Urban Water Management

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Ecology and Water Resources
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Part 1

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Overview

Contents today:

1. **Urban water management**
   - **subjects and aims**
   - **urban water cycle**
   - **management tasks**

2. **Water supply**
   - **water demand**
   - **water collection**
   - **water protection**

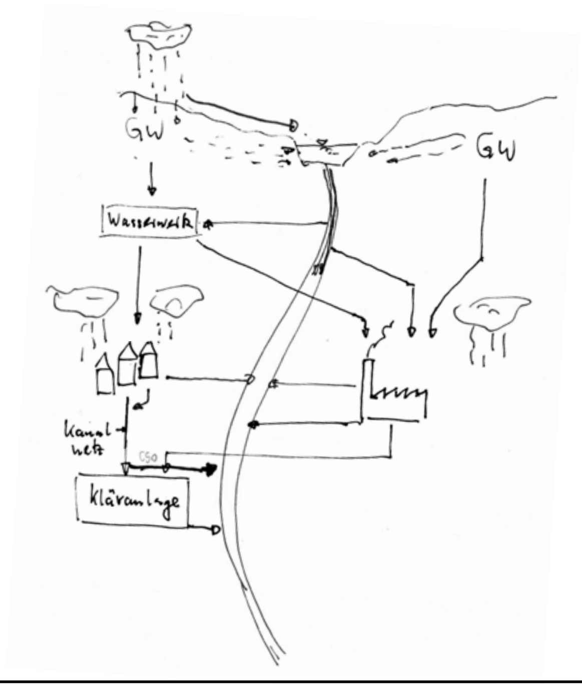
Urban water management

Runoff and loads from Urban Drainage Systems (UDS)

- various source
- various ways
- various possibilities for management

The urban water way: supply and drainage

- water collection / water catchment systems
- water distribution
- drainage / disposal of storm and waste water
- treatment of storm and waste water



Urban water management

Main subjects and aims

- How is groundwater affected?
  - abstraction
  - groundwater recharge (natural / artificial)
  - pollution

- Drainage system concepts
  - advantages / disadvantages
  - source control or end-of-the-pipe
  - conflicting objectives?

Urban water management

Main subjects and aims (continued)

- Treatment
  - central or distributed?
  - wastewater, stormwater, combined
- Flood protection
  - fluvial
  - pluvial

Conclusion

- a complex mixture of
  - tasks
  - solutions

Water cycle in urban areas

Differences to „normal“ cycle

- consumption / use much higher
- artificial supply and disposal
- surface sealing → large impervious areas
- water balance

P = R + ET

770 = 270 + 500 [mm]

↳ for use: 145 mm (within urban areas)

back into water courses → 122

„loss“ (ET etc) → 23

84% of „used“ water becomes „runoff“ again

= 8.5% of R
= 16% of „used“ water

Water management tasks

Balances (typically for a year)

- drinking water collection, processing, and distribution
- drainage design
- combined sewage treatment (CSO)
- process water (industrial, domestic)

Processes in urban areas

- small
- fast
- main runoff from impervious ares
- artificial drainage system

Water demand

Specific domestic use

- l/(c·d) litres per capita per day
- gcd gallons per capita per day
- Germany: 120 .. 140 l/(c·d)
- USA: 196 l/(c·d) (with conservation)
  .. 280 l/(c·d) (without conservation)
- higher values for design purposes

Water demand depends on

- spatial characteristics

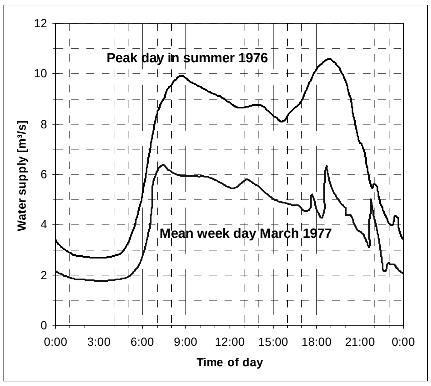
- population density
- industry and public institutions and facilities

- temporal characteristics

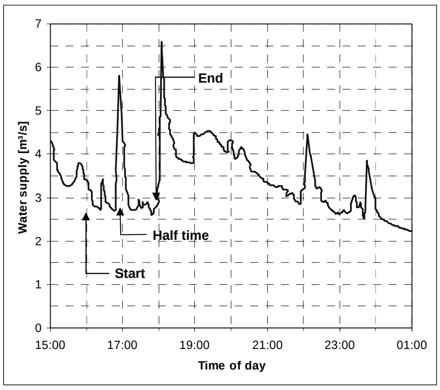
- season - higher demand in summer
  - holiday season: - holiday areas: extreme
  - at home: less
- day of the week - less on weekends
  - different diurnal variations
- time of the day
  - morning and evening peaks (sumetimes lunch peak)
  - irregular peaks at special events

Water demand (and supply)

Water supply curves Munich



World Cup final 1976



Water supply

Some general thoughts

- balance between demand and offer
- quality requirements
- processing
- costs and charges (cost recovery!)

