Lessons from ten years storm water infiltration in the Dutch Delta

Dix ans d'expérience sur l'infiltration des eaux pluviales dans le delta des Pays Bas

Beenen A.S.*, Boogaard F.C.**

* RIONED Foundation, PO Box 133, NL-6710 BC EDE, Netherlands (ton.beenen@rioned.org)

** Tauw bv, Zekeringstraat 43 g, 1014 BV AMSTERDAM, Netherlands (fcb@tauw.nl)

RESUME

Dans le cadre du développement de la politique concernant le design et la gestion des systèmes d'assainissement, des solutions innovantes pour l'infiltration des eaux pluviales ont été développées et appliquées au sein des communes Néerlandaises. Paradoxalement, si le concept de systèmes d'assainissement durable (Sustainable Urban Drainage Systems - SUDS) est largement répandu, les connaissances disponibles pour la gestion et la maintenance de ces systèmes alternatifs restaient limitées. La fondation RIONED est le centre de connaissance et d'information néerlandais pour l'assainissement. RIONED a donc chargé TAUW BV (Bureau d'ingénierie et d'études pour l'eau et l'environnement) de conduire une étude de terrain sur le comportement hydraulique et les impacts environnementaux des SUDS. Différents SUDS ont été analysés dans les communes d'Enschede, Zwolle et Eindhoven au cours des dix dernières années. Une attention particulière a été accordée à la perte de capacité d'infiltration et à l'accumulation des polluants au cours du temps, ainsi qu'aux moyens mis en œuvre pour l'entretien de ces systèmes mis en parallèle avec les résultats obtenus. Enfin, l'opinion des habitants sur l'application de ces systèmes a également été sondée. Ainsi, après dix ans de collecte de données, des conclusions ont pu être dégagées et cet article présente les recommandations pour le design, le gestion et la maintenance qui en ont été tirées.

ABSTRACT

New policy guidelines regarding the design and operation of urban drainage systems have brought several innovative systems in the Dutch municipalities for infiltration of storm water. Although the concepts of sustainable urban drainage systems (SUDS) are widely spread little knowledge was available for operation and maintenance of SUDS. RIONED foundation is the Dutch knowledge and information centre for urban drainage. RIONED contracted TAUW BV (Technical engineering and consultancy for water en environment) to conduct a field study monitoring the hydraulic and environmental behaviour of SUDS. In the municipalities of Enschede, Zwolle and Eindhoven several SUDS have been analysed in the past decade. Attention has been given to loss of infiltration capacity, accumulation of pollutants, efforts for and results of maintenance and the appreciation of the SUDS by the inhabitants. After ten years gathering data conclusions have been drawn and recommendations for design, constructing and maintenance are given in this article.

KEYWORDS

Design, guidelines, maintenance, monitoring, storm water infiltration, suds.

1 INTRODUCTION

Most scientists agree that the climate, including that of the Netherlands, will undergo dramatic changes in the coming decades. These changes will result in wetter winters, drier summers and a rising sea level (knmi, 2006). At the same time, the Netherlands is subsiding. We will have to contend with conditions of increasingly frequent and dramatic fluctuations in the water supply. The conditions in a country like the Netherlands – dominated by the sea and the mouths of four great rivers, with a high population density and an expanding economy – will more frequently result in enormous problems unless a structurally different approach is implemented to counteract them (Ministry of Transport, Public Works and Water Management, 2000).

1.1 Dutch policy guidelines

A good mix of spatial and technological measures is required to address safety requirements and reduce water-related problems, for which the Dutch government prefers constant consideration of spatial measures, including widening or lowering flood plains and construction of water retention and storage areas, in addition to technological measures, including dyke heightening and reinforcement, dewatering operations and damming.

For urban drainage this policy is translated to recommendations in the new Water Act (probably in force of begin 2007). The new Dutch Water Act contains a preferred storm water management train:

- Prevention of run-off (quantitative source control);
- Prevention of polluting run-off (qualitative source control);
- On site infiltration (on private and public properties);
- Local storage and retention (to prevend floodings);
- Treatment in a communal waste water treatment plant (as a outmost last resort).

Management of urban storm water with swales for retention and infiltration is an example of an approach complying with this policy.

