
24 hours
3 heavy thunder-storms
60 litres of rain per square metre
Everything under control.
Innovative protection of our property – solutions for state-of-the-art stormwater management systems
Cleaning, infiltration, retention, harvesting – to preserve the natural water cycle.
We care ...
FRÄNKISCHE
FRÄNKISCHE ROHRWERKE
Gebr. Kirchner GmbH & Co. KG | 97486 Königsberg/Germany
Phone +49 (0) 95 25 88 - 4 19 | Fax +49 (0) 95 25 88 - 4 12
www.fraenkische-drain.de

German
DWA Rules and Standards

Advisory Leaflet DWA-M 153E

Recommended Actions for Dealing with Stormwater

August 2007

Handlungsempfehlungen zum Umgang mit Regenwasser

Publisher/Marketing:
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.
German Association for Water, Wastewater and Waste
Theodor-Heuss-Allee 17 · 53773 Hennef · Germany
Tel.: +49 2242 872-333 · Fax: +49 2242 872-100
E-Mail: kundenzentrum@dwa.de · Internet: www.dwa.de

The German Association for Water, Wastewater and Waste (DWA) is intensively involved with the development of reliable and sustainable water management. Being a politically and economically independent organisation it operates specifically in the areas of water management, wastewater, waste and soil protection.

In Europe the DWA is the association in this field with the greatest number of members and, due to its specialist competence it holds a special position with regard to standardisation, professional training and information of the public. The approximately 14,000 members represent specialists and managers from municipalities, universities, consulting engineers, authorities and businesses.

Imprint

Published and sold by:
DWA German Association for
Water, Wastewater and Waste
Theodor-Heuss-Allee 17
53773 Hennef, Germany
Tel.: +49 2242 872-333
Fax: +49 2242 872-100
E-Mail: kundenzentrum@dwa.de
Internet: www.dwa.de

Translation:
Tanja Herzberg, Bochum

Printing (English version):
Vasen Big print, Hennef

ISBN:
978-3-941089-97-6

The translation was sponsored by
Fränkische Rohrwerke.

Printed on 100 % recycled paper

Foreword

Until now, urban drainage meant draining stormwater as quickly and completely as possible from residential areas through either a combined wastewater or stormwater sewerage system. This traditional drainage concept is currently changing. For several years now, there have been attempts to change current systems by using new approaches that consider ecological requirements. The main criticism on conventional drainage concepts is:

- strong decline in evaporation and storage of water in the ground from two thirds to one third of a year's height of precipitation due to the fact that originally vegetated areas are now sealed,
- increased and accelerated runoff from sealed surfaces compared to green spaces,
- shift of the ecological balance in the hydrological cycle with impact on the microclimate and local groundwater recharge,
- hydraulic load on wastewater and stormwater treatment plants due to great volumes of mildly polluted stormwater,
- hydraulic and qualitative impact on waterbodies due to high discharges at the sewage disposal points.

In the past years, retention and infiltration of stormwater were increasingly discussed as an alternative to conventional discharge and propagated as stormwater management (VSA 2002, Standard ATV-A 105E, Sieker 2003). They ease the prime disadvantages of the discharge principle and support the balance of the ecological water cycle. Fundamental considerations regarding stormwater management need to start already during urban land-use planning.

The Advisory Leaflet provides municipalities, those obliged to dispose sewage as well as planners with fundamental considerations regarding urban land-use planning or general drainage planning.

Standard ATV-DVWK-A 198E "Standardisation and Derivation of Dimensioning Values for Wastewater Facilities" made it necessary to adjust the abbreviations used, so that the Advisory Leaflet in the available version was edited; however, the contents corresponds to the version of February 2000.

Authors

This Advisory Leaflet has been elaborated by the Working Group 1.4.3 "Stormwater treatment"; after restructuring the sub-committees, this Working Group now belongs to the sub-committee ES-3 "System-related planning". The following persons contributed to the creation of this Advisory Leaflet:

BRUNNER, Paul Georg	Prof. Dr.-Ing., Karlsruhe
DREISEITL, Herbert	Überlingen
GEIGER, Wolfgang F.	Prof. Dr.-Ing., Essen
GROTTKER, Matthias	Prof. Dr.-Ing., Lübeck
JACOBI, Dieter	Dipl.-Ing., Berlin
JONASSON-SCHMIDT, Anja	Dipl.-Ing., Kamen
KAUL, Gerhard	Dipl.-Ing., Erkrath
LANGE, Gerd	Prof. Dr.-Ing., Oyten
MEIßNER, Erhard	Dr.-Ing., Munich (Spokesperson)
MICHELBACH, Steven	Dipl.-Geogr., Bad Mergentheim
RICHTER, Jürgen	Dipl.-Ing., Münster
ROTH, Hartmut	Dipl.-Ing., Karlsruhe
SCHMITT, Theo G.	Prof. Dr.-Ing., Kaiserslautern
SOPPERT, Hubertus	Dipl.-Ing., Berlin
UHL, Mathias	Prof. Dr.-Ing., Münster

Contribution as guests by:

HÜBNER, Martin	Dr.-Ing., Essen
KUTZNER, Ralf	Dipl.-Ing., Essen
PFEIFER, Rüdiger	Dr.-Ing., Ludwigshafen
WELKER, Antje	Dr.-Ing., Kaiserslautern

Project organiser within the DWA Head Office:

BERGER, Christian	Dipl.-Ing., Hennef Department Wastewater and Water Protection

Content

List of Figures

List of Tables

User Notes

This Advisory Leaflet has been produced by a group of technical, scientific and economic experts, working in an honorary capacity and applying the rules and procedures of the ATV-DVWK and the Standard ATV-DVWK-A 400. Based on judicial precedent, there exists an actual presumption that this document is textually and technically correct.

Any party is free to make use of this Advisory Leaflet. However, the application of its contents may also be made an obligation under the terms of legal or administrative regulations, or of a contract, or for some other legal reason.

This Advisory Leaflet is an important, but not the sole, source of information for solutions to technical problems. Applying information given here does not relieve the user of responsibility for his own actions or for correctly applying this information in specific cases. This holds true in particular when it comes to respecting the margins laid down in this Advisory Leaflet.

1 Scope

The Advisory Leaflet provides municipalities, those obliged to dispose of sewage as well as planners with fundamental considerations regarding urban land-use planning or general drainage planning.

The Advisory Leaflet contains recommendations on the treatment of stormwater in terms of volume and quality in modified drainage or separated systems. It analyses and structures the following complex backgrounds:

- pollution and volume of the stormwater depending on usage and cover of the surface of origin,
- protection requirement of the groundwater,
- protection requirement of surface waters,
- derived from that, the required stormwater treatment that may be necessary prior to infiltration or discharge into surface waters.

While Standard ATV-A 128E regulates the treatment of combined wastewater, the Advisory Leaflet at hand makes suggestions on how stormwater should be treated without mixing it with wastewater.

It contains a simplified assessment method that allows users to take the load of underground and surface water, originating from stormwater of roof areas and of traffic areas, into account in terms of quality and volume for pedestrians, bicyclists and motor vehicles.

The method can also be applied to airfields if the traffic volume of the areas that are used in different ways is correspondingly assigned to an area type of this Advisory Leaflet. In winter, additional considerations are necessary when using de-icers (FGSV-912 1998, BMU 1999). Criteria for areas, where substances that are hazardous to waters are used, as well as railway systems are not included.

Effective protection of waterbodies against immoderate pollution can be expected if stormwater is treated in line with the principles of this Advisory Leaflet. If detailed investigations become necessary for assessing water pollution prevention, certificates of precipitation-discharge models, polluting loads or water quality models that go beyond the scope of this Advisory Leaflet have to be provided.

Standard DWA-A 100E "Guidelines of Integrated Urban Drainage (IUD)" coordinates the individual topics of the field of urban drainage. Further requirements regarding precipitation-discharge calculations can be found in Advisory Leaflet ATV-DVWK-M 165, regarding planning, construction and operation of infiltration systems for precipitation in Standard DWA-A 138E and regarding structures of centralised stormwater treatment and retention in Standard ATV-A 166.

2 Definitions

The following definitions apply for the implementation of this Advisory Leaflet.

Table 1: Definition of basics

Symbol		Unit	Term	Definition
English	German			
A_C	A_E	ha	Catchment area	Area of the catchment area, e.g. area of a wastewater disposal area
$A_{C,p}$	$A_{E,b}$	ha	Paved area	Sum of all paved areas of a catchment area
$A_{C,s}$	$A_{E,k}$	ha	Sewered catchment area	Area of the catchment area that is sewered or defined by a drainage system
A_S	A_S	ha	Infiltration area	Area necessary for infiltration
A_{imp}	A_u	ha	Calculation value impermeable surface	Application-related calculation value for quantifying the part of a catchment area from which the runoff completely enters the drainage system after deducting all loss
B	B	-	Load of the discharge	Pollution of the runoff with substances in relation to the area
b_{Sp}	b_{Sp}	m	Surface width	Mean water surface width for *MQ*
D	D	-	Transist value	Parameter for comparative valuation of individual treatment measures
E	E	-	Emission value	Emission value of the areas affecting the discharge
e_w	e_w	-	Discharge value	Dimensionless discharge value with reference to the particle size of sediments
F	F	-	Type of the area of origin	Typification of areas affecting the discharge according to their substancial pollution
f	f	-	Area percentage	Area percentage of an impermeable sub-area in relation to the impermeable total area
G	G	-	Type of water	Typification of waters in terms of their need for protection
HQ_1	HQ_1	m^3/s	One-year flood discharge	Peak value of the discharge in one year (DIN 4049-3)
h	h	m	Water depth	Mean water depth with *MQ*
k_f-value	k_f-value	m/s	Coefficient of permeability	Flow rate of a liquid through a standard cross-section of a porous material with a standard groundwater gradient and at a defined temperature (DIN EN ISO 772)
Air	L	-	Type of air pollution	Typification of the air according to its substance pollution
MNQ	*MNQ*	m^3/s	Low water discharge	Arithmetic mean of the lowest discharges (DIN 4049-3)
MQ	*MQ*	m^3/s	Mean water discharge (mean discharge)	Arithmetic mean of the discharges within a certain period (DIN 4049-3)
Mq	*Mq*	l/(s·ha)	Mean discharge rate	Discharge rate: quotient of discharge and area of the corresponding catchment area (DIN 4045)
Q_{Thr}	Q_{Dr}	l/s	Throttled discharge	Limitation of the discharge from a storage to a planned maximum value
q_A	q_A	$m^3/(m^2 \cdot h)$; m/h	Flow rate	Volume that passes the system per time unit and in relation to the surface
q_R	q_R	l/(s·ha)	Runoff discharge rate	Runoff of an area in relation to a corresponding area
$r_{(D,n)}$	$r_{(D,n)}$	l/(s·ha)	Rainfall intensity	Rainfall intensity for the duration D and the frequency n
v	v	m/s	Flow velocity	Mean flow velocity for *MQ*
ψ_m	ψ_m	-	Mean discharge coefficient	Quotient of discharge volume and precipitation volume for a defined period
ψ_p	ψ_s	-	Peak discharge coefficient	
Note: A point is used as decimal sign				

3 Principles of Stormwater Management in Urban Areas

3.1 Hydrological Balance in Urban Areas

Figure 1 illustrates the distribution of the total annual precipitation to the sub-parts evaporation, surface discharge and groundwater recharge at the example of the hydrological balance of a town in north west of Munich with an average total annual precipitation of approximately 840 mm. Due to soil sealing on the originally overgrown area (left bar in Figure 1), the surface discharge of private and often even public green areas is separated from the surface waters due to backfill, abrasion, fencing, walling, paths and kerbs. Then, the garden and green areas are no longer connected to the watercourses but usually not to the sewer system either. The original discharge of overgrown areas is retained due to the development of urban areas and is only able to seep away particularly in even catchment areas.

