Design criteria for local stormwater facilities to meet pollution and flow requirements

Des design critères pour les installations d'eaux pluviales locales pour répondre aux exigences de la pollution et de debit

Thomas Larm* and Henrik Alm**

* StormTac corporation, Boo Strandv. 1J, SE-132 36 Saltsjö-Boo, Sweden
(thomas.larm@stormtac.com)
** Sweco Environment corporation, P.O. Box 34044, SE-100 26 Stockholm, Sweden
(henrik.alm@sweco.se)

RÉSUMÉ

Developement de l'impact faible (LID) et systèmes de drainage urbains durables (SUDS) sont des termes utilisés pour décrire à petite échelle "on-site" plantes pour protéger la qualité de l'eau et la réduction du risque d'inondation. La mise en oeuvre de ces installations d'eaux pluviales locales ont augmenté rapidement au cours des dernières années. Cependant, il y a eu un manque des design critières facile à utiliser, qui considerent les conditions spécifiques au site pour certaines de ces types d'installation. Les design critères proposées sont, depuis l'hiver 2014/15, mis en oeuvre dans le modèle des eaux pluviales et le modèle d'eau de surface StormTac (www.stormtac.com). Ce papier présente les derniers résultats pour le traitement des eaux pluviales pour les types d'installation suivantes: (1) les fossés d'herbe, (2) les fossés avec pente plat, (3) des tranchées d'infiltration (de fossés macadam) et (4) des biofiltres (système de rétention de bio ou raingardens). Le document présentera des design critères facile à utiliser, y compris les paramètres influencants les plus importants et des diagrams avec des fonctions des design paramètres differents et l'efficacité de la réduction.

ABSTRACT

Low-Impact Development (LID) and Sustainable Urban Drainage Systems (SUDS) are terms used to describe small-scale on-site facilities to protect water quality and reducing the risk for flooding. The implementation of these local stormwater facilities have increased rapidly during the latest years. However, there have been a lack of easy-to-use design criteria, which consider site-specific conditions for some of these types of facilities. Proposed design criteria are since the winter 2014/2015 implemented in the stormwater and recipient model StormTac (www.stormtac.com).This paper present these latest findings for stormwater treatment for the following kinds of facilities: (1) grass ditches, (2) swales, (3) infiltration trenches (macadam ditches) and (4) biofilters (bio retention systems or raingardens).The paper will present simple and easy-to use design criteria, including the most important identified influencing parameters and diagrams with functions of different design parameters and reduction efficiency.

KEYWORDS

Biofilter, design criteria, grass ditch, infiltratiion trench, swale.

1 INTRODUCTION

The implementation of local stormwater facilities have increased rapidly during the latest years as a supplement or replacement of end-of-pipe-facilities. Examples of such local facilities are: (1) grass ditches, (2) swales, (3) infiltration trenches (macadam ditches) and (4) biofilters (bio retention systems or rain gardens). Grass ditches and swales are of the same principal type, however swales have less slope and most data bases differ among these two regarding estimated reduction efficiencies. These four types of facilities have been selected since they are proposed and implemented increasingly in many urban development projects and since there are a lack of data and compiled design criteria for these. Proposed criteria cover both reduction efficiencies (pollutant treatment) and a quantitative (flow detention) design.

During the latest years, flow proportional concentration data (mg/l or µg/l) from in- and outlets and data of reduction efficiencies (%) from these facilities have been compiled. Furthermore, other design criteria data are in the process om being collected from literature studies, such as (I) facility area, (II) catchment area, (III) design runoff coefficients, (IV) design rain depths (mm) and the (V) recommended depth (mm) of different suggested material layers.

Equations and simple and easy-to use design criteria are presented for phosphorus (P), copper (Cu), zinc (Zn) and suspended solids (SS). These 4 substances are selected since there are much available data for these and since they are generally of priority in different countries, used in water quality criteria and as basis for designing stormwater treatment facilities.

2 METHODS

2.1 FACILITIES

Figure 1 presents the principles of the studied facilities, classified into three different types.

