



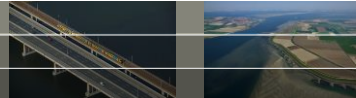
Air bubbles against salt intrusion: an application in the Rhine estuary

Yann Friocourt, Rob Uittenbogaard, Otto Weiler

Deltares, Delft, Netherlands

24 september 2014

Air bubbles in locks



- Designed in early 1960's
- By early 1970's in use at several major lock complexes throughout NL

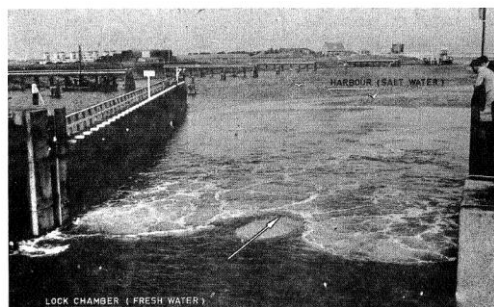
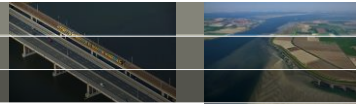
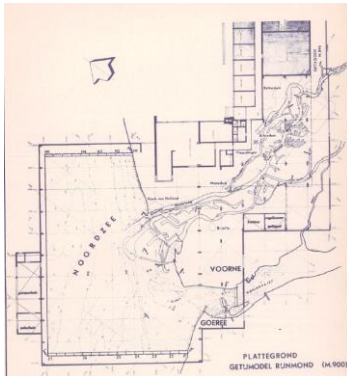


FIG. 12 FRESH WATER (MARKED BY ARROW) BREAKING THROUGH AIRCURTAIN NEAR CENTRE OF AIRCURTAIN IN ACCORDANCE WITH FIG. 9 c .

Air bubble in estuaries



- End 1960's, first experiments in USA by Simmons
- Early 1970's, first interest of Dutch government and City of Rotterdam
 - Mostly against sediment deposition in harbour

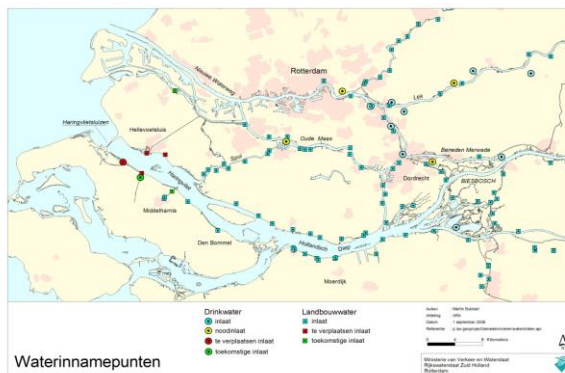


- Use of scaled physical models
- 1,5 km reduction of salt water intrusion length when using 175 m³/s of air
- Not cost-effective enough

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Water supply in the Rhine-Meuse estuary

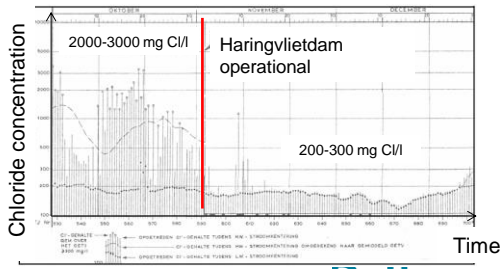
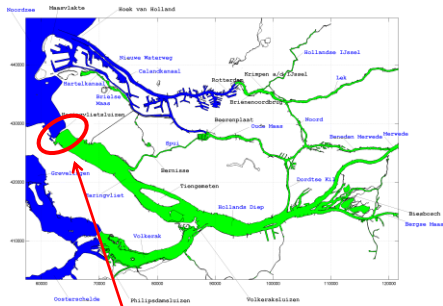
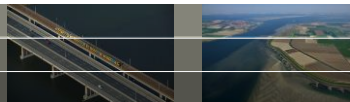


- Water intake points for drinking water, industrial use, and agriculture (high-profit crops: flower bulbs, fruits, vegetables, etc.)

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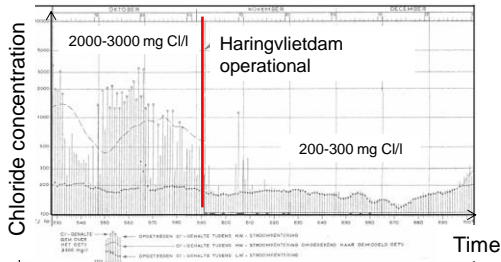
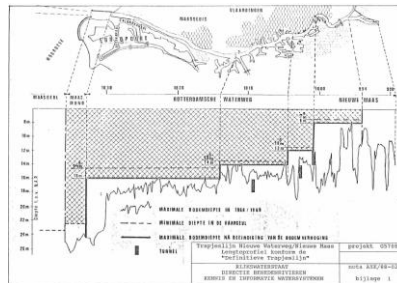
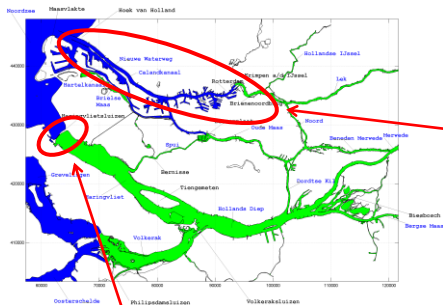
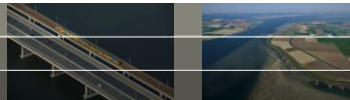
Limiting salt water intrusion



