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Determining Ecologically Acceptable Flow of the Modrac Dam

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Abstract:- Multi-purpose reservoir Modrac is the most important water resource in Tuzla canton. Ecologically acceptable flow on dam Modrac is not adjusted with the latest Rulebook about methods of determining ecologically acceptable flow. This article shows the methods used to determine ecologically acceptable flow on the Modrac dam, respecting the fact that reservoir Modrac is declared as protected water resource. The given calculation of ecologically acceptable flow is made for II level of evaluation.

Keywords:- *Reservoir, Dam Modrac, Ecologically Acceptable Flow, Protected Water Source, Eutrophication.*

I. INTRODUCTION

The Modrac reservoir is located in the northeastern part of BiH, and as such represents the most important water resource in this part of the country. It is the only real strategic source of surface water for the Tuzla region.

The area of the Tuzla Canton, which is located in the basin of Lake Modrac, includes the municipalities of Živinice, Kalesija and Banovići, as well as parts of the municipalities of Lukavac, Kladanj and a small part of the city of Tuzla. The total area of the Tuzla Canton is 2,649 km², of which the Modrac lake basin covers about 1,189 km². The area of the Modrac lake basin is inhabited by about 151,200 inhabitants.

The dam was built in 1964 to block the river Spreča. The rivers Spreča and Turija are the main tributaries of the lake. The main purpose of building the reservoir was to supply water for industrial use and supply the population with water. Other purposes are flood protection, electricity generation and recreation.

Fig 1 Location of the Modrac Reservoir on the Ortho-Photograph

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Ecologically acceptable flow (EAF) is the flow of water that must be provided downstream of the water intake in the watercourse, in order to preserve the natural balance of water ecosystems and water-related ecosystems.

Ecologically acceptable flow can be considered as the "ecologically acceptable minimum", that is, the flow that must be ensured in the riverbed for the normal survival and development of plant and animal life. It should be taken into account that the ecologically acceptable flow must be determined in accordance with the conditions necessary to meet the corresponding environmental protection objectives from Article 30 of the Water Act.

- *These Conditions Include:*

- Preventing deterioration of the surface and underground water bodies condition and achieving their least good condition;
- Achievement of good ecological potential and good chemical condition of artificial or heavily modified water bodies;
- Protection, improvement and restoration of water bodies of surface water and water bodies of underground water;
- Maintenance or improvement of water conditions in protected areas, which are intended to protect the habitats of plant and animal species or aquatic species, and in which maintenance or improvement of water conditions is an essential condition for survival and reproduction;
- Maintenance of the highest level of protection of land water reserves area, for which the establishment of a protected area establishes restrictions and bans on the loading of space and activities that may threaten their qualitative or quantitative state.

In the designed state of the Modrac dam, it was defined that, in order to reduce the high degree of pollution of the Spreča watercourse, the determined ecologically acceptable flow rate of Q = 4.7 m³/s is continuously released from the Modrac reservoir. In less favorable hydrological years, when the elevation of the reservoir is below 196.5 m.a.s.l., it is planned that, with the approval of the Ministry of Agriculture, Forestry and Water Management of the Tuzla Canton, 1.0 m³/s is discharged as an environmentally acceptable flow, which is slightly more than the minimum average flow. Flow of the river Spreča is 95% guaranteed, which is 0.824 m³/s. Such discharge lasts until the water level exceeds the specified elevation, and the discharge is regulated manually.

The determination of EAF in the territory of the Federation of Bosnia and Herzegovina is defined by Article 62 of the Law on Water (official new. FBiH No. 70/06), the Regulation on the method of determining environmentally friendly flow (official new. FBiH No. 4/13.) and the Regulation on amendments to the regulation on the method of determining environmentally friendly flow (official new. FBiH No. 56/16, No. 62//19 and No. 63//22).

Given that the quantities of water discharged as EAF at the Modrac dam are not in compliance with the above-mentioned applicable law and regulations, the obligation to determine the environmentally friendly flow on the Modrac dam profile has arisen.

II. DETERMINATION OF EAF BY HYDROLOGICAL METHOD

A. Basic Characteristics of the Drainage Basin of Modrac Accumulation

In hydrographic terms, the Modrac reservoir belongs to the Black Sea basin and consists of the Spreča and Turija rivers with their tributaries, as well as numerous small tributaries, which flow directly into the reservoir. The hydrographic network is broken up into intermittent and constant flows. Most of the tributaries are creeks and streams of intermittent character with a small amount of water.

The total area of the drainage basin of the Modrac reservoir is 1,189 km², of which the Spreča River basin is 832 km², the Turija River basin 240 km² and the immediate accumulation basin about 117 km². According to today's territorial-administrative division, the area of the Modrac accumulation basin covers the area of the municipalities of Banovići, Živinice, Kalesija, and partly Kladanj, Tuzla and Lukavac in the Tuzla Canton and the municipality of Osmaci in the Republic of Srpska.

