INSTITUTE OF LIFE SCIENCES

Scuola Superiore Sant'Anna

SMAQua
SMart ICT tools per l'utilizzo efficiente dell'AcQua

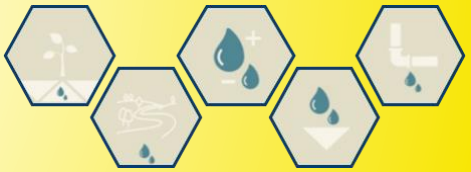
REWAT
sustainable water management in the lower Cornia Valley

Life

2nd International LIFE REWAT Summer School

Digital water management and water-related agroecosystem services: geostatistics, hydroinformatics and groundwater flow numerical modelling

September 9th—20th, 2019
Scuola Superiore Sant'Anna
Pisa, Italy



2nd FREEWAT International Workshop

FREEWAT platform as a groundwater modelling tool for coastal semi-arid environments: insights from different model applications

Andreas Kallioras
National Technical University of Athens, Greece
kallioras@metal.ntua.gr

FREEWAT
Free and Open Source Software Tools for Water Resource Management
EU HORIZON 2020 Project

EIP Water Action Group
Pooling resources – Innovating water

ict4water.eu

FREEWAT platform as a groundwater modelling tool for coastal semi-arid environments: insights from different model applications

Andreas Kallioras, Christos Pouliaris, Martha Perdikaki, Evita Koltsida, Thumios Chrysanthopoulos

National Technical University of Athens, Greece
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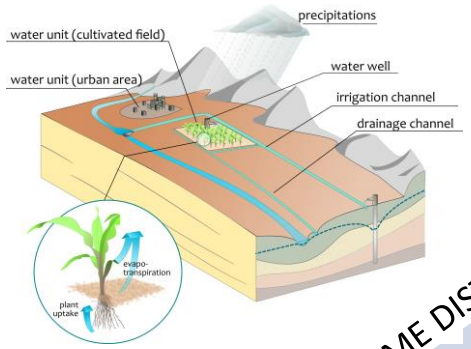
Why modeling with FREEWAT Platform?

FREEWAT



USGS science for a changing world

MODFLOW and Related Programs (MT3DMS, SEWAT, UCODE, etc.)

SPACE AND TIME DISTRIBUTED DATA

Surface and Groundwater Flow Simulation

Water quality issues

simulation and analysis tools

Rural water management module

Calibration

Sensitivity Analysis

Parameter estimation

UPSCALING from cell results

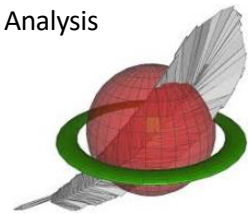
WATER MANAGEMENT AND PLANNING MODULE

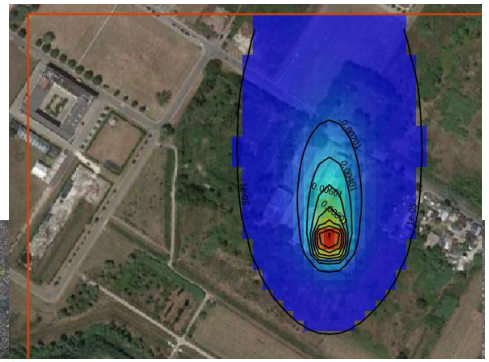
python

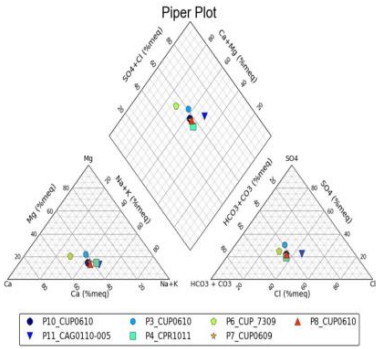
FloPy3

Observation Analysis Tool

GIS AND SPATIAL DATABASE







FREEWAT activities

Day seminars in International Conferences

- 10th World Congress on Water Resources and Environment της European Water Resources Association (EWRA), Athens, 5-9 July 2017.
- 11th International Hydrogeological Congress of Greece, hosted by the Hellenic Committee of Hydrogeology (Greek Chapter of the International Association of Hydrogeologists, I.A.H.), in collaboration with the Association of Geologists and Mining Engineers of Cyprus, Athens, 4-6 October, 2017.
- 3rd EWaS International Conference on "insights on the Water-Energy-Food Nexus", Lefkada, 27-30 June 2018.
- 15th International Congress of the Geological Society of Greece, Athens, 22-24 May 2019.

Week workshops in academic/research institutions

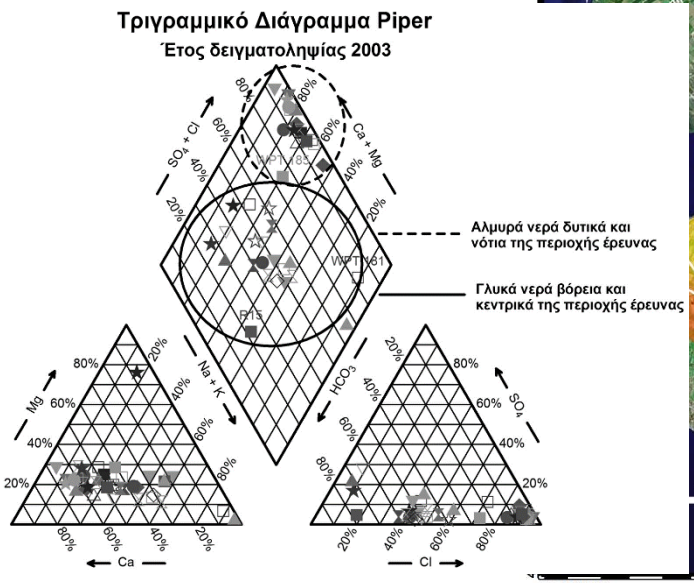
- National Technical University of Athens
- University of Patras
- Technical University of Crete
- University of Thessaly
- Democritus University of Thrace
- University of Ioannina

