Research Challenges in Design for ORE

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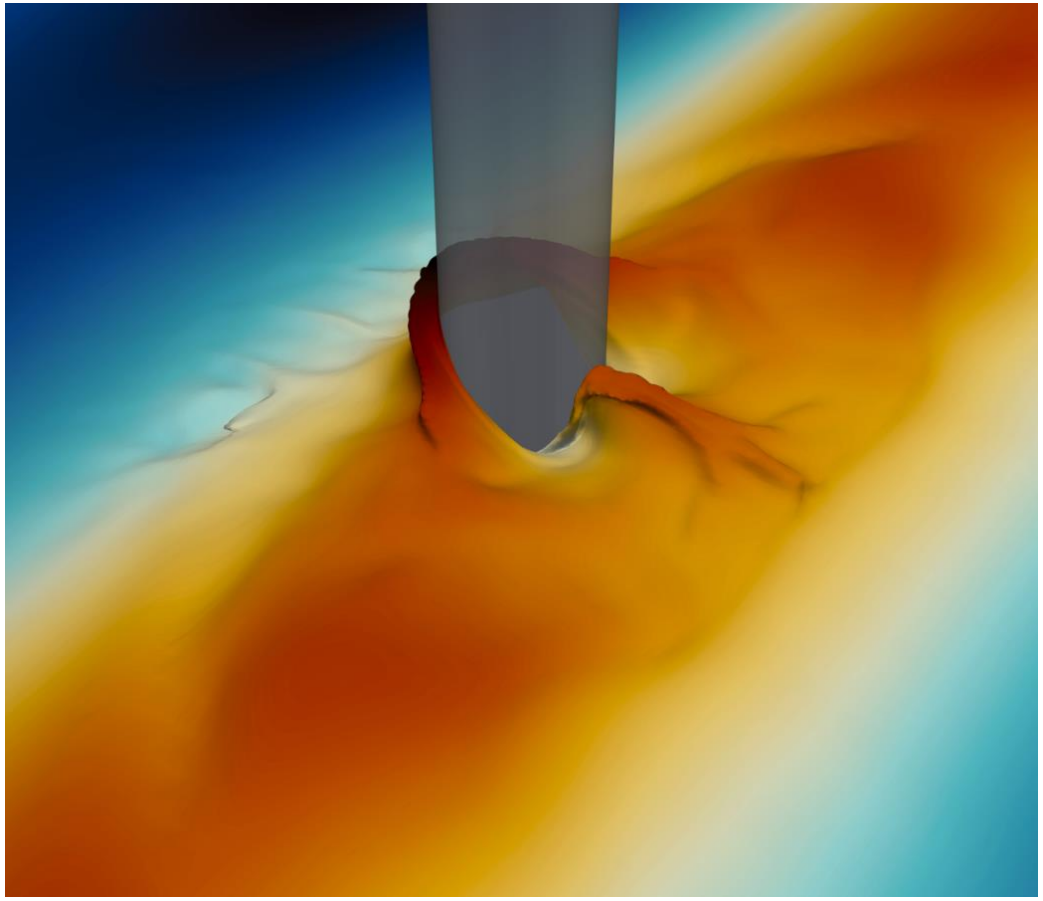

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Opening points

- Monopiles are the dominant WTF foundation solution
- Seabed mobility risk is a significant driver for O&M costs
- Floating wind has borrowed concepts from O&G needs

innovation in analysis tools

Extreme wave loading on monopile foundations

- Assessment of “ringing response” is a specific requirement for some certification authorities (from DNVGL-ST-0437):

> **4.2 Calculation of loads**
>
> 4.2.6 Hydrodynamic loads
>
> For the evaluation of load effects from wave loads, possible ringing effects shall be included in the considerations. When a steep, high wave encounters a monopile, high frequency nonlinear wave load components may coincide with natural frequencies of the structure causing resonant transient responses of the global bending modes of the pile. Such ringing effects are only of significance in combination with extreme first order wave frequency effects. Ringing should be evaluated in time domain with due consideration of higher order wave load effects. The magnitude of the first ringing cycles is governed by the magnitude of the wave impact load and its duration is related to the structural resonance period.

- Combination of ringing with other non-linear effects, such as wave slam, also needs to be considered:

> **4.5 Design situations and load cases for wind turbines**
>
> 4.5.6 Parked (DLC 6.1 to 6.5)
>
> In DLC 6.1, 6.2 and 6.3, the occurrence of the extreme design wave as defined in [2.4.4.4] shall be taken into account. The extreme wave kinematics of non-linearity, wave breaking and possible slap and slam loads shall be taken into account; see DNV-RP-C205.

