THE RAINFALL CHARACTERISTICS OF THE OSIJEK AREA

Siniša Maričić[1] and Tatjana Mijušković-Svetinović[2]
[1,2] Faculty of civil engineering University of Osijek, Drinska 16 a, 31 000 Osijek, Croatia
[1] E-mail: smaricic@most.gfos.hr
[2] E-mail: tatjanam@most.gfos.hr

Abstract: The urban drainage analysis is a current problem in Osijek, the capital of Slavonia and Baranja in Croatia. The basic combined sewage system of the city of Osijek, town with more than 100 000 inhabitants and significant industry, must be developed, reconstructed and completed. For the purpose of sewage system improvement functioning, the modelling is being prepared for the present, but also for the future state with completed primary sewage system and wastewater treatment plant.

The rainfall is one of the basic input data in the modelling. Because of this, the rainfall monitoring was established at first. It consists of five ombrographs in the different part of Osijek's area.

This paper shows the initial research of registrated rainfall events with the purpose to observe the space and time rainfall distribution on the city area. In frames of present financial possibilities a relatively thick network was established with automatic instruments which have a 5 minute interval of data reading. The analyses were pointed to the observation of simultaneous rainfalls with determined duration by the maximum values appearances on a location and to the internal structure of the characteristic rainfall episodes. The great differences in rainfall events across the city were observed which should be taken into consideration in the further engineering praxis.

Keywords: *rainfall, rainfall episodes, internal structure*

NIEDERSCHLAGSEIGENSCHAFTEN IN DER REGION OSIJEK

Zusammenfassung: Die Analyse der Urbanwasserableitung ist aktuelles Problem in der Stadt Osijek, die die Mittelpunkt der Region Slavonija und Baranja in Kroatien ist. Die Grundlage des gemischten Abwasserungssystems in Osijek – die Stadt mit mehr als 100.000 Einwohner und mit bedeutender Industrie – muss entwickelt, rekonstruiert und kompletiert werden. Mit dem Ziel der Verbesserung des Kanalisationssystems werden die Vorbereitungen für die Modelierung des Kanalisationssystems getroffen – wie jetzigen so auch zukunftigen Zustands (mit fertigem Hauptsammler und Kläranlage).

Die Niederschläge sind eins von Grundeingangsdaten für die Modelierung – deswegen ist Niederschlagmonitoring als erstes aufgestellt. Es umfasst 5 Ombrographs (Regenmesser) in verschiedenen Stadtteilen.

In dieser Arbeit wird die anfängliche Forschung der registrierten Niederschlagsdaten gezeigt, mit dem Ziel die räumliche und zeitliche Verteilung je nach Stadtteilen zu erblicken. Im Rahmen der finaziellen Möglichkeiten, ist ein relativ dichtes Netz der Instrumenten, die in 5-minutigen Intervalen die Angaben ablesen, eingesetzt.

Die Analysen sind auf die gleichzeitige Niederschläge, des bestimmten Dauers bei der maximalen Werten auf einer Stelle, aufgerichtet, wie auch an die interne Struktur des charakteristischen Niederschlagsepisoden. An verschiedenen Messstellen in der Stadt sind sehr grosse Unterschiede festgestellt und das sollte man in weiterer Ingenieurpraxis in Betracht genommen werden.

Schlüsselwörter: *Niederschläge, Niederschlagsepisoden, interne Struktur*

1. General

The success of the engineering solutions depends on the data quality of the rainfall in an area. The quality solutions are impossible without measuring data. These measurings have to be well theoretically organized, properly and continuously carried and adjusted to the engineering needs.

The problems caused by the showers(intensive rainfalls of short duration) are more dangerous and harmful and therefore they are in the first plan of the hydrologic interests of the engineering praxis. These are the intensive rainfalls (from 10 and sometimes 100 mm/hour) of mostly short duration of 1 hour, and surely of 24 hours, which can be therefore measured only by automatic recorders. To get the good vision of the internal shower structure (time and space intensity distribution within one event) it is necessary to have automatic ombrographs with short intervals recording (shorter than 5 minutes) and with thick network of their placing (cca. one instrument in the area of a couple of km). Due to high expenses of such monitoring it is difficult to expect the desirable data.

2. Characteristics of the Osijek area

Osijek is said to live by the Drava River. That is confirmed by the fact that the city has elongated shape with the length of about 9 km and the average width less than 2 km. So, the urban area of more than 170 km^2 is parallely stretched with the river watercourse in the direction east-west. In the east, about ten river kilometers downstream, there is the mouth of Drava into the Danube.

