



Groundwater Management in the MENA Region: Challenges and Opportunities for the Future

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Overview

Part A:

- Fresh, brackish, saline and brine/hyper-saline groundwater
- Requirements for “marginal” groundwater use

Part B:

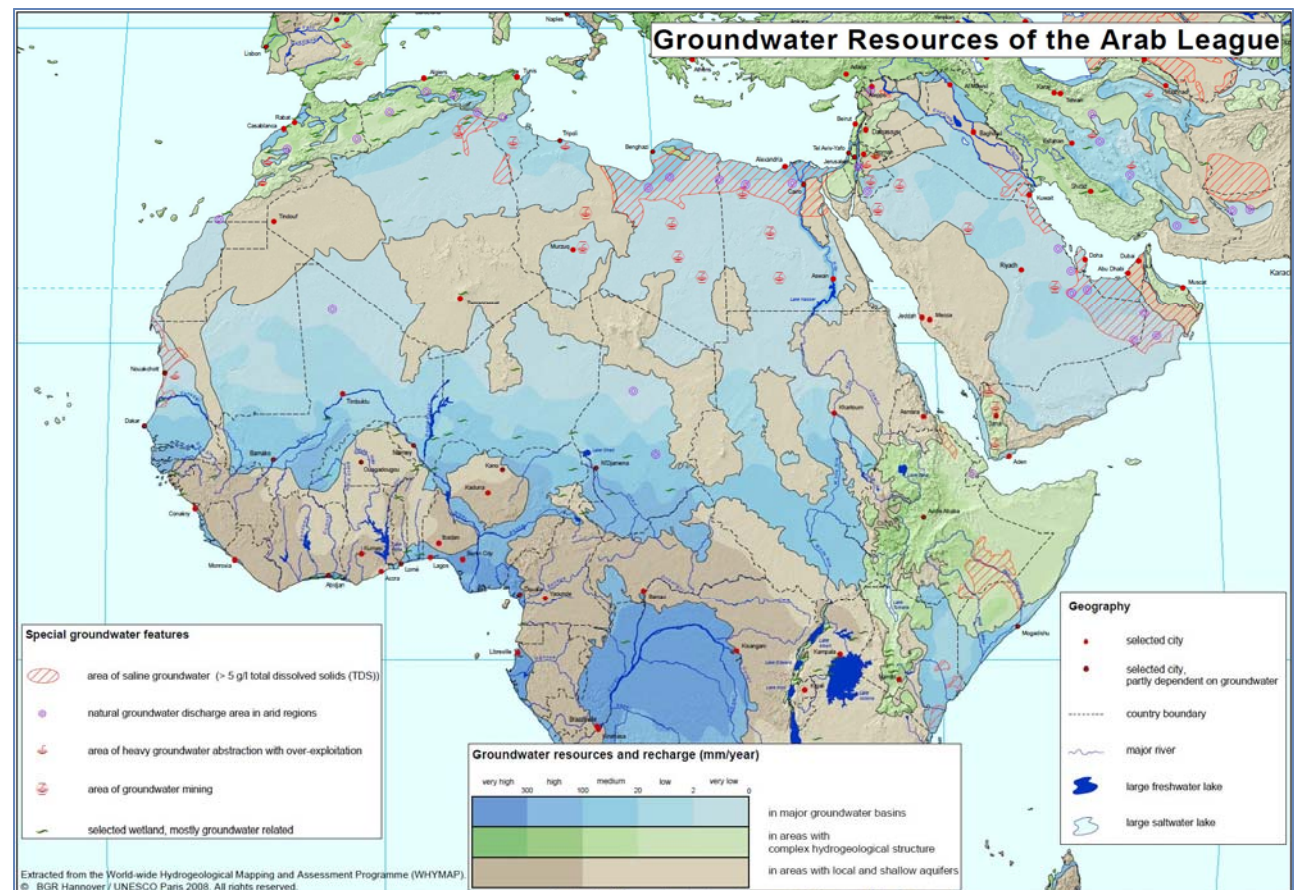
- SubSol - Coastal SUBsurface water SOLutions
- Preventing / remediating saline water intrusions through MAR

Conclusions & Recommendations

Groundwater Resources / Arab League

WHYMAP –
World-wide
Hydrogeological
MAPping and
Assessment
Programme
(BGR/UNESCO,
2008)

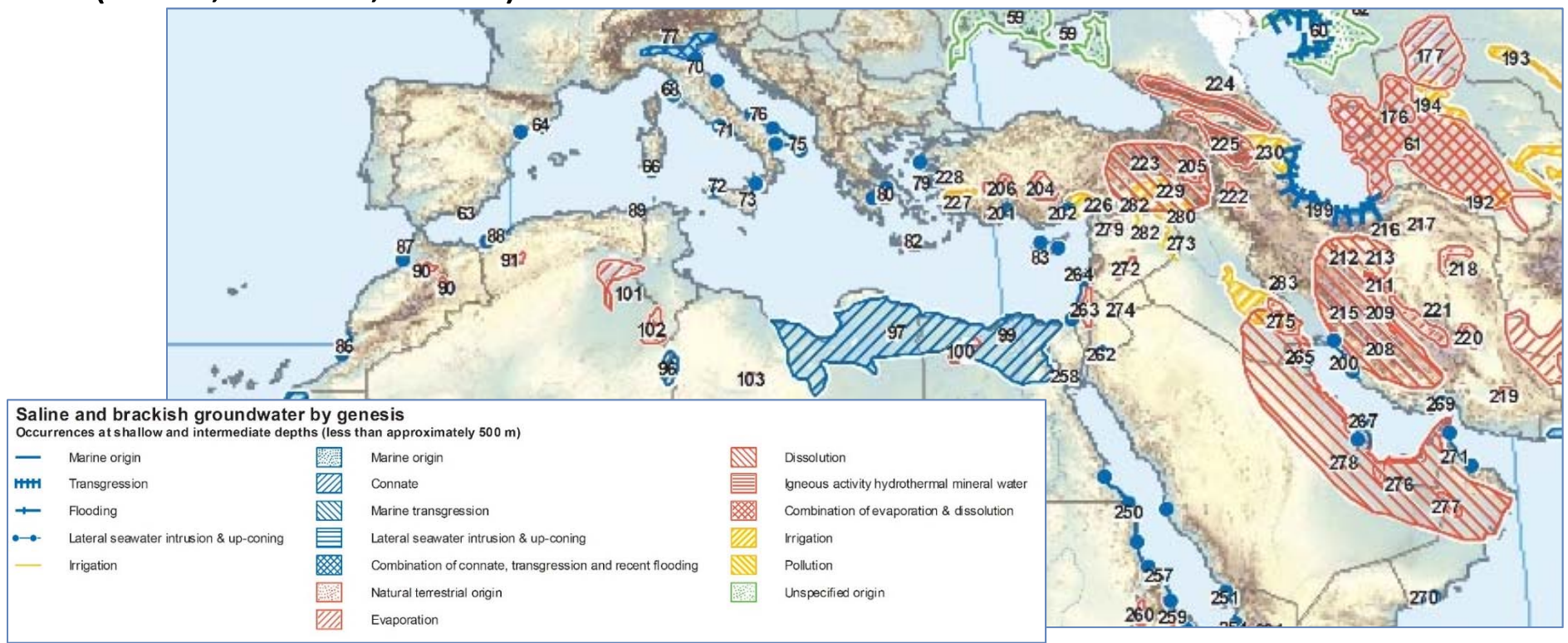
www.whymap.org



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Bahrain, 28-30 Mar 2017

Saline Groundwater / Global

Global Overview of Saline Groundwater Occurrence and Genesis
(draft, IGRAC, 2009)

