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GUIDELINES FOR DEWATERING DURING CONSTRUCTION

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Indian Standard

GUIDELINES FOR DEWATERING DURING CONSTRUCTION

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Indian Standard

GUIDELINES FOR DEWATERING DURING CONSTRUCTION

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 February 1981, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The problem of dewatering during construction is met with in most of the civil engineering constructions. The concerned technical committee has, therefore, felt that some guidelines for dewatering at least for the most common cases could be formulated. An attempt has, therefore, been made in this standard to give some guidelines for dewatering for normal construction works other than river valley projects (that is, the earth dams, etc, for which reference may be made to IS : 5050-1968*). In construction of power-houses in boulder/gravel reaches, the dewatering conditions are entirely different and are not covered in this standard.

0.3 In the formulation of this standard, considerable assistance has been rendered by the Central Building Research Institute, Roorkee, which has furnished the various data included in the standard.

0.4 This edition 1.1 incorporates Amendment No. 1 (March 1989). Side bar indicates modification of the text as the result of incorporation of the amendment.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard provides a guideline for dewatering during construction of foundation and excavation.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

*Code of practice for design, construction and maintenance of relief wells.

†Rules for rounding off numerical values (*revised*).

2.1 Anode — Positively charged electrode.

2.2 Cathode — Negatively charged electrode.

2.3 Discharge Line — Steel, aluminium or plastic conduits to conduct flows from pump.

2.4 Electro-Osmosis — Electrical drainage method for dewatering.

2.5 Equipotential Line — Line in flow region at all points on which the total head is the same.

2.6 Flow, Artesian — Flow through a pervious stratum bounded above and below by impervious layers.

2.7 Flow, Gravity — Flow under gravity through pervious soil.

2.8 Flow Line — Path followed by a particle of water through a saturated soil mass.

2.9 Flow Net — Graphical representation of flow through soils : comprising flow lines and equipotential lines.

2.10 Flow Net, Plan — Flow net which represents the plan view of the seepage pattern.

2.11 Flow Net, Sectional — Flow net which represents the sectional view of the seepage pattern.

2.12 Head Discharge — Head at which water is discharged from pump.

2.13 Head, Total Dynamic — Sum total of operating vacuum at the pump intake, discharge head and discharge friction losses.

2.14 Head Loss, Entrance — Head loss caused due to entrance of water through well screen.

2.15 Head Loss, Friction — Hydraulic head loss in pipes due to friction.

2.16 Head Loss, Total — Sum total of screen entrance head loss, friction head losses due to flow through well screen and riser pipe and the velocity head loss.

2.17 Head Loss, Velocity — Equals $v^2/2g$, where 'v' is the velocity of flow through the riser pipe, and 'g' is the acceleration due to gravity.

2.18 Line Source — River or stream adjacent to well system.

2.19 Operating Vacuum — Vacuum created at the wellpoint pumps limited by the atmospheric pressure.

2.20 Piezometric Level — Hydraulic head level comprising total head (sum of pressure head, datum head and velocity head for flow through soils).

2.21 Pipe, Header — The pipe which collects water from the riser pipe and leads on to the pump.

2.22 Pipe, Riser — Small diameter vertical pipes connected to the well-point.

2.23 Radius of Influence — Radius of the circle beyond which the well has no significant influence on the original ground water level or piezometric surface.

2.24 Well, Fully Penetrating — Well which penetrates to the full depth of pervious stratum.

2.25 Well, Partially Penetrating — Well which does not penetrate to the full depth of the pervious stratum.

2.26 Wellpoint — Small well screen made with self-jetting tips.

2.27 Wellpoint System — A system consisting of wellpoints around an excavation, attached to a common header pipe, and connected to a wellpoint pump.

3. GENERAL

3.1 Dewatering is the operation of lowering of ground water level. It is resorted to when excavations are made below natural ground water table, and is usually a temporary measure. Dewatering is also done to relieve the bottom of an excavation of artesian pressure.

3.2 A properly designed, installed and operated dewatering system can serve the following purposes:

a) Lowering the water table and intercepting seepage, which would otherwise emerge from the slope or bottom of the excavation.

b) Increasing the stability of the excavated slopes.

c) Preventing loss of material from beneath the slopes or bottom of the excavation.

d) Reducing lateral loads or sheeting and bracing.

e) Preventing rupture or heaving of the bottom of an excavation.

f) Providing a suitable working surface at the bottom of the excavation.

4. REQUIREMENTS FOR A DEWATERING PROJECT

4.1 Dimensions of the Excavation — The size and depth of the proposed excavation should be known.

4.2 Required Lowering of Water Table — The allowable ground water table or uplift pressure during construction should be ascertained.

4.3 Geological and Soil Condition

4.3.1 — *Subsurface Investigation*

4.3.1.1 *Use* — A thorough subsurface investigation should be made by boring or jetting tests in the immediate vicinity of the site, to ascertain the characteristics of the soil adjacent to and beneath the excavation. Soil type and characteristics, (*see* **6.3.1**) significantly affect the choice and design of a dewatering system.

4.3.1.2 *Spacing of borings* — IS : 1892-1979* may be followed in this respect. The number and spacing of bore holes will depend upon the extent of the site and the nature of structures coming on it. For a compact building site covering an area of about 0.4 hectare, one bore hole in each corner and one in the centre should be adequate. For smaller and less important buildings even one bore hole in the centre will suffice. For very large areas covering industrial and residential colonies, the geological nature of the terrain will help in deciding the number of bore holes. Cone penetration tests may be performed at every 100 m by dividing the area in a grid pattern and the number of bore holes decided by examining the variation in the penetration curves.

4.3.1.3 *Important boring observations* — The thickness of various strata and stratifications, if any, should be noted. Layers of clay or any other impervious material should be carefully recorded.

4.3.1.4 *Water table and substratum pressure* — The position of water table and substratum pressure should be reliably determined.

NOTE — It is preferable to collect records, if available, of the position of water table and hydrostatic pressure with the season of the year or river stage. Alternatively, if time permits, the water table of hydrostatic pressure should be observed over a period of time, since it will frequently vary with the season of the year and with the stage of an adjacent river.

4.3.1.5 *Permeability of pervious stratum* — Permeability of the pervious strata to be dewatered should be determined by field pumping test. A rough idea about the permeability of different soils can be had from the following table:

Type of Sand	*Coefficient of Permeability,* ($k \times 10^{-4}$) *cm/sec*
Very fine sand	1 to 50
Fine sand	51 to 200
Fine to medium sand	201 to 500
Medium sand	501 to 1 000
Medium to coarse sand	1 001 to 1 500
Gravel and coarse sand	1 501 to 3 000

NOTE 1 — For large excavations and excavations underlain by deep strata of sand, the permeability should be ascertained for the full depth.

*Code of practice for sub-surface investigation for foundations (*first revision*).

NOTE 2 — In case the 'pumping test' is not conducted at the site, the following approximate formula for determining the coefficient of permeability for fairly uniform sands in loose state with uniformity coefficient not greater than 2 may be used:

$$k = C_1 D^2_{10}$$

where

k = coefficient of permeability in cm/s;
C_1 = a constant, varying between 100 and 150; and
D_{10} = effective grain size in cm.

4.4 Source of Seepage

4.4.1 *Nature of Source* — The nature of the source of seepage should be properly determined. The source of seepage depends to a great extent on the geological features of the area and adjacent streams or bodies of water. If the wells are not close to a river or canal, and the only seepage is from the formation being dewatered, the source may be assumed circular. Streams close to the wells may act as line sources of seepage, depending on the distance of the wells from the effective source of seepage (*see* **4.4.3**).

