APUSS

Assessing Infiltration and Exfiltration on the Performance of Urban Sewer Systems

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Methodology for the assessment of infiltration / exfiltration from house connections in a large catchment

D. Kohout, I. Princ, J. Pollert
CTU

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INSA LYON
EAWAG
Swiss Federal Institute for Environmental Science and Technology
TECHNISCHE UNIVERSITÄT DRESDEN
Czech Technical University in Prague
Faculty of Civil Engineering
DHI WATER & ENVIRONMENT
HYDROPROJEKT CZ
MIDDLESEX UNIVERSITY
EMSCHER GENOSSENSCHAFT
IRSA CNR

PART 1. - INFILTRATION

INTRODUCTION

Infiltration into house connections (hereinafter referred to as HC) occurs upon fulfilment of the following conditions:

- the piping is damaged,
- the level of surrounding water (ground-water or percolation of rainwater) lies above the damaged places,
- the damaged place is surrounded by permeable soil or a cavern.

I. INDIVIDUAL HOUSE CONNECTIONS

I - 1. MATERIAL

Measurement requires the following survey equipment:

- volumetric measuring tank
- stopwatch
- TV camera with full equipment
- sealing balloons
- air compressor
- flow meter

I - 2. PROCEDURE

The measurement of the amount of water infiltrated to a HC comprises the identification of the defect and the measurement itself.

The application of particular measurement methods depends on the manner of connection of the HC to the sewer system, which reflects in the complexity of installation of the measuring equipment and the measurement itself.

Alternative connections are as follows:

A. Connection of HC in manhole
B. Connection of HC to passable sewer
C. Connection of HC to non-passable sewer

Different methods are applied for the individual measurement of a single HC and for the lumped measurement of a group of HC.

A detailed description of the procedures is given below.

1) **Cleaning of the household connection**
The household connection must first be cleaned mechanically or by flushing to enable the movement of the TV camera cart.

2) Checking by TV camera
For the examined connection, a TV camera is used to assess its conditions and any places of infiltration of external water. The check is begun against the gradient of the bottom of the piping. The defects are evaluated upon discovery by an operator, or by a technician viewing the recording. When viewing the image, the number of joints, the length, the material, the piping diameter, constructional defects, and the condition of the piping are checked. The defects are assessed according to ATV classification as grades 1 – 5 (grade 1 = largest extent of damage, 5 = small defect) (see Appendix 1).

3) Measurement of infiltration into a single HC

Infiltration to a single HC is measured as the amount of water infiltrated into a HC whereas the inflow from households is eliminated by blocking the inspection manhole and pumping the sewage into the sewer system (Fig. 1).

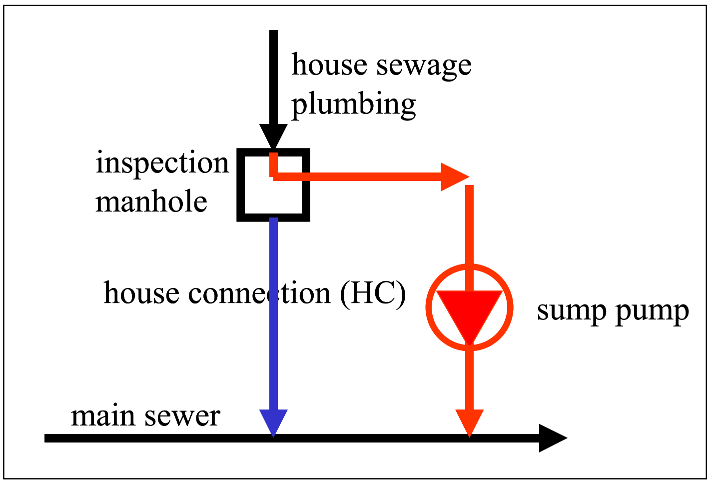

Figure 1: *Elimination of the inflow of domestic water from house sewage plumbing*

The installation of the measuring equipment and the measurement differ slightly for the different manners of the connection of the HC to the sewer system:

A) <u>Connection of HC to manhole</u>
This manner of connection of the HC (Fig. 2) enables the easiest measurement.

Figure 2: *House connection connected to manhole*

One possibility to perform the measurement is to install a measuring volumetric tank at the place of connection of the HC to the manhole (Fig. 3) and measure the time required to fill the tank several times, i.e. $I = \Sigma I_i/n$, and $I_i = V/\Delta t_i$, where “I” is infiltration rate, “n” is number of measurements, “V” is volume of the measuring volumetric tank, and “Δt_i” is time required to fill the tank.

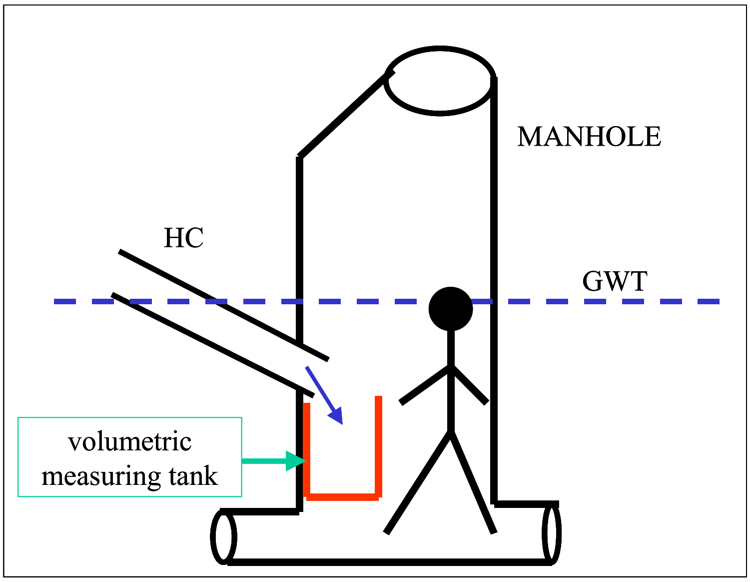

Figure 3: *Scheme of installation of the measuring volumetric tank in a manhole*

Another alternative, depicted in Fig. 4, is to use a passable sealing balloon, which is easily installed at the end of the HC. The sack is equipped with a transparent vertical pipe and a release valve. The vertical pipe enables observation of the gradual levelling of the surfaces in the HC and in the vertical pipe, i.e. V = f (t) (Fig. 5) and thus I = f (t) (Fig. 6). Infiltration rate is defined as the derivation:

$$I = \frac{dV}{dt} \quad (1) \qquad \text{resp. } I = \frac{\Delta V}{\Delta t} \quad (2)$$

$$\text{where} \quad \Delta V = \frac{\pi \cdot D^2}{4} \cdot \left(H_{t+\Delta t} - H_t\right) \quad (3)$$

