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DOCUMENTARY STUDY ON MONITORING BY THE MODERN METHODS OF THE STABILITY OF EARTH DAMS

BY

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Abstract. The study of hydrotechnical constructions allows knowledge of parameters which characterizes the changes over time at the structure of studied construction. Tracking behavior over time of earth masses, in particular of earth dams, aimes to avoid accidents or even breaks of dams. Earth dams are at risk of breaking phenomena due to, mainly, the seepage. This paper describes the methods of monitoring displacements and deformations of earth masses by topographic measurements, using modern geodetic technologies and equipment. The study presents the current state, both nationally and internationally, of the topo-geodetic methods and tools used to monitor earth dams. Modern monitoring methods are also described and compared with classical methods. The tracking process of hydrotechnical constructions is a continuous and long activity which is being carried out at precisely defined and respected intervals. Thus, the state of constructions is always know and any tendencies of atypical evolution can be remarked in time and repaired. In the paper will be described the contemporary methods used in the process of tracking the behavior of hydrotechnical constructions but also classical methods. The most efficient and expeditious monitoring methods are those that use combined GPS station, 3D laser scanner, robotic total station and drones.

Keywords: deformations; earth dams; geodetic equipment; GNSS; monitoring.

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1. Introduction

The current state of research indicates increasing the degree of automation in tracking the behavior of hydrotechnical construction, by improving the existing technology used for this purpose. Thus, collecting data is achieved with advanced temporal and spatial resolution.

Research studies the issue of the surest way to do the monitoring process, by using the current technology used to track deformation of dams. Total robotic station and GNSS (Global Navigation Satellite System), offers effective solution for measuring three-dimensional displacements. Also, remote sensing and terrestrial laser scanning allow the extension of measurements to hardly accessible areas.

Make a comparison between conventional techniques and innovative, modern dams monitoring techniques is effective in the development process. This highlights the reliability of modern tools and methods contrary to the classic ones.

The authors of the studied materials highlighted the modern solutions and methods for monitoring the dams, as well as understanding the future direction of their development.

The purpose of the paper is to present a synthesis of the current state, both at the national and international level of the dams monitoring process.

2. Material and Research Method

The research material is composed of hydrotechnical constructions such as dams of various categories of importance, located in Romania and Europe. The constructions analyzed on the territory of Romania are concrete arched dam, built of mortar stone masonry. These dams were built for energy purposes. (Prişcu, 1974)

Dams located in Italy and Spain, are embankments that are part of the category of the oldest type of dam. They are built from sands, argillaceous sands, sands clay, clay and grit. The materials used for the construction of the earth dam are waterproof. The cross section of the dam is usually trapezoidal, with slopes (upstream and downstream) line, resulting from stability condition. (Prişcu, 1974)

The research methodology is represented by the analysis of documentary materials at national and international level, especially articles presented at scientific sessions in Romania and foreign countries. The methods analyzed in the dams monitoring process are:

– topo-geodetic ground measurements method executed with high-precision topographic tools such as Leica total station and digital levels;

– satellite methods using modern LIDAR equipment (laser scanners, Global Positioning System – GPS, IMU system – Inertial Measurement Unit);

– using LIDAR data processing software (ALDPAT, HHViewer, LIDAR Analyst, ArcGIS, Lviz, MARS, Quick Terrain Modeler, Terrasolid);

– modern equipment based on LIDAR technology (for example PHOENIX AERIAL SYSTEMS drones);

– analysis of the images taken over by the radar satellites (ENVISAT-ASAR);

– analysis using automated systems adopting differential GNSS sensors (Global Navigation Satellite System);

– the real-time kinematic method (RTK).

3. Results and Discussions

The issue of monitoring hydrotechnical constructions such as dams is constantly studying due to deformations occurring at changes in the groundwater level, tectonic phenomena, etc.

Deformations refer to the changes that a deformable body suffers and which may affect its shape, size and position. Thus it is important to measure these changes for the purpose of assessing safety and preventing future disasters. (Bălă, 2014).

From the national analysis, it can be seen that monitoring is mainly done for concrete dams and topo-geodetic tracking methods are classic, using high precision ground measurement instruments.

Petrimanu dam area, in Valcea Country was analyzed during the refurbishment of the Ciunget hydropower plant. Petrimanu dam is a concrete arch dam with a crown heigh of 1,134 m (Gridan, 2012).

The Petrimanu reservoir has a total volume of 2.5 mil m^3. In the process of monitoring the Petrianu dam, through the measurements made, the horizontal and vertical displacements of landmarks were determined during four observation cycles.

Topographic measurements were made to the microtriangulation landmarks located on the downstream side of the dam and to the heigh marks fitted to the crest of the dam. The topographic instrument used was the Leica TC 805 total station.

The horizontal and vertical displacements presented in Table 1 were obtained by the difference between the planimetric and altimetric coordinates, determinated by the zero measurement and the same elements determinated in the subsequent measurement cycles (Grecea, 2012).

The authors, Alina Corina Bălă and Floarea Maria Brebu, present in the article ”Monitoring of hydropower construction using modern Geodetical methods”, the progress in the geodesy and topography domain through the implementation of modern measurement technologies and methods, adapted to civil engineering, to observ the behavior in time of the Cerna river dam located in the Gorj country. Cerna dam, also know as the Valley of Iovan , is a concrete arch dam with a height of 110 m.

Table 1

The Height Marks Displacements (Grecea, 2012)

Vertical landmark nr.	Differences from the"zero" measurement (mm)				Obs.
	Measuring cycle	Measuring cycle	Measuring cycle	Measuring cycle	
	May 1980	Sept. 2009	Sept. 2010	Oct. 2011	
RN1					Stationary
RFD					Stationary
RFS					Stationary
R1	0.00	3.08	3.40	3.93	
R2	0.00	3.52	3.39	3.34	
R3	0.00	4.59	4.73	5.38	
R4	0.00	4.39	4.43	4.67	
R5	0.00	5.25	5.47	6.13	
R6	0.00	3.65	4.09	4.9	
R7	0.00	4.08	4.44	6.16	
R8	0.00	2.41	3.20	4.47	
R9	0.00	0.95	1.93	3.3	
R10	0.00	0.89	1.80	3.30	
R11	0.00	–0.38	0.44	1.91	
R12					inactive

Microtriangulation network consist of seven pillars, 36 landmaks plots embedded in dam and 20 landmarks situated in crest of the dam (Bălă, 2014).

Measurements were made with the Leica TCR 1201 total station with a 1^{cc} accuracy.

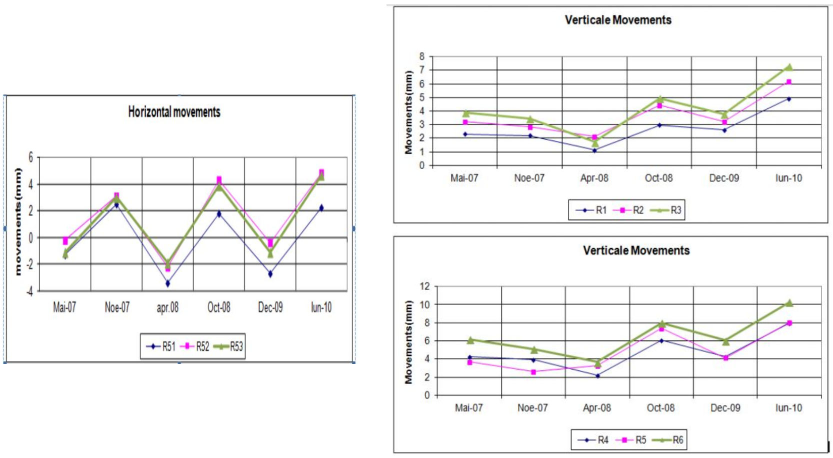
Leveling network consist of 15 landmarks located on the crest of the dam.

Following the measurements, the authors of the study dreaw three graphs which indicates the horizontal and vertical movements of tracking landmarks (Fig. 1).

In the proccess of monitoring dam the classic method is also used to study the behavior of the Valiug dam, located on the Barzava river, Caras-Severin county (Fig. 2). Valiug dam is a concrete arch dam with a height of 27 m.

Topographic network for observation and surveying is composed of 19 topographic mobile landmarks and 4 landmarks fixed on the crest and on both sides of the dam. Surveying were performed with Leica DNA 03 elecronic equipment and use levelling board.

In the article, ”Modern techniques for collecting topo-bathymetric data”, are described features of LIDAR technology to determine topography of the land. Values measured with LIDAR technology can be integrated into a GIS database. Using a GIS database you can always know and update areas exposed to floods, landslides etc., thus ensuring the safety of citizens (Pîrvulețu, 2016).



a *b*

Fig. 1 – Charts of the displacement of the landmarks fixed on the Cerna dam:
a – horizontal movements; *b* – verticale movements (Bălă, 2014).

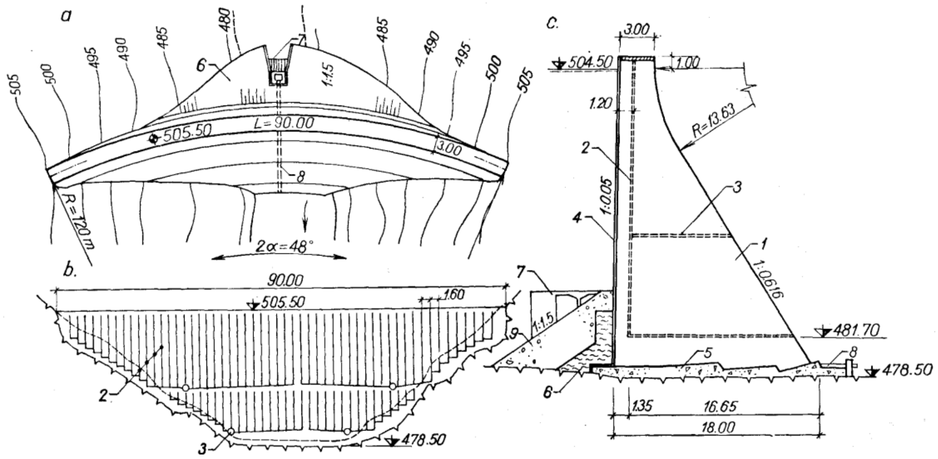


Fig. 2 – Valiug dam (Prişcu, 1974).

Of the known equipment, LIDAR technology (Light Detection and Ranging) is an advanced and active remote sensing technique through which data are obtained with high accuracy on topography, vegetation, buildings etc. LIDAR technology uses 3 base systems (Pîrvulețu, 2016):

- laser scanners – for accurate distance measurement;
- global Positioning System (GPS);
- Inertial Measurement Unit (IMU) to record the orientation.

Useful applications in processing LIDAR data are:

- ALDPAT – analyzes and classifies LIDAR data;

- HHViewer – allows viewing, analyzing and editing 2D and 3D data sets;
- LIDAR Analyst – extension of the ArcGIS application;
- Lviz – allows interpolation and 3D visualization of LIDAR data;
- MARS – analyze, process and manipulate large sets of data;
- Quick Terrain Modeler – process and view 3D large sets of data (about 200 million points);
- Terrasolid – processes large sets of data obtained by laser scanning.

There are many modern equipment based on LIDAR technology, which can be install on various road, rail, naval and air vehicles. Using drones is the most preferred option at this moment. An example of drones equipped with LIDAR devices are those in the PHOENIX AERIAL SYSTEMS range (Fig. 3).

Fig. 3 – Phoenix AL-2 device (Pîrvulețu, 2016).

The device weighs less than 10 kg and provides measurement and intensity information within a range of 1 m to 100 m with an accuracy of +/–2 cm .

At international level, one can notice the use of modern monitoring methods applied to tracking the behavior of the earth masses of the dam type.

Study on the Conza dam area in Italy, demonstrates the applicability and necessity of using photogrammetry in the context of determining the deformation affecting the stability of the target dam.

The analysis of the Conza dam in Italy is carried out using 51 images taken over by the radar satellites (ENVISAT-ASAR) between November 29, 2002 and July 30, 2010 (Di Martire, 2014).

The authors of the article ”Geodetic and Remote-Sensing Sensors for dam deformation monitoring” say that in recent years, measuring displacement to dams benefited from an improvement of the existing technology, which allow for a higher degree of automation. Data collection is done with a much better time and space resolution. Current technology, including the use of total robotic station and the GNSS (Global Navigation Satellite System), can provide effective solution for measuring 3D movements. Also, remote sensing, terrestrial laser scanning gives you the chance to expand the observed region.

Monitoring is not only intend to alert you in the event of a possible dam destruction, but it can also provide information needed to verify design parameters.

It was analyzed and found that modern geodetic measurements can detect horizontal and vertical surface displacement of control points located in key positions. Remote sensing techniques can generate a wider view of displacement throughout the structure of the dam and in the surrounding area.

In the case study for the Genzano dam in Italy, traditional methods are described and compare with innovative, modern dams monitoring techniques. The Genzano dam in Italy (Fig. 4), was built on the valley of the Ofanto River.

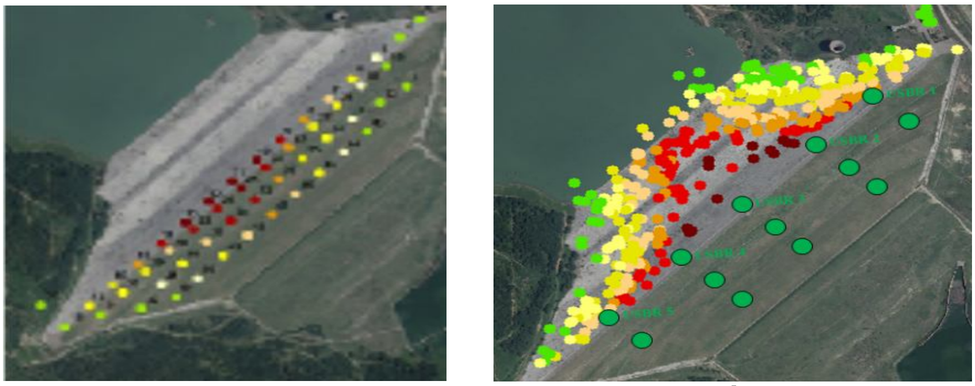
Fig. 4 – The site of Genzano dam (https://www.google.ro/maps).

Classical topo-geodesic measurements were performed with the TCA-2003 total station. The monitoring network consisted of 49 control points placed along the crest and on the downstream face (Fig. 5).

The displacement of the studied dam were highlighted by the DinSAR technique, through a palette colors, the green area being the most stable and red-sour area indicating the highest displacement values.

From analysis of topo-geodesic monitoring resulted important vertical movements of the studied dam. Between July 1999 and October 2010, it was measured, at control point no.11, a vertical displacement of 180 mm and the tendency is to move each year by 18 mm.

Monitoring of the Genzano dam's movements was also carried out between 1992 and 2007 with the aid of satellite imagery. Fifteen year old satellite imagery has clearly highlighted the part of the dam undergoing the compaction proccess, indicating a total of 24 cm throughout the monitoring period.



a *b*

Fig. 5 – Locating topographical control points: *a* – ground topographical points; *b* – comparison between ground topographical points and points obtained from satellite imagery.

By comparing the satellite monitoring methods with conventional, analytical ones, results the reliability of satellite methods (Fig. 5).

The article which presenting the case study of the Arenoso dam in Spain, analyzes deformations with modern high-precision geodetic technology.

For the purpose of monitoring it, control points were fixed around the dam and the measurement of displacement was performed in seven periods of time: in February and July 2008, March and July 2013, August 2014, September 2015 and September 2016.

The terrestrial measurement and GNSS technique were used to monitoring vertical and orizontal movements.

