Urban Water Management

Within the module:
Ecology and Water Resources
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Institut für Wasserwirtschaft,
Hydrologie und
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Part 4

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Overview

Contents today: Drainage (continued)

Waste water plus **storm water**

- amount and pollution
- drainage systems
  - → combined systems
  - → separate systems
- dimensioning of pipes
- storage
  - → stormwater overflow tanks
  - → stormwater retention tanks
- dimensioning of tanks

Drainage systems

Combined systems

- Stormwater overflow tanks (CSO tanks)
- in comparison to stormwater detention tanks:
  - less specific volume
  - other tasks
    → reduce the overflow **pollution**,
    not the peak flow

    → catch the „first flush“

    - keep it in the tank
    - release to treatment plant after rain event
- two types of tanks:
  - with and without limited (treated) overflow

Drainage systems

Stormwater overflow tanks

- with or without treated overflow
- in-line or off-line
- tanks or storage sewers

- limited capacity
- separation structure → excess overflow

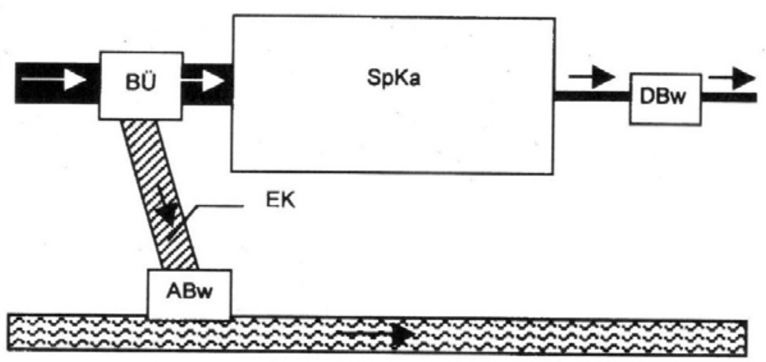
- treated overflow : limited
- excess overflow : unlimited
- overflow goes into receiving water,
  sometimes via retention tanks (hydraulic reasons)

Drainage systems

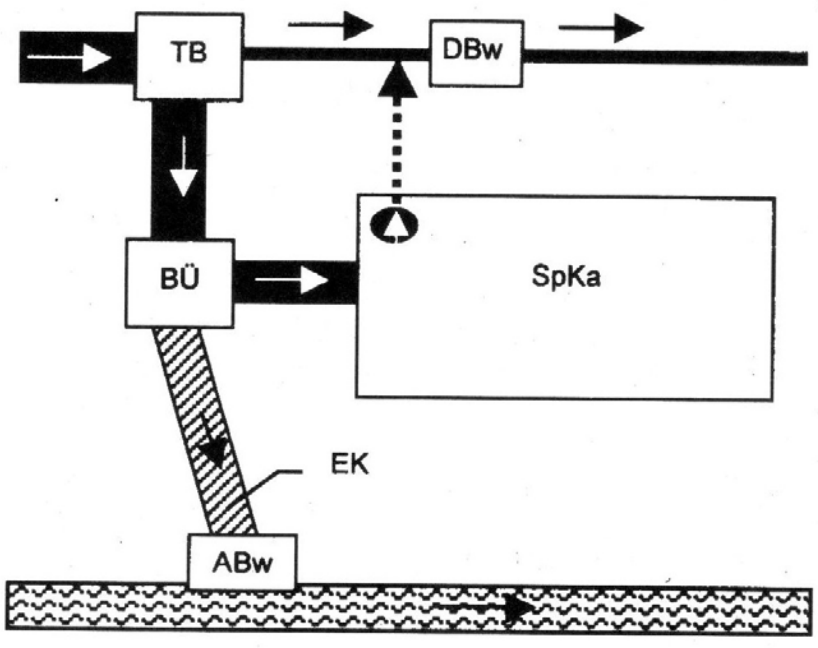
Stormwater overflow tanks

- **without** treated overflow
- for retaining the first flush

in-line location



off-line location



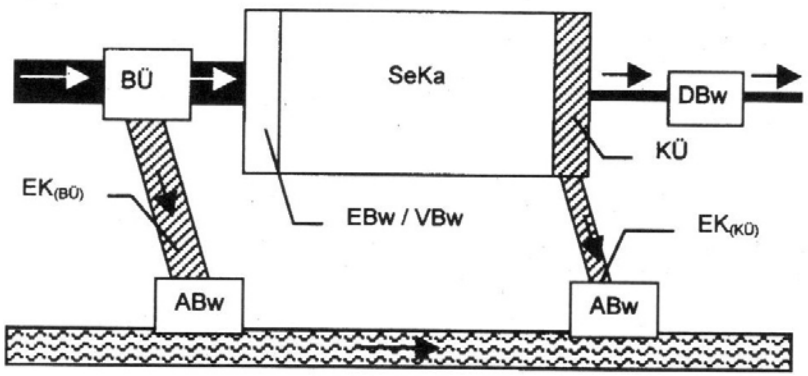
SpKa storage structure
BÜ excess overflow structure
DBw throttle device
EK overflow sewer
ABw outlet structure
TB separation structure

Drainage systems

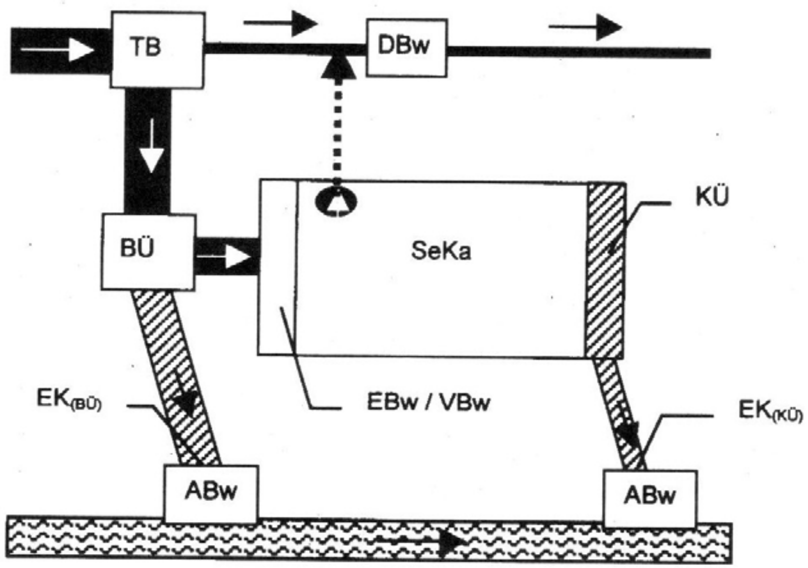
Stormwater overflow tanks

- **with** treated overflow
- runoff passed through for treatment = sedimentation
- treated overflow structure within the tank

