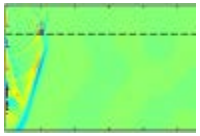
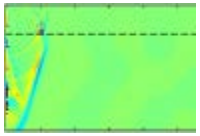


TNO innovation for life

Marine piling noise

modelling and reduction

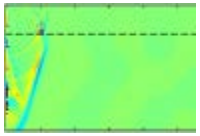
Christ A.F. de Jong



TNO (Netherlands Organization for Applied Scientific Research)

"TNO connects people and knowledge to create innovations that boost the sustainable competitiveness of industry and well-being of society."

TNO in 2011*:*
- 3932 employees
- 189 M€ government funding
- 388 M€ market income



Contents

1. Piling noise mechanisms and modelling
2. Noise mitigation results (Germany)

Acknowledgements:

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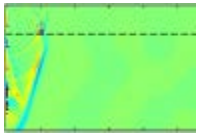
Dick Hazelwood, Steve Robinson, Pete Theobald (NPL), Paul Lepper (Loughborough Univ.)

Bob Jung (IHC Hydrohammer)

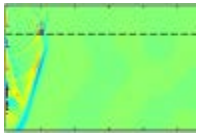
NL Ministry of Infrastructure and the Environment

Fabian Wilke, Karin Kloske & Michael Bellmann, May 2012:
ESRa – Evaluation von Systemen zur Rammschallminderung an einem Offshore-Testpfahl
(http://www.offshore-stiftung.com/60005/Uploaded/Offshore_Stiftung%7CESRa_TechnischerAbschlussbericht.pdf)

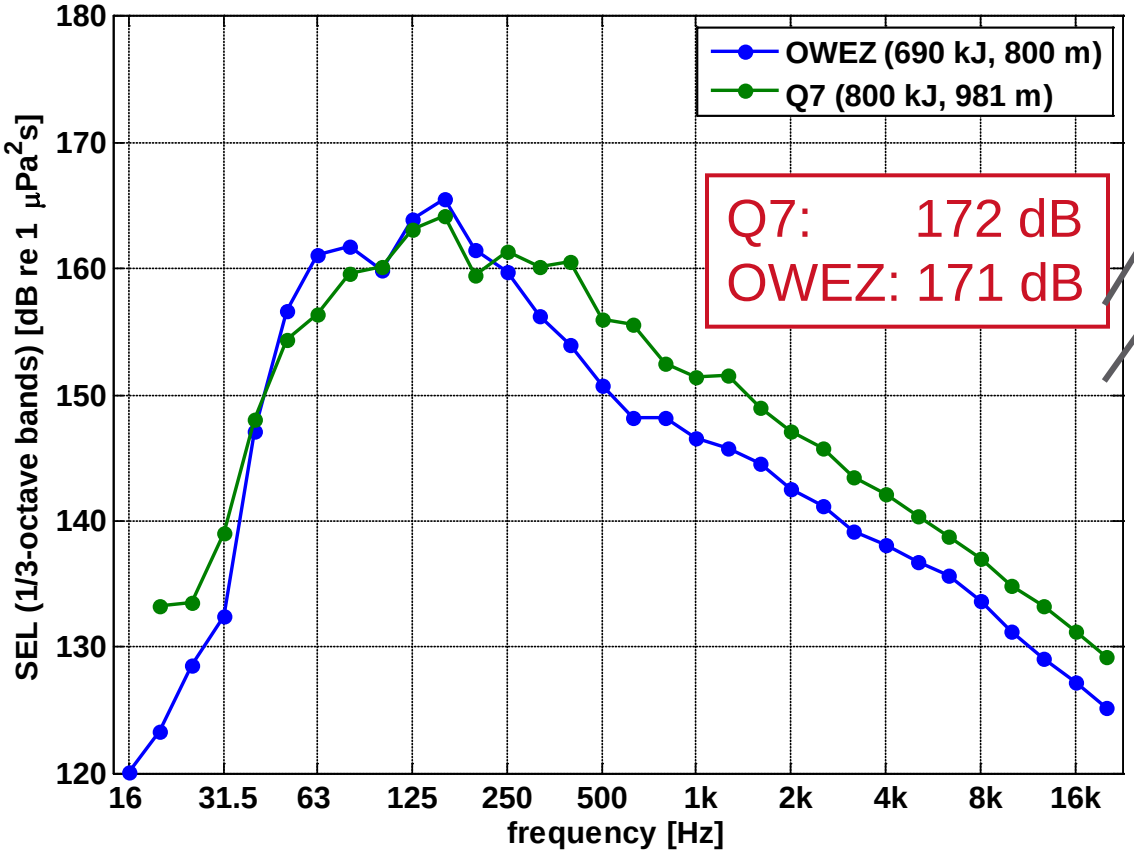
Why reducing marine piling noise?

