



Universiteit Utrecht

Deltares

Enabling Delta Life



Effect of large sand nourishments (case Sand Engine) on fresh groundwater resources

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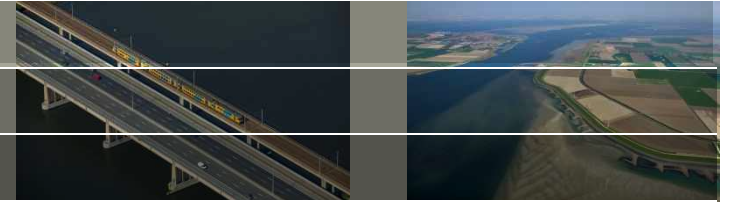
29 September 2015

Supervisors/tutors:

Marc Bierkens (UU, Deltares)

Gualbert Oude Essink (Deltares, UU)

The Sand Engine Project



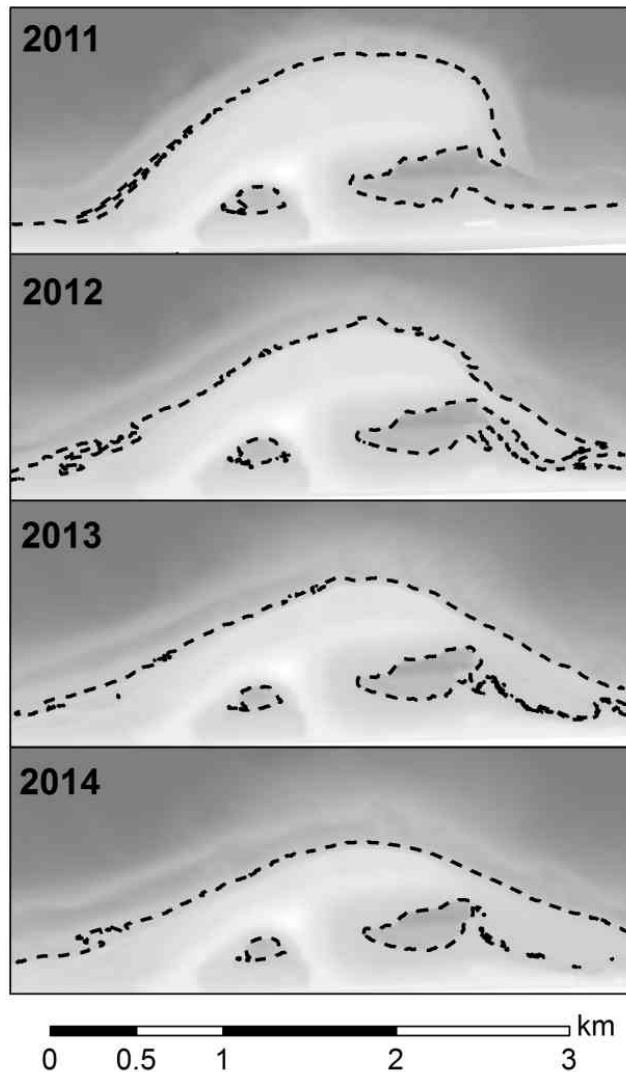
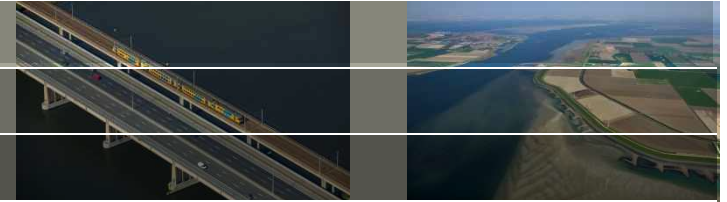
- The Sand Engine:
 - Large sand nourishment of 21 Mm³
 - Located southwest of The Hague
 - Constructed in March-October 2011
- Innovative method for coastal protection
 - Traditional maintenance
 - Building with Nature
 - Opportunities recreation and nature



(Stive et al., 2013)



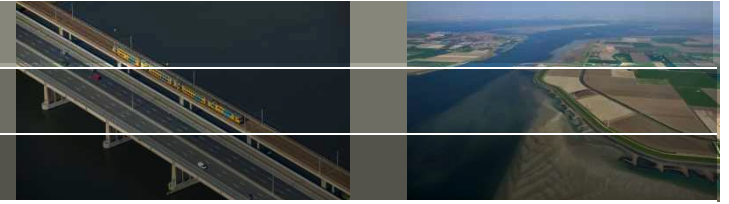
The Sand Engine Project



- Pilot project: Research by PhDs & Postdocs
 - Studying the distribution of sand
 - Ecosystem, groundwater, chemistry, recreation, swimmer safety
- Evolution of the Sand Engine since the construction in 2011, approx. $1\text{Mm}^3/\text{yr}$.

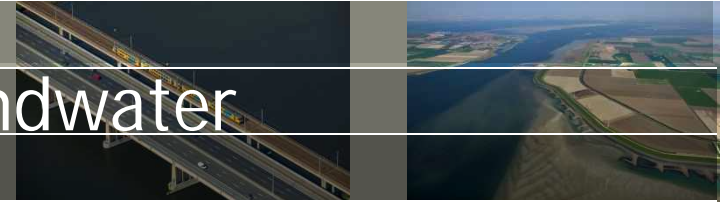
(Schipper et al., 2014)

Research subjects PhD



1. Can a mega-nourishment like the Sand Engine lead to a substantial growth in fresh ground water resources?
2. How do tides, storms and rain effect the interface between fresh and salt groundwater at the Sand Engine?
3. Do we observe a growth of the freshwater lens in the Sand Engine?
4. World wide applicability of mega-nourishments?
5. Interdisciplinary research (hydrology, ecology, geochemistry)

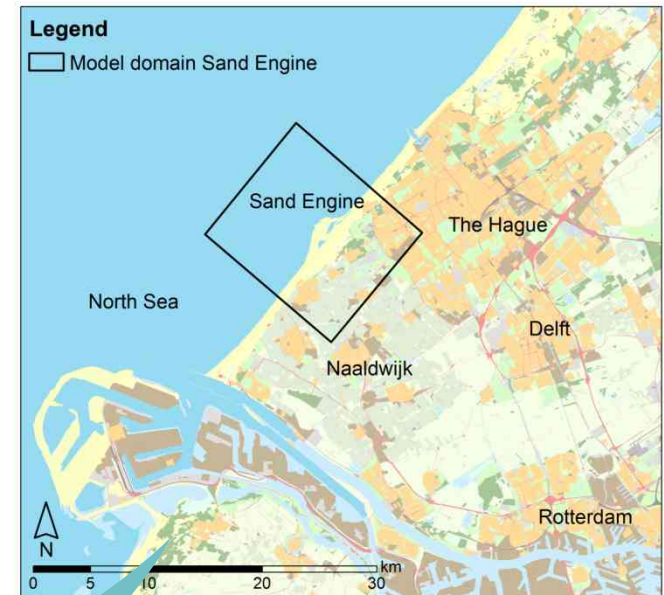
1 - Potential change in fresh groundwater



Research questions:

- What potential change in fresh groundwater resources does the construction of Sand Engine create?
- How is the calculation of the fresh groundwater resources effected by uncertainties in the morphological developments and climate change?

