ASPECTS REGARDING EXTERNAL STRESSES ON DAMS DURING YHE YEARS 2000 – 2016. CASE STUDY – 22 RESERVOIRS IN PRUT – BÂRLAD CATCHMENT

Isabela BALAN, PhD Engineer isabela.balan@yahoo.co.uk
Loredana CRENGANIȘ, Lecturer PhD, "Gheorghe Asachi" Technical University of Iasi, Romania, loredana.crenganis@gmail.com
Flaviana CORDUNEANU, PhD, corduneanuflaviana@gmail.com

Abstract: *The Prut - Barlad Water Basinal Administration has a complex program of observations and hydro meteorological measurements. For a number of 22 reservoirs, special behavior monitoring is carried out, according to the Normative for the Monitoring of Hydrotechnical Constructions NP 087-2003. The main external stresses monitored at the dams of these accumulations are: rainfall, temperatures, water level in the lake. A study period of 17 years between 1999 and 2016 was chosen for the analysis. The paper presents the multiannual evolution of the maximum water levels in the reservoirs chosen for the study.*

Keywords: *external stresses, reservoirs, average annual precipitation, average annual temperatures, maximum water levels*

1. Introduction

The hydrographic catchments of Prut and Bârlad rivers that form the patrimony of Prut - Barlad Water Basinal Administration have a total surface of 20267 km^2 and consists of:
- the middle and inferior catchment of Prut river
- the catchment of Bârlad river
- left tributaries of Siret river in Botoșani and Galați county

The Prut - Barlad Water Basinal Administration has a complex program of observations and hydro meteorological measurements. Primary data obtained from the observations and measurements are processed and interpreted flood defense purpose and consists of:

- 73 reservoirs (Total volume = 780,3 millions m^3): 41 reservoirs, 22 non-permanent accumulation, 10 polders
- 877,1 km river regularizations, 1104,8 km levees – 250,52 km for Prut river, 107,2 km river banks consolidations - 39,15 km for Prut river
- 3 derivations – headraces
- 2 hydrotechnical nodes
- 8 pumping stations
- 86 automated stations (DESWAT project)
- 74 automated stations (WATMAN project)
- 110 administrative spaces

For a number of 22 reservoirs, **special behavior monitoring** is carried out, according to the Normative for the Monitoring of Hydrotechnical Constructions NP 087-2003. In order to be able to assess the normality of the measured parameters, it is necessary to report on the dam external stresses, when making the current behavior monitoring measurements (water level in the reservoir, liquid and / or solid precipitation, wind speed, air and / or water temperature, ice bridge thickness). Knowledge of hydro meteorological factors, as well as short or long-term forecasts is also required for judicious exploitation of the objective.

