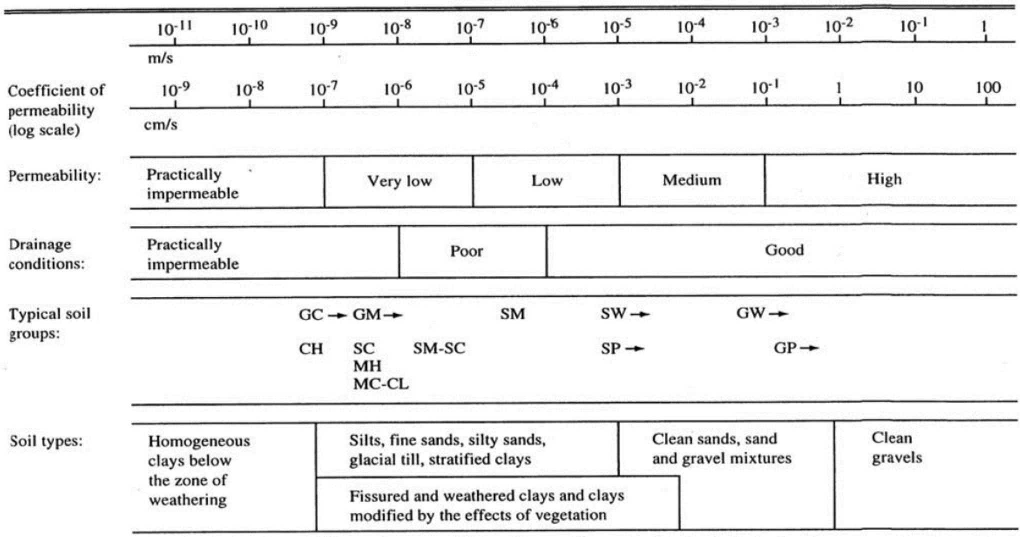
ENCE 3610
Soil Mechanics

Lecture 7
Empirical and Field Tests for Hydraulic Conductivity
Dewatering

Typical Permeability Values

Table 5-10

Typical permeability values in soils (after Carter and Bentley, 1991)



Note: The arrow adjacent to group classes indicates that permeability values can be greater than the typical value shown.

Table 5-11

Typical permeability values for highway materials (after Krebs and Walker, 1971)

Materials	Permeability (cm/sec)
Uniformly graded coarse aggregate	40 - 4×10^{-1}
Well-graded aggregate without fines	4×10^{-1} - 4×10^{-3}
Concrete sand, low dust content	7×10^{-2} - 7×10^{-4}
Concrete sand, high dust content	7×10^{-4} - 7×10^{-6}
Silty and clayey sands	10^{-5} - 10^{-7}
Compacted silt	7×10^{-6} - 7×10^{-8}
Compacted clay	Less than 10^{-7}
Bituminous concrete (new pavements)*	4×10^{-3} - 4×10^{-6}
Portland cement concrete	less than 10^{-8}

* Values as low as 10^{-8} have been reported for sealed, traffic compacted highway pavement.

Empirical Correlations and Typical Values Granular Soils

- Based on tests bolstered by a varying amount of theory
- Hazen's Correlation

$$k = CD_{10}^2$$

  - k in cm/sec
  - $0.8 < C < 1.2$ (typically C = 1)
  - Limited to soils with 0.1 mm < D_{10} < 3 mm and $C_u < 5$
- Typical values
- Assume laminar flow in soil