Inundational valley of the coming Danube (well known as Kopački rit) dominates on the north-eastern side of Osijek. That area is rich in swamps and woods. The industrial plants zone is located in the eastern part of the city. There is an interesting hydrologic question from the engineer's point of view: Do the present circumstances have the influence on the rainfall distribution across the city and what are the characteristics of these rainfalls?

For the city of Osijek as well as for the large surrounding area the weather station was established with the regular measurings under control of the National Meteorogical Institute (DHMZ). That weather station is in the south-eastern part of the suburbs (Agricultural University, Osijek) with the height above sea-level of 89 m above sea level. (**, 2002.) In that way the rainfall data gathering is possible for long time and on one location. Due to the war events, in a period of time during the nineties, the station was temporarily dislocated to the western location. As the adequate data which illustrate rainfall of the region one can use the values of the average monthly rainfalls for the period 1969-1998, which were gathered in that station. The data are given in Table 1. It is observed that the main problem connected to the rainfalls is recognizing the characteristics of their spatial distribution. It is especially revealed by the urban hydrology tasks, i.e. problems of the city sewage system development. Namely, the urban drainage is current problems in Osijek, the capital of Slavonia and Baranja, in Croatia. The basic, combined drainage system of Osijek, the town with more than 100 000 inhabitants and great industry, must be developed, reconstructed and completed.In the purpose of the sewage system improvement functioning, the modelling is being prepared for the present, but also for the future state with completed primary sewage system and wastewater treatment plant.

3. Research of the rainfall characteristics

In context of the program works on the project “Drainage model with the idea project for the sewage system of the city of Osijek” one of the planned activities is Monitoring (of rainfalls and drainage) (*, 2000). Faculty of Civil Engineering, Osijek was chosen for that activity as a subperformer. What was going to be measured, where and how was agreed with all for the project relevant clients.

By that occasion, the rainfall observation network inside the city was established among other things. It consists of five automatic ombrographs. They are distributed along the city zone according to the placing possibilities, undisturbed work insurance and the existing state of water gathering by the sewage system. The locations distribution of the rainfall

observations in the city of Osijek can be seen in the Picture (see the paper The parameters determination problem of the sewage system function).

. The measuring were at first planned in duration of four months (only to connect rainfall and drainage) , but afterwards it was agreed to continue the measurings.

Here are presented only some gathered data analysis for the observation period during the year 1999 (May-December) made with purpose to establish space and time distribution over the city area. The observed period includes exactly the shower season, which is, in principle, used for the intensive showers analysis. (Patrick, 1990; Bonacci, 1994)

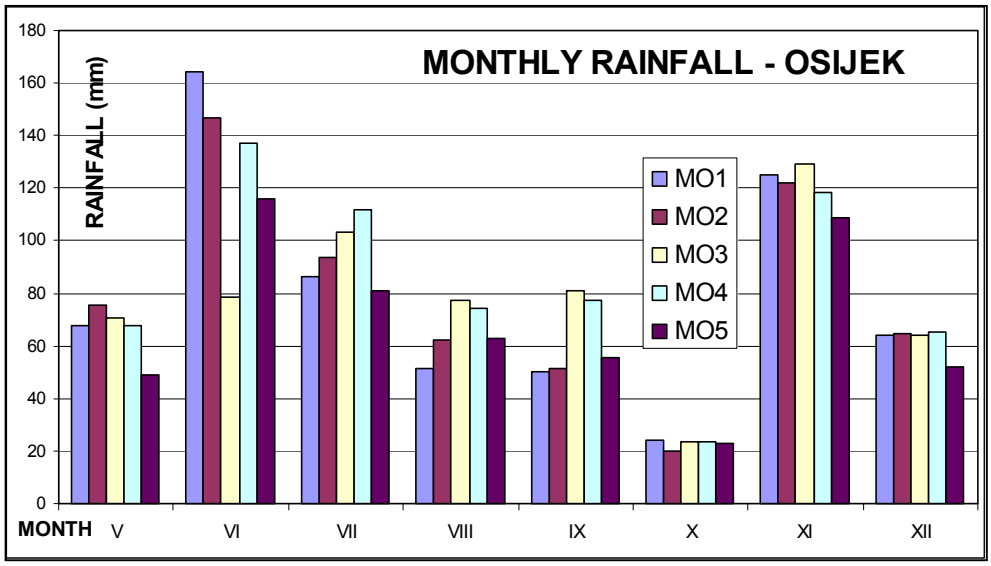
Table 1. The values of the average monthly rainfalls (mm) for the period 1969-1998 for Osijek's metheorological station

