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Original scientific paper

SEDIMENTATION RATES AND LIFESPAN ANALYSES IN THE RESERVOIR "KALIMANCI"#

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Erosion and filling of reservoirs with sediment is one of the main problems leading to reduced lifespan of the reservoir with large environmental and economic implications. Reservoir sedimentation also provides valuable information on erosion intensity and sediment transport within a drainage basin and it can serve as the outlet of a giant erosion plot. With the invention of the global navigation satellite system (GNSS), the bathymetric measurements of the sediment in the reservoirs became much easier. Measurements performed with GNSS-supported echosounder are completed much faster and with considerable accuracy. The subject of this study is the Kalimanci reservoir. The reservoir was built in 1969 and until the present there have been 13 measurements, and gathered data is of great service for examination of the rates of deposition. It can be inferred that two mayor deposition periods exist, with braking point in the mid-80s. In the first period, the average annual deposition in the reservoir was 493,055 m^3 / year, and in the second period the average annual deposition in the reservoir was 214.325 m^3 / year, i.e. the deposition rate has reduced more than double between the two periods.

Key words: water reservoir; sediment transport; bathymetry; soil erosion; lifespan

INTRODUCTION

Reservoirs are designed to operate for a limited amount of time, but often their lifespans are reduced by sedimentation. Despite the designed life, reservoirs realistically have a project life defined as the "period during which the reservoir can reliably serve the purposes it was originally constructed for". Reaching of the project life, the failure to meet designed needs occurs typically before half of the storage volume of the reservoir is reduced from sedimentation (Morris *et al.* [12]; Dendy *et al.* [4]; Murthy [13]). The storage capacity, or reservoir yield, is expressed "as a function of available storage volume in the conservation pool" Nikitina *et al.* [14].

Reservoir sedimentation is a serious consequence of soil erosion with large environmental and economic implications. On the other hand, reservoir sedimentation also provides valuable information on erosion problems and sediment transport within a drainage basin. *A reservoir can be considered as a large-scale experiment, as the outlet of a giant erosion plot* (de Vente *et al.* [7].

Reservoirs are a unique category of objects because their lifespan is little dependent on the constructive elements of the dam itself, but are largely dependent on erosion and sedimentation processes. If the sediment regime is properly managed, then the reservoirs can last much longer than their projected lifespan. Schnitter (1994) in his work emphasized the presence of 12 reservoirs which lasted over 2000 years. Four of these dams/reservoirs are still functional (Morris *et al.* [12]).

The primary purpose of a reservoir sedimentation survey is to determine the volume and weight of sediment accumulated between surveys, or during the recorded period of storage. Information obtained from reservoir sedimentation surveys may be used to: estimate sediment yield for a given watershed, evaluate sediment damages, provide basic data for

#Dedicated to academician Gjorgji Filipovski on the occasion of his 100th birthday planning and designing reservoirs, evaluate the effects of watershed protection measures, determine the distribution of sediment in a reservoir, and/or predict a reservoir's sediment storage life expectancy, or period of useful operation (Hall [5]).

It is estimated that more than 0.5 percent of the total reservoir storage volume in the world is lost annually as a result of sedimentation (White [18]). In comparison, for Republic of Macedonia, the reservoir "Tikveš" was built in 1968 with total storage of 475 10^6 m^3. The last measurements of the sediments in 1991 show accumulation of 29.3 10^6 m^3 of deposed sediment, or, an average annual deposition of 1.27 10^6 m^3, which is 0.26 percent of the total storage, little above the European average value (Trendafilov [16]). All previous measurements were done by the Water Development Institute of RM, using echosounder without GNSS (Global navigation satellite systems) support, with established geodetic polygonal network on already established measuring profiles. This approach included: setting up a polygonal network on already established measuring profiles, after which a boat with fitted echosounding equipment moved over established profiles and its position was determined by a geodetic instrument (distomat). This approach was very labor intensive and included mobilization of a lot of manpower.

With the invention of GNNS, bathymetric measurements of the sediment in reservoirs became much easier. The latest equipment for bathymetric measurements includes echosounder with spatial support of GNSS (mainly GPS). Measurements taken with GNSS-supported echosounder are completed much faster with considerable accuracy. Because the time needed for the measurements is much shorter, additional measurements can be taken, other than measurements of the established profiles. Thus, this new method allows for total measurement of the reservoirs on profiles and contour measurement.

The aim of this study was to define the regime of sedimentation within the reservoir Kalimanci and to calculate its lifespan.

