Exercise No. 1
Water supply

Water requirements planning
Dimensioning of wells

Contact

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and according to prior agreement!

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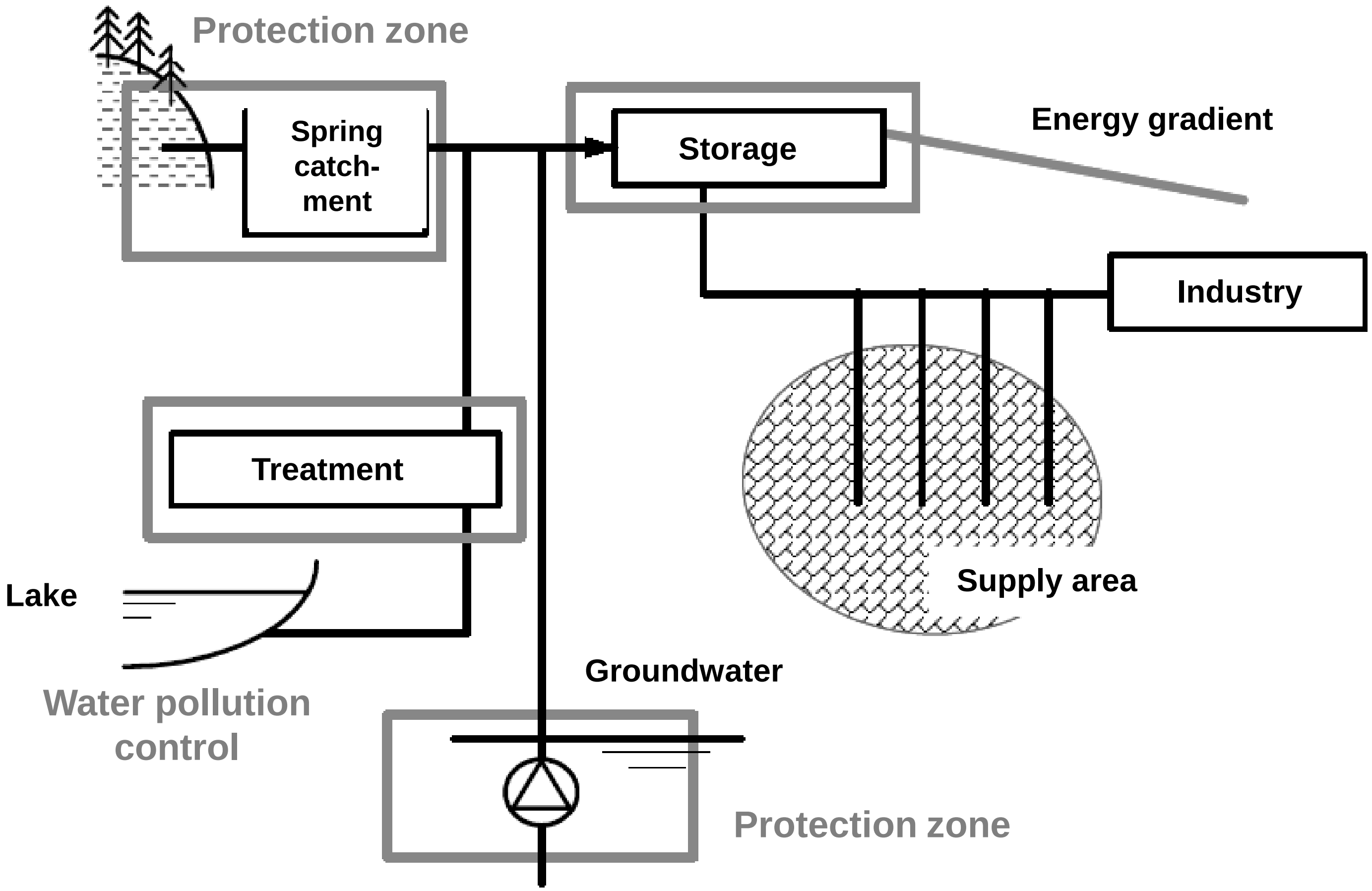
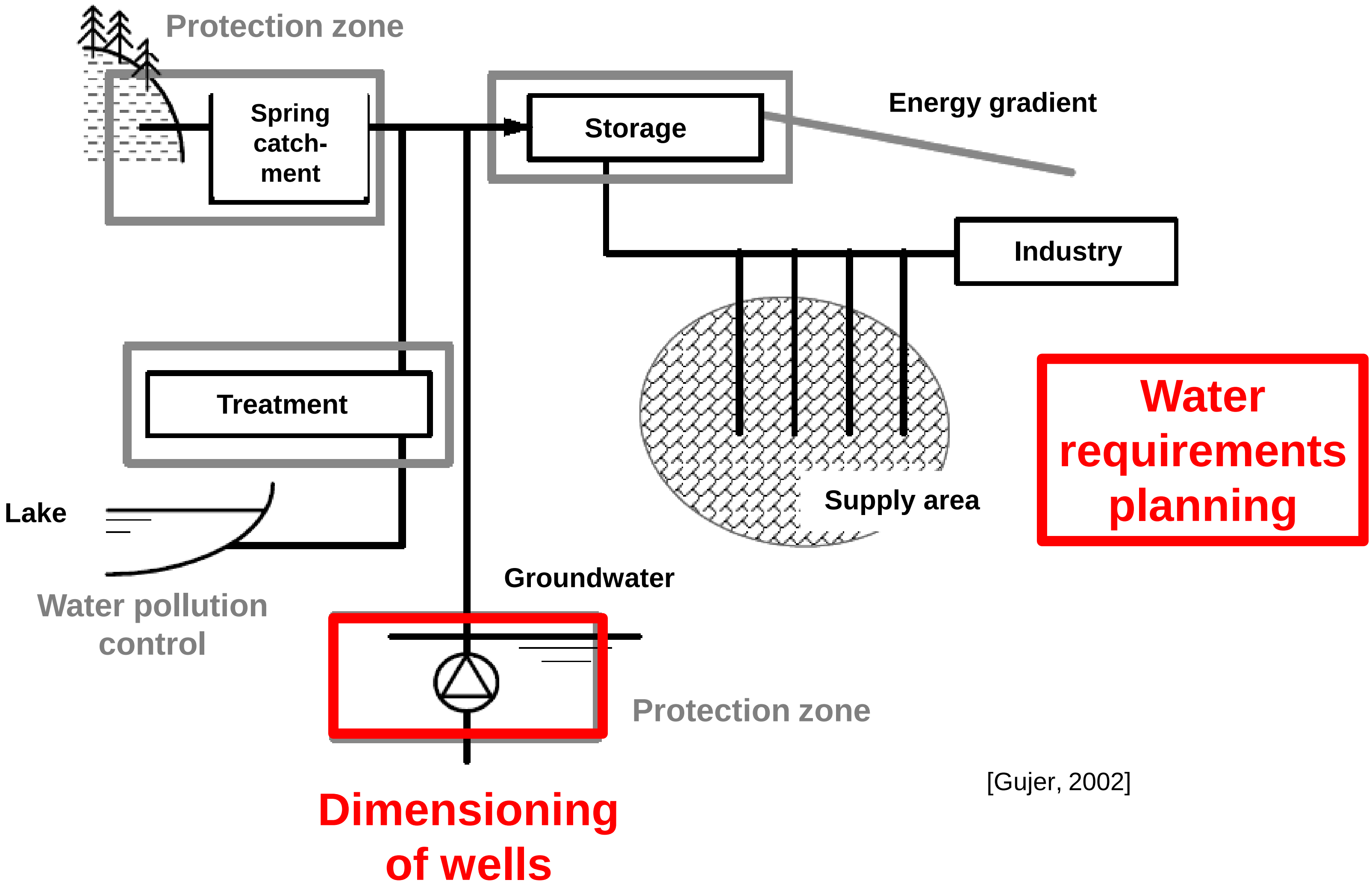
Water supply

