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Prediction discharge hydrograph due to dam failure by a two-dimensional shallow flow model.

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Abstract

The paper is dedicated to study of problem of dam break simulation, which must be used for estimation of life safety. Finite Volume Method (FVM) is applied to solve two Dimensional Shallow Water Equations (2D SWE) on structured mesh. Flux difference splitting method is utilized to construct numerical solvers of SWE. Besides, semi implicit method is used to solve the friction source term. The effectiveness and robustness of the above scheme is verified by some reference tests to handle the main challenges involved in the numerical simulation, such as: capturing discontinuities in the flow field without spurious oscillations, satisfying C-property and robust tracking of wet/dry fronts. A well-known test case Malpasset (France) and a case study of Thuong Tien reservoir - Hoa Binh province (Vietnam) are implemented to simulate flood hydrographs of dam collapsed scenarios.

Keywords: Finite Volume Method, Roe scheme; Discharge hydrograph

1. INTRODUCTION

Construction dams and reservoirs with several purposes, such as: hydroelectric production, water storage for consumption or irrigation, flood mitigation, etc. has been an important issue of water resources management in many countries. Along these benefits, however, dams pose serious flooding risks for downstream area if they collapse. The real case studies, such as: Gleno, Italy (1923); Malpasset, France (1959), etc caused many dead and catastrophic consequences are remarkable examples when dam collapsed. Thus, the estimation of the flood wave due to the breaking of a dam, for instant: outflow hydrograph, maximum water depth, flood arrival time is an important requirement to build an early-warning tool for downstream area. Especially, breach hydrograph is considered as a necessary input data to compute flood propagation to downstream valley. In this paper, the most applicable numerical method, Finite Volume Method (FVM) [11] is implemented to simulate it.

FVM is considered as the most applied numerical strategy to simulate most complicated shallow water flow phenomena, for instant: transcritical and supercritical flows; discontinuous type flow or moving wet/dry front, etc. The effectiveness and robustness of the presented scheme are demonstrated by comparing numerical results with analytical solutions of the reference test cases, indicating good application aspects [7]. Then, a well-known test case Malpasset (France) is applied to obtain outflow hydrograph and flooding map and a case study of Thuong Tien reservoir - Hoa Binh province (Vietnam) are implemented to simulate flood hydrographs of dam break scenarios.

2. NUMERICAL MODEL

2.1. Governing mathematical scheme.

The conservation form of 2D SWE can be written as (Cung et al, 1980) [5]:

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{F}(\mathbf{U})}{\partial x} + \frac{\partial \mathbf{G}(\mathbf{U})}{\partial y} = \mathbf{S}(\mathbf{U}) \quad (1)$$

Where: $\mathbf{U} = \begin{bmatrix} h \\ hu \\ hv \end{bmatrix}$; $\mathbf{F}(\mathbf{U}) = \begin{bmatrix} hu \\ hu^2 + 0.5gh^2 \\ huv \end{bmatrix}$; $\mathbf{G}(\mathbf{U}) = \begin{bmatrix} hv \\ huv \\ hv^2 + 0.5gh^2 \end{bmatrix}$; $\mathbf{S}(\mathbf{U}) = \begin{bmatrix} 0 \\ gh(S_{0x} - S_{fx}) \\ gh(S_{0y} - S_{fy}) \end{bmatrix}$

$$S_{0x} = -\frac{\partial z_b}{\partial x};\ S_{0y} = -\frac{\partial z_b}{\partial y};\ S_{fx} = \frac{n^2 u\sqrt{u^2+v^2}}{h^{4/3}};\ S_{fy} = \frac{n^2 v\sqrt{u^2+v^2}}{h^{4/3}}$$

U is the vector of conserved variables; **F** and **G** are flux vectors and **S** is source term accounting for bed slope term and friction term. x, y are orthogonal space coordinates on a horizontal plane and t is the time; h and z_b are water depth and bottom elevation; u, v are velocity components along x- and y- directions; S_{0x}, S_{0y}, S_{fx}, S_{fy} are bed slopes and friction slopes along the same directions; n is Manning roughness coefficient; g is gravity acceleration.

Based on Godunov type scheme, the flow variables are updated to a new time step by using the following equation:

$$\mathbf{U}_{i,j}^{n+1} = \mathbf{U}_{i,j}^{n} - \frac{\Delta t}{\Delta x}\left[\mathbf{F}_{i+1/2,j} - \mathbf{F}_{i-1/2,j}\right] - \frac{\Delta t}{\Delta y}\left[\mathbf{G}_{i,j+1/2} - \mathbf{G}_{i,j-1/2}\right] + \Delta t\mathbf{S}_{i,j} \quad (2)$$

where superscripts denote time levels; subscripts i and j are space indices along x- and y- directions; Δt, Δx, Δy are time step and space sizes of the computational cell.

Jha et al. (1995) and Hubbard and Garcia-Navarro (2000) [6] proposed Flux Difference Splitting Method to construct numerical solvers of SWE. The discretisation is performed in a manner which retains an exact balance between flux gradients and source terms; Roe scheme is used to approximate flux term (Roe, 1981) [10].

Considering the flux vector **F** in x direction and its Jacobian matrix A, a matrix K can be constructed to diagonalize the Jacobian A:

$$\mathbf{A} = \mathbf{K}\Lambda\mathbf{K}^{-1} \tag{3}$$

where Λ is a diagonal matrix with eigenvalues of matrix A in the main diagonal:

$$\mathbf{\Lambda} = \begin{pmatrix} u-c & 0 & 0 \\ 0 & u & 0 \\ 0 & 0 & u+c \end{pmatrix} \tag{4}$$

The matrix **K**, whose columns are the right eigenvectors has the form:

$$\mathbf{K} = \begin{pmatrix} 1 & 0 & 1 \\ u-c & 0 & u+c \\ v & c & v \end{pmatrix} \tag{5}$$

The matrix $\mathbf{\Lambda}$ can be splitted in the form $\mathbf{\Lambda} = \mathbf{\Lambda}^{+} + \mathbf{\Lambda}^{-}$, where $\mathbf{\Lambda}^{\pm} = \left(\mathbf{\Lambda} \pm |\mathbf{\Lambda}|\right)/2$, so that the Jacobian matrix A can be rewritten as:

$$\mathbf{A} = \mathbf{K}(\mathbf{\Lambda}^{+} + \mathbf{\Lambda}^{-})\mathbf{K}^{-1} \tag{6}$$

In the general case, the matrices $\mathbf{\Lambda}$ and **K** can be constructed using the eigenvalues and eigenvectors of J_n and introducing Roe averaging procedure; in this way the difference of the flux vector across the edge of a cell can be expressed as

$$\Delta(\mathbf{E}\cdot\mathbf{n}) = \tilde{\mathbf{K}}(\tilde{\mathbf{\Lambda}}^{+} + \tilde{\mathbf{\Lambda}}^{-})\tilde{\mathbf{K}}^{-1}\Delta\mathbf{U}, \tag{7}$$

that represents the splitting of flux gradient in left and right travelling parts; the notation '~' denotes Roe-averaged quantities [8], calculated in terms of mean velocities and celerities, defined as:

$$\begin{gathered} \tilde{u} = \frac{\sqrt{h_R}\,u_R + \sqrt{h_L}\,u_L}{\sqrt{h_R} + \sqrt{h_L}}, \quad \tilde{v} = \frac{\sqrt{h_R}\,v_R + \sqrt{h_L}\,v_L}{\sqrt{h_R} + \sqrt{h_L}} \\ \tilde{c} = \sqrt{g\tilde{h}}, \quad \tilde{h} = \frac{1}{2}(h_R + h_L) \end{gathered} \tag{8}$$

2.2. Stability condition, friction term and wet/dry treatment.

The stability condition for the numerical scheme described in section 2.1 is governed by the Courant–Fredrichs–Lewy (CFL) criterion, controlling the time step Δt at each time level. For Cartesian grids, CFL stability condition is given by Eq. 9:

$$\Delta t = Cr\left[\max\left(\frac{|\tilde{u}| + \sqrt{g\tilde{h}}}{\Delta x} + \frac{|\tilde{v}| + \sqrt{g\tilde{h}}}{\Delta y}\right)\right]^{-1} \tag{9}$$

where Cr is the Courant number specified in the range $0 < Cr \leq 1.0$.

