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International Water Association

Leading-Edge Asset Management

GEO-SYSTEMS CENTRE

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Strategic Asset Management

Strategies for integrating alternative groundwater sources into the water supply system of the Algarve, Portugal

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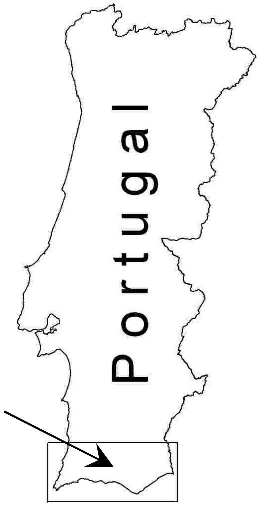
Objectives

- Present a method of "screening & selection" for integrating groundwater resources into a public water supply system
- Present the case study: Algarve, where the work is integrated into the project *OPTEXPLOR*, which aims to create a decision support model for an integrated water resources management (IWRM), under water scarcity



OPTEXPLOR: Partners of consortium

- ***Universidade do Algarve***
  - coordination, screening of water resources, groundwater flow simulations, mixing simulations
- ***CVRM/Instituto Superior Técnico Lisboa***
  - surface runoff and reservoir inflow simulations
- ***IMAR/Universidade de Coimbra***
  - decision support model development
- ***Águas do Algarve, S.A.***, Water Utility
  - collaboration and funding

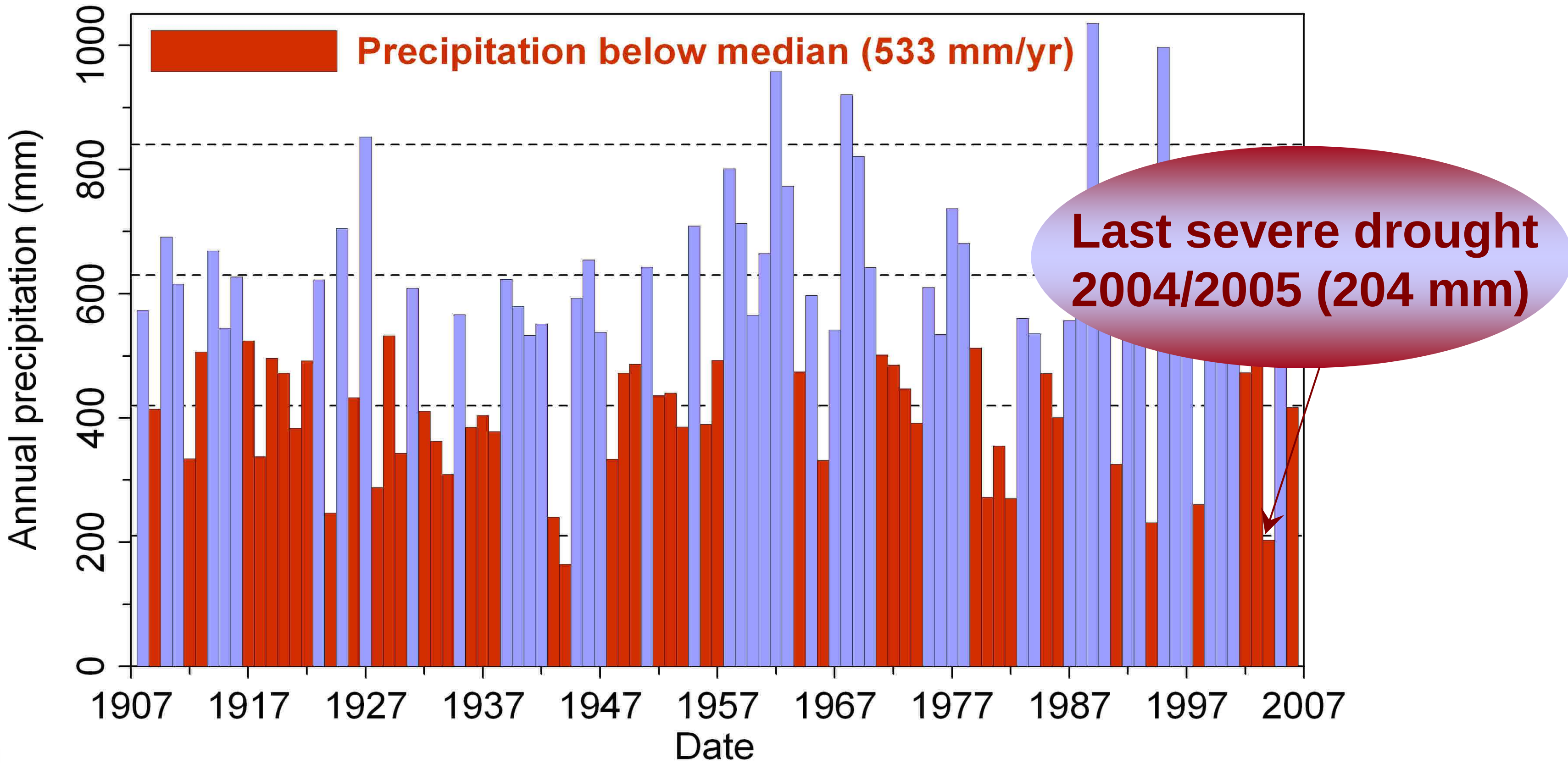
Why the need for an integrated water resources management?

- The extreme seasonal and annual variations in rainfall in semi-arid and arid regions pose serious challenges to a stable and sustainable water supply planning and management;
- The frequency, intensity and duration of droughts will increase in the future (SIAM - Climate Change in Portugal. Scenarios, Impacts and Adaptation Measures).

Why the need for an integrated water resources management?

