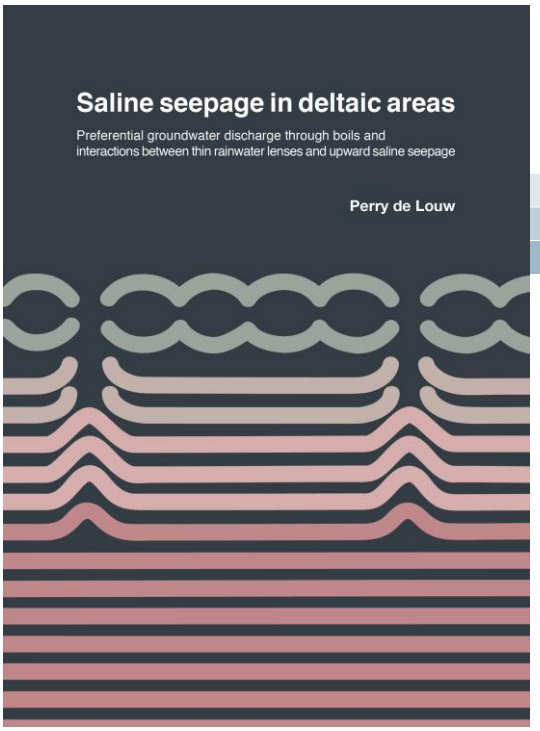
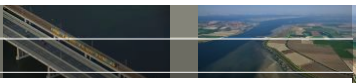


Deltares
Enabling Delta Life

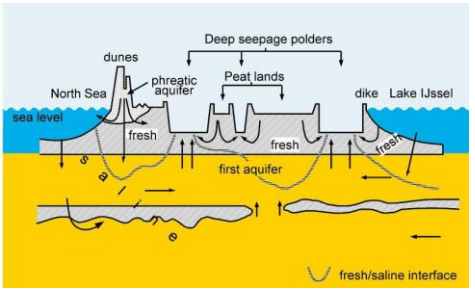
From problem to solutions

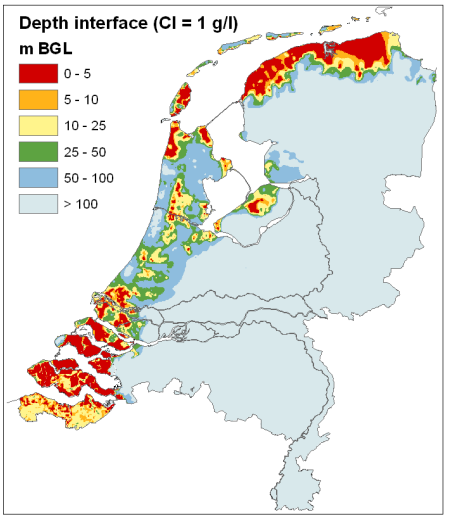
Saline seepage leads to:



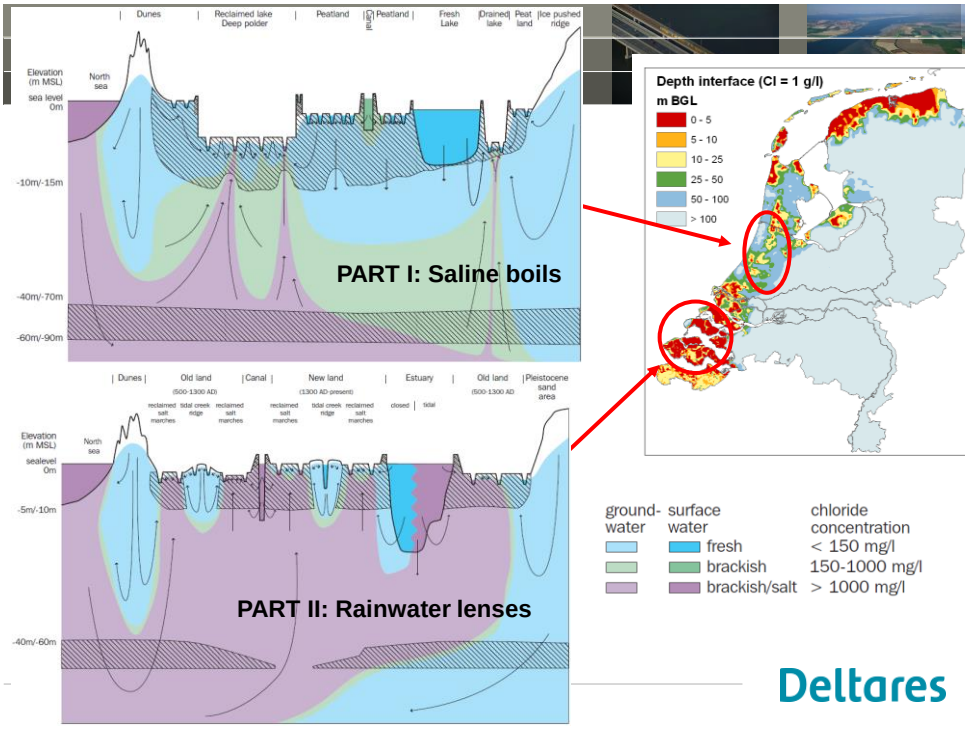
Depth of saline groundwater

- Salinization of
  - surface waters
  - shallow groundwater
  - root zone (crop damage)





Deltares



Deltares

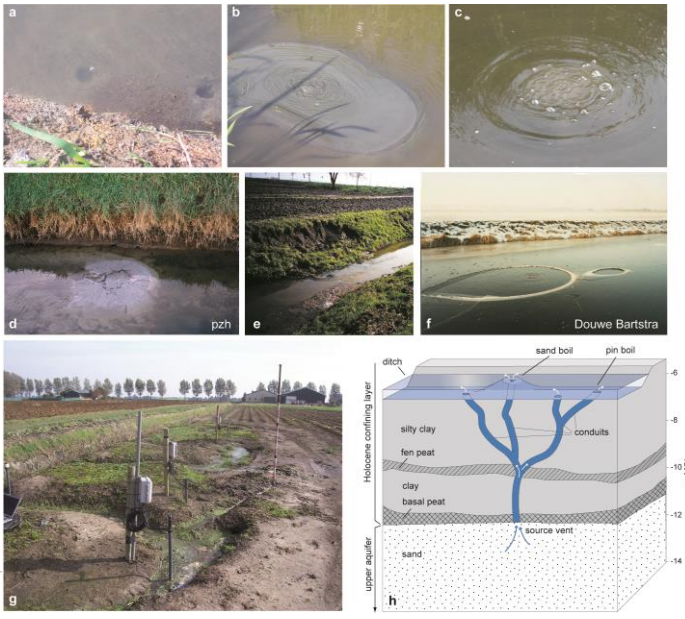
‘Boiling’ of water

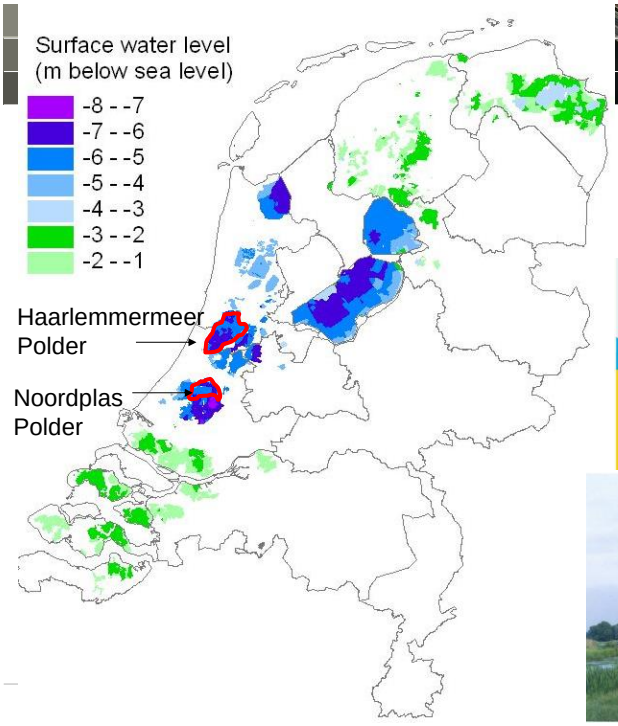
Deltares

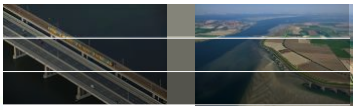
Preferential groundwater discharge at high velocities

