DATA ACQUISITION METHODS FOR GROUNDWATER INVESTIGATION AND THE SITING OF WATER SUPPLY WELLS

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Summary

Occurrence of groundwater in primary and secondary aquifers is investigated by means of geophysical methods, with experience based on past successes as a guideline. The various scientific methods, such as geophysical surveys, magnetics, electromagnetics, electrical resistivity, gravimetric, and seismic refraction are all reviewed, with examples shown.

The analysis of data from these methods towards successful location of drilling sites, and application to groundwater supply for both small and large undertakings, utilizing both primary and secondary aquifers, is discussed.

1. Introduction

The successful siting of drilled wells for water supply does not require the assistance of the occult or other mystical powers. It is a skill, obtained through a thorough understanding of groundwater science, the correct application of technology and to a large degree, hard–earned experience and local knowledge. The techniques involved in scientific groundwater investigations are briefly described in the following sections. Utilizing these principles based on sound data can eliminate guesswork and ensure a much higher success rate in successfully siting drilled wells for water production purposes.

2. Groundwater Occurrence and Replenishment

In considering the availability of groundwater for the purposes of the hypothetical user, one must first address three questions: Where does it come from? Where does it go to? And where is it to be found? These relate to its nature, conveyance, and sustainability for the envisaged use.

2.1. Where it Comes From

All groundwater originates from rainfall. When rain falls, some of it is intercepted by trees, plants, and buildings, and the rest falls on the soil and if rainfall is light this will be rapidly evaporated. During heavier rain showers the volume of water infiltrating the surface exceeds that which can be absorbed or held in the soil above the groundwater table. This excess may then flow laterally to a stream or pond or it may continue to infiltrate downwards to the groundwater table.

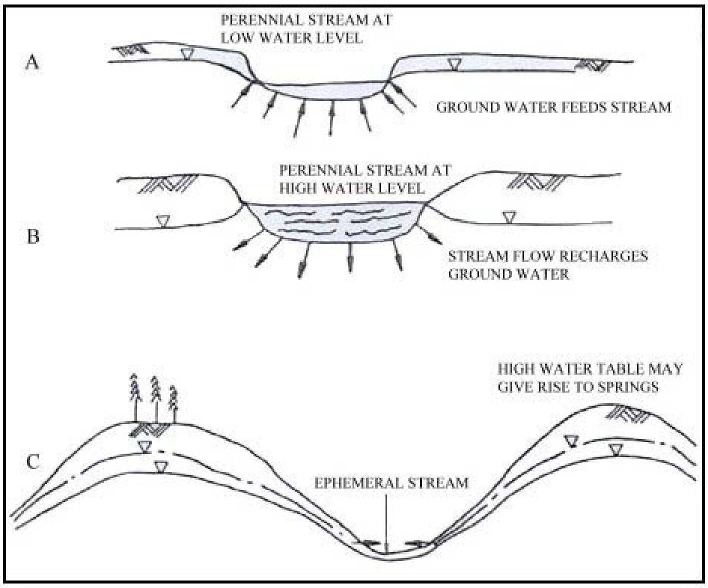

Figure 1. A. Stream Flow Augmented by Groundwater, showing water table and flow direction B. River Flow Recharging Groundwater, showing water table and flow direction C. Relationship Between Water Table and Topography.

Surface runoff occurs when rainfall intensity exceeds the rate of infiltration of the soil. However, the resultant overland flow along stream courses does not totally bypass the groundwater system. Most perennial streams are supported by base-flow originating from groundwater, but in periods of flood or high water stages the hydraulic gradient between the river and adjacent body of groundwater is reversed and water flows back into the aquifer through the river bed or indirectly via permeable river bank and flood plain sediments, (Figures 1A and 1B). This type of relationship is far less common with ephemeral streams; even so the groundwater table typically lies closer below the ground surface in valley bottoms as compared with hilltop locations, (Figure 1C).

2.2. Where it Goes To

The hydraulics of the flow of water beneath the ground surface is governed by the same natural forces as surface water. In order for groundwater to flow, there must be a hydraulic or potentiometric gradient. Groundwater moves in response to the hydraulic gradient (normally very slowly) until it reaches either a ground-water barrier (impermeable rock formation), or an outlet (spring, stream bed seepage, or the sea).

