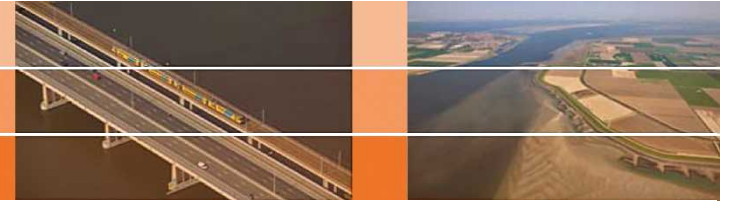




# Introductie piping

Vera van Beek

# Inhoud



- Het pipingproces
- Piping in Nederland
- WBI voor piping
- Model van Sellmeijer
- Nieuwe ontwikkelingen
- Oplossingsrichtingen



# Het piping proces



Photo: Beeldbank Rijkswaterstaat

# Het piping proces

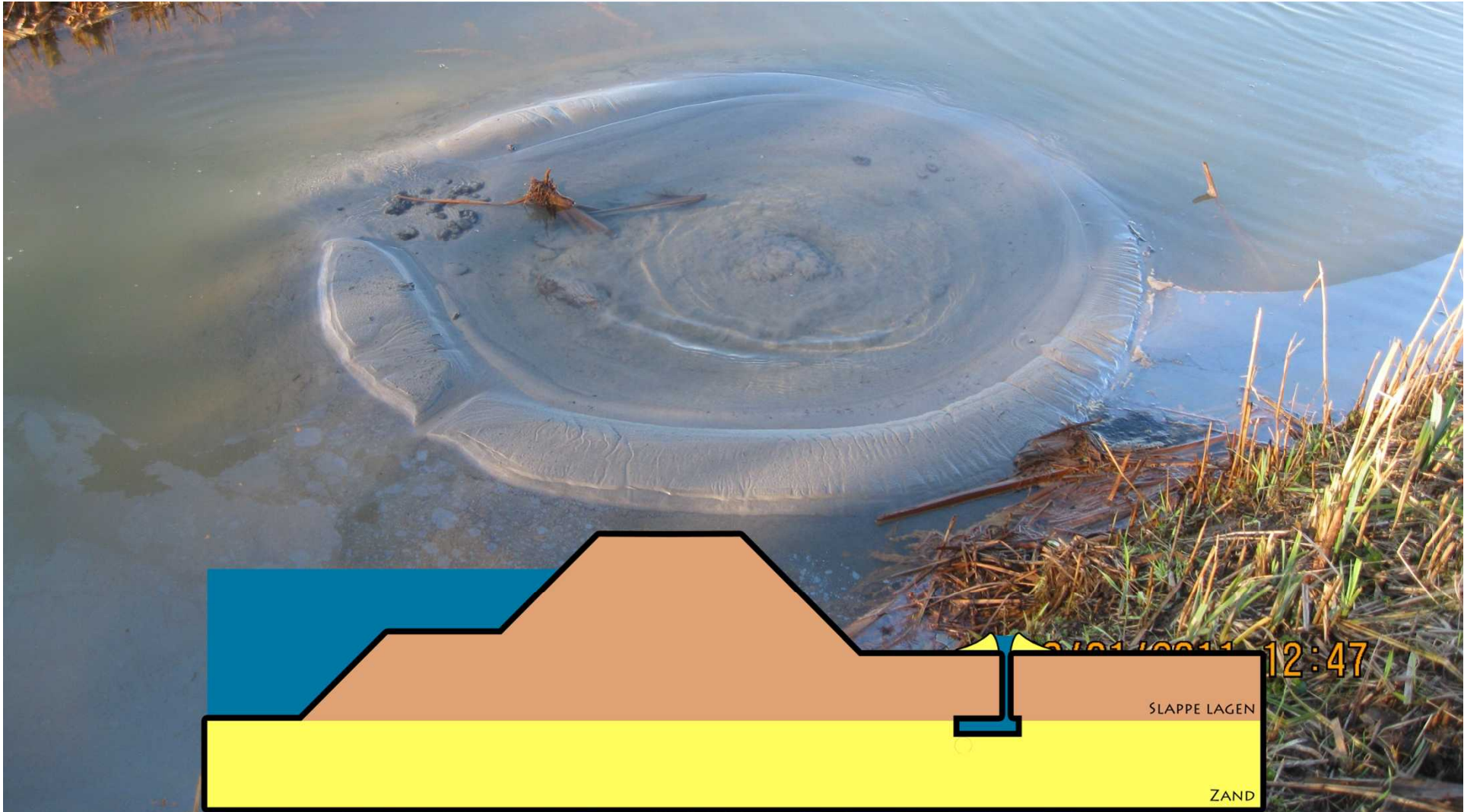
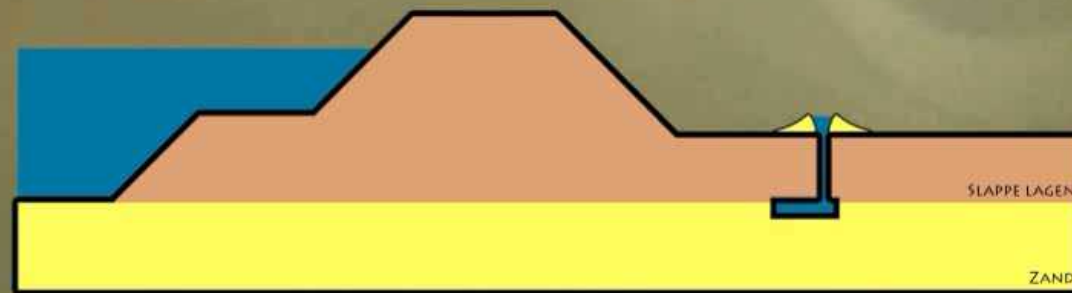