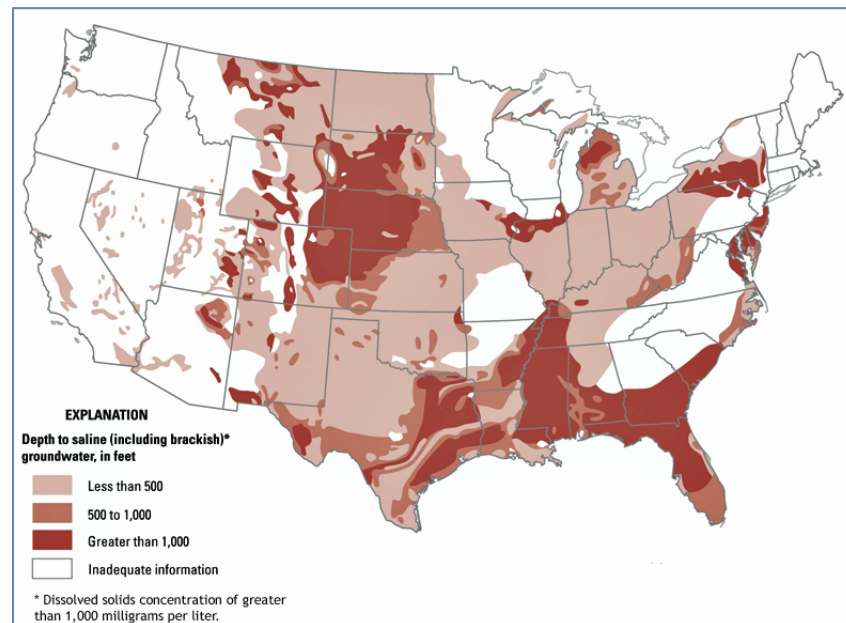


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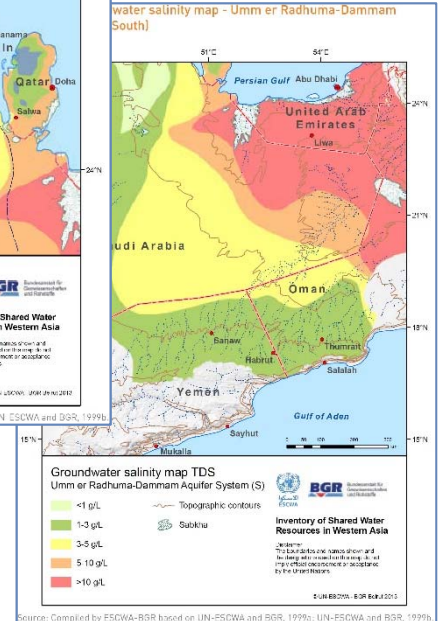
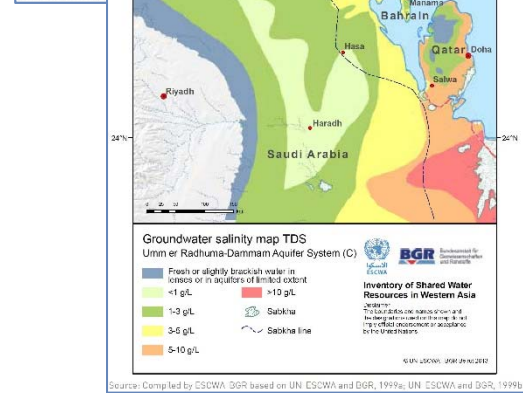
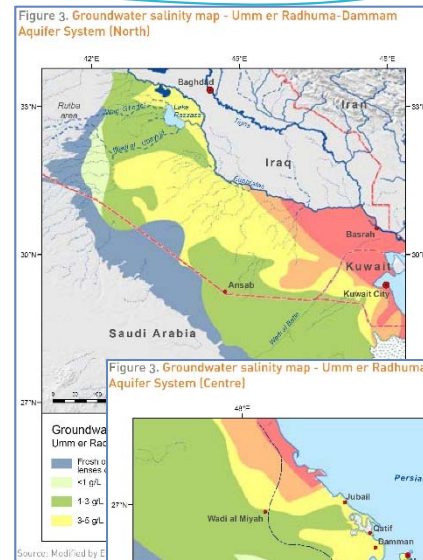
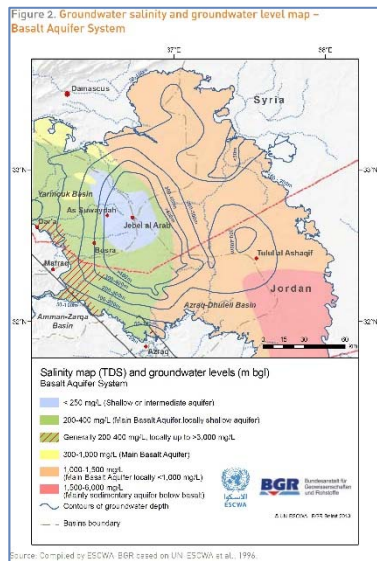
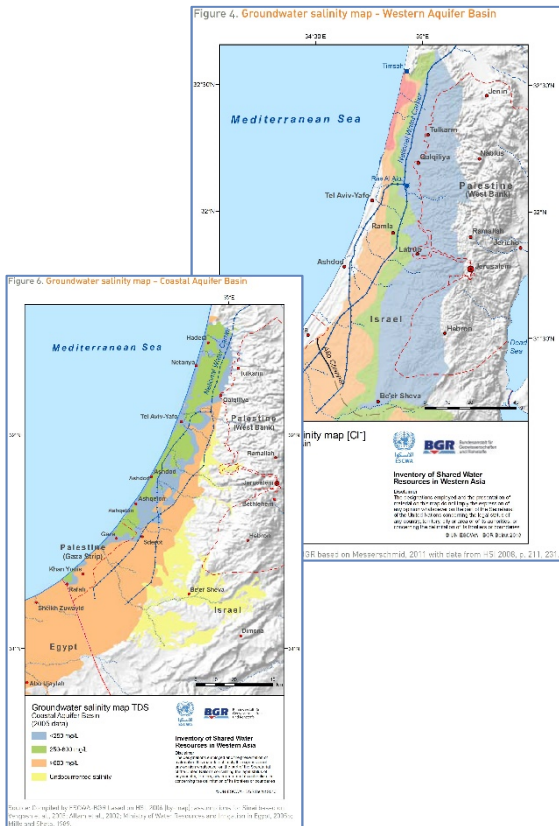
Fresh, Brackish, Saline and Brine/Hyper-Saline Groundwater

- Classification (after Freeze & Cherry, 1979)
- National Brackish Groundwater Assessment (USGS, 1965/2013)

Class name	Class limits (TDS range, in mg/l)	
Fresh water	0	1,000
Brackish water	1,000	10,000
Saline water	10,000	100,000
Brine	>	100,000