in-line location



off-line location

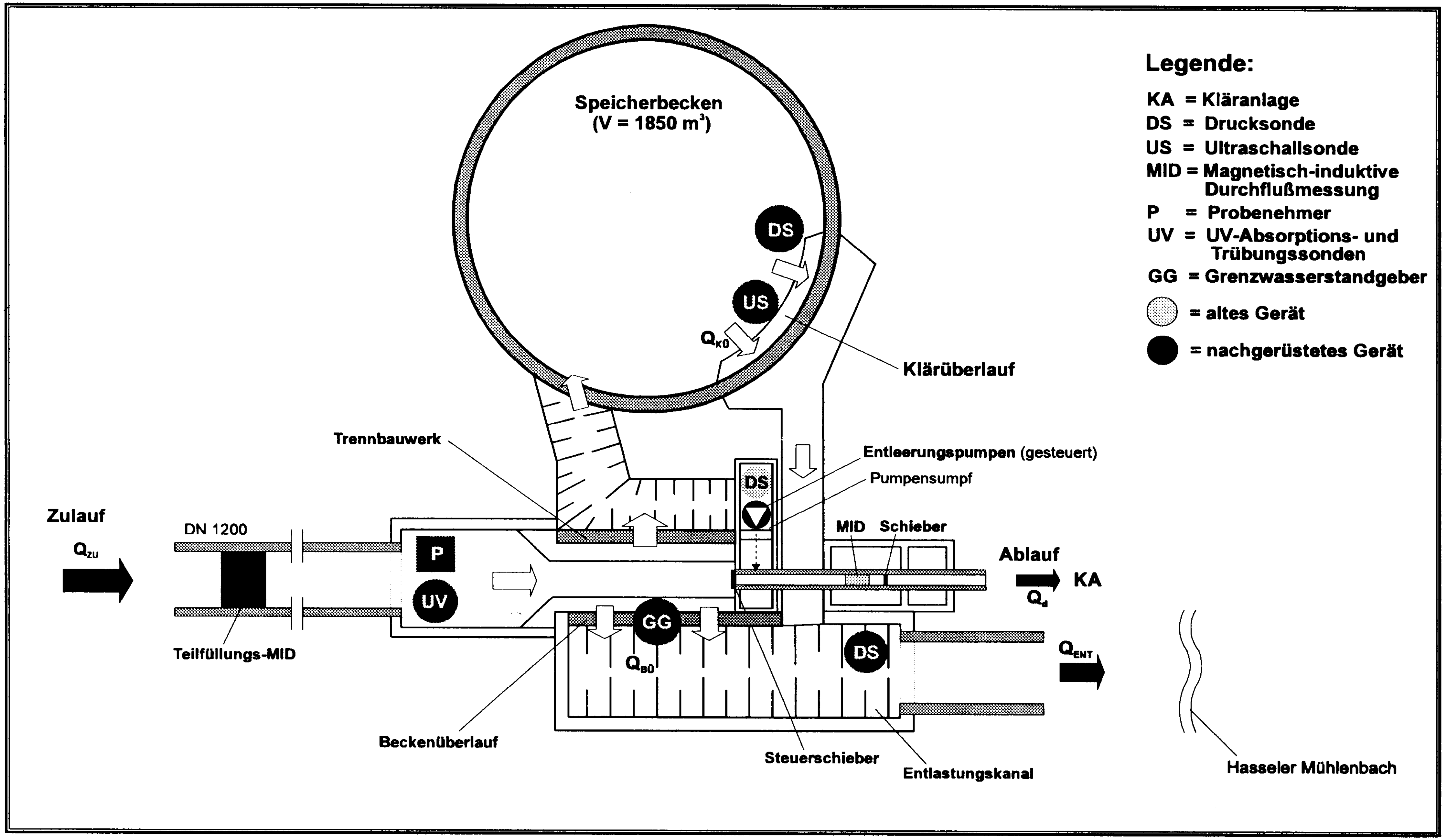


SeKa storage/sedimentation structure
BÜ excess overflow structure
DBw throttle device
EK overflow sewer
ABw outlet structure
TB separation structure
KÜ treated overflow structure