- Widespread concern about ecological impact
- ***EU Marine Strategy Framework Directive***:
  - Monitor the number of pile driving days per year per area
- ***Netherlands***
  - No impact pile driving between January 1st and July 1st
  - Just one building project at a time
- ***Germany***
  - UBA advice (http://www.umweltdaten.de/publikationen/fpdf-l/4118.pdf)
    - Single strike unweighted SEL at 750 m < 160 dB re 1 $\mu Pa^2 s$
    - Single strike peak to peak sound pressure level at 750 m < 190 dB re 1 μPa^2

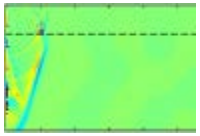


Example: NL Offshore Wind farms

(single strike SEL at ~1 km distance)



ACHIEVE > 12 dB REDUCTION?



NL R&D “Ecological Monitoring Wind at Sea”

Reports published September 2011:

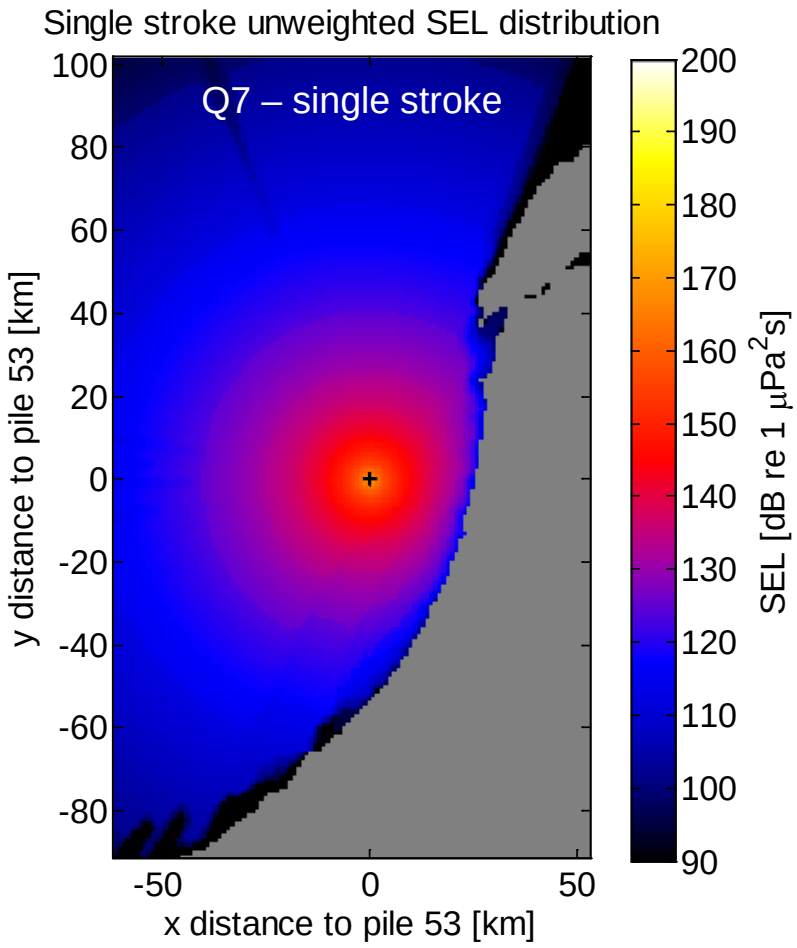
http://www.noordzeeloket.nl/ihm/themas/Shortlist_Ecologische_Monitoring_Wind_op_Zee/

- Masterplan Ecologische Monitoring Wind op Zee
- Standard for measurement and monitoring of underwater noise Part I physical quantities and their units
- Standard for measurement and monitoring of underwater noise Part II procedures for measuring underwater noise in connection with offshore wind farm licensing
- Final (short) report on TTS in seals & a porpoise
- Effect of piling noise on the survival of fish larvae (pilot study)