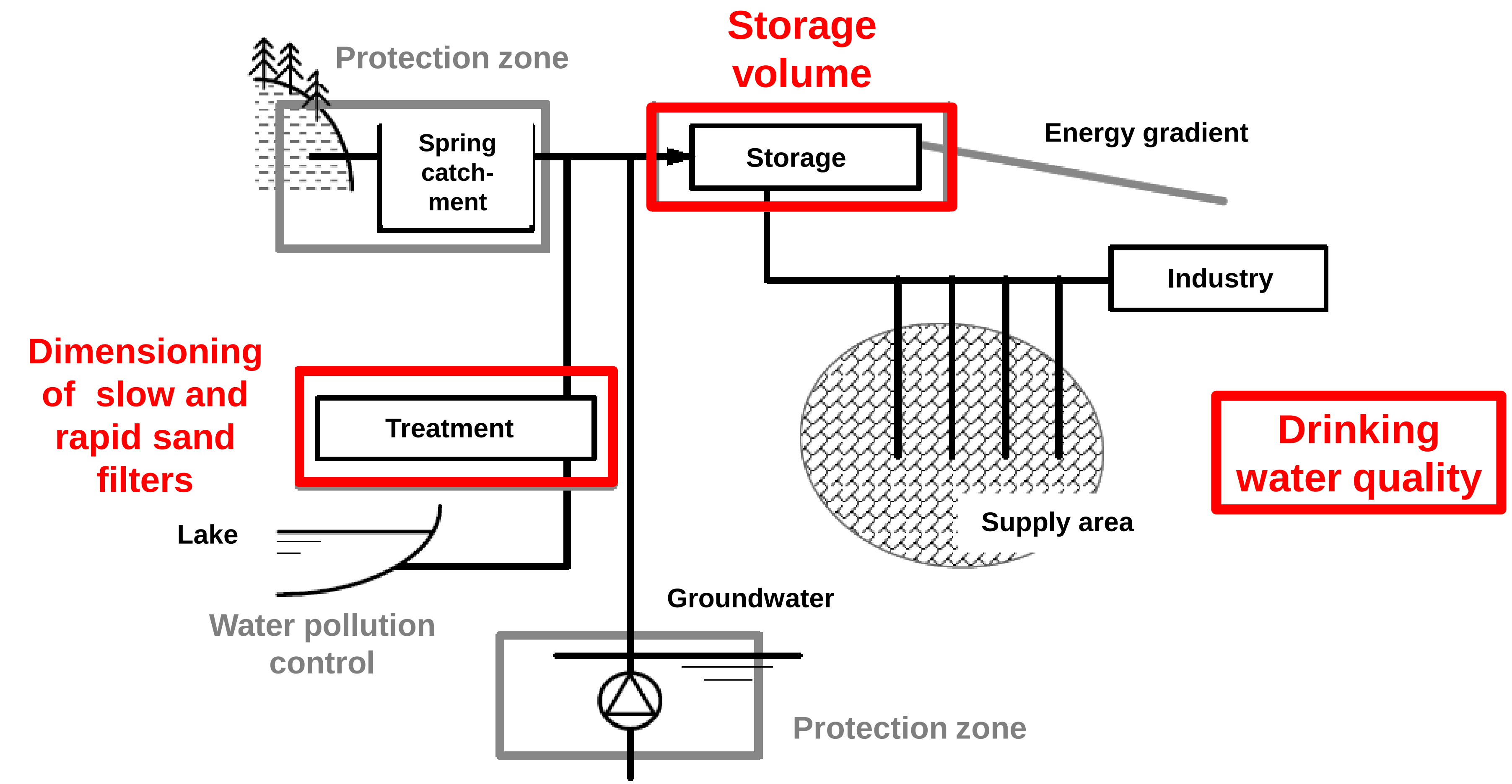


[Gujer, 2002]

Exercise: Today



Exercise: At a later date



[Gujer, 2002]

Example 1: Water requirements planning I

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Given:

Total number of inhabitants: 50,000 inhabitants

Average water consumption per day: 130 L/(P · d)

Water losses and self-consumption of the water works (filter washing + pipe cleaning): 7 %

Precipitation: P = 650 mm/a (average)