Groundwater Salinity in Western Asia



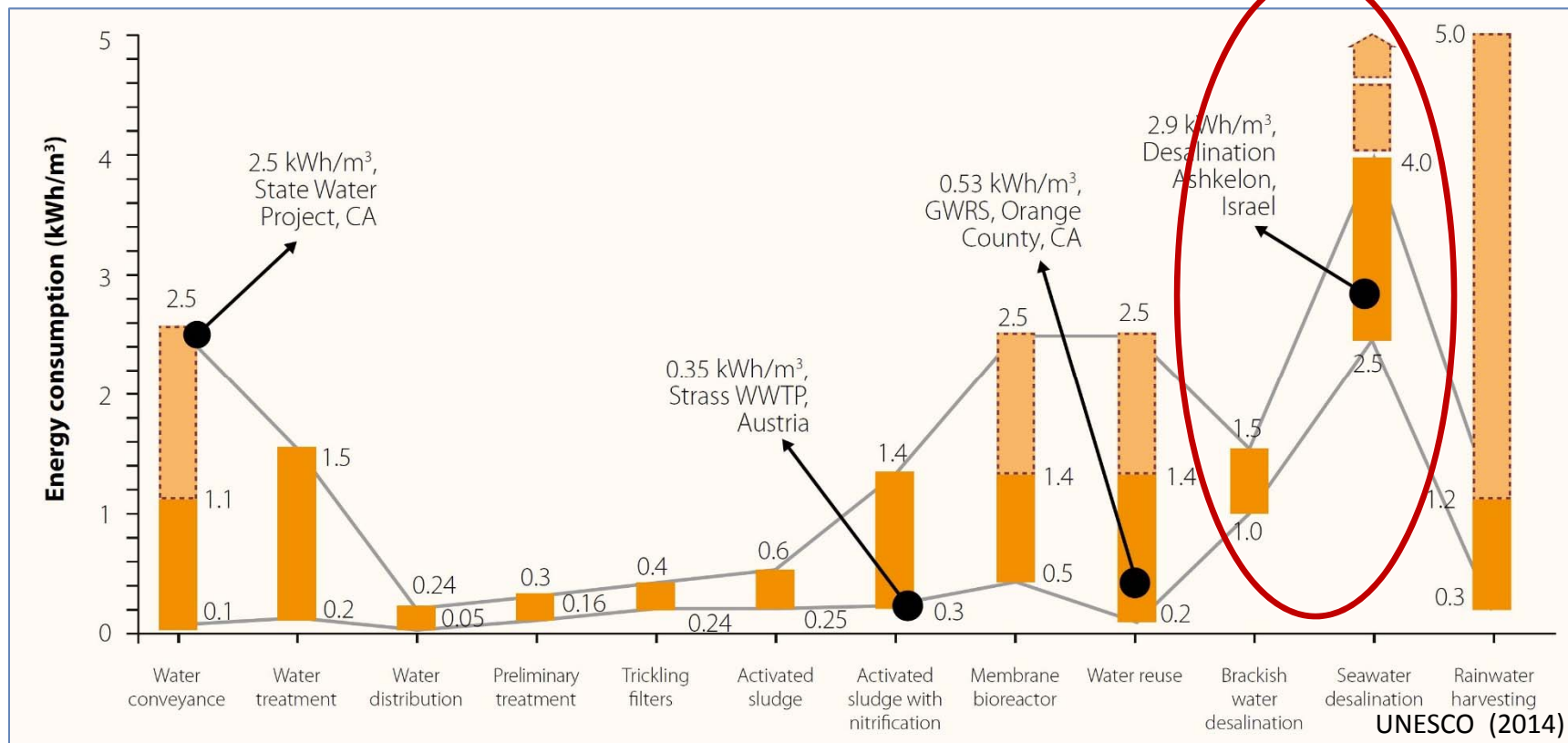
<http://waterinventory.org>

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Socio-Economic Cost-Benefit Analysis

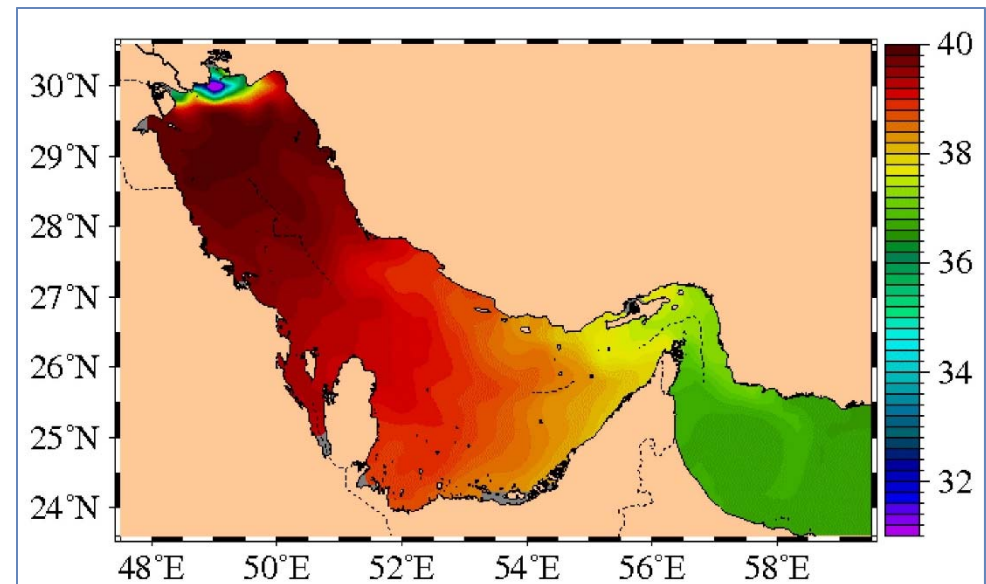
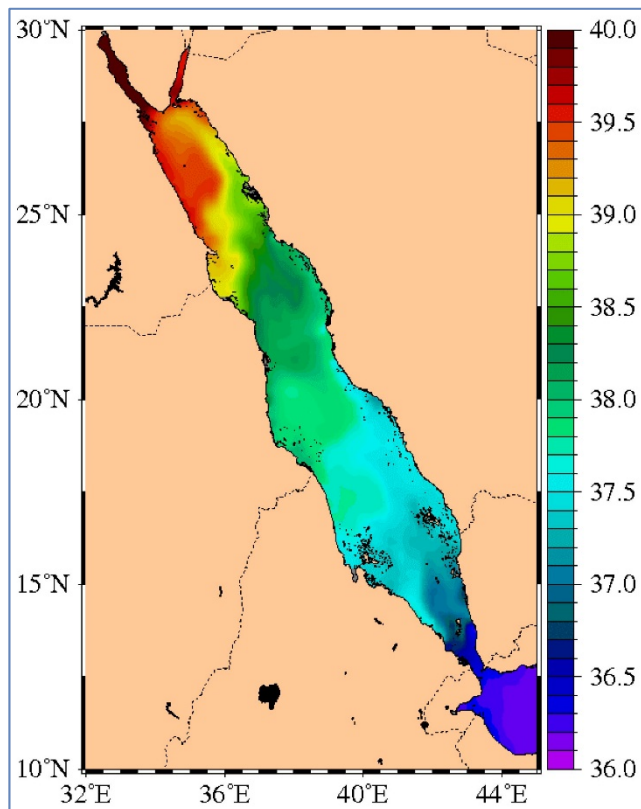
- Cost:
Sum of transport and production cost
 - Option 1:
Seawater (≥ 35 g/l) desalination
transported from nearest sea coast inland
and up to elevation
 - Higher costs for location of desal plant,
due to competing land use in coastal areas
 - Option 2:
Local brackish water (1-10 g/l) desalination
transported from source up to elevation

Socio-Economic Cost-Benefit Analysis



Socio-Economic Cost-Benefit Analysis

Salinity (g/l) of Seawater in Red Sea and Gulf



National Research Laboratory (2013)

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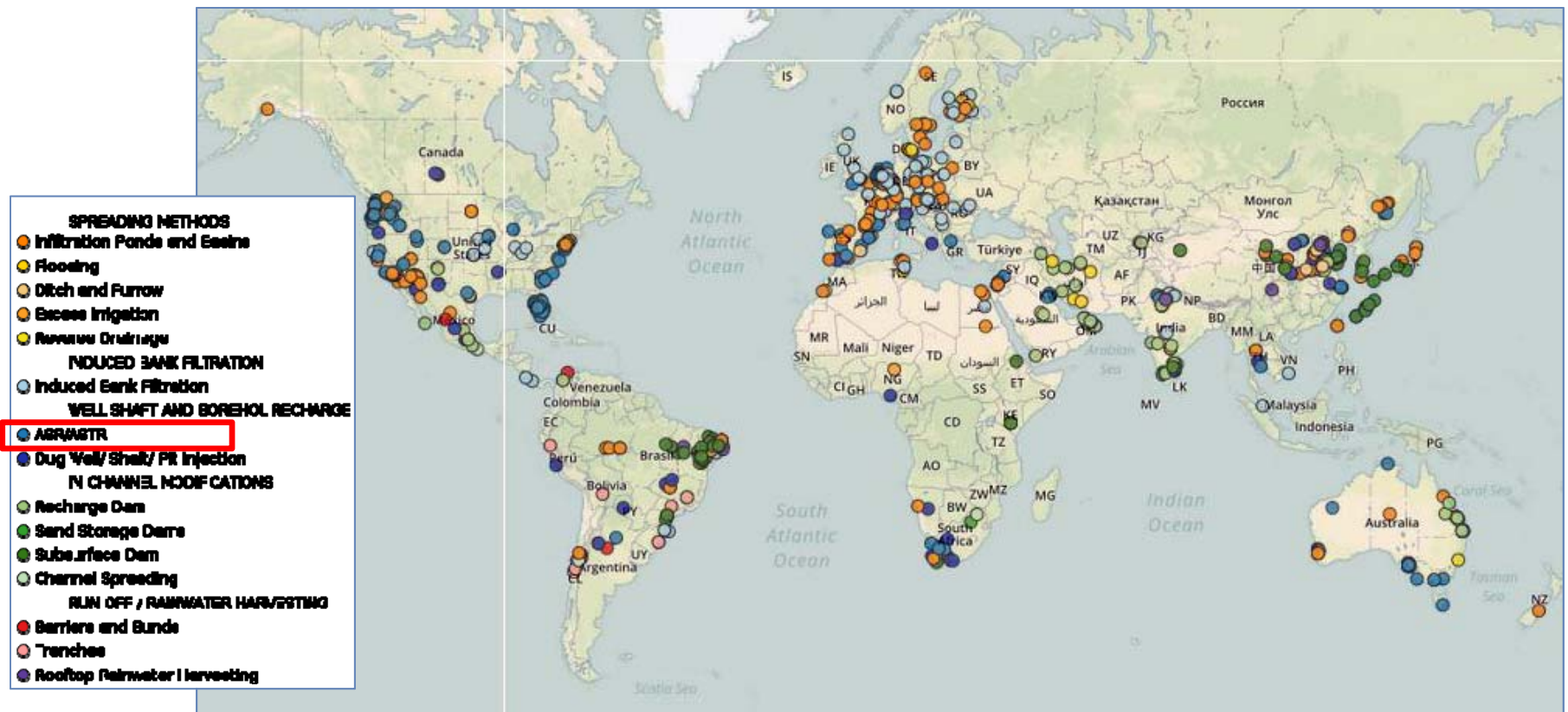
SubSol –

