# WATER ABSTRACTION MANAGEMENT AND ENVIRONMENT

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**Abstract**

*Water abstracted from rivers or groundwater sources is widely used and its volume is determined by the demand of the different consumers and its supply – by the available water resources. The irregularly distributed in time and space water abstractions with respect to resources, their pressure on the environment and acquired water rights in terms of the dynamics of socio-economic and climatic conditions, and the requirements of the European regulations, bring the necessity for reformation of the water sector. At present the efforts of the European Commission and the member-states are aimed at elaborating strategies, national and regional river basin management plans (RBMPs). In the new RBMPs still missing assessment of the quantitative status of surface water bodies and ecological flow, especially in the sections below dams and complex water reservoirs, will provoke negative remarks of EC and may block some commitments. From management point of view, this affects the objectivity of the licensing regime in Bulgaria while estimating the new water applications and reevaluating the licenses in force. In this regard, the report presents a methodology for assessment and mapping of water resources availability, vulnerability (reliability) of water use at different climate or drought scenarios, and modeling of water rights by the SIMYL simulation programme. The applicability of the approach is proved by a number of experimental studies of NIMH. The balanced water allocation will guarantee the water abstraction sustainability and investments and contribute to ecosystems protection. This is a step forward to the realization of the Catchment abstraction management strategies (CAMS), drought management plans and Development of Hydro-melioration in Bulgaria. Including in the so-called "regulated rivers" and water bodies (WBs technical pressure, WBs lake – large reservoirs and WBs indefinite resource depending on the technological flow from a dam or derivation).*

**Key words:** *available water resources, river basin management plans, ecological flow, water abstraction permit, license regime, modeling of water rights, abstraction management strategy*

## 1. INTRODUCTION

The pressure of water abstraction on the environment and on river ecosystems in particular is determined primarily by the amount, location and time of realization, the regime of water use and volume of water returned after use. The amount of water taken from water sources depends on the dynamics of the demand for drinking needs, industry, irrigation and power generation. The water levels reduced by the anthropogenic and climatic pressure threaten the supply for water users and the good ecological status of water on the one hand, and contribute to the manifestation of a number of effects on river ecology as enhanced impact of river rapids, including fish migration, higher sedimentation rate and erosion on the other hand. The mismatch in time, location and regime between water use and resource, the pollution of water sources, the failure to provide the ecological flow and the drought (water stress or deficit) foster the competition for sufficient water with good quality and are a threat to the environment.

Outlining the frame of water policy with the Water Framework Directive 2000/60, the European Commission focuses on the environmental "health" of aquatic environment (WFD, 2000) and requires that the member states establish integrated management on the basin principle. An essential element of this management is the sustainability of water abstraction for different purposes, based on the balance between water demand and supply for the first two priority water users (household and ecology needs), taking under consideration climate changes.

The national strategies and plans for water resource management stand on the first place. Since 2012 Bulgaria has a Strategy for management and development of the water sector, which outlines the common institutional framework and the financial policy. At the end of 2015, following an agreement with the Bulgarian Government, the World Bank introduced a Draft Common Strategy for Management and Development of Hydro-melioration and Protection against Harmful Effects of Water, proposing institutional, legal and tariff changes in hydromelioration sector, as well as an approach to adapt the EU requirements under the 2014÷2020 Rural Development Program (RDP).

The national sector strategies are followed by the river basin management plans (RBMPs) and their first updating is at the stage of public discussion, supported by approaches and strategies as Catchment abstraction management strategies (CAMS) for the license strategy of England and Wales (Environment agency, 2010). Progress is observed compared to the first RBMP in determining the driving forces (natural and anthropogenic), pressure (by category and type) and impact on surface and ground water with assessment of sources, but in evaluating the condition of water the assessment of the quantitative status of surface water bodies and ecological flow is still missing (Guidance Document No 31, Ecological flows, and No 34, Water balances in the implementation of the WFD, 2015). The achievement of good ecological status/potential in the so called regulated sections also requires provisioning of ecological flow in the rational allocation of dam water. All this, except the negative comments and difficulties in implementing the requirements of the European Commission (such as article 46 of Regulation 1305/2013 of the European Parliament on supporting rural regional development by the European Agricultural Fund for Rural Development), is a threat for the integrated management of the available water resources in submitting the water withdrawal permits and modernization of the water development systems.

## 2. METHODOLOGICAL FRAMEWORK FOR SUSTAINABLE WATER ABSTRACTIONS AND LICENSING REGIME

The sustainability of water abstractions in the context of integrated water management presumes an effective licensing regime, ensuring well substantiated and balanced allocation of the available water resources among the users, which protects the ecosystems and takes into account the more frequent extreme phenomena.

### 2.1. Water availability assessment and abstraction management under climate change and drought conditions

The demand for water is continually increasing in many regions of the world owing to the growing population,which is leading to increased pressure on global water resources as a result of consumption, land use changes, urbanization and climatic changes. Until now, most Europeans have been insulated from the social, economic and environmental impacts of severe water shortages. But as demand increases and the global climate changes, is Europe becoming more susceptible? The balance between water abstraction and availability has reached a critical level in many areas of Europe, the result of over-abstraction and prolonged periods of low rainfall or drought.

Addressing the issue of water scarcity requires not only a quantitative knowledge of water abstraction by each economic sector but also a strong understanding of the driving forces behind it. Critically, it is only by changing these driving forces that more sustainable management of water can be achieved. Europe needs a sustainable, “demand-led” approach to water resource management, focusing on conserving water and using it more efficiently. Integral to this is a more equitable approach to water abstraction that addresses not only the requirements of competing economic sectors but also the need for healthy freshwater ecosystems. (European Environment Agency, Report № 2, 2009).

***Water availability assessment and abstraction management***

To manage water effectively it is need to understand how much is available and where it is available, after considering the needs of the environment. A classical approach for assessment of the available water resources for the different purposes, including environmental in Europe is the Catchment Abstraction Management Strategy (CAMS) of England and Wales, developed for the first time in

2001÷2008 and updated annually (Environment agency, 2010). CAMS includes three main stages (Fig.1): *Stage 1* – Mapping of the available resources under certain statistics of flow and minimum flow in an annual section, based on the water balance calculation; *Stage 2* – Defining the license regime on catchment principle with assessment of the water available for new users, after providing for the existing users and the environmental needs and *Stage 3* – Assessing the pressure of water abstraction on the resource, the water source and the environment and of the measures by Restoring Sustainable Abstraction (RSA), comparing the existing situation with the predicted one after water abstraction. Comparing the available water resource with demand and ensured water supply reliability CAMS are determined on how much water is available for future licensing, drought permits and for the environment (Ilcheva et al, 2015; Nigolov I. et al, 2011÷2015).

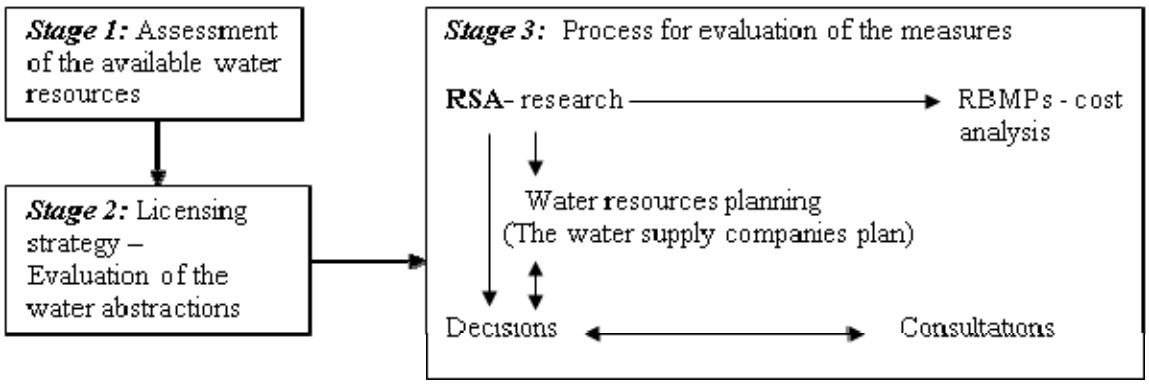



**Fig.1.** Stages of the Catchment Abstraction Management Strategy (Environment agency, 2010)

***Climate change, drought planning and environmental protection***

In international projects of the National Institute of Meteorology and Hydrology, a methodology for assessment and mapping of water resources availability and vulnerability (reliability) at different climate scenarios and future water demand is developed (CC_WaterS, 2012; CC-WARE, 2014; Mitigation vulnerability..., 2014). Based on the experience of England, a new framework for joint assessment of water stress areas, drought-risk of water supply management and ecological flow provision is elaborated at river basin level (Ilcheva I., D.Georgieva, A.Yordanova, 2015; Danube WATER, 2015). This is a step forward to the realization of the CAMS and drought management plans in Bulgaria - Fig.2. The methodological framework and tools are applied according to the purpose and planning framework – long-time or short-time risk assessment and management:

1. *First stage* - Modelling and estimation of climate factors, scenarios and indicators.
2. *Second stage* - Water balance modelling or Monte-Carlo modelling. Estimation of water resources trends at different climate and drought scenarios.
3. *Third stage* - Development of the calculation scheme of the water resource management system of the river basin and assessment of water utilization in the river basin.
4. *Fourth stage* - Estimation of present and future water consumption, water transfers and abstractions (incl. water permits) and ecological flow.
5. *Fifth stage* - Simulation modeling (by SIMYL model). Estimation and mapping of water resources availability, vulnerability (reliability) and adaptive capacity at different climate and/or drought scenarios, water demand and use schemes. Water scarcity and drought planning and management. A "concept of compensation", "regulated rivers" and ecological flow provision.
6. *Sixth stage* - Mitigation and adaptation Measures. Environmental and socio-economic aspects assessment. Adaptive management.

Research of the vulnerability and reliability is based to assessment of a system of indices. The results from the experiments show, that in case of the existence dams – the water exploitation index (WEI) gives higher values of water vulnerability, as the operation of the dams was not took into account (CC-WARE, 2012; Ilcheva I., D.Georgieva, A.Yordanova, 2015). In case of the areas supplied with water from surface fluent sources – the WEI index is lower and values for water quantity vulnerability are not able to identify the water shortage. For this reason, as it can be seen below, we propose to add to WEI, WEIeco, WEI+ an additional system of indices estimating the water supply system performance such as Water shortage index WSHI, reliability indices et al. The system is based on water allocation among the users in the river basin and water resource balance which give the degree of satisfaction of each one water user.

The changes of reservoir level are also an operational indicator (OI), of water resource availability (Ilcheva I., D.Georgieva, A.Yordanova, 2015). The definition of triggers and operational indicators for multireservoir water resource management systems is an issue that is accomplished by means of simulation-optimization techniques or simple Operational Rules (Niagolov, I., et al., 2011-2015).

Sometimes the information for CAMS is presented as "flow statistics". In the CC-WARE Project, maps of water exploitation are based on long-term annual average. But in RBMP or in other studies the method for estimating the "available water resources" may include critical low flow period or ecological water demand as well as a drought "design scenario" (Ilcheva I., D.Georgieva, A.Yordanova, 2015). For the surplus estimation, abstraction license, water exploitation and drought scenarios in Bulgaria, some flow statistics are applied: Q95 (low flow), Q75 (medium/low flow), Q50 (medium flow) (Water use and water resource balance…, 2006; CC_WaterS, 2012).




**Fig.2.** Drought planning, environmental protection and Catchment abstraction management strategy

According to the new aspects for e-flow and CAMS, Q30 statistics (high flow) or $Q_5$ can be applied. CAMS contribute to the WFD by (Managing water abstractions, 2013, EA, UK):

- Identifying water bodies that fail the flow conditions expected to support good ecological status;
- Preventing deterioration of water body status due to new abstractions;
- Providing results, which inform River Basin Management Plans (RBMPs).

Moor about concept of "compensation" and so-called "regulated rivers" is given below.

**2.2. Ecological flow assessment and sustainable abstraction**

The protection of ecosystems represents a focus in European water policy for achieving sustainability of water abstractions in the allocation of the available water resources, as part of their effective management.

***E-flow concept and sustainable abstraction***

Minimum flow is associated with the acceptable disturbance of runoff regime. The high priority of $Q_{min\ eco}$ is a necessary condition for achieving "good ecological status". Therefore the WFD requires that a minimum permissible streamflow into the rivers or ecological flow should be determined in RBPMs for the purpose of protection of aquatic ecosystems and wetlands, which in Bulgaria is only transposed in Art.117 of the Water Act (WA). The river runoff represents one of the elements of the hydromorphological conditions (Guidance No. 31, 2015; Acreman et al, 2010; Ilcheva I., et al., 2015).

There are various methods for determination of the minimum ecological flow. Most of them are based on the main hypothesis, which states that the fluctuations of the river runoff are the most important abiotic factor, determining the quality of living environment, a decisive factor for development of a biocoenosis. Benthic macroinvertebrates are used for characterization of the fluvial biocoenosis because: they are part of the food chain in the river and any change in their status will affect the development of all ecosystem structures and processes; they are sensitive to flow variation, water quality and environmental living conditions; they live longer and effects of long-term processes can be evaluated (Zaharieva V. et al. 2013). The total number is selected as a key indicator, characterizing the state of macroinvertebrates community (Zaharieva V., 2006). This selection coincides with the guidelines of Annex V of the WFD.

CAMS put the emphasis on the so-called "Environmental flow indictors" (EFI) and Lotic Invertebrate Flow Index (LIFI) are used to assess whether river flows are sufficient to support healthy ecology.

At this stage in Bulgaria, until the issuance of the methodology for determining the ecological flow, the provision of Art. § 125 is applied – the minimum permissible streamflow in rivers shall be set at 10 % of the mean multiannual runoff, but not less than the minimum monthly water quantity with a 95 % exceedance probability at the point of each facility for regulation of the streamflow or for water withdrawal (WA, 2000). In this connection in 2011 the Department of Water Management of NIMH developed a web-based daily updated map of the areas at risk in terms of ecological flow.

***Reservoir management, regulated rivers and concept of dotation for "good ecological potential"***

Environmental flow (good ecological status) can be impacted by abstractions, flow regulation, morphological alterations, etc., and its provision after water abstraction facilities and reservoirs is a necessary measure to mitigate impact (Acreman et al, 2010). Fig.3 shows analytical framework for assessment of hydrological pressures, impacts and measures, in which necessarily need to take into account the ecological flow.