1.2 Geohydrological situation in The Netherlands

In The Netherlands the groundwater tables are very high due to the very small difference between the levels of surface water and the built areas as The Netherlands are a delta of four major European rivers. One of the most typical elements of modern drainage systems in Dutch urban areas are the swales infiltrating rain water into the soil. At the bottom of the infiltration device underneath the swale drainpipes spread the water through the infiltration body and drain the area when ground water tables are high. To manage the groundwater in combination with storm water infiltration a special regulating device has been installed in every downstream manhole to lower the leel of drainage during winters and to store groundwater in summers. In this manner the swale system combines the drainage of ground and rain water in the wet winter periods with storage and infiltration during the dry summer periods.

2 MONITORING LOCATIONS

Three locations with sustainable urban drainage systems have been monitored to collect more information about the hydraulic and environmental behaviour in the long term, about the needed maintenance and about the appreciation of inhabitants of storm water infiltration devices. (Biesbroek and Boogaard, 2006) Each location and method of monitoring and research are described briefly below.

2.1 Eindhoven

The Runstraat in Eindhoven (a municipality in the south of the Netherlands) is a rustic and low dynamic street where the run-off from roves and paved areas is disconnected from the combined sewage system.

2.1.1 Situation

In 1997, a testing project has been initiated to analyse the functioning of sustainable urban drainage systems (SUDS) and to determine the hydraulic life expectations of two soakaway constructions made of ten plastic geocellular units wrapped in geo-textile. These systems are monitored over a long period of time in order to obtain representative data.

Run-off in the Runstraat in Eindhoven is disconnected to soakaways

2.1.2 Method

To obtain the necessary data to gain insights in the hydraulic functioning of the infiltration systems, water level data loggers were used. The loggers measured every 5 minutes the water level in the infiltration unit and the ground water around the infiltration system. The precipitation was measured In order to analyze the relation between precipitation and the water level in the infiltration system. Each month, the data was put in a database to analyze and visualize the hydraulic performance of this system in time. In 1996, the first measurements were conducted as reference for the follow-up research. In 200-2006, the infiltration systems were analysed again, comparing the outcomes with the initial data form 1996.

2.2 Zwolle

The infiltration units of Geren and Schellerhoek (two small urbanized areas in the municipality of Zwolle in the middle of the Netherlands) are placed in a rustic, low dynamic street. The municipality of Zwolle is located alongside the river IJssel and has fairly low infiltration capacity of the soil. In 1993-1995, two systems are placed as a test location for a new build-up area in order to infiltrate the stormwater runoff.

Construction of infiltration trench at Schellerhoek, Zwolle, Netherlands

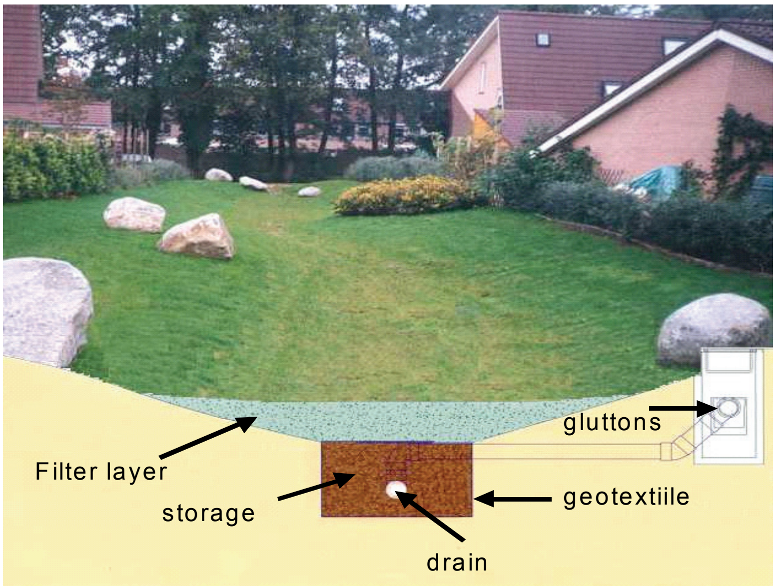
The infiltration trenches were measured in two phases. The first phase took place in 1994-1997 when several times the water level in the infiltration unit was measured. The second phase was conducted in 2005-2006. The measured variables in this second phase were the water level in the infiltration system, the groundwater levels and the precipitation.