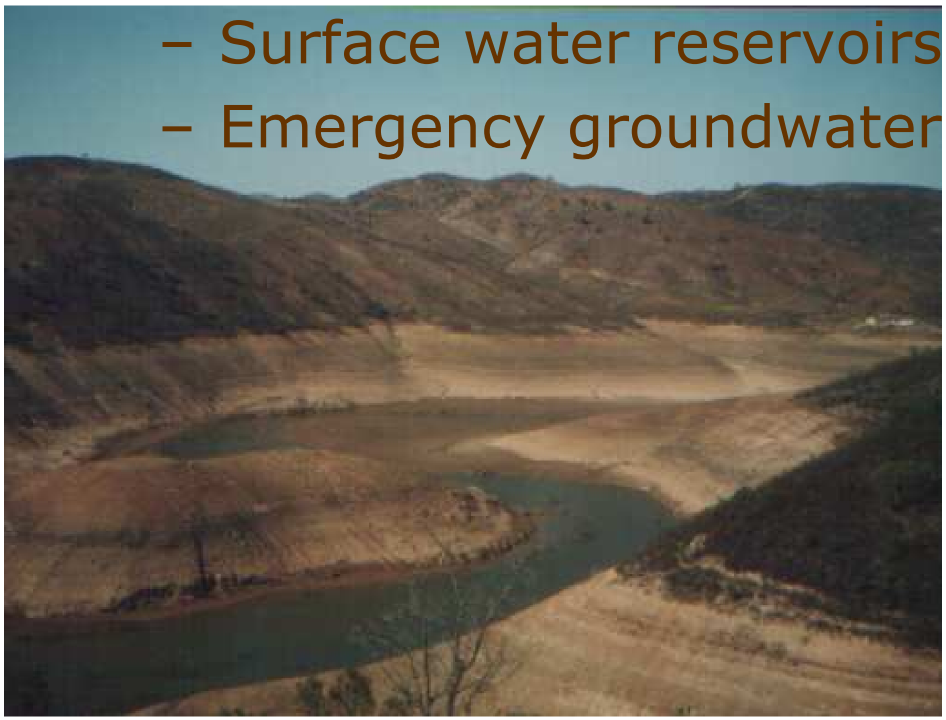
- Drought ***RISK*** = ***HAZARD* x *VULNERABILITY***
  - ***HAZARD*** = probability of occurrence of rainfall below average
  - ***VULNERABILITY*** = level of submission to hazard, due to water resource use, which depends on:
    - Population growth
    - Land use
    - Government policies
    - Environmental degradation, awareness

Precipitation time-series Algarve (coastal weather station) – indicator of *HAZARD*

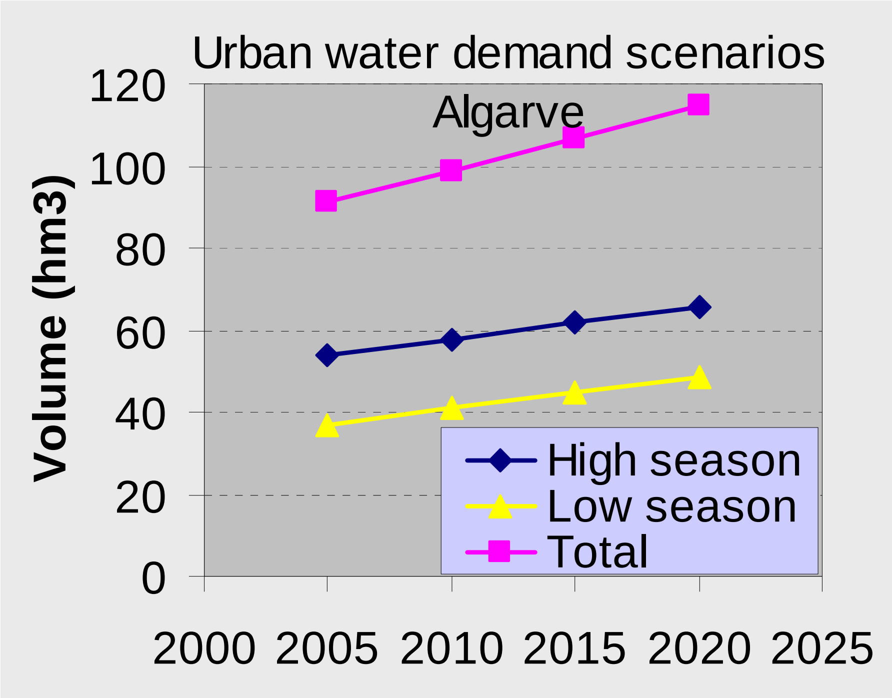


Public water supply policy based on single source ⇨ high *VULNERABILITY* ⇨ high *RISK*

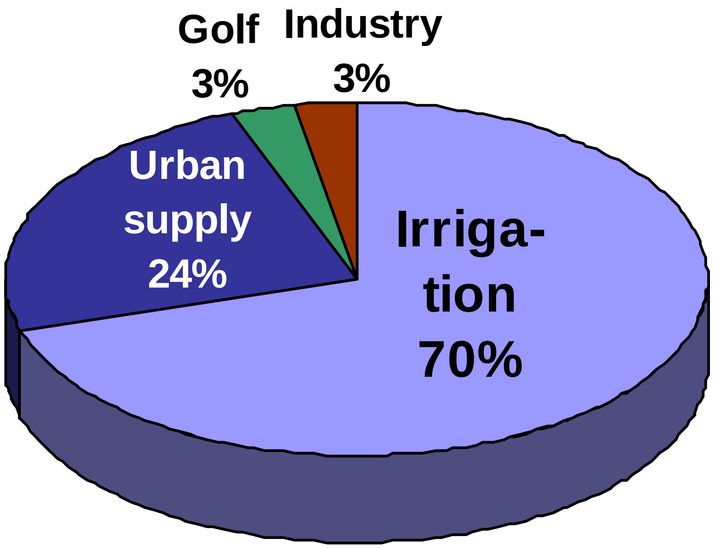
- Consequences during 2004/2005 drought:
  - Surface water reservoirs unable to fulfil demand
  - Emergency groundwater sources had to be used



