# EFFICACY OF HYDRAULIC BARRIERS IN COASTAL AREAS

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The purpose of the study is to verify the efficacy of hydraulic barriers in containing the diffusion of pollution in a coastal aquifer.
The aquifer is described with two different layer: the first layer is saturated with freshwater, the second one salt water; the layers are separated by a transition zone, named interface.
The analyzed area is subject to pollution due to presence of deposits of polluted refusal. The shape of saltwater intrusion and the thickness of the aquifer has been reconstructed using geophysics, and the piezometry has been obtained considering different water density, determined by different salty levels.
The water densities have been obtained from measures of electric conducibility in different points of the aquifer. The control piezometres highlights that the specific conducibility rises to values located between 10000 and 30000 μS/cm.
Figure 1 shows the graph used to convert conducibility values in density values. Following literature, the piezometric level h can be obtained measuring the level of the interface water – air in a well. It is usually referred to the sea level.
The piezometric level is given by two different contributes, zi and hi, where $h_i$ is:

$$h_{p,i} = \frac{p_i}{\rho_{i*g}}$$

This formulation of $h_i$ does not describe correctly the spatial hydraulic head changes, in an aquifer where also density varies. In fact, in a variable density system, at the same pressure can correspond different values of $h_p$, because there is a dependence of density.

It is necessary to normalize respect to a common density, usually the fresh water one. So, it is possible to substitute the water column with equivalent another one with equal density in all wells
The following formula allows to transform measured hydraulic heads in equivalent heads:

$$h_e = h_s * \left(\frac{\rho_s}{\rho_f}\right) - z * \left(\frac{\rho_s}{\rho_f}\right) + z$$

Collecting the term z, the expression results simpler:

$$h_e = h_s * \left(\frac{\rho_s}{\rho_f}\right) + z\left(1 - \left(\frac{\rho_s}{\rho_f}\right)\right)$$

The formula can be simply explained from a physical point of view: it represents the fresh water column sufficient to contrast the pressure of salt – water column hs which extends towards filtering system of well. However, a portion of salt water column is under the sea level (z*ps/pf). Subtracting from the total column the height of equivalent column under sea level, the total height of equivalent column is smaller, reaching the level of the portion emerging by the sea level. The piezometric level is obtained adding the distance of filters from 0 level (named z).
The Figure 1 shows the piezometric profile of the studied aquifer, and it is possible to observe that thickness of fresh water decreases approaching to coast line, where there are water fluxes towards the sea.

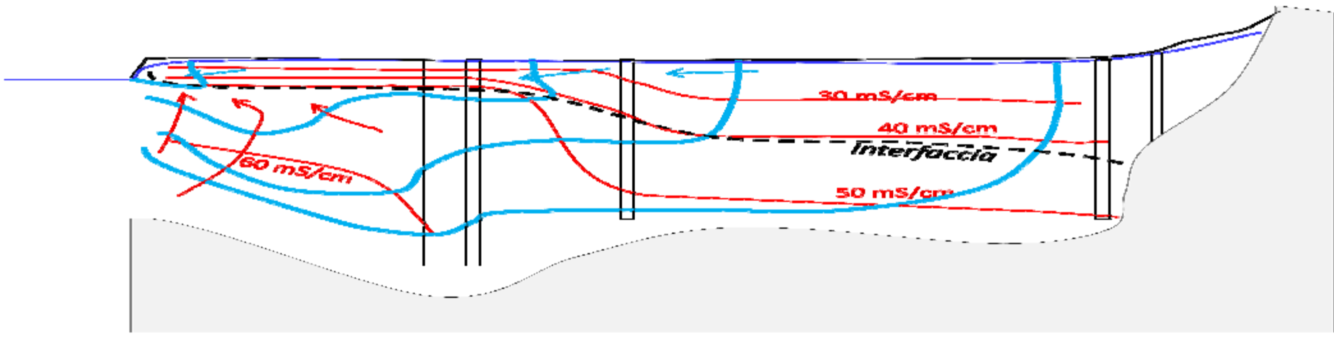


**Figure 2 – Piezometric profile based on equivalent freshwater head. The dashed line represents the interface, and the red lines the specific conductivity.**

The difference of effects due to pumping in fresh water or in salt water, can be detected studying how the piezometric profile changes in the two cases.
When there is only fresh water, the Dupuit's formula can be used. Isolating Y it is obtained :

$$Y = \sqrt{h^2 + \frac{Q * \ln\left(\frac{R}{r}\right)}{\pi * k}}$$

Instead, when pumping interests also salt water, the Dupuit's formula cannot be applied directly, but any modifications are necessaries:

$$q_z = -\frac{k}{\mu} * \left(\frac{\vartheta P}{\vartheta z} + \rho g\right)$$

When the well screens are located both in fresh and salt water to the substratum, it is possible to calculate the equivalent head using the average density, pondering respect to the salt water and fresh water density. In the study case, the average pondered density is equal to 1.0305 g/cm$^3$ considering the well 10 m in fresh water and 40 in salt water, considering the fresh water density equal to 1.0125 g/cm$^3$ and the salt water density equal to 1.035 g/cm$^3$.
Hf,i can be obtained using the following expression:

$$h_{f,i} = \left(\frac{\rho_a}{\rho_f}\right) * h_a$$

Where hf,i provides directly the piezometric level in m a.s.l. ha is measured directly in the well and it represents a data easy to obtain. In the studied area, ha is equal to 9.10 m a.s.l.
So, hf is 9,26 m.
Using equation (1) is possible to obtain Ya = 9.9 m
Pumping water in well having screens in fresh water causes a rise of the interface between salt and fresh water, causing an "upconing", whose shape can be forecast by means of several suitables techniques , as the Motz's method, that are well known.

It is also interesting to study the capture zone of wells of different depth, in order to select the most suitable well screen location, for a hydraulic containment of pollution. The following expression allows to evaluate the capture zone:

$$F = \frac{Q}{T * J}$$

Where F is the width of the capture front ; it's clear that a larger width can be obtained where the transmissivity (thereabout proportional to screen thickness ) is lower. Therefore, the shorter well is often more efficient in order to contaminants contain that the deeper well.

## CONCLUSIONS

These considerations improve the conclusion that, in order to contain the pollutants, the hydraulic barriers along coast lines can be designed on the basis of equivalent head theory, and that a good performance can be reached using wells which pump only from fresh water zones has to be preferred, because the capture zone when pumping only from fresh water zones is more extended.

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