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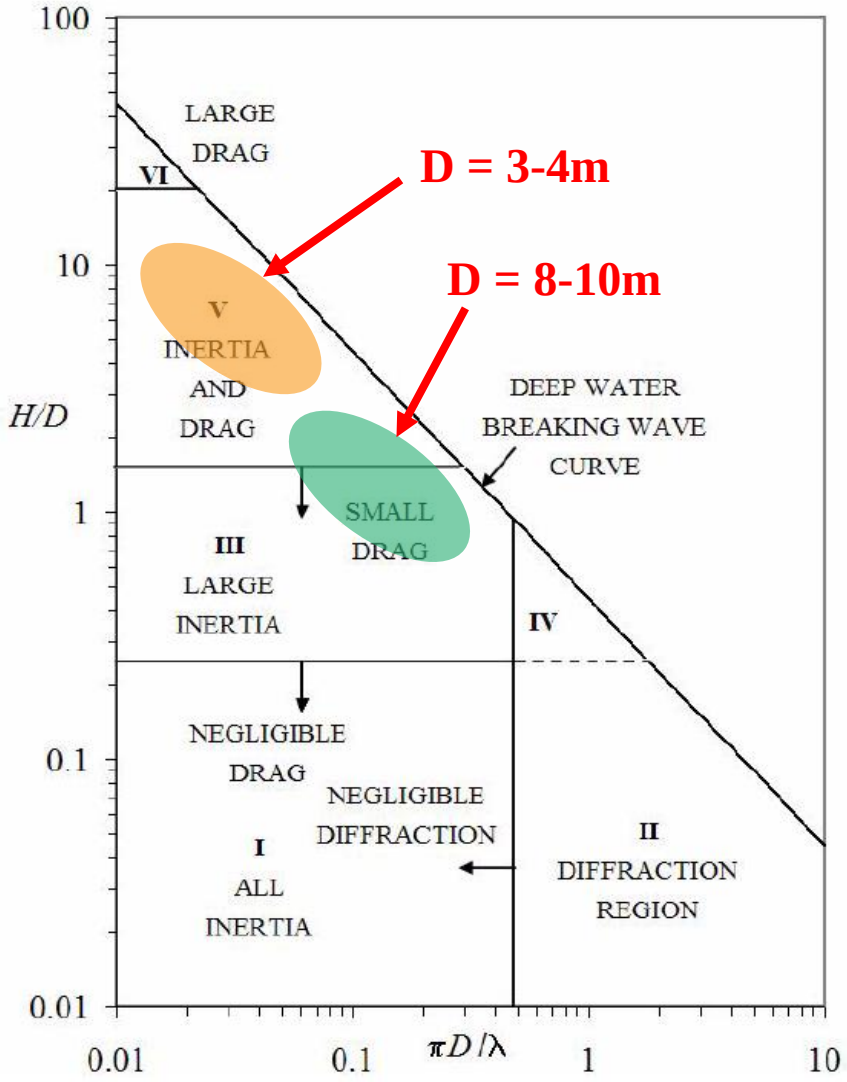
Potential for ringing in large monopiles

- Early monopiles drag dominated and possibly too stiff to suffer
- Latest generation of large diameter monopiles may be converging on ringing "sweet spot"



(from Chackrabarti)

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Indications for problematic ringing response

- Inertial loads dominant but not in diffraction regime
- 10-20m diameter
- Natural period at least 3-4s
- Peak period in the range 12-14s

HSE
Health & Safety Executive

Nonlinear potential flow forcing: the ringing of concrete gravity based structures