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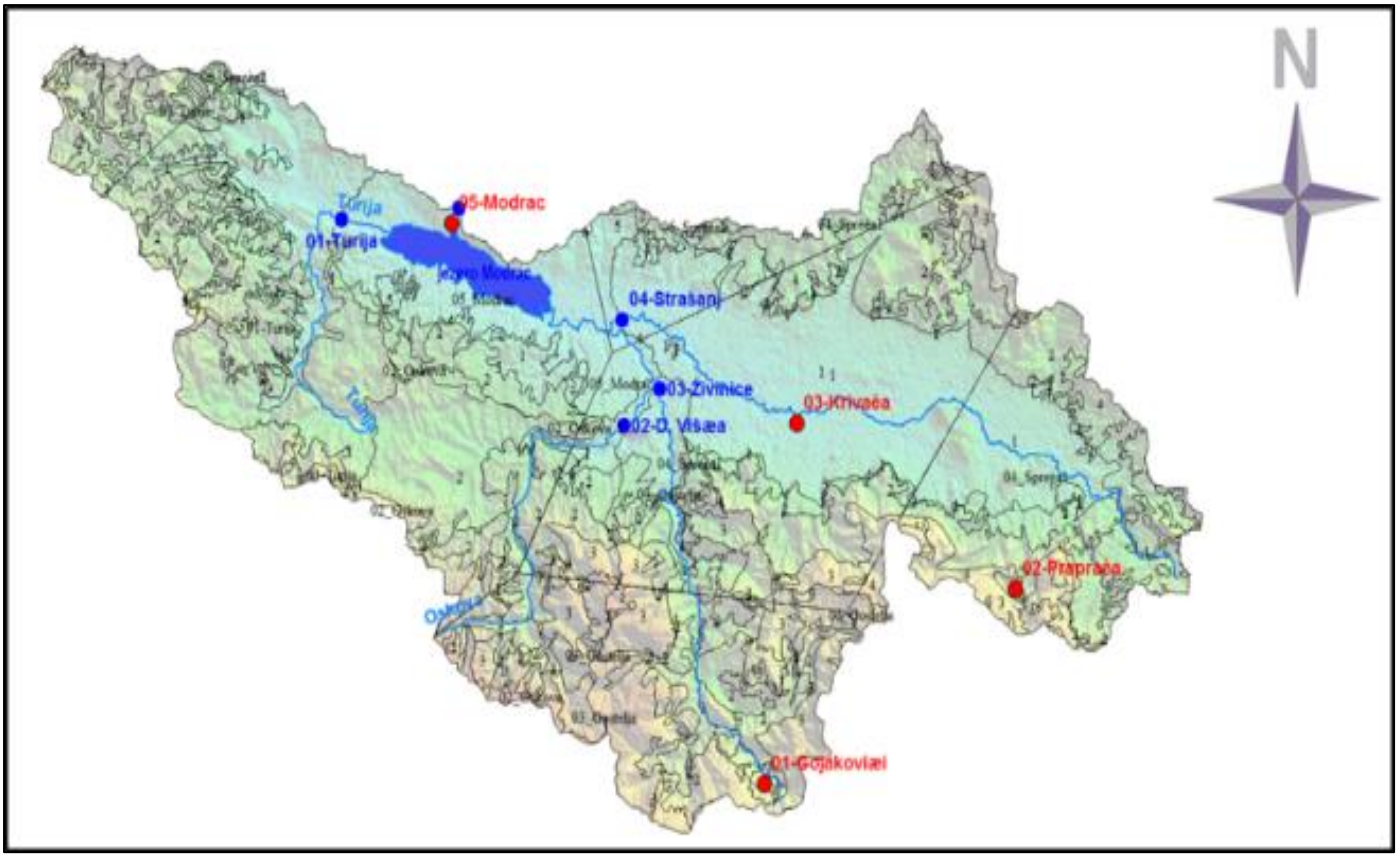

Fig 2 Modrac Accumulation Basin Area, (47)

The reservoir is formed by collecting waters from the Spreča River, Turija and smaller watercourses that flow directly into the reservoir. The water body has an area of P = 1673.98 ha, where in the municipality of Tuzla lies 30.00 ha or 1.8% of the total area, the municipality of Živinice lies 35.8% of the total area, and in the municipality of Lukavac the highest percentage, i.e. 62.4% of the total area of accumulation. Construction of the dam was completed in 1964. year.

In the period of exploitation of less than 60 years, data were collected on the change in the level of accumulation registered for the period from the beginning of 1987. by the end of 2020. year. During this period, depending on hydrological conditions, the level of the same oscillated in the range of + 3.20 to – 4.69 m compared to the normal operating level of accumulation of 200.00 m.a.s.l.. In this period, the following characteristic levels of Accumulation were registered:

- The average upper water level for the registered series of data is 198.14 m.a.s.l..
- The highest average daily level was recorded in May 2014 and was 203.20 m.a.s.l..
- The lowest level was recorded on October 28, 2012. year and amounted to 195.31 m.a.s.l.
- During the flood in May 2014, 1,000 annual waters appeared, and the maximum recorded level was measured at 1:00 p.m. on May 16, 2014, and was 203.42 m.a.s.l.
- In the period from May to October, evaporation from hydroaccumulation ranges from 0.79 to 4.14 mm/m²/day, with an average of 2.32 mm/m²/day. Therefore, water evaporation from the surface of the reservoir is on average about 36,000 m²/day.

B. Hydrological Calculation

For the purposes of creating the hydrological part of the calculation of the ecologically acceptable flow at the Modrac dam, data were collected on the average daily flow values from the water gauge station Modrac, which is located immediately downstream of the Modrac dam. Data for the periods 2002-2007 and 2013-2019 year were processed, which is a total of 13 years. The data used represent the latest available hydrological series on water gauge station Modrac, which is in accordance with the recommendations given in the Rulebook.

The calculation of the value of environmentally friendly flow is made based on the values of the parameters Qsr, srQmin, and srQ dek(j) of the water body in the profile for which the EAF is determined.

The values of these parameters are calculated on the basis of reference (relevant) hydrological data. Depending on the degree of hydrological investigation of the profile for which the EAF is determined, the value is determined in ways:

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➢ *Case when all the Data is Available*

$Q_{eaf} = 1{,}0 \times {}_{sr}Q_{min}$ za ${}_{sr}Q_{dek(j)} < Q_{sr}$ (1)

$Q_{eaf} = 1{,}5 \times {}_{sr}Q_{min}$ za ${}_{sr}Q_{dek(j)} \geq Q_{sr}$ (2)

➢ *Case when ${}_{sr}Q_{min} = 0$ ili ${}_{sr}Q_{min:}$ $Q_{sr} < 1 : 25$, Q_{eaf} will be Calculated based on the Equation:*

$Q_{eaf} = 0{,}10 \times Q_{sr}$ for ${}_{sr}Q_{dek(j)} < Q_{sr}$ (3)

$Q_{eaf} = 0{,}15 \times Q_{sr}$ for ${}_{sr}Q_{dek(j)} \geq Q_{sr}$ (4)

➢ *Case when Decadal Flow Values are not Available, Q_{eaf} will be Calculated based on the Equation:*

$Q_{eaf} = 0{,}10 \times Q_{sr}$ for the period May - October (5)

$Q_{eaf} = 0{,}15 \times Q_{sr}$ for the period November - April (6)

In this case, all data on decadal flows are available, and the method from **case A** was used.

