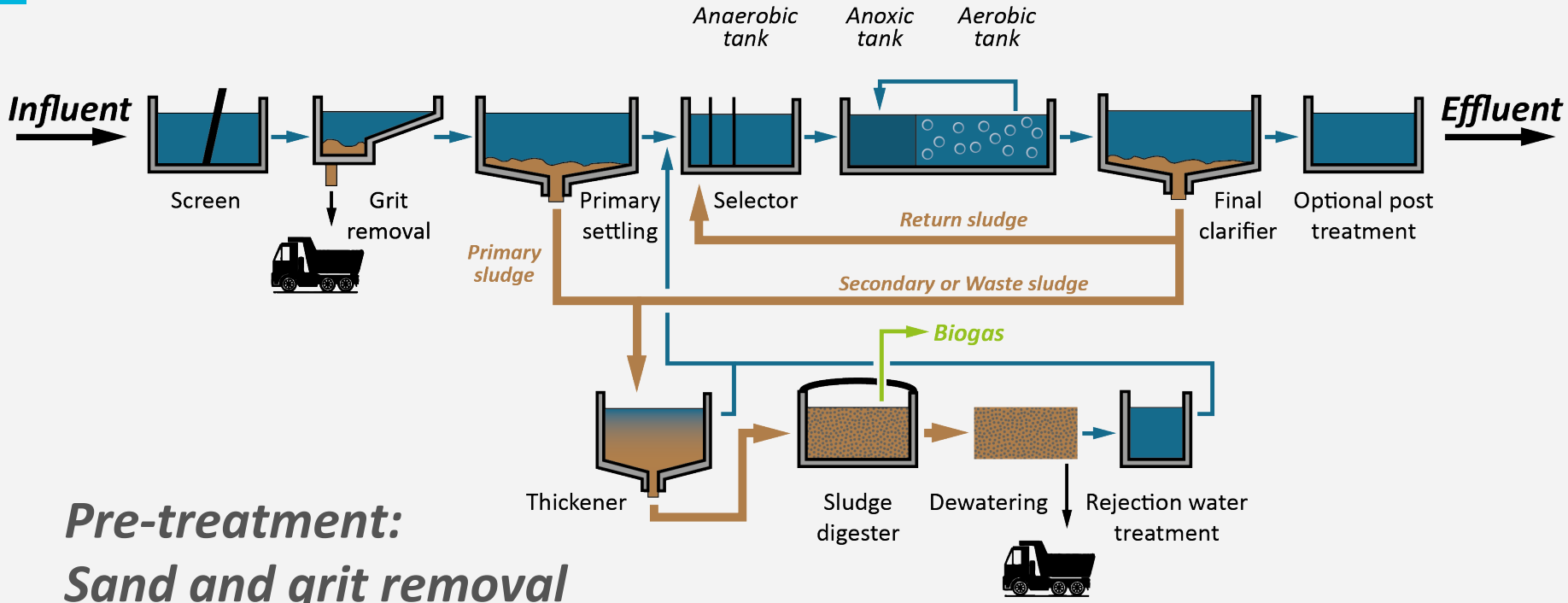
Grit removal design

CTB3365x Introduction to water treatment

Prof.dr.ir. Jules B. van Lier

Basic WWTP process units



Pre-treatment:

Sand and grit removal

Discrete settling: principles

Settling of discrete, non-flocculating particles:

- classical sedimentation laws by Newton and Stokes

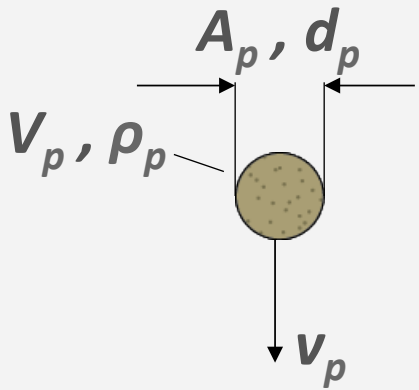
Newton:

$$F_d = \frac{C_d A_p \rho_w v_p^2}{2}$$

C_d = drag coefficient [-]

$$F_G = (\rho_p - \rho_w) g V_p$$

Surface area, Diameter:



Discrete settling: terminal particle velocity

Newton's law (spherical particles):

$$F_G = F_d \qquad A = \frac{\pi {d_p}^2}{4} \qquad V = \frac{4}{3}\pi\left(\frac{d_p}{2}\right)^3$$

$$F_G = (\rho_p - \rho_w) g V_p$$

$$F_d = \frac{C_d A_p \rho_w v_p^2}{2}$$

}

$$v_p = \sqrt{\frac{4g}{3C_d}\left(\frac{\rho_p - \rho_w}{\rho_w}\right) d_p}$$

terminal velocity of particle [m/s]