EBw/VBw inflow / distribution structure

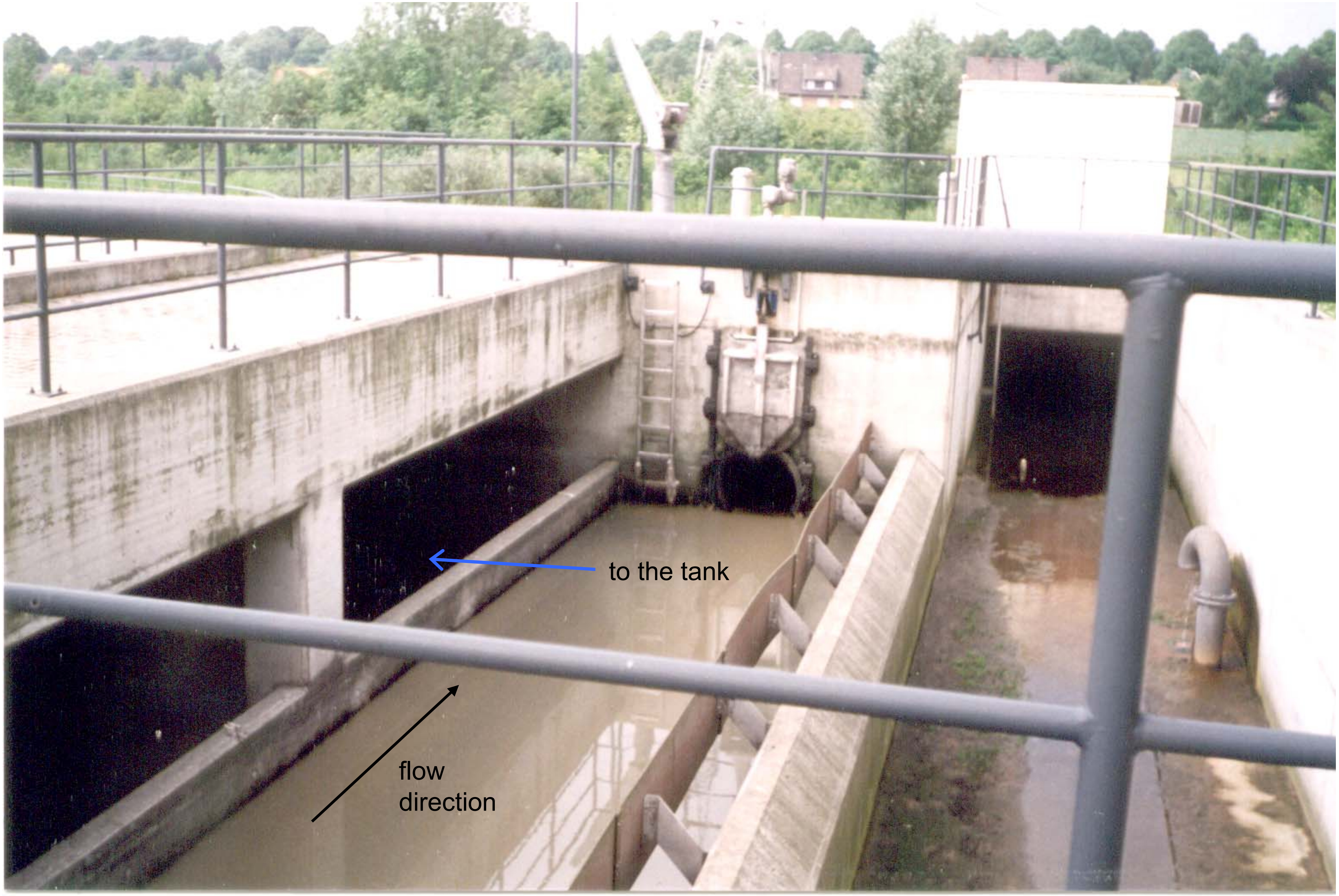
Drainage systems

Stormwater overflow tank off-line, with treated overflow



left: excess overflow weir **right: weir to the tank**

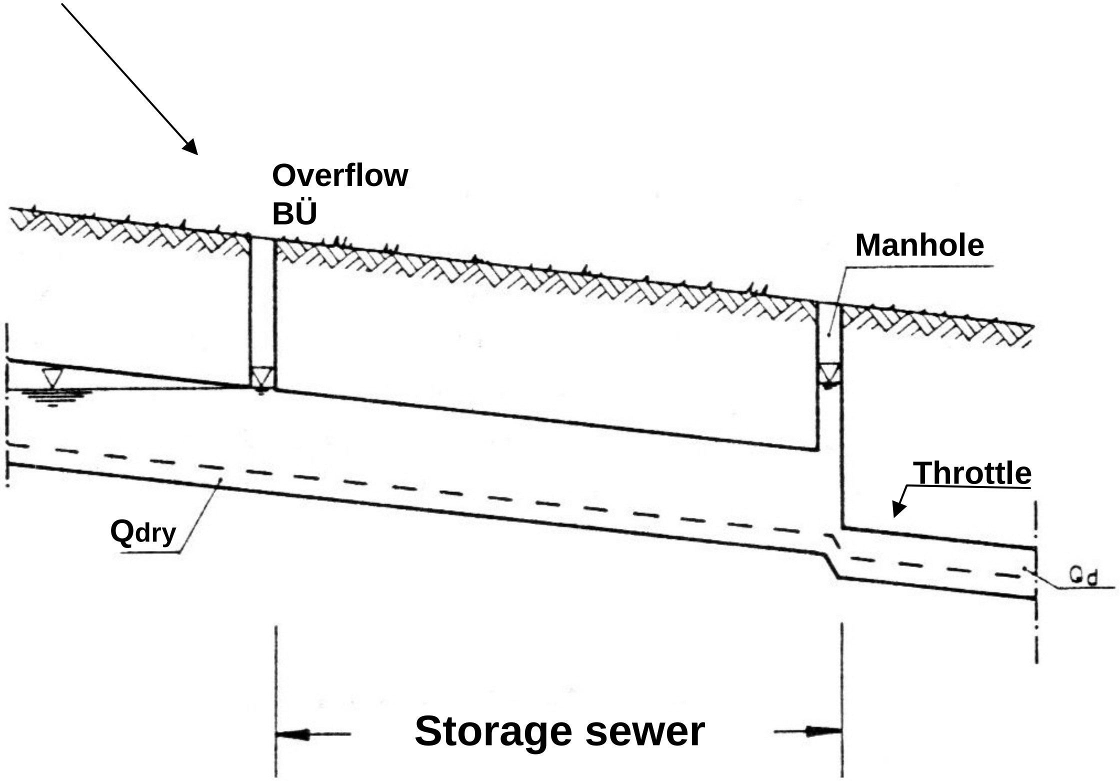

structure for treated overflow


to the tank
flow
direction

Drainage systems

Stormwater overflow storage: storage sewer

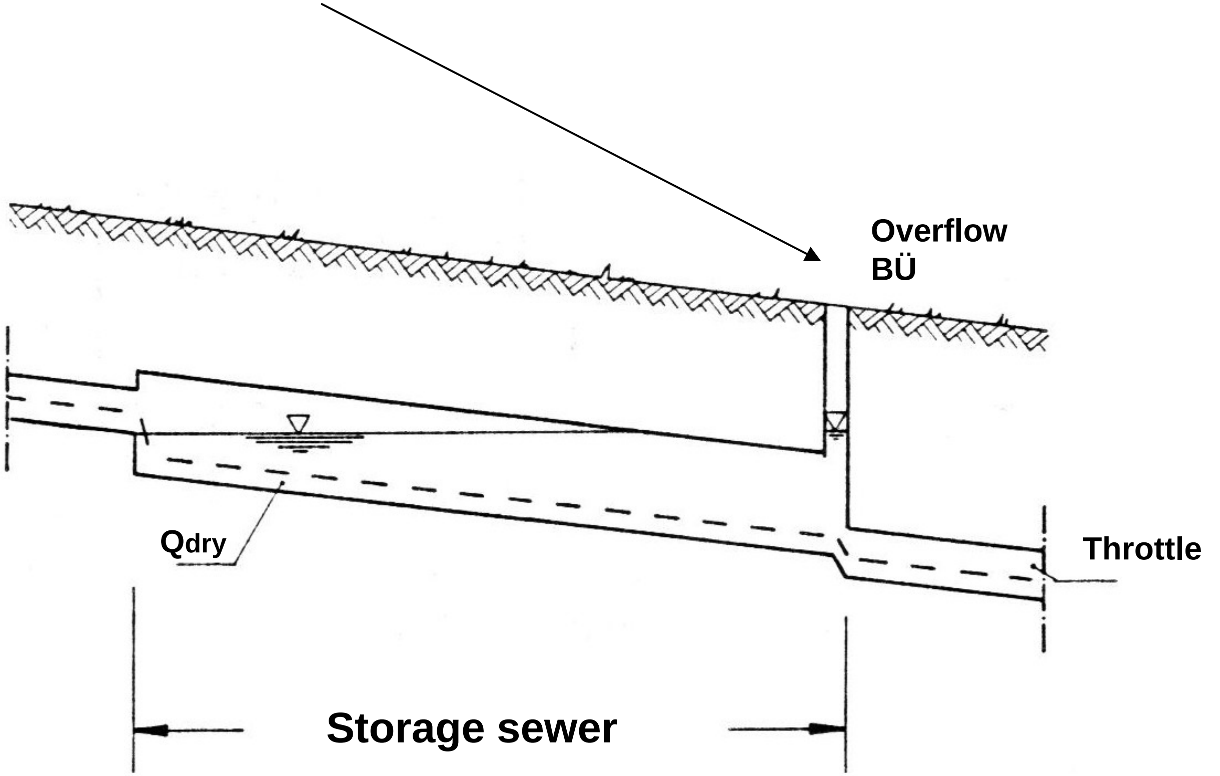
- **upper** or **lower** overflow structure



