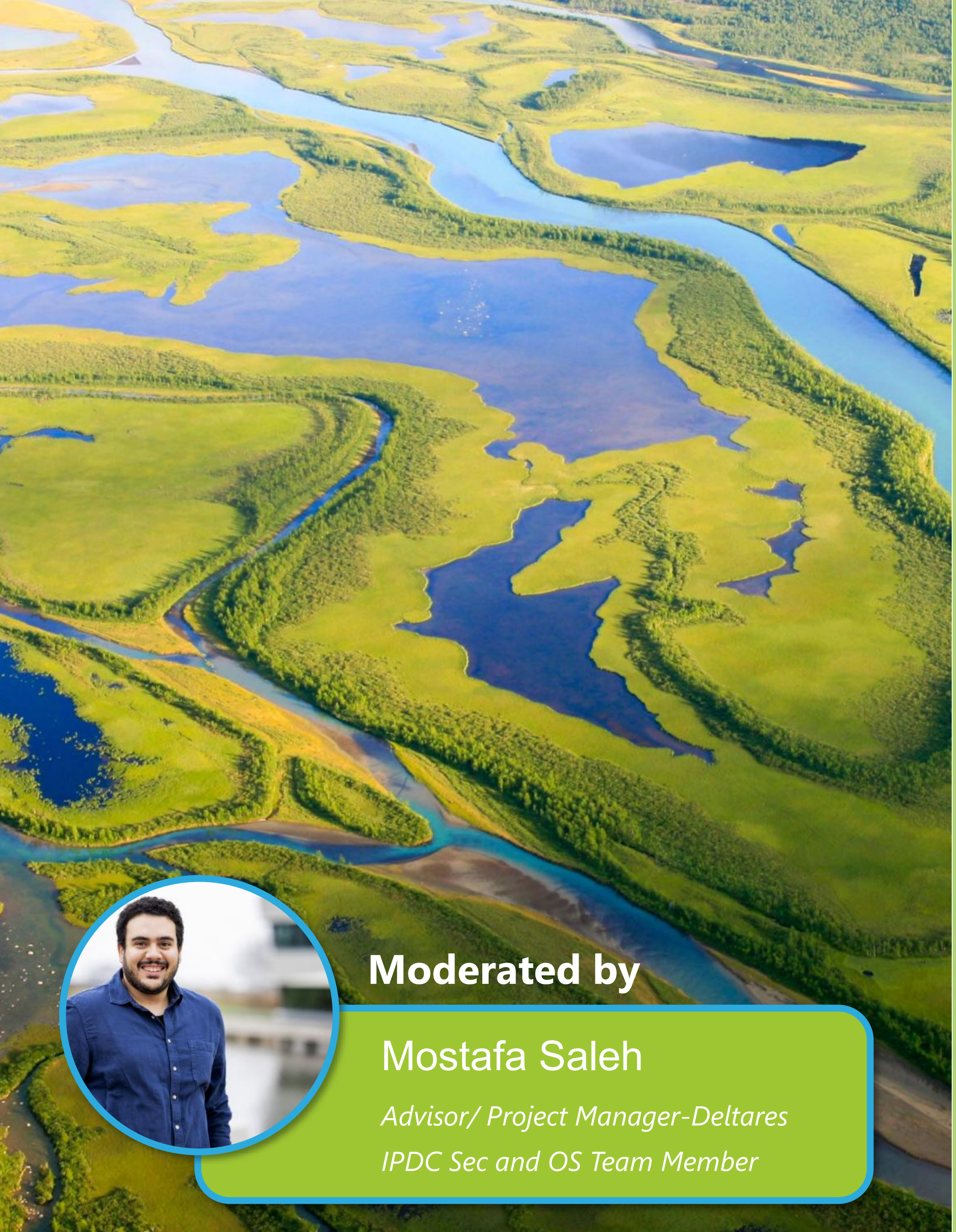

Moderated by

Mostafa Saleh

Advisor/ Project Manager-Deltares

IPDC Sec and OS Team Member

ONLINE SESSION

IPDC DEDICATED ACTIVITIES - SESSION 02: WATER SECURITY - SAFEGUARDING FRESHWATER RESOURCES IN EGYPT AND VIETNAM.

The session features presentations on two IPDC projects addressing freshwater security in Egypt and Vietnam, covering saltwater intrusion management and managed aquifer recharge, followed by a panel discussion with experts.

TUESDAY 19 MAY

10:00 - 11:30 CEST (NL TIME)

Practicalities

- Post your questions in the chat.
- Please turn your microphone off during presentations
- *Note: This session will be recorded and uploaded onto the IPDC website. By attending the session, you give your permission for your name to be featured in the recording.*

Today’s program

Opening and Introduction	Mostafa Saleh (Moderator) Sonja Pans (IPDC Secretariaat)
Egypt – dealing with groundwater salinisation	Betsy Romero / Gualbert Oude Essink
MAR Guidelines in Vietnam	Niels Mulder
Interactive discussion	Ms Nguyen Thu Phuong Eng. Walid Hakiki Dr Anwar Zahid Mrs Sonja Pans Mostafa Saleh (Moderator)
Closing	Sonja Pans Mostafa Saleh

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Opening words by the IPDC

Sonja Pans

IPDC Secretariat
Senior advisor, Deltares

IPDC Project #1 Saltwater Intrusion in coastal Egypt

Gualbert Oude Essink, Associate Prof.
Senior Specialist Groundwater Systems
Deltares
The Netherlands

Betsy Romero
Researcher/ Advisor Groundwater,
Deltares,
the Netherlands

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Egypt – dealing with groundwater salinisation

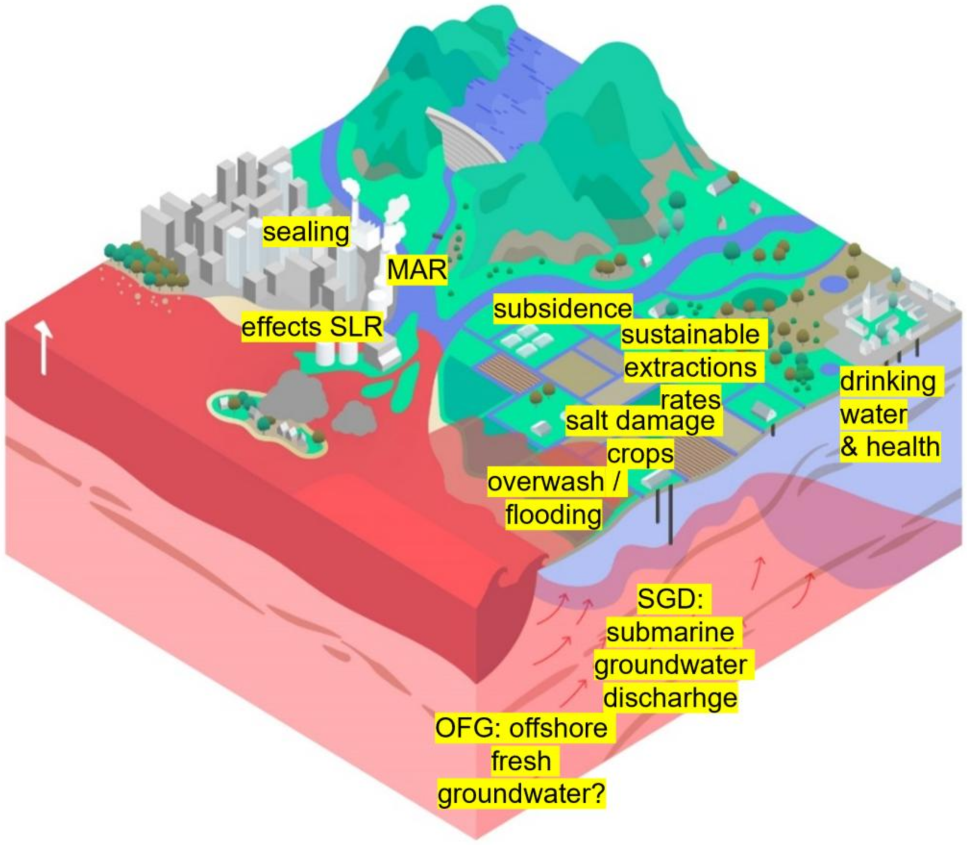
Assessing the impact of saltwater intrusion on the Egyptian North Coast

Gualbert Oude Essink

Betsy Romero

Introduction groundwater salinisation in the coastal zone

- Coastal fresh groundwater is **main water resource** for ~3**0%** of the **coastal world population**
- Groundwater is important for **drinking water, agriculture**, **industry**, as well as **ecosystems & river baseflows**
- **Right now**, fresh groundwater resources are threatened by **excessive pumping**, and **reduced replenishments**
- Projected climate change impacts, inducing **sea-level rise**, will worsen this situation



https://deltalife.deltares.nl/september_2022_en/salinisation_the_slow_disaster

Why this project is important for Egypt

- **Groundwater salinisation is already a major pressure**

  Shallow saline groundwater, overextraction and drainage reuse threaten fresh groundwater resources.

- **Climate change will worsen the problem**

  Sea-level rise and rising water demand will increase saltwater intrusion.

- **Better monitoring is needed**

  An optimal monitoring network is required to understand, predict and manage saltwater intrusion.

- **Knowledge must become practical action**

  By combining Dutch and Egyptian expertise, the project will deliver knowledge to support feasible mitigation of saltwater intrusion.

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Project in Egypt

- **Objective:**

  To improve understanding and management of saltwater intrusion in coastal Egypt through integrated system analysis, risk mapping, and optimal monitoring network design.

- **Approach:**

Task 1	Task 2	Task 3	Task 4	Task 5
Define monitoring objectives	**Build system understanding**	**Develop salinity risk maps**	**Design optimal monitoring framework**	**Capacity building**
• Main issues related to groundwater salinity • Data collection • Presentations	• Use of existing data (literature, global datasets) • Local shared information • Use and refine existing 3D groundwater salinity model	• For the coastal area • Use indicator-based methods (e.g. GALDIT, DRASTIC, Abu-Bakr 2020) • Define priority areas for monitoring	• Including: objectives, techniques, parameters, priority areas spatial density and frequency	• Knowledge exchange Egypt – The Netherlands • Field visits

Previous projects in Egypt on groundwater salinisation

1. Enhanced Water Resources Management project, under Global Environment Facility (GEF)

- Construct with recent hydrogeological data a 3D variable-density groundwater flow and salt transport model
- Assess effect of sea-level rise and groundwater extractions on fresh groundwater resources

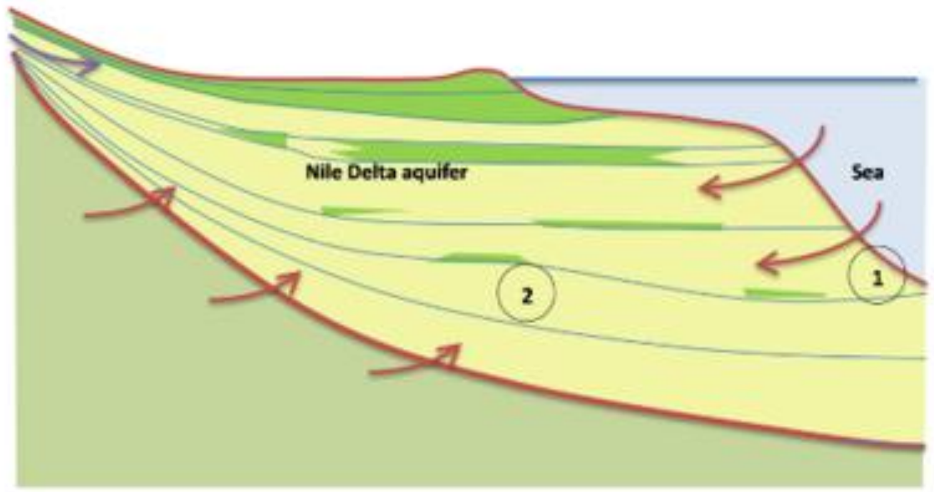
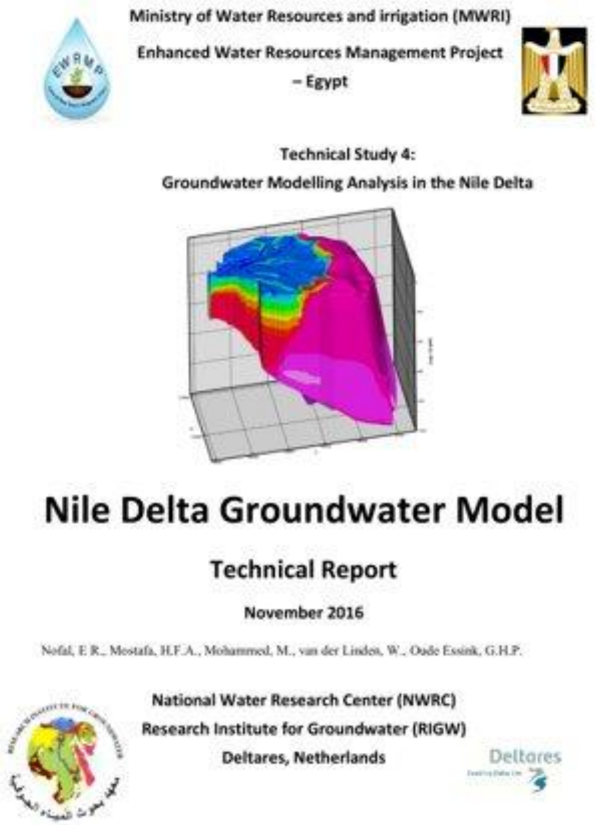


Figure 13. Schematic vertical lay-out of the Nile Delta model using continuous hydrogeological layers



Ministry of Water Resources and irrigation (MWRI)
Enhanced Water Resources Management Project – Egypt

Technical Study 4:
Groundwater Modelling Analysis in the Nile Delta

Nile Delta Groundwater Model

Technical Report

November 2016

Nofal, E.R., Mostafa, H.F.A., Mohammed, M., van der Linden, W., Oude Essink, G.H.P.