SWIM 2014

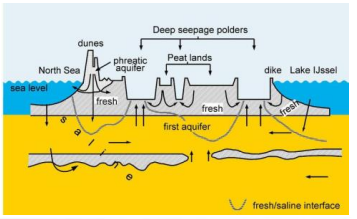
Boils in deep polders



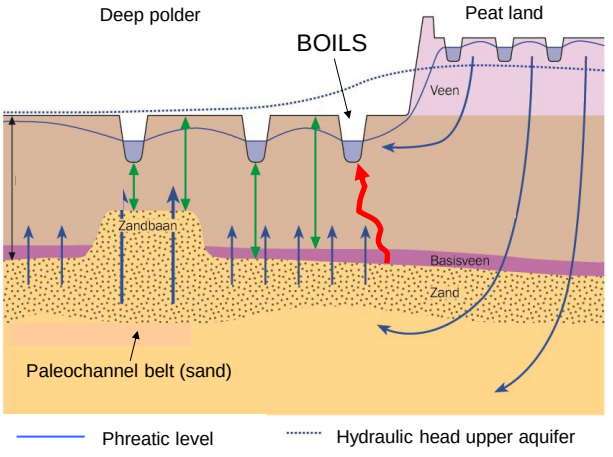




Deep polders in The Nederlands

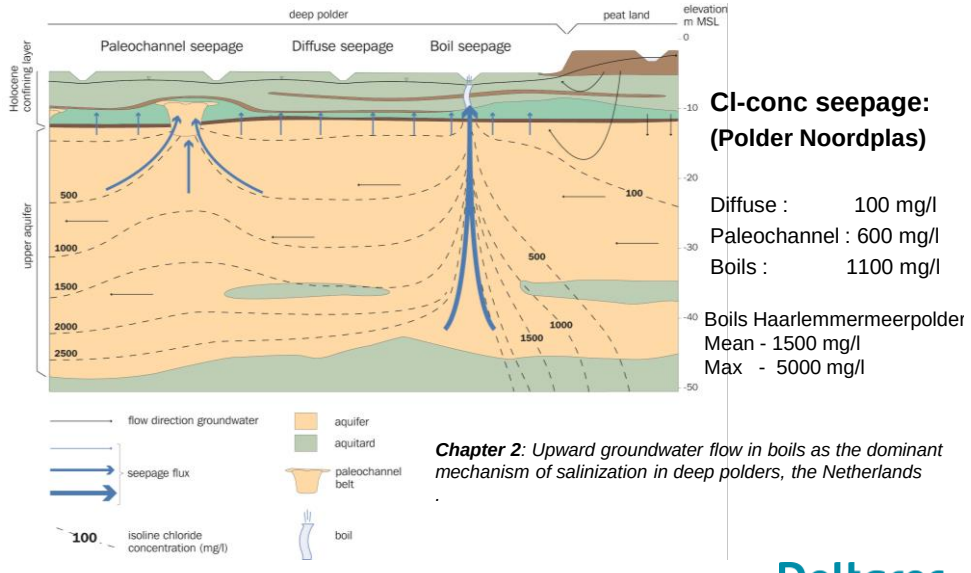


Boils develop when water pressure > weight overlying stratum



Deltares

Three types of upward groundwater seepage



Cl-conc seepage:
(Polder Noordplas)

