75
Professional paper
Doi 10.61892/STP202601096P
ISSN 2566-4484

Tamara Pantić, University of Novi Sad, tamara.pantic@uns.ac.rs
Marijana Milic, University of Novi Sad, marijana.milic@uns.ac.rs
Ljubomir Budinski, University of Novi Sad, ljubab@uns.ac.rs
Goran Jeftenic, University of Novi Sad, goran.jeftenic@uns.ac.rs
Danilo Stipic, University of Novi Sad, danilostipic@uns.ac.rs

APPLICATION OF THE EPA SWMM SOFTWARE PACKAGE FOR HYDRAULIC FLOOD SIMULATION IN THE AREA OF KNIĆANIN AND ČENTA DURING 2019

Abstract:

The Knićanin–Čenta subcatchment area, located in Central Banat, is a fertile agricultural region whose water regime is significantly influenced by the water levels of the surrounding rivers—the Danube, Tisa, Begej, as well as the Karaš canal. During May and June 2019, while the TurkStream gas pipeline was under construction, the area experienced heavy rainfall, resulting in flooding of approximately 35% of the total surface area of the Knićanin–Čenta system. The aim of this study was to determine whether, and to what extent, the construction of the gas pipeline—primarily the formation of barriers and the placement of pipes in the canals—affected the occurrence or extent of flood-related damage. For this purpose, a hydraulic model was developed using the EPA SWMM software package.

Keywords: Floods, melioration canals, TurkStream gas pipeline, flood maps, EPA SWMM

ПРИМЕНА EPA SWMM СОФТВЕРСКОГ ПАКЕТА ЗА ХИДРАУЛИЧКУ СИМУЛАЦИЈУ ПОПЛАВА НА ПОДРУЧЈУ КНИЋАНИНА И ЧЕНТЕ ТОКОМ 2019. ГОДИНЕ

Сажетак:

Подручје слива Книћанин-Чента, које се налази у Средњем Банату, представља плодно пољопривредно подручје чији водни режим је под значајним утицајем водостаја околних река- Дунава, Тисе, Бегеја, као и канала Караш. Током маја и јуна 2019. године, у периоду изградње гасовода Турски ток, ово подручје је било погођено обилним падавинама, након чега су уследиле велике поплаве које су захватиле око 35% укупне површине система Книћанин-Чента. Циљ овог рада био је да се утврди да ли је, и у којој мери, изградња гасовода- пре свега формирање баријера и постављање цеви у каналима- утицала на настанак или обим штете услед поплава. У ту сврху развијен је хидраулички модел коришћењем софтверског пакета EPA SWMM.

Кључне речи: Поплаве, мелиорациони канали, гасовод Турски ток, мапе плављења, EPA SWMM

1. INTRODUCTION

The study of floods caused by inland waters is of great importance for the region of Vojvodina, given that agricultural land has frequently been affected by flooding in the past. At certain times, these events reached severe, even catastrophic proportions, with tens, and in some cases, hundreds of thousands of hectares of arable land inundated. This issue has been addressed by numerous authors in their research [1], [2], [3], [4], [5], [6].

In Vojvodina, the primary objective of water management is removing excess water from and within the soil to maintain optimal conditions for agriculture. The occurrence of harmful inland water primarily results from large amounts of precipitation and its uneven temporal distribution. Considering the predominantly flat terrain and limited natural runoff, drainage challenges are particularly evident on shallow, poorly permeable soils, in local depressions, and within riparian zones during periods of elevated river water levels.

The Knićanin-Čenta rit region comprises reclamation zones located between the settlements of Knićanin and Čenta in Middle Banat, covering a total area of 9,217 hectares. The area is bounded by the Begej River to the north, the Tisza River to the west, the Danube to the southwest, the Karaš Canal to the south, and the Zrenjanin loess terrace to the east. The region extends approximately 14 kilometers north-south and 7 kilometers east-west.

According to data from the main project from 1975 [7], in geomorphological term, it is a slightly undulating plain with an average altitude of 71.5-74.0 m above sea level. The surface layers are dominated by sandy clay loam, yellow-gray clay, and fine-grained sand. The analyzed area includes the parcels of three cadastral municipalities: Knićanin, Čenta, and Perlez.

In the observed area, there is a system of melioration canals that is part of the DTD hydrosystem. The drainage system covers the entire surface of the ridge, forming a skeleton of large channels that converge into a single main channel, i.e., a pumping station in the south of the area. A detailed canal system with a total length of 74.7989 km was created based on the arrangement of drainage canals, according to the topography of the terrain, the type of land, the sectors of ownership, bearing in mind that the excess water from the plots is efficiently channeled into the drainage canals [7]. Figures 1a and 1b show the broader geographical location of the Knićanin-Čenta basin, together with the spatial distribution of melioration canals within the covered basin. In picture 1b the route of the TurkStream gas pipeline is marked in red.

