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REDUCING THE RISK OF FLOODING IN AREAS WITH HIGH VULNERABILITY WITHIN TIMISOARA CITY

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Abstract: In this paper are analyzed ways to reduce the risk of flooding in areas highly vulnerable during periods of heavy rainfall in Timisoara city. This phenomenon is caused by the inability of existing sewerage networks to carry storm flows during torrential rains. Solutions to combat flooding phenomena of passageways beneath railway lines, basements from some civil and industrial buildings and traffic arteries (auto and pedestrian), consist of arranging some waterstorage basins coupled with pumping stations or submersible electric pumps provided even in these buildings. Waterstorage basins will accumulate volumes of water collected from the surface of vulnerable areas during rain, and after the cessation of rain to be pumped into the existing sewer collector, or nearest emissary. Such arrangements were provided for those 6 passages from Timisoara city hearth considered at high risk of flooding during periods of heavy rainfall.

Keywords: collector sewerage, storm water, waterstorage basins, pumping stations, rain intensity calculation, flood risk.

1. GENERAL CONSIDERATIONS

Sewage are construction and installation assemblies, with which collect and carry water leakage from the hearth population centers.

Water leakage, consisting of household wastewater and storm water can be transported through different channels, in case of separation or together system through unique collectors in the integrated system..

Sizing sewage collectors for household wastewater is made at $Q_{orarmax}$ and those for rainwater at the flow determined by corresponding surface and rain intensity calculation, determined in relation to the corresponding standardized frequency channeled area.

If in case of household debits, variability in time of calculated debits is relatively low, instead storm debits may exceed, during periods of heavy rainfall, initial flow rates set at sizing channels, leading thus to overcome their transport capacity and thus, the basements flooding from civil and industrial buildings, traffic arteries and especially passageways beneath railways in areas with high vulnerability.

This situation should be correlated with reduced transport capacity of leakage channels by increasing roughness sewers, but also by reducing leakage sections due to deposition of sediments during periods when they are not insured self-cleaning speeds (V_{min} = 0.7 m/s).

Reducing the risk of flooding in areas with high vulnerability can be assured by setting waterstorage basins, equipped with pumping stations, capable of accumulating volume rainfalls during the rain, they will be pumped into existing sewers or emissary nearest vulnerable area.

Action arrangement of waterstorage basins must be correlated with degraded channel replacement and removal of sediment deposits, thereby ensuring increasing the transport capacity of existing channels.

2. PLANNING SCHEME FOR WATERSTORAGE BASINS AND PUMPING STATIONS

Waterstorage basins equipped with or without pump stations can be set on sewers or their adjacent areas. [3], [4], [5], [6].

Planning schemes of waterstorage basins are established according to the existing sewer system (separator for storm water or unitary for wastewaters and storm wtares), to the carrying capacity of leakage channels, but also the existence of emissaries near highly vulnerable area..

In Figure 1 is shown the scheme of arrangement of a pass waterstorage basin (BR) without pumping with discharge overflow (D) into a natural emissary R, specific to a separation system - storm water (Q_m).

In this case the inflow Q_i = Q_m and discharge flow Qe = Qp leakage flow rate at full.

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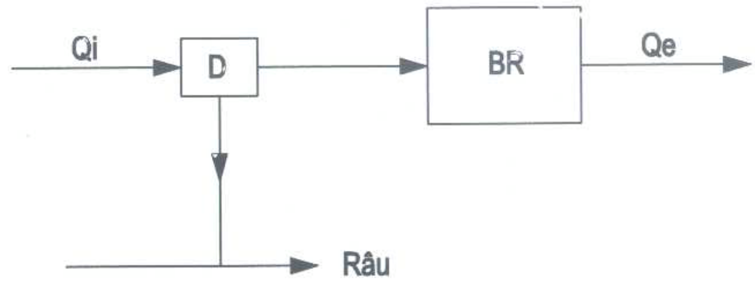


Fig. 1. Sewer separation system with waterstorage basin and overflow chamber

In figure 2 is shown the arrangement scheme of a waterstorage basin - lateral with pumping station (PS) equipped with submersible pumps, separator thickness (SG) and overflow discharge in emissary after filling the waterstorage basin.

