CALCULATION METHOD OF RAINWATER DISCHARGE

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ABSTRACT

A method for calculating rain flow probability of different recurrence was developed in 2010 thesis for the city Riga (R.Ziemelnieks). The aim of this paper is to develop a method for determining the rain flow for other major Latvian cities and populated areas. The data were collected over an extended period of maximum rainfall and the surface runoff coefficients were specified for different types of covering materials. The improvement of the existing rainwater flow calculation method is given in the Latvian Building Normative LBN 223-99, which is partly borrowed from the Soviet Union improved building standards and regulations СНиП 2.04.03-85 (SNIP)(Строительные нормы..,1985), which are based on the promotion work thesis by Soviet scientist Kurganov (Курганов) in 1978(Курганов, 1984). The paper gives the coefficient of Ψ values for different surfaces and the estimated k-values of Latvian towns, depending on the desirable flow of rainwater probability in 200-1% range. The method developed enables the calculation of the maximum rate flow of rainwater in urban areas with different probability.

Key words: rainwater, rain flow, k-coefficient, surface runoff, co-system.

INTRODUCTION

Data of research studies carried out as well as media news show that heavy downpours in Riga and other Latvian cities become more intensive year after year (Negaisa sekas.., Bauska piedzīvo..). Rain or co-system sewerage systems are not able to carry away all surface waters quickly from the squares and streets having the heavy impermeable cover (Ziemelnieks, Tilgalis, Juhna, 2008). At present parking places, pavements and roads having the impermeable hard cover increase fastly in towns (Ziemelnieks, Tilgalis, 2009). The problems caused by rain waters in the city territories have become actual recently beginning more and more to feel the presence of rain and snow melting waters in the sewerage systems. The situation becomes worse by the connection of rainwater sewerage collectors to the sewerage networks, which creates an additional load to the sewerage networks of the co-systems and pumping stations during the rain. Pumping and purification of rain waters create additional costs of electro energy for the service establishments. Coming of insufficient unpurified rainwater in the water reservoirs creates serious environmental pollutions.

MATERIALS AND METHODS

Processing of rain data

This study makes use of the rain observation data from different inhabited locations and towns using the publicly asseccible information of the agency of Latvia environment, geology and meteorology (LVGMA) (Tables of Meterological Observations.., Meterological and hydrological..). The rain observation data rows were summed up and supplemented in order to improve the existing calculation method of maximum rainwater discharge in the town of Latvia by means of the new k-coefficient. The data of rain intensity during the warm period from April till September were chosen and used when the downpours with the maximum intensity are observed in Latvia causing the flooding of territories and streets. The precipitation model groups were drawn up selecting the maximum empirical data quantities, in addition by taking into consideration the air temperature regime, the period of warm weather, thus the hard kind of precipitation – snow, ice was not estimated and was excluded from the investigation. The results of the measurements reflecting as „0" have been discarded because then the precipitation has been possibly very small, the system was not able to fix this amount or the precipitation has not been at all.

Rainwater discharge calculation methods

In order to be able to calculate the rain water discharge according to the data obtained with a larger possibility, some improvements of the existing adopted calculations were carried out, thus by improving the drawn up formula with k-coefficient of the rainwater maximum discharge by A.Zīverts (Zīverts, 1997):

$$Q_{max} = \Psi \cdot q \cdot k \cdot F \quad [\mathrm{l\ s^{-1}}] \qquad (1)$$

in which
Qmax – max 20 minutes rainfall discharge, $\mathrm{l\ s^{-1}}$;
Ψ – coefficient of surface runoff (Table 1);
q – runoff module $\mathrm{l\ (s \cdot ha)^{-1}}$ (Table 2);
k – coefficient depending on the calculation probability % (Table 2);
F – size of the surface area, ha.

