9. DEWATERING – CONTROL OF GROUNDWATER

Construction of buildings, powerhouses, dams, locks and many other structures requires excavation below the water table into water-bearing soils. Such excavations require lowering the water table below the slopes and bottom of the excavation to prevent raveling or sloughing of the slope and to ensure dry, firm working conditions for construction operations.

Groundwater can be controlled by means of one or more types of dewatering systems appropriate to the size and depth of the excavation, geological conditions, and characteristics of the soil.

Construction sites are dewatered for the following purposes:

1- To provide suitable working surface of the bottom of the excavation.
2- To stabilize the banks of the excavation thus avoiding the hazards of slides and sloughing.
3- To prevent disturbance of the soil at the bottom of excavation caused by boils or piping. Such disturbances may reduce the bearing power of the soil.

Lowering the water table can also be utilized to increase the effective weight of the soil and consolidate the soil layers. Reducing lateral loads on sheeting and bracing is another way of use.

A number of methods are available for controlling the inflow of water into an excavation; the choice of method will depend on the nature and permeability of the ground, the extent of the area to be dewatered, the depth of the water table below ground level and the amount by which it has to be lowered, the proposed methods of excavation and ground support, the proximity of existing structures, the proximity of water courses etc.

The available methods of groundwater control fall into the following basic groups:

1. Surface water control like ditches, training walls, embankments. Simple methods of diverting surface water, open excavations. Simple pumping equipment.
2. Gravity drainage. Relatively impermeable soils. Open excavations especially on sloping sites. Simple pumping equipment.
3. Sump pumping (see below)
4. Wellpoint systems with suction pumps. (See below)
5. Shallow (bored) wells with pumps. (See below)
6. Deep (bored) wells with pumps. (See below).
7. Eductor system (See below)
8. Drainage galleries. Removal of large quantities of water for dam abutments, cut-offs, landslides etc. Large quantities of water can be drained into gallery (small diameter tunnel) and disposed of by conventional large – scale pumps.
9. Electro-osmosis. Used in low permeability soils (silts, silty clays, some peats) when no other method is suitable. Direct current electricity is applied from anodes (steel rods) to cathodes (well-points, i.e. small diameter filter wells)

Exclusion methods; (not covered in this note)

1. Ground freezing (ammonium brine refrigeration or liquid nitrogen refrigeration). All types of saturated soils.
2. Slurry trench cut-off walls with bentonite or native clay and Diaphragm concrete walls. All soils. Curtain walls around excavations with flat buckets.
3. Impervious soil barrier. All soils. Relatively shallow applications (5-6m max.). Back-hoes form the clay filled barriers some distance from the excavation boundaries.
4. Sheet piling. All soils except soils with large boulders.
5. Secant (interlocked) piling or tangent piling with grouting in between. All soils except boulders.
6. Compressed air. All types of saturated soils and rock. Applications in tunnels, shafts and caissons.
7. Grouted cut-offs (jet grouting, cementatious grouts, chemical grouts etc.)

9.1.Sumps and sump pumping

A sump is merely a hole in the ground from which water is being pumped for the purpose of removing water from the adjoining area (Fig 9.1). They are used with ditches leading to them in large excavations. Up to maximum of 8m below pump installation level; for greater depths a submersible pump is required. Shallow slopes may be required for unsupported excavations in silts and fine sands. Gravels and coarse sands are more suitable. Fines may be easily removed from ground and soils containing large percent of fines are not suitable. If there are existing foundations in the vicinity pumping may cause settlement of these foundations. Subsidence of adjacent ground and sloughing of the lower part of a slope (sloped pits) may occur. The sump should be preferably lined with a filter material which has grain size gradations in compatible with the filter rules. For prolonged pumping the sump should be prepared by first driving sheeting around the sump area for the full depth of the sump and installing a cage inside the sump made of wire mesh with internal strutting or a perforating pipe filling the filter material in the space outside the cage and at the bottom of the cage and withdrawing the sheeting. Two simple sumping details are shown in Figures 2 and 3.

