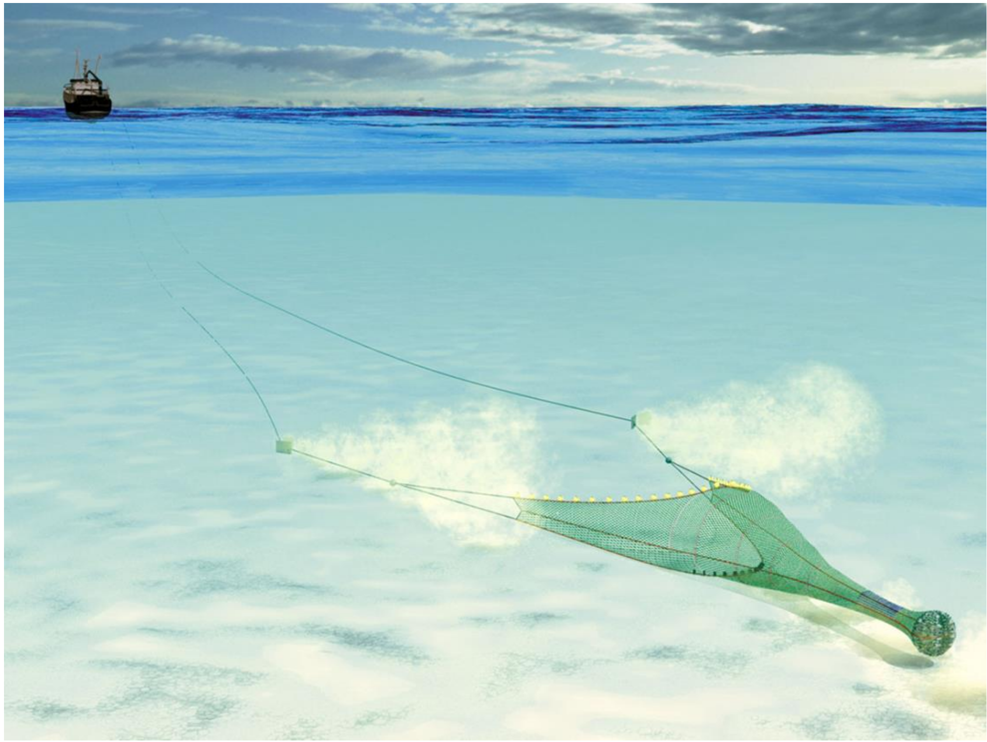
The physical impact of towed demersal fishing gears on soft sediments.

Barry O’Neill

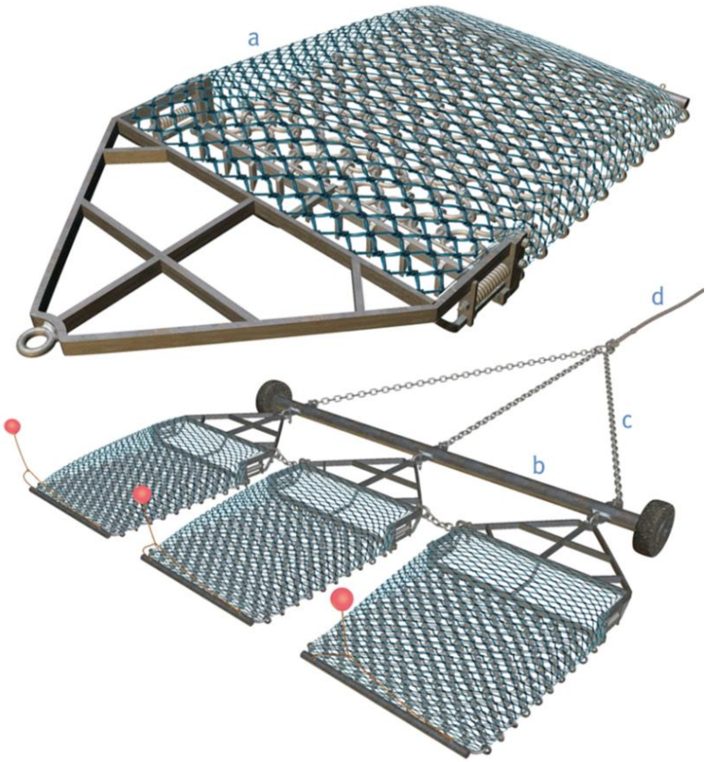
Marine Scotland Science

- baci experiments
- studies across fishing gradients



- little attention has been paid to the physical impacts

- focus on the physical impacts
- experimental work
  - large/small scale modelling studies
  - sand channels / sea trials
  - commercial/experimental fishing gears
- empirical/numerical modelling



predictive methods

- quantify impacts
- put in context / compare with natural disturbance
- identify, develop, design gears to mitigate impact

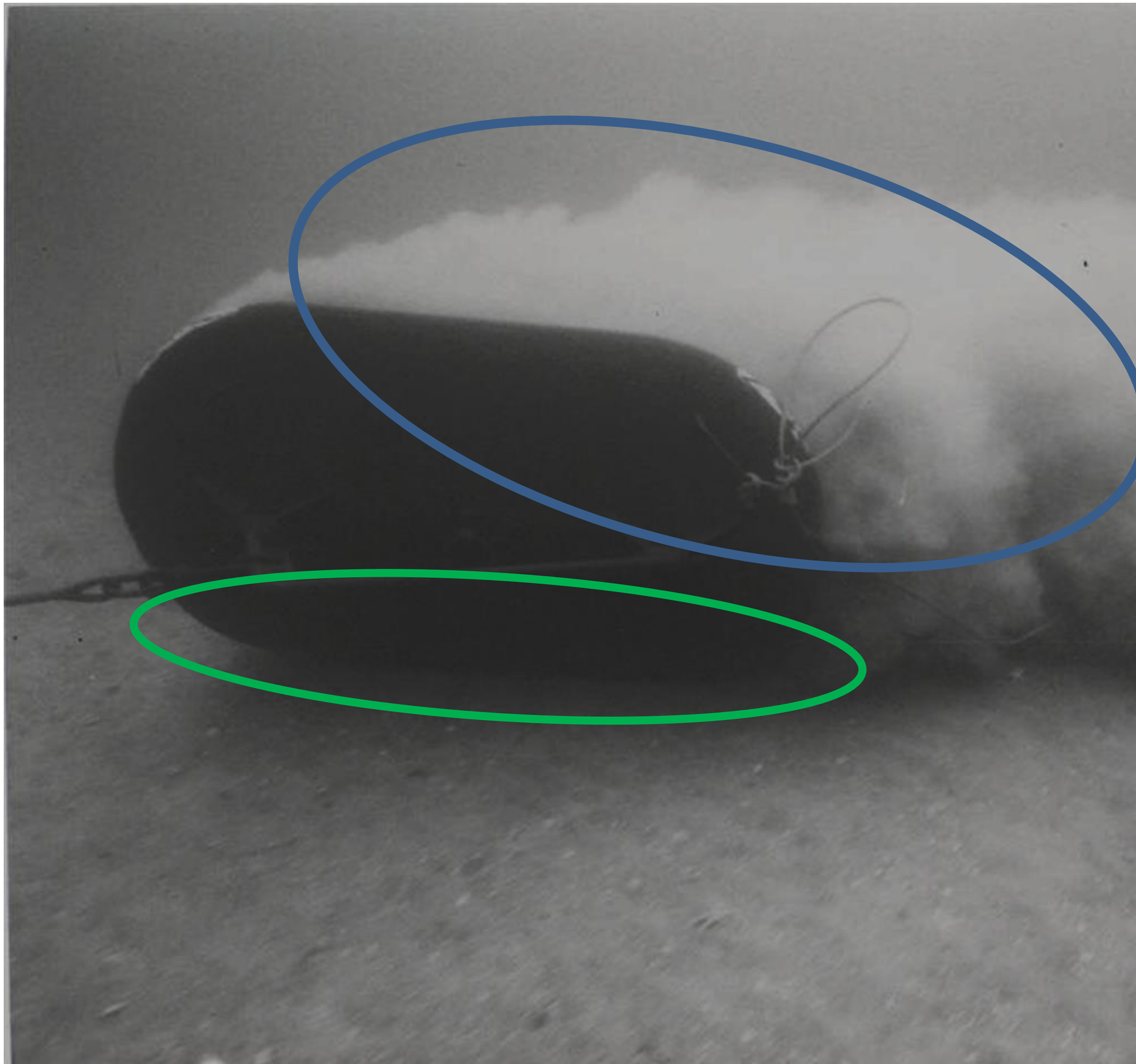
Physical processes

Hydrodynamic

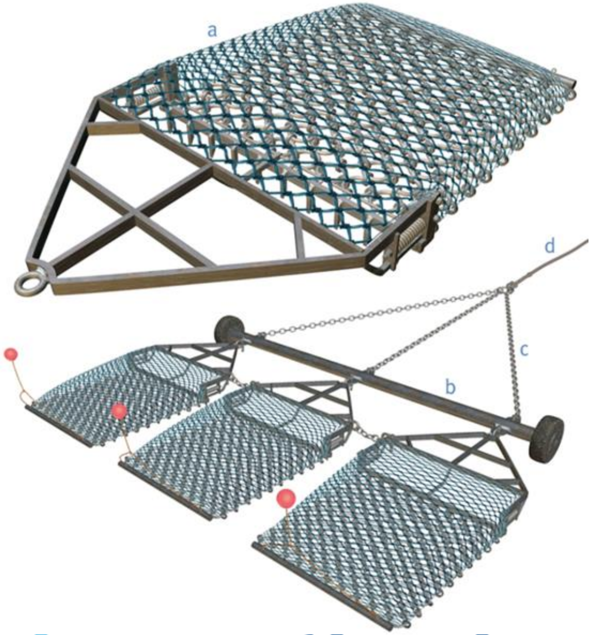
- Turbulent wake
- Sediment mobilisation

Geotechnical

- Penetration
- Lateral displacement
- Stress field



hydrodynamics

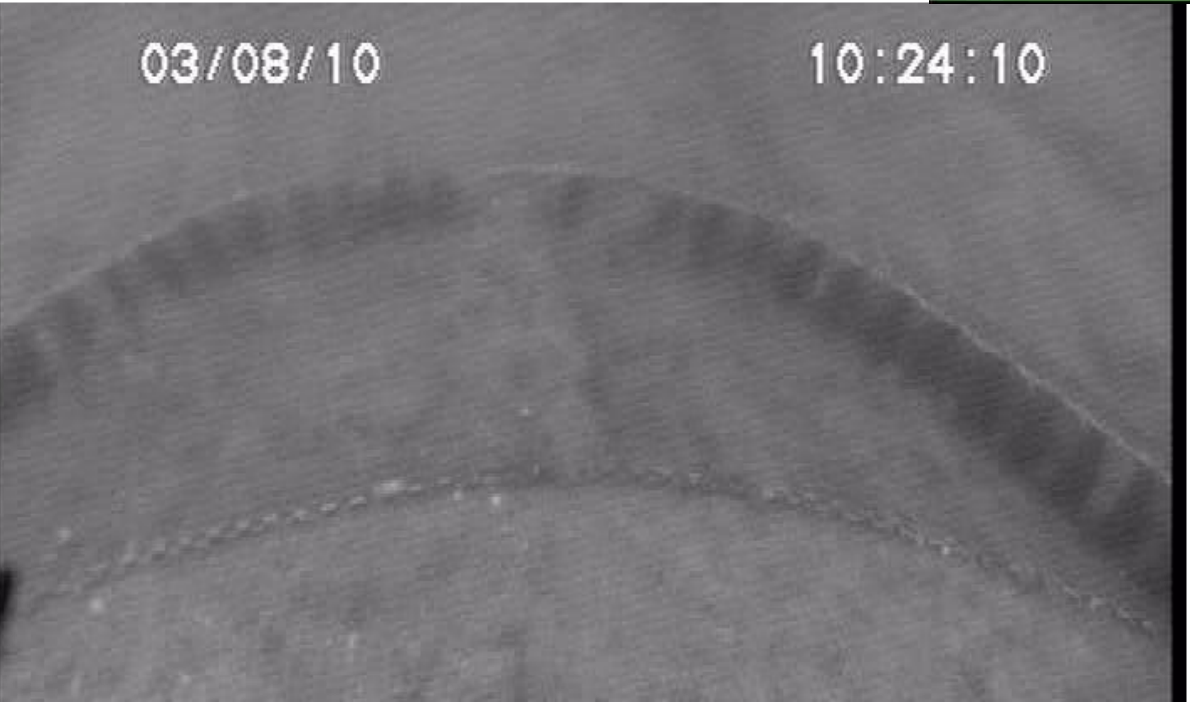


- **Black and Parry (1999)** scallop dredges
- **Dounas (2006)** groundrope
- **Dellapenna et al (2006)** shrimp trawl rig
- **Pravoni et al (2004)** clam harvesting gear
- **Durrieu de Madron (2005)** demersal survey trawl
- **O'Neill et al (2013)** scallop dredge

marinescotland

hydrodynamics

Sediment mobilisation

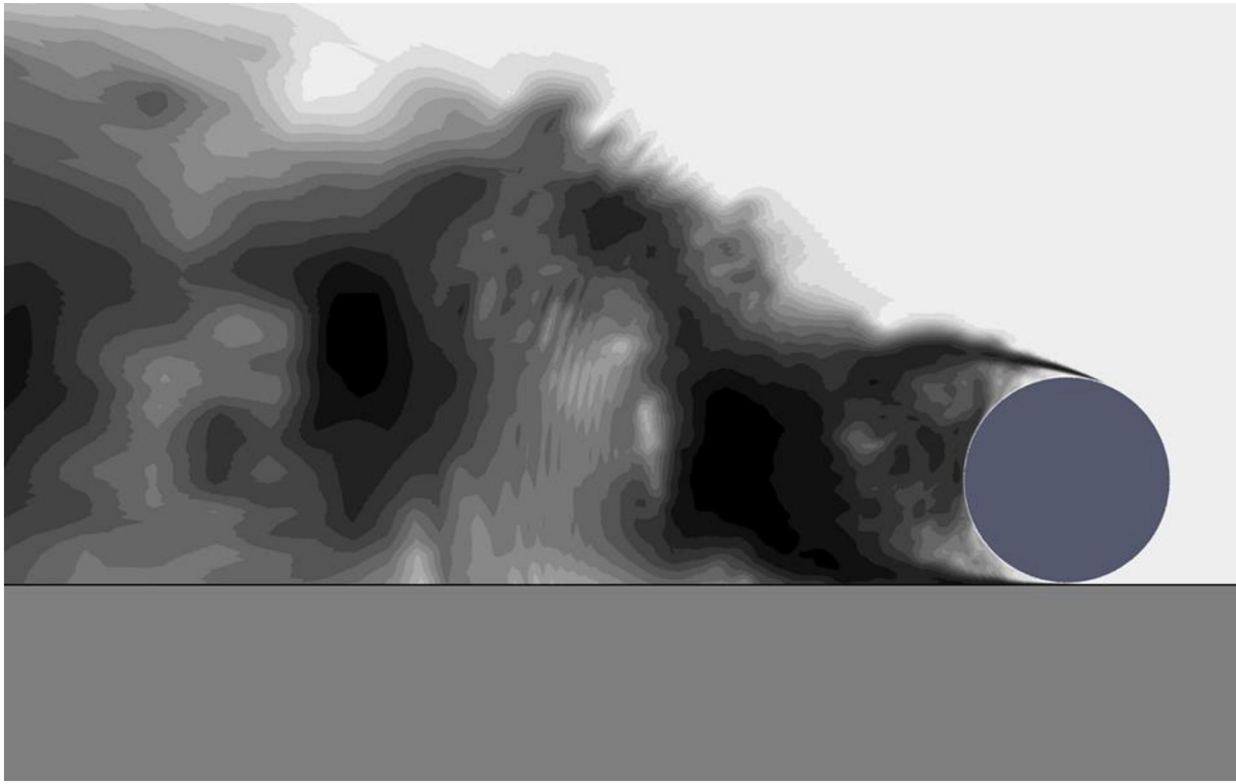


hydrodynamics

Sediment mobilisation

pressure drop

turbulent shearing



hydrodynamics

Can we quantify the turbulence?

Can we relate it to sediment mobilised?

