



TECHNICAL SOLUTIONS PROVIDED BY THE SPANISH GEOLOGICAL SURVEY (IGME) BY MEANS OF MANAGED AQUIFER RECHARGE (MAR) PROJECTS IN SPAIN

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HISTORICAL VISION

Since the 1980s, the IGME has carried out and managed several AR experiences in Spain. The most important are:

- Flood plain of the river Oja (Northern Spain)
- Rio Verde-Guadix plain (Southern Spain)
- Calcareous sandstones of Carmona (Southern Spain)
- Flood plain of the river Guadalquivir (Southern Spain)
- Mancha Real (Southern Spain)
- Alcalá la Real (Southern Spain)
- Gracia-Morenita aquifer (Southern Spain)
- Valley of the river Esgueva (Northern Spain)
- Vergel aquifer (Mediterranean coast)
- Crestatx aquifer (Majorca idland)
- Cubeta de San Andreu (Barcelona)

Most of them have been carried out in the “dry” Spain (the Southern part of the country and the Mediterranean coast)



ATLANTIC OCEAN

PORTUGAL



MEDITERRANEAN SEA

ARTIFICIAL RECHARGE IN THE FLOOD PLAIN OF THE OJA RIVER.



INFILTRATION POND

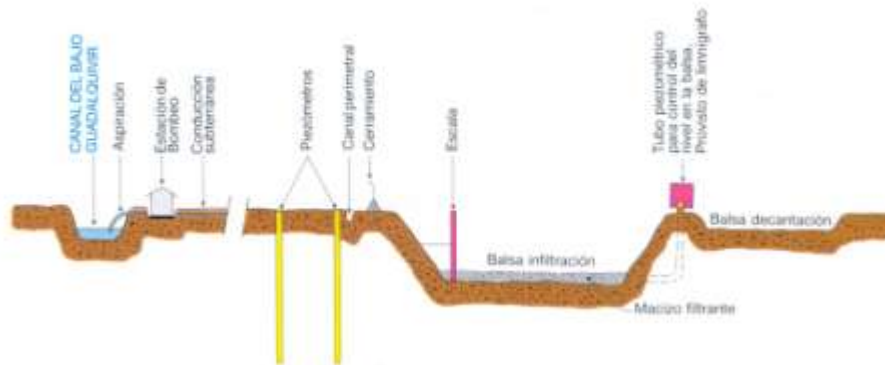
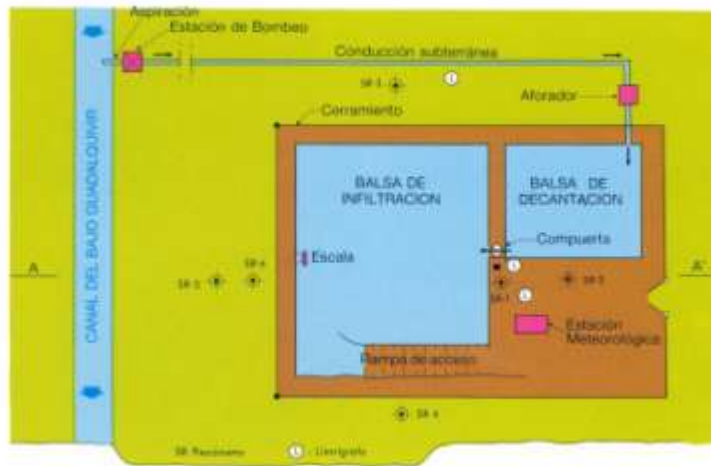
ARTIFICIAL RECHARGE IN THE VERDE RIVER- GUADIX PLAIN (GRANADA)

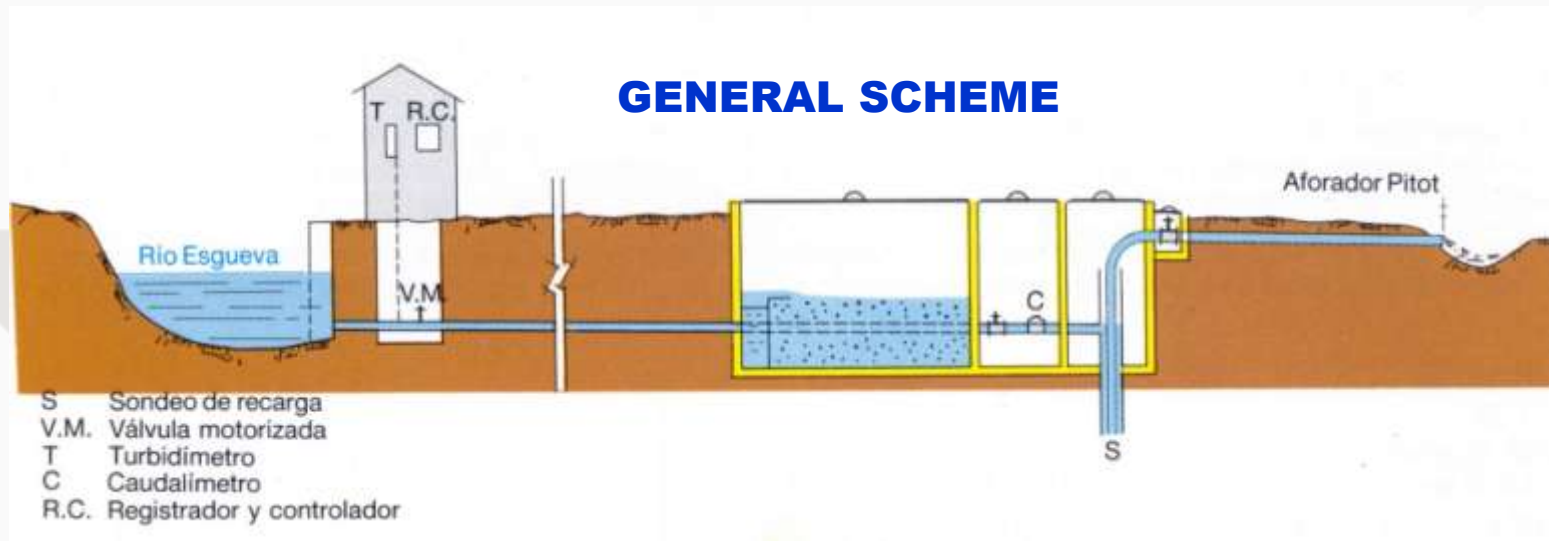


ARTIFICIAL RECHARGE IN THE FLOOD PLAIN AQUIFER OF THE RIVER GUADALQUIVIR



ARTIFICIAL RECHARGE IN THE CARMONA AQUIFER (SEVILLE)





WATER INTAKE FROM THE RIVER



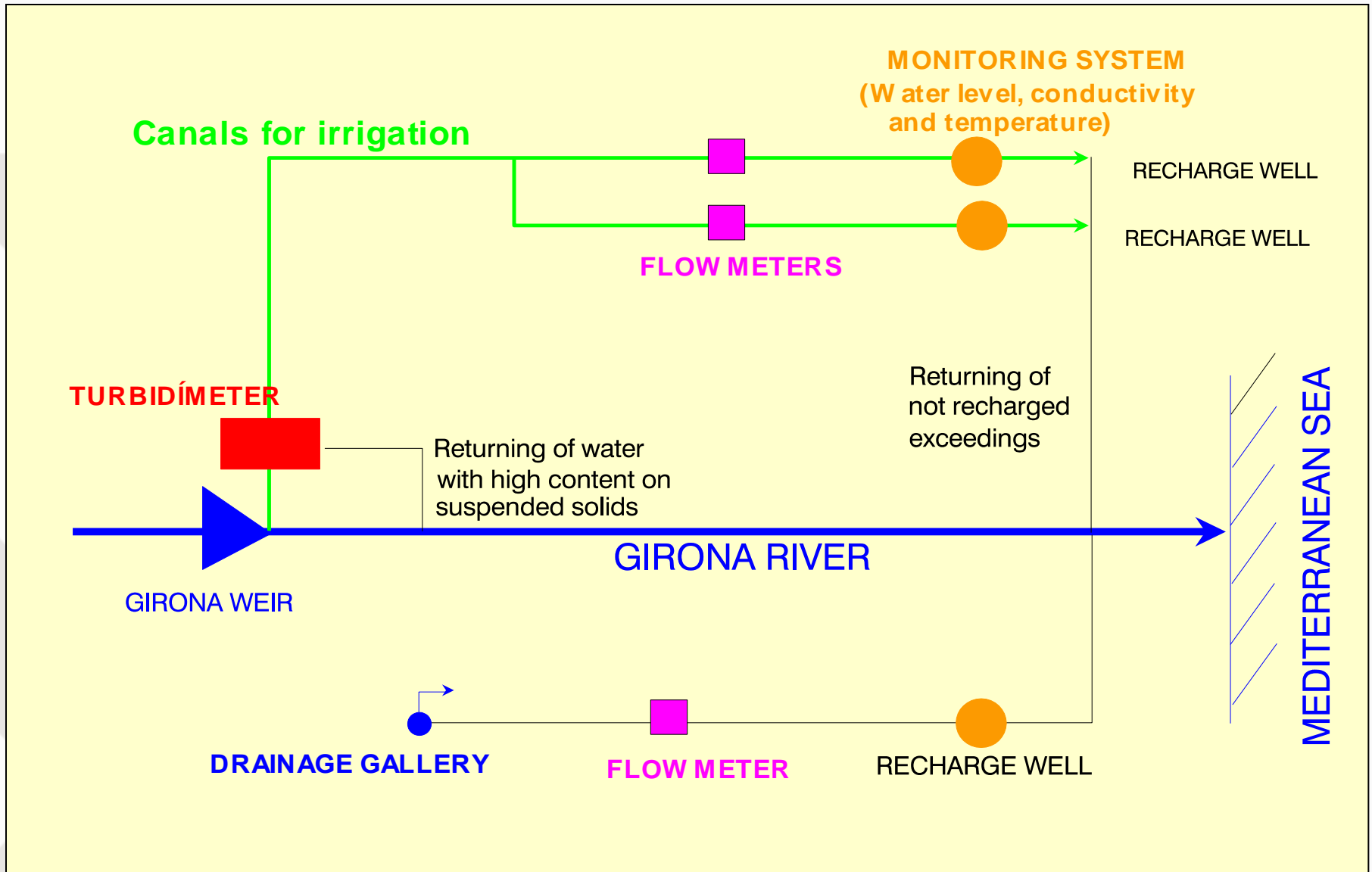
TURBIDITY METER





VERGEL AQUIFER (ALICANTE)

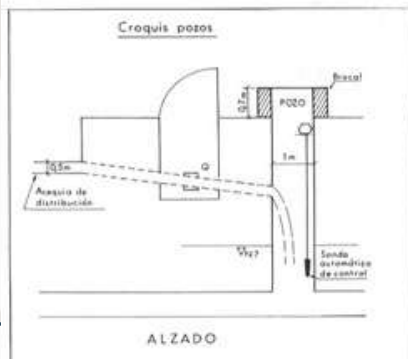
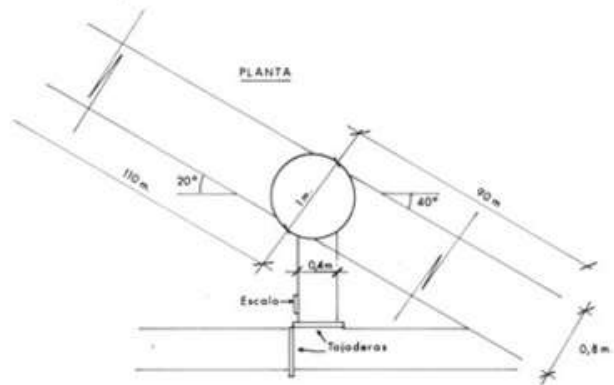
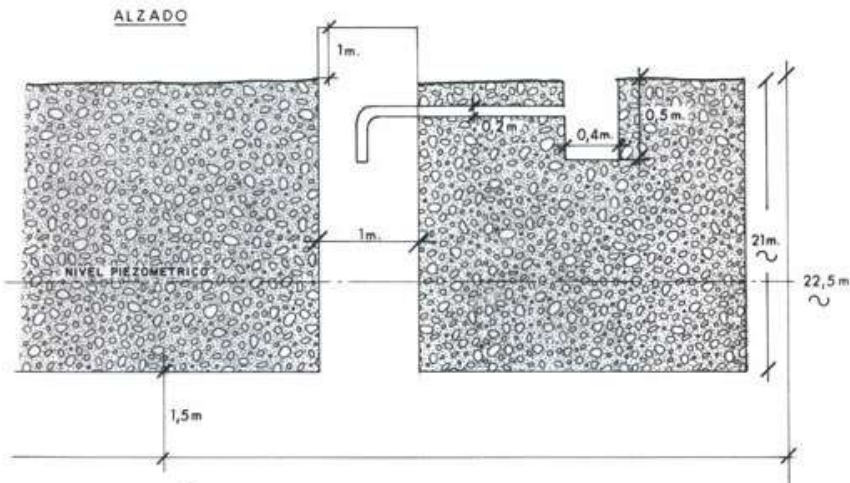
ARTIFICIAL RECHARGE IN THE VERGEL AQUIFER.





ARTIFICIAL RECHARGE IN THE VERGEL AQUIFER.

Croquis de los pozos de recarga



ARTIFICIAL RECHARGE IN THE VERGEL AQUIFER

- Detritic Quaternary
- 18 km² surface
- Water resources: 11 Mm³/year
- Transmissivity: 1000 to 10000 m²/d
- Effective porosity: 5% to 15%

- First made by the local farmers using irrigation surpluses from a drainage gallery. Since 1985.

- Water recharged comes from the same aquifer, drained by a gallery constructed to carry the groundwater to the farm lands.

- Recharged water has better quality than native groundwater.

- Actual recharged volumes: 0.8 to 1.2 Mm³/year



EFFECTS AND BENEFITS OF THE AR ON THE GROUNDWATER:

- Water level increases up to 2 m in the nearby of the recharge wells.
- A poor to moderate improvement of the groundwater quality, only detected in the recharge wells.
- A rise of 14% of the aquifer water resources.
- The very low cost of the operation, due to the use of available wells abandoned, and irrigation channels to transport the used recharge water and maintained by farmers. Cost is about 0,01 €/m³.
- No clogging problems detected, due to the very high infiltration rate of the recharge wells.