The original surface discharge of overgrown areas (in this example 13 % of the average total annual precipitation) is prevented by the development of urban areas, so that the original groundwater recharge increases to over 24 % with the start of development. With increasing sealing, the increased groundwater recharge declines again, as stormwater is unable to seep on sealed surfaces. At the same time, evaporation decreases due to conversion of forest, grass and field areas into paved ones.

The average sealing level within urban areas usually corresponds to a third to half of all developed areas. For this area, the following facts can be taken from Figure 1:

- evaporation is reduced significantly,
- surface discharge from the entire urban area increases compared to the original value,
- the groundwater recharge rate is still rather high with sealing levels of this kind.

At one single location, the hydrological balance may deviate more or less strongly from Figure 1. Nevertheless, the basic statements apply, which is confirmed by a survey carried out in Berlin where the groundwater recharge rate roughly corresponds to the natural value (GLUGLA 1999). Considering this context, important general aims of a desirable stormwater management in urban areas can be derived.

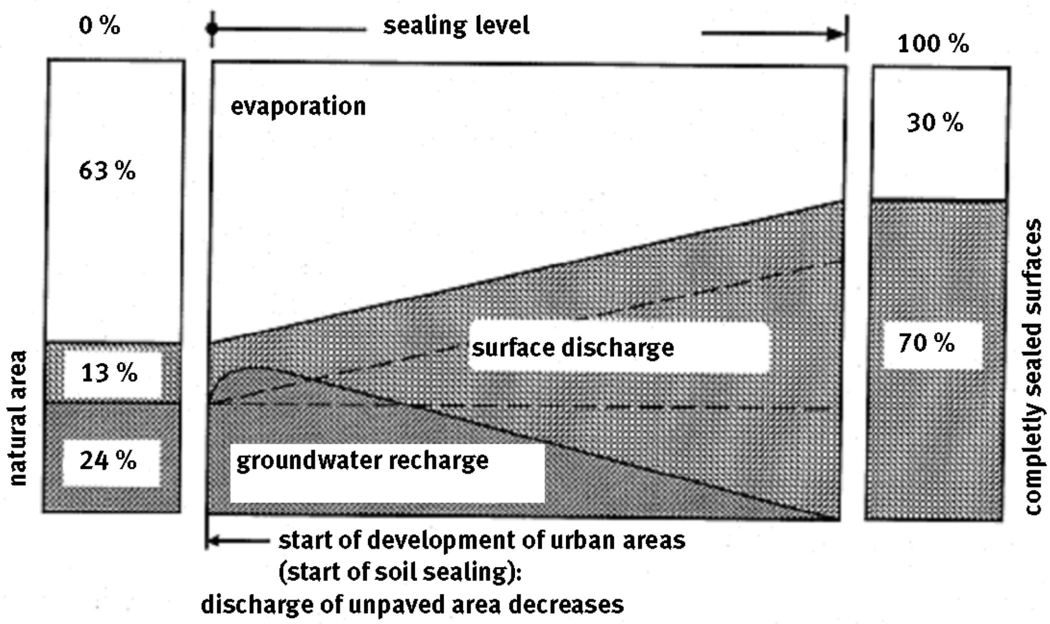


Figure 1: Qualitative change of the hydrological balance of an urban area with increasing development

3.2 Near-natural Handling of Stormwater

The art behind near-nature planning is to approximate the balance of the natural water cycle and the volume and frequency of discharge peaks from undeveloped areas as closely as possibly, and to keep the effort required for creating and maintaining systems of urban area drainage as low as possible. The most effective measure of stormwater management is to keep the number of sealed areas as low and as permeable as possible. In this way, stormwater is still able to seep away laminary at the point of occurrence.

If sealing cannot be avoided, e.g. for road and roof surfaces, attempts should be made to re-distribute the water on a greater area away from the location where it occurs in a very concentrated manner. In many cases, however, only an even smaller area than the original one is available for such distribution and laminar infiltration. In such cases, suitable retention measures need to ensure that the discharge is regulated and thus a smaller area can be used for infiltration.

On a property, laminar infiltration though overgrown topsoil can be achieved by designing garden areas appropriately, e.g. by grass-grown swales. Stormwater from paths, roads and squares should seep away with the smallest possible collection on the sides of the sealed surface. If local conditions, the condition of the subsurface or the volume of the resulting water do not allow laminar infiltration, infiltration via other infiltration systems should be considered depending on the hydrogeological conditions.

Besides the desirable, possibly laminar infiltration, it is also possible to discharge stormwater into sufficiently powerful surface waters. Special importance is attached to retention and throttled discharge. This also applies for discharge from unsealed areas if it can enter the drainage system in the event of intensive precipitation. Discharge from sealed, compacted or saturated urban areas affects flood peaks the stronger the smaller the catchment area of the water; for big rivers, the discharge from sealed areas is lower.

Infiltration and retention of stormwater in and on the area may affect the "home-made" increase in discharge in small waters positively. Even all individuals are given the opportunity to retain water on their land and property. Each cubic metre of water that is retained entails a benefit for nature and eases the local flood situation.

Planning, construction and operation of systems for stormwater infiltration are described in Standard DWA-A 138E. Standard DWA-A 117E regulates the dimensioning of rainwater storage.

3.3 Measures for Ecological Urban Drainage

Near-nature handling of stormwater is achieved by taking the following measures, for example:

- infiltrating away minimally polluted water from roofs on-site via overgrown topsoil,
- keeping construction of access roads in residential areas to a minimum,
- creating grass strips, green areas and woodland next to roads to increase evaporation and for infiltration,
- designing drainage systems as near to nature as possible and using organic material,
- designing slightly dirty traffic areas permeable by using semi-permeable surface sealing such as paving without joint sealant, grass pavers, interlocking pavers, etc. (examples: traffic-calmed and service streets, yards, rarely used car parks, parcel roads),
- extensive infiltration trough overgrown side-strips of roads, paths or squares,
- transferring stormwater through simple gutters and trenches to not directly neighbouring soil areas for retention and evaporation in ponds and plant beds or for infiltration in green areas,
- installing centralised infiltration systems if decentralised infiltration in not possible,
- collecting stormwater is indispensable; it is best done aboveground in overgrown gutters, swales and trenches to enhance retention, evaporation and infiltration,
- retaining stormwater by green roofs, water-filled roofs, ponds, plant beds, swales, trenches with cross bars, etc.,
- storing non-seeped away stormwater in ponds, swales, trenches or cisterns and discharging it into surface waters in a throttled way,
- storing stormwater to use it for various purposes (examples: watering in gardens, public parks, nurseries, tree nurseries, cemeteries, moisturising of tennis courts, riding stables, football grounds, golf courts, ice skating facilities, private and business utilisation of rainwater).

The design options to enhance laminar infiltration are manifold. They should be put into practice by building owners, architects, engineers and planners using fantasy and creativity.

Storages for stormwater utilisation of rainwater can reduce runoff and the use of drinking water, respectively, in the annual balance (BULLERMANN 1996). This includes rain barrels and cisterns. Open water surfaces such as ponds are able to evaporate parts of the discharged stormwater and thus influence the water volume balance positively. All storages require an overflow leading into a infiltration system or discharge system. The influence on the discharge peak in the discharge system depends on the size of the storage and its usage. Storages within the discharge system can result in mechanic cleaning as in a stormwater retention basin.

4 Area Determination

The discharge coefficient ψ_m serves as a basis for calculating the discharge of paved areas. With growing roughness of the cover, the discharge coefficient decreases and the evaporation volume increases. On squares, paths, gardens, lawns and cultivated land, the specific infiltration performance of the in-situ underground has a significant impact on the discharge coefficient.

The decisive impermeable area results from the total of all connected sub-areas, multiplied by the corresponding mean discharge coefficient:

$$A_{imp,i} = A_{C,i} \cdot \psi_{m,i} \qquad (4.1)$$

The area percentage f_i of the impermeable sub-area of the total area is:

$$f_i = \frac{A_{imp,i}}{\sum_{i=1}^{n} A_{imp,i}} \qquad (4.2)$$

4.1 Global Area Determination

In general, a global survey of the paved surfaces that are connected to the discharge location in horizontal projection (e.g. from the maximum permissible sealing according to the development plan) is sufficient for assessing runoff into the groundwater in terms of water management. Areas that are designed permeable to a great extent (e.g. car parks with grass pavers) may remain unconsidered.

The total of all remaining connected sub-areas $A_{C,i}$ results in the searched size of the impermeable area A_{imp}. For this, the discharge coefficient $\psi_m = 1$ is assumed. This is acceptable in that discharge percentages from green areas or other permeable areas enter the discharge point in case of very extreme hights of precipitation, which are then not included in the global determination.

4.2 Differentiated Area Determination

If a more precise determination of the impermeable areas is necessary in certain building measures or in other special cases, the type of paving of all sub-areas has to be known (see Table 2 and VSA 2002). The size of the impermeable partial areas results from equation (4.1).

Note:

The mean discharge coefficients ψ_m according to Table 2 are smaller than the peak discharge coefficients ψ_p. They **are not suitable for dimensioning sewers or larger storages** that are designed for rare overload frequencies.

Table 2: Recommended mean discharge coefficients ψ_m of catchment areas for calculations within the scope of this Advisory Leaflet

Area type	Type of paving	ψ_m
Pitched roof	Metal, glass, slate, fibre cement	0.9 – 1.0
	Brick, roofing cardboard	0.8 – 1.0
Flat roof (inclination up to 3° or approx. 5 %)	Metal, glass, fibre cement	0.9 – 1.0
	Roofing cardboard	0.9
	Gravel	0.7
Green roof (inclination up to 15° or approx. 25 %)	With humus < 10 cm high	0.5
	With humus ≥ 10 cm high	0.3
Roads, paths and squares (even)	Asphalt, concrete without joints	0.9
	Pavement with dense joints	0.75
	Firm gravel cover	0.6
	Pavement with open joints	0.5
	Loose gravel cover, grassed aggregate lawn	0.3
	Composite stones with joints, drain stones	0.25
	Grass pavers	0.15

Table 2 *(continued)*

Area type	Type of paving	ψ_m
Slopes, shoulders and trenches with runoff into the drainage system	Clayey soil Loamy sandy soil Gravel and sandy soil	0.5 0.4 0.3
Gardens, grass and cultivated land with possible runoff into the drainage system	Even area Steep area	0.0 - 0.1 0.1 - 0.3

5 Assessment of the Runoff

The composition of runoff on paved areas differs significantly in terms of dust pollution in the air, area utilisation and precipitation dynamics. If you wanted to record the process of the discharge load precisely regarding location and time in order to forecast water pollution as realistically as possible, the effort connected to this would be disproportionate to the precision that can be achieved in such forecasts.

However, it is desirable to be able to classify the load of the runoff that is to be expected already in the planning stage of the rainwater drainage and the pollution load capacity of the affected waterbody. For this, an assessment method will be introduced by means of which the necessity and the extent of reasonable stormwater treatment can be derived:

- classification of the waterbodies,
- influences from the air,
- pollution of the surface,
- effect of stormwater treatment.

