Nature based Infiltration Systems for onsite wastewater treatment

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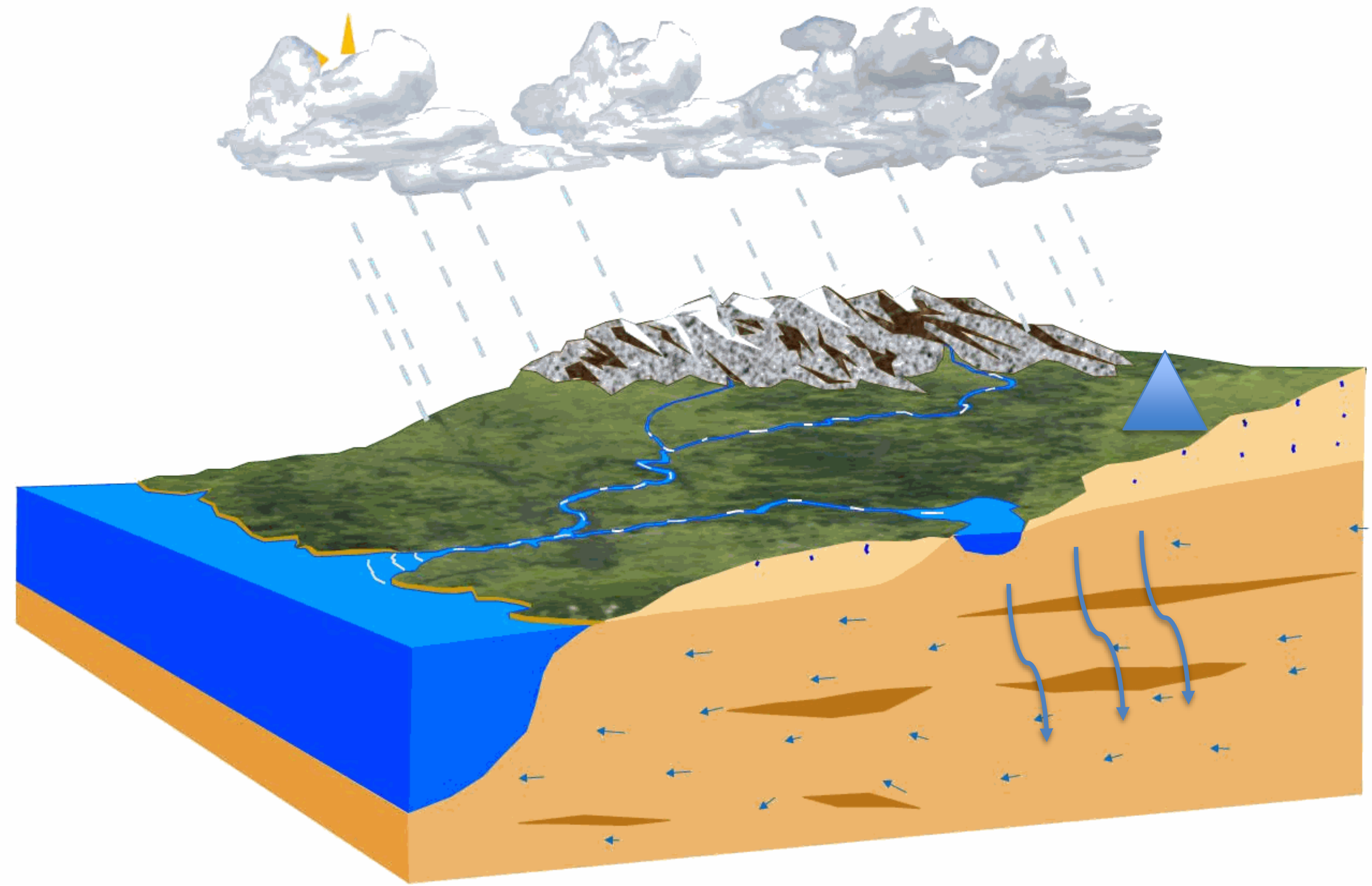
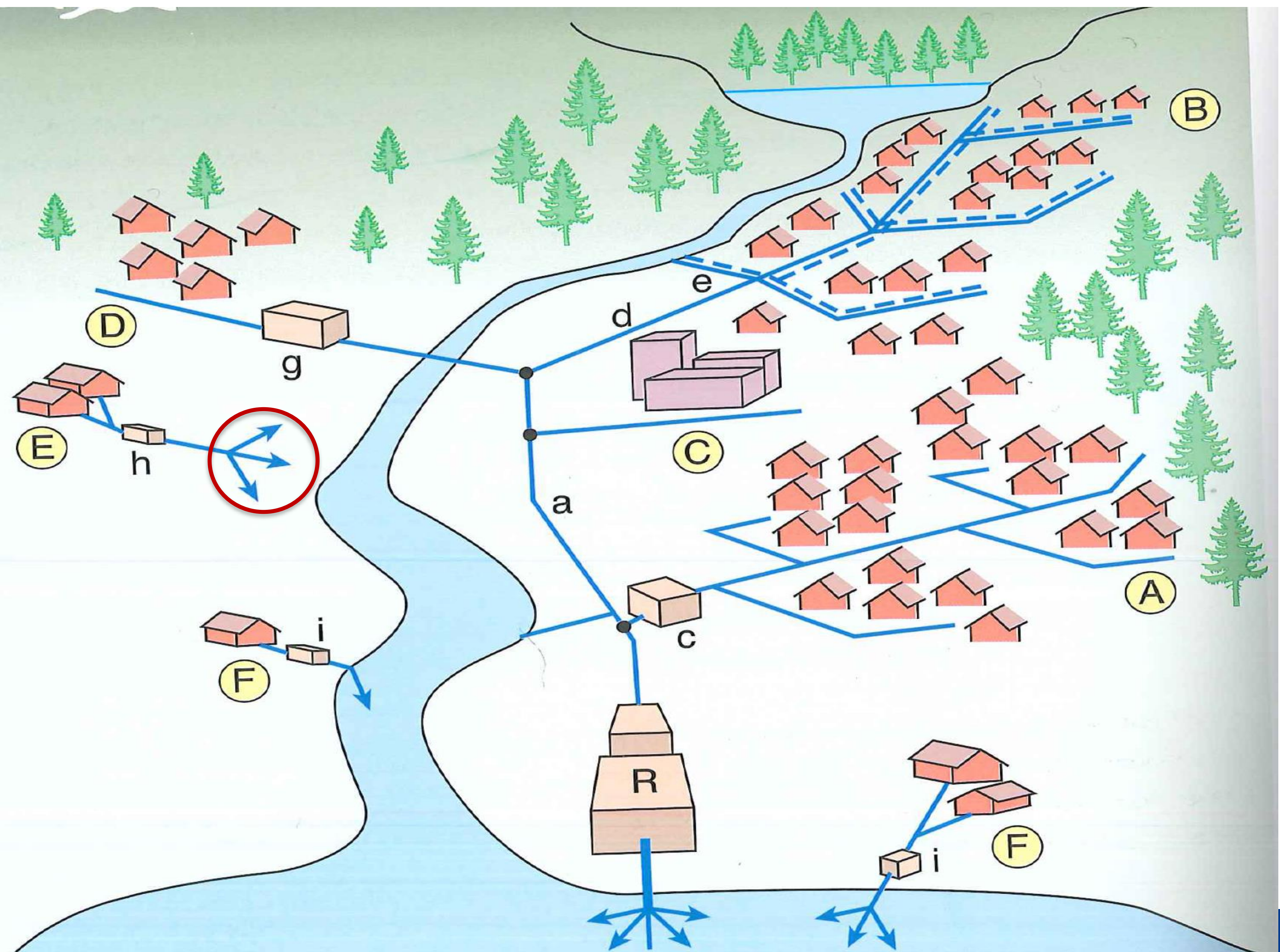
The water cycle

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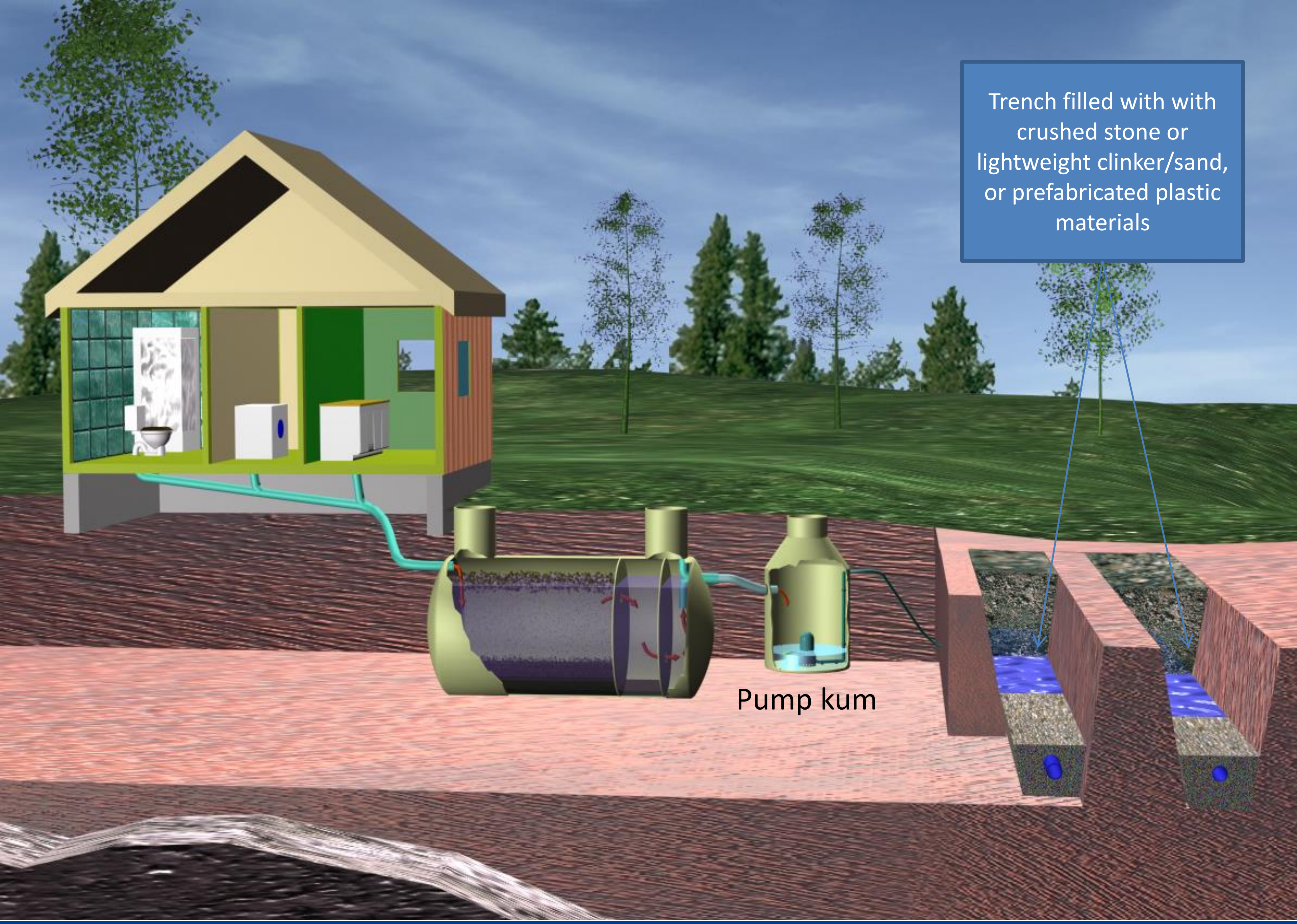
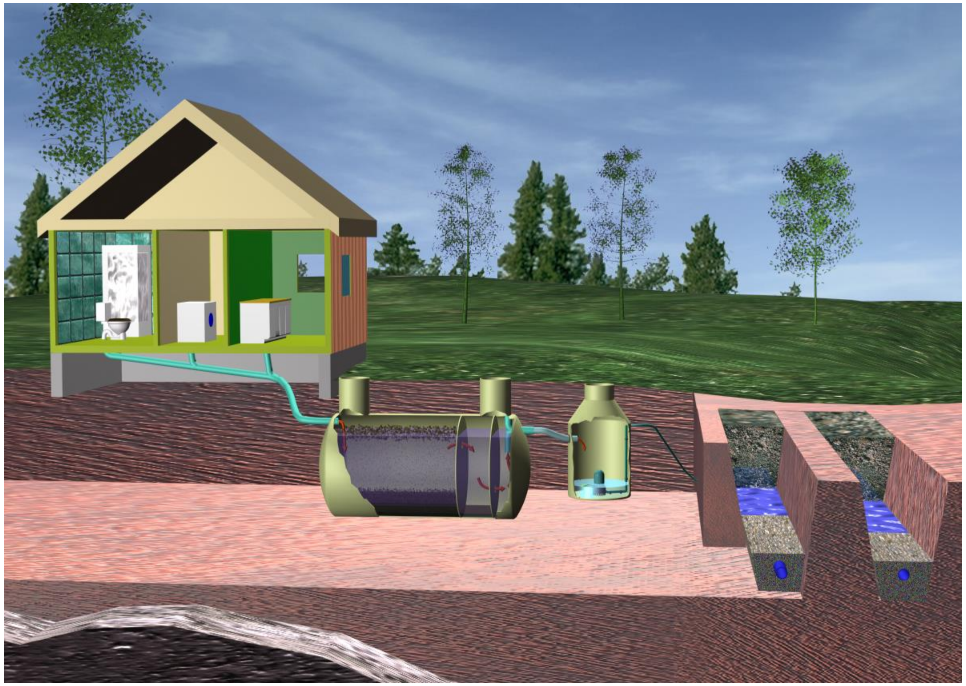