In this case inflow Q_i = Q_m and exhaust flow Q_e=Q_{uz}+Q_m+Q_p in the flow discharged into natural emissary after filling the waterstorage basin Q_d = Q_m.

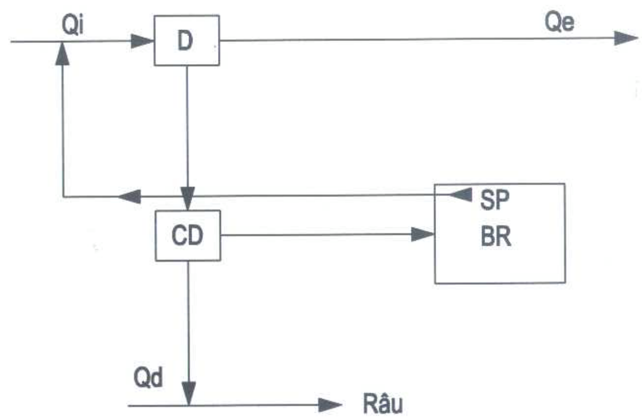
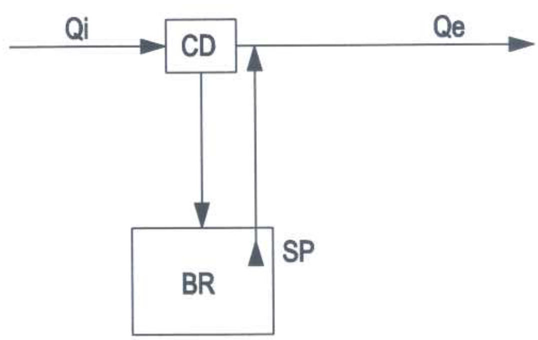


Fig.2. Unitary sewer system with lateral waterstorage basin with pumping station, separator thicknessa and overflow



In Figure 3 is shown the scheme of arrangement of a waterstorage basin - lateral with accumulation, with pumping station in basin and equipped with submersible electric pumps and overflow room (D) specific areas highly vulnerable to floods, channeled in unitary system.

This scheme was used to reduce the risk of flooding for 6 passages analyzed in the hearth of Timisoara city.

3. DETERMINATION OF STORAGE CAPACITY OF WATERSTORAGE BASINS

Storage capacity of waterstorage basins arranged in highly vulnerable areas at the heavy rainfall, in case of existing sewerage systems is established according to the rainfall volume accumulated during rain (t_p) [3], [7], [8]

$$V_{BR} = Q_m \cdot t_p \quad (1)$$

$Q_m = i\ .\ m \sum S\square i$ (2)

where:

V_{BR} - is waterstorage basin volume with storage during rain, in m^3;

Q_m - storm water flow in m^3/s;

t_p - during rain, considered to be equal to the leakage duration, in seconds;

i - intensity of the rain, in l/s·ha;

m - coefficient which takes into account the storage capacity of the sewerage network (m = 0.8 ÷ 0.9);

S - corresponding area of the channeled basin in ha;

Φ_i - average coefficient leakage of corresponding surface for sewage collectors.

Rain intensity in sewege (i_c =i), is the amount of rainfall per unit horizontal area in unit time

This intensity (i_c) in l/s·ha can be expressed depending on the intensity from Meteorology (i_m) in mm/min, through a relationship like this:

$$i = 166{,}6\ .\ h/tp \approx 170\ h/tp \quad (3)$$

in which: h is the height of water layer fell during t_p, in mm;

tp - during rain, in minutes, 170 - transformation coefficient of the intensity of Meteorology (im) in the intensity of the sewerage (ic). [1],[2],[3],[7].