A summary report

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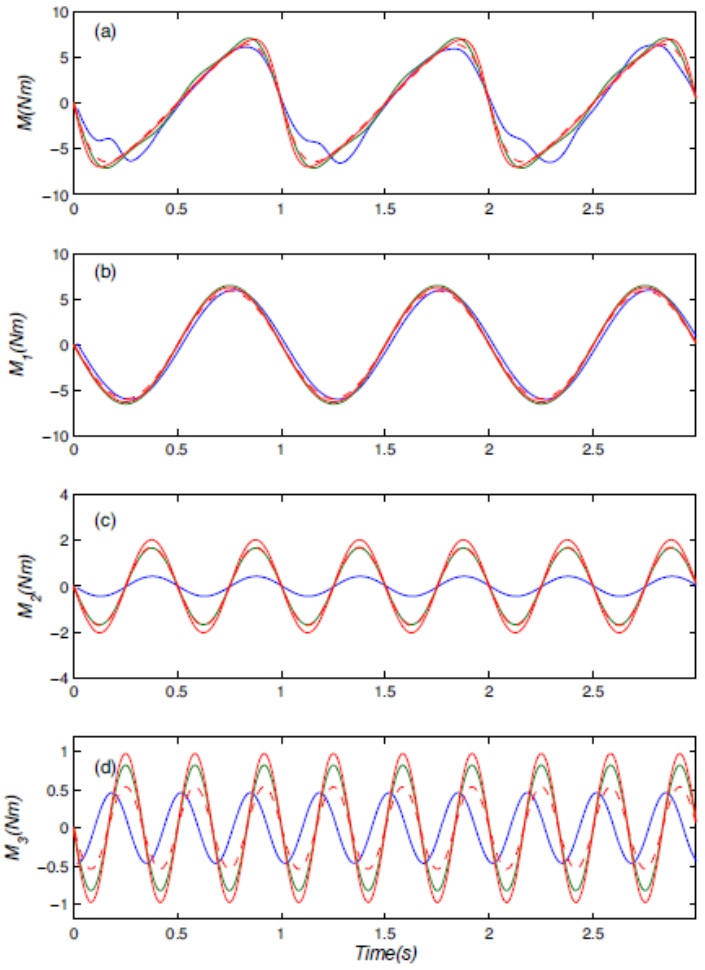
Ringing assessment methods

1. Non-linear analytical force models
2. Physical model testing
3. Computational Fluid Dynamics

Non-linear analytical force models

- Range of models proposed during 1990's
- Tend to over-predict magnitude of higher order components
- Don't predict the phases well
- Don't represent the physics
  - Wave scattering from surface of structure
- No possibility to include wave slap



(from HSE RR 468)

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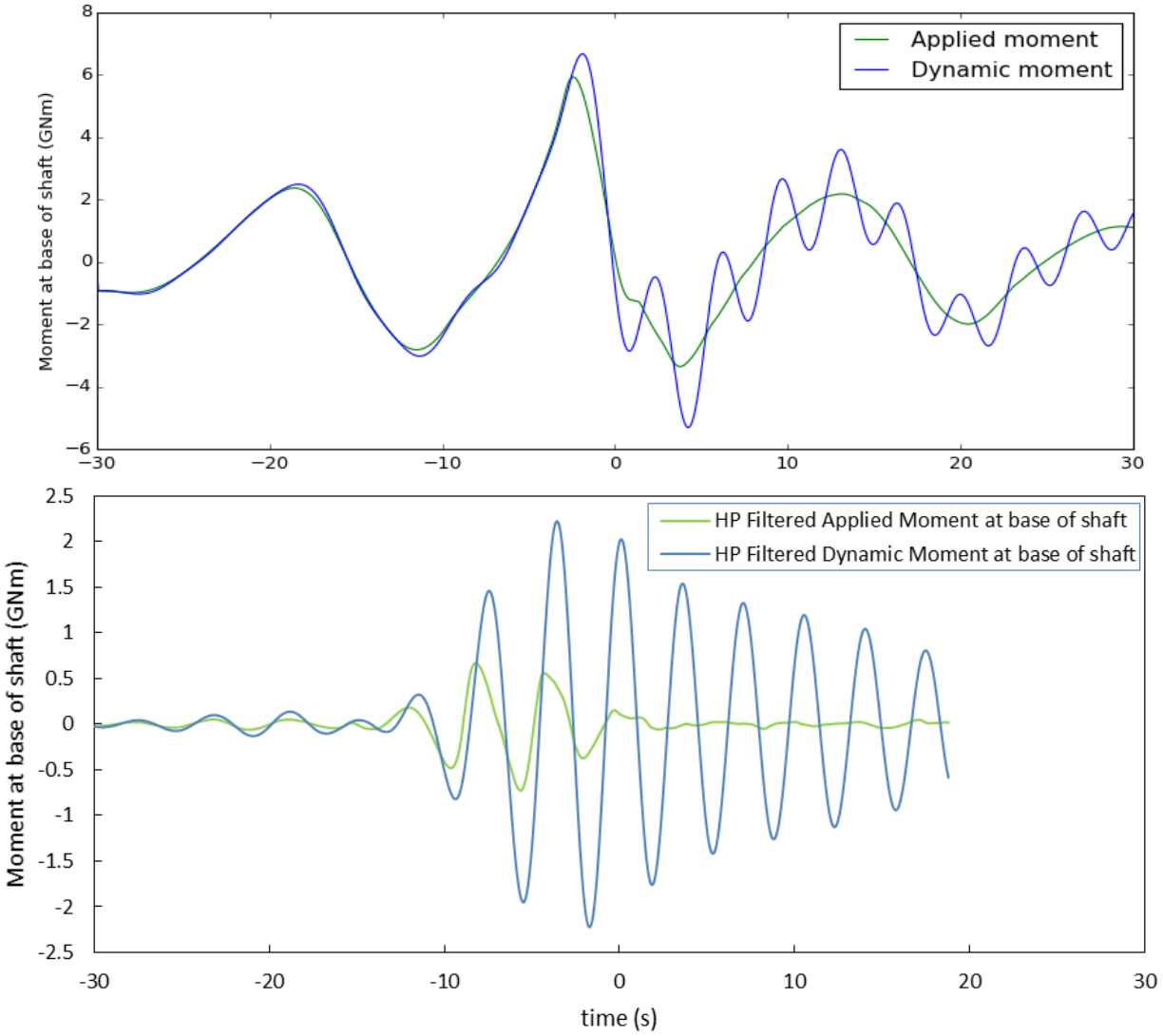
Simulated loads and response



