# MARSOL demonstration case-study areas: modeling studies to fulfill the aim of "comparable" modeling

*J.P. Lobo Ferreira*

**Joint International Workshop**

**EU FP7 MARSOL and EU HORIZON 2020 FREEWAT projects and EU EIP MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)**

***Pisa - April 21st 2015***

MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)

MAR Commission

# WP12 "MODELLING" - PART 1

**Partners:**

**Portugal, Algarve:**

J.P. Lobo Ferreira, Manuel M. Oliveira, Tiago Martins, Teresa Leitão (LNEC)

José Paulo Monteiro, Luís R.D. Costa (UALG), Tiago Carvalho (TARH):

**Israel, Menashe:** Daniel Kurtzman (Volcani)

**Lavrion Greece:** Laura Foglia (Geo.tu-darmstadt)

**Italy, Serchio:** Rudy Rossetto (SSSA) , Iacopo Borsi (Tea-group)

**Italy Brenta:** Michele Ferri (adbve)

**Spain, Barcelona:** Xavier Sanchez-Vila (UPC)

# Agenda 1st MARSOL WP 12 Modelling Workshop 14th-15th July 2014

**Date and time:** Monday, 14 July 2014, 14:00-18:30 / Tuesday, 15 July 2014, 09:00-13:00

**Venue:** LNEC, Lisbon, Portugal – Room 3, LNEC Conference Centre

## DAY 1

| Time | Topic | Presenter |
|---|---|---|
| 13:00 –13.50 | LUNCH at LNEC | Welcome, relax before starting |
| 14:00 – 14:10 | Welcome and introduction to Lisbon WP12 Workshop | *João Paulo Lobo Ferreira (LNEC)* |
| 14:10 – 15:30 | DoW requirements for WP 12 development | *João Paulo Lobo Ferreira (LNEC)* |

1. Review of WP 12 Objectives (as in DoW):
   - To present the current state of the art approaches for the modelling of MAR sites.
   - Evaluation of the modelling approaches of the MARSOL DEMO sites.
   - Definition of appropriate modelling approaches for MAR sites.
   - Preparations of guidelines for the selection of appropriate MAR modelling schemes.
   - Produce demonstration short movies of MAR for each DEMO site.

2. Review of WP 12 Tasks (as in DoW):
   - Task 12.1: Methods evaluation (Task Leader: LNEC)
   - Task 12.2: Water budget and conceptual modelling (Task Leader: LNEC)
   - Task 12.3: Climate change impact (Task Leader: LNEC)
   - Task 12.4: Hydrogeological modelling (Task Leader: LNEC; contributing partner: TUDa)
   - Task 12.5: Physical (sandbox) models (Task Leader: LNEC)
   - Task 12.6: Guidelines for best practice MAR modelling (Task Leader: LNEC)
   - Task 12.7: Visualisation (Task Leader: LNEC)

3. Review of WP 12 Deliverables (as in DoW):
   - D12.1 Water budget and climate change impact
   - D12.2 GIS database of the MARSOL DEMO sites
   - D12.3 Progress report on numerical models of the MARSOL DEMO sites
   - D12.4 Numerical models of artificial recharge at the MARSOL DEMO sites
   - D12.5 Physical modelling of selected MARSOL DEMO sites
   - D12.6 Video visualisation of MAR at the MARSOL DEMO sites
   - D12.7 White book on MAR modelling

1st MARSOL WP 12 Modelling Workshop

4. Conceptual ideas for the "comparable" modelling of MARSOL case-study areas:
   - regional aquifer/watershed modelling (for the hydrological "Alternative water sources" budget and regional groundwater flow lines assessment);
   - intermediate scale (e.g. 4x4 km2) modelling (for the MAR infrastructures and water sources (e.g. local river bed aquifer interaction) cause/effects of MAR);
   - local scale (MAR infrastructures, unsaturated zone, tracer tests, etc.).

| Time | Topic | Presenter |
|---|---|---|
| 15:30 – 16:00 | Coffee-break | |
| 16:00 –18:15 | CASE-STUDY PRESENTATIONS | MARSOL Partners |

1. Portugal (16:00 – 16:45)
   - Campina de Faro (GABARDINE/MARSOL modelling).
   - Querença-Silves: Universidade do Algarve (modelling) c/o Prof. José Paulo Monteiro / LNEC (PROWATERMAN groundwater recharge assessment)

2. Israel (16:45 – 17:30)
   - Menashe site regional scale model (c/o Dr. Yoram Katz of Mekorot)
   - The local scale modelling will be dealt (c/o Dr. Daniel (Dani) Kurtzman of Volcani)

3. Italy and Malta (via Skype 17:30 – 18:15)
   - Italy, Serchio: Rudy Rossetto (SSSUP) /
   - iacopo.borsi@tea-group.com
   - Italy Brenta: michele.ferri@adbve.it
   - Malta: paul.micallef@wsc.com.mt

18:15 – 18:30 Wrap-up for the 1st day

## DAY 2

| Time | Topic |
|---|---|
| 09:00 –11:00 | CASE-STUDY PRESENTATIONS |

4. Spain (09:00 – 09:45)
   - Llobregat (GABARDINE/MARSOL modelling, c/o UPC Prof. Xavier Sanchez / Albert Folch <folch.hydro@gmail.com>).
   - Arenales (DINA-MAR/TRAGSA, c/o Dr. Enrique Escalante)

5. Greece (09:45 – 10:15)
   - Lavrion Greece: foglia@geo.tu-darmstadt.de

# WP 12: Modelling

| | 2014 | | | | | | | | | | | | 2015 | | | | | | | | | | | | 2016 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| WP 12 Modelling | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 12.2: Water budget and conceptual modelling (Task Leader: LNEC) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Task 12.2: Water budget and conceptual modelling

- For selected sites, GIS layers of information for conceptual modelling are being prepared.

- This will include the use of vulnerability to pollution indexes (e.g. DRASTIC), vulnerability to salt water intrusion indexes (e.g. GALDIT), as well as parameters related to the unsaturated zone capacity for incorporating MAR water (e.g. depth to the water table will be one of the GIS layers of information available both in DRASTIC as well as in GABA-IFI).

- Water availability for artificial recharge is calculated closely linked with case studies' work packages by LNEC with case study partners, using watershed water balances in the area of interest of the MAR systems using the daily sequential soil water balance model BALSEQ_MOD.

- Each demo site should develop their conceptual models and water budget accordingly to their scopes:
  - River basin above the demo site (natural conditions)
  - Water availability (anthropogenic imported water)
  - Groundwater body / aquifer system that influences / is influenced by MAR
  - Local scale processes in the area influenced by the MAR

# WP 12: Modelling

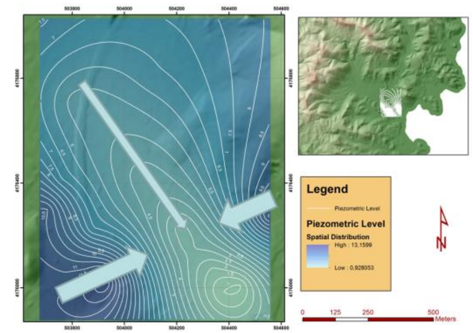
| 2014 | | | | | | | | | | | | 2015 | | | | | | | | | | | | 2016 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| WP 12 Modelling | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Task 12.2: Water budget and conceptual modelling (Task Leader: LNEC) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

MANAGED AQUIFER RECHARGE SOLUTIONS

## Task 12.2: Water budget and conceptual modelling

### Conceptual Modelling

- Demo site #1: Lavrion (Greece)

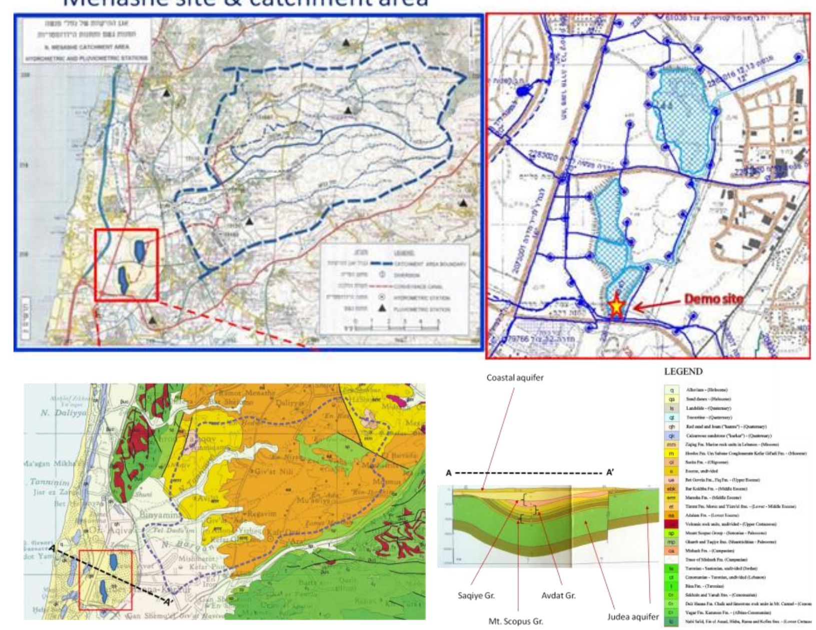



Lavrion: Piezometric map of the alluvial area, including the discharge axes of the alluvium (NW-SE) and the lateral contribution from the marble (NE-SW).

- Demo site #2: South Portugal → Examples next slides

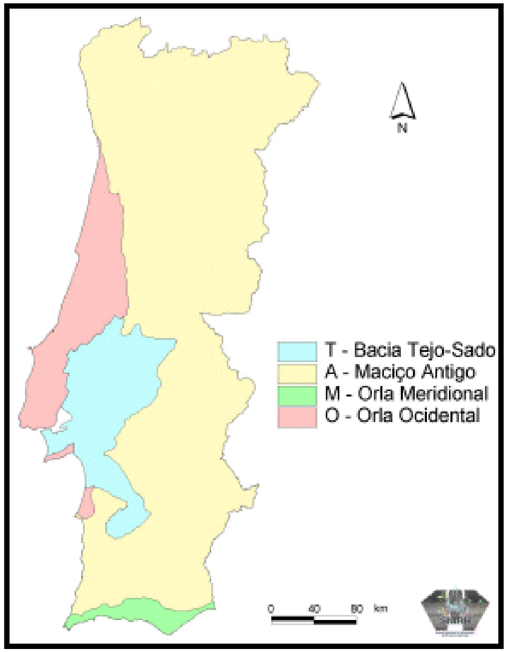
- Demo site #7: Menashe (Israel)

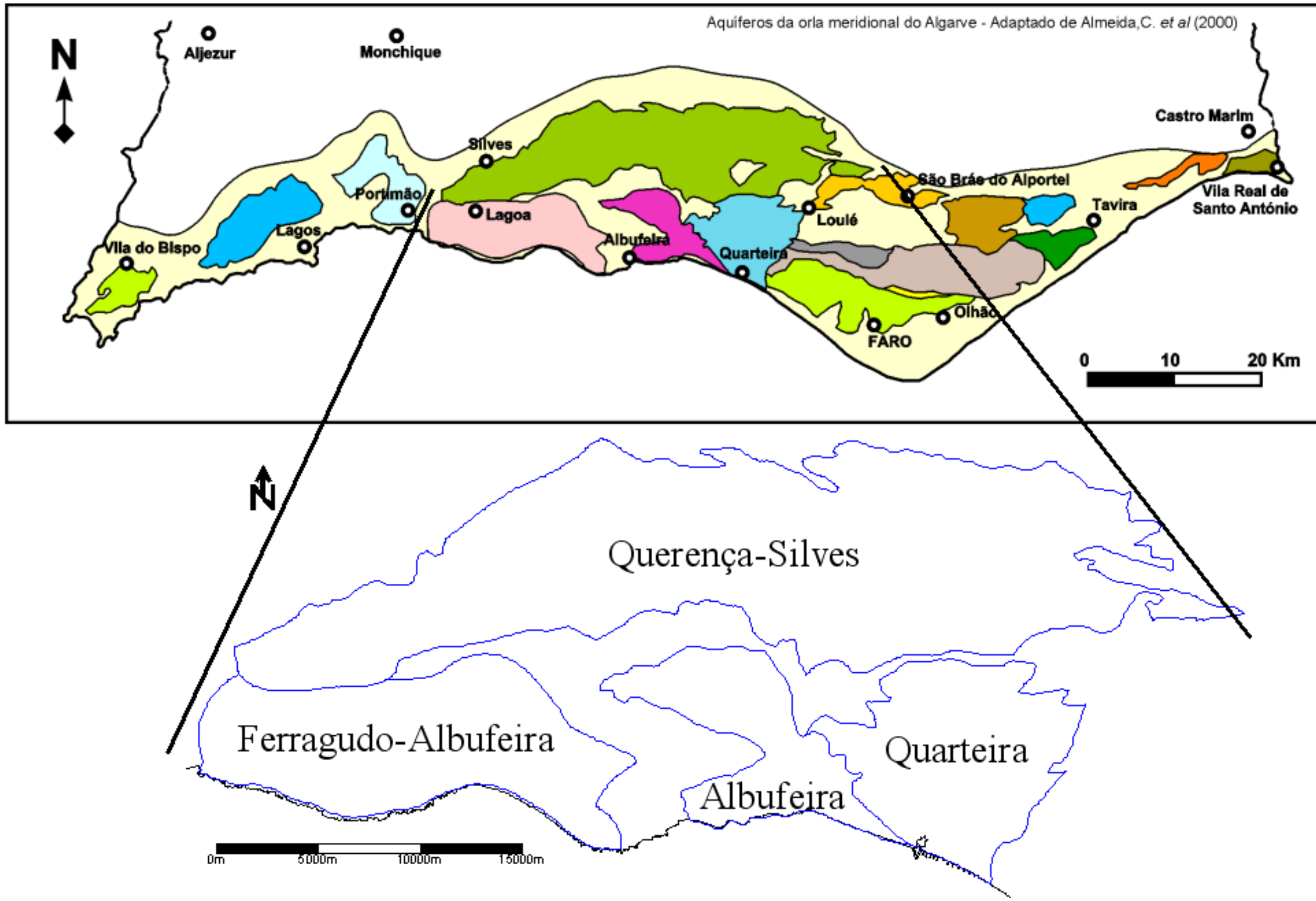
Menashe site & catchment area




- Demo site #3 to #6, #8: Started the definition of the conceptual model of all case study sites, during the Lisbon Modelling workshop of July 14-15, comprising the description of the hydrogeology of each site and of the hydrology of the watershed upstream the sites

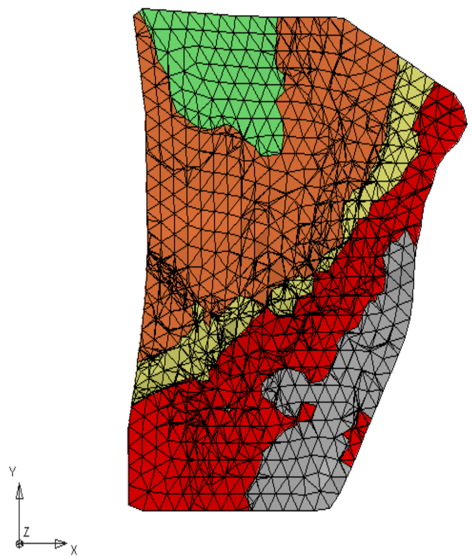
# PT demonstration sites
# Querença-Silves and Campina de Faro aquifer systems

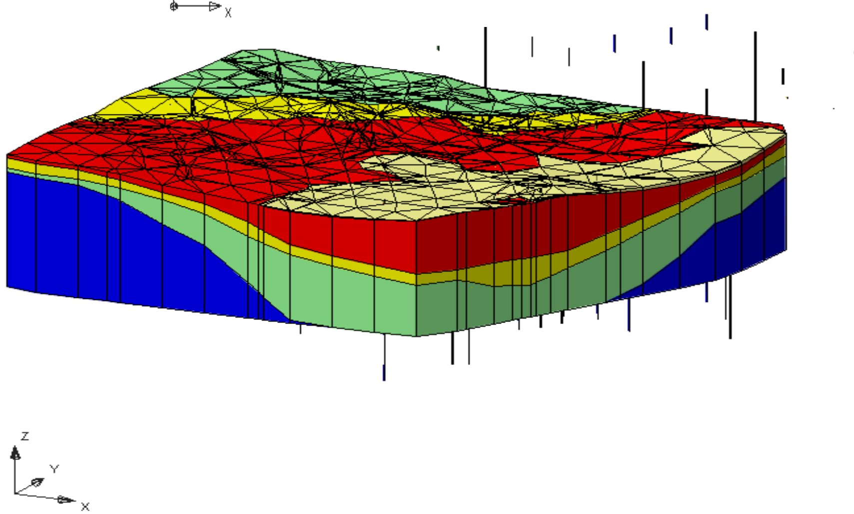


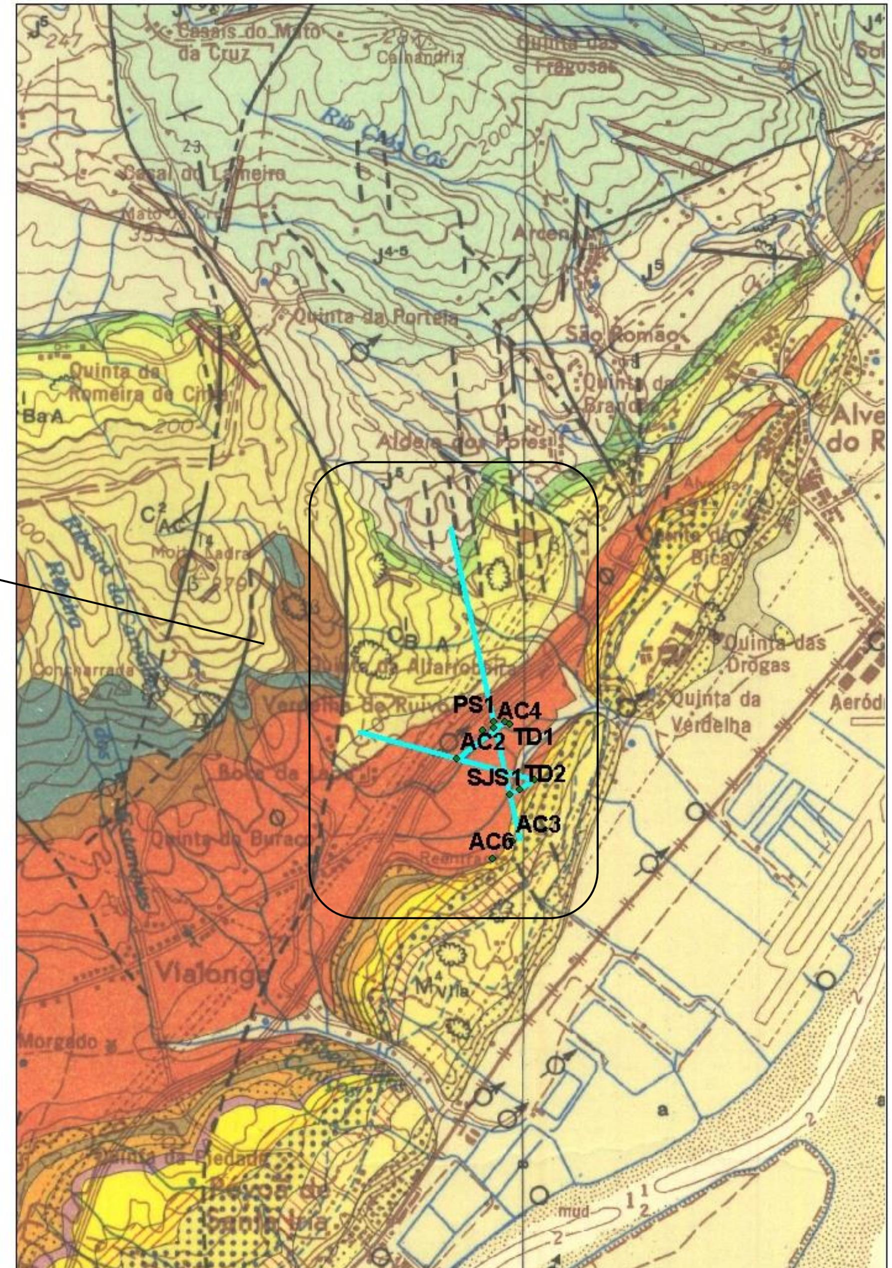




| Características gerais | Área | Produtividade Média | Transmissividade | Recarga Anual | Coeficiente de armazenamento |
|---|---|---|---|---|---|
| Maioritariamente Cársico; Sistema de livre a confinado | 318 $km^2$ | 12.2 L/s | De 83 a 3000 $m^2$/dia | 70 a 183 $hm^3$ | De $5*10^{-3}$ a $3*10^{-2}$ |