Methodology:



Field measurements
Sand Engine and
environment

Development
Regional model (3D)

Calibration
regional model

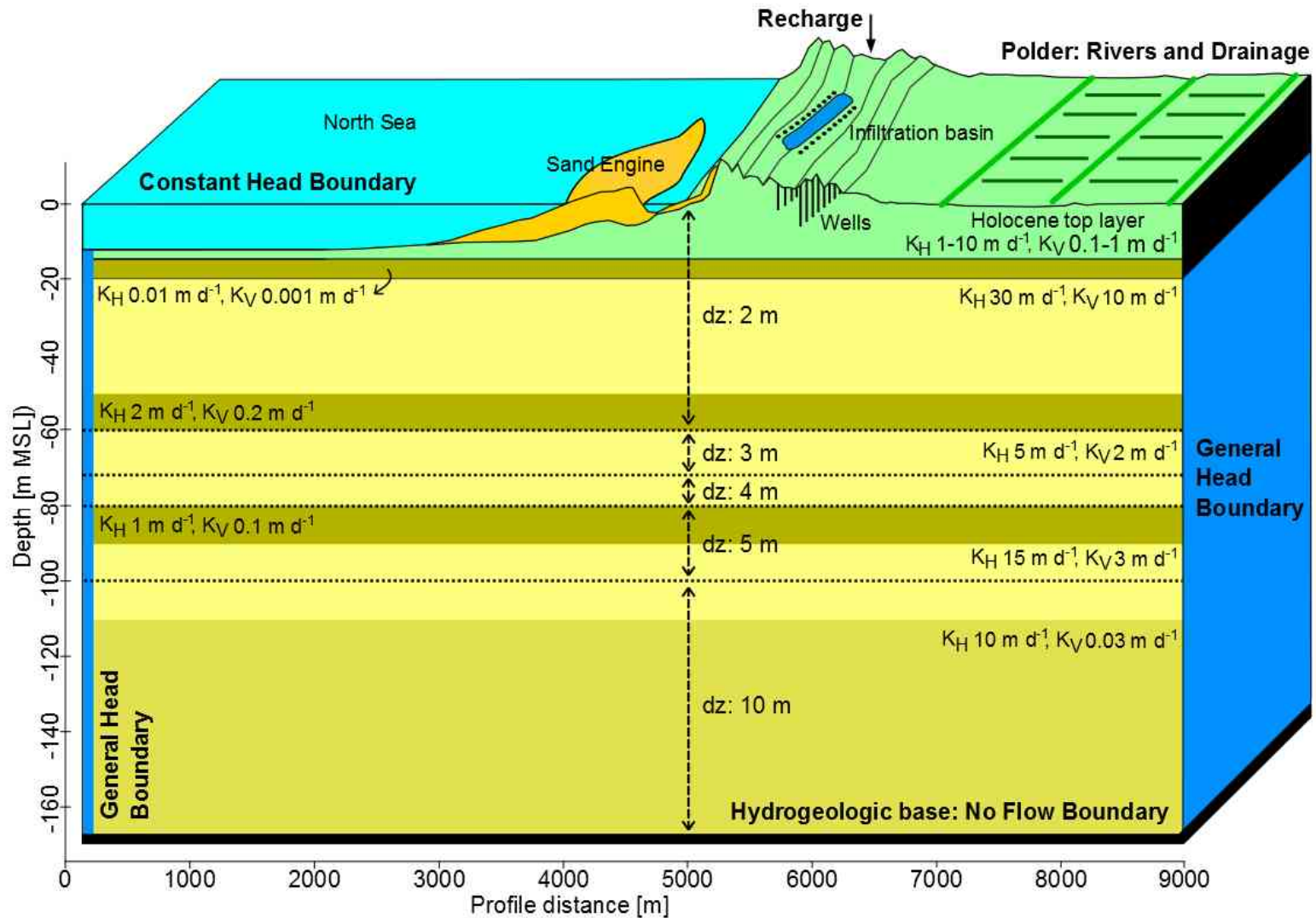
Transient
scenario's

Change in
fresh groundwater
resources

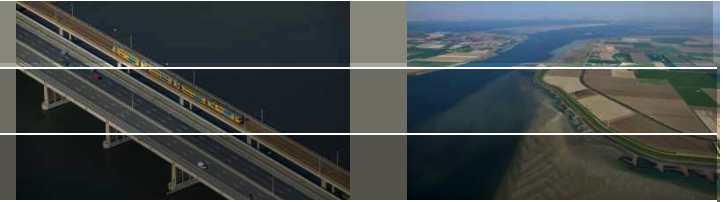
Collection of data

Construction and measurements of
monitoring wells

1 - Model schematization

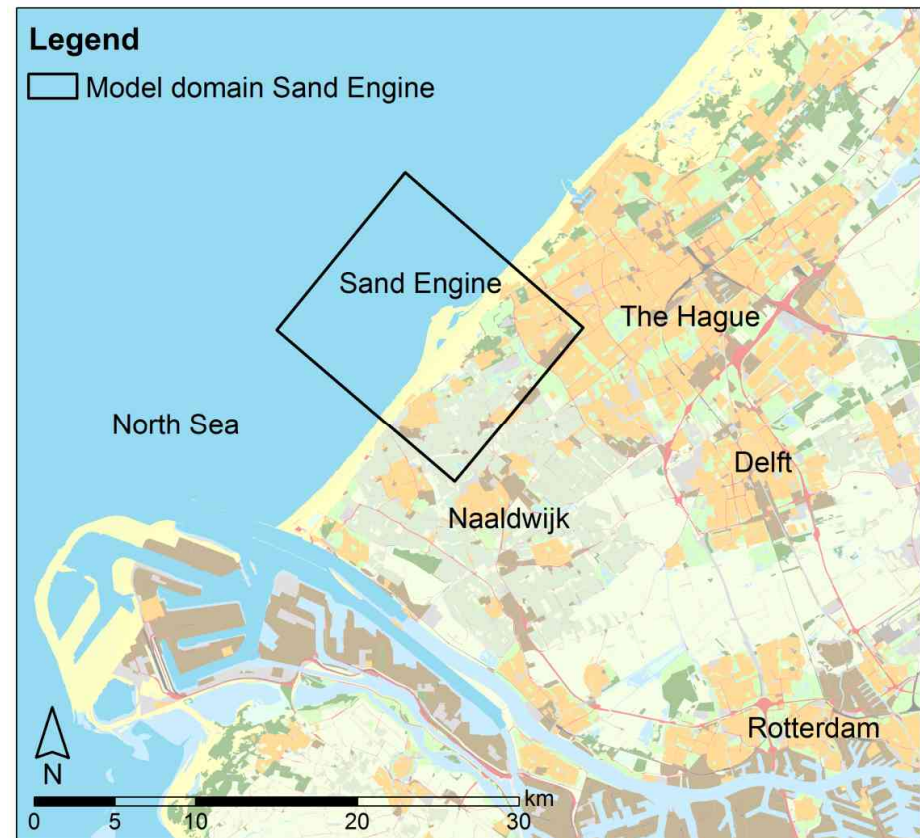


1 - Model simulations

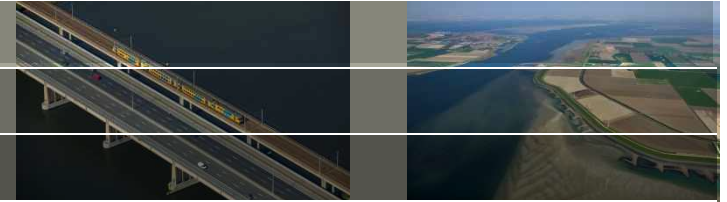


Model code: SEAWAT version 4
50 x 50 m cells, 50 model layers

- Initial situation 2011
 - before construction Sand Engine
 - equilibrium for situation in 1700
 - transient simulation 1700 - 2011
- Scenario:
 - construction Sand Engine
 - morphological changes
 - climate scenario's
 - period: 2011 - 2050



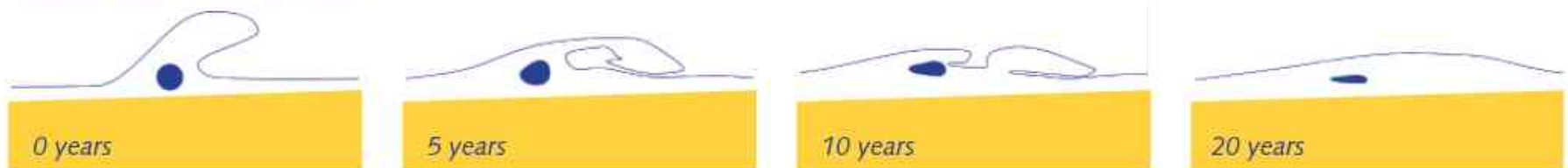
1 - Results



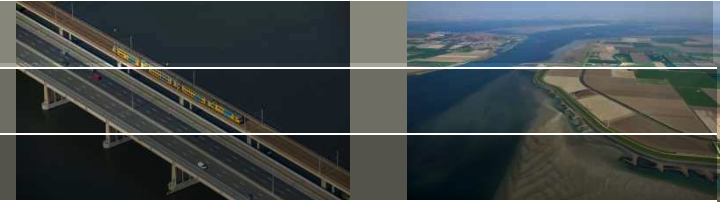
Modeling morphological development of the Sand Engine:

- Morphological development of the Sand Engine is predicted by a Delft3D model for every 3 months in the period 2011 - 2050
- The calculated yearly change of the morphology or surface elevation are enforced to the groundwater model by changing:
 - the height and thickness model cells
 - the boundary conditions
 - the precipitation surplus