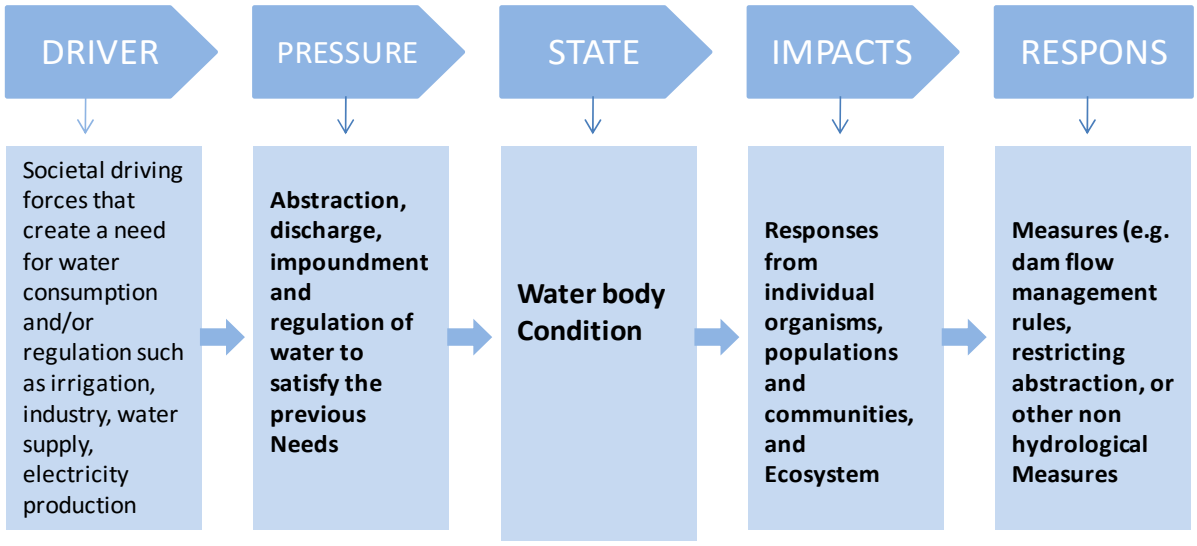



**Fig.3.** DPSIR framework of hydrological pressures and impacts (Guidance No.31, 2015)

In this context low flow management is related to water supply and ecological runoff estimation and provision (Ilcheva I., 2008). The so-called HMWB and "regulated rivers" have modified flow, which is influenced by reservoir compensation releases, or they have flows that are augmented. The availability of water is dependent on these operating agreements. The "concept of compensation", EFI and LIFI represents possibility for guaranteeing the ecological runoff and e-flow (Ilcheva I., D.Georgieva, A.Yordanova, 2015). The simulation modeling is a base for development of a conceptual model and gives an idea of the whole watershed (Ilcheva I., I. Niagolov, T. Trenkova, 2008). The calculated disturbance of the discharge by the simulation model in different points of the watershed gives an assessment of the water abstraction from surface and groundwater, runoff regulations, water transfer, water derivations, climate changes, etc.

It is good that in RBMP 2015÷2021 the so-called regulated areas have been already introduced. Three groups of water bodies in the following categories have been distinguished in the East Aegean Region BD when assessing the impact of water abstractions on the resource: *WBs technical pressure (with an added influx from water transfer or discharge), *WBs lake – large reservoirs, and *WBs indefinite resource depending on the technological flow from a dam or derivation, which actually represent such areas. In the Black Sea Region BD 74 % of the water bodies are identified with backwatered areas. However, as seen in the map in Fig.4, the basin directorates (BD) still do not take into account the context of Guidance No 31 for the regulated water bodies and rivers.

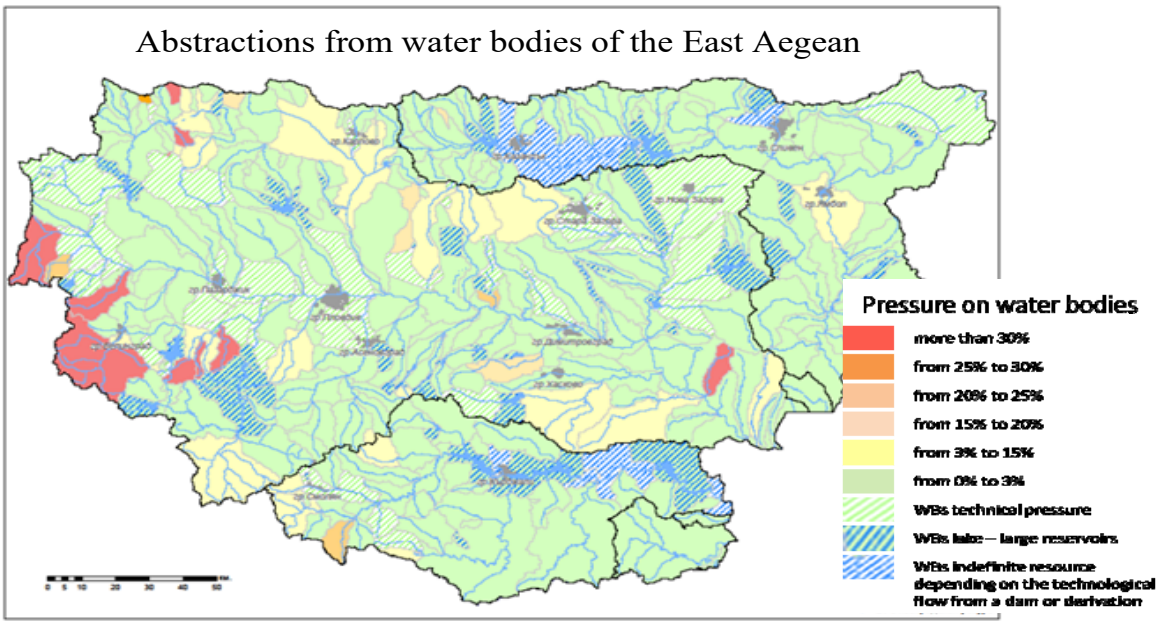



**Fig.4.** Map of water abstraction pressure on the resource for the water bodies in the East Aegean Region (RBMP of EABD, 2016÷2020)

At present 50 % of the complex and important dams from Appendix No 1 discharge such water for environmental purposes and minimum admissible flow for recharging wells for drinking water. All areas under these dams are regulated. These water reservoirs can ensure GEP, the necessary hydromorphological conditions and water use in the region. This will facilitate the World Bank investments. The Tundzha River after the Zhrebchevo dam can be given as an example of regulated area. Regulated water for environmental purposes, recharge of wells and irrigation is discharged from the dam into the river (Niagolov, I., et al., Agreement with MOEW, NIMH, 2011- 2015).

### 2.3. Permit regime and ensuring water use

The water legislation in force in Bulgaria, transposing the European legal requirements, includes well established permit procedure for acquiring water use rights. The competent authorities are clearly distinguished: the Minister of Environment and Water for water withdrawal from the dams covered under Annex 1 hereto and transfer of water between different basin management districts; the municipality mayor after a resolution of the Municipal Council for withdrawal of water, including from dams (municipal property) and the competent Basin Directorate Director in all other cases of water withdrawal. The required documents from the applicant, assessment procedures, commitments of the water user and terms and deadlines of licenses are described in sufficient detail. However, the second RBMP also do not provide the necessary assessments for the quantitative status of the surface water bodies pointed out in them. The lack of an assessment instrument makes the decisions of the competent authorities subjective and not entirely substantiated and hence the existing and new water abstractions – unsustainable.

This is not the case with the practices in the other European countries, where the experience of England and Wales with CAMS is the leading one, and as seen in paragraph 2.1 the license strategy is the major goal (*Stage 2)* to ensure balanced allocation of water resources between the users, including ecosystems.

To remove the subjectivism in Bulgaria, after studying the foreign experience, in 2012 Kr. Kolcheva proposed in her thesis a well founded water licensing regime, based on the water resources allocation simulation under water rights system through coordination of the proposed water rights requirements with the available water resources as well as the determination and running updating of unappropriated stream in the river basin for future water rights applicants.

The water management simulation is based on the Water Act priorities and criterion – exceedance probability of water right applications. The following problem is solved: for a given basin/sub-basin or river segment (water body) with available water resources and according to preliminarily set priorities for water use, an assessment is made how (under what conditions) and in what amount (annual limit or water share) the requested target water abstraction may be authorized so that the ecosystems and the existing water rights are protected. A similar problem was solved by (Wurbs, R. and W.B.Walls, 1989; Wurbs, R., 1996) but for different setting and legal regulations and with another mathematical model.

