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WATER RESOURCE BALANCE FOR VITOSHA NATURE PARK AND ADAPTIVE MANAGEMENT UNDER CONDITIONS OF CLIMATE CHANGE

Irena ILCHEVA
National Institute of Meteorology and Hydrology, Department of Hydrology, Sofia, Bulgaria
irena.ilcheva@meteo.bg

Anna YORDANOVA
National Institute of Meteorology and Hydrology, Sector IMIT, Sofia, Bulgaria
yordanova61@gmail.com

Vesela RAYNOVA
National Institute of Meteorology and Hydrology, Department of Hydrology, Sofia, Bulgaria
vesela.rainova@meteo.bg

Abstract

The "Development of Water Balance for the territory of the Vitosha Nature Park" is the first comprehensive study on the water resources of the Vitosha Mountain. Water and natural resources are under increasing pressure from climate change. In this context the emphasis is laid on the analysis of the trends in the natural and anthropogenic factors, climate change and extreme phenomena (floods and droughts), and recommendations for management. A new methodological approach to the assessment of the Water Balance has been elaborated. A simulation model is developed to assess the vulnerability of water resources. An innovative approach is applied to the development of measures for integrated management of the water and natural resources (forests, peatlands) for the purposes of the Vitosha NP and the surrounding settlements. The aim is to implement adaptive management and monitoring, under conditions of climate change, and to achieve the objectives of the Water Framework Directive (WFD) and Natura 2000.

Keywords: *Vitosha NP, water balances, vulnerability, climate change, drought, monitoring, adaptive management, ecosystem services, Natura 2000, WFD, simulation modeling*

1. INTRODUCTION

Vitosha is the first nature park in Bulgaria and on the Balkan Peninsula. The territory of the Vitosha Nature Park (NP) includes zones with special status: sanitary protection zones and reserves. There are the "Torfeno Branishte" and "Bistrishko Branishte" reserves. The Vitosha NP is included in the protected areas of the European ecological network Natura 2000. In addition, Vitosha is water supply zone. It is comprises the territory of three administrative units. There are 12 settlements at the foot of the Vitosha Mt., 4 quarters of the Sofia City and over 20 villa zones.

Climate factors are already exerting negative pressure on natural and social systems. As a result of climate change, the environment ecological conditions are also changed and the vulnerability of natural ecosystems is increased, which may lead to their degradation. Climate changes lead to the deterioration of the hydrological and regulatory role of natural ecosystems (forests, wetlands, etc.) in the results of which the infiltration decreases, while the surface slope runoff, risk of erosion, floods and drought risk increase. There is shortages for water supply of the settlements in the area, some of the peatlands dry up, forest fires occur, etc. (Mitigating Vulnerability, 2014).

Climate change exerts influence on water resources and runoff directly – by altering natural factors (precipitation, temperature, evapotranspiration) and indirectly – by induced as a result of climate change land use alterations (forests, wetlands, etc.). The most important expected climate change, impacts on land use, are: habitats changing; reduction of wooded areas in the lower altitudes and increasing forest area over timber line in the alpine zone; loss of biodiversity; risk of spreading invasive species, etc. The changes in climate and habitats, anthropogenic pressure, overexploitation of water resources and pollution are the key driving forces of the changes in the ecosystems.

The "Development of Water Balance for the Territory of the Vitosha NP" is the first comprehensive study of its kind on the water resources of the Vitosha Mountain and the possibilities of their use for the purposes of the integrated management of the park. The project is developed by experts of the National Institute of Meteorology and Hydrology (NIMH), the Geological Institute of the Bulgarian Academy of Sciences and the University of Architecture, Civil Engineering and Geodesy as part of the "Implementation of the priority activities of the Management Plan of the Vitosha NP – Phase II". The project is funded by the Environment 2007-2013 Operational Program.

An assessment is made for the main risks and trends in the natural and anthropogenic factors, and recommendations for adaptive management under condition of climate change and extreme phenomena (floods and drought) are given.

2. METHODOLOGICAL APPROACH AND MODELING

A new methodological approach to assessment of the Water Resource System Balance with integrated analysis of all elements (precipitation, temperature, evapotranspiration, land use, water intake and transfer, water resource system, etc.) has been elaborated (Ilcheva et al., 2015). An innovative approach has been applied to the development of measures and solutions for integrated management of water and natural resources.

The aim is to implement adaptive management and monitoring, under conditions of climate change and extreme events, and to achieve the environmental objectives of WFD and Natura 2000. The adaptive capacity of socio-economic and natural systems and ecosystem services (ESS) are considered – Figure 1 (Ilcheva *et al.*, 2015).

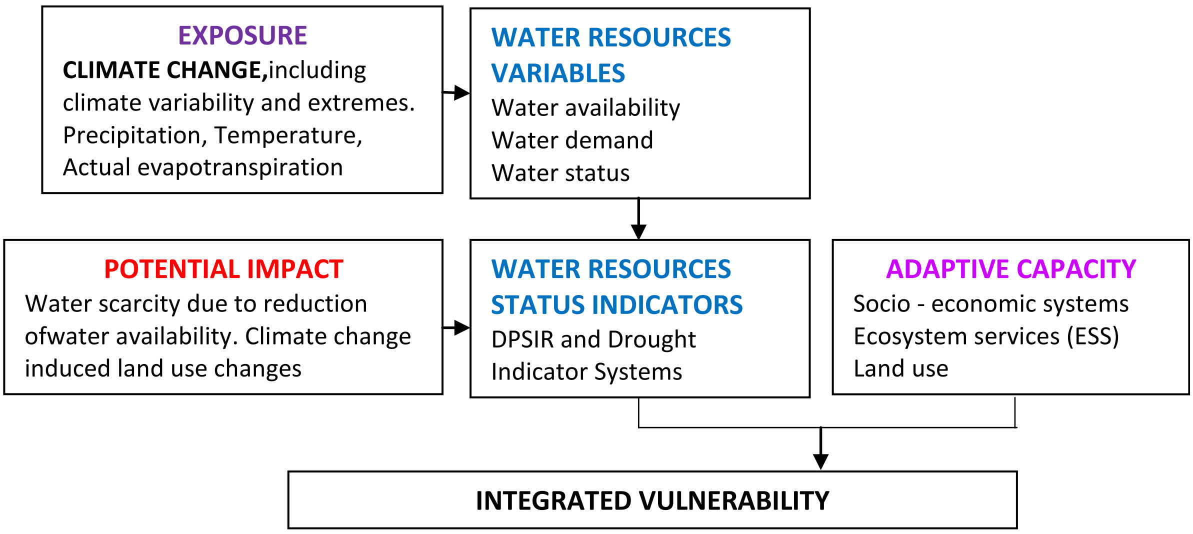


Figure 1. Components of Vulnerability (modified, source: CC - WARE, 2014)

A new and very important task is the adequate valuation of the ecosystem services (Mitigating Vulnerability, 2014; Nedkov *et al*, 2018; Burkharda *et al*, 2012). Based on the experience of NIMH in international projects in the developed methodology, the ecosystem services and land use changes are also part of the measures for reducing the vulnerability of water resources and water supply (CC - WARE, 2014). The relative potential of ESS to improve water supply is used as an indicator for ecosystems. There are maps of this indicator, developed for South East Europe (CC-WARE, 2014). Especially significant ecosystems are the forests, wetlands, peatlands, which together with their management represent important means for ensuring sustainable future supply of drinking water.