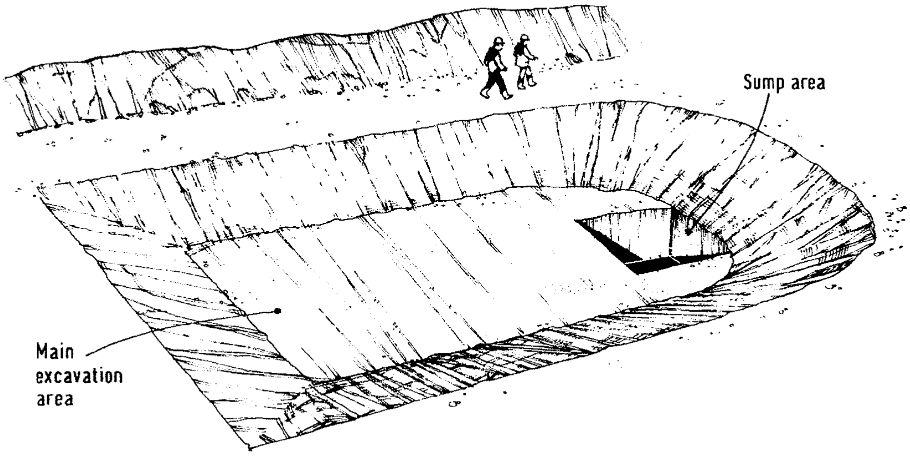


Figure 9.1 Sumps outside main construction area

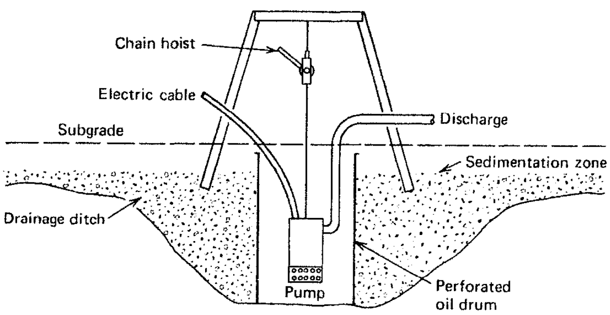


Figure 9.2 A small sump

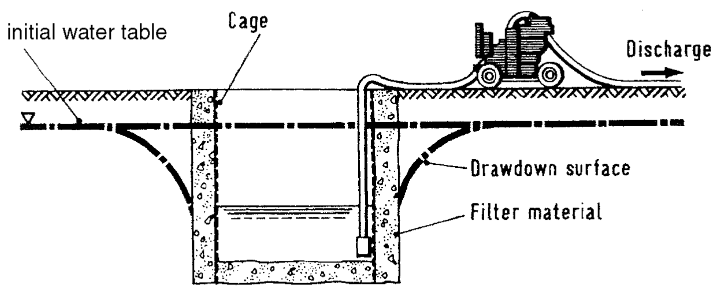


Figure 9.3 Pumping from sumps

9.2.Wellpoint systems

A wellpoint is 5.0-7.5 cm diameter metal or plastic pipe 60 cm – 120 cm long which is perforated and covered with a screen. The lower end of the pipe has a driving head with water holes for jetting (Fig 9.4.a,b). Wellpoints are connected to 5.0-7.5 cm diameter pipes known as riser pipes and are inserted into the ground by driving or jetting. The upper ends of the riser pipes lead to a header pipe which, in turn, connected to a pump. The ground water is drawn by the pump into the wellpoints through the header pipe and discharged (Fig 9.5). The wellpoints are usually installed with 0.75m – 3m spacing (See Table 1). This type of dewatering system is effective in soils constituted primarily of sand fraction or other soil containing seams of such materials. In gravels spacing required may be too close and impracticable. In clays it is also not used because it is too slow. In silts and silt – clay mixtures the use of well points are aided by upper (0.60m – 0.90m long) compacted clay seals and sand-filtered boreholes (20cm – 60cm diameter). Upper clay seals help to maintain higher suction (vacuum) pressures and sand filters increase the amount of discharge. Filtered boreholes are also functional in layered soil profiles (Figures 9.6.a,b,c,d,e)

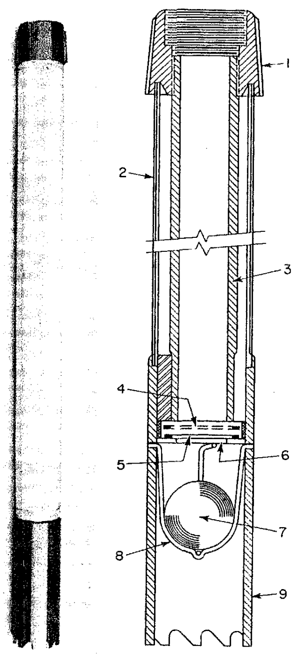


Figure 9.4.a Well point: (1) coupling; (2) screen cylinder - available in tin dipped cold rolled steel or stainless steel; (3) center tube; (4) ring valve - during jetting when small eddy currents, created by the ball seat, raise it to the upper position, closing off the annular space between the tip and the center pipe; (5) ring valve - at position of rest on ball seat when the is shut off; (6) ball seat; (7) ball valve; (8) retainer basket - clamps the ball seat in place and keeps the ball valve in the center of the tip during jetting, providing a streamlined, oversize exit for the full force of the jetting water; (9) jetting tip. Courtesy of the Moretrench Corp.

