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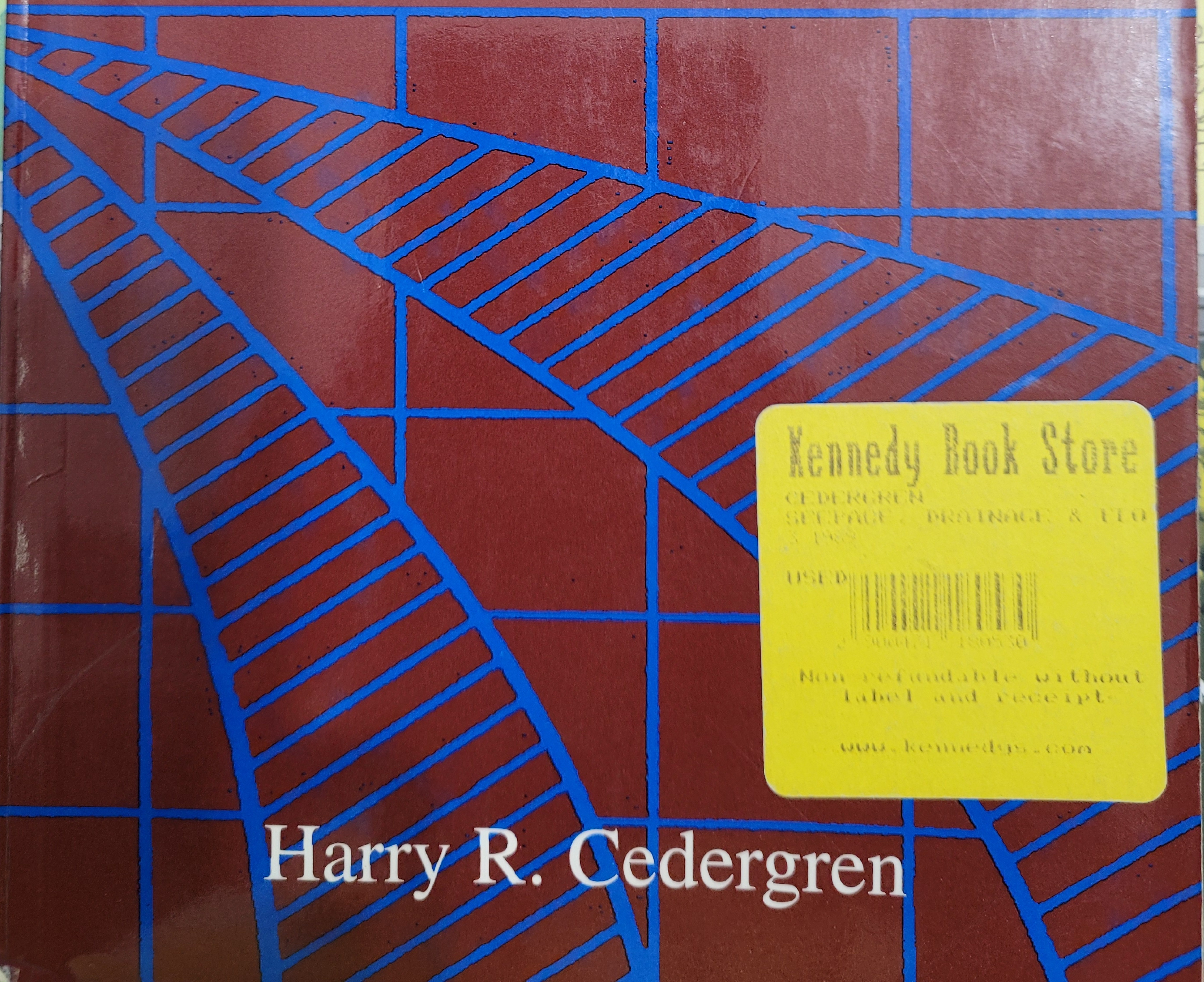
Seepage, Drainage, and Flow Nets

THIRD EDITION



Harry R. Cedergren

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A Wiley-Interscience Publication

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saturation. This is a basic assumption of the drain-design methods described in this section and illustrated in Secs. 5.5 and 5.6. The design of drains with flow nets has previously been described (Cedergren, 1961 and 1962), although the techniques are relatively new. The method is illustrated by an example in Sec. 5.6.

In some instances one flow net may provide enough information to design a drain; in others, however, a number of flow nets which permit a comparison of the costs of several designs may be well worth the time needed for their construction. To facilitate the study of seepage in drainage systems families of flow nets may be constructed and useful design charts developed, as described in Sec. 5.6.