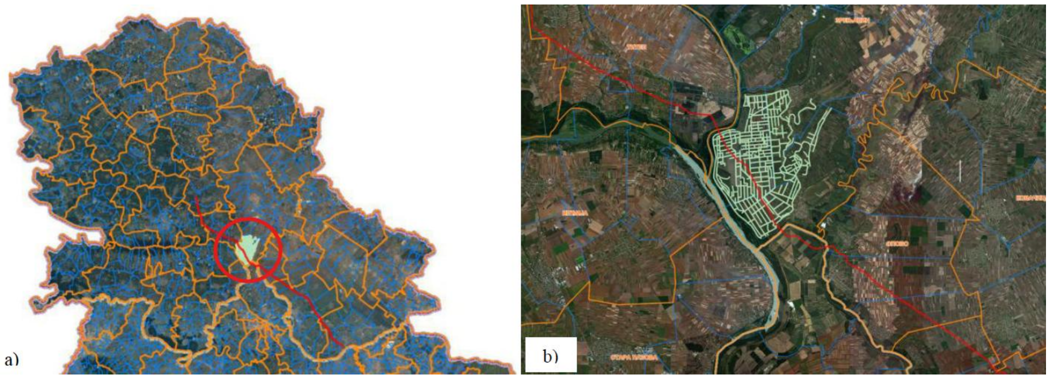

Figure 1. The location of the Knićanin-Čenta basin on the map of Vojvodina; b) Display of the analyzed basin with melioration channels (green) and the gas pipeline (red) that intersects with them

The TurkStream gas pipeline is a new export pipeline that transports natural gas from Russia to Turkey across the Black Sea. The total transport capacity of the pipeline is 31.5 billion m³ per year, with each of the two lines having a capacity of 15.75 billion m³. Gas delivery into the system begins at the Russkaya Compressor Station, which is part of Russia's unified gas supply system and is located near the city of Anapa. This compressor station provides the necessary pressure for transporting gas through both pipelines along a section more than 930 km long, all the way to the receiving terminal on the Turkish coast near the city of Midia.

In the period from March 2019 to the end of 2020, the TurkStream was built through Serbia - a gas pipeline with a length of about 400 km, which intersects in certain places with the melioration canal system in the Knićanin - Čenta watershed. At these crossing points, the gas pipeline was installed beneath the canals, with the canals being dammed across their entire cross-section during construction works. One or more pipes of different diameters were installed within these dams to allow water flow. After the construction of the barriers and the installation of the culverts in the canal were completed, during May and June 2019 extensive rainfall occurred on the site, and floods threatened an area of about 3,225 ha. This analysis aimed to determine whether the cause of the floods in the given watershed was a large amount of precipitation or the clogging of channels at points of intersection with the gas pipeline.

The EPA SWMM software package was utilized to develop a conceptual model and conduct numerical analysis. The United States Environmental Protection Agency's Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation tool employed to plan, analyze, and design stormwater drainage systems in both urban and non-urban settings [8]. EPA SWMM is used worldwide for planning, analysis, and design of atmospheric water drainage in reclamation and combined sewer systems [9], [10].

For the purposes of this analysis, a comparative study of four different models was conducted:

(1) a model without installed barriers and culverts,
(2) a model with barriers and culverts, where the invert level of the pipes is set at the bottom of the canal,
(3) a model with barriers and culverts, where the invert level of the pipes is set 15 cm above the bottom of the canal,
(4) a model with barriers and culverts, where the invert level of the pipes is set 15 cm, 30 cm, or 50 cm above the bottom of the canal, depending on the canal depth.

All models were calibrated using the same set of input data.

2. HYDRAULIC CALCULATION

2.1. ESTABLISHMENT OF THE EPA SWMM MODEL

To develop the hydraulic model in the EPA SWMM software package, it was necessary to input the geometry of the amelioration canals in the observed catchment area, as well as to define a set of relevant input parameters required for conducting the software simulation. The hydraulic model was tested on many different combinations of input parameters, and the relevant set adopted was the one that resulted in the greatest and most frequent water overflow from the canals. Each input parameter that was defined and entered into the model will be considered separately in the following sections, along with explanations and clear statements of the reasons why that parameter was selected.

Canal geometry

The canal geometry in the subject area (bottom width, section length, canal depth between two nodes, canal bottom slope, canal intersection stations, stations and depths of cascades) was entered into the hydraulic model based on the project documentation of the "Land Reclamation Development of the Čenta–Knićanin Area" prepared by the "Hidrozavod" company in 1975. [7]

Subcatchments were delineated using a polygon-based approach, where each contributing area was connected to the corresponding upstream node and routed downstream within the model. Although this configuration may not fully represent natural runoff conditions, it was adopted as a conservative (worst-case) scenario for assessing potential canal overflow. The method was used solely for the geometric definition of contributing areas around individual conduits and does not imply any rooftop or impervious-surface runoff assumptions. All subcatchments were parameterized using standard hydrological properties, including slope, impervious and pervious fractions, depression storage, and infiltration characteristics. Graphical representation of channel geometry and associated subcatchment areas in the analyzed area is given in Figure 2. The channel bed elevation at the outlet is 66.88 meters above sea level.

