AMSTERDAM INTERNATIONAL WATER WEEK

Enhancing Resilience in Decentralized Water Supply Networks Planning

Integrating Variable Water Quality and Reverse Osmosis Treatment in Water Network Optimization

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Date: 08/11/2023

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AquaConnect

Key technologies for safeguarding regional water provision in fresh water stressed deltas

Content

- Introduction
- Theoretical background
- Methodology
- Case study
- Numerical results
- Conclusion
- Limitations and future work

Introduction

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- **Climate change**
  - Extreme weather events
  - Drought
  - Floods
- **Increased uncertainty**
  - in water demand
  - in water supply
- **Water quality**
  - Anthropogenic pollution
  - Saltwater intrusion
- **A transition is needed**
  - from a safe and water-discharging delta
  - to a safe and water-retaining delta

Longing for rain: 'Greatest drought in more than 40 years'

All water managers in the Netherlands are longing for heavy rain showers in June, because it is much too dry. Streams and ditches dry up, the groundwater sinks far away and the water quality declines. And summer has yet to start.

Domestic editorial 24-05-20, 10:49 Last update: 24-05-20, 16:37

Persistent drought but still enough water

Published on: June 14, 2023 - Last updated: August 4, 2023, 11:20 AM

No precipitation has fallen in the Netherlands since mid-May 2023. The precipitation deficit has therefore increased to well above average. No precipitation is expected for the coming week and temperatures will remain high. The precipitation deficit will therefore increase even further.

Opinion: And whoosh, we're pumping away all that precious water

It would be better to store all that water from the Alps that puts pressure on our dikes, because in a few months we will be faced with drought again due to climate change, argues René Didde.

René Didde February 4, 2021 , 6:51 PM

It's too dry again. What are we going to do about it?

Water management The extreme drought of 2018 has shaken the Netherlands awake. It is also extremely dry now. Our handling of water needs to be overhauled.

Marcel aan de Brugh • May 15, 2020 • Reading time 6 minutes

Water quality in the Netherlands is at the bottom of the European rankings – is it really that bad?

The water in the Netherlands has become cleaner in many places (swimming in the canal!). Yet the Netherlands ranks last in a European ranking of water quality. And that assessment could have nitrogen-like consequences.

Tonie Mudde and **Frank Rensen** June 3, 2022 , 4:00 PM

During droughts, salt water rises into the fields, a nightmare for farmers

In North and South Holland, farmers experience a shortage of fresh water during dry periods. Old seawater rises from deep groundwater layers. Fixed water levels often force water boards to discharge the water they so desperately need later. The water board uses art and craft to bring in new fresh water from the rivers.

