ALOPEX stochastic optimization for pumping management in fresh water coastal aquifers

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Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
ΕΣΠΑ 2007-2013
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Saltwater intrusion

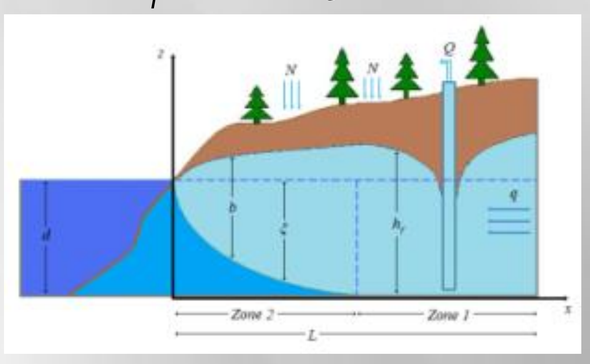
A stochastic optimization technique (ALOPEX) is implemented to solve the problem of uncontrollable freshwater pumping in coastal aquifers. The objective is to maximize the total volume of fresh water pumped by the aquifer wells, while protecting the pumping locations from saltwater intrusion.

Model equations

The model equations are based on:

- the ***sharp interface approximation*** and
- the ***Ghyben-Herzberg relation***:

$$h_f - d = \delta\xi$$



The ***flow potential φ=φ(x,y)*** is a continuous and smooth function across the boundary between zones 1 and 2, satisfying the differential equation:

$$\frac{\partial}{\partial x}(K\frac{\partial \phi}{\partial x})+\frac{\partial}{\partial y}(K\frac{\partial \phi}{\partial y})+N-Q=0$$

with *φ=0* at the coastline (Dirichlet conditions) *and* $\frac{\partial \varphi}{\partial n}=0$ at the no flow boundaries (Neumann conditions).
*Q:*pumping rates, *N*:rain factor and *K*:hydraulic conductivity.

Optimization procedure

maximize: $P = P(Q_1, Q_2, ..., Q_M) = e^{-\left(1-\frac{\sum_{j=1}^{M} Q_j}{\sum_{j=1}^{M} \overline{Q_j}}\right)^2}$

s.t.: $\underline{Q_j} \le Q_j \le \overline{Q_j}$

$$\sum_{j=1}^{M} Q_j \le \overline{Q_A}$$

$$x_{\tau,j} \le x_j - d_s, \quad j \in \{1,2,...,M\}$$

where:
$\overline{Q_j}, \underline{Q_j}$: maximum and minimum well pumping rates/day, $\overline{Q_A}$: total pumping capabilities of the aquifer/day, d_s: safety distance radius and
$x_{\tau,j}$: x-coordinate of the ***interface toes area*** opposite the j[th] aquifer well.

ALOPEX

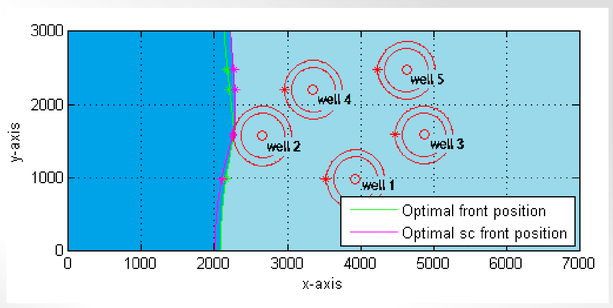
ALgorithm **O**f **P**attern **EX**traction is a stochastic iterative procedure, used to produce the new pumping rates in every iteration step.

$$Q_j^{(k)} = Q_j^{(k-1)} + c\left(Q_j^{(k-1)} - Q_j^{(k-2)}\right)\left(P^{(k-1)} - P^{(k-2)}\right) + g_j^{(k)}, \quad j \in \{1,...,M\}$$

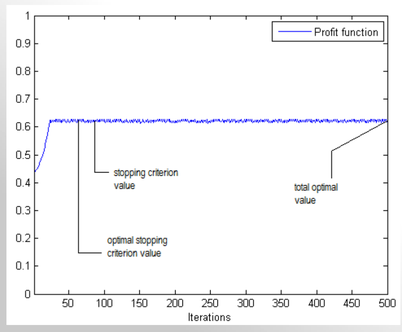
where:
c: acceleration factor and $g_j^{(k)}$: white noise for the j[th] well at k[th] iteration.