MONTH	THE VALUES OF THE MONTHLY RAINFALL (mm)												SUM
YEAR	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	(mm)
1969.	45,9	120,5	32,1	40,6	42,1	143,0	57,4	72,4	19,5	5,5	38,3	150,4	**767,7**
1970.	83,2	84,9	56,0	59,6	65,8	69,3	55,8	83,5	37,8	49,0	30,4	44,9	**720,2**
1971.	74,2	11,1	47,8	36,8	56,0	59,3	29,1	53,4	48,2	24,6	54,2	24,7	**519,4**
1972.	20,1	40,7	7,5	85,5	42,8	48,4	273,5	136,6	25,9	95,0	106,6	2,1	**884,7**
1973.	26,0	51,6	14,7	99,9	13,9	95,6	118,7	7,9	25,5	52,5	61,7	40,7	**608,7**
1974.	31,7	20,4	21,4	27,7	74,0	157,5	61,7	58,2	36,6	157,2	52,6	51,8	**750,8**
1975.	13,9	4,9	31,7	43,3	102,0	69,0	89,0	113,3	8,6	51,9	46,8	8,6	**583,0**
1976.	46,1	10,5	43,4	45,6	41,4	101,0	26,0	93,3	92,0	58,9	41,3	68,9	**668,4**
1977.	41,0	80,9	33,9	22,5	45,6	91,3	57,4	42,6	42,5	30,3	107,4	64,3	**659,7**
1978.	20,1	57,0	57,0	37,2	62,6	93,0	41,4	51,3	48,5	9,3	10,0	43,2	**530,6**
1979.	75,5	57,1	31,6	35,4	11,4	49,0	91,7	58,7	20,7	56,2	47,5	53,5	**588,3**
1980.	31,7	47,3	36,7	92,5	100,0	76,0	58,0	65,7	15,7	51,3	116,1	53,4	**744,4**
1981.	58,2	33,7	96,2	28,2	22,3	180,2	28,3	49,6	64,7	90,9	47,1	117,7	**817,1**
1982.	14,6	15,6	46,2	71,0	30,6	59,4	79,5	97,4	23,1	26,0	32,7	83,6	**579,8**
1983.	28,1	39,8	27,2	19,6	62,3	67,2	42,5	32,4	100,0	20,3	10,6	16,9	**466,9**
1984.	99,9	33,9	36,5	54,7	89,9	73,7	37,4	36,2	50,3	51,1	40,5	19,7	**623,8**
1985.	45,8	51,9	49,7	56,3	32,6	119,5	29,7	88,2	8,8	9,6	105,0	21,6	**618,7**
1986.	67,2	79,3	43,3	38,3	42,1	57,8	40,7	60,6	6,9	60,4	16,1	23,6	**536,3**
1987.	97,2	6,2	54,3	59,9	170,6	77,6	33,4	27,4	18,3	23,7	112,8	37,6	**719,0**
1988.	35,4	41,6	116,4	39,7	43,6	96,3	29,4	14,6	58,4	30,7	28,7	30,0	**564,8**
1989.	6,4	9,2	48,3	46,1	106,0	83,0	63,7	95,9	35,7	48,6	42,2	18,0	**603,1**
1990.	11,8	39,4	25,8	38,4	26,2	101,4	38,7	42,0	72,3	33,7	52,7	58,5	**540,9**
1991.	28,6	30,0	37,3	78,8	102,1	26,4	119,2	89,2	40,8	-	-	-	**-**
1992.	-	23,5	13,0	59,0	39,7	112,4	42,3	18,9	36,4	155,3	105,1	50,2	**-**
1993.	22,7	8,9	61,6	42,6	47,7	69,5	55,2	56,7	58,8	43,1	95,5	92,5	**654,8**
1994.	45,4	31,7	34,8	52,4	34,6	88,2	19,0	83,6	120,3	57,5	16,1	45,1	**628,7**
1995.	70,9	52,7	44,5	52,2	96,4	105,5	26,7	85,6	123,2	5,8	53,6	104,4	**821,5**
1996.	31,0	50,5	41,6	81,9	78,0	29,6	94,9	77,1	157,1	61,4	99,0	66,7	**868,8**
1997.	43,5	42,6	22,8	58,7	37,7	85,8	91,2	40,9	52,9	100,0	42,0	92,4	**710,5**
1998.	90,7	0,7	21,2	53,6	48,6	26,4	83,7	99,4	64,4	96,5	68,7	29,6	**683,5**
AVG	**45,1**	**39,3**	**41,1**	**51,9**	**59,0**	**83,7**	**63,8**	**64,6**	**50,5**	**53,7**	**58,0**	**52,2**	**662,7**