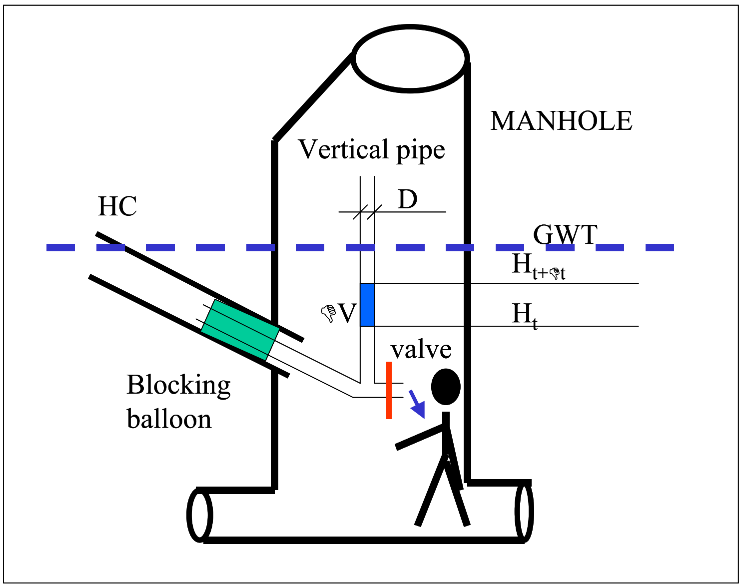

Figure 4: *Scheme of installation of a blocking balloon and a vertical pipe in a manhole*

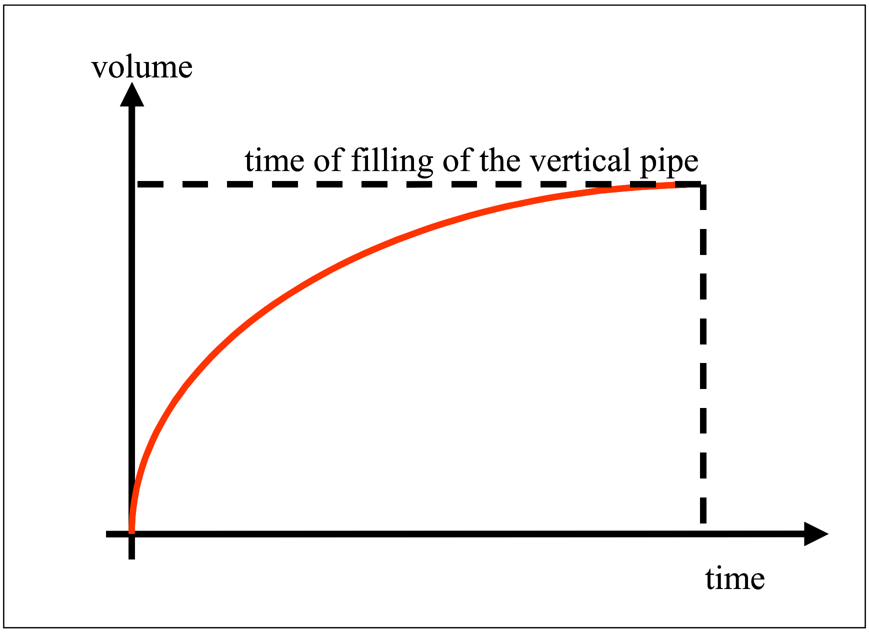

Figure 5: *Time of filling of the vertical pipe*

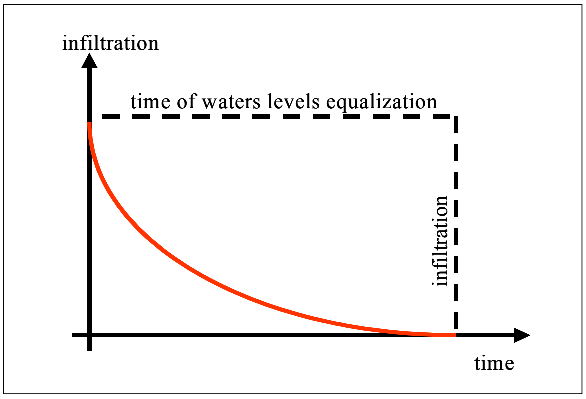

Figure 6: *Relation between infiltration and time of filling of the vertical pipe*

B) Connection of HC to passable sewer

The procedure is similar to that described for alternative **A),** with the exception that the outflow is ensured using a hose at the balloon. The HC must be sealed, in any case, with a passable balloon (Fig. 7 and Fig. 8).

Figure 7: *Sealing balloon*

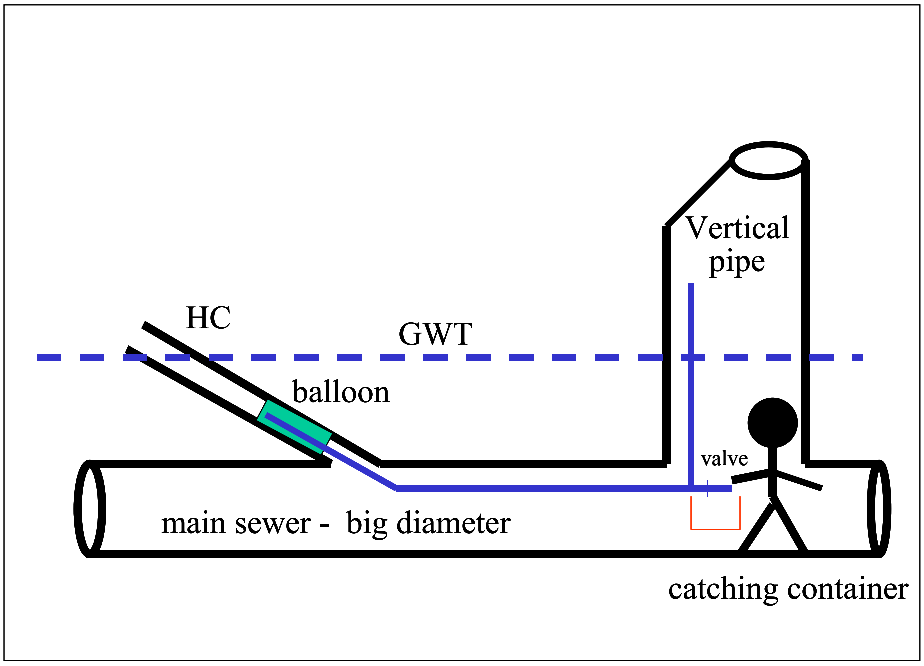

Figure 8: *Scheme of installation of the measurement equipment in a house connection connected to passable sewer*

