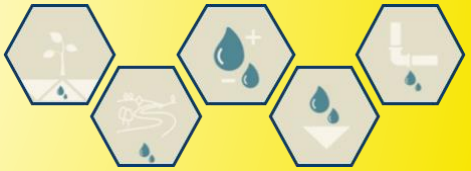
2nd International LIFE REWAT Summer School

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

Managing Induced RiverBank Filtration MAR schemes by means of modelling tools: the Serchio River IRBF

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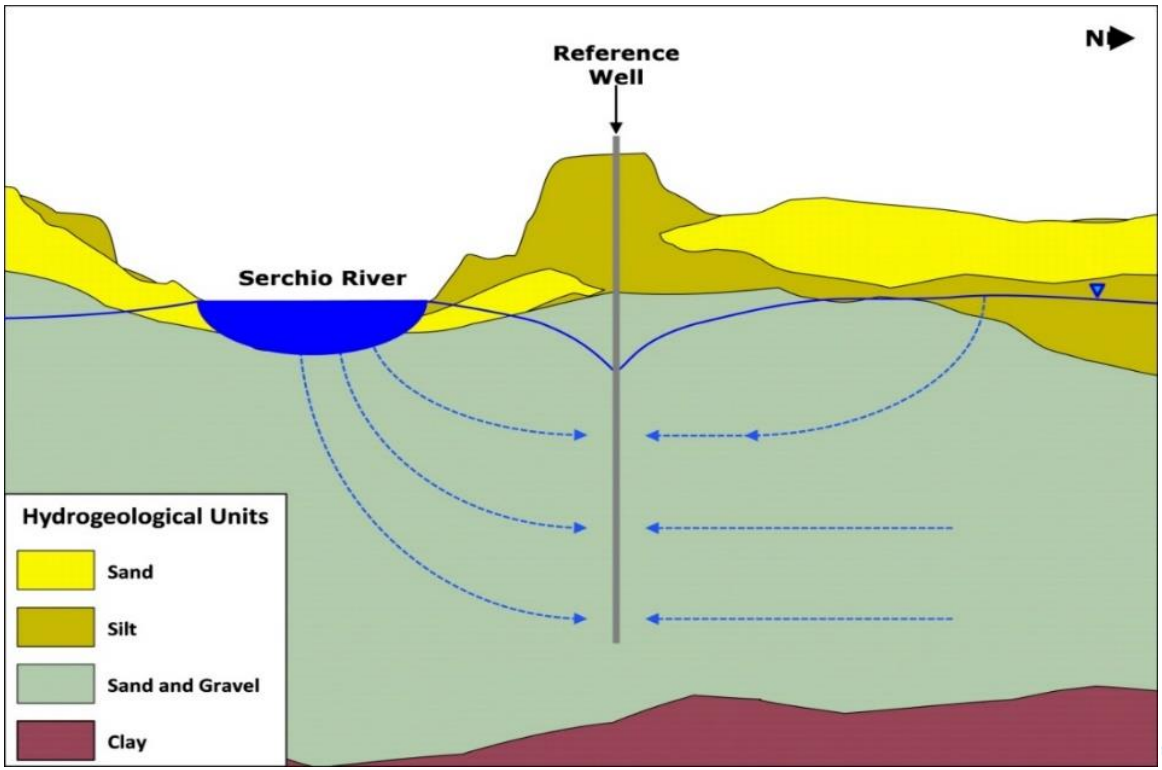
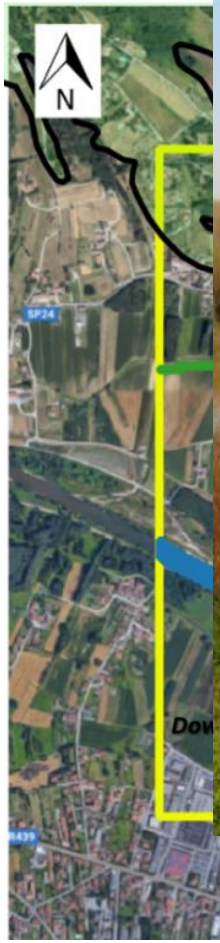
Induced RiverBank Filtration (IRBF)

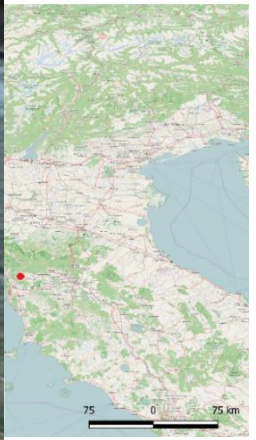
- A widely used technique in Managed Aquifer Recharge (MAR) schemes, when highly conductive aquifers are in hydraulic connection with surface water bodies, with proven positive effects on quality and quantity of groundwater
- It allows abstraction of a large volumes of water, avoiding large decrease in groundwater heads



The IRBF scheme

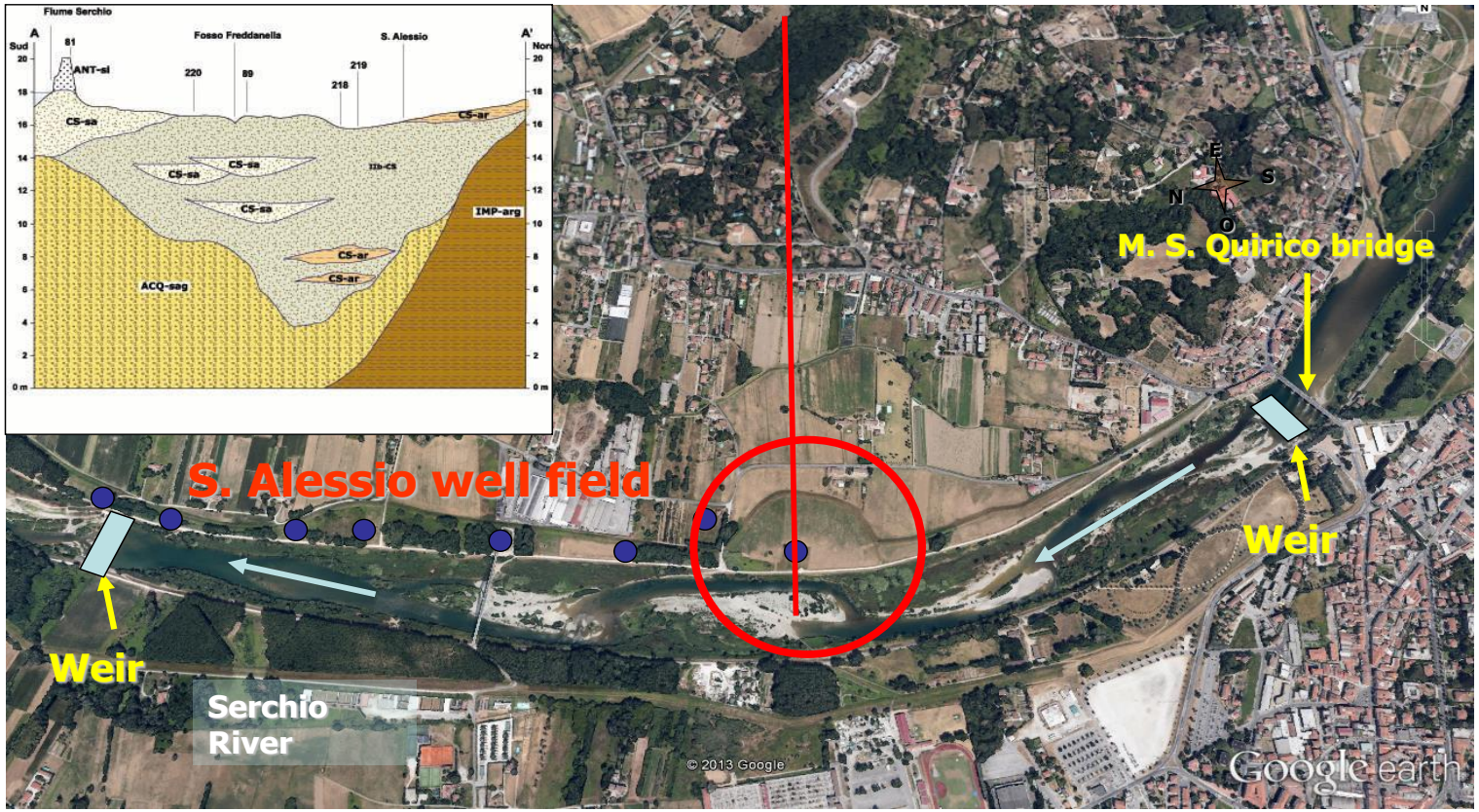
The Serchio River IRBF (Lucca, Italy) along the Serchio river allows abstraction of an overall amount of about 0.5 m^3/s providing drinking [illegible] mainly to the town [illegible]





