www.esa-conference.ru

Method of Calculation of the Maximum Rainwater Flow in Central Latvia

Jakovlevs Sergejs
Department of Architecture and Building, Faculty of Environmental and Civil Engineering,
Latvia University of Agriculture, Latvia

Abstract. *Altogether, the assumption (hypothesis) that the maximum intensity of rain (imax) is revealed within the first 20÷30 minutes proved to be false (Jakovlevs S., Gusta S. & Tilgalis E., 2017). The actual rain intensity (5÷6÷7 mm . min-1) for certain 3-hour periods is 30 to 115 minutes, and it can occur with a 3÷4÷5 multiple repetitions of the maximum intensity peaks, see Figure 1 (1; 2; 3; 4). The period of rain, where the maximum intensity peaks of precipitation can recur several times, usually leads to the flooding of the territories. The author believes that the existing method of calculation given in LBN 223-15, SNiP 2.04.03-85 and TPC 45-4.01-57-2012 (02250) and based on the data of maximum intensity of a 20-minute rain period provide no longer a practical and effective result, which is proved by regular floods in the recent years. It is proposed to apply the formula that takes into account the maximum precipitation amount within a 3-hour rain period. Today, the Latvian Environment, Geology and Meteorology Centre measures precipitations with a multiplicity of 3 hours.*

Keywords: *maximum amount of precipitation, period of precipitation recurrence, calculation formula, precipitation intensity, drain surface type.*

Nomenclature		
i	Precipitation intencity	mm · min^{-1}
T	Rain period	min
I	Cumulative amount of precipitation	mm
F	Estimated drainage area	ha
ψ	Ratio corresponding to the surface flow type taken according	
Q	Volume of precipitation	m^3

1. Introduction

The 1994 to 2004 data were paper files from the Latvian Environment, Geology and Meteorology Centre. Since 2005, the data were collected and processed with an electronic database at the website of the Latvian Environment, Geology and Meteorology Centre (LEGMC, 2016). The maximum precipitation amount of a three-hour rain in Riga (47.2 mm) was registered on July 30, 2005, from 18:00 to 21:00. In Jelgava, the maximum amount of three-hour rain precipitation (68.7 mm) was registered on August 20, 2011, from 06:00 to 09:00. In Bauska, the 54.2 mm rainfall was registered on July 12, 1998, from 00:00 to 03:00. In Dobele, the maximum amount of three-hour rain precipitation (44.2 mm) was registered on July 18, 2010, from 15:00 to 18:00. In Jurmala, heavy rainfall of 68.7 mm was registered on September 5, 2000, in the night. Ogre saw 49.4 mm of rainfall on July 28, 2011, from 18:00 to 21:00. (LEGMC, 2016).

2. Materials and methods

The proposed method of calculation of the maximum precipitation amount of rainwater was developed based on the climatic conditions of the Baltic region and the urban areas similar in the surface relief and buildings.

In this paper, the following research methods are used: statistical analysis of research data and their processing, the development of curves for the maximum precipitation duration with different probability periods, as well as expert's interviews and opinions.

Based on the analysis of the results of the previous studies (Jakovlevs S., Gusta S. & Tilgalis E., 2017) and for a more accurate calculation of the maximum rainwater flow

Table 1*. Surface Flow Ratio ψ depending on the Surface Type

No.	Surface type	ψ
1.	Roofs	1
2.	Asphalt and similar surface (black coatings)	0.9
3.	Pavements (including gravel roadway covering)	0.6
4.	Stone pavements	0.45
5.	Gravel surfaces (not treated with a binder)	0.4
6.	Garden soil and park lanes	0.3
7.	Ground coatings	0.2
8.	Lawn and grass	0.1
9.	In case the surface cannot be definitely classified	0.4

$Q_{MAX.}$, (m^3 · min^{-1}) in the central part of Latvia, we hereby propose the following formula:

$$Q_{MAX.} = I \cdot F \cdot \psi \cdot T^{-1}; \quad (1)$$

* Table 18, "Construction standards of Latvia (LBN 223-15)" "Sewer constructions", Riga, June 30, 2015, page 25.

ЕВРАЗИЙСКОЕ НАУЧНОЕ ОБЪЕДИНЕНИЕ
EURASIAN SCIENTIFIC ASSOCIATION
www.esa-conference.ru

where

I - is an amount of possible maximum precipitation within a three-hour rain period taken according to Table 2, mm · $3h^{-1}$;

F - is an estimated drainage area, ha;

ψ - is a ratio corresponding to the surface flow type taken according to the Table 1 (which corresponds to Table 18, LBN 223-15, page 25);

T - is a three-hour rain period in minutes (180 min).