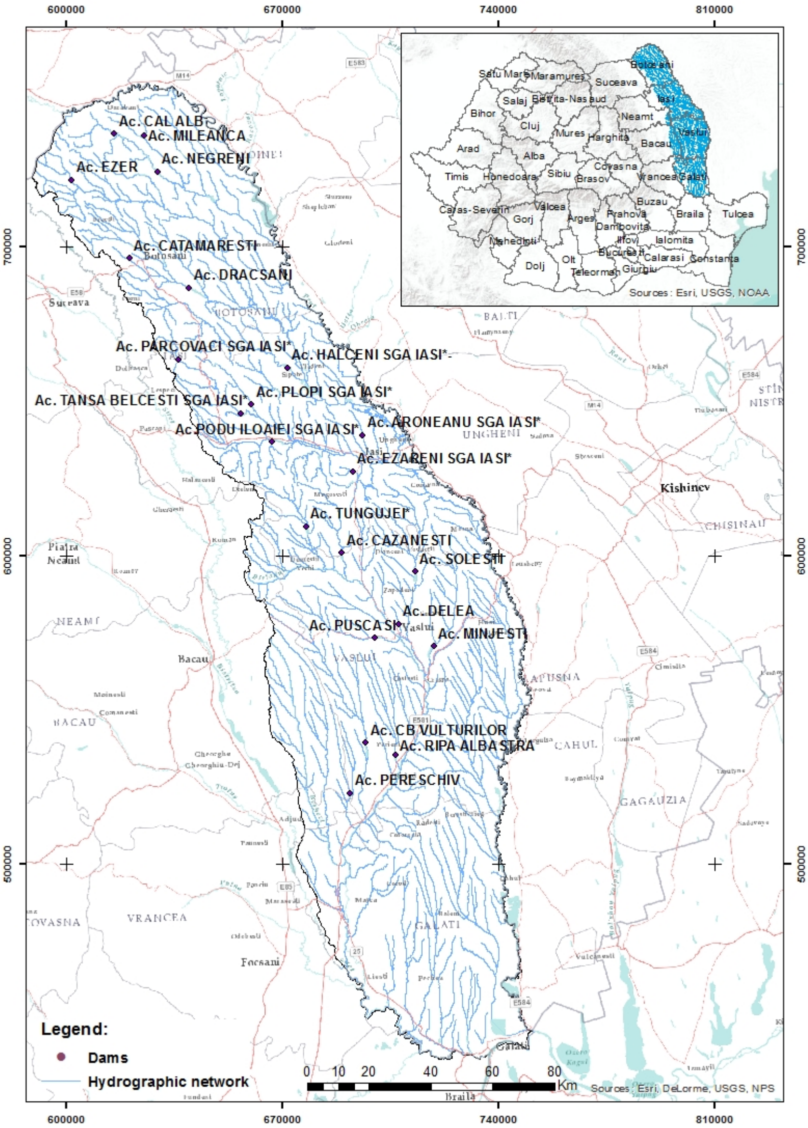

Fig. 1. Map with the positioning of the reservoirs

The main external stresses monitored at the dams of these reservoirs are: precipitations, air temperature, water level in the reservoir.

1.1. Precipitations

Atmospheric precipitation is the most important factor in determining the natural regime of both surface waters and groundwater. The precipitation phenomena are monitored at automatic stations or by direct measurements made at classical two-pipe pluviometers, located at the dams of these reservoirs. A study period of 17 years between 1999 and 2016 was chosen for the analysis. The maximum daily precipitation values were compared to the multiannual area averages established at nearby weather stations and multiplier coefficients were calculated.

Table 1. Multiplication coefficient for daily average precipitations

Crt. No.	Dam-reservoir	Maximum daily precipitation		Multiannual precipitation - area averages - mm	Monthly precipitation area averages - mm	Coefficient
		Value - mm	Day-Month-Year			
1	Reservoir Cătămărăşti	107.8	14.07.2000	1.55	47.2	69.5
2	Reservoir Cal Alb	110	14.07.2000	1.49	47.2	73.5
3	Reservoir Podu Iloaiei	73	01.09.2000	1.45	45.5	50.1
4	Reservoir Plopi	113.9	14.07.2000	1.39	45.5	81.5
5	Reservoir Tungujei	113.2	03.06.2016	1.39	45.5	81.1
6	Reservoir Hălceni	82.4	14.07.2000	1.49	45.5	55.2
7	Reservoir Pârcovaci	124.1	25.08.2008	1.39	44.3	88.7
8	Reservoir Soleşti	65.4	28.08.2004	1.56	44.3	41.9
9	Reservoir Pereschiv	95.7	05.09.2017	1.29	44.3	73.6
10	Reservoir Puşcaşi	104.8	28.08.2004	1.56	42.5	67.1
11	Reservoir Cuibul Vulturilor	84.7	05.09.2007	1.29	42.5	65.2
12	Reservoir Mânjeşti	85.1	22.08.2000	1.56	42.5	54.5
13	Reservoir Râpa Albastră	65.8	05.09.2007	1.29	42.5	50.6
14	Reservoir Ezer	67.3	30.06.2010	1.49	45.4	44.9
15	Reservoir Dracşani	57.9	19.08.2005	1.55	47.5	37.3
16	**Reservoir Negreni**	**133**	11.07.2000	1.49	47.5	**89.3**
17	Reservoir Mileanca	109	18.08.2005	1.49	47.5	72.9
18	Reservoir Ezăreni	71.1	01.07.2013	1.45	47.5	48.8
19	Reservoir Tansa – Belceşti	59.1	25.07.2008	1.39	39.5	42.3
20	Reservoir Delea	76.4	05.06.2001	1.56	39.5	48.9
21	Reservoir Căzăneşti	85.6	12.10.2016	1.40	39.5	61.1
22	Reservoir Aroneanu	52.5	01.07.2013	1.45	42.6	36.0

