3. Design discharges

Urban Hydraulic Systems
Prof. Dr. Michael Pfister

3. Design discharges

Content

Literature

BFU (1985). *Recommandations pour la détermination du coefficient d'écoulement maximal lors de l'établissement des plans directeurs des égouts*
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DWA (1994). *Planung der Kanalisation*. Ernst & Sohn, Berlin
Chow, V.T. et al. (1988). *Applied hydrology*. McGraw-Hill, New York
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VSA (2008). Messtechnik Siedlungsentwässerung. *Dokumentation*

3. Design discharges

Goals of this chapter

- Estimation of design discharge for fresh water supply
- Estimation of design discharges for sewer
- To validate an estimation, to know magnitudes
- To know how to measure discharges

Only pragmatic and simple approaches are presented here, as

- Each project has different conditions (hydrology, surface permeability, historic sewer, population, industry…)
- The national requirements and concepts vary
- Detailed “urban hydrology” is complex

Measurements are better than estimations

3.1 Introduction

3.1 Introduction

Urban water production

Natural water

Fresh water consumption
to design reservoirs and supply net

Sewer discharge during dry-weather
Relevant to avoid deposits in sewer

Relevant storm rain event

- Period and intensity
- Which part flows into sewer?
- Maximally expected storm discharge in sewer?

Evacuation system(s) (separated or combined)

3.1 Introduction

Design discharges sewer (ATV A118)

Separated system

Aspired system

Storm water net

Storm run-off (+ unavoidable base flow)

Sewer

Dry-weather discharge (+ unavoidable run-off from precipitation)

Combined system

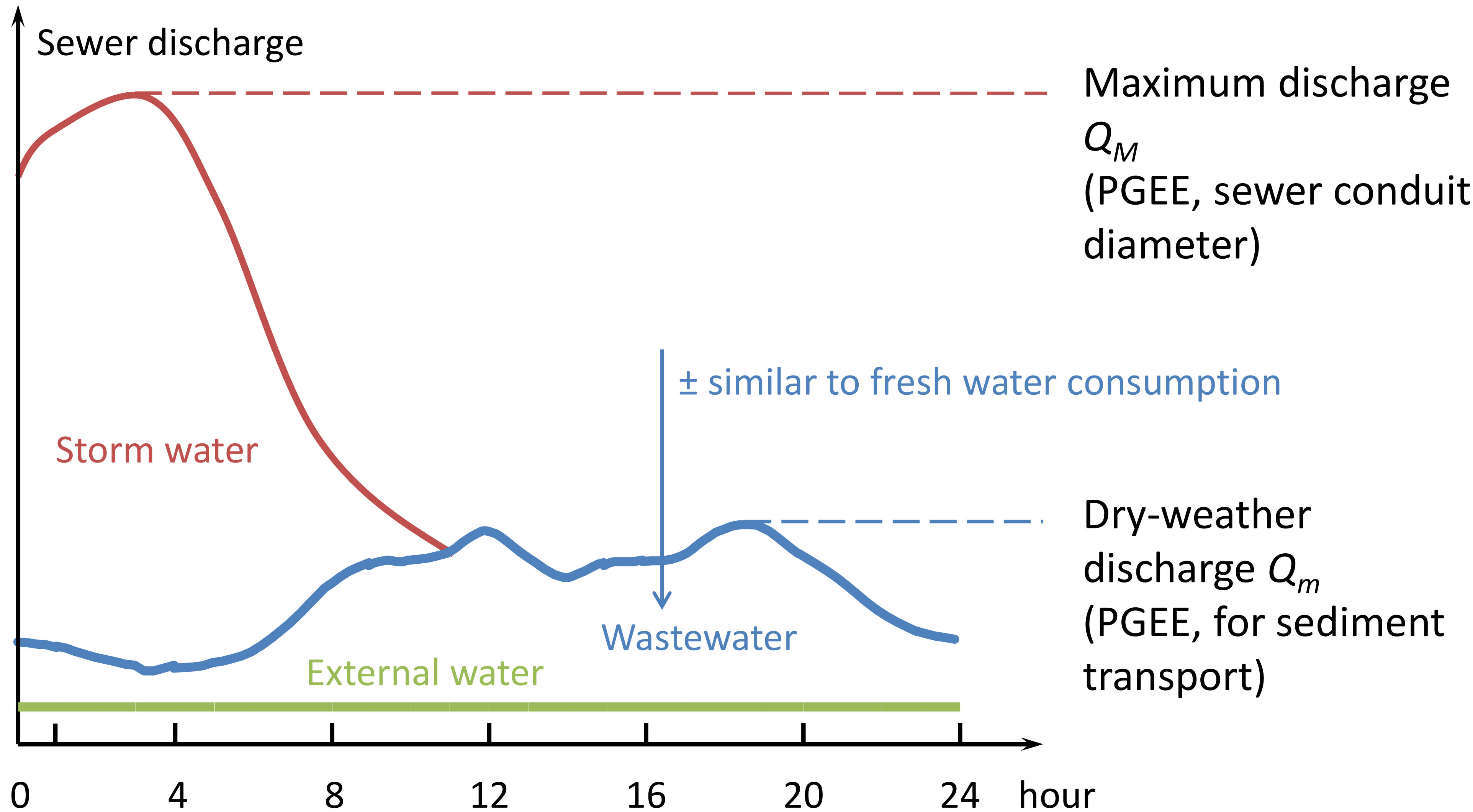
Historic system

Sewer

Storm run-off + Dry-weather discharge (+ unavoidable base flow)

3.1 Introduction

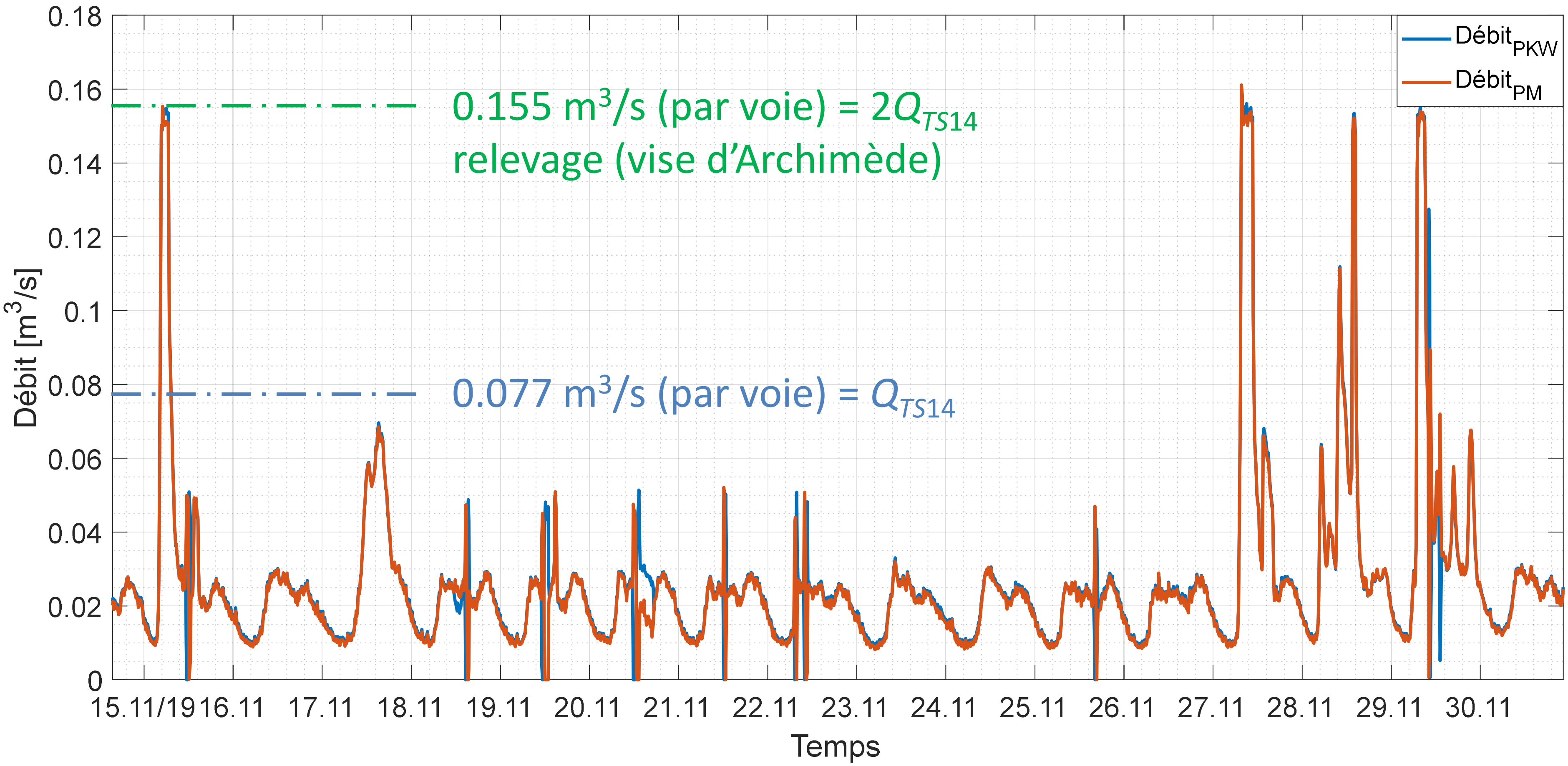
Combined system



3.1 Introduction

Combined system

Système unitaire, SETP de Vétroz-Conthey (fin 2019)

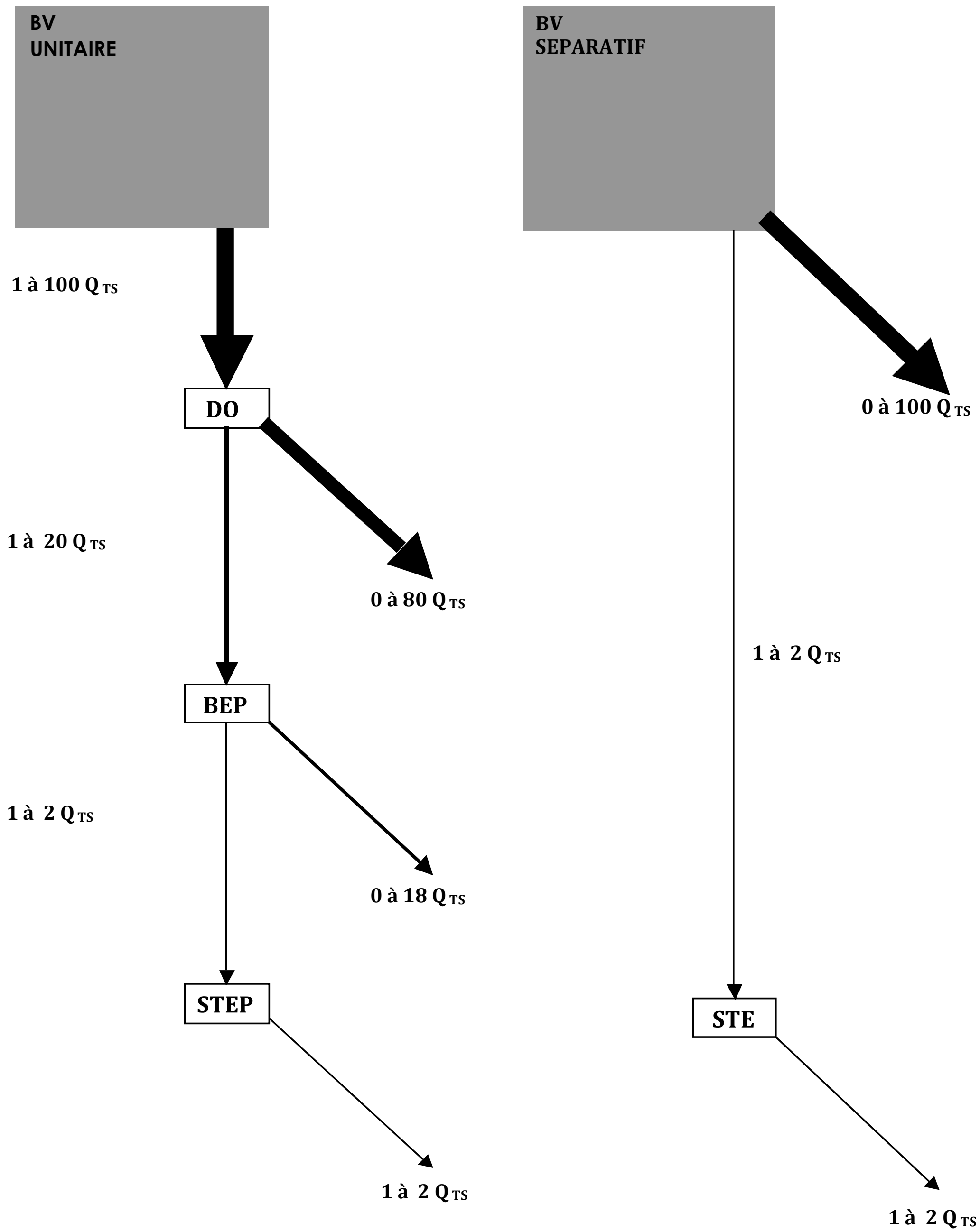


3.1 Introduction

Types of water

Eaux usées	Wastewater	External water	Storm run-off
Provenance	Consommateurs d'eau potable	Drainages fontaines	Surfaces imperméables
Apparition	quotidienne selon consommation	continue constante ou variable	occasionnelle aléatoire
Ordre de grandeur	**1 à 2 Q_{TS}**	**0 à 5 Q_{TS}**	**0 à 100 Q_{TS}**
Qualité	polluées	Non-polluées	Polluées puis non-polluées
Destination	**STEP**	**écoulements naturels**	**STEP puis écoulements naturels**

3.1 Introduction



Q_{TS} : Débit qui se produit par temps sec sans aucune composante d'eau de pluie

DO déversoir d'orage : Déversoir d'eaux mixtes dans un milieu récepteur

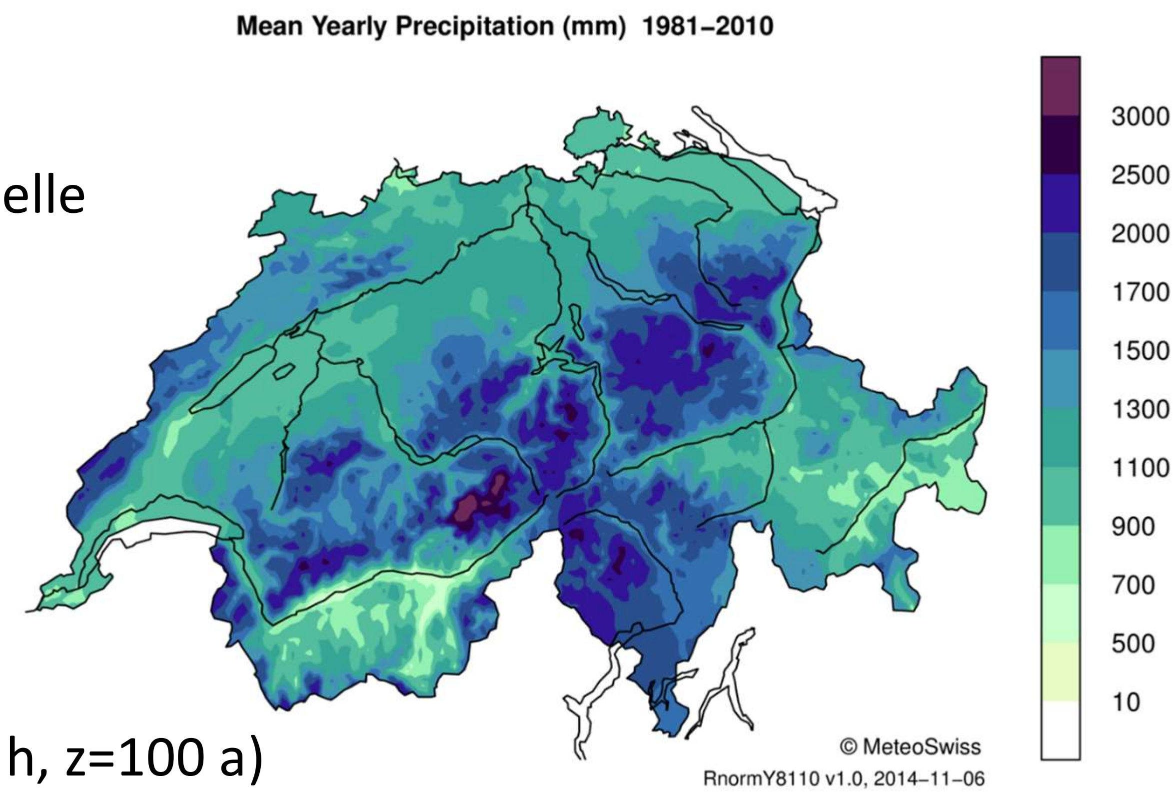
BEP bassin d'eaux pluviales : Ouvrage destiné à stocker temporairement les eaux excédentaires lors des pluies, avant de les restituer au milieu récepteur ou au réseau aval

STEP : Station d'épuration d'eaux usées

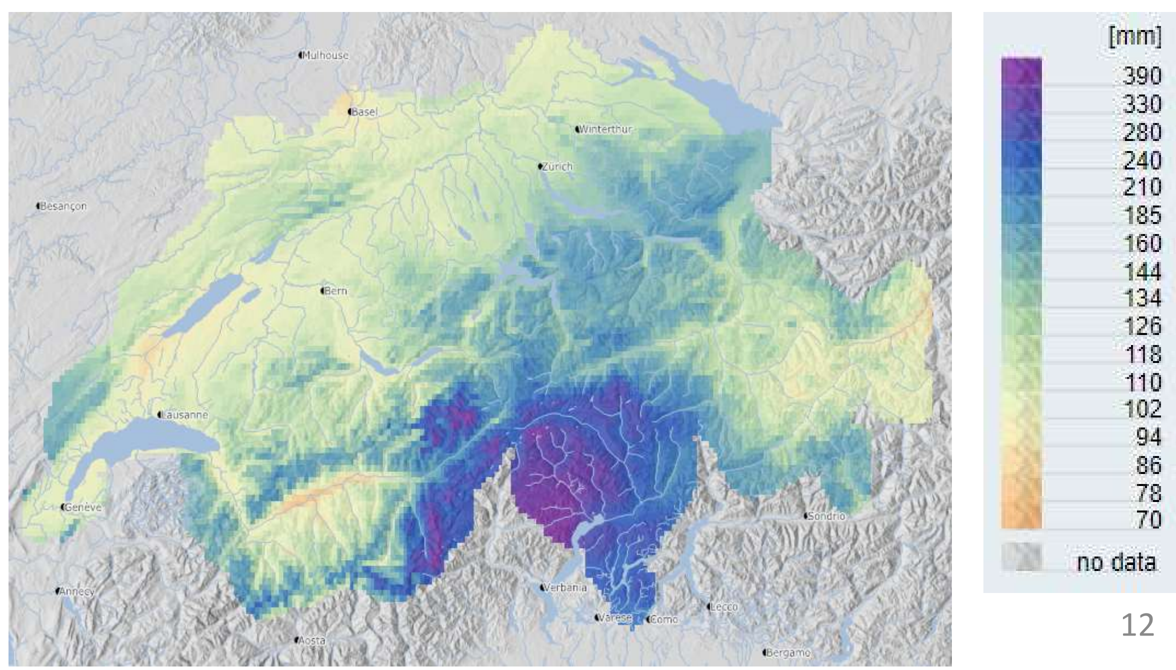
3.2 Storm run-off

3.2 Storm run-off

Précipitation moyenne annuelle



Précipitation extrême (T=24 h, z=100 a)