The solution follows a three-stage methodological approach:

- *Allocation of available water resources* – Based on simulating the allocation of the available resources in a given basin/catchment (considering the river basin as an integrated system where all water users are interconnected) between the existing water users, an investigation is made on their provision without and after the addition of a new water request. With the results obtained the estimate of the decision makers (DM) is formulated whether to admit or not the new participant to the system, taking under consideration the environmental needs;
- *Analysis and evaluation of the submitted requests for obtaining water use right* based on the results from the first stage – In case of disagreement of some applicant with the obtained solution the DM in dialogue may correct the applied water requirement with new water allocation. The results from the new water allocation will show if the decision made is a basis for the provision of water use right, and if it is not, follows a refusal or further discussion. In such a way every next change for which there is a ground and agreement is associated with a new simulation and evaluation;
- *Determination of the unused water undertaking the new water requests* – Simulations of different variants for the water use and water resources availability is meant to give a general assessment of the free volumes at a basin/sub-basin/water body level and the estimate "For" or "Against" a particular request, taking into account the interconnectivity between the users in a particular watershed requires the implementation of the first stage.

The main part of the assessment for authorizing the new water abstraction represents an evaluation of the probability of occurrence by years, months and water volumes for the respective users, and the water shortage based on the results obtained from the simulation with the SIMYL simulation program (developed in the Institute of Water Problems, now NIMH-BAS, and supplemented and adapted for the mentioned task). The approach has been repeatedly verified for water allocation in individual catchments (tributaries) or for the entire basin of the Tundja River to authorize new water requests and ensure the irrigation in pilot irrigation systems for the purposes of the Draft Common Strategy for Management and Development of Hydro-melioration and Protection against Harmful Effects of Water. A special attention is given to the administrative-legal aspect of water rights (Kolcheva K., 2012).

## 3. APPLICATION IN PRACTICE – EXPERIMENTAL STUDIES

### 3.1. Application in practice for River basin management, Basin Directorates and MOEW

The methodology, system of indices, simulation models (SYMIL) and operational rules have been used in the Basin Directorates as well as applied operatively in the Ministry of Environment and Water (Methodology for Reservoirs Water Allocation, 2004; Methodology for water resources balances of river basins, Contract with Ministry of Environment and Water (MOEW), 2004; Niagolov, I., et al., Operative water resource balances, NIMH, Agreement with MOEW, 2011÷2015).

According to the Water Act, 2015, Art. § 14, (2), until the RBMPs are composed (according to (1)) general schemes for water use are developed and on their base the water abstraction permits are issued. The SYMIL program and reliability indices are the basis of the research work "General schemes of water utilization in the regions of basin management", which was developed according to the Water

Act. The elaborated schemes and water resource balances of all river basins in Bulgaria became the ground for the first River Basin Management Plans elaboration and the first permits.

Under contract with MOEW the project "Water use and water resource balance of the Ogosta, Tundga, Struma, Kamchia" was developed (2006). The results are taken into account by the Basin Directorates.

During the last years, under an Agreement between NIMH and MOEW , "Operative water resource balances" (Niagolov, I. et al. 2011÷2015), a series of models were applied and calibrated for the complex and important reservoirs (Appendix 1 of the Water Act). The issued permits and ecological flow were taken into account. As of the present moment similar modules have been developed, for more than 14 reservoirs, from the four Basin Directorates ("Iskar", "Ticha", "Kamchia", "Diakovo", "Jrebchevo", "Arda cascade", etc.). For the needs of the Ministry in 2015 the schemes of all the 52 important reservoirs - Appendix 1 (Water Act) and the influx to 43 of them were updated.

This is a step forward to the realization of CAMS and River basin management plans in Bulgaria, including in the so-called "regulated rivers" and WB (*WBs technical pressure, *WBs lake – large reservoirs and *WBs indefinite resource depending on the technological flow from a dam or derivation).

### 3.2. Application for vulnerability assessment, including under climate change

A methodology for assessment of water resources vulnerability under different climate scenarios and different future water consumption at the level of river basin and watershed was validated and proposed (Mitigation vulnerability…, 2014; CC-WARE, 2014). The joint use of WEI and WSHI together with a system of indices makes it possible to obtain the full vulnerability characteristics of water resources – the degree of risk for water supply.

***Assessment and mapping of water resources vulnerability in the Ticha reservoir watershed***

The Ticha reservoir is designed on the Golyama Kamchiya River near the village of Ticha and its water resources are used for multiple purposes such as irrigation, domestic and industrial water supply, hydropower output and ecological discharge provision downstream of the dam. Part of the results for the 2021-2015 scenario, evaluated by the WEI and WSHI indices (exceedance probability), Index of reliability) are shown in Fig.5 and Table 1.

**Table 1.** Calculation of WSHI for the scenario 1961-1990 and scenario 2021-2050

| Name | Exceedance probability(%) | | | Index of reliability | Exceedance probability(%) | | | Index of reliability |
|---|---|---|---|---|---|---|---|---|
| | By volume | By years | By months | | By volume | By years | By months | |
| | scenario 1961-1990 | | | | scenario 2021-2050 | | | |
| WS Shumen - Preslav | 100 | 100 | 100 | 0,000 | 98,45 | 93,33 | 98,06 | 0,361 |
| WSTurgovishte | 100 | 100 | 100 | 0,000 | 97,89 | 93,33 | 97,78 | 0,669 |
| IR Vinitsa | 87,46 | 86,67 | 90,80 | 6,12 | 50,33 | 43,33 | 60,12 | 30,059 |
| IR Krasnoseltsi | 86,59 | 80,00 | 90,16 | 5,417 | 58,31 | 40,00 | 65,28 | 23,74 |
| IR Cherkovna | 98,65 | 96,97 | 98,45 | 0,123 | 88,57 | 86,67 | 91,19 | 5,030 |
| IR Guerlovo | 97,41 | 96,67 | 98,45 | 0,443 | 89,70 | 86,67 | 92,23 | 5,050 |
| HPP Ticha | 95,86 | 83,33 | 93,06 | 1,246 | 78,64 | 36,67 | 65,56 | 9,727 |
| Ecological flow | 100 | 100 | 100 | 0,000 | 100 | 100 | 100 | 0.000 |

The applied methodology upgrades the methodologies given before. As seen in the cases with the water reservoirs the indices (Index of reliability) yield much more precise and realistic results for the probability of the ecological flow, water use and issued permits than the indices for pressure assessment like WEI and WEI+.

Even for the 2020-2050 scenario, with significant flow reduction and maximum water use (according to permits), all probabilities are close to the normative value. The exception both now - CC-WARE and before - "Water use and water resource balance of the Kamchia River" (2006) is irrigation, moreover for the variant with 100 % irrigation of the suitable lands.

The water balances elaborated by the Black Sea Region BD for a year with 50 %, one dry year and two consecutive dry years are an indication for the available resources for the already issued and future permits but the results show also higher shortage of resources. This may lead to the prescription for reduced water use without being necessary.

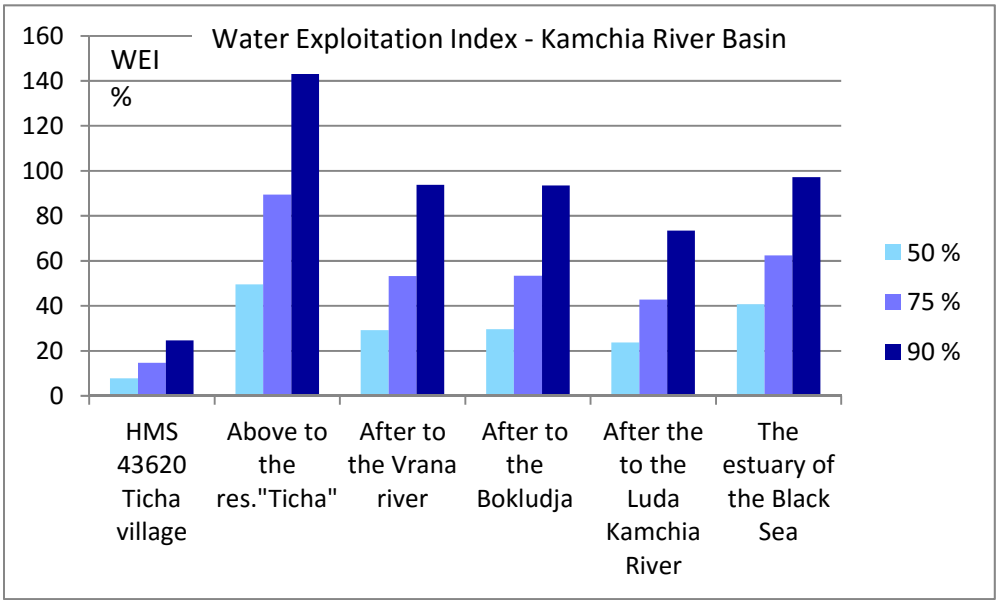



**Fig.5.** Water Exploitation Index, different flow statistics (Water use …, 2006)

Therefore, it is good to use also the results obtained in NIMH (as shown in Fig.6 and Table 1). One possibility for improving the reliability of water supply is to implement better management of the water supply reservoirs (Niagolov,I., et al., 2014). To this end NIMH has launched the development in stages of a Decision Support System with the respective modules (incl. for reservoir "Ticha").

