Water reuse in El Port de la Selva: Groundwater modelling of Soil Aquifer Treatment (SAT) for reclaimed water

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The DEMOWARE project

Subtask 12.2 SAT for indirect potable reuse and saltwater intrusion control

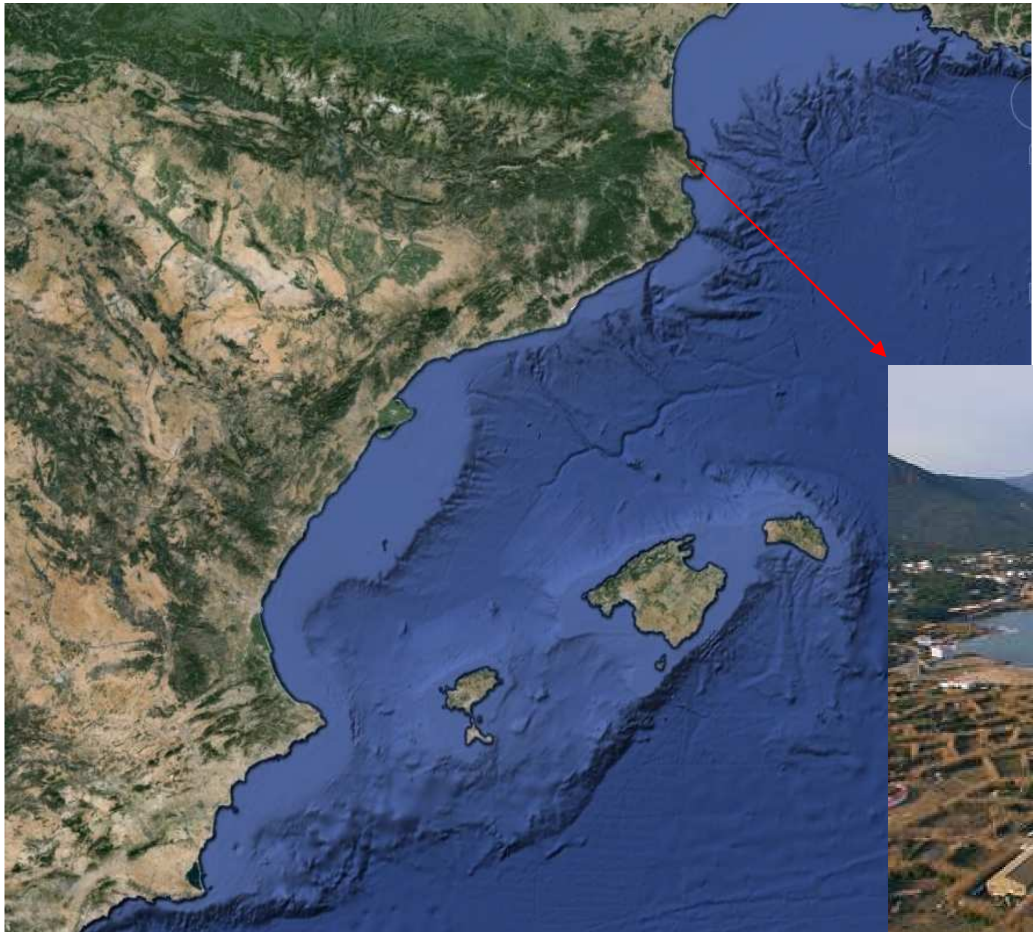
- Through the DEMOWARE project, in El Port de la Selva site, Soil Aquifer Treatment (SAT) will be demonstrated as an innovative hybrid and low cost/low energy filtration/disinfection reuse scheme including seasonal storage and additional benefits like seawater intrusion control and increased availability of groundwater for potable use.

Partners:

- Kompetenzzentrum Wasser Berlin (KWB)
- Veolia Water Systems Ibérica (VWSI)
- Amphos 21 (A21)
- Local partners (CCB, EMBACSA, SOREA, Ajuntament de El Port de la Selva)

Agencia Catalana de l’Aigua

The site



In el Port de la Selva water supply relies on **groundwater** as the village is not connected to the water network.

The site

Construction of infiltration basins and piezometers for monitoring.

Quartz sand of minimum 80% SiO_2
Specifications:

Filter layer	
Grain size, (mm) max 5% max 5 %	0.4-0.8 < 0.4 mm > 0.8 mm
Uniformity, d60/d10 (-)	<1.5
Bulk Density (t/m³)	~1.55 (1.4 – 1.7)
Pond design	
Area	160 m² + 160 m² + 190 m² Total: 510 m²
Thickness (m)	0.5
Total sand volume amount	255 m³ ~400 tons

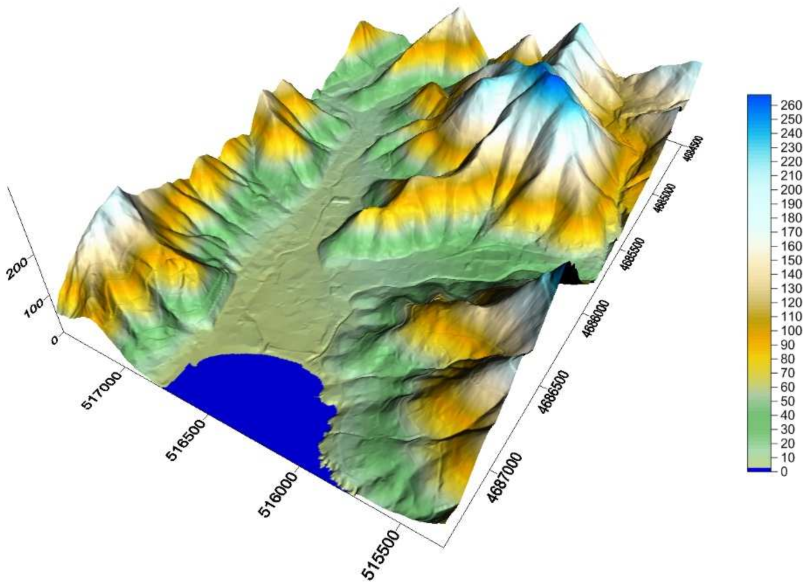
The site

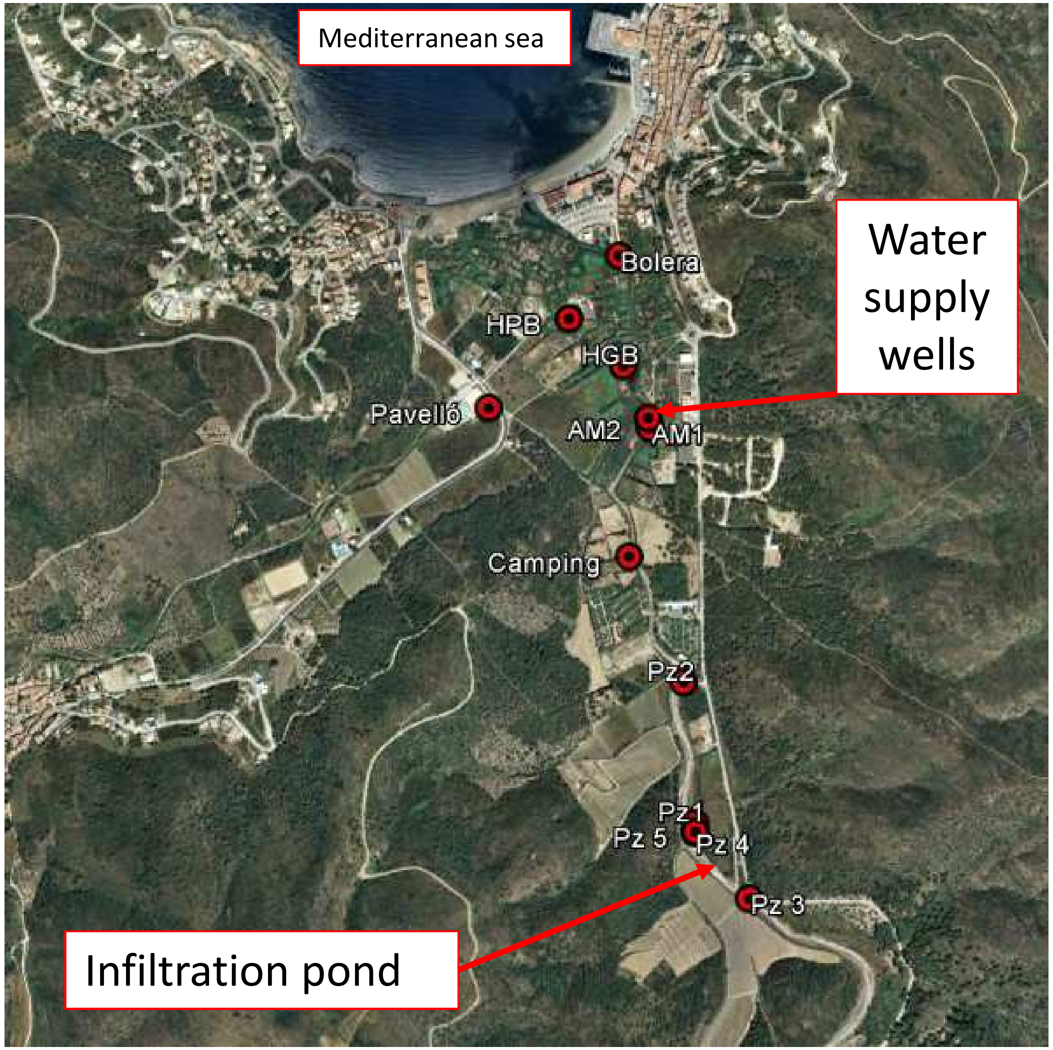
Infiltration basins in operation since 18 November 2015: picture trial test ≈ 60 m^3/h.

The site

-Basin: 10.5 Km^2.
-Alluvial formation: 0.66 Km^2.