CRESTATX AQUIFER (MALLORCA)

OBJECTIVE

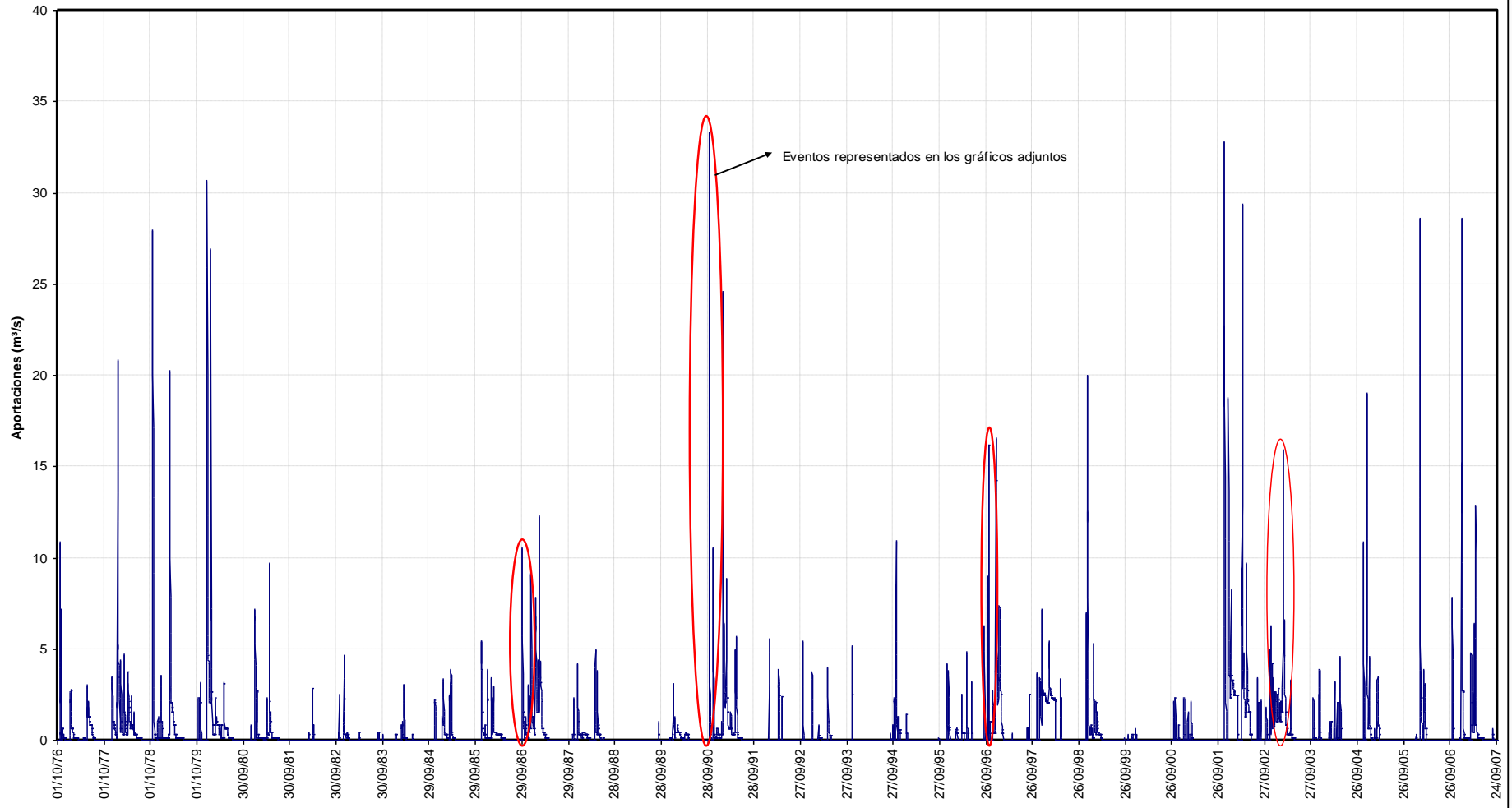
The Balearic Islands Government has planned as a water management target to replace drinking water catchments from the Inca-Sa Pobla plain aquifer (with high nitrate contents) by new water extractions from Crestatx aquifer increasing the exploitation of the latter, and compensating the greater water withdrawals with artificial recharge.

Recharge water will come from Ufanes de Gabellí springs surpluses. These fountains are located some kilometers upstream of Crestatx and their water quality is excellent.

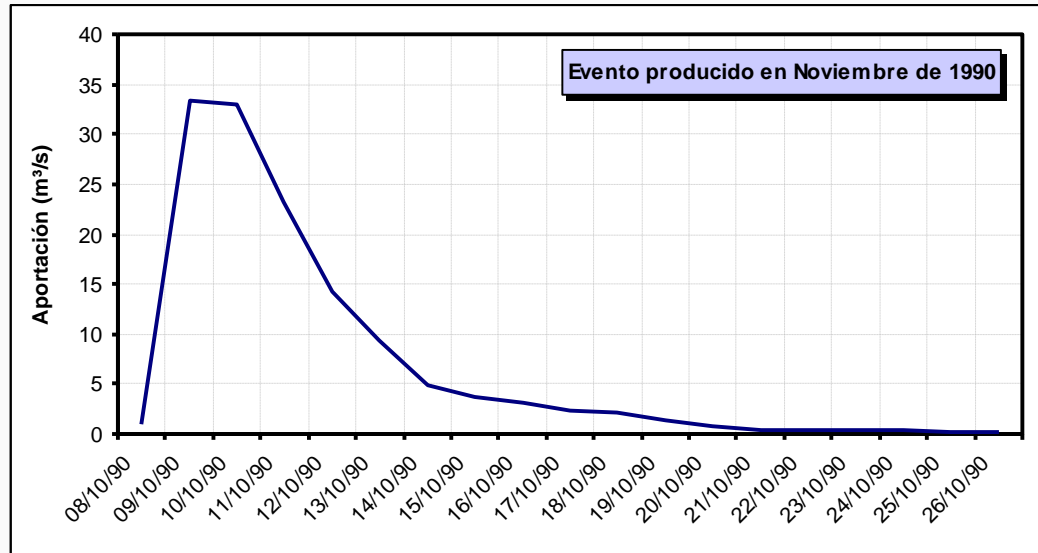
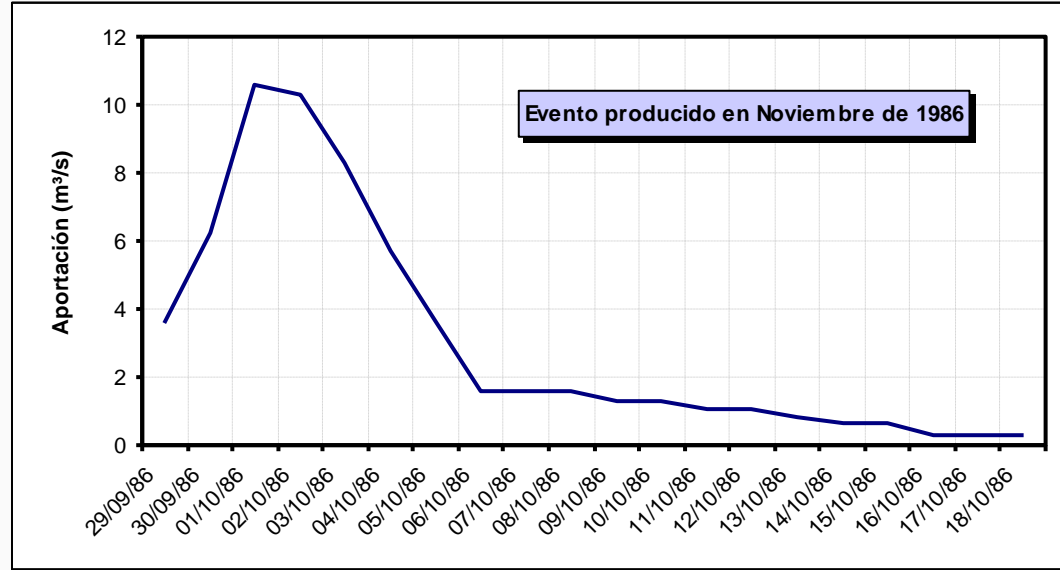
Recharge will be made using injection boreholes in the limestone Crestatx aquifer.



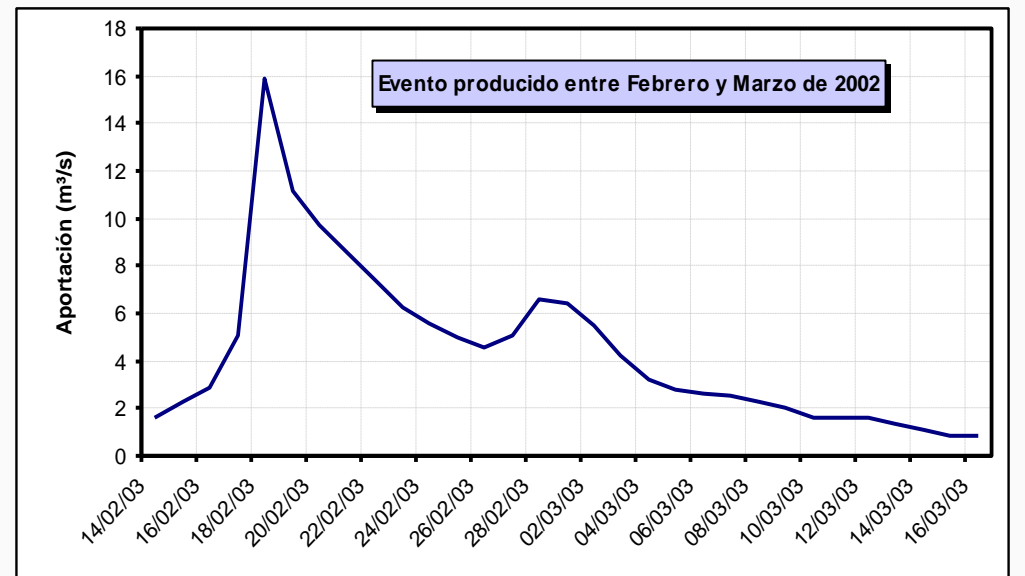
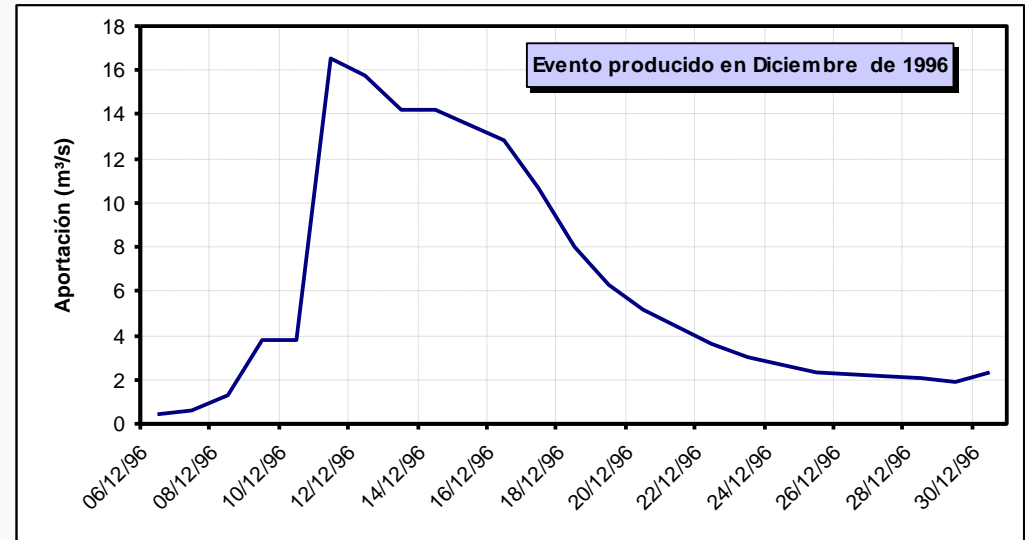
Aportaciones diarias registradas en la estación de aforos E11/04 Torrent de San Miguel (1976-2007)

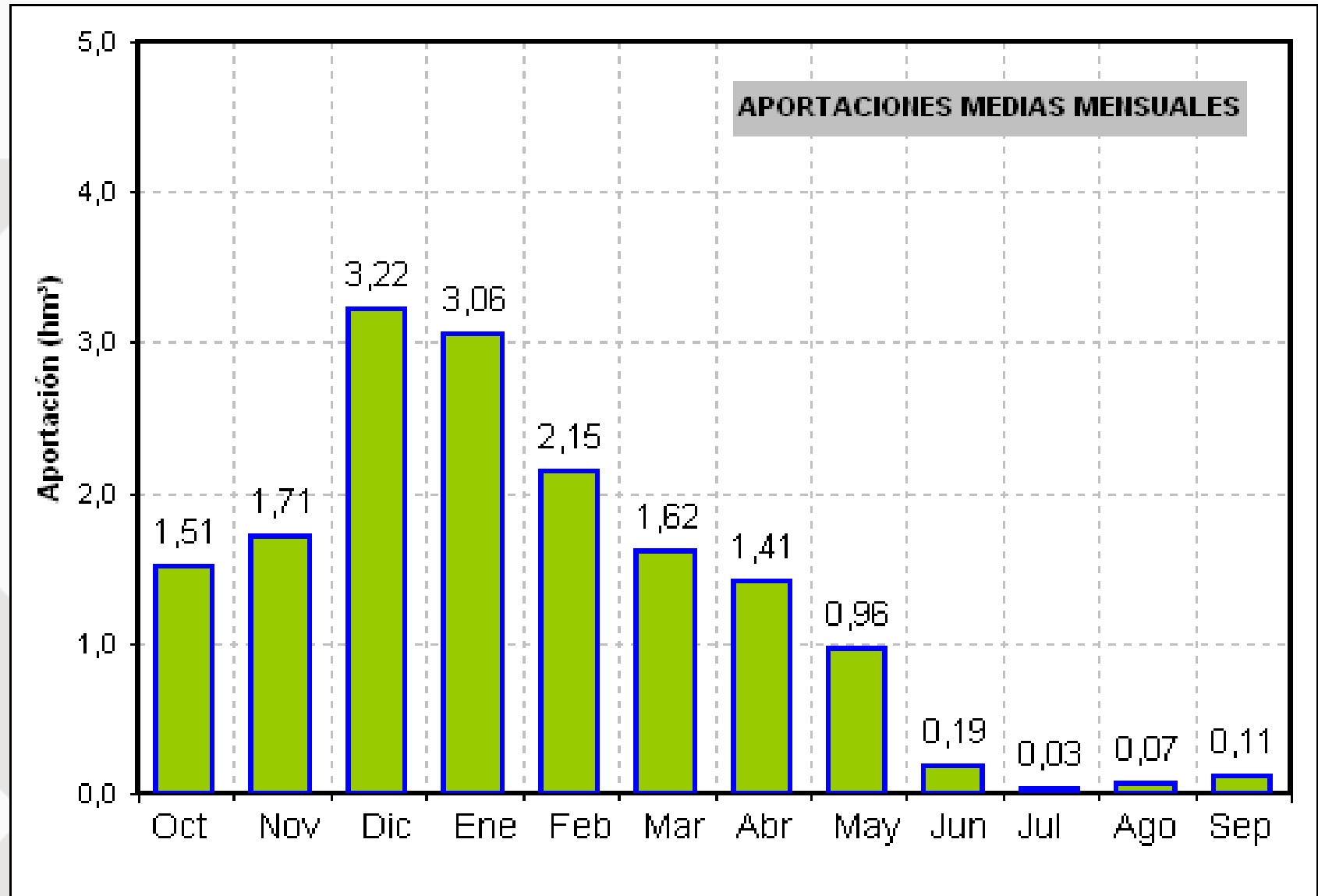


CRESTATX AQUIFER (MALLORCA)