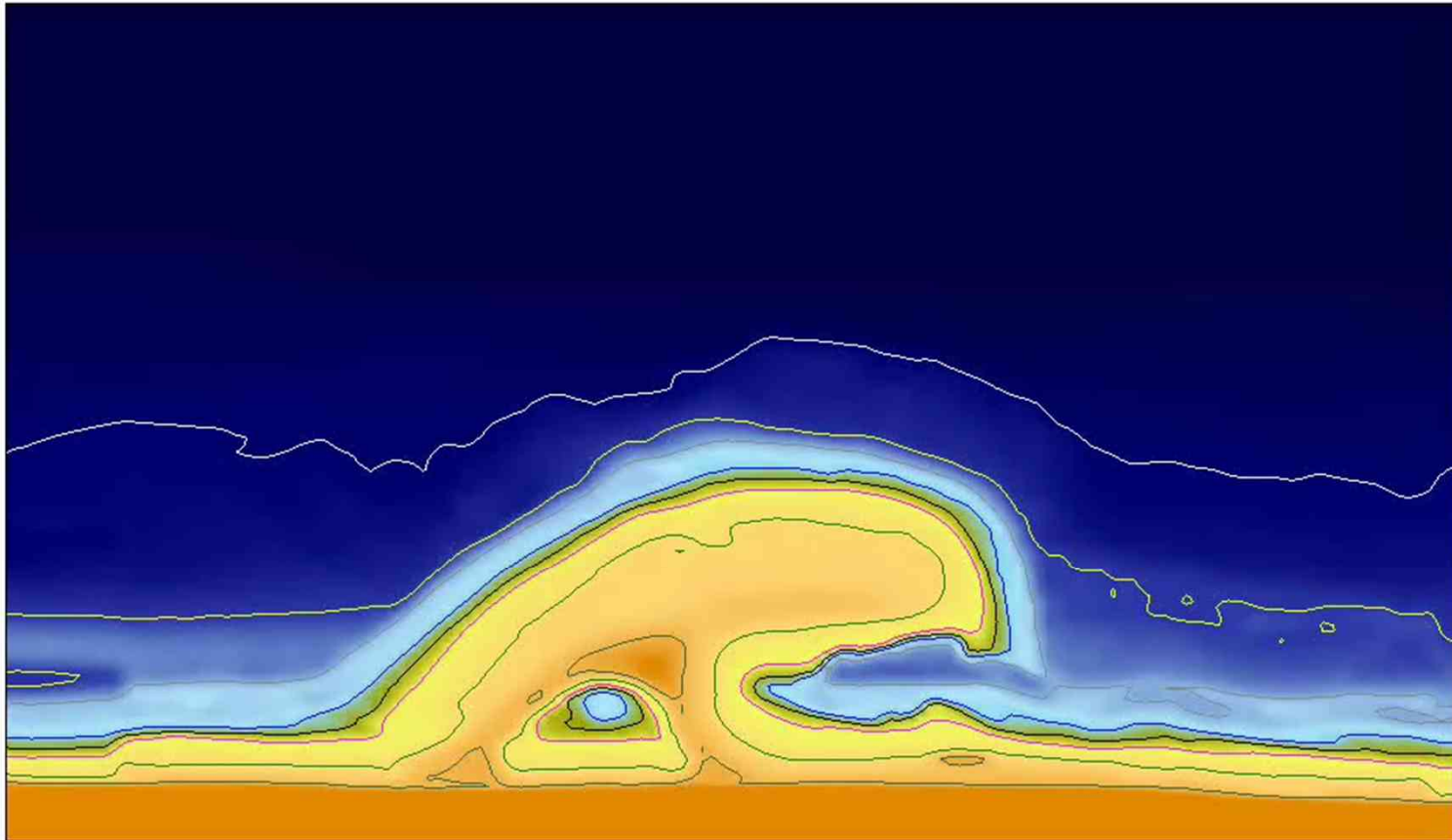
Development of the Sand Motor



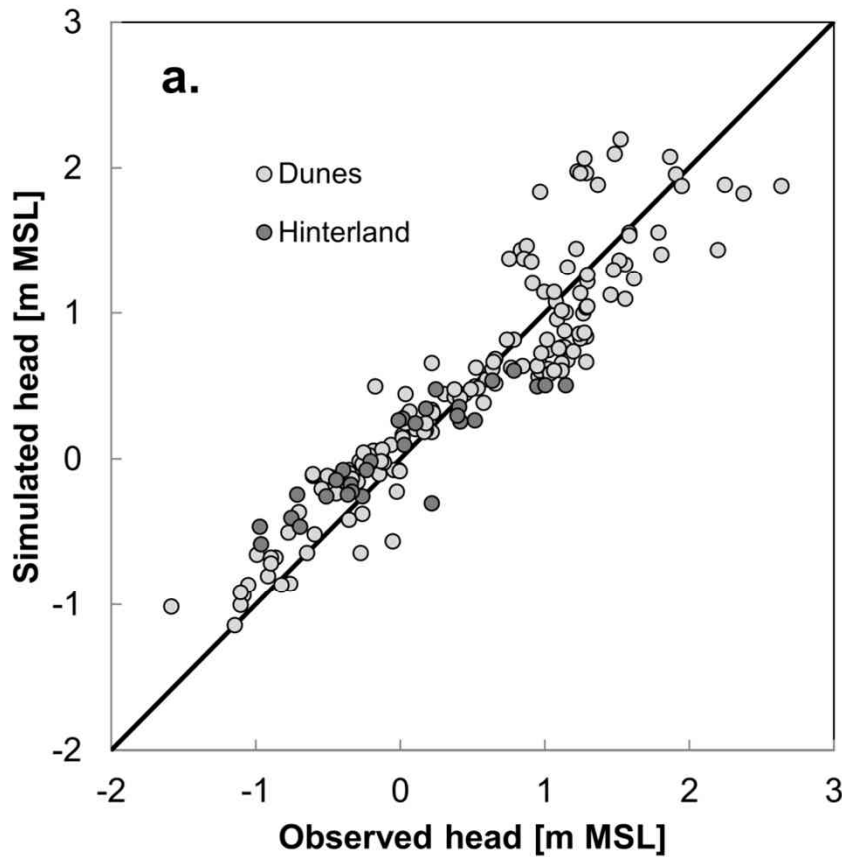
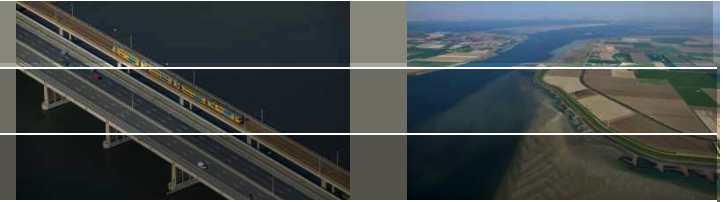
1 - Changing morphology