[hydromaps.ch]

3.2 Storm run-off

Precipitation

- Switzerland in average (entire country) 1’500 mm rain per year
- Extreme yearly average between 600 … 4’000 mm
- Swiss plateau some 1’200 mm rain per year
- Lausanne 1’100 mm/a, 123 days with rain/a (1961-1990, SMA)

classical hydrology: large catchment and period of hours/days
urban hydrology: small catchment and fast processes

Runoff generation

1. Rain falls on catchment area, with a spatial and temporal intensity
2. Run-off mobilization. The ground is wetted; storage, evaporation and infiltration
3. Concentration of run-off discharge: a part of the water flows to sewer, with a time offset as compared to the begin of the rain event
4. Water transport in sewer or storage to avoid floods in river course

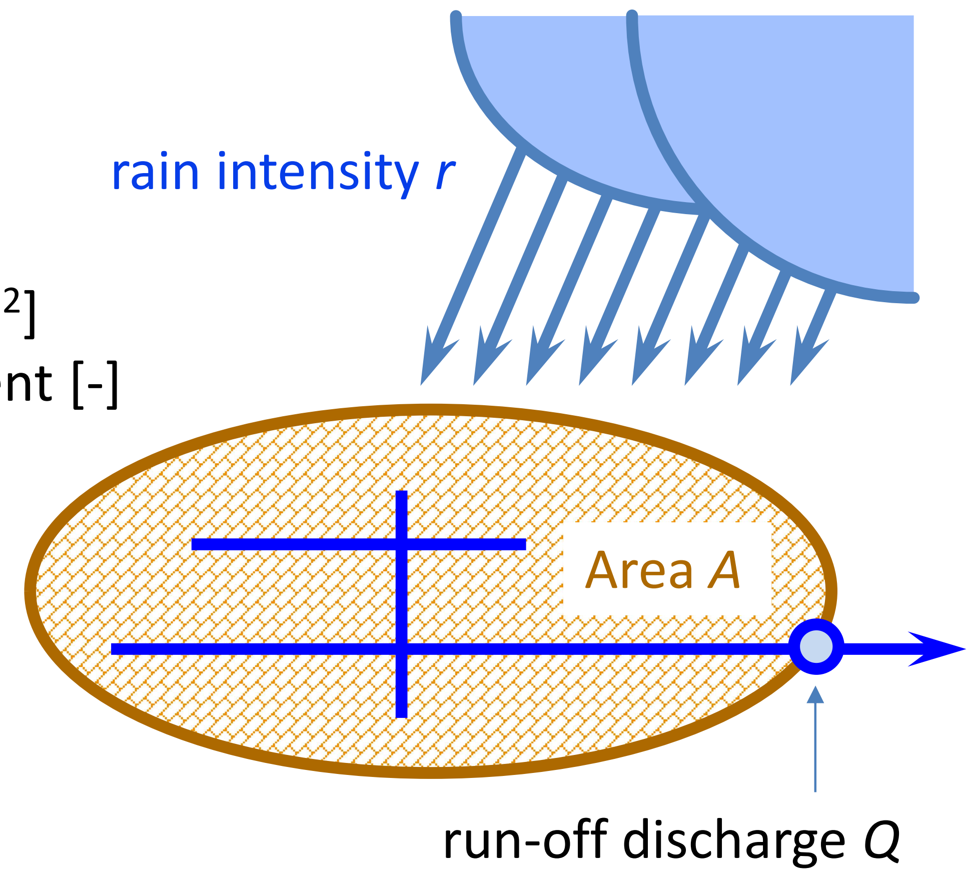
3.2 Storm run-off

Rational method

General approach to estimate run-off discharge of catchment induced by rain

$$Q_R = \frac{\psi\, r\, A}{3.6 \cdot 10^6}$$

Q_R	run-off discharge [m³/s]
r	rain intensity [mm/h]
A	considered catchment area [m²]
ψ	(maximum) discharge coefficient [-]
$3.6 \cdot 10^6$	units transformation



Better: use measurements of Q_R!

BWG (2003)

3.2 Storm run-off

Rational method

“Although valid criticisms have been raised about the adequacy of this method, it continues to be used for sewer design because of its **simplicity**. Once the layout is selected and the pipe size determined by the rational method, the adequacy of the system can be checked by dynamic routing of flow hydrographs through the system” Chow (1988)

Other methods are given by BWG (2003)

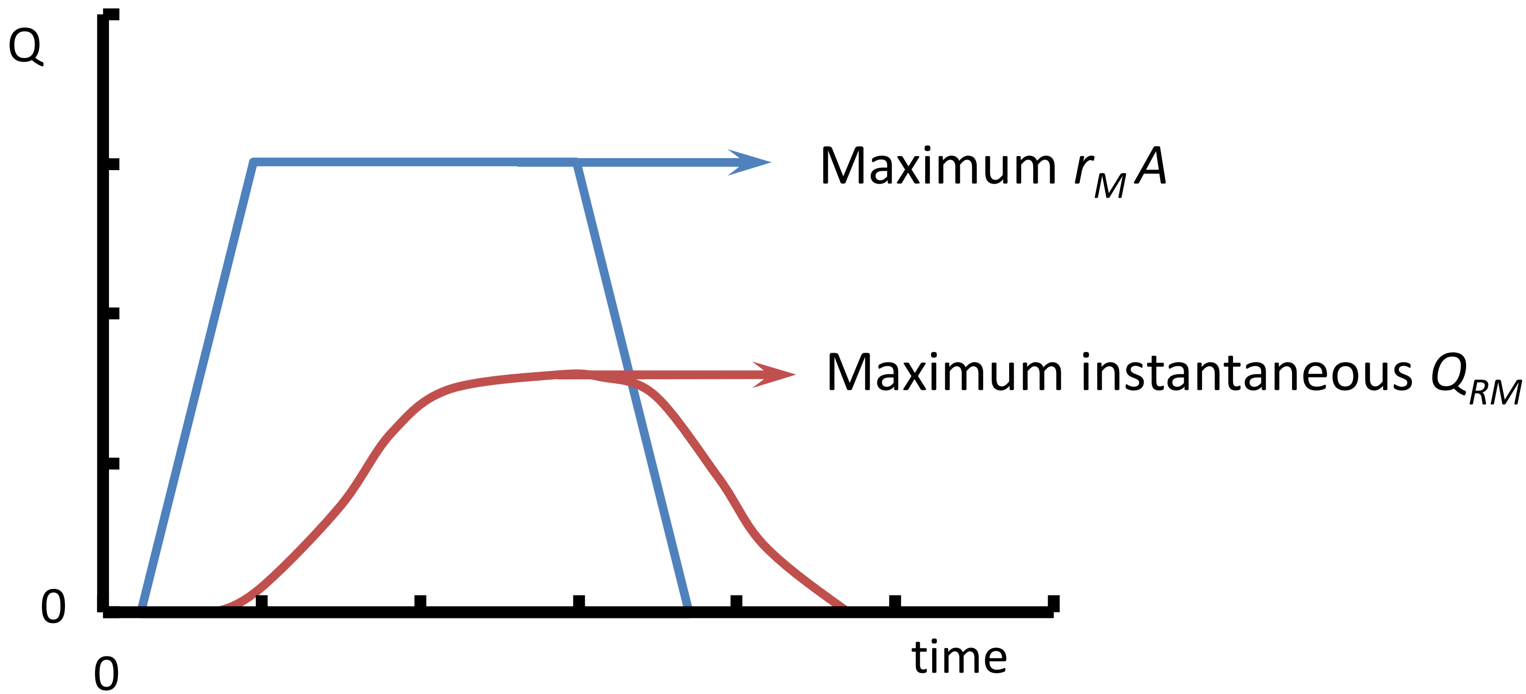
(SNV 640 350:2001, VSS , Oberflächenentwässerung von Strassen)

(Projektregen und Oberflächenabflüsse, Vollzugshilfe, Service de l’environnement, Etat de Fribourg)

3.2 Storm run-off

Maximum discharge coefficient

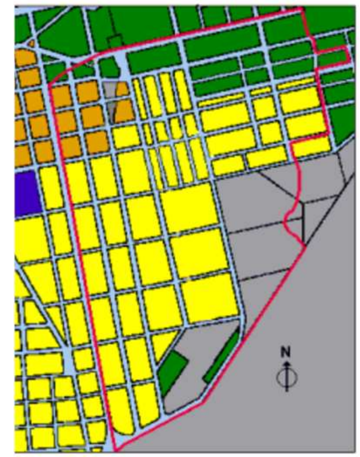
$$\psi_M = \frac{Q_{RM}}{r_M A}$$



3.2 Storm run-off

Maximum discharge coefficient: individual estimation
Analyze small-scale catchment area (air photo)

$$\psi_M = \sum_{i=1}^{m} \gamma_i \cdot \alpha_{Mi}$$



γ relative area (compared to total considered area)
α individual discharge coefficient

- Define segments with their relative area
- Classify types
- Deride ψ_M

3.2 Storm run-off

Maximum discharge coefficient: individual estimation

Discharge coefficient α

4.1 Surfaces aménagées

Le coefficient de ruissellement est fortement influencé par le type de surface ou de couverture du sol, comme le montre le tableau suivant :

Type de surface ou de couverture du sol			C
Toits plats et inclinés (indépendamment du matériel et de la couverture)			1.0
Toits plats recouverts de gravier (indépendamment de l'épaisseur de la couche)[2]			0.8
Toiture plate végétalisée, selon l'épaisseur de la couche végétale		>50 cm	0.1
		25-50 cm	0.2
		10-25 cm	0.4
		≤ 10 cm	0.7
Place et chemin	- avec revêtement en dur		1.0
	- avec gravillons		0.6
	- avec copeaux		0.6
	- avec revêtement filtrant		0.6
	- avec pavés filtrants		0.2
	- avec pavés-gazon		0.2

Tableau 2 : Coefficients de ruissellement pour différentes surfaces et couvertures du sol, selon SN 592 000

Etat de Fribourg, Pluies de projet et débits ruisselés, Aide à l'exécution, 4.2.007

3.2 Storm run-off

Maximum discharge coefficient: individual estimation

Discharge coefficient α

4.2 Surfaces non aménagées

Pour les surfaces non aménagées, la littérature fournit des valeurs de coefficient de ruissellement pour chaque type de sol, en relation avec la pente du terrain ou l'utilisation du sol.

Pente %	**Couverture du sol**		
	Forêts	Pré-champ	Culture dans le sens de la pente
0.5	--	0.005	0.12
1.0	0.01	0.020	0.13
2.0	0.02	0.040	0.18
4.0	0.04	0.070	0.23
6.0	0.05	0.090	0.27
8.0	0.06	0.110	0.31
10.0	0.07	0.130	0.34
15.0	0.08	0.170	0.40
20.0	0.10	0.190	0.45
25.0	0.12	0.220	0.50
30.0	0.13	0.250	0.55
35.0	0.14	0.270	0.59

Tableau 3 : Coefficient de ruissellement en fonction de la pente et de la couverture du sol, tiré du guide de la Division des améliorations structurelles de l'Office fédéral de l'agriculture

Etat de Fribourg, Pluies de projet et débits ruisselés, Aide à l'exécution, 4.2.007

3.2 Storm run-off

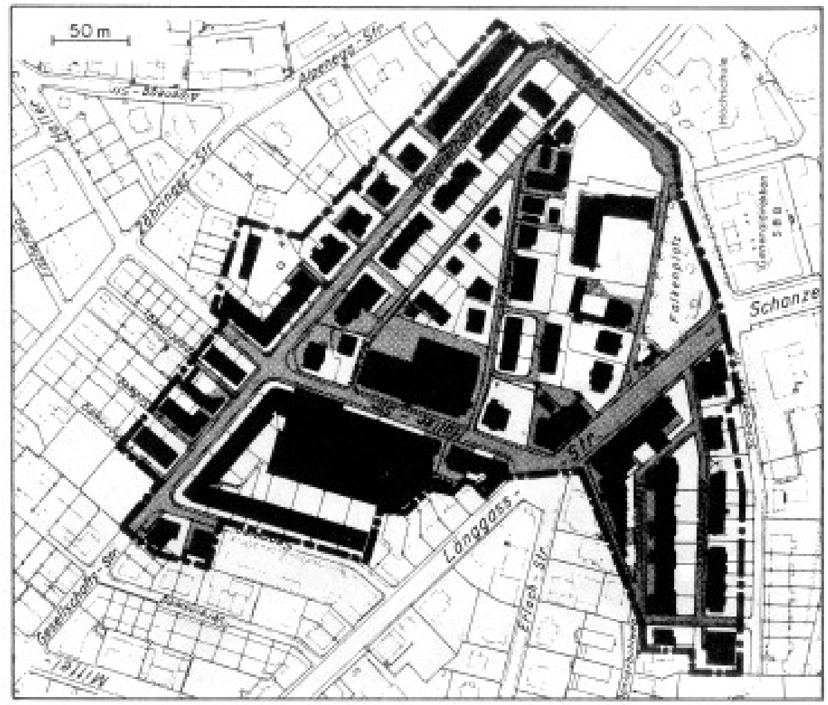
Maximum discharge coefficient: individual estimation

Horizontal green surfaces infiltrate everything … really?


Photo Thomas Rohr

3.2 Storm run-off

City centre



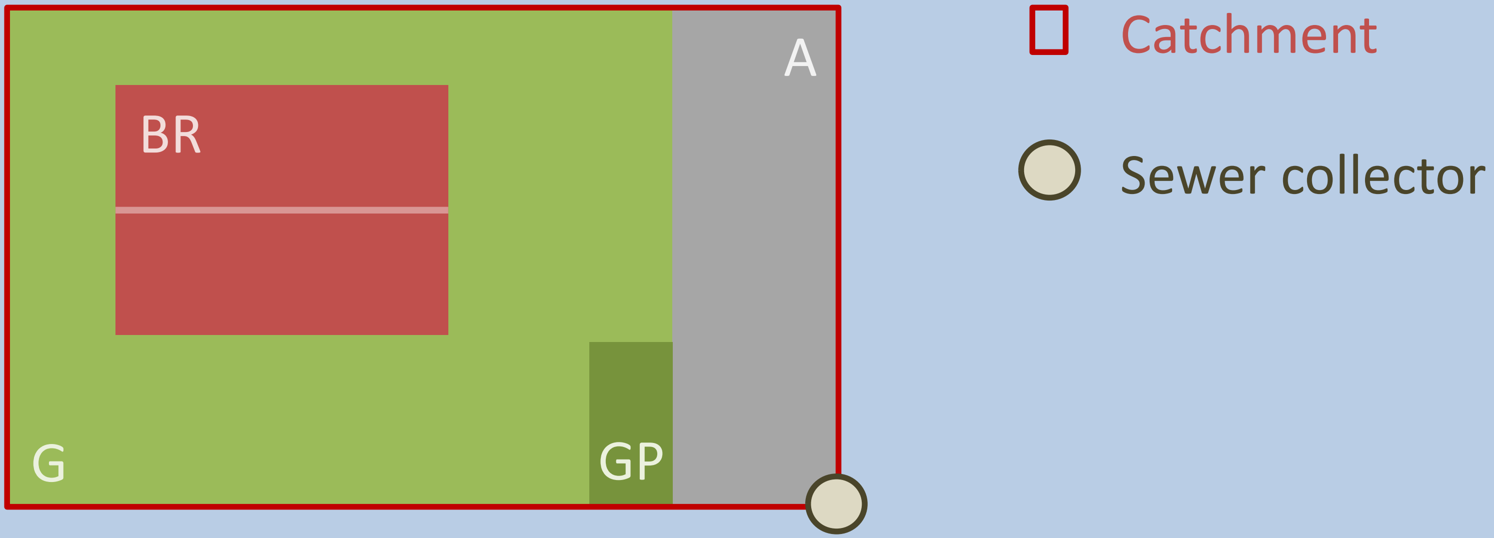
ψ_M=0.55

Type de surface	α_s	Surface effective m2	γ (%)	ψ_s
Toits				
Tôles	0,95	3'510	4,2	0,04
Eternit	0,95	5'335	6,3	0,06
Tuiles	0,90	15'115	18,0	0,16
Béton	0,80	3'760	4,5	0,04
Toits plats recouverts de gravier	0,25	6'610	7,9	0,02
Rues				
Asphalte	0,80	16'190	19,3	0,16
Parcs-autos, places, accès				
Asphalte	0,80	5'300	6,3	0,05
Pavage	0,50	3'770	4,5	0,02
Espaces verts et surfaces non drainées	0	24'380	29,0	0
TOTAL		83'970	100,0	0,55
			ψ_s =	0,55

BFU (1985)