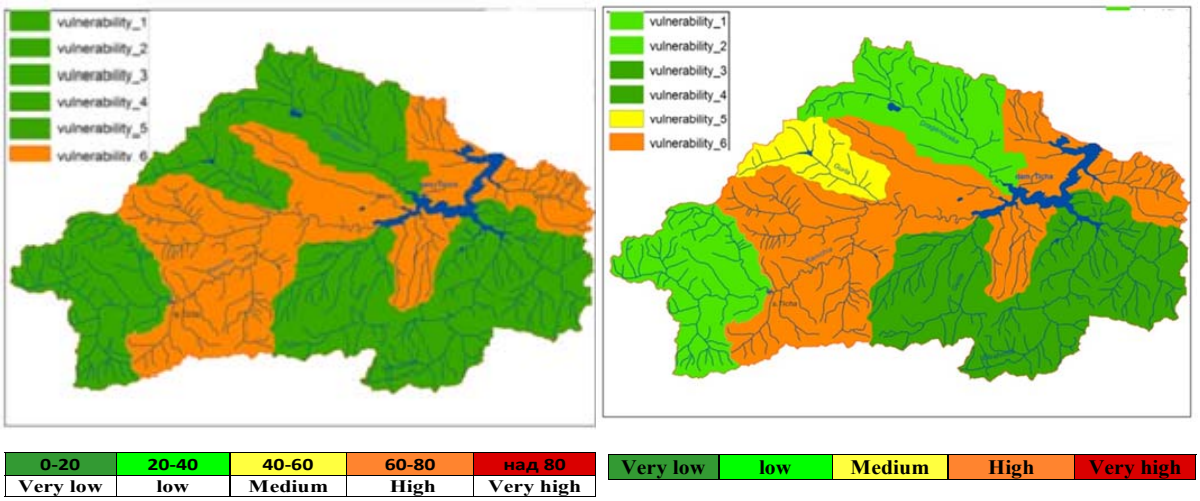



**Fig.6.**Vulnerability of the Ticha dam watershed according to WEI and WSHI, scenario 2021-2050, (Mitigation vulnerability…, CC-WARE, 2014)

### 3.3. Hydrological drought-risk management and ecological flow provision for CAMS

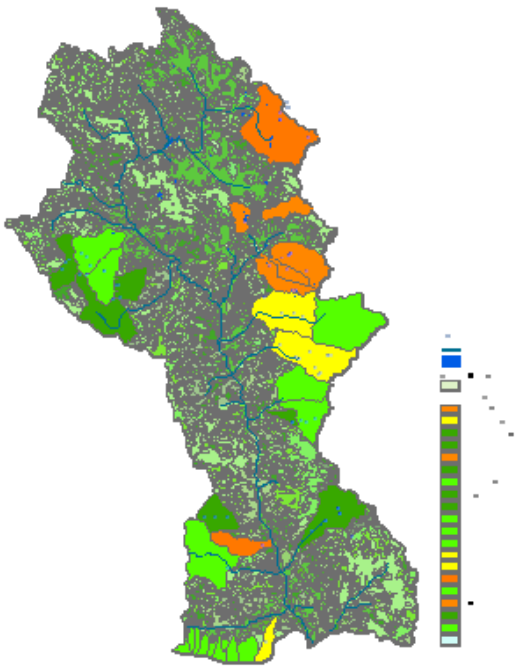
The accent in the Struma River basin is on the joint assessment of the so-called HMWB and regulated rivers on the example of the classical CAMS. But in contrast to the classical case different climate change and/or drought scenarios are considered here, not only "drought design" and "flow statistics" (Ilcheva I., D.Georgieva, A.Yordanova, 2015; Ilcheva, I., et al., 2015a; CC-WARE, 2015). The advantages of the proposed methodology are illustrated of Fig.7 by maps of the vulnerability dependence on WEI, WEIeco, maps, accounting the water supply system functioning and regulation role of the dams (WSHI and reliability indices). In addition, the methodology for estimating and mapping is based to the DPSIR indicators framework. Vulnerability, sensitivity and adaptive capacity are assessed.

***Concept of addition for ecological flow provision. Sustainable abstractions.***

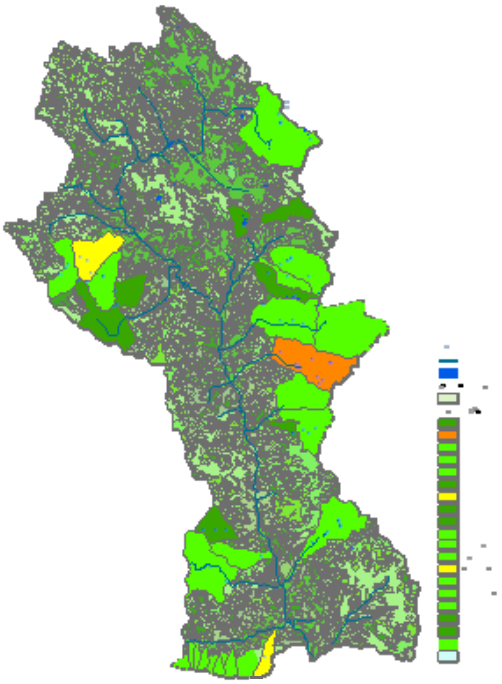
As it was mentioned the "concept of addition" represents possibility for low flow management and ecological runoff provision according to the e-flow concept (Ilcheva I., D.Georgieva, A.Yordanova, 2015; Guidance Document No 31, Ecological flows …, 2015; Project WFD82, 2008).

Experimental investigation is carried out for the Struma River basin (Fig.8) and the problems of its practical implementation are analyzed – environmental flow releases, management and ecological aspects, conflicts of interests, etc. (Ilcheva,I.,2008).

Problems in ensuring the ecological runoff exist within the framework of the entire river basin in the cases, when there are no significant water reservoirs and when there is a big difference between the runoff characteristics at the regulation point and at the point, where addition should be realized. There are no problems in ensuring the ecological runoff near the dams and in the runoff regulation along the tributaries. From the rest of the possibilities for ensuring the minimal quantities, it is rational to apply administrative management of water use, by means of the restrictions in the permits regime.