Joris Tieleman September 24, 2020 , 4:21 PM

Robust optimization of future water infrastructure

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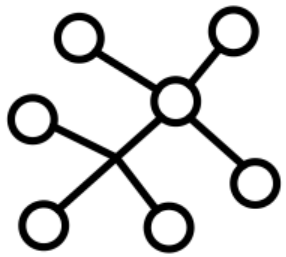
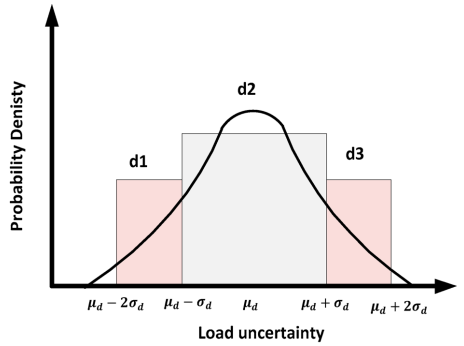
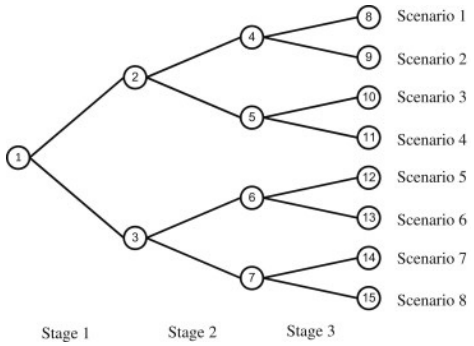
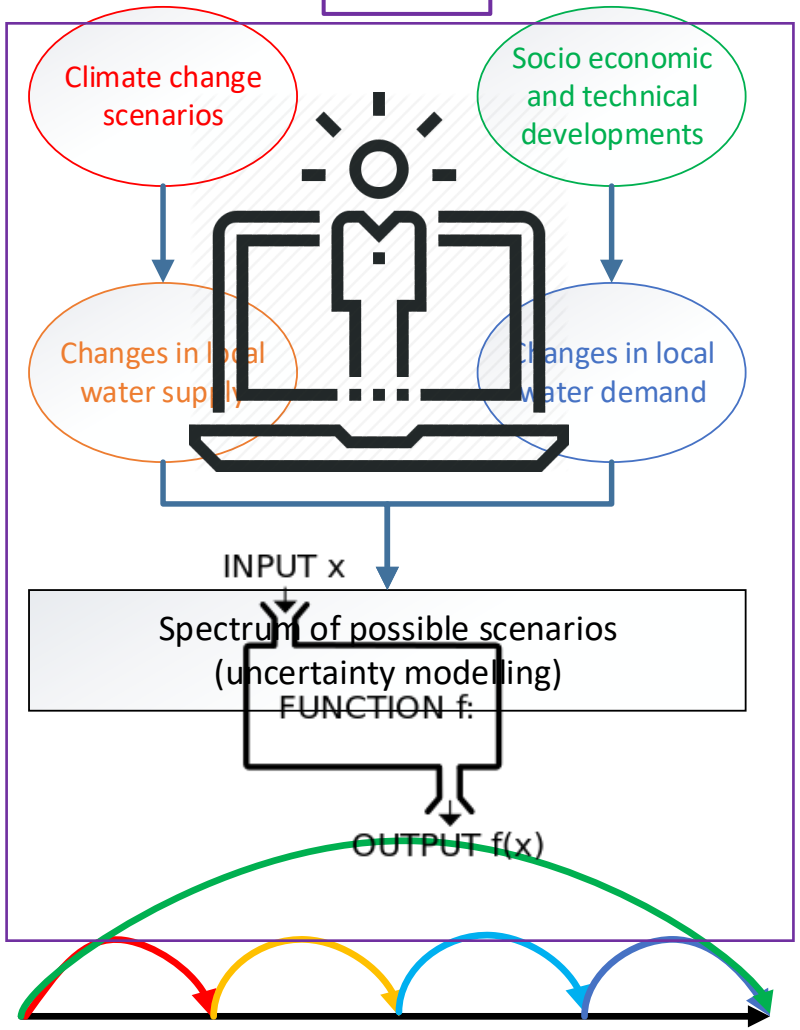
Input





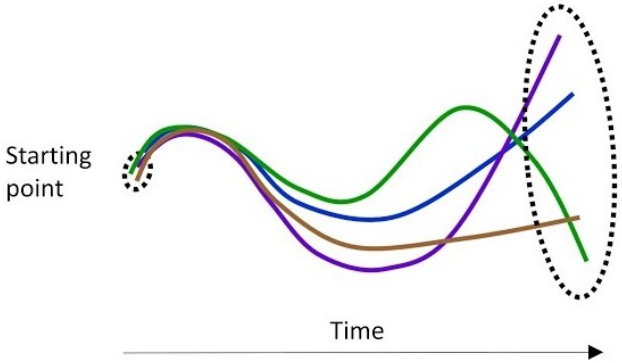


Model



Output

Planning decisions
Scheduling decisions
Operational decisions



Optimization for Water Network Planning

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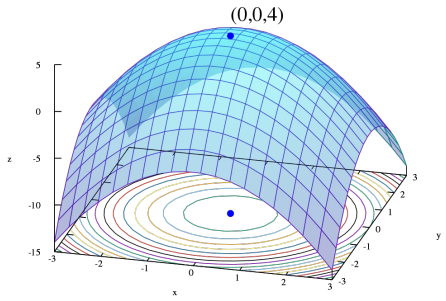
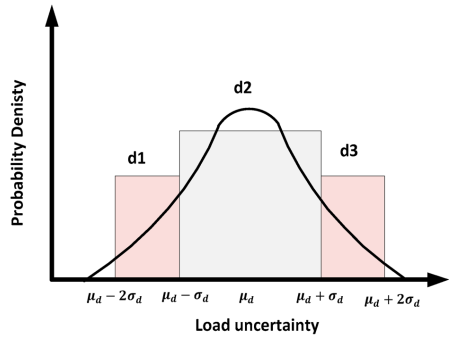
Challenges in mathematical programming