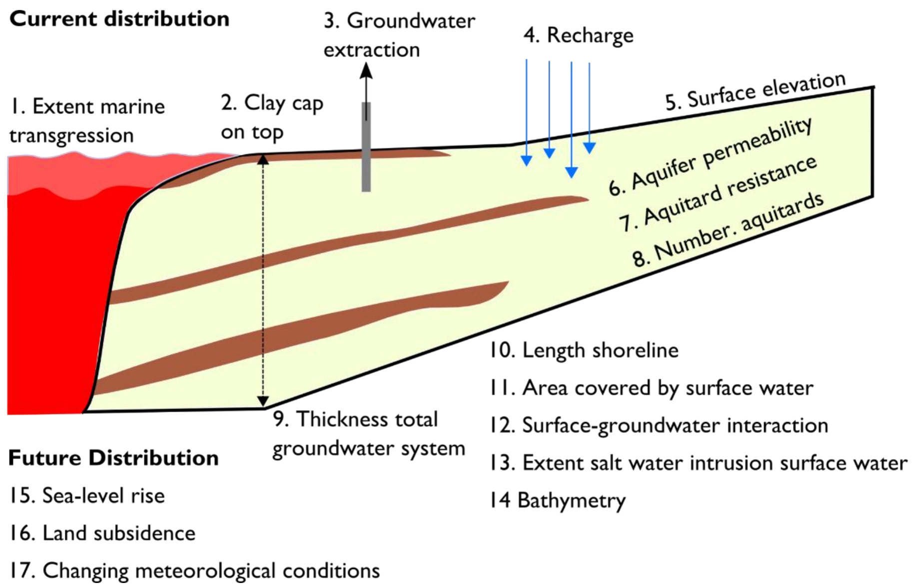
National Water Research Center (NWRC)
Research Institute for Groundwater (RIGW)
Deltares, Netherlands

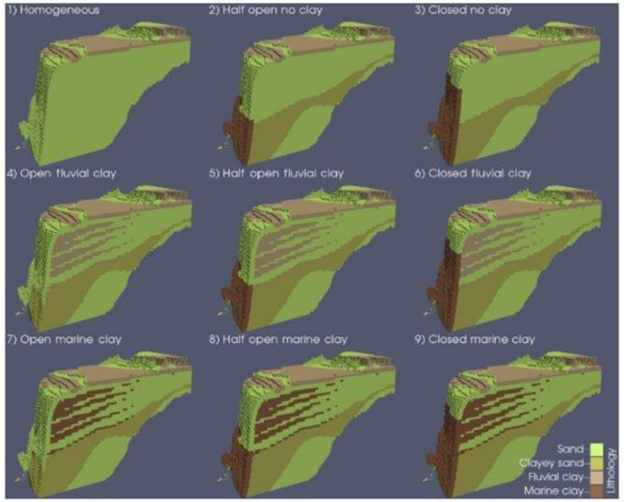
Nofal, E. R., Mostafa, H. F. A., Mohammed, M., Van der Linden, W., & Oude Essink, G. H. P. (2016). Enhanced Water Resources Management Project Egypt, Technical Study 4: Groundwater Modelling, Nile Delta.

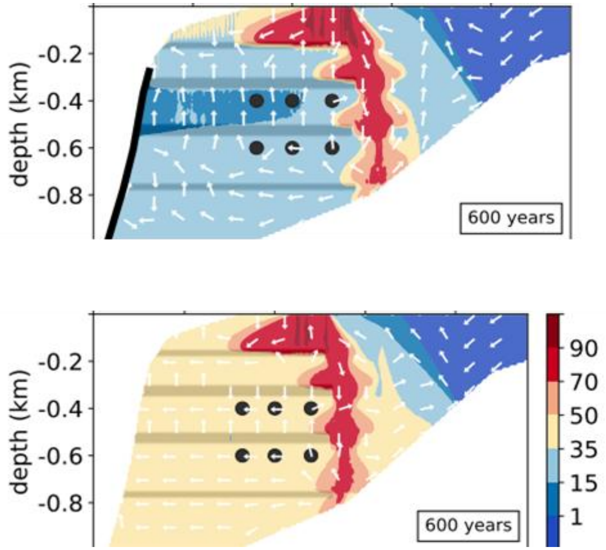
Previous projects in Egypt on groundwater salinisation

2. Fresh groundwater reserves in major deltas

- Evolution and current state of deltaic groundwater resources



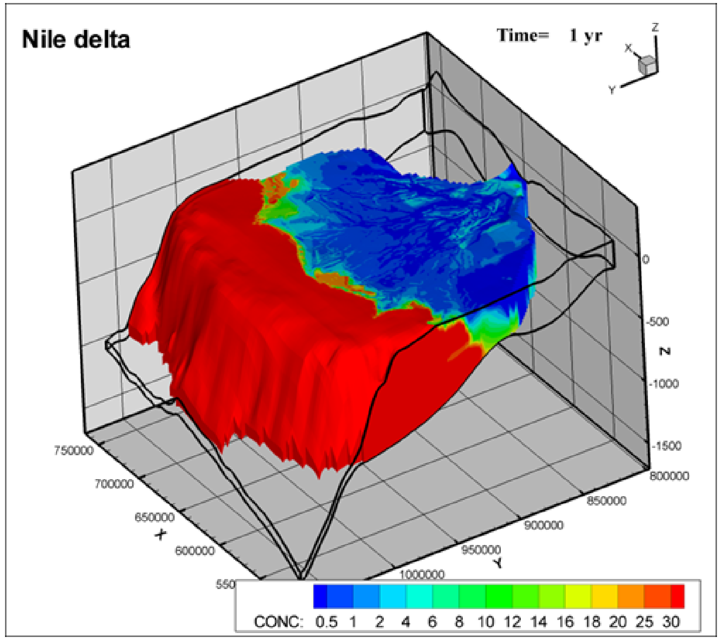




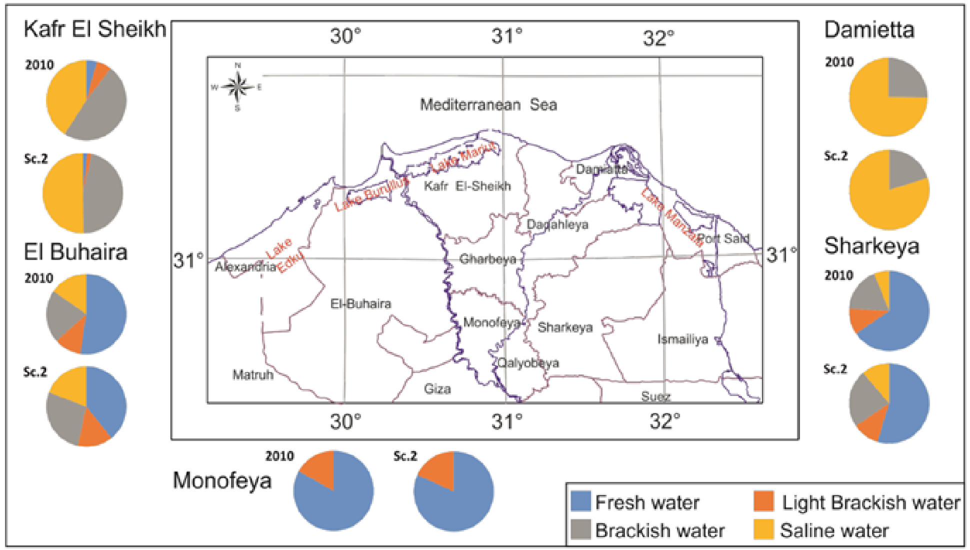
- *Van Engelen, J., Verkaik, J., King, J., Nofal, E. R., Bierkens, M. F. P., & Oude Essink, G. H. P. (2019). A three-dimensional palaeo-reconstruction of the groundwater salinity distribution in the Nile Delta Aquifer. Hydrology and Earth System Sciences, 23(12), 5175–5198. https://doi.org/10.5194/hess-2019-151*
- *Van Engelen, J., Oude Essink, G. H. P., Kooi, H., & Bierkens, M. F. P. (2018). On the origins of hypersaline groundwater in the Nile Delta aquifer. Journal of Hydrology, 560, 301–317. https://doi.org/10.1016/j.jhydrol.2018.03.029*

Previous projects in Egypt on groundwater salinisation

3. Climate change and development impacts on groundwater resources in the Nile Delta Aquifer



3D Model Groundwater Salinity (SEAWAT)



Percentages different groundwater types for selected governorates: 2010 and 2100 (1.5m sea-level rise)

•*Mabrouk, M. B., Jonoski, A., Oude Essink, G. H. P., & Uhlenbrook, S. (2019). Assessing the fresh-saline groundwater distribution in the Nile Delta Aquifer using a 3D variable-density groundwater flow model. Water (Switzerland), 11(Figure 1), 1–22.* https://doi.org/https://doi.org/10.3390/w11091946

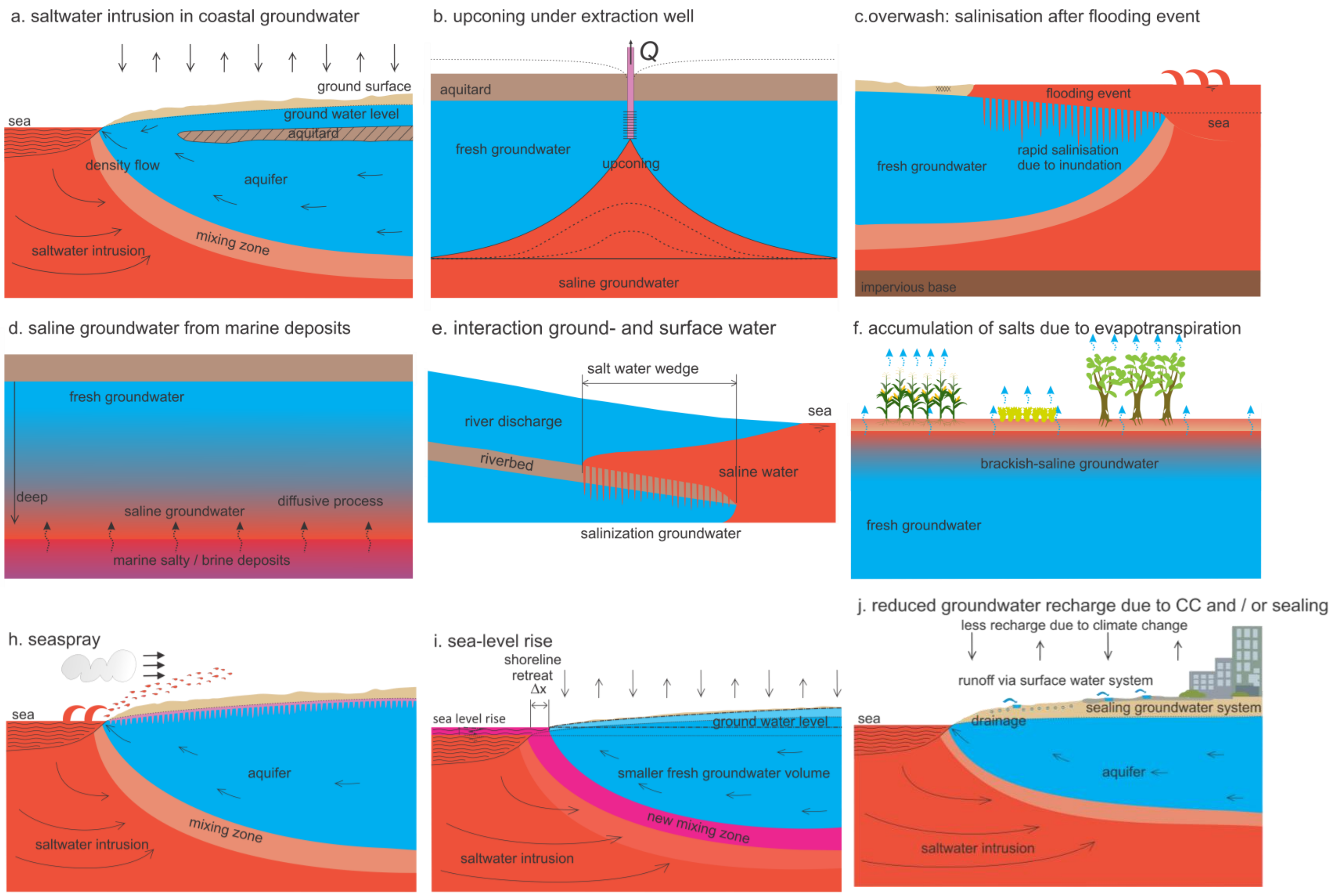
•*Mabrouk, M. B., Jonoski, A., Oude Essink, G. H. P., & Uhlenbrook, S. (2018). Impacts of sea level rise and groundwater extraction scenarios on fresh groundwater resources in the Nile Delta Governorates, Egypt. Water, 10(11), 1690.* https://doi.org/10.3390/w10111690

