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# Ecological Discharges and Demands for River Ecosystems

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ABSTRACT: The paper deals with the DECO method to ascertain required in-stream flow for preserving aquatic ecosystems. DECO is an ecological method relying on the relationship between discharges and habitat features needed for fish preserving. The output following the DECO method is approximately the same with the average of computed discharges in case other five methods for assessment of ecological discharges existing in the scientific literature are applied. The output discharges following the DECO method are greater than the minimum monthly discharges with 95% probability of exceedance for small river basins and approximately the same values of the DECO outputs in case of big river basins. The paper proposes a new relation to determine the ecological discharges. The relation is based on minimum monthly discharges with 95% probability of exceedance that have computed all over Romania.

In addittion, the paper deals with CECO method about ecological water demands for assuring the preservation and development of the ecosystems within the aquatic environment and riverane areas. Achieving the ecological water demands for each month is done relying on ecological discharges determined with DECO method and taking into account some issues about the diminishing effect of dissolved oxigen in water, about the fish reproduction season, about producing of "artificial floods" and about minimum monthly discharges with 95% probability of exceedance.

KEYWORDS: ecological discharge, aquatic ecosystems, ecological water demands

## 1. Introduction

Nowadays, a few attempts have been done to set up **the methodology to ascertain the ecological discharges and demands**. There has rarely been a method for each expert to agree upon. The attempts done by experts set up three main types of methods: hydrological, ecological and in-stream habitat simulation methods.

Ecological water demands in each month are determined starting from ecological discharges and taking into account the following issues:

- additional discharges to assure the counting–balance for diminishing the effect of the dissolved oxygen in water, in summer time;
- additional discharges for the fish reproduction season;
- providing flush discharges – artificial floods for washing up fine sediments laid down, in particular, on water sectors placed downstream reservoirs;
- providing additional discharges to get proper dilution when accidental pollution occurs.

Relying on the methods of ecological discharges lately, developed [1], in some countries, e.g.: USA, Switzerland, Germany, Japan, France, laws and standards that set up the methodology to ascertain the ecological discharges and demands have been established, as well as the priorities to supply water for the users.

In Romania, no permanent concerns to determine the ecological discharges, for the time being, a standard to ascertain ecological water demands has not been established yet. A methodology to determine ecological water demands and discharges is absolutely necessary having in mind the following reasons:

- For setting up the river basin water management Plan according to provisions of 2000/60 Water Framework Directive of European Union;
- For issuing water management consents and authorizations to satisfy water demands of the users;
- For solving conflicts coming from some interests that may appear among water users, on transboundary rivers, in particular.

## 2. DECO method

DECO (ECOlogical Discharges) method belongs to ecological methods and it relies on the relationship among discharges and habitat features needed to preserve ichthyofauna. The method considers as indicator specie the fish, taking into account that the discharges ascertained for it are sufficient for other aquatic beeings. Habitat features required for several fish species are shown in table 1 [2], [3], [4].

**Table 1** Habitat features for fish

| Fish Species | Water velocity (m/s) | Water depth (m) | Reproduction period |
|---|---|---|---|
| Trout | 1-2 | 0.2-0.5 | October-November |
| Grayling | 0.8-1.5 | 0.3-0.6 | March-April |
| Nase | 0,7-1 | 0.5-1 | April-May |
| Chub | 0.5-1.2 | 0.8-1.5 | May-June (in the south of Romania)<br>June-July (in the north of Moldova and in Transilvania) |
| Barbel | 0.5-0.8 | 0.5-2 | May (in south of Romania)<br>June-July (Moldova, Transilvania) |
| Carp | <0.5 | 1-2 | July-August |

In establishing the discharges needed to maintain adequate conditions for fish preserving, the procedure mentioned below should be followed:

- Drawing up the cross sections profiles in some sectors, in particular in fish passage area;
- Setting up the main fish species, for each characteristic cross-section, using the map pointing out the Romanian piscicultural areas [5];
- Establishing the stream section $A$, from the mentioned cross-sections, for the river depth, pointed in table 1, to correspond to the existent ichythyofauna. The water velocity ($v$) may be computed, using Chezy formula. The computed velocity should be within the boundaries mentioned in table 1;
- Computing the required in-stream flow by using the following equation:

$$Q_a = v \cdot a \tag{1}$$

where: $v$ is water velocity;
$A$ – area of the cross-section profile.