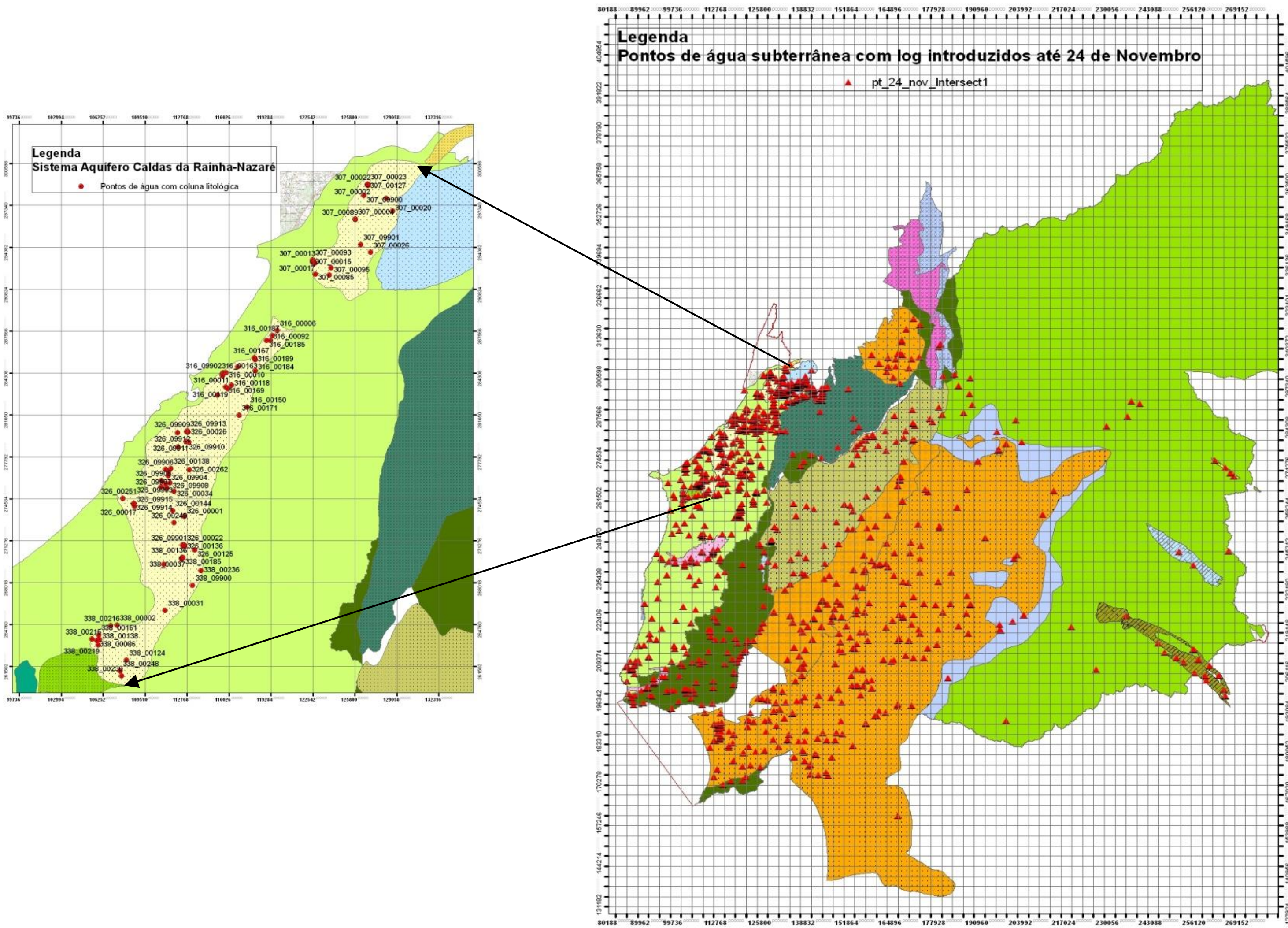
# Geology of the case study demonstration area

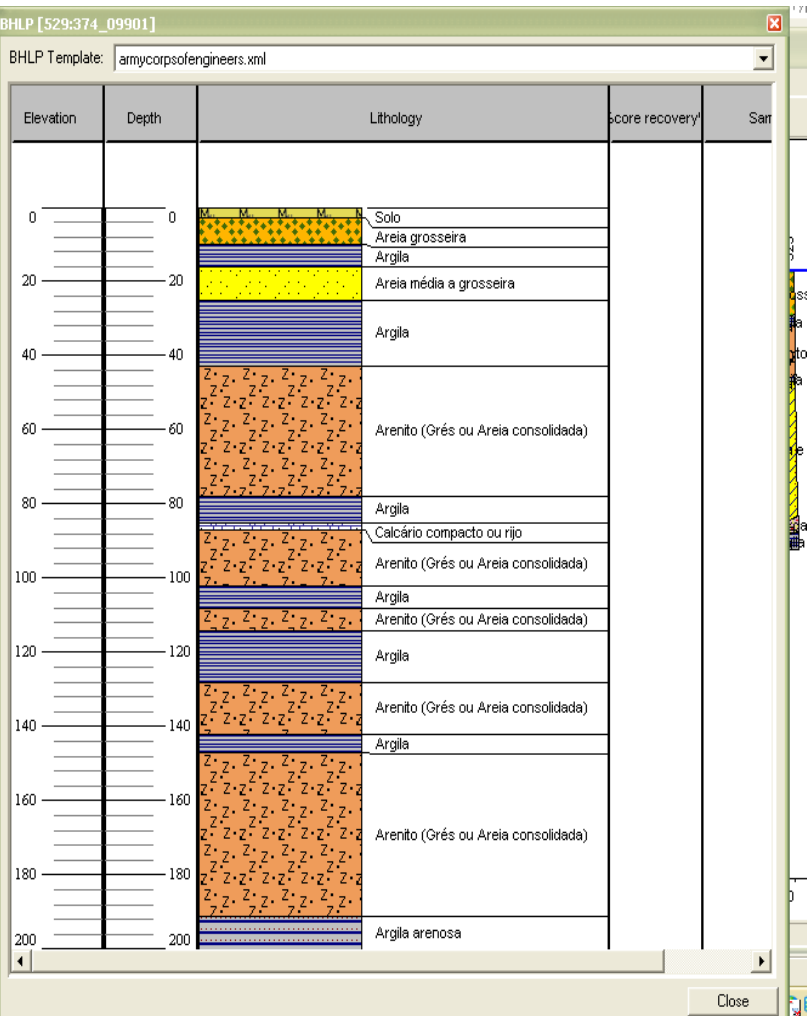


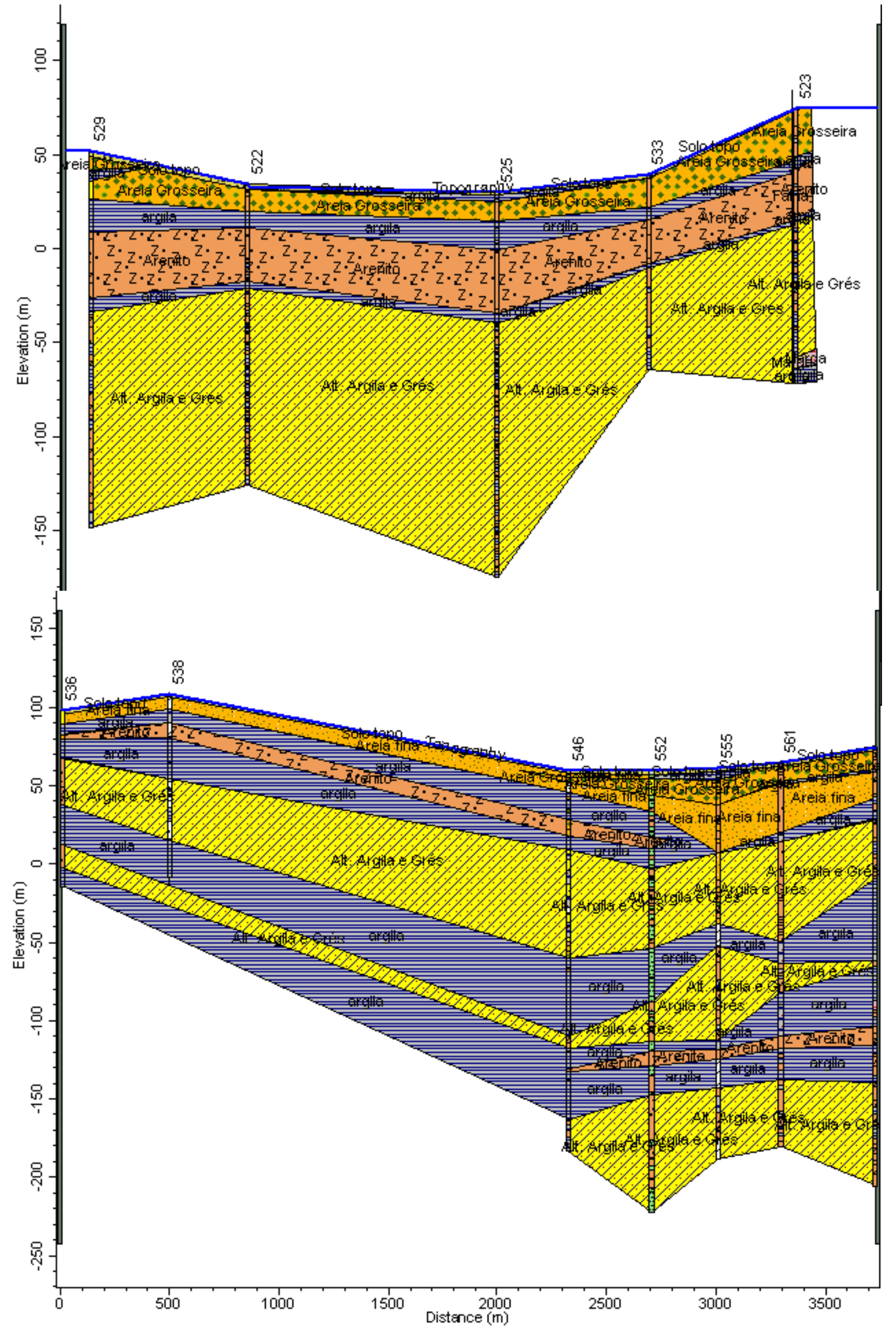




**PT RIVER BASIN MANAGEMENT PLANS INCLUDING GROUNDWATER WELLS INVENTORY WITH LOGs**
**(e.g. Tagus and Westerns rivers RBMPs, Nov. 2010)**




BHLP [529:374_09901]
BHLP Template:
armycorpsofengineers.xml
Elevation
Depth
Lithology
core recovery
Solo
Areia grosseira
Argila
Areia média a grosseira
Argila
Arenito (Grés ou Areia consolidada)
Argila
Calcário compacto ou rijo
Arenito (Grés ou Areia consolidada)
Argila
Arenito (Grés ou Areia consolidada)
Argila
Arenito (Grés ou Areia consolidada)
Argila
Arenito (Grés ou Areia consolidada)
Argila arenosa
Close


529
522
525
533
523
Areia Grosseira
argila
Arenito
Alt. Argila e Grés
Topography
Elevation (m)
536
538
546
552
555
561
Areia fina
Distance (m)

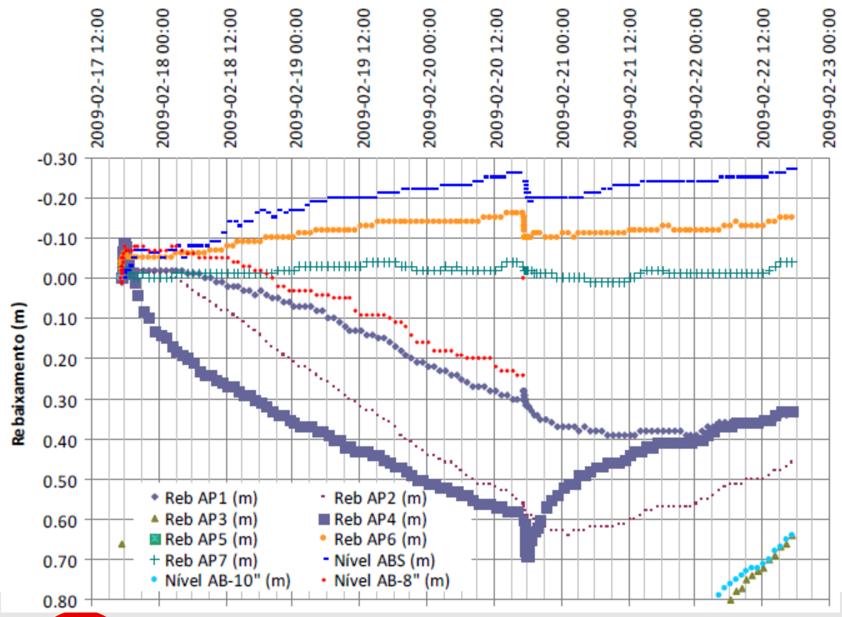
# **PIP 2009-2012:** Instrumentação, ensaios *in-situ* e em laboratório para suporte à investigação do meio hídrico subterrâneo

## Estudos em sistemas aquíferos Multicamada (NAL, NAER)

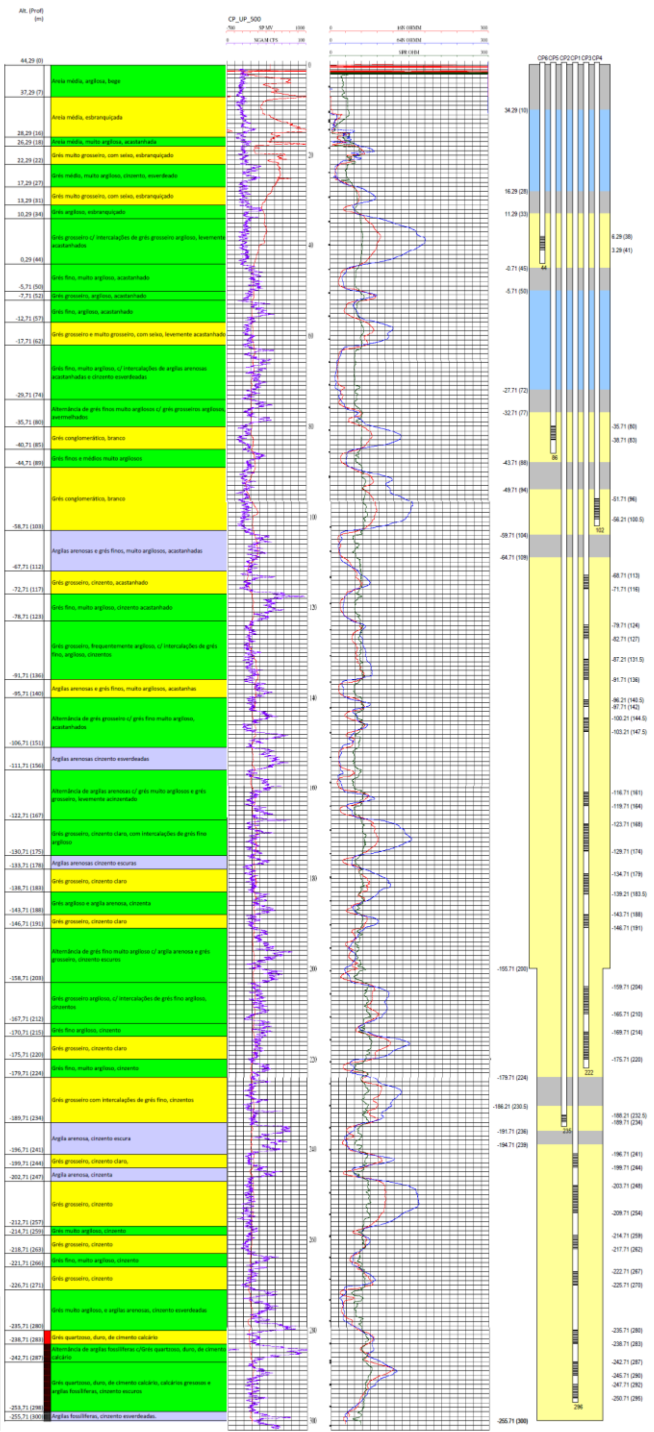
- Instrumentação dos piezómetros com sondas de registo automático
- Monitorização de níveis piezométricos em diferentes camadas durante ensaio de bombagem
- Efeito de Noordbergum

**Sondas de registo automático**

**Aspeto final dos piezómetros AP**

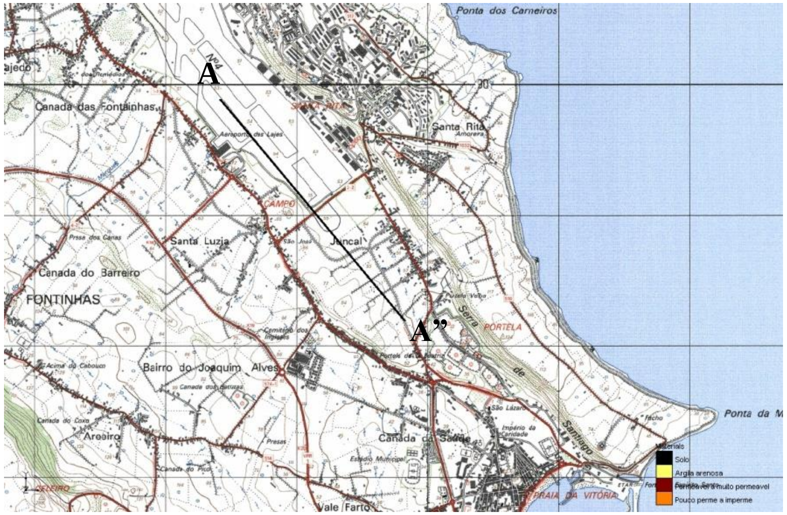


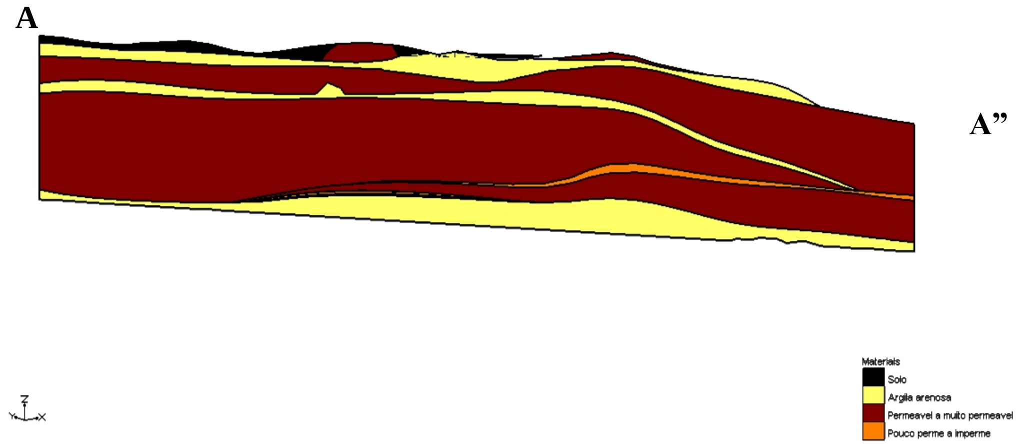

**Rebaixamento durante o ensaio de bombagem no troço intermédio do furo AB (Oliveira et al., 2009)**

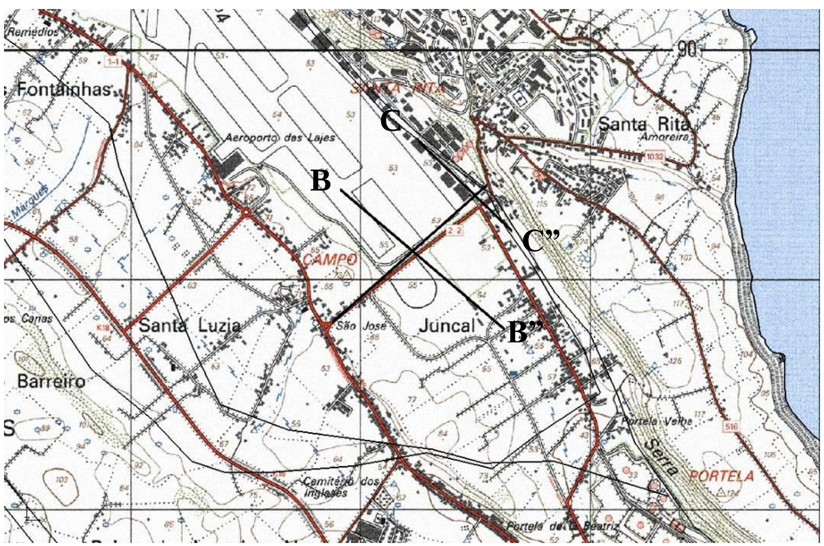


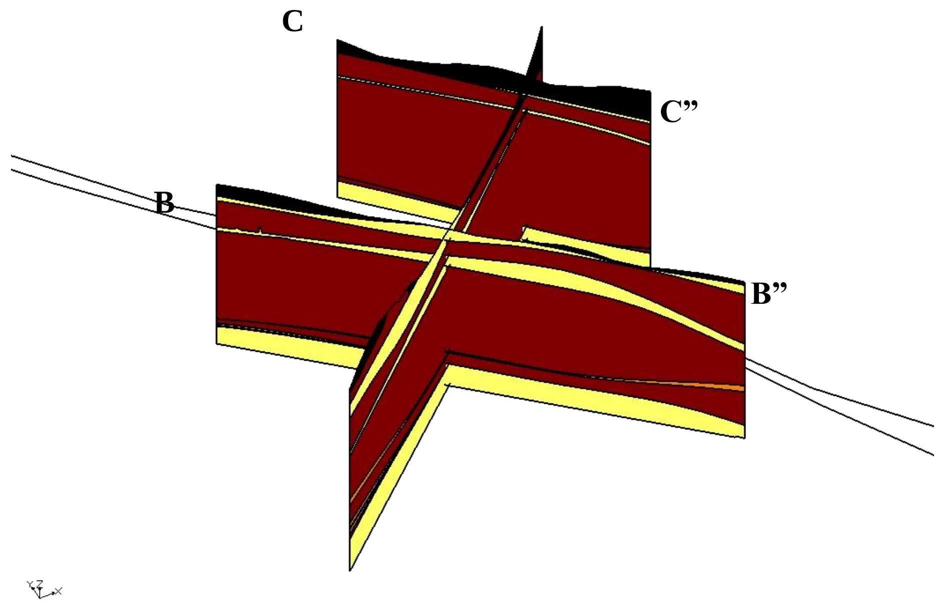
**Perfil da sondagem CP com diagrafias e desenho final dos piezómetros (Oliveira et al., 2009)**