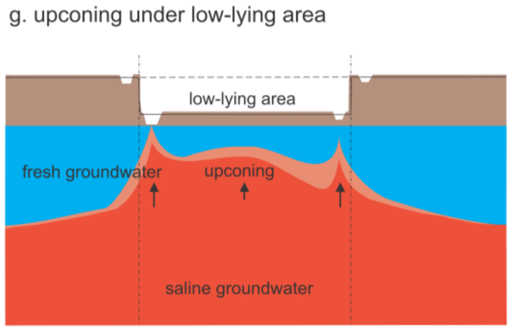
Activities of the project

1. System and process understanding, causes of salinization
2. Data collection
3. Monitoring network
4. Groundwater salinity modelling
5. Mapping of salinization risk
6. Measures
7. Field visits

Activity 1. System and process understanding

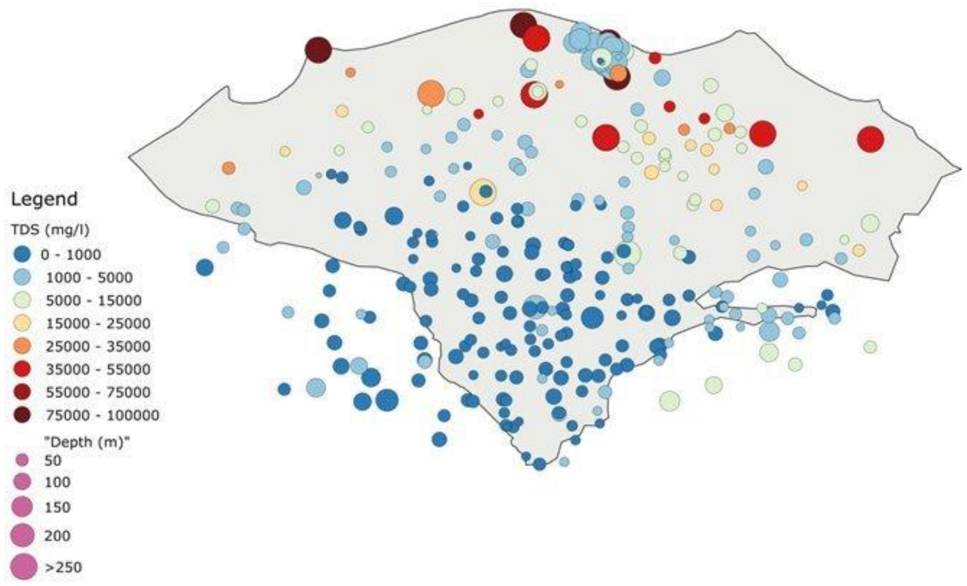
- Multiple causes of salinization



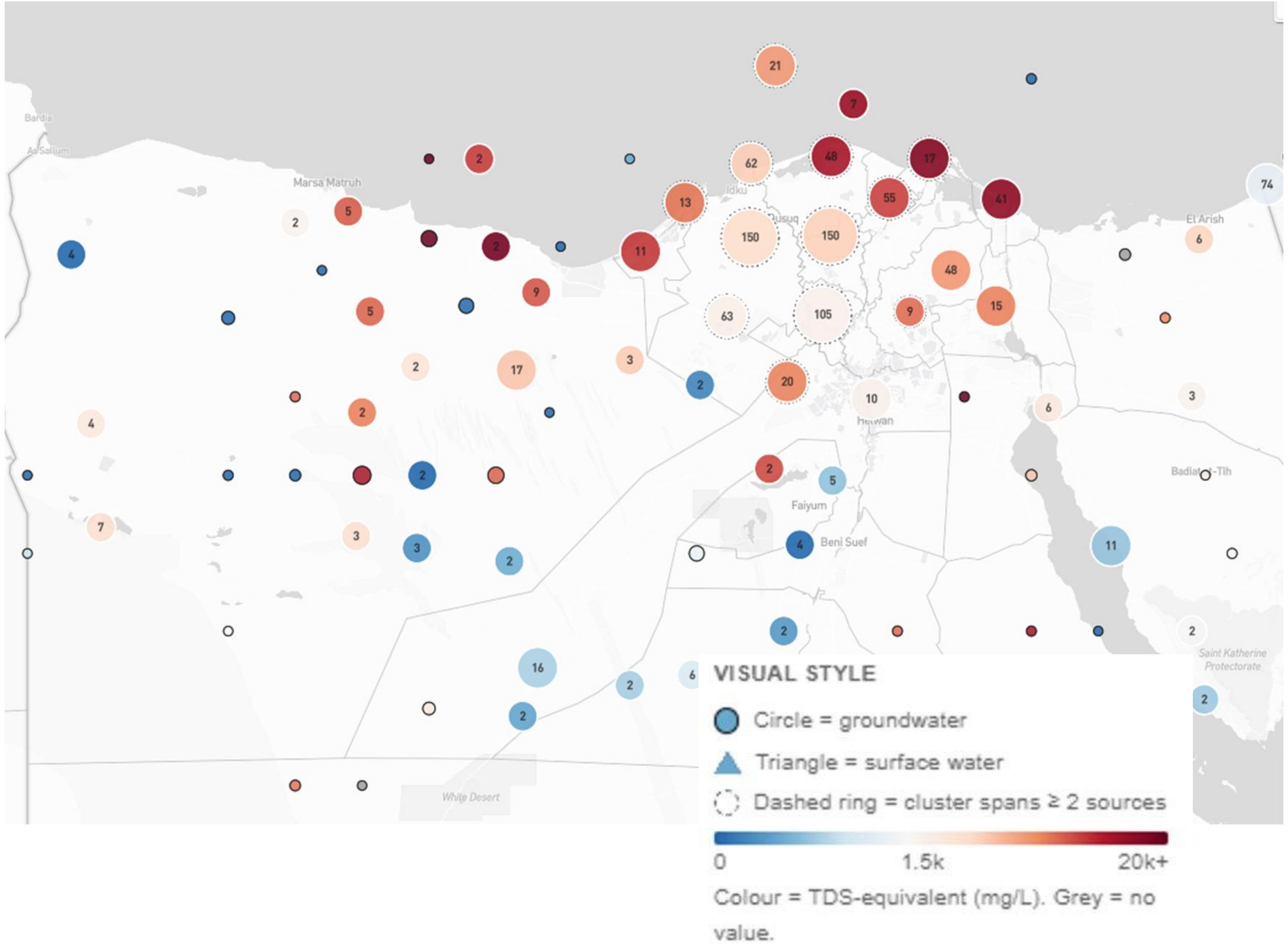


Activity 2. Data collection

- Data collected with EWRM Project



- Salt Miner: surface and groundwater salinity from pdf's (using an AI Large Language Model)



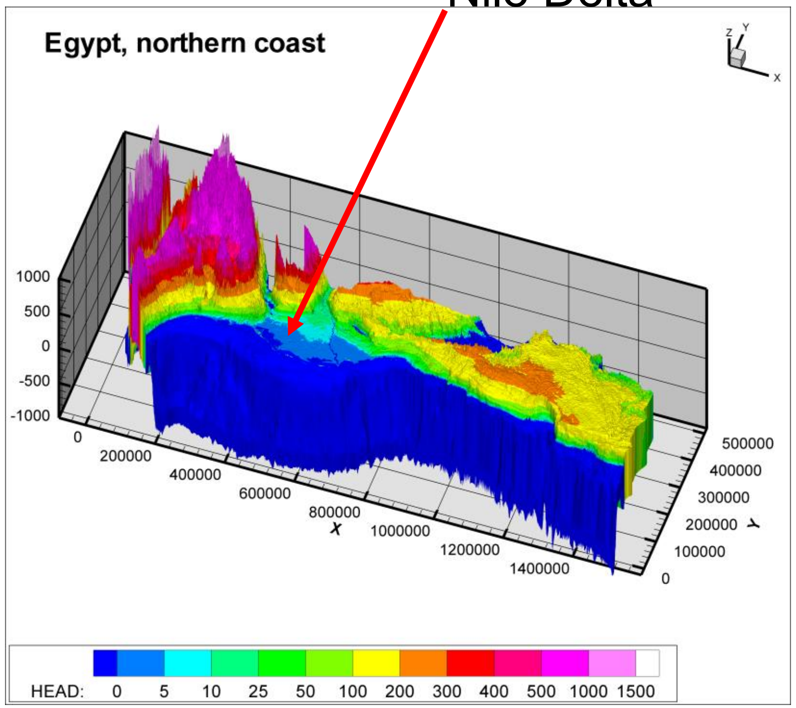
Activity 3. Monitoring network

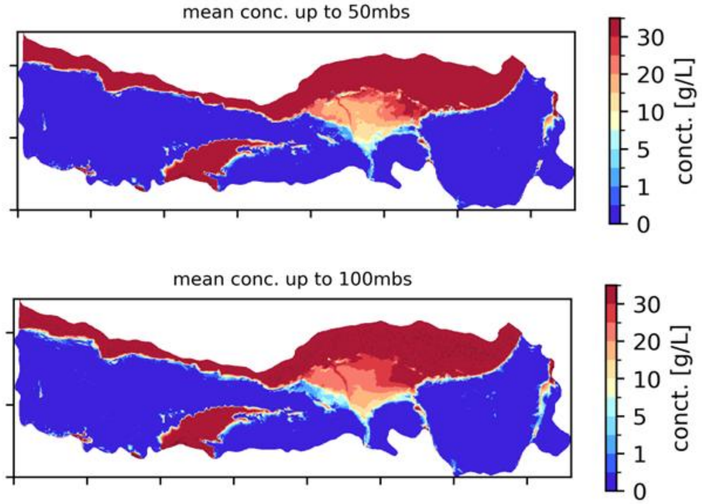
- **Location and problem definition**
  - Location
  - Draw (conceptual) model of the problem
  - Define objectives of the monitoring
  - What are the spatiotemporal characteristics and salinity range of the problem?
- **Current salinity distribution**
  - Available data (type, quality).
  - Definition of knowledge and data gaps
  - Definition of mapping requirements
- **Monitoring network**
  - Current status
  - Defintion of monitoring needs (spatiotemporal aspects)
  - Discussion of possible techniques
  - Budget

Activity 4. Groundwater salinity modelling

- 3D variable-density, salt transport
- Open-source tools like flopy, imod-python, ArchPy, imod-wq
- Using a python workflow
- Model covers ~15 million km^2, 1*1km^2, 20 model layers
- Parallel modelling iMOD-WQ (~MODFLOW/SEAWAT)
- Based on global datasets to provide a first estimate
- New local data will be added
- Paleoreconstruction: 25.000years
- Input for salinity risk mapping