The vulnerability is related to: "exposure of a water resource system to stressors at the river basin and local scale, and capacity of the ecosystem and society to cope with the threats to the healthy functionality of a water system" (CC-WARE, 2014). To this end climatic, ecological and socio-economic indicators, based on the DPSIR (Drivers – Pressure – State – Impact – Response) indicator framework were selected – Figure 1 (Ilcheva, I. *et al.*, 2015).

Environmental flow (Good Ecological Status – GES) can be impacted by water abstractions, flow regulation, morphological alterations, etc. (Ilcheva *et al.*, 2015). To manage water effectively it is necessary to understand *how much* is available and *where* it is available, after considering the needs of the environment. A classical approach to the assessment of the available water resources for different purposes, including environmental, in Europe is the Catchment Abstraction Management Strategy (CAMS) of England and Wales (Kolcheva and Ilcheva, 2016; Kolcheva, 2016). The CAMS includes assessment of: the available resources, based on the water balance calculation; the water available for new users, after providing for the existing users and the environmental needs; the pressure of water abstraction and Restoring Sustainable Abstraction (RSA).

The so-called heavily modified water bodies (HMWB) and "regulated rivers" have modified flow, which is influenced by reservoir compensation releases, or they have flows that are augmented. The Prague or the mitigation measure approach was agreed as a valid method for defining Good Ecological Potential (GEP).

The planning framework is based on three strategies (Ilcheva and Georgieva, 2018):

- Restoring Sustainable Abstraction and Catchment Abstraction Management Strategy;
- Water scarcity and drought management plans, flood prevention;
- Monitoring and adaptive management to achieve the environmental objectives of WFD and Natura 2000.

The main stages of the methodology are (Ilcheva and Georgieva, 2018):

1. *First stage*. Modeling and assessment of the climate factors, scenarios and trends.

Climate is the main natural driver of variability in water resources. The main climate variables are: precipitation, temperature, potential and actual evapotranspiration.

2. *Second stage*. Evaluation of the trends in water resource alterations, incl. under different scenarios of climate change or drought.

Some water balance models are developed and the hydrological regime and groundwater are evaluated (Ilcheva *et al*., 2015; Benderev *et al*., 2015).

3. *Third stage*. Developing a calculation scheme of the Water Management System.

The development of the calculation scheme is a start point for the next stages of modeling. In this stage are identified all water users, water transfer from/to other watersheds, water supply systems, water infrastructure, approved water rights, etc.

4. *Fourth stage.* Analysis of the demographic and economic development. Assessment of the current and future water consumption – optimistic, realistic and pessimistic variants.

Water demand includes the water needs for tourist centers, domestic water supply, industrial water supply, water ecosystems and reserves (for instance peatlands), requirements for hydro power generation as well.

5. Fifth stage. Evaluation of water shortage and risk of water resources and water supply. Assessment of vulnerability and adaptive capacity of socio-economic and natural systems for the purposes of WFD and Natura 2000. Identification of "critical issues and areas".

At this stage juxtaposition is made of the available water resources and the current and future water consumption. The SIMYL simulation model is used (Niagolov, 1996). Therefore the graphical scheme is represented as a system consisting of nodes and arcs. The nodes include water sources (reservoirs, water intakes), water users, tourist centers, and the arcs - river courses, derivations, channels, etc.

The methodology for minimum ecological flow assessment and for RSA is applied.

The main tasks and expected results from this stage are (Ilcheva and Georgieva, 2018):

- Development of CAMS and measures for sustainable water abstraction (RSA)
- Identification of HMWB and regulated rivers;
- Development of mitigating measures according to the Prague method;
- Development of water scarcity and drought management plans;
- Development of measures for the purposes of Natura 2000, protected zones and areas;
- Integrated vulnerability assessment with consideration of the measures taken. Taking into account the adaptive capacity of the socio-economic and natural systems;
- Identification of "critical issues and areas" (the so-called "hot spots").

6. *Sixth stage*. Analysis and formation of measures, monitoring and adaptive water management for WFD and Natura 2000 objectives.

3. APPLICATION OF THE METHODOLOGY AND RESULTS

Vitosha is a domed massif, formed by the highest, close to each other peaks Cherni Vrah, Big and Small Rezen. The massif is 18 km wide and 23 km long. The mountain has an average height of 1382 m, which makes it among our high mountains. According to the expressed river valleys, some geographers divide Vitosha into four major parts: North (Kamendelsky) East, (Kupenski), Southwestern and Northwestern (Smilishki). The ridges of these four main watersheds gather at the highest peak of the mountain - Cherni Vrah (2290 m). A digital elevation model has been developed – Figure 2.

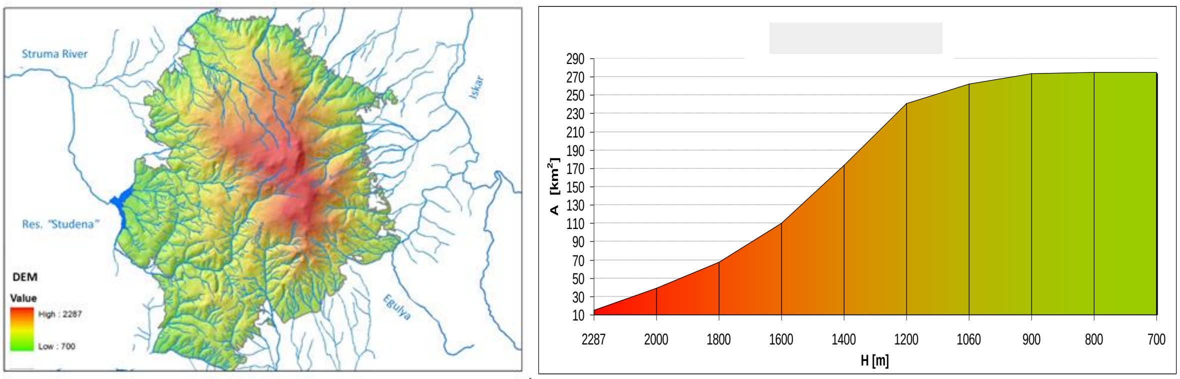


Figure 2. Digital elevation model and hypsographic curve (Source: Development of Water Balance, 2014)

3.1. Modeling and assessment of climate factors and trends

Climate conditions are one of the major factors determining the existence of ecosystems in a given area and its water balance. All factors forming the local climate are analyzed for the purposes of the water balance. Up-to-date information of NIMH has been used for more than

18 meteorological, climatic and precipitation stations in the region, at an altitude of 586 m (Sofia station) to 2286 m (Cherni Vrah station).

The results show that for the last 115 years the precipitation gradient of the studied area is markedly reduced – from 35 mm/ 100 m for the period (1896 - 1945), to about 22 mm/100 m for the last fifty years (Development of Water Balance, 2014) – Figure 3. The absolute maxima have become higher during the last 20 years.