-15 monitoring wells in alluvial formation.





Water balance

- Average rainfall is 630 mm/year but below 500 mm/year in dry years

$500\ mm/year$

25% Evapotranspiration

60% Surface run-off

15% Aquifer Infiltration

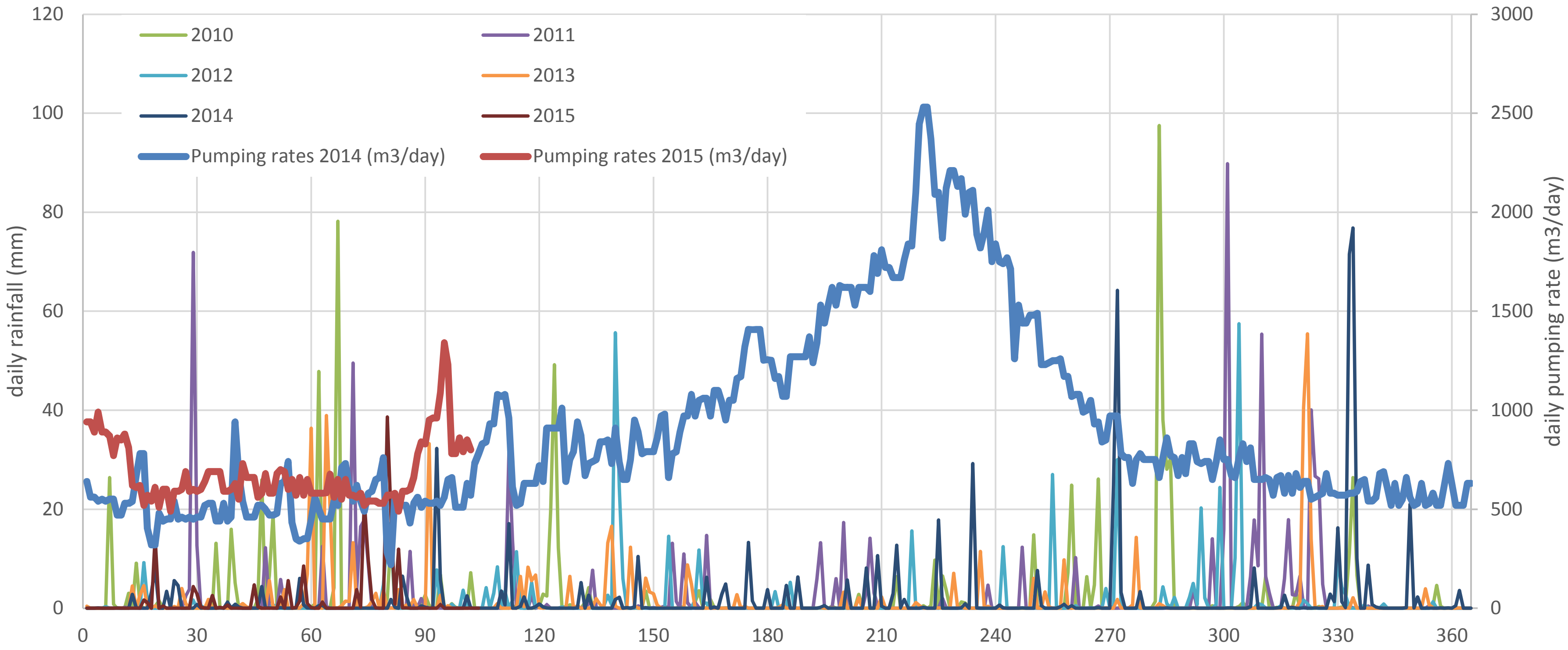
Average infiltration (entire basin: 10.5 Km^2):	2000	m^3/day
Pumping rates during winter	500-600	m^3/day
Maximum pumping rates (summer) :	2500	m^3/day

10000 inhabitants x 200 l/(day x person) = 2000 m^3/day

Initial amount of water infiltrating in basins:	200	m^3/day

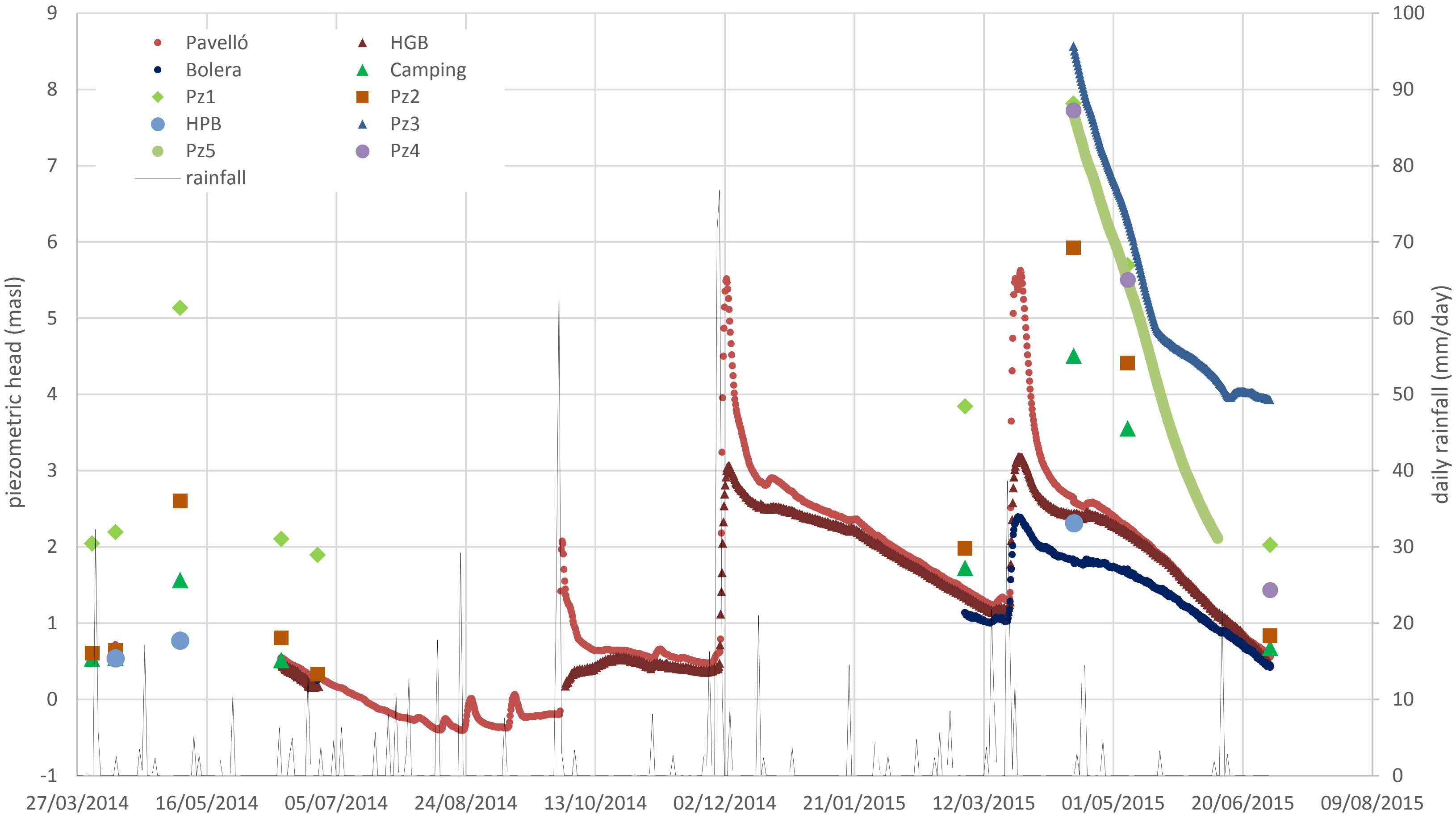
The need

- Water demand in summer is reaches 2500 m³/day
- Rainfall from 480 mm/year in dry years (2012) to 786 mm/year in (2011)



