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Drainage Engineering

(BTAI3103)

Module 4

Subsurface Flow to Drains and Drainage Equation

(Lecture-10: Hooghoudt Equation)

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Estimation of equivalent depth

Method I

Hooghoudt derived a relationship between the;

- Equivalent depth (d)
- Spacing (L),
- Depth to the impervious layer (D)
- Radius of the drain (r_0)

$$d = f(L, D, u) \dots\dots\dots(1)$$



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Estimation of equivalent depth ...contd.

$$d = \frac{D}{1 + 8D / \pi L \ln D / u} \text{ for } D < \frac{1}{4} L \dots\dots\dots(2)$$

$$d = \frac{D}{8 / \pi \ln L / u} \text{ for } D > \frac{1}{4} L \dots\dots\dots(3)$$

Where

u is wet entry perimeter (m)



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Estimation of equivalent depth ...contd.

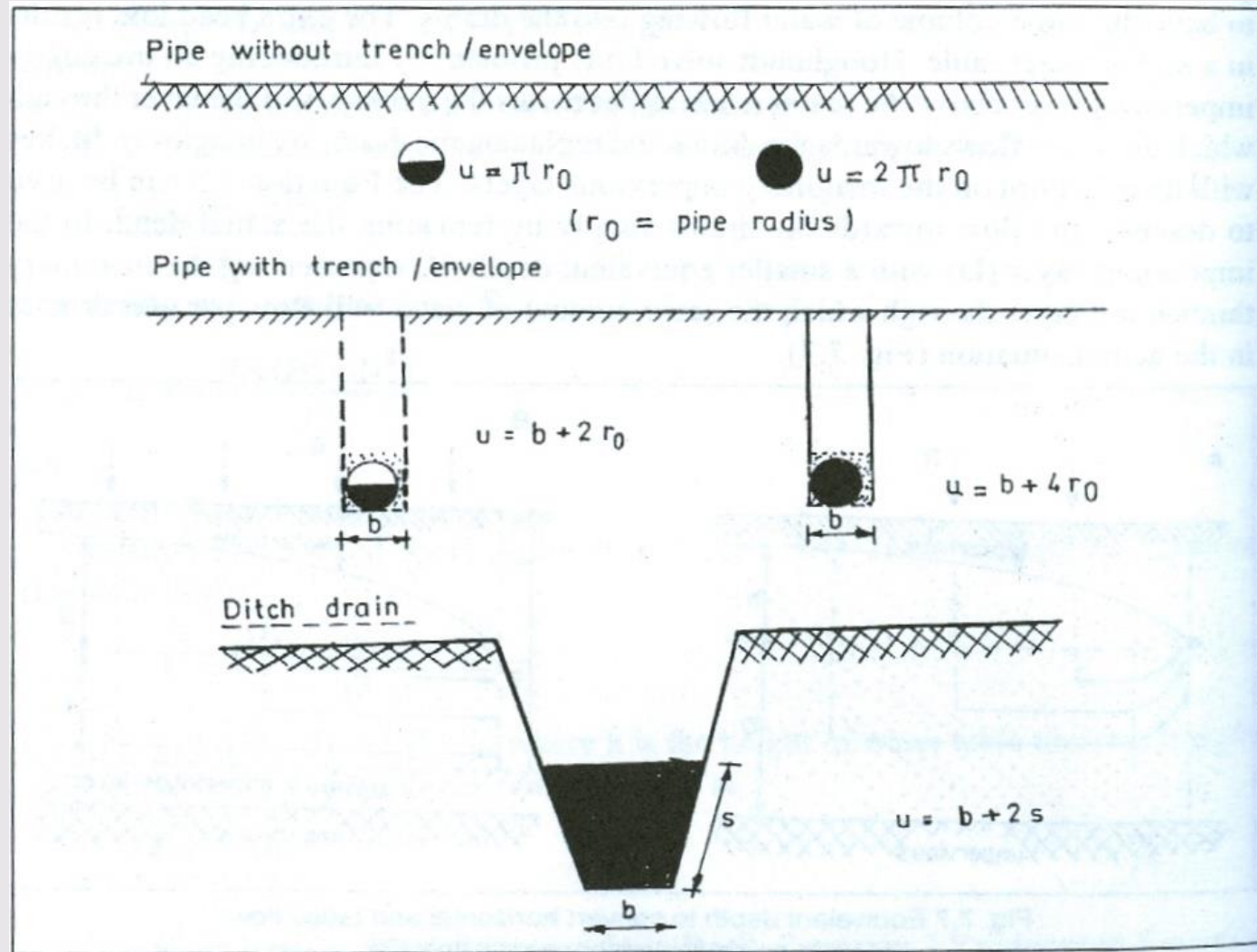


Fig. Wet entry perimeter under different conditions in pipe and ditch



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Estimation of equivalent depth ...contd.