Discrete settling: factors affecting v_p

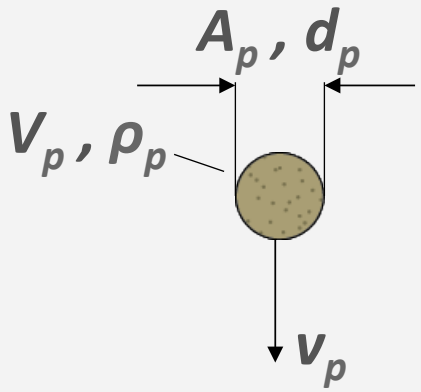
Nonspherical particles:

$$v_p = \sqrt{\frac{4g}{3C_d\varphi}\left(\frac{\rho_p - \rho_w}{\rho_w}\right)d_p}$$

Value C_d depends on flow regime

Sphericity factor φ:

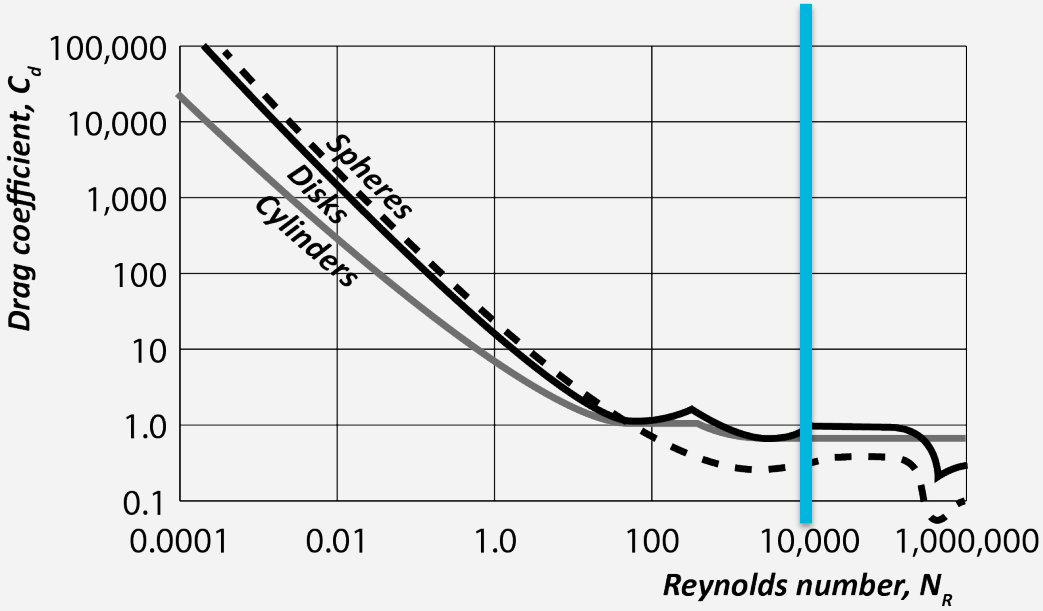
- Spheres: φ = 1.0
- Sand grains: φ = 2.0
- Up to 20+ for fractal flocs