# Perfis geológicos

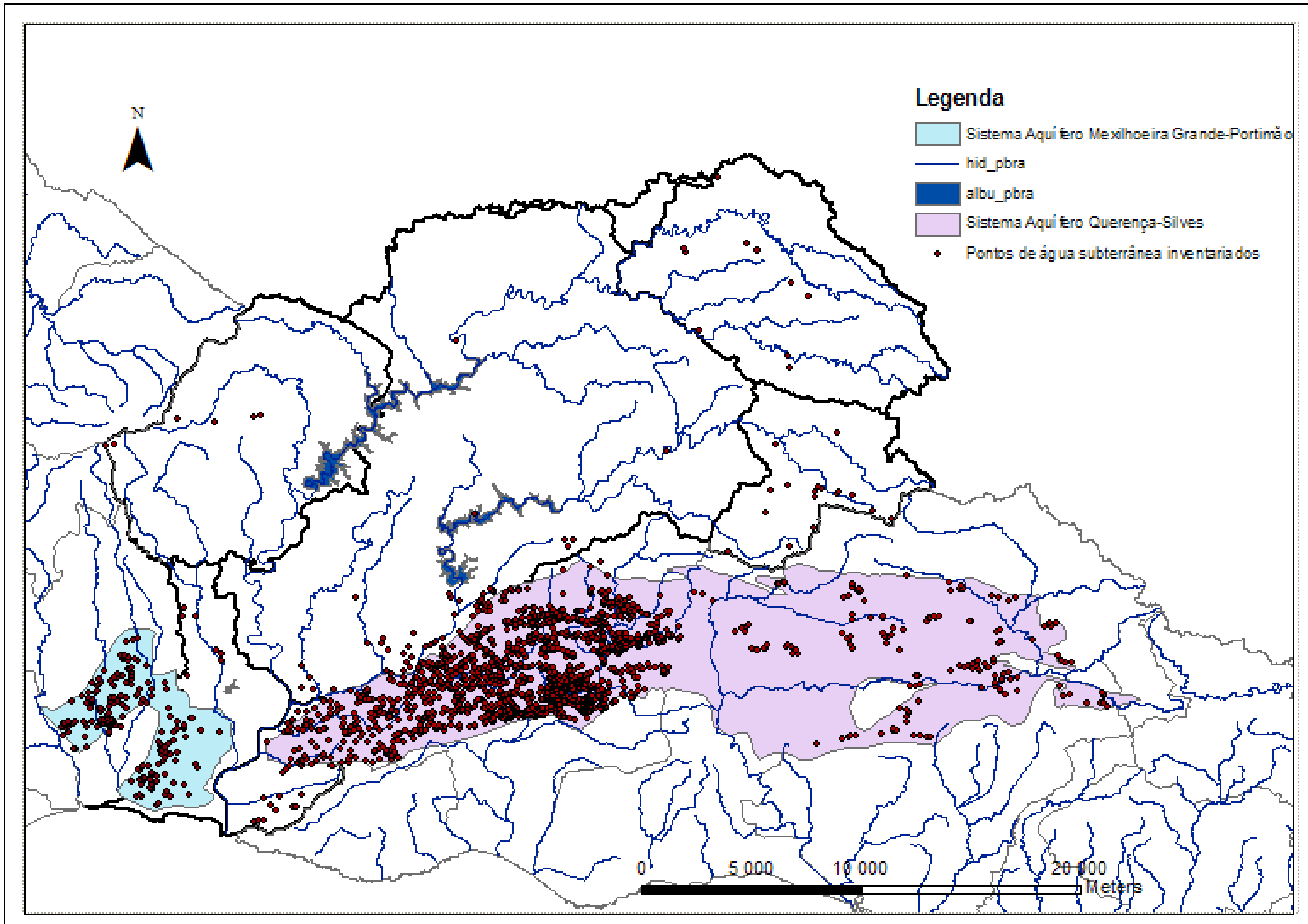


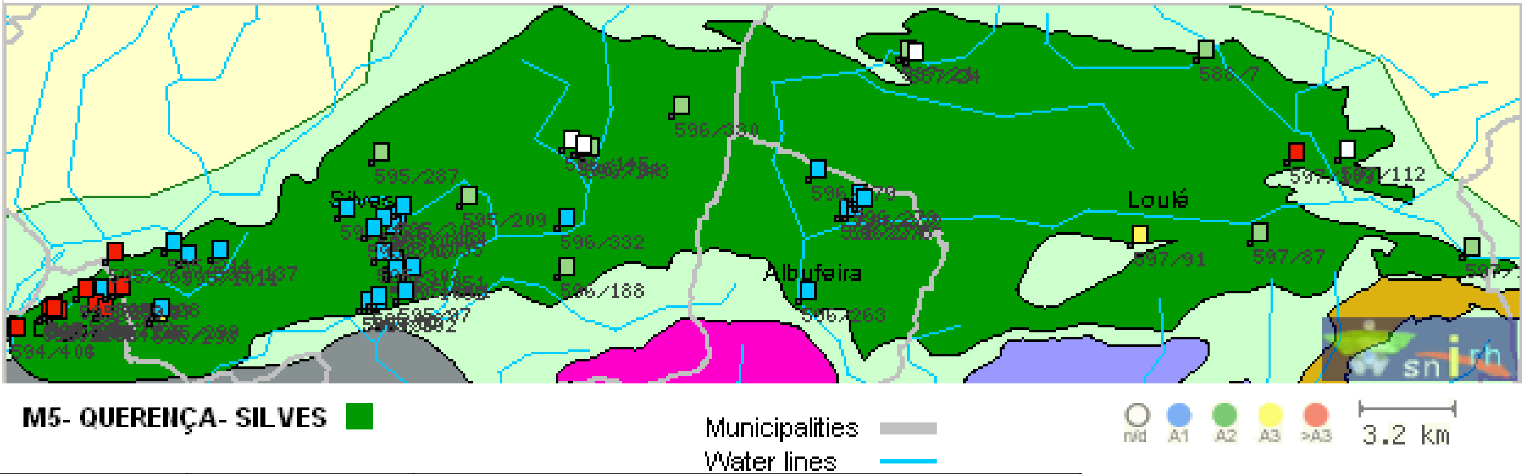



# Pontos inventariados pelo SNIRH (água subterrânea) – Zona de estudo no Algarve



# Salt water intrusion




| Ponto | Classificação | Parâmetro responsável pela classificação |
|---|---|---|
| 594/403 | >A3 | Condutividade |
| 594/404 | >A3 | Condutividade |
| 595/1094 | >A3 | Cloretos e Condutividade |
| 595/1095 | >A3 | Condutividade |
| 595/192 | >A3 | Condutividade |
| 595/193 | >A3 | Condutividade |
| 595/197 | >A3 | Cloretos e Condutividade |
| 595/198 | >A3 | Cloretos e Condutividade |
| 595/216 | >A3 | Condutividade |
| 595/260 | >A3 | Condutividade |
| 595/262 | >A3 | Cloretos e Condutividade |
| 595/269 | >A3 | Condutividade |
| 595/270 | >A3 | Condutividade |
| 595/271 | >A3 | Condutividade |
| 595/272 | >A3 | Condutividade |
| 595/959 | >A3 | Condutividade |
| 597/109 | >A3 | Condutividade e Nitratos |

**Water quality in Querença-Silves aquifer (2005, according to Decreto-Lei 236/98 classes)**

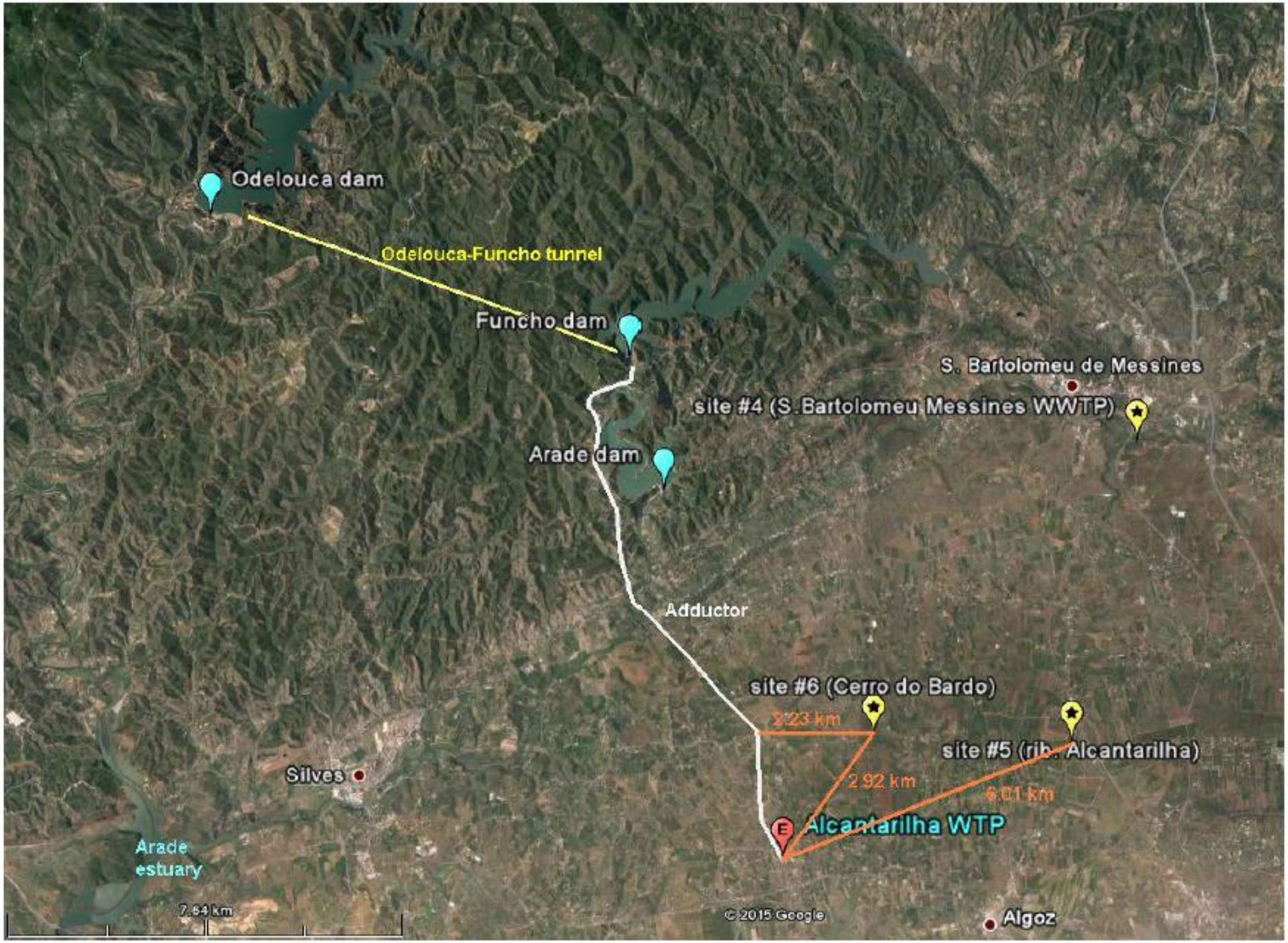
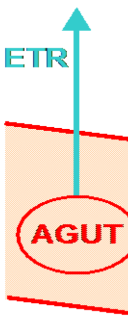
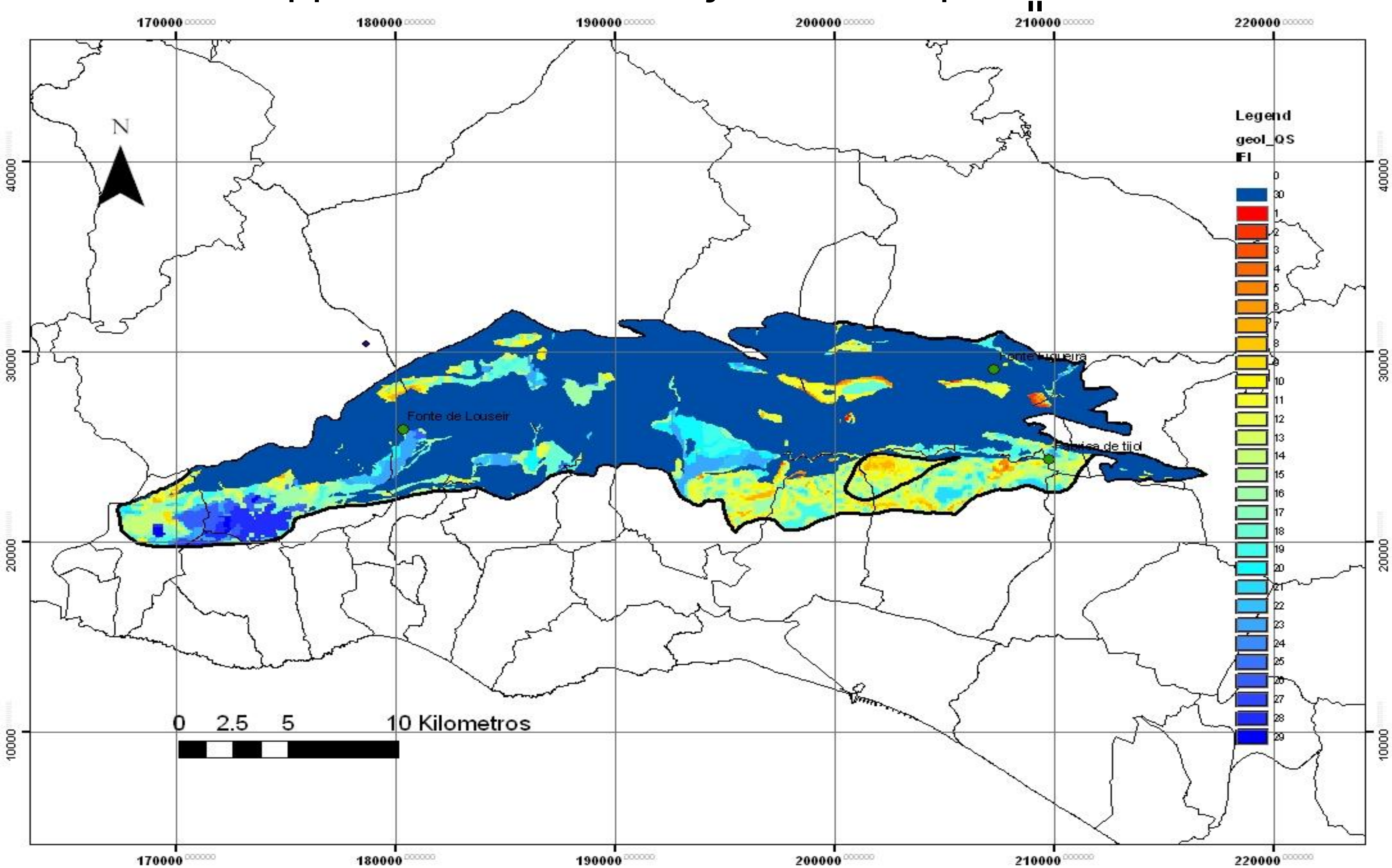



Figure 34 – Possible sources of water for MAR in Cerro do Bardo MAR system

# Background studies…

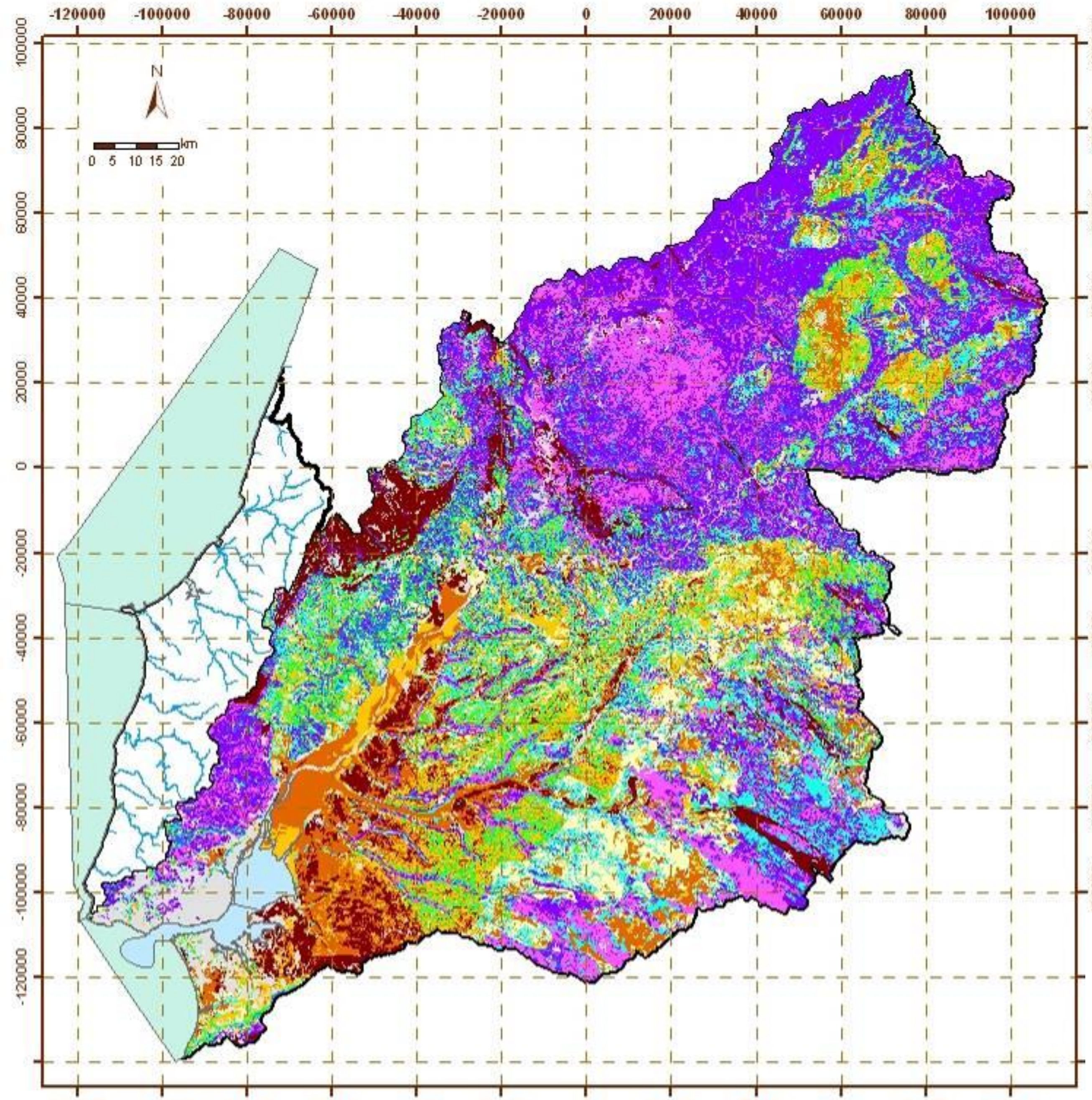
Index for Infiltration Facility assessment (IFI)
Application to Querença-Silves aquifer




Olivei
Ferrei

ARH TEJO Administração da Região Hidrográfica do Tejo I.P.

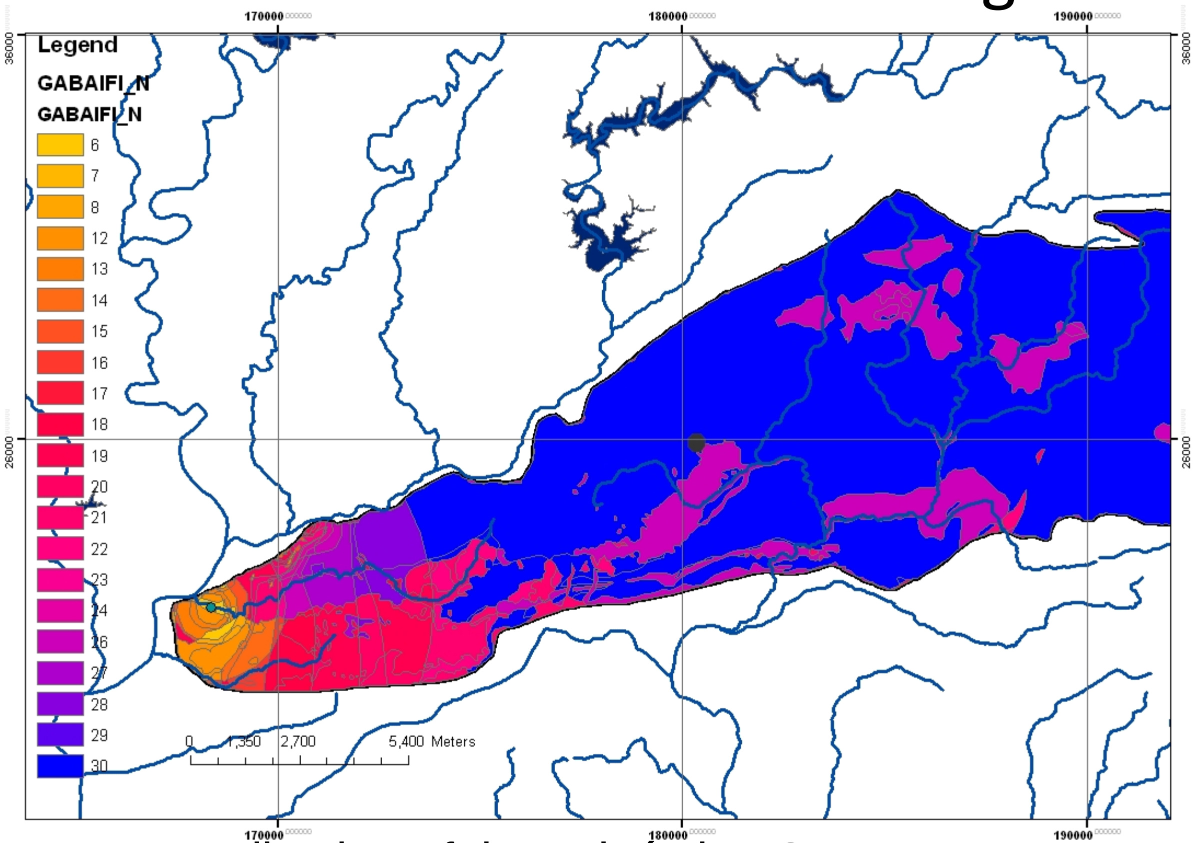



Índice de Facilidade de Infiltração (IFI)

**Índice de Facilidade de Infiltração:**

**O índice de facilidade de infiltração, desenvolvido por Oliveira e Lobo Ferreira (2002) requer a caracterização de quatro factores. O primeiro factor é geológico, e só por si pode fazer o IFI assumir o seu valor máximo (se for uma área carsificada ou muito fracturada). Caso não assuma o valor máximo então são caracterizados outros três factores: tipo de solo (A, B, C ou D), declive do terreno (<2%, 2-6%, 6-12%, 12-18%, >18%), quantidade máxima de água armazenável no solo e que pode ser utilizada para a evapotranspiração - AGUT (dez classes de 50 mm de intervalo, desde < 50 mm a > 450 mm). A cada classe é atribuído um índice entre 1 e 10, que no final se somam para produzir o IFI. O índice máximo (IFI = 30) significa as condições mais favoráveis para a infiltração e é obtido para um solo tipo A, declive do terreno <2% e AGUT < 50mm. Identificadas as zonas com IFI elevado (mais favoráveis à infiltração), estas deverão ser validadas com observações de campo, informações de residentes acerca do comportamento destas áreas durante a ocorrência de chuva, ou outro tipo de informação.**

# Area for the artificial recharge




- Application of the sub-índex GABA-IFI_N;

-“Fonte de Louseiros” is located near the Arade Dam and in lower altitude;

-“Fonte de Louseiros” have several abandoned agriculture fields and “noras” (large diameter wells)

MANAGED AQUIFER RECHARGE SOLUTIONS

## Water Quality Workshop Algarve Demonstration Site

24-26 June 2015, Auditório
Direção Regional de Agricultura e Pescas
Patacão, Faro, Algarve, Portugal

### APPLICATION FORM

Name: ..........

