Deltares

Sustainable Desalination:

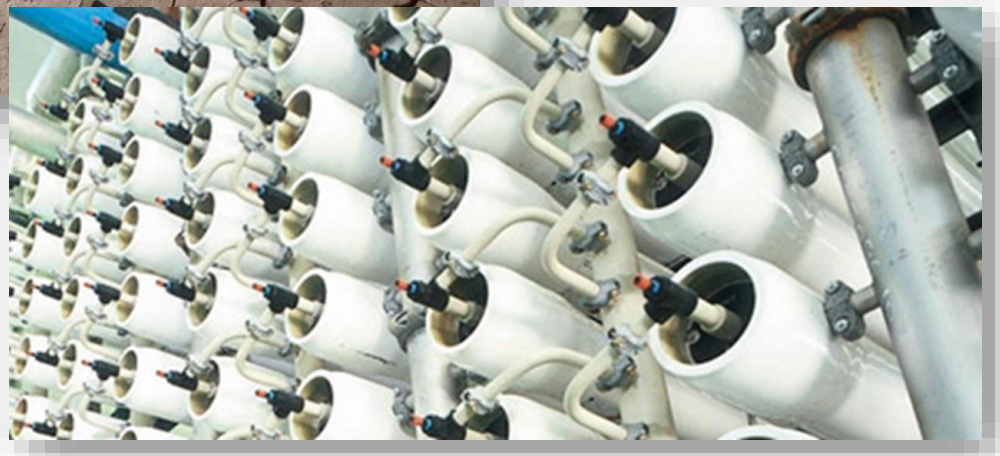
How to produce sufficient water towards the future, while protecting the marine environment

Robin Morelissen, Hydraulic Engineering, Deltares, The Netherlands,
email: Robin.Morelissen@deltares.nl

The need for desalination

Growing population, depleting groundwater levels, little to no rainfall

Almost complete dependence on desalination in the Middle East Gulf region

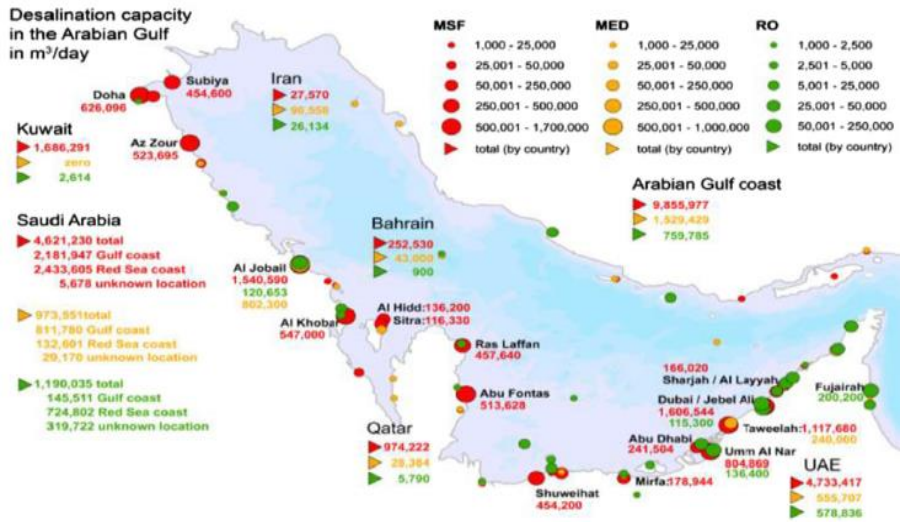


Deltares

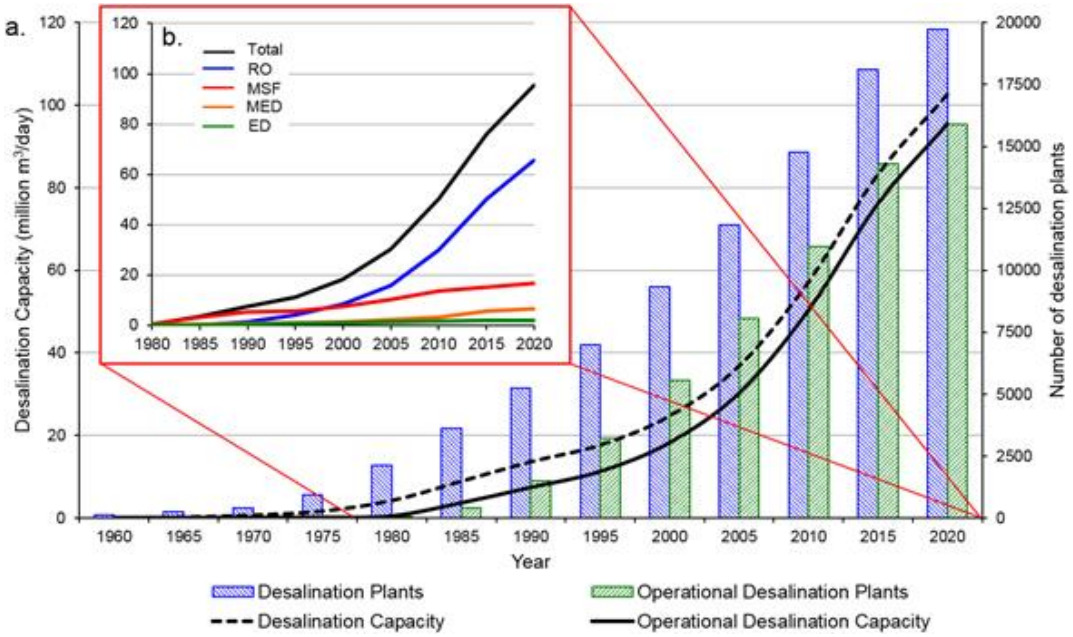
Growing desalination capacity

The total amount of desalination plants and their capacity has risen exponentially over the last few decades.

Desalinated water from reverse osmosis accounts for approximately 69% (~66 million m^3/day) of the global volume of desalinated water (~95 million m^3/day).



S. Lattemann, T. Höpner / Desalination 220 (2008) 1–15



Trends in global desalination by (a) number and capacity of total and operational desalination facilities and (b) operational capacity by desalination technology (Jones et al., 2019).

Deltares

Desalination technology – shift to RO

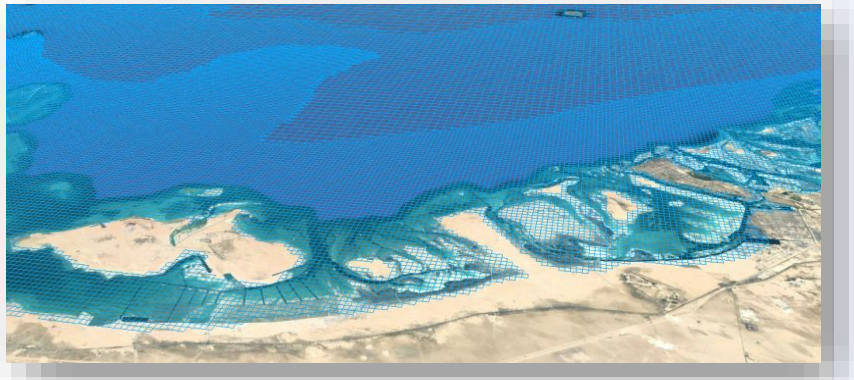
- Trend from thermal desalination technologies to seawater RO, globally and in the Middle East Gulf region.
- Trend in the market to decouple energy from water production - both technically and economically.
- Main difference between the technologies for the marine environment is the type and amount of brine effluent these technologies produce.