Discrete settling: impact of liquid turbulence

Drag coefficient C_d

$$C_d = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$$



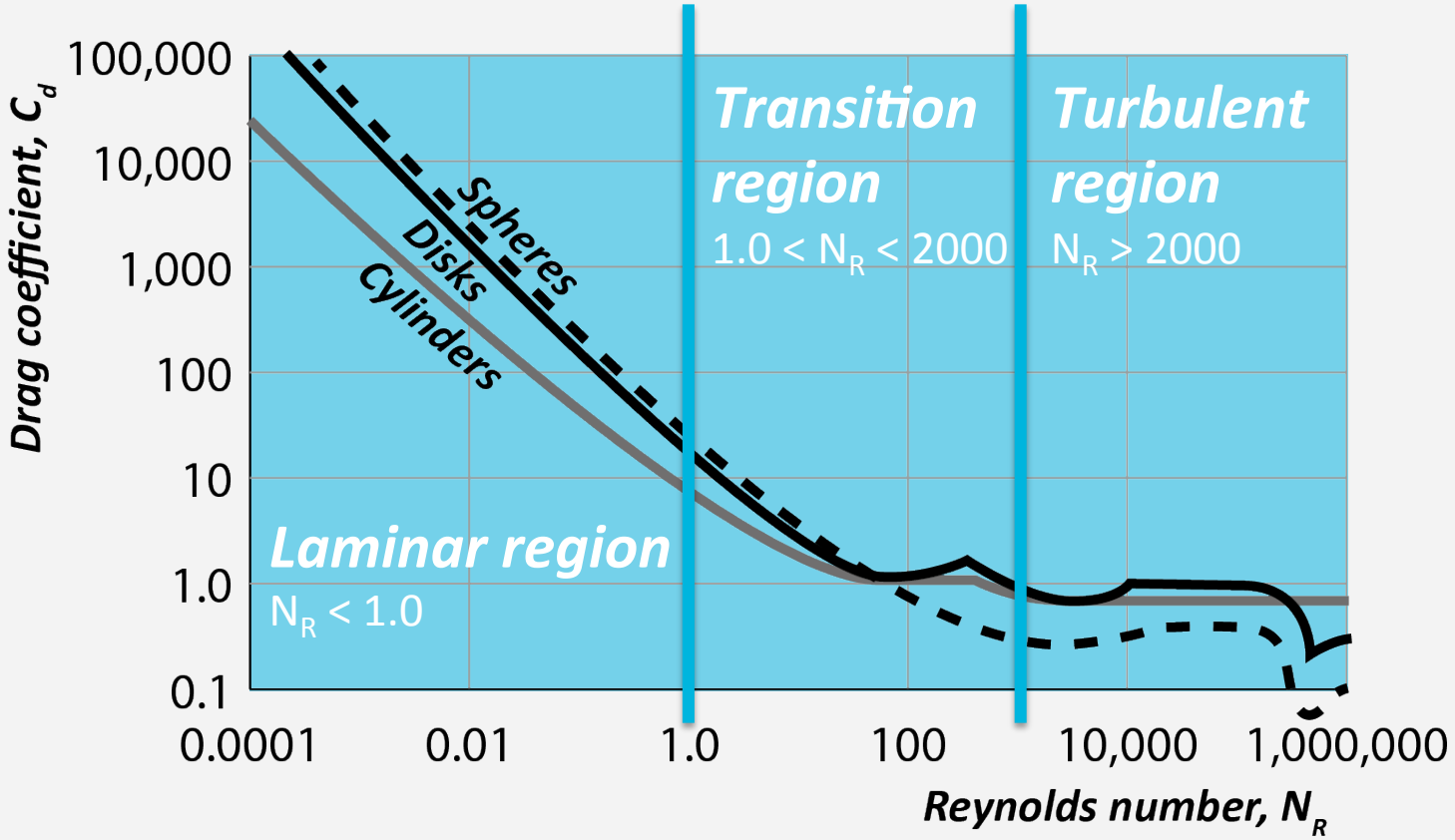
Depends on turbulence

$$N_R = \frac{v_p d_p \rho_w}{\mu} = \frac{v_p d_p}{\nu}$$

μ = dynamic viscosity [Ns/m²]
ν = kinematic viscosity [m²/s]