  (long distance supply or near-by sources with high processing needs)
- regional planning aspects

  (priorities, conflicts, developments)
- legal aspects

  (consents, existing rights)

Water catchment

Spring water

Groundwater

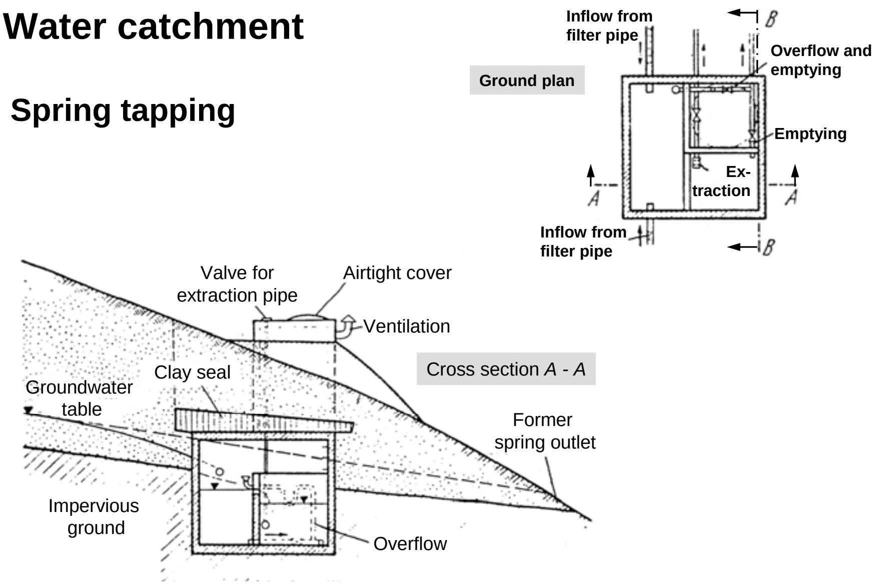
- horizontal filter wells
- vertical filter wells