2.3 Enschede

Enschede is a municipality in the eastern part of The Netherlands. The infiltration capacity of the soil is reasonably well although groundwater levels are quite high. In 1994 a new housing development, called *Ruwenbos*, has been started with high ambitions regarding the storm water drainage system. The 400 new houses in this urban area are built with respect to sustainability principles. The housing estate is designed as a garden district, with respect to existing trees and slopes. The storm water is drained by swales (Boogaard et al., 2006).

2.3.1 Situation

All run-off in *Ruwenbos* is guided through gutters along the streets and in this way is kept visible on the surface. The gutters guide the rain water to the swales. In each swale the water is stored to a level of approximately 0.25 metres, a level designed to be exceeded only once every two years. Above this level gullies, also called 'gluttons', discharge the surplus to a subsoil infiltration body made up of expanded clay grains wrapped in a geo-textile. Once every twenty-five years the water level in the swale reaches a depth of 0.35 metres. Above this level the water is discharged into the next swale and, in the end, into the surface water.



Swales in Ruwenbos

2.3.2 Method

From 1996 to 2006 three swales has been monitored. Quantity and quality of precipitation, run-off, groundwater and overflows has been analysed. Two enquiries among the inhabitants were made to establish the appreciation of this innovative urban drainage system. Ten years after the start of the monitoring program a part of the geo-textile around the soakaway unit has been digged up and analyzed for the actual infiltration capacity.

3 RESULTS

3.1 Hydraulics

The swales, soakawyas and infiltration units are mostly emptied within 24 hours. These measurements are confirmed by observations of the inhabitants. Analysis of times to empty with infiltration capacity tests shows no loss of infiltration capacities during the monitoring programme.

3.2 Pollutants

Run-off is contaminated by the surfaces. Concentrations in rain water vary greatly by type of pollutant or by type of water, but in general run-off from roofs is cleaner than from streets. PAH's and heavy metals accumulate in the top layer of the soil of the swale. These pollutants attach strongly to floating particles in the run-off and are deposited in the soil because of infiltration and adsorption processes. After ten years no significant accumulation of pollutants was found. All measured concentrations stayed below the limiting values.

3.3 Geo-textile

In 2005 three samples of the geo-textile around the expanded clay grains were taken and analysed. This showed a strong reduction in its infiltration capacity. Nevertheless the infiltration capacity was still higher than in the surrounding soil.

3.4 Costs

Costs for construction of a swale system are per square metre of discharging area less than the costs of a traditional sewer system. Costs for maintenance though are higher compared to a sewer system.

3.5 Inhabitants enquiry

Two enquiries in 1999 and 2005 have mapped the experiences of the inhabitants. In general the inhabitants were more satisfied with the swale system in 2005 compared to 1999: 98% of the inhabitants in 2005 to 94% of the inhabitants in 1999 declared they were satisfied with the functioning of the swales. If they move, only a 2% (2005) respectively 6% (1999) of the inhabitants wouldn't chose again for an area drained by swales.

3.6 Organisation

During the planning, the development, the construction, and the maintenance of *Ruwenbos* the municipality has gained a lot of valuable experience. Communication skills during planning turned out to be very important. Construction and maintenance demand special attention, among other things, the drainage during the construction phase, loss of infiltration capacity due to construction activities, the way the mowing is managed, the policy for gritting icy roads, and the maintenance of drainpipes. Technical knowledge of sustainable urban drainage systems is far from completed. National and some local policies don't keep up with good practices. In Ruwenbos the design of the urban drainage system turned out to be quite a job. On the other hand people appeared willing to discuss the issue of water. Maintenance

Due to the use of mowing machines, playing children, and the sedimentation of silt some parts of the grass vegetation in the swales have become bare. Mowing when the soil is still moist leads to tracks. Using heavy machinery also causes reduction of the infiltration capacity of the upper layer of the bottom due to condensing. Furthermore experience showed that the slope between the swale and the surrounding field should not exceed 1:3 in order to allow mowing machinery to enter the swale.

For good functioning the sweeping up of fallen leafs and rubbish is recommended. The municipality cleans the gluttons twice a year and the drainpipe once every year. Maintenance of the swales systems needs good gearing of the different activities to one another.