C) Connection of HC to non-passable sewer

This manner of connection is the most common and the measurement is most difficult in this case, since the sealing balloon cannot be installed from the main sewer. The blocking balloon must be pushed from the inspection manhole (Fig. 9), or two balloons can be used in the main gutter (Fig. 10). Such installations carry the risk of the balloon(s) being locked in the extension or gutter. Measuring of the infiltration is similarly difficult, since the water level can be observed only either using a camera placed in the HC, or by using a float in a narrow pipe inserted into the HC. Infiltration is then calculated using equations (1), (2) and (3).

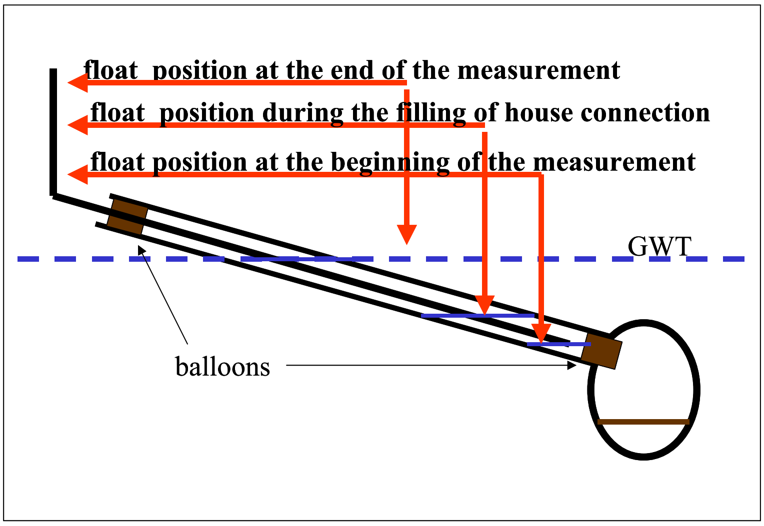

Figure 9: *Scheme of installation of the measurement equipment in case of a non-passable sewer*

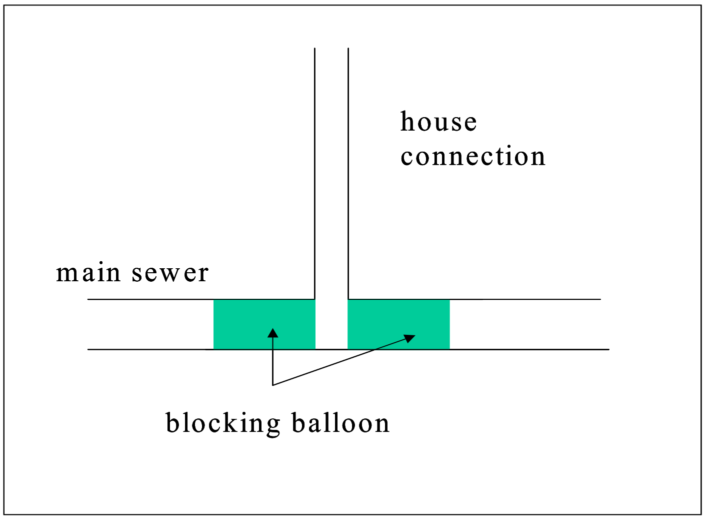

Figure 10: *Blocking of house connection using two balloons in main sewer*

II. GROUP OF HOUSE CONNECTIONS, LARGE CATCHMENT

II - 1. INTRODUCTION

A large urban drainage area, from infiltration point of view, is constituted of, at least two main sewers in catchment with a group of several house connections, which are connected to the main sewers.

In the proposed methodology, only catchments with homogeneous characteristics are considered, i.e. catchments with identical catchment shape, type of build-up area and population, analogical geologic and hydrogeology conditions, etc. The infiltration evaluation in a homogeneous urban large drainage area is based on measurements in a local referential catchment, which has identical or similar characteristics than the large catchment. Consequently, the local infiltration rate can be computed proportionally on the large catchment.

In case of large catchment with heterogenous characteristics, it is possible to isolate small „referential“catchments within the large catchment, make measurements on each of them and compute them for the large catchment.