To avoid unphysical flow inversion, friction term is discretized in a semi-implicit manner with the parameter θ is set equal to 0.5:

$$\begin{aligned} S^*_{fx} &= (1-\theta)(ghS_{fx})^n + \theta(ghS_{fx})^{n+1} \\ S^*_{fy} &= (1-\theta)(ghS_{fy})^n + \theta(ghS_{fy})^{n+1} \end{aligned} \qquad (10)$$

Preservation of C-property for the cells with wet-dry interfaces can be guaranteed by the local modification technique introduced by Hubbard and Garcia-Navarro [5] (2010).

The selected numerical model is written by Fortran90 and validated it with several test cases Le. (2014). Three tests with irregular topography are chosen in the following part in order to show the robustness and effectiveness of the proposed model.

3. VALIDATION

3.1. Preservation of still water surface

C-property is considered as one of the most important requirements that the numerical scheme should be satisfied. According to Bermudez et al. (1994) [2], it means that for hydrostatic condition water elevation remains constant and discharge value equals zero during computational time. An interesting test is described in Singh et al. (2011) [12] to verify well balancing property of proposed schemes. The computational domain is 50m long. Reflecting condition is imposed at both upstream and downstream ends.

The bottom elevation is defined by the following expression:

$$z_b(x) = \begin{cases} -0.0513x + 4 & \text{if} \quad 0 \le x \le 15\text{m} \\ -0.0762x^2 + 3.2108x - 27.766 & \text{if} \quad 15\text{m} \le x \le 29\text{m}, \\ 0.4824x - 14.472 & \text{otherwise} \end{cases} \qquad (11)$$

Two cases for initial water elevation are considered: Case 1: H = 10*m*, bottom is fully submerged accordingly to Singh's work; Case 2: H = 5*m*, bed is partly submerged. A uniform grid size $\Delta x = 0.5m$ is used for the simulation.

The results shown in Fig.1 were obtained by the proposed scheme. The numerical solution of water elevation remains at 10m and 5.0m and unit discharge is exactly equal to $0.0 m^2/s$ during the computational time. Thus, the presented models satisfy exact C-property.

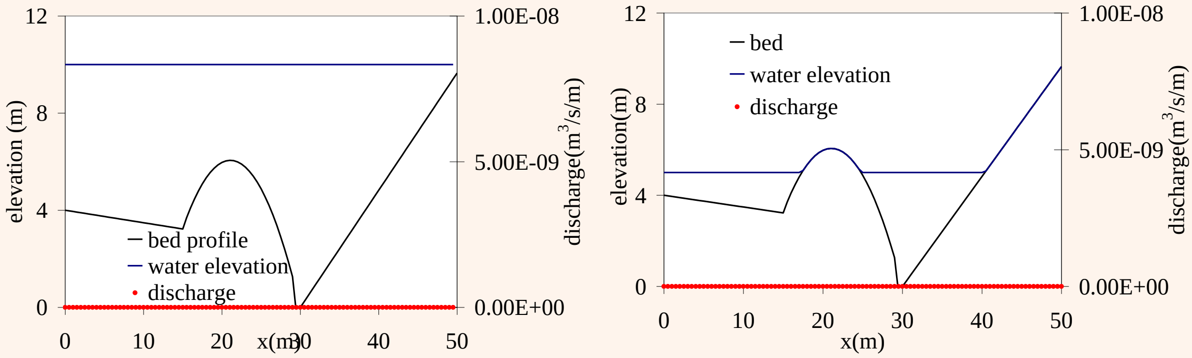

Figure 1: *Still water.*

3.2. Evolution of shorelines over a frictional parabolic topography

This interesting test allows verifying the behavior of the numerical model in dealing with bed slope and friction source terms as well as wetting and drying. The domain topography is defined by:

$$z_b(x) = h_0 (x/a)^2 \qquad 12)$$

where: h_0 and a are constants. The analytical solution is originally presented by Sampson et al., (2006) [11] and later by Liang (2009) [7]; Song et al., [13] (2011) depending on a bed friction parameter τ and a hump amplitude parameter $p = \sqrt{8gh_0/a^2}$. In this case, friction term is calculated by the equation: $S_f = -\tau \cdot h \cdot u$.

The numerical simulation is performed on a domain 10000m long. No boundary conditions are necessary because the flow never reaches the boundaries. For the case with $\tau < p$, the initial conditions of water elevation and velocity are imposed by:

$$\eta(x,0) = \max\left(z_b(x);\quad h_0 + \frac{a^2B^2e^{-\tau t}}{8g^2h_0}\left(\tau^2/4 - s^2\right) - \frac{B^2e^{-\tau t}}{4g} - \frac{e^{-\tau t/2}}{g}(Bs)x \right) \qquad (13)$$
$$u(x,0) = 0$$

And the analytical time history of the water surface elevation is:

$$\eta(x,t) = h_0 + \frac{a^2B^2e^{-\tau t}}{8g^2h_0}\left(-s\tau\sin 2s + \left(\tau^2/4 - s^2\right)\cos 2st\right) - \frac{B^2e^{-\tau t}}{4g} - \frac{e^{-\tau t/2}}{g}\left(Bs\cos st + \frac{\tau B}{2}\sin st\right)x \qquad 14)$$

where: parameter B is a constant and $s = \sqrt{p^2 - \tau^2}/2$.