REWAT
sustainable water management in the lower Cornia Valley

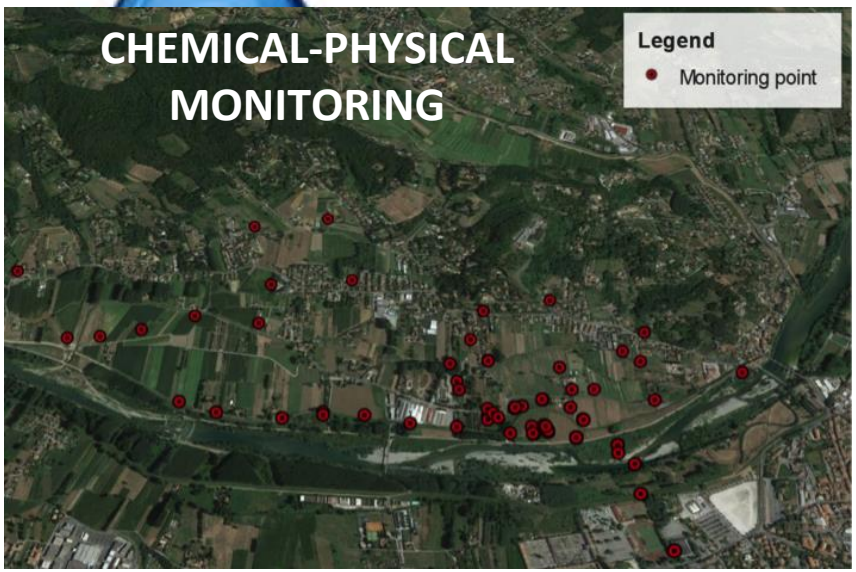
Hydrostratigraphic setup



- Superficial cover: sandy to silty-clayey sediments
- Alluvial aquifer: sandy-gravelly sediments
- Impervious clayey layer

MONITORING SYSTEM: discrete sampling

- 70 points
- 12 surveys
- 6 in situ parameters
- laboratory analyses



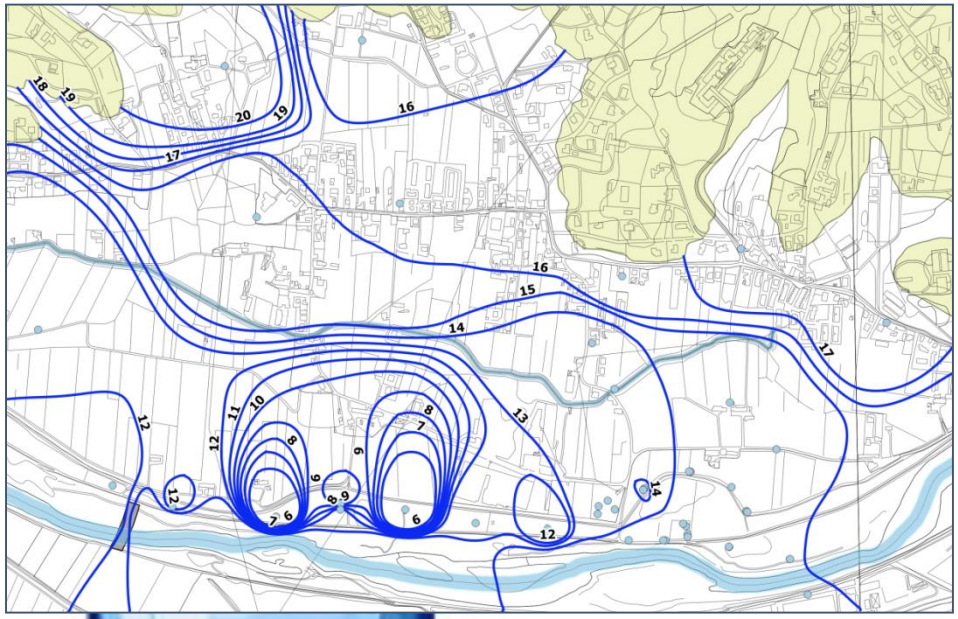
Type		n°
Surface water		4
Groundwater	Piezometer	36
	Well	15
	Pisa-Lucca pipeline	13

2014	2015	2016
November	January	January
December	February	March
	March	May
	May	July
		August
		September

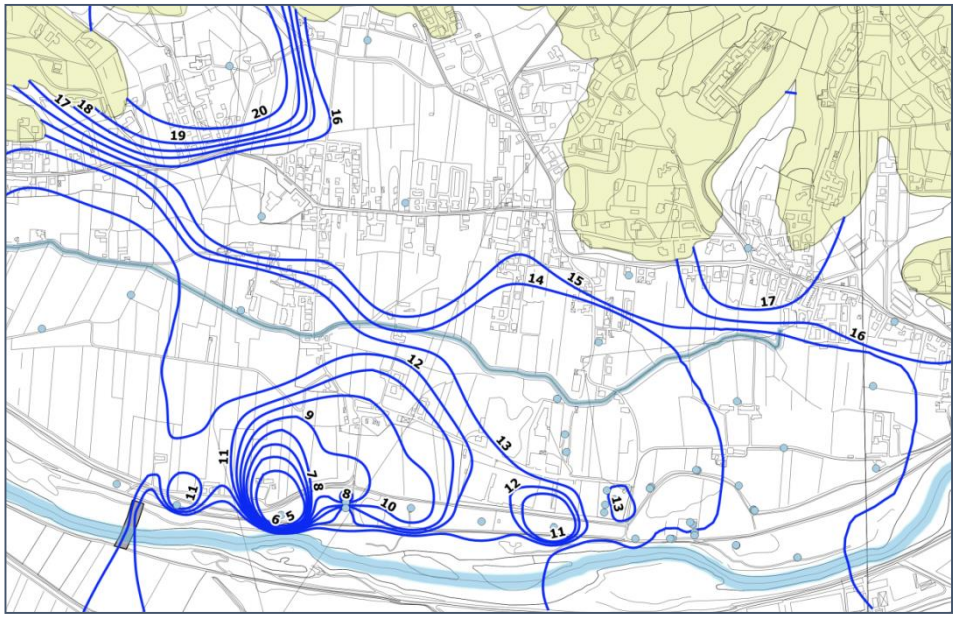
Water quality analyses
Major and trace elements
Stable isotopes ($\delta^{18}O$ and δD)
Microbiological parameters (E.Coli and Total Coliform)
Emerging contaminants

HYDRAULIC HEAD

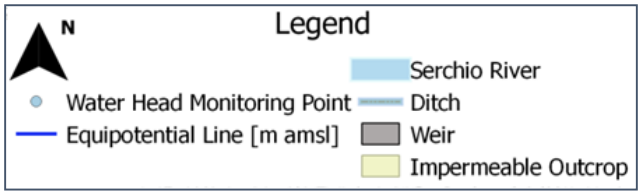
- 3 main flow directions
- no direction changes in time