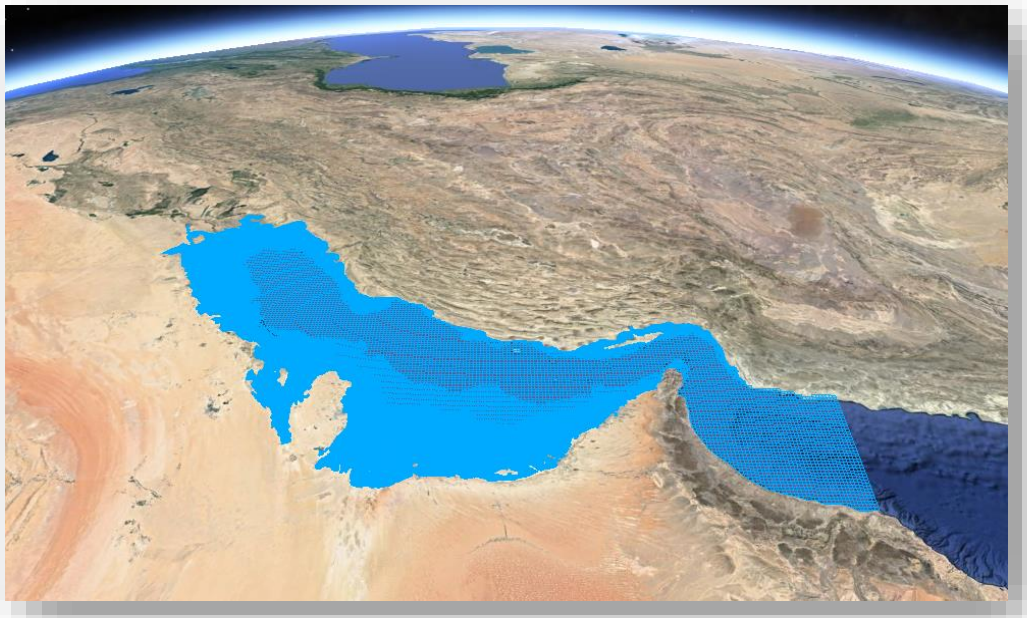
Deltares

Cooling water and desalination outfall modelling in Delft3D

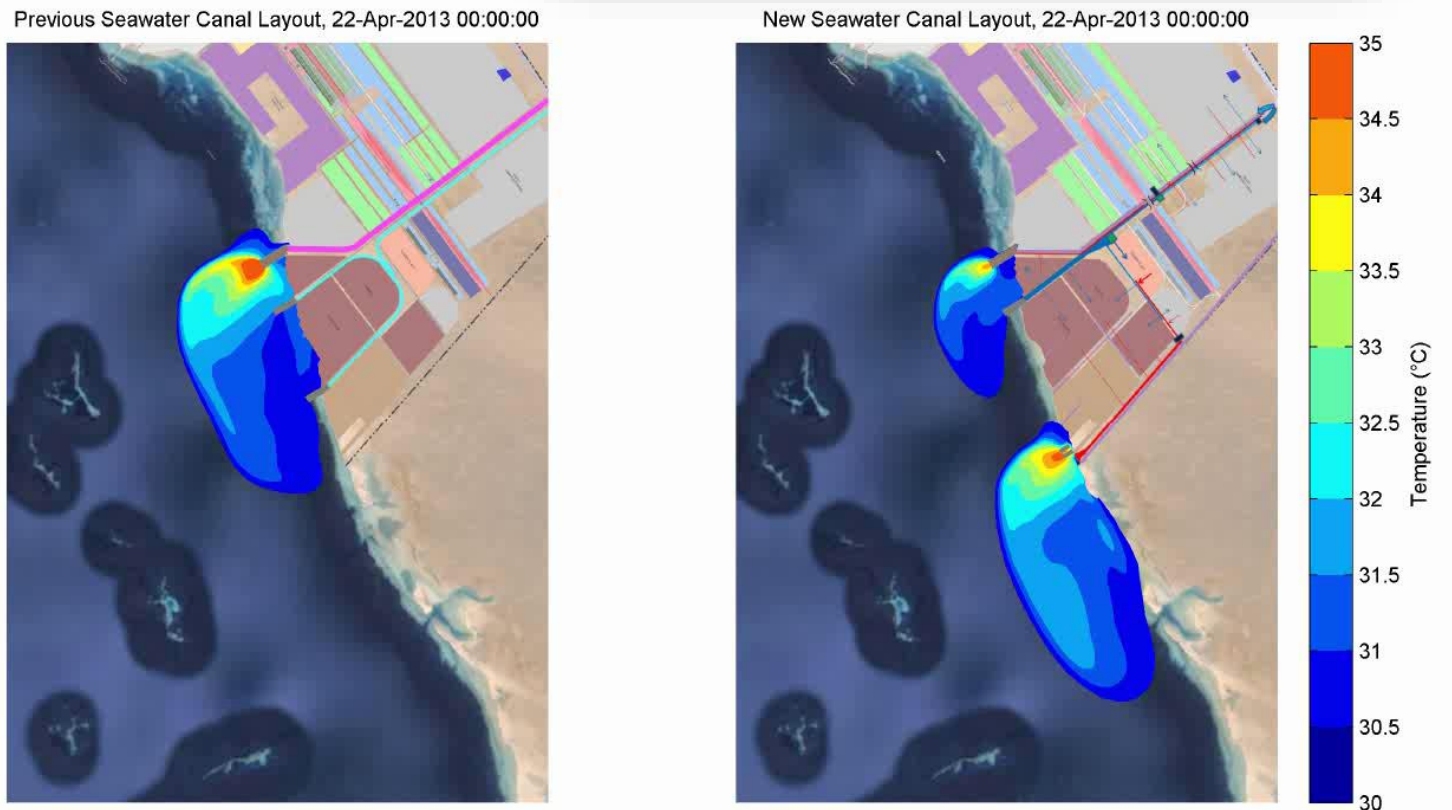
Using numerical models to simulate effluent dispersion

- Support design of the desalination plant intake and outfall
- Evaluate compliance with environmental criteria (input to EIA)
- Optimise plant operation – minimise recirculation





