# Developments in Scour and Erosion

1 More than 10 years ICSE conferences
2 Influence of Turbulence on Soil Erosion
3 Road to 2020

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August 29, 2012

ICSE-6 Paris 2012

# More than 10 years ICSE conferences

(2000) Melbourne
2002 College Station
2004 Singapore
2006 Amsterdam
2008 Tokyo
2010 San Francisco
2012 Paris

RESULT:
an overwhelming number of papers and:
- new formulas
- new monitoring methods
- results of field tests and lab experiments

**In addition, synthesised knowledge in manuals, for example:**

- **Melville & Coleman**
- **Hoffmans & Verheij**
- **Whitehouse**
- **Sumer & Fredsoe**
- **Annandale**
- **HEC**

Newton (1687)
Schoklitsch (1932)
Veronese (1937)
Jaeger (1939)
Eggenberger (1944)
Hartung (1957)
Franke (1960)
And so on



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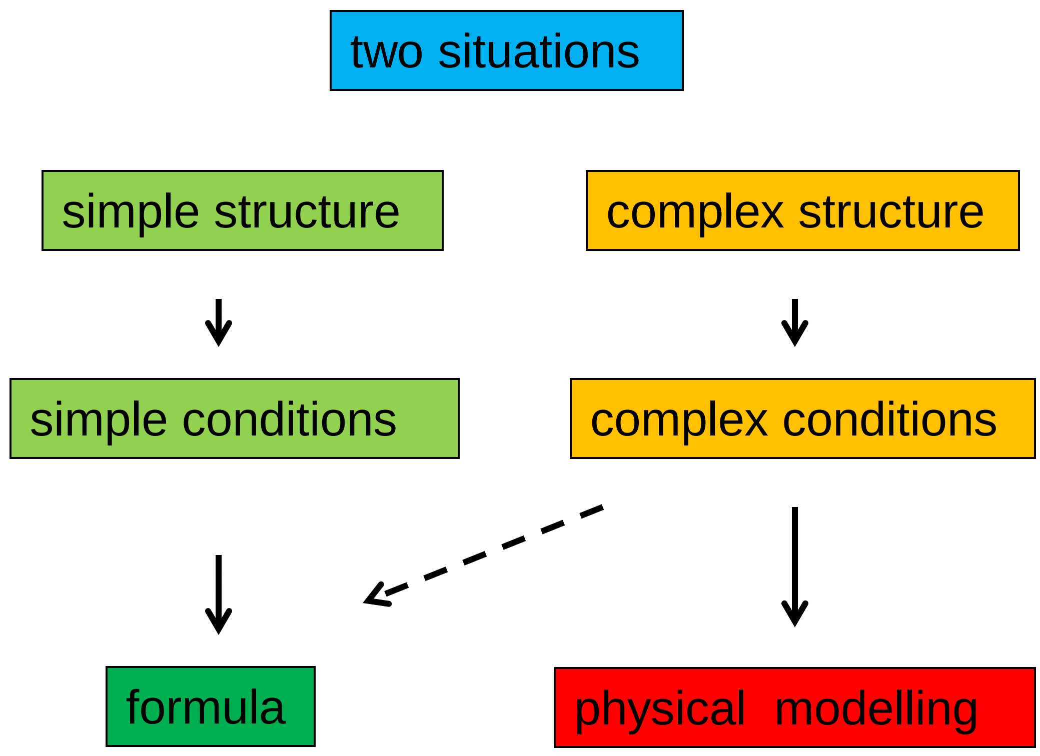
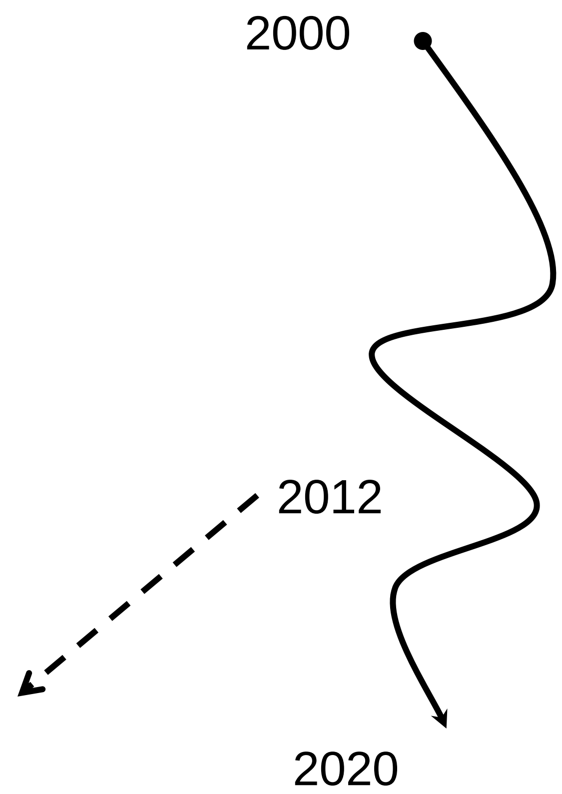
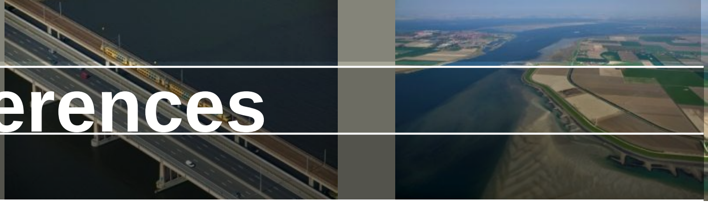
# More than 10 years ICSE conferences



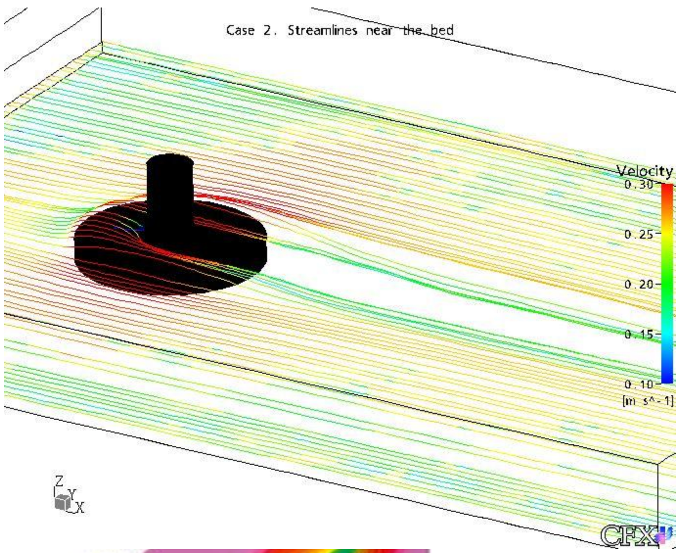



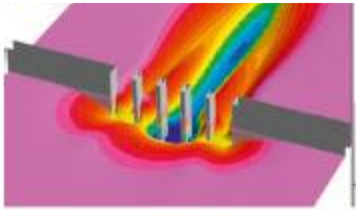

Do we make sufficient progress ?