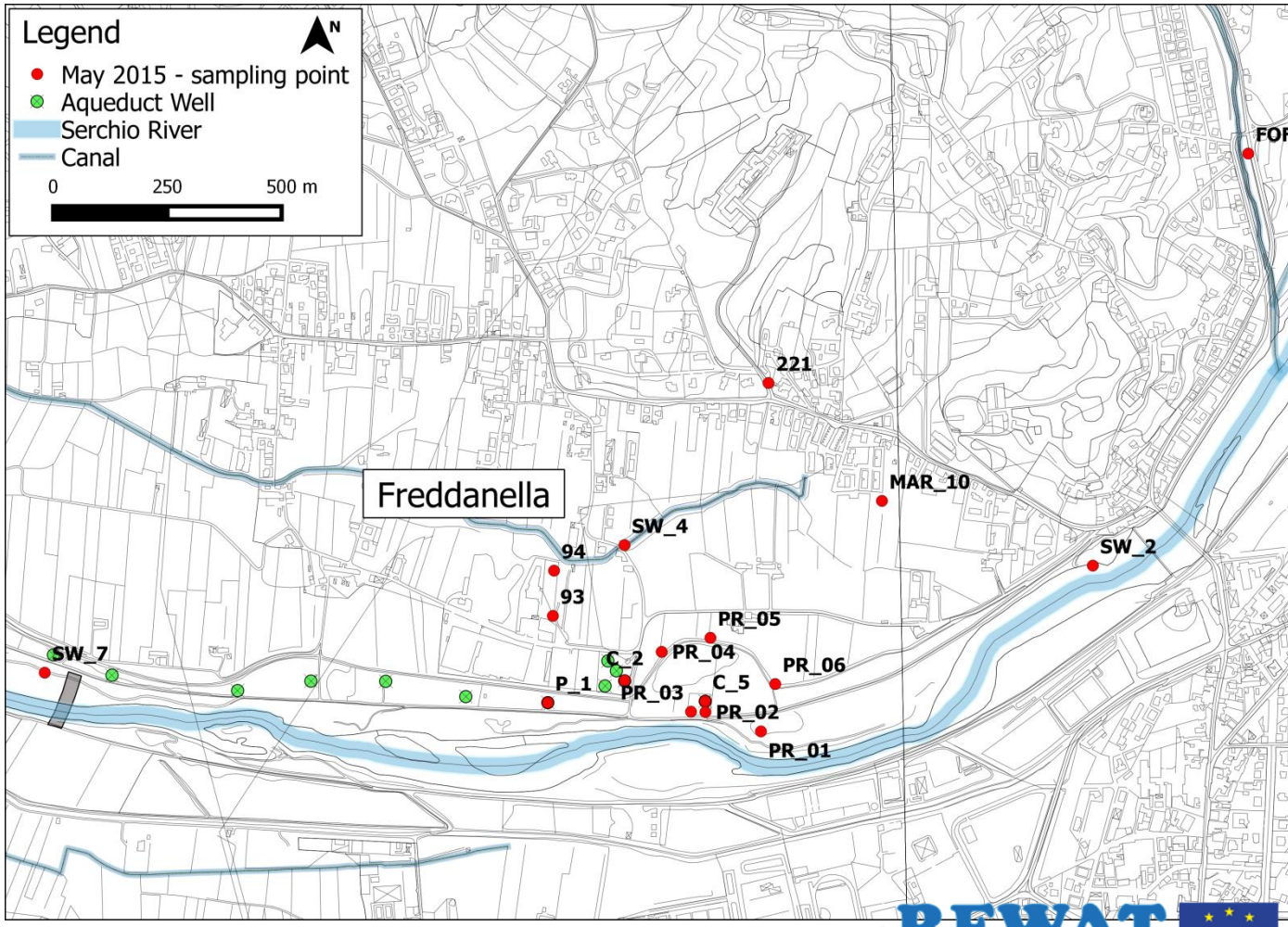
DECEMBER 2014



MAY 2015

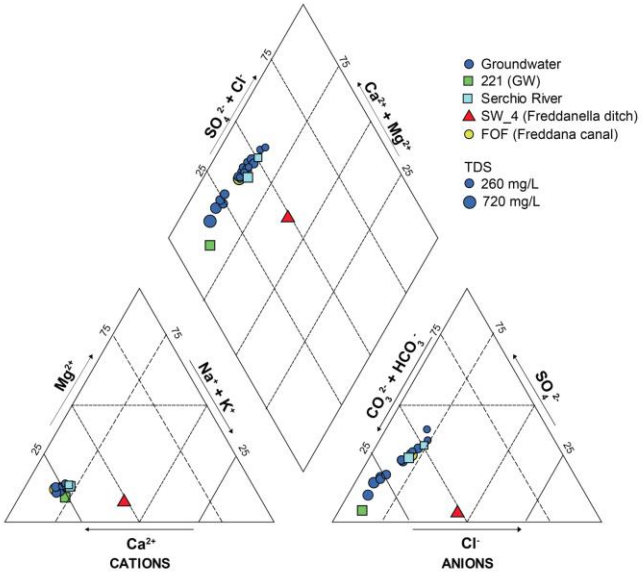


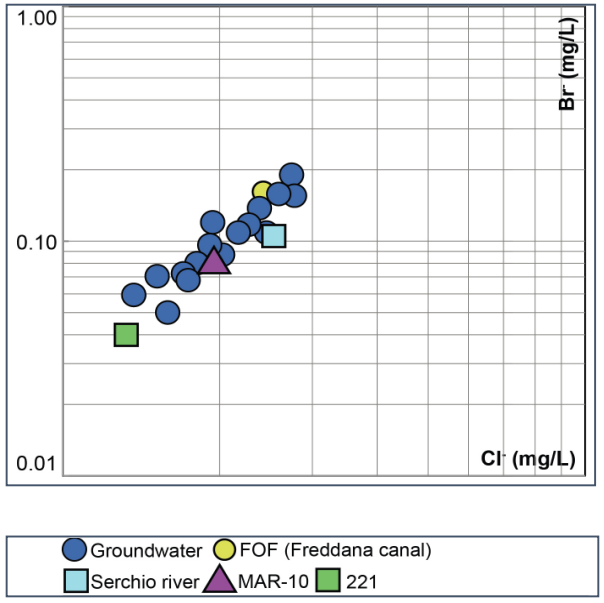
HYDROGEOCHEMICAL MONITORING

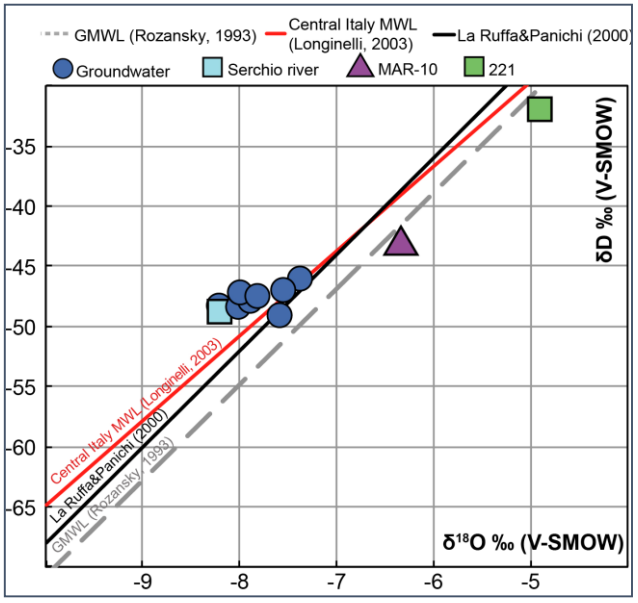


The main sources of the pumping well is the Serchio River water

The most conservative elements such as Cl^-, Br^-, and SO_4^{2-} clearly indicate mixing processes between the River Serchio water and groundwater in the pilot area.