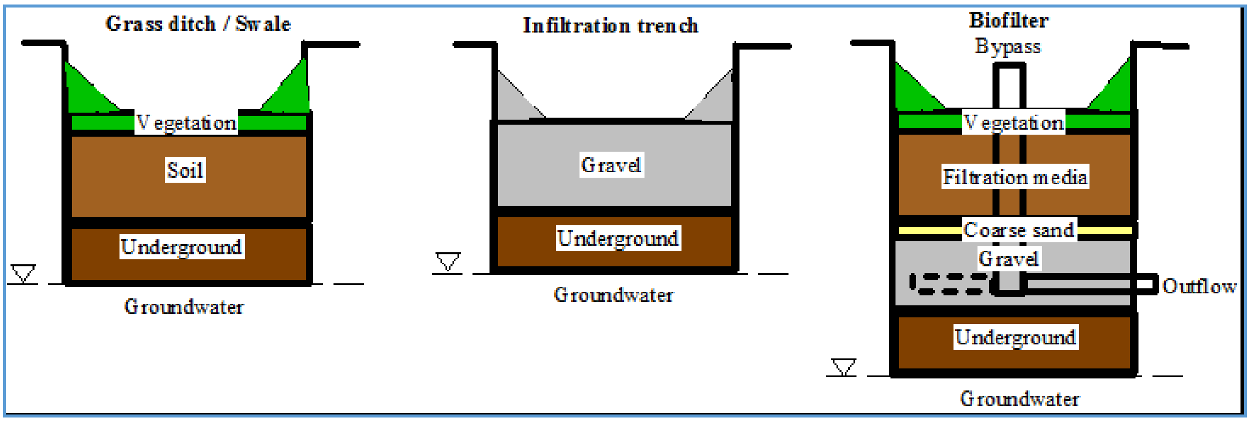

Figure 1. Principle pictures of Grass ditch and swale, infiltration trench and biofilter.

2.2 LITERATURE STUDY

Table 1 presents selected part of the relatively comprehensive literature study of reduction efficiencies (%) of the four types of facilities. More referred data are available for download from www.stormtac.com in an Excel database, including 13 reference field studies of grass ditches, 21 of swales, 17 of infiltration trenches and 46 of biofilters. Most case studies come from USA and Australia, but also from e.g. Great Britain, Sweden and Japan. There are data of around 20 different substances.

3 RESULTS AND DISCUSSION

3.1 COMPILED DATA

Table 1 presents compiled median, min and max reduction efficiencies (%) of P, Cu, Zn and SS from the literature study of the four facility types. The extreme values were deleted. The compiled regression constants Kφ are also results from the literature study and express the facility area percentage of the reduced watershed area, see Eq. (1). The latter constants will be further studied.

Table 1. Compiled facility regression constants K_{φ} (% facility area/reduced watershed area) and reduction efficiencies (%) for P, Cu, Zn and SS.

Facility	**K_{φ}**	**P**	**Cu**	**Zn**	**SS**
(1) Grass ditch					
Median	**5.0**	**32**	**33**	**58**	**73**
Max	18	44	49	86	80
Min	2.0	25	17	13	49
Number of ref. studies		*9*	*5*	*9*	*11*
(2) Swale					
Median	**4.0**	**30**	**60**	**65**	**68**
Max	14	54	74	85	85
Min	1.5	7.5	42	45	44
Number of ref. studies		*15*	*8*	*10*	*17*
(3) Infiltration trench					
Median	**3.5**	**60**	**88**	**88**	**89**
Max	12	65	90	91	100
Min	1.25	30	65	65	70
Number of ref. studies		*16*	*11*	*12*	*17*
(4) Biofilter					
Median	**2.5**	**65**	**66**	**86**	**76**
Max	11	77	93	99	96
Min	1.0	32	38	59	47
Number of ref. studies		*29*	*19*	*20*	*23*

3.2 DESIGN GUIDELINES

The four studied facilities have similar buildup and function and are assumed to all be designed using Eq. (1), but employing different regression constants K_{φ}. K_{φ} express the percentage of facility area of the reduced watershed area ($\varphi_V A$).

$$A_{SF} = \varphi_V \, A \, K_{\varphi} \qquad (1)$$

A_{SF}	Area of stormwater facility (m^2)
φ_V	Volume runoff coefficient (for small storms)
K_{φ}	Regression constant, facility specific (%)
A	Watershed (catchment) area (ha)

Either compiled land use specific volume runoff coefficients φ_V are used (StormTac, 2016) or are the coefficients calculated from a regression function of the calculated fraction of imperviousness i, see Eq. (2) (WEF and ASCE, 2012).

$$\varphi_V = 0.858\, i^3 - 0.78\, i^2 + 0.774\, i + 0.04 \qquad (2)$$

i	Watershed imperviousness fraction

Different K_{φ} results in different reduction efficiency, assumed to follow logaritmic functions, see Figure 2. The reduction efficiency RE is estimated from the trend line equations of data, see Eq. (3). Other site specific factors studied in Larm and Alm (2014) for wet ponds and wetlands have been added to Eq. (3), to be further studied for these four types of facilities.

$$RE = [k_1 \ln(K_{\varphi}) + k_2] * f_{Cin} * f_{veg} * f_{bypass} * f_{Vd} \qquad (3)$$