Drainage systems

Stormwater overflow storage: storage sewer

- **upper** or **lower** overflow structure



Design principle
for storm water overflow tanks

To reduce pollution load into receiving waters

Objective:

$$PL_{CSO} + PL_{WWTP(rain)} \leq PL_{SWS}$$

PL	pollution load
CSO	combined sewer overflow
WWTP	waste water treatment plant
(rain)	indicates the fraction due to rain induced surplus load from the WWTP
SWS	stormwater sewer

Drainage systems

Stormwater retention tanks

- reduce peak flow
- in-line or off-line

- objective: overflow only with certain return period

- Design values:

  throttle discharge Q_{lim} [m³/s]

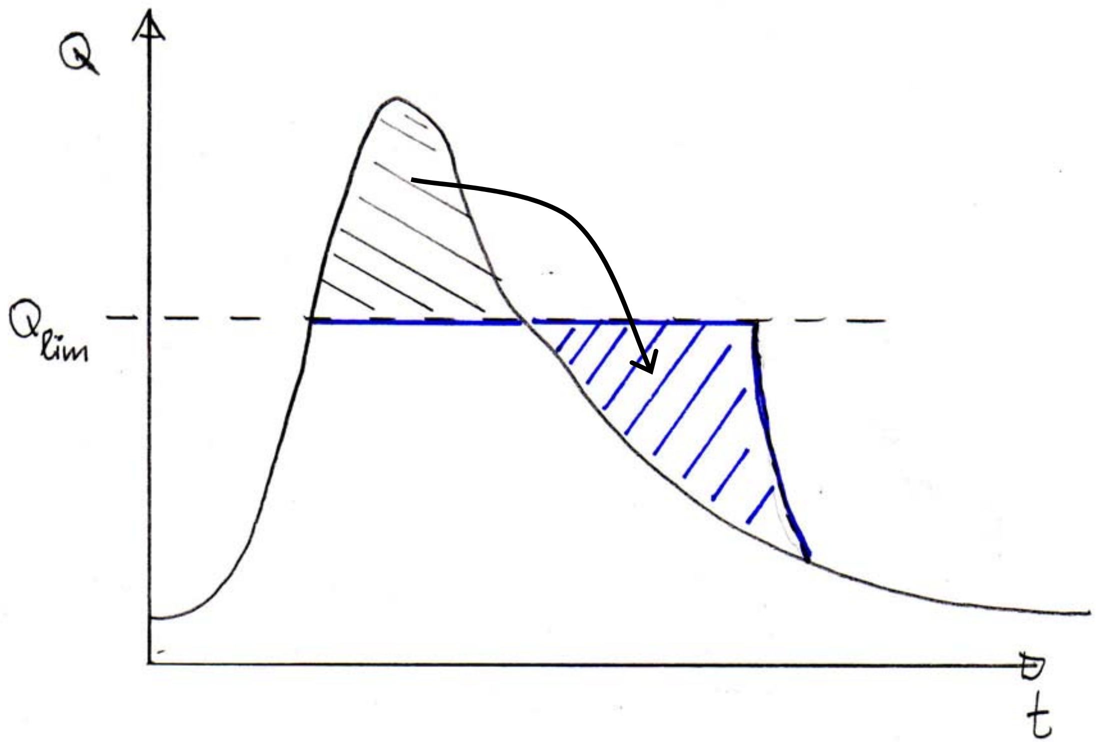
  return period of overflow T [a]

- to be found: required volume

Drainage systems

Stormwater retention tanks

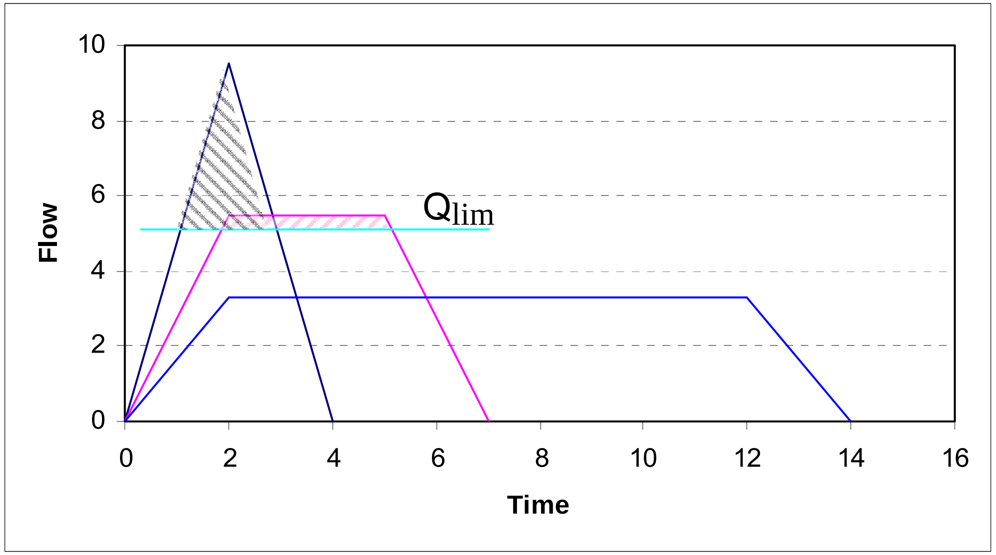
- required volume

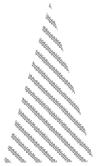
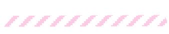


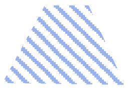
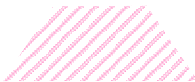
Drainage systems