4.4.2 *Radius of Influence* (*R*)

4.4.2.1 *Definition* — The radius of influence, *R*, is defined as the radius of the circle beyond which the well has no significant influence on the original ground water level or piezometric surface.

4.4.2.2 *Determination of R by field test* — The radius of influence, *R*, should be estimated from field pumping test, by determining the drawdown curve by means of piezometers.

NOTE — The radius of influence increases with increased drawdown and with pumping time. The magnitude of these effects is difficult to estimate numerically; therefore, the radius of influence should be estimated conservatively.

4.4.2.3 *Approximate formula for R* — The following empirical relationship* may be used for estimating *R*:

$$R = C^1 (H - h_w) \sqrt{k}$$

where

R = radius of influence in m,
C^1 = a constant=0.9 (for gravity flows),
H = depth of natural water table in metres,
h_w = head at the well in metres, and
k = coefficient of permeability in 10^{-4} cm/s.

4.4.3 *Wells Adjacent to River*

4.4.3.1 *Line source* — If the wells are close to a river, the source of seepage may be considered as the river, provided the distance *L* from the wells to the river is less than *R*/2.

4.5 Chemical Properties of Ground Water

4.5.1 *Corrosion and Incrustation* — Metallic well screens are

*Based on Sichordt's equation.

susceptible to attack by certain chemicals present in ground water causing corrosion and incrustation of well screens. Presence of chemicals like carbonates, hydrogen sulphide, sulphur dioxide, iron sulphide, iron sulphate, organic acids and dissolved oxygen should be tested by chemical analyses.

4.5.2 *Minimizing Corrosion* — Corrosion may be minimized by using metals in well screen which are resistant to corrosion, such as bronze, stainless steel, brass, galvanized iron, etc. Wood or plastics which are not subject to corrosion are preferable.

4.5.2.1 *Limits of corroding material in ground water* — The principal indicators of corrosion by ground water are low *p*H, presence of dissolved oxygen, hydrogen sulphide, total dissolved solids in excess of 1 000 ppm, carbon dioxide in excess of 50 ppm, and chloride content greater than 500 ppm. The principal indicators of incrustating ground water are total hardness greater than 330 ppm, total alkalinity greater than 300 ppm, iron content greater than 72 ppm, and *p*H greater than 8.0.

4.5.3 *Minimizing Incrustation* — For minimizing incrustation, the following methods can be adopted:

a) Wellpoints/wells should be installed so that water can enter the well with the least resistance possible,
b) Entrance velocity in the well should be kept low,
c) Water from any well should not be pumped more than necessary, and
d) Wells can be cleaned before the incrustation becomes excessive.

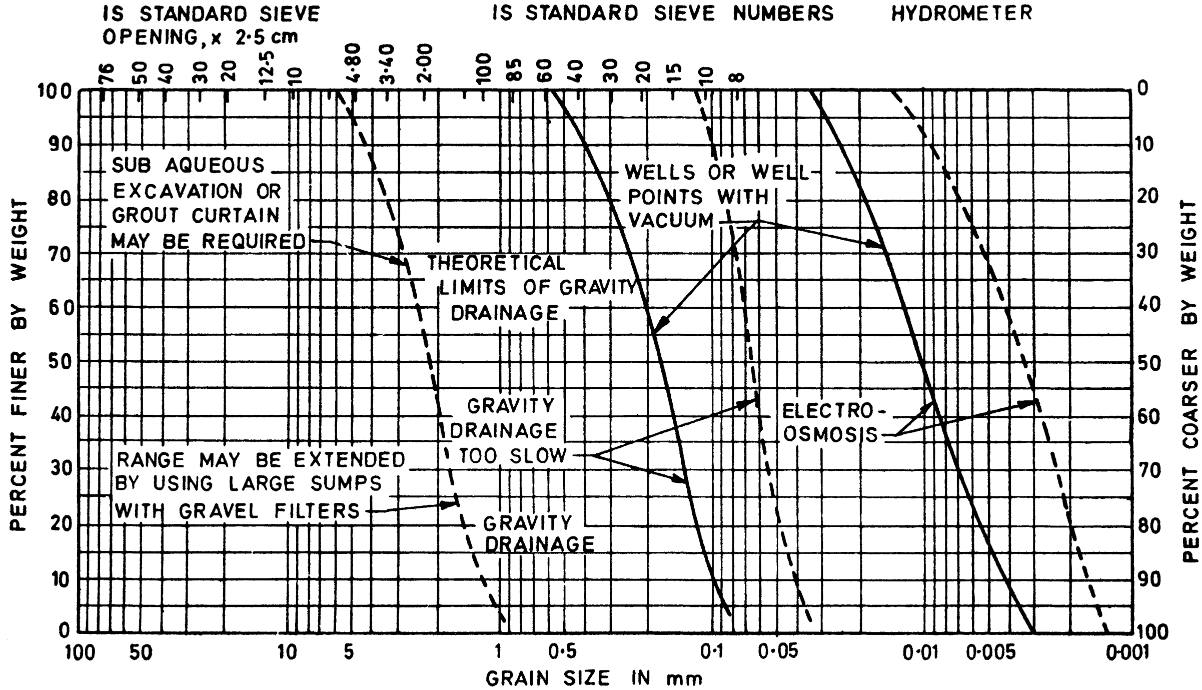
5. CHOICE OF DEWATERING SYSTEM

5.1 Soil Type — The subsurface investigations and their interpretations should provide the information needed to establish the kind of dewatering system that is required for an individual project. Table 1 provides a general guidance in this regard.

5.2 Particle Size Distribution — The particle size distribution of the soil influences the choice of a particular method in a dewatering project. The range of soil types over which the various processes are applicable can be obtained from the classification given in Fig. 1. To use these curves, the particle size distribution of the soil should be obtained by sieving tests and the grading curve should be plotted on the chart. The system applicable to the particular soil type can then be chosen easily.

6. ANALYSIS AND DESIGN OF A DEWATERING SYSTEM

6.1 Design Requirements — Design of a dewatering system requires determination of the number, size, spacing and penetration of the wellpoints or wells and the rate at which water must be removed from the pervious strata in order to achieve the required ground water lowering.



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

FIG. 1 DEWATERING SYSTEMS APPLICABLE TO DIFFERENT SOILS

6.2 Discharge Formulae

6.2.1 *Use* — The fundamental relationship between discharge from wells or wellpoints and the corresponding drawdown produced in the pervious strata is of primary importance. The appropriate formulae should be used in the design calculations, for a particular field situation. Since the wells are closely spaced in a wellpoint system, the line of wells is taken as a slot for computation purposes.

6.2.2 *Flow from Line Source to Slot* — The discharge and drawdown relationships are given in Tables 2 to 4. The line source and the slot are considered to be of infinite length.

6.2.3 *Correction for Finite Length of Slot* — Since a slot is actually composed of a finite number of wells only, corrections are applied to the head reduction computed for the slot. The head reduction at the wells can be obtained from Table 5.

6.2.4 *Flow from Circular Source to Single Well* — The discharge and draw-down relationships are given in Table 6.

6.2.5 *Flow from Line Source to Single Well* — The discharge and drawdown relationships are given in Table 7.

6.3 Essential Steps in Designing a Wellpoint/Well System

6.3.1 *Subsoil Properties* — An accurate determination of the subsoil profile and the permeability characteristics of the soil should be made as mentioned in **4.3.1**. The value of k, the coefficient of permeability of the water bearing stratum, should be determined for use in the design in accordance with **4.3.1.5**.