Coastal SUBsurface Water SOLutions

- Sophisticated MAR applications
- Improve water management in coastal areas
- Developed in the Netherlands
- Operational on pilot or full-scale
- Subject of further study in the EU financed project SubSol

- Managed Aquifer Recharge (MAR):
The purposeful recharge of water to suitable aquifers under controlled conditions for subsequent recovery or environmental benefit

Managed Aquifer Recharge – Global MAR Inventory

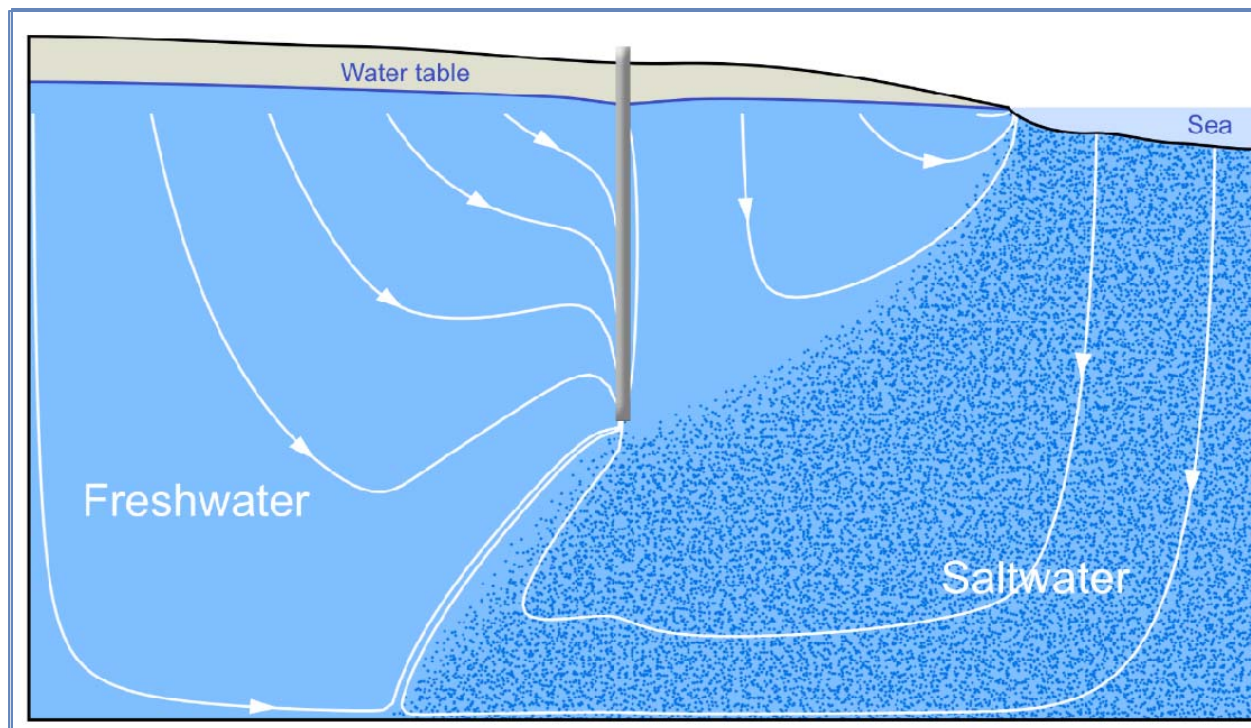


• <https://www.un-igrac.org/special-project/global-mar-inventory>

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Saline Groundwater in Coastal Settings

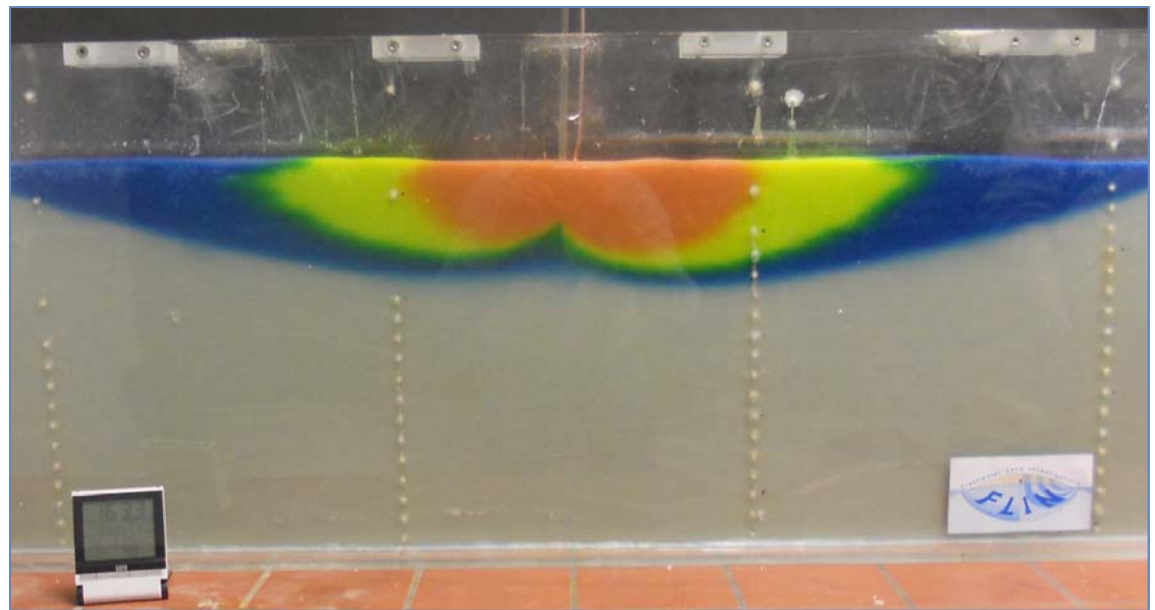
- Urbanization & industrialization - Increasing water demand
- Seawater intrusion into aquifers - Water unsuitable



Example:
Marine saltwater
intrusion due to
overpumping
Post (2016)

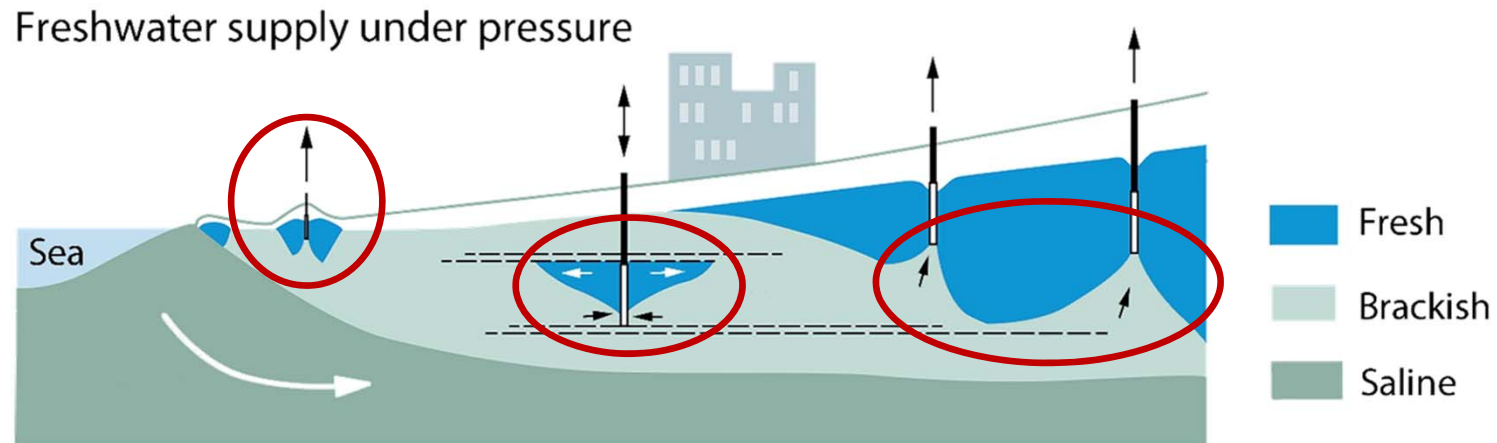
Saline Groundwater in Coastal Settings

- Understanding Freshwater Lenses, Freshwater Injections ASR Sand Tank Experiments