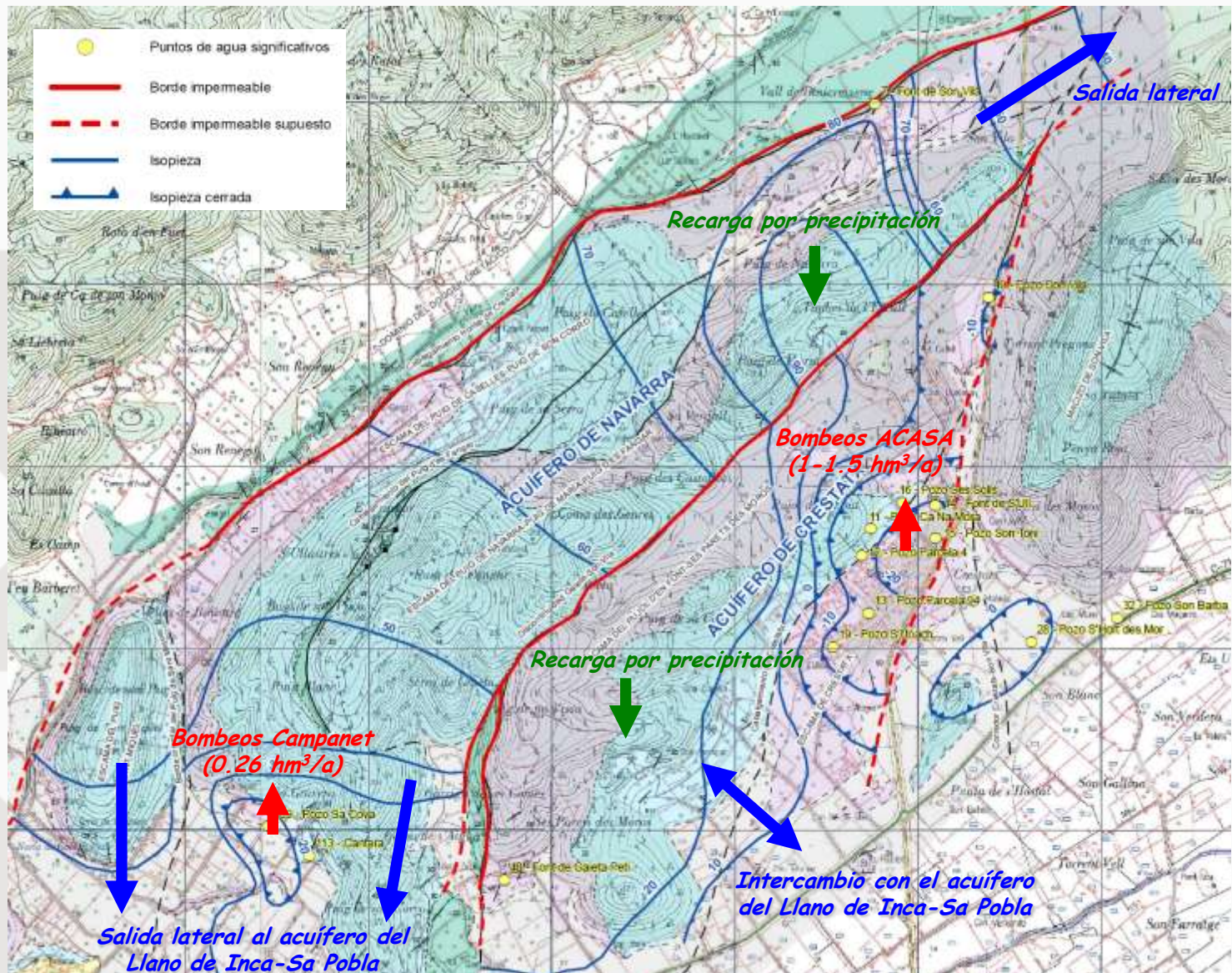


CRESTATX AQUIFER (MALLORCA)

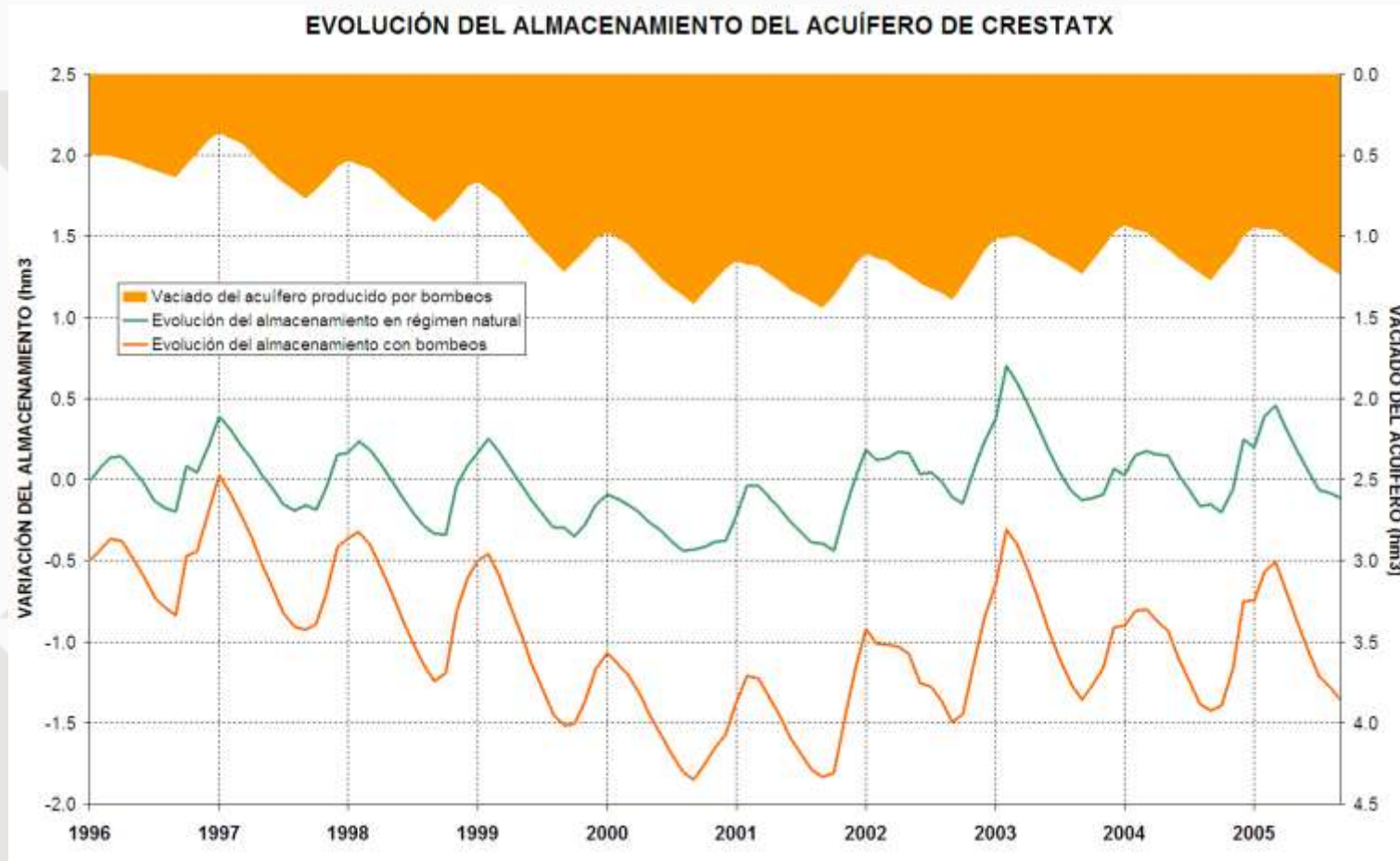




CRESTATX AQUIFER (MALLORCA)

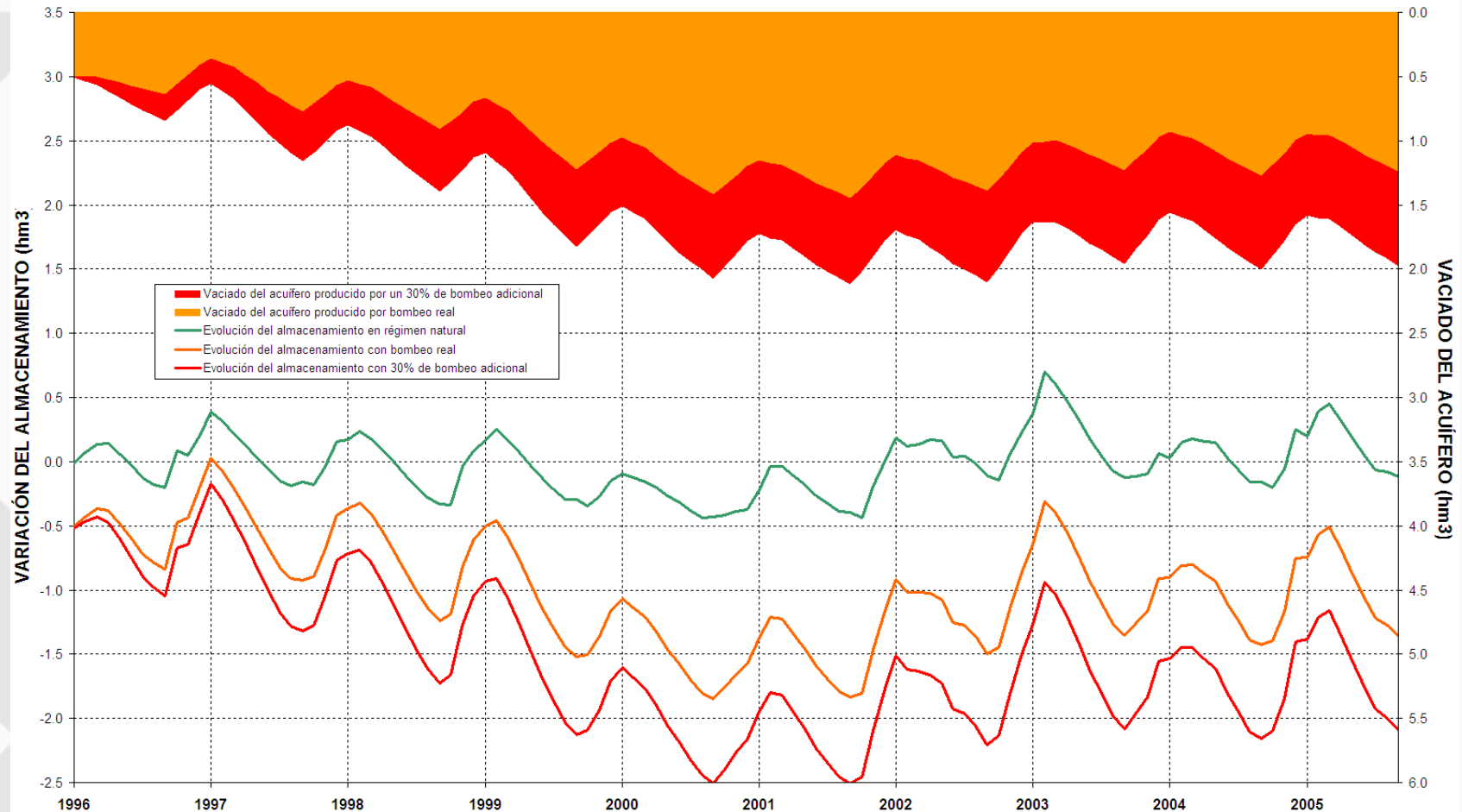


Aquifer emptying produced by current pumping



Aquifer emptying produced by current pumping increased by 30%

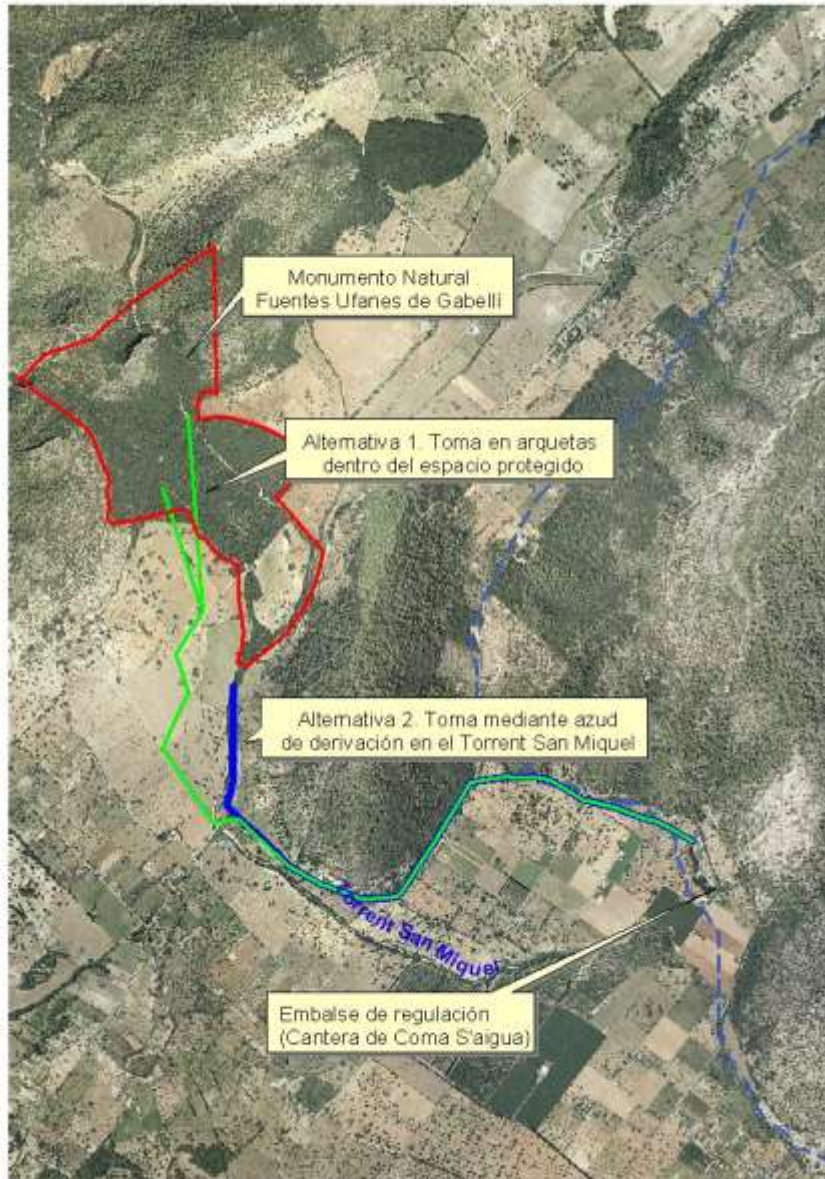
EVOLUCIÓN DEL ALMACENAMIENTO DEL ACUÍFERO DE CRESTATX