The terrestrial measurement were made with the LEICA DNA03 high precision digital level, over seven measurements cycles between 2008 and 2016.

The results obtained indicated downstream movements of the dam center during the winter.

Vertical displacement values indicated that the magnitude of the movements decreases over time, confirming that the dam tends to stabilize.

Horizontal movements were monitored over the same time with vertical displacements, using this time GNSS technology. During the two measurement cycles in 2008, the equipment used consisted of Leica GX 1200 receivers with AX1202 antenna.

Beginning with 2013, Leica GR10 receivers with AR10 antennas were used for all measurements.

The measurements obtained were processed using Leica Geo Office Software version 7.0. The results indicate the instability of the external pillars V100, V300, V500 (Fig. 6).

Station	Horizontal Displacement (mm)	Geodetic Azimuth of the Displacement Vector
V100	4.5	65°53′31.8″
V300	10.3	104°33′34.9″
V500	3.9	244°10′43.9″

Fig. 6 – The horizontal displacements estimated for V100, V300, V500
Pillars as part of the monitoring of Arenoso dam (Acosta, 2018).

4. Conclusions

Tracking dams is very important because unwanted events caused by design, execution and exploitation errors can be prevented.

Terrestrial measurements allow high precision monitoring of dams, but involves high costs and long execution time.

Satellite methods are more reliable than terrestrial ones, providing results with the same accuracy, generating a wider picture of the deformations of the dams, with the possibility of expanding the observed area.

At national level it is noted the necessity to implement modern techniques for tracking of concrete dams and of earth dams.

REFERENCES

Acosta L.E., Clara de Lacy M., Ramos M.I., Cano J.P., Herrera A.M., Aviles M., Gil A.J., *Displacement Study of an Earth Fill Dam Based on High Precision Geodetic Monitoring and Numerical Modeling*, Sensors, *18*, 1369 (2018).

Bălă A.C., Brebu F.M., *Monitoring of Hydropower Construction Using Modern Geodetical Methods*, Bul. Inst. Politehnic, Timişoara, **59 (73)**, *1*, 37-40 (2014).

Corsetti M., Aranno P.J.V.D., Giancola F., Marsella M., Scifoni S., Sonnessa A., *Satellite Techniques: New Perspectives for the Monitoring of Dams*, Engineering Geology for Society and Territory, **5**, 989-993 (2016).

Di Martire D., Iglesias R., Monells D., Centolanza G., Sica S., Ramondini M., Pagano L., Mallorqui J.J., Calcaterra D., *Comparison Between Differential SAR Interferometry and Ground Measurements Data in the Displacement Monitoring of the Earth-Dam of Conza della Campania (Italy),* Remote Sensing of Environment, *148*, 58-69 (2014).

Eleş G., Popescu D., Pişleagă M., *Monitoring the Văliug Dam Behaviour During Exploitation by Using Topographical Observations*, Scientific Bulletin of Politehnica University of Timişoara, Transactions on Hydrotechnics, **61(75)**, *2*, 5-10 (2016).

Grecea C., Gridan M.R., *Monitoring Special Constructions Behaviour, Using Topographical Modern Methods*, Bul. Inst. Politehnic, Timişoara, **57 (71)**, *2*, 51-56 (2012).

Gridan M.R., *Folosirea metodelor moderne din topografie pentru urmărirea comportării construcțiilor speciale*, Teză de doctorat, 2012.

Marco S., Maria M., Michele C. Vincenza T., Jin W., *Geodetic and Remote-Sensing Sensors for Dam Deformation Monitoring,* Sensors, *18*, 2018.

Pîrvulețu M. E., *Modern Techniques for Collecting Topo-Bathymetric Data,* Bul. Științific al Univ.Teh. de Construcții, București, *2*, 21-30 (2016).

Prişcu R., *Construcții hidrotehnice*, **I**, 523-633, Ed. Didactică şi Pedagogică, Bucureşti, 1974.

STUDIU DOCUMENTAR PRIVIND MONITORIZAREA PRIN METODE MODERNE A STABILITĂȚII BARAJELOR DE PĂMÂNT

(Rezumat)

Studiul construcțiilor hidrotehnice permite cunoaşterea parametrilor ce caracterizează modificările apărute în timp la nivelul structurii construcțiilor studiate. Urmărirea comportării în timp a masivelor de pământ, în special a barajelor de pământ, are ca scop evitarea producerii unor accidente sau chiar ruperi de baraje. Barajele de pământ sunt supuse riscului de apariție a fenomenelor de rupere datorită, în principal, infiltrațiilor. În prezenta lucrare sunt descrise metodele de monitorizare a deplasărilor şi deformațiilor masivelor de pământ prin măsurători topografice, fiind utilizate tehnologii şi echipamente geodezice moderne. Studiul prezintă stadiul actual, atât pe plan național cât şi internațional, a metodelor şi instrumentelor topo-geodezice folosite la monitorizarea barajelor. De asemenea sunt descrise metodele moderne de monitorizare şi sunt comparate cu metodele clasice. Procesul de urmărire a construcțiilor hidrotehnice este o activitate continuă, îndelungată, care se efectuează la intervale de timp stabilite cu precizie şi respectate. Astfel, starea construcțiilor este permanent cunoscută iar eventualele tendințe de evoluție atipice pot fi remarcate în timp util şi remediate. În cuprinsul lucrării vor fi descrise metodele contemporane utilizate în cadrul procesului de urmărire a comportării construcțiilor hidrotehnice, dar şi metodele clasice. Cele mai eficiente şi expeditive metode de monitorizare sunt cele care utilizează stațiile GPS combinate, scanerul laser 3D, stațiile totale robotizate şi dronele.

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INFLUENCE OF SLUDGE STORAGE AT THE WASTEWATER TREATMENT PLANT IN TOMEŞTI, IAŞI OVER THE GROUNDWATER

BY

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Abstract. The paper includes the results of a study on the impact of sludge deposit from the Tomeşti, Iaşi wastewater treatment plant on the groundwater. The study area is the sludge deposit at Tomeşti, Iaşi, which was built in 1994 by removing the soil layer from an area of 9.1 ha of land. The warehouse was divided into 11 compartments of different surfaces. Between the compartments there are breaches of water and sludge circulation. The total volume of the deposit is 225,000 m^3.

In order to study the effect of sludge storage on the Tomeşti platform on the groundwater, two drillings were made, a drilling was carried out on a depth of 300 cm on a witnessing ground near the deposit and the second drilling was carried out in the compartment 8 of the deposit on the same depth of 300 cm. The surface sample (0,…,20 cm) from the second drilling represents the sludge itself and from 100 cm in depth is the soil on which the sludge was stored. Following the sampling of the two drillings the concentration of heavy metals, macroelements and salts in groundwater was determined.

The research has found that groundwater is rich in soluble salts, especially in calcium, magnesium and potassium sulphates, but also in ammonium chloride and in Ca and Mg bikarbonates of water collected from the drilling on the sludge deposit Due to the high content of soluble salts this water is excluded from

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potability. Also, the sludge from the landfill caused a significant increase in the pollutant for N-NH4 and K.

The total concentration of heavy metals and salts in the groundwater is a relevant indicator of risk to human health and the environment. Knowing the total load of groundwater with heavy metals, macro-elements and salts is the basis for justifying the measures for remediation of contaminated waters.

The results of the research can be used as a scientific basis for the development of a proper groundwater management system in the study area.

Keywords: heavy metals; macroelements; salts; cations and anions.

1. Introduction

The Iaşi treatment plant is considered to be one of the largest in the country, with a daily flow rate of 4.2 m^3 / s being processed. The plant has three technological lines for waste water treatment, mechanical and biological processes, sludge fermentation reservoirs (methanthancs) and beds for natural dehydration of sludge (Lăcăuşu *et al.*, 2012).

The sludge resulting from the process of the treatment plant reaches up to about 3,600 tons per day (2,400 m^3/day). Sludge dewatering platforms occupy a total area of 5.0 ha. The fermented sludge has a moisture content of 98%, by dehydration, on the platforms, it reaches 85% or less, depending on the thickness of the sludge layer subjected to dehydration (Lăcătuşu *et al.*, 2006).

The surface treatment station platforms in the treatment plant is insufficient to the amount of sludge produced (3,600 t/day). For this reason, an amount of about 2,250 t/day is transported to the provisional platform located on a concession ground from the local council of Tomeşti commune (Negulescu, 1987).

Liquid sludge was pumped into compartments where it was stored. Due to combined flooding and air-drying processes, the sludge thickens, but water intake through precipitation largely contributes to the maintenance of a liquid blanket above the sludge. As a result of the oscillations between the amount of precipitation and the intensity of evapotranspiration and infiltration, the depth of the sludge layer, including the water mirror oscillates between 1.5 and 2 m (Dima *et al*., 2002).

1.1. Location of Research

The study was carried out in the area of the sludge depot in Tomeşti, Iaşi. The sludge deposit is located in the major river bed of the Bahlui River, on the right side of it at 350 m north of the road connecting Holboca commune of Tomeşti commune and about 400 m east of the road connecting Tomeşti to Iaşi. The straight line to Iaşi wastewater treatment plant is about 2,000 m. The mud deposit from Tomeşti was built in 1994 by removing the soil layer from an area of 9.1 hectares of land and the construction of surrounding and dividing dams (Murariu *et al*., 2007).

The warehouse was divided into 11 compartments (Fig. 1) of different surfaces. Between the compartments there are breaches of water and sludge circulation. The total volume of the deposit is 225,000 m^3.

Fig. 1 – Sludge storage in Tomeşti.

The average altitude in the storage area is 35 m, and in the adjacent areas it reaches up to 200 m. The area has an active dynamics, resulting in significant degradations due to surface washing, erosion and landslides (Murariu *et al*., 2006).

The analyzed area mostly belongs to the continental climate. In winter, the Eurasian Thermal Continental Anticyclone acts, and in the summer the Azeri dynamic anti-cyclone acts. Summer is dominated by dry weather with high temperatures, sometimes exceeding 35ºC, and in winter it reached –30º. The annual average is +9ºC. Precipitation has an annual average of 550 mm, and monthly averages are 60 mm in July and 40 mm in January.

The corridor on which the sludge depot is located allows for an increase in wind direction in the direction of the NV-SE. The average annual frequency is 21.5%. The average annual speed varies between 2 and 4.1 m/s, the maximum value corresponds to the dominant wind direction. Highest wind speeds exceed 40 m/sec. (S.C. Apa Vital S.A., Iaşi).

2. Materials and Methods

In order to study the effect of sludge storage on the Tomeşti platform on the groundwater, two drillings were made (Fig. 2): the first drilling (F1) was carried out on a depth of 300 cm on a blank soil located near the deposit and the second drilling (F2) was performed in the 8th compartment of the deposit at the same depth of 300 cm. The surface sample (0-20 cm) of drilling F2 represents the sludge itself and from 100 cm in depth is the soil on which the sludge was stored. The drilling F2 was placed in the compartment 8 of the deposit as the infiltration waters flow from compartment 1 to 8 to this compartment. Thus the samples in this compartment fully characterize the sludge and its influence on the groundwater.

Fig. 2 – Sampling water from the drilling.

3. Results and Discussions

The ground water was intercepted in the two 300 cm deep drillings. A sample of water was harvested, which was chemically analyzed. The pH values of the two samples are slightly different, *i.e*. the water sample collected from the blank drill has a neutral – slightly alkaline reaction (pH = 7, 89), while that in the sludge drilling has a neutral reaction (pH = 6.69). Differences appear in terms of content in macro elements (Table. 1).

Thus, the N-NH4 content is 72 times higher in the water collected from the drilling in the sludge storage. Also, the K content in the same water is 18 times higher than the water in the blank drill. The N-NO3 and P contents are close, much lower than those of N-NO3 and K, but are also superior to the permissible values for potability, according to STAS 1342-91.

Table 1
The Reaction and the Content of Macroelements of the Water Samples Taken from the Blank Drill (F1) and From the Sludge Drilling (F2)

Drill number	pH	N-NH4	N-NO3	P	K
		mg/L	mg/L	mg/L	mg/L
F1	7.39	2.0	1.0	1.9	5.4
F2	6.69	143.4	1.3	2.2	97.0

Therefore, the groundwater from the drilling in the sludge storage was significantly enriched in N-NH4 and K. The source of enrichment is the sludge above.

In addition to increasing the content of macroelements in the groundwater, there was also a slight increase in heavy metal content, especially Fe and Ni (Table 2). However, increases occurred under conditions of low levels of heavy metal content, mostly below the maximum permitted values of STAS 1342-91 (Table 2). Only Fe and Ni exceed these limits.

Table 2
Heavy Metal Content of Groundwater Samples Harvested from the Blank Drill (F1) and the Drilling on the Sludge Storage (F2), Compared to the Maximum Permissible Values for Potable Water

Nr.	Identification	Zn	Cu	Fe	Pb	Ni	Cr	Co
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	F1 at 300 cm	0.164	0.008	0.375	sld	0.095	sid	0.113
2	F2 at 300 cm	0.110	0.016	1.375	0.015	0.223	0.046	0.196
Drinking water: mg/dm^3	5.0	0.05	0.1	0.05	0.1	0.05		

The analytical data of the total salt content and the distribution of the anions and cations (Table 3) show an increase in the total salt content in the ground water collected from the drilling in the sludge storage. The increase was 1,193 mg/l or 1.3 times. The phenomenon is due to the washing of both natural and mud salts from the soil profile above the ground water table.

Table 3
Electric Conductivity, Total Salt Content and Anion and Cation Content of Groundwater Samples Collected from the Blank Drilling (F1) and Sludge Drilling (F2)

Location	Cond el.	Rez. Cond	Rez. mîn.	$HC0_3$	$SO4^{2'}$	Cr	$Ca^{2'*'}$	Mg^{2+}	Na^+	K^+
	CB/cm	mg/l		mg/l						
F1 at 300 cm	5,360	3,591	3,786	1,290	808	556	6.9	120	1,000	5.4
F2 at 300 cm	7,140	4,784	3,786	1,129	1,568	257	50.7	300	385	97

Enrichment in salts was made by increasing the concentrations of SO^{4-}, Ca^{2+}, Mg^{2+} and K^{+}. Therefore, the content of calcium sulphate, potassium magnesium, salts of predominantly groundwater in the sludge storage, to which are added bicarbonates of Ca and Mg and NH4Cl, coming from the NH4 present in the sludge, is added. The NaCl and Mg $(HCO_3)_2$ predominate in the drilling water. The high salt content of both types of groundwater excludes them from drinking. STAS 1342/91 admits exceptionally an electrical conductivity of 3,000 pS/cm, and the two samples have values of 5,360 pS/cm and 7,140 pS/cm respectively.

3. Conclusions

The groundwater intercepted in the two drillings in the control soil and in the soil beneath the sludge layer had some different chemical properties, namely the N-NH4 and K content. The sludge caused a 72-fold increase in the N- NH4 and 18 times K in groundwater.

Research has shown enrichment in soluble salts, especially in calcium, magnesium and potassium sulphates, but also in ammonium chloride and in Ca and Mg bikarbonates of the water collected from the drilling on the sludge deposit. Due to the high content of soluble salts this water is excluded from potability. Also, the sludge from the landfill caused a significant increase in the pollutant for N-NH4 and K.

REFERENCES

Dima M. et al., *Bazele epurării biologice a apelor uzate*, Ed. Tehnopress, Iaşi, 2002.

Lăcatuşu R., Stanciu-Burileanu M.M., Lazăr D.R., Lungu M., Rizea N., Catrina V., *Phytoremediation of a Sludge Depozit Proceeded from a City Wastewater Treatment Plant*, Carpathian Journal of Earth and Environmental Sciences, **7**, *1*, 71-79 (2012).