- **FLIN** – Freshwater Lens **IN**vestigations:
www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/F+E/Flin/flin_projektbeschr_en.html

Seawater Intrusion in Coastal Areas



Modified after KWR (2015)

Overexploitation
of freshwater
lenses

Low efficiency
of conventional
ASR systems

Upconing
of brackish/
saline water

SubSol Project

Freshmaker

Management of
freshwater lenses

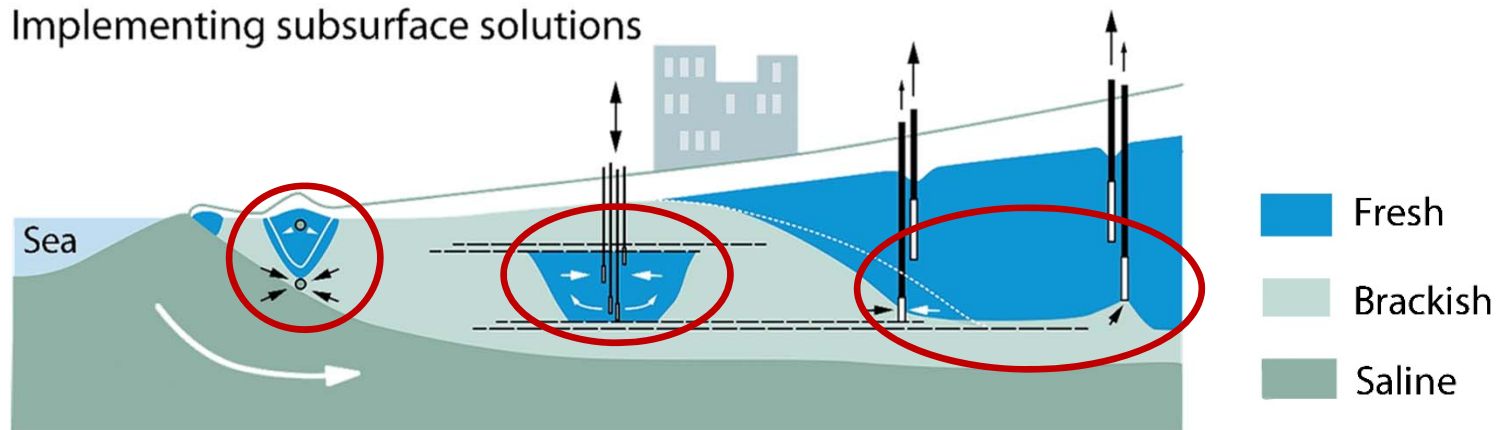
ASR Coastal

ASR with partially
penetrating wells

Freshkeeper

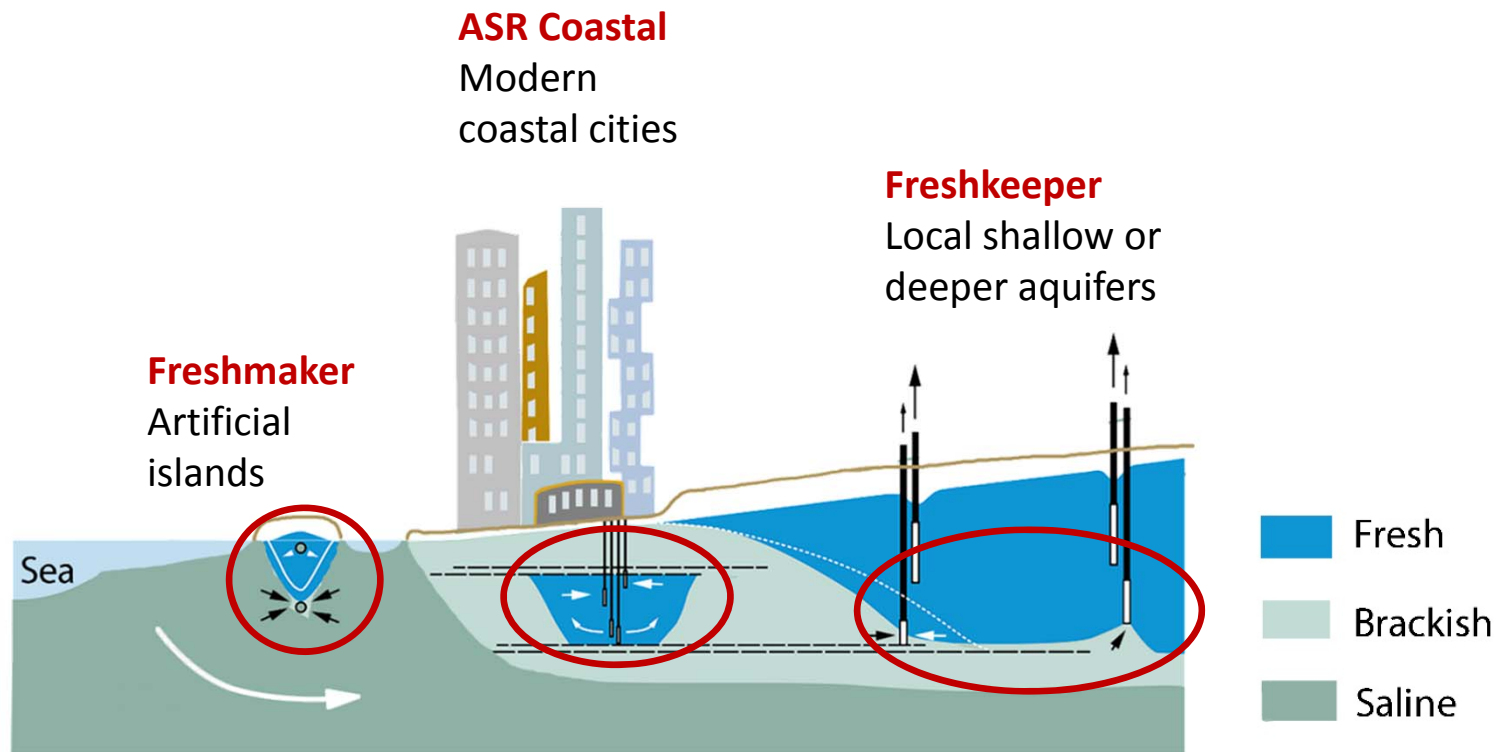
Well configurations to
prevent upconing

Implementing subsurface solutions



Modified after KWR (2015)

SWS in Different Coastal Settings



Modified after KWR (2015)

