https://doi.org/10.29321/MAJ.10.A03756

Ground water - its source and movement

by
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Introduction: Water is essential for every living being. It has become an essential raw material also. No farm produce can be made without water. There is no power generation, thermal or hydel, without water. There is no industry which does not use water. For example, petroleum refineries requirie 770 gallons of water for every barrel of petroleum refined; steel plants require 65,000 gallons of water for every ton of steel they turn out; synthetic rubber manufacturing concerns use 600,000 gallons of water for every ton of synthetic rubber they produce. A quantity of 1.25 million gallons of water is required to irrigate one acre of paddy crop.

Source of water: On the earth's surface taken as whole, water is available in abundance. Over three fourths of the earth's surface is eternally under water. The rest of the surface is not free either; it is filled with innumerable tanks and rivers; permanent ice caps and glaciers top many mountain ranges of the world; seasonal rains lash the earth, flood the lands and roll into the seas. Part of these rains, nearly one third, soaks into the soil and lie underground invisible from the surface. It therefore looks as though the water is abundant everywhere and the world needs can hardly equal a fraction of the available water.

Importance of ground water: The reality is not so; it is amazingly contrary and has sent man in quest of water from time immemorial; for, the man is deprived of the benefits of the greatest source of water, namely the oceans, forming 97.2 per cent of the world source, because it is unfit for human consumption. The next great source, rainfall, cannot also be fully utilized, since it is mostly eratic in distribution and, therefore, most of it goes back into the unavailable source of water, namely, oceans. Thus man is ever in need of water, for all its abundant presence around him. Hence attempts are made to conserve the available useful water for human consumption, plant growth and animal life.

Dams, tanks and ponds are constructed to impound the available surface water for regulated use all the year round. Still our requirements are not satisfied. In India, the average rainfall of 45″ over the entire country represents something of the order of 3,000 million acre feet of water.

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Received on 20—8—1966.

Of this, about, 1,000 million acre feet are lost through evaporation; roughly 650 million acre feet soaks into the soil and the rest 1,350 million acre feet flows to the seas. Of this 1350 million acre feet, only 450 million acre feet could be harnessed for our needs. Madras State has tapped roughly 90 per cent of the surface water resources, which is probably a world record, strangely though, our State is still very much in need of water. Drinking water continues to be a problem. The State is in the midst of an industrial boom. Intensive and extensive agricultural programmes are being launched. This means much more water should be made available. It is believed that out of the estimated water potential of our State of 24,000 T. M. Cft. (Thousand million Cft), as much as 7,000 T. M. Cft. lie underground as ground water. Having almost exhausted the surface resources, Madras State has now decided to explore the possibility of large scale exploitation of this ground water, which has thus assumed a significant importance and relevance at the present juncture.

Occurrence of groundwater: The presence of ground water is known from ages. Its relevance lies not in its presence; but in the possibility of its large scale exploitation to meet out needs. It is only in the recent past that any scientific study has been made of the ground water. Ground water is that part of the precipitation, (about one third as mentioned earlier) that soaks into the soil through the openings and keeps moving under ground. Below a certain depth all openings of the soil are filled with water and thus saturated. Ground water is therefore defined as a water in the zone of saturation. The potentiality of the ground water resources can be seen from the following: Where the average annual rainfall is 30″ we may assume one third of this soaks into the soil ie. 640,000 tons of water for every square mile. If half of this quantity could be extracted, it would yield a continous supply of one cusec for 136 days and thus would be sufficient for the irrigation of about 250 acres (Alfred Chatterton, 1912).

In Madras State ground water sources are concentrated in the alluvial deposits occuring in river valleys and deltas along the cost. This is also available in all river basins and about five miles on either side of each river and coastal belts of Rameswaram, Pudukottai, Thanjavur and Cuddalore right upto Madras. Water also exists in small pockets in the district of Chingleput, Thiruchirapalli and South Arcot. The three districts Salem, Coimbatore and Nilgiris constitute, what may be called, a 'dry belt'.

Ground water movement: Nearly all ground water can be thought of as part of the hydrological cycle, including surface and atmospheric water. Earths's crust is formed largely of layers of strata, some pervious to water and some impervious, lying one over each other. It is this physical feature of the earth's crust that is responsible for the storage and movement of ground water. Soil stratum which yields significant quantities of water is called an 'aquifer'. Most aquifers are large in extent and may be visualized as underground storage reservoirs. Water enters into this aquifer from a natural or artificial recharge, as illustrated in the figure A.