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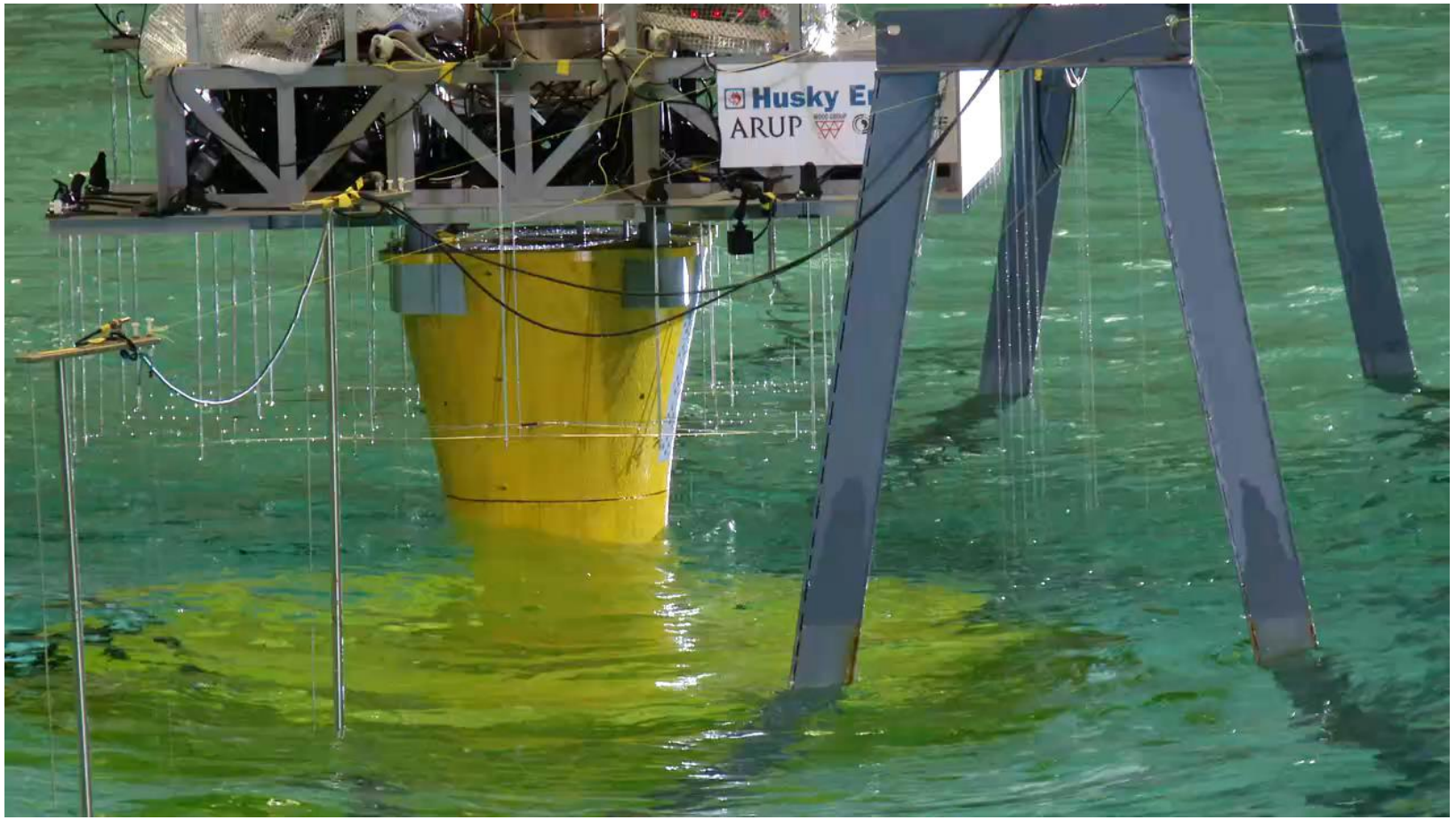
Hydro-elastic model testing