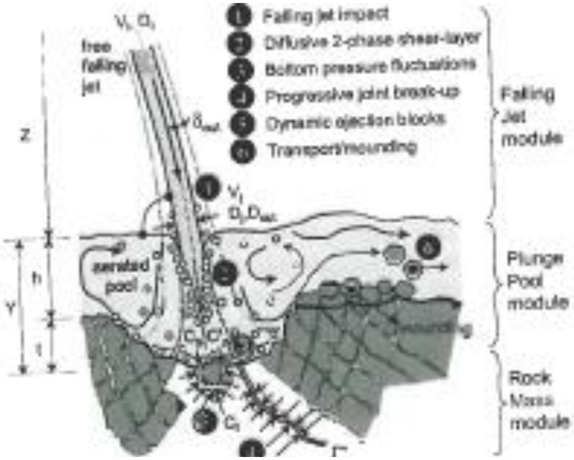


# More than 10 years ICSE conferences

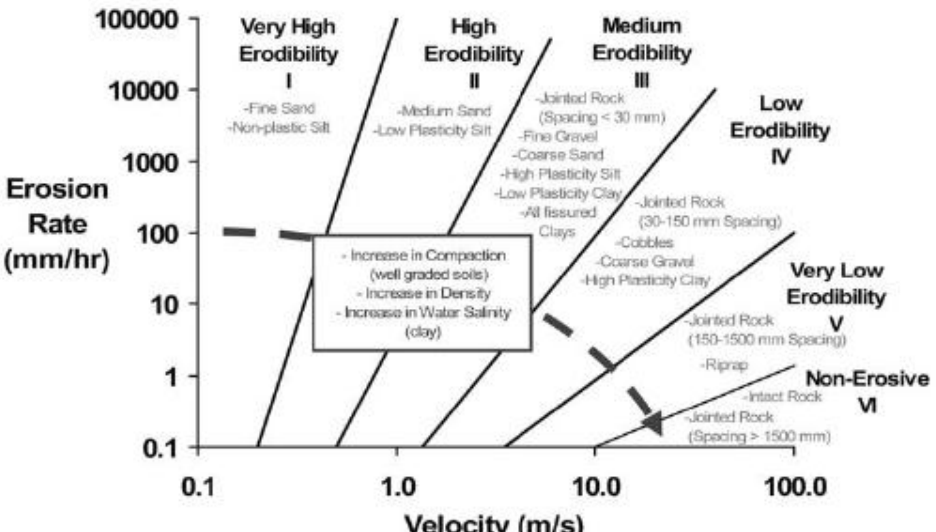
examples of recent developments



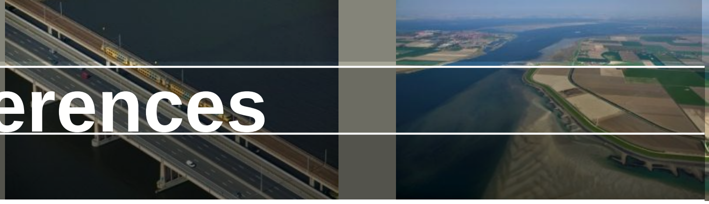



rock erosion:
power of the bubble
(Eric Bollaert)

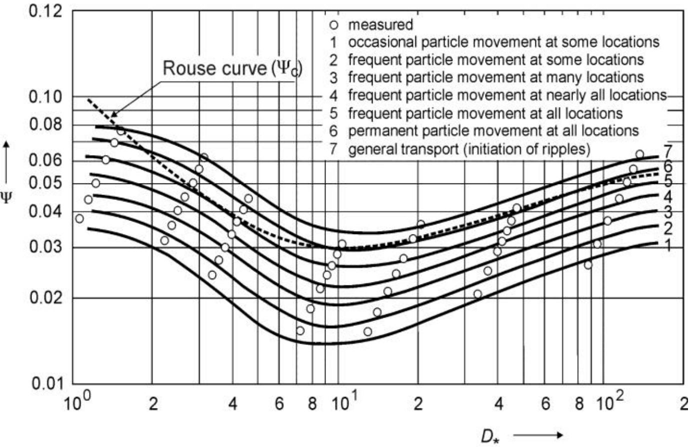



erodibility of materials:
EFA method
(Jean-Louis Briaud)