Turbulence ~ total flux of momentum

Conservation of momentum:

hydrodynamic drag = momentum flux

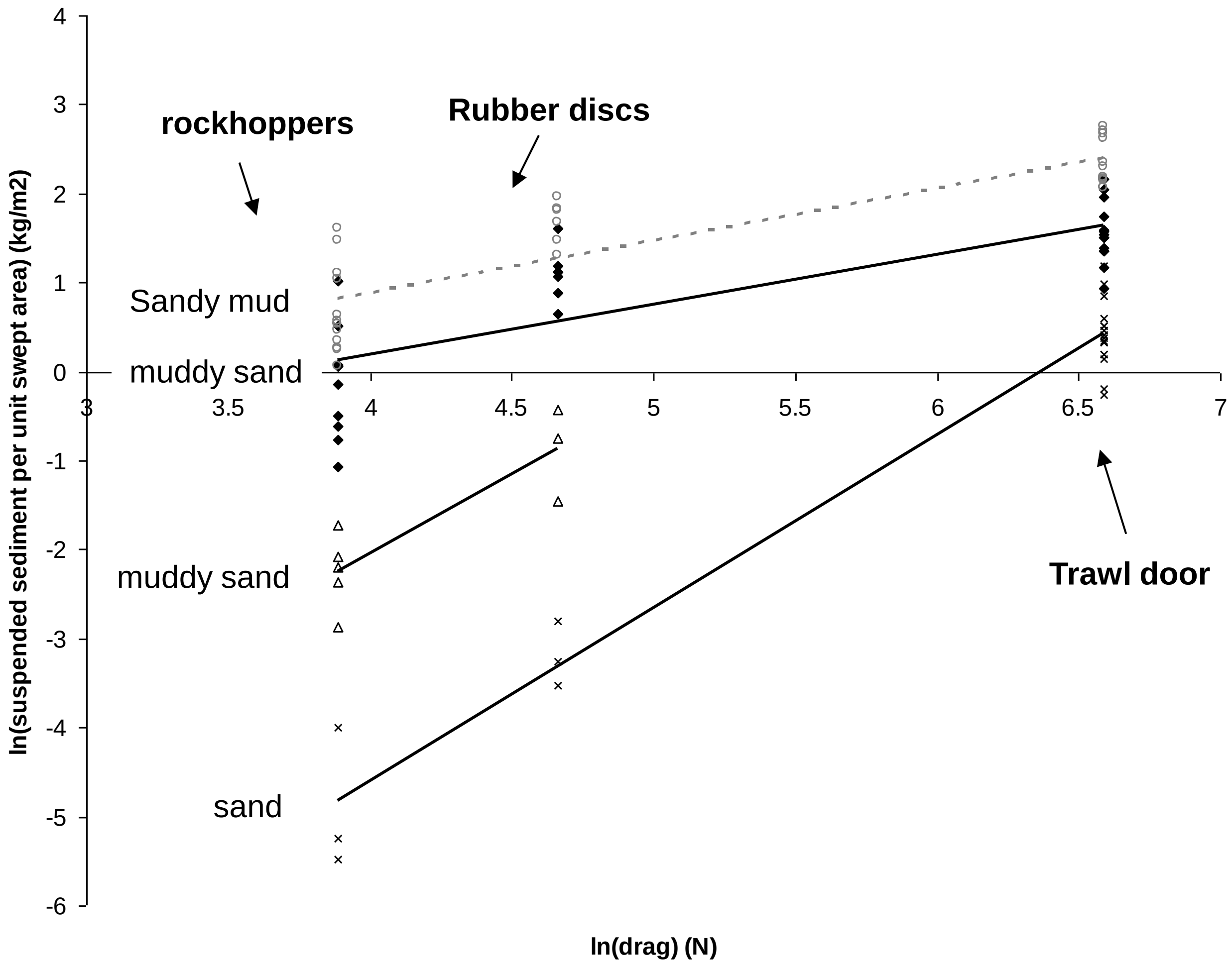
sediment mobilised ~ momentum flux

sediment mobilised ~ hydrodynamic drag

- LISST 100X
  - particle size analyser
- Towed sledge
- Gear components

Sediment mobilisation

- The greater the drag the greater the amount of sediment mobilised
- the finer the sediment the greater the amount mobilised



Towing faster more sediment mobilised

Weight and penetration does not influence quantity of sediment mobilised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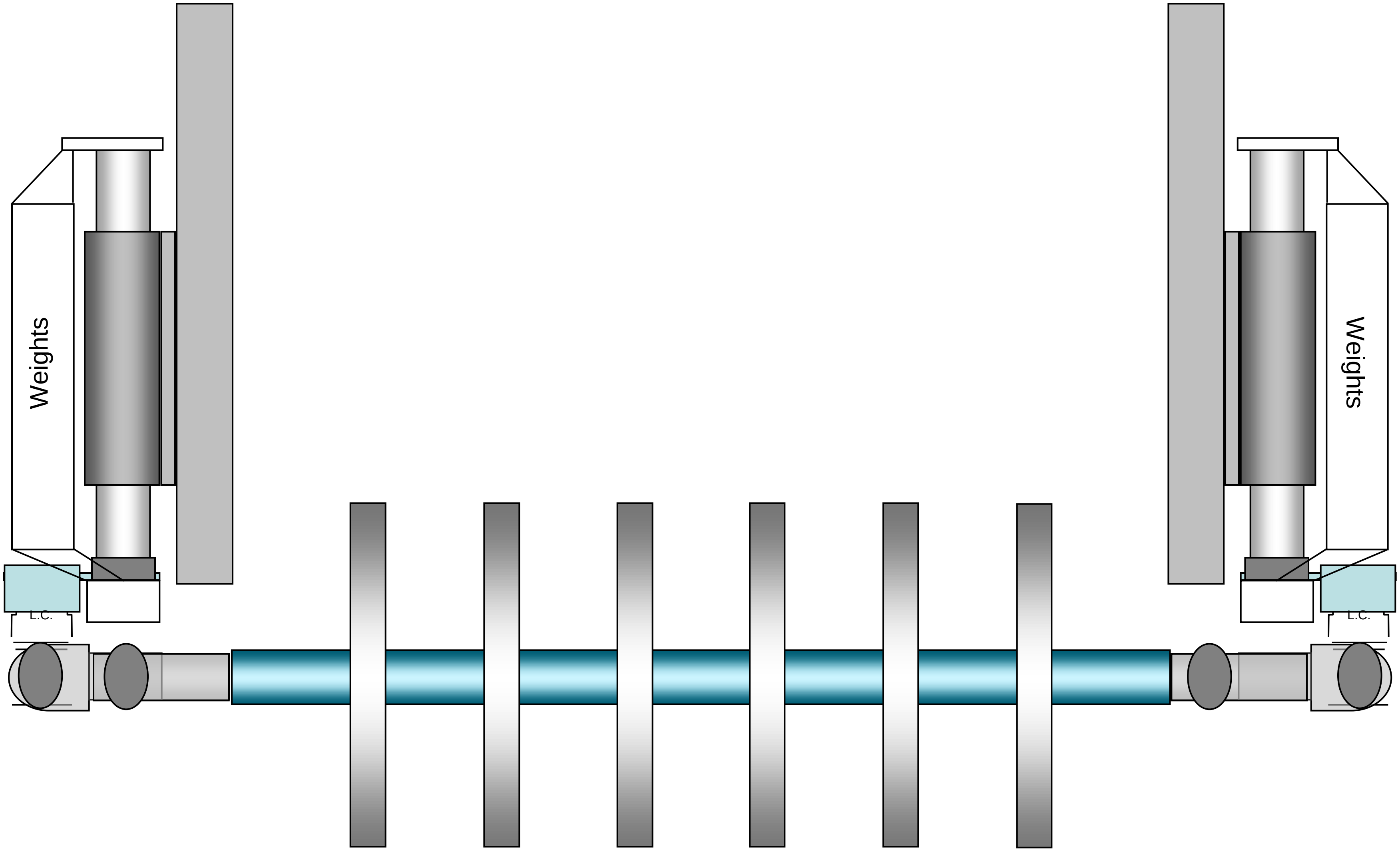
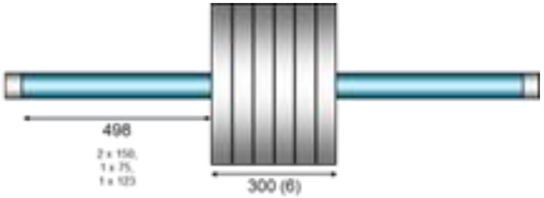
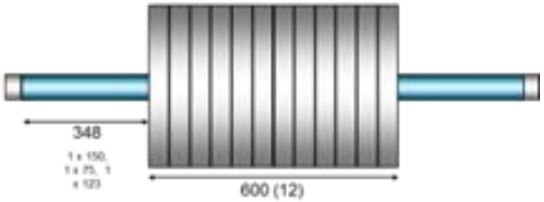
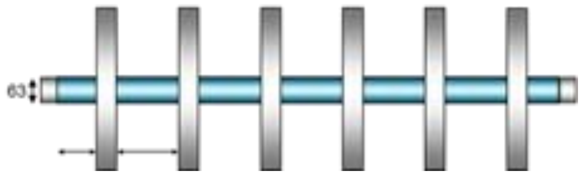


Weights
Weights
L.C.
L.C.


498
2 x 150,
1 x 75,
1 x 123
300 (6)


348
1 x 150,
1 x 75, 1
x 123
600 (12)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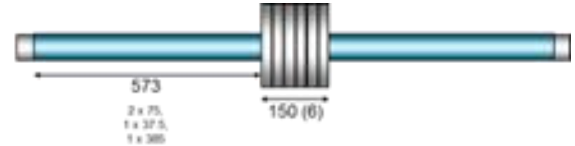
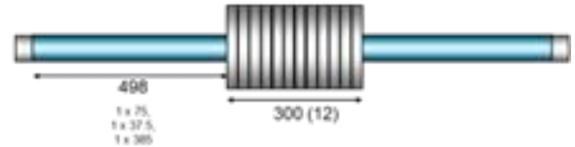
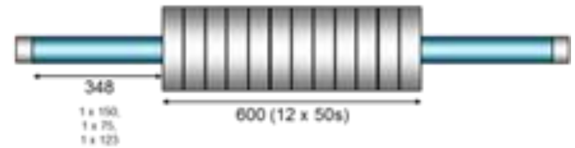
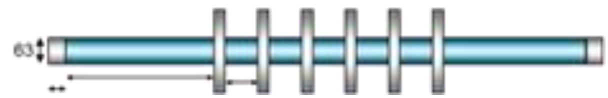

573
2 x 75,
1 x 37.5,
1 x 385
150 (6)


498
1 x 75,
1 x 37.5,
1 x 385
300 (12)


348
1 x 150,
1 x 75,
1 x 123
600 (12 x 50s)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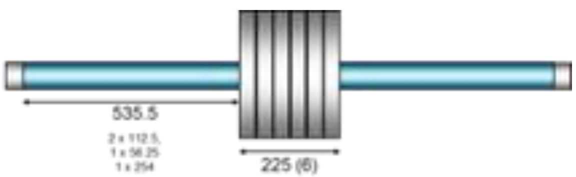
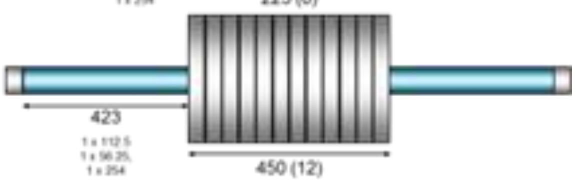
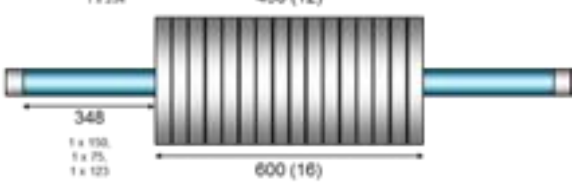
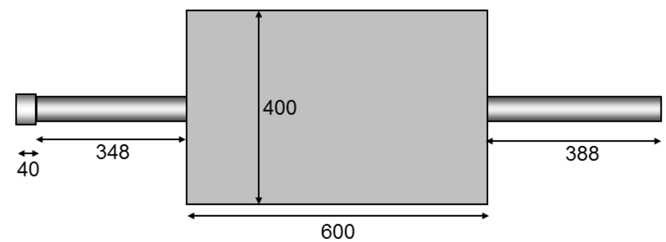
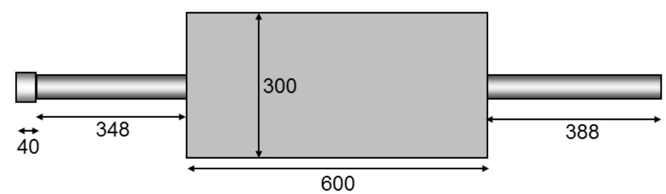
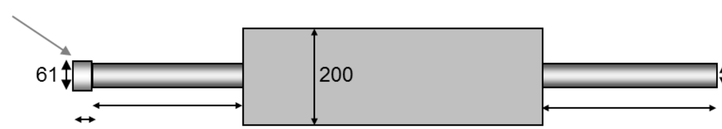

535.5
2 x 112.5,
1 x 56.25
1 x 254
225 (6)


423
1 x 112.5
1 x 56.25,
1 x 254
450 (12)

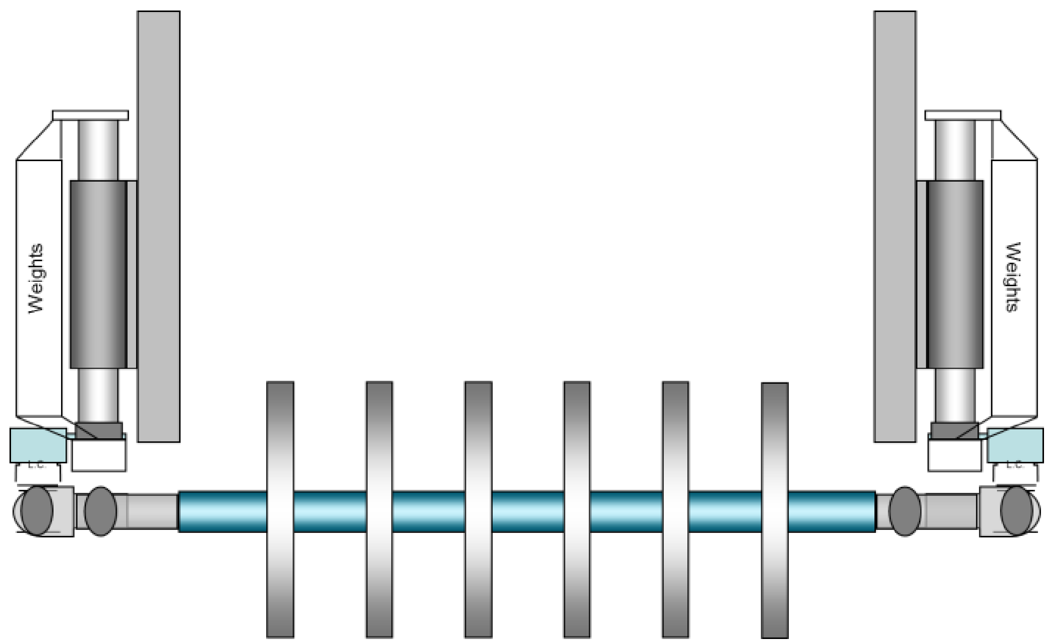

348
1 x 150,
1 x 75,
1 x 123
600 (16)

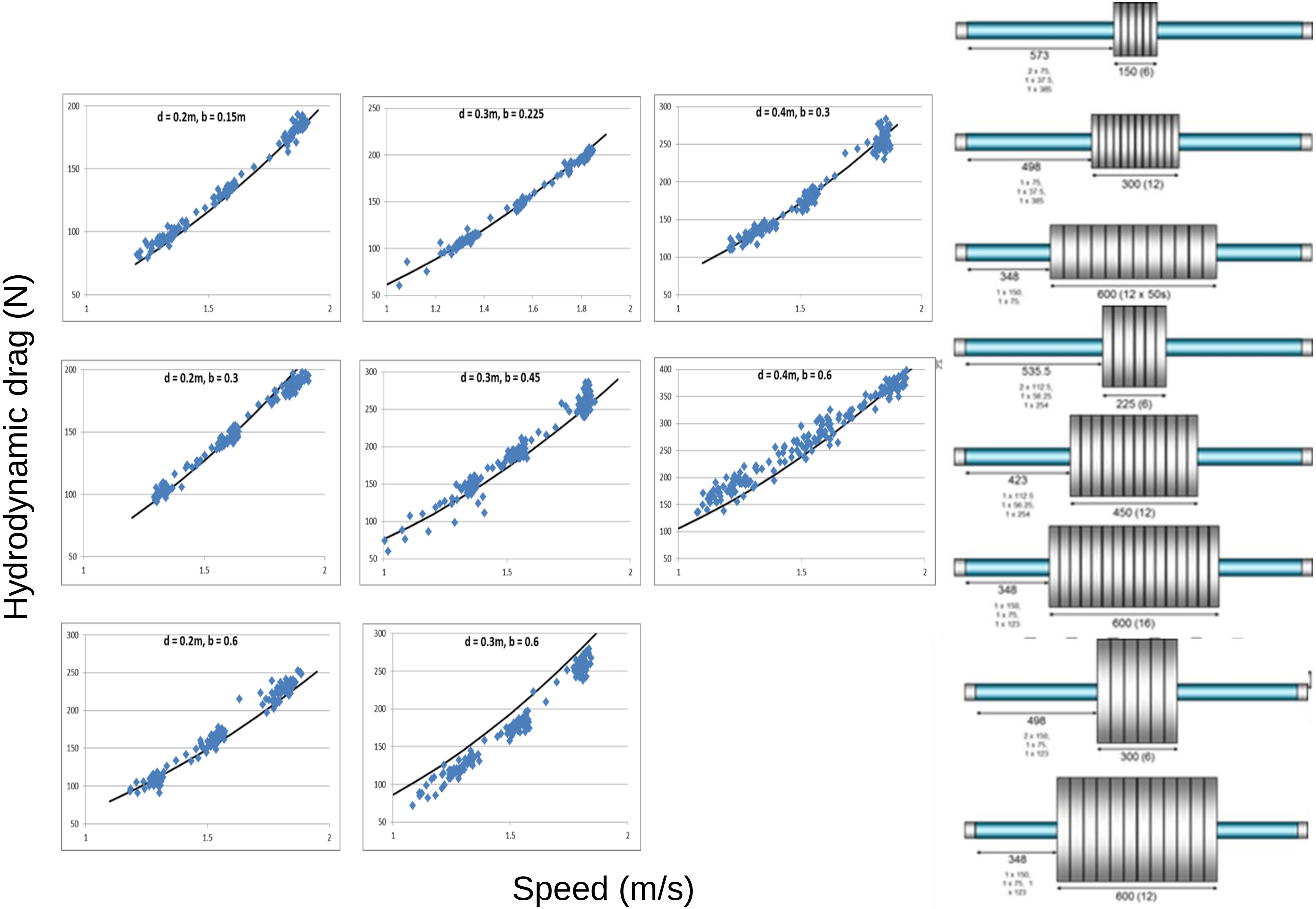

400
348
40
388
600


300
348
40
388
600


61
200

- Not touching the sea bed (tied up)
  - Hydrodynamic only
- Three different weights
  - ~ 60, 120, 180kg
  - Hydrodynamic and geotechnical
- Range of speeds
  - ~ 1 – 2 ms^{-1}
- Fixed and rolling
- sediment in wake and drag





Hydrodynamic drag (N)
Speed (m/s)
d = 0.2m, b = 0.15m
d = 0.3m, b = 0.225
d = 0.4m, b = 0.3
d = 0.2m, b = 0.3
d = 0.3m, b = 0.45
d = 0.4m, b = 0.6
d = 0.2m, b = 0.6
d = 0.3m, b = 0.6
573
150 (6)
498
300 (12)
348
600 (12 x 50s)
535.5
225 (6)
423
450 (12)
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600 (16)
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600 (12)