Ca-HCO_3 hydrochemical facies

As concern the nutrient species, nitrate content ranges between 0.2 mg/L and 9 mg/L in GW samples and between 0.8 mg/L and 3.2 mg/L in the Serchio river

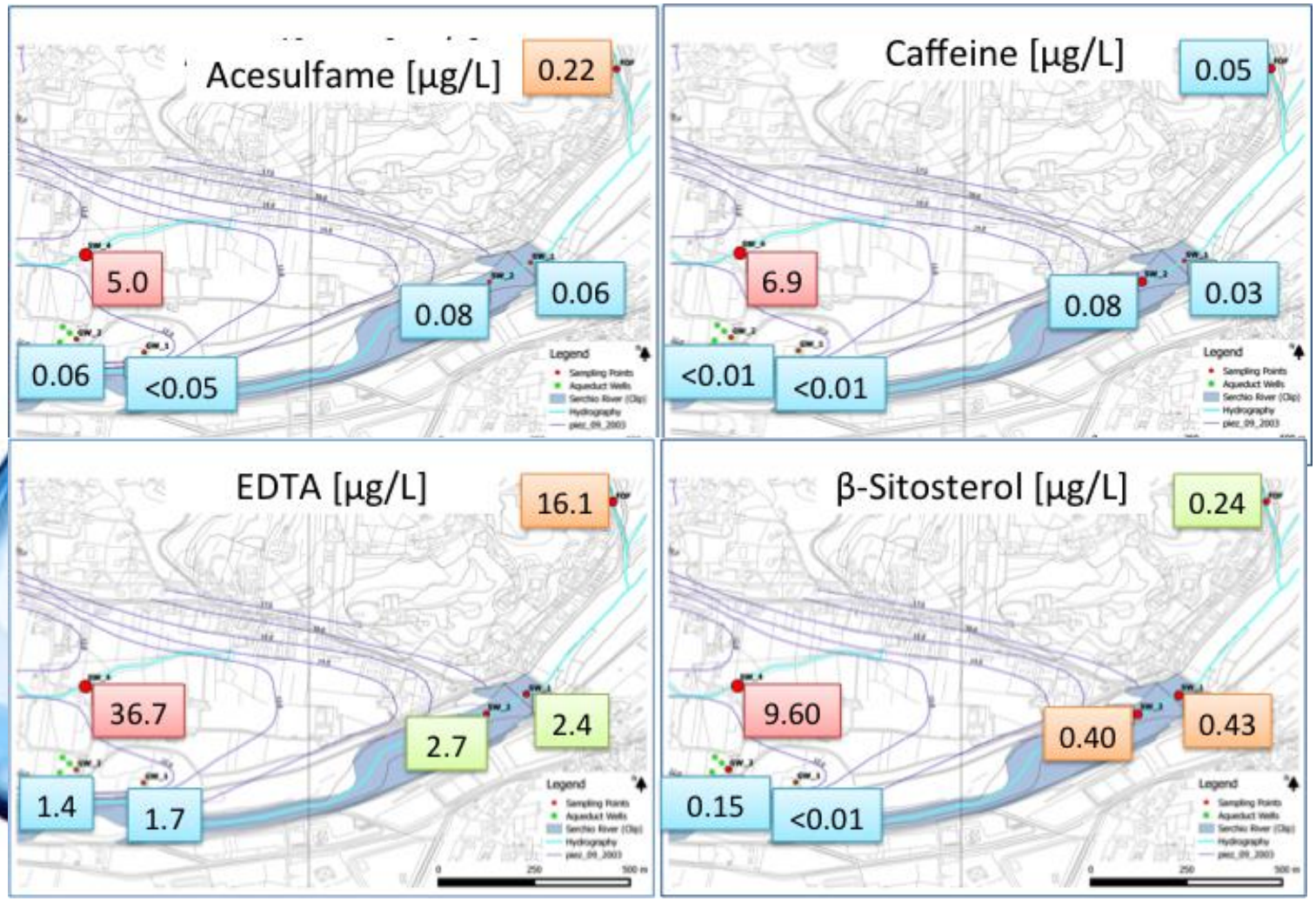
EMERGING POLLUTANTS: Pharmaceuticals

- selected points in different hydrological periods
- substances included in the **EU-watch list**
- evaluation on the medicines distributed in the territory (Northern Tuscany)

	October 2014	July 2015	March 2016	August 2016	September 2016	October 2016
SW	2	4	2	1	1	*coming soon*
GW	5	2	4	6	6	*(after IAH)*

Substances (ng/L)	C5	P2	PR01_A	PR08	Serchio	SW_4
Atenololo	N.D.	N.D.	0.06	N.D.	1.23	176
Claritromicina	0.69	0.51	0.81	N.D.	6.96	222
Eritromicina	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Deidro-eritromicina	0.81	0.98	1.62	N.D.	5.91	50.7
Ibuprofene	0.70	9.02	N.D.	N.D.	2.34	35.4
Diclofenac	N.D.	N.D.	0.51	N.D.	1.59	76.9
Naproxene	N.D.	N.D.	N.D.	N.D.	1.22	342
Estrone	N.D.	N.D.	N.D.	N.D.	10.4	1.2
Estradiolo	N.D.	N.D.	N.D.	N.D.	N.D.	2.5
Etinilestradiolo	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Carbamazepina	0.12	0.33	1.44	N.D.	2.04	15.6
10,11-Diidro-10,11-Diidrossi-	0.18	0.31	1.19	N.D.	2.36	27.0

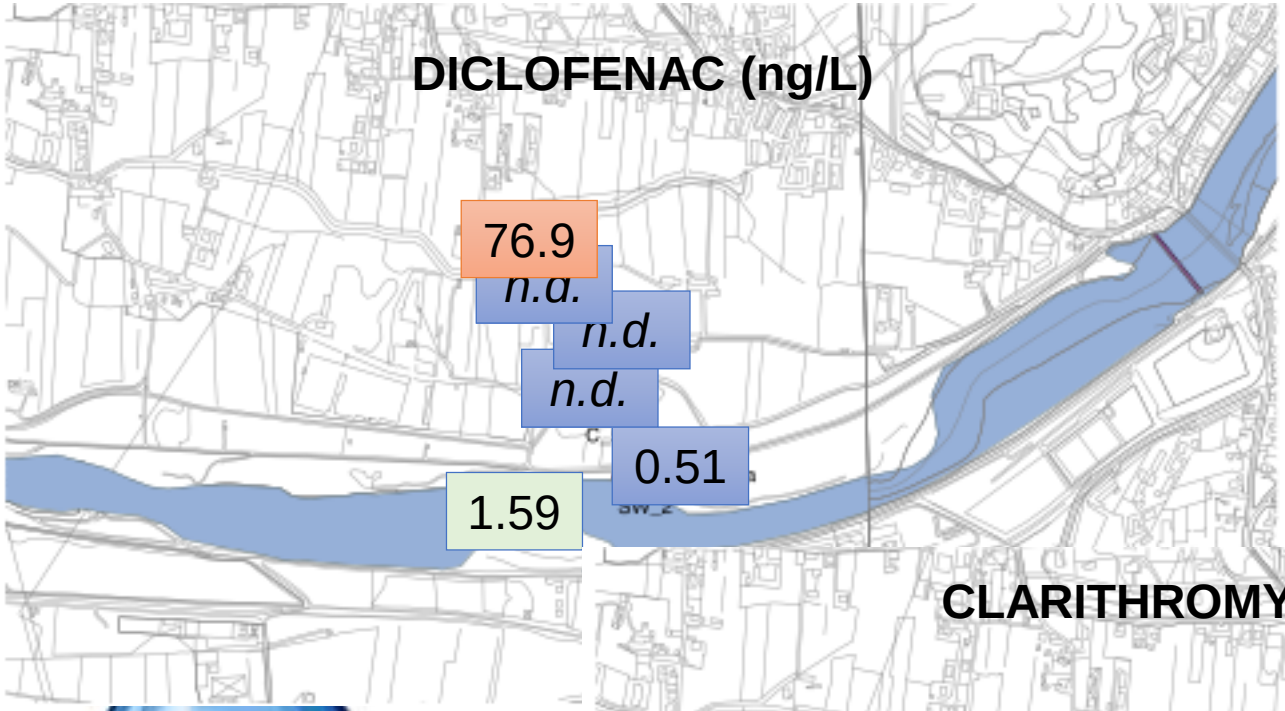
EMERGING POLLUTANTS: results of the first screening (2014)