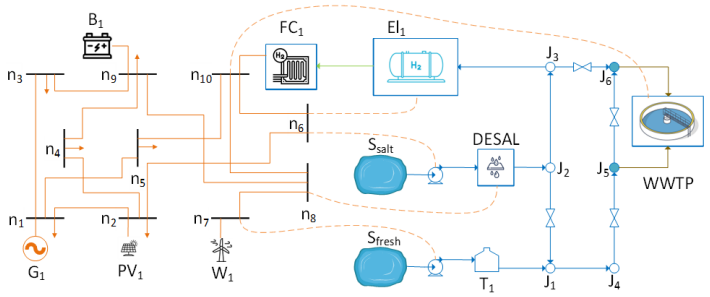
1. Physical feasibility of the network
2. Nonlinearity and nonconvexity
3. Computational tractability
4. Operational dynamics
5. Uncertainty modelling





Challenges in practical applications

1. Land use considerations in water network design
2. Considering multi-source and multi-quality networks
3. Consider source depletion and extraction limits
4. Seamless integration of water treatment and supply
5. Sector integration (e.g., energy sector)



Optimization for Water Network Planning

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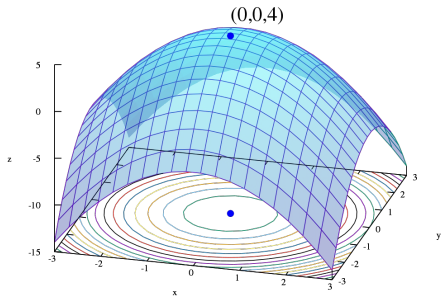

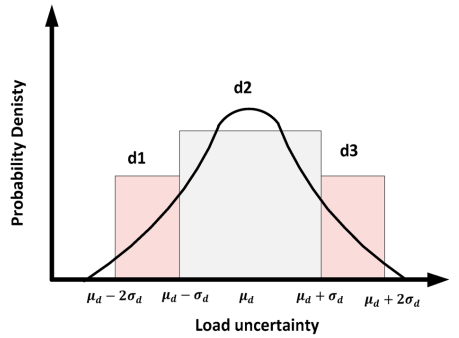

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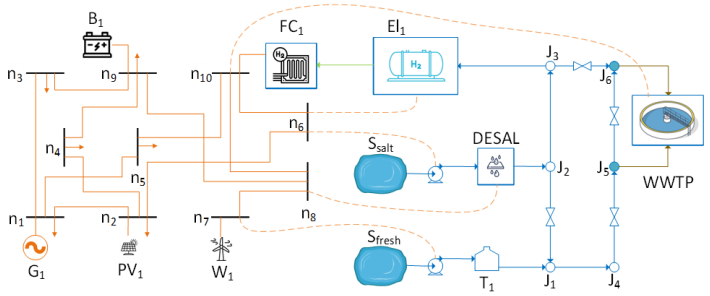

Towards a Comprehensive Framework for Multi-quality and Multi-source Water Network Planning

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$$
\begin{aligned}
\text{minimize} \quad & f(x, y, z) \\
\text{subject to} \quad & g(x, y) \leq 0 \\
& h(x, z) = 0 \\
& x \in R^n \\
& y \in Z^m \\
& z \in \{0, 1\}^p,
\end{aligned}
$$

$$
\begin{aligned}
\text{minimize} \quad & \text{Cost}(x, y, z) \\
\text{subject to} \quad & \text{Water network constraints,} \\
& \text{Water quality constraints,} \\
& \text{Water treatment constraints,} \\
& x \in R^n, \\
& y \in Z^m, \\
& z \in \{0, 1\}^p.
\end{aligned}
$$

The problem is formulated as a deterministic mixed-integer quadratic program (MIQP), implemented in Python, and solved with Gurobi.