Diffuse : 100 mg/l
Paleochannel : 600 mg/l
Boils : 1100 mg/l

Boils Haarlemmermeerpolder
Mean - 1500 mg/l
Max - 5000 mg/l

***Chapter 2**: Upward groundwater flow in boils as the dominant mechanism of salinization in deep polders, the Netherlands*
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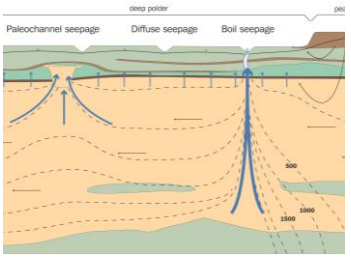
Deltares

Saline boils dominant mechanism of salinization in deep polders

	Area	Contribution % (± stdev.) to: Polder water Discharge	Total salt load
Diffuse seepage	31 km^2	**7 %** *(± 1.8)*	**4 %** *(± 1.7)*
Paleochannel seepage	6 km^2	**9 %** *(± 2.5)*	**19 %** *(± 6.2)*
Boil seepage	< 0.001 km^2	**13 %** *(± 4.7)*	**64 %** *(± 7.7)*



CHAPTER 3: *Quantifying water and salt fluxes in a lowland polder catchment dominated by boil seepage: a probabilistic end-member mixing approach GLUE*

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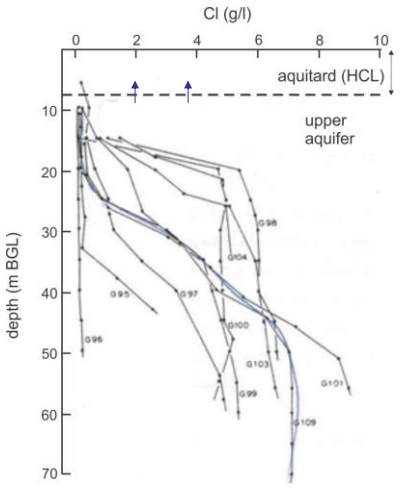
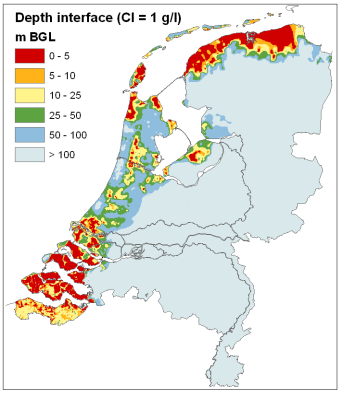
Deltares