➢ *In doing so, the Parameters used Represent:*

The mean flow ***(Q_{sr})*** means the arithmetic mean of the mean annual flow values in the watercourse profile in the considered period. It is expressed in m³/s. The average flow is calculated according to the formula:

$$Q_{sr} = \sum_{i=1}^{i=N} \frac{Q_{sr,i}}{N} \quad (7)$$

Where is:

$Q_{sr,i}$ - mean annual flow in i-th year

N - number of years in the considered period

Mean minimum flow ***(${}_{sr}Q_{min}$)*** means the arithmetic mean of the minimum annual values of mean daily flows in the watercourse profile in the considered period. It is expressed in m³/s and calculated according to the formula:

$$srQ_{min} = \sum_{i=1}^{i=N} \frac{Q_{min,i}}{N} \quad (8)$$

Where is:

$Q_{min.,i}$ - minimum average daily flow in the i-th calendar year

N - number of years in the considered period

The average decade flow ***(${}_{sr}Q_{dek(j)}$)*** denotes the arithmetic mean of the j-th decade of flow in the considered period. It is expressed in m³/s and calculated according to the formula:

$$srQ_{dek(j)} = \sum_{i=1}^{i=N} \frac{Q_{dek(j),i}}{N} \quad (9)$$

Where is:

$Q_{dek(j),i}$ - mean decadal flow in the j-th decade in the i-th calendar year,

N - number of years in the considered period

The following text provides a tabular calculation of the parameters necessary to determine the value of the EAF.

Table 1 Average Annual Flow, Minimum Decadal, Maximum Decadal and Minimum Annual Flow of the Spreča River on Water Gauge Station Modrac

Year	**$Q_{sr,i}$**	**${}_{dek}Q_{min}$**	**${}_{dek}Q_{max}$**	**$Q_{min,i}$**
2002	18.55	3.99	60.78	3.02
2003	8.83	1.20	17.40	1.20
2004	20.11	7.52	71.70	4.97
2005	27.21	3.22	101.46	2.34
2006	19.73	2.33	89.07	2.33
2007	7.78	1.02	51.71	0.85
2013	11.44	1.10	51.64	1.09
2014	5.95	3.35	311.40	1.53
2015	13.21	2.57	46.91	2.48
2016	12.87	4.33	47.55	4.21
2017	12.42	1.12	53.03	1.10
2018	13.76	1.22	46.39	1.19
2019	10.68	1.25	45.80	1.21

Table 2 Mean Flow and Mean Minimum Flow of the River Spreča at Water Gauge Station Modrac for the Periods from 2002 - 2007 and 2013-2019

Mean value for the period from 2003 to 2007. and 2013-2019. years (m³/s)	
Q_{sr}	14.04
${}_{sr}Q_{min}$	2.12

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➢ *Based on the Calculations, the Following Ecologically Acceptable Flow Values are Proposed for the Profile of the Modrac Dam (Case A):*

- QEAF1 = 2.12 m³/s, for the dry period during the year
- QEAF2 = 3.18 m³/s, for the wet period of the year