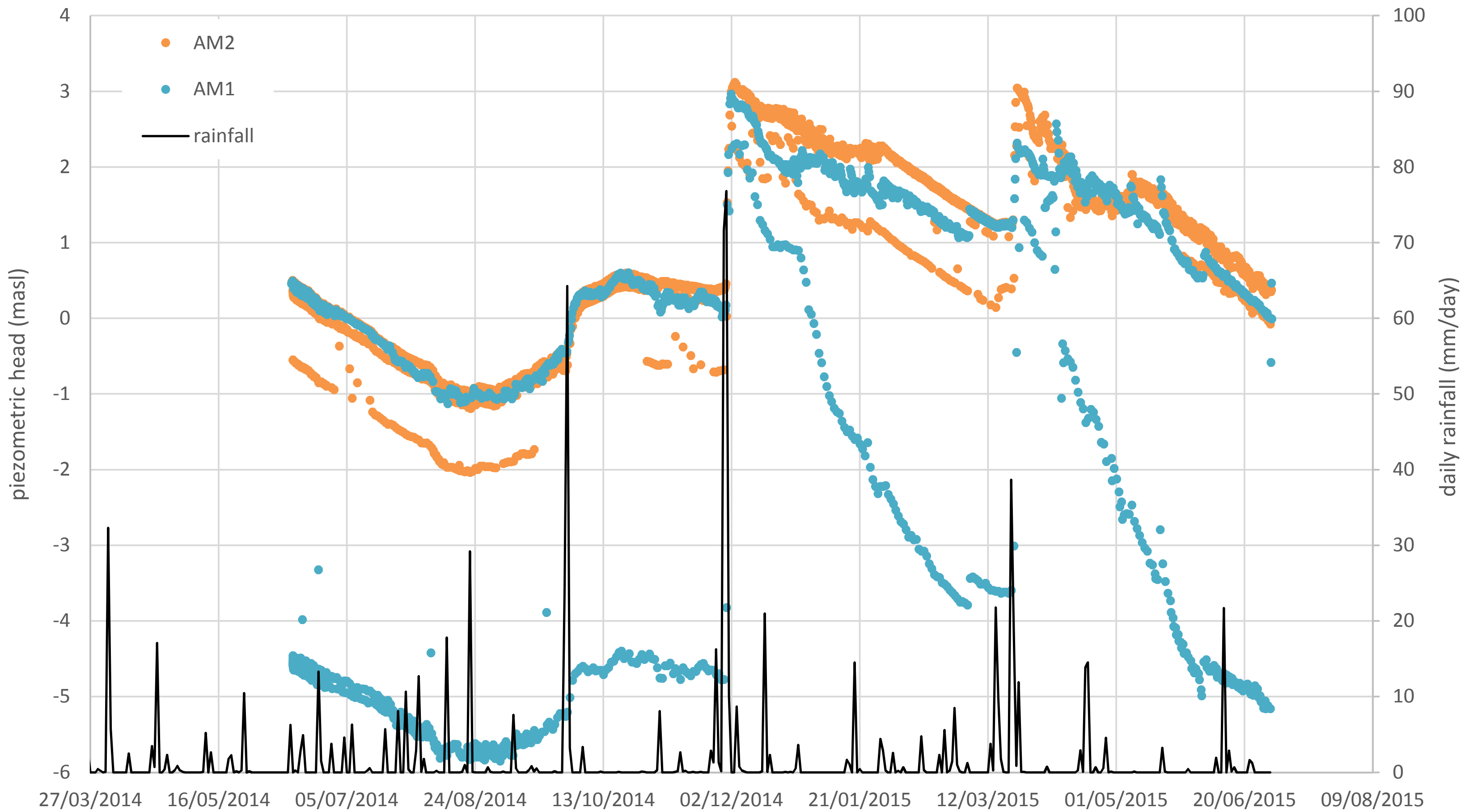
Monitoring hydraulic heads

Heads in monitoring wells

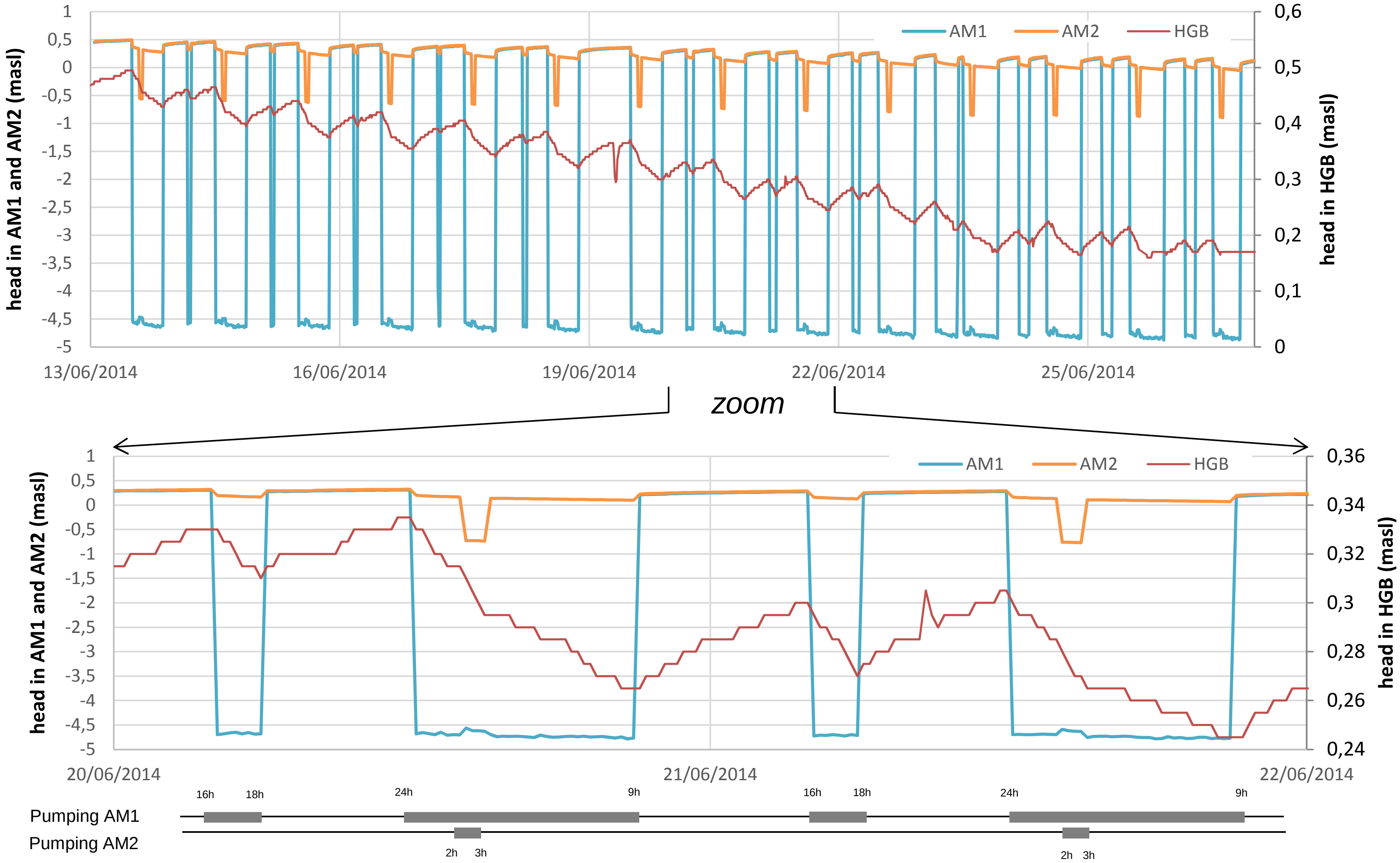


Monitoring hydraulic heads

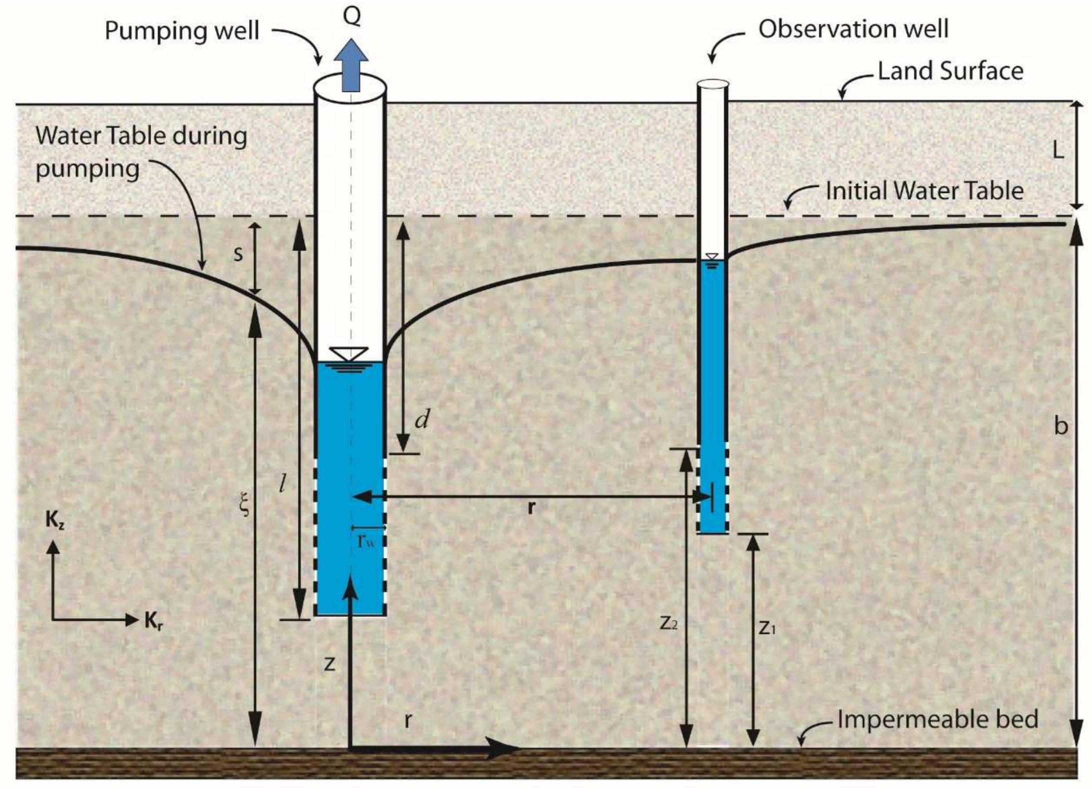
Heads in water supply pumping wells



Monitoring hydraulic heads



Estimates of hydraulic conductivity



Pumping well in an unconfined aquifer: Dupuit (1875)

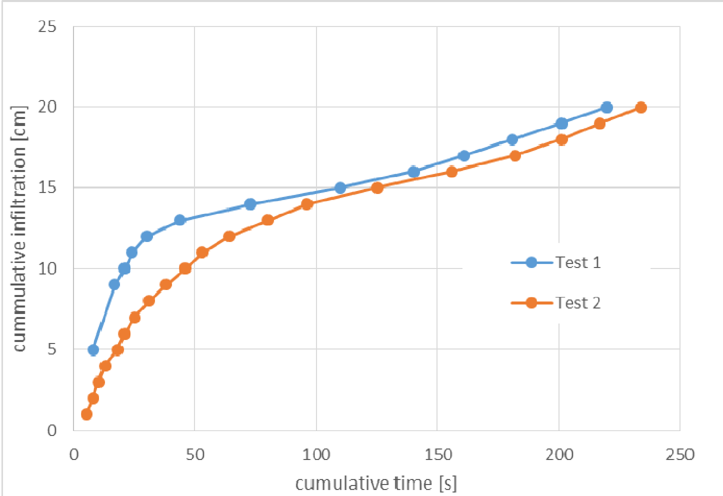
$$h^2(r_2) - h^2(r_1) = \frac{Q}{\pi K} Log\left(\frac{r_2}{r_1}\right)$$

