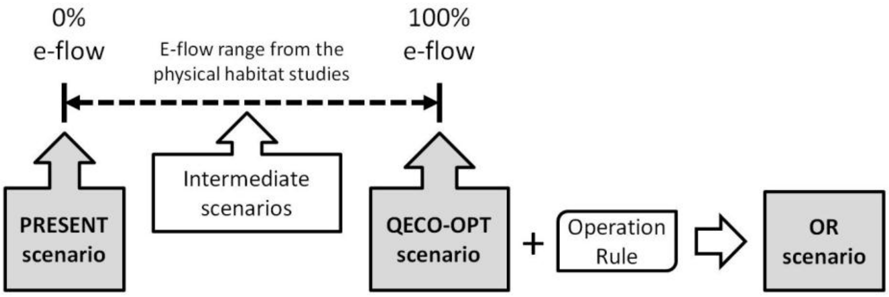
Authorities, respectively. Diffuse pollution also influences water quality in rivers, but its control is not assigned to any specific agent related to water issues.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

An integrated Decision Support System (DSS), covering water allocation, water quality and habitat availability models, was implemented in the TWRS. The design and practical performance of the integrative methodology was undertaken by the Technical University of Valencia (Group of Water Resources Engineering of the Research Institute for Water and Environmental Engineering), with the guidance of the Duero River Basin District Authority (DRBDA).

The case study consisted on analysing the behaviour of some target variables related to water allocation, water quality and habitat availability as the e-flows regimes were changed in several points of the river. To do so, a set of simulations were performed with the three coupled models at different e-flows levels (e-flows scenarios) within a pre-defined range. The figure below presents a diagram of the simulated scenarios.



For each simulation with the three models, several Simulation-Indicators were generated to assess the systems dynamic behaviour. They included the percentage of agricultural demand deficits as indicator of water management, the dissolved oxygen and ammonium concentrations as indicators of water quality, and the Habitat Time Series (Milhous et al., 1990) of the most affected species as ecological indicator.

3.2. Temporal and spatial scales

The spatial scale was the water resources system (or river basin), as this is the proper scale to carry out integrated water resources management and fits with the territorial management scenarios of the WFD. The models admit any spatial detailed required by the user. In this case study, the main reservoirs, water demands and returns, aquifers were considered. The Tormes River was represented in different river stretches, while its tributaries were included as runoff elements.

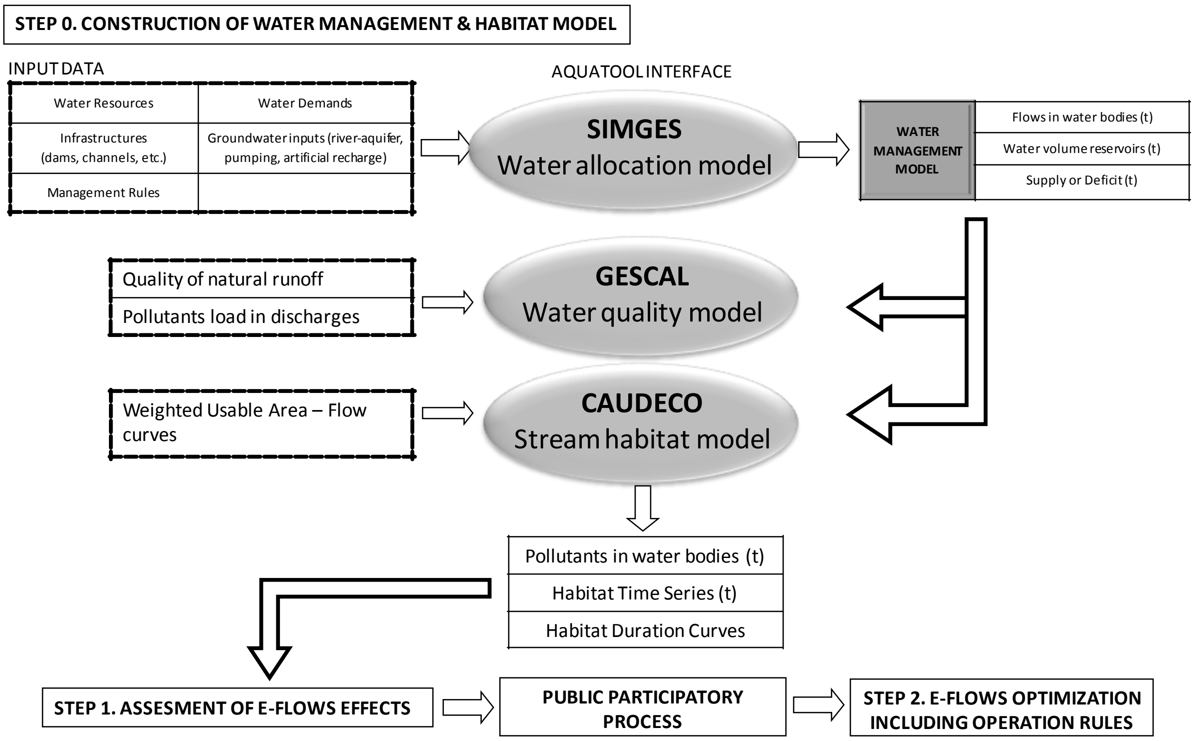
The appropriate time scale varies depending on the analysed issue. In the case of water management, the monthly scale is usually adequate. The same could be applied to water quality modelling. However, the environmental flows are usually analysed at lower scales. At present, this methodology works at monthly time scale and takes into account the main corresponding processes.

3.3. Type of analysis or tool

The proposed methodology is based on the linkage of a water allocation model, a water quality simulation model and a habitat availability model. The first step in the procedure includes the development, calibration and validation of the models in the TWRS. Next, the different scenario simulations are conducted. Initially, an e-flow regime is defined in the water allocation model. This model provides the flows in rivers and volumes in reservoirs. These results are used as inputs for the water quality and habitat availability models.

Once all the simulations are run, the results have to be analysed in order to select the e-flow regime which fits the legal prescription while satisfying the majority of stakeholders. In this case study, the public participatory process was skipped as it was a research work. Finally, the situation with the selected e-flow regime can improved through the implementation of operation rules which balance the functioning of the whole system.

The figure below presents the diagram of the integrative methodology and the models linkage.



3.4. Information and data requirements

As showed in the figure above, the data needs are conditioned by the models requirements. The DRBDA provided all the necessary data from their databases.

Depending on the type of information, it comes from real data measurements (water resources, quality of natural runoff, pollutants loads in discharges), from indirectly derived from measurements (water demands, weighted usable area-flow curves), from models (most of the groundwater inputs), from the original design of the water resources system (infrastructures, management rules), etc.

When deciding the management elements, pollutants and aquatic species to include in the models, the focus should be on their relevance as problem or solution drivers. This implies a good knowledge of the case of study and/or the advice of local actors. In this case, the DRBDA adopted the advisory role.

3.5. Testing of results

Given that the final e-flow regimes and the operation rule were not applied in reality at the TWRS, but in models, it was not possible to test the results. However, we expect them to be correct because the models were calibrated and validated from October 1996 to September 2006, and the results were satisfactory.

3.6. Current application of the method/initiative

We are widening the methodology by linking hydrological and diffuse pollution models. This will allow to determine the influence of the territorial management (basically land uses) on water availability and water quality.

In the near future, this integrative methodology will be applied to the Llobregat River Basin, but in this case, the three models will be used to test the effect of the implementation of some actions in the Program of Measures on the River Basin Management Plan.

In the presented case of study, the habitat availability model calculates the habitat availability only considering the instream flows. However, the main equation of the model includes a term which alters the habitat availability with respect to the water quality. This term was not implemented because of lack of data. Thus, a forthcoming research improvement will be to find the data to apply this water quality term.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of E-flows

The integrative methodology can be applied to any kind of river basin or water resources system. The only limitation is acquiring all the necessary data to feed the three models in the calibration, validation and simulation steps.