Nile Delta





Activity 5. Mapping of salinization risk

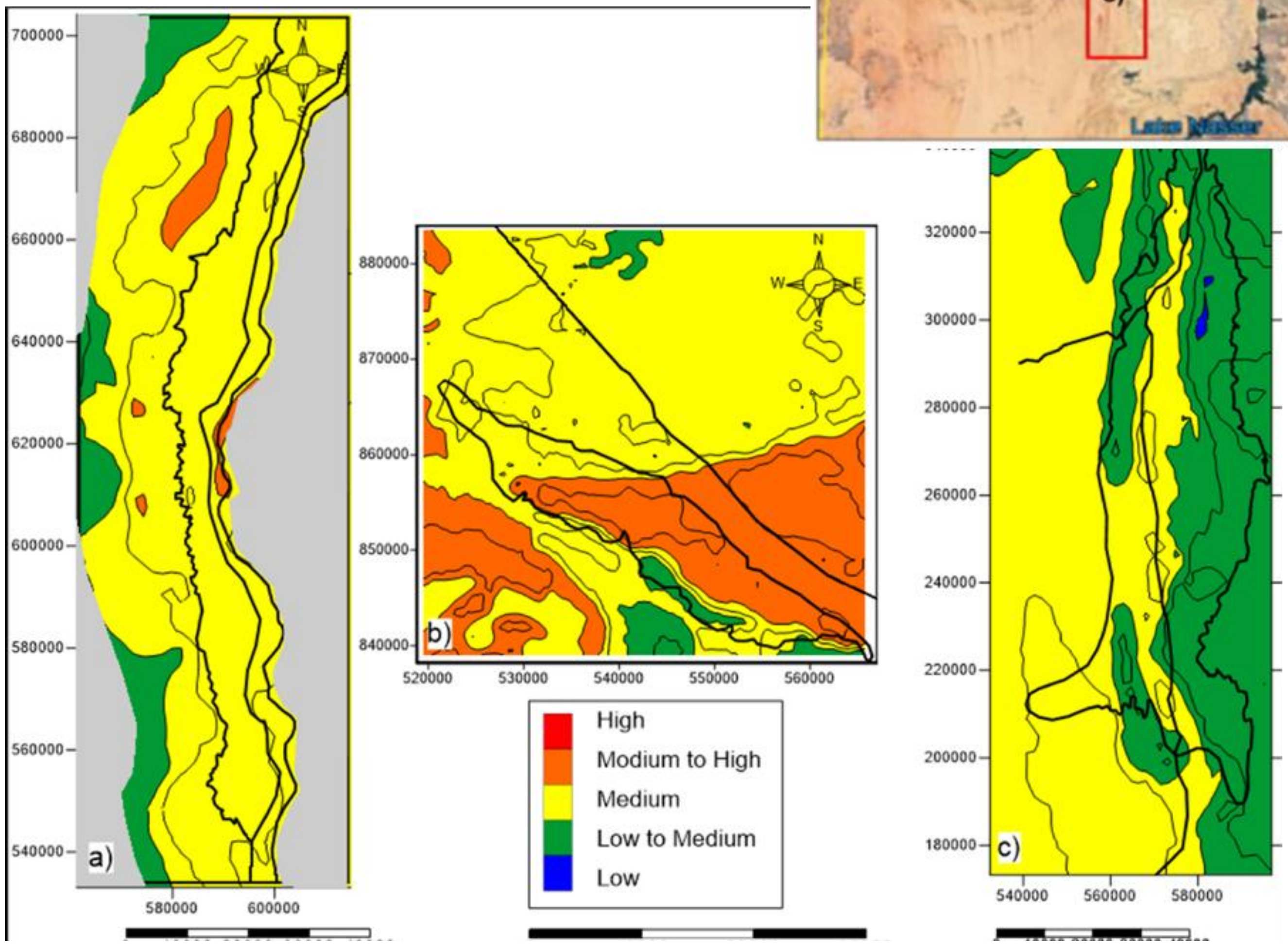
- Example: Groundwater vulnerability (Abu-Bakr, 2020)

Locations:
Nile Valley (a), Nile Delta fringes (Moghra) (b), Desert (c)

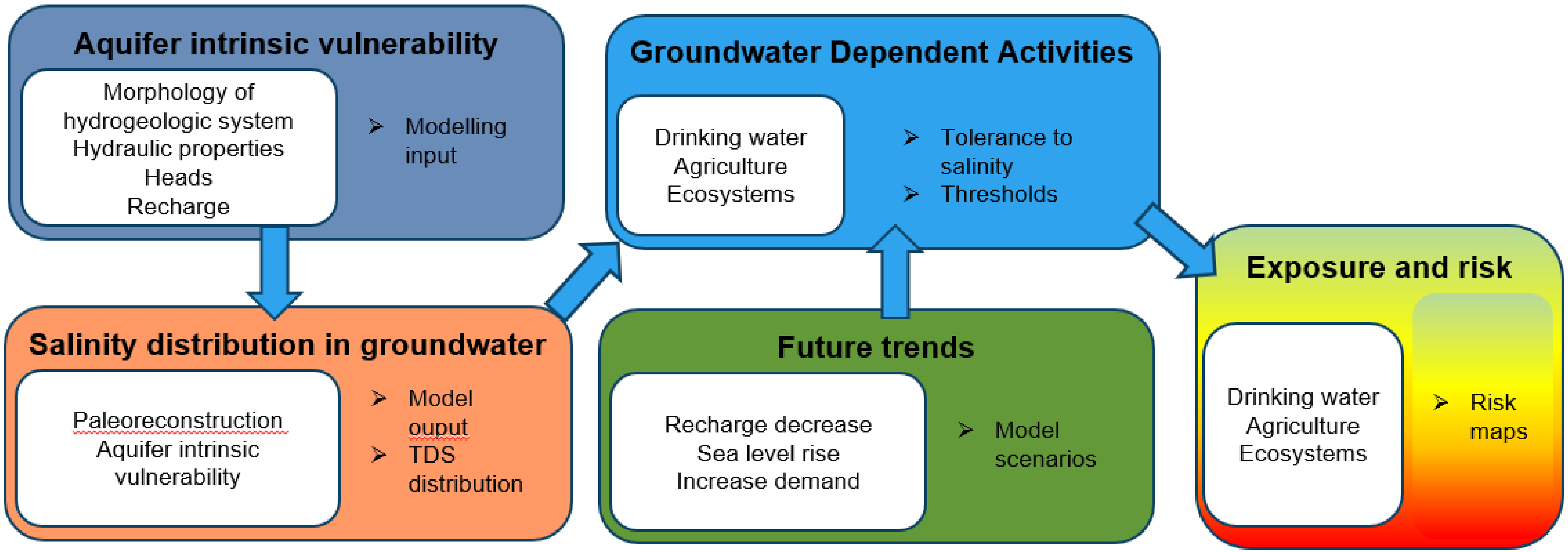
Factors:

- Depth to groundwater
- Hydraulic conductivity
- Saturated thickness
- Pumping density
- Aquifer media
- Topography
- Soil media
- Groundwater recharge

Classification specific per study area
Weights defined



Activity 5. Methodology of mapping salinization risk



Thresholds, examples:

- Drinking water wells – WHO guidelines – threshold for taste is 600mg TDS/l
- Crops – large variety of tolerance – threshold chosen 1000 mgTDS/l
- Coastal ecosystems – large variety, and problems related to changes – threshold chosen change >1000mg TDS/l

Activity 5. Approaches of mapping of salinization risk

G roundwater occurrence

A quifer hydraulic conductivity

L evel of groundwater above mean sea level

D istance from the shore

I mpact of existing seawater intrusion

T hickness of saturated aquifer

$$\mathrm{GALDIT}_{\mathrm{index}} = \frac{\sum_{i=1}^{i=6} (Wi \times Ri)}{\sum_{i=1}^{i=6} Wi}$$

→ **GALDIT most commonly used for seawater intrusion mapping**

D epth to groundwater

R echarge rate

A quifer

S oil

T opography

I mpact vadose zone

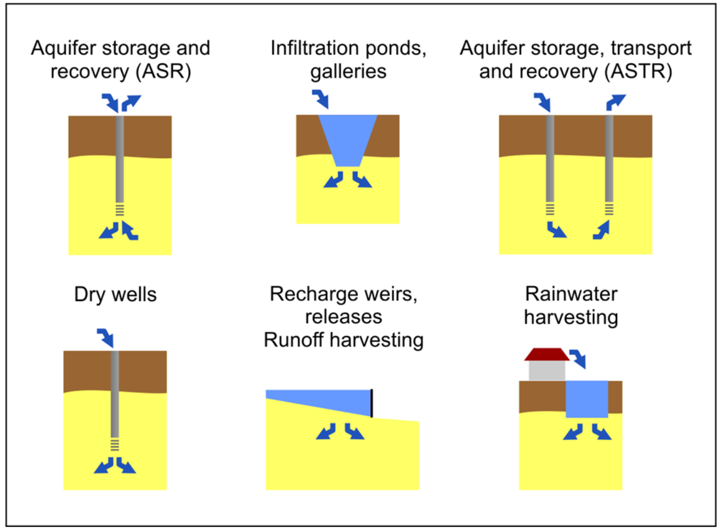
C onductivity of aquifer (hydraulic conductivity)

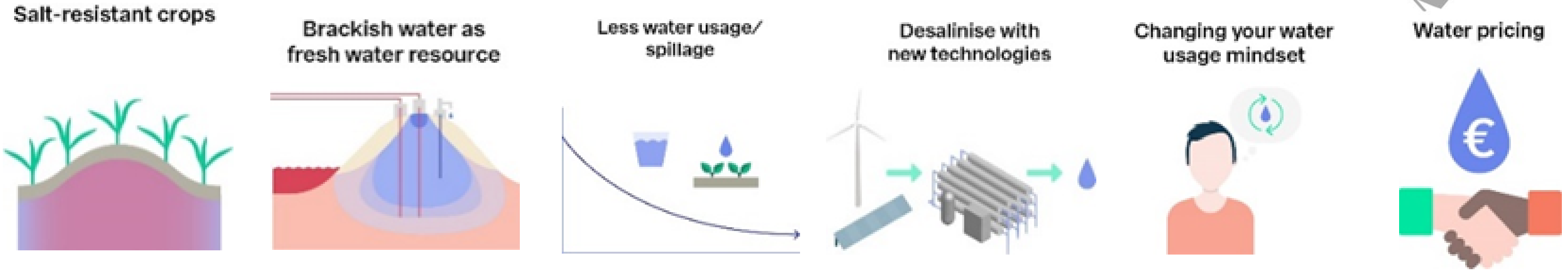
- **G** roundwater occurrence
- **O** verall aquifer class
- **D** epth groundwater table

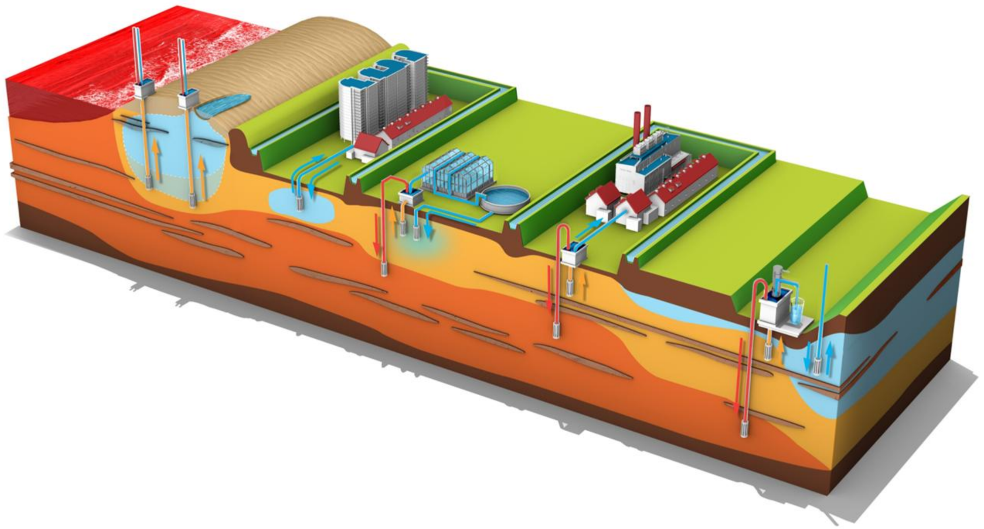
Using the model?