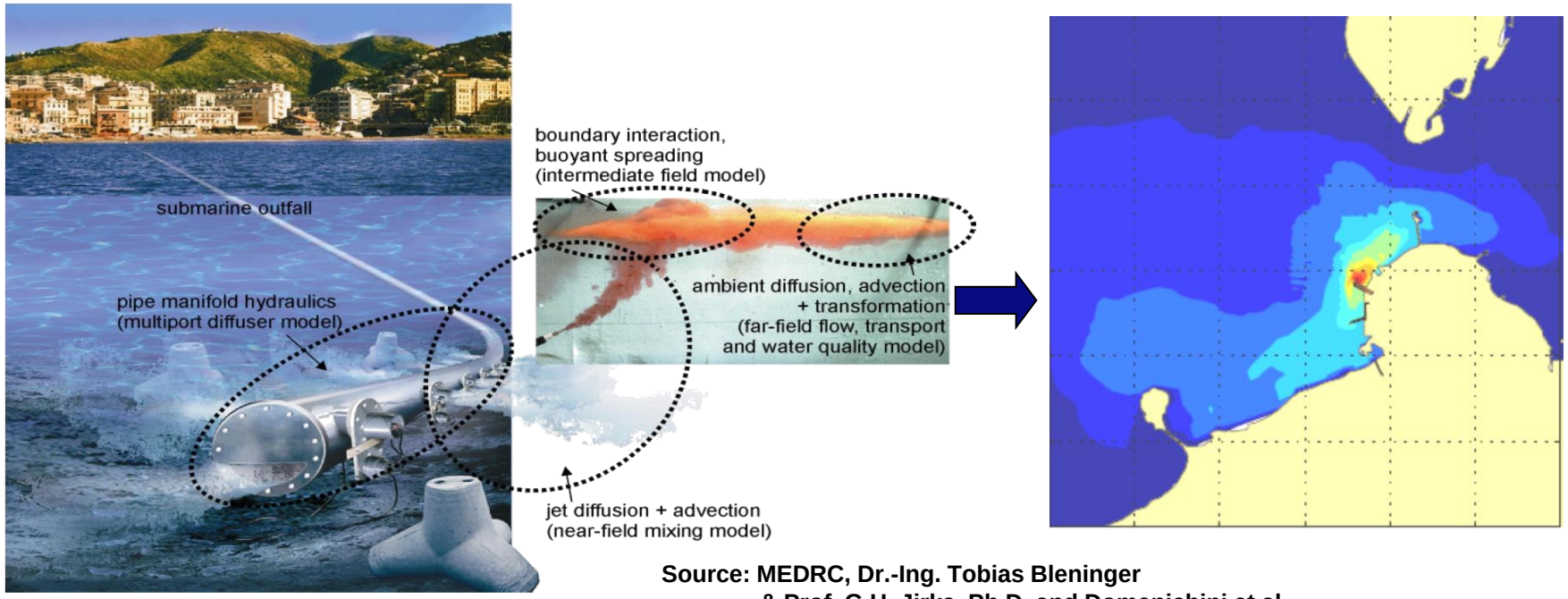
Deltares



Modelling desalination outfalls

Outfall plume behaviour over different scales; close to outfall (turbulence, (centi)metres) to effects/impacts kilometres away (large scale ambient flow)

No single model can cover these different scales efficiently and accurately



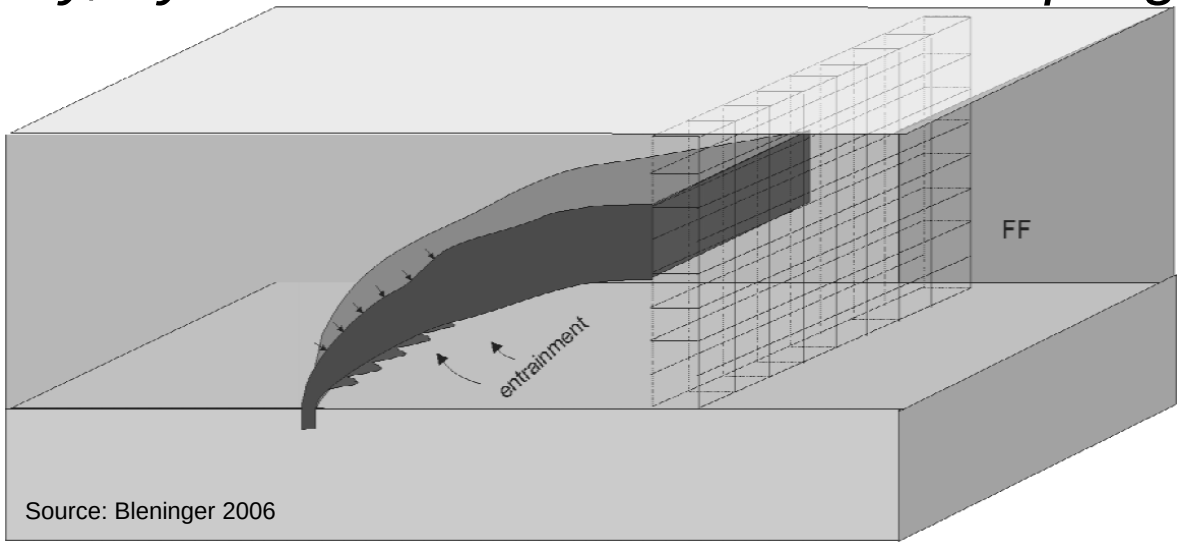
Source: MEDRC, Dr.-Ing. Tobias Bleninger & Prof. G.H. Jirka, Ph.D. and Domenichini et al.

Coupling near field and far field models

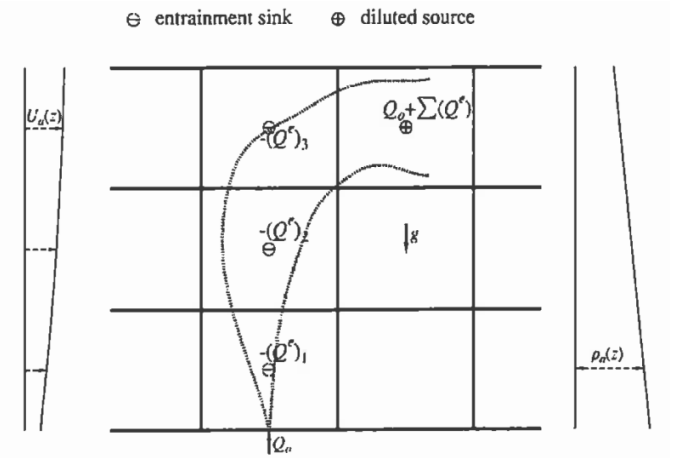
Cover different time and space scales by coupling near field (CORMIX, CFD, etc.) and far field models (like Delft3D)

Coupling methods:

- No coupling (direct insertion, undiluted source)
- One-way, fixed near field solution
- One-way, time-varying near field solution
- *Two-way, dynamic near field – far field coupling*