4. Contact information

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Case study 27 (Austria): "Restoration of eflows in the development of the 1st River Basin Management Plans"

1. Executive summary

Water abstraction is one of the most relevant pressures in Austrian rivers. The risk analysis showed that 10% of the Austrian rivers are affected by water abstraction leading to fail GES. The reason for water abstraction is in nearly all cases hydropower use. The majority (>85%) of the ~2000 existing hydropower plant are abstraction plants lacks regulatory requirements for ecological minimum flow. For any new water abstraction ecological minimum flow to ensure good ecological functioning of rivers is obligatory since 1990.
Studies were carried out to evaluate the impacts of the existing pressure (water abstraction) on the environment (on biological elements) as well as the impact of measures necessary to achieve good ecological status (GES) on hydropower sector.
By using scenarios possible impacts like loss of electricity production (base load as well as peak load/regulation services), investment costs, financial losses were evaluated on different scales and for the subsectors.
As > 60% of the national electricity production is coming from hydropower, this energy sector plays a very important role in Austria. According to the National Energy Action Plan of 2010 hydropower generation has to be increased to achieve the objectives of the EU RES Directive. Therefore losses in electricity generation due to minimum flow restoration have to be minimised as much as possible. It was evaluated that the restoration of the ecological minimum flow to achieve GES in water bodies affected by water abstractions due to hydropower use would lead to production losses of 3% of the total national hydropower generation.
To minimised negative effects on the Austrian hydropower generation it was decided to restore the ecological minimum (eflow) stepwise and following an ecological prioritisation. The stepwise restoration includes 2 steps. In the first step flow conditions have to be improved to allow fish migration (basic flow value and regulations for minimum depth and minimum flow velocity), in the 2nd step flow have to be further improved to achieve good ecological status for the biological elements.

2. General information

Member State(s): Austria

RBD(s): Danube (AT1000), Rhine (AT2000), Elbe (AT5000)

Location: priority rivers in 1st RBMP

Time period (start/end): 2010 to 2015 (at least)

2.1. Objective of the Case study

Restoration of good ecological status in Austrian rivers in consideration of the importance of hydropower production for electricity supply in Austria

2.2. Policy and management context

The particular challenges for Austria are the huge extent of river continuity and eflow restoration measures for hydropower sector necessary to achieve the goals of the WFD as well as 34% target for renewable energy according to the RES Directive and to cope with hydropower permits in place with either no expiring date or long durations.
60% of the river water bodies are not in a good ecological status; in most cases good ecological status is failed due to hydromorphological alterations (resulting in deficits in the Biological Quality Element Fish).
In the Austrian water Act in 2011maintaining river continuity and ensuring ecological minimum flows were declared to be State of the Art/BAT. This is relevant for new projects as well as for existing obstacles/migration barriers and water abstractions.

The high number of hydromorphological pressures (e.g. >30.000 continuity interruptions/migration barriers, >2.500 hydroelectricity plants not ensuring ecological minimum flow, thousands of kilometres of regulated/straightened river banks due to flood protection….) poses considerable challenges with regard to planning, technical and administrative efforts, costs and losses in hydropower generation. It is comprehensible that it is impossible to restore this huge amount of pressures to achieve good ecological status in all water bodies until 2015. Therefore, a phased approach was chosen for restoring GES taking into account ecological sensitivity/effects leading to an ecological prioritisation.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

1st WFD cycle (until 2015):

Priority rivers, key measures: river continuity and ecological minimumflow (first step)

In the first WFD cycle (2009- 2015) measures focus on those priority rivers which are defined by the habitat of the medium distance migratory fish species *Nase*, *Barbel* and *Danube salmon* and of the lake species *Lake trout and Perlfisch*. These fish species are ver much endangered and their habitats and main migration corridors are located in the larger rivers (hyporhitral and potamal zones). Those river stretches are heavily impacted by hydromorphological pressures (compared to smaller rivers and upstream parts); For these water body types almost no water bodies in high status and just a few in good status do exist. To start restoration measures and improve hydromorphology there is considered to have the most significant positive ecological effects.

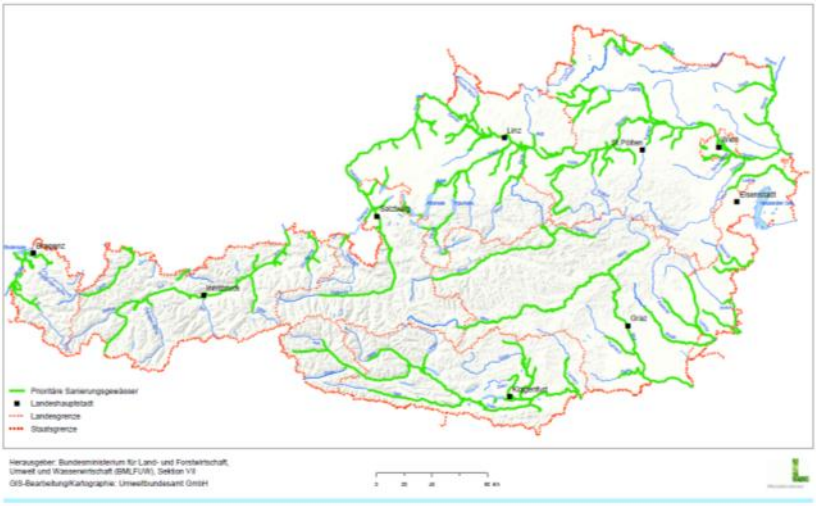

Figure 1: Priority area for river continuity and eflow restoration measures in first WFD cycle

Selection of key restoration measures:

In the first RBMP the main focus is on measures with the highest cost effectiveness and those which are "no regret measures" in cases where knowledge has still to be increased to decide on the extent of restoration measures to ensure achievement of GES/GEP. Restoration of river continuity including a flow ensuring passability of the rivers for fish are "no regret measures" at any rate in areas where fish naturally live.

The selection of relevant restoration measures is based on scientific knowledge and long-term experience from ecological monitoring. The impacts of certain pressures (interruption of river continuity, insufficient flow) and also effects of possible restoration measures are well known. Studies dealing with the impacts of existing hydropower plants on the environment (effect on fish, macroinvertbrates, ecological status…), with effects of restoration measures and also with impacts of restoration on the hydropower sector have been carried out during the recent years and strengthened the knowledgebase.

Both, measures for continuity restoration (including ecological minimum flow for fish passability) as well as for morphological restoration of banks will be necessary for achieving good ecological status; however restoration of river continuity (including ecological minimum flow for fish passabiliy) is considered to have the most significant positive effect on the ecological status of rivers and is thus prioritized.
The long-term ecological concept behind this prioritisation of measures is that restoration of river continuity (including ecological minimum flow for fish passability) for free migration of fish is seen as a prerequisite for achieving good status in the entire river basin and will ensure success in the long run. Habitat improvements without opening the migration routes would not make any ecological sense.Thus ecological conditions will be improved by 2015 by reducing pressures (continuity interruption, reduced flow due to water abstraction), even though further measures (e.g. restoration of banks…) may be necessary to achieve fully the goal of good status.

Within the Stigler Study 2005 ("Auswirkungen der Umsetzung der EU-Wasserrahmenrichtlinie auf die Wasserkraft) financed by the Water Management Ministry together with the hydropower companies) the effects of measures needed to achieve good ecological status on electricity production were defined, quantified , monetarised and evaluated. The study included calculations for different scenarios for ecological flow conditions and was the basis for further decisions. Losses of hydropower production due restoration of ecological minimum flow were estimated to reach ca. 3% of the total hydropower production in Austria.
In the first step flow conditions have to be improved to allow fish migration /passability (regulations for minimum depth and minimum flow velocity), in the 2nd step good ecological status has to be achieved by restoring the dynamic share of e-flow).
Measures to guarantee minimum flow in the 1st management cycle affect ca. 150 power plants. This leads to losses in hydropower production in a range between 8-15% for individual power plants, and < 1% based on the total Austrian hydropower production.

Legal instruments for the implementation of the program of measures

- The Austrian Water Act was amended due to the needs for the WFD implementation.
- River continuity was defined as *state of the art and technology* in the Water Act.
- The Austrian Water Act authorises the Länder to issue legal regulations (ordinances) with the aim to oblige all holders of permits to submit restoration projects related to river continuity and ecological minimum flow within a given time frame. Thus the existing permits do not have to be changed case by case but with a single legal regulation. This approach has been used by 5 Länder
- Classification of Ecological status is defined in the Quality Objective Ordinance – Ecological Status of Surface Waters, this includes also guideline values for ecological minimum flow.

2nd WFD cycle (until 2021)

The Plan is to achieve good status/potential in priority rivers of the 1st cycle (focus on morphological measures and ecological minimum flow) and to set priority measures (continuity, ecological minimum flow for fish passability) in all other water bodies with catchment area > 100 km² (+ important habitats of medium distance migratory fish in smaller tributaries).Further Details will be elaborated in the 2nd RBMP.