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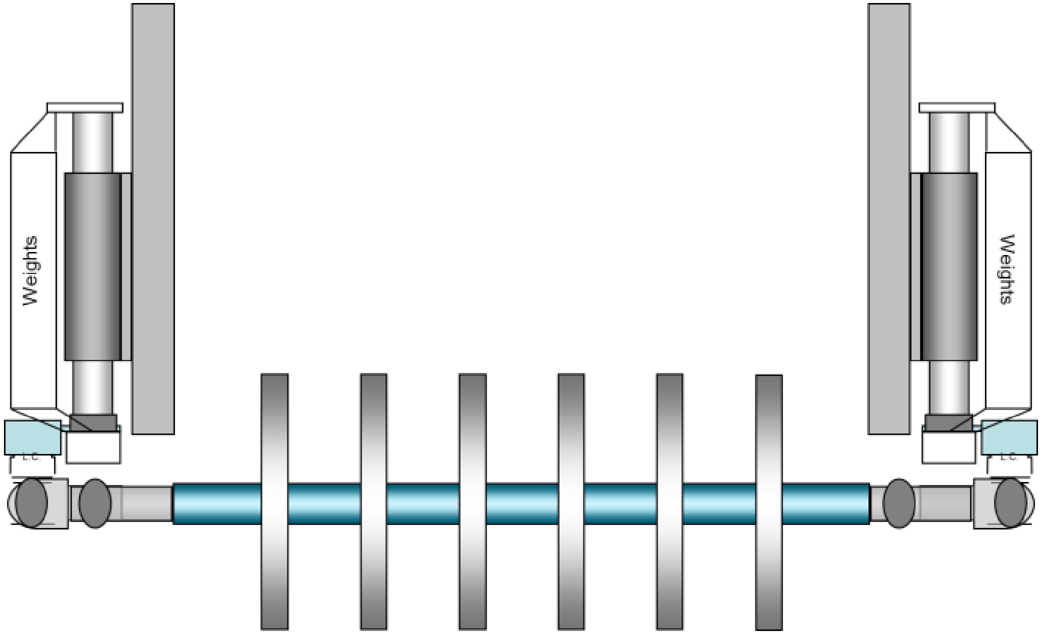
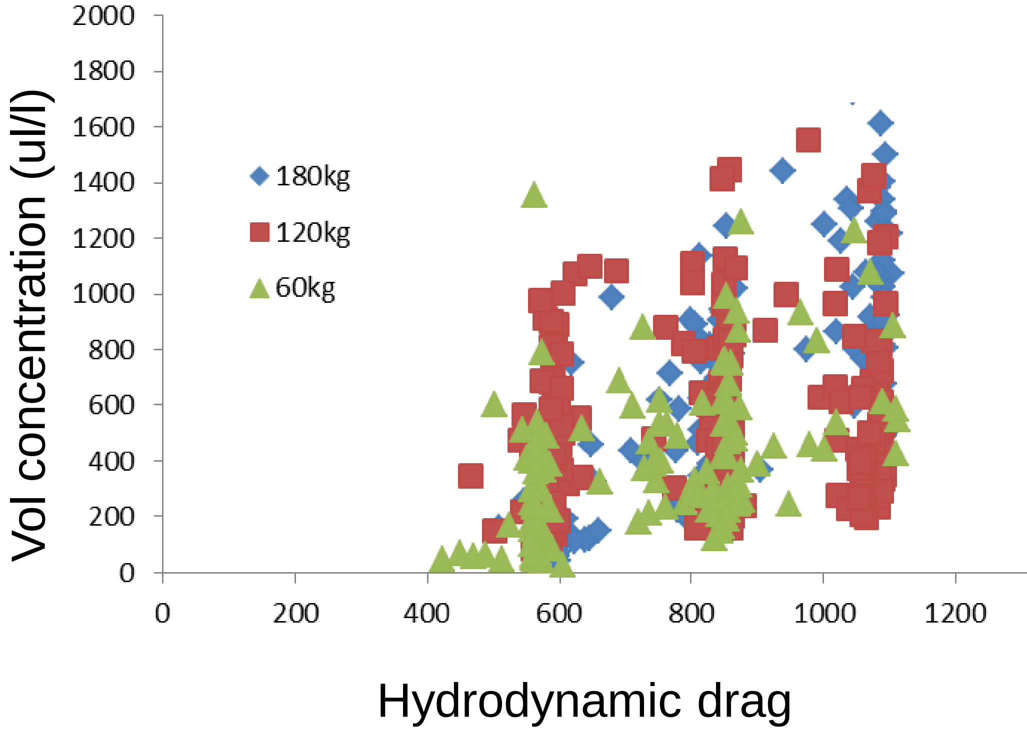


Hydrodynamics and mobilisation of sediment

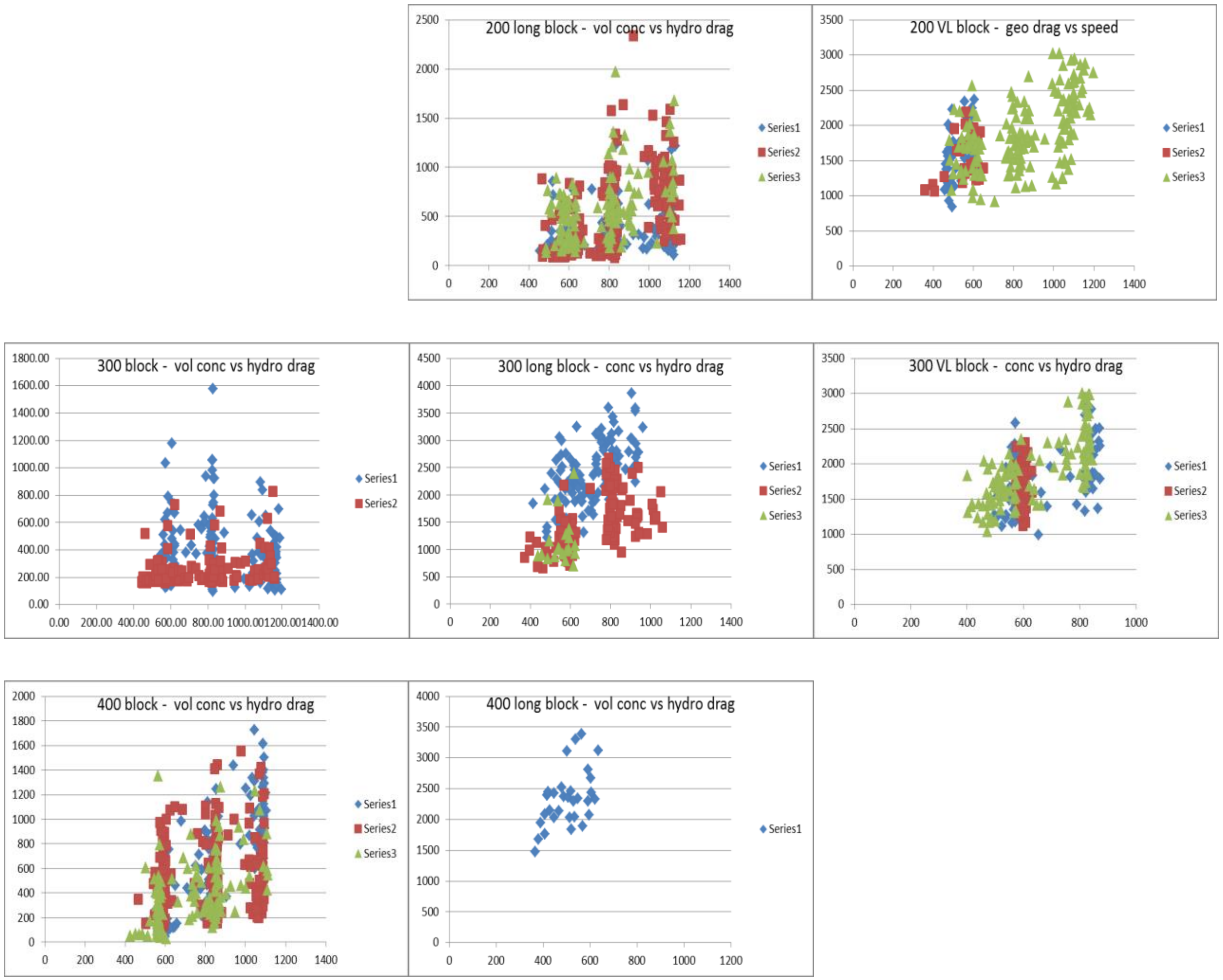
As speed increases the amount of sediment mobilised increases

Weight and penetration do not influence quantity of sediment mobilised

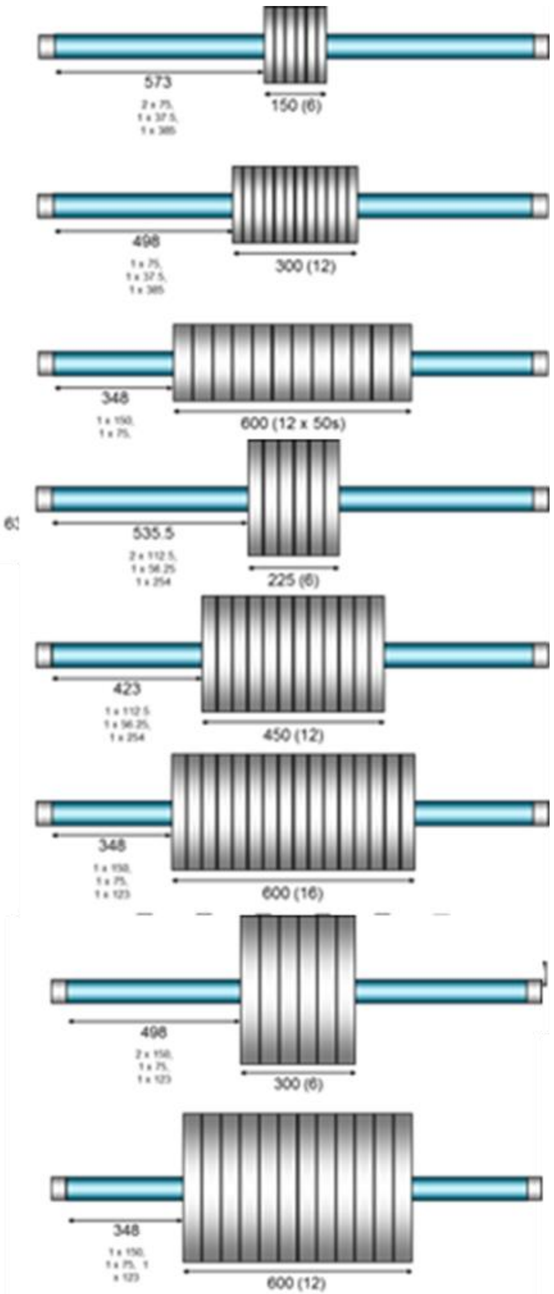


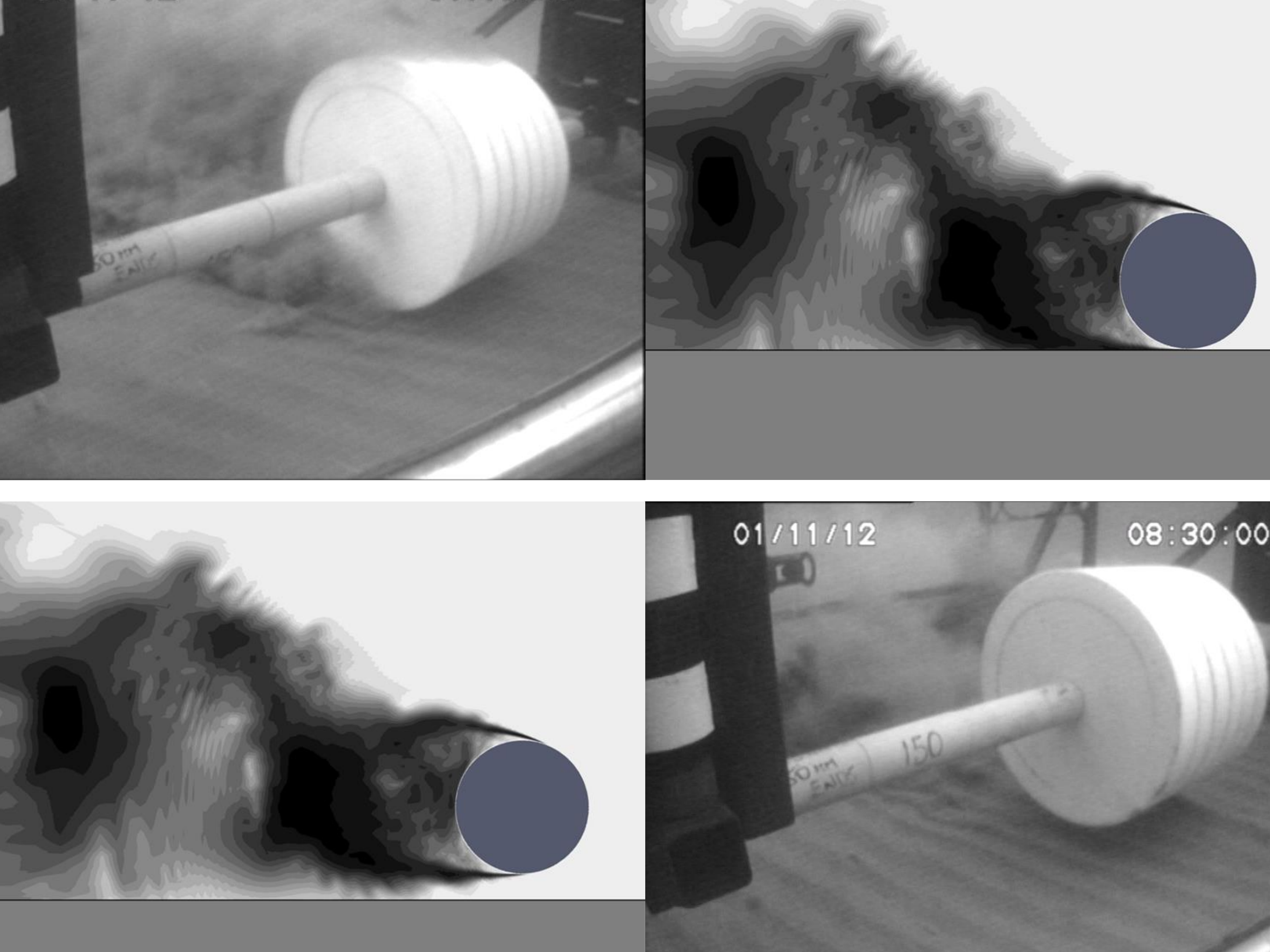
Hydrodynamics and mobilisation of sediment

Vol concentration (ul/l)



Hydrodynamic drag





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150

Hydrodynamics and mobilisation of sediment

Sediment mobilisation is primarily a hydrodynamic process

quantity of sediment mobilised ~ hydrodynamic drag

The finer the sediment the more sediment mobilised

weight and penetration do not influence quantity of sediment mobilised

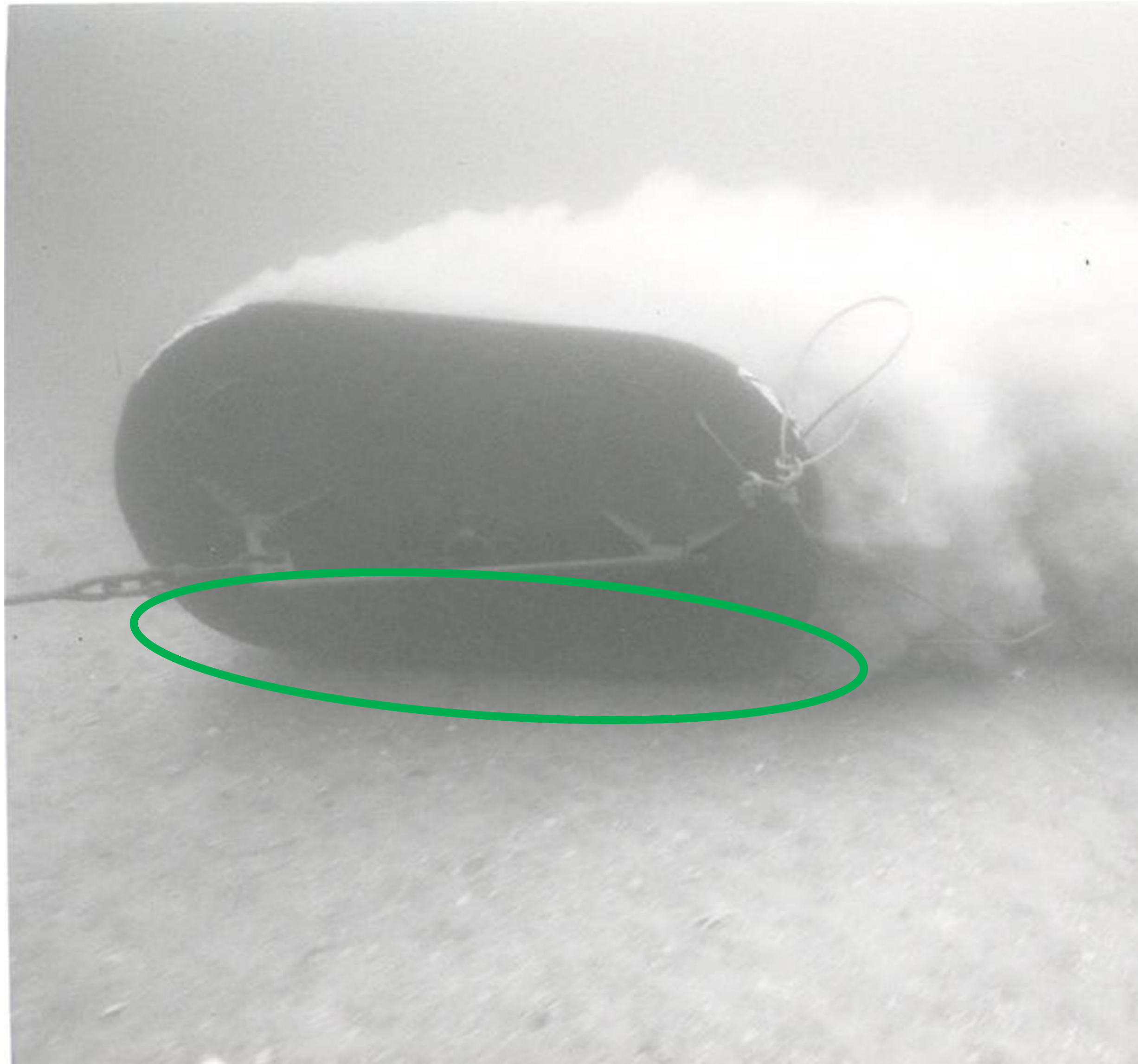
geotechnical

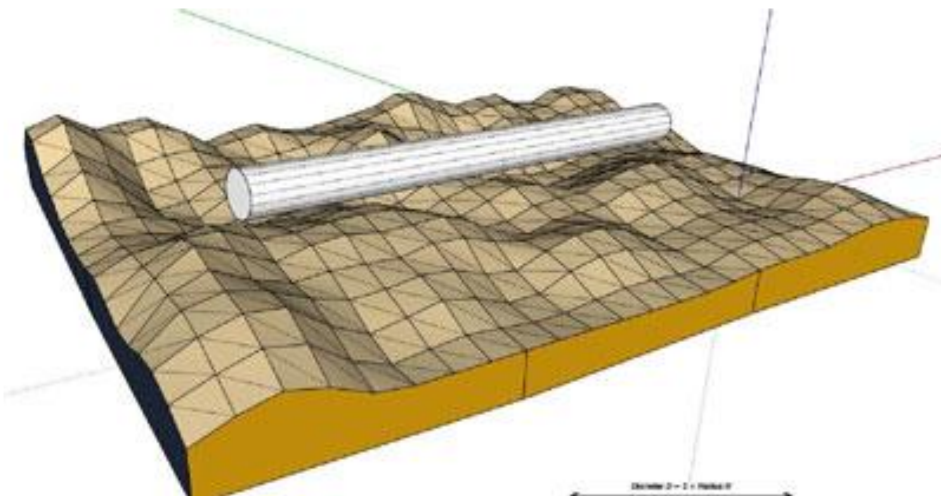
Hydrodynamic

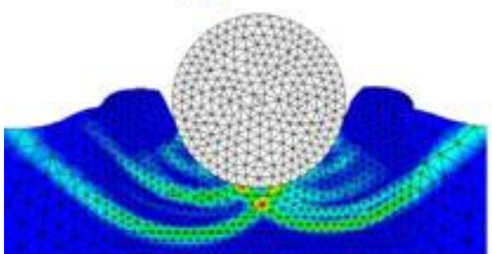
- Turbulent wake
- Sediment mobilisation