TNO Deltares IMARES WAGENINGEN UR SEAMARCO SEA MAMMAL RESEARCH COMPANY

Acoustical modelling

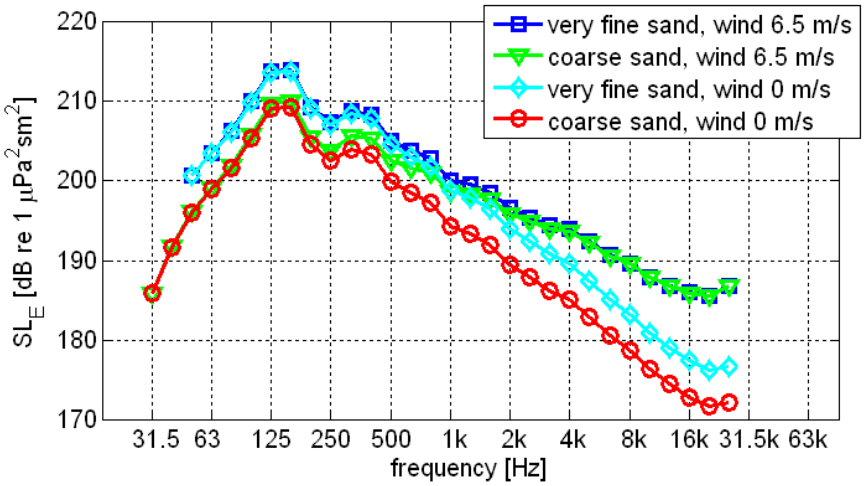
- Environmental Impact Assessment → 'noise maps'
  - Single stroke SEL (*behavioural effects*)
  - Cumulated SEL (physiological effects, static or moving animals)
- Project optimization
  - Design mitigation measures
  - Predict effectiveness



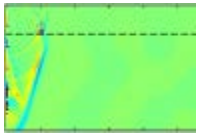
Source level of pile driving noise in water?

- Transient: SEL = SL_E – PL

- Published measurement of SL_E
  - From Q7 wind farm construction *
  - Point source assumed, far from boundaries
  - Needs to be made more realistic → physical modelling



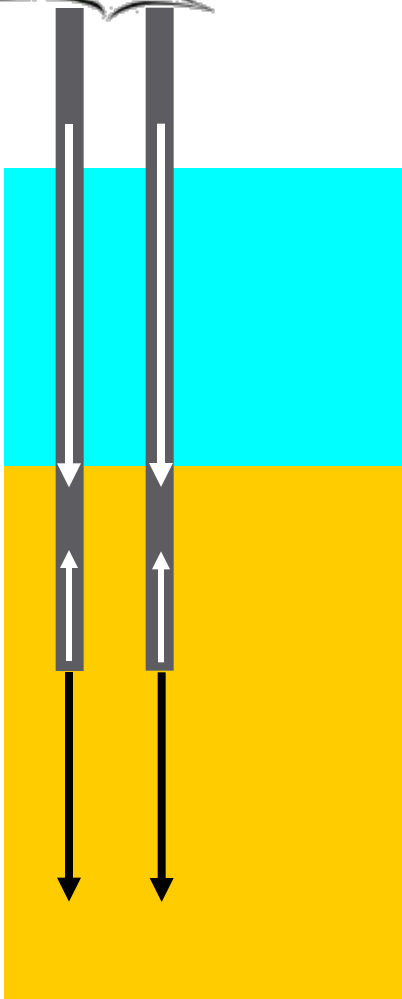
*M. A. Ainslie et al, 'What is the Source Level of Pile Driving Noise in Water?', Aquatic Noise, Cork (2010)



Physical aspects: the source

- Hammer blow
  - Mass: ~ 1000's kg
  - Speed on impact: ~ 10 m/s
  - Generates compressional wave.