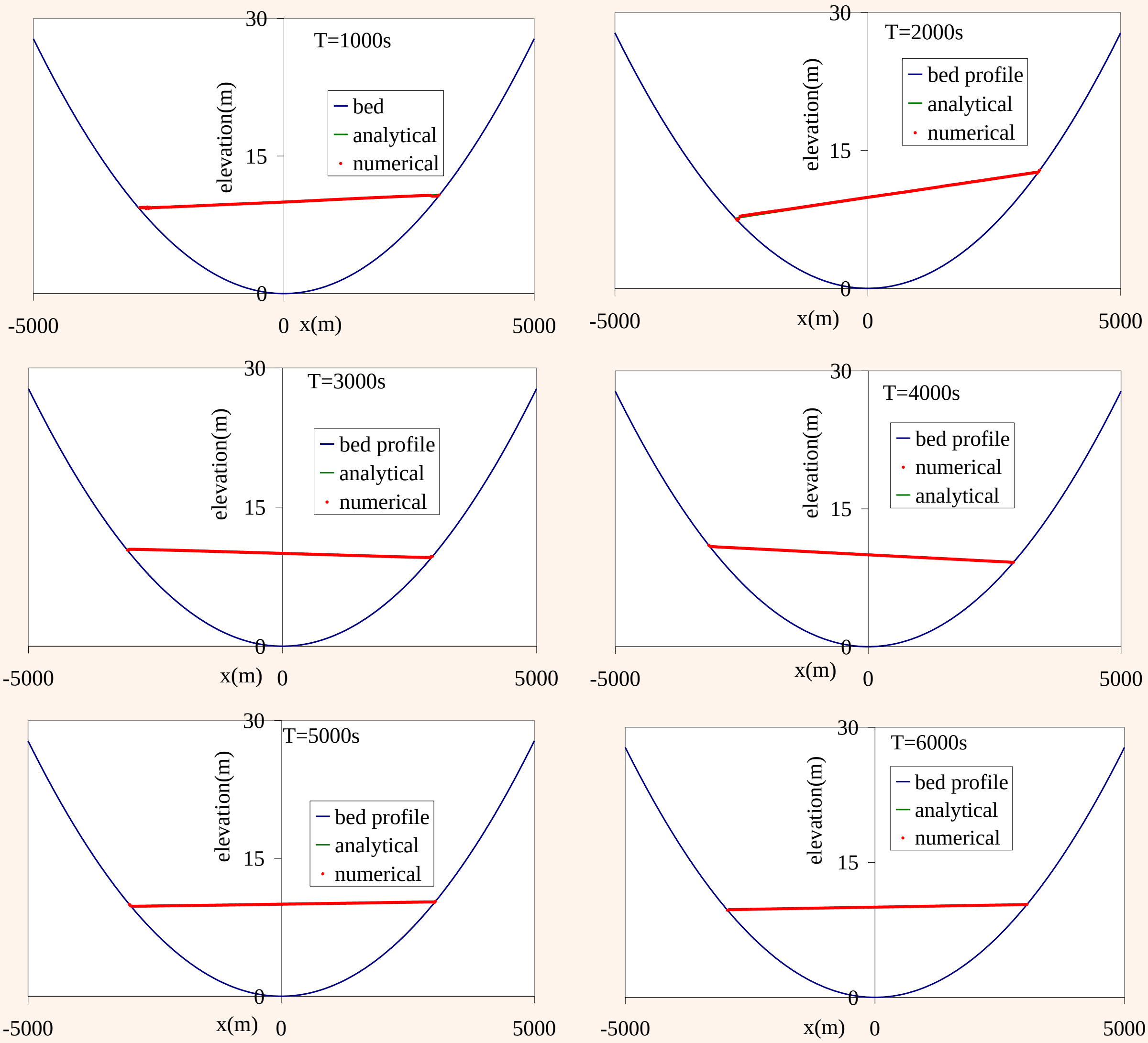

Figure 2: *Sloshing motions in a vessel with parabolic bottom topography.*

The relevant coefficients are selected as: a = 3000m, h_0 = 10m, τ = 0.001s^{-1} and B = 5m/s. Numerical time simulation of 6000s is taken the same as Song et al. (2011).

Fig. 2 shows the predicted water surface elevation obtained by Roe scheme [10] at difference output times on a uniform grid with 400 cells. Excellent agreement is observed between numerical predictions and analytical solutions. The wet/dry interfaces are correctly reproduced, thus validating the well-balanced wetting and drying algorithm.

4. APPLICATION

4.1. Malpasset test case.

In order to validate the capability of the presented model in simulating dam break flows referring to field-scale case studies, the well-known test case of Malpasset (France) is taken as a reference test. Actually, observed data as well as experimental results obtained by physical modeling are available for this dam break event. Malpasset case study, had a 66.5*m* high arch dam with a crest length of 233*m* and the maximum reservoir capacity of $55\times10^6 m^3$. The dam failure occurred during the night of 2nd December 1959 because of heavy rain in the preceding days. A total of 433 casualties were reported.

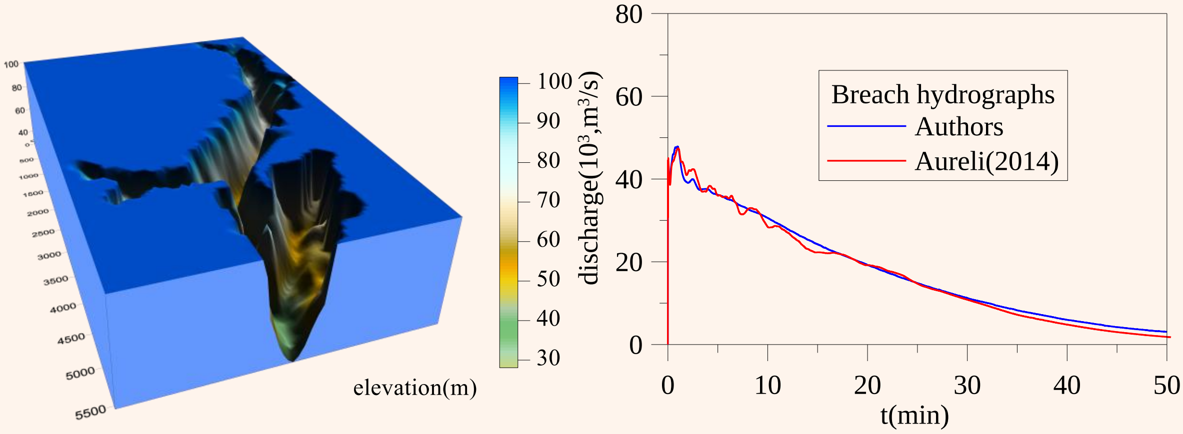

Figure 3. *a) Bed geometry of Malpasset reservoir; b) Breach hydrograph of total dam break.*

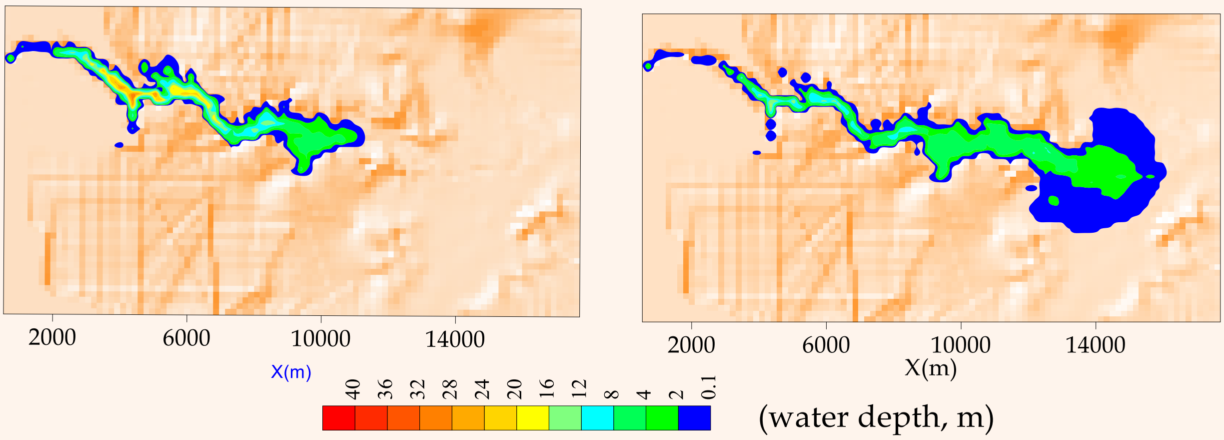

Figure 4. *Flooding maps at different times: t = 1000 s and t = 2400 s.*

The numerical model was applied to compute the discharge hydrograph at dam site, allowing a comparison with the result published by Aureli et al., (2014). For this purpose, a computational domain of regular grid size 10*m*×10*m* was used (Fig. 3a). A close agreement between predicted solution of breach hydrograph simulated by FDS method and the numerical result in Aureli's work is obtained [1]. On the other hand, the peak discharge predicted by the numerical model is about $48000 m^3/s$ and is fairly close to the estimation of $45000 m^3/s$ assumed by the CADAM workgroup. Furthermore, the flooding maps at different time can be generated by this present scheme (Fig. 4). In comparison with other works, such as Huang et al, (2013), a good agreement can be observed.

4.2.Thuong Tien dam break scenario

Thuong Tien reservoir constructed by Vietnam Hydraulic Engineering Consultants Corporation (HEC) is located in Boi River in Kim Boi district – Hoa Binh province (Fig. 5a). Its responsibility is to irrigate 1300ha of agricultural area and supply water to 20000 inhabitants. Thus, it plays an important role on the economic development of this province. However, the total storage capacity of Thuong Tien reservoir of $13.31*10^6 m^3$ can cause potential catastrophic consequences for downstream area if its dam collapses. Therefore, simulating dam break flood propagation should be considered to build early warning scenarios for downstream area of reservoir if Thuong Tien dam breaks.