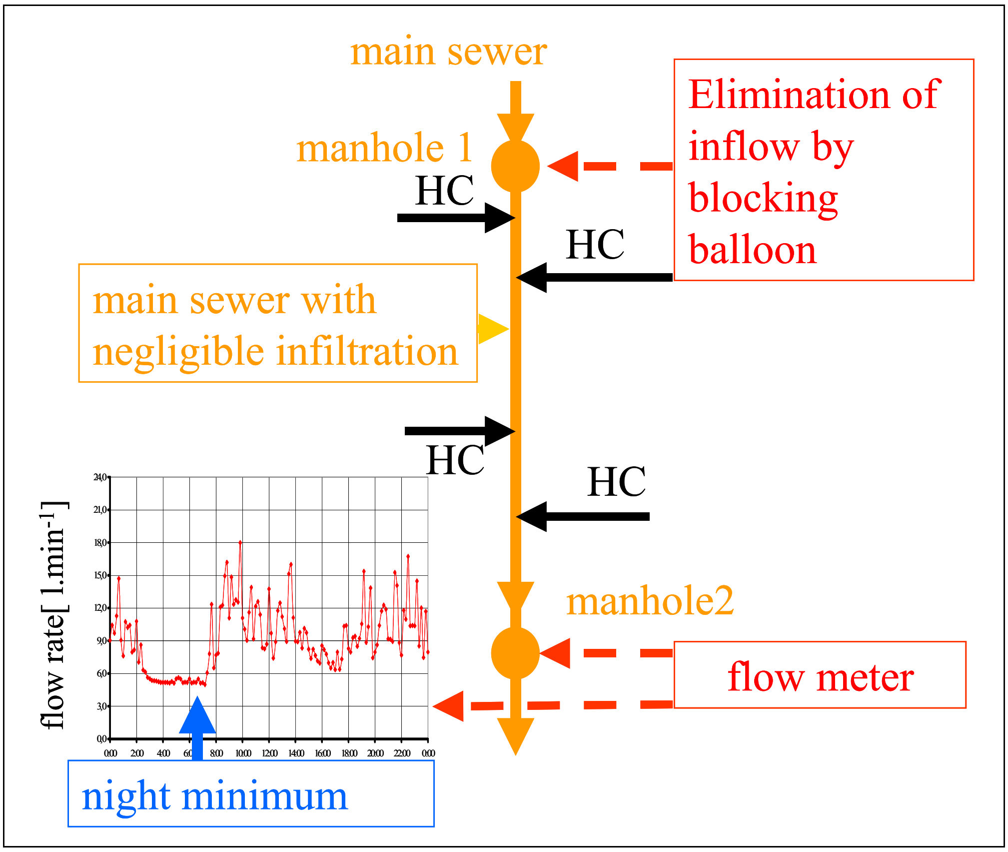

Figure 11: *Scheme of installation of the measurement equipment in small reference catchment*

II - 2. PROCEDURE

The methodology is based on the monitoring of minimal discharges during the night in a small reference catchment (see figure 11) and the chemical analyses of samples collected during the night for comparison with the minimal discharges. These chemical analyses indicate the dilution of wastewater. This result, which represents the pollution of the wastewater, is compared with the usual values of the wastewater pollution from the daylight hours. The appropriate indicators of pollution are COD (mg.l^{-1}), N-NH_4^+ (mg.l^{-1}), temperature (^{o}C), conductivity (S.m^{-1}). These parameters are typical for wastewater.

Parshall´s flume in a modified version for sewers can be used for the measurement of total discharges from the study area.

Use of Parshalls flume
Parshall flume is a flow rate device with a wide range of applications. It can be used for flow measurement in creeks, irrigation and/or drainage channels, sewer outfalls, Waste Water Treatment Plants, etc.
Main advantages can be summarised as follows:

- A relatively low energy loss(3-4 times lower than in sharp-crested weirs)
- A small sensitivity to a velocity distribution in an approach channel
- Flow rate measurement even under drowned conditions
- Velocities inside Parshall flumes are high enough to prevent them from the deposition of sediments or accumulation of debris
- Minimum maintenance requirements
- A wide range of flow rates
- A long lifetime

Critical flow flumes are contractions in the stream which cause the flow to achieve its critical depth within the structure. There is a define relationship between depth and discharge when critical flow exists. A widely used type of critical flow flume is the Parshall flume, the geometry of which is shown in Fig.12. The discharge depends on the width of the throat section L and the head H, where H is measured at specific location along the converging section of the flume.

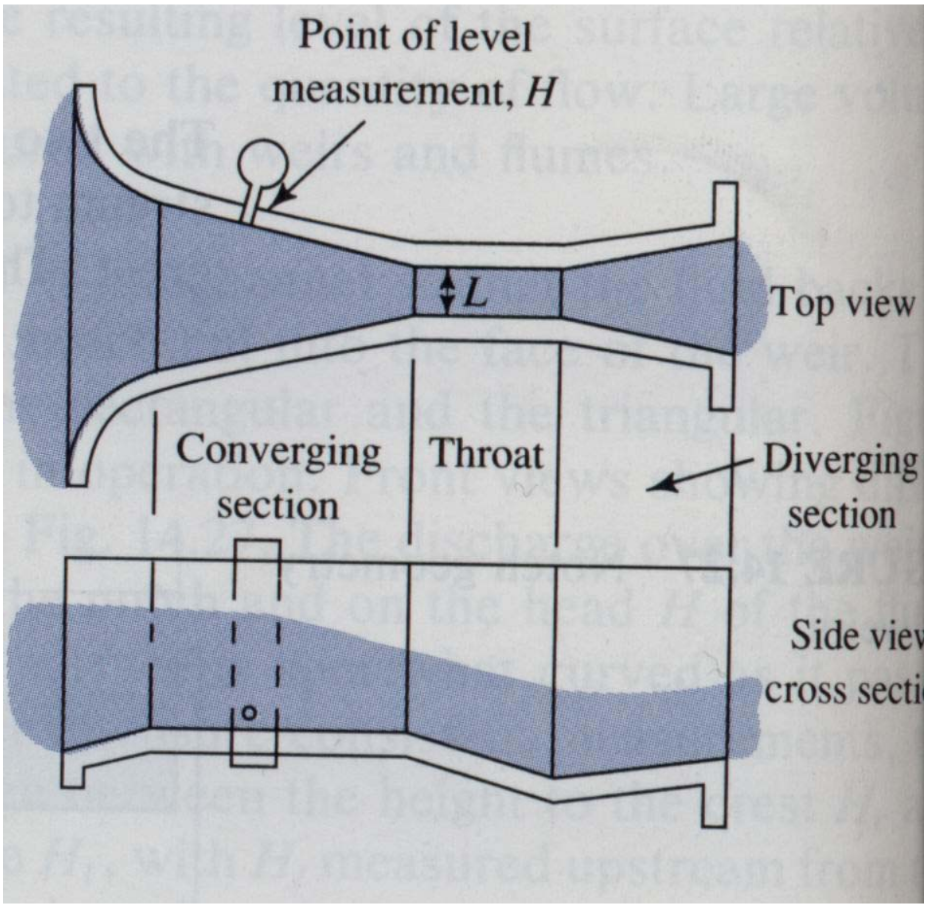

Figure 12: *Parschall flume*

Table 1: *D lists the discharges for several widths*

Throat Width	Flow Range	
L	min.	max.
m	l.s^{-1}	l.s^{-1}
0,08	0,0005	0,0311
0,15	0,0008	0,0639
0,23	0,0015	0,1458
0,30	3,1170	456,2154
0,61	11,9013	937,9335
1,22	36,8373	1924,0389
1,83	73,6745	2932,8133
2,44	99,1773	3952,9223
3,05	170,0182	5667,2721
6,10	283,3636	28336,3607
9,15	425,0454	42504,5411
12,20	566,7272	56672,7214
15,24	708,4090	85009,0821

Figure 13: *Detailed photo of Parschalls flume with water level meter installed in manhole*

Another alternative is to specify the total flow volume, including infiltration and wastewater, as follows:

$$V = \int_0^T Q(t)dt \qquad (4)$$

The total infiltration flow is calculated from the water consumption W obtained from water meters in the connected households:

$$I = V - W \qquad (5)$$

If the measurements from water meters are unavailable, the water consumption in the area can be estimated as follows:

$$W = n \cdot T \cdot q \qquad (6)$$

where “n” is number of inhabitants of the area, “T” is the duration of measurement, same as the upper limit of the integral in eq. (4), and “q” is the specific water consumption per inhabitant per day: (q = 110 litres × person^{-1} × day^{-1}, the approximate value for a residential suburb in Prague). However, in this case the value of W is only an approximation and the infiltration calculated from it is rather unsure.