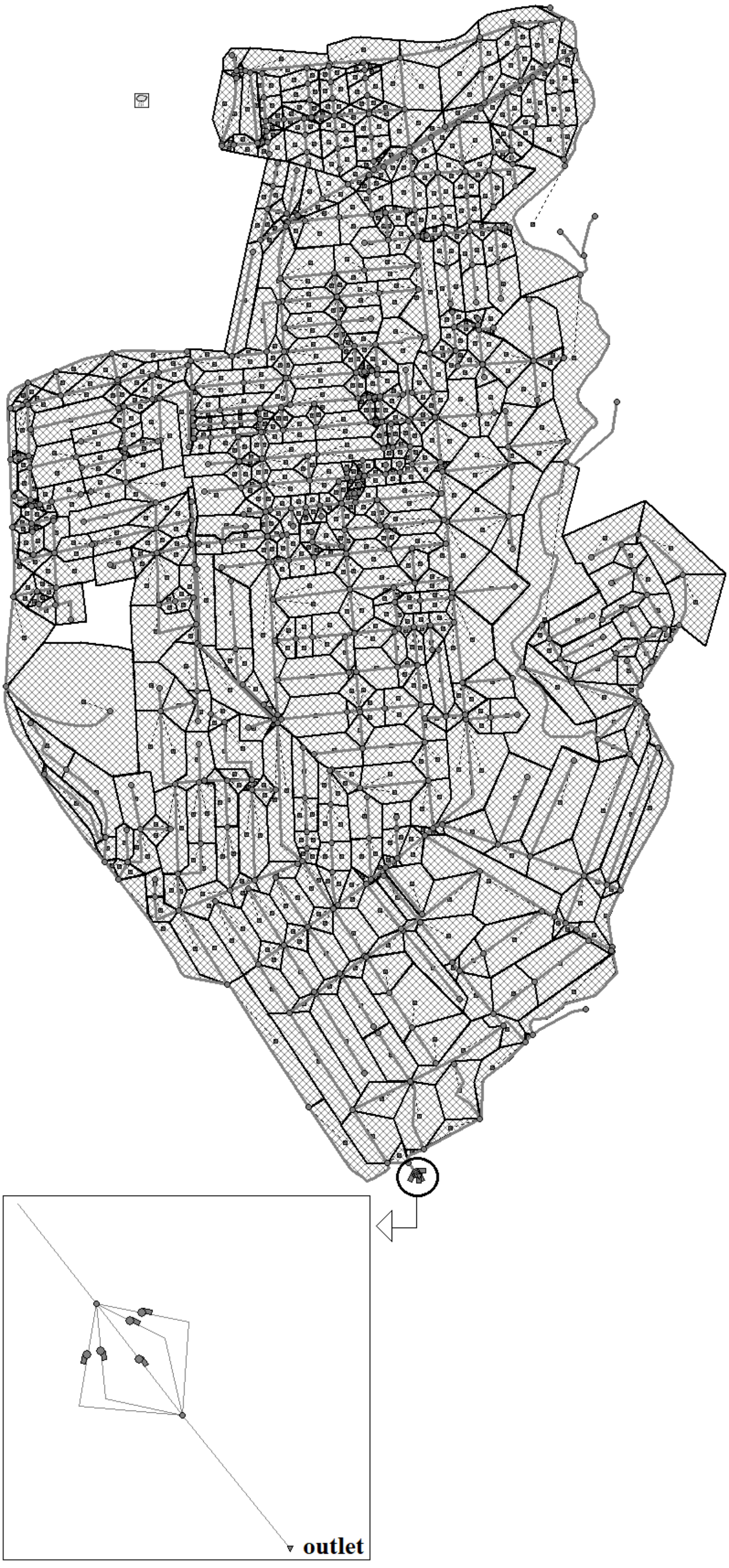

Figure 2. Graphical representation of channel geometry and associated subcatchment areas in the analyzed area

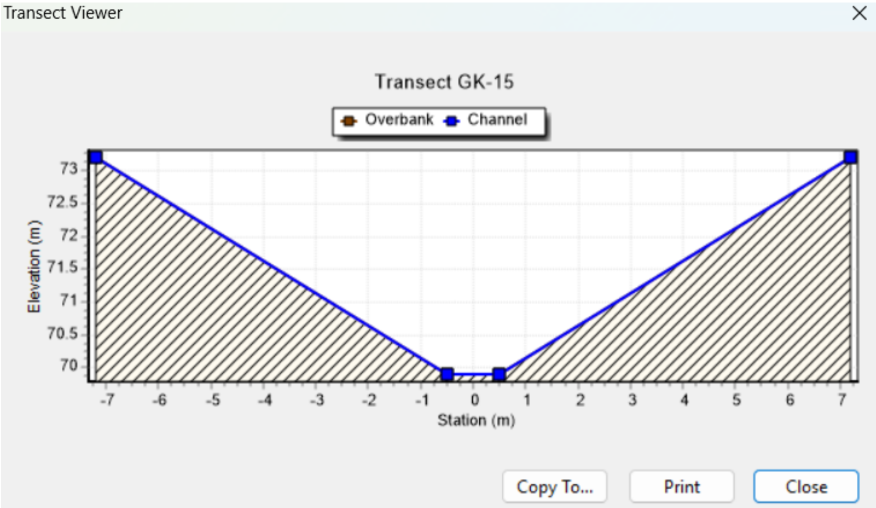

Figure 3. Cross-section of the first section of the Main Canal, between the confluence of Canal X and Canal G-25

Surface Roughness Coefficient (N-imperv and N-perv)

The roughness coefficient n (N-Imperv and N-Perv) is a parameter that describes the resistance to water flow due to friction between the water flow and impervious or pervious surfaces over which water runs off. Due to the lack of measurement results for the surface roughness coefficient in the subject area, values from the manual for the EPA SWMM software package [8] were adopted in the model, according to the known soil type.