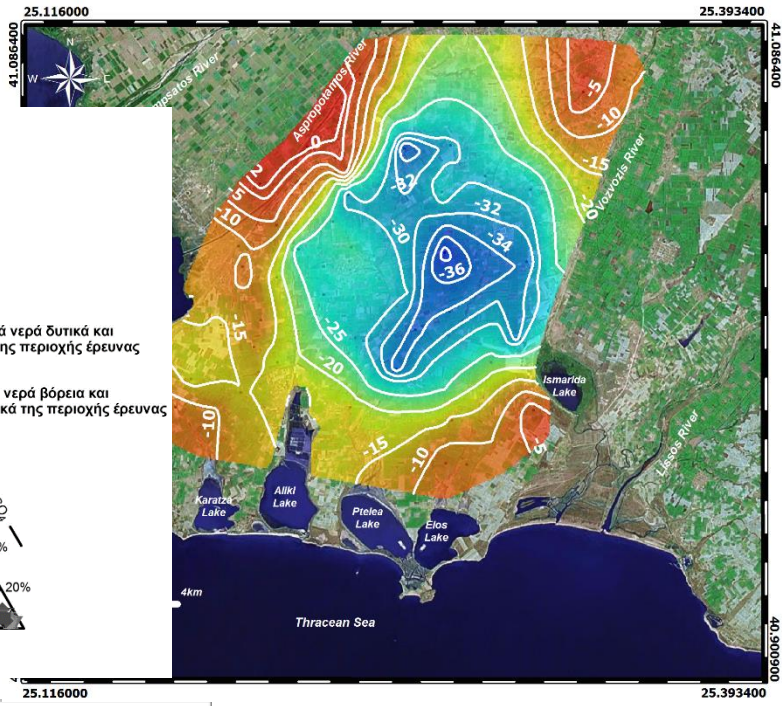
Model activities in EU Projects

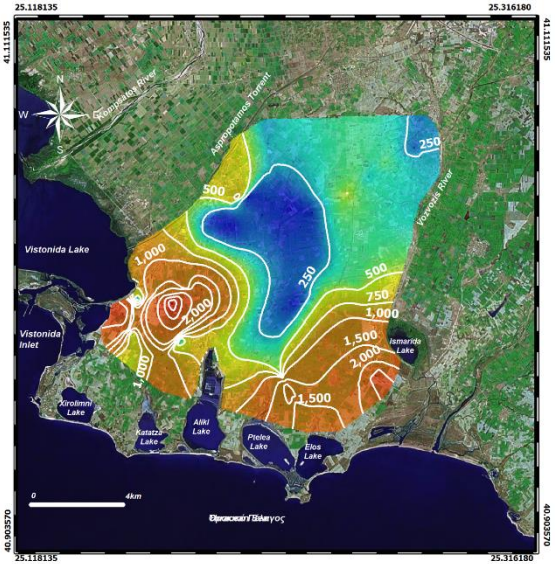
- MARSOL FP7
- FREEWAT H2020
- SUBSOL H2020
- MARSOLUT H2020
- LOTUS H2020

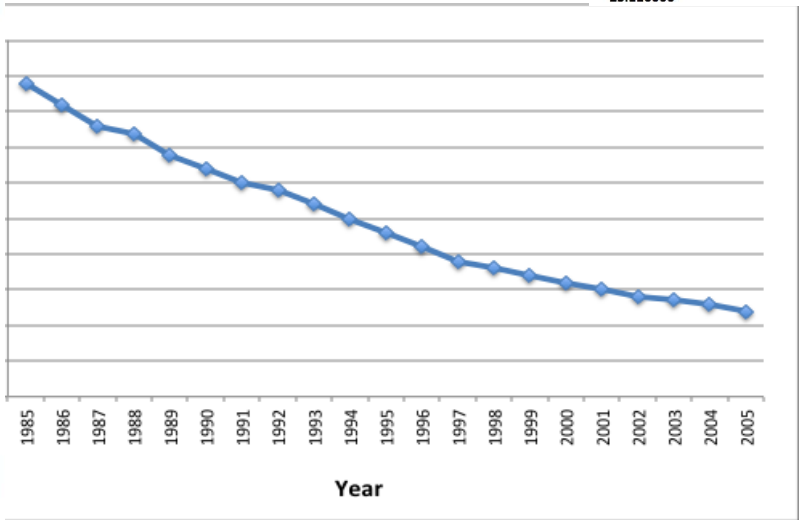
Rhodope coastal aquifer

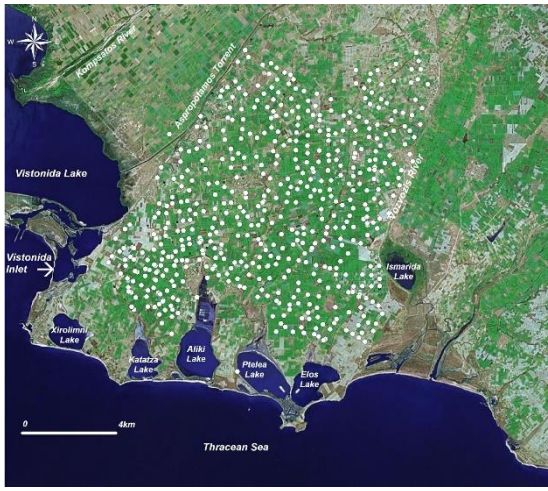
- Main water problems: overexploitation and seawater intrusion
- Hydrogeological setting: semi-confined alluvial aquifer