Wet perimeters

1. Pipe drain (semi-circle) without trench

- The Hooghoudt equation follows that drains are running half and have no entrance resistance,

$$u = \pi r_0$$

where;

u = wetted perimeter, (m)

r_0 = radius of drain, (m)

2. Pipe drain without envelope laid in trenches,

$$u = b + 2r_0$$



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Estimation of equivalent depth ...contd.

3. Pipe drain with envelope in trench,

$$u = b + 2(2r_0 + m);$$

open drains,

$$u = b + 2s$$

where;

b = bottom width (m)

s = length of wetted sides (m)

m = height of envelope above drain



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Van Beers (1979) prepared nomographs for estimation of 'd' using equation (11)

Procedure

- Connect D/u and D
- Find point P at the intersection with the vertical line L
- Connect 'P' with origin and read 'd'

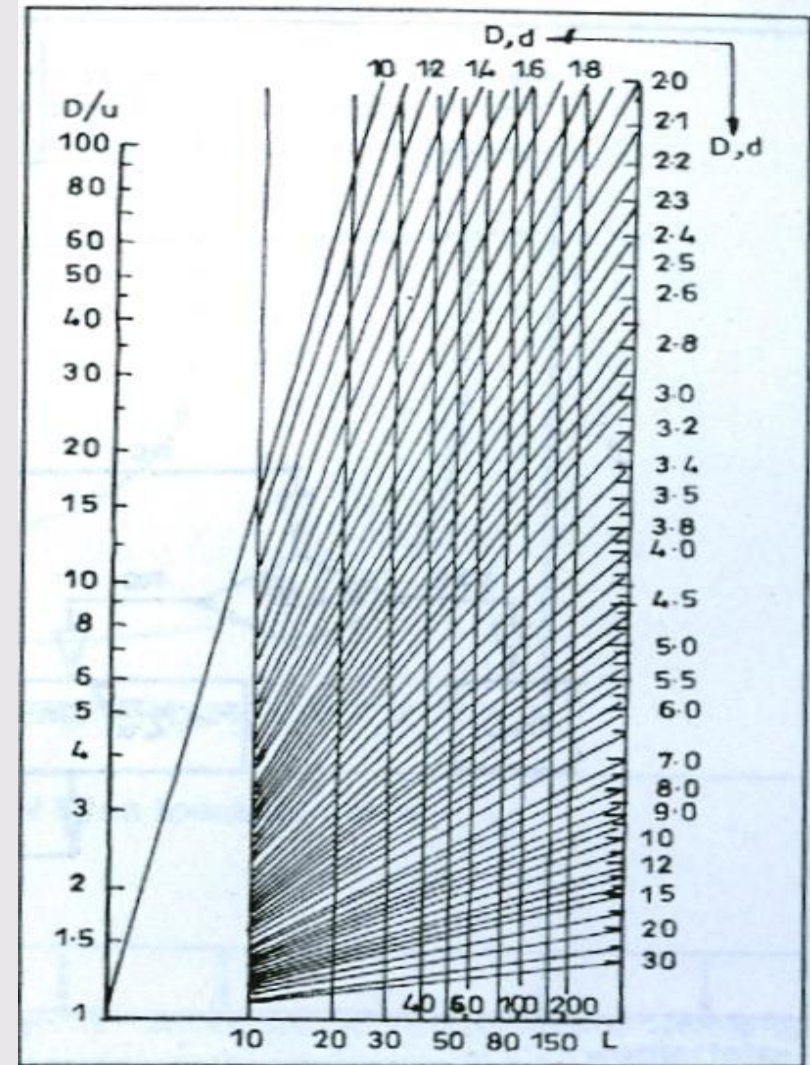


Fig. Nomograph for equivalent depth



Estimation of equivalent depth ...contd.