# More than 10 years ICSE conferences

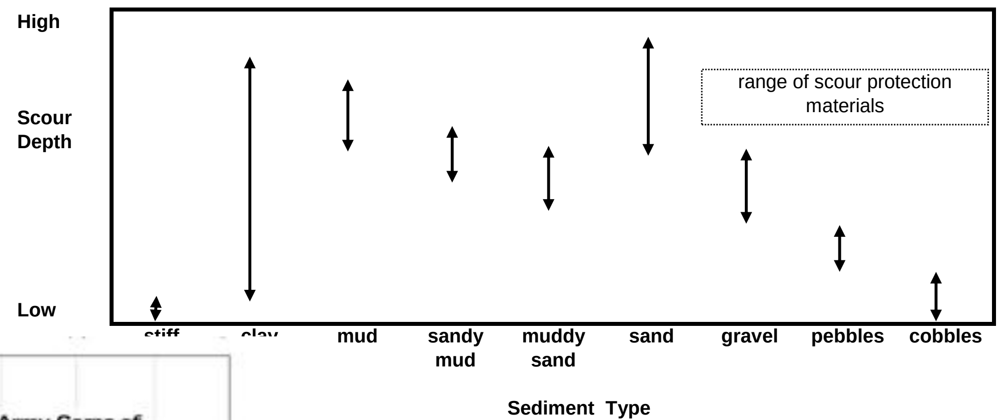


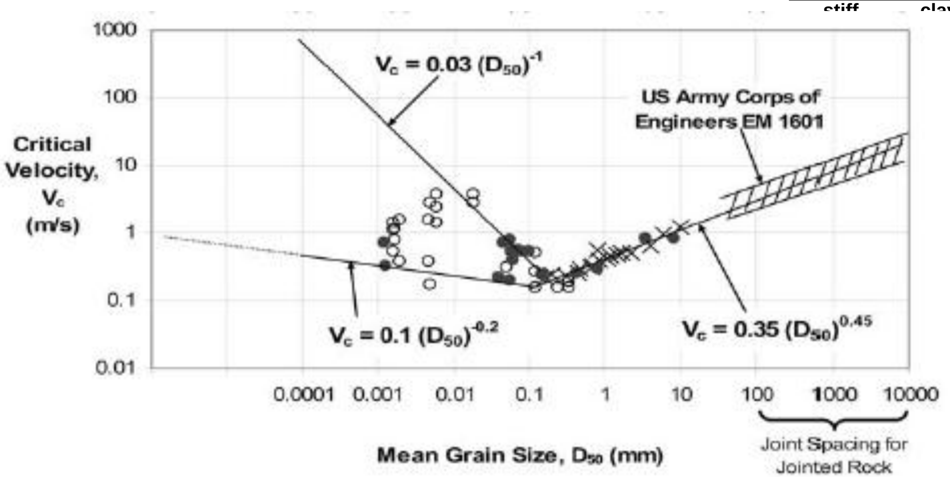
examples of recent developments




initiation / scour of bed materials:
(Sumer & Fredsoe, Whitehouse, Briaud, Shields)

Conceptual model of the relative scour depth for different sediments in the marine environment
Normal' current plus wave conditions




anything new?
1767 Brahms: Weight = Velocity$^6$

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# More than 10 years ICSE conferences

So, major steps have been taken.

Now a new milestone:

Influence of turbulence on soil erosion



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# New developments

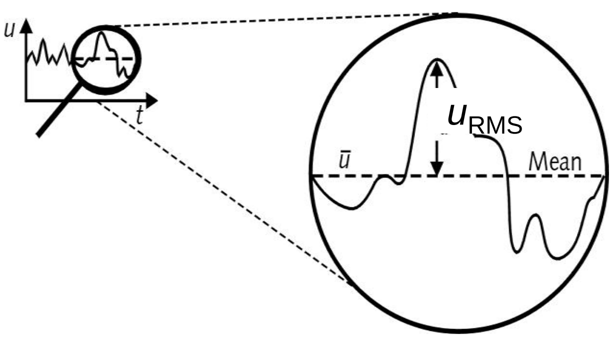
Influence of Turbulence on Soil Erosion

- ***Stone stability***
- Granular filters
- Erodibility grass
- ***Jet scour***
- Sill, bridge and abutment scour

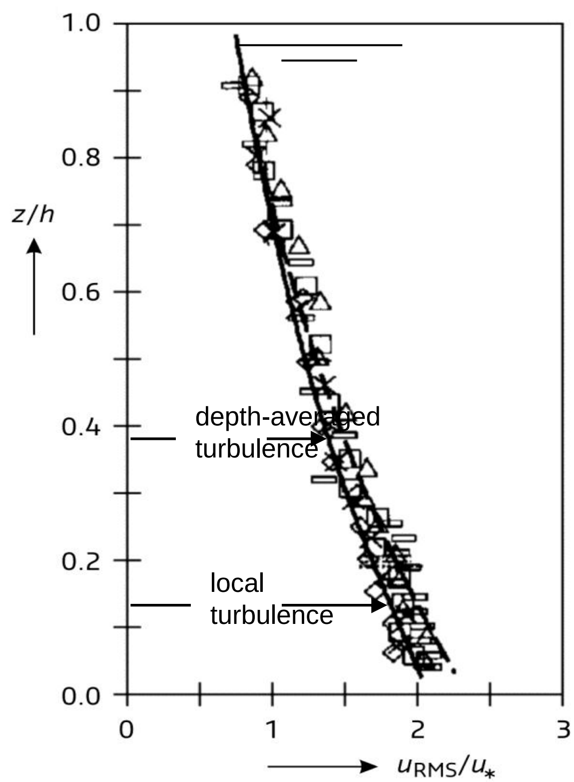
# Stone stability

## Modern load parameters

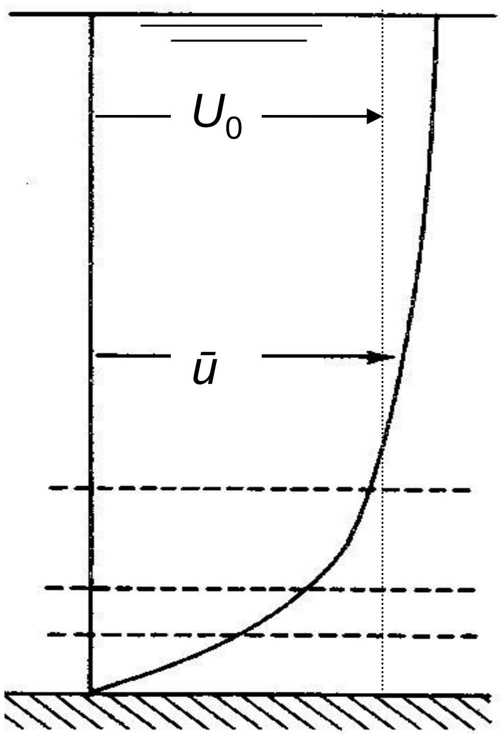
Turbulence




RMS value of fluct. vel.