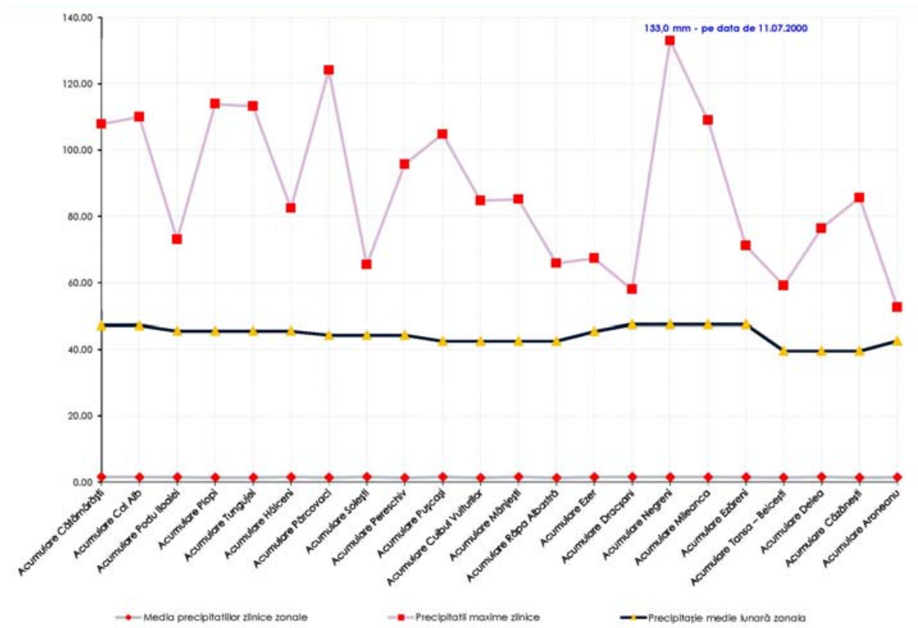

Fig. 2. Daily precipitations – maximum multiannual values

It can be noticed that the maximum daily precipitation with the value of 133.0 l / m2 was recorded on July 11, 2000 at the Negreni reservoir. The coefficient of multiplication relative to the multiannual zonal average precipitation (1.49 l / m^2) is 89.3.

With ARCGIS software, maps were made with the spatial distribution of maximum daily, total monthly and total annual precipitation, based on the measurements made at the studied reservoirs.

The method used was IDW - Inverse Distance Weighting, which is a widely used method for estimating missing data in hydrology and geographic sciences.

