Pergamon

Wat. Sci. Tech. Vol. 29, No. 1–2, pp. 277–282, 1994.

0273–1223/94 $7·00 + 0·00

ALTERNATIVE URBAN DRAINAGE CONCEPT AND DESIGN

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ABSTRACT

A System of INterconnected Infiltration POnds and Trenches (SINIPOT) is presented as an alternative to classical solutions for the extension and/or renovation of urban drainage systems in Germany. In many cities, modifications of the existing drainage network have been necessitated by restrictive pollution laws. For a catchment in the City of Gelsenkirchen, long term simulations with a hydrologic transport model have been performed for three different sanitation solutions. The most important comparison criteria are the Combined Sewer Overflow (CSO) quantities and the induced flow pattern in the receiving waters (a small creek).

KEYWORDS

Alternative urban drainage systems (UDS); system of infiltration ponds and trenches (SINIPOT); decentralised retention of rainwater; long term simulation of UDS; reduction of CSOs.

INTRODUCTION

In Germany, considerable pollution loads into the receiving waters are caused by CSOs during rainfall events. To meet the new regulations, control measures have become necessary in many UDS. Although the emissions can be reduced by extending the available storage capacity in the UDS (15-30 m^3 of storage per impervious hectare is presently recommended), this solution has several shortcomings:

- structural measures are expensive
- for extreme rainfall events, retention basins do not reduce overflows significantly
- the treatment plant (TP) receives a much greater amount of little polluted combined sewage and its treatment efficiency may be drastically affected.

On behalf of the Emscher Association, an Alternative Urban Drainage Concept has been developed, and it should prove better than the classical one in points 2 and 3. According to the principles of source control, rainwater, as long as it is unpolluted, is directed to an alternative drainage network employing decentralised infiltration of unpolluted rainwater (as far as the soil infiltration rates and open spaces allow) and, where infiltration is not possible or sufficient, separate delayed transport of surface runoff must be guaranteed.

DESCRIPTION OF THE DRAINAGE CONCEPT

The alternative drainage system called SINIPOT is shown in Fig.1. A basic element of this system is the dual satellite infiltration pond/trench. The rainwater is first directed to the infiltration pond and filtrates through the higher soil strata into the underlying trench, which can store up to 40% of its gross volume. Several trenches can be connected into a network, whose outlet drains into the receiving water. If the infiltration capacity of the surrounding soil is sufficient, the whole volume stored in the trenches flows into the groundwater. If not, the connected trenches transport the water to their outfall with a considerable delay and damping effect.

Small drainage (safety) pipes should be installed in the trenches and connected to a control system, which could be checked and adjusted at the so-called control manholes. During extreme rainfall events, if the normal transport and storage capacity become inadequate, these safety pipes would transport the overflow volumes without delay out of the catchment.

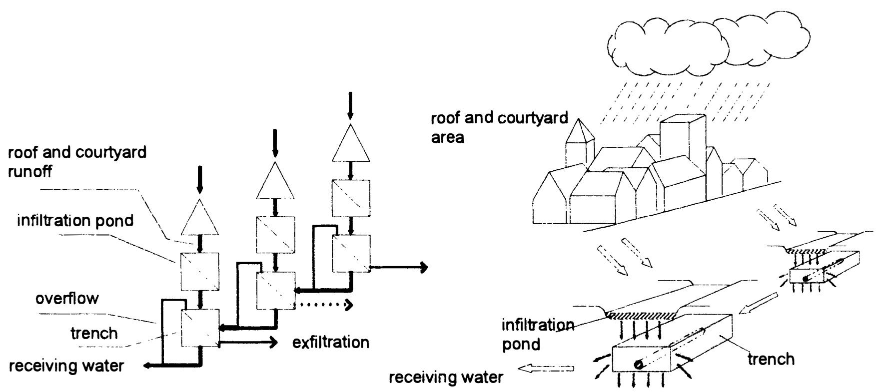

Fig. 1. Functional scheme of the SINIPOT drainage system

DIMENSIONING SINIPOT

Every single element (pond, trench) of the alternative drainage system is regarded as a storage element, whose outflow depends either on infiltration capacity (ATV-A138, 1990) or on the flow capacity of the drainage pipes (Fig. 1). In the case of trenches, it is important to correctly assess the inflow quantities (from the overlaying pond and the existing upstream trenches) and to assure that the safety pipes transport the total overflow from all the upstream trenches.