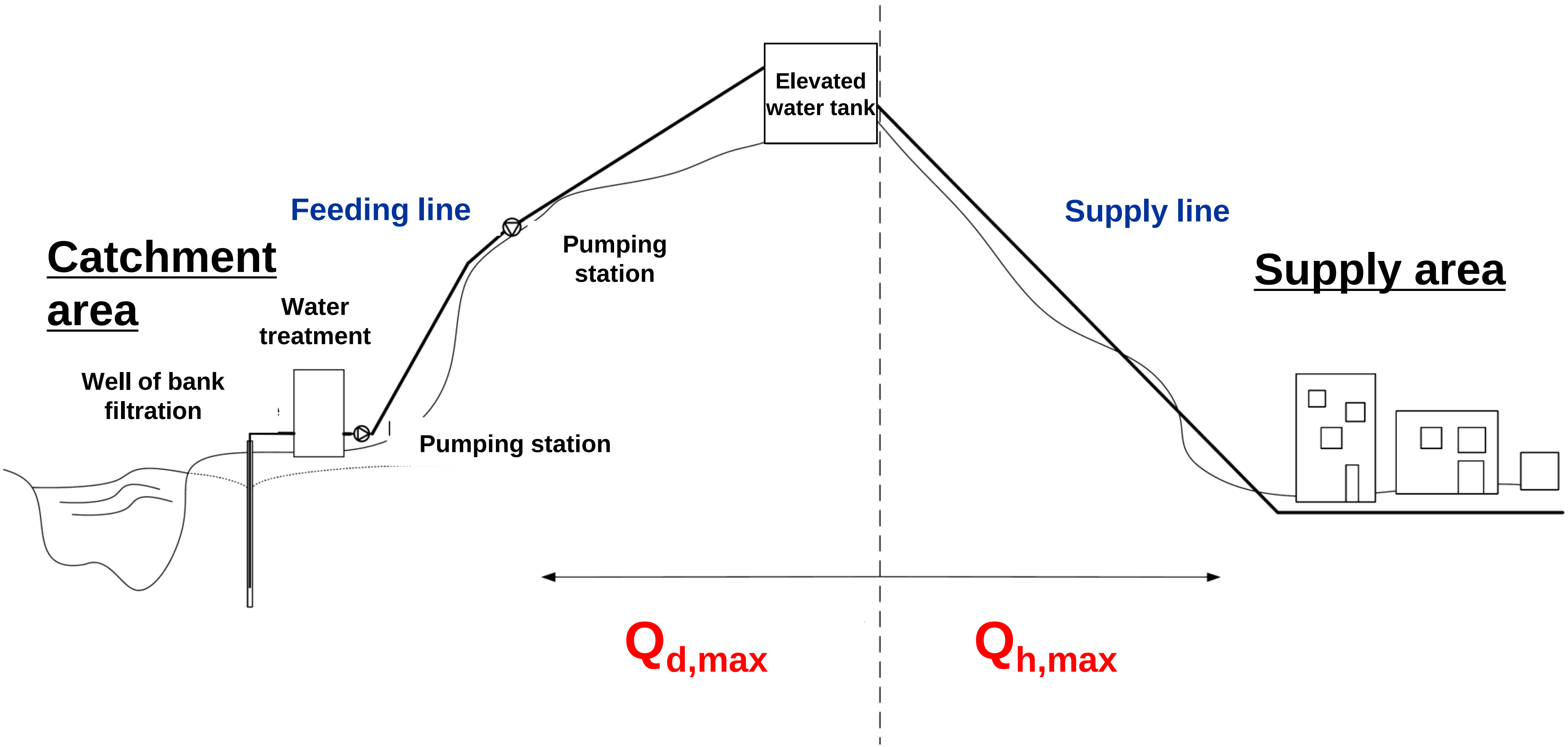
Evaporation: E = 400 mm/a (average)

Surface (overland) runoff: Q_O = 100 mm/a (average)

Calculate:

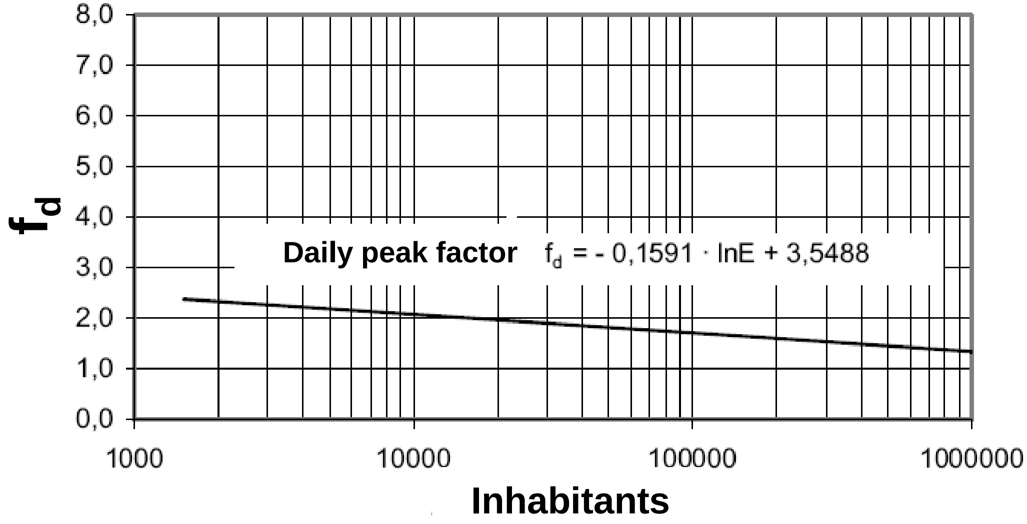
a)	Average annual water demand Q_a	[m³/a]
b)	Maximum daily water demand $Q_{d,max}$	[m³/d]
c)	Hourly water demand Q_h	[m³/h]
d)	Needed area for recharge of groundwater	[ha]