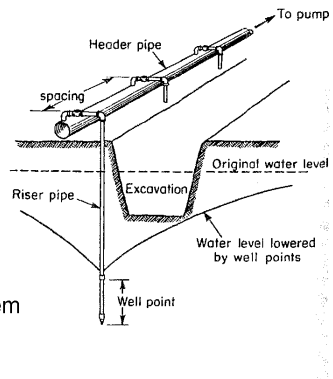


Figure 9.4.b Well point system

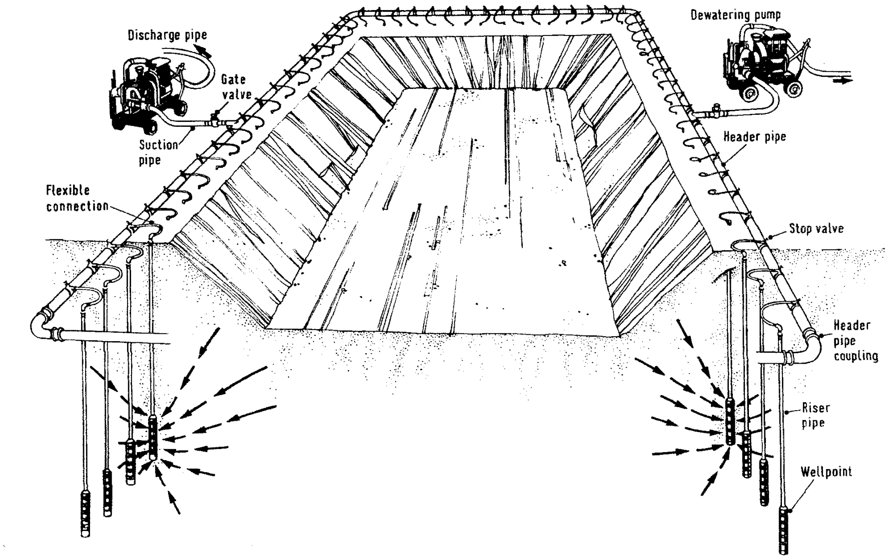


Figure 9.5 Wellpoint dewatering system components

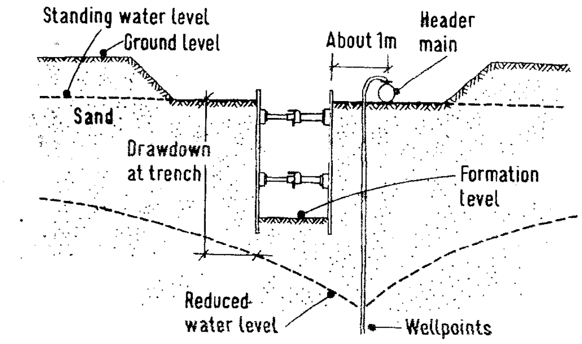


Figure 9.6.a Single-sided wellpoint system: variation a

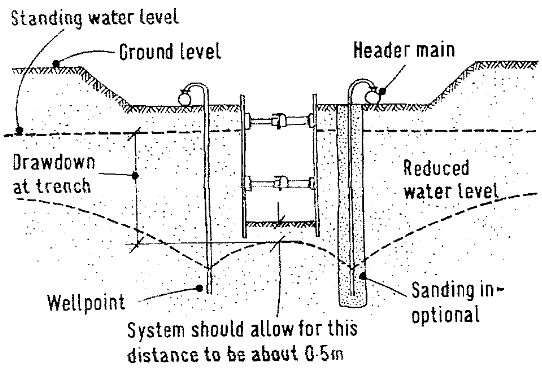


Figure 9.6.c Double-sided wellpoint system: variation a

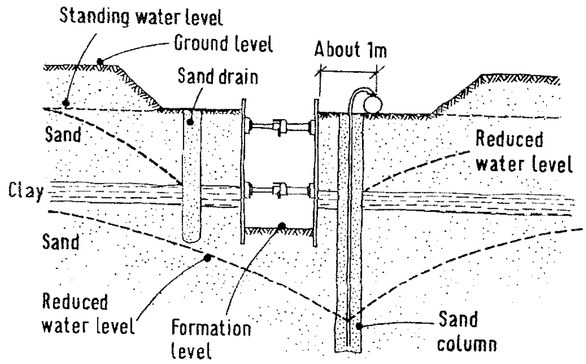


Figure 9.6.b Single-sided wellpoint system: variation b

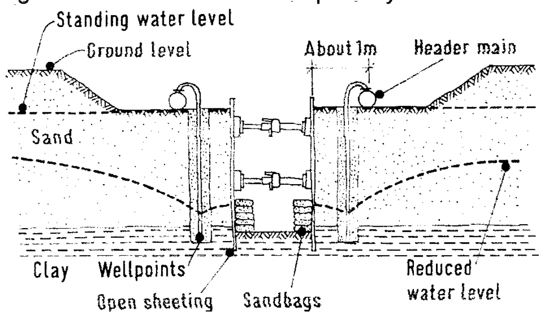


Figure 9.6.d Double-sided wellpoint system: variation b

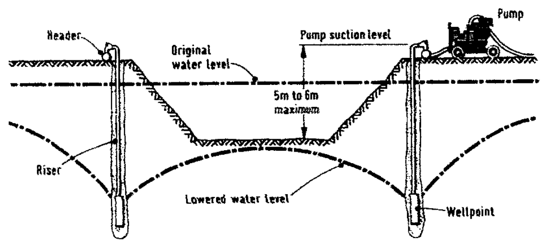


Figure 9.6.e Effect of wellpoints on both sides of wide excavation

Table 9.1 Typical spacings for some common soil types and the approximate time required for effective drawdown

Soil	Typical Spacing (m)	Time (days)
Silty sand	1.5-2	7-21(Could be longer)
Clean fine to coarse sand and sandy gravel	1.0-1.5	3-10
Fine to coarse gravel	0.5-1.0	1-2

The header pipe (15-30 cm diameter, connecting all wellpoints) is connected to a vacuum (Suction assisted self – priming centrifugal or piston) pump. The wellpoints can lower a water level to a maximum of 5.5 m below the centerline of the header pipe. In silty fine sands this limit is 3-4 m. Multiple stage system of wellpoints are used for lowering water level to a greater depth. Two or more tiers (stages) are used. (Fig 9.7). More pumps are needed and due to the berms required the excavation width becomes wider. A single wellpoint handles between 4 and 0.6 m^3/hr depending on soil type. For a 120 m length (40 at 3 m centers) flow is therefore between 160 and 24 m^3/hr.

