Deltares
Enabling Delta Life

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Comparison of water jets and conventional propeller jets

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Port Infrastructure Seminar
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conventional propellers

propeller with rudder

outflow velocity: 5 - 8 m/s

azimuthal system

bow thruster

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water jets

low-powered small boats

high-powered fast ferries

outflow velocity:

20 – 25 m/s !!!

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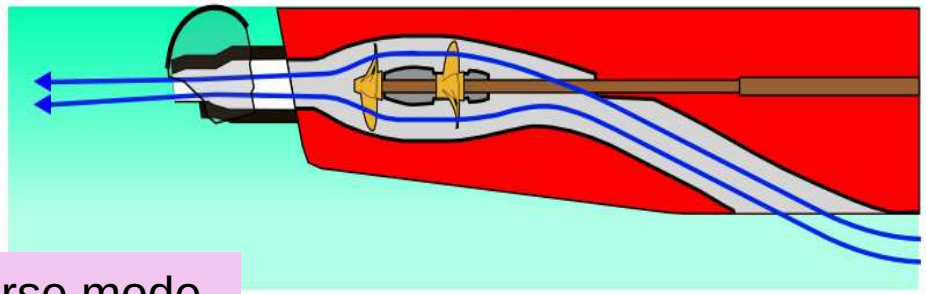
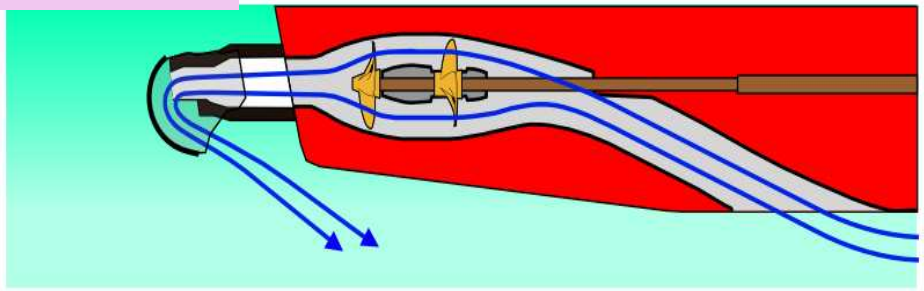
principles of water jets