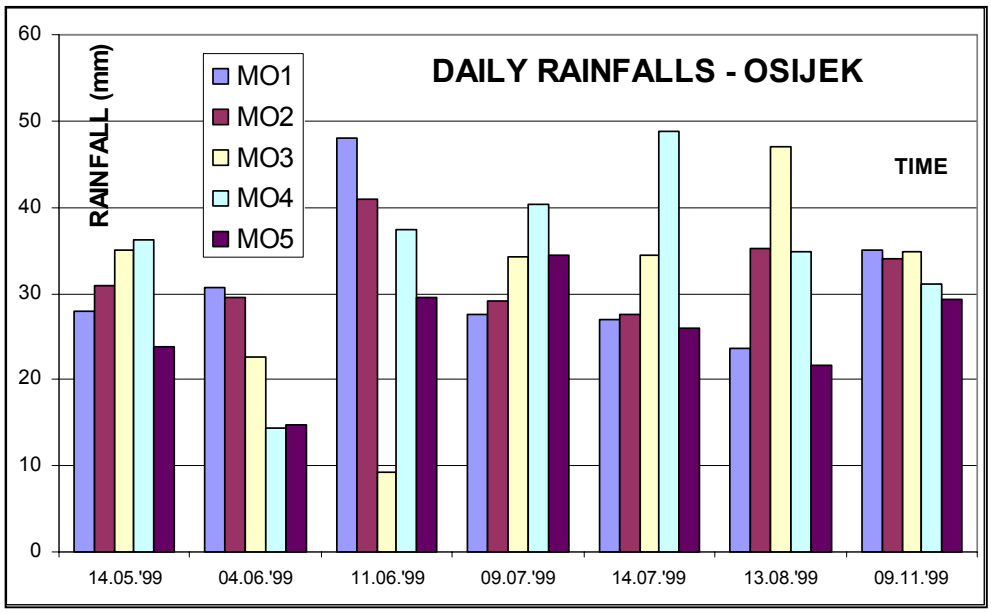
4. Research results

The data analysis of the average monthly rainfalls on various locations (table 2 and picture 1) shows the significant monthly differences (more than double) among particular locations. The state of permanent rainfall deficit or surplus on a location is not observed only the differences in manifestation. From the comparison with the average values within thirty years it can be seen that the year was a bit wetter, where June, July and September had rainfalls significantly above the average and October has rainfalls significantly below the average. It can be concluded that the observed period was adequate for shower analysis.

Rainfalls distribution differences along the city area are above the manifestation of the rainfall maximum of the limited duration. The data about the rainfalls of daily, hourly and 15-minutely duration are very illustrative. The following enclosures show the data about registrated rainfalls amount on all measuring locations in case of manifestation of maximum