AR plant has been designed using the following elements:

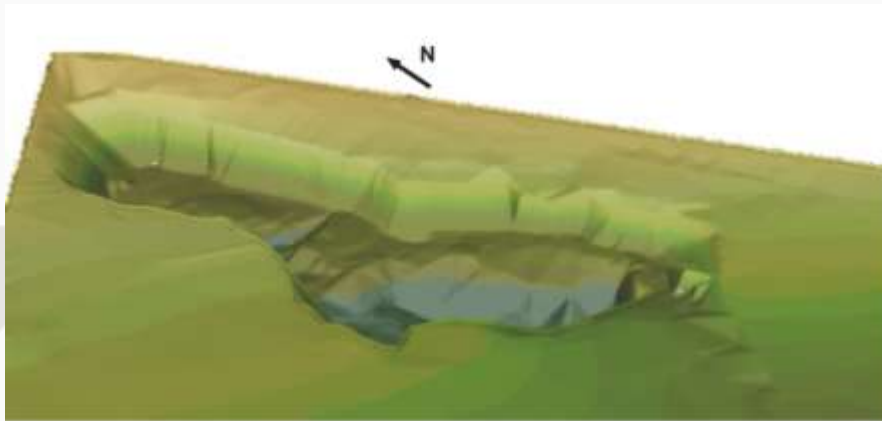
- Water intake from Ufanes spring.
- Intermediate regulating flow system.
- Decantation pond (artificial wetland).
- Injection boreholes.
- Water pipes to drive water.

This AR plant will be a mixed one combining both surface and underground methods, trying to obtain the best benefits of each one. On one hand, surface devices will allow to catch AR water, regulate it and channel it to the infiltration devices. Using an abandoned quarry as regulating system will allow to recover an environmentally degraded zone. The artificial wetland will give an additional value to the environment, because it will allow people to get a recreation use of the AR plant, and an ecological improvement of the AR area. On the other hand, injection wells will be cheaper than surface infiltration devices, like ponds, due to the high land value in Majorca island.

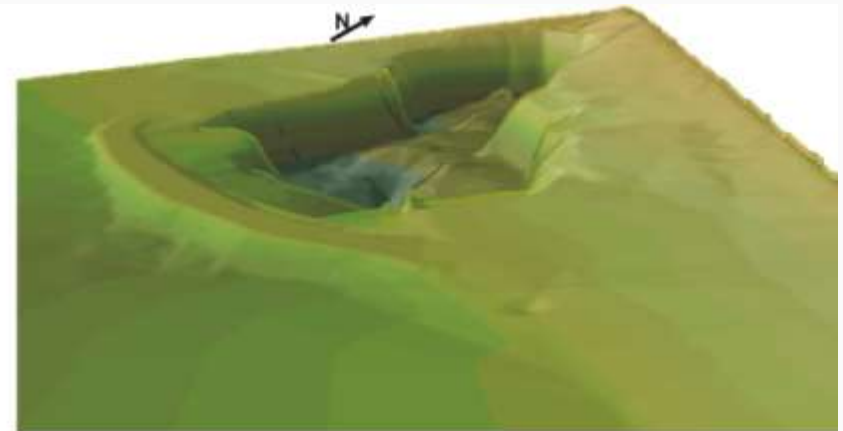




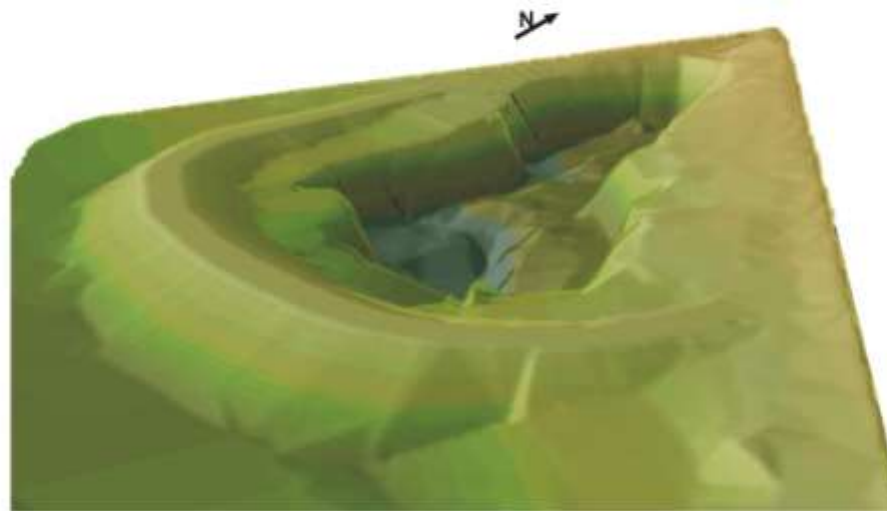




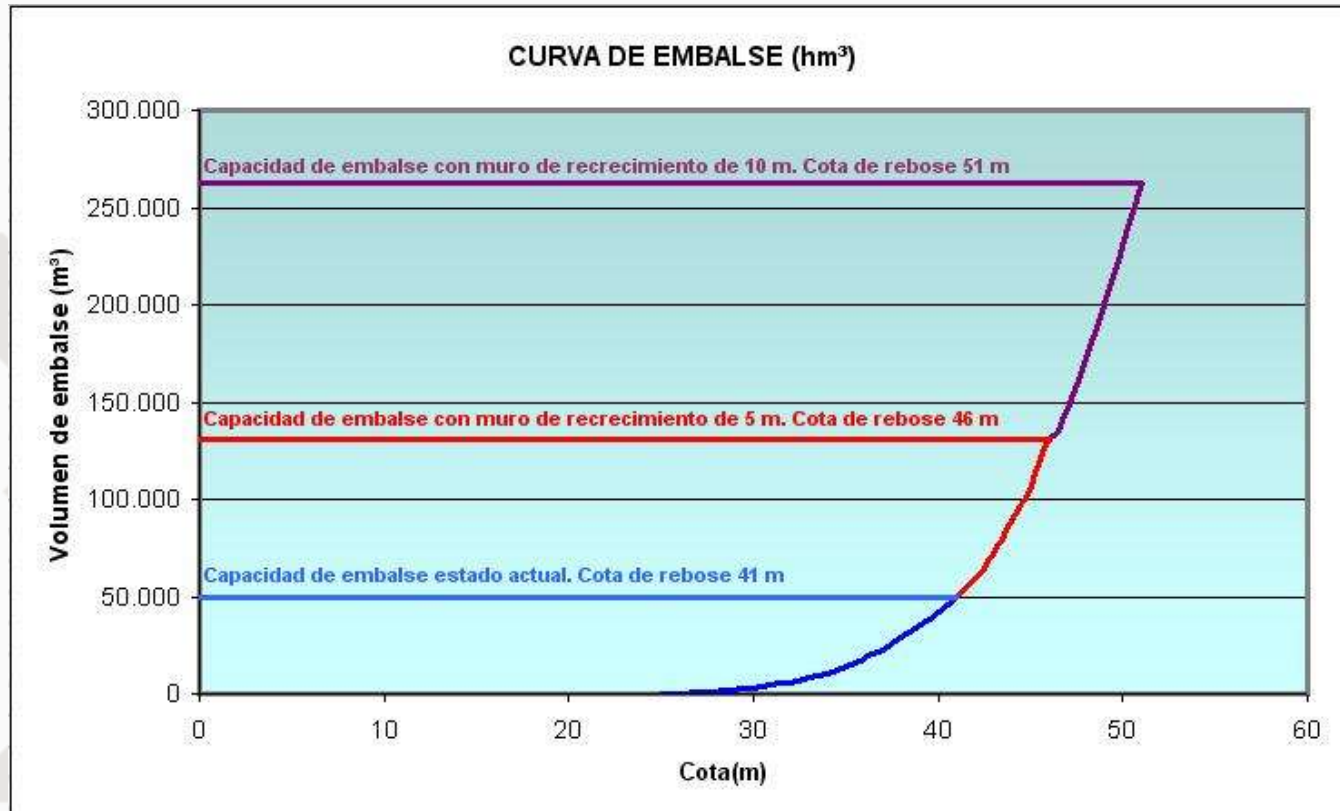
MODELO DIGITAL DEL TERRENO CANTERA COMA S'AIGUA
ESTADO ACTUAL



MODELO DIGITAL DEL TERRENO CANTERA COMA S'AIGUA
MURO DE RECRECIMIENTO DE 5 m
POR ENCIMA DE LA COTA DE REBOSE NATURAL



MODELO DIGITAL DEL TERRENO CANTERA COMA S'AIGUA
MURO DE RECRECIMIENTO DE 10 m
POR ENCIMA DE LA COTA DE REBOSE NATURAL



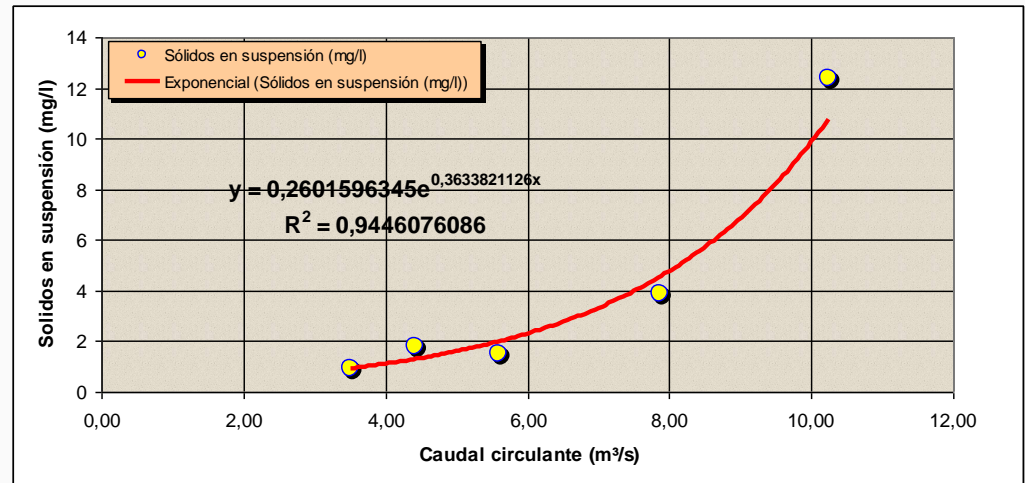
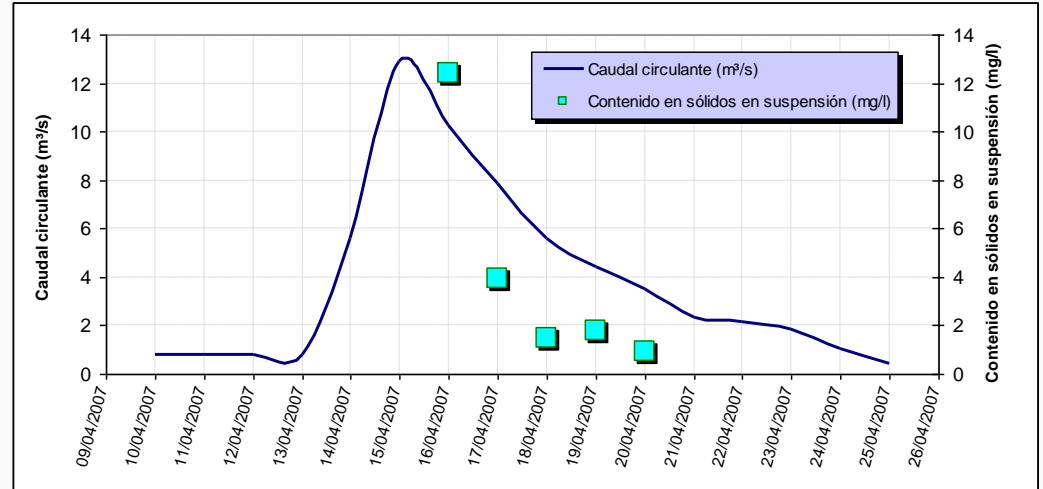
	Nivel mínimo de embalse (m.)	Nivel máximo de embalse (m)	Capacidad de embalse útil m ³
Embalse sin recrecer	25	40.0	42.000
Embalse con muro de 5 m	25	44.8	100.000
Embalse con muro 10 m	25	49.6	217.000



CRESTATX AQUIFER (MALLORCA)