5.1 Classification of Waterbodies

According to § 1a WHG [German Water Resources Act], waterbodies, as part of the ecosystem, have to be managed in such a way that they serve the collective good and the benefit of individuals. As various surveys have shown (Borchardt, Fischer, Mauch 1998), substantial and hydraulic load of runoff from urban areas into waterbodies have different effects depending on the water typology. Regarding their qualitative and hydraulic sensitivity, at least a rough classification of the different water types is therefore necessary. It does not correspond to the typification according to the EC Water Framework Directive but only applies within the scope of this Advisory Leaflet and replaces other natural scientific typifications. Further explanations on water typification according to the EC Water Framework Directive can be found in e.g. Feld, Rödiger, Sommerhäuser, Friedrich (2005).

For distinction, the classifications in Tables A.1a and A.1b are made under general considerations such as water surface width, flow velocity, mean water discharge or special needs for protection. Water types that are not listed should be classified correspondingly. The points for groundwater from Tables A.1.a and A.1.b should be assigned to waterbodies that dry out. When discharging into a waterbody that leads into another waterbody before a major part of the pollution has been degraded, this water needs to be looked at as well.

Spring region

A spring region is understood to be the spring and its direct surroundings. It refers to areas with a particular need for protection, which needs to be coordinated with the water authorities responsible in individual cases.

5.2 Influence from the Air

Depending on the local situation, precipitation is more or less strongly polluted. The substantial pollution can be contained in solute form, e.g. as acid rain, or as particles, e.g. soot. In industrial areas, dust additionally develops due to production, processing, storage and transportation. A more differentiated assessment is generally not necessary for assessing the discharged stormwater from urban areas exhaustively. The global allocation of assessment points according to Table A.2 is sufficient. In founded cases, intermediary values are acceptable.

5.3 Pollution of the Surface

5.3.1 General

Pollution of surfaces is assessed globally depending on their utilisation and material in the case of roofing. To keep pre-investigations as part of a drainage plan to a minimum, assessment points are simply allocated. For special conditions, assessment points need to be modified correspondingly. For inhomogeneous, larger areas, a mean pollution level can be determined via the area percentage of the respective area.

Table A.3 lists utilisation and composition of the individual surfaces that generally result in a certain level of pollution. The basis for the allocation is the actual and the planned utilisation, possibly also the feature of the catchment area by means of the urban land use planning. Founded deviating allocations are permitted. For a rough qualitative assessment, three types can be distinguished:

- Mild polluted areas = 1 to 15 points
- Medium polluted areas = 16 to 30 points
- Heavy polluted areas = 31 to 45 points

5.3.2 Copper-, Zinc- or Lead-covered Roofs

Generally, pollution of roof areas in residential areas is relatively low. Uncoated copper-, zinc- and lead-covered roofs can be considered an exception, as they can show high concentrations of metal in the runoff (not only in the first flush) in the case of acid rain. Until approved treatment measures are available to reduce these metals in the stormwater to be discharged, the assessment method according to Annex A will be applied also for these roof covers. Copper-, zinc- and lead-covered roofs are allocated to area type F6 with 35 points.

Infiltration

If stormwater is to be infiltrated away, it is required to plan a treatment measure in line with the treatment method according to Annex A Table A.4a or A.4b for a sufficient level of groundwater protection. If only small parts of a building's roof area up to a maximum of 50 m^2 of the total roof areas are covered with copper, zinc or lead such as roofing of entrances, dormers or gazebos, these parts may be categorised like the other roof areas in the qualitative assessment. The same applies for guttering and rain pipes.

Discharge into surface water

When discharging stormwater into surface water, it is tolerable within a water or waterside section of 1000 m length to equate the length of the discharge of copper-, zinc- or lead-covered roofs with non-metal roof areas up to a size of 500 m^2. The mean discharge rate of roof areas is a few litres per second and hectares as the annual mean. This gives small waterbodies a sufficient level of dilution to prevent ecological damage (WACHS 1998).

Discharging the stormwater from copper-, zinc- or lead-covered roof areas that are larger than 500 m^2 requires sufficient pre-treatment according to the assessment method provided in Annex A.

5.3.3 Areas in Business Parks and Industrial Estates

Areas in Business Parks and Industrial Estates can be classified according to their utilisation in Table 3, as long as it is not necessary to ensure that potential water pollution substances are handled there. For all other areas, it is recommended to discharge stormwater to a wastewater treatment plant if the water authorities have not defined a special treatment measure prior to infiltration or discharge into surface water for the individual case.

5.3.4 Mixed Areas

The aim of the modified drainage method is not to mix stormwater of areas with highly varying degrees of pollution, but to lead back mildly polluted water without further treatment in a decentralised way into the water cycle and to treat more heavily polluted water prior to discharge, if required.

The assessment method may tempt the user to dilute the discharge of areas with a high degree of pollution with the discharge of areas with a low degree of pollution. Diluting or mixing wastewater with clearly different degrees of pollution is not desired and does not supersede a possibly necessary pre-treatment. When determining the need for treatment, it may only be considered to a limited extent. The assessment method may therefore only combine four neighbouring area types, e.g. F2, F3, F4 and F5, if the water is to be discharged into the same stormwater treatment system (see Table A.3). When determining the decisive discharge pollution of a mixed area that also contains the "heavily" polluted area F6, the "mildly" polluted areas F1 and F2 have to be excluded. This applies also to the determination of the individual parts and the sum according to equation (4.2).

6 Necessity of Stormwater Treatment

6.1 Minimum Limits

Clause 5.3.2 deals with minimum limits for copper-, zinc- or lead-covered roofs. Moreover, the following conditions apply:

Infiltration

Qualitative

Irrespective of the size of the connected, impermeable area, it has to be checked for each infiltration system whether stormwater treatment according to Clause 6.2 is necessary.

Quantitative

The requirements of Standard DWA-A 138E have to be met.

Discharge into Surface Water

Qualitative

When discharging into surface water, stormwater treatment may be dispensed with if the following three conditions are fulfilled:

A: The available waterbody corresponds to water types G1 to G8 (see Annex A Table A.1a),

B: The impermeable areas correspond to area types F1 to F4 (see Annex A Table A.3),

C: Within a water or waterside section of 1000 m length, the stormwater of a total smaller than 0.2 ha (2,000 m^2) of an impermeable area is discharged.

Qualitative

Storages may be dispensed with if at least one of the following three conditions is fulfilled:

D: it is discharged into a pond or lake with a surface not smaller than 20 % of the impermeable area or into a river according to Clause 5.1,

E: the impermeable areas do not exceed 0.5 ha (5,000 m^2) within a water section of 1000 m length,

F: the required total storage volume according to Clause 6.3.4 is smaller than 10 m^3.

6.2 Qualitative Water Pollution

6.2.1 Assessment Method

The basic thought of the assessment method is that emission from areas with separate system is adapted to the need for protection of the groundwater or the surface water. If the runoff from the sum of an urban area's discharge is polluted more heavily than appropriate for the need for protection of the accepting waterbody, the runoff has to be sufficiently cleaned before discharge. Infiltration is also considered a treatment measure if the stormwater passes soil layers of sufficient thickness.

A method for immission-based assessment of runoff from separate and combined systems can be found in BWK-Merkblatt M3, for example.

Each treatment only retains parts of the substancial pollution. Moreover, other cleaning processes occur during a passage through overgrown upper soil than in a stormwater treatment tank or a mechanical filter. Depending on the substance looked at and the chosen treatment, the remaining levels of pollution vary.

For this reason, so-called transist values were defined for the individual treatment measures in global simplification in the given assessment method. Transist values are parameters that allow individual treatment measures to be compared to each other. They do not have a physical or chemical-biological basis, by means of which the measurable cleaning performance of a treatment system could be derived from. Moreover, the effect of retaining individual substances differs too strongly (GOLWER 1991). With this assessment method, it is not possible to prove sufficient protection of waters but to assume it. If particular substantial pollution is to be expected that cannot be covered by this global method, further investigation needs to be carried out or the water has to be led to a wastewater treatment plant.

Annex B contains a form, by means of which the necessity and the extent of a treatment measure can be estimated. The aim of the assessment method is to find the required stormwater treatment measure in order to clean polluted stormwater prior to discharge into the groundwater or surface water to an extent that approximately allows for the water's assumed need for protection:

Emission value $E \leq$ number of water points G.

The emission value E of areas affecting the discharge results from the pollution level of the drained stormwater (discharge pollution B) multiplied by the transist value D of the treatment measure. If there is no stormwater treatment, transist value D = 1:

$$E = B \cdot D$$

with:

E	Emission value
B	Discharge pollution
D	Transist value

The discharge pollution B consists of the air-related pollution Air_i and the pollution of the paved areas F_i. Differently used areas $A_{imp,i}$ are weighted according to their share f_i of the total catchment area A_{imp} of a treatment system:

$$B = \Sigma f_i \ (Air_i + F_i) \qquad (6.1)$$

with

$$f_i = A_{imp,i} \ / \ \Sigma A_{imp,i}$$

The thus determined discharge pollution B of the stormwater is compared to the water points G. If B is greater than G, a stormwater-treatment is usually necessary:

$B > G$	treatment usually required,
$B \leq G$	no treatment required.

The transist values D of treatment measures differ (see Annex A, Tables A.4a, A.4b and A.4c).

If the maximally permissible remaining pollution is adapted to the groundwater or the surface water's assumed need for protection after treatment, the result for the highest permissible transist value is the following:

D_{max} = Water points G / discharge pollution B.

6.2.2 Cascading Treatment Systems

The transist values D_i of cascading treatment systems are multiplied by each other in the case of the following combinations:

- filter system (Table A.4b) and subsequent soil passage (Table A.4a),
- sedimentation system (Table A.4c) and subsequent soil passage (Table A.4a),
- infiltration through several cover layers (Table A.4a).

When combining several sedimentation systems, only the lowest transist value D_i of the best individual system counts.

Notes:

In founded cases, deviations from the given transist values are possible. For systems and processes that are not listed, transist values have to be coordinated with the water authorities.

Infiltration in shafts, pipes or infiltration trenches without previous cleaning through overgrown upper soil passages or filter systems is only permitted in founded exceptional cases, even if a sufficiently low transist value can be calculated in combination with a preceding sedimentation system. Such exceptional cases would be given e.g. in the event of proven low substantial pollution of the runoff or with a particularly high potential of material retention (Standard DWA-A 138E).

6.3 Hydraulic load

Fast runoff from paved, compacted or saturated surfaces can increase flood peaks in surface waters. Suitable measures for retaining, storing and throttled transfer of the water can reduce these unwanted effects.

The discharged water shall not have the effect that the waterbody overtops the banks. In cases of doubt, the runoff discharge rate q_R has to be reduced and the water level of stagnant as well as flowing waters that can be expected has to be calculated. An appropriate free board dimension of 20 cm up to 100 cm has to be taken into consideration depending on the size of the waterbody. When discharging into ponds, sufficient overflow has to be considered.

If discharge of separate or combined sewage systems from residential areas is temporarily stored in larger storages, it may happen that the throttled discharge is drained into a stream for longer than 30 minutes until the storage space is emptied. In this case, the required interspace of subsequent discharge or the maximally permissible throttled discharge of each individual discharge shall be investigated separately. This particularly applies if more than 5 % of the water's natural catchment area have already been sealed at this location. In these cases, the test procedure of the ATV Working Group 2.1.1 has to be followed (ATV 1993, ATV 1997).

The proof of the maximum permissible throttled discharge and the required storage volume at one discharge location can be provided according to the following requirements. More precise statements on hydraulic load can be determined by further surveys near and in the waterbody as well as precipitation-runoff simulations. This is particularly necessary if the following values cannot be met.