Affiliation: ..........

Address: ..........

E-mail: ..........

**Free Registration. For administrative purposes please send this application form to tleitao@lnec.pt; lferreira@lnec.pt or by fax: (351) 21 844 30 16 until June 15, 2015.**

**INFORMATION / REGISTRATION**

LNEC LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Laboratório Nacional de Engenharia Civil

c/o Dr. Teresa Leitão / Dr.-Ing. JP Lobo Ferreira

Av. do Brasil, 101, 1700-066 Lisboa
Tel. (+351) 218443609 - Fax: (+351) 218443016
E-mail: tleitao@lnec.pt; lferreira@lnec.pt

MANAGED AQUIFER RECHARGE SOLUTIONS

## Demonstrating Managed Aquifer Recharge as a Solution to Water Scarcity and Drought

www.marsol.eu

**Workshop organized & sponsored by:**

- Laboratório Nacional de Engenharia Civil (LNEC), PT
- Universidade do Algarve (UAlg), PT
- Terra, Ambiente e Recursos Hídricos (TARH), PT
- TU Darmstadt, DE
- Rheinisch-Westfälisches Institut für Wasserforschung gGmbH (IWW), DE
- MAR Solutions - Managed Aquifer Recharge Strategies and Actions (EIP Water Action Group 128)

M.A.R. TO MAR-keT

LNEC LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

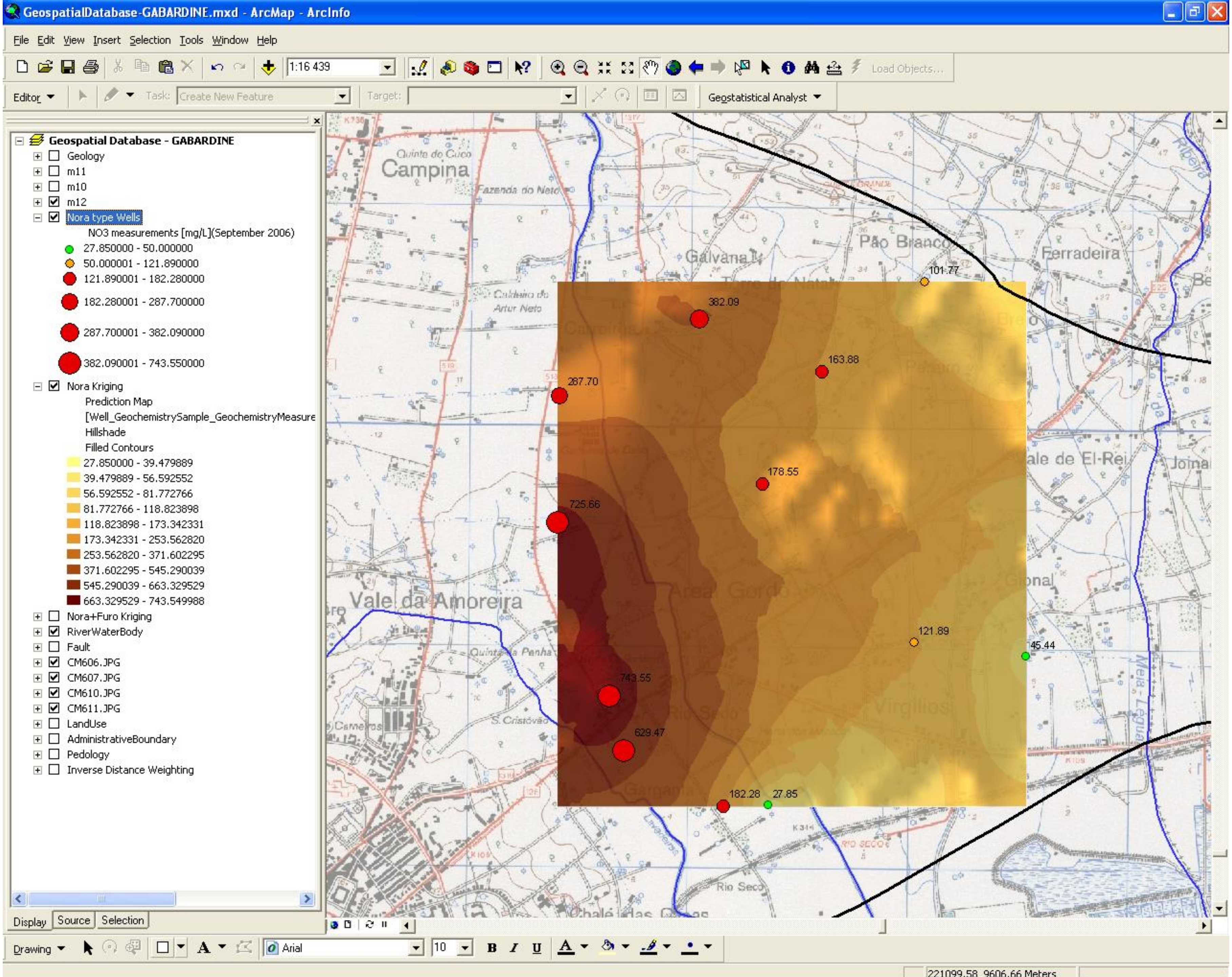
MANAGED AQUIFER RECHARGE SOLUTIONS

# MARSOL

## Water Quality Workshop Algarve Demonstration Site

24-26 June 2015, Auditório
Direção Regional de Agricultura e Pescas
Patacão, Faro, Algarve, Portugal

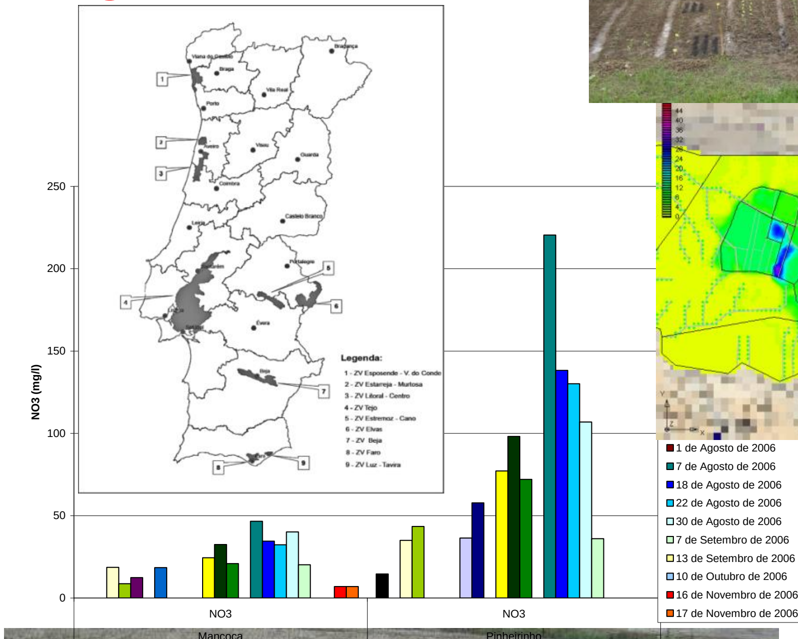
UAlg TARH TECHNISCHE UNIVERSITÄT DARMSTADT IWW

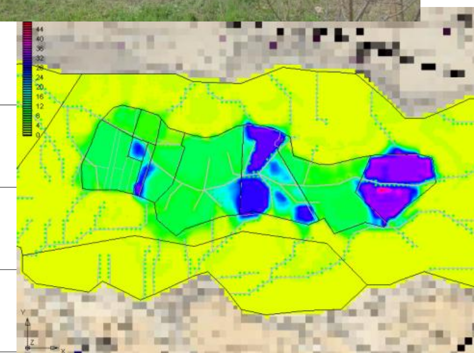


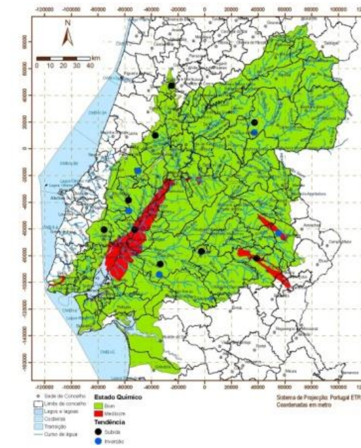
GeospatialDatabase-GABARDINE.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:16 439
Load Objects...
Editor
Task: Create New Feature
Target:
Geostatistical Analyst
Geospatial Database - GABARDINE
Geology
m11
m10
m12
Nora type Wells
NO3 measurements [mg/L](September 2006)
27.850000 - 50.000000
50.000001 - 121.890000
121.890001 - 182.280000
182.280001 - 287.700000
287.700001 - 382.090000
382.090001 - 743.550000
Nora Kriging
Prediction Map
[Well_GeochemistrySample_GeochemistryMeasure
Hillshade
Filled Contours
27.850000 - 39.479889
39.479889 - 56.592552
56.592552 - 81.772766
81.772766 - 118.823898
118.823898 - 173.342331
173.342331 - 253.562820
253.562820 - 371.602295
371.602295 - 545.290039
545.290039 - 663.329529
663.329529 - 743.549988
Nora+Furo Kriging
RiverWaterBody
Fault
CM606.JPG
CM607.JPG
CM610.JPG
CM611.JPG
LandUse
AdministrativeBoundary
Pedology
Inverse Distance Weighting
Display Source Selection
Quinta do Cuco
Campina
Fazenda do Neto
Pão Branco
Galvana
Ferradeira
Caldeira do Artur Neto
Vale da Amoreira
Vale de El-Rei
Quinta da Penha
S. Cristóvão
Rio Seco
101.77
382.09
163.88
287.70
178.55
725.66
121.89
45.44
743.55
629.47
182.28
27.85
Drawing
Arial
10
221099.58 9606.66 Meters

# NAS:
# PIP 2009-2012: ESTUDOS

## > Qualidade das águas subterrâneas: Agricultura





- Objetivos
  - Sustentabilidade ambiental da agricultura: redução de perdas e uso racional de fertilizantes

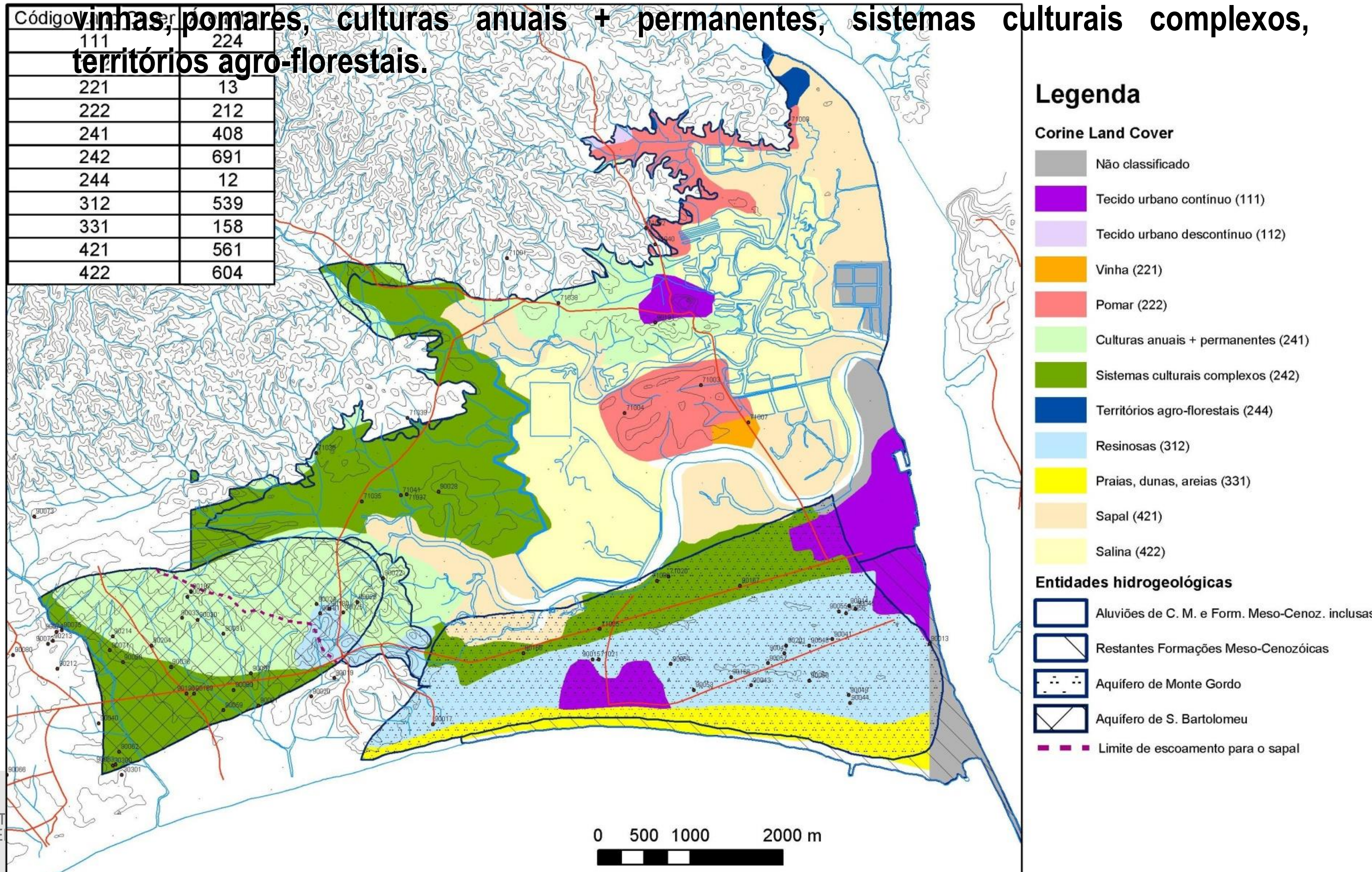

- Resultados
- Medidas de gestão integrada ao nível da bacia hidrográfica (S, ZV, ASP, AGS) para diferentes escalas espaciais e temporais


# Áreas onde pode haver fertilização

(Fonte: Corine Land Cover)

vinhas, pomares, culturas anuais + permanentes, sistemas culturais complexos, territórios agro-florestais.

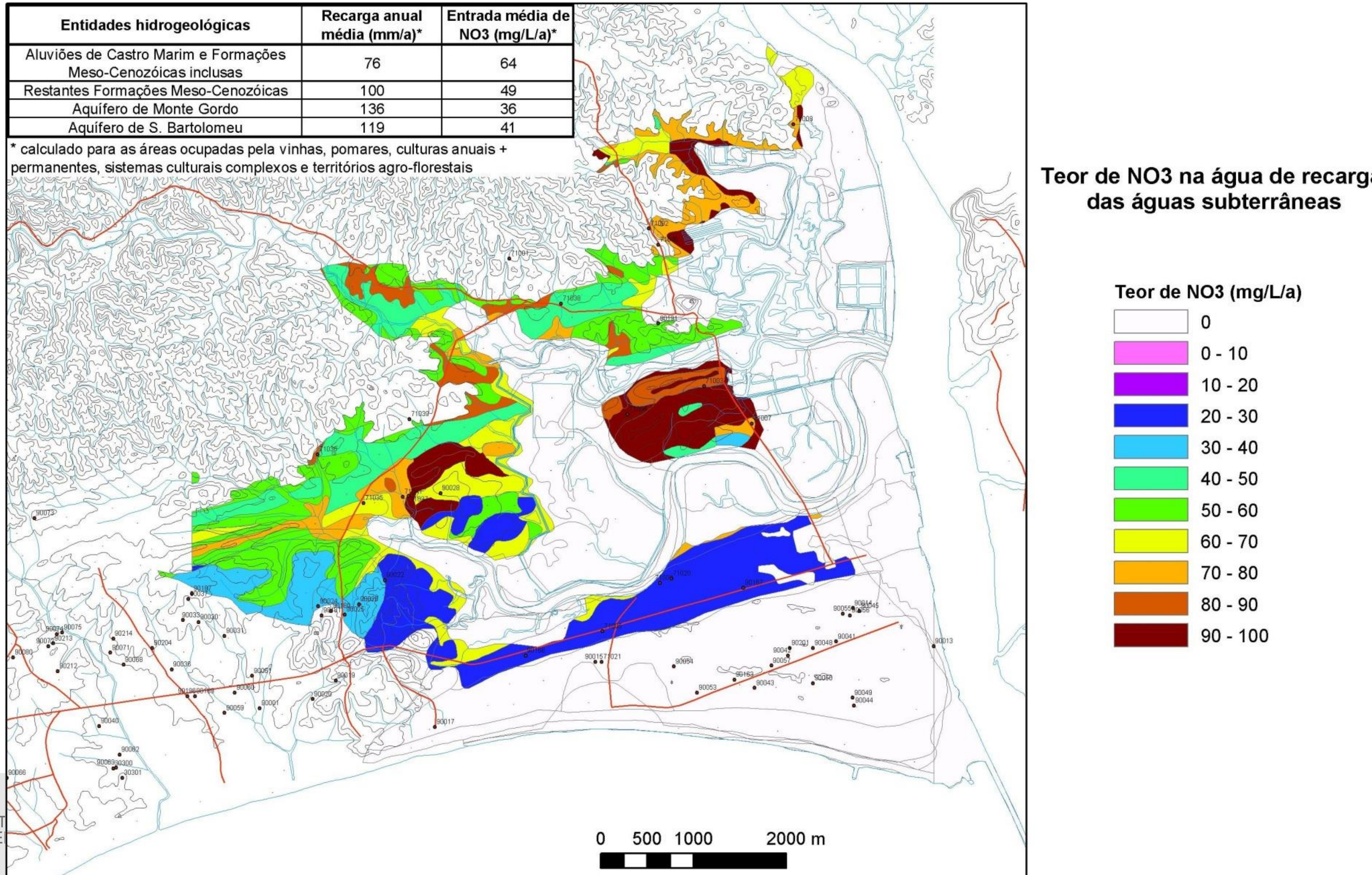
| Código [illegible] | [illegible] |
|---|---|
| 111 | 224 |
| [illegible] | [illegible] |
| 221 | 13 |
| 222 | 212 |
| 241 | 408 |
| 242 | 691 |
| 244 | 12 |
| 312 | 539 |
| 331 | 158 |
| 421 | 561 |
| 422 | 604 |



# Teor de NO3 (mgL) na água de recarga das águas subterrâneas

| Entidades hidrogeológicas | Recarga anual média (mm/a)* | Entrada média de NO3 (mg/L/a)* |
|---|---|---|
| Aluviões de Castro Marim e Formações Meso-Cenozóicas inclusas | 76 | 64 |
| Restantes Formações Meso-Cenozóicas | 100 | 49 |
| Aquífero de Monte Gordo | 136 | 36 |
| Aquífero de S. Bartolomeu | 119 | 41 |

* calculado para as áreas ocupadas pela vinhas, pomares, culturas anuais + permanentes, sistemas culturais complexos e territórios agro-florestais