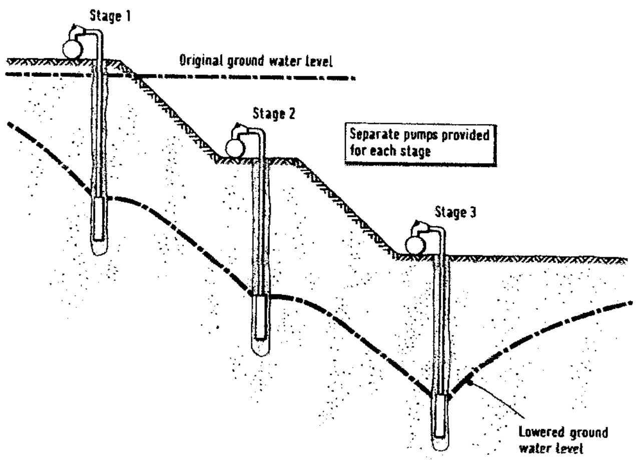
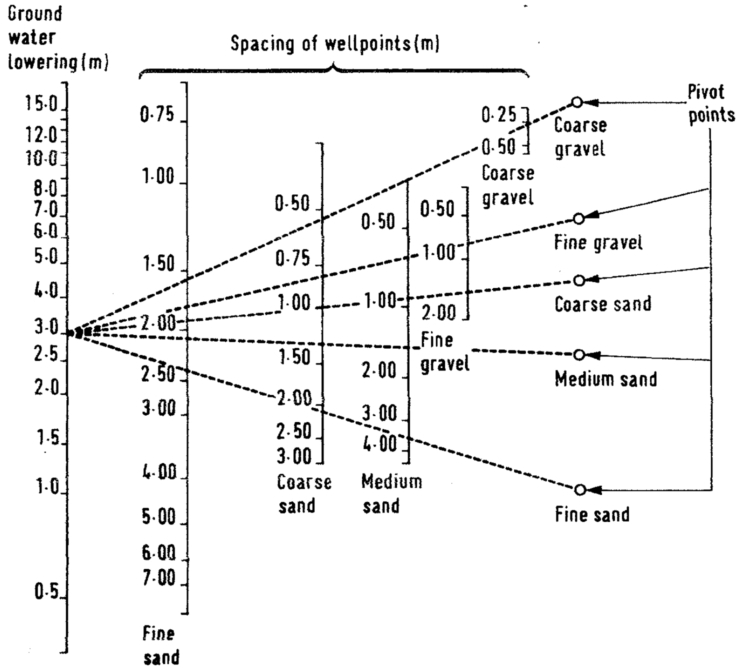


Figure 9.7 Three-stage wellpoint installation

Nomograms for selecting preliminary wellpoint spacing in clean uniform sand and gravel, and stratified clean sand and gravel are shown in Figures 9.8 and 9.9.

Figure 9.8 Nomogram for wellpoint spacing (m) in clean,uniform sand and gravel



Notes:
1. Design should be based on the most permeable of the strata.
2. The lower the permeability of the ground, the steeper the drawdown curve becomes.

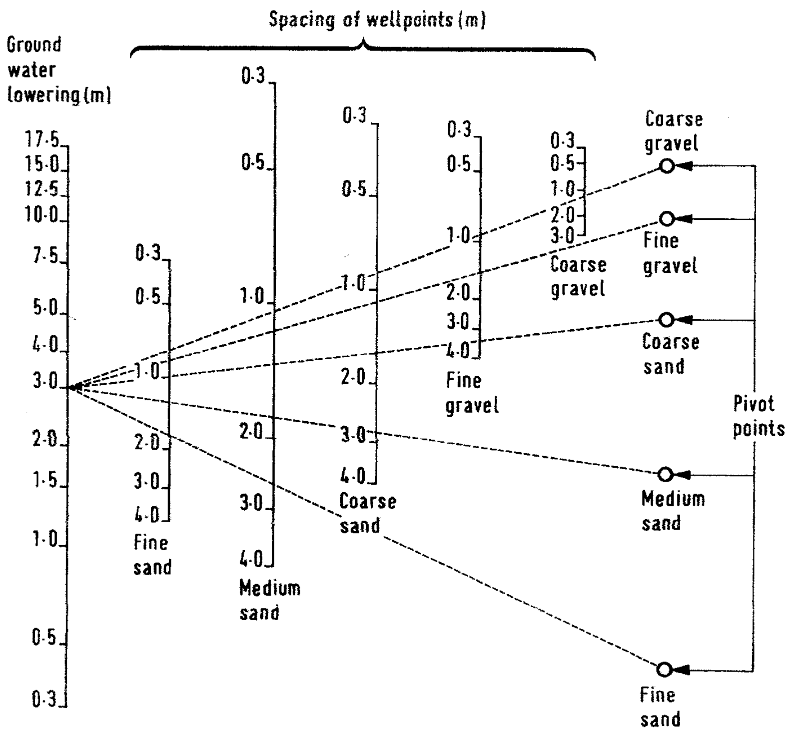


Figure 9.9 Nomogram for wellpoint spacing (m) in stratified clean sand and gravel