Source: Bleninger 2006



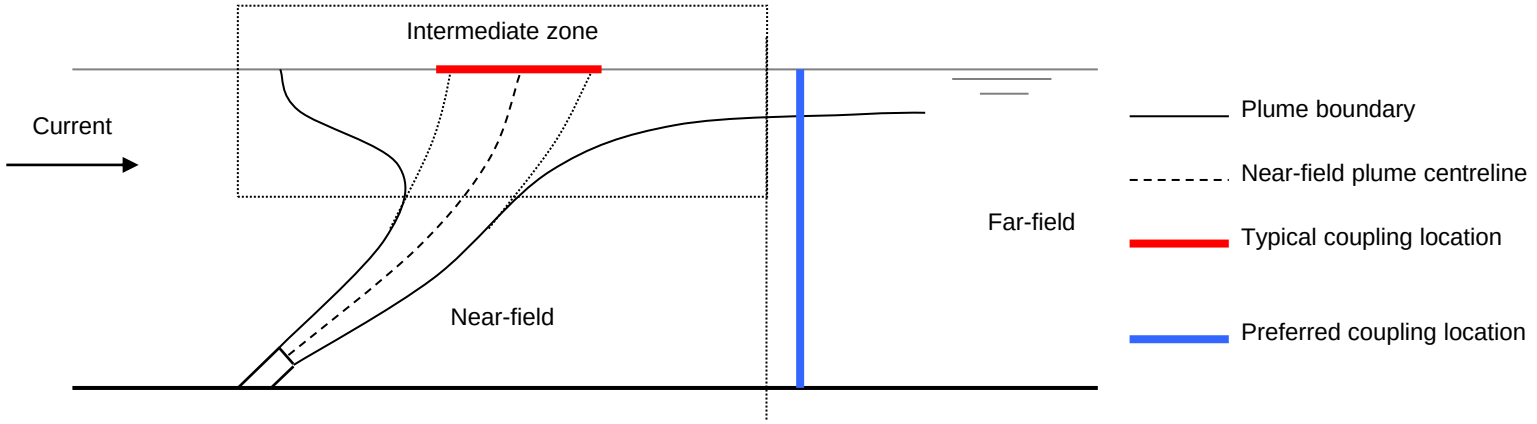
Source: Choi & Lee 2007

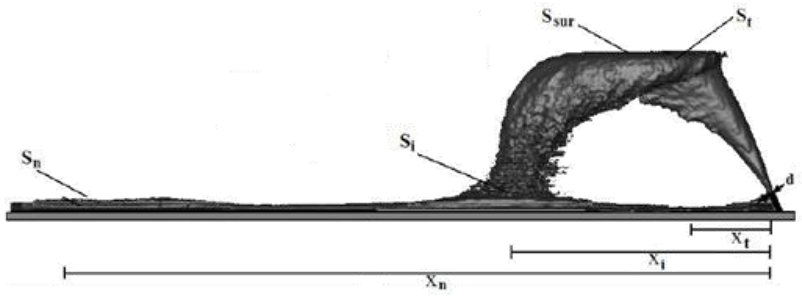
Deltares

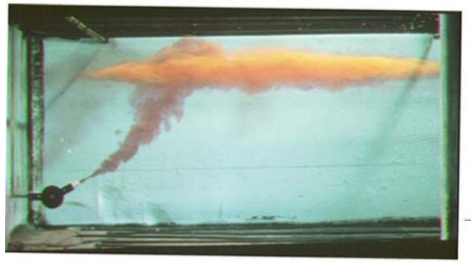
Development of the COSUMO coupling interface

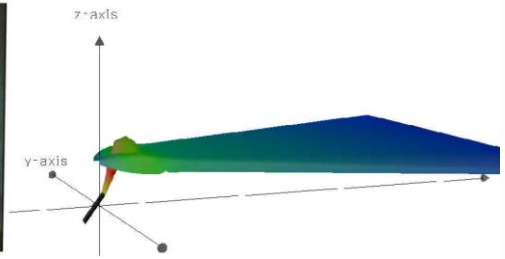
Coupling Delft3D with CORMIX with COSUMO:

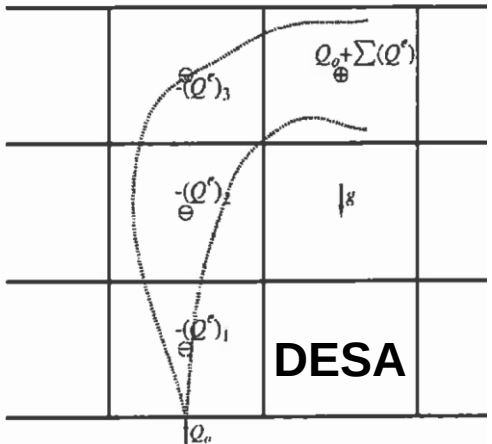
- physically suitable location for coupling to the far field model (including boundary interaction)
- include many different outfall configurations and flow conditions that are included in CORMIX
- Generic and flexible coupling of subgrid models with the COSUMO interface – also for other near field models and formulations









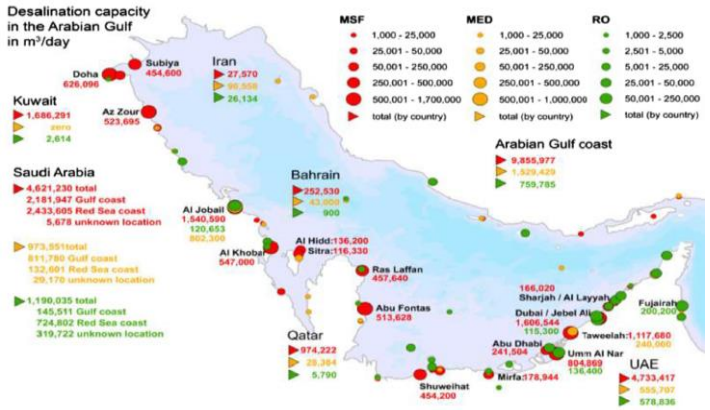


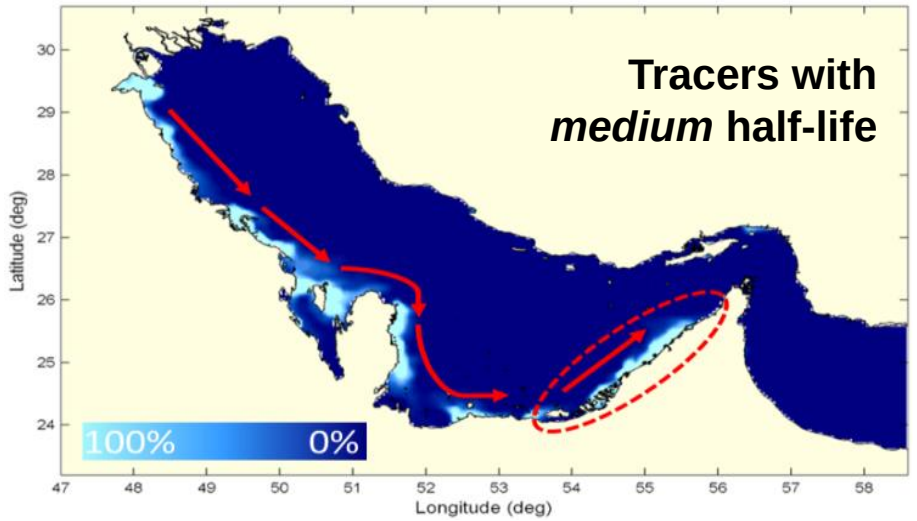
Dense jet plume trajectory from a laboratory experiment (Abessi and Roberts, 2015)