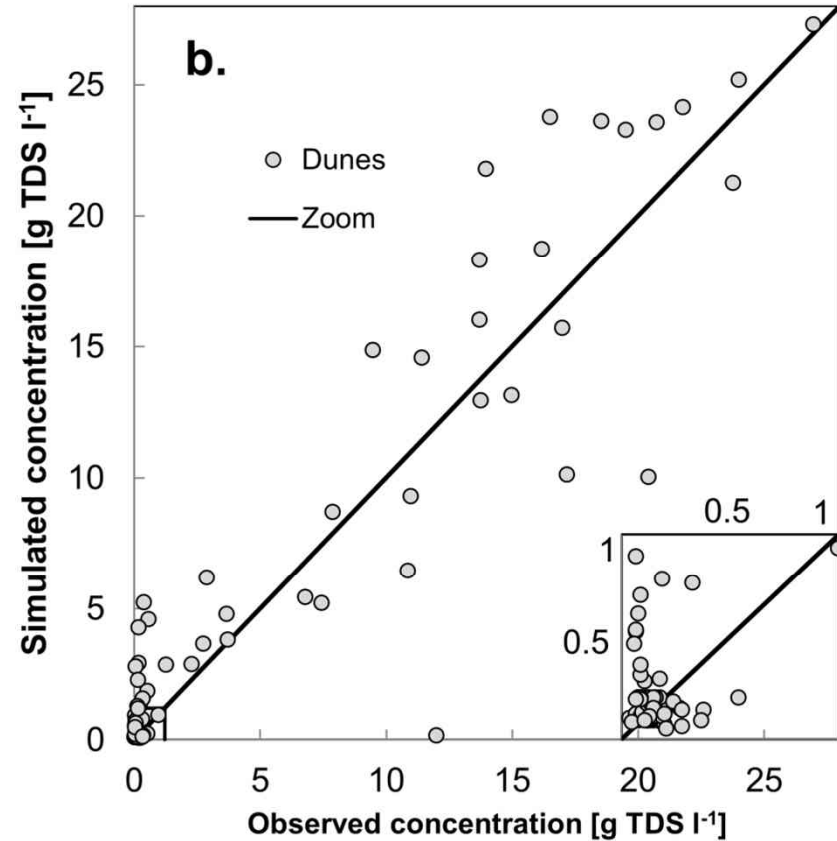
Computed bathymetry after 0.25 years



1 – Calibration of initial situation

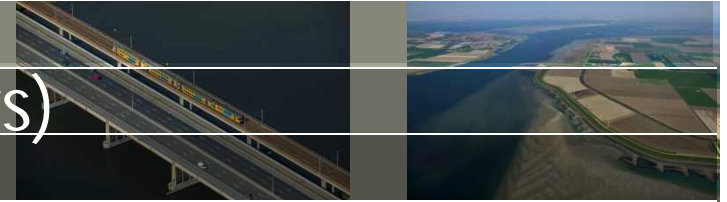


Average error = 0.04 m
Average absolute error = 0.25 m

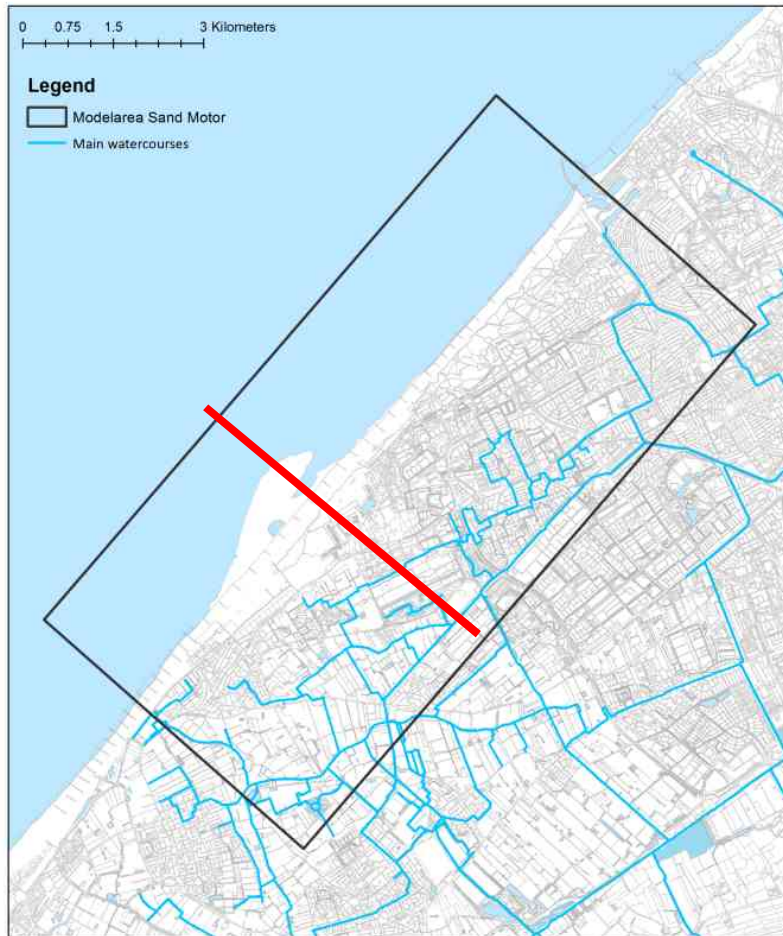


Average error = 0.36 g/l
Average absolute error = 1.2 g/l

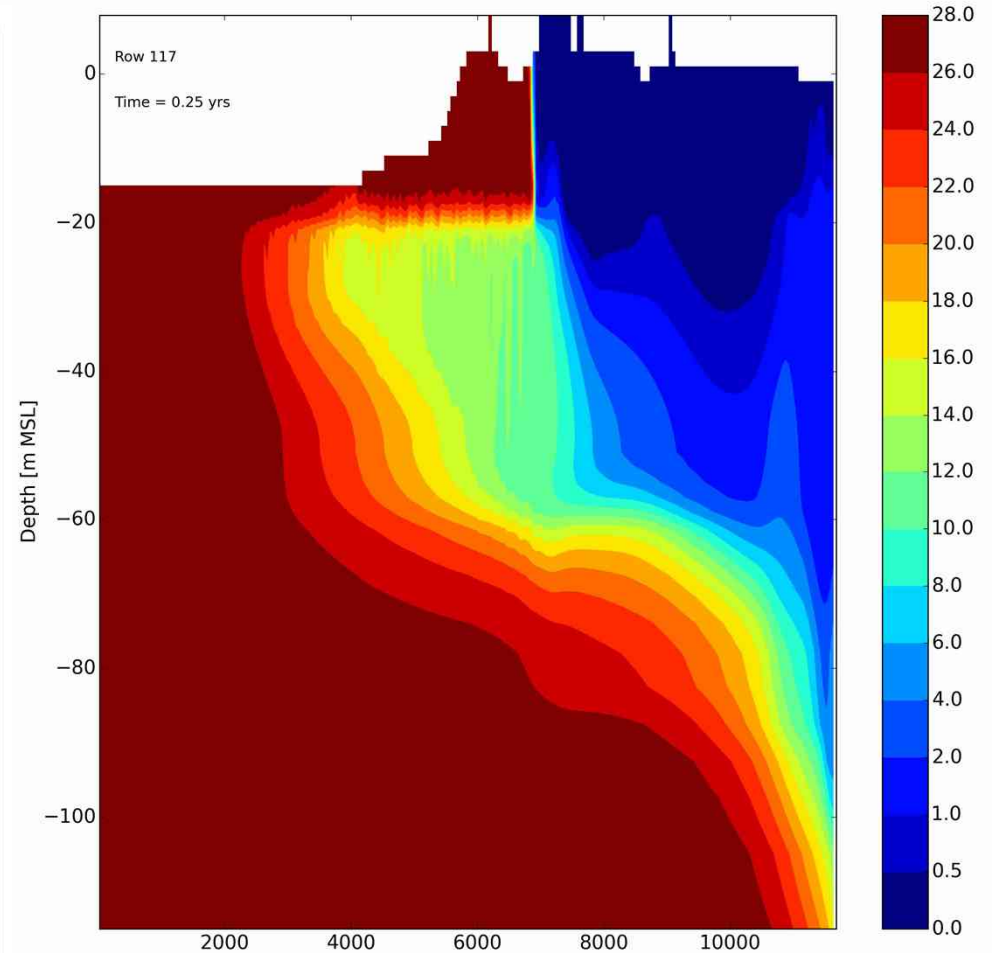
1 - Morphological change (40 years)