6.3.1 Throttled Discharge

To prevent peak discharges, it can become necessary to throttle the runoff for each single discharge into surface water. The function of throttle systems is to discharge a defined volume of water per time flow from retention systems. Retention systems such as flat roofs, ponds, trenches, stormwater tanks, storage capacities, etc. are emptied with delay, limiting the discharge peak from a catchment area. The maximum permissible throttled discharge has to be adapted to the erodibility of the water's sediments.

According to the principle of emission, the runoff discharge rate intensity of impermeable areas has to be limited at each single discharge location depending on the type of the receiving water when the quantitative minimum limit is exceeded (Clause 6.1) (see Table 3). For small flowing waters, this means that the "natural" discharge rate of the originally undeveloped area is usually not exceeded. For larger flowing waters, their hydraulic capacity and the commensurability of costly retention measures are taken into account.

The throttled discharge Q_{Thr} for limiting the discharged peaks at each discharge location is derived from the permissible runoff rate q_R and the impermeable total surface area A_{imp}:

$$Q_{Thr} = q_R \cdot A_{imp} \quad \text{in} \quad \text{l/s} \qquad (6.2)$$

with

q_R in l/(s·ha)

A_{imp} in ha

6.3.2 Maximum Discharge

At streams according to Clause 5.1, a maximum discharge $Q_{Thr,max}$ should not be exceeded considerably at an individual discharge location and not as a sum of several discharge location either. This can be approximated if, within a flow section of approximately 1,000 times the mean water surface width b_{Sp}, the discharge does not exceed the total of $Q_{Thr,max}$. In the streams the flow time of individual discharge peaks in case of thundershowers with a duration of 10 to 30 minutes for these distances is that long that an overlap with discharge peaks from further undercurrent discharges becomes unlikely.

In the case of construction projects near these streams that exceed the minimum limits according to Clause 6.1, thus the maximum permissible discharge $Q_{Thr,max}$ of sealed areas has to be observed. It is calculated by means of the discharge value e_w (Table 4) depending on the particle size of the water sediments and the mean water discharge MQ using the following formula (MICHELBACH, MEIßNER 1999):

$$Q_{Thr,max} = e_w \cdot MQ \cdot 1000 \text{ in l/s} \qquad (6.3)$$

with

e_w Dimensionless discharge value in flowing waters depending on the particle size of the sediments,

MQ Mean water discharge at the location of discharge in m^3/s.

Table 3: Permissible runoff rates of impermeable areas

Type of outlet water		Runoff discharge rate q_R in l/(s·ha)
Small lowland stream	$b_{Sp} < 1$ m, $v < 0.3$ m/s	15
Small hill country and mountain stream	$b_{Sp} < 1$ m, $v \geq 0.3$ m/s	30
Large lowland stream	$b_{Sp} = 1 – 5$ m, $v < 0.5$ m/s	120
Large hill country and mountain stream	$b_{Sp} = 1 – 5$ m, $v \geq 0.5$ m/s	240
Rivers	$b_{Sp} > 5$ m	not limited
Small ponds	surface < 20 % of A_{imp}	analysis of an individual case
Ponds and lakes	surface ≥ 20 % of A_{imp}	not limited

Table 4: Discharge value e_w depending on the particle size

Water sediment	Discharge value e_w
Predominantly loamy-sandy	2 – 3
Gritty (< fist-size)	4 – 5
Stony (> fist-size)	6 – 7

For verified very powerful waterbodies with a stable river bed, an intact interstitial and high re-settlement potential, discharges over 7 times the *MQ* are permitted as well. The annual flood discharge (HQ_1), however, should not be exceeded.

In founded cases, if required by e.g. rare or sensitive species living in the water, the maximum permissible discharge has to be reduced correspondingly despite erosion-resistant river bed. In individual cases, it may become necessary to adapt the maximum permissible throttled discharge to the low water discharge (*MNQ*) of a waterbody. This requires calculations according to models.

6.3.3 Mean Water Discharge

If the local mean water discharge *MQ* for determining the maximum permissible throttled discharge $Q_{Thr,max}$, is not known, *MQ* can be estimated. A simple and frequently used method is the determination of the mean discharge rate *Mq* from the hydrological maps and the calculation of the mean discharge *MQ* by multiplying the discharge rate by the catchment area of the receiving water's up to the discharge location.

If information on the mean discharge peaks or the size of the catchment area is not available, the discharge is determined by measurement. For this, the discharge *Q* of the stream at the location of discharge after several days with no precipitation has to be determined first:

$$Q = v \cdot h \cdot b_{Sp} \quad \text{in} \quad m^3/s \qquad (6.4)$$

with

v Mean flow rate in m/s,

h Mean water depth in m,

b_{Sp} Mean water surface width in m.

Afterwards, the discharge Q_{level} is measured at the next discharge level that is located downstream on the same day or it is taken from the level records for this day. Calculating the quotient of the long-term mean water discharge MQ_{level} at the level and the discharge Q_{level} on the day of the measurement and multiplying it by the discharge *Q* at the location of discharge with the ratio results in the approximate mean water discharge *MQ* for this location of discharge.

If a discharge level is missing in reasonable distance to the location of measurement, discharge *Q*, which was calculated by means of equation (6.4), is assumed as the mean water discharge *MQ*.

6.3.4 Storage Volume

Depending on the permissible throttled discharge, a more or less high storage volume has to be available in order to temporarily store precipitation discharge. The required volume depends on three factors:

- local precipitation conditions,
- size of the impermeable area,
- permissible throttled discharge of the storage,
- desired protection against overdammed backwater.

It can be calculated according to the requirements of Standard DWA-A 117E.

7 Measures

7.1 Effect of the Measures

Stormwater treatment is understood to be any natural or artificially caused process that leads to a reduction of substancial pollution. For example, laminar infiltration via the shoulders of a road can be considered a way of treatment, since the stormwater is more or less cleaned after passing the overgrown cover layer.

In Tables A.4a, A.4b and A.4c, so-called transist values are assigned to systems for infiltration, filtering and sedimentation. They assess the proportion of not retained discharge pollution that can either be given solute as well as in the form of particles in a relative way. It is not possible to derive a measurable level of efficiency for any substance from this, since substances of different nature are retained in different ways, e.g. solute minerals, organic compounds or mineral sediments. Transist values simply serve as qualitative ranking of the treatment system to achieve appropriate treatment before the stormwater seeps away or is discharged.

7.2 Soil passages

When passing soil layers, physical, chemical and possibly even biological processes retain pollutants from the passing stormwater, which are either stored or degraded (Standard DWA-A 138E). The absorptive capacity and the homogeneity of the effective soil layer as well as the biological activity are decisive for the cleaning performance. If pollution remains low in terms of hydraulics and load, siltation, stagnant moisture and exceeding of the degrading capacity can be prevented. Backwashing and thus targeted regeneration is not possible in the case of soil passages.

Passage through overgrown soil is significantly more effective than through soil zones that are not overgrown. Overgrown upper soil is naturally loosened in the root region where various pollutants are degraded and absorbed more extensively. Soil that is not overgrown or only covered by mulch is not sufficient for appropriately protecting the groundwater against polluted runoff.

For decentralised infiltration, generally a k_f-value $> 1\times10^{-6}$ m/s is required, for infiltration in the side areas of sealed surfaces $k_f > 2\times10^{-5}$ m/s. For centralised infiltration systems, a k_f-value $> 1\times10^{-5}$ m/s should not be underrun.

The soil used for infiltration must not be polluted beforehand (e.g. brownfields). A sufficient level of cleaning is achieved when the natural upper soil shows the following values:

- pH-value 6-8,
- humus concentration 1 % to 3 % and
- clay concentration under 10 %.

All required features of the upper soil should be confirmed by an expert prior to delivery.

Infiltration through overgrown upper soil is the favoured solution. Hydraulic overload can be met with constructive measures. Overgrown upper soil can be included for extensive laminar infiltration on green areas, swale infiltration and for infiltration basins without constant damming. The thickness of the unsaturated soil layer between the upper edge of the upper soil and the mean groundwater level should usually be at least 1 m for extensive laminar infiltration and swale infiltration. The requirement of a minimum interspace between the groundwater and the area used for infiltration ensures utilisation of the soil as a filter for stormwater treatment.

Underground infiltration systems (infiltration through infiltration trenches, pipes or shafts) can only be tolerated in extremely limited areas of application, e.g. for unproblematic roofing in residential areas with low pollution of the air. Requirements regarding the minimum interspace between the bottom of the underground infiltration systems and the groundwater can be found in DWA-A 138E.

The thickness of a cover layer above the groundwater determines the operational safety of a infiltration system und the duration until the break-through of noteworthy pollution rates. With increasing permeability, the required thickness of the soil layer increases in order to fulfil the function over a sufficient period.

Note:

The construction of infiltration systems shall not cause blocking, groundwater-protecting cover layers (e.g. extensive loam layers) to be penetrated.

7.3 Filter Systems

Filter systems are used for pre-treatment and filtration of stormwater (combination of stormwater treatment and filter basins). It is mandatory to remove settleable substances and light substances in the first preceding sedimentation system. In the simplest case, a filter system removes particulate substances. By means of the filter material, the thickness of the filter as well as influencing the retention period, solute substances can be removed besides particulate substances by means of biological processes and adsorption (soil filter). Moreover, the retention effect of the filter system has the effect that the waterbody is hydraulically eased, hydrobiological stress is reduced and the low water discharge is increased due to the long tailings.

Filter systems are usually built by excavation. The invert is sealed against the underground and drainage is included. The discharge is led to the waterbody in a throttled way. A filter layer, which is usually planted, is located above the drainage. A storage has to be planned in addition (BRUNNER 1998). Notes on planning, construction and operation of retention soil filter systems can be found in Advisory Leaflet DWA-M 178.

7.4 Sedimentation Systems

Systems with settling compartment are referred to as sedimentation system. Here, the flow conditions allow substances with a higher weight density than that of water to sink and substances with a lighter weight density to float. Constructive notes can be found in Standard ATV-A 166; Advisory Leaflet ATV-DVWK-M 176 gives examples.

If possible, retained solid matter should not be re-mixed with another wastewater stream (e.g. with municipal wastewater) to prevent the concentrated solid matter and thus the pollutants from spreading in the sedimentation system. Drainage and classification as well as subsequent storage or utilisation of the solid matter are suitable as specific treatment (cf. disposal of solid matter from gully or street cleaning). The ideal solution in terms of water management and economic efficiency has to be found in the individual case by considering the local conditions.

Stormwater treatment tanks are particularly effective for water protection if very fine fractions are also separated to a great extent before draining the stormwater that was mechanically treated via the overflow structure for settled combined water. The settled sediment should not be dispersed again even under very high hydraulic loads and should not be mixed with the flow. Only this way, exit via the overflow structure for settled combined water can be avoided.

Stormwater treatment tanks without permanent damming (ATV-A 166) are emptied and cleaned after each damming case. This requires a temporarily opened connection to a sewer or combined sewer.

Stormwater treatment tanks with permanent damming (ATV 1995a, ATV-A 166) are only emptied at long intervals for cleaning and inspection.

Ponds (GEIDER, DREISEITL 2001) are a type of stormwater treatment tanks with permanent damming designed in a near-nature way as earth basins. They also enhance biological cleaning. A preceding sludge trap is advantageous for operation.

