Water management in urban areas
Design, Getting started

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How to start?

How to start?

1. Objectives
   - Ambition / Vision
     - Sustainability
     - Robustness
     - Added value
   - Standards / Requirements
     - Freeboard
     - Drainage depth
     - Storage capacity
     - Flow velocity's
     - Quality aspects

2. Design load
   - Result from processes
     - Design storms
     - Rainfall duration curves
     - Stormwater runoff pollution

Content

- Objectives
  - Sustainability
  - Vulnerability
  - Risk management
  - Standards
- Design loads
  - Design storms
  - Rainfall duration curves

Objectives

Sustainability

- What is sustainable development?

  'Meeting the needs of the present without compromising the ability of future generations to meet their own'

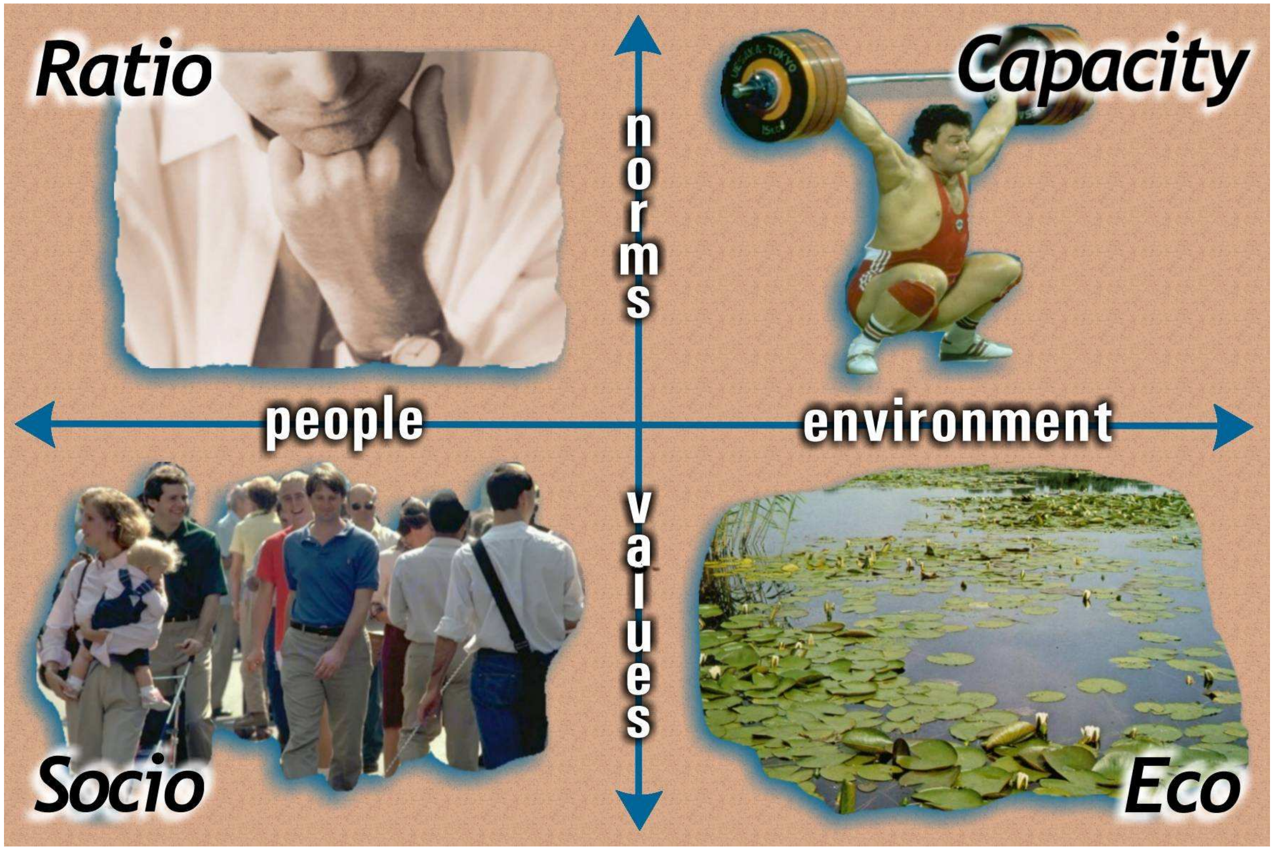
  'Maintaining the stock of natural capital'

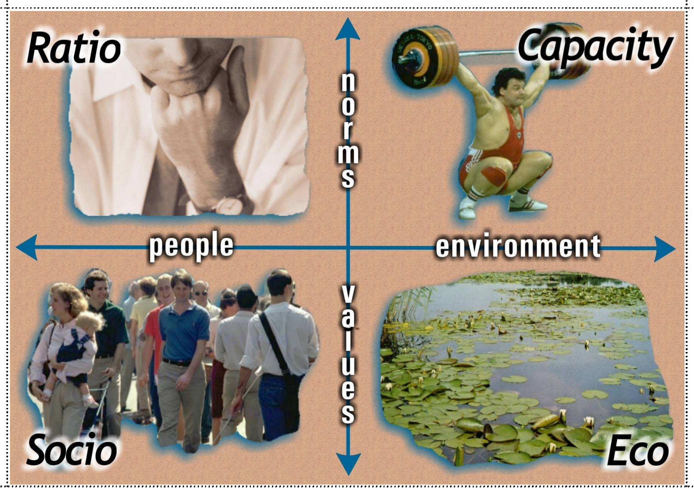
- Two aspects of approach
  - Perspective
  - Judgement

Objectives

Sustainability

Source: M.A. Rijsberman and F.H.M. van de Ven, 2000. Different approaches to assessment of design and management of sustainable urban water systems.