Future urban demand scenarios



Distribution of water demand



⇨ **VULNERABILITY will increase**

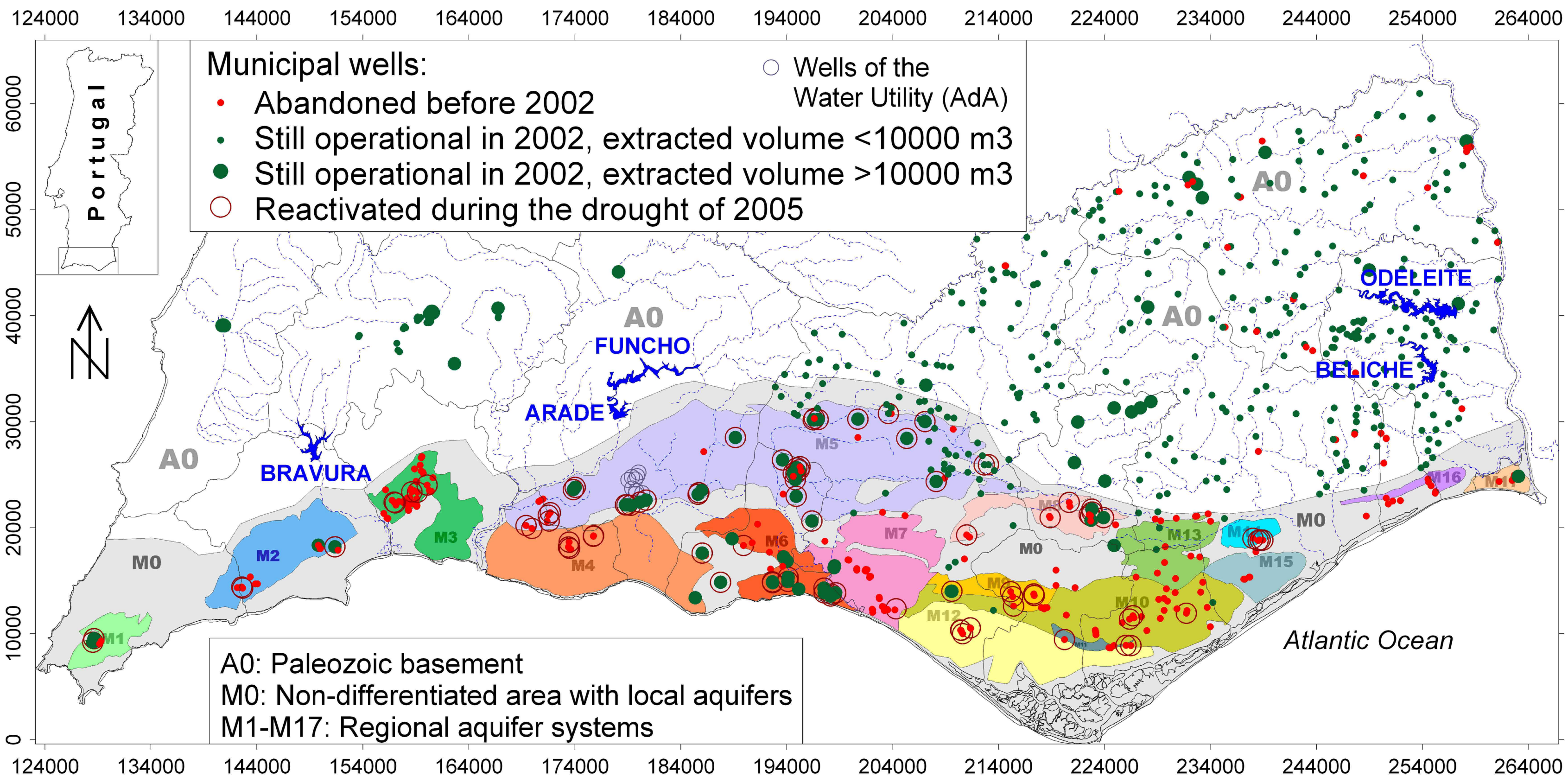
Integrated water resources management
Configuration of decision model

- Integration of economics
  - Determination of financial costs: e.g. treatment, pumping
  - Determination of the economic value of water for the different uses (scarcity costs)
- Classical structure of an optimization model
  - Objective function: minimize costs
- Constraints
  - e.g. water balances – dam operation/distribution system
  - ground water flow models for aquifer management
  - water quality modeling

Integrated water resources management Alternative water sources

- Besides additional surface water reservoirs (Odelouca dam under construction), alternative water sources need to be considered:
  - Groundwater
  - Treated waste water (for irrigation)
  - Desalinated water