Subcatchment Area Slope

In order to assess the most unfavorable scenario regarding possible flooding of parcels, two minimum terrain slope values for the Vojvodina region, cited in the literature, were considered in the model: 0.3% and 0.5%. Simulation results showed that the differences between these values are minimal, which is why a slope of 0.5% was adopted in the model as a conservative approach.

Manning's Roughness Coefficient

In the hydraulic model, Manning's coefficient is adopted in accordance with recommended values from professional literature [5] and relevant manuals [8], taking into account the actual condition of the channels in the field, in order to make the simulation of flow and water levels as realistic as possible. In the final simulation, a Manning's coefficient value of n = 0.0275 sm-1/3 was adopted.

Infiltration

In developing the hydrological model, the Horton infiltration model was applied. Input parameters were taken from [8], based on soil classification and typology.

Groundwater Level

The groundwater level at this location is closely linked to the water levels of the Tisa and Danube rivers, which affects the dynamics and variations of groundwater levels throughout the year.

Precipitation

Two hydrological-hydraulic models were tested, based on different sets of input data for precipitation. In the first simulation, water overflow from the channel was tested as a consequence of rainfall heights measured at the Farkaždin meteorological station, which the Republic Hydrometeorological Institute cites as the reference station for the Knićanin-Čenta catchment area. The second model was developed with an identical set of input parameters, except for precipitation data. In the second simulation, the model's behavior was tested based on daily precipitation for the areas of the cadastral municipalities of Knićanin, Čenta, and Perlez, with precipitation divided by cadastral municipalities. A detailed analysis of the results from both models determined that the more unfavorable scenario regarding the extent of flooding was recorded in the model based on precipitation from the Farkaždin precipitation station. The cumulative precipitation curve for the adopted station is given in the Figure 4.

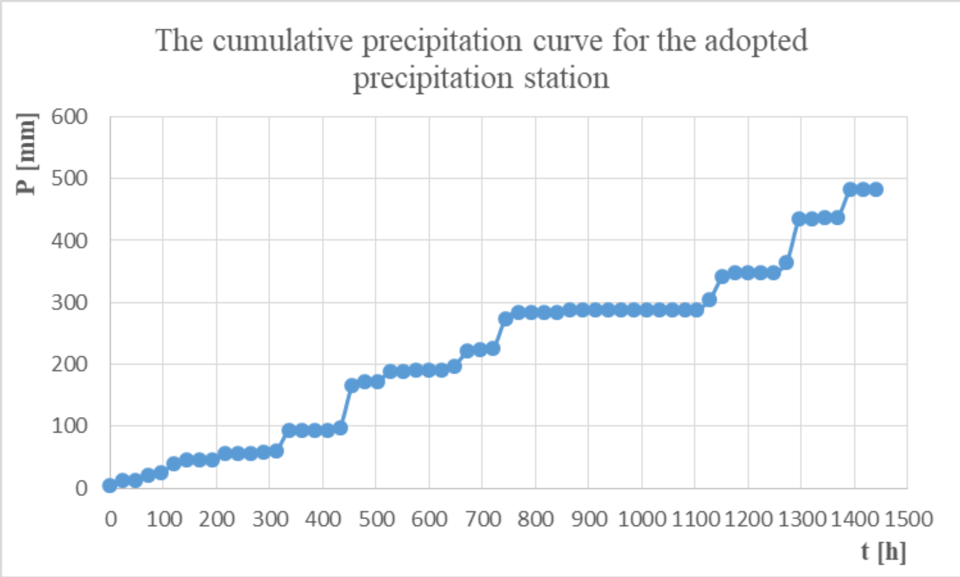

Figure 4. The cumulative precipitation curve for the adopted precipitation station

Pumping Station Operation

Pump operation logs for the period May-June 2019 at PS Čenta, obtained from VDP "Srednji Banat" d.o.o. Zrenjanin, were used for modeling the pumping station and the operation of pump units during the given period. With the operation of the Čenta pumping station, water is pumped over the embankment into the recipient—the Danube River.

Recapitulation of the Adopted Set of Input Data

As part of the analysis, a large number of simulations were performed with different combinations of input parameters, with the aim of identifying and adopting the most unfavorable scenario regarding flooding, i.e., the scenario that results in the greatest water overflow from the channel bed. Table 1 shows a tabular recapitulation of the group of hydrological data that were adopted for conducting further simulations of the impact of barriers and pipelines on water overflow from the canals.

Table 1. Hydraulic and hydrological input data adopted for modeling

Subcatchment Area Slope	Manning's Roughness Coefficient	Infiltration	Precipitation	Groundwater Level	Pumping Station Operation
i = 0.5%	n = 0.0275 s*m$^{-1/3}$	f_0=1.524 mm/h f_c=0.254 mm/h k=4 t=14 days	Farkaždin	1.0 m below ground surface	According to PS Čenta operation logs

3. RUNOFF SIMULATION FOR THE ANALYZED SUBCATCHMENT

In this study, runoff is estimated using the hydrological model implemented in EPA SWMM, where surface runoff is generated as a function of rainfall input and subcatchment characteristics, including area, slope, imperviousness, and infiltration parameters. Unlike traditional design approaches, SWMM does not require a predefined drainage hydromodule; instead, it computes time-dependent discharge hydrographs based on physical processes governing rainfall–runoff transformation.