EIP Water Online Market Place
Matchmaking for water Innovation

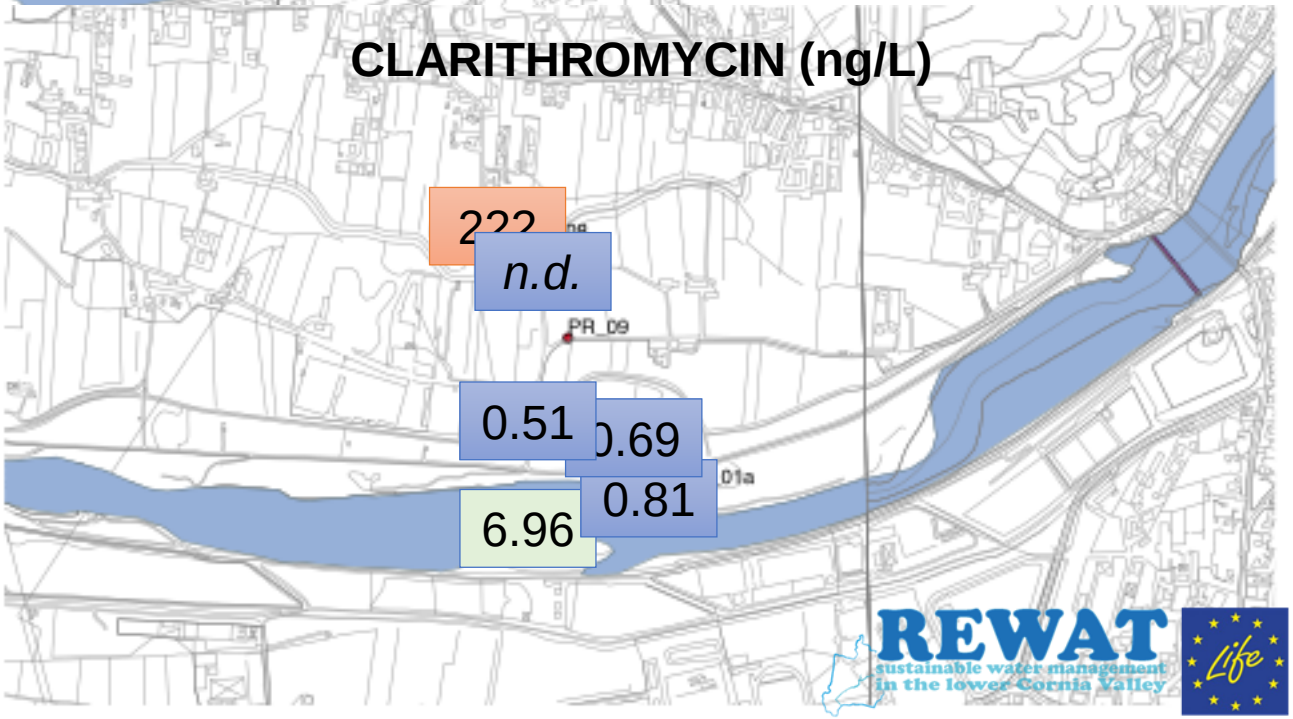
Sant'Anna
Scuola Universitaria Superiore Pisa

MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS



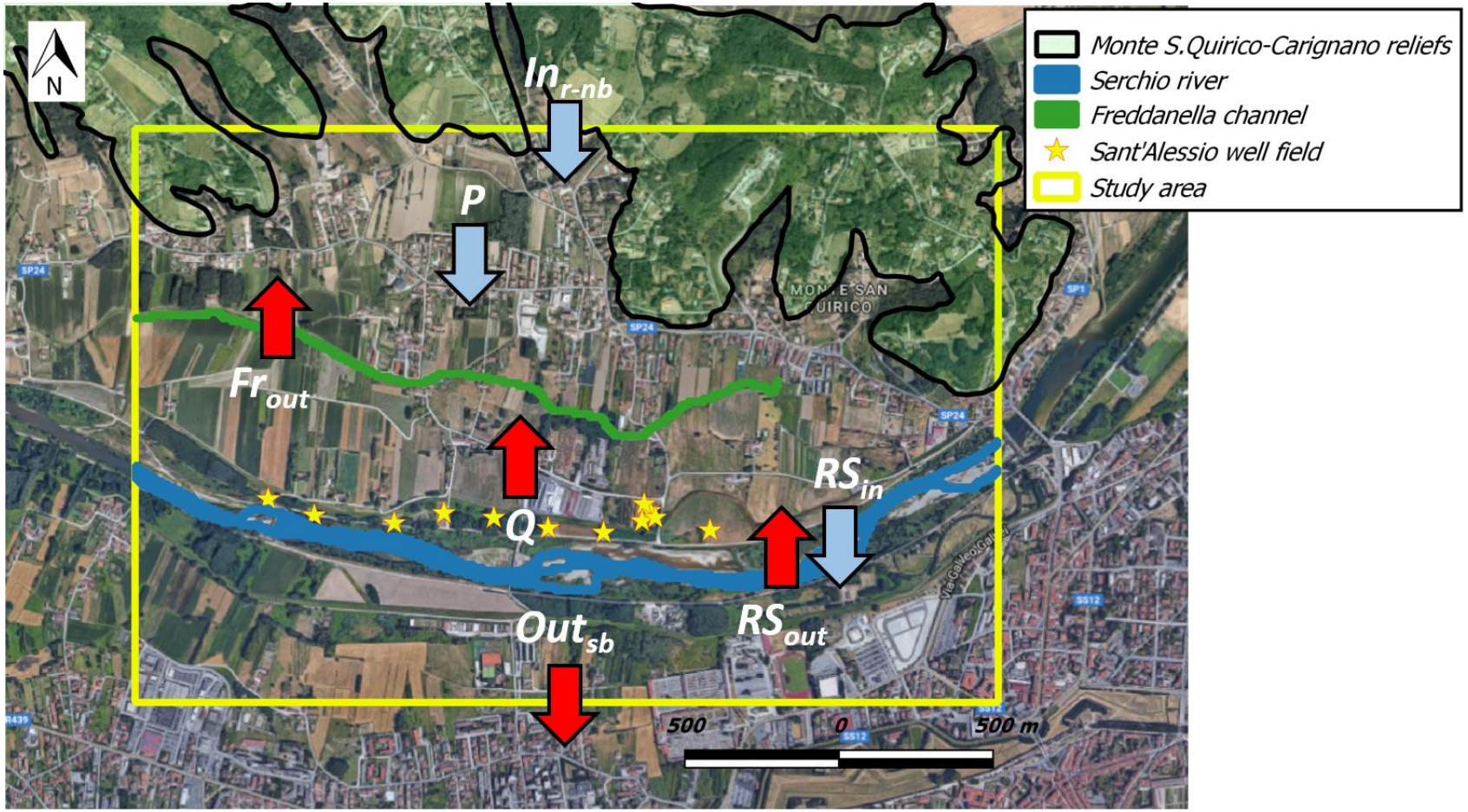
EMERGING POLLUTANTS:

results of the screening in March 2016



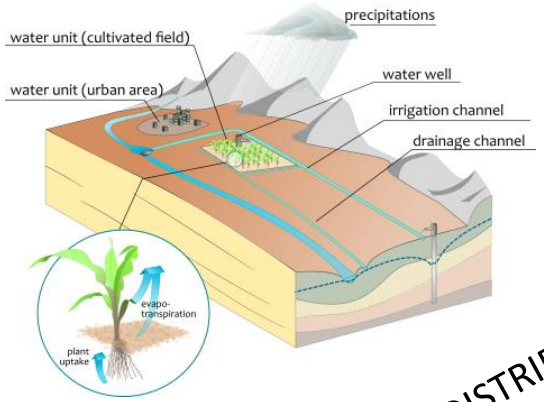
REWAT sustainable water management in the lower Cornia Valley
Life

Conceptual model



$$P + RS_{in} + In_{r\text{-}nb} + S_{in} = Q + RS_{out} + Fr_{out} + Out_{sb} + S_{out}$$