Surface water

River bank infiltration / ground water infiltration

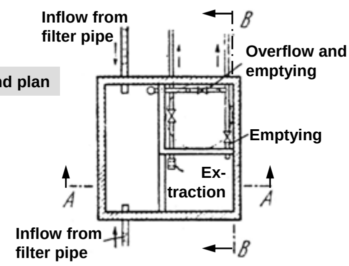
Water catchment

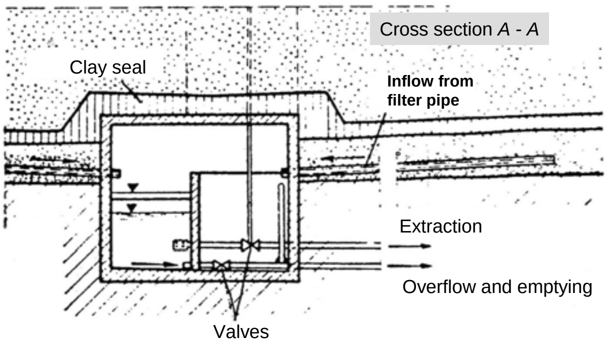
Spring tapping



Water catchment

Spring tapping

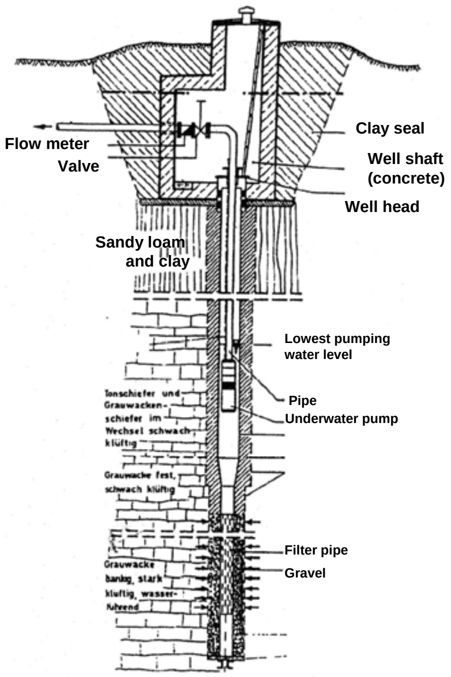




Water catchment

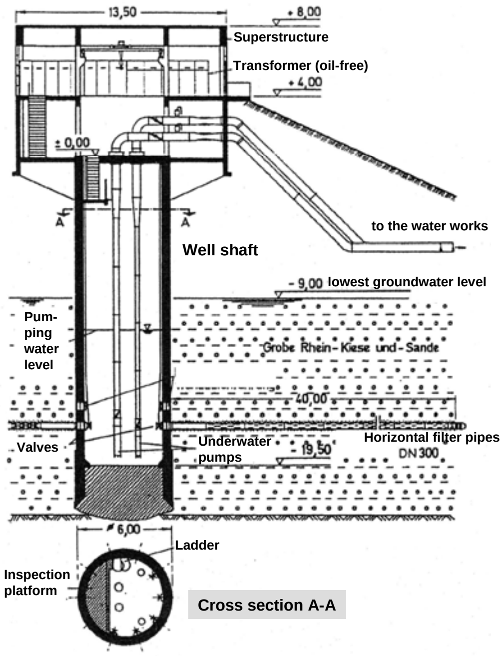
Ground water

Vertical filter well



Water catchment

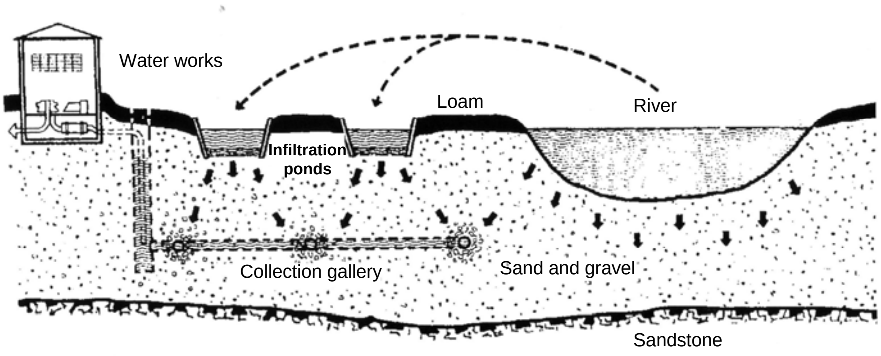
Ground water



Horizontal filter well

Water catchment

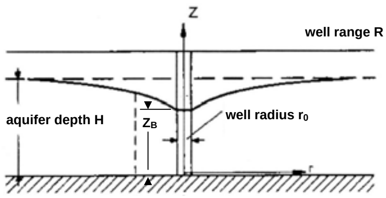
River bank infiltration / ground water infiltration



Groundwater flow and well performances

Darcy's law: $v = k_f \cdot i$

with k_f [m/s] permeability
i [-] slope : $i = dz/dr$



Well with depression cone

(slope is constant in r → centre symmetric)

$$v = k_f \cdot \frac{dz}{dr}$$

Water inflow: general $q = v \cdot A$

with infiltration area $A = 2\pi r \cdot z$ and $v = k_f \cdot \frac{dz}{dr}$

→ $$q = k_f \cdot \frac{dz}{dr} \cdot 2\pi r \cdot z$$

integrated with the boundary conditions $r = r_0 \dots R$ and $z = Z_B \dots H$

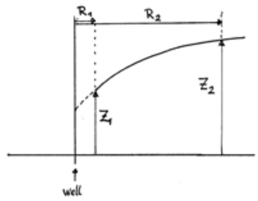
→ $$q = \pi \cdot k_f \cdot \frac{H^2 - Z_B^{\;2}}{\ln \frac{R}{r_0}}$$

Unknown: q pump rate
k_f permeability
R well range

Groundwater flow and well performances

Calculations

- determination of permeability k_f

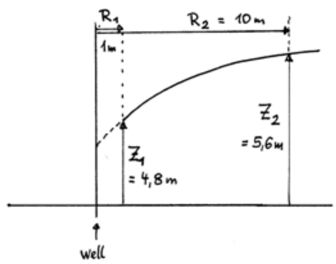


with pumping test
-1 pumping well
-2 observation wells, distance: R_1 and R_2
with water heads: Z_1 and Z_2
-q is known = pumping rate

$$q = \pi \cdot k_f \cdot \frac{Z_2^{\;2} - Z_1^{\;2}}{\ln \frac{R_2}{R_1}}$$ dissolved for k_f : $$k_f = \frac{q}{\pi} \cdot \frac{\ln \frac{R_2}{R_1}}{Z_2^{\;2} - Z_1^{\;2}}$$