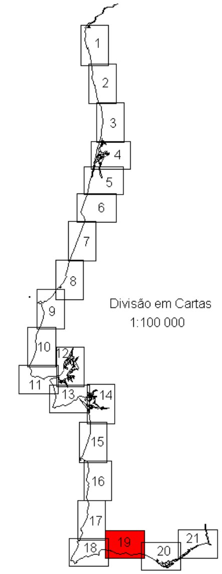

LABORAT
DE ENGE

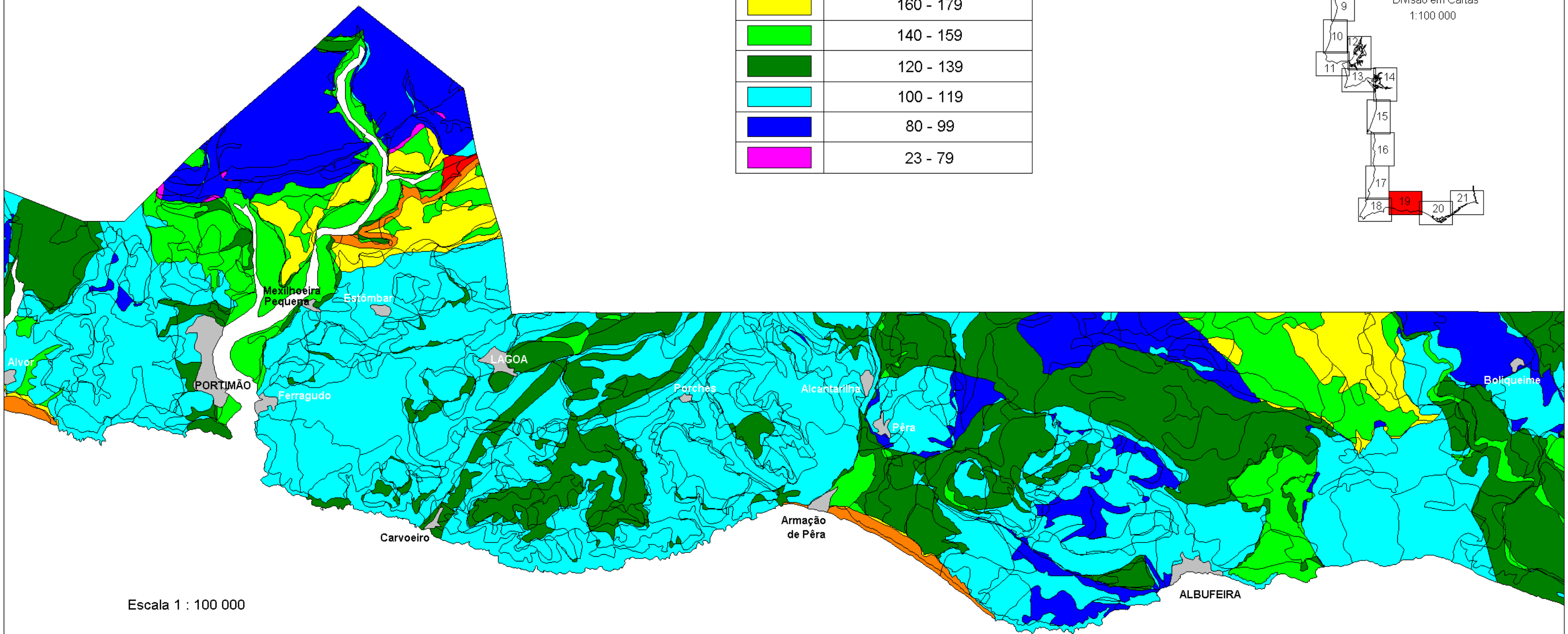
Carta 19: Índice de Vulnerabilidade DRASTIC

# DRASTIC Algarve Central (Oeste)

## ÍNDICE DE VULNERABILIDADE DRASTIC

| | Índice de Vulnerabilidade DRASTIC |
|---|---|
| | 200 - 226 |
| | 180 - 199 |
| | 160 - 179 |
| | 140 - 159 |
| | 120 - 139 |
| | 100 - 119 |
| | 80 - 99 |
| | 23 - 79 |



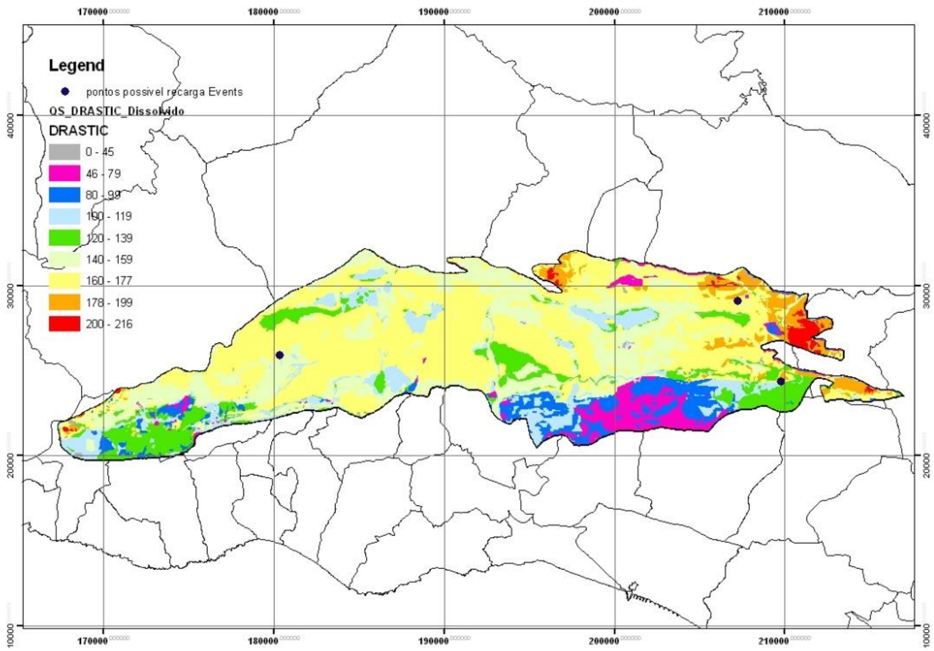

Escala 1 : 100 000

0 1 2 3 4 5 km

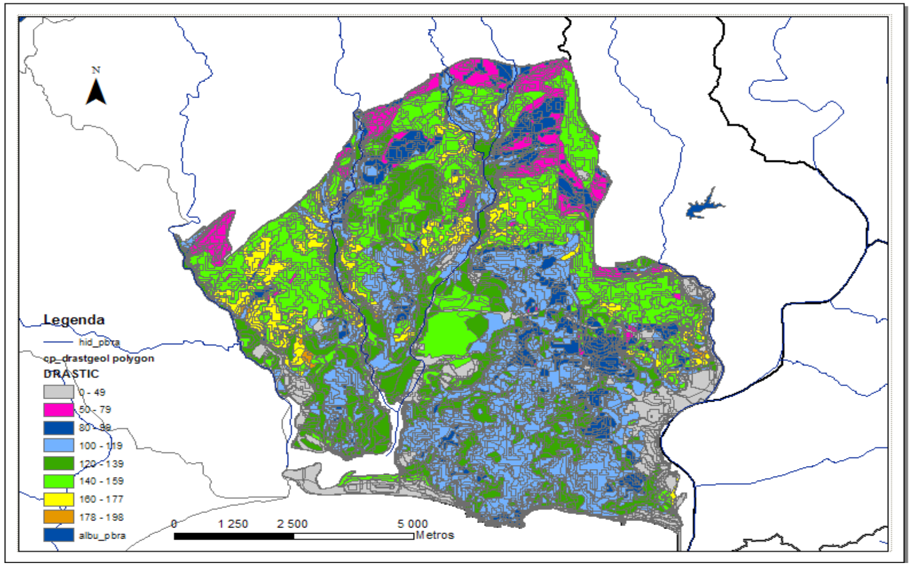
Localidade

LNEC - Proc. 607/1/11968

# DRASTIC



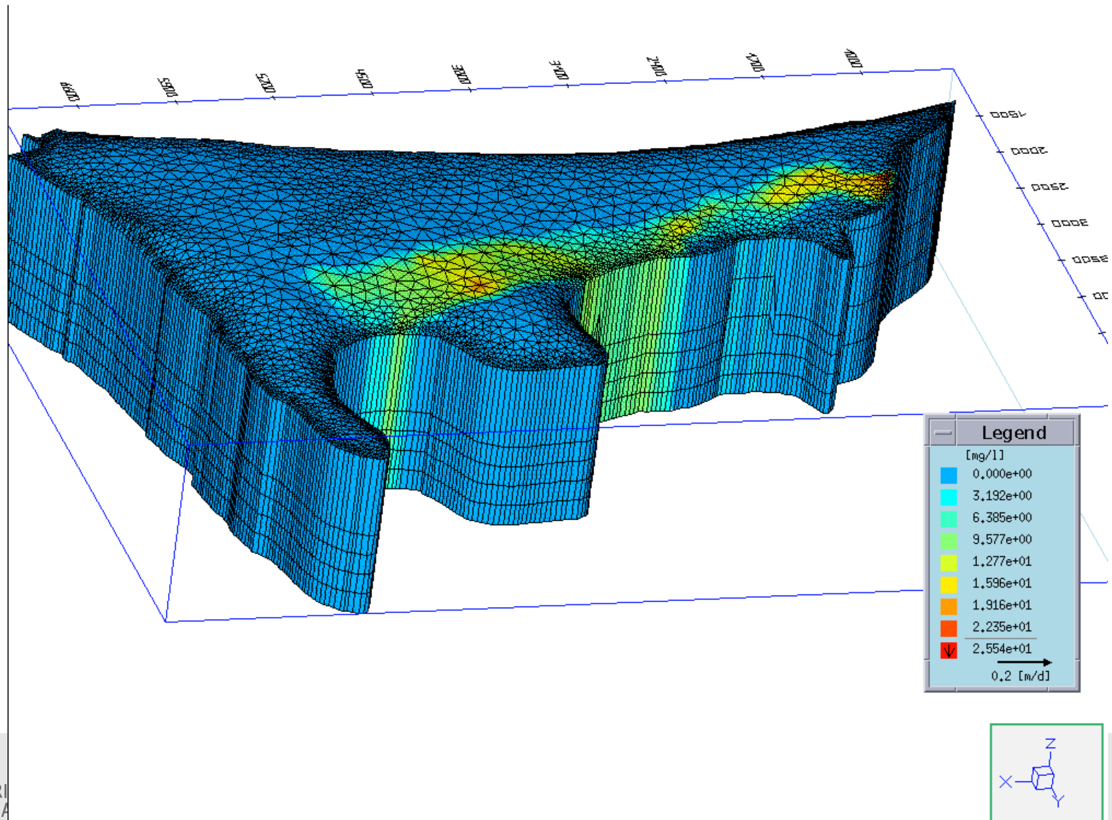
170000
180000
190000
200000
210000
40000
30000
20000
10000
Legend
pontos possivel recarga Events
QS_DRASTIC_Dissolvido
DRASTIC
0 - 45
46 - 79
80 - 99
100 - 119
120 - 139
140 - 159
160 - 177
178 - 199
200 - 216

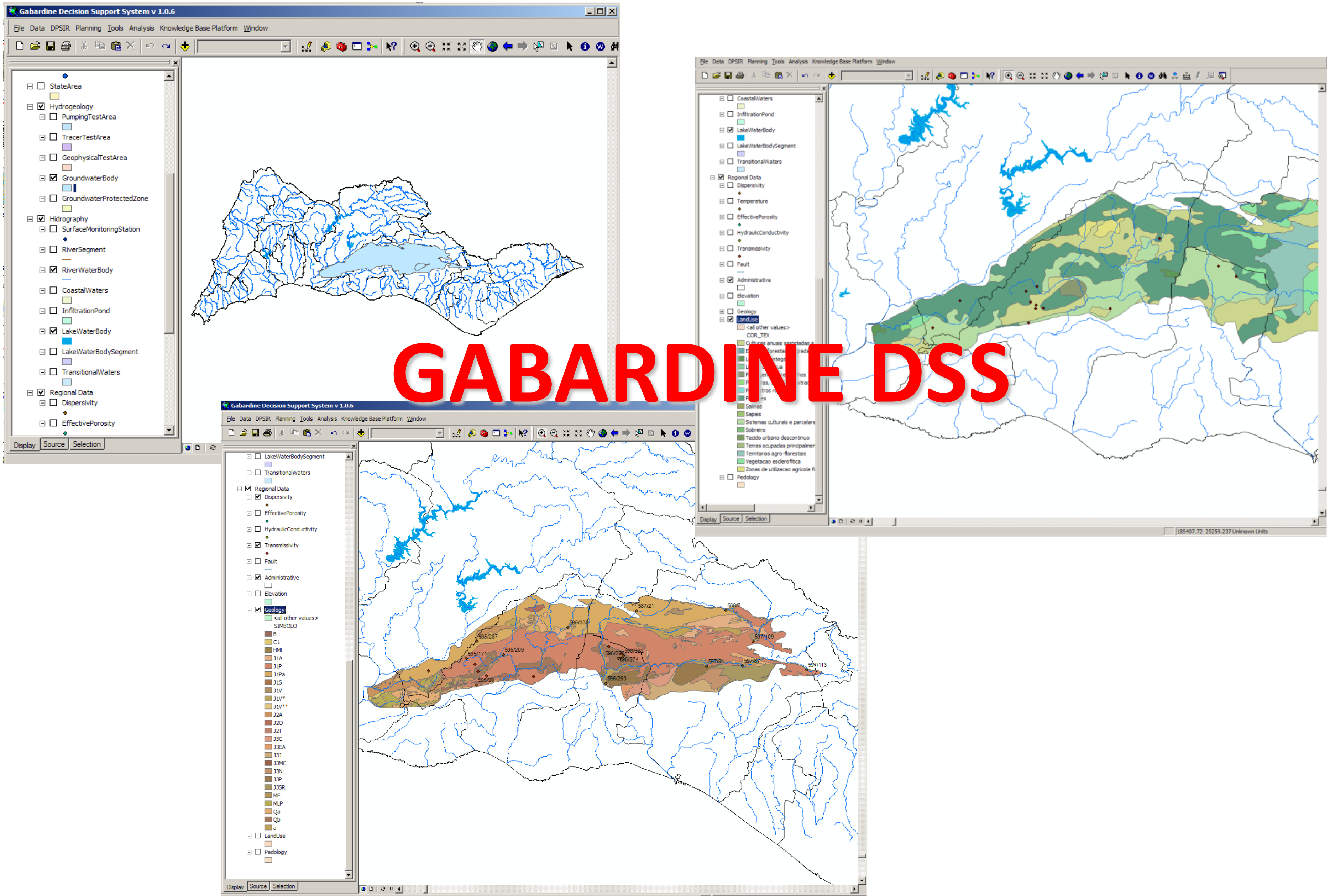
N
Legenda
hid_pbra
cp_drastgeol polygon
DRASTIC
0 - 49
50 - 79
80 - 99
100 - 119
120 - 139
140 - 159
160 - 177
178 - 198
albu_pbra
0
1 250
2 500
5 000
Metros

# Modelação do transporte de nitratos no sistema aquífero de Monte Gordo

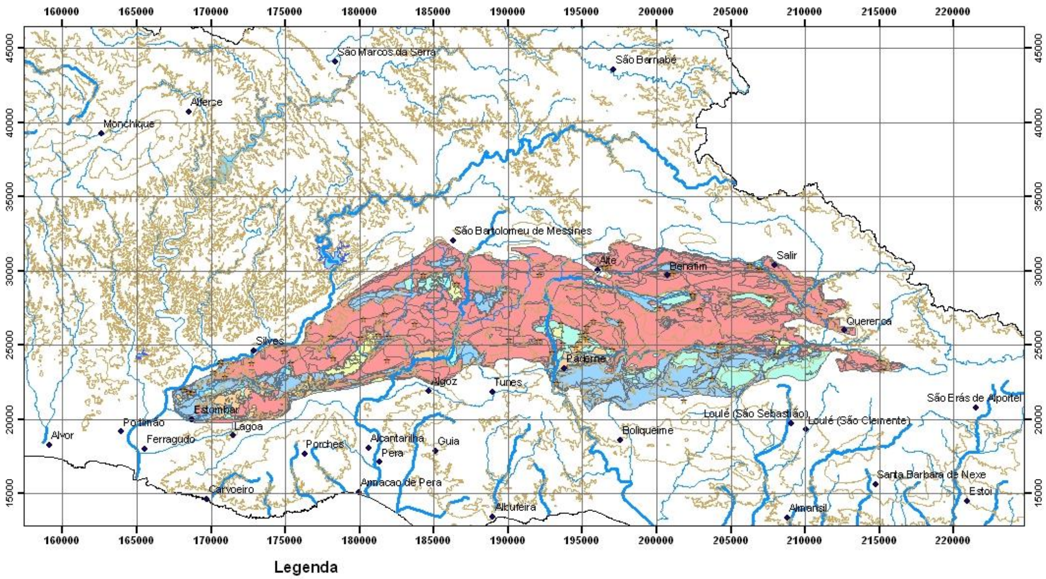
- **Visualização tridimensional da distribuição de nitratos no aquífero ao fim de 10 anos**

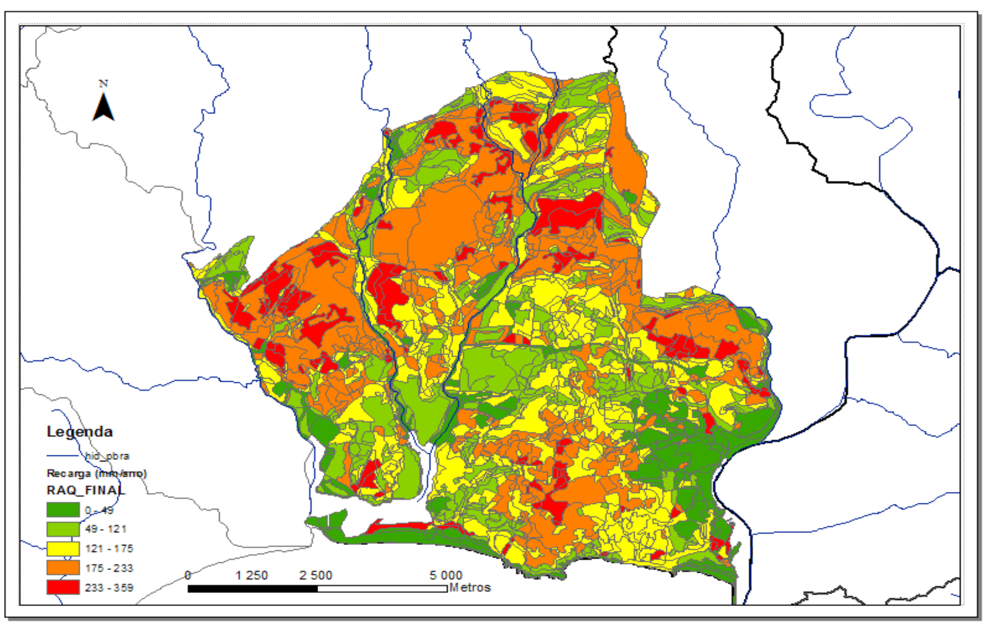


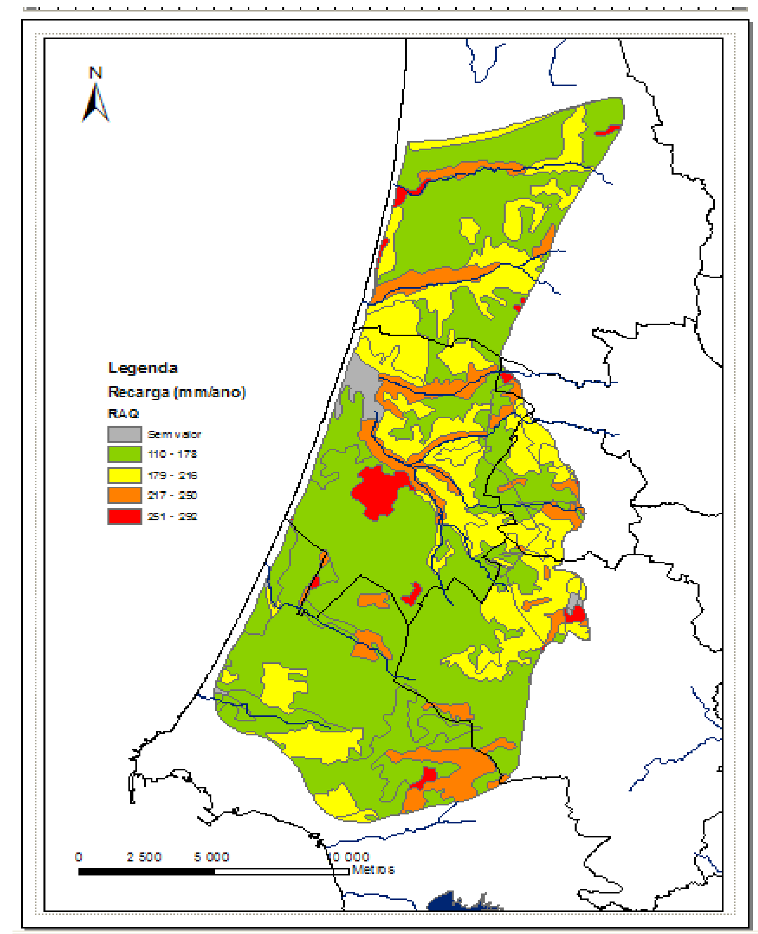
# Spatial Information



# LNEC BALSEQ groundwater recharge assessment model applied to Querença-Silves, Melides and Mexilhoeira Grande Portimão aquifers