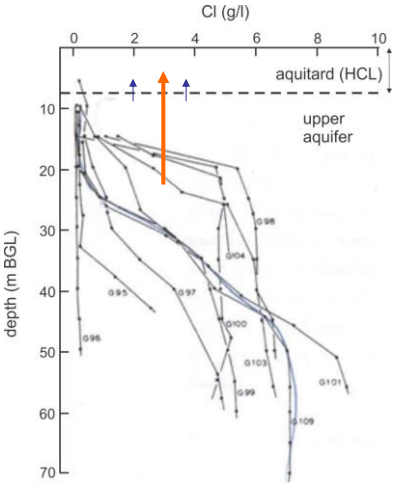
Typical salinity-depth profile

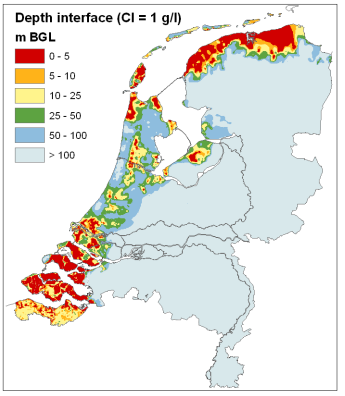




Deltares

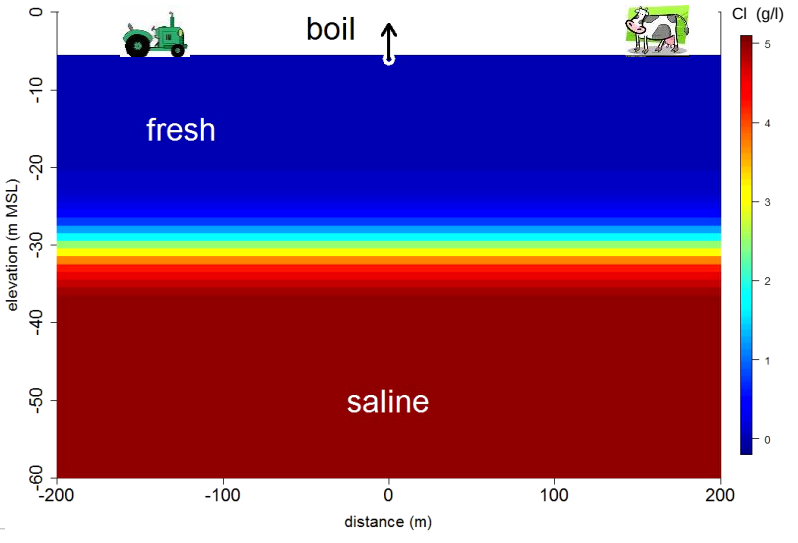
Typical salinity-depth profile





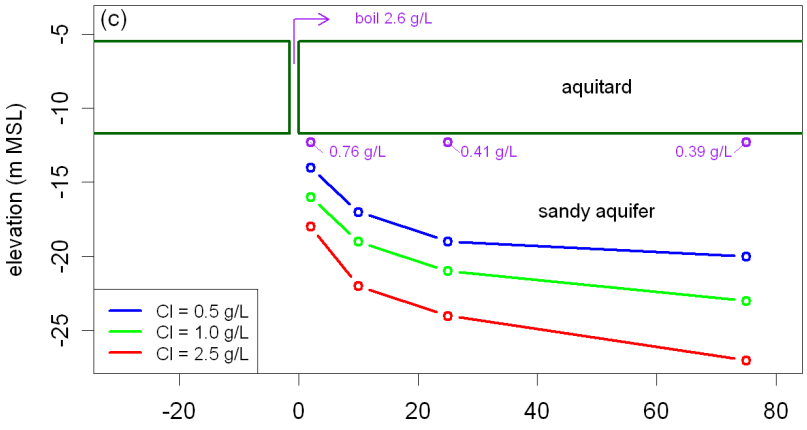
Deltares

Chapter 4: Natural saltwater upconing by preferential groundwater discharge through boils



