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The Rezé urban catchments database

E. Berthier, H. Andrieu, and F. Rodriguez

Division Eau, Laboratoire Central des Ponts et Chaussées, Bouguenais, France

Abstract. The database of the Rezé urban catchments includes not only rainfall and flow rates from two small catchments recorded continuously with a time step of 1 min over a 7-year period, but also tensiometric, piezometric, and meteorological measurements. This database has been complemented by information on the catchments themselves by means of digitized land use and topographic maps. This database is regularly updated and available to researchers through the Internet file transfer protocol.

1. Introduction

Interest in the hydrology of urban catchments rose significantly during the 1970s, a period which corresponded with the growth of metropolitan areas and the clear need for simulation models to design rainwater drainage systems [see, e.g., *Sieker and Verworm*, 1997]. The major efforts undertaken, which addressed quantitative as well as qualitative issues, resulted in models which are still in operational use today [*Huber and Dickinson*, 1988; *Danish Hydraulic Institute*, 1996]. During the same period many cities were equipping urban catchments with recording devices in order to better manage their rainwater systems (in France the systems implemented in Seine-St.-Denis or Marseille are good examples). The data obtained have indicated that the behavior of urban catchments is not as simple as it may appear. For instance, the flow coefficient of a catchment, defined as the ratio of the flow rate volume to the total rainfall volume during a rain event, is liable to display significant variations from one rain event to the next. This variability is more pronounced for typical rain events, that is, rain events of a few millimeters of rainfall. The hydrological significance of these typical rain events has increased, as has the attention paid to environmental issues and the priority given to the objective of reducing the pollution caused by urban runoff.

An analysis of the flow coefficients from 20 catchments [*Becciu and Paoletti*, 1997] has confirmed this variability, which the authors could only partially explain. Several processes might actually be exerting an influence which, until now, has gone relatively unnoticed. One helpful step would be to identify the real contribution of impervious surfaces to the flow rate. *Hollis and Ovenden* [1988] recorded both the rainfall and runoff from 10 streets, a parking lot, and 8 roofs over a 1-year period. At the scale of these very small catchments it appears that 50% of the flow coefficient variations remain unexplained. The evapotranspiration of urban areas has received little attention even though climatological studies have shown that the magnitude of its influence could be greater than usually accepted [*Grimmond and Oke*, 1991]. Moreover, the wide array of underground systems, such as trenches, base courses of streets, etc., could be significantly affecting the circulation of water within the urban subsoil by facilitating its drainage. In certain cases, the infiltration of groundwater into drainage systems through defects can contribute significantly to the flow rate [*Belhadj et*

al., 1995]. The aspects cited above are in no way intended to be exhaustive, yet they do help illustrate both the complexity of the hydrology of urban catchments and the need for a better understanding of hydrological processes in urban areas. Setting up experimental catchments is one means of improving the current level of understanding. With this perspective in mind, two urban catchments were equipped in 1991 in order to provide data suitable for research projects conducted in the field of urban hydrology.

2. Presentation of the Experimental Site

2.1. Characteristics of the Experimental Catchments

The experiment performed consists of surveying two small urban catchments located in Rezé, a suburb of the French city of Nantes. The experimental site is equipped with separate drainage systems. The rainwater system combines two catchments of 4.7 ha (P5) and 13.4 ha (P13), respectively, which exhibit comparable physical characteristics (Figure 1). The choice of small catchments enables one to maintain a spatial scale close to the physical processes themselves. The land use of the catchment areas is essentially composed of single-family dwellings, with a quarter of catchment P13 being occupied by small buildings. An in-depth investigation has been performed in order to map the land use of the two catchments as well as to distinguish impervious from pervious areas (Figure 1). The imperviousness coefficient, defined as the ratio of the impervious surfaces connected to the rainwater system to the catchment's total surface area, has been evaluated at 0.37 for P5 and at 0.39 for P13. The resulting map has then been discretized in accordance with a spatial resolution of $5 \times 5 \text{ m}^2$. A digital terrain model is available at the same spatial resolution and serves to complement this land use map. The soil of the catchments is a silty clay with a depth of a few meters; its hydraulic conductivity at saturation has been evaluated in situ at $5 \times 10^{-7} \text{ m s}^{-1}$. The water table presents sinusoidal variations lying between ~ 0.5 (in winter) and 2 m (in summer) below the surface.