Case Study

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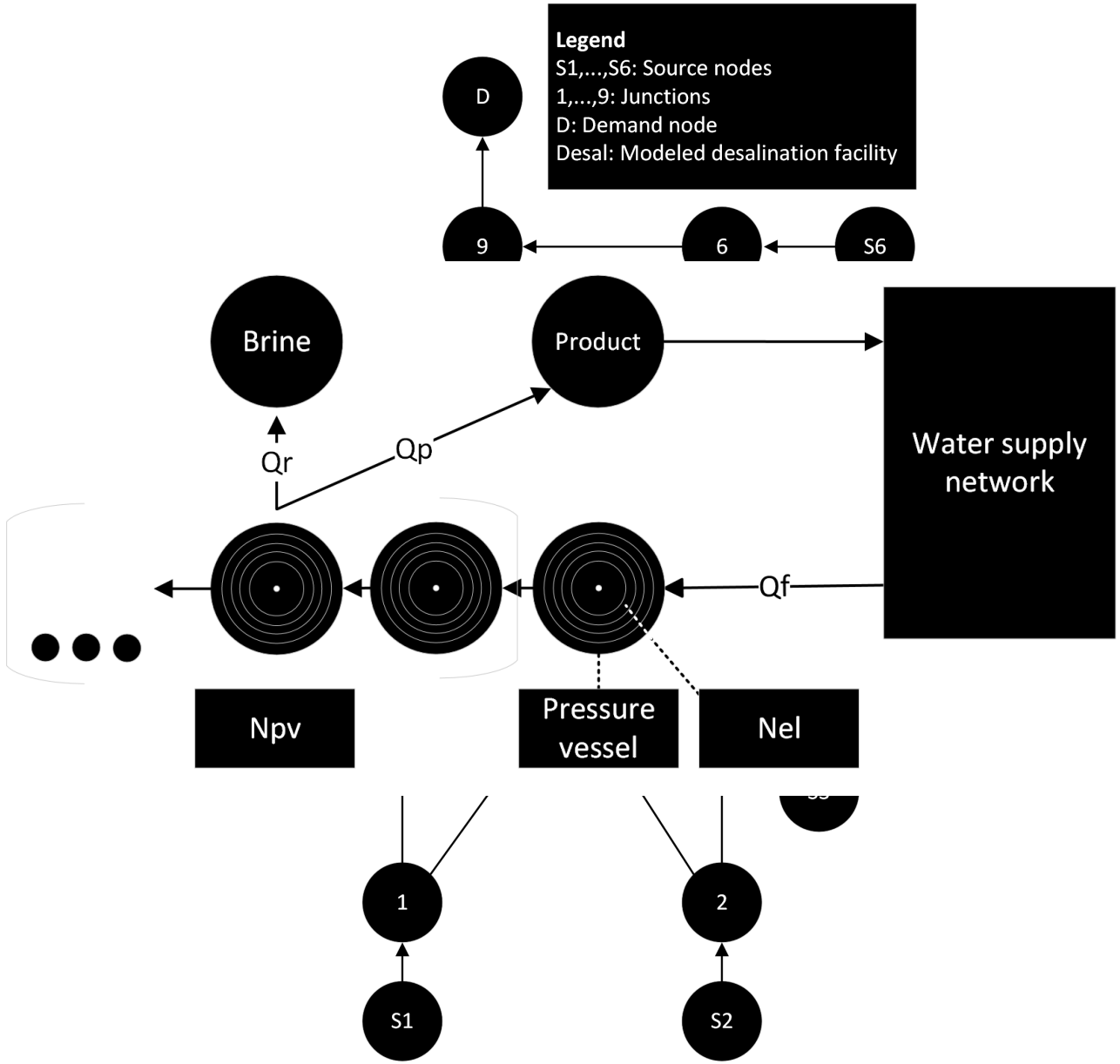
Area of Terneuzen