The dimensioning method, however, only considers a single large event and may fail if several rainfall events follow each other within a short period. The longer the time required for each element of the SINIPOT to empty, the more questionable become the design results. A long term simulation (ATV, 1985) is the only way to guarantee the reliability of the designed values.

STUDY CASE GELSENKIRCHEN: DESCRIPTION OF THE CATCHMENT

The district "Beckeradsdelle" is part of the City of Gelsenkirchen (Germany) and was developed as a residential area at the end of the last century. The existing combined UDS drains 75 ha and connects to a small creek named "Lohnmühlenbach" in the south-west. Infiltration experiments showed a small infiltration capacity of the natural soil (in some cases < 10^{-7} m/s), which makes it difficult to develop a drainage concept based only on decentralised infiltration. The presence of a very impervious stratum at a depth of around two metres, combined with a relatively high topographic slope, increases the danger of water damage in houses and cellars. A SINIPOT drainage system was therefore proposed, which interconnects 38 ponds and 56 trenches. At three outlets, the vastly reduced rainwater flows into Lohnmühlenbach Creek.

A detailed analysis of on-site conditions showed that around 40% of the surfaces can realistically be disconnected from the existing combined UDS and drained by the SINIPOT drainage system (Table 1). To distinguish from the existing "actual state" of the drainage system, the new configuration will be referred to as the "sanitation state".

TABLE 1 Comparison Between Present and Sanitation State

	Total Area (ha)	Roof Area (ha)	Courtyard Area (ha)	Street Area (ha)	Pervious Area (ha)
Actual state	32.9	10.8	8.7	9.9	3.5
Sanitation state	19.5	4.8	3.7	9.9	1.2
Disconnected area	13.4	6.0	5.0	0	2.3

A supplementary storage capacity of 4140 m^3 is available in the trenches. Related to the total connected area (32.9 ha), it gives a specific storage capacity of 126 m^3/ha.

THE SIMULATION RESULTS

The hydrologic effects of the SINIPOT drainage system can be divided into the effects on the transport performance of the existing combined UDS (characterised by the flooding and surcharge frequencies) and the effects on the receiving waters (CSOs, flow rate)

Comparison of the estimated CSO quantities

A long term simulation was performed with an hydrologic transport model for a period of 21 years for the following four drainage scenarios:

- Actual state — simulation of the existing UDS
- Actual state + SINIPOT — simulation of the existing combined UDS after disconnection of all the surfaces, which are drained by the SINIPOT drainage system
- Actual state + RB126 — in this configuration, the only modification of the existing combined UDS is the construction of a supplementary retention basin (RB) of 4140 m^3 ($\Rightarrow$ 126 m^3/ha) at its outlet
- Actual state + SINIPOT +RB12.5 — like case 2, but with a supplementary retention basin of 410 m^3 ($\Rightarrow$ 12.5 m^3/ha) at the outlet of the combined drainage system.

The overflow quantities have been calculated under two assumptions - according to the German regulations, the maximum allowable flow rate from the catchment into the TP has been set to 35 l/s (all flows in excess are considered as CSOs) and since the rainwater flowing into the SINIPOT drainage system is considered unpolluted, it is not accounted for as CSOs.