3.2 Storm run-off

Maximum discharge coefficient: individual estimation



Type	α	γ	αγ
Brick roof			
Asphalt			
Grass paver			
Garden			
Sum			

3.2 Storm run-off

Maximum discharge coefficient: approximate estimation

1) Assume that α_M=0.85, so that

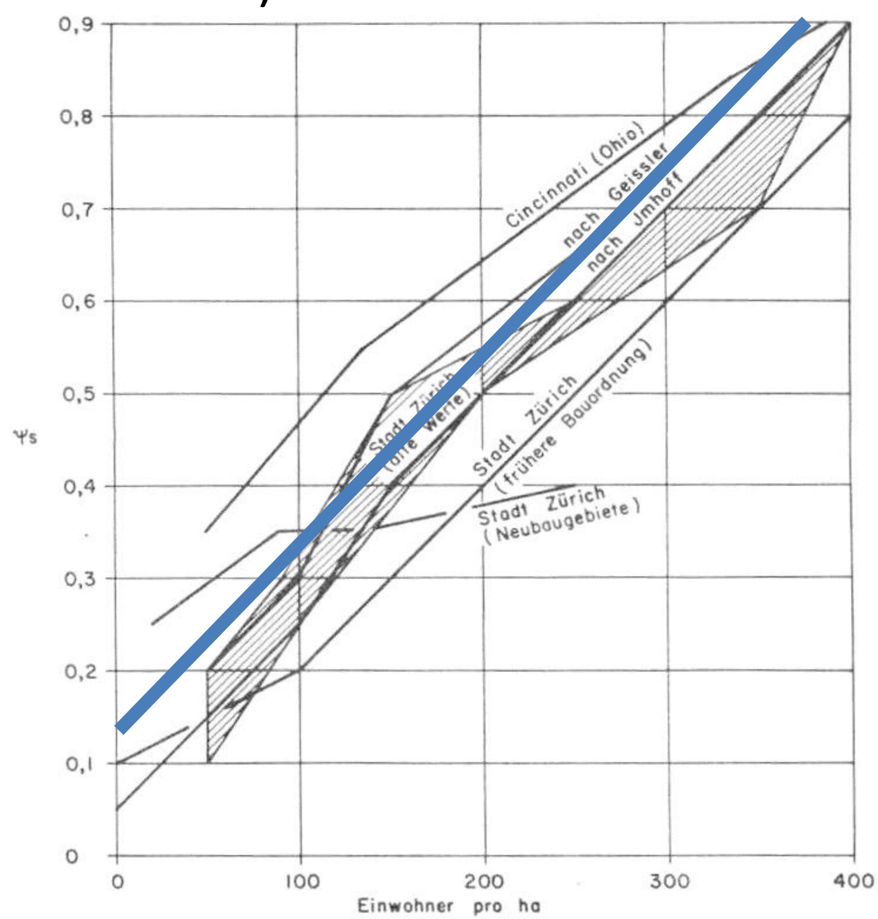
$$\psi_M = 0.85 \cdot \gamma$$

γ relative area (compared to total area) of artificial surfaces

2) Correlation between population density and ψ_M

$$\psi_M = 0.15 + 0.002E$$

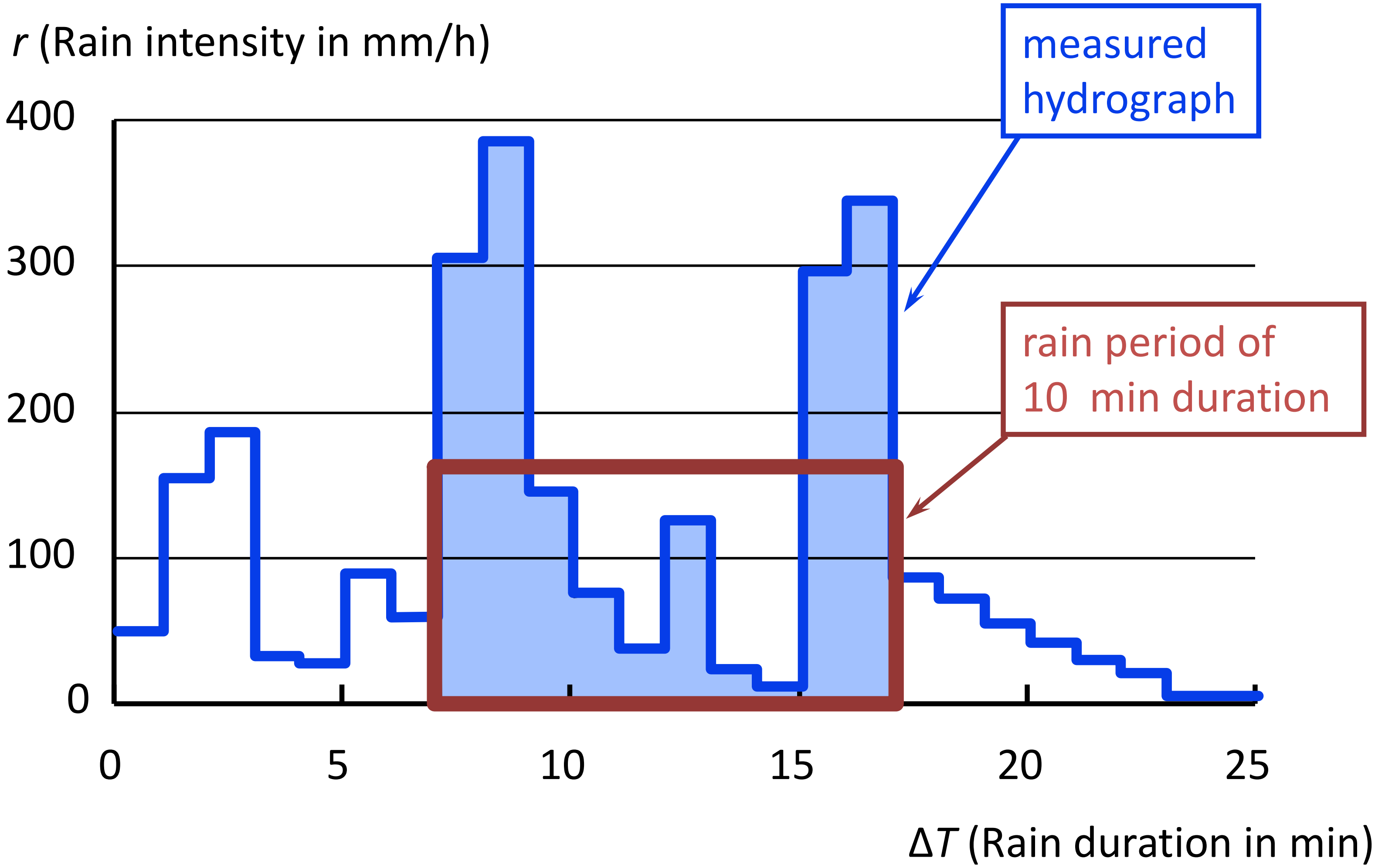
E population density [persons per ha]



3.2 Storm run-off

Rain intensity
Unit is velocity!

$$r = \frac{V_R}{\Delta T \ A}$$



Gujer 1999

3.2 Storm run-off

Rain intensity
Example for different durations ΔT

[l/(s·ha)]

Time		***intensity***	*intensity*	*intensity*
[min]		**[$ls^{-1}ha^{-1}$]**	ΔT=6 min	ΔT=10 min
0	2	0	0	0
2	4	0	0	0
4	6	60	20	12
6	8	10	23	14
8	10	30	33	20
10	12	90	43	38
12	14	140	87	66
14	16	240	157	102
16	18	310	230	162
18	20	150	**233**	186
20	22	110	190	**190**
22	24	40	100	170
24	26	30	60	128
26	28	10	27	68
28	30	5	15	39
30	32	0	5	17
32	34	0	2	9
34	36	0	0	3
36	38	0	0	1
38	40	0	0	0

3.2 Storm run-off

Rain intensity
Example for different durations ΔT

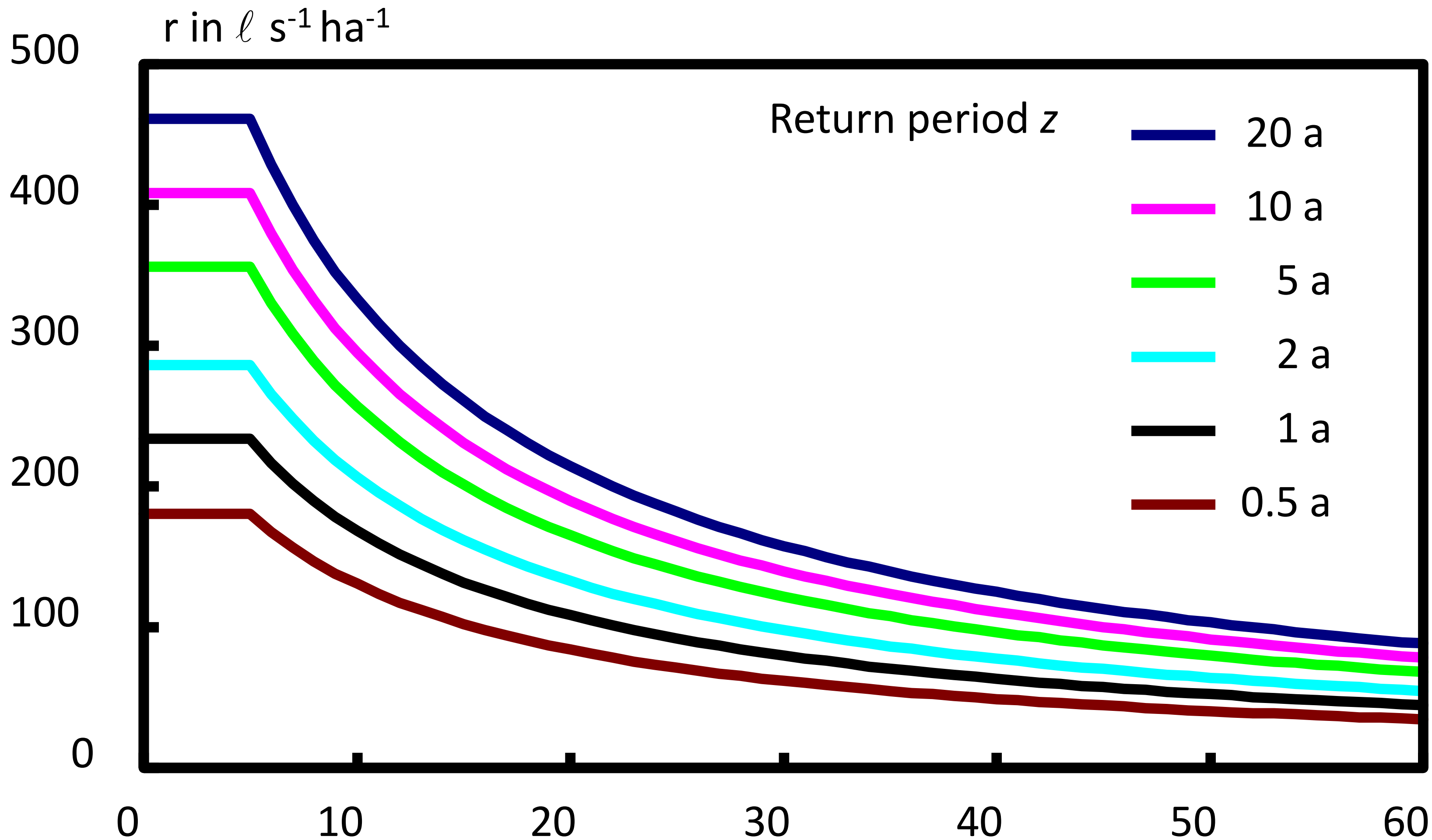
[l/(s·ha)]

Time		***intensity***	*intensity*
[min]		**[$ls^{-1}ha^{-1}$]**	ΔT=14 min
0	2	0	0
2	4	0	0
4	6	60	9
6	8	10	10
8	10	30	14
10	12	90	27
12	14	140	47
14	16	240	81
16	18	310	126
18	20	150	139
20	22	110	153
22	24	40	?
24	26	30	146
26	28	10	127
28	30	5	94
30	32	0	49
32	34	0	28
34	36	0	12
36	38	0	6
38	40	0	2

3.2 Storm run-off

Rain intensity

Effect of return period *z* for Berne (Hörler and Rhein, 1962)



3.2 Storm run-off

Rain intensity

- MeteoSuisse (https://hydromaps.ch), actuelles et avec l'effet du changement climatique
- MeteoSuisse Analyses des valeurs extrêmes https://www.meteosuisse.admin.ch/climat/climat-de-la-suisse/records-et-extremes/analyses-des-valeurs-extremes.html
- IDF charts (Intensité I – Durée T – Fréquence z), historique
- (VSS - Höhler et Rhein, historique et régionalisé)

3.2 Storm run-off

Rain intensity MeteoSuisse

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

Payerne: 490m, 46.81N, 6.94E

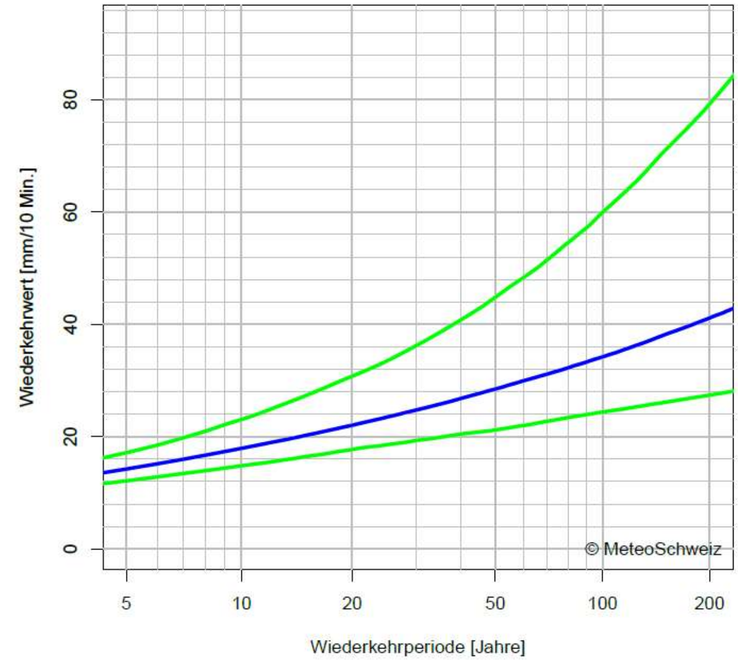
Extremwertanalyse

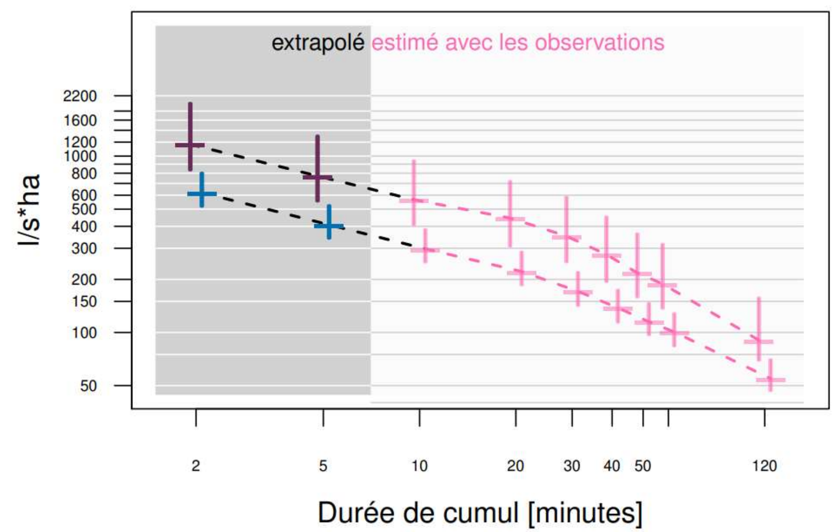
10-Minuten-Niederschlag

1982 - 2018 (Anzahl fehlende Jahre: 0)

Bayes (saisonale Maxima, GEV). **Zuverlässigkeit der Ergebnisse: gut.**

Wiederkehr-periode [Jahre]	Wiederkehr-wert [mm/10 Min.]	Konfidenz-intervall [mm/10 Min.]
2.33	10.5	(9.2 - 12.1)
5.00	14.2	(12.1 - 17.1)
10.00	17.9	(14.8 - 23.1)
20.00	22.0	(17.7 - 30.8)
30.00	24.7	(19.3 - 36.2)
50.00	28.5	(21.2 - 44.8)
100.00	34.2	(24.4 - 59.10

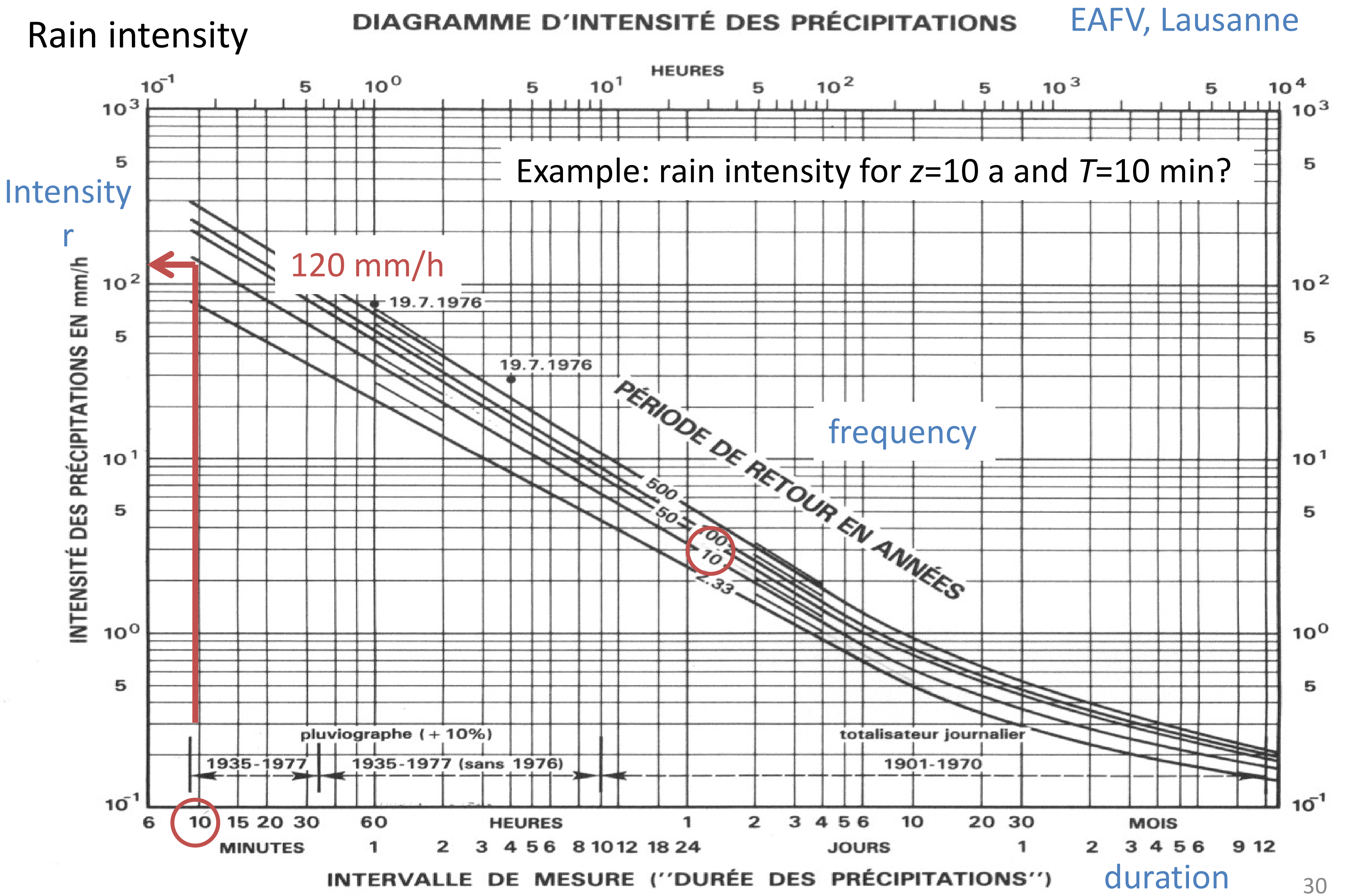




Niveaux de retour de l'intensité [l/s*ha] des précipitations cumulées sur 2, 5, 10, 20, 30, 40, 50, 60 et 120 minutes, pour des périodes de retour de 10 (courbe du bas) et 100 (courbe du haut) ans. Bleu (violet) : niveaux de retour extrapolés pour des cumuls sur 2 et 5 minutes. Rose : niveaux de retour éstimés indépendamment à partir des cumuls observés sur 10, 20, 30, 40, 50, 60 et 120 minutes.