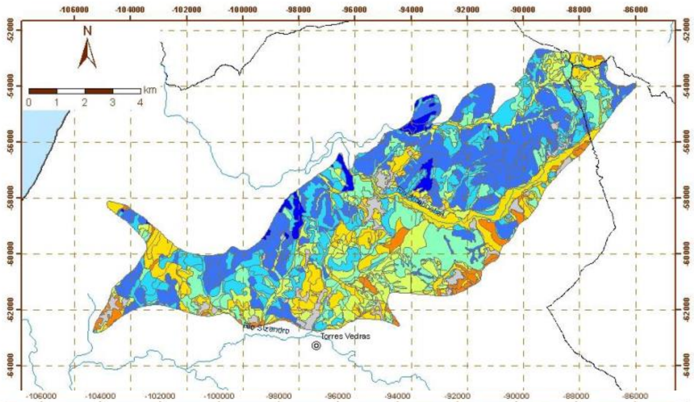


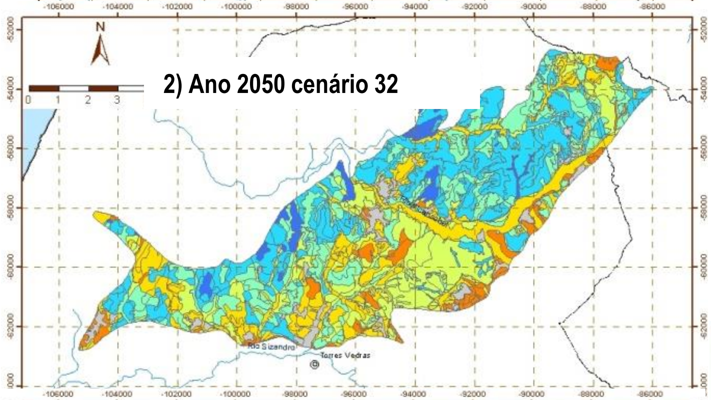



# Groundwater recharge under climate change conditions

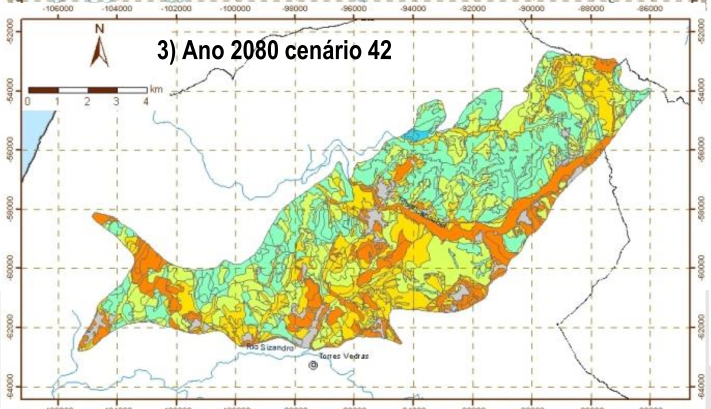
- Application of BALSEQ_MOD model to climatological series modified for the periods 2050 - 2080



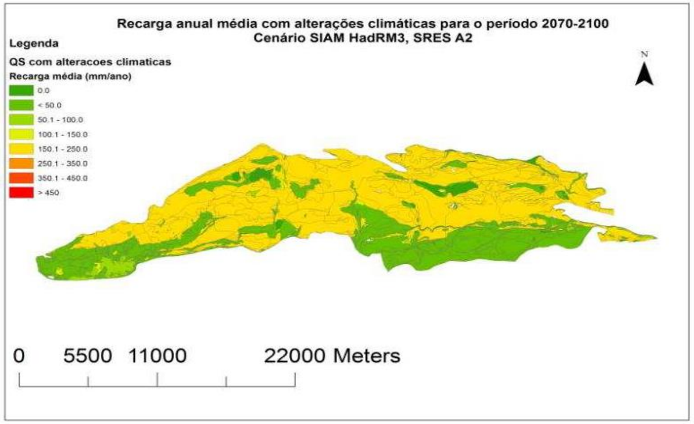

1) Today groundwater recharge in Torres Vedras aquifer



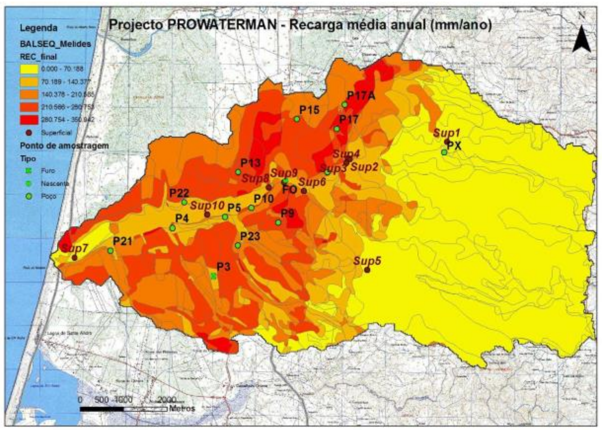

2) Ano 2050 cenário 32

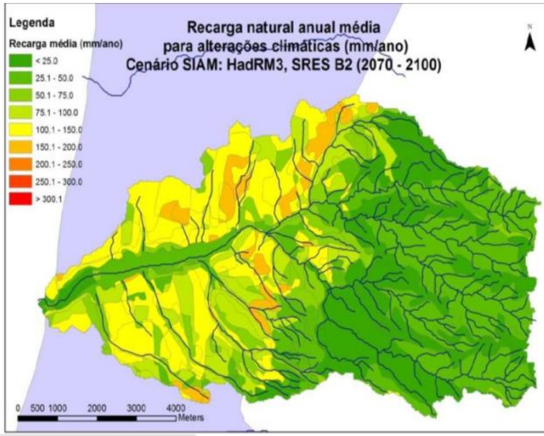



3) Ano 2080 cenário 42




4) Groundwater recharge in Q uerença-Silves aquifer 2070-2100

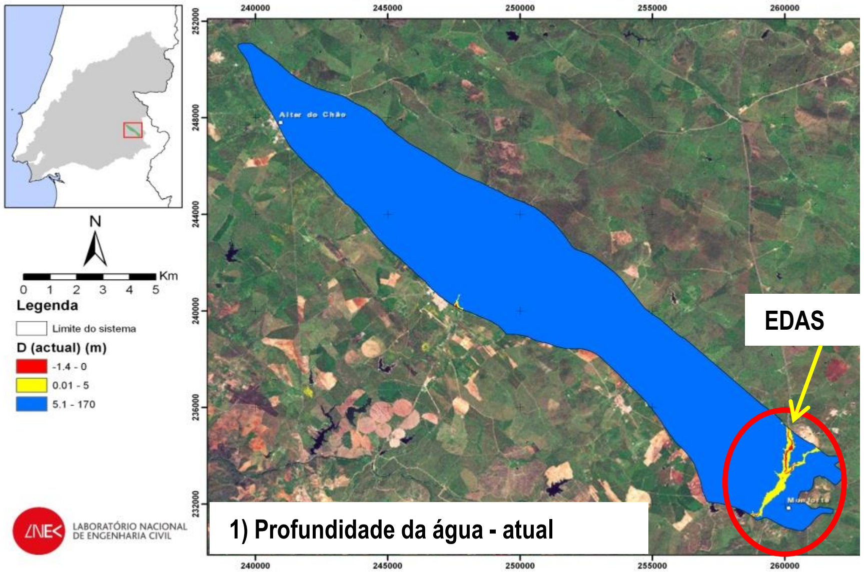


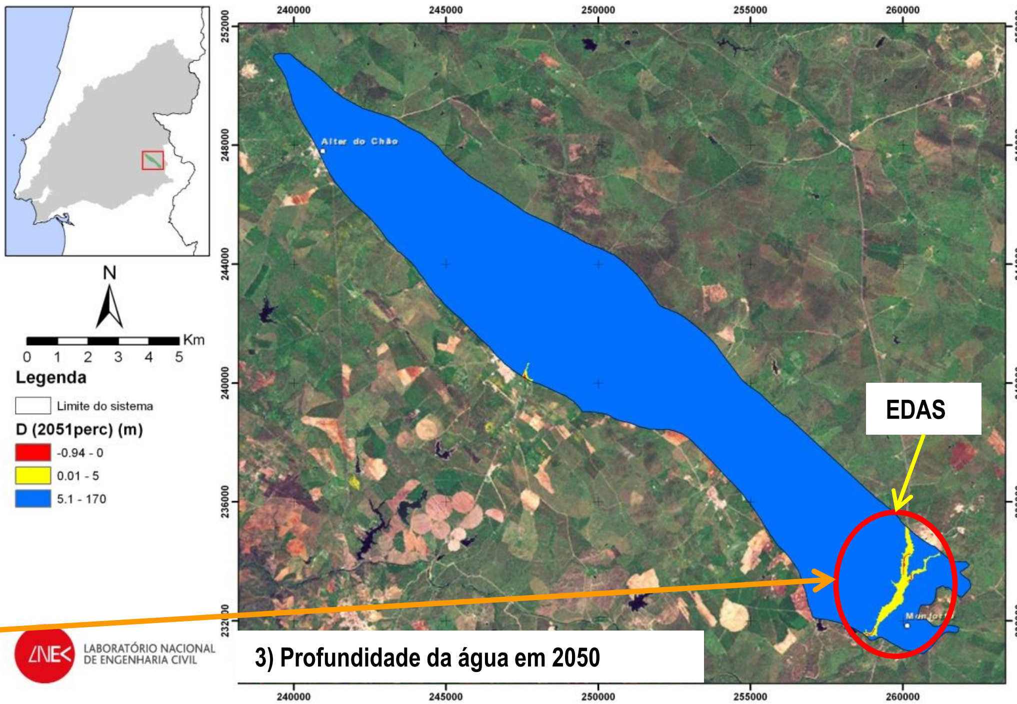

5) Melides aquifer – today and 2070-2100 groundwater recharge

# Changing the behavior of aquifer systems with impact on groundwater dependent ecosystems (GWDE)

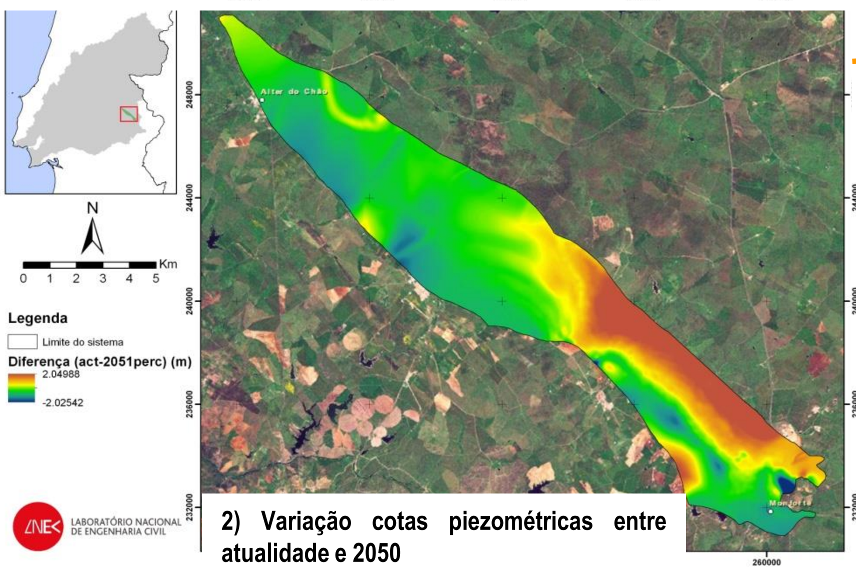
> Alterações na piezometria devidas às alterações climáticas: impacto sobre os EDAS



1) Profundidade da água - atual



3) Profundidade da água em 2050



2) Variação cotas piezométricas entre atualidade e 2050

> Consequências da alteração do funcionamento do aquífero:

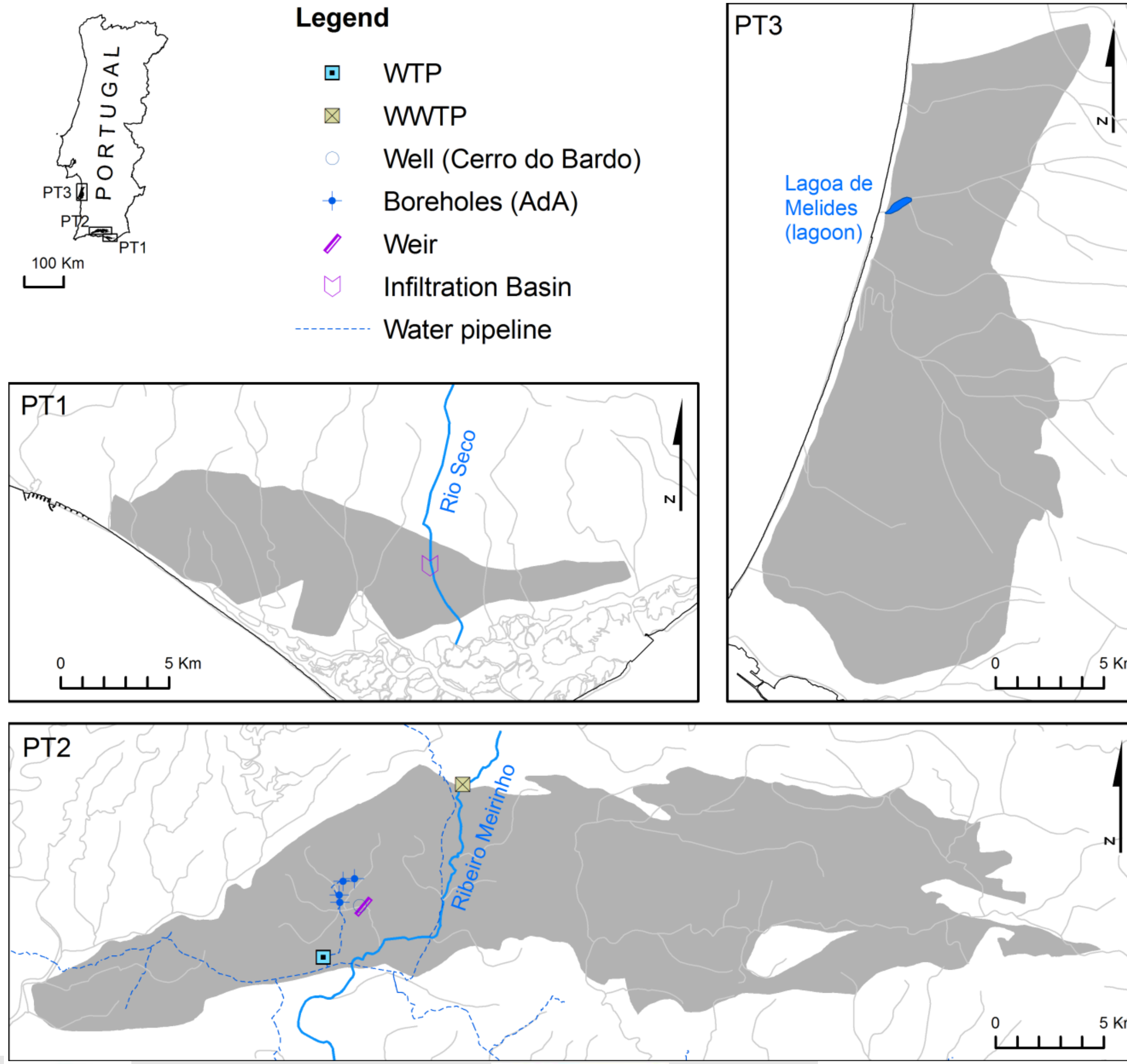
- **Modificação dos regimes/direções de fluxo**
- **Modificação dos volumes de água cedidos dos aquíferos para os EDAS**
- **Modificação dos períodos de alimentação**
- **Modificação do funcionamento dos EDAS (EDAS em risco provável)**

WP 4: DEMO SITES - PORTUGAL

# Regional scale water balances

MANAGED AQUIFER RECHARGE SOLUTIONS

- **PT1 Algarve, rio Seco (Campina de Faro aquifer)**
- **PT2 Algarve, rib. Meirinho (Querença-Silves aquifer)**
- **PT3 Alentejo, Melides (lagoon)**


LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

UNIVERSIDADE DO ALGARVE

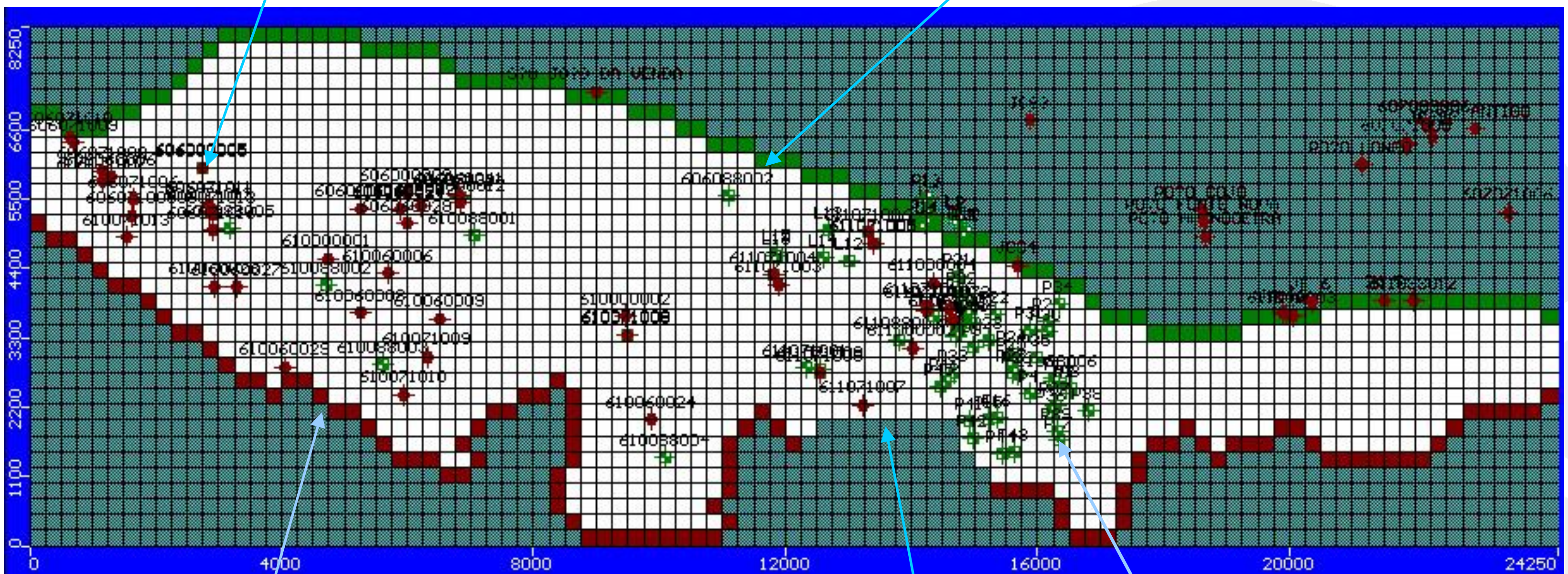
TARH

# Groundwater Flow Modelling – Regional Model

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

**Pumping well (red)**

**North - General Head Boundary (h = 7,5 m) in the three layers**




**South - Constant Head (h = 0 m) in the three layers**

**Observation well (green)**

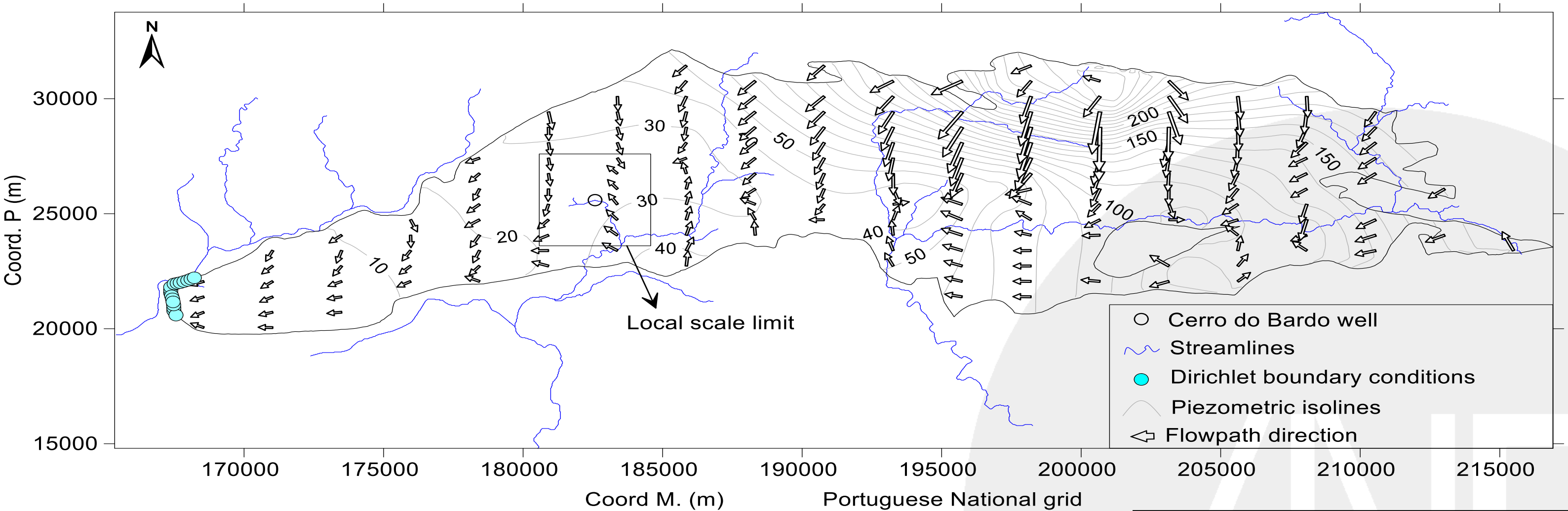
**Probable existence of a flow barrier (diapiric formations)**

**Layers**:

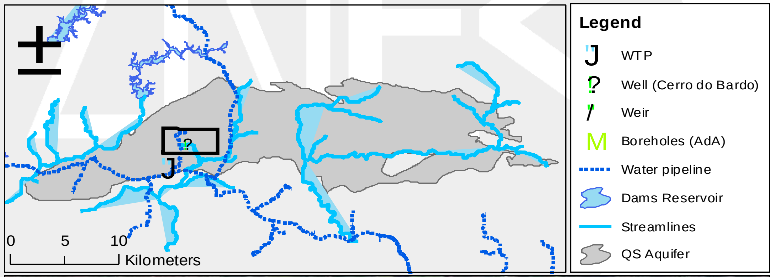
- **Layer 1**: phreatic detritic layer
- **Layer 2**: discontinuous clayey confining layer
- **Layer 3**: confined carbonated aquifer