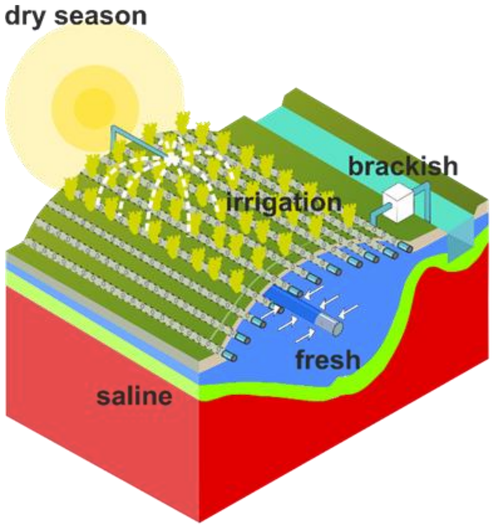
Pros: Quantifiable specific metrics, Evaluation of (future, policy) scenarios, Physics-based
Cons: Requires available trusted numerical model

Activity 6. Measures, MAR

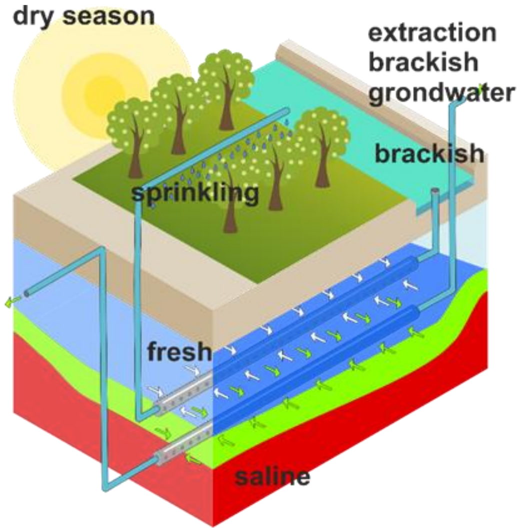




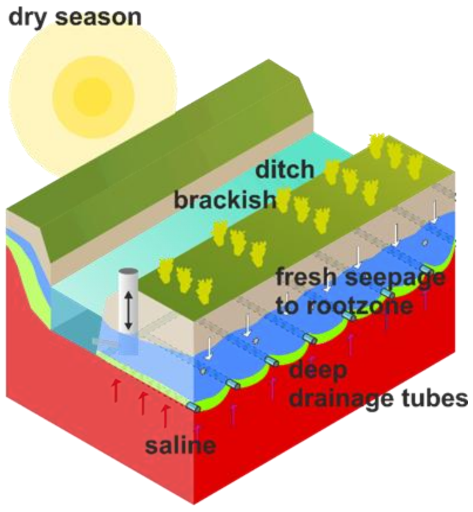




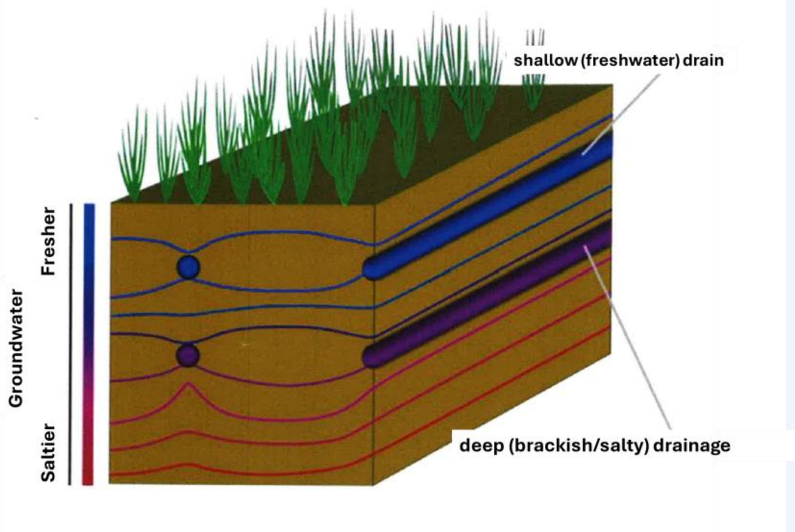
Creek Ridge Infiltration



The Freshmaker



DrainsBuffer



Activity 6. Measure brackish groundwater extraction, case Dunea, Netherlands

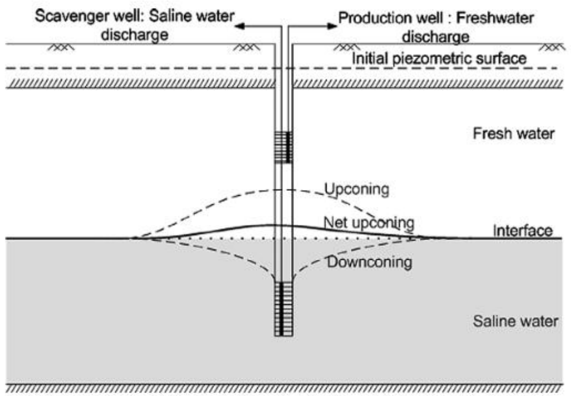
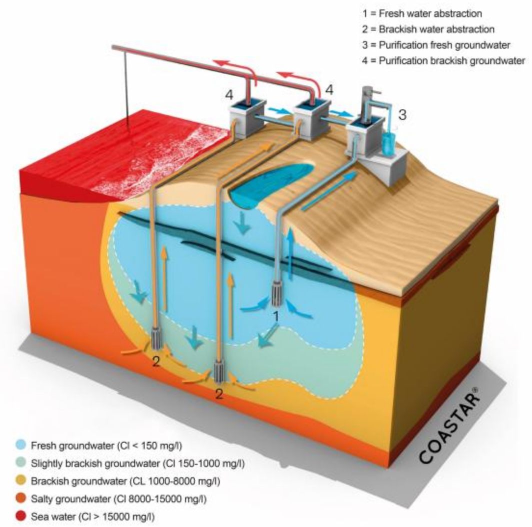
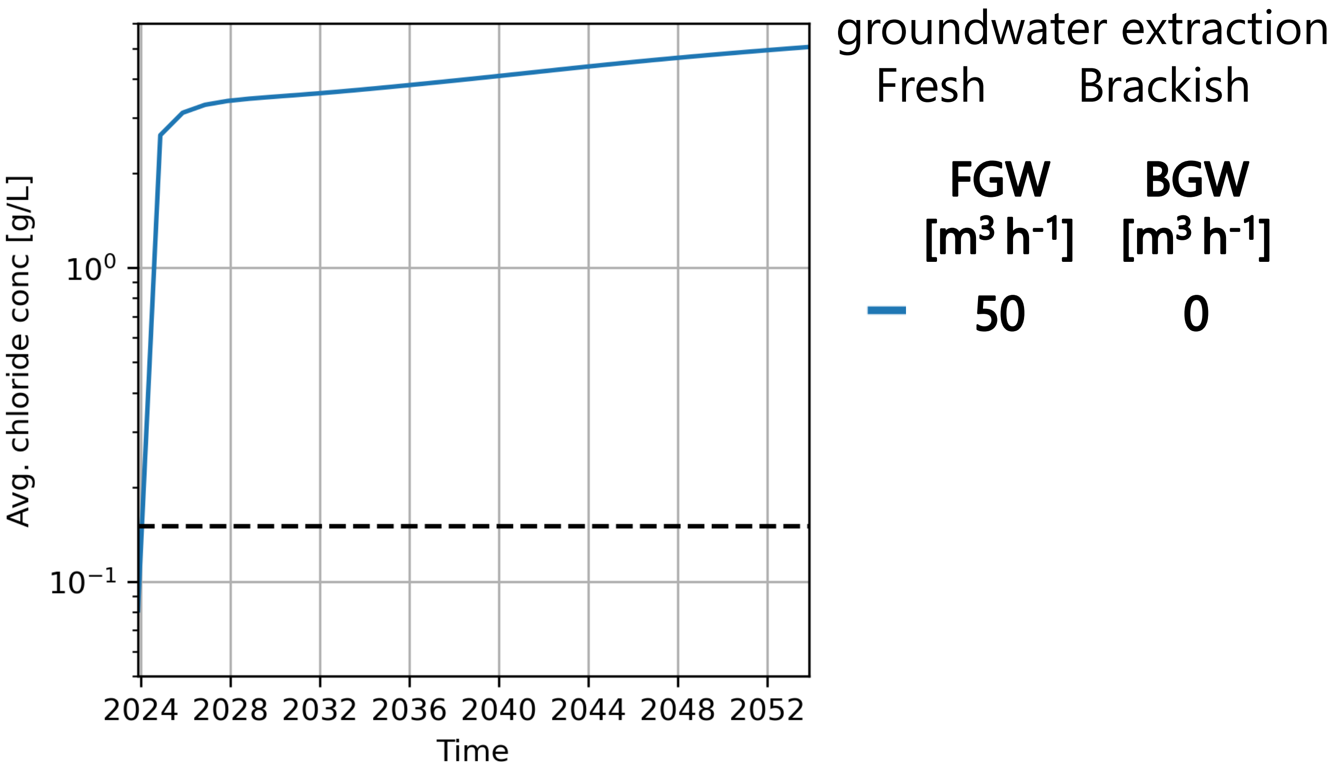
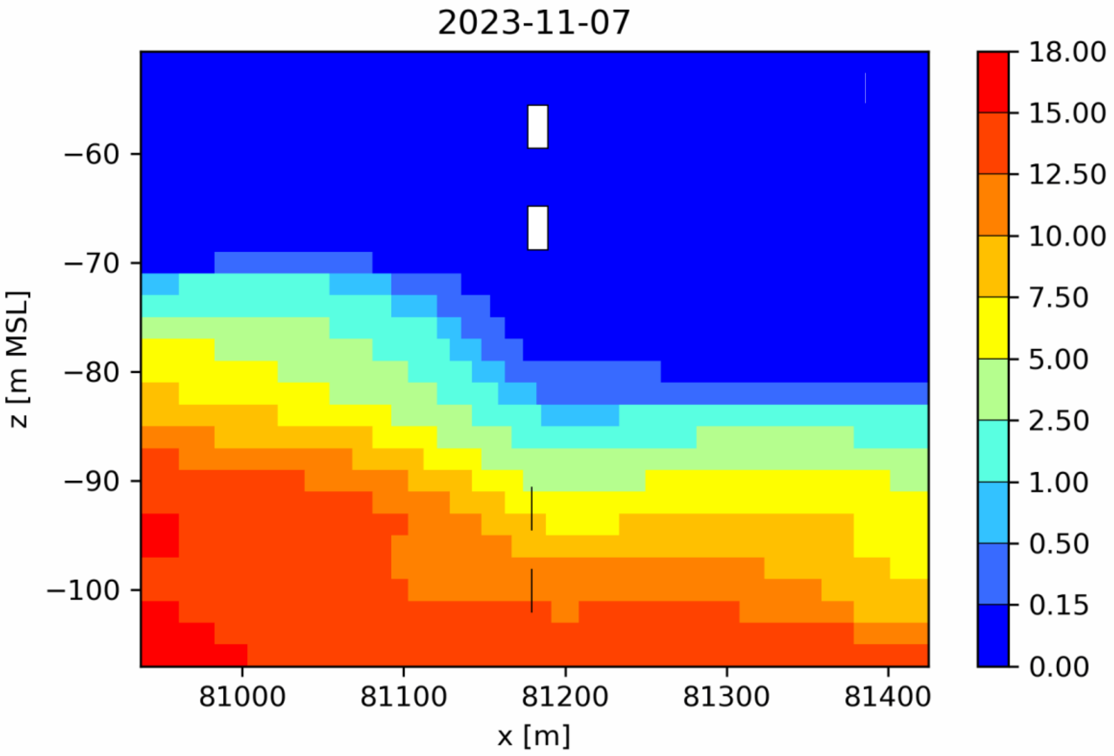


Fig. 1. Upconing under scavenger well.

