Consideration on Hydraulic Modelling and Evaluation of Surface Waters with Environmental Risk

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Abstract: *All groundwater catchments in a basin must be protected against pollution by establishing sanitary and hydrogeological protection areas, in order to ensure a good use of groundwater resources. The most precise method of determining the protection zones is the mathematical modeling. The paper presents a modeling of an erodible riverbed with environmental risk in the Dobrogea hydrographic Basin, as well as the assessment and analysis of environmental risk for the related.*

Keywords: *Surface water, protection, risk factor, assessment, vulnerability, probability*

1. Introduction

Dobrogea is composed of three major structural blocks namely: Dobrogea South, Central Dobrogea and North Dobrogea separated by faults Capidava -Ovidiu and Peceneaga - Camena (Fig. 1) [1]. More than 80% of Dobrogea appears to be siliceous rocks [2].

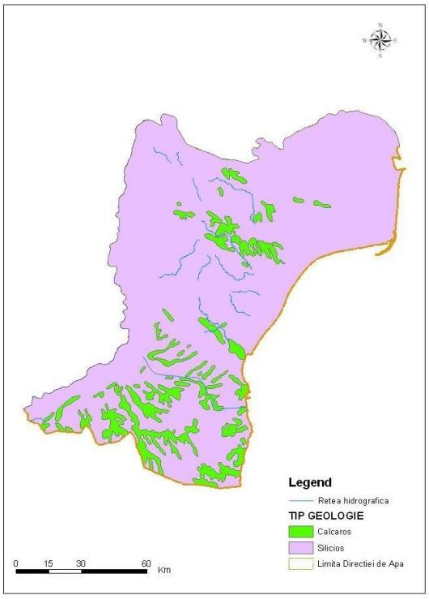

Fig. 1. The structural blocks from DOBROGEA

Dobrogea catchment area is very poor in own surface resources. Basically, they consist of several major rivers surface (so far there is no use in rivers due to low water flow permanently) and in coastal lakes and related Danube [3].
The catchment area Dobrogea identifies 16 rivers with areas greater than 10 km^2, 18 natural lakes and four water storages that are larger than 0.5 km^2.
DOBROGEA ARIA consists of Seaside and streams tributary to the Danube River catchment area corresponding Dobrogea (Figure 2) [4].

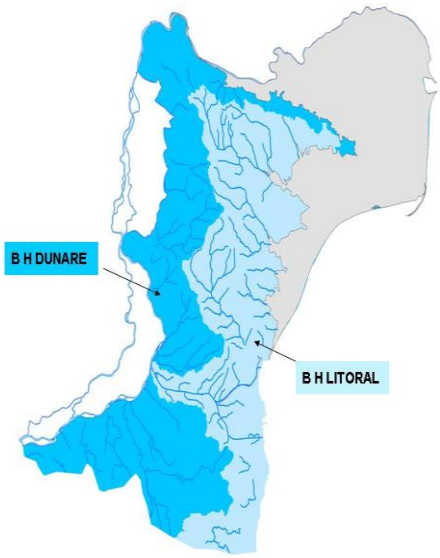

Fig. 2. DOBROGEA hydrographic basin

To characterize a basin is necessary to know its characteristic elements-morphological variables of the watercourse system (Fig. 3) [3].

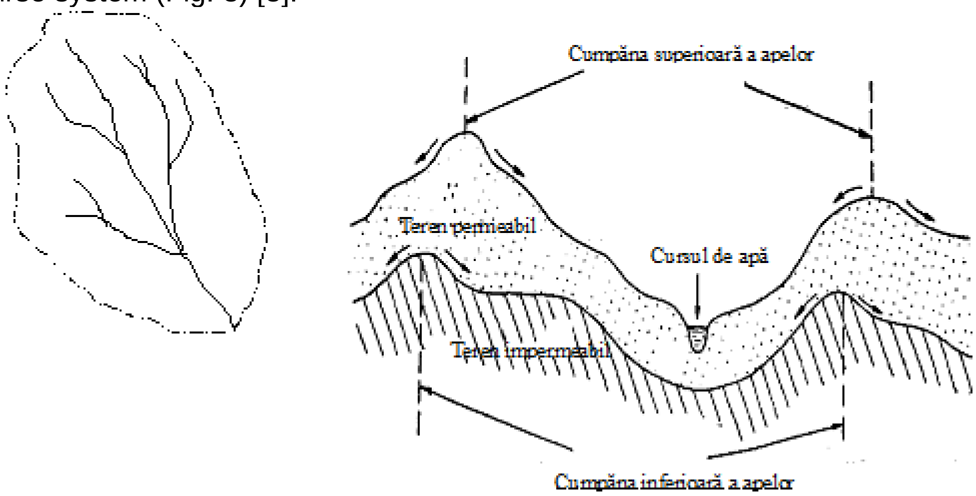

Fig. 3. Hydrographic basin-schematization and water scale

These can be divided into:

- Elements of hydrology and river network
- Geological features
- Features on vegetation.