Groundwater: principal source of public supply until the end of the 20th century



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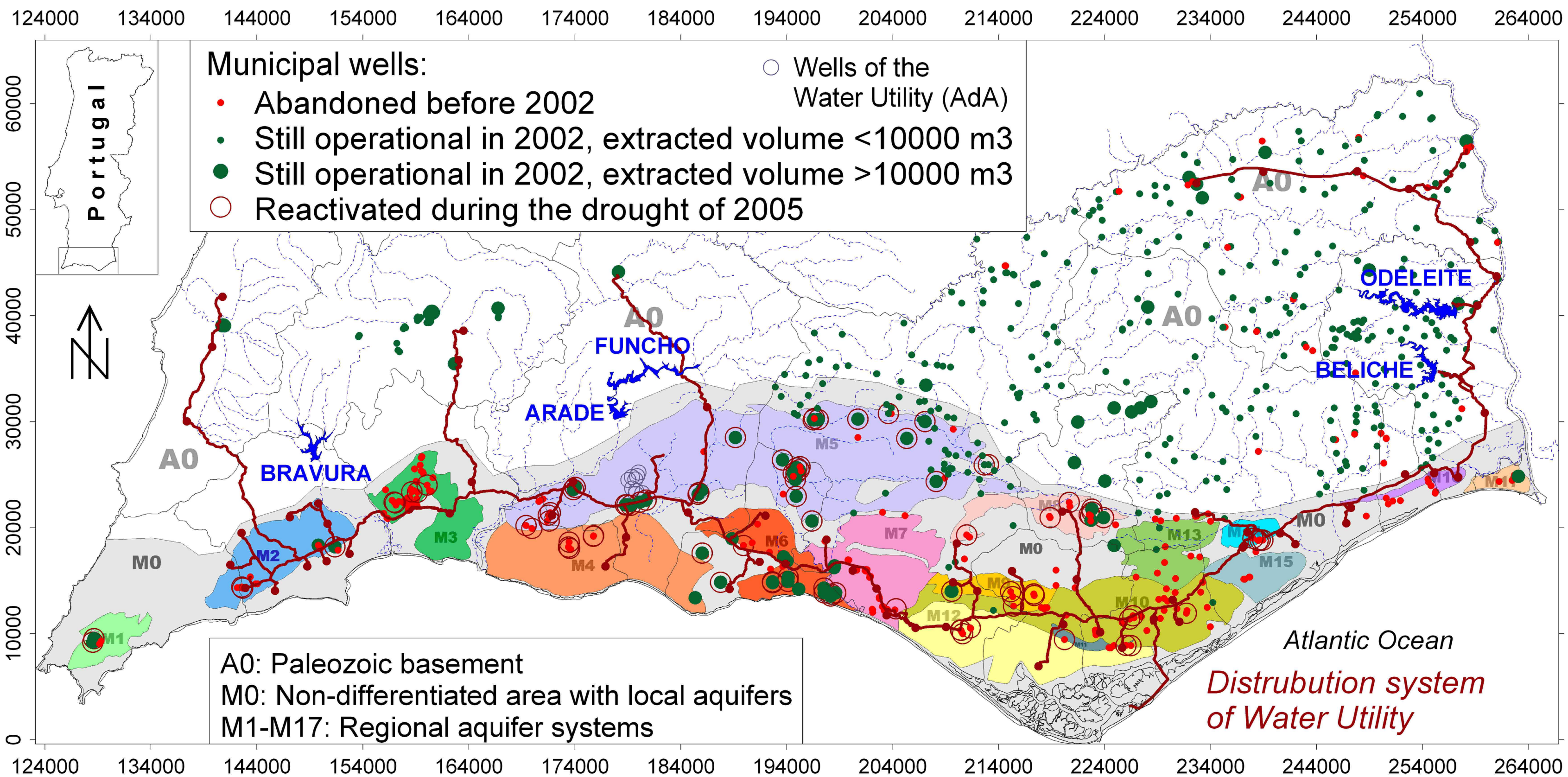
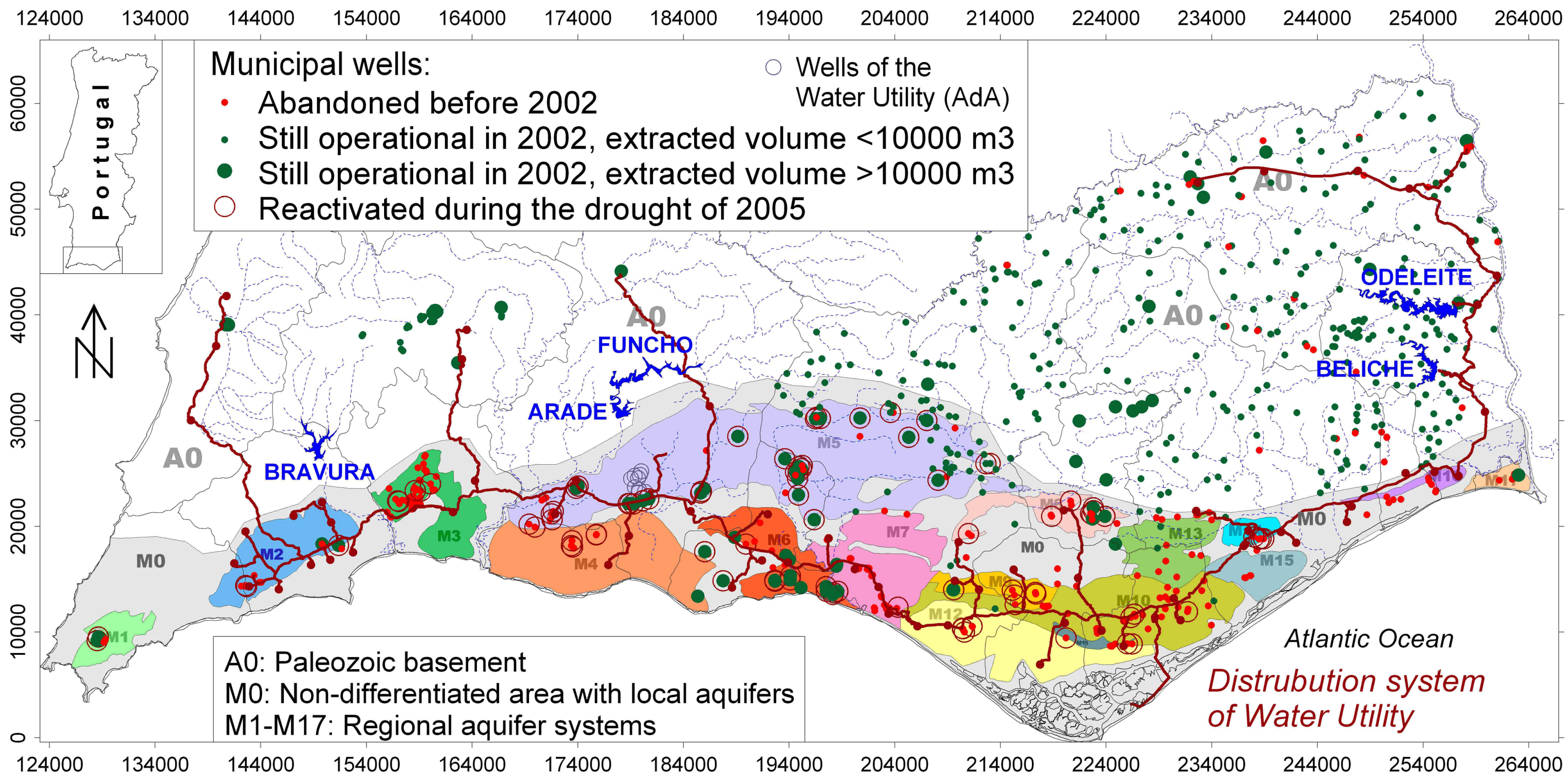
Groundwater: principal source of public supply until the end of the 20th century