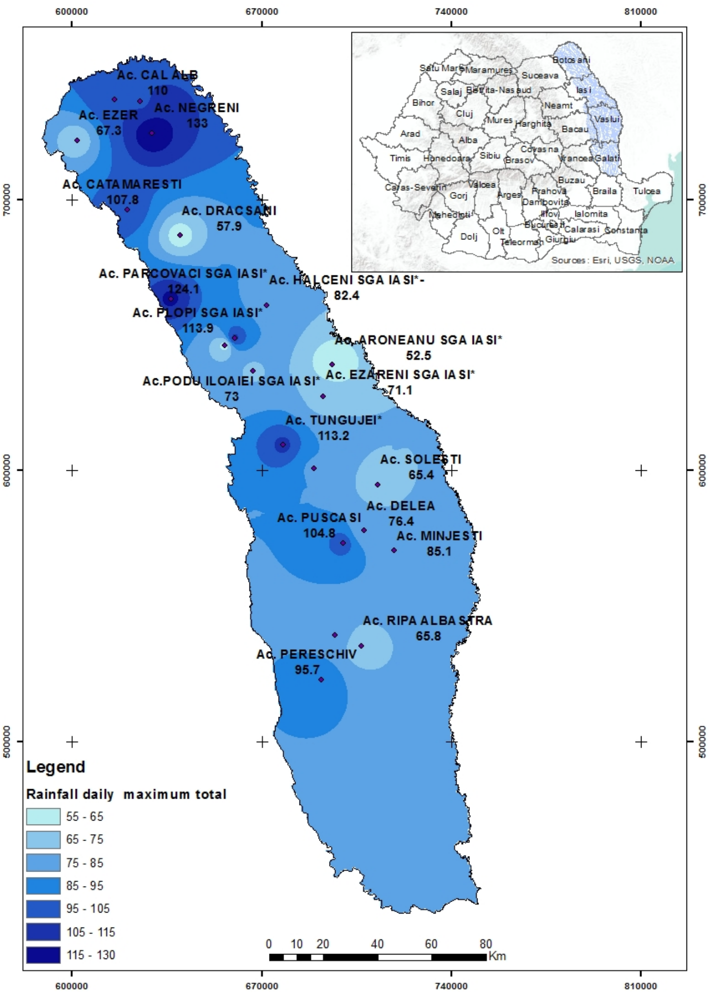

Fig. 3. Spatial distribution of daily precipitations – maximum values

The influence of a measured point is weighted according to the distance from the measured observation point to the point for which estimation is desired. The basic formula of these methods is:

$$Z(S_0) = \sum_{i=1}^{N} \lambda_i X(Si)$$

where Z (S0) represents the interpolation value at point S_0

Z (Si) is the value measured at point S_i

n represents the number of measurements

λ_i is the weight, that is calculated

$$\lambda_i = \frac{d^{-p'}{}_{i0}}{\sum_{i=1}^{N} d_{i0}^{-p'}}, \sum_{i=1}^{N} \lambda_i = 1$$

where p is an exponent

d_{i0} is the distance between an estimated point and a measurement point

Based on daily precipitation, monthly total precipitations were rainfall was calculated. Their maximum values were compared to the monthly multiannual area averages established at nearby weather stations and multiplier coefficients were calculated.

It is noted that the maximum monthly precipitation with the value of 304.1 l / m^2 was recorded in August 2005 at the Ezer reservoir. The multiplication factor over the multiannual monthly rainfall area (45.4 l / m^2) is 6.69.

Table 2. Multiplication coefficient for monthly average precipitations

Crt. No.	Dam-reservoir	Maximum monthly precipitations		Monthly area average precipitation - mm	Coefficient
		Value - mm	Month - Year		
1	Reservoir Cătămărăşti	234.1	August 2004	47.2	4.96
2	Reservoir Cal Alb	200.7	August 2005	47.2	4.26
3	Reservoir Podu Iloaiei	168.2	June 2013	45.5	3.70
4	Reservoir Plopi	163.4	July 2008	45.5	3.59
5	Reservoir Tungujei	266.5	June 2016	45.5	5.86
6	Reservoir Hălceni	241.1	July 2002	45.5	5.30
7	Reservoir Pârcovaci	202.3	October 2016	44.3	4.56
8	Reservoir Soleşti	176.4	May 2012	44.3	3.98
9	Reservoir Pereschiv	178.0	September 2007	44.3	4.02
10	Reservoir Puşcaşi	162.6	May 2012	42.5	3.82
11	Reservoir Cuibul Vulturilor	213.9	October 2016	42.5	5.03
12	Reservoir Mânjeşti	183.1	July 2002	42.5	4.30
13	Reservoir Râpa Albastră	168.5	October 2016	42.5	3.97
14	**Reservoir Ezer**	**304.1**	August 2005	45.4	**6.69**
15	Reservoir Dracșani	235.5	August 2005	47.5	4.96
16	Reservoir Negreni	232.1	July 2001	47.5	4.88
17	Reservoir Mileanca	267.4	August 2005	47.5	5.63
18	Reservoir Ezăreni	171.8	June 2010	47.5	3.62
19	Reservoir Tansa – Belcești	202.3	October 2016	39.5	5.12
20	Reservoir Delea	189.0	October 2016	39.5	4.78
21	Reservoir Căzănești	196.5	October 2016	39.5	4.97
22	Reservoir Aroneanu	183.0	July 2002	42.6	4.30

The multiplication factor over the multiannual monthly rainfall area (45.4 l / m^2) is 6.69.