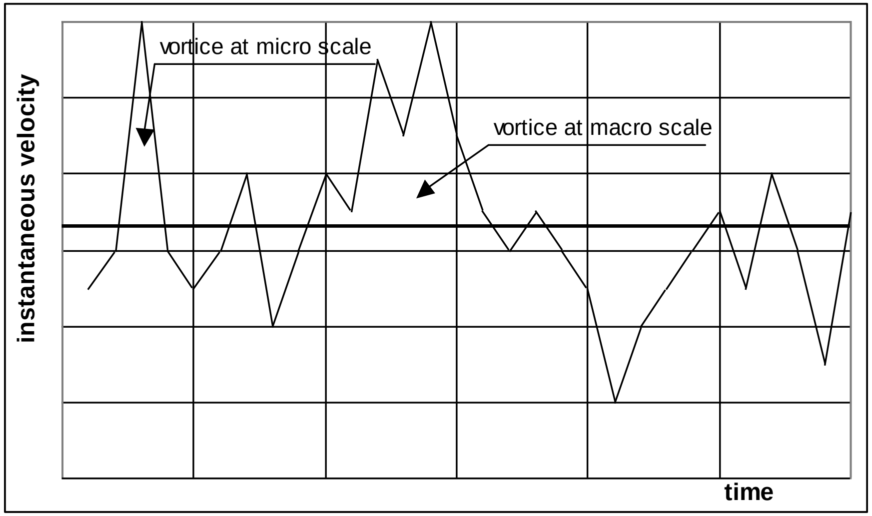

Flow velocity



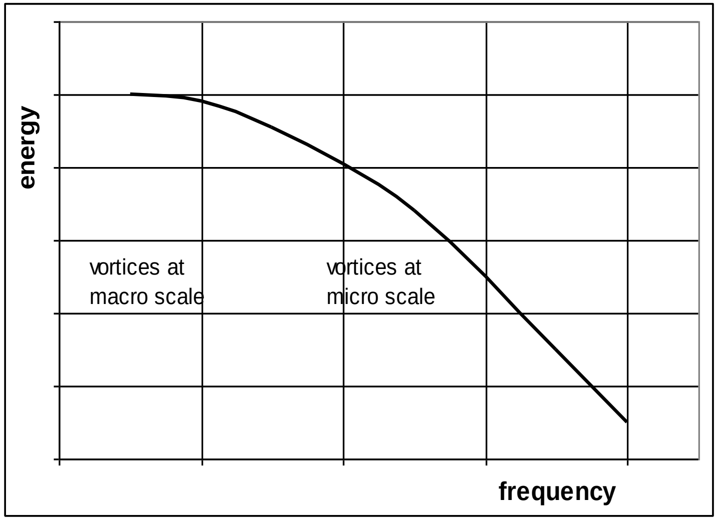
# Stone stability

Strength and load parameters:

- Strength is *f*(relative density, stone diameter, grading)
- Load is *f*(velocity, RMS-value of velocity and frequency)




Measuring signal




Energy spectrum



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# Stone stability

Definition of turbulence energy

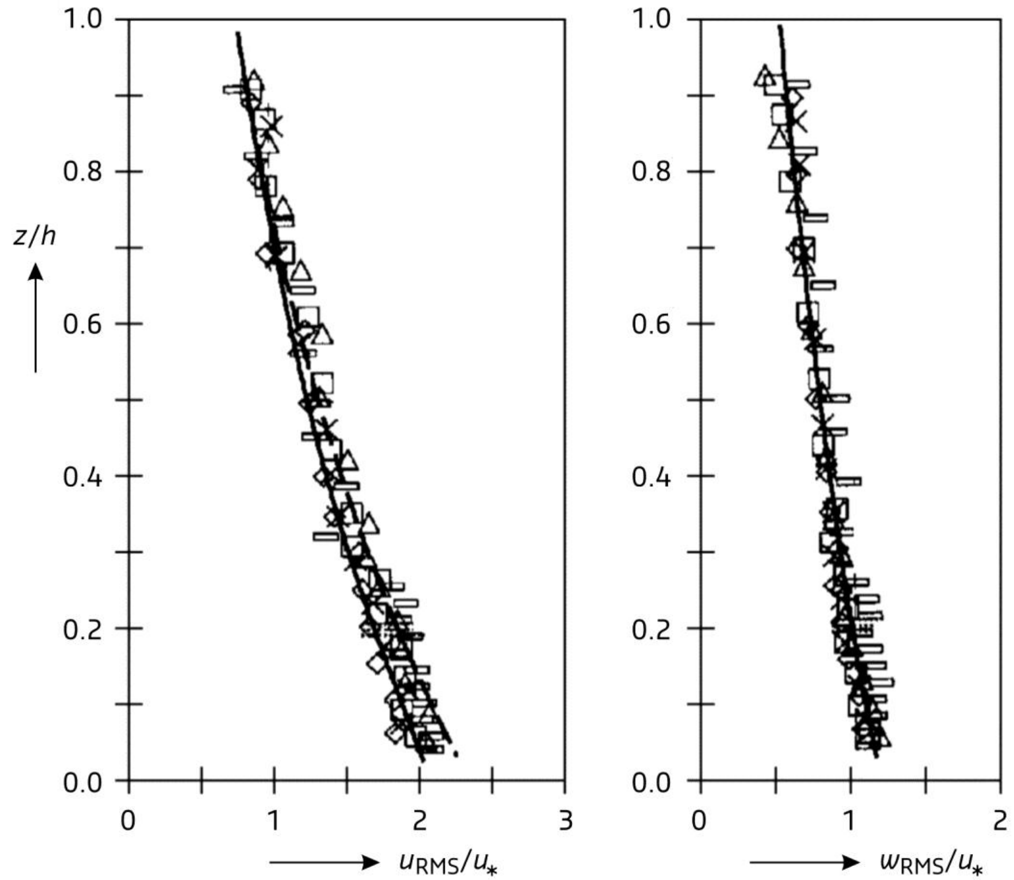
$$k(z) = \tfrac{1}{2}\left(u_{\mathrm{RMS}}^2(z) + v_{\mathrm{RMS}}^2(z) + w_{\mathrm{RMS}}^2(z)\right)$$

Depth-averaged value

$$k_0 = \frac{1}{h}\int_0^h k(z)\,dz$$

Depth-averaged relative turbulence intensity

$$r_0 = \frac{\sqrt{k_0}}{U_0} = 1.2\frac{u_*}{U_0} = 1.2\frac{\sqrt{g}}{C}$$




**Stability of Stones under Uniform Flow,** *J. of Hydr. Engrg*, 136(2),129-136

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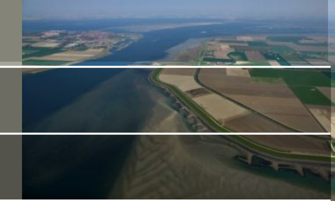
# Stone stability