Intensity of rainfall varies even when it rain.

In terms of designing sewerage, rains can be torrential (of short duration and high intensity) or abundant (long duration and low intensity). Torrential rains may have duration of 5-10 minutes and drizzles of days.

Duration and intensity of rain is in an inverse of each other.

The correlation between rain calculation intensity from sewerage (ic) and that of Meteorology (im) is as follows: 1 l/s m2 = 1 mm/s and 1 l/s ha = 0,006 mm/min

Rain calculation intensity (i) is a function dependent on rain duration (t_p) and rain frequency (f) expressed as:

$$i=F(t_p ,f) \quad (4)$$

Graphical representation of this function for the intensities from sewerage (i_c) and that of Meteorology (i_m), in relation to rain duration (t_p) are shown in fig.4 and 5. [3],[4],[5],[6].

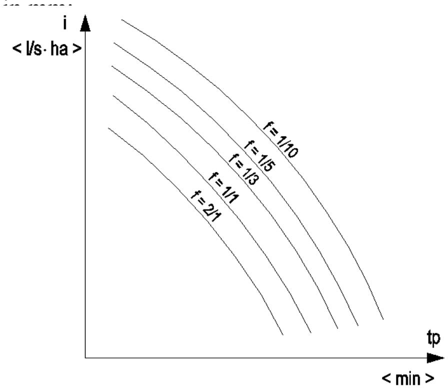


Fig.4 Diagram of rain calculation intensity in sewerage

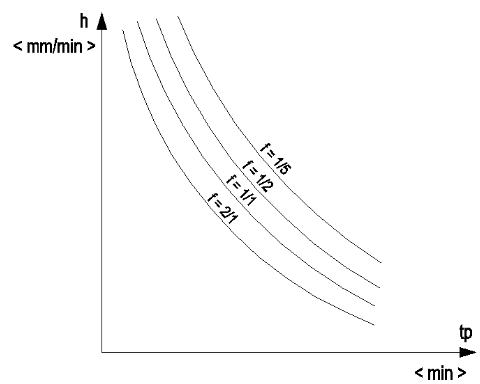


Fig.5 Diagram of rain calculation intensity in Meteorology

In Romania, rain intensity calculation for the 13 areas characteristic frequency is determined in relation to frequency (f) and duration of rain calculation, using diagrams from STAS 9470-73.[9]

Where necessary comparative technical and economic studies recommended, determining the intensity of rain calculation the relationship analytical of the form: [3]

$$i = t_p^{\alpha} \quad (5)$$

in which: a is a coefficient determined experimentally in relation to the frequency of calculation of each area; α - exponent determined for each of the 19 characteristic areas in Romania (α = 0,3-0,65).

Relationship for rain intensity calculation for Timis County (area 13) is:

$$i = a\ t_p^{-0{,}5} \quad (6)$$

Table 1

f	2/1	1/1	1/2	1/4	1/5	1/10	1/20
a	363	387	503	580	712	812	967

The intensity of torrential rain calculation can be determined by the relationship proposed by Reinhold, used successfully in Austria and European countries. [4],[5],[6],[15],[16].

$$i_f = 38\ (t_p +9)\ (f^{-1/4} - 0{,}369)\ i_{15(1/1)} \quad (7)$$

in which: if is the rain calculation intensity in l/s·ha; tp - rain calculation duration, in minutes; f - frequency calculation; i15(1/1) - intensity rain calculation for tp = 15 min and f = 1/1, which can be considered to 120 l/s·ha for lowland and hill areas, of 150 l/s·ha for mountain / alpine areas and of 105 l/s·ha for the city of Vienna. [4],[5],[6].

In Austria the intensity rain calculation is determined relatively simple using the diagram rendered in Leitfoden ÖWWV Norm (2007), Rain Sheet 11 and 19 [8], [11],[15]

4. ELIMINATE THE RISK OF FLOODING IN THE PASSAGES WITH HIGH VULNERABILITY WITHIN TIMISOARA CITY

Wastewater and storm sewer system from Timisoara is an unitary type, with some exceptions, in peripheral areas and of the industry in which they practice separation system.