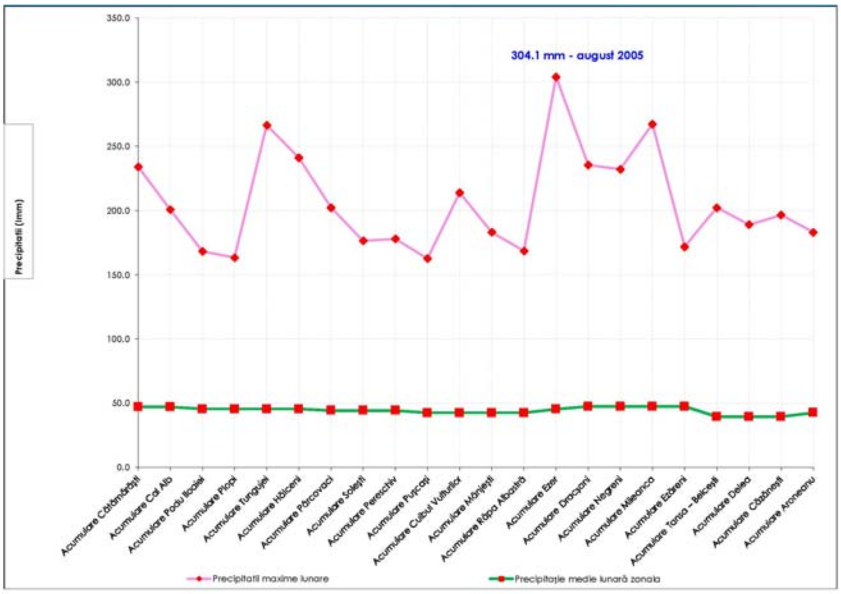

Fig. 4. Monthly precipitations – maximum multiannual values

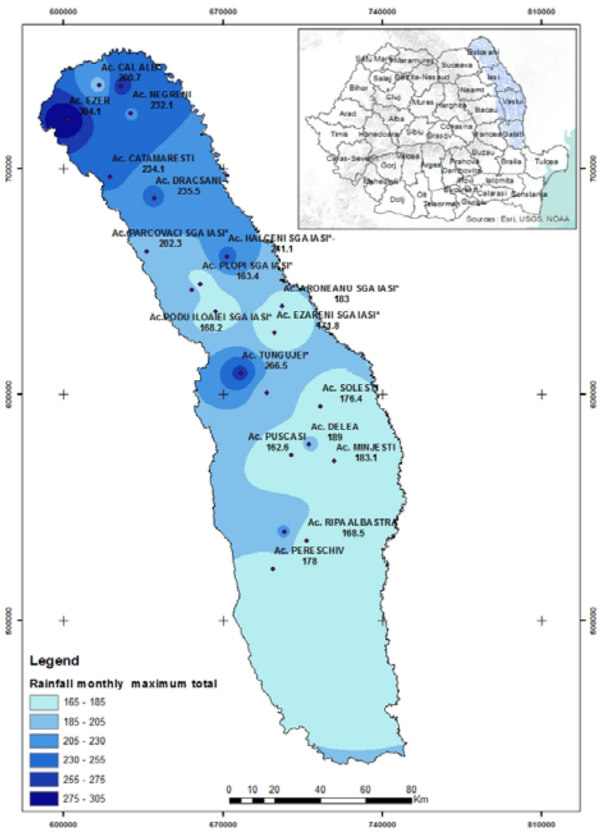

Fig. 5. Spatial distribution of monthly precipitations – maximum values

Based on daily precipitation, annual rainfall was calculated. Their maximum values were compared to the multi-year area averages established at nearby weather stations and multiplier coefficients were calculated.