Indicative values of the depth-averaged relative turbulence intensity

| $r_0$ | Turbulence intensity | Type of flow | Remarks | Hydraulic conditions |
|---|---|---|---|---|
| 0 | no turbulence | laminar flow | | |
| > 0 | | turbulent flow | | |
| < 0.08 | minor turbulence | uniform flow | | smooth |
| 0.08–0.15 | normal turbulence | uniform flow | channel/river flow | rough |
| 0.15–0.20 | high turbulence | uniform flow | channel/river flow | ↓ |
| 0.20–0.30 | very high turbulence | uniform flow | steep channel with limited flow depth | |
| 0.30–0.60 | extreme high turbulence | uniform flow | very steep channel with limited flow depth | |
| 0.15–0.20 | high turbulence | non-uniform flow | downstream of hydraulic structures (sills, bridge piers, abutments) | |
| 0.20–0.30 | very high turbulence | non-uniform flow | below hydraulic jumps, sharp outer bends, mixing layers (propeller) | |

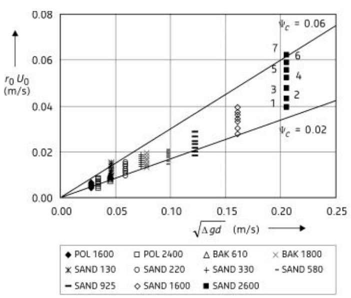
# Stone stability

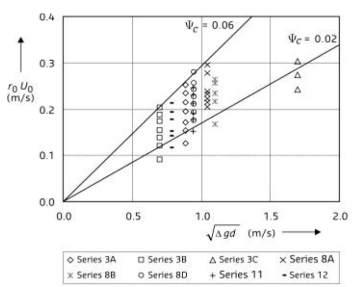
Uniform flow $\Psi_c = \frac{U_0^2}{\Delta d C^2}$

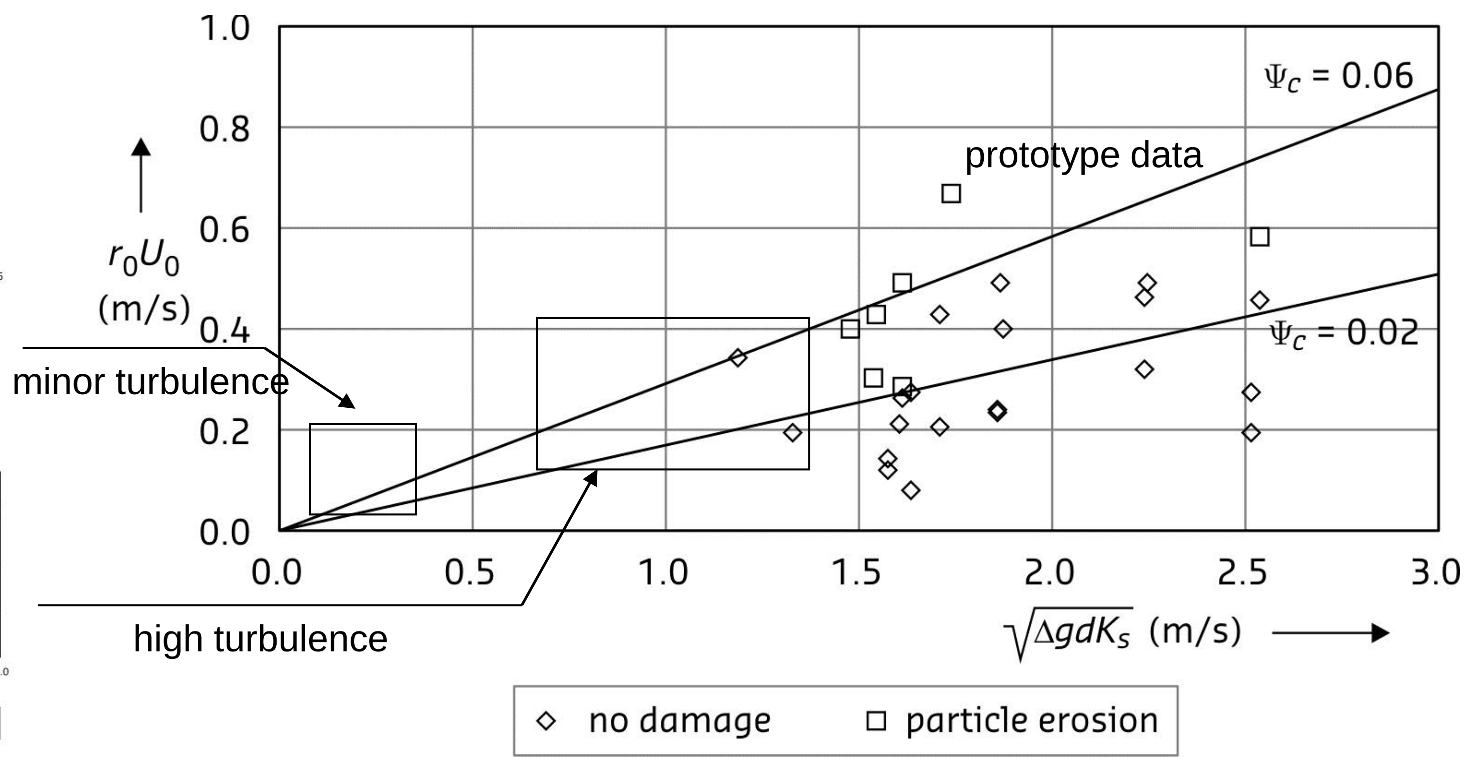
with $r_0 = 1.2 \frac{\sqrt{g}}{C}$

$$\Psi_c = \frac{\text{Load}}{\text{Strength}} = 0.7 \frac{(r_0 U_0)^2}{\Delta g d}$$