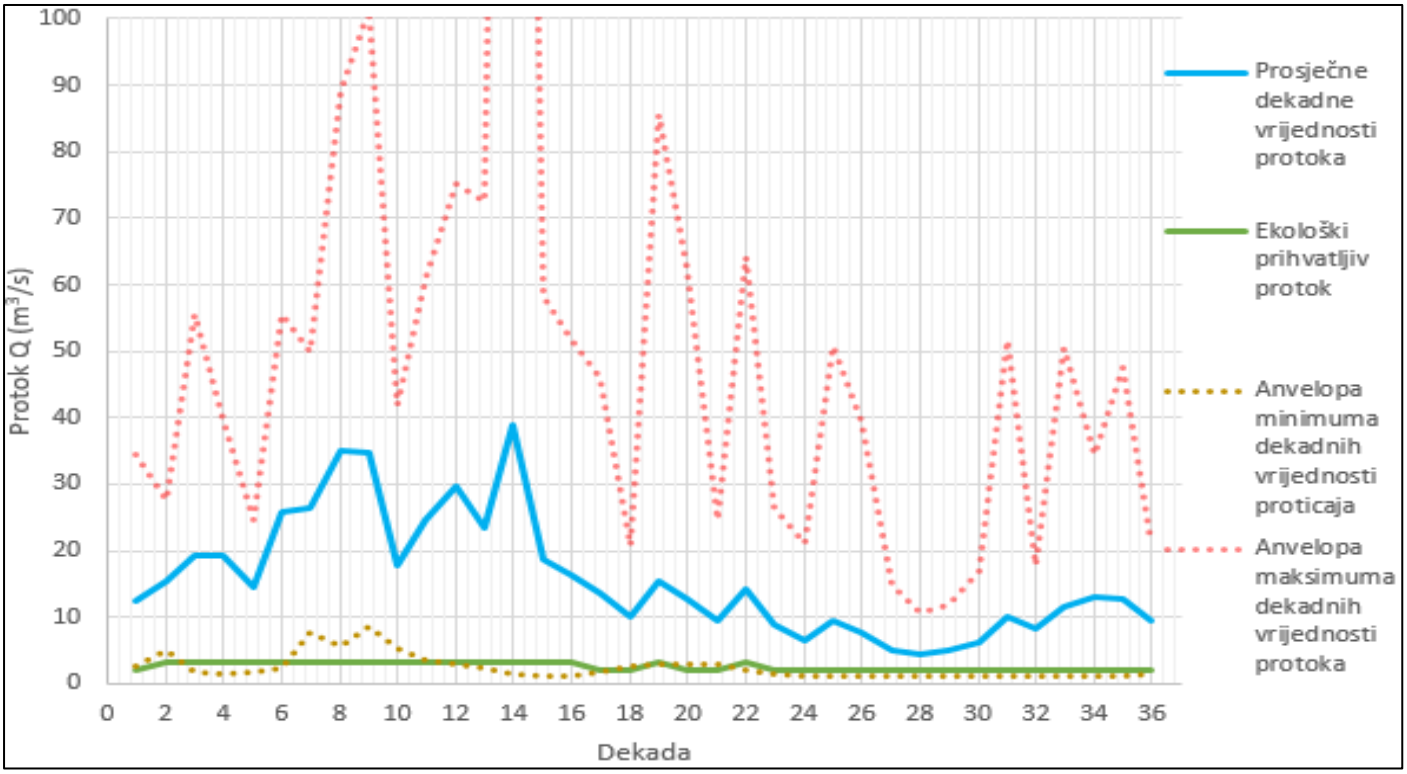

Fig 3 Overview of Average Decadal Flow Values and Ecologically Acceptable Flow (Period: 2002-2007 and 2013-2019)

The existing literature suggests several fast methods for the calculation of environmentally acceptable flow. In order to check how well the obtained results fit into the given recommendations, the EAF was also calculated using the quick methods mentioned in the aforementioned study.

- Q_E= 0.2 x Q_{80} (l/s)- the alarming threshold value of EAF that must not be exceeded

✓ Q_E= 0.2 x 8148 (l/s)=1629.6 l/s= 1.63 m³/s

- Q_E= 0.2 x Q_{80} +75 (l/s)- it is used for larger watercourses

✓ Q_E= 0.2 x 8148 +75 (l/s)=1704.6 l/s= 1.70 m³/s

- Q_E= (0.15 -0.2) x Q_{sr} = 0.15 x 14.04 m³/s = 2.11 m³/s
- Q_E= (0.7 -1.3) x $Q_{sr\,,min}$= 0.7 x 2.12 =1.48 m³/s
- The EAF value should not be below 2-3 l/s, km² of the catchment area

✓ Q_E= (2-3)l/s,km² x F_{sl}= 2 l/s x 1189 km² = 2.38 m³/s

Based on the calculations previously given, we can say that the obtained values of environmentally friendly flow, calculated by the hydrological method: Q_{eaf}=2.12 m³/s for the dry period and Q_{eaf}=3.18 m³/s for the wet period, meet the above literature recommendations on minimum values of environmentally friendly flow.

III. EVALUATION OF EAF IN PROTECTED AREAS

In the Rulebook on the method of determining ecologically acceptable flow ("Official Gazzete of the Federation of Bosnia and Herzegovina", no. 4/13; 63/22), two levels of assessment are defined. The first level of assessment refers to the general assessment of the EAF for all water bodies, which is calculated using the hydrological method. The second level of assessment implies a special EAF assessment for water bodies in protected areas declared in accordance with Article 65 of the Water Act and for other protected areas from the register of protected areas from Article 29, point 4 of the Water Act, as well as for areas that have not been declared protected, and which have exceptional values for conservation (presence of threatened habitats or species, historical-cultural and ambient values), and for heavily altered and artificial water bodies declared by the water management plan. In these cases, ecologically acceptable flow is determined using biological and ecological criteria (including holistic and hydraulic studies, and especially habitat models) in addition to the hydrological method.

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In this regard, the Law on Waters of the Federation of BiH ("Official Gazette of the Federation of BiH", number 70/06), Article 65 for water bodies that can be declared protected, with the aim of establishing special protection of surface and underground waters, habitats of plant and animal species or aquatic species and areas, implies the following categories:

- Areas intended for intake of drinking water,
- Areas intended for the protection of economically important aquatic species,
- Surface water bodies intended for recreation, including areas designated for swimming,
- Areas subject to eutrophication and areas sensitive to nitrates,
- Areas intended to protect the habitats of plant and animal species or aquatic species in which maintenance or improvement of water conditions is an essential condition for their survival and reproduction.

In addition to the above, according to Article 14 of the Rulebook on environmentally acceptable flow from 2022, a special assessment of EAF is also carried out for areas connected to ecosystems whose structure and functioning require a special approach for determining EAF, such as lakes and wetlands.

Of the categories listed above, the area covering the Modrac reservoir and the Spreča river, for which an environmentally acceptable flow is determined, is in the category of protected water resources, as an area subject to eutrophication and sensitive to nitrates. An area subject to eutrophication and sensitive to nitrates is an area in which the waters are polluted with nitrogen and/or phosphorus compounds or an area in which it is likely to become so if appropriate measures are not taken. Areas subject to eutrophication and areas sensitive to nitrates are determined in accordance with Articles 65 and 73 of the FBiH Water Law, i.e. based on the provisions of the Nitrates Directive (91/676/EEC) and Directive 91/271/EEC (Directive on Municipal Wastewater Treatment water). In 2009, the Rulebook on determining areas subject to eutrophication and sensitive to nitrates (Official Gazette of FBiH, number 71/09) and the Rulebook on monitoring in areas subject to eutrophication and sensitive to nitrates (Official Gazette of FBiH, number 71/09) were adopted in FBiH in 2009. On the initiative of the Agency for the Sava River Basin, the Federal Ministry of Environment and Tourism issues a decision dated 17 October 2018 year, number 0423 367/18, by which the Modrac reservoir area (BA_BOS_SPR_2) with an area of 5165.99 ha, Spreča upstream of Modrac (BA_BOS_SPR_3A) with an area of 6049.21 ha, and Spreča estuary (BA_BOS_SPR_1c) with an area of 3406.21 ha declares an area subject to eutrophication in the category sensitive to nitrates in the Federation of Bosnia and Herzegovina.

In addition to the mentioned category of protected water resource, the area of the Modrac reservoir is recognized as a potential NATURA 2000 habitat, although there is still no legal basis for protection in that category. Namely, in order to protect endangered habitats and species throughout the European Union, in 1992 the member states adopted the Directive on the Protection of Natural Habitats and Wild Fauna and Flora (abbreviated Habitats Directive 92/43/EEC). This Directive complements the Birds Directive 79/409/EEC adopted in 1979.