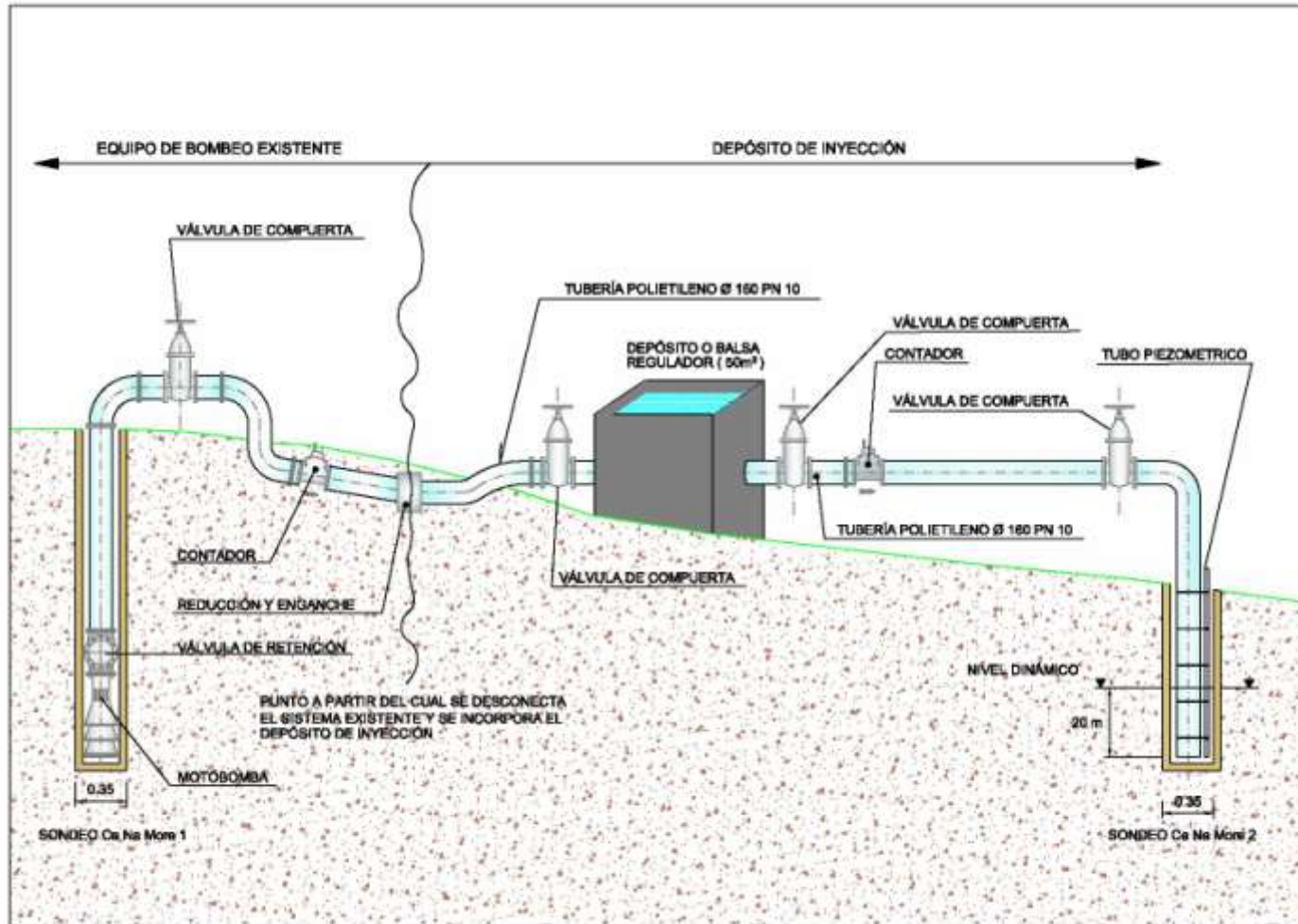


SUSPENDED SOLIDS ANALYSIS



Minimum	0,26
Average	56,0
Maximum	47.891,5
75 Percentil	0,57
85 Percentil	0,71
99 Percentil	64,95

INJECTION TEST



CRESTATX AQUIFER (MALLORCA)



SUSBIDENCE PROBLEMS AND COLLAPSES TEMPORARY ABANDONMENT OF THE PROJECT

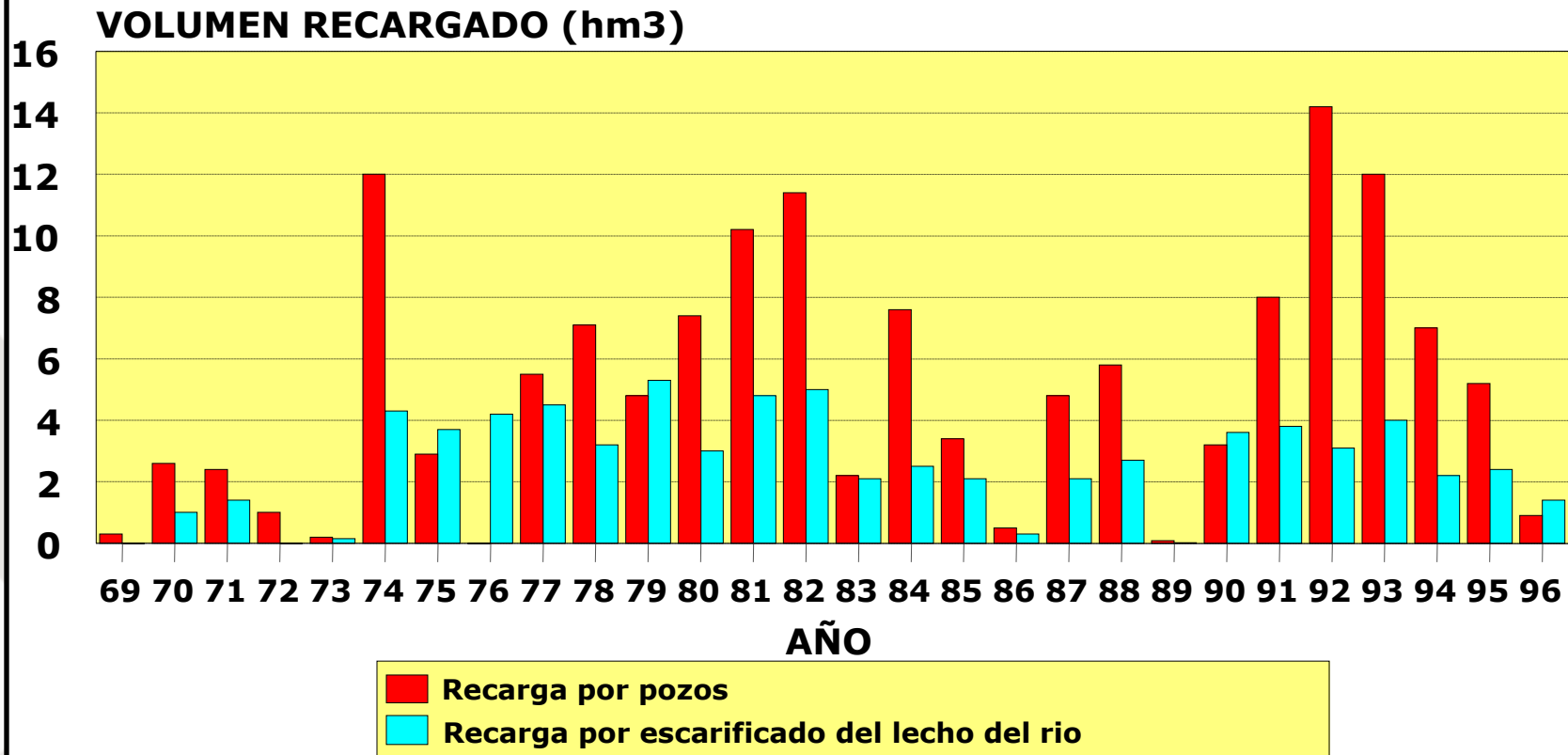




ACUÍFERO ALUVIAL DEL RÍO LLOBREGAT CUBETA DE SAN ANDREU, CASTELLBISBAL (BARCELONA)

Experiencias previas realizadas por la Agencia Catalana del Agua

VOLUMENES RECARGADOS EN EL ALUVIAL DEL RIO LLOBREGAT (AgBar 1997)





OBJECTIVE

To increase groundwater resources availability for augmenting the aquifer exploitation by the Cubeta de San Andres users association.

Artificial recharge is made using raw water from the Llobregat river. It is firstly treated in a decantation pond, which is an artificial wetland, and after it is infiltrated in a recharge pond.

The “Cubeta de Sant Andreu” aquifer is used for drinking Water for the nearby villages.

Putting into operation some industry factories in the area originated an increasing of the aquifer exploitation to meet their water demands.

The progressive land urbanization caused its waterproofing, reducing the natural recharge of the aquifer. So, groundwater resources diminished.

These reasons, together with a severe drought period, lead in 1985 to a deep decline in the groundwater level, and to the constitution of the CUACSA (Users association) to better manage groundwater. They decided to put into operation the artificial recharge of the aquifer.

CUBETA DE SAN ANDREU (BARCELONA)





Basses de Can Albareda (Castellbisbal)

PROJECTE EXECUTIU-BASSES SEGONS CONVENI ACA-CUACSA 114.439'10 EUR

ESTUDIS D'INVESTIGACIÓ SEGONS CONVENI IGME-CUACSA 177.989'00 EUR

CARACTERISTIQUES TÈCNiques

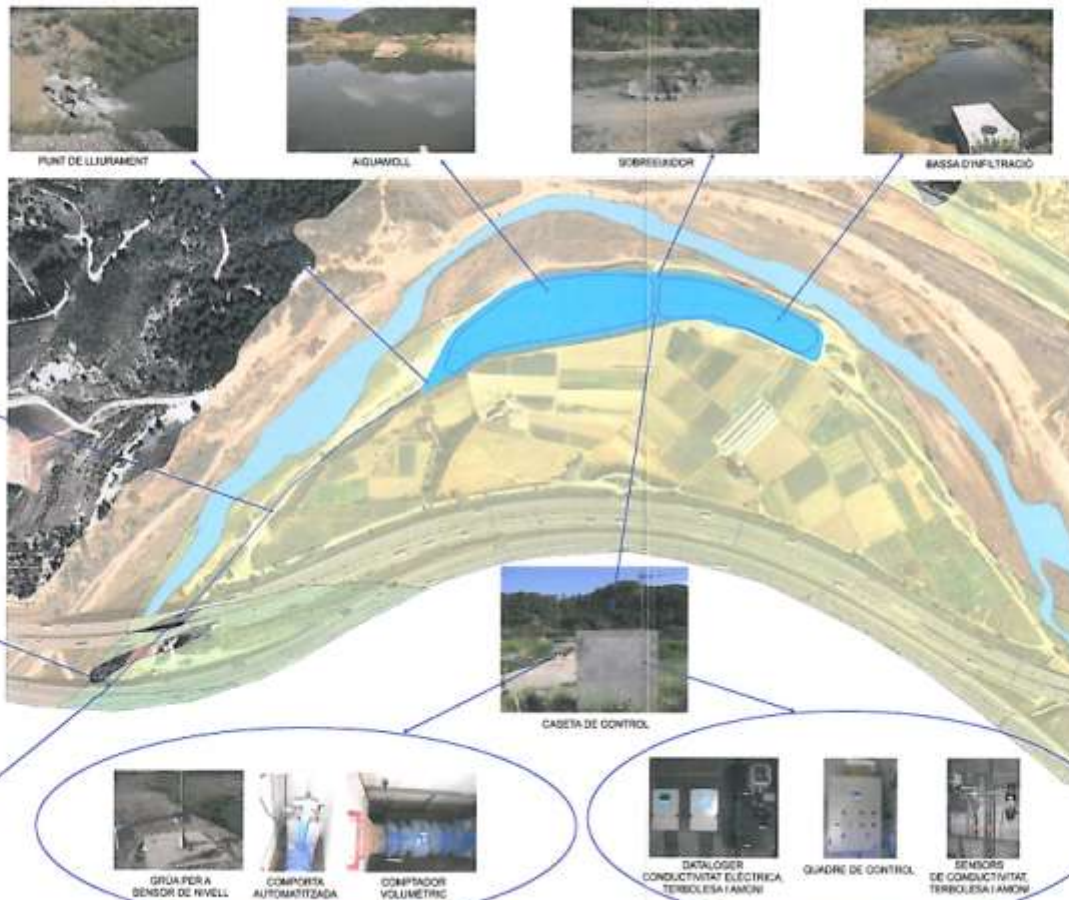
Superfície equitant	14.900 m ²
Superfície mitjana	6.000 m ²
Taxa d'infiltració prevista	1,2 m ³ /m ² /dia
Cabdal derivat mínim	Q ₁ > 5 m ³ /s ⇒ 300 L/s Q ₂ > 1 m ³ /s ⇒ 70 L/s Q ₃ > 2 m ³ /s ⇒ 6 L/s
Resistència mitja anual	1,8 km ³ /any
Conductivitat elèctrica	< 2 mS/cm
Amoníac	< 1,5 mg/L
Turbidesa	< 100 NTU

LLEGGENDA

RIU LLOBREGAT	GEOLOGIA
	Qas3
	Q3m
	Q30
	Q31
	Q32
	Q33



Març 2010
Departament Tècnic CUACSA





Water intake













CUBETA DE SAN ANDREU (BARCELONA)