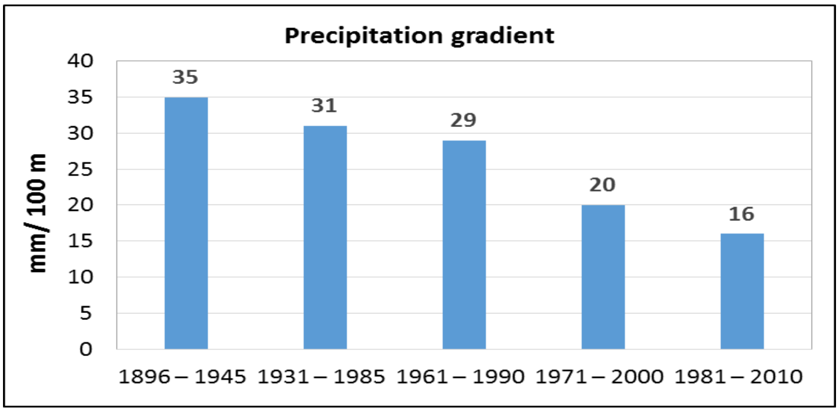


Figure 3. Precipitation gradient

3.2. Water balance modeling. Evaluation of the hydrological regime and groundwater

Vitosha is rich in water resources – springs, rivers, streams and waterfalls. The more significant rivers are: Struma, Vladaya, Boyana, Dragalevska, Bistritsa, Palakaria, etc.

The water balance model is developed for different periods – 1961-1990, 1961-2010 (Development of Water Balance, 2014) - Figure 4.

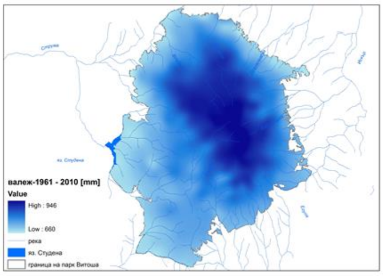
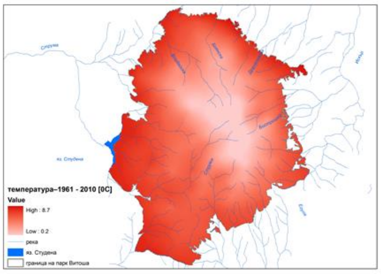
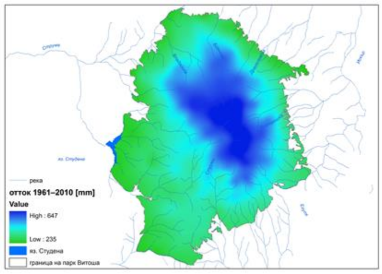
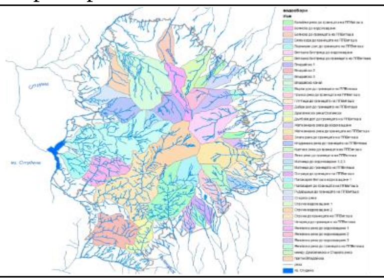
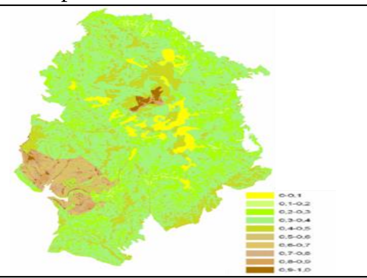
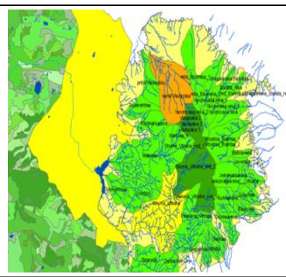
		
a. Spatial distribution of precipitation for 1961 - 2010	b. Spatial distribution of temperature for 1961 - 2010	c. Spatial distribution of runoff for 1961 - 2010
		
d. Evaluation of the hydrological regime and water resources of water intakes	e. Assessment of coefficient of underground recharge (Benderev et al., 2015)	f. Joint assessment of water stress, drought-risk and measures (Ilcheva and Georgieva, 2018)

Figure 4. Some results of the Water Balance for the Territory of the Vitosha

The area of the Vitosha Mountain is very poorly studied in hydrological terms as only three hydrometric stations (HMS) work, outside its territory: HMS 51650 - Pernik; HMS 18370 - Palakaria and HMS 18420 - Vladaya River. For the water resources assessment, updated information from NIMH was used. The three stations are used to derive regional dependencies. Therefore, the methods used for analysis of river flows are the method of analogy, probability analysis, water balance and available regional dependencies.

As a result of water balance modeling, the natural runoff for all river catchments at the boundary of the Vitosha NP, as well as for all major water intakes and water balance points, has been evaluated – Figure 4.d. and 5. The obtained results represent the basis for analysis and runoff series formation and for assessment of the parameters of water intake locations and water balance points (Vladaya, Boyana, Dragalevska, Bistritsa, Palakaria, etc.) – Table 1.

Typical for the rivers of Vitosha NP is that the runoff volume is 60 to 70 % of the annual runoff in high-water periods and only 10 % – in low-water seasons.

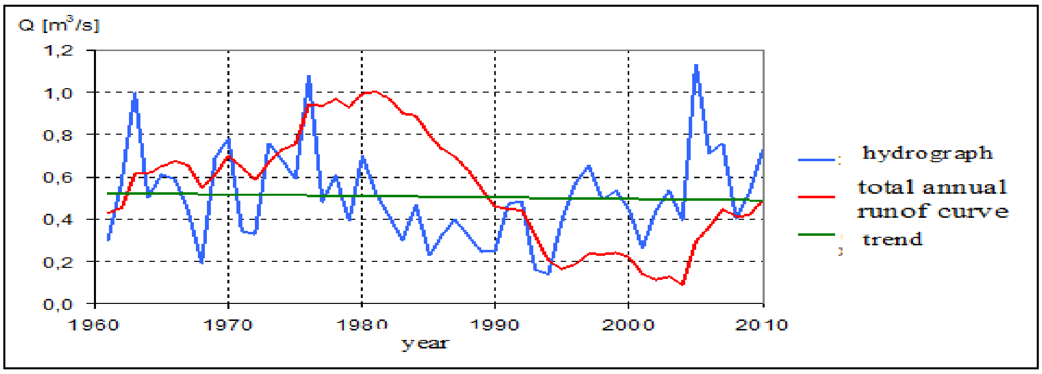


Figure 5. Runoff hydrograph, trend curve and total annual runoff curve at HMS18420

Table 1. Typical runoff quantities and volumes for three intakes on Vladayska river

Probability of exceedance	Intake 1		Intake 2		Intake 3	
%	Q [m^3/s]	W $10^6 m^3$	Q [m^3/s]	W $10^6 m^3$	Q [m^3/s]	W $10^6 m^3$
95	0,044	1,37	0,045	1,40	0,046	1,43
75	0,070	2,18	0,073	2,27	0,075	2,33
50	0,087	2,71	0,090	2,80	0,092	2,86

3.3. Development of a calculation scheme of the water management system

When developing the simulation model of water resource system balance, all water consumers, Water Supply Groups (WSG) and tourist sites are identified and described.