The objectives of this study were:

– collecting previous data about erosion intensity, reservoir siltation, other related data;

– modelling erosion processes and transported sediments in the current state;

– bathymetric measuring;

– calculation of deposed sediment;

– defining sedimentation regime over time;

– defining reservoir lifespan.

MATERIAL AND METHODS

Study area

The catchment area of the reservoir is situated in the eastern part of the country and covers the upper part of Bregalnica river, in the area of combined valley-hilly and mountain region that belong to old Balkan relief structures.

The watershed of Bregalnica is located in the eastern part of the country, draining surface waters from an area of 4307 km^2 or 16.7% of the country. The upper part of the Bregalnica watershed extends upstream of the dam od Kalimanci (in the most eastern part of the country), from 22°27’44” to 23°02’03” East longitude, and from 41°35’09” to 42°09’16” North latitude. It covers an area of 1124.7 km^2 which is 26.1 % of total area, or 4.4 % of the country. The climate in the watershed is conditioned by the geographical location of the area and its topographic features. Although Malesh and Pijanec are two adjacent areas, they differ significantly. Berovo Valley, which is on higher altitude, has a climate formed under the influence of eastern continental and mountain climate of the neighbouring mountains, and the climate is considered to be moderate-cold-continental. The Delchevo Valley, which is at lower altitude and open through Istibanjska Gorge, has a climate type determined as moderately-warm-continental. The highest parts of the basin are considered to be with typical mountain climate. The basin has 2 meteorological stations (Berovo and Delchevo) and 14 pluviometric stations. For the zone above altitude of 1200 m, there are no measurements. Lithology of the research area is represented by various metamorphic (gneiss, mica-schist’s, schist’s), magmatic (granitites, gabro) and clastic sedimentary rocks, with variable erodibility. It is important that huge areas in the central part of the catchment (up to 1200 m of altitude), are composed by easily erodible Pliocene sands and sandstones – deposits from the Neogene lacoustrine phase in the Malesh and Pijanec basins. Soil pattern consist of various soil types, fluvisols, colluvial, various cambisol, regosol, lithosol, ranker etc. Generally, land cover in the upstream part of the basin is not favourable to develop high-intensity and widespread erosion processes. Unfavourable conditions on some location even cause extreme erosion processes. On the other hand, in the part closest to the reservoir Kalimanci, as a result of mass deforestation in the distant past, erosion processes are considered as highest in the country (Kojcevska [8]).

The catchment area is characterized with high-intensity erosion processes and the mean erosion coefficient (Z) is higher than average value in the country.

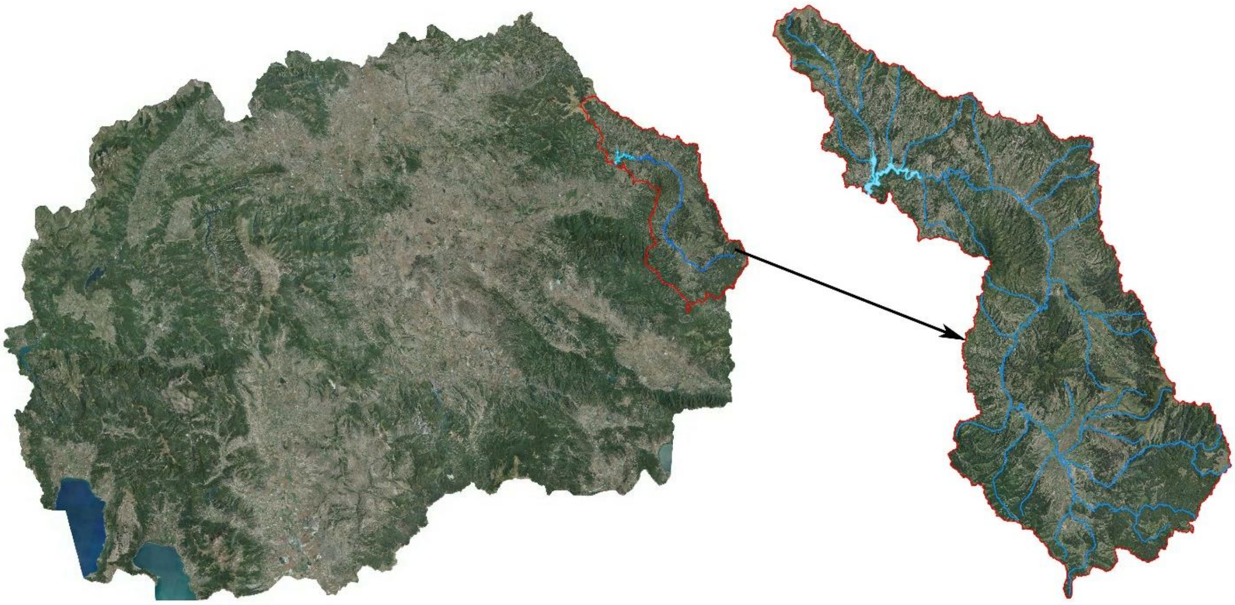

Figure 1. Location of the catchment of the reservoir Kalimanci

Collecting previous data about erosion intensity, reservoir siltation, other related data