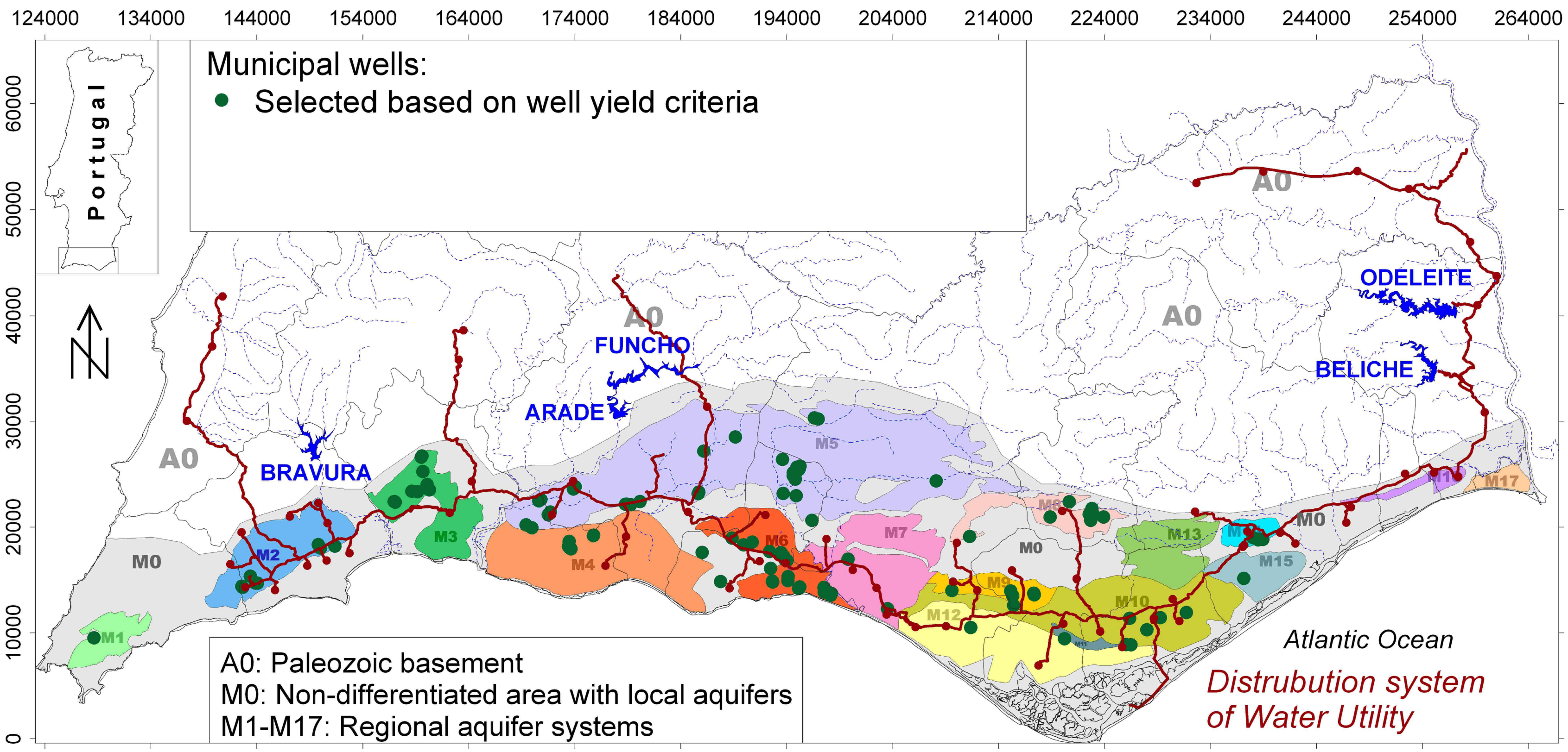
Screening Methods

- **Quantitative** screening based on:
  - Overall properties of regional aquifer systems;
  - Individual municipal well yields.
- **Quantitative** selection criteria:
  - Well yield ≥ 15 l/s;
  - Well yield < 15 (≈10) l/s and favorable location.

Spatial distribution of municipal wells



Results of quantitative screening



Screening Methods

- **Qualitative** screening based on:
  - Overall chemical and microbiological quality of regional aquifer systems;
  - Individual well water quality;
    - Calculation of a standard violation index (SVI) for each well, for different sets of variables, based on their parametric values (PVs) defined in the EC Drinking Water Directive (98/83/EC).

Screening Methods

- **<u>Qualitative</u>** screening based on:
  - Overall chemical and microbiological quality of regional aquifer systems;
  - Individual well water quality;

Set of variables

Time interval

Nr. of violations in well i

$$SVI_{i(j_1, j_2, ..., j_p, t_0 - t_u)} = \frac{N_{i,viol(j_1, j_2, ..., j_p, t_0 - t_u)}}{N_{i,anal(j_1, j_2, ..., j_p, t_0 - t_u)}}$$

Nr. of analyses of well i

Qualitative screening

Defined standard violation indices (t_0=1995, t_u=2005)

SVI	Descrição	N_{anal}	N_{viol}	$\%_{viol}$
SVI_{All}	All parameters	38362	3939	10.3%
SVI_{Toxic}	Toxic parameters	5670	15	0.26%
$SVI_{Microbiol}$	Microbiological parameters	3040	1077	35.4%
$SVI_{NO3,Cl}$	Nitrate and Chloride	5708	1029	18.0%
$SVI_{Fe,Mn}$	Iron and Manganese	4339	723	16.7%

Qualitative screening

Water treatment classes: maximum recommended microbiological presence

Parameter	Class A1		Class A2		Class A3	
	MRC	Freq.	MRC	Freq.	MRC	Freq.
Total coliforms	50	81.2%	5000	16.8%	50000	2.0%
Fecal coliforms	20	88.3%	2000	11.0%	20000	0.7%
Fecal streptococci	20	89.4%	1000	9.8%	10000	0.8%

(Units: No./100 ml)