Deltares

Measured saltwater upconing

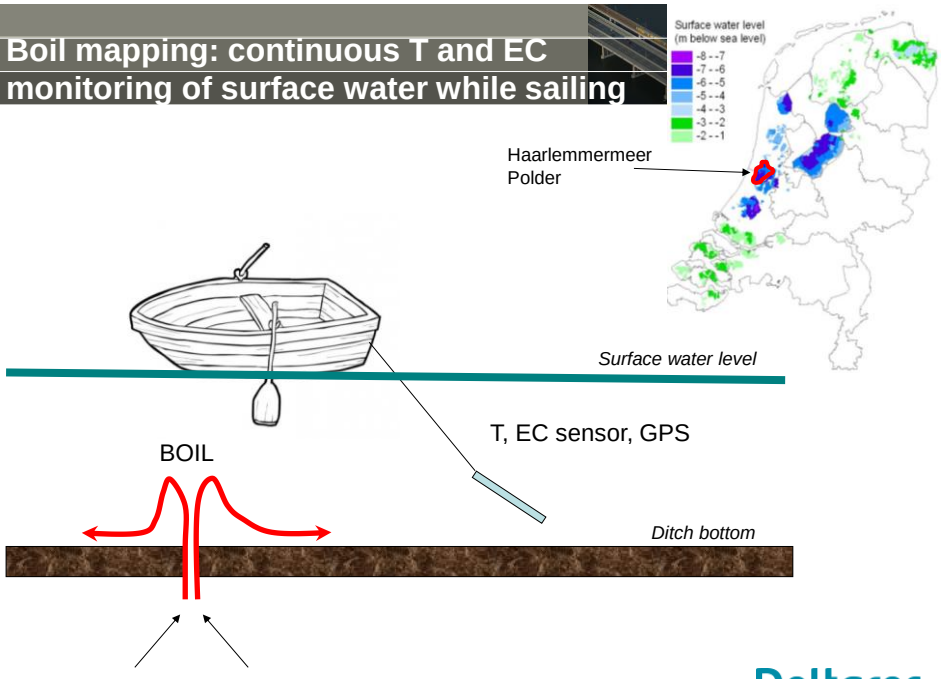


Deltares

Boils and temperature

Deltares

Boil mapping: continuous T and EC monitoring of surface water while sailing



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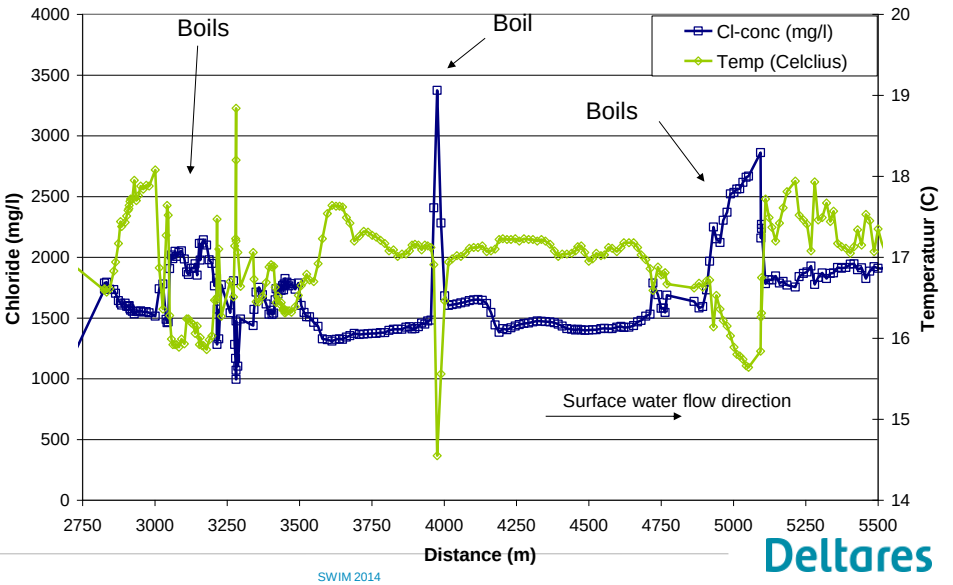
T en EC measurements in surface water (canal)



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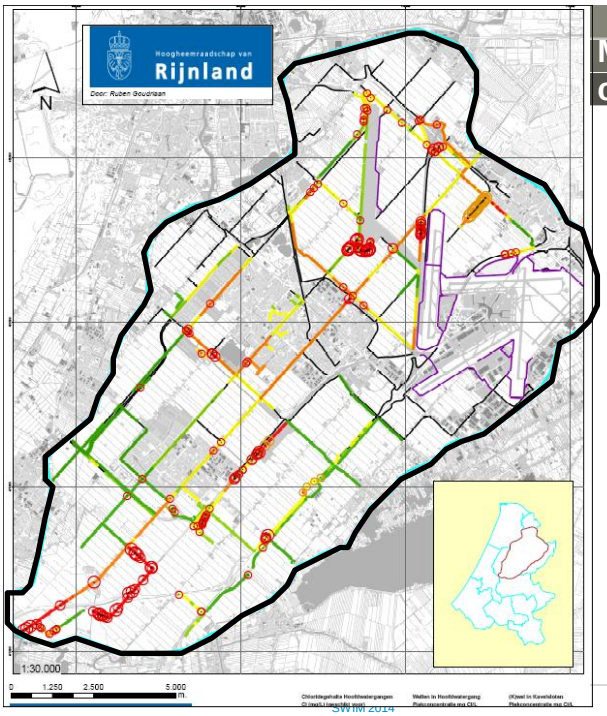

