# A. TOBLIN STAFF EXHIBIT 2

## NIRS/PC EC-1

proportional to the length of the flow path, and proportional to a coefficient $K$, depending on the nature of the sand. (Both Darcy and Dupuit failed to recognize the fact that $K$ depends on properties of the fluid as well as on characteristics of the medium.) Darcy's law may be expressed as

$$Q = KA[(h_1 - h_2)/dl] = -KA \, dh/dl \tag{1}$$

in which

$$h = z + (p/\gamma) + \text{arbitrary constant} \tag{2}$$

and

$$K = k(\gamma/\mu) \tag{3}$$

where $K$ is the hydraulic conductivity. In these equations $h$ is the energy per unit weight of fluid or hydraulic head in the case of water, $z$ is the elevation above an arbitrary datum plane, $p$ is the pressure sustained by the fluid in the pores of the medium, $\gamma$ is the specific weight of the fluid, $\mu$ is the dynamic viscosity of the fluid, and $k$ is the intrinsic permeability of the medium. When the fluid is water, the hydraulic gradient $\mathfrak{I}$ is defined as

$$\mathfrak{I} = dh/dl \tag{4}$$

The subscripts 1 and 2 in Eq. (1) refer to the value of $h$ at elevations $z_1$ and $z_2$.

Ground-water flow could be treated microscopically by the laws of hydrodynamics if the granular skeleton of the porous medium were a simple geometrical assembly of prismatic, unconnected tubes. The seepage path, far from being a prismatic channel, however, is tortuous, branching into a multitude of tributaries. In its original form, Darcy's law avoids the insurmountable difficulties of the hydrodynamic microscopic picture by introducing a twofold averaging macroscopic concept.

(1) It considers a fictitious flow velocity, the Darcy velocity or specific discharge $q$, through a given crosssection of a porous medium rather than the true velocity between the grains, as is evident from Eq. (1):

$$q = Q/A = -K \, dh/dl \quad \text{or} \quad q = -K\mathfrak{I} \tag{5}$$

(2) It considers average hydraulic values rather than local hydrodynamic values of this velocity.

These simplifying concepts were introduced by the nature of Darcy's experiment, which only permitted the measurement of average hydraulic values in the sand-filled cylindrical pipe.