The calculation simplified expression of the existing discharge module by E.Tilgalis (Tilgalis, 2004) was used as the calculation basis (2) presuming the length of the specific downpour up to 20 min and its average rain intensity 1 mm min-1.

$$q = 0.13 \cdot \alpha \quad [\text{l (s} \cdot \text{ha)}^{-1}] \qquad (2)$$

in which

α - rainfall amount in millimeters(mm), e.g., in Riga during the period without frost according to the summed up date by A. Zīverts, in Table 2 is 368mm, 71 years of observation.

The kind of material use of the surface cover may by different in the location of use of a conformable area, therefore the rainwater discharges change. In Latvia the coefficients of surface discharge have not been summed up in literature. The coefficients of rainwater discharge surface for the present surface cover areas have been studied in the world and their values are shown in Table 1.
The data of the table show clearly that it is possible to reduce the rainwater discharge several times by using the surface covering materials not dense enough of a conformable way.

RESULTS AND DISCUSSION

By determining the values of the precipitation intensity of maximum minutes and by specifying the coefficients of surface runoff for different kinds of covering materials, the calculation method of the existing discharge has been improved. The existing calculations in the Latvian building normative LBN 223-99 envisage the precipitation discharge having the repetition period once a year (100%), twice (200%) or thrice in a year (300%). Moreover the calculation given by LBN and recommendations partly adopted and improved from the building norms and regulations of the USSR СНиП 2.04.03-85 (SniP) are based on the basis of Kurganov, USSR scientist promotion paper worked out in 1978 and which have been improved during the course of time and later shown in the handbooks of different kind and number table materials (Kurganov, 1984). The calculations have been specified and about in 1986 Snip projecting materials are officially accessible (Metodiskie norādījumi lietus.., 1983).
The existing method of rainwater calculation amount according to MK Latvian building normative „MK regulations No.214" „Regulations about Latvian building normative LBN 223-99"Outer networks and buildings of sewerage" ("LV", 198/199 (1658/1659), 18.06.1999.) that came into force on 01.10.1999 with the alterations (regulations on LBN 223-99.., 2010), is complicated. In order to obtain the rain amount (l s^{-1}) it is necessary to use 7 different parameters.
The second popular method used in Latvia for calculation of the discharge amount is a simplified method worked out by A.Zīverts and Ē.Tilgalis (Tilgalis, 2004).

Table 1

Runoff coefficients

Use of areas or type of covering material of surface area	Coefficient, φ
Use of areas	
Town office	0.70 - 0.95
Commercial premises	0.50 - 0.70
Populated areas	
Detached house	0.30 - 0.50
Flat in a dwelling house	0.40 - 0.60
Flat (apartments)	0.60 - 0.80
Inhabited suburb district	0.25 - 0.40
Industrial district	
Light industry	0.50- 0.80
Heavy industry	0.60 - 0.90
Parks, green areas, cemeteries	0.10 - 0.30
Railway carriage park, playground	0.20 - 0.40
Meadows for pastures	0.10 - 0.30
Surface area covering material	
Street, pavement covering by asphalt or concrete	0.70-0.95
Concrete area	0.80-0.95
Concrete cobble stone covering	0.70-0.80
Pedestrian pavements and part for transport	0.75-0.85
House roof covering material (depending on material)	0.75-0.95
Grassland having sandy soil composition	
Sandy soil with 2% decline or less	0.05-0.10
Sandy soil with 2%-8% decline	0.10-0.16
Sandy soil with 8% decline or more (precipice, slope)	0.16-0.20
Grassland having clayey soil composition	
Decline 2% or less	0.10 - 0.16
Decline 2%-8%	0.17 - 0.25
Decline 8% and more (precipice, slope)	0.26 - 0.36

Source: Computer applications in hydraulic engineering (basic hydrology-rainfall) (translation report by R.Ziemelnieks)