Hydrodynamic separator systems (BROMBACH, WEIß 1997; HÜBNER 1997) are a special type of stormwater treatment tanks without permanent damming designed as solid tanks. They are round basins with tangential inlet. This creates a stable rotating current that leads to a cleaning of the basin invert and a gathering of the sediment in a sludge storage placed in the centre of the basin. Hydrodynamic separator systems are thus less sensitive to resuspension of settled solid matter than other types of stormwater treatment tanks without permanent damming. They are particularly suitable for small catchment areas (WEIß, BROMBACH 2000).

Stormwater retention systems (Standard DWA-A 117E) with basin shape and with a convenient design of the inlet and discharge can achieve a good cleaning performance with mostly high volume, if the exit of solid matter is prevented when emptying. If a permanent damming remains in a part of the basin after the precipitation has stopped, floating solids and light liquids can be retained by a scumboard. For stormwater retention tanks that are emptied completely after precipitation has stopped, a subsequent separator can be charged with the throttled discharge from the tank.

Settling plants (FGSV-539) are built prior to swales and basins used for infiltration to reduce sludge on the infiltration area and thus to maintain operation of the infiltration systems. Settling plants are used for sedimentation of settleable substances exceeding approx. 0.1 mm of particle diameter.

Light substance separators (FGSV-514) are predominantly used for retaining water-endangering substances. Light substance separators according to RiStWag (FGSV-514) can be used for stormwater treatment in combination with stormwater retention tanks.

7.5 Chemical-physical Treatment

Using chemicals for precipitation and coagulation improves the retention of solute and fine-particulate substances. While precipitation is a transition processes, in coagulation, solid matter with small particle diameters turns into greater solid compounds. Precipitation and coagulation require defined process conditions that can be met with relatively low effort in many applications.

The solids compounds developed by precipitation and coagulation can be separated by means of sedimentation, flotation or filtration. In existing stormwater treatment tanks, precipitation and coagulation allow the retention of solid matter to be increased significantly. The advantage of chemical-physical systems is the high level of retention regarding substances and the controlled, high discharge stability.

Surveys carried out in Berlin (HEINZMANN 1995) and Karlsruhe, Germany (PFEIFER 1998) prove that they can also be used for treating stormwater. The increased financial and operational effort in comparison to other methods justifies the use if special requirements regarding water quality make a high level of retention of substances from separated areas necessary. In individual cases, transist values have to be coordinated with the water authorities.

8 Planning of Runoff in Urban Areas

Planning runoff in urban areas has evolved from a mere drainage task into a management task, which is to be solved carefully by early, close coordination with other disciplines involved in the planning. For successful integration into urban land-use planning, the following procedure has proven.

8.1 Designation of Construction Areas

Areas for expansion (land-use planning) should be defined by paying particular attention to the necessary technical development effort and the available water situation. The areas for building, stormwater treatment or other purposes have to be coordinated previously with the concerns of urban, environmental landscape and traffic planning as well as urban areas drainage and water management. Particularly near-surface stream and arrangement of infiltration systems that are adapted to the topography have to be coordinated carefully with the other parties interested in the planning. In larger construction areas, it can be reasonable to develop model solutions that are made available to public infrastructure providers, clients and architects in a practical-guide as a tool or framework.

The following aspects have to be considered when assessing suitability and selection of areas:

- topography,
- ground and surface waters,
- hydrological situation,
- protective areas,
- brownfield potential,
- contamination of the surface runoffs,
- existing drainage systems,
- possible drainage concepts,
- possible stormwater treatment,
- development costs.

8.2 Notes on the Planning Procedure

According to the preliminary planning approval by resolution according to § 2 paragraph 1 BauGB [German Town and Country Planning Code], an initial discussion with all responsible authorities such as the real estate office, town planning office, housing office, environmental office, parks department and the agencies for public concerns is mandatory.

The framework for area drainage and water protection should be presented in a survey on urban drainage with reference to Advisory Leaflet ATV-M 101E. The survey has to contain a hydrogeological assessment of soil and groundwater conditions in the area of the planned buildings. The inclusion of the retention principle has to be clarified thoroughly by

- decentralised or centralised infiltration,
- delayed, near-nature discharge.

The results of the survey on urban drainage are part of the requirements regarding the draft for urban land use. The requirements may include:

- statement on areas that are sensitive to water management (surface water, groundwater),
- drainage conception,
- anchors in terms of water management,
- favoured location for building structure and development,
- statements on the building shape and grouping in terms of a beneficial surface water stream in the area.

In the case of urban planning competitions and drafts, it has proven advantageous to consult experts from the following fields:

- environmental engineering,
- traffic,
- energy,
- immission protection/noise protection,
- green area planning.

This ensures that the various concerns are included into the planning as arguments at an early stage. The urban planning draft is then discussed with the municipal authorities and modified, if necessary.

8.2.1 Creation of the Land-use and General Drainage Plan

Parallel to the land-use plan, a general drainage plan has to be created based on the survey on urban area drainage. The following has to be included in the general drainage plan:

- concept of area drainage,
- certified feasibility in the context of town planning,
- designation of position and size of areas required for infiltration, retention or delaying discharge as well as treatment of the runoff,
- suggestions for required regulations, notes and explanations in the land-use plan,
- comparison of variants and costs.

It has to be ensured that the general drainage plan conforms to municipal regulation law, water acts and possibly civil law. If detailed regulations of rainwater drainage are not requested in the land-use plan, the areas and/or processes required for infiltration or delaying discharge can be secured by:

- designation of the areas as public property,
- amendments to property purchase agreements,
- registration of easement on real estate in the land and property register,
- certification as part of the building permit.

Anyway, the land-use plan should point at the intended way of regulation.

8.2.2 Planning the Area Drainage

After having completed the land-use plan process, the draft and execution planning is developed for area drainage (wastewater and stormwater). In all cases, the planning has to be coordinated with

- the regulatory authority (e.g. lower water authority, federal environmental agency, lower district authority),
- the real estate office (purchase or sale of land, possibly required additional agreements in land purchase agreements),
- agency for municipal taxes (fees, development charges),
- utilities (alignment, construction processes).

For successful realisation of infiltration or delaying discharge, it is recommended that the planning be coordinated in close cooperation with

- landscape planners,
- traffic planners,

- architects,
- public infrastructure providers/clients.

Stormwater can be included as a stimulating element in an interesting way of landscaping. From a planning and constructive point of view, the long-term functioning of the land and area drainage functions with the usual comfort has to be paid attention to. The planner responsible for the area drainage has to ensure that the contributions of other parties involved in the planning serve the realisation of water management objectives.

9 Dimensioning of Storm-Water Treatment Systems

For economic reasons, stormwater treatment systems are not dimensioned for the maximum inlet volume from stormwater sewer systems or the drainage area. The difference between the maximum inlet volume and the permissible load has to be balanced in a stormwater retention storage or has to be discharged into the waterbody via a bypass without further treatment.

In this case, in a infiltration system, for example, storage and filter can be combined in one building. By planning from an economic point of view, the stormwater treatment system is better used by a preceding stormwater retention storage than by a system without storage. The discharge route has to be checked as to whether the entire system is overloaded in order to be able to estimate possible dangers of flooding.

Sedimention tanks and filter systems are dimensioned for rainfall intensity at which the stormwater overflow will come into action rated of at least 15 l/s per hectare of impermeable area. The annual mean-flow is clearly below this value with 3 (l/s·ha) to 5 (l/s·ha). For the described measures, dimensioning with the aim of observing given substantial limiting values has hardly been possible until now. Design values are given instead, such as retention time, flow rate, layer thickness and permeability. In this case, the boundary conditions of the testing facilities and large-scale surveys, from which the design values were derived, should be taken into account when transferring them to planned construction measures.

Thus, the flow rate refers to the evenly horizontally streamed building part with more or less constant flow cross-section, the overgrown soil layer refers to an active layer that regenerates within a short period without blocking up or developing larger anaerobic zones, and the thickness of a filter layer refers to the homogeneous, undisturbed filter body. For the dimensioning of individual treatment systems, please see the literature listed in Table 5.

Table 5: Literature on the dimensioning of stormwater treatment systems

Treatment system	Dimensioning according to literature
Laminar infiltration	DWA-A 138E, GEIGER/DREISEITL (1995)
Infiltration through swales	DWA-A 138E, GEIGER/DREISEITL (1995)
Infiltration basins	DWA-A 138E, RAS-Ew, LANGE/SCHEUFELE (1987)
Retention soil filter systems	DWA-M 178, BRUNNER (1998)
Passage through vegetation, trenches	BUWAL (1996)
Street outlets	FGSV-539 (RAS-Ew)
Light liquid separators	FGSV-514 (RiStWag)
Hydrodynamic separators	BROMBACH/WEIß (1997), GEIGER/USTOHAL (1998)
Settling plants	ATV (1995b), FGSV-539 (RAS-Ew)
Stormwater treatment tanks	ATV-A 166, ATV (1995a)
Stormwater retention systems	DWA-A 117E

10 Cost Effects

Compared to the existing regulations of the individual Federal German states, no additional costs can be expected for these recommended actions. Moreover, the variety of the treatment options suggested allows economically efficient planning.

So far, experience has shown that it does indeed make sense to compare the costs of modified methods with conventional solutions. Modified systems offer additional advantages that are hard to assess in terms of costs. They include e.g.:

- reduction of discharge peaks in waterbodies caused by urban areas,
- possibly further reduction of pollution loads in waterbodies,
- improvement of the microclimate in residential areas,
- increase of the quality of life if stormwater becomes visible again and can be experienced in gutters, swales and ponds.

The construction costs for an environmentally friendly handling of stormwater vary significantly, depending on what needs to be done in the individual case. Influencing factors include e.g.:

More competitive	More costly
Multiple usage of available green spaces	Additional land purchase
Individual system for each property	Linked system and entire specific land use area
Development of new building areas	Later conversion of old buildings
Execution with personal labour	Execution by professionals
Separating stormwater from the sewerage system	Utilisation of rainwater for domestic and industrial purposes
etc.	etc.

To make costs for environmentally friendly handling of stormwater comparable with the costs for conventional discharge systems, costs have to be determined in every individual case due to the local conditions.