The ecological discharges $Q_a$ have been ascertained using the DECO method, for the main gauging stations located on the Târnava and the Mureş river basins (table 2).

The method points out that there is a very good correlation between the required in-stream flows and the minimum monthly discharges with 95% probability of exceedance ($Q_{95\%}$) given in the following equation:

$$Qa = \alpha \cdot Q_{95\%} + \beta \tag{2}$$

where: $\alpha \geq 1$ and $\beta \geq 0$ are coefficients depending on river and measuring stations.

For measuring stations analyzed, (2) equation has the following shapes:

$$Q_a = Q_{95\%} + 0.1 \text{ for } Q_{95\%} \geq 200\ l/s \tag{3}$$

$$Q_a = Q_{95\%} + 0.04 \text{ for } Q_{95\%} < 200\ l/s \tag{4}$$

The required in-stream flows to preserve ichtchyofauna are greater than , for small river basins, and approximately equal with , for big river basins.

To ascertain the required in-stream flow, in cases when there are not enough cross-sections profiles along the studied river, the method propose the (3), (4) equations, taking into account that the have been determined all over Romania.

**Table 2** The required in-stream flows

| No. | River name | Cross-section | Qa ($m^3/s$) | $Q_{95\%}$($m^3/s$) |
|---|---|---|---|---|
| 1. | Toplita | Toplita | 0.60 | 0.33 |
| 2. | Gurghiu | Lăpuşna | 0.49 | 0.27 |
| 3. | Mureş | Glodeni | 4.95 | 4.90 |
| 4. | Târnava Mare | Brădeşti | 1.00 | 0.97 |
| 5. | Târnava Mare | Mediaş | 1.50 | 1.40 |
| 6. | Târnava Mică | Sărăţeni | 1.10 | 1.25 |
| 7. | Domald | Zagăr | 0.03 | 0.01 |
| 8. | Târnava Mică | Târnăveni | 1.40 | 1.45 |
| 9. | Târnava | Mihalţ | 3.35 | 3.00 |
| 10. | Mureş | Alba Iulia | 13.60 | 13.50 |

## 3. Numerical comparison of the DECO method with other methods

The main methods to determine the ecological discharges existing in the scientific literature, namely, Montana, Hoppe, Etiaj, SEPE and German method have been applied for the same river basins aiming to validate the required in-stream flows ascertained with DECO method.

**Montana method** [1] is a hydrological method relying on the observations done on the water depth, the width of the stream flow area and water velocity for 11 rivers in Montana, Wyoming and Nebraska. The method recommends for ecological discharges different percentage (between 10 and 30%) out of the average multiannual discharge, in winter and summer. A discharge equal with 10% out of average multiannual discharge is considered being a minimum discharge required for preserving aquatic ecosystems and a percentage of 30% out of average multiannual discharge is assigned to be the optimum discharge.

Hoppe, Etiaj and SEPE methods rely on the duration curve (measured in years) of daily average discharges.

**Hoppe method** [1] considers that the ecological discharge is the discharge equal or exceeded 80% in a year time. A module coefficient k = 0.35 for a duration of 292 days, meaning 80% out of a year, has resulted out of the duration curve (figure 1) for Br□de□ti measuring station on the Târnava Mare river basin. Using k the module coefficient, the ecological discharge has been computed by the following equation:

$$Q_e = k \cdot \overline{Q} = 0.35 \cdot 5.38 = 1.88\ m^3/s \tag{5}$$

where $\overline{Q}$ is the average multiannual discharge.

Similar to the already mentioned procedure, using Hoppe method, the other types of discharges can be assessed as following:

- Spawning discharge $Q_i$ is the discharge 40% equal or exceeded in a year;
- Flashing discharge $Q_s$ that is the discharge 17% equal or exceeded in a year.

**Etiaj discharge method** (Etiaj method) [6] is a hydrological method that has been established by French researchers. Ecological discharge is ascertained relying on average values in many years (minimum 15 years) of etiaj daily discharges, in natural regime. Etiaj discharge is defined being daily average discharge that may occur in 355 days in a calendar year.