Trench filled with with crushed stone or lightweight clinker/sand, or prefabricated plastic materials
Pump kum

Infiltration in local soil

- Infiltration systems treat wastewater via mechanical, chemical and biological processes.
- The wastewater is filtered through naturally stored soil masses.
- Infiltration systems are recommended in areas defined as sensitive and normal in the pollution regulations.
- Infiltration systems can also be an economical solution for meeting municipal wastewater treatment requirements.



Key design factors

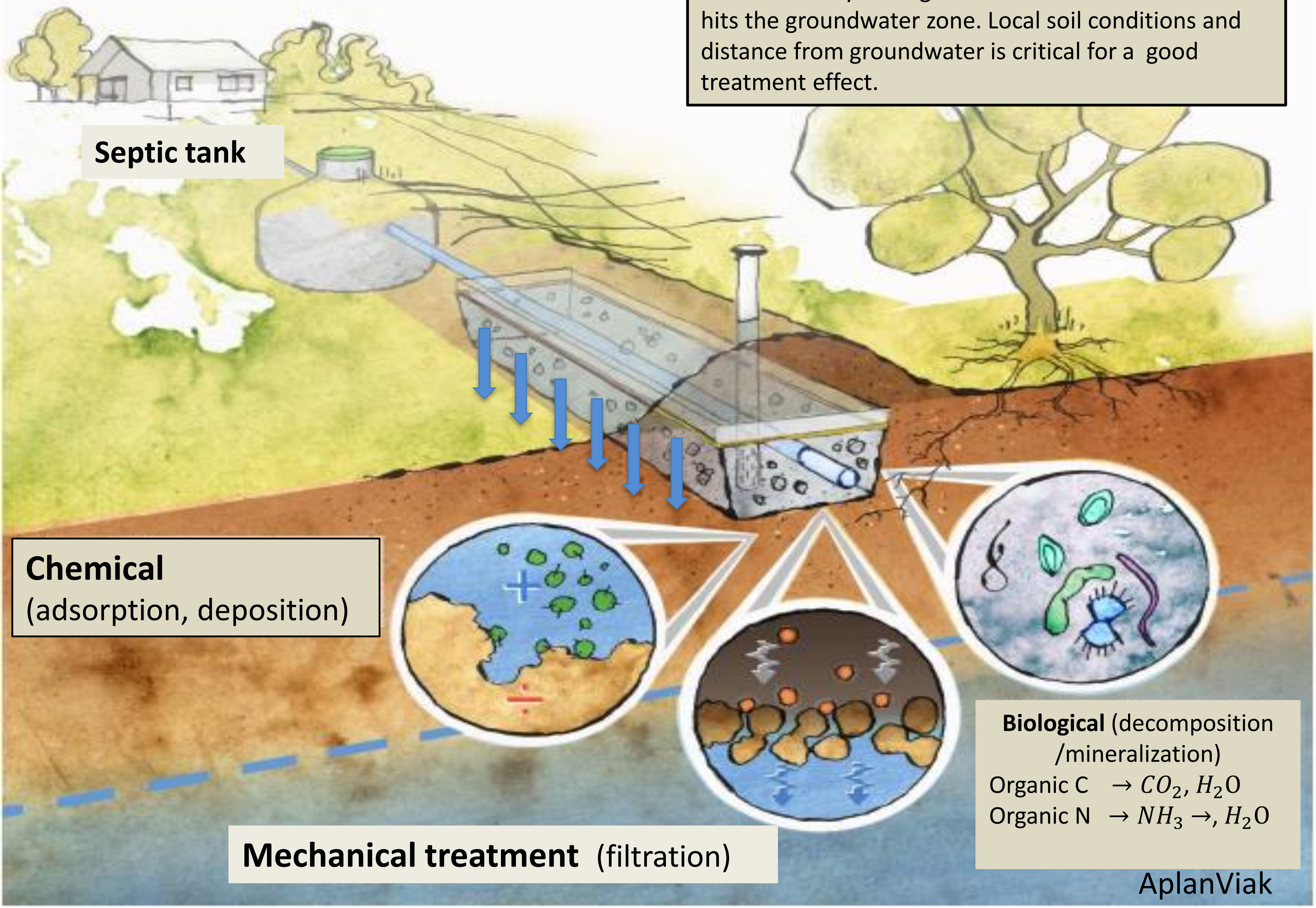
Key factors in the design of local infiltration systems include:

- Soil composition (chemical, etc)
- Soil thickness (profiling)
- Infiltration capacity
- Hydraulic capacity
- Recipient (groundwater level)

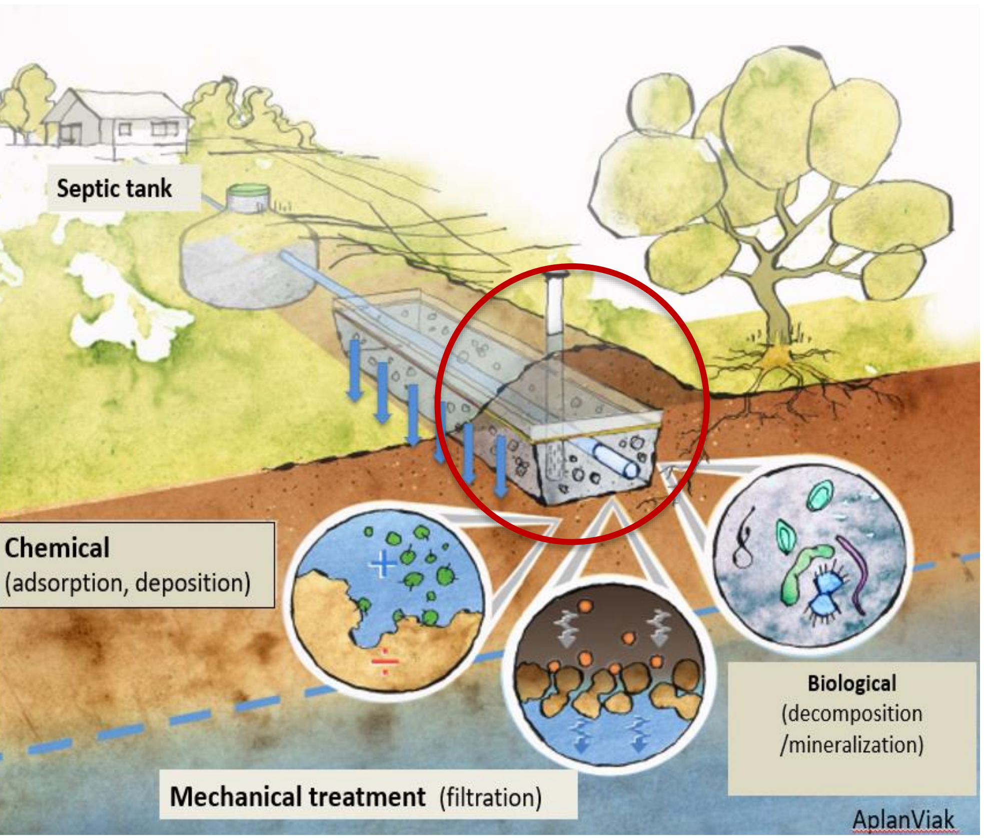
The placement of the infiltration unit in the soil profile will vary depending on local conditions.

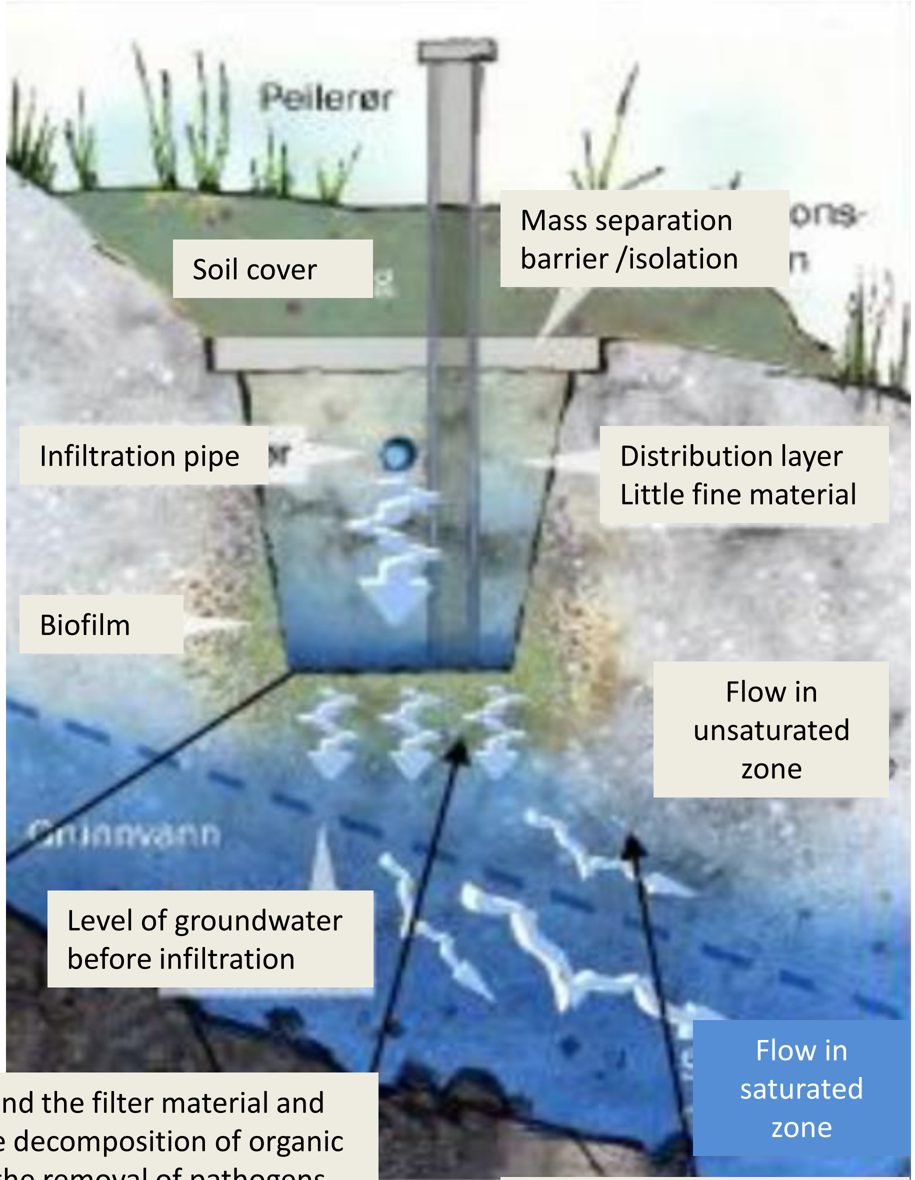
Treatment Mechanism

Septic tank effluent distributed over the soil/media, flows vertically through an unsaturated zone before it hits the groundwater zone. Local soil conditions and distance from groundwater is critical for a good treatment effect.