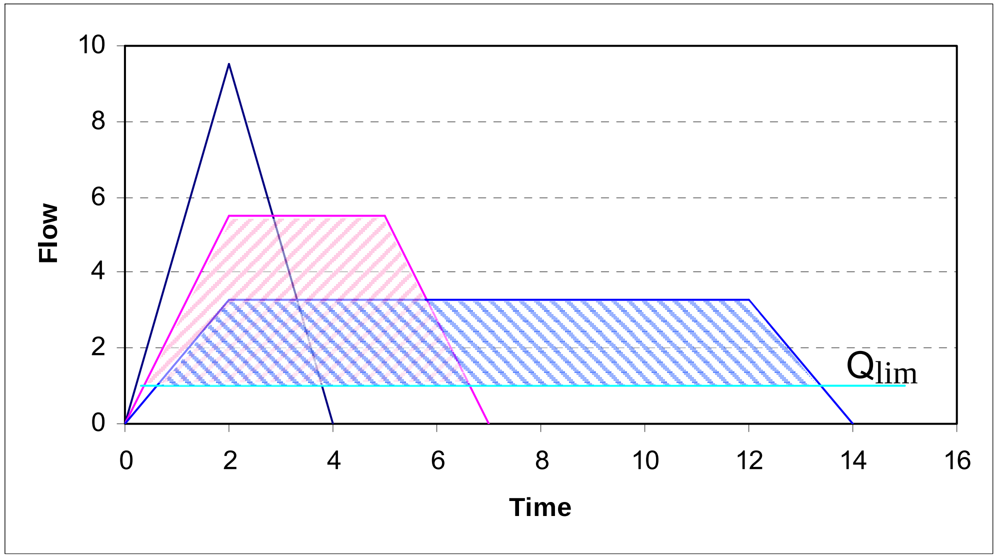
Stormwater retention tanks

- required volume



a)  > 

b)  > 



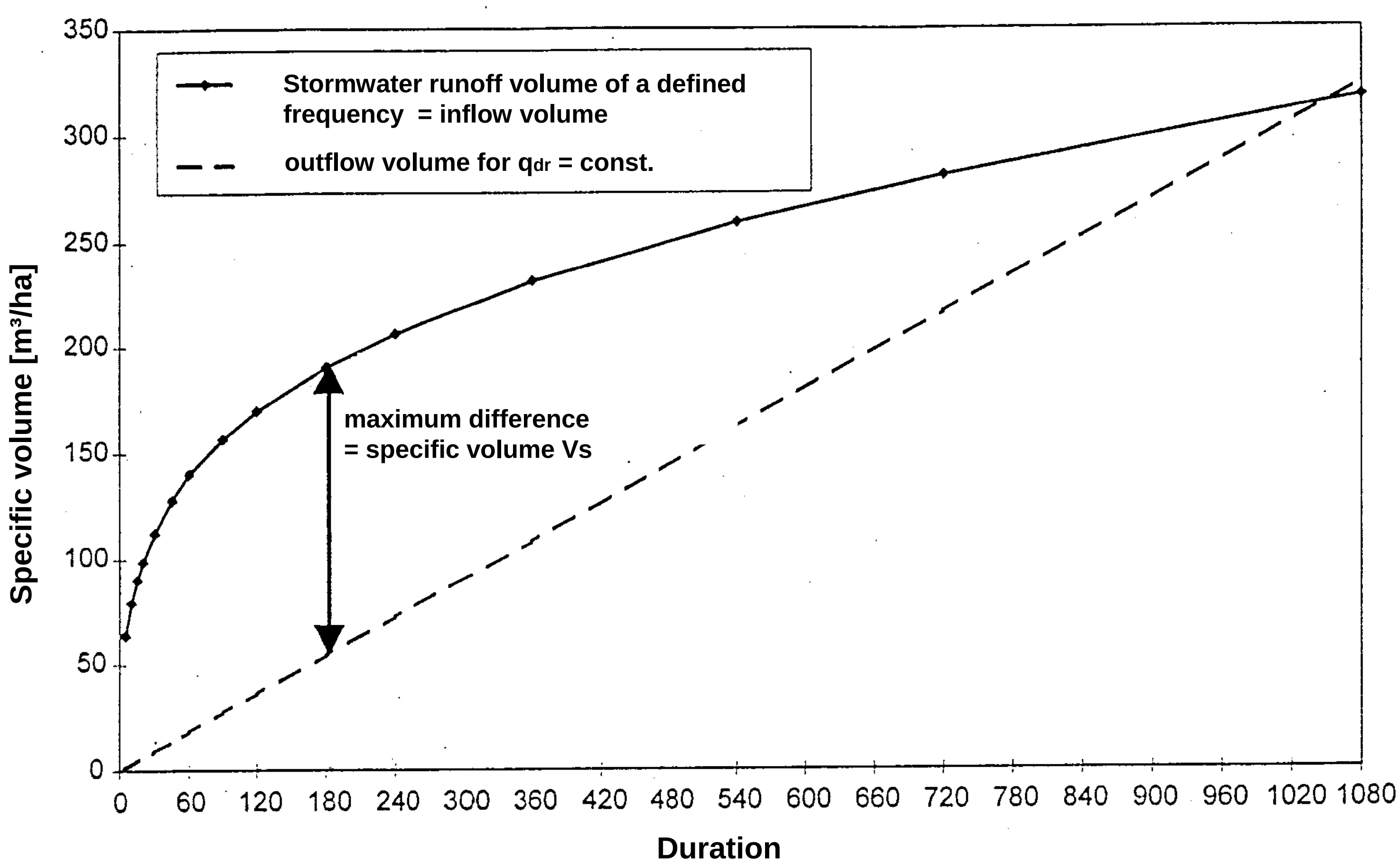
Drainage systems

Stormwater retention tanks

$$V_{in} = \frac{r_D \cdot D \cdot 60}{1000}$$

$$V_{out} = \frac{q_{dr} \cdot D \cdot 60}{1000}$$

- required volume



Drainage systems

Stormwater retention tanks

- required volume

Duration	Specific throttle runoff rate q_{dr} [l/(s*ha)] related to the impervious area of the catchmnent																
	1	2	3	4	5	6	7	8	9	10	12	15	20	25	30	40	≥ 50
< 15 min																	■
15 min																■	■
20 min														■	■	■	■
30 min												■	■	■	■	■	■
45 min											■	■	■	■	■	■	
60 min									■	■	■	■	■	■	■	■	
90 min								■	■	■	■	■	■	■	■		
2 h						■	■	■	■	■	■	■					
3 h				■	■	■	■	■	■	■	■						
4 h			■	■	■	■	■	■	■	■							
6 h		■	■	■	■	■	■	■									
9 h		■	■	■	■	■											
12 h	■	■	■	■	■												
18 h	■	■	■	■	■												
24 h	■	■	■	■													
48 h	■	■	■														
72 h	■	■															
> 72 h	■																

Drainage systems

Stormwater retention tanks

- required volume

$$V_{s,imp} = \left(r_{D,f} - q_{dr}\right) \cdot D \cdot 0{,}06 \cdot x_{corr}$$