The main anthropogenic factors disturbing the natural runoff regime that have been taken under consideration in the assessment of resources and water balances of the Vitosha NP, are: the collecting channels of Vladaya, Palakaria, Studena reservoir, the water intakes of the Vladaya, Boyana, Zheleznitsa, Vitosha Bistritsa and Yanchovska Rivers (for drinking water supply of Sofia Municipality) and the water intakes of the Struma, Rudarshtnitsa and Matitsa Rivers (for water supply of the town of Pernik, Batanovtsi, Rudartsi, Dragichevo, etc.).

3.4. Analysis of the demographic and economic development. Assessment of current and future water consumption

Water consumption of all Tourist Water Supply Groups (TWSG) is calculated according to Regulation № 4 and the Management Plan of the Vitosha NP. The demographic and economic development of water use is analyzed to assess the main trends.

3.5. Minimum ecological flow assessment and Restoring Sustainable Abstraction

For the Restoring Sustainable Abstraction and CAMS realization, the ecological runoff is assessed on the basis of the new hydrological information.

In context of CAMS, the ecological runoff is a part of the river runoff that should not be taken away from the river and the environment. In order to ensure it, an assessment has to be made of the extent, to which natural runoff regime could be changed without affecting the sustainable functioning of the environment.

The aim of the RSA is to identify over-abstraction in rivers and wetland sites and make again the abstraction sustainable, where possible (Managing Abstraction, 2012).

The ecological water quantities are assessed in some basic points of the Vitosha NP (Zaharieva, 2004). Emphasis is given to the places of water abstraction, water transfer, rivers at risk of not achieving good ecological potential ("hot spots"). The assessment of the impact on the river ecosystem is determined by the following scheme:

- The development of the zoobenthos is modeled in natural flow regime (undisturbed conditions), including periods of low and high water.
- Models for different drought scenarios of zoobenthos development are worked out.
- A comparison with the standard regime is done using Fisher criterion, for assessment of the importance of zoobenthos cenosis variations for different scenarios.

The results for Vladaya and Palakaria rivers show that the increase in the minimum allowed outflow does not substantially change the status of the cenosis. This is due to the severely reduced river flow during high water due to the high level of construction. For Vladay and Palakaria rivers it is proposed to accept a minimum permissible flow:

- 0,050 m^3/s – water intake of the Vladaya River, Vladaya collecting channel;
- 0,011 m^3/s – water intake of the Palakaria River, Palakaria collecting channel;
- In the months of April and May, 5-10 days to be provided, in which the catchments not to work, so that the rivers run through the entire natural flow to improve the status of the cenosis during the spring high water.

The increase of minimum allowed outflow for the of the Boyana River (Kameno Zdanie water intake) does not significantly change the status of the cenosis during summer low water, but improves its condition during spring high water. It is proposed to accept a minimum permissible flow 0,010 m^3/s.

For Zheleznitsa, Vitosha Bistritsa and Yanchovska rivers it is proposed a minimum permissible flow:

- 0,013 m^3/s – water intake of the Zheleznitsa River;
- 0,015 m^3/s – water intake of the Vitosha Bistritsa River;
- 0,011 m^3/s – water intake of the Yanchovska River.

A comparison with the permits issued has been made – Table 2.

In the simulation modeling of the water economic balances for Vitosha NP the ecological quantities are set with the highest priority. The main scenarios and experiments are carried out respecting the environmental quantities of the permits.

The so-called HMWB and regulated rivers have been identified. Accordingly to River Basin Management Plans (RBMP) three types of water bodies (WB) have been distinguished when assessing the impact of water abstractions on the resource: WBs technical pressure, WBs – large reservoirs, and WBs indefinite resource depending on the technological flow from a reservoir or derivation. These are: the Studena reservoir, the downstream reservoir zone, all the rivers and streams affected by the Vladaya and Palakaria collecting channels, Boyana River, affected by water transfer (from Vladaya II water intake), etc.

As a result of simulation modeling, appropriate measures (included in the Programme of Measures of the RBMP) have been applied to achieve the WFD objectives (Prague method): optimal water allocation of the water resources management systems, reservoirs and collecting derivations for ecological flow and water supply provision; environmental flow releases from reservoir and applying the concept of "compensation" to ensure ecological flow for good ecological status/potential and priority water users, during periods of prolonged drought, etc.

Table 2. Some results and ecological flow from the permits issued (fragment)

Location of water abstraction, water intake	Location of water water use	Estimated natural runoff 1961-2010 m^3/s	Ecological flow from the permits issued l/s
Vladaya river, water intake I	Vladaya, Marchaevo, tourist centers and tourist water supply groups	0.089	10
Vladaya river, water intake II	Possibility to water transfer from Vladaya to Boyana River	0.093	10
Vladaya river, water intake III	Vladaya, Marchaevo, tourist centers and tourist water supply groups	0.094	10
Vladaya river, Vladaya collecting channel	Water transfer from Iskar River Basin to Struma River Basin and Studena Reservoir	0.336	20
Boyana River, Kameno Zdanie water intake	Tourist centers, tourist water supply groups	0.086	10
water intake of the Zheleznitsa River	Sofia water supply in emergency situations	0.127	10
water intake of the Yanchovska River	Sofia water supply in emergency situations	0.109	10
water intake of the Vitosha Bistritsa River	Sofia water supply in emergency situations	0.151	10

3.6. Simulation modeling and Catchment Abstraction Management Strategy

A simulation model has been elaborated to assess the vulnerability of water resources and water supply under various scenarios: scenarios for the resource, including "drought" scenarios, different alternative water supply schemes, "with" or "without" water transfer, various management decisions and measures (Development of Water Balance, 2014).

The ***first*** basic scenario (maximum) is for the worst case of the water resource system balance of the Vitosha NP - maximum water consumption for the settlements and industry of the town of Pernik and for all tourist water supply groups and centers (100 % loading of the tourist huts and sites in the Park).

The ***second*** basic scenario is moderately realistic: for the long series, variant with 15 % loading of all tourist huts and variant 3 with reduced water losses in the settlements.

The ***third*** basic scenario is in fact a group of scenarios with a "***drought***" variant of 10 dry years. Analysis is made for climate change.

The ***fourth*** and ***fifth*** scenarios refer to the evaluation of the impact of different ***new schemes*** of water use, including water ***transfers*** and different strategical and tactical ***measures***.

The results of the simulation modeling show that for the maximum variant water supply is ensured close to the normative probability of exceedance (PE). There are deficiencies in drinking water supply of Pernik and settlements, but the probability of exceedance is 98,52 %

by volume, 97,59 % by years, 94,74 % by months and the Reliability index (RI) is 0,420. Water shortage is observed in low-water months, when water is supplied from water intakes. There are deficiencies for the settlements: Rudartsi, Dragichevo, Kladnitsa, etc. (Table 3).

Water shortage also occurs for the tourist groups, due to the same reasons (Table 4). The Vladaya River is most heavily loaded. The probability of exceedance for the tourist groups "Zlatnite mostove" and "Ofeliite - Koniarnika" is about 75 - 86 % by volume, 79 - 83 % by months, but only 15 % by years.