Example:
q = 4 l/s
R_1 = 1,0 m R_2 = 10,0 m
Z_1 = 4,8 m Z_2 = 5,6 m

$$k_f = \frac{0,004}{\pi} \cdot \frac{\ln 10}{5,6^2 - 4,8^2} = 3,52 \cdot 10^{-4}$$

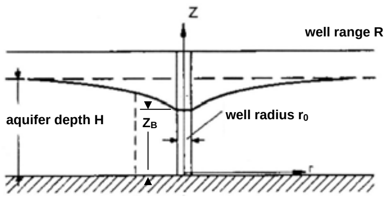


Groundwater flow and well performances

Calculations

- well range R

  a) with an empirical
  approximation formula (Sichardt)
  (dimensionally not accurate)



Well with depression cone

$$R \Leftarrow 3000 \cdot s \cdot \sqrt{k_f}$$

with $s = H - Z_B$

<u>Example:</u>
$k_f = 3,52 \cdot 10^{-4}$ m/s
H = 6,5 m Z_B = 4,0 m
→ s = 2,5 m

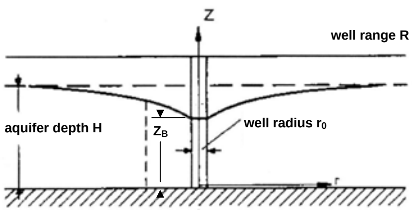
$$R \Leftarrow 3000 \cdot 2{,}5 \cdot \sqrt{3{,}52 \cdot 10^{-4}} \quad = \quad 141\,m$$

Groundwater flow and well performances

Calculations

- well range R

  b) with test pumping



Well with depression cone

$$q = \pi \cdot k_f \cdot \frac{H^2 - Z_B{}^2}{\ln \frac{R}{r_0}}$$

dissolve for R:

$$\rightarrow \quad \ln \frac{R}{r_0} = \pi \cdot \frac{k_f}{q} \cdot \left(H^2 - Z_B{}^2\right) \quad \rightarrow \quad R = r_0 \cdot e^{\frac{k_f}{q} \cdot \pi \cdot \left(H^2 - Z_B{}^2\right)}$$

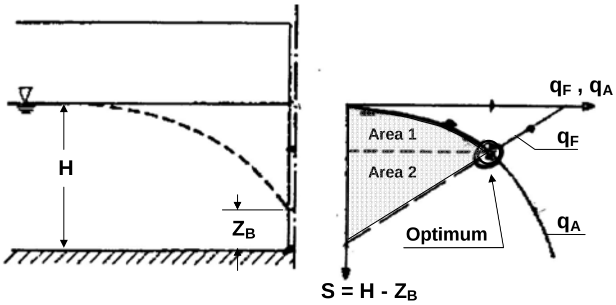
<u>Example:</u>
$k_f = 3,52 \cdot 10^{-4}$ m/s
q = 4 l/s
H = 6,5 m Z_B = 4,0 m
r_0 = 0,1 m

$$R = 0{,}1 \cdot e^{\frac{3{,}52 \cdot 10^{-4}}{0{,}004} \cdot \pi \cdot \left(6{,}5^2 - 4{,}0^2\right)} \quad = \quad 142\ m$$

Groundwater flow and well performances

Calculations

- Capacity and load potential of wells



Hydraulically optimal lowering of the groundwater table
from the comparison of

- filter intake capacity
  (how much can the well take in)

$$q_F = \frac{2r_0\,\pi}{15} \cdot Z_B \cdot \sqrt{k_f} \qquad \text{(empiric)}$$