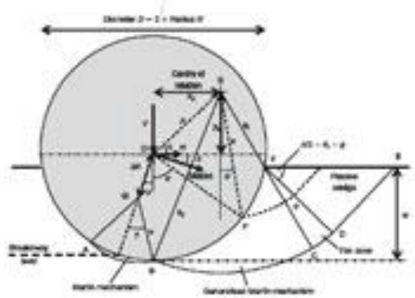
Geotechnical

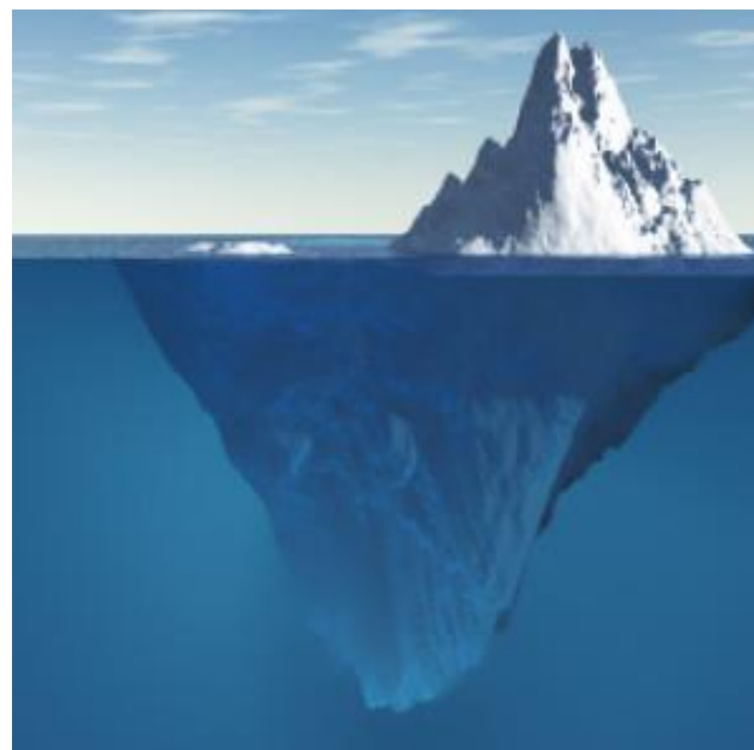
- Penetration
- Lateral displacement
- stress field









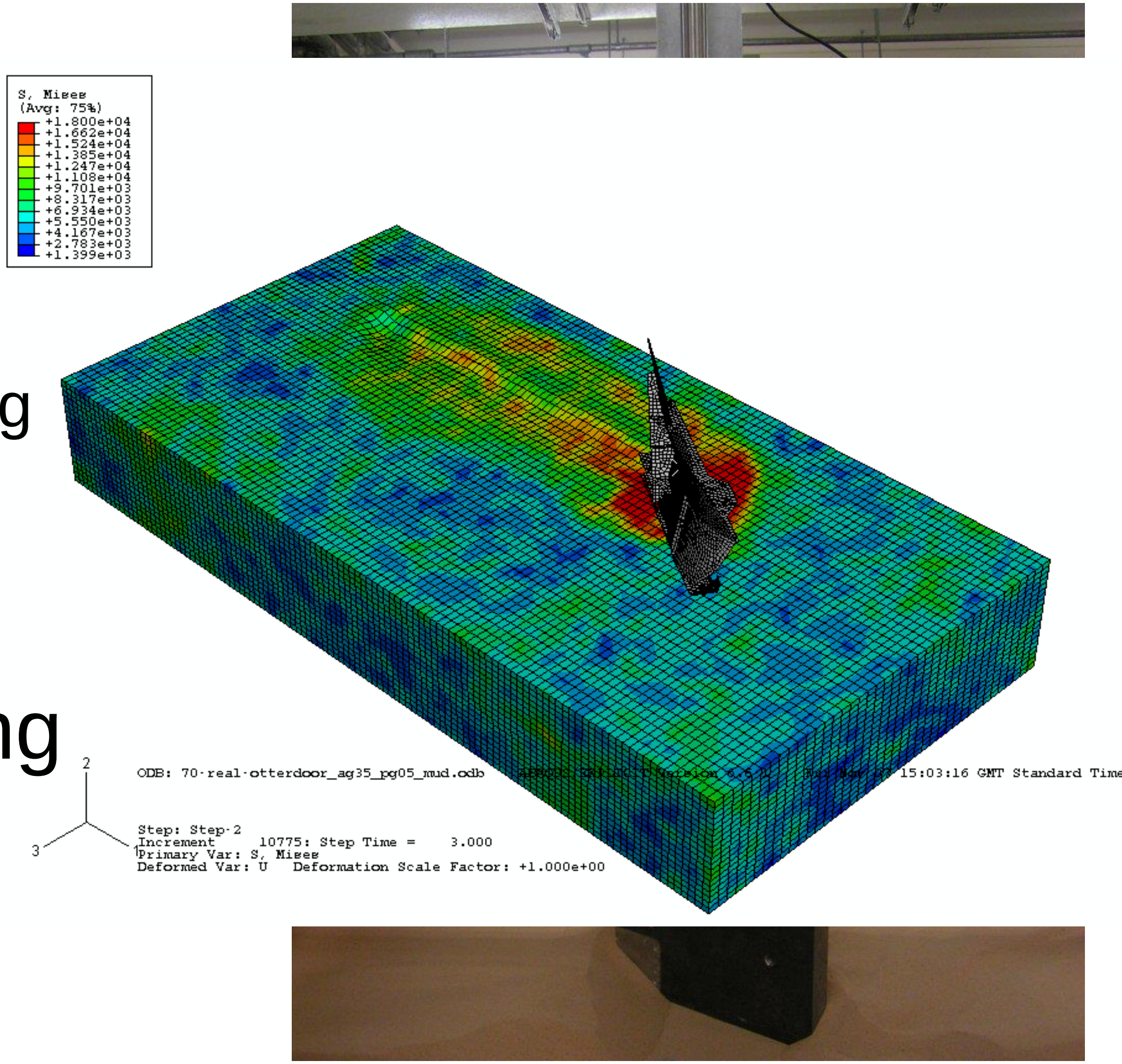


geotechnical

- physical modelling
  - sand channel
  - at sea

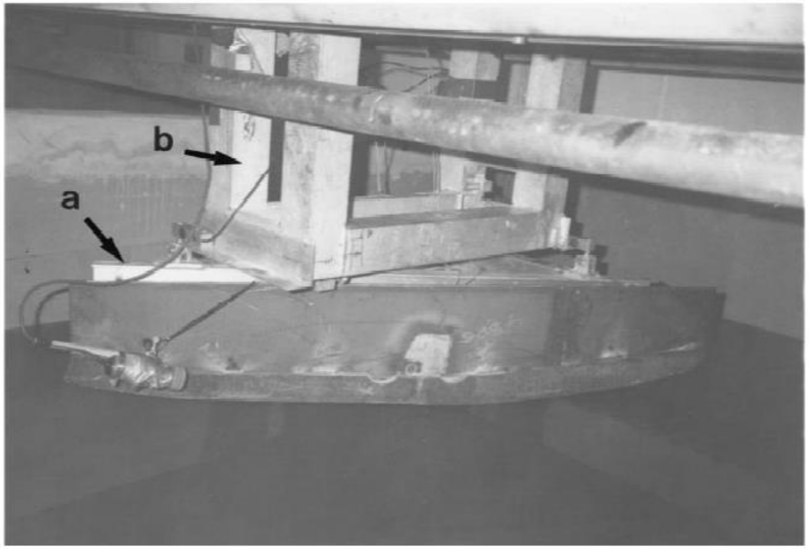
    model/full scale fishing

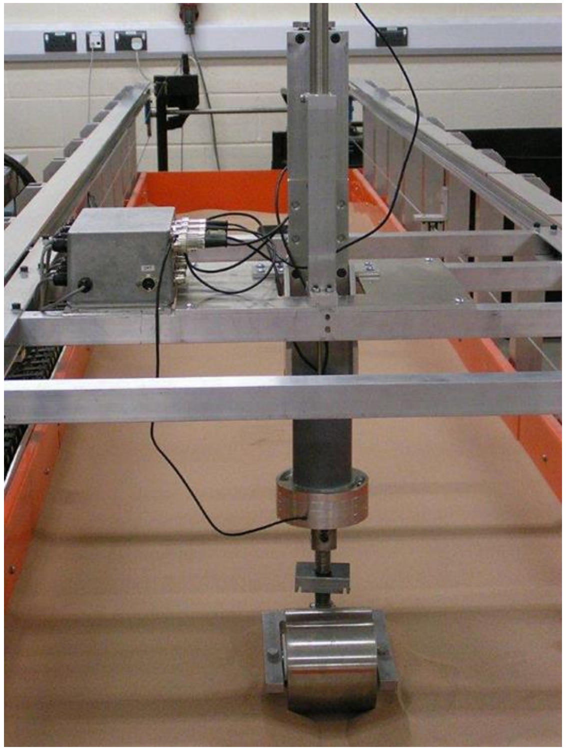
    gears/elements

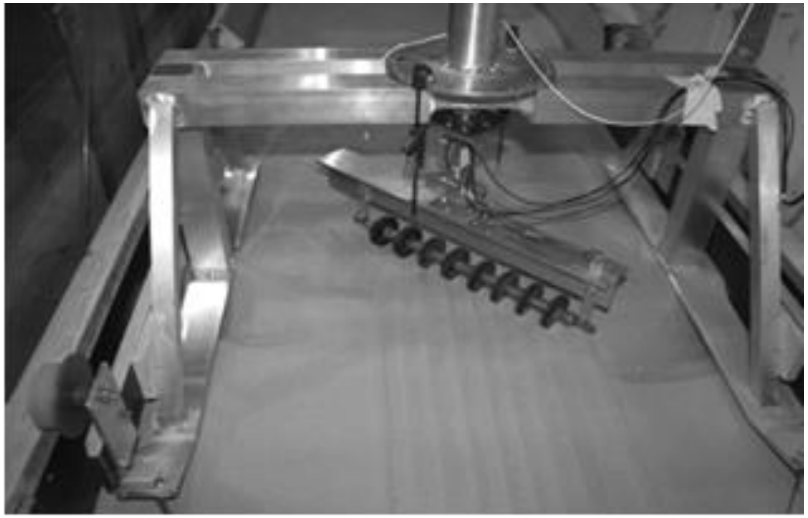


- numerical modelling

sand channels

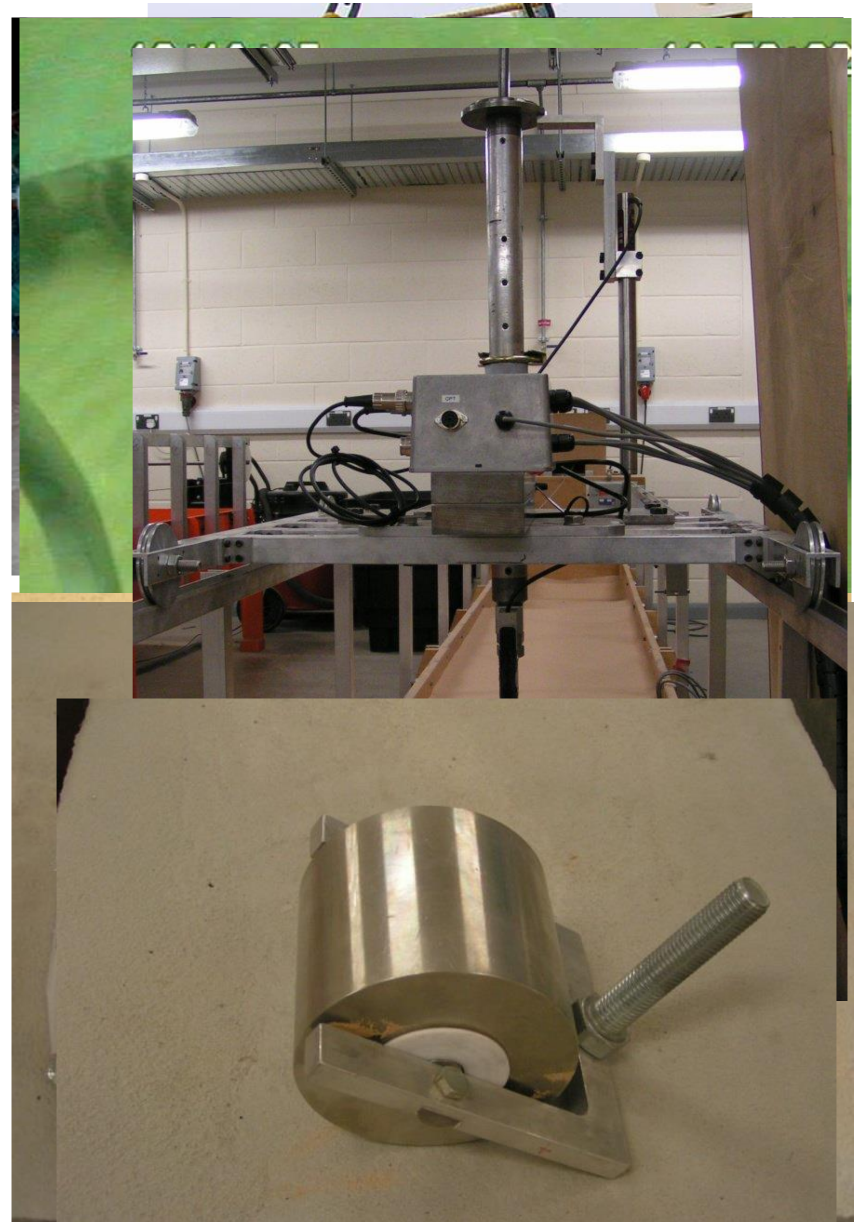




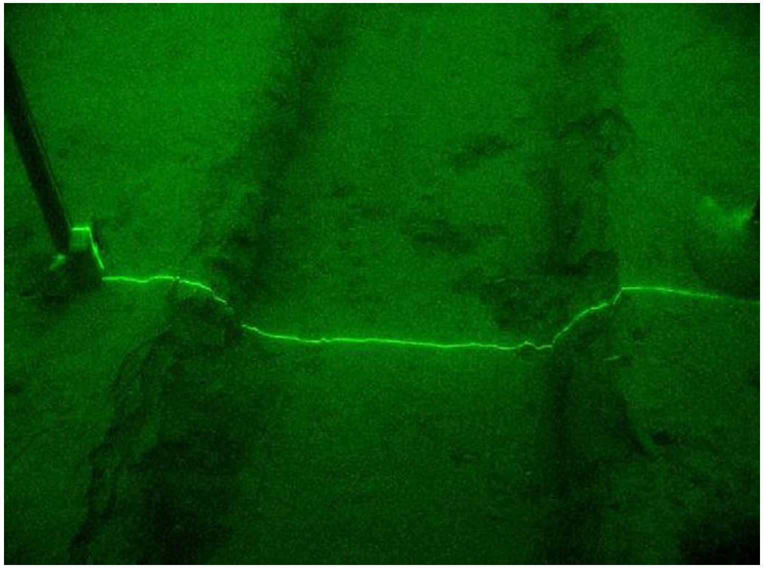


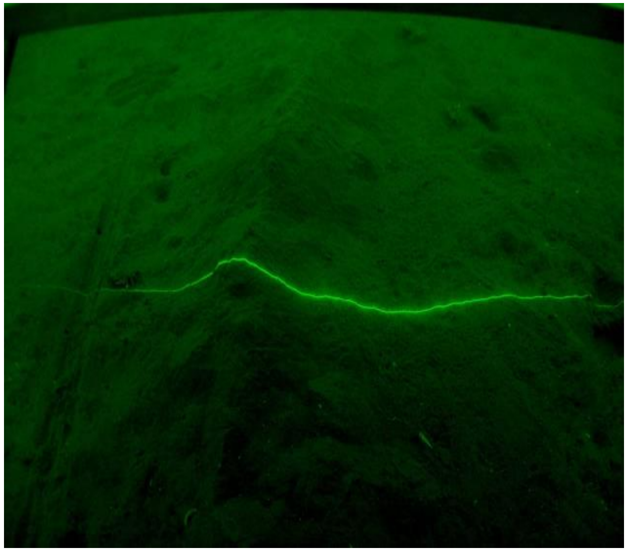
Physical modelling

- Better understanding of basic geotechnical processes
- Development of scale modelling laws
- Data for verification of numerical models