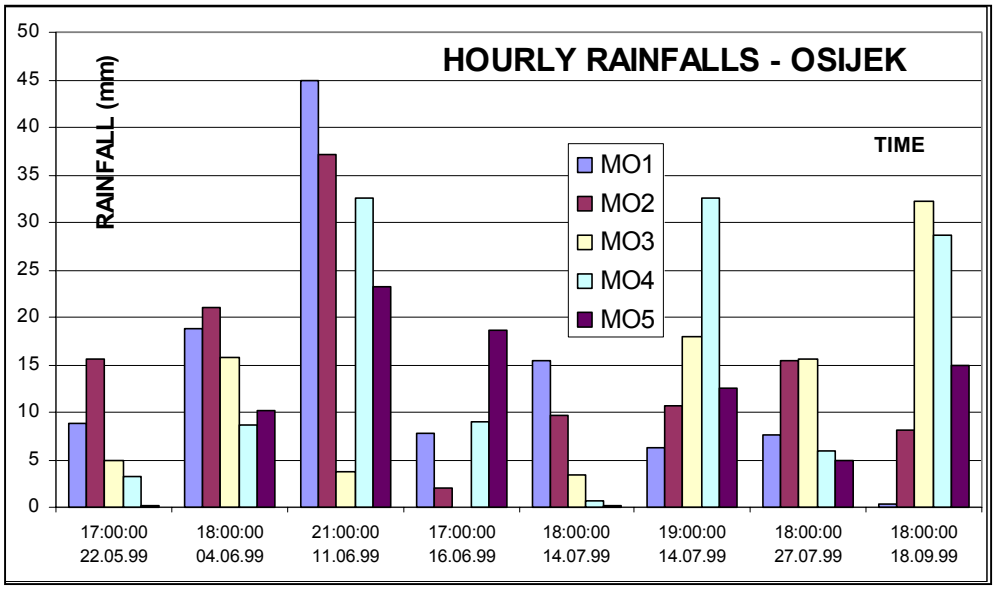


MONTH	MO1	MO2	MO3	MO4	MO5
V	67,40	75,8	70,8	67,4	49,2
VI	164,50	147	78,3	136,9	116,1
VII	86,50	93,5	103,3	111,5	81
VIII	51,10	62	77,5	74	62,6
IX	50,20	51,5	81,2	77,4	55,7
X	23,90	20,2	23,7	23,5	22,8
XI	125,10	122,2	129,3	118,4	108,5
XII	64,10	64,8	64,1	65,5	52,2

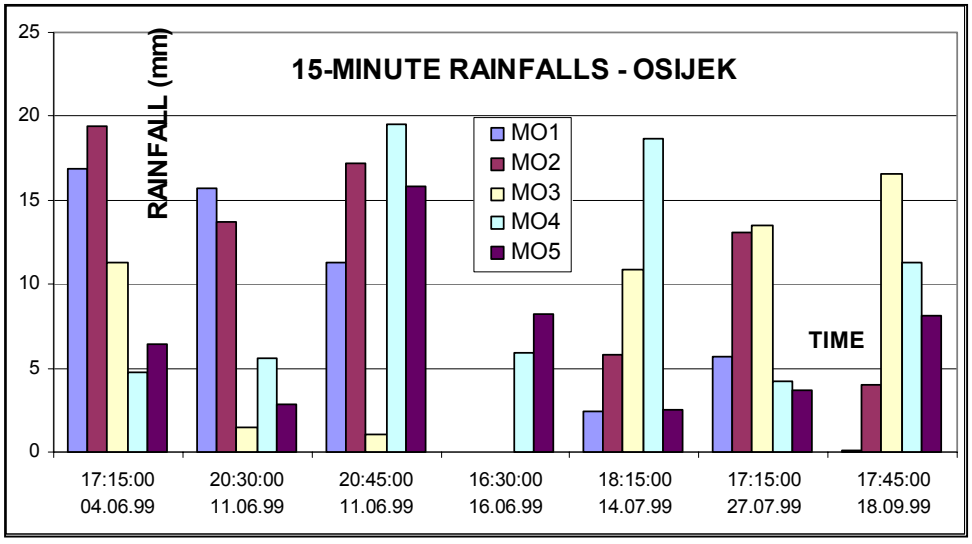


day	MO1	MO2	MO3	MO4	MO5
14.05.'99	28	30,8	35,1	36,1	23,9
04.06.'99	30,7	29,6	22,7	14,4	14,8
11.06.'99	48	41	9,2	37,4	29,6
09.07.'99	27,6	29,2	34,3	40,4	34,4
14.07.'99	27	27,5	34,4	48,8	26
13.08.'99	23,7	35,3	47,1	34,9	21,7
09.11.'99	35,1	34,1	34,8	31	29,3

Picture 2 and 3. The occurrence of monthly and maximal daily rainfalls at different location in the city



date	time	MO1	MO2	MO3	MO4	MO5
22.05.99	17:00:00	8,8	15,6	5	3,3	0,2
04.06.99	18:00:00	18,8	21	15,7	8,6	10,1
11.06.99	21:00:00	44,9	37,2	3,8	32,5	23,2
16.06.99	17:00:00	7,8	2	0	9	18,7
14.07.99	18:00:00	15,4	9,6	3,4	0,7	0,1
14.07.99	19:00:00	6,3	10,7	18	32,6	12,5
27.07.99	18:00:00	7,7	15,5	15,6	6	4,9
18.09.99	18:00:00	0,3	8,1	32,2	28,7	14,9



date	time	MO1	MO2	MO3	MO4	MO5
04.06.99	17:15:00	16,9	19,4	11,3	4,7	6,4
11.06.99	20:30:00	15,7	13,7	1,5	5,6	2,9
11.06.99	20:45:00	11,3	17,2	1,1	19,5	15,8
16.06.99	16:30:00	0	0	0	5,9	8,2
14.07.99	18:15:00	2,4	5,8	10,9	18,7	2,5
27.07.99	17:15:00	5,7	13,1	13,5	4,2	3,7
18.09.99	17:45:00	0,1	4	16,6	11,3	8,1