Treatment Mechanism

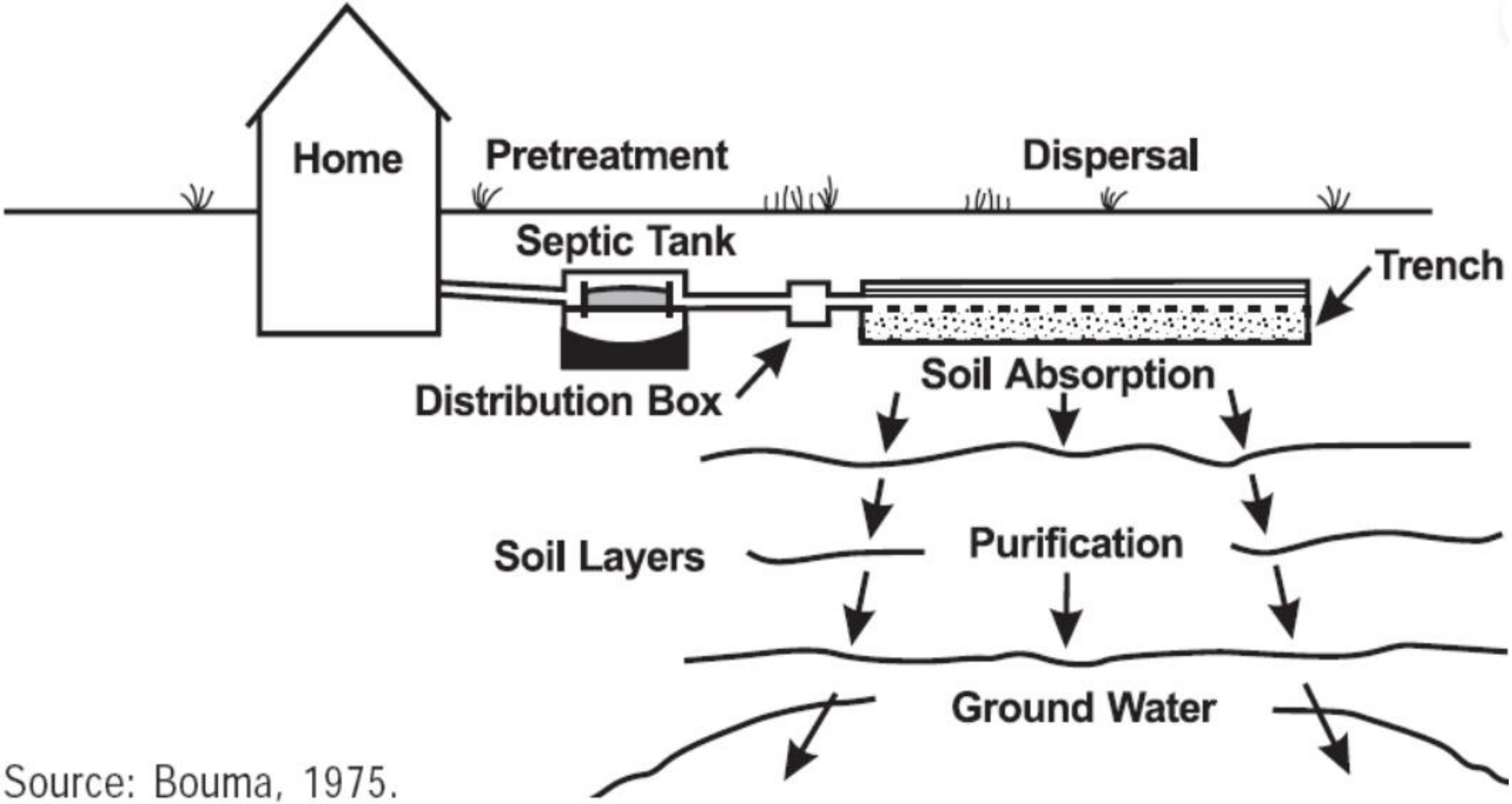




Biofilm forms around the filter material and soil resulting in the decomposition of organic matter, as well as the removal of pathogens

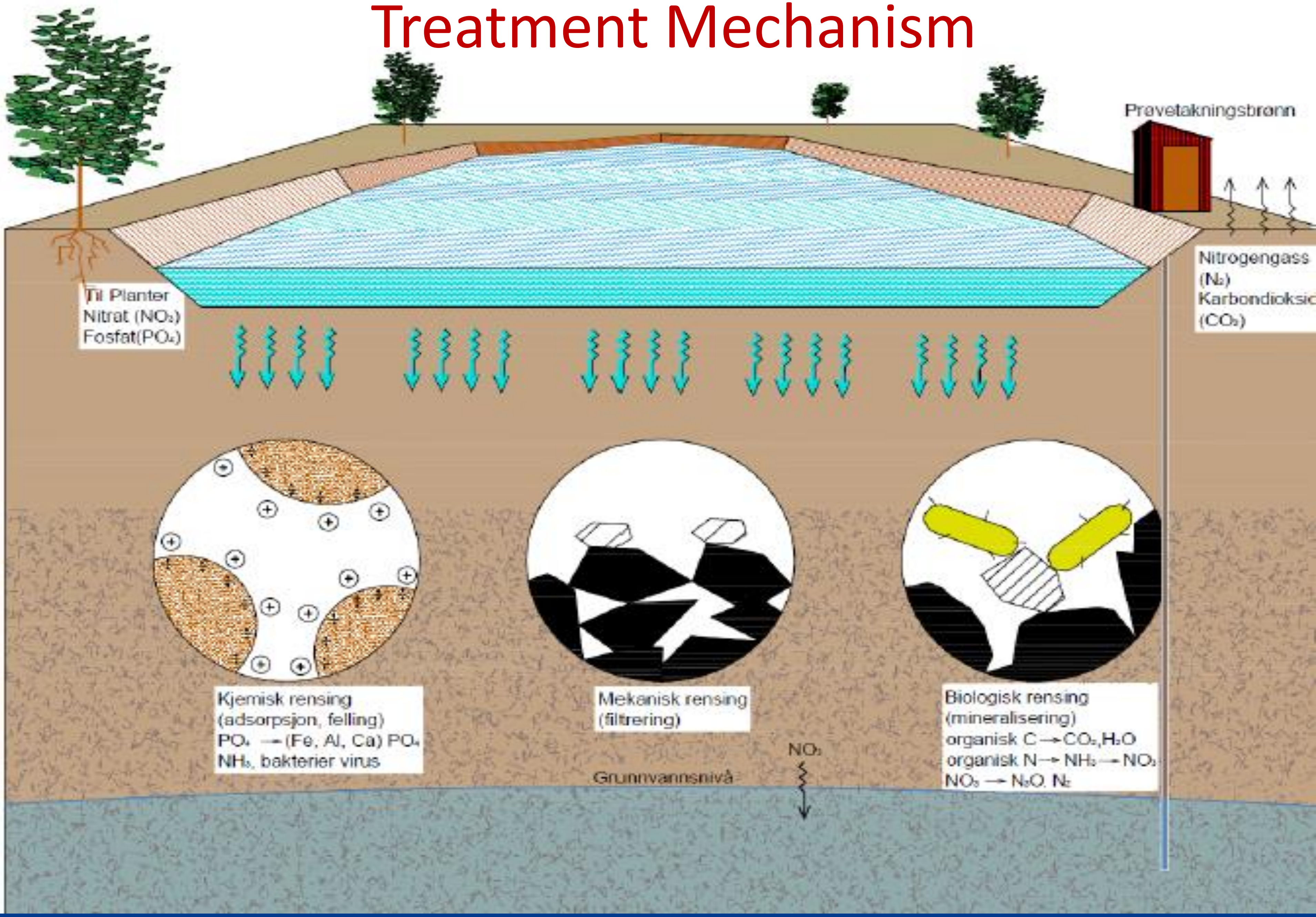
Dissolved phosphorus is bound to the soil in the unsaturated zone

Design Principle



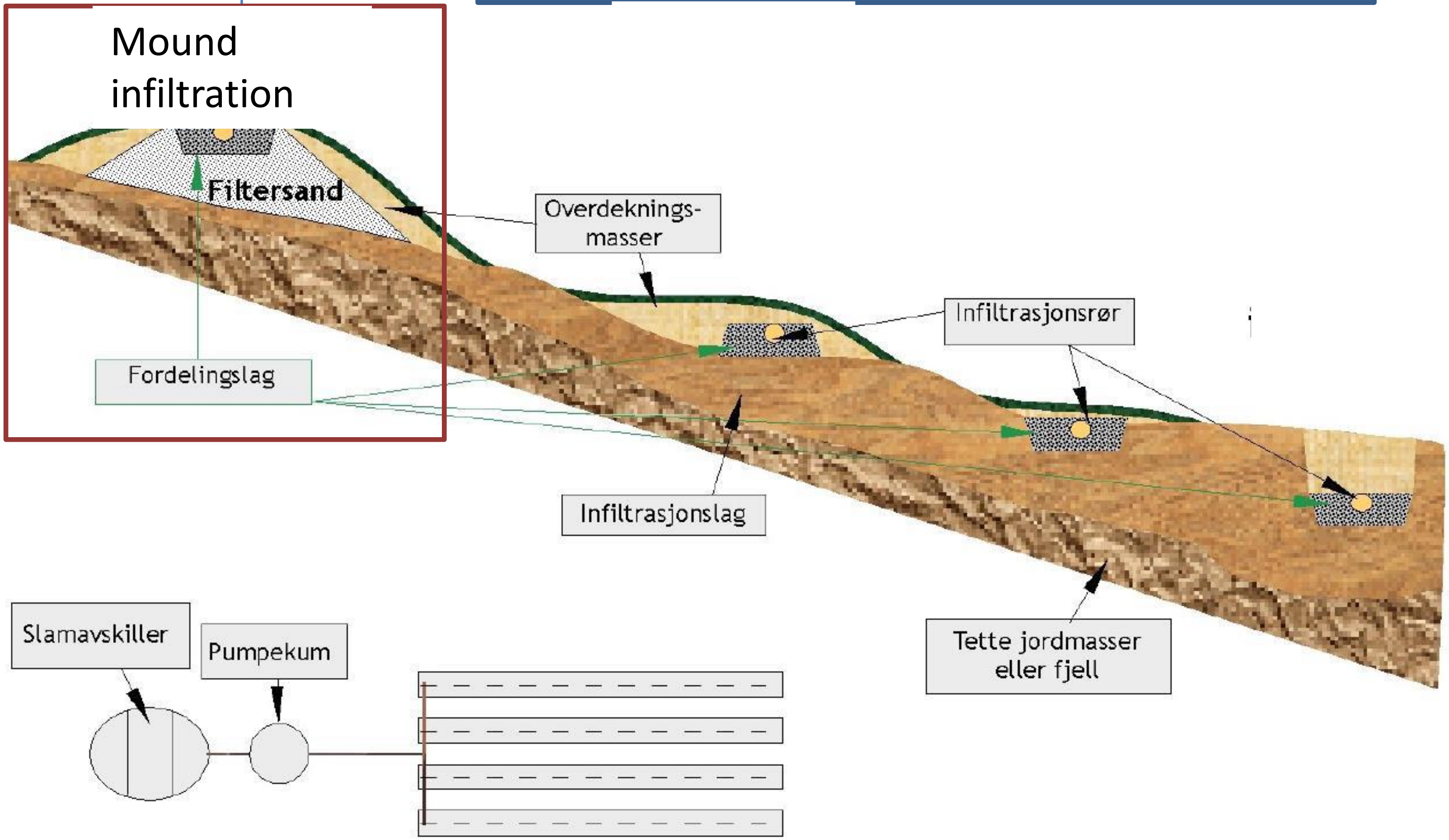
Source: Bouma, 1975.