Freshmaker - Concept

2 horizontal directional drilled wells (HDDW)
– shallow and deep

Injection phase

Freshwater injection in shallow HDDW1

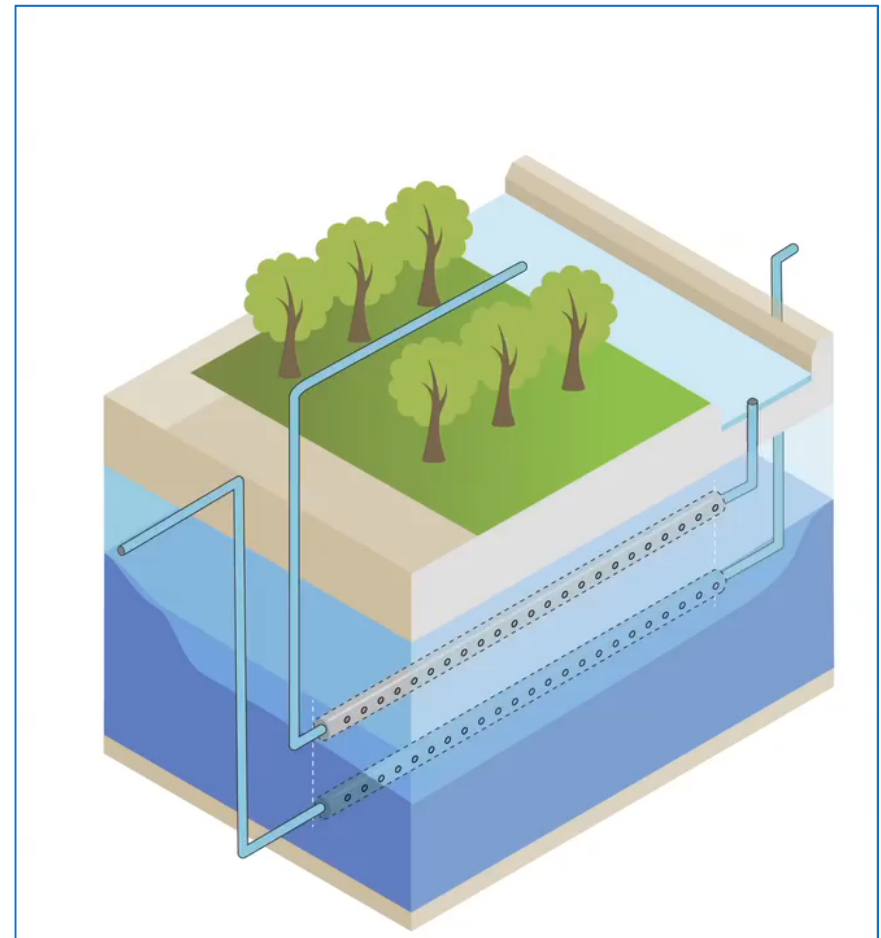
Saltwater abstraction in deep HDDW2

Abstraction phase

Freshwater abstraction in shallow HDDW1

Saltwater abstraction in deep HDDW2

→ Increase thickness of the freshwater lens;
prevent upconing during abstraction



ASR Coastal - Concept

Infiltration, storage and recovery of freshwater using multiple partially penetrating wells (MPPW) to deal with *buoyancy effects*

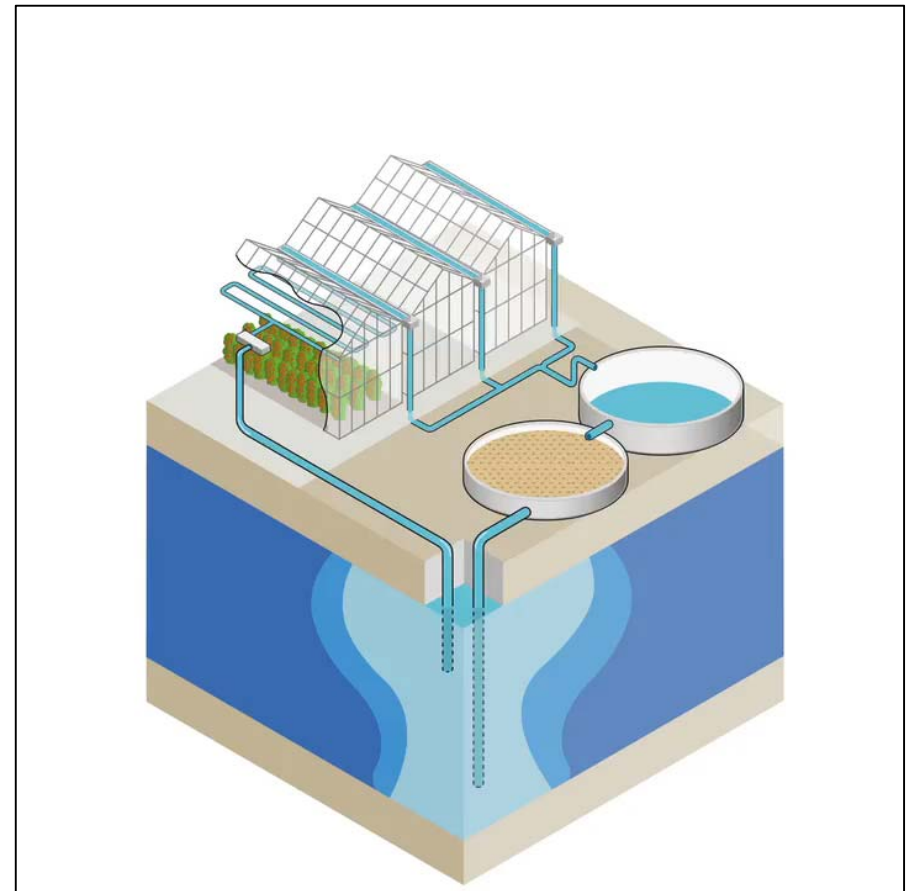
Injection phase

Freshwater injection in deeper wells

Abstraction phase

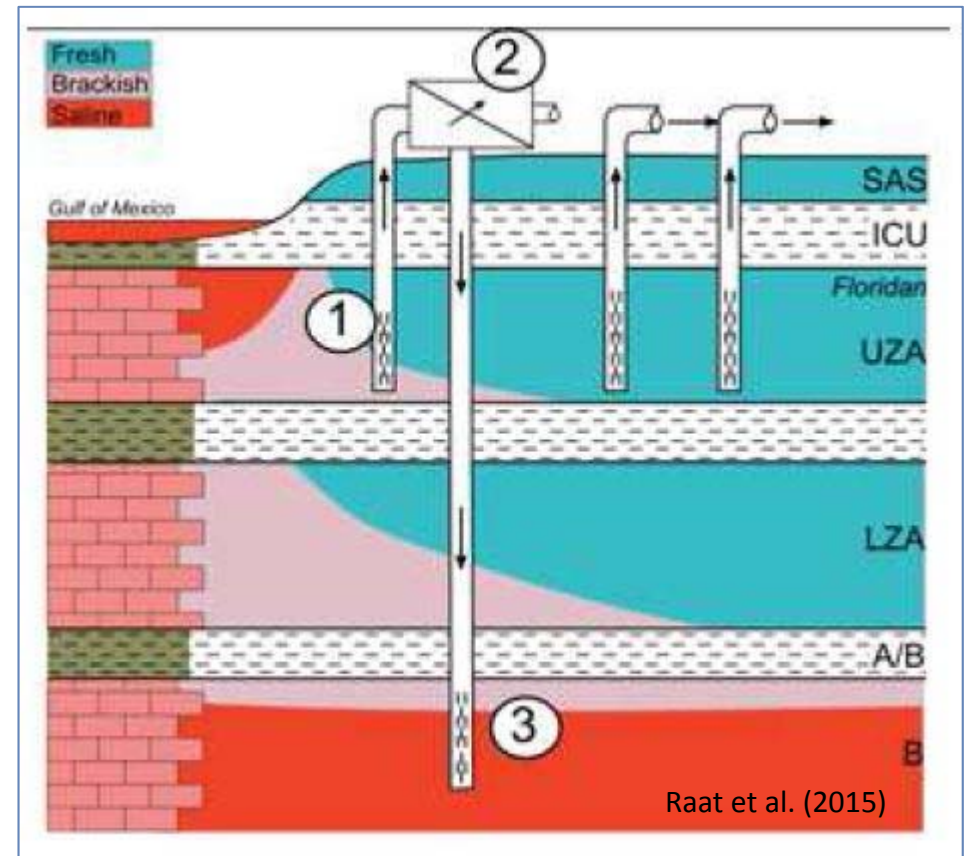
Option 1: Freshwater abstraction in shallow wells

Option 2: Additional brackish water abstraction in deeper wells; RO treatment



Freshkeeper - Concept

1. The freshwater wells inland are protected by interception of the intruding seawater.
2. The intercepted water is desalinated with reverse osmosis (RO)
3. The membrane concentrate is disposed to the underlying saline aquifer



Conclusion & Recommendations

- Groundwater can be fresh, brackish or saline:
Brackish and saline groundwater can provide important **marginal water resources** in local situation
- Need for **better mapping** of fresh, brackish and saline groundwater laterally and in depth
- Improve **socio-economic cost-benefit assessments** for potential use of brackish and saline groundwater
- **MAR/ASR** can offer solutions in coastal settings to **prevent and remediate saline water intrusion**
- **SubSol proven subsurface solutions for coastal settings** potentially also for GCC and Arab countries

Acknowledgement & Links

- **FLIN** – Freshwater **L**ens **I**Nvestigations:
Dr. Georg Houben, Dr.-Ing. Leonard Stöckl
www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/F+E/Flin/flin_projektbeschr_en.html
- **SubSol** - Coastal **SUB**surface water **SOL**utions:
Dr. Maike Gröschke and SWS team, www.subsol.org
- Desalination, brackish and saline waters:
Dr. Armin Margane