Systematic channeling of water leakage from the Timisoara city hearth dating from 1912, now totaling over 570 km.

Although sewer system from Timisoara has undergone over time, ongoing processes of expansion, enhancement and modernization, there are areas at risk of flooding of basements of civil and industrial buildings, blocking road traffic and the pedestrian areas, in viaducts area, railway crossings under.

Carrying capacity of sewerage networks is far exceeded in flood plains, especially in torrential rains, because due the climate changes, calculation rain intensities increased far beyond the amount that was estimated initial for sizing sewerage networks, causing flooding, especially, the passages and lower areas of the hearth of this city.

The carrying capacity of the sewerage network has been diminished by the fact that weather flows were doubled, by increasing the average coefficient of discharge from 0.35 to 0.70, due to changes in surface leakage structure.

Sewerage networks from areas vulnerable to flooding, being undersized, led to work under pressure in case of torrential rain, when rain calculation intensity is much exceeded than that taken in the design calculations.

High risk flooding areas analyzed in the case studies are: 700 Market Viaduct; Viaduct Passage Jiu, Popa Sapca Viaduct, Viaduct Ardealul, Viaduct N. Andreescu and Viaduct Gheorghe Lazar.

Sewerage networks from these areas are undersized and have a lifetime exceeded, concrete tubes wear has a great physical and moral issues that have led to increased roughness drains. In this situation adds sections decrease due to clogging drainage channels, increase leakage coefficients Φ afferent collector surfaces, due new constructions and diminishing green areas.

Studies undertaken for these areas aimed as medium and long term to ensure proper functioning viaducts during torrential/ heavy rains, without crossing passages to be flooded.

Viaduct 700 Market (Fig.6), collects stormwater, for a leakage area of approx. 13906 square meters, consists of paved surfaces, walkways, macadam and green areas, with an average coefficient of discharge $\Phi = 0.69$.

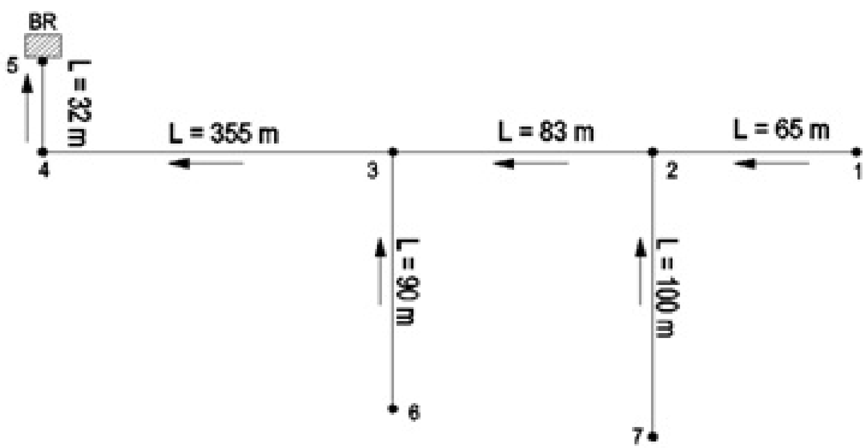


Fig. 6. Pluvial sewerage network - Viaduct 700 Market

Viaduct Passage Jiu (Fig.7), collects stormwater, for a leakage surface approx. 24770 sqm, constitutes of the asphalt, walkways and green areas, characterized by an average coefficient of discharge $\Phi = 0.77$.