Treatment Mechanism



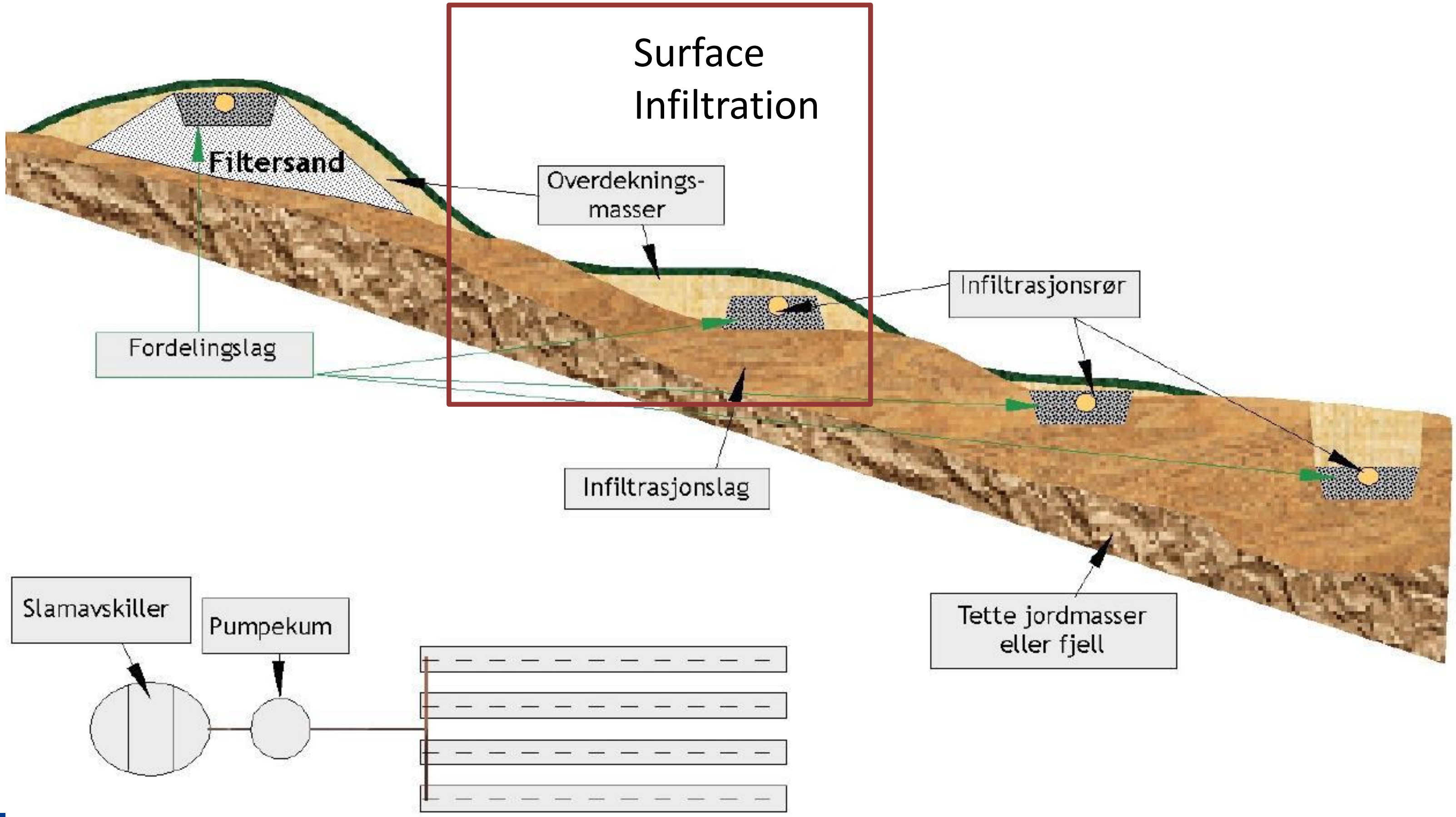
Design configuration

Established with additional filter material where the soil mass have very limited thickness



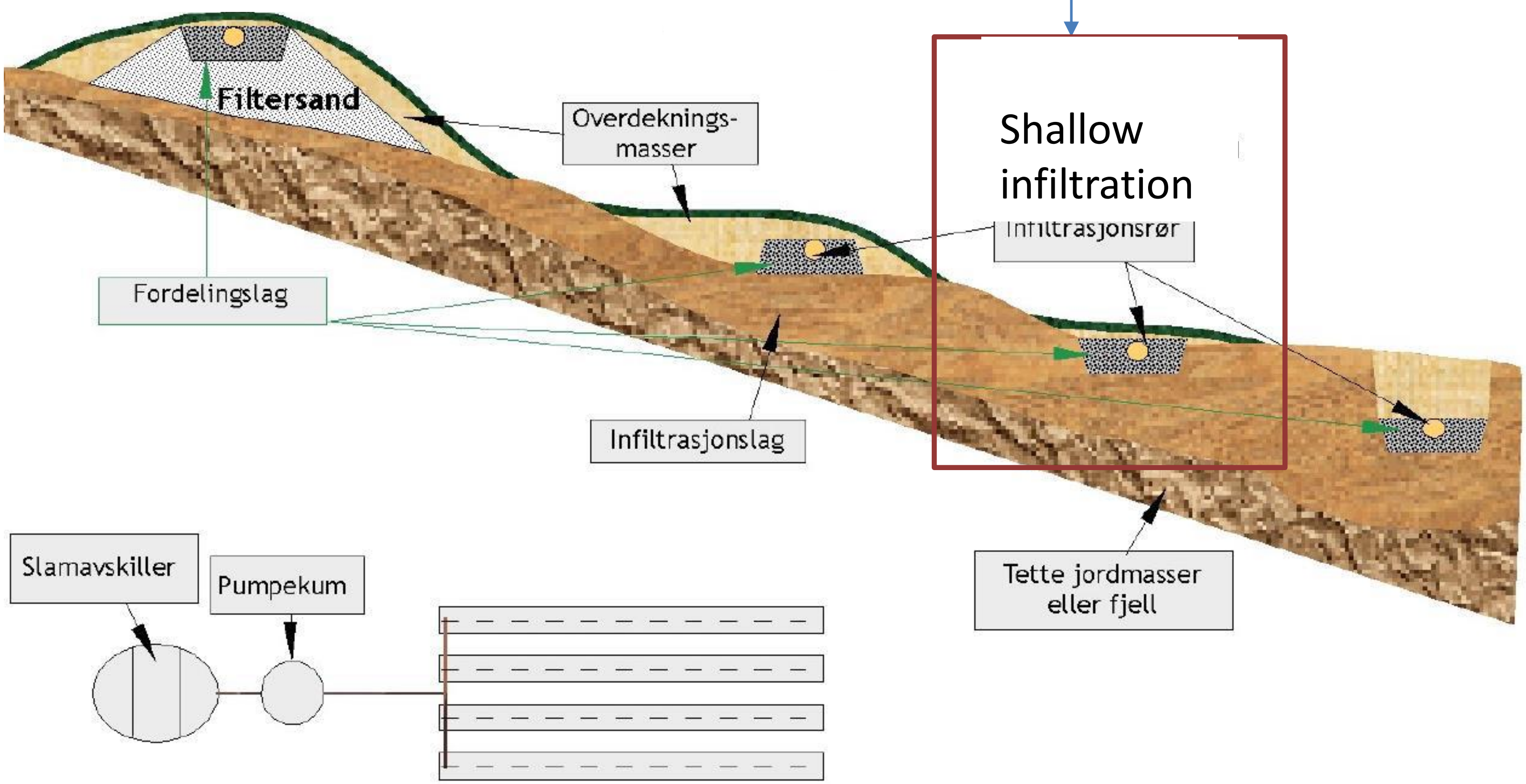
Design configurations

Surface filtration (0-20 cm depth); established wherethe soil has limited thickness.



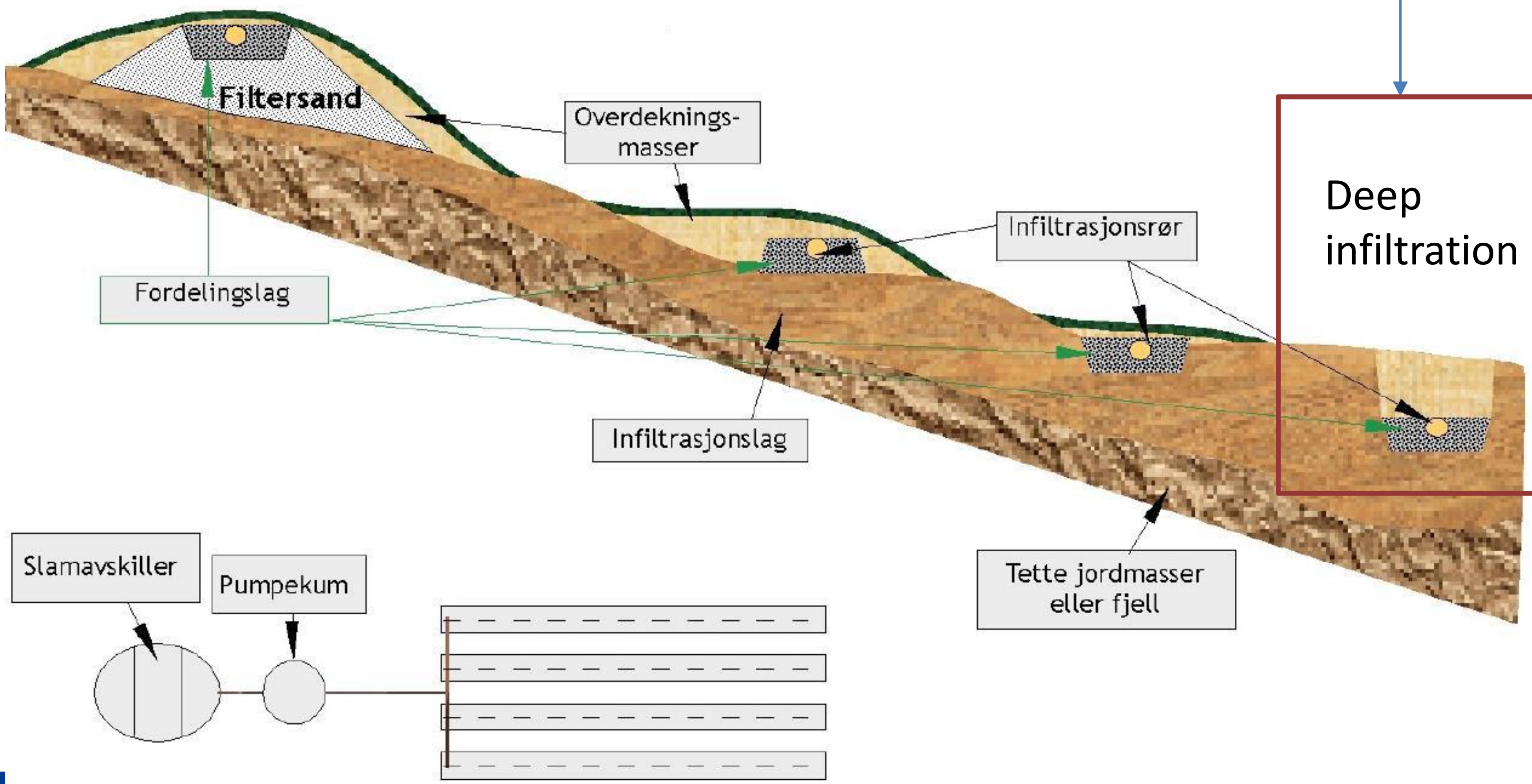
Design configuration

Shallow filter (20-60 cm depth); established where the soil has a certain thickness, but this is somewhat limited.