**SEPE method** [7] has been set up by Swiss Water and Environmental Protection Authority (SEPE) with the help of National Authority for Hydrology and Hydrogeology. Firstly, the method relies on computing the daily average discharge, that may occur in 347 days in a calendar year $Q_{347}$. It is determined out of the duration curve of daily average discharges, using minimum 10 years of recorded data, in hydrological natural regime. The ecological discharge is assessed using $Q_{347}$ and taking into account the importance of rivers (figure 2).

**German method** (GM) considers that the ecological discharge should be greater or equal than one third of the minimum monthly average discharge in many years (Qm).

For each method, the discharges, required for preserving aquatic flora and fauna, have been ascertained. The results of the analysis shown in table 3 put into evidence that Qa discharges determined with DECO method are closely to the average of the results that have been recorded with the other methods - $\overline{Q}_e$.

## 4. CECO method

CECO method (ECOlogical Demands) for ascertaining ecological demands relies on the ecological discharges determined with DECO method and takes into consideration the following issues: the counting–balance for diminishing the effect of the dissolved oxygen in water due to temperature increasing, the fish reproduction season, silting with fine sediments of bed streams, accidental pollution occurring.

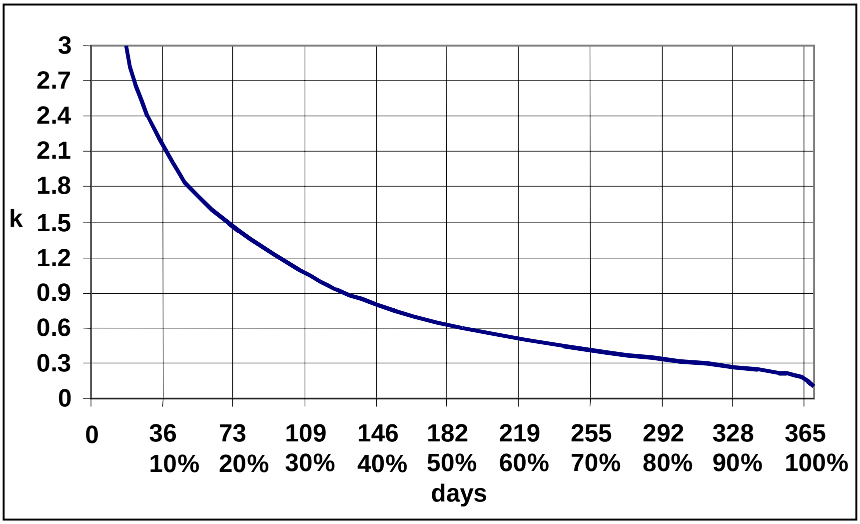


**Figure 1** The duration curve on daily discharges for Brădeşti gauging station on the Târnava Mare river

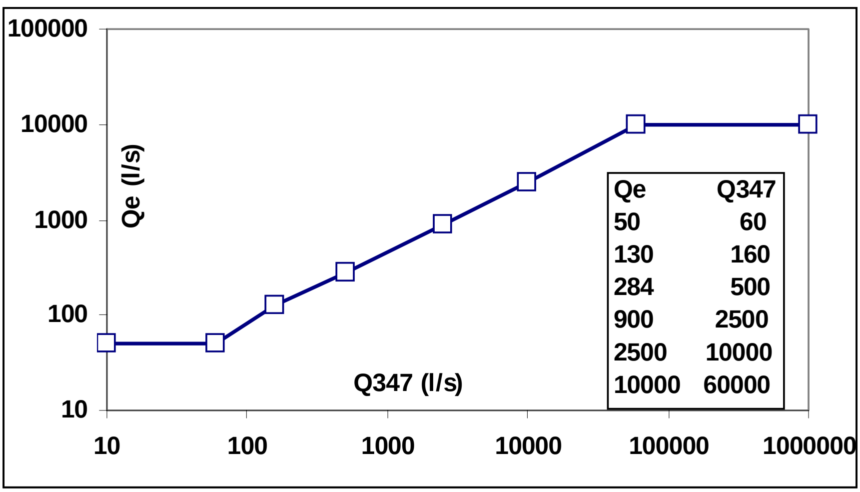


**Figure 2.** The variation of the ecological discharge depending on $Q_{347}$

### 4.1 Additional discharges to provide the counting–balance for diminishing the effect of the dissolved oxygen in water