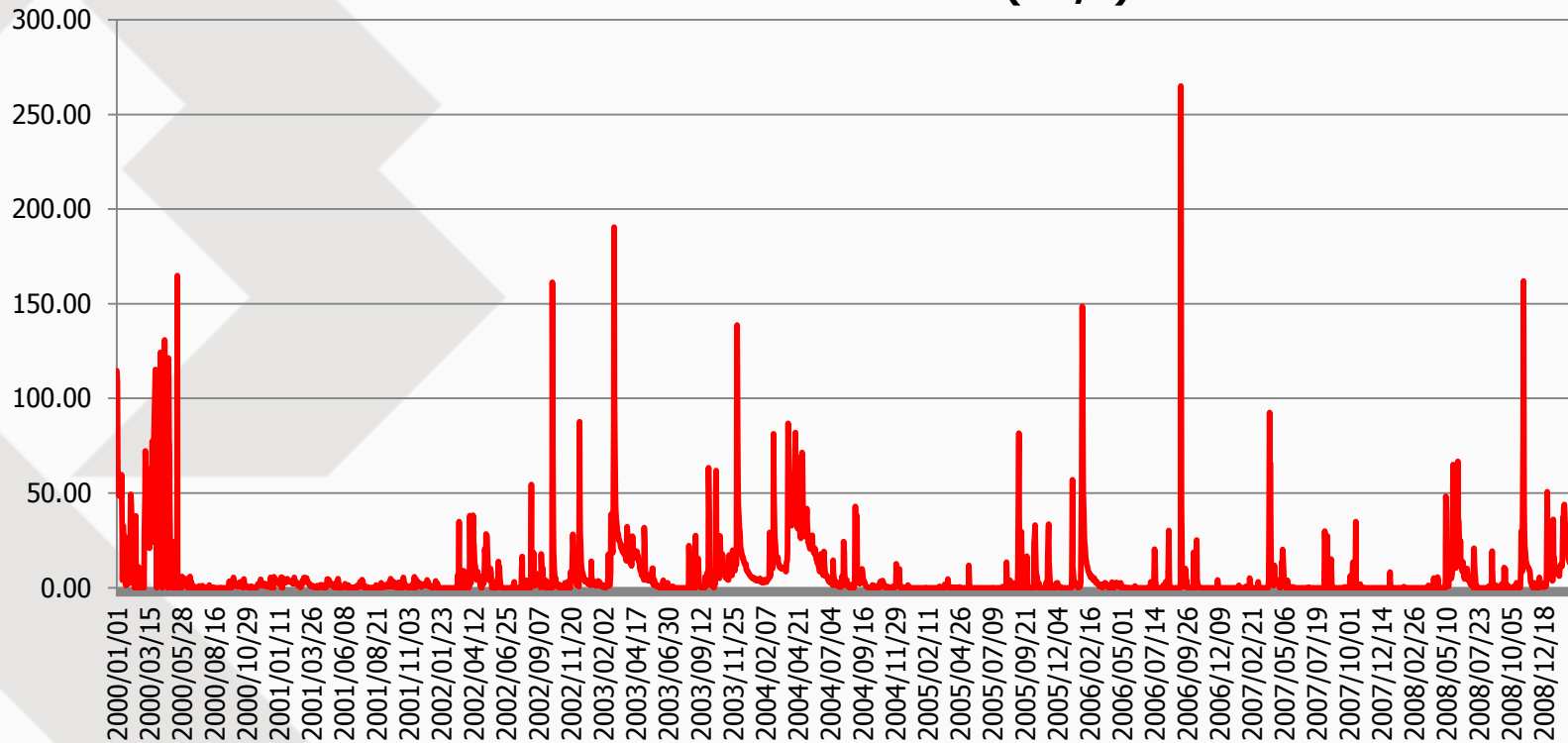




ASSESSMENT OF WATER SURPLUSES

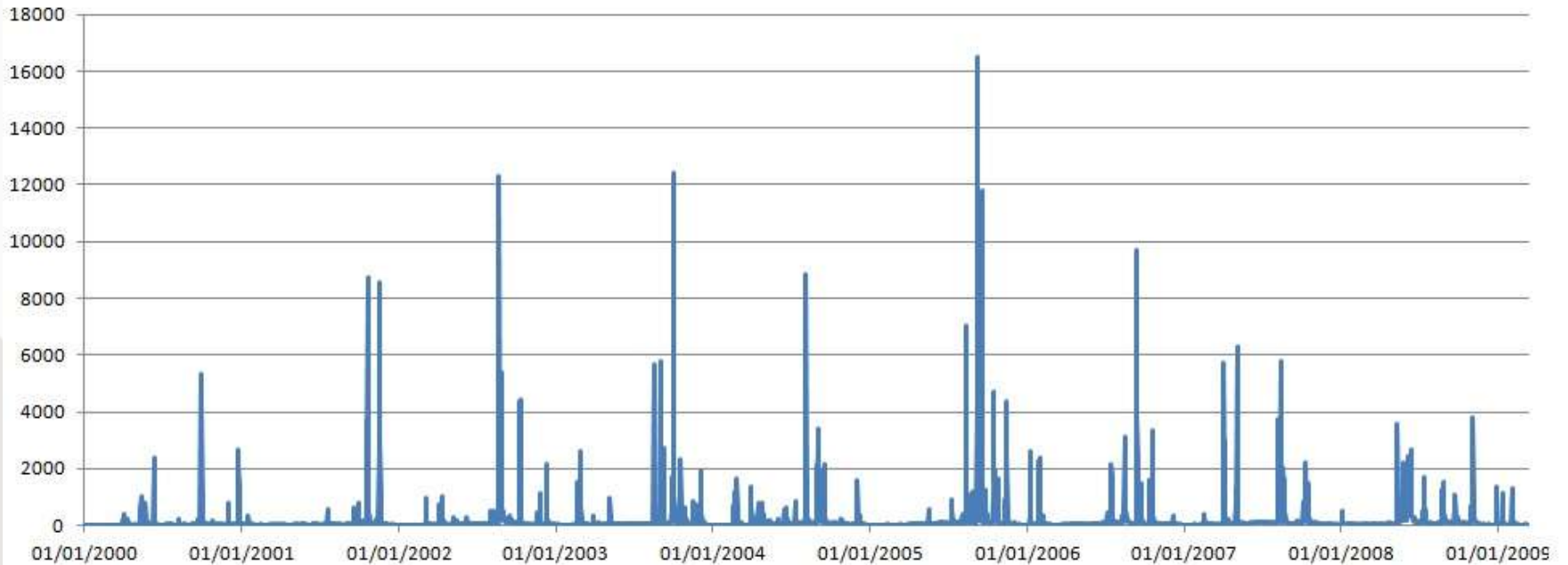
Environmental and drinking water flow: 4m³/s

Water flow available for AR(m³/s)

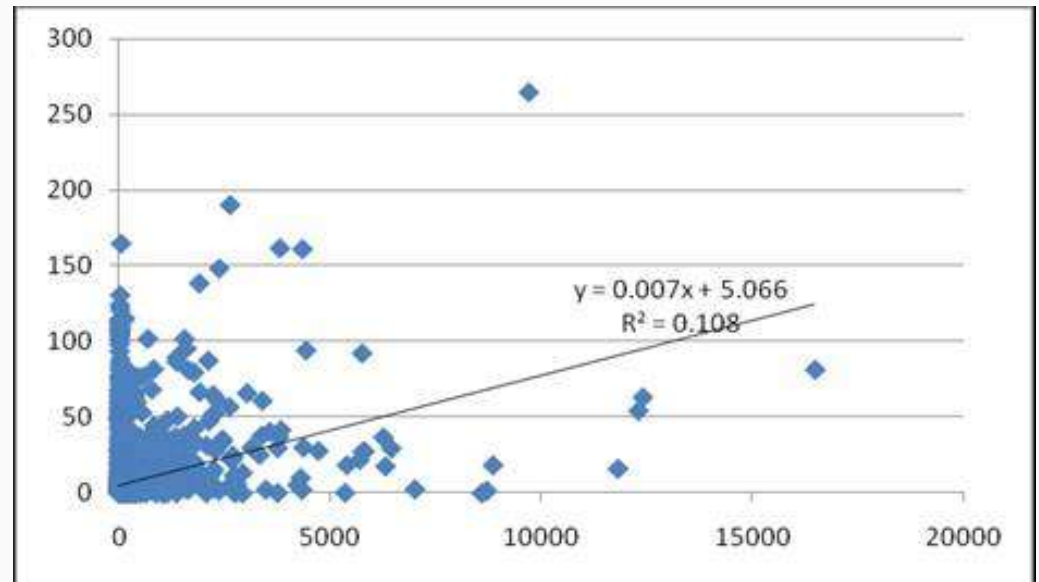
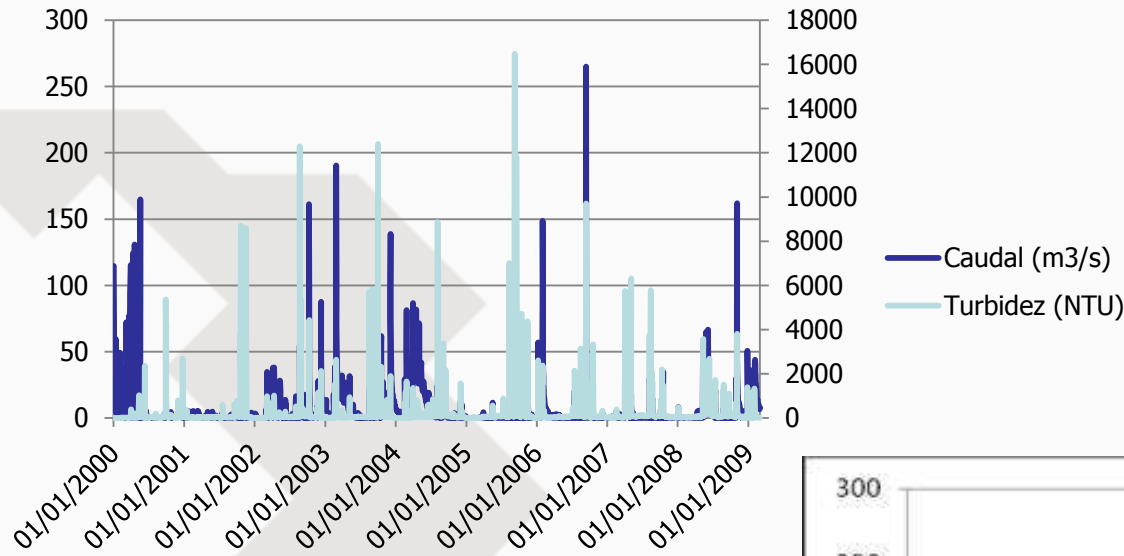


Turbidity

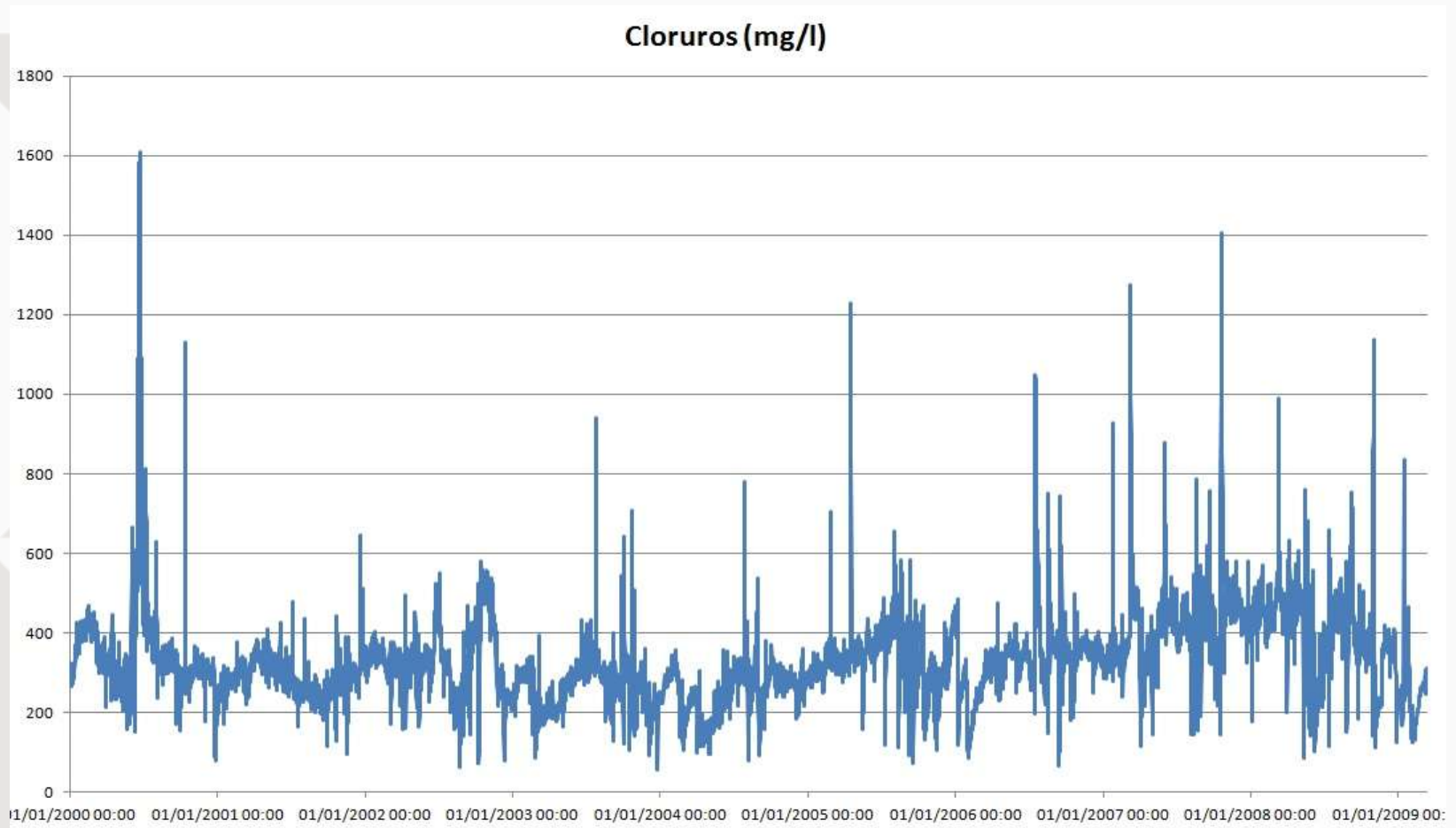
Turbidez media diaria (NTU)