FREEWAT architecture



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

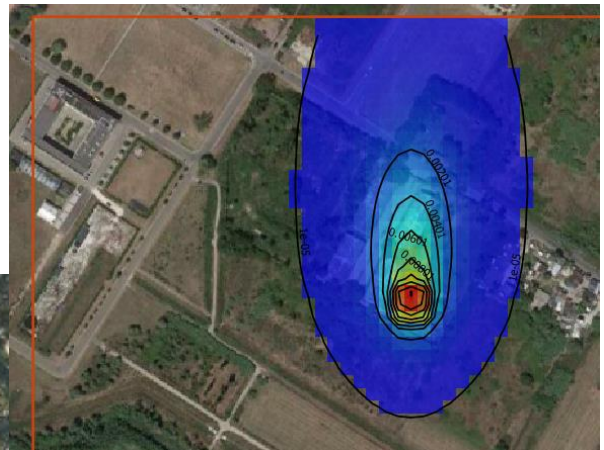
WATER MANAGEMENT AND PLANNING MODULE

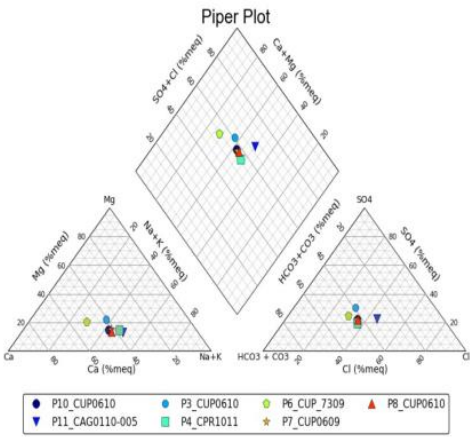
python

FloPy3

Observation Analysis Tool

GIS AND SPATIAL DATABASE



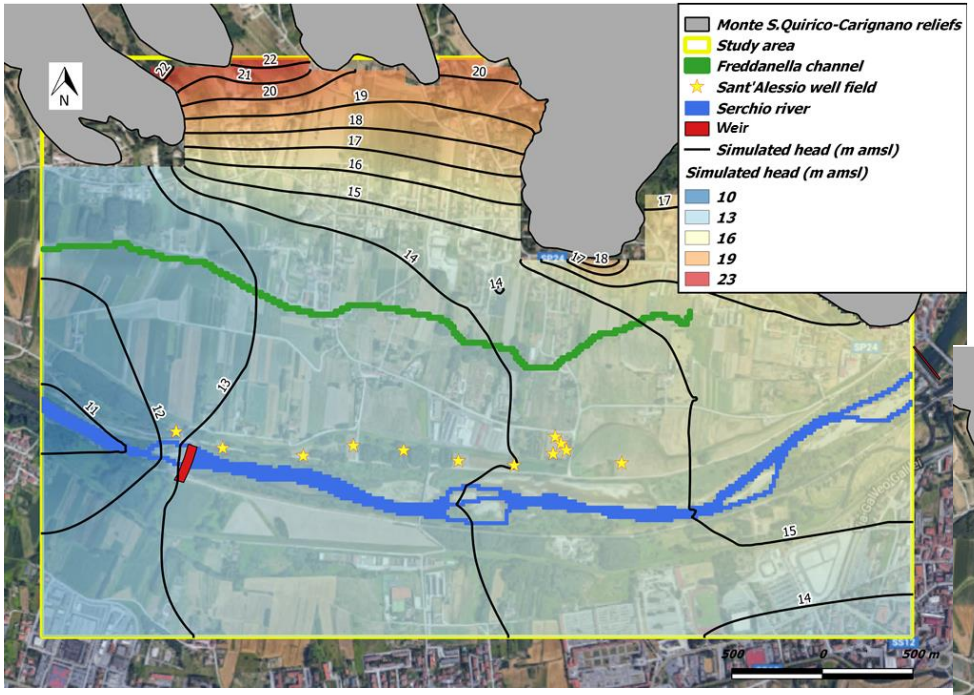


Model results/1

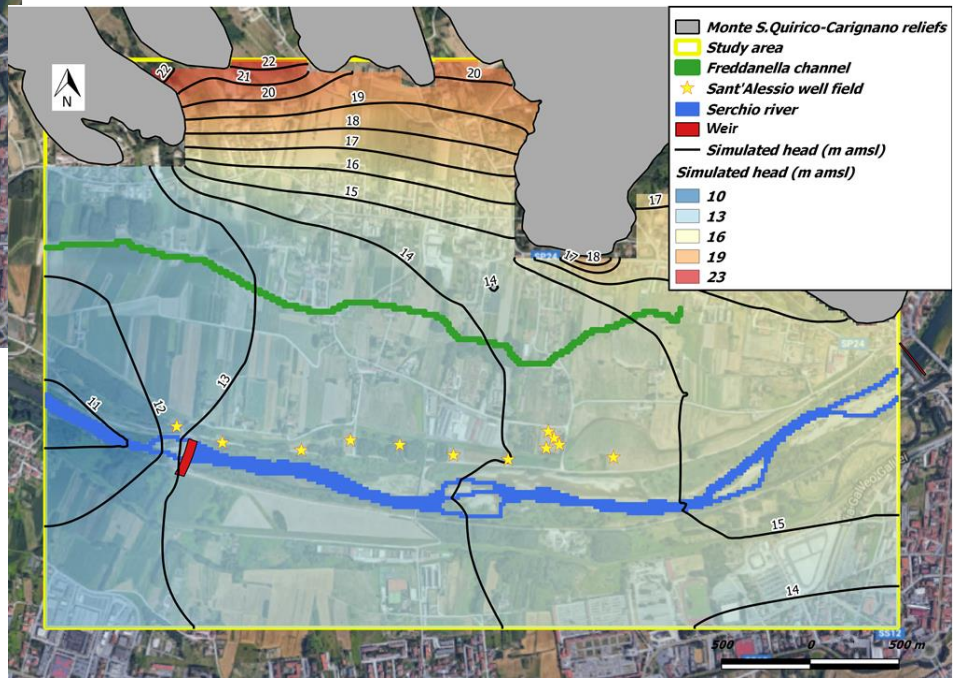
Inflow terms	Cumulative volume (m^3)	% over the total	Outflow terms	Cumulative volume (m^3)	% over the total
Storage	846	negligible	**Storage**	938	negligible
Inflow from the Monte S. Quirico – Carignano reliefs	207089	0.3	**Pumping wells**	15640341	26.4
Rainfall infiltration	673287	1.1	**Outflow from drain**	658	negligible
River leakage	58154744	98.2	**River leakage**	38439232	64.9
Southern boundary of the domain	160214	0.3	**Southern boundary of the domain**	5109272	8.6
TOTAL	59196180	100.0	**TOTAL**	59190432	100.0

Cumulative hydraulic balance during the hydrologic year October 2015 – September 2016

Model results/2



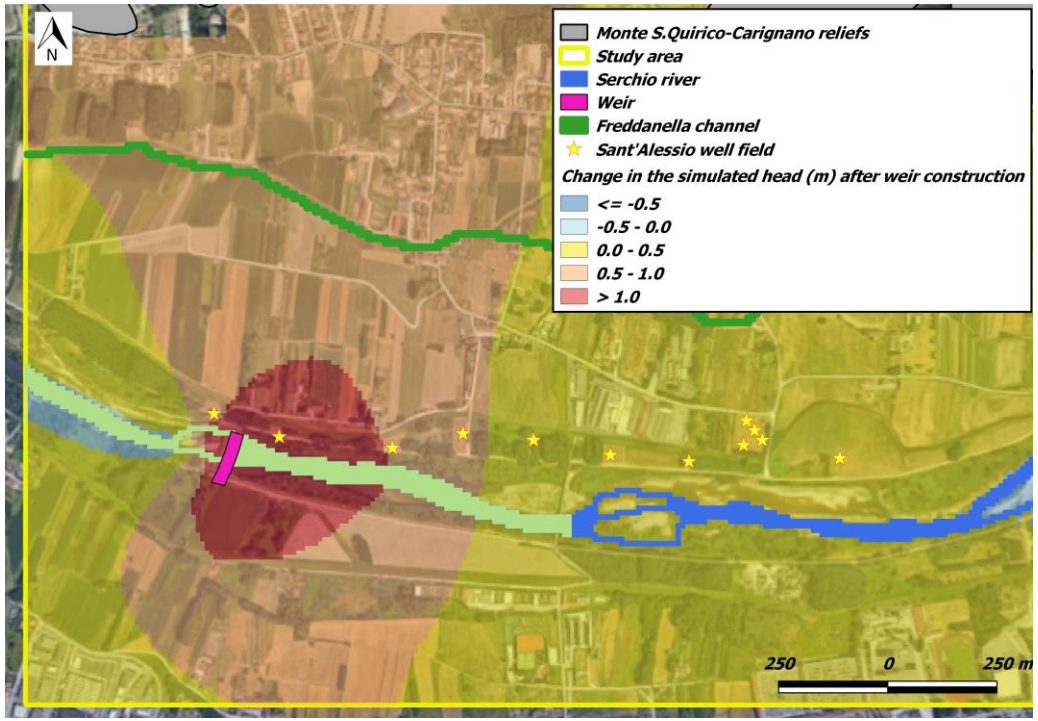
Simulated hydraulic head at the end of May 2016