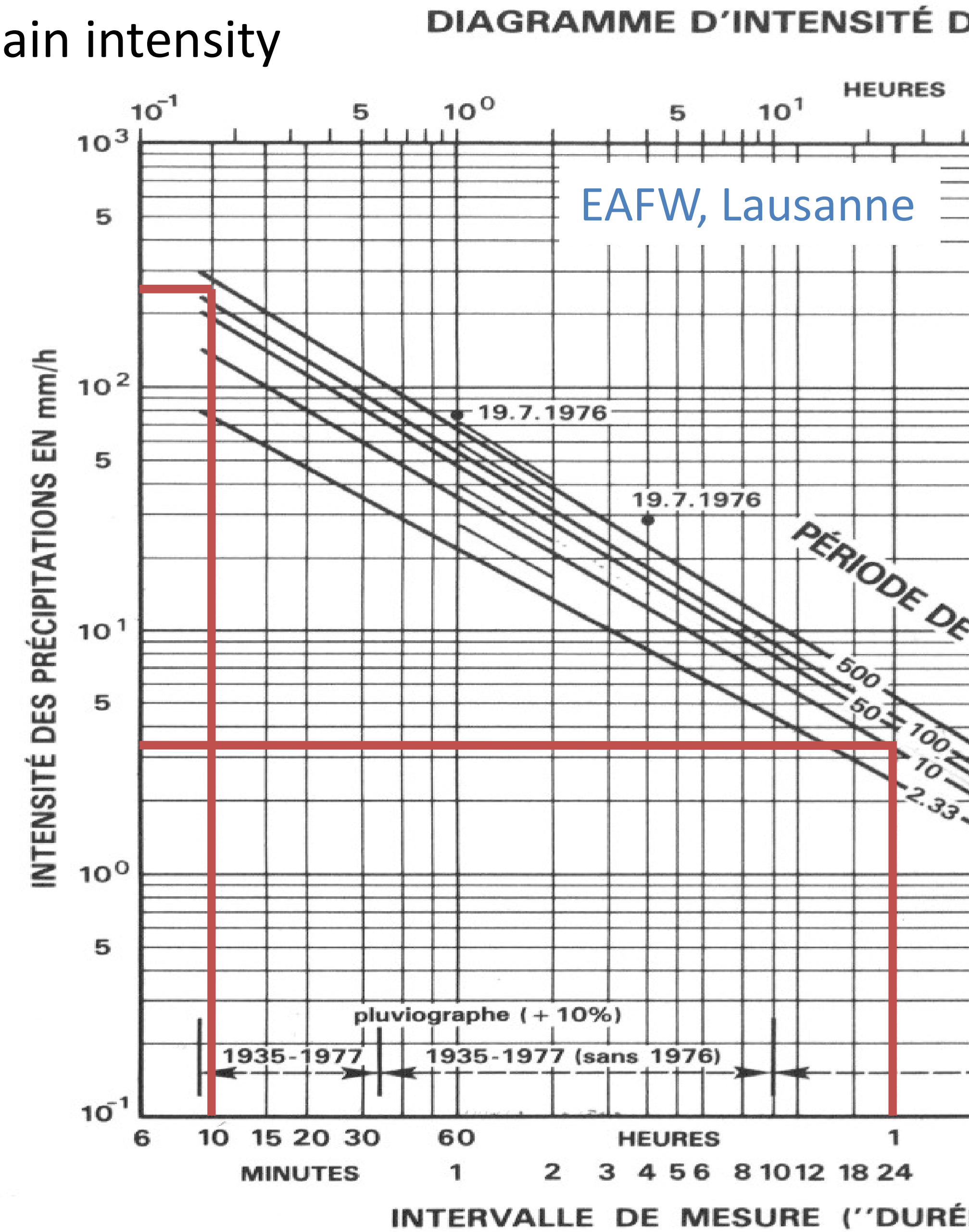
3.2 Storm run-off

Rain intensity



3.2 Storm run-off

Rain intensity



Regenmengen in 24 h bis Dienstag 06:30 Uhr

STATION	REGENMENGE
Lausanne/VD	78.1 mm

Die #Regenmengen in den letzten 24 h: Vor allem in der #Romandie fiel teils viel Regen. Zum Vergleich: im ganzen Juni normalerweise um 100 mm. ^gf

06:57 - 12. Juni 2018

Orage diluvien sur Lausanne et nouveau record de pluie en 10 minutes en Suisse

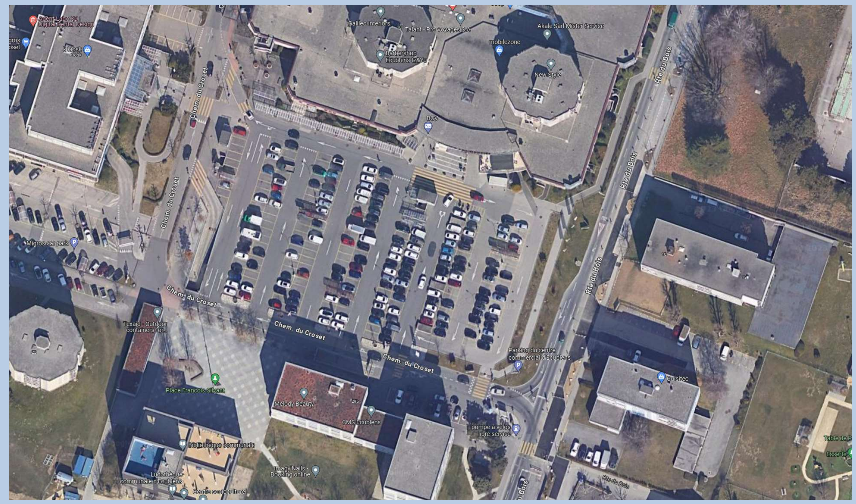
12 juin 2018
Thèmes: Météo

Lundi 11 juin vers 23h00, un orage diluvien s'est abattu sur la ville de Lausanne. En 10 minutes, il est tombé 41 mm de pluie. Il s'agirait des précipitations sur 10 minutes les plus intenses jamais relevées en Suisse depuis le début des mesures automatiques.

3.2 Storm run-off

Rain intensity

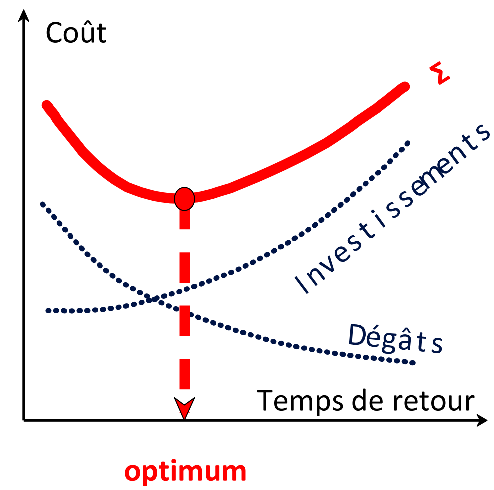
What is the storm run-off of a parking lot 90 m times 120 m in Lausanne?
(*T*=10 min and *z*=10 years)



3.2 Storm run-off

Which return period [z] and which rain period [T] are relevant?

- Flooding risk vs. cost
- Frequency of damages : how often fails a system
- Which rain period generated the maximum discharge in the system?



Note that

- The sewer design must include future urban development: “over-design” for present situation

Some cities/cantons apply a pragmatic approach

- SEn Fribourg : “En l'absence d'autres données spécifiques figurant dans le PGEE ou fournies par un spécialiste, le dimensionnement des installations d’évacuation des eaux pluviales se calcule avec : z=5 ans et T=10 minutes”

3.2 Storm run-off

Relevant return period *for sewer*

Switzerland ⇨

Return period for design rain (VSA GEP)	*z* (VSA GEP)	*Z* (SN 752:2008)	*Z* (VSA RWEnts)
City center and industry	10 … 20	30	5…10
City	10	20	5…10
Village and rural environment	5	10	2…5

Germany ⇨

Return period for design rain (ATV A118)	*z*
Underground systems	10
City, industry and trade	5
Village with rural environment	2

For combined sewer: account also for hygienic and environmental aspects, beside damages at infrastructure

3.2 Storm run-off

Relevant rain period *T*

- The rain starts simultaneously in the entire (dry) catchment
- It takes roughly 5 min until the first run-off flows into the sewer
- How long does it take until the run-off from the farthest collector manhole runs-off the considered catchment?
- It is assumed that then it is still raining ⇨ “long” rain period *T* with smaller intensities
- If it would not rain any more: affected catchment is small, resulting in lower discharges

Variation of *T* to find maximum volume for retention if infiltration facility is foreseen.

3.2 Storm run-off

Relevant rain period T

- The rain intensities are high for short events, and low for long events
- Short and intense rains are local, they do not contribute simultaneously to the run-off
- The length of a collector conduit affects the time until the run-off leaves the catchment

The highest run-off (storm weather discharge in sewer) results if the entire catchment is considered. The relevant rain period consists of

- Time for run-off generation, typically t_a=5 min (rain time needed to saturate surface until run-off occurs)
- Flow time in sewer until storm water leaves the catchment t_f

$$T = t_a + t_f$$

Chow (1988)

3.2 Storm run-off

Flow time t_f must be known to derive design discharge, but pipe diameter is not yet known as design discharge depends in flow time.

⇨ Interpolation
⇨ Assumption of flow velocity in sewer
⇨ Estimation Kirpich (1940)

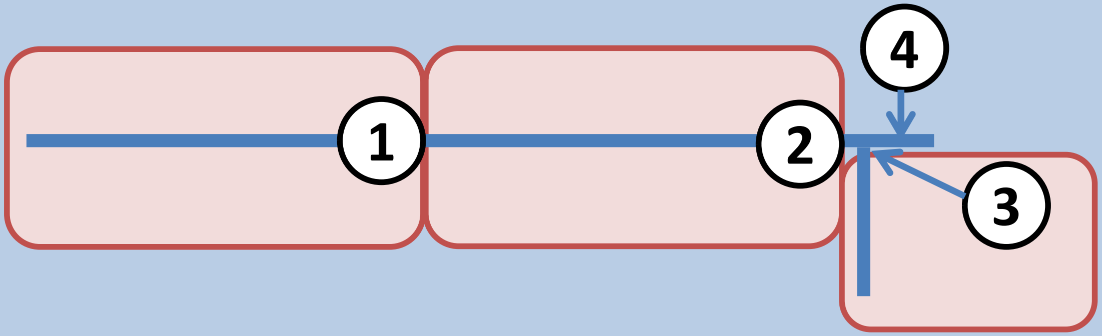
$$t_f = 0.0195\, L^{0.77}\, S_o^{-0.385}$$

with t_f in [min]
L maximum flow length [m]
S_o average conduit slope [-]

See Table 15.1.2 of Chow (1988) for other estimations

3.2 Storm run-off

Example
City of Lausanne



Catchment	1	2	3	4	
ψ	0.4	0.6	0.4		[-]
A	100’000	100’000	50’000		[m^2]
$A\psi$					[m^2]
L	300	300	200		[m]
V	0.625	0.625	0.556		[m/s]
t_f					[min]
$T=t_a+t_f$					[min]
$r[T, 2.3a]$					[mm/h]
$\Sigma A\psi$					[m^2]
Q_R					[m^3/s]

3.2 Storm run-off

Rational method gives Q_R (discharge generated by catchment)

What is done with that discharge (water volume)? Sponge city!

- Avoid the generation of Q_R (permeable surfaces, retention, ponds, vegetation)!!! Infiltration V_R (for unpolluted water), Evapotranspiration (drought summer)

- Rejection to water course or lake (with retention, separated sewer, water quality), rejection to sewer (combined sewer, retention)



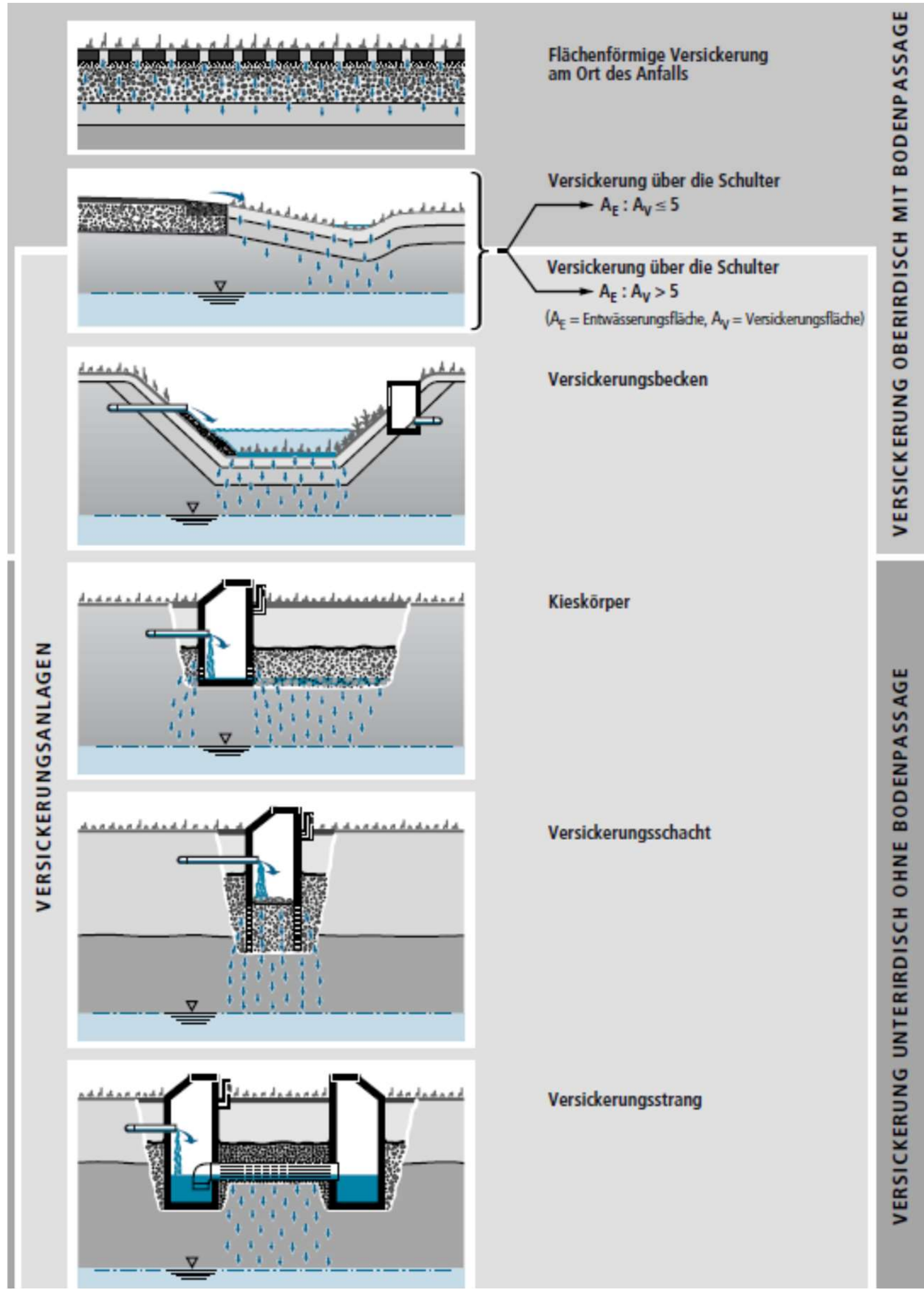
3.2 Storm run-off

Infiltration (with retention) (VSA)

$$V_R = \frac{(\psi\, r\, A - f_v A_v)t}{10^3}$$

V_R retention volume [m^3]
fv infiltration rate [mm/h]
A_V infiltration area [m^2]