Using this method it is possible to calculate the discharges with the possibility up to 200%. In addition, the determined k-coefficient dependent on the calculation possibility was determined basing on the previous carried out investigations in the promotion work (R.Ziemelnieks). The method elaborated provides for the possibility to calculate the maximum rainwater discharges in inhabited locations with a different possibility. In the result of the investigation it is possible to conclude that in Latvia it is advisable to use the calculations with the repetition possibility 50 or 25% (frequency of repetition once in 2 or 4 years). According to the table drawn up by A.Zīverts (Zīverts, 1997) several improvements were carried out, values of k-coefficients were determined and the runoff module was calculated at different provisions for the inhabited locations of Latvia. The numerical results are summarized in Table 2.

Table 2

Values of k-coefficients

No.	City, populated place	Dura-tion of observation, years	Size of the alpha value (rainfall April-September)	Values	200%	100%	50%	25%	10%	5%	1%
1	Cīrava	33	272	q, l (s ha)$^{-1}$	35	59	72	89	109	122	154
				k-coefficient	0,75	1,25	1,54	1,92	2,37	2,67	3,35
2	Dagda	27	268	q, l (s ha)$^{-1}$	35	58	71	87	107	120	151
				k-coefficient	0,75	1,23	1,50	1,84	2,33	2,60	3,30
3	Daugavpils	42	276	q, l (s ha)$^{-1}$	36	60	73	90	110	124	156
				k-coefficient	0,77	1,27	1,58	1,95	2,40	2,70	3,40
4	Dzērbene	33	428	q, l (s ha)$^{-1}$	56	92	113	139	171	192	242
				k-coefficient	1,17	2,00	2,47	3,00	3,70	4,12	6,10
5	Gulbene	39	391	q, l (s ha)$^{-1}$	51	84	103	127	156	175	221
				k-coefficient	1,05	1,77	2,23	2,74	3,40	3,80	4,75
6	Gureļi	37	447	q, l (s ha)$^{-1}$	58	96	118	146	178	200	252
				k-coefficient	1,23	2,07	2,54	3,15	3,85	4,35	6,65
7	Ieriķi	35	391	q, l (s ha)$^{-1}$	51	84	103	127	156	175	221
				k-coefficient	1,05	1,77	2,23	2,74	3,40	3,80	4,75
8	Jelgava	50	335	q, l (s ha)$^{-1}$	44	72	88	109	134	150	189
				k-coefficient	0,93	1,54	1,86	2,37	2,90	3,25	4,00
9	Kabile	41	291	q, l (s ha)$^{-1}$	38	63	77	95	116	130	164
				k-coefficient	0,80	1,33	1,63	2,05	2,50	2,80	3,57
10	Kolka	57	250	q, l (s ha)$^{-1}$	33	54	66	81	100	112	141
				k-coefficient	0,71	1,15	1,37	1,73	2,15	2,45	3,10
11	Kosa	25	428	q, l (s ha)$^{-1}$	56	92	113	139	171	192	242
				k-coefficient	1,17	2,00	2,47	3,00	3,70	4,12	6,10
12	Kuldīga	42	291	q, l (s ha)$^{-1}$	38	63	77	95	116	130	164
				k-coefficient	0,80	1,33	1,63	2,05	2,50	2,80	3,57
13	Lejasciems	29	484	q, l (s ha)$^{-1}$	63	104	127	158	193	217	273
				k-coefficient	1,33	2,27	2,74	3,45	4,24	4,63	7,90
14	Liepāja	63	235	q, l (s ha)$^{-1}$	31	51	62	77	94	105	133
				k-coefficient	0,68	1,05	1,30	1,63	2,03	2,30	2,85
15	Mālpils	38	409	q, l (s ha)$^{-1}$	53	88	108	133	163	183	231
				k-coefficient	1,12	1,86	2,35	2,85	3,55	3,95	5,60
16	Ogre	31	335	q, l (s ha)$^{-1}$	44	72	88	109	134	150	189
				k-coefficient	0,93	1,54	1,86	2,37	2,90	3,25	4,00
17	Pilskalne	35	277	q, l (s ha)$^{-1}$	36	60	73	90	111	124	156
				k-coefficient	0,77	1,27	1,58	1,95	2,43	2,70	3,40
18	Priekuļi	47	409	q, l (s ha)$^{-1}$	53	88	108	133	163	183	231
				k-coefficient	1,12	1,86	2,35	2,85	3,55	3,95	5,60
19	Ranka	34	391	q, l (s ha)$^{-1}$	51	84	103	127	156	175	221
				k-coefficient	1,05	1,77	2,23	2,74	3,40	3,80	4,75
20	Rēzekne	37	264	q, l (s ha)$^{-1}$	34	57	69	86	105	118	149