Table 3. Some results from the simulation modeling, Variant (maximum) – WS Groups

Settlements	WSG	Probability of exceedance (PE) %			Reliability index (RI)
		by volume	by years	by months	
Pernik and settlements	WS1	98,52	94,74	97,59	0,420
Rudartsi	WS32-R	94,33	65,79	93,20	1,208
Dragichevo	WS32-D	89,33	34,21	85,75	3,042
Vladaya	WS3-V	93,27	13,16	80,26	0,952
Marchaevo	WS3-M	99,90	97,37	99,56	0,004
Kladnica	WS2-K	90,53	21,05	82,89	2,047
Delta Hil	WS2-H	78,85	13,16	75,66	6,521
Chuipetlyovo	WS2-Ch	98,61	89,47	98,25	0,365
Radomir WSG	WS4-Ra	100,00	100,00	100,00	0,000
Bosnek	WS3-B	100,00	100,00	100,00	0,000
Yarlovo	WS60Y	99,51	89,47	98,25	0,365
Sofia and settlements	WS10	98,18	73,68	95,61	0,259

Table 4. Some results from the simulation modeling, Variant (maximum) – Tourist Groups

Tourist centers and TWS Groups	TWSG	Probability of exceedance (PE) %			Reliability index
		by volume	by years	by months	
TC Zlatnite mostove w.i. Vladaya III	WST1.3	76,07	13,16	78,58	8,150
Ofeliite-Koniarnika, w.i. Vladaya I	WST3.3	74,77	13,16	78,29	8,911
Ofeliite-Koniarnika, w.i. Vladaya II	WST3.1	85,90	15,79	82,68	3,084
Other huts – Vladaya river	WST2	94,97	71,05	94,96	1,078
Vladaya	WST4	93,51	71,05	94,96	1,761
Selimica	WST5	100,00	100,00	100,00	0,000
Tintyava	WST6	99,56	97,37	99,56	0,080
Aleko	WST7	99,87	97,37	99,56	0,013

Table 5. Some results from the simulation modeling, Variant (maximum) - ecological runoff

River Assessment point	E- flow	Probability of exceedance (PE) %			Reliability index
		by volume	by years	by months	
Vladaya river 1 – after water intakes	Vl R_1	97,52	65,79	94,30	0,354
Vladaya river 2 – Vladaya channel	Vl R_2	98,20	78,95	95,61	0,253
Boyana river – after Boyana HPS	Bo R_1	99,89	97,37	99,56	0,005
Palakariya – Palakariya channel	Pal R	99,51	89,47	98,25	0,057
Rudarshtitsa – Vladaya channel	Ru R_1	74,86	2,63	50,44	7,682
Kladnishka - Vladaya channel	Kl R_1	94,85	36,84	86,84	0,887
Struma river – under res. "Studena"	St R_1	100,0	100,0	100,00	0,000

Water shortage is also observed for the highest priority user – the ecological runoff (Table 5). The probability of exceedance of the ecological flow for the assessment point of the rivers in the Vitosha NP is approximately 97 – 99 % by volume, 70 - 90 % by years, 95 – 99 % by months and the Reliability index is 0,005 – 0,35. The PE for the assessment point Rudarshtitsa

River is only 74, 86 % by volume, 2, 63 % by years, 50, 44 % by months and the Reliability index is 7, 682.

The ecological runoff at the Studena reservoir is 100 % secured.

The needs of the Sofia capital, the industry of Pernik, the water supply of the Radomir group and the energy production of Boyana HPS are entirely ensured (100%).

The results accomplish the Catchment Abstraction Management Strategy.

3.7. Monitoring and adaptive management for the WFD and Natura 2000 objectives under conditions of climate change and extreme phenomena

3.7.1. Trend assessment

The main trends and risks are evaluated and the influence of climate change and extreme phenomena on water and natural resources is analyzed.

The Mann-Kendall trend shows a statistically significant increasing trend of temperature and decreasing trend of rainfall for Cherni Vrah (Figure 6 and Table 6).

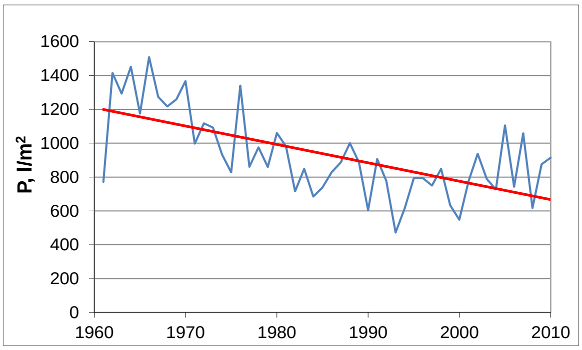


Figure 6. a Trend for Cherni Vrah annual precipitation 1961- 2010

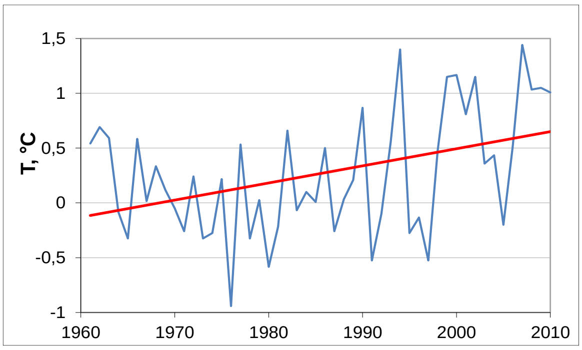


Figure 6.b Trend for Cherni Vrah annual temperatures 1961 - 2010

Table 6. Mann-Kendall test for Cherni Vrah precipitation and temperature (1961-2010)

Mann-Kendall test	Statistic s Z	Level of significance - α			Result
		α = 0,1	α = 0,05	α = 0,01	
Precipitation	4,417	$Z_{0,1}$ = 1,645	$Z_{0,05}$ = 1,96	$Z_{0,01}$ = 2,58	Very strong trend
Temperature	4,843	$Z_{0,1}$ = 1,645	$Z_{0,05}$ = 1,96	$Z_{0,01}$ = 2,58	Very strong trend

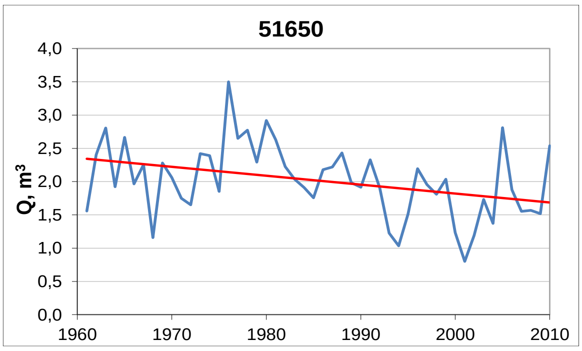


Figure 7.a Trend for HMS 51650 – Pernik

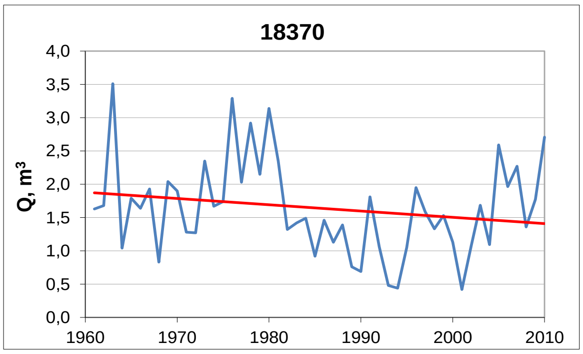


Figure 7.b Trend for HMS 18370 - Palakaria

The results for the HMS and runoff also show decreasing trends, that at HMS 51650 being statistically significant – Figure 7.