In contrast to the SWMM approach described above, the drainage hydromodule is a simplified, commonly used design parameter defined as the specific discharge per unit area (l/s/ha). It is typically derived from empirical data or regulatory guidelines and serves as a fundamental input for the preliminary dimensioning of drainage or irrigation networks.

If a design hydromodule is determined, it can be used to estimate the expected discharge by multiplying it by the drainage area. This value may then serve as a reference for calibrating SWMM model parameters, ensuring that simulated runoff aligns with accepted design assumptions.

In this way, the SWMM-based runoff calculation and the traditional hydromodule approach are not contradictory but complementary: the former provides a physically based, time-resolved representation of the system response, while the latter offers a simplified metric for design and verification.

Flow routing through canal sections (conduits) in the EPA SWMM software is based on the principles of conservation of mass and momentum for gradually varied, unsteady flow (i.e., on the Saint-Venant equations). SWMM users have the option to select the level of computational complexity to be used in solving these equations: Steady Flow Routing, Kinematic Wave Routing, or Dynamic Wave Routing. Each of these routing methods uses the Manning equation to relate flow to flow depth and bed slope (or slope induced by friction). For the calculations, the dynamic wave method was selected. This method enables the simulation of all gradually varied flow conditions, including backwater effects, network surcharging, and flooding. In SWMM flooding will occur whenever the water surface at a node exceeds the maximum assigned depth. Normally such water will be lost from the system. The option also exists to have this water pond atop the node and be re-introduced into the drainage system when capacity exists to do so.

After entering the subcatchment and channel network geometry, as well as all relevant hydraulic and hydrological parameters summarized in Table 1, runoff simulation was performed for the analyzed watershed as a result of rainfall during the May–June period. The simulation was carried out for the period from May 1, 2019 (start of simulation) to June 30, 2019 (end of simulation), with a time step of 30 minutes.

4. SIMULATION RESULTS AND DISCUSSION

Based on the adopted set of input data shown in Table 1, the results of the hydrodynamic model developed in the EPA SWMM software package were analyzed. In this study, four scenarios were compared, differing in the elevation at which the pipes were installed relative to the canal bed, with the aim of determining to what extent the position of the culvert installation affects the volume of spilled water and the spatial distribution of flooding. The following simulations considered:

- a model without installed barriers and without pipes in the barrier,
- a model with installed barriers and pipes, where the invert elevation of the pipes is level with the canal bed,
- a model with barriers and pipes where the invert elevation of the pipes is set 15 cm above the canal bed,
- a model with barriers and pipes where the invert elevation of the pipes is set 15 cm, 30 cm, or 50 cm above the canal bed, depending on the canal depth.

A comparative analysis of the maximum flooding maps for all four scenarios, viewed from the aspect of pipe placement within the canal, showed that mostly the same nodes were exposed to flooding, while the volumes of water at these locations were very similar across all considered variants (less than 2% difference in flood volume). This can be clearly seen in Figure 5, which shows the maps of maximum flooding (on May 21, 2019, at 16:30) for the scenario without pipes and for the scenarios in which the pipes are installed at different elevations relative to the canal bed, as indicated in the titles of the Figure 5.

The temporal and spatial distribution of water overflow from the canals was also analyzed by monitoring water level changes in longitudinal profiles during the two rainy months. In this case as well, no significant differences were observed in the spatial or temporal distribution of water overflow from the canals.