				k-coefficient	0,73	1,20	2,10	1,82	3,13	2,54	3,22
21	Rīga	71	368	q, l (s ha)$^{-1}$	48	79	97	120	147	165	208
				k-coefficient	1,00	1,68	2,10	2,60	3,12	3,60	4,50
22	Saldus	27	263	q, l (s ha)$^{-1}$	34	57	69	86	105	118	148
				k-coefficient	0,73	1,20	1,45	1,82	2,30	2,54	3,18
23	Stāmeriene	38	447	q, l (s ha)$^{-1}$	58	96	118	146	178	200	252
				k-coefficient	1,23	2,07	2,54	3,15	3,85	4,35	6,65
24	Stende	46	304	q, l (s ha)$^{-1}$	40	66	80	99	121	136	172
				k-coefficient	0,85	1,37	1,70	2,12	2,64	2,95	3,75
25	Subate	37	228	q, l (s ha)$^{-1}$	30	49	60	74	91	102	129
				k-coefficient	0,65	1,03	1,27	1,60	1,97	2,19	2,77
26	Užava	25	272	q, l (s ha)$^{-1}$	35	59	72	89	109	122	154
				k-coefficient	0,75	1,25	1,54	1,92	2,37	2,67	3,35
27	Ventspils	59	298	q, l (s ha)$^{-1}$	39	64	78	97	119	133	168
				k-coefficient	0,83	1,35	1,65	2,10	2,57	2,85	3,65

Source: Calculated and created by R.Ziemelnieks

In order to envisage the statistic indicators for at least the next 10-15 years, the data rows should be supplemented with new observations in order to calculate the forecast of the possibility and to determine the long-time average value of the duration curves. Approximately at least 5-year number rows are to be selected to envisage the precipitation amount minimally. At least registration data of 25 years measurements are to be used for a more accurate forecast possibility. The value of the error or the inaccuracy of the forecast are determined by the length of the number rows, the less the row, the larger – the inaccuracy. Tables and figures should be inserted in the width of one or two columns and should not exceed the margins of the document.

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CONCLUSIONS

1. The newly formed formula and the values given offer an accurate calculation of the rainwater discharge.
2. According to the values of k-coefficient numbers obtained, it is possible to conclude, that one may take into consideration larger possibilities of the consequences of the flood, while choosing the surface covering material with a less repetition possibility.
3. The elaborated calculation method of maximum rainwater discharge shows that LBN 223-99 method is imperfect and gives incorrect results in the rainwater system calculation, it is proved by the fact that during heavy downpours many Latvian streets are flooded.
4. In future the work must be continued at the improvement of the calculation methods of more accurate maximum rain water discharges as well as at different kinds of calculation methods in the territory of Latvia
5. By carrying out the calculations of rainwater discharges one is to take into consideration the given kinds of the use of squares and the covering type which may influence the amount of the discharge.
6. It is possible to regulate the discharge most effectively by rainwater infiltration locally using not dense enough surface covering materials.
7. According to the calculation results obtained, one is to conclude that it is more useful to invert the means in building the sewerage of separate system, because it is influenced by the electroenergy rise in price.

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