In order to calculate the residual volume (m^3) of rainwater on the "land" surface Q_{RES}, it is necessary to subtract the total amount of precipitation at a given area, the amount of precipitation absorbed into the soil, the amount of precipitation drained to the rainwater basins, pipes, network collectors filling reservoirs of pumping stations (if any) and the amount of precipitation drained into reclamation channels, fast flowing drains and ponds (if any) from the precipitation volume. According to the recommended formula (2):

$$Q_{RES} = Q_{ACT} - Q_1 - Q_2 - Q_3 - Q_4; \quad (2)$$

where

Q_{RES} - is the residual volume of rainwater on the "land" surface, m^3;

Q_{ACT} - is the total volume of precipitation for a given area, m^3;

Q_1 - is the volume of precipitation to wet the surface, m^3;

Q_2 - is the volume of precipitation absorbed into the soil, m^3;

Q_3 - is the volume of precipitation drained to the rainwater basins, pipes, network collectors filling reservoirs of pumping stations (if any), m^3;

Q_4 - is the volume of precipitation drained into reclamation channels, fast flowing drains and ponds (if any), m^3.

TABLE 2. THE % PROBABILITY OF THE POSSIBLE AMOUNT OF A THREE-HOUR RAINFALL IN MM FOR CITIES IN THE CENTRAL PART OF LATVIA

No	Probability	City					
	%	Riga	Jelgava	Bauska	Dobele	Jurmala	Ogre
1	0.01	63.0	108.7	99.1	62.4	146.1	77.9
2	0.05	59.1	96.5	85.7	58.4	124.2	70.5
3	0.1	57.4	91.0	79.9	56.5	114.7	67.2
4†	1	50.5	72.4	60.2	49.4	82.9	55.4
5	3	46.4	62.7	50.3	45.3	67.4	49.2
6	5	44.2	58.0	45.5	43.0	60.1	46.0
7	10	40.9	51.1	38.9	39.7	50.0	41.4
8	20	36.8	43.7	31.9	35.7	39.7	36.1
9	25	35.3	41.1	29.5	34.1	36.3	34.2
10	30	33.9	38.9	27.5	32.7	33.5	32.5
11	40	31.4	35.1	24.2	30.2	28.8	29.6
12	50	29.1	31.7	21.3	27.9	25.1	27.1
13	60	26.7	28.7	18.8	25.6	21.9	24.6
14	70	24.2	25.7	16.6	23.1	19.2	22.1
15	75	22.8	24.1	15.3	21.8	17.9	20.8
16	80	21.2	22.6	14.3	20.2	16.6	19.4
17	85	19.4	20.7	12.9	18.4	15.2	17.7
18	90	17.1	18.7	11.7	16.2	13.9	15.8
19	95	13.8	16.1	10.1	12.9	12.3	13.2
20	97	11.5	14.5	9.2	10.7	11.7	11.5
21	99	7.3	12.1	8.0	6.7	10.9	8.7
22	99.9	0.1	9.0	6.9	-0.2	10.4	4.5

To calculate the total area (ha) for the precipitation collection F_{PC}, it is recommended to divide the area under estimation (1 ha) into sectors of different surface types (roofs and roofing materials [tile, bitumen, "chips", sheet steel, etc.], lawns, pavements, roads and their surface types [cobblestones, asphalt, pavers, concrete, etc.] and play-grounds), and then to summarize them taking into account the surface drain factor $(\psi)^U$. The proposed formula (3) is as follows:

$$F_{PC} = \Sigma (F_i \cdot \psi_i); \quad (3)$$

† Possible maximum rainfall precipitation within a 3-hour period (at a probable single occurrence of one time in a hundred years), mm . $3h^{-1}$.

‡ the ratio corresponding to the surface drainage type taken according to Table 1 (which corresponds to Table 18, LBN 223-15, page 25).

www.esa-conference.ru

where

$F_i \cdot \psi_i$ - is the product of the area of a given type of surface by the surface drainage coefficient of a given surface material, ha.