Estimate of K from two observation wells:

$$K = \frac{Q}{\pi\left(h^2(r_2) - h^2(r_1)\right)} Log\left(\frac{r_2}{r_1}\right)$$

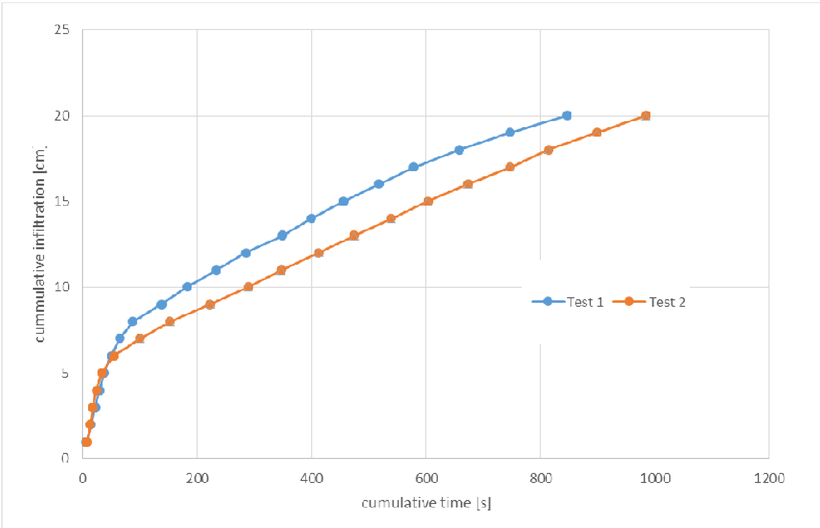
$$K = 218\, m/d$$

Estimates of hydraulic conductivity



Hydraulic conductivity
(river bed)

$$K = 34.6\, m/d$$

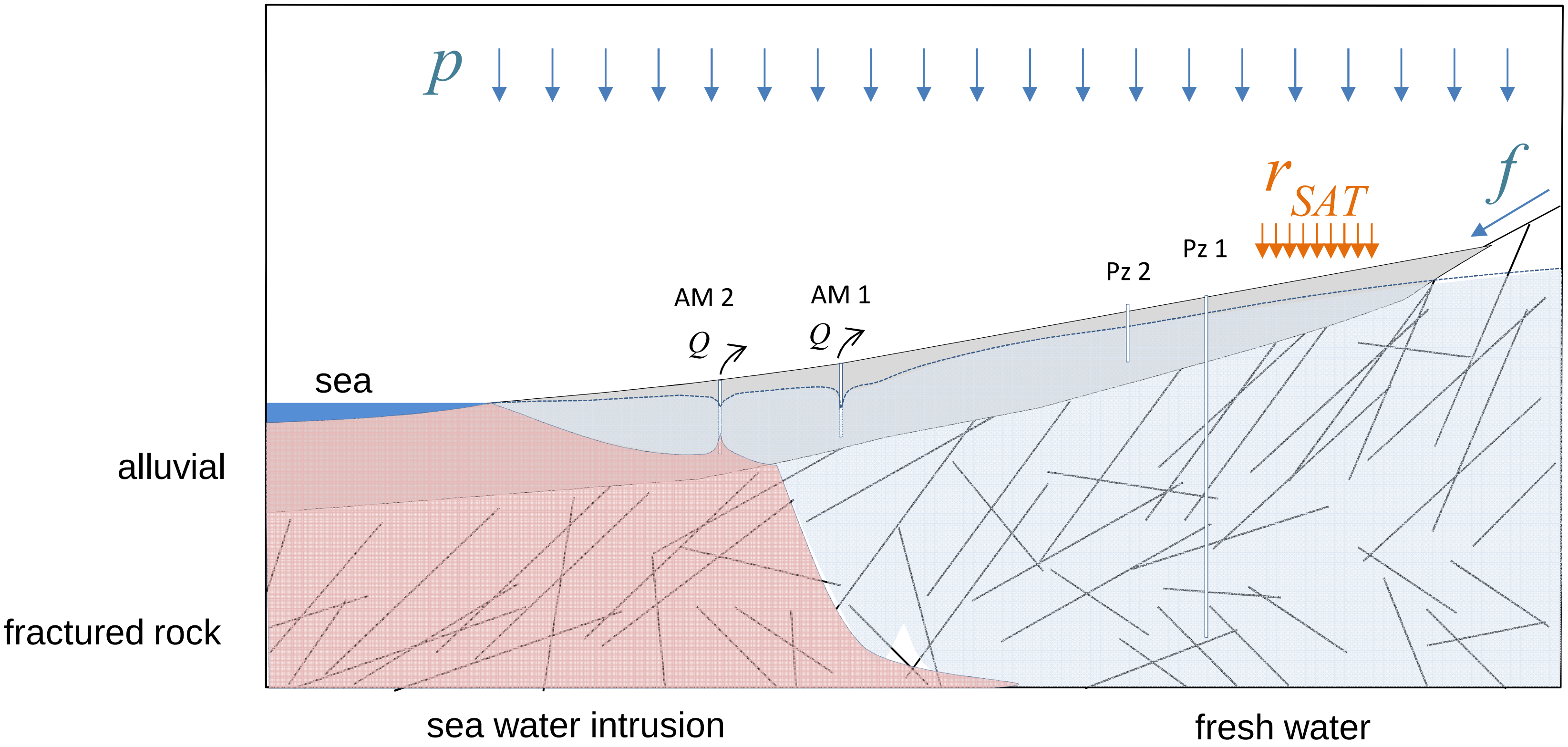


Hydraulic conductivity
(edaphic soil)

$$K = 13\, m/d$$

Hydrological conceptual model

-Water supply wells operate in alluvial aquifer.
-Hydraulic conductivity in alluvial aquifer 50 to 250 m/day.



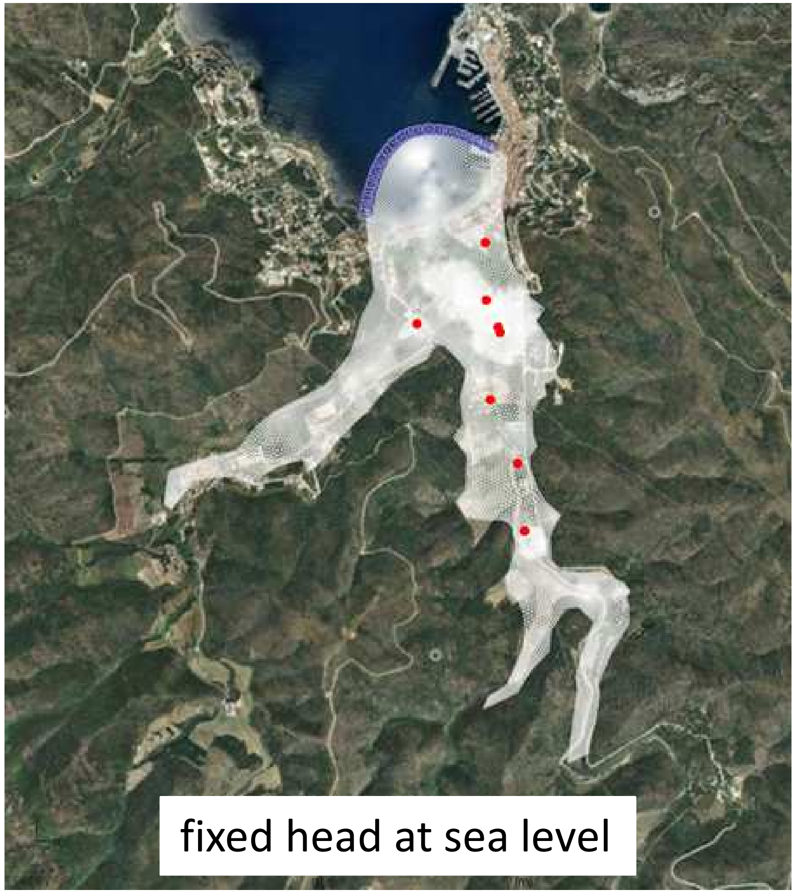
Numerical model development

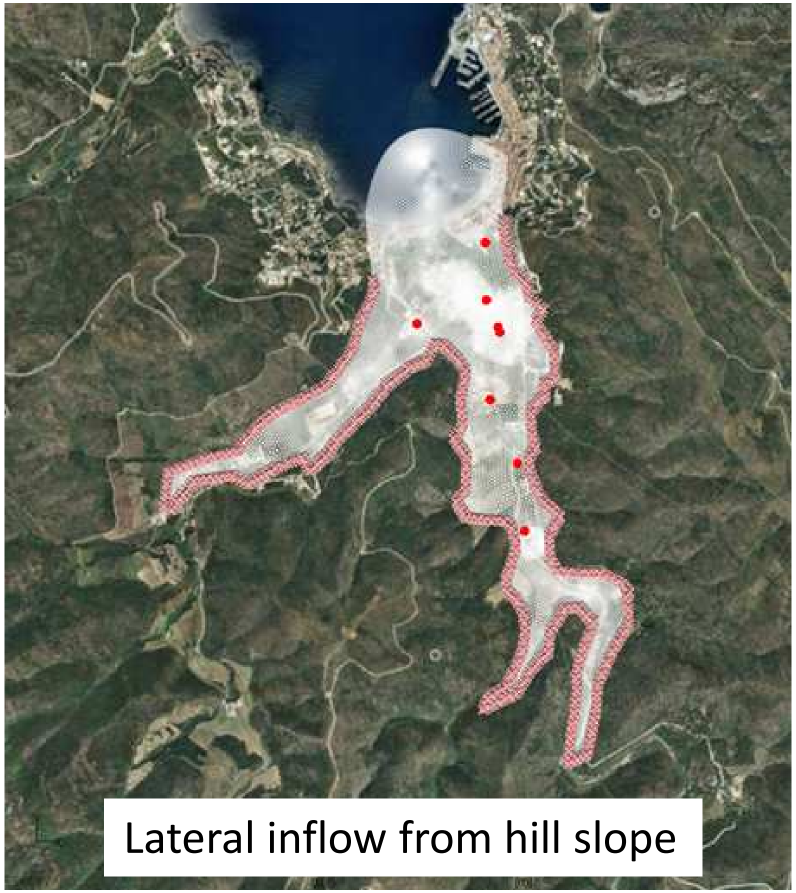
A Finite Element (FE) flow model has been developed to simulate the migration of groundwater downstream the infiltration ponds using FEFLOW (Diersch, 2014).