3.2. Temporal and spatial scales

Priority rivers – see 3.1

3.3. Type of analysis or tool

National strategy:
- to base decisions on restoration requirements on facts (and not only political statements
- to start discussions with the sector concerned as early as possible
- to work on facts in close cooperation with the sector concerned (for example Stigler-Studie).
- to make use of a prioritisation approach following transparent and ecologically driven criteria in case of large numbers of restoration projects needed
- to legally support the enforcement of restoration by

+ declaring river continuity and ecological minimum flow as state of the Art and Technology (relevant for new as well as existing projects/pressures)
+ ensuring a possibility to provoke restoration projects which mean a change of existing permits by Ordinances on provincial level instead of case by case

3.4. Information and data requirements

Detailed pressure and impact data are available from the impact and pressure analysis. The information for each pressure was collected with exact localisation (not only related to water body) and quantification (at least semi-quantitatively).
Studies on the conceivable impacts on specific use sectors (for example hydropower) were made together with the sector concerned.

3.5. Testing of results

3.6. Current application of the method/initiative

Restoration is in progress, ca. 200 measures to restore ecological minimum flow have already been set.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

Huge need for restoration measures: 60% of water bodies fail good status, mainly due to hydromorphological alterations (as a result of efforts of around 2 centuries for flood protection and hydropower production), 10% of Austrian rivers have no ecological flow

- Only extension of deadlines is used in case of missing e-flows
- Clear prioritisation, clear strategy for phased approach, clear targets available for each water body.
- Program of measures in the RPMP is broadly accepted by all parties involved, balancing achievement of quality objectives and losses in hydropower production.
- National strategy was successful

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Case study 28 (Austria): "Incentive to implement ecological flows in case of hydropower abstraction plants"

1. Executive summary

Hydropower plays an important role for Austria as more than 60% of the national electricity is generated by hydropower. To achieve the objectives set for Austria in the RES Directive it is necessary to increase the hydropower production by 3,5 TWh till 2020. In Austria more than 3000 small hydropower plants exists with very old, usually unlimited rivers are impacted by water abstraction due to hydropower and therefore failing good status. To achieve the objective of the RES Directive as well as WFD an advisory service in combination with specific financial support programs was developed in several provinces as an incentive to increase the hydropower production at small hydropower plants by modernisation and increasing efficiency and to restore the ecological flow at the same time.

2. General information

Member State(s): Austria

RBD(s): Danube;

Location: Province of Upper Austria, Lower Austria, Tyrol, Styria, Salzburg

Time period (start/end): 2008 -

2.1. Objective of the Case study

Advisory services in combination with specific financial support programmes as a tools to minimise the negative effects of eflow restoration on the small hydropower sector and to successfully solve the conflicting interests of the RES-Directive and WFD by increasing electricity production and efficiency as well as improving ecological status at the same time.

2.2. Policy and management context

Ensuring eflows was declared to be State of the Art and Technology in the Austrian Water Act. Guide values for ecological minimum flows were set in the Ordinance on water Quality Objectives for Surface Waters in 2010 on the national level which ensure the achievement of the biological values set for good ecological status. In the Program of Measure (POM) of the National Water Management Plan (NGP) a phased implementation of eflows was following a prioritisation approach which was mainly based on ecological effectiveness criteria. As the restoration of eflow leads to losses of electricity production up to 30% for a single plant, not only negative effects on the mall hp plant owner concerned is reasonable is to be expected but also conflicts with the achievement of the objectives of the Res-Directive arise which even requires an increase of hydropower production.

As the objectives of both directives (WFD, RES-D) have to be achieved it was clear that tools/incentives are necessary to sole the conflict and minimise the negative effect for the plant owners.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Around 2010 the provincial governments of Austria set target values for the increase of electricity production by renewables including hydropower. As at the same time the objectives of the WFD for good ecological status which includes the provision of eflows have to be achieved as well in the rivers till 2027 at the latest, initiatives were developed to achieve both objectives by implementing advisory services for technical and ecological optimisations of existing hydropower plants; Financial funding programs for technical and ecological investments were also established complementing the funding schemes on national level.

3.2. Spatial scales

The tool (advisory service and financial funding programmes) was initially developed by the province of Upper Austria and than adapted to specific requirements by 4 other provinces; Lower Austria, Tyrol, Styria and Salzburg The project is still ongoing. The tool is for small hydropower plants (< 10 MW) and helps to minimise negative effect on hydropower owner in case of eflow restoration.

3.3. Type of analysis or tool

The advisory service in combination with financial supporting programmes was installed in 5 Austrian provinces for the owners of small hydropower plants. The advice refers to
- technical solutions to increase electricity generation and improving plant efficiency
- ecological requirements/solutions to meet the legal eflow requirements
- most cost-effective measures
- financial support programmes in place on national and provincial level

Upper Austria – Ökostromprogramm ÖKOP

- Financial support program for investments to improve ecology of rivers (fish pass, morphological improvements):
  Plants < 1 MW: 24 % of the investments are sponsored (in addition to the 30% investment sponsoring financed by the National environment Fund).
  Plants 1-10 MW: 15 % of the investments are sponsored (in addition to the 30% investment sponsoring financed by the National environment Fund).
- Financial support program ÖKOP for technical investments to increase hydropower generation and improve plant efficiency: 25% of investments (max. 50.000 €)
- Advisory service: includes technical, ecological and economical advice for free – max. 2 days (including on-site inspection) and a final advice report

Lower Austria - "Revitalisation program for small hydropower plants" (Revitalisierungsprogramm) – Start: 2009 - ongoing

- Financial support programme for technical modernisation and increase of plant efficiency. 25% of investments (max. 50.000 €)
- Financial support program for investments to improve ecology of rivers (fish pass, morphological improvements): 25% of the investments are sponsored (in addition to the 30% investment sponsoring financed by the National environment Fund).
- Advisory service: One advice per year for every owner of a small hydropower pant is sponsored by the provincial government, the plant owner only has to contribute 200€ which usually is 10-20% of the total costs for the advice. The advice refers to technical revitalisations (modernisation of turbines, ..)
  The advice includes an o-site inspection of the hydropower plant, development of a revitalisation concept (several alternatives, if possible) including a cost-estimation.
  The advisory service was established together with the Austrian Small Hydropower Association.

Tyrol "Revitalisation of small hydropower plants in Tyrol –funding of Advices by the Government of Tyrolr" (Revitalisierung von Kleinwasserkraftwerken in Tirol - Beratungsförderung Land Tirol)
Advisory service:
- Initial consultation: technical, ecological economical advice in office is for free
- Detailed on-site inspection and report: 85% of the costs are funded by the provincial government

Styria

- - "Advisory service for hydropower plant up to 2 MW for technical and ecological optimisation" (Beratungsaktion Kleinwasserkraft Steiermark") - ongoing

- Advisory service: technical, ecological and economical advice; On-site inspection, concept development and report ; 90% of advice cost are funded by the provincial government (max. 1600 €)
- Financial support programs for technical and ecological optimisation similar to other provinces (see above)

Salzburg

- Advisory service: Start 2012 - ongoing
    - initial consultation in office for free
    - detailed on-site inspection and concept report: plant owner has to pay 1/3 of advice costs by himself (max. 500 €, in case of HP plant < 30 KW max 200 €)
- Financial support programs for technical and ecological optimisation similar to other provinces (see above)

Programs/services achieved high acceptance

3.4. Information and data requirements

- see above

3.5. Testing of results

- Programs/services achieved high acceptance. Electricity output was increased by 30% on average although ecological flow was implemented.

3.6. Current application of the method/initiative

Initiative/programs are ongoing. Original initiative of the government of Upper Austria was implemented in 4 other provinces (Lower Austria, Tyrol, Salzburg and Styria) with slight modifications

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

Initiative is recommended to be implemented in other area as it has proved to be very successfully.

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5. References

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Case study 29 (Eurelectric): "Analysis of consequences on production and regulation possibilities and ecological effects of ecological flows in the large-scale hydropower sector"

1. Executive summary

The report presents the result if general measures are applied to the large-scale hydro power in Sweden. The selection of general measures has been made in collaboration with the Swedish Agency for Marine and Water management. The study showed that a set of proposed ecological flows in dry water channels in the Swedish large-scale hydropower would give a production loss of 10-13 TWh per year. The loss corresponds to 15-20% of the yearly hydro power production. In this study it was shown that ecological flows in dry water channels and fish passages at hydro power stations can restore natural reproduction of Baltic salmon. However, this production only corresponds to 1,5% of the number fish used in compensatory stocking of Baltic salmon. Qualitative analysis of changes in short-term and seasonal regulation was also carried out. Reduced short-term regulation decreases the flexibility of the hydro power and thereby ability to integrate variable renewable production such as wind power. Changes in seasonal regulation e.g. creating more natural flow regimes in Swedish rivers with large-scale hydro would give large negative effects on the electricity system. The study showed that changed seasonal regulation gives electricity production excess during summer but a deficit during winter.