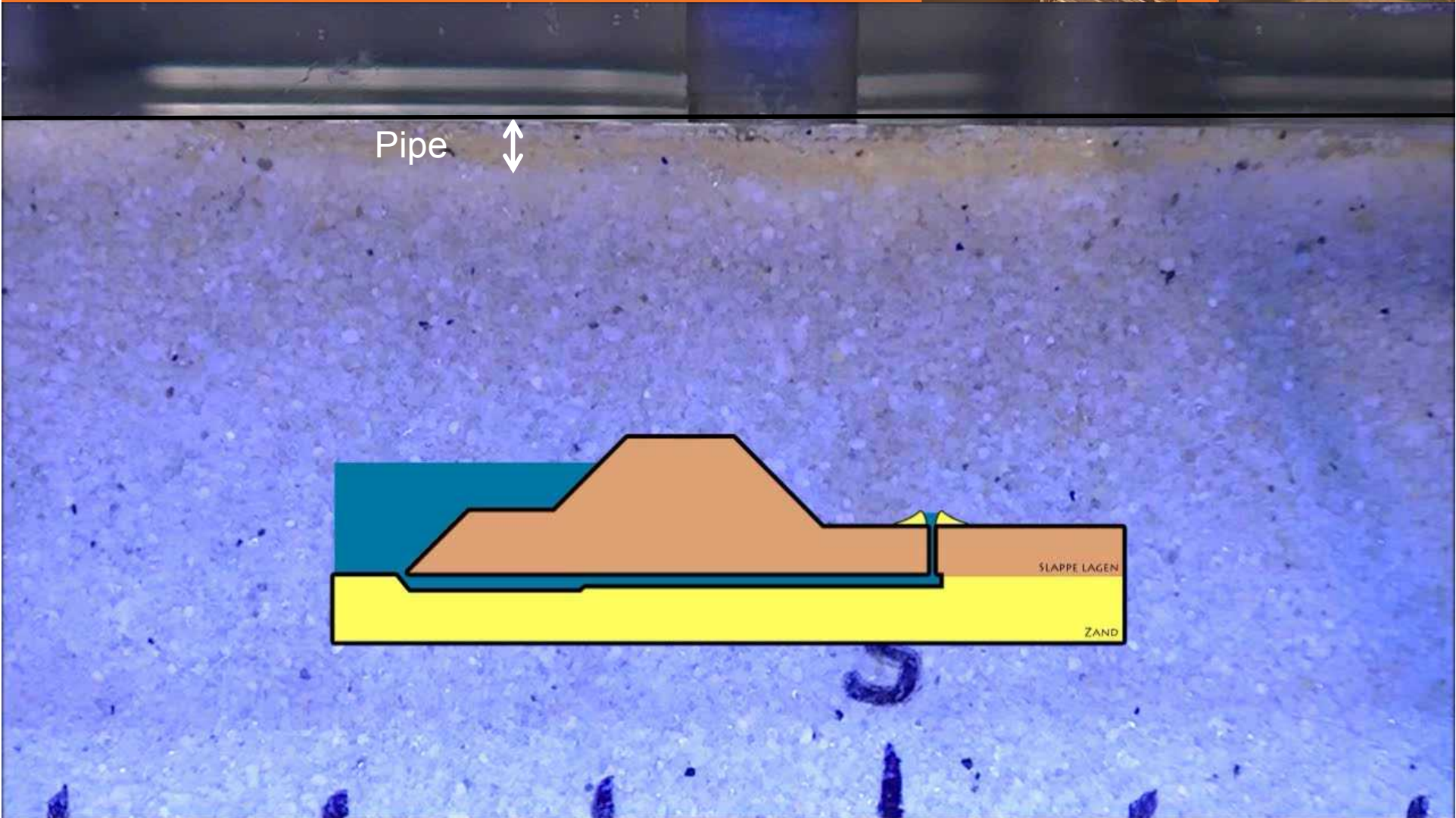
Photo: Beeldbank Rijkswaterstaat

**Deltares**

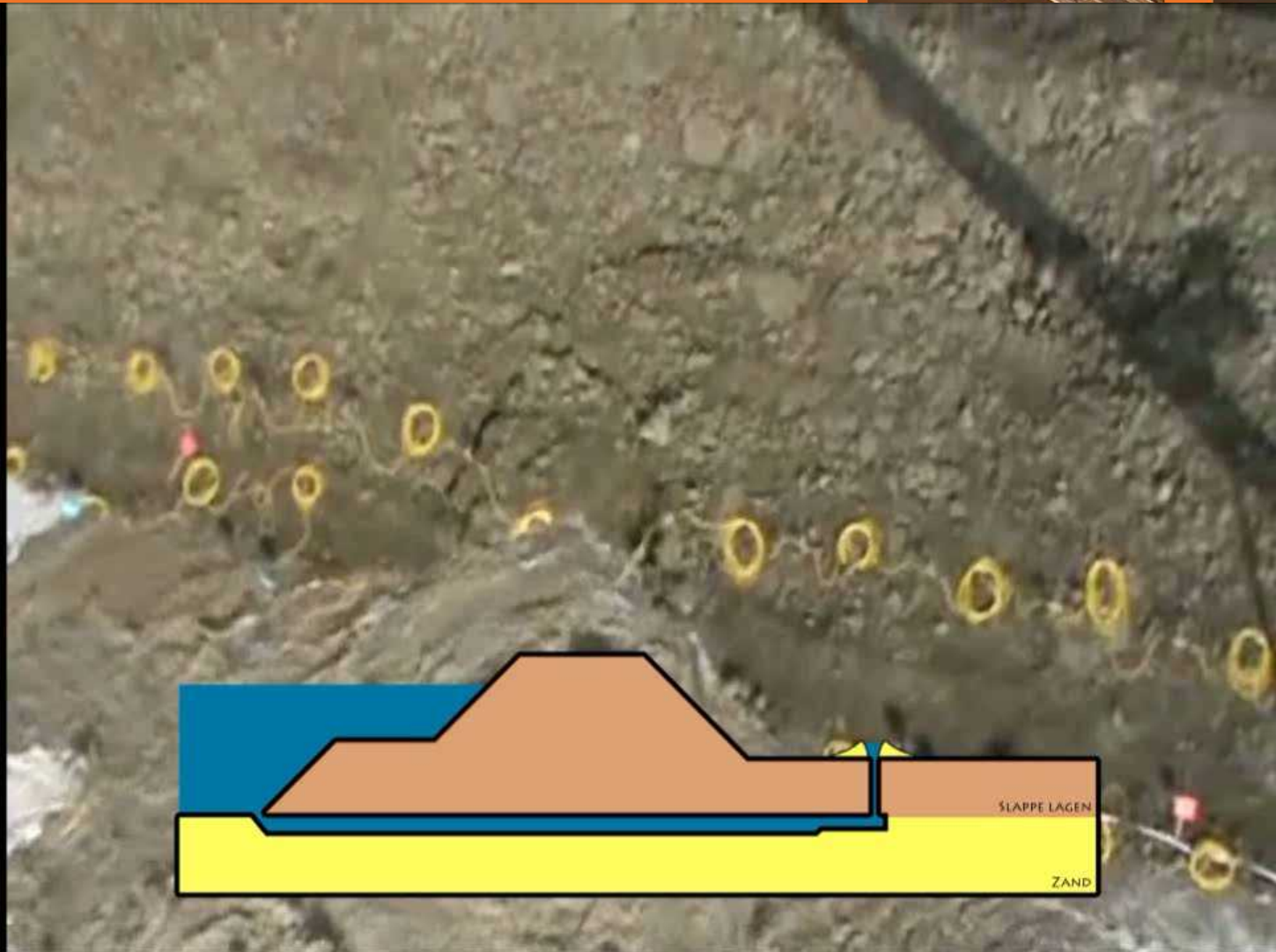
# Het piping proces



# Het piping proces



# Het piping proces

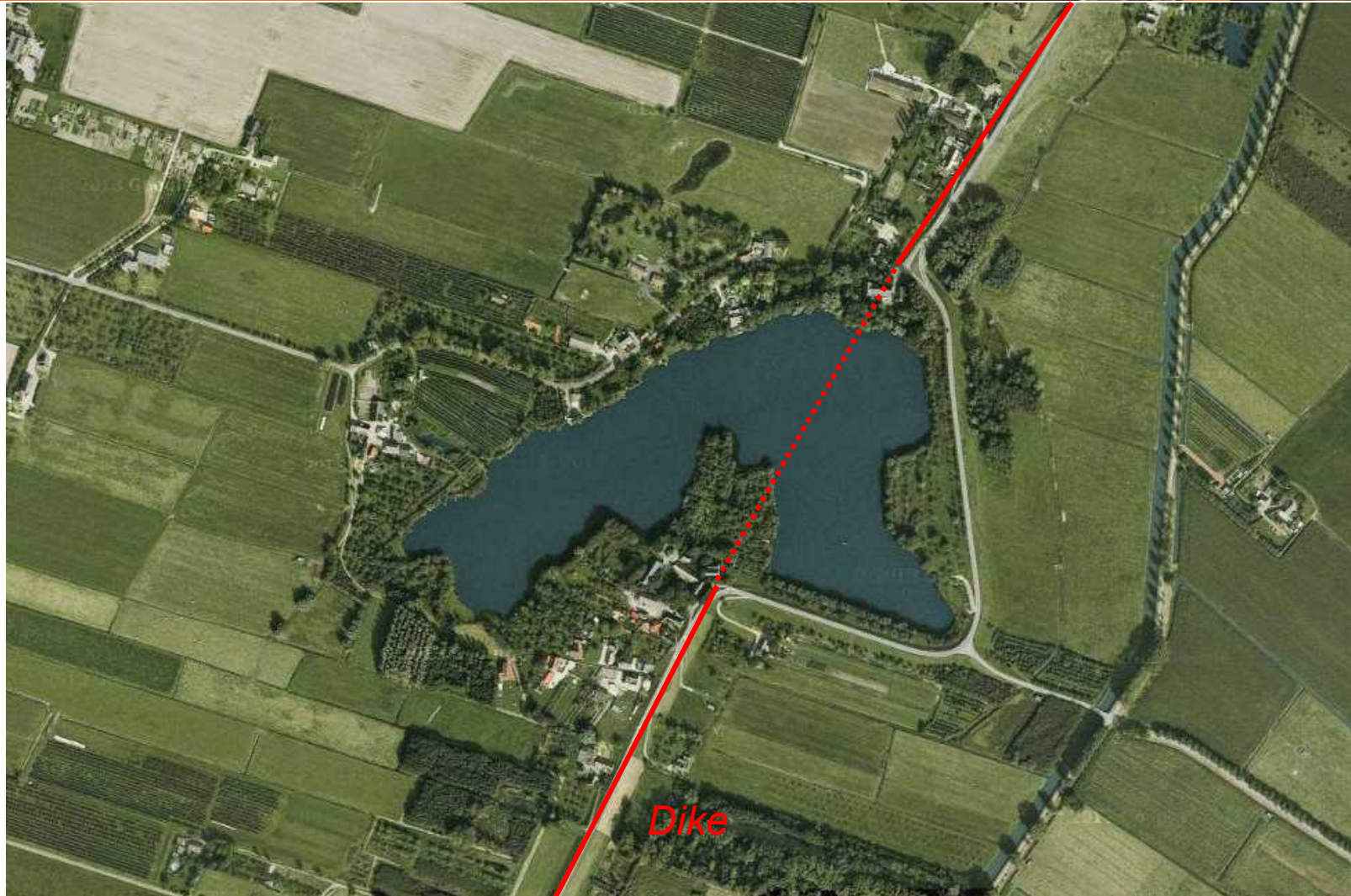
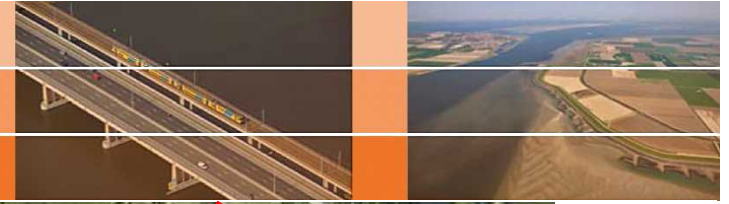