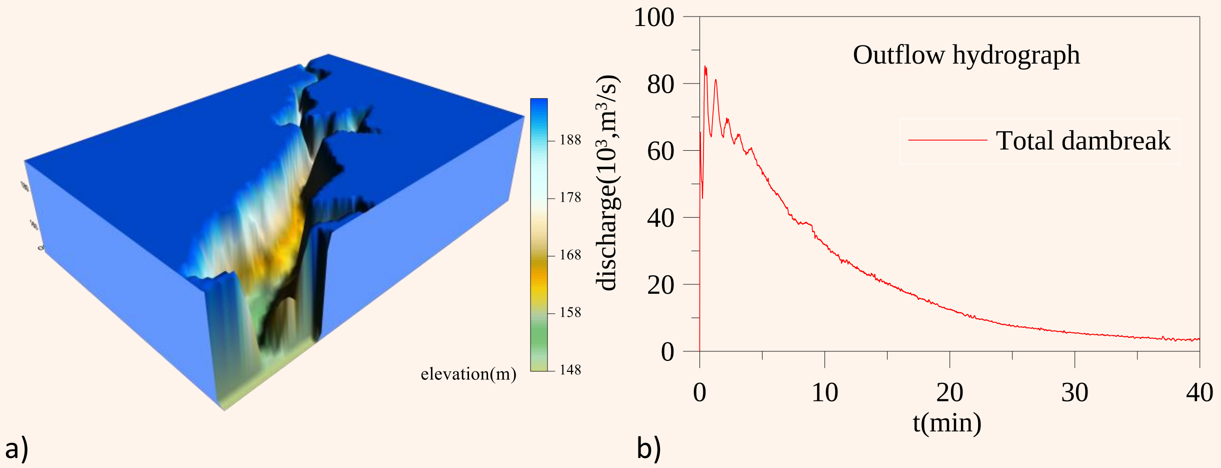

Figure 5. *a)Bed geometry of Thuong Tien reservoir; b) Breach hydrograph of total dam break scenario.*

In this work, the most dangerous hypotheses are set up: extreme water elevation in upstream is +194.22m. Water depth at downstream is set to equal zero and the total dam collapses instantaneously.

According to (Fig. 5b), the peak of discharge is around 85000 m^3/s and emptying time is around 40 minutes in case of total dam break scenario, This hydrograph can be used as input data for hydraulic simulation of flood propagation in downstream from reservoir, if geometry of downstream area is available. Moreover, we can use this data to assess the impact of the floods on the lives of people in downstream area. Since then propose measures to ensure life safety if the dam break incident occurs.

5. CONCLUSIONS

The estimation hydraulic characteristic such as outflow hydrograph, flooding map, etc. is necessary for building early warning scenarios for downstream area if dam of reservoir breaks. In this work, FVM is selected to generated a model to deal with this purpose. By two tests with uneven bed presented in this paper, the scheme demonstrated to behave satisfactorily with respect to their effectiveness and robustness in simulating complex flows on irregular topographies. A real case study of Malpasset (France) is simulated to obtain outflow hydrograph and flooding map. The numerical solutions are quite close with others in different works. Then, Thuong Tien reservoir (Vietnam) is utilized to generate the breach hydrographs of total dam collapse. In further study, if geometry of its downstream is available, the flooding map will be generated.

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Decreasing of the flowering blue-green algae of water reservoir with help of flow regulation.

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Abstract

The article is devoted to river flow regulation by water reservoir with consideration the flowering of blue-green algae in surface waters. Different variants of flow regulation are researched during summer when is observed intensive flowering of blue-green algae. It is proved that there is possibility to increase water exchange of surface water mass and to create conditions for decreasing flowering of blue-green algae of without reduce of water consumption.

Key words: water reservoir, runoff, flow regulation, blue-green algae.

Introduction

Last decades there is intensive development of blue-green algae (cyanobacteria) on water surface of reservoirs, lakes and ponds in the whole world. Intensive development of cyanobacteria changes the color of the water, reduces water clarity, degrades its organoleptic indicators, leads to a shortage of dissolved oxygen in the water, creates a significant obstacle for drinking and industrial water supply, worsens the conditions of operation of thermal station and hydroelectric power plants, reduce recreational quality of the reservoir [3,4,5,6]. Vast biomass of cyanobacteria dies off after the flowering period and then they highlight in the water the intracellular toxic substances and pigments.

Some countries have state programs for the study of toxic algal blooms, there are special centers for study and monitoring flowering cyanobacteria. In spite of the researches - the degree of influence various factors in respect to intensity of water flowering has not been defined fully. Moreover, the factors may differ significantly relative to different regions. However, we can influence on some factors with help of flow regulation by water reservoir, in particularly, on flow rate in water reservoir and on temperature of the water on the surface. We can influence these factors through flow regulation. The increasing of water drafts through dam spillway of water reservoir will increase the speed of movement of surface water masses, where their temperature will become less. Accordingly, conditions for water flowering will worsen and else part of blue-green algae will go out through spillway. Before such possibility was demonstrated with help of use flood capacity of water reservoirs [1, 9] however it is may be obtained without use flood capacity but with help short-time forecasts for rain runoff.

Object of the study

Ruzskoe water reservoir is located on west of Moscow region, it is formed of run-of-river dam - a structure of the first class. The reservoir is part of the Moskvoretskaya water system and has been operational since 1966. Main river, which inflows to the water reservoir is Ruza. Length of the river is 145 km, the catchment area of the water reservoir 1900 km^2. The average annual water flow near the town of Ruza — 13,1 m^3/s [2].

Moskvoretsky system consists of 5 reservoirs, it is designed for drinking water supply of Moscow and Moscow region. Therefore, the quality of their water (in particular, flowering water masses) is of particular relevance.

Aim and problems

Aim: to explore the possibility of decreasing of blue-green algae flowering in the reservoir with help of flow regulation.

Problems:

- to study the mode flowering in reservoirs Moskvoretsky system;

- to compare the mode of flowering with the mode of the inflow to the Ruzsky reservoir;

- to assess the degree of water exchange of useful capacity of the reservoir in the summer period with different variants of flow regulation;

- to select variant the flow regulation by the reservoir, which most prevents algae flowering, but not decreases water availability of the main water user.

Methods and materials

The research [3, 5] have showed that the Ruzsky reservoir has the most intensive process of flowering, this fact is explained by the exceptionally small rate of water exchange in the reservoir and by significant temperature in the shallows.

Research [3] has allowed obtain the distribution of amount of phytoplankton (Fig.1) according to decades (ten days) during summer.