exploitation optimising Multi-criteriaanalysis	reductionism technique risk /sensivity analysis quantitative dogmatic	Environmental science Environmental technology ‘ecological sustainable’ Life cycle analysis (LCA)
politics issues interests conflicts Stakeholders choices subjective		objective best available technique resilience (ir)reversible Precaution princples visio/‘religion
images Future value Experience value Usage value	pragmatic qualitative ‘guts’ ethics holism	Guidance principles ‘no regret’ strategy

Objectives

Vulnerability

- Definition (Leurs, 2003; Turner et al., 2003; IPCC, 2001; Schiller et al, 2001):

  ‘**sensitivity** of a system for exposure to shocks, stresses and disturbances, or the degree to which a system is **susceptible** to adverse effects’

- Environmental variation:
  - Variation of water levels
  - Variation of water resources
  - Variation of future climate
  - Etc

Objectives

Vulnerability

- To deal with environmental variation:
  - Reduce variation → Threshold capacity

Objectives

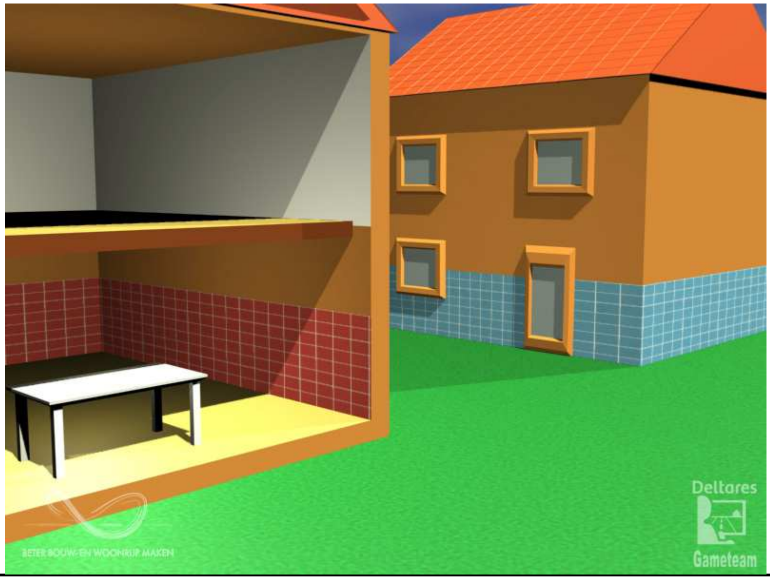
Vulnerability

- To deal with environmental variation:
  - Reduce variation → Threshold capacity
  - Reduce damage → Coping capacity

Objectives

Vulnerability

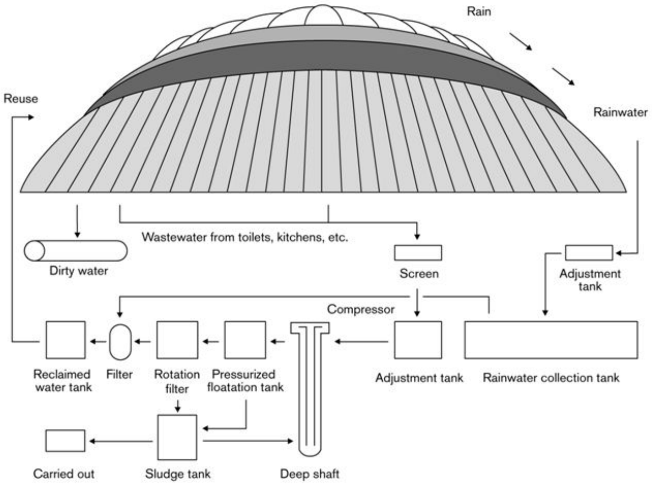
- To deal with environmental variation:
  - Reduce variation → Threshold capacity
  - Reduce damage → Coping capacity
  - Deal with damage → Recovery capacity



Objectives

Vulnerability

- To deal with environmental variation:
  - Reduce variation → Threshold capacity
  - Reduce damage → Coping capacity
  - Deal with damage → Recovery capacity
  - Deal with future variation → Adaptive capacity



Objectives

Vulnerability

Numerous 'hard' and 'soft' remedies

	Flood control	*Flood control*	*Water supply*	*Water supply*
Threshold Capacity	Higher dikes	Increase river capacity	Increase reservoir capacity	More efficient supply infrastructure
Coping Capacity	Improve risk perception	Emergency plan & warning	Backup supply facilities	Individual storage
Recovery Capacity	Disaster fund	Insurance	Multi source water supply	Disaster funds
Adaptive Capacity	Flood proof & flexible urbanization	Small scale pilot projects	Flexible portfolio of sources	Small scale pilot projects

Objectives

Vulnerability

	Type	*Time orientation*	*Responsibility*
Threshold Capacity	Damage prevention	Past	Clear
Coping Capacity	Damage reduction	Instant	Not clear
Recovery Capacity	Damage reaction	Instant/ future	Not clear
Adaptive Capacity	Damage anticipation	Future	Undefined

Objectives

Vulnerability

- Trying to control environmental variation with threshold capacity only introduces increased vulnerability for rare (and extreme) incidents
- Vulnerability of a system is difficult to assess because components of vulnerability are strongly interrelated.
- 4 component vulnerability framework supports a more comprehensive development strategy