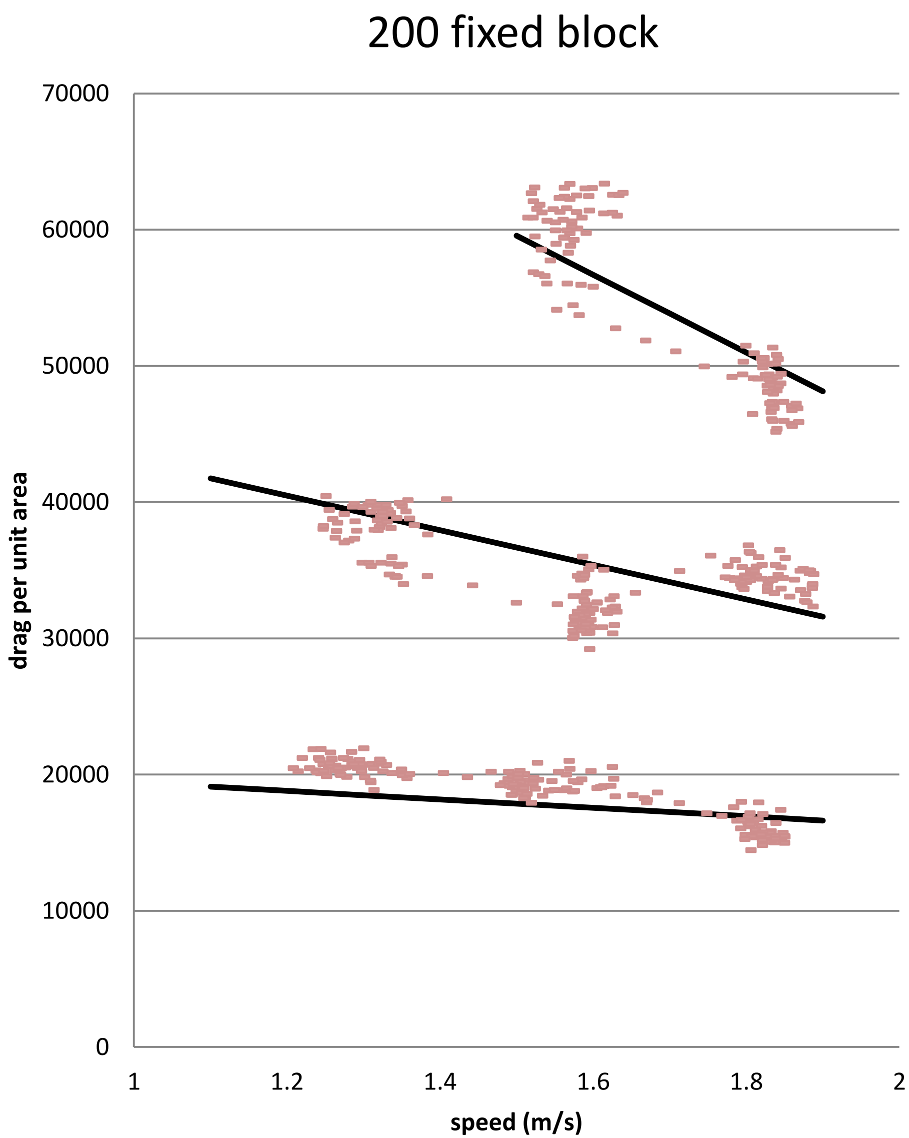
Physical modelling

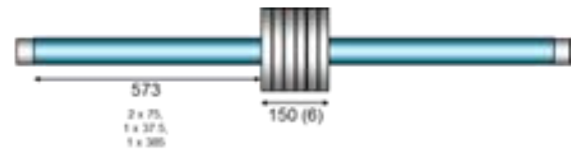


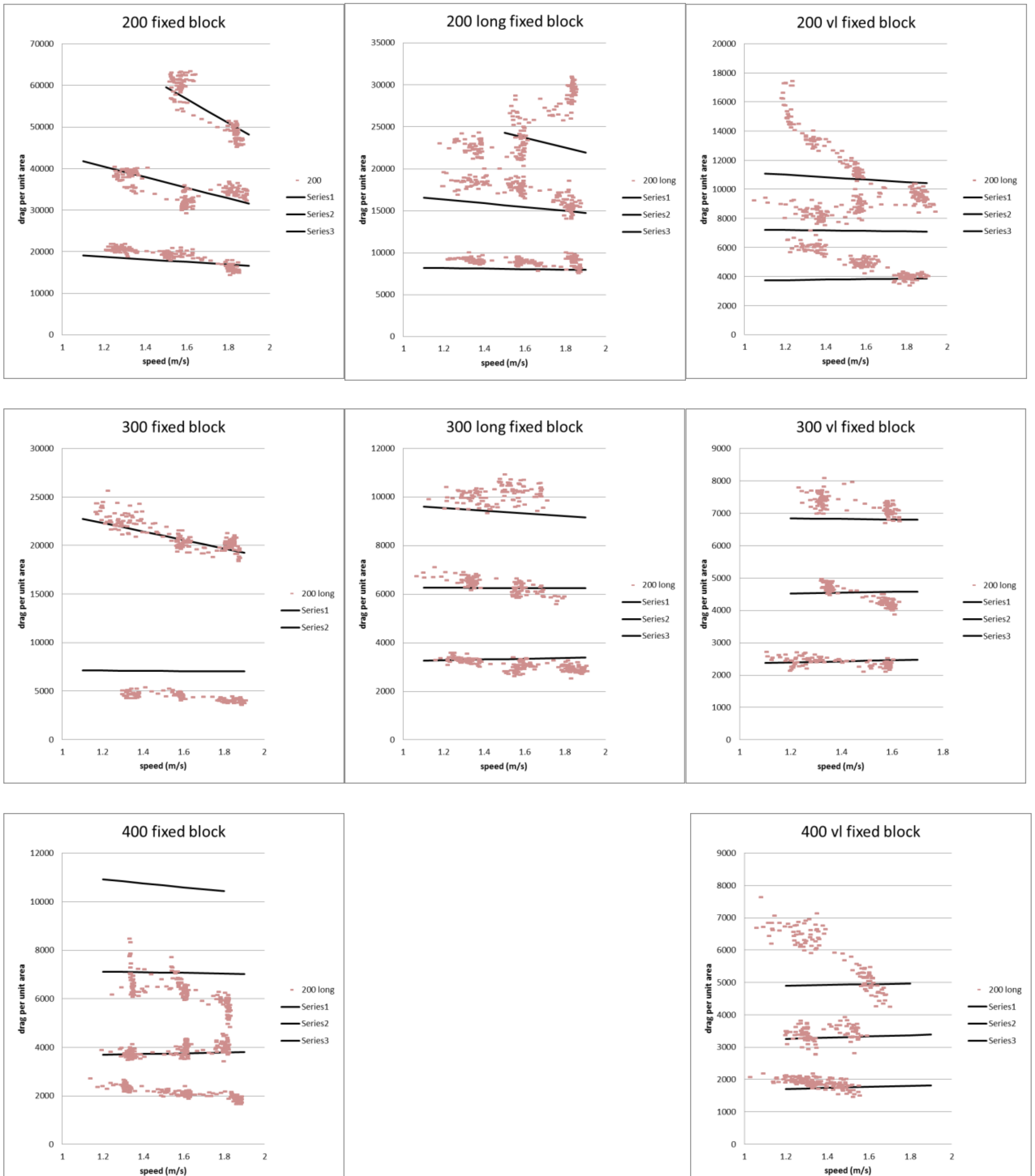


- not touching the sea bed (tied up)
  - Hydrodynamic only
- three different weights
  - ~ 60, 120, 180kg
  - Hydrodynamic and geotechnical
- range of speeds
  - ~ 1 – 2 ms^{-1}
- fixed and rolling
- sediment in wake and drag

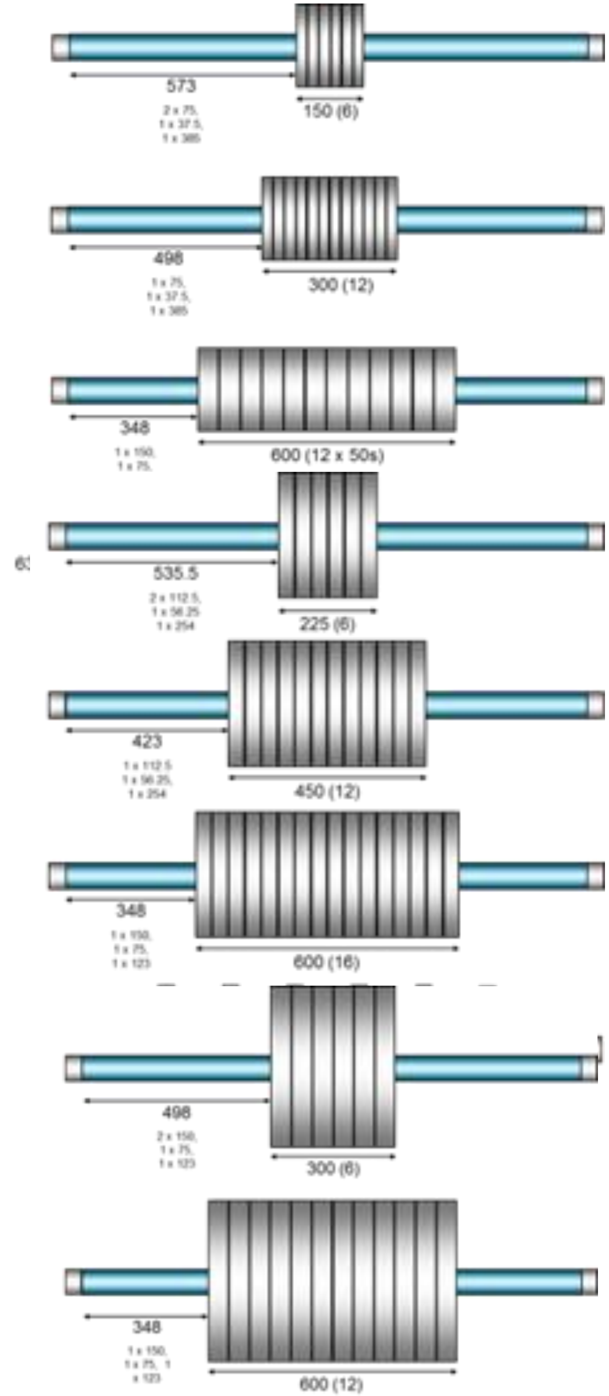
Geotechnical drag







200 fixed block
200 long fixed block
200 vl fixed block
300 fixed block
300 long fixed block
300 vl fixed block
400 fixed block
400 vl fixed block
drag per unit area
speed (m/s)
200
200 long
Series1
Series2
Series3



573
150 (6)
498
300 (12)
348
600 (12 x 50s)
535.5
225 (6)
423
450 (12)
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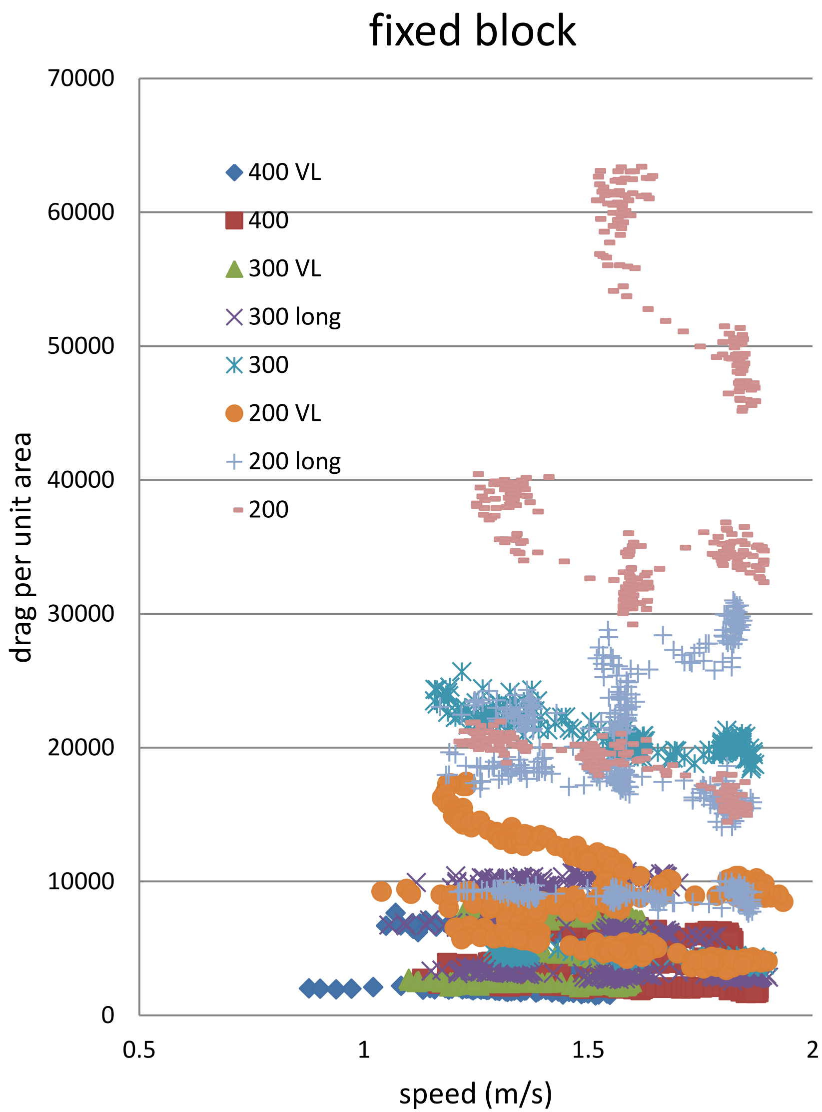
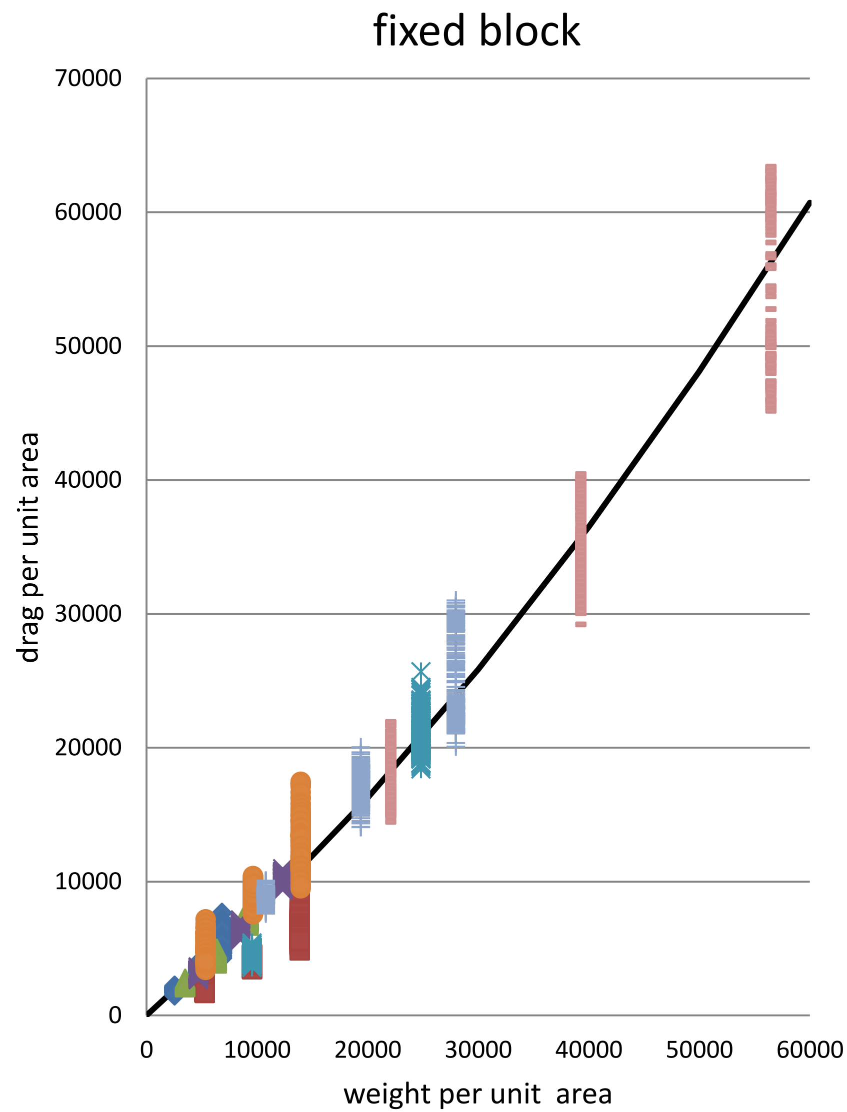
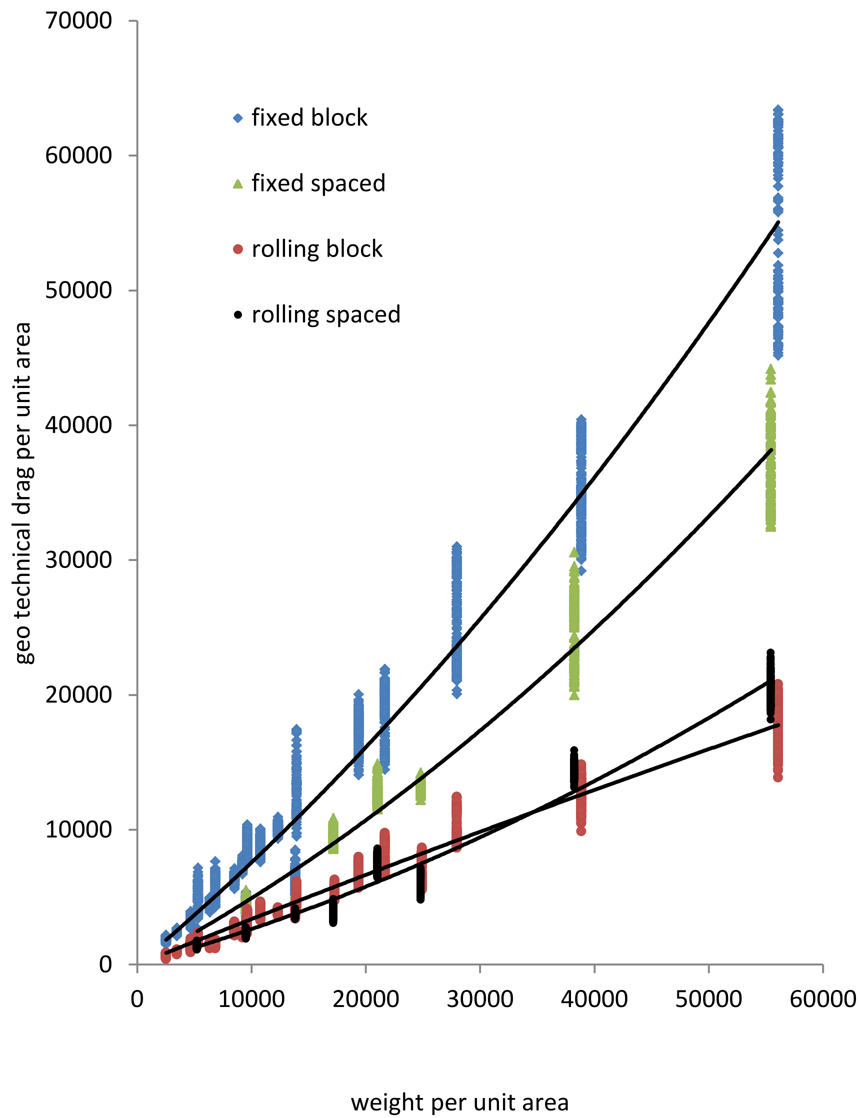
600 (12)

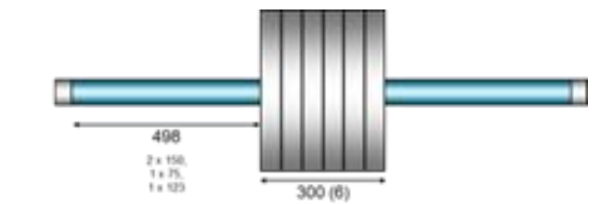


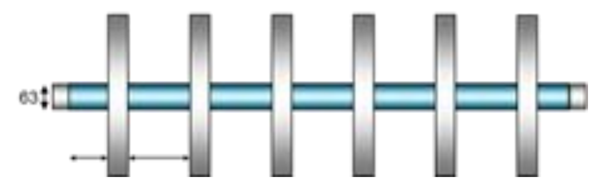
fixed block
70000
60000
50000
40000
30000
20000
10000
0
400 VL
400
300 VL
300 long
300
200 VL
200 long
200
drag per unit area
0.5
1
1.5
2
speed (m/s)



fixed block
70000
60000
50000
40000
30000
20000
10000
0
drag per unit area
0
10000
20000
30000
40000
50000
60000
weight per unit area