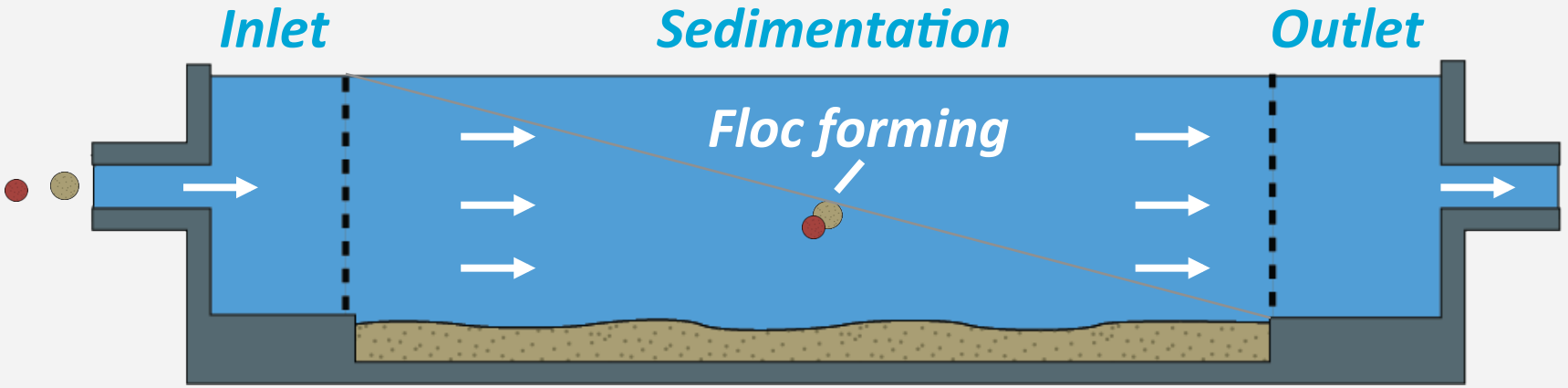
Discrete settling

$$C_d = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$$

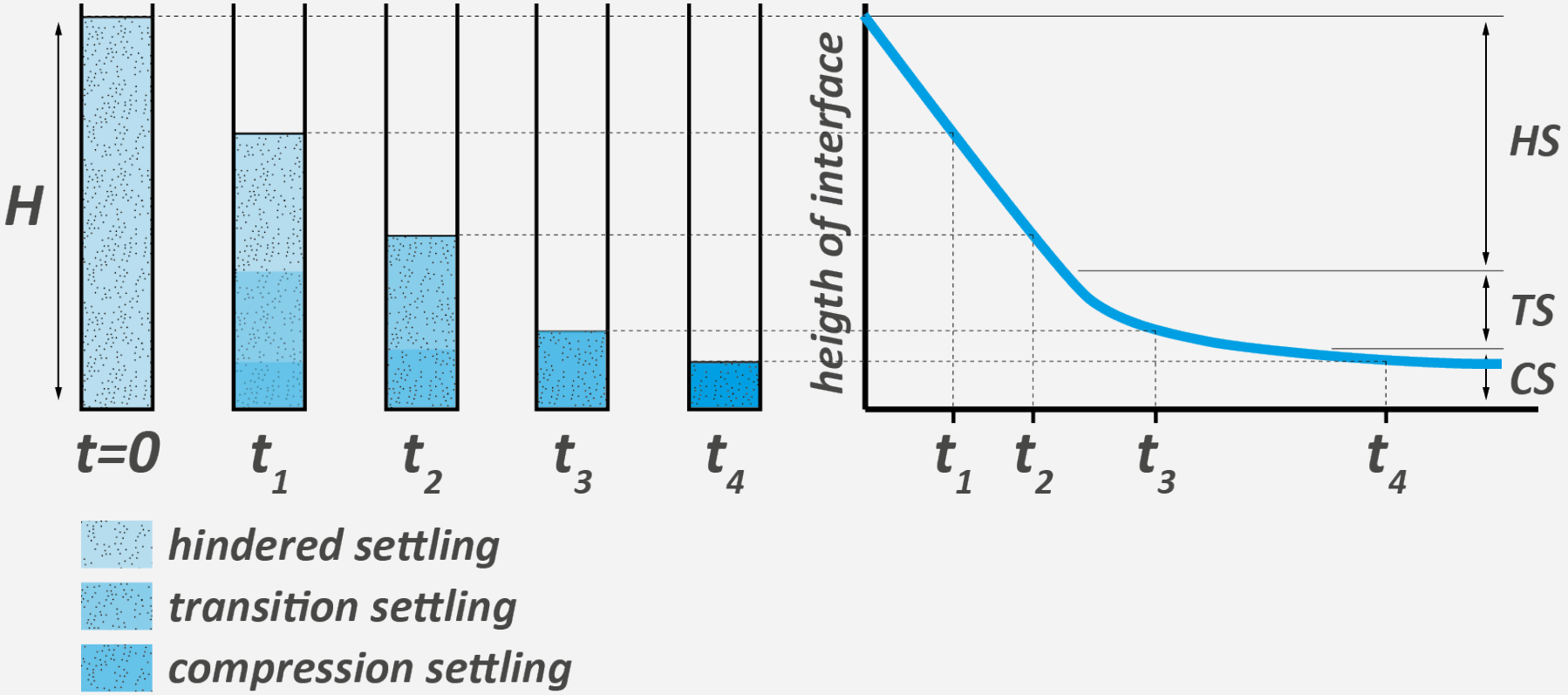


Flocculent settling

- *Flocculation causes increasing settling velocities*
- *Dilute suspension settling*