2. General information

Member State(s): Sweden

RBD(s): Bothian Bay (SE1), Bothian Sea (SE2), Skagerrak and Kattegat (SE5)

Location: River basins Sweden

Time period: 1/1 2014 – 30/10 2014

2.1. Objective of the Case study

The objective of the study was to analyse both consequences on production capacity, regulation possibilities and ecological effects of different proposed ecological flows for the Swedish large-scale hydropower. The analysis was divided in three parts, testing of different flow scenarios: a) different minimum flows in dry water channels, b) reduced short-term regulation (restriction to allow 10% change in flow per hour) and c) changed seasonal regulation (more natural seasonal flows represented by monthly minimum flows). Restoration of natural production of Baltic salmon in dry water channels and fish passages at hydropower stations was used to analyse ecological effects (Bostorp et al. 2014). The case study can be a contribution in the development of Maximum Ecological Potential. Our position is that Maximum Ecological Potential varies for each water body and it must therefore be identified with detailed studies for each of the water bodies.

2.2. Policy and management context

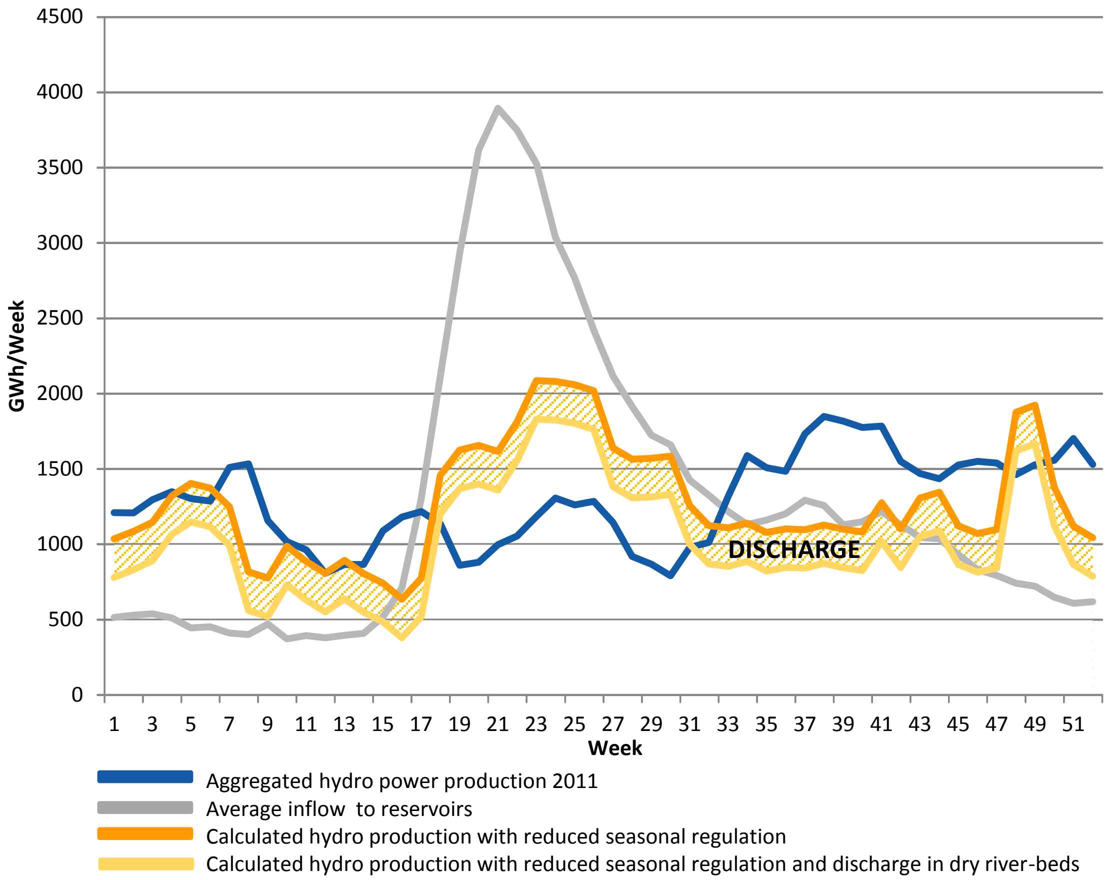
The Swedish large-scale hydropower stations are located in water bodies that have a provisional identification as Heavily Modified Water Bodies (HMWB). Water bodies identified as HMWB should achieve God Ecological Potential (GEP). The Swedish authorities have not decided how this should be implemented. The cost of ecological flows in HMWB must be evaluated in terms of production loss, balancing of the energy system and possibility to integrate variable renewable production such as wind power. However, ecological effects should also be considered in connection to achieve GEP. Restoration of ecosystem services such as natural production of salmon in dry water channels is in conflict with production and regulation possibilities of hydropower. More natural flows variations to increase biodiversity in water bodies affected from hydropower are a demand from many groups of stakeholders but the knowledge of the ecological effects of these measures regarding large-scale hydropower is still limited.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

An integrated energy model was used to evaluate loss of production and regulation possibilities of different flow scenarios. Both quantitative and qualitative analysis was carried out. A large amount of information regarding inflow to each of the rivers and historical hydro power production has been collected in the study. The data was used to calculate the impact on hydro power of the discussed general measures. The consequence for the energy supply has then been evaluated. The collection of information was made by Vattenfall and a consultant company ÅF AB. The energy market simulator PLEXOS® (http://energyexemplar.com/) was used to calculate the impact for each of the general measures. The calculation was based on a detailed model of the Nordic power system with representation of all existing interconnectors to neighbouring countries.

The impact from reduced seasonal regulation is presented in the Figure bellow. The deviation between blue and orange line illustrates how the production is affected. There will be a large surplus of production during the summer, which most likely must be exported or discharged. During the winter there will be a large shortage of production which must be imported or replaced by other flexible production. The impact from discharge in dry water channels is shown by the deviation between the orange and yellow line.



Restoration of natural production of Baltic salmon in dry water channels and installation of fish passages at hydropower stations was used to evaluate ecological effects of ecological flows. We used natural reproduction of salmon as an indicator of ecological benefits because it is easy to calculate natural reproduction and that salmon fishing is an example of an ecosystem services.

Monthly minimum flow was used as an example of ecological flows in dry water channels situated below natural barriers for Baltic salmon.

The combination of using methods to both evaluate effects of ecological flows and production and regulation possibilities and ecological effects was evaluated internally within the Swedish electricity company Vattenfall.

3.2. Temporal and spatial scales

The case study addresses future power system scenarios (both with increased intermittent production such as wind power and reduced nuclear production) at different ecological flows in water bodies with large-scale hydropower production. In the case study 200 Swedish hydro power stations with an installed effect of more than 10 MW was used to analyse consequences on production and regulation possibilities. To analyse ecological effects of ecological flows restoration of dry water channels for salmon reproduction areas was chosen. Only a selection of dry water channels was chosen. To make quantitative analysis of ecological effects is difficult therefore restoration of reproduction areas for salmon was used. An advantage to use salmon reproduction as parameter for an ecological effect is that salmon reproduction is a measureable ecosystem services.

3.3. Type of analysis or tool

PLEXOS® Integrated Energy Model is an energy market simulation software that uses mathematical programming and stochastic optimisation techniques to examine e.g. the effect of regulations on generation mix. The simulator can also be used for optimisation of both transmission and production capacity expansion. For this particular study the restriction for each of the general measures was applied to the large-scale hydro power to be able to evaluate the impact.

To evaluate ecological effects an equilibrium model was used since it can provide simple analytical solutions that may be explored for various aspects (Kriström et al. 2010). The model uses both number of fish passages at the hydropower stations and several other factors such as available area for reproduction of salmon, survivability during different life-stages and predation to calculate output of female spawning salmon. In the model different upstream passage efficiency and downstream passage mortality can be applied. The equilibrium model is freely available.

An innovative aspect of the case study was to analyse effects of ecological flows on hydro power in combination with integration of new and intermittent energy production such as wind power. This is important to analyse because ecological flows in large-scale hydro may reduce the possibility to use short-term regulation and therefore the ability to integrate wind power effectively. To combine analysis of ecological effects and consequences on electricity production and regulation possibilities is another innovative aspect.

3.4. Information and data requirements

Technical data about the hydro power stations was collected from the hydropower companies. Data about flow regimes was given from the hydropower companies and the Swedish Meteorological Institute (SMHI). The data was used to represent the restrictions of the large-scale hydro power and evaluate the impact on the production and balancing/regulation capacity.