Both of these directives represent a key basis for the creation of a network of sites of ecologically significant areas under the name "Natura 2000". The ecological network "Natura 2000" is a biological connection of ecologically significant areas (natural, approximately natural and protected natural areas) and their buffer zones, which are secured by ecological corridors. In 2011, the Government of the Federation of BiH adopted the Decree on the Natura 2000 program of the network of protected areas in Europe. By this Decree, certain areas in the Federation of Bosnia and Herzegovina are designated for the Natura 2000 program with the aim of inclusion in the international ecological network for the preservation of natural habitats and habitats of species. As part of the European Heart of Life project, habitat and species mapping in BiH was carried out in accordance with Appendices I and II of the EU Habitats Directive, based on data from the literature, and partial field verification as part of field research. In the period up to now, 122 potential NATURA 2000 areas have been identified throughout BIH. Under the code BA8300050 and the name Modrac-Gornja Spreča, and with a proposed area of 2884.8 ha, the Modrac reservoir is listed as a potential Natura 2000 area, due to the diversity of living things and habitats related to aquatic ecosystems. However, the proposed areas are still not officially adopted, nor protected by the competent institutions. In Bosnia and Herzegovina, even secondary legislation on NATURA 2000 for the protection of habitats and strictly protected plant and animal species has not yet been adopted. However, NATURA 2000 areas will become mandatory for protection after BiH joins the European Union (source: Water Management Plan for the Sava River Water Area in the Federation of BiH, 2022-2027).

Given that the examined area is declared a protected water resource in the category of areas sensitive to nitrates and eutrophication, and the reservoir area is additionally recognized as a potential Natura 2000 area, the assessment of environmentally acceptable flow cannot be determined by applying only hydrological methods, but requires the application of a second level of assessment environmentally friendly flow.

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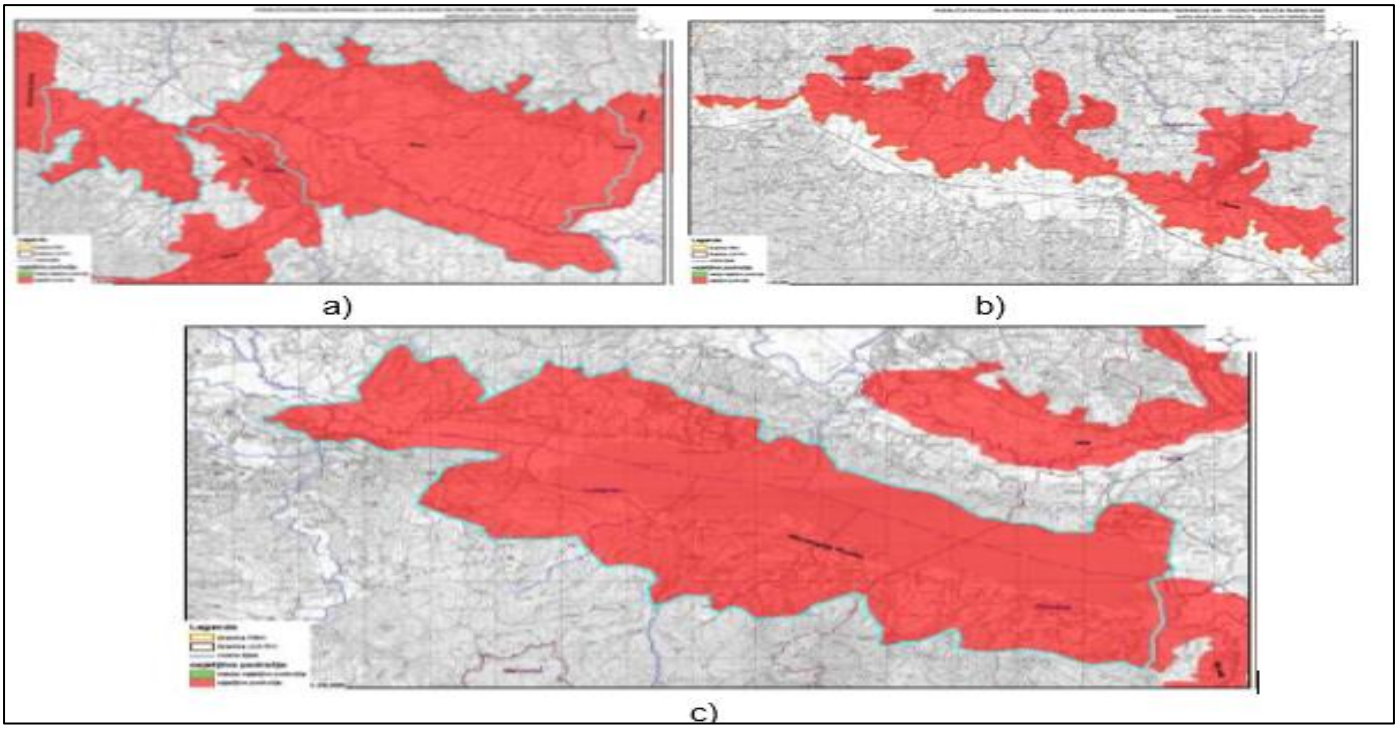

Fig 4 Protected Water Resources: a- Spreča Water Body Upstream of Modrac (BA_BOS_SPR_3A), b- Spreča Estuary (BA_BOS_SPR_1C) and c- Reservoir Modrac (BA_BOS_SPR_2), (Maps taken from the Initiative for Declaring Areas Susceptible to Eutrophication and Sensitive to Nitrates Protected Areas in the Sava River basin in FBiH).

When determining the ecologically acceptable flow in a protected area, in addition to the space of that area, elements of the hydrographic network outside the protected area, which may have a significant impact on that area, are also taken into account.

➢ *The Determined value of EAF in the Protected Area should Enable:*

- Ensuring, preserving the structure and function of the ecosystem and its associated elements;
- Ensuring the defined ecological needs of habitats and species (especially those most endangered and most sensitive to flow changes), to maintain the long-term ecological function on which they depend;
- Maintaining the required level of water quality.