- Highly industrialized area
- Most water sourced remotely: pipeline ~120 km
- Wants to increase the use of local water sources
- Surface & ground water are mildly brackish

Case Study


Legend
S1,...,S6: Source nodes
1,...,9: Junctions
D: Demand node
Desal: Modeled desalination facility
D
9
6
S6
Brine
Product
Water supply network
Qr
Qp
Qf
Npv
Pressure vessel
Nel
1
2
S1
S2

Results: Optimal Water Network Layout

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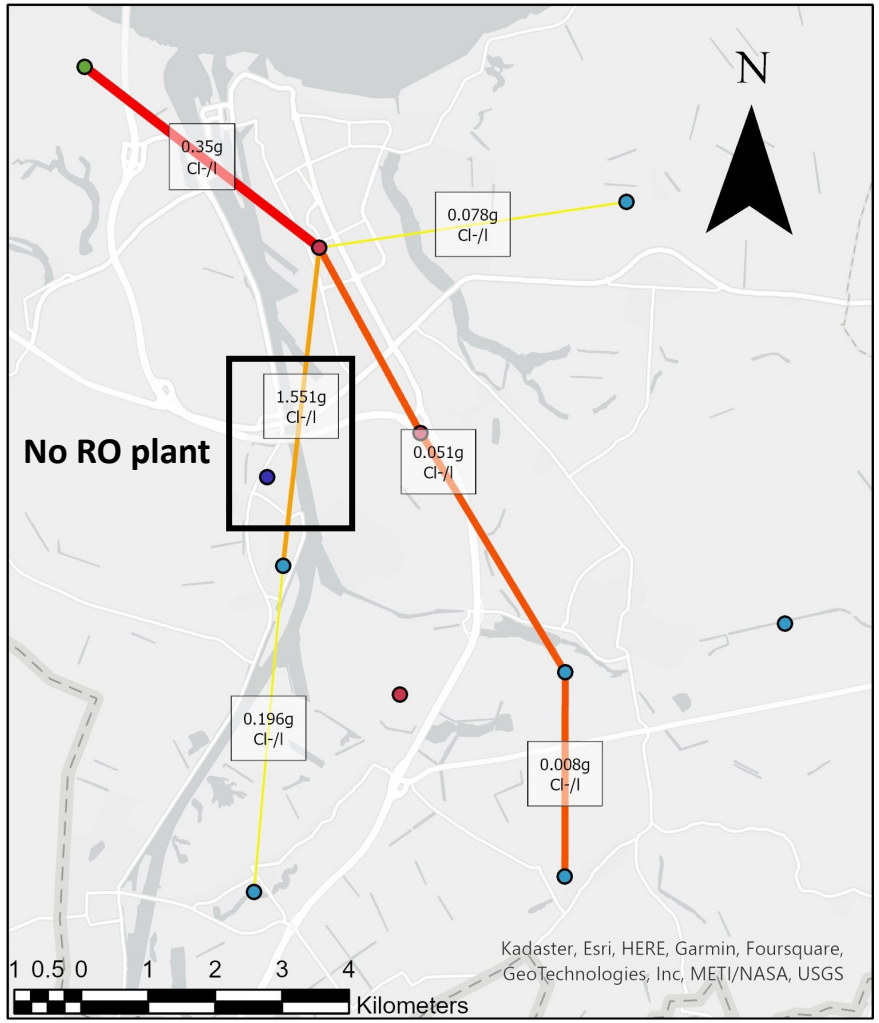
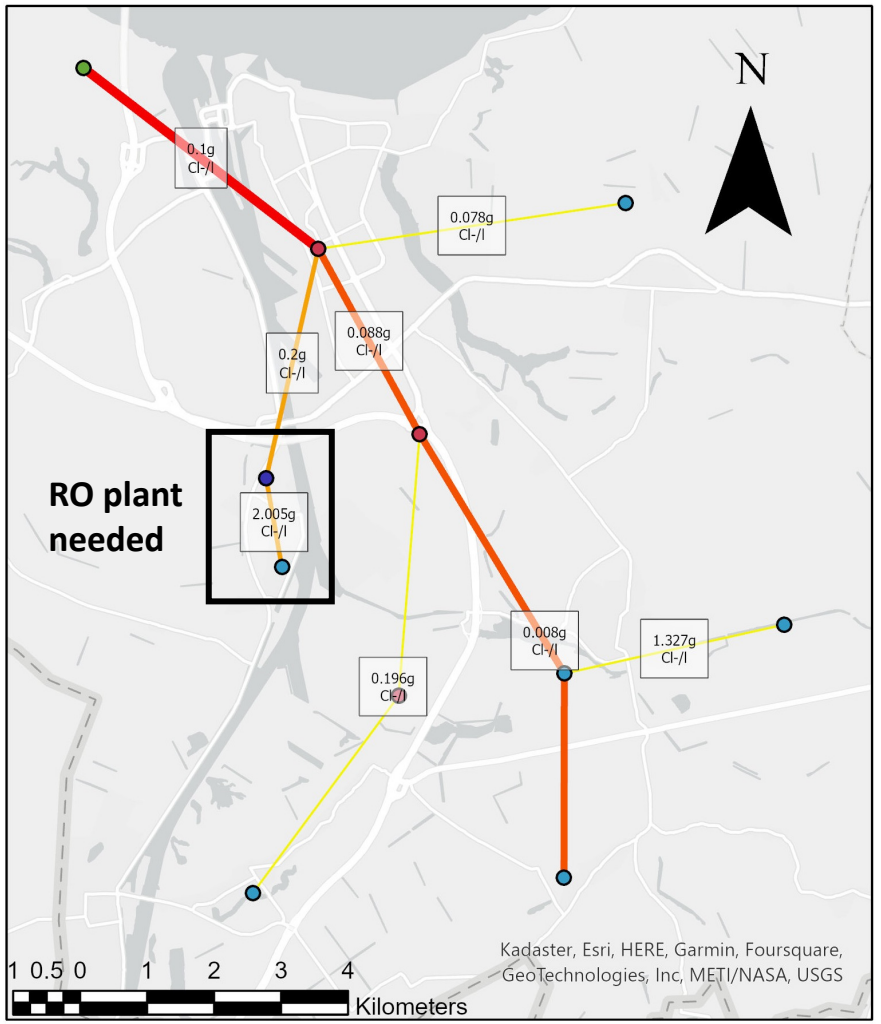
Type
- Demand
- Desal
- Junction
- Source