2.4. How and Where it Occurs

Water bearing formations capable of yielding water in sufficient quantity to be economically useful are known as *aquifers*. Almost all formations will yield a little water, but those not capable of meeting even modest water supply demands are called *aquitards*.

Water bearing formations can be one of two main types, *primary* and *secondary* aquifers:

2.4.1. Primary Aquifers

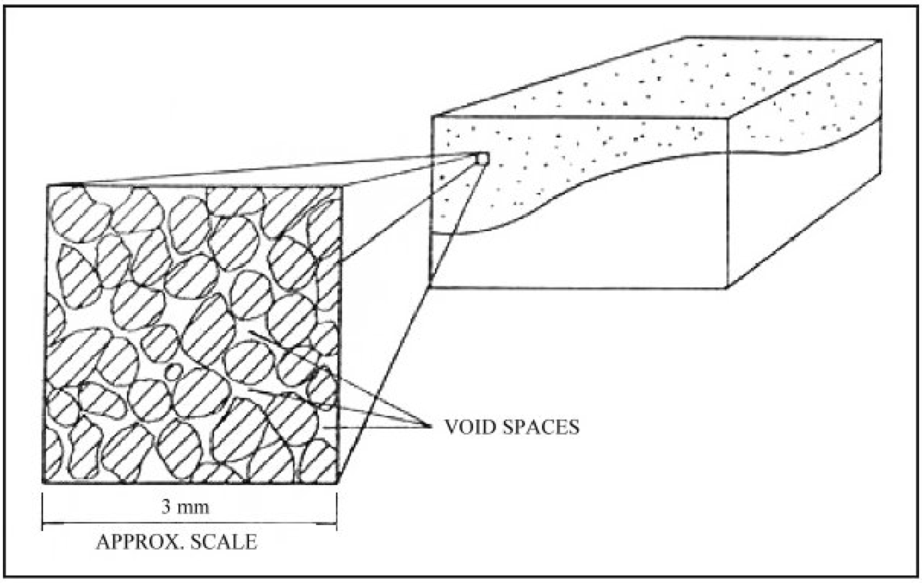

Figure 2a. Nature of Porosity in a Primary Aquifer

These are where water occurs in the mass of tiny pore spaces between grains in unconsolidated formations such as sands and gravels and in rock formations such as sandstones (Figure 2a).

2.4.2. Secondary Aquifers

Where water occurs in open joints, fractures, fissures, and solution openings in hard rock formations where the actual rock material has negligible porosity (Figure 2b). In both cases the aquifer is generally a static or very slow moving body of water occupying all the void spaces below the water table. Only in areas underlain by limestone or dolomite is it likely that groundwater flows in underground rivers or “veins.” This is because in some areas the carbonate minerals of the limestone have been dissolved resulting in enlarged solution cavities.