Design values for water requirements planning

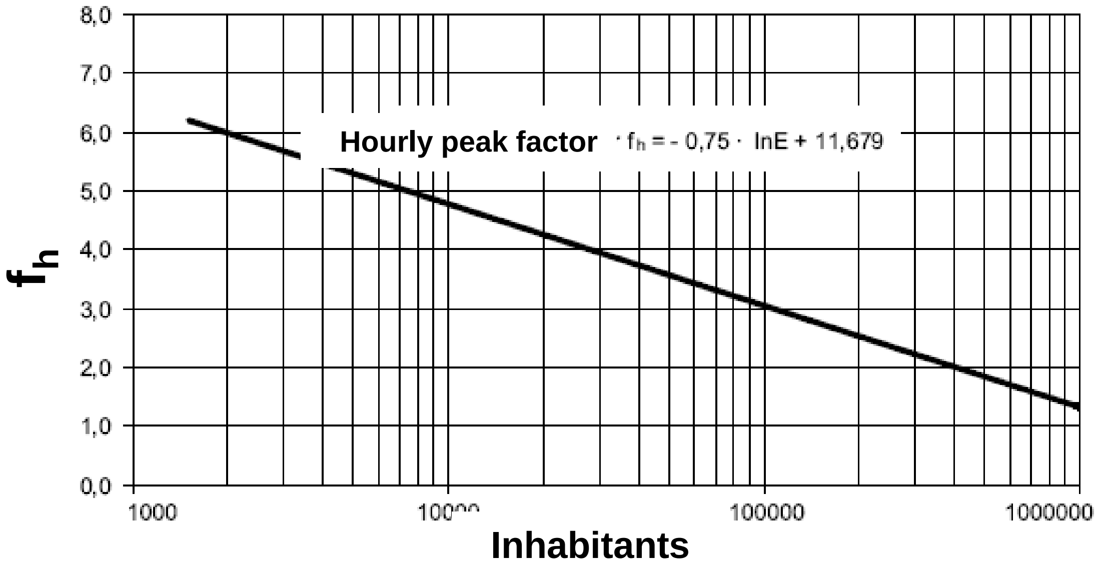


Design values for water requirements planning

Peak factor - daily

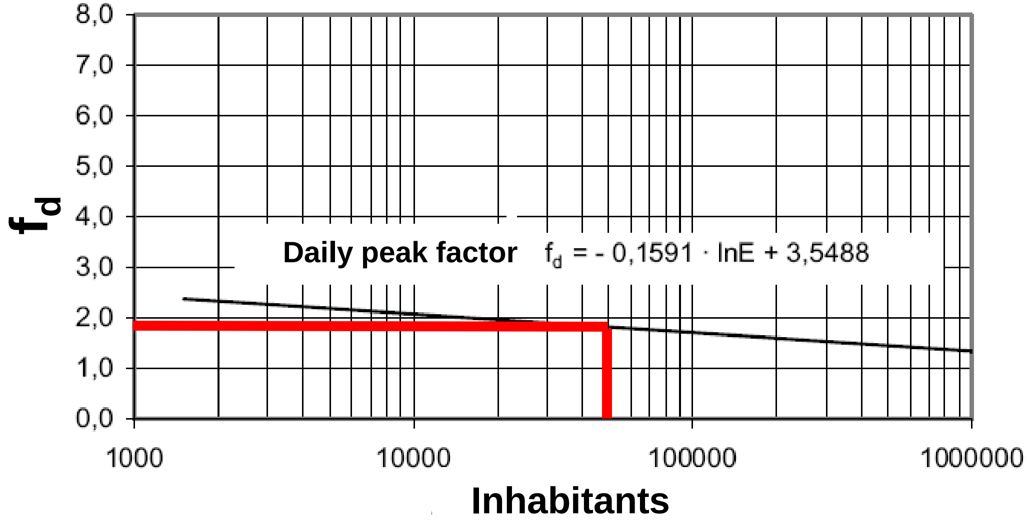


Peak factor - hourly

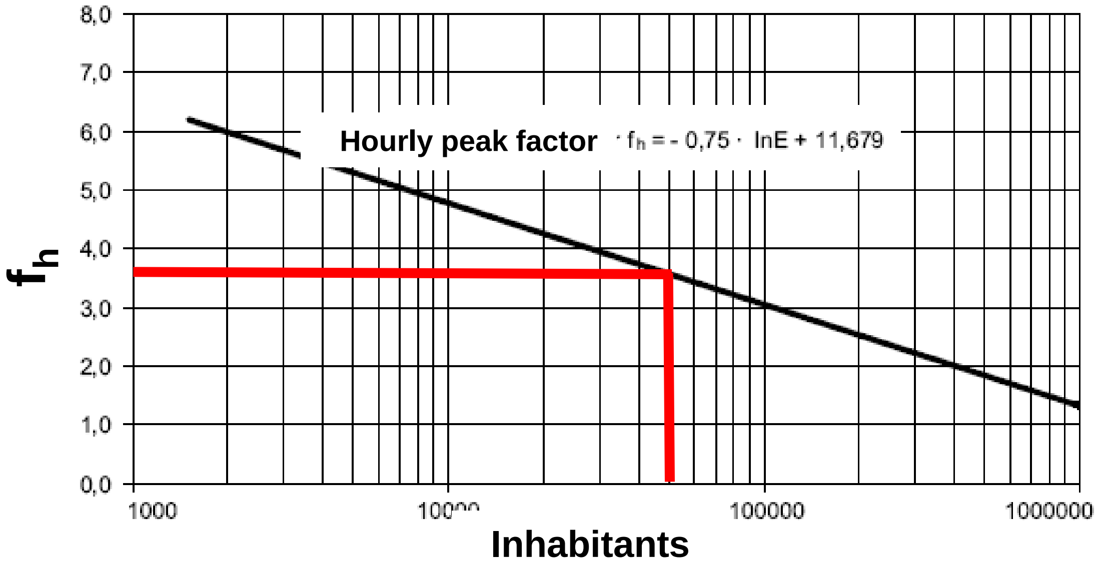


Design values for water requirements planning

Peak factor - daily



Peak factor - hourly



Example 2: Water requirement planning II

Given:

ISAH-Town:

Household	Old single- and double-family houses	5,500 inhabitants
	New single-familiy terrace houses, multi-storey houses	10,000 inhabitants
	Buildings with comfort apartments	2,500 inhabitants
	Modern mansions in best residental area	100 inhabitants
Small trade	1 Bakery	10 employees
	1 Butcher	15 employees
Agriculture	Cattle	50

Calculate:

Calculate the average and maximum daily water demand of ISAH-Town using the individual requirement calculation.

Neglect any water losses and self-consumption of the water works (filter washing + pipe cleaning)

Average per consumption-unit

	Consumers	Unit	Liter
1.	**Household, incl. small trade**		
1.1	**Household**		
	1. Old single- and double-family houses	l/(P · d)	70