Objectives

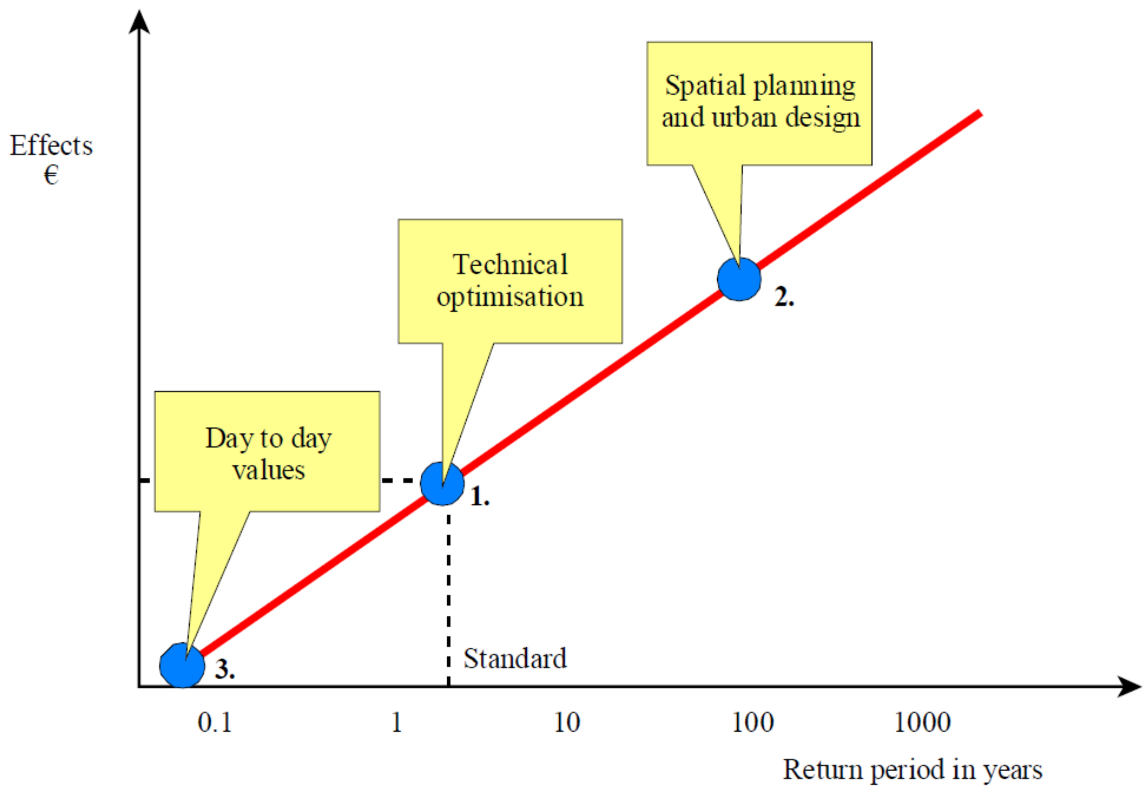
Risk management

- Basic approach in design is economical optimization of construction and management based on statistical standards
    - Capital charges
    - Maintenance costs
    - Energy costs
    - Management costs
    - Costs because of damage
    - Social-communal cost
    - Revenue (negative costs)

Objectives

Risk management

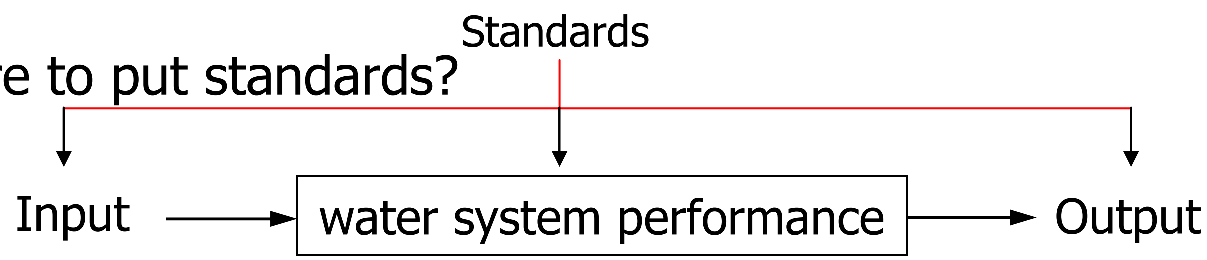
- Three points approach (Geldof and Kluck, 2008)



Objectives

Standards

Where to put standards?



- Input of the system
  - Rainfall duration curves
  - Runoff coefficients for sewer inflow
- System performance
  - Maximum flow velocity of surface water
  - Groundwater level range
- Output of the system
  - Maximum discharge to the surrounding

} Conflicts

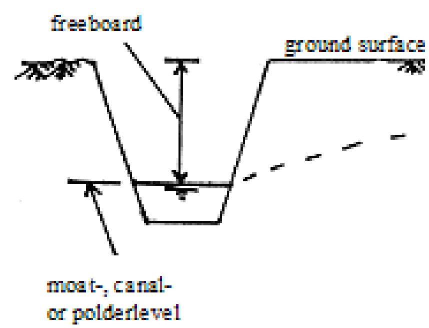
Standards

Open water → freeboard

- Prevention against flooding

- 0.9 – 1.3 m max level rise once in 100 years
  - Depends on inflow situation

- Related to Discharge capacity and Storage
  - *S (t+Δt)* = $S(t) + I - Q$
  - *H* = $f(S)$
  - *Q* = $Ch^{3/2}B$ or
  - *Q* = $Q_{pumping\ station}$



Standards

Open water →water depth

- Maximum water depth → 1.2 m
  - Maintenance
  - Prevention wealthy growth water plants
  - Safety
    - Drowning

Standards

Open water → Flow velocity

- Protection
  - Too fast → erosion
  - Too slow → algae
- Depends on soil type

Flow velocities

Canal	Structure locations
0.25 m/s	1 m/s

Standards

Open water → Storage capacity

- Input
  - Rain
  - River
- Location
  - Surrounding
  - Height / depth
  - Drainage system
- Output
  - Drainage capacity
  - Pump capacity

} Hydrological model

Standards

Open water → water quality

- Natural ecological environment
  - Flora → sediment
  - Fauna
- Recreation
  - Health
- Sewer overflows
- Traffic
- Dredging