2. Modeling the river bed with environmental eroding risk in DOBROGEA area

Modeling the riverbed with environmental eroding risk the following elements need to be studied:

- Data location and description of the catchment area, applicable to chosen location;
- Data on power sources aquifer basin, applicable to chosen location;
- Balance river flows in the basin area for a chosen period;
- Reporting to the climatological normal space basin [5].

Hydrometeorological regime for chosen catchment area reported to County statistics [6].

2.1 Choosing a white space erodible river in Dobrogea

The analysis will be done for the creek Nuntasi. Supply aquifer - is mainly from rainfall and the loss of irrigation water systems.
Balance flow to the hydrographic area Dobrogea (for 1999, 2004, 2007 and 2010) is shown in Table 1.

Table 1: Balance flow to the hydrographic area Dobrogea

Year	Balance flow	Feed rate [m^3/s]	Discharge rate [m^3/s]
1999[27]	Northern limit Western limit Southern boundary Black Sea Input from the surface	- - - - 91 367.34	5417.58 7 869.45 17 98.06 60 800.55 -
2004	Northern limit Western limit Southern boundary Black Sea Input from the surface	- - -175.33 - 98 452.89	5923.72 8104.57 1945.27 67845.13 -
2007	Northern limit Western limit Southern boundary Black Sea Input from the surface	- - -189.37 - 99 321.23	6123.48 8765.41 2006.39 69929.16 -
2010	Northern limit Western limit Southern boundary Black Sea Input from the surface	- - 143.28 - 39 987.25	2 320.63 4 248.47 8 579.01 24 998.52 -
TOTAL		329 636.69	286675.83

Nuntasi Lake River Basin lies between 280 37''30' NV and 280 45' N-E and also parallel 44° 30 'latitude and parallel 44° 35' [6].
Morphometric parameters are shown in Table 2 (River Data hydraulic).

Table 2: River Data hydraulic

River	Average depth (mdM)	Area (km^2)	Volume (mil. m^3)	Maximum Depth (m)	Length (m)	The diameter of the granules r (mm)	Specific gravity of the alluvium [N/m^3]	Friction slope
Nuntasi	10	145	9.8	2.3	14 000	8	26.5	0.002

3. Numerical modeling and flow simulation for riverbed

Study of modeling assumptions are:

- flow-permanent, two-dimensional, parallel throughout the riverbed,
- incompressible fluid and homogeneous,
- slope small bed, small variations in the parameters of cross sections
- hydrostatic pressure distribution date [7].

The equations for the flow cross-section are the Saint-Venant equations and for along the riverbed flow, the turbulent flow equations, i.e. equation for turbulent kinetic energy.

For the flow modeling we select a sector and we will note the geometric and hydraulic parameters and related to this sector, the settling flow diagram (Fig. 4) by hydraulic modeling [8]. In our case, the modeling will be done by using software MIKE 11 [8].

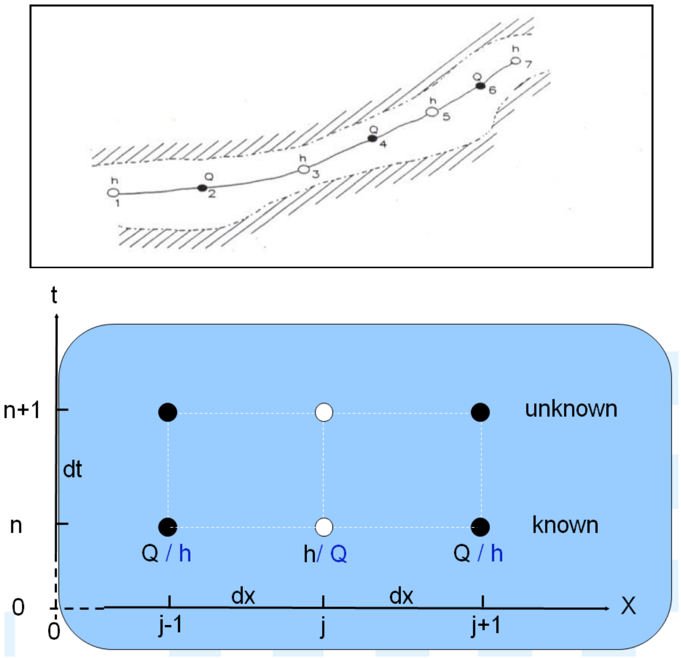

Fig. 4. The geometric and hydraulic parameters and the settling flow diagram

Flow stability is required for the convergence of the solution achieved by modeling, given the initial conditions and the approximation by finite differences that need to be consistent.
Explicitly provided stability is the number Courant (eq. 3.20) [8], where Cr <1.
Boundary conditions of the flow are:

- discharge flow upstream of the control section, downstream;
- tributaries flow;
- condition for convergence solution-end flow, Q = 0;
- water depth, h (1 ÷ 2.3) m;
- weather-wind, currents;
- conditions for Q / h downstream flow (never upstream).