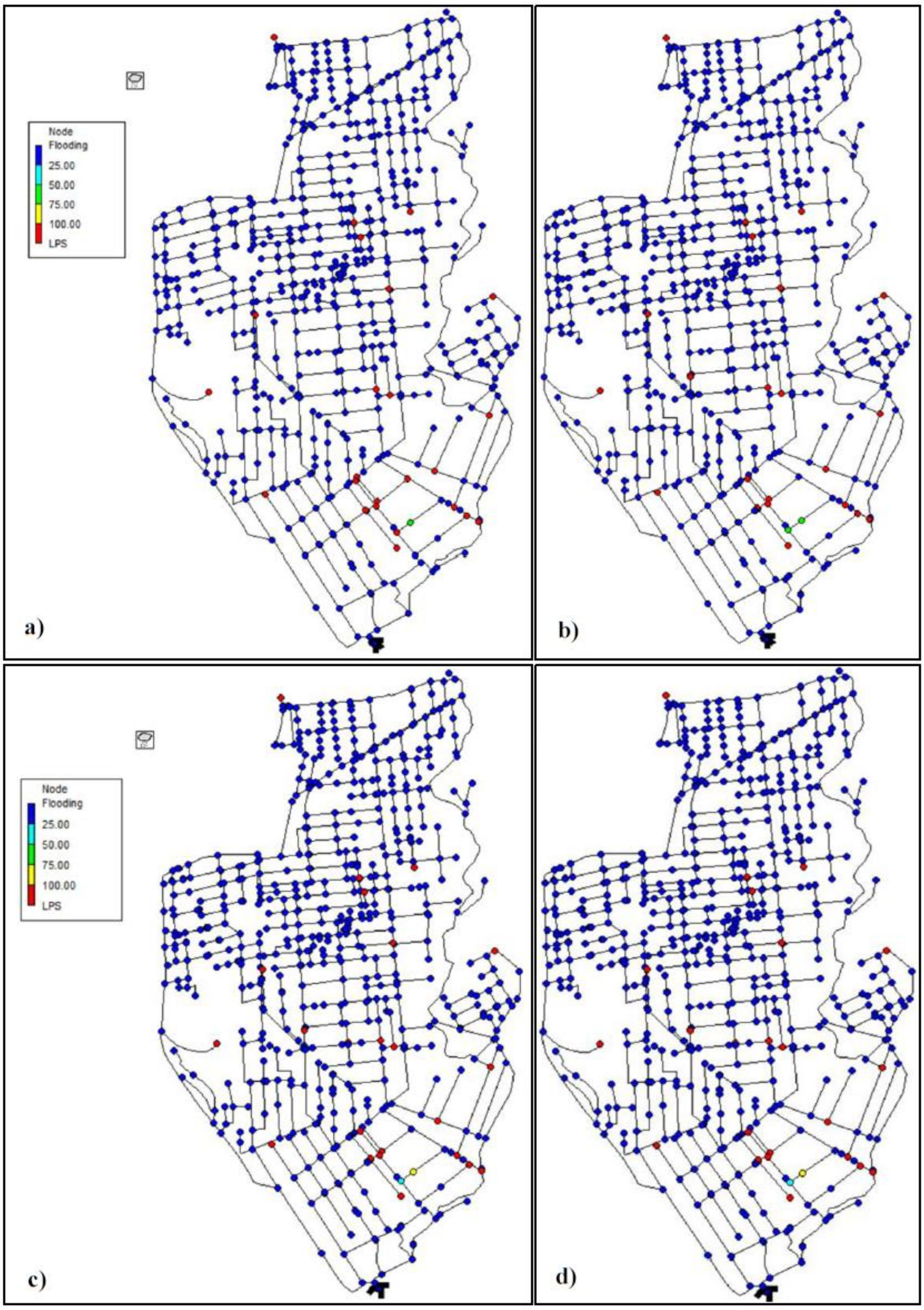

Figure 5. Map of maximum flooding
a) for the scenario without installed pipeline
b) for the scenario with installed pipeline, with the pipe invert set at the canal bed elevation
c) for the scenario with installed pipeline, with the pipe invert set 15 cm above the canal bed elevation
d) for the scenario with installed pipeline, with the pipe invert set 15 cm, 30 cm, or 50 cm above the canal bed elevation

Table 2. Channel overflow table

Table 2a. Channel overflow table for the scenario without installed pipeline

Node	Hours Flooded	Max Rate LPS	Day of Maximum Flooding	Total Flood Volume 10^6 ltr
156	3.63	4.48	21	0.034
161	47.56	508.87	21	46.968
211	373.09	3311.84	21	1676.199
212	455.22	2340.88	21	1826.869
275	82.11	1012.47	21	193.937
277	42.64	5152.53	21	496.231
290	76.09	742.31	21	136.558
299	28.87	1046.9	21	83.439
400	106.67	1379.38	56	282.581
436	109.17	959.77	56	159.774
469	24.99	708.83	56	39.674
481	102.65	1050.64	21	243.169
483	45.34	1192.17	21	136.914
491	45.02	1126.02	21	130.395
498	15.1	1220.77	20	52.459
464	14.73	7557.67	21	335.25
474	55.33	338.74	21	58.593
475	47.41	820.3	21	94.058
476	111.12	916.35	21	198.189
503	15.08	90.63	21	3.725
504	30.8	1070.06	20	75.71
505	110.41	1179.94	21	300.316
518	225.22	1218.35	21	579.391
521	5.34	217.32	56	2.978
529	135.06	2097.18	21	492.999
550	11.53	82.54	56	2.928
554	134.06	5008.77	21	1011.781
555	33.67	488.79	56	39.021
557	10.32	62.8	56	1.879
560	49.89	4947.27	21	551.214
562	65.64	2274.89	21	482.426
567	15.5	1006.68	21	49.416

Table 2b. Channel overflow table for the scenario with installed pipeline, with the pipe invert set at the canal bed elevation

Node	Hours Flooded	Max Rate LPS	Day of Maximum Flooding	Total Flood Volume 10^6 ltr
161	47.39	470.96	21	49.155
211	395.03	3268.95	21	1865.041
212	496.44	2313.06	21	2048.51
275	92.79	1061.74	56	240.902
277	43.49	4737.62	21	423.095
290	81.7	806.78	56	147.659
299	23.24	853.33	21	46.915
400	109.45	1352.6	56	283.375
436	112.15	959.78	56	159.783
469	24.49	708.83	56	39.207
481	112.69	1031.26	21	269.551
483	52.33	1159.62	20	157.548
491	43.79	987.71	21	106.514
498	1.4	336.99	20	1.141
474	56.92	338.74	21	59.674
475	47.18	715.88	21	77.106
476	117.18	852.64	21	184.354
503	13.76	90.63	21	3.592
504	12.44	174.63	20	2.736
505	115.95	1179.94	21	282.272
518	243.55	1146.51	21	604.587
521	5.34	217.32	56	2.978
529	150.9	2097.19	21	619.605
550	11.54	82.54	56	2.931
554	148.23	5008.85	21	1138.95
555	33.73	488.79	56	39.079
557	10.33	62.8	56	1.88
560	50.29	4266.97	21	451.411
562	73.66	2274.89	21	511.645
567	22.79	892.51	21	47.539
1262	3.88	108.99	56	1.058
1274	30.52	2318.13	20	144.922
1275	27.96	9878.76	21	599.341