Load - Strength diagram/depth-averaged approach



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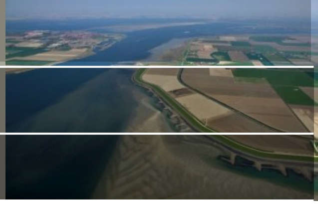
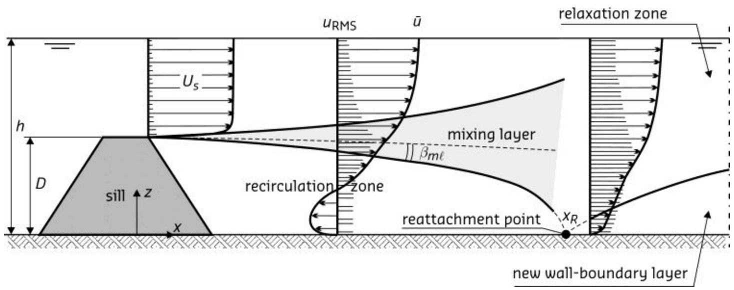
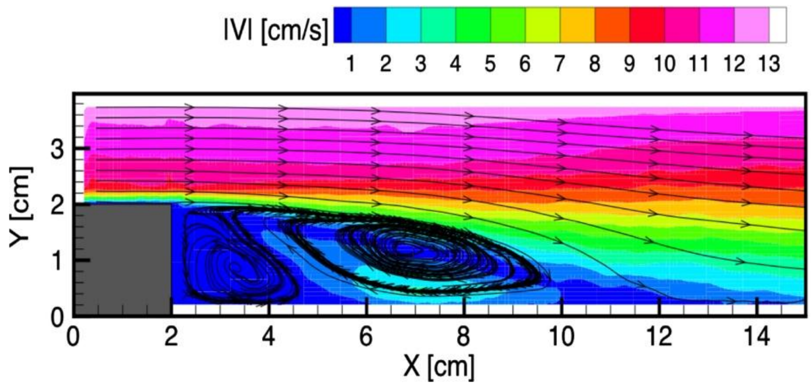


# Stone stability

Non-uniform flow conditions




$$\Delta d = 0.7 \frac{\left(r_0 U_0\right)^2}{g \Psi_c}$$

experiments of Uwland (1982) are used for validation

$$r_0\left(x\right) = \sqrt{0.0225\left(1-\frac{D}{h}\right)^{-2}\left(\frac{x-6D}{6.67h}+1\right)^{-1.08}+\left(1.2\frac{u_*\left(x\right)}{U_0}\right)^2}$$

**Two-dimensional mathematical modelling of local scour holes**, *J. of Hydr. Res*. 31(5), 615-634**.**



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# Jet scour

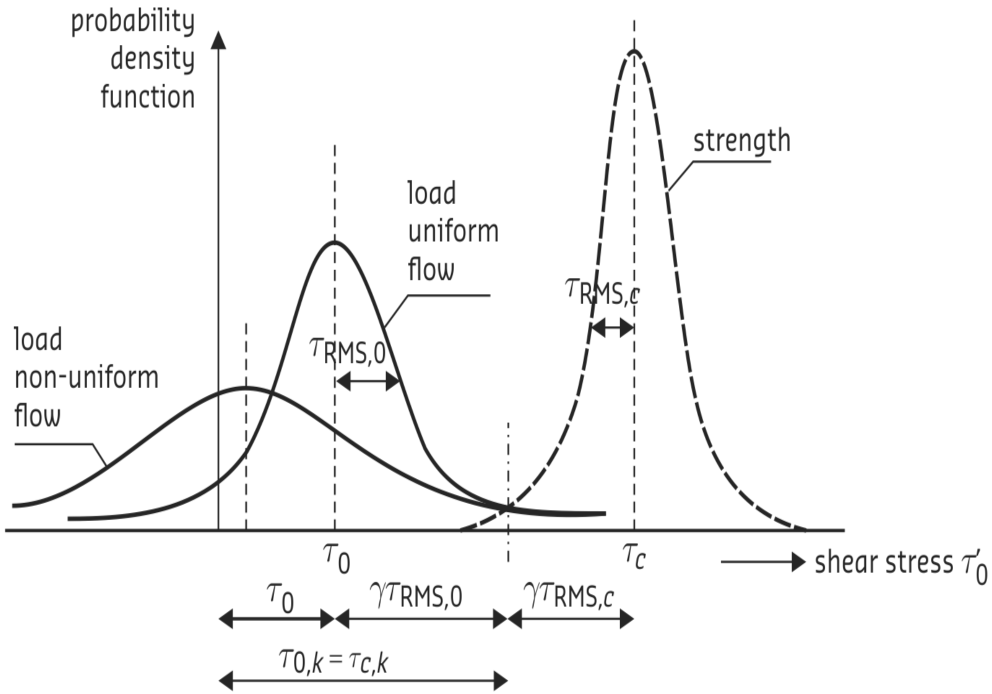
Scour parameters

Load

- Bed shear stress
- Turbulence

Strength

- Critical bed shear stress
- Grading or heterogeneity



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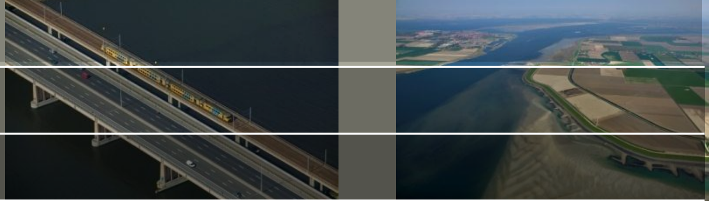
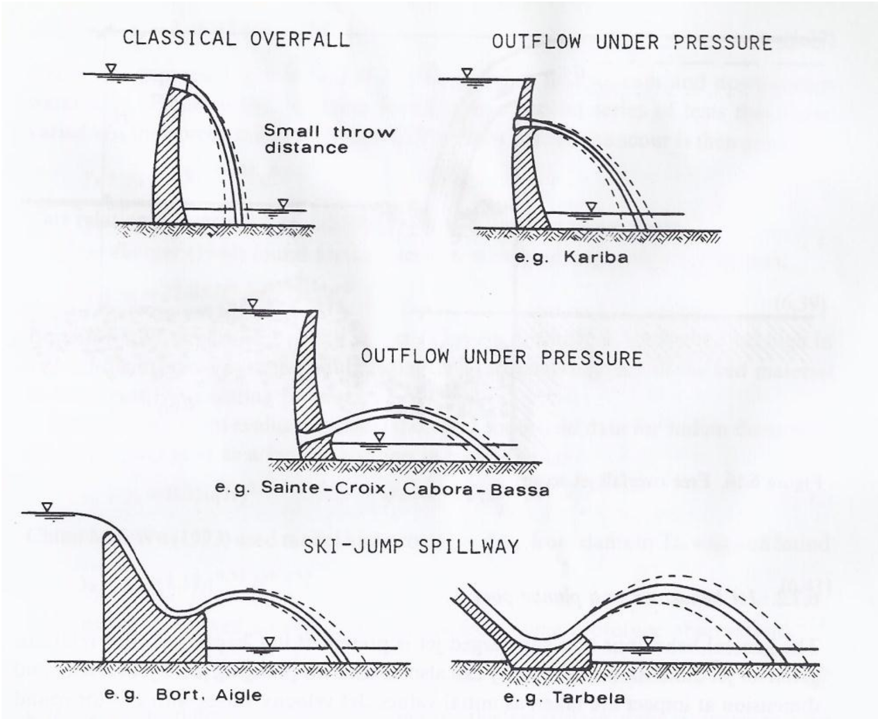
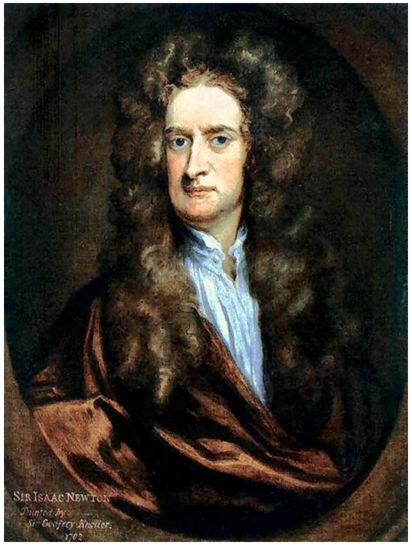
# Jet scour