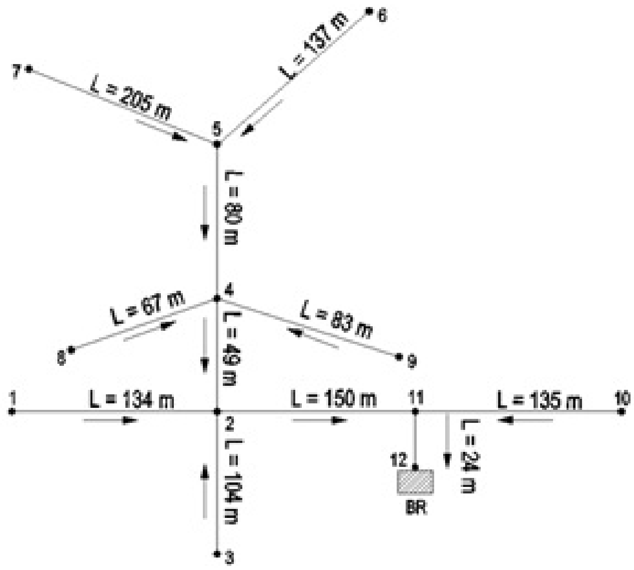


Fig.7. Pluvial channel network - Jiu Viaduct

Popa Sapca Viaduct (Fig.8), collects stormwater, corresponding to an area of about 20425 square meters, constitutes the paved surfaces, walkways and green areas, with an average coefficient of discharge $\Phi = 0.42$.

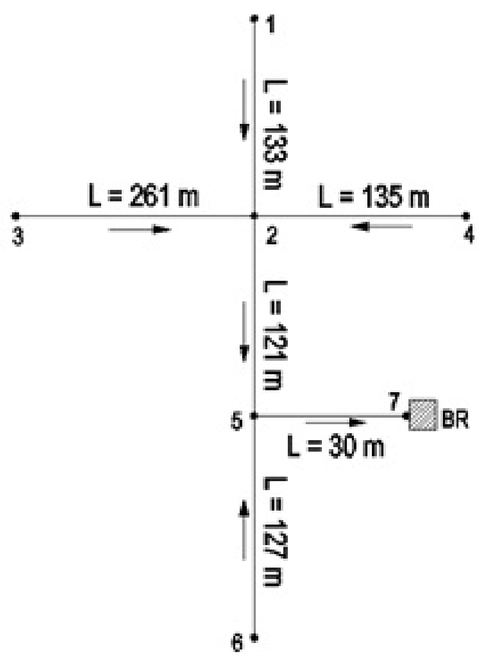


Fig.8. Pluvial sewerage network - Popa Sapca Viaduct

Viaduct Ardealul (Fig.9), collects stormwater, an area corresponding to approximately 17739.5 square meters, constitutes the asphalt, walkways and green areas, with an average coefficient of discharge $\Phi = 0.36$.

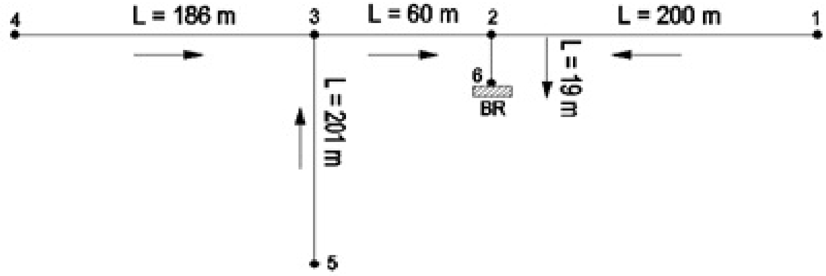


Fig.9. Pluvial sewerage network - Viaduct Ardealul

Viaduct N. Andreescu (Fig.10), collects stormwater, an area corresponding approximately 107635.5 square meters, constitutes the asphalt, walkways and green areas, with an average coefficient of discharge $\Phi = 0.45$.