The total infiltration is computed from the results on the referential catchment [Infiltration = f (X_1 , X_2 …..X_n)]. Each variable Xi represents e.g. groundwater table position, soil permeability, pipe abrasion etc. Overall standard deviation is estimated with respect to individual error contributions as following:

$$\sigma I = \sqrt{\sum_i^n \left(\frac{\partial I}{\partial X_i} \cdot \sigma X_i \right)^2} \qquad (7)$$

$$I = \hat{I} \pm \sigma I \qquad (8)$$

The assessment of infiltration on a large homogeneous catchment starts with an evaluation of the referential and the monitored catchments using the interactive matrix (Tab. 2. and 3.). This matrix shows the comparison between both catchments in significant items.

In case of acquired infiltration data from referential catchment and a percentage difference of the catchments evaluation in interactive matrix less than 30% (value based on long term experiences and literature), the infiltration rate from larger homogeneous catchment is calculated proportionally, for example, ratio of house connection pipes lengths in referential and large catchment multiply with infiltration rate from referential catchment (eq. 9).

$$Q_{LC} = Q_R \cdot \frac{\sum L_{LCi}}{\sum L_{Ri}} \qquad (9)$$

Q_{LC}	Infiltration in large catchment
Q_R	Infiltration in referential catchment
ΣL_{Ri}	Total length of HC pipe in referential catchment
ΣL_{Lci}	Total length of HC pipe in large catchment

Tab. 2: *Interaction matrix*

		damages															
		leakage joints			blocking				corrosion		cracks			others		factors	
		bad joints	connections m. sewer	connections manhole	sediments	incrustation	roots	overlap pipe to m sew.	outside	inside	lengthwise	crosswise	lost of pipe wall	abrasion	deformation	**average value**	**total mark**
factors	high permeability																
	med permeability																
	material																
	type of area																
	rain																
	life time																
	maintainance																
	implemantation																
	aggressive background																
	aggressive water																
	heavy traffic																
	pulsating GWL																
	subsoil settlement																
	age																
damages	**average value**																
	total mark																
CCTV	Inspection																
	total mark																

Tab. 3: *Protocol on measurement 1*

INFILTRATION		
Information about connections in large drained area		
date : Weather:		
drained area	type of catchment	
	year of HC construction	
	number of HCs	
	number of inhibitants	
	catchment size [ha]	
hydropedology	ground water level depth below surface [m]	
	type of soil	
	saturation of the soil	
	permeability	
main sewer	depth of connection (sewer / HC) [m]	
	type of connection (sewer / HC)	
	DN [mm]	
	shape	
	length [m]	
	material	
	classification according to ATV M143/2	
	type of damages	
house connections	total length of HCs [m]	
	material	
	DN [mm]	
	classification according to ATV M143/2	
	type of damages	
infiltration	**absolute infiltration [$l.s^{-1}$]**	
	relative inf. per meter of HC [$l.s^{-1}.m^{-1}$]	

PART 2. - EXFILTRATION

1. INTRODUCTION

House sewer connection (hereinafter referred to as HC) is standpipe which draining the house estate to the main sewer. In case of combined sewer system is one house connection per one house estate.
House connections are the most sensitive parts of whole sewer system. Frequently they are neglected during their construction and operational conditions.
The general constructional state of HC pipe, including point of connection to the main sewer, corresponds to potential leakage amount of wastewater to the soil environment.

The leakage of sewage water from household sewer connections occurs only upon the fulfilment of the following conditions:
1) the piping must be damaged (cracks, broken joints, holes, ...),
2) the ground water level (GWL) is lower than the level of the piping,
3) the piping is placed in a permeable environment.

1.1. Idea of "large catchment"

As defined in part I, a large urban drainage area, is constituted of, at least two main sewers in catchment with a group of several house connections, which are connected to the main sewers.

The head objective of this methodology is how to estimate exfiltration rate from large catchment on the basis of small catchment data, e.g. individual house connection measurement or small referential catchment measurement. The methodology proposed for exfiltration is based on the same principle than for infiltration. Only large catchment with homogeneous characteristics will be considered.

2. REQUIREMENTS

2.1. List of Material

Measurement requires the following survey equipment:

- CCTV camera set with full equipment: TV, optic cable, video recorder
- air compressor for inflation of balloons
- min. 1× sealing balloons for main sewer and sealing balloons for HCs
  (number of sealing balloons depends on number of HC pipes, which are connecting to main sewer)
- water tank for HC and sewer filling (clear water); e.g. mobile water tank
- levelling rod (or measuring rule), stop-watch

2.2. Manpower

Total 4 workers. Division of manpower per competences:

- one CCTV operator (TV camera controlling, evaluating)
- one for sealing of balloons and checking inside of sewer and HC pipes
- one for water decrease level measuring + other activities
- one for time measuring + other activities

Other activities include e.g. help out work, reserve manpower .

2.3. Time schedule

Total time per one experiment approximately 8 hours.

- CCTV inspection + evaluation .... 1 ~ 2 hour
- balloons sealing (1 piece) .... 0,5 hour (depends on number of blocking pipe)
- sewer and HC pipes filling .... 2 hours
- water level measuring .... 0,5 ~ 3 hour (depends on pipe condition)

3. PROCEDURE

Data from a referential catchment constituted by one single main sewer and several HCs can be used for extending on a larger catchment (scaling up). Nevertheless, these data have to be extrapolated only in one type of area or in area with similar conditions such as type of build-up area, pipe age, pipe constructional state, hydrogeology conditions, etc.

The administrator of the sewer network has to give the information about groundwater table before experiment.

Exfiltration assessment of the large catchment consists of:

1. evaluation of a small referential catchment (catchment information, pipe construction state)
2. Measurement of the exfiltration rate from HCs in the referential catchment
3. Extrapolation on the large catchment

3.1. Evaluation of a small catchment

For the evaluation of the small catchment, an interactive matrix is elaborated. This matrix contains the information about the types of damages occurring on HC pipe and main sewer pipe on one hand and the information about several causes on the second hand. Background is the result of CCTV inspection and professional evaluation of damages and causes impacts on a pipe (APPENDIX 1).