Picture 4 and 5. The occurrence of maximal hourly and 15-minute rainfalls at different location in the city

(first two) values on one of the locations. It is observed already at the daily value the significant (80%) reciprocal abberation of at the same time registrated data and it is logical that these abberations by the short duration rainfalls are more distincitive, even 100%. The cause of that is not time lateness of the rainfall due to clouds crowd movement (or possible discrepancy of instrument timers*) but spatial uneven rainfall distribution. *(Timers were checked every few months, and individual maximum tuning for the whole period was cca 5 min.)

The accuracy of the mentioned statement is supported by the picture 6-12. Each of them shows rainfall of one rain episode registrated at the same time on different locations. So, the internal structure of the separated rainfalls is shown. It is obviously a question of intensive rainfalls of short duration (showers) which are hydrologically the most interesting from the engineer praxis point of view. The choice was preceded by the separation of registrated rainfalls to the rain episodes with interinterval of different duration without rainfalls (24, 12, 6, 3 and 1 hour). Here are also registrated the significant differences of the registrated values among differently located instruments, but beside that they show the differences in total volume of the rainfall, which also has the great engineering-operating importance.

5. Conclusions

The given research is the initial part of the larger rainfall events observations for the Osijek's city area. It is important because it is the first research of the type in this city, and the achieved results should have some reflection on the engineering practices in this urban region.

The performed monitoring established undoubtfully that the rainfalls show the difference alo

ng the elongated urban area of the city of Osijek due to time and space asymmetry. For the longer period of observation the total rainfalls in the city are of equal amount, but for the shorter period the differences on the locations are evident. For the particular city showers the local character is noticable, which should be thought about the designing phase of city drainage objects. In one year research season the internal structure of the more important showers shows their great spatial asymmetry. Also, the reconstructed internal showers structure gives the possibility to observe the manifestations of shower forms and durations on different locations.

The researches should be continued by all means, in the first place by further measuring not only the rainfalls but also the sewage system drainage.