Horizontal wellpoints are used mainly for pipeline water. They consist of perforated pipes laid horizontally in a trench and connected to a suitable pump.

9.3.Shallow Wells

Shallow wells comprise surface pumps which draw water through suction pipes installed in bored wells drilled by the most appropriate well drilling and or bored piling equipment. The limiting depth to which this method is employed is about 8 m. Because wells are prebored, this method is used when hard or variable soil conditions preclude the use of a wellpoint system. These wells are used in very permeable soils when wellpointing would be expensive and often at inconveniently close centers. The shallow well can be used to extract large quantities of water from a single hole. On congested sites use of smaller number dewatering points is preferred (no hiderance to construction operations) hence shallow wells may be preferred to wellpoints. Since the initial cost of installation is more compared to wellpoints it is preferred in cases where dewatering lasts several months or more. Another field of application is the silty soils where correct filtering is important.

9.4.Deep Wells

When water has to be extracted from depths greater than 8 m and it is not feasible to lower the type of pump and suction piping used in shallow wells to gain a few extra meters of depth the deep wells are such and submersible pumps installed within them. A cased borehole can be sunk using well drilling or bored piling rigs to a depth lower than the required dewatered level. The diameter will be 150 – 200 mm larger then the well inner casing, which in turn is sized to accept the submersible pump. The inner well casing has a perforated screen over the depth requiring dewatering and terminates below in 1 m of unperforated pipe which may serve as a sump for any material which passes the filter. After the slotted PVC or metal well screen (casing) has been installed it is surrounded by backfill over the unperforated pipe length and with graded filter material over the perforated length as the outer casing progressively withdrawn (Fig 9.10). As with the shallow wells the initial pumping may involve twice the volumes when equilibrium is achieved.

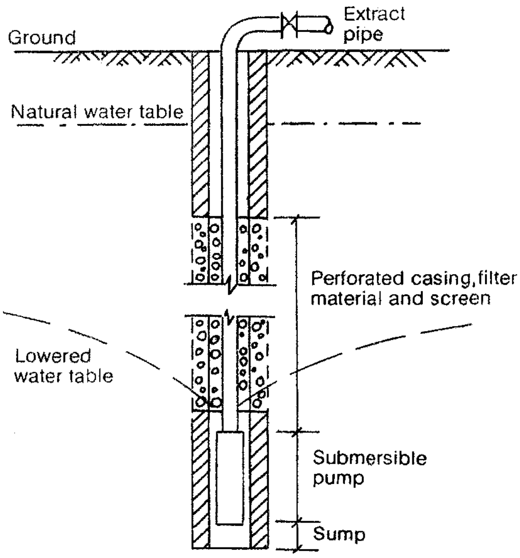


Figure 9.10 Typical deep well

Deep well systems are of use in gravels to silty fine sands and in water bearing rocks. They are priority or use with deep excavations and where artesian water is present below an impermeable stratum. If this type of installation is to be designed economically the ground permeability must be assessed from full scale pumping tests. Because of their depth and the usually longer pumping period these installations are more likely to cause settlement of nearby structures, and the use of recharge methods may have to be considered.

9.5. Eductor System

This system also known as the 'jet eductor system' or 'ejector system' or 'eductor wellpoint system' is similar to the wellpoint system. Instead of employing a vacuum to draw water to the wellpoints, the eductor system uses high pressure water and riser units, each about 30-40 mm in diameter. A high pressure supply main feeds water through a venturi tube immediately above the perforated well screen, creating a reduction in pressure which draws water through the large diameter rise pipe. The high pressure main feeds off the return water. The advantage of the eductor system is that in operating many wellpoints from a single pump station, the water table can be lowered in one stage from depths of 10-45 m. This method becomes economically competitive at depth in soils of low permeability.

Tentative economic ranges for groundwater lowering methods are shown in Fig 9.11.