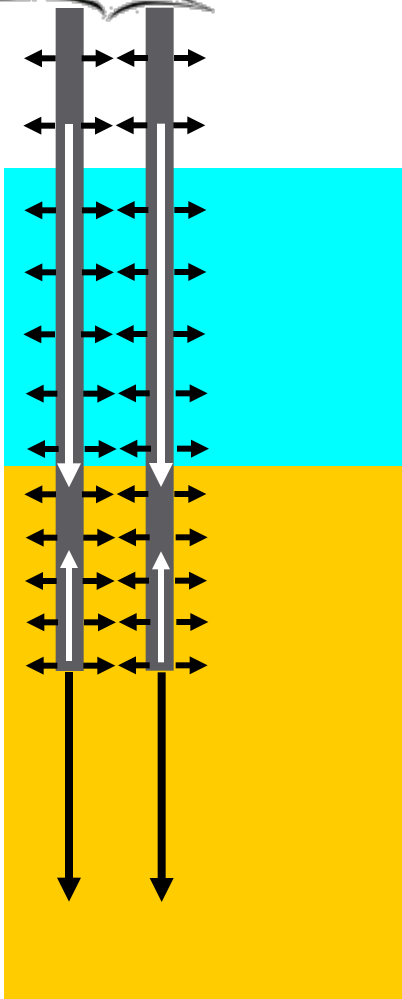
- Compressional wave
  - Reflects from bottom of pile
  - Pushes pile into ground on reflection.

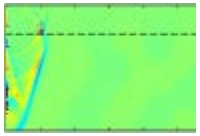


Zampolli et al 2013, 'Validation of finite element computations for the quantitative prediction of underwater noise from impact pile driving', Journal of the Acoustical Society of America (in press)

Sound radiation

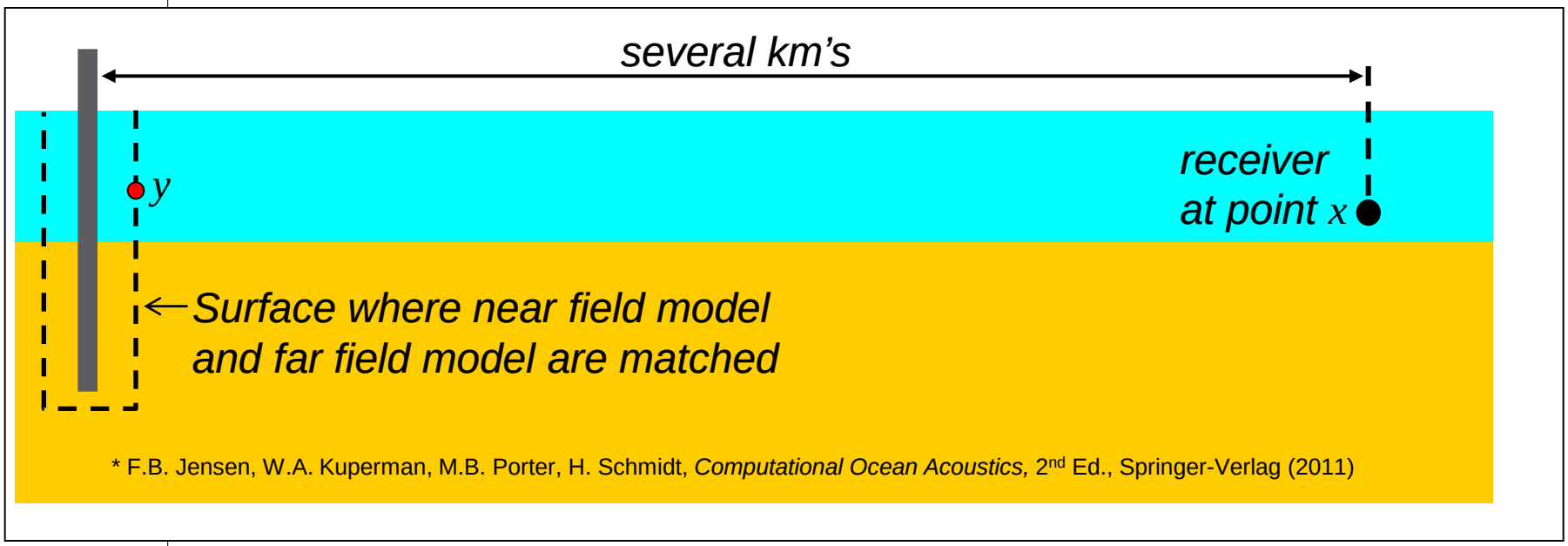
- Compressional wave:
  - Generate radial displacement (Poisson contraction). ← →
  - Sound radiation
- Sound propagation through the water:
  - The sound radiated by the pile bounces through the waveguide, reflecting from the boundaries.
  - Energy flow between water and sediment.