It can be noticed that the maximum annual precipitation with the value of 824.9 l / m^2 was recorded in 2010 at the Mileanca reservoir. The multiplication factor relative to the multi-annual rainfall area (with the value of 546 l / m^2) is 1.51.

Table 3. Multiplication coefficient for monthly average precipitations

Crt. No.	Dam-reservoir	Maximum yearly precipitations		Multiannual precipitations - area averages - mm	Coefficient
		Value - mm	Year		
1	Reservoir Cătămărăşti	791.6	2010	566	1.40
2	Reservoir Dracşani	704.5	2005	566	1.24
3	Reservoir Cal Alb	778.6	2010	546	1.43
4	Reservoir Ezer	761.8	2005	546	1.40
5	Reservoir Negreni	734.4	2001	546	1.35
6	**Reservoir Mileanca**	**824.9**	**2010**	546	1.51
7	Reservoir Podu Iloaiei	675.8	2010	532	1.27
8	Reservoir Ezăreni	671.5	2010	532	1.26
9	Reservoir Aroneanu	614.8	2013	532	1.16
10	Reservoir Pârcovaci	771.8	2010	510.4	1.51
11	Reservoir Plopi	605.6	2008	510.4	1.19
12	Reservoir Tansa – Belceşti	711.6	2016	510.4	1.39
13	Reservoir Tungujei	790.1	2016	509.7	**1.55**
14	Reservoir Hălceni	745.1	2002	545.2	1.37
15	Reservoir Delea	739.5	2014	570.2	1.30
16	Reservoir Soleşti	584.5	2016	570.2	1.03
17	Reservoir Mânjeşti	650.2	2014	570.2	1.14
18	Reservoir Puşcaşi	708.7	2011	570.2	1.24
19	Reservoir Pereschiv	694.8	2013	474.4	1.46
20	Reservoir Cuibul Vulturilor	673.4	2010	474.4	1.42
21	Reservoir Râpa Albastră	694.8	2013	474.4	1.46
22	Reservoir Căzăneşti	687.7	2016	511.2	1.35

The maximum multiplication factor over the multiannual zonal average precipitations, with a value of 1.55, was calculated for the Tungujei reservoir, for the precipitations produced in the year 2016.