A relation matrix indicates insignificant and most significant defects that require attention. Mutual interactions are classified using a five-grade scale (with 1 being the emergency condition and 5 describing a small defect) and are used for specification of sequences of individual causes. Total mark for factors, damages and CCTV inspections is the median of average values. Results from this matrix evaluate the catchment and the pipes of a small catchment from its structure conditions point of view.

3.1.1. Types of damages and their causes

Types of defects, which affect the total exfiltration rate, are the following: leaking joints (at socket, at manhole, at connection of the main sewer), a broken and loose pipe wall, obstacles (offset piping, tree roots, sediments, and incrustation), cracks, corrosion, and deformations.
Causal factors are: level of groundwater in relation to piping, permeability of soil environment, type of material, age, traffic load, service life span, implementation, rainy or dry season aspect.

3.1.2. CCTV inspection

The check is begun against the gradient of the bottom of the piping. The defects are evaluated upon discovery by an operator, or by a technician viewing the recording. When viewing the image, the number of joints, the length, the material, the piping diameter, constructional defects, and the condition of the piping are checked. The camera inspection is concluded by drawing up a protocol on the television camera check.
Examinations must be performed on the grounds of maps (*Figure 1*); it is best to use a layout chart of the sewer system corresponding to the actual structure. The materials must provide an indication of the position and location of the sewer and the HC, a profile, the length of the sections, entrance manholes – absolute elevation of the bottom, and an identification number.

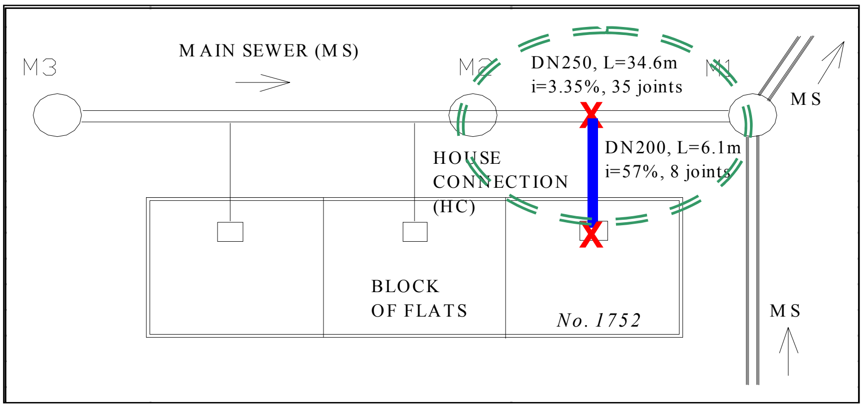

Figure 1 : *Sample map documentation (thick blue line – tested segment, crosses – sealing balloons, dashed line – examined section)*

The protocol must contain such data that will enable accurate identification of the examined section or locality at any time:

- marking or identification number of event
- name of customer, name of contractor
- place of survey (municipality, district, street)
- date, time and weather conditions
- name of operator and examination system used
- examined segment – shape of the sewer into which the HC is connected, dimension, material (separate segments can be identified with i.e. identification numbers of access manholes)
- examined extension – dimension, gradient, length, material and number of joints, if applicable
- survey and description of defects (findings)

- defects must be localised in accordance with the map documentation, starting point and the direction of the inspection

The five-grade scale is similar to the assessment resulting from defects discovered during the camera-aided inspection (CCTV) in accordance with the standard **ATV M143/2a**. Another evaluation of the damages should be classified accordance with the **European Standard prEN 13508-2:2001** (Establishment of the Condition of Drain and Sewer Systems Outside Buildings. Part 2: Visual Inspection Coding System).
The coding system for drains and sewers comprises a series of codes which shall be used to describe the defects and features found in the sewer, HC.
Each observation shall be recorded using an Observation type code, which is a *main code* that broadly describes the feature, together with the following additional information where required.

- *characterisation* - up to two codes which describes the feature in more detail
- *quantification* - up to two values which quantify the feature
- *circumferential location* - up to two clock face references which locate the position of the observation around the circumference
- *joint* - identifies when the observation is associated with a joint
- *longitudinal location* - the distance from the stated reference point including a method of recording observations which continue over a significant length
- *photograph reference*
- *video reference*
- *remarks* - text which describes aspects of the observation which cannot be described any other way

Classifying codes are in alphabetical order A, B, C, etc.

3.2. Measurement of exfiltration rate

House connections and connecting sewer in a small catchment *(Figure 2)* **:**

The exfiltration is measured on a pipe section between both end-manholes and with all connected HC pipes. The methodology for assessing the leakage volumes is based on testing the water-tightness of the piping. A decrease in the water level and time are measured for a closed section of a main sewer filled with water. The decrease of the water level is measured in an upstream manhole. The change of the water level corresponds to a change in volume ΔV over the time Δt (Exfiltration = dV / dt). The main sewer can be considered as type of HC pipe in terms of a similar conditions - DN, geology, flow rating, type of area, etc.

1. Closing the HC with the sealing balloons:
   After placement, the balloon is sealed by being inflated, using an air compressor, in order to seal off a portion of the piping. Steel wires are used to fix the balloon and are removed after the test.
   Number of balloons depends on number of connecting house connections and number of inlets to the manhole. First sealing balloon has to be installed at manhole M2 on connecting main sewer. Further balloons can block all inlets to the manhole M1.
   Rubber balloon, manufactured by VAPO, UPONOR, MULLER, etc., are used. The dimensions of the balloons are selected in correspondence with the dimensions of the examined piping.
2. Filling the main sewer and the HC pipes with clear water: the house connections pipe have to be full fill up.

3. Measuring the volume per time at manhole M1- observing the decrease of water level:
The piping is filled with water from a tank up to an overpressure of 0.01 MPa or 1.0 m of water height in the inspection manhole (maximum).
If the tested segment is subject to leakage, a drop in water level can be observed over a period of time. The decrease can be observed directly in the inspection manhole M1.
The duration of the test is usually 30 to 60 minutes. The test should be repeated after 2 to 12 hours. At this time, the balloons are released and the tested segment is flushed and readied for repetition of the test. The times for repeating of the test are set in accordance with the condition of the piping and the quantity of potentially leaking wastewater. The second measurement concludes the inspection (deflation of the sealing balloons, flushing of the piping and evaluation of the results). Minimum 2 hours is the limit for the water deletion from the sewer system and 12 hours is the maximum to perform the measurement on one day. The return time for the second measurement depends on the local conditions, e.g. on the saturation rate of the soil environment.
In case of extensive damage of the HC, the duration of the test may be shortened.