➢ *In doing so, it is Especially Important to Analyze the Response of Ecosystems (Processes, Habitats or Species) in Relation to Changes in Flow, and in Particular:*

- Components of water bodies to which they refer (individual species, communities, processes);
- "Events" that need to be protected (eg. fish migration, fish spawning, community biodiversity);
- Quantification of goals in the form of the value that the event should reach or the amount of deviation in relation to the natural value, etc.;
- "Success criterion", with detailed conditions to be met, in order to ensure the achievement of the goal;
- "Measure of success" or the variable to be measured, and the value that must be achieved.

➢ *Additionally, the Following Criteria are taken into Account to Determine the Water Needs of Lakes and Wetlands:*

- Water inflows through the hydrographic system that should maintain the water level (including surface and underground water);
- If they are dependent on the underground aquifer, surface water inflows should be determined so that disturbances due to human activities do not cause:

✓ Failure to achieve environmental protection goals for associated surface waters,
✓ Significant damage to terrestrial ecosystems that directly depend on groundwater;

- If the lake or swamp is part of the protected area, the water needs are determined by implementing the rules for the preservation of the protected area.

➢ *In the Process of Determining Water Needs for Lakes and Wetlands, it is Necessary To Determine the Following Elements:*

- Balance of the system, preferably identification of the inflow of surface and underground water, as well as the output and losses of water;
- Seasonal variations and the area and depth of intra-annual floods in natural conditions, with the identification of water periods;
- Seasonal and intra-annual variations of water hemism, in relation to composition and concentration;

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- Composition and structure of biological communities (with special attention to vegetation or other endangered or vulnerable species).

The Rulebook on environmentally acceptable flow of the Federation of Bosnia and Herzegovina prescribes the obligation to assess the flow for level II assessment, but does not strictly describe the assessment methodology. In the following text, different assessment methods for the II assessment level in BiH, the region and Europe are reviewed.

The first studies on watercourse flows related to habitat conservation began in the early eighties of the twentieth century (Bonacci, 2003). The methods were initially based on biologists assessments and aimed to protect the top of the food chain, i.e. the fish. After that, simple calculation methods followed, and later complex methods were developed that take into account hydrological and hydraulic changes over time and in space.

➢ *Bonacci Classified the Methods for Determining EAF into the Following 4 Basic Groups:*

- Quick and approximate procedures for determining EAF;
- Methods that use one or a smaller number of important criteria for determining EAF;
- Complex interdisciplinary methods of determining EAF;
- Methods of habitat simulation in open watercourses.

Fast and approximate procedures are based on experiential principles. Their source is in the measured hydrological substrates. They are acceptable and often used because they do not require too much data and time-consuming work. It is necessary to have hydrological foundations for small and medium flows. Roughly, it is necessary to know the geometry and morphology of the part of the watercourse for which the EAF is determined, as well as the general ecological and other conditions of the section under consideration.

➢ *Some of the Recommendations in Addition to Quick and Simple Methods that can be used are the Following:*

- The minimum depth of the watercourse should not be lower than 20 cm;
- The EAF value should not be lower than 2-3 l/s per km² of the basin area;
- The mean speed of the water in the stream should not fall below 0.2 to 0.4 m/s.
- The value of the water temperature should not rise above a certain limit, depending on the type of water flow.

Of the numerous and more commonly used techniques for determining EAF, the wetted volume method is among the simpler ones. Its positive feature is that it is based on natural conditions, and its main weakness is the fact that there is no explicitly expressed connection with aquatic habitats in the analyzed watercourse. The selection of a profile or an average profile on one river section should be made by a joint tour of the terrain by hydrologists and biologists. During this tour, biologists must determine the properties of the habitat at the bottom of the watercourse and the productivity of the bottom for bio-organisms, while the hydrologists must determine the hydrological and morphological properties as well as the composition and stability of the bottom.

Complex interdisciplinary methods for determining EAF are increasingly being used in the world. They have been included in various laws related to environmental protection. In addition to the mentioned factors, these methods include criteria related to the general attitude, wealth and development of society and its relationship to ecology and its socio-economic aspects. The goal of all methods is to preserve the ecosystem and enable the socio-economic development of the community. Their first and inevitable part represents an interdisciplinary analysis of numerous hydrological, morphological, hydraulic-dynamic, biological, ecological and chemical parameters.

The methods of habitat simulations in open watercourses are based on the connection of flow and natural and physical habitats with the development and life of selected species of aquatic animals in different hydrological conditions. In open watercourses, not only changes in physical habitats with changes in flow and/or water level are studied, but this information is combined with the most favorable habitats for several selected species in order to determine the abundance and suitability of habitats for various species in different hydrological conditions. It is usual for the results to be presented in the form of curves of the relationship of available habitats as a function of flow, water level or velocity. From such displays, optimal flow rates for different species are determined. Based on this, recommendations are made on which minimum flows should be ensured in an open watercourse during different periods of the year and during various life stages of certain aquatic species.

The recommendations of all studies mainly refer to minimum flow values. The minimum flow is usually treated as an instantaneous value more often than as a daily mean value, meaning that the flow in an open watercourse is never allowed to fall below this value. In addition to the minimum water flows in open watercourses, the recommendations also include the flows of necessary floods that are caused by artificial means, for example, when emptying reservoirs.

The experiences of developed countries show that it is possible to define the EAF based on the assessment of the influence of the retained inflow value calculated by hydrological methods on the characteristic communities of the observed watercourse or its individual members.

Certain types of fish are very often used as bioindicators. Namely, fish as the last members of the food chain, which inhabit a certain type or section of the watercourse, are a very important indicator of the bio-ecological balance of the watercourse. The assumption is that by ensuring the basic ecological conditions of the

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selected fish species, as the last members of the food chain, the conditions for the development of other autochthonous communities of the mother watercourse are also ensured. Using the hydraulic calculation for given parameters on a certain section of the watercourse, the EAF can be determined which will correspond to the basic ecological conditions for certain characteristic fish species. Characteristic species of fish for certain types of watercourses do not mean that they are present in reality, therefore it is necessary to make a detailed analysis in all the mentioned locations about the represented ichthyofauna and the possible possibility of returning the ecosystem to the state it was in before the change in the flow regime. When fish are used as bioindicators, the EAF must take into account the various stages of their development from spawning, through larvae, small fish to adults. Each of these stages requires different minimum depths, velocities and water temperatures as well as oxygen content.