Newton’s second law

$$\Sigma F = \frac{\mathrm{d}(mu)}{\mathrm{d}t}$$

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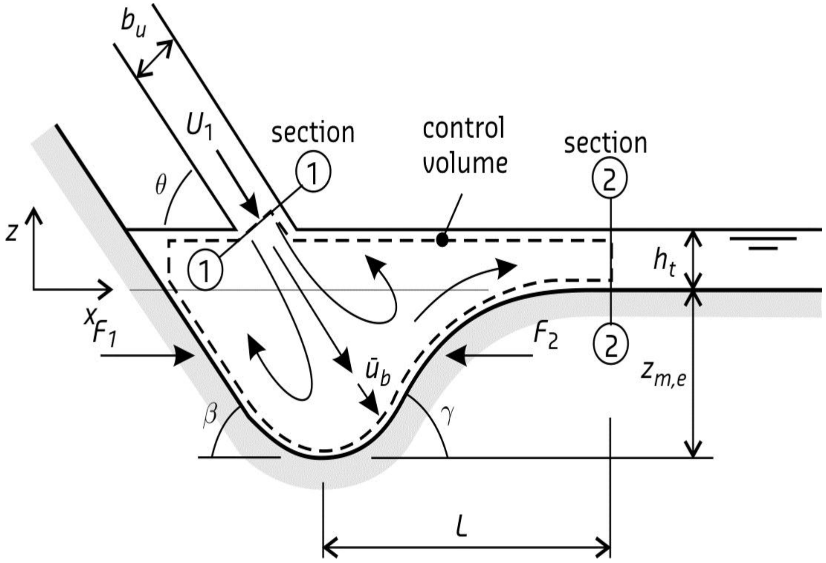
# Jet scour

In the equilibrium phase of the scour process the sum of forces on the fluid element equals zero

$$z_{m,e} + h_t = \frac{\text{load}}{\text{strength}} = \frac{\sqrt{qU_1 \sin\theta / g}}{\left(c_{2V}\right)^{-1}} \quad \text{with} \quad c_{2V} = \sqrt{\left(\frac{\alpha\alpha_b^2}{\Psi_c \Delta D_{90*}^{2/3}} - (1+\varepsilon)\tan\Phi\right)}$$




For $d_{90} < 0.0125$ m $c_{2V} = 20/(D_{90*})^{1/3}$ similar to Schoklitsch (1932)

For $d_{90} > 0.0125$ m $c_{2V}$ is 2.9 similar to Veronese (1937)

Closure problem to jet scour (2009) and Reply by Author (2011)
*Journal of Hydraulic Research,* 47(1) 100–109
*Journal of Hydraulic Research*, 49(2) 276–282



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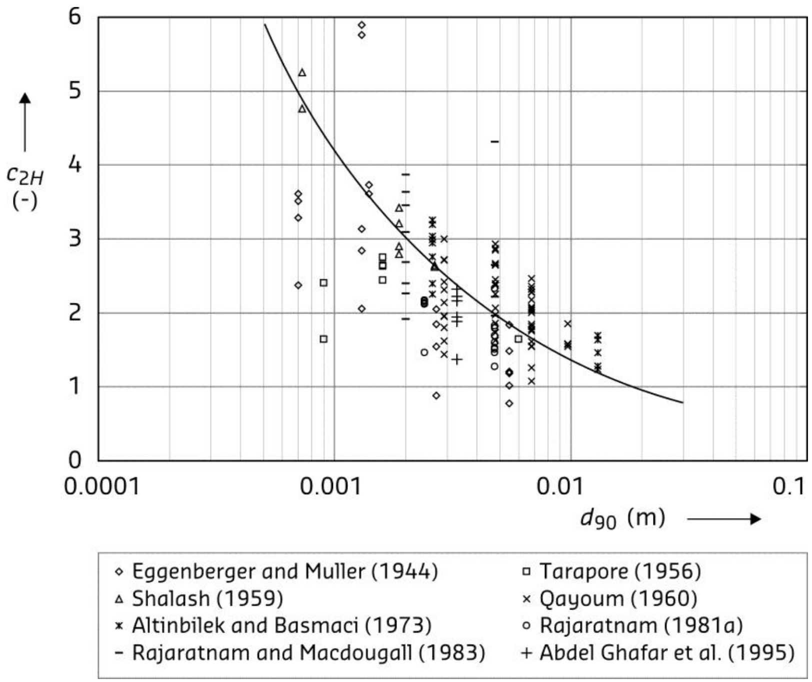
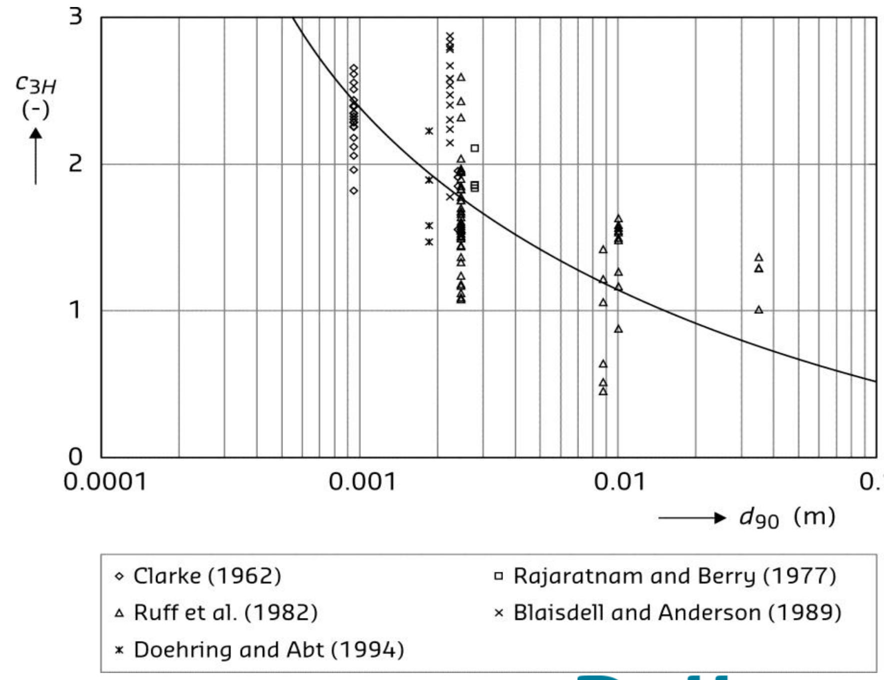
# Jet scour