$V_{s,imp}$	=	specific volume related to the impervious area r
$r_{D,f}$	=	rainfall rate of defined duration D and frequency f [l/s*ha)]
q_{dr}	=	throttle runoff rate [l/s*ha)]
D	=	duration [min]
x_{corr}	=	correction factor (safety, flow time, throttle runoff variation)

- solution

  calculate for all relevant durations to find maximum V_s

Drainage systems

Stormwater retention tanks

- required volume

calculation

with Excel:

an example

Drainage systems
Performance assessment

- Structural situation and hydraulic performance for :
  - Operation
  - Maintenance
  - **Rehabilitation planning and design**

- Performance

  Frequency with which a defined boundary condition is exceeded

  (water levels, peak flows, volumes)

- Assessment
  - Computational power
  - Models
  - Two concepts $\Rightarrow$ design rainfall

    $\Rightarrow$ continuous simulation

Performance assessment

Long time series of rainfall recordings

Load case principle

- **Statistical analysis** of rain data
- Select rain duration and frequency
- Construct design rainfall
- Rainfall runoff model
- Attach rainfall frequency to all results
- Maximum water levels, peak flows, volumes for one frequency

Time series simulation

- Rainfall runoff model
- Long time series of runoff data
- **Statistical analysis** of
  - water levels
  - peak flows
  - storage/overflow volumes
- Maximum water levels, peak flows, volumes as a function of frequency

Drainage systems

Design criteria and return periods

- Flooding (EN 752)

  ”condition where wastewater and/or surface water escapes from or cannot enter a drain or sewer system and either remains on the surface or enters buildings”

  - ⇧ connected with damage
  - ⇧ depends on local surface conditions

- Surcharge

  ”condition in which wastewater and/or surface water is held under pressure but does not escape to the surface to cause flooding”

- Manhole surcharge

  ”condition in which the water level reaches the surface and water escapes to the surface”

- Design storm

Return period ?

Drainage systems

Design frequencies

Recommended design frequencies in EN 752 and DWA-A 118

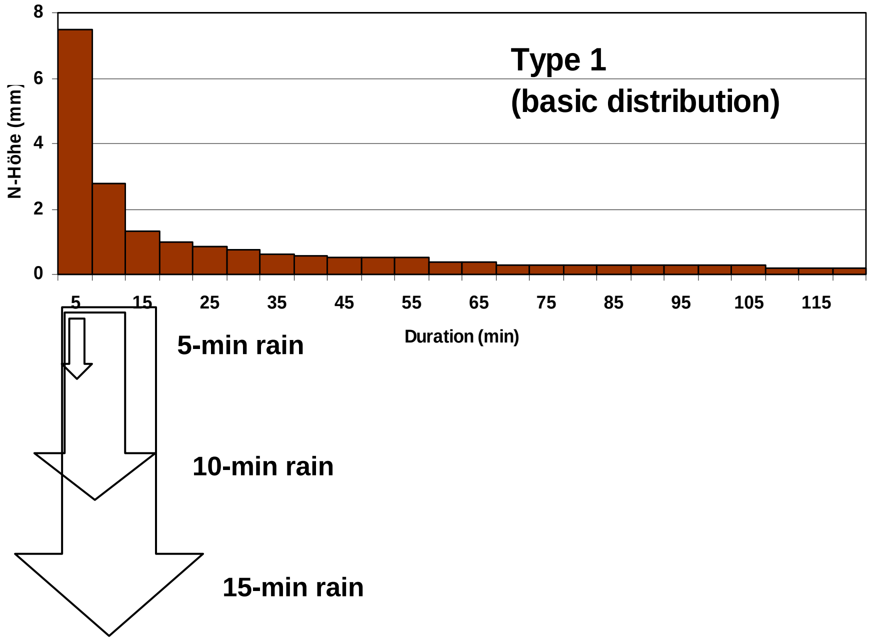
Design Storm Frequency * (1 in “n” years)	Location	Design Flooding Frequency (1 in “n” years)	Design Surcharge Frequency (DWA-A 118) (1 in “n” years)
1 in 1	Rural areas	1 in 10	1 in 2
1 in 2	Residential areas	1 in 20	1 in 3
 1 in 2 1 in 5	City centres, industrial/commercial areas - with flooding check - without flooding check	1 in 30	< 1 in 5
1 in 10	Underground railway/underpasses	1 in 50	< 1 in 10

* For design storms no pipe surcharge shall occur.

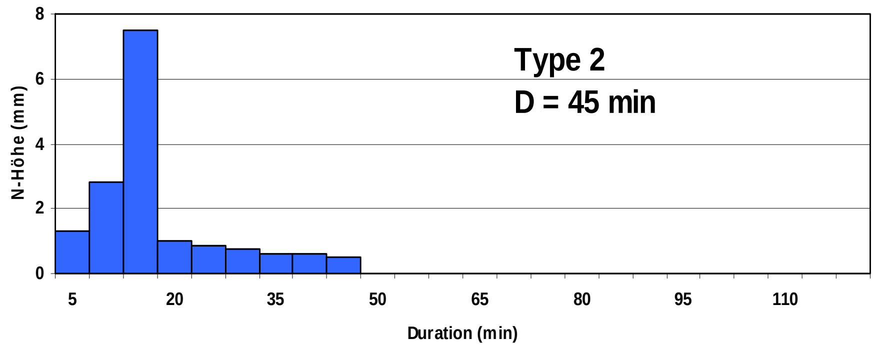
Drainage systems

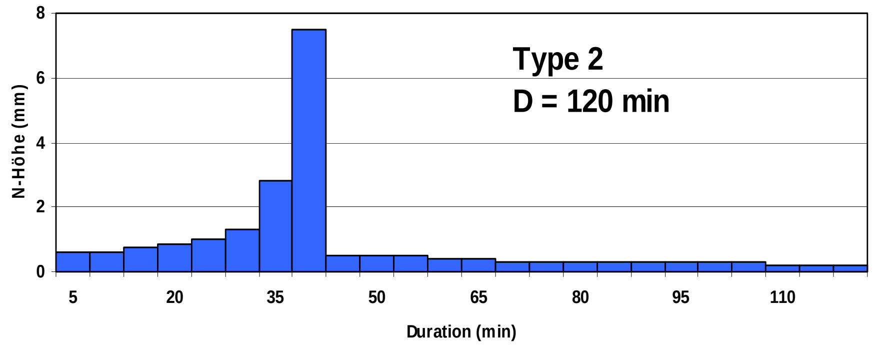
Performance assessment

- Load case principle:
  design rainfall construction



Type 2: invert first third





Drainage systems

Performance assessment

- Statistical analysis with time series simulation: frequency n of design limit exceedance