70000
60000
50000
40000
30000
20000
10000
0
0
10000
20000
30000
40000
50000
60000
fixed block
fixed spaced
rolling block
rolling spaced
geo technical drag per unit area
weight per unit area


498
300 (6)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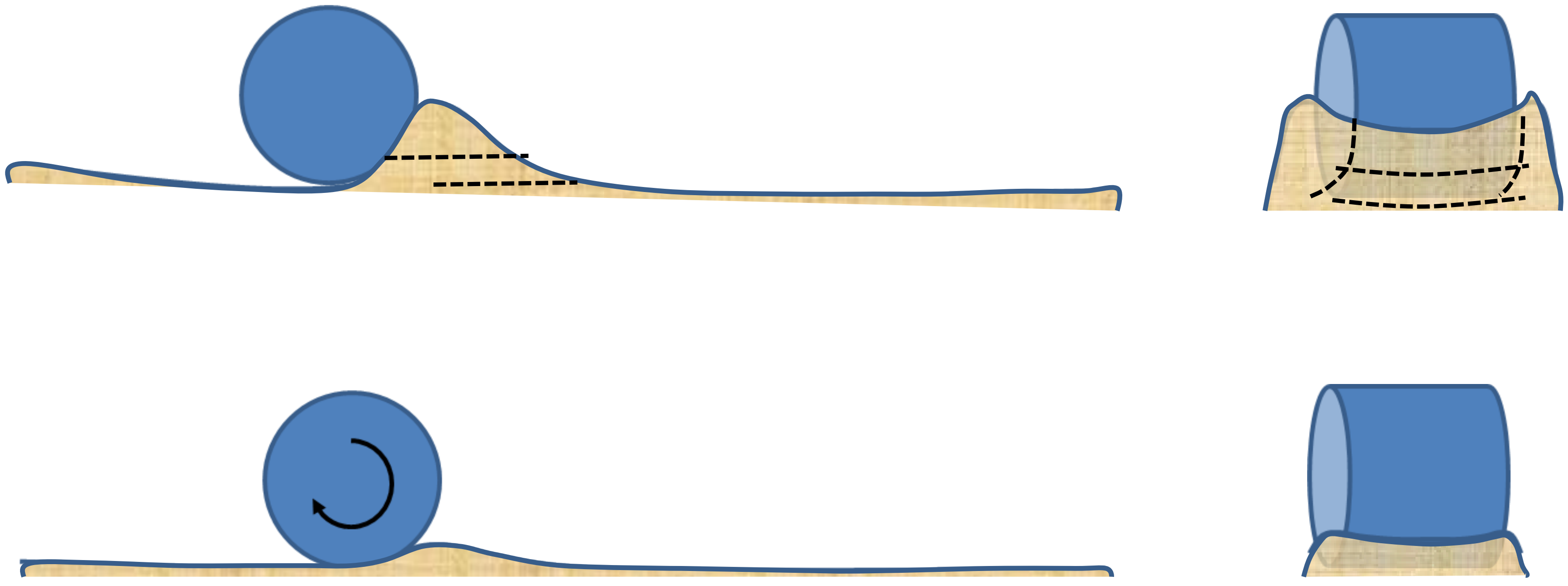
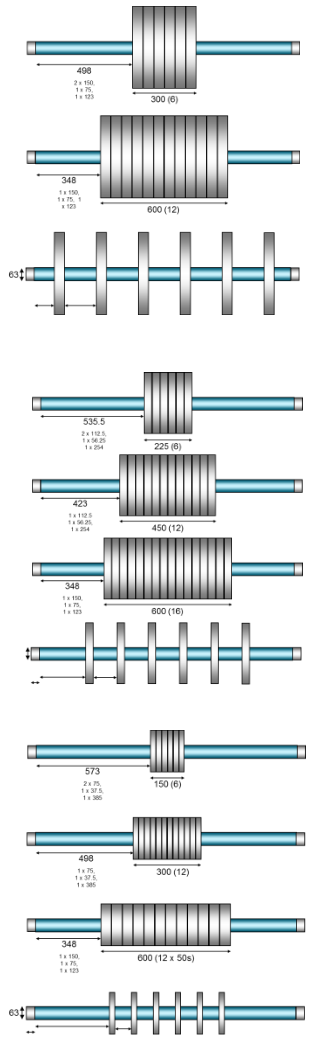


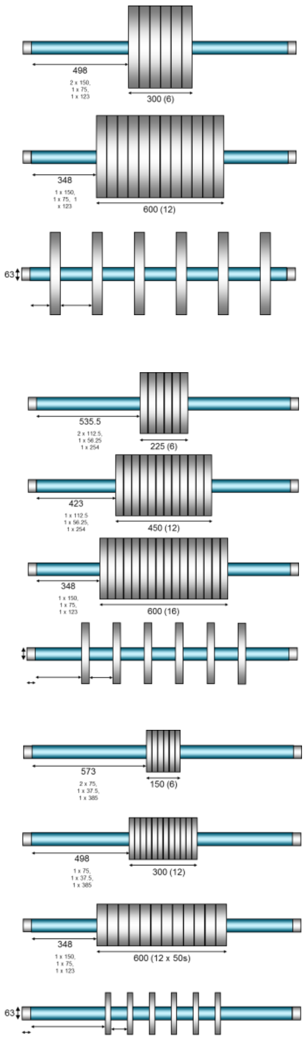
Geotechnical drag

- geotechnical drag per unit area ~ weight per unit area
  - Secondary effect related to towing speed (but maybe only for fixed heavier components)
- Differences between rolling and fixed components

- For rolling cylinders geotechnical processes are 2 dimensional
- For wider fixed cylinders geotechnical processes are 2 dimensional
- But perhaps not for thinner fixed disks



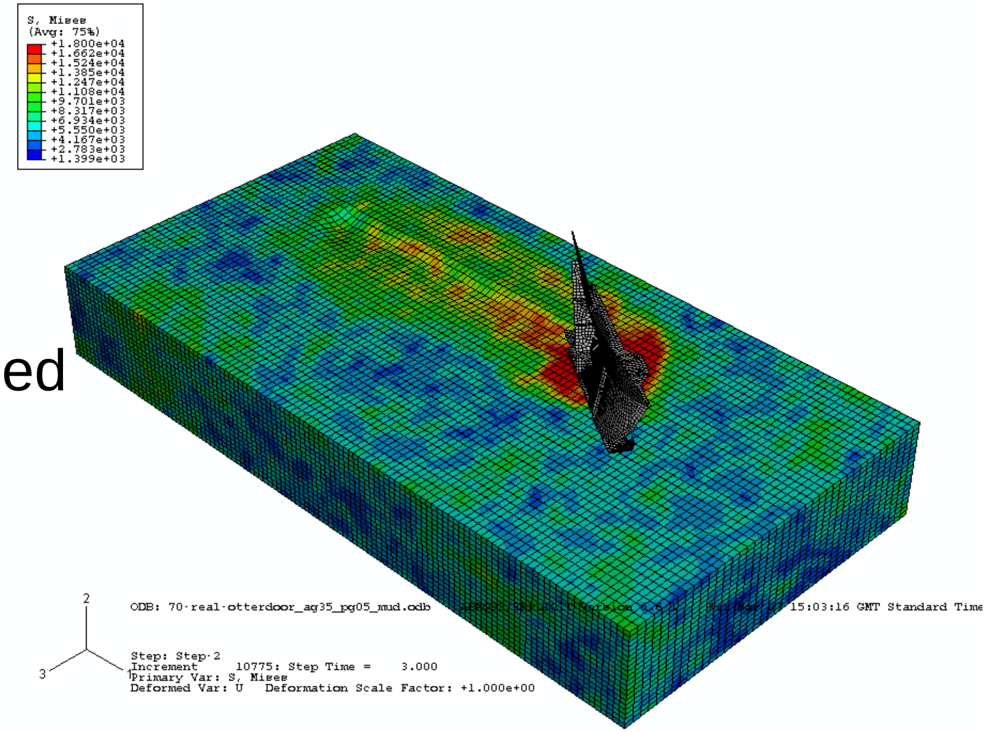
Geotechnical drag



- highlight the need to have a good understanding of the constitutive relationships

- stress / strain relationships which describe how the sediment behaves

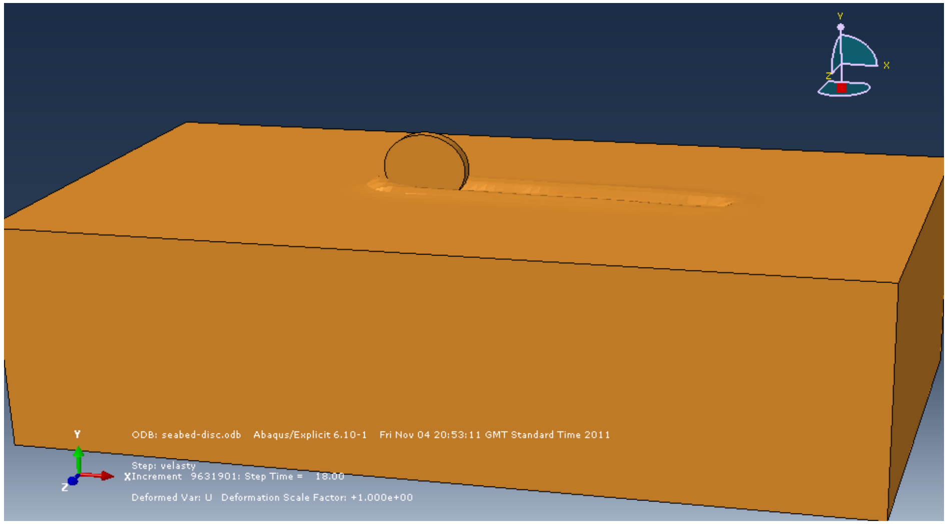
Numerical models

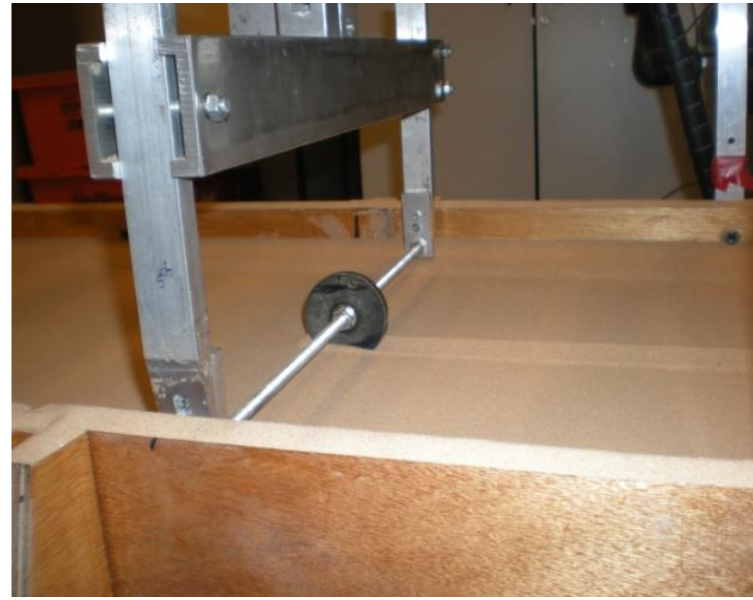


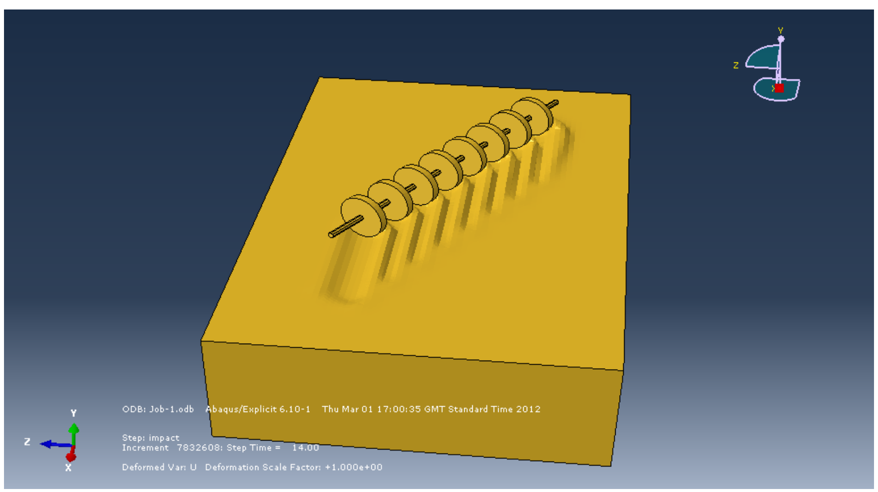
- Continuum models of the seabed
  - depth of penetration
  - drag
  - stress field in sediment

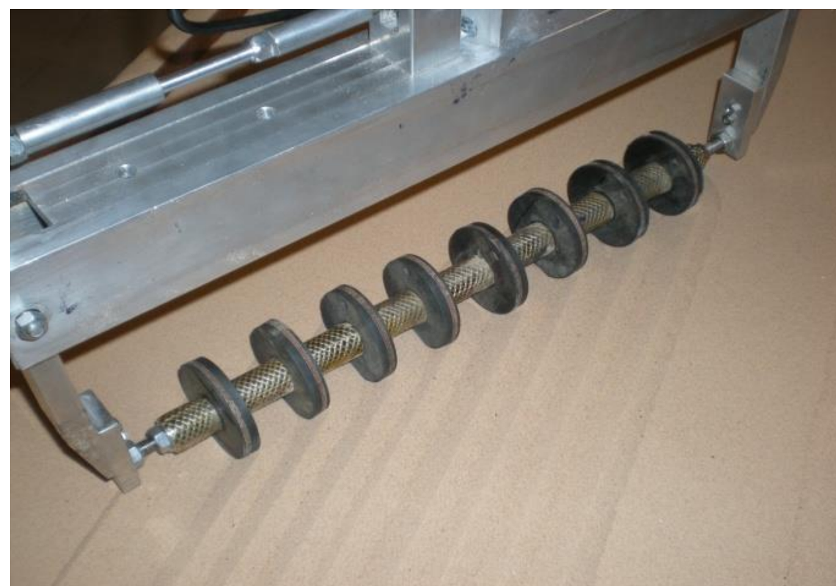
- Based on an understanding of the basic constitutive relationships
  - stress / strain
  - granular, cohesive, saturated, …
  - characterised by mechanical parameters such as Yield stress, Young's modulus, …