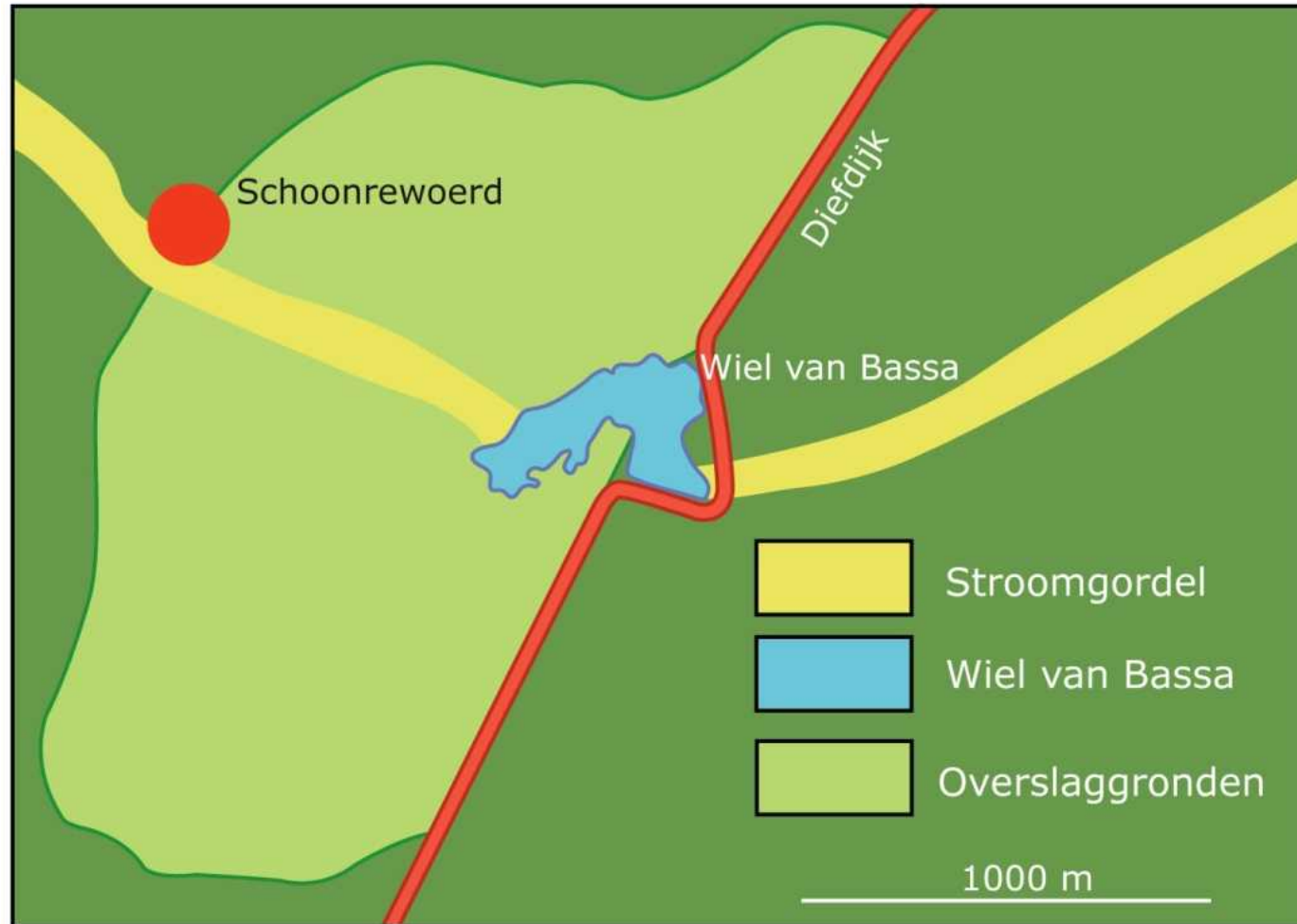
Bron: Navin 2016

# Dijkdoorbraken in Nederland



Wiel van Bassa (source: google maps)

# Dike breaches



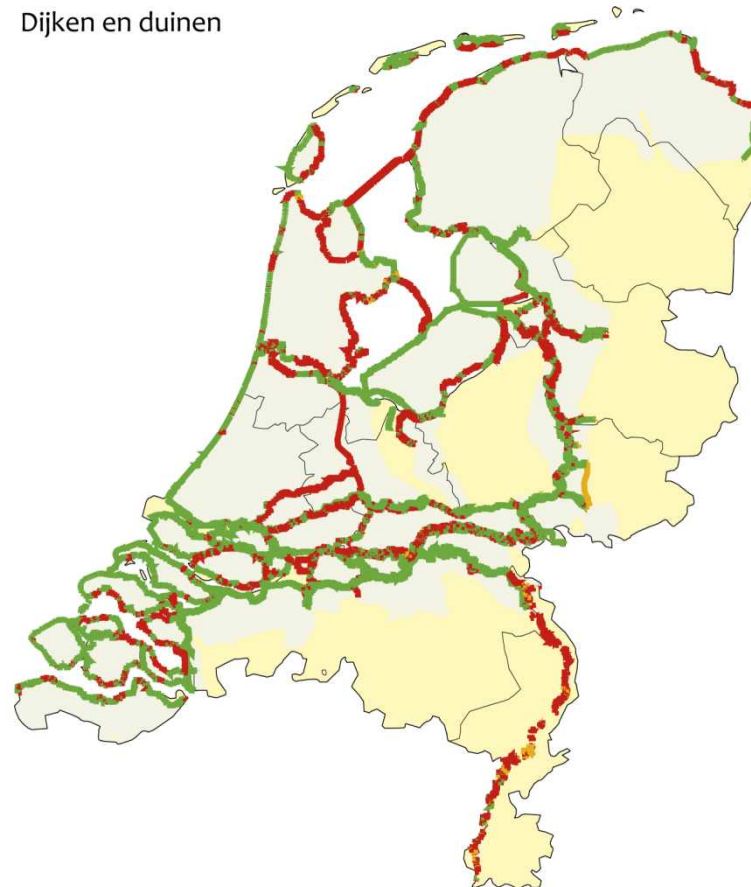
Illustratie Erik-Jan Bosch, Naturalis (<http://www.geologievannederland.nl/landschap/landschapsvormen/doorbraakgaten>)






# Piping in Nederland



## Veiligheid van onderzochte primaire waterkeringen, 2013

Dijken en duinen



-  Voldoet aan de norm
-  Voldoet niet aan de norm
-  Nader onderzoek nodig
-  Dijkringgebied
-  Hoge gronden en buitendijks gebied

Bron: Inspectie Leefomgeving en Transport, 2013.

PBL/jun14  
[www.clo.nl/nl204304](http://www.clo.nl/nl204304)

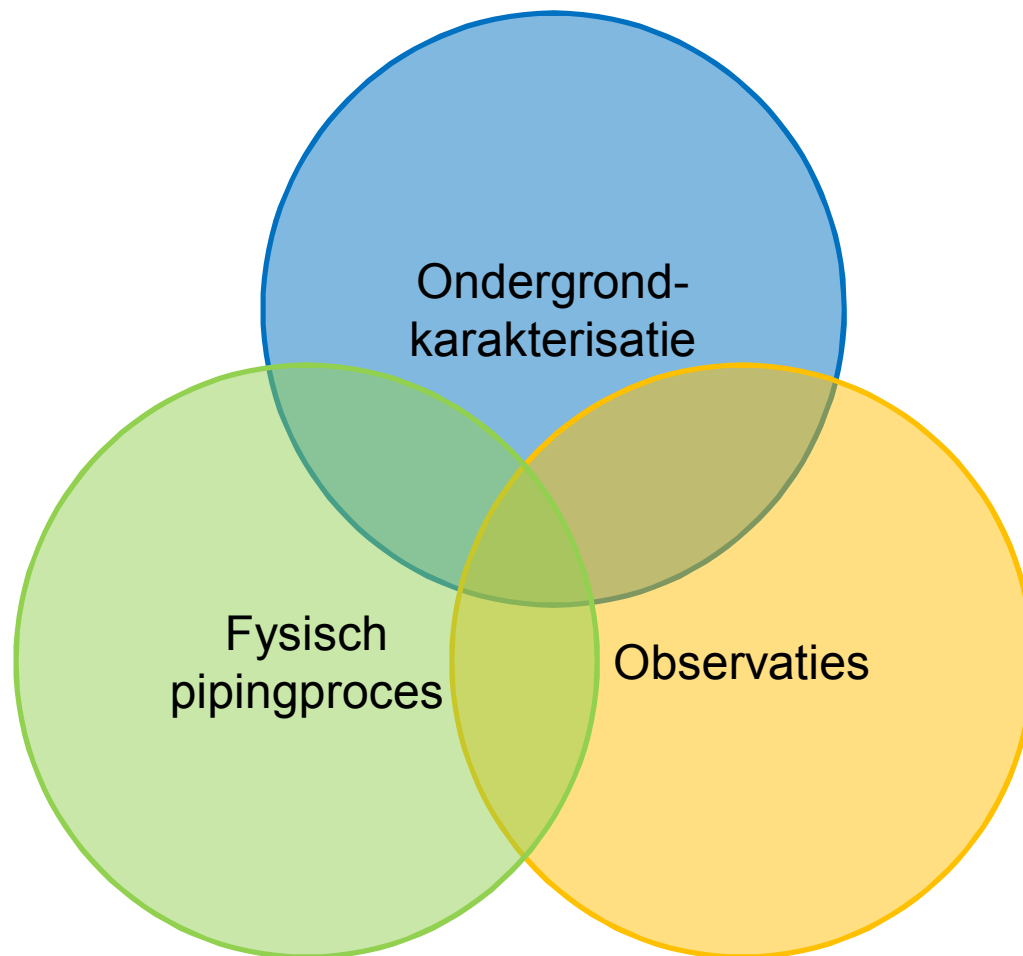


# Een visie op piping



Visie opgesteld door RWS, Deltares en POV-Piping: Omgaan met piping

1. No regret maatregelen voor urgente dijktrajecten
2. Beginnen met in kaart brengen van de ondergrond
3. Areaal beter vaststellen
4. Langere termijn: doorontwikkeling van pipingmodellen, innovatieve maatregelen en afwegingsmethodieken