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Research challenges

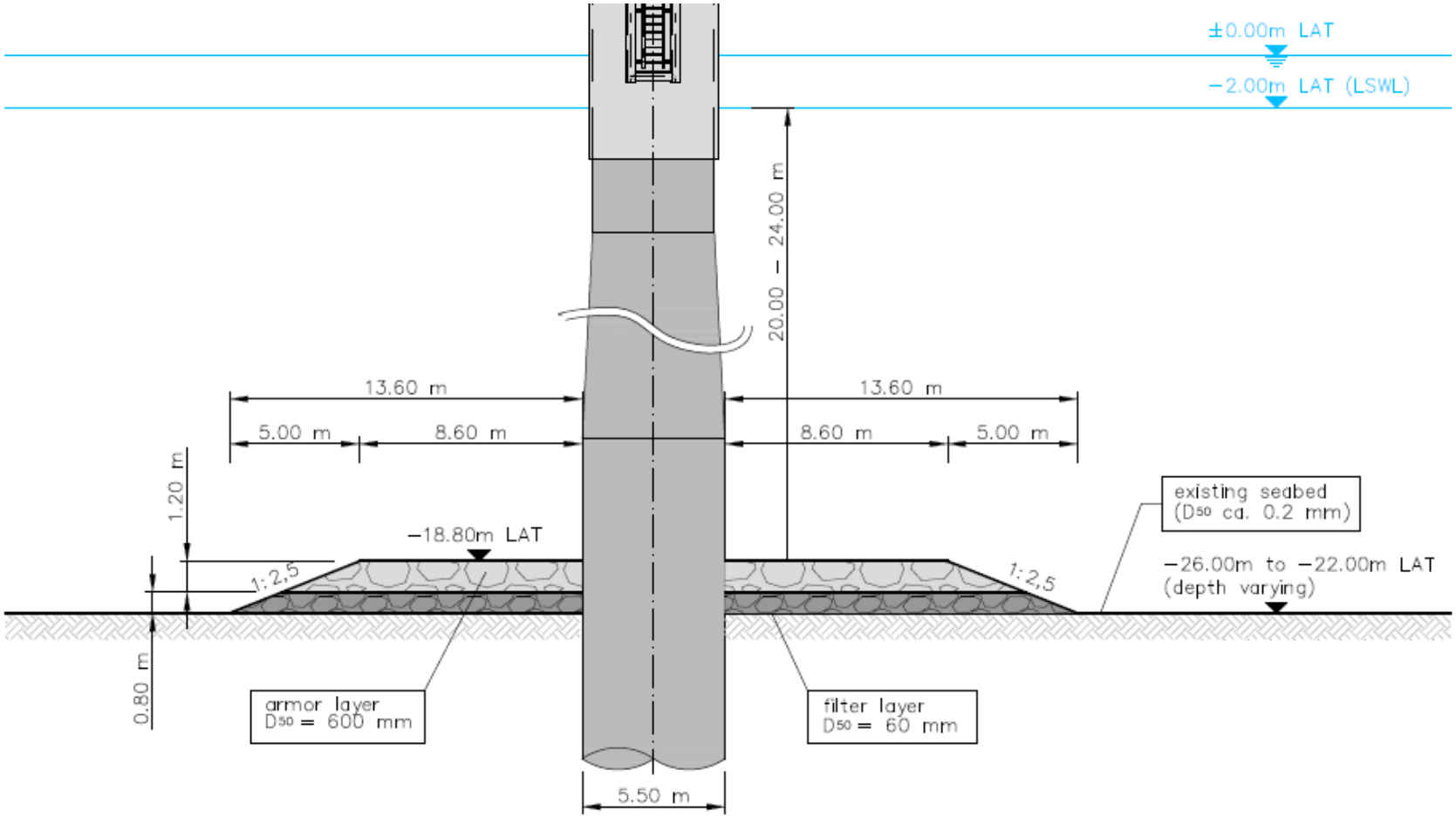
- How can we screen for dynamic response problems?
  - Inexpensive methods to identify if proper assessment is needed and, ideally, which wave forms we need to look at
- What is “right” loads model?
  - Possible underestimation of drag loads in state of the art methods for non-linear inertial load effects
  - Non-linear analytical models available but don’t represent the ringing physics correctly and can’t represent breaking wave effects
- **Is this also an issue for fatigue life?**
  - **Consider simultaneously with reduced damping from wind/wave misalignment**