Design configuration

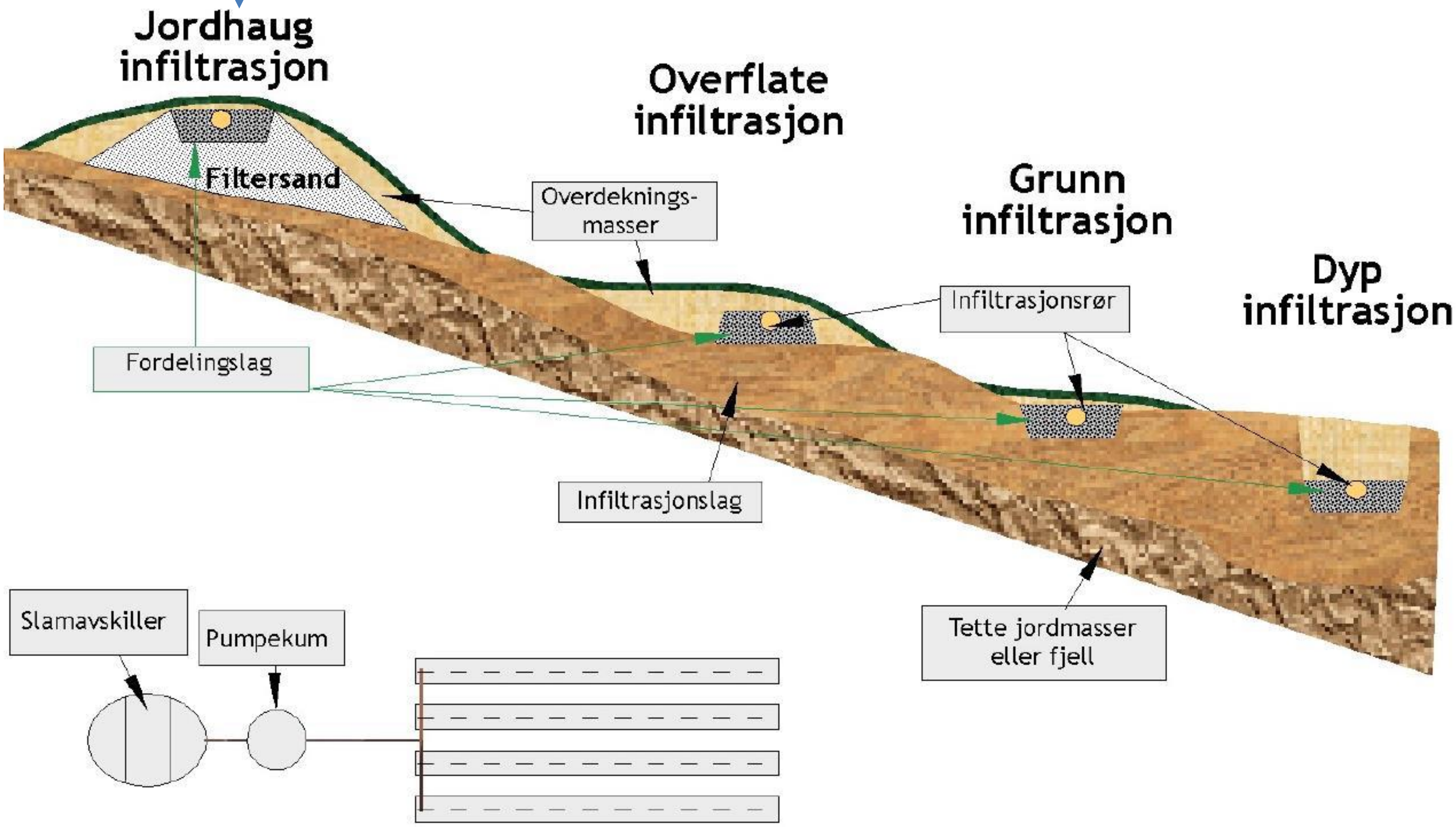
Deep filter (> 60 cm depth); established wherethe loose masses have great thickness.



Deep infiltration

Design configuration

Etableres med tilkjørt sandfang der jordmassene har svært begrenset mektighet

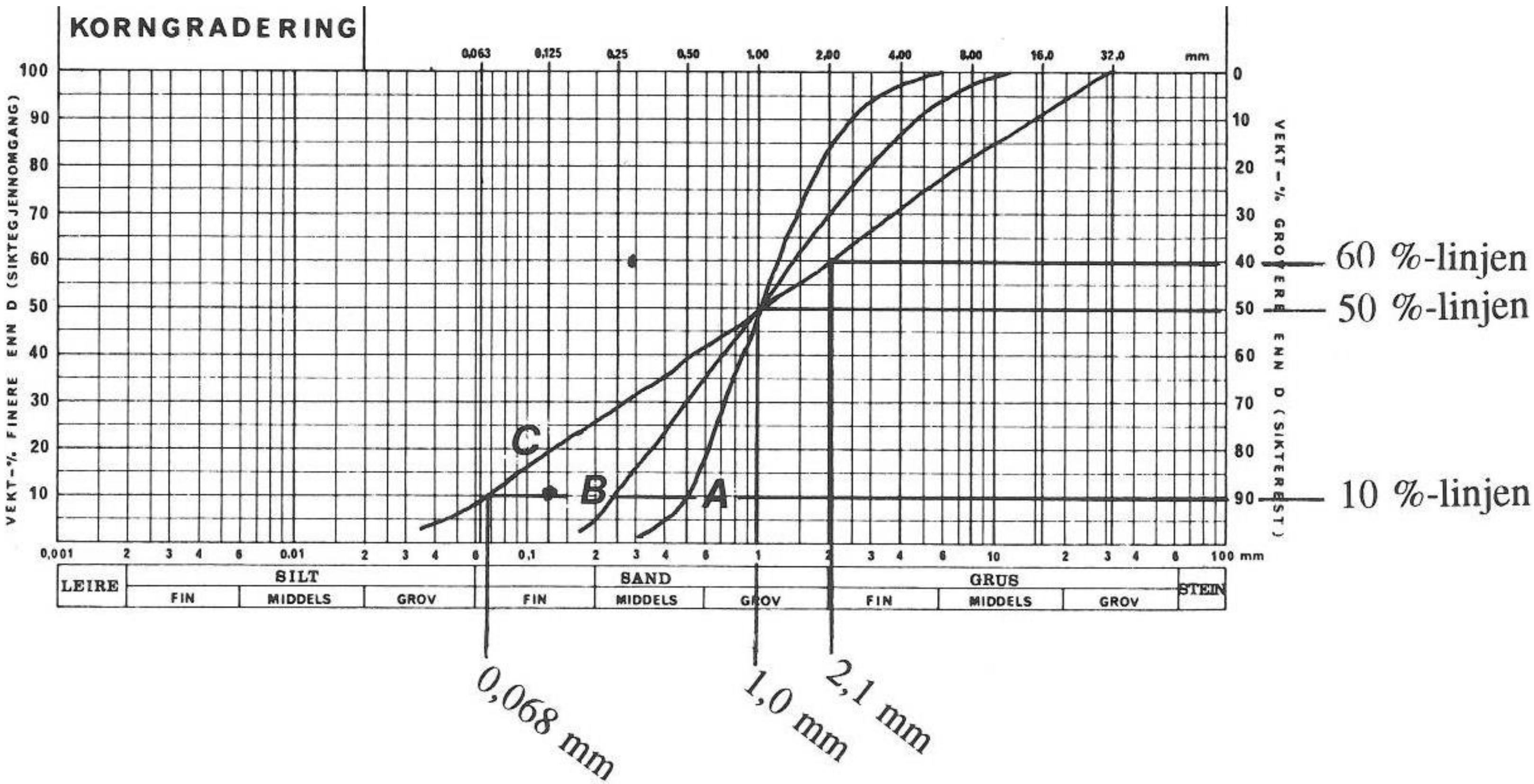


Soil Infiltration capacity

- Infiltration capacity is the amount of wastewater (e.g. effluent from septic tank) that can be infiltrated for a given soil material

- Infiltration capacity is determined from the soil *grain size distribution* and *hydraulic conductivity (water permeability)*.

Soil Infiltration capacity



Eksempel, kurve C: d_{10} = 0,068 mm

d_{50} = Md = 1,0 mm

d_{60} = 2,1 mm

So = d_{60}/d_{10} = 2,1/0,068 = 30,9

Soil Infiltration Capacity

- Sortering (S_O) describes the variation in the soil grain size distribution.

- Well sorted soil has low grain size variation.

- Determined as follows:

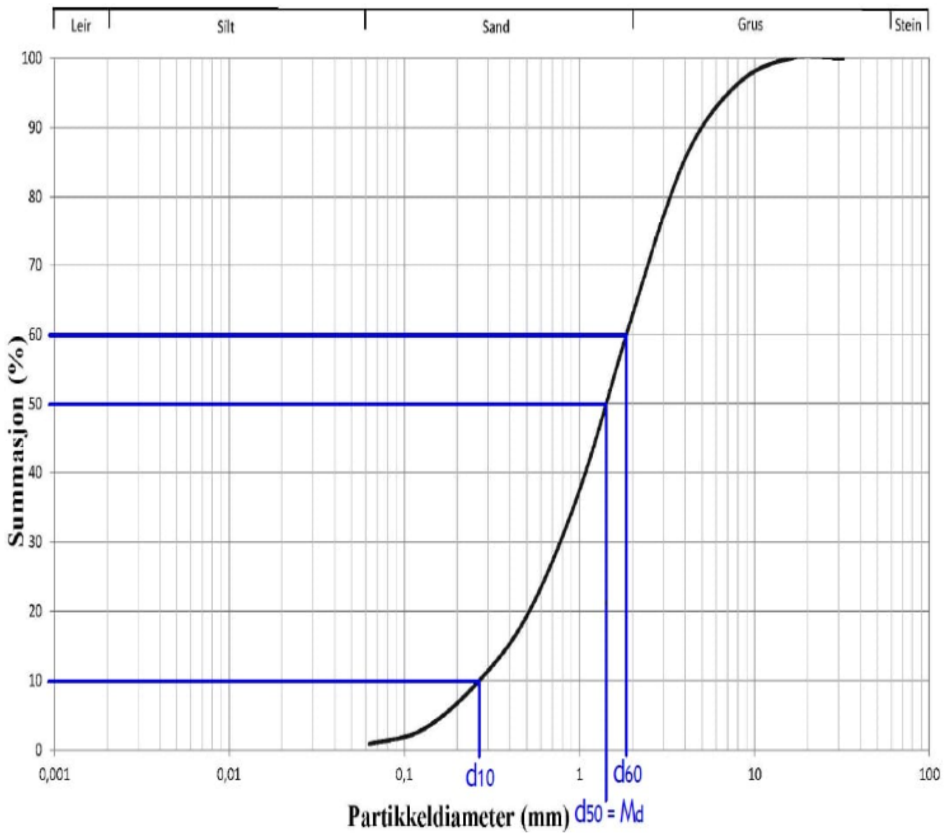
$$S_O = d_{60}/d_{10}.$$

d10 = grain size at the intersection of the 10% line and the grain distribution curve.

d60 = grain size at the intersection of the 60% line and the grain distribution curve.