Diameter
- 1
- 2
- 3
- 4

Demand of 3.5 Mm^3/y at 350 mg-Cl-/l



Demand of 3.5 Mm^3/y at 100 mg-Cl-/l



Results: Total Network Cost and Length

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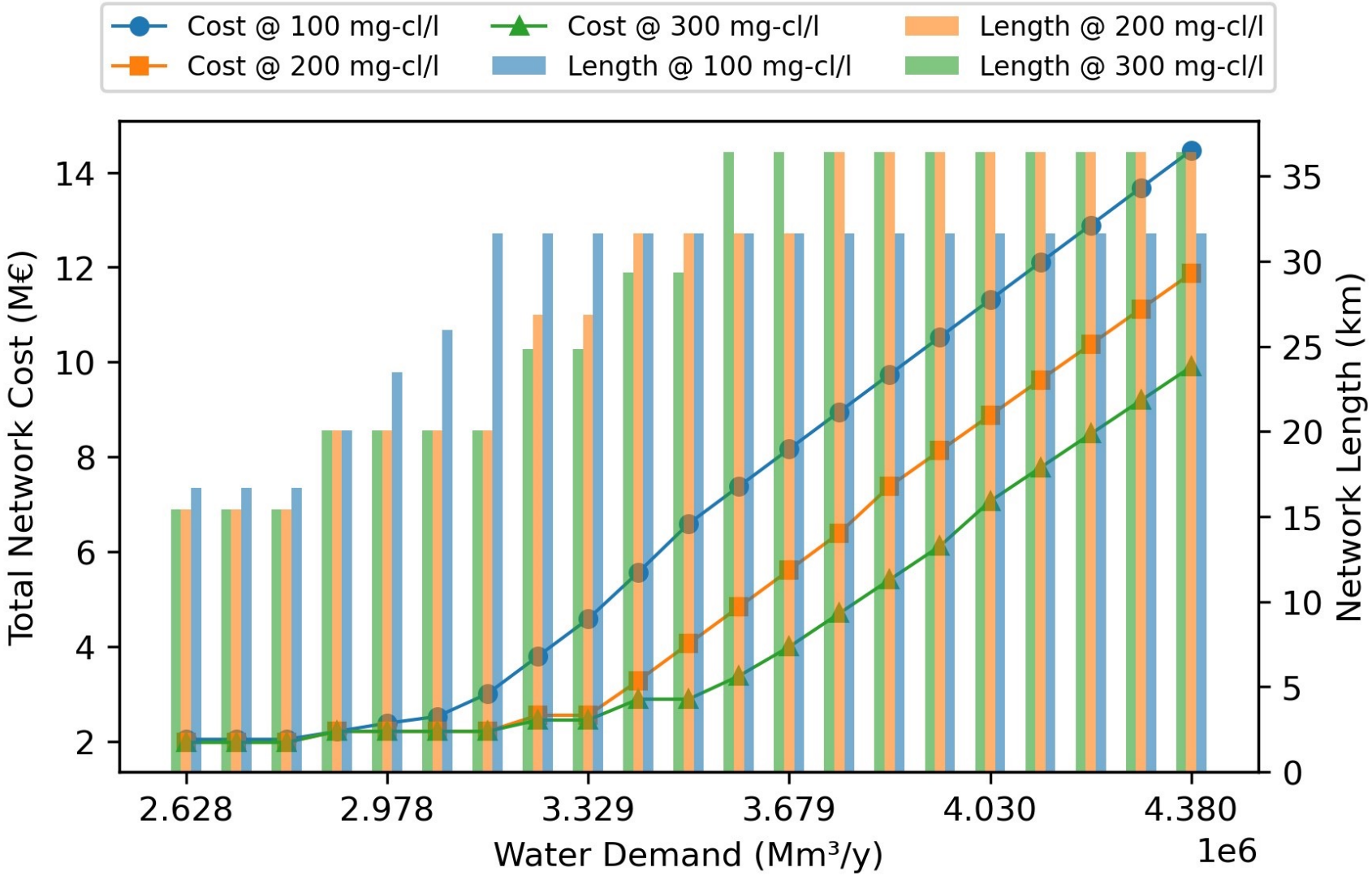
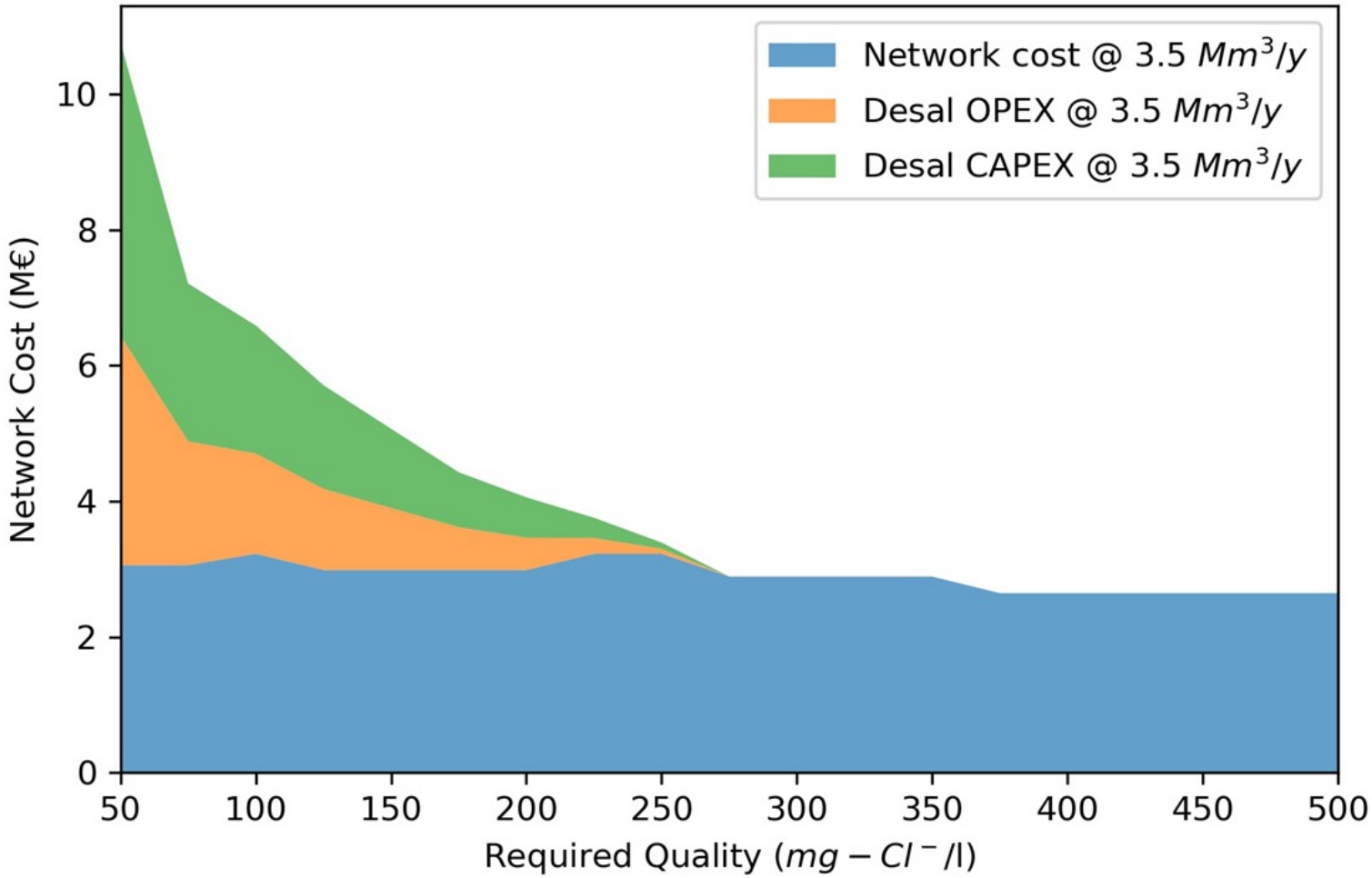