2.2. Experimental Setup

The experimental program has focused on two key points: (1) insuring a long-term experimental duration that helps to improve the understanding of the catchment behavior and (2) insuring that the data output stream remains continuous, including the dry periods which separate successive rain events. This particular point is quite original in urban hydrology, wherein the study of individual rain events is usually given

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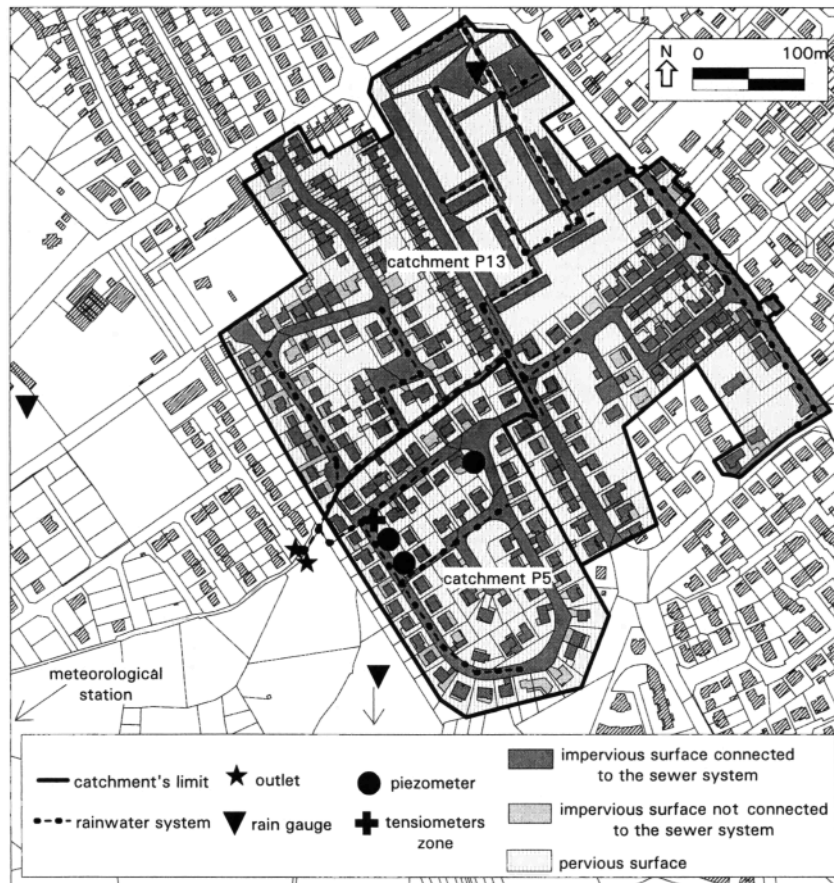


Figure 1. Map of the two small experimental catchments of the Rezé experimental site.

more emphasis. All recordings are stored in on-site data loggers and then transferred every 2 weeks to the laboratory. Table 1 indicates the length of the period of data availability for each measured variable as well as the data acquisition time step. The location of the measurement points is shown in Figure 1.

2.2.1. Rainfall. Three tipping-bucket rain gauges have been installed around each of the catchments in order to measure the rainfall rates. The rainwater collected by each rain gauge is also stored, and its volume is measured every 2 weeks.

2.2.2. Flow rates. The outlets of the two catchments are located at the same point. Flow rates have been deduced from measurements of the water's height in a calibrated gauging weir. Each outlet has been equipped with a weir and two water height sensors of different types (ultrasound and pressure).

2.2.3. Soil moisture in the urban subsoil. In order to generate information on both the moisture and water flows in the urban subsoil, the experimental site is equipped with seven tensiometers. Three of the tensiometers are set in a natural soil, at depths of 0.5, 1, and 1.5 m. The other four tensiometers have been installed below a street: One of them is 1.5 m deep in the trench of the drainage system's pipes, and three of them are 0.5, 0.6, and 1.5 m deep below the street structure. Furthermore, three piezometers serve to measure the level of the water table at various locations in the catchments.