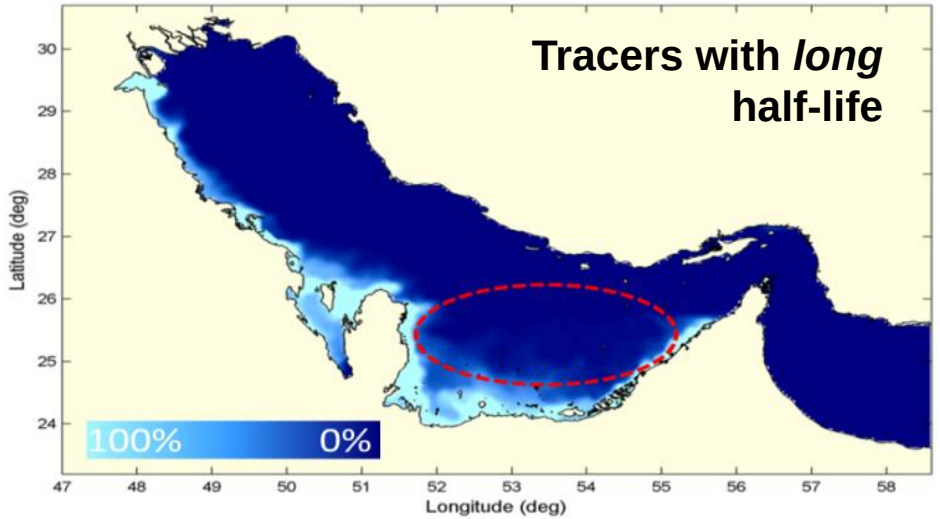
Deltares

Strategic water planning with models

Large-scale transport, marine spatial planning and site selection studies



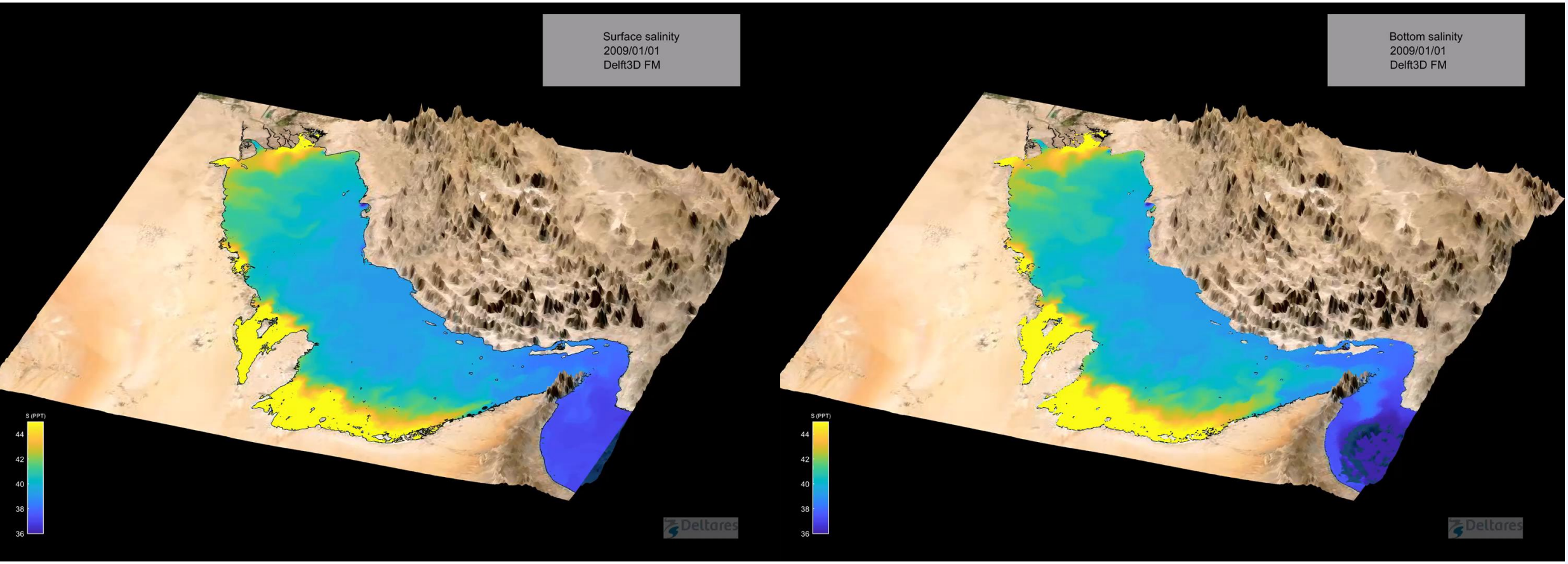




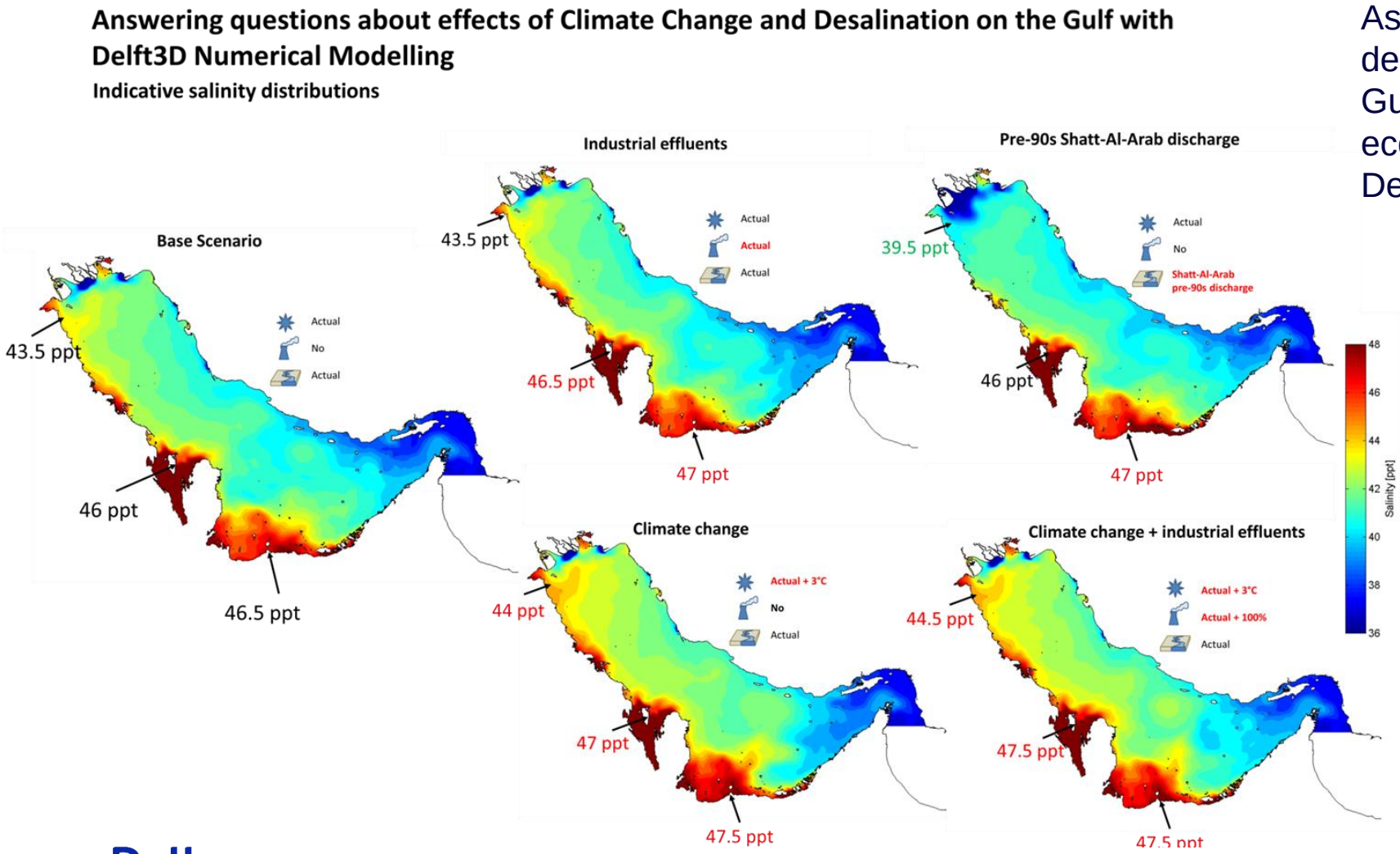
A well-validated numerical model could be used to provide guidance for plant siting, construction and operation, reducing operational risks and facilitating planning and permitting procedures