Input data are: topographic data, hydraulic data. There was used information provided by operating with ArcGIS software (Fig. 5) [8], software MIKE Zero (Fig. 6) [8] and Nuntasi topographic map of the basin (Fig. 7) [9].
Study parameters sections; limnimetric key to riverbeds (Figure 8); elementary hydrograph (Figure 9); values for peak flow conditions (Table 3, Table 4).
In the Nuntasi riverbed were analyzed aspects necessary for sizing the riverbed by means of graphic-analytical (flow, roughness, depth initial slope bottom and sloping embankment) (Table 5, Table 6), rising variation in the width b depending on the depth h (Figure 10) and changes the width b by block debit K (Figure 11).

These elements will help us to shape both flow into the riverbed and to analyze risk in the event of floods.

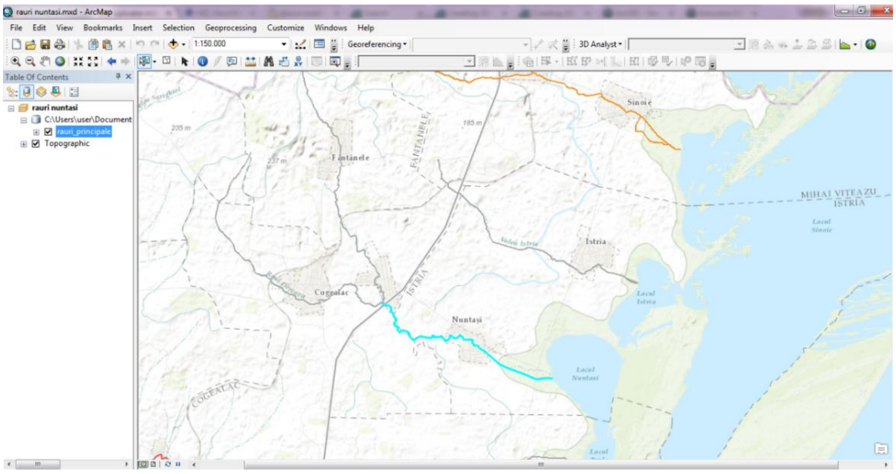

Fig. 5. Localization with the ArcGis program

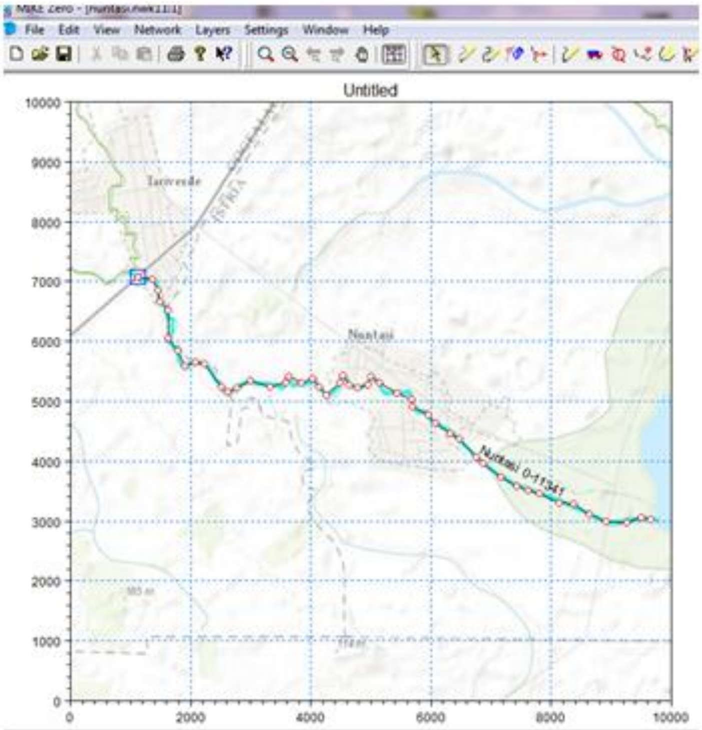

Fig. 6. Map construction with MIKE Zero program

Fig. 7. Location on the map of the Nuntasi hydrographic space

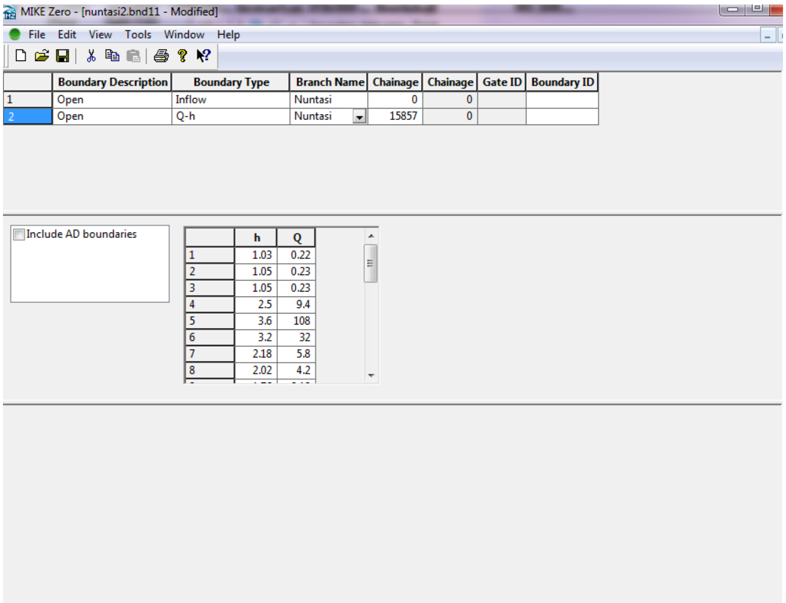

Fig. 8. The limnimetric key to riverbeds