Availability according to the WEI eco, scenario 2020-2050



Index of reliability and water management system simulation, scenario 2020-2050

**CAMS water resource availability colour according to the new methodology for risk management and mapping**

| |
|---|
| High hydrological status |
| Water available for licensing |
| Restricted water available for licensing |
| Water not available for licensing |

HMWBs Heavily Modified Water Body and regulated rivers These water bodies have a modified flow that is influenced by reservoir compensation releases or they have flows that are augmented.
The availability of water is dependent on Reservoir and Water Resource System Management. Concept of compensation for ecological flow provision. Demand-side and supply – side measures

| Very low | low | Medium | High | Very high |
|---|---|---|---|---|

**Fig.7.** CAMS water resource availability colour according to the new methodology for risk assessment

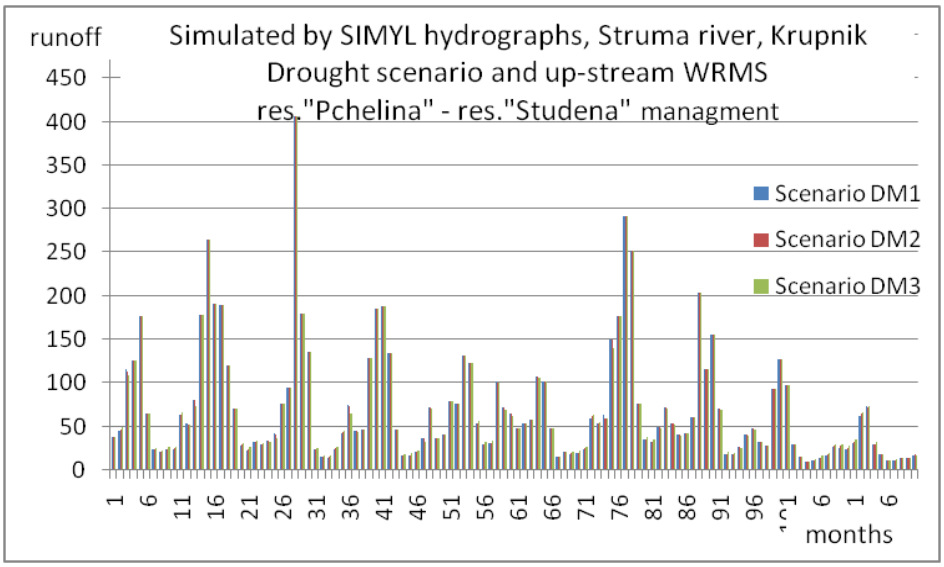



**Fig.8.** Environmental flow realise, concept of "compensation" and ecological runoff provision.

Drought scenario and management of the water resources systems "Pchelina" - "Studena"

A methodology for ecological flow determination is applied for the aims of the Vitosha Natural park management. Water resources balance for Vitosha NP, including analysis under condition of climate change and extreme phenomena has been developed (Ilcheva, I., et al., 2015a).

The results of this work and CC-WARE project are directly related to the Programme of Measures of the West Aegean and Danube Region Basin Directorates.

***Programme of measures***

According to the results of the analysis, the appropriate long-term or short-term policy measures were elaborated. The strategic plans should be included in the RBMP (Georgieva, D., I.Ilcheva, 2014).

### 3.4. Application in practice of the approach to effective permits regime

*3.4.1. Determination of the free volumes for new water abstractions on the Tundzha River*

Implementing at the third stage the methodological approach proposed by Kolcheva in 2012 for the Tundzha River, the free water volumes for issuing new water abstraction permits were determined. By means of several consecutive simulations in significant sections of the main river (with a larger number of water abstractions till 2008) the available water volumes for future users were elucidated. The obtained results, shown in Fig.9 along the downstream direction of the Tundzha River from the springs to the border, reveal the available (unused) resource and its growth after the dams and at the border.




**Fig.9.** Available water volumes for the river segments of the Tundzha River (Source: Methodological research to develop a licensing regime for water use, Kolcheva, 2012)

Such an assessment is useful for both the competent authorities in more efficient water management and for identifying the water bodies with water deficit or the so-called water stress, which will improve the efficiency of the permission procedure and the accuracy of the RBMP.

*3.4.2. Water resource system balance of the Stara Zagora Irrigation System*

***An example developed for the Draft Common Strategy for Management and Development of Hydro-melioration and Protection against Harmful Effects of Water***

Through the years the Stara Zagora Irrigation System has been the subject of a number of investigations and developed projects: General schemes 2000 and Water use and water resource balance of the Tundzha River and Methodology 2004÷2006 of IWP (contracted by MOEW), Project: Study on integrated water management in the Republic of Bulgaria" JICA (2006÷2008), Methodological research to develop licensing regime for water use (Kolcheva, 2012), Developed dispatcher graphics – model of the Koprinka dam NIMH, Operational water balance assessments (Agreement with MOEW - Niagolov, I. et al. 2012÷2015; Shopova, D., 2015; Shopova.,D.et al. , Agreement with MOEW, 2015) and River Basin Management Plan (RBMP) of the East Aegean Region 2010÷2015. A pilot study for ensuring the irrigation in the system was carried out in 2015 especially for the purposes of the Draft Common Strategy for Management and Development of Hydro-melioration and Protection against Harmful Effects of Water. The data used and the GIS information were based mainly on the mentioned developments.

*Brief description of the "Stara Zagora" Irrigation System*

A major water source of the Stara Zagora Irrigation System is the Koprinka reservoir ($V_{total}$=142,4*$10^6$$m^3$, F=12,483 $km^2$ and H dam wall = 44 m), built on the Tundzha River at the village of Koprinka in 1955. According to Annex No 1 of the Bulgarian Water Act the Koprinka reservoir pertains to the class of significant reservoirs with multipurpose water use. In the first RBMP this reservoir was defined as Heavily modified with bad ecological and good chemical potential.

*Basic scheme*

The "Stara Zagora" Irrigation System (Fig.10.) has a total equipped area of 33,768 ha and in 2007 was divided in two separated units, representing two independent subsystems:

- The Kazanlak Irrigation Field is situated in the Kazanlak valley on both sides of the Tundzha River and has two main canals – $M_L$ (left canal, north from the river) and $M_R$ (right canal, south from the river) from the Koprinka reservoir. The equipped area is 6,974 ha, according to data from 2007.
- The Stara Zagora Irrigation Field is situated south and east from the city of Stara Zagora and has an equipped area of 26,794 ha, of which 22,681 ha are supplied by the Koprinka reservoir through a canal originating just downstream of the dam and delivering water to the Stara Zagora Hydro-electric Power Plant (HEPP) (in the Southwestern part of the Stara Zagora city), and 4,113 ha (located east of the city) – Bedechka River through the R-17 irrigation canal. The M-1 canal (30.384 km) delivers water to 17,008 ha equipped area to the west and to the south of the city and M-2 (24.081 km) supplies with water twelve industrial enterprises, as well as irrigation area of 5,598 ha, which is located mainly to the east of the city. There are 12 secondary canals fed by the M-1 canal. The most important and most frequently used canals are R-3, R-10, R-11 and R-12, which deliver water to 2,205 ha of rice fields.