Various data was collected from the previous related research as follow: Erosion Map of the Republic of Macedonia (Water Development Institute – 1993), data in Blinkov [1], Trendafilov and Blinkov 2002 [17], Milevski [9], Kojcevska [8], Mincev [10, 11], mainly data about the previous state of the reservoir and catchment, bathymetric data, statistical data, climatic data.

Modeling erosion intensity and sediment transport

For this purpose, we employed the Erosion Potential Method by Gavrilovic. According to several authors, EPM is the most appropriate method for estimation of off-site damage, especially total annual transported material to any reservoir and the most appropriate for hilly-mountainous and mountainous regions (Blinkov and Kostadinov [3], Trendafilov [16], Spalevic *et al.* [15], Mincev [10, 11]).

The old erosion map was created through direct on-field mapping and later calculation of the produced sediments using EPM, produced mostly in the 1980's and beginning of 1990's. Later, digital data were developed based on available maps, as follows: soil map, geological map, map of visible erosion processes, map of land cover/use, precipitation map, temperature map. Special attention was stressed on the development of the "Xa" factor, where as a base was used Land cover data from topographic maps 1:25.000. Further on, the land cover map was fine-tuned for forests and transitional woodland classes using manual photointerpretation of aerial photo images. This fine-tuning proved to be a game changer since it significantly improved the results of the erosion map. Beside this step also was added a layer with gullies as an extreme form of erosion. All these analyses were done in GIS environment.

$$G = T\ H\ p * Z^{1.5}\ Rn \quad [\ m^3/km^2/year]$$

$$Z = \gamma * Xa * (\varphi + J_{sr}^{0.5}) \tag{1}$$

where G – quantity of transported sediment, Z – erosion coefficient

Bathymetry

Bathymetry is the measurement of the depth of water in water bodies. Acoustic echo-sounding relies on accurate measurement of time and voltage. A sound pulse of known frequency and duration is transmitted into the water, and the time required for the pulse to travel to and from a target (e.g., a submerged object or the bottom of a water body) is measured.

The distance between sensor and target can be calculated using the following equation:

$$D = (S \times T) \tag{2}$$

where D = distance between sensor and target, S = speed of sound in water, and T = round-trip time.

To acquire information about the nature of the target, intensity and characteristics of the received signal are also measured. The echo-sounder has four major components: transducer, which transmits and receives the acoustic signal; signal generation computer, which creates the electrical pulse; the global positioning system, which provides precise latitude/longitude coordinates; and the control and logging computer. Prior to conducting a bathymetric survey, geospatial data (including geo-referenced aerial photography) of the target lake are acquired, and the lake boundary is digitized as a polygon shape file. Transect lines are predetermined based on project needs and reservoir size. Immediately before or after the bathymetric survey, elevation of the lake surface is determined [6].

For the purpose of this study, it was done an additional measurement of the sediment in order to estimate the rate of filling the reservoir with sediment. The measurements were done with Color GPS chartplotter and sounder GPSMAP 521s. This was the main echo-sounder used for the lake bathymetry. This is not a professional echosounder and it has poor output capabilities. It was checked for accuracy on the field and it showed good results. This model has the capability of dual frequency measurements for the measuring the bottom level and the compaction of the sediment.

The bathymetry of Kalimanci reservoir was done in executed in June 2013. Before measurement we selected the most appropriate approach, dependent on previously available data.

For the measurement of reservoir Kalimanci performed by Water Development Institute of the Republic of Macedonia (WDI) in the past, polygonal net was established and fixed cross profiles. Geodetic data for the profiles and “0-measuring” of the bottom before closing of the dam were obtained.

First, the maps and profiles were scanned and moderated or georeferenced. The profiles, further, in the appropriate GIS software were digitized and the surface of the transverse profile in the "zero state" was determined. On the other hand, from data of previous measurements of the sediment, the total quantities of deformed deposits were taken over time periods.

The recording of the reservoirs was carried out on the already established profiles by WDI in order to enable the temporal continuity of the recording and to have comparability of the data.