6.3.2 *Distance of Wellpoints/Wells from Source of Seepage* — Depending on the geological condition, the value of R or L should be ascertained according to clause **4.4**. In this regard, the following considerations should be taken care of:

a) If the actual radius of influence is large compared with the radius of the well, only an approximate estimation of R may suffice, since the discharge is not much sensitive to the value of R.

b) An accurate estimation of L should be made for a particular dewatering system, since the discharge is inversely proportional to the value of L.

6.3.3 *Effective Well Radius*

6.3.3.1 *Wells installed without filter* — Half the outside diameter of the well screen should be taken as effective well radius.

6.3.3.2 *Wells installed with sand or gravel filter* — Half the outside diameter of the filter should be taken as effective well radius.

NOTE — Where a well screen has been installed without a filter but a natural filter around the screen is developed by surging, the extent of the developed filter becomes indefinite. In such a case, a conservative assumption of half the outside diameter of the screen should be taken as the effective well radius.

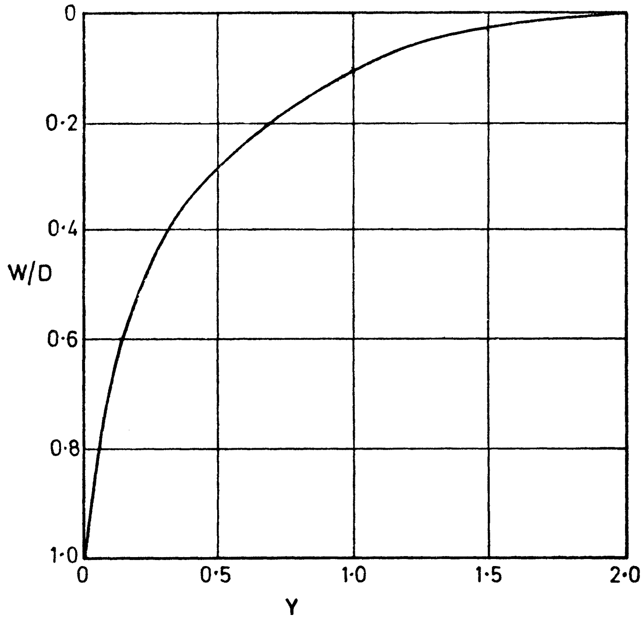
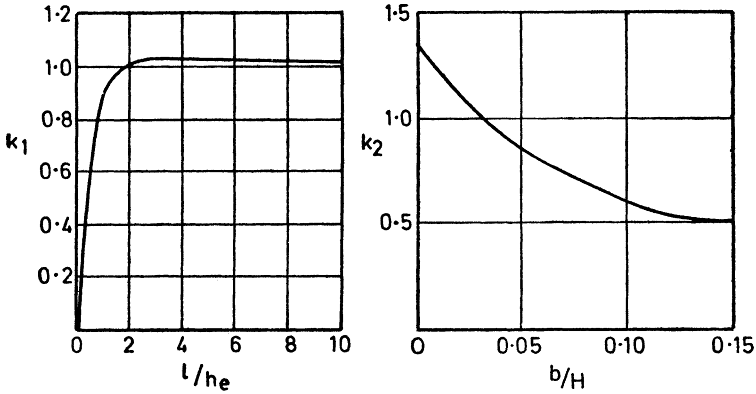


FIG. 2 FACTOR Υ VERSUS RATIO W/D



3a Factor k_1 **3b Factor k_2**

NOTE — 2 l is = distance between slots. (b = width of slots)

FIG. 3 COMPUTATION OF FACTORS k_1 AND k_2

6.3.4 *Discharge Computations*

6.3.4.1 Since the wellpoints are closely spaced, they can be considered as creating a continuous slot. Their spacing is so determined that the head along the line of wellpoints is essentially the same as would exist at a slot. The following procedure should be followed in this respect.

6.3.4.2 If H is the head corresponding to the natural water table and h_o is the head at the slot, then the head reduction ($H - h_o$) at a slot required to produce the desired residual head 'h_D' should be computed from equations given in Tables 2 to 5, read with Fig. 2 and 3.

6.3.4.3 Assuming that $h_o = h_D$, and that ($h_o - h_w$), the head difference (h_w being the head at the well) is small (assumed as 0.001 H), the well-point spacing can then be computed from the following equations:

a) *For artesian case*:

$$\frac{h_D - h_w}{H - h_D} = \frac{a}{2\pi L} \, ln \, \frac{a}{2\pi r_w}$$

where

L = distance of wellpoints from line source,
a = spacing of wellpoints, and
r_w = radius of wellpoints.

b) *For gravity case*:

$$\frac{h^2{}_D - h^2{}_w}{H^2 - h^2{}_D} = \frac{a}{2\pi L} \, ln \, \frac{a}{2\pi r_w}$$

NOTE 1 — For computation of wellpoint spacing method of 'flow-net', as given in Appendix B be followed.

NOTE 2 — In lieu of detailed computations, the approximate spacing of wellpoint required to produce a given groundwater lowering in various soils can be estimated from the nomographs shown in Fig. 4 and 5. However, these nomographs should be used with caution, since they are based on empirical data and are for average conditions.

6.3.4.4 After the wellpoint spacing and the head h_w at the wellpoint have been computed, the flow Q_w per wellpoint can be computed from the equation given in Table 5.

6.3.4.5 The above value of h_w should be equal to or greater than the value of h_w computed from the following equation. The total head loss in a wellpoint connection should be estimated afresh:

$$h_w = M - V + H_c + H_w$$

in which M = distance from base of pervious stratum,
V = vacuum at pump intake,
H_c = average head loss in header pipe up to pump intake,
and H_w = total head loss in each wellpoint and swing connection
= head loss due to screen entrance (H_e) +

friction loss due to flow through the well screen(H_s) + friction loss due to flow in the riser pipe (H_r) + velocity head loss (H_v).

NOTE — The top of the wellpoint screen should be set slightly below ($h_w - H_w$) to ensure that the wellpoint is submerged; otherwise excessive air may enter the dewatering system and reduce its efficiency.

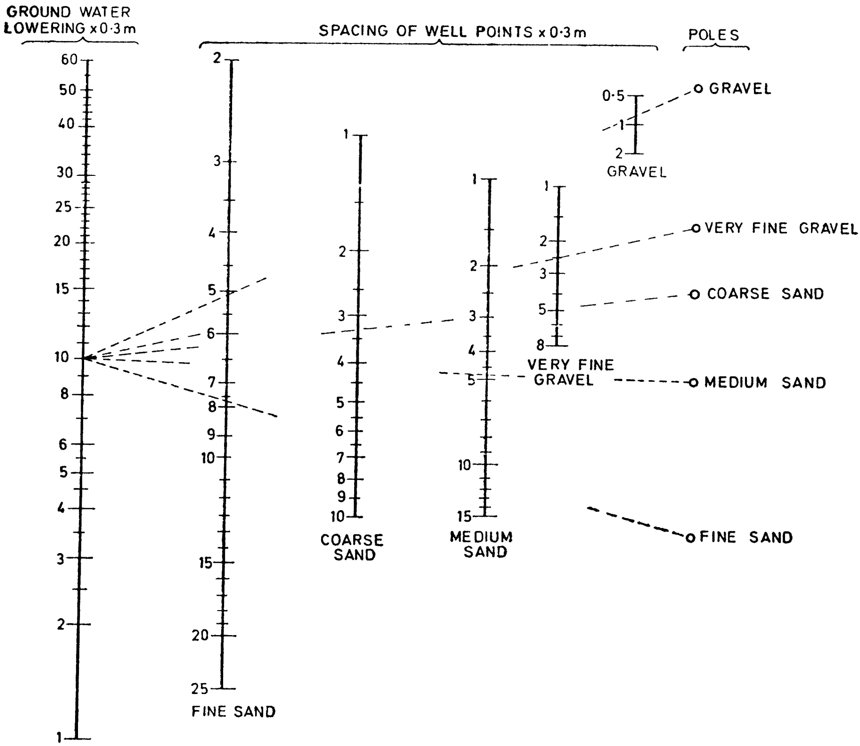


FIG. 4 WELLPOINT SPACING FOR UNIFORM CLEAN SANDS AND GRAVELS

6.3.5 *Design of Filters* — The requirements for filter material shall be as under:

Character of Filter Materials	*Ratio* R_{50}	*Ratio* R_{15}
Uniform grain size distribution (U=3 to 4)	5 to 10	—
Well graded to poorly graded (non-uniform); subrounded grains	12 to 58	12 to 40
Well graded to poorly graded (non-uniform); angular particles	9 to 30	6 to 18

$$R_{50} = \frac{D_{50} \text{ of filter material}}{D_{50} \text{ of material to be protected}}$$

$$R_{15} = \frac{D_{15} \text{ of filter material}}{D_{15} \text{ of material to be protected}}$$

NOTE — *Piping Prevention* — The phenomenon of piping may be prevented at seepage exits in an excavation by providing artificial devices such as drains and filters. Most drainage systems make use of porous filter aggregates to collect the water and conduct it to outlets, often with the aid of perforated or slotted pipes. Proper filter design is important for prevention of piping.

If a filter layer satisfies the criteria, it is virtually impossible for piping to occur, even under extremely large hydraulic gradients. Adequate specifications and careful constructions are required, if the works, as they are constructed, are to be completely safe from piping troubles.

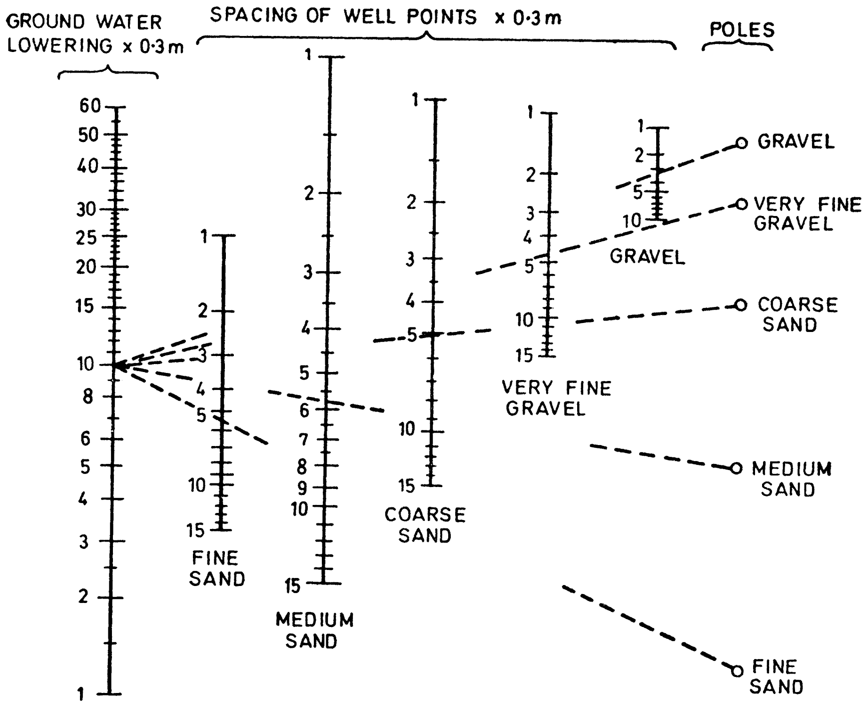


FIG. 5 WELLPOINT SPACING FOR STRATIFIED CLEAN SANDS AND GRAVELS

6.3.6 *Design and Selection of Well Screens* — The following criteria may be observed in designing and selecting well screens or wellpoints:

Slot width < D_{70} (filter or aquifer sand)

Hole diameter or width < D_{80} (filter or aquifer sand)

NOTE — Where silty soils are to be drained, the wellpoint should be provided with a graded medium to coarse sand filter designed in accordance with the filter criteria set forth in **6.3.5**.

6.3.7 *Horse Power of Pump* — The following formula shall be used to determine the required 'horse power' of the pump to be selected for the dewatering system:

$$\text{Horse power} = \frac{\text{Total discharge in gpm} \times \text{Total dynamic head}}{3\,960 \times \text{Efficiency of the pump and engine}}$$

where total dynamic head = operating vacuum at the pump intake +discharge friction losses.

6.3.8 *Layout Scheme* — A layout scheme should be chosen for the well/wellpoint system, depending on the size and shape of the excavation. The choice can be made of the following two systems:

a) *Progressive system* — This system is used for trench work. The header should be laid out along the sides of the excavation, and pumping should be continuously in progress in one length as further points are jetted ahead of the pumped down section and pulled out from the completed and backfilled lengths. For narrow excavations it is often sufficient to have the header on one side only. For wide excavations or in soils containing bands of relatively impervious materials, the header should be placed on both sides of the trench.

b) *Ring system* — The header main in this system surrounds the excavation completely. This is suitable for rectangular excavations.

6.3.9 *Collector Lines*

6.3.9.1 *Hydraulic head losses* — The wellpoints, riser pipes, header pipes and pumps should be of adequate sizes for the flow being handled, so that the hydraulic head losses in the wellpoint and collector systems are kept minimum. Head losses to be considered are those due to velocity and friction, and enlargements, tees, elbows, valves and other discontinuities in the line. For estimating losses due to irregularities in the line, the usual formulae on hydraulics can be used.

6.3.9.2 *Header pipes* — Header pipes commonly consist of relatively light weight steel or plastic pipes. Headers for wellpoints contain inlets for wellpoint connections at short intervals. Headers are normally of sizes varying from 15 to 30 cm of diameters.

6.3.9.3 *Non-return valves* — The connection of collector lines to the header pipes should be through non-return valves.

6.3.10 *Wellpoint Pumps*

6.3.10.1 *Selection of pumps*

a) *Vacuum pumps* — Centrifugal pumps are used for pumping through the collector pipes in a wellpoint system. The selected pumps should have sufficient air handling capacity, and they should be able to produce a high-vacuum. A wellpoint pump consisting of a self-priming centrifugal pump with attached vacuum pump proves to be adequate. It develops 6 to 7.5 m of vacuum. An assumption of 6 m of vacuum may be safely made in the design. Consideration should, however, be given for positive pressure head.

b) *Jet-eductor pumps* — If the depth of water table lowering is large (greater than 4.5 m) but the rate of pumpage for each wellpoint is relatively small (less than 10 to 15 gpm), installation of a single stage wellpoint system at the top of the excavation or water table, with attached jet-eductor pump may prove to be advantageous than a multi-stage wellpoint system. A jet-eductor wellpoint system can lower the water table by 15 to 30 m.

6.3.10.2 *Location and spacing of pumps* — The location and spacing of wellpoint pumps depend on the length of header pipe, discharge rate, and point of discharge. If a long collector line (say 150-300 m) is pumped by a single pump, the pump should be located at the centre of the line to obtain a maximum vacuum in the line. In short lines and where the flow is small, the pump can be located wherever convenient.

6.3.10.3 *Pump intake*

a) The intake of the pump should be set as low as practicable and it should not be more than 4.5 to 5.5 m above the bottom of the excavation.

b) If the discharge is large, the pump intake should be set at the same elevation as the collector lines.

6.3.10.4 *Selection of power unit* — In selecting the power unit to be used for driving the pumps, consideration should be given to the initial cost of the unit, and the cost of operation, including maintenance and fuel.