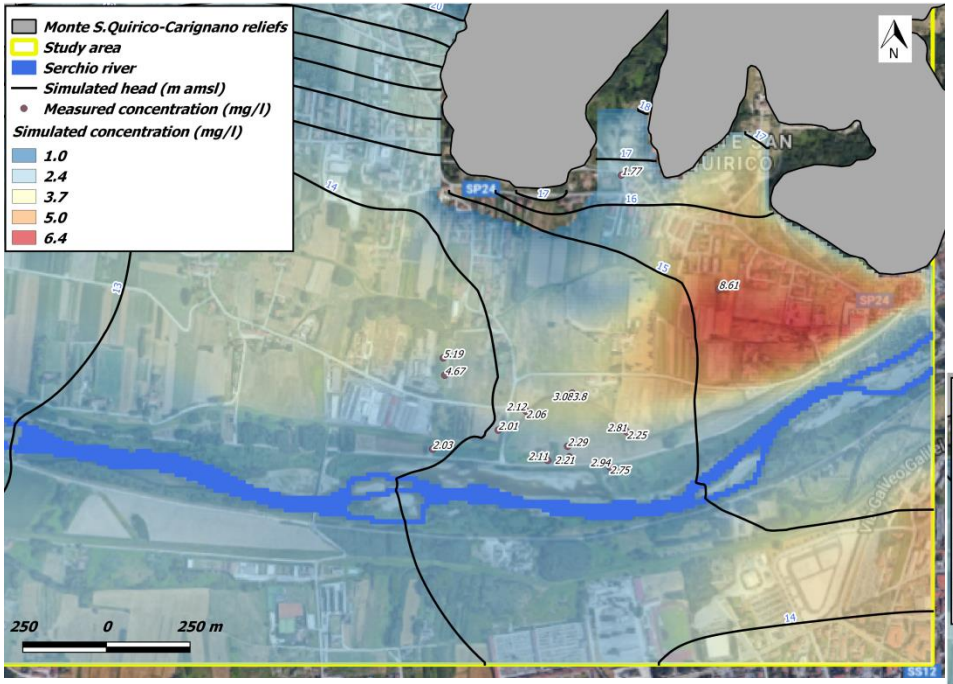
Simulated hydraulic head at the end of September 2016

Effect of the downstream weir

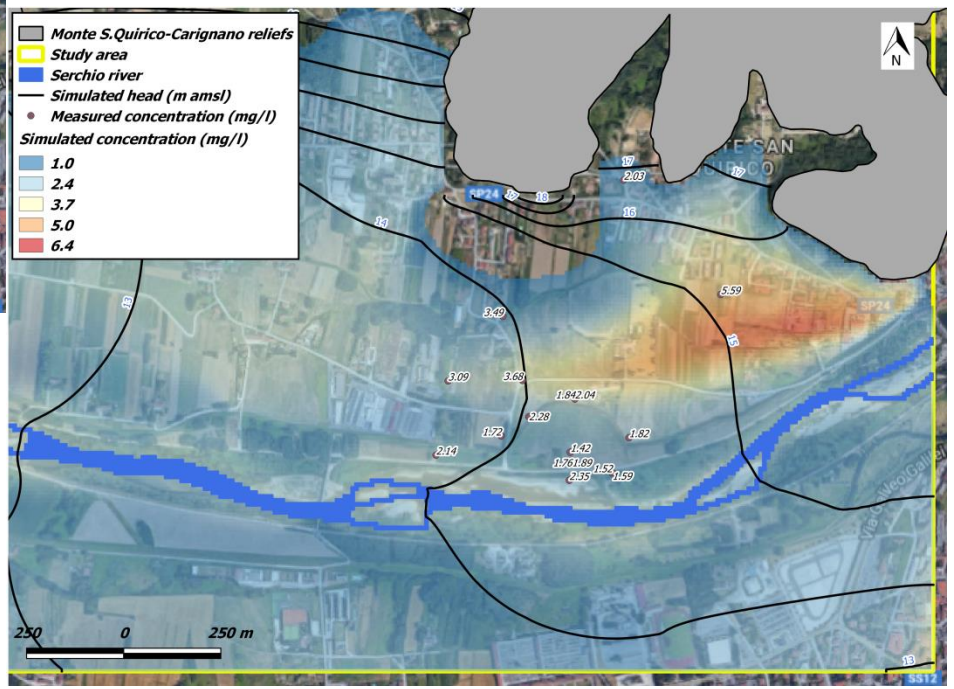
	no-weir/no-wells	no weir/average pumping 0.350 m^3/s	change in recharge (m^3/s)
Net aquifer recharge (m^3/s)	0,151	0,488	0,337
	no weir/average pumping 0.350 m^3/s	weir/average pumping 0.350 m^3/s	change in recharge (m^3/s)
Net aquifer recharge (m^3/s)	0,488	0,521	0,033
	weir/average pumping 0.350 m^3/s	weir/average pumping 0.430 m^3/s	change in recharge (m^3/s)
Net aquifer recharge (m^3/s)	0,521	0,609	0,088