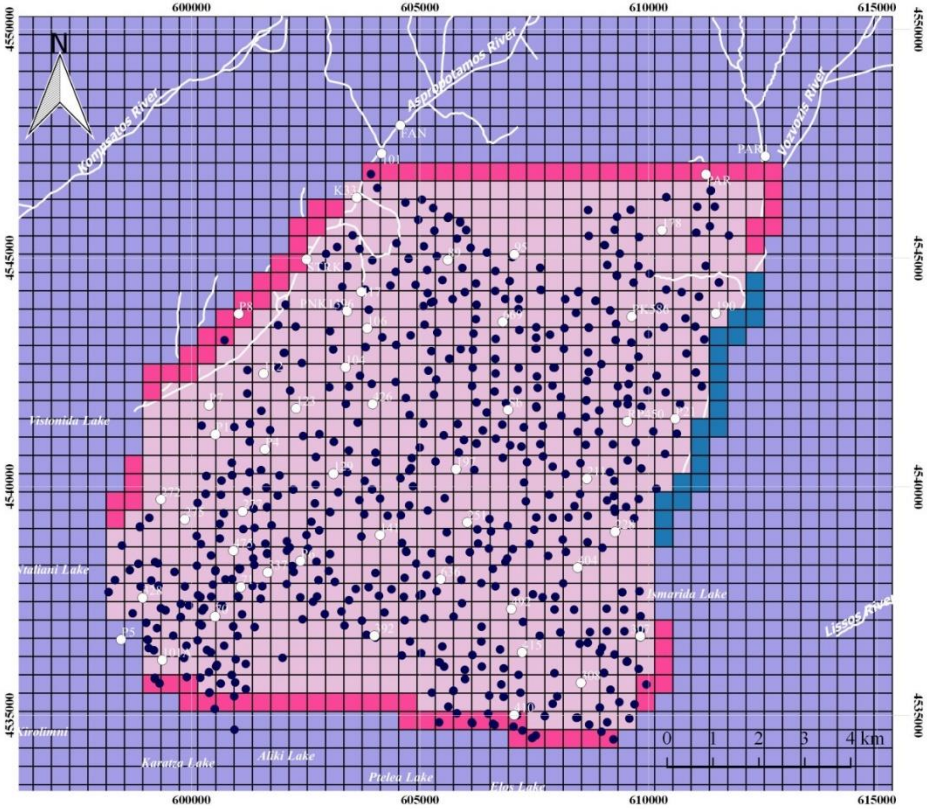


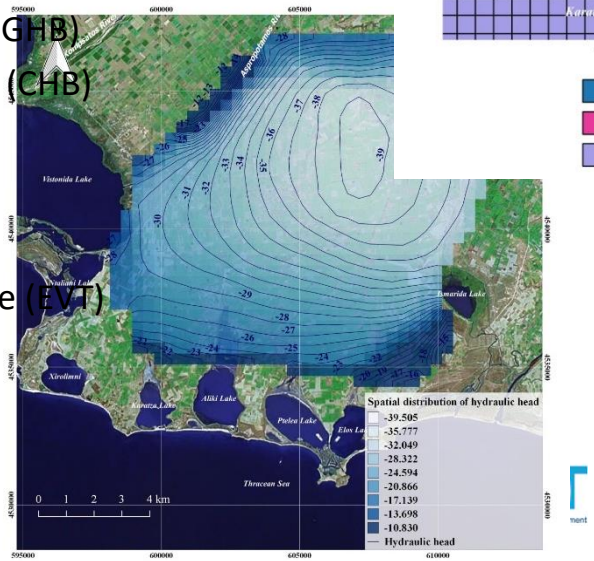


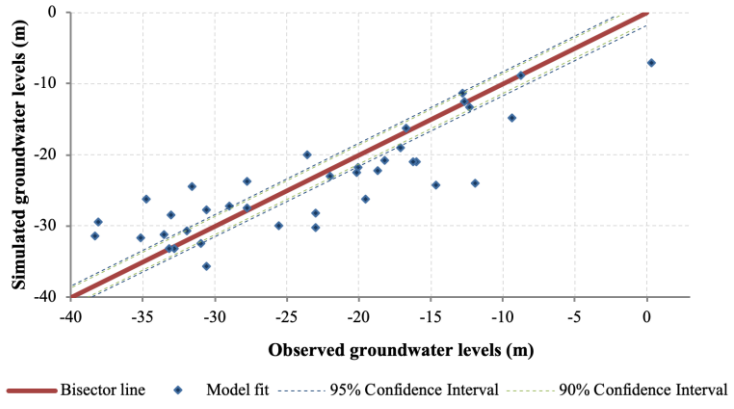


Rhodope model

- Active domain and spatial discretization: 35 rows and 40 columns and each cell has dimensions of 400x400 m each
- Time discretization: 16 stress periods, each representing a month. The number of time steps in each stress period corresponds to the number of days is each month. The first stress period is steady state, while the others are transient.
- Hydrologic boundary conditions:
  - General head boundaries (GHB)
  - Constant head boundaries (CHB)
  - River boundaries (RIV)
  - Well Package (WELL)
  - Recharge Package (RCH)
  - Evapotranspiration Package (EVT)
  - No flow boundaries

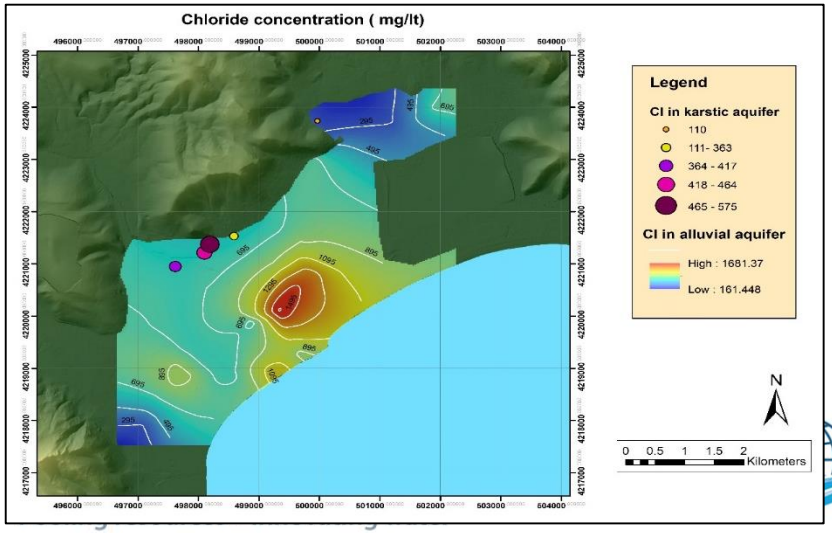






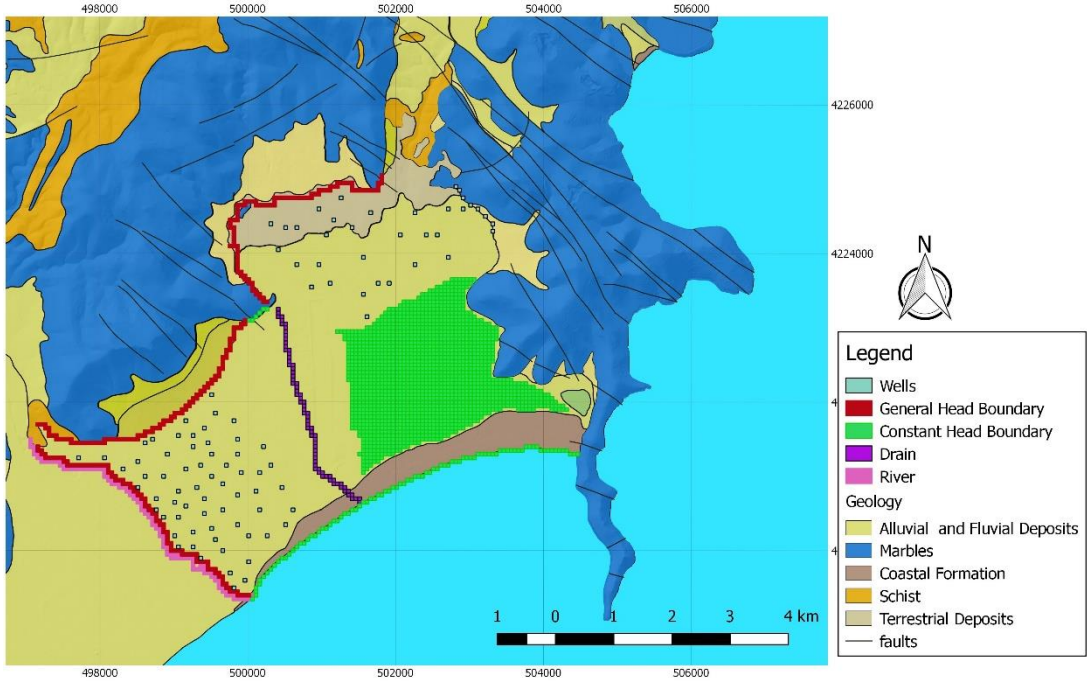
Marathon coastal aquifer system

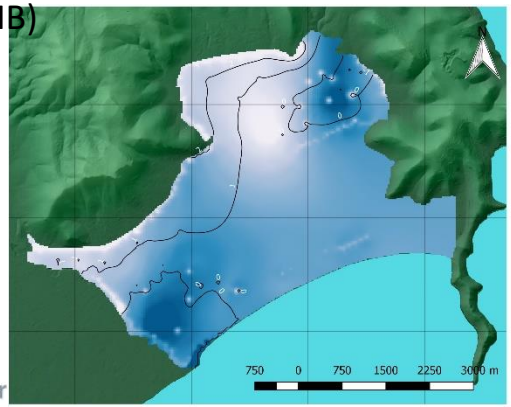
- Main water problems: seawater intrusion, nitrate contamination
- Hydrogeological setting: multi-aquifer system composed of alluvial and karstified limestones