3.7.2. Climate change and drought projection

The ALADIN model at NIMH is used. The results indicate that temperature rise and reduced precipitation are expected (Figure 8). The climate scenarios analyzed show an expected runoff reduction in the area of Pernik within the range of 15 % for the period 2020 - 2050 compared to the 1961 - 1990 (Marinov *et al.*, 2012; Ilcheva *et al.*, 2015).

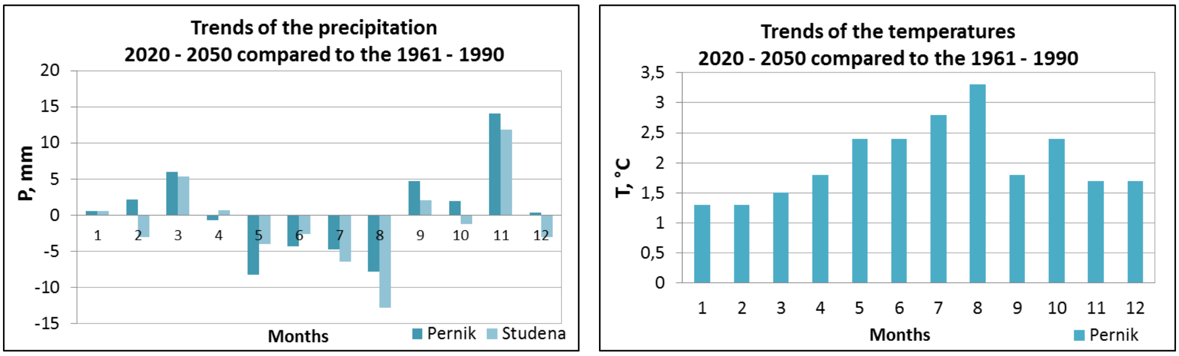


Figure 8. Changes in precipitation and temperatures. Scenario 2020 - 2050 versus 1961 - 1990

The higher temperatures, combined with the precipitation deficit, lead to high rates of evapotranspiration during the year. All this increases the risk of all types of drought - air, soil, hydrological and even socio-economic. The severity of the "prolonged drought" is related to its duration, specificities of the river basin, reservoir management and impacts. To this end drought indicators (such as SPI, SRI, standardized status index, etc.) as part of the Early Warning System, have been developed and applied (Ilcheva, I., *et al.*, 2018).

3.7.3. Simulation modeling under "drought" scenarios. Evaluation of the impact of different new schemes and measures.

On this basis, to assess the impact of drought on water shortage and water system operation, the analysis is carried out under different "prolonged drought" scenarios (Ilcheva *et al*., 2018). The analysis of "drought" scenarios shows that the deficits are aggravated during periods of prolonged drought and climate change.

In periods of drought and low water, part of the rivers and gullies even dry up – Figure 9.

As already pointed out, the fourth and fifth scenarios refer to the evaluation of the impact of different new schemes, including water transfers and different strategical and tactical measures. The results of the scenario with water transfer from the Vladaya to the Boyana River within the range of the Vitosha NP prove that the transfer of water quantities only for the needs of the tourist center and the sites supplied by Sofia Water does not affect the other water supply groups. The same refers to the possible future development of water supply by transfer of water from the Boyana River to sites of the Aleko center.

3.7.4. Floods – risk factors and preventive measures

Evaluation of high water for the period of 1961-2010 is developed (Development of Water Balance, 2014). Vulnerable zones have been identified. The main causes of flooding are: result of abundant precipitation, climate change, deforestation, erosion, forest fires, etc.

3.7.5. Assessment of adaptive capacity and vulnerability of ecosystems

The natural ecosystems are part of the measures for reducing the vulnerability of water resources. But they are also sensitive to climate change and human activity. Therefore, the proper management and protection of the ecosystems is crucial. For this purpose, some vulnerable areas are identified. For example, the peat vulnerability increases as a result of drought and anthropogenic pressure (Activities sustainable management, 2014) – Figure 10.

About 13% of peat complexes are in unsatisfactory condition, incl. some of the largest peat complexes in the Torfeno Branishte Reserve: peat 6 (point 43), peat 64 (point 13), etc. 6% are in poor condition.

Figure 9. Vladaya River (Source: Development of Water Balance, 2014)

Figure 10. Peatland № 30 (point 66) in poor condition (Source: Activities sustainable management, 2014)

The most common risk factors are the passage of hiking trails through peat bogs, trampling and natural drifting. Water changes related to drainage and water catchment, as well as fires, have the most negative impact.

3.7.6. Analysis and formation of measures, monitoring and adaptive management

According to the vulnerability of the water supply, water and natural ecosystems, reserves and Sanitary Protection Zones ("hot spots"), measures and monitoring are recommended.

As already pointed out above, there are no hydrometric stations on the territory of Vitosha NP. The aim of the "Development of a pilot project on building a monitoring system for water resources in the Vitosha NP" (Monev *et al.*, 2005) is to launch the construction of a monitoring

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system for the water resources in the Vitosha NP of a modern type. With priority the following monitoring points are proposed within the frames of the pilot project:

1. A hydrometric station on a river – analogue for the rivers at the western slopes of the Vitosha Mt. - Vladaya River. Hydrometric stations: existing HMS № 18420 near Knyazhevo and new station near Zlatni Mostove at an elevation of about 1400 m.
2. A hydrometric station on a river – analogue for the rivers at the northern slopes of the Vitosha Mt - Boyana River. New station at an elevation of about 1600 m.
3. A hydrometric station at the mouth of the Vladayski collecting channel in the Kladnishka River, from where the water is discharged in the Studena reservoir.
4. A hydrometric station at the mouth of the Palakaria collecting channel in the Struma River above the Studena reservoir.
5. Environmental monitoring for the purposes of Natura 2000, "hot spots" and taken measures.