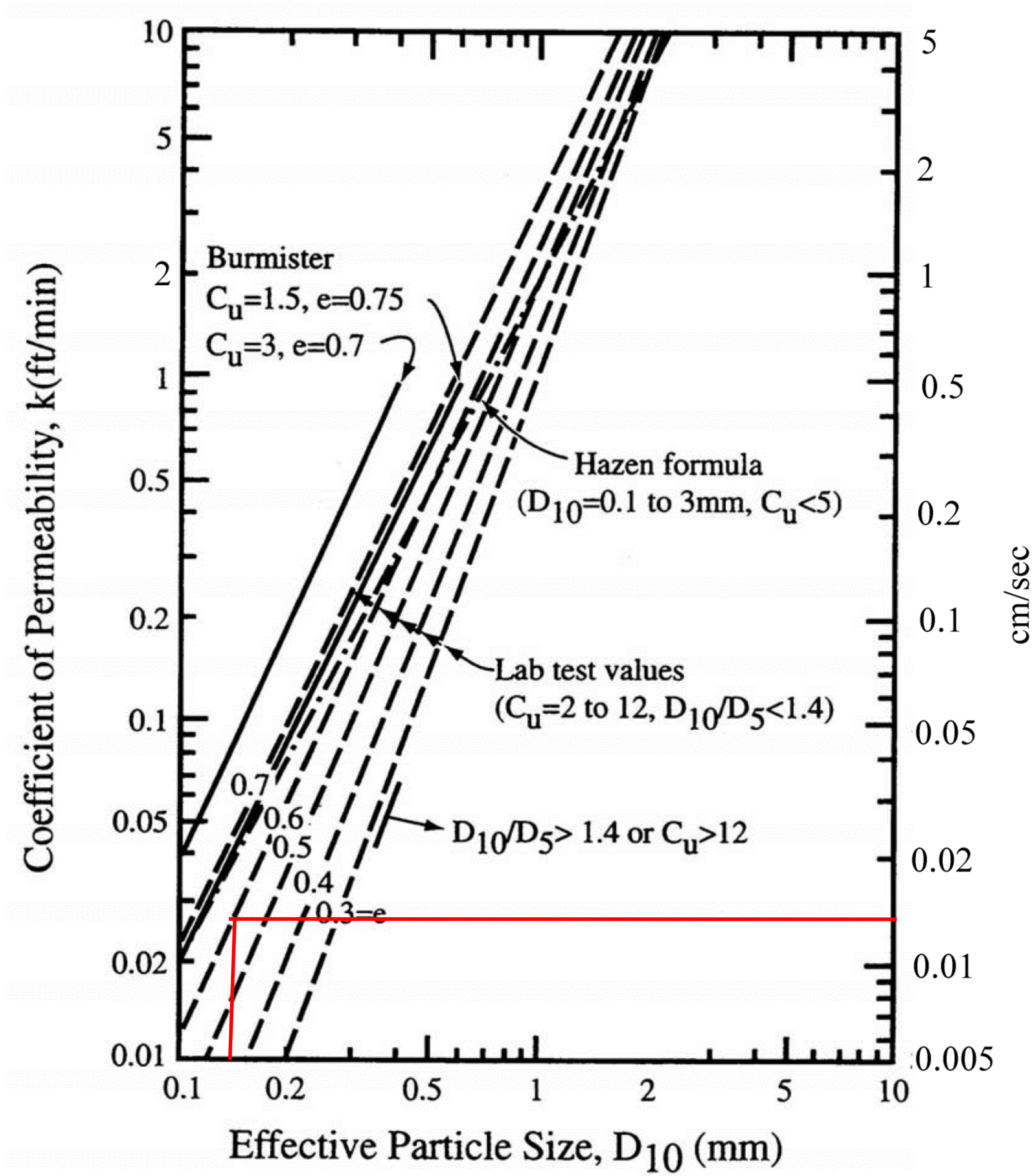


Figure 5-26. The permeability of sands and gravels (after NAVFAC, 1986a).

Note: In Figure 5-26, correlations shown are for remolded compacted sands and sand-gravel mixtures with C_u values as indicated.