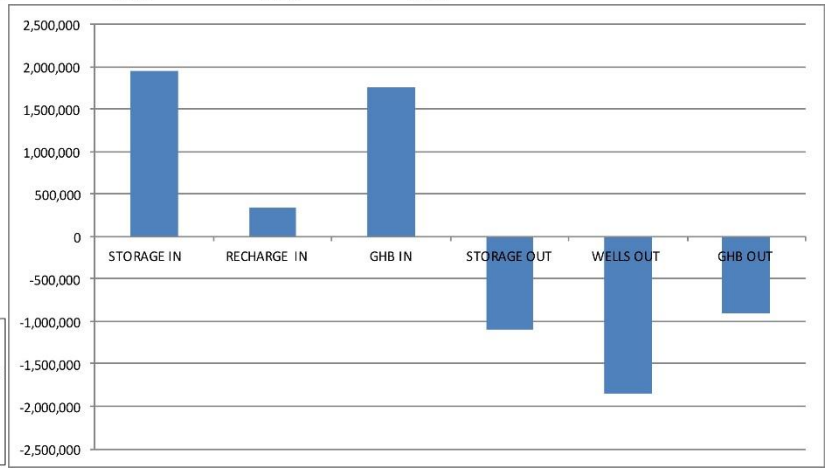


Marathon model

- Active domain and spatial discretization: 50 km2 region, divided in a 50 m × 50 m grid. This ends up to 18360 cells per layer, of which 14460 are active (in both layers)
- Time discretization: simulation period of the model is divided in 13 stress periods. The number of time steps in each stress period corresponds to the number of days is each month. The simulation period is from October 2016 to September 2017
- Hydrologic boundary conditions:
  - General head boundary (GHB)
  - Constant head (CHB)
  - Well (WEL)
  - Recharge (RCH)
  - Drain (DRN)
  - River (RIV)





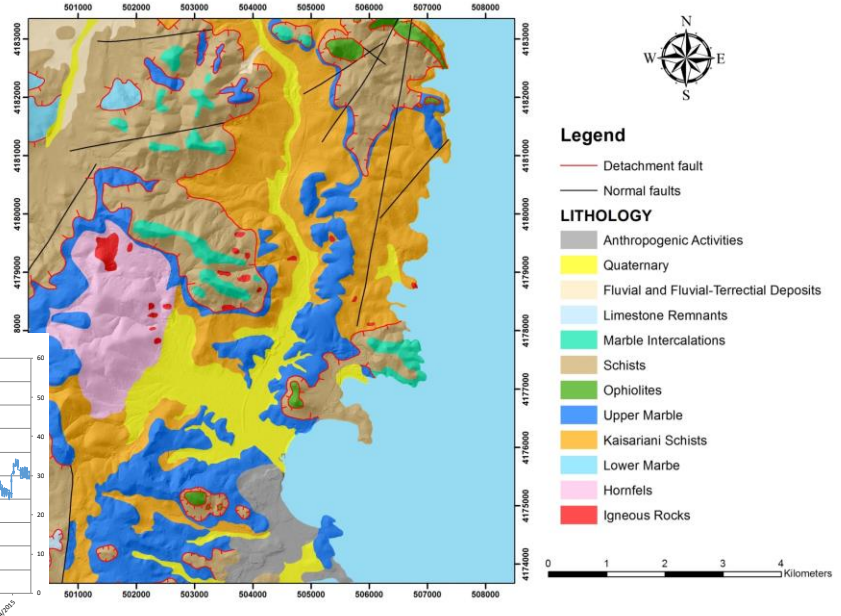


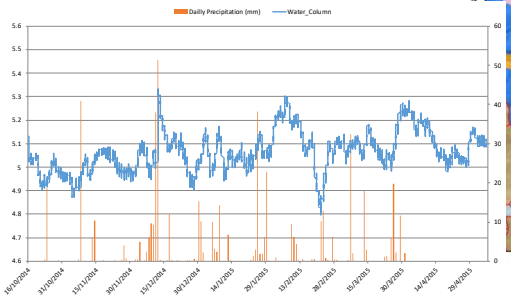
Lavrion coastal aquifer system

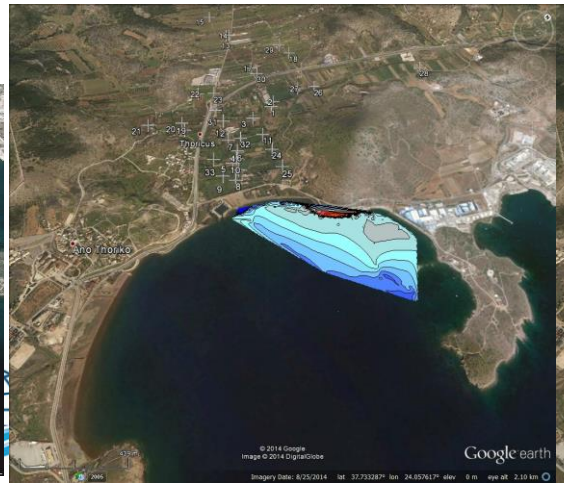
- The site offers a typical hydrogeological setting for a Mediterranean coastal aquifer system (containing both alluvial and karstified aquifer layers), supporting both irrigation as well as water supply demands of the area.
- The entire aquifer system suffers from:

(i) water shortage resulting from both anthropogenic activities (overexploitation) and natural conditions (decreasing precipitation trends due to climate change), as well as

(ii) (ii) contamination due to the intrusion of seawater.