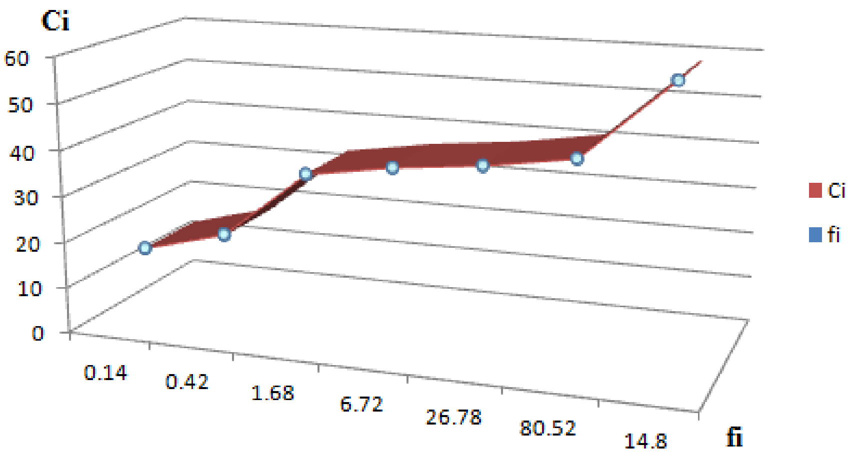

Fig. 9. The elementary hydrograph

Table 3: The values of the elevations of the curves of the surfaces between two contours

Curve	C_i [mdM]	f_i [km^2]
1	15	0.14
2	20	0.42
3	35	1.68
4	38	6.72
5	40	26.78
6	43	80.52
7	60	95.40

Table 4: The Pool characteristics

River	L, km	Total volume, mil. m^3	S, km^2	Alt, mdM	Q_{medma} (m^3/s)	$Q_{minImedma\ asig}$ 80% (m^3/s)	$Q_{minImedma\ asig}$ 90% (m^3/s)	$Q_{minImedma\ asig}$ 95% (m^3/s)	Q_{min}/Q_{max}*
Nuntasi	14	9.3	145	10	0.473	0.280	0.200	0.140	1/2250

Table 5: Initial data

Initial data	Q_i [m³/s]	n	h_0 [m]	i	m=ctgθ
Values	0.02	0.015	1.2	0.0165	1.732

Table 6: Grapho-analytical method [41], [42] for width variation as a function of flow modulus

No.	b [m]	A [m²]	P [m]	R [m]	C	K [m³/s]	h [m]
2.	7.2	4.033	9.1999	0.438374	58.103	155.1491	0.5
3	5.2	3.743	7.5999	0.5131	59.2452	155.656	0.6
4	3.85	3.54368	6.6499	0.5328	60.0272	155.28	0.7
5	2.9	3.42848	6.099	0.56205	60.5626	155.66	0.8
6	2.17	3.35592	5.769	0.5816	60.9091	155.88	0.9
7	1.5700	3.302	5.569	0.5928	61.103	155.347	1
8	1.0800	3.2837	5.479	0.5992	61.212	155.597	1.1
9	0.65	3.27408	5.449894	0.60076	61.23865	155.4052	1.2