forward mode



reverse mode



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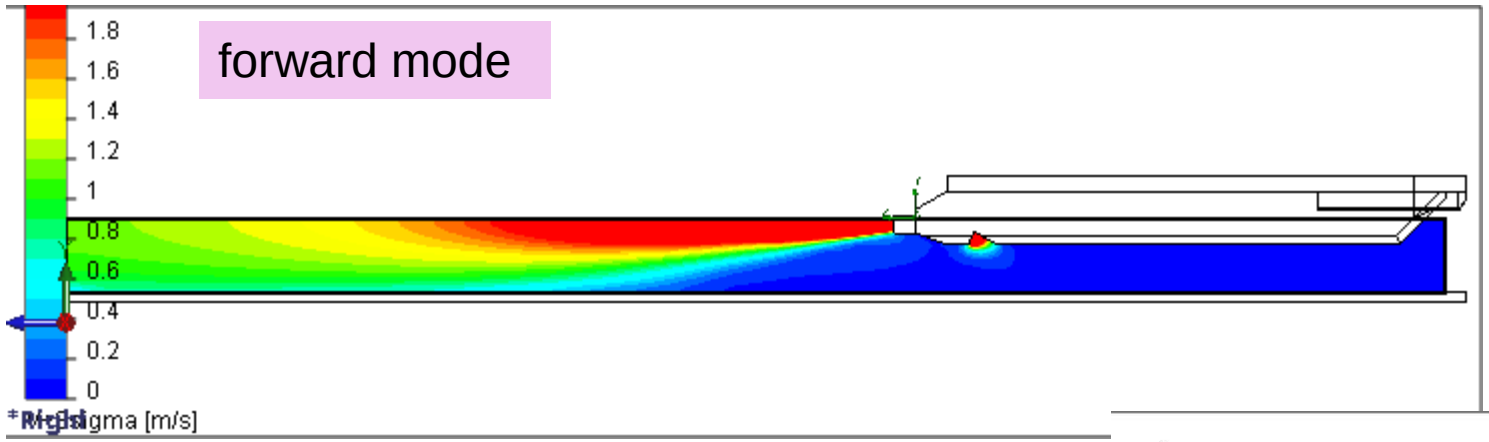
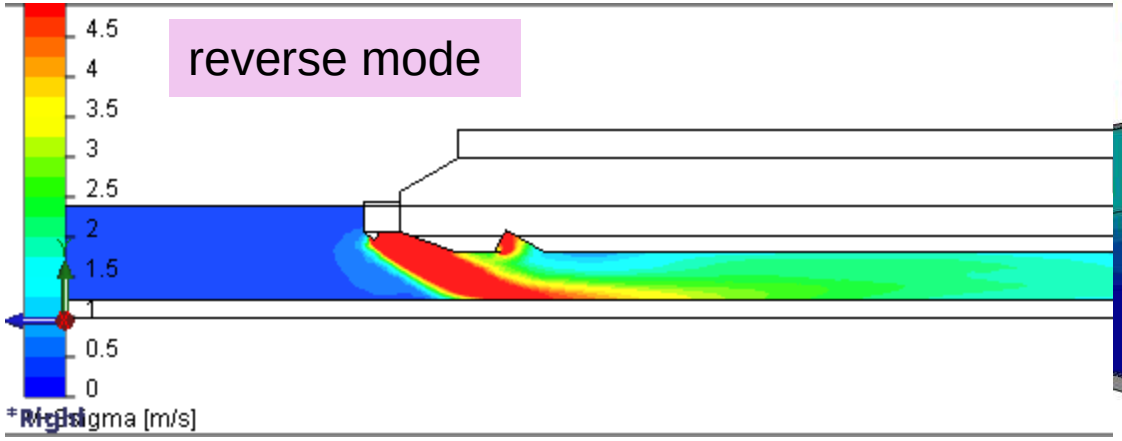
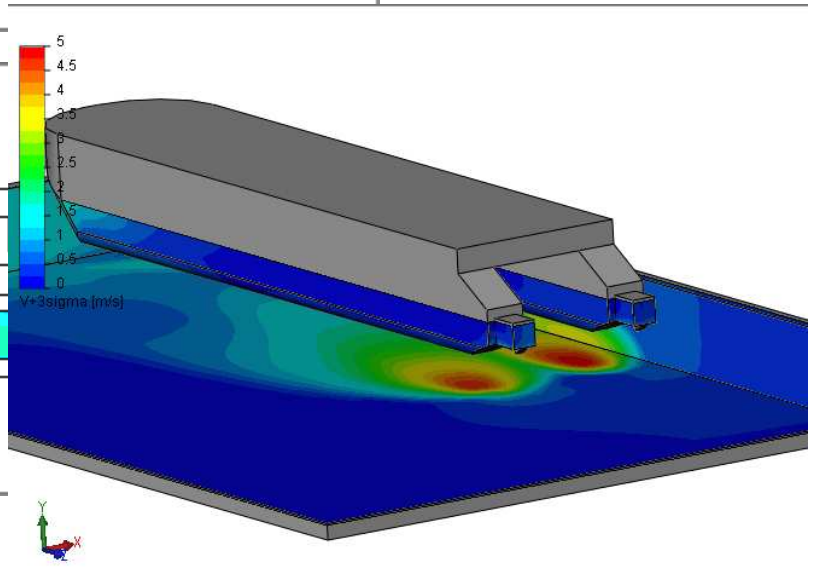
CFD simulations