6.3.10.5 *Standby equipments* — Standby units should be kept ready for immediate use in case of any emergency.

6.3.11 *Discharge Lines*

6.3.11.1 Discharge lines can consist of steel, aluminium or plastic pipes.

6.3.11.2 The pipes should be of proper size to conduct the flow with relatively small head loss.

6.3.11.3 Ditches can be dug to conduct the flow away from the site. However, such ditches shall be kept well back from the top of the excavation to prevent saturating the upper parts of the slope.

6.3.12 *Wellpointing in Deep Excavations* — Multi-stage wellpoints.

6.3.12.1 *General* — The limitations in the drawdown to 4.5 to 6 m by a single wellpoint necessitates successive stages of wellpoints to be installed if deeper excavation below standing water level is required. There is no limit to the depth of drawdown in this way, but the overall width of excavation at top level becomes very large.

6.3.12.2 *Position of header pipes* — The lowest header of multistage system should be located not more than about 4.5 m above subgrade to ensure that proper drawdown of the ground water level can be achieved with the vacuum available in the line.

6.3.12.3 *Observations* — Observations should be made immediately prior to and while pumping the upper stage, for discharge and ground water lowering. Comparison should then be made with the computed values to check the adequacy of the lower stage prior to its installation.

6.3.13 *Deep Bored Wells*

6.3.13.1 *General* — Large diameter deep wells can be used effectively where the depth of excavation below the water table is large (more than about 10 m), or where artesian pressure in a deep aquifer beneath an excavation must be reduced. Deep wells are suitable where the excavation penetrates or is underlain by sand or coarser granular soils. Where adequate submergence is available and the required rate of pumping is large, deep bored wells may be preferable to wellpoints.

6.3.13.2 *Design* — The procedure for designing a system of deep wells is similar to that for wellpoints. Clauses **6.3.1** to **6.3.7** can be referred to in this regard.

6.3.13.3 *Sizes of well and well screens* — The wells should be large enough for the pump required and to keep the head losses low. The well screen should be of sufficient length to admit the flow with small head loss. Deep wells normally have diameters of 15 to 45 cm with screens of 6 to 22.5 m length.

6.3.13.4 *Use of surface pumps* — Pumping from wells can be undertaken by surface pumps with their suction pipes installed in bored wells. However, the depth of drawdown by this method is not much more than 7.5 m. If centrifugal pumps are used in a deep well system, the pumps can be located on the excavation slopes and connected to a common header pipe. The top of the well screen in such cases should be set below the computed water surface in the well.

6.3.13.5 *Use of deep well pumps* — For deep excavations, electrically powered submersible pumps should be installed, with a rising main to the surface. It should be seen that there is sufficient depth of pervious material below the level to which the water table is to be lowered, for adequate submergence of well screen and pump. If wells are located at the top of the excavation, interference with the excavation and construction can be eliminated.

6.3.13.6 *Selection of deep well pumps* — Turbines or submersible pumps are used to pump large diameter (150 mm and above) wells. Proper selection of pumps should be made in respect of pump capacity, from the variety of deep well pumps that are available. Discharge from the well may often be limited by the pump, and not necessarily by the available yield of the pervious stratum. For determining the approximate maximum capacity of deep well pumps Table 8 may be used.

NOTE — Pumps should be selected to operate at their normal rated speeds. Additional capacity is available at speeds greater than normal. Thus, some margin of safety always exists.

7. INSTALLATION AND OPERATION OF WELLPOINTS

7.1 Pressure and Quantity of Water for Jetting Wellpoints — For jetting down wellpoints into the ground, water may be required to be at a pressure of up to 14.5 kg/cm^2 and up to 900 litres of water may be required for a single wellpoint.

7.2 Clay Overlying Pervious Stratum — If a layer of clay overlies the water bearing stratum, it is often more convenient to bore through the clay by hand auger, rather than attempting jetting through it.

7.3 Sanding in — The process of sanding in the points may be followed as an important safeguard against drawing fine materials from the ground which might clog the system or cause subsidence. 'Sanding in' should be done as follows:

> 'After jetting down the wellpoints to the required level, the jetting water supply should be cut down to a low velocity sufficient to keep the hole around the point open. Coarse sand should then be fed around the annular space to form a supplementary filter around the point and the water then cut off. A rapid pouring of filter materials tends to bridge the hole, while an intermittent pouring causes heavy segregation of the filter materials, resulting in obstructions to vertical drainage.'

7.4 'Sanding in' in Highly Permeable Gravel — There may be difficulty in sanding in a wellpoint in highly permeable gravels, because the jetting water will be dissipated into the surrounding ground and will not reach the surface around the riser pipe. Normally, a wellpoint does not need 'sanding in' in these conditions, but if it so happens that the coarse gravels are overlying sand with the wellpoints terminating in the latter, the well-points must be inserted in a lined bore hole, the lining tubes being withdrawn after the filter sand is placed.

7.5 Pervious Stratum Overlying Clay — If the pervious stratum is immediately underlain by clay, the wellpoints can be installed in holes penetrating about 1 m into the clay and backfilled with sand, so that the water level in the wellpoints during pumping can be maintained at or below the bottom of the pervious stratum. This procedure will reduce or eliminate seepage that would otherwise bypass the wellpoints if they were installed only with their tips at the top of the clay stratum.

7.6 Sand Drains

7.6.1 *Use* — Troubles may arise in a dewatering scheme in the form of breaks in the drawdown curves if impervious layers of silt or clay (even as thin as 3 mm) are met in water bearing sandy soils. These troubles can be largely overcome by installing sand drains. Holes can be jetted on the side of wellpoints away from the excavation and be filled with sand. These sand columns will provide a path down which the water can seep through the wellpoints more readily than towards the sides of the excavation. Weeping from the side of the excavation can thus be prevented.

7.6.2 *Design of Sand Drains*

7.6.2.1 *Hydraulic head losses* — The drains should be of such size, permeability and spacing as to conduct the flow to the lower sand stratum with small hydraulic head loss. Sand or gravel filled drains are not effective when installed in highly pervious soils, because they do not have enough hydraulic carrying capacity to permit flow to the lower stratum without excessive head loss.

NOTE — For design of sand drains standard formulae be used.

7.7 Installing Header Pipes — After selecting the required header pipes, the header pipeline should be fitted with plug cocks of suitable size at the required spacing, laid along the line. The wellpoints can then be connected to the respective plug cocks through flexible connections. The header pipeline should be connected through valves to pumps of required number and capacity which, in turn, should be connected to a common discharge pipe leading to a basin or a ditch at a considerable distance away from the side.

7.8 Wellpointing in Sheet Piled Excavation, Position of Wellpoints — In the case of wellpointing in sheet piled excavation, the wellpoints should be placed close to the toe of the sheet piles, to ensure lowering the water level between the sheet pile rows.

7.9 Dewatering Operation

7.9.1 *Necessary Checks before Starting* — The dewatering operation should be started only after checking up all engine parts and priming of the pumps. The whole pipe line system should be checked against leakage. If leakages are detected, they should be properly mended with paints and by tightening the joints.

7.9.2 *Air-Sucking by Wellpoints* — In cases where the flow per wellpoint is less than expected and the drawdown goes deeper, the wellpoints may start sucking air. This may be indicated by the fluctuations of the vacuum gauge fitted to the wellpoint pump, and discharge of excessive air from the vacuum pump outlet. The air sucking can be stopped by suitably adjusting the plug cocks to increase friction loss.

7.9.3 *Repairing Choked Wellpoints* — In spite of using graded filter materials, a few wellpoints may get choked by finer silty particles. These dead points can be made active by developing the shrouding material with jetting of water.