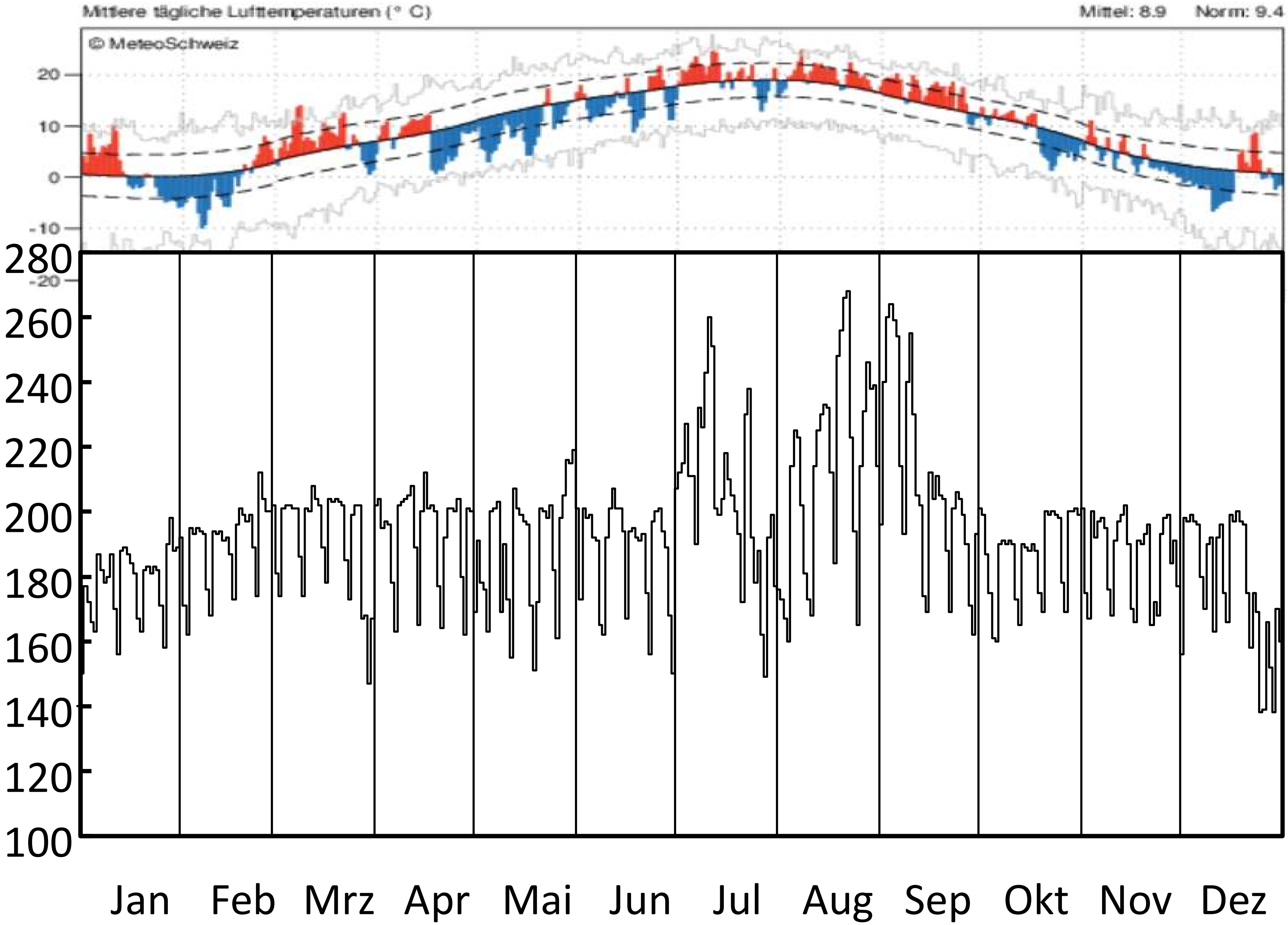
secondary retention on green roof, parking (oil & gravel trap); provide overflow



3.3 Fresh water consumption

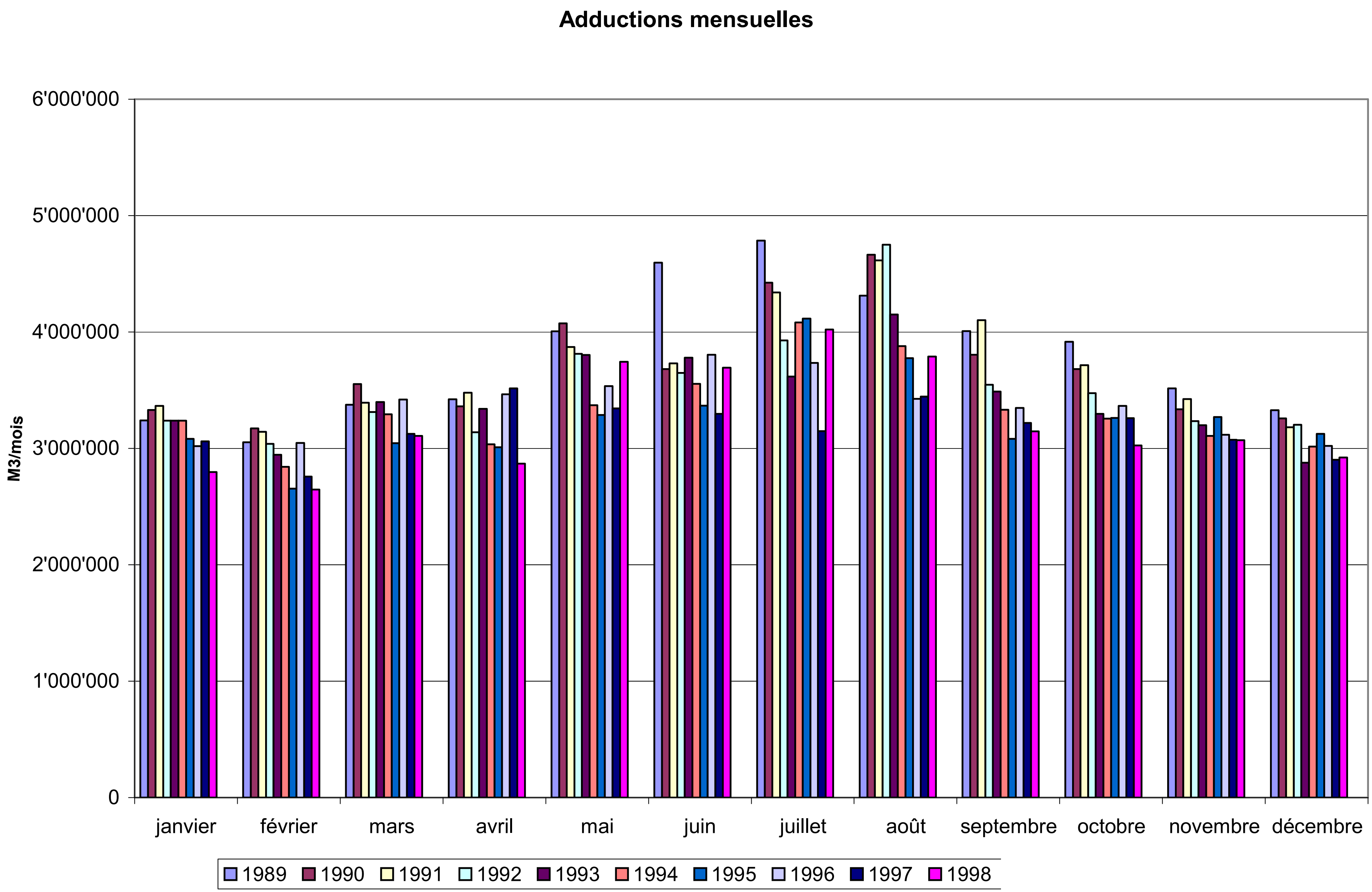
3.3 Fresh water consumption

Fresh water supply in Zürich as 1'000 m^3 per day: yearly variation (1991)



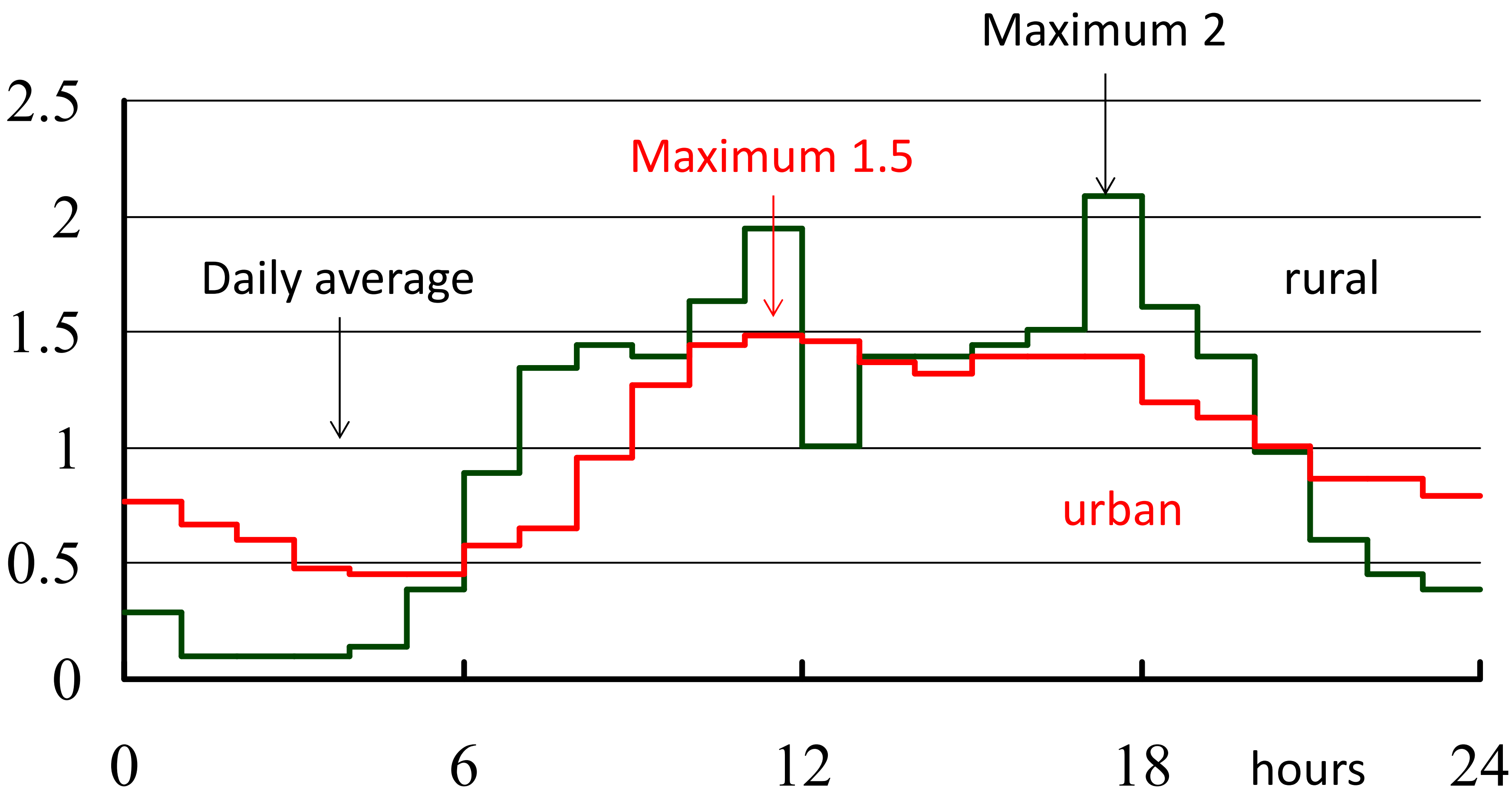
3.3 Fresh water consumption

Fresh water supply in Lausanne: seasonal variation



3.3 Fresh water consumption

Daily variation (as typical for Switzerland)
1 = daily average



3.3 Fresh water consumption

Intra-daily variation
Corresponds to daily routine, pronounced peak at noon and in the evening

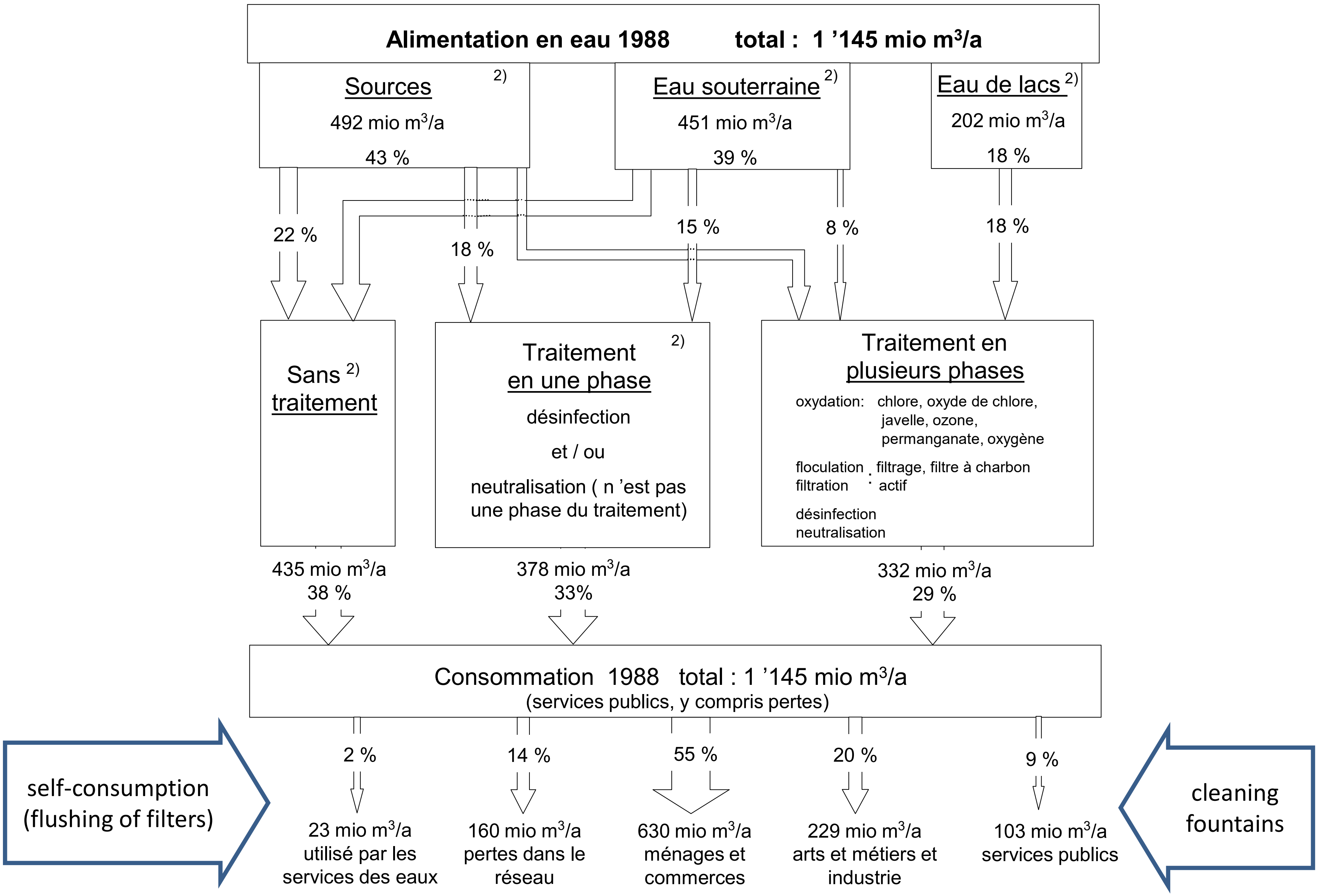
Daily variation (weekday vs. holiday)
Difference for week and weekend day. Less industry and trade activity on weekend day → lower consumption

Seasonal variation
Precipitation and temperature variation. Holidays and events affect consumption

Extreme discharge
Combinations of latter maxima: e.g. noon peak on a hot working day

3.3 Fresh water consumption

Fresh water cycle (Switzerland 1988, in Mio m³/a)



3.3 Fresh water consumption

Design of fresh water supply net

- Future demographic development during life-time of net (study the past)
- Population growth is small, but displacement trend from city to agglomeration (study public transport net)
- Check possible use of open commercial and industrial zones
- Lifetime of water supply system

Present fresh water consumption in Switzerland

- average daily production 300 liters per person (inducing households, trade, industry, and losses)
- DVGW 1995: average household consumes 140 to 150 l/d and person
- SVGW 2015 (internet): average household consumes 160 l/d and person
- SVGW 2013: residents and trade consume almost 200 l/d and person
- maximum daily production 460 liters per person (inducing households, trade, industry, and losses)

3.3 Fresh water consumption

An estimation of the fresh water consumption is difficult

- Use measurements of present consumption
- Extrapolate consumption of the system
- Extrapolate consumption of neighbor system

Use local experience and measurements to derive the fresh water need for a new system

Relevant factors

- Quality of supply net (water losses)
- Size of system (large cities have higher specific consumption due to manifold users)
- Population structure (residents, tourism)
- Activity rhythm (holidays, weekdays, events)
- Industry (some branches need large volumes of fresh water)
- Net pressure (high pressure induces increased water losses)
- Meteorology (sun hours, temperatures, rain)

3.3 Fresh water consumption

ATV

individual consumption

Tabelle 4.2-8
Mittelwerte des Einheits-Wasserverbrauchs

1. Haushalte; Wohngebäude		
1.1 Wohngebäude, einfachste Ausstattung (ohne Bad)	l/E/Tag	70 – 90
1.2 Wohngebäude, mittlerer Standard (mit Bad und WC)	l/E/Tag	120 – 180
1.3 Wohngebäude (Villen; Komfortwohnung)	l/E/Tag	180 – 275
2. Kleingewerbe		
2.1 Bäcker (1 Beschäftigter (B) pro 200 Einwohner (E))	l/B/Tag	150
2.2 Metzger (1 Beschäftigter (B) pro 1000 Einwohner (E))	l/B/Tag	200
2.3 Friseur (1 Beschäftigter (B) pro 500 Einwohner (E))	l/B/Tag	250
2.4 Gaststätte/Kantine	l/Gast/Tag	50
2.5 Dienstleistungsbetrieb	l/B/Tag	50
3. Landwirtschaft		
3.1 Großvieh (GV)	l/GV/Tag	50 – 75
3.2 Gärtnerei; Gemüseland	l/m^2	0,8 – 1,0
4. Großgewerbe		
4.1 Molkerei	l/l	4
4.2 Brauerei	l/l	3 – 15
4.3 Wäscherei (je kg Trockenwäsche)	l/kg	40
4.4 Kaufhaus	l/B/Tag	50 – 100
4.5 Hotel	l/Gast/Tag	200 – 600
5. Öffentliche Einrichtungen und sonstige Verbraucher		
5.1 Büro- und Verwaltungsgebäude	l/B/Tag	40 – 70
5.2 Schule ohne Sporthalle	l/Schüler/Tag	30
5.2 Schule mit Sporthalle	l/Schüler/Tag	40
5.3 Krankenhaus	l/Bett/Tag	350 – 500
5.4 Wohnheime; Unterkünfte	l/Bett/Tag	200 – 350
5.5 Schwimmbad	l/Besucher/Tag	50
5.6 Friedhof; Grünflächen	l/m^2/Tag	0,1
5.7 Markthalle	l/m^2	3
5.8 Feuerwehr (Übungen; einfache Brandfälle)	l/E/Tag	0,5