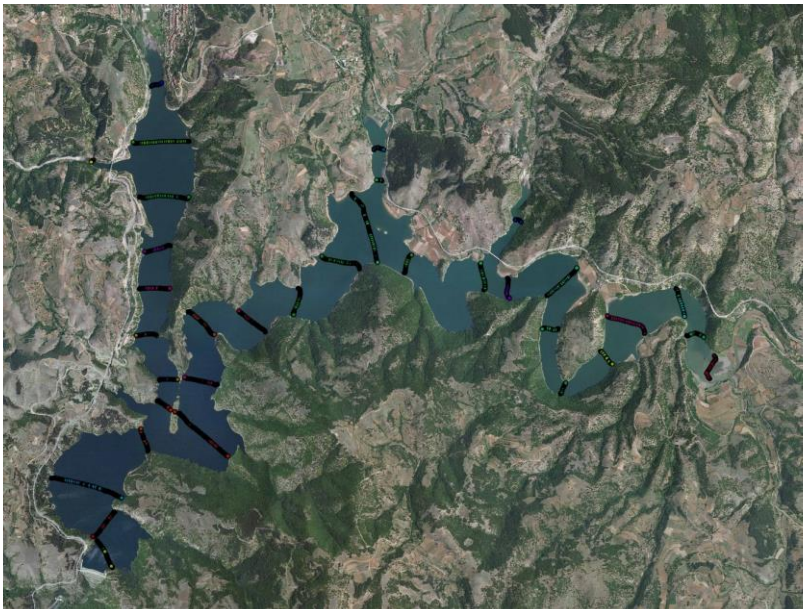

Figure 2. Position of measuring transect profiles on the reservoir "Kalimanci"

Calculation of deposed sediment

For further calculation we used the geodetic volumetric method using cross profiles. The volume of the total deposit is obtained as the product of the distances between the adjacent cross sections and the arithmetic mean of the surface of the coarser layer between two adjacent profiles). In the end, all these products are summarized and the total volume of settled deposits in one section of the reservoir is obtained. The same procedure is repeated for all tributaries of the accumulation and is summarized at the level of the reservoir.

Sedimentation Regime of the reservoir and lifespan analyses

For defining siltation regime in the case of Kalimanci reservoir, we used data from previous measurements and used an empirical curve that expresses the trend of siltation. To define variation of the siltation in various periods we analysed the following factors:

– change of climate parameters;

– migration processes and decrease of rural population;

– change of land use;

– the effects of erosion control;

– consolidation of the sediment (known phenomenon but is not researched in this study because of lack of equipment).

RESULTS AND DISCUSION

Erosion and sediment transport

The current erosion map was developed by modelling using the EPM method and the results were validated with bathymetric measurements of the reservoir from 2013. The Erosion map was developed during a period of 12–15 years with on-field mapping and the final map was published in 1993 but the data for the map show the state of erosion in the first half of the 1980's.