Deltares

Modelling salinity of the Gulf with Delft3D



Long-term impacts of desalination and climate change



Assessment of long-term impact of desalination and climate change on Gulf hydrodynamics, water quality and ecological impacts with the open-source Delft3D modelling software

Deltares

Modelling the Gulf together

Gulf Model Community

Gulf Model Community

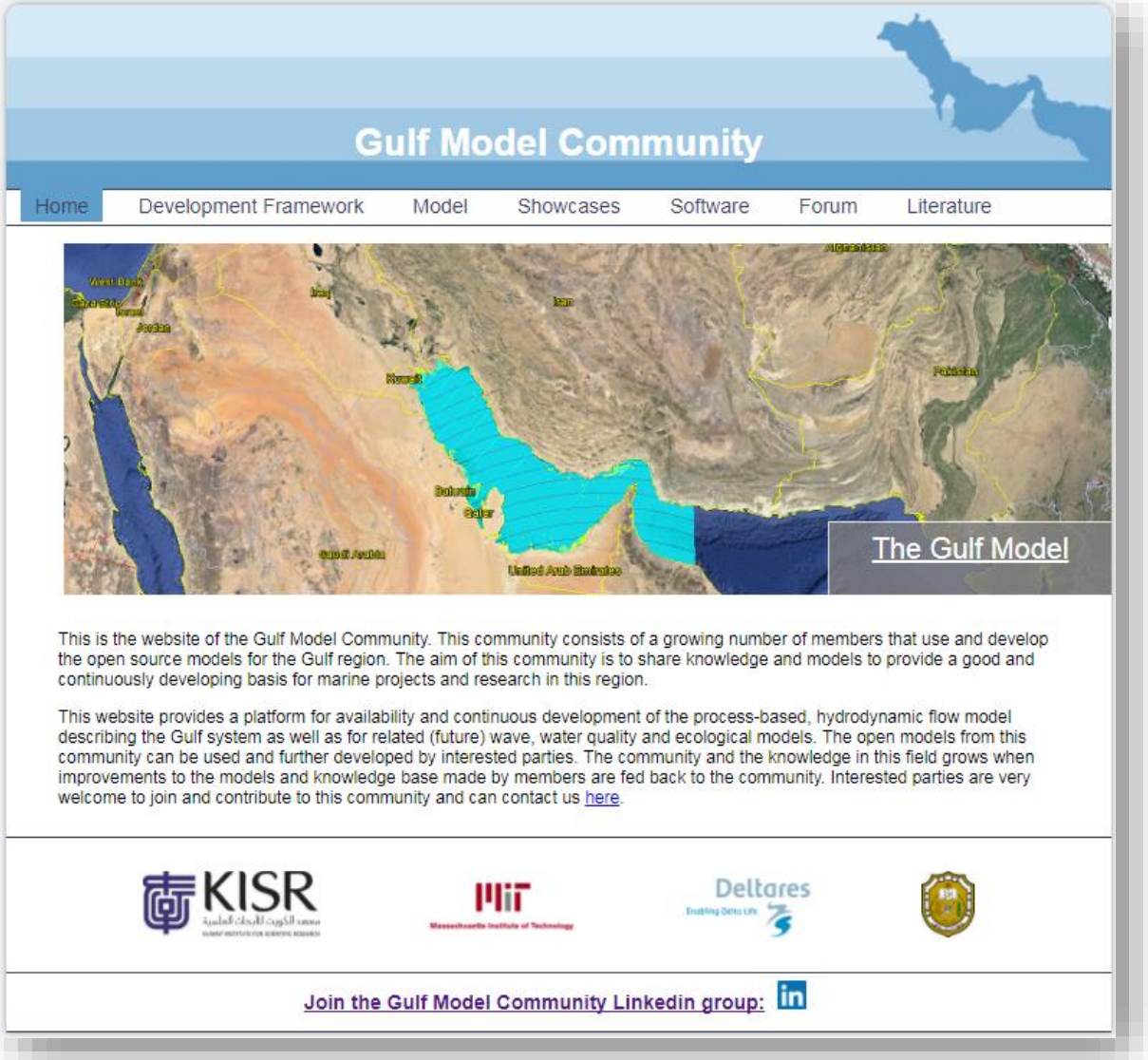
Open community - Share knowledge and models to provide a good and continuously developing basis for marine projects and research in this region.