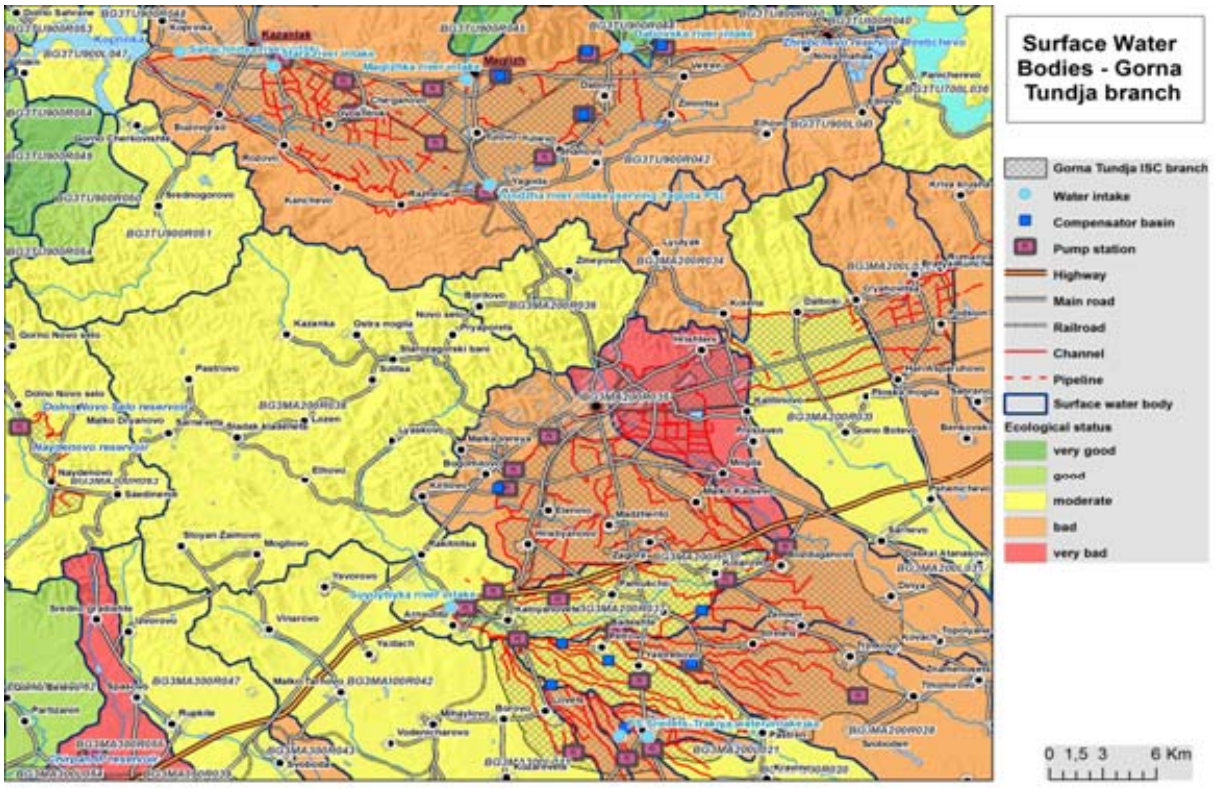



**Fig.10.** Stara Zagora Irrigation System and ecological status of the surface water bodies (Source**:** Project JICA, Irrigation System Company (ISC), RBMP of the East Aegean Region 2010)

*Water use from the Koprinka reservoir*

The water of the Koprinka reservoir is used primarily for irrigation. On the average for the period 2003÷2013 from the totally abstracted water volume of 106,558.$10^6$ $m^3$, 39,758.$10^6$ $m^3$ were used for irrigation and 0,554.$10^6$ $m^3$ for other purposes, with losses amounting to 62 %.

*Irrigation*

The changes in the total irrigated areas and these with rice for the period 2003÷2013 in the Stara Zagora IF (Koprinka Section) are shown in Fig. 11., according to which:

- for the total irrigated areas a decrease is observed during the first three years with a minimum in 2005, followed by an increase with a maximum in 2008 and smaller fluctuations, reaching in 2013 the level of almost $25.10^3$ da;
- the irrigated rice areas in the first five years of the period exceed $15.10^3$ da with a maximum in 2011, while the minimum is in the next year 2012.

Fig.12. shows that the priority crop in the Stara Zagora IF is rice, and it is the biggest water consumer with 96% share of the total water consumption.

The permitted limit, indicated in Table 2, is consistent with the monthly schedule for use of the water of the complex and important dams, approved by the Minister of Environment and Water. In the period 2007÷2013 in only two years the permitted limit was exceeded.

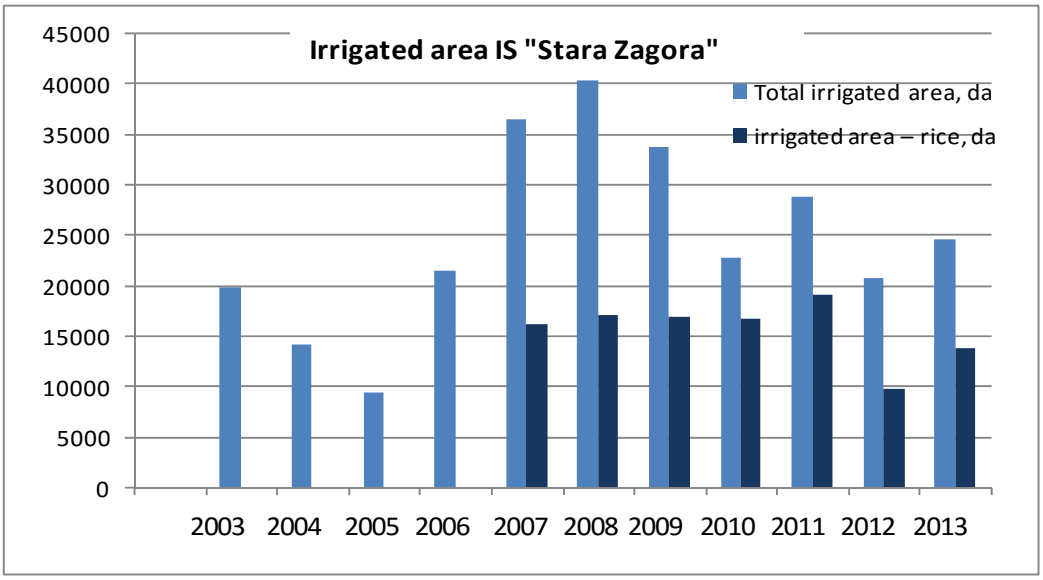



**Fig. 11.** Total irrigated areas with rice by years in "Stara Zagora" IF - Koprinka Section (Source: ISC)

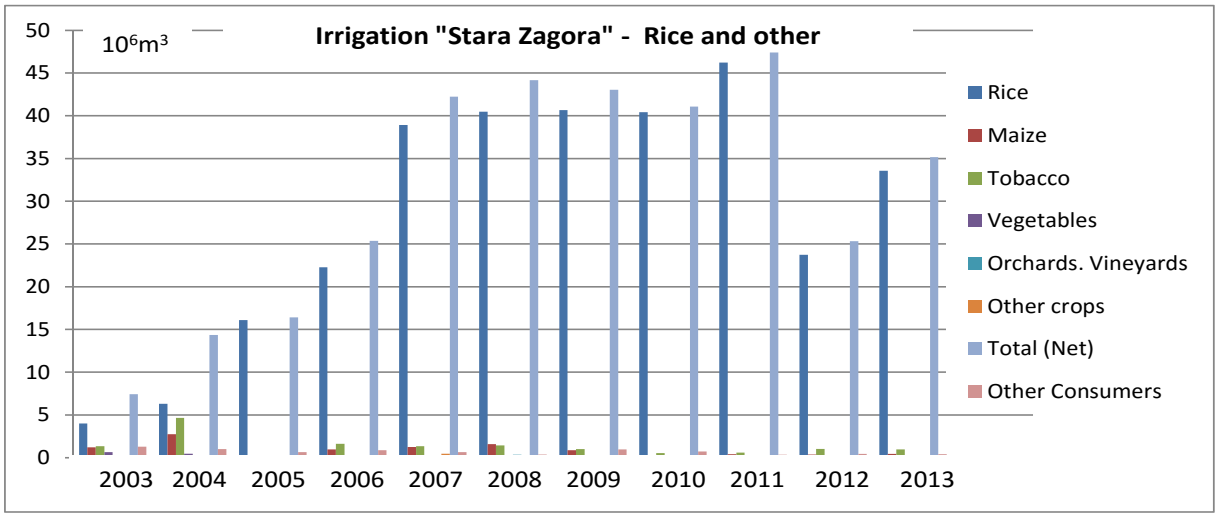



**Fig.12.** Irrigation by crops and years in "Stara Zagora" IF - Koprinka Section (Source: ISC)

**Table 2.** Water abstraction permit for the dam Koprinka (Source: RBMP of the East Aegean Region, 2010)

| | |
|---|---|
| **Permit No** | 0752 |
| **Start date/ Time limit** | 14.10.2005/14.10.2021 |
| **Titular** | „Irrigation systems“ Company |
| **Purpose of water use** | irrigation |
| **Water source** | Dam Koprinka |
| **Location** | v.Koprinka, Municipality Kazanlak, Stara Zagora District |
| **Location of water abstraction** | water intake tower |
| **Permitted limit $10^6$ $m^3$** | up to 110 |
| **Regime of water use** | April÷ October |
| **Location of water use** | Total - 355 567 da irrigated ares: 286 528 – Stra Zagora IF; 69 039 – Kazanlak IF |
| **Metering** | Total - 355 567 da irrigated ares: 286 528 – Stra Zagora IF; 69 039 – Kazanlak IF |
| **Conditions of water use** | daily monitoring and reporting of the used water volumes and annual report at the RBD-EAR |
| **Controller** | MOEW and RBD-EAR |