Site wide sediment mobility risk

- Local scour
  - Interaction with foundation wave loads
  - Risk of damage to cables
  - Potential issues at cable crossing structures

- Global bed motions
  - Sand wave migration
  - De-burial of inter-array and export cables

Local scour at WTG foundations



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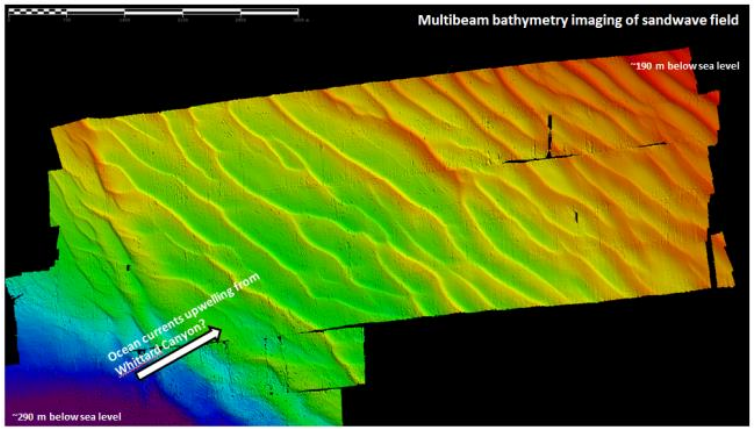
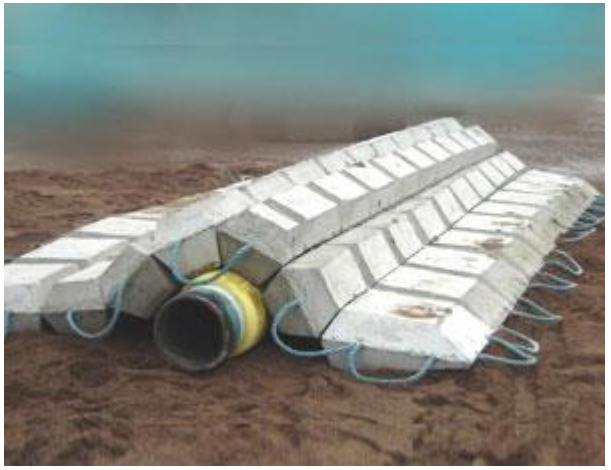
Sediment mobility risk to cable routes

- Cable burial profile almost impossible to preserve with mobile bedforms
  - How best to protect exposed cables?
- Sea bed is becoming increasingly congested
  - Cable crossing structures create huge financial risks if they fail
  - Design guidance not really available



(image from Lo Iacono, Gales and Carter)



(image from Subsea Protection Systems)

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Research challenges

- De-risking innovative scour protection design concepts
  - Physical modelling studies
  - Full scale trials
- Improving site wide mobility assessment methodologies
- Developing reliable methods to assess impact of local scour
- Remote monitoring strategies
- Demonstrate value of scour resistance testing in cohesive soils

Floating wind

- Market a long wave from consolidating around “best” concept
  - Role for academic research in presenting an unbiased view
- Main concepts borrow from O&G
  - Semi-sub, Spar, TLP
  - Is model testing a realistic part of offshore wind design cycle?
- Investment in advanced modelling tools likely to provide high impact:
  - Identified by Carbon Trust 2015 report as critical short term need
  - Ongoing joint industry research
  - Need to identify and test innovative software
  - Methods for assessment of wave impact loads

Thanks for listening.

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