- Homogeneous hydraulic conductivity (K=250 m/day).
- Aquifer thickness and transmissivity variable in space but independent of hydraulic head (constant in time).
- Transient flow model calibrated for the period 1/1/2013 to 12/4/2015 (877 days).
- Boundary conditions include areal recharge and lateral inflow from hill slope based on rainfall data and fixed head at the sea border.
- Real pumping rates at water supply wells.

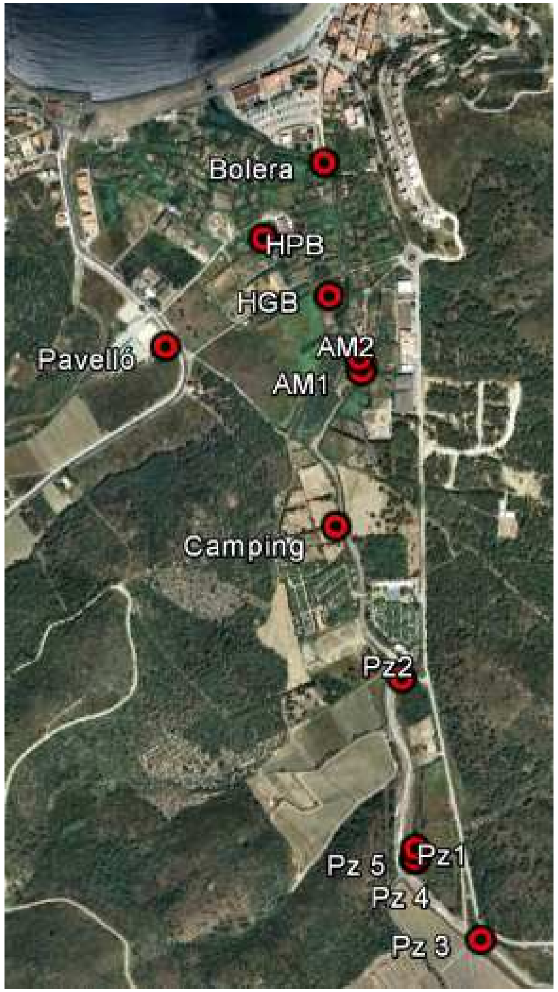
Numerical model development

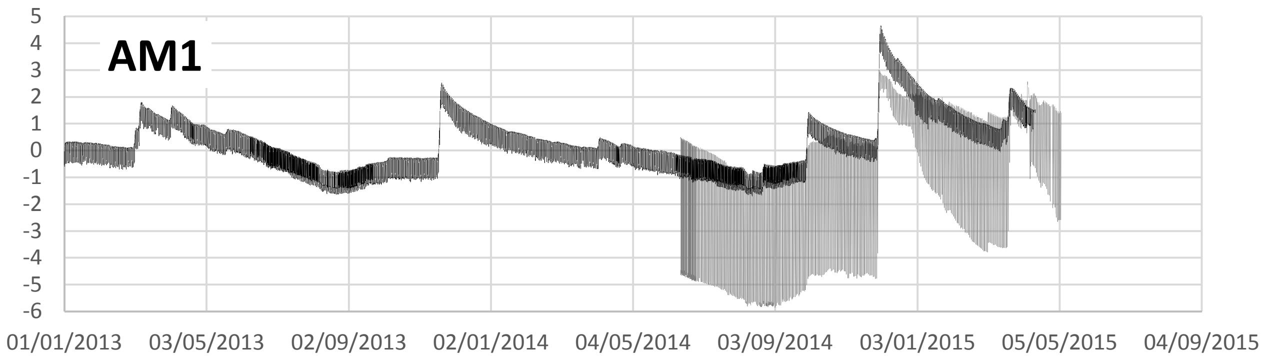
Model discretization, observation points (red dots) and boundary conditions.

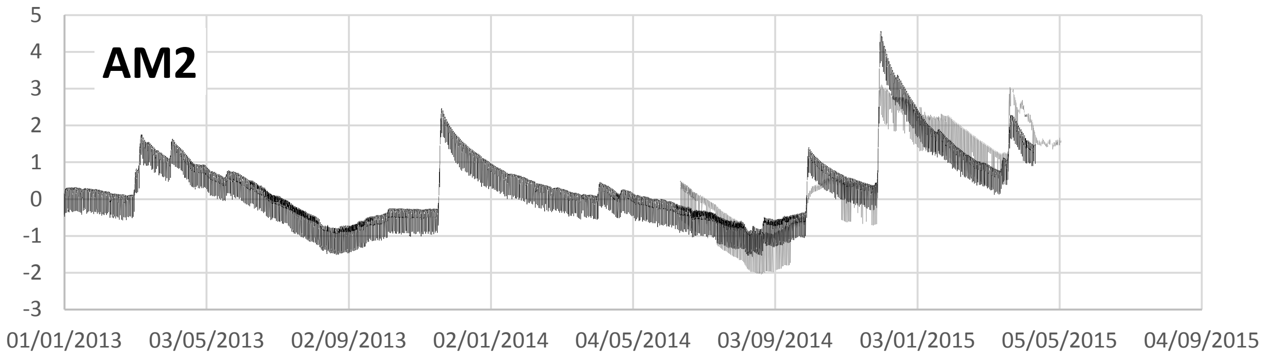




Numerical model calibration







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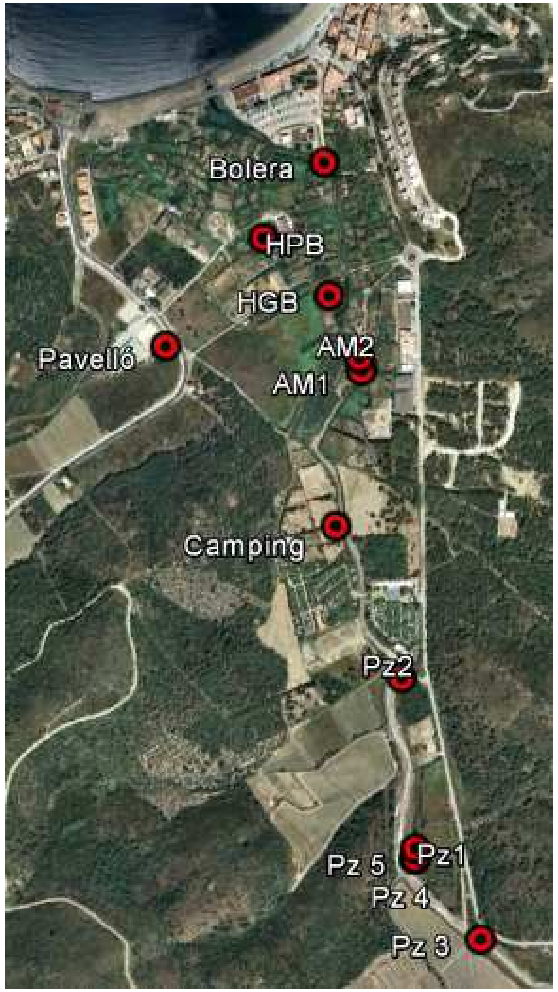