Lăcătuşu R., Dobra M., Viman V., *Determination of Concentration of Air and Soil Pollutant Heavy Metals by ICP-AES*, Revista de Chimie, 57:12, 1283-1286 (2006).

Murariu A., Stratu A., Costică N., Costică M., Secu C., Răşcanu D., *Researches Concerning the Impact Pollution with Heavy Metals of Soil And Vegetation on the Area of Domestic Waste Deposit at Tomeşti-Iaşi*, An. Şt. ale Univ. „Al. I. Cuza" Iaşi, **LIII**, s. II-a, Biologie vegetală (2007).

Murariu Al., Costică N., Costică M., Stratu A., Secu C., Lupaşcu A., Moglan I., Răşcanu D., 2006, *Research on the Impact of Tomesti-Iaşi Dumping Site on the Environment*, An. Şt. ale Univ. „Al.I. Cuza" Iaşi, **LII**, s. II-a, Biologie vegetală, 31-38 (2007).

Neag Gh., *Depoluarea solurilor şi apelor subterane*, Editura Casa Cărţii de Ştiinţă, Cluj, 1997.

Negulescu M., *Epurarea apelor uzate industriale,* Vol. **I** şi **II**, Editura Tehnică, Bucureşti, 1987.
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INFLUENȚA DEPOZITĂRII NĂMOLULUI DE LA STAȚIA DE EPURARE DIN TOMEŞTI, IAŞI SUPRA APEI FREATICE

(Rezumat)

În acestă lucrare s-a analizat impactul depozitării nămolului rezultat de la stația de epurare a apelor uzate de la Tomeşti ,Iaşi. Zona de studiu este depozitul de nămol de la Tomeşti din Iaşi care a fost construit în anul 1994 prin îndepărtarea stratului de sol de pe o suprafață de 9,1 ha teren. Depozitul a fost împărțit în 11 compartimente, de suprafețe diferite. Între compartimente există breşe de circulație a apei şi a nămolului. Volumul total al depozitului este de 225.000 m^3.

Rezultatele au fost obținute în urma prelevării probelor de apă din doua foraje, un foraj s-a realizat pe adâncimea de 300 cm într-un sol martor situat în apropierea depozitului şi al doilea foraj s-a realizat în compartimentul 8 al depozitului pe aceeaşi adâncime de 300 cm. Proba de suprafață (0,...,20 cm) din al doilea foraj reprezintă nămolul propriu-zis iar de la 100 cm în adâncime este solul pe care s-a depozitat nămolul. În urma prelevării probelor din cele două foraje s-a determinat concentrația în metale grele, macroelementele şi sărurile din apa freatică. În urma cercetărilor s-a constatat o îmbogățire în săruri solubile, în special în sulfați de calciu, de magneziu şi de potasiu, dar şi în clorură de amoniu şi în bicarbonați de Ca şi Mg a apei colectată din forajul executat pe depozitul de nămol. Datorită conținutul foarte mare de săruri solubile această apă se exclude de la potabilitate. De asemenea nămolul din depozit a determinat o creşterea semnificativă, la nivel poluant şi pentru N-NH4 şi K.

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THE ANALYSIS OF JUNE 2016 VORONEȚ RIVER FLOOD EFFECTS IN “VORONEȚ MONASTERY” AREA

BY

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Abstract. The paper presents an analysis of the hydroclimatic risk parameters in the Voroneț River hydrographic basin. The studies and researches were conducted on Voroneț River, on the sector located in the area of the “Voroneț Monastery” historical monument. The flood of June 2016 morphologically changed the Voroneț River minor riverbed, which influenced the shore protection stability. The flood effect also consisted in the degradation of the DJ 177D road on a length of about 125 m. Through the field research, the precipitation, liquid flows, the floods’ development and evolution, the volume of the resulting damages etc. were analysed. Data processing pointed to a number of factors which have prevailed over the last 20 years. The precipitation value was 71.6 l/m^2 over two days. The flow rate in the study section on the Voroneț River was 94.11 m^3/s (p = 1%). The effects of the floods have materialised through the excessive degradation of the Voroneț River shore protections in contact with DJ 177D county road. The floods have led to the destruction of some economical and social objectives in the riparian area. The hydroclimatic risk parameters highlighted through research require special conditions for the design of hydrotechnical works in the riverbed.

Keywords: degradation; flood; flows; riparian area; river improvement; road.

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1. Introduction

Climate changes which occurred worldwide during 1990 – 2018 have determined a series of influences on the hydrological regime in Romania. In recent years there have been changes in the annual distribution of precipitation and flow on hydrographic basins. The high value of the changes leads to an important hydroclimatic risk in the evolution of river flows and water levels, which favours floods development. The high frequency of floods influences the behaviour of the existing structures in the riverbed and the riparian area (Luca, 2007; Vamanu, 2002).

Hydrological risk elements affect the minor riverbed morphology, the stability of the riverbed constructions (bridges, regulation works) and shore structures (shore protections, dykes, houses, agricultural fields). Hydrological risk elements affect the existing habitat in the minor and major riverbed. Disastrous floods in recent years have caused significant degradation of the social and economic objectives in the Siret and Moldova Rivers hydrographic basins. The value of the damages has become very high, which has forced the allocation of large investments to restore the social and economic environment. The effect of the changes can be immediately noticed, or occurs after a longer time period. The restoration of river regulation and shore protection works depend directly on the hydrological parameters. The disturbance of the hydrological parameters determines the behaviour of the regulation works and, implicitly, the existence conditions of the river habitat.

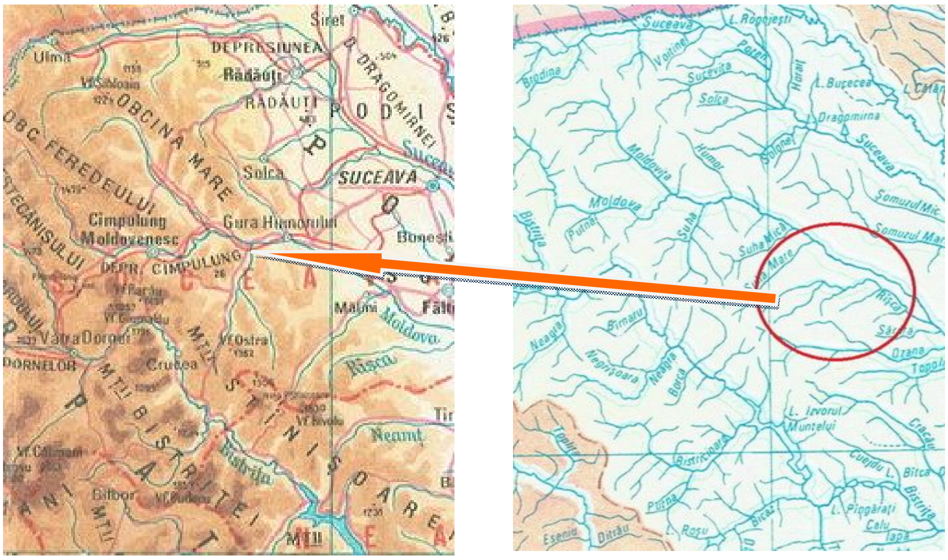
2. Research Material and Methods

The research area is located in the Voroneț River hydrographic basin, a right side tributary of Moldova River. The hydrographic basin is located in the Eastern Carpathians relief area, in Stânişoarei Mountains geomorphological unit with an elevation of 510,…,750 m and an average of 730 m. A number of heights called hummocks or hills are found in the area, such as Voroneț Hummock, Brusturosului Hummock, Mânăstirii Hill, Bătrânei Hummock etc. Voroneț River cadastral code is XII-1-40-26. Voroneț River has a number of streams and torrents tributaries such as: on the left side are the Maghernița, Brusturos, Slătioara streams and on the right side Varnița, Moara, Râla, Poiana etc. streams. Voroneț River hydrographic basin has a surface of 35 km^2 and an oval shape. The river has a length of 10 km and a slope of 3.17% (Fig. 1).

The research material consists of topographical, hydraulic, hydrological, geotechnical, safety during operation etc. studies conducted on the river section taken into account. Studies and researches are conducted over a differentiated time period (4 months – 4 years). The theoretical and experimental research was carried out in the following fields: (Luca, 2016):

1° Research of hydrological parameters in the study area. The analysed parameters were: flows (liquid, solid), levels, floods frequency, flood areas etc.

2º Research of hydraulic parameters on the study river sector. The analysed parameters were flows, levels, velocities, erosion and depth lengths in river study sections.



a *b*

Fig. 1 – Voroneţ River hydrographic basin location: *a* – study area physical map; *b* – hydrographic network of the Moldova River in the upper sector.

3º Research of hydrological risk parameters on the minor and major riverbed morphology on the study river sector.

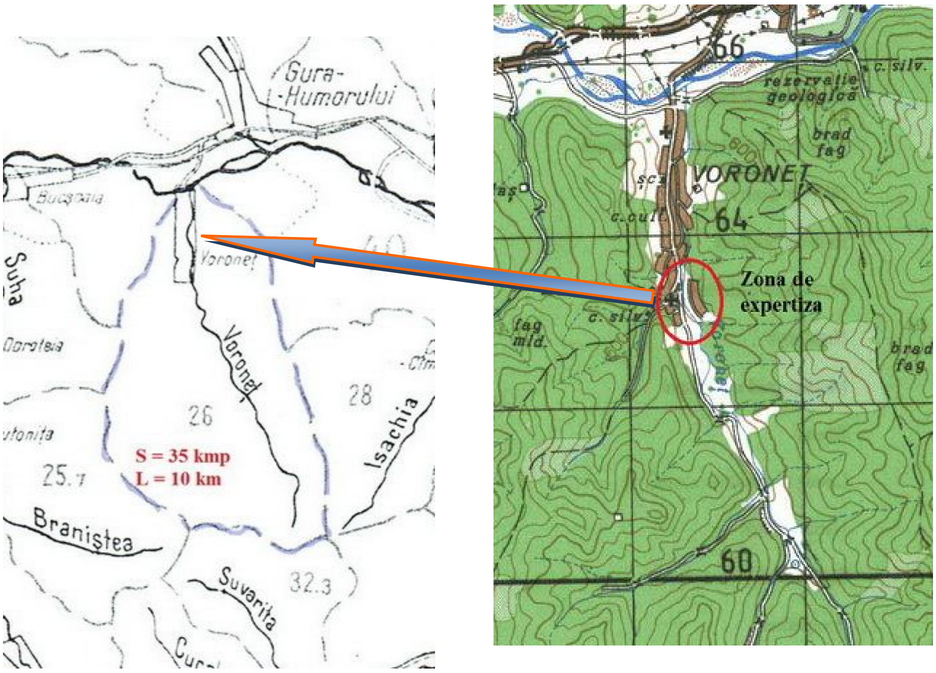
4º The effect of risk parameters on the riparian constructions and the habitat.

Primary data were processed using specialised computing programs (statistical, hydrological, hydraulic, resistance etc.) applicable to the research.

3. Results and discussions

The research was conducted out on about 60% of the Voroneţ River length, namely the sector located in the inhabited area and in contact with DJ177D (Fig. 2). The highest degradations of the riverbed and riparian environment were recorded on this sector. The sections selected in the research come from representative areas of the hydrographic basin.

The research used climatic data taken from meteorological stations placed in the analysed hydrographic basin. The meteorological data were taken on varying time intervals (from 5 to 45 years). The hydrological data were collected from hydrometric stations placed in the study river representative sections. The data from hydroclimatic risk periods were analysed by considering them over a long time period.



a *b*

Fig. 2 – The location of the study area on Voroneț River: *a* – Voroneț River hydrographic basin; *b* – examination area of the flood effects along DJ177D (Luca, 2016).

Voroneț River has a classic hydrographic basin with an ellipse shape, which enables a rapid flow concentration. The erosive action of the water has resulted in a large minor riverbed, with meandering areas and alluvial deposits specific to the mountain area. The presence of alluvial deposits allows for important morphological changes of the riverbed.

Gura Humorului hydrometric and meteorological stations were used for Voroneț River data analysis. In May and June 2016 in the Voroneț River hydrographic basin an abundant rainfall regime was recorded. In the analysed area, the rainfalls with the highest value were recorded during 18 – 20 June. The values recorded at Gura Humorului Meteorological Station were 71.6 l/m^2 (ABA Siret, 2016).

Voroneț River does not have a hydrometric station. The maximum flows were determined analytically. The maximum 1% probability flow rate for hydrographic basins larger than 10 km^2 was determined using the rational equation (Stăncescu *et al*., 1984):

$$Q_{1\%} = \frac{K\alpha I_{60\ 1\%} F}{(F+1)^m}, \tag{1}$$

where: k = 0.28 coefficient of rainfall transformation from mm/hour to m/s, km^2 to m^2; α – global leakage coefficient; $I_{60\ 1\%}$ – maximum hourly rainfall with 1% probability of exceedance; F – basin area in km^2.

The values of equation (1) parameters were taken from the paper (Stăncescu *et al.*, 1984) in accordance with the hydrographic basin characteristics. For the geographic area under consideration with a surface of 32 km^2 the resulting values were: $I_{60,\ 1\%}$ = 125 mm, α = 0.55, m = 0.49. From the calculations, the flow with 1% calculation probability in the downstream area of the river, respectively $Q_{1\%}$ = 118.12 m^3/s was obtained (Luca, 2016) (Table 1). The $Q_{1\%}$ flow rate was also determined in the section located around the "Monument" area, where degradations were recorded on the riparian structures; the resulting value was 94.11 m^3/s. This flow was not fully taken over by Voroneț River bed, which was also highlighted by the discharges on both banks and the important changes of the minor riverbed. The average multi-annual flow rate is 0.325 m^3/s. The average elevation of the hydrographic basin at influx, taken into account, is 728 m (it is 789 m in the middle section) (Luca, 2016).

Table 1
$Q_{1\%}$ Flows Computed and Estimated on Voroneț River During June 2016 Flood

No.	S (km^2)	Q_c (m^3/s)	Q_{sp} (m^3/s)	Q_{re}^* (m^3/s)
1	36.0	118.12	141.74	130,0
2	14.6	71.61	85.93	68.0
*- ABA Bacău 2016 source				

The rainfall which concentrated over a short time period influenced the water flow in the rivers from Voroneț hydrographic basin. The floods on Voroneț River were amplified by the rapid discharge of water from the slopes by torrential formations. The concentration time was diminished by the circular/ oval shape of the hydrographic basin. The streams have displaced alluvial material made of rocks (even with large dimensions), alluvial and forest material. The forest material and the rocks were engaged outside Voroneț River bed resulting in degradation phenomena to the shore protections. In some areas the shore was eroded on depths of 2,...,5 m.

DJ 177D county road was degraded by floods on a route starting from Voroneț District up to around „Camp Cristea” area. The county road is placed parallel to the Voroneț River bed, at distances of 1.0,...,45 m. County road DJ 177D crosses the Voroneț District and on some sections is located on the river bank (Fig. 3). In the contact area of the river with the road, shore protection works were executed in order to protect the road structure from the water action. The shore protection was executed nearly 45 years ago and consists of large concrete slabs placed on a concrete beam. The action of natural factors and the lack of repair works caused the excessive degradation of the concrete shore protection. It was replaced on a limited section of the riverbed with a stone-filled gabion construction (Fig. 4).

Fig. 3 – General view of the DJ 177D location at the border of Voroneţ River bed: 1 –Voroneţ District road route and near „Voroneţ Monastery”; 2 – the state of the shore protection (Photo Luca, 2016).