a) Counting

x surcharge events in M years

$\Rightarrow$ $n_s = x / M$

Example: $x = 7$, $M = 25$ a $\Rightarrow$ $n_s = 0{,}28$ 1/a
$T_s = 3{,}6$ a

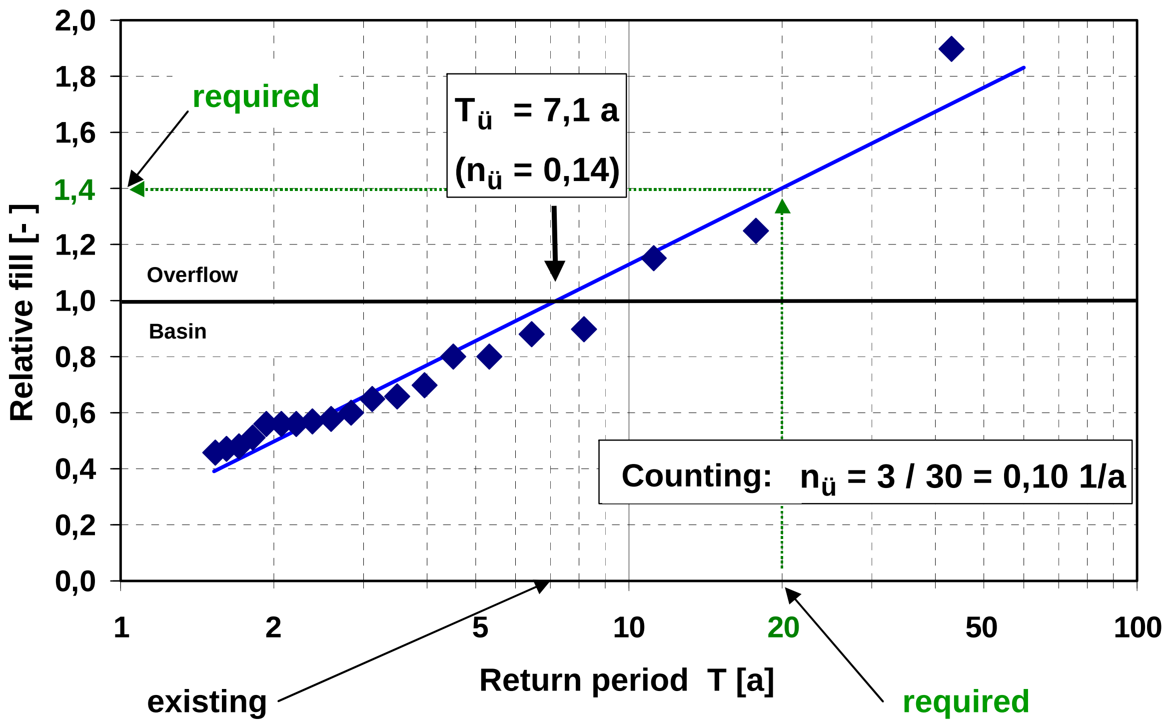
sufficient, if $M \geq 3 / n_{s,crit}$
or $M \geq 3 \cdot T_{crit}$

Drainage systems

Performance assessment

- Statistical analysis with time series simulation: frequency n of design limit exceedance

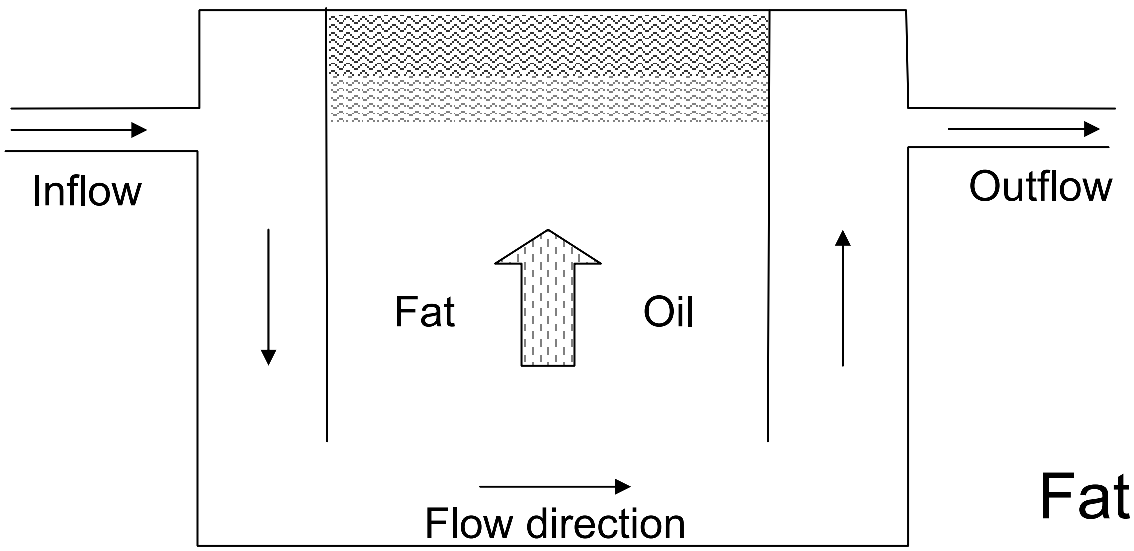
b) Distribution function



Drainage systems

Waste water treatment plants (some basic principles)

- Pre-treatment (within the sewer network)