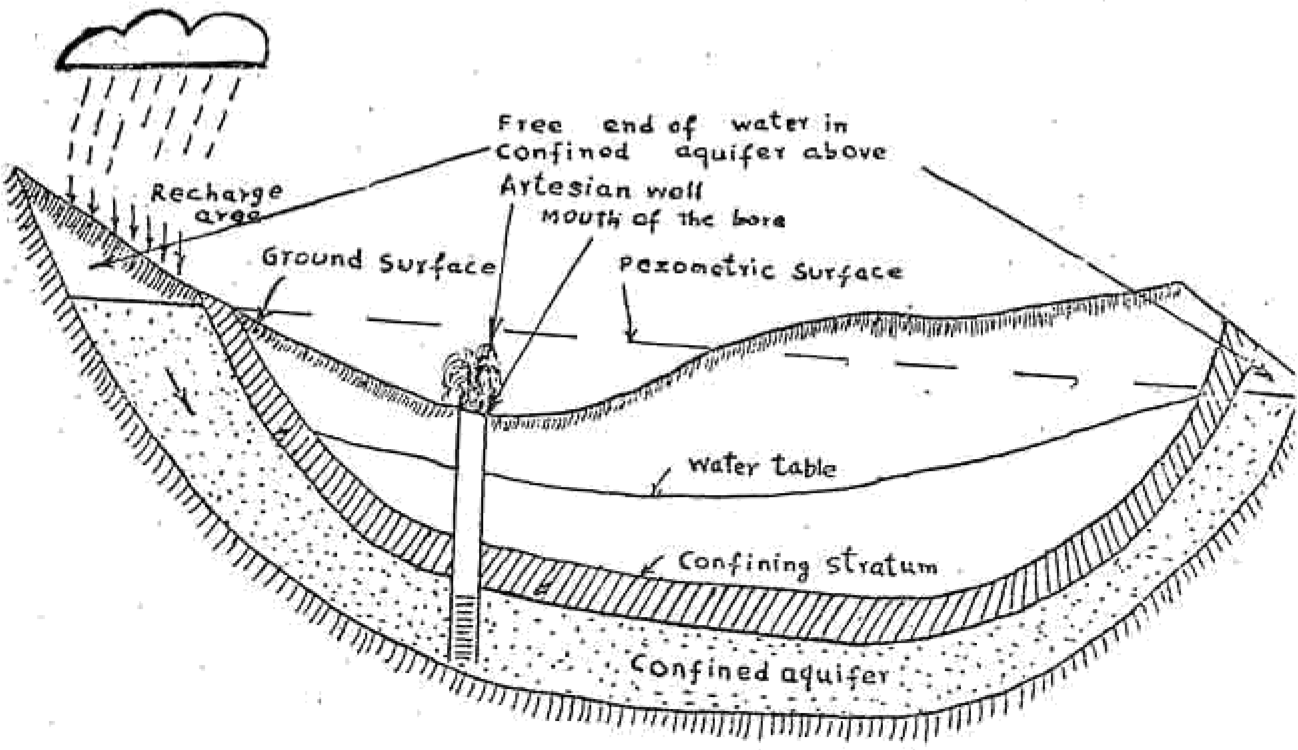

FIG. A.

Aquifers may be classified as confined or unconfined, according as the upper surface of the zone of water saturation is the bottom of an overlying impervious stratum or the free water table. A confined aquifer becomes unconfined, when the upper surface of the water saturation zone or the "piezometric surface" falls below the bottom of the overlying impervious layer and becomes free. The water that is available between the first impervious stratum and the ground surface is always under "unconfined conditions", as is obvious from the Figure A.

The free water surface of such an unconfined water is called the water table which more or less follows the configuration of the ground surface. The water table intersects the ground along perennial streams, lakes, swamps etc. into which the ground water discharges. Such a discharge fluctuates from season to season and from year to year and so does the position of the ground water table.