.

- The mean grain size (Md = d_{50}) is the grain size of the intersection between the 50% line and the grain distribution curve



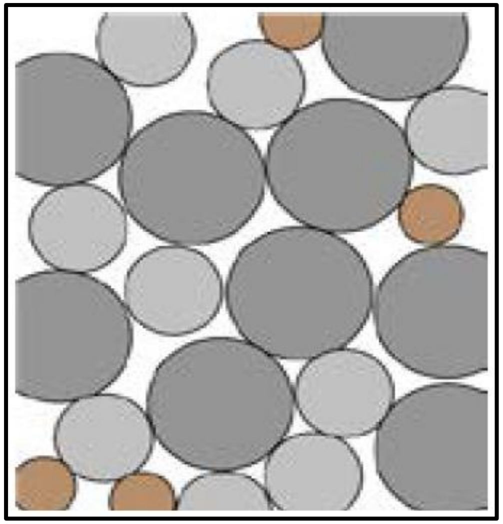
Soil infiltration capacity – Sorting

The value of (d_{60}/d_{10}) is low when the soil has good sorting.

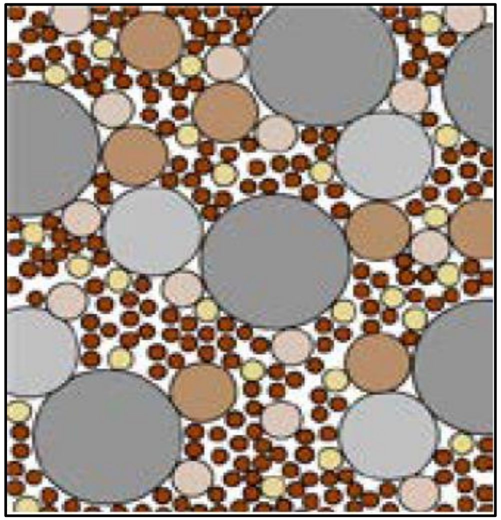
Well sorted soil: $d_{60}/d_{10} < 6$

Poorly sorted soil: d_{60}/d_{10} : 6 – 30

Unsorted soil: $d_{60}/d_{10} > 30$



Well sorted

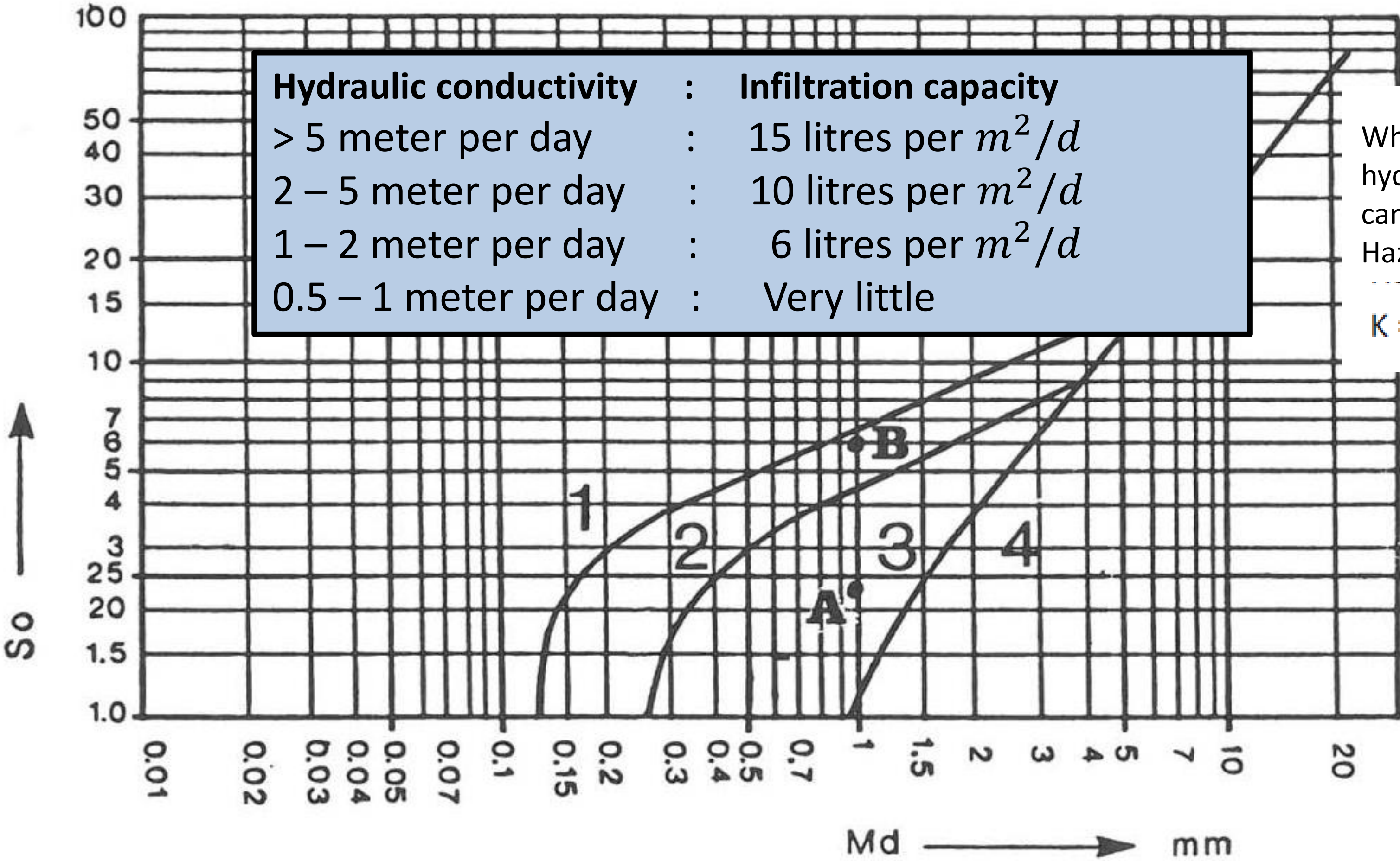


Poorly sorted

Infiltration Diagram

- The infiltration diagram is used to dimension the infiltration filter
- The grain size distribution curve is used to determine the location of the soil in the infiltration diagram.

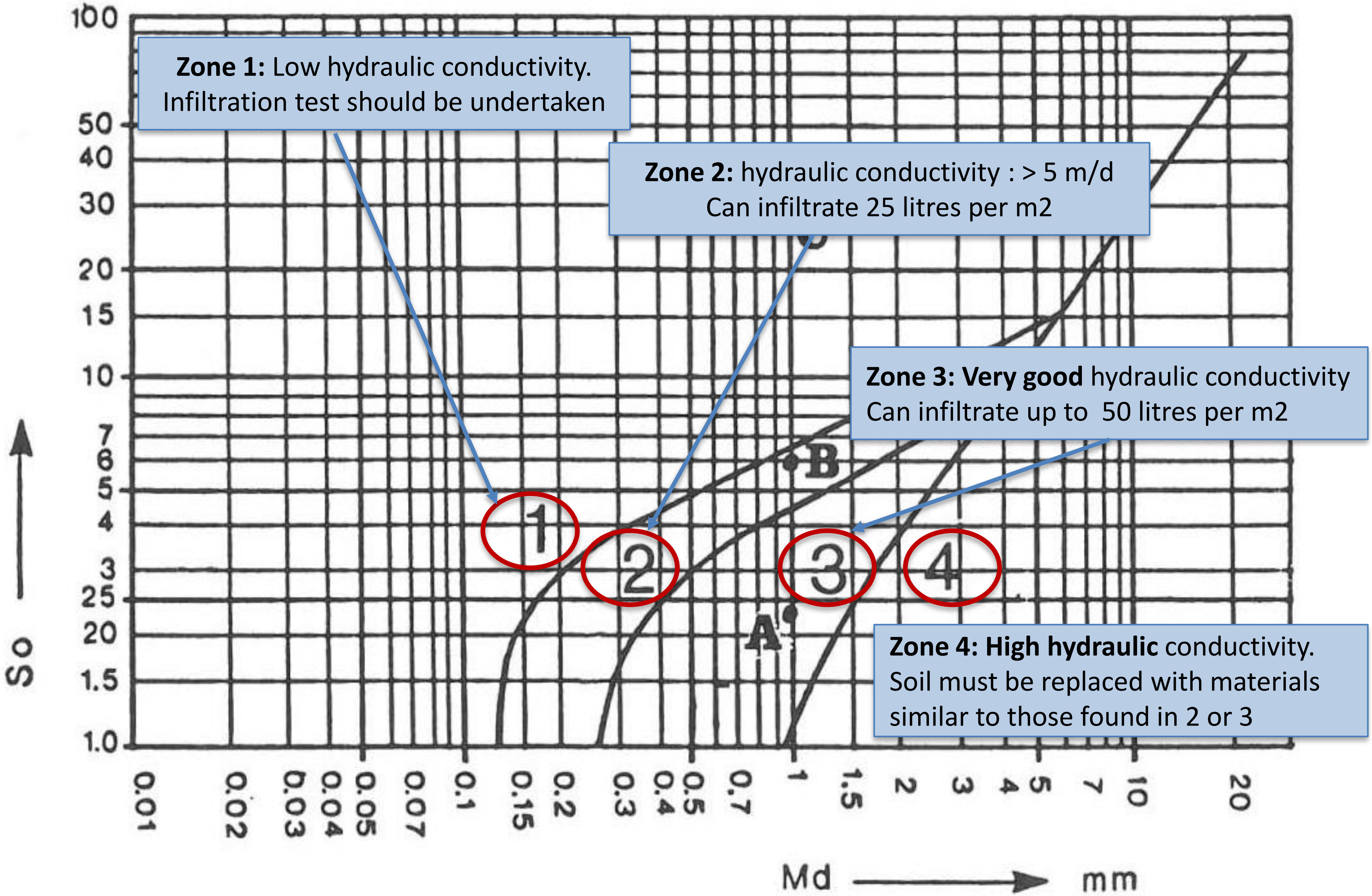
Hydraulic conductivity	:	Infiltration capacity
> 5 meter per day	:	15 litres per m^2/d
2 – 5 meter per day	:	10 litres per m^2/d
1 – 2 meter per day	:	6 litres per m^2/d
0.5 – 1 meter per day	:	Very little