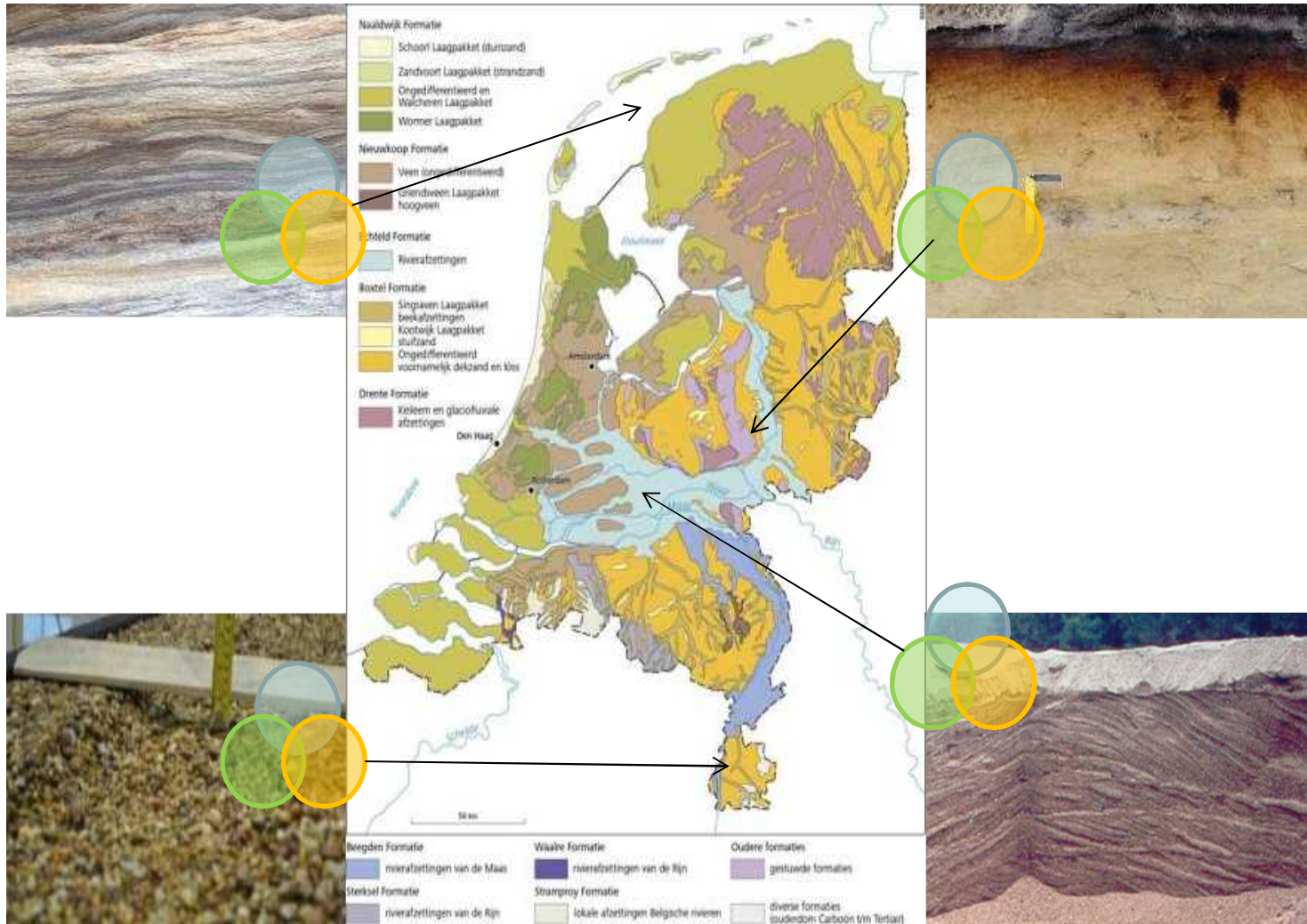
*naar de ondergrond  
**gedifferentieerd***