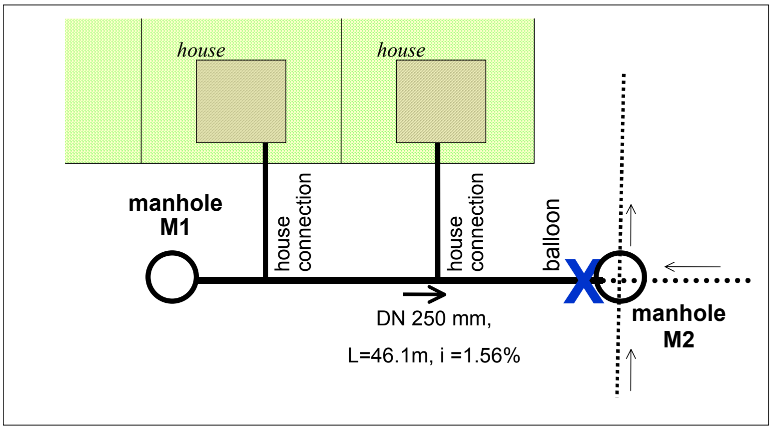

Figure 2 : *Layout of the experimental site. Measurement of the two HC pipes and connecting sewer (Prague-Troja catchment)*

3.3. Extrapolating on large catchment

For the assessment of the exfiltration rate on large catchment, it is necessary to do following:
- to evaluate the damaged range of pipes in a referential catchment (*APPENDIX 1*),
- to estimate the exfiltration rate in the referential catchment (*section 3.2*),
- to collect available information about the large catchment and evaluate the damaged range of HC and main sewer pipes in the large catchment (*APPENDIX 1*).

In order to evaluate the constructional state of all HC pipes and of all main sewer pipes in the large area, it has to be proven that the type of build-up area, hydro geological conditions, pipes age etc are similar and equivalent than those in the referential catchment.

The assessment of exfiltration on the large catchment is calculated proportionally, for example, ratio of HC pipes length in the referential and the large catchments multiply with exfiltration rate of the referential catchment (equation 10).

$$Q_{LC} = Q_R \cdot \frac{\sum L_{LCi}}{\sum L_{Ri}} \tag{10}$$

Q_{LC}	Exfiltration from large catchment
Q_R	Exfiltration from referential catchment
ΣL_{Ri}	Total length of HC pipe in referential catchment
ΣL_{Lci}	Total length of HC pipe in large catchment

In case of catchment with heterogeneous characteristics, exfiltration rate depends on the selection of suitable referential catchments. A referential catchment is characterized by similar conditions and is a sample catchment (specimen) inside the large catchment.

4. EVALUATION

4.1. Evaluation of amount of exfiltration

The leaked amount is calculated as the change in volume ΔV (calculated from the water level decrease) over time Δt for different water levels. The resulting value can then be related to the pipe filling (h), e.g. ¼ h, ½ h or 1 h. and further recalculated e.g. per 1 metre of the HC length or per number of joints. (see the example of measurement in *APPENDIX 3.*)

4.2. Protocol on measurement of exfiltration

In order to enable the comparison of the obtained data and further processing, results in tabular form are suitable. The sample table (*APPENDIX 2.*) shows a detailed description of the examined area, including the main sewer and the checked HC. The table contains all necessary data.

5. CONCLUSIONS

The methodology is based on standards applicable in EU countries and the Czech Republic, relevant for waterproofing of the water-tightness of sewer systems. The methodology has been modified to suit the conditions of the damaged piping in operation.
The value of leakage acquired must be compared to the permissible values as stated in the national technological standards.

The methodology for the assessment of leakage volumes is dependent on the condition of the soil environment, such as permeability, the type of filling, and the degree of solidification.

However, the catchment is characterized by relative exfiltration rate and by value from interactive matrix. Generally, the exfiltration from catchment is estimated as following:

$$Exf_{catchmentA} = f(Q; m) + i \tag{11}$$

$Exf_{catchment\ A}$	Exfiltration from current catchment
Q	Relative exfiltration rate per pipe joint ($l.s^{-1}.joint^{-1}$) or per one meter of pipe ($l.s^{-1}.m^{-1}$)

m Total mark which evaluates catchment conditions (APPENDIX 1)

i Related information about catchment (size, number of HCs, number of inhabitants, type of soil and other important notes – APPENDIX 2)

The final shape of the results is in the following table – the results should be used as suitable inputs for the data modelling (see example on Figure 3) :

catchment	exfiltration rate (Q)	catchment condition (m)
A	0,003 ($l.s^{-1}.m^{-1}$)	3
	0,004 ($l.s^{-1}.joint^{-1}$)	
B	0,006 ($l.s^{-1}.m^{-1}$)	3,5
	0,005 ($l.s^{-1}.joint^{-1}$)	

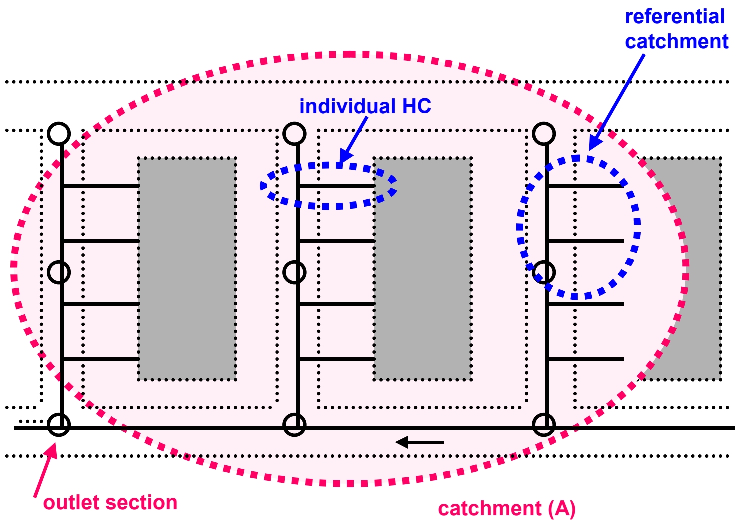

Figure 3 : *Example of large catchment and of type of results*

APPENDIX 1: Referential and large catchment:

The form on detailed evaluation of the damages and their influencing factors (with five degrease scale: 1- emergency condition and; 5- damage of small range):

		damages														factors	
		leakage joints			blocking				corrosion		cracks			others			
		bad joints	connections m. sewer	connections manhole	sediments	incrustation	roots	overlap pipe to m sew.	outside	inside	lengthwise	crosswise	lost of pipe wall	abrasion	deformation	**average value**	**total mark**
factors	high permeability																
	med permeability																
	material																
	type of area																
	rain																
	life time																
	maintainance																
	implemantation																
	aggress.background																
	aggressive water																
	heavy traffic																
	pulsating GWL																
	age																
	subsoil settlement																
damages	**average value**																
	total mark																
CCTV	Inspection																
	total mark																

APPENDIX 2: Protocol on measurement of exfiltration in referential catchment.