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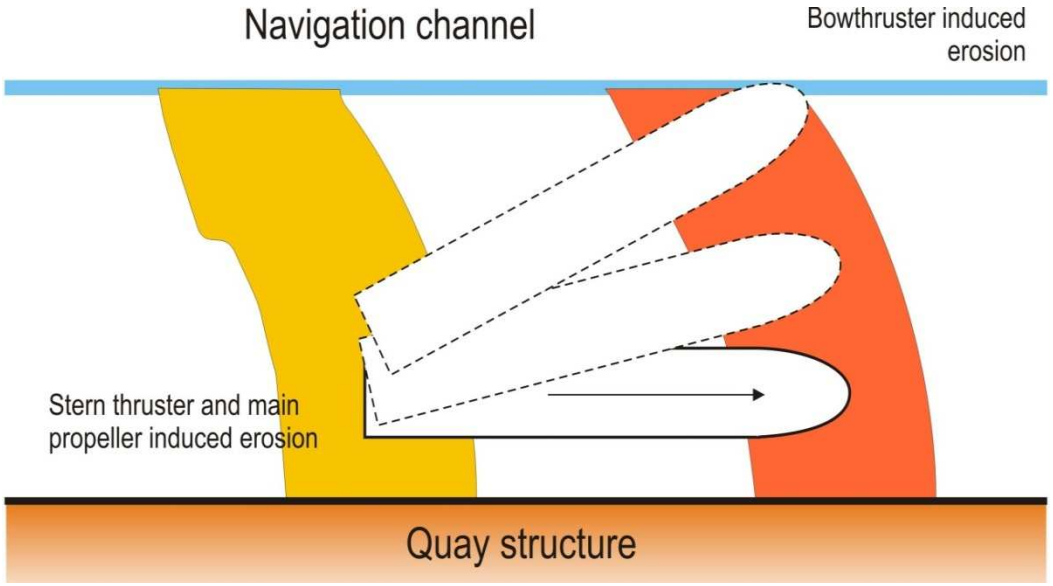
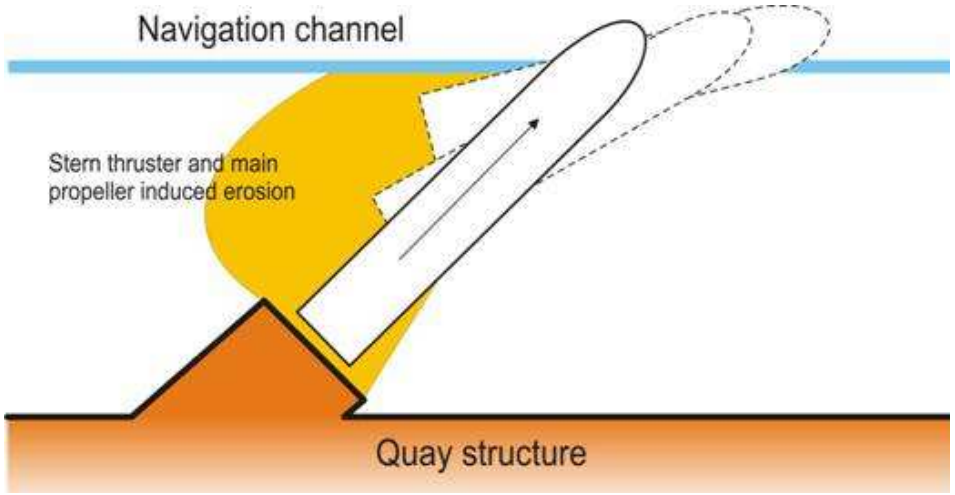
berthing manoeuvres

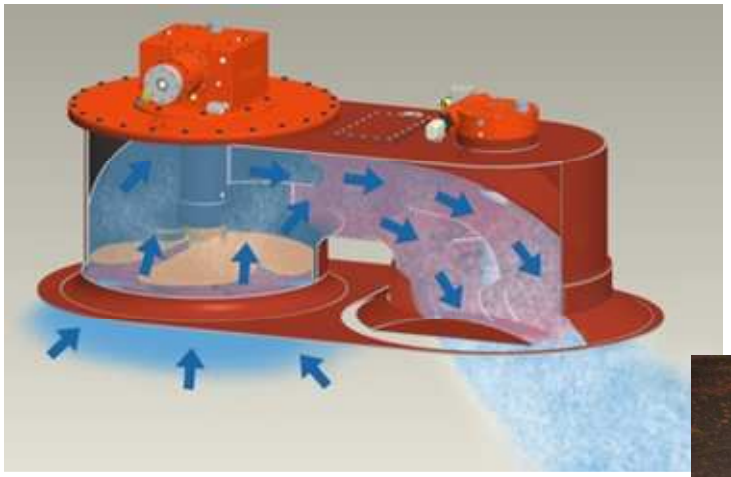
relevant aspects:

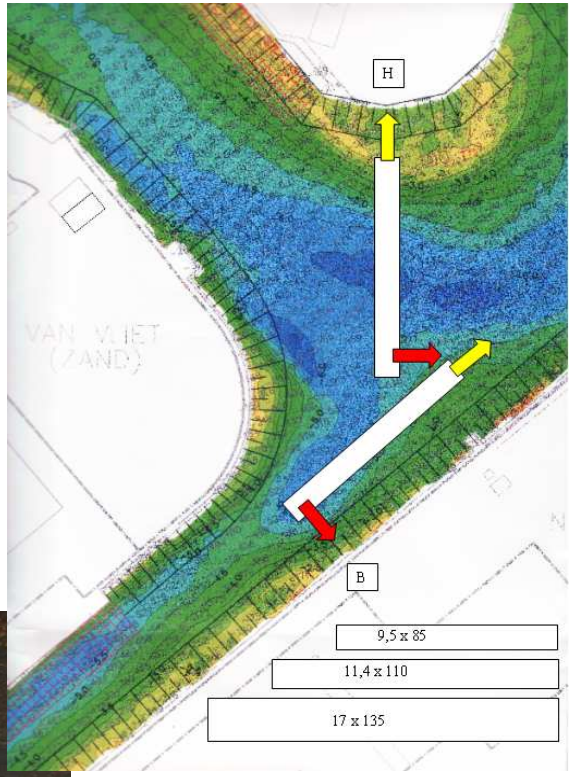
- **manoeuvres**
- **applied power**
- **location quay wall**