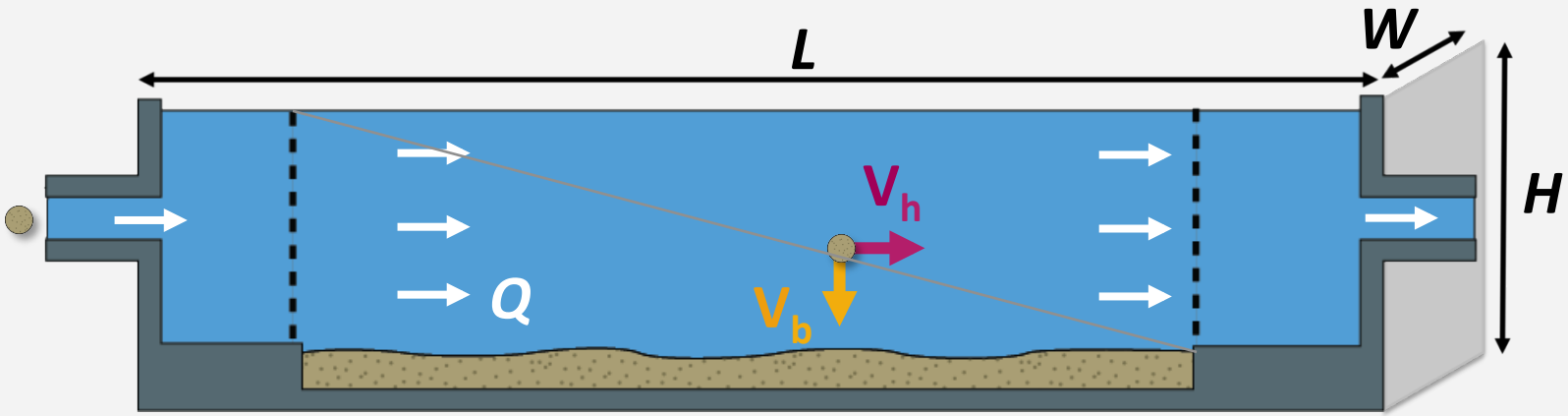


Flocculent settling: hindered settling



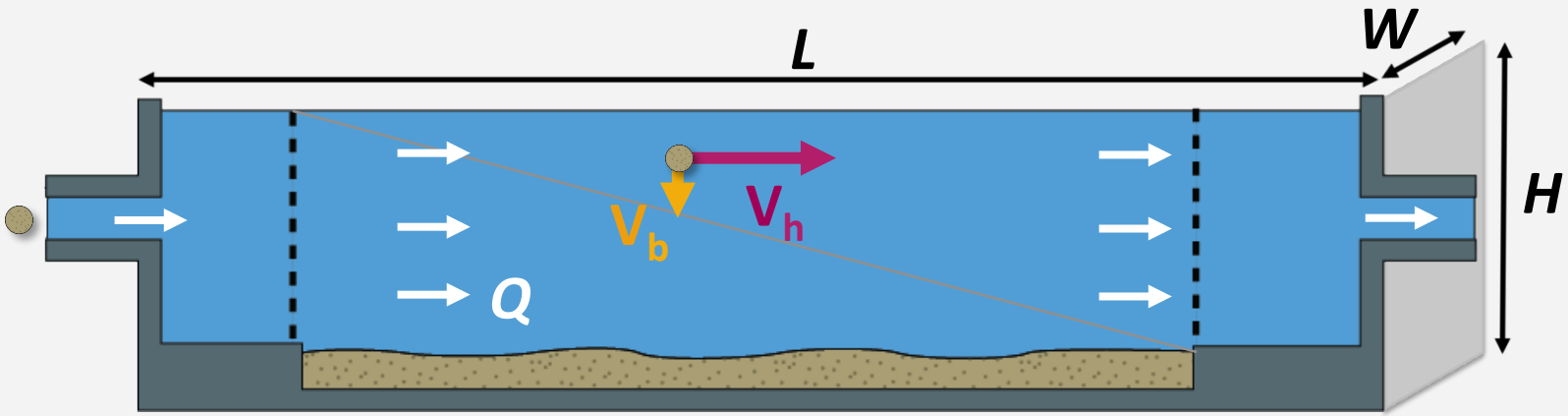
Application in STP: Grit removal

Discrete settling



Application in STP: Grit removal

Discrete settling



Application in STP: Grit removal

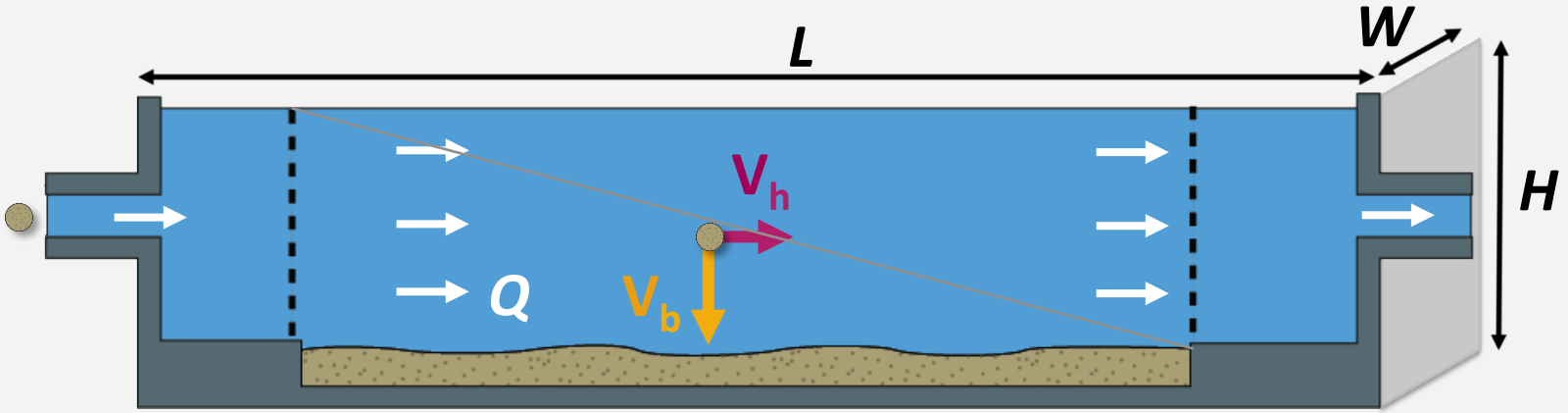
V_{HA} = Hazen velocity

Independent on tank height!

Discrete settling: Hazen's law

- Particle is retained if $t_{horizontal} < t_{vertical}$, or:

$$\frac{V_b}{H} > \frac{V_h}{L} \quad \textit{and} \quad V_h = \frac{Q}{A_v} = \frac{Q}{H \cdot W} \longrightarrow \frac{V_b}{H} > \frac{Q}{H \cdot W \cdot L} \longrightarrow V_b > \frac{Q}{A_h} = V_{HA}$$

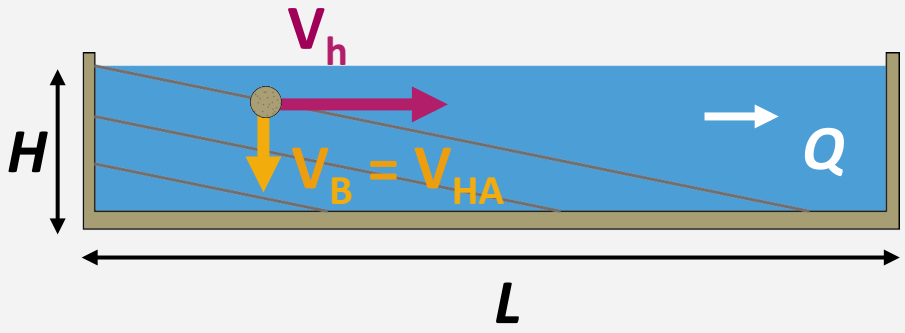


Application in STP: Grit removal

- All particles with settling velocity $v_b < v_{HA}$ will be removed

Feed water distributed over H:

- Also particles with $v_b < v_{HA}$ will be removed, in v_b / v_{HA} ratio



Grit removal

Important design features:

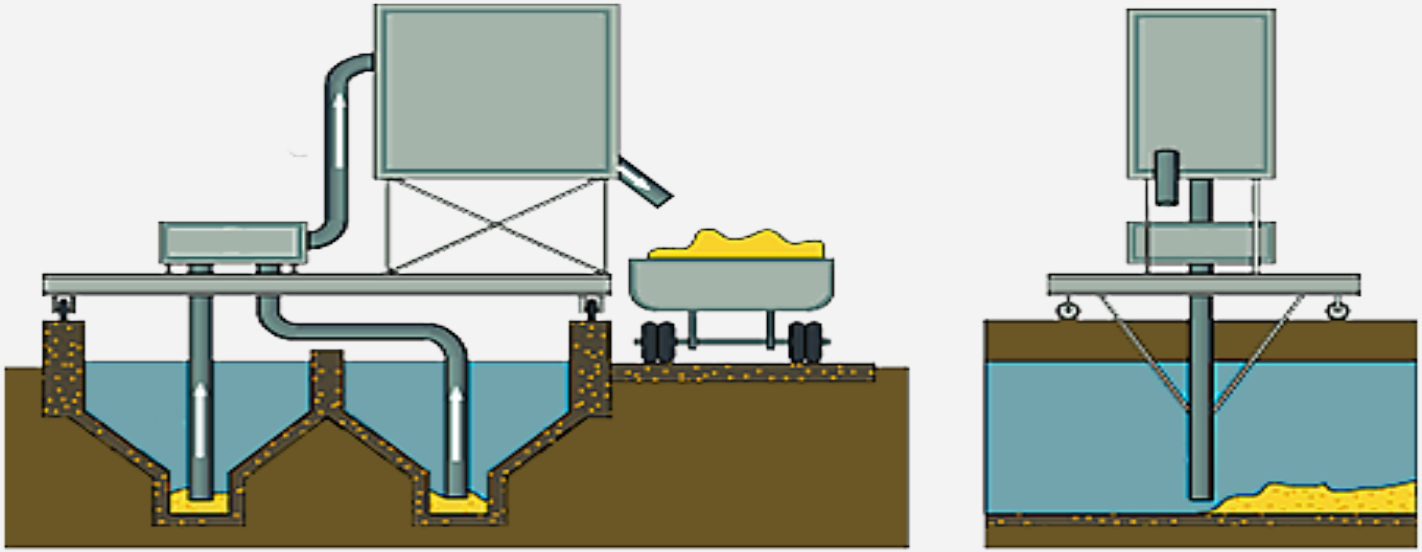
- Sand, surface load: $V_O = V_{HA} = 40 \frac{m^3}{m^2 \cdot h}$ or 0.011 m/s
- V_h = 0.30 m/s = V_S , Critical ‘scouring’ or ‘slip’ velocity