When So < 5, the hydraulic conductivity can be calculated using Hazens formula

$K = (d_{10})^2 \times 1000$

Infiltration Diagram



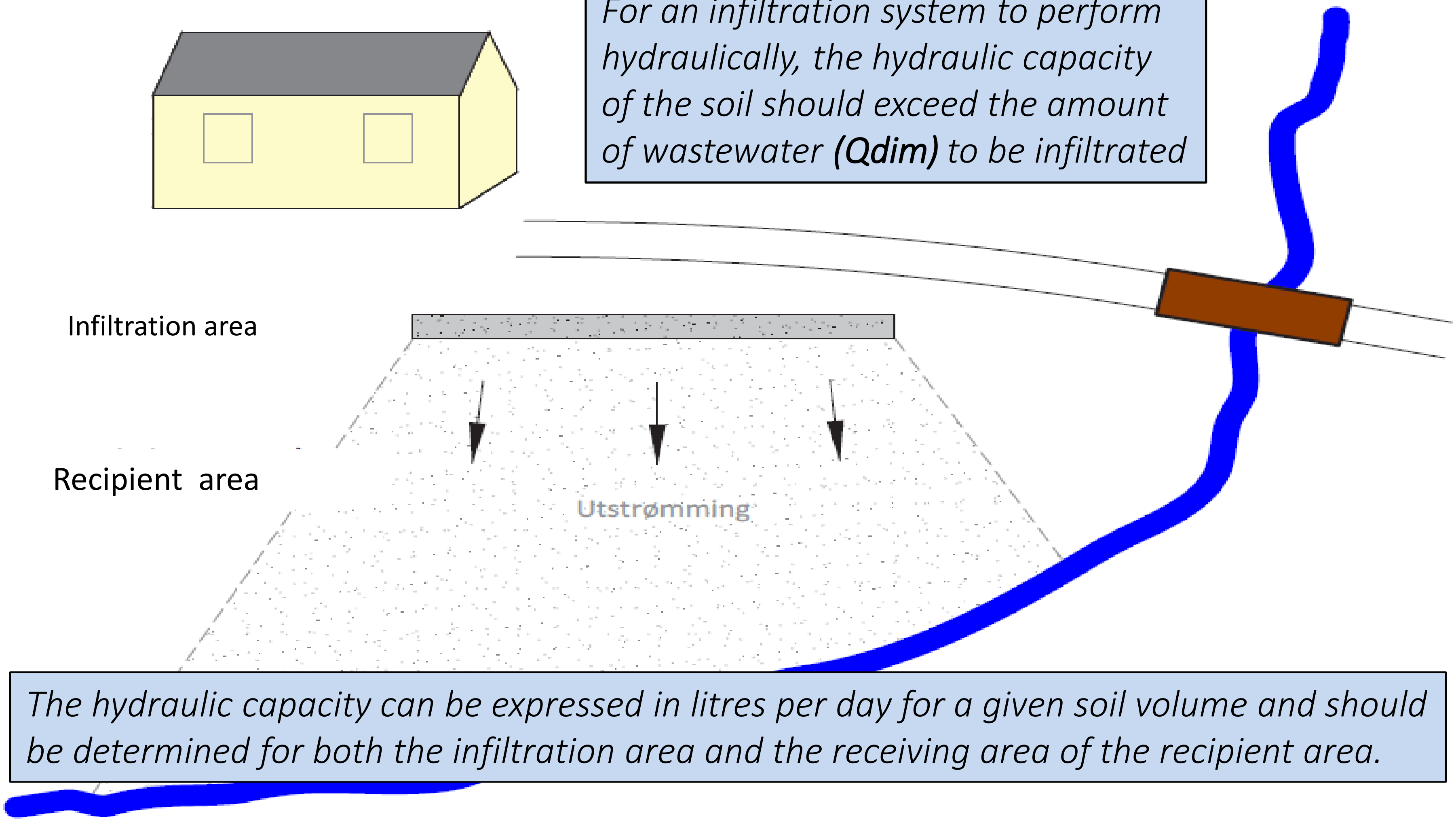
Infiltration Test – soil hydraulic conductivity

- En infiltrasjonstest måler jordas vannledningsevne med rent vann.
- Vannledningsevnen måles ved å registrere vannets synkehastighet i en prøvegrop.
- Testen utføres med et infiltrometer.
- Et infiltrometer kan bestå av en målesylinder, stativ og svamp

Determination of soil hydraulic capacity

Hydraulic capacity describes the ***soil's ability to transport infiltrated wastewater***.

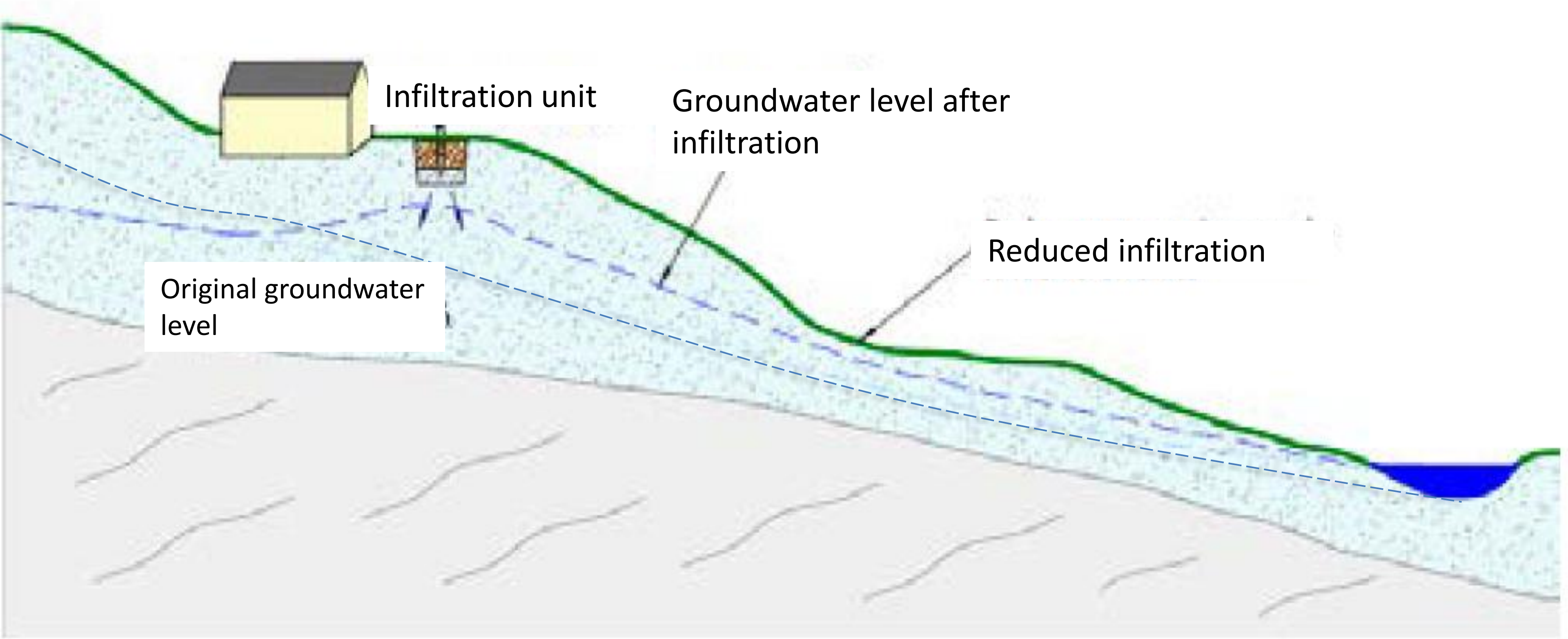
*For an infiltration system to perform hydraulically, the hydraulic capacity of the soil should exceed the amount of wastewater **(Qdim)** to be infiltrated*



The hydraulic capacity can be expressed in litres per day for a given soil volume and should be determined for both the infiltration area and the receiving area of the recipient area.

Hydraulic Capacity – groundwater

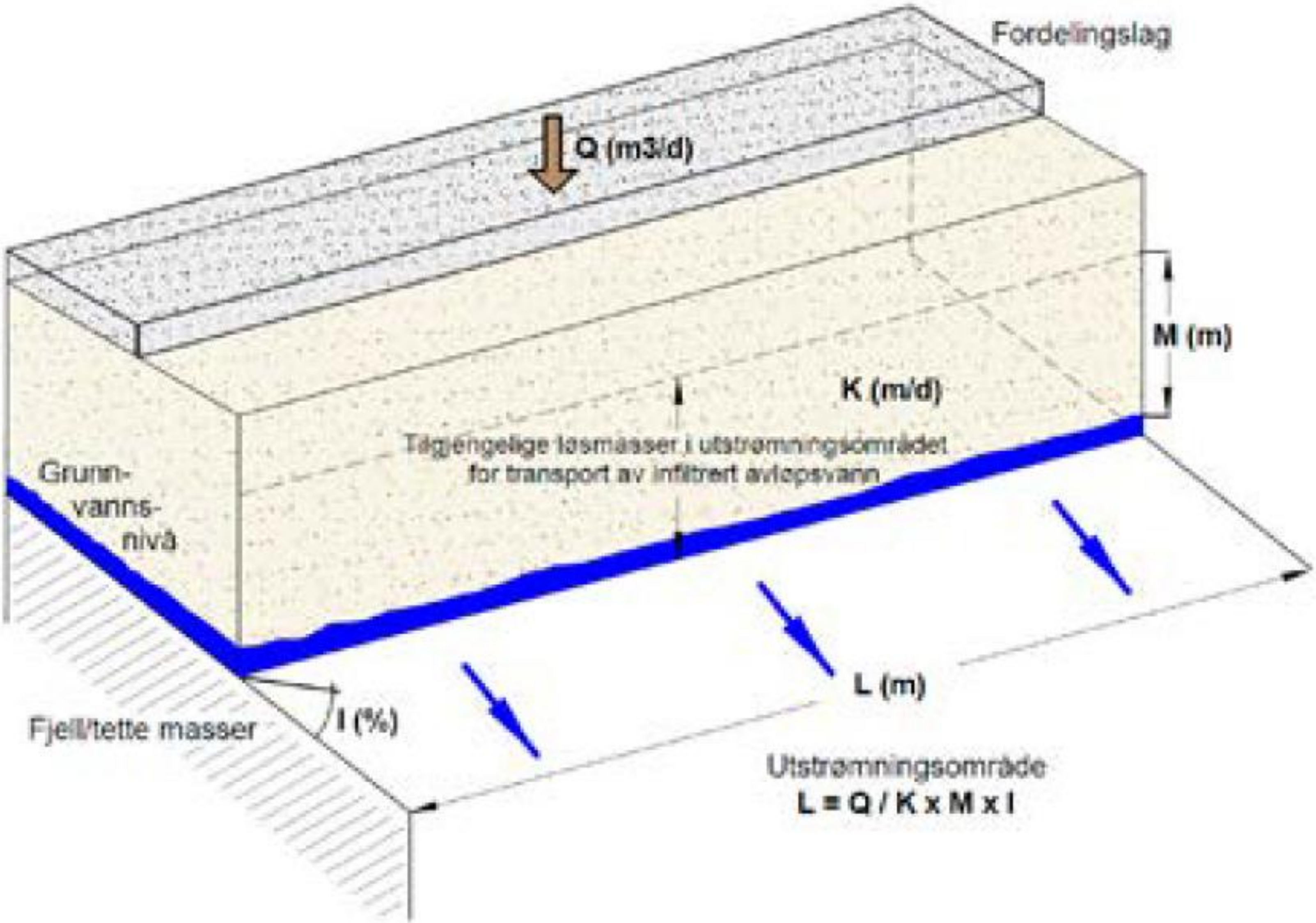
If the hydraulic capacity is exceeded, the groundwater level will rise, and the consequences will be that the wastewater is pushed up or runs out onto the terrain surface before it is sufficiently purified.



Key design considerations – hydraulic capacity

- The hydraulic capacity of the soil is critical for how the infiltration filter should be designed.
  - General recommendation is to establish long and narrow filters rather than short and wide ones.
- The capacity under the infiltration filters should be so large that during operation, the following are achieved under different variations of groundwater level:
  - a minimum of 0.5 m between the filter surface and the highest groundwater level (for systems1-25 pe).
  - a minimum of 1.0 m between the filter surface and the highest groundwater level (for systems > 25 – 50 pe)
- The hydraulic capacity of the recipient area must be so large that the water remains below the surface of the terrain to ensure that the use of the area is not impeded.