MTR

Max. allowed risk

Standards

Open water → water quality

- Oxygen
  - Below 5 mg/l → Fish mortality

- Ecotoxology
  - LD_{50} → Lethal Dose 50%
  - NOEC → NO Effect Concentration
  - MR → Maximum Risk
  - **MTR → Maximum allowed Risk**
  - SW → Target Value

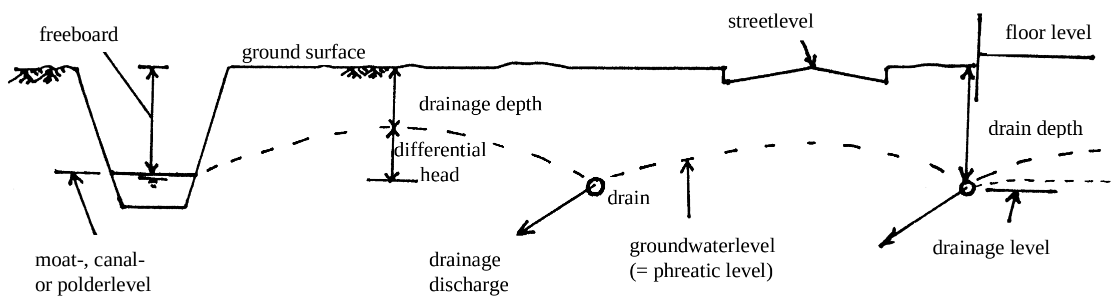
Eg. Zn, Cu, NH_4^+

Maximum concentration

Standards

Ground water → Drainage depth

Maximum groundwater level



Numerous land use function → GGOR

Standards

Ground water → Drainage depth

Activity/destination	**Steady drainage- computation**
	Drainage depth
I. during the construction phase	(m below ground level)
1. construction of structures	0.60- 0.70
1. laying of telephone-cables	0.50- 0.60
Low voltage cables	0.60
Gas lines	0.65- 1.00
High voltage cables	0.90
Sewer pipes	1.00- 3.50
1. construction of primary roads	1.00
secondary roads	0.70
squares, parking lots	0.40
1. accessibility	0.50-0.70
Summary: during the construction phase	0.70- 0.80

Activity/destination	**Steady drainage- computation**
	Drainage depth
II. the habitation phase	
1.structures	0.70
1.cables and pipelines	0.60- 1.00
1.primary roads	1.00
1.secondary roads	0.70
1.industrial areas, centre areas	0.70
Summary: the habitation phase	0.70
Gardens, public gardens, parks	0.50
Camping areas	0.50
Graveyards	0.30 below underside coffin
Sport fields	0.50
Non-steady drainage computation	0.70

Standards

Ground water → water quality

- Irrigation, process water, drinking water
- Materials in the ground
  - Aggressive groundwater
    - Low pH
    - CO_2
    - H_2S

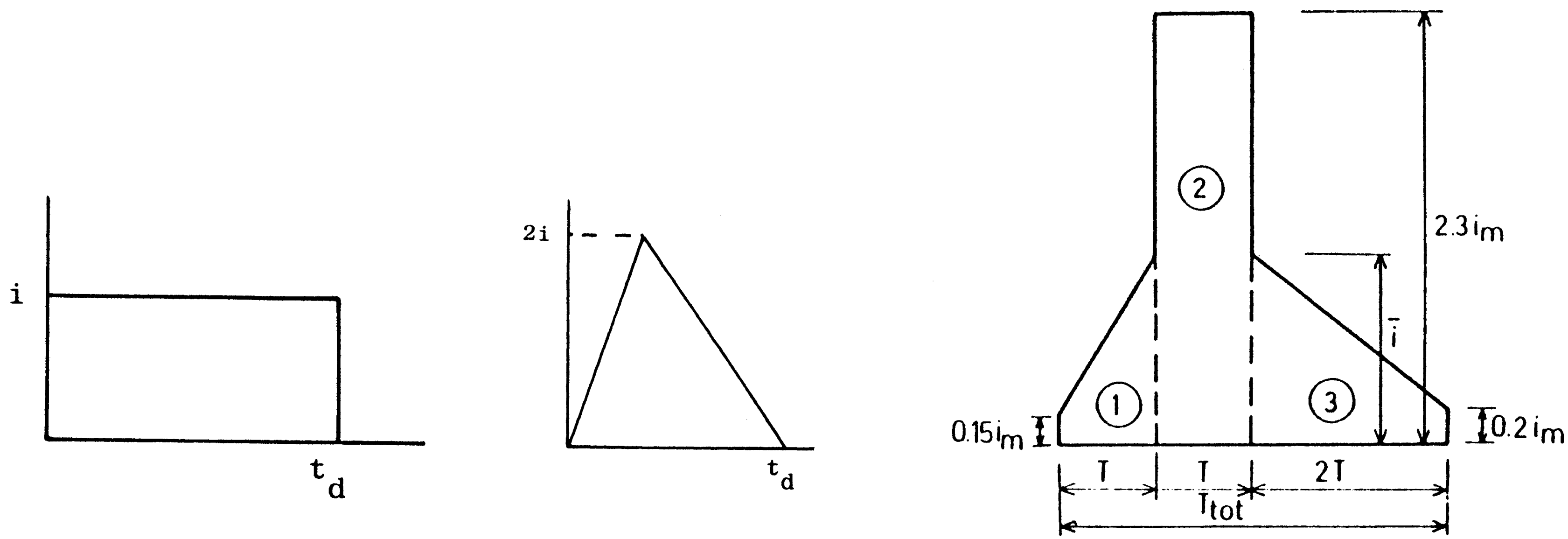
Class I	: not aggressive;
Class II	: lightly aggressive;
Class III	: moderately aggressive;
Class IV	: severely aggressive;
Class V	: very severely aggressive.