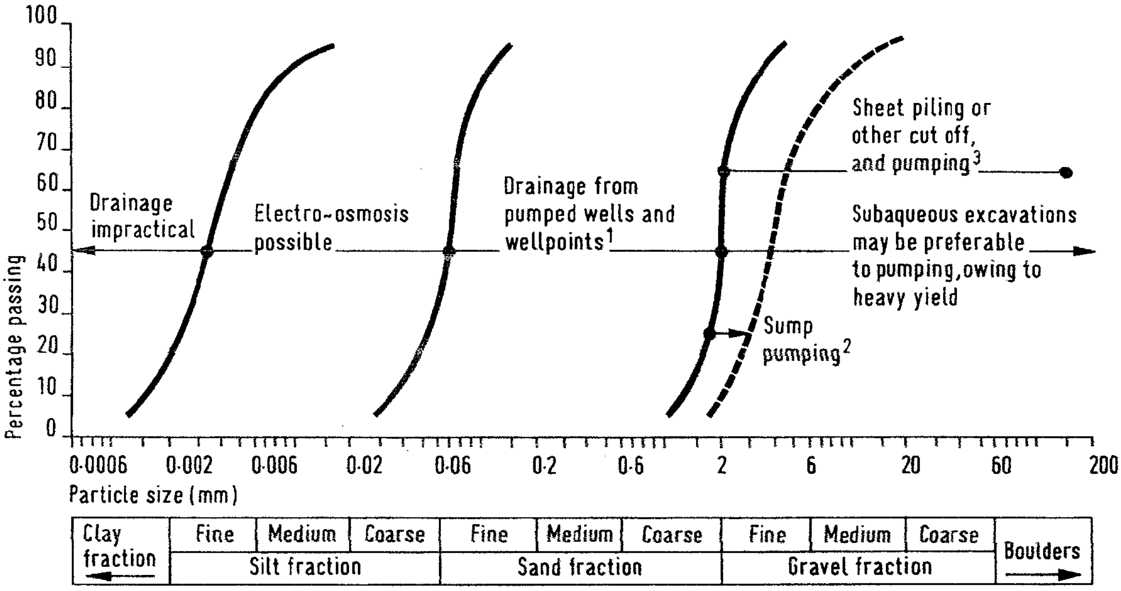


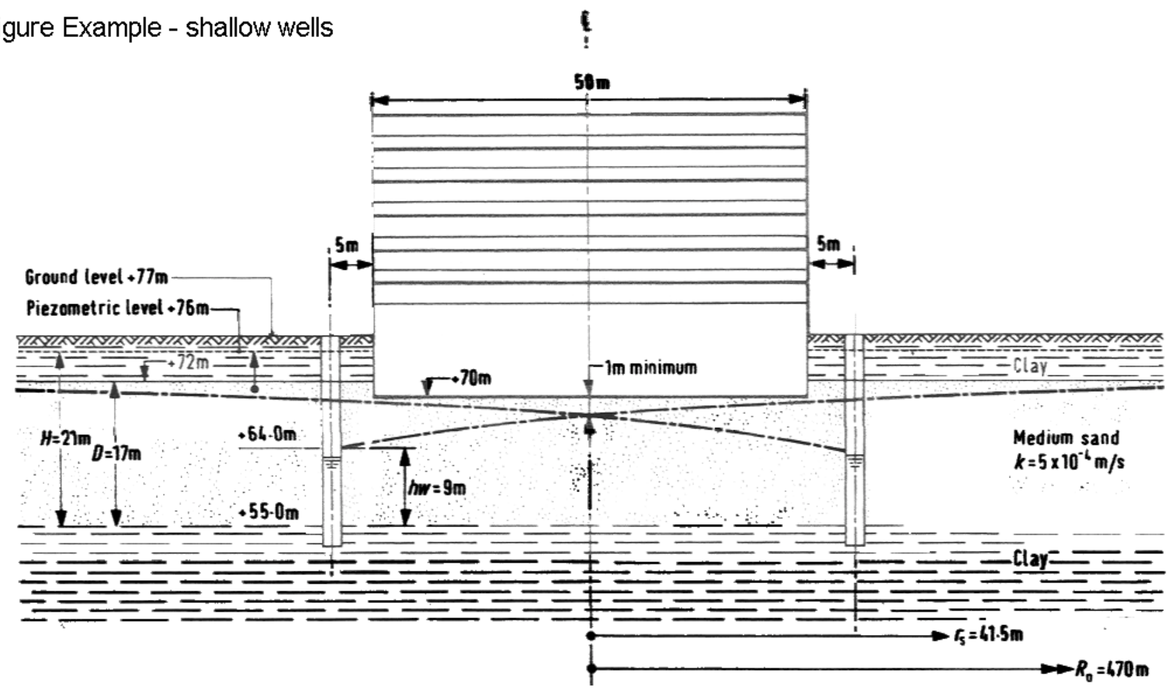
Figure 9.11 Tentative economic ranges for groundwater lowering methods

Notes:
1. Wellpoints in fine sands require vacuum.
2. Zone may be extended to finer soils by using large sumps with gravel filters.
3. To reduce the high water pressure on sheet piling it may be preferable to control pumping as excavation proceeds and to install the support system as the water level is lowered.