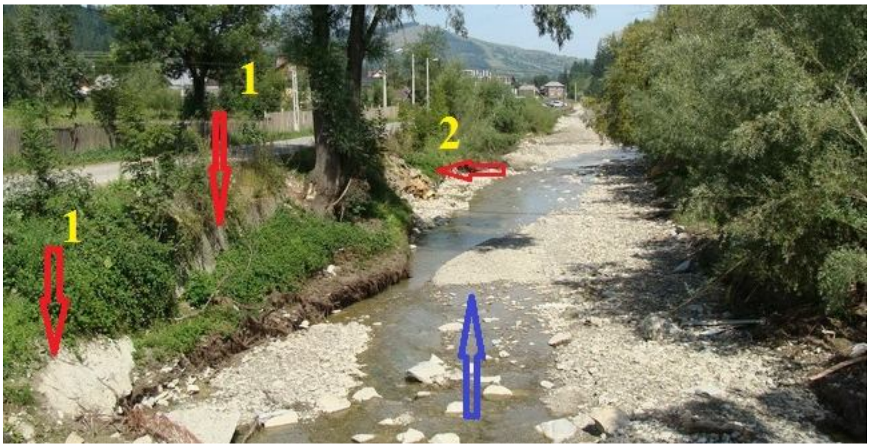


Fig. 4 – General view of the structural state of Voroneţ River shore protection, in contact with DJ 177D in Voroneţ District: 1 – completely degraded concrete slabs; 2 – erosion areas of road shoulder and road structure (Photo Luca, 2016).

The riverbed section located around Voroneţ Monastery was affected by erosion phenomena, with extension to the county road structure DJ177D. The road located directly on the river bank is influenced by the direct action of the water during floods (Fig. 4). The shore protection made of concrete slabs is aged and degraded up to total destruction.

The forms of degradation are vast: shore erosion, erosion of shore protection, erosion of road shoulder, erosion of road structure etc. The result of the action of natural factors is complemented by the action of anthropic factors.

The result of the combined action over time of the two factors resulted in the following degradation phenomena to the county road: erosion of the road shoulder, washing of the road supporting layer, degradation of the resistance structure, displacement of road sections. This phenomenon is present on the road section located near the monastery (Fig. 5).

Fig. 5 – General view of the DJ 177D degradation located in Voroneț District due to the erosive action of the water during floods: 1 – the erosion of the road shoulder with ingression in the road; 2 – the shore protection fully degraded and shore erosion (Photo Luca, 2016).

The analysis conducted in the field, in the area of Voroneț Monastery, highlighted the state of degradation of the former shore protection, but also the state of the one that replaced it (Fig. 6). In this context, the water flow and alluvial material intensifies the degradation state of the road and riparian constructions. The riverbed carries during floods an alluvial material in which gravel and stone of different sizes, including boulders, prevails. The alluvial material acts on the bank made of a layer of poorly cohesive rocks, but with intercalations of hard rocks, causing a strong erosion phenomenon. In this context, the selection of shore protection solutions should take into account the extremely strong and diversified hydro-transport phenomenon.

The interventions on the current shore protection rehabilitation on the Voroneț River within the locality are missing, or the ones made have not resisted over time to the erosive water action. Local interventions to limit the degradation of the Voroneț River left bank are not effective. The rock deposits strength is limited to high transport speeds generated by floods with 1% probability calculations as the one from 2016 (Fig. 7).

Fig. 6 – General view of the structural state of the shore protection on Voroneț River in Voroneț District – the monastery parking area (Photo Luca, 2016).

a b

Fig. 7 – Details on the erosion phenomenon of Voroneț River bank and the degradation of DJ 177D in Voroneț District; a – blocking of the shore erosion with large stones; b – highlight of the erosion area on the shore protection line (Luca, 2016).

The effects of the June 2016 flood on the Voroneț River are multiple. The most important are the structural degradation of the county road, the footbridges (17 footbridges), the bridges (5 bridges) and the pedestrian bridges, the shore protection works, the bank erosion in the urban area, the damage to the individual properties etc. The river banks were eroded (2600 m of shore) and the riverbed was morphologically transformed (Luca, 2016). The effects of the flood on the area where "Voroneț Monastery" is located are particularly negative, as it affects the road connecting with the exterior of the locality. The blocking of this road leads to the transfer of traffic on the road near the monastery and the appearance of some risk factors for the functioning of the historical monument.

The population must be informed and trained on how to place the structures in riparian area. Permission for housing on the waterfront should be limited. Town halls have to comply with legislation and inform the public about the legislation in the field.

4. Conclusions

1. The Voroneț hydrographic basin area has been affected in the last 15 years by disastrous hydrological phenomena, which have significantly influenced the riverbed morphology, with important influences on the riparian environment.

2. The Voroneț River floods of June 2016 have recorded flows with 1% probability, a situation which resulted in extremely destructive effects on the riparian area occupied by the county road and economical and social structures.

3. The Voroneț River flood of June 2016 resulted in significant degradation of the county road located around „Voroneț Monastery”, illustrated by the erosion of the road structure and also the damages to the riparian area structures.

4. The climatic phenomena produced in the Voroneț River hydrographic basin in the last 8 years can be characterised as hydroclimatic risk phenomena due to their destructive influence on the riparian area occupied by houses, the county road and the morphology of the riverbed.

REFERENCES

Avram M., *Cercetări privind impactul factorilor de risc hidroclimatic asupra proiectării, tehnologiilor de realizare şi exploatării lucrărilor de regularizare a râurilor - Studiu de caz. Raport 2 de cercetare*, Universitatea Tehnică „Gheorghe Asachi” din Iaşi, 2016.

Avram M., Luca M., Sion P.V., *Studies and Research of the Flood Effects of the June 2016 on the River Voronet, ”Camp Cristea” – ”Poiana Lui Macarie” Zone*, Bul. Inst. Politehnic "Gheorghe Asachi", Iaşi, **64 (68)**, *2*, s. Hidrotehnica, 59-68 (2018).

Luca M., *Expertiză tehnică „Refacere apărare de mal la pârâu Voroneț în lungime de 300 m (zona Slevoacă şi Monument) prin lucrări de gabionare pentru punere în siguranță drum DJ 177D, sector aflat în administrația oraşului” Gura Humorului*, S.C. Polias-Instal Iaşi, 2016.

Luca, M., Avram Mihaela, Marcoie N., *Analysis of the Floods Effects in June 2016 in the Voronet River Hydrographic Basin*, The Annals of “Dunărea de Jos” University of Galați, **IX**, Metallurgy and Materials Science, *2*, 5-10 (2017)

Stăncescu L., Moraru N., Ionescu V., Leinweber L., *Îndrumător tehnic pentru lucrări de îmbunătățiri funciare*, Editura Ceres, Bucureşti, 1984.

Ujvari I., *Geografia apelor României*, Edit. Ştiințifică, Bucureşti, 1972.

Vamanu E., Olariu P., *Riscuri hidroclimatice în Spațiul hidrografic Siret în contextul modificărilor geografice*, Sesiunea ştiințifică anuală INMH Bucureşti, 2002.

* * * *Atlasul Cadastrului Apelor din România*. Ministerul Mediului, Bucureşti, 1992.

* * * *Rapoartele de sinteză privind apărarea împotriva inundațiilor, fenomenelor hidro-meteorologice periculoase, accidentelor la construcții hidrotehnice şi poluărilor accidentale din județul Bacău*, Administraşia Bazinală de Apă Siret, 2018.

ANALIZA EFECTELOR VIITURII DIN IUNIE 2016 PE RÂUL VORONEȚ ÎN ZONA „MÂNĂSTIRII VORONEȚ”

(Rezumat)

Lucrarea prezintă o analiză a parametrilor de risc hidroclimatic în bazinul hidrografic al râului Voroneț. Studiile şi cercetările s-au efectuat pe râul Voroneț, pe sectorul situat în zona monumentului istoric ”Mânăstirea Voroneț”. Viitura din iunie 2016 a modificat morfologic albia minoră a râului Voroneț, situație ce a influențat stabilitatea lucrărilor de apărare de mal. Efectul viiturii s-a concretizat şi prin degradarea parțială a drumului DJ 177D pe o lungime de circa 125 m. Cercetarea realizată în teren a analizat precipitațiile, debitele lichide, modul de formare şi evoluția viiturilor, pagubele produse etc. Prelucrarea datelor a indicat o serie factori ce intervin preponderent în ultimii 20 de ani. Precipitațiile au fost de 71,6 l/m^2 în două zile. Debitul calculat pe râul Voroneț în secțiunea cercetată a fost de 94,11 m^3/s (p = 1%). Efectul inundaţiilor s-au materializat prin degradarea excesivă a lucrărilor de apărare de mal pe râului Voroneț, la contactul cu drumul județean DJ177D. Inundațiile au produs distrugerea de obiective economice şi sociale din zona riverană. Parametri de risc hidroclimatici evidențiați prin cercetare impun condiții speciale la proiectarea lucrărilor hidrotehnice din albia râului.

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PERFORMANCE EVALUATION OF THE PODU ILOAIEI TOWN WATER SUPPLY SYSTEM FROM THE "WATER LOSS" PHENOMENON PERSPECTIVE

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Abstract. The case study drawn up analyses the Iaşi County, Podu Iloaiei Town water supply system and evaluates its performances during 2015 – 2017. Data analysed show the annual water loss percentage fits in the value recorded for the entire Iaşi County operational area (30 %). However, monthly variations start at minimum values under 10 % of the water volume supplied to the system (values such as 5.79 % and 7.29 %) and go up to maximum values of over 40 % (40.85 % and 44.74 %). The water volumes annually supplied to the system are around 350,000 m^3, however, 20 % to 25 % of them are lost before reaching consumers. The paper presents a detailed analysis of the "water loss" phenomenon in Podu Iloaiei Town and the water supply system performances.

Keywords: degradation; detection; hydraulic model; pipe network; water loss.

1. Introduction

In the global warming context, the „water loss" phenomenon has become an intensely debated subject. The phenomenon was given increased attention, from specialised conferences to legislative regulation (GIZ, 2011; Lambert A.O. and Hirner W., 2000). The impact of water loss has implication in

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all branches that govern human existence. Their effect is felt in areas such as: quality of life, economy, health, environmental protection, politics, technology etc. (Chirica, 2017).

The water loss value is a major risk factor in the management of water supply systems. The amount of leakage recorded over an operating area depends on the complexity and the operating mode of the managed system (May, 1994). In a water supply system made of main water supply pipe, water treatment plant, pumping station, storage tank and distribution network, the largest water loss values are recorded for the pipes. Significant leakage values are also recorded within the other components. However, their nature makes it more difficult to highlight them (Farley & Trow S., 2003).

2. Research Material and Methods

The material which makes up the documentary study and represents the research subject consists of the water supply system components, from the catchment structure to the distribution network. The technical indicators which define the studied system (pipe lengths, number of connections and consumers, billed water volumes) and indicators which describe the system's performance (potable water quality parameters, the degree of connection to the water supply network, the achieved level of metering and the unbilled water volumes) were analysed within the research.

The research methodology aims at highlighting and assessing the water losses recorded in a water supply system extended in the urban and rural areas. The research of water losses in a water supply system is done using various methods, such as (Thornton, 2002):

- analytical methods (performance indicators computation, the water balance);
- hydraulic methods (pressure management, hydraulic modelling of networks, flow measurement);
- methods and procedures applied on the ground (acoustic equipment, ground penetrating radar, satellite detection).

The methods used can be applied independently within a system (using a single procedure) or can be applied simultaneously (using multiple methods for the same system). Effective water loss management is achieved through the use of multiple detection and control methods, so that the results obtained correspond to the real field situation (Mănescu, 2012).

3. Results and Discussion

Iaşi County, Podu Iloaiei Town serves about 6,000 people through a water supply system consisting of a storage tank with the capacity of 1,000 m^3, a pumping station and pipe network conveying water by gravity. The water supply of Podu Iloaiei system is ensured by two connections to the Timişeşti

AdI and AdII main water supply pipes (Fig. 1). Podu Iloaiei Town water supply system components are complex structures which, by construction and operational features, can record water losses with significant values.

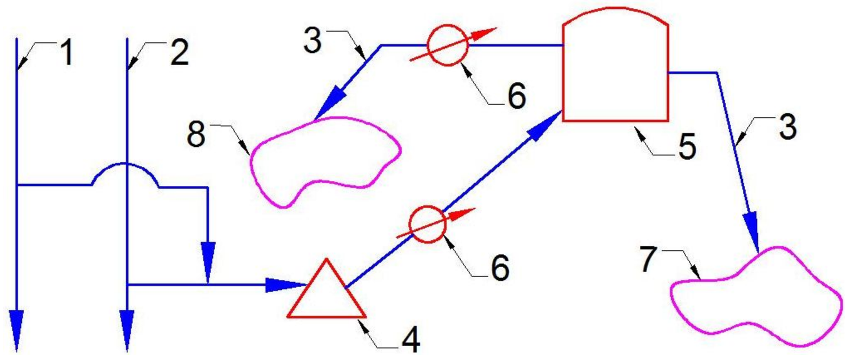

Fig. 1 – Podu Iloaiei Town water supply system; 1 - AdI main pipe; 2 - AdII main pipe; 3 – gravity fed distribution pipes; 4 – pumping station; 5 - 1000 m^3 storage tank; 6 – flow measuring equipment; 7 - Podu Iloaiei, Scobinţi, Henci localities; 8 – Budăi locality.

Podu Iloaiei Town water supply system technical indicators have been analysed over a period of three years, between 2015 and 2017 (S.C. APAVITAL S.A., 2017a). The research data in Table 1 reveals that the pipe network was not extended during the study period, with the length of the pipes remaining at about 27.63 km. However, at the same time, the number of water connections increased by up to 15%, and the number of consumers by 8.5%. The increased number of connections and consumers suggest a raised water demand. Nevertheless, the constant length of the pipe network indicates that the system was able to cover the increased water demand, with no need for its extension.

Table 1
Podu Iloaiei Town Water Supply System Technical Indicators

Indicator	2015	2016	2017
Distribution network length, [m]	27.631	27.631	27.631
Number of connections	1,417	1,484	1,629
Number of people served	5,199	5,318	5,643
Billed potable water volume, [m^3]	271,745	277,384	292,405

The billed potable water volume must be correlated with the water demand, and implicitly with the number of people served. At the end of 2016, study data show a 2.29% increase in number of consumers. At the same time, the billed potable water volume rises by 2.08%. In the next study period, assessed at the end of 2017, the number of consumers increases by 6.11% and the billed potable water volume rises by 5.42%.

The performance indicators of Podu Iloaiei Town water supply system analysed during 2015 – 2017 research period describe the model's evolution

(S.C. APAVITAL S.A., 2017b). The existence of some risk situations, which have led to the alteration of potable water quality has resulted from the data analysed (Table 2). Thus, in 2016, the potable water quality compliance is at 99.10%, compared to 100% achieved in the other study years. Possible risk situations include the presence of cracks or holes of various sizes on the pipe walls or at the tube joints. Their main effect is the emergence of water loss, but these are also entering paths for the contaminants located outside the pipe.

Table 2
Podu Iloaiei Town Water Supply System Performance Indicators

Indicator	2015	2016	2017
Compliance with the potable water quality, [%]	100	99.10	100
Connection degree to the water network, [%]	54.30	48.27	51.15
Metering rate, [%]	99.66	99.78	99.76
Unbilled potable water volume, [m^3]	59,807	71,362	32,810

The water network population connection degree reaches an average of 51.24 % on the entire research period. From an efficiency point of view, the system is oversized, being designed to cover a 100 % connection degree. The high metering rate shows a good control of the water volumes distributed to consumers. The metering of supplied flows is one of the basic measures to cut the value of non – revenue water and, implicitly, water losses. However, the difference up to 100 % creates a favourable framework for undetected water losses to develop.