Bundesanstalt für
Geowissenschaften
und Rohstoffe

G E O Z E N T R U M H A N N O V E R



GRIPP

GROUNDWATER SOLUTIONS
INITIATIVE FOR
POLICY AND PRACTICE

Associated Partner

<http://gripp.iwmi.org>

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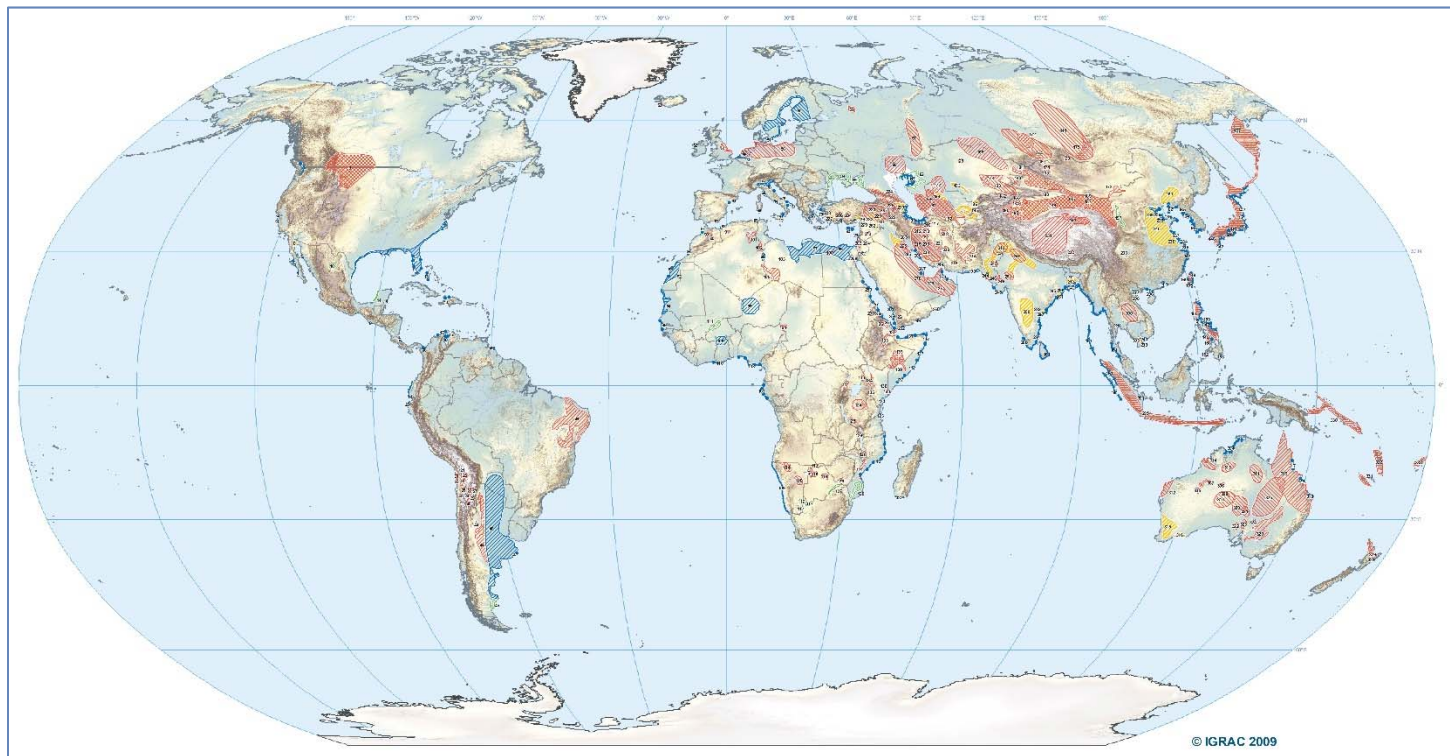
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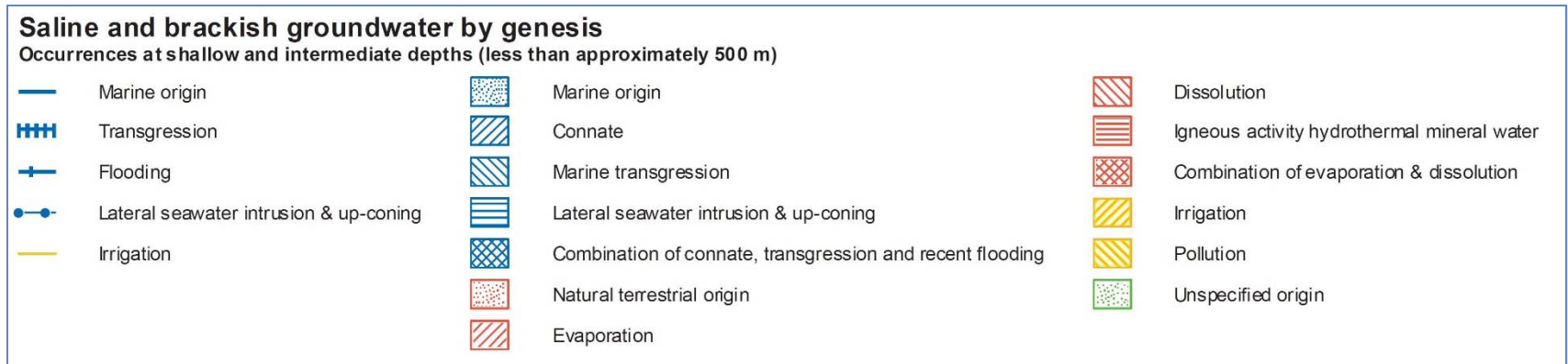
- Global Overview of Saline Groundwater Occurrence and Genesis (draft, IGRAC, 2009)



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Status of Groundwater Resources

- Global Overview of Saline Groundwater Occurrence and Genesis (draft, leghend, IGRAC, 2008)



Freshmaker - Challenges

Depth of HDDW2 is important design parameter

- if too shallow this HDDW can abstract costly freshwater
- if too deep it provides insufficient protection of the upper

HDDW

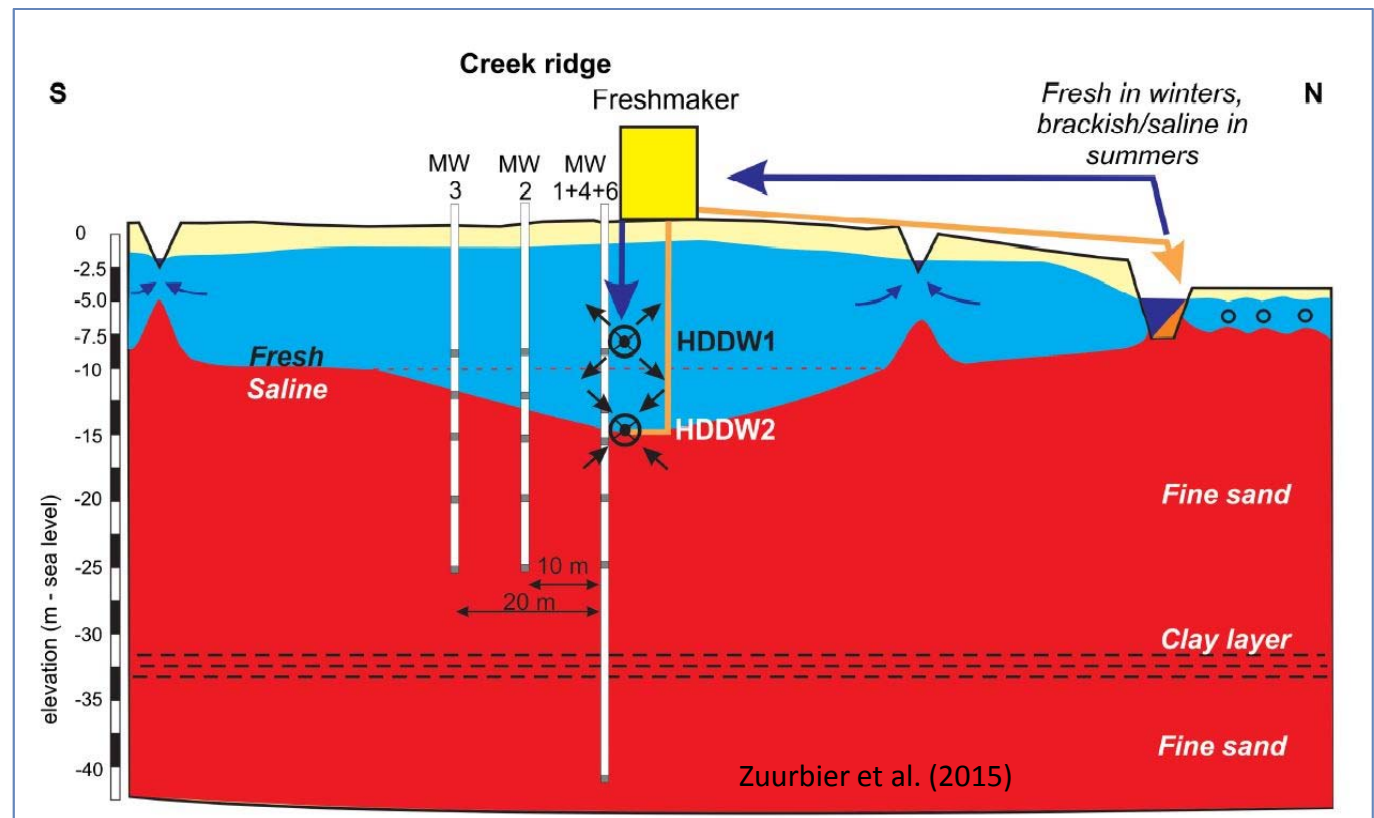
→ SEAWAT modelling to find optimum depth of HDDW2