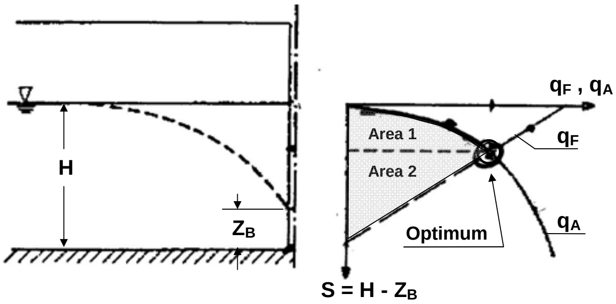
- afflux
  (how much can flow to the well)

$$q_A = \pi \cdot k_f \cdot \frac{H^2 - Z_B{}^2}{\ln \dfrac{R}{r_0}}$$

Groundwater flow and well performances

Calculations

- Capacity and load potential of wells



Solution:
- identify q_F with q_A
- solve for Z_B

$$q_F = q_A \quad \rightarrow \quad \frac{2r_0\,\pi}{15} \cdot Z_B \cdot \sqrt{k_f} = \pi \cdot k_f \cdot \frac{H^2 - Z_B{}^2}{\ln \dfrac{R}{r_0}}$$

$$Z_B = \pm\sqrt{H^2 + \left(\frac{r \cdot \ln R/r_0}{15 \cdot \sqrt{k_f}}\right)^2} - \frac{r \cdot \ln R/r_0}{15 \cdot \sqrt{k_f}}$$

Water protection

Water protection zones

- against pollution by human activities
- restrictions and prohibitions
- in Germany: 3 protection zones

Water protection zones

- I: Wellhead area / intake area
  - 10m radius for wells
  - 100m bank section for reservoirs
  - ➢ not to be impaired in any way
  - ➢ no trespassing

Water protection

Water protection zones

- II : Nearside protection area
  - wells: groundwater flowpath within 50 days
  - reservoirs: 250m from the banks,
    feeding water courses included 2,5 km upstream
  - or locally adapted
  - ➢ generally no settlement and development
  - ➢ no fertilizing, no excavating

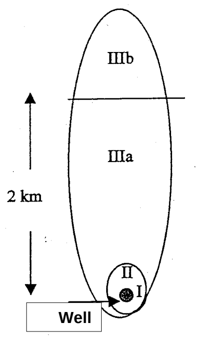
Water protection

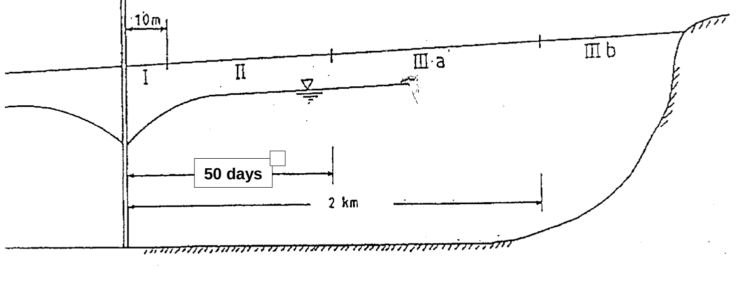
Water protection zones

- III : Extended protection area
  - the catchment area
  - separated into IIIa and IIIb if very large
  - maximum range of IIIa from well: 2km
  - ➢ no passing through of waste water or hazardous substances
  - ➢ no industry with hazardous products and materials

Water protection

Water protection zones for wells





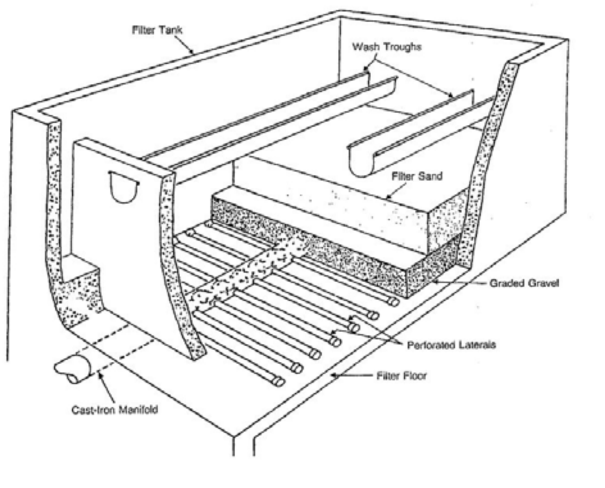
Water purification

Remove undesirable chemicals, materials, and biological contaminants by

- physical processes such as filtration and sedimentation
- biological processes such as slow sand filters or activated sludge
- chemical process such as flocculation and chlorination
- electromagnetic radiation such as ultraviolet light

- plus pH adjustment if necessary

Rapid sand filter



Water purification

Drinking water quality standards

- set by the governments or international standards

- EU: **Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption**
- in accordance with the WHO guidelines for drinking water

- standards for the most common substances
- regular monitoring (48 microbiological and chemical parameters
- nationally: additional or higher standards possible