It is necessary to provide additional discharges in summer time, for achieving a proper dilution of the nitrates and the organic substances consuming the oxygen. In summer, the values for dissolved oxygen in pure water are reduced at 8-9 mg/l due to very high temperatures, as compared with the natural values of 13-14 [8] mg/l measured in wintertime. The concentration values of the dissolved oxygen in water may be 5-6 mg/l, in summer, for

**Table 3** Methods comparison to ascertain the ecological discharges

| No. | River name | Cross section | F $km^2$ | L km | Hm m | Q $m^3/s$ | Montana $m^3/s$ | Hoppe $m^3/s$ | | | Etiaj $m^3/s$ | SEPE $m^3/s$ | GM $m^3/s$ | $\bar{Q}e$ $m^3/s$ | Qa $m^3/s$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Qs | Qi | Qc | Q | | | | |
| 1. | Toplita | Toplita | 215 | 28.7 | 1149 | 2.80 | 0.28-0.84 | 4.50 | 2.18 | 0.83 | 0.41 | 0.37 | 0.46 | 0.47 | 0.60 |
| 2. | Gurghiu | Lăpuşna | 98 | 10.1 | 1216 | 1.87 | 0.19-0.56 | 2.80 | 1.53 | 0.80 | 0.55 | 0.43 | 0.30 | 0.45 | 0.49 |
| 3. | Mureş | Glodeni | 3781 | 177.9 | 848 | 39.70 | 3.97-11.9 | - | - | - | 8.10 | 2.30 | 6.00 | 5.01 | 4.95 |
| 4. | T-va Mare | Brădeşti | 500 | 38.0 | 984 | 5.38 | 0.54-1.61 | 8.82 | 4.25 | 1.88 | 1.08 | 0.60 | 0.81 | 0.98 | 1.00 |
| 5. | T-va Mare | Mediaş | 2519 | 183.0 | 617 | 12.50 | 1.25-3.75 | - | - | - | 2.37 | 0.74 | 2.27 | 1.06 | 1.50 |
| 6. | T-va Mică | Sărăţeni | 454 | 33.4 | 913 | 6.29 | 0.63-1.89 | 9.34 | 4.78 | 2.52 | 1.76 | 0.72 | 1.09 | 1.05 | 1.10 |
| 7. | Domald | Zagăr | 51 | 11.0 | 440 | 0.19 | 0.02-0.06 | - | - | - | 0.03 | 0.06 | 0.02 | 0.03 | 0.02 |
| 8. | T-va Mică | Târnăveni | 1478 | 124.0 | 585 | 9.76 | 0.98-2.93 | - | - | - | 2.05 | 0.83 | 1.92 | 1.44 | 1.40 |
| 9. | Târnava | Mihalţ | 6151 | 255.0 | 532 | 30.50 | 3.05-9.15 | - | - | - | 4.57 | 1.60 | 4.82 | 3.51 | 3.35 |
| 10. | Mureş | Alba Iulia | 18055 | 397.3 | 625 | 110 | 11.0-33.0 | - | - | - | 19.8 | 4.70 | 17.9 | 13.4 | 13.6 |

waters with low and very low impurity, respectively I and II category [9], due to bailing out used water with consuming oxygen substances and nitrates under admissible limits.

As well, in summer, the oxygen in water is reduced due to accelerated development of algae, especially for low discharges when water velocity is very slow. Numerous cases on fish mortality have been recorded in rivers due to oxygen diminishing by combing the effects caused by very high water temperature with very low discharges.

Table 3 Methods comparison to ascertain the ecological discharges

Taking into account the above-mentioned issues the following equation is proposed to determine the monthly ecological discharges and demands:

$$Q_{el} = \frac{C_{ml}}{C_m} \cdot Qa \qquad (6)$$

where:
- $Q_{el}$ - the average monthly multiannual ecological discharge;
- $Q_a$ - the average multiannual required in-stream ecological discharge;
- $C_m$ - the average multiannual concentration of dissolved oxygen;
- $C_{ml}$ - the average monthly multiannual concentration of dissolved oxygen.

For example, the methodology to determine the ecological water demands form Zetea reservoir on the Târnava Mare river is shown below. To achieve the aim, the values of dissolved oxygen in the Cristuru Secuiesc cross-section (table 4 and figure 3) recorded within 10 years and ecological discharge (0.77 $m^3/s$) by DECO method have been taken into account.