Table 2c. Channel overflow table for the scenario with installed pipeline, with the pipe invert set 15 cm above the canal bed elevation

Node	Hours Flooded	Max Rate LPS	Day of Maximum Flooding	Total Flood Volume 10^6 ltr
161	47.23	469.96	21	48.833
211	377.97	3267.78	21	1789.582
212	467.48	2312.3	21	1941.749
275	87.59	1061.75	56	236.342
277	43.06	4725.2	21	416.961
290	81.07	806.8	56	146.64
299	22.87	847.17	21	45.855
400	109.35	1364.6	56	283.31
436	111.97	959.78	56	159.187
469	24.39	708.83	56	39.142
481	105.29	1028.53	21	252.568
483	51.41	1159.29	20	154.238
491	43.22	983.86	21	104.88
498	1.33	302.03	20	1.011
474	56.17	338.74	21	58.891
475	46.55	712.8	21	75.925
476	110.06	852.1	21	174.576
503	13.44	90.63	21	3.523
504	11.46	172.74	20	2.236
505	108.98	1179.94	21	265.993
518	228.27	1145.86	21	567.995
521	5.34	217.32	56	2.978
529	144.47	2097.19	21	593.812
550	11.54	82.54	56	2.93
554	140.57	5008.79	21	1121.758
555	33.71	488.79	56	39.058
557	10.33	62.8	56	1.88
560	49.63	4247.37	21	444.689
562	68.51	2274.89	21	496.999
567	22.55	889.33	21	46.877
1261	1.66	54.91	56	0.207
1274	29.89	2358.61	20	142.813
1275	26.97	9612.07	21	572.885

Table 2d. Channel overflow table for the scenario with installed pipeline, with the pipe invert set 15 cm, 30 cm, or 50 cm above the canal bed elevation

Node	Hours Flooded	Max Rate LPS	Day of Maximum Flooding	Total Flood Volume 10^6 ltr
161	47.22	469.96	21	48.821
211	375.6	3267.78	21	1781.845
212	462.88	2312.3	21	1927.62
275	87.17	1061.77	56	235.641
277	43.35	4725.2	21	416.139
290	80.85	806.84	56	146.436
299	22.59	847.17	21	45.53
400	110.35	1364.64	56	284.82
436	111.88	959.78	56	159.063
469	24.39	708.83	56	39.142
481	104.31	1028.53	21	250.422
483	51.04	1159.8	20	153.049
491	43.06	983.85	21	104.491
498	1.34	310.18	20	1.031
474	55.88	338.74	21	58.633
475	46.36	712.8	21	75.655
476	109.07	852.1	21	173.38
503	13.43	90.63	21	3.522
504	11.46	173.79	20	2.245
505	107.99	1179.94	21	263.943
518	226.75	1145.86	21	563.936
521	5.34	217.32	56	2.978
529	143.35	2097.19	21	590.894
550	11.54	82.54	56	2.931
554	140.08	5008.79	21	1120.172
555	33.71	488.79	56	39.058
557	10.33	62.8	56	1.881
560	49.43	4247.38	21	443.14
562	68.06	2274.89	21	494.155
567	22.57	889.33	21	47.054
1228	0.1	8577.07	32	1.229
1261	1.69	55.38	56	0.213
1274	29.63	2355.69	20	141.993
1275	26.56	9612.53	21	560.311

In the technical literature it can be found that the existing drainage systems in Vojvodina are designed to meet the requirements for the removal of the relevant excess water during the non-vegetation period, with a recurrence interval of 10 % and a return period of 10 years [11].

The drainage hydromodule represents the unit amount of water that needs to be removed from a unit area in a period of time. Its value characterizes the drainage needs of specific areas. According to the literature [7], the hydromodule for the area in question is q = 0.40 l/s/ha. If a relevant design month of 30 days is adopted, it follows that the excess water that the system can remove from the catchment areas during these 30 days is about 104 mm per hectare.

$$Q = q * A \; [m^3/s] \tag{1}$$

$$pv = \frac{Q*D*86400}{A*10000} * 1000 \; [mm/mes] \tag{2}$$

$$Q = 0.4 \frac{\frac{l}{s}}{ha} * 1\,ha = 0.4 \frac{l}{s} = 0.0004\, m^3/s$$

$$pv = \frac{0.0004 \; * 30 * 86400}{1 * 10000} * 1000 = 103.68 \frac{mm}{mes}$$

Where:
D (days) number of days in the representative month; it is assumed that the representative month has 30 days,
A (ha) area from which excess water is drained,
q (l/s/ha) system hydromodule,
pv (mm/month) excess water that can be removed from the observed area in one month

However, according to meteorological data measured during May and June of 2019, the cumulative precipitation values were significantly higher: in May, they amounted to 225 mm, and in June to 257 mm, totaling 482 mm. This also indicates hydrological overloading of the drainage system in the area.