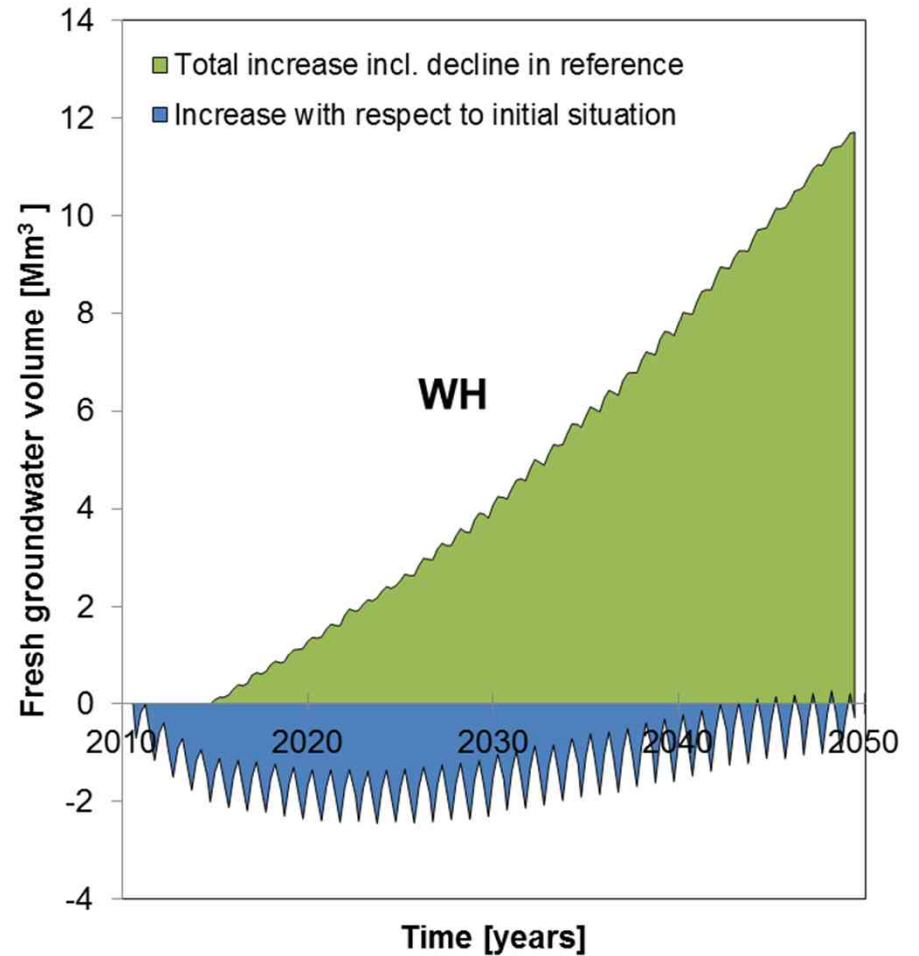
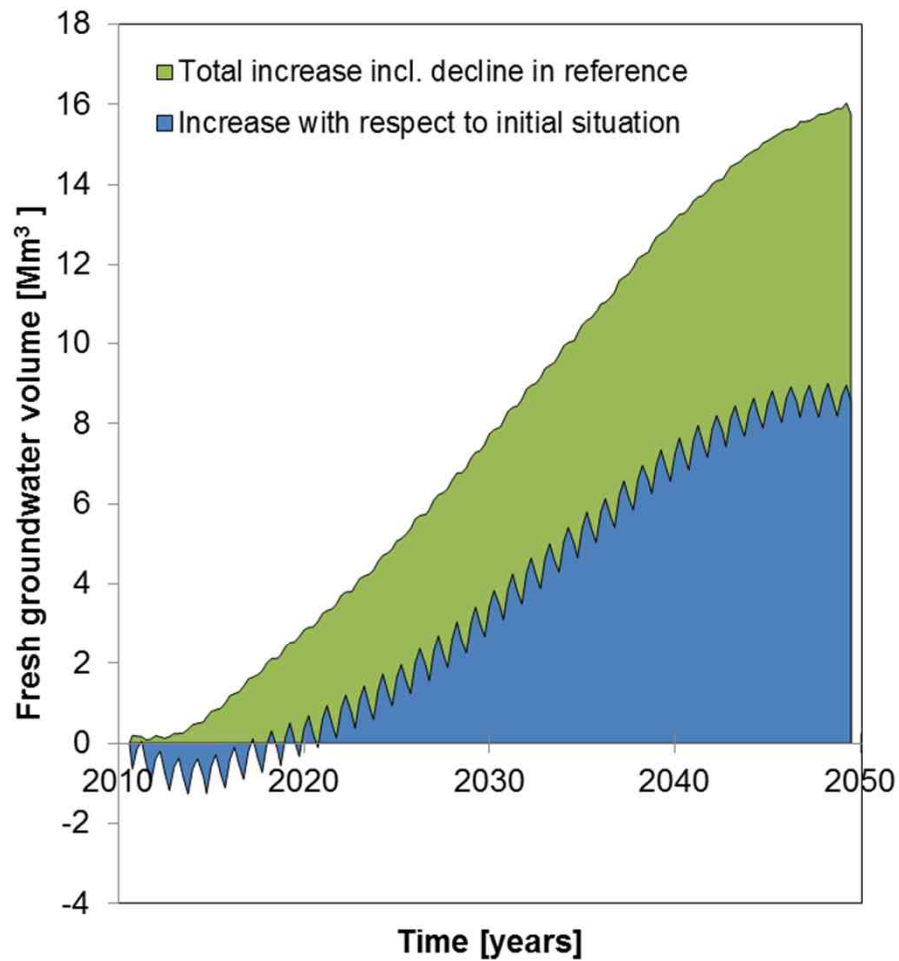
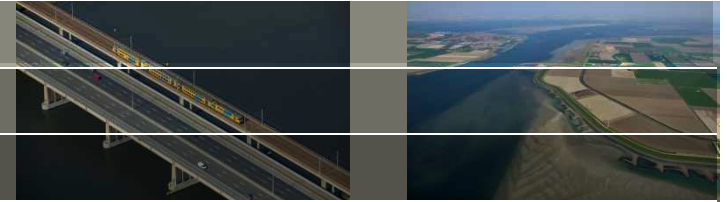
Transect West- East



Calculated concentration [g/l] of SC_50M_50L2_GH

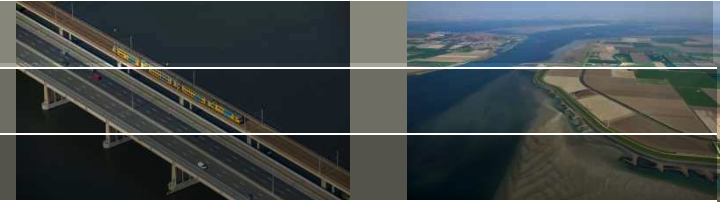


1 – Conclusion



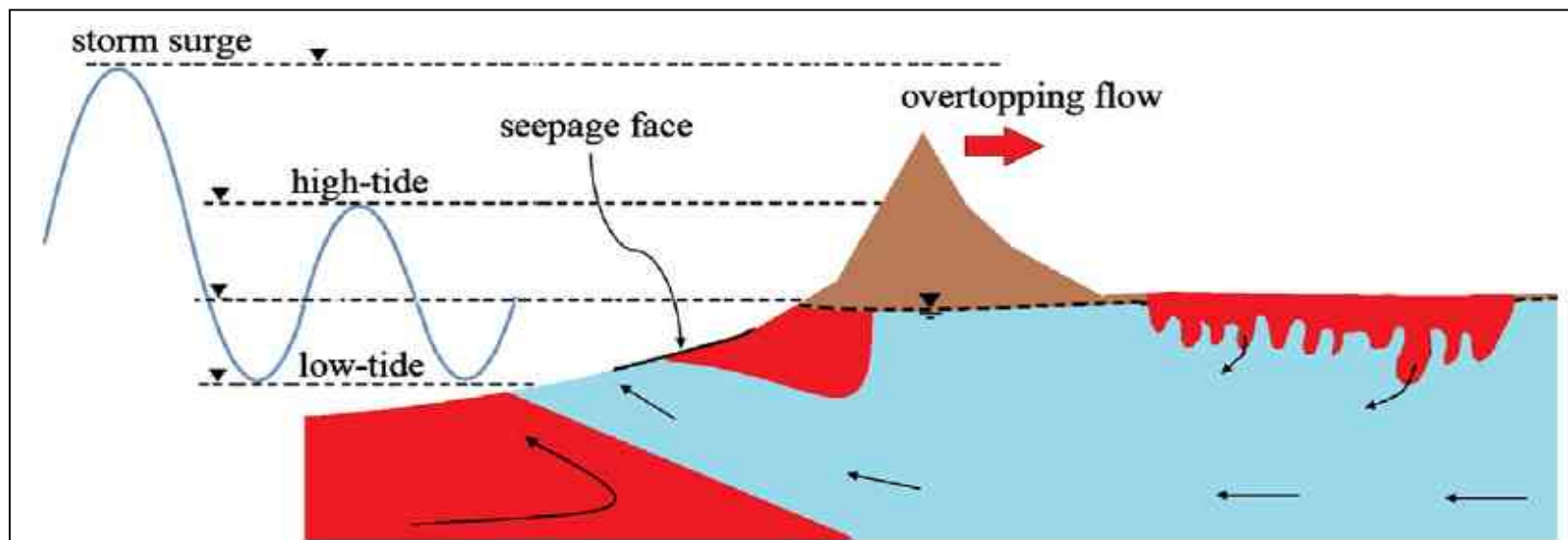
Growth in fresh water volume, effect smaller with increasing sea-level rise

2: Effect of tides and storms



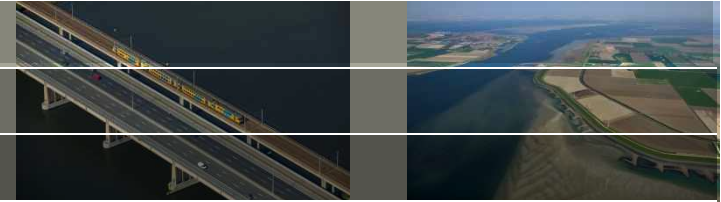
Research questions:

- What is the influence of tides and storm surges on the fresh-salt water interface within the Sand Engine?
- Do the expected influences of tides on the fresh-salt water interface zone occur at the Sand Engine?
- Which factors contribute to the development of the interface?