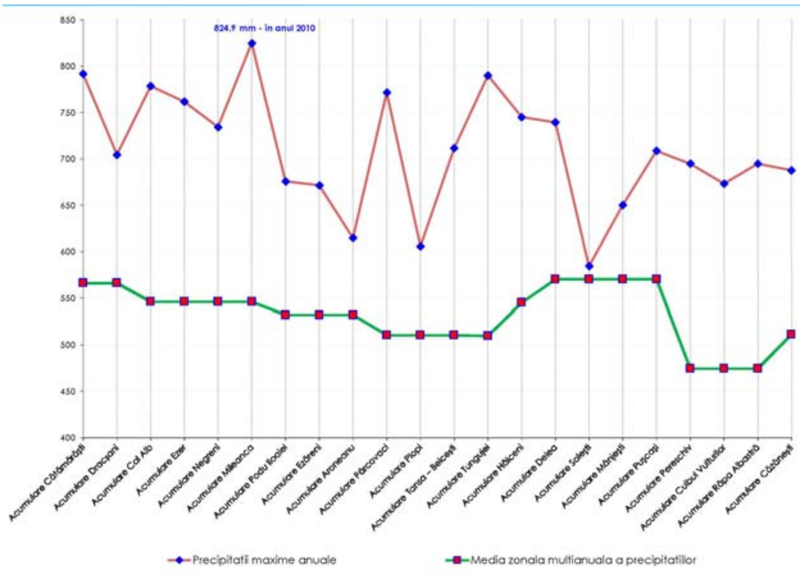

Fig. 6. Yearly precipitations – maximum multiannual values

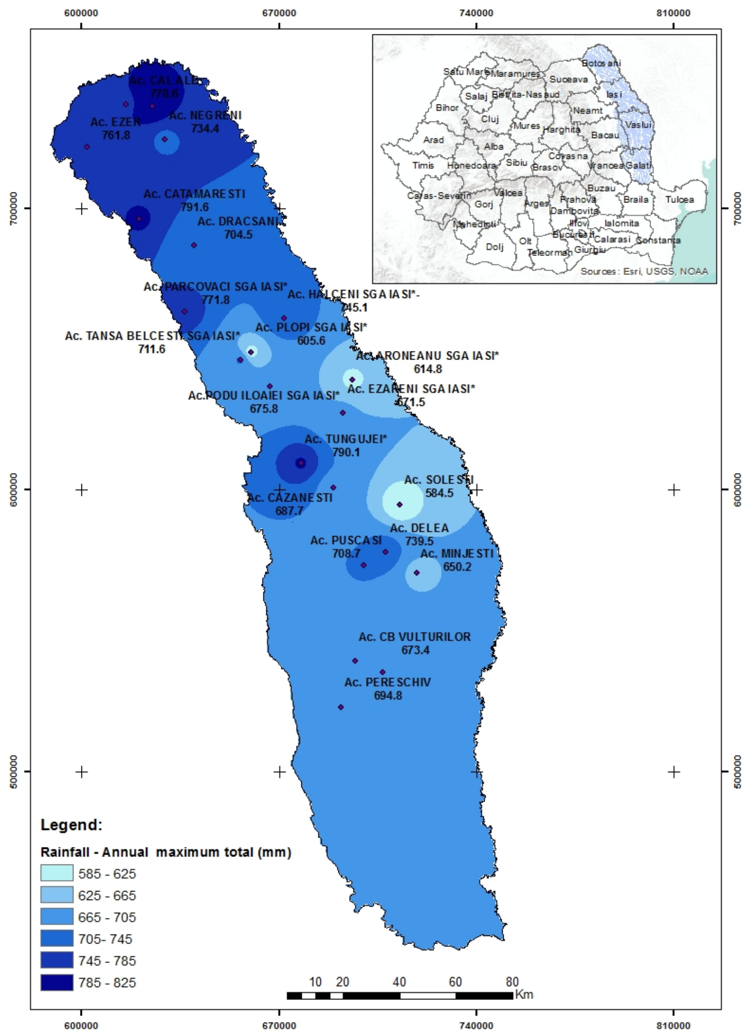

Fig. 7. Spatial distribution of yearly precipitations – maximum values

1.2. Temperatures

The temperature regime for the 22 reservoir is assessed by measurements at the 6 weather stations established in the Prut - Barlad hydrographic basin.

Average annual temperatures measured at weather stations over the period 2000 - 2016 were compared to the average multiannual temperatures.

Table 4. Average yearly temperatures at the meteorological stations

Weather Station	BOTOȘANI	COTNARI	IAȘI	VASLUI	NEGREȘTI	BÂRLAD
Multiannual average temperatures -°C	8.6	9.9	10.6	10.2	9.6	10.7

It can be noticed that the maximum difference between the annual average of the temperatures recorded in the period 2000 - 2016 and the multiannual average of the temperatures is 5.7 ° C and was calculated for Negreşti weather station (the year 2007).