***eenvoudig** waar het  
kan en **complex** waar  
het nodig is*

*slim en zinvol **meten***

*benutten **observaties**  
uit de praktijk*

# Differentiatie naar afzettingstype



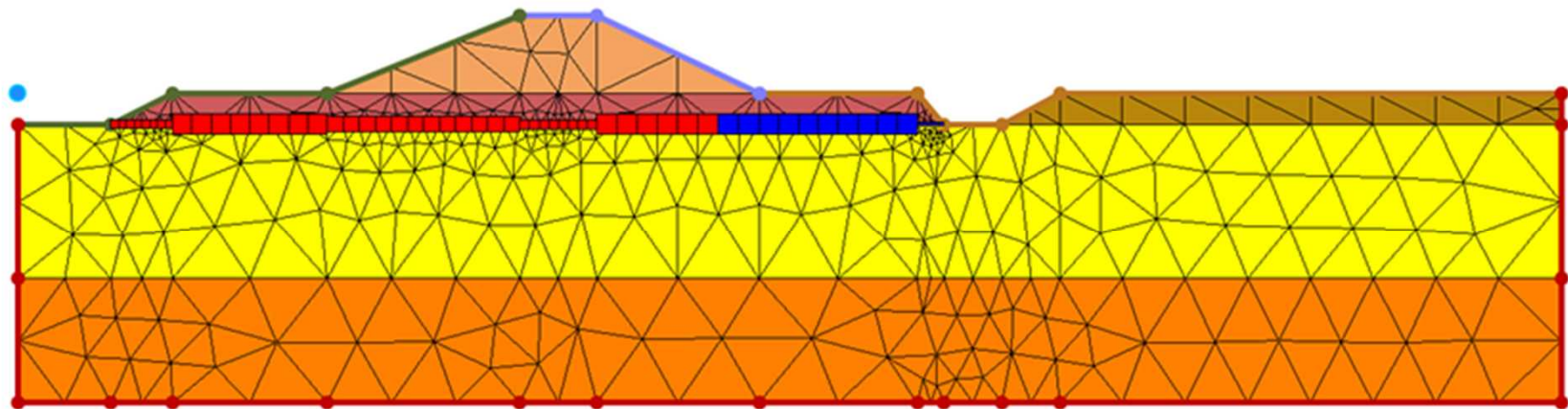


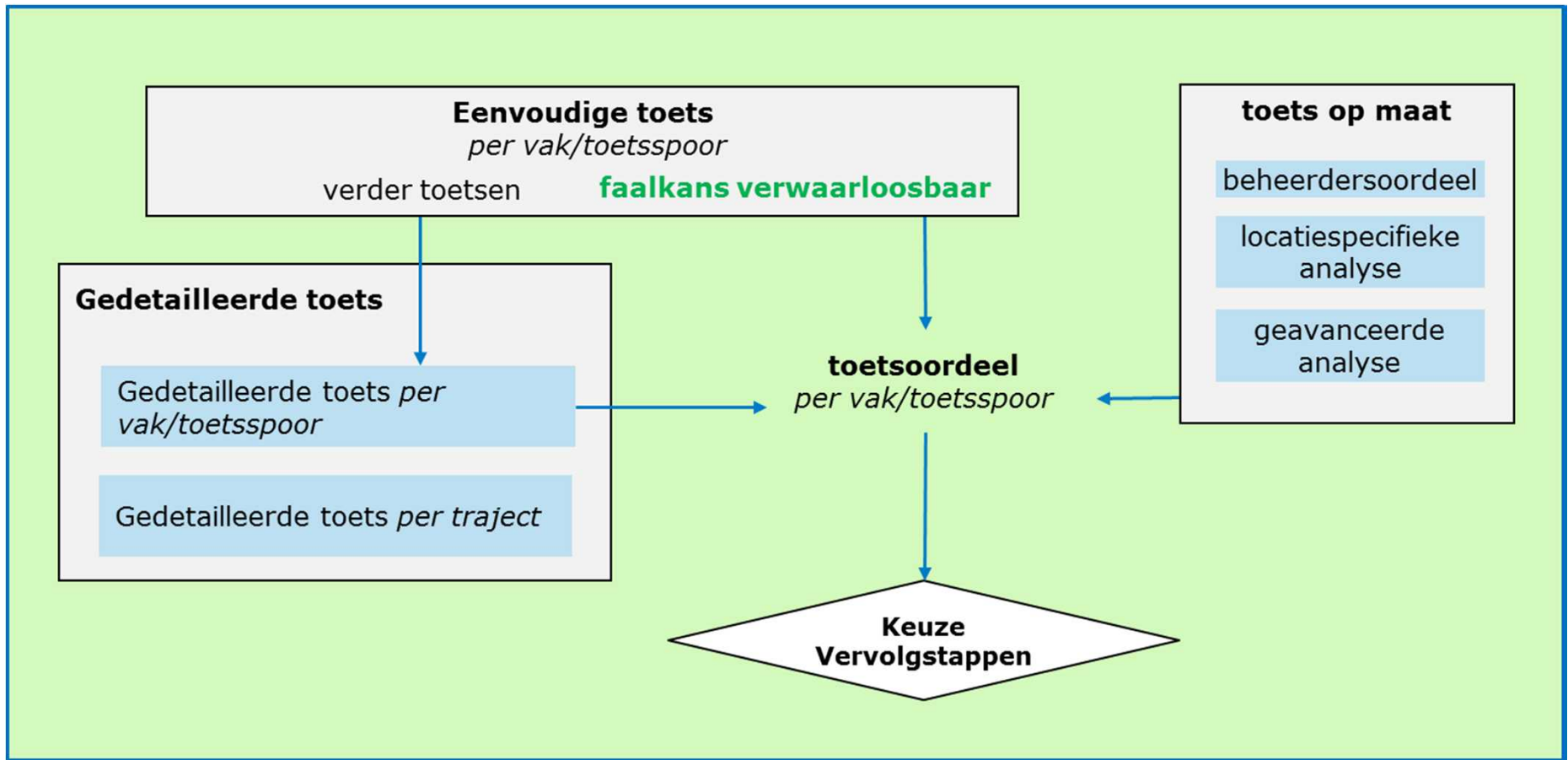
# D-Geo Flow – onderdeel van pipingvisie



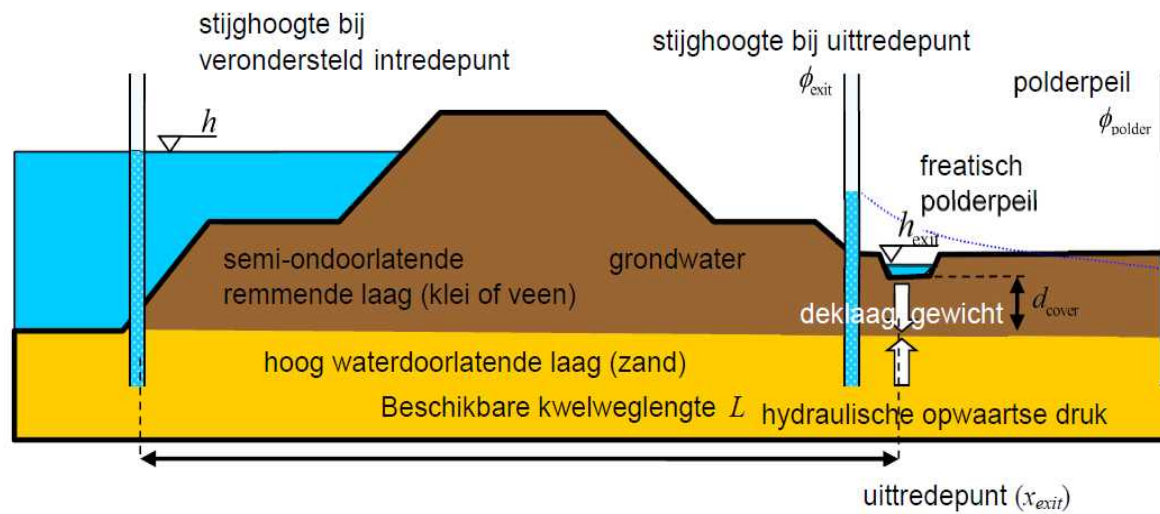
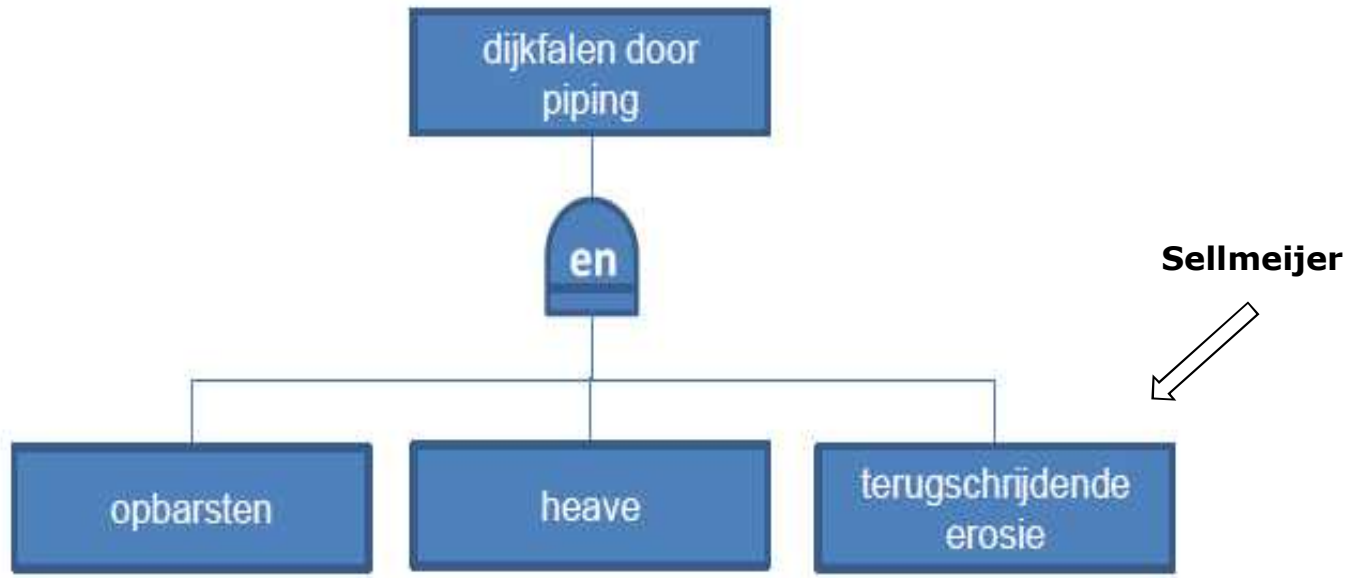
Binnen de gedifferentieerde aanpak is het nodig:

- Het effect van complexere configuraties mee te kunnen nemen in de pipingberekening
- Tijdsafhankelijk te rekenen

