Drainage by wells

On web page https://www.waterlog.info/lectures.htm

Well drainage means subsurface drainage of agricultural lands by wells. Agricultural land is drained by pumped wells (vertical drainage) to improve the soils by controlling water table levels and soil salinity. It is an alternative for horizontal drainage by pipes or ditches.

With a well drainage system one can lower the level of the water table, evacuate salts from the soil so that the growing conditions of the plants are improved.

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1. Design

Although one well may be sufficient to solve groundwater and soil salinity problems in a few hectares, one usually needs a number of wells, because the problems may be widely spread.
The wells may be arranged in a triangular, square or rectangular pattern.
The design of the well field concerns depth, capacity, discharge, and spacing of the wells.[1]

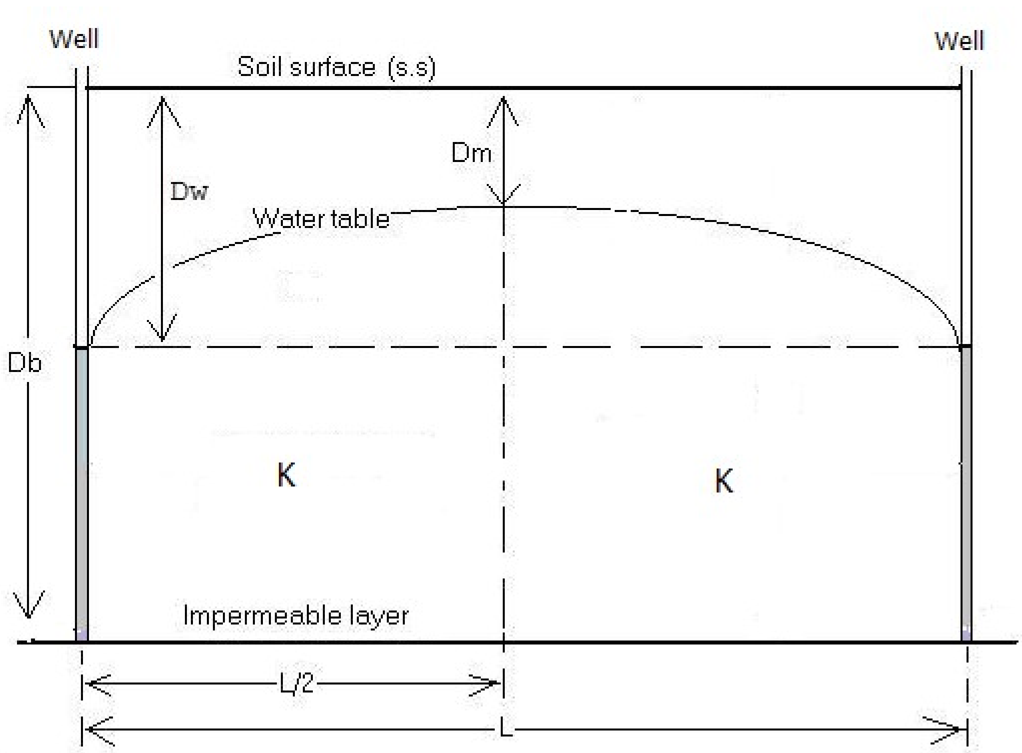
1. The discharge capacity is found from a water balance.
2. The depth is selected in accordance to aquifer properties. The well filter must be placed in a permeable soil layer.
3. The spacing between the wells can be calculated with a well spacing equation using discharge, aquifer properties, well depth and optimal depth of the water table.

The determination of the optimum depth of the water table is the realm of drainage research .

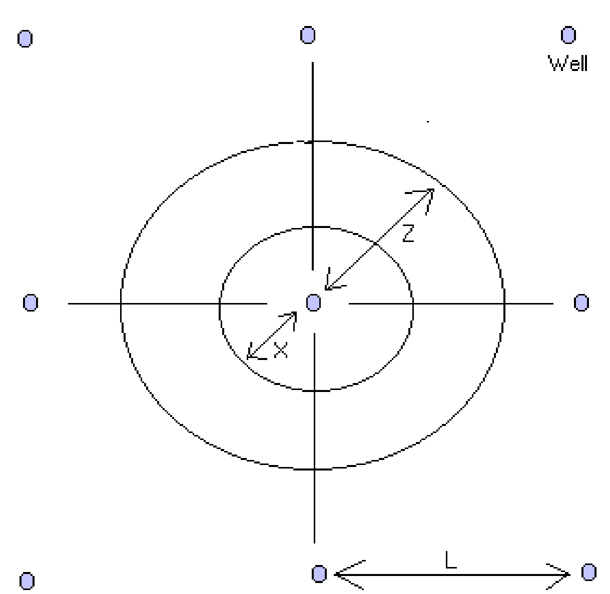
The basic, steady state, equation for flow to *fully penetrating* wells (i.e. wells reaching the impermeable base) in a regularly spaced well field in a uniform unconfined (preactic) aquifer with an hydraulic conductivity that is isotropic is:

$$Q = 2\pi\, K\, (Db - Dm)\, (Dw - Dm) / \ln\, (Ri / Rw)$$

where Q = safe well discharge - i.e. the steady state discharge at which no overdraught or groundwater depletion occurs - (m^3/day), K = uniform hydraulic conductivity of the soil (m/day), D = depth below soil surface (m), Db = depth of the bottom of the well equal to the depth of the impermeable base (m), Dm = depth of the watertable midway between the wells (m), Dw = the depth of the water level inside the well (m), Ri = radius of influence of the well (m) and Rw = the radius of the well (m).



Geometry of a system of wells penetrating completely an uniform and isotropic aquifer



Map of a well field for subsurface drainage with radial flow across concentrical cylinders representing the equipotentials

The radius of influence of the wells depends on the pattern of the well field, which may be triangular, square, or rectangular. It can be found as:

$$Ri = \sqrt{(At / \pi N)}$$

donde:

At = total surface area of the well field (m^2)
N = number of wells in the well field.

The safe well discharge (Q) can also be found from:

$$Q = q\ At / N\ Fw$$

en que:

where q is the safe yield or drainable surplus of the aquifer (m/day)
Fw is the operation intensity of the wells (hours/24 per day)

Thus the basic equation can also be written as:

$$Dw - Dm = \tfrac{1}{2}\, q\, At\ \{ \ln (At / \pi\, N\, Rw^2) \} / 2\pi\, K\, (Db - Dm)\, N\, Fw$$

With a well spacing equation one can calculate various design *alternatives* to arrive at the most attractive or economical solution for watertable control in agricultural land.

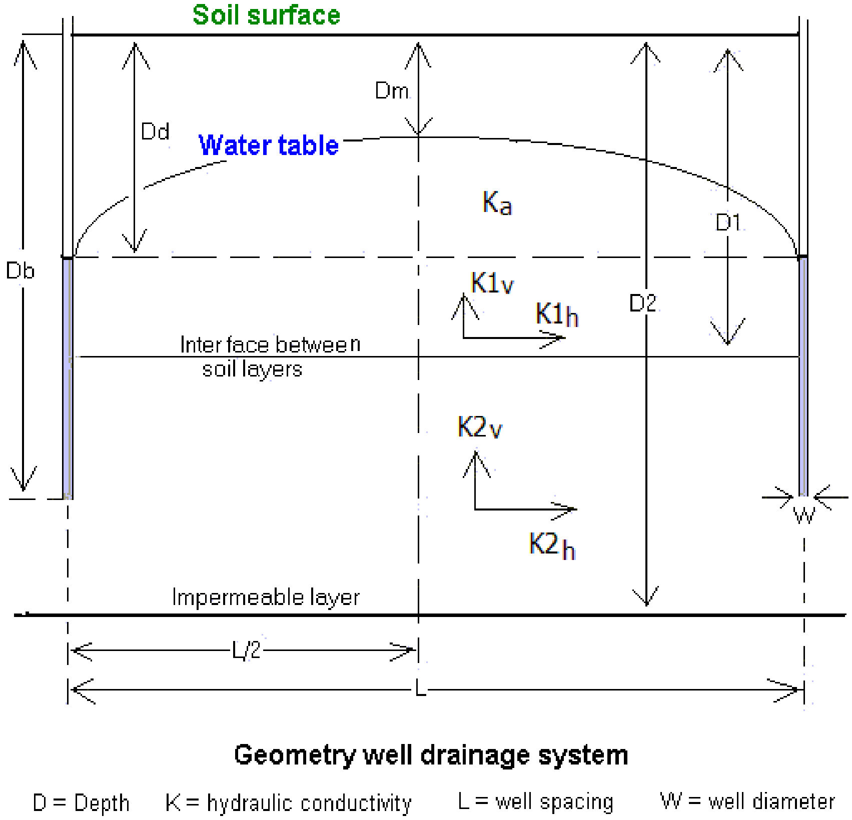
The costs of the *most attractive solution* can be compared with the costs of a horizontal drainage system - for which the drain spacing can be calculated with a drainage equation - serving the same purpose, to decide which system deserves preference.