Standard design storms

- What is a standard storm?
  - What is important for design purposes…

- How much mm water will fall?
- For how long will it rain?
- How intense is the rain?
- Where will the rain fall?
- How many times can we expect a heavy storm?
- ...?

Standard design storms



Depends on purpose

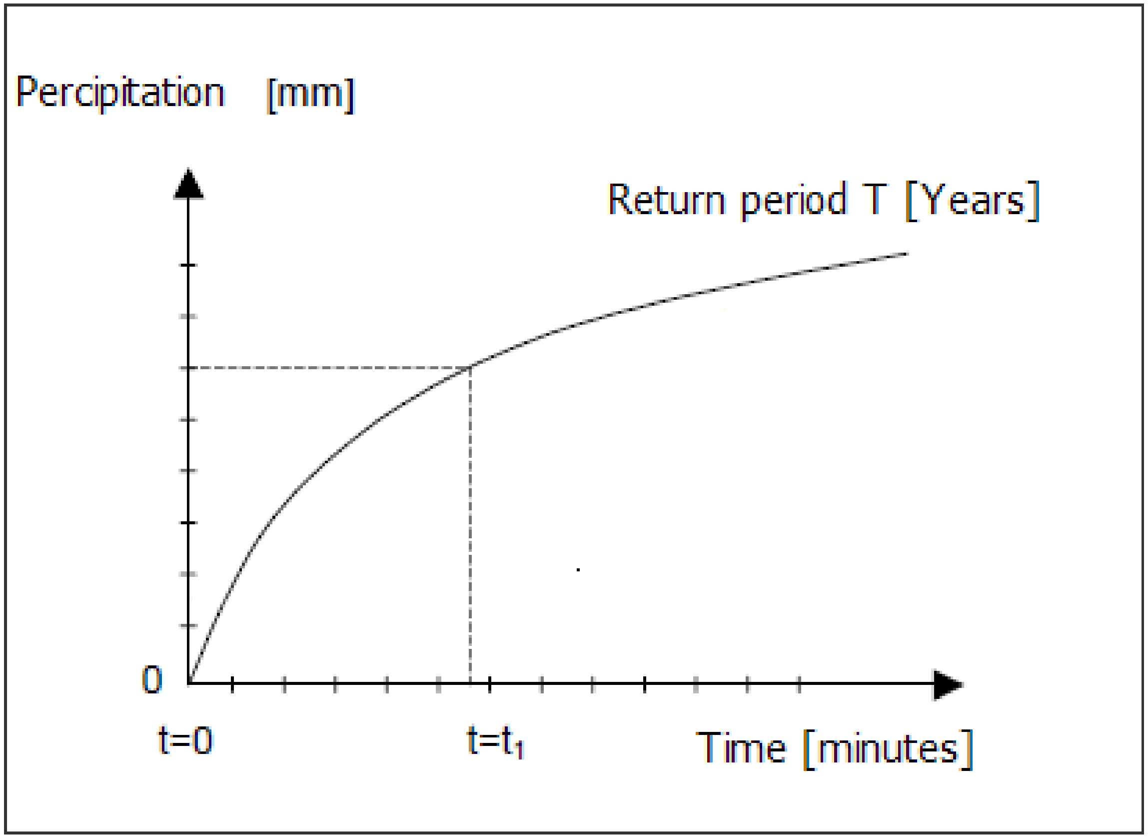
Depth-Duration-Frequency curve method

- Method for calculating discharge capacity/storage capacity

- Prediction of maximum rain within a certain time
  - t=0 (begin), t=1 (end)
- Prediction of maximum rain returning every T years
  - T=return period (Chance = 1/T*100% T>1 year)

- Presentation of historical rain data

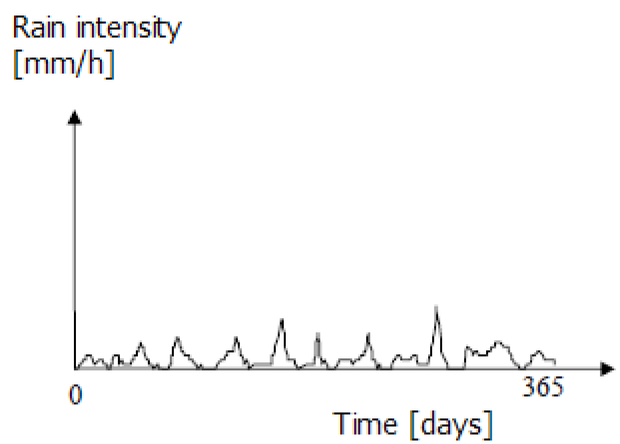
Depth-Duration-Frequency curve method



Constructing DDF-curve (1)

Annual maxima

- Input
  - Rain data
    - At least 2 times the desired T
    - Scale of x-axis must be the same as measuring interval
    - Continue data
  - For T = 2, 5, 10 years and t step is 10 minutes → 52560 measurements
    - Calculate the moving period for every year (max. rain 10, 20, 30 - 180 minutes)



Constructing DDF-curve (2)