Qualitative screening

Hardness classes

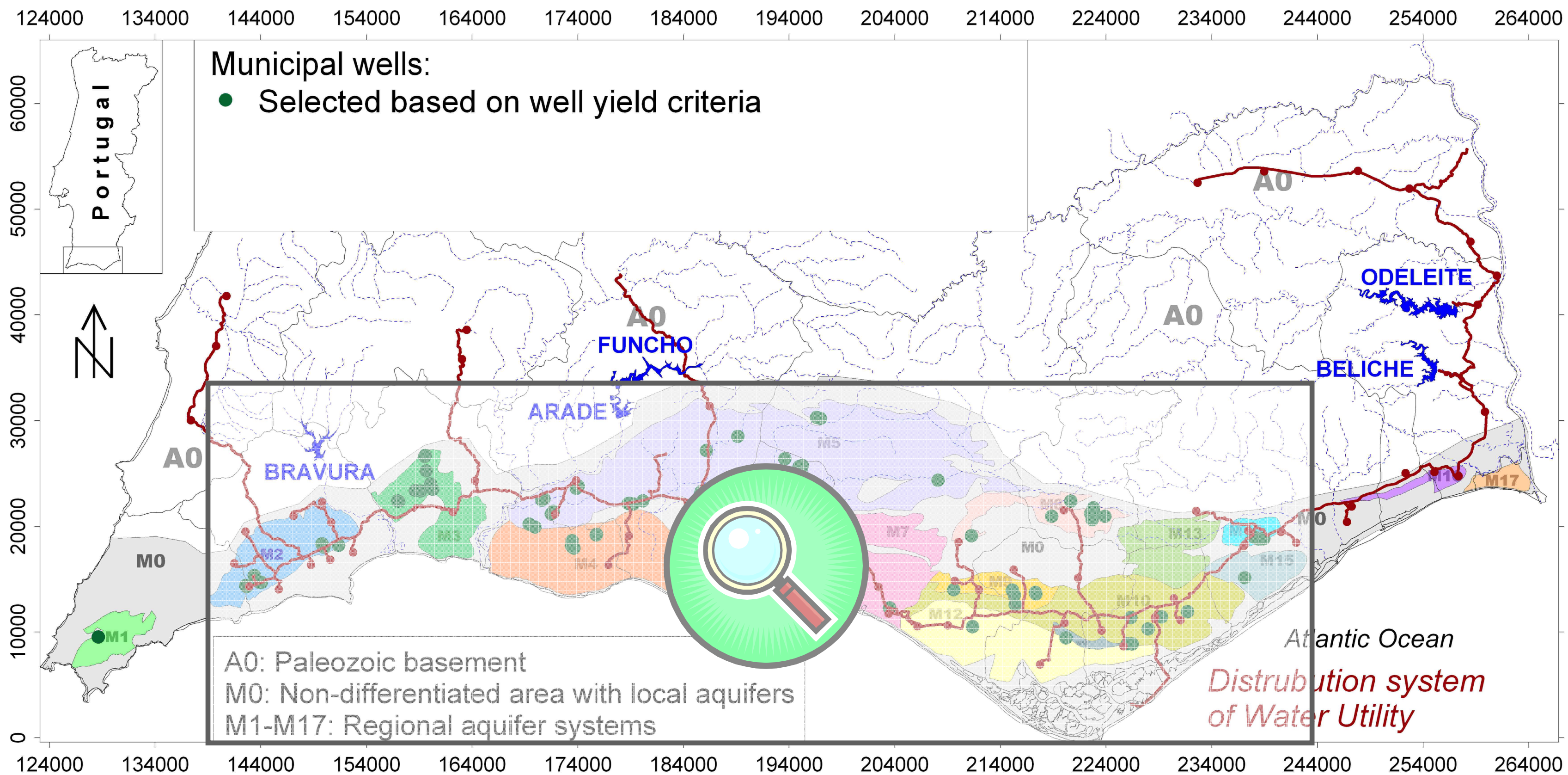
Class	Hardness	Hardness degree	Freq.
1	0-75	Soft	2.1%
2	75-150	Moderately hard	3.5%
3	150-300	Hard	7.2%
4	300-500	Very hard	60.8%
5*	> 500	Above MAC	26.5%

(Units: mg/l)

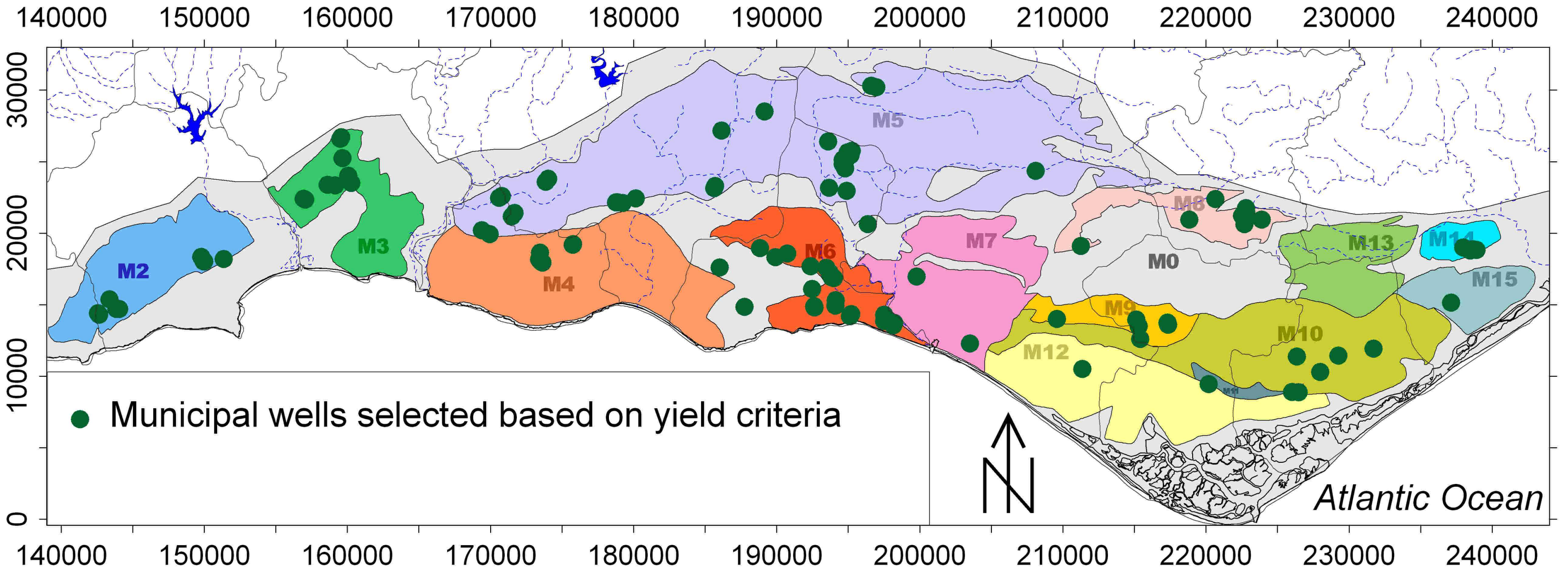
Screening Methods

- **Qualitative** selection criteria:
  - $SVI_{Toxic}=0$ **AND**
  - $SVI_{NO3,Cl}=0$ **AND**
  - $SVI_{Fe,Mn}\leq 0.25$ **AND**
  - Microbiology: treatment class = A1