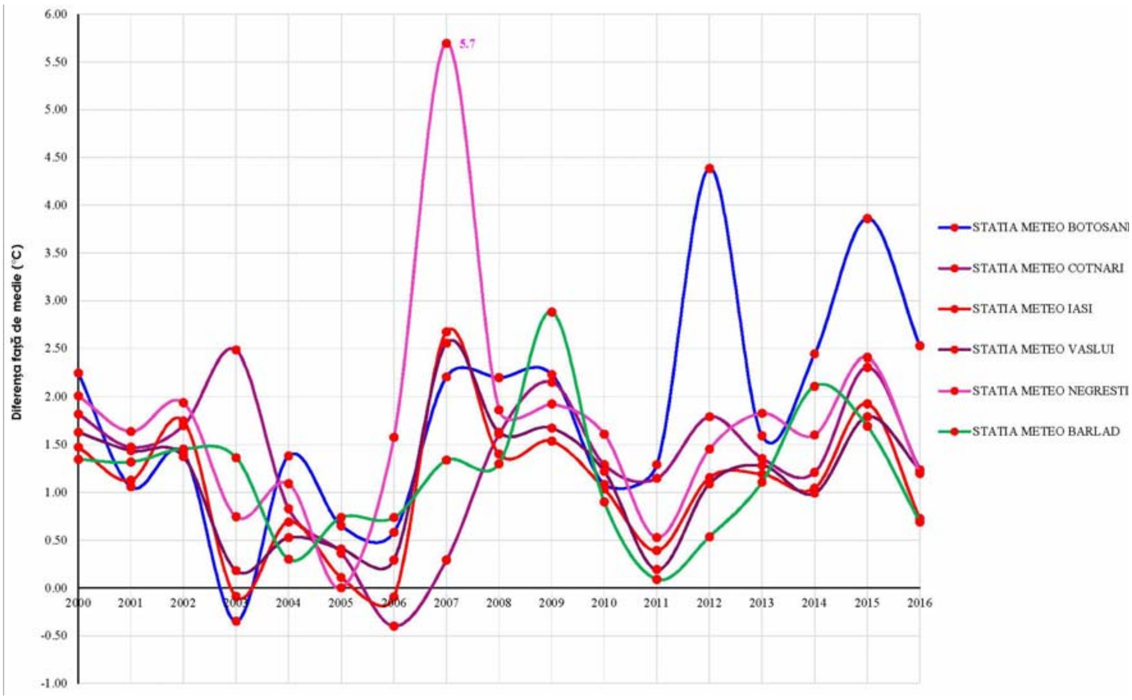

Fig. 6. Differences from average yearly temperatures at the meteorological stations

1.3. Water level in the reservoir

The water levels in the reservoir are measured with the hydrometric vertical gauges or automated sensors.

2. Response parameters of the hydrotechnical construction:

The response parameters of the hydrotechnical construction, to the intermittent or continuous external stresses to which it is subjected, may be different to the component parts of the reservoir.

The monitoring of the behavior is done separately and yet combined for the body of the dam body, the reservoir tank, the high waters spillway, adjacent buildings and installations.

Table 5. Maximum water level in the reservoirs between the years 2000 - 2016

Crt. No.	**Dam- reservoir**	**Niveluri maxime anuale**		**Spillway level - mdMN**	**Splashing balde - m**
		Water level – m.a.S.L.	Year		
1	**Reservoir Cătămărăşti**	120.15	2010	120.00	**0.15**
2	**Reservoir Dracșani**	78.98	2003	79.47	**0.49**
3	Reservoir Cal Alb	131.19	2005	131.32	
4	**Reservoir Ezer**	153.93	**2010**	153	**0.93**
5	Reservoir Negreni	104.99	2006	105.13	
6	**Reservoir Mileanca**	126.97	2008	126.16	**0.81**
7	Reservoir Podu Iloaiei	64.89	2008	65.45	
8	Reservoir Ezăreni	59	2013	60.85	
9	Reservoir Aroneanu	59.5	2013	60.55	
10	Reservoir Pârcovaci	174.3	2010	176	

11	Reservoir Plopi	77.82	2006	81.8	
12	Reservoir Tansa – Belcești	92.45	2008	93	
13	Reservoir Tungujei	161.22	2008	161.6	
14	**Reservoir Hălceni**	55.78	2002	55.23	**0.55**
15	Reservoir Delea	122.32	2005	128.43	
16	Reservoir Soleşti	120.02	2005	121.57	
17	Reservoir Mânjești	100.07	2003	103.3	
18	Reservoir Puşcaşi	116.21	2014	116.5	
19	Reservoir Pereschiv	91.84	2013	93.01	
20	Reservoir Cuibul Vulturilor	97.23	2013	99.7	
21	Reservoir Râpa Albastră	81.57	2004	83.71	
22	Reservoir Căzănești	133.8	2008	135.2	

3. Conclusions

In the period of time chosen for analysis, the average annual temperatures were higher than the multiannual averages set for all weather stations. The frequency of occurrence of important daily precipitations has increased substantially over the years.The intense study of external stresses and the response parameters of the dams can provide significant information regarding the safe operation of reservoir and thus ensuring their primal role in flood defense.

4. References

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