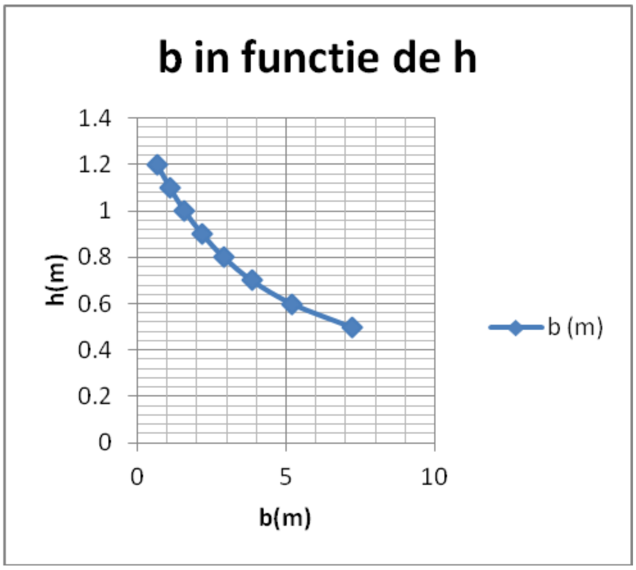

Fig. 10. Variation in width as a function of depth

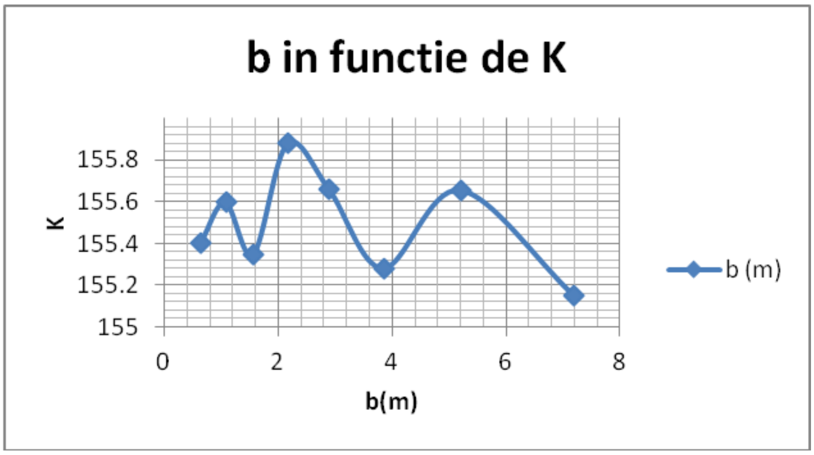

Fig. 11. Width variation depending on the flow module

3.1 Flow simulation in the riverbed by MIKE 11

Based on topographic data, initial hydraulic data and data obtained by graphic-analytical and also the limnimetric key of Nuntasi riverbed using MIKE 11 software was simulated a flow specific to a situation of flood in 2007 (Fig. 12) and compared to the level of 1999 (Fig. 13).