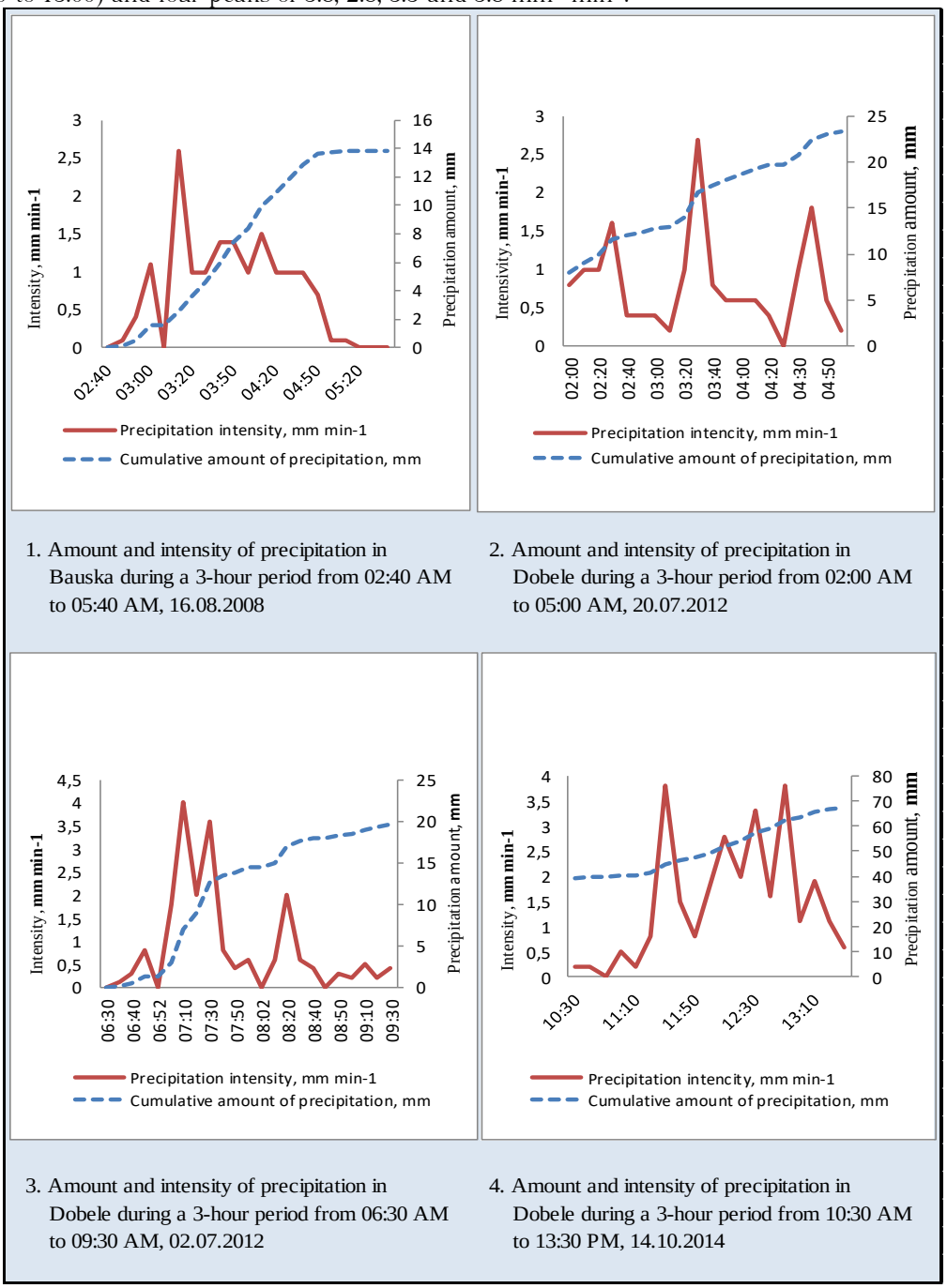
3. RESULTS AND DISCUSSION

According to diagram 1 (1), duration of rain within the considered three-hour period was 150 minutes (from 2:40 to 05:10), and the second greatest intensity period was 115 minutes (3:05 to 05:00). The maximum intensity peak was 2.6 mm · min^{-1} at 03:10.

Diagram 1 (2) shows a 3-hour rain period (02:00 to 05:00) in the city of Dobele on July 20, 2012. During this period, three maximum peaks of intensity were registered with a pluviograph: at 02:30, 03:30 and 04:40 the intensity was 1.6 mm · min^{-1}, 2.7 mm · min^{-1} and 1.8 mm · min^{-1}, correspondingly.