3.3 Fresh water consumption

Nomenclature

V_{da}	average daily volume [m^3]
V_{dM}	maximum daily volume [m^3]
Q_{iM}	maximum instantaneous Discharge [m^3/s]
f_d	Coefficient of daily maximum volume relative to daily average volume average day ⇨ maximum day
f_i	Coefficient of instantaneous maximum relative to daily average average day ⇨ maximum hour (instantaneous consumption)

Average daily volume

$V_{da} = V_{year\_production}/365$

Estimation of maximum daily fresh water production

$V_{dM} = V_{da} \cdot f_d$

Discharge during maximum hour

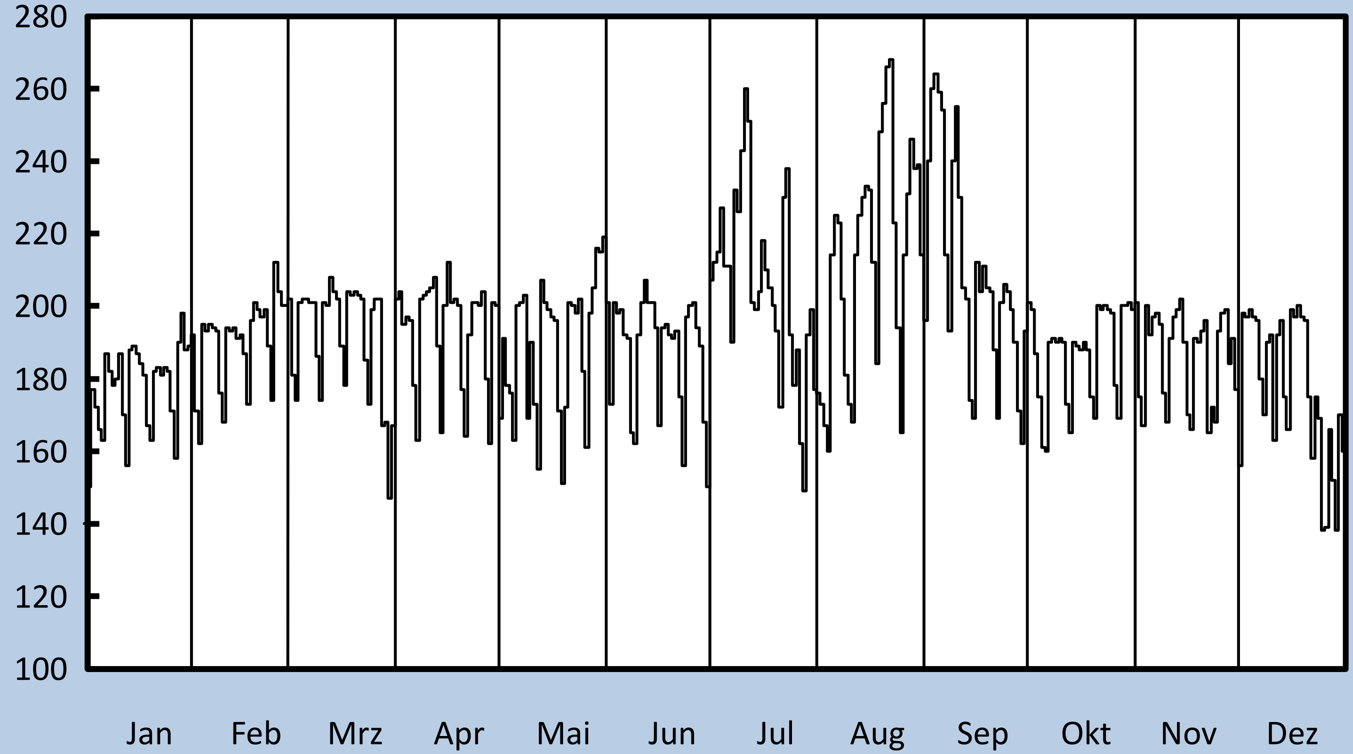
$Q_{iM}=(V_{da} \cdot f_i)/(86'400\ s)$

V_{dM}: Maximum value for capture and treatment (not reservoir)

Q_{iM}: Design value for supply net

3.3 Fresh water consumption

Example: City of Zürich



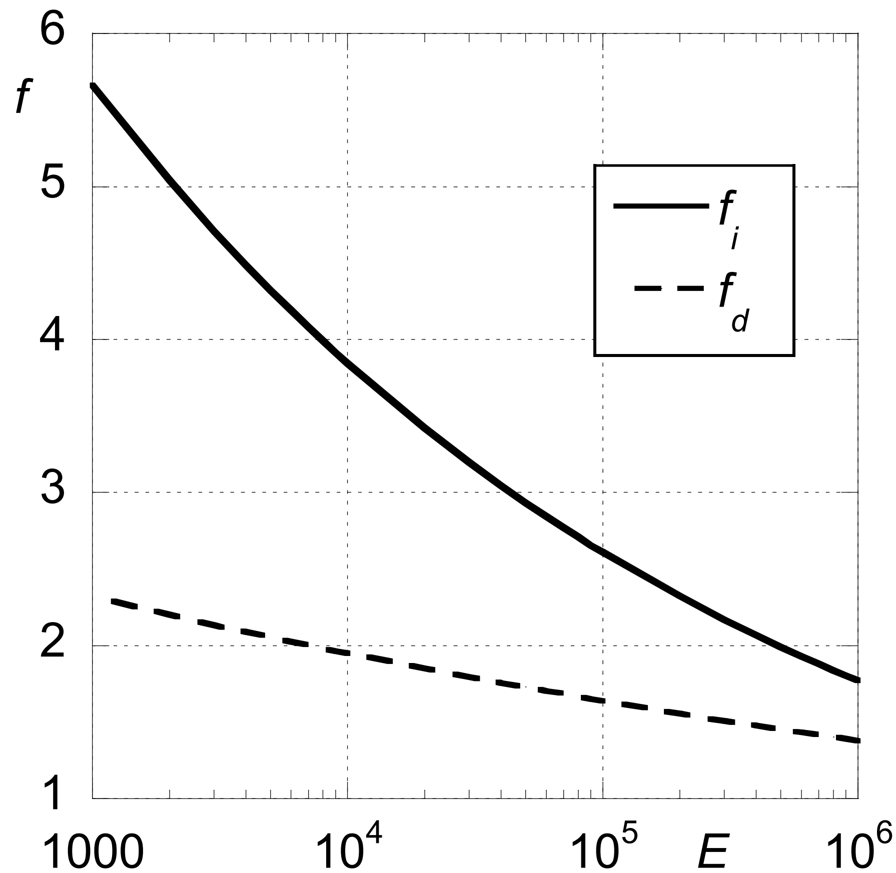
3.3 Fresh water consumption

Coefficient of daily and instantaneous maxima (compared to average daily consumption) (DVGW W 410, 2010)

$$f_i = 18.1 \cdot E^{-0.1682}$$

$$f_d = 3.9 \cdot E^{-0.0752}$$

With *E* as number of residents



Example Zürich (plus suburbs)
E=465'000
f_i=2.02
f_d=1.46
(effectively measured: 1991 f_d=1.40, 2009 f_d=1.21)

3.3 Fresh water consumption

Example:
City with 20’000 habitants. Potential increase of residents: +17%

Daily production volume (day storage)?

3.3 Fresh water consumption

Coefficients of extremes
Goodrich equation for residential agglomeration

Coefficient f_t [%] of maximum consumption during a certain period relative to average daily consumption

$$f_t = 180 \cdot t^{-0.1}$$

t	considered period in days (2 h = 0.08 d to 365 d)

t=0.08 d	max. consumption during 2 h is 270% of average daily consumption
t=1 d	maximum daily consumption 180%
t=7 d	max. weekly consumption 148%
t=30 d	max. monthly consumption 128%

Further coefficients of extremes: see SVGW W4

3.3 Fresh water consumption

Water supply

Always “enough” and hygienic clean fresh water with sufficient pressure

Fire services

In addition water to extinguish fire

- SVGW-Richtlinie W5 «Richtlinie für Löschwasserversorgung»: Löschwasserbedarf, Wasserverteilnetz, Hydranten, Innenhydranten, Sprinkleranlagen, Korrosionsschutz, Löscheinrichtungen in Tunnelanlagen
- The requested additional discharge is typically in the order of 0.01 to 0.08 m^3/s during 1 to 3 h (SVGW W4)
- Cantonal buildings insurances (Vereinigung Kantonaler Feuerversicherungen) or fire services (Feuerwehr Koordination Schweiz) define requested resources
- Often a buffer of some 100 m^3 in reservoir requested
- Large buildings are often equipped with sprinklers (SVGW W5)

Add discharge requested from fire service to Q_{iM}

Kantonale Gebäudeversicherungen

3.3 Fresh water consumption

Fire reserve

Feuerwehr Koordination Schweiz FKS
Fire reserve shall be available for 90 min at minimum

FKS (2019), Richtlinie Versorgung mit Löschwasser.

Art der Bebauung	Löschwassermenge minimale Durchflussmenge über 1 Hydrant (l/Min. bei 2 bar)	Löschwassermenge minimale Durchflussmenge im Netz (l/Min.)	Löschwassermenge minimale Durchflussmenge über alternative Bezugsmöglichkeiten wie Löschwasserbehälter oder Gewässer (l/Min.)	Distanz Hydrant bis Löschfahrzeug (max. Meter Schlauchlänge)	Vorhaltung Löschreserve (m^3)
Einzelobjekte					
Einzelnes Wohnhaus (ausserhalb Siedlungsgebiet) Einzelner landwirtschaftlicher Betrieb Weiler, kleiner Ort mit offener Bauweise	700 – 1'000	**700 – 1'000**	700 – 1'000*	bis 100 ***	30 – 100
Dorfgebiet					
Dorf mit offener Bauweise	700 – 1'000	**1'500**	**	60 – 100 ***	150
Dorf mit geschlossener Bauweise	1'800	**1'800**	**	60 – 100 ***	200
Dorf mit Gewerbezone	1'800	**2'200**	**	60 – 100 ***	200
Stadtgebiet (Hydranten evtl. mit 2 x Storz 75 mm)					
Städtische Überbauung mit Gewerbezone	2'400	**2'400**	**	40 – 80 ***	250
Stadtgebiet (Altstadt, Warenhäuser, Hotels, Büros, Spital, Alters- und Pflegeheime, Schulanlagen usw.)	2'400	**2'800**	**	40 – 80 ***	250
Industrie (Hydranten mit 2 x Storz 75 mm)					
Arbeitszone	2'400 – 3'600	**2'800 – 5'400**	**/****	40 – 80 ***	250 – 600

3.4 Dry-weather sewer discharge

3.4 Dry-weather sewer discharge

Basically

Water consumption + external water = dry weather discharge in sewer

No rainwater in sewer!

Dry-weather discharge

Consists of domestic, trade and industry wastewater (plus external water and melt water from snow in some regions)

Estimation of value

- For best prediction of the dry-weather discharge, use measurements just upstream of water treatment plant.
- Experience: Lausanne 200 to 250 l/day and resident arrive at STEP (industry included), Fribourg 170 l/day per equivalent-habitant EGW
- Otherwise, use standard models (VSA says 170 l/day and person))

Assume for standard model that

- Water consumption ≈ dry-weather discharge
- (losses fresh water ≈ external water)

3.4 Dry-weather sewer discharge

Standard model for water consumption

Débit temps sec :
Volume journalier spécifique $V_{TS,S}$ par équivalent-habitant (EH) *x* nombre d'équivalent-habitants EH, par durée de production ΔT

$$Q_{TS} = \frac{V_{TS,S} \cdot EH}{\Delta T}$$

$V_{TS,S}$ = 170 l/d·EH (expérience Fribourg. Lausanne: $V_{TS,S}$ = 200 l/d·EH).
ΔT : variable selon la taille et les particularités du bassin versant. Typiquement inférieure à 24 heures

Paramètre	Eaux usées brutes (par EH et par jour)	Eaux usées décantées (par EH et par jour)
Production d'eaux usées	170 l	170 l
Matières en suspension	90 g MS	50 g MS
Matières organiques	75 g DBO_5 50 g COT 150 g DCO	50 g DBO_5 35 g COT 105 g DCO
Azote	14 g N-Kj 7 g $N\text{-}NH_4$	12 g N-Kj 8 g $N\text{-}NH_4$
Phosphore (moyenne mensuelle)	2,2 g P_{tot}	1,9 g P_{tot}

Tableau 25 Charges spécifiques brutes des eaux domestiques (jour de dimensionnement)

Agglomération	durée de production ΔT [h/j]
urbaine	*14 à 18*
semi-urbaine	*12 à 14*
rurale	*8 à 12*

3.4 Dry-weather sewer discharge

Estimation based on measurements (water consumption + external water)

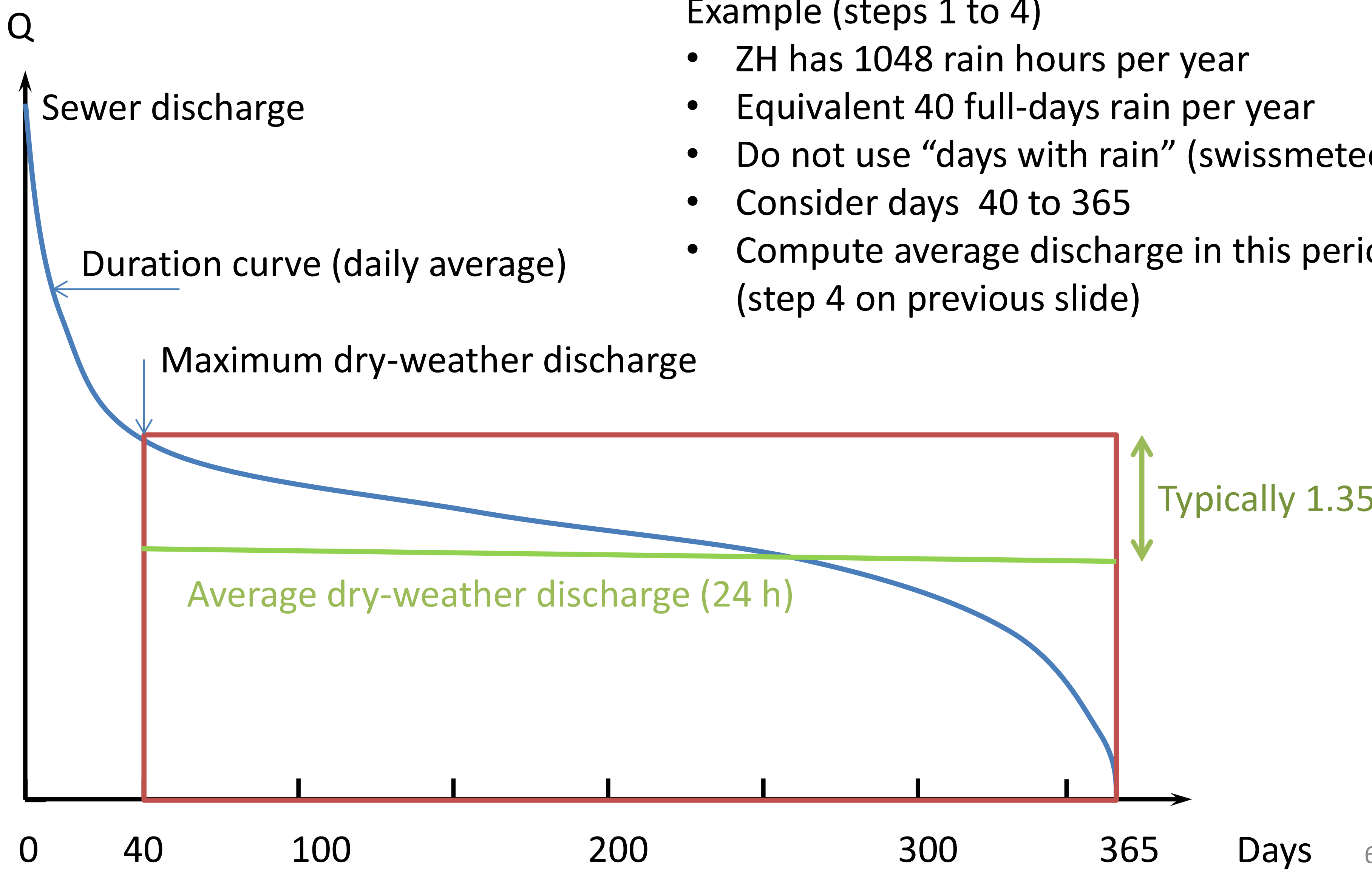
Procedure

1. Duration curve of sewer discharge (daily average)
2. Estimate number of yearly rain hours, compute *n* rain days
3. Cut these days off, i.e. consider days *n* to 365
4. Compute average discharge of these days
5. Compute daily (24 h) volume on the basis of the average dry-weather discharge ($V = Q \cdot 86'400$ s)
6. Distribute this volume over *m* hours (usually m=14 h, $Q_{TW} = V$ / 50'400 s) to reproduce the day-time value (night excluded, it does hardly contribute to V)

(it is assumed that the average dry-weather discharge during rain days is equivalent to that during other days)

3.4 Dry-weather sewer discharge

Estimation based on measurements (water consumption + external water)



Example (steps 1 to 4)

- ZH has 1048 rain hours per year
- Equivalent 40 full-days rain per year
- Do not use “days with rain” (swissmeteo)
- Consider days 40 to 365
- Compute average discharge in this period (step 4 on previous slide)