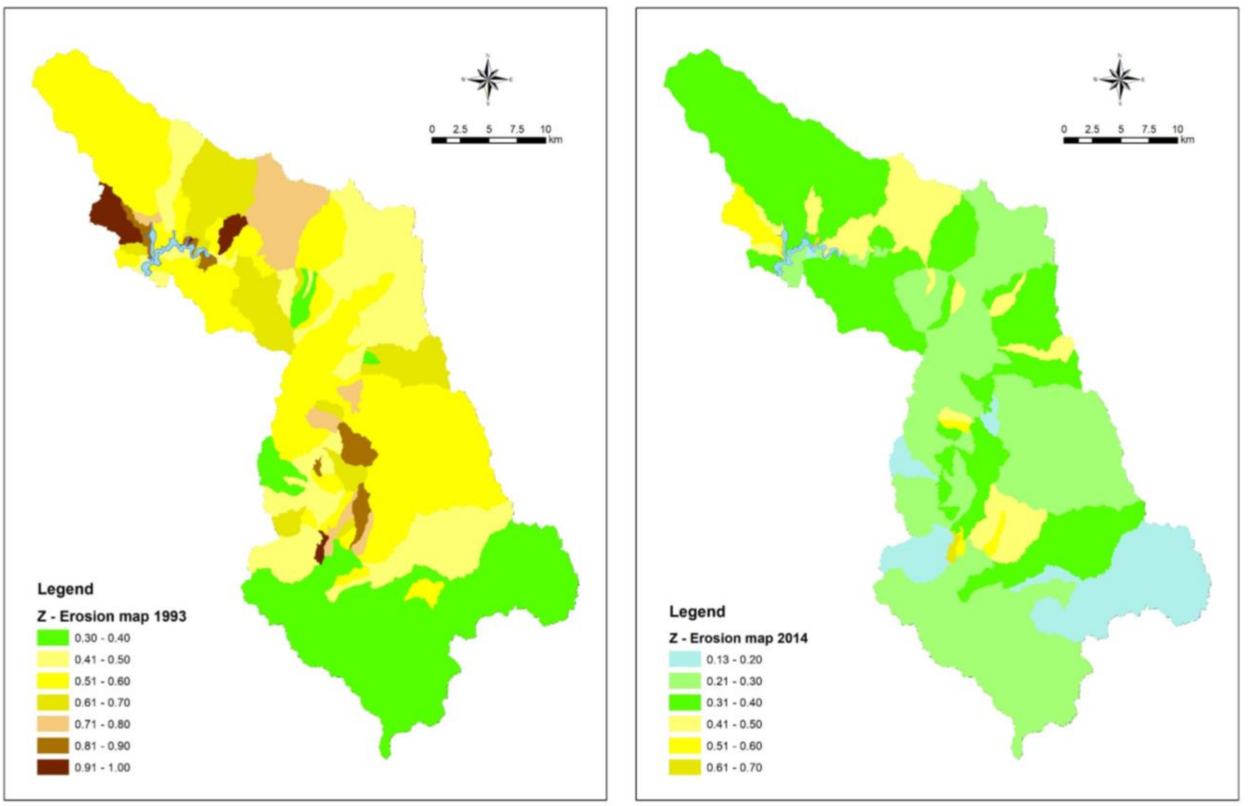

Figure 3. Change of erosion coefficient (1993 erosion map - 2014 erosion modeling)

The calculations for the coefficient "Z" were made by applying the previously calculated input coefficients at the level of the sub-catchment. Values at the level of sub-catchment for the reservoir "Kalimanci" range from 0.13 to 0.69 or averaged 0.36. For the catchment of the river Bregalnica "Z" is 0.33. This suggests that the river basin Bregalnica is less erosive than the other immediate tributaries of the Kalimanci reservoir (mean "Z" = 0.44). The average erosion coefficient in the erosion map of 1993 is 0.54 compared to the current state of 0.36.

The amount of transported sediment to the Kalimanci dam is 277.393 m^3 / year. It is estimated that 53% of the deposit or 146.404 m^3 / year is transported to the measured profile Ochipale on the river Bregalnica. This means that the remaining 47% of the total deposit comes from the immediate catchment of the reservoir or 130,989 m^3 / year [10].

Measured deposed sediment in the reservoir

The reservoir "Kalimanci" is designed at a total volume of 127 mil. m^3. Measurements in 2013 showed that the reservoir has 13.89 mil. m^3 deposits, or on average annually 315,682 m^3, or specific 278.13 m^3 / km^2 / year are deposited.

If Table 1 is analysed, it can be concluded that in the last measurement period 1997–2013 the annual deposited material is 136,319 m^3 / year, which is a considerable difference from the previous measurements.

Table 1. Volume of deposited sediment in the Kalimanci reservoir

No.	Year	Between two measurements	Cumulative	Mean Annually
		m^3	m^3	m^3/year
0	1969	/	/	/
1	1971	1,661,225	1,661,225	830,612.5
2	1972	258,075	1,919,300	258,075.0
3	1973	147,625	2,066,925	147,625.0
4	1975	2,210,590	4,129,890	1,105,295.0
5	1977	1,046,775	5,176,565	523,387.5
6	1978	323,225	5,499,790	323,225.0
7	1980	1,233,190	6,732,908	616,595.0
8	1984	749,9	7,482,880	187,475.0
9	1985	406,01	7,888,890	406,010.0
10	1991	1,514,690	9,403,580	252,448.3
11	1997	2,305,308	11,708,888	384,218.0
12	2013	2,181,112	13,890,000	136.319,5