Diagram 1 (3) shows the 3-hour rain period (06:30 to 09:30) in Dobele on July 2, 2012; here, we can see that the maximum intensity peak within a 58-minute period (06:52 to 07:50) with peaks of 4 mm · min^{-1} at 07:10 and 3.6 mm · min^{-1} at 07:30.

Diagram 1 (4) shows the maximum rainfall intensity within a three-hour period (10:30 to 13:30) lasting 100 minutes (11:20 to 13:00) and four peaks of 3.8, 2.8, 3.3 and 3.8 mm · min^{-1}.



1. Amount and intensity of precipitation in Bauska during a 3-hour period from 02:40 AM to 05:40 AM, 16.08.2008

2. Amount and intensity of precipitation in Dobele during a 3-hour period from 02:00 AM to 05:00 AM, 20.07.2012

3. Amount and intensity of precipitation in Dobele during a 3-hour period from 06:30 AM to 09:30 AM, 02.07.2012

4. Amount and intensity of precipitation in Dobele during a 3-hour period from 10:30 AM to 13:30 PM, 14.10.2014

Figure 1 (1;2;3;4). The amount and intensity of precipitation according to the hydrograph data in the cities of Bauska and Dobele in a three-hour period from 1996 to 2016 (LEGMC, 2016).

ЕВРАЗИЙСКОЕ НАУЧНОЕ ОБЪЕДИНЕНИЕ
EURASIAN SCIENTIFIC ASSOCIATION
www.esa-conference.ru

4. Conclusions

A greater danger may not be the amount of precipitation falling out within a short period of time, but their constantly varying intensity with large peaks (5ч6ч7 mm · min-1) repeated up to 3ч4ч5 times within a very short time (30ч60ч90 min) during a 180-minute rain.

The importance of this method of calculation of probable maximum precipitation amount during a 180-minute rain is not the calculation formula (it is simple), but the attached calculated data table showing probable repetitions of rain precipitation peaks (from once a year to once in ten thousand years) calculated according to the existing data (LEGMC, 2016) for the six cities in the central part of Latvia over the last 21 years (1996 to 2016).

This calculation method can be used to calculate the probable maximum amount of precipitation for other regions of Latvia, as well as for the nearby Baltic regions such as Lithuania, Belarus, the Western part of the Russian Federation and Estonia. Yet, provided that there are previously studied and processed data resulting in a table of possible repetitions of maximum rainfall in certain regions within the three-hour period over the past few decades.

This calculation method will be useful in solving problems in both civil and military aviation, in the rural and industrial sectors, as well as in industrial and civil activities.

References:

[1] Latvian Environment, Geology and Meteorology Centre (LEGMC), September 2016, www.meteo.lv, from http://meteo.lv/meteorologija-datu-meklesana/?nid=461

[2] Latvian Building Code LBN 223 – 15 “Structures of Sewage”, Riga, 30th June

[3] Jakovlevs S., Gusta S. & Tilgalis E. (2016), VESTNIK, Pskov State University, series “Technical Science”, COMPARISON OF MAXIMAL RAINWATER FLOW CALCULATION METHODS, pp. 95-100, Pskov, 2016, 108 pages

[4] Ziemelnieks R., Tilgalis E. Calculation method of rainfall flow rate. In: Research for rural development 2009: Annual 15th International Scientific Conference Proceedings, 20-22 May, 2009, Jelgava, Latvia. Jelgava: Latvia University of Agriculture, pp. 315-319

[5] Ratnaweera Harsha C., Norwegian University of Life Sciences (NMBU), Es, Norway, MATERIALS 5th International Water Forum «Water Resources and Climate», Part 1, October 5–6, 2017, Minsk, Republic of Belarus, pp. 19-23

[6] Jakovlevs S., Gusta S. & Tilgalis E. (2017), VESTNIK, Pskov State University, series “Technical Science”,ANALYSIS OF MAXIMUM PRECIPITATION IN THE CENTRAL PART OF LATVIA, pp. 83-90, Pskov, 2017, 94 pages

[7] СНиП 2.04.03-85 Строительные нормы и правила, „Канализация. Наружные сети и сооружения”, Госстрой СССР.- М.; Дата введения (1986-01-01)

[8] ТЕХНИЧЕСКИЙ КОДЕКС УСТАНОВИВШЕЙСЯ ПРАКТИКИ ТКП 45-4.01-57-2012 (02250), Системы дождевой канализации, Строительные нормы проектирования, Минск, 2012.; (Дата введения 2012-12-01)