inland navigation: pump jets





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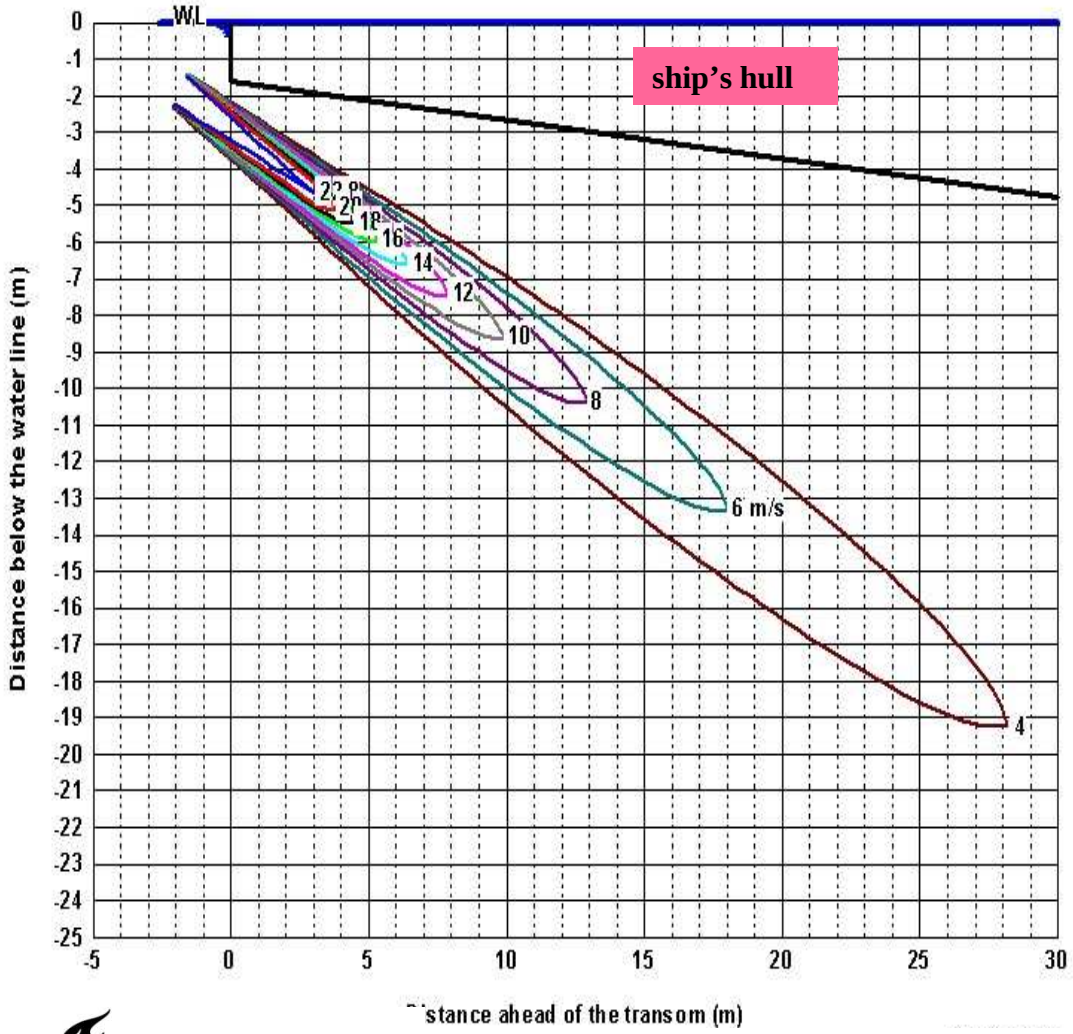
high-powered jets



Stena Discovery: 4 x 17,000 kW

resulting formulas:

$$V_0 = 0.9\left(\frac{f_p P}{\rho A}\right)^{0.33}$$

$$V_{x,r} = 12.4\left(\frac{1}{x}\right)^{1.17} V_0 \exp\left(-92.8\frac{r^2}{x^2}\right)$$