Literature

Laws

Baugesetzbuch (BauGB) *[German Town and Country Planning Code]* – German Town and Country Planning Code as of the announcement of 25 Sept 2004. BGBl. I pp. 2414

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. ABl. L 327 as of 22 Dec 2000, pp. 1–73

Wasserhaushaltsgesetz (WHG) *[German Water Resources Act]* as of the announcement of 19 Aug 2002. BGBl. I p. 3245

Technical Regulations

DWA Set of Rules

DWA-A 100E (December 2006): Guidelines of Integrated Urban Drainage (IUD)

DWA-A 105E (December 1997): Selection of the Drainage System

DWA-A 117E (April 2006): Dimensioning of Stormwater Holding Facilities

ATV-A 128E (April 1992): Standards for the Dimensioning and Design of Stormwater Structures in Combined Sewers

DWA-A 138E (April 2005): Planning, Construction and Operation of Facilities for the Percolation of Precipitation Water

ATV-A 166 (November 1999): Bauwerke der zentralen Regenwasserbehandlung und -rückhaltung – Konstruktive Gestaltung und Ausrüstung *[Structures of Centralised Stormwater Treatment and Retention – Constructive design and Equipment]*

ATV-DVWK-A 198E (April 2003): Standardisation and Derivation of Dimensioning Values for Wastewater Facilities

ATV-DVWK-A 400 (July 2000): Grundsätze für die Erarbeitung des ATV-DVWK-Regelwerkes *[Principles for the Preparation of German ATV-DVWK Standards]*

ATV-M 101E (May 1996): Planning of Drain and Sewer Systems; New Construction, Rehabilitation and Replacement

ATV-DVWK-M 165 (January 2004): Anforderungen an Niederschlag-Abfluss-Berechnungen in der Siedlungsentwässerung *[Requirements regarding Precipitation-Discharge Calculations in Urban Area Drainage]*

ATV-DVWK-M 176 (February 2001): Hinweise und Beispiele zur konstruktiven Gestaltung und Ausrüstung von Bauwerken der zentralen Regenwasserbehandlung und -rückhaltung *[Notes and Examples of Constructive Design and Equipment of Structures Used for Centralised Stormwater Treatment and Retention]*

DWA-M 178 (October 2005): Empfehlungen für Planung, Bau und Betrieb von Retentionsbodenfiltern zur weitergehenden Regenwasserbehandlung im Misch- und Trennsystem *[Recommendations on Planning, Construction and Operation of Retention Soil Filters for Extensive Stormwater Treatment in Combined and Separated Systems]*

DVWK-Regel 136 (1999): Bodenkundliche Untersuchungen im Felde zur Ermittlung von Kennwerten zur Standortcharakterisierung; Part III: Ableitungen zum Wasser- und Lufthaushalt von Böden *[Pedological Field Investigations for Determining Characteristic Values regarding the Characerisation of Locations, Part III: Derivations regarding the Water and Air Balance in Soils]*

Other Technical Rules

BWK M 3 (July 2004): Ableitung von immissionsorientierten Anforderungen an Misch- und Niederschlagswassereinleitungen unter Berücksichtigung örtlicher Verhältnisse. Pfullingen: Bund der Ingenieure für Wasserwirtschaft, Abfallwirtschaft und Kulturbau (BWK) e. V.

DIN 4049-3 (October 1994): Hydrology – Part 3: Terms for the quantitative hydrology

FGSV-514 (2002): RiStWag-Richtlinien für bautechnische Maßnahmen an Straßen in Wasserschutzgebieten

FGSV-539 (2005): RAS-Ew-Richtlinien für die Anlage von Straßen – Teil: Entwässerung mit RAS-Ew-Bemessungshilfen auf CD-ROM

FGSV-912 (1998): Merkblatt für die Entwässerung von Flugplätzen

VSA (2002): Richtlinie zur Versickerung, Retention und Ableitung von Niederschlagswasser in Siedlungsgebieten. Zürich: Verband Schweizer Abwasser- und Gewässerschutzfachleute

Further Reading

ATV (1993): Weitergehende Anforderungen an Mischwasserentlastungen. 1. Arbeitsbericht der ATV-Arbeitsgruppe 2.1.1: Grundlagen und Vorprüfung. In: KA – Korrespondenz Abwasser (1993), Volume 5, pp. 802–806

ATV (1995a): ATV-Handbuch: Bau und Betrieb der Kanalisation. 4th edition, Ernst & Sohn, Berlin 1995

ATV (1997): Weitergehende Anforderungen an Mischwasserentlastungen, Grundlagen und Vorprüfung (2. Teil) sowie Hinweise zur biologische Beurteilung mischwasserbelasteter Gewässer. 2. Arbeitsbericht der ATV-Arbeitsgruppe 2.1.1. In: KA – Korrespondenz Abwasser (1997), Volume 5, pp. 922–927

BMU (1999): Enteisungsabwasser von Flughäfen – Hinweise. Arbeitsgemeinschaft Deutscher Verkehrsflughäfen (ADV). Stuttgart: Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

BORCHARDT, D.; FISCHER, J.; MAUCH, E. (1998): Auswirkungen von Mischwasserentlastungen auf den Stoffhaushalt und die Biozönose von Fließgewässern. Ökologische und wasserwirtschaftliche Folgerungen. In: GWF Wasser Abwasser (1998), Volume 7, pp. 418–423

BROMBACH, H.; WEIß, G. (1997): Wirbelabscheideranlagen. Handbuch Wasser 4, Vol. 5. Karlsruhe: Landesanstalt für Umweltschutz Baden-Württemberg

BRUNNER, P. G. (1998): Bodenfilter zur Regenwasserbehandlung im Misch- und Trennsystem. Handbuch Wasser 4, Vol. 10. Karlsruhe: Landesanstalt für Umweltschutz Baden-Württem-berg

BULLERMANN, M.; KLEIN, B. (1996): Regenwassernutzung in privaten und öffentlichen Gebäuden – Qualitative Aspekte. Schriftenreihe fbr, Vol. 2, Darmstadt

BUWAL (1996): Gewässerschutzmaßnahmen beim Straßenbau – Grundlagenbericht. Schriftenreihe Umwelt no. 263 – Gewässerschutz. Bern: Bundesamt für Umwelt, Wald und Landschaft

FELD, C. K.; RÖDIGER, S.; SOMMERHÄUSER, M.; FRIEDRICH, G. (2005): Typologie, Bewertung, Management von Oberflächengewässern – Stand der Forschung zur Umsetzung der EG-Wasserrahmenrichtlinie. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung (Nägele u. Obermiller)

GEIGER, W. F.; DREISEITL, H. (2001): Neue Wege für das Regenwasser: Handbuch zum Rückhalt und zur Versickerung von Regenwasser in Baugebieten. 2nd edition, Munich: Oldenbourg

GEIGER, W. F.; USTOHAL, P.: Ermittlung des rechnerischen Speichervolumens eines hydrodynamischen Abscheiders. Fachgebiet Siedlungswasserwirtschaft und Abfallwirtschaft, Universität-GH Essen. Forschungsbericht (1998). ATV-Forschungsfond, Project no. 10/97

GLUGLA, G. et al. (1999): Langjährige Abflussbildung und Wasserhaushalt im urbanen Gebiet Berlin. In: Wasserwirtschaft (1999), Vol. 1, pp. 34–42

GOLWER, A. (1991): Belastung von Böden und Grundwasser durch Verkehrswege. Forum Städte-Hygiene 42 (1991), Vol. 5, pp. 266–275

HEINZMANN, B. (1995): Weitergehende Aufbereitung von städtischen Regenabflüssen durch Flockung. In: GWF Wasser, Abwasser (1995), Vol. 2, pp. 67 ff.

HÜBNER, M. (1997): Beurteilung und Ermittlung der Wirkungsweise von Anlagen zur Regenwasserbehandlung. Vol. 10, Forum Siedlungswasserwirtschaft und Abfallwirtschaft Universität Essen

LANGE, G.; SCHEUFFELE, G. (1987): Untersuchungen über den zeitlichen Verlauf der Versickerungsleistung von Versickerungsbecken und die Möglichkeiten einer Beeinflussung. Forschung Straßenbau und Straßenverkehrstechnik (1987), Vol. 515

MICHBACH, S.; MEIßNER, E. (1999): Begrenzung des Regenabflusses aus Siedlungen. In: KA – Korrespondenz Abwasser (1999), Vol. 6, pp. 910–918

PFEIFER, R. (1998): Schmutzstoffrückhalt durch chemisch-physikalische Regenwasserbehandlung im Trennsystem. Schriftenreihe des Instituts für Siedlungswasserwirtschaft, Universität Karlsruhe Vol. 92. Munich: Verlag Oldenburg

SIEKER, F. et al. (2003): Naturnahe Regenwasserbewirtschaftung in Siedlungsgebieten: Grundlagen und Anwendungsbeispiele; Neue Entwicklungen. 3rd edition. Renningen: expert-Verlag, p. 228

WACHS, B.: Ökobewertung der Schwermetallbelastung von Fließgewässern mittels Pflanzen- und Zoobenthon-Arten. In: Münchener Beiträge zur Abwasser-, Fischerei- und Flussbiologie (1998), Vol. 51, pp. 534–585

WEIß, G.; BROMBACH, H: Regenwasserbehandlung mit Wirbelabscheidern. In: KA – Wasserwirtschaft, Abwasser, Abfall (2000), Vol. 12, pp. 1793–1800

Sources of supply

DWA-Publications:
German Association for
Water, Wastewater and Waste, Hennef, Germany

DIN standards: Beuth Verlag GmbH, Berlin

FGSV set of regulations: FGSV Verlag GmbH, Cologne

Annex A Tables for the Assessment Method

Table A.1a: Assessment points for waterbodies (G) with normal need for protection

Water locations			
Type of water	**Examples**	**Type**	**Points**
Sea	Open coast region	G1	33
Flowing waters	Big river ($MQ > 50$ m³/s)	G2	27
	Small river ($b_{Sp} > 5$ m)	G3	24
	Big hill country and mountain stream ($b_{Sp} = 1–5$ m; $v \geq 0.5$ m/s)	G4	21
	Big lowland stream ($b_{Sp} = 1–5$ m; $v < 0.5$ m/s) Small hill country and mountain stream ($b_{Sp} < 1$ m; $v \geq 0.3$ m/s)	G5	18
	Small lowland stream ($b_{Sp} < 1$ m; $v < 0.3$ m/s)	G6	15
Stagnant and submerged waters	Shut off sea bay Big lake (over 1 km² surface) Submerged big river ($MQ > 50$ m³/s)	G7	18
	Submerged small river[1)] Bog waters	G8	16
	Submerged big hill country and mountain stream[1)]	G9	14
	Submerged great lowland stream[1)] (see also G24)	G10	12
	Small lake, pond (under 500 m² surface) Submerged small streams[1)]	G11	10
Groundwater	Outside of drinking water catchment areas	G12	10
	Karst areas without connection to drinking water catchment areas (evidence required)	G13	8

1) Submerged waters are usually classified behind the head of reservoir

Table A.1b: Assessment points for waters (G) requiring special protection

Water locations			
Type of water	**Examples**	**Type**	**Points**
Flowing waters	Less than 2 h flow time for *MQ* up to the next water protection area with bank filtration	G21	14
	Less than 2 h for *MQ* up to the next small lake		
	Discharge within a water protection area with bank filtration	G22	11
	Bathing waters		
Stagnant and very slowly flowing waters	Discharge into lakes in direct proximity of recreational areas	G23	11
	Flow rate for *MQ* under 0.10 m/s, except bog waters (see G8)	G24	10
Groundwater	Water protection zone III B	G25	≤ 8 [1)]
	Water protection zone III A	G26	≤ 5 [1)]
	Karst areas (see also G13)	G27	≤ 3 [1)]
	Water protection zone II [2)]		
Particularly sensitive waters	Water protection zone I	G28	0
	No discharge should take place in waters of quality class I and in spring zones		

1) Regulation for individual cases required (see also FGSV-514: RiStWag)
2) Infiltration in water protection zone II is usually not bearable

Table A.2: Assessment points for influence from the air (L)

Loads from the air			
Air pollution	**Examples**	**Type**	**Points**
Low	Urban areas with small traffic volume (average daily traffic below 5,000 passenger motor vehicles/24 h)	Air1	1
	Roads outside urban areas		
Medium	Urban areas with medium traffic volume (average daily traffic 5,000 to 15,000 passenger motor vehicles/24h)	Air2	2
Strong	Urban areas with high traffic volume (average daily traffic over 15,000 passenger motor vehicles/24h)	Air3	4
	Urban areas with regular domestic fuel (e.g. wood, coal)		
	In the sphere of influence of commerce and industry with dust emission caused by production, processing, storage and transportation	Air4	8

Table A.3: Assessment points of runoff depending on the area of origin (F)

Load from the area			
Area pollution	**Examples**	**Type**	**Points**
Low	Green roofs, gardens, grass and cultivated land with possible runoff into the drainage system	F1	5
	Roof areas[1)] and terrace areas in housing areas and comparable industrial estates	F2	8
	Cycle tracks and foot paths outside the spray area of roads (clearance over 3 m)	F3	12
	Courtyard areas and car parks without frequent change of vehicles in housing areas and comparable industrial estates		
	Less frequented traffic areas (up to 300 passenger cars/24h) in housing areas and comparable industrial estates, e.g. residential roads		
Medium	Roads with 300 to 5,000 passenger cars/24h, e.g. service, access and county roads	F4	19
	Backyard areas car parks without frequent vehicle change in mixed areas and industrial estates[2)]	F5	27
	Roads with 5,000 – 15,000 passenger cars/24h, e.g. main roads		
Strong	Car parks with frequent vehicle change, e.g. of shopping centres	F6	35
	Roads and squares with heavy pollution, e.g. due to agriculture, haulage companies, horse stables, markets		
	Roads with over 15,000 passenger cars/24h, e.g. main roads of supra-regional importance, motorways		
	Highly frequented lorry approaches in industrial estates and similar areas, e.g. landfill sites	F7	[3)] 45
	Lorry car parks		

1) Copper-, zinc- or lead-covered roof areas are to be regulated according to Clause 5.3.2.