Hydraulic Capacity



Aplanviak

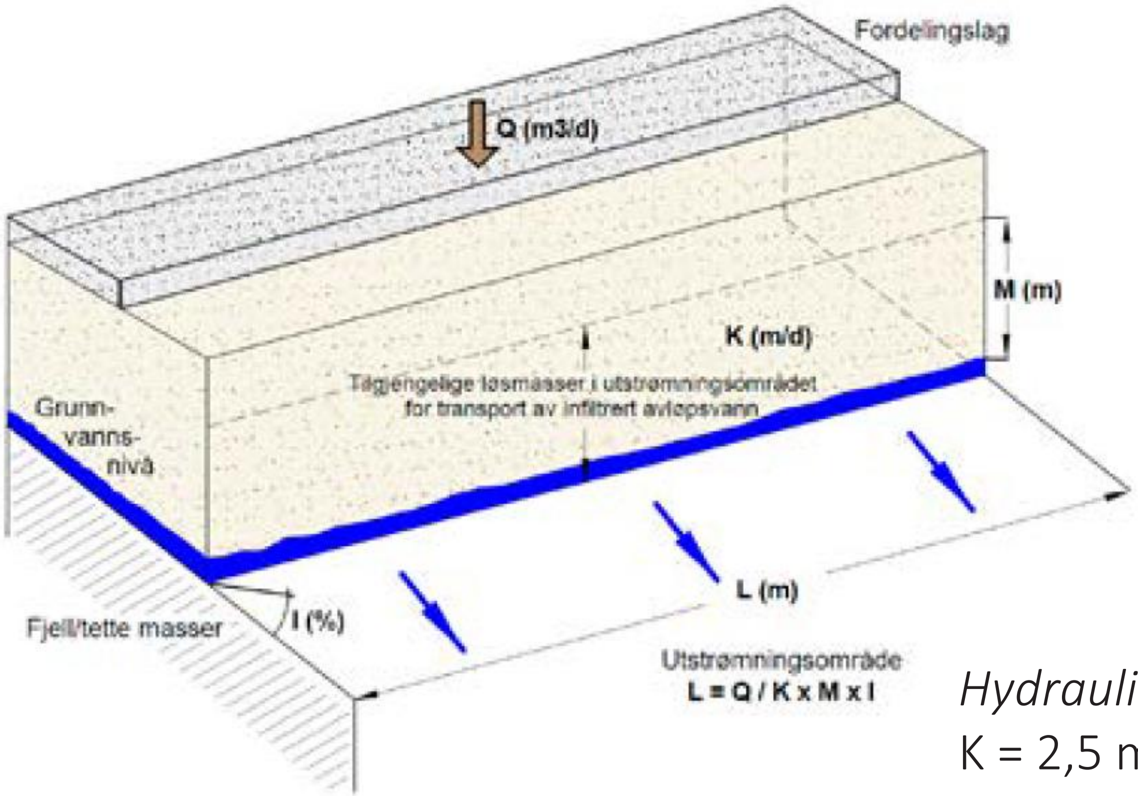
Hydraulic capacity

The hydraulic capacity is determined as follows:

$$Q = K \times M \times L \times I$$

Q = soil hydraulic capacity (m3 per day)
K = soil hydraulic conductivity (m per day)
M = thickness of the soil mass for the transport of infiltrated wastewater (m)
L = width of the area to be used to transport the infiltrated wastewater (m)
I = Groundwater gradient

Hydraulic capacity



Hydraulic capacity estimation:

K = 2,5 meter per day

M = 0,30 meter

L = 25 meter

I = h/l = 3m/50m = 0,06

Q = (2,5 x 0,30 x 25 x 0,06) m3 per day

Q = 1.125 m3 per day

Flow velocity in the soil – implications for contamination

Water flow velocity in the soil is often of great importance when contamination of recipients from infiltrated water is to be assessed.

Wastewater flow rate in the soil is dependent on the following:

- Soil hydraulic conductivity (determined onsite)
- Groundwater gradient (slope of the groundsurface) (determined onsite)
- Effective porosity of the soil (drenerbart porevolum)

Jordart	Effektiv porøsitet (n_e)
Grov silt	0,06
Fin sand	0,10
Middels sand	0,12
Grov grus	0,14
Fin grus	0,15

Flow velocity & travel distances – Implication for contamination

Darcy´s Law:

$$q = K*i$$

q = Darcy’s flow velocity (m/d)
K = hydraulic conductivity (m/d)
i = groundwater gradient

Average flow velocity in soil:

$$v = q/ne$$

v = average flow velocity through soil pores (m/d)
ne = effective porosity

Example: Flow velocity and distance

Measured hydraulic conductivity: **K = 5 m/d**

Groundwater gradient/terrain gradient:
i = 8% = 0.08

q = K*i = 5 m/d * 0.08 => q = 0.4 m/d

Assuming sand (effective porosity = 0.12)

v = q/ne = 0.4 / 0,12 => v = 3,3 m/d

How far does the water travel in the soil pores for 60 days?

3.3 m/d * 60 d = 198 meter

Determination of infiltration area

The following formular can be used to determine the infiltration area for the filter unit:

$$A = Q/k$$

Where

A = Filtration unit surface area
Q = Amount of wastewater to be infiltrated in liter (m3)
k = Soil infiltration capacity for the effluent from septic tank in liter per m^2 /day.

Eksempel filter area for 2 houses in Class 2 sand:

Q_{dim} = 10 pe * 200 l/d = 2000 L/d'

Areal loading= 25 liter/ m^2 /day (from infiltration diagram)

A = 2000 l/d / 25 l/m^2/d

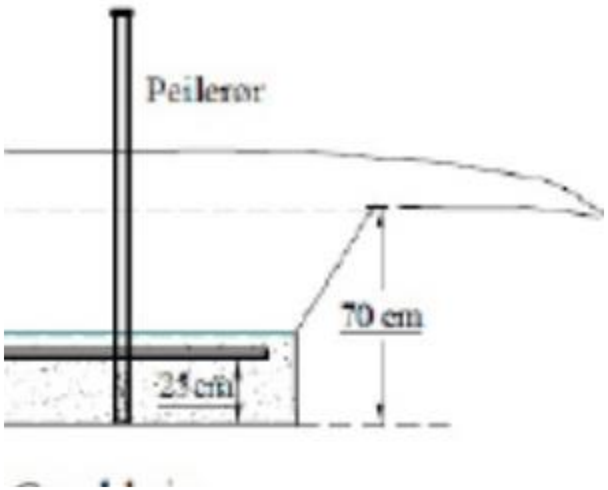
Filter area = 80 m^2.

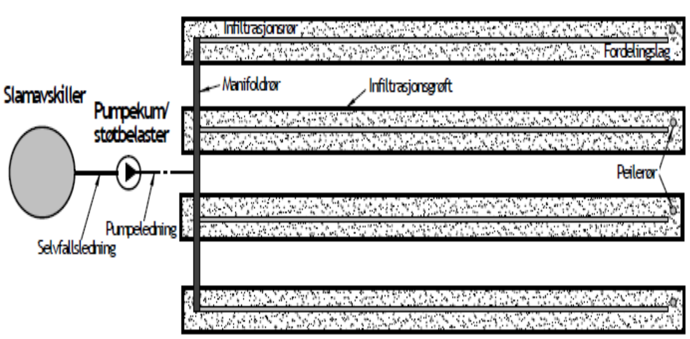
Design Guidelines

- Water level monitoring pipes should be installed in infiltration units to ensure that any water accumulation in the distribution layer can be registered.

- Gap between infiltration pipes in trenches
  - Same trench (basen) : 80-100 cm

  - Single trenches: 80 – 100 cm;
  - Gap between trenches should be a min. 1 meter

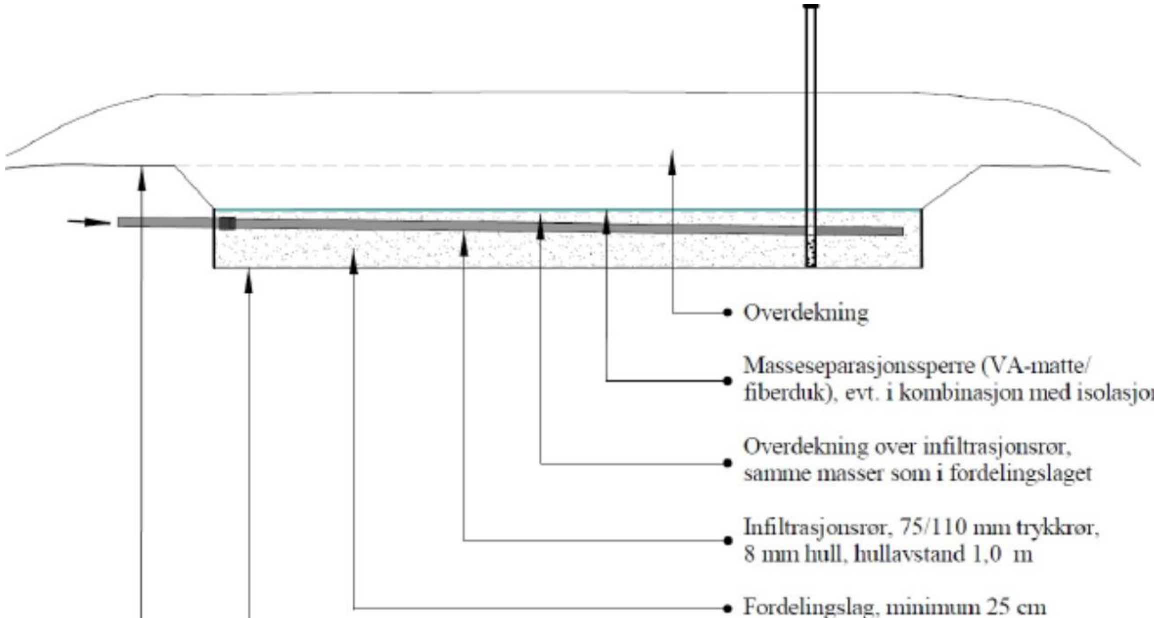




Figur 5. Infiltrasjonsfilterets beliggenhet i jordprofilet bestemmes av avstand til grunnvann, tette masser eller fjell.

Design guidelines- wastewater distribution

- **Gravity distribution**
  - A single pipe via a distribution chamber
- **Pressurised distribution**
  - Two or more infiltration trenches
  - Use a manifold pipe of 110 mm for optimal distribution
  - The infiltration pipe comprise plastic pipe (32 mm dia.)



Figur

lvfall.

Figur 4. Pumpekum med vippestyrt pumpe og alarm for høyt vannivå. Foto: NIBIO.

Jeremy: **Kanskje det er meningen at den skal være tre meter bred. I stedet for dyp!**

Erfaringsvis blir mange infiltrasjons-grøfter lagt for langt ned i bakken, ned i tette løsmasser eller ned i grunnvannet.

Frostfritt dyp har tidligere vært en norm.

Vi anbefaler ofte grunne løsninger og frostisolering.

Expected Treatment Efficiency

Parameter	% Treatment	Effluent concentration
Biochemical oxygen demand (BOD5)	95 %	11.4 mg/L
Phosphorus	> 95 %	0.45 mg/L
Nitrogen	50 %	34 mg/L
Thermotolerant Coliform Bacteria	99.9 %	< 1 per 100 mL

Infiltration in local soil

Advantanges

- It is an operationally efficient treatment solution that requires little supervision.
- Infiltration systems have very good treatment efficiency .
- Low investment and operating costs for an infiltration system compared to other types of systems.
  - Soil mound systems are somewhat more expensive to establish, but still compete with other types of treatment solutions in terms of total costs.

Disadvantages

- A certain available area of suitable loose soils with sufficient thickness is required.
- The plants have diffuse discharge of treated wastewater downstream of the infiltration area.
  - Placement of the plants in relation to drinking water sources and surface water is therefore important to avoid pollution.

Thank you