Alternative Method

- Another method for computing 'd' was given by van der Molen and Wesseling (1991)

$$d = \frac{\pi L / 8}{\ln L / \pi r_0 + F(x)} \dots\dots\dots(4)$$

where;

$$x = \frac{2\pi D}{L} \dots\dots\dots(5)$$

and $F(x) = \sum_{n=1}^{\infty} \frac{4e^{-2nx}}{n(1 - e^{-2nx})} (n = 1, 3, 5, \dots)$

.....(6)



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Estimation of equivalent depth ...contd.

$F(x)$ converges rapidly for $x > 1$

For $x \ll 1$, convergence is slow

For $x=0.5$, $F(x)$ can be approximated,

$$F(x) = \frac{\pi^2}{4x} + \ln \frac{x}{2\pi} \dots\dots\dots(7)$$

A flow chart of this method is given in Fig.

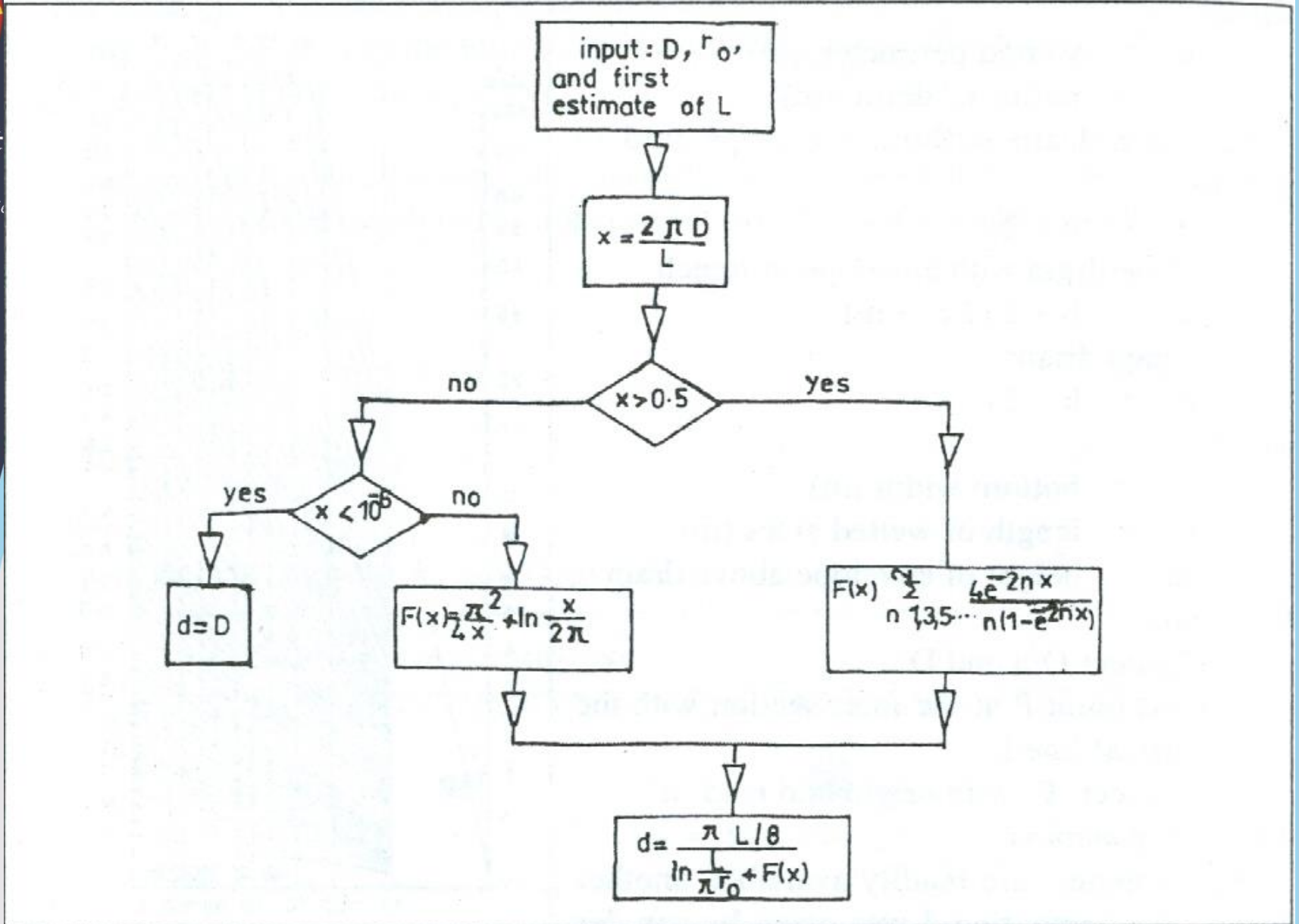


Fig. Flow chart for equivalent depth



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Curvature of water table

$$y^2 = Y^2 - q / Kx^2 \quad \dots\dots\dots(8)$$

The curvature of the water table is generally elliptical

Curvature/slope of water table increases towards drain due to

1. Flow rate increases,

$$Q_x = q \cdot x \quad (X_2 q > X_1 q)$$

Discharge through cross section, $Y_1 = X_1 \cdot q$

Discharge through cross section, $Y_2 = X_2 \cdot q$

2. Flow cross section (Y) towards drain decreases,

$$Y_2 < Y_1$$



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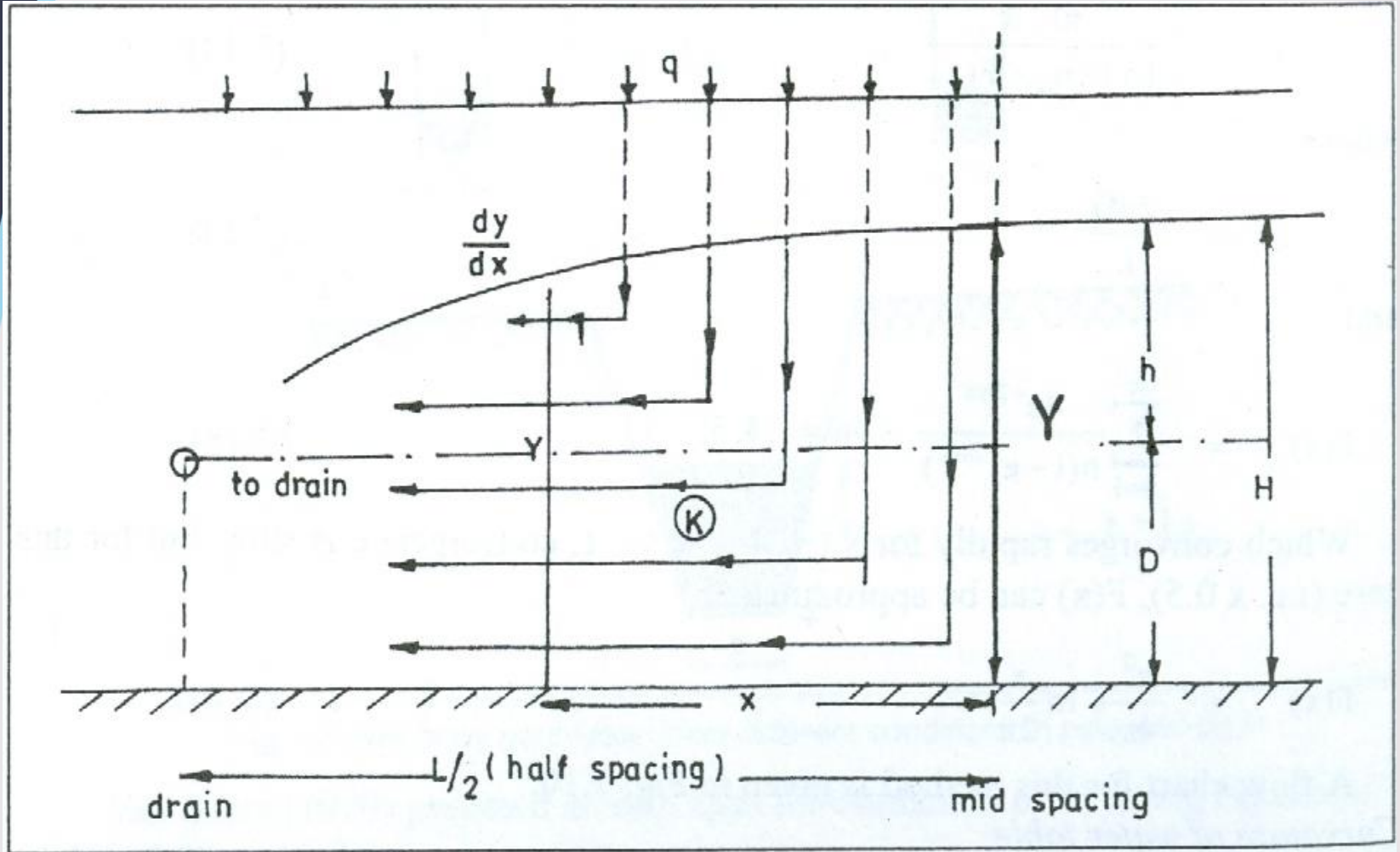