Unbilled water volumes consist of water losses, the system’s own usage and volumes used for fire extinguishing. Their value increases by nearly 20% in 2016, indicating the existence of significant water losses. The low value of the indicator in 2017, which decreases by 50% compared to the values from the previous year, point to the remediation of the circumstances which have led to large water losses.

The water losses variation chart (Fig. 2) shows that in all the studied years, the month of April recorded the highest water loss values, with a maximum of 44.72% corresponding to 2016. Also, the lowest values were recorded in September, with a minimum of 2.96% obtained in 2016. Data analysis shows that 2016 recorded the largest range of values (41.78%), followed by 2017 (29.29%) and 2015 (29.09%). Nonetheless, 2016 has the lowest average water loss percentage – 21.98, followed by 2015 – 22.84 and 2017 – 24.89. The obtained values fall within the average water loss value registered on the entire Iaşi County surface, of 30 %.

The year of 2015 shows the lowest variation in monthly water loss values. As the pipe network ages, the chart shape loses its linearity and frequently reaches extreme values, as it can be seen from the data recorded in 2016 and 2017. The 2017 chart shape is defined by the alternation between high and low values, from one month to the next. This variation suggests the rapid degradation of the water supply system. The remediation works do not manage to keep a low water loss level for a long time. Pressure variations, operational procedures or site loads cause system degradation and cancel the effects of previous remediation works. The lack of adequate measures to control and reduce leakage will lead to increased water losses and will affect the performance of the water supply system.

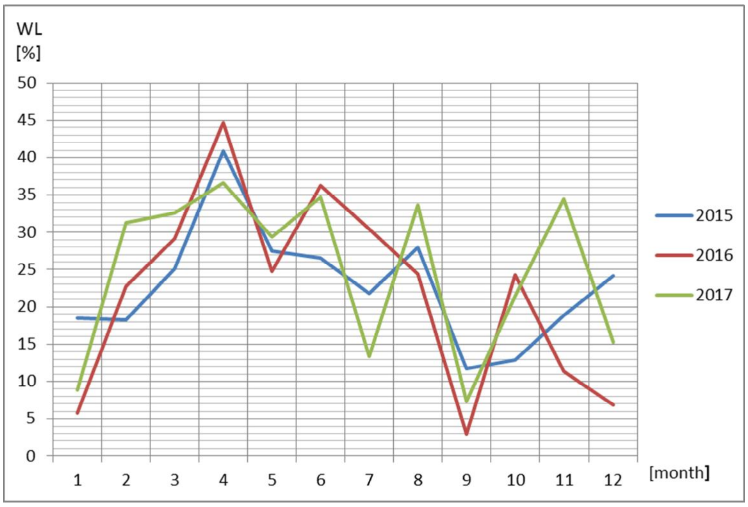

Fig. 2 – Monthly variation of water losses between 2015 and 2017.

4. Conclusions

1. The technical and performance indicators analysed for Podu Iloaiei Town describe a water supply system that manages to meet the water demand of consumers despite the existing water losses.

2. The variation of water losses in the time period studied shows maximum values in the month of April, namely 40.85 % - 2015, 44.72 % - 2016 and 36.58 % - 2017.

3. The average annual water loss does not exceed, in any analysis interval, the value obtained for the entire Iaşi County, reaching the maximum value of 24.89% in 2016.

4. The variation pattern of water loss from 2015 to 2017 points to the rapid degradation of the system and the need for leakage control and mitigation measures.

REFERENCES

Chirica Şt., *Raport de cercetare ştiinţifică nr. 1. Studiu documentar privind influenţa pierderilor de apă asupra managementului sistemelor de alimentare cu apă a localităţilo*r, Universitatea Tehnică „Gheorghe Asachi” din Iaşi, 2017.

Farley M., Trow S., *Losses in Water Distribution Networks: A Practitioner's Guide to Assessment, Monitoring and Control*, IWA Publishing, Alliance House, 12 Caxton St., London, UK, 2003.

Lambert A.O., Hirner W., *Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures*, International Water Association, 2000.

Mănescu Al., *Manual pentru controlul pierderilor de apă din sistemele de alimentare cu apă*, Ed. EstFalia, Bucureşti, 2012.

May J., *Leakage, Pressure and Control*, BICS International Conference on Leakage Control Investigation in underground Assets. London, March, 1994.

Thornton J., *Water Loss Control Manual*, McGraw Hill Professional, 2002.

* * * *Guidelines for Water Loss Reduction*, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) GmbH, Eschborn, Germany, 2011.

* * * *Raport de performanţă 2017*, S.C. APAVITAL S.A., 2017a.

* * * *Raport tehnic 2017*, S.C. APAVITAL S.A., 2017b.

EVALUAREA PERFORMANŢELOR SISTEMULUI DE ALIMENTARE CU APĂ AL ORAŞULUI PODU ILOAIEI DIN PERSPECTIVA FENOMENULUI „PIERDERI DE APĂ”

(Rezumat)

Studiul de caz întocmit analizează sistemul de alimentare cu apă al oraşului Podu Iloaiei din judeţul Iaşi şi evaluează performanţele acestuia în perioada 2015 – 2017. Datele analizate arată că procentul pierderilor de apă înregistrate anual se încadrează în valoarea obţinută pe întreaga arie de operare (30%). Variaţiile lunare însă pornesc de la valori minime situate sub 10 % din volumul de apă furnizat sistemului (valori precum 5,79 % şi 7,29 %) şi urcă până la valori maxime de peste 40% (40,85 %, 44,72 %). Volumele de apă introduse anual în sistem se situează în jurul valorii de 350.000 m^3, însă între 20 % şi 25 % dintre acestea se pierd înainte de a ajunge la consumatori. Lucrarea prezintă o analiză detaliată a fenomenului „pierderi de apă” în oraşul Podu Iloaiei şi a performanţelor sistemului de alimentare cu apă.

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CONSIDERATIONS ON GULLY EROSION IN ROMANIA AND COMBATING SOLUTIONS

BY

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Abstract. In Romania about 2/3 of the country's surface and over 36% of the arable land is situated on slopes. The areas most affected by water erosion are Moldavian, Getic, Transylvanian and Somesan Plateau.

The agricultural area in Romania subject to erosion processes is approximately 6.4 million hectares of which 3.6 million hectares of arable land. The largest areas of arable land affected by erosion are found in Botoșani (214,000 ha), Vaslui (205,000 ha), Cluj (159,000 ha), Iași (136,000 ha) and Sălaj (105,000 ha).

At national level, excessive erosion, associated with ravines and landslides, is recorded on an area of over 2 million hectares, and moderate - strong erosion on almost 5 million hectares.

The average amount of soil eroded in the Moldavian Plateau 11 t/ha/year exceeds the tolerable erosion rate of 1,…,3 t/ha/year, corresponding to the natural soil recovery capacity.

This paper is about the extent of degradation processes by monitoring the factors that occur in the erosion phenomenon.

Keywords: anthropogenic erosion; torrent formations; soil; precipitations.

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1. Introduction

Water erosion (surface and depth) is predominantly located in the hilly and plateau region but also in the sub-Carpathian hills with a surface area of 1376 × 103 ha (Biali & Popovici, 2006).

Gully erosion in known as “gully erosion” in SUA, “ravinement” in France, “ovrajnaia eroziia” in Russia, “eroziona per fosi” in Italy, “ravenare” in Romania, “lavaka” in Madagascar, “donga” in South of Africa (Castillo & Gomez, 2016).

Field research consist in monitoring degraded lands, priority have those afected by gully erosion caused by natural factors,in order to establish stategies for eliminating the economical, social and ecological consequences and introducing the affected land in productive land through hydrotechnical works.

The consequences resulting from soil degradation processes are the following: diminution of agricultural production, set-aside, clogging of water courses and accumulation lakes, destruction of communication routes and human settlements, environmental degradation and destruction of the ecological balance (Joldiş, 2014).

The northeastern part of the country is well-known for its intense land degradation, which is triggered and evolves against the background of a clayey substrate, climatic conditions, relief energy, etc. (Nicu, 2013 The northeastern part of the country is well-known for its intense land degradation, which is triggered and evolves against the background of a clayey substrate, climatic conditions, relief energy, etc. (Nicu, 2013).

The Moldavian Plateau is a great relief unit where the processes of soil degradation, especially surface erosion, deep erosion and landslides, are present. (Rădoane *et al*., 2009).

The authors of the studied materials highlighted modern solutions and methods for erosion monitoring, as well as understanding the future directions of their development.

The aim of the paper is to present a synthesis on the evolution of the erosion process at national and international level and methods of monitoring it.

2. Materials and Methods

Gully erosion represents at present around 10% of soil erosion research, a percentage that is at odds with being the worst form of soil degradation in agricultural areas. Despite the fact that it is an ubiquitous process all around the world, the worst stages of degradation take place where unsustainable human practices operate in erosion-prone conditions such as erodible soils, softlithologies or geotechnically instable slopes.

Anthropic influence is typically the main driver of gully erosion evolution and has acted differently in time and results across the countries depending on the history of land use and management practices.

Although gully erosion is known to be largely controlled by deep-profile properties, the study on subsurface processes has frequently remained mostly descriptive and it is losing ground to other more recent techniques aiming to assess morphological changes. (Castillo & Gomez, 2016).

Soil erosion due to natural factors is determined mainly by relief, climate (air temperature, wind, atmospheric precipitation, atmospheric pressure, air humidity, nebulosity, meteorological phenomena), soil, rock formation, vegetation and land exploitation. (Negruşier, 2015).

The anthropic factor is a consequence of its unreasonable intervention on the environment through abusive deforestation, excessive grazing, agro-technical works on the soil.

In general, most of these factors act simultaneously, conditioning each other, increasing or diminishing the intensity of the erosion phenomenon (Fig. 1).

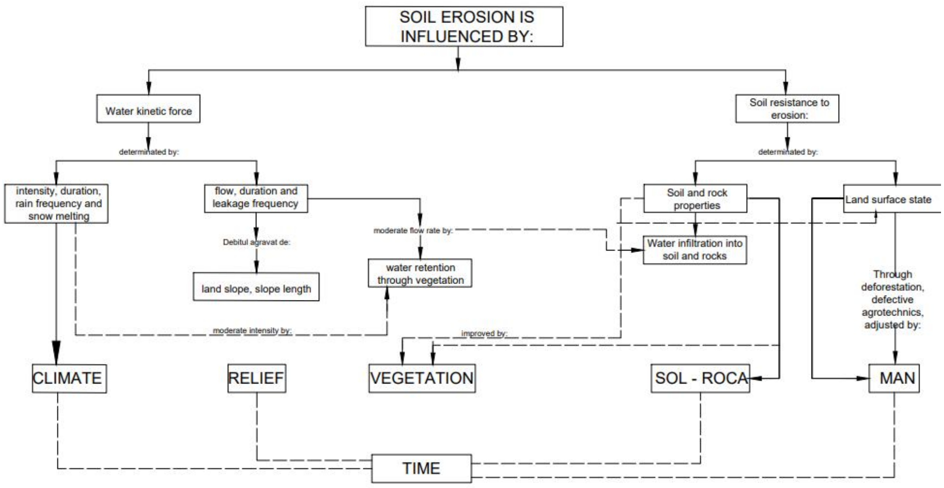

Fig. 1 – Factors that influence erosion (Biali & Popovici, 2006).

The research methodology has several stages:

– creating a database for each factor;

– sampling of data, topographical plans from the Agricultural Cadastral Office with level quotas and curves;

– mapping plans, pedological studies;

– digitization of plans to obtain a Numerical Land Mode;

– developing and continuously updating data;

– field studies.

By implementing these steps, a permanent monitoring of environmental factors and anthropogenic impact can be achieved to help control measures to improve the erosion phenomenon.

3. Results and Discussions

When ravens and rills are often branched, these leave between them unravened surfaces, but this areas are inaccesible to agricultural machinery and the whole becomes unusable for agriculture. In the first phase of gully erosion, the eroded soil is deposited at the base of the slopes or in the form of alluvium in the valleys of the valleys.

The abusive and unreasonable exploitation of agricultural and forest lands has led to severe and extensive erosion processes in all areas with the country's troubled relief (Băloiu, 1967)

Researchers have shown that the monitoring the factors that lead to erosion process, th one of the most damaging effects are precipitation on the soil.

At national level, studies have shown that there is a tendency to decrease the amount of rainfall, especially in the southern, southeast and eastern regions of the country (Fig. 2).

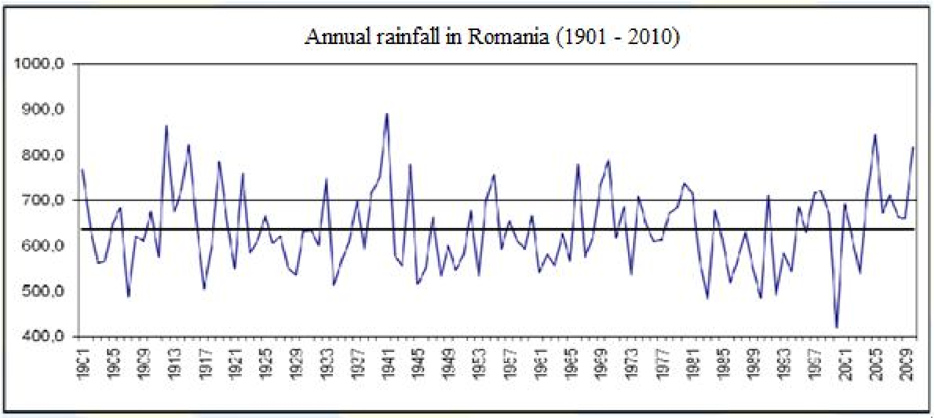

Fig. 2 – Changes in the evolution of annual rainfall quantities in Romania (1901 – 2010),

Between 1961 – 2010 is a general trend of decreasing the annual rainfall quantities.

In the article "Rainfall erosivity in Europe", collaborators consider the precipitation one of the "active engines of soil erosion".

In the universal soil loss equation (USLE), the R factor is the erosive index of precipitations falling within an hourly range (Figs. 3,...,5). The authors collected data over a 14-month period from 1,541 weather stations in all EU Member States and Switzerland in order to calculate the precipitation erosion factor (Table 1).