To calculate restoration of natural reproduction of Baltic salmon data from a selection of hydro power stations with dry water channels was used. Data needed was upstream passage efficiency and downstream passage mortality per hydropower station. Area of dry water channels suitable for salmon reproduction was also needed (Sparrevik et al. 2011).

3.5. Testing of results

Testing of introduction of the proposed ecological flows in the Swedish large scale hydro power stations has not been carried out.

3.6. Current application of the method/initiative

Some of methods used in this case study are replicated in a single river basin with large-scale hydro in Sweden. The advantage to make analysis on a single basin scale is that more detailed analysis can be carried out. To carry out analysis of consequences for hydropower and ecological effects of more scenarios of ecological flows are discussed.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

The different used methods and analysis carried out in this case study gives valuable information when evaluating costs for measures in water bodies identified as HMWB. Services delivered by hydro plants to balance electricity power generation to demand by season and in more short time (day-week) is evaluated via an overall power system perspective, since it is difficult to single out every plant´s contribution at every situation. Alternative economic, environmental and society costs for the same services, e.g. from fossil driven plants, will then be possible calculate. A single plants service value will then be possible to relate as a portion of this cost via its performance characteristics. The case study also shows how ecological effects can be calculated. In this case study a measurable ecosystem services as restoration of natural salmon reproduction was used. The balance between consequences on production and regulation possibilities for hydropower and ecological effects should be a base to have adequate demands on flow to achieve GEP.

4. Contact information

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Case study 30 (United Kingdom): "Consideration of drought impacts in assessing WFD status"

1. Executive summary

Droughts can cause deterioration in ecological status. The WFD allows for temporary deterioration in status caused by prolonged droughts. This case study provides an overview of the process and necessary requirements to identify if the provisions of Article 4.7 are being met.

2. General information

Member State(s): UK – Primarily England

RBD(s):

Location: England

Time period (start/end): Since 2000

2.1. Objective of the Case study

This case study provides the steps undertaken by which prolonged droughts are identified and water resource activities managed. It also provides the context for how environmental impacts are identified and reported for Article 4.6 and RBMP purposes.

2.2. Policy and management context

In certain circumstances (set out in Article 4.6 of the WFD) a temporary deterioration in status of a water body, caused by exceptional or unforeseen events such as extreme floods, prolonged droughts or accidents, is allowed. The exception does not apply to those effects of extreme floods and prolonged droughts which could reasonably have been planned for and prevented, nor does it apply in the case of accidents which could reasonably have been foreseen.

This exemption requires responsible authorities to demonstrate that:

- all practicable[2] steps were taken to prevent further deterioration in status
- the measures to be taken under exceptional circumstances are included in the programme of measures and will not compromise the recovery of the quality of the body of water once the circumstances are over;
- all practicable measures are taken to restore the body of water to its status prior to the effects of those circumstances as soon as reasonably practicable, and
- a summary of the effects of the circumstances and the measures taken are included in the next update of the river basin management plan.

In England, the main bodies responsible for managing water resources are the Environment Agency, water companies and the Government. All of these bodies have a role in drought management.[3] The Environment Agency and water companies prepare for droughts by producing Drought Plans detailing the actions that will be taken if a drought occurs.

We have identified actions that should be taken during a drought to ensure that the requirements of Article 4.6 are met. This is still work in progress and there are areas where further guidance can be developed to enable consistency in approach.

[2] Practicable is related to 'technical feasible, not disproportionately expensive and without natural conditions preventing the improvements' (Article 4.4(a)).

[3] For more details see Environment Agency report "Managing drought in England and Wales"; http://publications.environment-agency.gov.uk/pdf/GEHO0308BNTR-E-E.pdf

3. Detailed information

3.1. Tasks

Although Article 4.6 is applied in retrospect, the drought plans should ensure we are legally compliant and ensure we can demonstrate we are doing everything we can to maintain and improve the quality of the environment. These are the conditions that we use to ensure we remain legally compliant and demonstrate we are doing everything we can to maintain and improve the quality of the environment:

1. We must demonstrate that steps are taken to minimise the impact of the drought, such as the introduction of temporary use bans (e.g. hosepipes);

2. We must explain how we've defined a drought as being an exceptional event and we must describe the indicators we use to monitor the extent and severity of the drought; The principles on the case for an exceptional shortage of rain for drought permits/orders will be helpful here.

3. We must include the additional steps we have taken to minimise the impact of drought (e.g. where water companies have imposed temporary use bans, our restrictions on irrigation abstraction) when describing our progress with programmes of measures, and we must ensure that these additional steps do not compromise the recovery of the water body after the drought is over;

4. We must prove that we are regularly reviewing the steps that need to be taken to restore the water body to its status prior to the effects of the drought;

5. We must include a summary of conditions 1 to 4 in the next update of the river management plans.

3.1.1. Steps taken to minimise the impact of drought

During a drought a Water company is required to take steps to demonstrate it has reduced the demand for water as far as possible. These are set out in water company drought plans. These steps include measures such as:

- Hosepipe bans and other temporary use bans
- Advertising and publicity about the wise use of water
- Irrigation abstraction only on alternate days.

3.1.2 Establishing whether the conditions indicate it's an exceptional and therefore a drought.

Defining and then monitoring indicators (often called drought 'triggers') helps the Environment Agency and water companies decide when a drought is happening. As a trigger is approached or crossed, a water company or the Environment Agency will consider whether to implement a pre-determined action to reduce demand and/or increase supplies to preserve public water supplies and other water uses and protect the environment. The decision to take action will be based on a range of factors, including present and forecast weather conditions and how effective the action would be. The sequence of actions will not always be the same as all drought events are different and need to be managed on an individual basis.

The Environment Agency has a process developed for the determination of hydrological triggers. This helps to set a framework for ensuring that similar frequencies of events are classified similarly across the country.

3.1.3 Additional steps taken on minimising the impacts of drought

Monitoring and investigations to understand the impacts of drought compliments pre-drought monitoring to identify areas which are more vulnerable to drought activities, and post-drought monitoring to assess recovery.

At present there is no specific guidance around environmental flows during a drought or generic actions taken during a drought. These actions are generally determined on a case by case basis and supported by information which is provided within Water Company drought plans and Environment Agency drought plans.

3.1.4 Monitoring if there is recovery

Water companies are required to plan for the assessment of recovery after they have implemented any drought actions – and take restorative action if required.

There is a need to develop approaches so that classification tools can indicate if there has been a temporary deterioration in status.

3.1.5 Reporting in RBMP

It is intended that if there is evidence of a temporary deterioration caused by a drought the supporting information will be provided within the RBMP. At present there hasn't been any evidence of deterioration due to drought.

3.2 Learned lessons - Conclusions – Recommendations for application within the concept of Eflows

Standardised hydrological methodologies for developing drought triggers does enable a consistent understanding of when low rainfall and low flows are considered to be a drought, and what action is required.

At present although there is a requirement for environmental impact assessment of actions to be taken during a drought within Water Company drought plans and Environment Agency drought plans, constraints and limits are determined on a case by case basis. This can result in widely differing levels of understanding and potentially environmental protection. This does reflect though that all droughts need to be managed individually as all drought events are different.

4. Contact information

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Case study 31 (Finland): "Public participation and collaborative planning in water level regulation projects"

1. Executive summary

There are more than 300 regulated lakes in Finland and one third of the total lake area is under water level regulation. Most of the regulation projects have started before 70s to enhance hydropower production and flood defence protection. Changes of Finnish environmental legislation in 1994 enabled to revise regulation permits if they cause significant adverse impacts on the water environment or on its use. There have been more than hundred regulation development projects and 30 – 40 includes also principles of so called Ecological regulation practice (Hellsten et. al. 1996). These projects have led to changes in existing water regulation practice within the existing permits. As a part of these projects, Finnish environment institute SYKE has developed a participatory approach supported by multi-criteria decision (MCDA) analysis to improve the quality of the planning processes (Marttunen & Suomalainen 2005). In addition, a set of calculation tools to using hydrology-ecology-socio economical relationships based on empirical data or known correlations e.g. between littoral vegetation and winter drawdown (environmental flow *sensu lato*) (Keto et al. 2009). The opinions of different stakeholders to different water level regulation schemes have been found out in decision analysis interviews supported by MCDA software (Marttunen & Hämäläinen 2008, Hämäläinen et al. 2010). Wider public has also been involved by postal questionnaires and organizing open meetings. Finland is proposing "water course regulation development approach" as a case study due to its good applicability for environmental flow cases, too. The Lake Koitere development project carried out between 2004 and 2006 is a good example of the Finnish approach (Tarvainen et al. 2006).