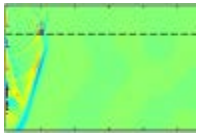


Modelling pile driving noise
Hybrid local model & propagation model

- Model the pile and its “near” surroundings using a full wave structural acoustic model, here a finite-element (FE) model.
- Compute the acoustic field far away from the pile using a high fidelity (and fast) propagation model.*

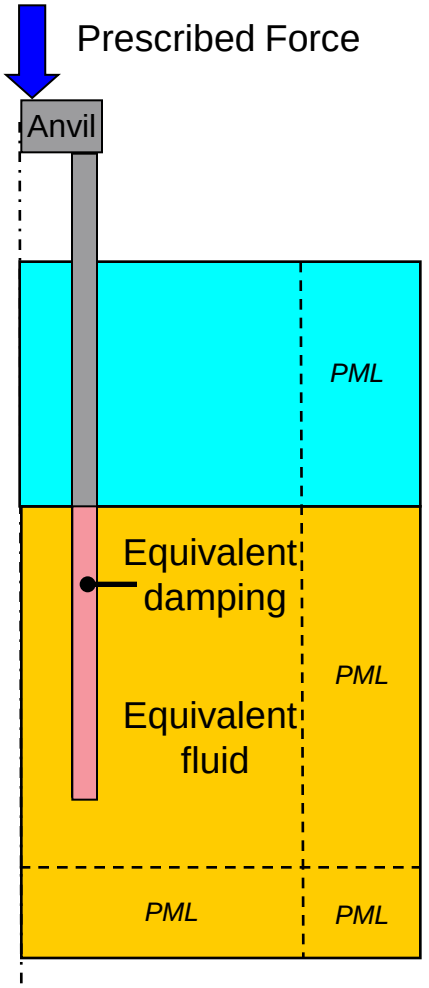


* F.B. Jensen, W.A. Kuperman, M.B. Porter, H. Schmidt, *Computational Ocean Acoustics,* 2nd Ed., Springer-Verlag (2011)