7.9.4 *Protection of Pump Base* — Care should be taken to see that the pump bases are not flooded due to the flow of water through the sandy soil. This may make the pump base quite slushy and cause tilting of the pumps. In such situations, a few wellpoints and sand drains can be installed on the basin side of the pumps to intercept this flow.

8. INSTALLATION AND OPERATION OF DEEP WELL SYSTEMS

8.1 Installation of Deep Wells — The following points should be taken note of while installing deep wells.

8.1.1 The outer casing of the bore hole, which is sunk first, should have a diameter some 20 to 30 cm larger than the inner casing. The diameter of the latter depends on the size of the submersible pumps.

8.1.2 The inner casing, which is inserted after completion of the bore hole, should be provided with a perforated screen over the length where the dewatering of the soil is required and it should terminate in a 3.6 m length of unperforated pipe to act as a sump to collect any fine material which may be drawn through the filter mesh.

8.1.3 The perforated screen may consist of ordinary well casing slots or holes burned through the well and brass mesh spot — welded round the outside. Slots are preferable to holes, since there is less risk of blockage from round stones.

8.1.4 The effective screen area can be increased by welding rods longitudinally or spirally onto the casing to provide a clear space between the mesh and the casing.

8.1.5 If centrifugal pumps are used in a deep well system, the tops of the screens should be set below the computed water surface in the well. If the wells are pumped by deep well pumps, the bottoms of the wells should be set to provide sufficient length of submerged screen to admit the flow without excessive head loss.

8.2 Pouring the Filter Material — After the well casing is installed, graded filter material can be placed between it and the outer bore hole casing over the length to be dewatered. The outer casing should be withdrawn in stages as the filter material is placed. The remaining space above the screen can be backfilled with any available material. The water in the well should then be surged by a boring tool to promote flow back and forth through the filter, to get rid of any unwanted fines which fall into the sump and are cleaned out by bailer before the submersible pump is installed.

9. SUMP PUMPING

9.1 General — The method is essential where wellpointing or bored wells cannot be used because of boulders or other massive obstructions in the ground, and it is the only practical method for rock excavations. However, it has the disadvantage that the ground water flows towards the excavation with a high head on steep slopes, and there is a risk of the collapse of the sides. There is also the risk in open or timbered excavation, of instability of the base due to upward seepage towards the pumping sump. The cost of installing and maintaining the plant is, however, comparatively low.

9.2 Essential Features

9.2.1 The sump should be made below the general level of the excavation. It can be placed at one or more corners or sides.

9.2.2 The floor of the excavation should be made clear of standing water. For this, a small ditch should be dug around the bottom of the excavation falling towards the sump. It should be sufficiently wide to keep the velocity low enough to prevent erosion.

Safeguards against erosion can also be taken by placing boards across the ditch, or by stone or concrete paving. Open jointed pipes can also be laid, surrounded by graded stone or gravel filter material.

9.2.3 Where the ground water is present in a permeable stratum over-lying a clay, and the excavation is taken down into the latter material, it is preferable to have the pumping sump at the base of the permeable stratum. This procedure reduces the pumping head and avoids softening of the clay at the base of the excavation.

9.2.4 The greatest depth to which the water table may be lowered by sump method is not much more than 7.5 m below the sump, depending upon its type and mechanical efficiency.

9.2.5 For large depth of excavation, the pumps can be installed at a lower level. Use can also be made of sinking pump or submersible deep well pumps suspended by chains and progressively lowered down a timbered shaft or perforated steel tube.

9.2.6 For deep excavations, a useful procedure can be to sink the pumping sump for the full depth of the excavation by means of a timbered shaft with spaces between the poling boards to allow the water to flow into the shaft. Gravel filter materials should be packed behind the timbers if excessive fine material is washed through. This method ensures dry working condition for the subsequent bulk excavation, and it also provides an exploratory shaft for obtaining information on ground conditions to supplement that found from borings.

9.2.7 Adequate standby pumping plant of a capacity at least 100 percent of the steady pumping rate should be provided for use in emergency.

9.2.8 Types of pumps suitable for operating for open sumps are given in Table 9.

10. CONTROL OF SURFACE WATER

10.1 General — In laying out a dewatering system, adequate measures should be taken to control surface water, as otherwise flooding of the pump can result in failure of the system. Uncontrolled run-off also can cause serious erosion of slopes. The measures include dikes, ditches, sumps and pumps, and mulching and seeding to minimise slope erosion.

10.2 Essential Factors for Surface Control Measures — In selecting and designing measures to control surface water, the following factors should be considered:

a) Duration of construction,
b) Frequency of rainfall occurrence,
c) Intensity of rainfall and the resulting run-off,
d) Size of area to be protected, and
e) Available sump storage.

10.3 Run-Off Measurement — The rate of run-off, Q can be computed from the following equation:

$$Q = 0.278\ C\ i\ A$$

where

C = a constant, ranging from 0 to 1;
i = rainfall rate in mm per hour;
A = drainage area, in sq km; and
Q = peak rate of flow, in Cu m/s.

10.4 Dikes and Ditches

10.4.1 A dike can be built around the top of the excavation to eliminate run-off into the excavation from the surrounding area.

10.4.2 Dikes should be high enough to prevent water from overtopping them and of sufficient section to withstand head against them. The top of the dike should be at least 30 cm above the computed elevation of the surface water to be impounded. The width of the dike should be 40 to 150 cm with slopes of 1 on 2 or 2.5.

10.4.3 Run-off retained by the dikes can be pumped off or conducted to sumps in the bottom of the excavation by pipes or line channels, and then pumped out of the excavation.

10.4.4 Ditches should contain ample allowance for silting, freeboard and storage. Velocities of flow shall be low enough to reduce the extent of maintenance necessary to keep the ditch unobstructed.

10.4.5 Dikes can be combined with ditches and located excavation slopes to control run-off and reduce slope erosion.

10.4.6 *Sumps and Pumps* — The required capacity of pumps for pumping surface run-off can be estimated from the following expression:

$$Q_D = Q_R - V/T$$

where

Q_D = total pump capacity,

Q_R = average rate of run-off,

V = volume of sumps, and

T = duration of rainfall.

11. SETTLEMENT OF ADJACENT GROUND SURFACE

11.1 General — The effective pressure at a point near an excavation where the ground water is being lowered by pumping is increased by an amount equivalent to the head of water which existed above the level before dewatering. This increase in effective pressure will cause consolidation of the compressible strata with corresponding settlement of the compressible strata with corresponding settlement at ground level. The effects are severe in soft clays and peats. Loose sands under condition of fluctuating water table also undergo appreciable settlements. Little or no trouble need be feared in dense sands and gravels, provided the ground water lowering system has efficient filters to prevent loss of fines from the soil.

11.2 Precaution — To maintain the existing ground water conditions in shallow deposits, the water can be discharged into an 'absorption' ditch at ground level. To maintain the existing head in lower pervious layers water can be discharged into the injection or 'recharging' wells.

APPENDIX A

(*Clause* 5.1, and *Table* 1)

METHOD OF ELECTRO-OSMOSIS

A-1. ELECTRO-OSMOSIS

A-1.1 Use — Some silts, clayey silts and fine clayey silty sands may be troublesome to drain, because capillary forces acting on the pore water prevent its flowing freely under gravity to a filter well or sump. In such cases successful drainage can be achieved by wells or wellpoints in combination with flow of electricity through the soil to the wells. The electrical drainage method, or electro-osmosis, is a costly method, but under certain circumstances, it is the only practical means of soil stabilization. There is also no advantage in applying this method for dewatering unless permeability of the soil to be drained is significantly lower than 0.5×10^{-4} cm/sec.