Results: Cost Breakdown



Conclusion

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The model considers:

1. Water supply network construction and operation
2. Desalination facility construction and operation
3. Sustainable extraction limits
4. Water quality requirements

The main outputs are:

1. Optimal investment decision
2. Optimal pipeline layout and diameters
3. Optimal water flows
4. Optimal water salinity at mixing points
5. Optimal RO facility configuration

Applied to the case of Terneuzen, the study showed the potential for implementing local water supply networks, facilitating trade-off analysis considering various technologies, demand, and quality requirements.

Limitations and Future work

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The limitations are:

1. High computational complexity
2. Limited scalability
3. Uncertainties not considered
4. Water storage not considered

In the future we will:

1. Enhance computational efficiency
2. Incorporate uncertainty in water demand and supply
3. Consider seasonal water buffering
4. Study water-energy sector integration

Our Team at Environmental Technology (WUR)

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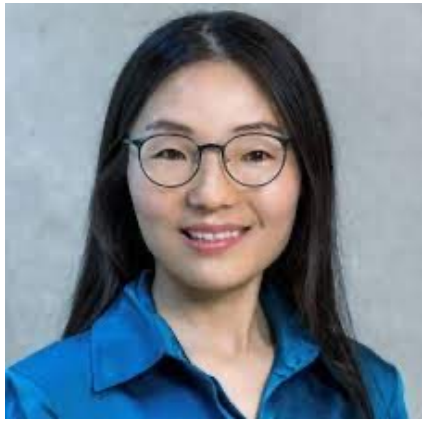
PhD candidates

Undregraduate researchers



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Prof. W.S. Chen

Prof. HHM Rijnaarts

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Thank you for your attention

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