Annual maxima

- Results cumulative rainfall

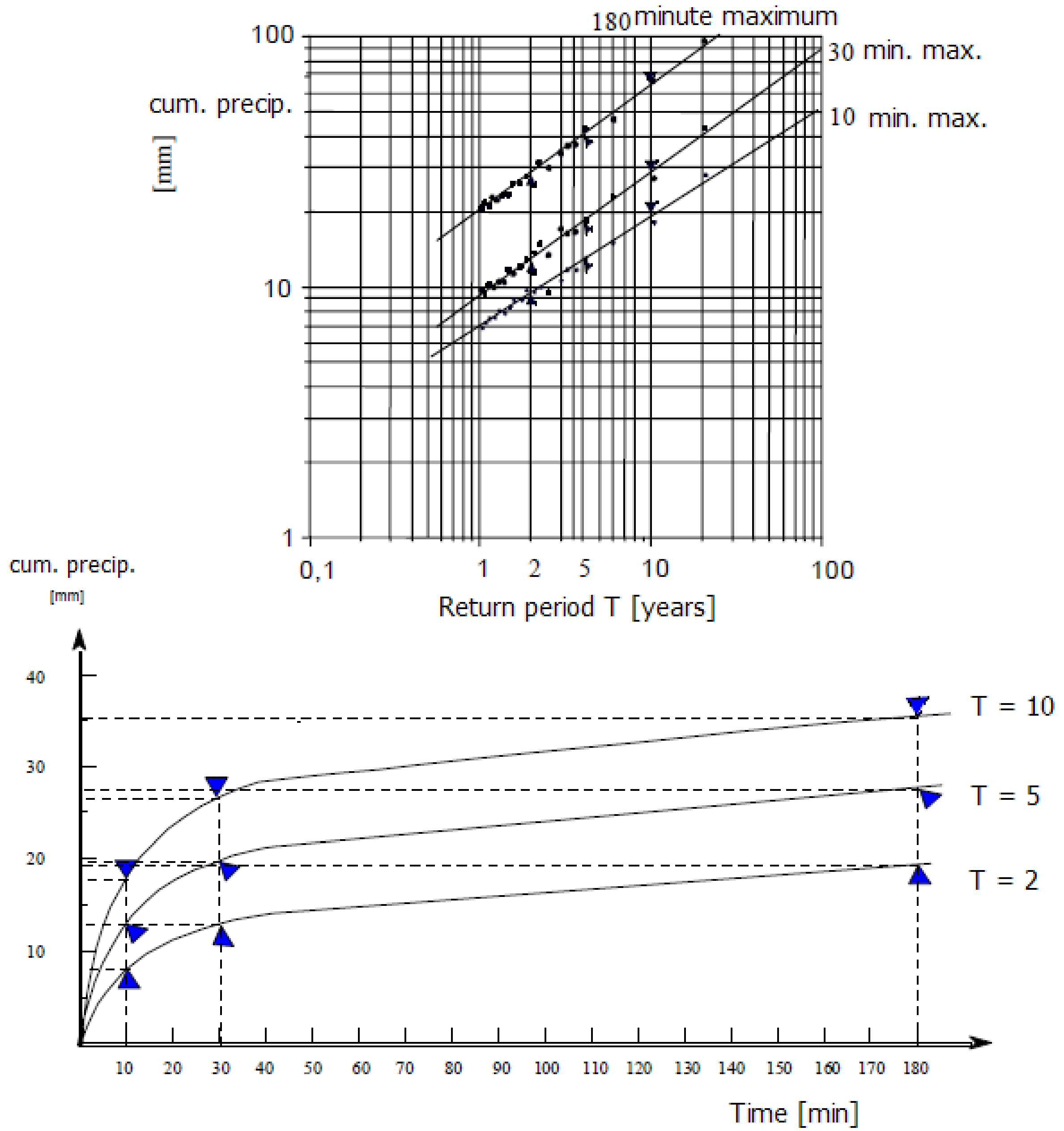
10 min. max.	20 min. max.	… … … …	170 min. max.	180 min. max.
mm. year 1 ($y_{10,1}$)	mm. year 1 ($y_{20,1}$)	… … … …	mm. year 1 ($y_{170,1}$)	mm. year 1 ($y_{180,1}$)
…	…	…	…	…
mm. year 20 ($y_{10,20}$)	mm. year 20 ($y_{20,20}$)	… … …	mm. year 20 ($y_{170,20}$)	mm. year 20 ($y_{180,20}$)

- Determine how many times a maximum returns for T=2, 5, 10 years

$$T(y_{i,j})=(N+1)/m(y_{i,j})$$

$$p = \frac{m - 0.44}{N + 0{,}12}$$

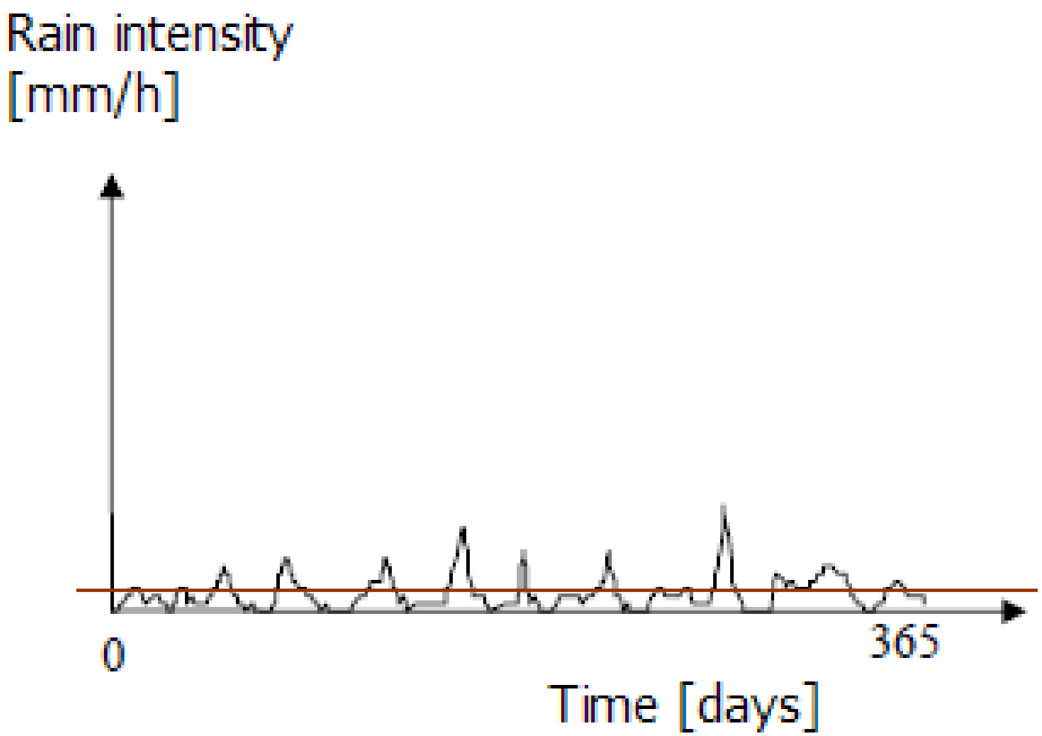
10 min. max.	Order	m	T
$y_{10,1}$	$y_{10,7}$	1	21
$y_{10,2}$	$y_{10,4}$	2	10.5
$y_{10,20}$	$y_{10,12}$	20	1.05