6. References

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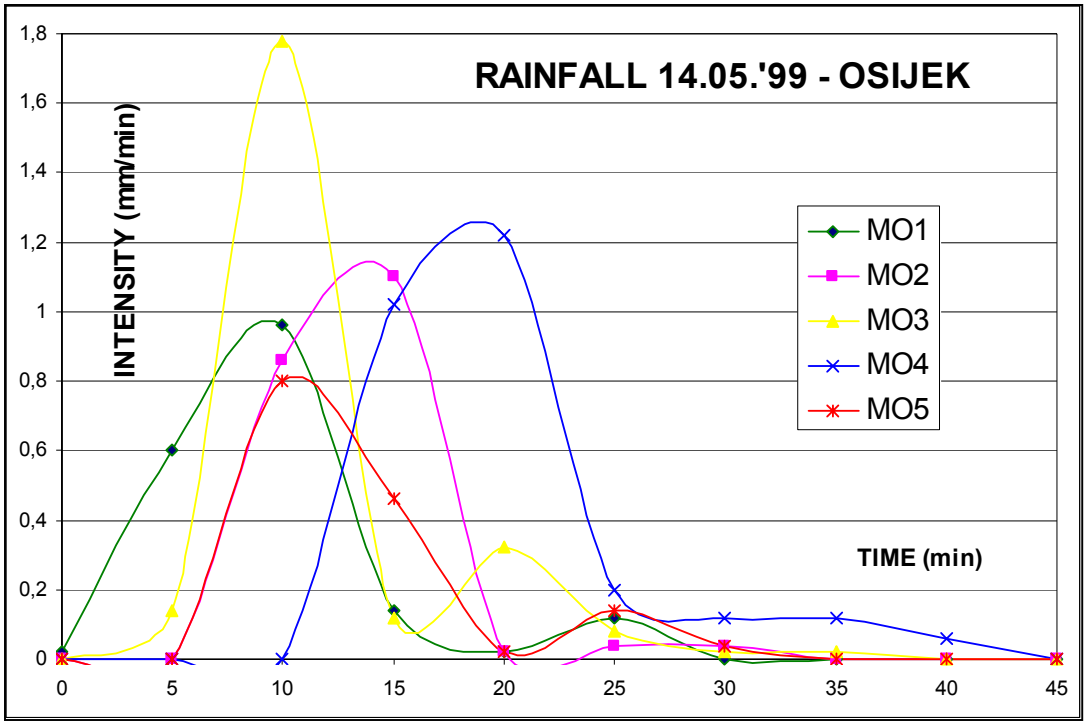
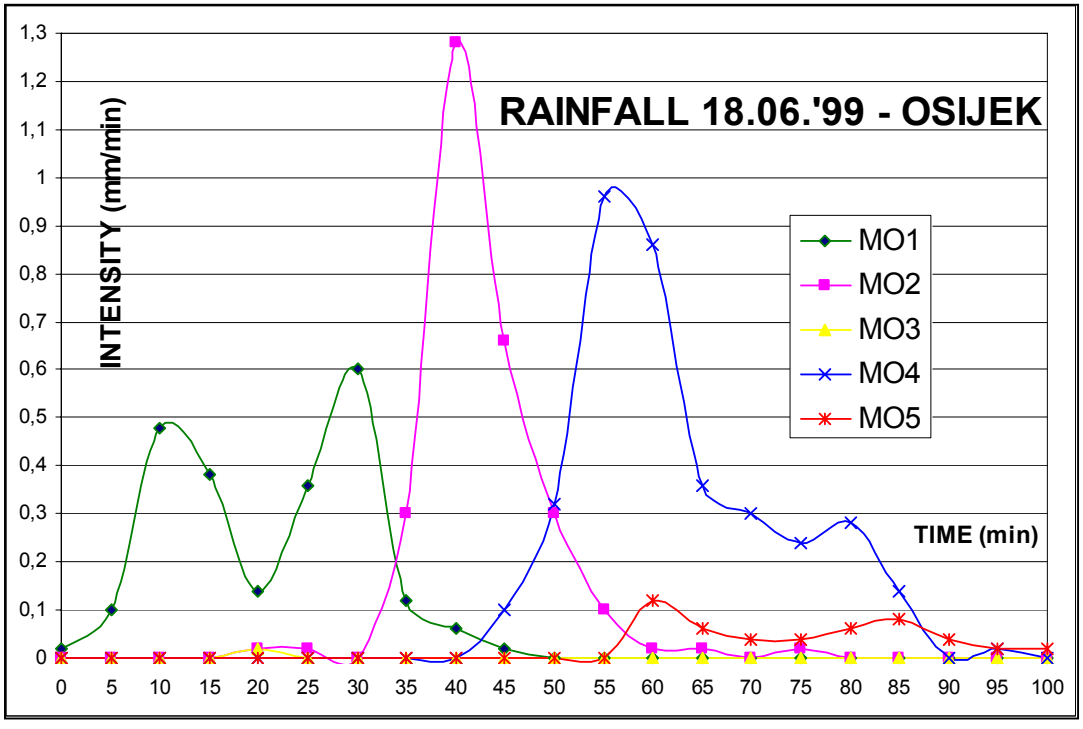
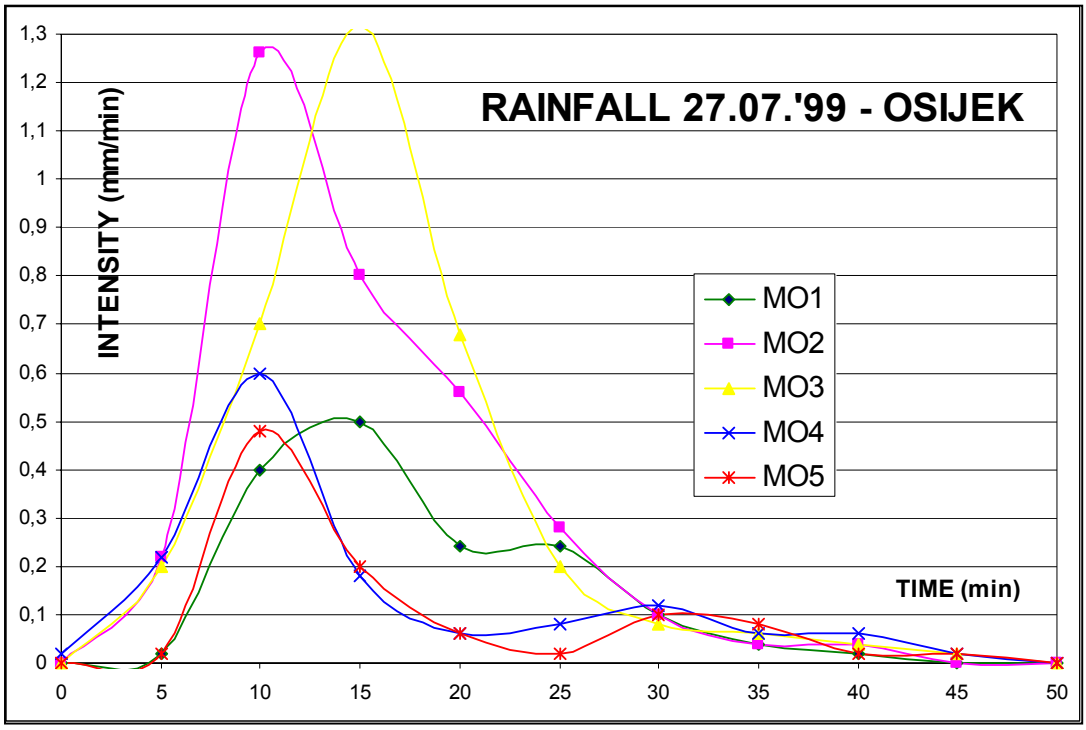