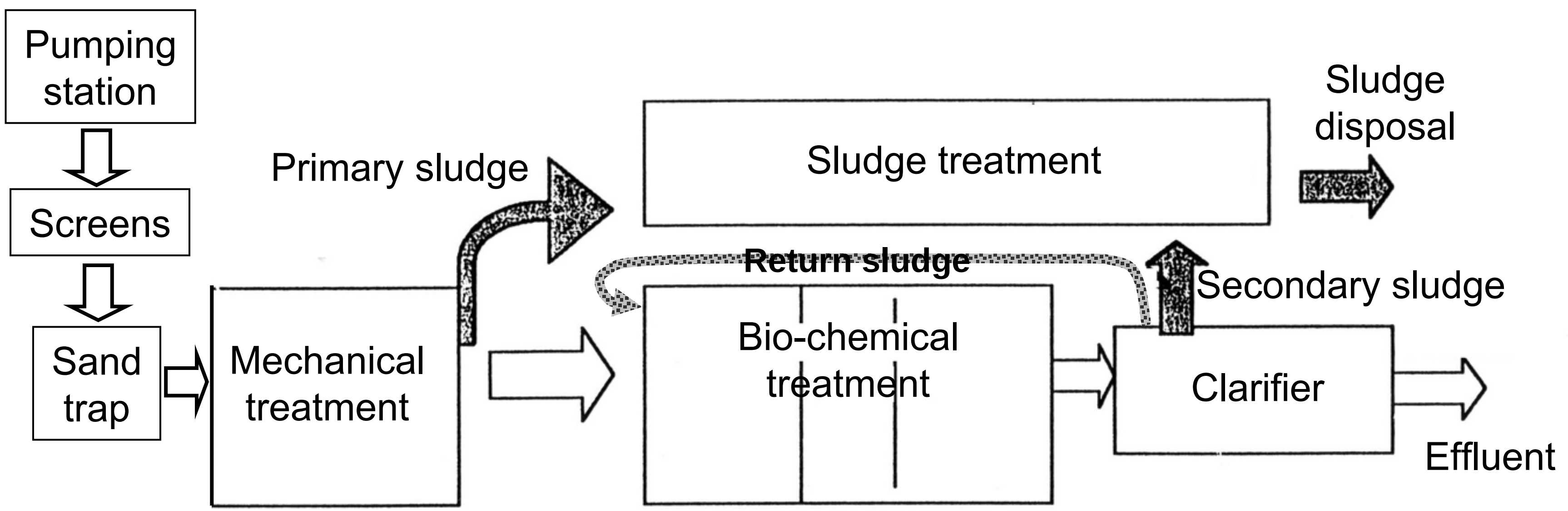
Fat separator

- Treatment plant

Drainage systems

Waste water treatment plant

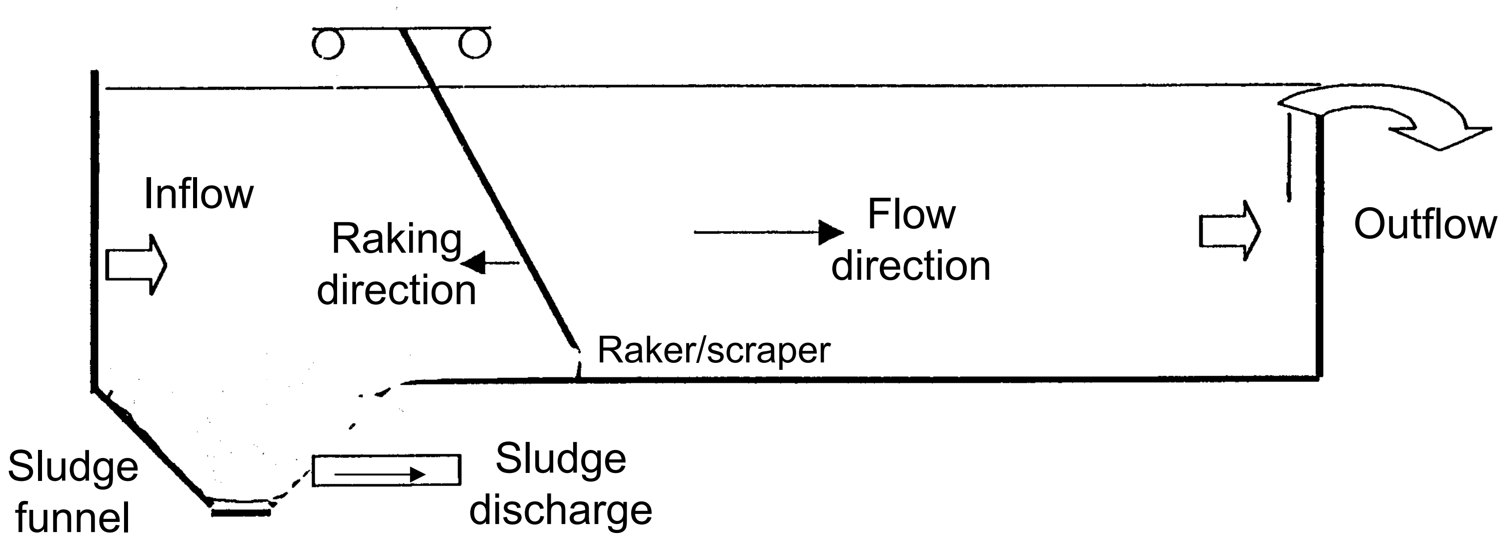
- General functioning scheme



Drainage systems

Waste water treatment plant

- Sedimentation / settling tanks

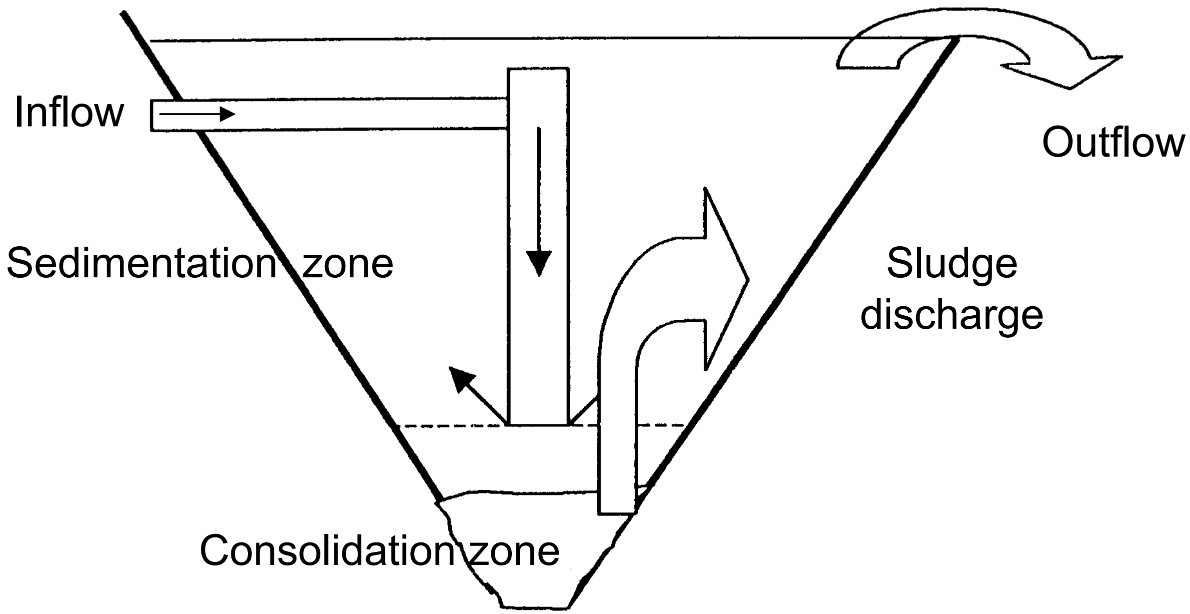


Clarifier with sludge raker

Drainage systems

Waste water treatment plant

- Sedimentation / settling tanks



Vertical flow settling tank