Comparison of numerical and physical model

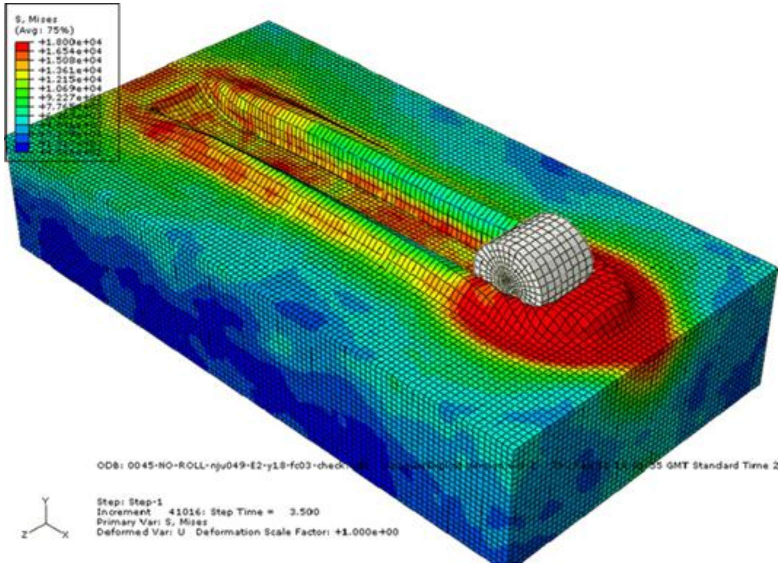


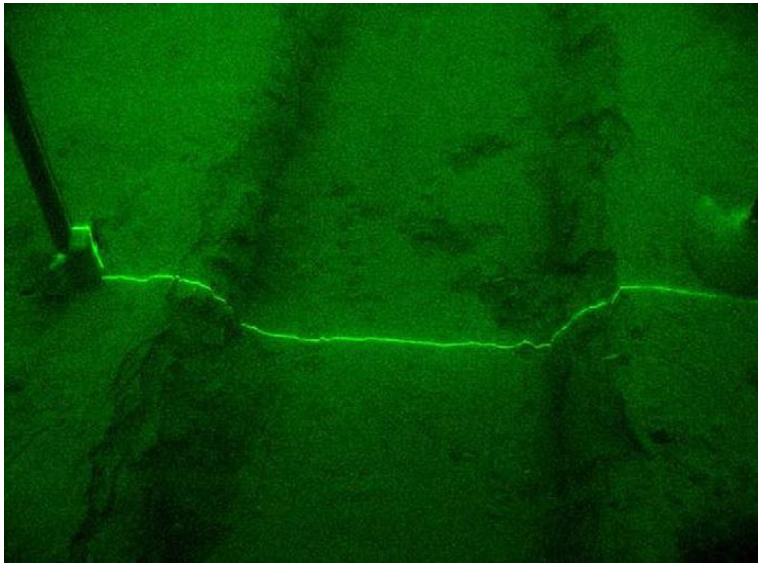


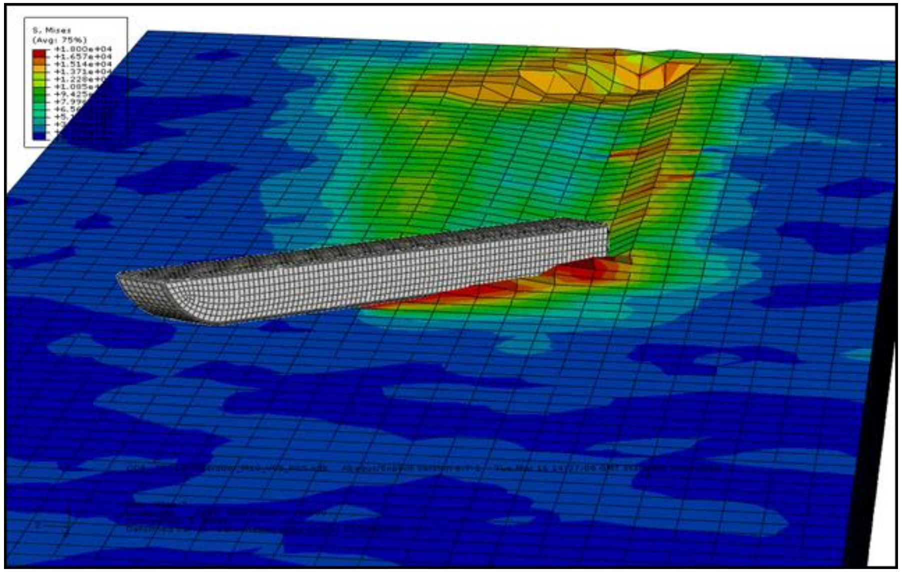


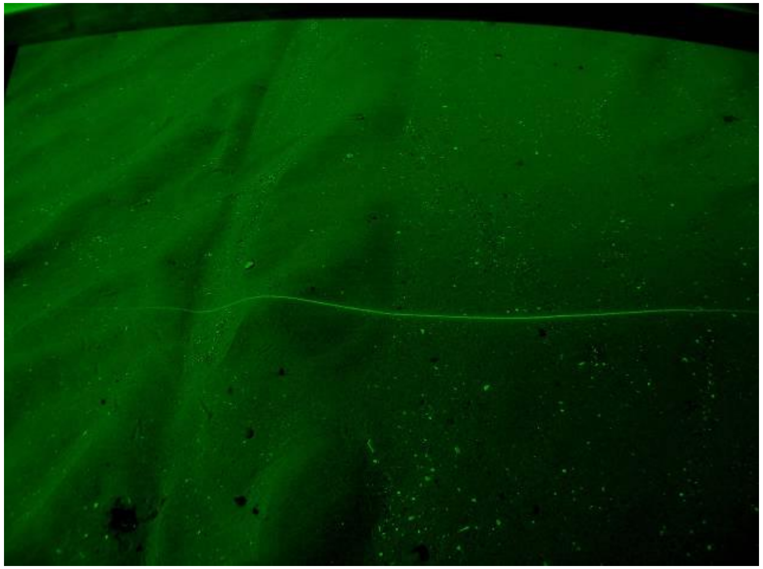


Comparison of numerical and physical model

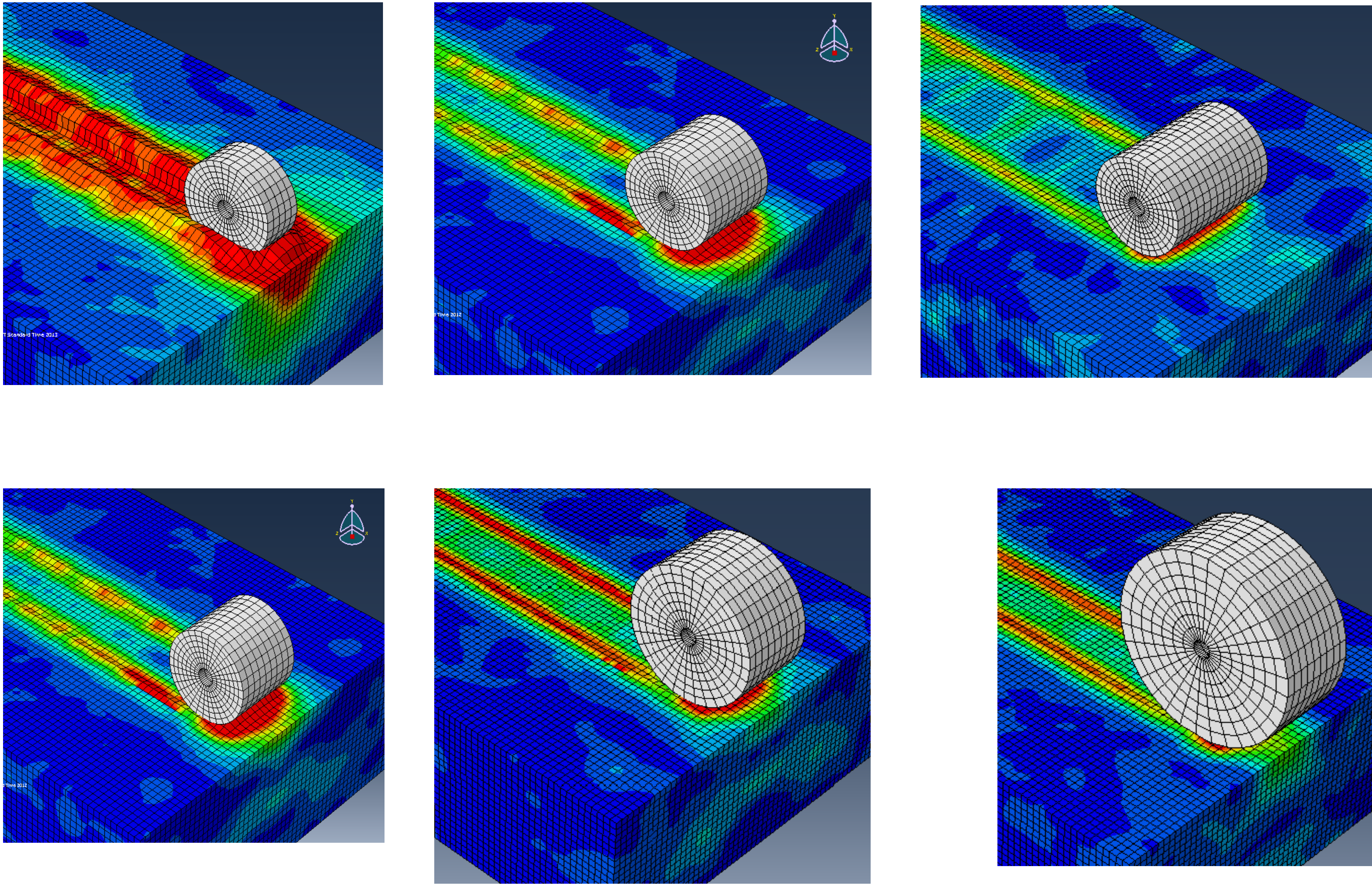




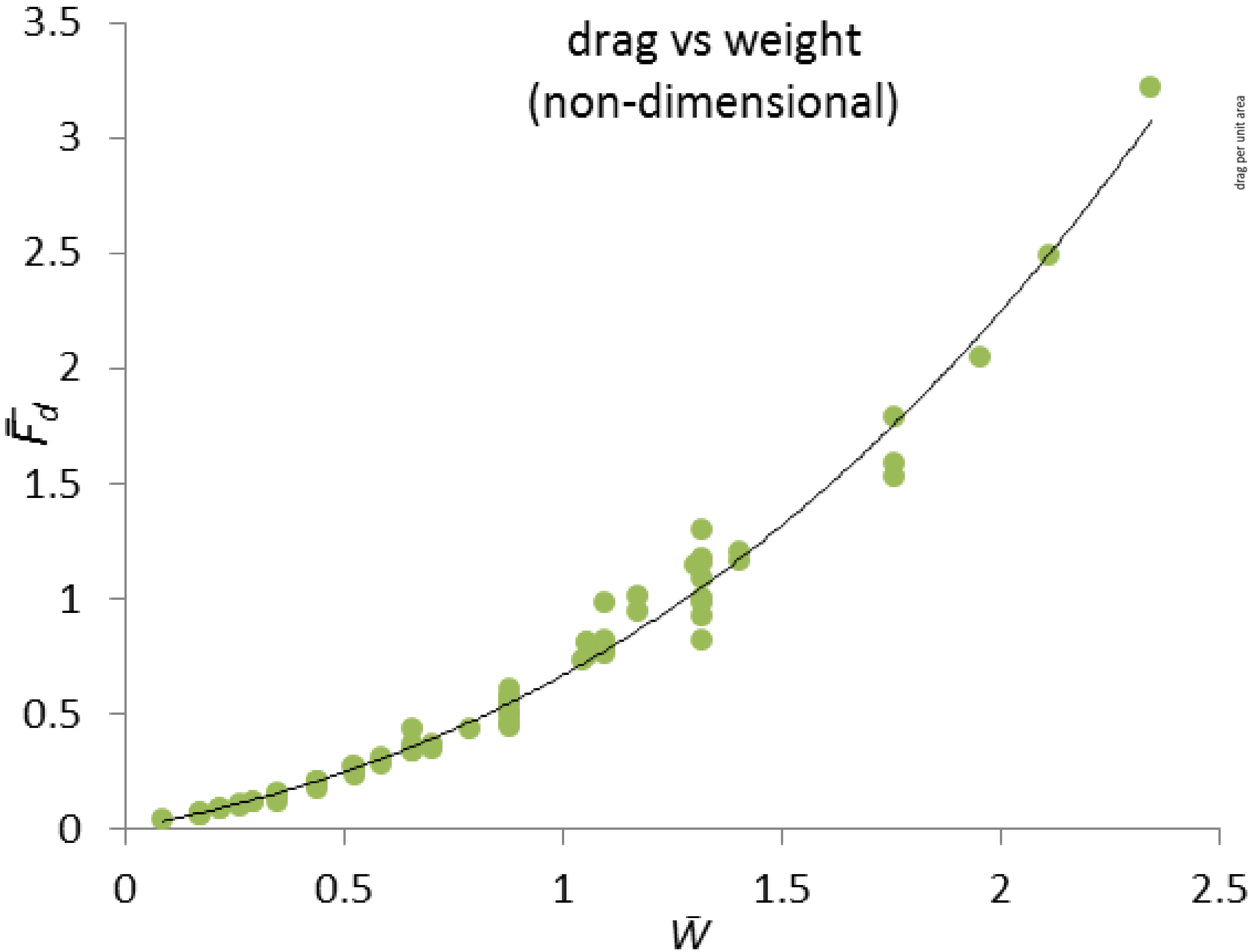


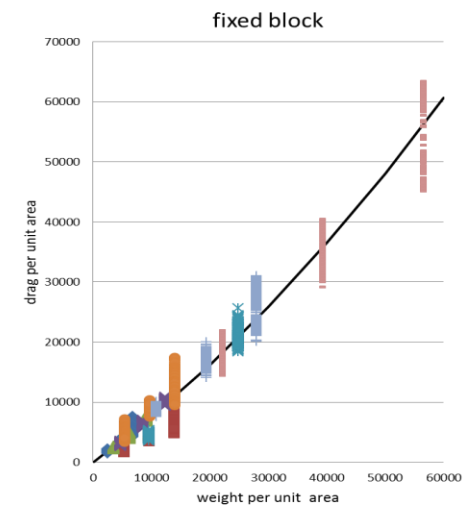


multiple simulations

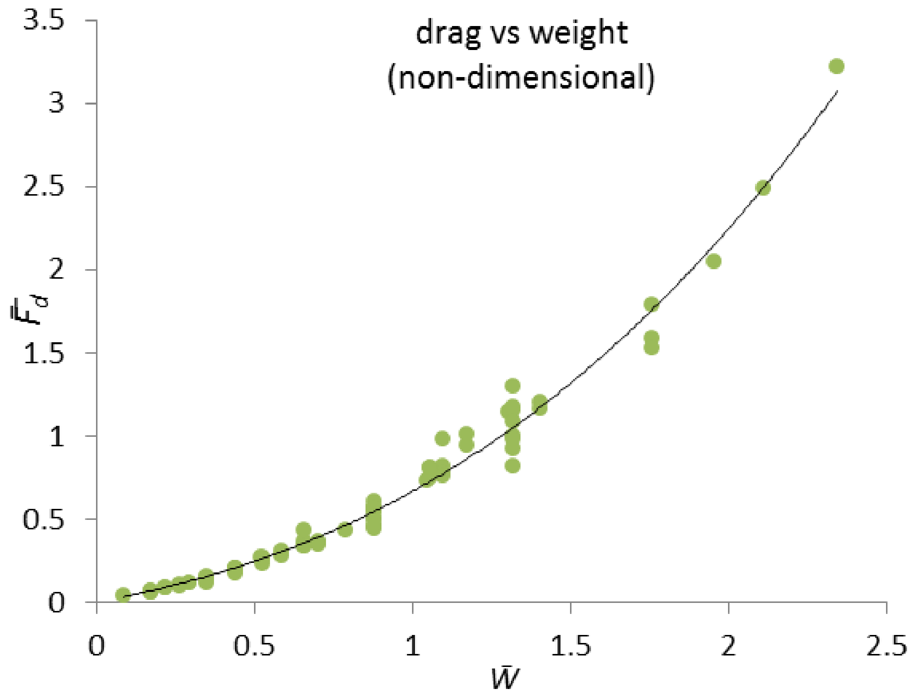


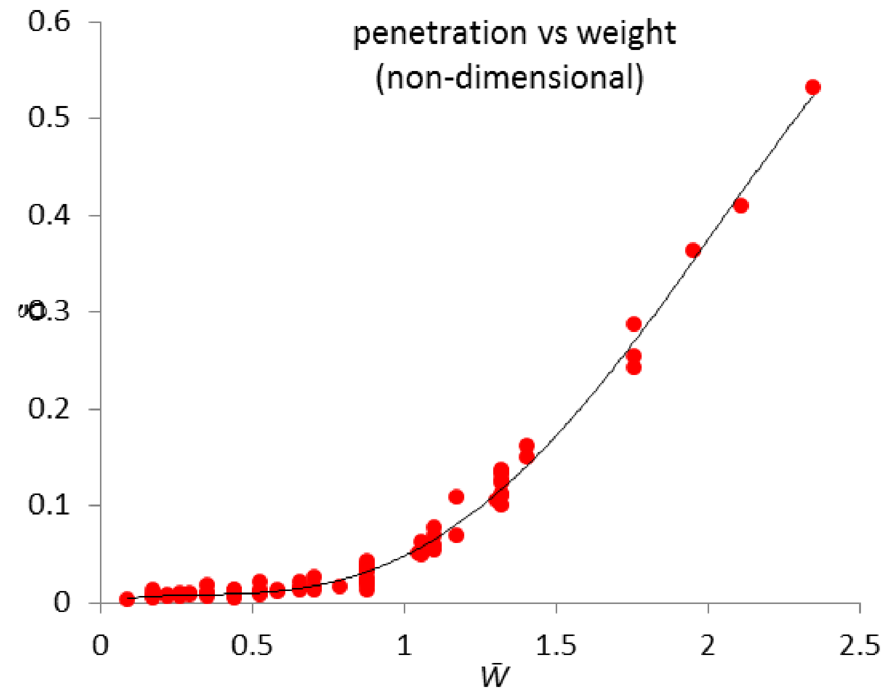
multiple simulations





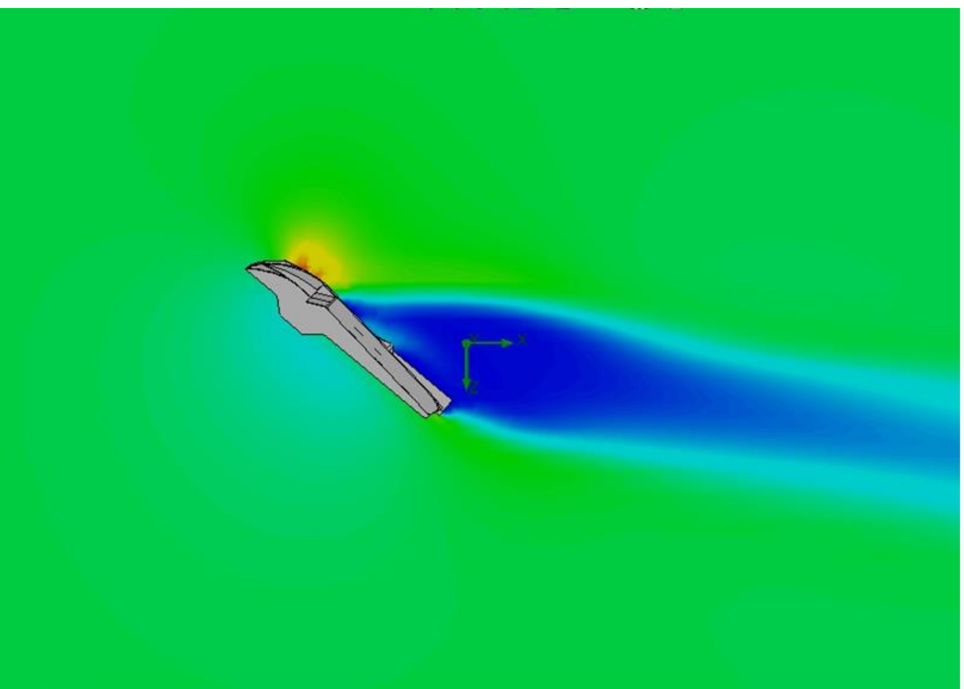
multiple simulations

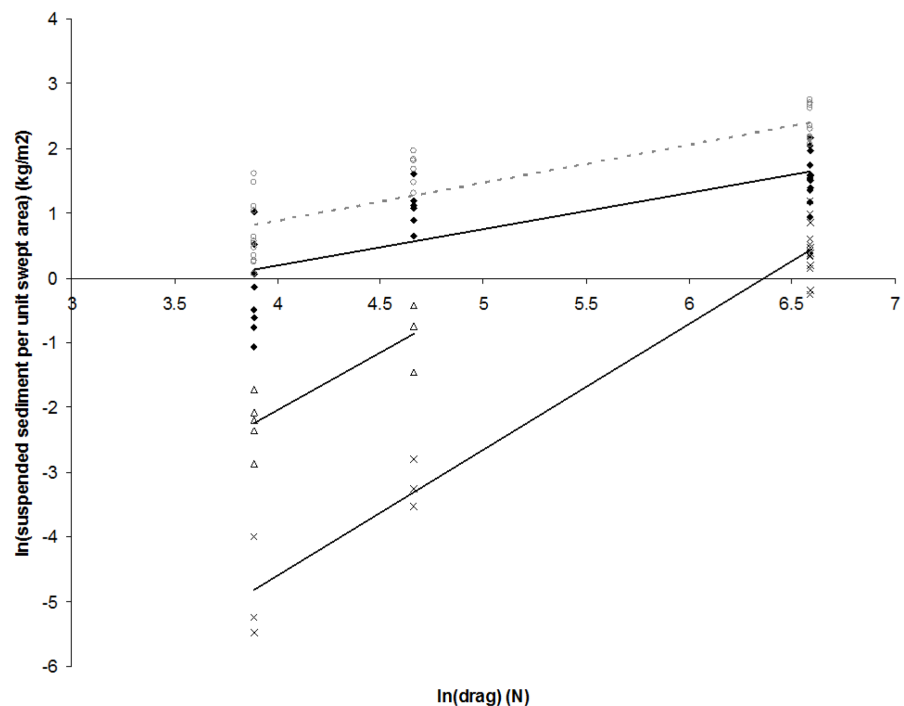




present situation

- better understanding of the physical processes
- empirical / numerical models





present situation

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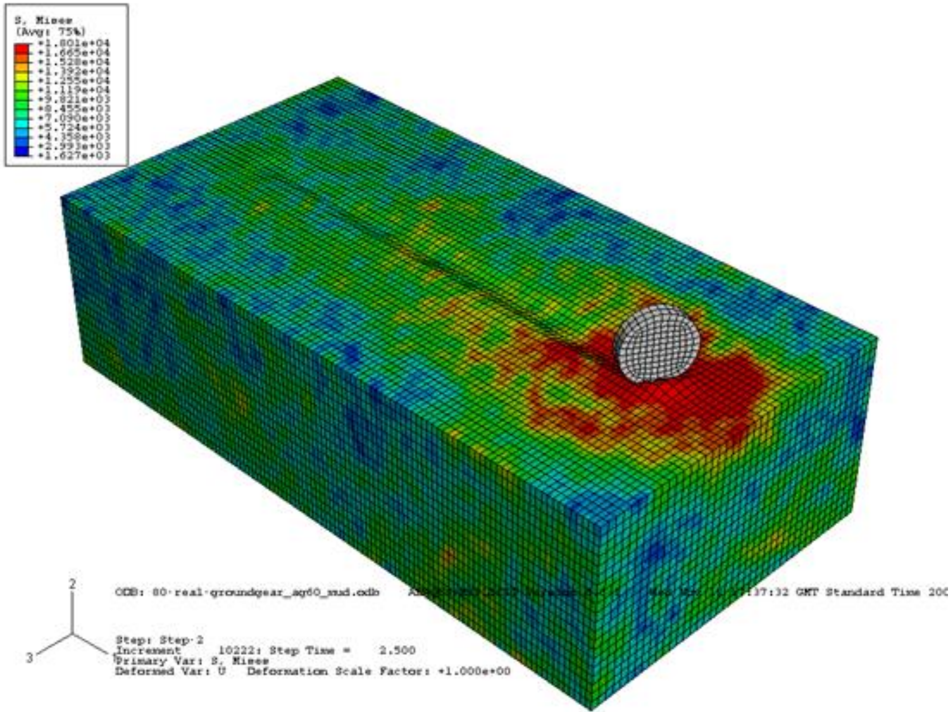
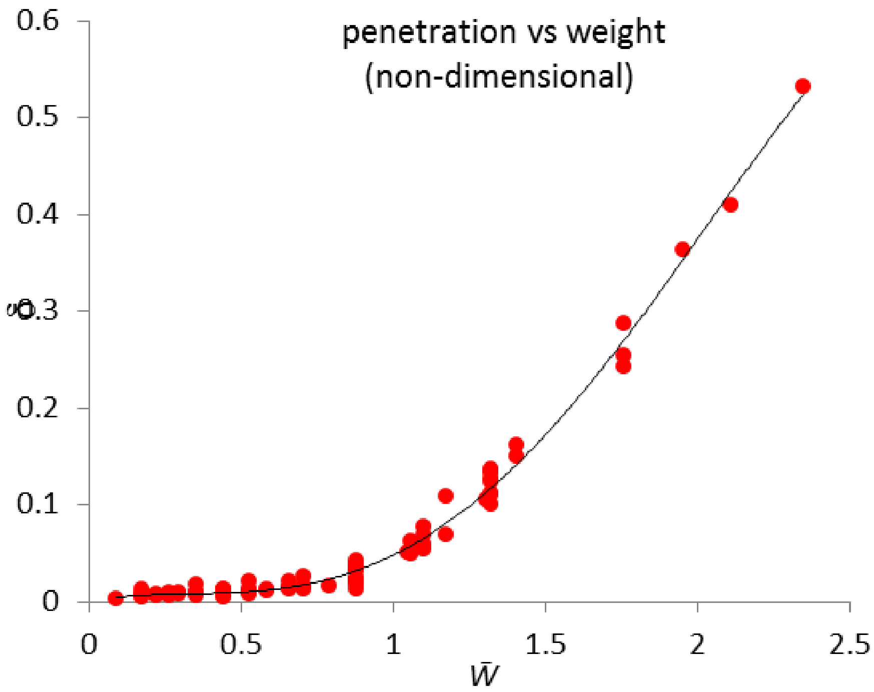
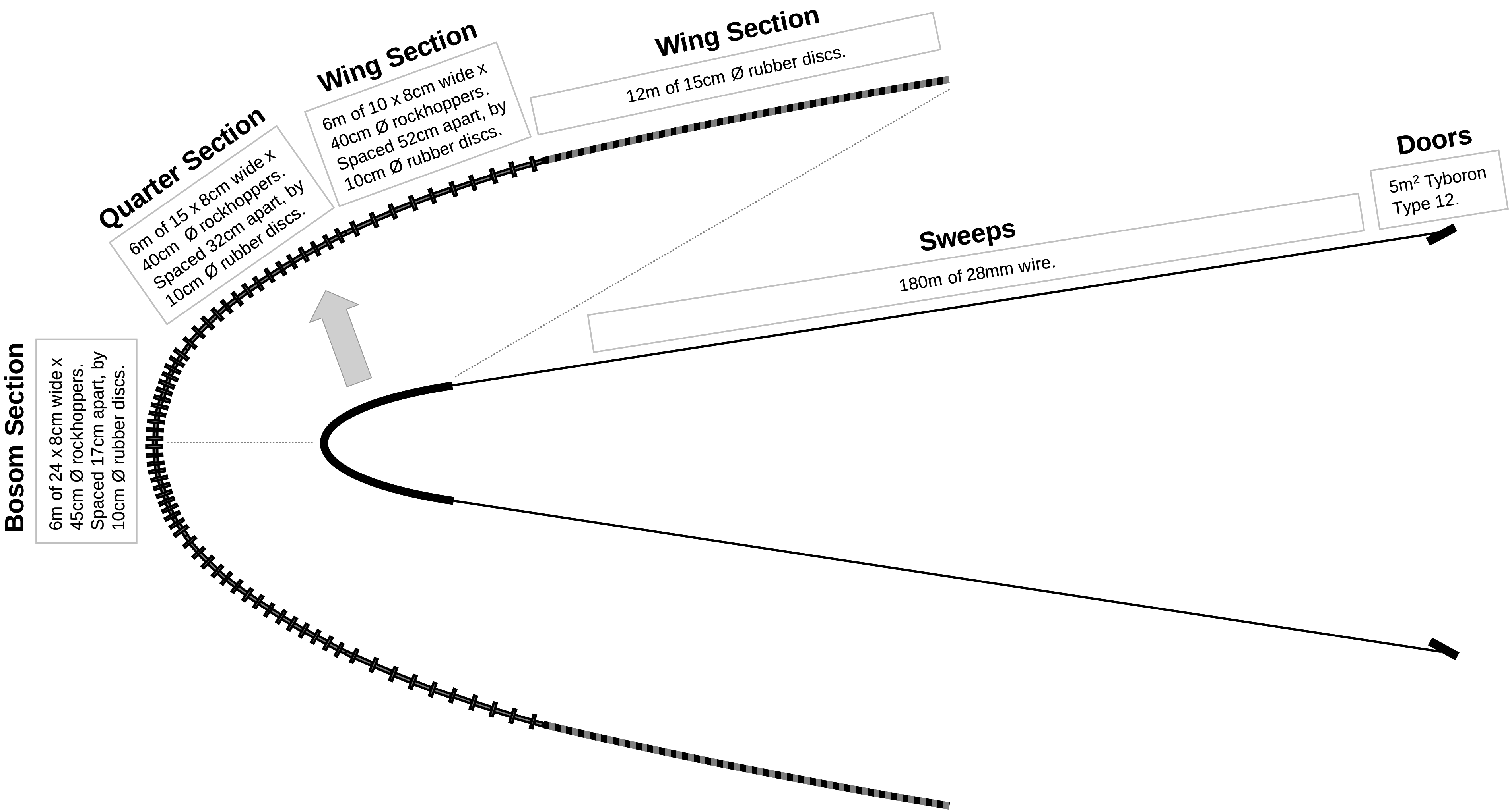




predictive methods

- quantify impacts
- put in context / compare with natural disturbance
- identify, develop, design gears to mitigate impact
  - physical perspective
  - if we can relate physical impacts to ecological / environmental effects ….

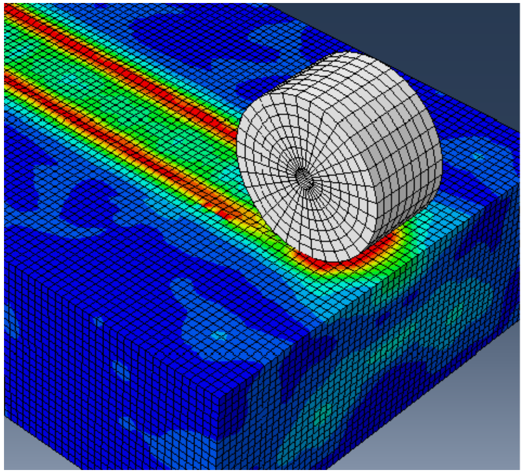
quantifying sediment mobilisation

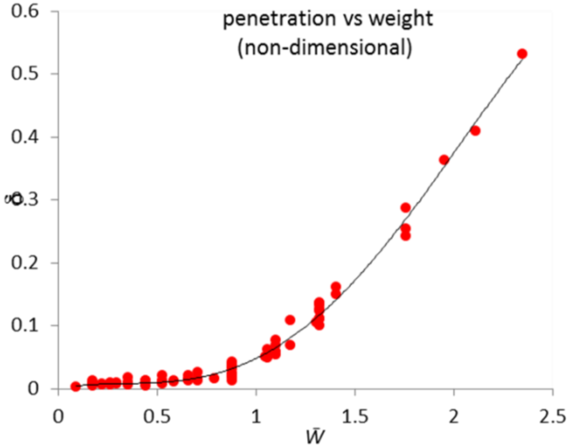


quantifying sediment mobilisation

	rock hoppers				
	half bosom section	quarter section	wing section	wing section	trawl door
Sand	0.13	0.5	0.9	0	6
muddy sand	1	2	3	0.8	14
sandy mud	2	4	6	1	30