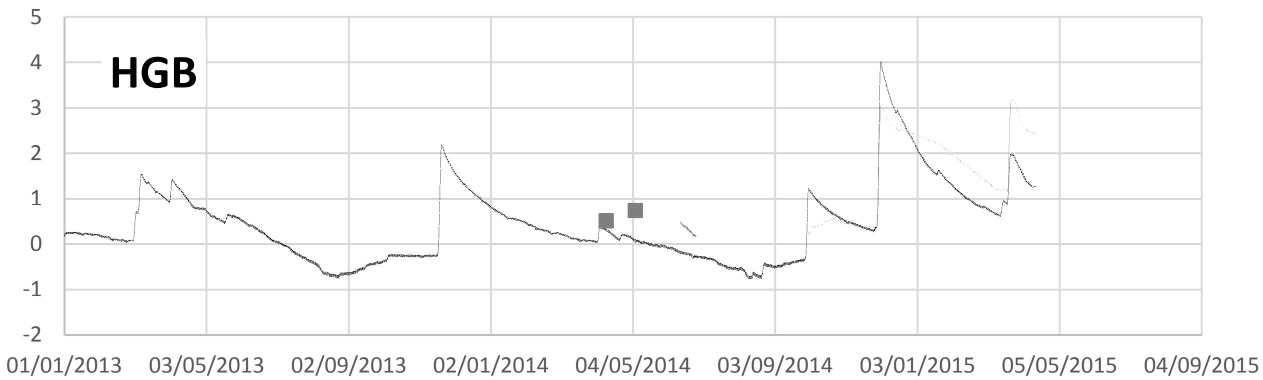

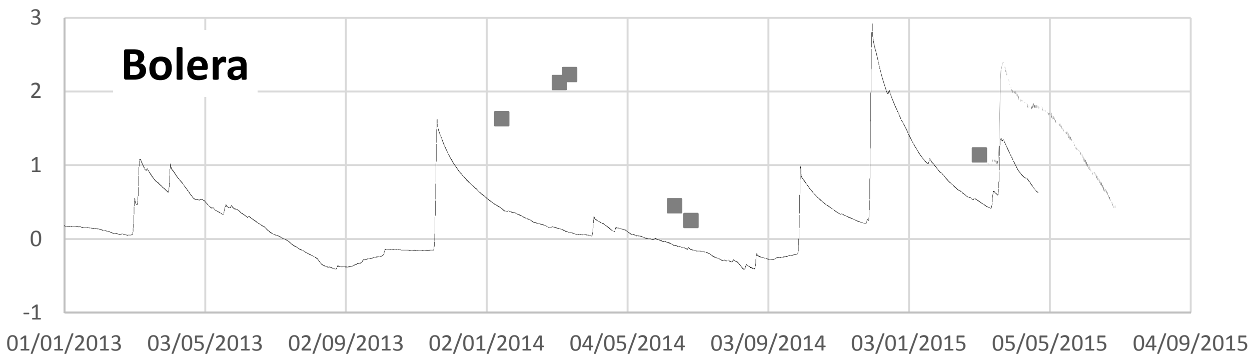

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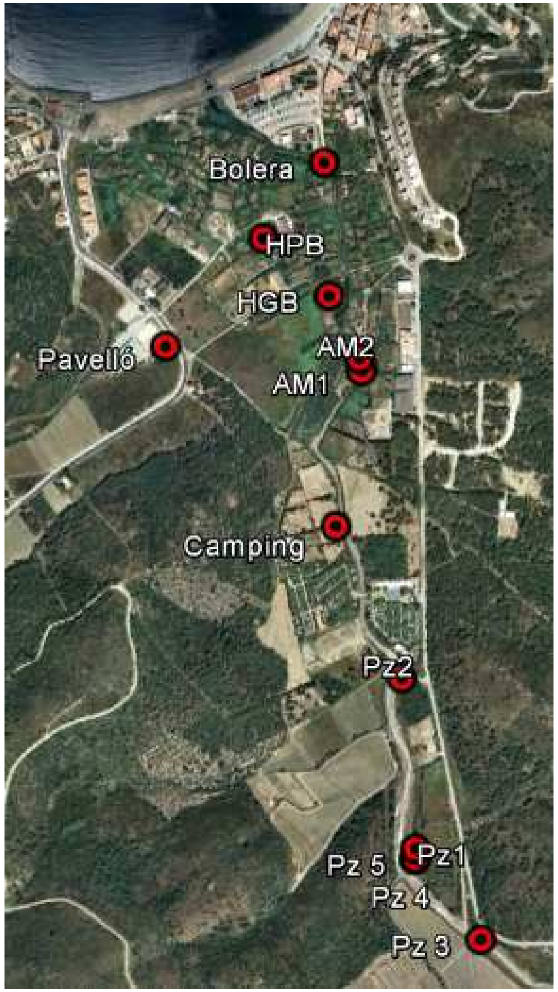

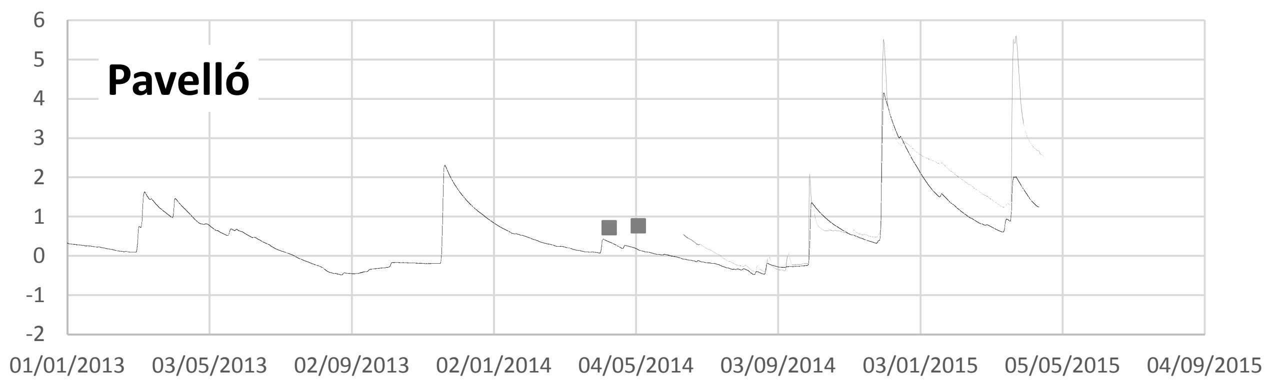

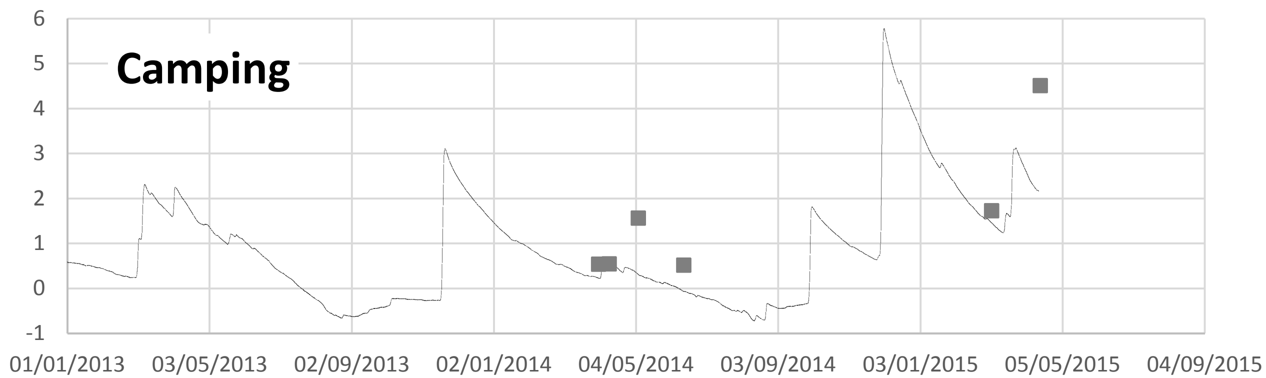

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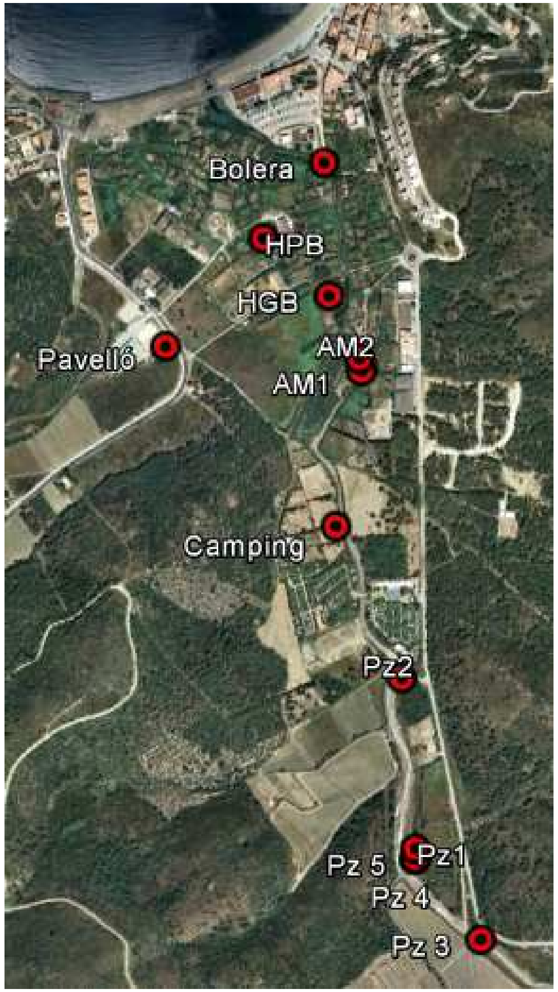