In confined aquifers, the water is under pressure except where the water is not in contact with the overlying impervious strata. If we bore through the overlying impervious stratum and into the confined aquifer, we may get water flowing out of the bore, if the free end of the confined water is above the mouth of the bore, as illustrated in the sketch. Such a flow is, called an 'artesian' flow and the rest 'sub-artesian'.

The ground water is under constant motion and this motion is induced naturally or artificially. In either case, unlike surface flow, the ground water flows through the open pores in the strata.

According to Tolman (1937), Hagen (1839), Poiseuille (1846), Darcy (1856) and Slichter (1902) have studied the general principles underlying the movement of ground water. One of the facts brought out by their studies is that under a given hydraulic gradient the velocity of ground perculation varies directly as the square of the size of the capillary openings through which the matter moves or approximately as the square of the average diameter of the constituent grains of water bearing material.

The flow through aquifers can be expressed by Darcy's law $V = K \frac{dh}{dl}$ where V is velocity of flow, K is coefficient of permeability and $\frac{dh}{dl}$ is hydraulic gradient.

From Darcy's law and equation of continuity, flow equation of ground water can be derived as under:

$$-\left[\frac{\delta(\rho vx)}{\delta x} + \frac{\delta(\rho vy)}{\delta y} + \frac{\delta(\rho vz)}{\delta z}\right] = \frac{\delta \rho}{\delta t}$$

Where vx, vy and vz are the velocities in the X, Y and Z directions respectively, 'ρ' is fluid density and 't' is time.

As ground water flows through and along permeable strata and not through impermeable one, flow lines become parallel to the impermeable boundary. Likewise, no flow crosses the water table and therefore water table becomes the boundary surface of the flow. For such specific boundary conditions, flow lines and what are called 'equipotentials' can be mapped in two dimensions to form a 'flow net'. Hence, if we know the water table or piezometer elevation of wells with reference to a datum, estimates of local ground water contours and flow directions can be determined, and so can be the zones of higher permeability. It may be seen that the flow lines, as already stated, do not cross impermeable boundary and water table; for they are parallel to them. It therefore follows that there can be no cross flows across two adjacent flow lines. This being so, wide contour openings between a pair of nearly parrallel flow lines, indicate (and it can be proved to) the presence of a higher permeable zone under ground, while the narrow openings indicate the presence of a lower permeable zone (Figure B).

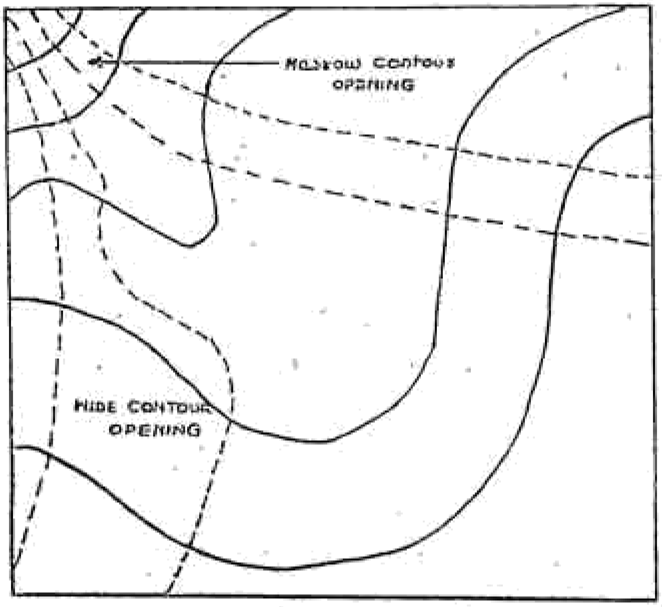

FIG. B

It is therefore apparent that contour maps of water tables along with the flow lines are quite useful data in locating new wells. Not only can areas be selected which suggest the best possible source of ground water supply but also areas of favourable permeability can be ascertained (Todd. 1959).

It is therefore clear that a scientific study of ground water, its source, location, movement etc. is of assistance to agriculture that depends entirely on well irrigation. It is also useful for economic planning of agriculture and other industries, which cannot be done in the absence of correct stock taking of water resources.

Acknowledgement: I am grateful to N. Sankaranarayana Reddy, Joint Director of Agriculture (Engineering) and Dr. B. W. X. Ponnaiya, Dean, Agricultural College and Research Institute, Coimbatore for their encouragement and guidance in the preparation of this article.

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