2. General information

- Member State(s): Finland
- RBD(s): Vuoksi River basin district FIVHA1
- Location: East-Finland, Lake Koitere
- Time period (start/end): 2004 to 2006

2.1 Policy and management context

Management of regulated lakes is a very important issue in Finland. There are more than 300 regulated lakes in Finland and one third of the total lake area is under water level regulation. Most of the lakes are regulated for common need of hydropower production and flood defence – therefore it is important issue in implementation of ecological classification according to WFD. It should be noted that most regulated lakes are not designated as heavily modified do to relatively small effect of water level fluctuation on ecological status. It is also notable that current process does not need changes in water permits and it is based on voluntary work between different stakeholder groups. It is also a measure to reach the environmental objectives in modified water body without significant effect on use.

2.2 Key messages

Water level regulation for hydropower production in lakes has negative impacts on ecological condition and recreational use of lake. Water level fluctuation in lakes is comparable on flows in rivers downstream and further represents environmental flow *sensu lato*. Simple water level analysis tool (REGCEL) with supplementary ecological surveys and focused questionnaires can be used when comparing different water level regulation practices. Multicriteria decision aiding tools (MCDA) can be used in comparing different regulation practices. Defining new more environmental friendly regulation is social learning process usually in expert group consisting of key stakeholders. Effective implementation of new regulation practice need open information exchange between decision makers and public. In most of the cases new regulation practice can be found without changing environmental permits. Proper monitoring of results is needed to support implementation of new fluctuation regime.

3. Detailed information

3.1 Objective of the Case study

Main objective was to develop water level regulation of Lake Koitere together with stakeholders and public to reach more environmental friendly regulation practice without significant effect on use of the lake.

3.2 Key Issues

Main aims of the Lake Koitere water level regulation development projects were:

- Evaluate the effects of water level regulation on ecology and use of Lake Koitere
- Investigate opinions of different stakeholder groups related to water level regulation and development options
- Estimate the restoration needs and develop a restoration plan
- Compare the effects of different regulation practices
- Propose a new regulation practice to minimise the harmful effects of regulation
- Promote co-operation and information exchange between different stakeholders.

3.3 Practical Tasks (in case of methods and/or procedures)

Water level regulation for hydropower production causes significant changes in ecology of lake. Water level is generally raised to increase regulation capacity, which causes significant changes on littoral zone. Additionally water level drawdown during the winter causes erosion and freezing of sediment when due to the down-dwelling ice.

Water level regulation of Lake Koitere (164 km2) started 1955 by building Pamilo hydropower plant (height of fall 49 m). As a part of development River Ala-Koitajoki (length 15 km) was drained and flow was directed into a tunnel. Water level regulation of Lake Koitere started in 1980 although water levels between 1955 and 1980 differed significantly from natural due to short term regulation of hydropower plant. In the beginning of 1980 water level of iceless period (May – October) was raised by 54 cm and winter drawdown was increased by 66 cm (Tarvainen et al. 2006). These small changes cause erosion of shoreline especially at open sandy shores.

First task of the development project includes careful evaluation of the effects of regulation by using different calculation tools like REGCEL which is based on daily water level and some key hydrological parameters like ice thickness and properties of water (Keto et al. 2008). By REGCEL tool different ecological effects are analysed rapidly. Lake Koitere project included also field surveys related to ice erosion, aquatic vegetation and benthic invertebrates. Additionally investigations related to near shoreline breeding birds and survival of winter spawning fishes were realised. Recreational users were interviewed and possibilities to restore eroding shoreline were investigated.

Stakeholder opinions were evaluated by selected interviews of different expert and stakeholder groups including environmental administration, hydropower producers, nature protection groups, fishermen and scientists. Key stakeholders are invited to participate on project steering group consisting of 18 persons. Steering group had eleven meetings lasting between 4 and 6 hours. Especially supportive multi-criteria decision aiding tool (MCDA) is used to establish common opinion for different water level regulation options (Marttunen & Hämäläinen 2005). MCDA tools are especially powerful when comparing nonmonetary and monetary values. MCDA tool WEBHIPRE was used in comparison (Hämäläinen et al. 2010).

Further different regulation options were incorporated separate decision analysis tool REGAIM, where pros and cons of different regulation options were compared and ecological, recreational use and hydropower production values calculated (Marttunen & Suomalainen 2005). Three different water level regulation options were established – it should be noted that all options were inside current regulation permit.

Final regulation practice was selected as a consensus between harmful effect of regulation and benefit of hydropower production. Further several suggestions to mitigate harmful effects of regulation and improve general environmental status of lakes were established.

Large public were informed of development by questionnaire submitted to 235 shore property owners and fisherman. In included several question of related to use of lake and also harmful effects of regulation. Total response rate was almost 60 %. Later also several open hearings including expert lectures of effects of regulation were organised. Public participation was also stimulated with several newspaper articles and radio forecasts.

3.4. Temporal and spatial scales

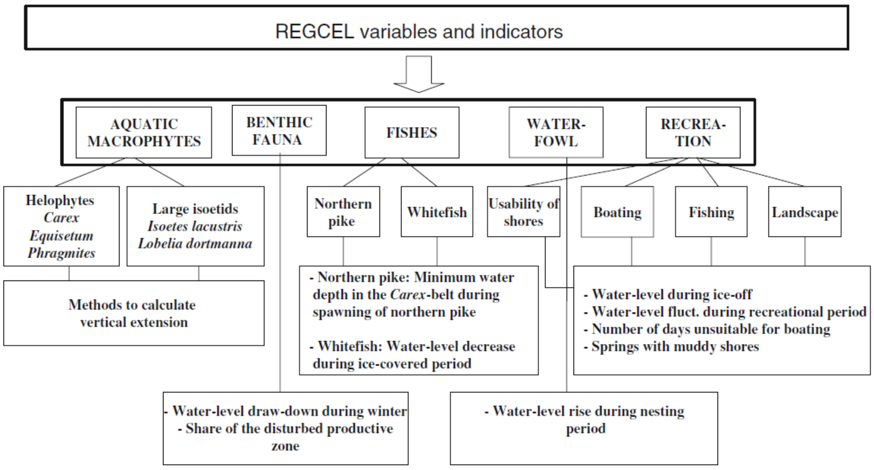
Research area consisted of large Lake Koitere and river stretch downstream. Tools were applied over lake area by using lake as one water body unit. Public participation was applied among shore property owners and active fishermen. Study was carried out between 2004 and 2006.

3.5. Type of analysis or tool

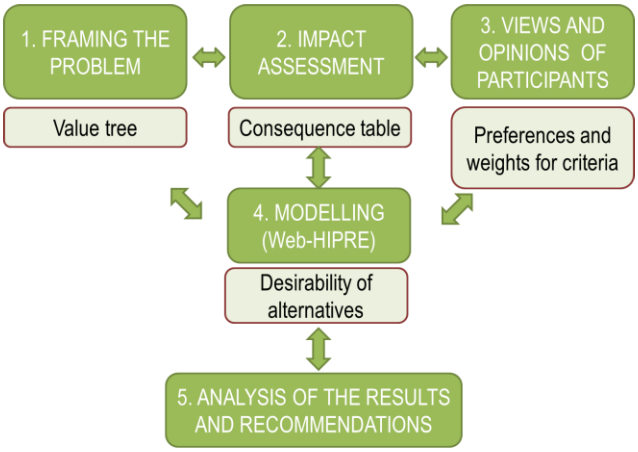
REGCEL-water level analysis tool can be rapidly applied in investigating ecological and recreational effects of water level fluctuation (Keto et al. 2008). REGCEL-tool includes also effect of water level regulation on flood depended vegetation and therefore it represent environmental flow application *sensu lato*. With REGCEL-tool also ecological status can be analysed by using water level winter drawdown as a proxy of ecological quality ratio (Sutela et al. 2013).
Ecological regulation practice for lakes including also downstream stretch is developed in several studies (Hellsten et al. 2006)
Multi-criteria decision aiding tools (MCDA) for developing common understanding between different expert groups (Marttunen & Hämäläinen 2005).
Extensive public participation procedure includes questionnaires and public meetings with detailed reporting and list of mitigation measures (Marttunen & Suomalainen 2005).