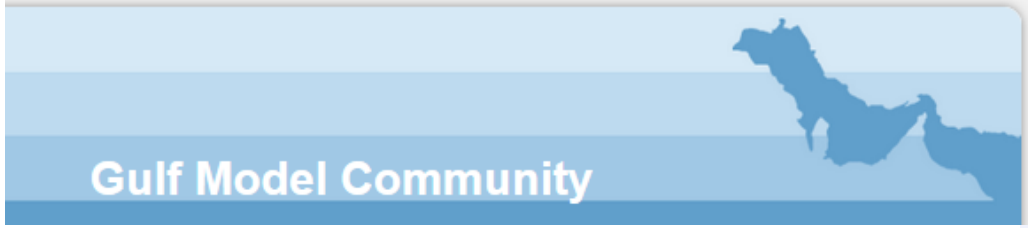
Work together with local universities, institutes and stakeholders on topics like Climate Change adaptation, environmental impacts and water safety

To enable different parties:

- to use and develop the models
- jointly increase the knowledge about the Gulf for the region
- new research projects to start from a more developed basis instead of reinventing the wheel
- contribute to the further development of the model and make publications about these developments

Modelling the Gulf together





Current contributing members

Kuwait Institute of Scientific Research

Massachusetts Institute of Technology

Sultan Qaboos University

Environment Agency Abu Dhabi

Deltares

www.agmcommunity.org

Towards sustainable desalination

- Current market dynamics for desalination plants - independent water plants often at the lowest metre cube water price, rather than the most sustainable design and operation.
- Challenge and opportunity for water companies to demand the highest levels of sustainability in addition to an economic preference.
- Steps are being made in this direction though and innovations are being developed.

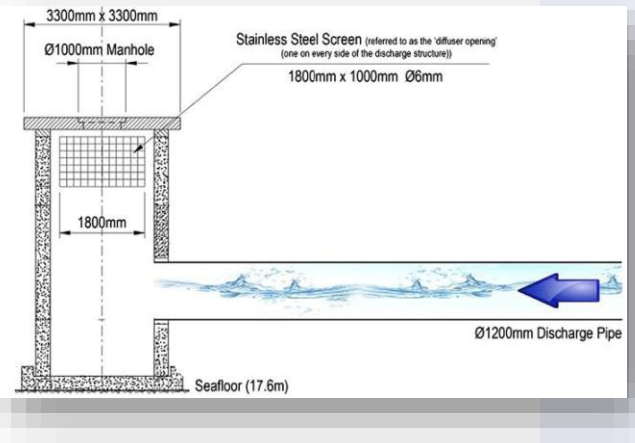
Deltares

Impacts of outfalls on ecology

Studies on ecological impact of desalination discharges

The King Abdullah University of Science and Technology (KAUST) Reverse Osmosis (RO) Desalination Plant
Study impact of brine on microbial abundance and coral (Fungiidae) resilience

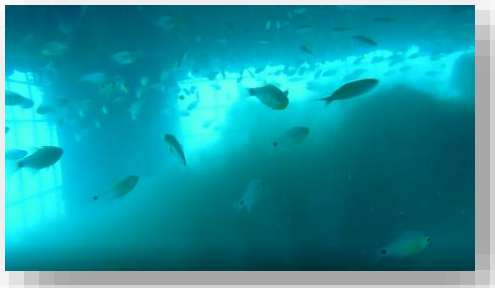
- Effect on microbial abundance only because of dilution
- *Fungia granulosa* did not show any significant response to elevated salinities in this experiment

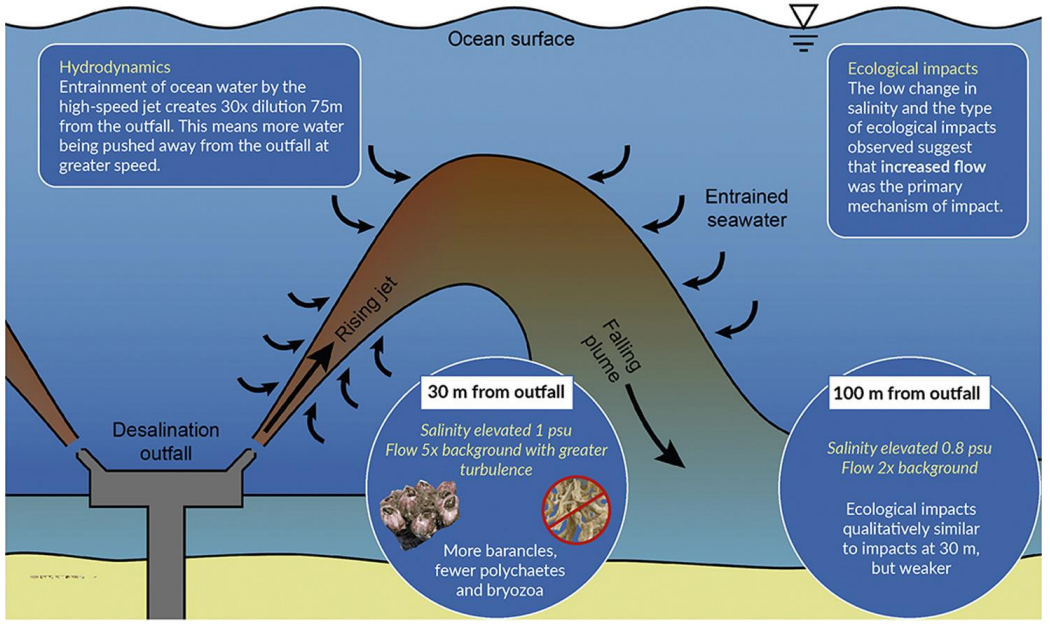


Deltares

Site-specific environmental criteria

- Important to adopt site-specific and ecologically relevant criteria for a desalination brine outfall.
- Often mixing zone criteria adopted from other parts in the world – could be either harmful to local ecosystems or be overly restrictive.
- Research to develop more relevant criteria that could be adopted by regulators and increase the sustainability of desalination in relation to the marine environment.





Graeme F. Clark, Nathan A. Knott, Brett M. Miller, Brendan P. Kelaher, Melinda A. Coleman, Shinjiro Ushiama, Emma L. Johnston, First large-scale ecological impact study of desalination outfall reveals trade-offs in effects of hypersalinity and hydrodynamics, Water Research, Volume 145, 2018

Deltares

Bio-opportunity vs Environmental impact

Opportunities

1. Creating **opportunities for nature** with the intake and outfall design
2. **Using natural processes and system** to optimise the functioning of the intake and outfall system
3. **Improve other, existing functions or operations** in the project area with the intake and outfall design

Potential benefits

- **More societal support** and **shorter permitting procedures** due to added value for developer and stakeholders
- Potential for **cost saving** on a life-cycle basis
- Potential for **creating new habitats**, which may replace mitigating measures

First guidelines on eco-friendly outfall structures

First guidelines to promote ecology around outfalls

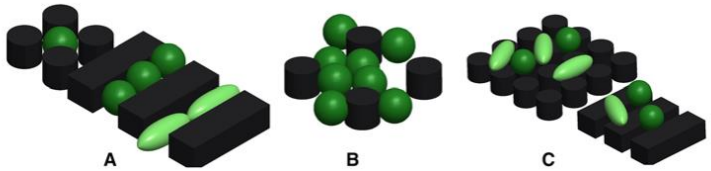
- Sand stone rocks (or concrete) suitable material for settlement of species in comparison to the more smooth whim stone rocks or other smooth materials, although some species prefer smooth surfaces

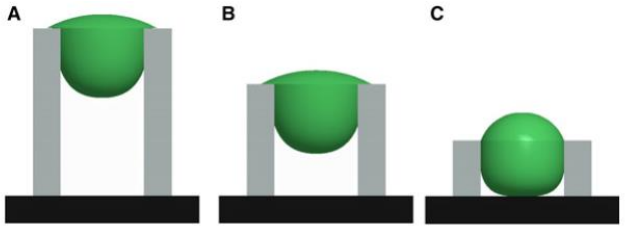
- Good basis for bacterial growth → settlement and growth of bryozoan, molluscs, tubular worms, tunicates, anemones and other marine species.