2) Turnover areas in industrial estates are to be regulated individually

3) Infiltration only permitted with control option after cleaning

Table A.4a: Transist values (D) in the case of laminar infiltration

Transist values in the event of soil passages					
Examples	Type	Area pollution 1) $A_{imp} : A_S$			
		a	b	c	d
Infiltration through 30 cm overgrown upper soil	D1	0.10	0.20	0.45	2)
Infiltration through 20 cm overgrown upper soil	D2	0.20	0.35	0.60	2)
Infiltration through 10 cm overgrown upper soil Paving stones and grass pavers with overgrown upper soil 3)	D3	0.45	0.60	0.80	2)
Soil passage under swales, infiltration trenches, shafts or similar through laminary consistent cover layers of at least • 3 m thickness, permeability $k_f = 10^{-4}$ to 10^{-6} m/s (e.g. fine sand, silty sand, sandy silt) • 5 m thickness, permeability $k_f = 10^{-3}$ to 10^{-4} m/s (e.g. sandy gravel, coarse sand, medium sand)	D4	0.35	0.45	0.60	0.80
Extensive infiltration through impermeable surfaces on an at least 30 cm thick frost-resistant superstructure such as • paving with non-overgrown, permeable areas • porous surfaces (e.g. drain concrete pavers) • checker or honeycomb bricks filled with crushed sand	D5	0.80	1.00		
Extensive infiltration without considering further soil passage through • smaller cover layers than named in group D4 • infiltration trenches, infiltration shafts, gravel or similar	D6	1.00			

1) **Explanation of the area loads $A_{imp} : A_S$ in columns a to d**
(relation of the impermeable area A_{imp} to the infiltration area A_s)
a: ≤ 5:1 — usually wide infiltration
b: > 5:1 to ≤ 15:1 — usually decentralised extensive infiltration and infiltration through swales
c: > 15:1 to ≤ 50:1 — usually centralised infiltration through swales and basins
d: > 50:1
For pavers and checked bricks, the permeable part counts as infiltration area,
for infiltration through pipes and trenches, the area pollution has to be determined individually.

2) Overgrown upper soil of this thickness is not sufficiently permeable for the intended hydraulic load without an impermissible high level of addition of sand. A reduction of the hydraulic load and thus a classification into column c is possible by a sufficient level of stormwater retention.

Table A.4b: Transist values (D) of filter systems

Transist values of overgrown filter basins with pre-cleaning and storage		
Examples	**Type**	**Value**
Retention soil filter systems for extensive stormwater treatment in separate systems according to Advisory Leaflet DWA-M 178E	D11	0.15
Sedimentation system[1)] with subsequent filter basin[2)] holding 60 cm sand of 0/2 graining	D12	0.25
Sedimentation system[1)] with subsequent filter basin[2)] holding 60 cm of gravel sand of 0/4 graining	D13	0.30

1) Filter systems require sedimentation systems in addition to the storage capacity in the filter basin to maintain functionality. It is to be dimensioned for a minimum flow rate q_A= 10 m³/(m²·h) in the case of a rainfall intensity of r_{krit} = 15 l/(s·ha). Their effect is already included in the transist values.

2) Filter basins are dimensioned to the following values per sqm in terms of hydraulics:
hydraulic filter load ≤ 40 m³/(m²·a),
runoff by the throttle ≤ 0.015 l/(s·m²) = 0.015 mm/s = 0.054 m/h

Table A.4c: Transist values (D) of sedimentation systems

Transist values of sedimentation systems					
		Critical runoff rate r_{crit} [1)]			
Examples	**Type**	**a**	**b**	**c**	**d**
Systems with a maximum flow rate of 9 m³/(m²·h) in the design rainfall intensity with the rainfall intensity $r_{(15,1)}$, e.g. separator for light liquids according to RiStWag (FGSV-514)	D21	2)	2)	2)	0.20
Systems with clearance and cleaning after the end of rainfall and a maximum flow rate of 10 m³/(m²·h) for r_{crit}, e.g. stormwater treatment tanks without permanent damming, hydrodynamic separator	D22	0.50	0.40	0.35	2)
Systems with a maximum flow rate of 10 m³/(m²·h) and a maximum of 0.05 m/s horizontal velocity for r_{crit}, e.g. drying, overgrown side trenches or vegetation passages (length > 50 m)	D23	0.60	0.50	0.45	0.25
Systems with permanent damming or constant flow conditions and a maximum flow rate of 10 m³/(m²·h) for r_{orit}, e.g. stormwater treatment tanks, ponds	D24	0.65	0.55	0.50	2)
Systems with permanent damming and a maximum flow rate of 18 m³/(m²·h) for r_{crit}, e.g. settling plants prior to infiltration basins or stormwater retention basins (see Clause 7.4)	D25	0.80	0.70	0.65	0.35
Road gullies for wet sludge	D26	2)	2)	2)	0.9
Standard road gullies	D27	2)	2)	2)	1.0

1) **Explanations of critical runoff rate r_{crit} in columns a to d**
a: 15 l/(s·ha)
b: 30 l/(s·ha)
c: 45 l/(s·ha)
d: $r_{(15,1)}$ (rainfall intensity with 15 min rainfall and annual recurrence)

2) The dimensioning of these systems is unusual for the given runoff rates

Annex B Assessment Method According to Advisory Leaflet DWA-M 153E

Project:

____

____

____

Waterbodies (Tables A.1a and A.1b)	**Type**	**Water points G**
	G__	G =

Area percentage f_i (Clause 4)		***Air_i*** (Table A.2)		**Areas F_i** (TableA.3)		**Discharge pollution B_i**
$A_{imp,i}$	f_i	Type	Points	Type	Points	$B_i = f_i \cdot (Air_i + F_i)$
		Air__		F__		
		Air__		F__		
		Air__		F__		
		Air__		F__		
Σ =	Σ = 1.0	Discharge pollution B = Σ B_i:				B =

No stormwater treatment required, if B ≤ G

Maximum permissible transist value D_{max} = G / B:	D_{max} =

Planned treatment measures (Tables A.4a, A.4b and A.4c)	**Type**	**Transist values D_i**
	D__	
	D__	
	D__	
Transist value D = product of all D_i (Clause 6.2.2):		D =

Emission value E = B · D:	E =

E = ... ; G = ... ; Target: **E ≤ G**

Check need for treatment more precisely, if: **E > G**

Annex C Examples

C.1 Example 1: Discharge into the Moat of The Castle in the City of Münster

Residential buildings with hospitals:
A_C = 52.85 ha, A_{imp} = 32.4 ha;
48 % roof areas (roof tiles), 44 % service streets,
8 % main roads;

Receiving waters: Moats, stagnant waters without natural inlet;

Stormwater pre-treatment: Little space,

One variant: Oil and grit chamber in the storage in bypass for r_{crit} = 5 l/(s·ha).

Waterbodies (Tables A.1a and A.1b)	**Type**	**Water points G**
Moats, stagnant waterbody	G11	G = 10

Area percentage f_i (Clause 4)		***Air_i*** (Table A.2)		**Areas F_i** (Table A.3)		**Discharge pollution B_i**
$A_{imp,i}$	f_i	Type	Points	Type	Points	$B_i = f_i \cdot (Air_i + F_i)$
15.6	0.48	Air2	2	F2	8	4.8
14.2	0.44	Air2	2	F3	12	6.16
2.6	0.08	Air3	4	F5	27	2.48
Σ = 32.4	Σ = 1.0	Discharge pollution $B = \Sigma B_i$:				B = 13.4

Maximum permissible transist value D_{max} = G / B:	D_{max} = 10/13.4 = 0.74

Planned treatment measures (Tables A.4a, A.4b and A.4c)	**Type**	**Transist values D_i**
Oil and grit chamber r_{crit} = 5 l/(s·ha) (Remark: Settling plants for the design discharge 5 l/(s·ha) worse cleaning performance than those for 15 l/(s·ha) according to D24a)	D24	0.85 (estimated)
Transist value D = product of all D_i (Clause 6.2.2)		D = 0.85

Emission value E = B · D:	E = 13.4 · 0.85 = 11.4

Result:

The emission value E = 11.4 exceeds the number of water points G = 10. The assessment method shows that an oil and grit chamber is not sufficient. This is a critical area that needs to be checked in more detail.

The space conditions are extremely difficult, so that an oil and grit chamber would be feasible as a maximum. During the summer months and even in the winter with ice, enormous problems have occurred (in some cases fish mortality) due to strong oxygen consumption. This was caused by organic substances in the discharge of sealed surfaces, due to leaves and dead wood of the old neighbouring trees and due to duck feeding. Discussions about this discharge were held between the City of Münster, the Federal German Environmental Agency and the regional government.

The following solutions should be investigated further and planned:

- Construction of a flow-dividing structure in the form of a stormwater overflow shortly before the point of discharge. A partial stream of Q_{crit} = 15 l/(s·ha)·A_{imp} is to be discharged in an individual pipe into the flowing water called Aa through the moat. The moat would only then be charged in the event of greater discharges. Treatment is not required before discharge into the river Aa.
- Silt clearance of the moat.
- Reduction of the leaves and dead wood entry by means of tree maintenance.

C.2 Example 2: Development Area Housing Estate with Central Infiltration System

In a development area housing estate for residential use, stormwater is to be collected and seeped away in a centralised manner for several reasons. The location is situated in a karst area. After having consulted the water authorities, the water is to be cleaned in such a way that water points G = 2 are achieved. It needs to be verified which treatment measure is required for the runoff from roofing and access roads prior to discharge into the groundwater.

It is intended to connect the following areas to the infiltration system:

Areas	Type of paving	$A_{C,s}$
Steep roofs of residential buildings	Roof tiles	0.40 ha
Hardly used traffic areas	Composite stones with joints	0.24 ha
Service streets	Composite stones with joints	0.16 ha
Car parks	Grass pavers	0.05 ha
Sum		0.85 ha

Area determination

a) Global area determination

Global area determination can also be used if the type of paving of individual sub-areas has already been defined. **Global determination with ψ_m = 1.0 resulted in 0.85 ha of impermeable area.**

b) Differentiated area determination

A differentiated area determination by means of discharge coefficients according to Table 2 is only possible if the type of paving has already been defined.