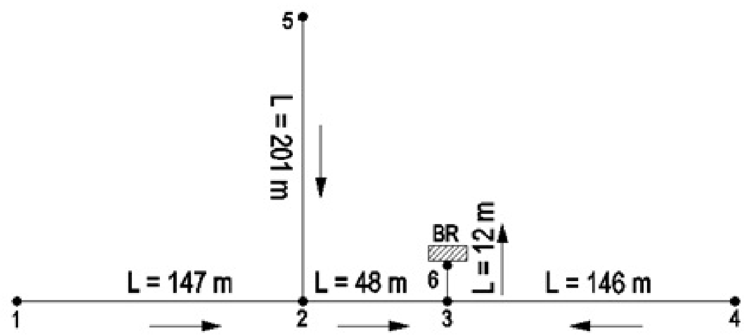


Fig.10. Pluvial sewerage network - Viaduct N. Andreescu

Viaduct Gheorghe Lazar (Fig.11), collects stormwater, corresponding to an area of approximately 12549.5 square meters, constitutes the asphalt, concrete platforms, walkways and green areas, with an average coefficient of discharge $\Phi = 0.74$.

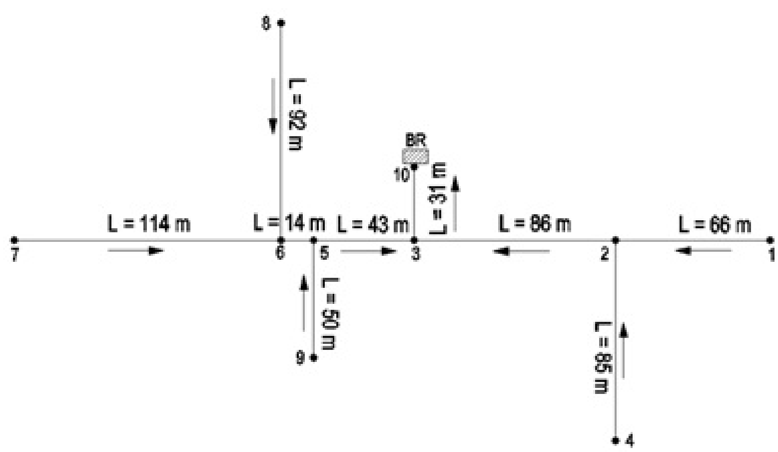


Fig.11. Pluvial sewerage network - Viaduct Gheorghe Lazar

Stormwater flows calculation of high flooding risk areas were determined by considering, in the case study, three technical-economic scenarios.

• Normal scenario (S_1) - no flooding, the rain calculation frequency was considered f = 1/2, SREN 752-2008, for not produces putting under pressure of the existing sewerage network.

• Scenario risk of flooding (S_2), in which the rain calculation frequency was considered f = 1/30, SREN 752-2008 and SR 1846-2007, which allows a flood of vulnerable areas, within an acceptable risk level.

Rain calculation intensity for the frequency considered (f = 1/30) was calculated with relation (7) proposed by Reinhold and accepted by some European countries. [11],[15],[22],[23],[24]

• Scenario particularly at risk (S_3), which was considered the most unfavorable situation, published in Timisoara, in 2010, when rainfall height recorded was h = 50 mm to a rain duration of tp = 40 minutes.

This situation is the result of climate changes in the last 15-20 years and the STAS 9470-73, in force does not give real consideration intensities in case of heavy rains. [16],[17],19],[21]

In Table 2 are shown calculated meteoric Qm debits for analyzed viaducts, volumes and geometric dimensions of waterstorage basins BR for scenarios S_2 and S_3 with accepted risk and high risk of flooding.