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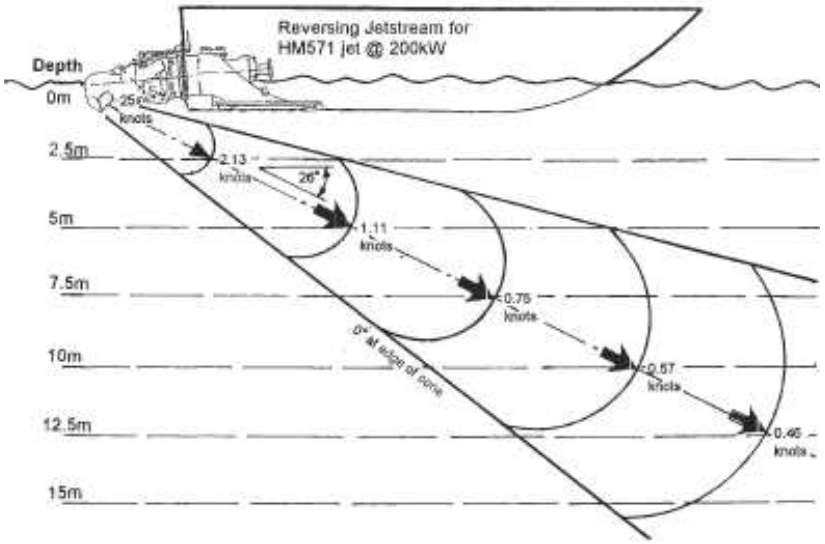
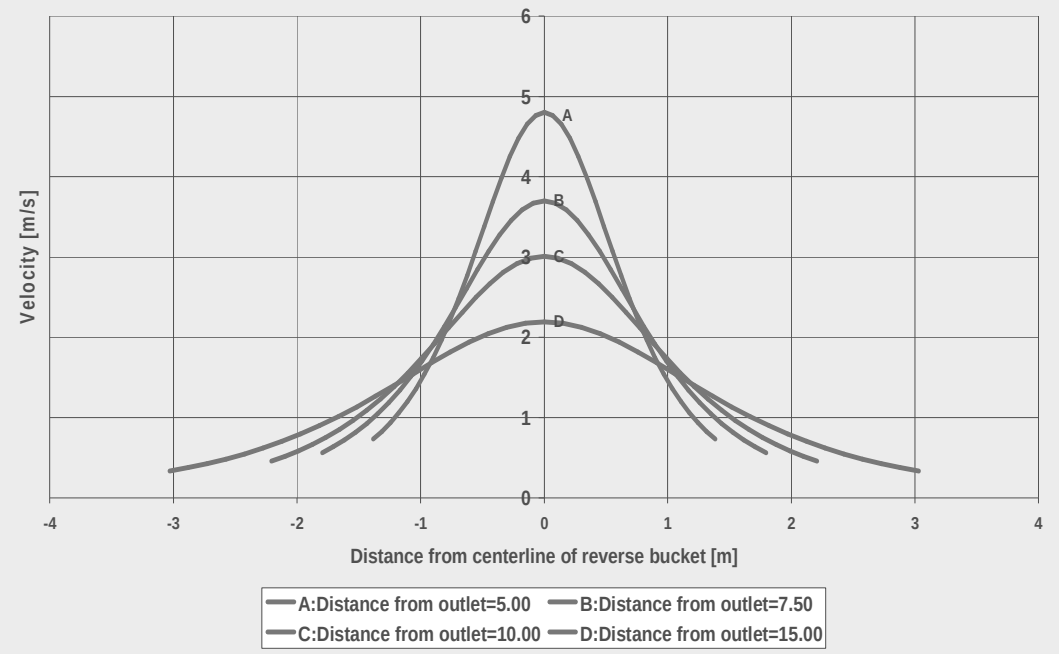
low-powered jets



ferry Terschelling: 2 x 750 kW



resulting formula:

$$V_{x,r} = 2.8 \frac{D_0}{(x)^{0.85}} V_0 \exp\left(-25 \frac{r^2}{x^2}\right)$$