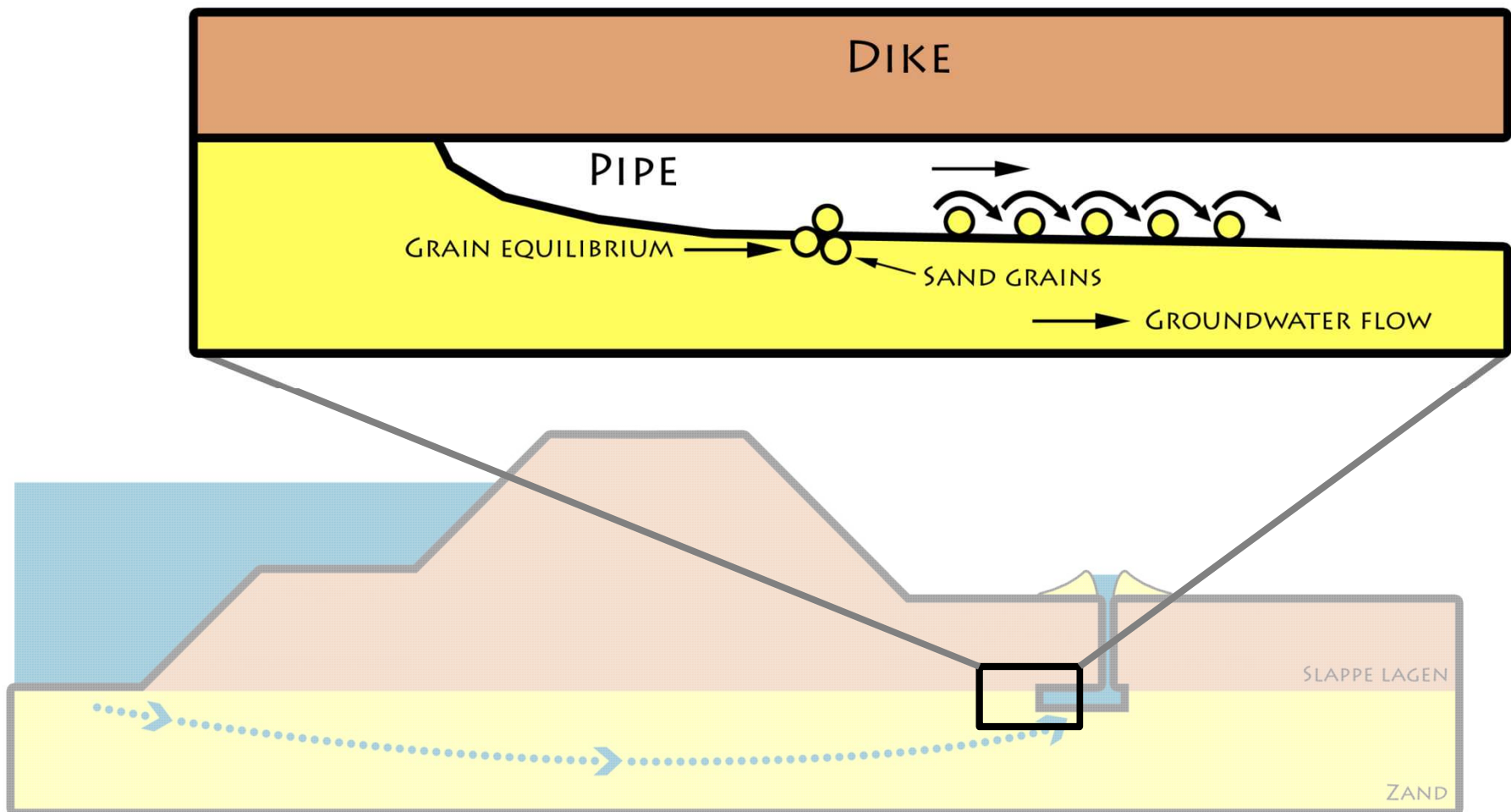
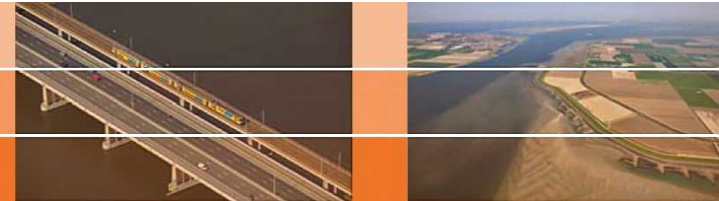




# De gedetailleerde toets



# Theorie piping in D-Geo Flow



# Het Sellmeijer model

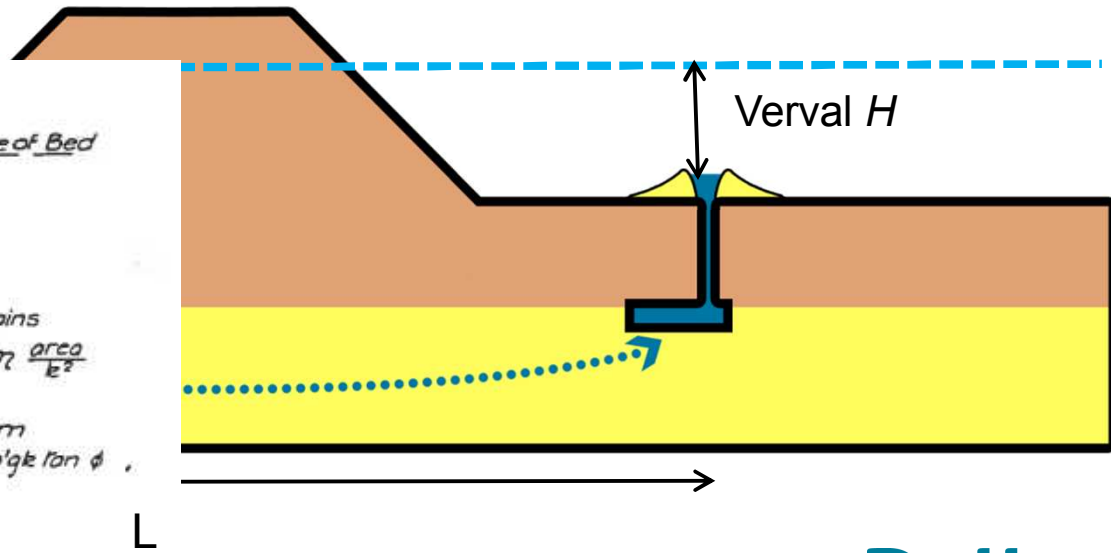
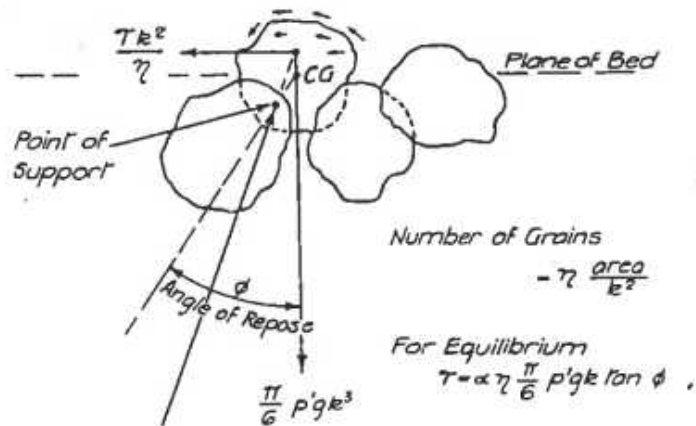
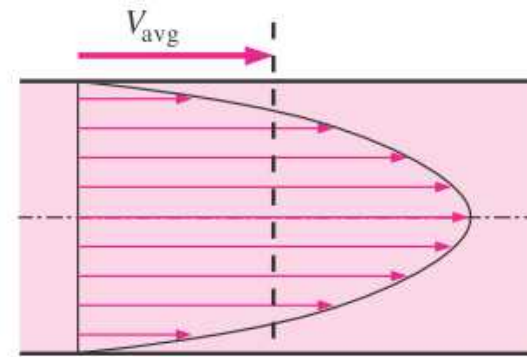


1. Stroming door het zandpakket
2. Stroming door de pipe
3. Evenwicht van korrels

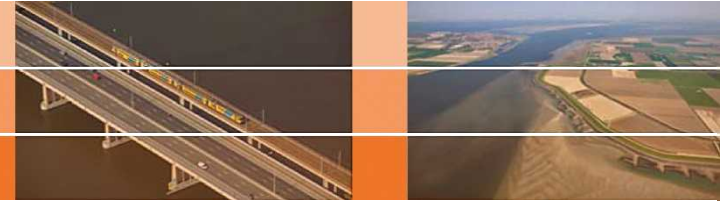
$$\tau_c = \eta \frac{\pi}{6} \gamma'_p d \tan \theta$$

$$\rho g \frac{d\phi}{dx} d^3 = 12q\mu$$

$$\tau_w = \frac{a}{2} \rho g \frac{d\phi}{dx}$$

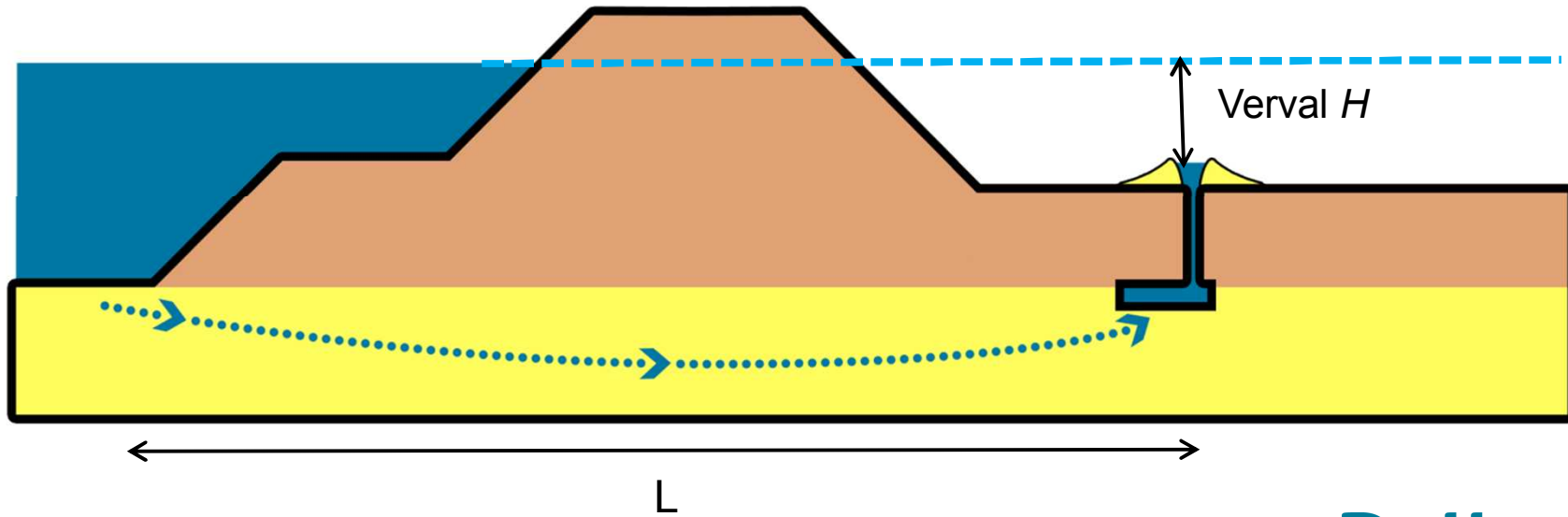
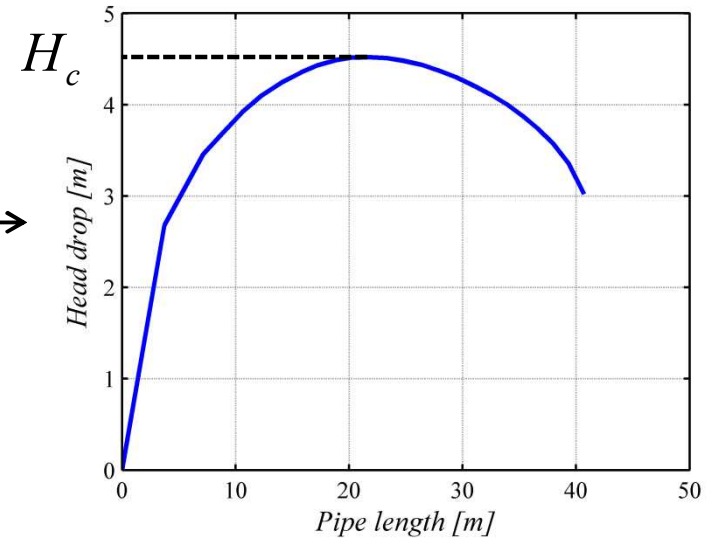