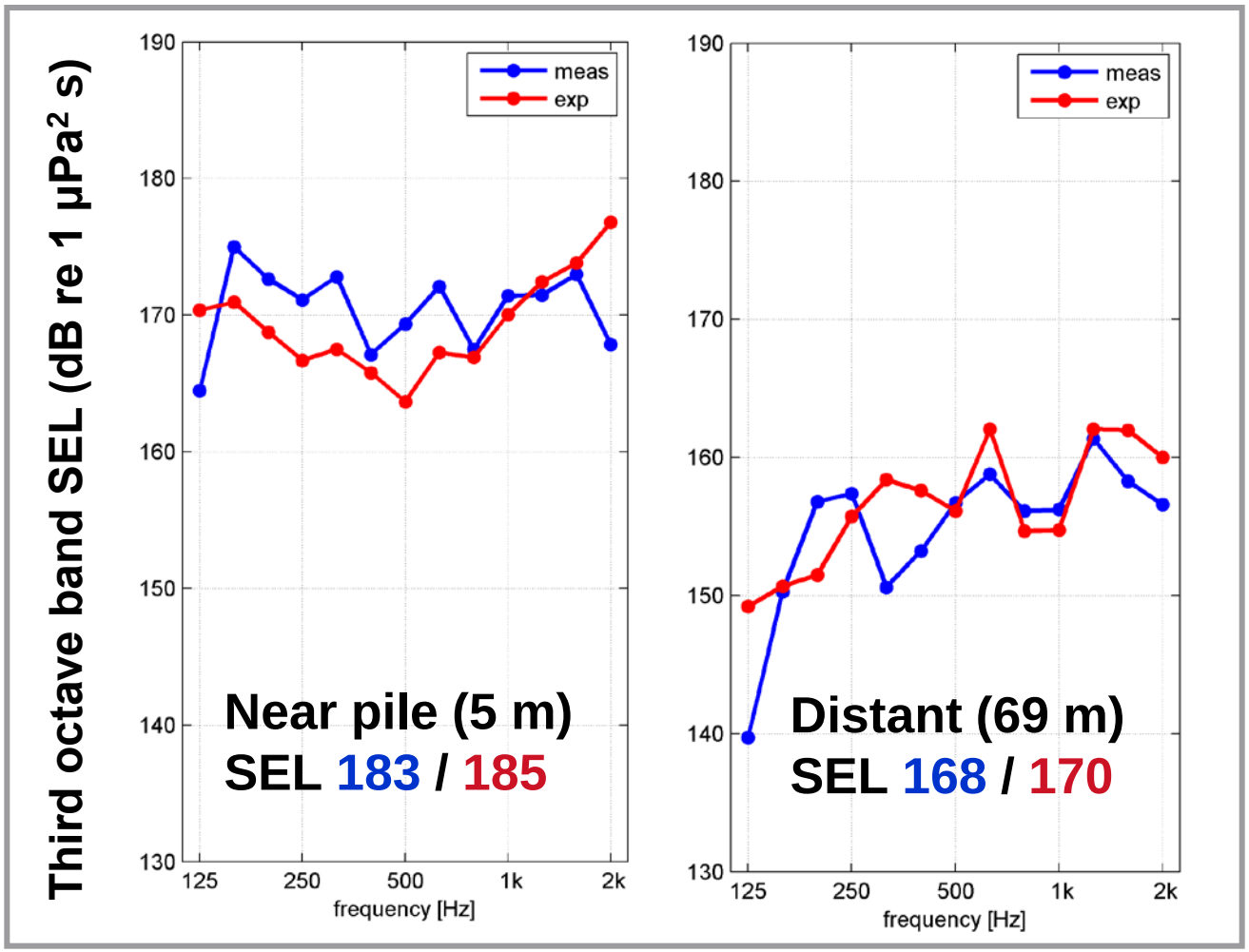
Finite Element Model

- Linear, axially symmetric, frequency domain
- Elastic solid / fluid domains
  - Coupling: - conservation of normal force/velocity
    - slip in tangential direction
  - Sediment / pile friction modelled as equivalent damping in the steel (buried section)
- Perfectly Matched Layers* (PML)
- Comsol 3.5a FE model
- Matlab pre- and post-processing



* J.P. Berenger, *J. Comp. Phys*. **114** (1994) , and M. Zampolli *et al.*, *J. Acoust. Soc. Am.* **122** (2007)

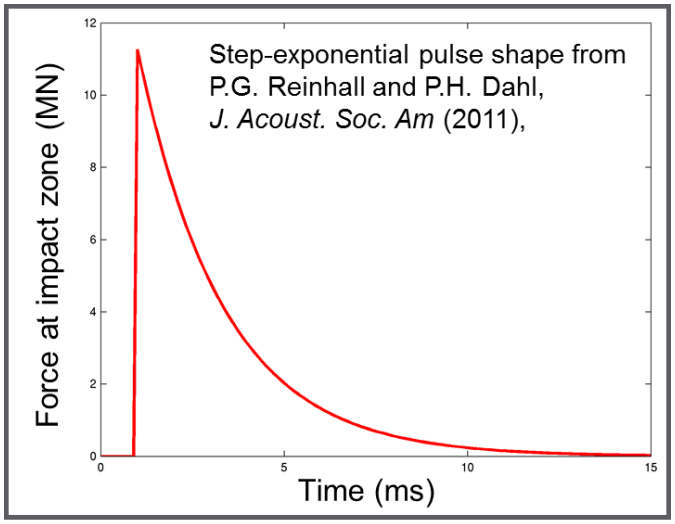
Model versus measurements 'Kinderdijk'