The well design proper is described in: W.K. Boehmer and J.Boonstra, 1994.

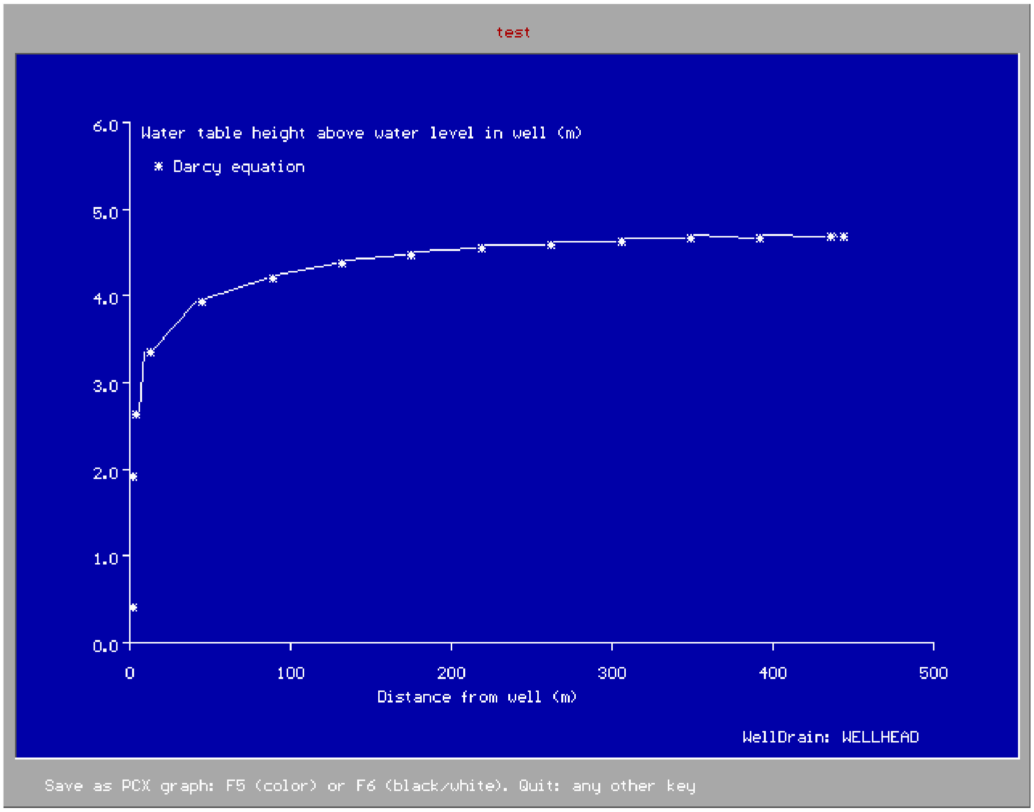
Non-uniform aquifers

The basic flow equation cannot be used for determining the well spacing in a *partially penetrating* well-field in a non-uniform and anisotropic aquifer, but one needs a numerical solution of more complicated equations.

The numerical computer program called WellDrain for well spacing calculations takes into account fully and partially penetrating wells, layered aquifers, anisotropy (different vertical and horizontal hydraulic conductivity or permeability) and entrance resistance.



Geometry of a partially penetrating well drainage system in an anisotropic layered aquifer



Output of WellDrain program, well-spacing=920m

References

1. - ILRI, 2000, *Subsurface drainage by (tube)wells: Well spacing equations for fully an partially penetrating wells in uniform or layered aquifers with or without anisotropy and entrance resistance*, 9 pp. Principles used in the "WellDrain" model. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. Download "WellDrain" software from: [1]

2. Boehmer, W.K., and J.Boonstra, 1994, *Tubewell Drainage Systems*, Chapter 22 in: H.P.Ritzema (ed.), Drainage Principles and Applications, Publ. 16, International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. pp. 931-964, ISBN 90 70754 3 39.