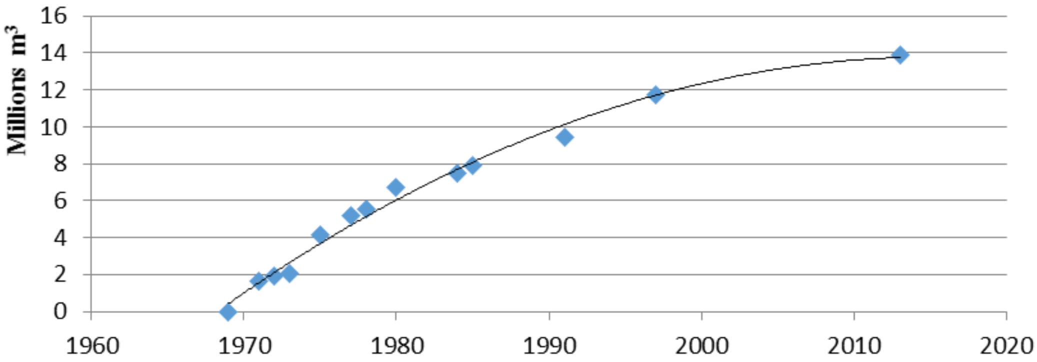

Figure 4. Rate of deposition of the Kalimanci reservoir (1969–2013)

Two periods can be deduced from the graph – 1969–1985 and 1986–2013. In the period 1969–1985, the average annual deposition in the reservoir is 493.055 m^3 / year, and in the period 1986–2013 the average annual deposition in the reservoir is 214.325 m^3 / year. In the first period the filling is more than double than in the second period.

When comparing the modelled erosion intensity from the Erosion map (mapped in the mid of 1980's) and mapped/modelled in 2013 show significant decrease of erosion intensity.

In the erosion map Z = 0.54, while current value is Z = 0.36.

What are reasons for this difference?

Several factors affect this phenomenon.

Change of climate parameters

From table 2, a decrease of annual rainfall by 2–12% and increase in temperatures by 0.5 to 1 °C is easily noticeable.

Table 2 Difference in precipitation and temperature for the periods 1971-1985 and 1986-2010

	Berovo	**Delchevo**	**Kochani**
	Precipitation		
1971-1985	638.1	580.8	546.3
1986-2010	603.3	563.8	478.5
decrease%	5.45	2.93	12.41
	Temperature		
1971-1985	8.4	10.1	13.0
1986-2010	9.0	10.0	14.0

Source: State hydro meteorological service

Migration processes

Migration processes and the decrement of the rural population during time (change of ratio of rural vs urban population from 76:24 in 1970, to 35:65 in 2010 [22, 23], also diminish the rural practices of the population such as deforestation, animal husbandry, agriculture.

Change of land use

Since the population in the rural area is missing, also the nature is going back to the abandoned agriculture land and pastures. So according to statistical data there is decrease of 3.056 ha arable land, decrease of bare land, and increase of forest for 14.250 ha and pastures for 9.856 ha; From this figures it can be seen that the pressure of the nature is diminished and all of the not used parcels are a new front for expanding natural areas [19–21].

Effects of erosion control measures

In the period after the building of the dam, according to Blinkov [1], in the catchment of the reservoir there are several bio-ameliorative erosion control measures undertaken. There are 1.544 cross objects built: 100 check dams, 64 thresholds, 1.308 stone rustically walls and other. Also, there are afforested 5.710 ha for the purpose of combating erosion.

All of these works had an immense effect of retention of erosive material in the upper catchments and after check dams and according to Trendafilov and Blinkov [2] approximately 1.5 million m^3 sediments were deposed behind check dams in Kamenicka River catchment. Over time, because of the diminished pressure of the local population they became even more effective, because after the afforestation there should be a period in which the forests will grow and forest cover will be closed.

Sediment consolidation and compaction in the reservoir

As mentioned in the beginning, the consolidation of the sediment has a big role in diminishing the volume of the deposited sediment and therefore it reduces the actual numbers of the bathymetry. Almost every time the modelled sediment transport has slightly larger numbers comparing with the actual measurements.

Lifespan analyses of the "Kalimanci" reservoir

The lifespan of any reservoir depends on: the bulk density of the deposited sediment, storage capacity, average annual suspended sediment load and the trapping efficiency. Trapping efficiency could be estimated using the Brune’s Curve that depends on a mechanical composition of the sediment (colloidal, fine grained sediments, primary highly flocculated and coarse-grained sediments) (Morris *et al*. [12]). In this study we used a modified approach because some of the data were missing.

Blinkov [1] presents high correlation between annual precipitation and high intensity precipitation with water discharge and with the sediment discharge.

Lifespan of the reservoir "Kalimanci" was calculated in 2 ways:

1. Using the current value of mean annual deposed sediment (Vann) for the period 1985–2013 corrected with the ratio (R) of mean annual sum of precipitation (P) and the precipitation for the period 1985–2013 (Pn).

$$R = P/Pn = 624/ 614 = 1.016287 \quad (3);$$

$$Vann = Vn *R = 214,000 * 1.016287 = 217,485 \text{ m}^3/\text{ann} \quad (4)$$

Up to 2013 from the total storage of 127 000 000 m^3, 13 890 000 m^3 are sediment i.e. free storage (Vf) is 113,110,000 m^3.