3.4 Dry-weather sewer discharge

If no information is available

Estimation based on experience

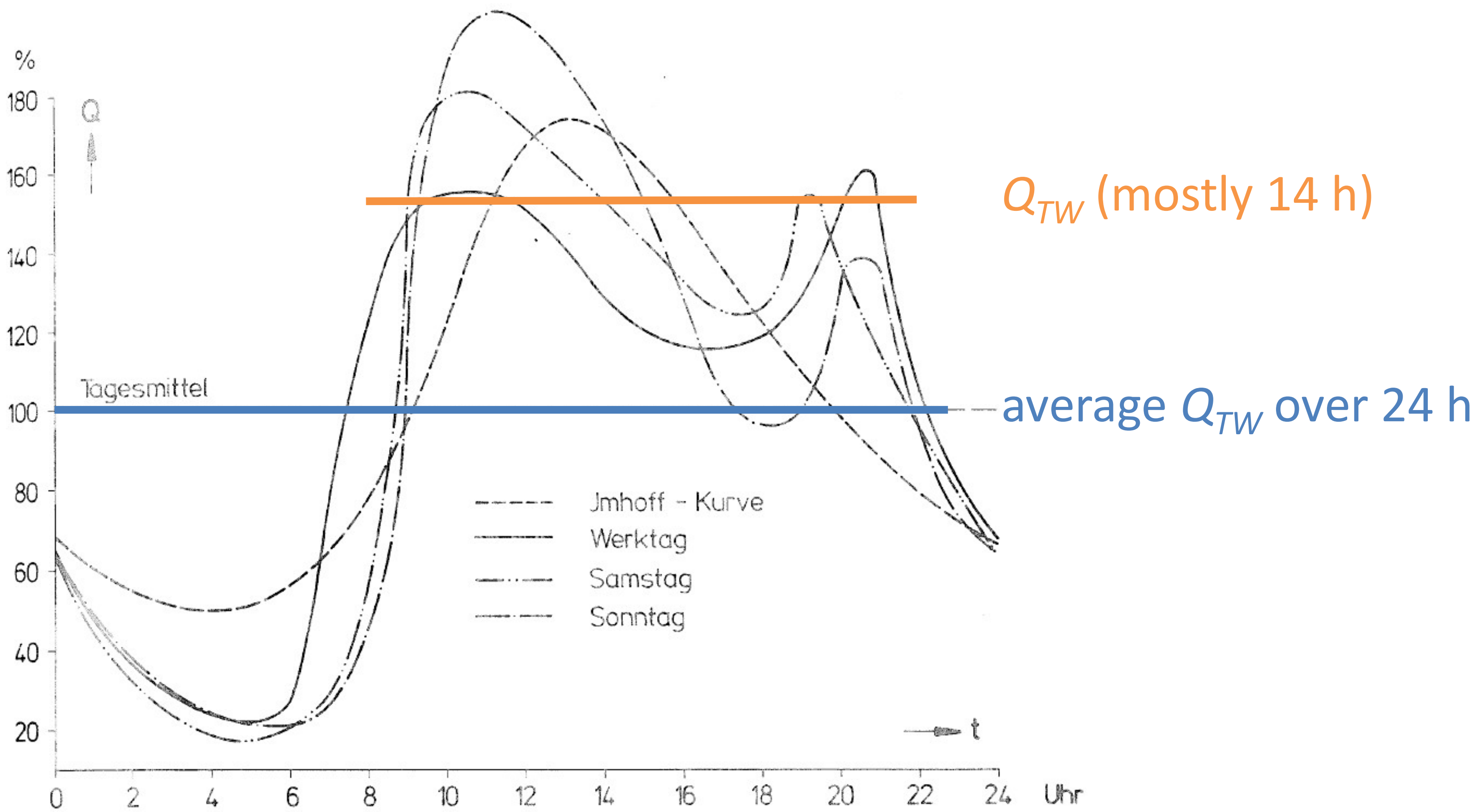
- Maximum water consumption 480 l/(d·person) = 0.0056 l/s (2012)
- External water from leakage, drainage water or faulty connections. Some 0.05 to 0.15 l/(s·ha) (ATV A118)
- Range from experience: wastewater dry-weather discharge 0.008 to 0.010 l/(s·person) (maximum day of year)
- The number of persons is defined using an "equivalent habitant" (EH)

Concept VSA (Switzerland)

- derive number of "equivalent habitants" (EH)
- each EH generates 0.01 l/s wastewater = 860 l/(d·EH) = high value = peak in the 1970s
- JQ_{TW}=0.01 · EH as dry-weather discharge
- Q_{TW}=2 · JQ_{TW} as peak during 24 h period (intra-day maximum)

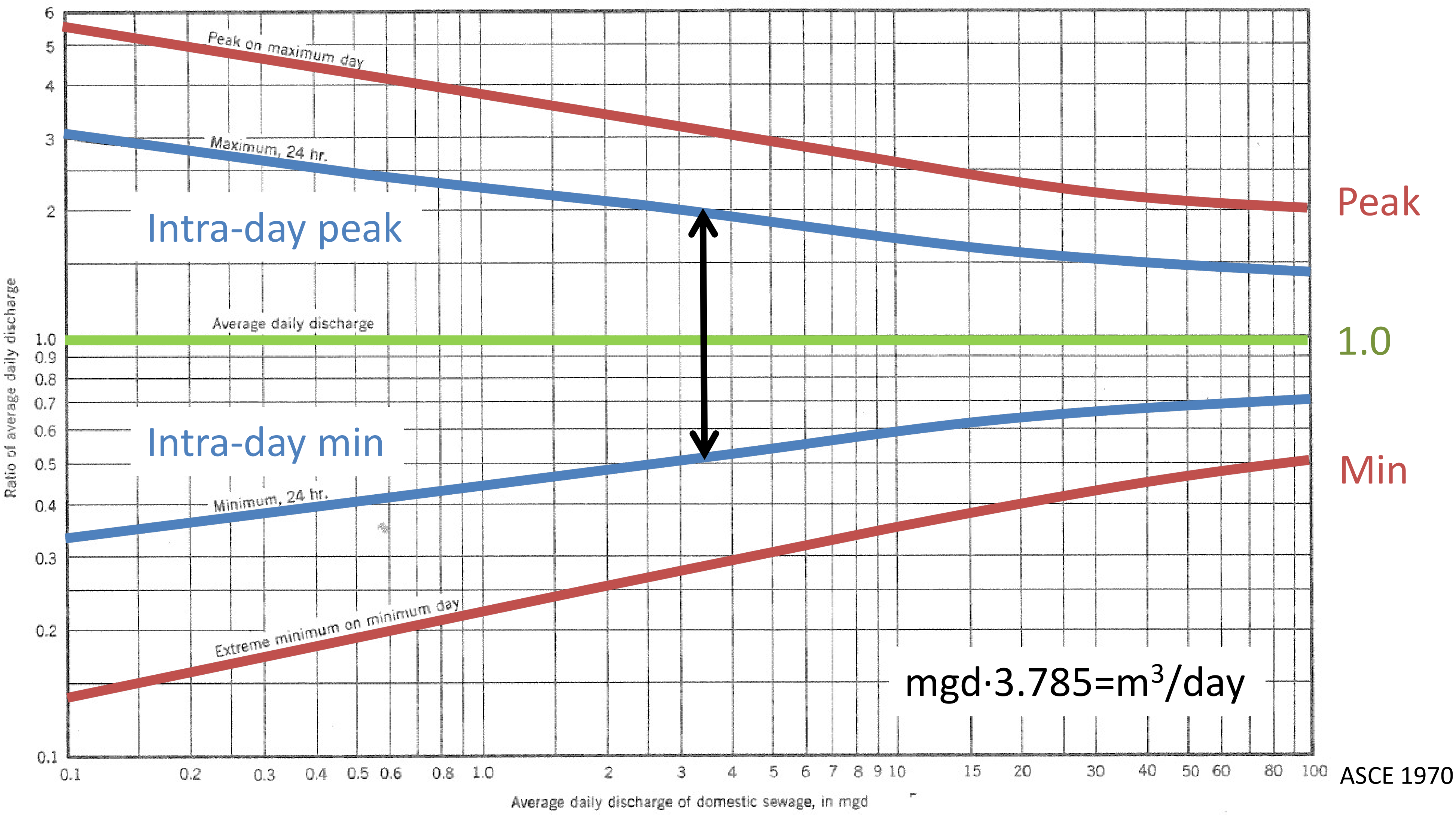
3.4 Dry-weather sewer discharge

Daily curve with noon peak
Similar curve as for water consumption



3.4 Dry-weather sewer discharge

Intra-daily maximum & minimum DWD compared to average daily flow



3.4 Dry-weather sewer discharge

Equivalent habitants (EH) (VSA)
Consider residents of a catchment plus tourism, commuter…

Description	Factor
Permanent resident	1.0
School	0.25
Trade	0.30
Hotel	1.0 (per bed), 0.3 (per place in restaurant)
Hospital (per bed)	2.5
Commuter train	0.3
Commuter way	0.7
Summer apartments	0.8
Industry	individually

3.4 Dry-weather sewer discharge

Equivalent habitants (EH) (SEn Fribourg)

«Définition et calcul des équivalents-habitants»

Type de construction / d'activité		Charges produites chaque jour		Equivalents-habitants			
				EH	EH	EH$_{constr}$ 1	EH$_{expl}$ 2
		g DBO_5	litres	Biochimique	Hydraulique	Construction	Exploitation
Habitation	par habitant	60.0	170.0	1.00	1.00	1.00	1.00
	par chambre habitable[3]	60.0	170.0	1.00	1.00	1.00	1.00
Ecole, sans salle de gymnastique	par élève	15.0	42.5	0.25	0.25	0.25	0.25
Equipement sportif	par douche	15.0	42.5	0.25	0.25	0.25	0.25
Bâtiment administratif ou commercial	par employé	20.0	56.7	0.33	0.33	0.33	0.33
Hôtel, chambre d'hôtes	par nuitée	60.0	170.0	1.00	1.00	1.00	1.00
Restaurant	par place assise	20.0	56.7	0.33	0.33	0.33	0.33
Café	par place assise	3.0	8.5	0.05	0.05	0.05	0.05
Cinéma	par place assise	1.5	4.3	0.03	0.03	0.03	0.03
Camping	par 1000 m^2	480.0	1360.0	8.00	8.00	8.00	8.00
Hôpital / Home	par lit	60.0	170.0	1.00	1.00	1.00	1.00
Stationnement militaire	par lit	60.0	170.0	1.00	1.00	1.00	1.00
Fromagerie	par tonne de lait transformé	1080.0	2000.0	18.00	11.76	13.84	15.92
Local de coulage	par tonne de lait coulé	480.0	1000.0	8.00	5.88	6.59	7.29
Abattoir	par unité de gros bétail (UGB)	3000.0	4000.0	50.00	23.53	32.35	41.18
	par unité de petit bétail (UPB)	720.0	2000.0	12.00	11.76	11.84	11.92
Boulangerie	par employé	90.0	255.0	1.50	1.50	1.50	1.50
Préparation de légumes	par tonne de conserve de légumes produite	4000.0	8000.0	66.67	47.06	53.59	60.13
	par tonne de pommes de terre transformée	25.0	8000.0	0.42	47.06	31.51	15.96
Distillerie	par litre d'alcool pur	650.0	30.0	10.83	0.18	3.73	7.28
Brasserie	par hl de boisson	120.0	150.0	2.00	0.88	1.25	1.63

3.4 Dry-weather sewer discharge

Dry-weather discharge
Example for computation of EH:
small village with 2987 residents, one hospital, no trade and industry

Description	Number	Factor	EH
Non-employed population	1413		
Working population (in catchment)	532		
Externally working population	1042		
Hospital	180 beds		
Summary			

JQ_{TW}= ? m³/s, Q_{TW}= ? m³/s

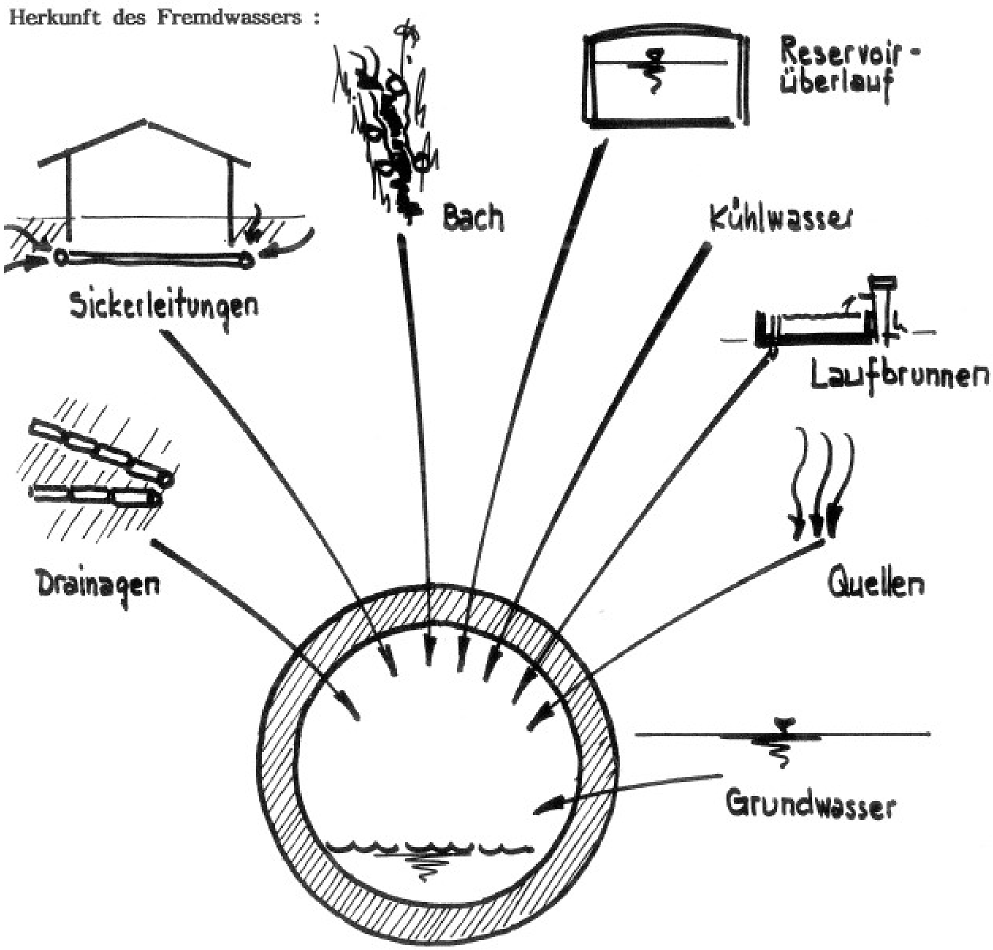
3.4 Dry-weather sewer discharge

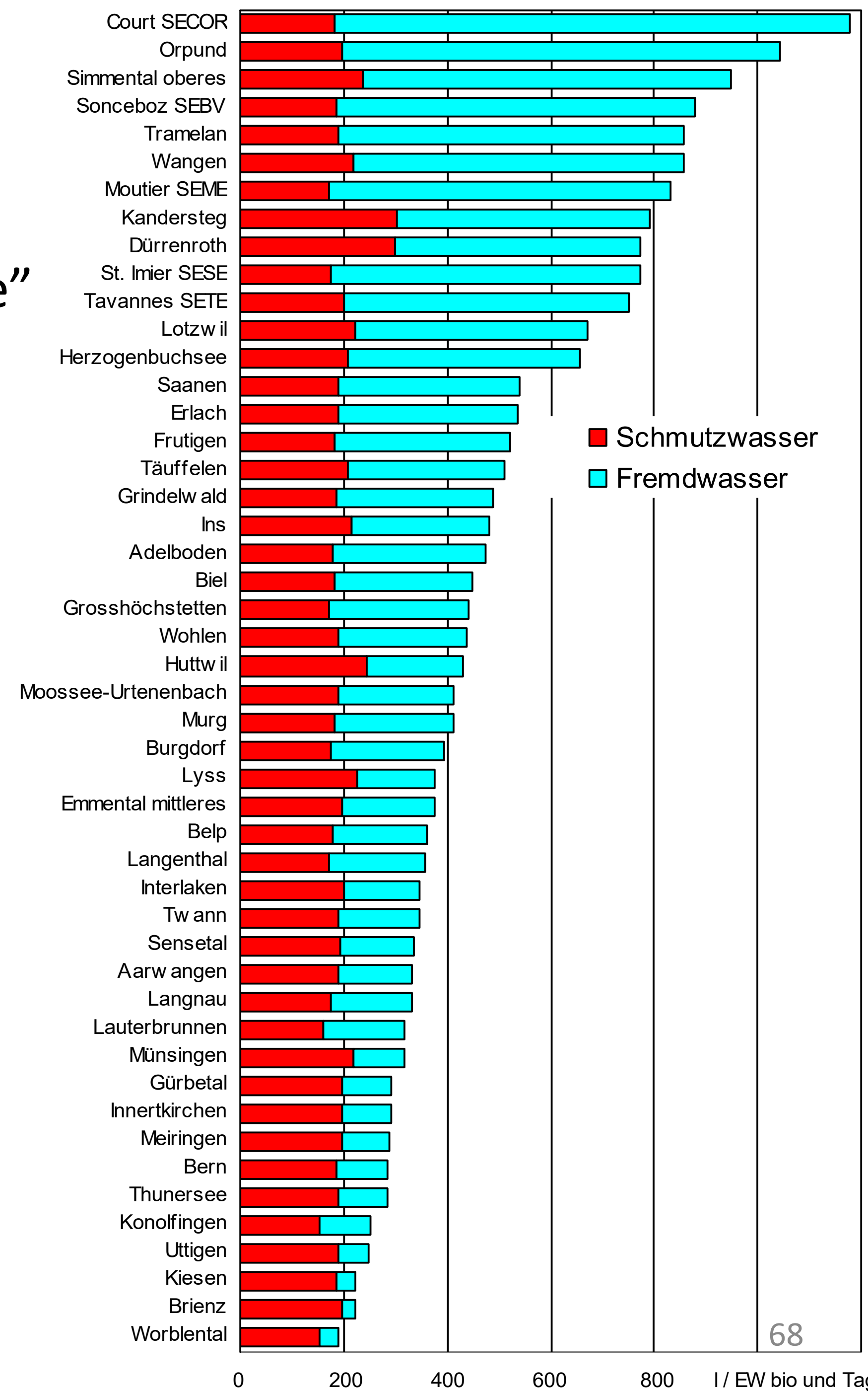
External water

(VSA GEP)

"not polluted water with a constant discharge"