	2. Simple multi-family houses, year of constr. before 1940	l/(P · d)	90
	3. Multi. storey houses with social apartments	l/(P · d)	120
	4. New single-family terrace houses, multi-storey houses	l/(P · d)	150
	5. Buildings with comfort apartments	l/(P · d)	180
	6. Single- and double-family houses in good residential area	l/(P · d)	200
	7. Modern mansions in best residential area	l/(P · d)	275
1.2	**Small trade**		
	1. Baker, 1 Employee / 200 inhabitants	l/(Employee · d)	150
	2. Confectioner, 1 Employee/ 1000 inhabitants	l/(Employee · d)	200
	3. Butcher, 1 Employee / 300 inhabitants	l/(Employee · d)	250
	4. Coiffeur, 1 Employee / 300 – 600 inhabitants	l/(Employee · d)	200
	5. Car-wash	l/car	80
	6. Commercial enterprises	l/(Employee · d)	250
	7. Restaurants	l/((Guest+Employee) · d)	50
1.3	**Agriculture**		
	1. Cattle	l/(Cattle · d)	50
	2. Cattle without litter	l/(Cattle · d)	60
	3. Cattle with litter	l/(Cattle · d)	75
	4. Small domestic animals (=1/5 cattle)	l/animal	1.5
	5. Milk collection station, per liter milk	l/(m^2 · d)	1.0
	6. Intensive agricultural irrigation)	l/(m^2 · d)	

[Mutschmann/Stimmellmayr, 1995]

Example 3: Dimensioning of wells

Given:

Hydrostatic level over groundwater bottom or thickness of water bearing layer: H = 20 m

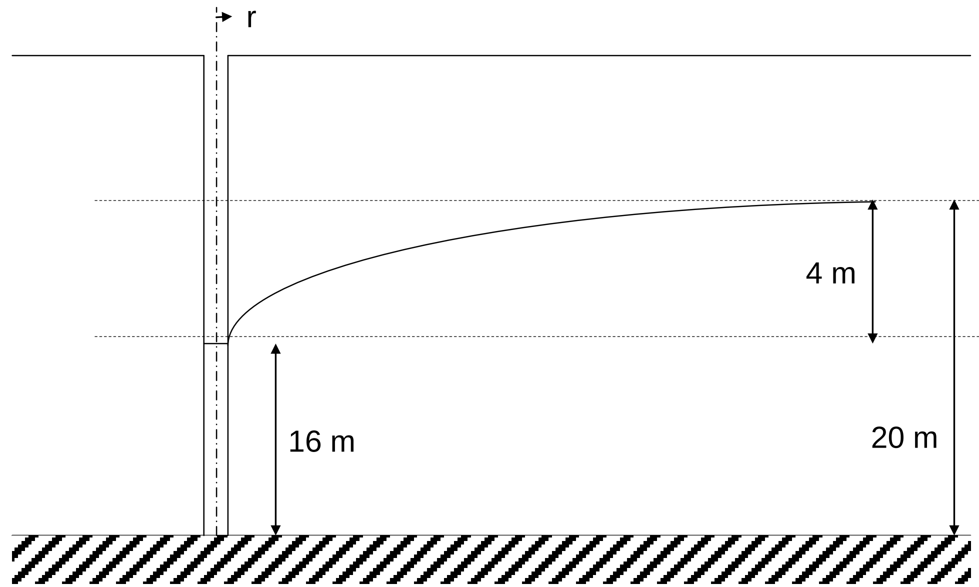
Lowered groundwater level in the well: h = 16 m

Hydraulic conductivity (coefficient of permeability) (fine sand): $k_f = 2 \cdot 10^{-4}$ m/s

Radium of the well: r = 0.15 m

Draw-down: s = 4.0 m

Water demand (see example No. 1)



Calculate:

a) Draw-down range R [m]

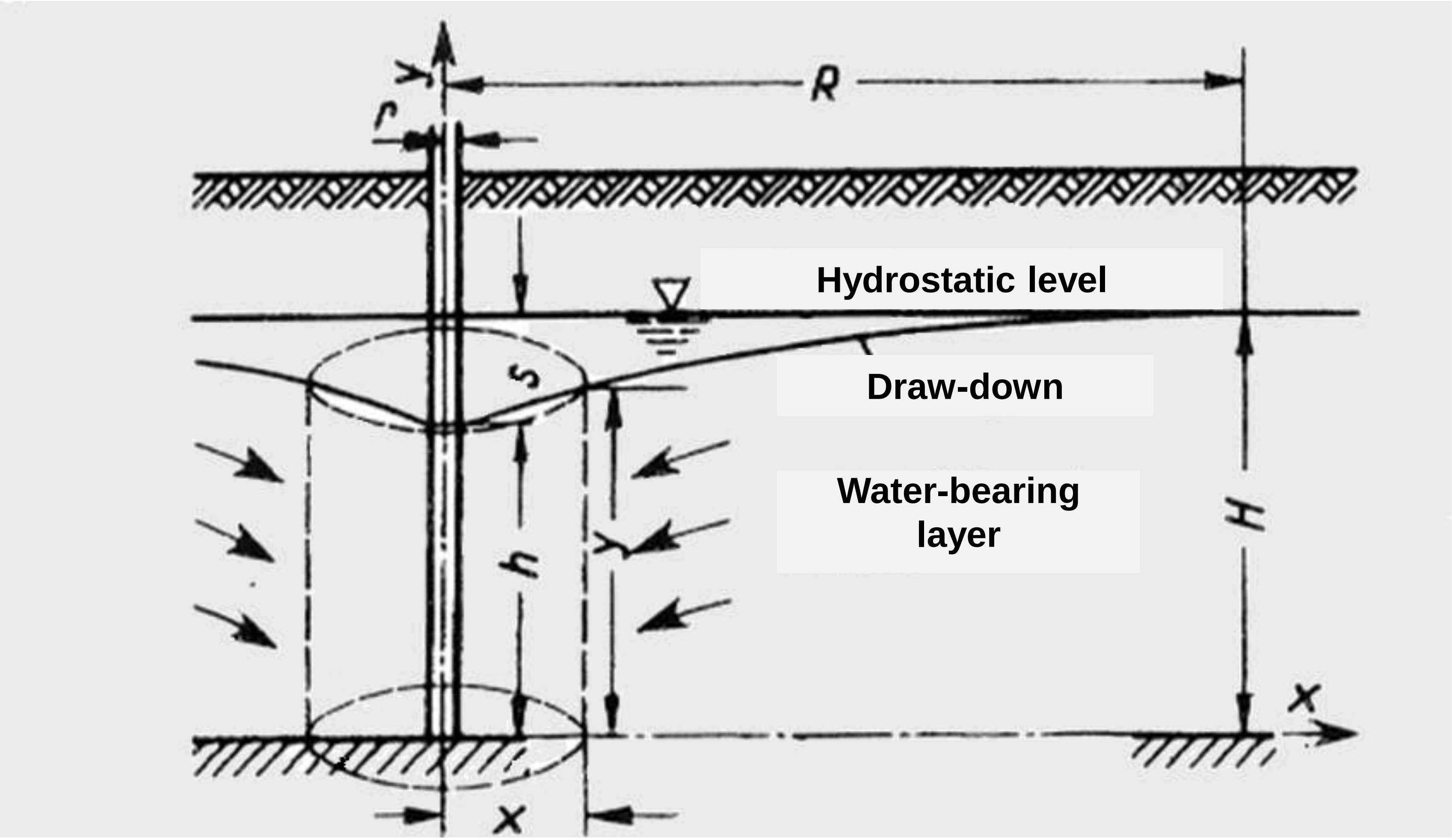
b) Yield of the well (groundwater inflow) Q_{GW} [l/s; m³/d; m³/s]