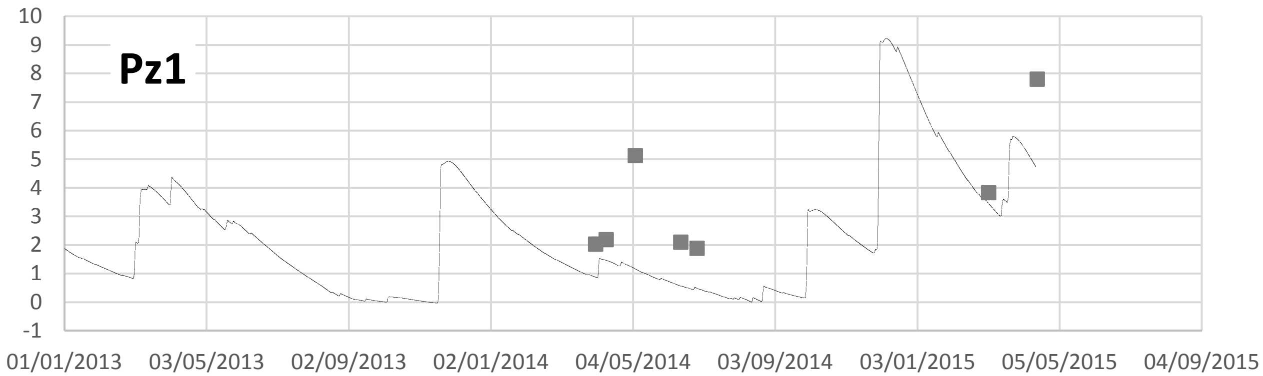

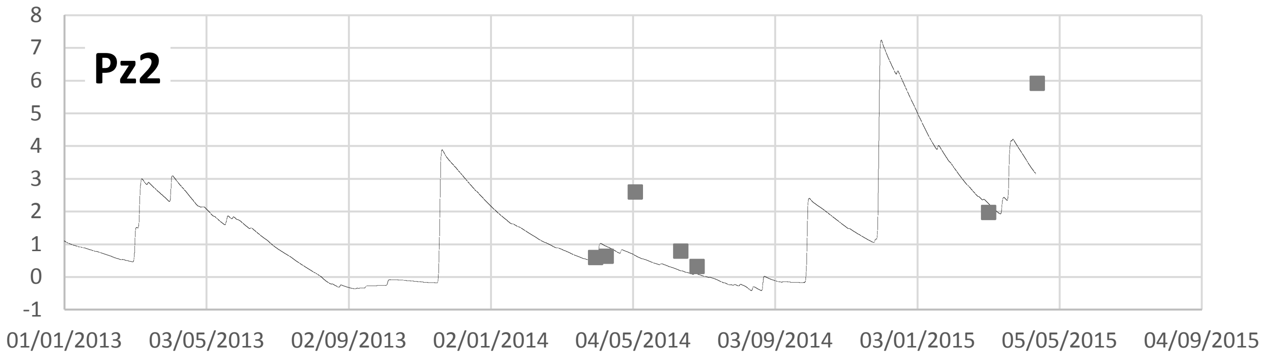

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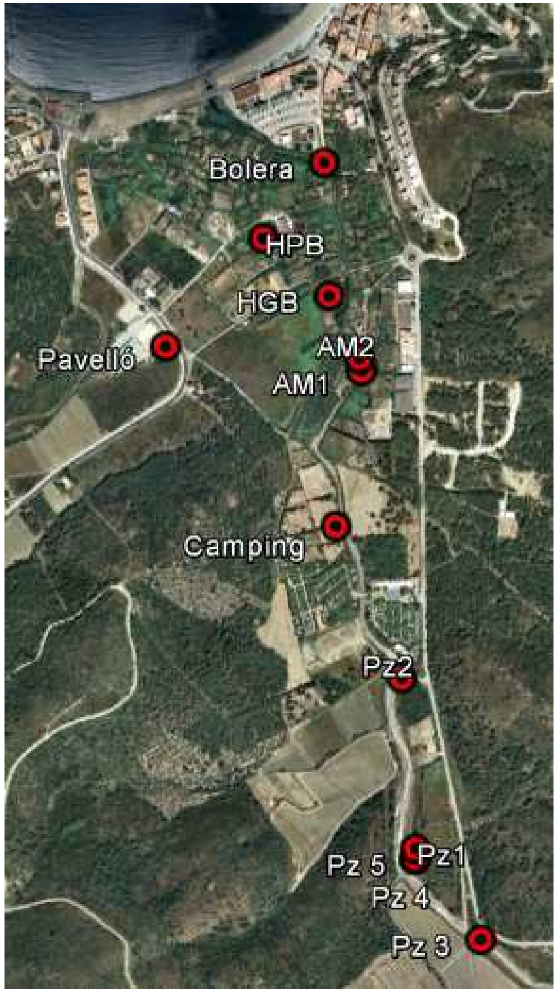
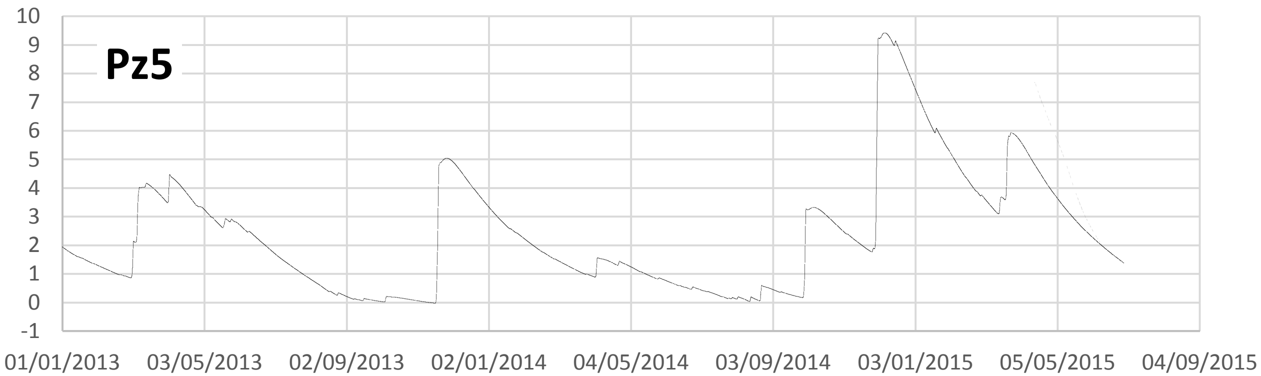
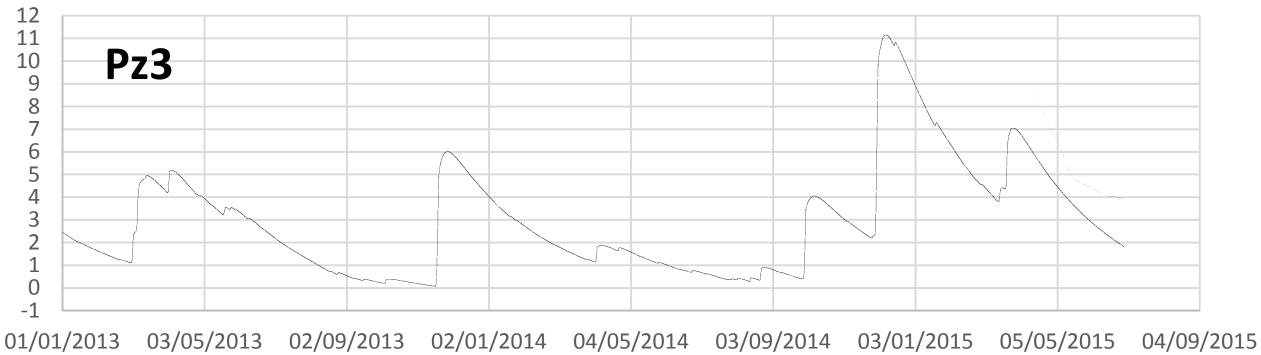




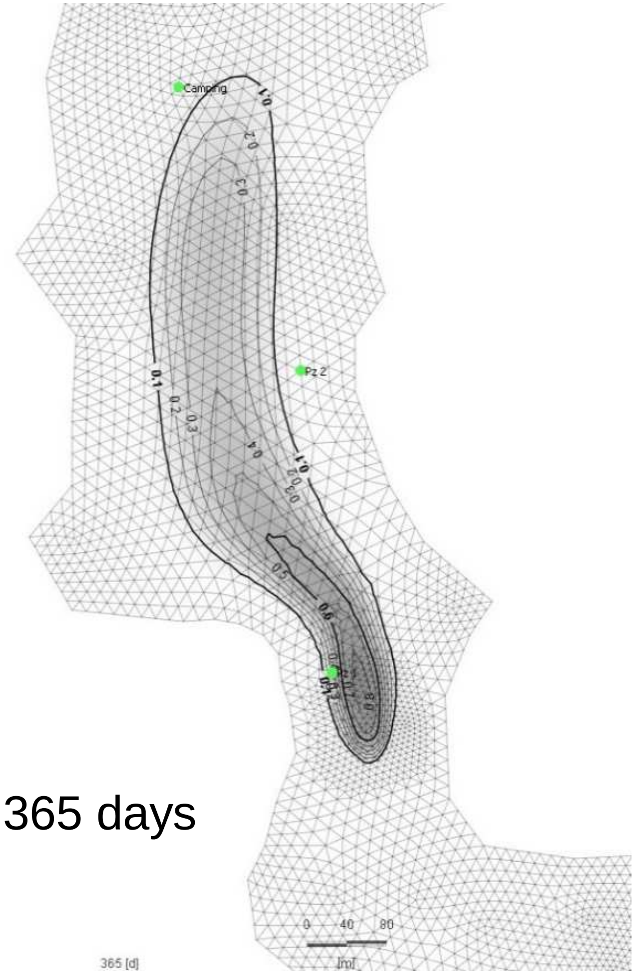


Transport modelling

To simulate the migration of infiltrated water we set up a transport model using the calibrated flow model.

- Homogeneous porosity (n_e=30%), longitudinal and transverse dispersivity (α_L=5 m ;α_T=0.5 m) and molecular diffusion (D=10^{-9} m^2/s).
- Transient flow and transport model for the period 1/1/2007 to 2/7/2015 (3100 days). Recharge and lateral inflow from hill slope from rainfall data sets.
- Average daily pumping rates at water supply wells. Data from 2014 used for all years.
- Infiltration pond starts operation with 200 m^3/day at the beginning of the simulation (1/1/2007)