3.6. Brief description including figures

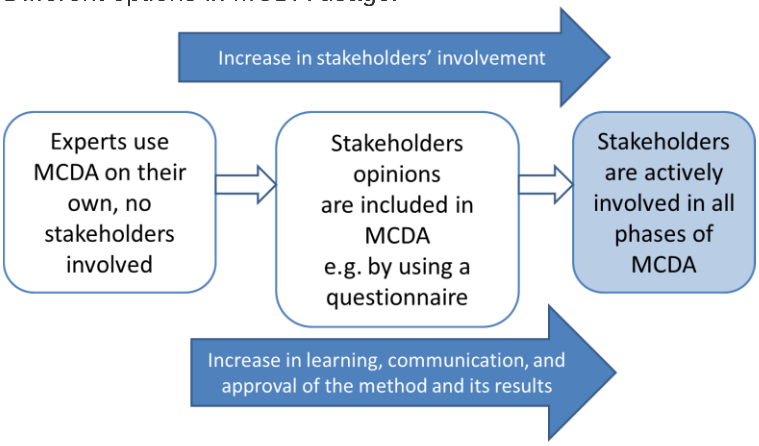
Assessment of the impacts of water level regulation by REGCEL-model (Keto et al. 2008)



Application of multi-criteria decision aiding tool in regulation project.



Different options in MCDA usage.



See further information in 3.3.

3.7. Information and data requirements

For application of REGCEL use only daily water level data and information of ice covered period and additional data of water colour (to calculate deepest growing depth of vegetation).
For ecological regulation practice practical information of aquatic macrophytes including flood dependent vegetation, benthic invertebrate distribution, fish stocks, birds nesting near the shoreline, recreational users and value of electricity produced by hydropower is needed.
For application of MCDA-tools expert group is needed and fed by some programs like WebHipre. There must also be some basic information of the effects of water level regulation on use of lakes.
For involving public normal or web-based questioner is needed to map opinions. Participation can be enhanced by newspaper articles and announcements. Public seminars are needed for dissemination of the results. To secure proper implementation of mitigation measures a clear monitoring program and information exchange plan is needed.

3.8. Current application of the method/initiative

See 3.5.

3.9. Applicability of the proposed method/initiative

Methodology has been applied in more than 80 lake regulation development projects. In almost all cases REGCEL-application is used to evaluate the effects of regulation. MCDA-tools are utilized in more than 20 cases.

3.10. Testing of results

Lake Koitere lake regulation development project led to new regulation practice starting from 2007 with less water level drawdown during winter and also lower water level during summer to reduce erosion. New practise was monitored between 2007 and 2011 (Sutela et al. 2012), see figure below. As a conclusion, most ecological and use indicators showed positive value, but hydropower production was slightly lower due to lowered summertime water level.

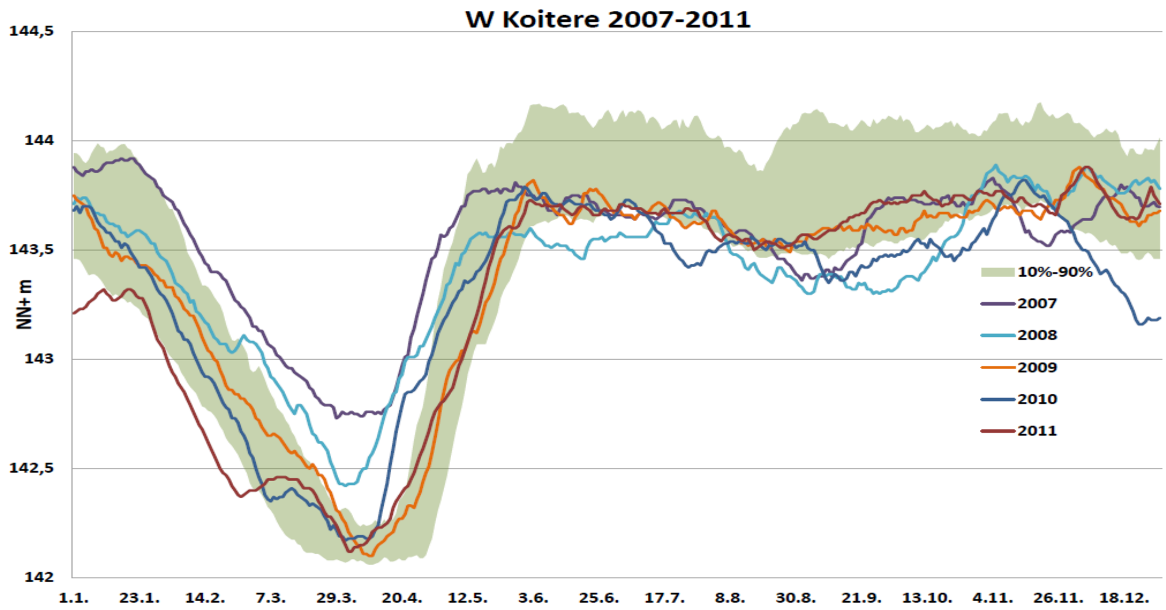


Fig. Water level fluctuation of Lake Koitere. Shaded area represents 10 – 90 % duration of water levels before development project 1980-2006. Note significant reduction in summertime water level.

3.11. Learned lessons - Conclusions – Recommendations

MCDA-tools are effective in participatory approach especially in cases with several conflicting interests with different monetary values. Compromising without time consuming environmental permitting procedure is always faster way to take into account different uses of water bodies. Simple water level fluctuation analysis tools like REGCEL can provide a coarse view of effects of different regulation practices.

Public participation must be open for all people interested and should be interactive.

In Lake Koitere case and all other cases regarding water level regulation development also a compromise was found which was more sustainable from ecological, economical and sociological point of view than original water level regulation.

4. Contact information

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- Websites referring to the case study: in Finnish
  http://www.ilomantsi.fi/Resource.phx/sivut/sivut-ilomantsi/koitere/koitere.htx
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Case study 32 (Spain): “Implementing e-flows in the lower Gaià River affected by a big dam built for industrial water supply”

1. Executive summary

Gaià is a highly seasonal Mediterranean river, with scarce discharge (around 0.25 m3/s of average annual flow), and small catchment area (422 km2), located in Catalonia (NE Spain). A big dam (Catllar dam) was built in 1976 in the lower Gaià River, in order to storage and supply fresh water for an oil refinery owned by Repsol. Water had not flowed from the dam after it was built, leaving 11 km downstream completely dry (from the dam to the sea). Several environmental groups and local residents have been steadily increasing their complaints about this situation from some years ago. Moreover, the new Water Framework Directive requirements, and the growing social concern for environmental protection, forced finding solutions to restore the lower Gaià River through implementing e-flows. That is why, the water authority in charge of managing the river flow (the Catalan Water Agency - ACA), and Repsol Company as the grantee (holder of the Catllar dam), started a process to meet a satisfactory agreement allowing a suitable e-flow without any significant unsustainable additional costs. Several solutions and options were analysed. The Water Authority suggested managing the reservoir at low water level in order to increase its efficiency (decreasing infiltration to groundwater), and so allow releasing e-flow downstream without any (or minimum) water supply loss for industrial purposes. In 2010, Repsol and the Catalan Water Agency signed an agreement to improve the water storage management policy in order to allow releasing e-flows downstream. A technical committee was set up to analyse e-flow availability and the possible further industrial impacts. Additionally, a public commission composed by stakeholders, NGOs, local authorities and residents was set up in order to monitor changes in river and to analyse the agreement evolution. Along these last 3 years, an e-flow regime has been restored in the lower Gaià River without any relevant cost and impact on the industrial activity so far.

2. General information

Member State(s): Spain

RBD(s): ES100

Location: Gaià River (NE. Spain)

Time period (start/end): 2010 up to now

2.1. Objective of the Case study

The case study illustrates a good experience of participation and agreement among a Water Authority (the Catalan Water Agency), an oil company as an user (Repsol company), some NGOs (environmentalists), and local authorities and residents in order to find a suitable strategy to restore river ecosystem and optimize water management stored in a big reservoir releasing e-flow downstream. A successful agreement was achieved in order to restore e-flows without any additional cost so far.