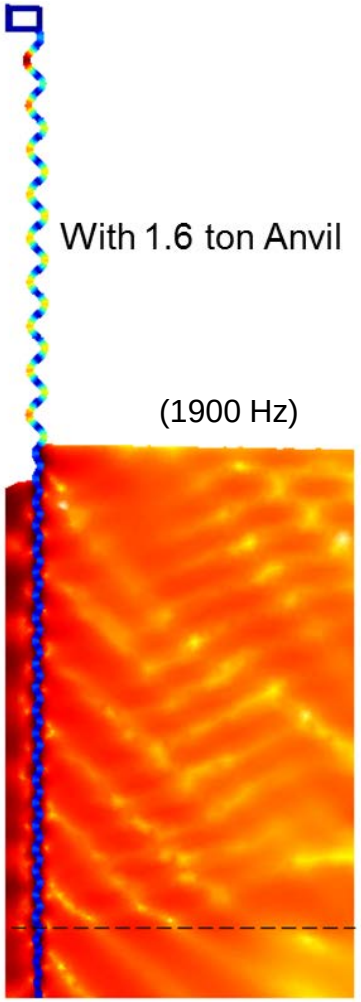


Blue: Measurement Red: Model

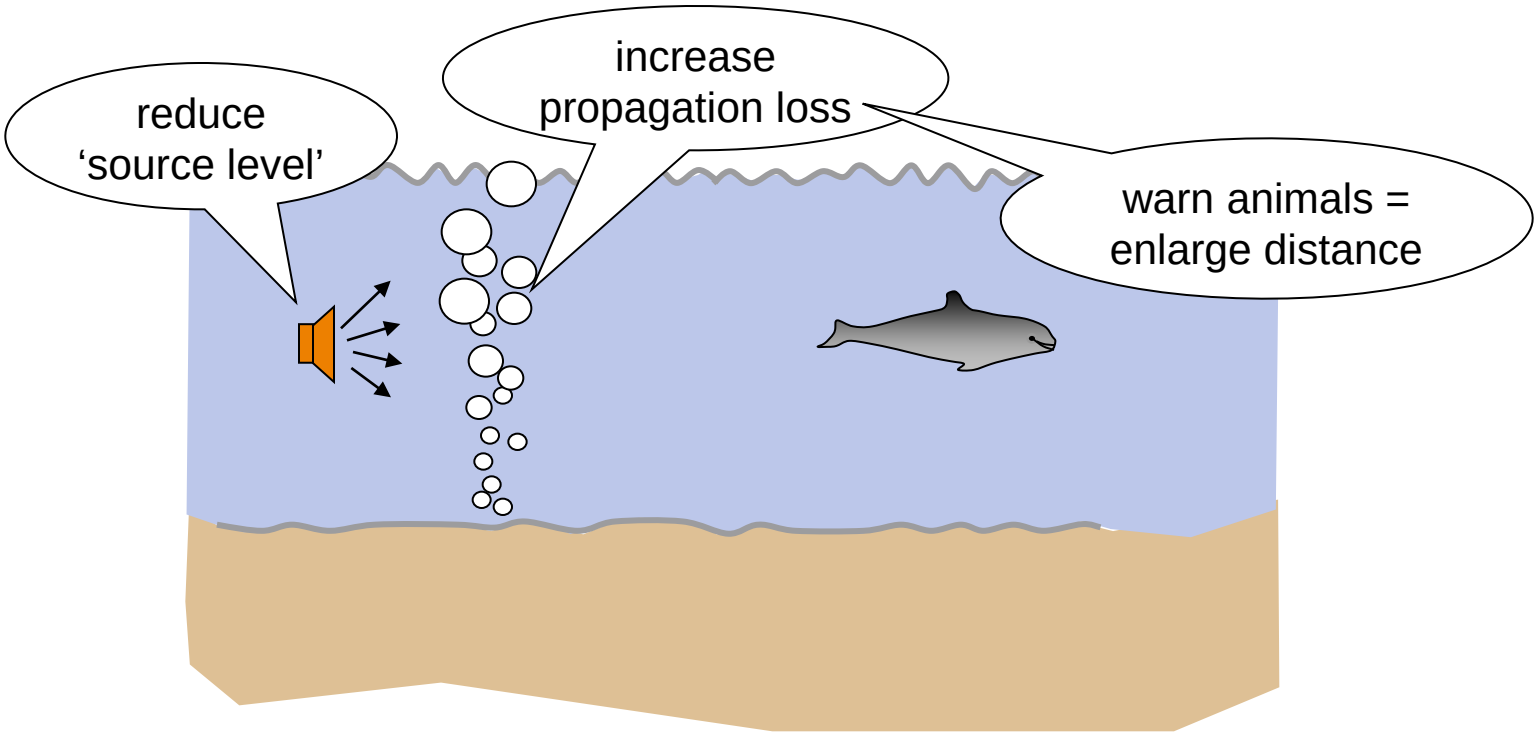
Challenges for modelling

- Representative Forcing function
- Modelling /accounting for the anvil
- Modelling / accounting for friction between sediment and pile: now a loss factor for the buried pile section
- Coupling with ‘noise mapping’ model





Options for mitigation



Germany: ESRa tests (2011)

1. The noise mitigation screen (NMS) from company IHC.
2. The fire hose system (FHS) of company Menck.
3. The Little Bubble Curtain (LBC) – company Weyres.
4. The Weyres BeKa-Shell
5. The Hydro Sound Damper (HSD) of TU Braunschweig / Dr. Elmer