9.6.EXAMPLE – SHALLOW WELLS

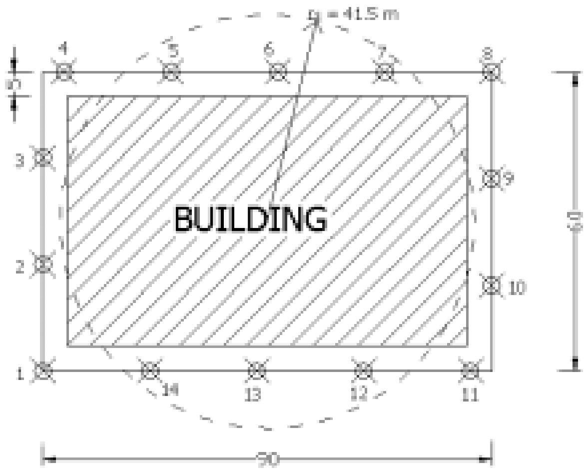
Consider the need to lower the water table for the construction of a 7 m deep basement, 80 m by 50 m at its base. The soil profile is shown below.

Figure Example - shallow wells



Drawdown to at least +69.0 m at the centre of excavation required which is 7 m minimum. This will require a number of wells surrounding the proposed basement area, the yield (discharge) from which may be computed assuming a single well with an equivalent radius r_s. This approach is known as "big well" approximate analysis. Another approach is to superpose the drawdowns due to several wells at the centre of the building. In both cases the well formulae are needed for the soil and hydraulic conditions at the site. The radius of the assumed "big well" is;

$$r_s = \sqrt{\frac{BxL}{\pi}} \quad = \quad \sqrt{\frac{60x90}{\pi}} \quad = 41.5m$$



where

B = width of excavation, b + 10m

L = length of excavation, ℓ+10m

In other words the wells are at 5m distance to the building. The radius of influence (R_o) is the radius within which the drawdown occurs. Drawdown of the water table at a point produces a cone of depression and the radius of influence (R_o) is a function of the drawdown (h) and the permeability (k) of the soil as shown below.

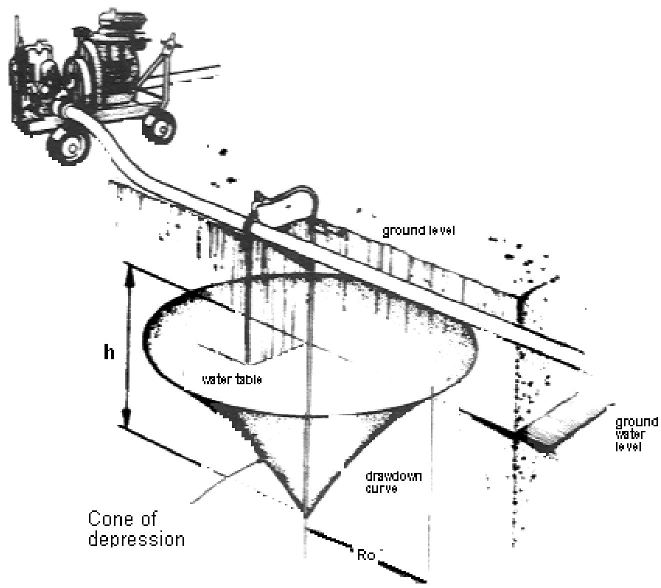
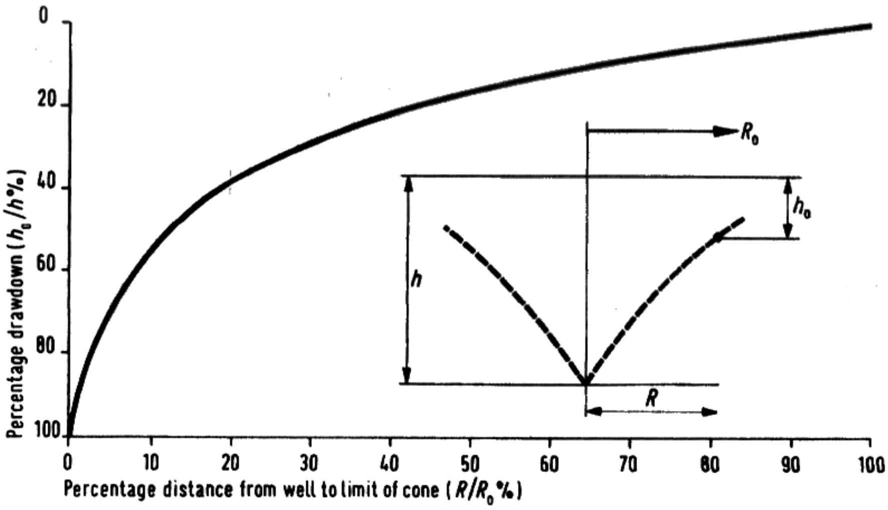


Figure Cone of depression resulting from drawdown

More permeable the soil means greater the radius of influence is $R_o = Ch\sqrt{k}$ is a proposed equation to calculate R_o where c is a factor equal to 3000 for radial flow to pumped wells and between 1500 and 2000 for line flow to trenches or to a line of wellpoints. R_o at the present case is, R_o = 3000(76-69) $\sqrt{5x10^{-4}}$; R_o= 470 m. The percent drawdown of the water table at any distance from the center of cone can be obtained from the following figure.

