Fetkovich Aquifer Drive @model

Motivation

The most accurate way to simulate Aquifer Expansion (or shrinkage) is full-field 3D Dynamic Flow Model where Aquifer Expansion is treated as one of the fluid phases and accounts of geological heterogeneities, gas fluid properties, relperm properties and heat exchange with surrounding rocks.

Unfortunately, in many practical cases the detailed information on the aquifer is not available which does not allow a proper modelling of aquifer expansion using a geological framework.

Besides many practical applications require only knowledge of cumulative water influx from aquifer under pressure depletion.

This allows building an Aquifer Drive Models using analytical methods.

Inputs & Outputs

Inputs		Outputs	
$p(t)$	field-average formation pressure at time moment t	$Q^{\downarrow}_{AQ}(t)$	cumulative subsurface water influx from aquifer
p_i	initial formation pressure	$q^{\downarrow}_{AQ}(t) = \frac{dQ^{\downarrow}_{AQ}}{dt}$	subsurface water flowrate from aquifer
J_{AQ}	aquifer Productivity Index		
$\tau = \frac{c_t \, V_\phi}{J_{AQ}}$	aquifer relaxation time		

Detailing Inputs	
$J_{AQ} = \frac{\theta}{2\pi} \cdot \frac{2\pi\sigma}{\ln \frac{A_{AQ}}{A_e} + 0.75}$	aquifer Productivity Index
θ	central angle of net pay area aquifer contact
σ	aquifer transmissibility
A_e	net pay area
A_{AQ}	aquifer area
$\tau = \frac{V_{AQ} \, c_t}{J_{AQ}}$	aquifer relaxation time
$c_t = c_r + c_w$	aquifer total compressibility

c_r	aquifer pore compressibility
c_w	aquifer water compressibility
$V_{AQ} = A_e \cdot h \cdot \phi$	aquifer volume
h	aquifer effective thickness
ϕ	aquifer porosity

Physical Model

Radial Composite Reservoir	
Const Productivity Index Aquifer	$J_{AQ} = \frac{q_{AQ}}{p_{AQ}(t) - p(t)} = \text{const}$
Pseudo Steady State Flow	$p_{AQ}(t) = p_i - \frac{Q_{AQ}(t)}{V_{AQ} \cdot c_t}$

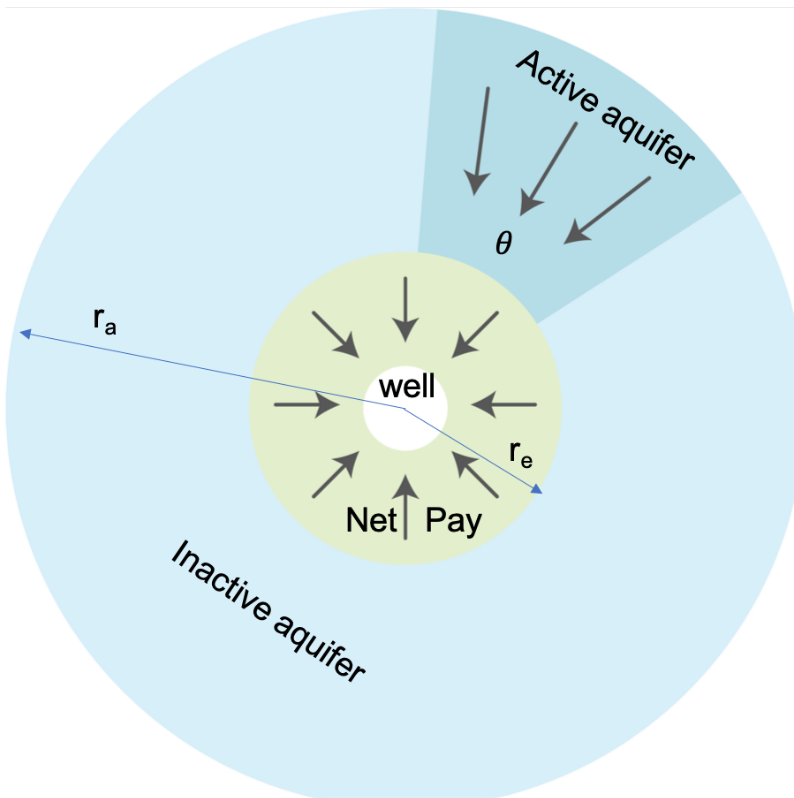

Fig. 1. Fetkovich aquifer drive schematic

Mathematical Model

(1) $\tau \cdot \frac{dQ^{\downarrow}_{AQ}}{dt} + Q^{\downarrow}_{AQ} = c_t\, V_\phi \cdot [p_i - p(t)]$	(2) $q^{\downarrow}_{AQ}(t) = \frac{dQ^{\downarrow}_{AQ}}{dt}$

which can be explicitly integrated:

(3) $$Q^{\downarrow}_{AQ}(t) = J_{AQ}\, \exp\left(-\frac{t}{\tau}\right) \int_0^t \left[p_i - p(\xi)\right] \exp\left(\frac{\xi}{\tau}\right) d\xi$$

Assumption #1 = Const Productivity Index Aquifer:

$$q_{AQ} = \frac{dQ_{AQ}}{dt} = J_{AQ} \cdot (p_{AQ}(t) - p(t))$$

Assumption #2 = Pseudo Steady State Flow:

$$p_{AQ}(t) = p_i - \frac{Q_{AQ}}{c_t\, V_\phi}$$

Eliminating $p_{AQ}(t)$ one arrives to (1).

See Also

Petroleum Industry / Upstream / Subsurface E&P Disciplines / Field Study & Modelling / Aquifer Drive / Aquifer Drive Models

Reference

1. Fetkovich, M.J. 1971. A Simplified Approach to Water Influx Calculations—Finite Aquifer Systems. J Pet Technol 23 (7): 814–28. SPE-2603-PA. http://dx.doi.org/10.2118/2603-PA