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Limiting salt water intrusion



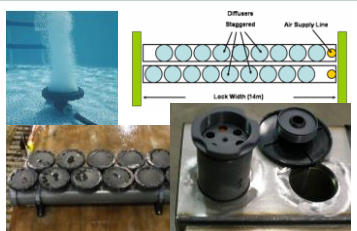
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Need for calamity measure

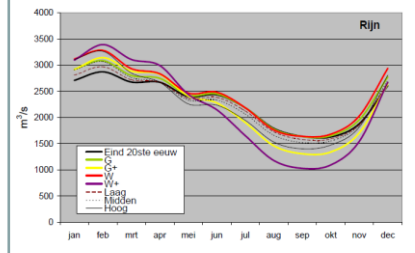


2003: low river discharge for several weeks



2010: Improved design for air curtain in locks (previous presentation)

Climate change: dry spells likely more frequent

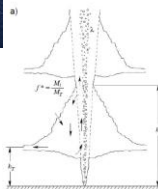
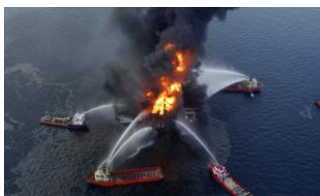


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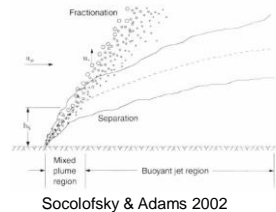
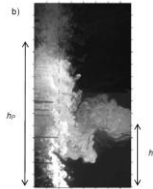
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Bubble plumes in Rotterdam Waterway

- 2010-2013: feasibility study in 3 phases
 - Client: Rijkswaterstaat, Ministry of Infrastructure and the Environment, Port of Rotterdam
 - Goal: working mechanism, effectiveness, technical design
 - Hired expertise (Dr. Socolofsky) from Texas A&M Univ.



Seol et al., 2009



Socolofsky & Adams 2002

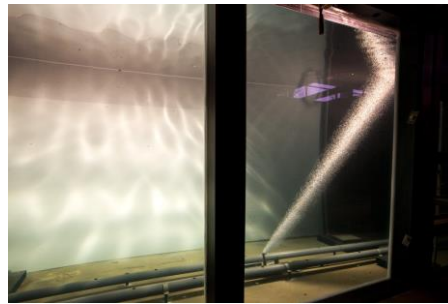
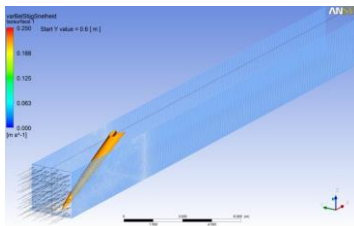
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Research methodology



- Lab. experiments in a 0.6-m deep tank
- Lab. experiments in 30-m long tank, 2.5-m deep
- CFD modelling
- Shallow water equation modelling

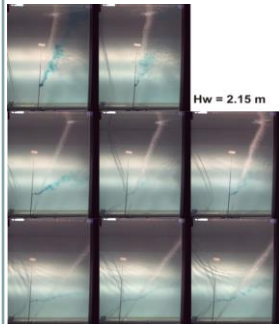
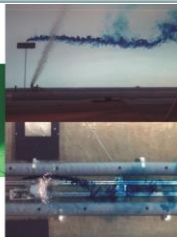


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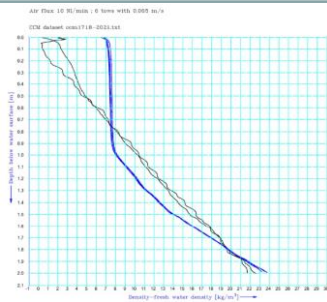
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Analysis methods

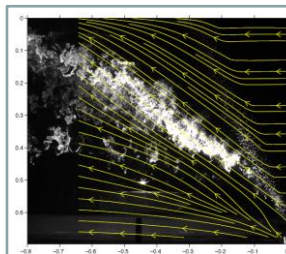
Dye injection



Mixing induced by towed bubble plume in salt-stratified tank



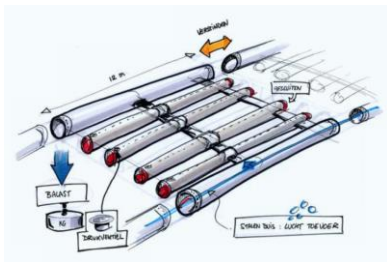
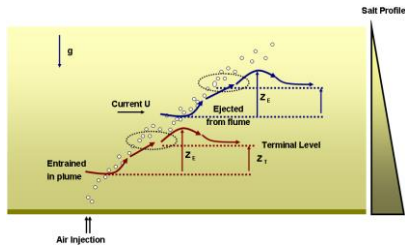
Particle Image Velocimetry



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Main results



- Describe working mechanism
- Estimate amount of air required
- Provide information for technical design
- Assess effect in terms of reduction of salt intrusion length
- Comparison with other measures (following presentation)

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Conclusions

- Large interest from Dutch water community
 - Success of bubble screens in locks
- As of now, air bubble plumes unlikely to be built in Rotterdam Waterway
 - Effective
 - Costly, less efficient than other measures, no structural improvement of water supply
- Air bubble plumes excellent vertical transporters of water
- May lead to other applications against salt water intrusion or in other fields



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