TABLE 2 Comparison of the Mean Yearly CSO Quantities

	Actual State	Actual State + SINIPOT	Actual State + RB126	Actual State + SINIPOT + RB 12.5
CSO vol. (m^3)	96556	48104	9646	23100
CSO vol. /tot. rain vol. (%)[1]	77.1	38.4	7.7	18.5
Rainwater vol. to the TP (m^3)	28628	25038	115538	50042
Number of CSOs (-)	180	155	3	29

[1]Proportion of CSO volume related to total rain volume flowing out of the impervious surfaces (29.4 ha)

On average, the efficiency of a large retention basin alone seems greater than drainage disconnection measures that are made possible by the construction of the parallel SINIPOT drainage system. In the case of actual state + SINIPOT the CSO percent volume does not even meet the local requirements (CSO vol. < 0.35 rain. tot. vol.). A small retention basin is therefore necessary.

On the other hand, the solution for actual state + RB126 has two great shortcomings:

- compared to any other solution, the volume of relatively little polluted water sent to the TP is much increased, which may induce a lower treatment efficiency or necessitate modifications of the TP itself (Table 2).
- the flow damping effects of the retention basin become negligible for extreme events (Fig. 2).

Figures 2a and 2b show the results of a statistical analysis of the simulation output data. The estimated maximum CSO flow rates and volumes are compared for return periods between 0.5 and 30 years. As expected, the efficiency of a retention basin (RB126) is great for small and medium rainfall events (return period < 3 years). For extreme events, however, its damping effect is very limited, despite the high specific retention volume. On the other hand, the values of both CSO variables (discharge and volume) in the case of actual state + SINIPOT are reduced to around 60% of the original values, for all return periods.

Increase of the mean flow rate in Lohnmühlenbach Creek

The reduction of CSOs and of the volumes delivered to the TP are not the only positive effects of a SINIPOT drainage system. Part of the unpolluted water is directed into the groundwater, and another part is directed to Lohmühlenbach Creek with a great delay. The volume partitioning depends on the infiltration capacities of the trenches.

The SINIPOT drainage network itself was simulated with a hydrologic model for a period of 21 years, in the same manner as the combined UDS, and the inflow volumes into the receiving water and the ground water have been compared for three cases :

- there is no exfiltration out of the trenches (in this case, the SINIPOT works only as a transport system and does not feed the groundwater)
- the exfiltration rate out of the trenches is $k_f = 10^{-7}$m/s (the measured values of k_f range between 10^{-6}m/s and 10^{-7}m/s in the catchment Beckeradsdelle)
- the exfiltration rate out of the trenches is $k_f = 10^{-6}$m/s.

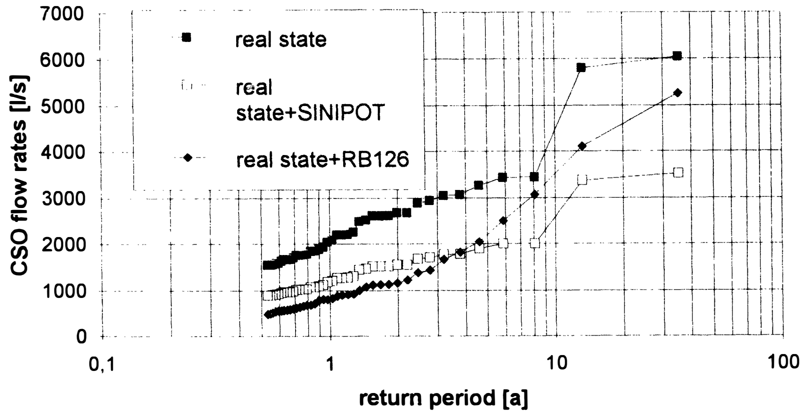

Fig. 2a. Statistical analysis of the CSO flow rates (m^3/s)

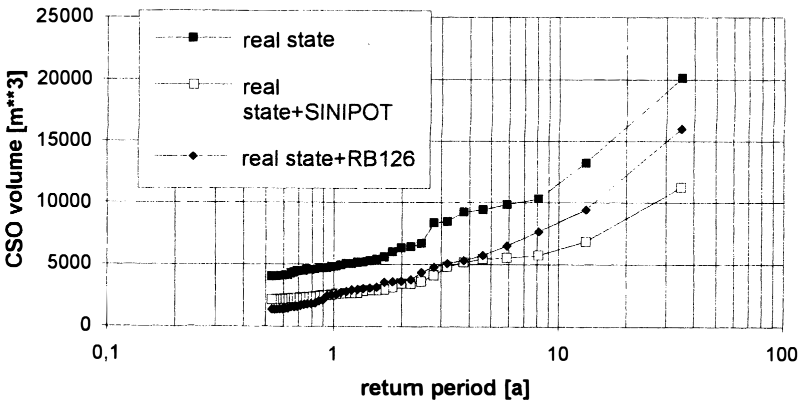

Fig. 2b. Statistical analysis of the CSO volumes (m^3)