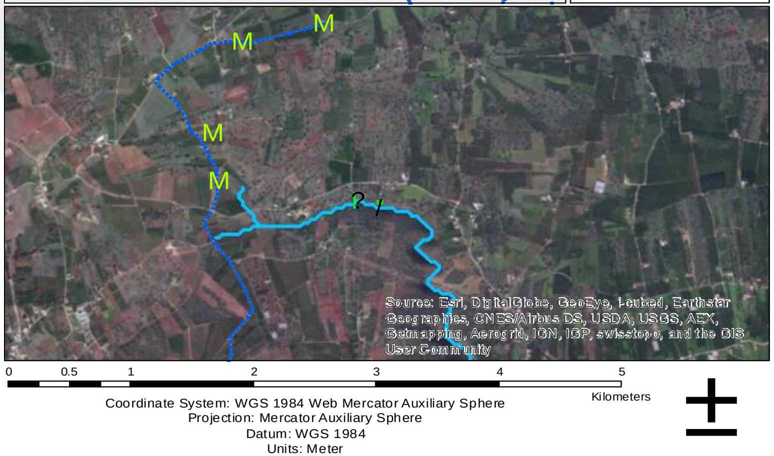
Cells dimension: 250 m x 250 m

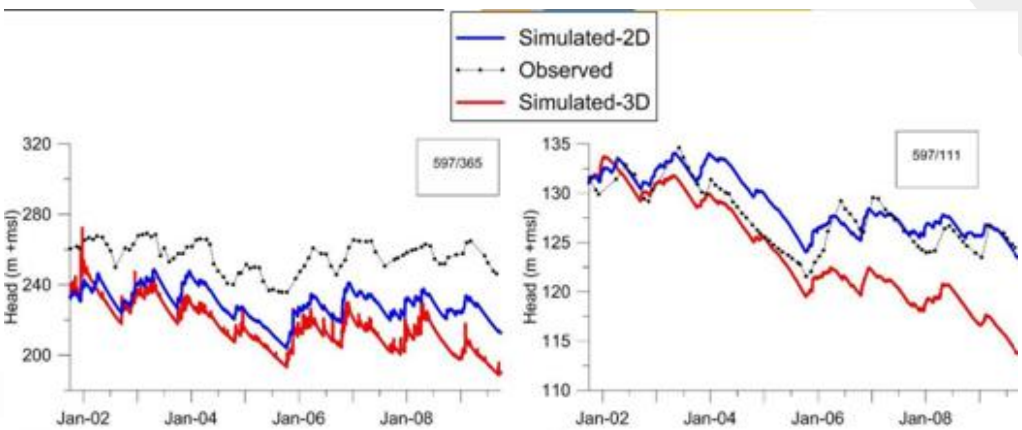
# Groundwater Flow Modelling – Regional Model




- **The numerical model simulation scales at Regional scale, local scale and test site scale predicted in the projected for Demo site 2 – PT 2 Querença-Silves Aquifer**



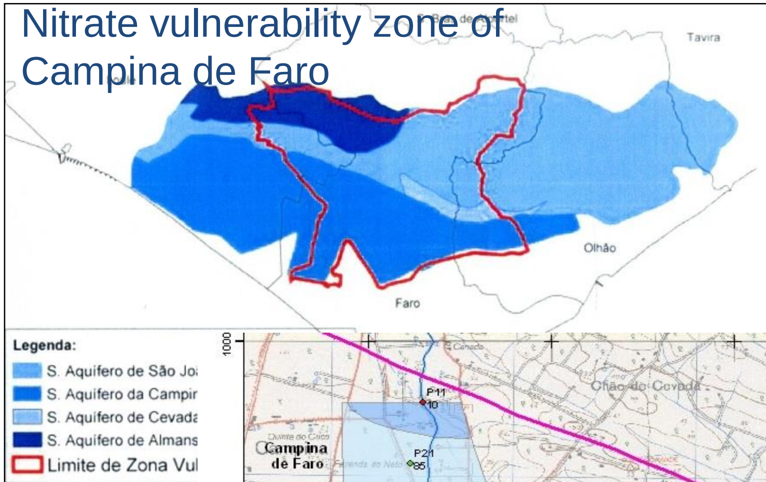



# WP 4: DEMO SITES - PORTUGAL

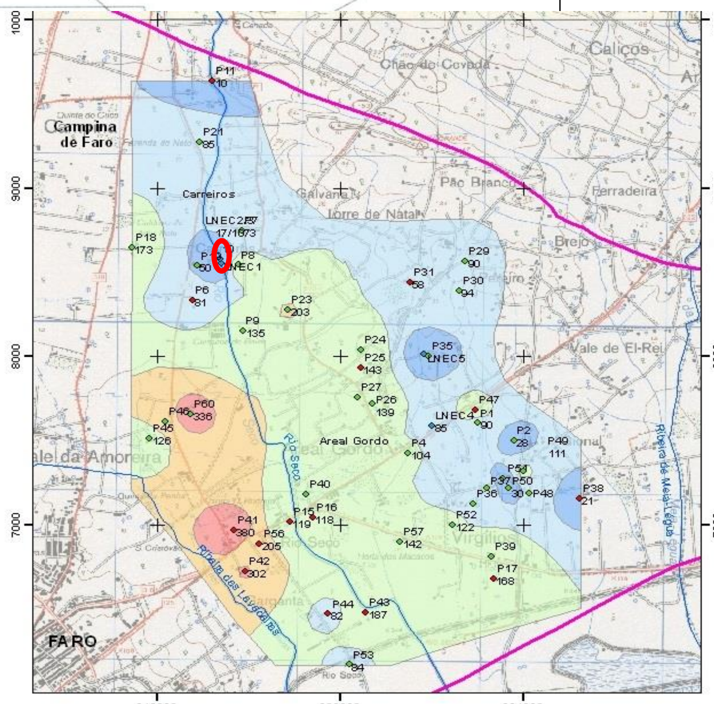
MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS

Nitrate vulnerability zone of Campina de Faro

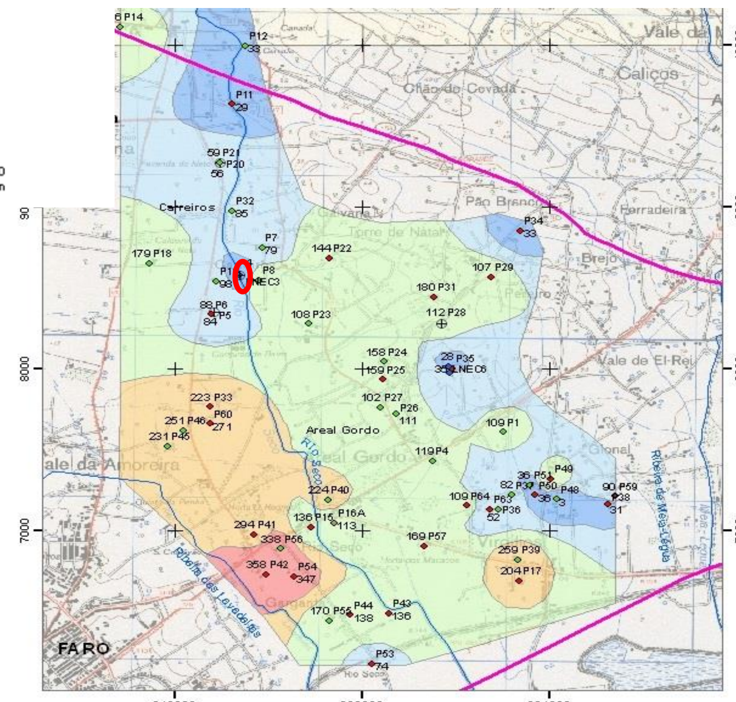



Legenda
Campina de Faro M12
Rede hidrográfica
Campanha maio/2014
NO3 (mg/L)
0-50
50.1-100
100.1-200
200.1-300
300.1-400
Tipo de ponto de água
Nora
Nora (com furo)
Piezómetro
Poço
Furo
0 250 500 1.000 m

## Intermediate scale environmental GW quality problems




April 2008



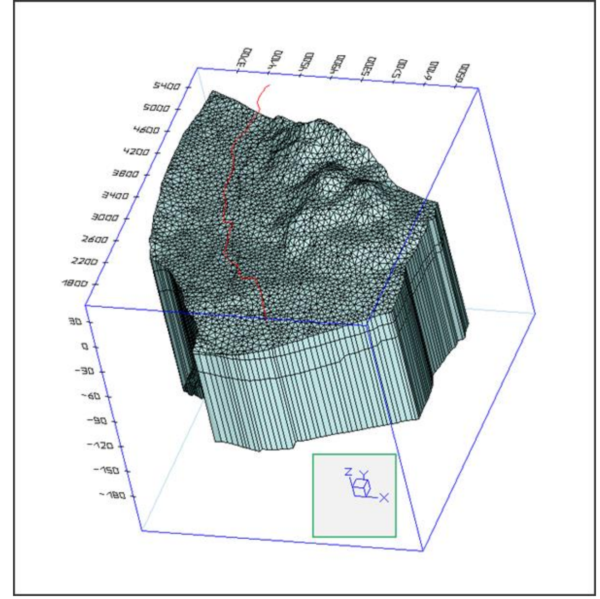

May 2014

LNEC LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

UNIVERSIDADE DO ALGARVE

TARH

# Groundwater Flow Model of central part of Campina de Faro aquifer system



- Hydrogeological characterization of the area
- Conceptual model

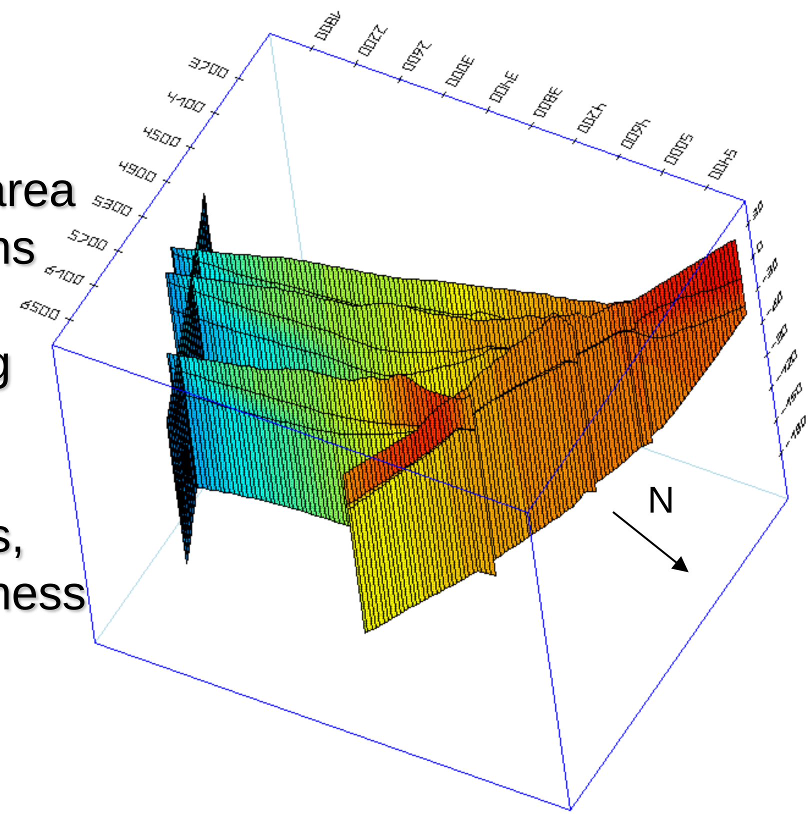
Unconfined sandy aquifer - Layer 1
(thickness varies in model domain – max. 77 m)

Confining layer - Layer 2 (thickness max. 28 m)

Confined sandstone aquifer – Layer 3
(thickness varies in model domain max. 153 m)

In the northern and more elevated part of the area a small outcropping of the sandstone formations – defined in model domain with the same hydraulic characteristics as the underling aquifer.

Also in this part, confining layer does not exists, so this layer is considered with minimum thickness



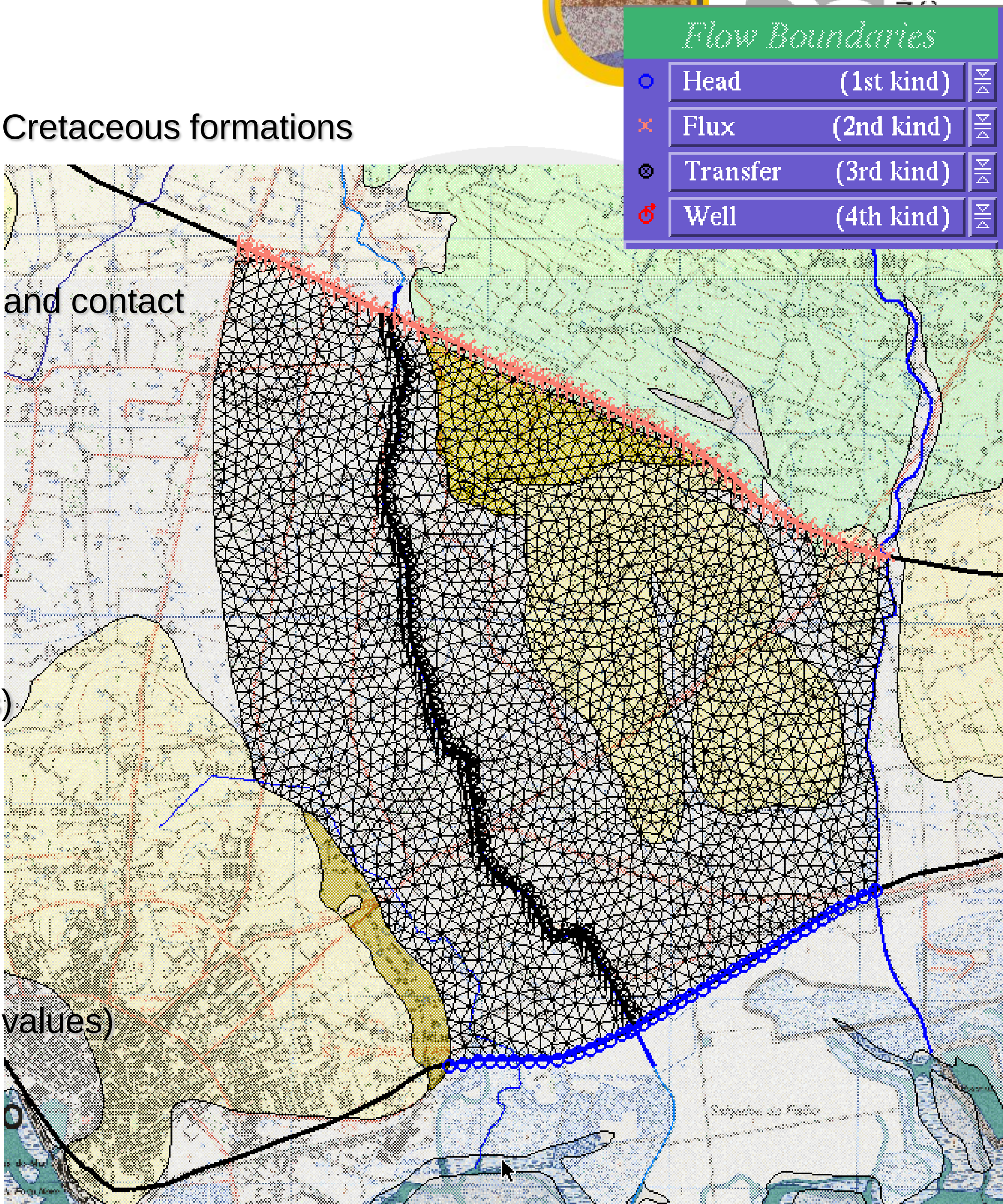
# Boundary conditions

2$^{nd}$ kind (Neumann)
Northern boundary in contact with Limestone Cretaceous formations
Integral Flux = -0.004 m/d (all layers)

1$^{st}$ kind (Dirichlet)
Southern boundary (border of aquifer system and contact with marshy zones of Ria Formosa)
Specified Head = 0 (all layers)

3$^{rd}$ kind (Cauchy)
Rio Seco (inside model domain)
Transfer integral is set (see file) just in Layer1

Impervious zones where no boundary conditions is defined (W and E boundaries)




## Boundary conditions constrains

1$^{st}$ kind
(constrained by max. Flux=0 $m^3$/d)

3$^{rd}$ kind
(constrained by head min and max. specified values)
File: Gradientes.xls
Source/sink rate in transfer = 9.7E-04 /d

# Artificial recharge in 25 large diameter wells (Nora) Scenario

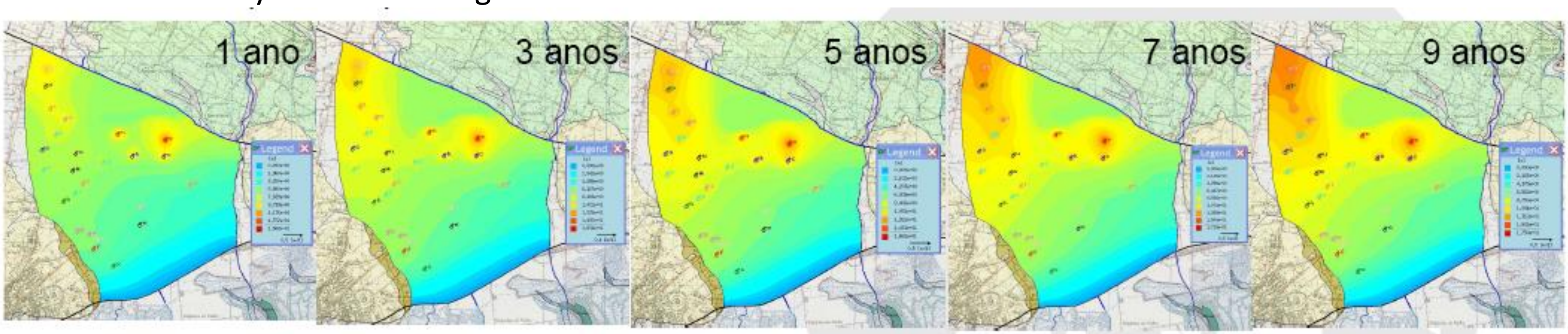
$Q_{i/nora} = 400\ m^3/d$

Injection time = 5 years

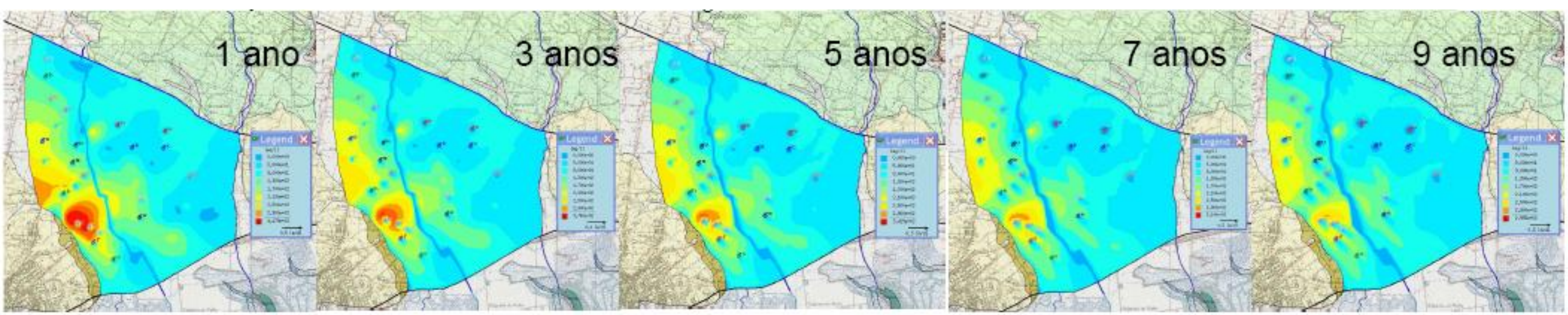
Simulation time = 10 years

Volume introduced in the aquifer = 3,65 $hm^3$/year = 18,25 $hm^3$

Piezometry variation along time after…




Nitrate concentration variation along time after…



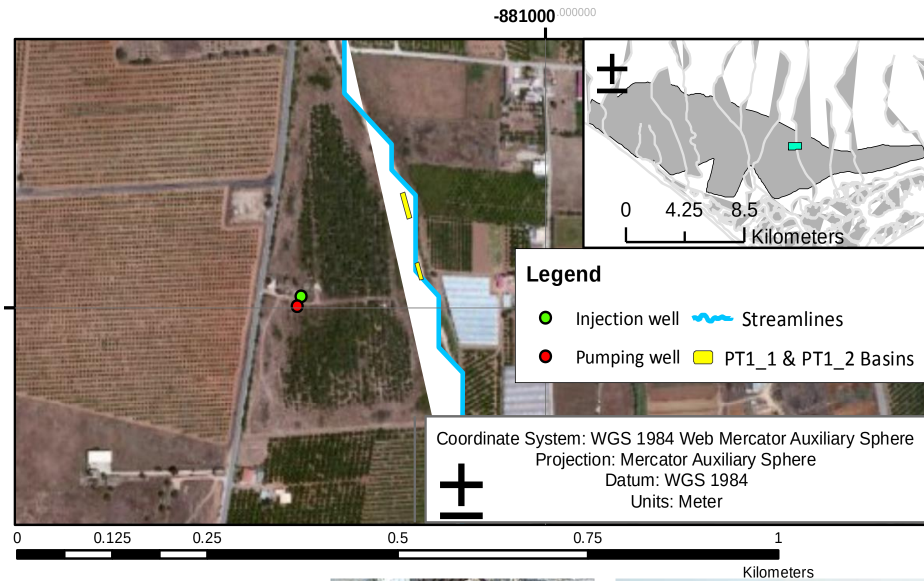

[NO3] máx. 421 mg/L

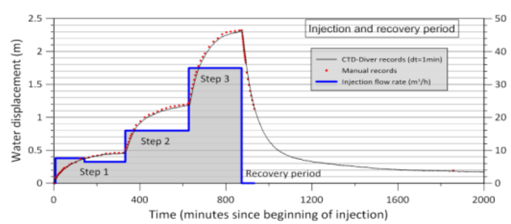
[NO3] máx. 293 mg/L

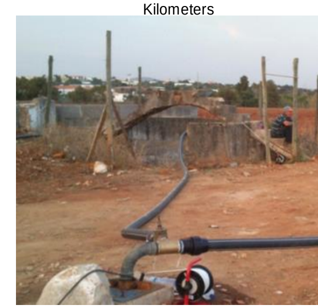
# WP 4: DEMO SITES - PORTUGAL

MAR SOL
MANAGED AQUIFER RECHARGE SOLUTIONS

## Local scale experimental MAR site Campina de Faro



LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

UNIVERSIDADE DO ALGARVE

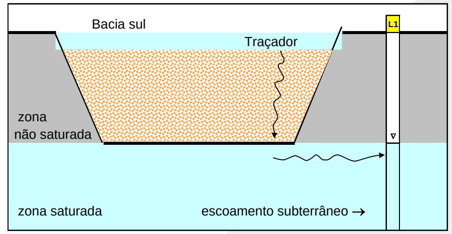
TARH

# Results from continuous monitoring (groundwater and surface water) in Rio Seco artificial recharge basins during winter time (Out.2007/Mar.2008) Carreiros test site