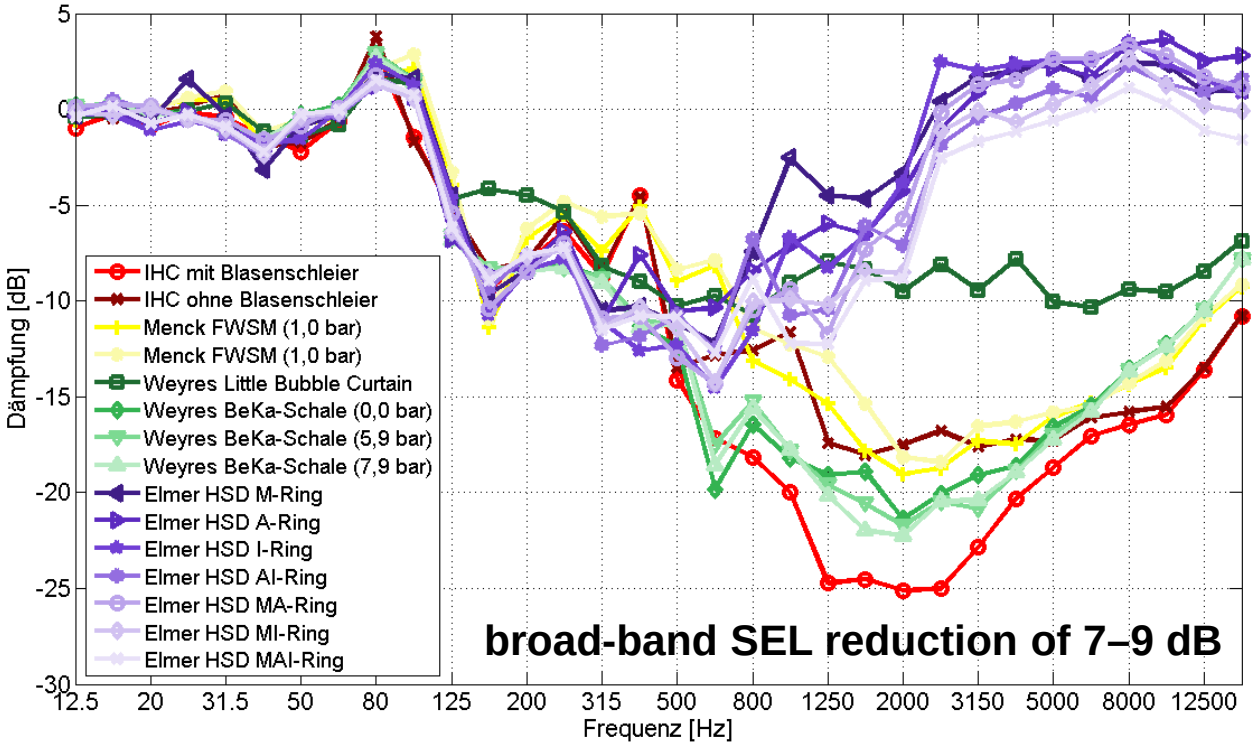
Position	N 53 59.877‘ E 10 54.489‘
Diameter	2.2 m
Height above waterline	5.5 m
Water depth	8.5 m
Embedment into soil	ca. 65.0 m
Wall thickness	50.0 mm

Menck MHU 270 T, max. 300 kJ

Fabian Wilke, Karin Kloske & Michael Bellmann, May 2012:
ESRa – Evaluation von Systemen zur Rammschallminderung an einem Offshore-Testpfahl
(http://www.offshore-stiftung.com/60005/Uploaded/Offshore_Stiftung%7CESRa_TechnischerAbschlussbericht.pdf)

Germany: ESRa tests (2011)

Acoustic insertion loss (ΔSEL) in 1/3 octave bands at 750 m distance



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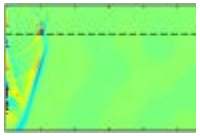

CONCLUSION

- Noise modelling tools are available and being further developed
- Noise mitigation techniques are available and being further developed, mainly thanks to German noise requirement and government funded research
- International standardisation is started: *(meeting Berlin May 2013)*
  - Underwater noise terminology: ISO TC43 SC3 WG2

    Convenor: Michael Ainslie, TNO
  - Piling noise measurements: ISO TC43 SC3 WG3

    Convenor: Stephen Robinson, NPL
- International harmonization of impact assessment ?