Table 1
R Factor Descriptive Statistics per Country

Country		Mean	Standard deviation	Minimum	Maximum	Coefficient of variation
		MJ mm $ha^{-1}h^{-1}yr^{-1}$				
AT	Austria	1,075.5	517.1	346.9	4,345.7	0.48
BE	Belgium	601.5	106.6	412.7	1,253.8	0.18
BG	Bulgaria	695	151.8	79.8	1,447.1	0.22
CH	Switzerland	1,039.6	449.3	367.2	4,249.6	0.43
CY	Cyprus	578.1	115.1	223.6	1,353.5	0.2
CZ	Czech Republic	524	118.5	218	1,093.5	0.23
DE	Germany	511.6	160.9	262.3	1,489.3	0.31
DK	Denmark	433.5	93.6	143.8	800.5	0.22
EE	Estonia	444.3	33.2	330.1	568.3	0.07
ES	Spain	928.5	373	164.8	3,071.2	0.4
FI	Finland	273	67	65.5	555.6	0.25
FR	France	751.7	353.5	235.2	2,661.1	0.47
GR	Greece	827.7	387.6	152	2,728.5	0.47
HR	Croatia	1,276.2	633.5	523.4	3,522.7	0.5
HU	Hungary	683.3	73.1	361.4	1,000.8	0.11
IE	Ireland	648.6	389.6	205.1	3,403.3	0.6
IT	Italy	1,642	598	477.6	6,228.8	0.36
LT	Lithuania	484.2	32.6	371.5	605.3	0.07
LU	Luxembourg	674.5	97.6	436.8	1,002.8	0.14
LV	Latvia	480.4	42.1	373.9	602.4	0.09
MT	Malta	1,672.4	65.6	1,491.4	1,869.2	0.04
NL	Netherlands	473.3	46.1	348.3	646	0.1
PL	Poland	537.1	100	247.7	1,055.3	0.19
PT	Portugal	775.1	317.5	226.4	2,758.1	0.41
RO	**Romania**	**785**	**95.6**	**462.2**	**1,150.1**	**0.12**
SE	Sweden	378.1	152.6	51.4	2,033.8	0.4
SI	Slovenia	2302	954.6	757	5,655.8	0.41
SK	Slovakia	579.7	93.6	330.8	1,111.2	0.16
UK	United Kingdom	746.6	604.9	78.1	4,107.4	0.81

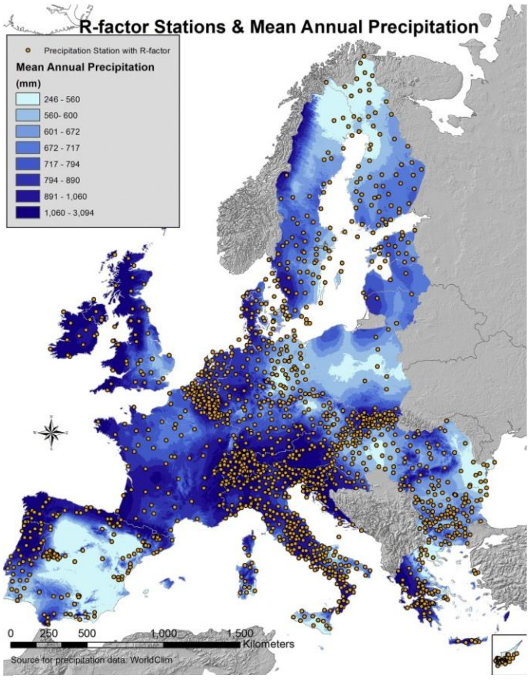

Fig. 3 – Spatial distribution of precipitation stations used for the R – factor calculation for Europe.

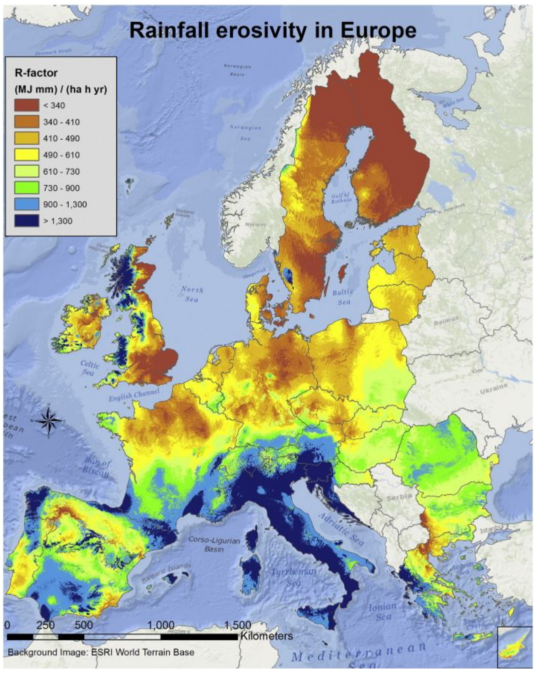

Fig. 4 – High-resolution map of rainfall in Europe.

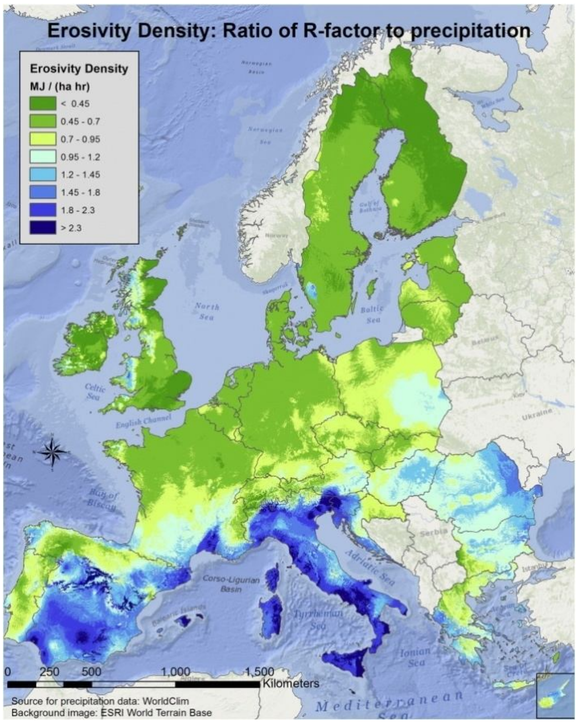

Fig. 5 – Erosivity density in Europe.

In the present study, the erosivity density is used for a post-assessment of rainfall erosivity patterns and type of precipitation involved in erosive events in Europe. Annual erosivity density is the ratio of the mean annual erosivity to the mean annual precipitation (Fig. 6).

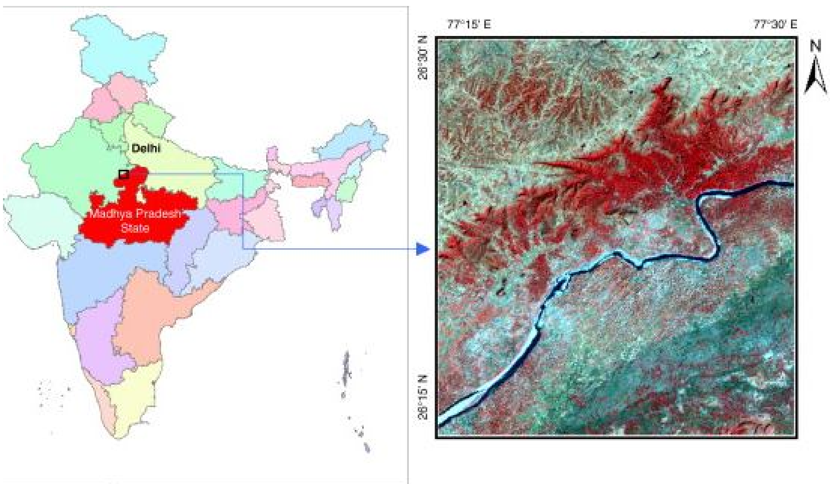

Fig. 6 – Location of the studied ravine in Madhya Pradesh, India.

The authors of the article "Interferometric SAR for the characterization of ravines as a function of their density, depth and surface cover" highlight the fact that the formation of ravens is also due to anthropogenic factor such as: poor agricultural practices, mining and deforestation. Author's research on India's ravages reveals that they occupy 0.5 million ha at the expense of fertile farmland (Fig. 7).

Fig. 7 – Types of ravines located in Madhya Pradesh, India.

The ravines in this area are very intense, with a depth of 60,...,80 m and are spreading a lot in the region and therefore have serious problems in land use planning and cause a huge loss in agricultural production.

4. Conclusions

Soil erosion is known as one of the most widespread and important forms of soil degradation that have a strong economic and environmental impact, especially in the agricultural sector, affecting about 10% of the world's surface and 14% of the European continent.

In time, tracking of the evolution of the erosion process is very important because undesirable events caused by natural and anthropogenic factors can be prevented.

Precipitation, one of the determining factors in the occurrence of the deep erosion process, should be observed for assessing the risk of soil erosion in the context of future land use and climate change in soil loss during torrential rain.

REFERENCES

Băloiu V., *Combaterea eroziunii solului şi regularizarea cursurilor de apă*, Edit. Didactică şi Pedagogică, Bucureşti, 1967.

Biali G., Popovici N., *Amenajări pentru protecția şi conservarea solului*, Edit. Performantica, 2006.

Castillo C., Gomez J. A., *A Century of Gully Erosion Research: Urgency, Complexy and Study Approaches*, Earth-Science Reviews, **160**, 300-319 (2016).

Chatterjee R.S., Saha S.K., Kumar S., Sharika M., Lakhera R.C., Dadhwal V.K., *Interferometric SAR for Characterization of Ravines as a Function of their Density, Depth and Surface Cover*, ISPRS Journal of Photogrammetry and Remote Sensing, **64**, 472-481 (2009).

Grudnicki F., Ciornei I., *Amenajarea bazinelor hidrografice torențiale prin lucrări specifice*, 2007.

Ioniță I., *Gully development in the Moldavian Plateau of Romania*, Catena, *68*, 133-140 (2006).

Joldiş R., *Cercetări privind utilizarea tehnologiilor GIS în monitorizarea terenurilor degradate prin eroziune, din județul Cluj*, Teză de doctorat, 2014.

Negruțier C., *Studiul învelişului de soluri din bazinul hidrografic al Anieşului şi influența sa asupra eroziunii de suprafață*, Cluj-Napoca, 2015.

Nicu C.I., *Analiza riscurilor hidrogeomorfologice care afectează siturile arheologice eneolitice din bazinul hidrografic Valea Oii (Bahlui). Studiu de caz., Iaşi*, Teză de doctorat, 2013.

Panagos P., Ballabio C., Borelli P., Meusburger K., Klik A., Rousseva S., *Rainfall Erosivity în Europe*, Science of the Total Environment, **511**, 801-814 (2015).

Rădoane M., Ichim I., Rădoane N., *Gully Distribution and Development in Moldavia, Romania*, Catena, *24*, 127-146 (1995).

Rădoane, M., Radoane, N., Cristea, I., Popescu, L., Barnoaia, I., Budui, V. Chiriloaiei F., *Monitorizarea evolutiei ravenelor test din Podişul Moldovei în perioada 1986-2008*, Analele Universității Ştefan cel Mare, Suceava, Serie Geografie, *17*, 7-19 (2009).

CONSIDERAȚII PRIVIND EROZIUNEA ÎN ADÂNCIME ÎN ROMÂNIA ŞI SOLUȚII DE COMBATERE

(Rezumat)

În România aproximativ 2/3 din suprafața țării şi peste 36% din suprafața arabilă se află situată pe pante. Zonele cele mai afectate de eroziunea prin apă sunt podişurile Moldovenesc, Getic, Transilvănean şi Someşan.

Suprafața agricolă din România supusă proceselor de eroziune este de aproximativ 6,4 milioane hectare din care 3,6 milioane hectare arabil. Cele mai mari

suprafețe de teren arabil, afectate de eroziune, se găsesc in județele Botoşani (214.000 ha), Vaslui (205.000 ha), Cluj (159.000 ha), Iaşi (136.000 ha) şi Sălaj (105.000 ha).

Pe plan național, eroziunea excesivă, asociată cu ravenări şi alunecări de teren, se înregistrează pe o suprafață de peste 2 milioane de hectare, iar eroziunea moderat-puternică pe aproape 5 milioane de hectare.

Cantitatea medie de sol erodat în Podişul Moldovei 11 t/ha/an, valoare depăşeşte rata eroziunii tolerabile de 1,...,3 t/ha/an, corespunzătoare capacității naturale de refacere a solurilor.

Această lucrare tratează amploarea proceselor de degradare prin monitorizarea factorilor ce intervin în apariția fenomenului de eroziune.

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THE ANALYSIS OF THE 2016 – 2018 FLOOD EFFECTS ON MOLDOVA RIVER IN PILDEŞTI AREA

BY

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Abstract. The paper presents an analysis of the hydroclimatic risk parameters on the lower course of the Moldova River in thePildeşti groundwater catchment area. The June 2016 flood morphologically changed the minor riverbed of the Moldova River, which influenced the intake requirements of the wells located on the river’s left bank. The effect of the 2012 – 2018 floods also materialised through the partial degradation of shore regulation and protection works. Through the documentary study and field research carried out, the hydrological, hydraulic and behavioural parameters of the hydrotechnical works were analysed on the studied river section. The floods in 2016 caused the degradation of bottom sills, riverbed jetties and shore protection works. During 2016 – 2017 works were carried out for the rehabilitation of the riverbed shape in cross sections and longitudinal profile, for the optimum operation of the wells. The hydrotechnical works carried out in 2017 succeeded in partially stopping the phenomenon of morphological riverbed change. The 2018 flood continued the morphological degradation of the riverbed in the wells catchment area.

Keywords: degradation; flood; flows; morphology; regulation works.

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1. Introduction

Significant climate changes have occurred over the last 30 years in Romania, which have generated a number of negative influences on the environment. Climate change has influenced the annual distribution of rainfall and flows in the rivers' basin. The seasonal change in meteorological parameters creates hydrological risk phenomena in the river basin. The risk phenomenon influences the formation and evolution of flows and levels on rivers, causing flood waves with disastrous effects. Hydrological parameters are continuously modified and influence the morphological evolution of the riverbed, but also the behaviour of structures located in the riverbed and riparian area.

Moldova River hydrographic basin hydrological regime is characterised in the last period of time by the high frequency of the floods. Floods over the last few years on the Moldova River have led to significant economical damage. The water catchment structures located on the Moldova River banks (Pildeşti wells water catchment and the Corun shore catchment from Neamț County) are degraded by floods passing through the lower river course.

The aim of the paper is to present the results of studies and researches on the behaviour of Moldova River bed and of the Pildeşti locality, Neamț County riparian area. Roman water catchment is located in this area, which consists of wells drilled in the river shore.

2. Research Material and Methods

The research was conducted on a Moldova River sector, located around Pildeşti locality, Corun Township, Neamț County (Fig. 1). Moldova River is a tributary of Siret River and the research area is located on its inferior course.

The research material consists of the area which includes the Roman drinking water catchment and a Moldova River sector which feeds the groundwater catchment. The research area includes the 66 wells and seven coffers designed to catch the groundwater. The main research material consists of Moldova River regulation works (jetties, bottom sills, closing rails) and right and left shore protection works on the minor riverbed.

The theoretical and experimental research was carried out in the following directions:

1. The research of Moldova River hydrological and hydraulic parameters in the study area.

2. The investigation of Moldova River bed regulation works behaviour over time in the wells location area.

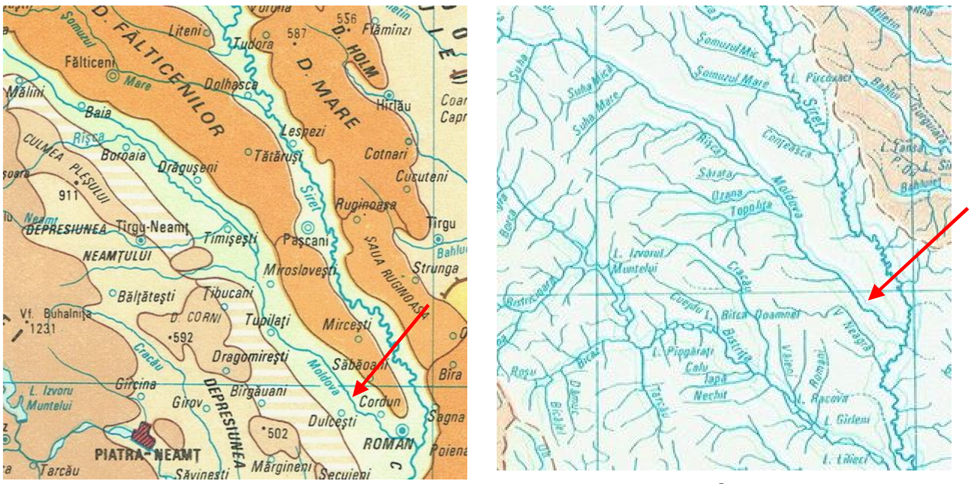
3. The investigation of Moldova River left shore regulation works behaviour over time in the wells location area.