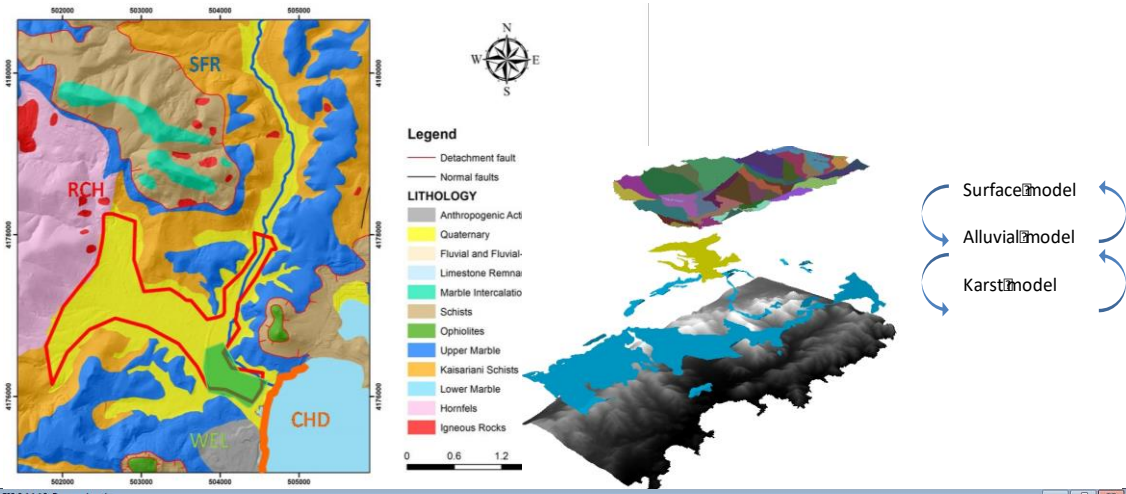


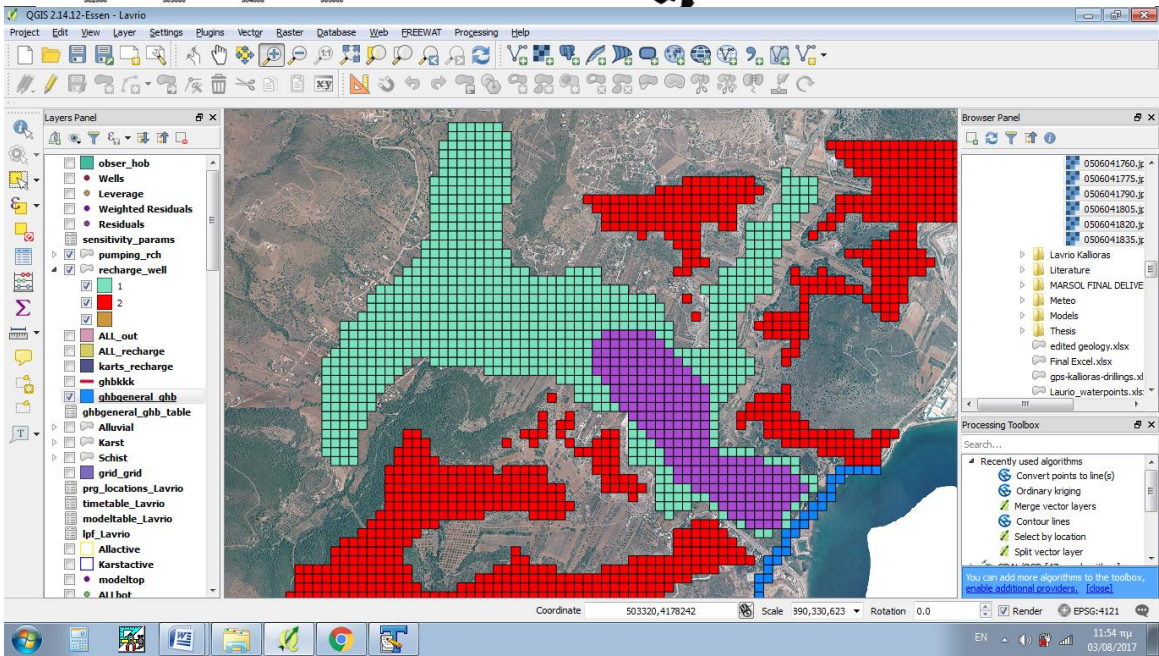




Lavrion model

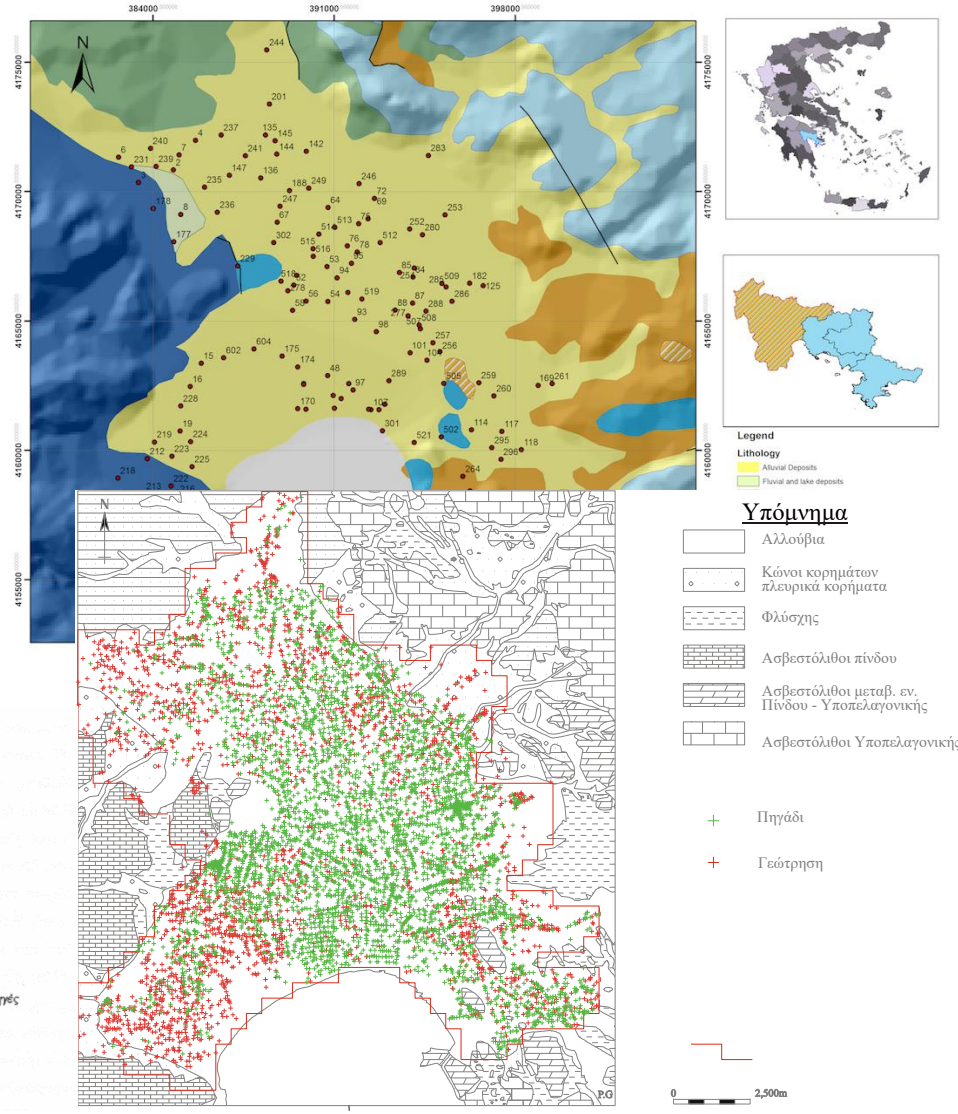
- Active domain and spatial discretization: The active domain of the model area includes a 60 km2 region, divided in a 50 m X 50 m grid. This ends up at 23661 cells per layer, of which 14460 are active (in both layers).
- Time discretization: 28 stress periods, each representing a month. The number of time steps in each stress period corresponds to the number of days is each month. The first stress period is steady state, while the others are transient. The simulation period is from January 2014 to March 2016
  - Hydrologic boundary conditions: General head boundary (GHB)
  - Well (WEL)
  - Recharge (RCH)
  - Constant head (CHB)