N = Vf / Vann = 113,110,000 / 217,485 = 520 years up to filling the reservoir storage (5)

2. Using precipitation as variable and creation correlation using cumulative values

The following equation was used:

$$Y = 355.01*x + 5,000,000 \quad (6)$$

where
Y – total deposed sediment into the reservoir – m^3
X – cumulative precipitation on meteorological station Berovo – mm

$$X = (113.110.000 – 5.000.000)/ 355 \quad (7)$$

i.e. X = 304.535 mm until full siltation
N – years until fulfilling the reservoir storage

$$N = X / P = 304,535 / 624 = 488 \text{ years} \quad (8)$$

Both approaches result in similar values (years until fulfilling the reservoir storage) 520 vs 488 years and that is much different than the first calculation based on the first erosion map and first measuring.

Although the lifespan of the reservoir is long there are 2 noticeable facts:

- Storage of the reservoirs is divided in "dead" storage (for Kalimanci reservoir it is 7 million m^3) and useful storage (120 million m^3). According to Trendafilov and Blinkov [17], there is a negative phenomenon in sedimentation regime i.e. 72.5% of the sediments are deposed in the useful storage.

- According to the engineering practice when the reservoir storage is 50% filled, then operation of the reservoirs is not effective.

It means that, in case of no significant changes of precipitation regime or land-use, practically the operation of this reservoir would be efficient for a maximum of 250 years.

But scenarios for climate changes are not favorable and continuation of erosion control works are recommended and the activities in agriculture and forestry sector should be sustainable with the aim of prolonging the efficient operation of the reservoir.

REFERENCES

[1] I. Blinkov (1998) Influence of precipitations on erosion intensity in the Bregalnica river catchment up to the profile “Dam Kalimanci” – Doctoral Thesis, Faculty of Forestry, UKIM, Skopje. (Блинков И. -1998) Влијание на врнежите врз интензитетот на ерозијата во сливот на р.Брегалница до профил брана „Калиманци“, докторска дисертација, Шумарски факултет – Скопје, УКИМ

[2] I. Blinkov, A. Trendafilov, I. Kaevski (2003), The role of the forests on the water and sediment discharge, *research project UKIM Forestry faculty Skopje.*

[3] I. Blinkov, S. Kostadinov, (2010), Applicability of various erosion risk assessment methods for engineering purposes, *BALWOIS conference 2010, Ohrid, Macedonia*

[4] F. E. Dendy, W. A. Champion, R. B. Wilson, (1973): Man-made lakes: Their problems and environmental effects, *in Reservoir sedimentation surveys in the United States. (pp. 349-357) edited by W. C. Ackerman, G. F. White, and E. B. Worthington, Geophysical Monograph No. 17, American Geophysical Union, Washington, D.C.*

[5] E. Hall Mark, (2010): Conducting simple sediment surveys using modern GPS, Sonar and GIS technology; *2nd Joint Federal Interagency Conference, Las Vegas, NV, June 27 - July 1, 2010,* http://acwi.gov/sos/pubs/2ndJFIC/Contents/P09_Hall_12_18_09_abstract-for-papers.pdf opened on 25.09.2014

[6] M. Jakubauskas, F. de Noyelles, (2008): Methods for assessing sedimentation in reservoirs, pp. 25, Book: Sedimentation in our reservoirs: Causes and Solutions, http://kars.ku.edu/media/astra/jakubauskas&denoyelles_methods.pdf, seen on 31.03.2015

[7] Joris de Vente, Jean Poesen & GertVerstraeten, (2000): Evaluation of reservoir sedimentation as a methodology for sediment yield assessment in the Mediterranean: challenges and limitations, *SCAPE-Soil conservation and protection for Europe;* http://eusoils.jrc.ec.europa.eu/projects/scape/uploads/107/Vente_etal.pdf - opened on 25.09.2014

[8] T. Kojchevska (2014) EPM for Soil Loss Estimation in Different Geomorphologic Conditions and Data Conversion by Using GIS, master thesis, Mediterranean Agronomic Institute of Chania.

[9] I. Milevski (2008) Estimation of soil erosion risk in the upper part of Bregalnica watershed – R. Macedonia, Based on digital elevation model and satellite imagery, 5th International conference on Geographic information system (ICGIS-2008), 2–5 July, 2008, Fatih University, Istanbul, Turkey.