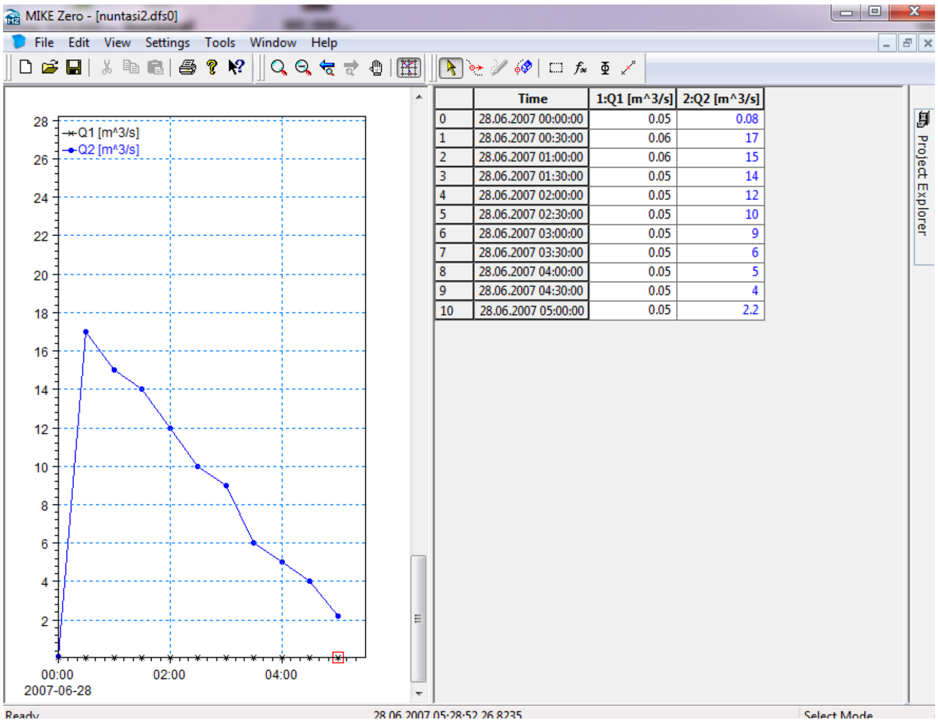

Fig. 12. Flow simulation for two flow discharge in 2007

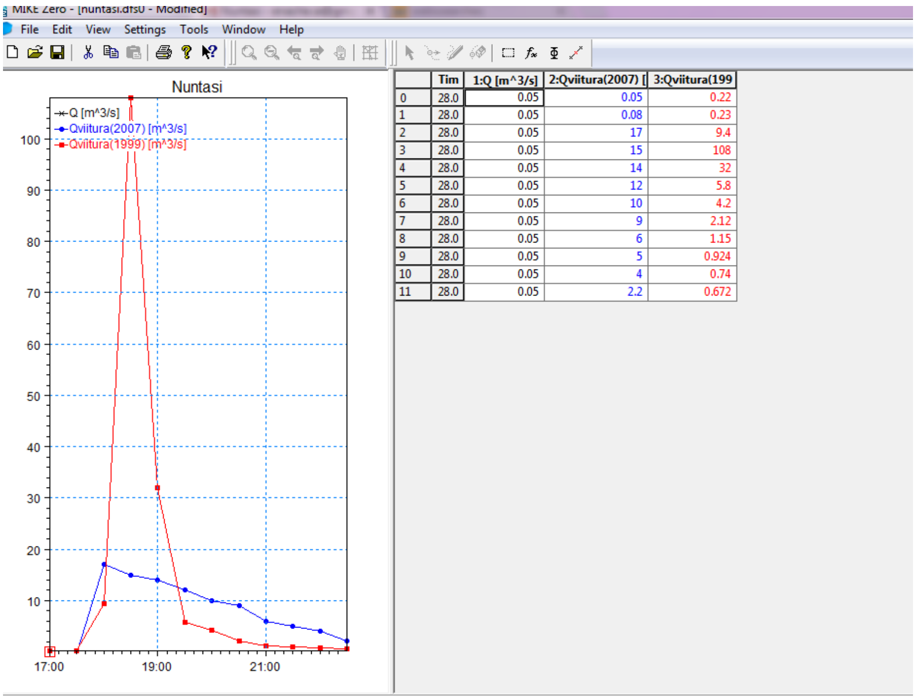

Fig. 13. Flow simulation for two discharge flow (flood in 1999 and 2007)

The result of the MIKE 11 simulation program consists of a contemporary representation while during flood flow path on the Nuntasi course, viewing velocity vector (green, Fig.14) for the entire length of the river.

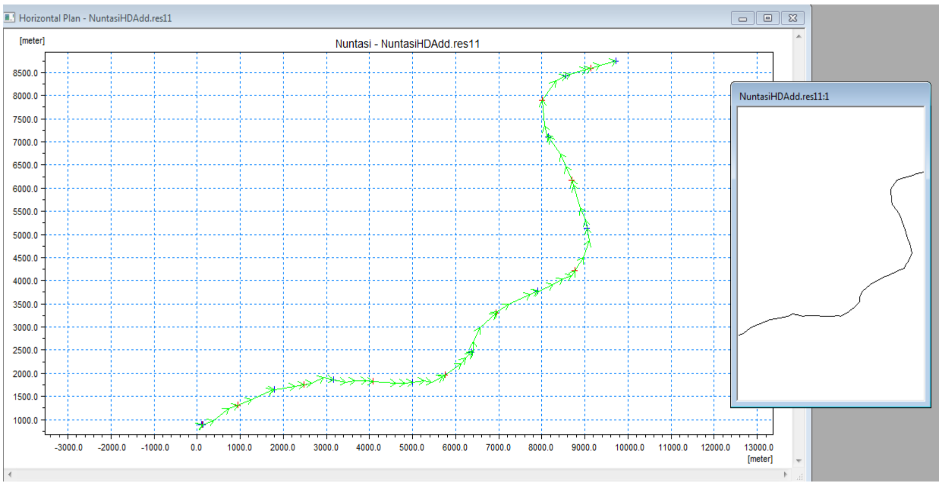

Fig. 14. Flow visualization and velocity vector along the riverbed Nuntasi.

The final results of modeling with MIKE 11 program are plotting and maximum rates for the flood of 2007 (Fig. 15) and flow profile along the riverbed Nuntasi (Fig. 16).