2.2. Policy and management context

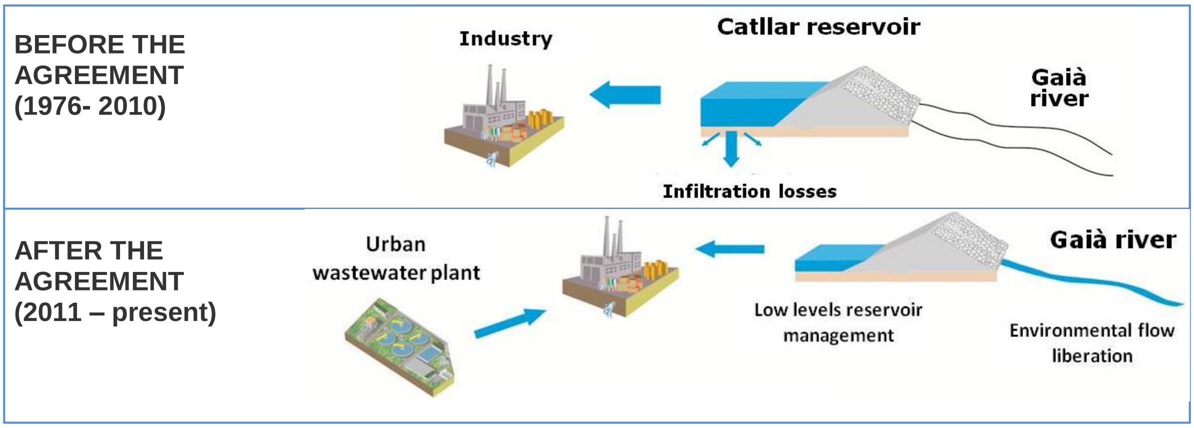
Since the construction of the Catllar dam in 1976, water flowing in the lower Gaià was totally interrupted, leaving 11 km of river bed completely dry, from the dam to the sea. The dam is held by Repsol (an oil company) that uses water for industrial purposes, and also shares water rights to some small irrigators located downstream. Total water rights come to 38 hm^3/year and are valid until 2061, while river natural flow regime is around 10 hm3/year. Thus, water is completely used and no water is available to be released downstream according to the water licenses granted. In addition, the reservoir has historically been losing a high amount of water due to high geological permeability. Therefore, the average water used is about 3.45 hm3/year of which 80% is for industrial use and 20% for irrigation. Environmental organizations and local authorities have continually claimed for water return to the river. The water authority (ACA) launched negotiations with Repsol Company in order to meet a satisfactory agreement in order to release environmental flows without any significant and additional economic impact. The agreement was finally reached in 2010, and has partially allowed restoring the lower Gaià River so far.

3. Detailed information

3.1. Practical Tasks (in case of methods and/or procedures)

Environmental flows were calculated in the whole Catalan River Basin District by using hydrological methods. Results were later validated using fish habitat modeling through the Instream Flow Incremental Methodology (IFIM) (ACA 2006a, 2008). Using this methodology, the Government of Catalonia approved a Plan to restore Environmental Flows (ACA, 2006). Environmental flows were defined as an environmental target for current uses, and as a mandatory requirement for new water uses. Hence, an implementation program to progressively restore e-flows is needed to be applied in existing water uses, especially on the most damaging. The Catalan Water Agency is nowadays redacting an e-flow implementation plan for each river basin according to the Catalan River Basin Management Plan. Therefore, the Catalan Water Agency started a work to analyze the existing water uses in the Gaià basin, where a big dam was built close to the river mouth in 1976, leaving 11 km. downstream completely dry. Several measures were analyzed to be applied in order to restore environmental flows, taking into account technical, economic and administrative issues. The main objective was focused on achieving environmental flows with minimum economic impact on current uses. A thorough analysis of data highlighted that the Catllar reservoir was highly inefficient when water storage was managed at high water levels or volume. A high amount of water is “lost” to groundwater when reservoir is managed that way, mainly due to the local high geological permeability. Thus, the conclusion was that managing the reservoir at low level rate will allow releasing e-flows and decreasing water loss. ACA conducted an analysis of the historical management of the reservoir and designed a model to predict the evolution of the reservoir level based on the management carried out so far. This model allowed comparing the evolution of the reservoir with or without environmental flows according to different water level scenarios. After many technical meetings between the Water Authority and Repsol Company, a satisfactory agreement was reached to allow restoring minimum flows without significant water supply losses or additional costs by managing Catllar reservoir at low water level. A water reuse facility from Tarragona urban wastewater treatment plant was used to preserve industrial water supply requirements in case of they were needed.

A technical committee (Repsol–ACA) was created to monitor the compliance and follow the agreement. Also, an informative and public commission composed by local authorities, irrigators, water users, environmentalists and local residents was set up in order to discuss proposals to improve the agreement. An e-flow regime has been restored and tested for the last 3 years in the lower Gaià River, combining minimum in-stream flows together with controlled small released floods according to the natural flow regime upstream. Over 20% of natural discharge has been released downstream the Catllar dam in terms of e-flow during the last 3 years (from 2011 to 2013), without any relevant cost and impact on the industrial activity.



3.2. Temporal and spatial scales

Meetings between the Catalan Water Agency and Repsol Company started in 2008-2009. The design of the reservoir management model used the available data with a period of 17 years. Once designed, the model works at annual scale, based on daily data. At the end of each hydrological year, the balance is closed and the model restarted. In terms of spatial scope, initially it was carried out a study for the entire basin. But for the implementation of measures it has been useful to focus efforts in this conflictive zone. The fact that the stretch of river is a relatively small area, affecting four municipalities, makes the participation meetings very useful and stakeholders feel really involved in the management of the river. The meetings of the technical committee are performed approximately every three or four months, and twice a year for the public commission.

3.3. Type of analysis or tool

Environmental flows were calculated in the lower Gaià River by using the QBM method (hydrological method) and monthly modulated to obtain an e-flow regime close to the natural flow regime meeting the good status objective of the WFD. The type of hydrological flow regime was defined by clustering the nearest or the most similar river flow close to natural for different sections of rivers grouped in hydroregions. Finally, e-flows were adjusted by using fish habitat modelling in order to establish the e-flow requirements to restore river ecosystem downstream the Catllar dam. On the other hand, a reservoir management model was built in order to analyze water inputs and outputs, responses to changes in the reservoir management, and possible impacts (water lost for industrial purposes) from e-flows released downstream. The reservoir management adopted a new threshold to maintain low reservoir levels and reduce water losses (mainly due to infiltration). This means that depending on the reservoir level, e-flow can be more or less released in order to minimize water losses by geological infiltration. The most innovative aspect is the reservoir management change to find solutions, and the cooperation among a big oil company a water authority and the public local residents and NGOs in order to meet a suitable agreement allowing e-flows without unsustainable industrial impacts.

3.4. Information and data requirements

Natural flow regime (average daily flows) by using a rainfall-runoff model for a minimum period of 20 years (from 1980 to 2000) was required to calculate e-flows, meeting the WFD requirements to defina the status of a water body. The reservoir management analysis required available daily data of water consumption (outputs), reservoir levels, incoming flows, and estimated water losses for a minimum period of 20 years. Additionally, hydrogeological studies were required to analyze local geological permeability.

Data is required to be remotely controlled in order to manage current e-flows according to the water level in the reservoir, and incoming flows. The input flows and reservoir levels affect the management decision to open or close environmental flows.

3.5. Testing of results

The reservoir levels, from which the environmental flows are released downstream the dam, are tested and sometimes adjusted according to environmentalist groups and local residents suggestions. In 2013, a controlled small flood was released during 24 hours in order to improve hydromorphological conditions downstream. This implied a warning system implementation and communications between water and local authorities and citizens. This was used as a test in to analyze flood effects and social responses.

The Catalan Water Agency and the Repsol Company produce an annual final report in order to test results and to inform citizens and NGOs. The river ecosystem is gradually recovering. The river stretch is partially recovered in the first 6 km out of 11 km from the dam to the sea. Therefore, eventual controlled floods and additional e-flow adjustments will be probably needed in the next years in order to completely restore river ecosystem from the dam to the sea.

3.6. Current application of the method/initiative

Currently, the agreement remains valid and minimum flows are liberated according to the incoming flows and reservoir levels. In 2014, an incorporated new controlled flood is expected to be released before summer. New water level thresholds will be analyzed to improve the reservoir management model increasing environmental flows.

3.7. Learned lessons - Conclusions – Recommendations for application within the concept of E-flows

Good experience of participation among a Water Authority, water users (industrial company and water irrigators), environmentalists (NGOs) and local citizens, who have improved water management. After two years, water irrigators, initially opposed to the liberation of environmental flows, have verified that this new water management has not involved any loss of resource or consumption. The social impact of this measure has been positive and the population of the area has regained the contact with the river. The river has not been fully recovered yet, but the aquatic ecosystem has been partially improved and progressive recovered by biological communities. This case shows the relevance of the minimum flows and small controlled floods to restore the river channel and aquatic habitats. Minimum flows are insufficient to connect river with the sea and to restore suitable habitats. It has highlighted the need for complementary actions such as river bed maintaining, sudden floods, etc. It has been a positive and pioneering case of reservoir management adaptation that allows environmental flow without additional unsustainable cost or water warranty lost for local uses. A very useful example on how stepwise the recovering of a river is possible even if high economic interests are implied.

4. Contact information

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