Mapped boils and Cl-conc. surface water

Boils

- Cl = 500 -2000 mg/l
- Cl > 2000 mg/l

Cl-conc surface water

- 0-300 mg/l
- 300-600 mg/l
- 600-1000 mg/l
- > 1000 mg/l

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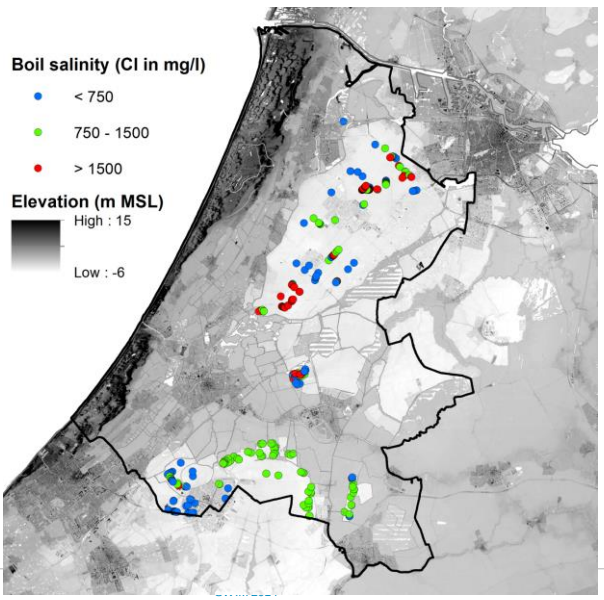
Mapped boils in water management area Rijnland



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Some solutions

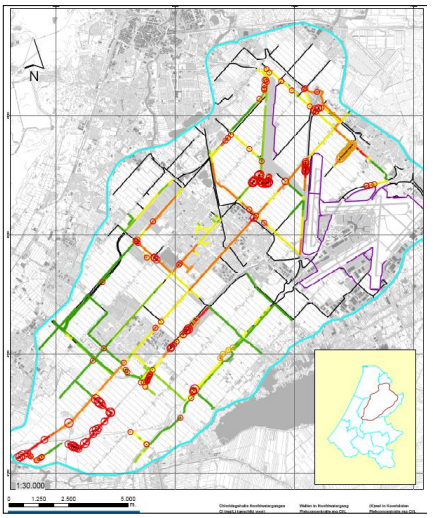
Increase surface water level to minimize head difference.

- Only in surface waters with boils
- Hydraulic head in aquifer must not be too high

Operational salt water management

- Based on dynamics of Cl-concentration
- Temporary storage of salt water during dry periods
- Discharge of salt water during rainfall events

Boil sealing



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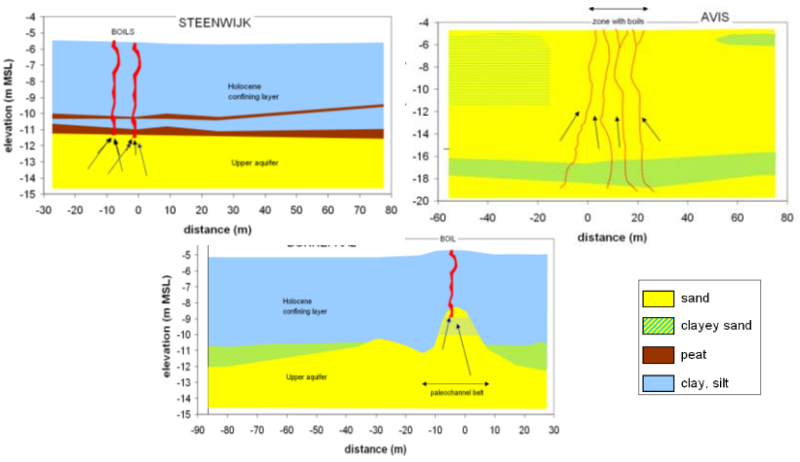
Detailed study around boils in three different geohydrological situations

Field research to examine possibilities of sealing boils



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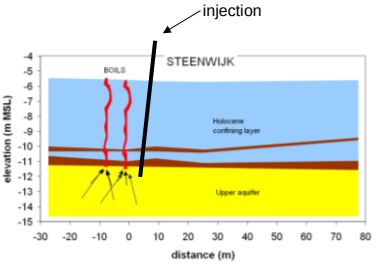
Sealing of boils is not a feasable measure

Injection of:

- Nutrients: Bio-sealing
- Expanding and persisting fluids



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Salt tolerant crops growing on boil water

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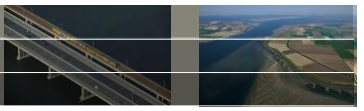
Concluding remark



Defining effective water management strategies and solutions only meaningful when the salinization processes are fully understood.