- *Habitat Simulation Method*

Given that the Modrac reservoir is a protected water resource, the completed hydrological calculation needs to be expanded and processed from the aspect of biological and ecological criteria. In the theory and practice of determining EAF, we can come across a large number of methods, from simple and fast to complex and complex. The habitat simulation method is one of the mentioned methods. This method takes into account the locally specific connections between flow, morphology and ecology.

The methods of habitat simulations in open watercourses are based on the connection of flow and natural physical habitats with the development and life of selected species of aquatic animals in different hydrological conditions. In open watercourses, not only changes in physical habitats with changes in flow and/or water level are studied, but this information is combined with the most favorable habitats for several selected species in order to determine the abundance and suitability of habitats for various species in different hydrological conditions.

The experiences of developed countries show that it is possible to define the EAF based on the assessment of the influence of the retained inflow value calculated by hydrological methods on the characteristic communities of the observed watercourse or its individual members. Certain types of fish are very often used as bioindicators. Namely, fish as the last members of the food chain, which inhabit a certain type or section of the watercourse, are a very important indicator of the bio-ecological balance of the watercourse. The assumption is that by ensuring the basic ecological conditions of the selected fish species, as the last members of the food chain, the conditions for the development of other autochthonous communities of the mother watercourse are also ensured.

Using the hydraulic calculation for given parameters on a certain section of the watercourse, the EAF can be determined which will correspond to the basic ecological conditions for certain characteristic fish species.

When fish are used as bioindicators, the EAF must take into account the various stages of their development from spawning, through larvae, small fish to adults. Each of these stages requires different minimum depths, velocities and water temperatures as well as oxygen content.

Table 3 Presentation of the basic Ecological Requirements of Certain Indicator Species

Biogeog. area	Life stages	Water depth in cm	Water speed in cm/s	Water temperature in °C	Oxygen in mg/l
Trout	Spawned	Greater than body height 20-65	Less than 2L 30-80	1-12 (9)	Above 6
	Larvae	Around 30	0,003	4-19 (13)	Above 9
	Juvenile fish	Around 30	15-70	4-19 (13)	Above 9
	Adult	Greater than body height	30-80	3,5-19(14)	Above 9
Thymallus	Spawned	Greater than body height 20-40	Less than 2L 30-55	4-17 (12)	Above 6
	Larvae	Up to 30	6-20	4-18 (17)	Above 9
	Juvenile fish	Up to 30	6-20	4-18 (17)	Above 9
	Adult	Greater than body height 20-60	30-70	4-17 (17)	Above 9
Barbel	Spawned	Greater than body height 20-45	35-50	4-17 (14)	
	Juvenile fish	Around 30	6-20	(15)	
	Adult	Greater than body height 20-45	35-50	4-20	
Bream	Spawned	Greater than body height 15-45	Less than 20	12-20	Around 5
	Juvenile fish	Greater than 30	Less than 20	12-20	Above 5
	Adult	Various	Less than 20	12-20	Above 5

Legend: L= the height of the spread tail fin of the female in cm ( ) = optimal value

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Through the hydraulic calculation, it was checked whether the calculated EAF obtained by the hydrological method meets the ecological conditions necessary for the preservation of indigenous watercourse communities. A model of the Spreča River bed was formed in a length of approx. 2300 m, from the mouth of the Jala River to the Modrac Dam.

➢ *The Input Parameters for this Calculation are as Follows:*

- Ecologically acceptable flow defined by the hydrological method
- Recorded transverse profiles for the considered stretch
- Roughness of the bed according to Manning

The hydraulic calculation, along with the known input parameters, checks whether the hydraulic parameters are suitable for the maintenance of characteristic fish species. Based on the previous studies of the diversity of the Modrac reservoir and the Spreča river, characteristic fish species were identified, namely barbel Barbus barbus and bream Abramis brama for the Spreča watercourse downstream from Modrac, based on whose requirements a habitat simulation was performed. The assumption is that by ensuring the basic ecological conditions of the selected fish species, as the last members of the food chain, the conditions for the development of other autochthonous communities of the parent watercourse on a certain section of the watercourse are ensured. The selected basic ecological conditions are the depth and speed of the water.

Table 4 Results of the Hydraulic Calculation for Eaf=2.12 m^3/s on the Stretch of the River Spreča from the Mouth of the River Jala to the Modrac Dam

Chainage	Q_{epp}	Depth of water in the waterbed	Elev. of the bottom of the water bed	Water level	Energy line elevation	Energy line drop	Water speed in the waterbed	Area of the flow profile	Width of the water face
	(m^3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m^2)	(m)
2330.2	2.12	0.26	182.78	183.17	183.18	0.003052	0.39	5.5	21.14
2304.79	2.12	0.3	182.57	183.15	183.15	0.000553	0.18	11.62	38.21
2211.46	2.12	0.52	182.23	183.11	183.11	0.000261	0.18	11.76	22.46
2102.38	2.12	0.16	182.77	183.02	183.03	0.00898	0.48	4.45	28.26
1846.22	2.12	0.43	181.83	182.36	182.37	0.001222	0.34	6.24	14.62
1744.64	2.12	0.26	181.82	182.21	182.22	0.001681	0.29	7.3	27.64
1644.14	2.12	0.21	181.56	181.94	181.95	0.004858	0.42	4.99	23.76
1548.3	2.12	0.31	180.99	181.57	181.58	0.003253	0.45	4.69	14.99
1447.02	2.12	0.31	180.88	181.36	181.36	0.001542	0.31	6.84	22.01
1344.38	2.12	0.36	180.7	181.17	181.18	0.002217	0.41	5.17	14.31
1194.69	2.12	0.44	180.38	181	181	0.000719	0.26	8.01	18.38
1093.83	2.12	0.41	180.46	180.93	180.93	0.000633	0.24	8.89	21.7
995.86	2.12	0.44	180.35	180.88	180.88	0.000436	0.21	10.17	22.96
893.39	2.12	0.32	180.22	180.79	180.8	0.002059	0.37	5.8	18
793.72	2.12	0.4	180.03	180.5	180.52	0.00396	0.58	3.66	9.2
696.19	2.12	0.44	179.85	180.39	180.39	0.000643	0.25	8.38	18.89
594.1	2.12	0.45	179.72	180.32	180.33	0.000626	0.25	8.42	18.82
494.99	2.12	0.43	179.69	180.23	180.24	0.001449	0.37	5.71	13.32
430	2.12	0.52	179.61	180.19	180.19	0.000433	0.23	9.24	17.73
298.69	2.12	0.44	179.6	180.13	180.14	0.000402	0.2	10.65	24.06
199.68	2.12	0.44	179.56	180.1	180.11	0.000248	0.16	13.68	31.37
98.79	2.12	0.57	179.45	180.09	180.09	0.000141	0.14	15.15	26.62
0	2.12	0.54	179.42	180.05	180.06	0.001025	0.36	5.91	11.04