EXFILTRATION		
Information about house connections in area :		
date : Weather:		
rain intensity: time before measuring: max. rain:		
house, area	type of catchment	
	year of construction	
	number of inhabitants per HC	
	drainage area (ha)	
hydropedology	ground water level depth (m)	
	type of soil	
	type of subsoil	
	humidity of soil	
	permeability K (m/d)	
connecting sewer	depth of connection (sewer/HC´s)	
	type of connection (sewer/HC)	
	shape of sewer	
	DN (mm)	
	material	
	slope (%)	
	length (m)	
	number of joints / (% bad)	
	state 1 to 5	
	type of damages	
	manhole M1 - water level over top	
	manhole M2	
house connections (HC1 ; HC2)	DN (mm)	
	material	
	slope (%)	
	length (m)	
	numbers of joints / (bad %)	
	state 1 to 5	
	type of damages	
	height of water level	
exfiltration	**absolute**	
	relative per meter	
	relative per joint	

APPENDIX 3: Example: Evaluating of Field Measurement of Exfiltration

Information:

- experimental measurement in the city district Prague-Troja small catchment.
- house-basements and water-supply manhole frequently get flooded from house connections as well as from the main sewer.
- CCTV inspection of the main sewer, including the house connections. The ascertained condition was classified as extended defects in several places, e.g. broken and loose pipe wall, gap in joint, etc.

Measurement of Exfiltration:
The field measurement of exfiltration was conducted for a section of main sewer (demarcated by the inspection manhole M1 and the connecting inspection manhole M2), at a length of 46.1 metres, with ceramic pipe DN 250 mm, and with connections of two house connections DN 200 mm (*Figure 4*). The standard measurement method was applied, as in the case of water-tightness test. The experiment was commenced by blocking the lower end of the selected sewer segment with a sealing balloon at manhole M2 and filling the sewer segment with water to a specified level, followed by measuring the water level decrease at manhole M1 in time. The exfiltration rate corresponds to the lost volume of water in the given time, expressed as volume change ΔV at manhole M1 in time Δt. The resulting volume of exfiltration related to water level is indicated in (*Figure 5*). Measuring was repeated approximately after 20 minutes.
As the second part of experiment, samples have been taken from water-supply manhole. Result of the sampling analysis proved that a discharge of waste water occurs from the house connection to soil environment consequently to basement and manhole.

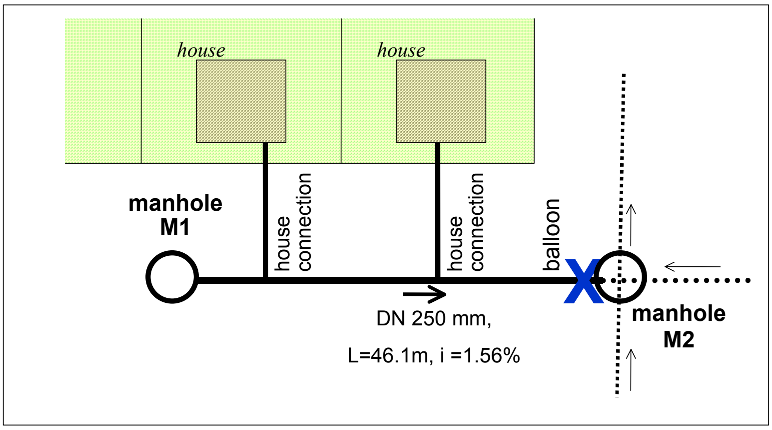

Figure 4*: Measurement of two HC pipes and connecting sewer in Praha-Troja catchment (sealing balloon- marked with blue cross)*

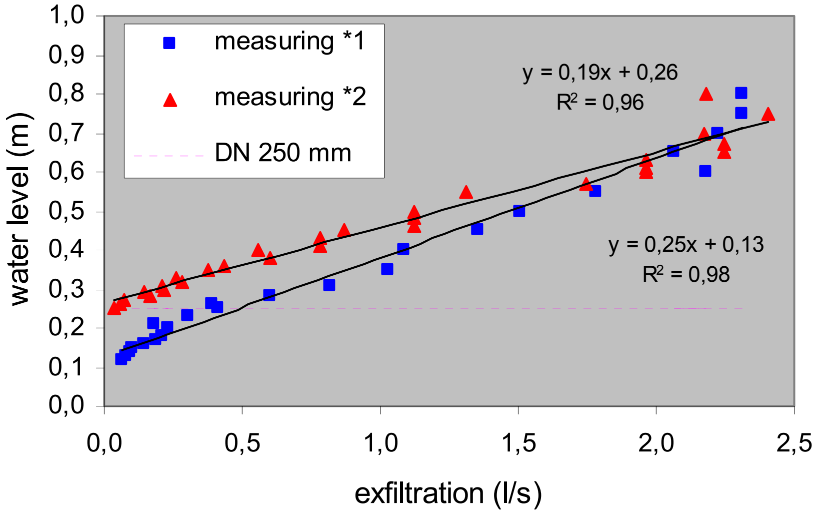

Figure 5 Exfiltration from sewer, observing water level in manhole M1.

The graph of exfiltration as shown on Figure 4 indicates that outflow from the piping is directly dependent on the water level in the pipe (h).

The exfiltration level is expressed as a relative value: for a 75% filling of the DN 250 mm pipe the exfiltration rate is 0.23 l/s. The relative exfiltration rate related to 1 meter of piping is 0.0035 l/s, and the exfiltration rate related to the piping joint is 0.0034 l/s.

(Due to the high levels of leakage, the test could not be executed in the full length of 30 minutes. The test was shortened in this case to 6 minutes).