A-1.2 Electrodes — Anodes can consist of any available conductor, such as steel pipe, rail, etc. Cathodes usually consist of small diameter wells or wellpoints, but with sufficient diameter to admit a suction pipe (usually 25 mm diameter) from a pump. Anodes and cathodes should extend in depth at least 1.5 m below the bottom of the slope or excavation.

A-1.3 Spacing of Electrodes — Cathodes can be installed in one or more lines and spaced on 7.5 to 10.5 m centres, with anodes installed midway between the cathodes.

NOTE — The proper spacing of electrodes depends mainly on the voltage available at the site. Potential gradients of more than 0.5 volt per cm between electrodes should not be exceeded for long term applications, because higher gradients result in excessive energy losses in the form of heating of the ground.

A-1.4 Voltage Requirement — Applied voltages vary between 30 and 100 volts, the lower voltages being satisfactory where the ground water contain a high concentration of minerals.

A-1.5 Power Requirement — Power required per well may range from 0.5 to 2.5 kW, for respective gradients of about 1.5 and 4 volts per 30 cm distance between electrodes.

A-1.6 Current Requirement — Current requirements range between 15 A and 30 A. The required current can be estimated from the following expressions. This equation is not applicable to very low clay contents:

$$I\,t = 4.1c - 25$$

where

I = current, in A, required per gram of water expelled;

t = time in sec; and

c = clay content of soil, percent (percent by weight of soil finer than 0.002 mm).

A-1.7 Collection of Water — When a direct electric current is passed between the electrodes, water contained in the soil will migrate through the soil from the anode to the cathode. Water collected in the well (cathode) can then be removed by pumping.

NOTE — Since the rate of discharge at a cathode is small, intermittent pumping may suffice.

A-1.8 Discharge — An estimate of the discharge Q_e to a well can be obtained from the following expressions:

$$Q_e = k_e \, i_e \, az$$

where

k_e = coefficient of electrosmotic permeability,
= 0.5×10^{-4} cm per volt per cm;

i_e = gradient in volts per cm, between electrodes;

z = depth of soil being stabilized in cm; and

a = effective spacing of wells in cm.

NOTE — For practical purposes, the value of k_e can be assumed to be the same for sands, silts or clay.

APPENDIX B

(*Clause* 6.3.4.3, Note 1)

FLOW NET METHOD

B-1. GENERAL

B-1.1 Use — A flow net can be a useful tool when designing dewatering systems, especially when complicated boundary conditions are present. A flow net may be constructed either to represent the plan view of the seepage pattern, or a sectional view, depending on the requirement in the design.

B-1.2 Flow Line — The path followed by a particle of water flowing through a saturated soil mass is called a 'flow line'.

B-1.3 Equipotential Line — It is the line at every point of which the total head is the same.

B-1.4 Flow Net — A combination of flow lines and equipotential lines, which satisfies the following characteristics, is called a flow net:

a) Flow lines and equipotential lines meet at right angles; and

b) Intersection of flow lines and equipotential lines forms curvilinear squares, when the permeability in all directions is identical.

B-1.5 Discharge from Flow Net — From the flow net, the discharge per unit length perpendicular to the direction of flow can be obtained by:

$$q = k\,(H - h_e)\frac{N_f}{N_e}$$

where

k = coefficient of permeability of the soil,

N_f = number of flow channels, and

N_e = total number of equipotential drops between the full head H and the head h_e at the point of exit.

B-1.6 Plan Flow Net — The plan flow net should be drawn with the assumption that the flow lines are horizontal and as such, the equipotential lines are vertical. The analysis thus essentially requires the flow to be two-dimensional. The slot/wells, therefore, need to be fully penetrating. Corrections to be made for partially penetrating cases are mentioned in **B-1.10**.

B-1.7 Discharge from Plan Flow Net — The total discharge Q is obtained from plan flow net by multiplying the value of 'q' (given in **B-1.5**) by the thickness D of the pervious stratum, as follows:

$$Q = q \cdot D$$

B-1.8 Spacing of Wellpoints/Wells from Flow — Wells should be spaced proportionally to the flow lines.

B-1.9 Limitations in the Use of Plan Flow Net — As mentioned in **B-1.6**, plan flow net analysis is effective for two-dimensional problems. The converging flows in the vicinity of partially penetrating wells present a three-dimensional case for which plan flow net analysis will give erroneous results, except when the penetration is at least 90 percent. Correction factors can, however, be applied for getting correct results from plan flow net. This is given in **B-1.10**.

B-1.10 Corrections to be Applied to Computations from Plan Flow Net — Corrected relationships between discharge Q_w per well and the head h_w at the well taking into consideration the penetration of the well, and also the fact that the system consists of a finite group of wells and not a continuous slot, are given below:

$$H - h_w = \frac{Q_w}{k_D} \left(n\frac{N_e}{N_f} + \frac{1}{2}\, ln\, \frac{a}{2\pi r_w} \right) : \text{for fully penetrating wells}$$

and

$$H - h_w = \frac{Q_w}{k_D} \left(n\frac{N_e}{N_f} + \theta_a \right) : \text{for partially penetrating wells}$$

where a is the well spacing; D is the depth of the pervious stratum, r_w is effective well radius, and θ_a is called 'uplift factor'. The values of θ_a for various penetrations of the well screen into the pervious stratum has been mentioned in various text books.

TABLE 1 COMPARATIVE STUDIES OF DEWATERING SYSTEMS

(*Clause* 5.1)

SL NO.	METHOD	SOILS SUITABLE FOR TREATMENT	USES	ADVANTAGES	DISADVANTAGES
(1)	(2)	(3)	(4)	(5)	(6)
1	Sump pumping	Clean gravels and coarse sands	Open shallow excavations	Simplest pumping equipment	a) Fines easily removed from ground b) Encourages instability of formation
2	Wellpoint systems with pumps	Sandy gravels down to fine sands (with proper control can also be used in silty sands)	Open excavations including rolling pipe trench excavations	a) Quick and easy to install in suitable soils b) Economical for short pumping periods of a few weeks	a) Difficult to install in open gravels and grounds containing cobbles and boulders b) Pumping must be continuous and noise of pump may be a problem, in a built up area c) Suction lift is limited to 4.5 to 6.0 m d) If greater lowering is needed multi-stage installation is necessary
3	Deep bored filter wells with electric submersible pumps	Gravels to silty fine sand, and water bearing rocks	Deep excavation in through or above water bearing formations	a) No limitation on amount of drawdown as there is for suction pumping b) A well can be constructed to draw water from several layers throughout its depth c) Wells can be sited clear of working area d) No noise problem if mains electricity supply is available	High installation cost

4 Electro-osmosis (*see* Appendix A)	Silts, silty clays and some peats	Open excavation in appropriate soils or to speed dissipation of construction pore pressures	Any appropriate soils can be used when no other water lowering method is applicable	Installation and running costs are usually high
5 Jet educator system	Sands (with proper control can also be used in silty sands and sandy silt)	a) Deep excavations (in space so confined that multistage well-pointing cannot be used) b) Usually more appropriate to low permeability soils	a) No limitation on account of draw-down b) Raking holes are possible	a) Initial installation is fairly costly b) Risk of flooding excavation if high pressure water main is ruptured c) Optimum operation difficult to control

TABLE 2 FLOW TO A SLOT FROM A SINGLE LINE SOURCE

(*Clause* 6.2.2)