**Table 4** The ecological water demand from Zetea reservoir

| Month | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oxygen mg/l | 10.9 | 10.9 | 11.0 | 10.7 | 10.0 | 7.50 | 7.80 | 7.80 | 8.00 | 9.10 | 10.5 | 11.0 | 9.60 |
| $Q_{el}$ $m^3/s$ | 0.66 | 0.66 | 0.66 | 0.67 | 0.76 | 0.96 | 0.93 | 0.93 | 0.91 | 0.79 | 0.69 | 0.66 | 0.77 |
| Ecological demand $m^3/s$ | 0.66 | 0.66 | 0.79 | 0.80 | 0.70 | 0.90 | 0.93 | 0.93 | 0.86 | 0.74 | 0.69 | 0.66 | 0.77 |

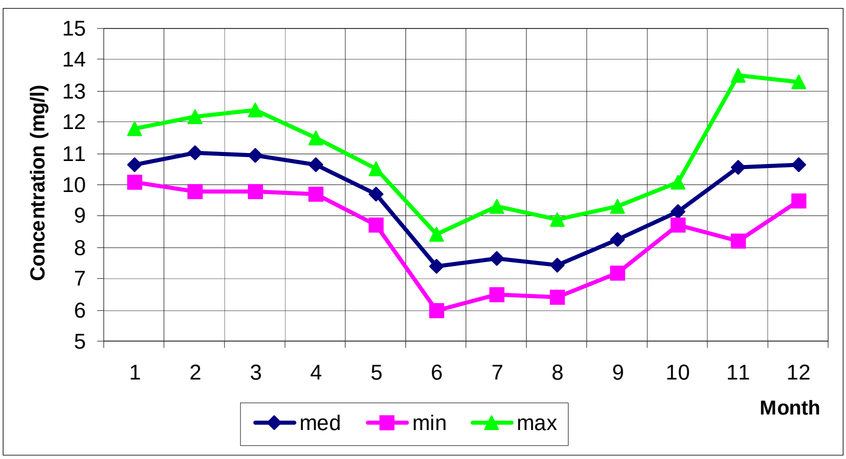


**Figure 3** The monthly concentration on the dissolved oxygen, registered over years on the Târnava river in the Cristuru Secuiesc cross section

### 4.2 Additional discharges within the fish reproduction season

It is necessary to provide some additional water discharges within the period when fish reproduction is on, which is shown in table 1 for the in-land rivers.

The computed discharges – see no. 6 formula - should be 20 % increased in March and April when the reproduction season for grayling is on (the grayling is the main species in the Zetea section), and in May, June, September and October the discharges are reduced adequately.

### 4.3 Providing flush discharges – artificial floods

On the rivers with water works, occurring moment, frequency and magnitude of flood period change affecting the space shape of the streambed, the material in streambed and the vegetation. All these issues imply a diminishing of the streambed transport capacity and the alteration of habitat that needs natural development of aquatic fauna.

With the view to diminish the negative effects, on rivers with water works, the artificial floods or flush discharges are necessary to be provided. The artificial floods will cause: washing the fine sediments for restoring the streambed permeability to create the suitable habitat for spawning; overflowing the river banks to make easier the migration of particular fish species, their spawning and the vegetation growing in flooding plain, what is a truly motherhood for fish.

Some recommendations should be considered to compute the features of artificial flood, namely, the maximum discharge, its occurring moment, increasing and decreasing time of the hydrograph, as following:

- the occurring time of artificial flood should coincide with the time of natural flood growing because the aquatic flora and fauna matches with the flood regime;
- increasing curve of the artificial hydrograph should be possible look like with the natural hydrograph to avoid the reservoir silting;
- decreasing curve of the artificial hydrograph should not be harsh so that it might to prevent the riverbed silting; it might be shorter than the increasing curve of the natural hydrograph taking into account that the biggest quantity of the sediment transport appears within the time of the increasing curve of the hydrograph;
- the maximum flood discharge should be chosen aiming to provide the overflowing of the riverbanks and not to move away the gravel from the streambed but only the fine alluvial deposits. Usually, it is less or equal with maximum discharge that occurs once in a year;
- supplying water demands for other uses.

Water demand to make an artificial flood is:

$$W = \gamma \, (Q_1 - Q_{el}) \cdot T_T \qquad (7)$$

Where: $Q_1$ - the maximum discharge with probability of occurrence once in a year;
$T_T$ - the total duration of the flood;
$\gamma$ - the shape coefficient of the flood.