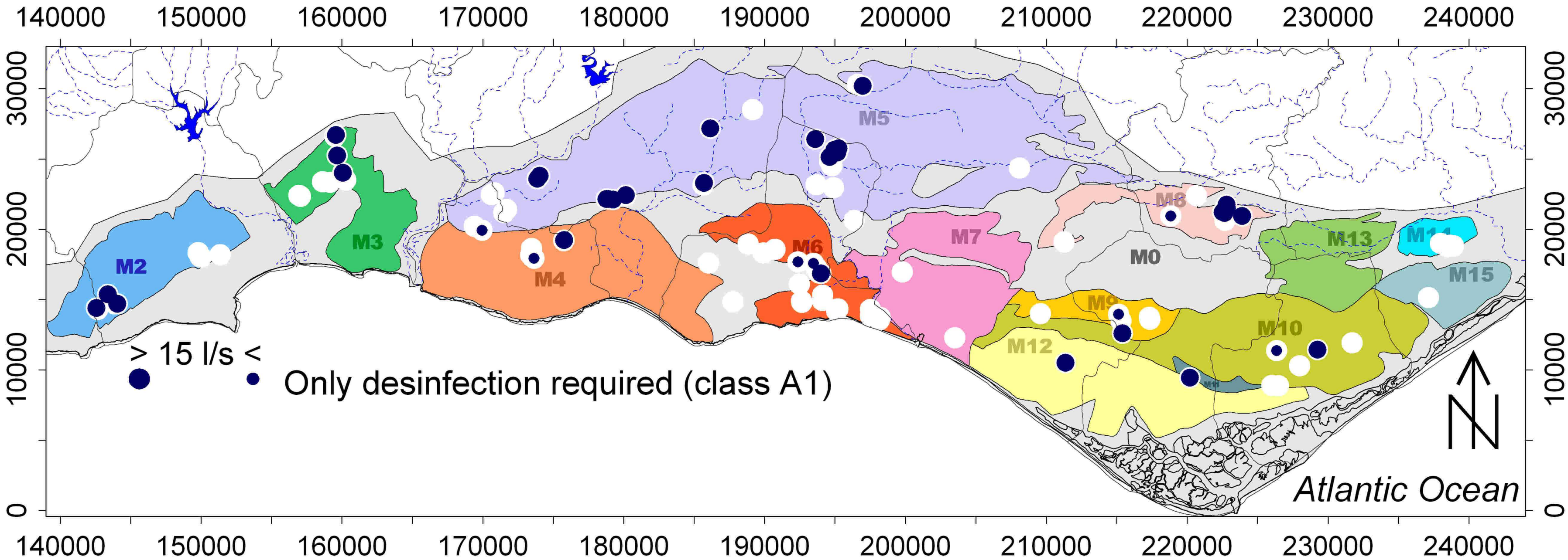
Results of quantitative screening



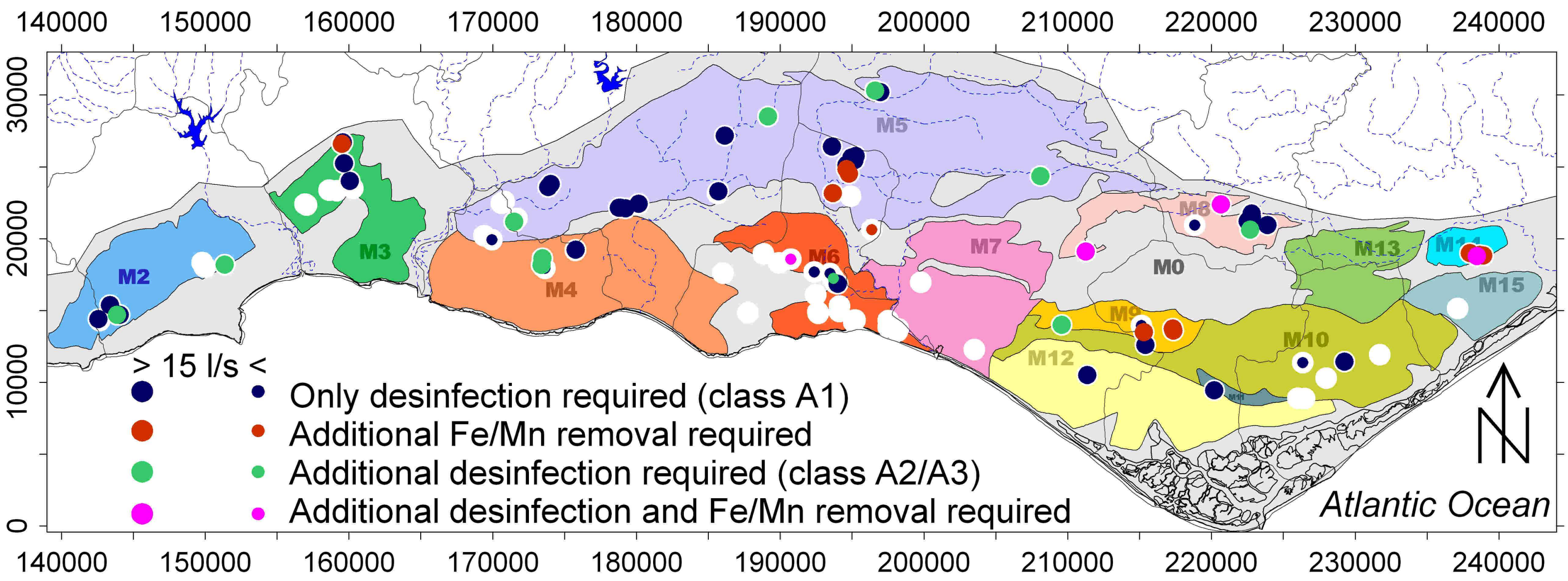
Results of quantitative screening



Results of qualitative screening: wells that only require disinfection



Results of qualitative screening: wells that require additional treatment prior to selection