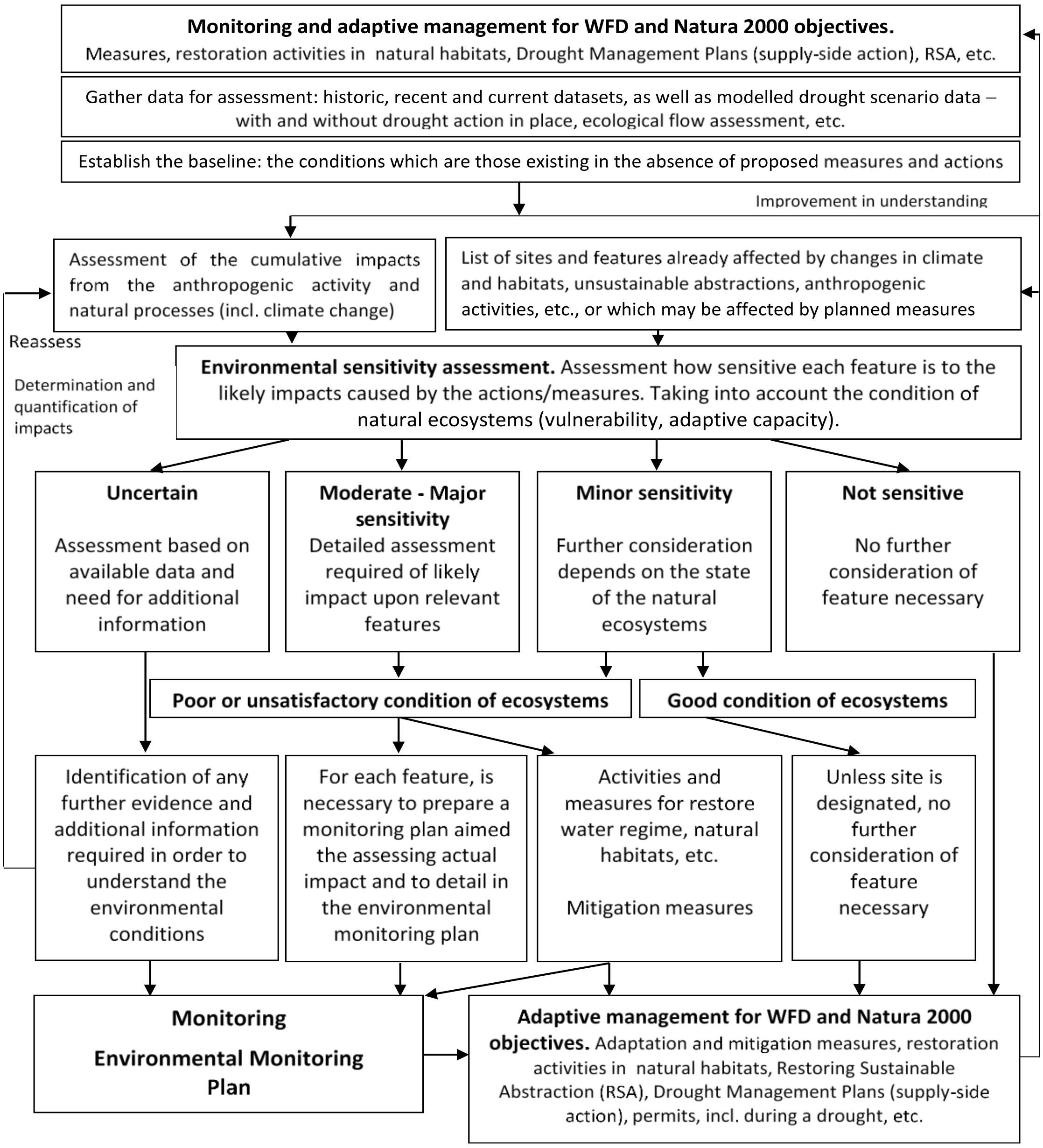

Figure 11. Environmental monitoring and adaptive management (modified, source: Water Company Drought Plan, 2017)

The monitoring is already being carried out within the framework of the project "Improving the conservation status of peatland complexes" and pilot site Peatland № 30 – Figure 10. The activities include: implementation of measures to restore water regime including preparation of the water balance of the bog, assessing the need to adjust the water level in the whole peat or in certain areas; construction of single or system pulls through partitioning existing flows; eliminating channels that drain the bog; monitoring.

Actually, the development realizes the Drought Management Plan (DMP) by the example of the UK, taking into account the protected areas, Natura 2000 and the ensuring of e-flow (GES/GEP) – Figure 11. On the one hand, on the basis of the available water resources, Water Companies develop their Strategic Investment Plans, DMP, environmental monitoring and update their water use permits. Depending on the level of planning there is three different plans to face water shortage risk due to drought – strategic, tactical, and emergency. On the other hand, in the context of Article 1 of (Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora), conservation means a series of measures, required for conservation or restoration of natural habitats. The measures to restore water regime and monitoring of the peatland complexes are non-traditional supply-side drought measures.

Therefore, we propose (Figure 11):

a) To analyze the planned drought measures (strategic and supply-side) and all other taken activities (for the Sanitary Protection Zones, restoration activities in natural habitats and Natura 2000, RSA, etc.);
b) To assess cumulative pressure from anthropogenic activity and natural processes (including climate change);
c) To take into account not only the sensitivity of the affected environment but also the state (condition) of the natural ecosystems, etc.

4. CONCLUSIONS AND RECOMMENDATIONS

There is a significant decrease in the precipitation gradient - from 35 mm / 100 m for the period 1896-1945 to 22 mm / 100 m for the period 1961-2010. The absolute maxima of temperature have become higher during the last 20 years. The results of the Mann-Kendall test show a statistically significant decreasing trend of rainfall for Cherni Vrah. Climate scenarios show decrease for expected runoff for the period 2020 - 2050 within the range of 15 % compared to the 1961 - 1990. That means, that climate change for South East Europe and Bulgaria is also valid for the Vitosha NP, although as a less pronounced change.

Climate factors are already exerting negative pressure on water resources, society, natural ecosystems and their ecosystem services.

The results from simulation modeling show that water supply is ensured close to the normative probability, but permanent small deficits occur basically in the settlements of the so-called Vitosha group. Water shortage is also observed for the tourist centers and the highest priority user – the ecological runoff. The deficits are aggravated during periods of prolonged drought and climate change, and part of the rivers and gullies even dry up.

Although the water shortages, the adaptive capacity of the social systems is high, because the largest cities Sofia and Pernik are secured from the Iskar and Studena reservoirs.

The water transfer from the Vladaya to the Boyana River for the needs of the tourist centers does not affect the other water users. The same refers to the possible future development of water supply by transfer of water from the Boyana River to sites of the Aleko center.

The model investigations of the zoobenthos development in natural and disturbed conditions are carried out. As a result of the environmental flow assessment and simulation modeling, the critical sections and problems are specified (Vladaya, Palakaria, Rudarshtitsa rivers, etc.). Due to the severely reduced river flow during high water (due to the high level of construction), the increase in the minimum allowed outflow does not substantially change the status of the cenosis. Some prescriptions for RSA are given.

The use of water and natural resources, climate change and anthropogenic activities leads to significant changes in the hydrological regime and natural habitats. The following most negative impacts on natural ecosystems are identified: habitat areas reduction, losse of peatland complexes, affected and damaged habitats - swamp forests, alluvial forests, riparian habitats, ecosystems degradation, etc.

An approach is applied to the development of measures and solutions for integrated management of the water and natural resources (forests, wetlands, etc.) for the purposes of the Vitosha NP and the surrounding settlements. The aim is to implement adaptive management and monitoring, under conditions of climate change and extreme events, and to achieve the environmental objectives of the WFD and Natura 2000.

Based on the results and identified “hot spots”, measures for integrated water and ecosystem (forest ecosystems, peatlands, etc.) management are proposed:

4.1. Adaptive management to achieve the objectives of WFD

Actually, the research realizes the CAMS and a Drought Management Plan by the example of the UK, taking into account the protected areas, Natura 2000 and ecological flow.