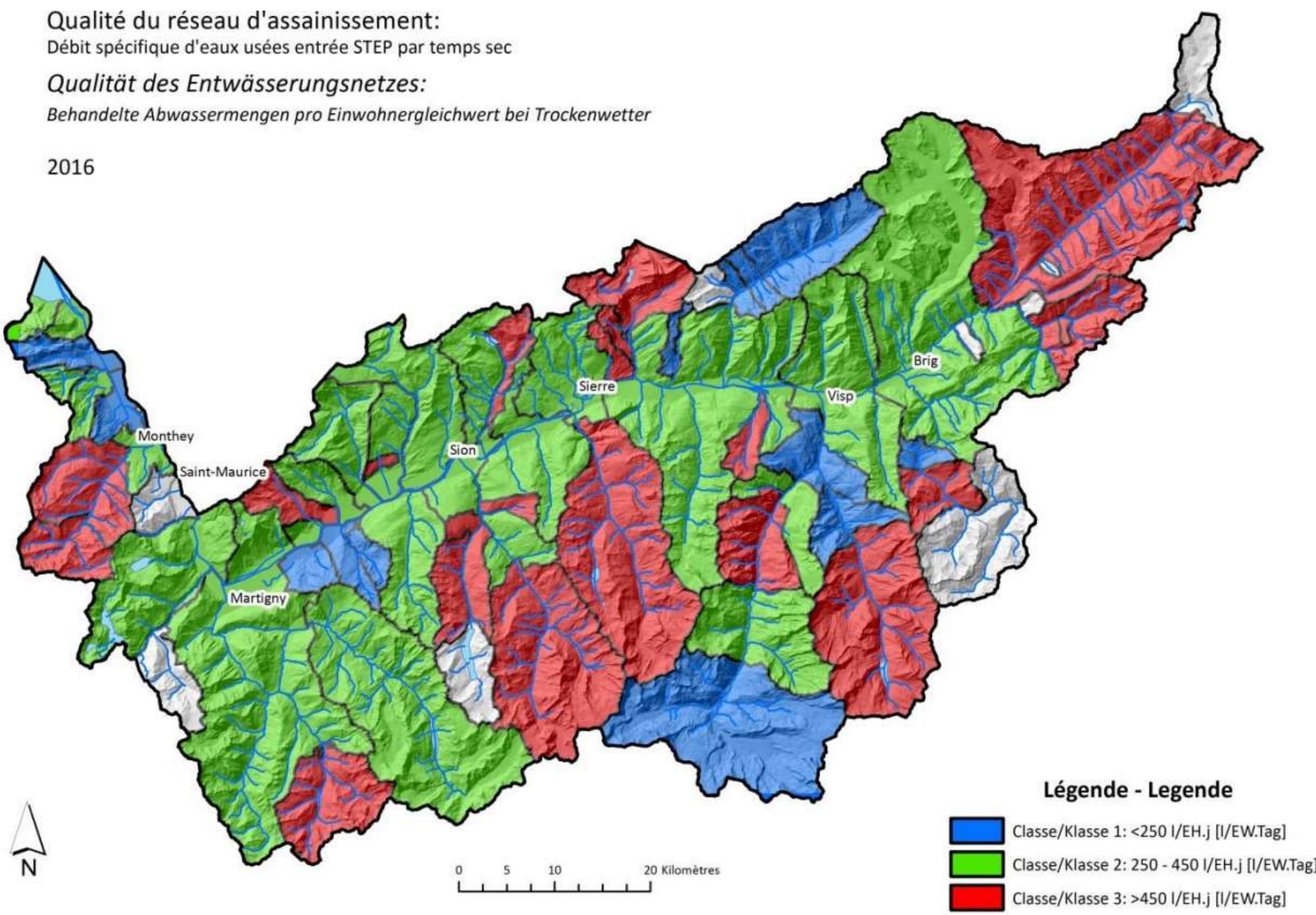
Lausanne roughly 30 to 35%





3.4 Dry-weather sewer discharge

Bilan de l'assainissement Canton du Valais, 2016



3.5 Discharge measurement

3.5 Discharge measurement

Why measuring?
- discharges (design, cost)
- mass transport (concentration)
- efficiency (cost)
- control and automating

Discharge measurement
- MID
- Ultrasonic Velocity Profiler (UVP)
- Surface measurement (sharp crested V-notch weir)
- (Venturi)

Calibrate the system!
Validate the measured values!

3.5 Discharge measurement

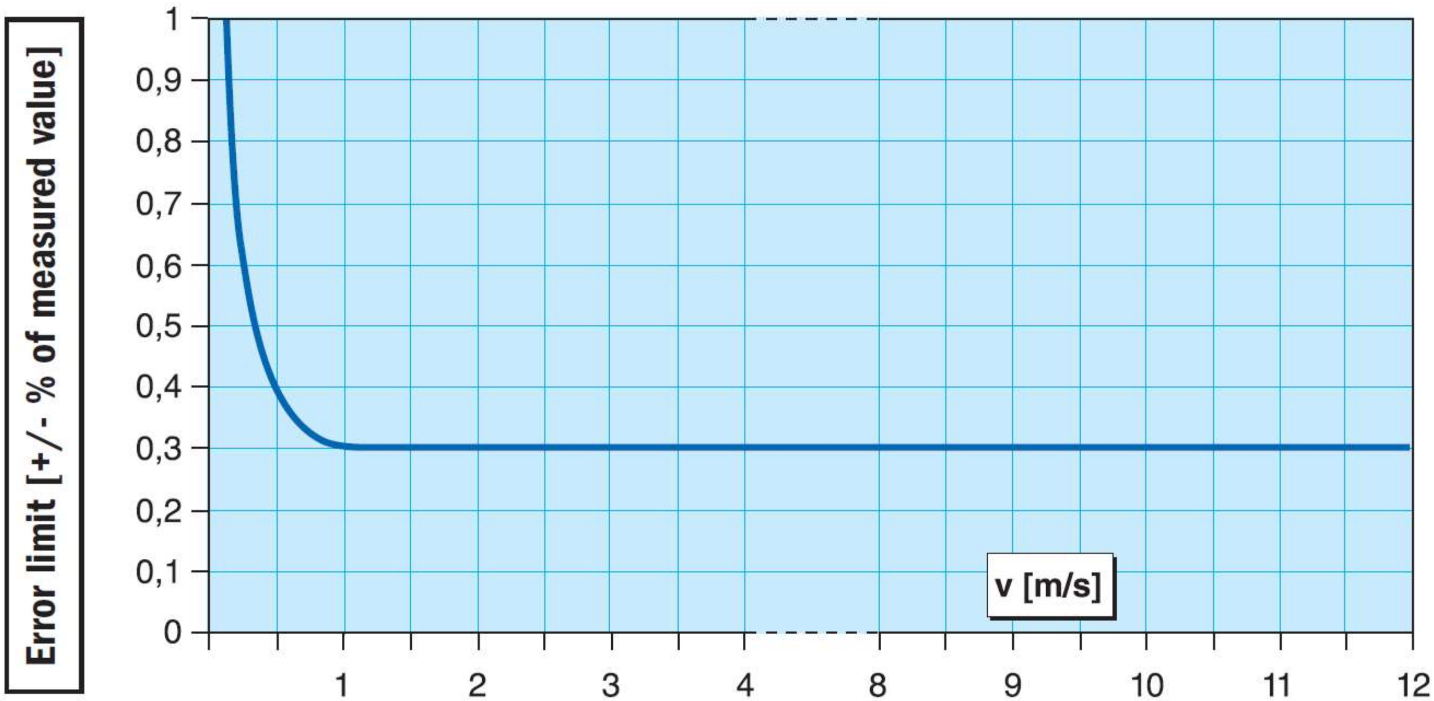
MID (Krohne)

- non-ferromagnetic tube
- electrodes arranged diametrically in contact with the liquid
- flows generates a magnetic field
- voltage is induced that is proportional to the flow velocity
- discharge via continuity equation

3.5 Discharge measurement

MID (Krohne)

- Measurement accuracy excellent for v>1 m/s
- Measures bi-directional
- Not disturbed by solids, if no deposition and low concentrations
- Air in the system falsifies measurement
- Special MID for partial conduit filling



3.5 Discharge measurement

MID (VSA)

Advantages
- Not intrusive: no energy-pressure losses, no blockage
- Independent on density and pressure of fluid
- High accuracy
- Large measurement range ($Q_m \rightarrow Q_M$)
- Long-life time cycle
- Small energy consumption
- Small dimensions

Disadvantages
- Expensive
- Sensitive to electromagnetic fields (pump motors)
- Minimum velocity required
- Biological film on electrodes falsifies measurement

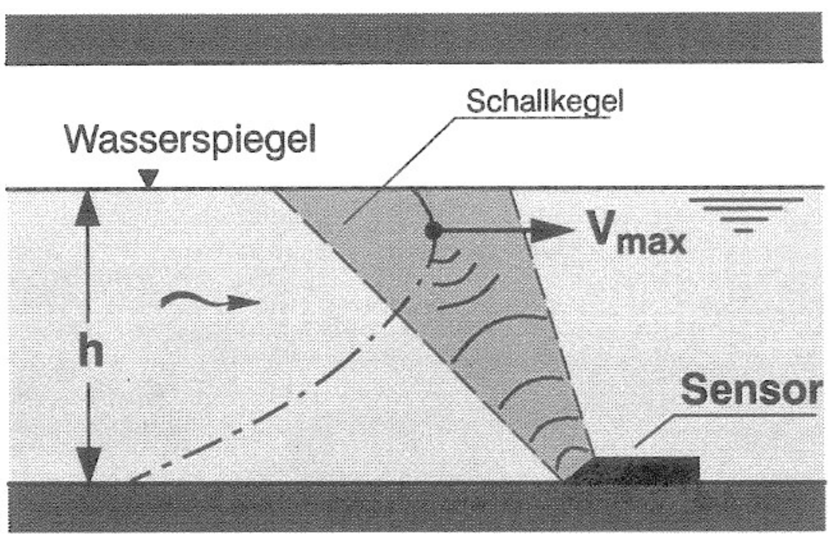
3.5 Discharge measurement

Ultrasonic Velocity Profiler (UVP) (VSA)

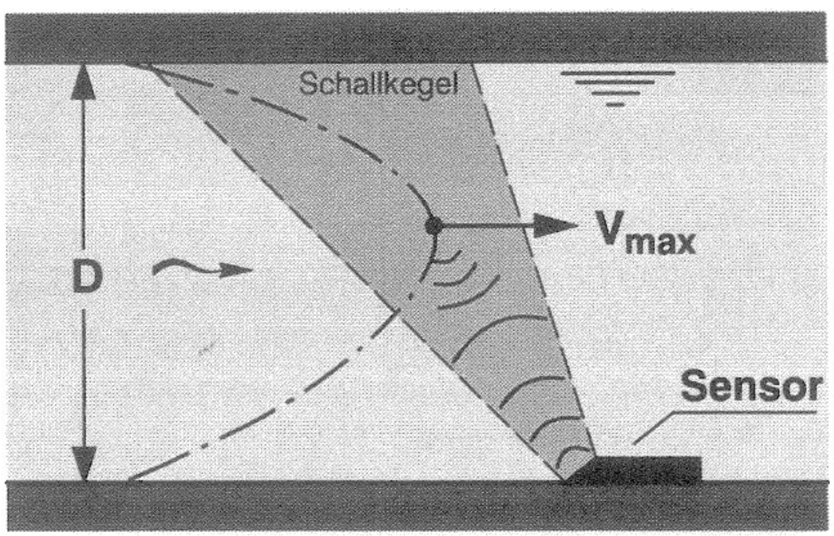
UVP measures liquid flows velocity as a function of distance, using a pulsed-Doppler based method. Suspended particles in the fluid reflect the sound.

Travel time = distance to measured point
Frequency modification = velocity

Partial filling



Pressure flow



3.5 Discharge measurement

Ultrasonic Velocity Profiler (UVP) (VSA)

Accuracy: 5 to 10%

Advantages

- Not intrusive (only transmitter)
- Large measurement range ($Q_m \rightarrow Q_M$)
- Long-life time cycle
- Small energy consumption
- Small dimensions
- For partial and full filling
- Cost independent of conduit diameter

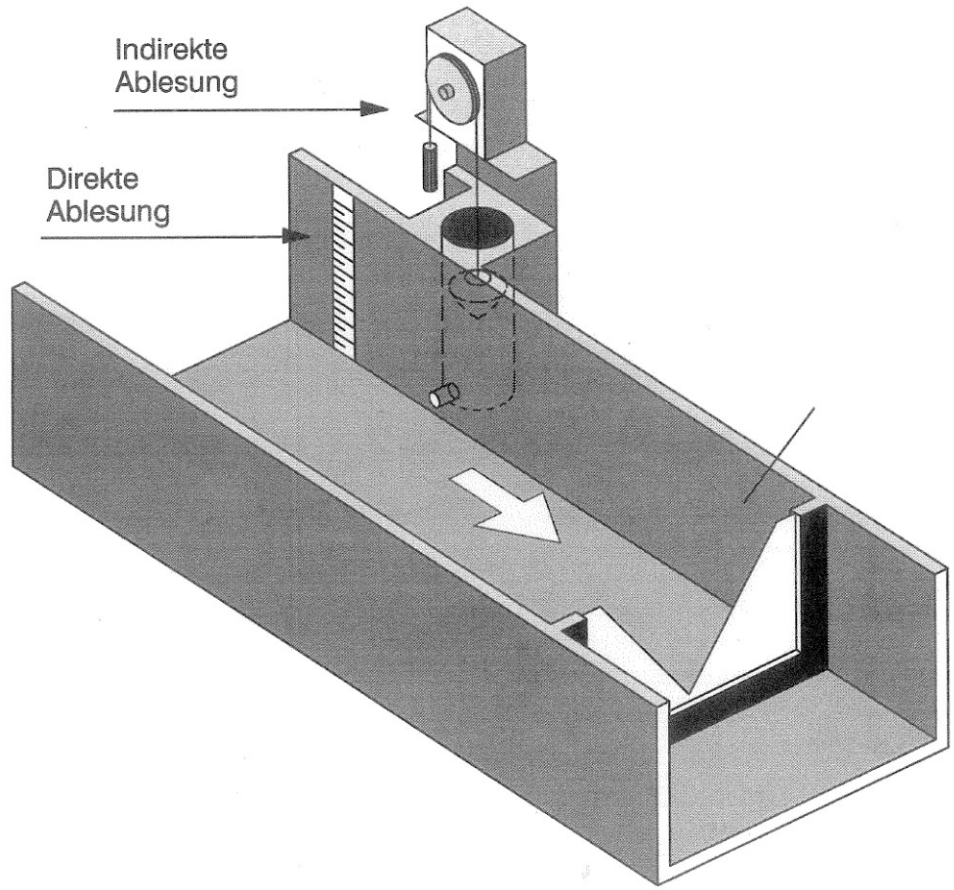
Disadvantages

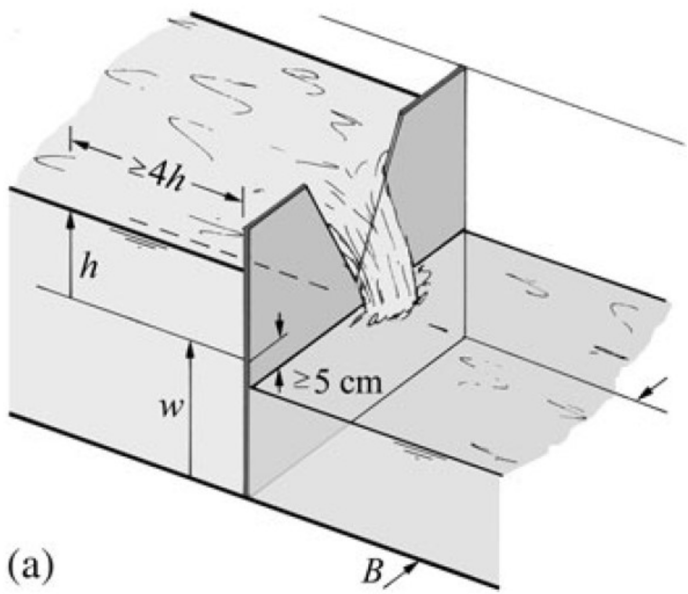
- Derivation of average velocity from measured profile
- Sensitive to high turbidity
- Air in system affects result

3.5 Discharge measurement

Sharp crested V-notch weir
(VSA, Hager 2010)

- Sensitive to small discharges
- No tailwater and approach flow effects allowed
- Respect minimum dimensions
- Accuracy ca. 5%





(a)

$$Q = 0.308\left[1 + \frac{0.66}{h^{3/2}}\right]\sqrt{2gh^5}$$

for a 45° V-notch and if approach flow velocity is negligible

3.5 Discharge measurement

Sharp crested V-notch weir
(VSA, Hager 2010)

Advantages
- Simple system
- Large discharge variability
- Simple validation (visually)

Disadvantages
- Size of structure
- Affects flow, energy loss
- May generate flow transition
- Only for free surface flow
- Sedimentation

3.6 Pro memoria

3.6 Pro memoria (I)

Design bases = design discharges

Fresh water net

- Maximal instantaneous water consumption plus water for fire services: for supply net capacity, beside requested pressure
- Maximal daily consumption plus reserve for fire services: for water production

Sewer

- Dry-weather discharge to avoid deposit, defines the conduit slope
- Dry-weather discharge plus storm discharge defines the conduit capacity, i.e. the diameter of a combined sewer
- Storm discharge defines the conduit capacity, i.e. the diameter of a separated sewer

3.6 Pro memoria (II)

Storm run-off

- Use measurements in existing sewer to derive relevant storm discharges
- If not available: Rational method

$$Q_R = \frac{\psi \, r \, A}{3.6 \cdot 10^6}$$

- Maximum discharge coefficient from literature
- For rain intensity, use IDF curves
- Relevant return period is typically 10 years
- Relevant rain period is run-off generation time (5 min) plus flow time

$$t_f = 0.0195 \, L^{0.77} \, S_o^{-0.385}$$

3.6 Pro memoria (III)

Fresh water consumption

- Use measurements in existing system or in neighbor systems
- Average water consumption per person decreased over past years
- Main consumers are households and trade
- Average total consumption per person and day (including all branches) is approximately 300 l
- With the individual concepts, the water need is specified more precisely
- Seasonal variation (warm summer), weekly variation (week day or weekend day), daily variation, intra-daily noon peak
- Coefficient of maxima describe these peaks relative to average daily consumption
- Instantaneous maximum consumption plus fire requirements to design supply net
- Maximum daily consumption to define reservoir volume

3.6 Pro memoria (IV)

Dry-weather discharge

- Relevant for sewer conduit bottom slope
- Is similar to water consumption plus external water
- Consists of domestic, trade ad industry wastewater plus external water
- Use measurements in existing system or in neighbor systems (duration curves), consider only “dry” periods without storm water in sewer
- Concept VSA: around 0.008 to 0.010 l/s per “equivalent consumer”
- Factor two for noon peak

Discharge measurement

- To measure a discharge is better than its estimation
- MID/UVP/V-notch weir, but there are other devices
- Calibrate and validate your measurement system