Freshmaker - Pilot

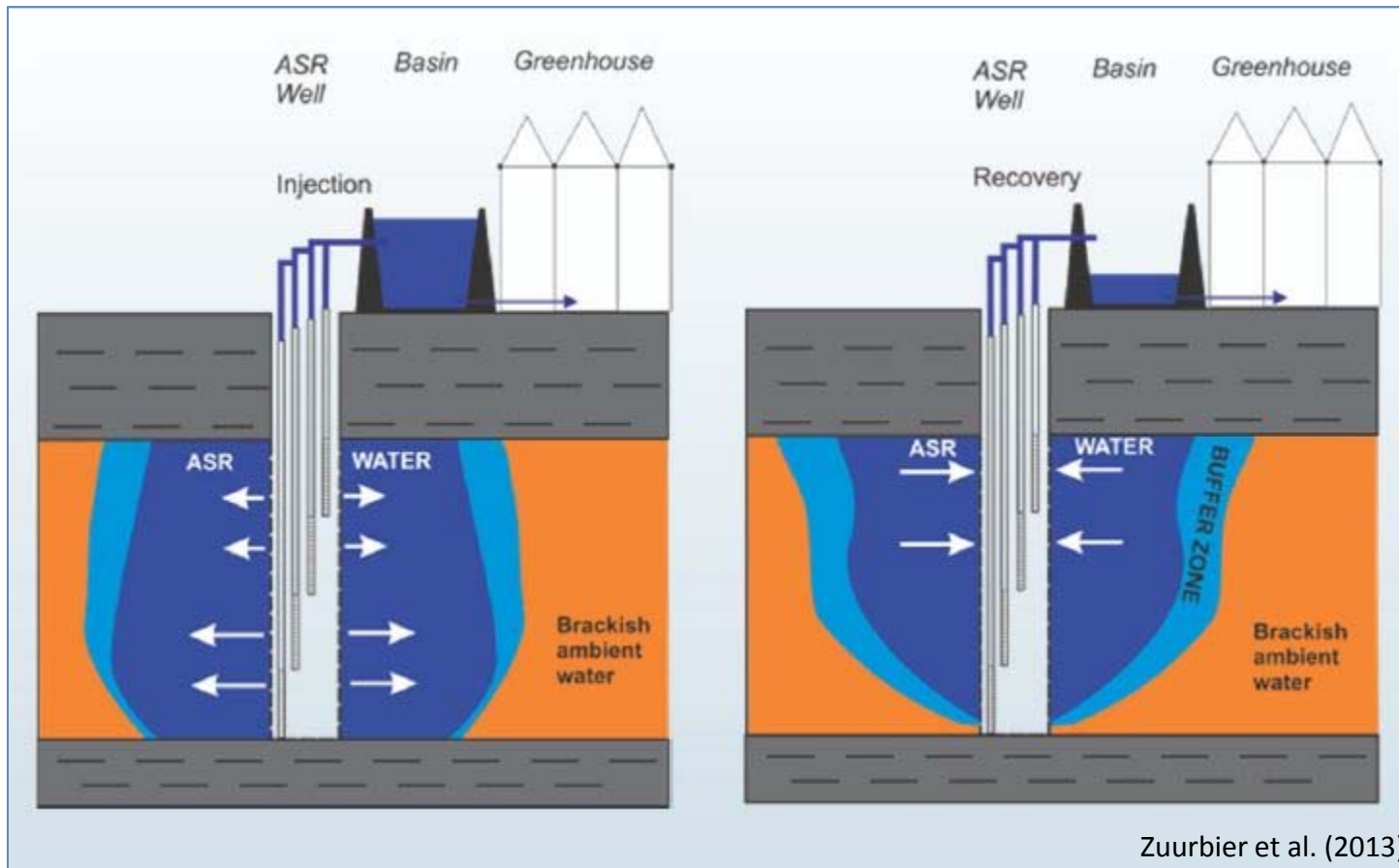
Ovezande, Southwest Netherlands

Freshwater is scarce due to the surrounding estuaries and saline seepage

Resources are limited to rainwater and local fresh groundwater lenses in sandy creek ridges



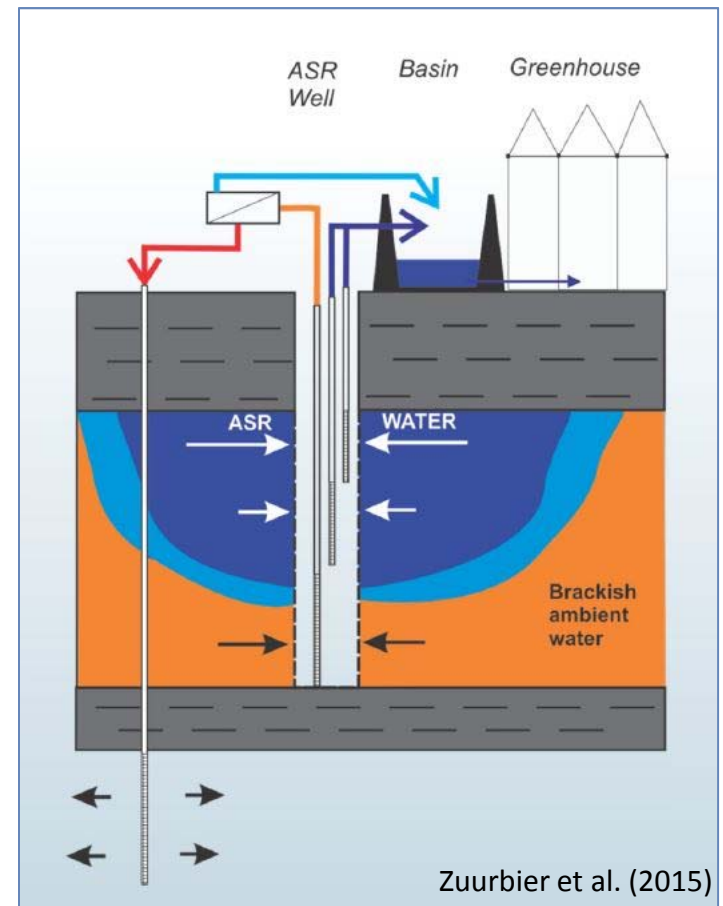
ASR Coastal - Option 1



ASR Coastal - Option 2

Recovery Phase:

- Freshwater abstraction in shallow wells
- Brackish water abstraction in deeper wells feeding an RO system
- Injection of RO brines into deeper saline aquifer or disposal in sea/ocean



SubSol - Project

EU project SUBSOL

“bringing coastal subsurface solutions to the market”

- Continue with scientific evaluation of the full-scale systems (reference sites)
- Demonstrate applicability in different settings (replication sites)
 - Denmark, Greece, Mexico
 - Pilot scale studies
- Assess applicability worldwide (target regions)
 - Europe, Gulf of Mexico, China, Brazil, Vietnam
 - Pre-feasibility studies