*Assessment of the provision of irrigation and other water users from the Koprinka dam for different variants*

The survey includes all water consumers by priorities, ranked in the following order - ecological flow, industry, rice and other crops. Here a high priority of rice is given compared with the other crops so that the analysis of irrigation development of the remaining fields should not influence the obtained rice reliability. Hydrological series are used (1961÷2004), extended to 2010. To investigate the probability of irrigation from the Koprinka water resource system the developed by Prof. Niagolov SIMYL program is used, which has been tested in the above mentioned works of NIMH. Simulations are made for the following variants:

- Variant 1 – existing state of rice irrigation and corresponding losses – $100.10^6$ $m^3$;
- Variant 2 – assessment of irrigation probability in case of increasing the rice production with additional 1500÷2000 ha at different losses;
  - Variant 2.1. – development of rice production, but decreasing the losses with total amount of water – $140.10^6 m^3$/annually;
  - Variant 2.2 – development of rice production in case of bigger losses with total amount of water – $180.10^6 m^3$ per year.

The needed amount of water for rice irrigation is computed at an irrigation rate of 240 $m^3$/ha. A uniform distribution of the rate is accepted, four months giving 600 $m^3$/ha each month. Irrigation is implemented during the period May – August. The other crops are irrigated according to their rates and the schedule of water delivered.

*Analyzing the results of Variant 1*

The results of water resource balance in Variant 1, shows: the rice irrigation is provided, the probability by volumes and by months is within the frameworks of the normative probability such as 94% -97% and 97% -99%. Only the probability by years is not reached, there is a little shortage, which means that in one part of the years, in some dry months there is an insignificant deficit. The ecological flow $Q_{eco}$ below the Koprinka dam is also provided in all variants now and in future (probability by volume 99,9% -100%). The industrial enterprises supplied by canal M-2 are also provided in all variants. The probability by years is about 94%, but by months and volumes the probability is within the frameworks of the normative values 98,17% - 98,67%.

At present, in addition to the rice, other crops are cultivated as corn, tobacco, vegetables, fruit-trees, etc. (Fig.12). The analysis in Variant 1 considers the case when the whole maximum of fitted for irrigation fields (100%) can be watered and the probability is high. By years it is 68%, but by months and volumes the probability is over the normative one – 88% -95%.

*Analyzing the results of Variant 2*

**Table 3.** Results of water balance – 2.1. and 2.2.

| | **Subvariant 2.1** | | | | **Subvariant 2.2** | | | |
|---|---|---|---|---|---|---|---|---|
| **Water user** | Gross water volumes for irrigation of rice 140 $10^6$ $m^3$ (filed even during the months of May to August) | | | | Gross water volumes for irrigation of rice 180 $10^6$ $m^3$ (filed even during the months of May to August) | | | |
| | $Provision_v$, % | $Provision_y$, % | $Provision_m$, % | Index | $Provision_v$, % | $Provision_y$, % | $Provision_m$, % | Index |
| Qeco after the dam Koprinka | 99.91 | 92 | 99.33 | 0.001 | 99.9 | 92 | 99.17 | 0.002 |
| Qeco after dam Koprinka | 67.69 | 62 | 86.25 | 13.761 | 52.64 | 38 | 77.19 | 24.562 |
| Kazanlak IF | 71.13 | 62 | 86.86 | 13.668 | 59.36 | 36 | 78.29 | 21.746 |
| St.Zagora IF P-17 | 97.98 | 90 | 97.83 | 0.584 | 97.79 | 88 | 97.67 | 0.598 |
| Industry St.Zagora | 69.11 | 56 | 84.86 | 15.106 | 53.83 | 28 | 76.29 | 25.489 |
| St.Zagora IF M1-M2 | 93.58 | 68 | 87 | 1.891 | 86.84 | 40 | 73 | 4.15 |
| Rice St.Zagora | 93.58 | 68 | 87 | 1.891 | 86.84 | 40 | 73 | 4.15 |

At variant 2 – Table 3 the results obtained show that in case of the development of rice production in the region the rice irrigation is provided – by years the probability is low but by volume and months it is in the framework of the norm. For variant 2.1. the probability by volume is 93,58%, by months – 87 %. At variant 2.2., when the losses are bigger, the probability by volume is 86,84%, by months – 73 %, which means that in some part of the years there will be dry months with small shortage. The deficit depends on the system's coefficient of efficiency. The ecological flow $Q_{eco}$ below the Koprinka reservoir is provided in all variants now and in future (the probability by volume is 99,9 % – 99,17 %). The industrial enterprises supplied by canal M-2 are also provided in all variants. The probability by years is about 88% -90%, but by months and volumes the probability is within the frameworks of the normative values 97,67 % - 97,98 %. The index of reliability is good.

In the analyses of variant 2 for all fields the possibilities are considered to irrigate the fitted fields cultivated with other crops except rice. The results show that irrigation of the remaining crops and

fields is also provided but not in the framework of 100 % of the fitted areas. It is more realistic to irrigate 30% -60% of the fitted areas beyond the rice-fields.

The conclusion is that the Koprinka water resource system has the potential to provide not only the irrigation of IRS "Stara Zagora" but of all remaining priority water users. However, the necessary ecological flow and hydro morphological conditions for reaching a good status are provided. The rice production and irrigation can be developed by recommending decrease of losses and increase of the coefficient of efficiency. Issuing a new permit and developing a new dispatcher graphics for use of water from the dam are necessary when exceeding of the used volume of water over the limit allowed until now, in the period of 5 years, linked to the periodic update of the RBMP (accordance with the last requirements of WA).

## 4. CONCLUSION

Environmental flow can be impacted by abstractions, flow regulation, morphological alterations, etc., and its provision after water abstraction facilities and reservoirs is a necessary measure to mitigate impact. A methodology for assessment and mapping of water resources availability, vulnerability (reliability) at different climate or drought scenarios and future water demand is developed. A framework for joint assessment of water stress areas, drought-risk of water supply management and ecological flow provision is elaborated. A methodological three-stage approach of water rights modeling is proposed.

The so-called HMWB and "regulated rivers" have modified flow, which is influenced by reservoir compensation releases, or they have flows that are augmented. The availability of water is dependent on these operating agreements. The "concept of compensation" represents possibility for guaranteeing the ecological runoff and ecological flow.

The presented methodological approach, which is experimentally verified, offers a scientifically based assessment tool for the first time in Bulgaria for acquiring water use rights under the conditions of changes in economy, structure of the water sector and climate. This approach focuses on legal and administrative issues on the one hand and on the other – the permitted water abstraction should be reflected on the sustainable use of water resources. The emphasis is laid on the development of models for management of individual basins and water systems with an assessment of available water resources and water use, grounded on adequate prioritization of regions.

The reevaluation of the licensing regime (already also required by the Water Act) becomes still more important due to the outlined tendency for enhanced extreme phenomena – occurrence of high water and prolonged droughts, in the context of the established regional and temporal heterogeneity of water in the country.

The methodology, system of indices, simulation models (SYMIL) and operational rules have been used in the Basin Directorates as well as applied operatively in the Ministry of Environment and Water. A pilot study for ensuring the irrigation in the system was carried out especially for the purposes of the Draft Common Strategy for Management and Development of Hydro-melioration and Protection against Harmful Effects of Water.

This is a step forward to the realization of the CAMS, drought management plans and Development of Hydro-melioration in Bulgaria. Including in the so-called "regulated rivers" and WB (WBs technical pressure, WBs lake – large reservoirs and WBs indefinite resource depending on the technological flow from a dam or derivation).

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