In the construction of flow nets for the purposes described here the shape of the saturation line in a drain is determined simultaneously with the construction of the flow net (see also Secs. 4.5 and 4.6), for it is not known in advance.

5.5 EXAMPLES OF THE USE OF DARCY'S LAW IN THE DESIGN OF DRAINS

"Chimney" Drain in a Dam

Assume that an earth dam is to be constructed to the cross section given in Figure 5.8a, with an inclined "chimney" drain *A* to intercept seepage through the dam and a horizontal drainage blanket *B* to remove seepage through the dam and its foundation. Determine minimum thicknesses and permeabilities of parts *A* and *B* to ensure ample factors of safety with respect to discharge capacities.

First estimate the probable rate of discharge through the dam and the foundation, using Darcy's law, $Q = kiA$, or Eq. 3.18, $Q = kh(n_f/n_d)$ (Sec. 3.4). If the foundation has a permeability that is different from that of the core of the dam, seepage quantities may be estimated with composite flow nets of the general types shown in Figures 4.7 and 4.8.

In this example (Fig. 5.8) it is assumed that seepage through the dam Q_1 has been estimated by appropriate methods as 2 cu ft/day; seepage through the foundation Q_2 has been estimated as 10 cu ft/day. Accordingly, the chimney drain must be capable of discharging $Q_1 = 2$ cu ft/day and the outlet portion of the drain must discharge $Q_1 + Q_2 = 12$ cu ft/day. These quantities are the discharge rates per running foot of dam and drain.

Assuming that the chimney portion of the drain in Figure 5.8 has been designed with a horizontal width of 12 ft to permit its placement with normal earth-moving equipment, the cross-sectional area normal to the direction of seepage within the chimney is about 11 sq ft (Fig. 5.8*b)* and its required permeability can be approximated as

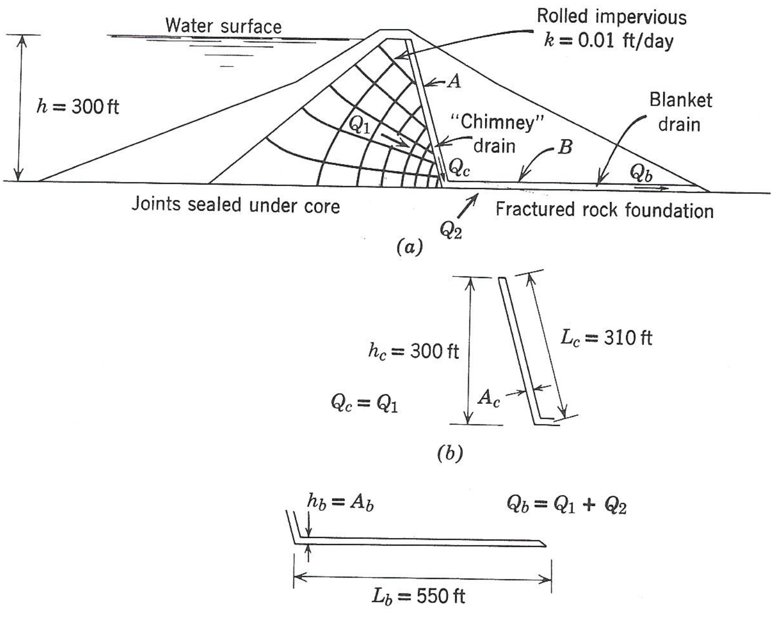

FIG. 5.8 Example of drain design procedure assuring adequate discharge capacity. (*a*) Cross section and flow net, (*b*) Key dimensions of "chimney" drain. (*c*) Key dimensions of blanket drain (outlet).

$$k = \frac{Q}{iA} = \frac{Q_1}{(h_c/L_c)(A_c)} = \frac{2 \text{ cu ft/day}}{(300 \text{ ft}/310 \text{ ft})(11 \text{ sq ft})} = 0.2 \text{ ft/day}$$

According to this approximation, a material with a permeability of about 5 ft/day would ensure reasonable discharge capacity for the chimney. Clean, washed concrete sand, low in fines, is usually about this permeable.

Outlet Blanket Drain for a Dam

With reference to Figure 5.8*c*, the outlet portion of the drain for this dam must be capable of discharging $Q_1 + Q_2 = 12$ cu ft/day (per foot). The relative values of Q_1 and Q_2 are fairly typical of many dams, for the amount of leakage through jointed or porous foundations is often greater than the amount of seepage through well-compacted dams.

On the assumption that the *allowable maximum head* h_b in the blanket can be no greater than its thickness A_b (Fig. 5.8*c*), its minimum permeability should be