2.2.4. Additional data. The experimental site is located at a distance of 5 km from a meteorological station of the French Weather Service (Météo-France). All of the meteorological environment's representative parameters are either continu-

Table 1. Acquisition Period, Acquisition Time Step, and Duration of Data Gaps for the Main Variables Measured on the Rezé Catchments

Variable	Acquisition Period (Time Step)	Duration of Data Gaps*						
		1991	1992	1993	1994	1995	1996	1997
Rainfall rate	Jan. 1991–... (1 min)	0	0	0	0	0	0	0
Flow rate								
P5	Jan. 1991–... (1 min)	0	16	5	0	0	0	0
P13		12	25	21	6	2	1	6
Soil moisture								
Tensiometers	May 1995–... (1 hour)	...	...	...	...	53	9	25
Piezometers	Sept. 1995–... (15 days)	...	...	...	...	0	0	0

*Rainfall rate and flow rate data are calculated as percentage of rain time; soil moisture data are calculated as percentage of total time.

REZE

Time step (minute)

Beginning date

Duration (days)

Recorded data

Rainfall detail error code

Flowrate P5 error code

P13 error code

Tensiometer

street structure 50 cm error code

60 cm

150 cm

trench of drainage system

natural soil 50 cm

100 cm

150 cm

Piezometer error code

low 400 cm

low 300 cm

high 400 cm

meteorological data

Rainfall

Air temperature (max, min, mean)

Air pressure

Air humidity

Wind (velocity and direction)

Water vapor pressure

Evapotranspiration

Soil temperature 10 cm 50 cm

20 cm 100 cm

OK

Cancel

Figure 2. Display of the main menu of the software REZE, designed to prepare the data according to the user requirements.

ously measured or estimated; these include wind velocity and direction, relative humidity of the air, potential evapotranspiration computed by the method developed by the Meteorological Office [Schoisnel, 1988], etc.

3. Data Validation

The stage of quality control is very important insofar as it determines the usefulness of the data. The existence of measurement devices in good working order does contribute to facilitating this stage. In the present work, all of the sensors are checked every other week, a procedure which limits the length of eventual periods of data gaps. The quality control of the data has been mainly based on the redundancy of sensors, which makes it possible to compare different measurements of the same variable. It has been decided to favor an "eyeball" comparison, without defining a specific methodology. This heuristic approach is a very rigorous one and still enables one to consider the limited number of measured variables. Moreover, every use of the data set for hydrological modeling purposes can contribute to this validation stage. The users of this data set have therefore been strongly encouraged to inform us of every major discrepancy noted between observed values and model results.

With respect to the rain gauges, the storage of the water crossing each rain gauge allows one to control the measurement of total rainfall and, ultimately, to calibrate the tipping bucket's contents. An additional control consists of comparing a particular rain gauge's series of measurements to corresponding data from the two adjacent rain gauges.

With respect to the flow rates, the availability of two water height sensors at each outlet facilitates the detection of discrepancies. Moreover, the presence of two catchments exhibiting similar characteristics does provide for an additional

means of comparison. The validation of flow rate measurements is mainly based on an analysis of the flow coefficient. This analysis is performed with two distinct time steps: a daily time step over the entire year in order to detect major anomalies and an hourly time step for individual rain events. Once an anomaly has been detected, the raw measurements of water height get carefully checked and compared, and the erroneous values are deleted. The validation of the tensiometer measurements is based on a visual analysis; their consistency with piezometric data is also checked when the soil is saturated.

The final contents of the validated database have been summarized in Table 1 for the time period extending from January 1991 to December 1997. The rainfall data present no missing entries. The missing flow rate measurements do remain below a low percentage value of the total rain time. Existing measurement problems mainly involve the tensiometers. Despite these concerns, the goal associated with the continuous and long-term surveying of urban catchments has nonetheless been reached. Additionally, the database includes the land use map and the digital terrain model discretized at a spatial resolution of $5 \times 5 \text{ m}^2$.

The validated database can then be accessed by means of a user-friendly software, called "REZE," which simplifies both the preprocessing of data and the first stage of the data analysis. This software combines various functions: (1) The main features of the catchments displayed are the land use map, digital terrain model, and drainage systems map. (2) The data to be extracted from the database are selected according to the time period and time step defined by the user. The software displays the selected data and then combines them into an easily readable output file. Figure 2 shows the software's main menu. (3) The output file's data are visualized through a simple graphics tool.