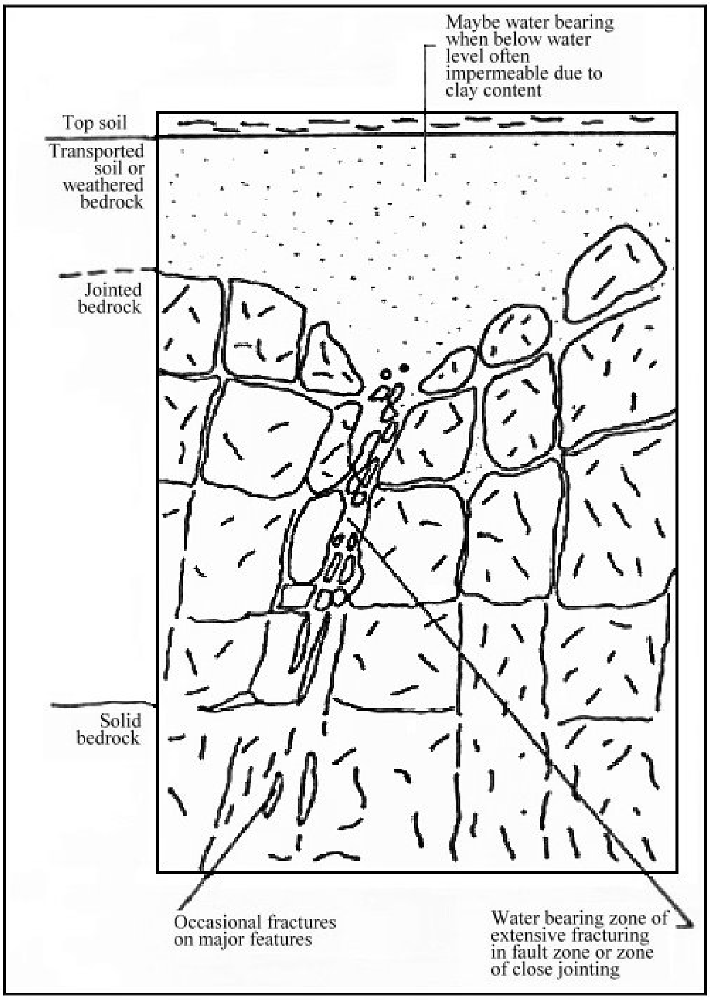

Figure 2b. Nature of Porosity in a Secondary Aquifer

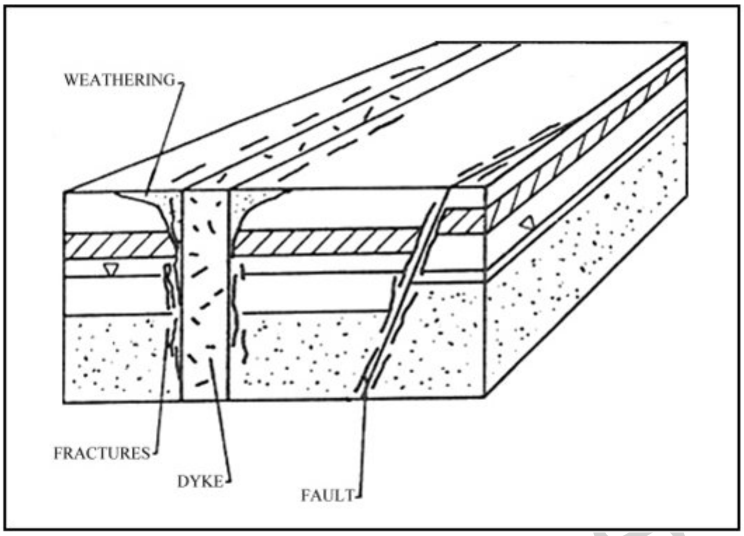

Figure 3. Water Bearing Conditions along Linear Geological Features

In non-carbonate rocks, concentrations of joints, fissures, and fractures can give rise to linear zones of enhanced water–bearing properties that can provide a good drilling target for water supply wells (Figure 3).

It is quite common for primary sand aquifers resulting from the weathering of hard rock formations such as granite, to be underlain by a jointed granite, secondary aquifer. But just as commonly, the weathered near-surface formations are clayey, impermeable, and yield no water. In hard rocks, groundwater occurs along joints, faults, and fissures. Such features may be isolated, concentrated in zones, or found in association with igneous intrusions especially the wall-like features called dikes, where magma has been forced into cracks in the bedrock. Dike contact zones may be favorable because the dike's magma intrusion occurred along a line of existing structural weakness or alternatively as a result of disturbance of the host rock caused by the force and heat of intrusion of the dike. Igneous dikes may have a high density of joints and be more water productive than either the country rock or the contact zones on either side.

The hydrogeology of each area is the product of the local lithology, structural geology, geomorphology, and climate. There is unfortunately no straightforward link between geology and potential water yields of drilled wells. In the next section, practical groundwater investigation methods are described that bridge the gap between knowing where the water should be and determining where it is.

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Biographical Sketch

Dr. Michael Foster is a hydrogeologist with extensive experience in groundwater exploration, management of resources, and regional groundwater investigations. He has directed the siting of water supply wells in South Africa and the United States, and currently works in San Francisco for Tetra Tech EM Inc., an international natural resource management company.