Role of dilution due to river aquifer recharge

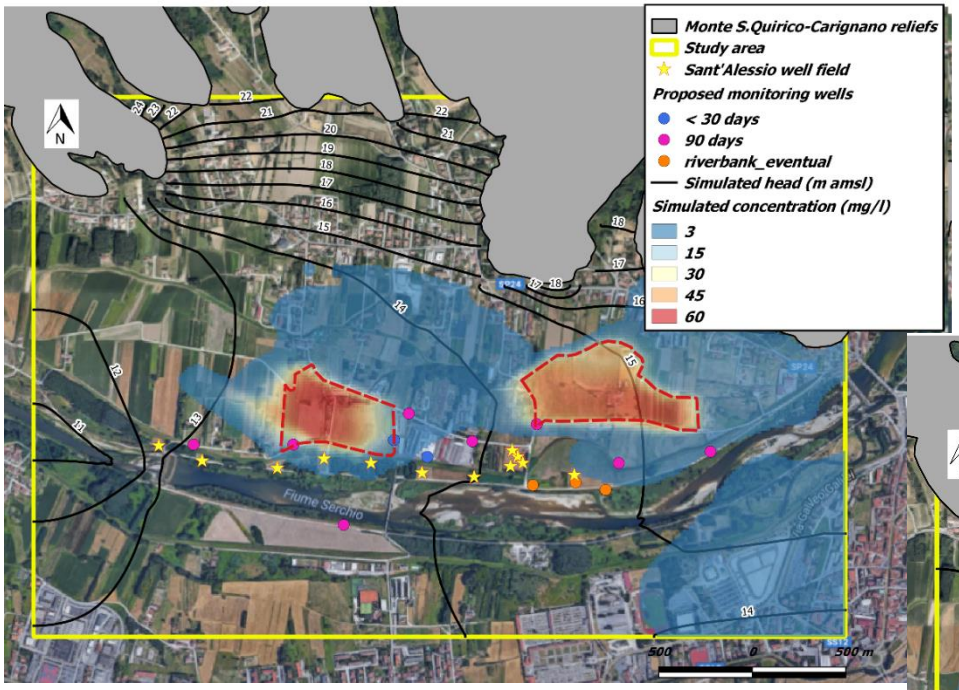


Simulated concentration at the end of May 2016

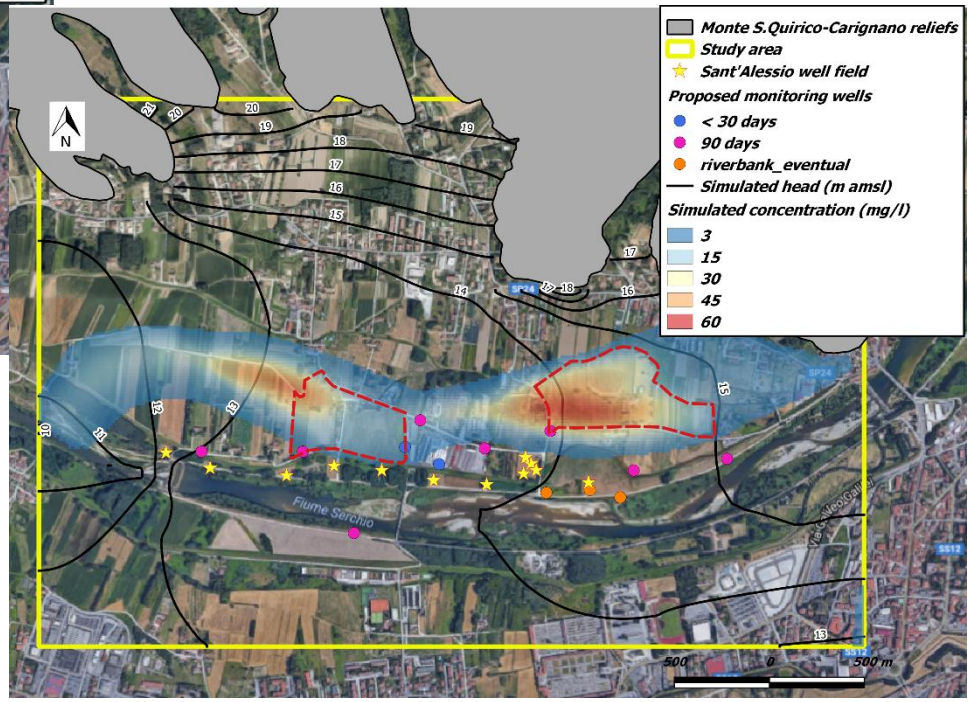


Simulated concentration at the end of September 2016

Groundwater contamination from agricoltural areas

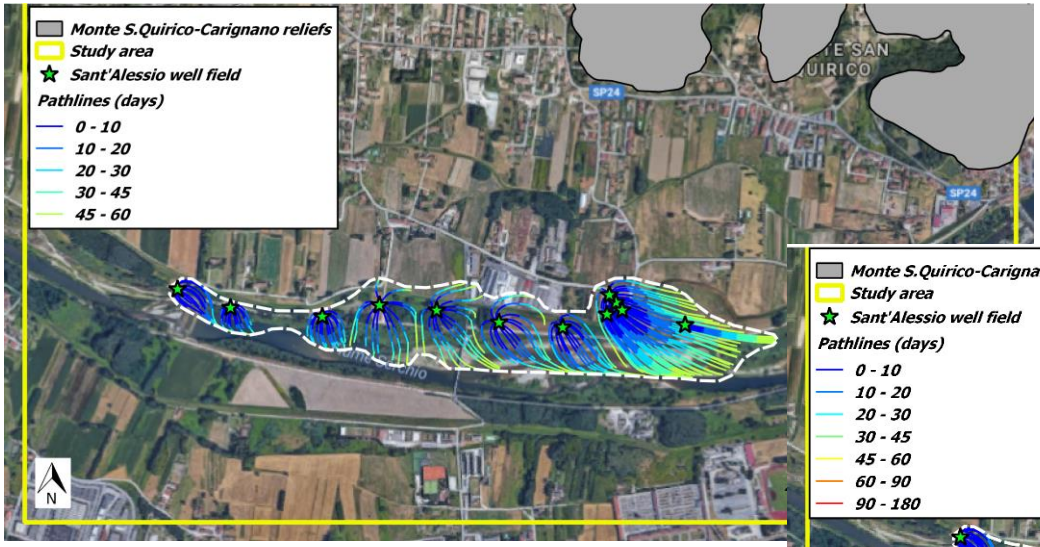


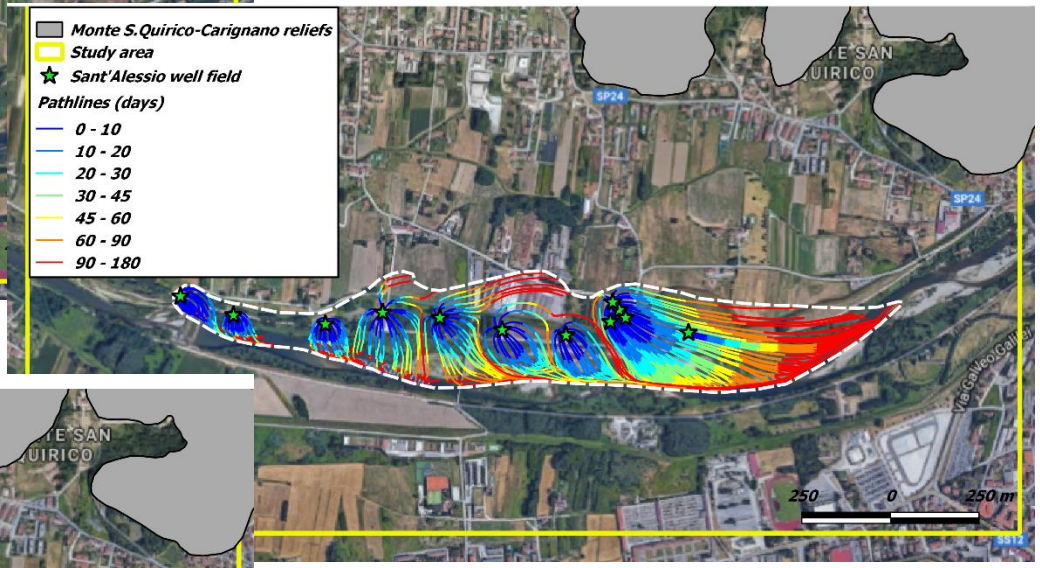
Simulated concentration at the end of January 2015

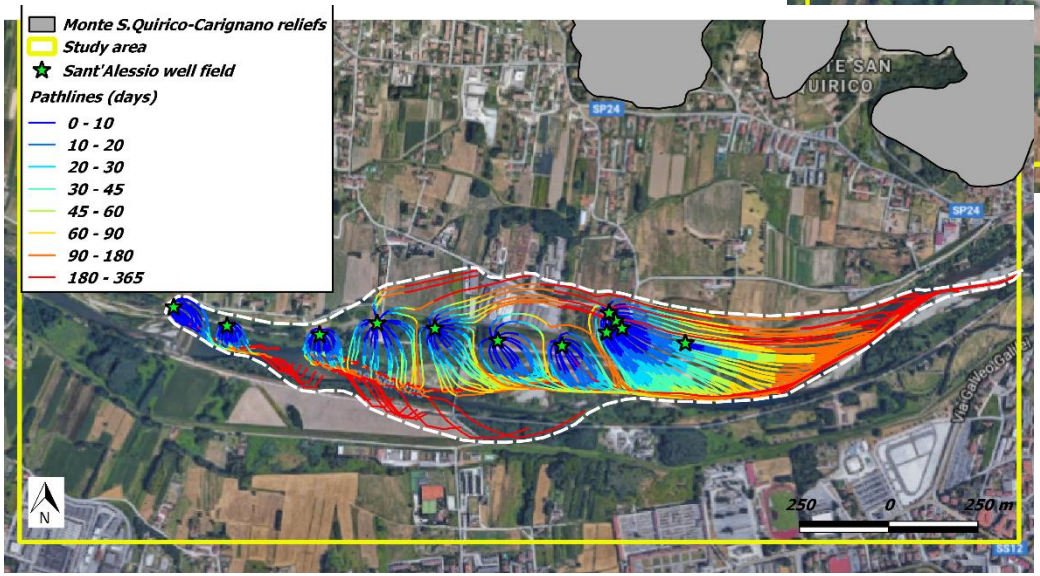


Simulated concentration at the end of September 2015

Wellhead protection areas







Conclusions

- Groundwater flow and solute transport numerical models are valuable tools to support management and planning of the MAR schemes, as in the Serchio River IRBF case study

- Several applications: estimate of the induced recharge, demonstration of the role of the weir, definition of wellhead protection areas, simulation of contamination events

- The IRBF scheme, if properly managed and monitored, is an important water supply scheme

- Implementing a management protocol based on discrete and continuous monitoring is needed

LIFE REWAT project partners

Supported by

LIFE REWAT project co-financers

Patronage

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