Local phenoma (saline boils) dominate salinisation at regional and national scale.

Without field research the dominant salinisation source was missed.

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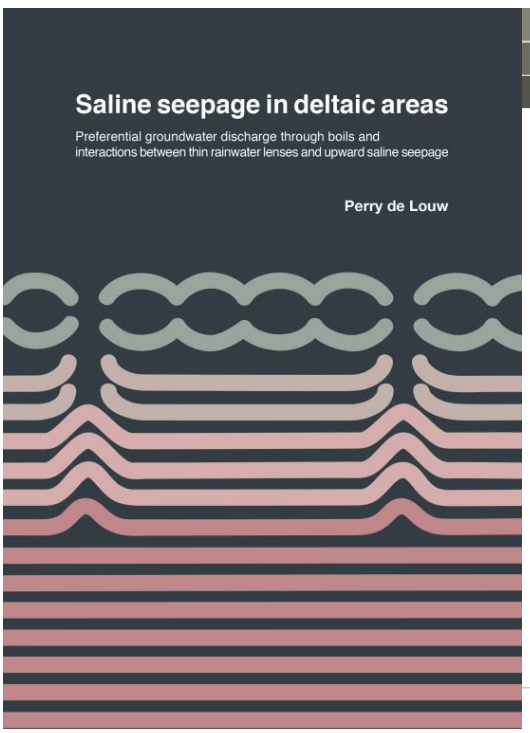
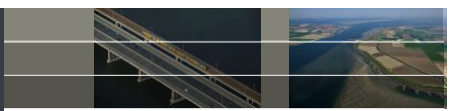




Thank you for your attention

Boils are found all around the world in different setting

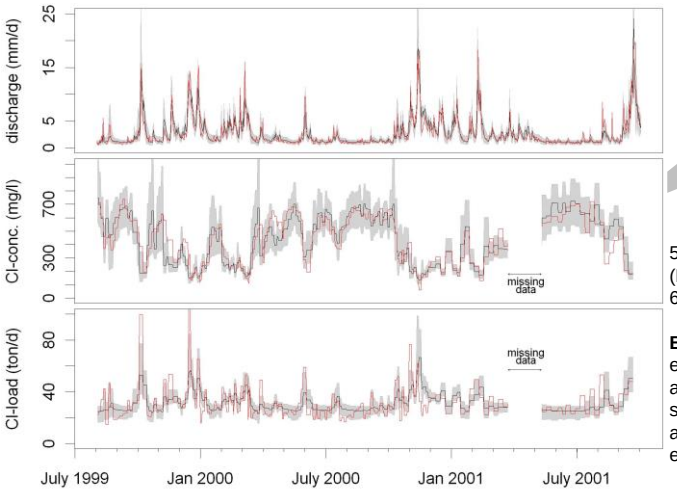
Boils are found in different settings: areas with high hydraulic gradients

- polders
- beaches
- submarine groundwater discharge
- lakes and lake shores
- river and brook valleys
- dikes, dams
- foot of dunes, ice-pushed ridges or other hills

Boils are everywhere

Deltares

Simulation of daily observed discharge, cl-conc and cl-load : End-member mixing approach - GLUE



observed

calculated (median)

Uncertainty bounds

5.10^8 model simulations (Monte Carlo)
60.10^3 behavioral runs

Behavioral when :
errors of simulated Q, Cl-conc and Cl-loads are small, both seasonal and daily dynamics and total water and salt balance error < 5%.

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