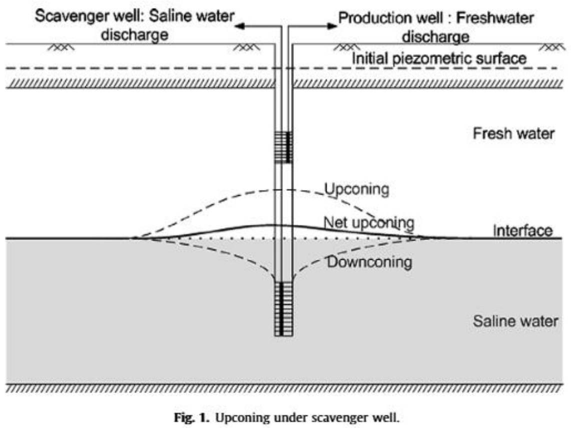






Zoet-zout in de ondergrond

Activity 6. Measure brackish groundwater extraction, case Dunea, Netherlands



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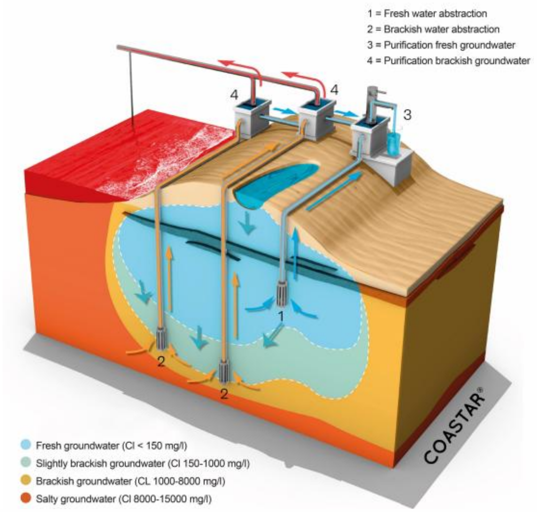
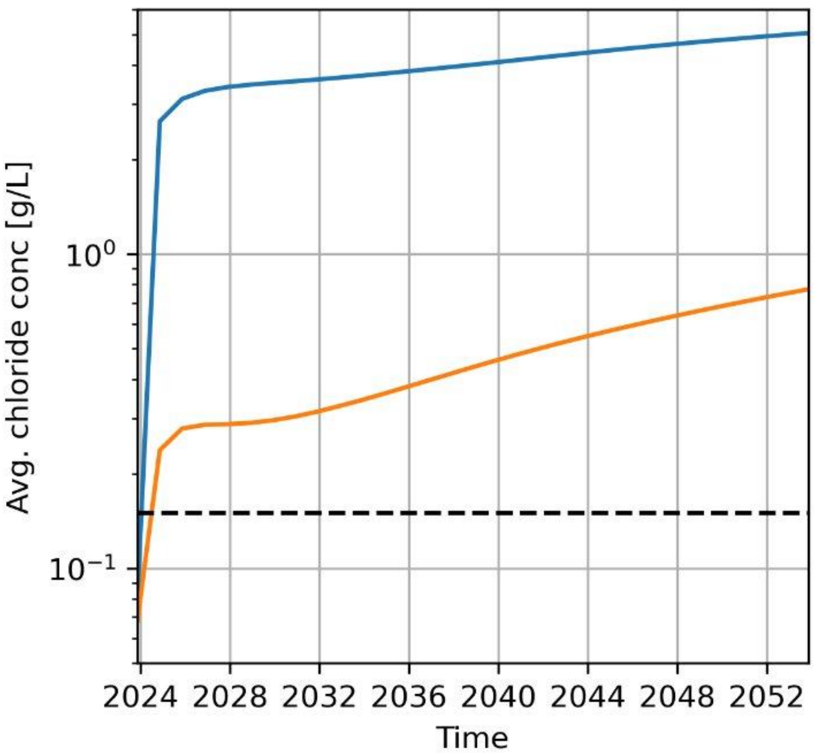
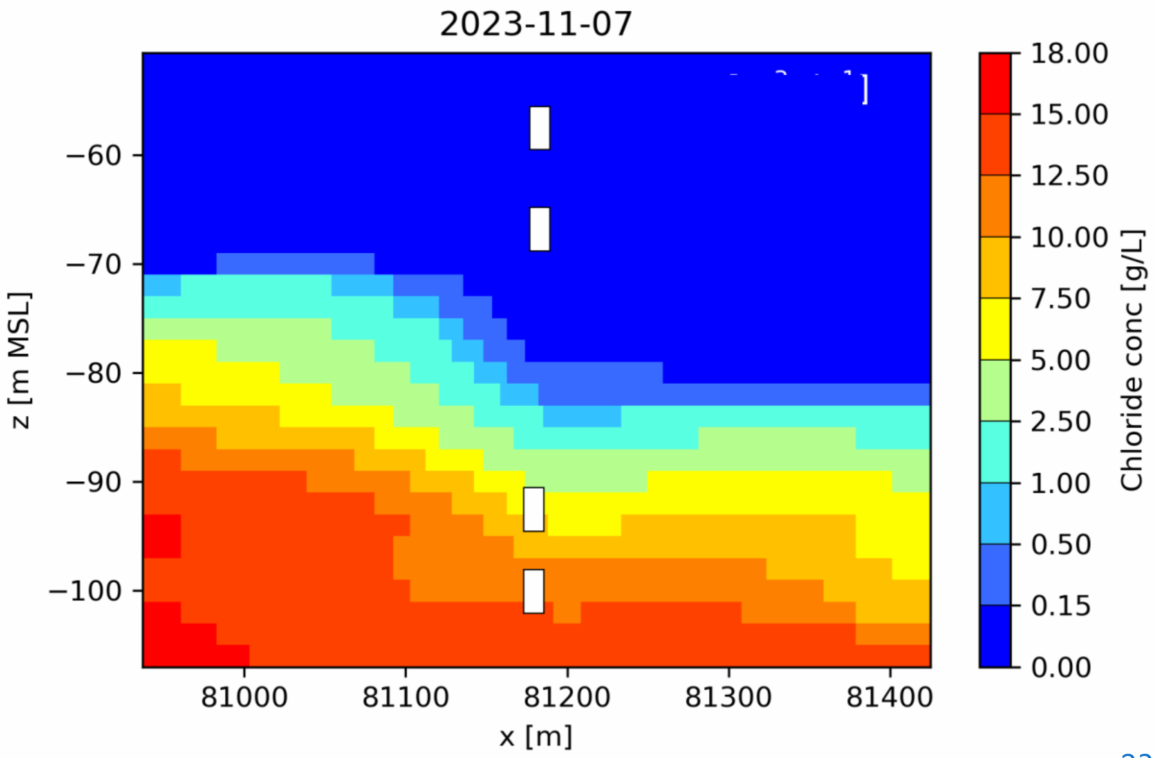




groundwater extraction

	Fresh FGW [$m^3 h^{-1}$]	Brackish BGW [$m^3 h^{-1}$]
blue line	50	0
orange line	50	50



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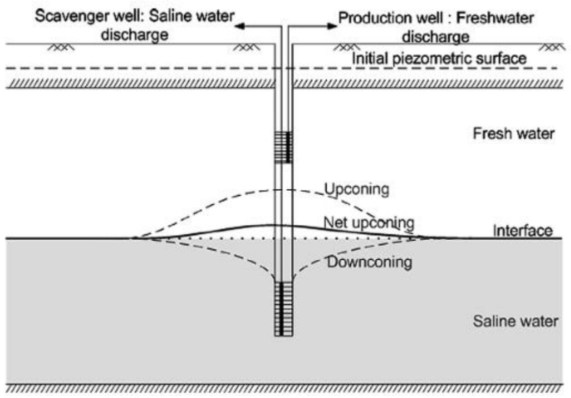

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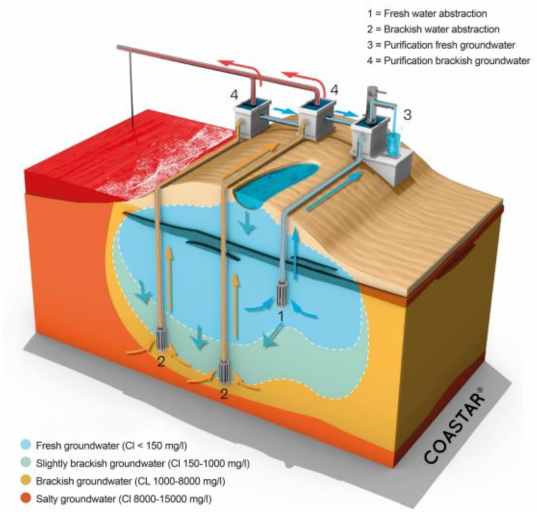
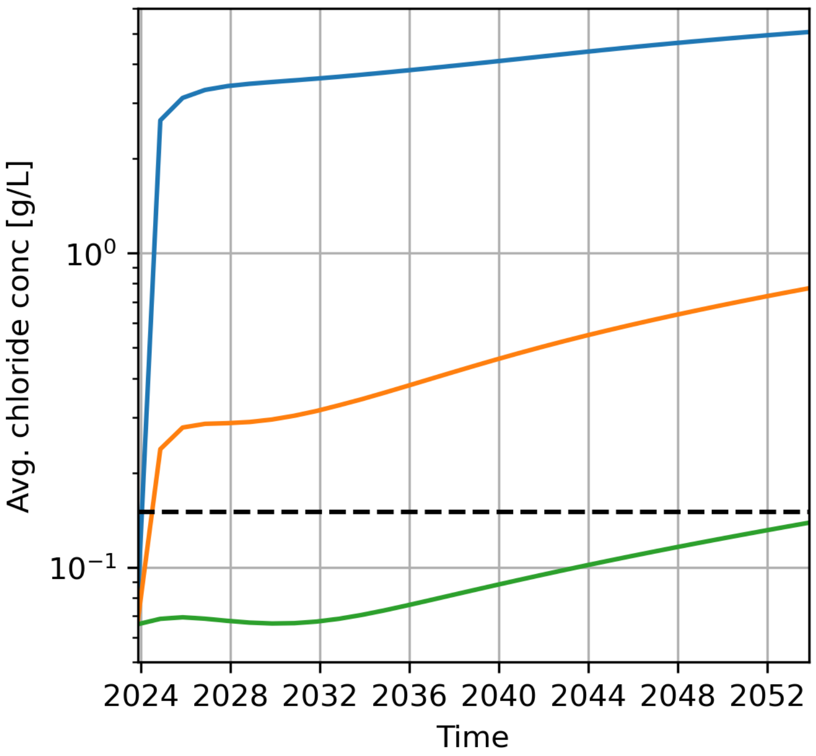
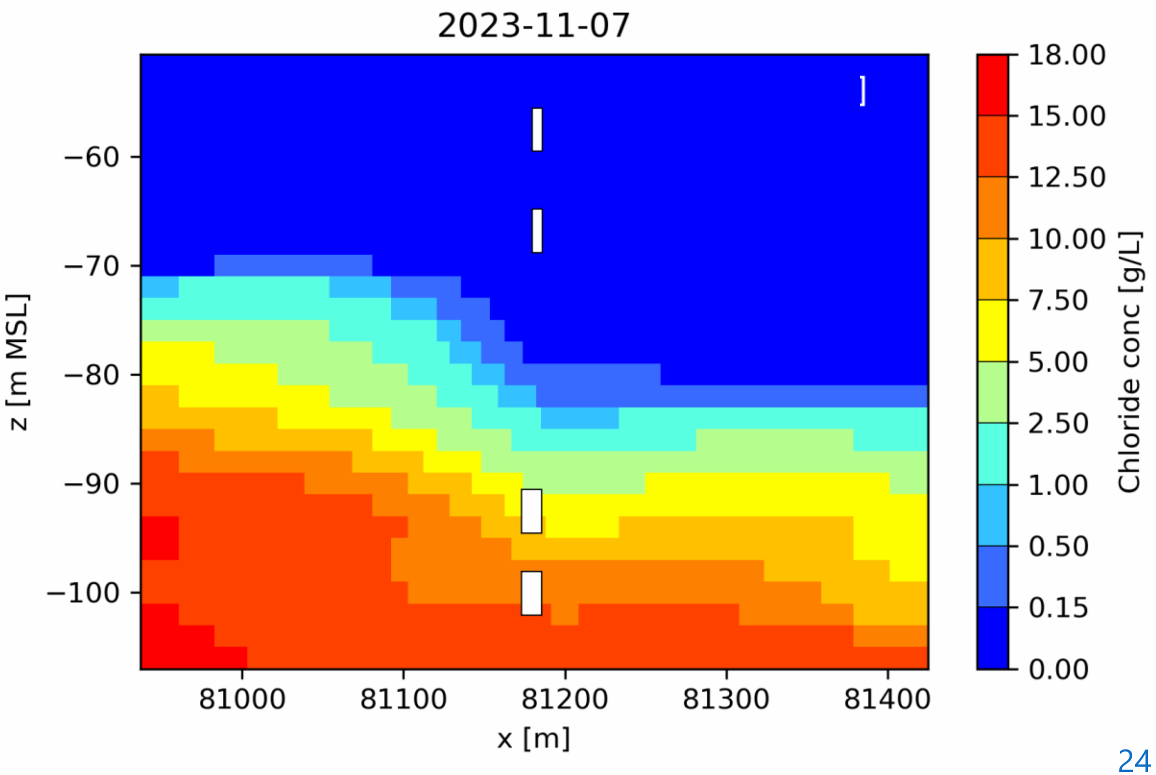




groundwater extraction

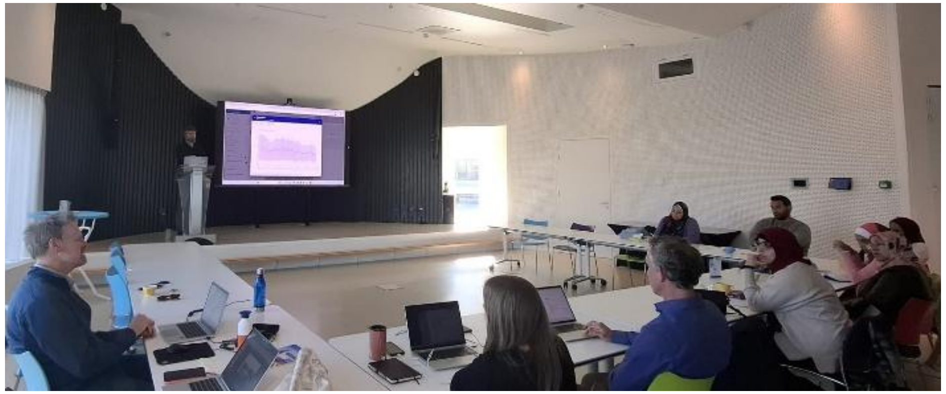
	Fresh	Brackish
	FGW [$m^3\,h^{-1}$]	BGW [$m^3\,h^{-1}$]
blue	50	0
orange	50	50
green	25	50



Activity 7. Field visits
Deltares -> Egypt

- Meetings at MWRI Groundwater sector
- Field visit Mava farm, West Delta and Dutch Embassy
- Saltwater intrusion modelling course
- Meeting representatives Cairo University and Helwan University

Activity 7. Field visits Egypt -> NL



- 5 days visit to the NL
- Presentations of relevant groundwater salinity topics: modelling, monitoring techniques, Aquality app, Dutch and international case studies, LLM and AI techniques.
- Visit polder area Haarlemmermeer to see drainage systems and salty boils, dune area Meijendel including Dunea MAR infiltration system.
- Visit to IHE Delft and IGRAC
- Visit to Zeeland to see implementation of solutions for salinity in agricultural setting

Next steps

- Development of groundwater salinity risk maps
- Report on monitoring network framework
- Assessment of sea-level rise and groundwater extraction impacts using numerical modelling
- Sharing of collected PDFs data on groundwater salinity
- Access to a protected version of the Salt Miner data dashboard
- Comprehensive reportin, including salinisation processes, monitoring design, modelling outcomes, and an overview of solutions (including MAR)

Questions?