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Tabel 1 Results of the Hydraulic Calculation for Eaf=3.18 m^3/s on the Stretch of the Spreča River from the Mouth of the Jala River to the Modrac Dam

Chainage	Q_{epp}	Depth of water in the waterbed	Elev. of the bottom of the water bed	Water level	Energy line elevation	Energy line drop	Water speed in the waterbed	Area of the flow profile	Width of the water face
	(m^3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m^2)	(m)
2330.2	3.18	0.33	182.78	183.27	183.28	0.002595	0.41	7.68	23.49
2304.79	3.18	0.40	182.57	183.25	183.25	0.000487	0.20	15.59	39.28
2211.46	3.18	0.58	182.23	183.21	183.21	0.00036	0.23	14.03	24.21
2102.38	3.18	0.23	182.77	183.10	183.11	0.005088	0.46	6.90	30.05
1846.22	3.18	0.49	181.83	182.45	182.46	0.001534	0.42	7.61	15.48
1744.64	3.18	0.32	181.82	182.28	182.29	0.001804	0.34	9.32	29.28
1644.14	3.18	0.27	181.56	182.02	182.03	0.004175	0.46	6.88	25.69
1548.3	3.18	0.38	180.99	181.66	181.67	0.003364	0.53	6.06	15.80
1447.02	3.18	0.40	180.88	181.47	181.47	0.001318	0.34	9.31	23.04
1344.38	3.18	0.45	180.70	181.29	181.30	0.002062	0.45	7.00	15.68
1194.69	3.18	0.52	180.38	181.12	181.12	0.000786	0.31	10.27	19.93
1093.83	3.18	0.50	180.46	181.04	181.05	0.000658	0.28	11.44	22.83
995.86	3.18	0.54	180.35	180.99	180.99	0.000482	0.25	12.76	23.71
893.39	3.18	0.42	180.22	180.90	180.91	0.001843	0.41	7.68	18.08
793.72	3.18	0.50	180.03	180.63	180.66	0.003675	0.65	4.91	9.79
696.19	3.18	0.56	179.85	180.53	180.54	0.0006	0.28	11.16	19.96
594.1	3.18	0.55	179.72	180.47	180.48	0.000597	0.28	11.33	20.72
494.99	3.18	0.50	179.69	180.38	180.39	0.001403	0.40	7.86	15.70
430	3.18	0.66	179.61	180.34	180.34	0.000432	0.27	11.94	18.19
298.69	3.18	0.59	179.60	180.29	180.29	0.000338	0.22	14.42	24.47
199.68	3.18	0.58	179.56	180.27	180.27	0.000202	0.17	18.85	32.46
98.79	3.18	0.70	179.45	180.25	180.25	0.000144	0.16	19.57	27.84
0	3.18	0.65	179.42	180.21	180.22	0.001038	0.41	7.75	11.89

Based on tables 4 and 5, it can be concluded that, for the value Q_{eaf}=2.12 m^3/s and Q_{eaf}=3.18 m^3/s, the depth of water in the bed of the river Spreča on almost all profiles is greater than the minimum required 20 cm. The speed of water in the river bed, at a flow Q_{eaf}=2.12 m^3/s, ranges from 0.18 m/s to 0.58 m/s, while the speed of water for a flow Q_{eaf}=3.18 m^3/s ranges from 0.20 m/s to 0.53 m /with. It should be emphasized that this is about the so-called mean cross section speed. Actual speeds at individual points along the cross-section may deviate from this average speed. In general, the flow velocity is higher at the top, and the lowest at the bottom and at the banks of the bed. These deviations are smaller if we are talking about shallower watercourses, and this is mostly the case when EAF flows through the bed, so then the mean velocity has a representative significance.

IV. CONCLUSION

Ecologically acceptable flow means the minimum flow that ensures the preservation of the natural balance and water-related ecosystems. It represents the dynamism of the quantity, quality and distribution of water in the river over time, which is necessary to ensure the survival and development of aquatic systems and the undisturbed life of people in the river settlements downstream from the facility.

Ecologically acceptable flow is determined with the aim of maintaining or restoring the structure and function of aquatic and water-related ecosystems, contributing to the reduction of water degradation and the achievement of environmental protection goals through sustainable water use.

For the existing facilities of the Modrac dam, an EAF was determined, in accordance with the applicable regulations and available literature, which was also a legal obligation for the user of the Modrac dam facility. The hydrological calculation for the profile of the Modrac dam determines the following ecologically acceptable flow values:

Q_{EAF1} = 2.12 m^3/s, for the dry period during the year

Q_{EAF2} = 3.18 m^3/s, for the wet period of the year

The stated values satisfy both the hydrological budget and the ecological conditions necessary for the maintenance of habitats and the preservation of aquatic and coastal ecosystems and are harmonized with the current legal legislation.

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