Example of Conductivity Estimate

- Given: Soil as Shown Below
  - $D_{10} = 0.15$
  - $D_5 = 0.08$
  - Uniformity Coefficient $C_u = 8$
  - Void Ratio e = 0.6
- Find
  - Hydraulic Conductivity, using a variety of methods
- Methods to be used if applicable)
  - Hazen's Correlation
  - Laboratory Tests Chart
- Solution
- Hazen's Correlation
  - $0.1 < D_{10} < 5$ is true, but cannot use since $C_u = 8 > 5$
- Lab Tests
  - Can use since $2 < C_u = 12$ and $D_{10}/D_5 = 1.88 > 1.4$
  - For $D_{10} = 0.1$ and e = 0.6, k = 0.015 cm/sec = 0.05 fpm (see chart on previous slide)

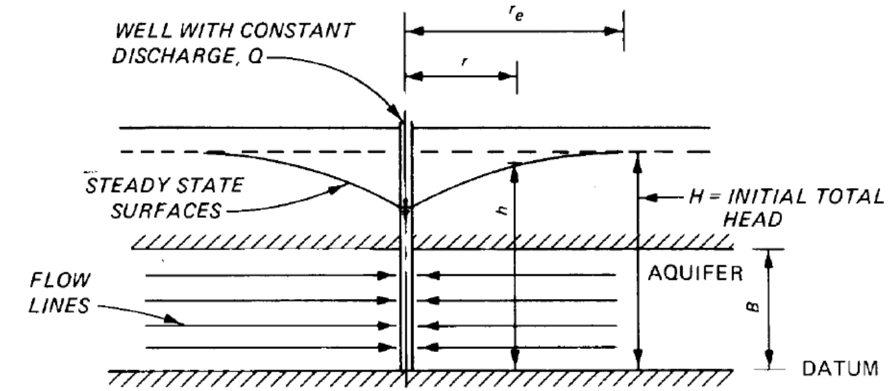
Field Permeability Tests and Dewatering Wells

- Field permeability tests measure the coefficient of permeability (hydraulic conductivity) of in-place materials.
- The area and length factors are often combined in a "shape factor" or "conductivity coefficient."
- Measurement of permeability is highly sensitive to both natural and test conditions.
- Field permeability tests are also the “inverse” of the pumping problem for dewatering.

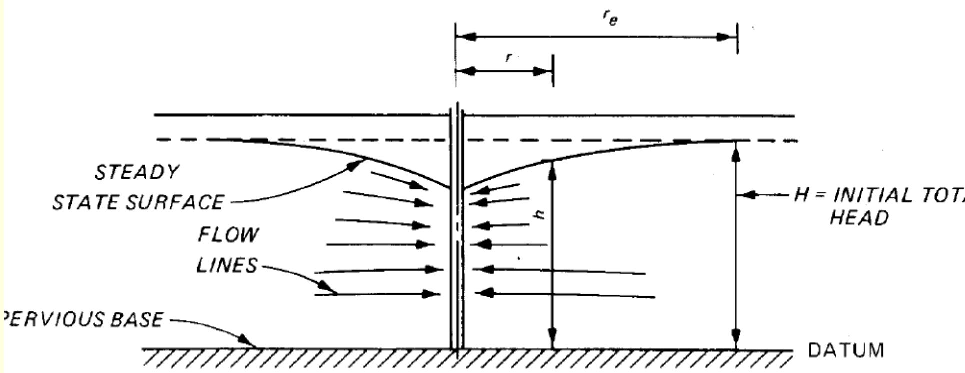
Test types parallel lab tests

- Constant Head Test
- Variable Head Tests
  - Rising Head Test
  - Falling Head Test
  - Infiltration Test
- Pumping Test
- Gravity and Pressure Tests

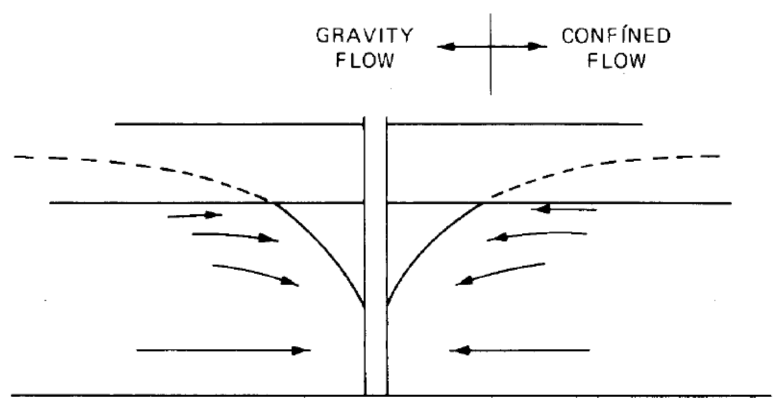
Confined and Unconfined Aquifers



a. HORIZONTAL AQUIFER CONFINED BETWEEN IMPERVIOUS STRATA (ARTESIAN FLOW)