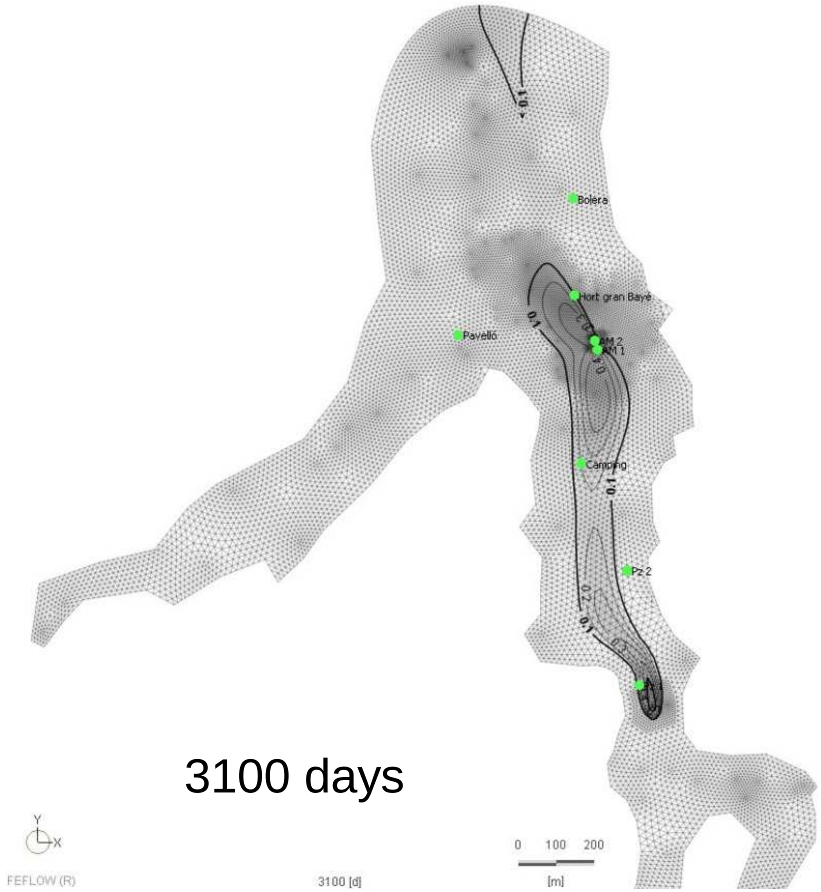
Transport modelling

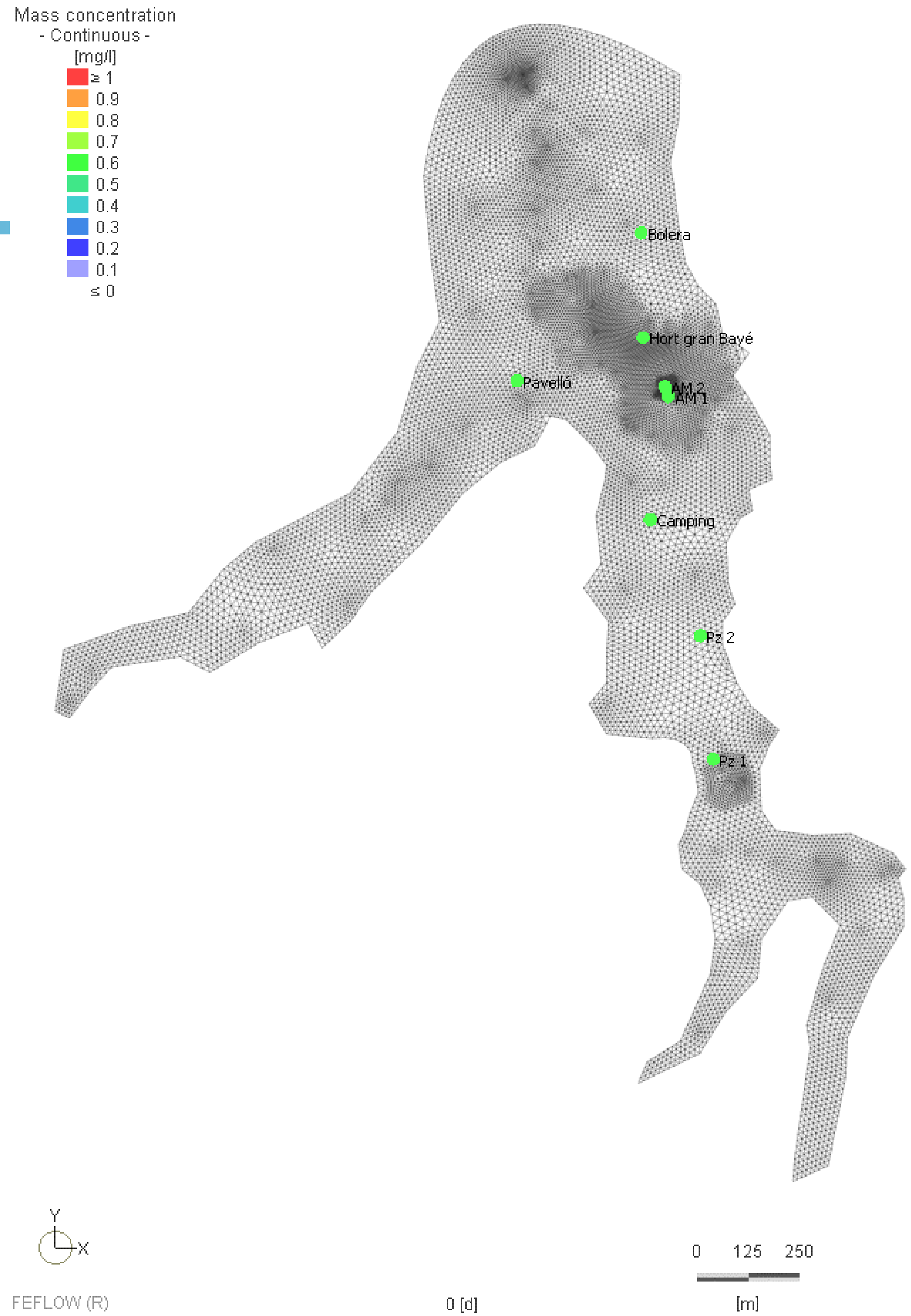


365 days

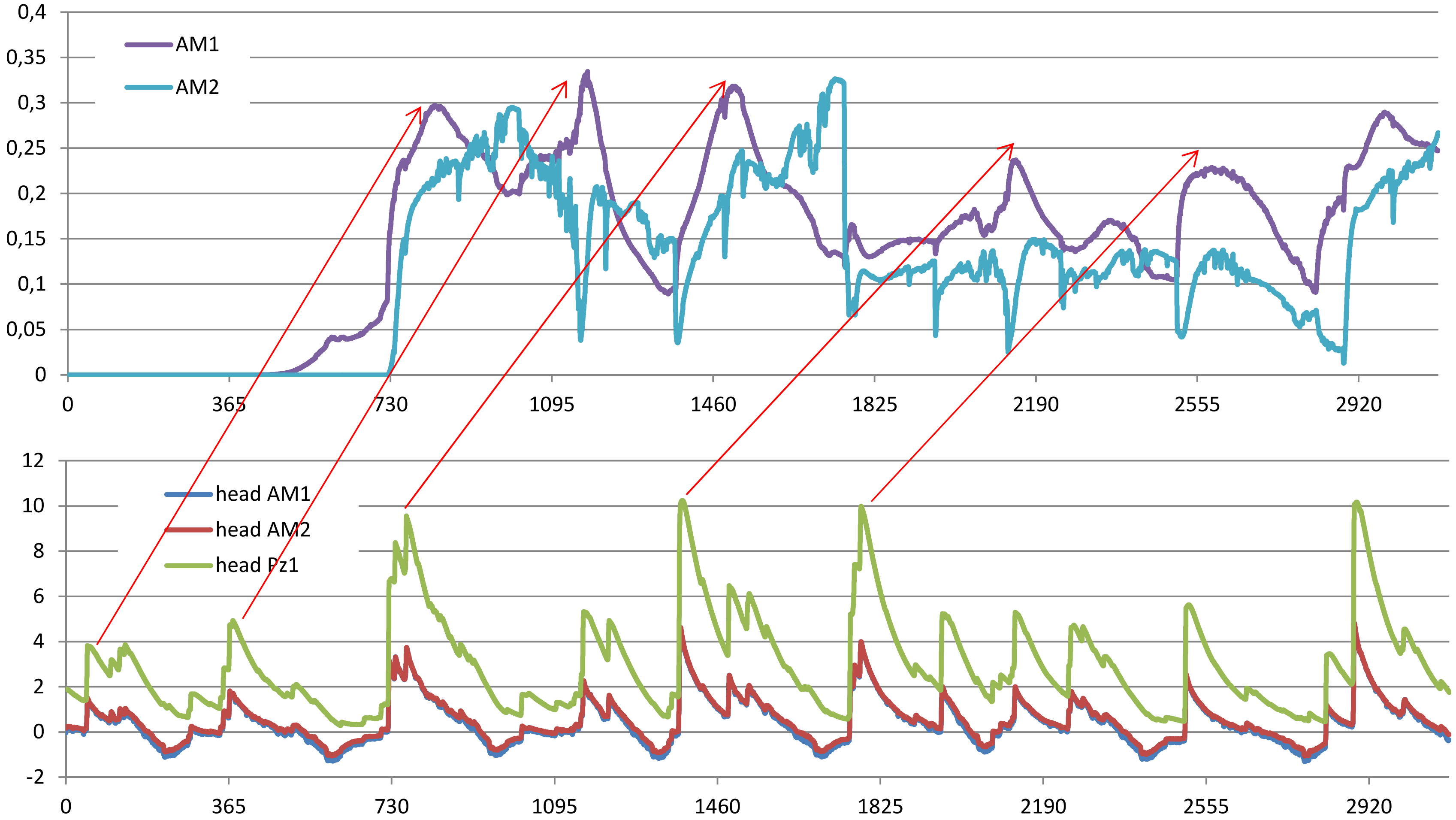
730 days

Transport modelling





Transport modelling



Conclusions

-The numerical model is capable of simulating aquifer response to rainfall events and pumping in water supply wells. It reproduces the observed hydraulic heads with a reasonable accuracy.

-Rainfall is highly variable in time and space.

-Numerical simulations show that breakthrough curves of infiltrated water are strongly influenced by rainfall events.

-Using the model, it will be possible to test the sensitivity of travel time and dilution rate to several aspects such as rainfall scenarios, infiltration rates, pumping rates in water supply wells and (uncertain) aquifer parameters such as porosity and hydraulic conductivity.

-Future work: implement new data on infiltration rates and updated rainfall data sets in the numerical model and process all the data from monitoring campaigns and measurements of E.C. near the basins.

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