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Analysing the risks of storing strong waste brine in a deep saline aquifer with particular reference to Potasio Rio Colorado mine in Argentina

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Appendices

A. Conversion table

Variable	Unit	SI Unit	Conversion (Multiply SI Unit)
Area	$hectare$	m^2	1 x 10^{-4}
Compressibility	psi^{-1}	Pa^{-1}	6897
Length	ft	m	3.28
Permeability	md	m^2	1.01 x 10^{15}
Pressure	psi	Pa	1.45 x 10^{-4}
Flow rate	bbl/day	m^2/day	5.434 x 10^{5}
Viscosity	cp	$Pa * s$	1000

Table 1: Conversions required for the calculations. Reproduced from (Economides et al., 2013).

B. Aquifer model equation

Let (x,y,z) be the coordinates in a Cartesian grid system, and let Z(x,y,z) be the depth of a horizontal reference plane, earth surface (Grove, 1977). The equation that describes the single-phase flow in a porous medium results due to combining the continuity equation, and Darcy's law in three dimensions as shown.

$$\underbrace{\nabla\cdot\rho\underline{u}}_{\text{Net Convection}} \quad \underbrace{q'}_{\text{Source}} \quad = \underbrace{-\frac{\partial}{\partial t}(\phi\rho)}_{\text{Accumulation}}$$

$$\underline{u} = -\frac{k}{\mu}(\nabla p - \rho g\nabla Z).$$

Combining these equations results in the flow equation:

$$\nabla\cdot\frac{\rho k}{\mu}(\nabla p - \rho g\nabla Z) - q' = \frac{\partial}{\partial t}(\phi\rho)$$

Energy equation is represented by change in internal energy:

$$\underbrace{\nabla\cdot\left(\frac{\rho k}{\mu}H(\nabla p - \rho g\nabla Z)\right)}_{\text{Net energy convection}} + \underbrace{\nabla\cdot\underline{\underline{E}}_H\cdot\nabla T}_{\text{Conduction}} - \underbrace{q_L}_{\text{Heat loss to surrounding strata}}$$

$$- \underbrace{q'H}_{\text{Enthalpy in with fluid source } q'} - \underbrace{q_H}_{\text{Energy in without fluid input}}$$

$$= \frac{\partial}{\partial t}\left[\phi\rho U + (1-\phi)(\rho C_p)_R T\right]$$

A material balance for the solute results in the concentration equation;

$$\underbrace{\nabla\cdot\left[\rho C\frac{k}{\mu}(\nabla p - \rho g\nabla Z)\right]}_{\text{Net convection}} + \underbrace{\nabla\cdot\rho\underline{\underline{E}}_c\cdot\nabla C}_{\text{Dispersion}} - \underbrace{q'C}_{\text{Sources}}$$

Where,

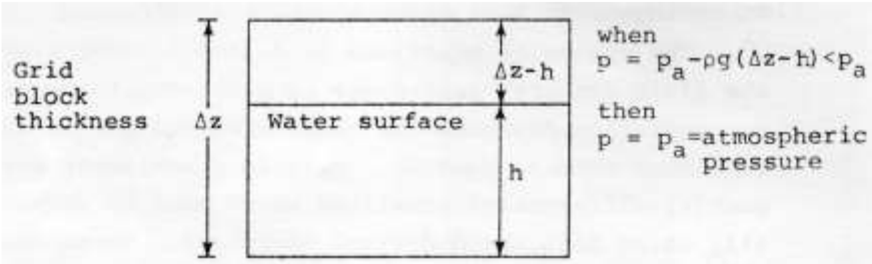
$$\phi\rho K_e C = \phi\rho C + (1-\phi)\rho_s C_s$$

$$\frac{\partial}{\partial t}(\phi\rho K_e C) = \frac{\partial}{\partial t}(\phi\rho C) + \frac{\partial}{\partial t}\left[(1-\phi)\rho_s C_s\right]$$

and makes the approximation:

The equilibrium absorption coefficient K_e is defined $K_e = 1 + \frac{\rho_B K_d}{\phi}$ as:

The grid block pressures are the fluid pressures at the top of the blocks. Hence, the magnitude of the pressure relative to the P_{atm} determines whether or not the free water surface occurs. If the free water surface was found to exist in a block, the volume of the fluid in the block is represented as:



An infini $V = \Delta x \Delta y \Delta z \phi [1+C_r(p-p_o)]$ ul $= V_o \; [1+C_r(p-p_o)]$ rter-Tracy function tables. A table has been constructed for a large aquifer which includes the numerical values of the dimensionless Carter-Tracy functions that can be found in Table 1 of Menard and Grove (1979). It must be noted that the change in pressure is governed by the pressure at the internal boundaries of the grid.