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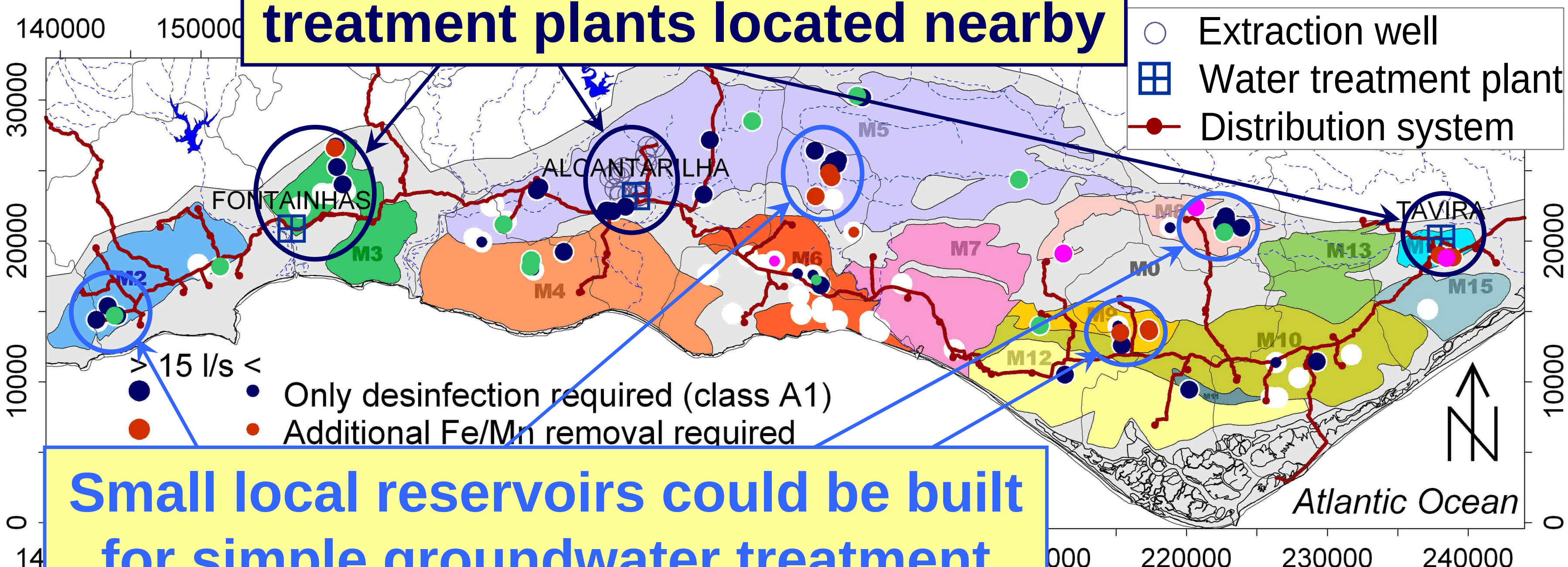
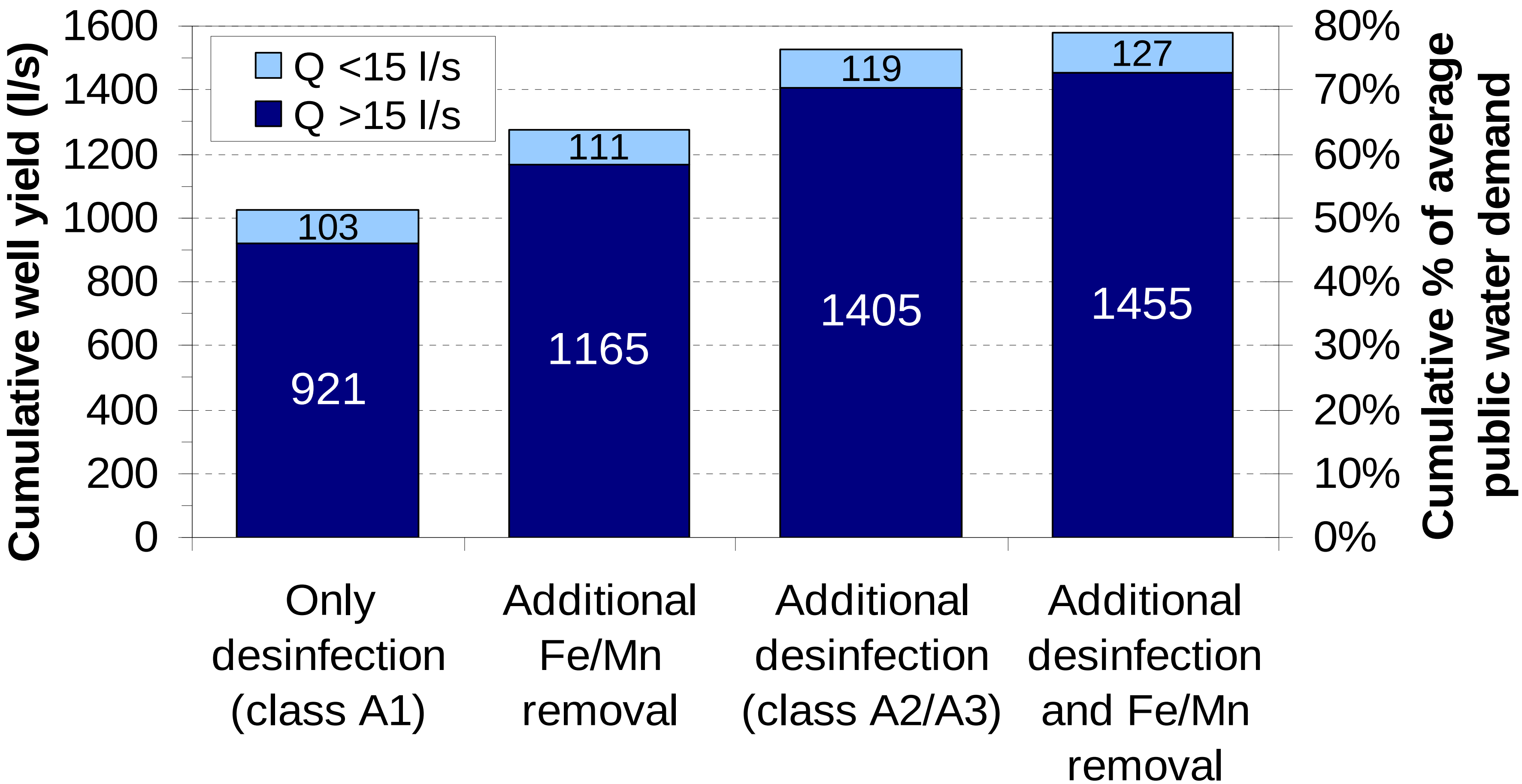
Location of selected wells relative to infrastructure of Algarve Water Utility

Groundwater can be diverted to treatment plants located nearby



Small local reservoirs could be built for simple groundwater treatment (i.e. disinfection, Fe/Mn removal)

Total yield of selected wells



Final considerations

- The standard violation indices (SVIs) prove to be useful tools for the spatial monitoring of groundwater quality and potability;
- Their application is simple and straightforward and based on well-established drinking water guidelines, so that their interpretation is unbiased;
- The screening selection is useful for the decision support model currently being developed, as it allows a reduction of dimension while not eliminating the most important alternative groundwater sources

Acknowledgements

- Funding for this work is being provided by the Water Utility *Águas do Algarve*, *S.A.*, closely collaborating in the project.

Thank you