4. Analysis of geotextile and geocontainers construction elements floods behaviour, located in jetties, block dams, bottom sills, shore protection and silting rails.

a *b*

Fig. 1 – The study area location: *a* – administrative map; *b* – Moldova River left bank general view on the length of the wells catchment area, year 2018.

The hydrological data analysis has highlighted a high floods frequency in the last 20 years. The value of maximum floods has been predominant in the last 12 years.



a *b*

Fig. 2 – Study area geophysical elements: *a* – study area physical map; *b* – area from the analysed hydrographic basin (Water Cadastral Atlas).

Moldova River has in the study area a slightly meandering route. The river sector considered in the analysis has a NW – SE orientation (Fig. 2).

The hydrological research analysed maximum flow parameters on the river section taking into account the flow rates recorded at Tupilați Hydrometric Station, Neamț County.

The analysis of the structural and functional state of the existing field structures was carried out through direct inspection, visualization of degradation forms, measurement of geometric parameters, taking of photos and video records etc. The field data were compared to those in the technical documentation, or in similar national or international works.

Data collected through documentation and field research have been processed using statistical, hydrological and hydraulic computation programs suited to the case study.

3. Results and Discussions

Roman City potable water catchment is located in Moldova River riparian area, near Pildeşti locality, Corun Township, Neamț County. The catchment area is located on the left shore of Moldova River and consists of 66 wells (P1 – P66 code), drilled at 7.50,...,14.0 m depths. The wells have a 250 mm diameter and are made of 250 mm diameter PVC tubes. The total average catchment flow is 387.35 l/s. The catchment water volume is supplemented by the water intake of seven reinforced concrete coffers, which collect an average total flow rate $Q_{tot,av}$ = 50.0 l/s. The total catchment rate of Pildeşti (wells + coffers) is 437.35 l/s (ApaServ Neamț, 2014).

The optimal wells and coffers operation is conditioned by the existence of an acceptable usage level in the Moldova River bed. The riverbed area on which the catchment is located has a width of about 350,...,400 m. The great bed width caused the appearance of meanders, but also the displacement of the minor riverbed after the floods. Regulation and shore protection works were designed and executed in order to preserve the minor riverbed near the shore with water catchment structures.

The Moldova River regulation and shore protection works in the catchment area were executed starting with 1996. The works execution continued with interruptions during 2000 – 2006. The initial regulation and shore protection works consisted of the following (ApaServ Neamț, 2014):

– regulation works: flow section calibration, profiling of the minor river bed near the left bank, flow routing through the use of a dyke etc.; the dike was made of large stones set on fascine;

– shore protection works: reinforced concrete slabs placed on slopes with 1:1.5 tilt; the tiles rest on a simple concrete beam.

After 2006 the works in the riverbed and shore protection were conducted by using geocontainers (geotextile bags filled with local material, mainly ballast). Subsequent works in 2017 (jetty, closing dyke, shore protection) were executed only with geocontainers.

On the river section research was carried out between 2014 and 2018 with reference to the behaviour of river regulation and shore protection works. At the same time, some design elements of the regularization works, as well as other materials representative of the studied problem were analysed.

The analysis considered hydrological and hydraulic parameters taken from the nearest hydrometer station and parameters computed in the section considered in the study. Main hydrological parameters were taken from the Tupilați Hydrometric Station. The analysis of transit flows was analysed at intervals of 10, 25 and 55 years. The extreme values of rainfall occurred in different periods of the year: May – 1972, June and July – 1969, July and August – 1991, September – 2001, April – 2005, July – 2008, etc. The torrential rainfall is much more present in the last 20 years on the surface of the Moldova River hydrographic basin (Table 1).

The multiannual precipitation rhythm change has generated high-value flows in a very short time. This situation was recorded in 1992, 2005, 2006, 2008, 2010, 2016, and 2018. The increase in precipitation frequency, especially the torrential ones, with significant quantitative values, led to the shaping of important floods on Moldova River. Floods have negatively influenced river regulation work on the river section considered in the research.

Table 1
H.S. Tupilați Multiannual Average Precipitation, [l/m^2]

Month	I	II	III	IV	V	VI	Annual
P, [l/m^2]	17.9	19.2	24.2	43.6	65.5	83.5	526.1
Month	VII	VIII	IX	X	XI	XII	Annual
P, [l/m^2]	86.1	62.9	47.7	28.5	24.3	22.7	526.1

The analysis of hydrological data has highlighted a high frequency of floods over the last 20 years. The maximum flow rate value has been predominant over the last eight years. From H.S. Tupilați data processing it resulted that the maximum annual flow rate during 1959 - 2018 is 1402 m^3/s (1991, July, calculating probability $p \approx 3\%$). The lowest maximum flow rate value was recorded in 1986 and 1990 (105 m^3/s). The minimum historical flow value was 1.00 m^3/s (1991, February). The hydrological studies conducted in the study area (the year 1993) showed the calculation and verification flow rates but without including the safety margin (Table 2).

Table 2
Moldova River Study Section Flows with Calculating Probability
(Aquaproiect, 2016)

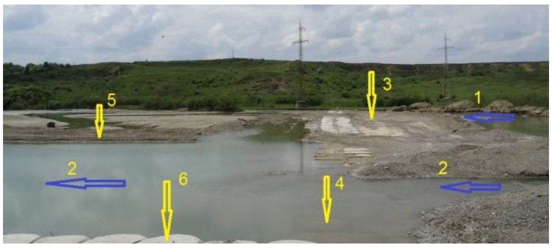
p, [%]	2	5	10	20	50	95
Q_{max}, [m^3/s]	1,650	1,275	1,000	558	31.0	2.13

Hydrological changes over the last period of time have an impact on the behaviour of regulation and shore protection works in erodible riverbeds. The morphological change over time of the riverbed leads to new actions on the stability of hydrotechnical structures serving as shore protection. The shore protection structures are made of natural materials (wood, stone), artificial (plain and reinforced concrete, plastics) and composites. Shore protection works can be rigid (reinforced concrete slabs, stone) and elastic (stone gabions, geocontainers). Rigid protection does not behave efficiently in erodible beds.

Field research highlighted the following:

a. Moldova River bed has a large width in the catchment area (about 250 – 300 m), which determines the displacement of the minor riverbed from the left shore to the right shore. The riverbed displacement is favoured by the presence of ballast layer from the bedding of Moldova River bed.

b. The minor riverbed was displaced towards the left bank through a jetty and by blocking the initial riverbed with a closing dyke (Fig. 3). The notations in Fig. 3 are as follows: 1 – enclosed riverbed, 2 – jetty, 3 – closing dyke, 4 – deviated riverbed, 5 – jetty and right riverbed shore deviated with shore protection, 6 – left bank shore protection.



a

b

Fig. 3 – Entrance section on the deviated riverbed of the Moldova River study section: *a* – general view of the closing dike; *b* – detail on the dyke geocontainers, year 2015 (Photo Luca, 2015).

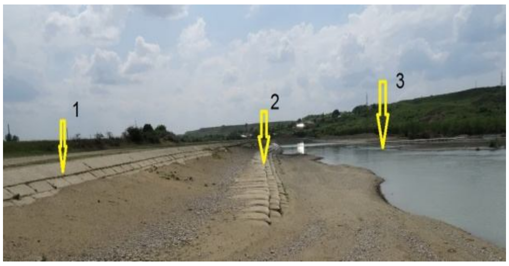
a

b

Fig. 4 – The placement of the catchment wells: *a* – general view of the site; *b* – detail on the well structure, year 2015 (Photo Luca, 2015).

c. After the 2008 – 2012 floods, a significant morphological change to the minor riverbed resulted through the closing dyke degradation towards the old riverbed (located on the right shore). The minor riverbed moved towards the right shore and diminished the flow carried by the bed which supplied the water catchment (Fig. 4).

d. The left shore protection work is made of the old structures (concrete slabs) and the new type of shore protection made of geocontainers (Fig. 5). The concrete slabs shore protection is discontinuous in length, being degraded in proportion of 35,...,80%. On some sectors it is completely degraded.



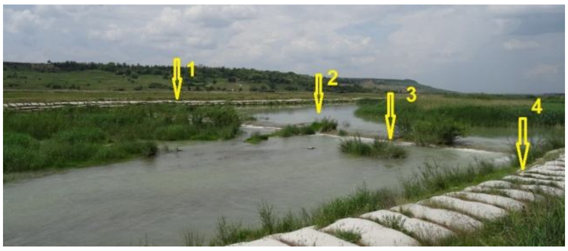
a

b

Fig. 5 – General view left bank shore protection downstream of deviation area: *a* – left bank with the old and new left bank shore, 1 – concrete slabs, 2 – geocontainers, 3 – deviated riverbed; *b* – geocontainers shore protection, year 2015 (Photo Luca, 2015).

e. The bottom sills were originally made of large stone (with the side of min. 30 cm) mounted on a fascine mattress. After 2006, bottom sills made of geocontainers were placed on fascine mattresses (Fig. 6). The floods from 2006 – 2012 degraded the structure at a number of bottom sills by displacing the geocontainers and degrading them by the floaters.

f. The 2016 flood caused significant degradations in the structure of regulation and shore protection works. The closure dyke of the old riverbed was broken, which affected the catchment flow rate of the wells (Fig. 7). This situation forced the urgent restoration of the dike.



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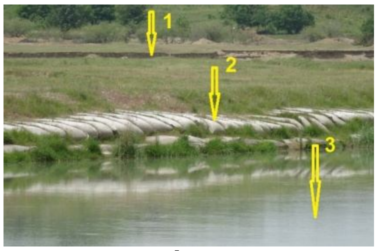

b

Fig. 6 – Constructive components made of geocontainers; a – general view of the riverbed and bottom sill, 1 - right shore, 2 - deviated riverbed, 3 - bottom sill, 4 - left shore ; b – detail on the right shore protection of the deviated riverbed, 1 - old riverbed, 2 - right shore geocontainers, 3 - deviated riverbed, year 2015 (Photo Luca M., 2015).

g. The flood of 2016 caused significant degradation to the constructive structure of the bottom sills by displacing the geocontainers, breaking them, emptying the material etc. The rehabilitation works applied in 2017 helped to restore the operating parameters of the bottom sills (Fig. 8).


a *b*

Fig. 7 – The state of the riverbeds separation area around the catchment: *a* – general view of the separation area with closing dyke; *b* – detail on the dyke degradation, year 2018 (Photo author).


a *b*

Fig. 8 – Aspects regarding the degradation of bottom sills on the deviated minor riverbed, year 2018; *a* – general view; *b* – detail on the bottom sill state (Photo Luca, 2018).

h. The 2016 flood caused significant degradations to the shore protection structure made of geocontainers by breaking the geotextile and partially emptying the material. Rehabilitation works applied in 2017 contributed to the restoration of the bottom sills’ operational parameters (Fig. 9).


a *b*

Fig. 9 – Degradation of shore protection made of geocontainers on the deviated minor riverbed, year 2018; *a* – elements degraded by floaters in water; *b* –geocontainers degradation on the superior side of the shore protection (Photo Luca, 2018).

The high frequency of floods has influenced the stability of rigid protection works (concrete walls). The geotechnical and hydrological conditions in the site favour the execution of geocontainers type protection works, considering the usage of the existing ballast in the site area. Elastic shore protection works operate efficiently with erodible river beds and do not have an impact on the surrounding environment.

4. Conclusions

The high frequency of floods on Moldova River sector in the Pildeşti area caused the diminishing of the optimal operational parameters for the potable water catchment with the help of shore wells.

The hydrological changes that occurred in last 25 years on the studied river sector caused the morphological change of the riverbed and the rapid degradation of the regulation works that ensured the intake requirements of the water catchment.

Repeated floods and with high flow rates on the studied river sector led to the rapid degradation of shore protection works made of reinforced concrete slabs.

The high cost of rehabilitation required the selection of shore protection with elastic constructive elements such as geocontainers filled with ballast topped with cement.

The high degree of hydrodynamic erosion of the floods in the erodible bed of Moldova River has contributed to the sequential degradation of the structures made of geocontainers during their operation, for about 12 years.

REFERENCES

Avram M., *Cercetări privind impactul factorilor de risc hidroclimatic asupra proiectării, tehnologiilor de realizare şi exploatării lucrărilor de regularizare a râurilor. Raport 2 de cercetare*, Universitatea Tehnică „Gheorghe Asachi” din Iași, 2016.

Ferguson R.I., *Sudden onset transition-to-sand gravel along the river sorting processes*, Geology, **312**, 159-162 (2003).

Luca M., E*xpertiză tehnică Obiectiv 5 „Refacere apărare de mal la Pârâu Voroneț în lungime de 300 m (zona între Pod Newburger şi Rl Quatro) prin lucrări de gabionare pentru punere în siguranță drum DJ 177D, sector aflat în administrația oraşului” Gura Humorului*, S.C. Polias-Instal Iaşi, 2016.

Luca M., Stoenescu I., *Current Issues Concerning Regularization Works Behavior under Disaster Conditions,* International Conference „Disaster and Pollution Monitoring – IC.DPM. 3”, Iaşi, 1-2 nov. 2007, 93-98.

Mitoiu C., Marin G., *Regularizarea albiilor de râuri,* Ed. BREN, Bucureşti, 1999.

Stăncescu L., Moraru N., Ionescu V., Leinweber L., *Îndrumător tehnic pentru lucrări de îmbunătățiri funciare*, Editura Ceres, București, 1984.

Ujvari I., *Geografia apelor României*, Edit. Ştiinţifică, Bucureşti, 1972.

Vamanu E., Olariu P., *Riscuri hidroclimatice în Spaţiul hidrografic Siret în contextul modificărilor geografice*, Culegere de lucrări, Sesiunea ştiinţifică anuală INMH Bucureşti, 2002.

* * * ApaServ S.A. Neamţ, 2014.

* * * *Atlasul Cadastrului Apelor din România,* Ministerul Mediului, Bucureşti, 1992.

* * * *Atlasul geografic al României*, Editura Didactică şi Pedagogică, Bucureşti, 1985.

* * * *Rapoartele de sinteză privind apărarea împotriva inundaţiilor, fenomenelor hidrometeorologice periculoase, accidentelor la construcţii hidrotehnice şi poluărilor accidentale din judeţul Bacău*, 2017, Admin. Bazinală de Apă Siret.

* * * *Refacerea amenajării râului Moldova în zona sursei de alimentare cu apă a oraşului Roman (frontul Pildeşti-Simioneşti*). jud.Neamţ, 2016, SC AQUAPROIECT SA Bucureşti.

ANALIZA EFECTELOR VIITURII DIN PERIOADA 2016 – 2018
PE RÂUL MOLDOVA ÎN ZONA PILDEŞTI

(Rezumat)

Lucrarea prezintă o analiză a parametrilor de risc hidroclimatic pe cursul inferior al râului Moldova în zona captării de apă subterană Pildeşti. Viitura din iunie 2016 a modificat morfologic albia minoră a râului Moldova, situaţie ce a influenţat condiţiile de alimentare a puţurilor amplasate pe malul stâng al râului. Efectul viiturilor din anii 2012 – 2018 s-a concretizat şi prin degradarea parţială a lucrărilor de regularizare şi de apărare de mal. Prin studiul documentar și cercetarea realizată în teren s-au analizat parametri hidrologici, hidraulici şi de comportare a lucrărilor hidrotehnice pe tronsonul de râu studiat. Inundaţiile din 2016 au produs degradarea pragurilor de fund, a digurilor de dirijare în albie şi a lucrărilor de apărare de mal. În anul 2016-2017 s-au realizat lucrări pentru refacerea formei albiei râului în secţiuni transversale şi profil longitudinal, în scopul funcţionării optime a puţurilor de captare. Lucrările hidrotehnice realizate în anul 2017 au reuşit să oprească parţial fenomenul de modificare morfologică a albiei. Viitura din 2018 a continuat degradarea morfologică a albiei râului în zona de captare a puţurilor.