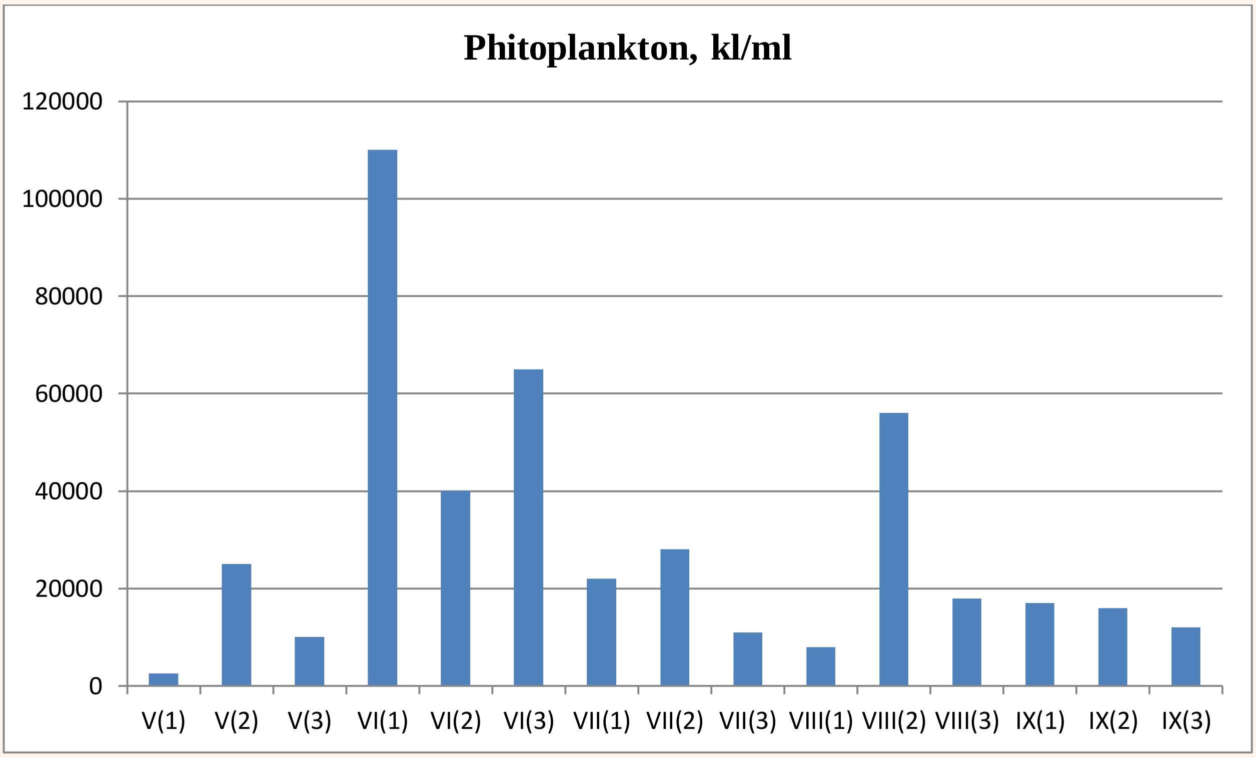

Fig. 1. Diagram of quantity distribution of phytoplankton from May to September on the Ruza reservoir.

We can see (figure 1) that the largest number of blue-green algae accounts for the month of June with the highest peak in the first decade, the second maximum is observed in the second half of August. Such a distribution of the number of blue-green algae and the intensity of flowering is fairly typical for water bodies of the

Northern hemisphere of the world [4, 5]. Here we should notice that total mass of phytoplankton contains 60% of blue-green algae usually [4].

The schedule of inflow to the reservoir of the probability of exceeding (P= 50%) is represented on figure 2.

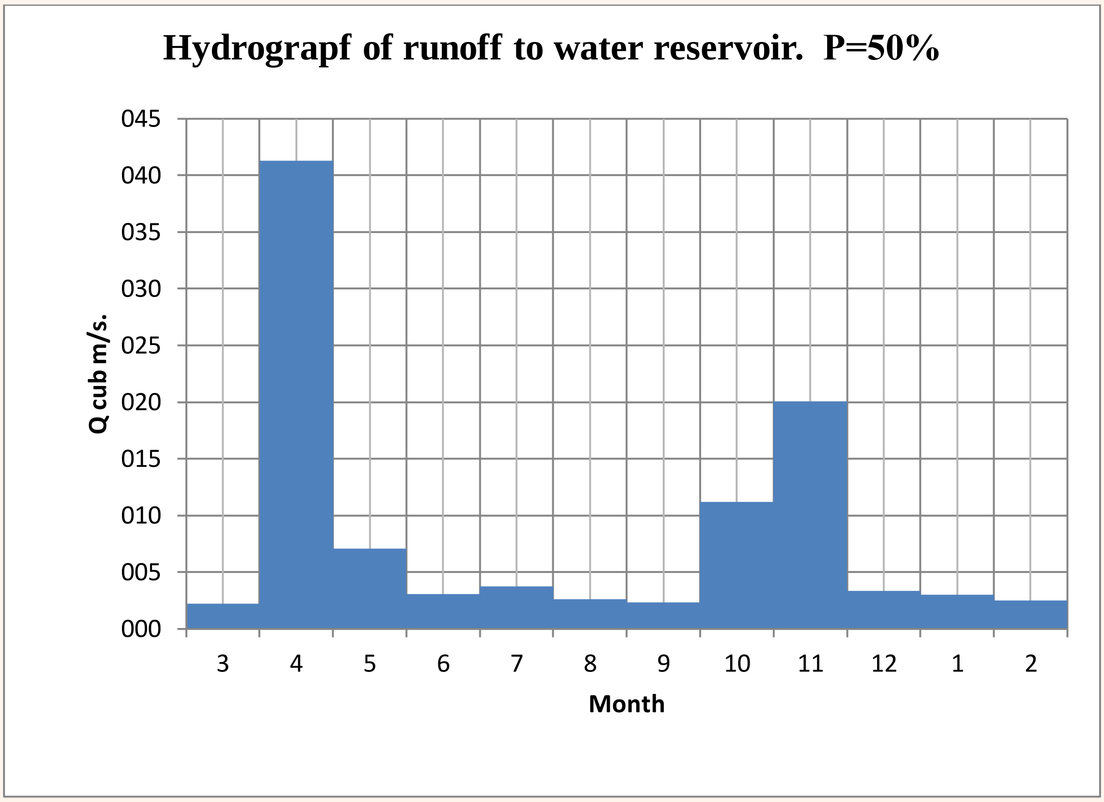

Figure 2. Schedule of runoff to the reservoir.

Comparison charts of the phytoplankton development and distribution of water flow to water reservoir is showing that maximum flowering coincides with limited runoff. However, small short torrential rains have place during these periods (especially during June) when the inflow to the reservoir is increased. So we have possibility to do flow regulation with consideration of runoff forecast.

Currently, the flow regulation is performed without taking into account short-term forecast of runoff to the reservoir in accordance with the dispatching schedule only. However, the inclusion of short-term forecasts gives opportunity to increase the water exchange in the reservoir in the summer period due to additional drafts into the downstream, which provides increased speed of surface water masses and thereby reduces the intensity of algal blooms.

The proposed approach to the flow regulation has required changes logical conditions of runoff control within the traditional solutions [7] of the basic balance equation available water resources reservoir for the current time interval (1), which was adopted equal to one decade (ten days):

$$V\textit{к}_{\textit{ф}} = V\textit{н} + W - U - S, \tag{1}$$

where:

*V*н – the initial volume to every interval;

Vкф – "fictive" volume at the end of the interval (without restriction by volume);

W – runoff during time interval;

U (Vк) –the water consumption during the time interval;

S – the possible water discharge (without use) in the case of excess water, or deficit in case of small volume of reservoir.

Usually this equation was used in the traditional rules of utilization of the available water resources of the reservoir in accordance with the dispatching schedule [7,9].

So, the equation (1) was solved in the framework of the model of runoff regulation of the Ruzsky reservoir with a 10-day (decadal) interval. Data observation (duration 90 years) of runoff to the water reservoir has served for modeling.

At first traditional variant (variant 1) of runoff regulation was used for the estimation of the frequency and total volume (during 90 years of model) of drafts through spillway during summer.

The second variant (Variant 2) of runoff regulation was modeled with imitation of the forecast runoff to water reservoir. Accordingly, the preliminary drafts through spillway were made before peak of the rain flood. Such preliminary drafts were started if the forecast value of runoff exceeded twice norm of water consumption.

Accordingly, the frequency drafts through spillway and their summary values relative to the time interval (ten days) during 90 years are shown on the graphs relative to both of the model variants of runoff regulation by Ruzskoe water reservoir (fig. 3 and fig. 4).