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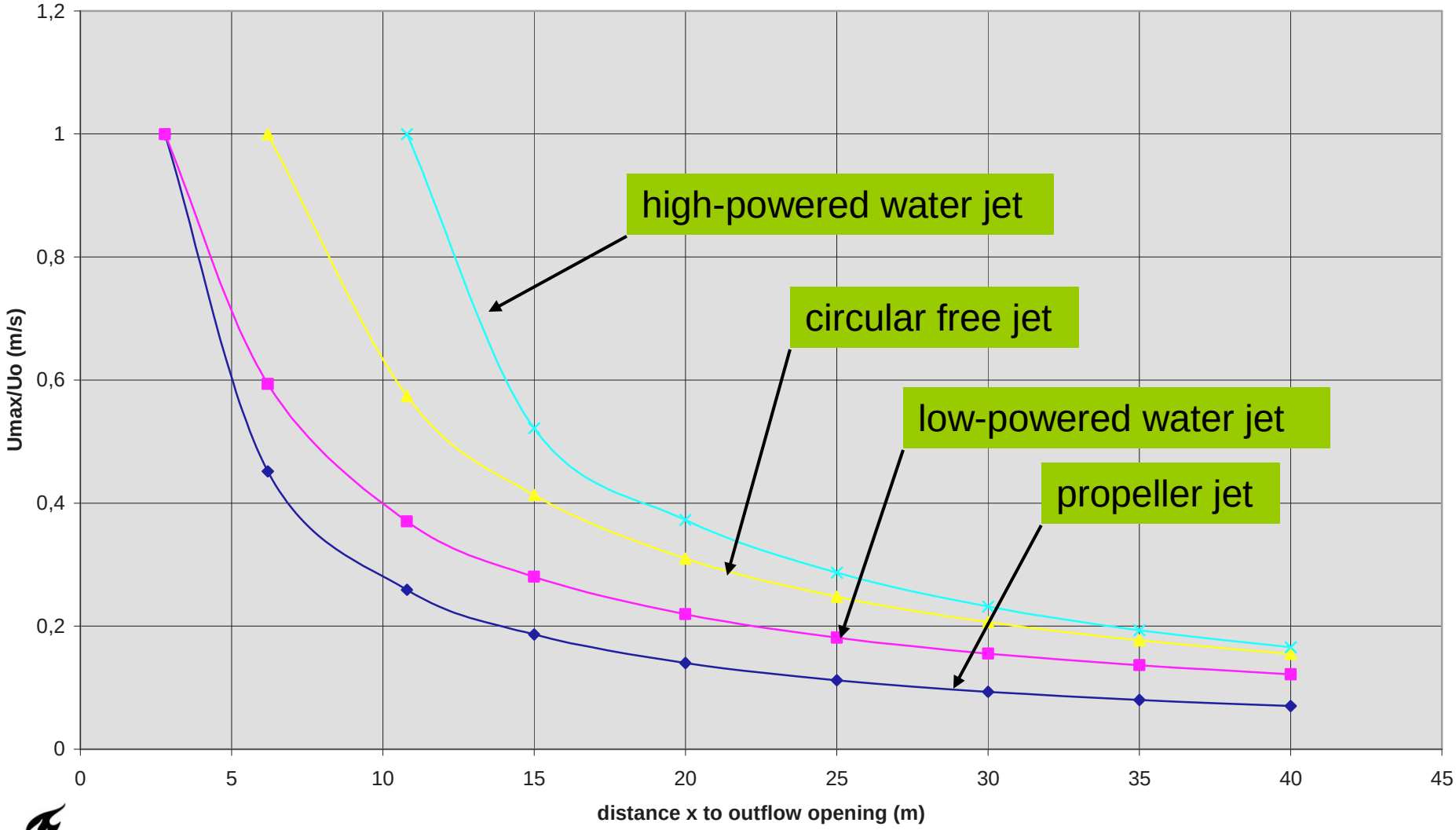
comparison of flow velocities in the jet axis



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comparison flow field formulas

thruster	outflow velocity	velocity in the jet
conventional propeller	$V_0 = 1.1\left(\frac{f_p P}{\rho D^2}\right)^{0.33}$	$V_{x,r} = 2.8\left(\frac{D}{x}\right)^{1.0} V_0 \exp\left(-15.4\frac{r^2}{x^2}\right)$
water jets: - low-powered	$V_0 = 0.9\left(\frac{f_p P}{\rho A}\right)^{0.33}$	$V_{x,r} = 2.8\left(\frac{D_0}{x}\right)^{0.85} V_0 \exp\left(-25\frac{r^2}{x^2}\right)$
- high-powered		$V_{x,r} = 12.4\left(\frac{1}{x}\right)^{1.17} V_0 \exp\left(-92.8\frac{r^2}{x^2}\right)$
circular free jet	$V_0 = \frac{Q}{A}$	$V_{x,r} = 6.2\left(\frac{D}{x}\right)^{1.0} V_0 \exp\left(-69\frac{r^2}{x^2}\right)$