PENETRATION	FLOW CONDITION	DISCHARGE FORMULAE	REMARKS
Fully penetrating slot	Artesian	$Q = \frac{kDx}{L} - (H - h_e)$	H = original ground water level h_e = ground water level at the use Q = flow rate L = distance of the slot from the line source D = depth of pervious stratum x = distance perpendicular to the direction of flow
	Gravity	$Q = \frac{kx}{2L} - (H^2 - h^2_e)$	
Partially penetrating slot	Artesian	$Q = \frac{kDx\,(H - h_e)}{L + E_A}$	
	Gravity	$Q = \left(0.73 + 0.27\,\frac{H - h_e}{H}\right)\frac{kx}{2L} - (H^2 - h^2_o)$ For $L/H \geq 3$	E_A = extra-length factor as described by various authors

NOTE — The maximum residual head, h_D downstream from the slot can be computed from the following expression:

(i) For 'artesian' case : $h_D = \frac{E_A\,(H - h_o)}{L + E_A} + h_e$.......... (0.0)

(ii) For 'gravity' case : $h_D = h_o\left[\frac{1.48}{L}(H - h_o) + 1\right]$............(0.0)

for $L/H \geq 3$

TABLE 3 FLOW TO A SLOT FROM TWO LINE SOURCES

(*Clause* 6.2.2)

PENETRATION	FLOW CONDITION	DISCHARGE FORMULAE	REMARKS
Partially penetrating slot	Artesian	$Q = \dfrac{2kDx\ (H - h_e)}{L + \Upsilon D}$	Q = flow to the slot Υ = a factor which depends on the ratio W/D where
	Gravity	$Q = \left(0.73 + 0.27 \dfrac{H - h_e}{H} \right) \dfrac{kx}{L} (H^2 - h_o^2)$	W = penetration of the slot into the pervious stratum (To be determined from Fig. 2)
Fully penetrating slot		The flow is twice that computed from Table 2 for the respective cases	NOTE — The slot is midway between the line sources

NOTE — At distances y from the slot, in excess of about 1.3 D the head h increases linearly as y increases, and can be computed as follows:

$$h = h_e + (H - h_e) \frac{y + D}{L + D}$$

TABLE 4 FLOW TO TWO PARTIALLY PENETRATING SLOTS MIDWAY BETWEEN AND PARALLEL TO TWO LINE SOURCES

(*Clause* 6.2.2)

Flow Condition	Discharge Formulae	Remarks
Artesian	Flow from one source to the closest of the two slots is obtained from equations of Table 2. Head 'h_D' midway between slots is obtained from Table 2.	
Gravity	Flow from either slot is determined from Table 2. The head 'h_D' midway between the slots is given by $h_D = h_o \left[\frac{k_1 k_2}{L}(H - h_o) + 1 \right]$	k_1 and k_2 can be obtained from Fig. 3

TABLE 5 HEAD REDUCTION FOR FINITE LENGTH OF SLOT

(*Clauses* 6.2.3 *and* 6.3.4.4)

Penetration	Flow Condition	Head Reduction at the Wells
Fully penetrating well	Artesian	$H - h_w = \frac{Q_w}{2\pi k_D} \, ln \, \frac{a}{2\pi r_w} + \frac{Q_w L}{k D_a}$
	Gravity	$H^2 - h^2_w = \frac{2 Q_w L}{k a} + \frac{Q_w}{\pi k} \, ln \, \frac{a}{2\pi r_w}$
Partially penetrating	Artesian	$H - h_w = \frac{Q_w}{k D} \left(\frac{L}{a} + \theta_a \right)$
	Gravity	The formula for fully penetrating case can be used provided Q_w is computed from an appropriate equation.

NOTE 1 — Q_w = discharge per well.

NOTE 2 — θ_a = uplit factor (for details as given in various text books).

NOTE 3 — h_w = head at the well.

TABLE 6 FLOW TO A SINGLE WELL CIRCULAR SOURCE

(*Clause* 6.2.4)

PENETRATION	FLOW CONDITION	DISCHARGE FORMULAE	REMARKS
Fully penetration well	Artesian	$Q_w = \frac{2\pi kD (H - h_w)}{ln (R/r_w)}$ NOTE — For a well located at distance E from the centre of the circle of influence, the flow is given by: $\frac{2\pi kD (H - h_w)}{ln [(R^2 - E^2)/Rr_w]}$	(i) Q_w = flow to the well (ii) h_w = head at the well (iii) R = radius of influence (iv) Well is at the centre of the circular sources
	Gravity	$Q_w = \frac{k\pi (H^2 - h^2_w)}{ln (R/r_w)}$	
Partially penetrating well	Gravity	$Q_w = \frac{k\pi [(H - S)^2 - t^2]}{ln (R/rw)}\left[1 + \left(0.3 + \frac{10rw}{H} \right) \sin \frac{1.8\ S}{H} \right]$	G = ratio of flow from partially penetrating well to a fully penetrating well, for the same drawdown at the periphery of the wells
	Artesian	$Q_{wp} = \frac{2\pi kD (H - hw) G}{ln (R/rw)}$	

NOTE — G is given by the following expression:

$$G = \frac{W}{D} (1 + 7) \sqrt{\frac{rw}{2W}} \cos\pi \frac{\pi W/D}{2}$$

in which w/D equals the penetration of the well screen into the pervious stratum expressed as a decimal.

TABLE 7 FLOW TO A SINGLE WELL-LINE SOURCE

(*Clause* 6.2.5)

FLOW CONDITION	DISCHARGE FORMULAE	REMARKS
Artesian	$Q_w = \frac{2\pi kD (H - h_w)}{ln (2L/r_w)}$	Q_w = flow to the well
Gravity	$Q_w = \frac{\pi k (H^2 - h^2_w)}{ln (2L/r_w)}$	$H — h_w$ = drawdown at the well

TABLE 8 CAPACITY OF DEEP WELL PUMPS

(*Clause* 6.3.13.6)

PUMP BOWL SIZE cm (MINIMUM *ID* OF WELL PUMP WILL ENTER)	PREFERRED MINIMUM *ID* OF WELL, cm	APPROXIMATE MAXIMUM CAPACITY 0.0036 m^3/m
10	12.5	90
12.5	15	160
15	20	450
20	25	600
25	30	1 200
30	35	1 800
35	40	2 400
40	45	3 000

TABLE 9 PUMPS FOR SUMP PUMPING

(*Clause* 9.2.8)

SL No.	Type of Pump	Output	Use
1	Handlift diaphragm	From 54.6 m^3/h for 3 cm suction; up to 655 m^3/h for 10 cm suction	Suitable for intermittent pumping in small quantities
2	Motor-driven diaphragm	From 983 m^3/h for 7.5 cm suction up to 1 747 m^3/h for 10 cm suction	Can deal with sand and silt in limited quantities
3	Pneumatic sump pumps	From 1 310 m^3/h against 15 m head to 2 620 m^3/h against 3 m head, at 7.3 kg/cm^2 airpressure	Useful for intermittent pumping on sites where compressed air is available, can deal with sand and silt in limited quantities
4	Self-priming centrifugal	From 2 184 m^3/h for 5 cm suction to 19 656 m^3/h for 20 cm suction	Sand and silt in water cause excessive wear on impeller for long periods of pumping, therefore, desirable to have efficient filter around sump or pump suction. Widely used for steady pumping of fairly clean water. Smallest units can be carried by one man
5	Rotary displacement (monopump)	1 638 m^3/h for 7.5 cm pump, against 6 m head	Can deal with considerable quantities of silt and sand
6	Sinking pumps	From 875 m^3/h for 5 cm suction to 10 920 m^3/h for 15 cm suction	Can pump against 60 m head. Suitable for working in deep shafts or other confined spaces where pumps must be progressively lowered with falling water table. Can be vertical spindle centrifugal pump or steam operated pulsometer type

(*Continued from page* 2)

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