Bron: Yang et al., 2013

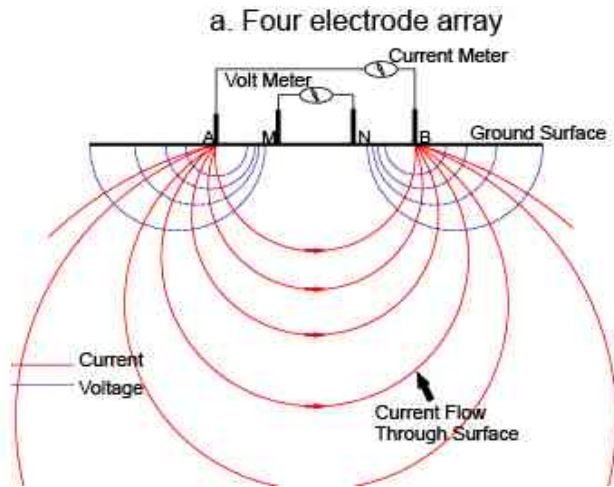
2 - Methodology



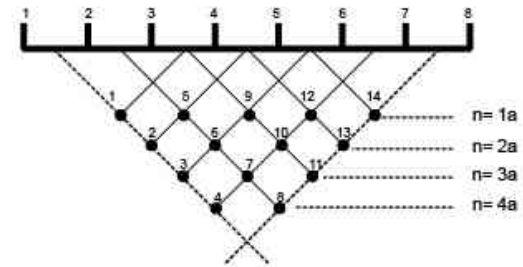
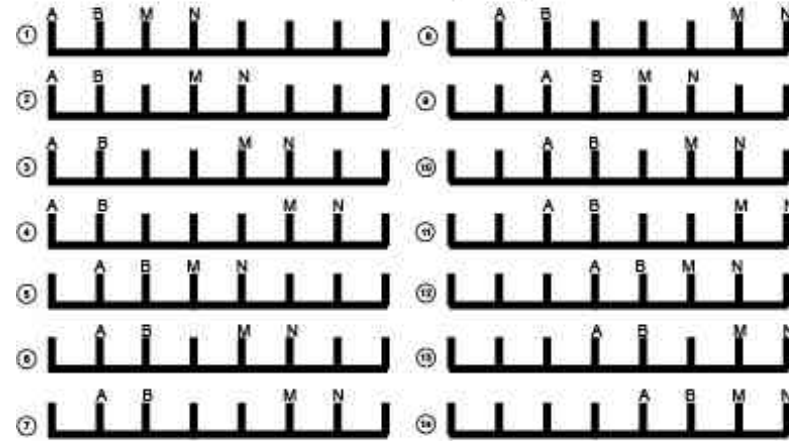
Measurement of influence tide, storm and precipitation by ERT:

Electrical Resistivity Tomography

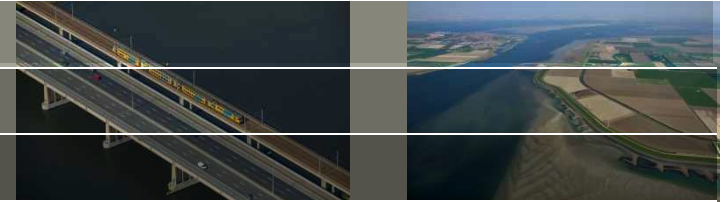
Measures resistance/conductivity by de current (I) en het potential difference (V)



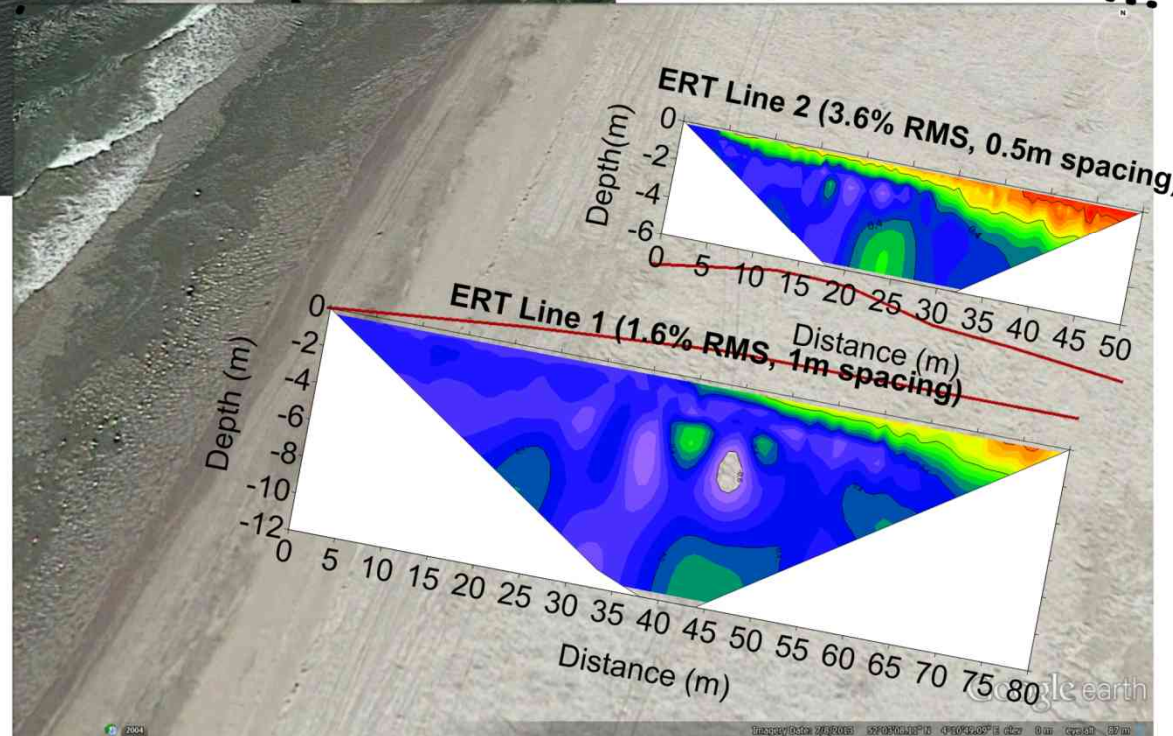
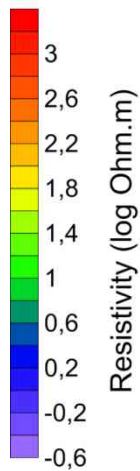
c. Resistivity acquisition