conclusions: 1. low-powered jets resemble conventional propeller jets

2. high-powered jets resemble circular free jets

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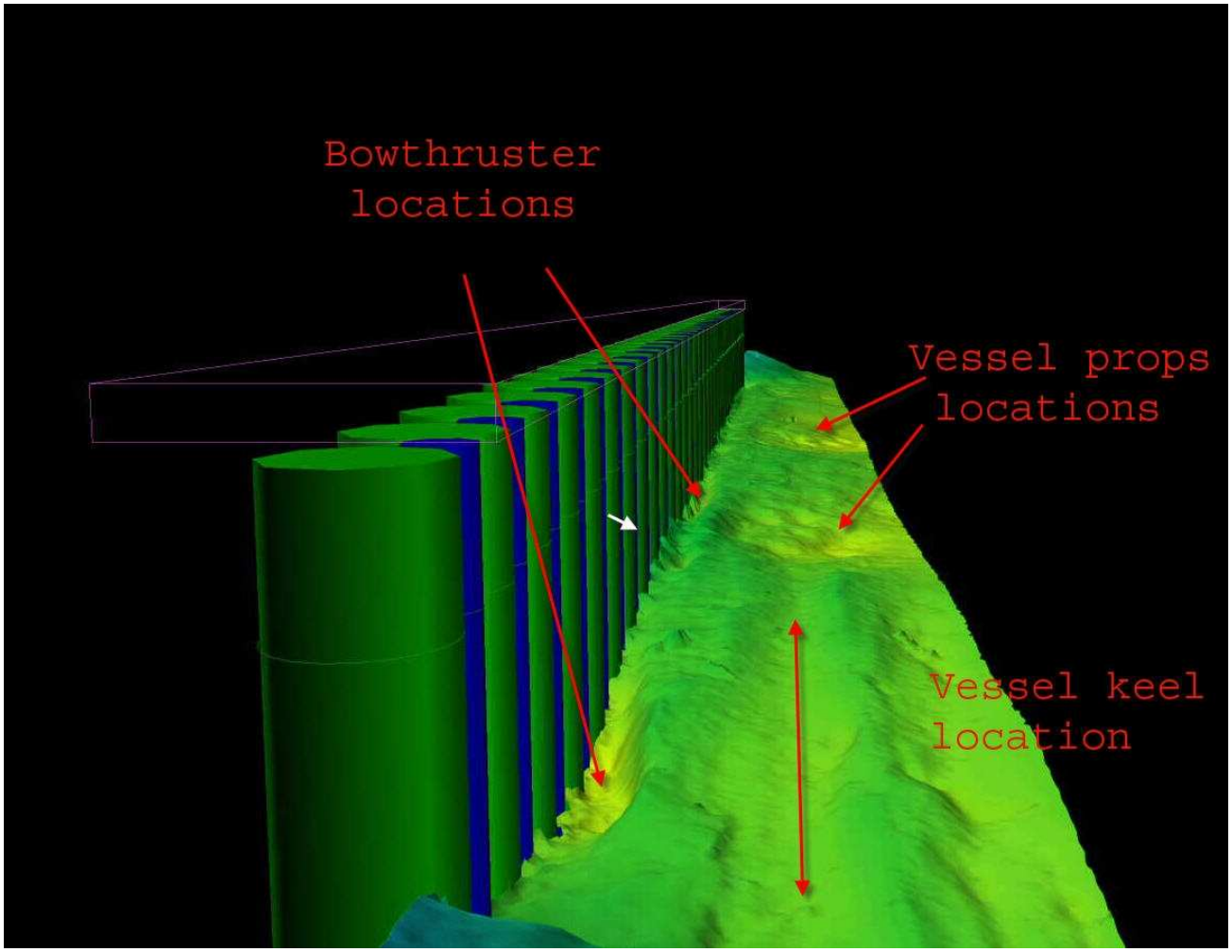
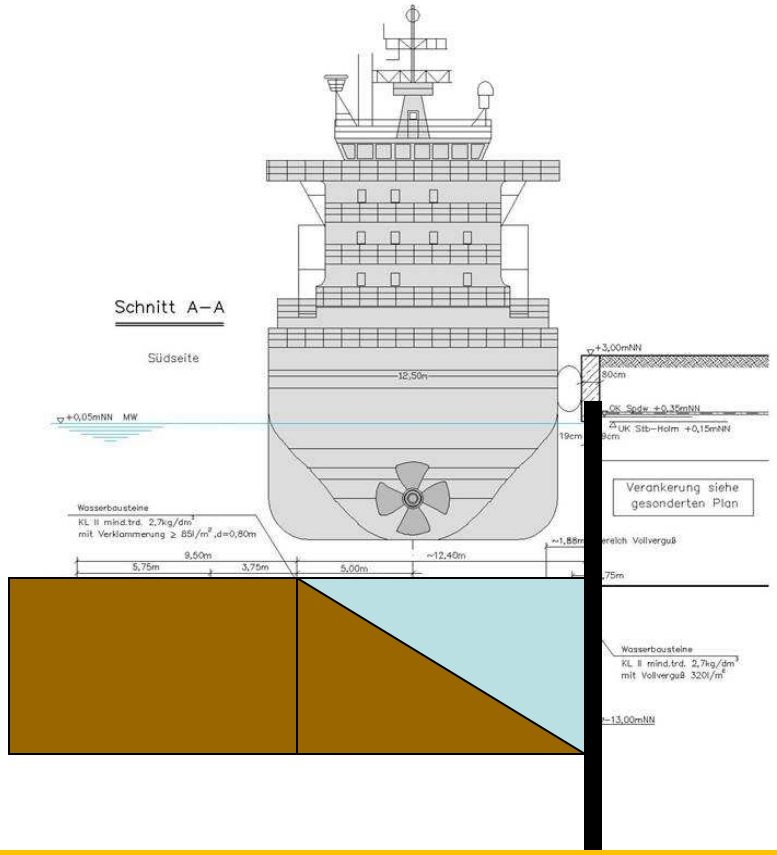
observed jet scour