c) Capacity of the well (tangible water inflow) Q_t [l/s; m³/d]

d) Number of needed wells n_{well} [-]

e) Name the groundwater protection areas and their requirements

Cross section: Vertical filter well



Calculation formula: Dimensioning of a well

Draw-down range R according to SICHARDT:

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

with:

k_f: Hydraulic conductivity (coefficient of permeability) [m/s]

s: Draw-down [m]

R: Draw-down range R according to SICHARDT [m]

Calculation formula: Dimensioning of a well

Considering the continuity equation and the filter law of Darcy, the following equation results:

$$Q_{GW} = \left(H^2 - h^2\right)\frac{\pi \cdot k_f}{\ln\left(R/r\right)}$$

with:

k_f Hydraulic conductivity (coefficient of permeability) [m/s]

Q_{GW} Yield of the well (groundwater inflow) [m³/s]

H Hydrostatic level over groundwater bottom or thickness of water bearing layer [m]

h Lowered groundwater level in the well [m]

R Draw-down range R according to Sichardt [m]

r Radium of the well [m]

Calculation formula: Dimensioning of a well

Capacity of a vertical filter well (tangible water inflow):

$$Q_t = \frac{2}{15} \cdot \pi \cdot r \cdot h \cdot \sqrt{k_f}$$

with:

k_f Hydraulic conductivity (coefficient of permeability) [m/s]

Q_t Capacity of a vertical filter well (tangible water inflow) [m^3/s]

h Lowered groundwater level in the well [m]

r Radium of the well [m]

Maximum well capacity

Leibniz Universität Hannover

Plot of the groundwater inflow QGW (theoretical well inflow) and the tangible water inflow Q_t as a function of the draw-down s.

- The **point of intersection** gives the maximum well capacity according to the maximum draw-down (in order to meet the requirements: $\mathbf{Q_t \geq Q_{GW}}$)

s	R	Q_{GW}	Q_t
0	0	0	0.0178
1	42	0.0043	0.0169
2	85	0.0075	0.0160
3	127	0.0103	0.0152
4	170	0,0129	0,0143
5	212	0,0152	0,0134
6	255	0,0172	0,0125
7	297	0,0191	0,0116
8	339	0,0208	0,0107
9	382	0,0224	0,0098
10	424	0,0237	0,0089
11	467	0,0249	0,0080
12	509	0,0260	0,0071
13	552	0,0269	0,0062
14	594	0,0276	0,0053
15	636	0,0282	0,0045
17	721	0,0290	0,0027
18	764	0,0285	0,0018
20	849	0,0286	0,0000