4 COMPARISION OF SEVERAL EUROPEAN GUIDELINES

In table 1 a comparision of guidelines for design and contruct of swales is being given. These guidelines are respectively published by:

- Germany (DWA, 2005)
- United Kingdom (CIRIA, 2004)
- Belgium (VLARIO, 2005)
- Netherlands (RIONED, 2006)

The recommended values for the design parameters are more or less in the same order. The german guidelines are somewhat more stricter regarding the distance between the bottom ofthe swale and the groundwatertables. This reduces the risks of hydraulic failures due to smaller infiltration capacities than assumed. Another striking difference is the recommendation for the time to empty the swale with regard to successive storms. In the UK, belgium and The Netherlands a time to empty of at most 24 hours. DWA in the contrary recommends a minimal retention time of six minutes.

		Recommended values			
Parameter	**Unit**	**Netherlands**	**Germany**	**United Kingdom**	**Belgium**
Infiltration capacity	m/day	> 0.5	0,86 < Kd < 86,4	-	> 0.086
Distance ground water	m	> 0.5	> 1		
Thickness of filter soil	m	0.3 – 0.5	> 0.1 (average 0.3)		0.3 - 0.5
Area swale to drained area	%	5 – 10	> 7 (average 5 - 20)		5 – 10
Distance to houses	m	> 1	1.5 depth constr. zone		
Overflowing frequency	n/yr	1 to 2	0.2		0.2 - 0.5
Swale water depth	m	< 0.3	< 0.3	< 0.1	< 0.3
Spare capacity	m	0.1		0.15	
Time to empty	hour	< 24	< 24	retentiontime > 10 min.	< 24
Width of bottom	m	> 0.5		0.6	0.5 - 1
Width of water surface	m	4			
Slopes	-	1 : 3 or less		1 : 4 or less	1 : 3 or less
fraction of humus in toplayer	%	3 - 5	2 - 10		
Max velocity	m/s			1 - 2	

Table 1. Comparision of design guidelines in four European countries

5 CONCLUSIONS AND RECOMMENDATIONS

SUDS can function quite well as long as design and maintenance is in accordance with the guidelines. After ten years of monitoring no significant loading of pollutants nor a significant loss of infiltration capacity has been found. Common failures in the design, construction and maintenance of SUDS are gathered from several locations and translated to recommendations. Important factors for maintaining the hydraulic performance are:

- a sound survey of infiltration capacities of the soil;
- investigation of statistics of groundwater tables;
- choice of the porewidth of geo-textiles;
- construction of the swales or soakaway units in dry conditions;
- drainage of the area during the construction phase in a housing project;
- mowing of swales only at sufficient dry weather conditons;
- proper use of SUDS need an adequate communication towards the inhabitants;

For the future further research is needed to gain more insight in the long term effects of polluting the soil and groundwater due to underground infiltration systems.

LIST OF REFERENCES

Biesbroek and Boogaard, F.C. (2006). Onderzoek naar het dichtslibben van percolatiesystemen. Stichting RIONED.

Boogaard, F.C., Bruins, G. and Wentink, R. (2006). Wadi's: aanbevelingen voor ontwerp, aanleg en beheer. Stichting RIONED.

CIRIA (2004). Sustainable drainage systems; hydraulic, structural and water quality advice. CIRIA, UK.

Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (2005). Arbeitsblatt DWA-A138 Planung, Bau und Betrieb von Anlagen zur Versickerung von Niederschlagwasser. DWA.

KNMI. (2006). Climate change scenarios 2006 for The Netherlands. KNMI, De Bilt, Netherlands.

Ministry of Transport, Public Works and Water Management. (2000). A Different Approach to Water, Water Management Policy in the 21st Century.

Sieker F. (1999). Urban water management in germany. Workshop on urban water management. Lissabon, Portugal.

Stichting RIONED. (2005). Leidraad Riolering. Module B2200, Ontwerp van regenwatervoorzieningen. Stichting RIONED.

Vaes G., Bouteligier R. and Berlamont J. (2004). Het ontwerp van infiltratievoorzieningen. Waterniveau, februari 2004.

Vlario. (2005). Katern afkoppelen, bufferen en infiltreren. 20 april 2005.