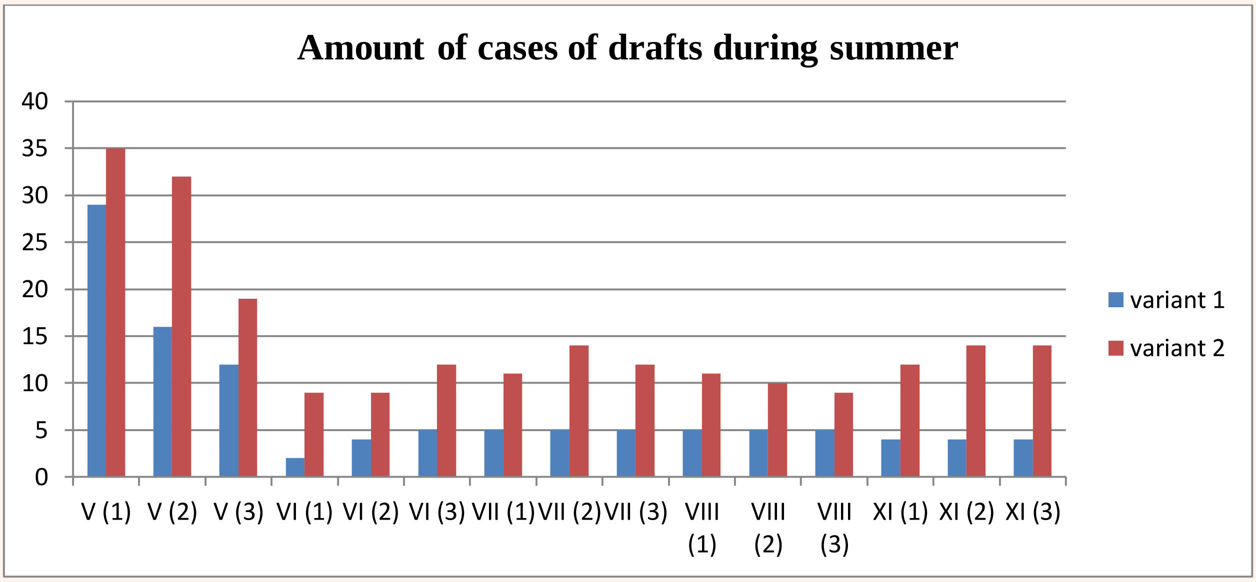

Figure 3. Distribution of amounts of cases of drafts through spillway for different variants of runoff regulation during summer.

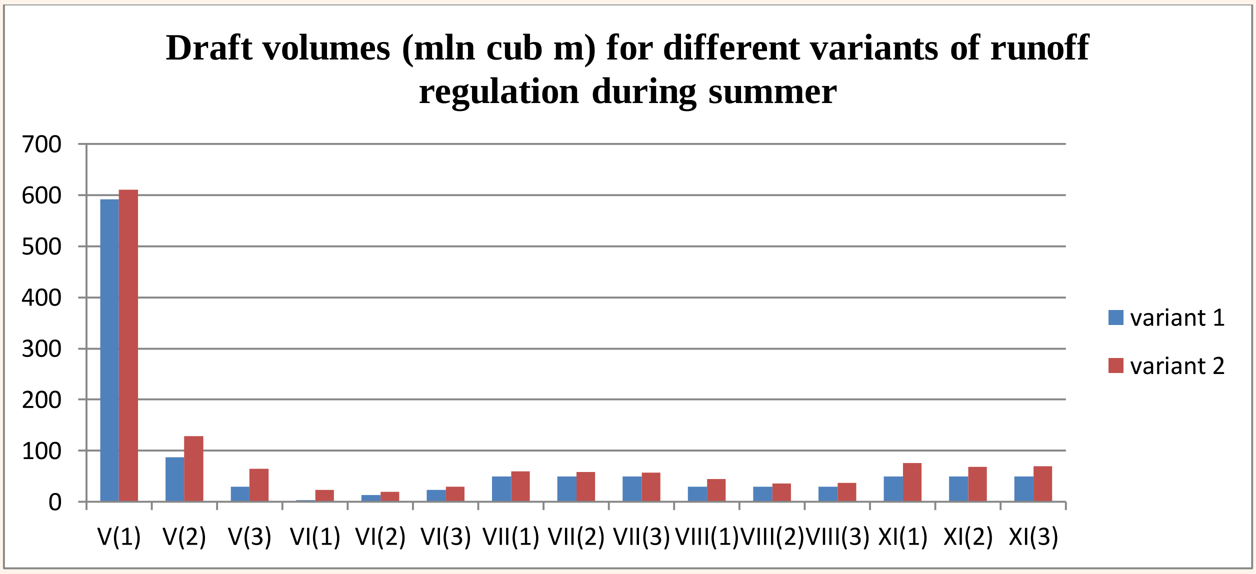

Figure 4. Distribution of drafts volumes through spillway for different variants of runoff regulation during summer.

It is seen from the comparison of variant 1 and variant 2 (fig. 3 and 4) that frequency and total volume of discharges into the downstream during the summer period is more in the case of second variant. Average mean of draft has been increased from 12,6 to 15,3 mln m3, so average value of water exchange relative to useful capacity of reservoir (216 mln m3) during summer in respect to average drafts has been increased. Coefficient of the water exchange during summer increased from 0,055 to 0,071.

All this provides: increased water velocity in the reservoir, reducing of the temperature of the surface water mass of the reservoir (the flowing water is heated less), the discharge of share of phytoplankton into the downstream reservoir. Such conditions can reduce the amount of blue-green algae in the reservoir.

Warranty of the consumption relative to both variants consisted 95,5%, the maximum annual deficit and the total deficit have not been increased.

Main results

Flow regulation by Ruzskoe water reservoir with consideration of short-time forecasting of runoff gives next main results in comparison to traditional rules of runoff regulation:

- The water exchange in the reservoir was increased during period from June until September month;
- Warranty of water consumption has not changed;
- The maximum annual deficit and the total deficit were not increased during 90 years of simulation;
- Draft maximum water discharge during summer was not higher than in the traditional rules of water reservoir operation.

Conclusions

The new rules of water reservoir operation are allowed increase the water exchange in the reservoir. That gives possibility to decrease the flowering of blue-green algae. General parameters of water reservoir operation are not changed.

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Ecological estimation of water reservoir with help of fractal analysis.

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Abstract

The paper is dedicated to application of fractal analysis for assessment of water quality of water reservoir. Biological oxygen demand for the 5 dais (BOD_5) was taken indicator of ecological status for water quality in reservoir. The results of the fractal studies fully corresponds Laden with regulations on BOD_5.

Key words: water reservoir, water quality, sustainability of system.

Introduction

The ecological status of water bodies is normalized and is currently estimated in the territory of different countries on the base of standards relative to physical and chemical parameters of water in a water body. Maximum permissible concentration (MPC) is an example of such standards. It should be noted that evaluation of the level of contamination of the water body to set standards is not always possible.

Different opinions are existing among discussion about the possible normative values of water pollution. The first opinion, that pollution is exceeding of MPS. Other opinion is pollution is the exceeding of the background concentrations.

The United States has implemented the concept of "risk assessment", which takes into account the combined effect of harmful factors on water bodies.

An assessment of the ecological status of the water body can be made by method fractal analysis, which is widely used in economic theory [1]. An economic theory is based on the research methods of nonlinear time series. Contaminants of water can also be seen as time-series of changes in a parameter of a physical or chemical contaminant.

Fractal analysis is applicable not only in terms of the analysis of time series, but also to analyze the system. Bak and Chen has created a model self-organized severity. According to Bak and Chen we have to study bunch of sand is the basic model of self-organized criticality. Sand has two phase states: resting phase and collapse. The main parameter is the angle of the surface. Some of the critical angle of even a small disturbance can cause the collapse of the system. Water bodies can also be destroyed because of the predominance of one or more parameters that affect the state of the system [2-4]. Possibility of application of fractal analysis methods to water bodies was studied by researchers of the Russian State Agrarian Academy and Tver State University [6].

Methods and materials.

The represented technology is used in this research relative to the upper part of the Istra reservoir, which is located in the Russian Federation, the Moscow Region, Istra district.

Accordingly the water reservoir is seen as a system. Each system has a critical value of the point at which there is uncontrolled change of the system.

Biological oxygen demand for the 5 dais (BOD_5) was taken indicator of ecological status for water quality in reservoir (table 1).

Table 1 - Results of monitoring BOD_5, mg /l.