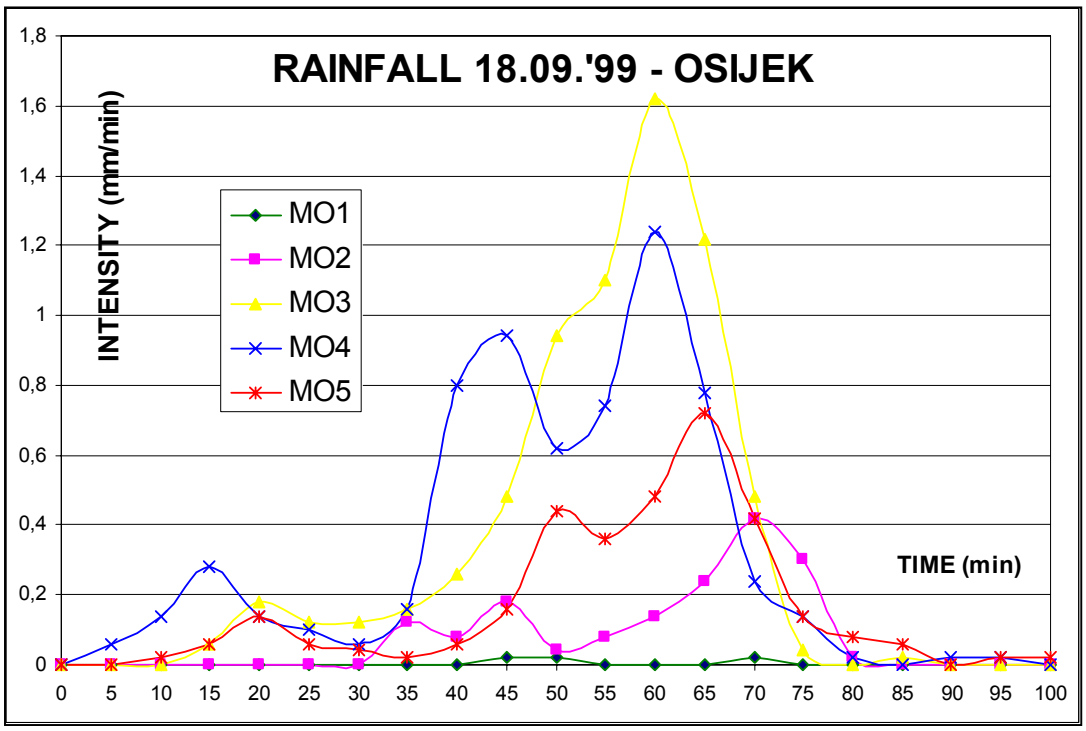




Picture 6 and 7. Monthly rainfall measured at five locations in the city of Osijek





Picture 8 and 9. Monthly rainfall measured at five locations in the city of Osijek