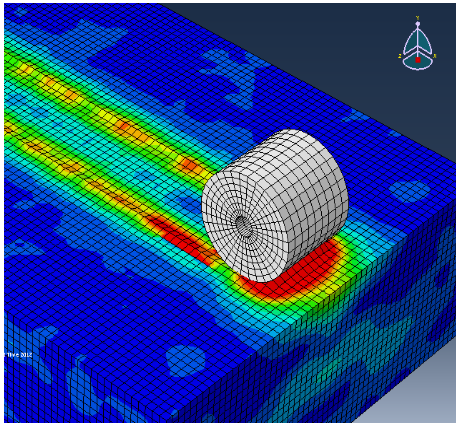
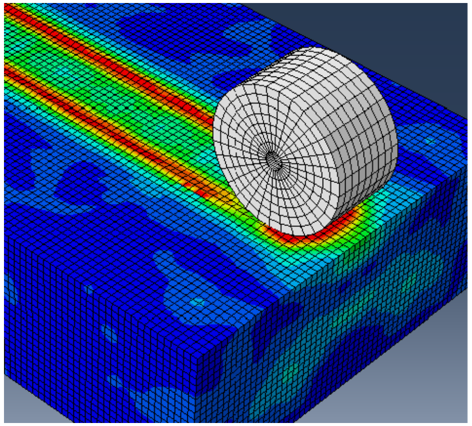
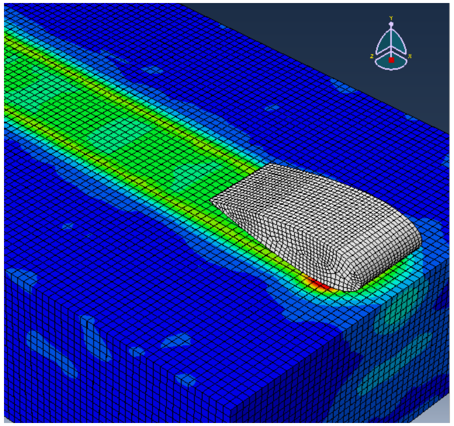
quantifying penetration





profile	W (N)	r (m)	b (m)	δ (mm)	F_d (N)
circular	8000	0.5	0.75	41	6000

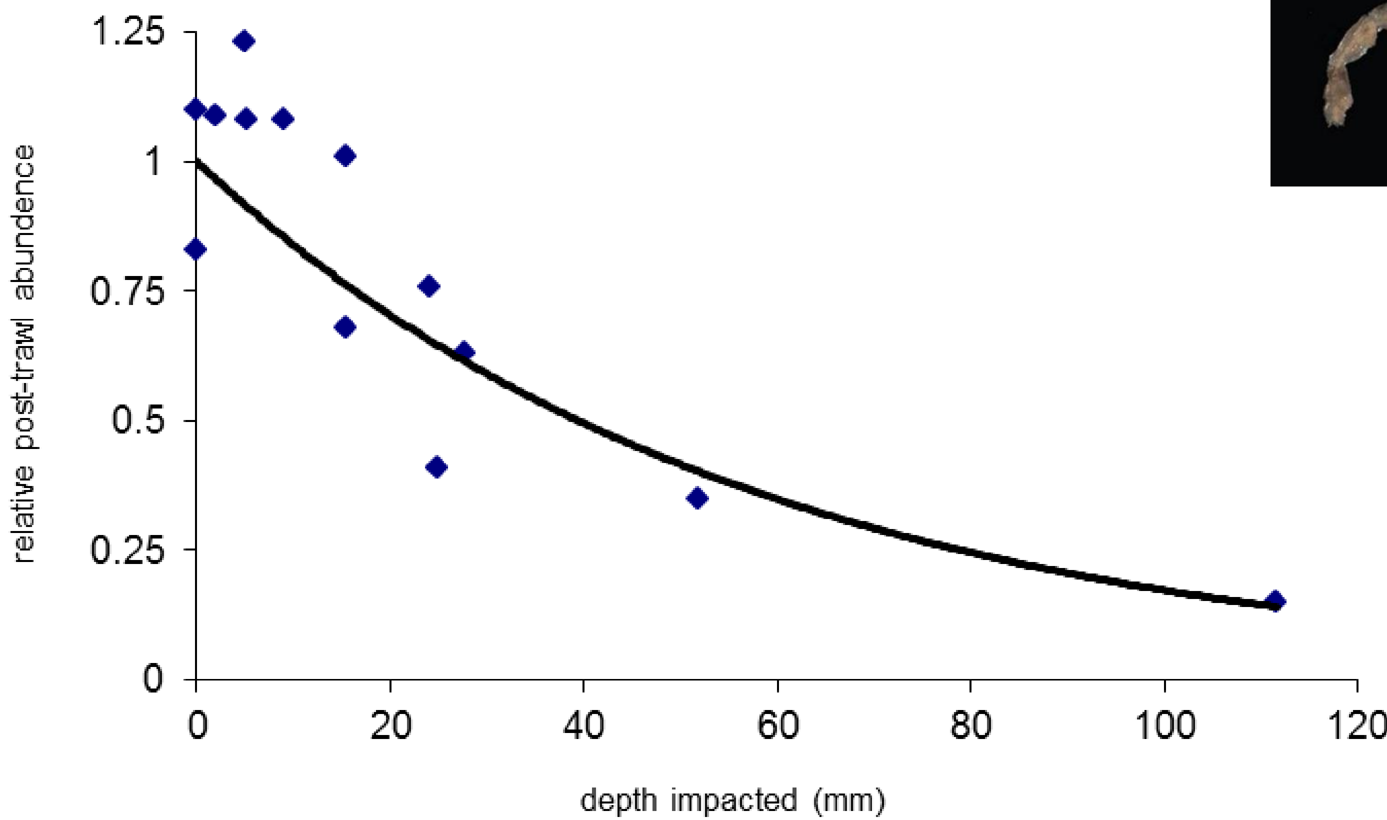
design studies

profile	W (N)	r (m)	b (m)	δ (mm)	F_d (N)
circular	8000	0.35	0.75	84	7850
circular	8000	0.5	0.75	41	6000
aerofoil	8000	0.35	0.75	7	2850

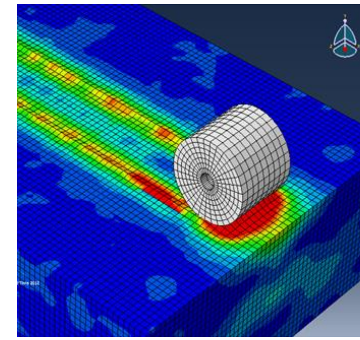
quantifying benthic impact

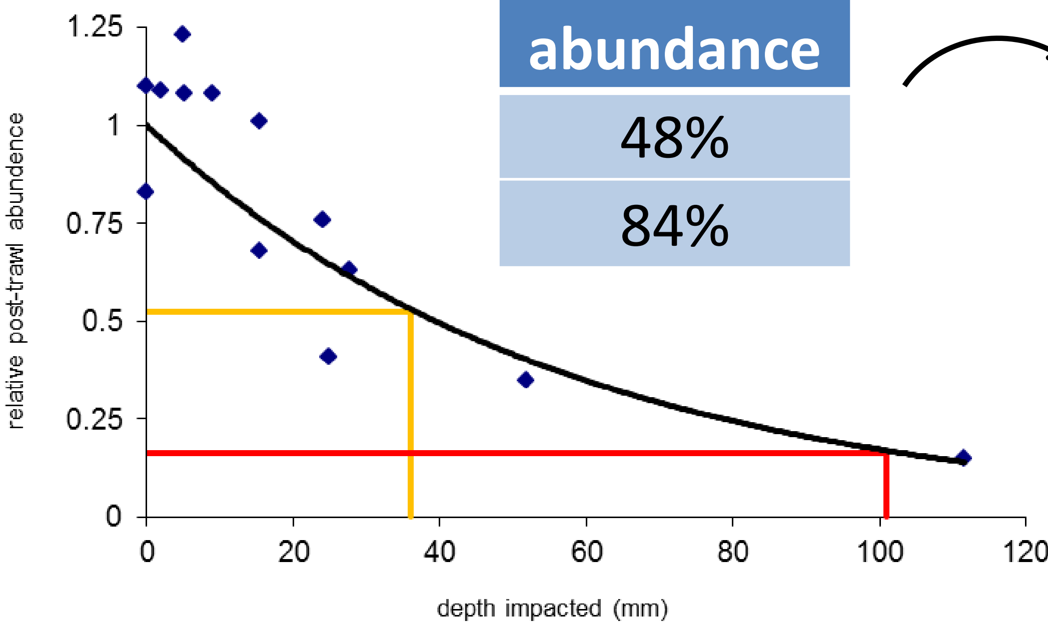
- if we assume abundance decreases exponentially with depth



quantifying benthic impact

r (m)	b (m)	δ (mm)
0.35	1.0	36
0.45	0.6	101





reduction in abundance
48%
84%

reduction in abundance
48%
50%

30% decrease mobilised sediment

concluding remarks

- in a position to begin predicting physical impacts
  - Still a need for model development / validation
- must consider impacts at the level of the gear component/element
  - scale up to the level of fishing gear
  - scale up to fleet level (using spatial and temporal fishing effort data)

concluding remarks

- put in context and compare with natural disturbance

- different spatial and temporal scales
  - haul, tide, season, year, …

concluding remarks

interpret/relate physical impact in terms of ecological / environmental impact

- sediment mobilisation ~ nutrient release, smothering, resupension of cysts, copepod eggs…
- penetration depth ~ infaunal damage /mortality, abundance …


Thank you