Areas	Type of paving	$A_{C,s}$	ψ_m	A_{imp}	f_i
Steep roofs of residential buildings	Roof tiles	0.40 ha	0.90	0.36 ha	0.77
Hardly used traffic areas	Composite stones with joints	0.24 ha	0.25	0.06 ha	0.13
Service streets	Composite stones with joints	0.16 ha	0.25	0.04 ha	0.08
Car park areas	Grass pavers (permeable)	0.05 ha	0.15	0.0075 ha	0.02
Sum		0.85 ha		0.4675 ha	1.00

Differentiated determination resulted in 0.47 ha of impermeable area.

Qualitative water pollution

Waterbodies (Tables A.1a and A.1b)	Type	Water points G
Groundwater in the karst area (according to water authorities)	G27	G = 2

Area percentage f_i (Clause 4)		Air_i (Table A.2)		Areas F_i (Table A.3)		Discharge pollution B_i
$A_{imp,i}$	f_i	Type	Points	Type	Points	$B_i = f_i \cdot (Air_i + F_i)$
0.36	0.77	Air1	1	F2	8	6.93
0.06	0.13	Air1	1	F3	12	1.69
0.04	0.08	Air1	1	F4	19	1.6
0.0075	0.02	Air1	1	F3	12	0.26
Σ = 0.47	Σ = 1.0	Discharge pollution B = Σ B_i :				B = 10.5

Intermediary result:

The collected stormwater may be discharged into waterbodies with at least 11 points. For the intended discharge into the karst groundwater with 2 points, the qualitative requirements are therefore not met. Stormwater treatment is required.

Maximum permissible transist value D_{max} = G / B:		D_{max} = 2/10.5 = 0.19
Planned treatment measures (Tables A.4a , A.4b and A.4c)	Type	Transist values D_i
Retention soil filter systems	D11	0.15
Emission value E = B·D:		E = 10.5·0.15 = 1.6

Result:

The planned filter system is sufficient as a treatment measure, since E = 1.6 does not exceed the value G = 2.

C.3 Example 3: Development Area Housing Estate with Discharge into a Small Stream

In a development area housing estate for residential use, stormwater is to be collected to a large extent for various reasons and is not to be seeped away. A small stream is available as a waterbody. Approximately 500 m after the planned discharge, the stormwater sewer of another district leads onto the stream. A maximum of 220 l/s are discharged there. It needs to be verified under which conditions the stormwater from roofing and access roads may be discharged into the stream.

Over a length of several hundred metres before and after the planned discharge point, the stream has a mean water surface width of approx. 80 cm and a flow velocity of 0.3 m/s to 0.4 m/s. It is approximately 30 cm deep. Thus, according to Clause 5.1, it is a small hill country and mountain stream. The sediment in the stream shows particle diameters of up to 15 mm and can be categorised as sandy to medium gritty.

This example connects the same areas to the point of discharge as in example 2. According to global area determination, they cover 0.85 ha and 0.47 ha according to the differentiated determination of total impermeable area.

Verification of minimum limits

Qualitative

Stormwater treatment can be omitted if the three conditions A, B and C according to Clause 6.1 are fulfilled at the same time.

A: fulfilled: the stream corresponds to the type G5.

B: fulfilled: the sealed areas correspond to the area types F2 to F4.

C: not fulfilled: within a water section of 1000 m length, the stormwater of more than 0.2 ha of impermeable surface is discharged.

Result:

It has to be verified to which extent the stormwater needs to be treated.

Quantitative

It is not necessary to create storage if at least one of the three conditions D, E or F according to Clause 6.1 is fulfilled:

D: not fulfilled: discharge into a small stream.

E: not fulfilled: the impermeable areas exceed 0.5 ha within a stretch of 1000 m length.

F: in order to verify F, the required storage volume has to be calculated.

Qualitative water pollution

Waterbodies (Table A.1a and A.1b)	Type	Water points G
Small hill country and mountain stream	G5	G = 18

Area percentage f_i (Clause 4)		Air_i (Table A.2)		Areas F_i (Table A.3)		Discharge pollution B_i
$A_{imp,i}$	f_i	Type	Points	Type	Points	$B_i = f_i \cdot (Air_i + F_i)$
0.36	0.77	Air1	1	F2	8	6.93
0.06	0.13	Air1	1	F3	12	1.69
0.04	0.08	Air1	1	F4	19	1.6
0.0075	0.02	Air1	1	F3	12	0.26
Σ = 0.47	Σ = 1.0	Discharge pollution B = Σ B_i :				B = 10.5

Result:

The collected stormwater may be discharged into waterbodies with at least 11 points. Therefore, for the intended small stream with 18 points, the requirements are fulfilled. Stormwater treatment is not necessary.

Hydraulic load

Throttled discharge

According to Table 3, the permitted discharge rate for the small stream is q_R = 30 l/(s·ha). If storage becomes necessary, according to equation (6.2), in the case of an impermeable area of 0.47 ha, throttled discharge has to be limited to

$$Q_{Thr} = 30 \cdot 0.47 = 14 \text{ l/s}$$

It has to be verified whether this planned discharge into the stream may lead to damage to the biocoenosis.

Maximum discharge

According to Table 4, the value e_w = 3 is selected as a discharge value. According to equation (6.3), a total of e_w-times, in this case three times, the mean water discharge *MQ* may be discharged.

In the given case, the essential discharge *MQ* in the stream cannot be derived from the water level records. Information on the mean discharge rate *Mq* in the stream's catchment area is missing. By means of equation (6.4), the mean discharge *MQ* is therefore estimated to be

$$MQ = (0.30 \text{ to } 0.40) \cdot 0.30 \cdot 0.80$$
$$= 0.072 \text{ m}^3/\text{s} \quad \text{to} \quad 0.096 \text{ m}^3/\text{s}$$

According to equation (6.3), the permissible maximum discharge is thus

$$Q_{Thr,max} = 3 \cdot (0.072 \text{ to } 0.096) \cdot 1000$$
$$= 215 \text{ l/s} \quad \text{to} \quad 290 \text{ l/s}$$

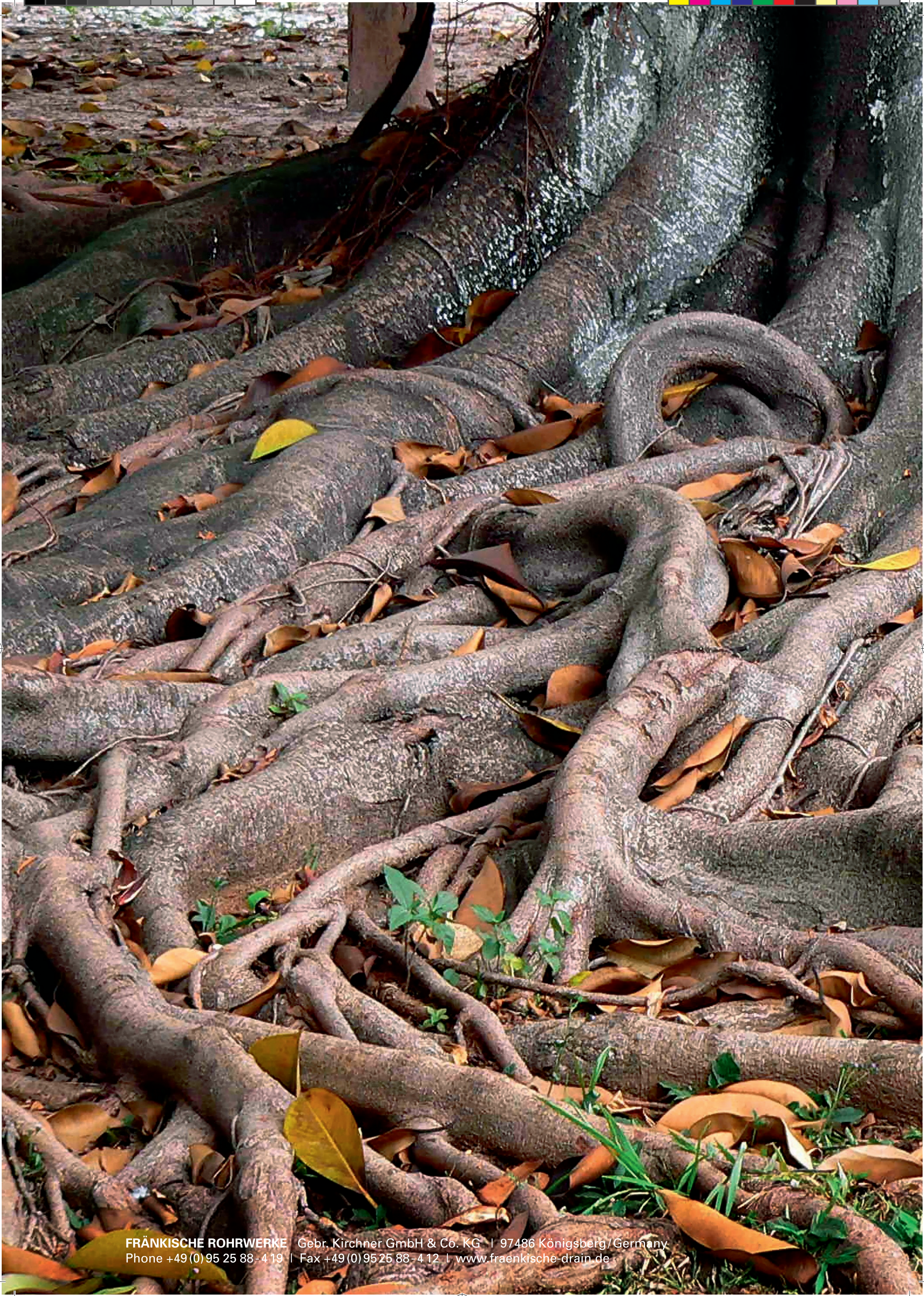
According to Clause 6.3.2, not much more than $Q_{Thr,max}$ is to be discharged within a flow distance of around 1,000 times the mean water surface width b_{Sp}. In this case, therefore a total of 234 l/s would be discharged over a stream distance of 1000 · 0.80 m = 800 m, at the planned point 14 l/s and around 500 m further downstream 200 l/s. The development area housing estate with a calculated throttled discharge of Q_{Thr} = 14 l/s can thus be connected without causing any damage. It is not necessary to reduce the chosen runoff rate.

Storage volume

The required volume is calculated according to Standard DWA-A 117E. The thus shown estimation results in a volume of approx. 125 m^3 taking Munich as an example with a throttled discharge of 14 l/s based on an overflow frequency of once in 5 years. According to the KOSTRA-Atlas 1997 by the Deutscher Wetterdienst Offenbach [German meteorological service Offenbach], the 60-minute rainfall with 33 mm height of precipitation from the station Munich-Riem with station number 92095 is decisive.

Result:

The required volume exceeds the minimum limit of 10 m^3 according to Clause 6.1 letter F, up to which the construction of the retention measure could be omitted. The storage of a total of 125 m^3 has to be built with a throttled discharge of 14 l/s. The volume can be distributed to the decentralised storage space if permitted by the drainage system.



FRÄNKISCHE ROHRWERKE Gebr. Kirchner GmbH & Co. KG | 97486 Königsberg/Germany
Phone +49 (0) 95 25 88 - 4 19 | Fax +49 (0) 95 25 88 - 4 12 | www.fraenkische-drain.de


Efficient water storage system
750 years to build
We don’t always have that much time.
Innovative protection of our water resources – solutions for state-of-the-art stormwater management systems
Cleaning, infiltration, retention, harvesting – to protect our most precious resource.
We care ...
FRÄNKISCHE