Reflection from Dr. Heba Abdelaziz Abubakr

Associate Professor in the National Water Research Center
& Deputy Groundwater Sector Head

ipdc

Contact

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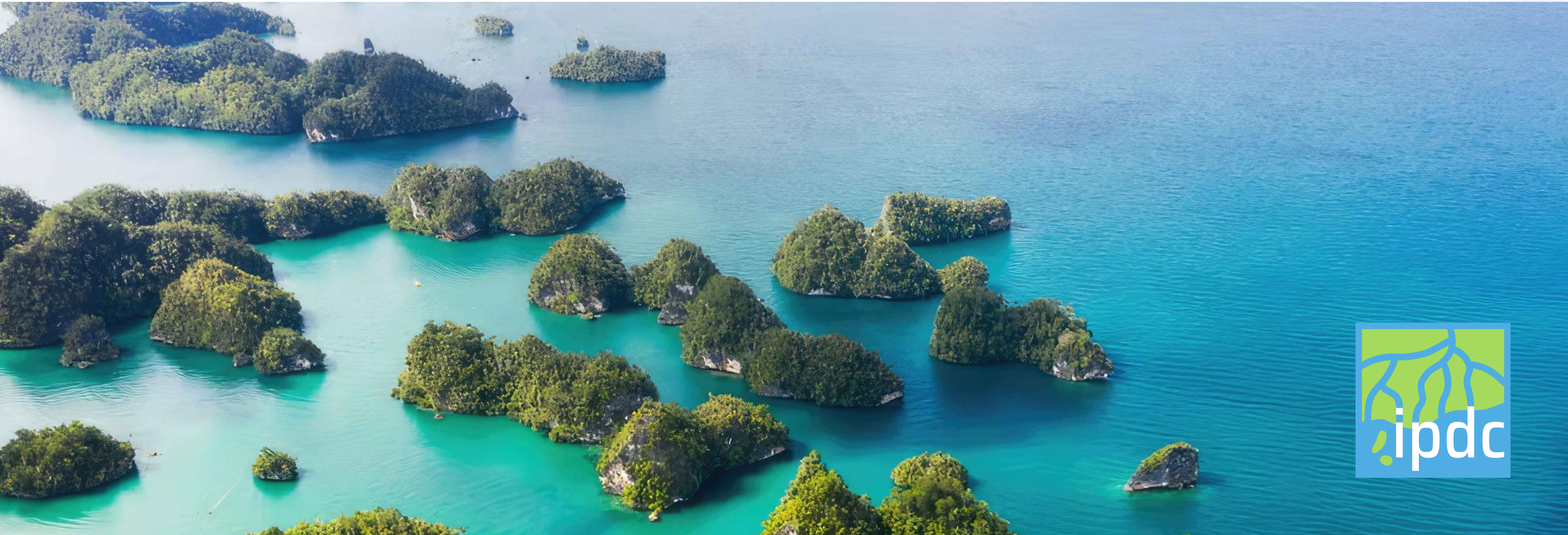
Boussinesqweg 1
2629 HV, Delft

deltasandcoasts.net

ipdc@deltares.nl



IPDC Project #2 MAR Guidelines in Vietnam

Niels Mulder

Advisor/Researcher Water Security

Deltares, the Netherlands

MAR Guidelines in Vietnam

Niels Mulder, Pham Van Tuan

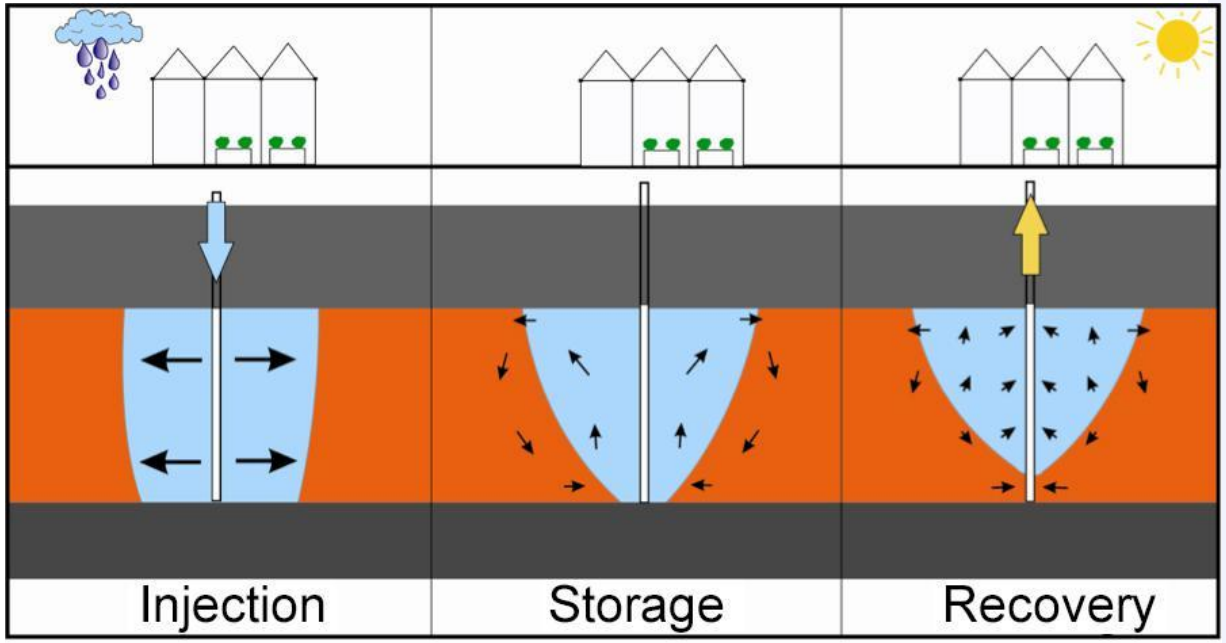
2026-05-19

Vietnam

Xishuangbanna Dai Autonomous Prefecture
西双版纳傣族自治州
Nanning
南宁市
Yulin
玉林市
Hanoi
Zhanjiang
湛江市
Maoming
茂名市
Haikou
海口市
HAINAN
Sanya
三亚市
Laos
NAN
Vientiane
ວຽງຈັນ
UDON THANI
Phitsanulok
เทศบาลนครพิษณุโลก
KHON KAEN
Hué
Da Nang
Paracel Islands
Thailand
SURIN
UBON RATCHATHANI
Vietnam
Bangkok
กรุงเทพมหานคร
Krong Siem Reap
Pattaya City
เมืองพัทยา
Cambodia
Preah Sihanouk
Ho Chi Minh City
Can Tho
Gulf of Thailand

Introduction

- Groundwater in Vietnam
- Managed Aquifer Recharge (MAR)
- Making guidelines to support the usage of MAR systems
  - Assist stakeholders in their part of MAR development
  - Using lessons learned from earlier pilots in Vietnam
  - In compliance with Vietnamese (groundwater) law
  - Using experience from Dutch experts & drinking water companies

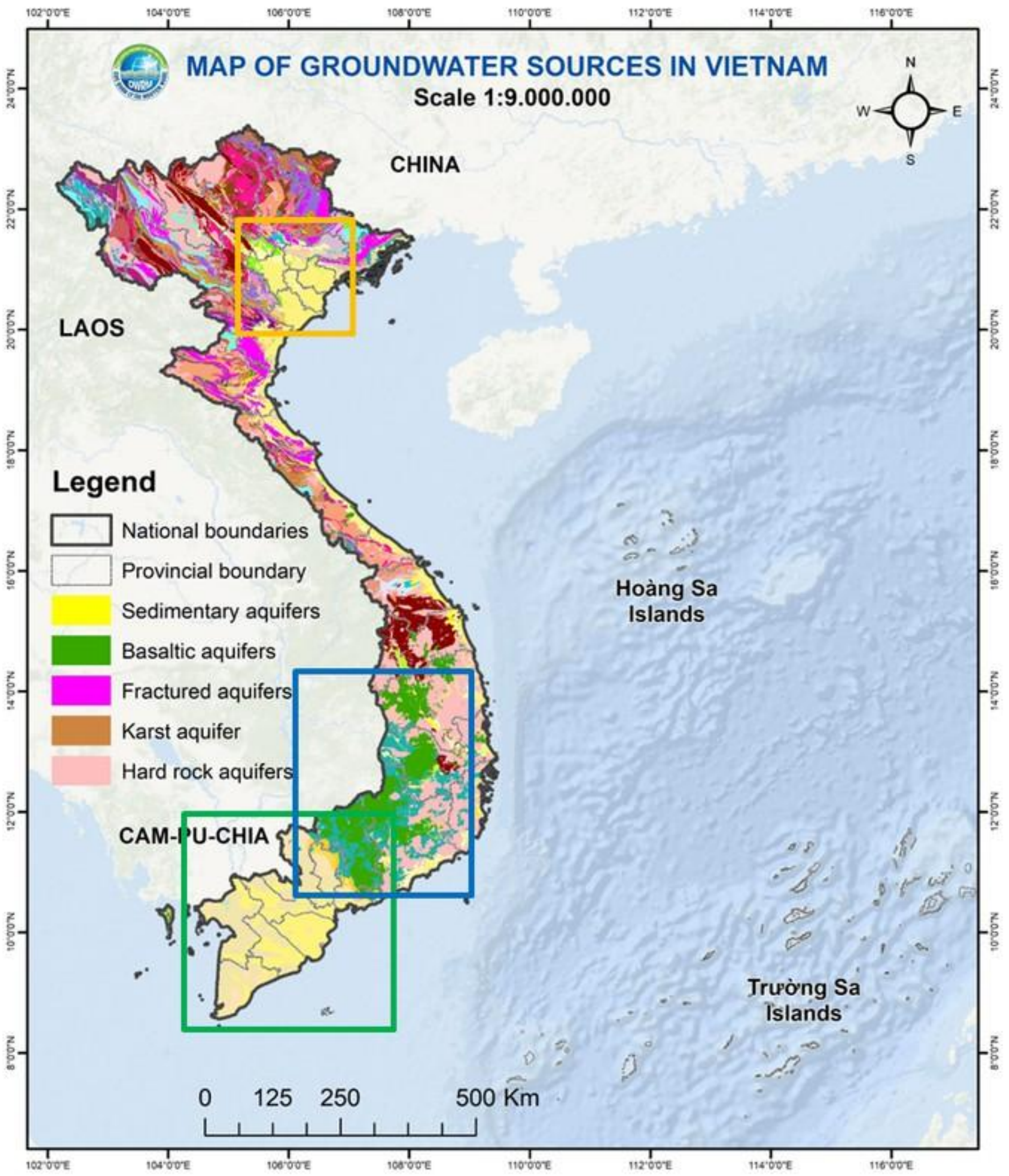


https://www.stowa.nl/deltafacts/zoetwatervoorziening/delta-facts-english-versions/aquifer-storage-and-recovery