180 minute maximum
30 min. max.
10 min. max.
cum. precip.
[mm]
100
10
1
0,1
1
2
5
10
100
Return period T [years]
cum. precip.
[mm]
40
30
20
10
T = 10
T = 5
T = 2
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Time [min]

Constructing DDF-curve

Peak over treshold

- More accurate for short periods



Gumbel probability distribution

$$\Pr\{\underline{x} \le t\} = \exp(-\exp(-t))$$

$$\Pr\{\underline{x} \le \hat{\alpha}(y-\hat{\mu})\} = \exp(-\exp(-\hat{\alpha}(y-\hat{\mu})))$$

$$\hat{\lambda} = \frac{N}{r} \qquad \frac{1}{\hat{\alpha}} = \frac{\sum_{i=1}^{r}\sum_{j=0}^{n_i} y_{ij}}{N} - q$$

$$\hat{\mu} = \frac{1}{\hat{\alpha}} \ln \hat{\lambda}$$

$\hat{\lambda}$ Is chosen between 2 - 3

Storage capacity

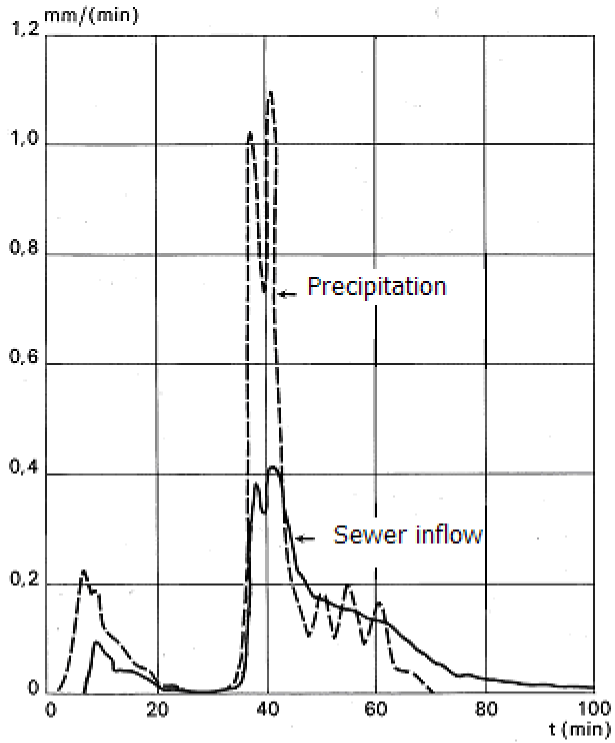
In – Out = Storage

Warning:

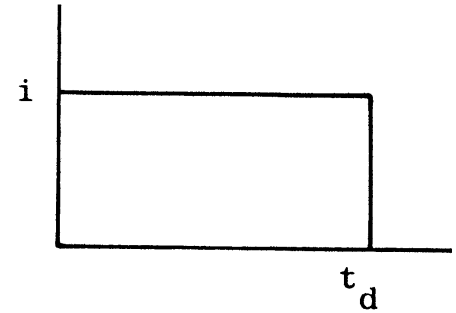
- DDF assumes no discharge delay
- DDF shows no information about the development of the storm
- DDF assumes no different flow symptoms
- Errors to 30 – 40 % are no exception!

Development of the storm

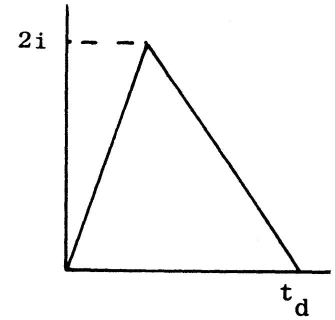
When does the peak occur?



Rainfall duration curve constant



Rainfall duration curve triangular



Improved design storm

Chicago storm

4. Intensity before peak

$$i = \frac{a\left\{(1-b)(t_b/r)^b + c\right\}}{\left\{(t_b/r)^b + c\right\}^2}$$

5. Intensity after peak

$$i = \frac{a\left\{(1-b)(t_a/(1-r))^b + c\right\}}{\left\{(t_a/(1-r))^b + c\right\}^2}$$

1. First movement of a storm

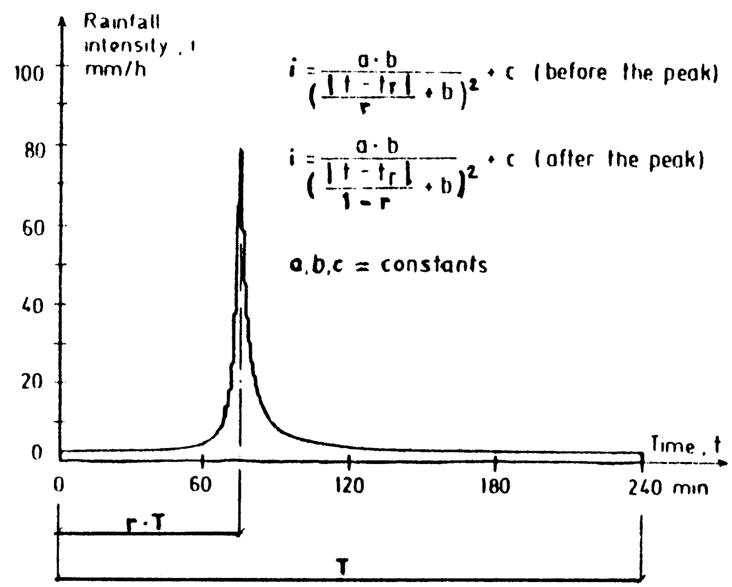
$$\bar{t} = \frac{\Delta t}{t_d P}\sum_{j=1}^{n}(j-0.5)d_j$$