Monitoring Station		10.05	09.07	08.03	07.06	06.01	05.05	04.06	03.02	02.09	01.12
Rainwater tower	on the surface	1,6	2,3	3,9	2,7	3,1	3,7	1,9	1,3	1,2	1,6
	at the bottom	4	3,3	4,4	2,9	3,4	3,7	2,4	1,6	1,5	1,5
N. Katishev	on the surface	2,5	3,3	4,8	3,5	3,4	6,4	2,5	3,3	4,8	3,5

Monitoring Station		10.05	09.07	08.03	07.06	06.01	05.05	04.06	03.02	02.09	01.12
	at the bottom	3	3	3	2,8	2,9	4,3	3	3	3	2,8
village Friday	on the surface	3,5	4,2	4,9	5,5	5,3	4,7	3,5	4,2	4,9	5,5
	at the bottom	3,6	4,2	4,4	5,3	5,1	4,4	3,6	4,2	4,4	5,3
villageBerezhki	on the surface	6,2	6,4	8	12,6	6,7	6,3	6,2	6,4	8	12,6
	at the bottom	6,8	5,2	7	9,6	6,1	9,2	6,8	5,2	7	9,6

According to the model of Bak and Chen [3,6], criterion of sustainability of the system is parameter D.

The fractal dimension D is defined by the formula (1):

$$D = 2 - tg(\alpha) \qquad (1)$$

tg(a) - slope of the line in the parameter of the averaged trend.

The topological dimension of a number is calculated according to the formula (2):

$$L(\delta) = n\delta \qquad (2)$$

n - the number δ measurement scales.

If the fractal dimension D lies in the range from 1 to 1.2, the natural system is super cooled, i.e. one parameter of system has crushed all others and the parameter became predominant.

If the fractal dimension D lies in the range from 1.2 to 1.4, the natural system is in equilibrium, all parameters balance each other, and the harmonic system is predictable.

If the fractal dimension D lies in the range from 1.4 to 1.7, the natural system is in a self-organized critical zone. According to the model Bak and Chen, such a system is orderly destroying that would counterbalance all your options and become harmonious. This zone is the most favorable for the external influences which will try to restore it, without destroying the system.

If the fractal dimension D lies in the range from 1.7 to 2, then natural system pass into a cascade of bifurcations. That is, there are a significant amount of positions where the system can go.

According to the formulas (1) and (2) and table 1 define the fractal dimension of the series relative to BOD_5, which are represented in table 2.

Table 2 Fractal dimension series BOD_5.

Place “Rain water tower”- surface	
$tg(\alpha)$	D
0,07	1,93
N. Katishev - surface	
$tg(\alpha)$	D
0,12	1,88
villageFriday - surface	
$tg(\alpha)$	D
0	2
villageBerezhki -. Surface	
$tg(\alpha)$	D
0,05	1,95
Rain water tower - bottom	
$tg(\alpha)$	D
0,02	1,98
N. Katishev - bottom	
$tg(\alpha)$	D
0,02	1,98
villageFriday - bottom	
$tg(\alpha)$	D
0,02	1,98
villageBerezhki -. bottom	
$tg(\alpha)$	D
0,11	1,89

The results of the fractal studies fully corresponds Laden with regulations on BOD_5. So for Russian sanitary rules and norms 2.1.5.980-00 Hygienic requirements for surface water protection BOD5 should not exceed 2 mg / l [7]. However the sampling points near N.Katysh samples d.Pyatnitsa and Berezhki have exceeded of the represented norms.

Conclusions.

The represented above fractal analysis has showed that the reservoir is in the process of bifurcation. Also proved statement which was written above, that can't be do assessments only on the standard indicators. So at the place "water intake tower" no exceedances of MPC, but the system is in the stages of destruction.

The fractal analysis can be used for assessment of sustainability of water reservoir relative to quality its water resources.

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Approach to assessment of asymmetry relative to probabilistic distribution of dangerous hydrometeorological phenomens.

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Abstract

The article is dedicated to problem of assessment of asymmetry for probabilistic distributions with help of non-standard methods, since standard method of moments gives significant errors in the case of using data series observations for the meteorological and meteorological values, which are limited by duration observations.

Key words: statistical ranks, probabilistic distribution, coefficient of asymmetry.

Introduction

Statistical ranks of data series observations for the storm meteorological and meteorological values have usually positive asymmetry relative to their lows of probabilistic distributions. This is due to the presence of rare but very extreme values in the observation series. Meteorological and hydrological statistical ranks are limited (30 – 100 years of observation) and we have significant errors of statistic parameters. Usually the first two statistical parameters can be defined enough exactly (average and coefficient of variation – Cv) by different methods already for the 30 years of observation however the third statistical parameter has significant statistical errors [2,3,5,6] even for 100 - 150 years of observation in dependence on variation coefficient (Cv) and duration of observations. Researchers Blohinov [1] and Ilinich [2,3] moved hypothesis that non-standard methods of definition coefficient of asymmetry allow define its value more exactly. The hypothesis was checked relative to special three-parametrical gamma distribution [4].

Equation of the probabilistic (p) distribution has next view:

$$P(Q, Q_{m,} \gamma,b)=[\Gamma(\gamma+b)/\Gamma(\gamma)]^{\gamma/b}/(\Gamma(\gamma)|b|Q_m)(Q_i/Q_m)^{\gamma/b-1}\exp\{[Q/Q_m\Gamma(\gamma+b)/\Gamma(\gamma)]^{1/b}\} \quad (1)$$

Here:

Q_i– the river discharges or any other hydrological values, *i*-numbers of years; Q_m – average mean of Q_i;

γ and b – parameters, Γ – gamma function.

For every attitude of the parameters γ and b there is concrete attitude of skew coefficient (Cs) to variation coefficient (Cv). The coefficients are expressed by next equations:

$$Cv = [\Gamma(\gamma)\,\Gamma(\gamma+2b)/\,\Gamma^2(\gamma+b)-1]^{0,5}\ ; \quad (2)$$

$$Cs=[\Gamma^2(\gamma)\Gamma(\gamma+3b)/\Gamma^3(\gamma+b)-3\Gamma(\gamma)\Gamma(\gamma+2b)/\Gamma^2(\gamma+b)+2]/[\Gamma(\gamma)\Gamma(\gamma+2b)/\Gamma^2(\gamma+b)-1]^{1,5} \quad (3)$$

The equations (2) and (3) contain gamma-functions: $\Gamma(\gamma)$, $\Gamma(\gamma+b)$. The represented probabilistic distribution has been obtained by transformation of known gamma-distribution. When b=1, both distributions are same. Usually represented distribution is characterized by parameters Q_m, Cv and Cs (with consequent connections between Cv and Cs) instead parameters γ and b.

Researches [2,3] contain the analysis of dependences between different non-standard parameters and the respective coefficients of asymmetry for different ratios between Cs/Cv. But the obtained graphs are need in clarification.

Accordingly, main aim of the research is clarification of dependences between new nonstandard asymmetry parameters and asymmetry coefficient for different variants of dependence between asymmetry coefficient and variation of the probabilistic distribution.

Method and materials.

The all parameters were estimated on the base coefficients Кр, which were chosen from tables of special three-parametrical gamma distribution [4]. In researches [2,3] 23 coefficients were chosen for estimations respect to probabilities (P) -P=50% and symmetrically located from that probability: P=40% andP=60%; P=30% andP=70% etc. So, the coefficients Кр were located on the equal distance from the median (Кр=50%) of the probabilistic distribution. Consequently graph dependences were obtained. However, configuration of graph has to depend from amount of points which are located on the equal distance from the median (Кр=50%) of the distribution. Accordingly an experiment consisted in the estimation of non-standard parameters relative to different numbers of coefficients Кр located on the equal distance from the median (Кр=50%).

The next non-standard parameters were studied at this stage of the research:

$$b = 1/n\sum \exp(Kp) \qquad (4)$$

$$d = 1/n\sum \lg(Kp) \qquad (5)$$

Here n – number of coefficients Kp.