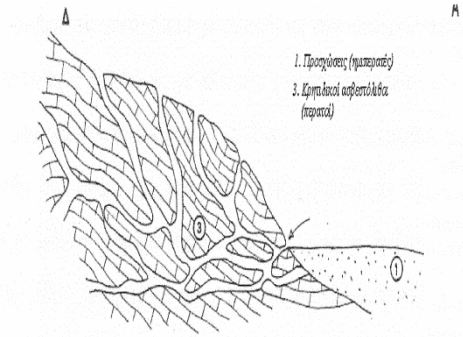


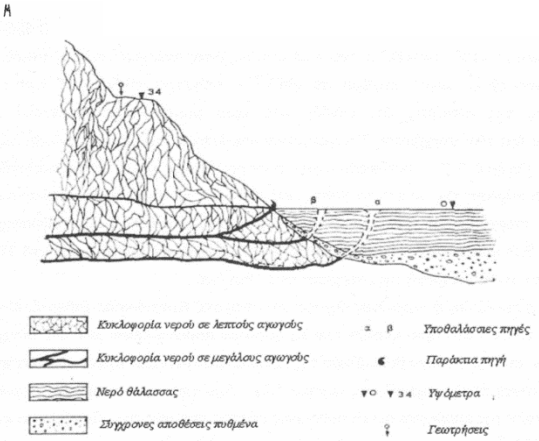


Argolis coastal aquifer system

- Main water problems: seawater intrusion, nitrate contamination
- Hydrogeological setting: multi-aquifer system composed of alluvial and karstified limestones
- Managed Aquifer Recharge optimization is needed
- Karstic spring systems that contribute to the recharge (2.4, 1.6, 14 m^3/sec)

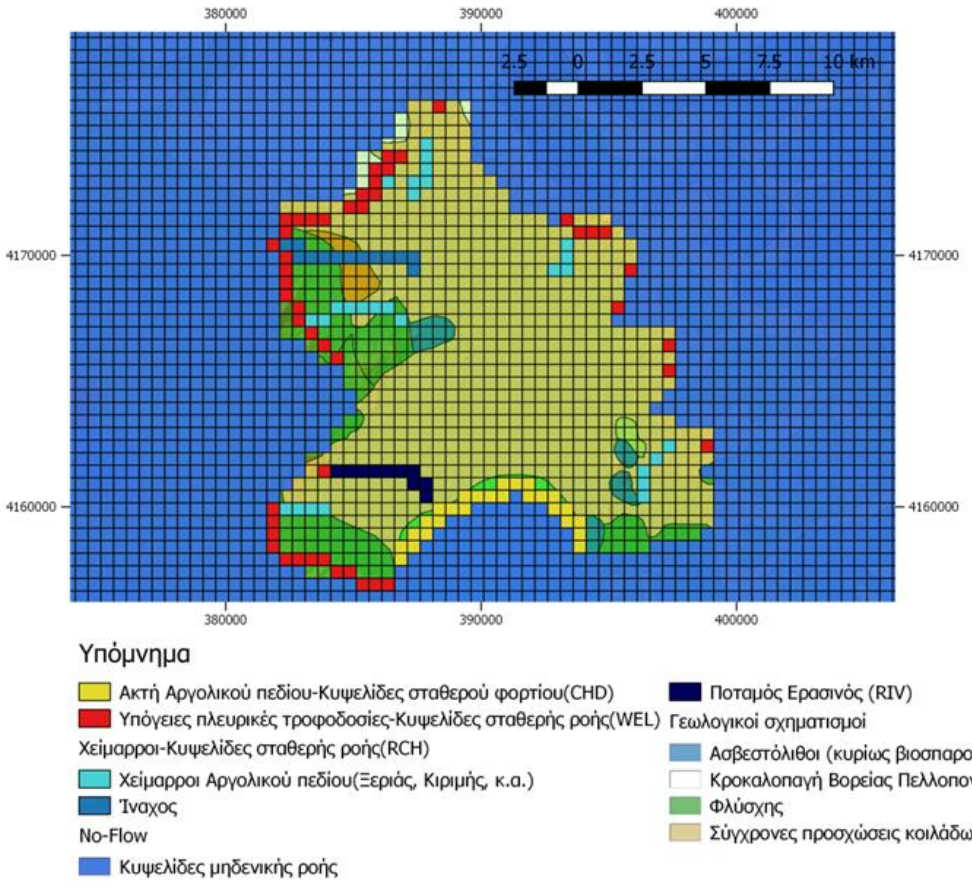


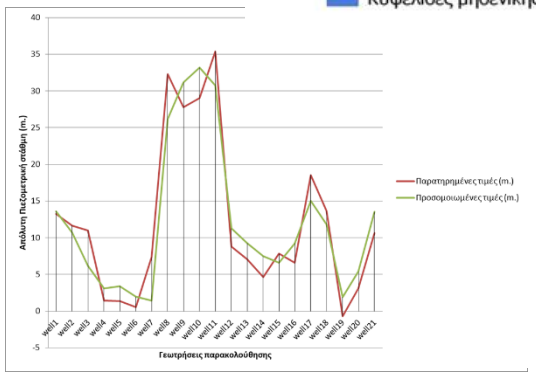


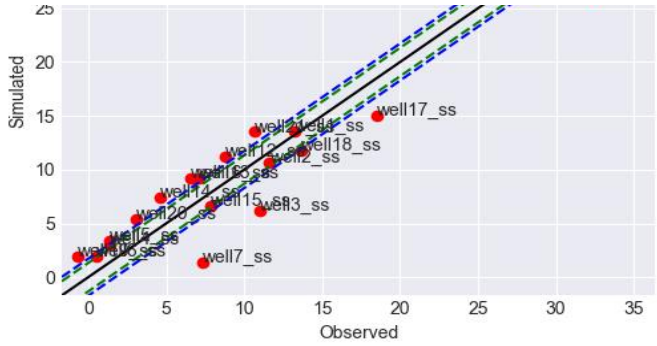


Argolis model

- Active domain and spatial discretization: The active domain of the model area includes a 17.5×20 km region, with cells of 500m.
- Time discretization: 18 stress periods, each representing a month. The number of time steps in each stress period corresponds to the number of days is each month. The first stress period is steady state, while the others are transient
- Hydrologic boundary conditions:
  - General head boundary (GHB)
  - Constant head (CHB)
  - Well (WEL)
  - Recharge (RCH)
  - Drain (DRN)
  - River (RIV)
  - No flow