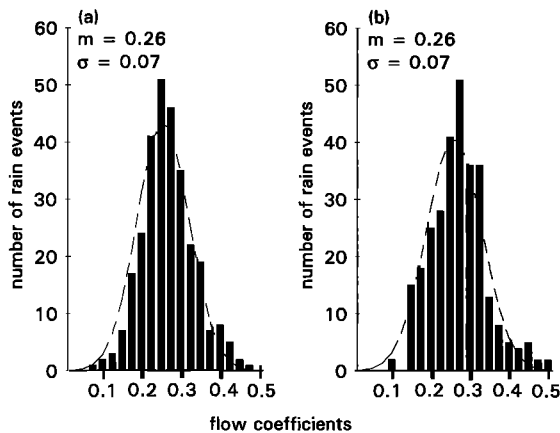


Figure 3. Histograms of the observed flow coefficients of the two experimental catchments: (a) catchment P5 and (b) catchment P13. The dashed lines represent the Gaussian distributions calculated with the mean value m and the standard deviation σ .

4. Example of Data Use

This database has already been used for several urban hydrology-related studies. *Andrieu et al.* [1993] studied the variability of runoff with the database. *Berthier et al.* [1998] and *Rodriguez et al.* [1996] tested rainfall-runoff models on the catchments. *Belhadj et al.* [1995] studied and then simulated the infiltration of groundwater through defects into the drainage system. For illustration purposes this section examines the variability of flow coefficients at the rain event scale. From the beginning of 1991 until the end of 1997, 291 events exceeding a rainfall of 2 mm have been selected. Figure 3 shows the histograms of the flow coefficients corresponding to this series of rain events. For both catchments the distribution of flow coefficients appears to be very well represented by a Gaussian law. The mean value (0.26) and standard deviation (0.07) of the flow coefficients are similar for both catchments. Most of the flow coefficient values are less than the imperviousness coefficients of the catchments. However, it has to be noticed that 5% of the flow coefficients exceed this imperviousness coefficient. The strong temporal variability of the flow coefficients from one rain event to the next is clearly illustrated in

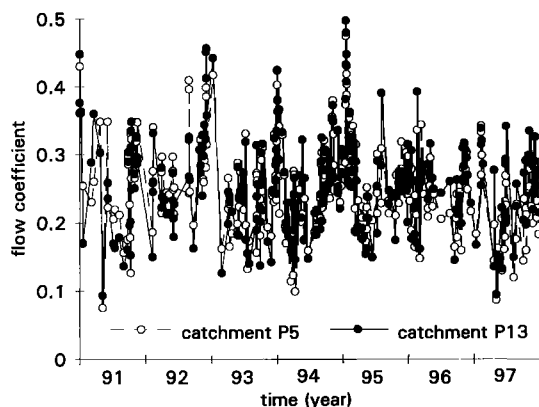


Figure 4. Representation of the variations of the flow coefficients of the Rezé catchments versus time.

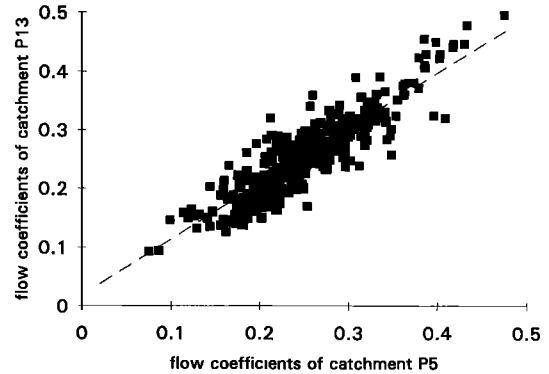


Figure 5. Scattergram of the flow coefficients of the two catchments. The dashed line represents the regression line.

Figure 4. The autocorrelation of the flow coefficients is equal to 0.47 for P5 and to 0.45 for P13, which is a significant yet moderate value. The comparison of the flow coefficients from the two catchments, however, serves to confirm that most of their variability can be ascribed to a physical interpretation: Figure 5 shows the scatter diagram of the flow coefficients of P13 versus those of P5, with a correlation coefficient of 0.89 between the two variables.

5. Data Availability

The database and software are available to all interested researchers from Laboratoire Central des Ponts et Chaussées (Bouguenais, France; anonymous ftp at ftp.lcpc.fr/incoming/reze). The database could eventually be provided on 3.5-inch diskettes or CD-ROM upon specific request made to the authors. However, the meteorological data in fact belong to Météo-France and are provided free of charge for noncommercial research projects. The software has been designed to run on a PC in a Windows operating environment.

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H. Andrieu, E. Berthier, and F. Rodriguez, Division Eau, Laboratoire Central des Ponts et Chaussées, BP 19, 44340 Bouguenais, France. (Emmanuel.Berthier@lpc.fr)

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