- Macro topographies encouraged more organisms to settle in research studies compared to micro topographies

- Availability of nutrients is typically not a limiting factor and composition of effluent could be further considered in the light of ecological suitability

Further research and pilot projects needed to optimise an ecological function of outfalls





Myan et al. Biointerphases 2013

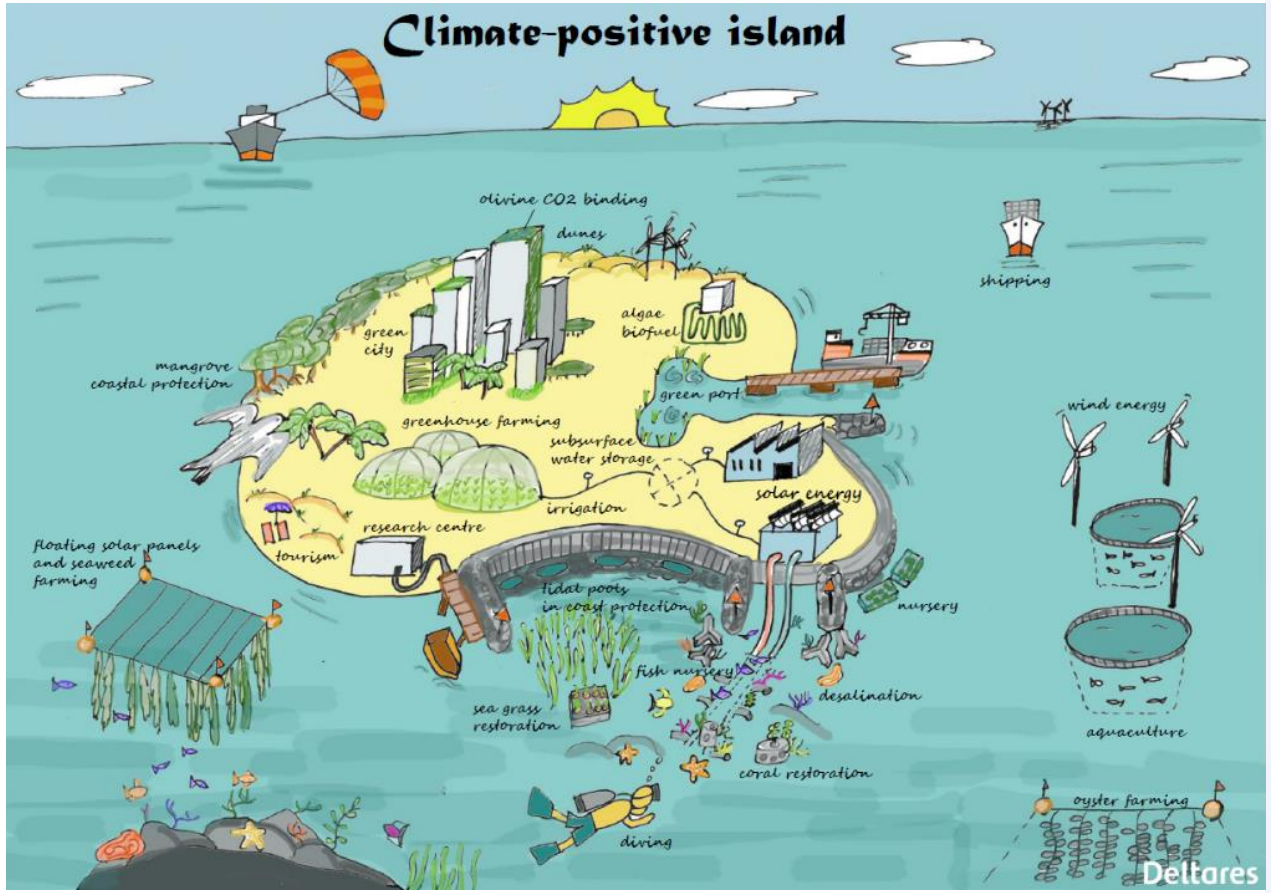
Climate-positive marine developments

From minimising climate impact

Via climate-neutral developments

Towards Climate-positive developments, creating opportunities for biodiversity and carbon sequestration in everything we develop

Build more than there was before



Deltares

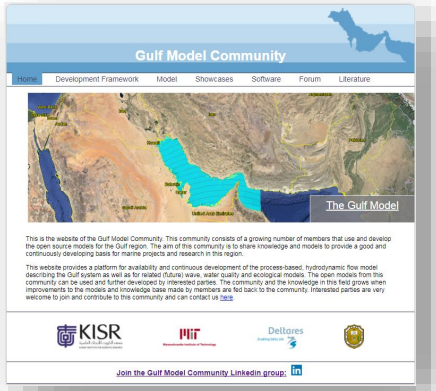
uniting water energy food

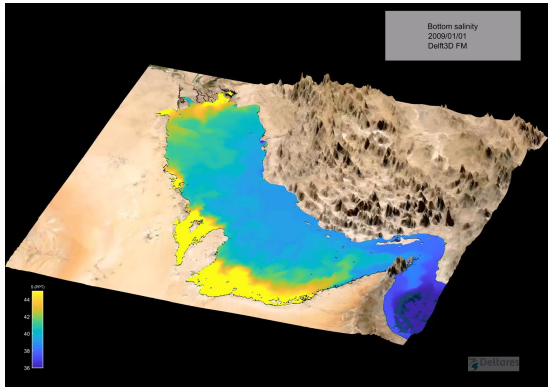
Netherlands

DUTCH DUBAI uniting water energy food

Summarising

- The Gulf region is an economically and environmentally important area and water is a crucial component in this
- To support the sustainable development of its marine environment, knowledge, data and numerical models are needed. The Gulf Model Community facilitates collaboration in this field with open source model software and models of the Gulf.
- Important topics for the marine environment in the region can be studied with this, such as impacts of climate change on desalination and environment, siting and spatial planning of coastal and offshore infrastructure and industry, but also flooding risk due to climate change, algae blooms and oil spills, etc.
- Integral knowledge, combining different disciplines, and collaboration allow for sustainable development of water resources in the Gulf region, while creating opportunities for nature.





Deltares

Deltares in the Middle East

MENA Regional Coordinator: Ir. Robin Morelissen (Robin.Morelissen@deltares.nl)

GCC area (local) manager: Dr Ahmed Elkadi (Ahmed.Elkadi@deltares.nl)

Egypt, Turkey and Levant manager: Dr Mohamed Yossef (Mohamed.Yossef@deltares.nl)

Deltares

Contact

www.deltares.nl

@deltares

linkedin.com/company/deltares

info@deltares.nl

@deltares

facebook.com/deltaresNL