INTRODUCTION TO TERRESTRIAL HYDROGEOLOGY

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Groundwater is present in all terrestrial environments, including humid temperate, arid or semi-arid, and polar environments. In the latter, groundwater exists as permafrost. Groundwater in unconsolidated materials, such as sand, silt and clay, is present in the void spaces between the individual grains. These void spaces, or porosity, can range from 25% to 70%. Groundwater in consolidated rocks is present in fractures or dissolution pores. Porosity in consolidated rocks is typically less than 1%. This discussion will focus on groundwater in porous media.

Groundwater is present in aquifers and aquitards. Aquifers are generally defined as subsurface formations that can transmit sufficient water to be used as a water supply. Aquifers comprise primarily fine sand and coarser materials. Aquitards transmit less water and comprise primarily silt and clay. Where aquifers are present at surface they are defined as unconfined. The water level, or piezometric elevation, in a well screened in an unconfined aquifer will coincide with the water table. Where an aquitard overlies an aquifer, the aquifer is confined. The water level in a well in a confined aquifer will rise to an elevation where the pressure in the aquifer equals atmospheric pressure, and this typically does not coincide with the water table elevation. If the aquifer is connected to a source of water with a higher elevation, the water level in the well can rise above the water table elevation, and can even rise above ground surface elevation.

Whereas surface water flows from areas of high elevation to areas of low elevation, groundwater flows from areas of high pressure to areas of low pressure. Pressure is a product of the density of water, gravitational acceleration and elevation relative to a specified datum to which the water rises in a well open to the atmosphere. In most groundwater applications, changes in the density of water and gravitational acceleration are negligible, leaving the groundwater elevation, which is called hydraulic head, as the determining factor for groundwater flow direction and velocity. Specifically, groundwater flow depends on the hydraulic gradient, which is the change in hydraulic head divided by the travel distance.

The ability of a porous medium to transmit water is measured as hydraulic conductivity, which is defined as the volume of water the medium can transmit through a unit area per unit time under a unit gradient. The units of hydraulic conductivity, which is denoted by the symbol K, are length per time, and is generally reported as centimetres per second or metres per second. Hydraulic conductivity can range over more than ten orders of magnitude. Hydraulic conductivity of aquifers used for domestic supply must generally be greater than 10^{-5} cm/s, and of aquifers used for municipal water supply exceed 10^{-2} cm/s.

Assembling the above concepts, the volumetric groundwater flow rate can be calculated as follows:

$$Q = KiA$$

where,

Q is volumetric groundwater flow rate (L^3/T)
K is hydraulic conductivity (L/T)
i is hydraulic conductivity (dimensionless)
A is cross-sectional area of flow (L^2)

Groundwater in porous media flows in a tortuous path around the individual particles in the subsurface. Therefore, the actual velocity of groundwater as it follows this tortuous path is essentially meaningless. Instead, the average linear groundwater is based on travel time and distance assuming a direct flow path. Because the groundwater only flows through the open and connected pore spaces in the subsurface, the volume taken up by solid material and unconnected pore spaces must be eliminated from the calculation. Therefore, the average linear groundwater velocity is calculated as follows:

$$\nu = Ki/\theta$$

where,

ν is average linear groundwater velocity (L/T)
K is hydraulic conductivity (L/T)
i is hydraulic conductivity (dimensionless)
θ is effective porosity (dimensionless)

Extrapolating to the lunar environment, higher concentrations of water are more likely to be found in unconsolidated materials, based on their higher porosity, than in consolidated rocks. Further, fine-grained materials typically have higher porosity, potentially as high as 50% to 70% in terrestrial environments, than coarse-grained materials, which typically have porosity in the range of 25% to 40%.

Investigations for the presence of water may be aided by the use of surface geophysical methods. Methods that have been used in terrestrial environments to search for the presence of groundwater include electrical resistivity, time-domain electromagnetic, frequency-domain electromagnetic, seismic reflection, seismic refraction and ground penetrating radar.