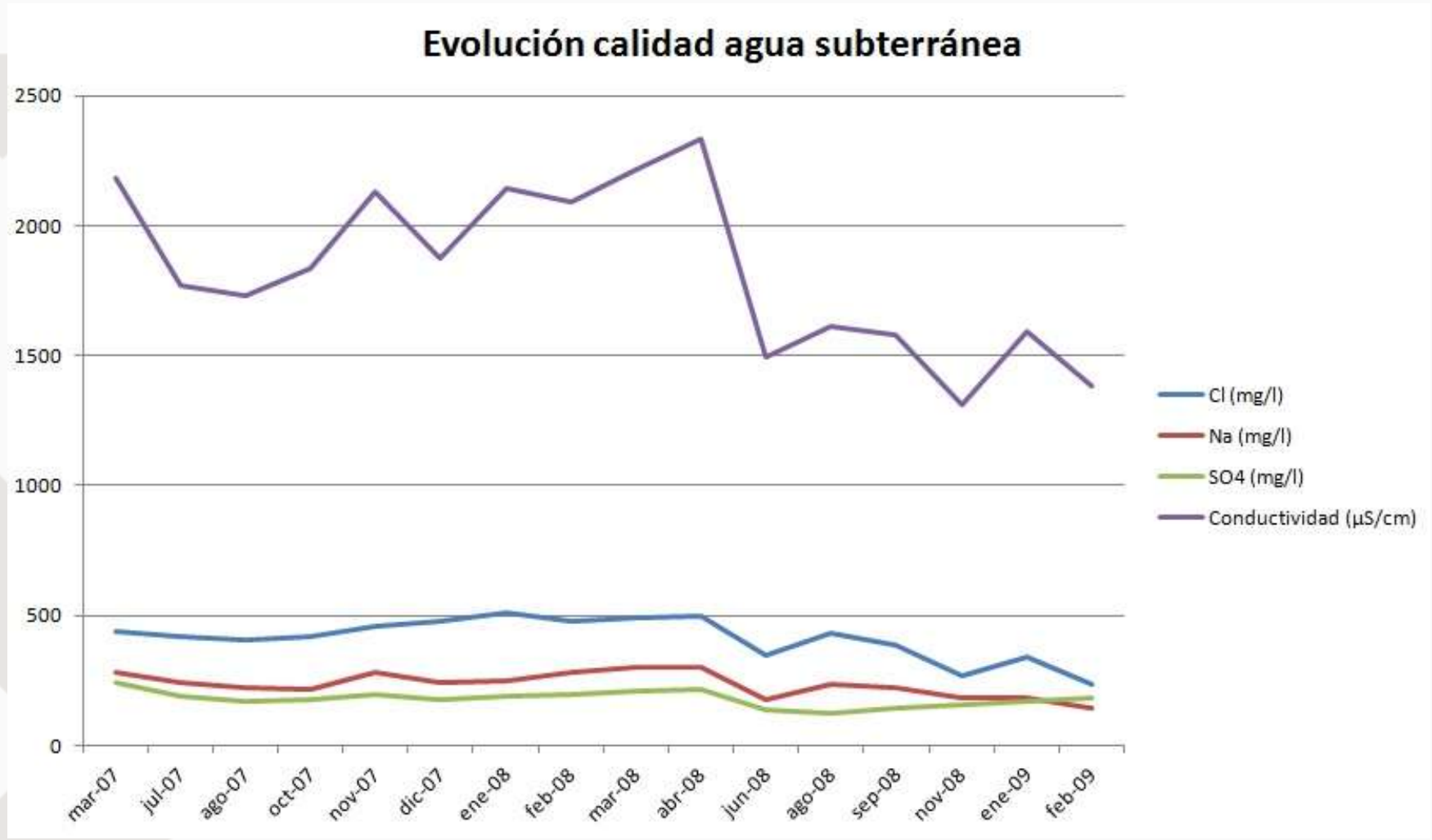
Turbidity vs. water flow:



Recharge water salinity

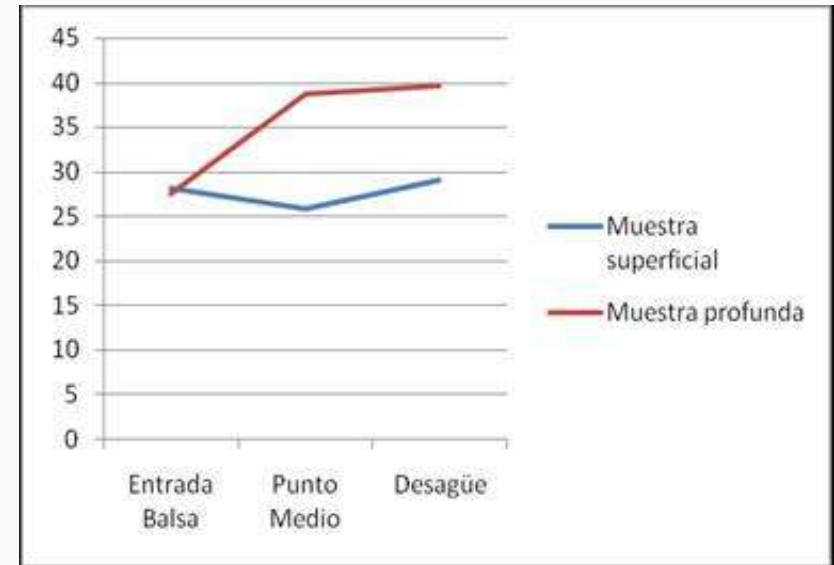


Groundwater quality monitoring



Behaviour of the artificial wetland against clogging:

- **Sampling water in the surface and at 80 cm depth**
- **Suspended solids content analyzed**



Clogging monitoring:

– Automatic equipment:

- Multiparametric probe for turbidity-conductivity-temperature



Clogging monitoring:

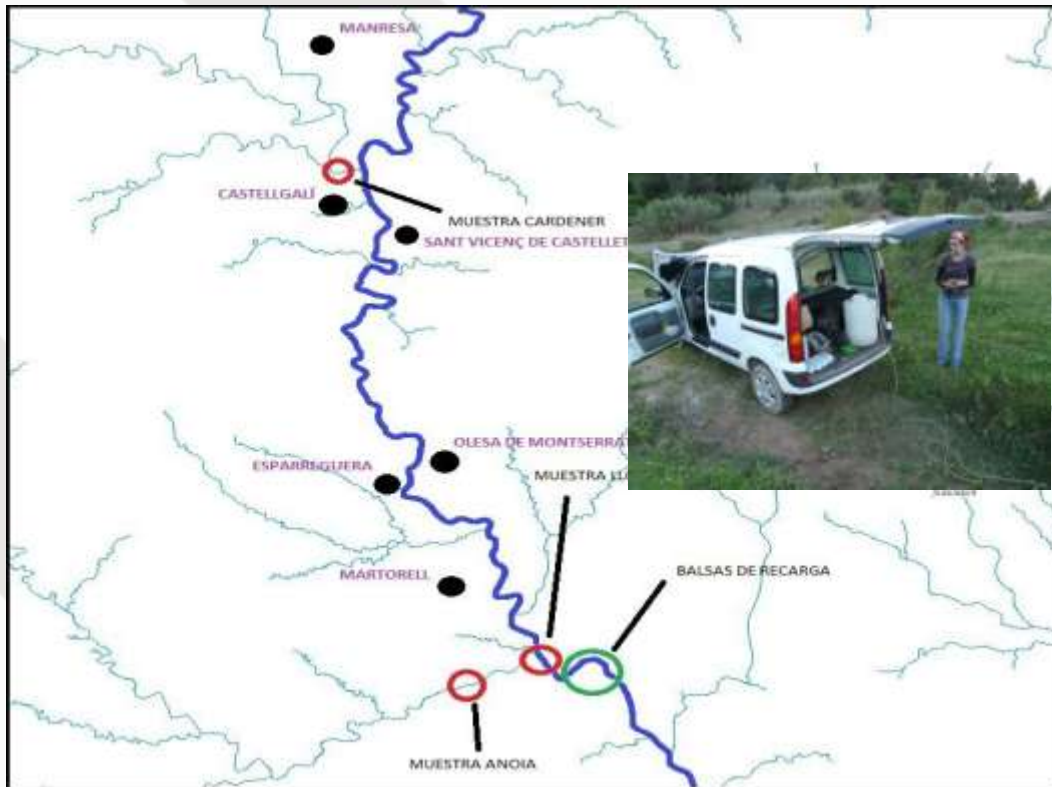
- **Automatic equipment:**
 - **Flowmeter at the entrance of the ponds**



CLOGGING STUDY

Suspended solids carried by the river

- River water sampling in several points
- Calculation of suspended solids
- Determinations of majority compounds of the solids (minerals)