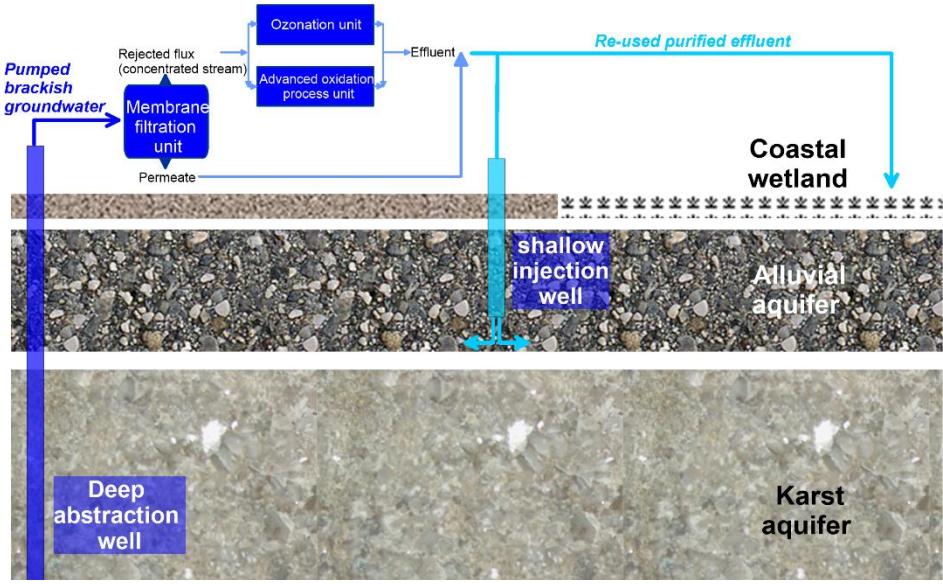


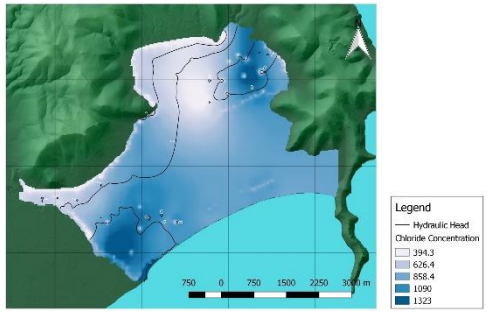


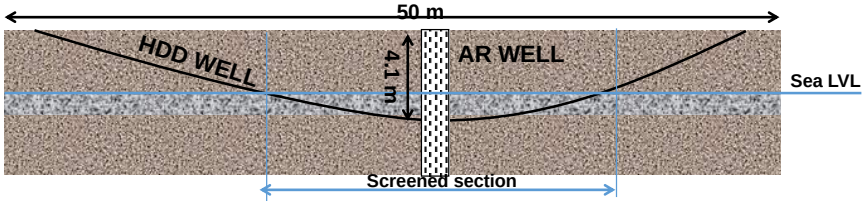


Marathon model expansion

- Utilization of deep GW resources of karst aquifer
- Advanced treatment of contaminated GW
- Dual use of treated GW:
  - Seawater intrusion barrier along the coast
  - Restoration of Schinias wetland
- Multi-directional drilling and MAR optimization schemes







Part 2. AOP-RO hybrid water treatment unit

- Novel AOP hybrid
- Reduces organic content (AOP)
- Reduces inorganic content (RO)
- Remotely monitored/controlled

Performance Data

Conductivity of raw water (average)	4600		µS/cm
	(typical)	(extreme)	
Feed water Temperature	25	46	°C
Conductivity of product water	167	309	µS/cm
Conductivity of rejection water	13532	14698	µS/cm
Conductivity of discharge water	6556	6309	µS/cm
Product water flow rate	2.5	2.4	m^3/h
Rejection water flow rate	1.2	1.0	m^3/h
Pressure RO membranes	8.9	6.5	bar
TOC of raw water (average)	2.2		ppm
TOC of product water (average)	0.2		ppm

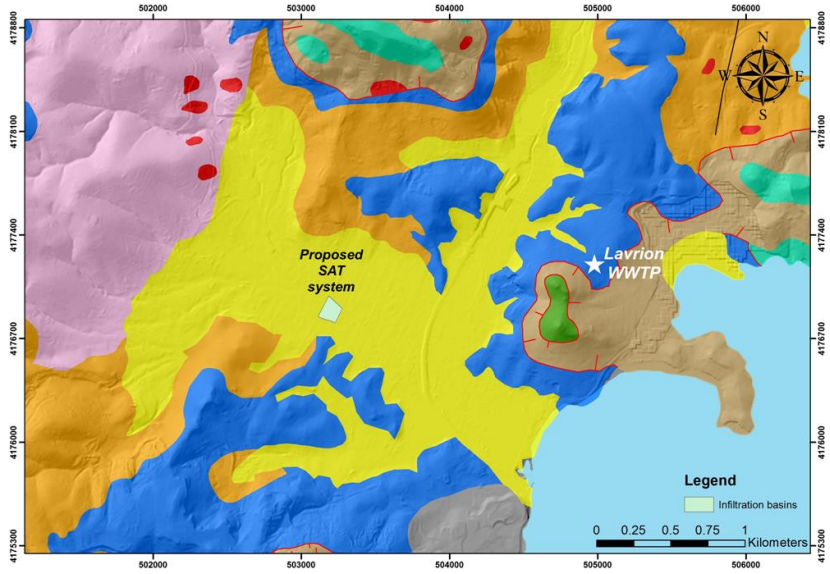
Lavrion model expansion

- The participatory modeling involved the main stakeholders:

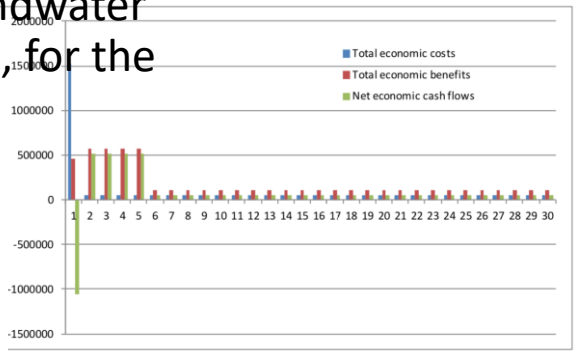
•Local Municipal Company for the Wastewater Management of Lavrion: Maximization of wastewater re-use of the local WWTP of the municipality.