# Het Sellmeijer model



1. Stroming door het zandpakket
2. Stroming door de pipe
3. Evenwicht van korrels

$$\longrightarrow H_{eq} \longrightarrow$$



# Het Sellmeijer model



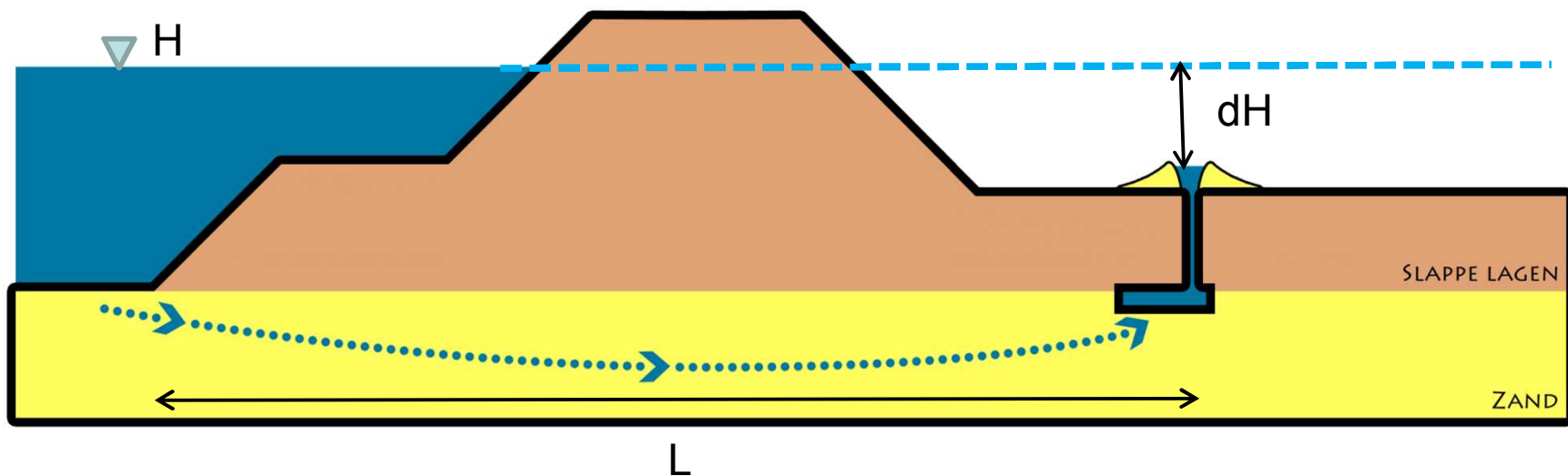
1. Stroming door het zandpakket
2. Stroming door de pipe
3. Evenwicht van korrels

$$\rightarrow \frac{H_c}{L} = F_R F_S F_G$$

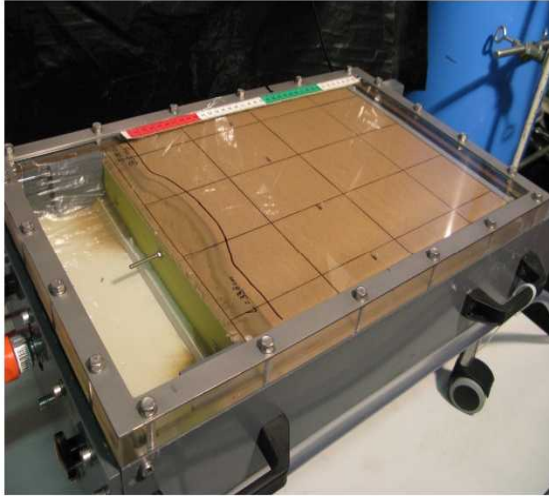
$$F_R = \eta \frac{\gamma'_p}{\gamma_w} \tan \vartheta$$

$$F_S = \frac{d_{70}}{\sqrt[3]{\kappa L}}$$

$$F_G = 0.91 \left( \frac{D}{L} \right)^{\frac{0.28}{\left( \frac{D}{L} \right)^{2.8} + 0.04} - 1}$$



# Empirische aanpassing Sellmeijer model (2011)



Adjustment Sellmeijer rule:

$$\frac{H_c}{L} = \frac{1}{c} = F_R F_S F_G$$

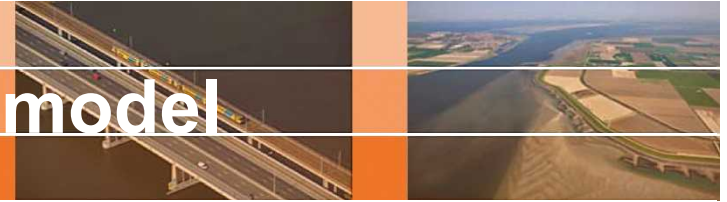
$$F_R = \eta \frac{\gamma'_p}{\gamma_w} \tan \vartheta$$

$$F_S = \frac{d_{70}}{\sqrt[3]{\kappa L}}$$

$$F_G = 0.91 \left( \frac{D}{L} \right)^{\frac{0.28}{\left( \frac{D}{L} \right)^{2.8} - 1} + 0.04}$$

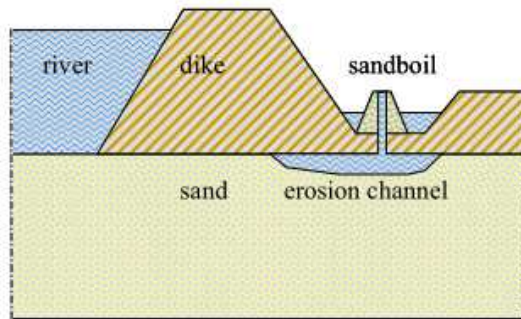


# Sellmeijer regel en Sellmeijer model



Sellmeijer rule: curve-fit met modelresultaten

- Standaard dijk geometrie



$$\frac{H_c}{L} = \frac{1}{c} = F_R F_S F_G$$

$$F_R = \eta \frac{\gamma'_p}{\gamma_w} \tan \vartheta \left( \frac{RD}{RD_m} \right)^{0.35} \left( \frac{U}{U_m} \right)^{0.13} \left( \frac{KAS}{KAS_m} \right)^{-0.02}$$

$$F_S = \frac{d_{70}}{\sqrt[3]{\kappa L}} \left( \frac{d_{70m}}{d_{70}} \right)^{0.6}$$

$$F_G = 0.91 \left( \frac{D}{L} \right)^{0.28} \left( \frac{D}{L} \right)^{-1 + 0.04}$$

$\Delta H_c$  : critical head over the levee

$\gamma_p$  : particle volumetric weight

$\gamma_w$  : volumetric weight of water

$\theta$  : bedding angle

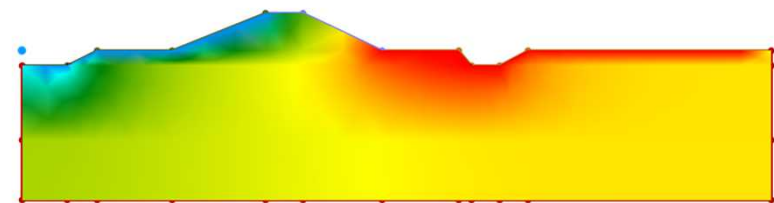
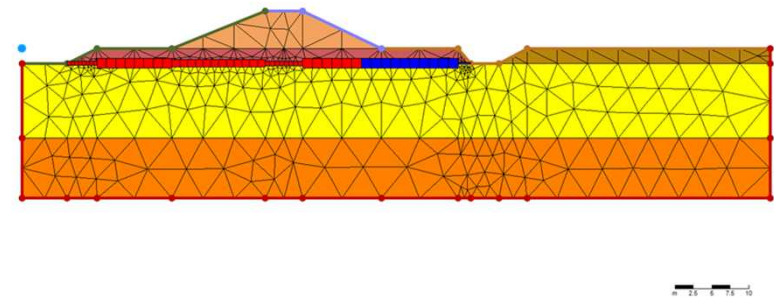
$\eta$  : coefficient of White