[10] I. Mincev (2015) Development of methodology for determination of protection zones around water reservoirs from aspect of soil erosion and sediment transport, Doctoral thesis, UKIM Forestry faculty in Skopje.

[11] I. Mincev (2018): Measuring v.s modeling sediment, case study: Kalimanci reservoir, Soil and water resources protection in the changing environment, (pp. 88-100) Ed.: Miodrag Zlatic; Stanimir

Kostadinov; Schweizerbart and Borntraeger science publishers; *Advances in Geoecology, Volume 45*, ISBN 978-3-510-65418-5.

[12] G. L. Morris, G. Annandale, R. Hotchkiss, (2007): Sedimentation engineering: processes, management, modeling, and practice*; in Reservoir Sedimentation (Chapter 12) edited by Marcelo H. Garcia; prepared by the ASCE Task Committee for the Preparation of the Manual on Sedimentation of the Sedimentation Committee of the Hydraulics Division, Published by American Society of Civil Engineers*, ISBN–13: 978–0–7844–0814–8 (pp. 579-612).

[13] B. N. Murthy, (1977): Life of reservoir, *Central Board of Irrigation and Power, New Delhi.*

[14] S. Nikitina, L. Reinhold, Angulo, Jenckins, Lebedev, Mcnef, (2011): Assessing the Lifespans of Reservoirs in Region 2 of Puerto Rico May 5, http://www.wpi.edu/Pubs/E-project/Available/E-project-050411-154137 /unrestricted/ Assessing_the_Lifespans_of_Reservoirs_in_Region_2_of_Puerto_Rico_ WPI_11.pdf - opened on 25.09.2014.

[15] V. Spalevic, I. Blinkov, A. Trendafilov, D. Mukaetov, V. Djekovic, N. Djurovic, (2015) Soil erosion assessment using the EPM method: a case study of the Ramcina river basin, Montenegro. *International conference on soil, Tirana, Albania, 4-6 May 2015.*

[16] A. Trendafilov, (1995): Erosion in the catchment of Crna Reka and sedimentation of the reservoir “Tikves”, *PhD thesis, University “Ss. Cyril and Methodius” – Skopje, Forestry faculty – Skopje.*

[17] A. Trendafilov, I. Blinkov, (2002): Granulometry and consolidation in few reservoirs in the Republic of Macedonia, International Conference «Erosion and torrent control as a factor in sustainable river basin management» 25-28 September 2007, Belgrade/Serbia.

[18] W. R. White (2001): Evacuation of Sediments from Reservoirs, *London: Thomas Telford.*

[19] Statistical review for the sector: Agriculture, 2011, Agronomy, animal husbandry and viniculture, *State statistical office of RM.*

[20] Regional Spatial plan of Eastern Macedonia, 1981, Institute for spatial planning – Ohrid.

[21] Forestry GIS layers, Public enterprise “Macedonian forests”.

[22] M. Panov, G. Milevski, (1980) Geographical position. Malesh and Pijanec, II, *MANU*, Skopje.

[23] Statistical gazette, 2013, *State statistical office of RM.*

ЗАПОЛНУВАЊЕ СО НАНОСЕН МАТЕРИЈАЛ И АНАЛИЗИ НА ЖИВОТНИОТ ВЕК НА АКУМУЛАЦИЈАТА „КАЛИМАНЦИ“

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Ерозијата и заполнување на акумулациите со наносен материјал е еден од главните проблеми за намалување на животниот век на акумулацијата со големи еколошки и економски импликации. Заполнувањето на акумулацијата, исто така, обезбедува информации за интензитетот на ерозија и транспортот на нанос во рамките на сливот и може да послужи како контрола за ерозивни модели. Со појавата на глобалниот навигациски сателитски систем (ГНСС), батиметриското мерење на наносот во акумулациите стана многу полесно. Мерењата направени со ехосондер со ГНСС-поддршка се прават многу побрзо со зголемена точност. Интересот на оваа студија е акумулацијата „Калиманци“. Изграден е во 1969 година и досега има 13 батиметриски мерења и затоа е идеален за испитување на интензитетот на таложење. Може да се издвојат два периода на таложење, со гранична точка во средината на 1980-тите години. Во првиот период, просечниот годишен транспорт на нанос во акумулацијата е 493.055 m3/г., а во вториот период просечниот годишен транспорт на нанос во акумулацијата е 214.325 m3/г. Стапката на таложење е намалена повеќе од двојно.

Клучни зборови: водна акумулација; транспорт на нанос; батиметрија; почвена ерозија; животен век