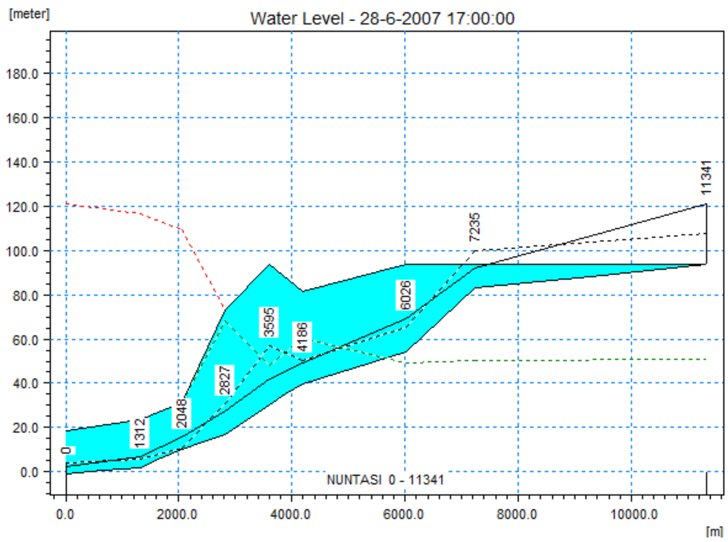

Fig. 15. Shares riverbed for flood in 2007

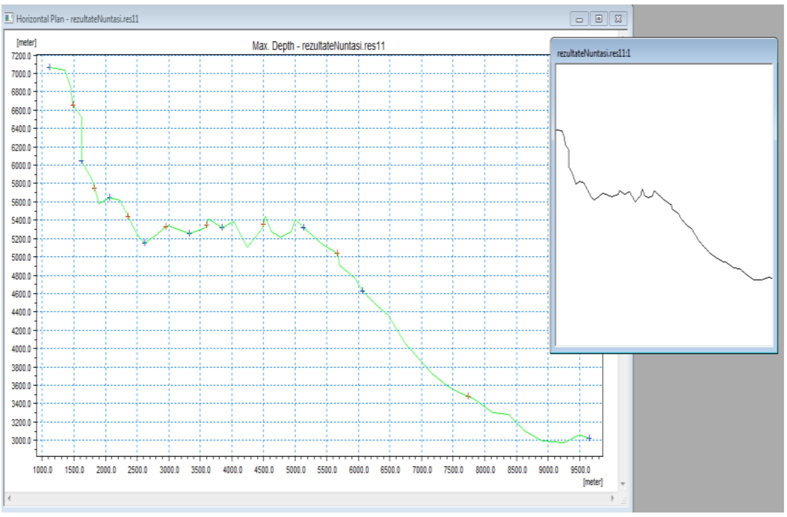

Fig. 16. The final flow profile along the riverbed

4. Assessment and risk analysis of environmental basin

The risk factors for chose catchment are the flooding and anthropogenic pollution.

4.1 The floods

One of the risk factors is represented by the floods. Approaching to flood hazard in Area Hydrographic Dobrogea consists of a first stage group watercourses cadastral three degrees of detail depending on the frequency of floods in recent years, the magnitude of their manifestation, the level of equipment with works flood protection, economic or social objectives subject to flooding hazard, etc (Fig. 17) [8]: level A - very detailed; Level B - detailed; Level C.

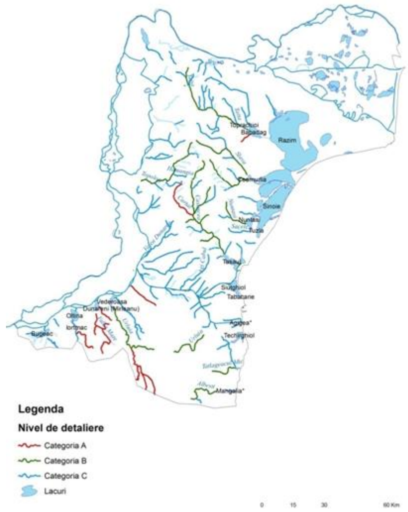

Fig. 17. Map of the hydrographic network Dobrogea Water Basin Administration

There were analyzed areas Nuntasi Basin - Nuntasi, Nuntasi Basin - Fantanele. In terms of structural measures, imposed costs on urban river engineering on the section Nuntaşi- Fantanele Basin and river engineering costs for the urban section Nuntaşi- Nuntasi Basin, aiming finally to avoid casualties. [12].

4.2 Anthropogenic pollution

Human activities lead to alterations in the riverbed morphology and dynamics to change its hydraulics. Aspects should be considered amending the short term (dams, bridges, erosion, etc.) and long term (changes generated by the embodiment Management work).

4.3 Risk analysis of hydrographic area

With the method of analysis of the possibilities of risk RFMEA (failure mode risk evaluation analysis) are measured and quantified four parameters [13], [14], [15], [16], [17]:

• vulnerability (exposure) (R);
• the probability (P);
• the effect of being an instrument of control / measurement / control / share (N);
• efficiency indicator of a new measure (F).