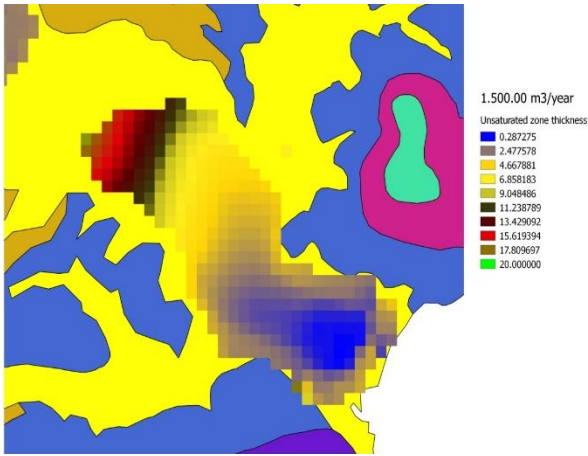
•Local farmers association: Increase of agricultural area extent and groundwater resources potential within the alluvial aquifer

•Water Authority of Attica: Preservation of the good ecological status of the groundwater systems of the entire Attica Region, for the



Total economic costs	1,521,600	57,550	57,550
Investment costs	1,521,600	0	0
O&M costs	0	57,550	57,550
External costs			
Total economic benefits	462.700	570,950	108,250
Operating revenues	0	108,250	108,250
External benefits (SWI reduction)	462,700	462,700	0
Net economic cash flows	**-1,058,900**	**513,400**	**50,700**





Argolis model expansion

Development of modelling concepts for MAR in coastal aquifers

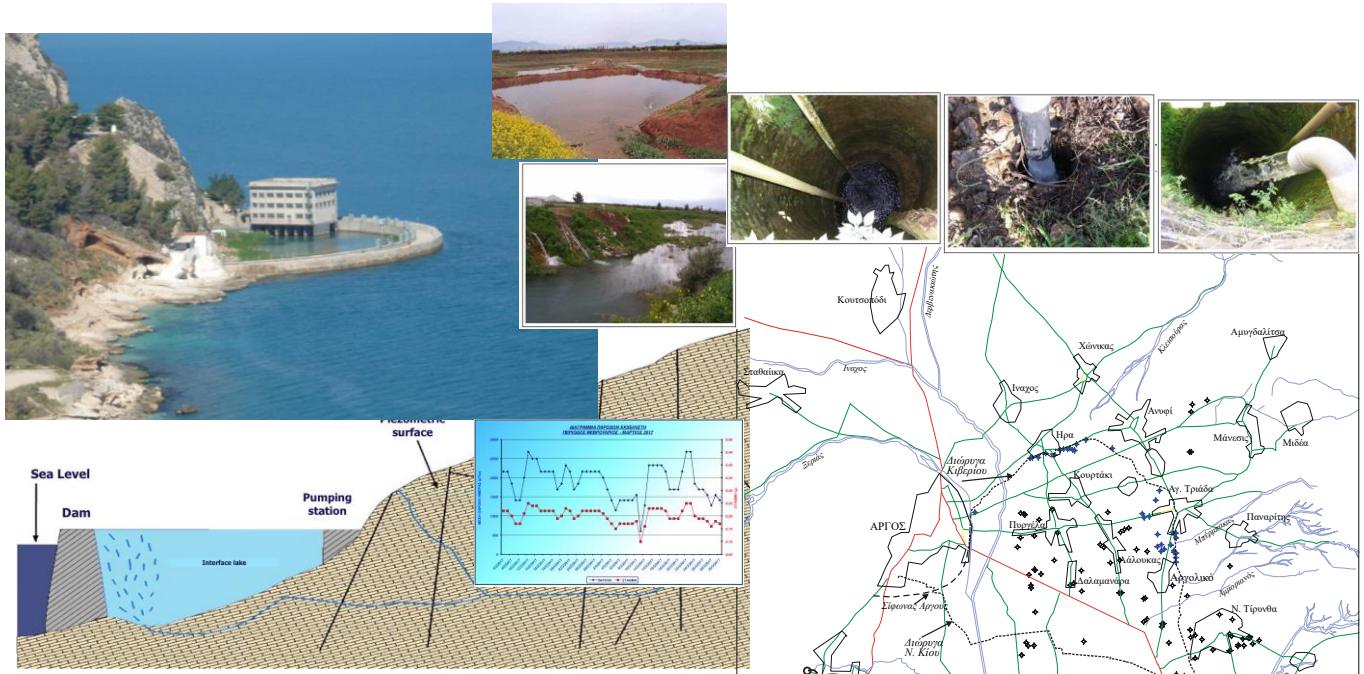
Full stakeholder involvement in WR modelling of MAR scenarios through participatory approach

Valuation of market and non-market uses and services of groundwater via deliberative valuation approaches

Identification of optimal sustainable management solutions to maximize social welfare through participatory modelling and deliberative monetary valuation findings

STAKEHOLDERS

- Special Secretariat for Water (Min. Env.);
- Regional Unit of Argolis,
- Dep. Of Agric. Development & Fishery;
- Local Union of Municipalities & Communities of Argolis;
- Union of Agric. Coop. of Argolida (34 Agric. Coop.);
- Fishery Associations of Nafplion & N. Kios;
- Hotel Associations of Argos, Mycenae, Nafplion



PERIOD	N. Kios Canal	Anavalos Canal	Total	Costs
1990-2017	28.3×10^6 m^3	77.1×10^6 m^3	105.4×10^6 m^3	982.978,64 €

Concluding remarks

- Current activities: model improvements, SEAWAT applications
- FREEWAT: what about QGIS3xx and CFP?
- Participatory modeling benefits
  - **Social benefits** – because they promote equity amongst users and avoid groundwater access being dominated by a few
  - **Economic benefits** - because they encourage balance with long-term potential of the resource, avoid resource collapse and optimize pumping costs
  - **Technical benefits** – because they usually lead to better estimates of water abstraction and more precise understanding of the groundwater balance
  - **Management benefits** – because they trigger local stakeholders initiatives to implement demand and supply measures and reduce the cost of regulation.

LIFE REWAT project partners

Supported by

LIFE REWAT project co-financers

Patronage

This presentation is given within the framework of the EU LIFE REWAT project. The REWAT project has received funding from the European Union's Life Programme LIFE 14 ENV/IT/001290.
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