2. t_m (Time peak occurs)

$$\frac{t_m}{t_d} = 3\bar{t} - 1$$

3. Fomula DDF curve

$$\bar{i}\ \frac{a}{t_d^b + c}$$

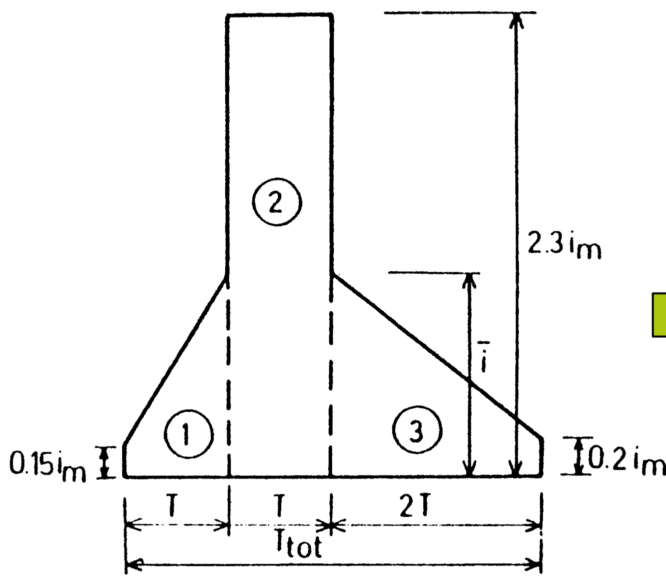


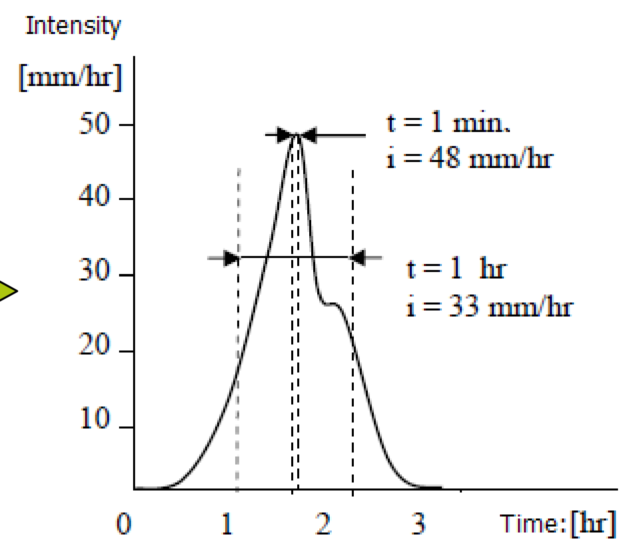
Improved design storm

Sifalda

Intensity and duration of part 2 from DDF

Example of observed storm



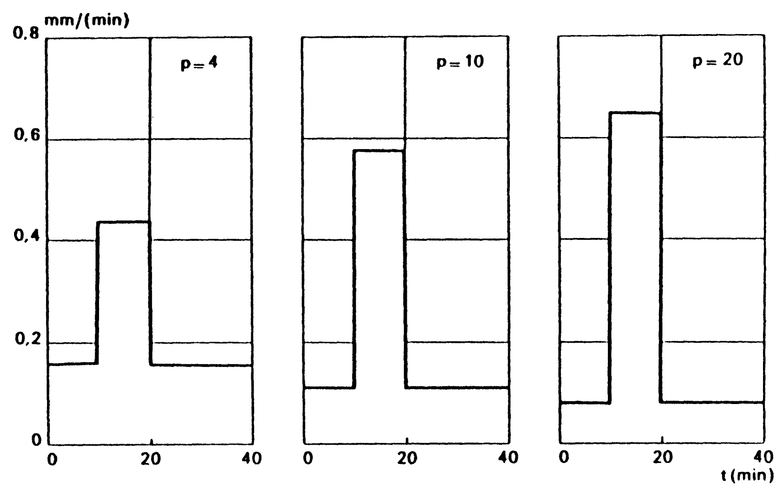


Part 2 shows no variation in precipitation intensity

Improved design storm

Inflow storm

- 40 minute storm with T=2 years
  - Peak return period = 2, 5, 10 years



Design storms

Overview

Design storm	Result of comparison (various sources)
Rainfall duration curve constant	Under estimates runoff peaks for large return periods (e.g. 50% under estimation of the peak runoff of an observed storm with a return period of 10 years).
	Limited under- and over estimation with before the storm wet conditions (in case in the area the ground is sensitive therefore).
	Under estimates the peak runoff (15-40%) for dry conditions previous to the storm, in areas with a low pavement-percentage.
	Under estimates the peak runoffs (5-20%) for areas not supplying runoff from un-paved area.
Rainfall duration curve triangular	Over estimates the peak runoff with wet conditions before the storm and smaller under- and over estimation with dry conditions before the storm.
Chicago design storm	Over estimates the peak runoff (ca. 75%) with time steps 1 and 2minutes
	Little over estimation of the peak runoff (ca. 5%) and some under-estimated peak runoffs
Sifalda	Under estimates the quantity of precipitation with storms of short duration and over estimates these with long duration.