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DEVELOPMENT OF UNIT HYDROGRAPH FOR JIJIA RIVER USING ArcGIS

BY

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Abstract. In order to develop a unit hydrograph numerous methods are available. Rainfall-runoff data are necessary for the development of it. Most of the Romanian river basins are ungauged, hence it is very difficult to develop the unit hydrograph. If the area that is under the unit hydrograph is unity the estimation will be admissible. This necessitates require the development of the unit hydrograph using the physical characteristics of the watershed. In this paper an attempt has been made, for Jijia river watershed, to develop the unit hydrograph by utilizing the physical characteristics of the watershed and then utilizing them to develop the unit hydrograph using the CWC formulas. The area under the unit hydrograph developed by CWC method was obtained close to unity, which implies the result is close enough to be right.

Keywords: floods; discharge; ArcGIS; raster; hydrographic.

1. Introduction

Water represent the most important natural resources that is mandatory for the sustenance of life and ecology. If the water resources that are available now are not managed efficiently it may result to drought and flood which will create severe problems to life and properties. The rainfall-runoff relationship of

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the catchment it is necessarily to be understand when deals with the importance of the reasonable use of current water resources.

Dorohoi, a small city of nearly 22,000 residents, suffered considerably when the northeastern part of the city witnessed deaths during the night of June 28-29, 2010, as floods rose to just over 1 meter in some places. Several roads, bridges and culverts were washed out or under water by the heavy rain that had been falling for close to a week. The Dorohoi officials discovered that they had little information about the flood prediction. They could turned to hydrographs, which are line graphs that determine how much water will discharge a stream during a rainfall event. A unit hydrograph model is proposed in which the watershed is decomposed into subareas which are individual cells or zones of neighbouring cells.

The objective of the study is to develop the unit hydrograph for a sector of Jijia river basin by utilizing the physical characteristics of its watershed. For this, parameters like peak discharge (qp), time to peak discharge (tp) and base width of the unit hydrograph (TB) are calculated by the CWC method.

Fig. 1 – Flood from 1 July, 2010.

2. Data and Methods

2.1. Area of Study

The case study has been made on a 5 km sector of Jijia River. The Jijia hydrographic basin is located in the north-eastern part of Romania, being part of the Moldavian Plain. From the hydrographic point of view, the Jijia basin area is part of the Prut River basin, the Jijia River being a tributary of its right. From the administrative and territorial point of view, the study area corresponds to the Dorohoi county (Fig. 2). The catchment is irregular in shape. The region is mainly a mix of 76.9% of urban, industrial and commercial area whereas the other 23.1% are the forestry, agriculture and water bodies.

Fig. 2 – Aerial photo of Dorohoi crossed by part of the Jijia, with the location of the sections.

2.2. Data and Methods

The spatial locations of the river and its properties were obtained from the digital map and DEM using GIS techniques. DEM data represents the input data for the hydrological analysis. The resolution of this raster dataset is aprox. 30 m. DEM datasets can also be download from a platform created by USGS that use Shuttle Radar Topography (Fig. 3). This technology is used to obtain digital elevation models which generate the most complete high resolution digital topographic database of Earth.

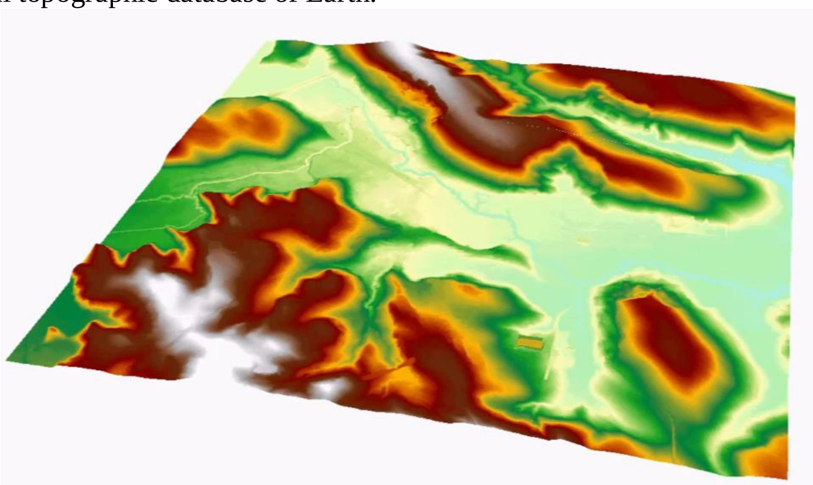

Fig. 3 – DEM data used.

2.3. Data Processing

For the development of a Unit Hydrograph, the watershed has to be processed in the GIS platform in order to achieve a better hidrological analysis. The software used for this is ArcGIS 10.4. The various processing steps such as fill, flow direction, flow accumulation, watershed delineation, stream order and stream to feature were processed. The results of all those works are represented below.

The first step that is it necessary in the delineation of watershed is ‘fill’. The tool fill in a surface raster is to remove small imperfections in the data. The result of this step will be a depression less DEM which will in turn be the basis of the rest of the process (Fig. 4).

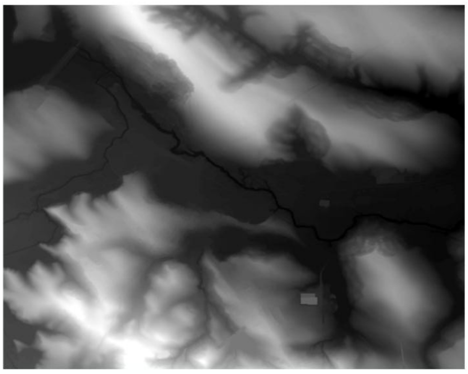

Fig. 4 – Filled map of watershed.

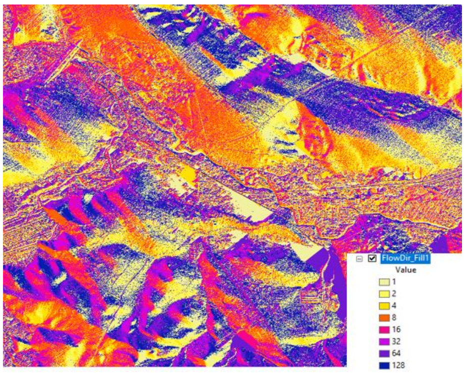

Fig. 5 – Flow direction.

‘Flow direction’ is created to compute the direction of flow out of each cell. This tool takes a filled surface as input and outputs a raster showing the direction of flow out of each cell (Fig. 5). These eight integers correspond to the eight possible flow directions (as any given cell is surrounded by eight cells).

In order to determine the stream’s exact location by calculating the areas where water accumulates the most, ‘flow accumulation’ tool calculates for each cell in the filled DEM array, the number of cells flowing into it. This tool creates a raster layer that indicates where water is most likely to accumulate (Fig. 6). Cells with high values of accumulation often coincide with the locations of flowing water bodies, where water collects and drains. These ones are white.

The delineated watershed is illustrated in Fig. 7. This watershed represents all of the area that flows to the specified outlet. The watershed comprises almost the entirety of Dorohoi's city boundaries, indicating that almost all rainfall that lands in Dorohoi will go rushing through the actual town, rather than draining away from it.

To determine the time it takes water to flow somewhere, it is necessary to determine how fast water flows. The speed of flowing water is calculated in a field and the result will be another type of raster layer. Many types of velocity fields exist, and they can be calculated with a wide variety of mathematical equations. For this paper, the equation proposed by Maidment *et al*. was used.

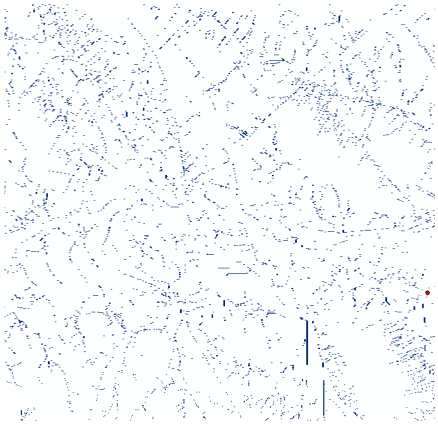

Fig. 6 – Flow accumulation.

Fig. 7 – Deliniated watershed.

The isochrones maps were created based on the weight grid raster layer (Fig. 8), the velocity raster and the flow length layer (Fig. 9).

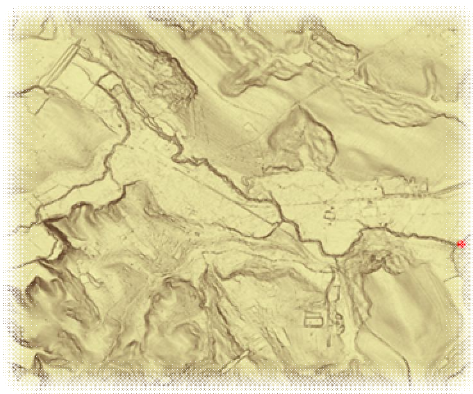

Fig. 8 – Weight raster.

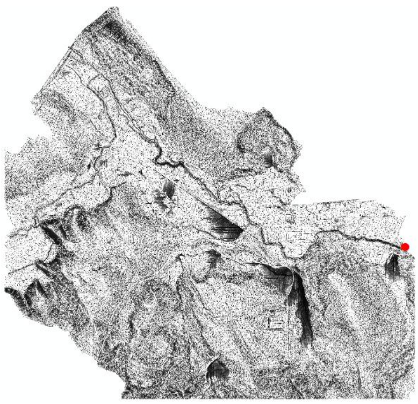

Fig. 9 – Flow length raster.

Isochrone curves are lines connecting the points in a watershed that have equal times of concentration. The isochrone farthest from the outlet represents the time required for the water from a uniform rainfall to reach the outlet from the entire watershed surface. They maps the time it takes the water to reach a specified location from anywhere else in an area.

The spatial pattern of the watershed response is shown by the isochrone map in Fig. 10. In this figure, the flow times for the cells have been divided into ten zones with an flow time limit of 1800 sec for each interval.

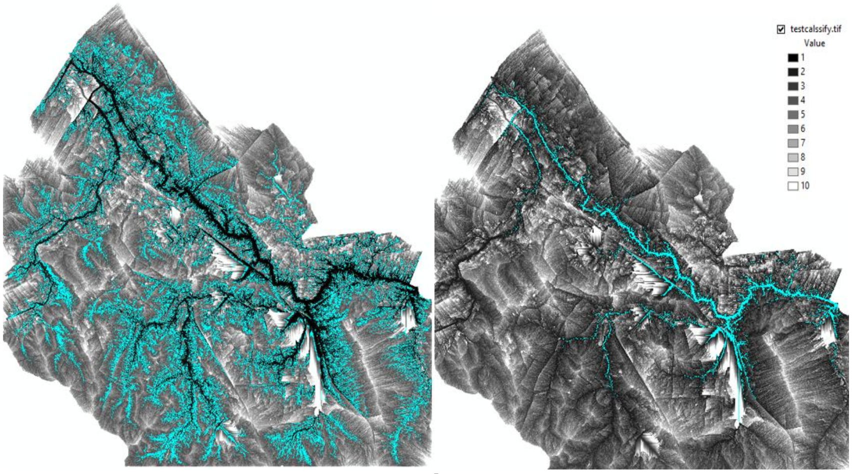

Fig. 10 – Isochrones map.

3. Results

In order to create a unit hydrograph for the study area it was necessary to derive a stand-alone table from the isochrone map’s attribute. This table measures the area for each isochrones. Based on the isochrones attribute table the unit hydrograph of the catchment was realized (Fig. 11) and this shows when water discharge at the outlet as its height during a predicted rainfall event.

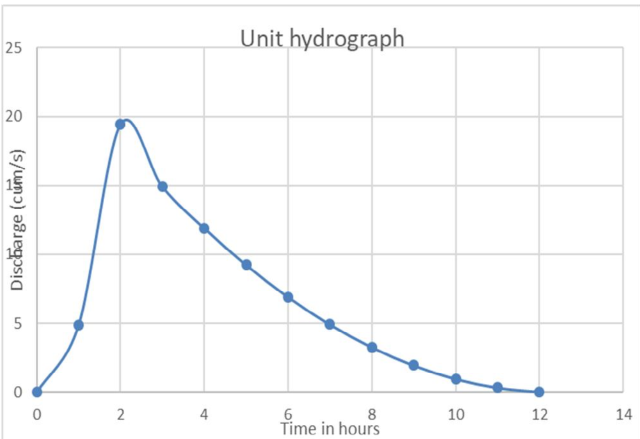

Fig. 11 – Unit hydrograph of catchment.

4. Conclusions

This paper investigated the use of the GIS and elevation data in developing unit hydrograph for different streamflow prediction and for use in the rainfall runoff modelling. The elevation data can be found either on the Internet, or can be prepared from paper based maps. This type of method produced UH comparable to those determined by conventional analysis as thus is a useful unit hydrograph approach. The results in Fig. 11 shows a discharge of 20 m^3/s for the present catchment area.

From this study it is observed that the GIS based approach has potential application in deriving unit hydrograph and can be applied for those watersheds that do not have any flow data. Spatial parameters considered for the development of unit hydrograph depends on the size of grids or resolution of the raster dataset. Any change in the grid size can causes a corresponding change in estimated value. As this method depends only on the spatial characteristics of the watershed, this method can be useful for the ungauged stations which aims an event prediction using few limited data.

REFERENCES

Andrews F., *On Hydrosanity: a Starting Point for Hydrological Analysis, in Oxley,* L. and Kulasiri, D. (Eds), MODSIM 2007 International Congress on Modelling and Simulation, 1540-1546, 2007.

Brunda G.S., Pramod M.P., Sharathchand U.B., *On Derivation of Unit Hydrograph & s Curve for Haridra River Catchment*, International Journal of Scientific Development and Research, Engineering and Technology, **6**, *4* (2017).

Cleveland T.G., Thompson D.B., Fang X., He X., *On Synthesis of Unit Hydrographs From a Digital Elevation Model*, Journal of Irrigation and Drainage Engineering-ASCE, **134**, 212-221 (2008).

Jain S.K, Singh R.D., Seth S.M., *On Design Flood Estimation Using GIS Supported GIUH Approach*, Water Resources Management, **14**, 369-376 (2000).

Noto L.V., La Loggia G., O*n Derivation of a Distributed Unit Hydrograph Integrating GIS and Remote Sensing*, Journal of Hydrologic Engineering, **12**, 639-650 (2007).

DEZVOLTAREA HIDROGRAFULUI UNITAR PENTRU RÂUL JIJIA UTILIZÂND ArcGIS

(Rezumat)

Pentru a dezvolta un hidrograf unitar sunt disponibile numeroase metode. Datele de scurgere a precipitațiilor sunt necesare pentru dezvoltarea acestora. Majoritatea bazinelor hidrografice româneşti sunt nemăsurate, de aceea este foarte dificilă dezvoltarea hidrografului unitar. Dacă zona care se află sub hidrograful unitar este unitară, estimarea va fi admisă. Acest lucru necesită dezvoltarea hidrografului unitar utilizând caracteristicile fizice ale bazinului hidrografic. În această lucrare a fost făcută o încercare, pentru bazinul hidrografic Jijia, de a dezvolta hidrograful unitar utilizând caracteristicile fizice ale acestuia şi apoi folosindu-le pentru a dezvolta hidrograful unitary folosind formulele CWC. Aria aflată sub hidrograful unitar dezvoltat prin metoda CWC a fost obținută aproape de o unitate, ceea ce presupune că rezultatul este suficient de aproape pentru a fi corect.