Table 2. Volumes and geometric dimensions of waterstorage basins to various risks of flooding

Crt. no.	Viaduct	S_a (mp)	Φ	Scenarios	tp=ts (min)	i (l/s·ha)	Q_m (l/s)	V_{BR} (m^3)	LxBx4 (m)
1	700 MARKET	13906	0,69	S1 S2 S3	26	115 299 376	88 229 289	135 352 695	- 9x13x2 22x13x2
2	PASSAGE JIU	24770	0,77	S1 S2 S3	24	119 313 337	182 476 515	262 688 1239	- 10x15x3 23x15x3
3	POPA SAPCA	20425	0,42	S1 S2 S3	22	122 336 619	84 231 425	110 302 1021	- 5x13x3 24x13x3
4	ARDEALUL	17739	0,36	S1 S2 S3	22	118 334 722	60 171 369	80 225 887	- 4x13x3 21x13x3
5	N.ANDREESCU	107635	0,45	S1 S2 S3	18	140 380 580	54 145 221	59 158 532	- 5x13x3 19x13x3
6	GH.LAZAR	12549	0,74	S1 S2 S3	17	150 400 351	112 298 261	112 300 628	- 7x9x3 20x9x3

Waterstorage basins were provided with pumping stations in order to pump volumes of water stored during the rain calculation, equal to the leakage period (t_p=t_s) and pump them into the existing sewerage network, after the cessation of rain .

Waterstorage basins, arranged in areas at risk of flooding, represent for the areas/localities channeled in unitary or separation system for stormwater, a viable alternative/possible to increase the carrying capacity of the sewerage network during periods of heavy rains.

In Table 3 are shown for scenarios S_2 and S_3, total investment costs (I) and those for construction-assembly (C+M), in EURO, necessary for sewerage networks (Cr), pumping stations (PS), waterstorage basins (BR) and those for road rehabilitation. (RC).

Table 3. Investment costs by category of works for the scenarios considered

Crt. no.	Viaduct	Scenarios	C' (EURO)	PS (EURO)	BR (EURO)	R.C (EURO)	I (EURO)	C+M (EURO)
1	700 MARKET	S_2 S_3	98415 95800	203272 203272	66857 163429	181250 181250	549793 643750	437593 531550
2	PASSAGE JIU	S_2 S_3	147014 147014	255986 268557	128572 295712	292000 292000	823572 985472	657943 807272
3	POPA SAPCA	S_2 S_3	90672 91957	201272 220129	55714 267429	196146 196146	549407 781264	443493 656493
4	ARDEALUL	S_2 S_3	47857 48757	77743 77743	44572 234000	166500 166500	336714 527000	301829 492114
5	N.ANDREESCU	S_2 S_3	36329 36329	75057 75057	37143 141143	315029 315029	315029 419029	281400 385400
6	GH.LAZAR	S_2 S_3	65529 59600	204343 204343	54000 154286	508375 508375	469264 563479	357064 451279

Recommended is that the flooding scenario (S_2), with f = 1/30, the risk of flooding to the probability of exceeding 3.33%. This scenario determines, in accordance with accepted risk of flooding, constructions and equipments with lower capabilities and investment.

Scenario S_3 (h = 50 mm and tp = 40 minutes) can be promoted in case you want a greater reduction in the risk of flooding to passages from the areas analyzed.

In this case the surfaces necessary for the six waterstorage basins are 3.2 times higher than those required by scenario S_2, the arranged area belonging entirely to public domain.

5. CONCLUSIONS AND RECOMMENDATIONS

Studies and research aspect of the work undertaken in the collected stormwater management on the hearth of urban population centers are located in the plain area, have resulted in: establishing general analytical relationship to determine the rain calculation intensity in the Western parts of Romania; highlighting the correlation between rain calculation intensity from sewerage (i) and rainfall height (h) respectively with rain intensity from hydrology; checking the validity of rain calculation intensity relationship, used in EU countries, for the Western part of Romania during periods of heavy rainfall; hydraulic sizing of sewerage networks for their operation under pressure; hydraulic sizing of waterstorage basins with a relationship in dimensionless sizes; technical-economic calculations of the hydraulic system consists of sewerage networks, pumping stations, to reduce the risk of flooding in some areas/districts of the population centers with high risk of vulnerability; the applicability of theoretical studies to reduce the risk to flooding in the 6 passages from Timisoara hearth through waterstorage basins coupled with pumping stations equipped with submersible pumps;

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