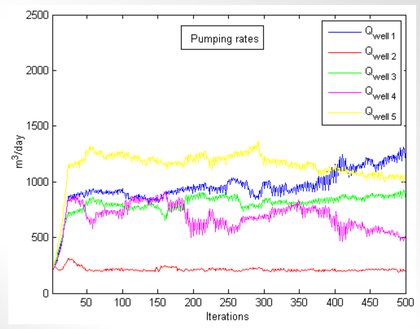
Εργαστήριο Εφαρμοσμένων Μαθηματικών και Ηλεκτρονικών Υπολογιστών

Kalymnos aquifer



Analytical solution in cooperation with **ALOPEX V** numerical results.



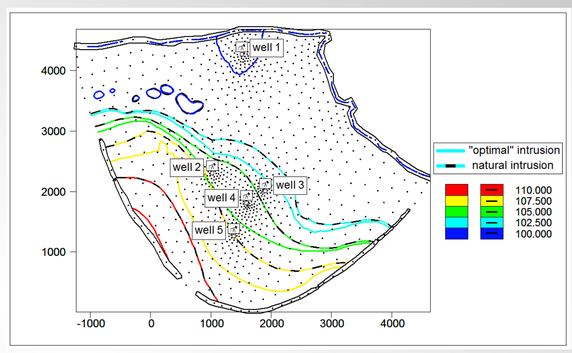


Optimal pumping rates :

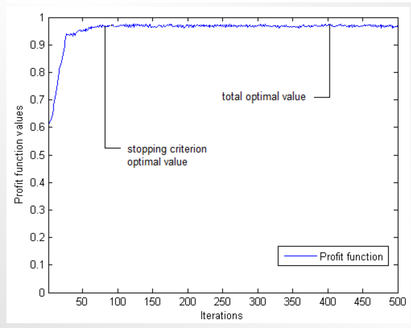
$\mathbf{Q}_{optimal}$ =[1303.05, 202.27, 912.85, 504.38, 1047.07] m³/day

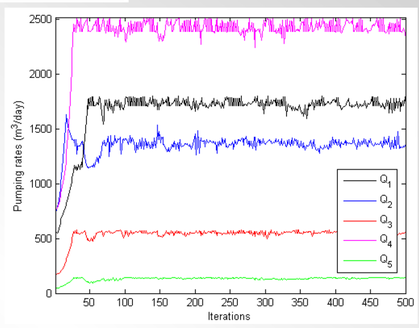
Σ($\mathbf{Q}_{optimal}$)=3969.62 m³/day

Hersonissos aquifer



PTC code in cooperation with **ALOPEX V** numerical results.





Optimal pumping rates :

$\mathbf{Q}_{optimal}$ =[1710.00, 1652.19, 557.41, 2342.64, 136.60] m³/day

Σ($\mathbf{Q}_{optimal}$)= 6398.84 m³/day

Publications

- P. Stratis, Y. Saridakis, E. Papadopoulou and M. Zakynthinaki, *ALOPEX Stochastic Optimization for Pumping Management in Freshwater Coastal Aquifers,* Journal of Physics: Conference Series, 490, 012112, 2014.
- P. Stratis, Z. Dokou, G. Karatzas, E. Papadopoulou and Y. Saridakis, *Stochastic Optimization and Numerical Simulation for Pumping Management of the Hersonissos Freshwater Coastal Aquifer in Crete,* Procs. of INASE/CSCCWHH 2015, Recent Advances in Environmental and Earth Sciences and Economics, 329-334, Zakynthos, 2015.
- P. Stratis, Z. Dokou, G. Karatzas, E. Papadopoulou and Y. Saridakis, *PTC Simulations, Stochastic Optimization and Safety Strategies for Freshwater Pumping Management: Case Study of the Hersonissos Coastal Aquifer in Crete,* September 2015, (Applied Water Sciences submitted).
- P. Stratis, G. Karatzas, E. Papadopoulou, M. Zakynthinaki and Y. Saridakis, *Stochastic Optimization for an Analytical Model of Saltwater Intrusion in Coastal Aquifers,* 2015 (PLOSone submitted).
- I. Athanasakis, Z. Dokou, E. Mathioudakis, P. Stratis and N. Vilanakis, *Combining Stochastic Optimization and Numerical Methods-Software for the Pumping Management of Coastal Aquifers: Case Study of a Rectangular Homogeneous Aquifer,* Conference in Mathematical Methods and Computational Techniques in Science and Engineering, November 28-30, Bratislava, Slovakia, 2015.