Grit removal

Rectangular grit chamber

- More gutters in parallel
- Long gutter with constant flow rate
- Constant discharge
- Surface loading rate: $V_O = \frac{Q}{A} = 40 \frac{m^3}{m^2 \cdot h}$
- Horizontal velocity V_h , approx. 0.30 m/s
- Length/width ratio: 10:1 – 15:1

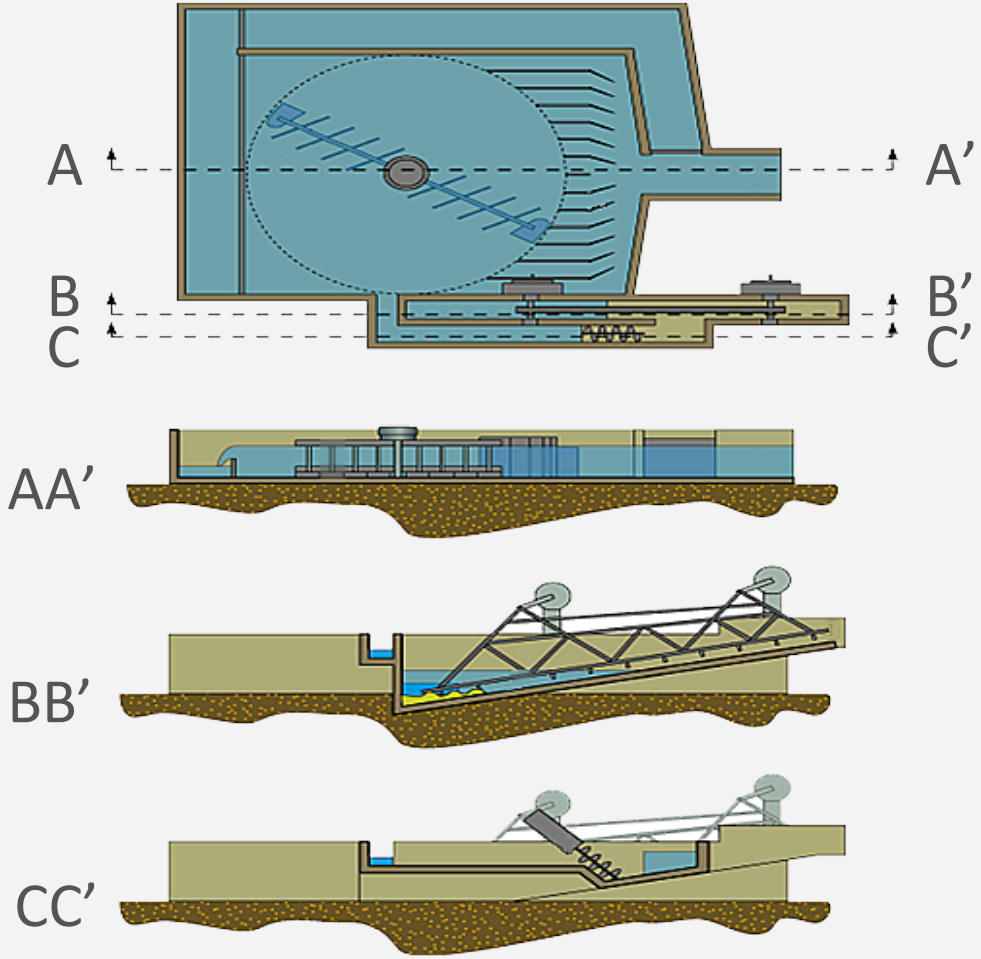
Grit removal: removal of sand with air-lift