Figure Relation of drawdown to distance from centre of cone of depression



Drawdown at centre of excavation by peripheral wells:

Distance from perimeter to centre = 41.5m

Percentage distance along radius of influence (R_o) :

$\frac{41.5m}{470m} x100 = 8.8\% \Rightarrow$ From the above figure % drawdown is 58 %.

Therefore, required drawdown at wells to obtain 7m drawdown at centre of excavation will be $\frac{7}{0.58} = 12m$. In practice since each line of wells will contribute to the drawdown, a somewhat lesser drawdown at the wells will be required. Alternatively, assuming a full 12 m drawdown will allow a margin of error.

For the confined aquifer case the flow (or yield) can be calculated by the following formula (Refer to sources containing well formulae for various profiles. References 2, 3 and 4 provide such formulae).

$$Q = \frac{2\pi kD(H - h_w)}{\ell n \frac{R_o}{r_s}} = \frac{2x\pi x5x10^{-4}x17x(21-9)}{\ell n \frac{470}{41.5}}$$

$Q = 0.264 \quad m^3/s = 246$ lt/s

Where;

Q = discharge from assumed single well (m^3/s)

k = coefficient o permeability (m/s)

D = height of piezometric level above base of aquifer (m)

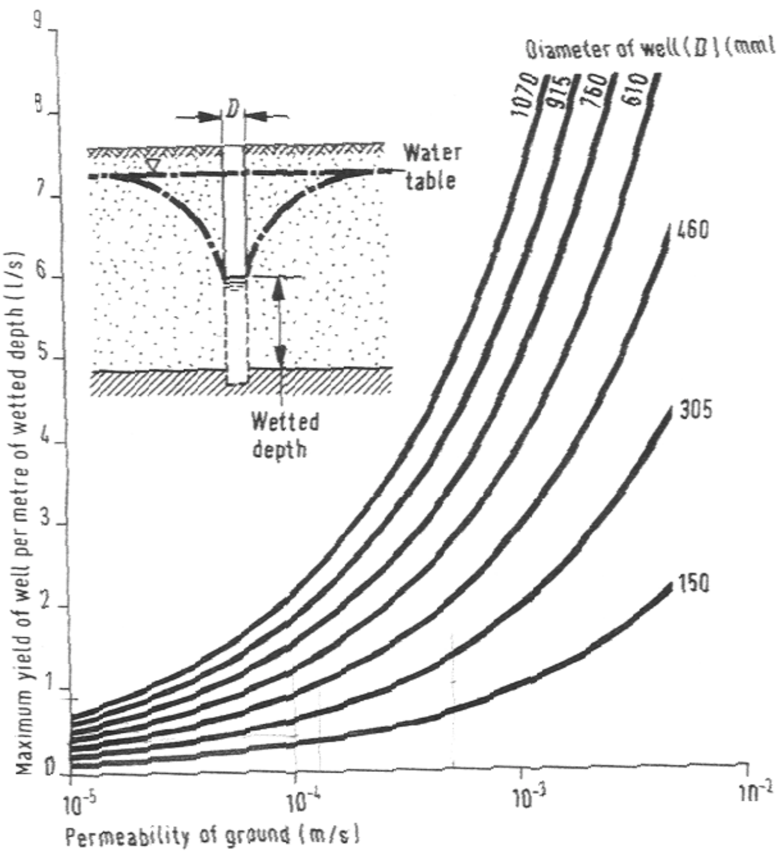
h_w= height of water at outside edge of pumping wells after drawdown (m)

R_o = radius of influence (m)

r_s = equivalent radius of assumed single well (m)

Assuming 450 mm diameter wells find the area of wetted depth (h_w) of wells for calculated yield using the following graph for $k = 5x10^{-4}$ m/s : Yield per metre of wetted depth = 2.1 lt/s

Figure Maximum yield of wells



Total wetted depth required $\frac{264}{2.1}$ =126 m approx. For drawdown to +64.0m at the wells (i.e. $h_w \cong 9m$) the intake level of the pumps must be at a level sufficiently lower to allow for the length of the pump and to avoid cavitation of the water above the pump. (Allow 1.5m for the length of pump and 5m for cavitation) It would there fore be necessary to set the pump inlet at, say, +57m. Allow also 2-3m below the pump inlet and bottom of the well screen should be at, say, 54.0m.

Yield per well = 9m x 2.1 lt/s = 18.9 lt/s .

Hence theoretical numbero f wells required:

$$\frac{264}{18.9} = 14$$

Add three (about 20%) to allow for variations in soil conditions, pump breakdowns etc. Plus margin of error and reserve capacity to establish equilibrium.

Selection of the pump:

Yield per pump : 264/14 = 18.9 lt/s

Total pumping head from pumping level = 12m. (76m – 64m)

Allow 4 m for velocity head and friction losses.

Therefore the total head is appoximately 16 m.

From pump manufacturer's performance curves (submersible pumps) select suitable pumps for installation inside 200/300 mm diameter casing screen (i.e. 450 mm less 75 mm annulus for gravel pack).

Check also conveying pipe sizes (250 mm dia. minimum required, allow 305 mm dia).

Design of wellpoints can be made after calculating the yield (flow) using formulae for trenchs (line sources) and then using the given nomograms.

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