Their values were estimated for different variants of coefficients Kp and different ratios between Cs/Cv relative to Cv=0,4. Such value of Cv is met most often in meteorological and hydrological extreme characteristics. In total next variants were anylised:

- relative to ratios between Cs/Cv 1) Cs/Cv=0,5; 2) Cs/Cv=1; 3) Cs/Cv=2; 4) Cs/Cv=3; 5) Cs/Cv=4; 6) Cs/Cv=4,5; 7) Cs/Cv=5; 8) Cs/Cv=5,5;

- relative to numbers (n) of coefficients Kp located on the equal distance from the median (Kp=50%) 1) 23; 2) 19; 3) 17; 4) 15.

Accordingly calculations were made and the consequent graphs were constructed (Fig. 1 and Fig. 2).

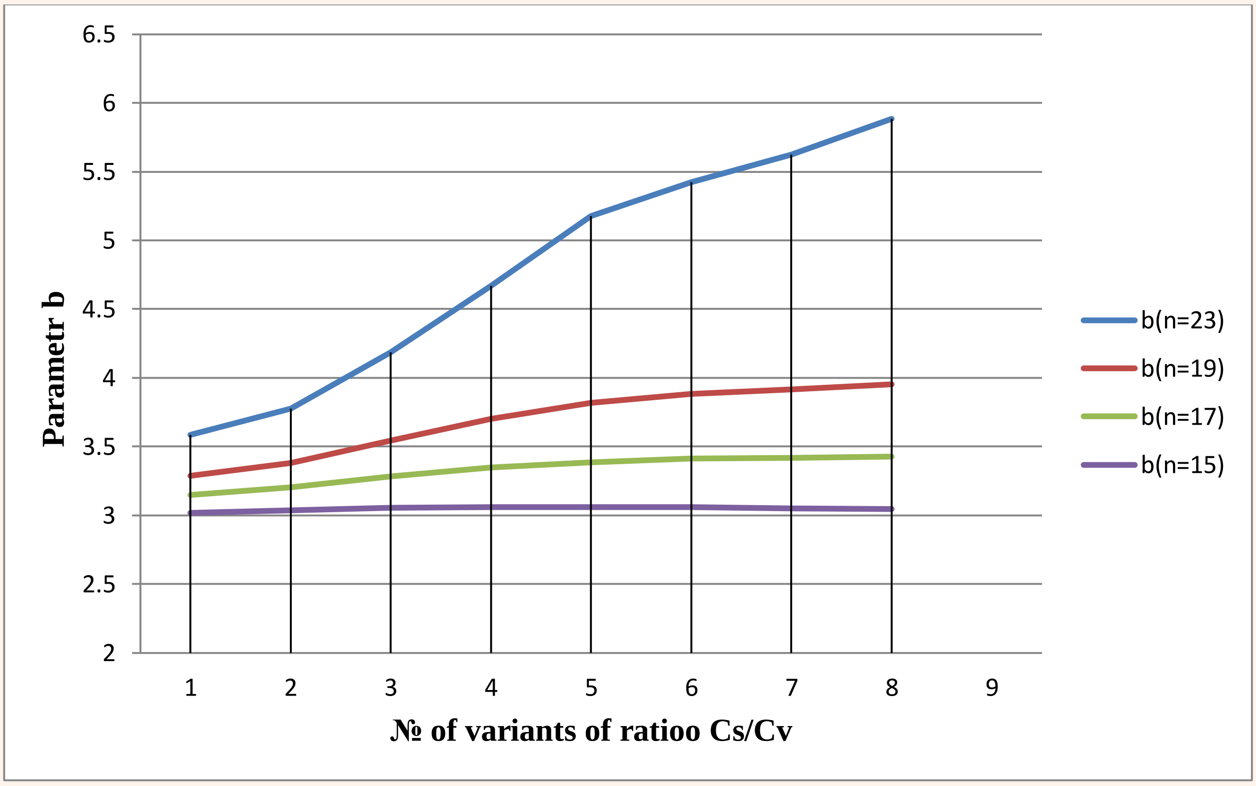

Fig. 1. Dependences between parameter b and ratios Cs/Cv relative to different amounts of coefficients Kp.

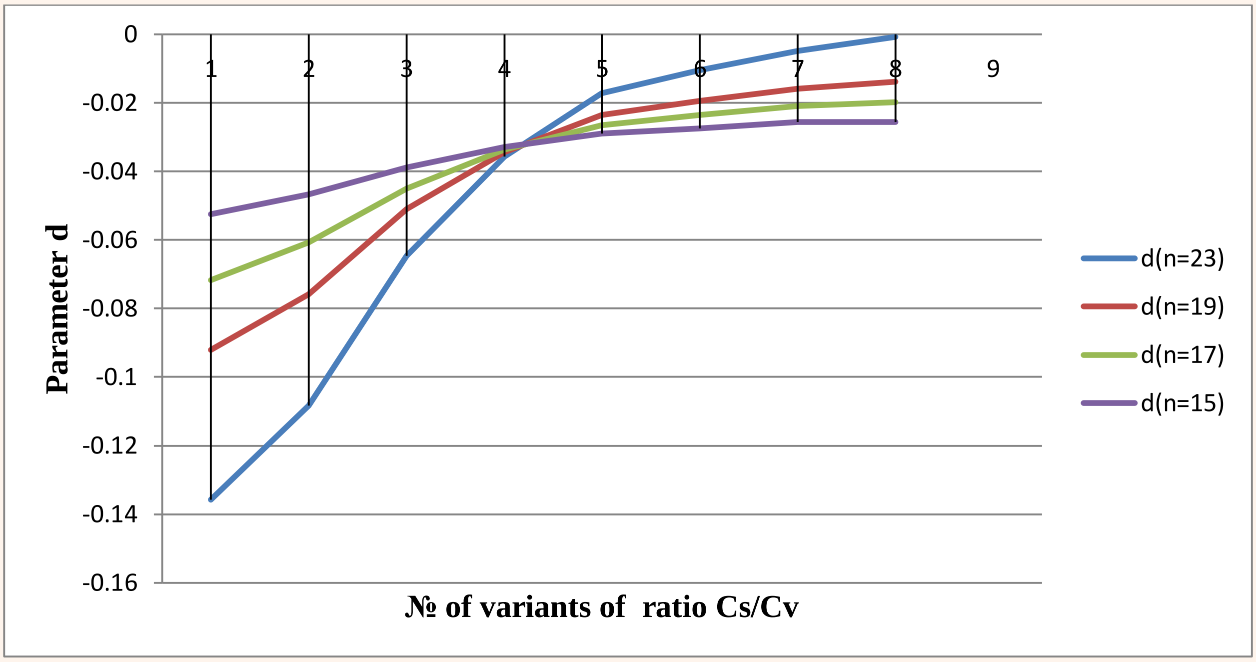

Fig. 2. Dependences between parameter d and ratios Cs/Cv relative to different amounts of coefficients Kp.

We can see that both parameters have clear dependences (but they are not analytical functions) between asymmetry coefficient and their values, but the dependences are differed significantly in dependence on numbers of coefficients Kp which were used for calculations.

Dependences of parameter b have minimum differences relative to ratio Cs/Cv=0,5 and maximum relative to ratio Cs/Cv=0,5.

Dependences of parameter d have minimum differences relative to ratio Cs/Cv=3 and maximums relative to ratios: Cs/Cv=0,5.

Conclusions.

Hypothesis about existing of clear dependences (not analytical functions) [///] between asymmetry coefficient and non-standard parameters has been confirmed again in frames of special three-parametrical gamma distribution of random values, which is used enough successfully in different countries for assessment of probabilistic characteristics of extreme meteorological and hydrological values.

However configuration of the obtained graphs is depended on numbers of the used coefficients of special three-parametrical gamma distribution of random values.

So, there is necessary to consider this fact in calculations of non-standard parameters for assessment of asymmetry coefficient on the base of data series of observation.

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