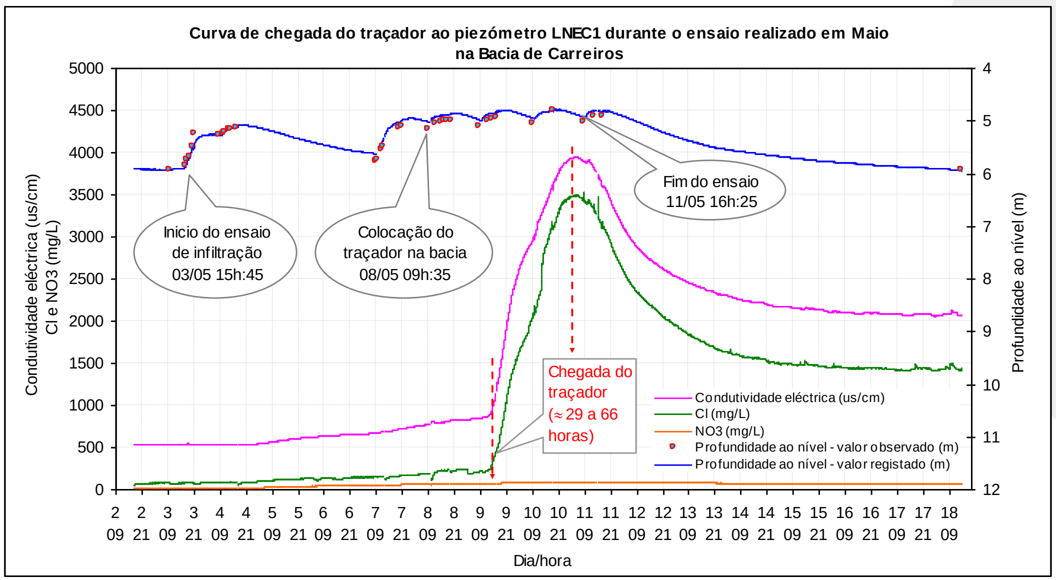
LNEC LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

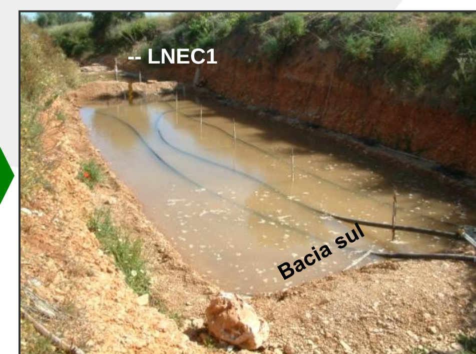
## Natural recharge monitoring

✓ Continuous monitoring in three piezometers





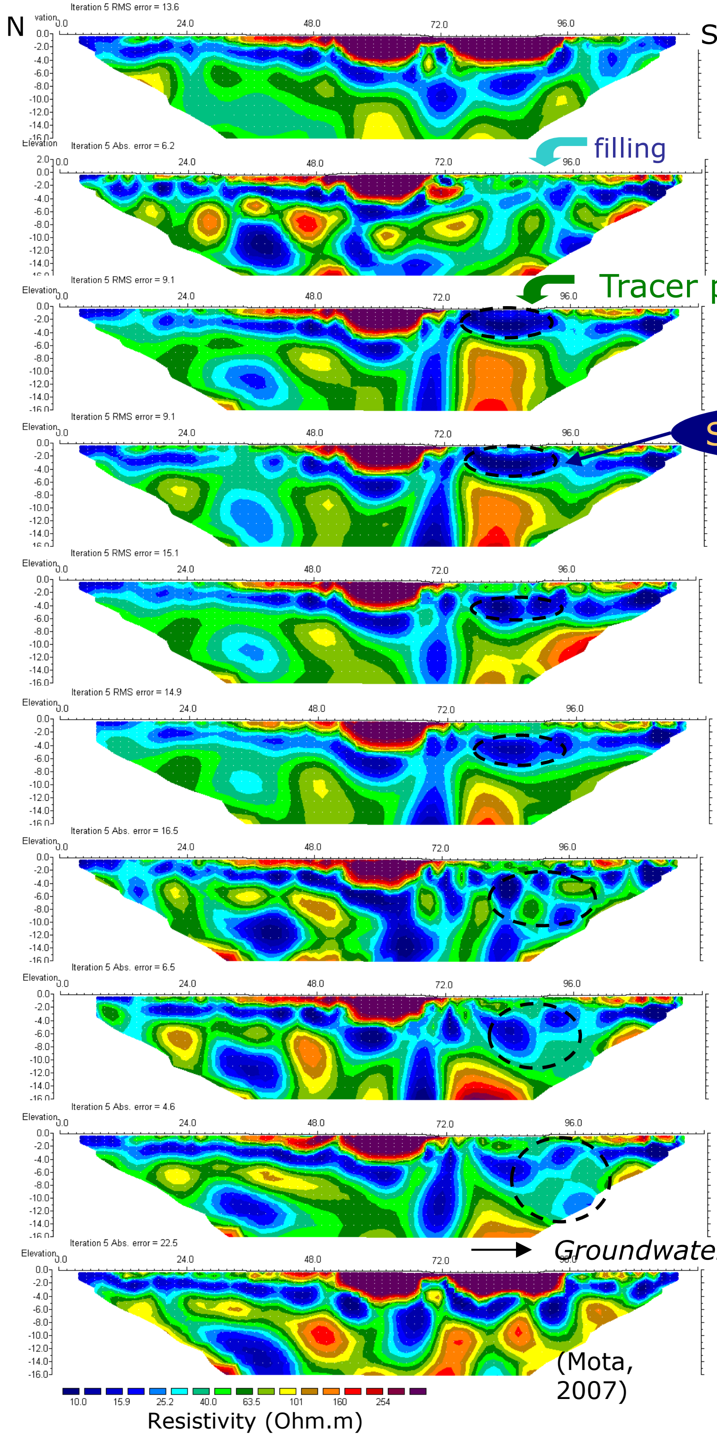




## Artificial recharge experiments

✓ Electrical resistivity assessment

May 2007

# Resistivity electrical models before, during and after the tracer test




02/May
(reference situation before filling the basin)

07/May
(reference conditions with the basin saturated, on the day previous to the test)

08/May 10h:55
(1,5 h after placing the tracer with the saturated basin)

08/May 17h:15
(7,8 h after placing the tracer )

09/May 8h:30
(23 h after placing the tracer )

09/May 16h:31
(31 h after placing the tracer )

11/May 14h:00
(77 h after placing the tracer )

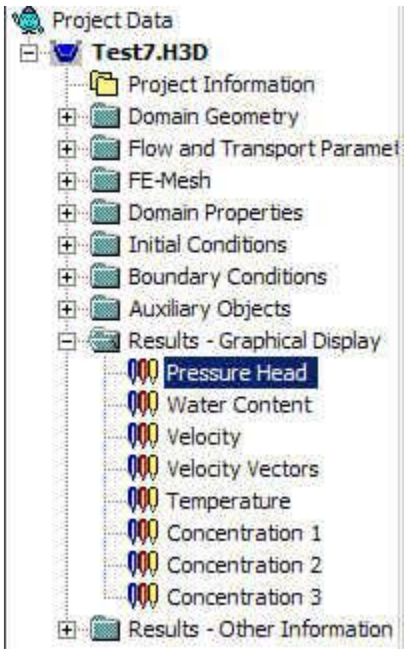
10/May 8h:35
(45 h after placing the tracer )

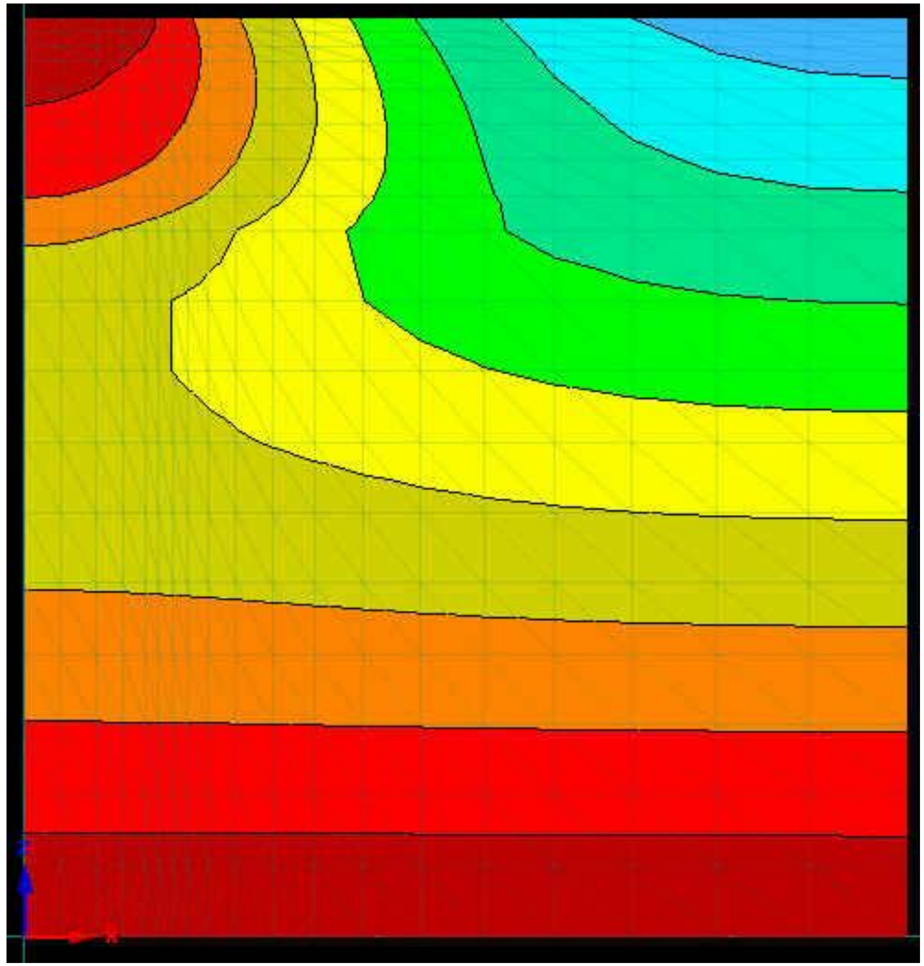
10/May 17h:00
(56 h after placing the tracer )

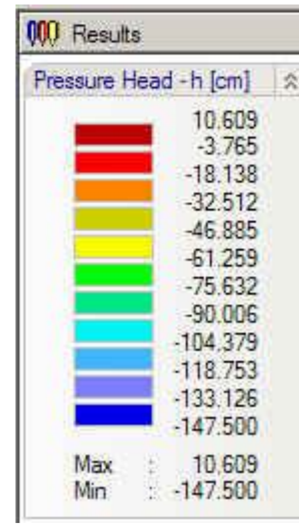
18/May
(240 h, 10 days after placing the tracer )

Hydrus.lnk

# Three-dimensional infiltration





## Local scale experimental MAR site Querença-Silves aquifer

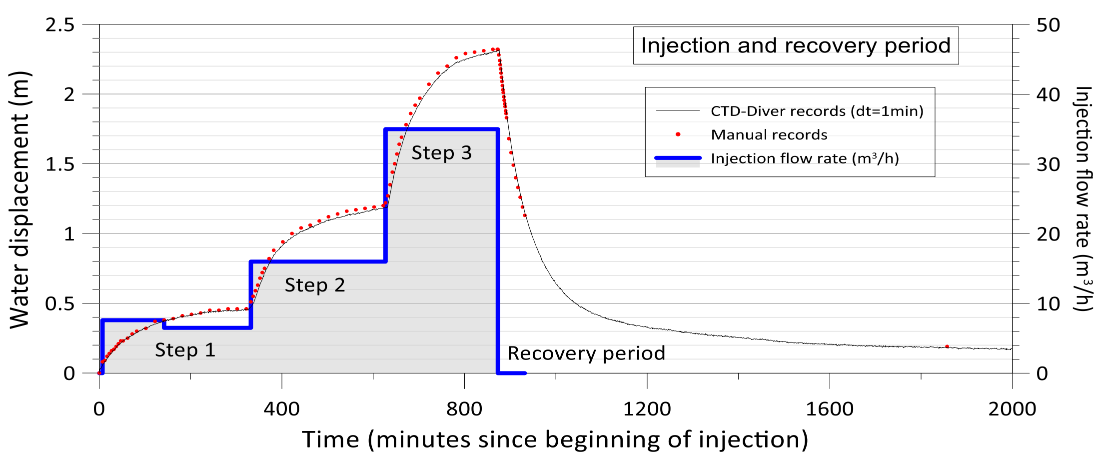


### WHAT WE HAVE DONE:

**Site #6:** PT2 Algarve, rib Meirinho dike

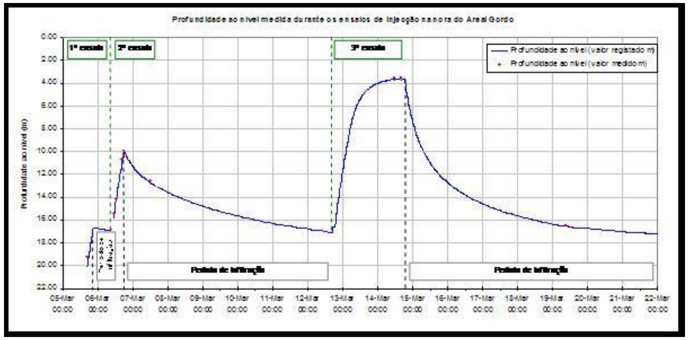
- Infiltration test in the large well (April 2014)
- Large Infiltration test with geophysics (Dec 2014)

- Dike rehabilitation
- Construction of monitoring infrastructures



# Modelling of the infiltration in a well ("Nora") in Campina de Faro

Code developed by the
Nottingham University

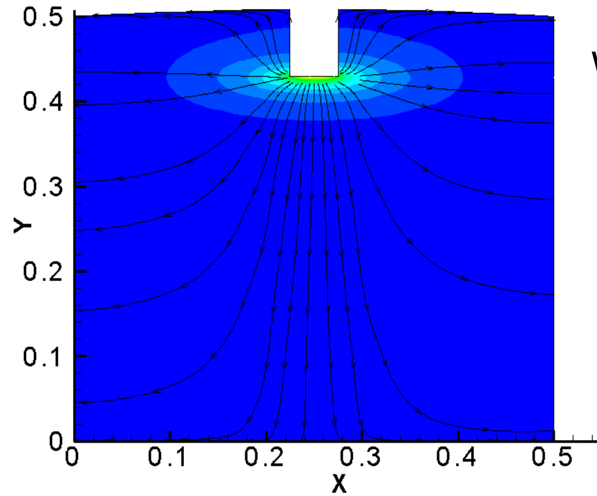



**Campina de Faro case-study**
**Injection test in a large diameter well ("nora")**

**Data for the groundwater flow simulation model**

<u>Data from the injection test (consider just the last injection test performed)</u>
Injection rate = 20 $m^3$/h
Duration of the injection test = 50 hours
Diameter of the well = 5 m
Depth to the water table before the injection test = 17 m
Depth of the well = 24 m

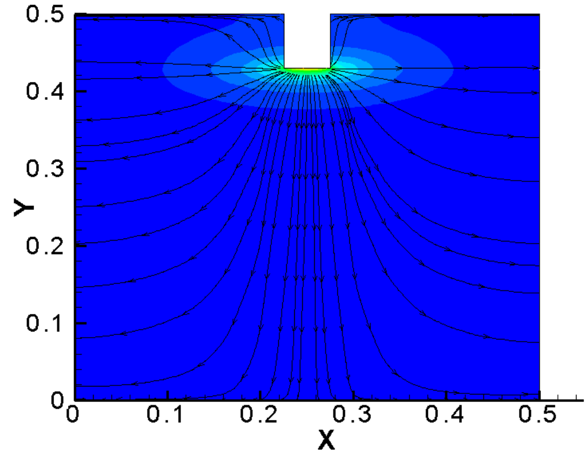
<u>Data from the aquifer</u>
Unconfined aquifer (sandy aquifer)
Estimated hydraulic conductivity = 35-45 m/d
Porosity = 0.33
Estimated saturated thickness = 50 m

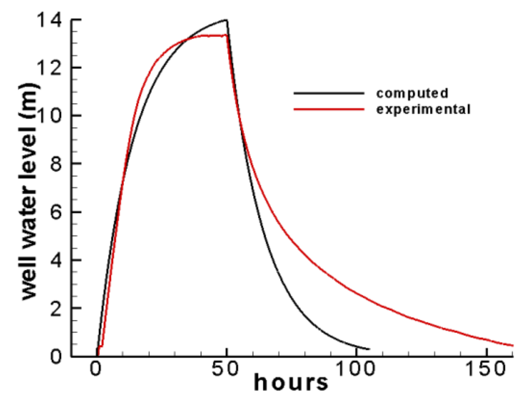



Water table maximum elevation: 0.84 m

t=110hours

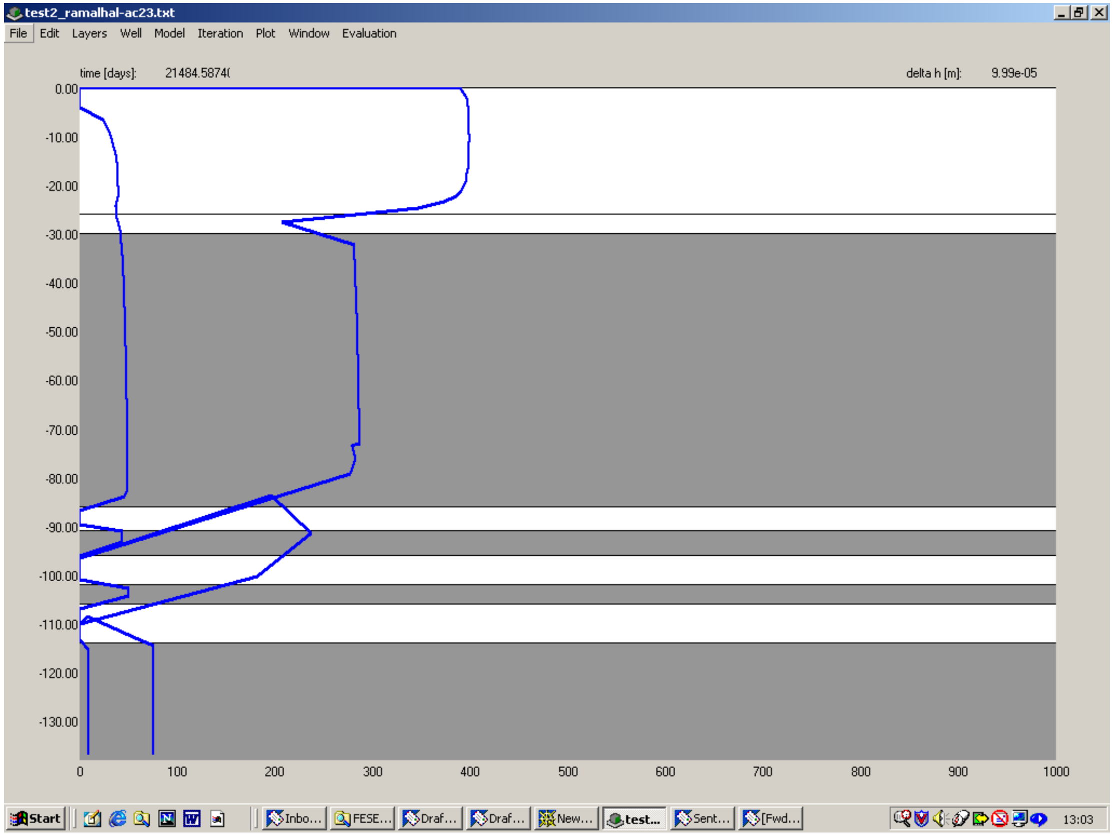
$k_x / k_y = 15$



# WellFlow

**Example of 50 and 3500 days isochrones with vertical influence (i.e. the stratification) of a potential pollutant, applied to a real pumping well located in Ramalhal, Portugal**



**Muito obrigado, grazie mille, thank you very much!**

**Advantages of using Numerical Modeling in Water Resources Management and Managed Aquifer Recharge schemes**

**Pisa, April 21st 2015**