2D-H $$z_{m,e} = c_{2H}\left(q\left(U_1 - U_2\right)/g\right)^{1/2}$$ with $$c_{2H} = 20\left(D_{90*}\right)^{-1/2}$$

3D-H $$z_{m,e} = c_{3H}\left(Q\left(U_1 - U_2\right)/g\right)^{1/3}$$ with $$c_{3H} = 7\left(D_{90*}\right)^{-1/3}$$

2011, Jet scour, *Maritime Engineering*, Vol. 164 Issue MA4, 185-193

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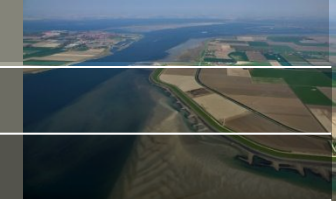
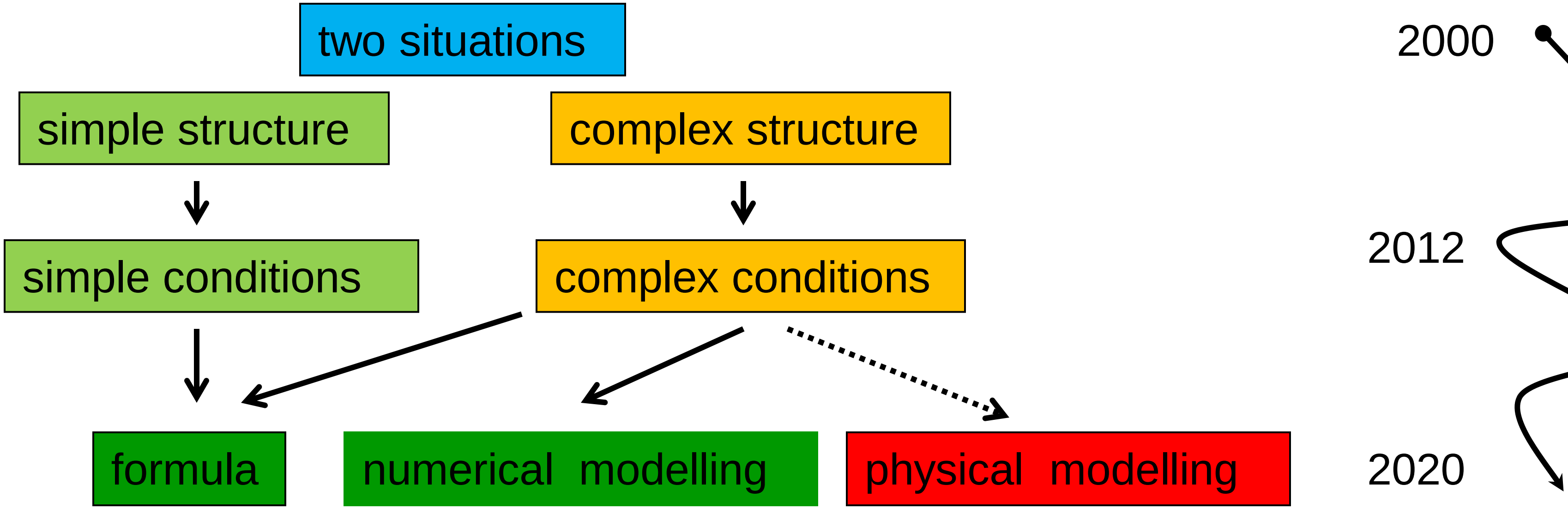
# Road to 2020




Continuation:

more specific semi-empirical formulas,
field tests, et cetera

Or

Common steps to improve the scour and erosion issue



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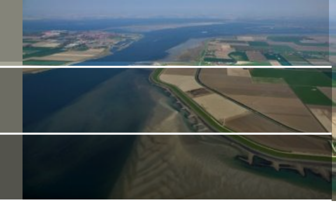
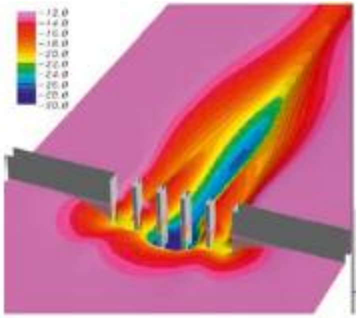


# road to 2020

Goal:

- theoretically based formulas / approach for scour and erosion prediction
- numerical modelling ⟶ software available



Roadmap

2014 ICSE conference: state-of-the-art report

2015 – 2020 Joint Effort

2020 ISCE conference: presentation results

Coordination: TC 213


# road to 2020

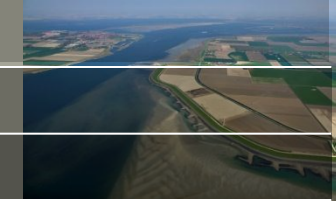
Let us keep in mind:

Nature is simple, however we make complicated formulas because we do not understand it.

1767 Brahms: Weight = Velocity$^6$

Einstein: $E = m c^2$

2012 milestone: roughness = f (turbulence)



Thank you for your attention

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