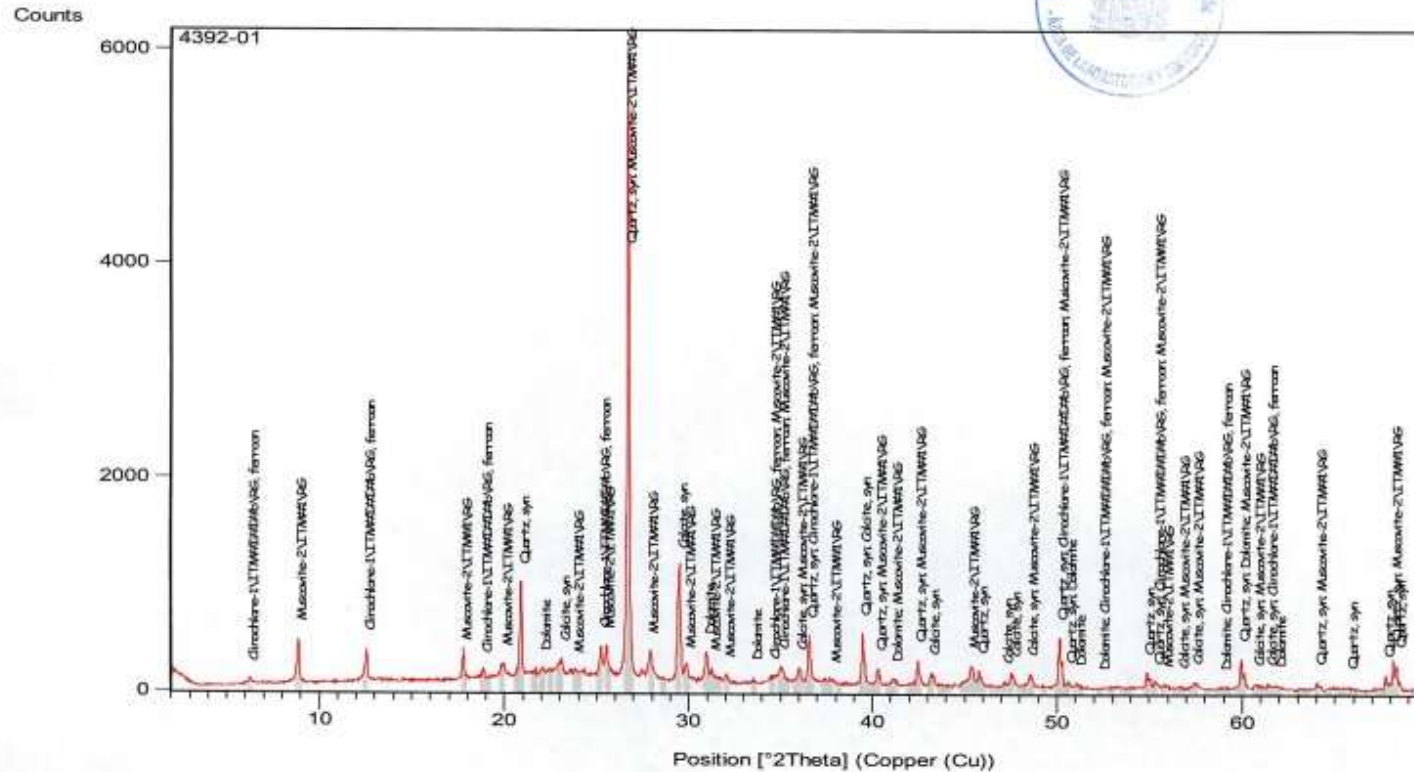


CLOGGING STUDY

Date: 17/05/2013

File: 4392-01

IGME RX



Page: 1 of 1

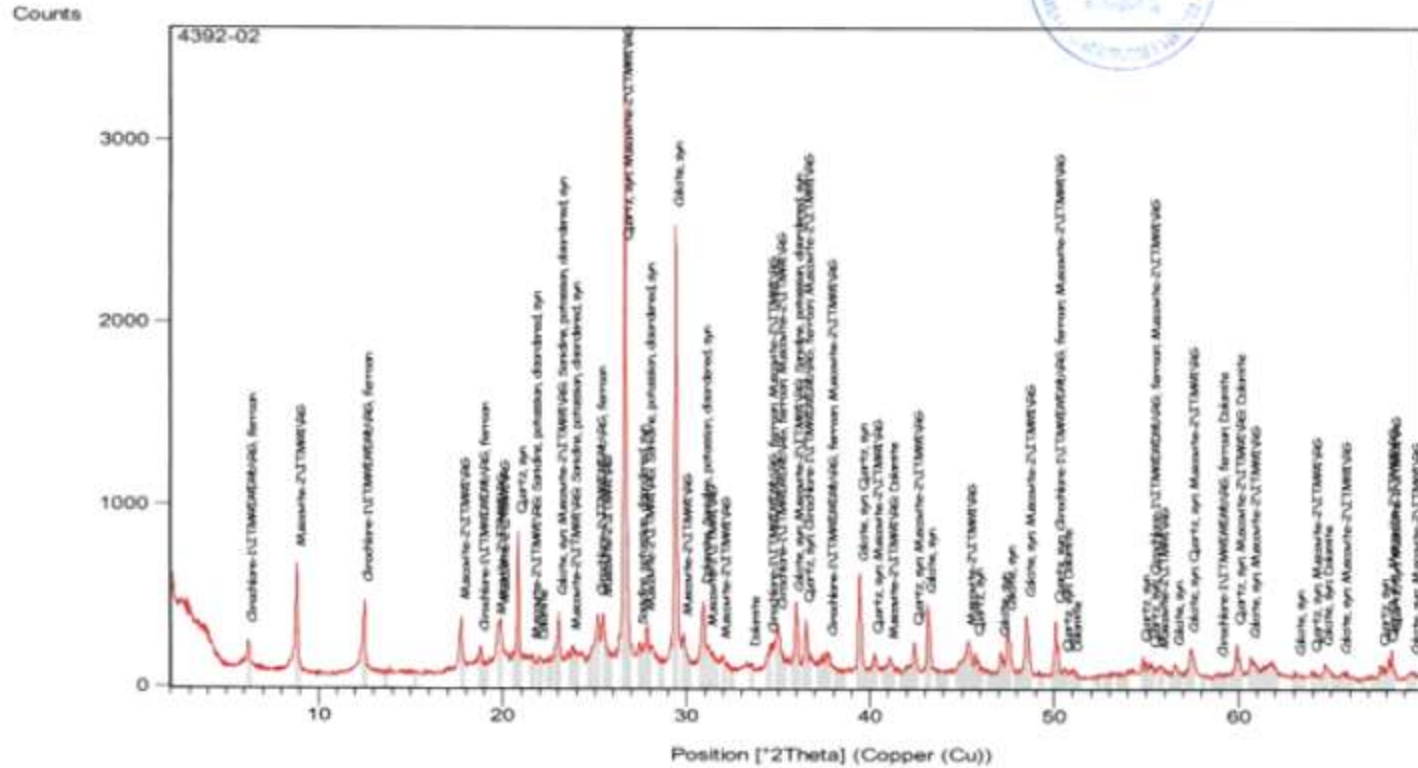
Anoia river sample

CLOGGING STUDY

Date: 17/05/2013

File: 4392-02

IGME RX

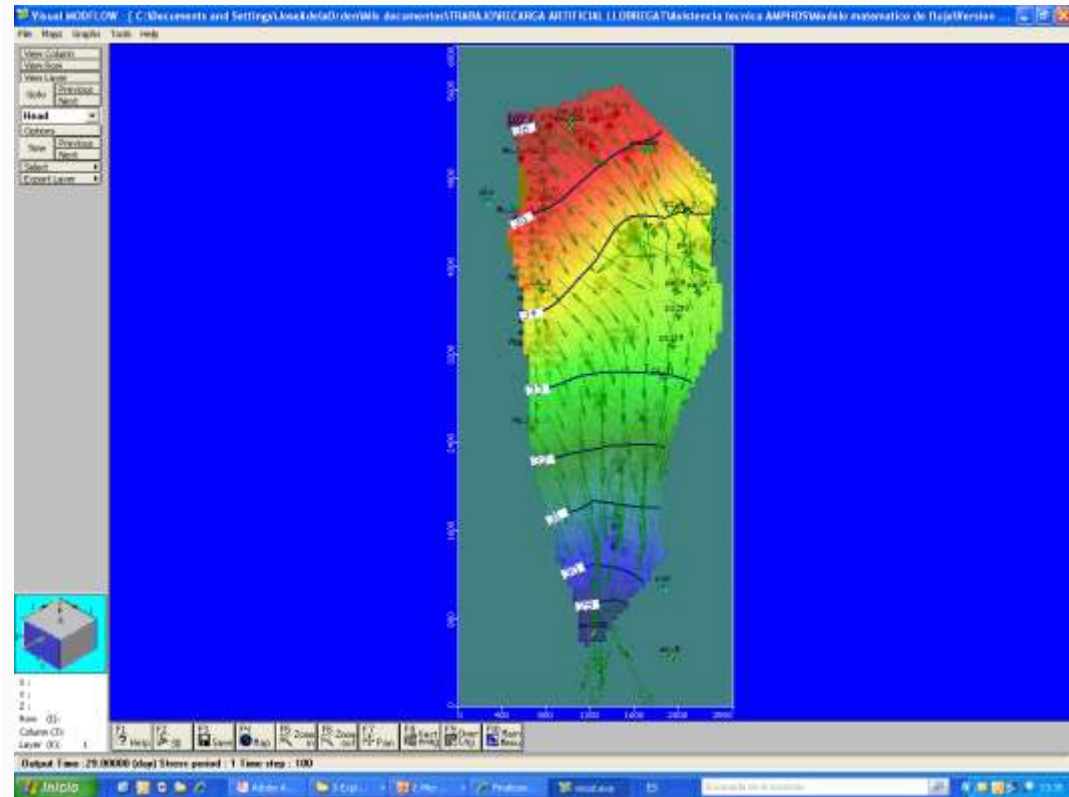
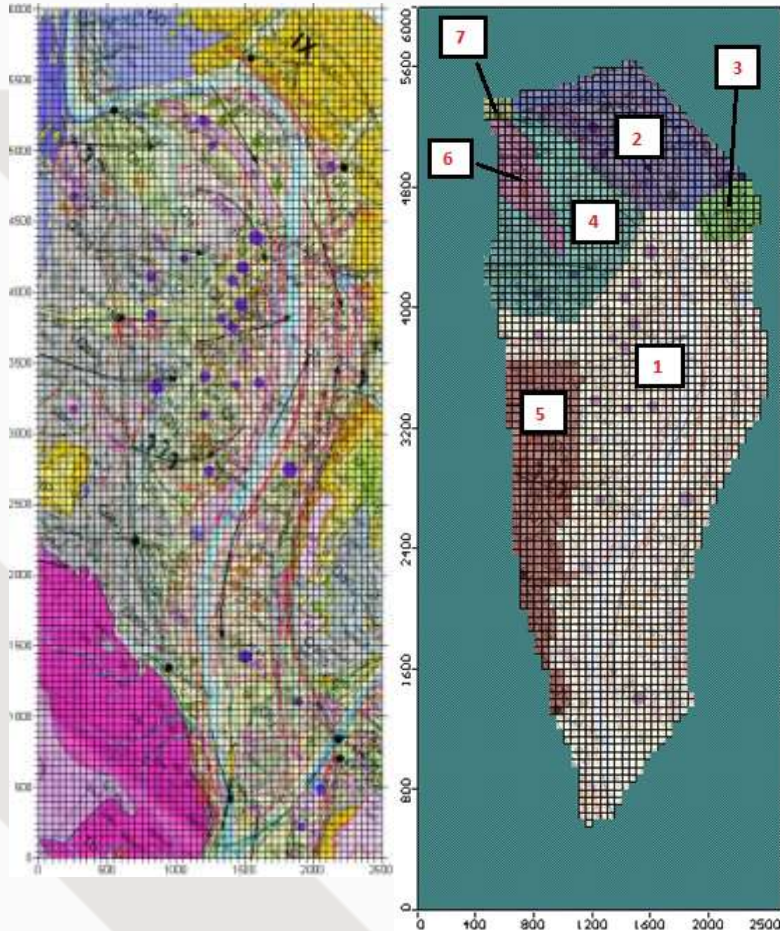


Llobregat river sample

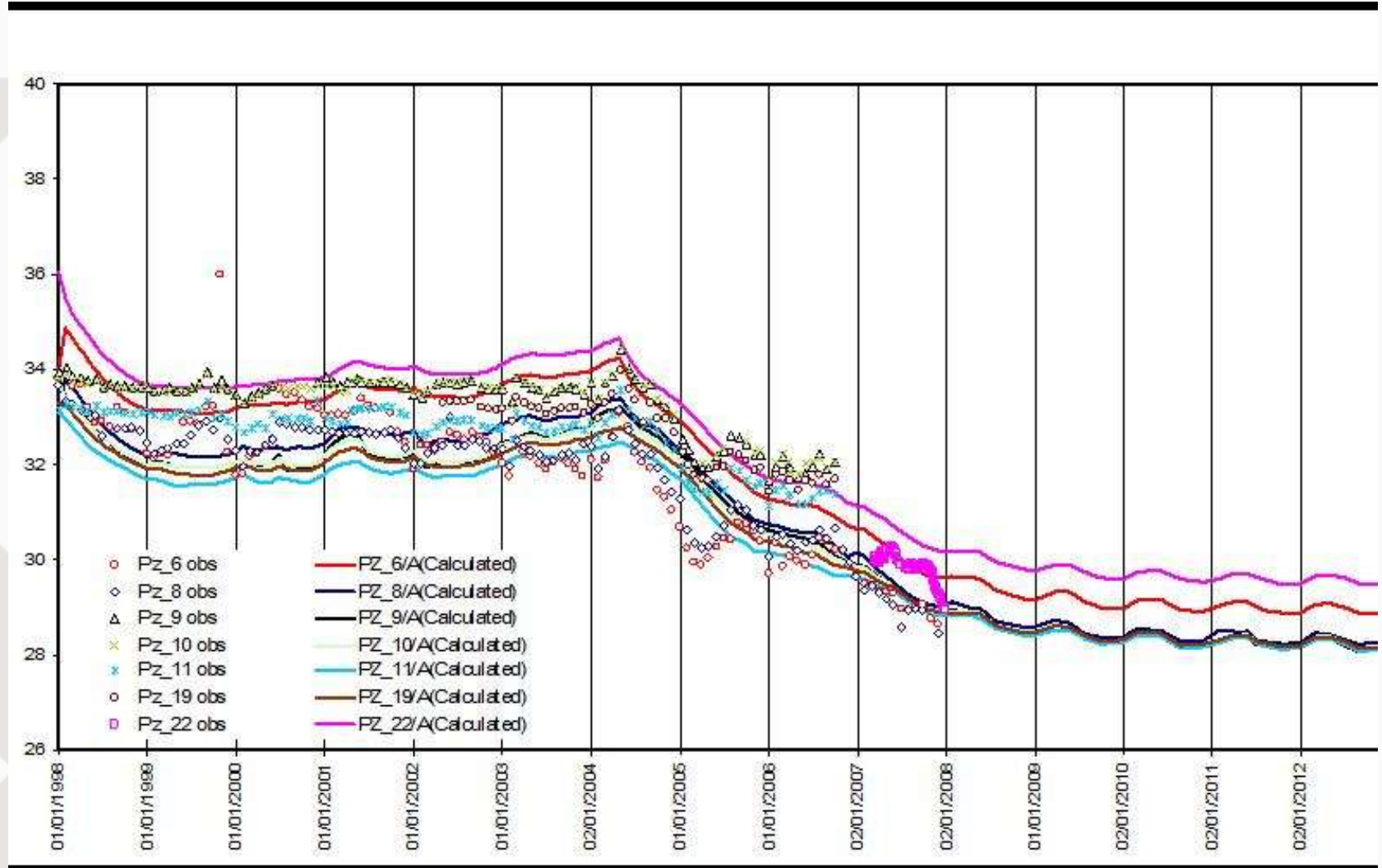
AQUIFER FLOW MODEL



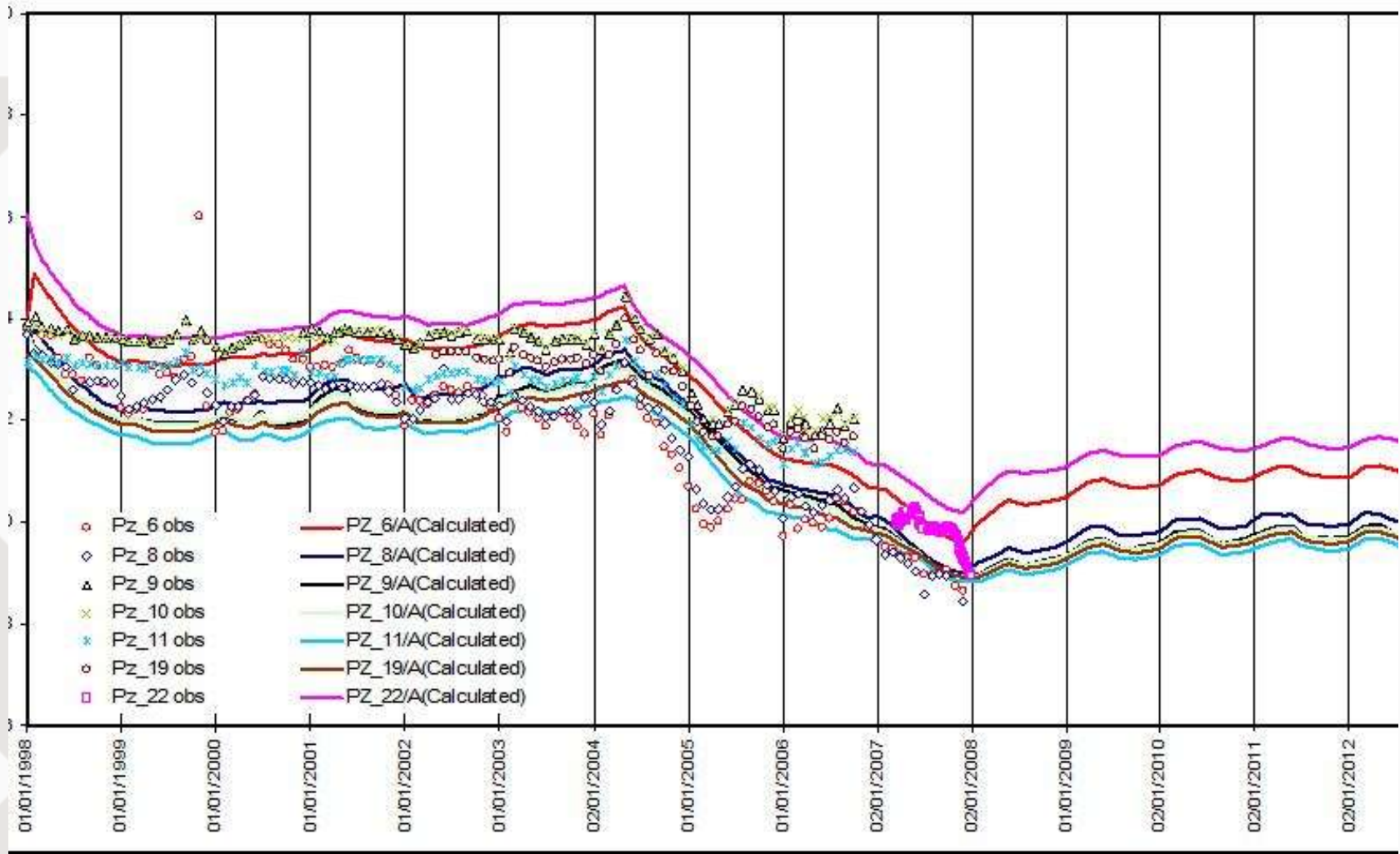
AQUIFER FLOW MODEL



AQUIFER FLOW MODEL



AQUIFER FLOW MODEL



CONCLUSIONS OF PRELIMINARY WORKS

- ▶ **1) Complying the water restrictions for other uses, there is enough water for the AR**
- ▶ **2) There are no problems related to artificial recharge water quality to use it for AR, excepting the suspended solids content.**
- ▶ **3) The decantation pond (artificial wetland) behaviour hasn't been as expected**
- ▶ **4) The flow model shows a rise of water level in the vicinity of the AR pond, and an increasing of groundwater storage. The negative effect is a rapid ground discharge of recharged water into the river.**

CURRENT WORKS:

- **Assessment of artificial recharge, both quantitative and qualitatively.**
- **Clogging study. Sampling the sediment from the decantation pond bottom, its mineralogical characterization. Correlation between the sediment composition and rainfall over the river basin, specially during floods.**
- **Study of the unsaturated zone as a pollutants purificator**
- **Study of the presence of emergent pollutants and their distribution along the unsaturated zone before reaching the Groundwater level.**

**MANY THANKS TO THE "MARENALES"
WORKSHOP ORGANIZERS FOR INVITING ME**

**THANK YOU FOR YOUR
ATTENTION**



GOBIERNO
DE ESPAÑA

MINISTERIO
DE ECONOMÍA
Y COMPETITIVIDAD



Instituto Geológico
y Minero de España