Table 3 shows the influence of the exfiltration parameter (k_f) on the volume balance. Fig. 3 shows the influence of k_f on the exceedance durations of given flow rates in Lohnmühlenbach Creek (dry weather flow = 0.3 l/s). Without the SINIPOT system, the flow rate exceeds 1 l/s 46 days in a year (13 % of the time). For $k_f = 10^{-6}$ m/s the improvement is hardly perceptible, the flow rate exceeds 1 l/s only 18 % of the time. For $k_f < 10^{-7}$m/s, the situation changes completely. The flow rate exceeds 1 l/s more than 47% of the time.

TABLE 3 Volume Repartition (Yearly Mean Values During 21 Years)

Case	Inflow Volume to the Receiving Waters	Infiltrated Inflow Volume
Without exfiltration	65 419 m^3 - 100%	0 m^3 - 0%
Exfiltration $k_f = 10^{-7}$m/s	47 054 m^3 - 72%	18365 m^3 - 28%
Exfiltration $k_f = 10^{-6}$m/s	9 531 m^3 - 15%	55888 m^3 - 85%

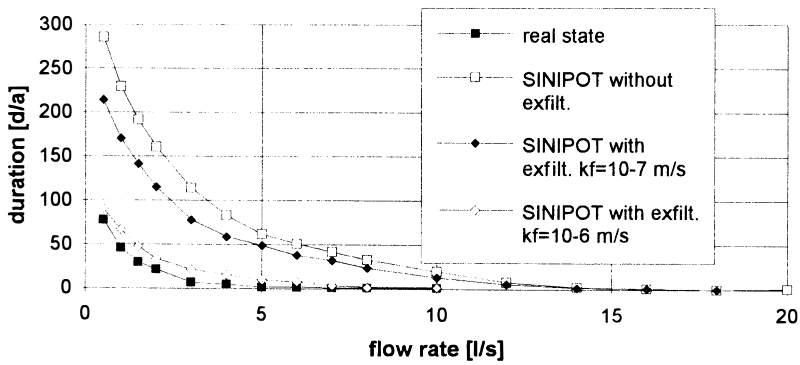

Fig. 3. Influence of the SINIPOT system on the flow rates of the Lohnmühlenbach

CONCLUSIONS

In order to reduce the CSO quantities in Germany, many large retention basins are being built. In West Germany alone, the costs of such structures are estimated at 2 billion DM a year with a total predicted investment of 50 billion DM. The present study shows that an increase of storage capacity may induce negative consequences if the treatment plant and groundwater are also considered, notwithstanding the limited damping effect of retention basins during extreme events.

The SINIPOT network is a combination of infiltration and transport elements which separately drain unpolluted rainwaters, regardless of the soil characteristics. Besides sharing the outflow rates, it also reduces the outflow volumes. If possible, the transport of the unpolluted or slightly polluted rainwater should occur on the catchment surface, to increase the runoff lag time and to permit an immediate control of the drainage process. The infiltration should occur through a "green stratum" in the ponds, so that a supplementary cleansing effect by the plants can be realised. Highly polluted rainwater should flow to the existing combined UDS.

The design, construction and maintenance of a SINIPOT network necessitates more coordination effort than a classical scheme. Engineers, urban planners and even ordinary citizens should collaborate to find an appropriate solution in each case. The cost of such alternative systems should be of the same order as the classical UDS. Their maintenance necessitates an adapted jurisdictional arrangement and good organisation, especially if the drainage elements are located on private properties.

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