The analysis of water resource distribution via water resources systems and reservoirs, the water balances represent an instrument for identification of permanent and temporary deficiencies and “critical issues and areas”.

Recommendations are given for management under conditions of water shortage and prolonged drought on the territory of the Vitosha NP and the adjacent settlements. A systems of drought indicators and indexes are developed (as part of the Early Warning System).

Regulated areas are identified, in which the ecological runoff and GEP are ensured by the Prague method. Some mitigating measures (included in the Programme of Measures of the RBMP) are assessed: optimal water allocation of the water resources management systems, reservoirs and collecting derivations; applying the concept of “compensation” to ensure ecological flow and priority water users, during periods of prolonged drought, etc.

The given prescriptions for the ecological flow and RSA must take part into practice.

4.2. Adaptive management to achieve the objectives of Natura 2000.

To achieve the objective of Natura 2000, a series of measures and good practices should be implemented to improve the water retaining and regulating role and to prevent the negative impact of extreme phenomena in the Vitosha NP: restoration of riparian habitats; restoration of forest habitats; restoration of water regime and water retention function of peat lands, etc.

One of the most important tasks is to restore and preserve the Torfeno Branishte and Bistritsa Branishte reserves, giving the origin of one of the most important rivers in the area – the Vladaya, Boyana and Dragalevtsi Rivers and a water-source zone. In this connection it is advisable to continue the research aimed at studying and preserving the Torfeno Branishte reserve, integrating the opportunities and the results of the developed water balance.

4.3. Monitoring and adaptive management under conditions of climate change and extreme phenomena

According to the identified critical issues and areas (“hot spots”), measures and monitoring are recommended. An approach for adaptive management to achieve the objectives of the WFD and Natura 2000 under conditions of climate change and extreme events is applied.

The building of a monitoring network for complex observation of the runoff regime, climate factors and water quality is the basis for evaluation of the trends and for adaptive management of the water and natural resources. Therefore a project for construction of a monitoring network for the water resources and environment is proposed.

In the developed methodology, the ecosystem services and land use changes are part of the measures. The proper management and protection of the forests, wetlands and peatlands is crucial to ensuring sustainable future supply of drinking water, water regulation, as well as mitigating the impact of climate change. On the other hand, some measures (such as to restore water regime of the peatland complexes) are non-traditional water management (supply-side drought) measures.

Therefore, we propose to assess cumulative impact from anthropogenic activity (incl. all taken measures - restoration activities in natural habitats and Natura 2000, RSA, etc.) and natural processes (incl. climate change).

As a result of approach, measures with synergistic effects are recommended – not only to protect water quantity and quality, but also for flood risk prevention, erosion control, increasing water retention capacity, etc.

The results and application in practice are related to the RBMP, the water supply of the settlements in the region, Program of Measures of the West Aegean and Danube Region Basin Directorates, and adaptive management for the purposes of WFD and Natura 2000.

REFERENCES

Activities sustainable management of Vitosha NP (2014). Project financed by the European Regional Development Fund and Operational Program "Environment 2007 – 2013"

Benderev, A., Orehova, T., Kolev, S., Hristov, V. and Ilieva, I. (2015). Groundwater contribution to the river runoff in the Vitosha Nature Park, *Review of the Bulgarian Geological Society*, vol. 76, part 2–3: 109–121

Burkharda, B., Krolla, F., Nedkov, S. and Müller, F. (2012). Mapping ecosystem service supply, demand and budgets, *Ecological Indicators* 21, 17-29

CC_WaterS (2012). Climate Change and Impacts on Water Supply, *Monograph*, SEE

CC-WARE (2014). Mitigating Vulnerability of Water Resources under Climate Change, SEE

Development of Water Balance for the Territory of the Vitosha Nature Park 2014. Project financed by Operational Program "Environment 2007 – 2013", National Institute of Meteorology and Hydrology, Contract with the Vitosha NP. Project leader - Ilcheva, I.

Ilcheva, I. and Georgieva, D. (2018). Drought Management Plans for river basins, water supply and ecological runoff, *Annual of the University of Architecture, Civil Engineering and Geodesy,* Sofia, Volume 51, Issue 6: 95 - 111

Ilcheva, I., Georgieva, D. and Yordanova, A. (2015). New methodology for joint assessment of drought risk of water supply under climate change, water stress areas identification and ecological flow provision WFD, *Journal of International Scientific Publications Ecology & Safety,* Volume 9, ISSN 1314-7234: p. 413 - 433

Ilcheva, I., Niagolov, I., Balabanova, S., Yordanova, A., Zaharieva, V., Rainova, V., Vatralova, A. and Georgieva, D. (2015). Water resource balance of Vitosha Natural Park, including analysis under conditions of climate change and extreme phenomena, *Iinternational Scientific Conference „Sustainable mountain regions: make them work“,* e-book ISBN 978-954-411-220-2: p. 246 - 253

Ilcheva, I., Yordanova, A. and Raynova, V. (2018). Application of Standardized Status Index for Prolonged drought identification and River Basin management. *Scientific Conference with international Participation "Geography, regional Development and Tourism"*, 23 to 24 November 2018, University of Shumen

Kolcheva, K. (2016). Experimental research on the effective water abstraction permitting regime, *Bulgarian Journal of Meteorology and Hydrology*, vol. 21, No 1-2, p. 72-92

Kolcheva, K. and Ilcheva, I. (2016). Water abstraction management and environment, *Journal of International Scientific Publications Ecology & Safety*, Volume 10: p. 145 – 165

Managing water abstractions (2013), Environmental Agency, UK

Marinov, I., Velizarova, E., Njagolov, I., Nikolova, K., Ilcheva, I., Zlatanov, T., Mirchev, P., Zaharieva, V., Yordanova, A., Nikolov, I., Pavlova, E. and Mitev, S. (2012). Climate changes and their influence on forest ecosystems and water resources in the catchment area of the Struma River watershed. *BON Publishers*, ISBN: 978-954-395-081-2

Mitigating Vulnerability of Water Resources under Climate Change (2014). Prepared by Executive Forest Agency, Forest University, Forest Research Institute and NIMH (Spiridonov, V., I. Ilcheva, K. Nikolova, S. Balabanova, I. Niagolov)

Monev, E., Marinov, R., Ilcheva, I. and Yordanova, A. (2015). Development of control monitoring for the purposes of integrated water resource management of the Vitosha Natural Park. *Journal of International Scientific Publications Ecology & Safety*, Volume 9, ISSN 1314-7234: 383 – 393

Nedkov, S., Zhiyanski, M., Borisova, B., Nikolova, M., Bratanova, S., Semerdzhieva, L., Ihtimanski, I., Nikolov, P., Aidarova, Z., (2018). A geospatial approach to mapping and assessment of urban ecosystem services in Bulgaria, *European Journal of Geography* 9 4 34–50

Niagolov, I. (1996). A model and investigation for rational water resources systems control in case of stochastic and multicriterial approach, *Water problems*, BAS, Volume 28

Water Company Drought Plan, Technical Guideline, 2017, *Natural Resources Wales*

Zaharieva, V. (2004). Mathematical models for minimum river flow determination. *Annual of the University of Architecture, Civil Engineering and Geodesy*, Vol. XLI