RE	Reduction efficiency (%)
k_1	Regression coefficient 1, specific for each substance and facility
k_2	Regression coefficient 2, specific for each substance and facility
f	factor
Cin	inlet concentration
veg	vegetation
bypass	bypass
Vd	detention volume

The trend lines in Figure 1 have been created from three points; median, min and max in Table 1, which is an assumption. These points will be replaced with data from the reference studies. Maximum RE from Table 1 is used if Eq. (3) results in larger values than this max. The equations above are implemented in the StormTac model (www.stormtac.com) and are continuously being updated with changed functions when new data are added to the database (StormTac, 2016). StormTac has been calibrated and validated for other types of facilities, such as wet ponds, and has been calibrated but is to be further validated for practical case studies of the four types of facilities presented here.

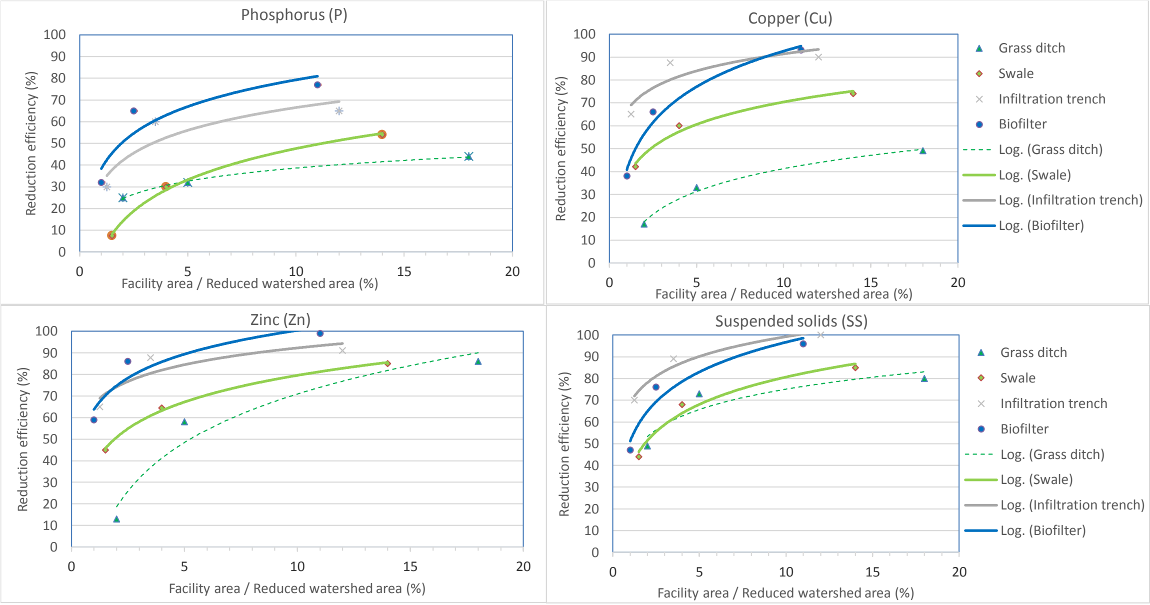

Figure 1 Regression constants K_{φ} (% facility area/reduced watershed area) as a function of reduction efficiencies (%) for P, Cu, Zn and SS.

StormTac also includes calculation of design flow and flow detention volumes of the studied four facilities, employing the following parameters: infiltration capacities (mm/h), share of pore volume (%) in different materials, material depths (mm), climate factor, rain intensity (l/s/ha), design runoff coefficients (φ)) and design outflow (l/s). The chosen design area and volume of studied facilities are dependent of both the design for quality (pollutant reduction) and quantity (flow and flow detention).

4 CONCLUSION

This study compiles data of pollutant reduction efficiencies from literature studies of grass ditches, swales, infiltration trenches and biofilters. Updated design criteria are also compiled and are being implemented in the stormwater and recipient model StormTac (www.stormtac.com). The criteria as well as the model is being continuously updated by collecting more specific design criteria data from case studies of each facility type, such as facility area, watershed area, runoff coefficients or imperviousness fractions, bypass depth, material depths, pore volumes and infiltration capacities.

LIST OF REFERENCES

Larm T. and Alm H. (2014). *Revised design criteria for stormwater facilities to meet pollution reduction and flow control requirements, also considering predicted climate effects.* Water practice and Technology.

StormTac (2016). *Database with stormwater and baseflow land use specific concentrations, land use specific runoff coefficients and facility reduction efficiencies.* www.stormtac.com.

WEF and ASCE (2012). *Design of urban stormwater controls.* WEF manual of practice No. 23, ASCE manuals and reports on engineering practice No. 87.