Fig. Curvature of water table



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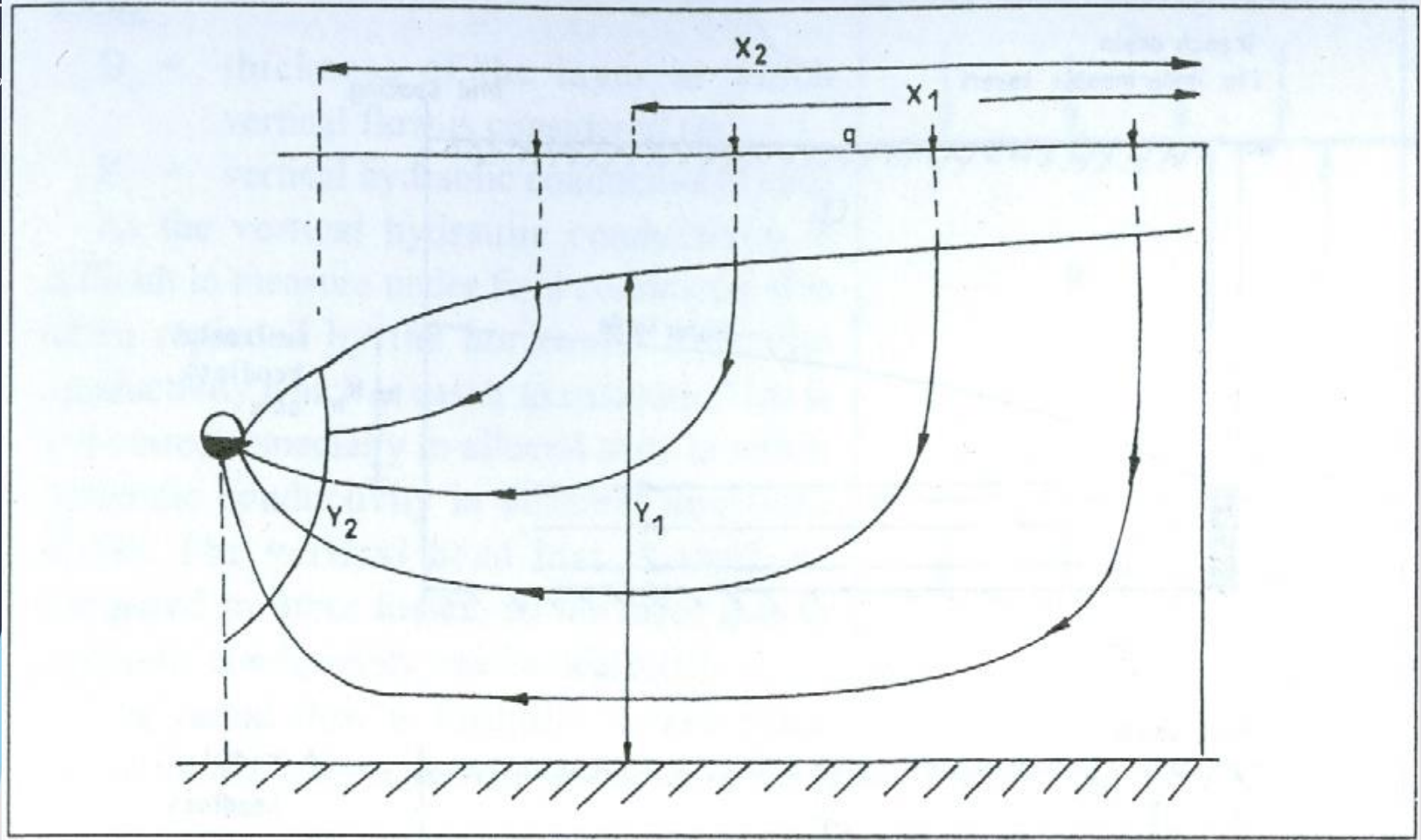


Fig. Flow and cross-sectional area towards drain



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