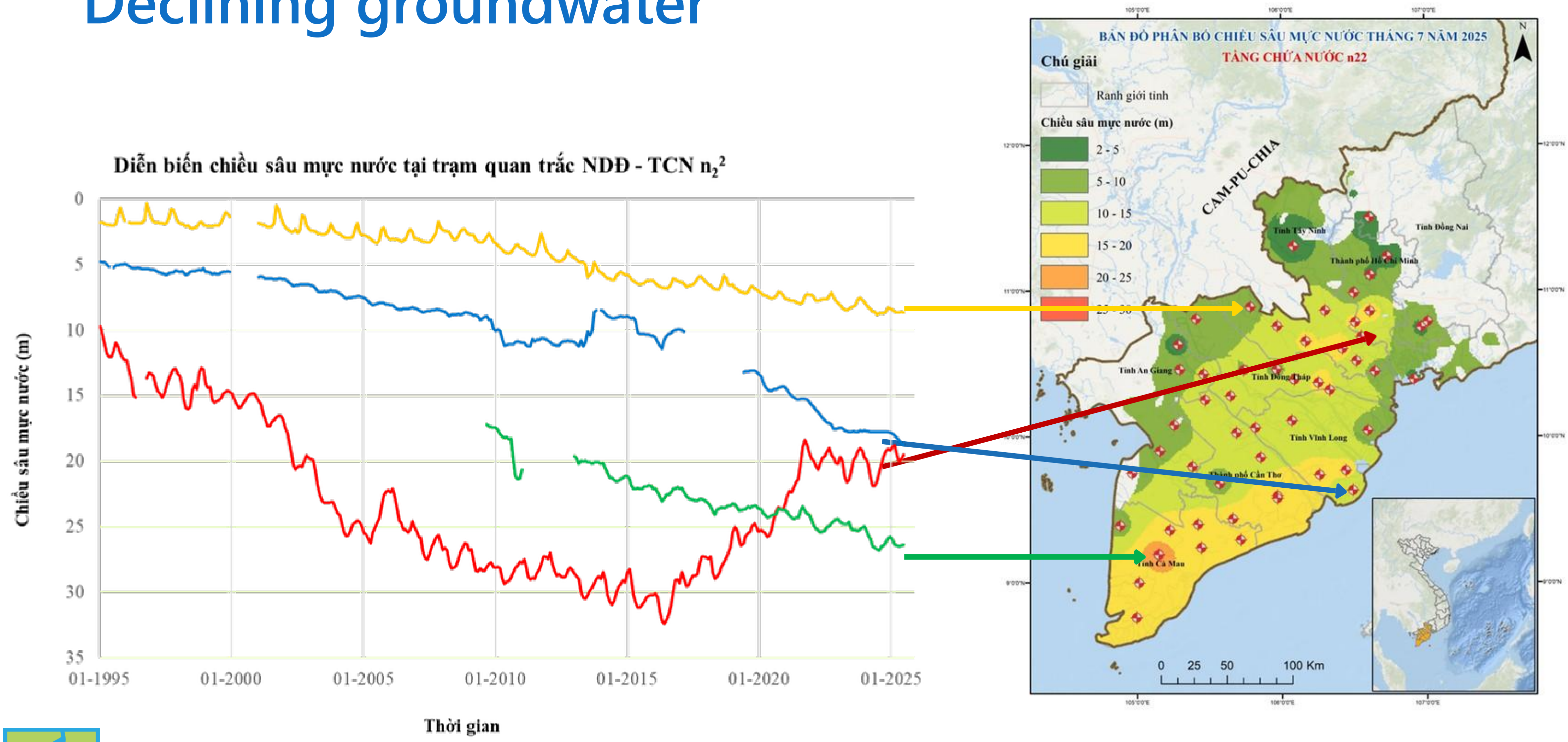
Aquifers

Major aquifer systems

- Sedimentary aquifer system in Northern Plain (3 aquifers)
- basalt aquifer system in Central Highland
- Sedimentary aquifer system in Southern Plain (transboundary)



Declining groundwater



MAR to the rescue?

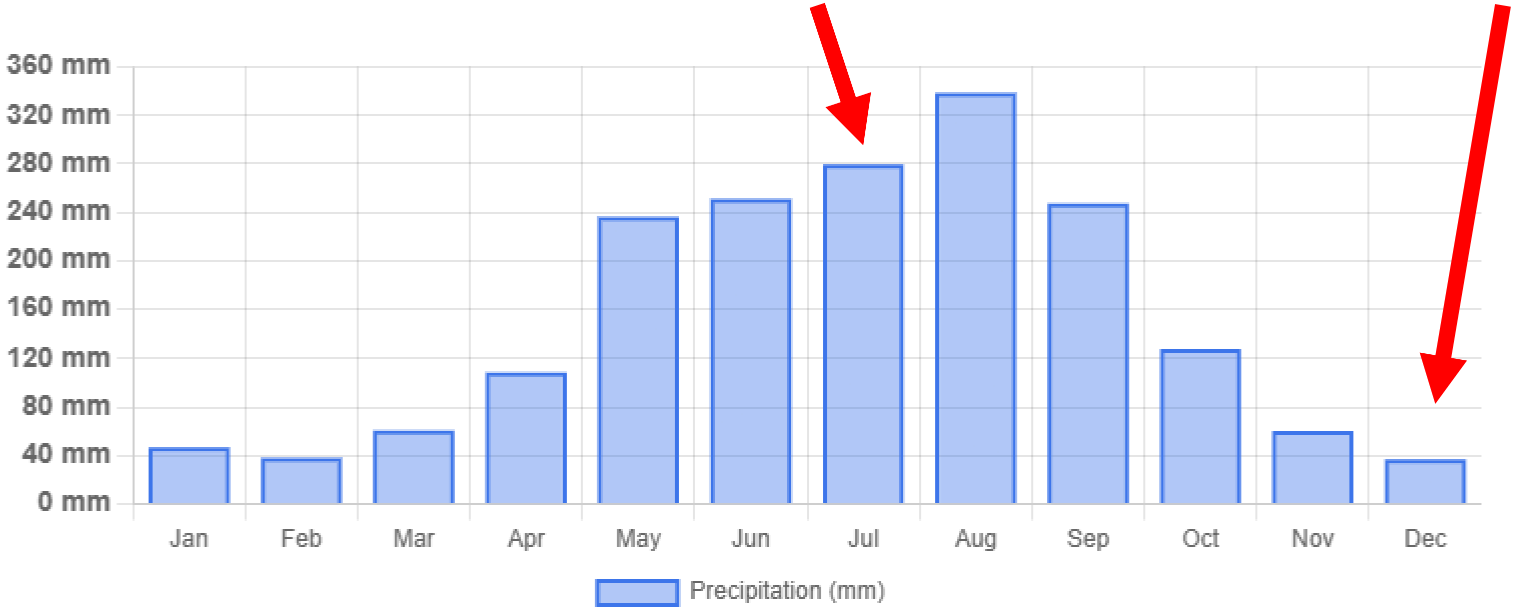
Pre treatment

Infiltration

MAR to the rescue!

Precipitation surplus

Precipitation shortage



With MAR you can “move” water from the wet season to the wet season

History of MAR in Vietnam

- Early 2000s, there were a number of text books, articles and researches to explore MAR feasibility in several area in Vietnam such as central highland, islands ...
- From 2010s, MAR pilots (small scale) started to be implemented: store rain-havesting in aquifers, sand dam, trench, infiltration lake
- **Law of Water Resources 2012**
- From 2015 to present: applied more MAR methods such as injection well, ASR in Mekong Delta, filtration plant (Hau Giang, Tra Vinh provinces ...), bank filtration in Hanoi, Binh Dinh province; submerged dike in Cao Bang province;
- **Law of Water Resources 2023**
- **Circular 03**
- Technical guideline 2026
- National standard 20??

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Valuable lessens learned from previous pilots

- Learn how to **install and to maintain a robust and cheap ASR systems** (pump, pipes, monitoring devices, etc.)
- **Teach skilled installation technicians** who can adapt the system to local circumstances. It is an art, not a science.
- **Share knowledge** with (farmers) associations, institutions and authorities over the provinces
- Sustain operations and maintenance of the system after deployment
- **Clogging** is the no. 1 operational risk (plan for it up front)
- **Geochemistry** can create surprises (iron, redox shifts, etc.)
- Social acceptance depends on **visible performance and local incentives**

Current status

- A large number of pilots
- Legislation (Law, Circular) on groundwater use and water resources
- Several groundwater related problems: salt water intrusion, lowering water table.

We need to bridge the gap from pilot to production

Pilot MAR projects

- **GTK-CEWAFO:** Viet MAR - ensure sustainable groundwater availability and quality under ongoing climate change and fast economic development in Vietnam
- **BGR-NAWAPI:** CRMGG project - Climate resilient management of groundwater and geohazards
- **HUNRE:** Research and development of big data analytics software to support water resource warning and forecasting.
- **CGIAR:** Piloting MAR in the central highlands to sustain groundwater supplies for irrigated smallholder coffee production.
- **Deltares:** Freshwater Availability in Mekong Delta - implementation of shallow Aquifer Storage and Recovery.

MAR Guideline

We need to bridge the gap

from pilot to production

There is a need for <u>MAR Guidelines</u>

- To guide stakeholders through their part of the process
- From “We have this water issue" to “this new MAR can help me solving the issue"

3 Harmonized Guidelines

- Three **Harmonized** guidelines, tailored to the three different user groups' needs & whishes.
- Guidelines describe for each stakeholder their role, tasks and deliverables.
- Including concrete checklist and actionable plans.

Three user groups

- **Investors**
  Role: Project initiation, resource allocation, and strategic direction.
  Goal: Optimize costs, solve water scarcity bottlenecks, and ensure financial viability.

- **Consultants & experts**
  Role: Technical design, hydrogeological assessment, installation.
  Goal: Ensure technical accuracy, control risks, and design robust monitoring systems.

- **Government**
  Role: Evaluation, licensing, and operational oversight.
  Goal: Protect groundwater resources, ensure environmental safety, and verify legal compliance.

Making the guidelines

- Team of local, Vietnamese experts
- Several sessions and workshop with all user groups
- Experience from Dutch drinking water companies (VEI)

Overview of the guidelines (draft)

	Step 1: Feasibility	Step 2: Site location	Step 3: Design & Planning	Step 4: Construction & Piloting	Step 5: Appraisal & Licensing	Step 6: Official Operation
Key Activities	Water balance. Water availability. Financial plan.	Preliminary hydrogeological assessment Identify recharge sources. Financial plan	Select technology (Infiltration / ASR / RBF) Design monitoring networks and warning thresholds	Build infrastructure and pre-treatment systems. Conduct low-to-medium capacity testing	Evaluate recharge efficiency (target 70–90% capacity) Verify groundwater quality protection	Implement adaptive management Conduct periodic monitoring and system maintenance
Output	Feasibility report	Feasibility report & site selection	Design dossier & operations plan	Real-world monitoring data	Operational approval	Sustainable water storage
Chapters	Chapters 1–2 (Context, Legal Framework, Feasibility)	Chapter 3 (Initial Screening & Site Selection)	Chapter 4 (Design & Planning)	Chapters 5–6 (Construction & Pilot Operation)	Chapters 7–8 (Appraisal process, monitoring, risk control)	Chapters 9 (Management during operation)
Key user group	Investor	Investor, Consultant	Consultant	Consultant, Government	Government	Consultant, Investor

Some interesting findings so far

- Monitoring is key: but what and how frequent is not a simple question
- The value of interviews and workshops can not be overstated
- Detailed checklists and thresholds are highly appreciated by different parties
- The questions about (long term) price per usable liter is importance, valid but also hard to answer.

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Next steps & Expected outcome

- A comprehensive set of guidelines, tailored to the user groups
- Specific for Vietnam, using the experience gained in the previous pilots
- Workshop and hands-on training later this year

- Hopefully, many MAR systems will be installed, infiltrating water

Questions?

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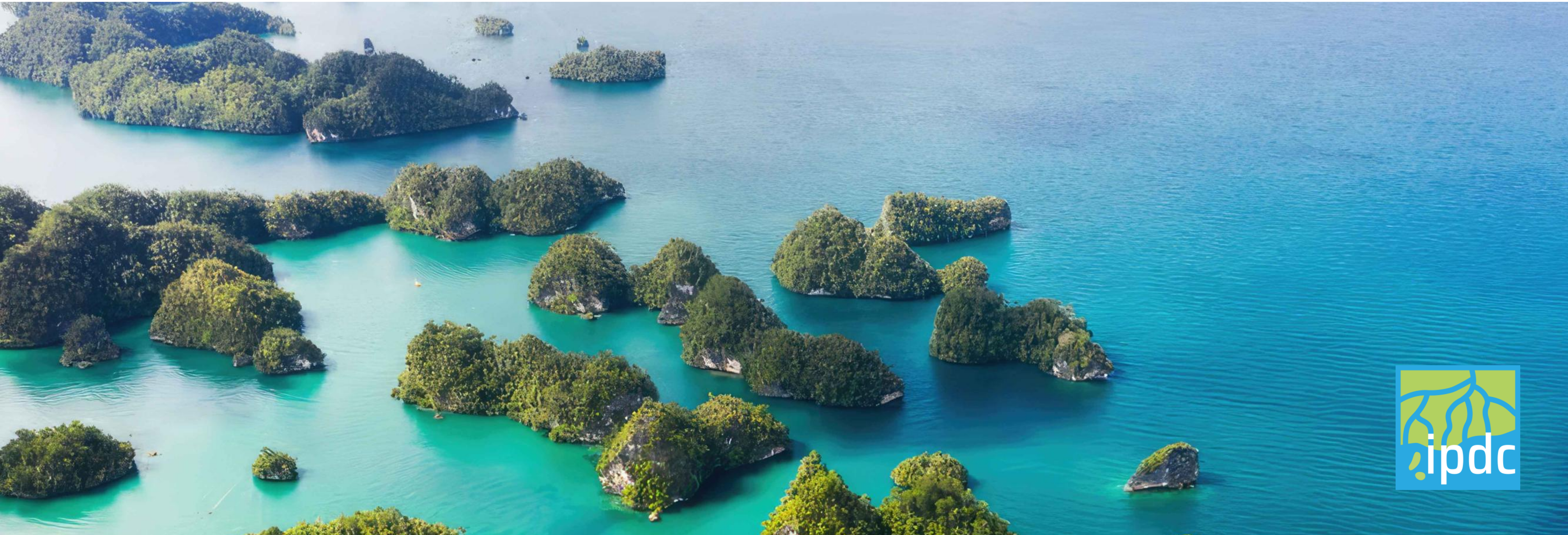

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