The paper recommends that artificial flood should be created in springtime. April was chosen for the Zetea cross section. In our example, Qel is 0.79 $m^3/s$; Ql is 10.4 $m^3/s$, $T_T$ is 75 hours and $\gamma$ is 0.30. Water demand to create a flush flood, in the Zetea cross section, in April was 0.78 millions $m^3$.

- The paper proposes the (3), (4) equations to be used to compute ecological discharges.

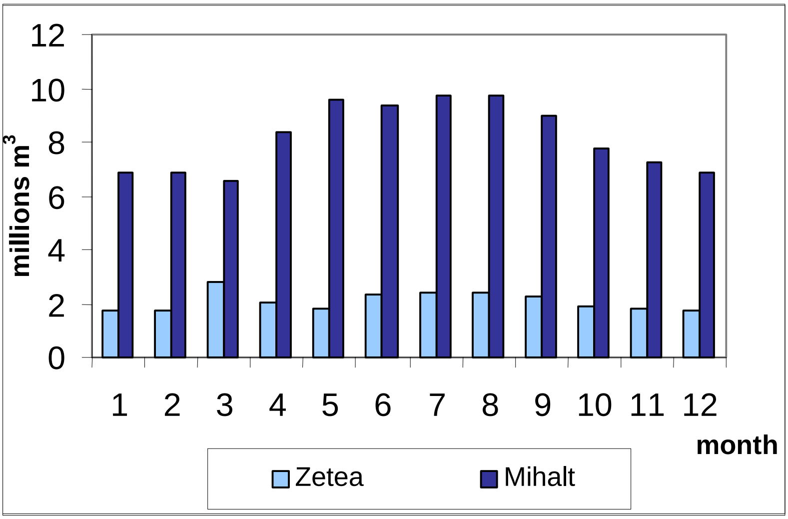


**Figure 4** Ecological water demands in the Zetea cross section on the Târnava Mare river and the Mihalţ cross section on the Târnava river

Ecological water demands in the Zetea cross section on the Târnava Mare river and the Mihalţ cross section on the Târnava river are shown in figure 4.

Figure 4 Ecological water demands in the Zetea cross section on the Târnava Mare river and the Mihalţ cross section on the Târnava river

### 4.4 Providing additional discharges to achieve a proper dilution when some accidental pollution occur

Additionally to the ecological water demands previously mentioned above, water demands are needed to provide some dilution discharges with the aim to prevent and diminish the effects of water accidental pollution should be considered. Water demands for dilution should be considered 10 – 20 % out of the ecological water demands depending on the risk to occur some accidental pollution on the studied river sector.

## 5. Conclusions

- The DECO method, which ascertains the required in-stream flow to preserve the aquatic ecosystems, relies on the relationship between the habitat features and water discharges.
- The output discharges on applying DECO method are close to the average discharges ascertained by using the following methods: Montana, Hope, Etiaj, SEPE and German method.
- The discharges determined by DECO method are greater than the minimum monthly discharges with 95% probability of exceedance () in case of small river basins and close to the value for big river basins.

- Ecological demands are needed to be taken into account for reservoir designing and operating as well as domestic, industrial, agricultural demands, etc.
- The ecological water demands needed for the preservation and the development of the aquatic ecosystems are variable during the year. They vary between 0.66 $m^3/s$ in wintertime and 0.93 $m^3/s$ in summer time, for the Târnava Mare river, Zetea-Odorheiul Secuiesc sector.
- Proving the ecological water demands bigger than usual in fish reproduction season is in need. For the river sector previously mentioned above, the ecological water demands have values between 0.79 $m^3/s$ in March and 0.80 $m^3/s$ in April that are reproduction months for grayling – the predominant species in the sector.
- Important ecological water demands to be provided in summertime to refresh water including an adequate dilution to diminish the reduction effect of the dissolved oxygen in water. The ecological water demands are 0.90 $m^3/s$; 0.93 $m^3/s$; 0.93 $m^3/s$, for the studied river sector, in summer.
- Providing additional water volumes in reservoirs to protect water quality so that may be used when accidental pollution events occur. The additional volume is about 2 millions $m^3$ for Zetea reservoir.

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