5. CONCLUSION

The process of surface water runoff in hydrology is a complex phenomenon that depends on the interaction of a large number of parameters and therefore requires a comprehensive analysis. The factors determining whether, in what form, and in what quantity water from subcatchment areas will enter the drainage system (canal network) and lead to flooding are not limited to the amount and duration of precipitation. They also include the initial soil moisture, infiltration rate, the previous water level in canals, flow resistance coefficients on subcatchment surfaces and within canals (Manning's roughness coefficient), water loss dynamics from the canals, groundwater level, the operational regime of the canal network, as well as the dynamics of pump station operations. All these parameters are interdependent, and their combined effect is the fundamental cause of the complex runoff behavior from drainage areas.

The Knićanin – Čenta catchment area represents a region characterized by its distinctive geomorphological and hydrographic features. Due to its specific location, the basin is threatened by both external and internal waters. What further distinguishes it is the fact that a gas pipeline passes through the area, which at certain points intersects the network of existing drainage canals in the watershed. During May and June 2019, floods occurred in the subject basin that endangered part of the catchment area and caused significant material damage. The question naturally arose as to whether and to what extent the construction of the gas pipeline, the blocking of canals, and the installation of culverts at the crossing points of the gas pipeline with drainage canals, was related to the floods that occurred. A review of the literature preceding this work revealed that most studies and analyses addressing this issue examine the problem through hydromodulus analysis of the system.

The only correct approach to the problem is to conduct an analysis using an appropriate hydrologic-hydraulic model that will take into account all of the previously mentioned parameters and their interactions. Based on the previously defined set of input data, the model was calibrated, after which the results obtained from simulations within four hydraulic models implemented in the EPA SWMM software package were analyzed. Using the results from these four models, the impact of the depth at which culverts were installed in the barriers on the drainage system and the occurrence of flooding in the study area was assessed.

Analysis of the maximum flooding maps, together with monitoring the location and timing of flooding, showed that the comparison of the four models resulted in less than 2% difference in flood volume. This indicates that the culverts were adequately sized, leading to the conclusion that the new gas pipeline did not have a significant impact on the volume of spilled water. Instead, the primary cause of the flooding was the large amount of rainfall that occurred in the area.

While fine-scale spatial prediction is uncertain, the comparison of four constructed scenarios consistently shows that pipeline-related modifications did not increase flood extent or volume under the tested conditions.

ACKNOWLEDGRMENT

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-34/2026-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project ‘Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad 2026’ (No. 01-3609/1).

The research has been conducted within the project "Enhancement of teaching and scientific research capacities through the application of modern technologies in the fields of civil engineering, geodesy, and disaster risk management and fire safety", developed at the Department of Civil Engineering and Geodesy, Faculty of Technical Sciences, University of Novi Sad, Serbia.

LITERATURE

[1] S. Belić et al., “Zaštita zemljišta od suvišnih unutrašnjih voda (odvodnjavanje),” u *Hidrotehničke melioracije u Vojvodini*, Novi Sad: Poljoprivredni fakultet, Institut za uređenje voda, 1995, pp. 93-124.

[2] A. Bezdan, M. Vranešević, and S. Belić, “Ugroženost površina poljoprivrednog zemljišta u različitim režimima pumpanja,” *Melioracije 12*, pp. 30-36, 2012.

[3] A. Bezdan, “Procena rizika od suficita i deficita vode na melioracionom području,” Doktorska disertacija, Poljoprivredni fakultet, Univerzitet u Novom Sadu, Novi Sad, 2014.

[4] S. Kolaković, “Vode Vojvodine - neki aspekti funkcionalnosti sistema za zaštitu spoljnih i unutrašnjih voda na području Vojvodine,” Fakultet tehničkih nauka, Univerzitet u Novom Sadu, Novi Sad, 2003.

[5] S. Kolaković and S. Trajković, *Hidrotehničke melioracije – Odvodnjavanje*. Novi Sad: Fakultet tehničkih nauka u Novom Sadu i Građevinsko-arhitektonski fakultet u Nišu, 2006.

[6] S. Kolaković, “The analysis of the pump station operations on the drainage systems in Vojvodina,”in *Proceedings of the BALWOIS 2006 Conference on Water, Climate and Environment*, Ohrid, R. Macedonia, 2006.

[7] Land Reclamation Development of the Čenta–Knićanin Area, Hidrozavod, 1975.

[8] L. A. Rossman, *Storm Water Management Model User's Manual Version 5.1*, EPA/600/R-14/413b, U.S. Environmental Protection Agency, Cincinnati, OH, 2015.

[9] L. M. Ermalizar and A. Junaidi, “Flood simulation using EPA SWMM on small subcatchment urban drainage system,” *MATEC Web of Conferences*, vol. 229, 2018, Art. no. 04022, doi: 10.1051/matecconf/201822904022.

[10] Y. Yang et al., “Linking a Storm Water Management Model to a Novel Two-Dimensional Model for Urban Pluvial Flood Modeling,” *International Journal of Disaster Risk Science*, vol. 11, pp. 508–518, 2020, doi: 10.1007/s13753-020-00278-7.

[11] M. Vranešević, “Biotehničke mere kao mogućnost za povećanje efikasnosti sistema za odvodnjavanje,” Doktorska disertacija, Poljoprivredni fakultet, Univerzitet u Novom Sadu, Novi Sad, 2015.