C. Physics behind groundwater storage

The basic assumptions accompanied within a confined aquifer (Menard and Grove, 1979):

- The flow of fluid in an aquifer can be represented by Darcy's law for flow through a porous medium.
- Density is a function of pressure, temperature, and containment fluid.
- Containment fluid is completely miscible with the current one. (water+ brine)
- Energy equation can be represented as the change in internal energy.
- Aquifer properties vary. Boundary conditions permit water flow in an aquifer, vertical recharge in the uppermost layer.

The reason for specifying these basic assumptions is due to the attention given to the realism of the scope.

D. Schematic diagram of aquifers potential for the disposal of brine

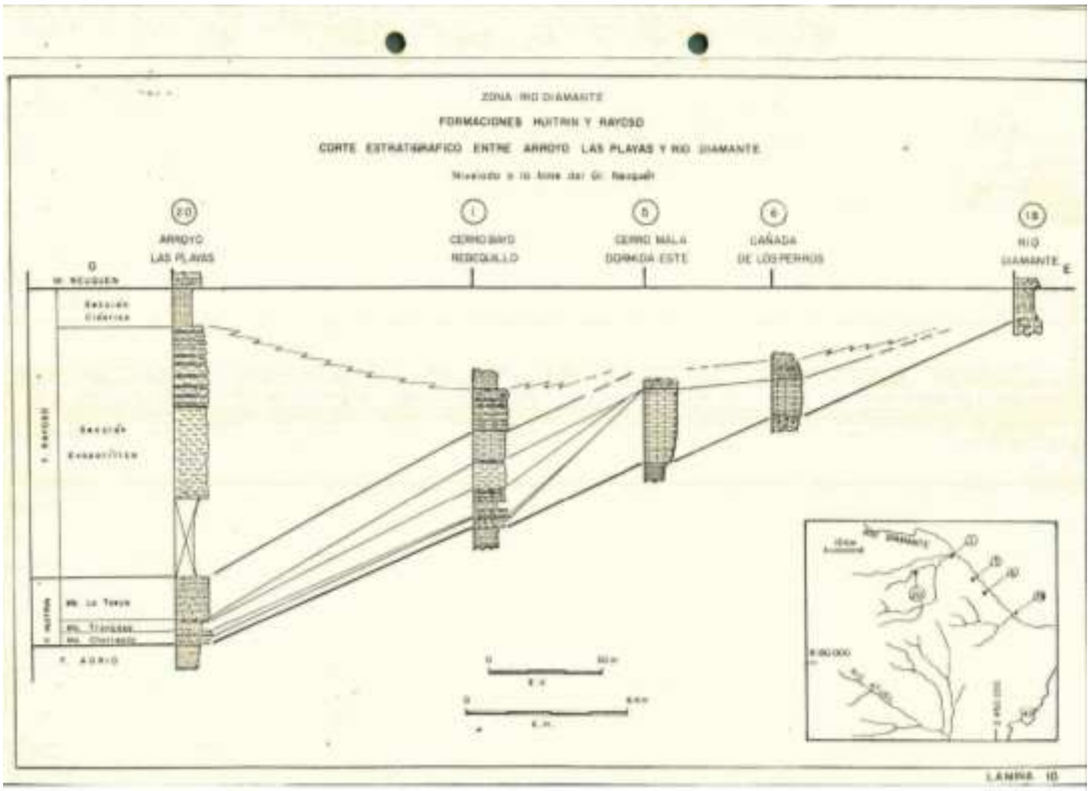


Figure 13: Stratigraphic diagram of the permeable and impermeable layer.

E. Links for all the calculations

https://www.dropbox.com/s/cg1tafmfq07bdvo/2Mt-%20Submit%20.xlsm?dl=0

https://www.dropbox.com/s/1vit22ga3yogxvz/4Mt-%20Submit.xlsm?dl=0

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https://www.dropbox.com/s/b1p9bs1p1pqcwnr/Validation-%20Submit%20.xlsm?dl=0