$\kappa$  : intrinsic permeability

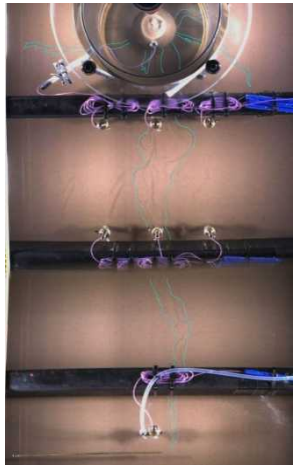
L: length of the seepage path

Sellmeijer model:

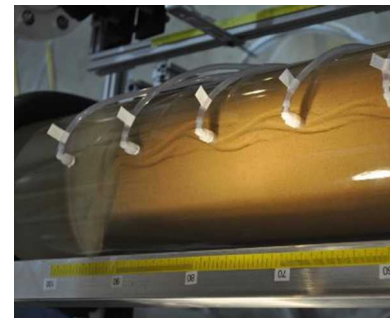
- Numerieke grondwaterstromingsberekeningen zijn geschikt voor meer complexe ondergrond configuraties.



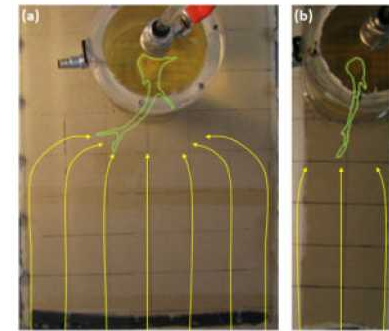
# Nieuwe ontwikkelingen



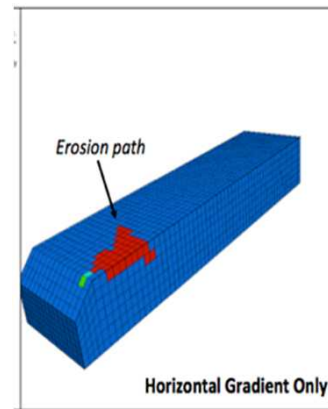
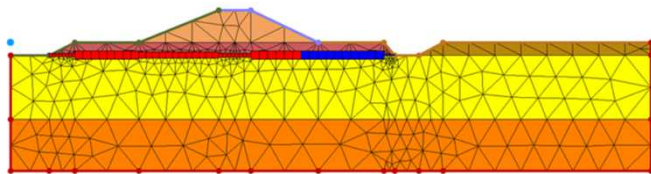
Yao, 2014



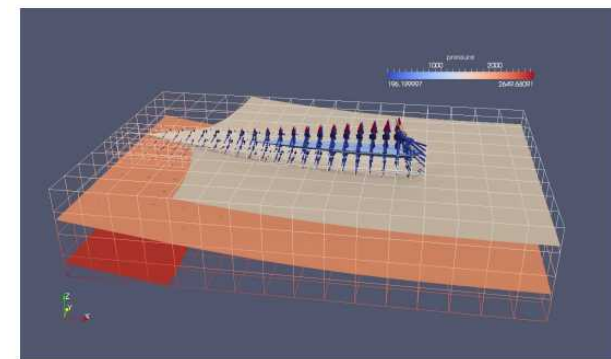
Robbins et al. T.b.p



Vandenboer et al. 2015 ICSE7

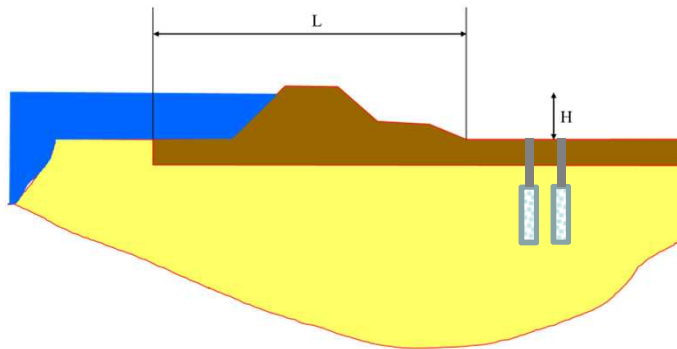
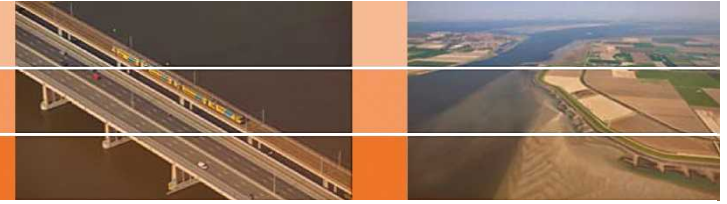


Robbins et al. 2016

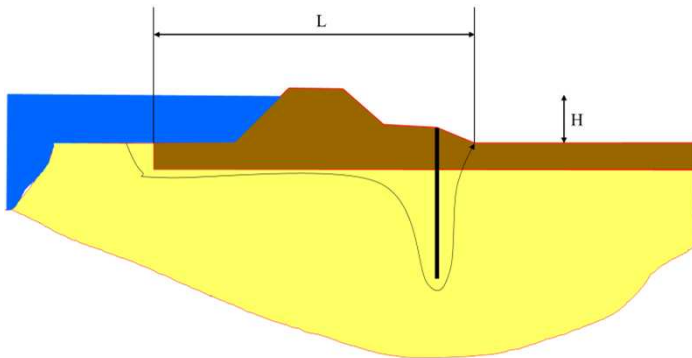


Van Esch

# Maatregelen

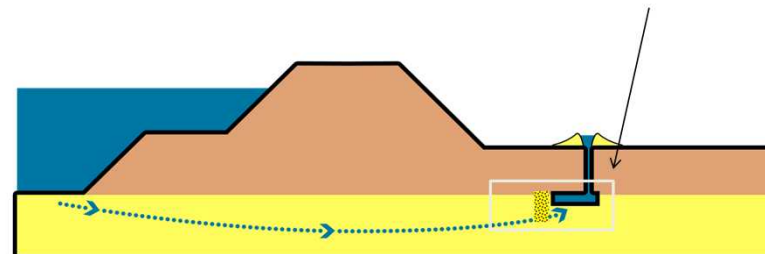
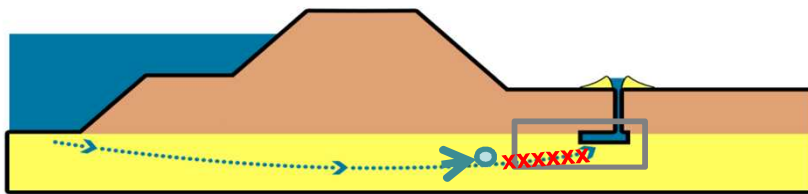
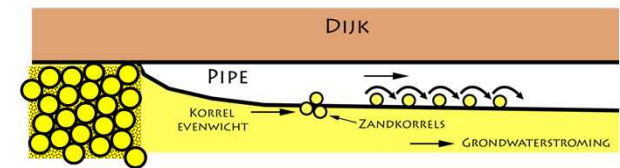


Doorsnede dijk

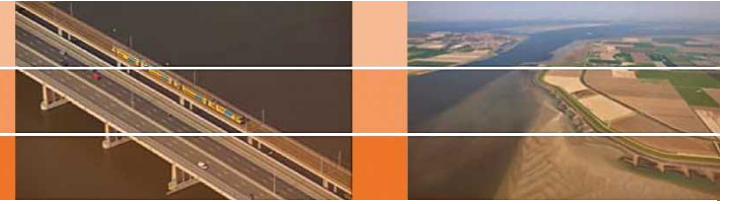


Kwelscherm

Bron: Van der Berg, 2015



# Samenvatting



- Piping is een geleidelijk proces dat zonder duidelijke waarschuwing tot bezwijken kan leiden
- Het model van Sellmeijer voorspelt of een bestaande pipe kan doorgroeien: de kritieke pipe-lengte is  $<1/2 L$
- Uit het model van Sellmeijer is de regel van Sellmeijer afgeleid d.m.v. curve fitting.
- Meer complexe configuraties kunnen nu doorgerekend worden in D-Geo Flow, wat past in de visie van RWS en Deltares
- Er zijn internationaal veel nieuwe ontwikkelingen m.b.t. piping, ook op het gebied van maatregelen, zoals rekenen met 3D configuraties en bijvoorbeeld de grof zand barriere.