Grit removal

Square grit chamber

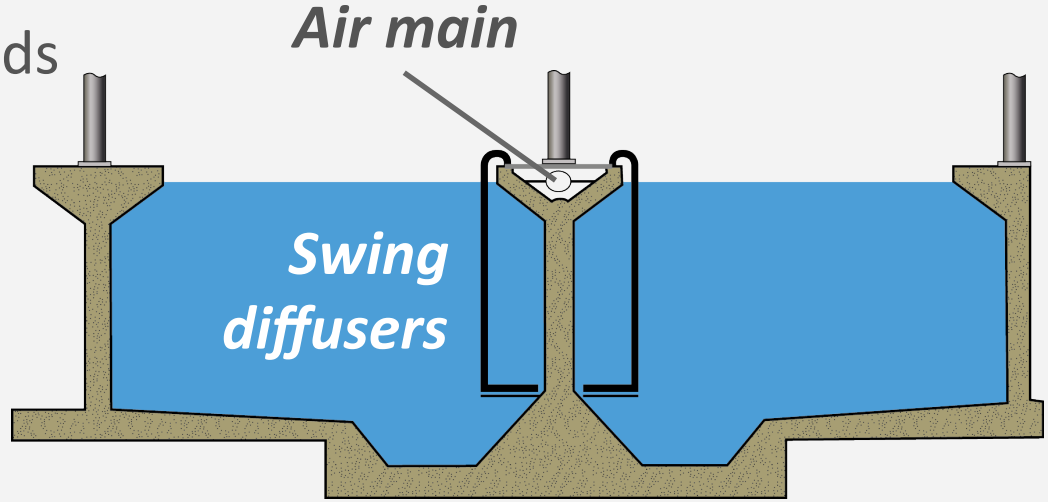
- Water depth 0.8 – 1m
- Square or circular
- $V_{O,\,max} = 30\ \frac{m^3}{m^2 \cdot h}$
- Fluctuating discharge
- External sand washer



Grit removal

Aerated grit chamber

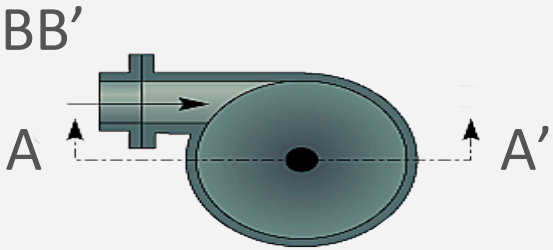
- More turbulent
- Increased V_p of sand particles
- Slurry: both sand and solids
- Ex-situ separation

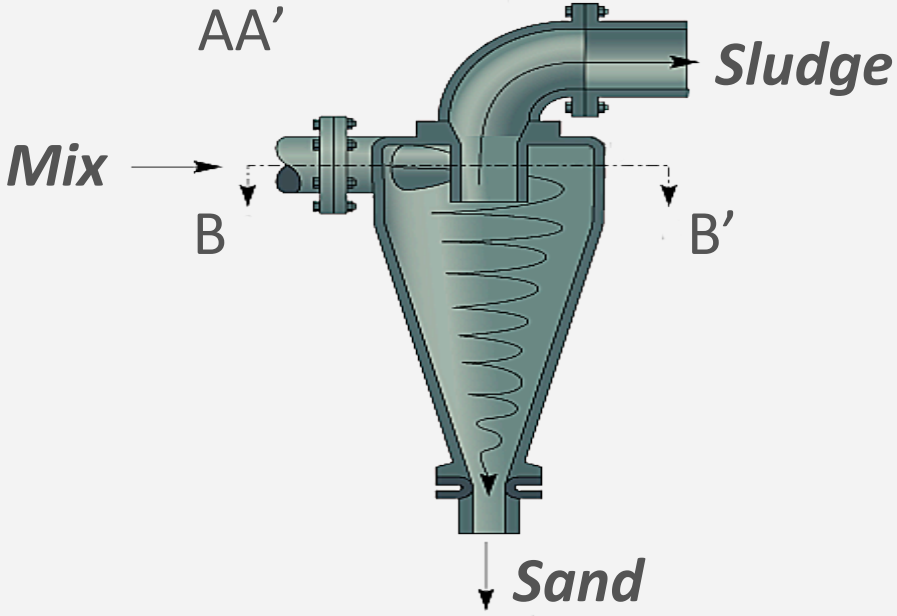


Grit removal: Hydroclone

Slurries:

⟶ sand – solids separation





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