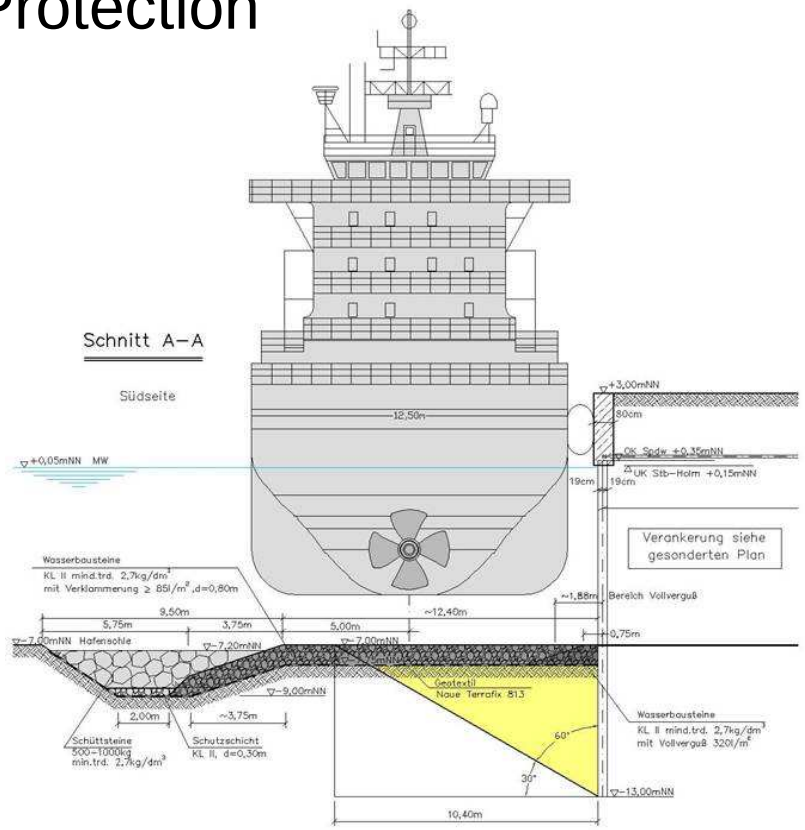


cracks in a road
due to jet scour

extent of scour/protection

Scour <> Protection





Scour: means a longer sheet piling taking into account scour depth
Protection: means additional dredging to realize the constriction thickness

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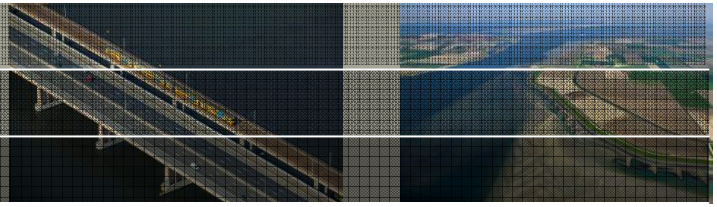
mitigating measures



scour or a bed protection is the consequence of the chain:

captain/pilot – ship – thruster – flow field – scour/protection

- **bed protection:** $d \geq 0.5 \frac{V_{bed}^2}{2g}$

  rock <> mattrasses:
  a rock protection is thicker than a mattress, but might be cheaper

- **no protection but allowing the development of a scour hole:**

$$\frac{S}{d_{85}} = \frac{h_p}{d_{85}} C_{ad} C_{m,r} \left[a_\alpha \frac{B}{B_{crit}} - 1 \right]$$

- **avoiding scour forces by reduction of the applied engine power to less than 10%**

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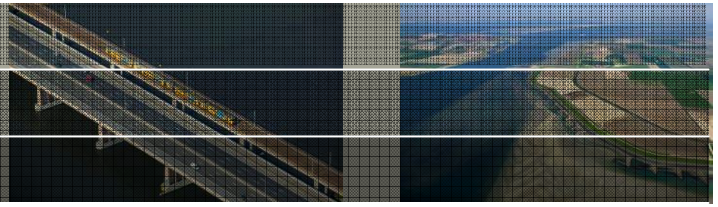
conclusions



- there are significant differences between a high-powered jet and a low-powered jet regarding:
  - the decrease of the flow velocities in the jet axis, and
  - the diffusion of the jet in radial direction
- the characteristic flow field seems to depend on the power and induced turbulence
- low-powered jets resemble the flow field of a conventional propeller jet, although the flow velocities are about 50% higher
- high-powered jets resemble the flow field of a circular free jet
- pump jets installed in inland vessels: probably comparable with a low-powered jet, but no proof