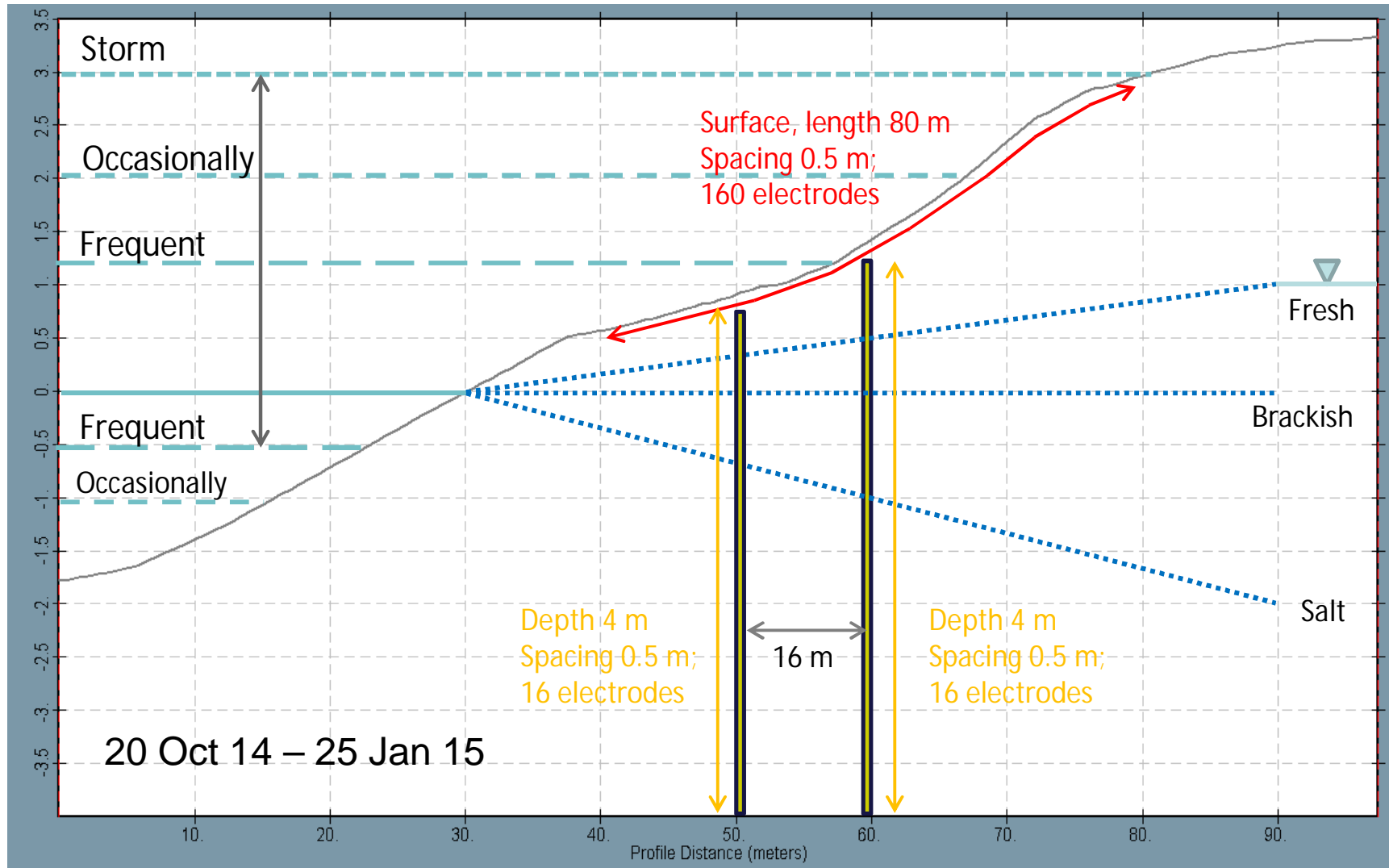
2 - Field measurements



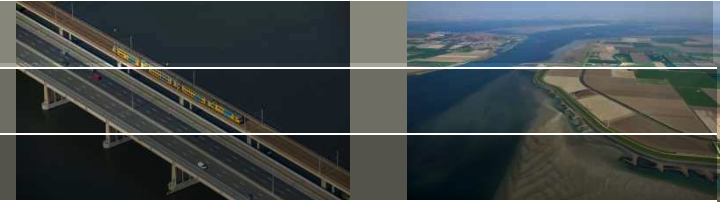
Blue: salt water
Red: fresh/unsaturated water

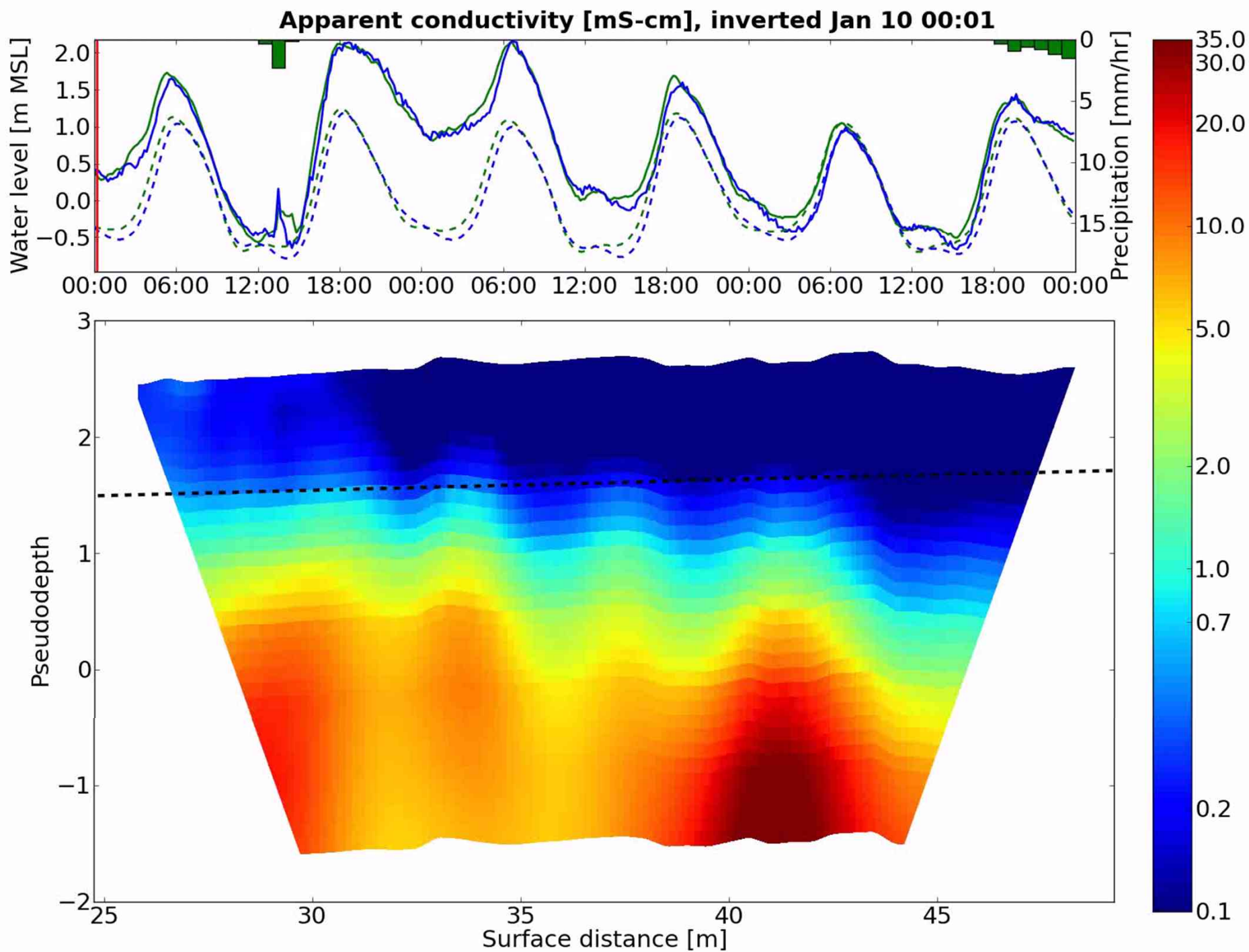


2 – Visualization ERT measurement (transect)

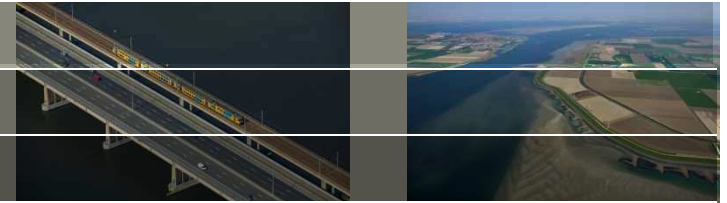


2 – Photo's ERT installation

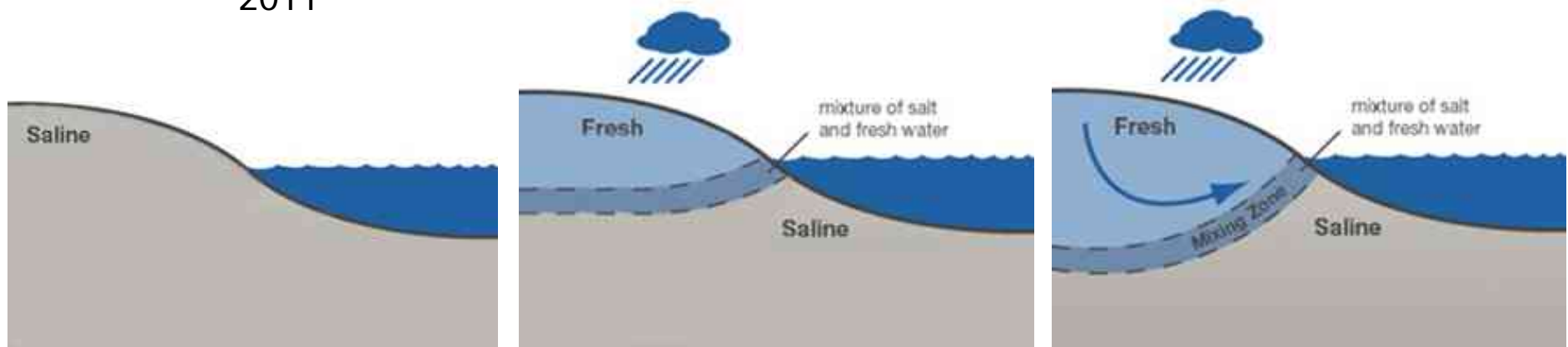




3: Growth fresh water lens



Construction 2011 → Growth → Final / Maximum



Research questions:

- Which factors contribute to the development of the fresh-salt water interface/mixing zone?
- Can the measured development of the fresh-salt water interface/mixing zone be reproduced with the groundwater model?

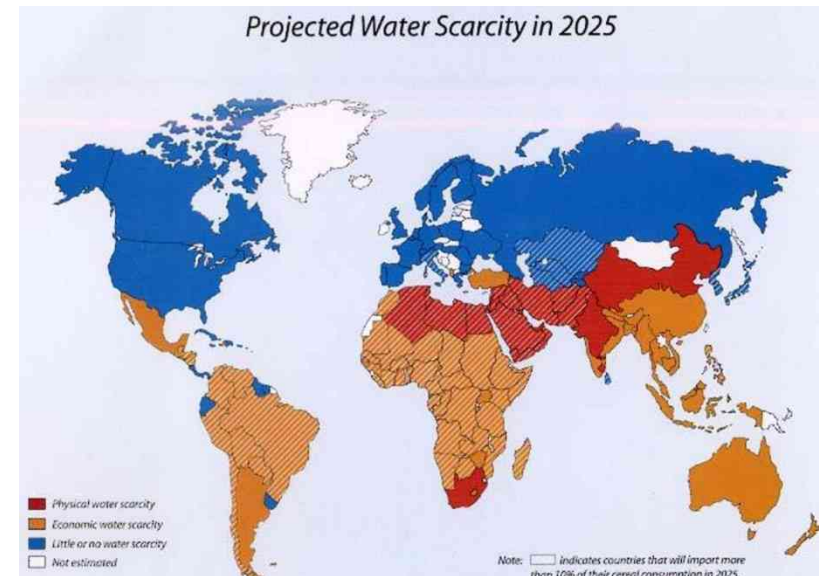
3 – Measurement freshwater lens

- 8 monitoring wells on the Sand Engine, 4 with shallow and deep filters. Measurement of groundwater levels since May 2014
- Frequent SlimFlex measurements (electromagnetic)



- Analysis of salinity from groundwater samples
- Sampling monitoring wells

4: Worldwide applicability

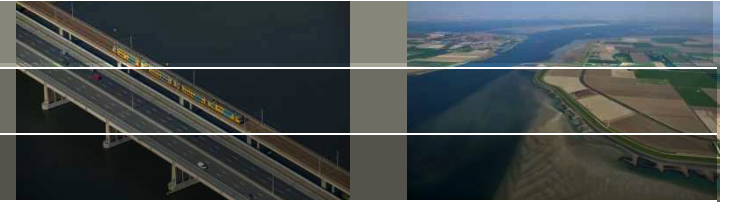


Bron: International Water Management Institute

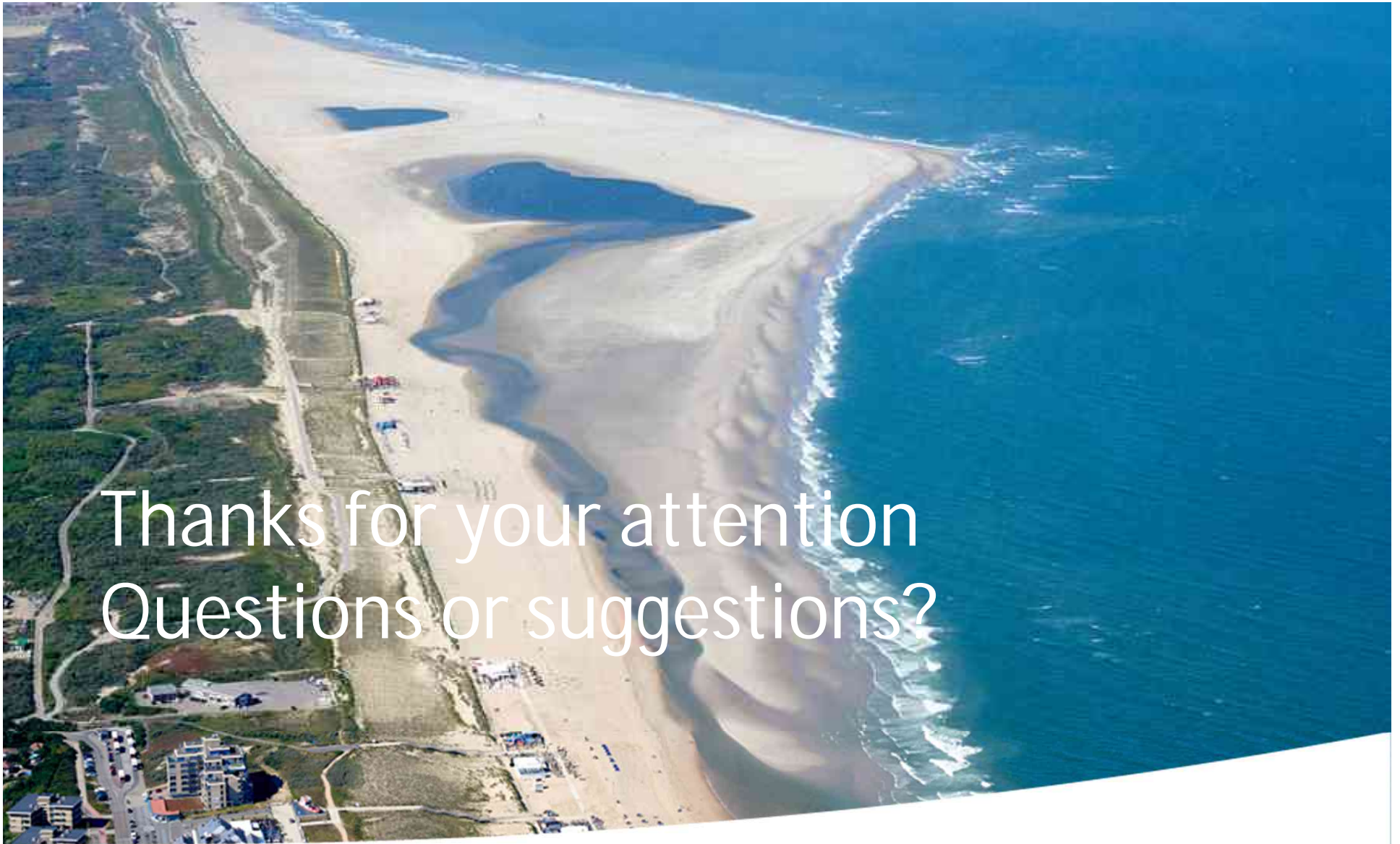
Research questions:

- What are suitable locations for mega-nourishments in the world?
- What are the possible effects of mega-nourishments on the fresh water availability and seawater intrusion in other parts of the world?

Progress



- Submission first paper: October 2015
- Analyze & simulate conditions of geo-electrical measurements (ERT)
- Second paper on ERT measurement & simulations: Spring 2016
- Field measurements of current groundwater salinity:
 - SlimFlex measurements in monitoring wells
 - (direct) sampling and analyses of groundwater salinity
- Third paper on actual groundwater salinity Sand Engine Analysis, model simulations and paper: Summer 2016
- Fourth paper on global analysis mega-nourishments: Winter 2016
- Finish PhD thesis in spring/summer 2017



Thanks for your attention
Questions or suggestions?