b. HORIZONTAL UNCONFINED AQUIFER (GRAVITY FLOW)



c. COMBINED AND CONFINED AND GRAVITY FLOW

Confined Aquifer: Determination of Height

- Governing Equation:
  - h=height from bottom of well to water level at well
  - h_0=water table height from bottom of well to water table
  - Q_0=flow from well
  - k=coefficient of permeability
  - H=thickness of permeable layer
  - r=radius of well or wherever h is measured
  - R=outer boundary of influence of well, or wherever h_0 is measured

$$h = h_0 + \frac{Q_0}{2\pi kH}\ln\left(\frac{r}{R}\right)$$

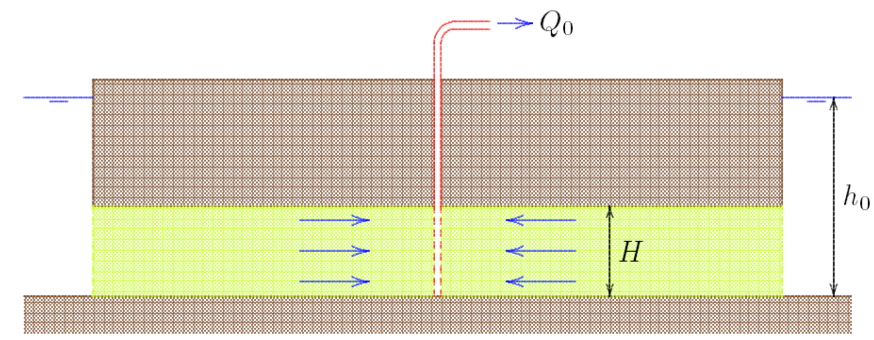


Figure 11.1: Single well in aquifer.

$$Q_0 = \frac{2\pi kH}{\ln\left(\frac{r}{R}\right)}\left(h - h_0\right)$$

$$k = \frac{Q_0 \ln\left(\frac{r}{R}\right)}{2\pi H\left(h - h_0\right)}$$

Unconfined Aquifer

- Only difference is that upper layer is the same (pervious) as lower layer
- Equations have same variables, but expression is different:

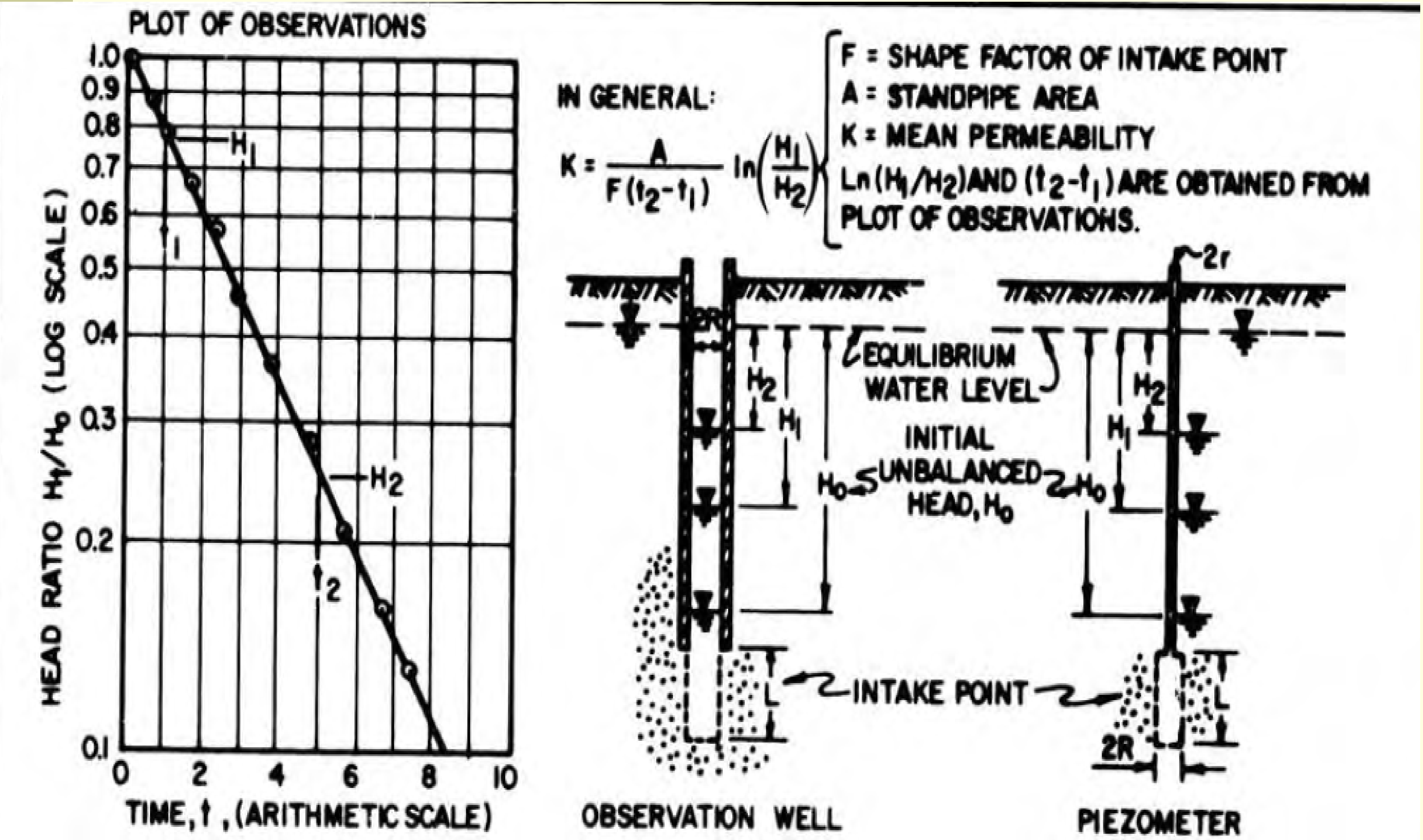
$$h^2 = h_0^2 + \frac{Q_0}{\pi k} \ln\left(\frac{r}{R}\right)$$

$$Q_0 = \frac{\pi k}{\ln\left(\frac{r}{R}\right)} \left(h^2 - h_0^2\right)$$

$$k = \frac{Q_0 \ln\left(\frac{r}{R}\right)}{\pi\left(h^2 - h_0^2\right)}$$

Dewatering

Measuring Permeability in Cohesive Soils (Rising Head Test)



Layered Soils

- "Resistor Model" except that we're dealing in conductivities, not resistances
- For horizontal layers:
  - Vertical flow is a single flow through several hydraulic resistances in series

$$k_{V(eq)} = \frac{H}{\sum_{1}^{n} \frac{H_n}{k_{V_n}}}$$

  - Horizontal flow is several flows through several hydraulic resistance in parallel

$$k_{H(eq)} = \frac{1}{H} \sum_{1}^{n} k_{H_n} H_n$$

Anisotropy in Permeability

$$k_H \neq k_V \text{ (Anisotropic Soil)}$$

$$k_H > k_V \text{ (in general)}$$

- Can be significant, esp. with some types of clays, esp. varved clays
  - Varved clay: “alternating seams or layers of sand, silt and clay” (SFH Table 4.7)
  - Result of sediment deposits with vary in nature due to seasonal fluctuations, etc.

Questions?