The first three provide the level of risk or risk factor (RPN). Parameter (F) of the method of analysis is an indicator of the effectiveness or urgency of a new measure or a series of prevention and control measures. It includes the economic effect of the control measure and compares the estimate of the consequences of a probable accident or disaster with the financial and human loss. All these four parameters form the complex risk factor (RPNF).

Vulnerability characterize exposure to risk factors analyzed location. The probability (P) an event in a year can be classified with another likely in the coming year, when more accurate data are available. The same is true with other factors in the selection process (Table 7).

Table 7: The probability

Probability for a disaster event	Probability (caz/ani)	Value
Very high, very often	>1 ... 2	10
	1 ... 3	9
High : repeated accidents	1... 5	8
	1 ... 10	7
Average: from time to time	1 ... 15	6
	1 in 20	5
	1 in 25	4
Low: very rare accidents	1 in 35	3
	1 in 50	2

Measures of control- the means of prevention and protection present actions and active policies. These are defined mainly by preventing complex parameter-control measure (N) (Table 8).

Table 8: Control measures

The measure of prevention, control or effect of the action	Description of the effect	Value
Nothing; Without measure	Absolutely no measures, controls or actions are currently in place	10
Almost no effect	Almost no effective measures for control or prevention, impact on system protection against destruction, loss of life or warning	9
Very low effect	Extremely inefficient or unproven for all measures to control, prevent and protect human lives and long-term consequences	8
Quite low effect	Quite low effect of the measure, control or action to protect human lives and long-term consequences	7
Low	Low effect, but there are some chances of protecting human lives and long-term consequences	6
Relative	Relative effectiveness of the measure, control or action to protect loss of human life, but protect human victims and mitigate long-term consequences	5
Relatively high	Relatively high effect of the measure, control or action to protect human lives, and diminishes the long-term consequences	4
High	High insurance which means a measure, control or action that prevents losses and reduces long-term consequences.	3
Very high	Very high insurance, which means a measure, control or action that prevents losses and reduces long-term consequences.	2
Safe effect	Safe measure, control or action that prevents losses and reduces long-term consequences. In the case of NUNTASI, the execution of a covered trapezoidal section was proposed which involves: • regularization of the riverbed on the urban section Bazinul Nuntaşi-Fântanele in the amount of 3,767,390.90 € • regularization of the riverbed with dams in the amount of € 2,029,612.20 • regularization of the riverbed on the urban section Bazinul Nuntaşi-Nuntaşi in the amount of € 3,737,263.25 • regularization of the riverbed with dams in the amount of € 666,872.58	1

The level of risk can be simply determined (RPN), or determined by the efficiency factor F (complex level of risk, RPNF).
Automatic calculation of the level of risk (value RPN) is done by multiplying the three values.
The risk levels based on RPN values are chosen so (Table 9):
• High (marked in red) for RPN values> 250;
• Intermediate (marked in yellow) є RPN values (41 .... 250);
• Low (marked in green) for RPN values є (1 .... 40).

Table 9: Calculation of values for RPN and F

Economic factor of efficiency F - costs for damage and prevention	Damage rate / prevention costs	Value F
Very high - the estimated damage is considered higher than the prevention budget	>50 1	10
	>20 to 1	9
High - the estimated damage is considered much higher than the prevention budget	10 1	8
	5 to 1	7
Almost equal - the estimated damage is slightly above the prevention budget	2 to 1	6
Equal	1	5
The prevention budget is higher than the estimated damage	1 to 5	4
The prevention budget is considerably higher than the estimated damage	1 to 20	3
	1 to 100	2

5. Conclusions

For studying the flow in the Nuntasi riverbed eroded with environmental risk were analyzed elements: location and description of the hydrographic area, data sources feeding the aquifer basin data sources feeding the aquifer basin balance flows to the hydrographic area Dobrogea for 1999, 2004, 2007 and 2010, reporting to the climatological normal catchment area Dobrogea; hydrometeorological regime for the guests catchment area reported at Constanta County; morphological and morphometric elements of the bed of the guests; Nuntasi riverbed proper flow modeling; risk analysis in the event of floods.
The conclusion of the risk analysis was: Nuntasi riverbed fits at "low risk prevention measure without any serious urgent implementation RPNF with values between (1 ... 150)". Following theoretical and experimental findings about river conditions change in response to the liquid phase flows and sediments are:

- current depth is directly proportional to fluid flow and inversely proportional to the flow of solid material dragged;
- limits the embankments of river bed varies in direct proportion to the flow of liquid and solid material;
- varying flow is directly proportional to the variation solid ratio width / depth;
- slope of the river bed varies in direct proportion to solid and grain alluvial flow and inversely proportional to fluid flow;
- river meanders rate is directly proportional to the variation in relief and inversely proportional to the solid flow.

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